

Mees Observatory CCD camera checklist

Last revised 3 November 2016 DMW

This guide is meant to be used as a cookbook, not for light reading, or as a tutorial in observations. Have it at hand at the beginning of observations, and follow the steps as they appear in these pages, as you would a recipe. Even if your memory is great, it will still prove useful to have the recipe at hand. Dan always does.

Sorry this cookbook is more verbose than the telescope setup/shutdown cookbook; unfortunately running the camera and taking useful astronomical images is more complicated than running the telescope. For even more instructions on observations and data acquisition, see the CCD Imaging Lessons, under the Mees tab at www.pas.rochester.edu/~dmw/.

If something goes wrong, and you're stuck somewhere in the middle of the steps, call Dan on his cell phone (585-414-1004) in order to be talked through the problem.

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I. CCD camera startup

1. Usually the camera and filter wheel will be found already mounted on the telescope, but: If it's still in its carrying case, take it upstairs and unpack it. Remove the protective cover from the camera's permanently-installed mounting plate by unscrewing the four bolts that hold it, and use these same bolts to fasten the camera to the bottom of the black box, in the orientation shown in Figure 1: that is, with the electrical connectors and most of the filter-wheel enclosure on the west (polar axis) side.
2. Move the mirror lever to its vertical position (Figure 1).
3. Connect the CCD camera's power supply and cables. These things are stored in a black nylon case below the dome floor's workbench. The RJ-11 and USB cables run from the camera (Figure 2) to the connections on the panel at the base of the telescope. Usually we use USB port 2 and autoguider port 2. Make sure those same ports are cabled in the connector panel in the control room (Figure 3).

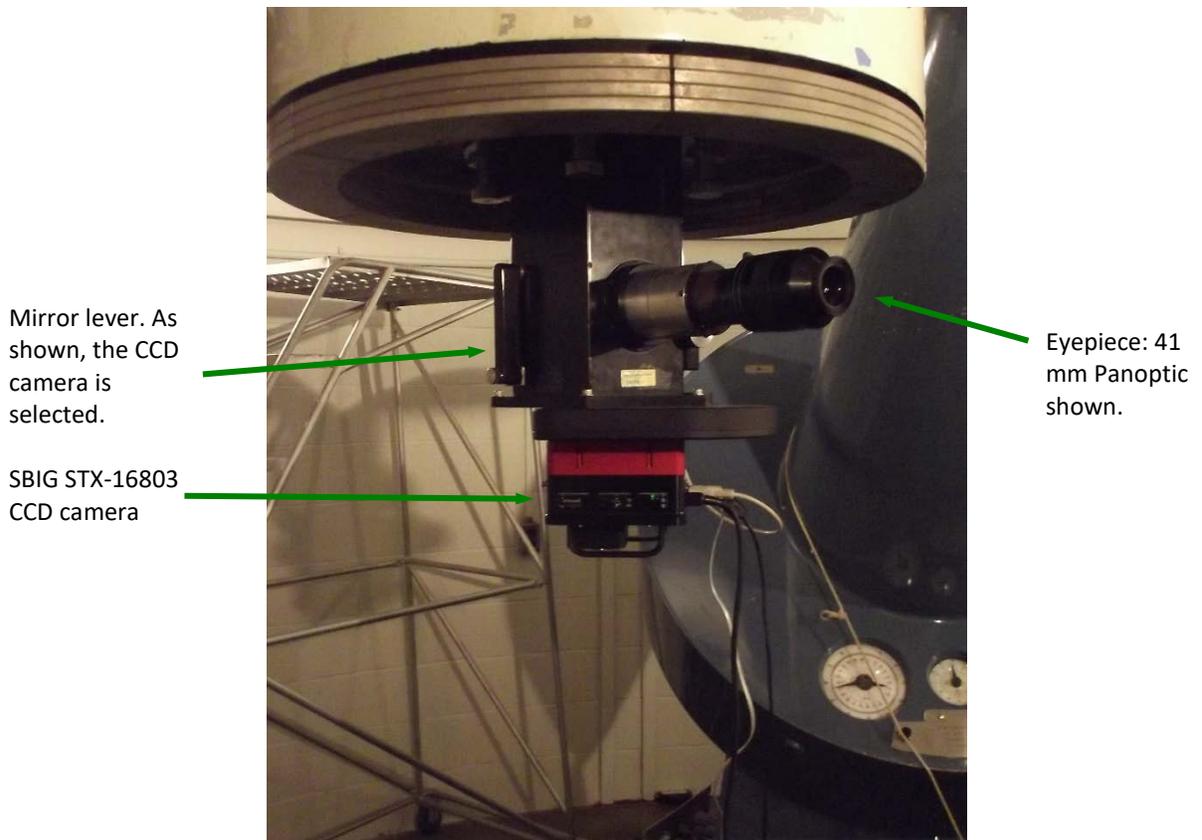


Figure 1: the back of the telescope viewed from directly north, showing the Black Box, the SBIG STX-16803 CCD camera and FW-5 filter wheel, the eyepiece, and the diagonal-mirror lever that switches the telescope between the two. In this orientation of the camera – filter wheel and cables protruding directly west, toward the telescope’s polar axis – the rows and columns of the main imaging CCD lie E-W and N-S, and images will appear on the CCD camera’s control software in normal orientation: north up, east left.

