

MaxIm DL

CCD Imaging Software

Version 4

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MaxIm DL User Manual

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Chapter 1. Introduction

MaxIm DL is a program specifically designed for imaging with scientific-grade CCD cameras. In addition to a host of functions suitable for any high sensitivity, high bit depth application, it includes functions specifically designed for astronomical applications.

MaxIm DL is available in two versions. The basic version includes only the image processing and analysis functions. The full MaxIm DL/CCD version includes image processing plus full instrumentation control, including support for a large variety of CCD cameras, filter wheels, focusers, autoguiders, and telescopes.

System Requirements

MaxIm DL requires Windows 98™, Windows 98 SE™, Windows ME™, Windows NT™ 4.0, Windows 2000™, or Windows XP™ (or higher).

The following hardware is required:

- Processor –Pentium™ or equivalent, or higher
- Memory – minimum 16 MB (Win 98/ME), 24 MB (Win NT/2000/XP); more for larger images. Preferred memory size is 32 to 64 MB for small to medium format CCD sensors. Processing large images will require larger memory.
- Disk Space – 20 MB for program, 100 MB swap file recommended.
- Video Display – 800x600, **16-bit color** or higher (monochrome images only can be displayed on 8-bit color video cards). 1024x768 or higher is recommended.
- Mouse
- Internet Explorer (required for Help system)

Note that MaxIm DL benefits greatly from increased memory size, particularly if large images are to be processed. Also Windows NT does not support USB devices.

Alternative Operating Systems

The following configurations have been demonstrated to work with MaxIm DL, but these configurations have not been tested by our staff and are not supported:

- Windows 95™
- Apple Macintosh with SoftWindows™

- Apple Macintosh with VirtualPC™

Only serial and USB interface devices will work on Macintosh systems. Windows 95 and Windows NT does not support USB devices.

Linux/UNIX is not supported.

Installation

MaxIm DL is available either on CD-ROM or via Internet download. Please follow the appropriate instructions.

CD-ROM Installation

If you purchased MaxIm DL with a CD-ROM, insert it into your drive. The Launcher should automatically start; if not, then open Windows Explorer, browse to the CD-ROM drive, and double-click the file Launcher.exe.

The Launcher has various buttons for installing programs and drivers.

1. Click the Install MaxIm DL button. InstallShield will start and take you through the process of installing MaxIm DL. The default settings will install the full software package and all options. You may be asked to reboot the PC if certain files in use by Windows need to be updated.
2. If you purchased the full MaxIm DL/CCD version and are planning to use Telescope or Focuser control, click the Install ASCOM button. This will take you through the procedure of installing the ASCOM Platform, which contains various drivers and utility programs. You can also optionally install source code for most of the included software.
3. Some CCD cameras require the manufacturer's drivers to be installed in order for MaxIm DL/CCD to communicate with them. Please see Driver Installation and Setup for more information.
4. If you use an SBIG CCD camera, click Install SBIG Driver to load the drivers for operating these cameras.
5. A 30-day trial version of MaxPoint is available. Click the Install MaxPoint button and follow the instructions.

The CD-ROM also contains a copy of the Guide Star Catalog, which is useful for performing astrometric analysis and telescope pointing updates using the included PinPoint LE astrometric engine.

Once you have installed the software, run it by double-clicking the MaxIm DL icon. At

this point you will be prompted to enter your license. The license is included with the CD-ROM in the back of the manual. Enter the license exactly as printed, and please pay attention to upper and lower case.

The screenshot shows a 'User Registration' dialog box with the following fields and values:

- Name: Fred Finkle
- E-mail: fred@finkle.com
- Expiry: Year: 2004, Month: 1, Day: 1
- Serial: BDV/G.mudS.vhu/LNfo-S+QBw

A note at the bottom of the dialog box reads: "Note: For permanent licenses, Expiry indicates the date upon which your free upgrades expires. The software will continue working after this date, but you will not be able to upgrade. For temporary and demo licenses, the software will stop working on this date."

If you purchased through a dealer, you will have a temporary license that works for 30 days after installation. To get your permanent license, click **Help** menu **Register Online** or go to http://www.cyanogen.com/support/register_main.htm. You can also call Diffraction Limited at (613) 225-2732 during regular business hours. Note that you cannot return the product after the permanent license is issued.

Internet Installation

For Version 4 minor upgrades via download, please see **Upgrades**.

Go to the demo download page http://www.cyanogen.com/downloads/maxim_main.htm. Fill in the form, including full name and e-mail address. You will then be allowed to download the installer. Save this in a temporary folder on your hard drive.

You will be automatically sent via e-mail a 30-day MaxIm DL/CCD demo license. The license will be required the first time you run the software.

Install the software by double-clicking on the downloaded file. Follow the instructions to install; if you choose the default settings, all program features will be installed.

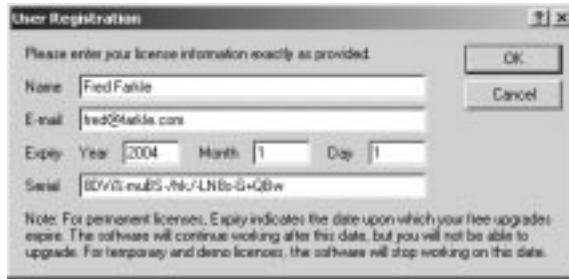
Start MaxIm DL by clicking on the program icon. The first time you run it, you will be presented with the **User Registration** dialog box. Enter the demo license you received via e-mail (use your permanent license if you have already purchased the software).

Note: all text must be entered *exactly* as shown on the license. You can enter the serial number more easily if you select it in your e-mail using the mouse and copy it to the clipboard (**CTRL-C**). You can then paste it into the User Registration dialog box (**CTRL-V**).

When you have successfully entered your license, the OK button will enable. Click **OK** to launch MaxIm DL. The demo license will expire on the date shown.

Each time you start the software using a Demo license, you will be advised of the

number of days remaining, and given the opportunity to enter a new license. You can also enter a new license using the **Help** menu **Enter License** command.



Once a permanent license has been entered, MaxIm DL will continue to work indefinitely. However, after the expiration date shown (one year after purchase), it will no longer be possible to upgrade the software. At that time you may wish to purchase an additional year of upgrades. See <http://www.cyanogen.com> for details.

Upgrades

To check for new software upgrades, click the **Help** menu **Check For Updates** command. This will launch **Internet Explorer** and take you to a web page which will automatically check for any necessary software updates.

Privacy Notice: The only information transmitted to our web site is the current version number you are running. This is required so that the web server can determine if an upgrade is available. This information is only used to find the correct download file, if any, and is not stored on our server.

You can also download from http://www.cyanogen.com/download/maxim_v4.htm. Be sure to check the release notes before you download.

Note: Owners are entitled to one year of free upgrades after date of purchase. After that time, the installer will inform you that your free upgrades have expired. Do not continue to install the software, or the program will not function. At that time you may wish to purchase an additional year of upgrades. See <http://www.cyanogen.com> for details.

Installation Troubleshooting

If you are unable to enter the software license, please try logging in as Administrator, or see the instructions under **User-Level Accounts**.

If you are experiencing poor quality image display with color images, you need to set your computer's video mode to at least 16-bit color. Please see the instructions under **Poor Image Display**.

If you experience glitches in the video display, you need to upgrade your video drivers. Problems with defective video drivers are very common. Please see **Video and Printer Display Problems** for more information.

User-Level Accounts

Normally software installed on Windows NT/2000/XP from Administrator-level accounts will work on User-level accounts. In rare cases, however, users who do not have Administrator privileges will not be able to access the license information and the software will not run.

The default Windows Registry security settings will allow user-level accounts to access the serial number that was entered by the installation software. However, it is possible to set up the default Registry permissions in such a way as to disable user-level access. This occasionally occurs in large institutions that have central administration of their computer systems. To fix this, do the following:

1. Log in as Administrator.
2. Go to the Start menu and click Run...
3. Enter regedt32 and click OK.
4. Open HKEY_LOCAL_MACHINE
5. Open SOFTWARE
6. Open Diffraction Limited
7. Open MaxIm DL
8. Select 4.0
9. Using the Security menu Permissions, click Add... and include the class of users you want to have access to this key. Make sure they have at least **read** access. Write access is required to install the software and enter the license.
10. Click OK.

Poor Image Display

If color images do not display properly, but monochrome images do, you are in the 256-color video mode, which is not fully supported by MaxIm DL. It is strongly recommended that High Color (16-bit) or a higher video mode be used.

To change video modes:

1. Click on the Start button, select Settings, and choose Control Panel.

2. Double-click on the Display icon.
3. Under Color Palette, change the setting to High Color (16-bit).
4. Click OK.

Depending on your video card, you may have to restart your computer.

We recommend that you shut down MaxIm DL and restart it after changing modes.

If High Color mode is not available, you need to select the correct video driver (Advanced Properties). Please contact your computer or video card vendor for more information.

Video and Printer Driver Problems

Many problems encountered with Windows-based PC's can be traced to problems in the video or printer drivers. Driver bugs can often result in stability problems with Windows itself or cause odd behavior in applications software. Some printer drivers can actually cause problems completely unrelated to the printer operation. Often these bugs will affect some applications and not others, depending on what driver features the particular application uses.

The following problems have been traced to defective video or printer drivers:

- Video screen corruption at certain zoom levels (video driver)
- Failure to draw certain user interface details (printer driver)
- Math coprocessor corruption, potentially resulting in software crash (printer driver)
- Excessive consumption of system resources (video driver)
- Unrepeatable random crashes (video or printer driver)

If any of the above situations occur, we recommend obtaining new drivers for both your printer and video card from the manufacturer. It is usually possible to download updated drivers from the manufacturer's web site.

Basic Operation

In the following discussion, it is assumed that the reader is generally familiar with programs that run under the Windows operating system.

We **strongly** recommend that the user read through the tutorials. They provide a basic introduction to MaxIm DL operations, including things that may not be entirely obvious to a new user at first glance.

Accessing Images

You can quickly switch between images using the tabs running across the top of the main window.

For most image processing commands, you can still access the image while the command is open. You can **pan** and **zoom** it, or use tools such as **Screen Stretch** and **Quick Stretch**, shown on toolbars or in the context menu displayed when you right-click on the image. In many cases statistical analysis and image inspection tools such as the **Information** and **Line Profile** windows can be used while an image processing command is open.

Usually just the window you are working on is active; but for some commands that operate on multiple images, all open image windows are available.

Note that the small **preview window** on the dialog box can be adjusted for Screen Stretch, as well as the main image window.

High Bit Depth Images

Most point-and-shoot digital cameras produce 8-bit data. Scientific-grade CCD cameras typically produce 16-bit data. Moreover, if you attempt to stack 16-bit data, you end up with more than 16 bits.

For this reason, MaxIm DL works with images in 32-bit floating-point format. This requires more memory than a standard “paint” program, but it means you have almost unlimited data range available.

This has two major effects on how you work with the package:

- When you view images, you have to “Screen Stretch” the image – that is, adjust its brightness and contrast so you can see it
- When you save images, you have to make sure the file format can accommodate the bit range

Viewing Images

Let’s assume we have a 16-bit image. The brightest pixel in such an image has a value of at most 65535. For an astronomical image, we might have a few stars this bright, but much of the information – especially nebulosity – will be much fainter.

Unfortunately your computer screen can only display 8-bit images, or a data range of 0 through 255 (in reality it is not even this good; you cannot distinguish 256 different brightness levels on a computer monitor). How do we bridge this gap?

Simple – by scaling the data so the interesting parts are in the correct range. In MaxIm

DL, we have the **Screen Stretch** window. You set values for the **Minimum** and **Maximum** levels. When an image is displayed, any pixel value below the minimum is set to 0 (black), and any pixel above the maximum is set to 255 (white). The values between minimum and maximum appear as shades of gray. This means adjusting the sliders or numbers in the screen stretch window will change how the image looks on the screen, but will not actually modify the image.

MaxIm DL will try to automatically figure out the best values for you. When you load a new image, it typically defaults to the **Medium Auto Stretch** mode. (Files saved in FITS format may contain a recommended initial **Screen Stretch**, while 8 bit images automatically display the entire range.) You can change to different auto-stretch modes using the **Screen Stretch** window. These automatic modes have to be a compromise; they will produce decent results for almost any image, but not necessarily the “best”.

You can easily adjust any image manually. The fastest and easiest way is to use **Quick Stretch**. Simply point the mouse at the image. Hold down the **Shift** key and then press and hold the **left** mouse button and **drag** it on the image. **Up/Down** will adjust the brightness of the image up/down. **Right/Left** will increase/decrease the contrast of the image. The image adjusts continuously as you move the mouse.

When using Quick Stretch, it is best to use short motions, lifting the mouse button in-between. This gives you the best control. Practice a bit on the sample images to get the hang of it – you will be using it a lot. If you get lost, just flip it back to Medium in the Screen Stretch window.

Saving Images

Suppose you take a 16-bit image with your CCD camera, and want to save it as an 8-bit JPEG that you can post on your web site. How can you make sure the image appears correctly?

Often the data in a 16-bit image will never go as low as 255; if you simply save the image in JPEG, it will come out as all white!

To fix this, the File menu **Save As** command has an option called **Auto Stretch**. What this does is apply the Screen Stretch setting to the file before it saves it to the disk. If you then load up the picture in your web browser, it will now look exactly the same as it did in MaxIm DL.

You can also do these adjustments manually, if you so desire, using the Process menu Stretch command. That said, it is usually easiest just to set the Screen Stretch and save using Auto Stretch.

Preview Image

MaxIm DL allows you to quickly evaluate the effects of image processing steps using Previews.

Some image processing functions take a substantial amount of time to process a large image. In this case, it is handy to use the small **Preview Image**, built into the processing command's dialog box. Other functions occur quite quickly, and it is more helpful to see the effect on the entire image.

The **Preview Image** is a small image window that appears in many of MaxIm DL's processing dialogs. It is small, typically 128 by 128 pixels, and acts as a scrollable peephole into the parent document on which you invoked the processing function. By **zooming** the **Preview Image** in on an area of interest, you can very quickly evaluate the effects of any given image processing function, even those which take a substantial amount of time on large images.



This is a typical dialog containing a **Preview Image**, which shows a portion of the main image window. The preview image can be panned using the **scroll bars** or by **dragging** with the **left mouse button** while holding down the **CTRL** key. The **Zoom** buttons allow you to zoom **in** (🔍) or **out** (🔍).

When the **Preview** button is off, the image is stretched in the same manner as the main buffer. When **Preview** is on, the processed version of the image has independent stretch settings which are reflected in the **Screen Stretch** window. (You can click on the title bar of the original image window to direct the attention of the Screen Stretch window back to that image, if you need to change its stretch settings. Clicking on the command dialog reconnects the Screen Stretch window to the **Preview** image again.)

Quick Stretch is also available for the Preview Image; simply point the cursor at the preview image, hold down the **Shift** key, and drag the mouse **up/down** for brightness

and **left/right** for contrast.

Whenever dialog settings are changed, the image changes back to the original, and the **Preview** button pops out. However, if the upper **Auto** button (to the left of the **Preview** button) is on, the processing function is automatically applied to the preview image whenever the dialog settings are changed. **Note:** if you type in a number directly, instead of using the up/down "spin" controls, you have to hit the **Enter** key to get the automatic preview. This prevents the processing from starting while you are still typing. Although the Preview button greys out when Auto mode is on, when text is entered it is reactivated and you can click it instead of hitting Enter.

The **Full Screen** preview works exactly the same way, except that the whole image is updated. Note that you can pan, zoom, and stretch (adjust brightness and contrast) the image. The **Auto Full Screen** button works exactly the same way as that for the Preview Image. Note that processing large images may take quite a while for some functions, such as FFT Filters; for those functions using the small Preview Image is often better. Histogram Specification, on the other hand, is fast and it is very helpful to use the Auto Full Screen mode with that command. Experience will tell you which method to use with which command.

Note that the two **Auto** modes are mutually exclusive; you cannot use both at once.

*Note: in some cases, performing a **Full Screen** preview causes the "undo buffer" associated with the image to be discarded. If so, you can still **Cancel** the current command and see the unmodified image, but you will not be able to **Undo** the previous operation applied to this image.*

Simple Mouse Tricks

MaxIm DL has a number of handy features that are accessible with the mouse, as follows:

To	Use
Pan	CTRL-click on the image and hold while dragging the image.
Zoom and re-center	Right-click on the image and select Zoom In or Zoom Out . The image will zoom and pan so that the spot you clicked on is now the center.
Quick Stretch	SHIFT-click on the image and hold while dragging up / down / left / right.
Select a region of the image	Click and drag the mouse on the image to select a rectangle. The rectangle can be adjusted by gripping and edge (move) or a corner (resize).
Turn on Crosshairs	Right-click on the image and select Crosshairs .
Adjust Information window aperture	Right-click on the image to select the aperture, gap, or background annulus size.
Center the telescope on an object in an image you just exposed	Right-click on the point you want centered, and click Point telescope here . (Note: Auto-center must be calibrated using the Telescope Control window.)
Lock the Information window cursor	Double-click on the image window. You can move the locked cursor around using the arrow keys. (Information window must be open.)
Get Help on any control	Click ? in the upper-right corner of the dialog box, and then click on any control.

Keyboard Operations

This table lists the most commonly used shortcut keys.

To	Press
Activate Help	F1
Activate Context-Sensitive Help	Shift-F1
Zoom in (limit 1600%)	PgUp
Zoom Out (limit 25%)	PgDn
Switch windows forward	F6
Switch windows backward	Shift-F6
Undo an operation	CTRL-Z
Redo an operation	CTRL-Y
Close an image	CTRL-F4
Close MaxIm DL	ALT-F4
Open a file	CTRL-O
Save a file	CTRL-S
Create a new file	CTRL-N
Access a menu	ALT-menu character (underlined letter in menu item).

Context (Right-click) Menu


Clicking the right mouse button anywhere in an image window causes a pop up menu (also called a context menu) to appear . The entries in this menu can vary depending on which MaxIm DL/CCD command is currently being executed, if any, and in some cases on exactly where in the image you clicked. The menu contains commands to manipulate the circular cursor described in Mouse and Keyboard Operations, configure the way in which the image is displayed, and fine-tune the pointing of an attached telescope. Other functions appropriate to the current activity may also be included; context menu entries of this kind are described along with the MaxIm DL/CCD command that places them there.

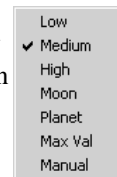
The most common variety of context menu looks like this:





The first three groups of menu items are used to control the size of the circles in the circular cursor. To adjust the inner circle, use **Increase Aperture**, **Decrease Aperture**, or the **Set Aperture Radius** sub-menu. To adjust the gap width between the aperture and the outer background measurement annulus, use **Increase Gap Width**, **Decrease Gap Width**, or the **Set Gap Width** sub-menu. Finally, to adjust the outer background measurement annulus, use **Increase Annulus**, **Decrease Annulus**, or the **Set Annulus Thickness** sub-menu.

Crosshairs simply superimposes blue vertical and horizontal lines across the centre of the image window. These can be useful when composing a CCD image. They are never stored as part of the image and do not affect the data, intensity measurements, etc.

The **Screen Stretch** sub-menu provides convenient access to the seven presets of the **Screen Stretch Window**. Selecting one of these is completely equivalent to changing the stretch mode drop-down combo box in the Screen Stretch Window. You can use this sub-menu without having the Screen Stretch Window open, even when working with commands that disable the  toolbar button.



Zoom In and **Zoom Out** are similar to the  and  buttons: they increase or decrease the image 'magnification' to the next step larger or smaller. But unlike the toolbar buttons, these scroll the image window so that the point that you had clicked the right mouse button on is centered, as far as that is possible. Think of them as "zoom here" and "unzoom here".

Point telescope here is enabled only when the image is the most recent image captured from the CCD camera, a telescope is connected, and telescope centering calibration has been performed. It slews the telescope by the necessary amount so that the next image is centered on the point where you clicked the right mouse button. This function is more fully explained in the description of the **Center Tab** of the Telescope Control Window.

Any additional context menu entries specific to the command currently being performed

normally appear at the top of the context menu.

Technical Support

Before requesting technical support, please review this manual for troubleshooting instructions.

When requesting technical support, you must include the following information:

- Your name as it appears on the license
- Telephone number
- E-mail address
- Version of Windows
- **Any error message displayed**
- **Describe step-by-step how the problem occurred.** We must be able to replicate the actions that caused the problem. If we cannot duplicate your problem it will be very difficult to resolve it.

To submit your message, please go to: www.cyanogen.com/support.

If you do not have web access, then you can submit by fax at (613) 225-9688.

Upgrades are available free of charge from our web site for a period of one year from the date of purchase.

Manual Conventions

In the text, Menus, commands, keys, and controls will be highlighted in **bold**.

“**Click** the mouse” always means **left-click** unless otherwise stated.

SHIFT-click means press and hold the **Shift** key while clicking the mouse. **CTRL-click** means press and hold the **CTRL** key while clicking the mouse.

“**Drag** the mouse” means **click** the mouse and move it while holding the button depressed. Release the mouse button when the desired effect has been achieved (brightness adjustment, rectangle drawing, etc.).

When describing keyboard operations, **CTRL-key** always means press and hold the **CTRL** key while pressing the designated key.

Chapter 2. Tutorials

We **strongly** recommend that the user read through the tutorials. They provide a basic introduction to MaxIm DL operations, including things that may not be entirely obvious to a new user at first glance.

The sample images used are available in C:\Program Files\Diffraction Limited\MaxIm DL V4\Samples (assuming default installation folder).

Image Processing Tutorials

These tutorials provide a basic introduction to image processing, including opening an image file, adjusting brightness and contrast, filtering, stretching, histogram specification, and saving.

The Adjust Brightness and Contrast tutorial is particularly important. Since MaxIm DL handles high bit depth images that your computer screen is incapable of displaying fully, knowing how to adjust the image appearance is critical to using the software effectively.

Open a File

The first and most basic step is to open and display an image file.

 Click on the **Open** button on the **Toolbar** to bring up the **Open** dialog.



Set **File Filter** to **All Files (*.*)** and turn **Interpolate Pixels to Square** off.

Use the **Look In** control to select the **Samples** folder under the **MaxIm DL** program directory. If you used the default installation directory, this directory will be located at:

C:\Program Files\Diffraction Limited\MaxIm DL V4\Samples

Click once on the file named **“DG_HaleBopp.fits.”** This is a CCD image of Comet Hale-Bopp taken while it was still far from the sun.

The **File Details** box should now display information on the file size, pixel width and height, and file format.


Click Open to open the file.


 If the image does not fit within the screen area, **click** the **Zoom Out** button on the **Toolbar**.

The image will appear as follows:



Adjust Brightness and Contrast

 If you have not already done so, open the **DG_HaleBopp.fits** file in the Samples directory. (For help on opening files see the **Open a File Tutorial**.)

 Make sure the **Screen Stretch** window is visible. If it is not, **click** the **Toggle Screen Stretch** button on the **Toolbar**.

The **Screen Stretch** window should look something like this:



The large histogram graph at upper left shows the relative number of pixels (vertical scale) at each intensity level (horizontal scale) in the image. The graph shows that most of the pixels are grouped on the left (dark) side of the histogram, and that the number of pixels drops off rapidly at brighter levels (right side).

The red caret (pointer) indicates the brightness level that is displayed as black on the screen. The brightness level of the red caret is indicated in **Minimum**. Similarly, the green caret indicates the brightness level that is displayed as white on the screen; this brightness level is indicated in **Maximum**.

Click on the drop-down list with the mouse and select **Low**. The image should change as follows:



The **Low Stretch** setting makes the image darker, allowing details in the brighter part of the comet to be visible. Try selecting the **High Stretch** setting and see what happens. Each of the three views reveals different parts of the comet. Note that selecting the stretch mode has no effect on how the image is stored; it only changes how it is displayed.

Quick Stretch

The fastest way to adjust the image brightness and contrast is to use the **Quick Stretch** control. This method gives instant updates as the mouse is dragged, and is particularly

fast for monochrome images. The **Quick Stretch** control is the shaded box at the upper right of the Screen Stretch dialog box.

Point the mouse at the **Quick Stretch** box and **press** and **hold** the **left** mouse button down. The mouse cursor changes to a “four arrows” shape. You can now adjust the image contrast and brightness as follows:

- Move the mouse **upwards** to **increase brightness**
- Move the mouse **downwards** to **decrease brightness**
- Move the mouse **right** to **increase contrast**
- Move the mouse **left** to **decrease contrast**

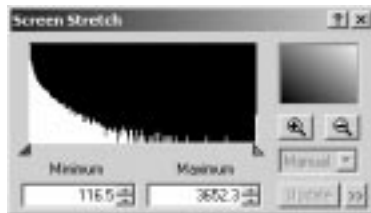


This function is also available without using the **Screen Stretch** window. Simply point the mouse at any image window. Hold down the **shift** key, then **press** and **hold** the **left** mouse button down. You can now make the same adjustments described above.

Manual Controls

Adjustments can also be made by adjusting the position of the pointers along the bottom of the histogram. **Click** and drag the **Green** caret (pointer) under the histogram image. This controls the brightness level that corresponds to full **white** on the screen; i.e. the maximum output level. Drag it right or left; when it is dropped, the image will update with the new settings. The **Maximum** field also updates to show you the corresponding brightness level in the image.

The **Red** caret controls the **black** or **background** level. Try adjusting it and see what the effect is. The **Minimum** field updates as you adjust the setting.



Placing the **Red** and **Green** carets close together produces a high contrast; conversely

placing them far apart produces a low contrast. Reversing the positions of the two carets (**Red** to the right of **Green**) will produce a negative image.

When moving the carets with the mouse, experiment with holding down either the **SHIFT** or **CTRL** keys. The **SHIFT** key makes the carets move together, keeping the contrast constant but changing the brightness. The **CTRL** key makes the carets move in opposite directions.

You can also modify the **Maximum** and **Minimum** fields directly by typing in a new number and then pressing **Enter**. **Note:** if you type in the numeric entry fields, you *must* press **Enter** or click **Update** for the new value to take effect.

When adjusting monochrome images by moving the carets with the mouse, the screen updates as you drag the caret. When adjusting color images, the screen does not update until you release the mouse button. Since updating color images is slower, this allows you to make large changes without having to wait for the updates.

Notes

Remember, these functions only affect the image *display*. They have no effect on the image buffer itself. This allows you to conveniently change the stretch at any time without affecting any later image processing operations.


Tip: The **Screen Stretch** window is normally left turned on, and can be accessed at almost any time – even while a dialog box is active. When a dialog box is active, you can adjust the stretch of the **Preview Image** using the **Screen Stretch** window. In most cases, if the **Preview** button is depressed, the **Preview Image** has separate stretch settings. You can stretch it by clicking on the dialog box, then adjusting the **Screen Stretch** window settings.


If the **Preview** button is not depressed, the **Preview Image** and main **image** window **share** the same stretch settings.

Filtering

Filtering allows you to smooth or sharpen an image. There are several types of filters, including **FFT**, **Kernel**, **Unsharp Mask**, and **Digital Development**. The latter two commands are particularly useful for enhancing astronomical images.

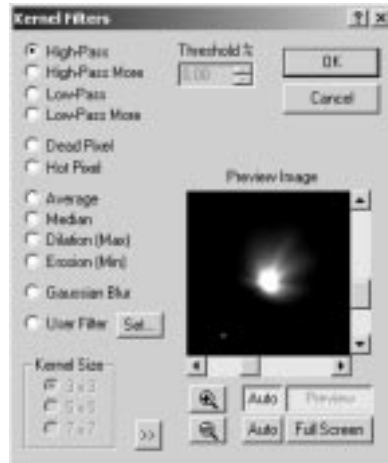
We will demonstrate the **Kernel Filters** command.

 If you have not already done so, open the **DG_HaleBopp.fits** file in the Samples directory. (For help on opening files see the **Open a File Tutorial**.)


 Click on the **Kernel Filters** button on the **Toolbar**. This will activate the **Kernel Filters** dialog.

Using the **left** mouse button and holding down the **CTRL** key, **click and drag** the **Preview Image** until the brightest part of the comet is visible, holding the button down while dragging. Then turn on the **Auto Preview** control, and select **High Pass More**. A high-pass filter sharpens the image; in this case, the image is fairly sharp already and the filter just increases the noise, making the image "grainy".

Now select **Low Pass More**. The **Preview Image** will appear smoother. **Click** on **Average**. The image will be smoothed slightly more. In this mode, the **Kernel Size** function is available. Select **7 x 7**, the strongest filter, and the preview image will become much blurrier.




Switch back to **High Pass More** and click **OK**. After a few seconds, the entire image will update.

 If you don't like this result, you can undo this change by pressing the **Undo** button on the **Toolbar**.

Be sure to try the various other filters mentioned above.

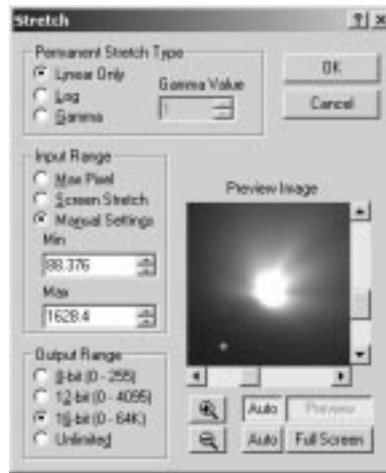
Stretching

Although the **Screen Stretch** window allows you to adjust the brightness and contrast of the image on the screen, sometimes you want to change the data in the image buffer. For example, you might want to adjust an image so it will fit in the 8-bit range of a JPEG file. You might also want to try a "non-linear stretch" to compress the dynamic range of the image. These operations are performed with the **Stretch** command.

 If you have not already done so, open the **DG_HaleBopp.fits** file in the Samples directory. (For help on opening files see the **Open a File Tutorial**.)

Press the **Stretch** button on the **Toolbar** to bring up the **Stretch** dialog.

Set **Permanent Stretch Type** to **Log**, **Input Range** to **Max Pixel**, and **Output Range** to **16 bit (0-64K)**. Turn on **Auto Preview**. As you can see in the **Preview Image**, these settings will dramatically compress the dynamic range of the image so that the brightest and faintest parts of the comet are both visible at once.




Perhaps this setting is a bit harsh. We can better control the amount of dynamic range compression by changing the **Permanent Stretch Type** to **Gamma**. Set **Gamma Value** to **0.2** and click **OK**.

Now set the screen stretch to **Low** using the **Screen Stretch** window. You can toggle back and forth between the processed and original version of the image using the **Undo** and **Redo** buttons on the **Toolbar**. Notice how the faint outer details in the comet are enhanced, but the brighter details are still visible.

Various effects can be achieved with the **Stretch** command; the following are some suggestions you can try:

- To prepare a file for export to a **JPEG**, **BMP**, **PNG**, or **8-bit TIFF** format, set **Permanent Stretch Type** to **Linear Only**, **Input Range** to **Screen Stretch**, and **Output Range** to **8 bit**. In this mode, you can adjust the **Screen Stretch** of the **image window** to change the **Input Range** settings; the **Min** and **Max** fields will update as you adjust the stretch.
- To greatly compress the dynamic range of an image, set **Permanent Stretch Type** to **Log**, **Input Range** to **Max Pixel**, and **Output Range** to **Unlimited**.
- To emphasize faint features, set **Permanent Stretch Type** to **Gamma**, **Input**


Range to Max Pixel, and **Output Range to Unlimited**. Reduce the **Gamma Value** to **below 1.0** and adjust until you are happy with the effect in the **Preview Image**.


At this point, some additional explanation of the **Preview Image** is in order. You will notice that the **Screen Stretch** window is still available; if it is not on, you can turn it on using the  button on the **Toolbar**. Which image the **Screen Stretch** window affects is determined by the state of the **Auto (Preview)** push button and by where the focus is, that is, on which window you last clicked. If **Auto** is **off**, both the image buffer and the **Preview Image** always adjust together. If **Auto** is **on**, the **Preview Image** actually becomes a different image and is separately adjustable. When you start a command dialog, or after clicking on it, the **Preview Image** has the focus and is therefore adjusted. If you click on the main image window or its title bar, it gets the focus and the **Screen Stretch** window will now adjust it instead. To adjust the **Preview Image** again, click anywhere on the dialog box.

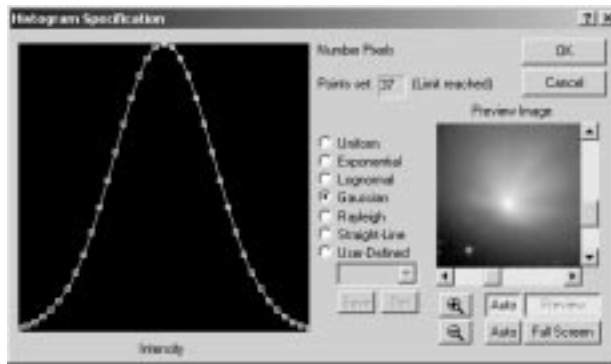
You can also preview the result of the processing on the **Full Screen**. Refer to the documentation of the **Preview Image** in the Command Reference for details of **Full Screen** previewing.


Histogram Specification

Histogram Specification is similar to Log or Gamma stretching, but allows more direct control by allowing you to specify the exact shape of the desired histogram.

 If you have not already done so, open the **DG_HaleBopp.fits** file in the Samples directory. (For help on opening files see the **Open a File Tutorial**.)

 Click the **Undo** button on the toolbar to remove the stretch from the previous tutorial.



 Select the **Histogram Specification** command on the **Process** menu. Select the **Gaussian** option and click **OK**. Since this command can significantly change the

dynamic range (min and max values) of the image, you may want to adjust the **Screen Stretch** window settings after processing completes. In this case, setting the mode to **Low** gives pleasing results.

This processing highlighted the outer tail of the comet, but did not saturate the inner core. Histogram specification is useful for making details visible simultaneously at greatly differing brightness levels.

Try experimenting with different settings, including manually-drawn histogram shapes. When drawing manually, it is often easier to start from the **Straight-Line** or **Uniform** options and then modify the graph: **click** on the graph shape to add a point, or move an existing point by **dragging**. (If you drag a point left or right past its neighbor, the neighbor will be removed automatically.)

Deconvolution

We will now sharpen an image of galaxy NGC4565 using *Deconvolution*. The image was taken with a PC-Lynxx CCD camera and a 16-inch telescope that was out of alignment (collimation) resulting in a distortion called **coma**, which makes the stars look like “V” shapes. We will remove the effects of the collimation error and reduce the effect of atmospheric seeing.

In this tutorial, it is assumed that MaxIm DL has just been started. (To start MaxIm DL, **click** on the program icon under the **Start** button’s **Programs** sub-menu.) It is also assumed that the toolbars are visible. If not, use the **View** menu **Toolbar** command to switch it on.

 Open the **N4565.CCD** image in the **Samples** directory. (For help on opening files see the **Open a File Tutorial**.)

 **Click** the **Zoom In** button on the **Toolbar** once. Notice how the star images are distorted by the collimation error.

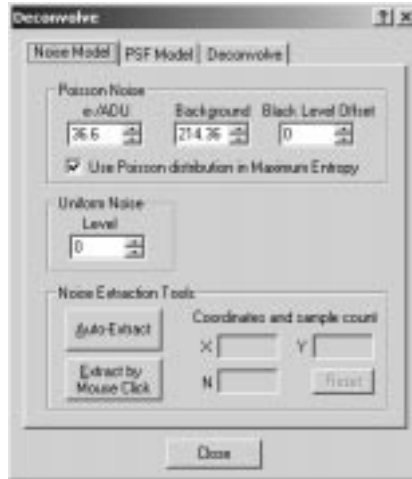
Go to the **Filter** menu and select **Deconvolve**. A tabbed dialog box will appear, with **Noise Model**, **PSF Model**, and **Deconvolve** tabs.

First we need to set up the noise model. This helps the deconvolution algorithm account for noise in the image. Enter 36.6 **e-/ADU**, the photoelectrons per ADU or Gain of the CCD camera. This is necessary in order for the noise model to match the actual statistics in the image. The value entered here is for the PC-Lynxx camera; for images from your CCD camera you can use the **Photons Wizard** to determine the correct value.

Next turn on **Use Poisson distribution in Maximum Entropy**.

To determine the correct background level, click **Auto Extract** under **Noise Extraction**

Tools.



Next, we will choose a Point-Spread Function (PSF) model. This model tells MaxIm DL how the image was blurred, so that it can try to remove the blur from the image. **Click** the **PSF Model** tab. Select **From Image** for **Function Type**, turn off **Clean Up**, and **click Select From Image**.




Adjust the **circular cursor** to a radius of 8 pixels (as shown in the **Information** window) by **right-clicking** and selecting the appropriate radius. **Click** on the bright star in the lower center of the image (if necessary, you can move the dialog out of the way by dragging the title bar).

Click the **Deconvolve** tab. Set **Image** to **Actual**, and **Number of Iterations** to **15**. Choose either **Maximum Entropy** or **Lucy-Richardson** deconvolution. Click **Go**.



Watch the iterations proceed on the image. When the processing is complete, alternately hit **Undo** and **Redo** to see what the effect is on the image.

Saving the Image

 If you have not already done so, open the **DG_HaleBopp.fits** file in the Samples directory. (For help on opening files see the **Open a File Tutorial**.)



On the **File** menu, choose the **Save As...** command. Set **File Format** to **JPEG**. Turn off the **Auto Stretch** check box.

The **File Details** box will now show: *"Warning: Selected file format cannot*

accommodate largest pixel value in image. Please enable Auto Stretch or use Stretch... button to scale image."

Now turn **on** the **Auto Stretch** check box. The message will change to, "*NOTE: Maximum pixel value exceeded. Auto Stretch will rescale image buffer.*"

When **Auto Stretch** is on, any image that will not fit into the range of the file format is automatically adjusted based upon the current **Screen Stretch** settings. This means that any data outside the range displayed on the screen will be lost, so make sure this is what you really want to do.

(If you want to adjust the stretch manually, click the **Stretch** button. The **Stretch** dialog will appear. If you set **Permanent Stretch Type** to **Linear Only**, **Input Range** to **Screen Stretch**, and **Output Range** to **8 bit**, you will get the exact same result as **Auto Stretch**.)

Now click **Save** to save the file.

Camera Control Tutorials


The MaxIm CCD camera control window is a powerful utility with many options and modes of operation. It is highly recommended that new users follow this tutorial to learn the basic concepts of operating the camera.

The tutorial uses a CCD camera simulator. The simulator behaves like a CCD camera but requires no actual hardware. It generates an image of five "stars", and includes the ability to add random noise to the image. It can simulate the behavior of an autoguider, including simulating periodic error, random drift, and guiding corrections. It also simulates the operation of a color filter wheel.

The CCD camera simulator emulates a dual-chip camera, similar to the SBIG ST-7 series. The operation is identical if you are using separate CCD cameras for the main imager and autoguider.

You can also configure the same single-chip CCD camera to be both the autoguider and main camera; however only one of the functions (expose or autoguide) is available at a time. This can be handy when focusing the autoguider.

Basic Setup

1. Start MaxIm DL and open the camera control window by clicking on the  toolbar button.



2. Move the **MaxIm CCD** camera control window to a convenient location on the screen. To do this, point the **mouse** at the **title bar**, **click and hold the left mouse button**, and **drag**.
3. The **Setup** tab should appear first; if it is not displayed click on the **Setup** tab near the upper right corner of the window.
4. Select **Simulator** for the **Main CCD camera** by clicking on the associated **Setup** button, and picking **Simulator** for the **Camera Model**. Also, set **Noise** to **Off**, **Guide Errors** to **Both**, **FWHM** to **Default (5)**, and **Guide Angle** to **45 degrees**. Click **OK**.



5. Control returns to the **Setup** tab. Now set up the **Autoguider**. Click the associated **Setup** button, and set the **Camera Model** to **Same as main camera**. The simulator works like two separate cameras; one as the main camera, the other as the guider.



- Next set up the filter wheel. Click the **Setup** button, and select **Filter or Controlling Camera Model to Simulator**. Type in **Red** for **Filter 1**, **Green** for **Filter 2**, and **Blue** for Filter 3. Click **OK**.



- Now we are ready to connect to the equipment. Click **Connect**.
- The Simulator's main camera has a programmable temperature. Click **Cooler On** to activate it, and then click the associated **Cooler** button to set the temperature. Set the temperature setpoint to -20 degrees C and click **OK**. **Note:** At the end of an imaging session, you should click the **Warm Up** button and wait for the temperature to return to ambient before turning off the cooler or disconnecting from the camera.



- Once all of these settings are made they will be remembered. The next time you want to start MaxIm CCD, just click the **Connect** button and then **Cooler On**.

Focusing

After setting up the camera and initializing the cooler, the first step in using a CCD camera is to focus.

Tip: when using two cameras, set up the autoguider initially as the main camera and use the built-in main camera focusing tools. Then switch it over to be the autoguider, and set up the main camera.

- Select the **Focus** tab by **clicking** on it with the **mouse**. The **Focus** tab includes many of the controls from the **Expose** and **Settings** tabs, but condensed into one compact

form

The **Focus** tab settings are completely independent of the **Expose** and **Settings** tabs. This means that you can have two completely different sets of exposure settings and flip back and forth quickly between the two.

- The simulated camera doesn't have any dark current, so turn off the **Dark** control to save time. Usually this is turned on to provide a lower-noise display, but can be disabled to speed things up slightly.



- Turn **Continuous** mode **off** for now. **Continuous** mode takes a series of images that can be stopped by clicking **Stop**. This mode is useful when you want fast updates while you adjust the focuser.
- Set an exposure of 1 second using the **Seconds** field. You can use the up/down "spin" control (arrow) buttons to rapidly dial from 0.001 second (0.01 seconds for some cameras) to thousands of seconds.
- Set the **Delay** to 0 seconds. If a delay is set, there will be a brief pause between exposures. For some cameras the controls are locked out during download to prevent pattern noise; in this case, a slight delay may make it easier to operate the controls, particularly in **Continuous** mode.



- Click **Start Focus** to take an exposure. After a few seconds, a simulated CCD image

appears.

7. Most cameras are too slow for easy full-frame focusing. To speed up the focus download, select a subframe. To do this, point the **mouse** just to the top-left of a star, **hold down** the **left mouse button** and **drag** to create a rectangle around the star as shown above. The subframe settings will be automatically entered. (You can also automatically select a small subframe by clicking the **Auto** button. To restore full-frame imaging, click **Reset**.)
8. Click **Start Focus**. Only the selected part of the image will be downloaded. Most cameras will operate much faster if a subframe is selected.
9. Click on the **Inspect** tab.



10. The **Inspect** tab will show a three-dimensional representation of the star image. The narrower the star the sharper the focus. The **X**, **Y** position of the selected star is also shown, along with the Full-Width Half Maximum (FWHM) horizontally and vertically, and the maximum pixel value (**Max**).
11. If we were connected to a real camera and telescope, we could now adjust the focus. The **Start Focus** and **Stop** buttons duplicate those on the **Focus** tab; other focusing options, including **Continuous** mode, must be set on that tab. Adjust focus until the graph shows a narrow peak, the **FWHM** values are as small as possible, and **Max** is as large as possible. Note that the **Max** value will usually bounce up and down due to seeing; when very close to focus you should take the best of several readings.

Aiming the Telescope

Aiming a telescope cannot be illustrated easily in this simulation, but a few pointers are in order.

Once the telescope is in focus, the biggest challenge can be finding your the target. CCD cameras do not have a viewfinder, and it can be very frustrating to aim if the images take more than about 20 seconds to appear. It can also slow things down if you have to keep changing exposure settings. All this can be solved using the focus mode, as follows:

1. Use the **Focus** tab for aiming instead of the **Expose** tab. This way you don't have to keep changing the settings – the two tabs have completely separate settings.
2. Use a high binning factor for aiming. **Binning** combines multiple pixels into one "super-pixel" with greater sensitivity.
3. Take a short exposure. With a binning factor of 2 or 3, most cameras will show a faint but usable image with an exposure of only 10 seconds.
4. Use the telescope hand paddle (or a software control panel) to move the image. If you insert the camera so that North is at the top, you can orient the paddle to match. Calibrate yourself by seeing how far a count of five will move the image. You can then position the object just by holding down a button and counting. Note that RA and Dec will generally have different rates.
5. Once you're aimed, switch over to the **Expose** tab and take pictures.

Note that some cameras have an optional "high-speed" mode which takes less time to download but produces a lower quality image. Depending on the camera, this can be enabled in the camera's **Setup** dialog box. If enabled, fast readout will occur automatically in **Focus** mode but not in **Expose** mode.

You will also want to look at the **Telescope Control** window. If you have a "Go To" telescope mount, this control can make centering objects quick and painless.

Taking Exposures – Basic

Now that we have the target object focused and in our camera's field of view, it is time to take some images. CCD cameras can collect a usable image in only 30 or 60 seconds, but the best results are always obtained by taking longer exposures.

1. First check your settings. Bring up the **Settings** tab.



2. Click the **Reset** button to make sure the entire CCD chip is selected. When this tab is visible, you can set subframe settings by **dragging the mouse** on the image (same as **Focus** mode).
3. Most cameras support binning, which allows you to combine pixels for higher

sensitivity at the cost of resolution. For the highest resolution, set the **Binning** controls to 1. (Some cameras, including the simulator, do not support different binning in the X and Y directions; in this case, the **Y** field is disabled.)



4. **Options** allows you to flip or mirror the image on download, as well as lock the MaxIm CCD window on top.
5. **Auto Calibration** can be set to automatically calibrate each image as it is taken. The **Simple Auto-dark** mode will automatically take a new dark frame whenever the exposure settings are changed. For better performance, use the **Full Calibration** option. This applies all the calibration capabilities of MaxIm DL's **Set Calibration** command. This is highly recommended if you want maximum performance from your camera. For now, leave **Auto Calibration off** – the simulator is "perfect" and doesn't need any calibration.



6. Next, switch to the **Expose** tab. Set **Type** to **Light** (normal image frame), dial in an exposure of a few seconds using the **Minutes** and **Seconds** fields, set **Delay** to zero, and the filter selection to **Red**.
7. Click **Expose** and the test pattern will appear.

Taking Exposures – Advanced

We can now proceed to more advanced camera control operations.

1. Click on the **Sequence** tab.
2. This tab allows you to set up a set of monochrome, tricolor, or multi-filter

exposures.

3. Enter a base file name such as “Test Image” in the **Autosave Filename** field. The filenames for Individual exposures taken by the sequence will be composed of this, a sequence number, and a filter-specific suffix.



4. Click the **Options** button, select **Set Destination Path** from the resulting menu, and browse to a convenient location on your hard drive to save the images. Click **Open** when you have found the correct folder.
5. Select the **Setup Sequence** command to configure the exposures.



6. As shown in the diagram, enable the first three slots, and disable the rest by clicking on the appropriate **Enable** check boxes. Use the scroll bar at the right-hand side to view slots 7–16 and make sure they are also disabled.
7. Set the exposure **Type** for slots 1, 2, and 3 to **Light**. Set their **Filter** selections to **Red**, **Green**, and **Blue** respectively and enter **R**, **G**, and **B** in the corresponding **Suffix** fields. When the images are taken, the suffix will be added to the end of the file name to designate the particular slot (exposure type, filter identification, etc.).
8. Set the **Exposure** time for each slot. For the purposes of this tutorial, you can set them to 1 second so the images will appear more quickly.
9. Set the **Binning** factor to 1 so the images will download in full resolution. The range of this field is automatically limited depending on what model of camera you

are using.

10. Select **Same Repeat Count for All** from the **Options** menu at the bottom of this dialog, then set the **Repeat** count of the first slot to the number of exposures to be taken. Use **3** for the purposes of this demonstration.
11. If the **Script** entry for any enabled slot is non-blank, make sure **Same Script Name for All** is checked in the **Options** menu. Then click one of the buttons and click on **None**.
12. Set **Delay First** and **Delay Between** to zero. These can be set to provide delays before the first image in the sequence, and/or between individual images in the sequence. Delays are measured in seconds.
13. Set the desired exposure ordering. If **Group by Slot** (in the **Options** menu) is checked, all red images will be taken consecutively, followed by all green, followed by all blue. If **Group by Slot** is not checked, MaxIm CCD will take one exposure of each color and then repeat the cycle.
14. Click **OK** to return to the **Sequence** tab.
15. Make sure none of **Dither Images via Guider**, **Dither Images via Mount**, **Capture Mosaic**, **Continue Mosaic** or **Astrometric Resynchronization** is checked in the **Options** menu. These are advanced features described in the reference section for the **Sequence Tab**.
16. Turn on **Overwrite Files** in the **Options** menu. This makes sure that your exposure sequence doesn't stop if you hit a pre-existing file. **Note:** when operating in the field, turn this **off** if you want to make sure you don't overwrite anything; turn it **on** if you want to be sure your exposure sequence never stalls.
17. **Warning:** Incorrect use of the **Overwrite Files** setting could result in lost data.
18. Select **Full Frame** in the **Options** menu. (If you wanted to use the subframe defined on the **Settings** tab, you would select **Subframe from Settings tab** instead.)
19. Enter **1** in the **Start at** field. The images will be saved as Test Image001R.fit, Test Image001G.fit, Test Image001B.fit, Test Image002R.fit, etc.
20. Now click the **Start** button. The camera will start taking exposures. You can monitor the progress on either the **Sequence** or **Expose** tab. When the image sequence is complete, check that all the files you expected to see were actually created.

Tip: You can use the **Sequence Wizard** command in the **Options** menu to create several different types of sequences including the tricolor RGB sequence of this example. The **Sequence Wizard** performs the equivalent of steps 2–10 of the above

procedure.

Autoguiding


Autoguiding appears at first to be a rather complex task. However, the autoguider controls in MaxIm CCD are actually quite easy to operate.

This tutorial demonstrates the operation with the simulator, which behaves like a dual-chip CCD camera/autoguider. The operation is the same when using two separate cameras for these functions. It is also possible to configure the same single-chip CCD camera to operate as both the main camera and autoguider; in that case, only one function (expose or guide) is available at a time.

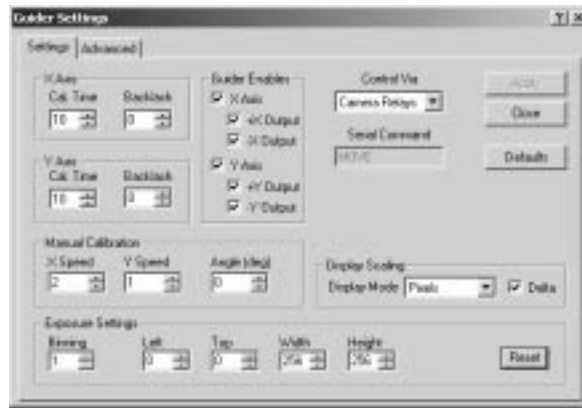
Tip: When using separate imaging and autoguiding cameras, first start the guider running. Once it is operating, switch to the **Expose** tab and start the camera. The guider keeps running until you stop it, even if you are using a camera with a built-in autoguider such as the SBIG ST-7, ST-8, ST-9, or ST-10. You can take as many exposures as you want – you can even run a tricolor exposure sequence.

1. Switch to the **Guide** tab.



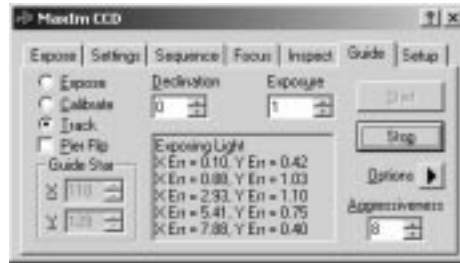
2. First, we should set up a few things. Click on the **Options** button  and make sure that **Watch Star** and **Auto Dark** are checked. This will cause MaxIm CCD to display autoguider exposures during tracking so we can monitor the star. Set an exposure of, say, **0.5** second. Select the **Expose** guider mode radio button and set the **Declination** to zero. Select the **Guider Settings** command from the **Options** menu.
3. Click the **Defaults** button and click **Yes** to confirm that you want to set all fields to their recommended initial values. (The **Manual Calibration** and **Exposure Settings** controls are excluded.) Among these are:
 4. The **Cal Time** controls specify how long MaxIm CCD will "hold the button down" (i.e., actuate the telescope guiding motors) during guider calibration, before measuring how far the star has moved. Calibration is an essential step to determine how fast the guiding motors move the telescope and thus how much correction to apply for a particular measured position error. (Note: if there is a speed control, it


should be set to 0.5X or 1X for guiding purposes.) **Cal Time** is measured in seconds and can be specified independently for each axis.



5. The six check boxes in the **Guider Enables** group are all turned on, enabling guiding in each axis, and enabling guiding motor operation in each direction.
6. **Control Via** is set to **Camera Relays**. This setting informs MaxIm CCD how the guiding motors (or in this case simulator) are controlled.
7. **Display Mode** is set to **Pixels**, with **Delta** should be on. This causes measured guide star positions to be converted to errors from nominal and displayed in units of camera pixels.
8. Make sure **Binning** is set to 1 and click the **Reset** button to reset the subframe settings.
9. Select the **Advanced** tab of the **Guider Settings** dialog, click its **Defaults** button and confirm that you want to set all fields to their recommended initial values. If a filename appears in **File Path**, click **Clear**.
10. **Click OK** to return to the **Guide** tab. These settings only need to be made once; they are remembered the next time you start the software.
11. Now click the **Start** button. After a few seconds the simulated **Autoguider Image** will be displayed. The brightest star will automatically be selected as the guide star. With a real autoguider, if you wanted to select a different star, you would **click on the star**. *Do not draw a box around it!*
12. Now switch the guider mode to **Calibrate**, and click the **Start** button again. The camera will take a series of pictures; each time moving the simulated "telescope mount" by sending a command to the simulated "autoguider relays." The stars will move to the right, back to center, downwards, and back to center again (with real

autoguider the actual direction depends on the orientation of the camera). As it does so, red lines are added to the **Autoguider Image** indicating where the guide star has been. Each motion must be long enough (20 pixels or so) to ensure a good calibration, but not so far as to move off the CCD chip. That is the reason for the **Cal Time** setting.



13. We're now ready to guide. Switch the guider mode to **Track** and click **Start**. The **Autoguider Image** is reduced to the small 32x32 pixel image used during tracking. You can zoom in on it using the  button on the **toolbar**. The simulator imitates some large guider errors, so you'll be able to see the star moving off-center and then being pulled back again.
14. You can now switch to the **Expose** tab and start an exposure. Note that a minimum five second delay is forced for exposures on the main CCD. This is to allow time for the autoguider to settle between exposures. If needed, this delay can be increased by setting **Delay (s)** to a higher value.

A few final notes. The calibration settings change if you move the telescope in declination. To avoid having to recalibrate for every image, you can use declination compensation. Set the **Declination** field to the declination of your calibration star before you calibrate. Then reset the **Declination** value whenever you change guide stars. If this is done, you should never need to recalibrate; in fact, if you always insert the autoguider into the telescope in the same orientation, you won't even have to bother recalibrating each night. If you have a "GOTO" telescope, you can configure the MaxIm DL to update the **Declination** value automatically by setting **Use Scope Dec** in the **Options** menu; see the **Telescope Control Tutorial** for details on connecting to your telescope.

If you have a large amount of backlash in your mount, you might want to adjust the **Backlash** settings. Be careful not to set them too high, or it will make things worse instead of better.

Shutdown Procedure


It is a good idea to properly warm up the CCD cooler before closing MaxIm DL/CCD, unless you plan to restart the software.

To avoid thermal shock, many camera controllers have a means to gradually ramp up the CCD chip to the ambient temperature. This can be done using the **Warm Up** button on the **Setup** tab. The period of time required for the warm-up depends on the particular camera model; some cameras switch off quickly, while others gently raise the temperature over an extended period of time.

Most camera models allow you to force the cooler to switch off rapidly by clicking **Cooler Off**.

Telescope Control Tutorials

Basic Control

1. The first step is to set up a telescope. For this tutorial we will use the Telescope Simulator. Activate the Telescope Control window using the  **toolbar** button or **Telescope Control Window** from the **View** menu.



2. On the **Setup** tab, select **Telescope Simulator** from the **Telescope** drop list. Click **Connect**.
3. The **Scope Simulator** display may appear. Move this to a convenient place on the screen.
4. Click the **Options** button in the **Telescope** frame and click on the **Slew Limits** command. Ensure that neither **Minimum Altitude** nor **Maximum Declination** are checked.



5. Switch to the **Telescope** tab.

- Click a **Nudge** button to move the telescope in one of the eight available directions. You will see the telescope position change. You can set the distance moved with each nudge.



- After a nudge or move, if the **Take image** check box is on, the **MaxIm CCD** camera control window will also be activated to take a picture of the region of the sky. (If the camera simulator is selected, you will get the test pattern). You can set up exposure settings for these images using the **Exposure** button. Usually this is just set to a quick binned exposure so you can tell whether the telescope is on target.
- You can enter a position in the **RA** and **Dec** fields. You can enter a Right Ascension as hours, hours and minutes, or hours, minutes and seconds; similarly a Declination can be expressed as one, two, or three numbers. The last number entered can have decimal places; e.g. 12 34.5 is the same as 12 34 30. Click **Go To** to start the telescope moving. **Abort** will stop the telescope motion.
- You can define the observing location by clicking the **Site** button. This is required when determining the locations of the planets or if you want the telescope's azimuth and elevation displayed in the status area. It is also recorded in the FITS header of any images taken.
- Now switch to the **Catalog** tab.



- Set **Object type** to **Deep sky**, and click the drop-down list arrow. Pick **Messier**, and type the number of a Messier object (e.g., 32). You can use the mouse and the displayed "keypad" (convenient when working in the dark), or the computer keyboard. Click **Go To** to slew to the object.

- Click the **Nearby** button. This brings up the Nearby Objects dialog box.



- In **Included catalogs**, turn on the Messier and NGC check boxes, and turn off the others. Set **Brighter than mag** to magnitude 10, and the **Max slew distance** to 10 degrees. Turn off **Include objects with unspecified magnitude**. Click **List objects**. Click on an object (e.g., NGC185) and its **RA** and **Dec** are displayed. Click on **Go To**, or double-click on the object name, and the telescope will slew to the object.
- When working with a real telescope, you can also synchronize or "align" the telescope position. Slew to an object, say a bright star on the **Named Stars** list, and center it using the **Nudge** controls on the **Telescope** tab (or see below for Auto Center). Then click the **Sync** button to update the telescope controller's coordinates to that of the object. Alternatively, use the **PinPoint Astrometry** function on the **Analyze** menu to calculate the exact center of the image, and click **Sync** to align on the measured position.

Auto Center

Auto Center permits extremely rapid object centering. This tutorial will require a real telescope and camera operating under the night sky. We will assume that the **Telescope Control** is already linked to a telescope, and the **MaxIm CCD** camera control window is linked to a camera.

- Make sure the Telescope is synchronized on the sky so that the Right Ascension and Declination matches the telescope position. Also make sure the CCD camera is focused and ready to go.

2. Select the **Center** tab. Select the **Calibration Type** to **Auto**. Set the **Auto Slew Distance** to **8** arc minutes (note: if your camera has a smaller field than this, reduce the number; it should be set to about 1/4 of the field size).



3. Locate a reasonably bright, isolated star and roughly center it in the camera. This can be done using the **Catalog** tab to find the star, and the **Telescope** tab **Nudge** controls. Set the **Exposure** settings to reasonable values.
4. Click **Calibrate**. The software will take an image and measure the current star position. It will then slew east and take a second image. The difference in position between these two images will be used to calibrate the **Image Scale** and **Orientation**. The telescope will be returned to the original position and a third image will be taken to confirm this.
5. Once the function is calibrated, you do not need to repeat the operation unless you rotate the camera or change equipment. Removing and replacing the camera will very likely change the angle, so you should recalibrate.
6. Now you can center any object on the image. Simply **right-click** on it and select **Point Telescope Here** from the right-click menu. The telescope will slew a short distance. If **Acquire new image after centering** is checked (recommended), a quick exposure will be taken after each centering movement.

Autofocus Tutorial

Autofocus requires a compatible digital focuser (see Telescope Control Reference). This tutorial assumes you have the camera already linked and attached to a working telescope.

1. The first step is to set up the focuser. Activate the Telescope Control window using the **telescope toolbar** button or **Telescope Control Window** from the View menu.
2. Select your focuser model using the **Focuser** drop list on the **Setup** tab. Click the Focuser **Options** button and select the **Setup** command from the displayed menu to configure the communications port if required. Click the Focuser **Connect** button to

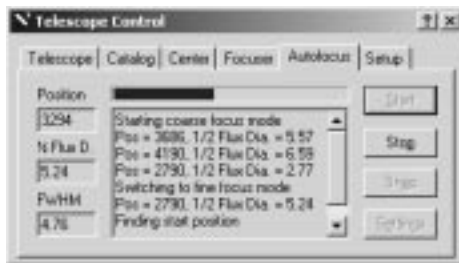
establish the link with the focuser.



3. If you have a computer-controllable telescope you can set it up and connect it as well. This is convenient for adjusting the telescope pointing but not required.
4. Switch to the **Focuser** tab.



5. Check that you can adjust the position of the focuser. Change the **Absolute** position value and click **Move To**. The focuser should move to the new position. You can also adjust incrementally; set the **Incremental** step size to 50 and click **Move In** or **Move Out**. Take an image with the camera to verify that the focuser is actually moving and the focus is changing.
6. Now switch to the **Autofocus** tab.



7. Before starting autofocus, click the **Settings** button. There are several parameters that must be set up correctly for autofocus to work.

8. The **Telescope Focal Ratio** is essential. It determines the depth of focus, and therefore the step size that is used when hunting for best focus. The focal ratio is often found in the telescope manual; it can also be calculated by dividing the focal length by the aperture.



9. Also essential is the **Focuser Step Size**. Some digital focusers know what this is inherently; you can click the **Auto** button to fill in the information. Other digital focusers do not have this information; they are just motors hooked up to focusers from other manufacturers. In this case, take out a ruler! Move the focuser 1000 steps, measure the distance it moves, and divide that by 1000. Enter that into the Focuser Step Size (be sure to set **Microinches** or **Microns** as appropriate). (Tip: if you cannot see the focuser move, as for a Schmidt-Cassegrain telescope, focus the telescope with an eyepiece, move the focus out 1000 steps, and then pull the eyepiece out of the focuser until the image is sharp. Measure the distance the eyepiece is moved.)
10. You also need to set the **Target $\frac{1}{2}$ Flux Dia.** The Half Flux Diameter is a measure of how large the star images are, in pixels; obviously we want them to be as small as possible. The target needs to be set somewhat higher than the optimum; typically by 2 pixels. This is required because the measurements are made on either side of focus, not right at focus. Typical values are 5 to 7, but it depends on how small your star images are at best focus.
11. You should also set up the exposure for the camera. In the **Find** mode (coarse focus), the images are usually binned to speed up readout; usually **Bin 2x2** will do. The **Subframe Width** and **Height** are used during fine focus; smaller values speed

up the process, but if they are too small the star may shift out of the box and the focus procedure might fail.

12. Once the settings are made, click **OK** to close the dialog box. Usually you only need to set these once. After this, focusing requires but a single click!
13. Now click the **Start** button. Focusing takes a minute or two as MaxIm CCD first performs coarse focusing, then switches to fine focus mode and determines the change in star image size on both sides of the region of best focus, and finally computes and moves to the optimum focus position. As long as there is a reasonably bright star visible which is not ridiculously out of focus (Half Flux Diameter less than about 70), autofocus will bring it into accurate focus.

Chapter 3. Guide to CCD Imaging

This section introduces the essential concepts required for capturing, analyzing, and processing images using MaxIm DL.

For a basic introduction to using MaxIm DL, we strongly recommend reading the tutorials in the previous section.

CCD Sensors

Imaging is the process of detecting light from a scene and creating a digital representation of it. There are several types of imaging detectors in use today, but the most common for high-performance applications is the Charge-Coupled Device or CCD. When a photon (an individual “particle” of light) strikes an atom of silicon in the CCD sensor, it excites an electron into a higher energy state. Because silicon is a semiconductor; electrons are only free to move when they are in this higher energy condition, called the *conduction band*. Once enough excited electrons (*photoelectrons*) have accumulated, they can be read out and digitized.

In order to make a detector capable of forming images, you need more than one detector. A CCD contains thousands or millions of light-sensitive “pixels” in an array. In a CCD array, the pixels are defined by insulating strips in one direction, and by a set of electrodes in the other direction. The charge in each pixel can be slid down the array simply by changing the voltage on these electrodes. The electrons (electrical charge) that accumulate in each pixel are shifted (coupled) from one pixel to the next until they reach a readout register along one edge. It shifts the charge one pixel at a time into a readout amplifier in one corner of the device. This process gives the sensor its name, the Charge-Coupled Device.

Many modern devices use CCD detectors, such as video cameras and point-and-shoot digital cameras. Low-light and scientific-grade imaging cameras use special techniques to minimize noise and maximize sensitivity.

High-Performance CCD Cameras

The biggest limitation to the performance of low-light cameras is “dark current.” It turns out that light is not the only thing that can excite electrons in the detector. Heat – which is simply the vibration of individual atoms – can occasionally bump an electron up into the conduction band. The warmer the array is, the more likely this is to happen; dark current typically doubles with every 5 to 8 degrees Celsius increase in temperature.

This causes two problems. First of all, if the dark current production rate is high enough, it will swamp the detector. Each pixel has only a limited capacity to store electrons (the “well capacity”). For most sensors, dark current can fill the well in a matter of seconds at room temperature.

A second problem arises because of the randomness of the dark current. Although it accumulates at a steady average rate, the dark current is quite random. The more dark current that accumulates, the more random *noise* it contributes to the image. Noise makes it difficult or impossible to detect the *signal* – photoelectrons produced by photons; in order to detect an object reliably, you need at least three times as much signal as noise. For low-light levels and long exposures, some means of reducing dark current is essential.

Since dark current increases with temperature, the obvious solution is to cool the sensor down. Scientific-grade cameras typically operate at freezing temperatures – typically anywhere from 0° C to -70° C. Some CCD sensors are specially designed to minimize dark current and can operate near the upper part of the range; others require more cooling. The cooling may be provided by liquid nitrogen, or by more a convenient but less powerful thermoelectric cooler (TEC).

Large well depth is also important for good performance. For highly accurate measurements, very good signal-to-noise ratio (SNR) is required, meaning that more photoelectrons must be detected. A larger well allows more electrons can be collected, resulting in more accurate measurements. Large well depth also results in greater *dynamic range*; that is, the range of brightness over which the sensor will operate. At the bottom end is the *noise floor*, below which the SNR is inadequate for detection. At the top end is “saturation”, where the well fills up and may even start to *bloom* (bleed into adjacent pixels). A high dynamic range is extremely important for imaging astronomical targets, which have extreme differences in brightness levels.

Low well depth cameras limit the number of digital light levels that can be extracted from the pixels. There is no point in recording too much below the noise floor, nor too much above the saturation level. Smaller pixels make for lower well depths; point-and-shoot digital cameras often cannot produce even 256 different discernable levels (8-bit images). High performance CCD cameras can often produce 65536 levels (16-bit), although quite a few cameras are marketed as being 16-bit when they cannot produce nearly that many distinct brightness levels.

The images produced by CCD cameras are not perfect. Each pixel in each camera tends to produce a particular voltage offset, rate of dark current production, and sensitivity to light. These flaws can be very accurately corrected using calibration frames, one each for offset (the bias frame), dark current (the dark frame), and sensitivity variations (the flat-field frame). Calibration makes a huge difference to the accuracy and sensitivity of the camera; therefore calibration is also one of the most important functions of MaxIm DL.

Using CCD Cameras

CCD cameras can be difficult to use at first, particularly in astronomical applications. This section describes some useful techniques for the efficient use of CCD cameras.

Polar Alignment

Good telescope polar alignment is important for long-exposure CCD imaging. When acquiring targets using the small field-of-view typical of many CCD imaging systems, accurate positioning requires good polar alignment. Inaccurate alignment also leads to drift, which limits the amount of time an exposure can be taken before the stars begin to blur. Even if you are autoguiding, larger drift makes for more corrections and potentially lower guiding accuracy. Finally, with large CCD frames and high declinations, field rotation becomes a significant factor.

Polar Alignment Scope

Many telescopes include a “polar alignment scope.” These can work reasonably well if they are aligned properly with the mount. Unfortunately they rarely come from the factory aligned with the polar axis, and some of these devices change alignment if the focus is adjusted! Even if they are well adjusted, the accuracy of the polar alignment is limited to the resolution of the alignment telescope.

Telescope mount modeling software, such as MaxPoint, builds up a model of mechanical errors in the mounting by looking at the difference between the commanded position and the actual telescope position. This naturally includes the polar alignment error, which can simply be read off as a pair of numbers. Achieving accurate results requires measuring the pointing error at a number of points spread around the sky, and the process has to be repeated from scratch every time an adjustment is made to the system. Although this procedure can be a little time-consuming, it does work very well if a sufficient number of measurement points are used.

Drift Alignment

A technique known as Drift Alignment has been used for many years, and can achieve an extremely accurate polar alignment. Unfortunately it is very time consuming, since the drift of a star over time must be observed. This can be greatly speeded up using a CCD camera, since sub-pixel centroid measurements can easily be made. Here is a suggested procedure:

1. Mount your CCD camera with north at the top.
2. Connect MaxIm DL/CCD to the camera, configured as an autoguider.
3. If you have an autoguider connection to the mount, remove or disable it. This

can be done by disconnecting the cable, or by going to the Guide tab Settings and turning off Enable X and Enable Y.

4. Point to a star at the meridian, near the equator.
5. Start the guider in **Track** mode, and watch the error reading in Declination only. It is okay to enable guiding in Right Ascension, if needed (for instance if the star drifts rapidly out of the field of view). Due to the sub-pixel measurement capability of the autoguider function, you will be able to see any error quite quickly. Note which way it is moving and how quickly. (For extremely high precision alignment for a permanent mount, you may wish to wait several minutes to see the drift.)
6. Now stop guiding and switch to **Focus** mode. Set up a very short exposure, binned for speed, and continuous exposures. Adjust the mount in azimuth, watching the star move. This way you can tell exactly how far you are moving the mount (see below for calculating image scale).
7. If the star drifts North, adjust the azimuth to the East. If the star drifts South, adjust the azimuth to the West.
8. Re-center the star using the telescope slow motion controls and repeat steps 4 through 6 until the drift is small.
9. Point to a star near the East horizon, close to the equator. Make sure the star is at least 20 degrees above the horizon, to avoid excessive refraction.
10. Start the guider in **Track** mode, and watch the north/south drift as before. Note which way the star is moving, and how quickly.
11. Stop guiding and switch to **Focus** mode; again, use continuous, short binned exposures. Adjust the mount in elevation, watching the star motion to see how much you are moving it.
12. If the star drifts North, move the polar axis down. If the star drifts South, move the polar axis up.
13. Recenter the star using the telescope slow motion controls, and repeat step 10 through 12 until the drift is small.
14. Go back to step 4 and start again, until the drift is small in both positions. Remember to reconnect or re-enable your autoguider when you are done.

Polar Imaging

Paul Boltwood has pioneered a very simple and effective technique for polar alignment. Using a planetarium program, create a chart of the area around the pole (north or

south). Make sure that the proper pole location is labeled on the chart.

Next, do a rough polar alignment, and then take a 60-second CCD image of the pole. Halfway through the exposure, rotate the telescope about the RA axis as far as it will go. Move it just fast enough to complete the arc in 30 seconds. You will create an image with the stars clearly visible, plus a set of near-circular arcs centered on the position of the *telescope's* pole. You can now easily see the difference in position between the telescope's polar axis and the correct pole location. In fact, you can measure this distance in X and Y using the Information window, and get a very accurate number. Now adjust the mount by that distance (tip: set a rapid binned exposure mode and watch the stars move as you adjust). After one or two iterations you have an extremely accurate polar alignment.

PolarAlignMax

This is a new method from Larry Weber and Steve Brady, the inventors of the Half-Flux Diameter focus measurement technique and the free FocusMax utility. It uses several images taken across a region of the sky. The rotation of the fields is measured using the PinPoint astrometric engine. From there, calculations are performed to determine the location of the telescope's axis compared to the proper pole location. Their easy-to-use PolarAlignMax utility will work with the included PinPoint LE astrometric engine. This utility can be obtained from <http://focusmax.org>.

Focusing

Focusing can be difficult because you cannot “look through” a CCD camera. Instead, you must view the image on a computer screen. Although some CCD cameras are capable of updating the screen multiple times a second, this is the exception rather than the rule. At low light levels, the exposure time required is often too long. Even where a bright target is available, the digitization circuits are often deliberately slow to give the best low-noise performance; in other cases, simply transferring a large volume of data to the computer takes some time.

When the screen updates only a few times a minute, it becomes extremely difficult to tell which way to adjust the focus. Two techniques can be used to speed up the update rate. The first – binning – combines together four or more pixels into one “super-pixel”, producing a smaller, brighter image that can be downloaded faster. This is great for coarse focus, but the loss of resolution makes fine focus difficult. The second method – subframing – requires you to pick a small area of the array and only read out that region. This also speeds up the download rate, but reduces the area available. Despite their disadvantages, these techniques are essential for efficient focusing.

MaxIm DL/CCD provides some tools for focusing. The Focus tab provides a separate set of exposure controls, which allows you to switch rapidly back and forth between

focusing and normal imaging. The Inspect tab allows you to view the quality of focus both graphically and numerically. Of particular interest is the Half-Flux Diameter and Full-Width Half Maximum measurements, which tell you the diameter of a star image. The focus is simply adjusted for the minimum star size.

To speed up the focusing process, it is helpful if the focus is approximately correct before you start. A useful technique is to “parfocalize” an eyepiece with the CCD camera. First carefully focus the camera using the standard techniques. Next, without changing the focus settings on the telescope, remove the camera and replace it with an eyepiece. Depending on the eyepiece, it may be necessary to use an extension tube. Without adjusting the focus setting, slide the eyepiece in and out until focus is achieved. Now mark the point of best focus on the eyepiece barrel. The best way is to make a small metal ring with setscrews that can be locked in place. The next time you need to focus, use this special eyepiece first, and visually adjust the focus to the approximately correct position. Now only a small refinement is necessary.

In the past, manual focusing was the most tedious and time-consuming part of CCD imaging sessions. However, this has changed with the advent of reliable autofocus techniques. The SharpStar™ autofocus capability of MaxIm DL/CCD can reliably focus as well as or better than manual focusing. It does require a digitally controlled focuser. Some less-expensive motorized focusers can also be used for autofocus, by using the FocusMax add-on. This free program is highly recommended, and can be downloaded from <http://FocusMax.org>.

Aiming

Aiming a CCD camera can be difficult, since there is no facility to “look through” the camera. The Focus tab can be a very useful tool for aiming. Once the camera is focused, set up the Focus tab to take a very short duration, binned image. You can then switch quickly back and forth between the Focus tab and the Expose tab, which is usually set up to take a long, high-resolution exposure. Although the focus frame will be a very short exposure, the use of binning will boost the signal-to-noise ratio and make it possible to see faint objects. This will allow you to easily take a quick snapshot to help with aiming.

If you have a GOTO telescope, several helpful features are available.

You can use PinPoint Astrometry as a digital finderscope. If you slew to an object but it does not appear on the chip, perform a PinPoint reduction using the Spiral Search option. Once PinPoint has found the solution, switch to the Telescope Control window and press Sync. You will be asked if you want to sync to the PinPoint solution. Click OK to align the telescope’s controller to the accurate PinPoint measurement, and then click the GOTO button again.

If your object appears on-chip but not centered, you can use the Auto Center feature of

the Telescope Control. Once Auto Center is calibrated (**Center** tab), you can right-click the object on the image and select **Point telescope here**. The telescope will be slewed to move the point you clicked on to the center of the image. (If there is significant backlash in the mount, you may need to do this a second time.)

You should also consider using MaxPoint, which is available at extra cost (www.cyanogen.com). MaxPoint models the errors in a telescope mount and corrects for them. Even on inexpensive GOTO telescopes, you can easily achieve pointing accuracies of 1-2 arc-minutes, which is sufficient to put objects near the center of your CCD sensor over the entire sky.

Autoguiding

When taking long exposures on astronomical telescopes, tracking is required to compensate for the Earth's rotation. Typical astronomical telescope mounts are not accurate enough for long exposure imaging without some form of guiding.

Tracking errors are usually sufficiently small on short duration images (15 to 90 seconds depending on the mount) that guiding is not required. Therefore a series of short exposure images can be taken and combined together later using the **Combine Files** command. However, in many cases a single long exposure is superior due to the elimination of extra readout noise and the residual blurring caused in realigning the images.

Although telescopes can be guided manually, many observers are now using CCD autoguiders. In some cases these are stand-alone units that are interfaced directly to the telescope. However, some units can or must be controlled from software. MaxIm CCD provides support for several different CCD autoguiders, and can run them in parallel with the main camera.

Instructions for installation of the autoguider are included with the unit. Generally speaking, the autoguider connects electrically to the telescope's guide controller using a standard RJ-11 jack. In some cases, special connections are required. Many GOTO mounts can be controlled using the Telescope Control window. Optically, the autoguider is connected either to a guide telescope attached mechanically to the main telescope, or to an off-axis guider. The off-axis guider includes a pick-off mirror that diverts light from the telescope into the autoguider. Normally the pick-off mirror is positioned outside of the main camera's field of view.

Some cameras include two autoguider sensors, either in the same package or not, with both operating through the same interface. Most SBIG camera models work this way, as do some Starlight Xpress cameras. If both sensors are looking through the same instrument, this ensures that mechanical flexure is not an issue, although limited field-of-view and losses due to filters can be a problem.

Focusing

Focusing is not as critical for autoguiding as for imaging; however, poor focus can result in a loss of sensitivity.

For dual-chip SBIG cameras and STAR2000 equipped Starlight Xpress cameras, the tracking CCD is automatically in focus once the main camera is focused.

For all other cameras, you can use the **Focus** and **Inspect** tabs to help with focusing the guider. The **Inspect** tab provides a variety of tools for determining best focus.

Autoguider Calibration

In order to properly control the mount, MaxIm CCD must calibrate the system. The exact orientation of the autoguider, the focal length of the guide telescope optics, and the speed of the motor drive all affect the calibration.

For best results, place a bright star in the field of view of the autoguider imager, near the center of the field. Take an exposure using the Guide tab's Expose mode; the guide star will be picked automatically, or you can click on one using the mouse. Now start the calibration function by selecting the Calibrate mode and clicking Start. MaxIm CCD will take a series of five full-frame exposures, moving the mount between each exposure. This will allow it to determine how fast the mount moves in each direction. The motion between successive exposures are in the +X, -X, +Y, and then -Y direction.

The star must move at least five pixels between each exposure for an accurate measurement, and preferably more. If the star does not move at least five pixels, an error message will be displayed at the end of the calibration cycle. The algorithm can be confused if another star appears in the frame; to minimize this risk, it always uses the star with the brightness most similar to that measured in the first image.

If the star does not move far enough, or moves too far (i.e. the star leaves the field), the duration of the calibration move commands can be adjusted by clicking the **Settings** command and changing the **Cal. Time** fields (measured in seconds). A longer calibration time will increase the motion of the star; a shorter time will decrease the motion. Typical values range from five to ten seconds, depending on the correction speed, focal length, and pixel size.

Using the **Guide** tab's **Settings** dialog, you can also set a **Backlash** setting to run out any backlash caused by changing the direction of motion (also entered in seconds). See below for more information.

The **Aggressiveness** control on the **Guide** tab allows you to adjust how vigorously star motions are tracked out. An **Aggressiveness** setting of 10 means that the autoguider attempts to track out 100% of the motion, whereas a setting of 1 means that the autoguider only tracks out 10% of the motion. Usually a setting of around 8 or 9

provides the best tracking, since it reduces overshoot and helps ignore random motions due to atmospheric seeing and wind loads. You may have to reduce it further if for some reason your calibration is inaccurate (this could be caused by significant backlash). You should experiment to determine the best setting for your particular telescope.

The calibration may also be adjusted manually using the Settings command. The X Speed and Y Speed parameters allow you to enter the apparent speed of motion of the star during guide corrections in pixels per second. For example, if the star moves three pixels in one second, the speed is 3 pixels per second. The number can be negative if a positive correction causes a negative motion. If the autoguider sensor is not aligned with the telescope axes, the rotation angle is entered in Angle (deg).

Backlash and Stiction

Backlash can occur when the direction of motion on an axis is reversed. The telescope may not immediately start moving in the reverse direction, even though the motor is turning. The usual cause is loose meshing of the gears in the drive train. In the case of worm gears this can often be largely adjusted out; unfortunately in some cases, attempts to adjust the gears can result in too much friction resulting in motor stalls. If the backlash is inside a gearbox it generally cannot be fixed without redesigning the drive system.

Generally backlash is only an issue on the Declination axis, because the Right Ascension axis is always moving forwards due to sidereal tracking.

Backlash can be compensated for – to a degree – in software. If the drive takes 1.2 seconds to turn around, the software could automatically add 1 second of drive time whenever the direction changes. A suitable backlash time can be entered into the Guide tab Settings dialog box for each axis. This number is used for both calibration and for guiding. You should always set this to less than the estimated backlash time; if it is too high, it will result in chronic overcorrection. If in doubt, set it to zero.

Note that some mount drive systems include built-in backlash compensation. It is recommended that this be turned off during autoguiding.

