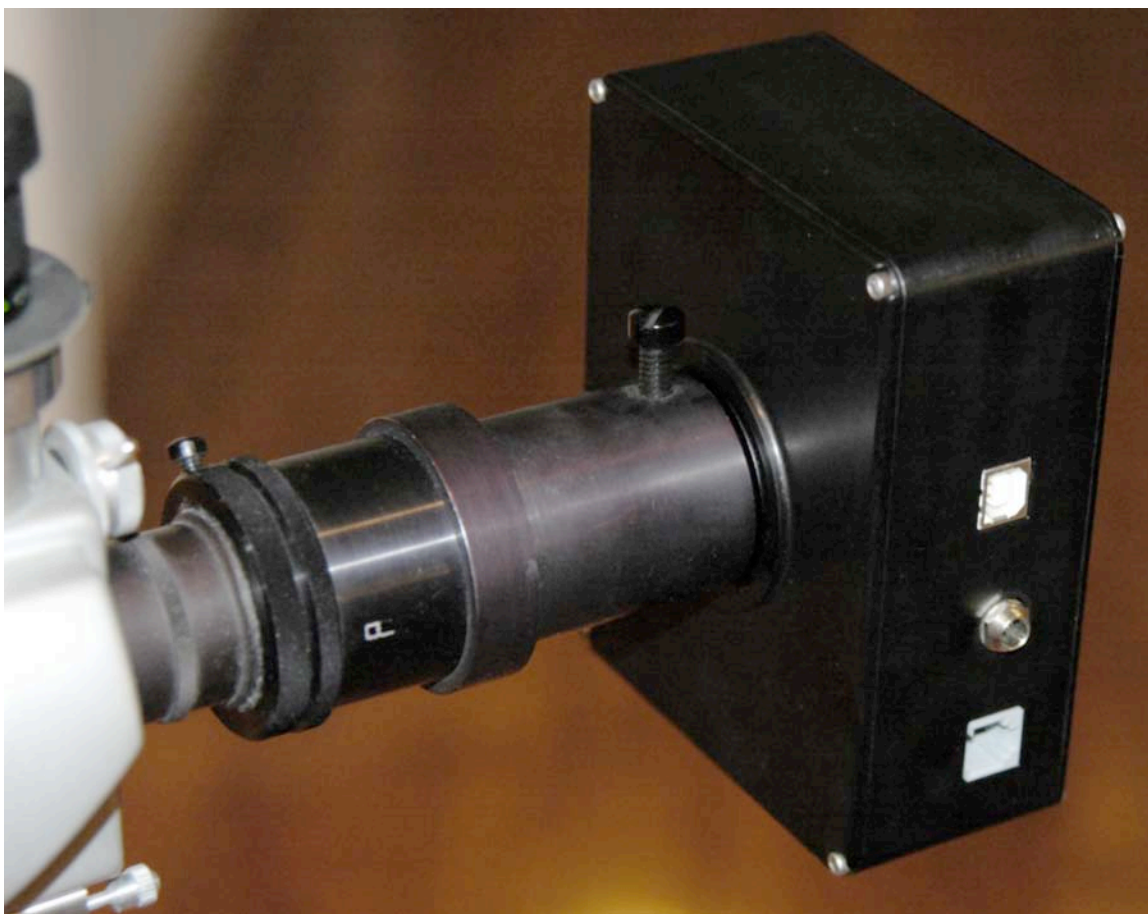


SBIG ST402 Astro-Camera

by Suk Lee



An “Entry Level” Cooled Astro-Camera/Autoguider

Santa Barbara Instruments Group (SBIG) is a leader in the astronomical camera field, having a broad range of products, from entry level cameras, standalone autoguiders, self-guiding spectrographs, to self-guiding cameras in various sensor sizes up to multi-megapixel, full frame (equivalent to a 35mm frame) cameras.

SBIG announced their replacement for their venerable ST237 camera in 2004 and delivered the ST402 shortly thereafter in early 2005. The ST402 is a B&W camera with temperature regulated Peltier cooling, and a 765x510 pixel, 9 micron square B&W sensor. The sensor is an ABG (anti-blooming gate) sensor, with microlenses built into sensor to offset some of the sensitivity loss from the ABG structures on the chip. The camera can optionally be ordered with an internal LRGB filter wheel, with parfocal filters. The review sample came with the internal filter wheel.

Unlike the other cameras in the SBIG portfolio, the ST402 is a single sensor camera, so it can be used as an imager, or an autoguider, but cannot do both functions at the same time, i.e. it's not a self-guiding camera.

What's in the box?

The ST402 comes nicely packaged with everything needed to start imaging. Clockwise from top left:

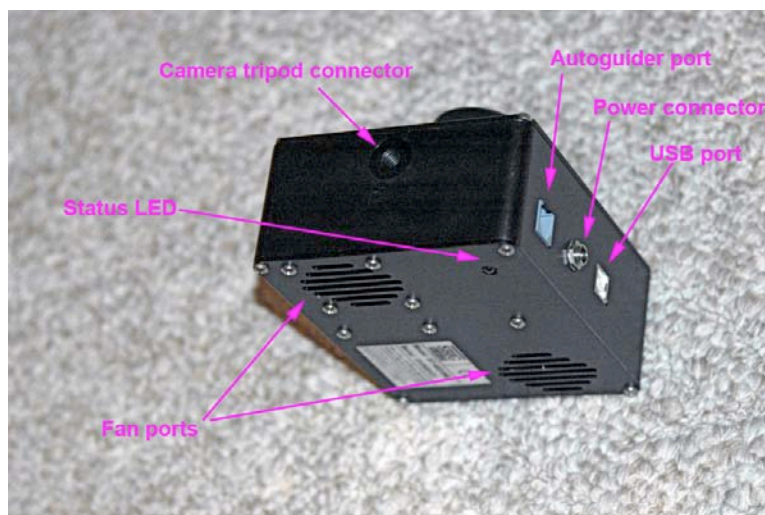
- Heavy duty wall wart power supply
- Camera
- Two CDs with a comprehensive set of camera and planetarium software
- QA checklist
- Camera manual and warranty card
- 6 wire "twisted" autoguider cable
- USB cable



As mentioned above, the camera was supplied with the RGB filter wheel, which is internal to the camera.

ST402 camera body

The ST402 is an anodized black metal box. On the front is the nosepiece and on one side are the electrical connections. The back has a single status LED which blinks when the camera is actively communicating with a PC, or taking images, and two ports for the fan.



All camera functions are carried out via the USB port – there are no external controls. While it's a tidy and lightweight package, it's larger than it looks in picture – compare to

the Nikon D70 below. The pictured SBIG ST2000 has the CFW8 color filter wheel “direct attached” which makes it the heaviest and bulkiest of the cameras shown. The Meade DSI is between the Toucam and ST402 in size and weight.