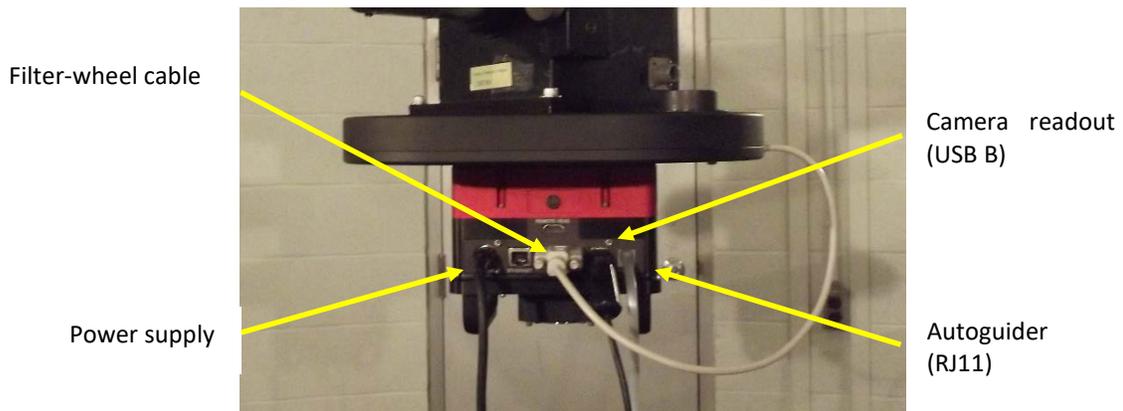


Figure 2: connector side, SBIG STX-16803 camera.

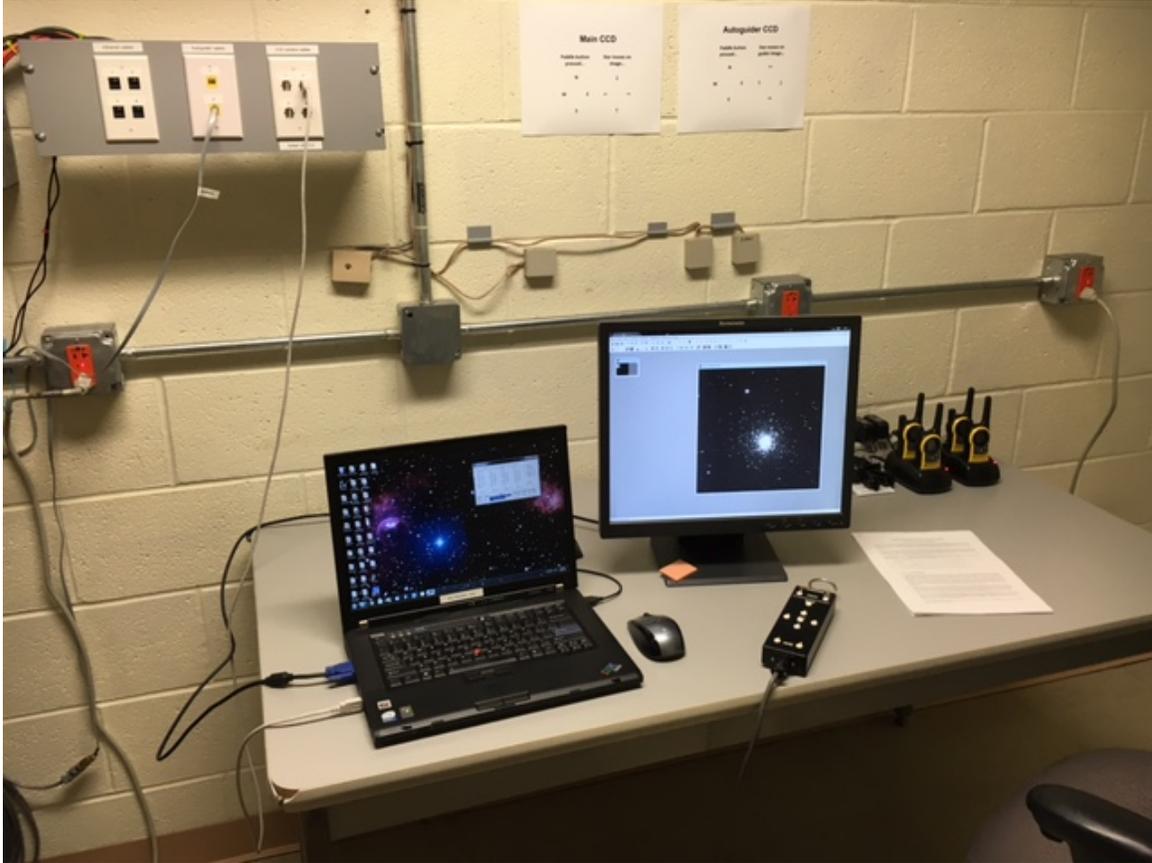


Figure 3: CCD camera computer in action in the control room. As shown, the computer is connected to camera cable #2, and the TCS autoguider input is connected to autoguider cable #2. The patch-panel connector layout matches that of the identical-looking panel at the base of the telescope, to which the cables from the camera itself are connected.

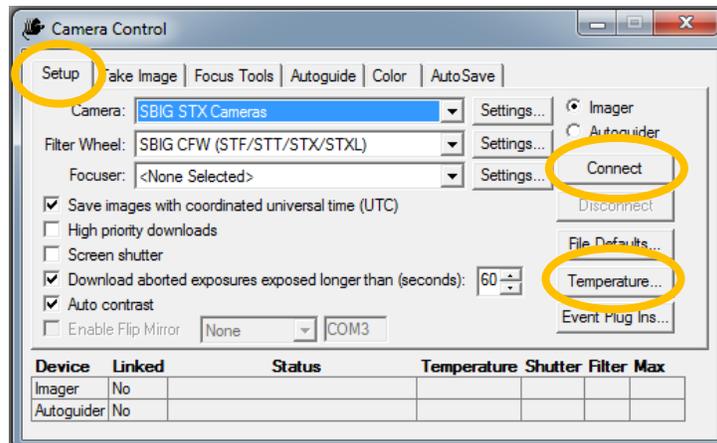


Figure 4: connecting the camera and setting the CCD's temperature.