The term “stiction” comes from “static friction.” Static friction occurs when two objects in contact are at rest or moving very slowly relative to each other. Dynamic friction occurs when the two objects are in motion. Static friction is always larger than dynamic friction, so when an object starts moving, the amount of friction present can change very rapidly. An example of this happens when you brake your car. Just before the car stops, you have to let up on the brake pedal; otherwise the car jolts to a stop (if you’ve been driving for years, you may not even be aware you are doing it).

Stiction occurs between the teeth in a gear system. Of particular interest here is the effect on worm drives, which are typically used in astronomical telescopes. When the

drive is stationary, the gears “stick together.” When the worm starts rotating, it pulls on the teeth of the worm wheel. In this situation, the wheel can bend, or the mounting or bearings can flex, at right angles to the normal rotation. The resulting motion is usually backwards – you try to move the mount North, and it goes South! This only happens for a brief period of time after reversing directions; eventually the worm turns enough that the gear is forced to move in the correct direction.

Stiction problems can be complex mechanically; it can often be hard to determine what the root cause is. Many telescope mounts – even high-end models – suffer from this problem, and it may vary between different samples of the same model. The problem has a terrible effect on guiding because it forces overcorrection, and it cannot be effectively solved in software.

If you experience bad guiding in declination and cannot resolve it through adjusting the calibration or aggressiveness, you may have a stiction problem. One solution that works is to note the average drift in declination, and disable corrections in that direction. The guider should only be able to push against the average drift, not with it. This works surprisingly well. Some users deliberately adjust their polar alignment slightly off to ensure that the drift is in a consistent direction. You should avoid large offsets that may cause field rotation.

You can disable one guide direction by clearing the appropriate **Output** checkbox in the **Guider Settings** section of the **Guide** tab **Settings** dialog. These check boxes only affect tracking corrections, not calibration, so you do not have to re-enable the direction in order to calibrate the guider.

Declination Compensation

When the telescope is pointed near the pole, the apparent motion of the stars slow down. This can be easily seen by noting that Polaris is almost stationary. Unfortunately, this variation in speed affects the calibration of the autoguider. If you calibrate at the equator and then move to a polar region, the autoguider will compensate too slowly in RA. If you calibrate near the pole and then move to the equator, the autoguider will badly overcompensate. Either situation can lead to poor guiding.

The obvious way to overcome this is to recalibrate prior to each exposure. This is time-consuming and largely unnecessary. The recommended procedure is to calibrate once and use the **Declination** field to adjust for the position of the telescope.

When you first calibrate, you should do so on a star near to the equator. Enter the declination of the calibration star in the **Declination** field. When you move to a different position on the sky, reset the **Declination** field to match the new telescope position. MaxIm CCD will now automatically adjust its calibration to compensate for the change in telescope position. Whenever you reposition the telescope, adjusting this field to

match the declination of the telescope will eliminate the need to recalibrate.

If you have an active link to a telescope in the **Telescope Control** window, the **Declination** field will be automatically filled in for you.

When using German Equatorial mounts, it is necessary to rotate the telescope 180 degrees to switch between East and West. This affects the calibration of the guider since it reverses the apparent direction of motion on the RA axis. The **Pier Flip** control can be used to compensate for this if the X axis outputs are connected to the RA axis of the telescope (the usual convention). Simply toggle this control when you flip the telescope over the mount.

Troubleshooting

Autoguiding is a deceptively complex operation, since it is a two-axis closed loop servo system with troublesome mechanical problems like backlash and stiction.

A detailed **step-by-step guide** to diagnosing autoguiding problems is included in the main **Troubleshooting** chapter.

Here are some quick things to check:

- Use the Graphical Track Log to monitor guiding performance. See if problems are happening in Right Ascension or Declination, or both, and whether there is any pattern to it. Periodic behavior suggests incorrect calibration or too high aggressiveness. Sudden jumps suggest a mechanical problem such as backlash, stiction, or mount balance.
- For most mounts, set the Aggressiveness between 5 and 8. You can adjust the Aggressiveness during tracking to see what effect it has.
- If the mount has built-in backlash compensation, turn it off. If you are not sure how to set the MaxIm CCD backlash controls, set them to zero.
- Make sure the guide rate on the mount is between 0.1X and 1X.
- During calibration make sure the guide star moves in an “L” pattern and moves at least 10 pixels – preferably 20 or more – on each leg.
- Make sure that your mount is balanced so it is slightly heavier on the East side. This may require rebalancing when you flip a German Equatorial mount over the pier.
- Some mounts have significant stiction on the Declination axis. Stiction causes the mount to continue to move forwards briefly when you reverse directions. A common solution is to disable declination corrections in one direction only. You should disable the direction that pushes in the same

direction as the average drift. You can disable one direction using the Guide Tab, Settings, More. Some observers even deliberately offset their polar alignment slightly to ensure a very slow drift.

- You can adjust the mount response in RA and Dec separately by tweaking the manual calibration parameters. The number displayed is the rate of star movement during tracking in pixels per second. If the axis is overcorrecting, increase the number; if it is undercorrecting, decrease the number.
- Try adjusting the rate at which updates are sent to the mount. Some mounts work best with multiple updates per second, while others work better with a slower update rate. For example, LX200 mounts generally work best with a 3 second update rate. In most cases you can simply increase the guider exposure time to slow down the updates; however, a delay-after-correction function is available if needed.

Image Scale

To obtain the best images, it is very important to match your CCD camera to your optical system. While wide-field panoramas are certainly possible with a CCD camera, the high sensitivity makes them particularly well-suited to high resolution imaging.

Resolution depends on both the focal length of the telescope, and the size of the pixels in the CCD array. Long focal lengths and small pixels result in higher resolution. Too much resolution and the images will be fuzzy. Too low resolution and you will not be achieving the full potential of the instrument – you may even end up with small square-looking stars.

Often the matching can be adjusting by using auxiliary optics (reducers and barlows) or binning. The key to good performance is achieving proper Nyquist sampling.

Nyquist Sampling

The Nyquist Sampling Theorem sets the fundamental limits on any system that digitizes signals, whether it be a CD player, a telecommunications system, or a CCD camera. The theorem tells you how fine sampling is required to produce a “perfect” representation with no loss in quality.

The American physicist and electrical engineer Harry Nyquist proved that if the sampling is at least twice the highest spatial frequency component in the image, no distortion will occur and you can reconstruct an exact replica of the original image. The theorem really requires the image to be filtered (smoothed) to remove any higher frequency components; but in practice, the limitations of the optics and seeing take care of this for you.

For that reason, for optimum performance, you need to have at least two pixels across the core of a star image. By “core” we mean the Full-Width Half Maximum (FWHM); i.e. the diameter at which the star intensity falls to one-half its peak value. For practical purposes, the sampling really needs to be 2.5 to 3 pixels across the FWHM. For high performance applications, such as profile-fitting photometry, even higher sampling is required to represent the exact shape of the star image.

There is a second part to the Nyquist Sampling Theorem – the image you capture isn’t a perfect representation of the original image; it just contains all the information necessary to reconstruct it. To properly view the image, you need to pass it through a reconstruction filter. In a digital system, this can be done only by resampling the image to a higher resolution and then low-pass filtering it. MaxIm DL can do this with the **Double Size** command.

Matching Small Optics

For small optics (microscopes, telescopes under 10 cm or 4 inches), the focal ratio is the important factor. The pixel size needs to match the spot size, which for a perfect optical system is the diameter of the *Airy disk*, the image created by a perfect point source such as a star. The spot size can be calculated with the following formula (assuming a wavelength of 550 nm):

$$\text{spot size (microns)} = 1.38 * f/\text{ratio}$$

If you adjust the focal ratio so that the spot size is at least twice the pixel size, you will have adequate sampling.

Matching Large Optics

The effects of *seeing*, the random star motion caused by atmospheric turbulence, increases the practical spot size for larger instruments. In this case, the seeing disk in arc-seconds and the focal length are the important parameters. You can calculate the size of a pixel in arc-seconds using the following formula:

$$\text{pixel size (arc seconds)} = 206 * \text{pixel size (microns)} / \text{focal length (mm)}$$

(The result can be quickly estimated by rounding off the constant in the equation to 200. For example, suppose a camera with a Kodak KAF0401 sensor, which has a pixel size of 9 microns, is attached to a telescope with a focal length of 2000 mm. The pixel size is $9 * 200 / 2000 = 0.9$ arc seconds.)

For long-exposure astronomical imaging at most sites, the seeing disk is often up to 3-4 arc seconds across. Typically an image scale of 1-2 arc-seconds per pixel is optimal. At superior sites you can use 0.5 arc-seconds per pixel; however, imaging at this level requires excellent optical quality and a very stable mounting or a high-speed tip/tilt

guider such as the SBIG AO-7.

Planetary Imaging

The short exposures used during planetary imaging can “freeze” the seeing and allow full-resolution imaging even with very large instruments (assuming good optics). For planetary imaging with short exposures, start with an image scale of 0.25 arc seconds per pixel; use trial-and-error to determine the best image scale for your equipment, conditions, and the planet being imaged. Since seeing is highly variable, it is recommended to take many exposures and keep only the best.

Using Multiple Exposures

The simplest way to take a long exposure is to simply open the shutter for the desired duration. Taking a single exposure certainly minimizes the contribution of camera readout noise in the image.

However, for astronomical imaging two difficulties are often encountered. First of all, the telescope must remain aligned with the sky to a fraction of an arc-second throughout the exposure. This is extremely difficult (expensive) to achieve mechanically, so in most cases some form of guiding is required. Secondly, bright stars within the frame will rapidly saturate and bloom. This affects not just the saturated pixels but also adjacent ones as the excess electrons become trapped and spread along the column during readout.

Both these problems can be greatly reduced by taking a series of shorter exposures, then combining them together afterwards. MaxIm DL provides support for this in the form of the **Combine** command. This command allows you to combine a number of images into one equivalent long exposure. The image alignment feature allows you to remove the effect of telescope drift, and the floating-point representation used means that saturation can be avoided.

Many telescope worm gears have positions where there is some relatively rapid drift. If some of the shorter images are unsuitable due to trailing, they can be examined and removed from the sequence using the **Combine** command. All of the images should be calibrated before combining them.

Color Imaging

A few cameras on the market are single-shot color cameras. Each image from the camera is encoded with color information. This is achieved by placing microscopic filters over the individual pixels on the chip. The **Convert RGB** and **Convert MX** commands can be used to transform these encoded images into color.

The conventional way to take color images with a CCD camera is to use a set of Red,

Green, and Blue filters. Individual images are taken through these filters and combined in software. MaxIm DL/CCD has extensive features to support RGB color imaging.

LRGB Imaging

In LRGB imaging, a Luminance (L) frame is added to the standard RGB mix. The Luminance fully or partially replaces the luminance information from the filtered images. Often the Luminance image is taken with a longer exposure. The RGB images are sometimes binned to allow shorter exposures. Since the human eye has lower resolution in color than in luminance, the difference between binned and non-binned RGB components is generally not discernable. (Note: binning is often counter-productive on moderate to long exposures due to photon shot noise from the sky background. Experimentation is recommended to determine the best approach for your observing site and equipment.)

MaxIm DL fully supports automated LRGB imaging via the **Sequence** tab. You can configure different exposure and binning settings for the various filters. When combining the L frame with the RGB frames using **Combine Color**, MaxIm DL can automatically rescale the binned color frames to match the luminance frame.

CMY Imaging

An alternative technique that has been promoted in recent years is the use of Cyan, Yellow, and Magenta filters. The advantages quoted include wider bandwidth resulting in more light and therefore higher signal-to-noise ratio. CMY imaging is fully supported in MaxIm DL.

Unfortunately there are several problems with CMY filters. To build a usable RGB image from the CMY set, the images have to be added and subtracted from each other. Since the noise in the three channels is uncorrelated, the resulting noise in each R, G, and B channel is larger than that in the CMY channels. As a result, the improvement in SNR is extremely tiny, and is not worth the extra effort required.

CMY filters have additional complications. Attaining an accurate color balance with a subtractive system in the presence of the varying sensitivity of the camera across the band is a difficult proposition. Also atmospheric dispersion effects will be worse with the wider filters. As a result, although MaxIm DL supports CMY imaging, it is not recommended in practice.

Infrared Sensitivity

CCD cameras are very sensitive to near-infrared light. This can lead to an unexpected problem with reflections inside the optical instrument. Generally optical systems have flat black inside surfaces and baffles to absorb stray reflections. Usually metal parts are

anodized black; unfortunately most types of anodizing are highly reflective in the infrared. The result is that the camera can see the reflections, but the human eye cannot. This type of reflection can be most troublesome when trying to perform flat-field calibration, generating a “hot spot” in the center of the image.

The simple solution to this problem is to *paint* the anodized surfaces flat black. This is particularly important for tubular structures just in front of the camera. A baffle can also be added just in front of the camera to block stray light, but care must be taken to avoid vignetting.

When taking tricolor images using a CCD camera, it is important to note that most blue filters strongly leak infrared light. Therefore an infrared blocking filter is essential. Some modern filters include a built-in infrared blocking layer.

Signal to Noise Ratio

A CCD camera is essentially a photon counting device. Signal to noise ratio (SNR) can be calculated by summing over all the pixels within an aperture as follows:

$$\text{SNR} = \frac{S\sqrt{T}}{\sqrt{S + \sum (B + D + R^2/t)}}$$

where:

- S = signal in photoelectrons
- B = sky background in photoelectrons
- D = dark current in electrons
- R = readout noise in electrons
- T = total integration time in seconds
- t = integration time per image in seconds

A signal-to-noise ratio of three is usually considered the minimum for detection. A higher SNR is required for photometric measurements.

This has several implications for CCD imaging:

1. Best SNR performance is achieved by keeping the star size small, subject to the Nyquist criterion (at least 2.5 pixels across FWHM).
2. On very short exposures, or sequences of short exposures, the readout noise performance may be the limiting factor.
3. In most cases, for long exposures the sky background is the limiting factor for performance, even at dark sky sites.
4. If properly calibrated, dark current noise is usually only important for narrowband

imaging (spectroscopy, narrowband interference filters, etc.).

To improve performance in the read-noise limited case, consider increasing the exposure (particularly if summing a sequence of exposures).

In all cases, increasing telescope size, camera quantum efficiency, or exposure time will improve your limiting magnitude (faintest detectable objects).

Bit Depth

Most CCD cameras produce 16-bit images, with pixel values ranging from 0 through 65535. Subsequent processing can increase the bit depth beyond this point.

By default, images taken with the CCD camera are saved in FITS 16-bit format. If you perform processing that increases the bit depth, you should save in FITS IEEE Float format.

Novice users often have trouble saving images in formats like JPEG, which can only handle 8-bit data. The **File** menu **Save As** command warns you in a text box when the data in the image exceeds the capabilities of the file. If this happens, make sure the **Screen Stretch** is set appropriately, and turn on the **Auto Stretch** check box. The image will automatically be scaled so the saved image will look just like the image on-screen. Note that when this is done, data precision is permanently lost. It is strongly recommended to first save your images in a high bit depth format like FITS or 16-bit TIFF, so that you do not lose data.

Image Processing Basics

Most image processing functions either adjust the range of all pixels together (stretching) or modify pixels based on the value of their neighbors (filtering). This section introduces the basic concepts and explains some of the variations available for each technique.

For information on using these functions to best effect, please see Advanced Image Processing.

Stretching

The single most important image processing function is known as stretching. In its simplest form, stretching is the same as adjusting the brightness and contrast of your television. Your television has these controls because it cannot display the world as it really is. Unlike your eyes, which can work on a sunny day or a moonless night, a television can handle only a very limited range of brightness. The huge dynamic range of the eye has never been duplicated by video display technology.

While video displays and printers still suffer from this severe limitation, the cameras do not. Modern high-performance CCD cameras can record up to 65,536 different brightness levels, yet most computer monitors can only display about 64 brightness levels (even if more levels are available, they usually cannot be distinguished on the monitor). This huge gap can be bridged using stretching techniques.

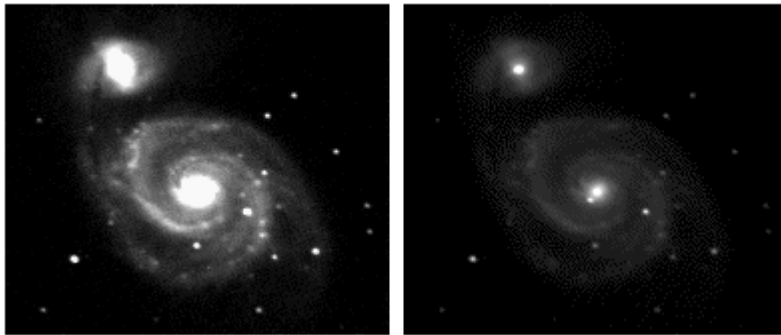
Basic Stretching

In its simplest form, stretching works as follows. A typical CCD image represents each pixel as a number from 0 to 65,535. This has to be mapped into the video monitor's range of 0 to 255. A simple formula is applied to each pixel:

$$\text{New Value} = \text{Old Value} \times \text{Scale} + \text{Offset}$$

If the resulting new value is greater than 255, it is set to 255. If it is less than zero, it is set to zero. The *Scale* and *Offset* numbers control how the image appears on the screen.

Where do these two "magic" numbers come from? The user provides them by trial-and-error. Although MaxIm DL can try to determine the settings for you automatically, the best results are obtained by tweaking the numbers until the most pleasing display appears.



Whirlpool Galaxy – Two Different Stretches

In MaxIm DL, the numbers are entered a bit differently. The two values entered are **Minimum** and **Maximum**. A pixel that is at the minimum value is set to zero, and a pixel at the maximum value is set to 255. This method is more convenient because it leads to a simple way to display the stretch numbers graphically using a slider bar. In MaxIm DL, this slider bar appears in the **Screen Stretch** window (histograms are described below).

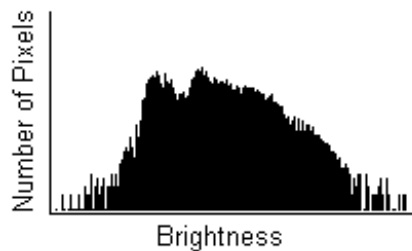
Instead of entering numbers, it is faster to use the **Quick Stretch** facility. This allows you to modify the image appearance with small up/down and left/right movements of the mouse. To do this, hold down the **Shift** key, then click and drag the mouse on the

image.

The problem with stretching is determining exactly how to stretch the image for best effect. Often there are several different possibilities for the same image. For example, two different views of the same image of the Whirlpool Galaxy (M51) are shown above. The first image reveals all the detail in the spiral arms, but the core of the galaxy is burnt out. In the second image the spiral arms are all but gone, but now we can see the supernova adjacent to the core of the galaxy.

Histograms

To better understand the more complex stretching techniques, it is helpful to understand histograms. A histogram is a simple bar graph that shows the range of brightness in an image. Each bar in the graph represents a range of brightness; the first bar represents the dimmest pixels, and the last bar is for the brightest pixels. The height of the bar is the total number of pixels in that brightness range in the image. Every image has a different histogram depending on how much of the image is bright or dark.



Typical Histogram

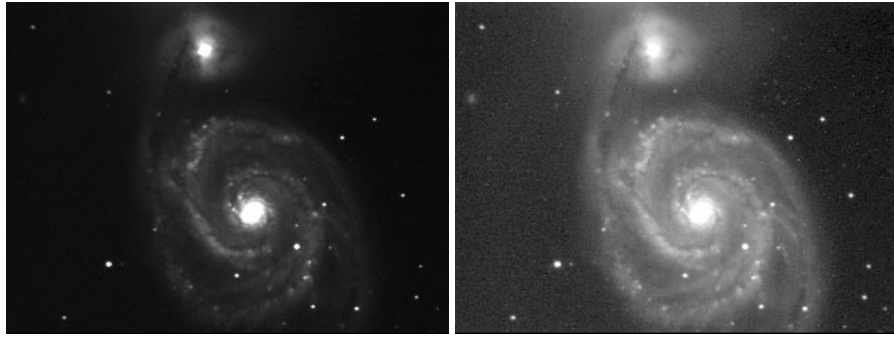
A typical histogram will have a peak that shows the most common brightness in the image. For astronomical images this is often the sky background. A part of the histogram where there is a dip reveals that few pixels have brightness in that range. When stretching, we do not want to emphasize those areas because they contain little information.

Any stretching operation can be viewed as reshaping the histogram. Some functions do this in a fixed manner; others actually force the histogram to have a particular shape. Both types of techniques will be described below.

Nonlinear Stretching

When we do a stretch we can do much fancier things than just subtracting and multiplying numbers. A popular method is called "**log rescale**". All pixels in the image are put through a logarithm function. This may seem like an arbitrary choice, but there are reasons for choosing it. The astronomical magnitude scale is logarithmic so that it

can encompass a wide range of brightness. The human eye itself responds to light in a fashion that is close to logarithmic.



Before and After Gamma

What the log rescale function does is stretch different parts of the images differently. This allows you to see the bright details – at lower contrast – while still seeing the faint details. The logarithm function actually changes the shape of the histogram itself.

On many images log rescale is a bit aggressive – the image will look washed out. In some cases we might even want to do the opposite, highlighting bright objects at the expense of faint details. *Gamma correction* is a more general technique. It is related to log rescale in that it also uses logarithmic functions, but it is a bit more complicated. A number, called **Gamma**, controls the exact shape of the curve.

Histogram Specification

All stretching operations can be visualized by looking at the effect on the histogram. We can modify the shape of the histogram to improve the view of the object. By using a process called histogram specification we can make the histogram flat, sloped, or any curve we want.

The process is similar to how some teachers "bell curve" marks. The students are listed by order of grade on the exam. The top student on the list gets 100%, the next 99%, and so on. If the teacher wants most of the class to get a mark near 75%, she can assign more students grades in the 70-80% range. With this technique, the student's final grade depends on his rank in the class, not on the actual mark. The teacher can generate any distribution at will.

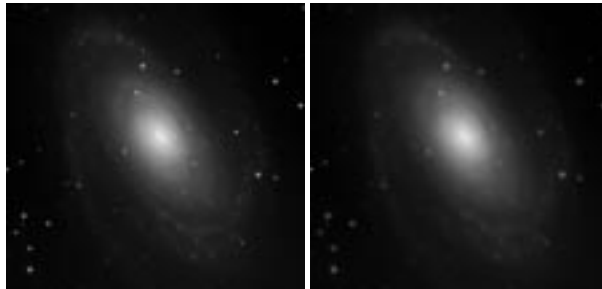
When the same process is applied to images, it allows us to force any shape onto the image histogram. This technique is particularly useful for compressing out regions of the histogram that have very few pixels.

Spatial Filtering

Spatial filtering is widely used for extracting detail and controlling noise. Filtering is not like stretching, which works on each individual pixel in isolation. When filtering an image, each pixel is affected by its neighbors. This actually moves information around the image.

Low-Pass Filtering

The most basic of filtering operations is called "low-pass". A low-pass filter, also called a "blurring" or "smoothing" filter, averages out rapid changes in intensity. The simplest low-pass filter just calculates the average of a pixel and all of its eight immediate neighbors. The result replaces the original value of the pixel. The process is repeated for every pixel in the image.



Before and After Low-Pass Filter

This low-pass filtered image looks a lot blurrier. But why would you want a blurrier image? Often images can be noisy – no matter how good the camera is, it always adds an amount of “snow” into the image. The statistical nature of light itself also contributes noise into the image.

Noise always changes rapidly from pixel to pixel because each pixel generates its own independent noise. The image from the telescope isn't "uncorrelated" in this fashion because real images are spread over many pixels. So the low-pass filter affects the noise more than it does the image. By suppressing the noise, gradual changes can be seen that were invisible before. Therefore a low-pass filter can sometimes be used to bring out faint details that were smothered by noise.

MaxIm DL allows you to selectively apply a low-pass filter to a certain brightness range in the image. This allows you to selectively smooth the image background, while leaving the bright areas untouched. This is an excellent compromise because the fainter objects in the background are the noisiest, and it does not degrade the sharpness of bright foreground objects.

Filtering can be visualized by drawing a “convolution kernel”. A kernel is a small grid showing how a pixel's filtered value depends on its neighbors. To perform a low-pass filter by simply averaging adjacent pixels, the follow kernel is used:

$+1/9$	$+1/9$	$+1/9$
$+1/9$	$+1/9$	$+1/9$
$+1/9$	$+1/9$	$+1/9$

When this kernel is applied, each pixel and its eight neighbors are multiplied by $1/9$ and added together. The pixel in the middle is replaced by the sum. This is repeated for each pixel in the image.

If we didn't want to filter so harshly, we could change the kernel to reduce the averaging, for example:

0	$+1/8$	0
$+1/8$	$+1/2$	$+1/8$
0	$+1/8$	0

The center pixel contributes half of its value to the result, and each of the four pixels above, below, left, and right of the center contribute $1/8$ each. This will have a more subtle effect. By choosing different low-pass filters, we can pick the one that has enough noise smoothing, without blurring the image too much.

We could also make the kernel larger. The examples above were 3×3 pixels for a total of nine. We could use 5×5 just as easily, or even more. The only problem with using larger kernels is the number of calculations required becomes very large.

A variation on this technique is a Gaussian Blur, which simply allows you to define a particular shape of blur kernel with just a single number – the radius of a Gaussian (“normal”) distribution.

High-Pass Filtering

A high-pass filter can be used to make an image appear sharper. These filters emphasize fine details in the image – exactly the opposite of the low-pass filter. High-pass filtering works in exactly the same way as low-pass filtering; it just uses a different convolution kernel. In the example below, notice the minus signs for the adjacent pixels. If there is no change in intensity, nothing happens. But if one pixel is brighter than its immediate

neighbors, it gets boosted.

0	-1/4	0
-1/4	+2	-1/4
0	-1/4	0

Unfortunately, while low-pass filtering smoothes out noise, high-pass filtering does just the opposite: it *amplifies noise*. You can get away with this if the original image is not too noisy; otherwise the noise will overwhelm the image. High-pass filtering can also cause small, faint details to be greatly exaggerated. An over-processed image will look grainy and unnatural, and point sources will have dark donuts around them. So while high-pass filtering can often improve an image by sharpening detail, overdoing it can actually degrade the image quality significantly.

Low-pass and high-pass filters are both available from MaxIm DL's **Kernel Filter** command, together with some related variants.

Unsharp Mask

An **unsharp mask** is simply another type of high-pass filter. First, a mask is formed by low-pass filtering an image. This mask is then subtracted from the original image. This has the effect of sharpening the image.

Usually the mask is scaled before it is subtracted; this allows the user a great deal of control in the amount of sharpening that is applied. The strength of the low-pass filter used can also be adjusted. A very strongly blurred mask can be used to remove large-scale brightness differences, while a slightly blurred mask will sharpen fine detail.

A variation of this technique uses a **geometric mean mask**. In this method, a logarithmic function is applied to the image before the mask is calculated. This technique is very useful for sharpening images that have faint details superimposed on large brightness variations. Among other things, this technique is very useful for revealing dust jets coming from the nucleus of a comet.

Another variation is called **Digital Development Processing**. This technique was invented by Dr. Kunihiro Okano. He noticed that standard film processing chemistry applied a hyperbolic stretch (gamma with an "S" curve) and compensated for the flattened appearance by adding an edge enhancement effect (created by developer depletion in bright areas). He devised a simple and highly effective method to emulate this effect digitally, using a hyperbolic stretch and unsharp mask.

FFT Filtering

Filtering with large convolution kernels can be extremely time consuming. Fortunately, there is a better way to do filtering. The method uses something called a **Fast Fourier Transform**, or **FFT**. After an FFT is performed, the result doesn't look anything like the original image. If there are large but slow brightness variations in the original image, the FFT image looks brighter in the corners and around the edges. If there are very large, rapid brightness variations, the center of the image will look brighter. Usually the image looks like something out of a kaleidoscope.

This may not sound very useful, but FFTs can be reversed to get the original image back. And you can make changes to the FFT'ed image before you reverse it. If the right changes are made, the result will be a filtered image. Because the FFT rearranges the image so that rapidly changing features are in one place, and slowly changing features are in another, just about any filter can be easily applied.

Usually the filter shape is generated first – either by taking an FFT of a convolution kernel, or by directly generating a shape called a “transfer function.” Then an FFT is taken of the image. Each pixel in the FFT'ed image is multiplied by the corresponding pixel in the filter array. The FFT is reversed and voila, you have a filtered image. Mathematically, the process is identical to **kernel filtering**; but the processing occurs much more quickly.

The big advantage of FFTs is their speed. Any filter, no matter how complicated, takes exactly the same amount of time. A second advantage is that the exact shape of the filter can be very carefully controlled to finely adjust the amount of blurring or sharpening. Often the filter shape is calculated using a "Butterworth" equation, but there are other ways to get the shape.

Median Filtering

There is another method of low-pass filtering that is even better at eliminating noise. Instead of replacing a pixel with the average of its neighbors, it is replaced with the median of its neighbors.

A median is calculated by sorting the values in increasing order. The value in the middle of the list is the median. Half the pixels are brighter than the median, and half are dimmer.

With a median filter, any pixel that is much different from its neighbors is eliminated. It therefore suppresses “impulsive” noise, such as hot pixels and cosmic ray hits, very strongly. Unlike the other filters described so far, the median filter is non-linear. This has some disadvantages; for example, an attempt to produce an unsharp mask with a median filter can result in artifacts – structures that do not exist in the actual image.

Deconvolution

The filtering techniques described so far use a technique known as **convolution**. In fact, any linear filtering technique can be described mathematically as a convolution – including the effects of blurring due to poor focus, motion blur, and atmospheric seeing.

The math suggests that it might be possible to “undo” a convolution. For example, a filter is applied by taking the FFT of both an image and the convolution kernel, multiplying the two together, and taking the inverse FFT of the result. One might wonder if it would be possible to divide instead of multiply, producing a deconvolution filter. If this worked, you could take an image that was filtered using convolution, and restore the original image using deconvolution. With a simple inverse filtering operation, you could remove the effects of motion blur or atmospheric seeing, resulting in a sharper, cleaner image. In practice, though, things are not quite so simple.

Deconvolution requires a division operation. If any part of the filter shape is zero, you end up dividing by zero and you get a nonsense answer. Even if there are no zeros, there will always be areas with small values, and taking the inverse of a small number results in a very big one. That means that any small amount of noise will be greatly amplified; and in real images, noise is always present.

A method called Weiner filtering solves the divide-by-zero problem, but with this technique the noise amplification is so severe that it is not practical for most images.

The solution to all this is to use something called an iterative deconvolution algorithm. With an iterative algorithm, the computer first calculates an approximation of the deconvolved image. The same process is repeated, using the first approximation as input to calculate a better approximation. This process is repeated again and again until the process “converges” to the correct result.

There are some relatively simple iterative algorithms, but they do not work well on typical real-life images, in particular due to noise amplification. **Maximum Entropy** and **Lucy-Richardson Deconvolution** are highly complex iterative algorithms that are designed to overcome noise amplification problems.

Other Filters

Rotational Gradient is a method for emphasizing subtle detail in an object that is nearly rotationally symmetrical, such as extracting jets from a comet image.

Rank Filters take the area around a pixel, sort the values within that area, and then pick out a value according to its percentile (ranking) in the list. These filters strongly emphasize small differences between adjacent pixels.

Local Adaptive Filters selectively emphasize image features that are lower contrast, by boosting brightness differences in areas that have low standard deviations compared to

the average brightness level. The **Local Adaptive Filter** is very effective for extracting faint details from planetary images, but it can cause excessive noise amplification if over-applied.

Raw Data Quality

The best way to produce good images is to have excellent raw data. Capturing good data requires patience and practice. The following steps are mandatory:

1. Ensure that the images have good focus, sampling, and guiding. See Using CCD Cameras for recommendations on imaging techniques.
2. Calibrate your images. As a minimum subtract a dark frame. Even better, use dark subtraction and flat-fielding, and combine multiple calibration frames to ensure the best signal-to-noise ratio.
3. Expose for a long period of time. For deep-sky images, it is usually best to stack many exposures of between 60 and 300 seconds. Using shorter exposures reduces the chance of guider errors, wind gusts, and other transient phenomenon. It allows you to remove or correct images that have defects. Use longer individual exposures if you are imaging with narrowband filters or your camera has a high noise floor.
4. When using the LRGB color technique, use more exposure in the luminance band than for the color bands. Increase the exposure in any color band that has poor sensitivity relative to the others (e.g. some cameras have poor blue sensitivity). Consider using binning the color exposures to increase sensitivity, bearing in mind that this may make things worse in high sky brightness conditions.

Preserving Bit Depth

An important feature of MaxIm DL is that it stores images internally in 32-bit floating-point format. Although this increases memory consumption compared to standard desktop image editing programs, it gives much greater flexibility and helps preserve data precision.

If you were to sum or average together 256 individual 16-bit images, the actual bit depth of the result could be as high as 24 bits. In reality, you probably have only 12 to 14 bits of usable data in each image; nevertheless the final result would still have 20 to 22 bits. Obviously if you store this result in a 16-bit or 8-bit file format, you will need to rescale the image and clip and/or truncate part of the useful data. If you scale the image so that

you maintain faint image detail and good background statistics, you will end up clipping off the brighter objects. Therefore when working with images like this, it is best to save them in FITS format with IEEE Float pixel format.

Most desktop image editing programs only work at 8 bits. Even if you plan to export data to a desktop editing program for final tweaks, it makes sense to do as much processing as possible at high bit depth first. When that is completed, you should save the result to a high bit depth format, and then export the data to a format compatible with your editing program. This way if you find you need to make additional adjustments you can easily go back without having to start over.

Recommended Processing Sequence

What is the best order to apply the processing functions in? There is no single way to do things, but generally speaking the following is a recommended ordering:

1. Image calibration
2. Bad pixel removal (or hot pixel/dead pixel kernel filter) and/or bloom removal
3. Make pixels square (for cameras with non 1:1 pixel aspect ratios)
4. Image stacking (with alignment if required)
5. Deconvolution
6. Filtering (DDP, unsharp mask, low-pass)
7. Color combine
8. Color adjustment
9. Additional Filtering
10. Stretching (Curves histogram specification, gamma stretch, etc.)

Generally speaking, image calibration should always be done first. Deconvolution, if performed, should be done after calibration, clean up, and combining, but before any other processing steps.

The filtering in Step 6 should be done on the Luminance frame if you are doing LRGB combination. This will have the effect of filtering the entire image, without significantly altering the color representation. **DDP** in particular is best done prior to color combine, because it will tend to reduce color saturation (although this can be compensated for using the **Color Saturation** command).

There is a great deal of flexibility in the latter steps. Generally speaking it is better to perform linear filters on images before they are stretched in a non-linear fashion, but

there may be reasons to change the order of the steps.

A common technique for the final stretching is to gradually boost the mid-range by repeatedly using the **Curves** command. Another useful technique is to smooth the darker parts of the image while sharpening the brighter parts. The various filter commands have this capability built-in.

The most important rule to remember is: experiment!

Image Calibration

Image calibration sounds like a boring topic, but proper calibration is of the utmost importance in producing good quality images.

Despite many years of refinement, no electronic imaging device is perfect. Each CCD chip has a different *bias level* (zero point), *dark current* (sensitivity to temperature), and sensitivity to light. These effects don't just vary from camera to camera; they vary from pixel to pixel in the same camera. Each of these effects corrupts the intensity represented in every pixel of the image in a specific way.

Fortunately, the majority of the problems caused by these variations can be removed by calibration. Performing basic calibrations on CCD images can result in as much as a 400% improvement in the signal-to-noise ratio, resulting in much greater sensitivity. Calibration is particularly important for long exposures using cooled CCD cameras, as is the norm in astronomical imaging and many other scientific applications.

Some CCD camera users do not bother with calibrations because they are "difficult." This is a waste of the camera's capabilities. The three basic steps are bias, dark, and flat-field calibration. Each of these will be discussed in turn.

Bias Frame Calibration

Bias is an offset that occurs when a pixel is read from the CCD camera. Unfortunately, every pixel in the image often has a slightly different bias level. If this pixel-to-pixel bias variation is not removed, it becomes a source of noise in the image.

A bias frame is essentially a zero-length exposure (or as close as possible to zero length) with the shutter closed. Each pixel will have a slightly different value, but except for a small amount of noise, the value for any one pixel will be consistent from image to image. Since the bias is consistent from image to image it can be subtracted.

The bias frame itself contains a small amount of readout noise. This readout noise is produced inside the electronics that read the pixels. It can be very low in sophisticated cameras, but it is never zero. This noise can be easily suppressed by combining a number of bias frames together.

Ideally, the other types of calibration frames (dark and flat-field) should themselves be bias frame calibrated. MaxIm DL does this automatically when bias frame files are selected.

The bias for a particular CCD camera is generally constant over a substantial period of time. This means that you can take bias frames just once, and use them on all your images for many months to come. Note that some CCD cameras may have a small bias dependency on temperature. Small bias offsets are not important of themselves, but they can degrade the effectiveness of the flat-fielding calibration.

Dark Frame Calibration

Every CCD camera produces a certain amount of dark current, which accumulates in the pixels during an exposure. The dark current is produced by heat; high-performance cameras cool their CCD chips to minimize this effect.

The main problem with dark current is that it accumulates at a different rate in every pixel. If not compensated for, this will add a large amount of noise into the image. Fortunately, this effect can be easily removed by subtracting a dark frame. A dark frame is an exposure taken under the same conditions as the light exposure, but with the shutter closed. Since each pixel is consistent in its dark current at any one temperature, the dark frame can be subtracted from the light frame to remove the effect.

Unfortunately, while the rate of dark current is constant, the actual accumulation of dark current is random. Doubling the dark current increases the random noise produced by the square root of 2 (~1.414). Most CCD arrays have some *hot pixels* that produce larger amounts of dark current; this also means they produce significantly more noise. Since the noise is random and therefore unpredictable, it cannot be removed. You can improve the hot pixels, but you cannot completely fix them.

Over the course of an exposure, the pixel-to-pixel variation in dark current produces a significant variation in the black level for each pixel. The result is a “salt and pepper” appearance. Simply subtracting a dark frame greatly improves the image quality. Perhaps counterintuitively, it also increases the overall noise level in the image. The average dark current subtracts, but noise always increases as the square root of the sum of the squares of the individual contributions. Therefore simply subtracting one dark frame increases the noise level 41%. Averaging ten dark frames together reduces that to about 5%; more frames will reduce the added noise to negligible levels.

Since *hot pixels* have extra noise, you may still find your image has “speckles” after calibration; they are just smaller, and now some are dark and some are bright. There are several techniques for removing these noisy pixels. One way is to simply replace them with the average of the surrounding pixels (in MaxIm DL both Kernel Filter and Remove Bad Pixel commands can do this). A better way is to “dither” the pointing of the camera slightly between exposures, thus distributing the noise contribution of each

hot pixel to a different position on the image, and then combine a number of images together using a median or sigma clip algorithm, which will reject the hot pixel contributions altogether.

The longer the exposure you take, the more dark current accumulates. This means that the dark frame and light frame must have the same exposure time in order for calibration to work. They must also be taken at exactly the same temperature, because the rate of dark current accumulation varies strongly with temperature. Many CCD cameras include coolers with high precision temperature regulation; this greatly simplifies management of the dark frames.

Of course, some cameras do not have temperature regulation. If the temperature changes, the dark frame will no longer work. It is common in astronomical applications for the temperature to drop as the night progresses. Taking dark frames throughout the night minimizes the differences, but this can lead to situations where a dark frame is not available to properly calibrate an image.

So what can you do if you do not have a calibration frame that matches the exposure duration and/or temperature of an image? Exposure compensation is the answer. Use a dark frame whose temperature and exposure duration are as close to correct as possible, and select Auto-Optimize in the Set Calibration command. MaxIm DL will automatically compensate for the differences and produce an image that is properly calibrated. Using a bias frame is strongly recommended in this situation (bias is constant and does not scale with exposure time).

If you do have a temperature-regulated camera, you can take a set of “master frames” at various temperature settings and exposures. These can be used to calibrate any matching exposure taken with the same camera. Exposure compensation can also be used if an exact match is not available (use Auto-Scale, which adjusts the scaling based on exposure time). If you enter multiple sets of calibration frames into MaxIm DL, it will automatically choose the frames that best match the exposure conditions.

Some users just take a single set of long dark frame exposures and use the exposure compensation feature for shorter light exposures. Most CCD cameras are highly linear, so this technique can work very well.

Flat-Field Frame Calibration

Each pixel in the CCD camera has a slightly different sensitivity to light. These sensitivity differences add another noise component to the image (known as flat-fielding error) unless steps are taken to compensate. While flat-fielding correction is important for achieving good quality images, it is absolutely essential for accurate photometric measurements.

With a bright sky background, any pixel-to-pixel variations in sensitivity are imprinted

into the image; the more sensitive pixels show up as brighter dots. Unless you have a space telescope you will always have sky glow; natural atmospheric emissions ensure some sky glow even at prime observing sites. When long exposures are used to detect extremely faint objects, much fainter than the sky glow, the ultimate sensitivity limit is determined by how precisely the flat-fielding error can be removed.

There are several common sources of flat-fielding variations. Typical CCD sensors have pixel-to-pixel variations on the order of 1%. Vignetting in the optical system can reduce the light flux at the corners of the sensor. Dust on optical surfaces near the sensor can cast shadows (often called “dust donuts” due to their appearance in centrally-obstructed optical systems).

To create a flat-field frame, the optical system is illuminated by a uniform light source and an exposure is taken. To avoid non-linearity at the top and noise at the bottom, the exposure is usually chosen to get an average value of 30% to 50% of the saturation level. The flat-field is then renormalized by dividing each pixel into the average value in the array. Any pixel that is more sensitive will be assigned a number slightly below 1; any pixel that is less sensitive will be assigned a number slightly above 1. When this frame is multiplied by a raw image, it removes the sensitivity variations.

Flat-fielding is the most troublesome calibration method. The entire aperture of the optical system must be evenly illuminated with light – if this is not done very carefully, then the flat-field will be wrong. Light leaks will ruin the calibration by adding unfocussed light that did not pass through the optical system. Once calibrated, the CCD camera cannot be moved or refocused. Some sensors have significant flat-field variation as a function of wavelength (color), and it can be difficult to create a reasonable facsimile of the normal illumination spectrum. Given all these problems, a good flat-field can be very difficult to achieve in the field, and so this calibration is sometimes skipped.

If there is no vignetting and dust donuts are not an issue, calibrating the camera alone may be sufficient. Cover the end of a roughly six-inch long opaque tube with a translucent material (a few layers of white photocopy paper will do in a pinch). Place this over the front of the CCD camera, gently illuminate the assembly with white light (natural or incandescent, not fluorescent or LED), and take an exposure which produces a brightness level of roughly 30% of full scale. The resulting images can be used to flat-field the camera, regardless of the optics used. Note that the window must be clean (no dust spots) for this to work properly.

A common technique for astronomical applications is to use “twilight flats,” where the twilight sky is used as a diffuse light source. Rapidly changing light levels can be troublesome, but the illumination can be very uniform if care is taken to avoid recording stars (or to remove them by shifting the telescope between exposures and using median combine with renormalization). A more advanced technique is to use “sky flats.” This is

described in more detail below.

The flat-field frames themselves must be calibrated to remove bias, and for longer exposures dark correction must also be performed. It is essential that both the flat-field frames and light frames are properly bias corrected; otherwise the flat-field operation will not work correctly (mathematically, subtraction and division are not commutative). You can do this manually first, or just let MaxIm DL do it automatically as part of the full calibration procedure.

Combining Frames

All imaging frames recorded by a CCD camera include noise. When you add or subtract images, the noise always adds. Subtracting a single dark frame from an image will remove large pixel-to-pixel variations in the average accumulation of dark current. It will also **increase** the random dark current noise in the image by 41%. If instead you averaged ten dark frames together prior to subtraction, the noise will only be increased by 5%. If you use 20 or 40 frames, the added noise will be negligible.

The standard combine method is to average the frames. This produces the best results for purely random Gaussian noise. Unfortunately if there is an “outlier” pixel on one frame (e.g. cosmic ray hit or a star in a twilight flat) then it will be included in the average.

Median combine is much more effective at suppressing outlier pixels. Unfortunately, median combine increases the noise level 25% compared to averaging. When median combining flat-field frames, renormalization is also required. This ensures that each frame is at the same average brightness (MaxIm DL does this automatically).

An alternative to median is to use Sigma Clipping or Standard Deviation Masking; these techniques throw out outlier pixels and then average the remaining. They are in effect a compromise between median and average, combining the noise reduction advantages of average with the outlier pixel rejection of median combine. The user can also select renormalization options for these methods.

Are All Three Necessary?

Not always. All image frames taken with a CCD camera naturally include the bias. If you subtract a dark from the light frame, and subtract a flat-dark (one that matches the exposure duration of the flat) from the flat-field, then bias is already subtracted from both. You do not need a separate bias frame.

Bias frame are required if:

- You are using exposure scaling for the dark frames, or
- You are using flat-field frames and do not have dark frames with the same

exposure duration as the flat-field frames (“flat-darks”). In that case you can either just subtract bias frames, or use them to help auto-scale dark frames.

Our recommendation is that you use bias frames – they are after all exceedingly easy to capture – and that you always average together at least 10 frames to avoid adding extra noise into your images.

If the flat-field exposure is short, then dark current is negligible and you can just subtract the bias frame from the flat. You must subtract bias or dark from flat; otherwise the flat-field will not work properly.

If you are not doing photometry (brightness measurement), and the image is sufficiently clean for your purposes, then you do not absolutely need a flat-field frame. Nor is a flat-field absolutely necessary for astrometry since the centroid algorithm used is quite robust; however it may help if the signal-to-noise ratio is poor. For general imaging, there are alternative methods to correct overall vignetting, such as the **Flatten Background** command. A can of compressed air is very effective for dust donuts. Nevertheless, if you want the best performance from your camera, or are doing photometric measurements, then a flat-field frame is mandatory.

As an absolute minimum, you should always subtract at least a dark frame. The MaxIm CCD camera control window includes an auto-dark feature that should be turned on if you are not otherwise calibrating your images. It is however always better to average dark frames if at all possible.

Sky Flats

Sky Flats have the advantage of exactly replicating the illumination pattern and spectrum of actual imaging conditions, simply because actual sky images are used.

Sky Flats are especially important for back-illuminated thinned CCD sensors, which can suffer from an effect known as “fringing.” Fringing is an interference pattern in reflections between the front and back surfaces of the sensor; the pattern seen is due to very tiny variations in the thickness of the sensor. The pattern is only noticeable in monochromatic light; unfortunately emission lines are present in the sky background from both natural and artificial sources. Since the sky background is dominant in deep exposures, fringing can be a significant problem. Due to variations in manufacturing, fringes may be more objectionable in some sensors than others.

Sky flats work well because they exactly represent the sky illumination, including the emission lines. This technique is essentially the same as for twilight flats, where the twilight sky is used as the light source, except that it is done with the sky background itself.

The first step is to set up the camera and focus. You should avoid repositioning the camera once the flat-field frames are taken.

Next take a large number (>30) of images of the night sky in a sparse part of the sky, using a different field for each exposure. Often the clock drive is turned off to allow the stars to trail; this reduces the peak level of the stars and ensures that different fields are used for each exposure. Ideally for flat-fields the overall illumination should be at 30% of the full well capacity, but this may require too long an exposure for night sky flats.

You should also take a similar number of bias and dark frames. Enter all of these calibration frames using the **Set Calibration** command. Make sure that Median, SD Mask, or Sigma Clipping is used for the flat-fields. You are now ready to calibrate light images using the sky flats.

In some cases, such as survey imaging, you can use actual light-frame exposures to generate your sky flats. This was done, for example, for the Desktop Universe all-sky CCD mosaic; several thousand mosaic frames were combined to produce an extremely clean master flat.

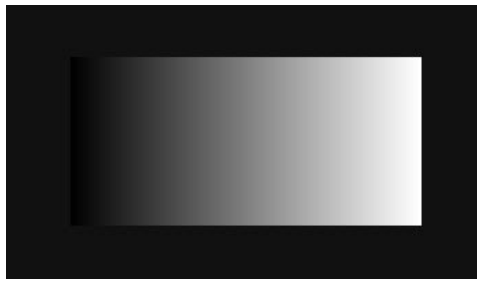
Stretching

The primary goal of stretching is to compress the dynamic range of the image to suit the limitations of your video monitor. Since processed images can have a depth of 16 bits or more, it is impossible to properly represent these images on a computer monitor or printer. Most output devices are limited to 256 grey levels (8 bits) and rarely can you actually distinguish more than 64 grey levels (6 bits).

This is a very serious limitation; as a result, you must perform a stretch operation in order to properly view a CCD image. Simple screen stretch operations do not change the image; rather they adjust the way it is displayed. Screen stretch operations can be made “permanent” so that the image can be exported to other software. More complex stretch functions attempt to adjust to reduce the dynamic range of images so features at very different brightness levels can be seen at the same time.

Monitor Setup

Before you start adjusting your images, make sure your monitor is adjusted properly. Brand-new monitors are often very badly adjusted; manufacturers know that most computer stores have bright overhead fluorescent lighting, and they want their demo units to look bright. So they excessively boost the brightness and contrast, and set the color temperature too high (too blue).



Monitor Calibration Tool

By displaying the above Monitor Calibration Tool in the on-screen Help, you can properly adjust the contrast and brightness settings on your monitor. Make sure that you can distinguish different grey levels across the entire strip. A very badly adjusted monitor will look like this:



Excessive Contrast

The improperly adjusted image is solid black on the left side, and solid white on the right side. Ideally you should be able to see shades of grey almost to the edge.

While you are adjusting your monitor, you might want to check if your monitor allows you to set the color temperature, and set it to around 6500K. (Unfortunately if you just have red, green, and blue intensity adjustments, you would need a color temperature meter to set it accurately.)

Gamma

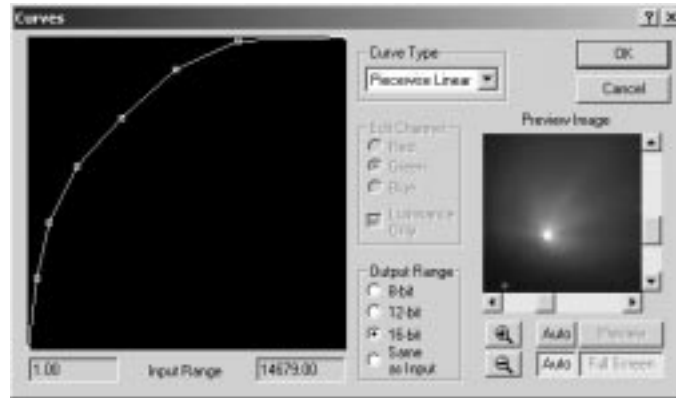
Gamma allows you to adjust the overall image. A gamma less than one will increase the brightness of mid-intensity pixels, and de-emphasize brighter pixels. A gamma greater than one will have the opposite effect.

Often gamma is used as a final “tweak”, to punch up the image a little, or to pull back if the previous processing was a little too aggressive. Gamma can be adjusted using the **Process** menu **Stretch** command.

Curves

The Curves command provides you with a great deal of control over the image. You can boost the contrast in one brightness range by making the curve steeper, while reducing contrast elsewhere by flattening it out.

Many astronomical images have a few extremely bright regions (e.g. bright stars, cores of galaxies), some mid-range features, interesting but very faint details (e.g. outer spiral arms), and a large amount of background. The trick is to boost the contrast of the interesting details while decreasing the contrast of brightness ranges which are of lesser interest or contain little detail. In addition, you wish to avoid “burning out” the very brightest details while doing this. MaxIm DL’s high bit depth capability makes this easier to do.



Using the Curves Tool

Start out by adjusting the Screen Stretch so that the very brightest areas of the image are not saturated, and the darkest areas are not clipped off. When you run the Process menu Curves command, your screen stretch values will appear as the Input Range. Turn on the Auto Full Screen preview so you can see the effect of the changes as you make them.

Now increase the slope of the line where you want more contrast, and decrease it where you need less contrast. Usually you need to increase the slope at the low end (left side) to bring up the faint details. To avoid “blowing out” the brightest details, make sure the line never goes completely flat at the top. It is best to work incrementally, running the command several times in succession, tweaking the image a bit at each step. In the example image, the tight “false nucleus” of the comet is still apparent, even though the dust jets have been boosted up to make them visible. In a subsequent iteration, the faint outer tail would be boosted to help distinguish it from the background.

Some artistic sense is in order. Try not to excessively boost the contrast, burn out the bright regions, or over-exaggerate the faint details. If you have a heavy hand the result

will be a gaudy, unnatural looking image. The trick is to make all of the image features visible, while maintaining a light touch so the image looks natural.

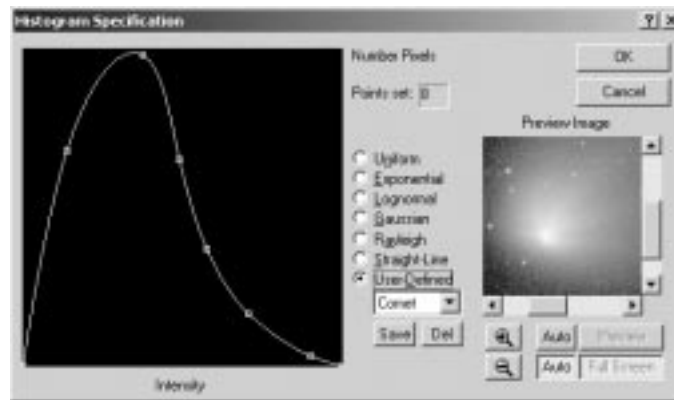
Histogram Specification

Histogram Specification is a powerful algorithm that allows you to force the image histogram into just about any shape. If an image contains a lot of detail at the bright end and low end, but nothing in-between, reshaping the histogram will automatically compress out the empty range in the middle.

The histogram shows you how many pixels are present in different brightness ranges. Equalizing the histogram makes every pixel brightness level equally likely. While that optimally accentuates contrast in all brightness ranges, the effect is very harsh. Some brightness levels might have fewer pixels but more interesting information. Instead of equalizing across the board, picking a suitable curve can emphasize detail where you need it.

Start out by adjusting the Screen Stretch for your image so that the background is not completely black, and even the brightest objects are not fully white. Now launch the Histogram Specification command, and turn on Auto Full Screen preview.

Try each of the pre-defined curves to see what effect they have. Certain curves work best with certain types of objects.



Adjusting a Comet Image with Histogram Specification

Once you have found the curve that gives the best effect, you may tweak the curve (by clicking, and then dragging, the individual points on the curve) to improve the final result. Some experimentation will show you how to get the best effect; for example, if the brightest areas of the image are being washed out, lower the height of the curve on the right side of the graph (the bright intensity region).

Background and Gradient Removal

Often we are taking images under less than ideal circumstances. Light pollution, full moon, and other effects can cause a large variation in the background across the image plane. A bright background, which otherwise could be simply subtracted, may become highly visible if there is vignetting in the optical system, which causes a fall-off of brightness towards the edges of the frame.

Simple gradients can be effectively removed by creating an artificial image containing only a smooth plane, with a slope matching that of the background of your image. If you then subtract this artificial image from your image, the background will be leveled out and the gradient eliminated.

The **Flatten Background** command does exactly this, when **Background Fit** is set to **Simple (bilinear)**. Areas of the image that contain only background are first identified. Measurements are made in each area, and then a plane is fitted to the data. Finally this plane is subtracted off, eliminating the gradient. The measurements can be made automatically, but it is difficult for the software to determine which areas contain only background. It is always best to specify these areas manually using the mouse. Point the mouse at the image and, using the right-click menu, set a medium aperture size – large enough to collect a good sample of background, but not so large that it will be hard to fit in-between the stars. Now click on a few widely spaced areas of the image that are obviously background, and then click **OK**.

If you have vignetting, the light level will fall off towards the edges. In some cases you may have glows with an odd pattern, due to a light leak or readout amplifier glow. The **Flatten Background** command also allows you to correct for this. Set **Background Fit** to **Complex (8th order)**. First select a dozen or so points around the image, then turn on the **Auto Full Screen** preview. Do not turn on the preview at first, otherwise when you have just a few points, the poorly-constrained model may make it difficult to see what you are doing. If parts of the image background still look to bright or too faint, add measurement points in those regions. If you click in the wrong spot, grab the circle with the mouse and move it. Once the image background looks smooth and level, click **OK** to make the changes permanent.

Filtering

Filtering is primarily used for two purposes – sharpening fine detail, and smoothing out noise. Since noise and fine detail often appear in different parts of an image, with careful application it is frequently possible to do both at the same time.

Noise Reduction

Low-pass (smoothing) filters make an image blurrier. However, they also have the effect of reducing noise. If you take a set of measurements of the same quantity, and average them together, the resulting combined result will be more accurate and have less noise.

Similarly, if you sum the results from several adjacent pixels, any correlation between the pixels is amplified, and any differences are reduced. Noise is always uncorrelated, because each pixel makes its own independent measurement. There is always some correlation between pixels in a properly sampled image, because by definition there are no spatial frequencies higher than half the sample rate. Therefore simply averaging together adjacent pixels will reduce the noise more than it smoothes the signal.

A “boxcar average” filter is rather harsh; in practice we use a less aggressive filter. Nevertheless, smoothing an image to reduce noise reduces sharpness in a rather visible fashion.

In the bright “foreground” and “midrange” regions of an image, there is frequently a lot of fine detail. The signal-to-noise ratio is intrinsically good because the bright data overwhelms the noise sources. So usually no smoothing is required for bright areas.

The background of the image, on the other hand, intrinsically has poor signal-to-noise ratio. There may be detail there as well, but the poor SNR makes it difficult to discern. Therefore smoothing those areas, reducing the noise, may actually enhance the perception of faint details.

The best solution is therefore to selectively smooth the background areas of an image. One way to do that is to use the pixel range limitation feature of MaxIm DL’s filters. On the Kernel Filters or FFT Filters dialog box, click the >> button to reveal the pixel range restriction controls. Measure the pixel values in the background area using the Information window (this can be opened while the filter command is active). You need to select a number between the typical background levels and typical midrange levels. Set the filter to work only on pixels between 0 and that number.

For very fine control of the amount of blurring, the **Kernel Filter** command has a **Gaussian Blur** option. Simply specify the blur radius in pixels; a larger radius produces a stronger blur.

Sharpening

High-pass or sharpening filters are widely used because they emphasize faint, fine details. However, care has to be taken in using these filters because they emphasize noise, and can produce image artifacts.

You can perform a high-pass filter directly, but you can get much better control by using an Unsharp Mask. A mask is created by low-pass filtering a copy of the image. That

copy is scaled down by some factor and then subtracted from the original image. This produces a sharper image. This works because you are partially removing parts of the image that are smoother, while leaving untouched the parts of the image with fine detail. Usually the math is adjusted so that the average pixel values in the final image are the same as the original.

Unsharp Mask is preferred because of the fine level of control available. The amount of sharpening is controlled by the scale factor. If the mask is very blurry, you remove only the grossest large-scale variations in the image. If the mask is only slightly blurry, then only the very finest details are boosted.

Unsharp Mask is particularly good for planetary images, but is also used for general deep-sky imaging. The **Geometric Mean Mask** mode can be used with objects that have extremely rapidly changing brightness, like comets and galaxy nuclei.

Since high-pass operations boost noise, you may want to restrict the range operated on by the filter. Usually bright areas have higher signal-to-noise ratios, so you may want to restrict the filter so it only operates on the midrange or brighter parts of the image.

Digital Development Processing

This process is intended to simulate the photographic development process on digitally recorded images. The algorithm simultaneously applies a combination unsharp mask and a gamma correction to the image, producing two important effects: an edge emphasis and a non-linear stretch. The resulting image has a more natural appearance similar to what is achieved with conventional film or what can be perceived visually. This function works very well on many types of astronomical images, such as galaxies.

Special-Purpose Filters

The **Rotational Gradient** filter is intended for use on objects which are mostly circularly symmetrical, to extract detail from non-symmetric features. A typical application is highlighting jets from the core of a galaxy or a comet nucleus. By changing the angle of the filter, you can emphasize details with differing angular size.

The **Local Adaptive** filter sharpens fine details in areas of the image that have low contrast. It is particularly good at extracting subtle detail in planetary images; however, it can also cause excessive noise amplification so it should be used with care.

Median filtering can strongly remove “outlier” pixels, such as hot pixels. However it also has a strong low-pass effect and is a non-linear filter – severe artifacts can result if used improperly (such as using it with Pixel Math to do an unsharp mask).

A better approach for outlier pixels is to repair just those pixels. There are several approaches. One is to use the **Kernel Filter** hot/dead pixel removal filters, which detect

and replace bad pixels with the average of the surrounding pixels. They are very effective and only affect pixels that exceed the threshold, so their overall effect is much better than a median filter. A similar effect is achieved using the **Remove Bad Pixels** command, which does the replacement using a map of “known bad” pixels.

The best method is to take a series of exposures, and “**dither**” the camera position slightly between each exposure (MaxIm DL can automatically dither using the autoguider, telescope control, or AO-7 control). You then combine the images using median, Sigma Clip, or SD Mask combine. This very effectively suppresses hot pixels without artificially substituting pixels.

Color Processing

All image processing functions work on both monochrome and color images. This section describes some additional processing commands for color images, and some special considerations that apply when working with color images.

Creating Color Images

Color images may be created from filtered black and white images using the **Combine Color** command. The simplest and best method is to take images through red, green, and blue filters. If the exposures are balanced, the three color images can be combined together directly to make a color composite, with perhaps only an alignment adjustment.

For “single-shot color” cameras, the **Convert MX** and **Convert RGB** commands can be used to create the color image from information encoded in the image itself.

The **Color Stack** allows you to stack an arbitrary number of filtered images together, and assign each a unique color. This can be useful in creating “false color” images, or in integrating additional filter channels, such as Hydrogen-Alpha.

Finally, you can create artificial color based on brightness levels using **Pseudo Color**. In some cases this can reveal structures that are difficult to see in the original image.

Adding Luminance

The straightforward method of creating a color image is to combine red, green, and blue filtered images together. This works well because the human eye works exactly the same way; there are individual red, green, and blue receptors (cone cells) in the retina.

When working with low light levels, it can be difficult to achieve sufficient exposure time in all three color bands to produce a clean, low-noise image. The LRGB technique is a shortcut that can be used to reduce the total exposure time required, by adding a Luminance frame to the three standard color planes.

A common technique is therefore to take an unfiltered image set with a very long exposure time. To get the color information, separate red, green, and blue sequences are taken with a shorter total exposure time. The three planes are combined together to produce a color image, and then the luminance of that composite is replaced with that from the long unfiltered exposure set. This **LRGB** technique can be done using the **Combine Color** command. MaxIm DL is also designed to capture LRGB filtered image sequences quickly and easily, using the MaxIm CCD Sequence tab. The **Sequence Wizard** provides a quick method for setting up these sequences.

The human eye is far more sensitive to luminance changes than it is to color changes. This technique has been used for many years to reduce the bandwidth required for transmitting color television. The black-and-white component of the television signal is transmitted with full bandwidth, and the color components are transmitted at about 1/3 bandwidth. When the image is reassembled on the TV screen, the eye simply does not notice the lower resolution of the color components.

This technique can also be exploited for LRGB by taking binned exposure for the color planes, and a full-resolution exposure for the luminance plane. In many cases, binning will improve the signal-to-noise ratio, allowing for shorter exposure times. Be aware, however, that high sky background and low spatial resolution can combine to lower the signal-to-noise ratio for stars. Stars don't get brighter with additional binning once they are undersampled, and yet more background light enters the bigger pixels. This adds more photon shot noise into each pixel, but no more signal, thus reducing the signal-to-noise ratio. For more information, see the snr.xls spreadsheet, available in the MaxIm DL Extras section of our web site, http://cyanogen.com/products/maxim_extras.htm.

Color Balance

The sensitivity of most CCD cameras as a function of wavelength (color) is different than the response of the human eye. The filters used for creating color composites also have their own characteristics, as do the telescope optics. Although "perfect" color rendition is an elusive if not impossible goal (all individuals see colors slightly differently), it is straightforward to get "good" color balance with simple weightings.

The **Color Balance** command adjusts the three color planes so that proper white balance can be achieved. The first step is to remove any background cast by clicking the **Auto Background** button (manual adjustment is also possible). The next step is to set the scaling factors for the red, green, and blue filters. The simplest way to do this is identify an object in the image that is white, and then click on it.

Usually you will find a number of stars in an image that are "white enough" to use as an accurate reference for color balance. For better accuracy, it is best to calibrate using a source known to be pure white. Stars vary in color according to their spectral class, but the Sun is considered to be white. Therefore any star of the same G2V spectral class (or

close to it) should also be white. The following table (ref. Berry et.al., Sky & Telescope Magazine, December 1998) lists a number of these “solar analog” stars:

RA	Dec	Mag	Class	Name
00h 18m 40s	-08d 03m 04s	6.467	G3	SAO128690
00h 22m 52s	-12d 12m 34s	6.39	G2.5	9 Cet (SAO147237)
01h 41m 47s	+42d 36m 48s	4.961	G1.5	SAO37434
01h 53m 18s	+00d 22m 25s	9.734	G5	SAO110202
03h 19m 02s	-02d 50m 36s	7.052	G1.5	SAO130415
04h 26m 40s	+16d 44m 49s	8.10	G2	Hyades vB 64 (SAO93936)
06h 24m 44s	-28d 46m 48s	6.374	G2	SAO171711
08h 54m 18s	-05d 26m 04s	6.008	G2	SAO136389
10h 01m 01s	+31d 55m 25s	5.374	G3	20 LMi (SAO61808)
11h 18m 11s	+31d 31m 45s	4.85	G2	Xi UMa B (SAO62484)
13h 38m 42s	-01d 14m 14s	9.975	G5	105-56 (SAO139464)
15h 37m 18s	-00d 09m 50s	8.433	G3	107-684 (SAO121093)
15h 44m 02s	+02d 30m 54s	5.868	G2.5	23 psi Ser (SAO121152)
15h 53m 12s	+13d 11m 48s	6.084	G1	39 Ser (SAO101792)
16h 07m 04s	-14d 04m 16s	6.314	G2	SAO159706
16h 15m 37s	-08d 22m 10s	5.494	G2	18 Sco (SAO141066)
19h 41m 49s	+50d 31m 31s	5.976	G1.5	16 Cyg A (SAO31898)
19h 41m 52s	+50d 31m 03s	6.237	G3	16 Cyg B (SAO31899)
20h 43m 12s	+00d 26m 15s	9.977	G2	SAO126133
21h 42m 27s	+00d 26m 20s	9.074	G5	SAO127005
23h 12m 39s	+02d 41m 10s	7.708	G1	HD219018 (SAO128034)

To calibrate your exposures, take an image of one of these stars, taking care to ensure that it is at a high altitude to avoid extinction. Then simply use the Color Balance command to determine the proper scaling.

Another approach is to use a photographic grey scale card (available from Kodak) and sunlight. Arrange for your telescope, preferably shielded from sunlight, to image a grey card placed in sunlight. It will probably be necessary to stop down the instrument to reduce the light levels sufficiently to take an exposure without saturating.

The **White Balance** command is a simplified version of the same command, which allows you to select a region of the image by creating a drag rectangle with the mouse. It is more suited for lab imaging applications, e.g. calibrating microscope imaging, where a large white area can be imaged.

You can also adjust color balance using the **Color Adjust** command. This command allows you to see the image with various adjustments applied, and then pick the image with the best appearance.

Color Saturation

Some processing commands, such as Digital Development Processing, can reduce the color saturation of a color image. This can be compensated for using the Color

Saturation command. It is also possible to exaggerate color to make it more visible. Note however that it is quite easy to overdo this and create an artificial-looking image. It is best to use a light touch when enhancing color.

Smoothing Colors

The human eye is far more sensitive to intensity variations than to color variations. Since CCD cameras typically vary in their sensitivity across the spectrum, it is not unusual to have excessive noise in one of the filter bands. This results in color speckling. Since the human eye effectively has less resolution in color than in luminance, it is possible to mask the color variations.

The **Color Smoothing** command allows you to apply a filter to the color only. It works by extracting the luminance information, filtering the three color planes, and then recombining the filtered color planes with the unfiltered luminance plane. This is a handy method for quickly cleaning up an image with color noise.

Mosaics

MaxIm DL/CCD includes a mosaic generation capability on the Sequence tab. Using this feature, it is possible to build up image mosaics covering a large area of the sky. It ensures that the individual tiles are evenly spaced across the area of interest, which greatly simplifies assembling the mosaic afterwards.

The mosaic should be captured with a certain amount of overlap between tiles. This provides an area for “feathering,” which gradually blends the output from one image to the next. This prevents hard edges and other artifacts.

Starting out with a large blank document, use the **Mosaic** command to add the individual tiles. For images containing stars, you can automatically align tiles as you place them; simply place a tile approximately in position, then click **Snap** to pop it into place automatically. If you turn on **Auto Background Equalization**, the overlap areas on the edges of the tiles will be compared and an adjustment automatically made to match them up in brightness.

Try to make sure that the source images have the same exposure and that the sky conditions are the same. If the background levels change, it can cause problems with the blending. Flat-fielding is particularly important; any vignetting will show up as a pattern in the final mosaic. If necessary, use the **Flatten Background** command on each time prior to building the mosaic.

You should also make sure that there are no edge artifacts from your camera. If there are, they should be cropped off before trying to assemble the mosaic.

Editing

Small glitches and artifacts can be readily removed using the **Edit Pixels** command. Using this command, you can pick up or select a color, then apply it to one or more pixels.

The **Clone** tool is much more powerful. You can select any size aperture using the right-click menu. You can then copy data from one region to another. You can copy pixels from one place in an image to another; you specify the source region, and then click on the destination where you want the pixels copied to. As you move the cursor around, the source region moves in parallel. This allows you to copy strips or areas. This is extremely useful for cleaning up areas that have significant background in them. If you can find a source area with the same background characteristics, your repair can be seamless.

The Clone tool also allows you to copy from one image to another. In addition to copying from any area in the source image to any area in the destination image, you can lock the two positions together. This is handy for merging information from two slightly different versions of the same image; for example, you could use this to smooth or sharpen some region of the image. You can use the Undo buffer of the image as the source; this allows you to selective undo processing operations on certain areas of an image.

Bloom Removal

All CCD cameras have a maximum “well capacity.” If the number of photons detected exceeds this amount, the pixel will overflow into adjacent wells. Normally the photoelectrons are held in place by electric fields generated by the overlying electrodes. But when too many electrons accumulate, their own electric field swamps out that from the electrodes. The electrons are still constrained horizontally, because the columns are defined by insulating oxide, so they migrate vertically. In addition, some electrons become stuck in “charge traps” and do not leave the pixel until after a number of clocking operations. These effects cause the overflow to “bloom” vertically.

For science observations, the data in these pixels is lost. On the other hand, for general imaging purposes the blooms can be simply edited out. This is very tedious to do by hand, but the **Bloom Removal** tool can do this quickly and effectively. First the bloom is identified. Then the bloom is deleted and replaced by interpolated data. Finally the star image is cleaned up to make it round.

To ensure a clean removal, the tool automatically adds noise to the pixels it is replacing. This emulates the appearance of the background present in adjacent areas. The

background statistics are obtained by looking at pixels near the bloom; but they can be manually adjusted for best effect.

Deinterlace

Some video sources scan twice, with even and odd lines being imaged at slightly different times. If there is rapid image motion, perhaps due to atmospheric seeing, the image shows jagged edges. This can be removed, and the overall resolution improved, by splitting the image in two using the **Deinterlace** command. The resulting even and odd field images are each interpolated to replace the missing pixels.

Binning and Resizing

Sometimes it is useful to shrink images. The **Binning** command does this in the same manner as binning in a CCD camera – simply combine the adjacent pixels together into a single “super-pixel”. Unlike a CCD camera, this function averages the values instead of summing them; however the effect is otherwise identical.

Simple binning does not ensure that the result meets the Nyquist Sampling Criterion. This means that small point sources like stars can all but disappear. The “correct” way to resize an image is to first low-pass filter it, so that no spatial frequencies exceed one half the new sample interval. This prevents the addition of aliasing distortion into the image. The **Half Size** command includes such a Nyquist filter.

Deconvolution

Maximum Entropy and Lucy-Richardson Deconvolution are advanced image restoration algorithms that can remove the effects of blurring in an image. These algorithms, first pioneered for radio astronomy, became very important for visible-light astronomers when the problems with the Hubble Space Telescope were discovered.

Outside of astronomical applications, the same image technique can be applied to just about any image, from microscope pictures to security camera video frames. The only essential requirement is that the image be blurry! Note that images taken with very short focal length cameras may have limited resolution, yet they may have too few pixels to properly sample the blur that is in the image. If the pixels in the camera do not resolve the blur, then no image processing algorithm can improve the resolution; deconvolution will not improve the image.

Two things are required for deconvolution to work. The first is a model of the blur, known as the Point-Spread Function (PSF). The PSF tells the deconvolution algorithm

how the image was blurred; it is essentially an image of a perfect point source taken with the same camera. For astronomical images, it is often easy to determine the point-spread functions since every single star image represents the PSF. For other types of images, it may be necessary to guess at a model; MaxIm DL includes features that help you choose the best model.

The second piece of information required is some information on the noise level and the average background level in the image. MaxIm DL has to know how hard to work at deconvolving each pixel; it uses a noise model and knowledge of the background level to do this.

Basics

When an image is blurred, mathematically it is convolved with a point-spread function (PSF). This blurring can be removed through a process of deconvolution. A convolution can be calculated quite easily by taking the Fast Fourier Transform (FFT) of the image and the PSF, multiplying the two together pixel-by-pixel, and taking the inverse FFT. In principle, deconvolution can be performed in the same fashion by using division instead of multiplication. However this is not practical in reality due to the possibility of zeros in the PSF and strong noise amplification in areas where the values in the PSF is small.

Iterative methods such as **Maximum Entropy** and **Lucy-Richardson** overcome this problem. An initial guess image is constructed, and then adjusted in a series of steps called iterations. These iterations continue until the process converges on a solution.

The iterative process is as follows: start with a guess, usually a blank image. Blur the “guess” image using the point-spread function. Compare it against the original image, using statistical methods. Now adjust the “guess” image using this information, creating a new “guess”. Repeat the process until the image converges on the correct result.

The iterative process can be unstable, so it has to be controlled to prevent large excursions. This is done using constraints. The major difference between the various algorithms is the choice of constraints that are applied to the processing. **Maximum Entropy Deconvolution**, as the name implies, chooses the solution that has the maximum information theory entropy. This forces the solution to the maximum likelihood estimate. Lucy-Richardson has different but equally effective constraints.

The decision on when best to stop the iterations is a topic of ongoing debate. If the iterations are stopped too soon, the image is not sharpened completely. If the iterations are stopped too late, noise amplification becomes a problem. Since the user must make this decision, MaxIm DL shows the result of each iteration on the screen.

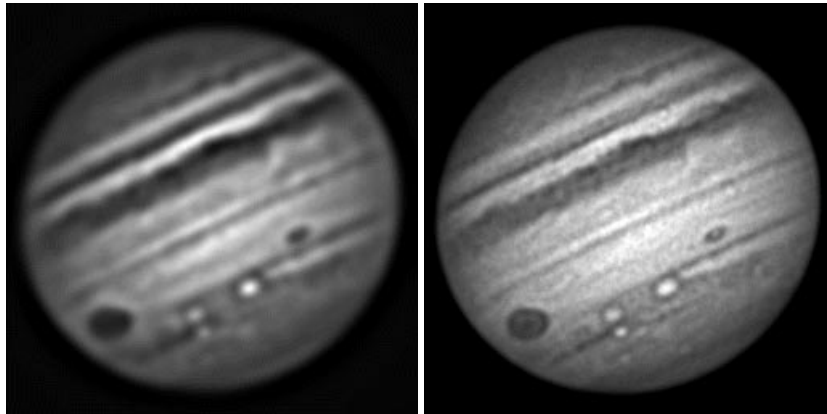
Point-Spread Functions

No image is a perfect representation of the real world. All images have noise in them

caused by the detection process in the camera. All images are also blurred to some extent, whether by focus problems, fundamental limitations or errors in the optics, motion blur, or the effects of air currents in the atmosphere. All of these blurring effects can be modeled by a single Point-Spread Function (PSF). Mathematically speaking, the PSF is convolved with the original (perfect) image to produce the (blurred) picture at the detector.

Let's assume you took a photograph of something that you know is a perfect point of light. An example of this would be a star image – aside from the Sun, stars are much too far from the Earth to be resolved by conventional optical systems. The actual image on the photograph would not be a perfect point like the real star because of various blurring effects. The intensity profile of the blur in the picture is actually itself an accurate measurement of the PSF which blurred the image. If the image contained many stars, each would be blurred by the same PSF. (In some cases, the PSF actually varies across the frame. In this case, the image may have to be processed in segments.)

Ideally, the PSF should be noise-free. Of course any measurement taken from the image itself will be subject to noise. The first criterion should be to take the star image with the greatest signal-to-noise ratio – for a linear CCD detector this is usually the brightest non-saturated star in the image. In some cases this should be cleaned up further.



Curdled (left) and Correctly Sharpened (right)

MaxIm DL provides two different methods to clean up the PSF. You can use the extracted star as-is with the “**Clean-Up**” button selected. When selected, this option cleans up the tails of the PSF distribution by replacing the faintest parts of the PSF with a fitted Gaussian curve. This option should only be used when the background is very noisy, as it can lead to extended “donuts” around the stars.

The best option in most situations is to select a **Gaussian** or **Exponential** curve mathematical model. The only input parameter used is the radius of the curve (the

standard deviation of the distribution). MaxIm DL allows you to automatically find the best-fit curve to a star or other point source in the image. Noise in the image may affect the measurement of the radius, but because a number of pixels contribute to the calculation the noise is greatly reduced.

Some CCD cameras do not have square pixels. If you are using such a device, it is best to use the **Make Pixels Square** function prior to deconvolution.

If your image does not include a usable point source to help initialize the PSF model, you may have to guess. There is a simple trial-and-error procedure for doing this.

Examine the image details and try to generate a first guess at what the radius of the blur is. Select a region of the image (to speed up processing) and deconvolve it. If the image is not enhanced, decrease the **PSF Radius**. If the image becomes “curdled”, decrease the **PSF Radius**. Repeat the procedure until you are satisfied with the results.

Noise Models

Every image has noise. This noise is unavoidable, and greatly complicates the deconvolution process.

To provide the optimum deconvolution, MaxIm DL needs to know something about the noise and background level in the image. When these parameters are set properly, the algorithm converges more strongly towards the correct solution.

Two predominant noise sources are usually encountered. The first is photon shot noise – random variations in light itself. The **Poisson** noise model approximates this.

MaxIm DL automatically calculates the noise level in each pixel based upon the number of photoelectrons detected in that pixel. In order to do this, it needs to know the gain of the camera, a value known as **Photoelectrons per ADU** or simply **Gain** (this can be determined using the **Photons Wizard**). The estimated amount of noise in a pixel simply corresponds to the square root of the number of photons detected.

Another noise source is the electronic read noise. On average, the same amount is present in every pixel, so it is usually modeled using a **Uniform** noise model. To obtain a measure of the uniform noise level (i.e. the standard deviation of the distribution), the variance in pixel values can be measured in some part of the image that contains no foreground data. Often it is best to average the results from several locations. If the image has no background, due to high light levels, then you may need to measure the noise in a dark frame.

Deconvolution also requires an input parameter that indicates the average background level in the image. Even for astronomical images, the background is almost never black (zero) due to sky glow, light pollution, and other effects. Sometimes an image has had a background level previously added or subtracted; in that case, this amount (the black

level offset) should be supplied so that the algorithm knows where the true zero point is. MaxIm DL provides easy-to-use tools to extract the necessary information from the image itself.

Convergence

Deconvolution is performed using an iterative procedure. This means it starts with a blank image and adjusts it in steps until the desired output is obtained. The decision on when to stop iterating is a difficult one, and is the subject of some debate (see below).

The image may not converge if the input parameters have not been set properly. This usually becomes apparent quickly as the image fades out, bounces back and forth between two states, or just remains fuzzy. The rate of convergence varies from image to image, depending on the distribution of information in the image. Often 10-15 iterations are sufficient for the image to converge.

The image should be noticeably converging after about five iterations. If not, consider changing the Photoelectrons per ADU, noise model, or point-spread function. *The most common reason for convergence failure with the Poisson noise model is an incorrect setting for Photoelectrons per ADU.* For the uniform noise model, try adjusting the noise level setting. Increasing the uniform noise level or background level will often make it easier for the algorithm to converge. Note that increasing the uniform noise level or background level too much may reduce the effectiveness of the deconvolution.

Stopping Criteria

The question of when to stop iterating is a matter of judgment. Too few iterations will result in an image that is not completely deconvolved. Too many iterations will cause excessive noise amplification, particularly in areas with faint, continuous details.

General guidelines are as follows:

The image should obviously look sharper than the original version. Often the brighter areas will deconvolve first, followed by the fainter features.

Some images are much more difficult to deconvolve than others. Often 10-15 iterations are sufficient; occasionally 40 or more are required. If the image converges too slowly, check the PSF and Noise model settings.

It is quite possible to overdo it. Once the image is sharpened, very little additional improvement will be seen. But the algorithm will continue to try to deconvolve the noise floor, which was not blurred by the PSF. The background will start looking noisy and “curdled.”

General Recommendations

There are certain processing steps that should be performed before deconvolution.

Calibration and image stacking should be done first. Hot and dead pixels should be fixed. If the camera does not produce square pixels, it is recommended that you interpolate them to a square aspect ratio before proceeding. It is strongly recommended that any other processing functions be deferred until after deconvolution is run.