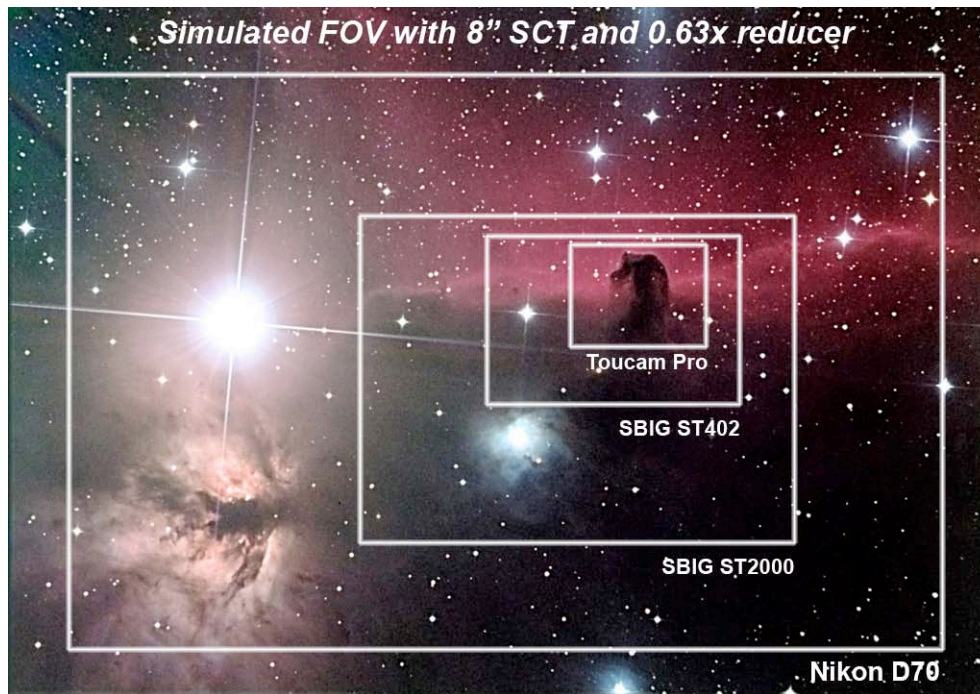


Sensor size comparison

By coincidence, the relative fields-of-view the cameras will generate with a given telescope go up roughly as $D70 = 2 \times ST2000 = 4 \times ST402 = 8 \times Toucam\ Pro$, by linear dimension:



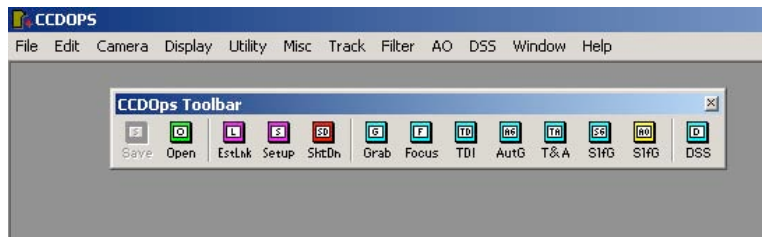
Here's what you can expect in terms of image field-of-view on a typical 8" SCT with a 0.63x reducer:



Getting started with CCDOPS

The ST402 comes bundled with SBIGs CCDOPS program. It is a full featured program allowing you to control all aspects of camera operation, but is not as sophisticated as other programs such as CCDSoft or Maxim DL/CCD. However, it is entirely enough to learn how to use your camera and start taking pictures (including automatically acquired tri-color images).

Starting CCDOPS brings up the following window and toolbar:



From left to right, the CCDOPs toolbar commands are:

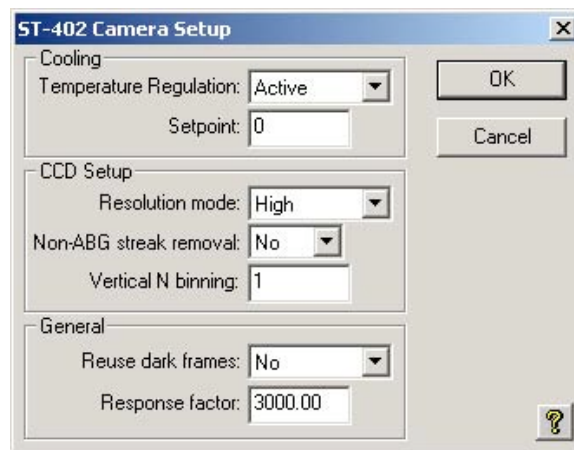
Save	Save the current image
Open	Open an image from disk
EstLink	Establish a link to the camera

Setup	Setup the operating parameters for the camera (e.g. temperature)
ShtDn	Perform an orderly shutdown of the camera prior to power down
Grab	Take a picture
Focus	Start focus mode
TDI	Take a “drift scan” image, not applicable to the ST402
AutG	Use the camera as an autoguider
T&A	Take a set of “track and accumulate” images
SIfG	Self guide, not applicable to the ST402
AO7 SIfG	Self guide using the AO7, not applicable to the ST402
DSS	Set up the spectrograph, not applicable to the ST402

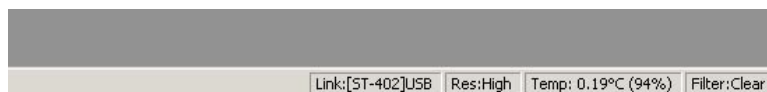
At the bottom right of the window (not shown above) is the status area which tells you the current operating status of the camera. Clicking on “EstLink” will establish a link to the camera. The status area changes to show the following:



Of particular interest is the Temperature readout and the 0%, indicating that the cooler is off (although the fan will already be on – it’s loud). Click on “Setup” in the toolbar and you’ll get the following popup:

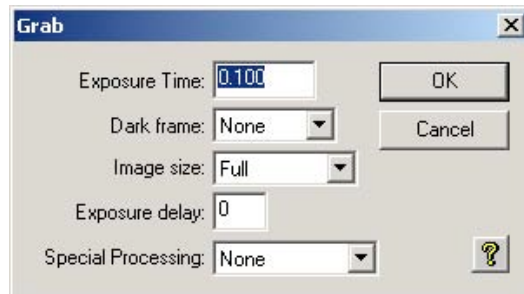


Select the options as shown and click “OK” and you’ll set the camera to turn on temperature regulation at 0C. Give the camera some time to cool down from room temperature (a couple of minutes) and the status area should show:

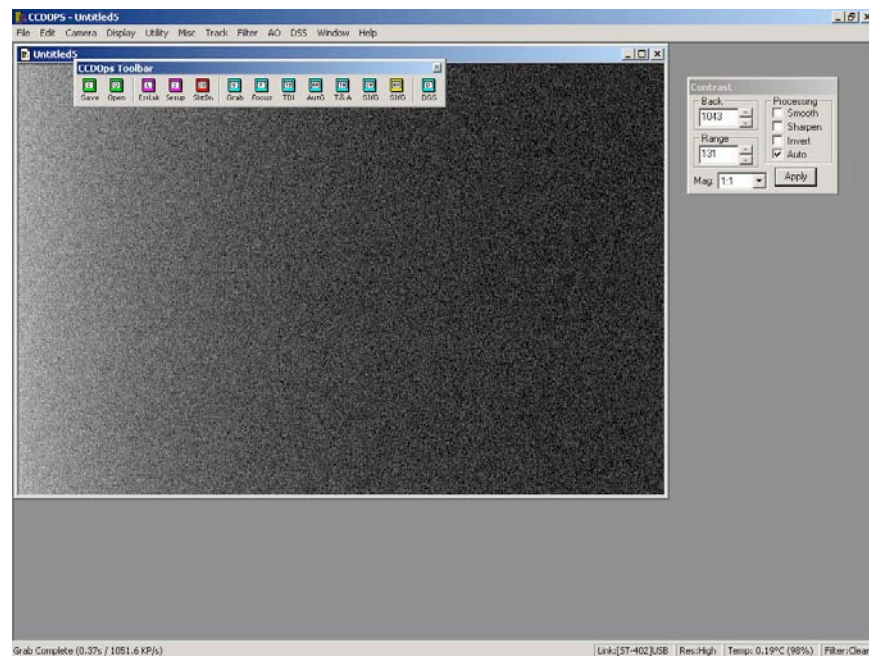


In my case the temperature was flipping slightly above and below the setpoint of 0C, and you can see that most of the cooler capacity was used up as the camera was running at 94% cooler capacity.

