# Observing Variable Stars

## at the Harry D. Powell Observatory

## East Tennessee State University

# ST-9 Telescope and CCD Camera

# Instruction Manual

Susan Dyer
Astronomy 3
December 13, 2002
Modified: June 4, 2003
Rachel Baker

# Using the C-14 Telescope and the ST-9 CCD Camera

## Opening the C-14 Telescope

To open the C-14 telescope, follow these steps:

1. Locate and plug in the four AC power cords:
    - As you stand at the top of the stairs facing the telescope, the dome shutter cord is on your right and plugs into the right wall near the floor.
    - The dome rotation cord is on the wall behind the telescope (opposite the stairs) and plugs into the back wall near the floor.
    - The telescope mount cord is a gray cord and plugs into the front of the pillar that holds the telescope. **Note: This should already be plugged in.**
    - The CCD camera cord is a black cord on the power supply box behind the telescope and plugs into the front of the pillar that holds the telescope. **Note: This should already be plugged in.**
2. Locate the CCD black box next to its power supply box behind the telescope pillar. An orange light indicates that the CCD camera is on. **Note: The power switch stays on.**
3. Use the switch on the dome shutter control to open the upper dome shutter. It stops by itself when the shutter is fully open.
4. For safety, unplug the dome shutter cord from the wall, and then unplug the extension cord for the dome shutter so it does not wrap as the telescope turns.
5. Hand crank the bottom dome shutter open. If conditions are windy, leave it closed. You may not need to open the bottom shutter if you are looking high in the sky.
6. Take the covers off the main telescope and the finder telescope lenses.
7. To cool the telescope, open the doors to the control room to let air circulate.
8. Hang the oscillating fan on the step ladder about two feet from the heat sink fins of the telescope camera, and turn it on.

Turn off the lights and use only the red lights as needed in the telescope room. You are now ready to turn on the computers.

## Starting the Computers

There are two computers in the control room downstairs from the telescope: the one on the left controls the CCD camera, and **it should stay on at all times**; the one on the right controls the telescope. **Note:** The UPS controls both the CCD camera computer and telescope computer, and it should stay on at all times.

To start the telescope control computer follow these steps:

1. Press the button on the CPU (Central Processing Unit) to turn the computer on.

2. Turn the monitor on.

The telescope control computer on the right runs DOS. No login is required.

Follow these steps to start the CCD control computer when power has been lost:

1. Turn on the UPS underneath the table in the control room. The ON button is the top button. When the UPS is on, a green light appears directly above the ON button.

2. Log on to the CCD computer on the left as "`localadmin`". Enter the password "`obsadm1n`", where `1` is the number one, and there are no spaces.

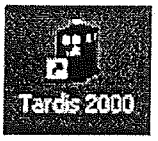
## Setting the Clock

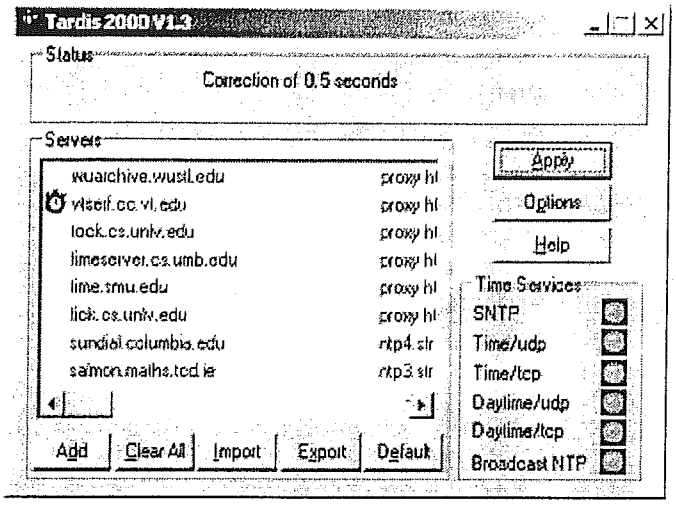
You are now ready to set the clocks to Universal Time (UT). The exact UT time is critical for accurate pointing of the telescope.

1. On the CCD (left) computer, right-click the Tardis program located to the left of the task bar next to the Maxim DL program and select **Restore**. This is the Tardis program which sets the CPU clock using the Internet (see picture below). Go ahead and **Minimize** the Tardis dialog.

2. Tardis should already be running, i.e. the clock should already be updated.

**Note:** If power has been lost you must locate the Tardis program and open it. Wait for the Tardis software to connect to an Internet site to reset the clock. Then minimize the Tardis dialog; the clock updates automatically as Tardis runs in the background.