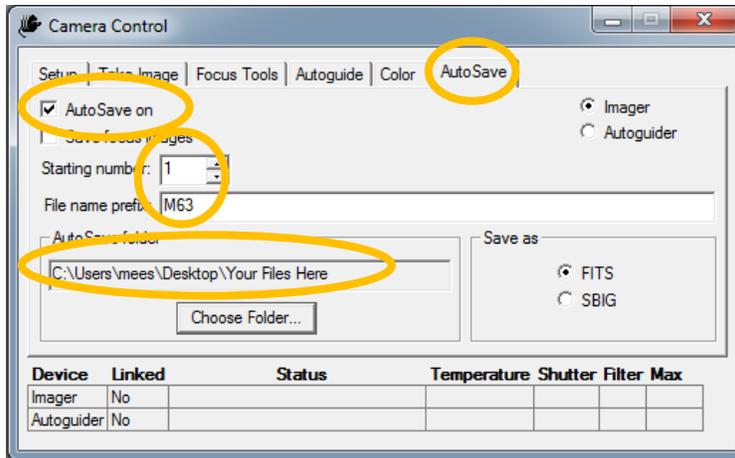


Figure 5: setting file saving parameters.

4. Start the CCD camera's laptop (Figure 3). Once it is up, start CCDSoft, using the icon in the task bar at the bottom.
5. If CCDSoft's **Camera Control** window does not come up automatically, start it from the **Camera** menu. This window contains most of the commands you will use; keep it open on the left screen, and leave the main CCDSoft window on the right for image display, as shown in Figure 3.
6. On **Camera Control > Setup** (Figure 4), push the **Connect** button to connect CCDSoft with the camera. (If it doesn't connect, check the cables again.)
7. Then push the **Temperature** button and set the CCD temperature to -20°C . Watch the temperature readout at the bottom of the window; let the temperature stabilize before proceeding to take data.
8. On **Camera Control > AutoSave**, set the working data-file directory and the file-name prefix (Figure 5). We recommend file names of the form **ObjectName_mm-dd-yyyy**, and that the working directory be on the computer's desktop. Check the **AutoSave On** box. Note that you'll probably be using the **Color** mode, which adds useful extensions to the file name, so you don't have to include filter information in the file-name prefix.
9. On the TCS, make sure the telescope is still pointed to zenith with tracking off; the diagonal mirror is out of the way of the camera; and the telescope focus is set to the last observer's last setting for the camera, usually written in the observing logbook and/or on the whiteboard in the control room. **Then wait for the sun to set.**
10. If indeed you have reached this point at sunset or before, and you are interested in scientifically-useful images or long-exposure pretty pictures, take a fresh set of flat-field data, following the instructions in Section V.
11. Point at a star suitable for telescope focusing: On the TCS computer, turn tracking **ON**. Then, on TheSky, choose a 6-8 magnitude star close to zenith. Click on this star to produce the **Object Information** window (Figure 6). Point the telescope at it by clicking the **Slew Telescope** button on this window, and answering **Yes** to the slew confirmation dialog box.
12. On **Camera Control > Focus Tools** (Figure 7), set **Exposure** to 1 second, check the **Continuous** box, insure that **Subframe** is *not* checked **On** and the **Bin** dropdown box is set to 2×2 , and push the **Take Image** button.

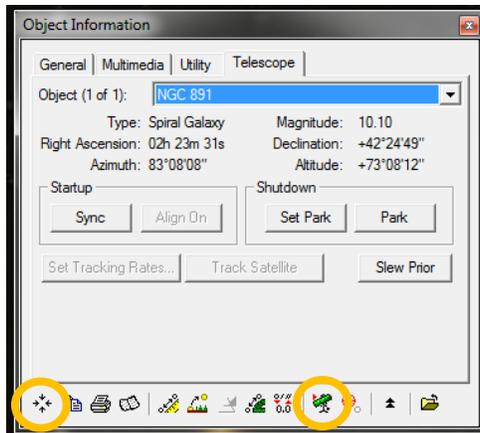


Figure 6: TheSky object information window, currently with NGC 891 selected. Useful buttons on the bottom of the window are circled: Center View on Object and Point Telescope to Object, left to right.

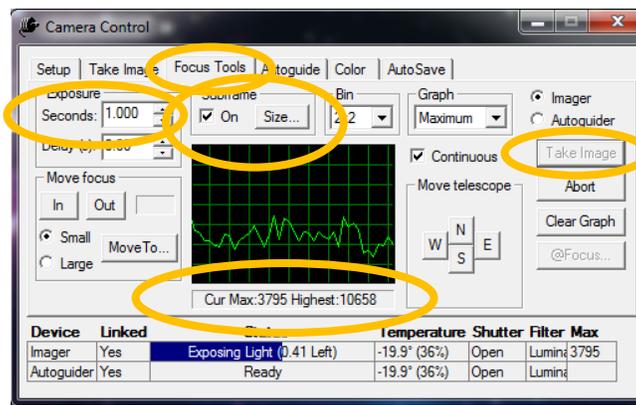


Figure 7: Camera Control's focus tools.

- Center the focus star: Use the sequence of images, and the buttons on the telescope paddle, to move the star close to the center of the image, at pixel coordinates X,Y = 1024,1024. To be reminded of which way the stars move when each paddle button is pressed, glance at the poster on the wall behind the monitors (Figure 3).

Pushing a direction button alone moves the telescope one arcsecond, per second the button is held down. If the paddle's SET button is held down along with a direction button, the telescope moves one arcminute per second. The imaging CCD's footprint on the sky is 15.4 arcminutes square.

- On TheSky's Object Information > Telescope, push the Sync button.
- Back on Camera Control > Focus Tools, push the Abort button.
- Define a small subframe around the star: Check Subframe On, click the Size... button, and choose the corner coordinates and size. For example, if the star were right at the center of the frame, one could choose the subframe's corner coordinates to be X,Y = 960, 960 and its dimensions to be 128x128, and the star would still be in the center. Zoom in on the resulting image til individual pixels can be seen.