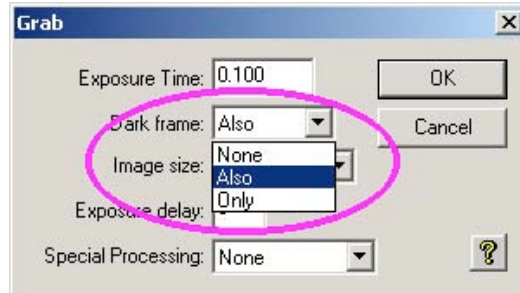
Click on “Grab” on the toolbar to get:



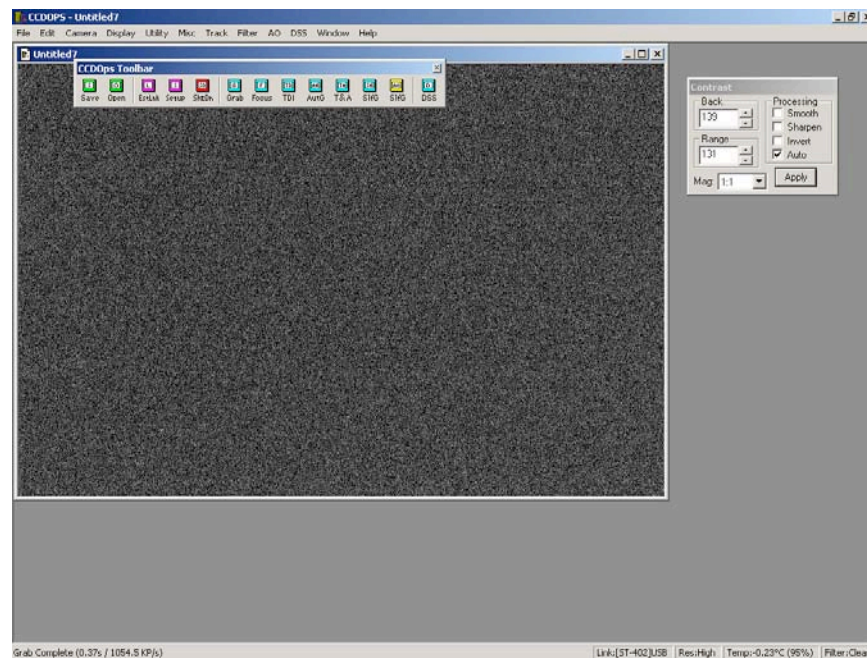
Setup as above and click “OK”. If you have the camera covered, you’ll get the following image:



Note the contrast control window which has popped up (upper right), and that the processing mode is set to “Auto” in the window. This automatically stretches the histogram so you can see whatever’s captured. In general it’s a good idea to leave this set to auto. Notice the slightly grainy image – that’s thermal noise in the sensor. Also notice that there’s a gradient across the image. Dark frames (frames taken with no light input) are used to get rid of these thermal noise gradients. In general, you will want to take lots of darks frames and “calibrate” your images with these frames to reduce the overall noise in your image. CCDOPS has an automatic dark frame mode which can be used for quick and dirty imaging. To turn on, go to the “Grab” popup and set “Dark Frame” to “Also”.



This will set the camera to automatically take two images, one in “regular” mode, and then a second, of the same length, with an internal shutter in place to take a dark frame. Obviously this doubles the length of your exposure, so this is not desirable for long pictures, but is handy for short exposures. Clicking “OK” gives you the following image:



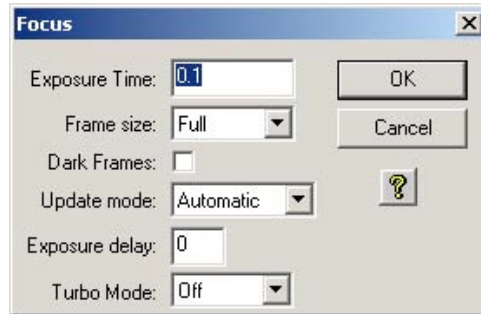
The image is still grainy because of the random nature of thermal noise, but notice that the gradient is now gone because of the automatic dark frame removal. At this point you’re ready to try focusing for the first time!

CCDOPS Focus Mode

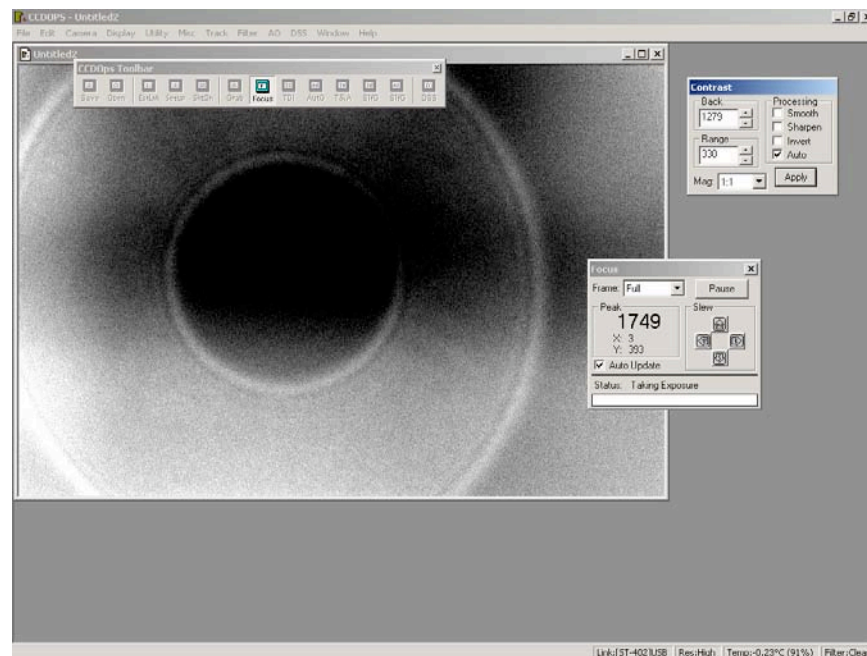
If you’re familiar with webcams, you’ll find focusing is very different (and challenging) because there’s no live image. Instead, CCDOPS has a focus mode which take a series of successive images instead of having a live video window. So, just getting the object centered on the chip can be a challenge.

The first time out, get moderate focal length eyepiece, say 20mm or so, and focus on a bright star. Remove the eyepiece and insert the camera. If you have a flip-mirror, this is where it comes in handy!