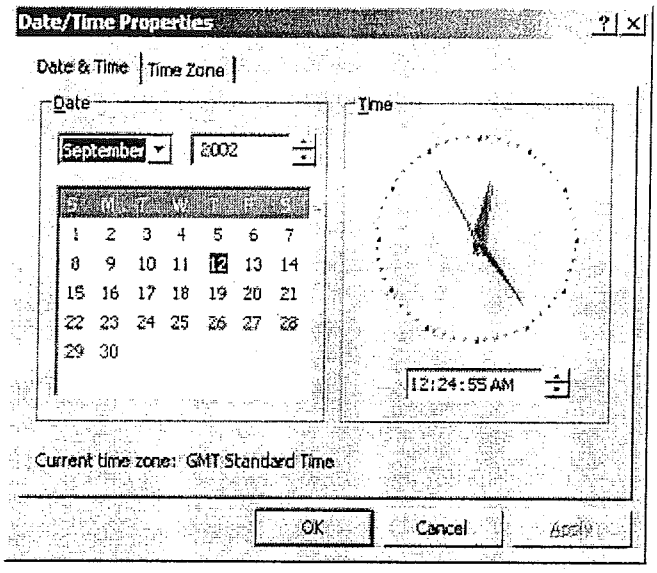





*Continue this procedure on the next page.*

3. To view the computer's clock, double-click on the time display in the lower right corner of the screen. The clock is displayed as shown in the picture below.

   **Note: Since the clock is set to Universal Time, if you are observing in the evening, it may already be tomorrow! This is important for reporting purposes. Use the UT date and time on your logsheets.**




4. The telescope control computer on the right is running DOS. To set the clock, type the word "`time`" on the command line and press **Enter**.

5. The screen displays the current time (in UT) in the format **hh:mm:ss**. It should be accurate within about a minute, depending on the last time it was set.

6. Below the current time, there is a prompt for the new time. To give yourself time to enter the value, type in a new time that is 10 or 15 seconds **later** than the time on the computer clock on the other computer. Use the same format (**hh:mm:ss**) and add **a** for am or **p** for pm.

7. Wait for the computer clock to catch up to your new time and then press **Enter**. The two clocks should now tell exactly the same time.

8. To start the control software on the telescope computer, type the command "`tcscom`" on the command line, and then press **Enter**.

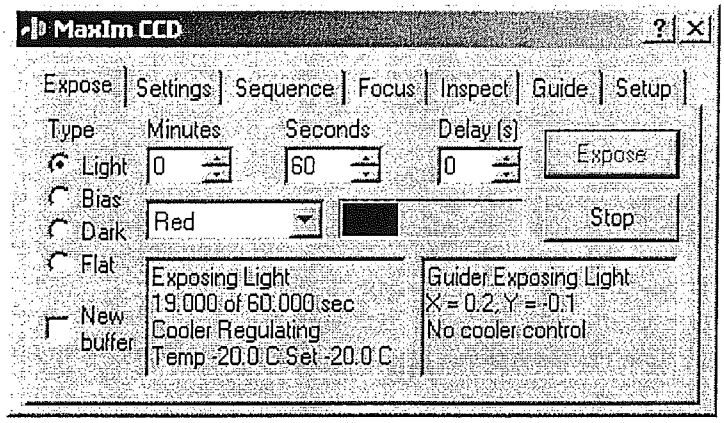
Leave the program running while you get the CCD camera ready.

## Preparing the CCD Camera

To prepare the CCD camera for taking pictures of your stars, follow these steps:

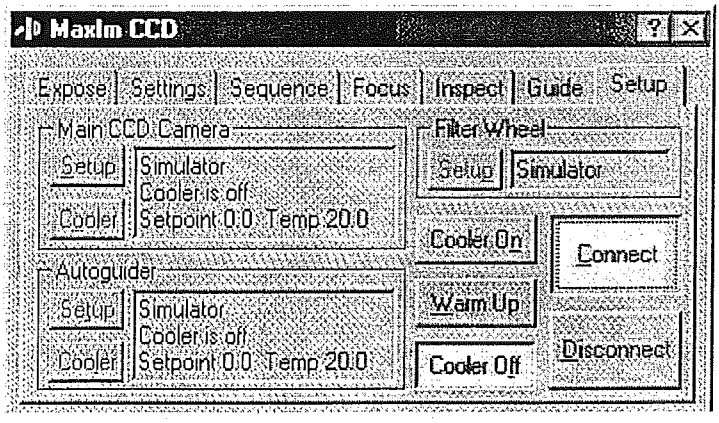
1. On the CCD (left) computer, **Restore** the MaxIm DL icon to initialize the CCD control software. The MaxIm DL icon is located at the left corner of the task bar and has a picture of a telescope on it.