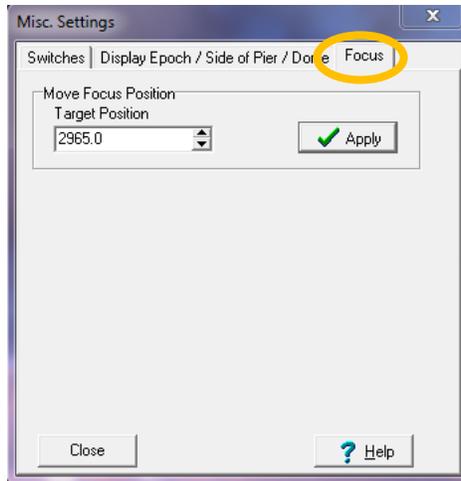


Figure 8: DFMTCS Telescope > Misc. Settings > Focus, a tool for moving the focus to a specific value of Focus. Type a number in the box and push Apply.

17. On DFMTCS, move the focus out (larger Focus values) by about 200 units past the initial focus position. Then move it in, examining the shape and brightness of the star's image in 9-10 different settings centered on the initial focus position, **always moving the focus in** (decreasing Focus values). At each setting take stock of the sharpness of the image (how few pixels across it is) and what its peak brightness is. DFMTCS's Telescope > Misc. Settings > Focus tab has a useful tool for moving to a specific Focus value (Figure 8). Camera Control > Focus Tools has a useful readout and graph to help you keep track (Figure 7). You'll find it useful during this process for one teammate to run the focus settings on the TCS, and the others to request the settings and watch the results in CCDSoft.
18. Identify the focus setting with the smallest and brightest stellar images; then use Telescope > Misc. Settings > Focus to move the focus out by about 200 units, and then back in to the optimal value. Record this optimal value of Focus in the observing logbook and on the control room's whiteboard. Uncheck Subframe On in Camera Control > Focus Tools.

The camera is now ready for observations.

II. Autoguiding

If you're just sightseeing, or if you're only using exposure times shorter than a few minutes – as in the Messier Marathon project in AST 142 – you may skip to Section III. Otherwise your exposures should all be autoguided, as follows.

1. On TheSky, search for your target (Ctrl-F for the search window), click on it to bring up its information window. Make sure it's above the telescope's artificial horizon (elevation > 20°). Do not point the telescope at it, if it's not.
2. Center the target's view in TheSky (Figure 6, lower left button), and zoom in until you see the outline of the camera's fields of view, as in Figure 9.
3. Find a star brighter than 14th magnitude which can be in the autoguider's field of view while your target is still covered by the imager's field of view. Brighter is more important than optimal centering.
4. Click on the chosen guide star, center this star in TheSky's display, and point the telescope at it, using the commands you saw in Figure 6. Now this star will lie within in the imager's field.

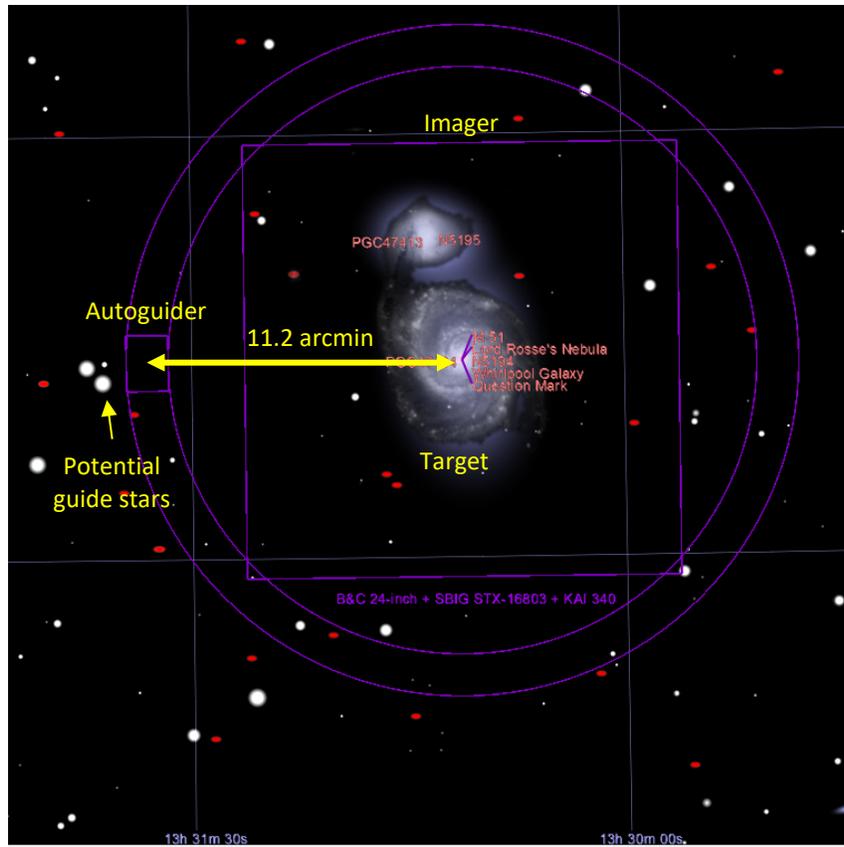


Figure 9: TheSky's view of a target (M 51), centered and zoomed in to show the camera's footprint on the sky. Note the potential guide stars near the autoguider's footprint.