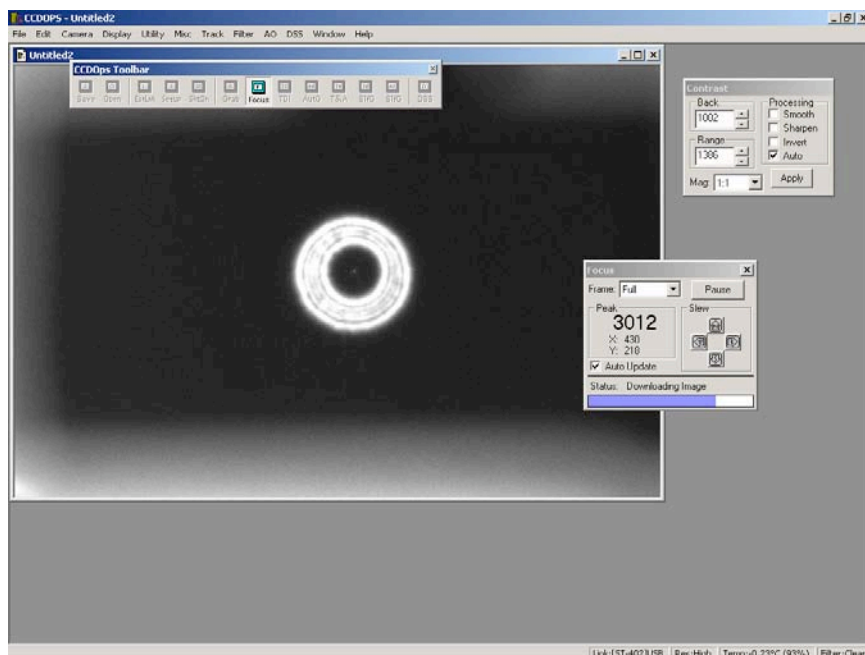
Click on “Focus” on the toolbar:



Set the exposure time to 0.1 seconds, which should be good for any bright star. Too bright a star will actually be a problem, we'll take care of this later. Note the “Frame size” pulldown. For cameras with large CCDs, you want to download only a portion of the image in order to get a good refresh rate. For the ST402 the small CCD means you can get a good refresh rate downloading the entire frame, so it's easiest to set use the entire frame so you can see whatever the camera sees. Click OK:

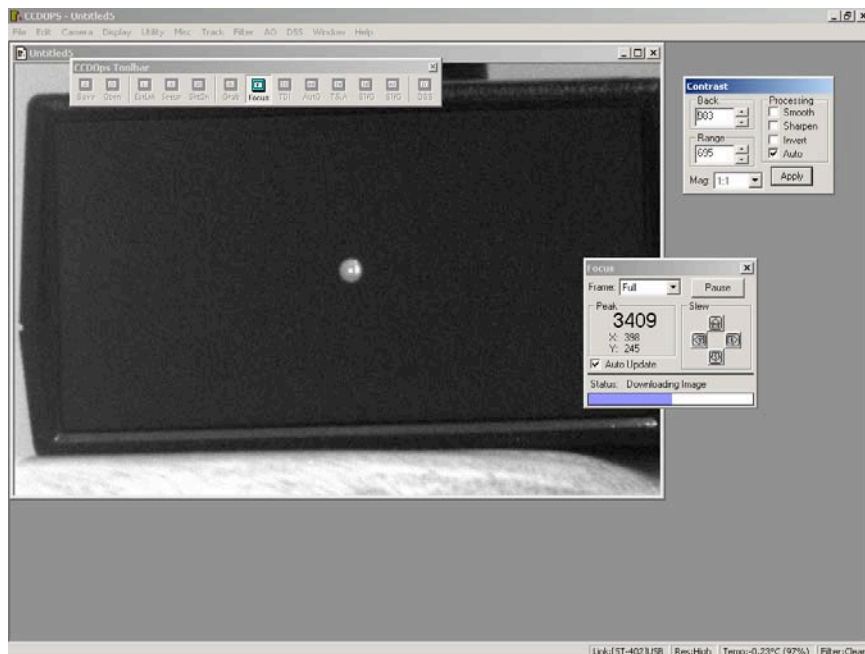


As before the “Contrast” window pops up, but now you also get a “Focus” window. The bold number in the window is the peak brightness of the star. The ST402 has a 16 bit DAC and so has a peak brightness of 65k – we're a long way from that. To the right of the peak brightness indicator are some slewing buttons. If your mount is autoguidable, and you've connected your camera to the mount (which we haven't done yet...), you can click these buttons to slew the telescope around to help get a star centered on the chip. Given the quick update rate of the ST402, you can start adjusting focus and seeing the results in virtual realtime:



Note that the peak brightness has increased. You want to adjust focus to maximize this number. Note that I mentioned before that a really bright star can be a problem. If you find that you're getting close to 65k, you could saturate the CCD, which won't harm it, but make finding peak brightness impossible. You can either reduce the exposure time, or find a less bright star if this is the case.

Finally, here's the in-focus "star" which is actually an artificial star.



In practice, I find the peak brightness method of finding focus a little difficult, as seeing conditions will make the peak number bounce around. At this point of approximate focus I usually switch to a Hartmann mask to achieve final exact focus. For information on how to focus with a Hartmann mask, take a look at:

<http://www.cloudynights.com/lab/astrophotography/meadelpi2.pdf>

and

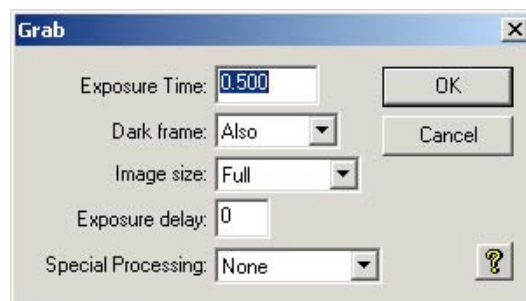
<http://www.cloudynights.com/howtos2/hartman/hartman.htm>

Tri-color RGB Imaging with Optional Color Filter Wheel

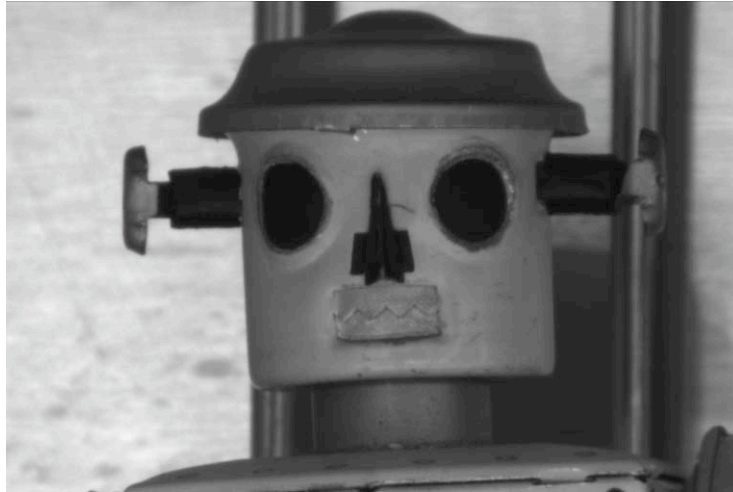
The ST402 is a black and white camera. Actually ALL solid-state (CCD or CMOS) sensors are fundamentally black and white. “One-shot” color cameras actually have a matrix of tiny filters built into the chip. Software then takes the image information and creates a composite color image out of the individually filtered pixels.

The ST402, with the optional internal color filter wheel, uses a different method called tri-color imaging to create color images. 3 successive images are taken through red, blue, and green filters, and then combined in CCDOPS to create an RGB color image.