2. To set the filter to optical (visual) wavelengths, select the **Expose tab and select light then select visual** from the drop-down box that lists the different filters bar. **(Change Red to Visual in the drop-down box pictured below.)**




3. Cooling the camera to the appropriate temperature is vital for good images. Select the **Setup** tab from the menu bar. See picture below.

4. In the Setup dialog, the **connect** and **cooler on** modes should already be selected as on. Enter minus 20 or a reasonable temperature depending on the season (see instructor) under the Main CCD Camera field. (Make sure there is a minus sign!) The temperature is in degrees Celsius. The other settings should default to their appropriate values.




**Give the camera about 15 minutes to cool while you check the pointing and focusing of the telescope. Make sure it reaches the correct temperature.**

## Pointing the Telescope

Although the telescope should not require much adjustment, your night will be more successful if you carefully initialize the telescope before you take your data. To improve the aim of the telescope, follow these steps:

1. On the telescope (right) computer, use the right/left arrow keys to navigate to **Motion** at the far left of the menu bar at the bottom of the screen, and press **Enter**.

2. Use the up/down arrow keys to select **Tracking**, and press **Enter**. Use the up/down arrow keys to select **Bias**, and press **Enter**.

3. Using the arrows and the **Enter** key as above, navigate to the **Source** menu, select **User Catalog**, and select **REDVAR** as your catalog.

4. Navigate to the **Position** menu, select **Next**, and press **Enter**.

   A scrollable star list appears. You can use either of the first two stars (Vega or Deneb) for initializing the pointing. Use the third star (Epsilon Cyg) for focusing. The rest of the entries are the variable stars. The stars used for initializing and focusing change depending on the season - **see instructor for the appropriate stars.**

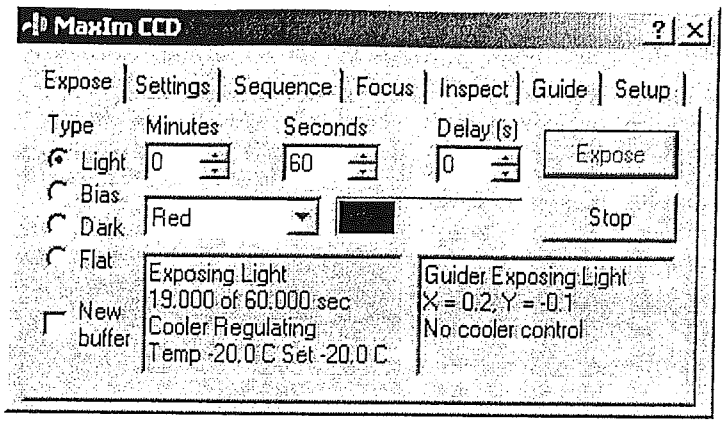
5. Select **Vega** and press **Enter**. Vega and its data appear in the **Next** position field at the center of the screen.

6. Before you command the telescope to move to the new star, go up to the telescope room and move the stepladder away from the telescope. If you set the back feet of the ladder well into the alcove, it should be a safe distance away. Keep the fan pointed at the heat sink fins.

7. Back in the control room, on the telescope (right) computer, navigate to the **Move To** menu, select **Next**, and press **Enter**. The telescope slews to Vega. Stirring music accompanies the action.