If you are using a Uniform noise model you might also try experimenting with the Uniform Noise Level. A higher noise level will reduce the convergence rate (making it easier to converge), and a lower one will increase it. For either noise model some experimentation with the Background Level may also be in order, since selecting a proper background level is essential for good results.

You can use subframe deconvolution to determine whether your settings will work. Deconvolution algorithms use Fast Fourier Transforms; this means they work only on images whose width and height are both powers of two dimensions (e.g. 256, 512, 1024, 2048...). If your image size is not of this form, it will be padded up to the next larger size. If your image is just slightly larger than a power of two, it is best to crop it slightly – this will produce better convergence and faster processing.

One problem is the tendency for deconvolution to dig round holes around stars (“donuts”). To minimize these, make sure the background level is set appropriately. For non-scientific applications, these donuts can be cosmetically eliminated using the **Clone** tool.

Astrometry

Astrometry is the precise measurement of the position of celestial objects, such as stars, minor planets (asteroids), supernovae, and comets. In the case of new discoveries, this can be extremely important for orbit determination and for planning follow-up observations. The determination of an accurate orbit for a new object requires multiple precise positions over a period of time. Until the advent of CCD cameras and analysis software, this was a time-consuming and difficult procedure. Now highly accurate measurements can be made quickly and easily.

For performing astrometric measurements, MaxIm DL includes the PinPoint LE Astrometric Engine from DC3 Dreams, SP (<http://acp.dc3.com>), which integrates seamlessly with MaxIm DL. (Additional capabilities are available with the full version of PinPoint, which is also compatible with MaxIm DL.)

Once PinPoint is set up for the star catalog and the general characteristics of your images (rough image scale, etc.), the analysis is fully automatic. When using the MaxIm CCD camera control and Telescope Control windows, a rough position is added to the FITS header for each image. PinPoint uses this as a starting point. It finds all the stars in the image, matches against catalog positions for stars in that vicinity, and then

calculates a mapping between the catalog and the image.

This mapping is stored as World Coordinate System (WCS) values in the FITS header of the image. This WCS header information is standardized, so it is compatible with many other software applications.

Once the WCS information is available, MaxIm DL can provide precise measurements of the position of any object in the image, using the Information window. Under typical observing conditions, the measurements are often accurate and repeatable to a fraction of an arc-second.

Telescope Control Benefits

The astrometric information can be used for more than scientific measurements. PinPoint can be used as a “digital finderscope.”

During telescope operations, the information from PinPoint can be used to synchronize the telescope position with the sky. After a long slew, a quick astrometric reduction will allow you to accurately resynchronize the telescope position – without having to manually align the target. With the spiral search option, it will determine the telescope position even if you missed the target field entirely. After the sync, the user can click the Go To button again, and the object will be perfectly centered.

Photometry

Photometry is the measurement of the amount of light from an object. Accurate photometric measurement is a fundamental and important means for understanding the physics behind astronomical objects and events.

Prior to CCD cameras, photometric measurements were made visually, photographically, or using photomultiplier tubes. The former two methods suffer from accuracy problems; whereas the latter are rather difficult and time-consuming to use. CCD cameras permit the simultaneous capture of quantitative data for both the target star or object and other comparison stars.

Typically photometric measurements of stars are performed using filters. Several filter systems are in use, including Johnson UBVRI, Kron/Cousins UBVRI, and Bessell.

Comparing different filter bands allows the determination of a color index for a star. Fundamental physical parameters for a star can be determined using these methods. Many stars vary in brightness; analyzing the light curves can be used to set constraints on physical models, measure distances, etc.

MaxIm DL includes two photometric measurement tools, both based on aperture photometry – measuring the total light within a circular aperture. The simplest is the

Information window, which can be calibrated to a star of known magnitude on an image. Then other stars can be measured using that calibration.

The **Analyze** menu **Photometry** command can be used to perform more accurate measurements and plot them over time. This command performs a careful background subtraction using median-mean techniques, and also takes partial pixels into account when integrating the light inside the measurement aperture. Data can be plotted for measured stars, comparison stars, and check stars.

The aperture used for the measurements is fully adjustable. An annular region for background measurements is also fully adjustable. This allows you to include the total light from a star, and pick the best region for use for the background measurement.

A detailed explanation of photometry is beyond the scope of this manual. A good place to start for further research is the American Association of Variable Star Observers, <http://www.aavso.org>.

Exporting Images

If you wish to display your images on a web site, you will need to export to an image such as JPEG, which has limited dynamic range. In such a case, it is necessary to stretch the image so that it will appear correctly when output in that format and later loaded into another application.

The Process menu Stretch command allows you to perform such a stretch by defining the desired output range. For most formats, the 8-bit setting is appropriate. Normally the Input Range is set to Screen Stretch, the Output Range is set to 8-bit (0-255), and the Permanent Stretch Type is set to Linear Only.

Setting the **Input Range** to **Screen Stretch** tells MaxIm DL to use the values from the **Screen Stretch** window for the stretch. When **OK** is **clicked**, the image buffer will look exactly the same, but the pixel values will now range from 0 to 255. The image can now be saved as a TIFF, JPEG, BMP, or PNG image; and it will be stretched properly when loaded into another application.

Tips for Public Presentation

With the widespread availability of computer video projectors, public presentation of CCD images is easier than ever. However, these displays have limited dynamic range and are often set up poorly; often the contrast settings are excessive. This can have a severe impact on the appearance of astronomical images with faint details.

If you can access the video projector's controls prior to your presentation, then try

projecting a grayscale strip or at least an image with large dynamic range. A grayscale strip is built into Desktop Universe software; various others are available on the Internet. Most importantly for astronomical images, adjust the contrast and brightness so that you can see the difference in shades of black at the dark end. Also try to make sure that you can discern brightness levels at the top end, to avoid excessively saturating bright parts of the images.

If you cannot adjust the projector prior to the show, then consider displaying the images using MaxIm DL. The Quick Stretch feature will allow you to quickly adjust the images for best display. If this is not possible because you are using PowerPoint, then it may be advisable to pre-adjust the images for lower contrast and brighter background, just to be sure the fainter details will be visible.

In the event that a video projector is not available, there are a number of options available for transferring images to slide film or overheads. However, most of these methods are expensive or have a long turn-around time. It is quite simple to photograph images directly from the screen, if due care is taken.

The **Full Screen** command on the **View** menu scales the selected image to fill the screen, and suppresses display of all other objects on the Windows desktop. For better results, you should first use the **Process** menu **Resize** command to scale the image to match the screen. This command interpolates the image, which will give a smoother representation.

The room lights should be off during the exposure. If your monitor has LED indicators, it is a good idea to temporarily cover them with two layers of black electrical tape.

Load a 35 mm SLR camera with ISO 100 slide film, and attach it to a tripod. Use a lens that allows you to fill the picture with the screen image (try to pick a lens which can be placed some distance from the screen – this will minimize geometric distortion). Align the camera square to the monitor and focus. Set the exposure to 1 second and the f/stop to approximately 4.5 (some bracketing may be required on your first attempt – be sure to record your settings). The long exposure will average out the effects of the monitor's refresh scans.

The photograph will tend to increase contrast. To compensate for this, adjust the monitor controls so that the image looks washed out. This should be done in the dark so you can better see the image. By turning the contrast control down and increasing the brightness control, you can reduce the intensity of the bright areas while bringing the dark areas up (the background *should* look bright enough to the eye that the image is fairly washed out). The image will look terrible, but it will be just right for the camera. Again, some experimentation may be required for the best results.

When taking the picture, either use a cable release or the camera's built-in timer to reduce any vibration.

Chapter 4. Equipment Setup

MaxIm DL/CCD controls a wide variety of equipment, including many different models of CCD cameras, autoguiders, filter wheels, telescopes, and focusers. It can also synchronize with an observatory dome using the ASCOM Dome Control Panel.

Driver installation and setup is described in the next section.

For equipment troubleshooting, please refer to the chapter on **Troubleshooting**.

Driver Installation and Setup

The majority of hardware used with MaxIm DL is connected through drivers provided by the equipment manufacturers. For CCD cameras, filter wheels, and autoguiders, MaxIm DL has a "plug-in driver" for each type of equipment, but in many cases our driver is just a bridge to the manufacturer's own drivers. For that reason, it is extremely important that the third party drivers be installed and operational prior to attempting to connect from MaxIm DL.

Important: In order for many drivers to work correctly under Windows NT/2000/XP, MaxIm DL must be installed from an Administrator level account.

Telescopes, Focusers, and Domes

These devices require the ASCOM Platform, available from <http://ascom-standards.org/downloads.html>

Dome control and synchronization with the telescope is performed using the ASCOM Dome Control Panel. This control panel is connected to the telescope and dome. Applications such as MaxIm DL that need to connect to the telescope are instead connected to the dome control panel. See **ASCOM Hubs** for more information.

CCD Cameras and Autoguiders

Third-party Plug-in drivers are normally installed by placing their files in the MaxIm DL program installation directory (you must restart MaxIm DL after installation). Please refer to the documentation included with the driver for additional installation and setup information. Also note that the manufacturer provides software support for the plug-in drivers.

For information on writing Plug-in Drivers, please visit the MaxIm DL Extras section at <http://www.cyanogen.com>.

MaxIm DL User Manual

Camera Model	Installation	Select in MaxIm DL
Apogee	<p>Drivers for Apogee AP, KX, and SPH cameras are included with the MaxIm DL installation.</p> <p>Drivers for Apogee Alta are also included; however these are new cameras and the drivers are updated fairly frequently. It is essential that you install any driver update disk that is supplied with the camera.</p>	<p>Apogee for AP, KX, SPH</p> <p>Apogee Alta for Alta cameras</p>
Audine and Genesis	The Audine camera driver must be downloaded and installed.	Audine
Celestron PixCel cameras	See SBIG.	SBIG Universal
DTA	Drivers are supplied by the manufacturer, including the plug-in driver for MaxIm DL.	Consult manufacturer's instructions.
Cookbook CB245	All drivers required for these cameras are built into MaxIm DL.	CB245
Finger Lakes Instrumentation	<p>FLI drivers must be installed separately. They are available from http://www.fli-cam.com/software.htm</p> <p>Please note that FLI's web site actually includes two different versions of their drivers. It is recommended that you use the older generation of drivers with older parallel port cameras; in MaxIm DL, you select FLI 1st Gen to run with the older drivers.</p>	<p>Finger Lakes for USB and Ethernet cameras</p> <p>FLI 1st Gen for parallel port cameras</p>
Hi-SIS	All drivers required for these cameras are built into MaxIm DL.	Hi-SIS 22 or Hi-SIS 44
ISI CCD800, CCD1600	Drivers are supplied by the manufacturer, including the plug-in driver for MaxIm DL.	Consult manufacturer's instructions.
Meade	<p>All Meade cameras are capable of operating through the serial port. All drivers required for operating in serial mode are built into MaxIm DL.</p> <p>The 416XT and 1616XT cameras are also capable of operating on the SCSI interface for higher speed. Please follow Meade's recommendation on SCSI adapters; only the models they recommend will work properly. You must have the latest Adaptec driver for your host interface card installed. You also must have the latest Adaptec ASPI driver installed. These can be obtained from http://www.adaptec.com</p>	<p>Meade 208XT for Pictor 208XT</p> <p>Meade 216XT for Pictor 216XT</p> <p>Meade 416/1616 for Pictor 416XT and Pictor 1616XT in serial port mode</p> <p>Meade SCSI for Pictor 416XT and Pictor 1616XT in SCSI mode</p>

<p>Roper (Princeton and Photometrics models)</p>	<p>Roper cameras are supported using the Roper PVCam software, provided with the camera. This software must be installed and configured before you can link to the camera.</p>	<p>Roper</p>
<p>SBIG</p>	<p>SBIG provides drivers for all cameras that are currently in production, except the STV. The SBIGDriverChecker, supplied with the camera, is used to install and update the drivers. It includes a built-in download facility. If you do not have this installed, you can fetch it from ftp://ftp.sbig.com/pub/SetupDriverChecker.exe</p> <p>For the STV, and several obsolete cameras (ST-4, ST-5 without "C" suffix, ST-6) only a serial interface is required, and SBIG does not provide drivers. The drivers for these cameras are built into MaxIm DL.</p>	<p>SBIG Universal for all parallel port, USB, and Ethernet cameras, including ST and STL series.</p> <p>SBIG w/AO-7 when using the AO-7 tip/tilt guider option</p> <p>For all dual-chip cameras, set the autoguider to Same as main camera.</p> <p>SBIG STV for the STV guider. A special STV remote control panel is available for controlling the built-in autoguider capabilities.</p> <p>SBIG ST-4, SBIG ST-5, SBIG ST-6 for obsolete serial port camera models.</p>
<p>Simulator</p>	<p>Useful for testing purposes, this selection emulates the operation of a camera. No drivers are required.</p>	<p>Simulator</p>
<p>Starlight Xpress</p>	<p>Parallel port cameras do not require any additional drivers.</p> <p>For USB cameras you must install the software that is supplied with the camera. We strongly recommend that you download the latest version of this software from http://www.starlight-xpress.co.uk/software.htm.</p> <p>For most drivers, the "C" version of the camera is supported using the same driver as for the monochrome camera. The only exception is the MX7C when connected via USB; separate drivers are used to ensure proper color data recovery (not required for parallel port driver).</p>	<p>SX HX5 for HX516 parallel port</p> <p>SX HX5 USB for HX516 USB port</p> <p>SX HX9 USB for HX916 USB port</p> <p>SX MX5 for all MX5 series with parallel port</p> <p>SX MX5 USB for all MX5 series with USB port</p> <p>SX MX7/9 for all MX7 and MX9 series cameras with parallel port, including color camera</p> <p>SX MX7/9 USB for MX716</p>

		<p>and MX916 cameras with USB port. Note extra Camera Type selector.</p> <p>SX MX7C USB for MX716 cameras on USB port</p> <p>SXV-H9/H9C for SXV-H9 and SXV-H9C cameras. For optional secondary guide head, set the autoguider selection to Same as main camera.</p>
Starlight Xpress with STAR2000 autoguiding	Supported only for USB cameras.	<p>STAR2K MX5 for all cameras in MX5 series</p> <p>STAR2K MX7/9 for MX716 and MX916</p> <p>STAR2K MX7C for MX7C color camera</p>
Video DirectShow	Video sources such as webcams, VIVO video cards, frame grabbers, and Firewire inputs are supported using this interface. It works through the Microsoft DirectX platform; it is therefore recommended that you install the latest version of DirectX, available from http://www.microsoft.com/downloads/ . Also any drivers provided with your device must be installed; again we recommend updating to the latest version available from the manufacturer's web site.	Vid DirectShow

Filter Wheels

The table below lists the drivers that are included with the current release of MaxIm DL. Other drivers may be made available by third parties. Third-party Plug-in drivers are normally installed by placing their files in the MaxIm DL program installation directory (you must restart MaxIm DL after installation). Please refer to the documentation included with the driver for additional installation and setup information. Also please note Diffraction Limited cannot provide technical support for third-party plug-ins.

For information on writing Plug-in Drivers, please visit the MaxIm DL Extras section at <http://www.cyanogen.com>.

Equipment Setup

Filter Wheel Model	Installation	Select in MaxIm DL
ACE SmartFilter	Uses serial port; no installation required.	ACE
Apogee	Camera driver installation required.	Apogee or Apogee Alta
CRI Micro*Color Tunable LCD Filter	Uses serial port; no installation required.	CRI Tunable
CVI AB-301	Uses serial port; no installation required.	CVI
DFM Engineering FW-82	Uses serial port; no installation required.	DFM FW-82
Finger Lakes Instrumentation	FLI camera driver installation is required.	Finger Lakes or FLI 1st Gen
Meade 216XT with 616	Uses serial port connection through camera.	Meade 216XT
Meade 416/1616 with 616	Uses serial port connection through camera.	Meade 416/1616
Meade SCSI with 616	Works through Meade SCSI camera driver; no additional driver installation required.	Meade SCSI
Optec IFW	Uses serial port; no installation required.	Optec IFW
True Technology Custom Wheel	Uses serial port; no installation required.	True Tech
SBIG and SBIG-Compatible including Homeyer, Optec MaxFilter and IFW in SBIG mode, True Technology in SBIG mode	Many different options are available. Please see SBIG-Compatible Filter Wheels for more information.	SBIG Universal, SBIG ST-5, SBIG ST-6, SBIG STV, or Homeyer Please see SBIG-Compatible Filter Wheels for instructions on selecting the correct driver.
Manual Filter Wheel	None; user is prompted to manually change the filter. This driver is primarily used to simplify entry of FITS header filter selection information.	Manual

Plug-In Camera and Filter Wheel Drivers

MaxIm DL has a “public” interface available for adding custom CCD camera and filter wheel drivers. This interface does not change from version to version; so third-party drivers will work with any release from Version 1 through Version 4.

Go to http://cyanogen.com/products/maxim_extras.htm to download the plug-in driver kit. It requires Microsoft Visual C++ 5.0 or higher.

Note: the plug-in camera driver kit is supplied without warranty or support. If you wish to purchase support for plug-in driver development, the cost is US \$50 per incident.

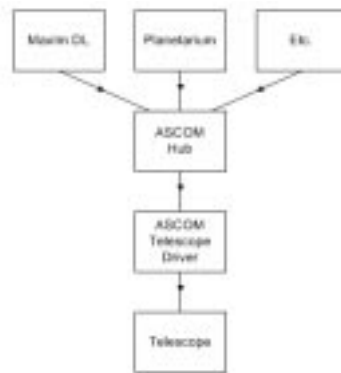
ASCOM Hubs

In the past, astronomical software all had built-in custom drivers, written especially for that application to talk to particular models of telescopes, focusers, etc. If your equipment was not supported with a particular program, you could not connect it. Even worse, if you wanted two or more programs to share the same telescope, it could not be done. With the advent of ASCOM, all of this has changed.

The **A**stronomy **C**ommon **O**bject **M**odel (ASCOM) is a standardized interface for communicating with astronomical equipment. Standardized interfaces allow applications to talk to hardware without having to be customized for the particular command set of each device. As part of this effort, a set of mostly open-source drivers have been made available via the ASCOM Platform. For more information on ASCOM, and to download the latest version of the platform, please visit <http://ascom-standards.org>.

Applications may also communicate by ASCOM-compliant interfaces, although these are not standardized. In certain cases, however, the existing driver interfaces can be used for inter-program communication.

A simple example is multiple applications sharing one telescope, as follows:



In this example, MaxIm DL is configured to connect to a telescope driver that isn't actually a telescope. It's the **POTH (Plain Old Telescope Hub)** application that is included with the ASCOM Platform. Similarly, the planetarium program and other software is set up the same way. The hub itself is configured to talk to a specific telescope driver, e.g., Meade LX-200 and Autostar. In this way, all of the applications can monitor the telescope at the same time. Any one of them can send a command to the telescope, such as a GOTO command, and all of the programs will monitor the telescope as it moves across the sky.

Hubs represent a very simple, yet powerful technique for linking applications together. We can take this a step further, by adding extra features into the hub program itself. The **ASCOM Dome Control Panel** can connect to an ASCOM-compliant dome controller and a telescope at the same time. Commands being sent to the telescope are intercepted, and used to calculate what position the dome slit should be rotated to (POTH now includes the same capability). Applications such as MaxPoint (<http://www.cyanogen.com>) and FocusMax (<http://focusmax.org>) also act as hubs and provide extra capabilities. MaxPoint, for example, models errors in the telescope mount and adjusts the commands sent to the telescope in order to achieve better pointing accuracy.

The very simplicity of hubs can sometimes make things a little confusing at first, since there can be many different ways to hook the blocks together. Just spend a few minutes drawing a block diagram like that above, and you will quickly see how to connect things up.

Some general principles:

1. The MaxPoint hub should always connect directly to the telescope, if at all possible. Any application that connects below MaxPoint will not have the benefit of the pointing corrector. Therefore it should be the main hub, and all other applications should connect to it.

2. If you are using TheSky, the TelescopeAPI plug-in that comes with the ASCOM Platform can be used to connect it to ASCOM telescope drivers, instead of using the built-in drivers. This is recommended, since it allows TheSky to work with other programs. However, certain mounts (e.g. Paramount) can only be controlled by TheSky. In this case, there is a special “TheSky-controlled telescope” driver that lets other programs connect to it. Special settings are required; be sure to review the instructions in **TheSky Controlled Telescope**.
3. FocusMax, an excellent freeware autofocus utility, can act as a hub for focusers and telescopes. You should connect MaxIm DL's telescope interface to FocusMax, and then connect FocusMax directly to the telescope (or MaxPoint or other hub if used). You can do the same for the Focuser interface; but this is not essential, and you should only do so if you wish to use MaxIm DL's built-in focuser controls as well as those in FocusMax.
4. If you think you have too many hubs, try to simplify the configuration. For example, Desktop Universe has a hub, but if you're already using POTH to link in the dome control, you should just ignore the Desktop Universe hub. Simply connect DTU to POTH alongside your other programs.

CCD Camera/Autoguider Setup

MaxIm DL includes several dozen different camera drivers, described in the following pages. Note that in order for these drivers to function, they may require the manufacturer's camera drivers to be installed. Specifically, the manufacturer's drivers must be installed for cameras from:

- Apogee
- Audine / Genesis (except parallel port)
- DTA
- Finger Lakes Instruments
- ISI CCD800, CCD1600
- Meade SCSI (Adaptec ASPI and SCSI card drivers)
- Princeton and Photometrics models from Roper (PVCam software)
- SBIG camera except serial port interface models
- Starlight Xpress USB cameras

- All video sources require manufacturer's drivers

In MaxIm DL, all cameras can be used as autoguider. Note, however, that some cameras may not be recommended for use as autoguiders due to shutter reliability or response time problems. Some cameras have the necessary "camera relays" for sending autoguider control pulses to the telescope mount. Other cameras require using either the Telescope Control window and a GOTO telescope with ASCOM PulseGuide capability, a Starlight Xpress autoguider interface, a custom connection through a parallel port, or other means.

Same as Main Camera

This option is available only for the autoguider. When selected, the main camera is also used as the autoguider. If the camera is capable of simultaneous imaging and autoguiding, then it appears as two separately controlled cameras. Otherwise the camera is only available in one mode at a time.

If you set both the main camera and autoguider to the same model, you will see a warning message suggesting that you need to use this selection. If you actually intended to connect two different cameras that both use the same driver, then ignore this warning (note that some manufacturers do not support multiple cameras on the same computer).

Plug-In Camera

Plug-in drivers may be included with MaxIm CCD or supplied separately by third-party vendors. Some third-party drivers may also be included on the MaxIm DL/CCD distribution disk as a convenience to customers. Technical support for all third-party drivers is provided by the camera manufacturer.



The driver determines the controls that appear on this dialog. There may be up to five **input parameters**, and optionally one **Initialization File**, **Ethernet Address**, or **Advanced Setup** button. The Initialization file may contain camera initialization settings; the path may be selected using the **Browse** button. The **Ethernet Address** is for certain cameras that use an Ethernet interface. The **Advanced Setup** button brings up an additional options dialog box. For some camera models, the Advanced Setup dialog is also available while the camera is operating.

For information on settings, please consult the documentation supplied with the driver.

Apogee AP / KX / SPH / AM Series

For this driver, choose **Apogee** on the **Setup** tab.

The Apogee camera drivers support all models including AM, AP, KX, and SPH series operating on ISA, PCI, and parallel port interfaces. (Note: PCI requires Windows 98 or higher.)

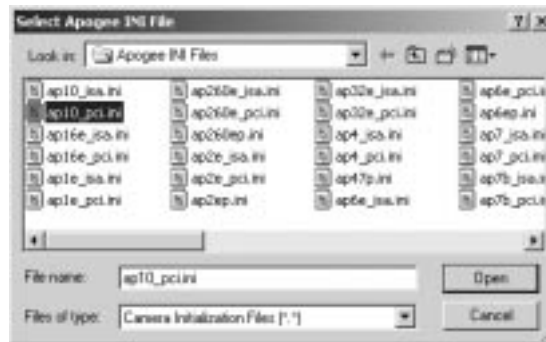
For Apogee Alta cameras please use the separate Apogee Alta driver.



When initializing an Apogee CCD camera, MaxIm CCD needs information on the parameters of the camera being used. Apogee cameras use a wide variety of detectors, and there are differences in the camera electronics between the various models. This information is obtained from an **“.ini”** file that is provided by the manufacturer with the camera. INI files for all current camera models are also provided in a subdirectory to the MaxIm DL program directory called **“Apogee INI Files.”** For assistance in setting up INI files please contact **Apogee Instruments** (www.ccd.com).

The **Browse...** button allows you to select the INI file to use with your camera. The selection sub-dialog appears as shown below. Select the appropriate file and click **Open**.

Note: Old **“.ini”** files used with Version 1 and Version 2 of MaxIm CCD are *not* compatible with the modern drivers; if you experience problems or do not have a file for your camera, please contact Apogee Instruments Inc.



Shutter allows you to set shutter options. **Normal** is the usual setting. **Freeze** prevents the shutter from moving unless it is switching from dark frame exposures to light frame exposures or vice-versa. Freezing the shutter open increases shutter lifetime when using the camera as an autoguider, but can cause streaking or image saturation.

The **External Trigger** control enables external triggering of the camera. When enabled and the **Expose** button is clicked, the camera will wait for the external trigger before starting the exposure. This should be switched off unless the camera is configured for an external trigger.

Priority Level can be set to **High** to prevent other programs from interrupting the download cycle. This is advisable for high-performance camera models such as the AP7. On some systems, the mouse pointer may freeze during download when the priority is set to High.

TTL Control, when enabled, brings up a control window. This window allows you to turn on and off the eight TTL outputs provided by the camera hardware. Note that you should not simultaneously use the autoguider pulse output feature and the TTL output feature.



For one-shot color cameras, the **Color Filter Offset** is used to specify the origin of the color filter pattern that covers the chip. This information is necessary in order for the camera to automatically produce color images. Individual cameras can have the filter pattern offset by one pixel in either or both of the X & Y axes. If automatic color synthesis fails to produce color images that look reasonable, try changing this setting until the color quality improves.

Important: For ISA interfaces, some computers require a **BIOS** setting to be adjusted for the Apogee ISA plug-in card to operate properly. The **16 Bit I/O Recovery Time** setting should be set to **N/A** (on some computers, this is the “off” or just the lowest setting).

Apogee Alta

For this driver, please select **Apogee Alta** on the **Setup** tab.

All settings for the Apogee Alta are under the **Advanced...** button. The same dialog box is available while the camera is connected, by clicking the **Options** button on the **Settings** Tab and selecting the **Camera Settings** command.

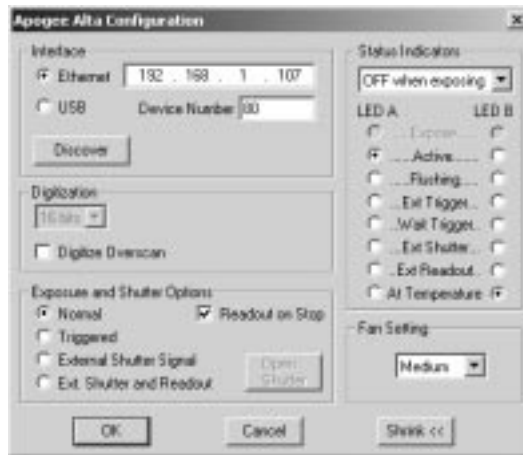
The first step is to specify the location of the camera. For cameras with a network interface, select **Ethernet**, enter the **IP address** of the camera, and set **Device Number**

to its TCP port number. If the camera is selected as **USB**, only the **Device Number** control is available; set it to the camera identifying number, as enumerated by the operating system.



While the camera is connected, the **Interface** controls are not available; they are replaced by a **Status** area.

If you do not know the location of the camera, you can search for it using the **Discover** button. See below for an explanation of the camera discovery feature.



Alta cameras connected via USB can operate in two **Digitization** modes. The **12-bit** mode provides the highest speed, while the **16-bit** mode provides the highest dynamic range. Cameras connected via Ethernet support only **16-bit** mode. You can also indicate whether to **Digitize Overscan**. Normally this is turned off, but in some applications the overscan region is used as part of the calibration process.

The **Exposure and Shutter Options** include the exposure trigger modes: **Normal** performs a simple timed exposure started by software, **Triggered** instructs the camera to wait for a TTL input before the exposure actually starts, **External Shutter Signal** allows the shutter to be gated open and closed during the exposure by an external TTL-level signal, and **Ext. Shutter and Readout** provides both a gated shutter and the ability to

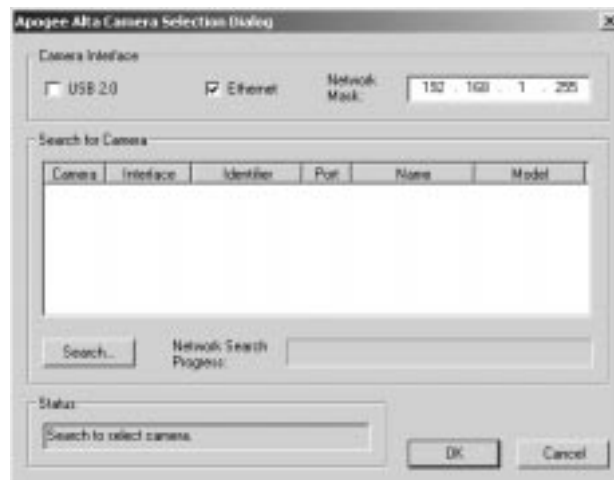
trigger the start of readout using a TTL-level signal.

Readout on Stop causes the exposure to read out when the **Stop** button is clicked, instead of simply aborting the exposure. **Open Shutter** forces the shutter open immediately; this control is only available when the camera is connected.

The two **Status Indicator** lights can be configured to provide basic status information. To prevent light contamination under very low-light imaging conditions, you can select **OFF when exposing**. You can also select **Always OFF** or **Always ON**.

The two Light Emitting Diodes (**LED A** and **LED B**) can be configured individually. They can be set to illuminate when the camera is in **Expose** mode (unless disabled by **OFF when exposing**), when the camera is **Active**, during **Flushing** to remove charge from the array, when an **Ext Trigger** is received, **Wait Trigger** to show when the camera is waiting for a trigger, **Ext Shutter** to show the state of the external shutter, **Ext Readout** to show the state of the external readout trigger, and when the camera has stabilized **At Temperature**.

To save screen real estate, the dialog box can be shrunk to show just the **Interface** section.



The camera selection dialog box is brought up when the Discover... button is clicked. Select **USB 2.0** and/or **Ethernet**. If Ethernet, you must specify a **Network Mask**, which limits the subnet that is searched.

When you click **Search...** the software will generate a list of available cameras, if any. You can select the camera by clicking on it in the **list** and then clicking **OK**.

Audine / Genesis

For this driver, choose **Audine** on the **Setup** tab.



The Audine/Genesis driver is selected using the **Audine** selection in the Setup tab.

The driver supports shutter operation and up to 8x8 binning.

Select the parallel port address using **Port**. If your Audine is connected using a QuickAudine USB interface, connect to it by selecting the **USB** option from the **Port** drop-down.

In order to prevent image corruption caused by readout delays, interrupts can be disabled during readout in Windows 98/ME by setting **Interrupts** to **Disable**. **Focus Fast Flush** turns on/off a fast flushing mode. The slow flushing mode more thoroughly empties all residual charge from the sensor, but takes longer. **Sensor Type** can be set to **KAF-400** or **KAF-1600** to match the size of sensor in the camera. No special settings are required for different versions of the sensor (e.g., "blue plus" sensors). The **Shutter Logic** control can be used to invert the polarity of the shutter driver output.

These cameras use open-loop cooling, so the cooler controls are not enabled when this camera is in use.

Cookbook CB245

For this driver, choose **CB245** on the **Setup** tab.



The parallel port address must be entered in **Port**. The **Base Resolution** determines the binning used on the horizontal axis when 1x1 binning is selected. The options are 252, 378, and 756. The vertical axis is always at 242. Each of these modes can also be binned

2x2 via the **Focus** or **Settings** tab.

On-chip Binning controls whether the binning is performed on-chip (analog) or off-chip (digital). When in analog mode, as much of the binning operation as possible is performed on-chip; however, depending on the **Base Resolution** and binning settings, some part of the binning operation may be done off-chip. This is due to restrictions caused by the CCD sensor's readout structure. Unlike the DOS Cookbook software, off-chip binning is not rescaled and results in values above 12 bits. This is normal; it is preferable to keep the scaling constant so that Photons per ADU setting is not changed in different binning modes.

LDC & Shutter allows you to select two options. You can enable the **Low Dark Current** (LDC) option, and/or the **Shutter** option. Both of these options require special modifications to the camera. If shutter mode is not selected, the user is prompted for dark frames.

The driver includes support for the optional shutter. No user settings are required to activate the shutter.



When the camera is started up, a small window appears to display the Reset and Reference levels. This is to facilitate adjustment of the camera. If you do not wish to view the display, click the close button at upper right. To redisplay the window, disconnect the link and restart it.

These cameras use open-loop cooling, so the cooler controls are not enabled when this camera is in use.

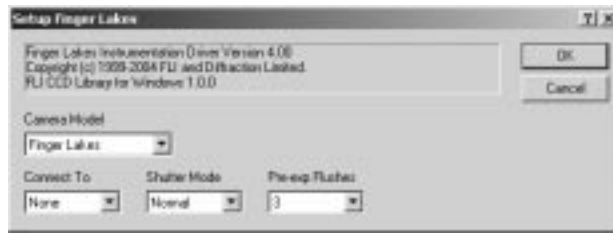
Important Note: In **Windows NT/2000/XP**, MaxIm DL must be installed from an Administrator-level account in order for this driver to be properly installed.

Finger Lakes Instruments

For this driver, choose **Finger Lakes** on the **Setup** tab.

All Finger Lakes Instrumentation CCD cameras are supported by this driver, including "Dream Machine" and MaxCam series. It supports parallel port, USB, and Ethernet interfaces.

Please note that you may need to update your FLI driver installation in order for this interface to work, even if older software functions with your camera. New drivers may be downloaded from <http://fli-cam.com> You may need to run both FLIDriverInstall and the FLI Windows Update Utility.



The driver will auto-detect the camera upon startup. You may select the camera from the drop list under **Connect To**.

The **Shutter Mode** option can select the shutter behavior for autoguiding operation. When selected to **Normal**, the shutter opens only during an exposure. When set to **Main w/Guider**, the shutter is closed during download but it is opened between exposures, to allow the autoguider to reacquire lock following download (the shutter is located in front of the autoguider pick-off port). When set to **Guider**, the shutter is held open continuously, to prevent excessive wear (the very slight blurring during readout does not affect guiding accuracy).

Pre-exp Flashes allows you to configure how many flush cycles are run before the exposure starts. Increase this to ensure that residual charge is completely flushed; decrease it to reduce the delay at the start of the exposure.

Note: some older parallel port interface cameras will not work with this driver. You can use the **Finger Lakes 1st Generation** driver for these cameras.

Finger Lakes First Generation

For this driver, choose **FLI 1st Gen** on the **Setup** tab.



Older Finger Lakes Instrumentation parallel port CCD cameras are supported by this driver, including “Dream Machine” and MaxCam series. Some older parallel port cameras may require you to use this driver instead of the newer, standard ones.

Please note that you may need to update your FLI driver installation in order for this interface to work, even if older software functions with your camera. New drivers may be downloaded from <http://fli-cam.com>. You may need to run both FLIDriverInstall and

the FLI Windows Update Utility.

Very old cameras may require both a **COM Port** and a **Parallel Port**. Normally just a parallel port is required; in this case, set **COM Port** to **None**. Be sure to select the correct **Parallel Port** address.

Select **Guider Control** to **Yes** if the camera will be used as an autoguider. In this mode, the shutter is held open and the guider relay outputs are enabled.

Note: USB and Ethernet cameras use the standard Finger Lakes Instruments driver.

HiSIS-22

For this driver, choose **HiSIS-22** on the **Setup** tab.



The HiSIS-22 camera requires only the selection of a parallel port address. The camera does not have temperature regulated cooler control; the cooler power level is selected from the power supply box.

Cooler settings are controlled via manual switches, so the cooler controls are not enabled when this camera is in use.

HiSIS-44

For this driver, choose **HiSIS-44** on the **Setup** tab.



The camera does not have temperature regulated cooler control; the cooler power level is selected from the power supply box.

Cooler settings are controlled via manual switches, so the cooler controls are not enabled when this camera is in use.

Meade Pictor 208XT

For this driver, choose **Meade 208XT** on the **Setup** tab.



The communications port to which the camera is connected must be selected in the **COM Port** field. The **Baud Rate** field is used to control the communications speed; higher speeds provide faster image downloads, but slower speeds may be more reliable if communications are marginal.

The **Gain** control can be used to boost the signal from the CCD chip prior to readout. This is normally set to **1X**, but can be increased in situations where the image is extremely faint.

The **Anti-Blooming** control allows you to control the camera's anti-blooming gate. Saturated pixels can produce streaks across the image; the anti-blooming reduces this problem. Turning the anti-blooming gate on allows more saturation before a streak will appear, but decreases the sensitivity of the camera somewhat.

Important Note: Please allow **30 seconds** for the camera to initialize **after power-on** before attempting to connect. Once a link is established, set up the cooler temperature and **wait for the CCD temperature to appear** before taking the first exposure.

Note on autoguiding: The 208XT telescope control relays are not available under software control. Autoguiding control is still possible via other means, such as the **Telescope Control** Window. Due to the readout speed, we strongly recommend setting 2x2 binning when using this camera for autoguiding.

Meade Pictor 216XT

For this driver, choose **Meade 216XT** on the **Setup** tab.

Meade Pictor 216XT cameras are connected via serial port.

The communications port to which the camera is connected must be selected in the **COM Port** field. The **Baud Rate** field is used to control the communications speed; higher speeds provide faster image downloads, but slower speeds may be more reliable if communications are marginal.

Serial Mode can be set to trade off bit depth against download speed. The **16-bit** mode

provides the highest resolution but slowest speed. Normally this is set to either **16-bit Compr.** (compressed) mode or **12-bit Compr.** mode.



The **Gain** control can be used to boost the signal from the CCD chip prior to readout. This is normally set to **1X**, but can be increased in situations where the image is extremely faint.

The **Anti-Blooming** control allows you to control the camera's anti-blooming gate. Saturated pixels can produce streaks across the image; the anti-blooming reduces this problem. Turning the anti-blooming gate on allows more saturation before a streak will appear, but decreases the sensitivity of the camera somewhat.

Important Note: Please allow **30 seconds** for the camera to initialize **after power-on** before attempting to connect. Once a link is established, set up the cooler temperature and **wait for the CCD temperature** to appear before taking the first exposure.

Note on autoguiding: The 216XT telescope control relays are not available under software control. Autoguiding control is still possible via other means, such as the **Telescope Control Window**. Due to the readout speed, we strongly recommend setting 2x2 binning when using this camera for autoguiding.

Meade Pictor 416XT / 1616 XT Serial Mode

For this driver, choose **Meade 416/1616** on the **Setup** tab.



Note: Prior to using MaxIm CCD to control older Pictor 416XT and 1616XT cameras, we recommend downloading the latest **PictorView** software from the Meade web site (<http://www.meade.com>) and using the **Camera** menu **Update Camera Software** command to update the camera's built-in firmware.

The communications port to which the camera is connected must be selected in the **COM Port** field. The **Baud Rate** field is used to control the communications speed; higher speeds provide faster image downloads, but slower speeds may be more reliable if communications are marginal.

The **Binning** control turns on/off on-chip binning. On-chip binning reduces readout noise. Turning the control off may reduce blooming, at the cost of slightly higher readout noise.

Note that if the camera determines that the PC cannot keep up with the transfer rate, it will automatically switch to a “slow-speed download” mode. This can only be reset by powering off the camera.

Important Note: We recommend waiting 30 seconds after powering up the camera before starting a connection, to allow the camera time to initialize. Once the connection is established, you should wait for the CCD temperature to appear before starting the first exposure.

Meade Pictor 416XT / 1616XT SCSI Mode

For this driver, choose **Meade SCSI** on the **Setup** tab.



Some computers may attempt to start download before the camera is ready; if that happens, the camera aborts the exposure and a “CCD Camera Error (-4)” message appears. The **Extra Delay** setting is available to prevent this. Increase the delay by the smallest amount which prevents the error from occurring; usually 0.5 seconds is sufficient. Note that running other software during camera operation may cause image downloads to fail.

Important Note: Meade Pictor cameras are SCSI-I devices, but the modern Adaptec 32-bit drivers assume SCSI-II. This has led to a limitation on which SCSI adapters can be used with the Pictor cameras. Meade recommends the following adapters only:

Computer Type	Adapter
Laptop (PCMCIA)	Adaptec 1480A, B, or C
Desktop	Adaptec 2940UW

Unfortunately most other SCSI adapters do *not* work with the Pictor cameras and the modern 32-bit SCSI-II drivers. If the incorrect adapter is used, a “CCD Camera Error (-4)” will always occur during image download.

Please see <http://www.meade.com/catalog/pictor/pview7.00/pvsa.pdf> for complete details on SCSI compatibility.

Important Note: You must power up the camera and allow it to initialize (“beep-beep”) **before** powering up the computer. Once the computer has powered up, the camera display should show "Connect SCSI" if the camera has been located by the operating system. The camera should also appear in the Control Panel / System / Device Manager list; if it does not, MaxIm DL/CCD will not be able to locate it.

Upon starting MaxIm DL/CCD, open the camera control window and select **Meade SCSI** for the camera. Also select **Meade SCSI** for the filter wheel if you have a Meade 616 filter wheel attached.

Roper (Princeton/Photometrics)

For this driver, choose **Roper** on the **Setup** tab.



Princeton and Photometrics brand cameras from Roper that use the PVCAM interface are supported.

PVCAM supplies information on each installed camera when the MaxIm CCD control window is first opened. The list of available cameras is displayed in **Camera Name**.

The user should indicate whether the camera has a built-in shutter for dark frames in **HasShutter**. Cameras with interline or frame transfer sensors may be "electronically shuttered", which means they cannot take dark frames automatically. Select **Yes** for full-frame sensors which have mechanical shutters; otherwise select **No**.

Options for **Speed Table** and **Gain Setting** are filled in depending on the capabilities of the camera. These control the various readout modes of the camera. Consult the camera documentation for more information on these settings.

Important Note: The Roper driver will not appear in the **Camera Model** drop list unless the Roper **PVCAM** software is installed.

SBIG Universal

For this driver, choose **SBIG Universal** on the **Setup** tab.



This driver supports the Santa Barbara Instrument Group ST-7, ST-8, ST-9E, ST-10E, and ST-2000 cameras.

For parallel port cameras, select the parallel port address in **Connect To**. For USB cameras, select **USB**. For Ethernet connection, select **Ethernet** and enter the correct **IP Address** for the camera. The IP Address is ignored when connecting to a parallel port or USB camera.

Swap Chips, when activated, reverses the main sensor and autoguider sensor.

The **Guide Chip** setting only affects the ST-L camera. It is used to select whether the built-in guide chip is used for guiding, or the separate guider head that comes with the ST-L. Other cameras, which only have the built-in chip, ignore it.

Important Note: Some cameras use a TC-237 guide sensor instead of the original TC-211 guide sensor. These sensors have much smaller pixels; it is strongly recommended to operate these sensors at 2x2 binning.

When using the integrated autoguider, set the autoguider to **Same as main camera**.

A set of **Advanced** settings are also available for the camera. These settings can be changed using the camera setup dialog, before connecting, or changed while connected using the Options button on the Settings tab of the CCD Control Window.

Guider ABG affects the anti-blooming control for the autoguider CCD only. Anti-blooming for the main CCD is determined by the type of CCD chip installed in the camera.

Setting **Binning Mode** to **Off-chip** is useful when a non-anti-blooming CCD chip is installed. When enabled, it causes any binning to be performed after the CCD chip has been read (normally, binning is done inside the CCD chip before readout). Selecting this option results in slightly higher readout noise but greatly reduces blooming. This control has no effect for anti-blooming CCD chips, and has no effect for 1:1 binning. You can also set Binning Mode to **Spectroscopy**. In this mode, the main sensor can be binned Nx1 to Nx3, where N ranges from 1 to 255.



The **Download Priority** can be adjusted. **Very High** will ensure that no lines appear in the image due to readout delays, but may make it difficult to operate the mouse.

The **Enable Fan** setting can be used to activate or deactivate the camera fan. This can be useful if camera vibrations are affecting image quality.

SBIG Camera with AO-7

For this driver, choose **SBIG w/AO-7** on the **Setup** tab.



When using the AO-7 tip/tilt autoguiding accessory, set to **SBIG w/AO-7**. If a **CFW-8** filter wheel is connected via the camera, set the **Filter** selection to **SBIG Universal**.

Usually the **Autoguider** is set to **None**, since the **Guide** tab is not normally used with the AO-7. You can however use **Same As Main Camera** if you wish to use the **Guide** or **Focus** tab functions with the guide sensor when the AO-7 is not running.

For parallel port cameras, select the parallel port address in **Connect To**. For USB cameras, select **USB**. For Ethernet connection, select **Ethernet** and enter the correct **IP Address** for the camera. The IP Address is ignored when connecting to a parallel port or USB camera.

The download **Priority** can be adjusted. **Very High** will ensure that no lines appear in the image due to readout delays, but may make it difficult to operate the mouse.

Guider ABG turns on/off the anti-blooming gate for the autoguider sensor; turning it on reduces blooming if the sensor saturates, but decreases sensitivity slightly. Normally it is left off.

Setting **Binning Mode** to **Off-chip** is useful when a non-anti-blooming CCD chip is installed. When enabled, it causes any binning to be performed after the CCD chip has been read (normally, binning is done inside the CCD chip before readout). Selecting this option results in slightly higher readout noise but greatly reduces blooming. This control has no effect for anti-blooming CCD chips, and has no effect for 1:1 binning. You can also set Binning Mode to **Spectroscopy**. In this mode, the main sensor can be binned Nx1 to Nx3, where N ranges from 1 to 255.

Important Note: Some cameras use a TC-237 guide sensor instead of the original TC-211 guide sensor. These sensors have much smaller pixels; it is strongly recommended to operate these sensors at 2x2 binning.

Please see **SBIG AO-7 Control** for full details on operating the AO-7.

SBIG ST-4

For this driver, please select **SBIG ST-4** on the Setup tab.



The Santa Barbara Instrument Group ST-4 cameras connect to the PC via a standard serial port.

The communications port to which the camera is connected must be selected in the **COM Port** field. The **Baud Rate** field is used to control the communications speed; higher speeds provide faster image downloads, but slower speeds may be more reliable if communications are marginal.

The **Gain Expansion** control allows you to adjust the sensitivity of the camera. The 4X Gain setting provides the highest sensitivity, but the image will be more noisy and the camera will saturate on bright objects. Use the lowest setting that provides good sensitivity for your equipment configuration.

The **Anti-Blooming Gate** control allows you to control the camera's anti-blooming gate. Saturated pixels can produce streaks across the image; the anti-blooming reduces this problem. Turning the anti-blooming gate on allows more saturation before a streak will

appear, but decreases the sensitivity of the camera somewhat.

This camera has no shutter. When operated as an autoguider, the user will be prompted to cover the camera when dark frames are required.

SBIG ST-5 (Serial)

For this driver, please select **SBIG ST-5** on the Setup tab.

The SBIG ST-5 is an older version of the ST-5C that uses a serial port interface.

The communications port to which the camera is connected must be selected in the **COM Port** field. The **Baud Rate** field is used to control the communications speed; higher speeds provide faster image downloads, but slower speeds may be more reliable if communications are marginal.



The **Anti-Bloom** control allows you to control the camera's anti-blooming gate. Saturated pixels can produce streaks across the image; the anti-blooming reduces this problem. A higher anti-bloom level allows more saturation before a streak will appear, but decreases the sensitivity of the camera somewhat. Use the lowest setting that prevents blooming.

The ST-5 can support a CFW-8 filter wheel; to use this option, set the Filter Wheel to **SBIG ST-5**.

SBIG ST-6

For this driver, please select **SBIG ST-6** on the Setup tab.



The Santa Barbara Instrument Group ST-6 cameras connect to the PC via a standard

serial port.

The communications port to which the camera is connected must be selected in the **COM Port** field. The **Baud Rate** field is used to control the communications speed; higher speeds provide faster image downloads, but slower speeds may be more reliable if communications are marginal.

The **Anti-blooming** control allows you to control the camera's anti-blooming gate. Saturated pixels can produce streaks across the image; the anti-blooming reduces this problem. A higher anti-bloom level allows more saturation before a streak will appear, but decreases the sensitivity of the camera somewhat. Use the lowest setting that prevents blooming.

SBIG STV

For this driver, please select **SBIG STV** on the Setup tab.

The SBIG STV connects via serial interface. The correct **COM Port** must be selected, and the **Baud Rate** must match the setting accessed using the front panel on the STV.

When used as an imaging camera, two **Mode** settings are available. **Hi-Res** produces a 320x200 image with 7.4 micron pixels. Hardware 2x2 binning is also available, which produces a 160x100 image with 14.8 micron pixels.



In **Lo-Res** mode, the STV produces a 320x200 image with 14.8 micron pixels. Software 2x2 binning is also available, which produces a 160x100 image with 29.6 micron pixels.

Gain allows you to control the gain level used in the STV.

Turning on **Auto-Dark** tells the STV to automatically take its own dark frames as needed. The dark frames are not actually downloaded to the PC. Note that this requires double the normal exposure time when a new dark frame is needed, although subsequent images with the same settings will automatically re-use the dark frame. Attempts to use the normal auto-dark functions in MaxIm will be ignored, and any dark frames taken manually will be all zero.

The STV can be used as a guider via the **Guide** tab, but the internal relays are not available in this mode. You must select another method using the **Control Via** setting in

the Guide tab **Settings**.

A special guiding mode is available for the STV. Set the Mode to either **Hi-Res Guider** or **Lo-Res Guider** (note: Hi-Res and Lo-Res affect only the imaging mode of the camera as described above, not the guiding). When this mode is selected, a special **STV Guider Control** panel appears. (The panel initially appears over the MaxIm CCD control window but can be moved to a convenient position on the screen).



The STV Guider Control allows you to command the STV to autoguide using its built-in algorithms. When the STV is not actively guiding, you can also take images normally. Typically the STV will be configured as the guider in the Setup tab, but the Guide tab is not used. Single images can be taken using the Focus tab, with the camera selector set to **Guider** (assuming the STV was selected as the guider).

The **Focal Length (mm)** of the instrument used must be entered; this is required by the STV's built-in guiding algorithms. You can enable or disable the two axes using **Enable X** and **Enable Y**.

The STV must be calibrated prior to guiding. To calibrate, it takes a series of images in slightly different telescope positions. Normally the STV automatically determines the exposure and relay activation times during calibration. If you wish to force manual settings, turn on **Use Manual Settings** and enter the desired **Exposure Time (s)** used during calibration, and the **Activation Time (s)**, which determines how long the relays are activated during calibration moves.

The **Track Settings** allow you to select the **Exposure Time (s)** during guiding. You can set **Max Correction (s)** to limit the maximum relay activation time for a single correction. The **Aggressiveness** setting adjusts the "loop gain". Back off this setting if the guider over-corrects; increase it if the response time is too slow (in most cases a setting of 8 or 9 is recommended). **Use Large Track Box** allows you to select a larger track box size, which is useful if the star image is especially large, but may produce slightly slower guide rates.

To start a calibration cycle click **Cal**. The progress of the calibration will be displayed in the status box to the left.

To start guiding, click the **Guide** button. The guider offset will be displayed in the status box during guiding.

If you need to stop guiding, or need to abort the calibration cycle, click **Abort**.

Simulator

For this driver, choose **Simulator** on the **Setup** tab.

The **CCD Camera Simulator** is a learning and testing tool. It can simulate the behavior of a dual-chip CCD camera with autoguiding capability and integrated filter wheel. No external hardware is required. It is also very handy for **testing scripts**. For more information, please see the **MaxIm CCD Tutorial** section.

When an exposure is taken, the simulator will produce a pattern of five stars of different intensities. If the **Noise** option is turned on, a small amount of random noise is added to each image (this also increases the “download time”).



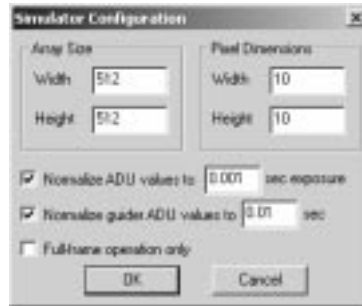
For simulating autoguider operation, you can select a variety of **Guide Errors**. **Sinusoidal** will produce a back-and-forth motion in the X axis with a period of four minutes – just like a real (if poor) telescope drive. **Random** will produce erratic X and Y motions. Selecting **Both** will superimpose both types of guider errors. The five simulated star images will actually move around the frame over time. You can calibrate the autoguider (we recommend 10 second calibration times for X and Y) and actually track on the simulated star images.

FWHM (full-width half maximum) allows you to dial in the diameter of the star images, in pixels. Using this you can simulate good or poor seeing/focus.

Guide Angle can be used to learn about the operation of the autoguider. Setting this changes the angle at which the guide star moves during guider operations; in effect, it rotates the virtual camera. **Guide Direction** can be used to flip the sense of the autoguider corrections. When the guider is calibrated, this will reverse the sign of one of the guider calibration settings.

Clicking the **Advanced...** button brings up the **Simulator Configuration** dialog box. This can also be accessed by clicking the **CCD...** button on the **Settings** tab.

You can specify the **Array Size** in **Width** and **Height** that the simulator creates. You can specify the **Pixel Dimensions** that the camera reports; this is used in various calculations and is stored in the FITS header. You can **Normalize the ADU values** to a particular exposure length, for both the main camera and the guider. When turned on, the normal test image is scaled by the length of the exposure. The default test pattern levels are produced when the exposure taken matches the normalization value. **Full-frame operation only** disables subframing in the simulator.



Starlight Xpress HX5

For this driver, choose **SX HX5** on the **Setup** tab.

The Starlight Xpress HX516 cameras connect to the PC via a standard parallel printer port.

The computer's parallel port address must be selected in **Port**. Set **Interface** to **Fast Parallel** if the fast parallel interface option is being used; otherwise select **Direct**.



The **Speed Adj.** is normally set to 100%, but can be used to adjust the download speed of the camera. Many users adjust this to the highest setting that does not corrupt the image, to provide the highest download speed. Note that when using the Fast Parallel Interface, the adjustment inside the interface box has a greater effect on the download speed.

Interrupts can be set to **Disable** to prevent other programs from running during the program download if other programs are interfering with the download and causing

spurious noise. When using this mode it is recommended to include a 1 second delay between exposures when doing rapid focus frames; otherwise it may be difficult to stop the exposures since the mouse freezes. This option has no effect under Windows NT/2000/XP (nor is it necessary).

These cameras use open-loop cooling, so the cooler controls are not enabled when this camera is in use.

Tip: for best performance, the USB interface upgrade is highly recommended.

Starlight Xpress HX5 USB

For this driver, choose **SX HX5 USB** on the **Setup** tab.



The Starlight Xpress HX516 USB cameras connect to the PC via a USB port. The appropriate Starlight Xpress USB drivers that come with the camera must be installed for the camera to work. This driver does not work under Windows NT.

There are *no settings* for this camera.

The Starlight Xpress cameras use open-loop cooling, so the cooler controls are not enabled when this camera is in use.

Starlight Xpress HX9 USB

For this driver, choose **SX HX9 USB** on the **Setup** tab.



The Starlight Xpress HX916 cameras connect to the PC via a USB port. The appropriate Starlight Xpress USB drivers that come with the camera must be installed for the camera to work. This driver does not work under Windows NT.

There are *no settings* for this camera.

The Starlight Xpress cameras use open-loop cooling, so the cooler controls are not enabled when this camera is in use.

Starlight Xpress MX5

For this driver, choose **SX MX5** on the **Setup** tab.

The Starlight Xpress MX512, MX516, and MX5-C cameras connect to the PC via a standard parallel printer port.

The Starlight Xpress MX512, MX516, and MX5-C (single-shot color) cameras are identical from a control standpoint.



The computer's parallel port address must be selected in **Port**.

Set **Interface** to **Fast Parallel** if the fast parallel interface option is being used; otherwise select **Direct**.

The **Speed Adj.** is normally set to 100%, but can be used to adjust the download speed of the camera. Many users adjust this to the highest setting that does not corrupt the image, to provide the highest download speed. Note that when using the Fast Parallel Interface, the adjustment inside the interface box has a greater effect on the download speed.

Interrupts can be set to **Disable** to prevent other programs from running during the program download if other programs are interfering with the download and causing spurious noise. When using this mode it is recommended to include a 1 second delay between exposures when doing rapid focus frames; otherwise it may be difficult to stop the exposures since the mouse freezes. This option has no effect under Windows NT/2000/XP (nor is it necessary).

No special settings are required for 12-bit or 16-bit cameras.

Important Note: On Windows NT/2000/XP systems, MaxIm DL must be installed from an Administrator-level account in order for this driver to be properly installed.

The Starlight Xpress cameras use open-loop cooling, so the cooler controls are not

enabled when this camera is in use.

Tip: for best performance, the USB interface upgrade is highly recommended.

Starlight Xpress MX5 USB

For this driver, choose **SX MX5 USB** on the **Setup** tab.



The Starlight Xpress MX512 USB, MX516 USB, and MX5-C USB cameras connect to the PC via a USB port. The appropriate Starlight Xpress USB drivers that come with the camera must be installed for the camera to work. This driver does not work under Windows NT.

There are *no settings* for this camera.

The Starlight Xpress cameras use open-loop cooling, so the cooler controls are not enabled when this camera is in use.

Starlight Xpress MX5 USB STAR2000

For this driver, choose **STAR2K MX5** on the **Setup** tab.



This driver supports STAR2000 operation for the Starlight Xpress MX512 USB, MX516 USB, and MX5-C USB cameras. The appropriate Starlight Xpress USB drivers that come with the camera must be installed for the camera to work.

If you have connected a STAR2000 dongle and wish to use it for outputting autoguider commands, select the appropriate **COM Port**; otherwise set it to **None**. Select the appropriate output mode; either **ST4** for autoguider pulses, or **LX200** for serial port. If you wish to use a Starlight Xpress Autoguider Interface box (non-STAR2000) set **COM**

Port to **None** and go to the **Guide** tab **Settings** and change **Control Via** to **SX COM**.

The Starlight Xpress cameras use open-loop cooling, so the cooler controls are not enabled when this camera is in use.

Note: When configuring this driver in the **Setup** tab, set **Main CCD Camera** to **STAR2K MX5**, and the **Autoguider** to **Same as main camera**.

Starlight Xpress MX7 / MX7C / MX9

For this driver, choose **SX MX7/9** on the **Setup** tab.

The Starlight Xpress MX7C, MX716, and MX916 cameras connect to the PC via a standard parallel printer port. These cameras are identical from a control standpoint.

The computer's parallel port address must be selected in **Port**.

Set **Interface** to **Fast Parallel** if the fast parallel interface option is being used; otherwise select **Direct**.

The **Speed Adjust %** is normally set to 100%, but can be used to adjust the download speed of the camera. Many users adjust this to the highest setting which does not corrupt the image, to provide the highest download speed. Note that when using the Fast Parallel Interface, the adjustment inside the interface box has a greater effect on the download speed.



Interrupts can be set to **Disable** to prevent other programs from running during the program download if other programs are interfering with the download and causing spurious noise. When using this mode it is recommended to include a 1 second delay between exposures when doing rapid focus frames; otherwise it may be difficult to stop the exposures since the mouse freezes. This option has no effect under Windows NT/2000/XP (nor is it necessary).

Set **Readout Mode** to **Interleave** for full resolution images, or **Fast** for interpolated images. Interleave will automatically switch between the "progressive" and "interlaced" mode when set to Interleave, depending on the exposure duration.

Important Note: On Windows NT/2000/XP systems, MaxIm DL must be installed from an Administrator-level account in order for this driver to be properly installed.

The Starlight Xpress cameras use open-loop cooling, so the cooler controls are not enabled when this camera is in use.

Tip: for best performance, the USB interface upgrade is highly recommended.

Starlight Xpress MX7 / MX9 USB

For this driver, choose **SX MX7/9 USB** on the **Setup** tab.



The Starlight Xpress MX716 USB and MX916 USB cameras connect to the PC via a USB interface. These cameras are identical from a control standpoint. (For best results with the MX7C camera, use the special MX7C version of this driver.)

Set **Readout Mode** to **Interleave** for full resolution images, or **Fast** for interpolated images. Interleave will automatically switch between the "progressive" and "interlaced" mode when set to Interleave, depending on the exposure duration.

The Starlight Xpress cameras use open-loop cooling, so the cooler controls are not enabled when this camera is in use.

Starlight Xpress MX7 / MX9 USB STAR2000

For this driver, choose **STAR2K MX7/9** on the **Setup** tab.



This driver supports STAR2000 operation for the Starlight Xpress MX716 USB and MX916 USB cameras. The appropriate Starlight Xpress USB drivers that come with the camera must be installed for the camera to work. (For best results with the MX7C camera, use the special MX7C version of this driver.)

If you have connected a STAR2000 dongle and wish to use it for outputting autoguider

commands, select the appropriate **COM Port**; otherwise set it to **None**. Select the appropriate output mode; either **ST4** for autoguider pulses, or **LX200** for serial port. If you wish to use a Starlight Xpress Autoguider Interface box (non-STAR2000) set **COM Port** to **None** and go to the **Guide** tab **Settings** and change **Control Via** to **SX COM**.

The Starlight Xpress cameras use open-loop cooling, so the cooler controls are not enabled when this camera is in use.

Note: When configuring this driver in the **Setup** tab, set **Main CCD Camera** to **STAR2K MX7/9**, and the **Autoguider** to **Same as main camera**.

Starlight Xpress MX7C USB

For this driver, choose **SX MX7C USB** on the **Setup** tab.

The Starlight Xpress MX7C USB camera connects to the PC via a USB interface.



Starlight Xpress MX7C USB cameras connect to the PC via a USB interface. The appropriate Starlight Xpress USB drivers that come with the camera must be installed for the camera to work. (For MX716 use **STAR2K MX7/9**.)

Set **Readout Mode** to **Interleave** for full resolution images, or **Fast** for interpolated images. Interleave will automatically switch between the "progressive" and "interlaced" mode when set to Interleave, depending on the exposure duration.

The Starlight Xpress cameras use open-loop cooling, so the cooler controls are not enabled when this camera is in use.

Starlight Xpress MX7C USB STAR2000

For this driver, choose **STAR2K MX7C** on the **Setup** tab.

This driver supports STAR2000 operation for the Starlight Xpress MX7-C USB camera. The appropriate Starlight Xpress USB drivers that come with the camera must be installed for the camera to work.

If you have connected a STAR2000 dongle and wish to use it for outputting autoguider commands, select the appropriate **COM Port**; otherwise set it to **None**. Select the appropriate output mode; either **ST4** for autoguider pulses, or **LX200** for serial port. If

you wish to use a Starlight Xpress Autoguider Interface box (non-STAR2000) set **COM Port** to **None** and go to the **Guide** tab **Settings** and change **Control Via** to **SX COM**.



The Starlight Xpress cameras use open-loop cooling, so the cooler controls are not enabled when this camera is in use.

Note: When configuring this driver in the **Setup** tab, set **Main CCD Camera** to **STAR2K MX7C**, and the **Autoguider** to **Same as main camera**.

Starlight Xpress SXV-H9

For this driver, choose **SXV-H9** on the **Setup** tab.



The Starlight Xpress SXV-H9 camera connects to the PC via a USB interface. It optionally includes a second guider head, in which case the camera works as a dual-chip camera. For autoguider support, please select **Same as main camera** for the autoguider on the **Setup** tab.

When installing the camera for the first time, the Starlight Xpress software should be installed first since the installation loads the camera firmware.

If multiple cameras are connected, you can select the camera you want using **Connect To**. When the autoguider head is installed, you can swap the main camera and autoguider using **Swap Chips**. The **Update Progress** setting is used to disable progress bar updates during image download. Doing so can prevent horizontal streaking caused by pauses in the readout.

The Starlight Xpress cameras use open-loop cooling, so the cooler controls are not enabled when this camera is in use.

Video DirectShow

For this driver, choose **Video DS** on the **Setup** tab.

This option provides video capture facilities through the Microsoft DirectX system. It is strongly recommended that the latest version of **DirectX** be downloaded from the Microsoft web site and installed prior to using this driver. Also any **drivers** required by the video source must be installed; we recommend downloading the latest driver version from the manufacturer's web site.

Supported devices include most frame grabber and video input cards, including VIVO (video-in, video-out) display cards, FireWire (IEEE 1394) Digital Video (DV) cameras, and webcams.



When the driver is connected, a preview window will appear on-screen. The window can be resized using the mouse, although this does not change the intrinsic video resolution (this can be done via live setup; see below). The window can also be minimized if needed.

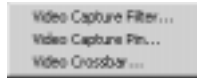
When the **Expose** button is pressed, the driver copies the current video frame into an image buffer in MaxIm DL. In most cases no exposure duration control is possible, but special integration modes are available. Binning can be set to 1x1 or 2x2, and subframes are supported. Autoguiding is possible if an ASCOM PulseGuide-compatible telescope mount, guider motor relay control box or similar independent output device is used.

Integration controls different integration modes. **Off** means that a single video frame is grabbed each time **Expose** is clicked. **Frame Int.** provides a frame integration feature, whereby multiple frames are summed. To integrate 10 frames, set the **Exposure time** to 10 seconds. When **Expose** is clicked ten frames will be grabbed and added together automatically. Typically this will happen in significantly less than 10 seconds.

Webcam 378 selects a modified, parallel port-controlled integrating webcam on the parallel port address of 378 (usually LPT1). Similarly the addresses **278** and **3BC** are available. When this is selected, a frame transfer control pulse is output on the selected parallel port during the exposure. This allows for on-chip integration with a modified webcam. We recommend lowering the frame rate to 5 frames per second when using this mode.

Source chooses the video source to use. The selections available depend on what video hardware is installed in your computer. You may have multiple selections available if there are several video sources. The drop-down will be empty if no video sources are available.

Several “Live Setup” features are also available. For the main camera, click the **Camera Setup** menu item on the popup menu display by the **Options** button on the **Settings** tab. For the autoguider, use the **CCD...** button on the **Guide** tab **Settings** dialog. When the button is clicked, a pop-up menu appears with various options; which options appear depends on the particular device you are using. Commonly-available options include **Video Capture Filter**, **Video Capture Pin**, and **Video Crossbar**.



Video Capture Filter usually has two tabs, **Video Decoder** and **Video Proc Amp**. The latter allows you to adjust the video device’s brightness and contrast.

Video Capture Pin allows you to select the **Frame Rate** in frames per second, and **Output Size** in pixels. The latter is particularly useful since some devices default to relatively low resolution modes.

Most live setup features are not retained when the link is disconnected; however, frame size is restored automatically. For other settings you must reset them each time you connect to the device.

Filter Wheel Setup

Most filter wheels connect via USB or Serial interface. Some models connect directly to the CCD camera, or are internal to the camera itself.

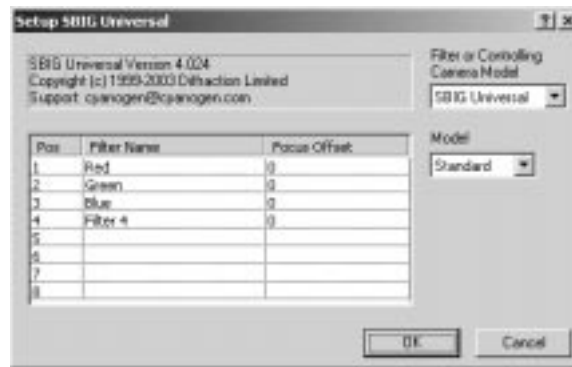
Several models are compatible with the pulse protocol used on SBIG cameras. These wheels can be connected directly to an SBIG camera, or may be connected directly to the PC via the serial or parallel port. Please see SBIG-Compatible Filter Wheels for more information.

Plug-In Filter Wheel

Plug-in drivers may be included with MaxIm CCD or supplied separately by third-party vendors. Some third-party drivers may also be included on the MaxIm DL/CCD distribution disk as a convenience to customers. Technical support for any plug-in drivers supplied by the filter wheel manufacturer is provided by the manufacturer.

The user can assign names for each of the color filter slots, under **Filter Name**. If your

filter wheel has fewer slots than allowed for by this driver, or if there are slots you do not want to use, simply leave the corresponding **Filter Name** entries blank; these slots will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.

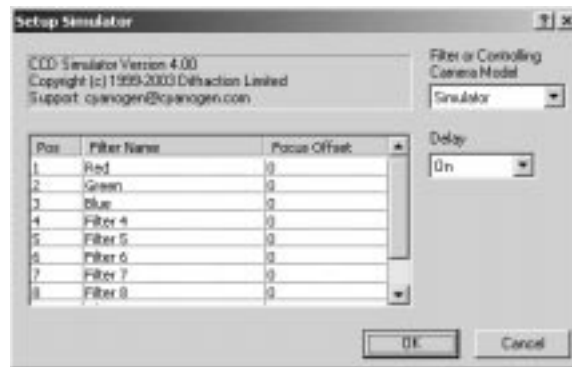


There may be up to three additional controls on the right side of the dialog; the exact function of these fields depends on the particular driver. For information on settings, please consult the documentation supplied with the driver.

Enter the name for each of your filters in the appropriate slots. If your filter wheel has fewer slots than allowed for by this driver, simply leave the extra slots blank. Blank slots are allowed only at the end of the list. The blank slots will not appear in the drop-down filter selector lists.

Filter Wheel Simulator

For this driver, select Simulator on the Setup tab.



The filter wheel simulator just simulates the behavior of a filter wheel driver without doing anything. Aside from enabling filter wheel controls, the settings have no actual effect on the operation of the software, except that the filter names will appear in the **Expose** and **Sequence** tabs. This is useful for tutorials and for testing scripts.

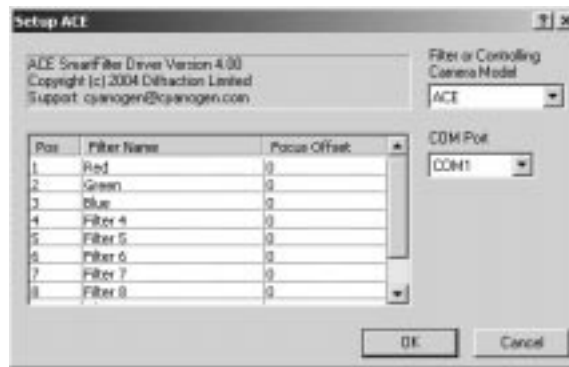
A **Delay** option is available to simulate the time required for the filter wheel to rotate.

The filter slots can be named according to which filter is installed in each slot. Blank slots are allowed only at the end of the list. Blank slots will not appear in any drop-down lists in the software.

If you wish to simulate a filter wheel with fewer slots, simply leave the extra slots blank. Blank slots are allowed only at the end of the list. The blank slots will not appear in the drop-down filter selector lists.

ACE SmartFilter

For this driver, select **ACE** on the Setup tab.



The ACE SmartFilter connects via a serial port, as selected by **COM Port**.

The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.

If you wish to control a dual wheel ACE SmartFilter, you must create an ACE.INI file and put it in the MaxIm DL program directory.

ACE.INI must be a text file containing one line per filter slot. Each line has two numbers, separated by a comma. The first number indicates which filter to use in the first wheel, and the second number indicates which filter to use in the second wheel. Here is an example:

```
1,1
2,1
3,1
4,1
5,1
5,2
5,3
5,4
5,5
5,6
6,6
5,7
5,8
6,8
7,8
8,8
```

In this example, the third filter slot will move filter wheel 1 to slot 3, and filter wheel 2 to slot 1.

Apogee

For this driver, select **Apogee** on the Setup tab.



This selection is used for Apogee filter wheels that are controlled directly through the camera. This is only available for certain camera models.

The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended

to ensure repeatability.

Apogee Alta

For this driver, select **Apogee Alta** on the Setup tab.



This selection is used for Apogee filter wheels that are controlled directly through the camera. This is only available for certain camera models.

The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.

CRI Micro*Color

For this driver, select **CRI Tunable** on the Setup tab.

CRI Micro*Color LCD tunable filters have no moving parts. They work by changing the color of a liquid crystal element.

COM Port must be set to the serial port the filter is connected to.

The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.

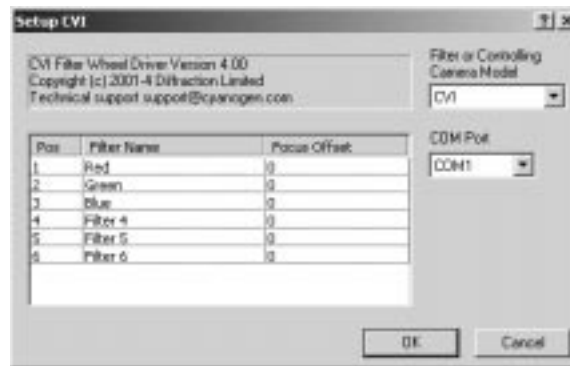


CVI AB-301

For this driver, select **CVI** on the Setup tab.

CVI AB300 series filter wheels are selected on the **Setup** tab by choosing **CVI** in the Filter slot, and clicking the **Filter** button to set it up.

The AB300 connects via a serial port, as selected by **COM Port**.



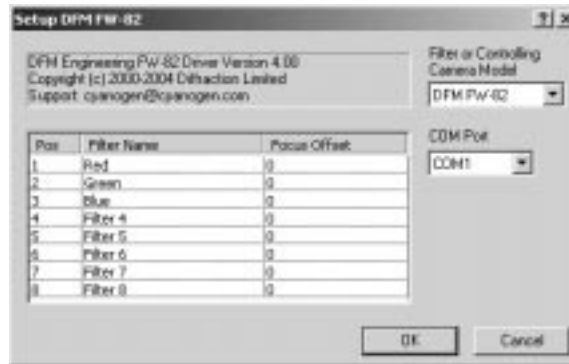
The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.

DFM Engineering FW-82

For this driver, select **DFM FW-82** on the Setup tab.

The FW-82 connects via serial port. If you are using a single wheel, select the correct port under **COM Port 1**.

The FW-82 connects via serial port. If you are using a single wheel, select the correct port under **COM Port**.



The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.

This driver also supports operating two filter wheels simultaneously. To enable this capability, put a DFM.INI file in the MaxIm DL program directory. When this is done, you can select both **COM Port 1** and **COM Port 2**. See below for a definition of the DFM.INI file.

DFM.INI must be a text file containing one line per filter slot. Each line has two numbers, separated by a comma. The first number indicates which filter to use in the first wheel, and the second number indicates which filter to use in the second wheel. Here is an example:

```
1,1
2,1
3,1
4,1
5,1
5,2
5,3
5,4
5,5
5,6
6,6
5,7
5,8
6,8
```

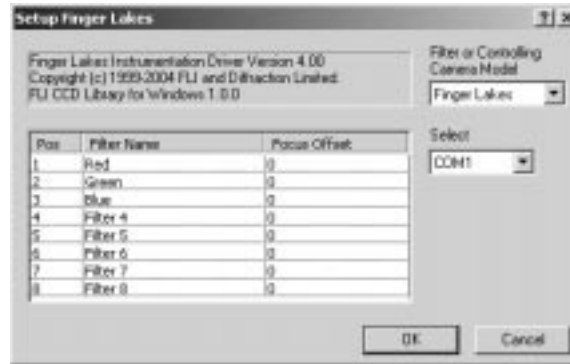
7.8
8.8

In this example, the third filter slot will move filter wheel 1 to slot 3, and filter wheel 2 to slot 1.

Finger Lakes Instrumentation

For this driver, select **Finger Lakes** on the Setup tab.

The Finger Lakes Instrumentation CFW-1 and CFW-2 connect via a serial or USB port, as determined by the **Select** option.



The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.

Finger Lakes First Generation

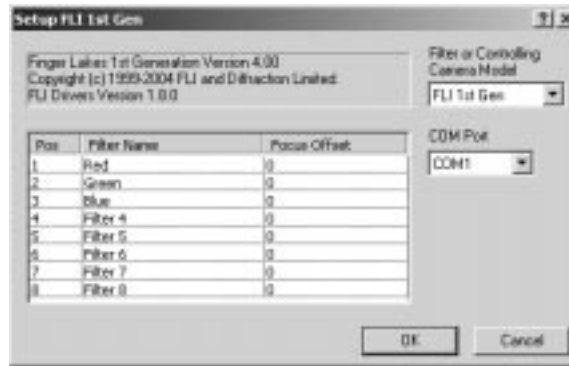
For this driver, select **FLI 1st Gen** on the Setup tab.

Normally the standard **Finger Lakes Instrumentation** filter wheel driver is used. This version uses the older FLI drivers.

The Finger Lakes Instrumentation CFW-1 connects via serial port. Set **COM Port** to the COM port you are using.

The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters

vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.



Manual Filter Wheel

For this driver, select **Manual** on the Setup tab.

This driver will simply prompt the user to set the filter wheel manually. The primary purpose of this driver is to provide a convenient means to enter the filter selection into the FITS header. It can also be used to prompt the user to set the filter during long imaging sequences.



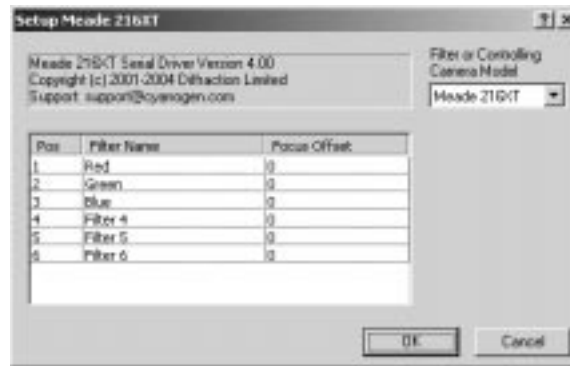
The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter

position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.

Meade 216XT With 616

For this driver, select **Meade 216XT** on the Setup tab.

The Meade Pictor 216XT can directly control a Pictor 616 filter wheel. No special settings are required.



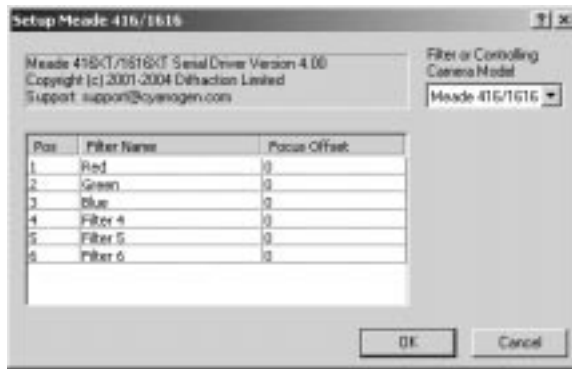
The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.

Meade 416XT/1616XT With 616

For this driver, select **Meade 416/1616** on the Setup tab.

The Meade Pictor 416XT and 1616XT in serial mode can directly control a Pictor 616 filter wheel. No special settings are required.

The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.



Meade SCSI With 616

For this driver, select **Meade SCSI** on the Setup tab.

The Meade Pictor 416XT and 1616XT in SCSI mode can directly control a Pictor 616 filter wheel. No special settings are required.



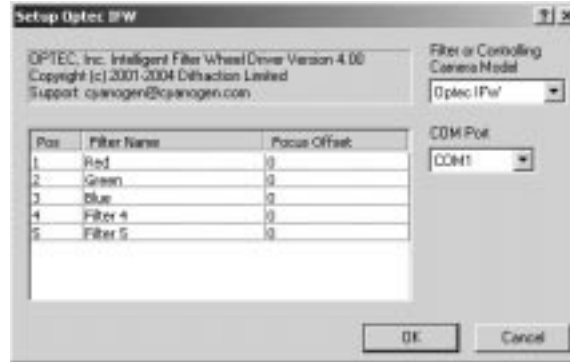
The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.

Optec IFW

For this driver, select **Optec IFW** on the Setup tab.

The Optec Intelligent Filter Wheel connects via a serial port, as selected by **COM Port**.

The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.



True Technology Custom Wheel

For this driver, select **TrueTech** on the Setup tab.

This driver supports **serial port operation** of True Technology Custom Wheels. Some models also support SBIG compatibility mode. See the next section for information on configuring these wheels in SBIG mode.



The Custom Wheel connects via a serial port, as selected by **COM Port**.

The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name

in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.

SBIG-Compatible Filter Wheels

For all CFW8 and compatible filter wheel models connected directly to an SBIG CCD camera, please see **SBIG Universal Filter Wheel**.

For filter wheels connected via SBIG serial port based cameras, refer to the entry below for the specific camera model.

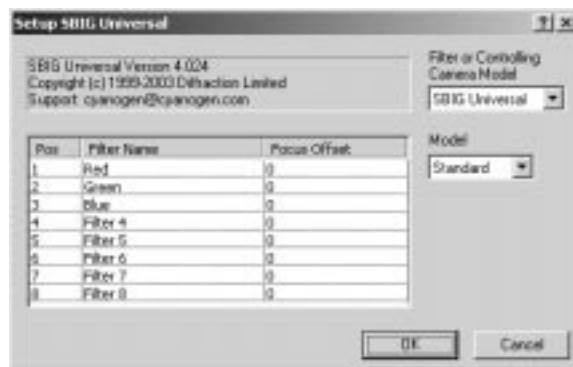
For connecting SBIG CFW-8 or compatible filter wheels to the PC parallel port, please see SBIG Parallel (CFW-8, Homeyer, Optec) below. Also see **Notes On Direct Parallel Port Connection**.