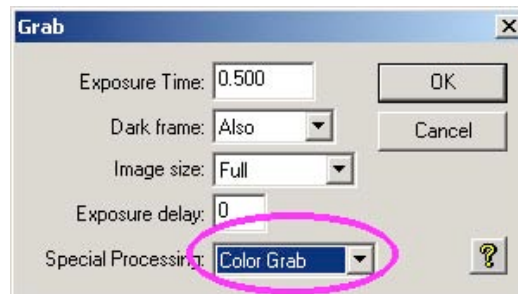
First, set up and focus in normal black and white mode and then click “Grab” on the toolbar:



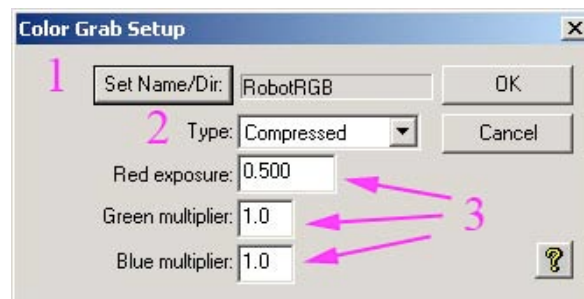
Click “OK” to capture a regular B&W image:



You're ready to take a color photo now. Click on "Grab" again, but now set the "Special Processing" pulldown to "Color Grab":

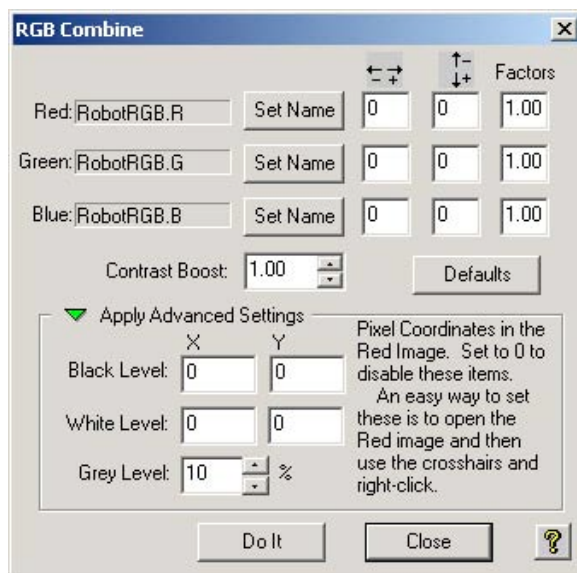


Clicking on "OK" will bring up another window:

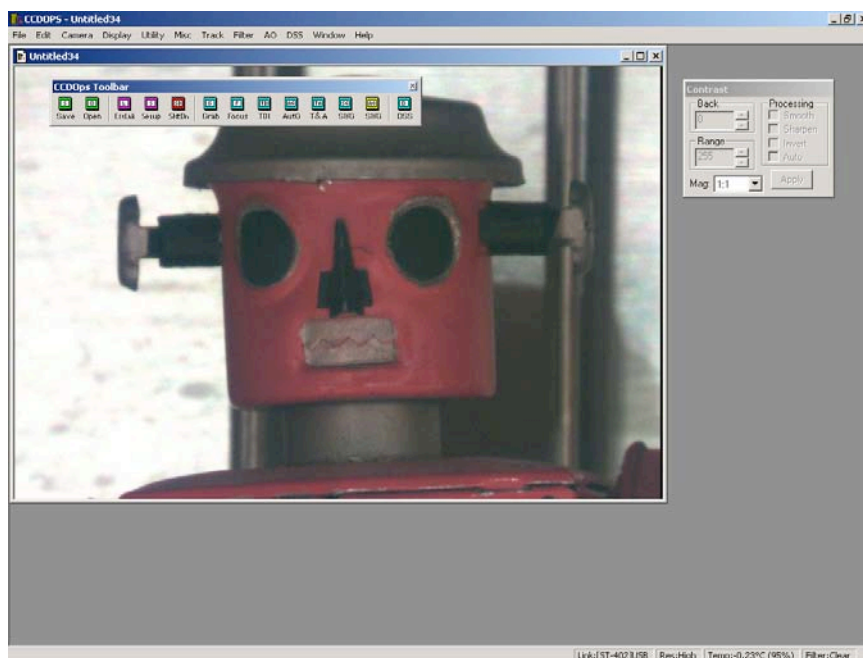


Under (1) set the name and directory for the files to be stored. Under (2), set the file type to "Compressed" as shown. Finally under (3), you set the initial exposure time for the red channel, and the multipliers for the green and blue channels. I left the green and blue multipliers to 1.0 and the exposure to 0.5 seconds again.

Clicking on "OK" will cause the camera to automatically take three exposures, rotating through the filters before taking exposures. These are black and white images that need to be combined together into a tricolor RGB image. Selecting Utility -> RGB Combine... brings up the following popup:



This popup allows you to move the layers with respect to each other, additionally scale the brightness of the layers and set the black and white levels. Simply clicking “Do It” will merge the layers as is:



Simple and easy!

First Astro Light – Greyscale DSO

First “real” light was done in greyscale, capturing M1 with my standard imaging rig of a Mewlon 250, AP900, and Megrez80/STV guidescope. In order to increase the FOV, I used a Celestron 0.63x reducer:



I focused on Zeta Tauri using a Hartman mask, then swung over to M1 and capture 12 5 minute exposures. Here's an example of an unprocessed 5 minute exposure:



You can see above that a 5 minute exposure has captured a lot of signal, but the signal to noise of the picture is poor, with lots of speckles and graininess (the apparent highlight blow-out in the middle of M1 is an artifact of the histogram stretch).

To get rid of the noise, multiple images are added together, but before summing the images, each image must be "calibrated" to remove the offset noise caused by the dark current in the sensor itself.

With a non-temperature regulated camera, this generally means taking a series of “dark” frames, pictures with the telescope covered, of the same exposure length as the main imaging pictures, right after or before the main imaging session, to try to capture the dark frames at the same temperature as during imaging. The dark frames are then subtracted from the raw images to remove the dark current offset so the resulting “calibrated” images can be stacked.

With a temperature regulated camera, a set of “bias” and “dark” frames, taken at arbitrary but fixed, known, temperatures, can be used to calculate how much dark current will accumulate over a specific time interval or temperature. That way, a “master” set of bias and dark frames can be taken in advance of the imaging session, saved, and then re-used over multiple sessions, eliminating the need to take dark frames each imaging session.

Remember $y = mx + b$? At any specific temperature if you substitute:

y = total dark current accumulated at a specific temperature i.e. a dark frame

m = rate of dark current accumulation

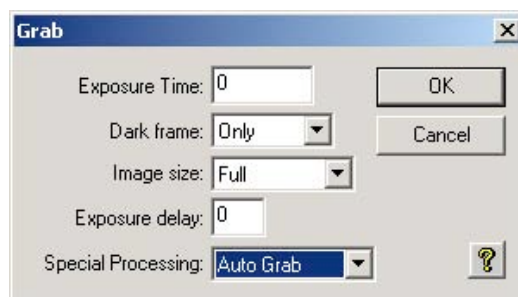
x = time

b = minimum current accumulated at 0 time, i.e. a bias frame

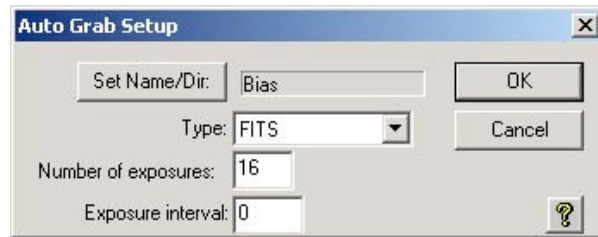
A “bias” frame is the minimum dark is “ b ” in the equation above – the minimum current that will accumulate in 0 time. Given a “dark” frame, y , of known exposure time and temperature, software packages such as CCDSharp, or Maxim DL, or AstroArt, can calculate the dark current accumulation rate and extrapolate/interpolate across different temperatures and exposures times. All you have to do is supply a set of low noise bias and dark frames and the software will do the rest. Low noise bias and dark frames can be generated simply by taking a lot of them and then letting the software average them together. The resulting frames are called Master Bias and Master Dark frames.