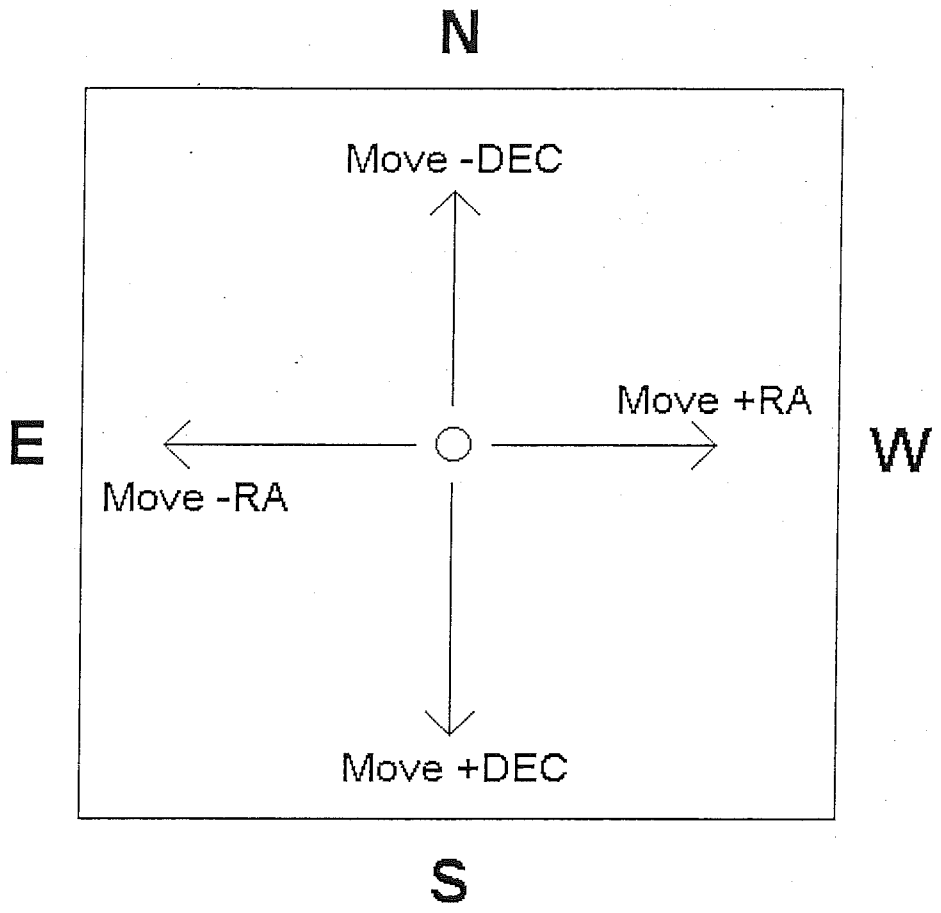
   **Note:** After the telescope reaches its new position, go back to the telescope room to check to see if the opening in the dome lines up with the telescope. Use the dome rotation lever on the back wall to make any adjustments. Stand behind the telescope (as if you were looking through it) to make sure that you have a clear view through the dome shutter.

8. On the CCD (left) computer, select **the Expose Tab**. In the Expose dialog, set the exposure time to .01 seconds. Accept the defaults for the other fields and click **Expose** to take an exposure of Vega.




9. If the exposure is all right, but Vega is not visible in the image, go to the telescope and look through the finder lens. Move the telescope with the hand paddle to center Vega in the crosshairs. Any misalignment is probably east/west, rather than north/south.
10. When you get Vega in the picture, you can center it more precisely using the telescope (right) computer. Navigate to the **Position** menu, select **Offset**, and press **Enter**. Then press **Enter** again to select **Direct**.
11. Type the appropriate offset to center Vega, and press **Enter**. Use these guidelines to estimate your offsets:
    1. Right Ascension (RA) is about 36 seconds from left to right. **Never use the minutes and hours!**
    2. A negative RA moves the star left (east); a positive RA moves the star right (west).
    3. Declination (DEC) is about 9 arcminutes from top to bottom.
    4. A negative DEC moves the star up (north); a positive DEC moves the star down (south).

See the picture below for a visual guide to offsets. Note that east and west are not where you might expect them to be!




12. To move the telescope to your offsets, navigate to the **Move To** menu, select **cur+Offset**, and press **Enter**.

13. On the CCD (left) computer, click the **Expose** button on the Expose dialog to take another exposure. Repeat steps 9-12 until you have Vega in the center of the image.

14. When you have Vega properly centered, navigate to the **Declare As** menu on the telescope (right) computer, select **Init Next**, and press **Enter**. Press **Y** to confirm.

You are now ready to focus the telescope.

## Focusing the Telescope

To sharpen the focus of the telescope, you can use the star Epsilon Cyg from the scrollable star list (see instructor for appropriate star). Follow these steps:

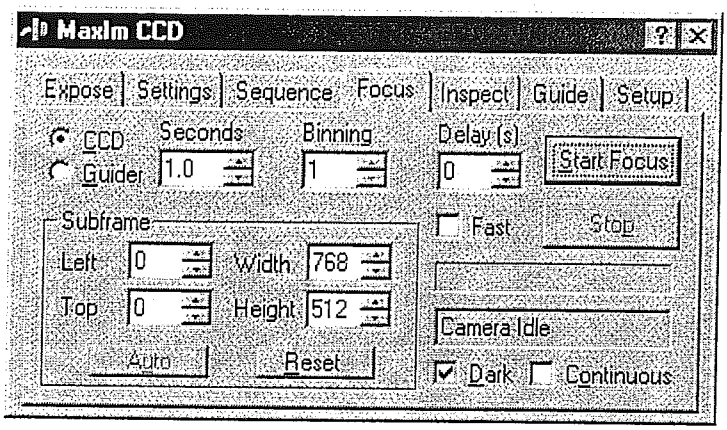
1. On the telescope (right) computer, navigate to the **Position** menu, select **Next**, and press **Enter** to bring up the scrollable star list.