For connecting Homeyer or other SBIG CFW-8 filter wheels to the PC serial port, please see Homeyer below. Also see **Notes On Direct Serial Port Connection**. (Note: a special adapter circuit is required for non-Homeyer wheels.)

SBIG Universal Filter Wheel

For this driver, select **SBIG Universal** on the Setup tab.

The SBIG Universal filter wheel setup is used with all SBIG that use the **SBIG Universal** or **SBIG w/AO-7** camera driver. (This does not include serial port interface cameras.)



The **Model** of filter wheel can be selected to **Standard**, **CFW8** or **CFW-6A**. In CFW8 mode it also supports Homeyer, Optec MaxFilter, and True Technology Custom Wheels with the optional SBIG compatibility mode. The **Standard** mode is used when

controlling the integrated filter wheel for the STL, ST-5C, or ST-237.

SBIG CFW-6A filter wheels require a FILTER.CFG file. This file is produced by using the SBIG CCDOPS software to calibrate the filter wheel. The file must be copied from the CCDOPS program installation directory to the MaxIm DL program installation directory.

The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.

SBIG ST-5 With CFW8

For this driver, select **SBIG ST-5** on the Setup tab.

The SBIG ST-5 can control an SBIG CFW-8 filter wheel. No settings are required. The camera can also be used with Homeyer, Optec MaxFilter, and True Technology Custom Wheels with the optional SBIG compatibility mode.

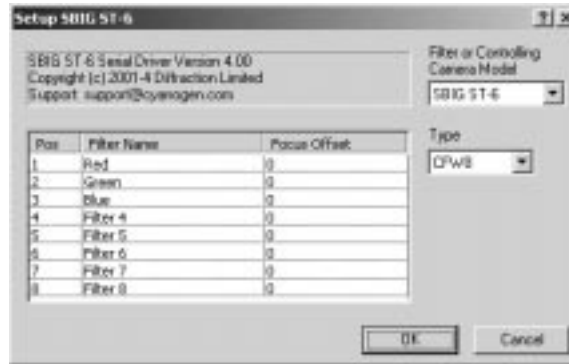


The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.

SBIG ST-6 With CFW8 / CFW6-A Filter Wheel

For this driver, select **SBIG ST-6** on the Setup tab.

The SBIG ST-6 can control an SBIG CFW8 or CFW-6A filter wheel. You must select the appropriate filter wheel **Type**. The CFW8 setting can also be used for Homeyer, Optec MaxFilter, and True Technology Custom Wheels with the optional SBIG compatibility mode.



SBIG CFW-6A filter wheels require a FILTER.CFG file. This file is produced by using the SBIG CCDOPS software to calibrate the filter wheel. The file must be copied from the CCDOPS program installation directory to the MaxIm DL program installation directory.

The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.

SBIG STV

For this driver, select **SBIG STV** on the Setup tab.

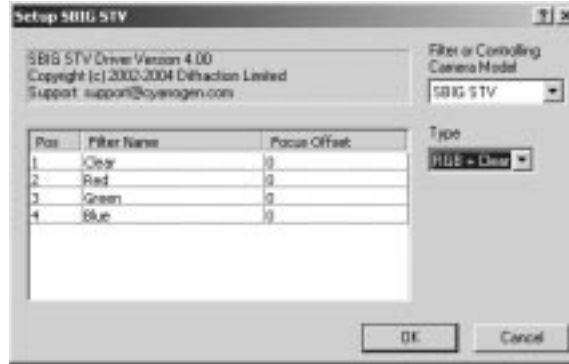
The SBIG STV driver is used with an SBIG STV with an installed SBIG CFW5 filter wheel.

When **Type** is set to **RGB + Clear**, all four filter positions are valid. The **Filter Names** should be set as follows:

Position	Filter Name
----------	-------------

1	Clear
2	Red
3	Green
4	Blue

When **Type** is set to **Lunar**, only the first two positions are valid. Position 1 should be identified as Clear, and Position 2 should be identified as Lunar. The remaining two slots should be left blank, so that they will not be available in the filter selection drop list (if they are not blank and the slot is selected, the lunar filter will be selected).



Focus Offset should be left at 0 for each slot.

SBIG Parallel

For this driver, select **SBIG Parallel** on the Setup tab.



Important note: if the filter wheel is connected via an SBIG camera, you must select **SBIG Universal** not **SBIG Parallel**.

Using this driver requires special wiring. Please see **Notes on Direct Parallel Port Connection** for information on wiring connections.

The **SBIG Universal** filter wheel driver allows direct control of SBIG CFW-8 compatible filter wheels from the PC's parallel port. This is useful when running these filter wheels in conjunction with non-SBIG cameras.

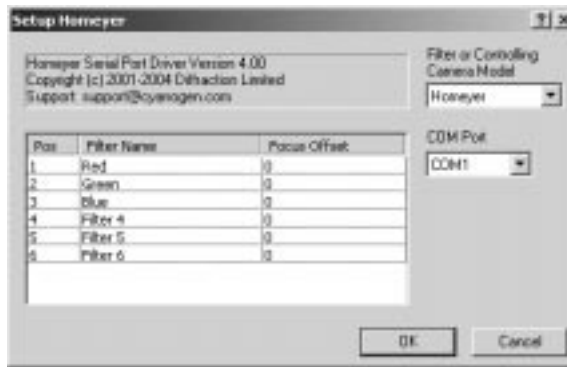
This driver will run **SBIG CFW-8, Optec MaxFilter, Homeyer, and True Technology Custom Wheels** with the SBIG compatibility option (use the **TrueTech** driver for serial interface wheels).

Select the Parallel Port address in Port. In most cases, if a parallel port camera is used, this must be a different parallel port.

The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.

Homeyer

For this driver, select **Homeyer** on the Setup tab.



This driver allows direct connection of a Homeyer filter wheel to a PC serial port. Please see **Notes On Direct Serial Port Connection** for information on making the necessary connections.

This wheel emulates an SBIG CFW8. Please refer to **SBIG-Compatible Filter Wheels** for information on connecting this wheel through an SBIG camera.

Connection to a PC parallel port is also possible. See **Notes On Direct Parallel Port Connection** for more information.

The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the Filter Name in the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.

Please see **Notes On Direct Serial Port Connection** for information on making the necessary electrical connections.

Optec MaxFilter

This wheel emulates an SBIG CFW8. Please refer to **SBIG-Compatible Filter Wheels** for information on connecting this wheel.

True Technology with SBIG Compatibility Mode

True Technology Custom Wheels with the optional SBIG compatibility mode should be controlled using **SBIG Universal** (if controlled via an SBIG camera), **SBIG Parallel** (if connected directly to the PC parallel port), **SBIG ST-5** (if controlled via an ST-5 serial camera), or **SBIG ST-6** (if controlled via an ST-6 camera).

Notes On Direct Parallel Port Connection

This method uses the PC to generate precise timing pulses on the parallel port. PC's are not very good at real-time signal generation, so some special programming was required to make this work. Please verify that filter wheel operation is reliable before attempting to use this driver for imaging. Due to operating system differences, performance on Windows NT/2000/XP machines is superior to Windows 98/ME.

The **SBIG Parallel** driver must be used for this connection.

Special wiring is required. Two connections are used – pulse and ground. Connect as follows:

Signal	PC Parallel Port	Filter Wheel
Pulse	Pin 2	Pin 2 or White wire
Ground	Pin 25	Pin 5 or Black wire

Please take care to connect this properly or damage to the computer may result.

Powering an SBIG CFW8

If you wish to connect an SBIG CFW8 without using an SBIG camera, then you must supply power to the filter wheel. The connections are as follows:

Signal	Filter Wheel
+12V Power	Pin 8 or Red wire
Ground	Pin 5 or Black wire

Please take care to connect this properly or damage to the filter wheel or computer may result.

Notes On Direct Serial Port Connection

Warning: Only the **Homeyer** filter wheel is designed to connect directly to a PC serial port. All other filter wheels may be **damaged** if they are connected directly to a PC serial port.

For a Homeyer filter wheel, the connector on the wheel may have to be modified to connect to the PC. The connector is normally configured for direct connection to an SBIG camera; the connections required for a serial port are different.

Here are the required connections:

Signal	PC Parallel Port	Filter Wheel
Pulse	Pin 3	Pin 2 or White wire
Ground	Pin 25	Pin 5 or Black wire

Connecting non-Homeyer filter wheels to the PC serial port

The following circuit will limit voltages from the serial port to levels acceptable to the filter wheel. These parts are readily available from suppliers such as <http://www.digikey.com>

Voltage Limiting Circuit

Warning: Use this circuit at your own risk. Incorrect connection could damage the filter wheel. Damage to the wheel may also occur if the ground connection to the circuit below is unconnected. Assembly by qualified personnel is highly recommended.

Telescope Setup

Telescope Setup



Telescope drivers used by MaxIm DL/CCD comply with the **ASCOM Standard**. These drivers may be supplied by third-party equipment manufacturers, or included as part of the ASCOM Platform.

The ASCOM Platform is a collection of drivers, most of which are open-source. These drivers have been contributed by interested individuals as well as astronomical product companies including Diffraction Limited.

The ASCOM Platform is free and can be downloaded from the ASCOM web site. A copy is also included on the distribution CD-ROM, although the on-line version may be newer as drivers are added and updated on a regular basis.

Please see <http://ascom-standards.org> for more information. Additional information on specific drivers is available below. Many other ASCOM drivers are available from the ASCOM website, from equipment manufacturers, or from other third parties. Documentation for such must be obtained from the creator of the driver.

ASCOM ACP Telescope

Astronomer's Control Program Version 3 from DC-3 Dreams (<http://ACP3.dc3.com>) integrates with MaxIm DL to provide completely automated observing. The optional built-in web server supports browser-based Internet astronomy. ACP3 exposes a telescope object that MaxIm DL can link to. This allows MaxIm DL to control the telescope through ACP, retrieve RA/Dec information for the FITS header, etc.

This option only appears if ACP3 is installed.

Desktop Universe

This option is available if Desktop Universe planetarium software is installed on your system. Desktop Universe is the first planetarium program to show the entire sky as actual images instead of as a plotted chart.

When using this driver, first connect Desktop Universe to the telescope, then connect MaxIm DL/CCD to Desktop Universe. The user may then control and monitor the telescope from either package. This allows the simultaneous use of MaxIm DL/CCD features such as **Auto-Center** with the extensive catalog lookup features of Desktop Universe.

MaxPoint Telescope Hub

MaxPoint is a tool for modeling telescope mount errors and correcting them. It connects between MaxIm DL/CCD (or other ASCOM-compliant software) and the telescope. As commands are sent to the telescope, MaxPoint corrects the position to account for errors in polar alignment, optical tube alignment, non-perpendicular axes, flexure, etc.



MaxPoint also provides a hub, which allows multiple programs to access the telescope at once.

Telescope Simulator

The Telescope Simulator is a very powerful tool for testing scripts and learning about the operation of the telescope control features. When activated, a floating window appears that simulates the hand paddle of the telescope. You can directly manipulate the telescope position from the hand paddle and watch the position change in the Telescope Control window.

The **Setup** dialog allows you to set the **Site Information** for the virtual telescope, and select what type of mount it emulates. The **Always on Top** check box controls whether the hand paddle floats on top of all other windows. The **Advanced >>** button allows you to view a set of controls for switching on and off various functions of the telescope simulator.

The ASCOM Platform must be installed for this option to appear.

TheSky Controlled Telescope

This driver allows you to link MaxIm DL to Software Bisque's TheSky™ planetarium software. This allows you to control any telescope compatible with TheSky, including the Paramount™, and also to use facilities such as TPoint™. The link will also transfer RA/Dec coordinates from TheSky into MaxIm DL for addition to the image FITS headers.

With the latest version of TheSky, the connection does not require any additional programs, but some settings are required. **Start TheSky**. Select **Telescope/Server Settings**. In the **Remote Client Capabilities** area, make sure **all options are enabled** (check marks in the boxes). Also enable **Remote clients use Orchestrate's "Image then slew-to" command** with a check mark in its box. Click **OK** to close the Server Settings dialog.

Once this is done you should be able to connect to the telescope.

Note: if you have the *Remote Astronomy Software Component Object Model* (RASCUM) installed, which comes with Orchestrate, then you may need to set additional settings as follows:

1. Download and install the latest versions of all Software Bisque software you are using.
2. Start TheSky
3. Set the Telescope/Server Settings as described above.
4. Connect TheSky to your telescope (Telescope/Link/Establish).
5. Open the "ob" program (located in the Orchestrate folder).

6. In the Ob Observatory menu, select Server Connections. Turn on only TheSky for now. Turn off CCDSoft and AutomaDome.
7. Select File New, the document should report that it is offering connections to TheSky and Telescope.
8. Close Ob.
9. Try to start the link in the Telescope control Setup tab. You may get an Internet Explorer “unsafe” warning; ignore it and answer Yes. Try to move the telescope; if you get a “Permission Denied” message, check step 2 above. If you get an “out of memory” message, run Ob, do a File new and try again. There seems to be some mystery about this, but if only TheSky is selected in Ob's Server Settings, this problem usually does not occur. If you get another error message like "ActiveX can't create object", you don't have all of the Software Bisque components needed to use their VB Scripting support. Refer to Software Bisque documentation for more info.

The ASCOM Platform must be installed for this option to appear.

Focuser Setup



Focuser drivers used by MaxIm DL/CCD comply with the **ASCOM Standard**. These drivers may be supplied by third-party equipment manufacturers, or included as part of the ASCOM Platform.

The ASCOM Platform is a collection of drivers, most of which are open-source. These drivers have been contributed by interested individuals as well as astronomical companies including Diffraction Limited.

The ASCOM Platform is free and can be downloaded from the ASCOM Download page <http://ascom-standards.org/downloads.html>. A copy is also included on the distribution CD-ROM, although the on-line version may be newer as drivers are added and updated on a regular basis.

Please note that “relative mode” focusers based on DC motors rather servo or stepper motors may not be suitable for use with the built-in SharpStar autofocus. It may be possible however to use FocusMax with them.

Please see <http://ascom-standards.org> for more information

Focus Simulator

This driver simulates a focuser without one actually being present. It is useful when testing scripts, but can also be used when learning how to operate the MaxIm DL user interface.



Chapter 5. Working With Other Software

MaxIm DL is able to interoperate with other software through several means. It uses standardized file formats for storing images and associated data. It has an open interface architecture that allows other programs to exercise its functions and access its data. It also has standardized ASCOM-compliant interfaces for connecting to external equipment; these can also be used to interconnect with other software.

FITS File Header Definitions

The native file format for MaxIm DL images is FITS (Flexible Image Transport System), a standard widely used in the astronomical community. This is an excellent choice for all types of CCD images since the format supports 16-bit and floating-point data, and it includes a flexible and highly extensible header. Various standard and widely used non-standard keywords can transfer information about the image between applications. In addition, public domain “C” source code for reading and writing FITS files is available on the web.

One shortcoming of the FITS standard is that the 16-bit number format is signed, producing a range of -32768 to +32767. The range of data from many CCD cameras is 0 to 65535. To overcome this problem, MaxIm DL subtracts 32768 from each pixel prior to saving. The FITS standard requires that the BZERO and BSCALE keywords be used when the value in the array is not the physical value; MaxIm DL sets BZERO to 32768 and BSCALE to 1. Other applications that interpret these keywords correctly should automatically add 32768 to the image pixels, resulting in a correct image display. This default behavior can be overridden using the **File** menu **Settings** command.

The FITS compression method used by MaxIm DL is proprietary and is not compatible with other software packages. If you need to transfer images to another package, you must save the images as uncompressed. If you need to convert a large number of images, use the **File** menu **Batch Save and Convert** command.

MaxIm DL is compliant with the SBIG proposal for FITS keyword extensions. This means that various optional and non-standard keywords are written in a fashion that is compatible with a number of other astronomical imaging packages.

Mandatory FITS keywords are as follows:

- SIMPLE – always “T”, indicating a FITS header.
- BITPIX – indicates array format. Options include unsigned 8-bit (8), signed 16 bit (16), signed 32 bit (32), 32-bit IEEE float (-32), and 64-bit IEEE float (-64). The standard format is 16; -64 can be read by MaxIm DL but is not written.

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- NAXIS – number of axes in the data array. MaxIm DL uses 2 for monochrome images, and 3 for color images.
- NAXIS1 – corresponds to the X axis.
- NAXIS2 – corresponds to the Y axis.
- NAXIS3 – present only for color images; value is always 3 (red, green, blue color planes are present in that order).

Optional keywords defined by FITS standard and used in MaxIm DL:

- OBJECT – name or catalog number of object being imaged, if available from Telescope Control window or specified by the user in Settings.
- TELESCOP – user-entered information about the telescope used.
- INSTRUME – CCD camera information. Either user entered or obtained from the camera driver.
- OBSERVER – user-entered information; the observer's name.
- DATE-OBS – date of observation in the ISO standard 8601 format (Y2K compliant FITS): CCYY-MM-DDThh:mm:ss.sss. The Universal time at the start of the exposure is used. Note: the alternate format using DATE-OBS and TIME-OBS is not written, but MaxIm DL will correctly interpret it when read.
- BSCALE – this value should be multiplied by the data array values when reading the FITS file. MaxIm DL always writes a value of 1 for this keyword.
- BZERO – this value should be added to the data array values when reading the FITS file. For 16-bit integer files, MaxIm DL writes 32768 (unless overridden by the Settings dialog).
- HISTORY – indicates the processing history of the image. This keyword may be repeated as many times as necessary.

Non-standard keywords used in MaxIm DL:

- EXPTIME – duration of exposure in seconds.
- DARKTIME – dark current integration time, if recorded. May be longer than exposure time.
- CCD-TEMP – actual measured CCD temperature at the start of exposure in degrees C. Absent if temperature is not available.
- XPIXSZ – physical X dimension of the CCD pixels in microns (present only if the information is provided by the camera driver). Includes binning.

- YPIXSZ – physical Y dimension of the CCD pixels in microns (present only if the information is provided by the camera driver). Includes binning.
- XBINNING – binning factor used on X axis
- YBINNING – binning factor used on Y axis
- XORGSUBF – subframe origin on X axis
- YORGSUBF – subframe origin on Y axis
- EGAIN – electronic gain in photoelectrons per ADU.
- FOCALLEN – focal length of the telescope in millimeters.
- APTDIA – diameter of the telescope in millimeters.
- APTAREA – aperture area of the telescope in square millimeters. This value includes the effect of the central obstruction.
- CBLACK – indicates the black point used when displaying the image (screen stretch).
- CWHITE – indicates the white point used when displaying the image (screen stretch).
- PEDESTAL – add this value to each pixel value to get a zero-based ADU. Calibration in MaxIm DL sets this to 100.
- DATAMAX – pixel values above this level are considered saturated.
- SWCREATE – string indicating the software used to create the file; will be “MaxIm DL Version x.xx”, where x.xx is the current version number.
- SWMODIFY – string indicating the software that modified the file. May be multiple copies.
- SBSTDVER – string indicating the version of the SBIG FITS extensions supported.
- FILTER – name of selected filter, if filter wheel used.
- TRAKTIME – exposure time of the autoguider used during imaging.
- SET-TEMP – CCD temperature setpoint in degrees C. Absent if setpoint was not entered.
- IMAGETYP – type of image: Light Frame, Bias Frame, Dark Frame, Flat Frame, or Tricolor Image.
- OBJECTDEC - Declination of object being imaged, string format DD MM SS, if

available. Note: this is an approximate field center value only.

- OBJECTRA – Right Ascension of object being imaged, string format HH MM SS, if available. Note: this is an approximate field center value only.
- SITELAT – latitude of the imaging site in degrees, if available. Uses the same format as OBJECTDEC.
- SITELONG – longitude of the imaging site in degrees, if available. Uses the same format as OBJECTDEC.
- NOTES – user-entered information; free-form notes.

Some of the above parameters can be viewed in the **File Open** dialog. All are visible in the **FITS Header Window**.

Planetarium Software

MaxIm DL is commonly operated alongside a planetarium program, for telescope control and observation planning. If the planetarium program has an ASCOM interface, it is possible to connect MaxIm DL to the planetarium. This has several advantages:

1. The approximate Right Ascension and Declination from the telescope are automatically entered into the FITS Header. This is helpful for determining where an image was taken, running PinPoint astrometric analysis, etc.
2. MaxIm DL's Auto-Center function is available. You can slew to an object catalog position using the planetarium, and then take a quick binned exposure. Right-click on the object in the image, and select Point telescope here. The object is automatically centered in the CCD image.
3. You can monitor the telescope position inside MaxIm DL, abort slews if a problem develops while the Planetarium is minimized, use the Nudge controls, etc.

Usually both the planetarium and MaxIm DL are configured to connect to an ASCOM Hub, such as POTH (included with ASCOM) or MaxPoint (for pointing corrections).

In some cases, it may be necessary to hook MaxIm DL directly into the planetarium. An example is the situation where a telescope can only be controlled directly from the planetarium itself (e.g. Paramount). For TheSky you can connect directly to it using the "TheSky controlled telescope" driver. Please see Telescope Setup for information on setting this up.

Other planetarium and catalog programs known at the time of writing to have ASCOM support include Desktop Universe, Easy Sky Pro, Hallo Northern Sky, NGC View,

Power Age Sky Simulator, Ricera, SkyMap Pro, SkyTools 2, Star Atlas: Pro, SkyObserver, and Starry Night Pro. For a complete list see <http://ascom-standards.org>

ACP Observatory Control Software

ACP Observatory Control Software, available from DC-3 Dreams S.P., is designed for automating and remotely operating observatories. It uses MaxIm DL/CCD for all camera control operations.

ACP provides completely automated scripted control, allowing hundreds of images to be taken a night without human intervention.

ACP also contains a built-in web server for remote control. Two versions are available, one for intranet operation and one for full remote control over the Internet.

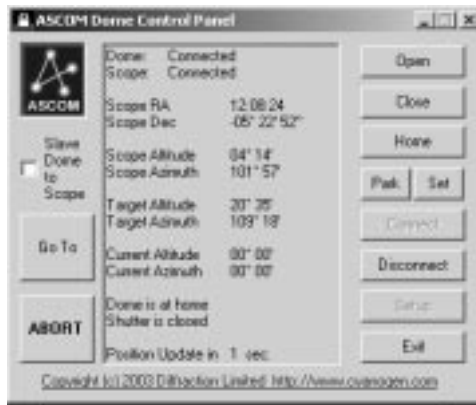


For more information, please see <http://acp3.dc3.com>

ASCOM Dome Control Panel

The ASCOM Dome Control Panel is an open-source program written by the makers of MaxIm DL. It works as an ASCOM hub, intercepting telescope control and status information in order to calculate the required coordinates for the dome slit. It also provides functions for homing, parking, opening, closing, etc.

Dome Control is installed with the ASCOM Platform. Also included is the **POTH Telescope Hub**, which can also provide a dome interface.



FocusMax

FocusMax is a third-party tool that integrates with MaxIm DL/CCD to provide enhanced autofocus capabilities. It is fast and extremely accurate, and can handle “relative mode” focusers, i.e. those that use DC motors and cannot produce fully repeatable positioning.

Connecting FocusMax can be a little confusing. It links to MaxIm DL’s camera control interface automatically. It needs to connect to an ASCOM focuser. It optionally connects to an ASCOM telescope, to provide special functions (such as automatically moving to a nearby focusing star and then returning to the original coordinates).

MaxIm DL can also connect to the focuser at the same time, by connecting to RoboFocus as the driver. However, it is simpler to use the POTH hub for both the focuser and telescope, and connect FocusMax and MaxIm DL directly to POTH, and POTH to the focuser and telescope.

Please see <http://focusmax.org> for more information.

Image Processing Plug-ins

MaxIm DL has an open architecture that allows other programs to access its processing and imaging functions. You can also build a plug-in that appears on the menu. Plug-ins can use a mix of built-in MaxIm DL functions plus their own code to produce new capabilities.

Both freeware and commercial plug-ins are available from third parties. A partial list is available at http://cyanogen.com/products/maxim_extras.htm

Source code for a very simple example plug-in is included with the MaxIm DL installation, under the program folder. Both Visual Basic and Visual C++ versions are included. Also see the Scripting section for information on working with MaxIm DL's objects.

MaxPoint

MaxPoint models errors in your telescope mount, and automatically corrects these errors to improve your pointing accuracy. This is extremely useful when working with the limited field-of-view of many CCD cameras.



MaxPoint works as an ASCOM Hub: you connect MaxIm DL to it, and it connects to the telescope. That way it is able to intercept all commands sent to the mount and automatically correct them. You can also connect other ASCOM capable programs to MaxPoint at the same time, allowing multiple programs to access the same telescope mount.

A 30-day trial version is included on the MaxIm DL CD-ROM. You can also download a MaxPoint trial from <http://www.cyanogen.com>

PinPoint Full Version

Although PinPoint LE comes included with MaxIm DL, you may wish to use the more powerful capabilities of the full version. MaxIm DL supports the full version and adds some extra capabilities. For example, the Information Window will display full catalog information on stars identified in the image.


The full version also includes Visual PinPoint, which can be used for asteroid and


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supernova discovery and batch processing of images. It can automatically detect asteroids in image sets and generate MPC reports for the observations. For more information, see <http://pinpoint.dc3.com>

Chapter 6. Command Reference

This section describes all of the commands available in MaxIm DL. For information on the equipment control features provided with MaxIm CCD, please refer to the separate MaxIm CCD section at the back of this manual.

 All of this information is available from the context-sensitive Help. **Click** the **Toolbar Help** button and then either **double-click** on the menu item or **click** on the dialog itself.

Help on individual dialog controls can also be obtained by **clicking** the  help button on the dialog title bar then **clicking** on the control.

File Menu

New

The **New** command can be used to create a blank image document. This is most commonly used before executing the **Mosaic** command (Edit menu).



The desired image **Width** and **Height** and **Color Type** must be selected. Width and height are measured in pixels. Upon clicking **OK**, a blank image of the appropriate size will be created. All pixels in the image will be zero. The image contents can be modified using any of the image editing or processing commands.

This command is useful for generating new image buffers to be used in generating **mosaics**. The completely blank image buffer helps the blending feature work properly.

Open

The **Open** command is used to load image files into an image buffer. A variety of file formats are supported, including **FITS**, **SBIG** monochrome formats, **BMP** files, 8-bit or 16-bit depth **TIFF** images (except those using LZW compression, which is protected by patent), **JPEG** and **PNG** compressed images, **PC-Lynxx** images, and **RAW** format

images (with optional header skip). **RAW** and **FITS** images can have 8-bit, 16-bit, and 32-bit integer formats or IEEE floating point format. Note that the **RAW** format can be used to read files from Starlight Xpress camera control software.



The MaxIm DL **Open** dialog is based upon the standard Windows Open dialog. Multiple files of the same format can be opened simultaneously using standard Windows file multi-select features (**Shift** to select a range of files, **CTRL** to select multiple individual files).

If the **File Filter** is set to “**All Files (*.*)**,” then the separate **File Format** combo box is enabled. If the file has a recognized extension and valid header, then the file format will automatically be shown when the file is selected. When the file format matches the type of file, details on the file will be shown in the **File Details** box. If no display is shown in the **File Details** box, then the file is not compatible with that format and a different format selection should be used.

For **RAW** files, the correct size format (8-bit, 16-bit or 32 bit integer or 32-bit IEEE float) must be selected, as well as the correct image dimensions. The **File Details** box will indicate the dimensions if the file size matches, otherwise it will display “Incorrect dimensions” and show the number of pixels in the image. This can help determine the correct image dimensions. The **Skip** field allows you to skip a fixed-sized file header at the beginning of the file. Simply enter the number of bytes to skip to find the first pixel in the image. This is useful for opening many unsupported image formats.

The **Interpolate Pixels to Square** feature instructs MaxIm DL to adjust for the pixel aspect ratio while loading the file (bilinear interpolation is used). The pixel dimensions

are normally extracted from the file header, but the user can override them if required. If **Interpolate Pixels to Square** is not selected, MaxIm DL remembers the pixel aspect ratio for use in the **Set Point-Spread Function** and **Resize** dialogs.

To read a “raw” file created with Starlight Xpress camera software, select **Raw** format, set **Size Format** to 16-bit Int, and set the **Width** and **Height** to match the size of the image. For example, for MX5 cameras set **Width** to 510 and **Height** to 290; for HX516 cameras set **Width** to 660 and **Height** to 500. (When Starlight Xpress cameras are operated under MaxIm CCD the images are automatically stored in FITS format.)

For **FITS** files, if the keywords **BZERO** and **BSCALE** are present they will be taken into account when loading the data. Some software packages store unsigned 16-bit integers in FITS files. Although not sanctioned by the FITS standard, this is common practice. If negative numbers appear in an image file, MaxIm DL will assume it is an unsigned integer file and adjust the image accordingly. Note that the **FITS** file format is affected by controls on the **General** tab of the **Settings** command of the **File** menu.

Limitations on File Formats

- Color SBIG files are not supported.
- BMP files must be uncompressed.
- To avoid patent infringement, LZW compressed TIFF files are not supported (use uncompressed).

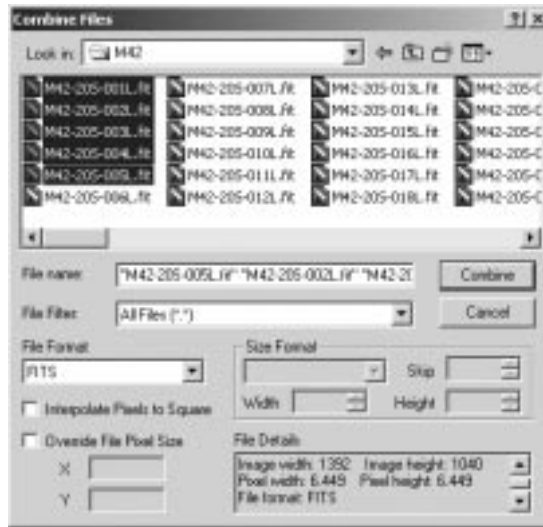
Combine Files

The **Combine Files** command adds the contents of multiple files together to reduce noise, with optional realignment to remove any translation or rotation. One common application of this command is to eliminate the need for accurate guiding during astronomical CCD image exposures. Instead of a single long exposure, a series of shorter exposures are taken. They are then aligned and added together to simulate the effect of a single long exposure.

Select Images

Two separate dialogs are used for this function. The first is identical to the **File Open** dialog. First select the files to be combined. This is done in the standard Windows fashion by holding the **Shift** key down and selecting a set of files with the mouse, or by holding the **CTRL** key down and selecting the files individually. All of the files have to be of the same type (file format). You can include all the files in a sequence even if some of them are known to be of poor quality since the second dialog allows you to reject poor images.

Once you have selected the desired files, click the **Combine** button. A second **Combine Files** dialog is presented.



Combine Files

When the **Combine Files** dialog box appears, a special Align image buffer also appears.

The first step is to select the **Output** mode. This determines how the images are combined. The options are **Sum**, which adds up the pixels in all the images; **Average**, which sums all the pixels and divides by the number of images; and **Median**, which takes the median or middle value from all of the images. The **Sum** mode provides the best performance in most conditions (e.g. when Gaussian noise is present). The **Median** mode is useful when some pixels are extremely bright or dark (hot/dark pixels, cosmic ray hits). If **Median** mode is used, a **Normalize** option is available. Normalize will remove differences in the image scaling which could interfere with the median processing. The **Sigma-Clip** and **SD Mask** combination modes attempt to combine the best features of the **Median** and **Average** modes, but require more intensive calculations. These algorithms require additional settings, which are discussed below.

When the **Sigma-Clip** or **SD-Mask** (Standard Deviation Mask, a custom algorithm contributed by Ray Gralak) combine algorithms are selected, additional parameters are required to control how the images are combined. Both algorithms work by calculating the mean value of each pixel across all of the input images, as well as the standard deviation of those pixel values. If **Ignore Black Pixels** is checked, then any pixel with a value of 0 is excluded from the mean/standard deviation calculation.



When using the **Sigma-Clip** algorithm, the pixel value that deviates the most from the mean will be discarded, provided that the deviation is greater than the number of standard deviations given by the **Sigma Factor**, and a new mean will be calculated without the discarded value. This value is assigned to the corresponding pixel in the output image.



When the images are rotated or resized, MaxIm DL will interpolate the values of the pixels in the input images to produce a more accurate result in the output. Two interpolation modes are available. **Bicubic Resample** uses a higher-order resample algorithm that produces a crisper result, but requires more processing time. When turned off, a simple bilinear interpolation is used.

The next step is to select the **Align Mode**. The methods available are:

- None
- Auto - correlation
- Auto - star matching
- Manual 1 star - shift only

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- Manual 2 stars
- Astrometric
- Planetary
- Overlay

The auto modes require no further operator input – just click the **OK** button. Even in the automatic modes you can remove bad images by stepping through using the **Next Image** and **Previous Image** buttons, and turn on/off the **Reject Image** button.



Manual modes allow for image alignment using a variety of techniques. Each alignment method is described below.

None

In this mode, no change is made to the alignment of the images. The images are summed, averaged, or median combined without any other adjustments.

Auto - correlation

A cross-correlation is performed between each image to determine the relative offset. If point sources (stars) are available in the image they are used to refine the alignment to sub-pixel accuracy. The images are only shifted horizontally and vertically; no rotation is performed. This function only works properly if the offset between images is relatively small. To determine if it will work satisfactorily, click the **Overlay All Images** button to

produce a preview.

Auto - star matching

In this mode, the images are matched up by comparing star patterns. If the match is successful, the images are automatically aligned to sub-pixel accuracy, using both shifting and rotation. To determine if the results are satisfactory, click the **Overlay All Images** button to produce a preview.

Manual 1 star - shift only

This is the fastest manual adjustment method. Each image is presented in turn; the user simply **clicks** on a particular star or other recognizable feature in each image. The images are aligned using shifting only; no rotation is performed.

In order to speed up the alignment, turn on the **Auto Next** check box. Every time the mouse is **clicked** on the image, the next image will automatically be displayed. When all of the images have been registered, the computer will **beep**.

If **Auto Next** is not being used, you can move through the images using the **Next Image** and **Previous Image** buttons.

If the reference point is a star or similar object, turn on the **Use Centroid** check box. At each clicked location a centroid will automatically be calculated and used to refine the adjustment to the sub-pixel level.

One of the images can be set as the reference image using the **Set As Reference** button. The selected image will not be moved, and all other images will be adjusted to align with it.

If any image in the sequence is of poor quality, click the **Reject Image** button to remove it from the list. You can restore it by clicking on the button again. Also any image that is not registered by clicking on it with the mouse is automatically rejected.

To determine if the results are satisfactory, click the **Overlay All Images** button to produce a preview.

Manual 2 stars

This method is similar to the **Manual 1 star** method, but performs both a shift and rotate using two registration points. Each image is presented in turn; the user simply **clicks** on a particular star or other recognizable feature in each image.

In order to speed up the process, turn on the **Auto Next** check box. Every time the mouse is **clicked** on the image, the **next image** will automatically be displayed. When the first registration point has been set on each image, the computer will **beep** and the first image will be displayed again. Move to a **second star** and **repeat** the process until the computer **beeps** a second time. The **Star 1** and **Star 2** buttons will toggle to show

you which point is being set.

If **Auto Next** is not being used, or you want to change a single registration point, use the **Star 1** or **Star 2** button to control which reference point is being changed. You can move through the images using the **Next Image** and **Previous Image** buttons.

One of the images can be set as the reference image using the **Set As Reference** button. The selected image will not be moved, and all other images will be adjusted to align with it.

If the reference point is a star or similar object, turn on the **Use Centroid** check box. At each clicked location a centroid will automatically be calculated and used to refine the adjustment to the sub-pixel level.

If any image in the sequence is of poor quality, click the **Reject Image** button to remove it from the list. You can restore it by clicking on the button again. Also any image that is not registered by clicking on it with the mouse is automatically rejected.

To determine if the results are satisfactory, click the **Overlay All Images** button to produce a preview.

Astrometric

This method uses the World Coordinate System (WCS) entries in the FITS header to determine how much to shift, rotate, and scale each image into alignment with the reference image. The WCS information characterizes the precise image center, pixel scale, "roll angle" and other information describing the mapping between RA and declination and pixel (X, Y) coordinates. It is added to the FITS Header when an image is solved using the **PinPoint Astrometry** command or another astrometric package. Only images that have been successfully solved can be aligned in this way; all unsolved images are automatically rejected.

Since aligning an image changes its center, orientation angle, and/or scale, the existing WCS is invalidated on all images except the reference. By default, the reference image is the first image in the list, but you can select another one by moving to it with **Next Image** or **Previous Image**, then clicking **Set As Reference**.

To determine if the results are satisfactory, click the **Overlay All Images** button to produce a preview.

Planetary

This method is intended for aligning images of planets. It will work only when each image to be aligned contains a single substantial disk, that is, an approximately circular region of bright pixels completely surrounded by background. The images are shifted to bring the centroids of their disks into coincidence. No rotation or scaling is performed. The **Reject** and **Set As Reference** buttons are available in planetary mode and work as

previously described.

To determine if the results are satisfactory, click the **Overlay All Images** button to produce a preview.

Overlay

This mode is useful when no clear registration points are visible, such as planetary images with indistinct features.


You **must** first set one of the images as the reference image. Look through the images using the **Next Image** and **Previous Image** buttons. Pick an image and click the **Set As Reference** button (in many cases the first image can be used).

Next, move to another image using the **Next Image** or **Previous Image** button. This image will be overlaid on the reference image, with the reference in magenta and the new image in green. The **Overlay Controls** can now be used to adjust the position of the image to match the reference.

There are four shift buttons with **up**, **down**, **left**, and **right** arrows. There are also two rotation buttons with **rotate clockwise (right)** and **rotate counterclockwise (left)** arrows. Each time you click a button the image moves. The distance moved is controlled by the **Nudge Size (pixels)** control. With these controls you can position an overlaid image to a fraction of a pixel.

In order to use the **rotation buttons**, you must first pick a **rotation point**. This is the point that the image will pivot about as it is rotated. The best procedure is to align a feature that appears on both of the overlaid images, then **click** on the feature. Look at another point in the image some distance away and adjust the rotation to line up the second point.

To determine if the results are satisfactory, click the **Overlay All Images** button to produce a preview.

For information on individual dialog controls, close this help window and use the  button in the dialog's title bar.

Close

This command closes the currently-selected window. If the image has not been saved, the user is asked whether to save the image (**Yes**), discard it (**No**), or cancel the Close operation. If the image has not previously been associated with a file, the Save As dialog will be initiated when **Yes** is selected.

Save

The **Save** command will save the file in the current file format. If the image has not yet

been associated with a file, then the **Save As** dialog will be automatically initiated.

Save As

The Save As command can be used to save an existing file to a new name or format, or to determine the name and format to use for a new image. The Save As dialog is based on the standard Windows version, with several additional features.



The **File Filter** will set the format and extension for the file; only files of the type selected will be displayed under **Save In**. If "All Files (*.*)" is selected, then all files will be displayed, and the **File Format** combo box must be used to select the file format.

For **TIFF**, **FITS** and **RAW** format files, the **Size Format** must be set. **TIFF** files can be stored as **8-bit** or **16-bit** integers; **FITS** and **RAW** format accept these plus **32-bit integer** and **32-bit IEEE float**. Other formats are fixed at **8 bit** depth (**PNG**, **JPEG**, **BMP**, **ST-4**), **12 bit** (**PC-Lynxx**), and **16-bit** (**SBIG**).

Certain file formats support selectable file compression. For these formats, the **Compression Type** combo box can be used to determine the compression settings. Note that the **FITS** file format includes an option for compression, which is non-standard. This option can save disk space, but should not be used if you intend to open the **FITS** file in another software package.

The **File Details** box will indicate the maximum pixel value in the image, and the maximum allowed by the file format. If the brightest pixel exceeds the maximum allowed value, a warning message will appear. If the image is saved while this warning message is present, any pixels above the maximum allowable value will be saturated. In

some cases this may badly affect the image.

To avoid exceeding the available file format range, the **Stretch** dialog may be initiated directly by clicking the **Stretch** button. This will allow you to rescale the memory buffer to values compatible with the file format.

The **Auto Stretch** feature may be activated to automatically stretch images before they are saved. When enabled, images that contain pixels exceeding the maximum allowed value for the selected file format will be automatically stretched before they are saved. The screen stretch settings will be used to determine the zero and maximum pixel values used. Images that do not exceed the file format maximum pixel value will not be affected by **Auto Stretch**.

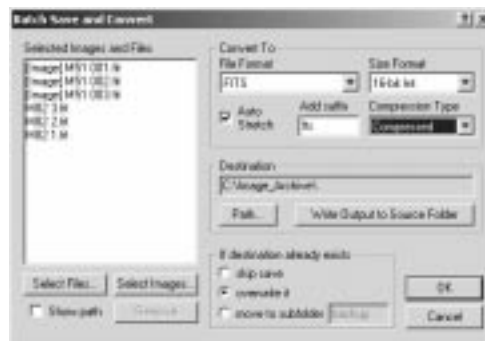
Note that the **FITS** file format is affected by the **File** menu **Settings** command. The **FITS** standard does not support unsigned integers, which limits the maximum pixel value to 32767. To provide a full 16-bit data range, MaxIm DL will by default use **BZERO** and **BSCALE** keywords to offset the data range. Some software packages use non-standard unsigned integers instead; MaxIm DL can be set to save images in this fashion using the **General** tab of the **Settings** command on the **File** menu.

Save All

This command saves all currently-open images as if a **Save** operation had been performed for each. For images which do not have an associated disk file (e.g., those captured from CCD or created by combining other images), a **Save As** dialog is shown. Clicking **Cancel** in a **Save As** file selector skips writing that image to disk, but **Save All** will continue with the remaining files.

Batch Save and Convert

Batch Save and Convert can be used to save files in memory, change the format of image files, and move files from location to location on the hard drive.



The first step is to select a set of images or files. Files can be selected from disk using the **Select Files...** button. You can browse to a location on the disk where your files are located, and select a number of files. Use **CTRL-click** to select individual files, and **SHIFT-click** to select a range of files.

You can also select images already open in MaxIm DL for transfer to disk by clicking the **Select Images...** button. This is useful for saving a large number of images, in bulk, to a particular directory. Again, use **CTRL-click** and **SHIFT-click** to select multiple images.



You can see the path for the selected images by turning on the **Show Path** check box. Images from memory do not have a path; they are tagged with [Image] when Show Path is not checked.

You can remove images from the list by selecting them with the mouse and clicking the **Remove** button.



Once all the images are selected, use the **Convert To** settings to select the **File Format**, **Size Format** (if required by the file format used), and **Compression Type**. **Auto Stretch** can be used to save images that exceed the allowable range of data values for

that format; if any pixels exceed the allowed range, the **Screen Stretch** settings are applied to the image automatically prior to saving. You can also use the **Add suffix** option to append characters to the end of the file name prior to saving. The suffix is inserted before the extension, unless it contains a period (.), in which case it replaces the default file extension which would otherwise be used for the selected file type.

Select the location for the saved files using the **Path** button, or click **Write Output to Source Folder** to cause the files to be saved back into the folder from which they were loaded. (This option cannot be used when an image has never been saved, for example, one freshly acquired from a CCD camera.) In the event that saving a file will cause it to overwrite an existing file, you can select **skip save, overwrite it, or move to subfolder**. You can specify the subfolder name in the adjacent field.

Click **OK** to start the batch save operation. Successfully converted and saved files are removed from the list box, leaving only those for which an error occurred. In this case, the OK button will change to **Retry**. To find out what error occurred, point the mouse cursor at an image name in the list. The appropriate error message will appear in the Status Bar at the bottom of the MaxIm DL main window. This allows you to view any error message produced for each of the files.

Revert

The revert command reloads the last saved version of the currently-selected image. The currently selected file format (**File Open** dialog) should match the type of image. You will be prompted before discarding the current image. Note that this operation disables the **Undo** command, since the image buffer is destroyed.

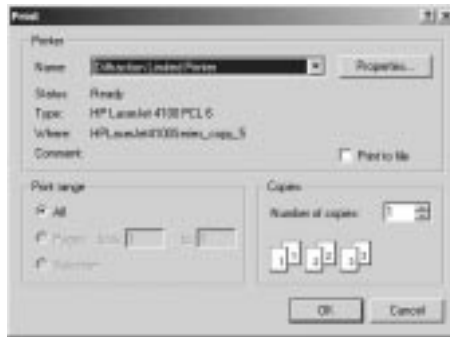
Page Setup

The page setup command allows you to select page orientation and margins for the printed image. You can select paper size and source, page orientation, and margins.



Print

The **Print** command allows you to print the currently selected image on a graphics printer. You can select a printer using the **Name** field, set up the printer using **Properties**, and select the number of copies to print using **Copies**.



Settings

The Settings dialog is a tabbed dialog box containing various tabs for configuring program behavior and defaults. In MaxIm DL/CCD, there are four tabs:

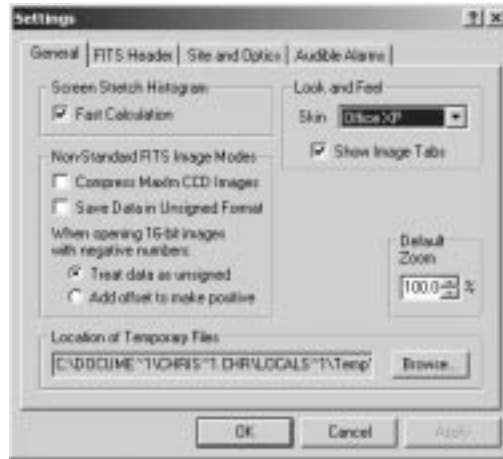
- General
- FITS Header
- Site and Optics
- Audible Alarms

NOTE: In the image-processing only version of MaxIm DL, only the General and

Audible Alarms tab are available.

General

The **Fast Calculation** setting, when enabled, causes MaxIm DL to skip some image pixels when developing the histogram for the **Screen Stretch** window. This greatly speeds the histogram calculation, but reduces accuracy somewhat. Using this will improve program responsiveness for large image files.



Controls in the **Look and Feel** area affect the visual appearance of the MaxIm DL application. The **Skin** dropdown allows you to choose among several different styles of menu, toolbars, and status bar. When **Show Image Tabs** is checked, MaxIm DL reserves a small horizontal band near the top of the application window in which to display "tabs" similar to those on file folders, one for each open image window. Clicking on one of these tabs transfers application focus to the corresponding image window, and is a convenient alternative to picking the window from the list in the **Window** menu. When there is not enough space to present tabs for all open image windows at once, a pair of horizontal scroll arrows at the right end of the tab bar are enabled; these scroll the tabs horizontally to allow access to those that are not currently visible.

Compress MaxIm CCD Images will cause all FITS format images taken with the MaxIm CCD camera control window to be saved using the proprietary compression mode. This is very helpful when using large format cameras, but the resulting FITS images cannot be loaded by other applications unless they are first uncompressed using MaxIm DL. (**Batch Save and Convert** is useful for this purpose.) The compression format is lossless, and a 3:1 compression ratio is common for typical astronomical images.

Save Data in Unsigned Format will cause 16-bit integers to be written to FITS files as

unsigned numbers. Normally BZERO and BSCALE are written to the file to offset the data values.

When opening 16-bit images with negative numbers can be selected to **Treat data as unsigned** or **Add offset to make positive**. It is common for astronomical software packages to save 16-bit numbers as unsigned even though this violates the FITS standard; the first option automatically detects this situation and adjusts the image when it is loaded. The second option is used when images really do have negative pixel values. MaxIm DL cannot process such images directly; this option adds a pedestal to force the image to be positive. The value of the pedestal is added to the FITS header.

Default Zoom determines the zoom level for all new images when they are opened.

Location of Temporary Files can be used to set the temporary file location used by MaxIm DL. Temporary files are used during median combine operations and maximum entropy deconvolution.

After changing any control on this tab, you must click **Apply** or **OK** to cause the change to take effect.

FITS Header

The **FITS Header** tab allows you to enter information that is automatically added to the FITS header when a new image is acquired from the camera. Five predefined FITS keywords are available, all of which contain string data:

- **OBJECT**: the identification of the object being imaged
- **TELESCOP**: the name or description of the telescope used
- **INSTRUME**: the model or type of CCD camera used
- **OBSERVER**: the name of the observer
- **NOTES**: a brief note about the object, observation, conditions, etc.

The above information appears in the **Details** field of the **File Open** dialog when browsing to a file. All except for **NOTES** are standard FITS keywords.

One obsolete FITS keyword also appears in the list: **TIME-OBS**, the universal time at which the observation was made. Normally the time is included as part of the **DATE-OBS** key; if you choose to add **TIME-OBS** to your FITS headers, **DATE-OBS** records only the year, month, and day. You cannot specify the value of **TIME-OBS**, only whether it is added to the header or not. This setting is used on output only; when reading FITS files, MaxIm DL will properly determine the observation time regardless of how it is set.

In addition, you can create keywords of your own devising to record additional information as desired. User-defined keywords can represent data in any of the four FITS data types, string, integer, real or logical. Key names consist of from 1 to 8 upper-case characters, hyphens and underscores; character string data is limited to a maximum of 68 characters. Note that user-defined keys are not displayed in the **File Details** field of the **Open** or **Save As** dialogs and do not have a **Description** (comment) in the **FITS Header Window**.



You cannot use the **FITS Header** tab to insert FITS keywords that already have meaning to MaxIm DL. This restriction is imposed in order to prevent creating inconsistent or erroneous FITS files.

To enter a value for a new FITS keyword, type its name in the **Key** combo box. Then select the **Type** for the data and enter the desired **Value**. Click the **Set** button to create the new entry, or replace the old one. (If the key is already present in the list box, **Set** is only enabled when the entered **Value** is different from the existing one. **Set** is also disabled if the contents of the **Value** field cannot be translated into the correct type, for example, if the entered value for an Integer key contains non-digits.) Use the same procedure to edit an existing entry. In this case, you can start by simply picking its name from the droplist or clicking on it in the Keyword column of the list box.

To remove a user-defined keyword from the list, select it as if you were going to edit it, then click **Unset**. The five predefined FITS keywords cannot be deleted, and MaxIm DL always makes entries for them. You can, however, set them to empty strings.

Two of the predefined entries, OBJECT and INSTRUME, have associated checkboxes that enable automatic updating of the FITS Header.

1. MaxIm DL will automatically fill in the FITS OBJECT keyword with the same

object identification it displays in the "Slewing to" or "Positioned on" messages in the Telescope status area if the following conditions are all met:

- **Set OBJECT from Telescope Control's catalog ID if available** is checked,
- you have **connected to the telescope**, and
- you used the **Telescope Catalog** tab to position the telescope on the object.

When this control is checked, any entry shown for OBJECT in the **Keyword/Value** list box is used only when the Telescope Control does not report an object (i.e., the object is not in the catalog, you didn't use the Telescope Catalog to position the scope there, or the telescope alignment is sufficiently bad that you had to nudge the telescope beyond the limits of where MaxIm DL thinks the object is).

2. If **Set INSTRUME from camera plug-in** is checked, MaxIm DL will obtain the name of the CCD camera from the camera plug-in when it takes an image, and automatically fill in the INSTRUME keyword. Some plug-ins cannot identify the camera model; in this case, the name of the plug-in is inserted instead. (Please note that the camera model or plug-in name is not shown in the **Keyword/Value** list box.)

After adding, editing, or deleting FITS keywords or changing the checkboxes, you must click **Apply** or **OK** to cause the change to take effect.

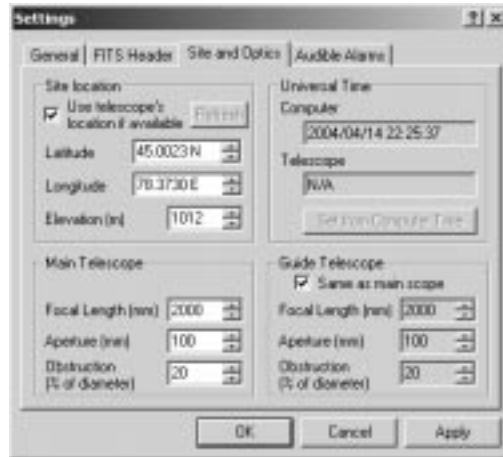
Site and Optics

The **Site and Optics** tab allows you to enter and/or verify information about your geographical coordinates, current time, and optical configuration that is automatically added to the FITS header when a new image is acquired from the camera. Site location and time are also used when calculating planet positions and the altitude and azimuth of an object.

Site location can be loaded from the telescope driver, if available, by turning on the **Use telescope's location if available** check box. (If you modify the telescope location, for example by means of the hand controller, while MaxIm DL is connected to the telescope, you will have to click **Refresh** to cause the new coordinates to be read in again.) When **Use telescope's location** is selected and geographical coordinates are available from the telescope, the **Latitude**, **Longitude** and **Elevation (m)** edit boxes are set to read-only. Otherwise you can use them to enter your observatory's Latitude, Longitude, and Elevation (in meters) manually. The Latitude and Longitude fields work the same way as similar fields elsewhere in MaxIm DL: you can enter decimal degrees;

degrees and decimal minutes; or degrees, minutes, and decimal seconds. You can also adjust the individual degrees, minutes, and seconds fields by positioning the cursor on one and clicking the spin control (up/down) buttons.

MaxIm DL always labels a newly acquired image with the date/time from the computer clock. The **Computer** field shows the current time, allowing you to verify that your computer clock and time zone are set appropriately. Similarly, the **Telescope** field reports the time as reported from the telescope, if it is available.



Fields in the **Main Telescope** frame are used to specify the **Focal Length**, **Aperture**, and percentage **Obstruction** of the telescope (or other optical system) through which your imaging camera is looking. This information is added to the FITS Header of acquired images. If you are using a Barlow, focal reducer, or other optical device which changes the image scale of the instrument, you must adjust the Focal Length accordingly. For instance, if you have an 8" F/10 SCT with a nominal focal length of 2000mm, but you are using a focal reducer to operate at F/6.3, you would set **Focal Length (mm)** to 1260.

Fields in the **Guide Telescope** frame are used to specify the **Focal Length**, **Aperture**, and percentage **Obstruction** of the telescope (or other optical system) through which your guiding camera is looking. This information is added to the FITS Header of images acquired from the guider. In many cases, guiding is done with a pick-off mirror from the same optical system used for primary imaging, or with a dual-chip CCD camera head. In these cases, you can check **Same as main scope** to use exactly the **Main Telescope** settings with guider exposures.

After changing any control on this tab, you must click **Apply** or **OK** to cause the change to take effect.

Audible Alarms

The **Audible Alarms** tab is used to associate WAV files with various conditions and events. On the occurrence of an event, MaxIm DL will play the associated WAV file through your computer's sound card, alerting you that it has occurred. If you use a different sound for each event that you are concerned about, you can determine what has happened without even looking at the screen. Alarms need not always be used to report problems, either; by associating a brief, unobtrusive sound with events such as "Camera Exposure Completed" and "Guide Correction Started", you can set up a sort of "MaxIm heartbeat" that assures you everything is working normally.



A particular condition is either associated with a sound file or it is not. In the first case, it appears in the **Condition** column of the list control; in the second, it appears in the **Disabled Alarms** droplist.

To add a new alarm to the list control, select it from the droplist and click **Add**. A file selector box opens, permitting you to select the desired WAV file for this alarm. WAV files can be in any directory, and need not all be in the same place. Pick the sound you want, and click **OK** to return to the **Audible Alarms** tab.

New alarms are always added at the end of the list, and the position of an alarm in the list indicates its priority relative to the others. Higher priority alarms will preempt lower priority ones, but not vice-versa. Also, "one-shot" alarms of lower priority do not resume sounding on completion of a higher priority one which interrupted it. You can move an alarm up and down in the list, thus changing its relative priority, by clicking on it to select it, then clicking the up or down arrows in the upper right corner of the list control.

When a new alarm is added to the list control, its **Repeat** checkbox is initially unchecked. This means that it is a "one-shot" alarm: when the associated condition

occurs, the sound will play through just once – again, provided a higher priority alarm is not already occurring, nor is triggered while the sound is playing. If you check **Repeat** for a particular alarm, the occurrence of that condition will cause the sound to play repeatedly until you click the **Mute** button. (For your convenience, the **Settings** dialog automatically opens to the **Audible Alarms** tab when a repeating alarm is triggered.) Unlike one-shot alarms, unacknowledged repeating alarms are restarted when a higher-priority alarm finishes sounding.

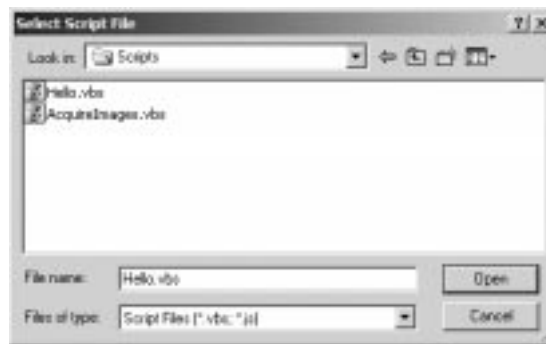
To delete an alarm and return it to the **Disabled Alarms** droplist, select it by clicking on it in the list control, then click on the red "X" icon near the upper right of the list control.

To change the sound associated with an alarm without deleting and reentering it, select it in the list control, then click once on the filename. The file selector box will open to the directory containing the WAV file currently associated with the alarm. You can pick another file, navigate to another directory and pick a file, or click **Cancel** to leave the associated sound file unchanged.

After changing alarms in any way, you must click **Apply** or **OK** to cause the change to take effect.

Run Script

This command allows you to start a VBScript or JScript running. Scripts can be set up to perform just about any image processing or exposure function via MaxIm DL's COM Automation interface (also known as ActiveX).



COM Automation/ActiveX is an industry-standard method for different programs to communicate with each other. MaxIm DL's COM interface conforms to the ASCOM standard (<http://ascom-standards.org>). Complete documentation of MaxIm DL's objects, properties, and methods is provided in the on-line help.

The **Select Script File** dialog allows you to browse your hard disk or network to locate a

VBScript or JScript file. Open the file to start the script running. The Windows CScript command processor is used to run the script, and a window appears showing the progress of the script execution.

Scripting is built into all versions of Windows 98, Windows ME, Windows NT 4.0, Windows 2000, and Windows XP and higher.

Scripting can also be accessed from other scripting and programming languages, including Java, Perl, Visual Basic, Visual C++, etc.

Most Recently Used File List

The **File** menu includes a list of recently used files. Selecting one of these files will open it if the file extension is recognized and previous settings are correct for RAW files.

If MaxIm DL cannot recognize the file extension, it will initiate the **File Open** dialog with the file path already entered. This allows the user to select format options such as RAW file pixel format and aspect ratio interpolation.

Exit

The Exit command causes MaxIm DL to shut down. All open image buffers will be closed. The user will be prompted to save any modified images that have not already been saved to file. There are several other standard Windows methods to close the application, such as clicking the close button on the right side of the title bar.

If MaxIm CCD is active (if a link has been established or attempted to be established with a camera, autoguider, or filter wheel), you will be asked to confirm before shutting down MaxIm DL. You will also be asked for confirmation if there are any unsaved files, or if any other applications or scripts are currently accessing MaxIm DL.

Edit Menu

Undo

The **Undo** command reverses the last processing operation. After selecting Undo, the results from the last processing operation can be restored using the **Redo** command.

Redo

The **Redo** command restores the processing operation previously canceled by the **Undo** command.

Copy

The **Copy** command copies the currently selected image to the clipboard. The copied image will have a color depth of 8 bits, and will display exactly as shown on the screen; i.e., the current screen stretch will be used in rendering the image.

CTRL-C may be used to copy text from windows and dialog boxes.

Paste

The **Paste** command copies an image from the clipboard into MaxIm DL. The image on the clipboard must be in a compatible bitmap format.

CTRL-V may be used to copy text into dialog box edit fields.

Crop

The **Crop** command can be used to reduce the size of the image. The desired area can be selected using the **mouse** by **pressing and holding the left mouse button** while **dragging** across the image. The resulting crop rectangle can be resized by grabbing the corners with the mouse, or moved by grabbing a side.



Alternatively, you can enter new values, in pixels, for **Width**, **Height**, **X Offset**, and **Y Offset**. To see the area selected in the image window, click **Update**. When **Update** is clicked, the values are checked, and if they exceed the image dimensions they will be automatically readjusted. Click **OK** to crop the image.

The **Reset** button will set the boundary to include the entire image.

Mosaic

The **Mosaic** command allows you to combine a set of images together into a single, large, seamless image. **Mosaic** does not enlarge or reduce the individual contributing images, so they must all be at the same scale.

Before running the **Mosaic** command, you should normally open all the images you intend to

combine. You may also want to adjust the screen stretch of one of them for optimum visibility of faint stars, nebulosity, etc., then use **Equalize Screen Stretch** in the **View** menu to make all images uniform in appearance. Then **create a blank image** buffer using the **File** menu **New** command. Be sure to create a **monochrome** image or **color** image as appropriate. The new image buffer must be large enough to include the entire mosaic. It can be cropped later if necessary.



Once you have created your blank image, run the **Mosaic** command. A small toolbox will appear in the top left corner of the MaxIm DL window. Select your first image (referred to as a "tile" of the mosaic) using the **list** at the top of the toolbox and click **Place**. The selected image will appear in the mosaic image. **Click on the image, hold down the button, and drag** the image to a suitable location in the mosaic buffer. When you are happy with the position of the image, click the **Blend** button to lock it in place.

Next, select a different image using the **list** at the top of the toolbox, and click the **Place** button again. (Images you have already used in this mosaic still appear in the list, but the **Place** button is disabled.) The second image will now appear in the Mosaic image buffer. **Drag it** around using the **left mouse button**. Areas which overlap with previously-blended images will appear translucent.

Now adjust the positioning of the newly-placed image until its features match up with those previously-placed. Besides mouse-dragging, several fine adjustment features are available to control the registration of the new image. Immediately after placing a new tile, or whenever the mosaic image has the focus, the four arrow keys will move the new tile left, right, up, or down by the number of pixels indicated by the **XY Step** control. If you press and hold the **Ctrl** key, the left and right arrow keys rotate the new tile by the number of degrees shown by the **Angle Step**; **Ctrl** plus **Home** returns the tile to the original orientation (0°). The status line at the bottom of the MaxIm DL window displays a hint about how to use keystrokes for fine positioning, plus the current tile center coordinate (in the frame of the mosaic image buffer) or, if **Ctrl** is pressed, its

rotation angle.

Note that after clicking on the **Mosaic** toolbox to enter or adjust **XY Step** or **Angle Step**, the mosaic window has lost the focus and arrow keystrokes are not processed. Simply click on the title bar of the mosaic image or its document tab to restore focus to it and reenable use of the arrow keys.

You can use the **Snap** button to automatically fine tune tile placement provided there are enough stars in the region of overlap between the current tile and previously blended ones, . Drag the tile to the approximate position, preferably in such a way that you can see a pattern of stars in the floating tile and the same pattern (perhaps at a different angle) in the blended data behind it. Click **Snap**. The tile should jump to the correct position. If it did not, either the initial placement was too far off, or the star patterns in the area of intersection were insufficient or ambiguous.

When mosaicing images taken under different conditions, e.g., with different exposure times or sky brightness levels, you may need to adjust the background level of a loose tile as you blend it. Three **Background Equalization** modes are available from the drop list. **Auto** calculates the background levels of pre-existing data and the new tile within the area of overlap, and adds their difference to the new tile as it is blended. This difference is automatically displayed in the **Bgd Offset** edit field. In **Manual** equalization mode, you must set **Bgd Offset** to the amount to add when blending the tile. You can initialize this to the background offset which **Auto** would apply by **right-clicking** on the mosaic document within the confines of the newly-placed tile and selecting **Compute Equalization** from the head of the resulting **context menu**. Equalization mode **None** does not adjust the tile data for differences in background during blending.

If the images were taken under widely varying conditions, it may be necessary to balance the backgrounds and dynamic range (gain) of each individually prior to building a mosaic. This requires measuring the levels of the background and the brightest stars in the overlapping areas using the **Information** window. Then use **Pixel Math** to add/subtract values to make the backgrounds equal and scale the results to the same dynamic range. This is rarely necessary if all images were taken with the same camera and exposure time.

Since the effect of equalization is seen only after clicking the **Blend** button to lock the new tile into place, it is important to be able to undo a blend operation. Simply click **Unblend** and the tile becomes loose again; you can change its equalization and/or position and blend it again, or you can **Remove** it altogether. (**Remove** is the opposite of **Place**, just as **Unblend** is the opposite of **Blend**.) Tiles can be unblended in any order; you are not restricted to unblending the most recent one.

Sometimes you need to know exactly where a particular tile was placed in the mosaic. If

Frame Active Tile is checked, the tile currently selected in the **list** is outlined on the mosaic image with a blue rectangle. This applies to both placed and blended tiles.

To reduce the appearance of seams in the image, a blending process is applied. At each pixel in the area of overlap between two or more tiles, **Mosaic** calculates a weighted sum of the corresponding pixels in the contributing images. The weights given to a pixel depends on its distances from the nearest edge of each contributing tile. This method gives good results when tile background equalization has been performed correctly, and requires no manual adjustments.

You do not have to start **Mosaic** with a completely black destination image; that is, you can add tiles to a mosaic that was partially created previously. In this case, the **Mosaic** command no longer knows the positions (edges) of the tiles that were blended in the earlier session, nor has access to their pixel data. Because of this, it cannot directly apply the weighted sum technique to combine the old and new data. Instead it approximates the blending process by setting the weight for every preexisting data pixel equal to its distance D from the nearest zero (non-data) pixel, up to the limit set by the **Blend Area** control. (The limit exists because it is very time-consuming to compute these weights for large values of D , and because limiting them has little visible effect on the image as long as the background is properly equalized.) **Blend Area** is not strictly a "feathering distance" because background pixels further than this from the "edge" can still be combined with data from tiles in a weighted sum; it is just that their weights cease to drop off with distance. **Blend Area** values of 20 to 30 are typically quite adequate. It has not effect at all if **Mosaic** is started on an "empty canvas".

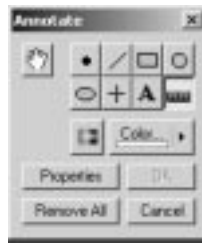
Once you have placed and blended all of the images, click the **Close** button. If the image buffer extends significantly beyond the tile data in any direction and you do not plan to add more tiles later, you may wish to use the **Crop** command to eliminate the unneeded areas.

Duplicate

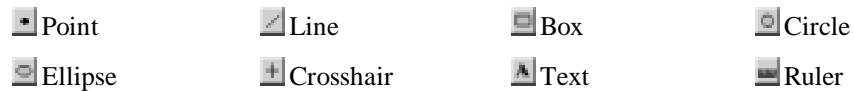
The **Duplicate** command will cause a second copy of the selected image to be created. All image parameters will be identical, except that no file will be associated with the new image.


Annotate


Images can be annotated with Lines, Points, Boxes, Circles, Ellipses, Crosshairs, Text, and Rulers. Select the appropriate type of annotation, and draw on the image using the mouse.

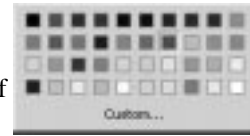


Select the annotation's shape by clicking one of the eight push buttons. The available shapes are Line, Point, Circle, Ellipse, Crosshair, Text and Ruler. The shape associated with each push button is given below:




If the image is monochrome, then the **Colorize** button  will be enabled. Clicking this button will transform the current image buffer from a monochrome image to a color image. The resulting color image will appear the same as the monochrome image, with all three color channels set the same values as the input image. Once the image is changed to color the button is disabled.

The **Color** button  is enabled for both monochrome and color images. Clicking it displays a color palette that allows you to select the color of the next shape to be placed into the image. If the image is monochrome, the palette contains a series of shades of grey; if it is color, the palette contains a selection of colors. The **Custom...** selection is only available for color images. Clicking it will display a standard Windows color dialog that allows you to specify the exact red, green and blue values for the color.



If you select **Text**, clicking on the image will automatically bring up the **Shape Properties** dialog box. You can then enter the **Text Caption** and click OK.

The properties for new annotations can be set up using **Properties**. The features available depend on the current drawing mode.


You can edit an individual annotation by **right-clicking** on it and selecting **Properties**, or delete it by selecting **Remove** on the right-click menu. **Click and drag** on the endpoints of lines or corners of boxes to resize them; **click and drag** elsewhere on the annotation to move them. You may wish to select the **hand tool**  first; while moving and resizing annotations can be done with any of the normal annotation-drawing tools active, selecting the hand prevents inadvertently adding an unwanted new annotation.

You can remove all annotations by clicking **Remove All**. Clicking **OK** makes the annotations permanent: they become part of the image and can no longer be edited.

(They can be still be removed with **Undo** until another processing command modifies the image further.) If you click **Cancel**, you will be asked whether to make the annotations permanent or not.



The Shape Properties dialog box allows you to select the **Line Width**, **Text Caption** for text annotations and rulers, the **Font** and **Font size** for text annotations and rulers, and the **Ruler Properties**.

To add a new ruler, click the **arrow** button  and select **Add**. This brings up the **Ruler Properties** dialog box. You can set the **Ruler Name**, which will appear in the drop list. You also need to set a **Caption**, which can be different from the name, a **Length (pixels)**, and the number of **Divisions (tics)** on the ruler.



To delete a ruler, select it with the drop list, click the **arrow** button, and select **Delete**. To edit an existing ruler, select it with the drop list, click the **arrow** button, and select **Edit**.

Flip

The **Flip** command reverses the image top-to-bottom.

Mirror

The **Mirror** command reverses the image left-to-right.

Rotate Left

The **Rotate Left** command rotates the image 90 degrees to the left (counter-clockwise).

Rotate Right

The **Rotate Right** command rotates the image 90 degrees to the right (clockwise).

Rotate 180°

The **Rotate 180°** command rotates the image 180 degrees. This is exactly equivalent to two Rotate Left commands, two Rotate Right commands, or a Flip followed by a Mirror.

Rotate

The **Rotate** command allows you to rotate an image by an arbitrary **Angle** clockwise (**CW**) or counter-clockwise (**CCW**). The image must be resampled unless the angle is a multiple of 90 degrees; this can either be done as a bilinear resample or a **Bicubic** resample. Bicubic takes more time but can produce a sharper final image.



Edit Pixels

The **Edit Pixels** command can be used to make cosmetic changes to an image. Unlike most paint programs, however, the actual value painted depends on the screen stretch (as set by the **Screen Stretch** window). This allows for editing any image, not just those restricted to 8-bit values. It does, however, have the side effect of making the paint value dependent on the stretch settings.



The paint color may be determined in four different ways. A monochrome value may be entered manually by typing a value into the **Intensity** field and pressing **Enter** or clicking Update. For **Color** images **red**, **green** and **blue** values may be entered in the same fashion. Alternatively a value may be picked up from the image using the **Pick Up Color** mode. When selected, the user clicks on a pixel whose value is to be used for painting. A color may also be selected from a palette using the **Choose Color** button.

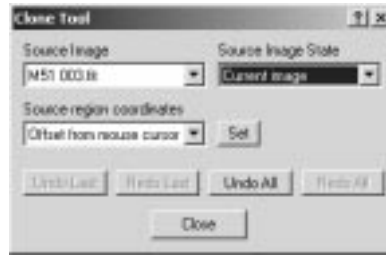
Undo is provided for both the **last** paint action and **all** paint actions. Similar **Redo** functions are also provided.

Clone Tool

The **Clone Tool** lets you alter images by copying circular regions defined by the aperture of the mouse rings cursor from one location to another. You can do this either within an image or copy areas from different images. It can be used to eliminate localized defects such as satellite tracks by replacing them with sky background. Another important application is the removal of the "donuts" that can occur around bright stars embedded in nebulosity processed by the **Deconvolution** command . In this case the image is often esthetically more pleasing if the original region around these stars is restored.

As with most MaxIm DL commands, activate the image you want to modify before starting the **Clone Tool**. This image will be selected as the default **Source Image** from which regions are copied, but you can pick any other open image which has the same color type as the destination. In addition you can set the **Source Image State** to specify

whether you want to copy from image in its present condition ("Current Image") or that prior to the most recently executed command that changed it ("Pre-Command Name"). The previous state is subject to both availability of the undo buffer and its color compatibility with the destination image.



Set the **Source region coordinates** dropdown to indicate the the relation between the source and destination coordinates for the region to be cloned. "Same as destination" means that when you click on the destination image, pixels will be copied from the source image in the region at exactly the same X,Y location as the mouse cursor. (If the source image is smaller than the destination and the mouse coordinates would be off the source image, no action occurs. You can copy continuously by dragging the mouse while holding down the left button. To avoid skipping regions, be careful not to drag the mouse too quickly.

The second **Source region coordinates** option, "Offset from mouse cursor", enables copying from one set of coordinates to a different one. After selecting this mode, the **Set** button is enabled and automatically pushed to remind you that you need to set a source location. (This also happens whenever you change to a different **Source Image** in this mode.) Click the mouse on the location in the source image that you want to copy from; an orange circle the size of the aperture is drawn there and the **Set** button pops up. Now change back to the destination image and click at the location that you want the data copied to. Once the spatial relationship between source and destination regions is established, the orange source region marker tracks mouse cursor movements in the destination window, showing you where regions will be copied from at all times. Drag the mouse to copy regions larger than a single aperture; as before. To change the relationship between source and destination regions, click the **Set** button again and pick a new starting point. Alternatively, right-click at the starting point and pick the command-specific **Set source region** item at the head of the **context menu**.

The third **Source region coordinates** option, "None (copy disabled)", prevents image cloning. It is provided in case you need to inspect image statistics in the **Information Window**, particularly when using Area mode which requires you to click and drag out the rectangle of interest.

Whichever cloning mode is in effect, the size of the region copied is that of the aperture

(the innermost circle of the mouse cursor). You can change this in the usual way, that is, by right-clicking the mouse and picking an aperture adjustment from the context menu. The orange source region indicator is resized simultaneously, if shown.

Undo and **Redo** buttons are provided both for **all** copy operations and the **last** copy operation. Each mouse-click or drag on the destination image constitutes an operation. Clicks on all other images are ignored, except when setting the source point for offset mode.

Bin 2x2

The **Bin 2x2** command decreases the size of an image by a factor of two in each dimension. It does this by subdividing the original image into two-by-two blocks of pixels and computing the average of each block of four pixels; the average becomes a single pixel in the new image.

This operation corresponds to two-by-two binning in a CCD camera, except that a camera integrates (adds) the charge from each contributing pixel instead of averaging it. To achieve this result, use **Pixel Math** afterwards to scale the image up by a factor of four.

If each image dimension is not an exact multiple of two, the row and/or column of the input image are ignored.

Binning is very fast, but a slightly smoother result can be obtained using the Half Size command

Bin 3x3

The **Bin 3x3** command decreases the size of an image by a factor of three in each dimension. It does this by subdividing the original image into three-by-three blocks of pixels and computing the average of each block of nine pixels; the average becomes a single pixel in the new image.

This operation corresponds to three-by-three binning in a CCD camera, except that a camera integrates (adds) the charge from each contributing pixel instead of averaging it. To achieve this result, use **Pixel Math** afterwards to scale the image up by a factor of nine.

If each image dimension is not an exact multiple of three, the last one or two rows and/or columns of the input image are ignored.

Deinterlace

The **Deinterlace** command is intended for use on images captured from an interlaced video camera. It separates the image into two frames, one consisting of the even-

numbered rows and the other of the odd-numbered ones. The rows that were omitted from each image (that is, odd-numbered rows from the even image, and even-numbered rows from the odd one) are replaced by interpolating vertically from the adjoining rows. In cases where the first or last line has to be replaced, the second or second last line is simply replicated.


On completion of the command, the original image window contains the even frame, and a new image window is created to contain the odd frame. Normally the titles of both windows are set to the original image name with the words "Even" and "Odd" suffixed. If, however, the image name already contains "Even" or "Odd", the original is left unchanged and the new window is simply called "Copy of ...".


View Menu


Zoom command

The Zoom level can be controlled in several different ways:

- View menu Zoom command – invokes Zoom dialog
- View Menu Zoom In command – zooms in 2 X
- View Menu Zoom Out command – zooms out 2 X
- Right-click menu – zooms around mouse cursor
- Toolbar buttons, described below

The **Zoom In** command can be invoked by the  toolbar button or the **PgUp** key.

The **Zoom Out** command can be invoked by the  toolbar button or the **PgDn** key.

 The toolbar zoom combo box can apply arbitrary zoom factors from 6.25% to 1600%. You can select a predefined zoom level, or type in your own value.



The **Zoom** dialog allows direct selection of several different zoom levels, as well as entering a **Custom** zoom level in the same manner as the toolbar combo box.

Note that the zoom level automatically “rounds” itself off to an even binary number.

Full Screen

The **Full Screen** command temporarily suppresses the display of all menus, status bar, toolbar, windows, and other applications. The selected image is scaled to the maximum size which will fit within the screen boundaries. Any areas not covered by the image will be black. The **mouse cursor** will also **disappear** after a couple of seconds.

This command is useful for photographing an image from the screen. Good photographs can be obtained by using a macro lens at f/4.5 with ISO 100 film and a 1 second exposure with the room lights off. This will suppress the raster scanning of the video monitor. A tripod and cable release or timer are recommended to reduce vibration and motion. Be sure to cover up any indicator lights on the monitor.


Since photographic film tends to increase contrast, the video monitor’s contrast and brightness controls need to be adjusted to compensate. Reduce the image contrast so that the brightest parts of the image are less intense than normal, and adjust the brightness level to make the background appear fairly bright. The resulting image will not look very good on the monitor, but it will be represented correctly on the film.

To **exit** Full Screen mode and restore the normal display, **click the mouse** or press the **ESC** key.

CCD Control Window


This function is available only if the **MaxIm CCD** option is purchased.

This command toggles the optional **MaxIm CCD** camera control window on and off. See **MaxIm CCD Camera Control Window** for information on operating CCD cameras.

This command can be also activated through the toolbar  icon.

Telescope Control Window


This command toggles the optional **MaxIm CCD** telescope control window on and off. See **Telescope Control Window** below for complete information.

This command can be also activated through the toolbar  icon.

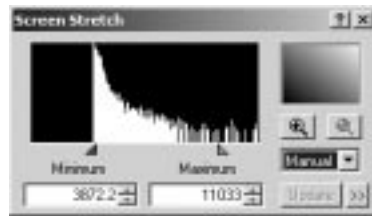
Screen Stretch Window

The **Screen Stretch** window controls the brightness and contrast of the displayed image without affecting the contents of the stored image. There are several **automatic** stretch settings. There are two graphical methods to manually control screen stretch: **Quick**

Stretch and **Histogram**. You can also set the stretch settings using the **keyboard**. With a few exceptions, the **Screen Stretch** window is available even while a processing dialog box is active.

Display of the **Screen Stretch** window is controlled by the  button on the **toolbar**, or by the **Screen Stretch Window** command in the **View** menu. The window can remain open as a **floating toolbox** without interfering with other commands.

You can stretch image buffers, or the **Preview Image** that appears in most processing dialog boxes. **Click** anywhere on an **image** to select it, or **click** anywhere on the **dialog box** to select the **Preview Image**. (Note: when the **Preview** button is down, the preview image has a separate stretch setting; when it is up, the preview image and main image buffer share the same settings). A **Full Screen Preview** is stretched exactly the same way as the original image in whose window it appears. **Full Screen Preview** stretch settings are lost as soon as the preview is dismissed or regenerated, typically when you change a control in the processing dialog.



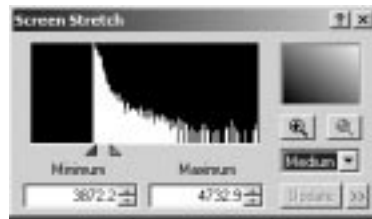
Although the image data pixel values are unaffected by changes to **Screen Stretch** settings, you should be aware that the stretch mode and limits are saved to FITS files as part of the header, in the keys **CSTRETCH**, **CBLACK**, and **CWHITE**. When the file is loaded into MaxIm DL later, the **Screen Stretch** window will be reset to the state which was in effect when the file was saved, giving the same display appearance.

Once you have selected an image, you can use one of the following methods to stretch it.

Manual Stretch

The **Minimum** field sets the brightness level in the image that corresponds to **black** on the display. The **Maximum** field sets the brightness level in the image that corresponds to **white** (full brightness) on the screen.

Modifying the values in the **Minimum** and **Maximum** fields directly will only change the stretch when you press the **Enter** key or click the **Update** button. It will force the **stretch mode** combo box to "**Manual**".

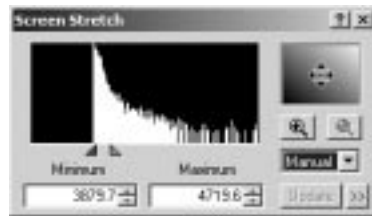


You may have encountered the terms "**background**" and "**range**". **Background** is equivalent to as **Minimum**, and **range** is equal **Maximum** minus **Minimum**.

Automatic Stretch

Automatic stretch is the default behavior for a new image. You set the stretch mode using the drop-down stretch mode combo box (shown set to Medium above). The available settings are:

- Low – low contrast setting with dark background
- Medium – a medium contrast setting with dark background
- High – high contrast setting with dark background
- Moon – even higher contrast setting with dark background, slightly saturated pixels
- Planet – highest contrast but adjusted so that no feature in the image saturates
- Max Val – adjust so that the brightest pixel is set to the maximum brightness, and the zero level is set to black.
- Manual – user adjustments either using the mouse, histogram, or Minimum and Maximum field.