If you’re taking a set of master bias and darks ahead of time, you need to select a temperature that the camera can maintain during the course of all the exposures. A save temperature inside a house is typically 0C.

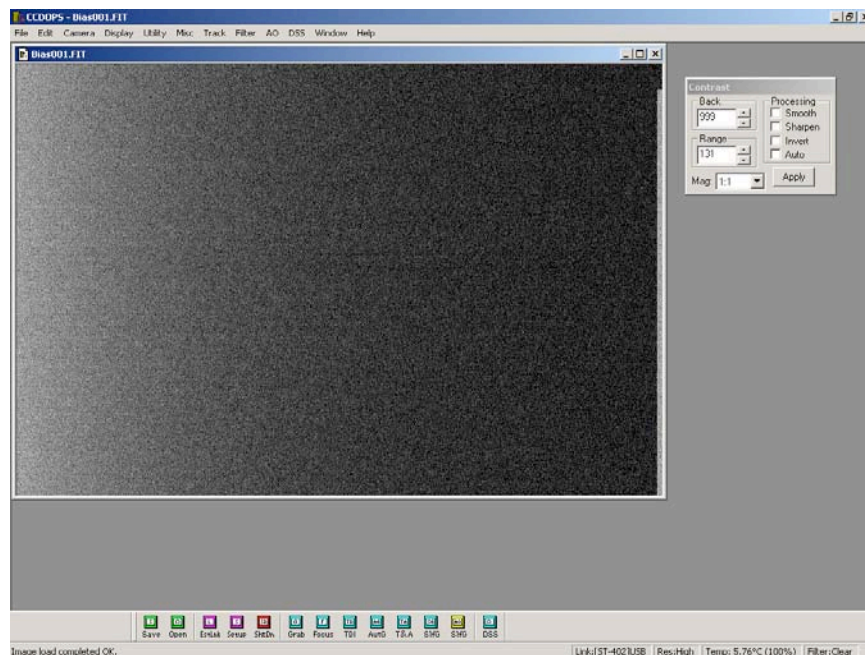
To take bias frames, select “grab” and set it up as follows:



This brings up the auto-grab menu, set the file name to “Bias”, the file type to “FITS” and select how many images to take. I usually take a minimum of 16 bias frames to create a “Master Bias”:



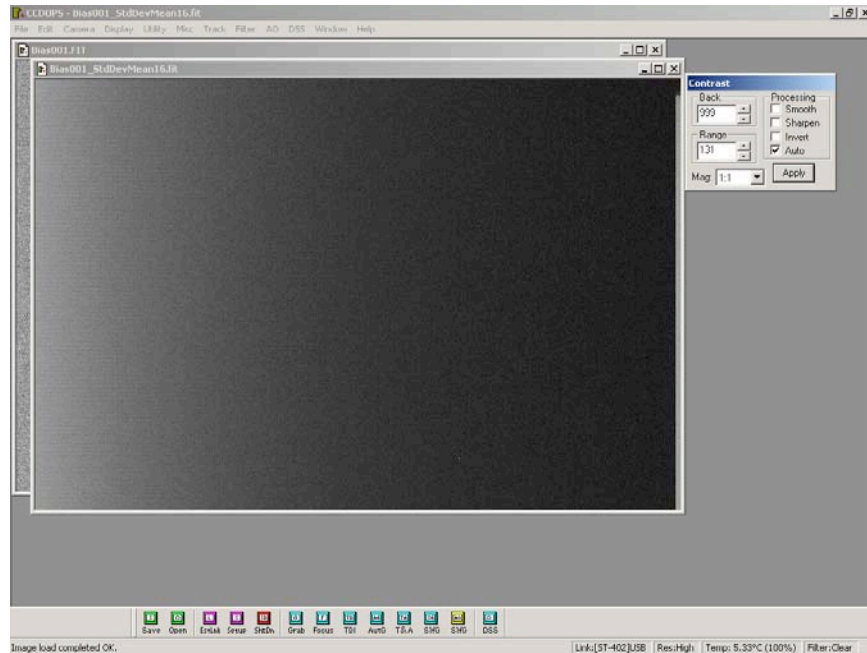
Clicking on OK will cause the software to take and save 16 bias frames. Here’s an example of a raw bias frame:



To create a Master Bias, the 16 frames you took should be averaged together. There’s a freeware package that uses advanced statistical methods to do low noise image stacking called “Sigma”, available from Ray Galak’s site. Go to:

<http://www.galak.com/Sigma/>

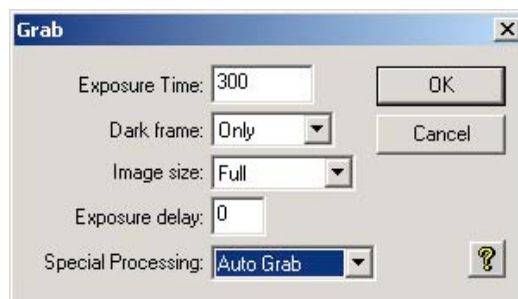
Make sure you download the “Pre Beta 11” version, as there’s a bug in saving 16-bit FITS files in earlier versions. Ray provides full instructions on how to create bias and dark frames using his software. I used his software to combine the 16 raw bias frames together into one low noise Master Bias:



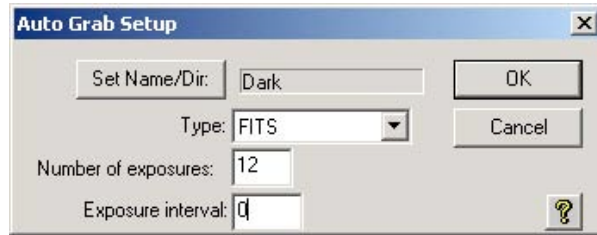
Note how much smoother the Master Bias is. That's because in any one bias or master frame there's a significant random element. You take multiple bias and master frames to eliminate the random element and just capture the average amount of current.

Save this file for later use.