2. Use the down arrow key to select **Epsilon Cyg** and press **Enter**. Epsilon Cyg and its data appear in the **Next** position box at the center of the screen.

3. Navigate to the **Move To** menu, select **Next**, and press **Enter**. The telescope slews to Epsilon Cyg.

   **Note:** After the telescope reaches its new position, go back to the telescope room to check if the opening in the dome lines up with the telescope. Use the dome rotation lever on the back wall to make any adjustments. Stand behind the telescope (as if you were looking through it) to make sure that you have a clear view through the dome shutter.

4. On the CCD (left) computer, select the **Focus Tab**.




5. In the Focus dialog, set the Exposure Time to .01 or .02 seconds.

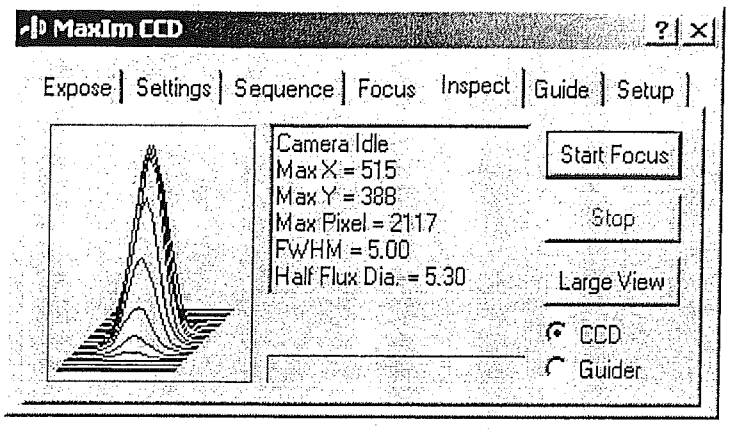
6. Turn off the **Dark** control. Select the continuous mode to take a series of images.

   Accept the defaults for the other fields, and click **Start Focus** to take an exposure of Epsilon Cyg.

7. The focus download can be sped up by selecting a subframe of the image. A subframe is created by putting a rectangle around the star. Adjust the **mouse** at the top-left of a star, **hold down** the **left mouse button** and **drag**. (The **Auto** button automatically selects a small subframe for you.) The **Reset** button puts the frame values to default. Click **Start Focus** to take another exposure of Epsilon Cyg. Only the selected part of the image will be downloaded this time, which enhances the speed of the camera focus.

8. Now, click on the **Inspect** tab (See image on next page). The inspect tab is used in conjunction with the focus tab.

   The Inspect tab can be used to start and stop focus downloading. The 3-D isometric plot is used to determine how well the image is focused. The above image is a good representation of how well the camera should be focused. The full width at half maximum (FWHM) and half flux diameter are both used to determine the quality of focus. The FWHM will produce several readings when close to focus; the best result should be used. A good value for FWHM is 4.00 or 5.00 as well as for the Half Flux Diameter.




9. Use the black Motofocus box on the table between the computers to adjust the focus. The left and right buttons focus in and out. The knob at the bottom adjusts the speed of focusing.

   **Note:** If the telescope doesn't seem to be responding to manipulations with the focus box, you can unplug it from the computer and plug it in to the telescope upstairs instead.

10. Look for the smallest, brightest image of the star that you can get and the highest numbers in the Peak field of the Focus dialog.

11. When you are satisfied with the focus of the telescope, click the **Stop** button to stop the camera. (You may have to click more than once.)

12. Close the image. There is no need to save the image.

You are now ready to take pictures of your variable stars.

## Preparing the Variable Star Field Image

This is the fun part—observing your variable stars! Follow these steps:

1. On the telescope (right) computer, navigate to the **Position** menu, select **Next**, and press **Enter** to bring up the scrollable star list.

2. If your star is not immediately visible on the list, press the **PageDown** key to scroll to it. When you have it on the screen, use the arrow keys to select it, and press **Enter**.