5. As you did in the telescope focusing (Section I, step 13), take images in [Camera Control > Focus Tools](#), and move the guide star to the center of the imaging array. You will probably need [Exposure](#) to be 10-20 seconds, and if you are going to be taking color images it's best to do all this with the B filter.
6. Once the guide star is centered, update the telescope coordinates to its coordinates using the [Sync](#) button on TheSky, [Object Information > Telescope](#) (Figure 6).
7. Now move the guide star onto the autoguider, and your target onto the main CCD, by moving the telescope 11.2 arcminutes (= 672 arcseconds) West. Do this with [DFMTCS Telescope > Movement > Offset/Other](#): enter -672.0 into the [RA Offset](#) box, then push the [Apply](#) and [Start Slew](#) buttons (Figure 10). RA increases toward the East; hence the minus sign. TheSky's display will now look like Figure 12.
8. Back on [Camera Control > Take Image](#), check that the B filter is still in the beam, and take a 60-second exposure of your target. This too should look like Figure 12. If it does, proceed; if the target doesn't seem to be there, repeat, starting with Step 4, and make sure you got the right star.
9. On [Camera Control > Autoguide](#) (Figure 11), select the [Autoguider](#) radio button. Set [Exposure](#) appropriate to the guide star's magnitude: 10 sec if $\leq 12^{\text{th}}$ mag, 25 sec if 13^{th} mag, 60 sec if 14^{th} mag. Set [Declination](#) equal to that of the guide star, which can be looked up on its information window on TheSky.

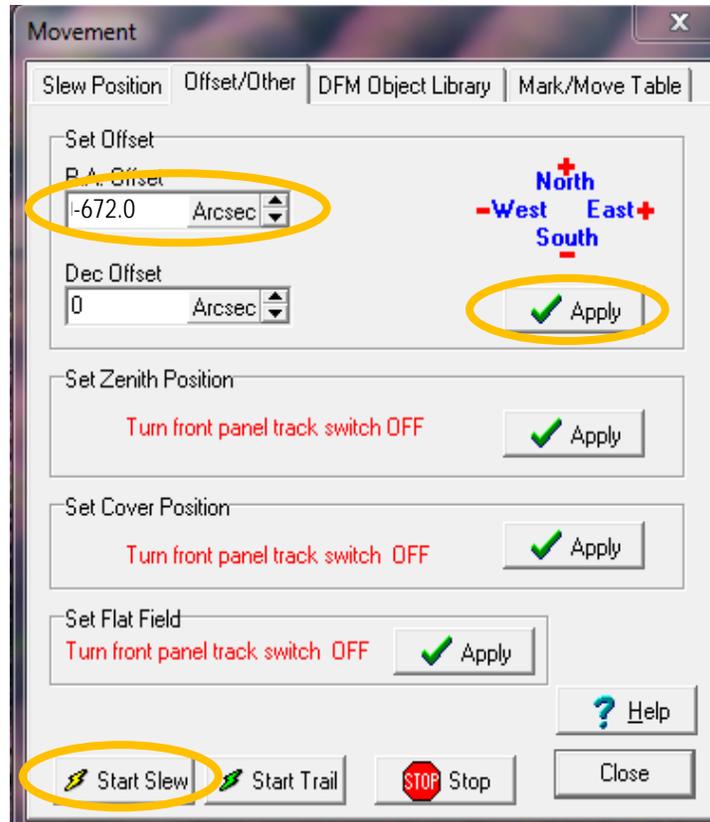


Figure 10: DFMTCS Telescope > Movement > Offset/Other, and offsetting the telescope.

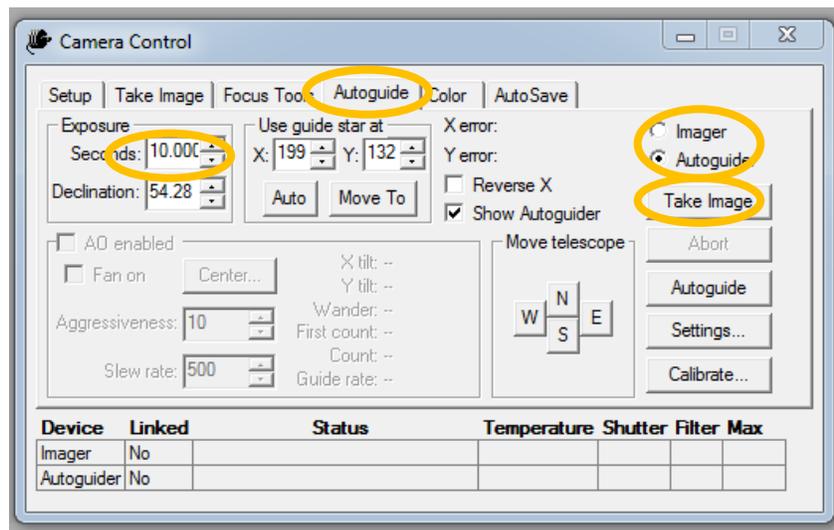


Figure 11: autoguider control.