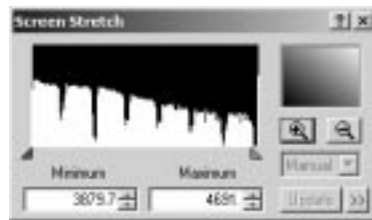
Recall that the **stretch mode** can also be set through the image **context menu**, which appears when right-clicking on an image.

Quick Stretch

The **Quick Stretch** box is located in the upper right corner of the Screen Stretch window. To activate quick stretch, first select the image you wish to adjust by clicking on it with the mouse. Point the mouse cursor at the Quick Stretch box and **press and hold** the **left mouse button**; it will change into a four-way arrow cursor (shown above). **Drag** the mouse to control the stretch as follows:

- Up – increase brightness
- Down – decrease brightness
- Right – increase contrast
- Left – decrease contrast

Monochrome images update in "real time" as the adjustments are made. If you are making very large adjustments you should release the cursor occasionally to allow the software to re-optimize the palette. Color images may update more slowly depending on their size.



Quick stretch can also be performed directly on image windows and Preview windows. **Point** the **mouse** cursor at the image you wish to adjust. Hold down the **Shift** key, then press and hold the **left mouse button**. **Drag** the mouse to control the stretch. This allows you to adjust the stretch without using the **Screen Stretch** dialog.

Histogram

The **histogram** is a graph which shows how many pixels are in the image in different brightness ranges. It is the large box shown on the upper left of the window.



The zero point (black) is at the left side, and the brightest pixel represented is at the right side. The highest point on the graph corresponds to the most common brightness level in the image. (Note that the vertical scale is logarithmic.)

The **histogram** allows you to conveniently adjust the stretch for any displayed image. The **red caret** controls the black level (**Minimum**). Moving the **red caret leftwards** makes the **background** of the image **darker**. The **green caret** controls the white level (**Maximum**). Moving the **green caret leftward increases** the image **contrast**, but tends

to saturate bright parts of the image. Contrast is highest when the two carets are close together. If the **carets** are switched, the image will appear **reversed**, like a photographic negative. The carets are affected by the other controls in the window, but they can also be moved with the mouse.

Both **carets** can be moved together by holding the **Shift** key down while using the **mouse** to move the carets. This allows you to keep the contrast constant but change the brightness. Similarly, the carets can be moved in **opposite directions** by holding the **CTRL** key down.



When using manual stretch, you can also **zoom in** on the histogram. Adjust the **green** and **red carets**, then **click** the  button. The histogram will be **zoomed in** so that the **carets are moved to the edge**. To **zoom out**, click the  button.

Automatic Stretch Setup


Several of the automatic stretch settings can be adjusted. The Low, Medium, and High modes can be set up; Manual, Moon, and Planet cannot.

To change a setting, select the appropriate stretch mode and click the >> button. This expands the dialog box to reveal the auto-stretch settings. Click << to hide this information.

The **Minimum Percentile** and **Maximum Percentile** can be adjusted. These affect the corresponding **Minimum** and **Maximum** pixel values. To adjust, click either the spin control, or type in new values and click **Set**. You can also restore the default setting by clicking **Default**.

To understand the percentile settings, if you set **Minimum Percentile** to 10%, then the stretch will be adjusted so that 10% of the pixel values are below the red caret. (This convention is for ease of use – the actual calculation is performed using a more sophisticated algorithm than simple percentiles.)

Information Window

The Information window displays a variety of information on selected areas of the image. The window can be switched on and off using the **Information Window** command on the **View** menu, or by using the  button on the **Toolbar**. The window can remain open as a floating toolbox without interfering with other commands.

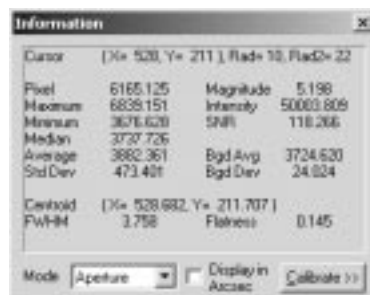
The **Information** window has four modes of operation: **Aperture**, **Region**, **Area**, and **Astrometric**. There is also a **Magnitude** display that can be calibrated to show accurate stellar magnitudes. Except in **Area** mode, the mouse cursor will change to a crosshair and "bullseye" when the **Information** window is active and the mouse is over the selected image or preview. The sizes of the various elements of the circular cursor can be changed using the mouse with the **right-click** menu.

To lock the cursor at a specific position and freeze the information display, **double-click** on the **image**. When locked, the circular cursor can be moved using the **arrow keys**. You can then copy text from the status area of the **Information** window to the clipboard using the **mouse** and **CTRL-C** (or **right-click** the mouse in the status area and select **Copy** from the resulting context menu). To restore normal operation, **click** the mouse again on the image.

Aperture

Aperture mode shows statistics on the area under the circular cursor as the mouse is moved around the image. The current **Cursor** position and inner and outer radii are shown at the top. The **Pixel** value directly under the cursor is also shown.

The following measurements are made only within the aperture (inner circle): the **Maximum**, **Minimum**, **Median**, **Average**, and standard deviation (**Std Dev**).



The following measurements are made inside the aperture after first subtracting the average value in the annulus (between the middle and outer circles): stellar **Magnitude** (as calibrated using the **Calibrate** button), **Intensity** (sum of all pixels within aperture less background), and signal-to-noise ratio (**SNR**). SNR is calculated as the ratio of

intensity to the standard deviation of the background times the square root of the number of pixels. When measuring a star, a SNR of 3 is usually considered the minimum necessary for detection.

The following measurements are made using only the background annulus (between the middle and outer circles): background average (**Bgd Avg**) and background standard deviation (**Bgd Dev**).

The **Centroid** is calculated within the inner aperture. It is an indication of the “center of gravity” of the star image, and is calculated to a fraction of a pixel. The full-width half maximum or **FWHM** is also calculated. This is a measurement of the diameter of the star image at ½ of the maximum intensity. It is calculated by fitting a Gaussian shape to the star. The **Flatness** is an indication of how out-of-round the star image is. A flatness of zero is perfectly circular, while a flatness of 0.1 indicates that the star is longer in one dimension than the other by 10%.

When **Display in Arcsec** is checked, the **FWHM** is displayed in arc-seconds instead of pixels. The **Calibrate** section below describes how to set up the arc-seconds display.

Please note that the **Photometry** function can provide more accurate **Magnitude** measurements than the Information window can. The Photometry function performs more complex and accurate background subtraction computations, and uses partial pixels. In the interest of speed the Information window performs a simpler calculation.

Region

Region mode is a simpler version of the Aperture mode, which provides separate information for the **Red**, **Green**, and **Blue** planes of a color image.

Cursor	[X= 526, Y= 173], Rad= 10, PixD= 22		
	Red	Green	Blue
Pixel	3713.964	3709.695	3735.638
Maximum	3781.803	3746.718	3760.179
Minimum	3673.075	3685.051	3653.082
Median	3710.247	3715.053	3717.791
Average	3712.129	3712.667	3711.368
Std Dev	18.020	15.639	26.952
Centroid X	520.594	526.000	526.000
Centroid Y	171.525	173.000	173.000
FWHM	12.834		
Flatness	0.152		

Mode: **Region** Display in Arcsec **Calibrate >>**

Pixel is the value directly under the cursor center. All other measurements are calculated within the central aperture. This includes **Minimum**, **Maximum**, **Median**, **Average**, **Std Dev** (standard deviation), **Centroid X**, **Centroid Y**, full-width half maximum (**FWHM**), and **Flatness**. For a description of these values please see the previous section discussing the Aperture mode.

Area

This mode displays statistics for a rectangular region of the image. The default is to show data for the entire image, but an area can be selected by **holding the left mouse button** down while **dragging** on the image. This will draw a rectangle on the image; the statistics data now applies to the region inside the rectangle.

Note that the rectangular region can be moved and resized with the mouse. Grab it with the mouse in the middle of a side to reposition it, or at a corner to resize it.



The displayed values include **Maximum** and **Minimum** pixel values, **Average** pixel value, and standard deviation (**Std Dev**). The **Diagonal size** of the box in pixels is shown, which allows you to measure distances on the frame, and the total **Number of Pixels** included in the box is also displayed.

When **Display in Arcsec** is checked, the **Diagonal Size** is displayed in arc-seconds instead of pixels. The **Calibrate** section below describes how to set up the arc-seconds display.

Astrometric

The Astrometric mode uses the included PinPoint LE (light edition) Engine, or the full edition if installed. This powerful analysis tool can be used for extremely precise measurements of star positions in the sky. Astrometric analysis works by identifying the stars in the image and matching them against an accurate catalog of star positions. The software is then able to calculate accurate positions for every object in the image. The full edition of PinPoint, available from DC-3 Dreams, provides additional capabilities, and has tools for discovering asteroids and supernovae, generating MPC reports, and more. For more information visit the DC-3 Dreams web site at <http://pinpoint.dc3.com>.

To display information, the image needs to have World Coordinate System (WCS) entries in the FITS header. These are added automatically during image analysis by PinPoint, but they can be obtained from other software as well.

The Information window shows the following information in **Astrometric** mode:

Cursor X, Y pixel coordinates and annulus radii, along with the Right Ascension and Declination of the pixel under the mouse cursor. **Centroid** of the star under the circular cursor in both X, Y coordinates and RA, Dec; and the magnitude of the star within the aperture, as measured by MaxIm DL using the current calibration (see below).



For users with the **full version** of PinPoint, extra information is available after you perform a PinPoint analysis on an open image. **Image Star** provides the position and magnitude of the star within the aperture (that closest to the center is used if there is more than one) as determined by PinPoint. **Catalog Star** provides information on stars that were identified in the catalog used during analysis. This includes the identity of the star, the position, and magnitude as provided by the catalog. The table of the catalog and image stars detected in the image, which is used to display **Image Star** and **Catalog Star** information as you probe the image with the circular cursor, is not recorded when an image is saved to disk. This information is therefore not available when an image is loaded unless you re-solve the image using **PinPoint Astrometry**.

Calibrate

Various displays can be calibrated by clicking the Calibrate button.

Magnitude Calibration sets up the **Magnitude** display on the Information window. You need to enter the **Intensity** and known **Magnitude** of a star on the image, as well as the **Exposure** time used for the image. Once these values are known, the magnitude calibration will be accurate for any image taken with the same camera (note: some cameras have multiple modes which may affect this).

Although the magnitude for the star must be obtained from other sources, **Intensity** can be entered easily using the mouse. Click **Extract from image** and point the mouse cursor at a star in the image for which the magnitude is known. Adjust the aperture to include the entire star image. Click the mouse, and the intensity value for the star will be measured and filled in.

Click the **Set from FITS** button to set the Exposure. If the FITS header for the image includes exposure information (which it will if it was taken with MaxIm CCD), then

this information will be automatically entered. The exposure information is used to scale measured intensities so that images with different exposure lengths can be compared.



Please note that the **Photometry** function can provide more accurate measurements than the Information window can. The Photometry function performs more complex and accurate background subtraction computations, and uses partial pixels. In the interest of speed the Information window performs a simpler calculation.

The **Spatial Calibration** function is used to convert from pixel units to arc-seconds. The two **Pixel Scale** values shown are in arc-seconds per pixel. If **FITS scale** is checked, they will be set automatically from the World Coordinate System (WCS) information recorded in the FITS header by PinPoint or other astrometric analysis tools. In the absence of WCS, pixel scale is automatically calculated from the camera pixel dimensions and telescope focal length if these are available. If neither type of information is present, the small status field to the right of the **FITS scale** check box shows "not available" and the most recent pixel scales (possibly from some other image) are reused.

The **Pixel Scale** values can also be set up using the **Set...** button. This brings up the **Pixel Scale Editor**.

If the pixel scale is already in the FITS header, just select **Pixel Scale** and click **Load from FITS**. Alternatively, you can also enter values manually in the **X** and **Y** fields in this mode. The scale is in arc-seconds per pixel.

Another method is to use the **Calculator** mode. Enter the **Pixel Size (microns)** and **Focal Length (mm)**, or click the **Load from FITS** button within the Calculator frame to

extract the values directly from the FITS header. Most cameras supported by the MaxIm CCD camera control window provide pixel dimensions automatically when an image is taken, while the telescope focal length can be specified on the Site and Optics tab of the Settings dialog. The required value can often be found in the manual for your telescope, or can be determined by multiplying the aperture by the f/ratio. Click **Calculate scale** to compute and display the pixel scale. Then click **OK** to close the window and return the values to the **Information Window**.



Zoom Window

Zoom Window is an inspection tool that allows you to examine “up close” any part of the image you choose without changing the zoom of the overall image. Simply point the **mouse** at the part of the image you wish to see.



FITS Header

The **FITS Header viewer/editor** can be used to inspect and modify standard and custom FITS header keywords.

FITS is the standard storage format for astronomical images. It includes a header containing various types of information. The header includes both mandatory and optional keywords, each of which has associated data. These keywords are used to store information about the image, such as exposure time, equipment used, object identification, etc.

When reading **SBIG** format files, header information from the file is also transferred to equivalent **FITS** keywords. This is for data retention purposes only, not for compatibility with other software. We strongly recommend the use of **FITS**, as it is the internationally recognized standard format for astronomical images.



The window is opened using the **View** menu **FITS Header** command. The window can remain open as a floating toolbox without interfering with other commands. You can select different images by **clicking** on them with the mouse. To close the window, click on the **Close** button or use the **View** menu **FITS Header** command.

View Mode

In the **View** mode, the FITS header is presented essentially as it appears in the file itself. The data in the View mode only updates when the file is written to disk; it will not include changes made with the **Edit** mode or other MaxIm DL functions until the file is saved.

Edit Mode

Switch between the **View** and **Edit** modes using the tabs at the top. In the **Edit** mode, the individual keywords can be modified by the user. Keywords can also be added or deleted.

The **table** at top includes a list of **keywords**, the **value** of the keyword, and for standard keywords a brief **description**. The three columns can be **resized** using the **mouse** by **dragging** the **vertical bars** in the title row. This allows you to view text that is longer than the assigned column width. **Scroll bars** allow you to move horizontally and vertically to view the entire table if necessary.

To **modify** a keyword, either **click** on it in the **Keyword** column, **select** it from the drop-down **Key Name** list, or **type** its name in the **Key Name** field directly. A value may then be entered in **Value**.



To add a keyword to the header, select it from the default values in the **Key Name** drop list, or create a new keyword by **typing** in a name. The keyword name must be alphanumeric and not exceed 8 characters in length. Keyword names may include letters, numbers, underscores and hyphens. Select a mode with the **Type** control; you can select an **integer** number, **real** number, a character **string**, or a **logical** format. When you have finished entering the data, click the **Set** button.

To **delete** a key, **click** on it under the **Keyword** column or using the **Key Name** drop list. **Click** the **Delete** key to remove it.

Note that you cannot remove or modify certain mandatory keywords (required by the FITS standard).

Command Sequence

The **Command Sequence** tool is used to record commands drawn from the MaxIm DL application menu into sequences, sometimes called "macros", and to edit them and play them back. For interactive commands, that is, those which invoke a modal dialog box to obtain control parameters, the complete set of values as they were at the time the command was recorded are all saved in the sequence. The same command can be used more than once in a single sequence, each time with different control parameters. Alternatively, command(s) can be marked as requiring user interaction; on playback, the sequence will open the command's dialog with the various controls preset to the recorded values, but will then pause and allow you to change settings. You can preview the operation as necessary in the usual way and even cancel the command dialog, but the

remainder of the sequence will continue normally.

Command sequences are perhaps most useful when you need to perform the same processing operations on a set of similar images. You record the sequence once by working through the processing steps on a single image, then play it back to process the others, either individually or in one or more groups. You can save sequences to disk for later use.


The principal advantages of sequences as compared to scripting is in ease of creation: no programming knowledge is required, and it is quick to set up a sequence for an *ad hoc* job. In addition, the sequence mechanism readily allows operator intervention for fine tuning the processing. Its main disadvantages are that it is slower to execute than a script and it is also less flexible because it provides no conditional structures such as ifs and loops. In addition, it can be difficult to ensure that MaxIm DL's focus goes to the desired document during window switching (**F6**, **Alt+F6**), creation (e.g. **New** and **Duplicate**), and deletion (**Close**). Although these operations can be recorded, care is advised.






The other thing you need to remember when using sequences is that each command is still treated individually by MaxIm DL. In particular, you cannot **Undo** the effect of the whole sequence, only the last command executed. For this reason, you should consider saving images before you process them with a sequence, and avoid recording **Save** and **Save All** operations in a sequence; this will permit you to get back to the original image if necessary. **Save As** is safer because it always pauses to allow you to specify the destination filename, but you are then responsible for avoiding overwriting valuable data.


The upper part of **Command Sequence** window contains a list of **Operations**, initially empty. There is a small toolbar at the upper right corner of the window, which used for


deleting or changing the order of steps in the sequence at the upper right. The lower part contains a status message area and seven buttons used for controlling recording, playback, and sequence management.

To start recording a script, click the Record button . The red circle "lights up" to a brighter color and the status line changes from "Idle" to "Recording". Now perform the desired commands. Only commands shown in the MaxIm DL application menu can be recorded; operations initiated using buttons on the CCD Control or other modeless tool windows named in the View menu are not. As each command is completed, its name is added to the end of the **Operations** list. (Commands are not added if you **Cancel** out of the command dialog.) To the right of the new command in the list, the **Manual** checkbox indicates the disposition of this command during playback; when checked, playback will pause to allow you to modify the command's settings. Some commands never interact with the user, or alternatively always require user intervention; for these, the checkbox is gray and the disposition cannot be changed. A few commands simply cannot be recorded; you are warned about this and asked if you want to execute the command anyway.


If you record an incorrect command by mistake, **select** it in the **Operations** list and click the Delete  button. This will not reverse any effect it had on the image, so you may need to **Undo** it as well; if so, don't forget to delete the Undo entry from the list too. You can reposition a recorded command in the list by selecting it and then clicking the Move Up  or Move Down  buttons. Sequence editing can also be performed after recording has been stopped.

Note that you cannot close the Command Sequence window while recording is in progress.

When you have completed the sequence, either click Record a second time, or click Stop . You can resume recording at any later time by clicking Record again; this does not erase previously recorded commands.

To play back a sequence on a single image, select that image by clicking on it or its tab (if shown), then click on the Play  button. The status line displays the name of the image being processed and playback starts at the first command in the sequence and normally proceeds automatically to the end. During playback, the command currently being executed is highlighted in the **Operations** list. When a **Manual** command is encountered, playback pauses with that command's dialog open and waits to allow you to modify then command settings, then resumes when you click **OK**. If you **Cancel** a command or if any other error occurs during processing, the sequencer displays a message asking if it should continue to execute the rest of the sequence; click **Yes** to continue, or **No** to abandon the sequence. You can also abort sequence playback by clicking the Stop button; it is not possible to resume an sequence from the point of interruption. (You could of course modify the sequence by deleting the commands

already processed.) Note that a few commands behave slightly differently when sequenced than when performed manually; for example, **Crop** ignores any drag rectangle present in the image in favor of the recorded rectangle position and dimensions.

To play back a sequence on a group of images, click the Play All  button. The sequencer displays a **Select Images** dialog listing all open images. This is a multiple-selection listbox; **click** to select a single image, **Control-click** to select additional images or deselect images already selected, and **Shift-click** to select the range extending from the previous **single-** or **control-click**. To select the entire list, **click** once on the first entry, scroll to the bottom if necessary, and then **shift-click** on the last entry. Click **OK** to start the playback. The first selected image is automatically brought to the front and the entire sequence performed on it; then the next selected image is processed, and so on. During multiple-image sequence playback the status line shows the number of the image within the queue and the total number of images being processed as well as the name of the current image.

To erase a sequence, click **Clear**. Typically you use this before recording a new sequence.

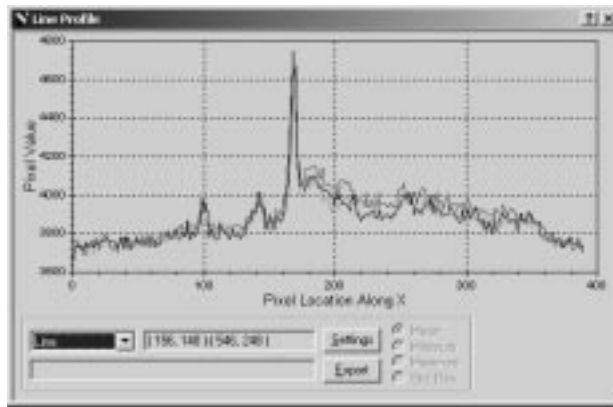
To save a sequence to disk for future use, click **Save...**, enter a filename in the **Select Command Sequence** dialog and click **OK**. Similarly, to load a sequence from disk, click **Load...** and pick the desired file. The file selector remembers the last directory you used for command sequence files, but you can navigate to another if desired.

Line Profile

The **Line Profile** window can display graphical data derived from an image. The window works as a floating window or “toolbox”. When it is open, all other program functions are available and you can switch between images just by clicking on them. Also, the line profile window can be **resized** by dragging the raised border with the mouse. Within limits, you can make the graph as large or as small as you wish.

Note: when using Line Profile in certain modes, *the usual box drawing functions of the mouse cursor are changed*. You may wish to turn off the Line Profile command when using other functions.

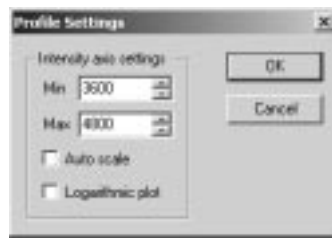
The region on the screen to be viewed can be selected using the mouse. **Point** at the start position then **press and hold** the **left mouse button**. **Drag** the mouse to the end position and **release** it (as noted below, some modes just require a single **click**). Depending on the mode, a line or rectangle will be displayed to show you the area that will be plotted. The coordinates of the region will be displayed on the dialog box (bottom, left of center).



If you point the **mouse** at the line graph, a **vertical cursor** will be displayed. The **brightness level** at that point in the graph will be displayed at the bottom of the dialog box (bottom, right of center), along with the corresponding image **coordinates**. A tic mark will also be shown on the image itself in the corresponding position.

Lines drawn on the image can be **moved** and **resized** using the cursor. Grab a corner of a box to resize it, or grab the end of a line to reorient it or change its length. You can also move the entire box or line by grabbing it with the mouse anywhere except on the ends or corners.

The **Settings** button allows you to set up the vertical plot axis. You can use **Auto Scale** (default), or enter in the **Min.** and **Max.** values to appear on the axis.



The Export button allows you to save a comma separated variable (CSV) file to disk. CSV files can be imported into other applications such as spreadsheets. Except as otherwise noted below, the exported file contains either two or four values per line for monochrome and color images respectively. The first value is always an integer and is the horizontal coordinate of the graph, "Pixel Location along X" [or Y]. The remaining value(s) give the value for the single monochrome or three color channels (red, green, and blue).

There are a number of modes of operation, as follows:

Line

This is the normal mode of operation. When the **mouse** cursor is **dragged** across the image, a line is drawn from the start to end point. The graph represents the pixel values along that line. The line can be moved and resized using the mouse.

Horizontal Line

In this mode, **clicking** anywhere on the image will select a horizontal line extending the full width of the image. Dragging the mouse will simply move the line up and down. As for Line mode, the graph represents the pixel values along that line.

Vertical Line

In this mode, **clicking** anywhere on the image will select a vertical line extending the full height of the image. Dragging the mouse will simply move the line left and right. As for Line mode, the graph represents the pixel values along that line.

Horizontal Box

When the **mouse** is **dragged** a **box** will be drawn on the image. The values inside the box will be **combined vertically** (column by column) and the results plotted for each column across the box horizontally. The box can be resized and dragged using the mouse.

The pixels can be combined using either **Mean** (average), **Minimum**, **Maximum**, or **Std. Dev.** (Standard Deviation).

Vertical Box

When the mouse is **dragged** a **box** will be drawn on the image. The values inside the box will be **combined horizontally** (row by row) and the results plotted for each row across the box vertically. The box can be resized and dragged using the mouse.

The pixels can be combined using either **Mean** (average), **Minimum**, **Maximum**, or **Std. Dev.** (Standard Deviation).

Area Plot

When operating in **Area Plot** mode, a 3-D representation of a portion of the image is displayed. A region must first be selected; nothing will be displayed until you select a rectangular region for display.

Exporting an Area Plot creates a file containing either three or five values per line, for monochrome and color images respectively. The first two values are always integer and are the X and Y coordinates of a pixel within the region of interest. The remaining

value(s) give the value for the single monochrome or three color channels (red, green, and blue). The data points are recorded left-to-right and top-to-bottom with the X axis changing fastest.

Night Vision

Selecting **Night Vision** toggles the night vision mode on and off. Night vision mode sets the screen display to **red**, which has less effect on dark-adapted eyes since the "rod" cells are not very sensitive to red light.

All menus, dialog boxes, etc., are switched to red. Monochrome images are displayed red, but **color images are displayed in their normal colors**. This allows the user to inspect a color image in night vision mode without switching the entire screen back to normal colors.

Since this function changes the "system colors" to red, **other applications will be affected**. The brightness of the individual colors is selected based upon the brightness of the colors in the current desktop scheme. Therefore changing the desktop scheme prior to initiating Night Vision mode has an effect on the brightness of the various screen elements.

Night vision mode is **automatically switched off** when MaxIm DL is **shut down**.

Please note that the use of a red filter over the screen is recommended as superior to using night vision mode on the computer screen. Most displays, especially LCD displays, still produce a substantial amount of light outside of the deep red area of the spectrum.

Toolbars

MaxIm DL has eight customizable toolbars, rectangular arrays of buttons providing quick access to nearly every command in the MaxIm DL application menus. Each toolbar can be positioned to float anywhere convenient on the screen or "docked" against any of the four edges of the main application window. Toolbars can be independently hidden or displayed. There are seven toolbars associated with the normal application menus: **File, Edit, View, Analyze, Process, Filter** and **Color**. There is also a **Standard** toolbar that contains commonly accessed functions of the software. All buttons on the **Standard** toolbar are also found on one of the other seven, but it groups the commonest and most Windows-generic functions together for legacy reasons. It also provides a convenient **zoom combo box** which is not found elsewhere.

There are two ways to determine the command associated with a toolbar button. First, simply **point** at the button with the **mouse**; after a brief delay, a "tooltip" will be displayed giving the name of the command. Alternatively, you can configure the toolbar to display the name of the command either underneath or instead of a toolbar button's

icon. For more details on this, refer to the **customization dialog**.

To **display or hide a toolbar**, use the commands in the **Toolbars** submenu of the **View** menu; this submenu can also be called up by simply right-clicking on any background or border area of the main MaxIm DL/CCD application window. To make an **anchored** toolbar a **floating** toolbar, or vice versa, **double-click** on either the toolbar title bar (if visible), the "thumb" at the left end of a horizontal toolbar or at the top end of a vertical toolbar, or on any separator between groups of buttons. You can also **drag** the toolbar from one part of screen to another using any of these reference points. During a drag operation, the position and orientation of the toolbar's ghost outline warns you if the toolbar will float or be docked on releasing the mouse button. Docking normally occurs when the dragging destination is near the edge of the application window, but you can prevent this by holding down the **Ctrl** key.

Note: When dragging a toolbar to reposition it to the left or right of another toolbar on the same row, release the mouse button when the cursor is at or above the horizontal midline of its neighbor. If you release the mouse button when the cursor is in the lower half of an existing toolbar, the toolbar will be inserted in a new band just below.

When a toolbar is **floating**, it can be resized by dragging either of the lower left or right corners, thus altering the shape of the toolbar and rearranging the buttons within it.

Standard

The commands on the **Standard** toolbar are listed below; click on the icon for more information. Note that most of these are found on other toolbars as well, as indicated.



Open – open a file. *(also found on the **File** toolbar)*



Save – save a file. Activates Save As dialog if the file does not yet exist. *(also found on the **File** toolbar)*



Undo – undo the last image processing operation. *(also found on the **Edit** toolbar)*



Redo – redo the last processing operation. *(also found on the **Edit** toolbar)*



Screen Stretch – toggles the Screen Stretch window on and off. *(also found on the **View** toolbar)*



Information – toggles the information window on and off. *(also found on the **View** toolbar)*



CCD Control Window – toggles the MaxIm CCD control window on and off. (requires MaxIm CCD option). *(also found on the **View** toolbar)*



Telescope Control Window - toggles the MaxIm Telescope control window on and off. (requires MaxIm CCD option). *(also found on the **View** toolbar)*





FITS Header – toggles the FITS Header viewer/editor window on and off. *(also found on the **View** toolbar)*





Zoom In – zooms in by factors of 2, limit of 1600%. *(also found on the **View** toolbar)*

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 Zoom Out – zooms out by factors of 2, limit of 25%. (*also found on the **View** toolbar*)


 Zoom – set any arbitrary zoom level from 6.25% to 1600%.


 Help – activates context-sensitive help. Note that help on individual dialog controls is obtained using the  button within the dialog.


File


The commands on the **File** toolbar are listed below; click on the icon for more information.

 New – create a new file.


 Open – open a file.


 Combine Files – combine multiple files with optional automatic or manual image alignment.

 Close – close the currently selected window.

 Close All – close all image windows.


 Save – save a file, activates Save As dialog if the file does not yet exist.


 Save As – save an image to disk, always requesting the filename of the destination.


 Save All – save all images that have been modified, requesting filenames when necessary.


 Batch Save and Convert – save selected images and/or convert existing files to a new format.

 Revert – reload the last saved version of the currently selected window.

 Page Setup – select paper size, page orientation, and margins for printed output.


 Print – print the currently selected image.


 Settings – configure program look-and-feel, data format, default FITS keys, site location, telescope description, audible alarms, etc.


 Run Script – start a procedure written in VBScript or JScript.

















Edit

The commands on the **Edit** toolbar are listed below; click on the icon for more information.

 Undo – undo the last image processing operation.








 Redo – redo the last processing operation.

 Copy – copy the currently-selected image to the clipboard.









-  Paste – create a new image from the contents of the clipboard.
-  Crop – trim the currently-selected image to a user-specified rectangle.
-  Mosaic – combine multiple partially-overlapping images into a single large image.
-  Duplicate – create a new image that is an exact copy of the currently-selected one.
-  Annotate – annotate an image with lines, boxes, circles, text, etc.
-  Flip – reverse the currently-selected image top to bottom.
-  Mirror – reverse the currently-selected image left to right.
-  Rotate left – rotate the currently-selected image 90° to the left (counter-clockwise).
-  Rotate right – rotate the currently-selected image 90° to the right (clockwise).
-  Rotate 180° – rotate the currently-selected image 180°.
-  Rotate – rotate the currently-selected image by a specified amount in either direction.
-  Edit Pixels – "draw" on the currently-selected image, setting pixels to specified values.
-  Copy Region – copy circular region(s) defined by the mouse cursor from one image to another.
-  Bin 2x2 – decrease the size of an image by averaging pixels in 2x2 blocks.
-  Bin 3x3 – decrease the size of an image by averaging pixels in 3x3 blocks.
-  Deinterlace – split an image into odd and even frames.

View

The commands on the **View** toolbar are listed below; click on the icon for more information. The commands which appear on the Standard toolbar are indicated with “(standard)” written after the command name.




-  Zoom – invoke the Zoom dialog, to display the currently selected-image at a specified zoom factor.
-  Zoom In (*standard*) – zooms in by factors of 2, limit of 1600%.
-  Zoom Out (*standard*) – zooms out by factors of 2, limit of 25%.
-  Full Screen – display the currently-selected image full-screen, without window frames, menus, etc.
-  Screen Stretch (*standard*) – toggles the Screen Stretch window on and off.
-  Information (*standard*) – toggles the information window on and off.
-  CCD Control Window (*standard*) – toggles the MaxIm CCD control window on and off (requires MaxIm CCD option).

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-  Telescope Control Window (*standard*) - toggles the MaxIm Telescope control window on and off (requires MaxIm CCD option).
-  Zoom Window – toggles the Zoom Window inspection tool on and off.
-  FITS Header (*standard*) – toggles the FITS Header viewer/editor window on and off
-  Line Profile – toggles the Line Profile data inspection tool window on and off.
-  Command Sequence – toggles the Command Sequence (macro record/playback control) window on and off.
-  Night Vision – toggles Night Vision (red screen display).mode on and off.
-  Animate – display a sequence of images in a single window, with automatic timed advance or manual forward/back controls.
-  Equalize Screen Stretch – adjust the screen stretch of all other images to match that of the currently-selected one.









Analyze










The commands on the **Analyze** toolbar are listed below; click on the icon for more information.

-  PinPoint Astrometry – solve the currently-selected image for astrometric star positions.
-  Photometry – extract accurate brightness measurements from a set of images.
-  Open Photometry File – display light curves of data saved during previous photometry sessions.

Process













The commands on the **Process** toolbar are listed below; click on the icon for more information.

-  Calibrate – calibrate the currently-selected image. Loads previous settings if Set Calibration has not been activated manually. Only available for monochrome images.
-  Calibrate All – calibrate all currently uncalibrated open images for which calibration data sets exist.
-  Set Calibration – invoke the Set Calibration dialog, to create, edit, or delete calibration data sets.
-  Align – align a set of images.
-  Combine – align and combine a set of images into a single new image.
-  Remove Bad Pixels – replace hot or dead pixels due to defects in the CCD array.
-  Add Noise – add noise to the currently-selected image.
-  Remove Bloom – remove CCD bloom from bright stars in the currently-selected image.

-  **Resize** – change the size and/or aspect ratio of the currently-selected image.
-  **Double Size** – double the size of the currently-selected image.
-  **Half Size** – reduce the size of the currently-selected image by a factor of two.
-  **Make Pixels Square** – resample the currently-selected image so that the resulting pixels subtend the same angle horizontally and vertically.
-  **Stretch** – invoke the Stretch dialog to permanently stretch an image buffer.
-  **Histogram Specification** – invoke the Histogram Specification dialog to perform a histogram-based stretch.
-  **Curves** - perform a user-defined stretch specified by a tone curve.
-  **Threshold** – apply a threshold to either limit, or set to zero, pixels outside a specified range.
-  **Pixel Math** – add, subtract, multiply, or divide two images, or scale and offset a single image.














Filter

The commands on the **Filter** toolbar are listed below; click on the icon for more information.

-  **Kernel Filters** – invoke the Kernel Filter command, to sharpen or blur an image
-  **FFT Filters** – invoke the FFT Filter command (Fast Fourier Transform filters), to sharpen or blur an image
-  **Unsharp Mask** – invoke the Unsharp Mask command to sharpen an image
-  **Digital Development** - invoke the Digital Development Processing command, which emulates photographic development to enhance an image
-  **Rank Filter** – invoke the Rank filter processing command, which enhances structure in an image
-  **Local-Adaptive Filter** – invoke the Local Adaptive Filter command, which enhances images by sharpening details only in areas of low contrast
-  **Rotational Gradient** – apply a Rotational Gradient filter, which enhances radial structure in an image.
-  **Deconvolve** – sharpen an image by applying either Maximum Entropy or Richardson-Lucy deconvolution, mathematical techniques which undo the effect of systematic aberrations on an image..
-  **Photons Wizard** – invoke a wizard to assist you in determining the gain of your CCD camera.
-  **Flatten Background** – remove a background that varies in brightness across the image by subtracting a two-dimensional polynomial fit to the background at user-specified points.
-  **Auto Flatten Background** – automatically remove a background that varies in brightness across the image by subtracting a two-dimensional polynomial fit to the background at software-determined points.
-  **Auto Remove Gradient** – automatically remove any background gradient present in the image.

Color

The commands on the **Color** toolbar are listed below; click on the icon for more information.

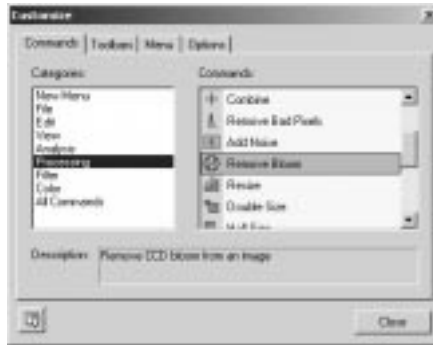
-  Color Combine – invoke the Color Combine command, which combines RGB, LRGB, CMY, LCMY, or two-color image sets into a color image. Color Combine also handles tricolor images from the electronically tunable CRI filter, which are not true RGB images.
-  Color Stack – combine a group of mono images to make a color image. Useful for generating false-color images based on wavelengths of light invisible to the human eye.
-  Split Tricolor – separate a color image into three new images, each containing the data from one of the color planes (R,G,B).
-  Convert to Mono – convert a color image to monochrome by averaging the three color planes.
-  Pseudo Color – invoke the Pseudo Color command, which assigns colors to different brightness levels.
-  Realign Planes – manually register the three planes of a color image with each other.
-  Color Balance – adjust the three planes of a color image for scaling and offset.
-  White Balance – adjust the color planes of an image to make the selected area white.
-  Adjust Saturation – adjust the saturation (color purity) of a color image.
-  Color Smoothing – activates the Color Smoothing command, which smoothes color information without affecting sharp luminance details.
-  Color Adjust – activates the Color Adjust command, which assists in color balance by showing how the image will look after various modifications.
-  Convert MX Image to Color – convert raw Starlight Xpress MX series camera images to color.
-  Convert RGB Image to Color – convert raw "one-shot" camera images (other than MX) to color.

Customize

The **Customize** dialog is a dialog box containing four tabs which are used to customize MaxIm DL/CCD's menus and toolbars. It is invoked from the **Toolbars** submenu of the **View** menu, or from the context menu displayed when you **right-click** the right mouse button on unused (non-image-window) space in the MaxIm DL/CCD application window. While the **Customize** dialog is active, MaxIm DL/CCD works in a special "customize" mode that generally restricts the user input to customization commands only, although operations involving MaxIm CCD, telescope control, and the currently active command dialog [if any] are not affected.

Commands Tab

The **Commands** tab allows you to add, move, or remove commands from MaxIm DL/CCD's menus, submenus, and toolbars. This tab presents all customizable commands, divided into **Categories** by menu header; the customizable entries in each menu appear in the **Commands** list. For the special category **New Menu**, the list contains a single entry "New Menu", used to create a new menu item in the MaxIm DL/CCD application menu bar, a submenu within a menu dropdown, or a menu button on a toolbar. **All Commands** is a convenience that repeats all customizable commands in a single long list, and is useful for those occasions when you can't remember exactly where a particular command is found.



The customization procedure is the same, whether the target is a menu or a toolbar, and whether the entity being added is a command or a new menu:

1. **Select** the appropriate entry in **Categories** so that the item you want to add is shown in **Commands**.
2. Using the left mouse button, **click and drag** the item from the **Commands** list to its desired location. As you are dragging, a small grey rectangle representing the item is shown attached to the mouse cursor arrow; in addition, a boxed "x" is shown just to the lower right of the arrow if the mouse cursor is not in an appropriate location for dropping the item; releasing the mouse button at this point simply cancels the drag operation.)
3. When the mouse cursor is over a toolbar, a heavy black "I-beam" indicator appears between the two closest buttons, showing where the new item would be placed if you release the mouse button. On menus, which open automatically as the mouse cursor travels over them, and on vertically-aligned toolbars, the I-beam indicator is horizontal. Simply move the mouse so that the indicator is where you want the item to be placed and **release the mouse button**.

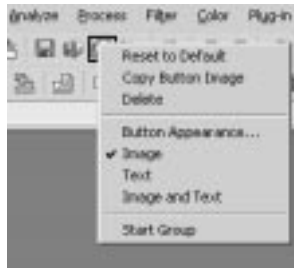
To move a button from one toolbar to another, or to a different position on the same

toolbar, click and **drag the button** from its original location to its desired destination. Again, the mouse cursor indicates when the **drop** will be successful; however dropping an existing button or menu (as opposed to one from the **Commands** list in the **Customize** dialog) will remove it from the source toolbar or menu. Another way to delete an item is to use the right-click menu shown below.

To copy a button from a toolbar, follow the same procedure but hold down the **Ctrl** key. In this case the mouse cursor contains a boxed "+" to indicate that a copy operation rather than a move is in progress.

The same procedures work for menu items, and you can move or copy commands between toolbars and menus at will.

To change the appearance of a button or menu item, **right-click** on it. A pop-up menu appears:



Select **Image** (for buttons only), **Text**, or **Image and Text** to specify whether you want toolbar icon only, command name only, or both. To change the button or menu item label, click **Button Appearance** and enter the new **Button text**; an ampersand in this string marks the character following as the hotkey used in conjunction with **Alt** for quickly selecting that menu item. **Reset to Default** restores the original button text. You can also **Delete** the button or menu item using the pop-up menu.

To insert or remove a separator, **right-click** on the button or menu item that follows (or will follow) it and check or uncheck **Start Group**.

Note: You cannot customize context (right-click) menus or fly-out menus in dialogs (menus that pop up when you click the  button).

Toolbars Tab

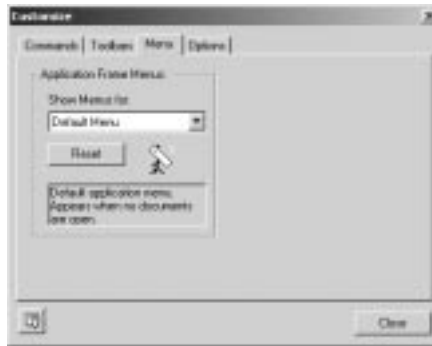
The **Toolbars** tab is an alternative way of controlling which of the eight MaxIm DL/CCD toolbars are displayed. Simply check or uncheck the entry for the specific toolbar. In addition, text labels can be displayed against all toolbar buttons in a particular toolbar by first selecting the specific bar in the **Toolbars** list, then clicking **Show text labels**.

This tab is also used to restore MaxIm DL's menu and/or toolbars to their original configuration, undoing any customization that has been performed. Select the bar and click **Reset**. You can also **Reset All** toolbars and the menu bar at once. In either case, a confirmatory dialog is displayed before the reset occurs.



Menu Tab

The **Menu** tab provides an alternative way of resetting the MaxIm DL/CCD application menu to its original configuration. Simply click **Reset**, then confirm that you wish to reset the Default Menu. [The **Show Menus for** dropdown is reserved for future use.]



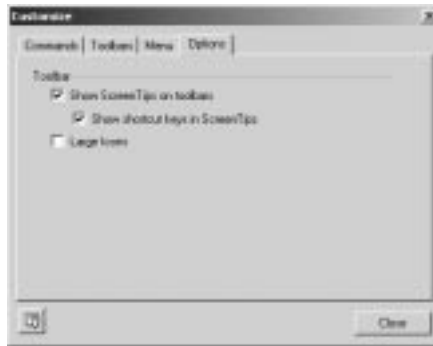
Options Tab

The **Options** tab allows control over the display of tooltips, explanatory tags that are displayed if the mouse is left stationary over a toolbar button for a brief time, and the way toolbar icons are displayed.

Click **Show ScreenTips on toolbars** if you want tooltips to be displayed. When this item is selected, you can also choose to **Show shortcut keys in ScreenTips** as a reminder. "Shortcut keys" are the keystroke combinations that activate the corresponding

command without using the mouse.

Click **Large Icons** if you want toolbar icons to be displayed at double size. Although this takes more screen real estate, it can be useful when operating the program in low light conditions (i.e., with the monitor brightness turned down) or when gloves or mittens reduce manual dexterity.



Status Bar

The **Status Bar** command toggles the display of the status bar on and off. The status bar displays transient information on the current operation, the size of the currently selected image, the zoom factor, the coordinates of the mouse on the image, the intensity of the pixel under the cursor, and for color images, the red, green, and blue intensities of the pixel under the cursor.

For Help, press F1 512x511 100% (425, 207) i: 22.667 r: 22.000, g: 16.000, b: 30.000

Animate

This command allows you to blink back and forth between two images, or create an animation from a group of images. This function is often used for detecting moving solar system objects such as asteroids or objects that change in brightness (variable stars, novae, supernovae).

Prior to animation/blinking, you may wish to apply the **Equalize Screen Stretch** command to adjust all images to the same brightness and contrast. The Equalize Screen Stretch command can also be used while **Animate** is active as long as it appears on a displayed toolbar (the **View** menu item itself is disabled during animation).

Using the **Animate** command is a three-step process: **selecting** images, **aligning** images, and **viewing**.

Select Images

When the command is activated, a **Select Images** dialog box appears first. It allows you to select the images to be included. Select one or more of the images in the **Available Images** list on the left using the **mouse**, then click the “>>” button to copy them to the **Selected Images** list on the right. You can also remove images by selecting them on the right and clicking the “<<” button. Note that ranges of images can be selected using **SHIFT-click**, and individual images can be picked using **CTRL-click**.

The **Add All** button adds all of the **Available Images** into the **Selected Images** list, and the **Remove All** button clears the **Selected Images** list.

When more than two images are selected, the order may be important. The images may be sorted alphanumerically by name using the **Sort List** button. The direction of sort is increasing downward unless the **Reverse Sort** check box is selected, in which case the sort is decreasing downward.

Individual images may be moved up and down the list by **selecting** them with the **mouse** and clicking the **Move Up** or **Move Down** button as required.



If the images are already aligned, the OK button should be clicked to start viewing. If the images need to be registered, click the Align button. At least two images must be selected before you can proceed.

Align Images

This step is optional; you will need to use it if your images are not already registered. If the **Align** button was clicked in the previous step, the **Align Images** dialog will appear, along with a special **Align** image buffer. Refer to **Process** menu **Align** for a full description of how to align images.

On completing image alignment, you are automatically returned to the **image selection** step. Click OK there to move on to the **Animate** dialog itself.

View Images

When **OK** is clicked in the **Select Images** dialog boxes, the small **Animate** toolbox appears. If visible, the **Information** and **Screen Stretch** windows disappear so that time is not wasted updating them during the animation. MaxIm DL/CCD shows a temporary image buffer named **Animate**, suffixed with the name of the currently displayed image. As for any image buffer, it can be panned and zoomed. You can adjust the screen rendition using the **Quick Stretch** method (**SHIFT-click** on image, **hold down** the button and **drag**); animation is automatically suspended while you are doing this. When you quick stretch the **Animate** buffer image, the resulting screen stretch settings are propagated to the other images involved in the animation. If you need to tweak the stretch settings for a particular image, click on that image (or its image tab, if present), and perform the necessary quick stretch; stretches applied to individual images are not automatically propagated to the others.

The topmost button is the **Close** button which terminates animation. Below that is the **speed control**, which selects the delay in seconds before the next image is presented.



The next four buttons resemble those on a tape recorder or VCR. The two broken arrow buttons allow you to **step forwards** and **backwards** through the image list. The “**play**” button (**arrow**) starts the animation process, and the “**stop**” button (**square**) stops it.

If **Loop** is checked, **play** cycles back to the first image after the last image has been displayed. If it is unchecked, animation stops after the last image has been displayed. **Loop** has no effect on the operation of the **step forwards** and **backwards** buttons.

Equalize Screen Stretch

This command adjusts the screen stretch of all images so that their brightness and contrast are equal. This is very useful when the images are to be blinked. Manual operations in the **Align**, **Combine**, and **Mosaic** commands are also eased, even though the final results of these commands do not depend on the rendering of the input images.

The **Minimum** and **Maximum** settings on the **Screen Stretch** window for the currently selected image are applied to all other open images, after being adjusted for the differences in background and dynamic range between "source" and "destination" images. This process depends on overall similarity of the distributions of bright,

medium, and dark pixels in each image, and may not produce optimal results if their histogram shapes differ significantly.

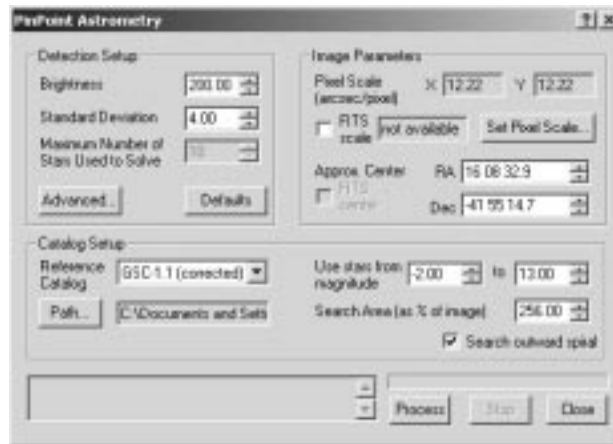
Analyze Menu

PinPoint Astrometry

The PinPoint Astrometric Engine from DC-3 Dreams (<http://pinpoint.dc3.com>) is a tool for precise position measurement or astrometry. When manually or automatically controlling a telescope, it can also be used as an incredibly accurate “digital finderscope.” PinPoint works by matching stars from a catalog with those in the image.

MaxIm DL includes PinPoint LE (light edition). The full version of PinPoint, available from DC-3 Dreams, adds a number of capabilities, including additional information on detected and catalog stars, asteroid and supernova detection, generating output in MPC format, and more.

PinPoint requires an accurate star catalog, such as the Guide Star Catalog. For information on downloading catalogs, please see [http://support.dc3.com/wsx/\\$webstar.exe/prob?129](http://support.dc3.com/wsx/$webstar.exe/prob?129)



Although PinPoint is fully automatic, there are various setup parameters that are required for it to work. Once these are set up, they should suffice for any image taken with the same equipment.

The **Detection Setup** is used to recognize stars and differentiate them from non-stars, and to limit the number of image stars that will be used for solving. Any object less than **Brightness** will be ignored. The **Standard Deviation** multiplier is multiplied by the

standard deviation of the background noise, and any object less than the resulting value is ignored. If there are more than the **Maximum Number of Stars Used to Solve**, only the brightest down to this number are taken (This control is disabled if you are using an older version of PinPoint which does not support the Plate.MaxSolveStars property.). There are also advanced parameters that are accessed using the **Advanced...** button. These parameters are described below.

The **Image Parameters** give PinPoint a starting point for its analysis. It requires an approximate image scale and position on the sky. PinPoint needs to be given a starting point on the sky. The Right Ascension (**RA**) and Declination (**Dec**) can be entered manually, but are more often obtained from the FITS header OBJCTRA and OBJCTDEC keys. **MaxIm CCD** inserts these keys automatically when an image is acquired if the **Telescope Control** window is linked to a telescope.

The **Pixel Scale (arcsec/pixel)** gives the scale of the image in each axis. If **FITS scale** is checked, these will be extracted from the FITS header keys CDELTA1 and CDELTA2 if they are available, or in their absence, calculated from the camera pixel size XPIXSZ and YPIXSZ and the telescope focal length FOCALLEN. Most cameras supported by **MaxIm CCD** provide the pixel dimensions automatically, and the instrument focal length can be configured on the **Site and Optics** tab prior to imaging. If an image has no pixel scale information available in its FITS header, you can specify it manually using the **Pixel Scale Editor**, described below.

Finally, we have the **Catalog Setup**. You can select the catalog to use from the list. The choice of catalog depends on which catalogs are available and the scale of the image. One common choice is **GSC-1.1 (corrected)**, which uses the Guide Star Catalog with adjustments to improve its accuracy. You need to select the location of the catalog using the **Path...** button. Please see [http://support.dc3.com/wsx/\\$webstar.exe/prob?129](http://support.dc3.com/wsx/$webstar.exe/prob?129) for more information on catalogs.


To make sure the analysis is performed quickly, you can instruct PinPoint to ignore catalog stars outside of a particular **Magnitude Range**. Enter appropriate minimum and maximum magnitudes into the two fields labelled **Use stars from magnitude**. Stars outside this range will be ignored. This is useful if the catalog goes much deeper than the image you are analyzing. The **Search Area** is usually set to include more area than the image itself. This allows for additional stars to be brought in from the catalog, which is important if the image is offset from the expected position.

If you think the image might be substantially off-target, turn on the **Search outwards spiral** check box. Then, if a solution fails because the image stars cannot be matched against those in the catalog at that location, MaxIm DL will try to solve it using a sequence central image positions that spirals outward from the original, assumed position.

Once everything is set up, click the **Process** button to start the analysis. The progress will be shown as the search proceeds. If the analysis is successful, this will be indicated, and you can close the dialog box. Otherwise you may wish to adjust some settings and try again. You can abort an analysis with the **Stop** button.

Once you have analyzed an image, World Coordinate System (WCS) information is added to the FITS header. You can now inspect the image using the **Information** window's **Astrometric** mode. For users with the full retail PinPoint version, additional catalog and image star information is available in the Information window display. This extra information is retained only as long as the image is open.

When using MaxIm CCD's **Telescope Control** window, the solved image can also be used to synchronize the telescope position. A typical use is to resynchronize the telescope after a long slew; if the polar alignment is not sufficiently good the image may be completely off-target. To fix this quickly and easily, run an astrometric analysis with the **Search outward spiral** option enabled. When the analysis is complete, click the **Sync** button on the **Telescope Control** window, select the **Solved Position** and click **OK**. Now click the **Go To** button again to position the telescope precisely on the intended coordinates.

For information on individual dialog controls, close this help window and use the  button in the dialog's title bar.

Advanced PinPoint Parameters

PinPoint has a number of advanced parameters which do not normally require adjustment by the user except in special cases. Access to these is through the **Advanced PinPoint Parameters** dialog. Each numerical parameter has an associated **Auto** checkbox; when set, PinPoint determines the optimum value for this parameter itself. This allows you to override only one or two parameters without having to worry about values for all of them.

Projection Type specifies the mathematical model used to map the Cartesian coordinates of image pixel locations to the angles inherent in spherical coordinates used to describe object positions in the sky. This is usually set to **Gnomonic (tangent plane)(TAN)**. Please see the PinPoint documentation for more information on projections.

The **Maximum Residual (arc sec)** is checked against the actual residual in the image, which is a measurement of how accurate the analysis results are. The residual is calculated by measuring how far off predicted catalog star positions are from their actual positions in the image. If the maximum residual limit is enabled, and the residual exceeds the entered value, the astrometric reduction fails.

Minimum Number of Stars to Identify sets a lower limit on how many stars must be

used for the reduction. If too few stars are used, the analysis may not be accurate. This ensures that the astrometric reduction will fail if the results are inaccurate due to too few matched stars.



The **Fit order** specifies the minimum order of the fitting polynomial used.

The **Border Width (pixels)** is used to discard edge artifacts, including objects cut off by the edge of the image.

Any object less than **Size (pixels)** is ignored.

Please see the PinPoint documentation for more information on any of these parameters.

Pixel Scale Editor

If the pixel scale is already in the FITS header, simply select **Pixel Scale** and click **Load from FITS**. Alternatively, you can enter values manually in the **X** and **Y** fields in this mode. The scale is in arc-seconds per pixel.



Another method is to use the **Calculator** mode. Enter the **Pixel Size (microns)** and **Focal Length (mm)**, or click the **Load from FITS** button within the Calculator frame to extract the values directly from the FITS header. Most cameras supported by the MaxIm CCD camera control window provide pixel dimensions automatically when an image is taken. The **Focal length (mm)** field will contain the telescope focal length if it was specified on the **Site and Optics** tab of the **Settings** dialog. This required value can often be found in the manual for your telescope, or it can be calculated by multiplying the aperture by the *f*/ratio. Click **Calculate scale** to compute and display the pixel scale.

Then click **OK** to close the window and return the values to the **Information Window**.

Photometry

The Photometry tool provides highly accurate photometric measurements, and allows for the plotting of light curves. The accuracy of the photometric tool is higher than that of the **Information window** display. It uses a “median-mean” algorithm for background subtraction. It also takes into account partial pixels inside the measurement annulus.

The size of the measurement annulus is determined using the **right-click** context menu for the circular cursor. Right-click on an image to bring it up. Please see the description under **Information Window** for more details.

Image Selection and Object Tagging

The first step is to decide what information best characterizes the abscissa (X axis) information for the plot. This will depend on the source of your data and on whatever preliminary processing may have been done. Use the **Time/identification field** dropdown to specify how MaxIm DL should derive this information. This control should be set at the beginning of analysis since changing it resets the photometry tool. The available choices are:

- **Date/time from FITS.** This is the most common setting. MaxIm DL takes the time from the DATE-OBS FITS key, supplemented by TIME-OBS or UT if no hr:min:sec information is present in DATE-OBS. This is further modified by adding half the exposure duration as supplied by one of the keys EXPOSURE, EXPTIME or FEXPTIME if any of them is present. This setting works with images captured by MaxIm CCD and many other camera control packages. Images appear in the **Image list** in chronological order; those lacking sufficient information to derive a time are omitted from the list.
- **File Timestamp.** Images not containing FITS information, but which have been not been modified since their acquisition, or whose timestamps have been artificially restored, can be processed using this setting. MaxIm DL takes the time from the directory entry's modification date.
- **Sequence Number.** In the absence of any other useful information, images can simply be assigned a "sequence number", i.e. is a number starting at 1 and counting up for each subsequent image in the **Image list**, listed in alphabetical order. Excluded images, described below, are also allotted a sequence number. When using this option, it is recommended that you close all images except for the ones being analyzed. You will also want to record the correspondence between image names and sequence numbers.
- **Arbitrary FITS key.** When this option is picked, the **Time/identification field**

displays **[Enter FITS key]** and is enabled for input. Type the name of any FITS keyword present in your image headers which contains a value that can be interpreted as a date/time. String-valued keys containing slash- or hyphen-delimited year-month-day and colon-delimited hr:min:sec values are interpreted correctly. A time in hours, minutes and seconds without a date is arbitrarily assigned a date of 2000 Jan 01. Integer- and real-valued FITS keywords are used directly as the X axis data. Images lacking the specified keyword are omitted from the **Image list**.

In all cases, the "time" value obtained for a file is displayed in the read-only **Time of Image** edit box.

Next, select the images to analyze. The **Image list** contains all the currently open images in date/time order (the date/time must be present in the FITS header, which will be true if the images were taken with MaxIm CCD). You can exclude an image from photometry analysis by selecting it and clicking the **Exclude** button. In the **Image list**, the names of excluded images are shown in a gray strikethrough font. When such an image is selected, the **Exclude** button changes to **Include**, and serves to restore the image to the data being plotted. In practice, images are often excluded from analysis only after a preliminary plot has shown that they yield noisy measurements; this can be done from the plot itself, and is described below.

When you select an image in the **Image list**, it is displayed in the **Photometry** image window. You need to tag the object(s) that are to be measured, as well as at least one reference star in each image. In addition, you may tag one or more check stars. This is accomplished by picking the type of object you want to tag from the **Mouse click tags as** dropdown, then clicking the mouse cursor on the object itself in the **Photometry** image window.

Set **Act on all images** if you want MaxIm DL to automatically find and tag the star on each image. Auto-tagging is performed by finding the closest star in each adjacent image. If **Use star matching** is enabled, the auto-tagging is done by pattern matching the star patterns in each image; this allows you to use images taken with the camera shifted or rotated by a large amount between images (this may take some time on the first object, since the star patterns on each image must be matched). You can turn on **Snap to centroid** to ensure that the measurement annulus is accurately centered on the star in each image.

You can reposition the label on the tagged object by dragging it with the mouse, or move the tag itself by dragging the circular measurement target. You can also adjust the measurement radii by **right-clicking** on a tag to bring up the right-click menu.

When you tag a reference star, you need to set its known magnitude in the **Ref Mag** field. By definition, a reference star has the same magnitude in every image. If you tag more than one reference star, you must set the magnitude for each; the results will be

averaged. You can edit the reference magnitude at any time by selecting the star in the **Tagged objects** list and typing the new value in **Ref Mag**.

You can continue to select additional stars, including **New Object** for objects to be measured, **New Moving Object** for a non-stationary object such as an asteroid, and **New Check Star**. Check stars are usually included in measurements to monitor data quality and ensure that the selected reference stars are not themselves variable.



Moving objects must be manually tagged on at least two different images to enable the Photometry tool to calculate a "track" giving the probable location of the object at the time associated with every image in the set. Therefore, when a **New Moving Object** is initially tagged, **Act on all images** is ignored. After changing to a different image, pick the identification assigned to the new moving object from **Mouse click tags as** and click on the object in the new image. For best results, you should usually tag moving objects in the first and last images of a data set.

If you want to remove a tag from a star, select it in the **Tagged Objects** list and click **Untag**. **Act on all images** controls whether the object is deleted from every image in which it appears, or only the one named in the **Image list** and currently appearing in the photometry image window. Objects which are not tagged in the currently selected image do not appear in the **Tagged Objects** list, but do appear in **Mouse click tags as**.

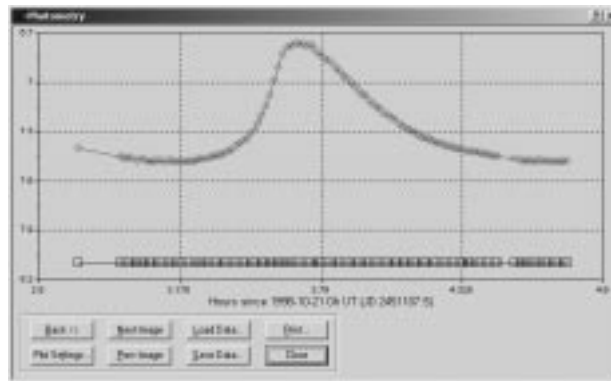
When all the objects have been tagged, click **View Plot...** to see the results. At a minimum, you must identify at least a reference star on every included image, though images that lack objects to be measured are somewhat pointless!

Clicking **Close** will finish the photometry session. If you have unsaved work, MaxIm DL asks you if you really want to discard it. Saving is done from the **Photometry Plot** dialog, described next.

Photometry Plots

The **Photometry** window will now appear. A graph will be displayed showing the light curves of the tagged objects. Each object will have a separate curve with different markers or colors. The window is resizable by dragging edges or corners.

The **Next Image** and **Prev Image** buttons will move the associated **Photometry** image buffer back and forwards along the list of images. You can also **click** on any measurement in the graph to display the image from which it was derived and highlight the corresponding annulus. You can view the tagged objects and make sure that everything is tagged properly. If not, click the **Back <<** button to return to the **Photometry** image selection and object tagging dialog.



Right-click on any point in the graph to display a pop-up menu showing the name of the file contributing that point and the three files immediately before and after. Files which were processed are checked, while those for which **Exclude** was checked are not. You can change the inclusion/exclusion status of any of these files by clicking on its name in the pop-up menu. The graph is immediately drawn with or without the affected point.

The **Save Data...** button allows you to save the photometric data to disk as a Comma Separated Values (.CSV) file. These files are compatible with other software such as Microsoft Excel™, which can be used to perform additional analysis. **Precision** allows you to set the numeric format for magnitudes in the file. You can also use the **Load Data...** button to import previously saved data and add it to the plot. See the **Open Photometry File** command for more information, and note that you cannot display the original images, tags, or filenames for imported data points.

The **Print...** button allows you to print the graph. The standard Windows print dialog box will appear.



You can adjust the appearance of the plot using the **Plot Settings...** button. The **Photometry Plot Settings** dialog box will appear.

You can change the appearance of the lines and symbols for the various tagged items. Select the object whose curve you want to edit in the **Symbology** list. Select the **Symbol** you want from the list, and select its **Color...** and **Size** in pixels. You can also set the **Line** thickness and **Color**.

The **Plot Limits** determines how the axes appear. Both the **Time axis** and **Magnitude axis** can be set to **Auto**. The plot will be automatically adjusted so that all data will be visible. Alternatively, you can turn off Auto and enter the values manually. The Time and Magnitude axes both require a **Min** and **Max** entry.

You can specify a **Period folding** modulus to overlay measurements from different cycles of periodic phenomena. The period can be expressed in **hours** or **days**, or folding can be turned off (**none**). If the horizontal axis variable is a **Sequence Number** or **Arbitrary FITS key**, the choices for **Period folding** are simply **units** or **none**. **Line** mode is ignored when **period folding** is in effect.

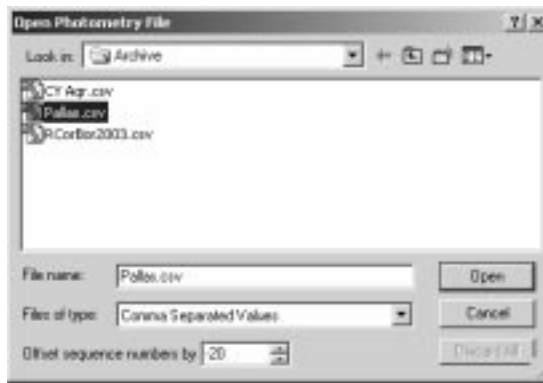
Offset (JD) allows you to set the reference time that is subtracted from every measurement time and is shown at the bottom of the plot window. When **period folding** is used, **Offset (JD)** adjusts the phase of the display curve. It is expressed as a Julian date when the horizontal axis is time, and in the units of the abscissa variable otherwise.

You can see the effect on the plot immediately by clicking **Apply**. Once you are satisfied with the appearance of the plot, click the **OK** button to make the changes permanent.



Open Photometry File

This command brings up the **Photometry** plot without analyzing new data. Instead, data is read from a **Comma Separated Values** (.CSV) file. Once the file has been loaded, the standard **Photometry** plot is displayed. Please see the **Photometry** command for an explanation of the **Photometry** plot.



The dialog box allows you to browse the computer disk and select a .CSV file. When you have selected the file, click **Open** to load it into the plot. The **Discard All** button is enabled only if data has already been loaded. Clicking **Discard All** erases all previous loaded data from the plot and returns to the **Photometry** plot. Otherwise, the new data

will be loaded on top of the old data.

Data can be combined into a single plot from multiple files only if the same type of abscissa ("time") information is used in all of them, otherwise an error is reported.

When the abscissa is a sequence number, you can set **Offset sequence numbers by** to an arbitrary integer; this value is added to the newly imported data to distinguish it from data loaded earlier, or analyzed in the current Photometry session. Typically, the offset should increase from one file to the next by the number of measurements in the earlier file. Alternatively, to load a sequence-numbered file immediately to the left of the current data, set the offset to the negative of the number of points in the file being loaded.

Process Menu

Calibrate

The **Calibrate** command will calibrate the currently selected image. If a valid calibration is not set, then an error message appears. If the calibration was set on a previous MaxIm DL session, the calibration files will be loaded again, if still available.

Only monochrome images can be calibrated, and they must have the same dimensions as the calibration frames.

Calibrate All

The **Calibrate All** command will calibrate all open images that:

- Have not already been calibrated during this MaxIm DL session,
- Are monochrome, and
- Match the image dimensions of the selected calibration frames

This is useful for calibrating a large group of images simultaneously.

Set Calibration

The **Set Calibration** command allows you to initialize the calibration function.

Calibration is used to overcome limitations in CCD cameras, as well as other instrumental effects (e.g. vignetting). **Calibration** greatly improves the signal-to-noise ratio and photometric accuracy of images.

Calibration is performed using a group of calibration images taken with the same CCD camera under the same conditions as the actual image. Calibration images must be full-frame images, although they can be binned. The **Bias Frame** is used to remove offsets,

the **Dark Frame** is used to remove variations in dark current, and the **Flat-Field Frame** is used to remove differences in sensitivity across the CCD chip. For all three types of calibration frames, it is best to acquire multiple frames. This reduces the effect of readout and thermal noise in the calibration frames themselves. For more information on calibration, please refer to the appropriate sections of the manual.



MaxIm DL allows you to specify multiple groups of calibration images using the **Set Calibration** command. During calibration, MaxIm DL will select the three groups of calibration frames - bias, dark and flat - that best match the currently active image. MaxIm DL will select the flat field whose filter name matches that of the image to be calibrated. If no flat-field with a matching filter name exists, then MaxIm DL will fall back to finding a flat field whose filter name is "FLAT", but whose other properties match those of the data image. If the image to be calibrated is a subframe, then MaxIm DL will perform calibration using the matching area from the calibration images. This allows you to set up calibration frames for both the guider and main camera, under a variety of conditions, without needing to switch manually between different groups of calibration images.

Since calibration can be complicated, you may wish to use the **Calibration Wizard** to help you select the correct settings.

MaxIm DL allows you to create an arbitrary number of groups of calibration images.

Each image group is identified by the properties of the images that it contains, including the image type (bias, dark or flat), filter used for flat field, duration, image size, binning and camera temperature. All images in a group must be the same size. These input images are combined to produce a single master frame for each group, which is then used for calibration. Each image group has different properties specifying the algorithm used to combine the images. Groups of dark frames have additional settings that control whether and how they are scaled to match the exposure duration of the image to be calibrated.

The **Calibrate Bias**, **Calibrate Dark** and **Calibrate Flat** check boxes are used to enable or disable the use of the associated type of group for calibration. If bias and dark subtraction are both enabled, then the dark frame will always have the bias frame subtracted from it. Flat fields are themselves calibrated before being used to calibrate a light frame, but it is possible to disable the bias subtraction and dark subtraction steps using the **Dark-Subtract Flats** or **Bias-Subtract Flats** check boxes.

The **Add Group** button allows you to create a new, empty group. The group is assigned the filter name that is present in the combo box next to the **Add Group** button. If **<AUTO>** is selected, then the group will be assigned the filter name of the first file that is added to it. **Remove Group** is used to delete the selected group, and the **Clear All Groups** button deletes all of the existing groups.

The **Group Properties** for the selected group are displayed below the list of groups. Each group contains a set of images that are combined to produce a master image, that latter being used for image calibration. Clicking the **Add** button displays a dialog that allows you to add new files to the list. **Remove** deletes the currently selected files from the group. Normally, the list of files shows the full path to each file. If you click **Show File Names Only**, then only the file name will be displayed.

The **Combine Type** combo-box allows you to specify the algorithm to be used for combining the images in the group into a single, master image. The available algorithms are **Average**, **Median**, **Sigma Clip** and **SD Mask**.

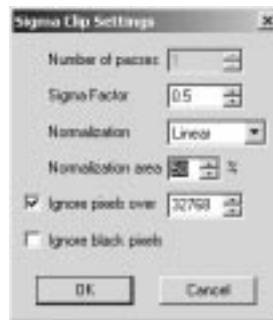
Median can be useful for suppressing “hot” pixels, cosmic ray hits, and other types of impulsive noise. **Median** combining strongly suppresses outlying pixel values, but it is slightly less effective than averaging in reducing the overall noise level. A median calculation produces an RMS noise level about 25% higher than that when averaging, but combining more calibration frames can compensate for this. Flat-field frames are normalized prior to the median calculation so as to compensate for any change in overall illumination levels. The **Sigma Clip** and **SD Mask** settings attempt to provide the benefits of both **Median** and **Average**, but require more intensive calculations. These algorithms require additional settings, which are discussed below.

The **Dark Frame Scaling** mode allows you to select one of several dark frame scaling

modes. The available modes are **Auto-Scale** (applicable to FITS and SBIG format files only), **Auto-Optimize**, **Manual**, and **None**. The **Scale Factor** is entered as a multiplication factor to be applied to the dark frame. **Auto-Optimize** is particularly useful for non-temperature regulated cameras.

If **Apply To All** is checked, then any change to the group settings (excluding the addition or removal of files) will be propagated to all of the groups. Normally these settings affect only the currently selected group.

Instead of creating the groups and adding files to them manually, the **Set Calibration** command provides the ability to automatically divide a set of images into appropriate groups, by clicking the **Auto-Generate** button. The **Source Folder** will be scanned, and any FITS images present will be divided into groups containing images with similar properties. If **Include Subfolders** is checked, then the **Auto-Generate** command will also find all of the files in the subfolders of the **Source Folder**, and add them to groups as well.



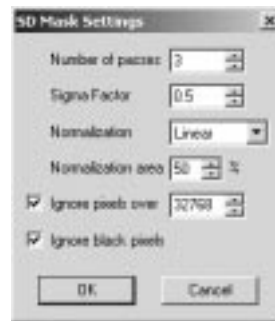
When the **Sigma Clip** or **SD-Mask** (Standard Deviation Mask, a custom algorithm contributed by Ray Gralak) combine algorithms are selected, additional parameters are required to control how the images are combined. In both cases, the input images are normalized to the same intensity level before they are combined. Normalization works by examining a rectangular **Normalization area** that occupies the center of each input image; the size of the rectangle is a proportion of the input image, as specified by the **Normalization area**. Two algorithms are available for normalizing the images. If **Delta-Level** is selected, then only the image background levels will be modified by normalization. If **Linear** is selected, then linear regression is used to determine a combination of changes to the background level and the scaling of the image data, resulting in images with equivalent overall intensity levels.

Both algorithms work by calculating the mean of each pixel value, for all of the input images, as well as the standard deviation of those pixel values. If **Ignore Black Pixels** is checked, then any pixel with a value of 0 is excluded from the mean/standard deviation calculation. If **Ignore Pixels Over** is checked, then any value exceeding the specified

value will also be excluded from the mean/standard deviation calculation.

The **Sigma Clip** algorithm works as follows. Once the mean and the standard deviation of the input pixels are known, the pixel that is farthest from the mean is selected. MaxIm DL will then calculate the number of standard deviations between the mean and the outlier pixel's value. If the outlier pixel's value is fewer than **Sigma Factor** standard deviations from the mean, then the calculated average is assigned to the output. If the outlier pixel's value is greater than **Sigma Factor** standard deviations from the mean, then the outlier pixel is discarded from the set of input pixels, and the mean of the inputs is re-calculated, excluding the outlier. The new mean is then assigned to the output pixel.

When using the **SD-Mask** algorithm, a similar technique is used. The SD-Mask algorithm works by repeatedly applying the same process to the image, for a number of times given by the **Number of passes**. With each pass, the input images are normalized to the same intensity level (see above for a description of normalization). Then, for each pixel in the output image, the standard deviation of the set of input pixels is calculated. If the standard deviation exceeds the **Sigma Factor** (note that this parameter has a different effect and purpose than in **Sigma Clip**) then the median of the input values is assigned to the output. Otherwise, the output is the mean of the inputs. The idea is to use the mean where possible because it does a better job of suppressing gaussian noise, and to use the median only when there is reason to expect that the input data contain outliers.



Calibration only operates on monochrome images. Settings are saved between sessions. If you calibrate an image without first running the **Set Calibrate** command, the previous calibration files will be loaded.

You can access the master calibration images created with this command using the **Create Master Frames** command. You must create the master frames immediately after using **Set Calibration** and before calibrating any images.

Calibration Wizard

The **Calibration Wizard** command takes you through the calibration setup process in a step-by-step fashion. The Wizard fills in the appropriate settings for the **Set Calibration** dialog based upon your input, then will calibrate the selected image. If you wish to apply the same calibration to a second image, simply invoke the **Calibrate** command using the **Process** menu or the **Toolbar**.

This command only operates on monochrome images.



Create Master Frames

This command only becomes available if you have just clicked OK in the **Set Calibration** dialog, but haven't yet calibrated any images. It generates one master image for each image group created by Set Calibration, and displays them as image buffers. They can then be saved for future use in the Set Calibration command.

This function saves recalculation time and disk space if a set of calibration frames is used repeatedly. Many CCD users generate a library of master calibration frames which are used over and over. Often a large number of calibration frames are recorded at a variety of temperature settings.

Align

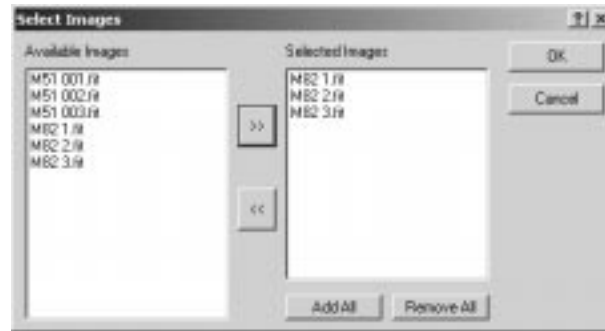
The Align command is used to align a set of images. Two dialog boxes appear: **Select Images** followed by **Align Images**.

Select Images

When the command is activated, a **Select Images** dialog box appears first. It allows you to select the images to be included. Select one or more of the images in the **Available Images** list on the left using the **mouse**, then click the “>>” button to copy them to the **Selected Images** list on the right. You can also remove images by selecting them on the right and clicking the “<<” button. Note that ranges of images can be selected using **SHIFT-click**, and individual images can be picked using **CTRL-click**.

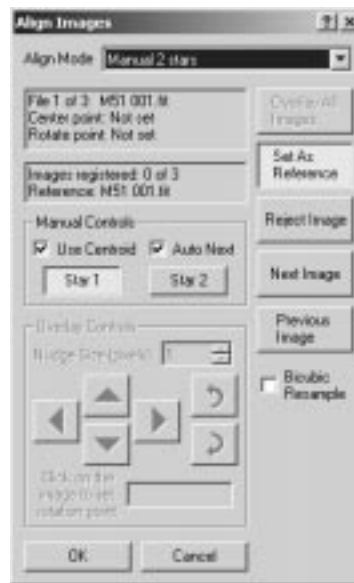
The **Add All** button adds all of the **Available Images** into the **Selected Images** list, and the **Remove All** button clears the **Selected Images** list.

Click **OK** to start the alignment process. At least two images must be selected before you can proceed.



Align Images

When the **Align Images** dialog box appears, a special **Align** image buffer also appears. This image buffer is used to display the contents of the current image while aligning.



Two interpolation modes are available. **Bicubic Resample** uses a higher-order resample algorithm that produces a crisper result, but requires more processing time. When turned off, a simple bilinear interpolation is used.

The first step is to select the **Align Mode**. The modes available are:

- None
- Auto - correlation
- Auto - star matching
- Manual 1 star - shift only
- Manual 2 stars
- Astrometric
- Planetary
- Overlay

The auto-correlation, auto star-matching, astrometric, and planetary modes require no further operator input – just click the **OK** button. The other modes allow manual adjustment of each image using a variety of techniques. Each alignment method is described below.

None

In this mode, no change is made to the alignment of the images. This mode is usually used only for the **Combine** command.

Auto - correlation

A cross-correlation is performed between each image to determine the relative offset. If point sources (stars) are available in the image they are used to refine the alignment to sub-pixel accuracy. The images are only shifted horizontally and vertically; no rotation is performed. This function only works properly if the relative offset between images is relatively small. To determine if it will work satisfactorily, click the **Overlay All Images** button.

Auto - star matching

In this mode, the images are matched up by looking for patterns of similar triangles among automatically identified stars in each image. If the match is successful the images are automatically aligned to sub-pixel accuracy, using shifting, rotation, and scaling. To determine if the results are satisfactory, click the **Overlay All Images** button to produce a preview.

Manual 1 star - shift only

This is the fastest manual adjustment method. Each image is presented in turn; the user simply **clicks** on a particular star or other recognizable feature in each image. The images are aligned using shifting only; no rotation is performed.

In order to speed up the alignment, turn on the **Auto Next** check box. Every time the mouse is **clicked** on the image, the next image will automatically be displayed. When all of the images have been registered, the computer will **beep**.

If **Auto Next** is not being used, you can move through the images using the **Next Image** and **Previous Image** buttons.

If the reference point is a star or similar point source of light, turn on the **Use Centroid** check box. At each clicked location a centroid will automatically be calculated and used to refine the adjustment to the sub-pixel level.

One of the images can be set as the reference image using the **Set As Reference** button. The selected image will not be moved, and all other images will be adjusted to align with it.

If any image in the sequence is of poor quality, click the **Reject Image** button. Rejected images are shown with a large red X superimposed; they are excluded from the alignment process, and will be unaffected even if you click OK. You can restore a rejected image by clicking on the button again. If you have not clicked on an image, then no reference point exists for that image, it cannot be aligned, and it will be automatically rejected when you click OK.

To determine if the results are satisfactory, click the **Overlay All Images** button to produce a preview.

Manual 2 stars

This method is similar to the **Manual 1 star** method, but performs both a shift and rotate using two registration points. Each image is presented in turn; the user simply **clicks** on a particular star or other recognizable feature in each image.

In order to speed up the process, turn on the **Auto Next** check box. Every time the mouse is **clicked** on the image, the **next image** will automatically be displayed. When the first registration point has been set on each image, the computer will **beep** and the first image will be displayed again. Move to a **second star** and **repeat** the process until the computer **beeps** a second time. The **Star 1** and **Star 2** buttons will toggle to show you which point is being set.

If **Auto Next** is not being used, or you want to change a single registration point, use the **Star 1** or **Star 2** button to control which reference point is being changed. You can move through the images using the **Next Image** and **Previous Image** buttons.

One of the images can be set as the reference image using the **Set As Reference** button. The selected image will not be moved, and all other images will be adjusted to align with it.

If the reference point is a star or point source, turn on the **Use Centroid** check box. At each clicked location a centroid will automatically be calculated and used to refine the adjustment to the sub-pixel level.

If any image in the sequence is of poor quality, click the **Reject Image** button to remove it from the list. You can restore it by clicking on the button again. Any image that has not had two reference points clicked on cannot be registered and is therefore automatically rejected.

To determine if the results are satisfactory, click the **Overlay All Images** button to produce a preview.

Astrometric

This method uses the World Coordinate System (WCS) entries in the FITS header to determine how much to shift, rotate, and scale each image into alignment with the reference image. The WCS information characterizes the precise image center, pixel scale, "roll angle" and other information describing the mapping between RA and declination and pixel (X, Y) coordinates. It is added to the FITS Header when an image is solved using the **PinPoint Astrometry** command or another astrometric software package. Only images that have been successfully solved can be aligned in this way; all unsolved images are automatically rejected.