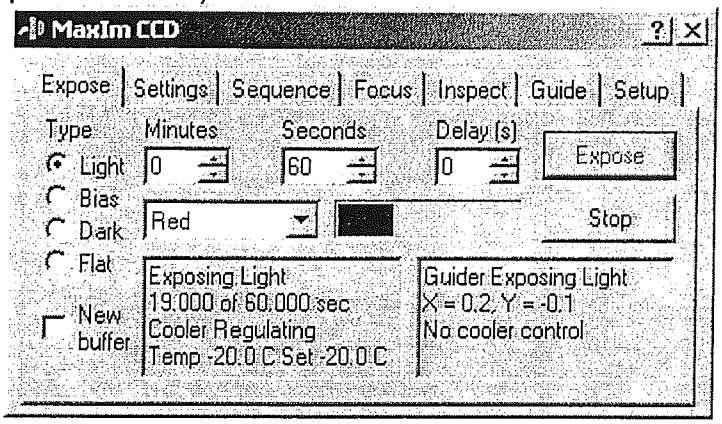
3. Navigate to the **Move To** menu, select **Next**, and press **Enter**. The telescope slews to your variable star.

   **Note:** After the telescope reaches its new position, go back to the telescope room to check if the opening in the dome lines up with the telescope. Use the dome rotation lever on the back wall to make any adjustments. Stand behind the telescope (as if you were looking through it) to make sure that you have a clear view through the dome shutter.

4. Next, you need to get your variable star and at least two comparison stars centered on the image. Use the star charts in the green folder on the shelf to the left of the computers. You may have to turn the chart upside down to match the star field with the one in your image!

5. On the CCD (left) computer, select the **Expose** tab.

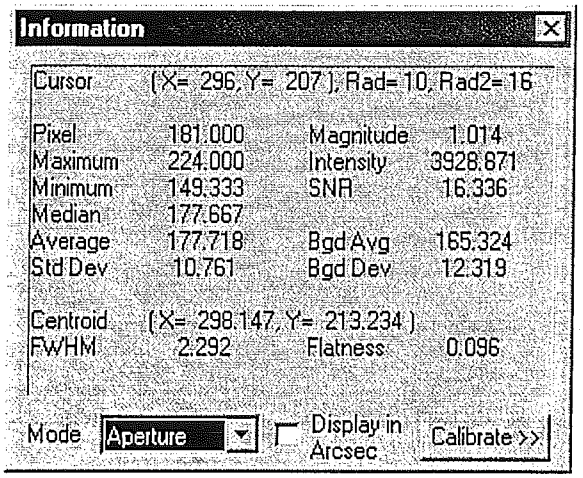
6. In the Expose dialog, set the Exposure Time to **15** seconds for a trial exposure. Make sure the **Type is Light and Visual (Change Red to Visual in the drop-down box pictured below.)**




7. Click **EXPOSE** to take an exposure of your star.

8. When your image appears, use the Offset procedure to make sure that your variable star and its two (or more) comparison stars are included in the image. (Your variable star itself doesn't have to be at the center.) For the Offset procedure, return to the section called "Pointing the Telescope," and follow steps 9-14 in that section.

9. After your star field is properly centered in the image, you need to make sure you have a long enough exposure time for good contrast. Use the information window shown below. It can be opened with the view menu or the following icon:




10. The crosshair appears in the image as a small circle. The circle aperture can be changed to any size to fit your star. While the mouse is on the image, right clicking the mouse allows you to set the radius aperture value. The information displayed in the information window comes from whatever is within the aperature.

11. The Signal-to-Noise Ratio (SNR) is a ratio of the intensity of light to the standard deviation of the background noise multiplied by the square root of pixels. While three is the minimum of light detection for measuring stars you should aim for a signal-to-noise ratio of at least 100.

12. If your ratios are not high enough, you need to extend the exposure time. More time increases the brightness of the stars more than it increases the brightness of the background, so your contrast will increase as you add more time. You may have to take two or three exposures to find the best time.

    **Note:** Look for a maximum count under 35,000.

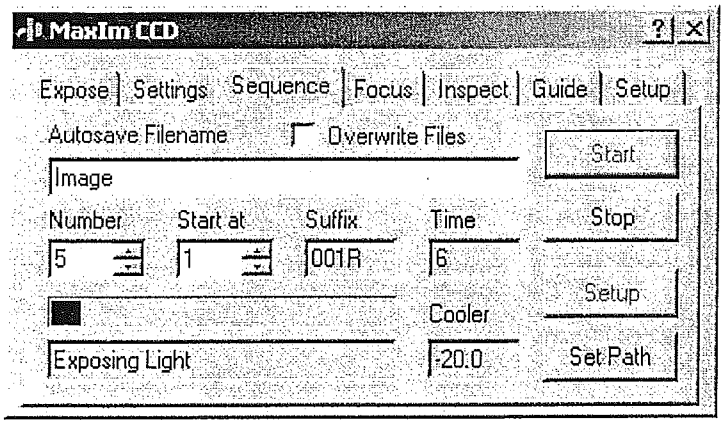
13. Once you have taken a good exposure you will need to save the image under your folder, which is most likely located on the local disk (C:). Include the star name, the date, and the extension **.fit** in the file name. For example, AYAur01-0202.fit. The name of this star is AYAur. 01 represents that is the first image taken that night, and 0202 is the date Feb. 02. It's a good idea to create separate folders for each night of observing.