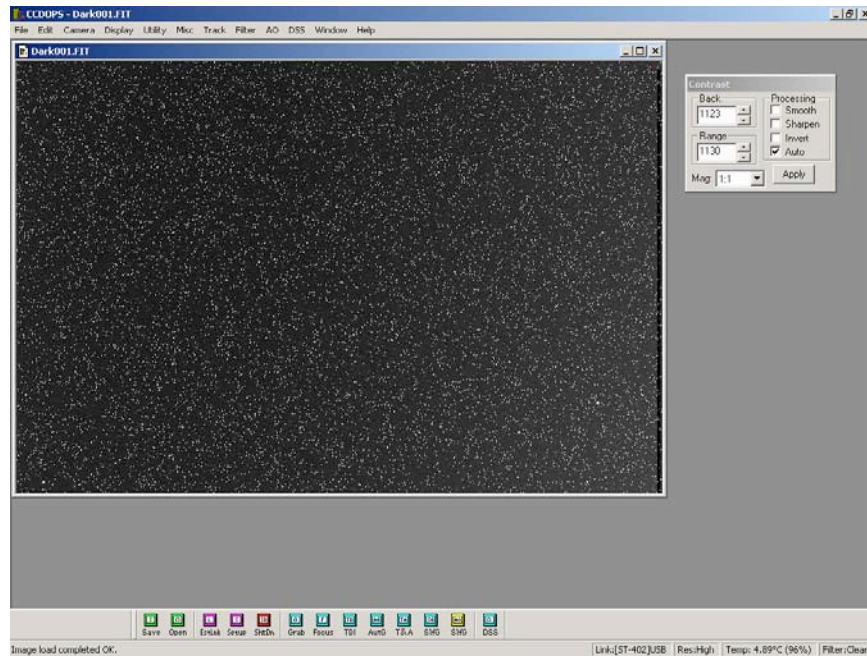
Now we'll take some dark frames. Again, you want to do it at a specific temperature, and take a number of them to average together. In addition, you want to take longer exposures, in order to capture a representative amount of dark current. Too short and it won't be very accurate. Too long just wastes time. Generally I take dark frames of between 5 and 20 minutes, depending how obsessive I'm going to be. For this review I created a Master Dark based on twelve 5-minute exposures. Select "grab" again and set up as follows:



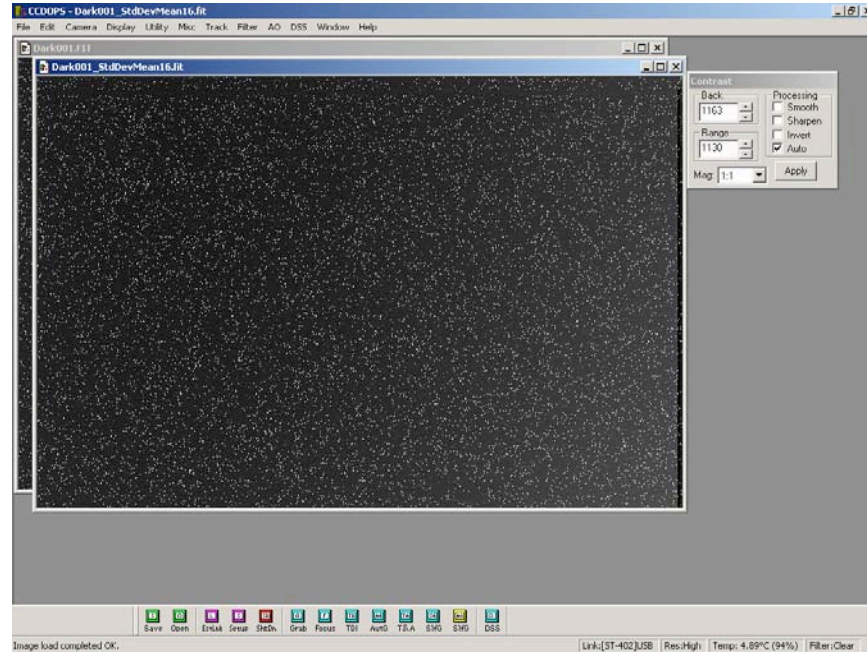
Set the filename to “Dark”, and make sure the filetype is still “FITS”:



Again, here's an example of a single dark frame:



And again, after taking 12 images and averaging together in “Sigma”:



Save this Master Dark frame.

There's an additional step of creating a “flat” frame. This is a set of pictures, taken through your telescope, with exactly the same configuration and focus that you used to take the original images, of a perfectly illuminated, flat, field. Hence the term “flat” frame. Since CCDs are generally linear, this type of frame can be used to eliminate the effects of vignetting and dust in your optical train.

Flat frames can be created numerous ways, via “sky” flats, a lightbox, t-shirts, etc. The point is to create an illumination source that isn't too bright (since the CCD camera is VERY sensitive), and is even across the entire frame. Ron Wodaski has an excellent discussion on how to create flats in his book “The New CCD Astronomy”:

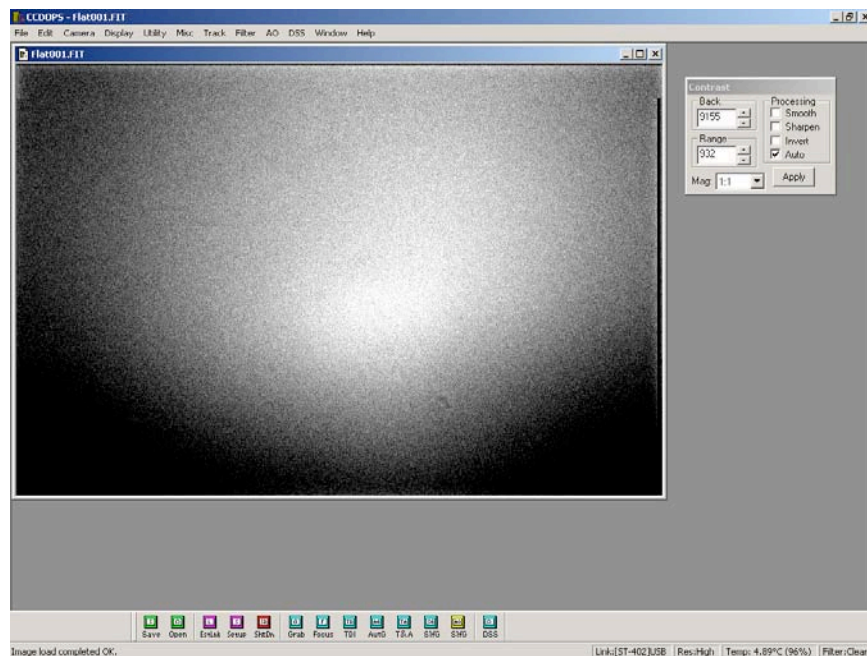
<http://www.wodaski.com/newastro/default.asp>

I built and use a lightbox, instructions are at my website:

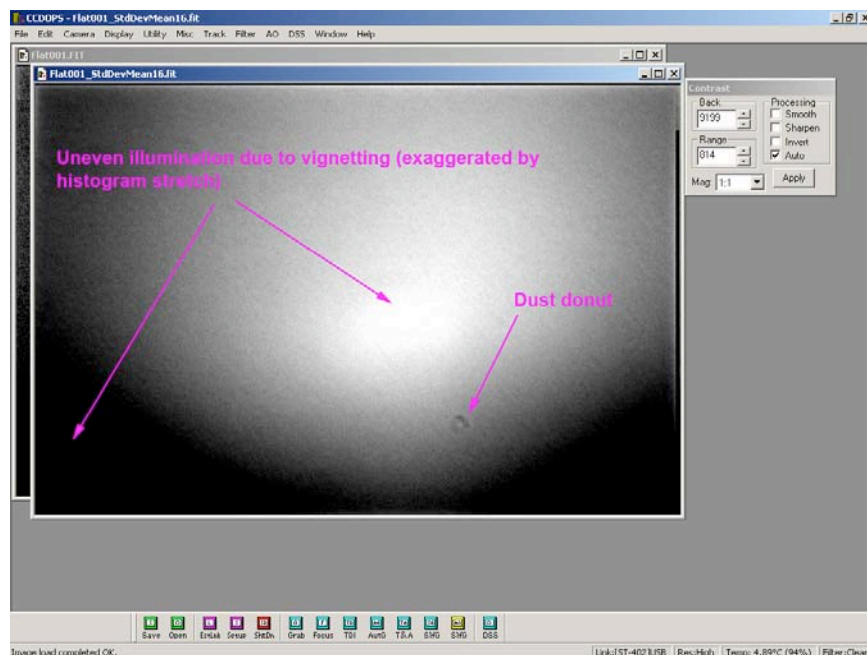
<http://home.att.net/~lee.suk/root/diy/lightbox/root.html>