Since aligning an image can change its center coordinates, orientation angle, and scale, the existing WCS is invalidated on all images except the reference. By default, the reference image is the first image in the list, but you can select another one by moving to it with **Next Image** or **Previous Image**, then clicking **Set As Reference**.

To determine if the results are satisfactory, click the **Overlay All Images** button to produce a preview.

Planetary

This method is intended for aligning images of planets. It will work only when each image to be aligned contains a single, substantial disk, that is, an approximately circular region of bright pixels completely surrounded by background. The images are shifted so as to bring the centroids of their disks into coincidence. No rotation or scaling is performed. The **Reject** and **Set As Reference** buttons are available in planetary mode and work as previously described.

To determine if the results are satisfactory, click the **Overlay All Images** button to produce a preview.

Overlay

This mode is useful when no clear registration points are visible, such as lunar images with indistinct features.

You **must** first set one of the images as the reference image. Look through the images using the **Next Image** and **Previous Image** buttons. Pick an image and click the **Set As Reference** button (in many cases the first image can be used).

Next, move to another image using the **Next Image** or **Previous Image** button. This image will be overlaid on the reference image with the reference in magenta and the new image in green. The **Overlay Controls** can now be used to adjust the position of the image to match the reference.

There are four shift buttons with **up**, **down**, **left**, and **right** arrows. There are also two rotation buttons with **rotate clockwise (right)** and **rotate counterclockwise (left)** arrows. Each time you click a button the image moves. The distance moved is controlled by the **Nudge Size (pixels)** control. With these controls you can position an overlaid image to a fraction of a pixel.

In order to use the **rotation buttons**, you must first pick a **rotation point**. This is the point that the image will pivot about as it is rotated. The best procedure is to align a feature that appears on both of the overlaid images, then **click** on the feature. Look at another point in the image some distance away and adjust the rotation to line up the second point.

To determine if the results are satisfactory, click the **Overlay All Images** button to

produce a preview.

Combine

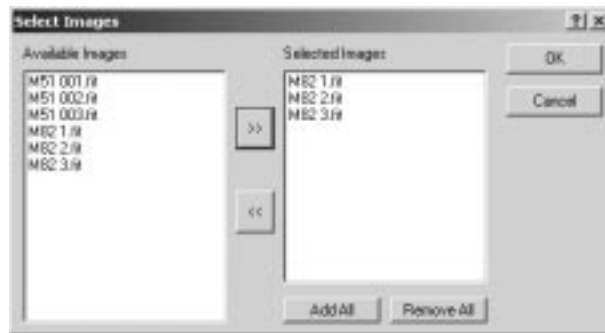
The **Combine** command is used to align, and then either median, average, or sum combine a set of images. Two dialog boxes appear: **Select Images** followed by **Combine Images**.

Select Images

When the command is activated, a **Select Images** dialog box appears first. It allows you to select the images to be included. Select one or more of the images in the **Available Images** list on the left using the **mouse**, then click the ">>" button to copy them to the **Selected Images** list on the right. You can also remove images by selecting them on the right and clicking the "<<" button. Note that ranges of images can be selected using **SHIFT-click**, and individual images can be picked using **CTRL-click**.

The **Add All** button adds all of the **Available Images** into the **Selected Images** list, and the **Remove All** button clears the **Selected Images** list.

At least two images must be selected before you can proceed.

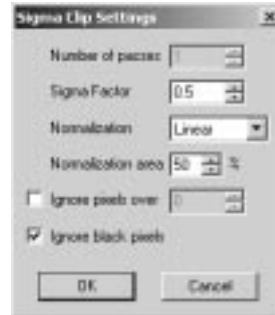


Combine Images

When the **Combine Images** dialog box appears, a special **Combine** image buffer also appears. It is used to display the currently selected image, or a preview of the results, if **Overlay All Images** is clicked.

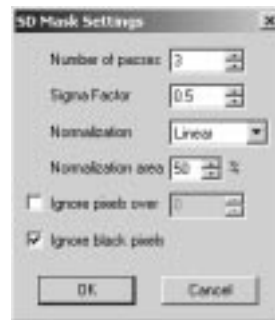
The first step is to select the **Output** mode. This determines how the images are combined. The available options are **Sum**, **Average**, **Median**, **Sigma-Clip** and **SD Mask**. **Sum** adds up the pixels in all the images. **Average** sums all the pixels and divides by the number of images. **Median** takes the median or middle value from all of the images. The **Sum** mode provides the best performance in most conditions (e.g. when

Gaussian noise is present). The **Median** mode is useful when some pixels are extremely bright or dark (hot/dark pixels, cosmic ray hits). If **Median** mode is used, a **Normalize** option is available. Normalize will remove differences in the image scaling which could interfere with the median processing. The **Sigma-Clip** and **SD Mask** combination modes attempt to combine the best features of the **Median** and **Average** modes, but require more intensive calculations. These algorithms require additional settings, which are discussed below.



When the **Sigma-Clip** or **SD-Mask** (Standard Deviation Mask, a custom algorithm contributed by Ray Gralak) combine algorithms are selected, additional parameters are required to control how the images are combined. Both algorithms work by calculating the mean value of each pixel across all of the input images, as well as the standard deviation of those pixel values. If **Ignore Black Pixels** is checked, then any pixel with a value of 0 is excluded from the mean/standard deviation calculation.

When using the **Sigma-Clip** algorithm, the pixel value that deviates the most from the mean will be discarded, provided that the deviation is greater than the number of standard deviations given by the **Sigma Factor**, and a new mean will be calculated without the discarded value. This value is assigned to the corresponding pixel in the output image.

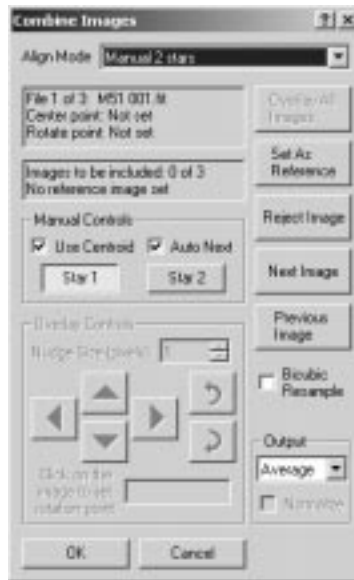


When the images are rotated or resized, MaxIm DL will interpolate the values of the pixels in the input images to produce a more accurate result in the output. Two interpolation modes are available. **Bicubic Resample** uses a higher-order resample algorithm that produces a crisper result, but requires more processing time. When turned off, a simple bilinear interpolation is used.

The next step is to select the Align Mode. The methods available are:

- None
- Auto - correlation
- Auto - star matching
- Manual 1 star - shift only
- Manual 2 stars
- Astrometric
- Planetary
- Overlay

The auto modes require no further operator input – just click the **OK** button. Even in the automatic modes you can remove bad images by stepping through using the **Next Image** and **Previous Image** buttons, and turn on/off the **Reject Image** button.



Manual modes allow for image alignment using a variety of techniques. Each alignment method is described below.

None

In this mode, no change is made to the alignment of the images. The images are summed, averaged, or median combined without any other adjustments.

Auto - correlation

A cross-correlation is performed between each image to determine the relative offset. If point sources (stars) are available in the image they are used to refine the alignment to sub-pixel accuracy. The images are only shifted horizontally and vertically; no rotation is performed. This function only works properly if the offset between images is relatively small. To determine if it will work satisfactorily, click the **Overlay All Images** button to produce a preview.

Auto - star matching

In this mode, the images are matched up by comparing star patterns. If the match is successful, the images are automatically aligned to sub-pixel accuracy, using both shifting and rotation. To determine if the results are satisfactory, click the **Overlay All Images** button to produce a preview.

Manual 1 star - shift only

This is the fastest manual adjustment method. Each image is presented in turn; the user simply **clicks** on a particular star or other recognizable feature in each image. The images are aligned using shifting only; no rotation is performed.

In order to speed up the alignment process, turn on the **Auto Next** check box. Every time the mouse is **clicked** on the image, the next image will automatically be displayed. When all of the images have been registered, the computer will **beep**.

If **Auto Next** is not being used, you can move through the images using the **Next Image** and **Previous Image** buttons.

If the reference point is a star or similar point source, turn on the **Use Centroid** check box. At each clicked location a centroid will automatically be calculated and used to refine the adjustment to the sub-pixel level.

One of the images can be set as the reference image using the **Set As Reference** button. The selected image will not be moved, and all other images will be adjusted to align with it.

If any image in the sequence is of poor quality, click the **Reject Image** button to remove it from the list. You can restore it by clicking on the button again. Any image that has not had a reference point clicked on cannot be registered and is therefore automatically

rejected.

To determine if the results are satisfactory, click the **Overlay All Images** button to produce a preview.

Manual 2 stars

This method is similar to the **Manual 1 star** method, but performs both a shift and rotate using two registration points. Each image is presented in turn; the user simply **clicks** on a particular star or other recognizable feature in each image.

In order to speed up the process, turn on the **Auto Next** check box. Every time the mouse is **clicked** on the image, the **next image** will automatically be displayed. When the first registration point has been set on each image, the computer will **beep** and the first image will be displayed again. Move to a **second star** and **repeat** the process until the computer beeps a second time. The **Star 1** and **Star 2** buttons will toggle to show you which point is being set.

If **Auto Next** is not being used, or you want to change a single registration point, use the **Star 1** or **Star 2** button to control which reference point is being changed. You can move through the images using the **Next Image** and **Previous Image** buttons.

One of the images can be set as the reference image using the **Set As Reference** button. The selected image will not be moved, and all other images will be adjusted to align with it.

If the reference point is a star or similar point source, turn on the **Use Centroid** check box. At each clicked location a centroid will automatically be calculated and used to refine the adjustment to the sub-pixel level.

If any image in the sequence is of poor quality, click the **Reject Image** button to remove it from the list. You can restore it by clicking on the button again. . Any image that has not had two reference points clicked on cannot be registered and is therefore automatically rejected.

To determine if the results are satisfactory, click the **Overlay All Images** button to produce a preview.

Astrometric

This method uses the World Coordinate System (WCS) entries in the FITS header to determine how much to shift, rotate, and scale each image into alignment with the reference image. The WCS information characterizes the precise image center coordinates, pixel scale, "roll angle" and other information describing the mapping between RA and declination and pixel (X, Y) coordinates. It is added to the FITS Header when an image is solved using the **PinPoint Astrometry** command or another astrometric software package. Only images that have been successfully solved can be

aligned in this way; all unsolved images are automatically rejected.

Since aligning an image can change its center coordinates, orientation angle, and scale, the existing WCS is invalidated on all images except the reference. By default, the reference image is the first image in the list, but you can select another one by moving to it with **Next Image** or **Previous Image**, then clicking **Set As Reference**.

To determine if the results are satisfactory, click the **Overlay All Images** button to produce a preview.

Planetary

This method is intended for aligning images of planets. It will work only when each image to be aligned contains a single, substantial disk, that is, an approximately circular region of bright pixels completely surrounded by background. The images are shifted so as to bring the centroids of their disks into coincidence. No rotation or scaling is performed. The **Reject** and **Set As Reference** buttons are available in planetary mode and work as previously described.

To determine if the results are satisfactory, click the **Overlay All Images** button to produce a preview.

Overlay

This mode is useful when no clear registration points are visible, such as planetary images with indistinct features.

You **must** first set one of the images as the reference image. Look through the images using the **Next Image** and **Previous Image** buttons. Pick an image and click the **Set As Reference** button (in many cases the first image can be used).

Next, move to another image using the **Next Image** or **Previous Image** button. This image will be overlaid on the reference image, with the reference in magenta and the new image in green. The **Overlay Controls** can now be used to adjust the position of the image to match the reference.

There are four shift buttons with **up**, **down**, **left**, and **right** arrows. There are also two rotation buttons with **rotate clockwise (right)** and **rotate counterclockwise (left)** arrows. Each time you click a button the image moves. The distance moved is controlled by the **Nudge Size (pixels)** control. With these controls you can position an overlaid image to a fraction of a pixel.

In order to use the **rotation buttons**, you must first pick a **rotation point**. This is the point that the image will pivot about as it is rotated. The best procedure is to align a feature that appears on both of the overlaid images, then **click** on the feature. Look at another point in the image some distance away and adjust the rotation to line up the second point.

To determine if the results are satisfactory, click the **Overlay All Images** button to produce a preview.

Remove Bad Pixels

Many CCD cameras have physical flaws which prevent individual pixels, columns or rows of pixels from responding properly to incoming light. The result is that portions of the image are at either the saturation level or the bias level, regardless of the amount of light that they've received. This command ameliorates the effects of these bad pixels, whether individual, or arranged in groups, columns or rows

The user can select one of five **Bad Pixel Maps**. It is possible to customize the name of each **Bad Pixel Map** by typing a new name in the **Bad Pixel Map** field.

The **table** lists the bad pixels, rows, and columns. The **Mode** shows whether it is a column, row, or point defect. The **X** and **Y** coordinates give the location of the defect. **Begin** and **End** indicate the starting and ending positions for a partial row or column.

Bad pixel maps can be generated **automatically**, **manually** using the **mouse**, or **manually** using the **keyboard** (see below).

The image is trimmed if a bad column or row is at the edge of the image. Bad pixels within the image are replaced by interpolating from surrounding good pixels. A small amount of Gaussian noise can be added to the interpolated values to improve the cosmetic appearance (only bad pixels are affected). The standard deviation of the noise can be entered using the **Noise** field.



Clicking the **Save Map** button will save the current map and close the dialog without processing the image. **Process** will save the current map, process the current image, and close the dialog. The **Cancel** button will close the dialog without saving.

Automatic Map Generation

Clicking the **Auto Generate** button will bring up the **Auto Generate** sub-dialog.



All pixels which have a value below the **Dead Pixel Threshold** will be marked as bad. All pixels which have values above the **Hot Pixel Threshold** will also be labeled as bad.

One method for generating the map is to take a flat-field exposure (evenly illuminated source) and knock out all pixels which are much above or below the average. To eliminate hot pixels, it is often better to take a dark frame and eliminate all pixels above a threshold.

Mouse Map Generation

Turn on the **Use Mouse** check box, and select the **Mode** as follows:

- Point – click on a single pixel to mark as bad
- Row – click anywhere on a row to set
- Column – click anywhere on a column to set
- Partial Row – click and drag to select a portion of a row
- Partial Column – click and drag to select a portion of a row

The selected region will be added to the table automatically.

Keyboard Map Generation

This works the same as **Mouse Map Generation** except that the coordinates are entered manually using the **X**, **Y**, **Begin**, and **End** edit boxes. When the correct values are entered, click the **Add** button to add it to the table.

Entries can also be deleted or modified. First **select** the desired entry in the table by clicking on the item in the **leftmost column** of the row (**Mode** column). If you wish to modify the entry, change the appropriate edit field and click **Modify**. If you wish to delete the entry, click the **Delete** button.

Add Noise

This command is used for cosmetic improvement of images. Adding a small amount of noise can cover up minor blemishes. It can also solve the problem of areas with gradual

changes in brightness; the human eye is very effective at detecting the shift from one color or brightness level to the next, resulting in a banded or contoured appearance (Mach bands). Adding a small amount of random noise can eliminate this visual effect.



The **Amplitude** of the noise can be controlled, as can the **Type** of statistical distribution. **Gaussian** noise is typical of CCD images and is usually the best choice. When **Gaussian** is selected, the **Amplitude** controls the **standard deviation** of the noise. **Uniform** noise can also be selected, in which case **Amplitude** controls the peak-to-peak variation in the noise.

Remove Bloom

The **Remove Bloom** command is used to improve the appearance of an image by removing blooms, the trails that emanate away from bright stars up and down the columns of a CCD array. Blooming occurs when the wells that collect the charge during the exposure overflow and spill their charge into adjoining pixels. Bloom removal is a cosmetic process, because it is not possible to restore the information that was lost when the excess charge slopped over into the bloomed pixels. What this command does is try to restore those pixels to the same level as the local background.

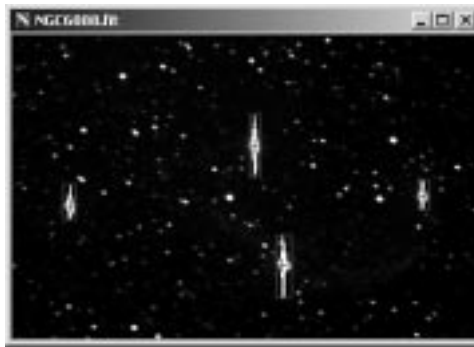


Bloom removal is a two-step process. First, MaxIm DL identifies bloomed regions in the

image; next, it replaces the pixels within those regions. In many cases the process can be performed almost without operator intervention by clicking **Automatic** to perform the first stage, then **Preview** to do the second and view the result. **Automatic** searches the image for pixels that exceed the specified **Saturation Level** and which are organized into non-circular areas. This process is not very sensitive to **Saturation Level**, and a value of around 75% of the maximum pixel value possible from your camera usually gives good results. If the **Saturation Level** is set too high, some blooms may escape identification; if set too low, small regions of unusually-shaped stellar concentration may be erroneously tagged. In extreme cases, when set either too high or too low, you will get the error "No blooms detected in image".

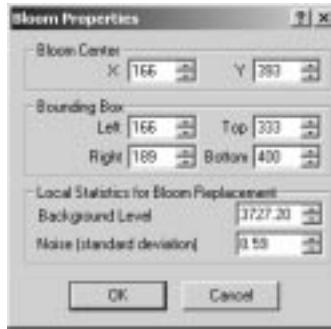
Each identified bloom is highlighted by a red rectangle which contains a red cross (+) positioned at the center of energy of the bloom. This should be the location of star that caused the bloom:

If you are not satisfied with the size or shape of a bloom's bounding box, you can reposition or resize it by **dragging** a side or corner. Similarly, you can reposition the center of energy by dragging the cross. To remove a bloom bounding box and its associated center of energy altogether, **right-click** on either the box or cross and pick **Remove** from the pop-up menu that appears. This might be necessary if a close double star was misidentified as a short bloom. (If **right-clicking** presents the standard image pop-up menu for aperture adjustment instead, you didn't click exactly on the marker.) It is advisable to zoom in to 200% or 400% magnification when making this kind of adjustment.



An alternate method of adjusting bloom bounding boxes and centers is to call up the **Bloom Properties** from the **right-click menu**. This allows you to specify values for the **Bloom Center X** and **Y** coordinates, and the **Left**, **Right**, **Top** and **Bottom X** and **Y** values for the **Bounding Box** either by typing the numbers, or more conveniently by using the **up/down spin buttons** to increment or decrement them while observing the effect on the box in the document. You can also set the **Background Level** and **Noise**

(**standard deviation**) used for this bloom; for example, increase the **Noise** value somewhat if the replaced pixels appear too smooth or "smeared".



You can also manually tag blooms by clicking on the **Manual** button in the main **Remove Bloom** toolbox and then dragging out a bounding box with the mouse. The center of energy is automatically compute, but you can use the techniques just described to reposition it or to adjust the box.

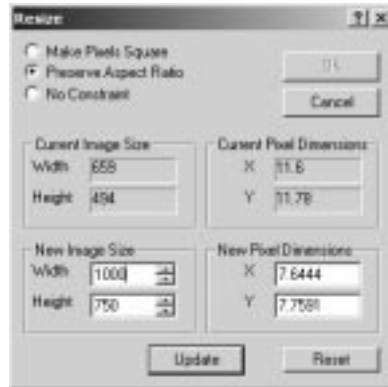
When you click **Preview**, MaxIm DL scans along the midline of the bloom from the center outwards, computes the background level and noise characteristics in the vicinity and replaces bloomed pixel values with plausibly synthesized values. Replacement stops only when the first pixel at or below the local background level is encountered. Because of this, a faint star that happens to touch a bloom can be removed along with the bloom. If possible, reduce the size of the bounding box to prevent this. If this is not possible, you may be able to use the **Edit Pixels** command beforehand to isolate the erstwhile "vanishing" star from the bloom with a few background-level pixels.

Pixels close to the center of energy are replaced according to a model of the star's line profile, averaged in several different directions. If the center of energy was not correctly located, the result can be a slightly bloated star. The example image of NGC6888 shown above illustrates a poor central energy position. In addition, its bounding box is arguably a couple of pixels too wide.

Resize

The **Resize** command allows you to change the size and/or aspect ratio of an image. When **No Constraint** is selected, the image can be enlarged or shrunk by typing in new values **Width** and **Height**. Upon pressing the **Enter** key (or clicking **Update**) the new physical dimensions of the pixels will be displayed (nominally, the pixel dimensions are measured in microns). Alternatively, new pixel dimensions can be entered and the **Width** and **Height** will be updated. This allows you to directly change the aspect ratio of the image.

If an image has non-square pixel dimensions, selecting **Make Pixels Square** will force the pixel dimensions to square. By default, one image axis will be enlarged and the other will be left as-is. You can simultaneously scale the image by modifying the **Width** or **Height** and pressing **Enter**; the other dimension will update to reflect the change.



Selecting **Preserve Aspect Ratio** will cause the current aspect ratio to be maintained. If one of the dimensions is changed, pressing **Enter** will cause the other dimension to update appropriately so as to maintain the aspect ratio.

Clicking **Reset** will cause the image dimensions to be reset to the current values.

Once the desired dimensions have been entered, clicking **OK** will cause the image to be resized. A bilinear interpolation algorithm is used.

Double Size

This command will double the size of the selected image. This command uses a more sophisticated interpolation algorithm than the **Resize** command.

Half Size

This command will reduce the size of the selected image by a factor of two in each dimension. This command uses a more sophisticated interpolation algorithm than does either of the **Resize** or **Bin 2x2** commands.

Make Pixels Square

This command provides a one-step adjustment of the image aspect ratio. It uses the pixel aspect ratio determined by the file header and interpolates the image to make the aspect ratio 1:1.

The pixel aspect ratio can be viewed and modified using the **FITS Header**

viewer/editor. The appropriate keywords are **XPIXSZ** (pixel width in microns) and **YPIXSZ** (pixel height in microns).

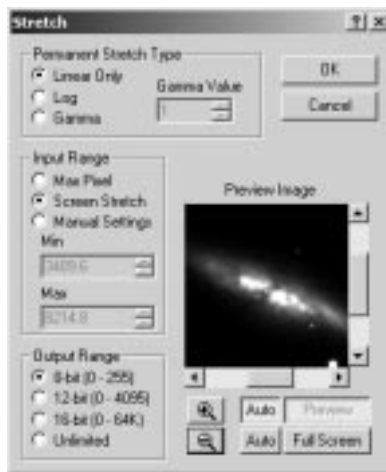
Stretch

The **Stretch** command modifies the brightness and contrast, and optionally the range (maximum and minimum pixel values) of an image. Unlike the screen stretch settings in the **Screen Stretch** window, which only affects the how an image appears on the display, the Stretch command actually changes the image data pixel values in the memory buffer.

There are three elements which must be set: the **Permanent Stretch Type**, the **Input Range**, and the **Output Range**.

The **Linear Only** mode is useful for adjusting the range of pixels to match a particular file format. The **Log** mode is useful for compressing the dynamic range of the image, but can be rather harsh. The **Gamma** mode allows you to selectively emphasize bright or dim parts of the image by entering a suitable **Gamma Value**. A **Gamma** of **1** has **no effect**, **less than 1** will **emphasize faint details**, while a value **greater than 1** will **emphasize bright details**.

The **Input Range** can be set to **Screen Stretch**, which produces an output in **Linear Mode** that matches the current screen appearance. (Note that the minimum and maximum values are always taken from the **Screen Stretch** window for the original image, not that of the preview.) This is useful in producing final images for output to 8-bit image formats which have limited range. The **Max Pixel** selection sets the input range from 0 to the brightest pixel in the image. This prevents any image pixels from being saturated in the final result, but may produce images with low contrast. You can also **manually** set values in a similar fashion to the **Screen Stretch** window.



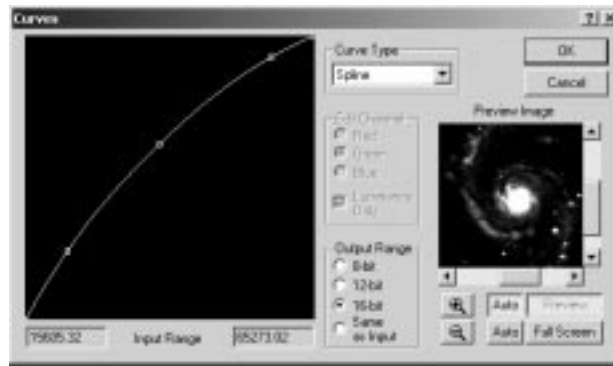
The **Output Range** is used when preparing a file to be saved in a format that has limited range. The input range maps **Min** input to **zero**, and **Max** to **255**, **4095**, or **65535** depending on the settings (i.e. output value = input value * output range / input range). Any values that exceed the limits are clipped. The **Unlimited** setting disables all limiting and is recommended when performing **Gamma** and **Log** stretches; it is appropriate when the image will be saved in floating point format.

Curves

This command allows you to specify a transfer curve for the image. The line graph is a mathematical transfer function with input along the horizontal axis and output along the vertical axis. A flat line from bottom-left to top right corner has no effect on the image.

Clicking on the graph area places control points which describe the curve. The effect of these points depends on the **Curve Type** setting. When **Piecewise Linear** is selected, MaxIm DL generates a curve by drawing straight lines between each of the control points. When **Spline** is selected, a smooth curve is generated that is guaranteed to pass through each of the control points. Selecting **Modified Spline** is the same as selecting **Spline**, except that MaxIm DL automatically adds additional points to the curve to smooth it out still further. Certain combinations of control points can produce curves with unexpected characteristics when using the **Spline** function, but this problem can often be corrected just by switching to the **Modified Spline** function.

The curve shown in the diagram is similar to applying a gamma function to the image. More complex curves are possible; you can create a very non-linear mapping between the input levels and the output levels.



For color images the **Edit Channel** selectors will be available. You can adjust the overall luminance by selecting **Luminance Only**, or tweak the three color planes individually. When Luminance Only is off, the transfer graph shows three lines, one for each color. Select **Red**, **Green**, or **Blue** to edit the transfer graph for that color plane.



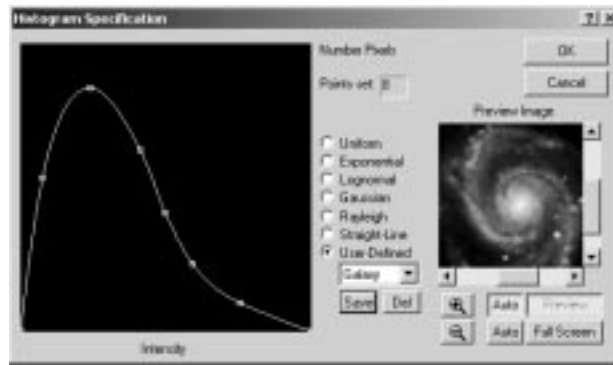
When editing the line, you can **right-click** on the graph to bring up a menu. If the image is monochrome, you are always working in monochrome mode, and the right-hand pane of the menu will not be displayed. If the image is color, then the right-hand pane is displayed, and is used to select the color plane that will be modified when you click on the graph. Clicking **R**, **G**, **B** or **Mono** is equivalent to clicking on the **Red**, **Green**, **Blue** or **Luminance Only** controls in the **Edit Channel** group box. **Insert a point** inserts a point, just like left-clicking the graph. The **Delete a point** option is only available if you right click on a point that's already been created; selecting it deletes the point. Select **Same As** and a further popup menu appears. Selecting the items **R**, **G**, **B** on the popup will change the curve for the current plane to match the clicked one. Choosing **Reset curve** resets the curve to a straight line.

The **Input range** for the transfer function is the minimum and maximum pixel value in the image, and is displayed just beneath the graph. The **Output range** is user-specified. The available choices are **8-bit** (the output range is 0-255), **12-bit** (range is 0-4095), **16-bit** (range is 0-65535) or **Same as input**, in which case the transfer function produces an output image with the same minimum and maximum intensity as the input.

Histogram Specification

Histogram Specification is a generalized version of histogram equalization, a standard image processing operation. An equalized image has an equal number of pixels at all

brightness levels, resulting in a straight horizontal line on the histogram graph. When you specify a histogram, you actually define the desired shape of the histogram, and a nonlinear stretch operation is applied to force the image's histogram to have that shape.



Histogram specification is useful for compressing the dynamic range of an image in order to remove pixel values that contain very little information. This makes an image easier to view on a video monitor. It also allows you to emphasize information that appears at certain brightness levels. You can specify the curve by drawing it manually, or select from the pre-defined list of curves. Predefined curves include **Uniform**, **Exponential**, **Lognormal**, **Gaussian**, **Rayleigh**, and **Straight-Line**.

Note that the histogram shown in this dialog has a linear vertical axis, unlike the **Screen Stretch** window, which has a logarithmic vertical axis.

The user can **manually** create any desired curve by **clicking on the graph**. **Click and drag** an existing point to change the shape, or add another point by **clicking** in a blank area of the graph. To **remove** a point, use the **mouse to drag it** past a neighbor. To reset the graph to a simple state before manually drawing points, set the mode to **Uniform** or **Straight-Line**.

You can save and recall manual curves. To save, click the **Save** button, enter a name, and click **OK**. To select an existing curve, **select** it from the list (warning: this will replace any curve you may have manually entered but not saved). To remove a curve, **select** it on the list and click **Del**; you will be asked to confirm before the entry will be deleted.

The dialog includes displays indicating how many points have been set, and a warning when the maximum number of points (37) has been reached.

Threshold

The Threshold command can be used to suppress pixel values above and/or below certain values. Data exceeding the threshold level can be either set to zero, or to the

threshold value.



The **Maximum Threshold** can be turned on/off using the **Enable** check box. If **Zero** is on, values above the threshold level are set to zero. If **Zero** is off, values above the threshold level are set to the threshold level.

The **Minimum Threshold** can be turned on/off using the **Enable** check box. If **Zero** is on, values below the threshold level are set to zero. If **Zero** is off, values below the threshold level are set to the threshold level.

Pixel Math

The **Pixel Math** command allows you to perform a pixel-by-pixel mathematical operation on either a single image or two images.

The **Image A** and **Image B** fields allow you to specify the images; only **Image A** is available if the **Operation** is **None**. **Scale Factors** (in percent) can be applied to each image before the operation, and a **Constant** can be added after the operation. After the constant is added, any negative values are forced to zero.

When performing **Pixel Math** on a single image, the only operation available to be performed on it is **Scale Factor**. A value of 100% results in no change, while 50% and 200% would change pixel values to one-half and double their original values, respectively.

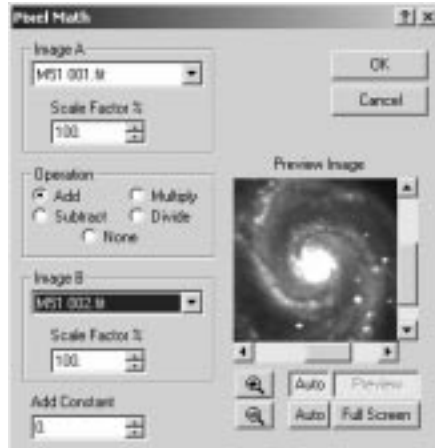
When working with two images, the order of operations proceeds as follows:

- Pixel values in both **Image A** and **Image B** are multiplied by their respective Scale Factors.
- Depending on the operand selected in **Operation**, the mathematical operation

is performed as either **A plus B (Add)**, **A minus B (Subtract)**, **A times B (Multiply)**, or **A divided by B (Divide)**.

- The value in **Add Constant** (which can be made negative) is added to the result obtained by the preceding **Operation**.

If the **Operation** is division, zero values in **Image B** result in zero values on output (before the addition of the **Constant**).



Filter Menu

Kernel Filters

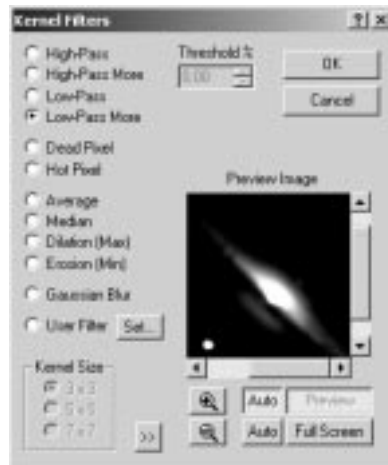
Kernel filters provide low- and high-pass filtering (smoothing and sharpening, respectively) using a kernel. Several default filters are available, and the user can supply up to twelve different **User filters** defined using a subsidiary dialog called up by clicking the **Set** button, and described **below**.

In addition to standard **High-Pass** and **Low-Pass** filters of two strengths, several special-purpose kernels are available. These include **Gaussian Blur**, **Dead Pixel** and **Hot Pixel** removal, **Median** filter, **Dilation**, and **Erosion**. For these filters, you can adjust the size of the kernel using the **Kernel Size** control.

The **Average** filter is simply a "boxcar" low-pass filter which takes the average of the surrounding pixels.

Dead pixel removal is useful for removing the effects of unresponsive pixels in the CCD camera. The filter removes any pixels that are darker than a certain fraction of the

darkest neighboring pixel. The fraction is determined by entering a **Threshold** level in percent. If a pixel is to be replaced, the median of the surrounding pixels is used.



Hot pixel removal is useful for removing CCD image defects caused by cosmic rays or pixels that have very high dark current. This filter replaces any pixels that exceed the level of the brightest neighboring pixel by more than a percentage of its brightness. The desired percentage is entered in the **Threshold** field. If a pixel is to be replaced, the median of the surrounding pixels is used.


The **Erosion** filter replaces pixels with the darkest of the surrounding pixels, while the **Dilation** filter replaces pixels with the brightest of the surrounding pixels.

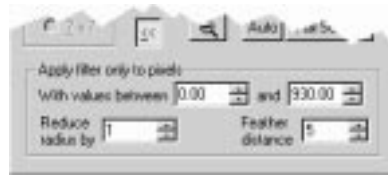
The **Gaussian Blur** filter removes fine detail and noise by convolving the image with a circularly symmetric gaussian curve, whose standard deviation you specify in the **Radius** field (which replaces **Threshold** when this filter type is picked). In effect, each pixel's energy is redistributed into a three-dimensional "bell curve", and the resulting values added at every pixel in the destination image. The effect is to blur the image as if through an out-of-focus lens. In common with other kernel filters, points within half the kernel size of the edge of the image are not processed. Bear in mind that due to the bell-shaped **Gaussian Blur** kernel, pixels will be affected out to size times the specified radius.

Pixel Range Restriction

The **Kernel Filters** dialog supports an advanced feature called "pixel range restriction", which allows you to apply the filter to a subset of the image. One example of its use is to apply a low-pass filter only to the darker areas of an image, so as to reduce the effect of noise there, yet not soften the edges of stars. Some care is required in its use, and a little

experimentation and experience will teach you how and when to apply it.

Click the otherwise unlabelled "unfold" button  to expand the **Kernel Filters** dialog, revealing the **Apply filter only to pixels** restriction:



Enter the minimum and maximum values of pixels to be affected into the two **With values between** fields. Pixels within **Reduce radius by** pixels of a pixel whose value is outside this range are completely protected against the operation of the filter. The filtered values of qualifying pixels that lie within **Feather distance** of a protected pixel are blended with the original value using a weight that varies with the distance; for example, with **Feather distance** equal to 3, pixels adjacent to a protected pixel receive only one-quarter the effect of the full filter, those two pixels away receive half the effect, and those three pixels away receive three-quarters. When **Feather distance** is zero, 100% filtered pixels can be adjacent to completely unaffected ones.

When not using pixel range restriction, it is advisable to keep the **Apply filter only to pixels** restriction "folded up" and inapplicable. When it is displayed, it is possible for inappropriate minimum and maximum pixel range values to silently prevent a filter from having any effect at all.

User Filter Definition

The user can specify one of three **Kernel Sizes** for each of twelve kernels. Once a kernel is defined it is automatically stored for future use. A user-supplied **name** can be applied to each kernel to allow quick selection. The kernel is automatically normalized to unity by the filtering algorithm; i.e. the weights are adjusted so that their sum is one (1).



FFT Filters


FFT Filters provide precisely controlled low- and high-pass filtering (smoothing and sharpening, respectively) using a Butterworth characteristic. The image is converted into spatial frequencies using a **Fast Fourier Transform**, the appropriate filter is applied, and the image is converted back using an inverse FFT.



By selecting **High-Pass** or **Low-Pass**, you can perform **sharpening** or **smoothing**. The **Filter Hardness** selector enters pre-defined values into the **Cutoff** and **Weight** fields. The **Cutoff** is entered as a percentage of the image dimensions. For a **Low-Pass** filter, spatial frequencies shorter than the radius are suppressed (a small radius yields a stronger effect); for a **High-Pass** filter, spatial frequencies longer than the radius are suppressed (a large radius yields a stronger effect).

Pixel Range Restriction

The **FFT Filters** dialog supports an advanced feature called "pixel range restriction", which allows you to apply the filter to a subset of the image. One example of its use is to low-pass filter only to the darker areas of an image so as to reduce the effect of noise there, yet not soften the edges of stars. Some care is required in its use, and a little experimentation and experience will teach you how and when to apply it.

Click the **Pixel Range Restriction** "unfold" button  to expand the **FFT Filters** dialog, revealing the **Apply filter only to pixels** restriction:



Enter the minimum and maximum values of pixels to be affected into the two **With values between** fields. Pixels within **Reduce radius by** pixels of a pixel whose value is outside this range are completely protected against the operation of the filter. The filtered values of qualifying pixels that lie within **Feather distance** of a protected pixel are blended with the original value using a weight that varies with the distance; for example, with **Feather distance** equal to 3, pixels adjacent to a protected pixel receive only one-quarter the effect of the full filter, those two pixels away receive half the effect, and those three pixels away receive three-quarters. When **Feather distance** is zero, 100% filtered pixels can be adjacent to completely unaffected ones.

When not using pixel range restriction, it is advisable to keep the **Apply filter only to pixels** restriction "folded up" and inapplicable. When it is displayed, it is possible for inappropriate minimum and maximum pixel range values to silently prevent a filter from having any effect at all.

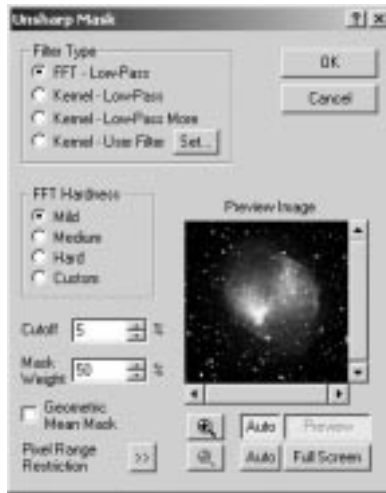
Unsharp Mask

Unsharp masking is a method of sharpening or high-pass filtering an image. It amounts to subtracting a low-pass filtered version of an image from itself. The low-pass filtered version is called the mask.

The **Unsharp Mask** dialog provides a number of different mask modes. You can specify **FFT** filters and pre-defined or user-defined **kernel** filters. The mask filters work identically to those in the **FFT Filter** and **Kernel Filter** commands. The **Set User Filter** button also works identically to that in the **Kernel Filter** dialog.

For **FFT Filters**, the **Cutoff** field controls the strength of the filter. The **Cutoff** radius is entered as a percentage of the image dimensions. Entering a smaller value produces a

stronger filter. A strong filter is useful for removing large-scale brightness variations, while a weak filter is useful for emphasizing fine detail.




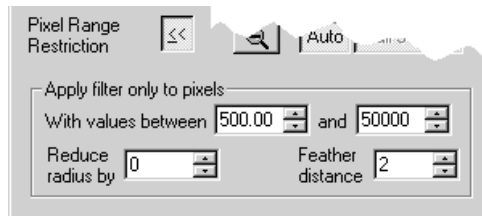
The **Mask Weight** is used to control the strength of the mask. The mask weight is in percent; the higher the number, the stronger the mask.

The **Geometric Mean Mask** mode is useful for extracting faint structure from images that contain large variations in brightness, such as are found near the nuclei of comets. When this mode is selected, the mask is performed in a logarithmic domain.

Pixel Range Restriction

The **FFT Filters** dialog supports an advanced feature called "pixel range restriction", which allows you to apply the filter to a subset of the image. For example, you could unsharp mask only the lighter areas of an image, thereby avoiding accentuating noise in darker regions. Some care is required in its use, and a little experimentation and experience will teach you how and when to apply it.

Click the **Pixel Range Restriction** "unfold" button  to expand the **FFT Filters** dialog, revealing the **Apply filter only to pixels** restriction:

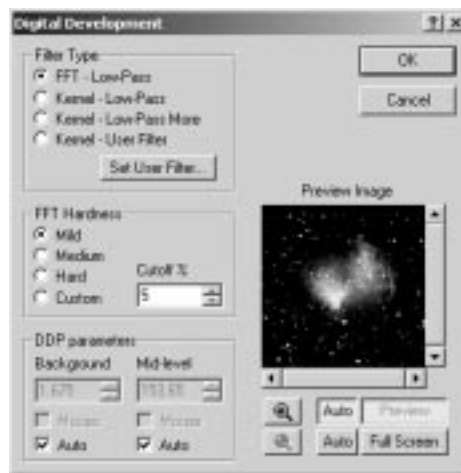


Enter the minimum and maximum values of pixels to be affected into the two **With values between** fields. Pixels within **Reduce radius by** pixels of a pixel whose value is outside this range are completely protected against the operation of the filter. The filtered values of qualifying pixels that lie within **Feather distance** of a protected pixel are blended with the original value using a weight that varies with the distance; for example, with **Feather distance** equal to 3, pixels adjacent to a protected pixel receive only one-quarter the effect of the full filter, those two pixels away receive half the effect, and those three pixels away receive three-quarters. When **Feather distance** is zero, 100% filtered pixels can be adjacent to completely unaffected ones.

When not using pixel range restriction, it is advisable to keep the **Apply filter only to pixels** restriction "folded up" and inapplicable. When it is displayed, it is possible for inappropriate minimum and maximum pixel range values to silently prevent a filter from having any effect at all.

Digital Development

Digital Development Processing is an interesting algorithm invented by Dr. Kunihiko Okano. It performs a combination of **gamma** stretching and **unsharp masking** intended to simulate the effect of photographic development on images. It is particularly effective at processing objects such as galaxies.



Like **Unsharp Mask**, this command requires a **low-pass filter** setting. You can select either an **FFT** or **kernel filter** of various strengths. The filters work identically to those in the **FFT Filter** and **Kernel Filter** commands. The **Set User Filter** button also works identically to that in the **Kernel Filter** dialog.

For **FFT Filters**, the **Cutoff** field controls the strength of the filter. The **Cutoff radius** is

entered as a percentage of the image dimensions. Entering a smaller value produces a stronger filter. A strong filter is useful for removing large-scale brightness variations, while a weak filter is useful for emphasizing fine detail.

There are two other parameters that need to be set. **Background** should be set to the average background level in the image. This can be calculated automatically by selecting the associated **Auto** check box. Normally this is sufficient; however, the level can also be set manually or by using the mouse. Turn off the **Auto** check box to edit manually. To use the mouse, turn off **Auto** and turn on **Mouse**. Point the **mouse** at a background area in the image (not the preview) and **click** the **left mouse button**.

The **Mid-level** setting is more critical. It controls the "break point" in the transfer curve, and should be set to a middle level in the image. It can be calculated automatically, but using the **Mouse** input method is recommended. The best procedure is to activate **Auto Preview** mode, and **click** the **mouse** in various foreground areas of the image buffer (not the preview) until you are satisfied with the preview image. Note that the **Mid-level** setting must be **higher** than the **Background** setting.

Rank Filter

The Rank Filter amplifies faint detail by replacing each pixel by its position or rank within the sorted list of the values of its neighbors within a specified **Radius**. This procedure accentuates small differences among nearby pixels at the cost of the loss of information about the relative brightnesses of pixels separated from each other by greater distances.

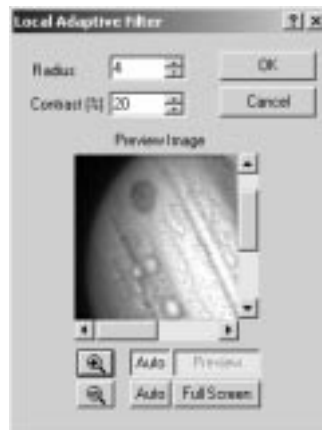


Because the rank filter algorithm is intrinsically very harsh, its effect usually has to be diluted by mixing it with the original image, thereby preserving more of the information about large-scale brightness variations across the image. The **Weight** controls how

strongly the filter is applied.

Local Adaptive Filter

This filter sharpens any fine image details that are of low contrast. It determines the contrast of a region by calculating a ratio between the average value in the neighborhood and the standard deviation of the same neighborhood. The difference between the pixel and the average background is then multiplied by this contrast factor. Thus, variations in areas of low contrast are preferentially amplified. This algorithm can be very effective for extracting subtle details from planetary images; however, it can also cause excessive noise amplification so it should be used with care.



Radius controls the region that is considered “local”. Smaller regions result in more amplification of smaller details, but also tend to amplify noise more. **Contrast (%)** determines how much of the contrast amplification is applied.

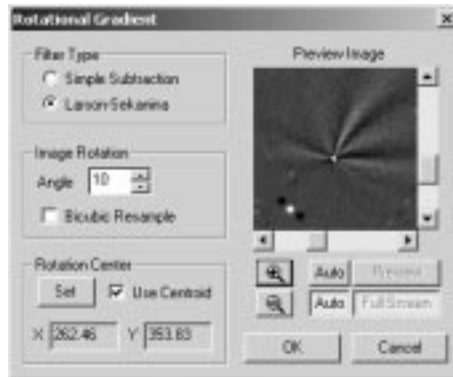
Rotational Gradient

The **Rotational Gradient** filters are useful for enhancing low contrast structures that are radially organized about some point in an image. They are particularly suited to bringing out details such as jets in comets, such as near-nucleus jets and gas tail structure. Two types are provided: the **Simple Subtraction** filter takes the difference between two oppositely-rotated copies of the image from each other, while the **Larson-Sekanina** filter adds the two and subtracts the result from twice the original image. In either case, a constant is added so as to make the minimum pixel in the result zero.

Select the **Filter Type** desired. The **Simple Subtraction** filter is the more aggressive of the two, but fine detail tends to get lost. Moreover, the output is not symmetric, in that positive and negative features are rotated in opposite directions, and the eye tends to notice the former more readily, resulting in an apparent rotation. This is particularly

obvious when blinking the filter output against the input. The **Larson-Sekanina** filter shows finer detail but its output is also more subtle.

Both **Rotational Gradient** filters require a **Rotation Center**, which should normally be positioned - in the case of a comet - on the nucleus. MaxIm DL attempts to set this automatically when you open the tool by searching the image for the likely candidate. However, if the object of interest is small, faint, or there are bright stars in the image, it is possible that MaxIm DL will pick the wrong point. To set the **Rotation Center** manually, click the **Set** button, then click the mouse on desired center point in the image (not the thumbnail). The coordinates of this point will be transferred to the **X** and **Y** fields. If **Use Centroid** is checked (recommended), the centroid of the current rotation center pixel will be used and displayed instead, irrespective of whether it was specified automatically or manually.



Set the **Angle** field (in degrees) to the amount by which the image is to be rotated. Typically this will be in the range from 1–5 degrees, though values of up to 90° can be used for special purposes. Two modes are available with which to perform pixel interpolation during the rotation: **Bicubic Resample** uses a higher-order resample algorithm which requires more processing time than the bilinear method used when this control is not checked.

Deconvolve

This command performs either Maximum Entropy or Lucy-Richardson deconvolution of an image. Deconvolution is an advanced image restoration technique which can remove the effects of blurring in an image. This technique, first pioneered for radio astronomy, became very important for visible-light astronomers when the problems with the Hubble Space Telescope were discovered. Even after the installation of corrective optics on the Hubble's instruments, deconvolution techniques have remained important and widely used tools for processing and improving images both from HST and from ground-based observatories.

Outside of astronomical applications, the same image techniques can be applied to just about any image, from microscope pictures to security camera video frames. The only essential requirement is that the image be blurry! Undersampled images, such as those taken with very short focal lengths, will already be as sharp as is possible. If the pixels are too big to resolve the blur, then deconvolution cannot improve the resolution.

Only limited image processing should be performed before deconvolution. CCD images should be calibrated first to minimize consistent effects introduced by the camera (gain, thermal noise) and optical system (flat fielding). If you are combining images or files to reduce noise this operation should also be performed before deconvolution. If the camera does not produce square pixels, it is recommended that you interpolate them to a square aspect ratio before proceeding. Hot and dead pixels should be fixed. If you do not wish to deconvolve each channel separately, color combining of RGB or CMY images may be done beforehand; for LRGB and LCMY images, you will achieve better results by deconvolving the luminance image before color combining. It is strongly recommended that all other processing functions be deferred until after deconvolution.

The success of deconvolution depends critically on the Point-Spread Function and Noise models, which must be initialized before you can perform the processing itself. If the selected noise model is Poisson, or when using the Lucy-Richardson method, the correct Photoelectrons per ADU setting must be entered; this can be done within the Deconvolve dialog, or separately using the Photons Wizard. Images acquired by MaxIm DL/CCD already include this parameter in the FITS header for many camera plug-ins. Settings of all these parameters persist within a particular MaxIm DL session, but you must be careful to avoid processing a mix of images from different cameras or telescopes without resetting them for each different configuration.

Since experimentation is sometimes required to determine the settings which will produce the best results, a mechanism is provided to allow quick evaluation by operating on a subset of the image.

The **Deconvolve** command is implemented as a tabbed dialog box with tabs for each of the three steps in the process:

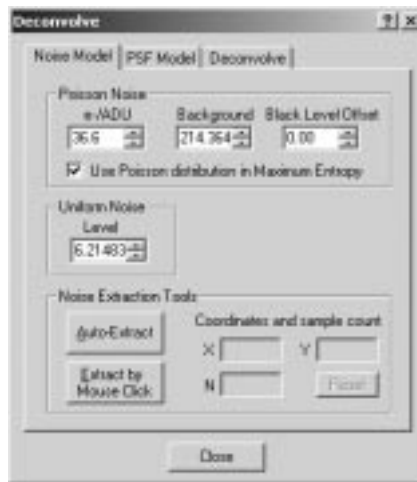
- Specifying the Noise Model
- Specifying the PSF Model
- Deconvolving the image

Noise Model

The **Noise Model** tab is used to initialize the noise model utilized used by deconvolution. This is used to determine how strongly to deconvolve different parts of the image. Areas that are mostly noise are not deconvolved as strongly so as to prevent

noise amplification; the algorithm will preferentially work on areas of the image that contain information.

The **Poisson Noise** distribution is required when using the Lucy-Richardson method, and is recommended when using the Maximum Entropy method on images from high-performance cooled CCD cameras; in the latter case, you must check **Use Poisson distribution in Maximum Entropy**. The **e-/ADU** (photoelectrons per ADU) setting is used to indicate the CCD camera gain, and is required because Poisson noise statistics are based upon photon shot noise. The value for **e-/ADU** is set automatically from the EGAIN keyword in the FITS header, if present, or can be entered manually or using the **Photons Wizard**, which helps determine the proper setting for your camera. The **Background** field is set just below the average background level in the image. The **Black Level Offset** specifies the value of any offset that was added to the image before deconvolution, and is set automatically to the negative of the value of the PEDESTAL keyword in the FITS header, if present. Otherwise set it to 0 for raw images or 100 if the image was calibrated in MaxIm DL.



The usual choice for the **Uniform Noise Level** is the standard deviation of the pixel values in a part of the image that contains no detail. This value is required when using the Lucy-Richardson method.

Click **Auto-Extract** to automatically determine the correct settings for **Background** and **Uniform Noise Level**. Alternatively, you can extract these values from the image manually using **Extract by Mouse Click**. When this button is pressed, you can use the mouse to select one or more regions, each the current size of the aperture (innermost circle of the mouse rings cursor) where the background level is to be measured. (**Right-click** on an image to change the aperture size via the standard context menu .) Point the

mouse to a dark area of the image which contains no detail, then **click**. If more than one area is selected the results are averaged; red marker circles are left to indicate the region(s) that you have sampled. **X** and **Y** show the coordinates of the most recent area sampled, and **N** shows the number of areas included in the measurement; you can click **Reset** to start over.

You can sample the noise statistics from any open image. Normally you will want to sample from the image you are about to deconvolve, but in special cases you might choose to obtain the noise statistics from a different one. Just click on the title bar or image tab of the desired image before clicking **Auto-Extract** or **Extract by Mouse Click**.

PSF Model

The key to successful deconvolution is obtaining a good point-spread function (PSF). The PSF is a model of how the image was blurred. Deconvolution uses this information to remove the blur from the image. Given the importance of obtaining a good PSF, a number of tools are supplied for this purpose.



Three types of PSF are available. **Gaussian** is commonly used for removing blur caused by atmospheric seeing. **Exponential** is often used to model blur from optical systems. **From Image** allows you to extract a point-like object (such as a star) from the image to use directly as the PSF; this is especially useful when the blur is not symmetrical. All three types of PSF are represented internally as a small image of 64x64 pixels, and the **From File** option provides for loading such a PSF from a file.

The **Function Type** must be set up first. **From Image** can be used when a clean star or other point source is available in the image, and is recommended if there is trailing

(resulting from poor guiding) in the image. Otherwise, the **Gaussian** or **Exponential** models should be used.

If **From Image** is selected, a star must be extracted from the image (see below). This extracted star image is used directly as the point-spread function. If the background behind the star is very noisy, the **Clean Up** function can be used to remove this noise. Use the **Clean Up** option *only* when the background around the PSF is very noisy, as it can lead to "donuts" around stars.

When using **Gaussian** or **Exponential** point-spread function models, the **PSF Radius** (i.e. the standard deviation of the distribution) must be determined. A point-like object (star) can be extracted from the image to initialize the model. The selected distribution is fitted to the object in order to calculate the best-fit radius. If no suitable object is available to extract, you can estimate the required **PSF Radius** by inspecting the image.

Whether initializing either the **Gaussian** or **Exponential** modes, or **extracting** a point-like object to use directly as the PSF, a means of extracting such an object from the image is required. The **Automatic Select** button runs an algorithm which attempts to locate a point-like object having a high signal-to-noise ratio, and when found marks it with a red circle; this is particularly suitable for astronomical images containing stars. Alternatively, the **Select from Image** button allows you to select a specific object. When this button is pressed, use the mouse to **click** on a suitable point source in the image and mark it as the source of the PSF. Both methods display the coordinates in the **X** and **Y** field, which you can change directly if desired. The **Select from Image** button pops up automatically when you select a new PSF.

You can obtain the Point Spread Function from any open image, although normally you will want to take it from the image you are about to deconvolve. To capture it from a different one, click on the title bar or image tab of the desired image before clicking **Automatic Select** or **Select from Image**.

When the **From File** option is selected, you can click the **Select File** button to bring up the **Open** dialog. MaxIm DL will take the brightest pixel in the file as the center of the PSF. The resulting PSF is cropped or expanded to 64x64 pixels if necessary.

Once a PSF has been created, you can view it in its own window by clicking on the **Show PSF** button. An image buffer will be created containing the PSF image, which you can save to a file for later reuse with the **From File** option. The window is a copy of the PSF and not the PSF itself; that is, if you filter or process the image in any way, or close its window, you will not affect the current PSF. **Show PSF** is a latching button and remains depressed as long as the PSF window exists. Clicking the **Show PSF** button again (causing it to pop back up to the raised state) causes the PSF image window to be closed.

Point-spread functions can be sampled from color images, but are always themselves

monochrome. When conversion is necessary, it is done automatically.

Deconvolve

The **Deconvolve** dialog is where the actual deconvolution processing is initiated. The Noise and Point-Spread Function models must be initialized before you can start deconvolution.

Since there are a number of settings required, and sometimes experimentation is required to determine the best results, a mechanism is provided to allow quick evaluation by operating on a subset of the image.



When the dialog is invoked, the **Deconvolution Method** radio buttons are enabled, allowing you to select between the **Maximum Entropy** and **Lucy-Richardson** methods. This setting can only be changed when the iteration count shown in the **Status** area is at zero. The **Image Chi Square** readout appears only in **Lucy-Richardson** mode and can be used to monitor convergence.

Because processing speed is much faster for small images, **Operate On** allows you to choose between processing the **Full Image** or a subset of specified **Width** and **Height**. The latter is intended for quick turnaround while experimenting with the **Number of Iterations**, or determining the best noise or PSF models. The dimensions of the subset rectangle are constrained to powers of two because the use of FFTs in the deconvolution algorithm makes them the most efficient sizes to process; they can only be changed using the drop-downs. You can select which part of the image you want to deconvolve by **dragging** the white framing rectangle that appears on the image when you specify a subset of **Width** and **Height**. Once deconvolution has begun, you cannot change the size of the processing rectangle; to change its size, first re-initialize by clicking **Undo**,

whereupon **Status** will show the iteration count as zero.

To start deconvolving, enter the **Number of Iterations** to perform and click **Go**. The progress bar will start moving, and the **Status** display will report on the progress. If an image subset is being processed, the framing rectangle is redrawn in green to indicate it is no longer draggable; this is necessary since a given series of iterations must work on a consistent part of the image. Deconvolution is interruptible only at the end of each iteration. If you want to stop, click the **Stop** button and wait until the current iteration completes. Once stopped, you can reset to the initial conditions by clicking **Undo**, or resume the interrupted run by clicking **Go** again, perhaps after modifying the desired **Number of Iterations**.

Once you are satisfied with the results of a preliminary run, click **Undo** to return to the original image and reset the iteration count, which will allow you to change to **Full Image** mode. When only a subset of an image has been deconvolved, a **Cancel** button appears, warning you that closing the dialog will automatically restore the original image. If you really want an image of which only a part has been deconvolved, click the **Save permitted** checkbox to show the **OK** button in place of **Cancel**. Clicking this will terminate the deconvolution dialog while keeping the image exactly as shown. Such an image could be used as a source for the **Clone Tool**, allowing individual deconvolved stars to be copied back to a mostly original image.

When deconvolution is not iterating, you can also use **Undo/Redo** to toggle between views of the original and latest deconvolved images.

Color images can be deconvolved. The software automatically extracts and deconvolves the luminance image, recombining it with the color information when displaying intermediate and final results. If the results are not acceptable, you can use the **Split Tricolor** command to split the image into separate Red, Green, and Blue channels, deconvolve each separately, and then use the **Combine Color** command to reassemble the color image.

In Case of Convergence Problems

If your image will not converge, try the following:

1. Make sure the **Background Level** in the **Set Noise** command is just below the average background level in the image.
2. If you are using the **Poisson** noise model (recommended for most deep-sky images), make sure you have **Photons per ADU** set correctly.
3. If you are using the **Uniform** noise model, adjust the noise level to match the reading seen in the **Information** window's "**Dev**" field when you point the cursor at a smooth area of the image.

4. Try adjusting your point-spread function; an inaccurate setting could cause convergence problems.
5. If you are using the **Poisson** noise model with the **Maximum Entropy** method, try switching to **Uniform Noise** model instead.
6. Try doubling the **Uniform Noise Level** incrementally, beginning with the value recommended by **Auto-Extract**. Retry deconvolution each time until the image converges. Do not increase the **Uniform Noise Level** beyond that required to obtain convergence – try to find the minimum setting that works.

Why is the Subset Better?

If you are finding that a subset image looks better than the final processed result, chances are that you have poor noise model settings. In many cases, smaller images can converge more easily than larger ones. Try adjusting your noise model settings.

Photons Wizard

The **Photons Wizard** helps you determine the gain of your CCD camera. This information about the gain is needed for use with the **Poisson** noise model when initializing deconvolution. The Wizard explains how to determine this information. Three different techniques are available: enter the value from the camera's manual, calculate the value based upon full well capacity and bit depth, or calculate the value using statistics gathered from a set of bias and flat-field calibration frames. The latter is often more accurate since some CCD camera manufacturers do not control the camera gain carefully.

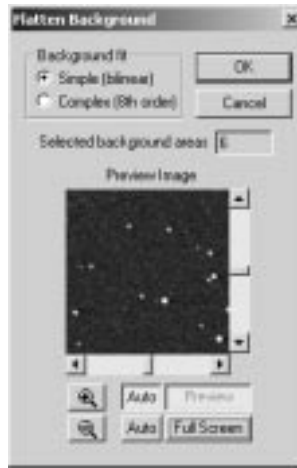


Flatten Background

The **Flatten Background** command can be used when the image background level

across the frame varies in a systematic way, and not due to the subject itself. Causes of these kinds of variation include a radial falloff in brightness due to instrumental vignetting, the proximity or inclusion in the image of bright stars or planets, or gradients due to sky glow, moonlight or light pollution.

Such problems can be reduced or even eliminated in many images by using this command. You specify four or more regions of the image to sample; the command then estimates the background level at those positions and fits either a plane or a higher-degree polynomial surface to the measured background at those locations. The resulting surface is subtracted from the image, thus reducing the variations. Because the command is interactive, you can preview the result and decide to add, delete, or move sample points. You can also work around any foreground objects that would bias the background extraction in the **Auto Remove Gradient** and **Auto Flatten Background** commands.



From **Background Fit**, pick the model you would like to use: **Simple (bilinear)** or **Complex (8th order)**. Now **click** the mouse on different background areas in the image window. Avoid areas of nebulosity, and try not to include stars in the aperture of the mouse (innermost circle of the rings cursor). You can change the size of the aperture over which the average measurement is made by **right-clicking** and picking **Increase Aperture**, **Decrease Aperture**, or **Set Aperture Radius** in the standard image **context menu**. If you right-clicked on a green circle marking an existing sample region, you will recompute that one sample with the new radius as well as setting the size of subsequent samples. You cannot place a sample circle so that it intersects a previously placed sample. You can **drag** the green circle for a previously-placed sample area to a different location or remove it entirely by right-clicking on it and picking **Discard background sample** from the head of the context menu.

You must place at least four samples before background flattening can occur. With fewer samples, attempts to update the **Preview Image** and/or the **Full Screen** preview are ignored, and clicking **OK** displays the error message "You must select at least 4 background points". For **Simple (bilinear)** mode, locations near the corners of the image are recommended. In **Complex (8th order)** mode, you will typically need eight or more points, more or less uniformly distributed. Good results can often be obtained by operating with **Auto Full Screen** preview enabled, and adding new samples in the lightest and darkest areas of the interim image. For critical work, you should set the **Screen Stretch** to **High** or to **Manual** with the **Minimum** and **Maximum** settings close together so as to exaggerate contrast.

Auto Flatten Background

The **Auto Flatten Background** command can be used when the image background level across the frame varies in a systematic way, and not due to the subject itself. Causes of these kinds of variation include a radial falloff in brightness due to instrumental vignetting, the proximity or inclusion in the image of bright stars or planets, or gradients due to sky glow, moonlight or light pollution.

Such problems can be reduced or even eliminated in many images by using this command. It estimates the background level in various regions of the image and then fits a two-dimensional polynomial surface to the background points. The resulting model is subtracted from the image, thus reducing the variations.

Note that the algorithm works best on star fields; images with a large foreground object consuming a significant part of the field can bias the background extraction.

Auto Remove Gradient

The **Auto Remove Gradient** command can be used when the image has a bright background that varies linearly across the frame. Typical causes of gradients in astronomical images are sky-glow, moonlight and light pollution.

This problem can be reduced or even eliminated in many images by using this command. It estimates the background level in various regions of the image and then fits a bilinear equation to the background points. The resulting model is subtracted from the image, thus reducing the variations.

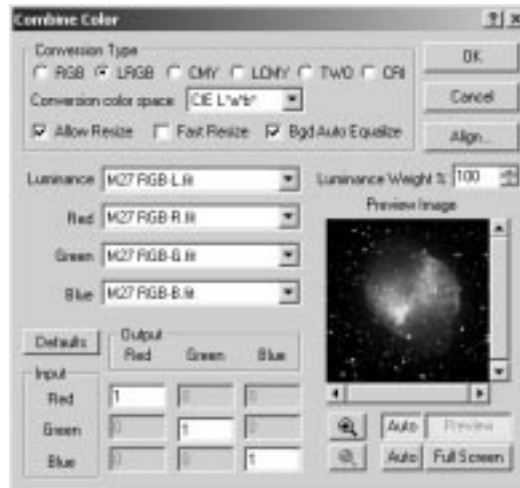
Note that the algorithm works best on star fields; images with a large foreground object consuming a significant part of the field can bias the background extraction.

Color Menu

Combine Color

The **Combine Color** command is used for combining up to four monochrome CCD images into a single color image. Most CCD cameras require that monochrome images be taken through various color filters and then combined afterwards into a color composite image.

This command can also be used to compare two or three unfiltered images by producing a composite and looking for color differences. Comparisons can also be done using the **Animate** command.



The first step in color conversion is to select the **Conversion Type**. Six options are available:

- **RGB** – red, green, and blue filters
- **LRGB** – red, green, blue, filters and luminance (white/unfiltered)
- **CMY** – cyan, magenta and yellow filters
- **LCMY** – luminance (white/unfiltered) and cyan, magenta and yellow filters
- **TWO** – two arbitrary images are combined as the red and green channels
- **CRI** – red, green, and blue images taken using a CRI Micro*color tunable filter; this setting can also be used for "mixing" images so that each image

contributes to more than one color plane

When using **LRGB** or **LCMY**, you can select the **Conversion color space**. The first option is **CIE L*a*b**, where the color space is converted to the L*a*b model, the luminance frame is replaced, and the image is converted back to RGB. The second option is **RGB**, where the luminance image is directly modified based on the color ratios between the three color planes.

The second step is to **select the images** to be combined. The image which was active prior to invoking the command will appear in one of the slots, as determined by examining the **first letter** of the value of the **FILTER** keyword in the FITS header, or in the absence of a **FILTER** keyword, the **last letter** of the file name. In **RGB** and **LRGB** modes the letters **R**, **G**, **B** are taken to denote Red, Green, and Blue images respectively, while in **CMY** and **LCMY** modes **C**, **M**, **Y** denote Cyan, Magenta, and Yellow. When using the **FILTER** keyword, any other letter is taken as luminance(**L**); when parsing frame information from the filename, only **L** or **W** (white) is accepted for this. Using the same identification algorithm, the command automatically inserts into the other dropdowns any other open images that were assigned the appropriate filters and whose filenames match the key image name. [When the **FILTER** keyword method is used, an approximate match is accepted.] All images are entered in every control, so you can use the **drop list** to correct a wrong selection.

When using **LRGB** or **LCMY** combine modes, the images are automatically resized to a common binning factor used, if needed. The resultant binning will be that of the image with the smallest binning, which is usually the luminance frame. The scale factors are determined from the **XBINNING** and **YBINNING** keywords in the FITS header.

Combine Color normally uses the **Double Size** command in order to achieve the best final results when the destination binning is half that of the source (for example, converting a 2x2-binned images to match an unbinned luminance image). If you prefer to use the equivalent of a straight **Resize** command, check **Fast Resize**. This control is not enabled unless it is applicable to the particular images being combined; when none of the selected images have binning ratios of 2:1, **Fast Resize** is always implied. Resizing for **Preview Images** also always uses the fast method.

If the images are not aligned prior to executing this command, this will be obvious in the **Preview Image**, provided **Auto Preview** is on (leaving this on is **recommended**). Click **Align** to invoke the **Align** dialog and register them. The first image (Red, Cyan, or Luminance, depending on the combine mode) is automatically selected as the reference to which the others are adjusted. Changes made in **Align** mode modify the selected image buffers, even if **Combine Color** is subsequently canceled, but can be rolled back via **Undo** if necessary. Control will automatically return to the **Combine Color** command when the **Align Images** dialog box is closed. Performing an alignment restricts the channel selection droplists to the set of images that were aligned. Also, you

cannot perform an alignment more than once in the same **Combine Color** activation.

The next step is to set the balancing adjustments (**Input / Output** matrix). For standard **RGB** imaging, there are only three slots in the matrix available – **Red Input / Red Output**, **Green Input / Green Output**, and **Blue Input / Blue Output**. If the exposures in the three color bands are equal and the transmittance of the filters are comparable, these can all be set to 1 (click **Default** for this setting). If the exposure level in the blue band, for example, is half that in the other two, it should be set to 2 and the others to 1. The simplest way to determine the correct settings is to image a standard gray card using the same camera and optical system used for imaging. Adjust the exposures or the scaling so that the resulting image looks gray.

The balancing is more complex in **CMY** mode because it is a subtractive method. The default setting (obtained by clicking **Default**) corresponds to:

Red = Magenta + Yellow - Cyan

Green = Cyan + Yellow - Magenta

Blue = Cyan + Magenta - Yellow

CMY imaging is a more difficult technique which requires some effort in order to obtain correctly calibrated results. The simplest method is to take an image of a gray card, and adjust the exposures or scaling so that the resulting image looks gray. The simplest scaling adjustment is to use the same absolute value for each row in the table (keeping the additive/subtractive recipe as shown above). This is equivalent to scaling the exposure duration. More complex transformations are possible using different numbers in all nine slots.

If a **Luminance** plane is selected (**LRGB** or **LCMY**) the color information is taken from the three color images, and the luminance (brightness) level for each pixel is taken from the **Luminance** image. The human eye is less sensitive to color variations than brightness variations. This opens up the possibility of combining lower-resolution, short exposure color images with a single longer exposure for luminance. When **Lum Wt %** (Luminance Weight) is set to 100%, the luminance value derived from the color planes is completely replaced by the luminance frame; smaller values blend the luminance frame with information from the three color frames. You can see the effect of the **Luminance** information by switching between **Conversion Types** (e.g. **LRGB** to **RGB**) with **Auto Preview** enabled.

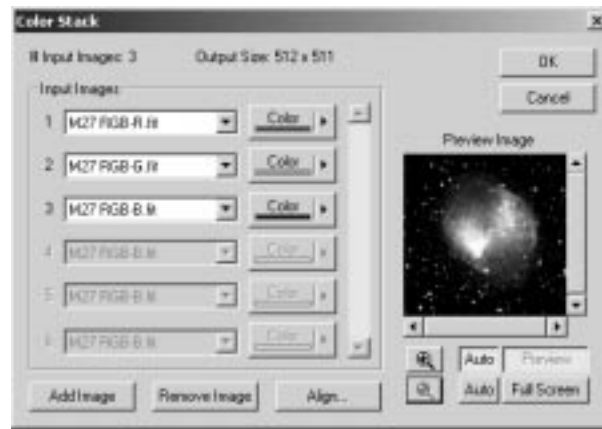
The **Bgd Auto Equalize** check box turns on **automatic background equalization**. It adjusts the images to compensate for any differences in the average background level. In most cases this should be turned **on** to equalize the sky background. In some cases it may be necessary to turn this off and make any necessary adjustments later in the **Color Balance** command. An example is an image which is completely full of dense

nebosity – there is no background in the image.

Color Stack

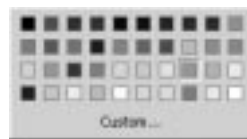
The **Color Stack** command is used to create a color image from a set of monochrome images.

If the images are not aligned prior to executing this command, this will be obvious in the **Preview Image** if **Auto Preview** is on (leaving this on is **recommended**). Click the **Align** button to adjust them. This will display the **Align Images** dialog, which operates in the same way when invoked by the **Color Stack** dialog as it does when invoked from the menu. Note that changes made in **Align** mode modify the selected image buffers, even if **Color Stack** is canceled. Control will automatically return to this command when the **Align Images** dialog box is closed.



Click the **Add Image** button to add a new image to the list of images that will be combined. Clicking the **Remove Image** button will remove the **last** image from the list of inputs. A maximum of twenty images may be combined into a single output image.

The images to be combined are specified using the combo-boxes in the **Input Images** group box. Each combo box contains a list of all of the monochrome images currently open, as well as the color associated with the image. Clicking the associated **Color** button will display a dialog allowing you to choose from a palette of predefined colors, or to define a custom color that will be used for that input image.



The pixel values in the output image are calculated as follows. The color for each input image is converted to a set of ratios, normalized to the highest-valued component. For instance, if the input color was {128, 64, 0}, the color assigned to that input image would be {1, 0.5, 0}. The value for each output pixel is calculated as the sum of the input pixel from each of the input images, multiplied by the color ratio for that image, and then divided by the total number of images.

Split Tricolor

The **Split Tricolor** command works only on color images. It will create new image buffers that correspond to the red, green, and blue image planes from the color image. A -R, -G, and -B will be appended to the name of the image to identify the three color planes.

Convert to Mono

The **Convert to Mono** command works only on color images. It will remove all color information from the image, resulting in a gray scale (monochrome) image. This is done by averaging the values in the red, green, and blue planes.

Pseudo Color

Pseudo Color creates false color images from monochrome or color images. Ten different schemes can be set up using the **Color Scheme** selector. To name a scheme, just **type** in the **Color Scheme** field.

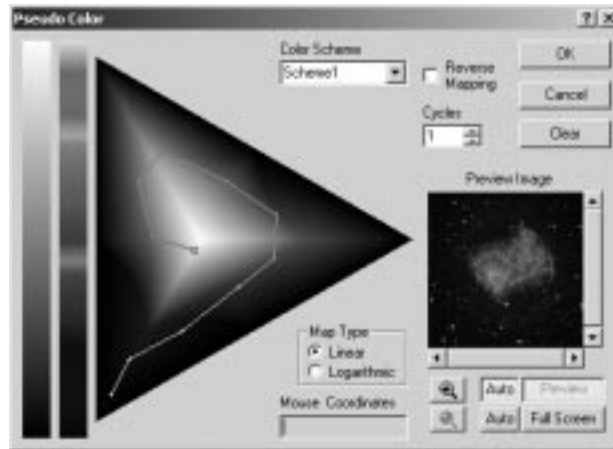
At left are **two color bars** that form the **translation index**. The **gray levels (left bar)** correspond to brightness levels in the selected image. These are based on the current screen stretch settings; changing the **screen stretch** on the selected image will change the effect of the processing (Note: you can adjust the screen stretch of an image while this dialog box is open if you first select the image with the mouse).

The **right hand bar** indicates what **color** the **corresponding gray shade** will be translated into. The **color scheme** in this bar is created by **drawing a line** on the **triangular color map**. The color map shows a "gamut" of color levels.

To draw a new color scheme, select the desired slot in **Color Scheme**, and **click** the **Clear** button if necessary to remove any previous lines. **Click** once on the **map** on a color which you wish to correspond to black (the exact **red**, **green**, and **blue** coordinates in color space are shown under **Mouse Coordinates**). To set the point corresponding to **white** (maximum brightness), click a **second point**. A **line** will be **drawn** between the two points, and the **color translation** bar will be **updated**. If the **Auto Preview** check box is on, the **Preview Image** will show what the final image will look like (to reposition the preview image, **drag** it while holding down the **right mouse button**).

As an **exercise**, start by **clicking** on the **rightmost point** in the triangle, then move to the **brightest red color** (about half-way to the center) and **click again**. Make sure **Cycles** is set to **1**. The image will be converted from gray scale to shades of red.

You can add a **third point** by **clicking** again on another **color**. Additional points can also be added; a line will connect the new point with the one that was previously placed. If you wish to **move** a placed point, position the **mouse** over it, **hold down** the **left mouse button**, and **drag** it to a new location. You can also **delete** a point by **right-clicking** on it.



The **map** can take on different styles, designed to shift the range of colors in the gamut. The **Logarithmic** mode shows more **cyan**, **yellow**, and **magenta** shades. The **Linear** mode produces linear color changes along a straight line.

You can reverse the order of the colors by turning on **Reverse Mapping**. You can change the number of times the colors repeat by adjusting the **Cycles** control; for example, setting **Cycles** to **2** will make the color scheme repeat twice. This control can be used to generate the appearance of a contour map.

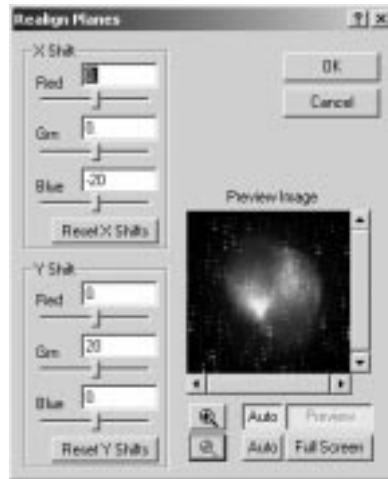
Realign Planes

The **Realign Planes** command can be used to manually tweak tricolor images if the three color planes are not precisely aligned to each other. You can shift any of the three color planes in **X** and **Y** directions. The **Preview Image** is useful for determining when the images have been properly registered. You can **zoom** in on a particular object in the image to make a more precise adjustment. The image planes can be adjusted to a fraction of a pixel (the command uses a bilinear interpolation algorithm).

The **X** and **Y** shifts for all three image planes can be entered manually in units of pixels,

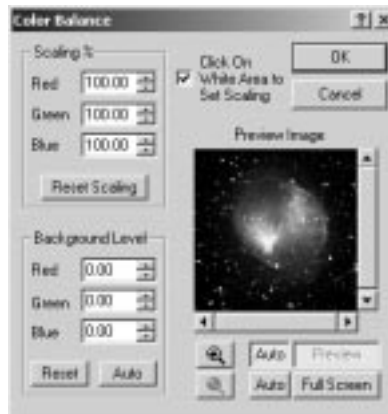
or they can be adjusted using the sliders. The **Reset** buttons restore a zero shift condition.

This command only operates on color images.



Color Balance

The **Color Balance** command only works on color images. The color balance of an image can be adjusted in two ways. A simple scaling can be performed on each of the planes, or a background level can be subtracted from each image plane.



Color images from CCD cameras typically require a background level adjustment. This is accomplished by bringing the background level (or bias) in each color plane down to

zero. Each of the **Background Level** values is **subtracted** from every image pixel in its color plane. Any pixel values that become negative are forced to zero. The **Reset** button resets the background level subtraction to zero on all planes. The **Auto** button automatically determines the settings necessary to equalize the image background in all three color planes.

Scaling adjustment (percent) allows you to compensate for transmittance differences between the filters used to acquire the three color planes. Values of 100% result in no change. The scaling percentages can be typed in or adjusted using the spin controls. The **Preview Image** is particularly helpful in monitoring the results when using the spin controls. The **Reset Scaling** button resets to 100% on all three planes.

The **Click On White Area to Set Scaling** check box enables the operation of the **mouse** to set the **scaling**. Set the **Background** level first, then **click** on a white object (e.g. a neutral-colored star) in the **image** (*not* the preview) with the **mouse**. The **Scaling** settings will automatically be adjusted to make the selected point appear white. If an area of the image is known to be white (or gray), this is an easier way to determine the scaling factors, and can be used to instantly color balance the image.

This command only operates on color images.

White Balance

This command only works on color images. The **White Balance** command is used to adjust the color balance of an image, by rescaling the individual color planes of the image.



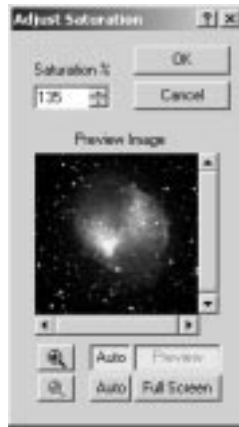
White Balance is useful when the color balance of an image is incorrect, but it contains an object which you know should be white. Either click on the area that you know to be white, or drag to select a rectangular area containing more than one pixel. For a **single-click** selection, the **Selected Area** field shows the **X** and **Y** coordinate of the pixel and its **R**, **G** and **B** color values. For a rectangular area selection, the area's upper left and lower right **X** and **Y** coordinates and *average* **R**, **G** and **B** color values for all pixels are shown.

White Balance transforms an image by generating a set of scale factors that will equalize the color values in the **Selected Area**, so that the selected color is changed to white. The scale factors are then adjusted according to the selected **Output** type. If **No Rescale** is chosen, then the scale factors are set so that the **Selected Area** has the same intensity after the **White Balance** operation. If **Output** is set to **8-Bit**, the scale factors are set so that the output intensity of the **Selected Area** is 255. If **Output** is set to **16-Bit**, then the scale factors are set so that the **Selected Area's** output intensity is 65536.

This command performs essentially the same task as the **Color Balance** but is easier to use, provided image contains an area that is known to be white.

Adjust Saturation

The **Adjust Saturation** control allows you to adjust the saturation (purity) of the colors in the image, without affecting the actual hues. Setting the **Saturation** field **above 100%** will **increase** the saturation of the colors; setting it **below 100%** will **decrease** the saturation.

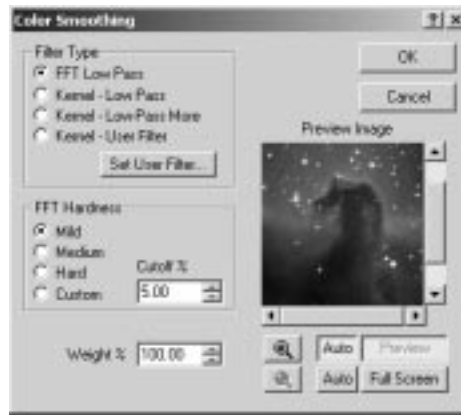


Color Smoothing

This command smoothes the color variations in the image without affecting the overall

image sharpness. Color composites can often contain color noise, especially when CCD cameras with low blue sensitivity are used. Since the human eye is more sensitive to brightness variations than color variations, the appearance of an image with color noise can be improved without losing sharpness.