## Taking the Darks and Biases

Darks and Biases should be taken every night after your variable stars have been observed.

Follow these steps:

1. First click on the Sequence tab (see figure below)




2. Enter the filename under **Autosave Filename.** When naming files specify whether the image is a dark frame or bias, for example, dark-0202 and bias-0202.

3. Now go to the **Number** box. Use the small arrow tabs or enter with the keyboard the number of images to be exposed. **Note: Take five darks and ten biases each night.**

4. Next, move to the **Start at** box and enter where to start subscripting your files. This will automatically add to your file name the image number. For example dark-0202 will become dark-0202-001 when 1 appears in the **Start at** box, and it will continue in a sequential order until the **Number** of images specified are completed (**Number:** 5 produces dark-0202-005).

5. Next select the **Setup** button under the **Sequence** tab. See the picture at the bottom of the page.

6. Under the Enable heading you want to check what images you will be taking. **Do Darks and Biases separately. The Biases will always have a zero second exposure time, and you want to enable the dark frame that has an exposure time equal to your longest exposure time of your star.** The headings should already be defaulted for you.

   For biases you will need to enable the defaulted line that says **Filter:Bias, Suffix: None, Exposure:0,** and **Binning:1**

   For darks you will need to enable the defaulted line that says **Filter:Dark, Suffix: Time of longest exposure, Exposure: Time of longest exposure,** and **Binning:1**

   **Note:** The suffix is added on to the file name also. For example an exposure time of 180 sec would produce the file name: dark-0202-001180.

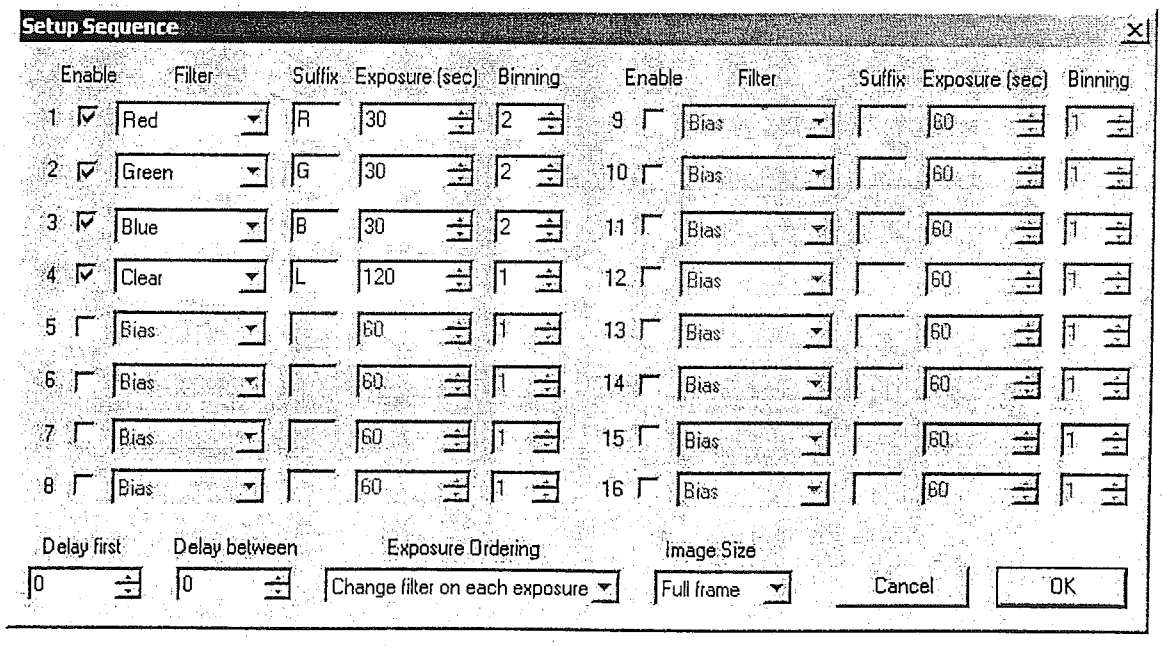
   After you have enabled the correct heading select **OK.** This will bring you back to the **Sequence** Tab.