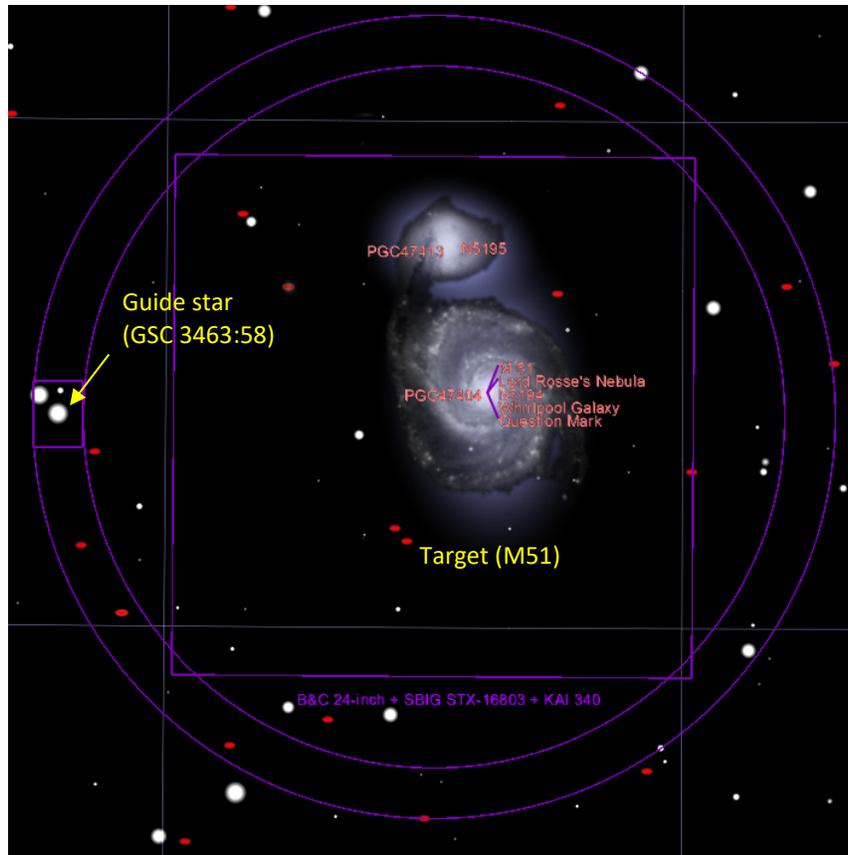


Figure 12: target and guide star, properly positioned in TheSky and within the CCDs.

10. Push the **Take Image** button. An **Exposure** time later, an autoguider image will appear in the main CCDSoft window beside the last imager output. Check to see that the guide star is well positioned on the autoguider CCD; move it with the paddle buttons if it's not. Note, on the poster on the wall beyond your monitor, that the paddle buttons move the stars differently on the autoguider than on the imager.
11. Click on your guide star in the autoguider image. Briefly you will see a small box enclosing the star; back on **Camera Control > Autoguide** you'll see the **Use guide star at...** X and Y coordinates update to the guide star's. Now click the **Autoguide** button.
12. Every **Exposure** time thenceforth, you will get a new postage-stamp image of the guide star, as it is placed within the box that briefly appeared in Step 11 (Figure 13). Watch for a few images to make sure the star stays put. If there are prominent hot (white) pixels within the image, push the **Abort** button, move the star slightly to avoid these pixels, then click on the star and the **Autoguide** button again. If the star drifts around a great deal within the box, then **Abort**, increase the exposure time, and restart autoguiding.

Now the telescope will remain precisely pointed at your target for many hours, as long as the sky stays clear and stable.

If the system should lose track for some reason (e.g. clouds, or dome taking the long route to a new position), simply push the **Abort** button, take another full image with the autoguider array, click on the guide star, and push the **Autoguide** button to resume guiding. You will also, unfortunately, have to abort and restart whatever you were doing with the imaging CCD as well.

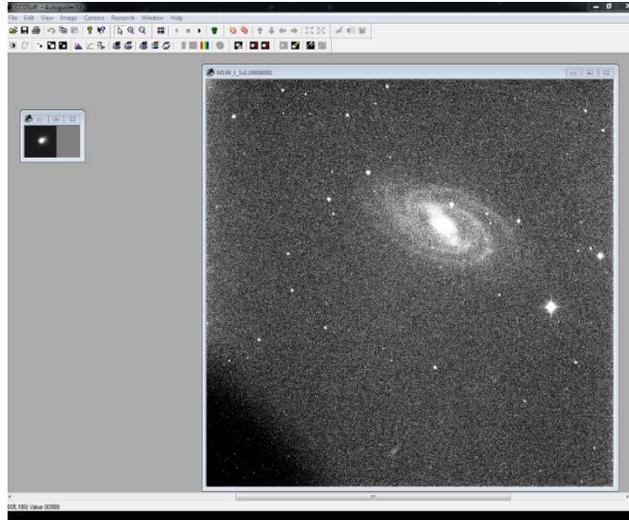


Figure 13: Main CCDSoft window during autoguiding. Postage-stamp of guide star at left; target (M 109, in this case) at right.

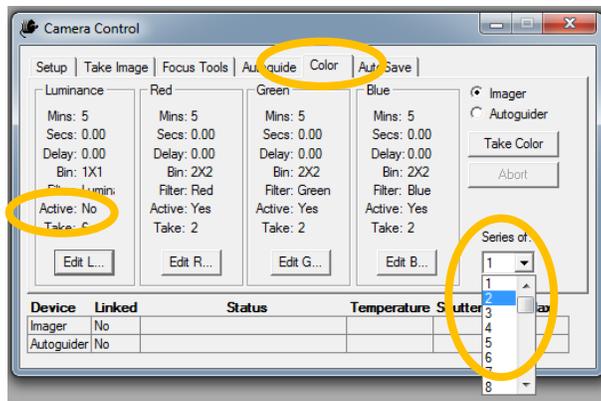


Figure 14: CCDSoft's color-image tab.

III. CCD imaging

A detailed set of observation and imaging-reduction instructions is available in the CCD Imaging Lessons, which can be viewed at <http://www.pas.rochester.edu/~dmw/Mees.html>. Whether taking color images or not, use the **Camera Control > Color** tab to collect data.

1. Make sure you have the directory and filename prefix you want, and **Autosave On** checked, in **Camera Control > Autosave**.
2. On **Camera Control > Color** (Figure 14), **Edit** the exposure settings for each filter. Make sure, first of all, that the filter selected for each corresponds to that of the heading. If there's significant moonlight, set all the exposure times to 5 minutes; if it's moonless, and you'll be taking many images, use 8-10 minutes. Use 1×1 binning for **Luminance** up for 5 minute exposures, and 2×2 binning for **Red**, **Green** and **Blue**.