This command is also useful for “single shot” color cameras. Due to the arrangement of color filters on the detector, color “aliasing” effects can appear around bright stars. A mild filter with this command removes the unwanted color effects.



The **Filter Type** options work identically to those in the **FFT Filter** and **Kernel Filter** commands. The **Set User Filter** button also works identically to the control of the same name in the **Kernel Filter** dialog.

For **FFT Filters**, the **Cutoff** field controls the strength of the filter. The **Cutoff** radius is entered as a percentage of the image dimensions. Entering a smaller value produces a stronger filter; i.e. it increases the radius of the blur.

The **Weight** field (percent) is used to control how much filtering is applied. At 100%, the full strength of the filter is applied. At lower percentages, a portion of the color information from the original image is used in addition to that of the filtered image.

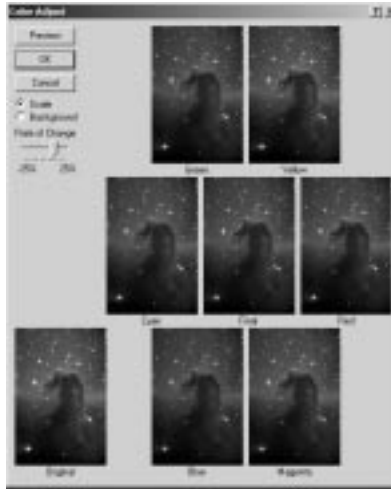
Color Adjust

This command helps you adjust the color balance of an image by showing you the effect of various changes. You can configure it to adjust the **Scale** of each color or the **Background** color of the image. The **Rate of Change** slider controls the amount of change.

An array of eight different versions of the image is shown. The **Final** image, in the center, shows how the image will look after the adjustment is made.

Surrounding the Final image are images marked with various colors. The images that

are on opposite sides have the opposite effect; **Green** is opposite **Magenta**, **Yellow** is opposite **Blue**, and **Red** is opposite **Cyan**.



If you click on one of these images, it replaces the Final image. You can do this repeatedly, with different settings for **Rate of Change** and **Scale/Background**, until the image has a satisfactory appearance. If you get too far off track, click the **Original** image to reset and start again.

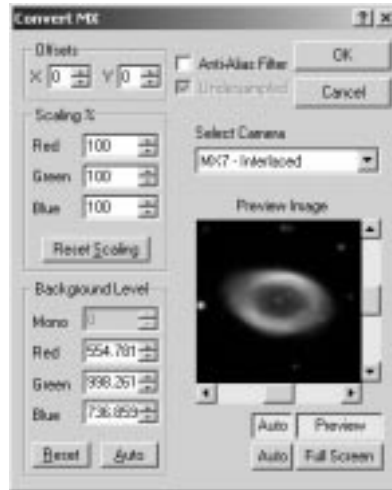
Convert MX

This command is specific to the Starlight Xpress "single-shot color" CCD cameras.

This command converts a raw (monochrome) MX image into a color image. The raw MX image is actually an image taken with a color video CCD chip (these detectors utilize an alternating pattern of color dyes, or filters, in front of the pixel array). The **Convert MX** command converts the color information present in the raw image into the standard **RGB** color plane format used by MaxIm DL and other programs, and provides controls for color balancing.

Select Camera is used to control the conversion process. **MX5** is used for the MX5-C camera. The **MX7 - Fast Mode** and **MX7 - Interlace Mode** settings are used for the MX7-C. If you use the Starlight Xpress software to operate the camera, it should be noted that Interlace Mode is used for both Progressive and Interlace modes (MaxIm CCD auto-switches between these modes and does not differentiate between them as far as there user is concerned). The **MX5 - Optimized**, **MX7 - Fast Mode - Optimized** and **MX7 - Interlaced - Optimized** settings perform the same tasks, but use an iterative algorithm that produces more accurate colors at the expense of processing time. The optimized algorithms were contributed by Magnus Nyborg.

Color images from CCD cameras typically require a background level adjustment. This is accomplished by bringing the background level (or bias) in each color plane down to zero. Each of the **Background Level** values is **subtracted** from every image pixel in its color plane. Any pixel values that become negative are forced to zero. The **Reset** button resets the background subtraction to zero on all planes. The **Auto** button automatically determines the settings necessary to equalize the image background in all three color planes.



Scaling adjustment (percent) allows you to compensate for differing sensitivity between the color planes. Values of 100% result in no change. The scaling adjustments can be typed in or adjusted using the spin controls. The **Preview Image** is particularly helpful in monitoring the results when using the spin controls. The **Reset Scaling** button resets to 100% on all three planes.

The **X Offset** and **Y Offset** selections are used to correct for any misalignment of the color mask in the CCD camera. Normally these are turned off. If the converted images exhibit an obvious color imbalance, try selecting different combinations of these two options.

In most situations, clicking the **Auto** background level button and then clicking **OK** can obtain accurate colors. The conversion routine is already calibrated for good color balance with MX series cameras. Further adjustments to the color balance can be made using the **Color Balance** command.

The color pixel grids in the MX series cameras (and others which use similar on-detector filter matrices) can cause color aliasing which manifests itself as colored fringing, particularly around bright stars. Enabling the **Anti-Alias Filter** setting applies

a low-pass filter to the image to smooth out these sharp color variations. This can also be fixed using the **Color Smoothing** command.

When one of the **Optimized** conversion settings is chosen in **Select Camera**, the **Undersampled** option will become available. Enabling this setting causes the algorithm to exaggerate the resulting colors slightly. This produces more accurate colors when the image exposure was too short to provide good color information.

This command only works on raw (monochrome) images taken with the Starlight Xpress MX5-C and MX7-C cameras. Using this command on images from other cameras will produce gibberish.

Convert RGB

This command converts RGB-encoded CCD matrices to a color image. Two examples of compatible cameras are the SBIG ST-2000XM Color and Starlight Xpress SXV-H9C. Monochrome images taken with the camera are actually encoded with RGB information in adjacent pixels.

These sensors have an alternating pattern of color dyes in front of the pixels. The **Convert RGB** command converts this color information into the standard **RGB** color plane format used by MaxIm DL and other programs, and provides for color balancing.



Color images from CCD cameras typically require a background level adjustment. This is accomplished by bringing the background level (or bias) in each color plane down to zero. Each of the **Background Level** values is subtracted from every image pixel in its color plane. Any pixel values that become negative are forced to zero. The **Reset** button resets the background subtraction to zero on all planes. The **Auto** button automatically determines the settings necessary to equalize the image background in all three color planes.


Scaling adjustment (percent) allows you to compensate for differing sensitivity between the color planes. Values of 100% result in no change. The scaling adjustments can be typed in or adjusted using the spin controls. The **Preview Image** is particularly helpful in monitoring the results when using the sliders. The **Reset Scaling** button resets to 100% on all three planes. Tip: For ST-2000XM Color cameras, set **Red** scaling to 77%, the other two channels to 100%, and be sure to click the **Auto Background** button.

The **X Offset** and **Y Offset** selections are used to correct for any misalignment of the color mask in the CCD camera. Normally these are turned off. If the converted images exhibit an obvious color imbalance, try selecting different combinations of these two options.

In most situations, clicking the **Auto** background level button and then clicking **OK** can obtain accurate colors. Further adjustments to the color balance can be made using the **Color Balance** command.

The color pixel grids in these cameras (and others which use similar on-detector filter matrices) can cause color aliasing which manifests itself as colored fringing, particularly around bright stars. This can be fixed using the **Color Smoothing** command.

Using this command on images that are not RGB encoded will produce gibberish.

For information on individual dialog controls, close this help window and use the  button in the dialog's title bar.

Plug-in Menu

The Plug-in menu allows users to add their own image processing functions into MaxIm DL. As the functions are added, they will appear in the menu list.

Sample code for Visual Basic and Visual C++ are included in subdirectories to the MaxIm DL program directory. These sample plug-ins merely allow you to add a constant to the image; they are intended for demonstration purposes only.

It should be noted that plug-ins can use both algorithms developed by the user and those built-in to MaxIm DL itself, via MaxIm DL's COM (ActiveX) scripting interface.

For more information, refer to the source code for the sample plug-ins.

Add/Remove Plug-in

Plug-ins can be added to the menu using this command. Click **Manually Add Plug-In** and browse to the DLL file and select it. It will automatically be added to the menu.

To remove an existing plug-in, select it using the **Remove Plug-in** drop-list. The menu name will be displayed below. When you are certain you wish to remove this plug-in, click the **Remove** button.



Supernova Search Tool

Ajai Sehgal, a member of the Puckett Observatory Supernova Search Team, wrote a Supernova Search Tool for use with MaxIm DL. It is an excellent example of how MaxIm DL's scripting interface allows it to be integrated with other applications. The tool has been included as a bonus feature on the MaxIm DL disk.

The tool controls MaxIm DL to assist in examining before/after image pairs when looking for supernovae. It has been used to discover literally dozens of supernovae.



The initial screen allows you to select the **Before** and **After** directories, as well as a location to save **Reshoot** images – images that contain suspects which need to be followed up on. The **Before** and **After** directories must contain sets of image pairs with the same names, although they can be of different file types (e.g. FITS and JPEG).

You can optionally turn on the **Start from beginning** check box to start at the first image.

Once you click **Start**, the **Supernova Search Control** will pop up, and MaxIm DL will

be launched if it is not already open. Move the **Supernova Search Control** to a convenient location, say at the bottom of the screen, to get it out of the way.

Every time you click the **Next** or **Back** buttons, a new image pair will be shown. You can also type in the image number into **Current Index** to go directly to a particular image. The name of the object will appear in **Current Image**; this is retrieved from the OBJECT keyword in the FITS header.

Several options are available. **Flip New Images** and/or **Mirror New Images** can be set to reorient new images to match the other side of the pair. If the two images are at the same scale, **Auto Blink** will cause them to be auto-aligned and blinked. You must close the **Blink** dialog box manually before using any other controls on the search control.



Get POSS will launch Internet Explorer and command it to retrieve the Palomar Optical Sky Survey image for the selected object. The object name must appear in **Current Image** for this to work. The control sets the fields in the web page and starts the retrieval process automatically.

In similar fashion **Recent SN** will launch a web page showing all recent supernova discoveries, and **Minor Planets** will launch another web site to search for nearby minor planets that might be masquerading as supernovae.

Re-shoot will save the **After** image in the Reshoots directory for follow-up. **Flip After** and **Mirror After** provide a quick way to manually flip images if they are in the wrong orientation. **Blink** will auto-align the images and start the **Animate** tool operating; you must manually close the **Animate** tool before continuing.



The small **Options** button at top left will bring up the **Options** dialog box. **Blink Interval** sets the interval between image changes for the **Animate** command. **POSS Format** indicates the image format to use when downloading POSS images (GIF, to be displayed in Internet Explorer, or TIFF to be saved and loaded into MaxIm DL). **POSS Type** (first or second generation, blue or red) indicates the POSS image set from which to download an image. **POSS Size** sets the angular size of the retrieved image.

Window Menu

New Window

The **New Window** command will create a second view of the currently selected image. The new view can be independently pan and zoomed, but will have the same stretch as the original window.

Fit To Image

This command toggles the **Fit to Image** mode on and off. The Fit to Image mode causes the window for the image to be adjusted to the same size as the image. If the view is zoomed out, the window will shrink with it. If the view is zoomed in, the window will grow until it fills the main window.

Cascade

This command will stack all non-minimized image windows starting at the top left corner of the screen.

Tile Horizontally

This command will tile all non-minimized image windows running horizontally across the screen. This command turns off the **Fit to Image** mode.

Tile Vertically

This command will tile all non-minimized image windows running vertically across the screen. This command turns off the **Fit to Image** mode.



Arrange Icons

Image windows can be minimized, at which point they become small bars (icons). If these have become scattered about the main application window, the Arrange Icons command will stack them neatly at the bottom of the window.

Help Menu

Help Topics

The Help Topics command initiates the Windows Help system and brings up the Help Topics page.

The  toolbar button activates context-sensitive help. Click on this button, then on any dialog or menu item for complete information on the command. Help on dialog fields can also be obtained using the  button within the dialog.

The main help window includes several panes. The left-hand pane includes three tabs, **Contents**, **Index**, and **Search**. The Contents tab provides a layered table of contents much like the one in this manual. The “books” can be opened by clicking the “+” sign to access sub-topics. The Index tab provides an alphabetical list of all topics in the help. The Search tab allows you to search for keywords in the help pages.

The right hand pane shows the topic text. Above it is a control pane that allows you to tab forwards and backwards through the nearby topics. A topic list is shown, and you can pop ahead to another topic just by clicking on it. You can also select major books from the drop list.

The toolbar at top allows you to hide the left-hand pane, go back a topic, print a topic, and select options.

Help on individual dialog fields can also be obtained using the button within the dialog. This brings up so-called “What’s This?” help.

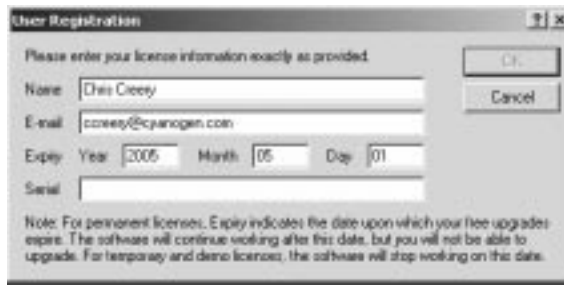
Check For Updates

Selecting this command will open your web browser to a special page on the Diffraction Limited website. Opening this page will check and see what version of MaxIm DL is currently installed, and whether or not an upgrade is available. If an upgrade is available you will be given the option of downloading and installing it.

Enter License

The **Enter License** command opens the **User Registration** dialog, allowing you to enter your licensing information. When you purchase a copy of **MaxIm DL**, you will receive an email containing the user name and email address that you provided to us, the expiration date of your software, and the serial number that will activate your copy of **MaxIm DL**. Entering this information will update your **MaxIm DL** license, changing the expiration date and potentially the license type.

When **MaxIm DL** is first installed, this dialog is displayed, and you must enter a valid license before proceeding. However, the license entered can be a temporary or a demo license (both types of licenses are for evaluation of the software before purchasing), as well as a permanent license. If you decide to purchase **MaxIm DL**, the **User Registration** dialog is used to enter the permanent license received at the time of sale. The dialog is also used to renew permanent licenses, for instance, if you decide to purchase a second year of support after the first runs out.



Register Online

This option is only available when running an unregistered retail license. When you purchase MaxIm DL from a dealer, a temporary license is supplied that works for 30 days. During that time, you must register your software so you can receive your permanent license. The permanent license is not locked to any particular machine.

Simply click this menu item to bring up Internet Explorer and navigate to the registration page. Fill in the required information, and you will be automatically registered.


If you prefer, you may register by telephone. Call (613) 225-2732, Monday to Friday (except holidays) between 10:00 am and 5:00 pm.


About MaxIm DL

This command displays the program icon, copyright notices, authors, and version information. Click **OK** to close the window.

Camera Control Window

This section describes all of the controls in MaxIm CCD. All controls are located in the MaxIm CCD control window, which takes the form of a tabbed dialog box.

 All of this information is available from the context-sensitive Help. **Click** the **Toolbar Help** button and then **click** on the window or dialog. Different help is available for each tab.

Help on individual dialog controls can also be obtained by **clicking** the  help button on the **MaxIm CCD** window title bar then **clicking** on the control.

Expose Tab

The **Expose** tab is used to control CCD exposures, in conjunction with the **Settings**. The

functions of this dialog are only active if a CCD camera has been activated using the **Setup** tab.



The **Expose** button starts an exposure or exposure sequence. During an exposure, the **Expose** button is disabled, and the **Stop** button is enabled. The **Stop** button allows you to terminate the current exposure or exposure sequence. *Note that some camera drivers lock up the computer during camera readout to prevent other programs from interfering with the readout process. Therefore it may not be possible to abort an exposure during readout.*

The exposure duration is determined by **Minutes** plus **Seconds**. You can enter an exposure from 0.001 seconds up to the maximum allowed by the particular camera. *If the exposure is set lower than the particular camera allows, the minimum permitted exposure will be used.*

The **Delay** field allows you to specify a delay time after the **Expose** button is pressed before the exposure will begin. When a sequence of images is taken, this delay is added before each exposure in the sequence. When the autoguider is running, a minimum delay of **five seconds** is automatically added to allow time for the autoguider to settle before each exposure; if necessary you can increase this time by setting **Delay** to a value greater than **5**.

The type of exposure can be set using the **Type** radio buttons (Note: this function is disabled if **Simple Auto Dark** is enabled on the **Settings** tab). **Normal** exposures are usually taken using the **Light** setting; the exposures may be automatically calibrated as determined by the **Settings** tab. The remaining exposure types are used for taking calibration frames; as such, these images are *not* automatically calibrated. The **Bias** frame is a minimum-duration dark frame (shutter closed). The **Dark** frame is a normal exposure with the shutter closed. The **Flat** exposure setting is used for taking flat-field frames; it differs from the **Normal** setting in that automatic calibration will not occur. If the camera does not have a shutter, you will be prompted to cover and uncover the aperture as required.

The **Pause** button will pause the exposure temporarily by closing the shutter and suspending the exposure timer. The button will only appear if the camera supports this

feature.

The **New Buffer** control forces MaxIm DL to create a new image buffer for each CCD image. When this control is off, the previous CCD image buffer will be used, if available.

The **drop-down** combo box under the **Minute** field allows you to select a **filter** for the exposure. This control is only available when a **filter wheel** is selected in the **Setup** tab.

Changing the settings during an exposure or exposure sequence is allowed, but **has no effect** on the current imaging activity. The new settings only take effect when the **Expose** button is clicked.

Two status fields are provided. The left-hand status field shows the status of the main camera. The right-hand status field shows the status of the autoguider, if present. Status information includes the camera state, exposure time, and cooler status. There is also a **progress bar** that shows graphically the progress of the exposure.

Note: **Subframe** settings can only be changed when the **Settings** tab is displayed. Dragging the mouse on the image when the **Expose** tab is visible will have **no effect**.

Settings Tab

The **Settings** tab allows you to set up various camera features.

The **Subframe** setting allows you to select a portion of the CCD chip to be read out. The settings can be made manually using the dialog, but it is more convenient to use the **mouse** (see below). The **Reset** button can be used to restore the **Subframe** to include the entire CCD chip.




To set the subframe area using the mouse, simply bring up this tab and **drag the mouse**, while **holding down** the **left button**, on an image taken with the CCD camera. The subframe will automatically be set to include the area selected using the mouse. **Note:** using the mouse to select a subframe can only be done while the **Settings** tab is displayed.

Auto Calibration is used to set up automatic calibration of the images as the exposures

occur. There are three settings. **None** disables automatic calibration. **Simple Auto-dark** causes the software to automatically take a dark frame whenever the settings have changed and the **Expose** Tab's **Expose** button is pressed. The dark frame is then automatically subtracted from all later exposures. **Full Calibration** uses MaxIm DL's main calibration function, which is set up using the **Set Calibration** command. This allows advanced calibration features such as averaging or median combining multiple frames, scaling dark-frame exposures, etc. Note that the calibration frames must first be set up with the **Process** menu **Set Calibration** command.

The **Binning** settings allow you to combine a number of pixels together to create one "super-pixel". This increases sensitivity but reduces camera resolution. **Binning** is recommended when using a CCD camera with an optical system that produces a spot size much larger than 3 pixels FWHM. The maximum binning setting depends on the particular CCD camera. Some cameras allow the user to independently set the binning in the **X** and **Y** directions; if this is not possible, the second binning control (**Y Binning**) is grayed out and tracks the **X Binning** control.

The **Options** button  displays a menu of additional commands. The following commands always appear:



Always On Top allows you to specify whether the MaxIm CCD window stays on top of all other windows. **Note** that when On Top is enabled (i.e., the menu entry is checked), *the MaxIm CCD window should never be placed in the middle of the MaxIm DL application window*; as it may otherwise hide any small dialog boxes produced by MaxIm DL. If this happens, you will not be able to see the message and MaxIm DL operation may mysteriously lock up until you hit the **Enter** or **Esc** key to dismiss the hidden dialog.

Auto-dark Subframe Extraction modifies the **Simple Auto-dark** calibration for subframes. Instead of taking a new auto-dark frame every time a subframe is selected, resized, or moved, the appropriate piece will be extracted from the most recent full frame dark exposure. If the full-sized dark frame is not available, then a new exposure will be taken. For some camera models, extracted subframes do not always accurately match real subframes; in this case, you should turn this option off.

Pause FocusAide is an option to disable focuser movements by the third-party focusing

tool FocusAide during CCD image download. This applies to both the main camera and autoguider. Some CCD camera drivers disable interrupts during download, which can cause erroneous focuser motion if FocusAide is actively moving the motor. If FocusAide is not present or inactive, selecting this option will have no effect.

Of the three options **No Rotation**, **Rotate Image 90° CW**, and **Rotate Image 90° CCW**, only one can be selected at a time. These control automatic rotation of each image acquired from the camera immediately after it is downloaded. The image can be left unrotated, rotated 90 degrees clockwise (CW) or 90 degrees counter-clockwise (CCW). The rotation options affect images taken with the autoguider as well as the main camera. *Note that guider calibration must be repeated after a change in rotation.* Guide star position and any guider subframe that is in effect may also need to be reset.

Flip Images Horizontally causes MaxIm CCD to flip images left to right as they are downloaded from the camera. Similarly, the **Flip Images Vertically** option flips the images top to bottom. These options are useful with some optical configurations, and when using certain CCD chips which have the readout amplifier in an unusual position. The flip options affect images taken with the autoguider as well as the main camera. As with the rotation options, guider calibration, guide star position and guider subframe typically require reestablishing after a change.

The **Shutter Latency Measurement** command displays a dialog box which is used to determine the intrinsic delay between issuing the command to start an exposure and the instant at which the shutter actually opens. Depending on the design of the camera hardware, interface, firmware and drivers, this delay can be significant (0.25 to 1 sec). However long this delay is, in most systems it is quite consistent, so characterizing it allows MaxIm CCD to time-tag exposures to a precision of 1/100th of a second (10 msec), assuming that the computer's clock is set to a like accuracy. The measurement procedure, described below, requires fitting a camera lens to the CCD camera and moreover is normally done indoors, rather than in the observatory.

Additional commands may appear in the **Options** button menu for certain camera models. **Camera Settings** allows you to control various advanced camera features, if any are available for the currently connected camera. See the CCD Camera/Autoguider Setup section for your particular camera model for more information. If advanced settings are not available for the selected camera, the command does not appear in the menu. **Download Image on Stop** controls whether an exposure terminated by clicking the **Stop** button on the **Expose Tab** is downloaded or simply discarded. If the camera does not have this capability, the command does not appear in the menu.

Tip: You can enable a beep, or any other sound of your choice, at the end of each exposure using the **Audible Alarms** tab of the application **Settings** command found in the MaxIm DL **File** menu. Select **Camera Exposure Completed** in the drop list of events of this dialog, click **Add**, and select the .WAV file to play on completion of the

exposure. You can configure sounds for **Guider Exposure Completed** and many other events as well.

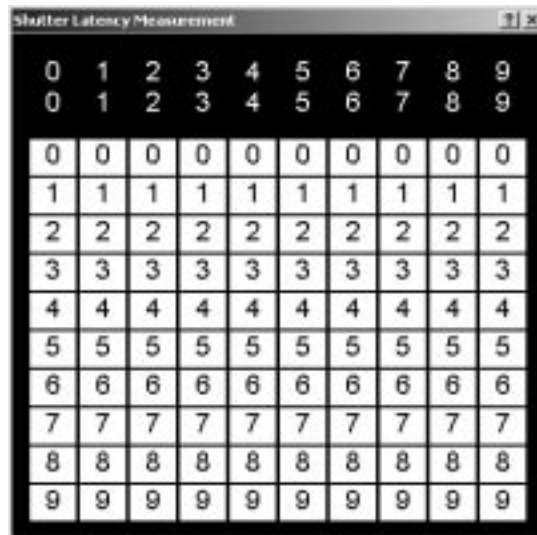
Shutter Latency Measurement

Clicking the **Shutter Latency Measurement** command on the **Settings Tab's** button menu displays the Shutter Latency Measurement tool. It is used to determine the intrinsic delay that occurs between the instant of issuing the command to start an exposure and the instant at which the shutter actually opens. This allows the DATE-OBS FITS keyword to be more accurately set for images obtained from the main camera. Although this delay can be significant (0.25 to 1 sec, depending on the particular camera system), in many cases it is quite uniform and repeatable.



The measurement procedure is described in the Shutter Latency Measurement window, which also serves as a dynamic test target. You should mount your CCD camera on a tripod, then fit it with a short focus lens so that you can image the full window as displayed on your computer's monitor. Therefore this test can be performed from the comfort of home.

Click **Aim Mode** to display the "checkerboard", a static version of the test target that you use to focus the camera and frame the image:

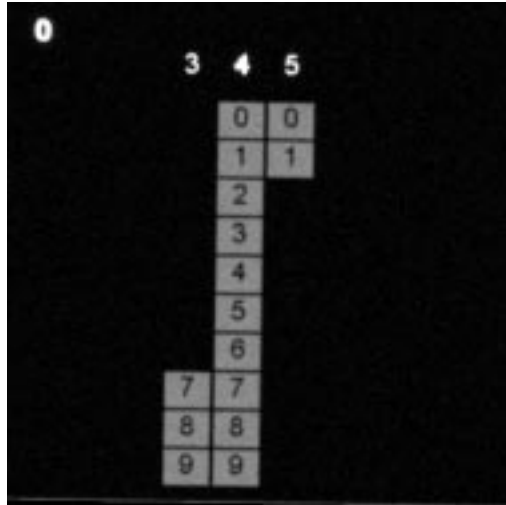


You will need to be able to see the entire window in your captured images, and distinguish the individual digits, or at least be able to reliably determine them from their relative positions. You should use as wide an aperture and as brief an exposure duration as possible during focusing. This is because during the actual measurement, each of the white blocks in the lower part of the target will be displayed for only 1/100th of a second, and it is important to be able to capture them. It is recommended that you reduce or extinguish room lighting if possible.

When you have focused the camera and framed the test target, **click the mouse on the checkerboard** to dismiss the static test target. Leaving the Shutter Latency Measurement window open, switch back to the **Expose Tab** of the **CCD Control Window**. Set the exposure to 0.5 sec or less and click **Expose**. The latency window will immediately show a dynamic display with a single white block, moving every 1/100th of a second to the next location in succession. One white digit in each of the top two rows is also illuminated at any given instant; this shows the time in seconds and tenths of seconds since the camera was commanded to take the exposure. The display continues updating as long as the camera is exposing.

When the exposure has been downloaded, adjust the screen stretch to make the white blocks more visible if necessary and examine the image. You need to determine the time delay which occurred before the shutter opened. This is normally given by the leftmost digit in each of the top two rows (seconds and tenths), and the number of the top illuminated block in the first column that has any blocks lit; in the example below, the delay is 0.37 seconds. Note that if the delay is such that the shutter opened near the end of a second and the exposure ran into the next second, we want the first lit tenth and

hundredth whose predecessors are not lit. Thus if both "00" (top left corner) and "99" (bottom right) are lit, the delay will be given by the first lit block in the right-hand grouping of contiguous lit blocks.



Enter the three digits of the measured delay in the **sec**, **10ths**, and **100ths** fields and click **Apply**. It is advisable to repeat the test several times to be sure that the results are sufficiently consistent to warrant time-tagging images to the nearest 100th of a second. Finally, it is necessary that the computer's clock be set accurately to Universal Time; commercial packages are available to set the computer time by dialing up time services such as WWV. Alternatively, satellite time receivers, including computer-interfaceable GPS receivers, may come with software for this purpose.

When shutter calibration has been successfully performed, MaxIm CCD sets the DATE-OBS FITS keyword to one-hundredth of a second precision. If you wish to discontinue use of high-precision exposure time-tagging, **set each field to blank** and click **Apply**. In this case, DATE-OBS is recorded only to one-second accuracy. Images taken with the autoguider are always written to only one-second accuracy, and shutter calibration cannot be performed on the guiding camera.

When shutter calibration is complete, click **Close** so that MaxIm CCD does not continuously generate the dynamic test target during all CCD exposures.

Sequence Tab


The **Sequence** tab is used to set up sequences of exposures and capture them automatically. Multiple images of the same area of sky can be combined later using the **Combine Files** command to improve the image quality (signal to noise ratio), or

analyzed to study the behavior of a short-period variable or the motion of an asteroid. If you have a computer-controllable telescope mount, you can also configure the **Sequence** tab to capture images over a specified rectangle of sky and combine them later into a wide-field **Mosaic**.



Specify a base filename for the images in the **Autosave Filename** control. A **three-digit sequence number** is automatically appended to this filename to identify each exposure, followed by a user-specified suffix that distinguishes each different 'type' of exposure within the sequence (e.g., different filter, binning, etc.). The suffixes are specified in the Sequence Setup dialog described below. Do not include a file extension in the **Autosave Filename**; images acquired by a sequence are always saved in **FITS** format with the “.fit” extension. The sequence number and unique suffix for the image currently being exposed, downloaded, or saved are concatenated and displayed in the read-only **Suffix** field.

The **Start at** field allows you to specify the first sequence number that will be used. This allows you to use the same base filename without overwriting previous files or changing the destination directory for the acquired images.

With the exception of the **Start** and **Stop** buttons, described below, all other controls for configuring a sequence are accessed from the **Options** button  menu:

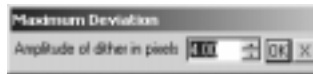


The exposure times, filter selection, exposure count, etc., for each image in the sequence are configured using the **Setup Sequence** dialog, activated by the **Setup Sequence** command. Alternatively, you can use the Sequence Wizard, which provides a simple step-by-step procedure for configuring four different types of sequences. (Sequences initially created by the wizard can be further customized using the **Setup Sequence** dialog.)

The **Set Destination Path** command brings up a folder selection dialog that allows you to select the folder into which the files are saved.

In some cases, it is desirable that the images in a sequence not all be centred at exactly the same point in the sky, but instead cluster around the specified position. For example, you might want this if your CCD camera had a significant defect that could not be remedied by the usual image calibration procedures. The Sequence tab provides two ways of doing this: **Dither Images via Guider** and **Dither Images via Mount**. The first method requires that an autoguider is available and running (see the **Guide** tab). In effect, MaxIm CCD automatically adjusts the coordinates of the guide star between exposures of the sequence such that the centers of the images are randomly distributed near the initial position. The second method requires that your mount be controllable by the computer, and accomplishes the same thing by slewing the telescope to randomly-picked nearby locations between exposures. The two methods are mutually exclusive, so that selecting one deselects the other. You can, of course, turn dithering off altogether by clicking on the dither command in the menu that is currently checked.

In either case, the size of the random excursions from the nominal center position is controlled by the **Maximum Dither Deviation** command, which brings up a small dialog allowing you to enter the desired maximum excursion, in pixels:



Enter a value up to 10 pixels and click **OK**, or click the **X** (Cancel) button to dismiss the dialog without changing the dither amplitude.

Select the **Setup Mosaic** command to display the dialog used to define the geometry and placement of a mosaic at each "tile" of which the complete sequence is to be automatically captured. You must also ensure that **Capture Mosaic** is checked in the **Options** button menu. If you turn this option on and the telescope is not connected, MaxIm CCD will display a reminder that you must do so before starting the sequence.

The **Continue Mosaic** command is enabled if you aborted the previous mosaic before it completed. If **Continue Mosaic** is checked, starting the sequence will resume capturing the mosaic from where it left off. This allows you to suspend a mosaic in the event of clouds, incipient dawn, etc., and continue later when conditions permit. The information needed to continue the mosaic is stored as the settings of the **Setup Mosaic** dialog, so

with certain exceptions you must not change those if you want to proceed later. Refer to **Setup Mosaic** for further information.

Astrometric Resynchronization is an automatic mechanism that corrects for drift (e.g. poor polar alignment) in the telescope mount when not using an autoguider. (In fact the command is not available when an autoguider is present and running.) When **Astrometric Resynchronization** is enabled, MaxIm CCD automatically "solves" the first image in a sequence to obtain the precise center coordinates of the image. It also solves every Nth image (a number that you choose) thereafter, computes the slew necessary to recenter on the original position, and commands the telescope to go there. Image solving is done via the **PinPoint Astrometry** command, whose settings you must first configure to be compatible with your telescope and camera pixel size (image scale). You must also specify the astrometry catalog you want to use and the brightness range of the stars you want to use, and you may need to set other parameters controlling the star detection algorithm. If a scheduled image cannot be solved, **Astrometric Resynchronization** allows a scant 3 seconds for you to intervene by closing the dialog box reporting the error, in which case you will be left in control of the Astrometry dialog and can try adjusting the parameters. If you do not intervene, the error dialog is dismissed automatically, the current image remains unsolved, and the next one in the sequence will be attempted instead. This prevents a sequence from hanging up due to a failure to solve one image.

Select the **Resynchronization Interval** command to set the number N between solved images. This command displays a small dialog similar to that for entering Maximum Deviation (above), but labelled **Resynchronization Interval**.

The next two commands are mutually exclusive and control whether the sequence uses the **Full frame** of the CCD camera or the **Subframe from Settings Tab**. The latter setting causes the sequenced exposures to use the subframe definition (though not the binning, which is selectable for each different exposure of the sequence) on the **Settings** tab. A sequence cannot specify an arbitrary subframe nor use different subframes in different exposures. The selection of full frame or subframe is displayed on the **Sequence Tab** itself as **1x1 Image Size**. Note that the subframe dimensions shown in this control are always normalized to the unbinned CCD array, even if all the images of the sequence are at a higher binning.

When **Overwrite Files** is checked, MaxIm CCD will always save files regardless of whether there was a file with the same name already on the disk. When it is switched off, an attempt to overwrite a file will cause the exposure sequence to abort.

Run Scripts Minimized is used to control how scripts launched automatically by a sequence are executed. If this option is checked, the command-line-based script host (cscript.exe) is executed in a minimized window, otherwise it runs in a normal command window. cscript command windows can be manually restored or minimized at

any time during the execution of the script. For more information on scripts run by sequences, see the **Setup Sequence** dialog.

To capture a sequence, click the **Start** button. MaxIm CCD will automatically slew the telescope to the starting location if **Capture Mosaic** or **Continue Mosaic** is selected and it is not already pointing in the proper direction, and then begin imaging the sequence. (See the description of the **Setup Sequence** dialog for details on the order in which exposures are performed.)

Note: With the exception of modes where its usage is either required by or incompatible with the sequence options, autoguider operation is independent of sequence execution and can be turned off and on at any time. Normally, if the autoguider is active at the start of a sequence, it will continue to run throughout. This is true even for cameras with integrated autoguider capability. Autoguider imaging is paused during main camera readout, with the guide star being automatically reacquired after the readout is complete. A delay of five seconds is imposed in order to allow time for the guider to settle, the value of which you can increase by setting Delay between on the Setup Sequence dialog to more than five. A longer delay is advisable if Dither Images via Guider is in effect since the guide star coordinates are also being changed between exposures.

If the filter wheel is in front of the autoguider, make sure that there is enough light for all filter bands; often the blue filter has the lowest transmission. This caveat also applies to images submitted for solution by Astrometric Resynchronization.

Setup Sequence

A sequence contains from one to sixteen exposure definitions, referred to as "slots". It is presented as a table with one column of controls for each exposure attribute. Only six slots can be seen at a time, but you can use the **scroll bar** at the right-hand side to view the rest.




Each slot contains an **Enable** check box that turns it on and off. Any number of slots up to 16 can be enabled, and they do not have to be contiguous. The order in which slot

exposures is acquired is discussed below.

The **Type** drop-list specifies the kind of exposure, one of **Light**, **Bias**, **Dark** or **Flat**, as with the radio buttons on the **Expose** Tab. If a filter wheel is present and the exposure type is **Light** or **Flat**, the **Filter** drop-list allows you to select the filter to use. The **Suffix** specifies a string composed of letters, digits, hyphens and underscores which is appended to the base file name for the exposures made with that slot. It must be unique across all enabled slots, although one can be empty. Specify the **Exposure** time in seconds and the image **Binning** factor; sequenced exposures are taken with equal X and Y binnings, even if the camera permits them to be different. Set the **Repeat** count to the number of exposures of this slot to be acquired during a sequence. When a mosaic is being imaged, this count applies to each position [tile] in the mosaic.

The **Script** field displays the name of a Windows Script Host script, typically written in VBScript or JavaScript, that will be executed every time the exposure specified by the slot completes. To set this field, click the corresponding "..." button to its right and browse to the desired folder and script. When the script is executed, it is passed the filename of the image that has just been acquired (including the full path) as a parameter.

In addition, you can set **Delay first**; the number of seconds to delay before starting the exposure sequence. This is useful if you need to do something manually after starting the sequence before the shutter opens (e.g. move to manual guiding eyepiece). You can also set **Delay between** to enforce a delay between each exposure in the sequence. Note that a minimum delay of five seconds is automatically inserted if the autoguider is running. MaxIm CCD computes the estimated time for the entire sequence from the exposure times and repeat counts and these two delays and displays it in **Duration (s)**. However, this is just a lower bound as it does not include the time to change filters, execute scripts, solve images for **Astrometric Resynchronization** (described with the **Sequence** Tab), or allow the guider to settle.

Several additional options and commands are available from the menu called up by the  **Options** button:



Group by Slot affects the order in which exposures are taken by the sequence. When **Group by Slot** is checked, all exposures for a particular slot are done together before any exposures from the next slot, minimizing filter wheel rotation. When it is not

checked, if each slot has the same **Repeat** count, a single exposure is done for each slot in succession and the set repeats that many times. If different **Repeat** counts are set for different slots, the order is more complicated because MaxIm CCD attempts to distribute each slot's exposures uniformly over the entire sequence. This mode is more appropriate if imaging a rapidly rotating planet, or if there is some risk that the entire sequence may not complete successfully due to clouds, etc.

Frequently you will want the same number of exposures for each slot. Rather than having to enter the same value in every **Repeat** field, select the **Same Repeat Count for All** command from the button menu. When this is checked, all **Repeat** fields are set to the same value, and they are slaved together so that changing any of them affects them all. The 'independent' or 'unlocked' values are remembered and restored if you turn **Same Repeat Count for All** off.

Similarly you can select **Same Script Name for All** to force all slots' scripts to the same one.

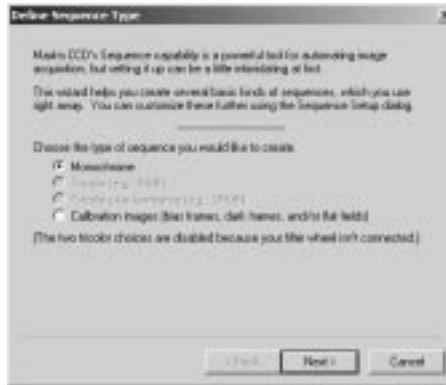
Although the sequence definition is saved when you click **OK** to close the **Setup Sequence** dialog, it is also possible to save sequences separately, allowing you to build up a library of the types of sequences you use most. Select **Load Sequence** to call up a file selector dialog allowing you to navigate to and pick a ".seq" file containing a previously saved sequence. To save a sequence as a ".seq" file, select **Save Sequence** or **Save Sequence As**; the distinction is that the former updates the sequence file that was last loaded without prompting for a filename while the latter displays a file selector dialog and permits you to change the filename. Note that **Save Sequence** is disabled until you have actually loaded a sequence and thereby established the default sequence filename.

Load/Save Enabled Slots Only affects whether the content of disabled slots (those for which the **Enable** box is not checked) is restored from, or saved to, the .seq file. Deselect this option if you are including both "primary" and "secondary" exposures in a sequence, that is, you want to define a group of slots which are always used, and some which you may or may not use depending on your needs at the time. By contrast, if **Load/Save Enabled Slots Only** is checked, then save will record only those slots that have **Enable** checked, and load will not disturb the definition of any slots that are not enabled in the .seq file (although it does clear their **Enable** check boxes). You can use this feature to "mix and match" partial sequences provided they use different slot numbers.

Sequence Wizard

The **Sequence Wizard** command sets up a sequence for you based on step-by-step input. The first page gives you a choice of one of four basic types of sequence to produce:

- Monochrome (M identical exposures of the same field)
- Tricolor (N exposures with each of three different filters, the exposure duration depending on the filter)
- Tricolor plus Luminance (M luminance [white-light] exposures and N exposures with each of three different filters with exposure durations depending on the filter; binning can be coarser for the color exposures)
- Calibration (an arbitrary number of exposures for each of flat fields, dark frames, and bias frames)



Depending on the type of sequence chosen, the wizard requests the image counts, exposure durations, filter selections, image suffixes, binning factors, and finally the destination directory. It finishes by displaying the **Setup Sequence** dialog with the completed sequence definition, which you may modify if desired; for example, you can add binning to a wizard-generated calibration sequence or change it to generate multiple flats with different filters. The wizard always uses sequence slots 1 up to 4, depending on how many are needed; the **Enable** check boxes for slots which are not needed are cleared, but their content is not otherwise disturbed.

You must close the **Setup Sequence** dialog by clicking **OK** to finalize the new script; closing the dialog via **Cancel** will discard it and keep the previous sequence settings.

Setup Mosaic

A mosaic specification defines the number and spacing of the individual image "tiles", and a position on the sky about which the images are taken, that will ultimately be combined to create a wide-field image. The overall mosaic is always in the shape of a rectangle, although you can terminate image acquisition early or begin it late to modify the shape. Since the final mosaic itself is built by the interactive **Mosaic** command, you also have the freedom to exclude certain parts or include other adjoining areas

The size of an individual tile is defined by your optical configuration (effective focal length) and the physical dimensions of your CCD camera array. You must determine this reasonably accurately before you can properly configure a mosaic specification; the **Pixel Scale Editor** available from the **Spatial Calibration** area of the **Information Window** is a helpful tool in this regard.



The **Mosaic Geometry** is defined as a rectangle of **W** tiles wide by **H** tiles high, with the tiles separated by **Spacing (arc min)**. The spacings across and down the mosaic are independently specified in order to accommodate cameras with a significantly non-square aspect ratio. Do not set the **Spacing** values to the actual horizontal and vertical field of view of the camera on your telescope; you must allow sufficient overlap to permit you to accurately align the tiles with each other later on, using star patterns or other features in the area of mutual coverage. For cameras with non-square CCDs, the horizontal and vertical spacings must take into account the camera's orientation with respect to the grid of RA and declination (camera rotation).

You can specify the pattern in which the mosaic rectangle is built up during image acquisition using the eight possible settings for **Direction** in conjunction with the **Alternating directions** check box. **Direction** always indicates a pair of directions, the first giving the primary or fastest moving axis as well as its preferred sense, the second the secondary. For example, in the figure above, "East to West, North to South" means that successive tiles will be to the west of the first captured, until the row is complete; then the second row will begin one tile to the south of the first. When **Alternating directions** is checked, images on even-numbered rows are captured in the direction opposite to odd-numbered rows, minimizing telescope motion and time lost when slewing back across the mosaic.

The position of the mosaic on the sky is specified by either that of the tile at the starting **Corner** (*actually the center of the corner tile*) or by the **Center** of the mosaic as a whole. Having identified which scheme you are going to use by the left-hand radio buttons in the **Mosaic Position**, you must also either supply a starting **RA** and **Dec**, or if the telescope is already properly pointed, select **Current telescope position**. The former is appropriate if your system is well-aligned and trustworthy, the latter if you have just completed finding and focusing on the object.

Starting tile number should normally be set to one (1) to instruct MaxIm CCD to capture the entire mosaic. Its range is up to and including the product of the **W** and **H** mosaic dimensions. It is updated automatically as each tile's image is acquired, and is primarily intended for resuming after an interruption. But you can set the **Starting tile number** to the index of any tile in the mosaic, though you must be sure you understand the numbering scheme implied by your selection of **Direction** and **Alternating directions**. Setting this control to a tile number other than one(1) causes the **Continue Mosaic** command on the **Sequence Tab Options** list to be enabled. Note that it is automatically reset to one(1) if you **Start** a sequence mosaic with **Capture Mosaic** checked on the **Sequence tab Options** list. Note also that if a mosaic sequence is aborted part way through a particular tile, the **Starting tile number** will be incremented as the sequence terminates. Therefore, unless you interrupted the sequence exactly between tiles, i.e., while the telescope is slewing to the next tile, you should decrement the **Starting tile number** before resuming if you want to be sure of gathering the full complement of sequence exposures at that location. Before continuing a sequence you may also wish to reset the **Start at** index number on the **Sequence Tab**, since it is always increased to one greater than the largest sequence index used whenever a sequence terminates. However, in practice, it usually doesn't matter if images from different tiles are not numbered consistently.

Set the **File naming** drop-list to select the desired naming scheme to be applied to images from mosaic tiles. Because the sequence is repeated once for every tile, images from each tile have to be stored with unique names. Three choices are available:

- **Sequence number only:** the sequence numbers assigned by the **Sequence** tab are allowed to increase across tile boundaries. This provides the shortest file names, but makes it difficult to determine the position of a particular image in the mosaic from its filename alone. Although you can always inspect the **OBJECTRA** and **OBJECTDEC** FITS keywords, it is often useful to be able to group tiles of the same area together more easily, for example, for purposes of combining them.
- **Insert tile index (xxyy):** the horizontal and vertical offsets of a particular tile from the starting tile of the mosaic (tile #1) are inserted into the filename between the root name and the sequence index, and separated from them by

underscores (*rootname_xxyy_nnn*). These offsets are always in the range of 0 to **W**-1 and 0 to **H**-1. If neither **W** nor **H** exceed 100, two digits are allotted to each, otherwise three digits are used. The horizontal tile offset is always specified first, even if the primary scan direction is North-South. In this mode, the sequence index is always reset to the original value when a new tile is started, so that the *nnn* values are the same for every tile. The exception to this is when a sequence is aborted, as described above.

- **Insert tile RA and Dec:** the RA and Declination of the tile center are each expressed as six digits, concatenated together and inserted between the root name and the sequence index, and separated from them by underscores (*rootname_hhmmss±ddmmss_nnn*). As with the **Insert tile index** mode, the sequence index number is always reset to the original value when a new tile is started.

Focus Tab

The **Focus** tab provides a duplicate set of exposure controls, condensed into a compact format. While the **Expose** tab is used for taking images that will be saved, the **Focus** tab is primarily used for taking images for focusing and for centering objects in the field. The separate controls make it is easy to switch back and forth between two different exposure settings. The Focus tab can be used for the main **CCD** or the **Guider**, by clicking the appropriate radio button.



The **Start Focus** button starts an exposure or exposure sequence. When an exposure is in progress, the **Start Focus** button is disabled, and the Stop button is enabled.

The focus tab does not change the filter wheel position. If you need to change the filter selection, do so using the **Expose** tab.

The exposure duration is set using **Seconds**. The minimum exposure setting is 0.001 seconds. Note that some cameras cannot achieve this shutter speed and will use their lowest possible setting instead.

The **Binning** control allows you to combine multiple pixels together to produce “super-pixels” covering more area. The **Delay(s)** control specifies a delay time, in seconds,

before each exposure is taken. For cameras that lock the computer during readout, it is a good idea to set the Delay to 1 to make sure there is enough time to stop a continuous exposure sequence.

The **Subframe** controls allow you to specify a limited area on the CCD chip to read out. This is useful for speeding up the readout when focusing. As with the **Settings** tab, you can drag the mouse on an image while holding the left button to draw the desired subframe area. This function is only available when the **Focus** tab is displayed. The **Reset** button restores the subframe settings to include the entire CCD chip. The **Auto** button locates the brightest pixel in the image and specifies a small subframe region around it.

The **Dark** check box enables automatic dark frame subtraction. A dark frame exposure will automatically be taken when required, and applied against all later images with the same settings. If the camera does not have a shutter, you will be prompted to cover and uncover the aperture as required.

The **Continuous** check box enables continuous imaging. When the **Start Focus** button is pressed, images will be acquired continuously until the **Stop** button is pressed.

A **progress bar** is included just below the **Stop** button. It illustrates graphically the progress of the exposure. Just below the progress bar is a status field which indicates the current camera activity.

The **Focus** tab is usually used in conjunction with the **Inspect** tab, which provides helpful information on the image focus. The **Start Focus**, **Stop**, and camera selection controls (i.e. **CCD/Guider** radio buttons) are replicated on the **Inspect** tab.

Inspect Tab

The **Inspect** tab is used in conjunction with the **Focus** tab. The **Start Focus** and **Stop** buttons replicate the functions of the buttons on the **Focus** tab. These buttons are not available until the **Focus** tab has first been activated. This ensures that the settings are checked before a focus exposure is started.

You can select between the controls and displays for the main **CCD** camera or the **Guider** using the radio buttons.

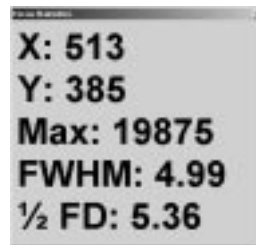


The diagram on the left side of the dialog shows a 3-D isometric plot of the area surrounding the brightest pixel in the image. Assuming the brightest pixel is part of a point-source object such as a star, the narrowness of the peak shows graphically how good the focus is.

Camera and focus information is displayed in the status field. This includes the current camera activity, the location of the brightest pixel in **Max X** and **Max Y**, the value of the brightest pixel in **Max Pixel**, the full-width half maximum in **FWHM**, and the Half Flux Diameter in **Half Flux Dia.**

Both the FWHM and Half Flux Diameter are measurements of the quality of focus. FWHM is the diameter of the star at half the peak brightness. It is calculated by fitting a Gaussian profile to the star image. When you are very close to focus, the FWHM number will tend to bounce around, so you should look at several readings and take the best result.

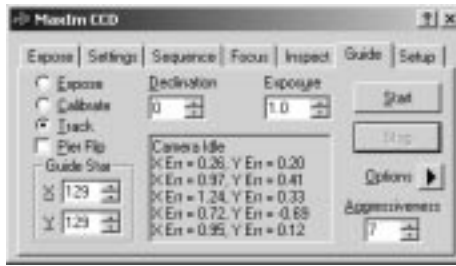
Half Flux Diameter is a new measurement technique invented by Larry Weber and Steve Brady. It determines the diameter of a circle that encloses half the total flux (count) in the star image. It can handle much larger diameter stars than FWHM (up to 100 pixels), and is often more consistent from image to image.



A larger display of the focus statistics can be invoked by clicking the **Large View** button. The following information from the **Inspect** tab is displayed in large print in the **Focus Statistics** window: **X**, **Y**, **FWHM**, $\frac{1}{2}$ **FD**, **Max**. The window can be closed by clicking on the close button on the title bar, closing the **MaxIm CCD** window, or by switching to a tab other than **Focus** or **Inspect**.

Guide Tab

TIP: Autoguiding can be a complex operation. If you are having trouble autoguiding, please see the **Autoguider Operating Tips** and **Troubleshooting** sections.



The **Guide** tab is used to control an auxiliary autoguider CCD. An autoguider is used on astronomical telescopes to maintain accurate pointing during an exposure. Some CCD cameras include a second CCD chip that is used for tracking; in other cases, a second CCD camera can be used to provide this function. Autoguider operations may seem somewhat complex at first. *It is highly recommended that you review the tutorial.*

MaxIm CCD can take sequences of exposures while the autoguider is running, even for cameras that share a shutter between the guide CCD and imaging CCD. During download the shutter is closed and the guider cannot operate. MaxIm CCD automatically reacquires the guide star after each exposure. If a multi-filter sequence is in progress, it waits for the filter wheel to finish rotating before reacquiring the guide star.

When taking exposure sequences, a five second delay is automatically inserted between exposures to allow time for the autoguider to settle. This is necessary because the guider cannot operate during camera download and the telescope may drift. If needed, you can increase the delay time; use the **Delay** field on the **Expose** tab for individually triggered exposures, or **Delay Between** on the **Setup Sequence** dialog for sequences.

Before starting, is a good idea to review the **Guider Settings**. You can display them by **selecting** the **Settings** item from the **Options** button menu.

To set up the autoguider, first select the **Expose** option. Choose an **Exposure** duration, and click the **Start** button. When the image appears, check that a suitable guide star is present; if not, you may need to adjust the telescope position or increase the exposure.

The **Guide Star** position in **X** and **Y** should automatically update to reflect the star's location on the chip. You can also manually select a different star by clicking on it.

The autoguider needs to be calibrated every time the telescope is repositioned, unless the **Declination** field is in use (see below).

Before calibrating, ensure that the selected star is near the center of the display. Select **Calibrate** mode and click the **Start** button. MaxIm CCD exposes a single image, and then activates the **X** relay for a specified time. It then takes a second image, and then reverses the motion of the telescope. This procedure is repeated for the **Y** axis. A total of five exposures are taken in all. As each exposure is acquired, the position of the star is displayed in the status window and a red line showing the history of the guide star motion is added to the current **Autoguider Image** window. When the sequence is complete, you can see the results for all five images. The guide star path should be L-shaped, with each arm traced twice. The "L" can be oriented at any angle, but the two arms must be perpendicular to each other and should be roughly the same length (the precise relationship depends on the relative speeds of two axes and their calibration times). If a rectangle or other shape is drawn instead, your guider cabling is probably incorrect. You must rectify this before MaxIm CCD can successfully guide exposures.

If your mount is only capable of corrections in one axis, you can disable the other axis from the **Guider Settings** dialog. In this case there will only be three exposures and the guide pattern should be a pair of straight lines of equal length superimposed on each other.

Once the calibration exposures are complete, MaxIm CCD calculates the required calibration setting, which you can view or change in the **Guider Settings** dialog. If the star leaves the field during the exposure or does not move sufficiently far (at least five pixels) in one or both directions, an error message will be displayed. If the star moves too little or too much, open the **Guider Settings** dialog and change the calibration time for the appropriate axis. Note that a second star entering the field could confuse the calibration routine if it happens to have a brightness similar to that of the calibration star. A specially designed software routine reduces this possibility by trying to match the star closest to the initial position that has a similar brightness.

Once the guider is calibrated, use the **Expose** mode to take another image and confirm that a suitable guide star is still present. The brightest star will automatically be selected in the **Guide Star X** and **Y** fields, but you can pick a different star by clicking on it. Switch to **Track** mode, and click **Start**. The autoguider will immediately start running. A running error display will be shown; the errors should settle down to small numbers after a few cycles. You can then switch to the **Expose** tab or **Sequence** tab and start taking images with the main camera.


Before calibrating the autoguider, it is useful to set the **Declination** field to the approximate declination of the telescope. This makes it unnecessary to recalibrate the autoguider after a slew to a different declination; instead, simply reset the **Declination** field to the new declination of the telescope and the calibration will be automatically adjusted to match. The exception is that when using a German Equatorial mount, the calibration sense has to be reversed for one axis flipping the mount over, as occurs when

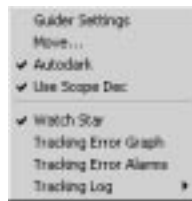
moving the telescope from eastern to western sky and vice versa. Toggle the **Pier Flip** check box to switch the direction of the calibration settings when this is necessary.

You can have the Declination field automatically updated for you provided your telescope is connected via the **Telescope Control** window. See **Use Scope Dec** below. If you do not wish to use the **Declination** feature, leave it set at zero during calibration and tracking.

Aggressiveness is used to adjust the guiding stability. A value of **10** means that the guider will attempt to guide out **all** of the detected motion; whereas a value of **1** means that the guider will attempt to guide out **10%** of the detected motion. You can set it to **0**, thus suppressing all corrections but still measuring the guiding errors; in this case the background of the control is set to **yellow** as a warning. A high value can result in overshoot, particularly if there is atmospheric turbulence or flutter caused by wind loads. A low value will result in slow correction. A value of **8** or **9** often provides optimum tracking. **Aggressiveness** is a "hot" control, meaning that changes made to it while the guider is running take effect immediately, unlike the other controls on this tab which are sampled just once when **Start** is clicked.

To terminate guiding, click **Stop**. The current exposure is aborted and MaxIm CCD ceases making guiding adjustments to the telescope.

The following commands are included in the menu actuated by clicking the  **Options** button:



Guider Settings displays the **Guider Settings** dialog, described below.

The **Move** command brings up the Move dialog, which allows you to move the telescope slightly to adjust the position of the guide star. This is particularly useful when autoguiding a spectroscope; it can be used to place a star directly on the slit. It also allows you to manually move the telescope, which is handy for rough positioning, testing motor interfaces, etc. It is not intended for slewing significant distances; to position the scope at specific coordinates expressed numerically or from a catalog, or on an object visible in a camera image (**Auto Center** function), refer to the **Telescope Control** window.

Autodark turns on or off dark field subtraction for autoguider images. When it is enabled, a whole-image dark frame is taken during the preliminary exposure used to

locate a guide star. During tracking, the necessary subframe is extracted from this dark exposure and is subtracted from the current tracking exposure subframe. In this way the dark frame does not have to be taken again. It also allows dark frame subtraction to work during offset tracking, described under **Advanced Settings**. If you change the exposure and restart **Track** mode without taking a new image in **Expose** mode, no full-frame dark exposure is available and MaxIm CCD takes a guide box sized dark frame instead.

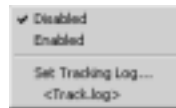
If MaxIm CCD is guiding on an extremely bright star, **Autodark** can be turned off to speed up autoguider operations.

When **Use Scope Dec** is checked, MaxIm CCD reads the declination from the telescope at the start of tracking and updates the **Declination** field automatically. This provides automatic compensation for the declination of the telescope and eliminates the need to recalibrate after slews where declination changes. Note that users of German Equatorial mounts will still need to set the **Pier Flip** control when flipping the mount over..

If **Watch Star** is checked, the star being tracked will be displayed on every update in a small image window. This allows you to continuously monitor the tracked star. Note that if you are exposing multi-filter sequences and the filter wheel is in front of the autoguider camera, you should make sure that the exposure is sufficient for all filter positions. Blue filters are often problematic since they tend to have the lowest transmission, and this is further compounded by those cameras that are not very blue sensitive.

The **Tracking Error Graph** is a resizable window that shows the recent history of the guiding errors in one or both axes, and is described in its own section.

The **Tracking Error Alarms** command displays a dialog that lets you set up an alarm to warn you if the guiding error becomes larger than a limit you set, or if the guide star fades out (e.g., due to clouds). It is described in its own section.



A **Tracking Log** is an ASCII text file containing a record of the times, measurements, and corrections made during tracking. To output a tracking log, select the **Enabled** command from the **Tracking Log** submenu. Select the folder and filename for the log file by clicking on **Set Tracking Log**, navigating to the desired folder, entering a name in the **File Name**, and clicking **Open**. The first time you start guiding in a new session of MaxIm DL, the log file will be cleared. Each time you start the guider again, new data is appended onto the end of the file. The file is only open while writing.

You can turn off logging by clicking **Disabled**. If you reenables logging during the same

MaxIm DL session without selecting a new log file, data will be appended to the old one. You cannot turn logging on and off while tracking is active.

A track log looks like this:

```
Track Log Started at UT 1999-06-18 22:43:40
UT Time, Star X, Star Y, OffsetX, OffsetY, Corr X, Corr Y, Bright
22:43:44, 513.71, 384.88, -0.29, 0.88, 0.11, -0.74, 2036
22:43:48, 513.58, 384.24, -0.42, 0.24, 0.16, -0.20, 2020
22:43:51, 513.60, 383.97, -0.40, -0.03, 0.15, 0.02, 2029
22:43:54, 514.40, 384.18, 0.40, 0.18, -0.15, -0.14, 2023
22:43:57, 513.78, 383.81, -0.22, -0.19, 0.08, 0.16, 2037
22:44:01, 513.42, 384.09, -0.58, 0.09, 0.22, -0.07, 2024
22:44:04, Guide Star Fade
22:44:07, 514.07, 384.41, 0.07, 0.41, -0.02, -0.34, 2026
22:44:10, 513.71, 384.50, -0.29, 0.50, 0.11, -0.42, 2010
22:44:23, 514.08, 384.15, 0.08, 0.15, -0.03, -0.12, 2044
```

The time is shown in Universal Time (UT Time). The system time zone and daylight savings time settings must be correct in order for this to show the correct time. Star X and Star Y show the coordinates of the star relative to the CCD chip in pixels. OffsetX and OffsetY show the position relative to the center of the guide box in pixels. Corr X and Corr Y show the duration (in seconds) of the correction made for the two axes. Bright shows the peak brightness of the star. If the star disappears momentarily, Guide Star Fade will be shown. This “comma delimited” format is compatible with loading into a spreadsheet application for plotting.

The filename currently set for the tracking log is displayed at the bottom of the submenu, under **Set Tracking Log**. This is for information only, and clicking on this menu entry has no effect.

Guider Settings

This section describes the first of the two pages comprising the **Guider Settings** tabbed dialog, which is activated from the **Options** button menu of the **Guide** tab.



The **X Axis** and **Y Axis** fields work identically. Normally **X Axis** refers to the **Right Ascension** drive and **Y Axis** refers to the **Declination** axis; however, this depends on the exact wiring between the autoguider and telescope controller. Note that the direction of the **X** and **Y** axis on the screen may not correlate with these directions, depending on the orientation of the camera.

Cal. Time is used to set up calibration. The value entered here indicates the time, in seconds, that the motors are actuated during calibration. The calibration sequence actuates the motors for this period of time, measures the displacement of the star image, then reverses the motors for the same period of time. This must be set large enough for the guide star to move a sufficient distance during calibration (10-20 pixels is recommended), but not so far that it leaves the guide window.

The **Backlash** control is used to run out backlash in the drive motors. Enter the time, in seconds, to actuate the relay to run out the backlash. Whenever the motor direction reverses, this time is added to the correction. This is usually not necessary on the telescope's Right Ascension axis because the sidereal tracking constantly runs out the backlash. The Declination axis often benefits from some backlash compensation. If the **Backlash** is set too high, the autoguider will overcorrect whenever it changes direction. If the **Backlash** is set low, it will take longer for the correction to occur when the direction reverses. The setting may also affect the accuracy of the calibration if set inappropriately. When in doubt, leave this value at zero.

The **Guider Enables** check boxes turn on or off corrections in the **X** and **Y** directions. This may be useful if, for example, the mount can only be controlled in Right Ascension. Under special circumstances you may want to disable guide motion in only one direction of a particular axis. This can be useful if your mount exhibits a stiction phenomenon that causes the telescope to move in the wrong direction initially when declination corrections reverse direction. To avoid declination reversals, you can slightly

misalign the mount so that stars tend to drift consistently in one direction, say northward. Then disable corrections that push the telescope in that direction, relying instead on the gradual creep. In this way, the declination corrections never reverse and trigger a large swing. To do this, clear one of the four check boxes **+X Output**, **-X Output**, **+Y Output**, or **-Y Output** to disable the particular guider relay output responsible for that motion. (Experimentation may be required to determine which one should be turned off.) If a guider axis is disabled, then that axis will be skipped during calibration. Only one axis may be disabled at a time. If a guider output is disabled, then no corrections in that direction will take place while tracking. The guider output settings do not affect calibration.

The calibration can be set manually using the **X Speed**, **Y Speed**, and **Angle** controls. These values are normally filled in by the automatic guider calibration function. The speed values are entered in pixels per second; that is, how many pixels a star will move when the motors are actuated for one second. The Angle is zero if north is at the top.

Display Scaling controls how data is displayed in the scrolling autoguider position/error display on the **Guide** tab. When **Display Mode** is set to **Pixels** and **Delta** is checked, the errors **X Err** and **Y Err** (difference between measured and desired position) are displayed in pixel units. When **Display Mode** is set to **Arc-seconds**, **X Err** and **Y Err** are displayed in arc-seconds; the effective focal length of the guider telescope must be set on the **Site and Optics** tab of the **File Settings** menu in order for the angular measure to be computed. The **Delta** check box is disabled in **Arc-seconds** mode.

When **Display Mode** is set to **Pixels** and **Delta** is not checked, the scrolling autoguider position/error display shows the measured star position **X Pos** and **Y Pos** in pixel units, rather than the errors.

Control Via is used to set the output method for the autoguider. Many cameras include built-in relays that can be used to output pulses to the motor controller; select **Camera Relays** for this option. Alternatively, you can output pulses on a parallel (**LPT**) port or select a **COM** port to which serial commands can be sent (COM port mode is recommended for advanced users only). You can also connect to a Starlight Xpress relay box if you select **SX COM1** through **SX COM20** (note: for **STAR2000** leave this set to **Camera Relays**). You do not have to be using a Starlight Xpress camera in order to use the relay box.

To send autoguider commands to the telescope via the **Telescope Control** interface, select **Telescope**. This requires an active link to a telescope that has Pulse Guide capability, such as an LX-200. If the telescope is not linked, or a linked telescope does not have this capability, then no motion will occur.

For parallel port autoguider output, select the port address to use. The connections are: ground pin 18 through 25, +X pin 2, -X pin 3, +Y pin 4, and -Y pin 5. Active low

signals are also available: /+X pin 6, /-X pin 7, /+Y pin 8, and /-Y pin 9. **Warning:** the PC parallel port should not be connected directly to a telescope mount without a relay box. Incorrect hardware connections could cause damage to the computer.

For serial port autoguider output, the selected COM port is initialized to 9600 baud, 8 bits, no parity. The **Serial Command** field allows you to enter a text command that will be sent to the port. For example, if **Serial Command** is set to "MOVE", a typical output command will be MOVE 1.23 -2.34<CR>. The first number indicates the number of seconds to actuate the X motor, and the second number indicates the number of seconds to actuate the Y motor. A minus sign indicates to move the telescope in the minus direction.

The **Binning** control allows you to combine multiple pixels into larger "super-pixels." This increases sensitivity and reduces download time, but reduces resolution. It is only recommended when using a large autoguider CCD chip with small pixels on long focal length instruments.

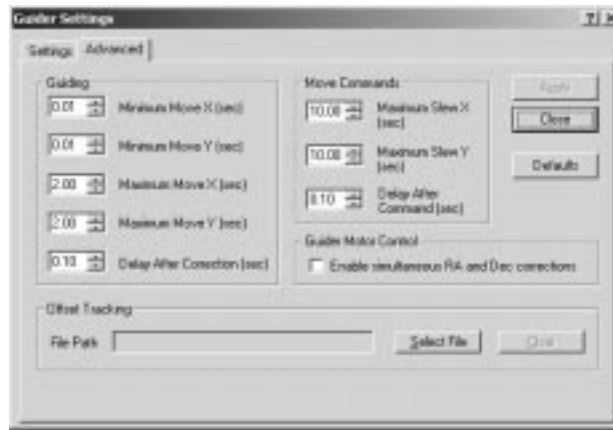
The **Left, Top, Width, and Height** controls set the subframe area used for the **Expose** and **Calibrate** modes. These can be set from the image using the mouse and a previously acquired autoguider image: **hold down the left button and drag the mouse** on the **Autoguider Image** while the **Autoguider Settings** dialog is open to this page. The **Reset** button restores the subframe settings to the entire CCD array.

Changes to most controls on this dialog do not take effect until you either close the dialog or click the **Apply** button. When a control has been altered, the **Apply** button enables automatically to remind you that it has not yet taken effect.

The **Defaults** button resets most controls to their "factory defaults". The exceptions are the calibration values **X Speed, Y Speed, and Angle (deg)**, which must be measured on your own equipment, and the subframe definitions **Left, Top, Width, and Height**, which have their own **Reset** button.

Advanced Settings

This section describes the second of the two pages comprising the **Guider Settings** tabbed dialog, which is activated from the **Options** button menu of the **Guide** tab.



The **Guiding** controls set limits for track mode operations. The **Minimum Move X** and **Minimum Move Y** sets the smallest motion the autoguider will make. This provides a small “dead band” which can be useful for preventing oscillations in the guide star position due to unnecessary corrections, and to help overcome the effects of backlash. The **Maximum Move X** and **Maximum Move Y** can be used to limit the maximum amount of motion permitted during guiding. Lowering this value can prevent the guider from tracking out a momentary large error, such as might occur if a large wind gust occurs.

A non-zero value in the **Delay After Correction** field causes a time delay after each guider output command. This allows time for the telescope to settle (or, in the case of serial output command mode, for the guider activation itself to complete) prior to taking the next guider image. A small delay is also recommended when using Losmandy mounts.

The **Move Commands** settings control the behavior of the **Move** dialog (accessed using the **Guide** tab’s **Move** button). **Maximum Slew X** and **Maximum Slew Y** limit the maximum slew that will be performed using this command. These limits can be set to prevent large, accidental slews. The **Delay After Command** control allows you to program in a delay after each move command. It should be used in the same situations for which **Delay After Correction** is recommended.

Because not all mounts are capable of running the right ascension and declination axis guide motors simultaneously, MaxIm CCD sends correction commands to each axis sequentially. If your mount is capable of guiding in both axes at the same time, you can turn on **Enable Simultaneous RA and Dec Correction**. Please consult the documentation for your mount before using this option because it can potentially damage equipment not capable of simultaneous operation in both axes.

Enable Simultaneous RA and Dec Correction is ignored when **Control Via** is set to

Telescope because the ASCOM telescope interface does not permit this mode of operation.

Offset Tracking is an advanced feature that allows you to specify a series of positions for the guider to track to. This can be used to track solar system objects such as asteroids and comets, or to compensate for flexure in your system.

Click the **Select File** button under **Offset Tracking** to select the offset file. Locate your file and open it, then click **OK**. The next time you start a tracking session the offset mode will be started.

The format of the offset file is flexible. Times and positions can be specified either in relative or absolute coordinates.

The format for relative coordinates is as follows:

```
ss +/-x.x +/-y.y
```

where:

ss - Time delay from last movement

+/- - Direction of movement; i.e. either + or - (required)

x.x - Amount of movement in X direction (in pixels)

y.y - Amount of movement in Y direction (in pixels)

An example of this might be:

```
15 +0.5 -0.5
```

```
15 +0.5 -0.5
```

```
15 +1.0 -1.0
```

Fifteen seconds after guiding starts, the guide point would be moved half a pixel to the right, and half a pixel up. The same thing would happen 30 seconds into the exposure, and so on. Avoid moving the guide point more than a small amount in each step. If the guide star reaches the edge of the frame, offset tracking will be disabled.

The format for absolute coordinates is as follows:

```
hh:mm:ss x.x y.y
```

where:

hh:mm:ss UT time in hours, minutes and seconds

x.x New X position in absolute coordinates

y.y New Y position in absolute coordinates

An example of this might be:

22:30:15 255.0 255.0

22:30:45 255.5 255.0

22:31:15 255.5 253.5

In this example, at UT 22:30:15, the guide point will be moved to coordinates X=255.5, Y=255.0. You must be careful to move the guide point slowly or the lock could be lost.

To disable **Offset Tracking**, click the **Clear** button.

Changes to most controls on this dialog do not take effect until you either close the dialog or click the **Apply** button. When a control has been altered, the **Apply** button enables automatically to remind you that it has not yet taken effect.

The **Defaults** button resets all controls except the **Offset Tracking** group to their "factory defaults".

Move Dialog

The **Move** command is accessed using the **Guide** tab's **Move** button. It allows you to reposition the telescope using the autoguider output relays. Since this is done at guiding speed, only small movements are possible. For slewing large distances, and for **Auto Center** operations, use the **Telescope Control** window.



There are two methods for moving the telescope. The first is to designate a **From** and **To** position and click the **Move** button. Note that the accuracy of this movement depends on the accuracy of the autoguider calibration and the mechanical characteristics of the telescope mount.

The positions may be entered manually, or by clicking on an image from the autoguider using the mouse. The **Click to Set** selector determines which field the data is entered into when the mouse is clicked. The **Auto** button allows you to automatically select the

brightest star in the image as the object to be moved. The **Lock** button allows you to lock the **To** field so it cannot be accidentally changed. This is useful if the star must be positioned accurately; for example, when aligning it with a spectrograph slit.

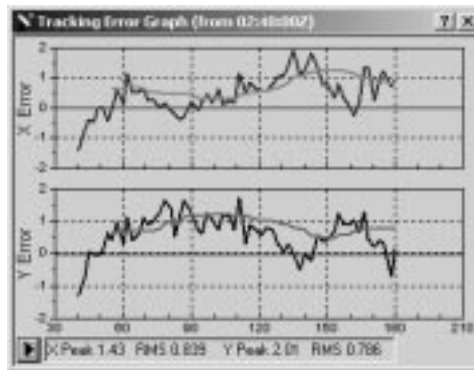
The manual controls allow you to activate one of the output relays for a time determined by the **Sec** field. Clicking one of the buttons moves the mount in the desired direction. The buttons may be reassigned using the **Swap X** (reverses X buttons), **Swap Y** (reverses Y buttons) and **Swap Axes** controls (switches X and Y buttons).

If the **Auto Expose** control is on, the autoguider will automatically take an exposure after every move operation. The **Guider Status** field shows the current autoguider activity.


The **Abort** button allows you to abort slews initiated by both the **From/To** and manual motion controls. The **Close** button closes the dialog.

Tracking Error Graph

The **Tracking Error Graph** is a graphical presentation of the most recent 15 minutes of guiding errors. You can choose to display the errors in either or both axes, with or without RMS trend lines, and expressed in either the camera (X–Y) or telescope (RA–Dec) frame of reference. The graph is scrolled toward the left automatically when the right edge is reached. The vertical scale and time duration of the graph are selectable. The peak excursion and current RMS value of each error are displayed at the bottom of the graph for quick reference. The window can be resized to any desired size; the graph automatically stretches or shrinks to fill it.



Tracking errors are always collected whether this window is active or not, so you can turn it on to check for guiding anomalies if you suspect one has occurred based on inspection of a main camera image.

All options are selected from the button menu  at the bottom left corner of the window:



The **Plot** submenu contains commands to select what is plotted. Choose **Camera Axes** or **Telescope Axes** depending on whether you want to see the guiding errors as measured in the camera frame of reference, or as rotated to the telescope frame. The latter setting can be useful when determining if poor guiding results from a mechanical problem in the telescope mount.

Select **X Error** to display only the error in the X axis, **Y Error** for that in Y, **X and Y Errors** for both to be superimposed on one graph, or **X and Y (separate)** to display them in separate graphs within the same window, as in the example shown above. **X** errors are always plotted in dark green and **Y** errors in dark blue.

Select **Show RMS Trends** to display the root-mean-square error as well as the instantaneous error. The RMS error is a moving average based on the measurements made over an adjustable interval called the **RMS Window**, discussed below. RMS Trends are not available when **X and Y Errors** are plotted on the same graph. They are shown in a lighter color than the raw measurements.

The graph can be plotted with symbols at each sample: small triangles for raw error measurements and plus signs for RMS averages. Alternatively, you can request that **Lines** joining points of the same type instead, which is easier to see if the graph window is not very big. Intervals when guiding is inactive or the guide star was lost are indicated by breaks in the line.

The **Vertical Scale** submenu allows you to select the Y axis range. The available scales are ± 0.5 , ± 1 , ± 2 , and ± 5 pixels. You cannot display tracking error plots in arc-seconds.

The **Time Span** submenu allows you to select how much data is plotted in the graph, based on a time range ending at or near the time of the most recent measurement. The available choices are 1, 3, 6, 10, and 15 minutes. Data is not lost when the selected **Time Span** is shortened, only when the data point ages beyond the maximum limit of 15 minutes.

The **RMS Window** submenu allows you to specify the length of time over which data is averaged when computing the RMS error. You can choose between 30 seconds, 1, 2, 3 or 4 minutes. RMS information is not plotted for a measurement if there is insufficient data in the interval of this duration immediately preceding it.

Plot type, **Vertical Scale**, **Time Span**, and **RMS Window** length can be adjusted at any time and the display is automatically updated.

The **Peak Values** submenu allows you to specify whether the extrema displayed in the status area at the bottom of the graph **Reset Automatically**, as soon as the peak data point is no longer displayable, i.e., is 15 or more minutes older than the most recent point, or are **Reset Manually**, on user command. When in manual reset mode, use the **Reset Now** command to reset the peak display to zero. As new measurements are made, the peak values will creep upwards.

Click **Save Data** to record the available measurements to a disk file. This calls up a file selector dialog with which you navigate to the desired destination folder and specify a filename. The file is written in the same format as the **Tracking Log**.

Click **Load Data** to load and display a previously saved graph or a **Tracking Log**. (Tracking Logs exceeding 15 minutes in duration are automatically clipped. If necessary, you can divide them into shorter segments with any text editor.) If you start the guider after loading a file, old data will be automatically flushed as soon as the first measurement is made.

The **Alarms** display calls up the **Tracking Error Alarms** window. This is an alternative to using the Tracking Error Alarms command in the **Options** menu of the **Guide** tab.

The **Clear Graph** command erases all data from the graph. If the guider is active, the next measurement made will begin a new graph, resetting the reference time shown in the window title to the current time.

Tracking Error Alarms

The **Tracking Error Alarms** window allows you to define both the conditions that warrant a tracking alarm and the actions that MaxIm CCD is to take when they occur. It is also used to acknowledge (reset) an alarm condition.



The two check boxes in the **Trigger Alarm** section define the conditions under which

an alarm is issued. The first, **If error exceeds**, specifies a limit on the guide errors (**X Err** and **Y Err** as reported on the **Guide** tab), together with the number of consecutive **cycles** (autoguider images) that the error must be out of limits before the alarm is triggered. The second, **If guide star not detected**, specifies that an alarm is raised if the guide star is lost or fades below the level at which MaxIm CCD recognizes it, again for a certain number of consecutive **cycles**. You can select either, both, or neither type of alarm.

The **Alarm Actions** specify how MaxIm CCD signals the occurrence of an alarm condition. First, the **Tracking Error Alarms** window is always displayed, regardless of which other actions are selected. In addition, if **Flash this dialog box** is checked, the caption bar will be flashed in Windows' traditional way of drawing attention. If **Audible alarm** is enabled, the WAV file named in the associated edit box is played. (Click the browse button just to its right to call up a standard file dialog box for navigating to and picking the sound file.) If **Repeat** is checked, the sound will loop continuously until the alarm is acknowledged, otherwise it will play only once. **Execute script** can be used for more elaborate alarm actions through the agency of a Windows Script Host script which you supply and whose actions you define. You specify this script with the file selector dialog activated through the browse button on this line.

What can a script do? It might, for example, capture a new full-frame autoguider exposure and examine it for potential guide stars, or simply abort any main camera exposure or sequence in progress. If the system is running unattended, it might be appropriate to send an email message reporting the problem. (Refer to the description of **Scripting** to learn about the capabilities MaxIm DL/CCD extends to scripts and the kinds of things that are possible.) An alarm script is executed by the command shell-based script host `cscript.exe`. If you do not want the command window to pop up in front of MaxIm DL, you can specify that it should run **Minimized**; the script window will still appear on the Windows Task bar and can be restored as long as it is still active.

When a tracking alarm occurs, the **Acknowledge** button is enabled. Clicking this button disables the button again and also silences WAV file playback if it is sounding.

Click **Close** to close the **Tracking Error Alarms** window. You can close the window even without acknowledging an active alarm, but the audible warning will continue (if enabled), and no further alarms will be reported. MaxIm CCD checks for tracking alarm conditions only after the previous alarm has been acknowledged.

Setup Tab

The **Setup** tab is used to initialize camera hardware and control temperature regulation.



Setup for each component – **Main CCD Camera**, **Autoguider**, and **Filter Wheel** – works in much the same fashion. Click the **Setup** button to select and configure the hardware. For cameras and autoguiders, the dialog box will list cameras and show options for those cameras.



You can change the camera selection using the **Camera Model** field. Various options will appear depending on what model is selected.

When setting up the autoguider, you have an additional choice. Setting the **Camera Model** to **Same as main camera** will make the same camera work as both the main camera and autoguider. If the camera is capable of simultaneously guiding and imaging, for example a dual chip camera, then the two “halves” of the camera will behave like two completely independent cameras. If the camera is not capable of simultaneous guiding and imaging, then you will only be able to use it for one function at a time.

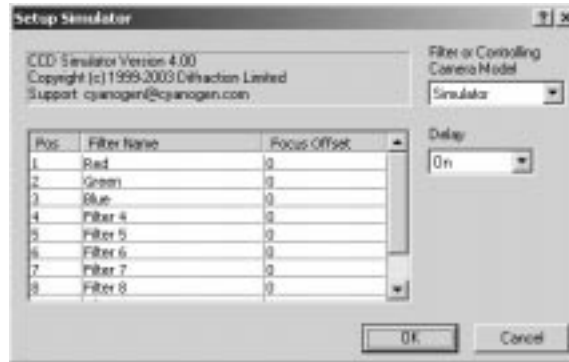
If you want to select two *different* cameras of the same model for main camera and autoguider, then simply choose the same camera model in both places; do *not* select **Same as main camera**. Each camera will have separate settings, so you can configure them for different ports.

The **Filter Wheel** is set up the same way, although the dialog box is different. The filter wheel type is selected in **Filter or Controlling Camera Model**. Select the filter wheel model if the wheel is connected directly to the PC. If the filter wheel is controlled via a CCD camera, select the appropriate camera model in the list. In this case it has to match the selected CCD camera model.

There can be up to three filter wheel-specific configuration parameters, located on the right side under the OK and Cancel buttons. See the **Filter Wheel Setup** section for

information on the parameters available for different filter wheels.

The user can assign names for each of the color filter slots, under **Filter Name**. If your filter wheel has fewer slots than allowed for by this driver, simply leave the extra slots blank; they will not appear in the drop-list filter selectors. If the filters vary in thickness, a **Focus Offset** can be entered for each filter. This causes the focus position to be offset appropriately every time an exposure is taken with a new filter position. The offset is expressed in focuser steps. If this feature is used, absolute positioning focusers are strongly recommended to ensure repeatability.