7. Under the **Sequence** tab you now want to select **Set Path** and choose the proper directory to put the images in. Choose the folder that the star images are in.

8. Press **Start** whenever you have completed the steps above.

**Note:** Flat field frames will need to be taken at least three times during the semester. See the instructor on directions on how to take these.

## Setup Sequence Box



## Shutting Down the Telescope

When you are all finished taking pictures, and if no one else is using the camera tonight, you can shut down the telescope. (If someone else is using the camera, skip this procedure and go directly to "Calibrating the CCD Image.")

To shut down the telescope and minimize the camera program, follow these steps:

1. First go to the **setup** tab and put the camera to the appropriate temperature (**see instructor for cooling temperature**).
2. On the CCD (left) computer, select the icon in the upper right-hand corner to minimize the program; it is the square icon with a __. **LEAVE THE PROGRAM RUNNING (AS WELL AS THE COMPUTER AND MONITOR).**
3. On the telescope control (right) computer, navigate to the **Shutdown** menu at the far right, select **Auto Shutdown**, and press **Enter**. The TCS program automatically moves the telescope to the home position and disables all motion actions.
4. Wait for the telescope to reach its home position. When you see the prompt **Abandon TCS for system?** Press **Enter** (not **Esc**) to exit the TCS program.
5. In the dome, replace the two telescope lens covers.

   **Note:** Always cover the lenses before you move the shutters, so that no dirt or debris falls on them from the dome.
6. Turn off the oscillating fan.
7. Use the dome rotation lever on the back wall to move the shutter to the East (center it over the alcove in the east wall).
8. Crank up the lower shutter by hand.
9. Plug in the extension cord and the main cord to the dome shutter, and use the dome shutter lever on the right wall to close the upper shutter.
10. Unplug the two power cords to the shutter only; everything else stays powered.

Now you are ready to calibrate your images.

## Calibrating the CCD Image

The images that you take with the CCD camera have not been corrected for bias and dark frames. (Always remember to take dark frames and biases each night.)

The next step is to calibrate or "reduce" these images with a flat field frame. You will use the same Maxim DL software for this task.

When you have finished taking data for the night, you should "flat field" your images before you save them to your ZIP disk. Follow these steps:

1. On the CCD (left) computer, double-click the Maxim DL icon to start the program. You can close the blank image that appears in the dialog.


2. Click **File > Open** on the Maxim DL menu bar. Locate all the images that you want to calibrate under your personal folder in the **C:** directory. Select the images by holding down the **Ctrl** key while you click their file names. Click **Open** to open all of them at once. You will see the images pop up on the screen.

3. Click **Process > Set Calibration** on the menu bar.

4. At the bottom of the Set Calibration dialog, in the Flat Frame field, click the **Select File** button.

5. Select the file that has your flat field images in it, and click **Select**. Enter the darks and biases for each night of observations.

6. Click **Process > Calibrate All** on the menu bar. The program automatically calibrates the images. You should see the appearance of your images change as they are calibrated.

7. If you want to see details about one of your images, click on the image, and select **View > FITS Header** from the menu bar. The header contains useful information about the image that you can enter in your logbook, such as the object name, the UT date and time, the filter used, and the CCD temperature.

8. **For each image individually**, select **File > Save As** from the menu bar, and save your file with a new name, so that you will have both the original and the flat-field calibrated versions. For example, you can save the reduced (calibrated) file of AYAur01-0202 and save it as AYAur01-0202-rdc. Select **File > Close** from the menu bar to close each file after you save it.

9. Copy your calibrated files to the ZIP disk for later reduction with the IDL software. Keep your original data images on the hard drive.

# Doing the IDL Reduction

The last step in reducing your star field images is the IDL reduction. This procedure counts the photons for each star in your image and converts them into magnitudes.

To perform an IDL reduction, follow these steps:

1. On a computer with the IDL program loaded, double-click on the IDL icon. The IDL program opens.

2. In the command line at the bottom of the screen, type `reduce` and press **Enter**.

3. A box asks you to enter the location of the stars to be reduced. Check the location of the star image that you want to do the IDL reduction on. Be sure to choose the stars that have already be reduced for dark frames and biases. Specify that directory path to the IDL program.

4. The IDL program gives the number of stars that it found to meet the program's criteria. IDL produces three new files under your directory. The only one that is needed for our purposes is the .dat file. Go ahead and delete the others.

5. Select the entire table, including its header row, and copy it (right-click and select **Copy**).

6. These files can later be pasted into Excel with the data formatted conveniently into columns, where you can easily find the magnitude of each variable star for each night.