3. If you are after pretty, APOD-quality color images, set **Active** to **Yes** for all four filters. Set **Take** to 6 for **Luminance** and 2 for each of the other filters. With five-minute frames, this set of images would take one hour to complete. Set **Series** for the number of sets you want. Most of the images on the [Mees observers page](#) took 4-5 hours. Most of APOD's deep-sky images by amateurs took 10-50 hours.
4. If you need scientifically-useful color images, you don't need to use the L filter; uncheck the **Active** box for **Luminance**. For most purposes you can set **Take** to 4 for each filter. If your target is a globular cluster, or other type of object with stellar variability on hour-to-day time scales, set **Take** to 1 for **Red** and **Green** and 2 for **Blue**, and set **Series of** to correspondingly larger values.
5. If you will only be paying short visits to lots of targets, such as one would get in a Messier Marathon: it's more convenient to use **Camera Control > Take Image** instead of **Color**. In this case you will probably want to use just the L filter, and 2x2 binning.

In every case, **Take Color** (or **Take Image**) starts the series.

IV. CCD camera shutdown

1. Select the L filter, and take a very short image, just so that this filter turns back into the beam. (This is the least expensive of the filters.)
2. Close CCDSoft on the camera-control computer.
3. Back up in the dome, unplug the USB, autoguiding and power cables from both ends, coil them up in untangled fashion, and stow them in their case (black nylon SIRTIF bag).
4. Usually it is OK to leave the camera mounted on the telescope. If you do, turn the diagonal mirror to the Eyepiece position, to offer a little more dust protection for the exposed L filter.
5. If you are taking the camera back to campus, though: carefully remove the 1/4-20 bolts and detach the camera. Using these same bolts, immediately attach the camera's protective cover, hopefully found in the camera's black Pelican case. Stow the covered camera in its case.

V. Flat fielding

If the goals of your observations include either scientifically useful observations, or pretty pictures made from several hours of exposures, you need to flat-field your data. Make sure you use the most recent flat fields available. If they're more than a few days old, you should make new ones. Flat-field observations are best made right after sunset, although right before sunrise will work in a pinch.

1. At sunset, make sure tracking is turned off, and point the telescope to the zenith. On DFMTCS, **Set Zenith Position** is a command under **Telescope > Movement > Offset/Other**.
2. On **Camera Control > Take Image**, set the **Frame** dropdown box to **Flat-Field**, **Bin** to 2x2, **Exposure Time** to 2 seconds, **Series Of** to 1, and **Filter** to R (Figure 15). On **Camera Control > AutoSave**, choose an appropriate filename prefix, such as **Flat_R_mm-dd-yyyy**. Then push the **Take Image** button and examine the resulting image, reading the signal **Value** in the pixel under the cursor in the lower left corner of the CCDSoft main window (Figure 16). If **Value** is typically larger (smaller) than 40000 (30000) data numbers, reduce (increase) the exposure time and try again until **Value** typically lies between 30000 and 40000.

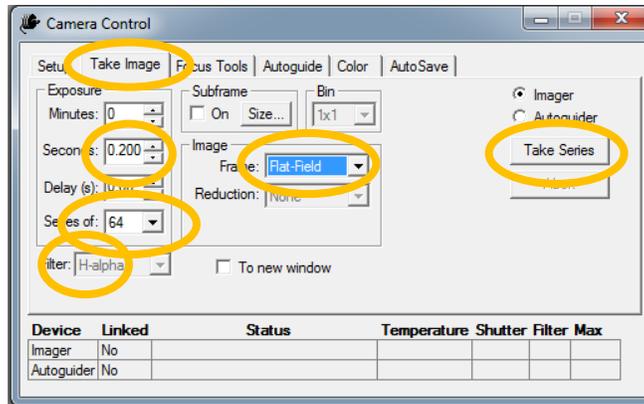


Figure 15: setting up and taking flat-field images.



Figure 16: cursor readout at lower left in CCDSoft's main window, showing pixel coordinates X and Y, measured from upper left, and the value of the signal in this pixel, in DN.

3. Then set **Series Of** to 32 – 16, if you're starting more than a few minutes after sunset – and push the **Take Series** button.
4. Repeat Steps 10 and 3, first for the G filter, then for the B filter, then for the L filter. Reset the filename prefix each time. Set **Bin** each time to the binning you intend to use in your observations; this is normally 2×2 for R, G, and B, and 1×1 for L. Unless you're really pressed for time, please take the full set of flat fields, even if you plan only to use one filter and binning tonight.
5. This completes the acquisition of flat-field data. Set the **Frame** dropdown box back to **Light Image**.
6. To convert these data into master flat fields, start CCDStack, using the icon in the Windows taskbar.
7. In **Process > Create Calibration Master > create master Flat**, select all the R flat-field images you collected during your observations (Steps 10-4), say **Yes** to the dialog box asking about bias/dark subtraction, and choose the appropriate (e.g. -20 C, 2×2 binning) Master Bias frame.
8. In the subsequent **Combine Settings** dialog, choose **sigma reject Mean** from the dropdown box, specify 3 and 1 for **sigma multiplier** and **iterations**, make sure the **normalize** box is checked, and click **OK**. In the next dialog, save the result under an evocative name, such as **Flat_Master_Red_mm-dd-yyyy**, within easy reach of your other data files.
9. Repeat Step 7 for the G, B, and L flat-field data. This results in four separate flat fields to go with the master dark and bias frames.

VI. Calibration of autoguiding

We don't need to calibrate the autoguiding very often, but it doesn't take very long, so don't hesitate to do it if you have any reservations about how well the autoguiding is keeping a sufficiently-bright guide star locked in place.