Once the camera, autoguider, and filter wheel have been selected and configured, click the Connect button to initiate links to the hardware. An error will be produced if any hardware fails to connect; if so, all links will be disconnected.

Once the camera(s) are connected, you may need to set up the cooler. Most supported cameras have closed-loop cooler systems that can be set to a particular temperature. Click **Cooler On** to start the cooler(s). If control is available, you can then use the **Cooler** buttons for the main camera and autoguider to set the temperature.



Dial in the desired cooler temperature **Setpoint (C)** and click OK. Note that the cooler temperature should be set as low as possible without exceeding the camera's cooling capacity. There should be a bit of room at the bottom to allow for proper temperature regulation.

If a camera's cooler is already on when you connect to the camera, the three cooler control buttons will pop up. This is done because the main camera and autoguider may not be in the same state; it is reminding you to set up the coolers.

When you prepare to shut down, the first task is to warm up the cooler(s). Click the **Warm Up** button to start the cameras warming up. The period of time required for the warm-up depends on the particular camera model; some cameras simply turn off the cooler, while others gently raise the cooler temperature over a period of time. If you need to switch off the cooler rapidly, click **Cooler Off** to immediately power down the coolers. Note, however, that this could result in thermal shock, especially on cameras with very large delta-T. Repeated thermal shock could potentially damage the sensor or cooler stack. Usually this is not an issue if the delta-T is less than about 20 degrees C.

The setup dialog boxes for each individual camera model and filter wheel model are described in the **CCD Camera/Autoguider Setup** and **Filter Wheel Setup** section. All cameras are supported as autoguiders, although not all include built-in relays for controlling telescope mounts directly (n.b. a few models have relays that cannot be controlled by software). Note that certain camera models may have poor performance for autoguiding due to slow update rates.

For cameras that do not have internal relays, the following options are available: Starlight Xpress relay box, direct parallel port control, and control via the Telescope Control window.

To determine the correct selection for the camera, autoguider, and filter wheel mode, please see **Driver Installation and Setup**.

Telescope Control Window

Telescope Tab

The Telescope tab allows you to position the telescope manually, either by supplying Right Ascension and Declination coordinates, or by nudging it in a prescribed direction by an adjustable amount.



To go to a specific position on the sky, enter the Right Ascension (**RA**) and Declination (**Dec**). These should be entered as hours/degrees, minutes, seconds. You can skip the seconds field, or skip both the seconds and minutes fields. The last number entered can

be entered with a decimal point; for example, 12.8417 is the same as 12 50.5 or 12 50 30.

The **RA** and **Dec** can be entered using the spin controls (up/down buttons). Position the cursor on the hours/degrees, minutes, or seconds and click the spin control. Only the selected field will be adjusted.

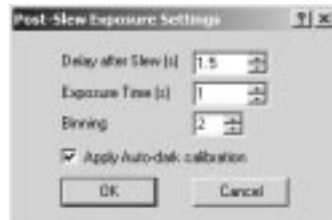
Once a position is entered, click the **Go To** button to start the telescope slewing to the desired position. If you want to stop the telescope motion quickly, hit the **Abort** button.

You can nudge the telescope in eight cardinal directions using the appropriate **Nudge** buttons. The distance moved is determined by the settings below the buttons. This is handy for centering objects; however, the Auto Center function is much quicker. See the **Center** tab for more information.

If you need to synchronize the telescope's position, you can click the **Sync** button, whereupon the **Sync Telescope** dialog pops up. If a PinPoint astrometric solution has been calculated for the current image, you can synchronize the telescope to that. Otherwise, you can synchronize on the currently entered position. Click **OK** to confirm the new synchronization.



If **Take image** is checked, then an exposure will automatically be taken after every slew operation. Click the **Exposure** button to provide settings for these automated exposures, whereupon the **Post-Slew Exposure Settings** will pop up.



You can enter the **Delay after Slew (s)**, which provides for some delay time before starting the exposure. This may be necessary to allow time for the clock drive to settle before taking the picture. **Exposure Time (s)** is usually set fairly low (1-10 seconds) to grab a quick exposure so you can tell where you are pointing. **Binning** is best set fairly high to increase the sensitivity of the quick exposure and also to reduce the download

time. The maximum binning level depends on the camera that is in use. **Apply Auto-dark calibration** turns on the auto-dark feature, which automatically subtracts a dark frame from the exposure so as to increase signal-to-noise ratio.

The **Site...** button brings up the **Site and Optics** page of the **File Settings** dialog box, which together with the time is used to calculate the orientation of the sky.

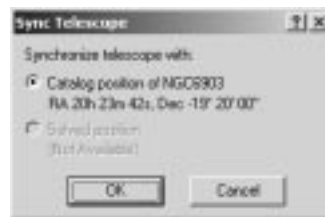
Catalog Tab

The Catalog tab provides a convenient way to locate astronomical objects. You can extract the object position from a built-in catalog (provided courtesy of the Saguro Astronomy Club).



Select the **Object type** to **Deep sky**, **Solar system**, or **Named stars**. Then click the drop-down list button and select an object or catalog. If a catalog is picked, you can then enter the catalog number by typing it into the field, or by **clicking the numerical keypad buttons** with the mouse. The keypad buttons are useful when you are working in the dark and cannot see the keyboard. In addition to numbers, there are backspace, decimal point, and +/- (change sign) buttons on the keypad.

Once you have selected your object, you can use the **Go To** or **Sync** buttons. These work exactly as on the **Telescope** tab. The Sync button gives you the option of synchronizing the telescope to a PinPoint solved position, or on the current position as given by the catalog.



You can also search for objects by clicking the **Nearby** button. You can select which catalogs to include using the check boxes under **Included catalogs**. You can limit the maximum magnitude (faintest object) using the **Brighter than mag** field.

Dark nebulae, which have no magnitude specified, can be included by turning on **Include dark nebulae**. You can also opt to **Include objects with unspecified magnitude**.

The **Max slew distance** (in degrees) can be entered. This restricts the search to only those objects within the specified distance of the current telescope position.



When you have established the search criteria, click **List objects**. A listing of objects meeting your search criteria will appear. The object **Type** and **Magnitude** will be shown. To determine the position on the sky, click once on the **Catalog Identification**, and the **RA** and **Dec** will be shown. Click the **Go To** button to immediately slew to the object, or **Close** to close this dialog. You can also slew to an object by double-clicking on the **Catalog Identification**.

Center Tab

The Center tab is used to adjust the position of the telescope in order to center any object visible in the most recent image. Once this auto-center function has been calibrated, you can instantly center any object in an image. Calibration is described below.

To center an object, first take an image of it. **Right-click** on the point in the image that you want to be at the center of the camera field of view, then select **Point telescope here** from the context menu. The telescope will automatically slew the distance required to center the object.

If **Acquire new image after centering** is on, an exposure will automatically be taken using the settings in the **Exposure** button's **Post-Slew Exposure Settings** dialog (see the

Telescope tab for an explanation of the exposure settings). . This allows you to quickly see whether the object has been satisfactorily centered.

You can also center an object by clicking the **Select New Center Point** button and then clicking on the image. It is usually more convenient to use the **right-click menu**.

Calibration is very simple, and need only be done once unless you remove or rotate the camera, or change equipment.



The software needs to know the **Image Scale** in arc-seconds per pixel for unbinned exposures, and the **Orientation** of the camera in degrees, where zero degrees means that north is at the top of the image. You can enter these values explicitly by setting the **Calibration Type** to **Manual**, but it is simpler to perform an automatic calibration.

To do this, select **Auto**. Enter an **Auto Slew Distance** in arc-minutes. For good results, this should typically be set to about $\frac{1}{4}$ of your CCD field of view. Image a field containing a suitable calibration star and roughly center it in the camera using the **Nudge** buttons on the **Telescope** tab. MaxIm CCD will use the brightest star in the field, so for reliable calibration all other stars in the field should be measurably fainter. On the other hand, the star must not be so bright as to saturate or "bloom" the CCD. Click the **Calibrate** button.

The camera will now take an exposure using the settings in the **Exposure** button's **Post-slew exposure settings** dialog. Then the telescope will slew eastward by the amount specified by **Auto Slew Distance**, and the camera will take a second exposure. The distance (in pixels) and angle of motion of the star across the CCD are measured, the calibration values are calculated, and the **Image Scale** and **Orientation** are displayed. The telescope will automatically move back to the original position and take another exposure so that you can verify this. Finally, check **Mirror** if your optical system has an odd number of reflecting surfaces, for example, if you are imaging through an AO-7 or star diagonal. You are now ready to use the auto-center feature.

If for any reason you need to stop the operation, **Abort** will stop the telescope motion.

The **Pier Flip** setting is used with German Equatorial mounts. **Pier Flip** should NEVER be used with a fork mount. When a German Equatorial mount flips from one side of the

pier to another, the camera physically rotates 180 degrees. Enabling the **Pier Flip** setting compensates by rotating the calibration data by the same amount.

Focuser Tab

The Focuser tab will let you control the telescope's focuser.

We recommend the use of a digitally controlled, absolute positioning focuser. Generally speaking these focusers use stepper motors for precise, repeatable positioning, and can be commanded to specific locations by the computer. This repeatable positioning facilitates accurate autofocus.



For absolute positioning focusers, you can set a position in the **Absolute** field, and then click **Move To**. The focuser will automatically move to that position. You can abort the move by clicking **Stop** (note: some focuser models do not support the stop command).

If the focuser features automatic **Temperature Tracking**, you can turn on the check box to activate this. During temperature tracking, the focuser position cannot be changed manually.

You can also move in incremental steps. This is very useful during manual focusing. Set an **Incremental** step size, and then click **Move In** or **Move Out**.

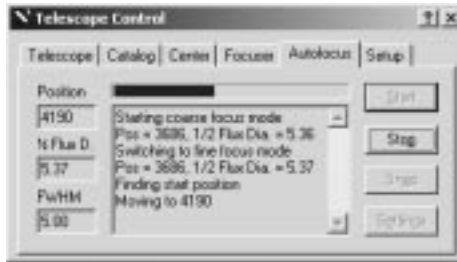
Autofocus Tab

This tab operates the SharpStar™ autofocus algorithm. SharpStar is designed for highly accurate, fully automatic autofocus.

SharpStar autofocus uses the Half Flux Diameter measurement technique, a highly accurate and repeatable method of measuring the star diameter. Half Flux Diameter is the diameter that encompasses half of the total light received from the star. It can handle extremely large “donuts” from centrally obstructed systems without trouble.

The highly robust Half Flux Diameter method was invented by Larry Weber and Steve Brady. For more information on HFD focus methods, and an excellent autofocus utility program designed for use with MaxIm DL/CCD, please see <http://www.focusmax.org>.

Once Autofocus is set up, merely click the **Start** button and wait. SharpStar is designed for reliability and accuracy, not speed. It may take several minutes to find best focus. However, this is often much faster than can be achieved manually!



It is extremely important before starting autofocus to click the **Settings** button and set up parameters for your telescope. If this is not done, the autofocus will almost certainly fail. Once the settings have been set up properly for your equipment, they do not need to be adjusted again.



The **Telescope Focal Ratio** is essential. It determines the depth of focus, and therefore the step size that is used when hunting for best focus. The focal ratio is often found in the telescope manual; it can also be calculated by dividing the focal length by the aperture.

Also essential is the **Focuser Step Size**. Some digital focusers know what this is inherently; you can click the **Auto** button to fill in the information. Other focusers do not have this information; they are just motors hooked up to focusers from other

manufacturers. In this case, take out a ruler! Move the focuser 1000 steps, measure the distance it moves, and divide that by 1000. Enter this value into the Focuser Step Size. Be sure to select the proper units for the focuser step size, either **Microinches** (millionths of an inch) or **Microns** (millionths of a meter) as appropriate.

Tip: if you cannot see the focuser move, as for a Schmidt-Cassegrain telescope, focus the telescope with an eyepiece, move the focus out 1000 steps, and then pull the eyepiece out of the focuser until the image is sharp. Measure the distance the eyepiece is moved. If the motion is small, move more steps and divide by the total number.

You also need to set the **Target ½ Flux Dia**. The Half Flux Diameter is a measure of how large the star images are; obviously we want them to be as small as possible. The target needs to be set somewhat higher than the optimum; typically by 2 pixels. This is required because the measurements are made on *either side of focus*, not right at focus. Typical values are 5 to 7, but it depends on how small your star images are at best focus.

You should also set up the **Exposure** for the camera. In the **Find** mode (coarse focus), the images are usually binned to speed up readout; usually **Bin 2X2** will do. The **Subframe Height** and **Subframe Width** are used during fine focus; smaller values speed up the process, but if they are too small the star may shift out of the box and the focus procedure might fail.

The **Delay (sec)** should normally be set to zero for fastest operation. If your camera locks the system during download, you may wish to use a longer delay, in order to ensure that you can abort the autofocus manually.

You can optionally subtract an **Auto-dark** frame from the focus exposures as they are downloaded. Normally a single dark frame is exposed at the start of the sequence, and then the appropriate subframe is extracted from that image as needed. Some cameras may not work well in this mode; if problems are encountered, then check **Force full frame**.

Once you have set up the parameters, click **OK** to close the **Autofocus Settings** dialog box. Now click **Start** and watch!

Troubleshooting

The software moves the focuser in steps based upon the focal ratio and focuser step size you have entered in the **Autofocus Settings** dialog box. You want the fine focus mode measurements to be about 1 to 1.5 half flux diameter units apart (except near focus, where the value changes more slowly). Watch the log during autofocus operation and verify that this is the case.

If the focal ratio is incorrectly entered as longer than it really is or the step size is made too big, the focuser will move too quickly. It will either not find focus at all in coarse

focus mode, or will scan through focus too quickly in fine focus mode. If it scans too quickly, it may miss best focus; if you see the half flux diameter exceed 20 in fine focus mode, chances are that the steps are much too large.

If the focal ratio incorrectly entered as shorter than it really is or the step size is made too small, the focuser may move too slowly. In this case, it will take an excessively long time to find focus. If far too many steps are taken the autofocus algorithm will abort.

Setup Tab


The Setup tab allows you to configure the telescope and focuser links.



Select the **Telescope** type in the drop list. Note that most telescopes require configuration before they can be used for the first time. This is done using the **Setup** command described below.

Select the focuser type under **Focuser**. Again, most focusers require some initial configuration, as described below.

Once your telescope and/or focuser are set up, click the associated **Connect** buttons to establish the links. You can also click **Disconnect** to stop a link. You can **Connect** and **Disconnect** telescope and focuser independently. The links will be automatically terminated when you close MaxIm DL.

Just below the **Telescope** selector and connection status field is the **Options** button  which displays the following menu:



Select **Setup** to display a dialog allowing you to specify interface information such as port, baud rate, etc., and any other options affecting basic telescope operation. Generally speaking this only needs to be done once. **Setup** dialogs are specific to the particular

model of telescope and are described elsewhere.

The **Slew Limits** command displays a dialog allowing you to constrain telescope position above a specified **Minimum Altitude** and/or below a specified **Maximum Declination**. (The latter is used with fork-mounted Schmidt-Cassegrain and similar telescopes where there is insufficient clearance between the base of the fork and the back of the optical tube to accommodate a CCD camera when the instrument is pointed near the pole.) You can enable either, both, or neither limit with the associated check boxes. If a limit is in effect and a commanded slew (e.g., the **Go To** button on either the **Telescope** or **Catalog** tabs) would take the telescope beyond that limit, an error message is displayed and the request is ignored.




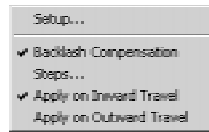
Display Alt-Az controls whether the Altitude and Azimuth of the telescope are computed and displayed in the status fields on the **Telescope** and **Catalog** tabs in addition to the Right Ascension and Declination as reported by the telescope (and the name of the current target object, if known). In order to compute telescope Altitude and Azimuth, the geographical coordinates of your observing site must be entered in the **Site and Optics** tab of the MaxIm DL **Settings** page, or the option to read latitude and longitude from a GPS-equipped telescope must be enabled. If any required information is unavailable, the status display will show "Alt N/A Az N/A".

The **Park** and **Unpark** commands are only enabled if your telescope's ASCOM driver supports them. Parking a telescope positions it in a manufacturer-recommended orientation, and may also involve automatic application of axis locks, stowing pins, etc. Unparking a telescope is returning it to the operational status from the parked configuration. The ASCOM interface does not provide a way of determining whether the telescope is parked, so both commands are enabled during a MaxIm DL session until one of them has been issued. Consult your telescope owner's manual for precautions regarding parking and unparking.

The last two entries in the menu control the coordinate frame MaxIm DL uses to display telescope orientation. When **Display RA,Dec in J2000** is selected, it assumes all coordinates you enter apply to epoch J2000.0, the celestial coordinate reference corresponding to the position of the equator and equinox at the beginning of the year 2000. This is the reference frame used in most current catalogs. Note however that when you select this mode, the celestial coordinates reported in the status field of the **Telescope** tab will typically differ slightly from those reported by any digital displays on

the telescope itself. That is because the telescope must necessarily work in the frame "Epoch of instant", also known as JNow. MaxIm DL precesses coordinates from J2000.0 to JNow when sending them to the telescope and precesses positions reported by the telescope back to J2000.0. If you select **Display RA,Dec in JNow**, all coordinates shown in the status windows are JNow. (Coordinates of objects given in the listbox on the **Nearby Objects** dialog are always shown in J2000.0 regardless of this setting.)

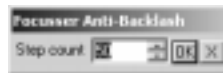
Just below the **Focuser** selector and connection status field is the **Options** button  which displays the following menu:



Select **Setup** to display a dialog allowing you to specify interface information such as port, baud rate, etc., and any other options affecting basic focuser operation. Generally speaking this only needs to be done once. **Setup** dialogs are specific to the particular model of focuser and are described elsewhere.

Some focusers exhibit backlash, which arises primarily from looseness in the mechanical parts which move the focuser. Despite the use of stepper motors and digital control circuits, the focuser does not move to exactly the same physical position (extension) even when the controlling mechanism has moved by an identical amount in both directions. Selecting **Backlash Compensation** instructs MaxIm DL to always approach a target focuser position in the same direction, thus eliminating this problem. If the target position is in the "wrong" direction, i.e., opposite to the preferred sense, MaxIm DL runs the focuser past the desired position by a certain distance and then reverses direction to approach from the "correct" direction.

Click **Steps** to display a dialog allowing you to specify the amount of overshoot, expressed in focuser steps. You should use the smallest value which eliminates backlash issues. Click **OK** to accept the entered value or **Cancel** to leave the existing value unchanged.



You can choose the direction in which **Backlash Compensation** is applied. Select **Apply on Inward Travel** or **Apply on Outward Travel** according to taste, experience with your equipment, or the recommendation of your focuser manufacturer.

Please see below for details on setting up various telescope and focuser drivers. Both use open-standard ASCOM interfaces (<http://ascom-standards.org>) so additional drivers

may be available.

SBIG AO-7 Control Window

The SBIG AO-7 is a tip/tilt autoguider accessory that integrates with the SBIG dual-chip CCD cameras. The AO-7 requires a radically different user interface than that provided by the standard MaxIm CCD autoguider functions; therefore, the Guide tab is not used.

It is strongly recommended that this entire section be read before attempting to use the AO-7 tip/tilt autoguider unit. The documentation supplied with the AO-7 should also be read to familiarize yourself with the characteristics of the device.

The SBIG AO-7 device uses a special driver which controls both the camera and the AO-7 unit itself. The **Guide** tab is not used; instead, a special **AO-7 Control** window appears. The **AO-7 Control** window is similar to the **MaxIm CCD** window in that it is a tabbed dialog.



The **AO-7 Control** window cannot be hidden as long as the AO-7 is connected; however it will minimize when the **MaxIm DL** application is minimized.

The four AO-7 Control tabs are:

- **Locate** – Take exposures to locate and select the guide star, including choosing exposure and binning settings. Also used to calibrate the motor drive (if used) and the AO-7 mirror.
- **Track** – Track a star and monitor its position both visually and numerically. Control the exposure duration (track time) and certain guiding parameters, and monitor the guide star position.
- **Drive** – Setup auxiliary correction using the telescope mount motors. This is optionally used to keep the guide star within range of the tip/tilt mirror when mounts having large drift or periodic error are used.
- **Setup** – Select the track box size, view or edit AO-7 tip/tilt mirror

calibration settings, exercise the tip/tilt mirror system to check operation, and dither exposures to compare guided and unguided star images.

When the AO-7 is in operation, all of the regular **MaxIm CCD** exposure controls operate normally. This means that exposure sequencing and automatic tricolor operation is supported while tracking with the AO-7. **It is strongly recommended that a five second exposure delay be set to allow the AO-7 to reacquire the guide star before the next exposure starts.**

Note that the **AO-7 Control** requires significant CPU resources while tracking. Other system functions may become sluggish, especially under Windows 98/ME.

Before operating the AO-7, please read the **Overview of AO-7 Operation**.

SBIG Camera with AO-7

When using the AO-7 tip/tilt autoguiding accessory, set to **SBIG w/AO-7**. If a **CFW-8** filter wheel is connected via the camera, set the **Filter** selection to **SBIG Universal**.



Usually the **Autoguider** is set to **None**, since the **Guide** tab is not normally used with the AO-7. You can however use **Same As Main Camera** if you wish to use the **Guide** or **Focus** tab functions with the guide sensor when the AO-7 is not running.

For parallel port cameras, select the parallel port address in **Connect To**. For USB cameras, select **USB**. For Ethernet connection, select **Ethernet** and enter the correct **IP Address** for the camera. The IP Address is ignored when connecting to a parallel port or USB camera.

The download **Priority** can be adjusted. **Very High** will ensure that no lines appear in the image due to readout delays, but may make it difficult to operate the mouse.

Guider ABG turns on/off the anti-blooming gate for the autoguider sensor; turning it on reduces blooming if the sensor saturates, but decreases sensitivity slightly. Normally it is left off.

Setting **Binning Mode** to **Off-chip** is useful when a non-anti-blooming CCD chip is installed. When enabled, it causes any binning to be performed after the CCD chip has been read (normally, binning is done inside the CCD chip before readout). Selecting this

option results in slightly higher readout noise but greatly reduces blooming. This control has no effect for anti-blooming CCD chips, and has no effect for 1:1 binning. You can also set Binning Mode to **Spectroscopy**. In this mode, the main sensor can be binned Nx1 to Nx3, where N ranges from 1 to 255.

Important Note: some cameras use a TC-237 guide sensor instead of the original TC-211 guide sensor. These sensors have much smaller pixels; it is strongly recommended to operate these sensors at 2x2 binning.

Please see **SBIG AO-7 Control** for full details on operating the AO-7.

Overview of AO-7 Operation

Before setting up the AO-7 unit, the camera should be focused using the **MaxIm CCD Focus** tab and the temperature should be near the **Setpoint**. Once focused and at a stable temperature the AO-7 must be calibrated (see **Locate** tab). Once you have calibrated your AO-7 unit the settings are stored; you should not need to recalibrate again unless the unit is serviced or equipment such as a filter wheel is inserted between the AO-7 and the camera.

The telescope drive must also be calibrated (see **Locate** tab) if corrections are enabled for one or more mount axes while autoguiding (see **Drive** tab). This calibration must be done so that **MaxIm CCD** can correlate the direction the mount moves with the motor relays; if this is not necessary, this function can be turned off. If the orientation of the camera with respect to the telescope motions remains constant the calibration only needs to be done once.

In order to guide an exposure with the AO-7, a guide star must first be located using the **Locate** tab. Next, switch to the **Track** tab, select a **Track Time** (guider exposure duration), and click **Start**. If everything works correctly, the guide star should appear and then be pulled into the center of the guide box immediately. The **Track Time** should be as short as possible to allow for the fastest update rate, but long enough to ensure a clear image of the guide star. To adjust the Track Time, momentarily stop the guider – click the **Stop** button, dial in the new duration, and click **Start** again. The **Aggressiveness** and **Max. Move** can then be adjusted while autoguiding to tweak the tracking stability.

With a short **Track Time**, extremely fast guide rates are possible using the AO-7. This provides the optimum guiding and can often have a noticeable effect on the resolution of the resulting images. Note that higher rates may be possible using the Windows NT/2000/XP operating system as opposed to Windows 98/ME.

Since autoguiding with the AO-7 is very CPU intensive, users may find that it is more convenient to stop the AO-7 while adjusting the exposure settings in the **MaxIm CCD** control window. Once all the relevant exposure parameters are set, start the AO-7

autoguider and then switch back to the **MaxIm CCD** control window to start the exposure.

MaxIm CCD can take sequences of exposures while the autoguider is running. During download the shutter is closed and the guider cannot operate. The AO-7 Control window will automatically reacquire the guide star after each exposure. If a tricolor sequence is in progress, the software waits for the filter wheel to finish rotating before reacquiring the guide star. However, before starting a tricolor sequence it is a good idea to make sure that the guide star is bright enough when the filter wheel switches to blue.

When taking exposure sequences, at least a five second delay should be inserted between exposures to allow time for the autoguider to settle (use the **Delay** field in the **Expose** tab). This is necessary because the guider cannot operate during camera download and the telescope may drift. The software is designed to automatically reacquire the star even if it has drifted out of the track box.

During reacquisition, the AO-7 will take two exposures using the settings on the **Locate** tab, then start tracking using the settings on the **Track** tab. This procedure allows it to reacquire the guide star even if it has drifted out of the track box. Sufficient delay time must be allowed for this process to occur before the next exposure starts. Typically a five second delay is sufficient, but this may not be enough if longer tracking exposures are used.

AO-7 Locate Tab

The **Locate** tab is primarily used to locate a guide star. It also allows the user to calibrate the telescope drive motor and the AO-7 mirror deflection. Selecting one of the three **Mode** options (**Locate**, **Calibrate Drive** or **Calibrate AO-7**) allows changes the operation that will be executed by the **Start** button.



Locate Mode

In order to find a suitable guide star to track on, first select the **Locate** mode. Choose an **Exposure** duration (in seconds), and click the **Start** button. If necessary, a dark frame

will be taken and subtracted from the light frame. Once the image is taken, MaxIm DL will automatically select the best guide star candidate in the image, and report its information in the **Guide Star** group box. The **Guide Star X** and **Y** fields display the guide star position, in pixels, within the CCD chip, and its maximum pixel brightness is shown in the **Brightness** field below the coordinates. A small cross is drawn on the image to indicate the star's position. If you wish, you may click on any other star in the image to override the automatic star selection and select a new guide star to track.

Use the **Binning** control to enter the binning value to use when acquiring images through the guide camera. With larger bin sizes the exposure time can be reduced while still obtaining a useable image. The maximum binning allowed for cameras with a TC211 guide chip is 2x2; if a TC237 chip is used, the maximum binning is 3x3.

Check the **Contin.** (short for **Continuous**) check box to enable constant imaging. When this check box is checked, and the **Start** button is pressed to acquire an image in **Locate** mode, the camera will return images constantly until the **Abort** button is pressed.

If a suitable guide star cannot be located, reposition the instrument, turn on binning, or increase the exposure.

Calibrate Drive Mode and Calibrate AO-7 Mode

Both the **Calibrate Drive** mode and **Calibrate AO-7** mode operate identically, except in the former case the motor drive is activated, and in the latter case the AO mirror is tilted.

Before calibrating, ensure that a star is near the center of the image by using the **Locate** mode; adjust the telescope position if necessary. Set the **Exposure** duration (in seconds), select the desired star with the **Auto** button or the **Mouse**, and then click the **Start** button. The **AO-7 Control** will then take a series of five exposures comprising a reference image, and one image in each instance after moving the mirror (or mount) in the +X, -X, +Y and -Y directions. A dark frame will also be taken if necessary. Each time a new image appears, a small cross will be superimposed on the selected guide star. If for some reason the cross does not appear in the correct location for every exposure, the calibration has failed. Normally this would only happen if the star left the field of view. (Note that if you disable one motor drive axis on the **Drive** tab only three exposures will be taken in the **Calibrate Drive Mode**.)

The location and brightness of the star used in the calibration will be displayed in the **Guide Star X**, **Y** and **Brightness** fields after each exposure. From the collected data, the **AO-7 Control** will then calculate the required calibration settings. These settings can be viewed on the **Drive** tab for **Calibrate Drive** mode or the **Setup** tab for **Calibrate AO-7** mode.

If you have trouble calibrating the AO-7 mirror, try enabling the **Cal Pause** setting. This

setting pauses the calibration for three seconds after each mirror deflection, ensuring that the mirror position has stabilized before taking an image to measure the star's movement. **Cal Pause** has no effect on the drive calibration.

If during the calibration the star leaves the field, moves at a 45 degree angle, or does not move sufficiently in one or both directions (minimum 5 pixels), an error message will be displayed. If the star moved too little or too much in one axis during the **Calibrate Drive** routine, click the **Drive** tab and change the **Calibration Time** for the appropriate axis. Note that the software has been designed to ignore, as much as possible, a second star entering the field.

Usually the **Binning** should be set to 1x1 when calibrating the AO-7 in order to increase the image resolution and hence calibration accuracy. For motor drive calibration image resolution as great a concern (see **Drive** tab).

AO-7 Track Tab

The **Track** tab is used to start and stop the AO-7 autoguider, and to monitor its performance. Before the AO-7 can start autoguiding a guide star must be selected using the **Locate** tab.



Use the **Binning** check box to change the image binning. This allows you to effectively increase the star brightness and decrease the exposure time. The maximum binning allowed on cameras with a TC211 guide chip is 2x2, for TC237 guide chips, 3x3. Due to the small pixel size of the chip, it is recommended that you use at least 2x2 binning when tracking with a TC237.

The **Track Time** is the duration of the tracking exposure, and this will determine the update rate at which the AO-7 can correct for stellar wander. This can only be changed when the AO-7 is idle.

The **Aggressiveness** is a scaling factor used to refine the amount of correction applied when the guide star is off center. The required correction in pixels is multiplied by the **Aggressiveness** divided by 10. Therefore if the **Aggressiveness** is set to 5 and a correction of 6 pixels is required to center the guide star, the AO-7 mirror will tilt such

that the star is moved $6 \times 5 / 10 = 3$ pixels towards the center. If the **Aggressiveness** is set too high (>10) the star may oscillate, too low and the system will be slow to respond to stellar wander. You can adjust **Aggressiveness** while the AO-7 is tracking; set it to a value which minimizes the **RMS Wander**. A value of 6 to 8 usually provides optimum tracking.

The **Max. Move** field sets the maximum correction in pixels that can be applied in a single cycle. (Note that the absolute maximum deflection the AO-7 unit can accommodate is about +/- 15 pixels for an ST-7 or ST-8). Lowering **Max. Move** will allow the AO-7 to ignore large fluctuations occasionally caused by brief wind gusts that are too fast to track out. Decreasing this value too much will reduce the effectiveness of the AO-7. As with the **Aggressiveness** setting, this field can be adjusted while autoguiding and should be used to minimize the **RMS Wander**.

Clicking on the **Start** button will initiate autoguiding on the star that was selected using the **Locate** tab. Before the small tracking image is displayed in the dialog, the computer will accumulate eight dark frames in order to have a low noise dark frame to subtract from the short duration light frames. The autoguiding can be stopped at any time by clicking on the **Stop** button.

While autoguiding the image of the guide star (magnified 400%) will be continuously updated. As well, the values for **RMS Wander**, the **AO-7 Tilt** position, the update **Rate** and the **Total Counts** will be updated.

The **RMS Wander** is the average deviation of the guide star from the center position, and is measured in pixels. Minimizing this value will improve the quality of the main exposure by minimizing the spot size of the stars.

The **AO-7 Tilt** displays the current AO-7 mirror tilt (in percent) in the X and Y directions. When autoguiding commences the mirror is set to the home position (i.e. 50% x 50%), which is the same position used when locating a guide star with the **Locate** tab.

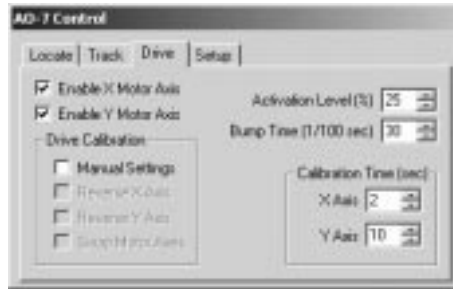
The update **Rate** is measured in Hertz and is the number of full cycles (each cycle comprising image acquisition, image download, processing, mirror tilt and display update) completed per second. The update **Rate** will generally be limited by the **Track Time**, however for short track times (< 0.05 sec) the image download and mirror movement times will have a greater impact on performance. Note that slightly faster update rates can be achieved by guiding on a star located near the top edge (but not too near!) of the guide chip, since the download time is slightly shorter. A larger improvement in the update rate can be achieved by reducing the **Track Box** size on the **Setup** tab.

The **Total Counts** field displays the current number of counts accumulated in the **Track Box** during the **Track Time** versus the number of counts accumulated in the initial

tracking image. The number of **Total Counts** will be proportional to the guide star's brightness.

AO-7 Drive Tab

The **Drive** tab is used to set up the motor drive for autoguider operation. Unlike normal autoguiders, the AO-7 tip/tilt mirror will be doing most of the corrections while autoguiding. The motor drive will only be activated occasionally. This means that the exact calibration speed is unimportant; only the directions must be set correctly.



The **Enable X Motor Axis** and **Enable Y Motor Axis** check boxes determine whether the mount's drive motors will be used to apply additional, automatic corrections in the X and Y directions when drift exceeds the AO-7's abilities to guide out. Individual selectors are useful if, for example, the mount can only be controlled in Right Ascension. Turn off both these fields to completely disable mount control. This can be done if the mount tracking is sufficiently accurate or if the user manually adjusts the mount (while monitoring the mirror position with the **Track** tab).

The motor directions **Reverse X Axis** and **Reverse Y Axis** can be automatically set using the **Calibrate Drive** mode on the **Locate** tab. However the directions can be set manually if the **Manual Settings** check box is checked. The **Swap Motor Axes** check box is turned on when the X axis of the autoguider image corresponds to the Y correction axis. Assuming the X axis relay controls the **Right Ascension** axis, the check box is turned **off** when the camera is oriented so that **North or South** is at the top, and **on** when **East or West** is at the top. This check box is also automatically set by the **Calibrate Drive** function.

The **Calibration Time** determines the length of time for which the **Calibrate Drive** operation activates the motors. If the **Calibrate Drive** operation reports that the guide star has not moved sufficiently or has moved off the frame during the calibration adjust these values accordingly.

The **Activation Level** sets the range about the home position (50%) which when exceeded will result in application of a bump from the appropriate drive motor. For

example, if a value of 10% is entered, the motor drive will be bumped so as to move the guide star towards the center of the track box when the AO-7 mirror tilt is greater than 60%, or less than 40%. If the **Activation Level** is set to 50% (i.e. 100% mirror deflection) the motor drive will never be bumped.

The **Bump Time** specifies the number of centiseconds (hundredths of a second) for which the motor drive is actuated when a bump occurs. In the example above, the **Bump Time** is entered as 30/100, or 0.3 seconds.

AO-7 Setup Tab

The **Setup** tab is used to set various AO-7 options and to test the AO-7 unit.

The **AO-7 Tracking Speed** is the distance a star is moved (in pixels) by a 50% mirror deflection (i.e. from 50% tilt to 100% tilt) multiplied by 5. These values should be filled in using the **Calibrate AO-7** function on the **Locate** tab. Normal **X** and **Y** values are in the 60 to 90 range. These values may be larger if a filter wheel is installed between the AO-7 and the camera, due to the extra distance between the mirror and the detector. The **X** and **Y** values should be within a factor of two of each other.



If star drift during the AO-7 calibration is too great, the **AO-7 Tracking Speed** values may be incorrectly set. This could occur because of very poor polar alignment or periodic error. If both the **X** and **Y** directions are incorrect by the same amount, adjusting the **Aggressiveness** while autoguiding would compensate for the tracking speed. However if the stars on the main exposure are oval shaped, either the **X** or the **Y** (but not both) **AO-7 Tracking Speed** will have to be manually adjusted (N.B. Increasing the **Tracking Speed** is akin to decreasing the **Aggressiveness** and vice versa). Calibrating using a very bright star and a very short exposure will minimize this problem. Remember that the AO-7 calibration only needs to be done once unless the hardware is modified.

The **Reverse X**, **Reverse Y** and **Swap Axes** check boxes are automatically set using the **Calibrate AO-7** mode on the **Locate** tab. However they can be set manually if the **Manual Settings** check box is checked. The **Swap Axes** check box is turned on when

the **X axis** of the autoguider image corresponds to the **Y deflection axis** of the tip tilt mirror.

The **Track Box** determines the size of the tracking image displayed on the **Track** tab while autoguiding. A smaller **Track Box** will increase the update rate but will also increase the chances that the guide star is lost due to a large instantaneous deviation. In most cases an **8x8 Track Box** is a good compromise.

Enabling the **Dither Exposures** option causes the AO-7 tracking position to change by a small amount after each main chip exposure. This is used to produce a sequence of images centered on a particular location, but with each one offset by a small random amount. The maximum number of pixels that the tracking position will be offset is minimum of the Amplitude setting and one half of the size of the Track Box. For instance, if an 8x8 track box is used, and the **Amplitude** is set to 5, then dithering will offset each exposure by up to 4 pixels.

The **Test Mode** option allows you to evaluate the performance of the AO-7. During a test mode exposure the AO-7 mirror will be periodically deflected from its tracking orientation to 0% x 0% (full deflection in both axes) and held for five seconds, then will return to normal guiding for five seconds. This produces an image with two sets of stars, one of which was corrected by the AO-7, and the other uncorrected.

The **Exercising** controls allow for visually checking the operation of the tip tilt mirror. Remove the AO-7/camera combination from the telescope and look at the tip/tilt mirror. When this function is activated, the mirror will repeatedly move between the four extreme positions. The **X Axis** and/or the **Y Axis** can be tested independently and the time spent while stationary (in milliseconds) at each extreme can be varied with the **Speed** setting. All these settings can be changed while the AO-7 is exercising.

Chapter 7. Scripting

MaxIm DL provides an ActiveX Automation interface for scripting and externally controlling the CCD camera operations. Some simple sample scripts are included on the distribution disk. ActiveX is a *platform-independent* method for linking different applications together.

ActiveX can be accessed from just about any standard scripting or programming language, including VBScript, JScript, Java, Perl, Visual Basic, Visual C++, etc. Using ActiveX, you can even control MaxIm DL from Excel spreadsheet macros.

MaxIm DL is compliant with ASCOM scripting. This allows it to operate with a wide variety of astronomical software products such as planetarium programs, telescope control software, and dome control systems. Sample scripts are available for downloading from the ASCOM web page <http://ascom-standards.org>.

Scripting Languages

The most commonly-used scripting languages on the Windows platform are VBScript and JScript.

VBScript looks like a simplified version of Visual Basic (thus the name), but you *do not* require Visual Basic to create or run scripts. VBScript code is run by the Windows Scripting Host, which is included in Windows 98, ME, NT 4.0, and 2000 and later versions of Windows 95.

Similarly, JScript looks like Java code. JScript is run by the very same Windows Scripting Host that runs VBScript. Deciding which version to use is simply a matter of user preference.

VBScript and JScript allow you to write simple scripts using only the **Notepad** text editor, and run by double-clicking them in the Explorer or using MaxIm DL's **Run Script** command.

Full documentation on the scripting languages is available for download; please see <http://www.msdn.microsoft.com/scripting/>.

Sample Scripts

In **VBScript**, you can take a picture as follows:

```
Dim cam ' "The" Camera object
Set cam = CreateObject("MaxIm.CCDCamera")
```

```
cam.LinkEnabled = True
if Not cam.LinkEnabled Then
  Console.WriteLine "Failed to start camera."
  Quit
End If
wscript.echo "Camera is ready, Exposing."
cam.Expose 1, 1, 0
Do While Not cam.ImageReady
Loop
cam.SaveImage "Script.fit"
wscript.echo "Exposure is done, Image saved as Script.fit"
```

If you want to try this, just copy the above code into a text file named "test.vbs". You can edit the file with Notepad. Double-click on the file to run it.

An improved version would use the ASCOM utility object `Util.WaitForMilliseconds` to add a slight time delay inside the wait loop. This would reduce unnecessary CPU overhead.

In **Visual Basic** you can access the `MaxIm` object in this fashion, or by clicking **References** under the **Project** menu. Scroll down to **MaxIm** and turn on the appropriate check box and click **OK**. You can create a `MaxIm` camera object and take a picture as follows:

```
Dim Camera as new MaxIm.CCDCamera ` MaxIm camera object
Camera.LinkEnabled = True ` Start link to camera
Camera.Expose 60, 1, 0 ` Start a 60 sec exposure, shutter open, filter 0
```

Tip: Use the **CCD Camera Simulator** and **Telescope Simulator** to test your scripts.

MaxIm DL/CCD Objects

The following objects are available; please see the Help for a complete description of the properties, methods, and events:

An **Application** object corresponds to a `MaxIm DL` session, whether started from a script or by the user. The methods and properties of the `Application` object allow your scripts to access the documents that are open to `MaxIm DL`, and to perform calibration setup and several other operations that either affect the program as a whole or at least do not involve a single specific document.

A **CCD Camera** object allows you to control a `CCD Camera`, `Autoguider`, and `Filter Wheel`. You must have the `MaxIm CCD` option installed to use this object.

A **Document** object corresponds to an image open in `MaxIm DL`, whether it was loaded from a file or acquired by your `CCD camera`. The methods and properties of the `Document` object allow your scripts to perform almost all the image processing operations that you can do using `MaxIm DL`'s menus and dialog boxes, and to access or change the image's pixel values.

A **Documents** object is a collection of Document objects. Calling `Application.Documents` will return a collection of all open image documents. Note that if you subsequently open or close another document, you will have to fetch a new Documents object; it is not updated automatically.

Image Processing Plug-In Modules

Plug-in modules allow third-party image processing functions to be added into MaxIm DL. The modules use ASCOM-compatible (COM/ActiveX) interfaces exclusively. This allows for some exciting new possibilities, because the image processing functions that are built into MaxIm DL are available for use by the plug-in modules. The plug-in author can blend together existing functions with new code to quickly build a powerful processing function.

A partial listing of available plug-ins can be found at www.cyanogen.com.

Installing Plug-Ins

Installing plug-ins is very simple. The plug-in is supplied as a DLL file. Save the file on your hard drive (a handy place would be the MaxIm DL program directory). Then bring up the Plug-In menu **Add/Remove Plug-Ins** command. Click the **Browse** button to the DLL file, and double-click it. The plug-in will automatically be registered with Windows and added to the menu.

Writing Plug-Ins

Writing plug-ins is surprisingly easy. You will require a compiler such as Microsoft Visual Basic or Microsoft Visual C++. Sample projects for both compilers are provided in subdirectories of the MaxIm DL program directory.

Visual Basic

Copy the sample Visual Basic sample code to a new place on your hard drive. You need to change the name of your plug-in object so it will not conflict with others.

Open the project in Visual Basic. Select the project **Properties** on the **Project** menu. Change the **Project Name** and **Project Description**. You should also copy the **Project Description** text into the **Object Browser** as follows:

1. Open the **Object Browser** using the **View** menu **Object Browser** command.
2. Where it says **<All Libraries>**, select the name you entered for **Project Name**.
3. Right-click on **PlugIn**, and enter the same text used in **Project Description**.

You are now ready to modify the plug-in code to add your own algorithms.

Visual C++

You can copy the sample code and modify it, but it is probably just as simple (and more instructive) to start with a new project. You can refer to the sample code as needed (tip: load both projects into a single workspace).

In **Developer Studio**, click **File** menu **New**. Select the **Projects** tab and click **ATL COM AppWizard**. Type in a project name and specify a location for it. If the sample plug-in is already open, you can select Add to current workspace. Click **OK**.

On the page that appears, select **Dynamic Link Library (DLL)**, and turn on **Support MFC**. MFC allows you to easily build a simple dialog box. Click **Finish**. When prompted click **OK**.

In the **Class View**, **right-click** on your project (e.g. MyProjectName Classes) and select **New Class**. Leave all settings as-is and type "**PlugIn**" for the **Name**.

Make sure your classes are expanded (+) and right-click on **IPlugIn** and select **Add Method**. Enter "**DoModal**" for Method Name, and "**IDispatch * Doc**" for **Parameters**.

Right-click on your project again and select **Add Property**. For **Property Type**, select from the drop list (or type) "**BSTR**". For the **Property Name** enter "**Name**". Turn off the **Put Function** check box, but leave the **Get Function** check box on. Click **OK**.

Now access the **Class Wizard (View menu)**, and click **Add Class**, and select **From a Type Library**. Browse to the **MaxIm DL** program directory, type **MaxIm_DL.exe** for **File name**, and click **OK**. This will create a wrapper class used to access MaxIm DL functions.

You now have a usable program shell for making your own plug-in. The functions you need to write can be accessed from the **Class View** as follows: **Open PlugIn**, open **IPlugIn**, and double-click on **DoModal** or **get_Name**.

Follow the example in the sample plug-in to learn how to access the image buffer and MaxIm DL functions.

To test the plug-in, select **Debug** menu **Run** or click **F5**. When prompted, browse to the **MaxIm_DL.exe** file and it will launch MaxIm DL. Then install the plug-in and try to use it. You can set breakpoints inside the plug-in, inspect variables, etc.

Chapter 8. Glossary

Annulus	A ring – the area between two concentric circles.
Airy Disk	The disk of light that is produced by a telescope or other optical system when imaging a perfect point source such as a star (assuming good optics and no atmospheric degradation of the image). This disk is produced because of the wave nature of light and the limited size of the objective lens or mirror.
Aliasing	Distortion caused by sampling, such as digital sampling of audio, or the pixelated sampling a CCD performs on the incoming light. If the sampling rate is too low, the information will be distorted; for example, if you take a digital picture of lines that are spaced less than a two pixels apart, you will not see the original lines. Instead you will see “ghost” lines spaced farther apart. The same effect makes wagon wheels appear to turn backwards in movies, which are a series of pictures (the samples) updated only 24 times a second.
Aspect Ratio	The ratio of width to height for the pixels in the image. Normally, one wants pixels with a 1:1 aspect ratio, but many cameras which are based on video CCD chips have non-square aspect ratios and must be interpolated to produce correct images.
ADU	Analog to Digital converter Unit. The CCD detector outputs a voltage representing how many electrons were detected on a particular pixel. This voltage is amplified and filtered and then passed to an Analog to Digital Converter, which turns the voltage into a number. That number is measured in ADUs. If you multiply by the Gain, also known as Photoelectrons per ADU, you will get the number of electrons detected by the pixel.
Bias Frame	bias frame is a zero-length image taken using a CCD camera with the shutter closed. It is used to compensate for pixel-specific offsets in the CCD chip and camera electronics.
Binning	A method of increasing the sensitivity of a CCD camera at the expense of resolution. Adjacent pixels are summed together into “super-pixels” which have better signal-to-noise ratio.
Butterworth Filter	A Butterworth filter is a particular filter shape that is widely used both in image processing and signal processing. It was originally developed as an analog electronic filter, but was later translated to the digital domain.
CCD	Charge-Coupled Device – a semiconductor device containing an array of light-sensitive pixels. The device is exposed to light, then is read out by shifting the photoelectrons to a readout transistor in one corner of the array.
Centroid	A measurement of the “center of gravity” of an image. A centroid measurement of a star image, for example, can locate the exact center of the star to a fraction of a pixel.
Collimation	Alignment of an optical system. Misalignment is a common problem, particularly with reflecting telescopes. Poor collimation results in optical distortions – particularly Coma, which results in v-shaped star images.
Comma Separated Value (.CSV)	A simple text file format (.csv extension) where numerical or other values are separated by commas. Many software applications (especially spreadsheets) can read this format directly.

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Convolution	A mathematical operation, related to multiplication, which can be performed on two mathematical functions or images. For imaging, any filter that emphasizes particular spatial frequencies is a type of convolution. Examples include high-pass “sharpening” filters and low-pass “smoothing” filters. Convolution is most easily performed by transforming both an image and the desired filter shape using a Fast-Fourier Transform (FFT), multiplying them together, and performing an inverse FFT on the result. In other words, multiplication in the frequency domain is equivalent to convolution in the spatial domain. Convolution is the opposite of deconvolution.
Correlation	The process of comparing two images to determine how strongly they match at different position offsets. Mathematically, the cross-correlation is simply the sum of the products of the pixels in the two images calculated as a function of offset.
Coma	An optical aberration that is commonly seen off-axis on an optical system, especially in fast Newtonian reflectors. It makes the stars look like V shapes; they are often described as looking like comets or seagulls. If an optic is aligned properly (see Collimation), then there should be no coma at the center of the field. There may however be coma in the corners of the field, because they are off-axis. If an optical system is not aligned properly, coma may be visible throughout the field.
Dark Current	Every CCD camera produces a certain amount of dark current, which accumulates in the pixels during an exposure. The dark current is produced by heat, and is a source of noise in images. The noise results from randomness in the dark current and pixel-to-pixel variations in the amount of dark current. The pixel-to-pixel variations in dark current can be removed by subtracting a dark frame, but the associated noise cannot be removed.
Dark Frame	A dark frame is an exposure taken using a CCD camera with the shutter closed. The duration of the dark frame should match that of the images being taken, and it should be made at the same temperature. It is used to compensate for pixel-to-pixel variations in the dark current.
Dead Pixel	A dead pixel is a defect in the CCD array; the pixel is usually stuck at zero or some fixed level, causing it to appear considerably darker than the surrounding pixels. A dark – but not dead – pixel may also occur in images after dark frame subtraction, usually because of a “hot pixel” which has a much higher rate of dark current accumulation than the average.
Deconvolution	Deconvolution is the opposite of convolution. It is a mathematical means of sharpening images, which is used to restore the original appearance of an image before it was blurred by convolution. Since convolution is equivalent to multiplication in the frequency domain, deconvolution is equivalent to division in the frequency domain. Deconvolution is more difficult to perform in practice, due to the possibility of dividing by zero, and the problem of noise amplification.
Distribution	See statistical distribution.
Dynamic Link Library (DLL)	A Dynamic Link Library or DLL is a Microsoft Windows file that contains executable code, but cannot run on its own – it can only run when loaded by another program. Many Windows programs, including MaxIm DL, are comprised of an “EXE” executable program and a set of DLL components that plug into it.
Dynamic Range	For imaging, dynamic range is the range from brightest to darkest pixel value. For example, a 16-bit CCD camera has a dynamic range of 0-65535.

Entropy	In information theory, a measurement of the amount of information in a signal or image. If P is the probability of a pixel value, then calculate $-P \log_2 P$. The entropy of the image is the sum of this value for all pixels.
Exponential	A statistical distribution.
Fast Fourier Transform (FFT)	Taking a Fourier Transform of an image simply converts the image into a new representation. This representation is useful because it can be reversed (by an <i>inverse</i> FFT), and because it breaks the image down by spatial frequency. The <i>Fast</i> in FFT refers to a special algorithm which calculates the Fourier Transform very efficiently.
File Formats	File formats are used to store image information in a consistent way so that they can be shared between applications. The files often include “headers” which contain extra information on the image, such as dimensions and exposure time. The following formats are supported by MaxIm DL: BMP – Bit Map graphics file, used in Windows and OS/2 systems CCD – format used by PC-Lynxx cameras FITS – Flexible Image Transport System, the standard for astronomical images. This is the recommended format. JPEG – a widely-used “lossy” format used for high image compression ratios PNG – Portable Network Graphics, a new file type with lossless compression Raw – unformatted image; a binary array of integer or real values ST... – formats used by Santa Barbara Instruments Group cameras TIFF – Tag Image File Format, a widely-used image format
Filter	A processing operation that changes pixel values based on the values of their neighbors. A filter can emphasize objects with a particular spatial frequency. A filter is implemented as a convolution operation.
Flat-Field Frame	A flat-field frame is an image of an evenly-illuminated source. These frames are used to compensate for both pixel-to-pixel variations in sensitivity and the effects of optical obstructions (vignetting and dust).
FITS	Flexible Image Transport System – the standard file format used in astronomical applications. Includes extensive support for header information to describe the image and the equipment and procedures used to produce it.
Full-Width Half Maximum (FWHM)	A measure of the size of a star or other image. Half maximum means the distance from the center at which the brightness drops to one half of the center value. Full width means the measurement is given as a diameter rather than a radius. The FWHM of a point-source in an image, divided by two to get a radius, can be used as an estimate for the radius of the point-spread function model.
Gain	Gain for an amplifier is the ratio of output / input. In a CCD camera, the gain determines the Photoelectrons per ADU; i.e. how many photoelectrons it takes to make the A/D converter output increase by one count.
Gaussian	The most common type of statistical distribution – the “bell curve” distribution. The shape is very common because a sum of a large number of random distributions always tends towards a Gaussian shape (due to the so-called central limit theorem). The effects of atmospheric seeing tend to impose a Gaussian shape on star images for this reason. Also known as the “normal” distribution.
Geometric Mean	The geometric mean is the square root of the product of the terms. It is equivalent to taking the logarithm, computing the average, and then taking the exponent. The Unsharp Mask command has a Geometric Mean Mask mode which works in

the logarithm domain.

Half Flux

A measurement that is an improvement on the older Full-Width Half Maximum measurement, invented by Larry Weber and Steve Brady. The half-flux diameter is the diameter in pixels that contains half the energy in a star image. In other words, if you add up the ADU values (less the background) inside the diameter, and outside the diameter, you will get the same number. This measurement gives a very similar answer to FWHM, but it is much more robust in the presence of seeing and noise, and can handle images that are so out-of-focus that they look like "donuts". The Half-Flux Diameter also varies linearly with focus position, except very close to best focus. This makes reliable autofocus possible..

High-pass

A filter which removes or reduces low frequency (slowly varying) components of the image while leaving high frequency (quickly varying) components untouched. A high-pass filter will sharpen an image.

Histogram

A histogram is a graph plotting intensity on the horizontal axis and number of pixels on the vertical axis. This shows the distribution of pixels within various intensity ranges. The most common pixel value corresponds to the highest point on the graph.

Hot Pixel

A hot pixel has an unusually high level of dark current. A hot pixel may be much brighter than the surrounding pixels even after dark frame subtraction. This can occur – at random – because of the extra noise produced in the pixel by the high dark current.

IEEE Float

The Institute of Electrical and Electronics Engineers (IEEE) has many different standards for electronics and computers. One of these is a standard for the format of floating-point numbers (numbers with decimal fractions) stored on computers. Most modern computers use IEEE floating-point format.

Image Buffer

Images in MaxIm DL are stored in Image Buffers, which are displayed on the screen in image windows.

Kernel Filter

A kernel filter works by applying a kernel matrix to every pixel in the image. The kernel contains multiplication factors to be applied to the pixel and its neighbors. Once all the values have been multiplied, the pixel is replaced with the sum of the products. By choosing different kernels, different types of filtering can be applied.

Lossless Compression

To reduce the file size on disk, images are often compressed. Lossless compression algorithms reduce the size without throwing out any information. Lossy compression algorithms throw away some data in order to make the files even smaller. JPEG compression is lossy, whereas MaxIm DL's proprietary FITS compression is lossless.

Logarithm

A basic mathematical operation. A base-10 logarithm function converts 100 to 3, 10 to 2, and 1 to 1. The stellar magnitude scale uses a logarithm of base 0.4.

Lognormal

A statistical distribution based on the logarithm of the Gaussian or normal distribution.

Low-pass

A filter which removes or reduces high frequency (rapidly varying) components of the image while leaving low frequency (slowly varying) components untouched. A low-pass filter will smooth an image.

Lucy-Richardson

An iterative deconvolution algorithm which avoids noise amplification by approaching the result in a serial of small steps.

Luminance	In color imaging, luminance is the component of the image which corresponds to total "brightness."
Magnitude	Astronomical magnitudes are a logarithmic measurement scale where larger values indicate fainter objects. The sun is -26 magnitude, the brightest star about -1.6 magnitude, and the faintest star the human eye can see is around 6.5 magnitude. The faintest objects that can be imaged using sub-meter class telescopes are around 24 th magnitude.
MaxEnt	Short for Maximum Entropy Deconvolution, an iterative deconvolution algorithm which avoids noise amplification by approaching the result in a series of small steps.
Maximum Likelihood Estimate	A mathematical term for a technique by which a set of parameters are adjusted to maximize a probability density function. The resulting parameter values are called the maximum likelihood estimates of the true values.
Median	In a list of values, the median is the "middle" value. For example, if the list is 5, 10, 15, 20, 105; the median is 15. The average of the same list would have been 31. A median filter rejects any values which are substantially different from the others, and so rejects "impulsive" noise like hot pixels or cosmic ray hits. When filtering Gaussian noise, however, taking the median value is about 25% worse at suppressing noise than taking an average.
Noise	Any measurement always contains a certain amount of random variation called noise. There are many sources of noise in a CCD imaging system, including photon statistics, dark current, and readout noise. The ratio of signal to noise in a measurement is a fundamental indication of accuracy. Since the signal-to-noise ratio is lower for fainter objects in an image, the practical limit on sensitivity is determined by the noise.
Nyquist Sampling Theorem	Sampling a sound (using a microphone)) or image (using a CCD camera) can introduce a distortion into the signal called "aliasing." Aliasing takes many forms; for example the apparent backward motion of wagon wheels in western movies, which occurs because the movie is actually a sequence of still frames. Nyquist showed that if the sampling rate is twice the highest frequency component, then aliasing does not occur. For CCD cameras, a sufficiently high pixel density (2X the highest spatial frequency in the image; at least 2 pixels across the full-width half maximum of a star image) will guarantee a distortion-free representation of the image. Note that proper display of a "critically sampled" image requires a reconstruction filter – interpolation to a higher sample rate – for proper image display.
Permanent Stretch	A stretch function affects the brightness and contrast of an image. A Permanent Stretch function does not just affect the appearance of an image on the screen; it changes the values in the image buffer. The Stretch dialog performs a permanent stretch, while the Screen Stretch window controls the screen stretch.
Photometric Measurements	Photometry is the accurate measurement of brightness. This is a commonly used scientific tool, particularly in astronomy.
Photon	Light is radiated in small energy packets called photons. Although photons are often visualized as particles, they also have the characteristics of a wave. Photons from a light source are emitted in a random fashion following a Poisson distribution. This is a fundamental source of noise in any measurement of light.
Photoelectrons per ADU	ADU stands for Analog-to-Digital Unit. For CCD cameras, the number of Photoelectrons per ADU tells you how many photoelectrons are required to

increase the pixel value by one count. A photoelectron is produced whenever a photon (light packet) is detected by the pixel.

Pixel

One of the tiny light-sensitive areas of a CCD chip. Thousands of pixels are required to build an image.

Pixel Format

Pixels are represented as a digital value. MaxIm DL stores pixels internally as floating point numbers. When saved to a file, the format is usually an 8-bit integer, 16-bit integer, 32-bit integer, or IEEE floating point. The PC-Lynxx format uses a 12-bit integer format.

Poisson

An important type of statistical distribution. A Poisson distribution results when the arrival time of an infrequent event is measured. When measuring the amount of light from a source, a Poisson distribution describes the arrival rate of the photons of light.

Point-Spread Function (PSF)

A function which describes the blur that was applied to an image. The ideal point-spread function for an astronomical image is a noise-free image of a star taken under the same conditions.

Quantization

Quantization occurs in digital systems because a signal (e.g. intensity in an image) can only be measured in discrete levels. For example, if a pixel's true value is 7.3, it will be truncated to 7. This adds noise into an image. For this reason, high-quality CCD cameras have A/D converters with a large number of bits. An 8-bit camera produces poor quality images, while only a very good camera can fully utilize a 16-bit converter.

Rayleigh

A statistical distribution.

Root Mean Square (RMS)

RMS is calculated on a set of data points (pixels) by taking the square of each pixel, calculating the sum of those squares, and taking the square root. The result is scaled by the number of pixels. RMS gives an accurate measurement of the amount of noise present.

Scaling

Image scaling is simply the process of multiplying every pixel by a constant. This increases or decreases both the brightness and contrast of an image.

Screen Stretch

A stretch function affects the brightness and contrast of an image. The Screen Stretch only affects how an image looks on the screen; it does not affect the pixel values in the memory buffer. The Screen Stretch is controlled using the Screen Stretch window.

Stretch

See screen stretch and permanent stretch.

Signal to Noise Ratio

See noise.

Spatial Frequency

A region of an image where the pixel values vary slowly is said to have a low spatial frequency. A region where the pixel values vary quickly has a high spatial frequency.

Standard Deviation

The Standard Deviation is a measure of the noise in a data set. It is computed in a root-mean-square fashion. The standard deviation is also a measure of the spread of a statistical distribution, and the radius of the point-spread function model.

Statistical Distribution

A curve where the value of a measurement is plotted on the horizontal axis and probability (frequency that the particular value is obtained) is plotted on the vertical axis. If a series of measurements are made and plotted on such a graph, a statistical distribution results. Many types of phenomenon follow particular types

of statistical distributions. The most common are Gaussian (normal) and Poisson.

Subframe

A subframe is simply the result of reading out only a portion of the CCD chip. When using a CCD camera, it is often convenient to use a subframe to reduce the amount of time required to read the camera. This is particularly true when focusing, which requires fast updates.

Unsharp Mask

An unsharp mask is a type of spatial filter. A mask is created by low-pass filtering (smoothing) an image. The mask is scaled and then subtracted from the original image, producing a sharpening effect. Unsharp mask is a commonly used technique because the user has a substantial amount of control over the effect. A strongly-blurred mask can remove large-scale brightness variations, while a slightly-blurred mask will strongly emphasize fine detail. The strength of the filter can be controlled by adjusting the scaling factor.

Vignetting

The obstruction of an optical system in the off-axis parts of the image. When imaging using a vignetted optical system, the corners of the detector will see less light. This can be compensated for using flat-fielding, but it is usually preferable to avoid vignetting if possible.

Wavelength

Literally the length of a wave. Light is comprised of waves; different wavelengths correspond to different colors. Also equal to the inverse of frequency.

Weiner Filter

The first useful type of deconvolution filter developed. The Weiner filter avoids the problem of division-by-zero that confounds simple deconvolution. In imaging applications, a Weiner filter almost always causes severe noise amplification.

Chapter 9. Troubleshooting

Camera-Specific Error Codes

Some MaxIm CCD error messages have an extra code from the camera driver appended. These error codes may indicate a problem with the camera hardware or interface driver. For models not specifically listed, please see the “Plug-in Camera Drivers” list at the bottom of the table.

Equipment	Code	Meaning
Generic codes for all drivers	-1	Generic Error (unknown cause)
	-2	Out of Memory
	-3	Illegal Input (check settings)
	-4	Link Fail
	-5	Filter wheel connection requires compatible camera
	-6	Internal driver error
	-7	Port not available
	-8	Dual chip mode could not find main camera
	-9	Autoguider shutter conflict
	-10	Configuration file for filter wheel is missing
Apogee	-1	Generic error (unknown cause)
	1	No configuration (INI) file specified
	2	INI file missing required data
	3	Loopback test failed; camera not found
	4	Memory allocation failed; System error
5	NTL/O Driver not present	
Finger Lakes 1 st Generation	-1	Generic error (unknown cause)
	1	Not supported
	2	Invalid parameter
	3	Invalid COM port
	4	COM port error
	5	Failed reset
	6	COM timeout
	7	Bad data
	8	No calibrate
	9	Device not configured
	10	COM write
	11	Invalid device
	12	Function not supported
	13	Bad bounds
	14	Grab timeout
	15	To data HB
	16	To data LB
	17	ECP not ready
	18	ECP read timeout HB
	19	ECP read timeout LB
	20	ECP read timeout
	21	ECP reverse timeout
	22	ECP write timeout HB
	23	ECP write timeout LB
	24	ECP write timeout
	25	Forward timeout
	26	Not ECP
	27	Function not supported
	28	No devices
29	Wrong OS	

Equipment	Code	Meaning
SBIG ST-6	-1	Generic error (unknown cause)
	1	Camera not found
	2	Camera type not supported
	3	Unsupported ROM version
	4	Link lost
All SBIG and Celestron cameras except for serial port models	5	Could not change baud rate
	-1	Generic error (unknown cause)
	1	Camera not found
	2	Exposure in progress
	3	Exposure not in progress
	4	Bad PC command
	5	Bad camera command
	6	Bad parameter
	7	Transmission timeout
	8	Receive timeout
	9	Received NAK (negative acknowledgment)
	10	Received CAN (cancel)
	11	Unknown response
	12	Bad length
	13	A/D converter timeout
	14	Keyboard ESC
	15	Checksum error
	16	EEPROM error
	17	Shutter error
	18	Unknown camera
	19	Driver not found
	20	Driver not open
	21	Driver not closed
	22	Share error
	23	TCE not found
	24	AO error
	25	ECP error
	26	Memory error
	27	Next error
	28	Device not open
	29	Device not closed
	30	Device not implemented
	31	Device disabled
	32	OS error
	33	Socket error
34	Server not found	
35	Filter wheel error	

Missing Telescope and Focuser Drivers



MaxIm DL/CCD uses the ASCOM Platform, a collection of mainly open-source drivers developed by the astronomical community. This software must be installed in order to

access telescopes and focusers.

A copy of the ASCOM Platform is included on the MaxIm DL/CCD CD-ROM. Simply double-click the file to install. (Earlier versions of MaxIm DL/CCD automatically installed the platform, but this was removed to avoid repeated installation).

If you downloaded a Version 4 upgrade, then you must download the package from the ASCOM web site. You may also want to check the web site for updates, since new drivers and improvements are being added on a regular basis.

To get the latest version of the ASCOM Platform, please visit <http://ascom-standards.org/downloads.html>

Camera Fails After Operating System Upgrade

Windows 98/ME use different drivers from Windows NT/2000/XP. The MaxIm DL/CCD installation program automatically installs the correct drivers for your operating system. If you upgrade a 98-based operating system to an NT-based operating system, the camera drivers will be non-functional.

The solution is to reinstall MaxIm DL/CCD. The installation program automatically detects which operating system is in use and installs the correct drivers.

Poor Image Display

If color images do not display properly, but monochrome images do, you are in the 256-color video mode, which is not fully supported by MaxIm DL. It is strongly recommended that High Color (16-bit) or a higher video mode be used.

To change video modes:

1. Click on the Start button, select Settings, and choose Control Panel.
2. Double-click on the Display icon.
3. Under Color Palette, change the setting to High Color (16-bit).
4. Click OK.

Depending on your video card, you may have to restart your computer.

We recommend that you shut down MaxIm DL and restart it after changing modes.

If High Color mode is not available, you need to select the correct video driver (Advanced Properties). Please contact your computer or video card vendor for more information.

Incorrect UT Date/Time in FITS Header

Some users set their system time zone to "(GMT) Greenwich Mean Time: Dublin, Edinburgh, Lisbon, London" instead of their local time zone, and turn off "Automatically adjust clock for daylight savings time" setting. The intention is to have the system time display showing UT (Universal Time). This works correctly in Windows NT/2000, but not in Windows 98/ME.

In Windows 98/ME, the system still assumes that daylight savings is in effect and that the user has manually adjusted for it. Therefore when MaxIm DL asks for the GMT time (UT) for entry in the FITS header, if daylight savings is supposed to be in effect the system adjusts for it. This produces an incorrect time stamp in the FITS header. Windows NT/2000 clock systems work differently and does not have this problem (98/ME uses local time for the system clock; NT/2000 uses GMT for system time).

Windows 98/ME users should set the system time zone to "(GMT) Casablanca, Monrovia." This zone does not use daylight savings time and thus avoids the problem.

Apogee Cameras

MaxIm CCD uses a driver provided by Apogee; most technical support inquiries should be directed to Apogee Instruments.

- In Windows NT/2000, MaxIm DL must be installed using an Administrator level account in order for the drivers to be installed properly. If you have already installed from a user-level account, install again over top of the existing installation using the Administrator account.
- Parallel port cameras may require editing the INI file to set the parallel port address
- Parallel port cameras may require editing the INI file to set "ecp=on"
- Parallel port cameras may require setting the parallel port configuration to "Bidirectional," "ECP," or "EPP" in the BIOS.
- If using an ISA interface card, make sure the BIOS setting "16-bit I/O Recovery Time" is set to either "off" or "none." If neither of these two settings is available, use the minimum setting.
- Check the ISA bus address on the card. The value in the INI file should match; if not, edit the INI file.
- Check for ISA bus conflicts; if you are having problems with the card, try another address.

- Make sure you are using the current INI file for the particular model of camera. Older INI files may not work because they are missing certain parameters required by the newer drivers. If in doubt, contact Apogee Instruments.

Meade Cameras

416XT and 1616XT

- Make sure the latest version of firmware is loaded into camera using PictorView
- Wait for 30 seconds after powering up camera before attempting to connect. The camera is not quite ready when the "beep beep" sound occurs; it is still trying to reset the filter wheel (even if it doesn't have one).
- After connecting, turn on the cooler and set temperature; wait for temperature display to appear before attempting to take an image
- Be sure to use a subframe when focusing; this greatly enhances download speed
- Serial Mode: If the computer appears to be too slow to keep up with serial communications, the camera will automatically revert to a "slow-speed readout" mode. This can happen if the computer is disconnected by accident. The only way to restore normal operation is to power down the camera.
- SCSI Mode: "Abort" appearing on the camera's display is normal
- SCSI Mode: You must have an Adaptec 1480A or 2940UW card installed. Slower SCSI cards will not work with the Pictor cameras in 32-bit programs. The link will always fail during download if you use a slower card.
- SCSI Mode: If you have trouble connecting, make sure that the Pictor camera shows up as a scanner in the Windows Device Manager (under Control Panel). The 32-bit Adaptec drivers must be installed as well as the ASPI drivers. These drivers can be found on the Adaptec web site. Note: contrary to Adaptec documentation, ASPI drivers *are* required for Pictor operation under Windows 2000.
- SCSI Mode: If you get Link Fail (Error -4) messages when running other applications such as planetarium programs or remote control programs, update your SCSI and ASPI drivers. Unfortunately, on some machines it may not be possible to download while other programs are running. This is due to a compatibility problem between the Windows drivers and the camera (SCSI-I versus SCSI-II).

208XT and 216XT

- Wait for 30 seconds after powering up camera before attempting to connect

SBIG and Celestron Cameras

The drivers for all SBIG and Celestron cameras, except for serial port interface cameras, are provided by Santa Barbara Instruments Group. Please contact SBIG for more information.

When running under Windows NT/2000, other applications which run the older version of the SBIG drivers may uninstall the driver used with MaxIm DL/CCD. If this occurs, run the SBIG Driver Checker program to reinstall the driver. This program is automatically installed with MaxIm DL, and is typically located in the folder C:\Program Files\SBIG\Driver Checker\. Re-installing the driver must be done from an Administrator level account.

Note: under Windows NT/2000, due to the design of SBIG's camera driver, the **Port Address** (camera setup dialog) may not correspond to the actual address on the system. If you cannot connect to the camera try all three addresses.

For parallel port cameras, make sure the parallel port is set to Standard (not ECP or EPP) in BIOS. This sometimes causes communications errors.

Error 17 (shutter error) may indicate a problem with the camera shutter. This problem can be intermittent; MaxIm CCD will retry on shutter errors up to a point. If you get this error often, contact SBIG.

The drivers for serial port cameras were developed by Diffraction Limited.

Starlight Xpress Cameras

Starlight Xpress camera drivers were developed by **Diffraction Limited** based upon information provided by Starlight Xpress. Please note the following:

- In Windows NT/2000, MaxIm DL must be installed using an Administrator level account in order for the parallel port drivers to be installed properly.
- For USB cameras, you must install the latest version of the drivers and firmware for the camera. This is included with the Starlight Xpress software installation.
- Color conversion may require adjustment of the Offset X and/or Offset Y settings in the **Convert MX** dialog box. This is required because the color

information is recorded by "quads" of cyan, yellow, magenta, and green pixels. If the quads are not aligned properly, the color information will be distorted.

- The Starlight Xpress "anti-alias" function is replaced by the **Color Smoothing** command in MaxIm DL.

Autoguider Troubleshooting

The following is a very thorough step-by-step procedure for diagnosing autoguider trouble. Autoguiding is a complex activity; we strongly recommend going through the whole procedure to check each possibility.

1. Go to the **Guide** tab and click **Guider Settings**. Click **Defaults**. If you have a dual-chip camera with a TC-237 sensor, set **Binning** to **2**.
2. Set **Control Via** to **Camera Relays** if you connect to the mount through the autoguider camera or STAR2000 dongle; otherwise set to **Telescope** for connecting through the **Telescope Control** window, or **SX COMn** for connecting to a Starlight Xpress autoguider interface.
3. Switch to the Advanced tab and click **Defaults**. Under **Offset Tracking** click **Clear**. Click **Apply**. (Tip: Losmandy mount controllers do not work with simultaneous corrections in X and Y. If you have such a mount, disable simultaneous corrections and make sure **Delay After Correction** is at least 0.1 seconds.)
4. Returning to the Guide tab, set the **Aggressiveness** to **7**. (Decreasing this number slows the guider response but makes it more stable; increasing it does the opposite.)
5. Make sure you have the telescopes mount's guide rate set between 1X and 0.1X, if it is adjustable.
6. Check whether the mount has excessive backlash. Try to rock the axes back and forth with the brakes on. If it goes click-click back and forth with a noticeable amount of movement, then you need to adjust your worm gear engagement. Check both RA and Dec axes for this. The gears should be tight enough that there isn't excessive movement, yet not so tight that the motors bind.
7. If the mount has anti-backlash correction, turn it *off*. If set wrong it can completely mess up guiding. If set correctly and the delay is large enough it will cause a severe phase lag that will make guiding unstable. If you need backlash compensation, you should only do it in MaxIm DL.
8. Check your balance. The balance should be set so the gears are pushing a little,

not just allowing the weight to fall. For German Equatorial mounts, this means when the telescope is on the East side – it is coming up – that the counterweight should be adjusted so the telescope end is a little heavier. On the West side, the counterweight end should be a little heavier. If it isn't set this way, the telescope will move in little jerks as the gears bounce back and forth, and it will be impossible to guide.

9. Check that you can send autoguider commands to the mount. Under **Guide** tab **Options** click **Move**. Using the **Manual Control**, set the time to **10 seconds** and then click each of the **+X**, **-X**, **+Y**, **-Y** buttons in turn. Make sure the telescope actually moves each time; either by watching or listening to the motors operate. If it does not move in one direction you have an electrical problem. Check the autoguider cable and connectors first – the cable is a very common failure point. If it does not move at all, then also check the **Control Via** setting, and any settings specific to the output method and mount. Note that some telescopes do not support the ASCOM PulseGuide method, and thus cannot be commanded using the Telescope method. The most common interfaces that do not support PulseGuide are some Celestron models and “TheSky controlled telescope”.
10. Make sure your telescope drive is behaving itself. Unplug the autoguider cable from the mount. Go to the **Guide** tab and take an image. Make sure you have a good bright guide star with an exposure time of 1 second or less. Turn on **Watch Star** and start the guider. Watch the star and the **X Error**, **Y Error** data coming from the Guide tab, and try to guide manually using the telescope's hand paddle. If you cannot do this, there is probably a mechanical or electrical problem of some kind.
11. If all is good so far, **Stop** guiding and plug the cable back in.
12. Take an exposure of 1 second or less with the **Guide** tab and make sure you have a nice, bright star, reasonably near the center of the chip.
13. **Start** the calibration cycle. Watch the star. It should move in one direction, move back again, move at right angles, and move back again. To make this easier to see, MaxIm DL automatically draws a line following the star. Look at the numbers that the display window on the Guide tab shows you. Make sure the star moved at least 10 pixels in each direction, and that it returned close to its starting point. If the star does not move very far, then increase the corresponding **Cal. Time** value in the settings (first motion is X – usually RA, last is Y – usually Dec). If the star moves so fast that the star goes off the chip, then check whether the mount's guide speed is higher than 1X.
14. If you see any error messages, stop and figure out why; otherwise the

calibration will be invalid.

15. Turn on the **Graphical Track Log**.
16. Switch to **Guide** mode. **Start** tracking. Watch the star and the track log, and watch for guide star motion. If it starts bouncing back and forth, then reduce the Aggressiveness setting. If you are having trouble, note which axis it is -- Right Ascension or Declination. (Usually the X axis is wired to Right Ascension.)
17. If you are seeing regular back-and-forth motion, you have oscillation. The autoguider is overcorrecting for the error, causing the telescope to go the other way. Reduce the **Aggressiveness** and see if it stabilizes. A poor calibration is the most likely cause of instability. Tip: you can independently adjust the aggressiveness of each axis. To reduce aggressiveness for the X or Y axis alone, *increase* the **Manual Calibration X Speed** or **Y Speed** setting, as appropriate (Manual Calibration is automatically set for you by the Guide tab calibration, so at the very least you have a good starting point for adjustment).
18. If you are having trouble in RA, check the mount balance again. Also make sure that the worm gear is clean and working smoothly.
19. If you are having trouble in Declination, you might have a stiction problem. This is a tendency for the mount to continue moving forwards when the guide motor reverses direction. Put in a high power eyepiece and try rocking a star back and forth in Declination with the hand paddle. If you see the star move briefly in the wrong direction when you try to reverse, you've got stiction. The solution for stiction is to note which way the star is drifting in declination. Then go to the **Guider Settings** and disable the guider output that pushes the star in the direction of the drift. That way it will only ever push in one direction – against the drift. That prevents the stiction from occurring.
20. If the eyepiece test shows a *lot* of backlash – the star just sits there for a few seconds before reversing, then we can try the backlash adjustment in MaxIm DL. Don't worry about RA backlash – the sidereal tracking eliminates that. Only Dec matters (the Y direction if your guider cable is wired normally). Watch the star in the eyepiece and time (with a stopwatch if possible) how long it takes for the star to reverse. Enter that value (in seconds) *less 1/2 second for safety* into the backlash setting. If you put in too high a number, guiding will utterly fail – it is way better to use zero than too much.
21. If you find that the guider works properly in one part of the sky, but poorly elsewhere, check that your balance isn't causing you trouble. Also consider using the Declination compensation feature instead of recalibrating the guider for every exposure (be sure to set **Pier Flip** if you flip the mount to the opposite

side from which it was calibrated).

22. If you are finding the guiding inaccurate, try adjusting the Aggressiveness. If this does not work, try increasing or decreasing the guider update rate (easiest method is to adjust exposure time). Some mounts work best with multiple updates per second, while others work better with a slower update rate. Losmandy mounts like fast updates, whereas LX200 Classic mounts tend to prefer a 3 second cycle time.

Filter Wheel Troubleshooting

Problems with filter wheels are relatively rare. Most filter wheels connect via a serial port or a particular manufacturer's brand of CCD camera.

SBIG cameras use a pulse protocol to communicate with their filter wheels. This was developed because the original CFW-6A used the pulses to control a servo motor. Modern filter wheel models use stepper motors and a microcontroller to interpret the pulses. Several brands of filter wheels have emulated this protocol to support direct connection to an SBIG camera.

PC's are not very good at "real-time" tasks like generating accurate timing waveforms. The SBIG Parallel driver attempts to emulate the SBIG camera to drive the filter wheel. In Windows 98/ME this is done with a special calibrated timing loop; it works on most machines, but some computers do not appear to handle this very well. The timing under Windows NT/2000/XP is far more accurate since it uses a kernel-level driver to generate the pulses. Therefore these operating systems are preferred for use with this driver.

After powering up Meade cameras, you should wait until the filter wheel has fully reset (no more motor noise) before trying to link to the camera. If the camera is connected by SCSI interface, do not even power up the computer until the filter wheel is reset.

Telescope Troubleshooting

For most telescopes, everything will work properly if you can establish a link. In the event of problems, check the cabling first – cables are usually the first things to get damaged.

The serial port on some telescope mounts can be damaged by static electricity. The human body can produce large static discharges after simply walking across a carpet. You should ground yourself by touching a metal part of the telescope mount before connecting or disconnecting cables. Also, when a telescope is not in use, it is a good idea to disconnect all power and communications cables if you are in an area subject to

lightning storms. We have heard many tales of telescopes, cameras, and computers being destroyed by lightning strikes – it doesn't take a direct strike to destroy sensitive electronics.

Focuser Troubleshooting

Focusers are usually reasonably trouble-free. Make sure the communications cable is connected properly and not damaged. For FLI focusers, make sure the latest FLI drivers are installed.

Autofocus Troubleshooting

The built-in SharpStar autofocus only works with stepper motor or servo motor based focusers that have absolute position control. This includes JMI SmartFocus, Optec TCF-S, TI RoboFocus, and RC Optical Systems. It does not include DC motor focusers like the Meade 1206. For these relative-mode focusers, please use **FocusMax**, available free at <http://focusmax.org>.

If autofocus fails, it is usually because the **Telescope Focal Ratio**, **Focuser Step Size**, or **Target Half Flux** is set incorrectly.

If coarse focusing fails, the focal ratio or focuser step size are very wrong.

Watch the autofocus log during fine focusing. It should move approximately 1.5 half-flux units on each step, except near focus. If it is moving in larger steps than this, increase the **Focuser Step Size**. If it is moving in smaller steps, decrease the number.

If the focuser passes through focus and keeps on going forever, check that the **Target Half Flux** is at least two pixels higher than the minimum value seen in the log. If this is not the case, the software will never detect that it has passed best focus.

We strongly recommend that you follow the step-by-step procedure in the **Autofocus Tutorial**. This will help you set up the parameters correctly.

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