1. Using TheSky, identify a fairly bright star (3-5 magnitude) not too far away from the first target on which you want to autoguide, and center it on the guiding chip by taking images in the **Camera Control Autoguide** tab with the **Autoguider** radio button selected. You may find it convenient to point at the star, get it centered in the imaging CCD and sync its coordinates, and then move the telescope 11.2 arcminutes west, as in Section II, steps 5-7 Make sure this star is isolated. Autoguiding calibration works best if this star is the only one in the frame; if this is not convenient, make sure at least that it is by far the brightest star in the frame, and that no competing stars are within 15-20 arcsec of the frame. Settle on an appropriate exposure time that avoids saturating the star.
2. Push the **Calibrate** button, choose the duration of the calibration moves. These durations correspond to the time the system will effectively hold down one of the paddle buttons (without Set or Slew), which in our system moves the telescope an arcsec per second; the duration in seconds will be roughly the number of arcseconds the system will displace the star during its four calibration moves. If the star is roughly centered in the chip and is isolated, then 15-second calibration in X and 20 second in Y works pretty well.
3. Press **OK** to start the calibration sequence.

After you start it, the system will take an image and measure the centroid position of the star. Then it will move the telescope by your chosen calibration durations, one at a time in both directions, and measure the position of the star after each move. (Recall that the directions are not like those in the imaging CCD; see the posters on the wall behind your monitor, visible in Figure 3.) It will use these measurements to calculate the vector displacement of the star in response to a telescope move, in pixels per second and degrees of position angle. In our camera the vectors should turn out orthogonal, should lie along the cardinal directions, and should have magnitudes near 5 pixels per second, as in Figure 19.

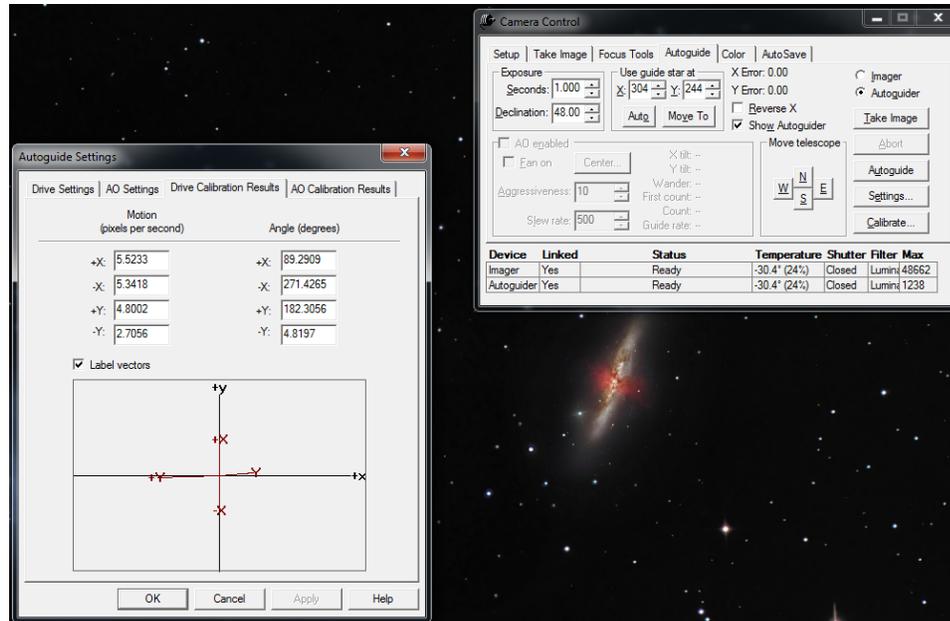


Figure 17: result of a typical autoguider calibration on a third-magnitude star. Note that the drives are found to be essentially orthogonal. The axes $+x$ and $+y$ are rightward and upward on the autoguider image as displayed in CCDSoft. That the rates for $\pm X$ (right ascension) are approximately the same indicates that there is little backlash in this direction; the difference between the $\pm Y$ (declination) rates indicates the contrary.

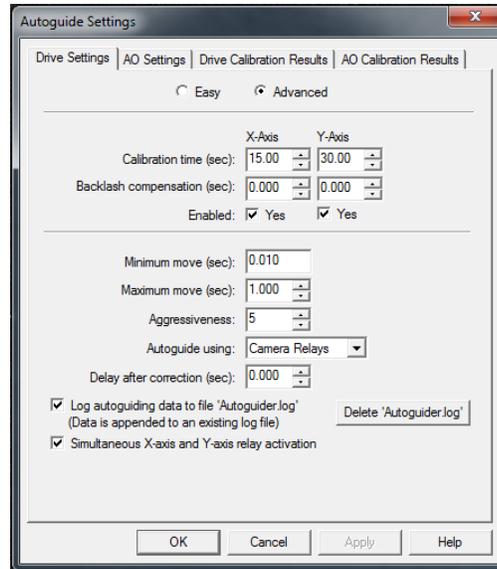


Figure 18: advanced autoguider settings.

If the calibration fails, look around more extensively for a brighter, more isolated star on which to calibrate, and consider making the calibration moves longer in duration. The longer one can make them, the more immune the measurements will be to backlash.^{1,2,3}

4. While you're at it, check the current values under **Setting > Drive settings > Advanced** (Figure 20). Use the default values for all the parameters except **Aggressiveness**, for which a smaller value (3-5) than the default (10) works best on our system. Click **OK** when you're done, to return to the **Autoguide** tab.

¹ For the term "backlash," consult [https://en.wikipedia.org/wiki/Backlash_\(engineering\)](https://en.wikipedia.org/wiki/Backlash_(engineering)).

² If one knows how long it takes backlash to be overcome when the direction of motion changes, one can take that out by using the backlash compensation settings under the **Advanced** features of autoguider **Settings...** button.

³ In the manuals one will read that re-calibration is necessary when the target crosses the meridian. This is also due to backlash, but it assumes a telescope that shifts against the opposite faces of the gear teeth as the telescope's center of mass -- slightly imperfectly balanced -- crosses the polar axis. This happens as the target crosses the meridian, in most English-style telescope mounts. In telescopes like ours, the weight is always on one side or the other of the polar axis, so we don't actually need to recalibrate when crossing the meridian. This is one advantage of the German-style mount of our telescope.