When taking flat fields, you have to make sure you get enough signal to get a decent signal-to-noise ratio, but not so much that you're going to overdrive the CCD into non-linearity. SBIG cameras use 16-bit A to D converters, so the maximum signal count is 64k. I generally shoot to get a maximum signal of about 10k. With this camera, telescope setup, and lightbox this ended up being an exposure of 0.9 seconds.

I took 16 shots, using “AutoGrab” and setting the filename to “Flat”. Here’s 1 raw frame:



And here’s the Master Flat averaged in “Sigma”. Note the overall smoothness of the flat, the vignetting, and the “dust donut”. The vignetting and dust donut are embedded in the raw images, the overall calibration process will remove them from the final image.

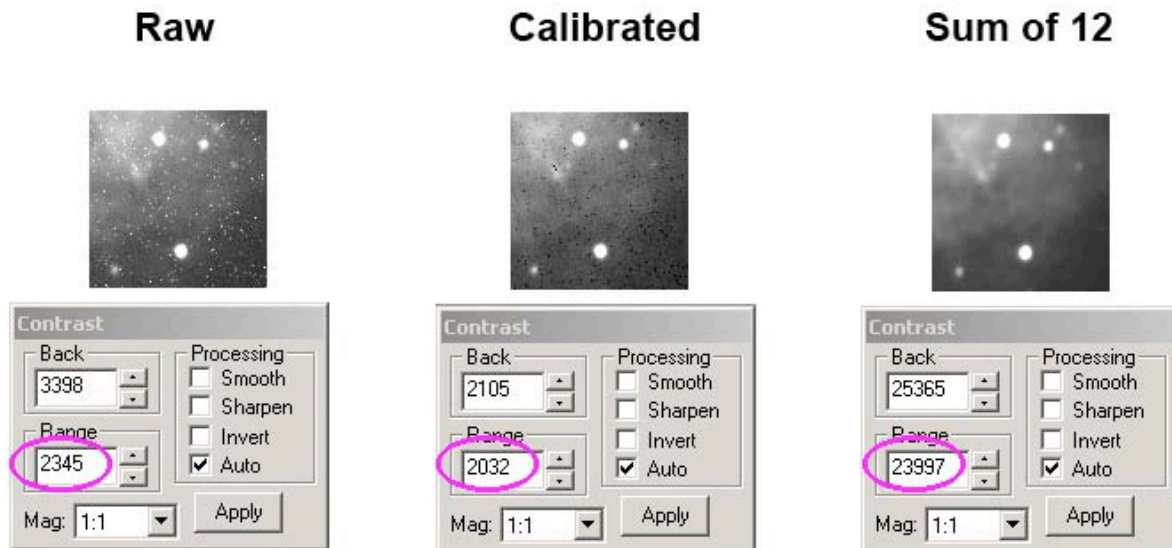


We now have Master Bias, Master Dark, and Master Flat frames for calibration of the raw images. Unfortunately, CCDOPS, while having the ability to capture all these images, does not have the full image processing functionality to do a complete image

calibration. For that I used CCDSoft, from Software Bisque (www.bisque.com). Other packages that are capable of image calibration are Maxim DL, AstroArt, etc.

I won't go into the calibration process itself because the steps are specific to whatever software package you end up using, although the actual mathematical process is the same regardless of which package is used.

Here's a comparison of the raw, calibrated, and stacked images:



The calibrated image shows that the “sparkles” from the raw image have been removed, but now some dark pixels have been left behind as a result. Note that also the dynamic range is mainly unchanged (it has changed slightly as a result of the flat fielding). On the right you can see the final summed calibrated image. The dark pixels have been eliminated in the stacking process with “Sigma” and you can see that the dynamic range is far greater, leading to a high signal to noise ratio and a smooth image, ready for further processing.

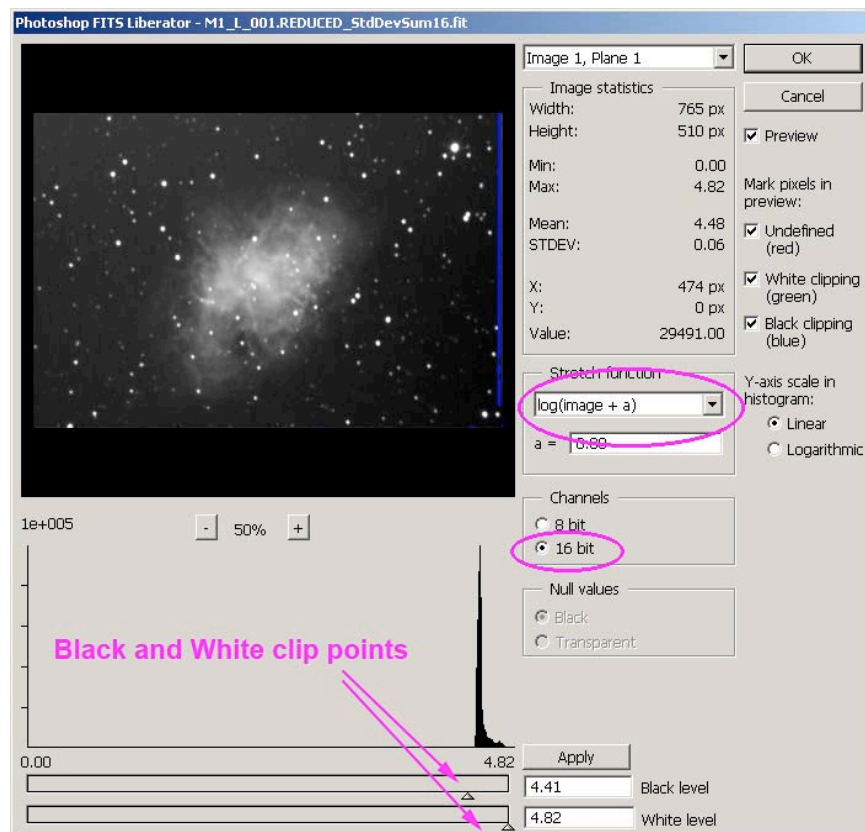
Image processing is an entire subject and art in itself, I'll show some basic steps to getting a final image of M1.

The first step is to import into Photoshop or another image processing package for final processing. I use Photoshop CS because of long personal familiarity with the package - it's a very powerful program that's the standard of the graphics industry, but the learning curve is steep and it's expensive. However, one of the best books on image processing, “Photoshop for Astrophotographers” (<http://www.astropix.com/INDEX.HTM>) is based on Photoshop, so I consider it a good investment.

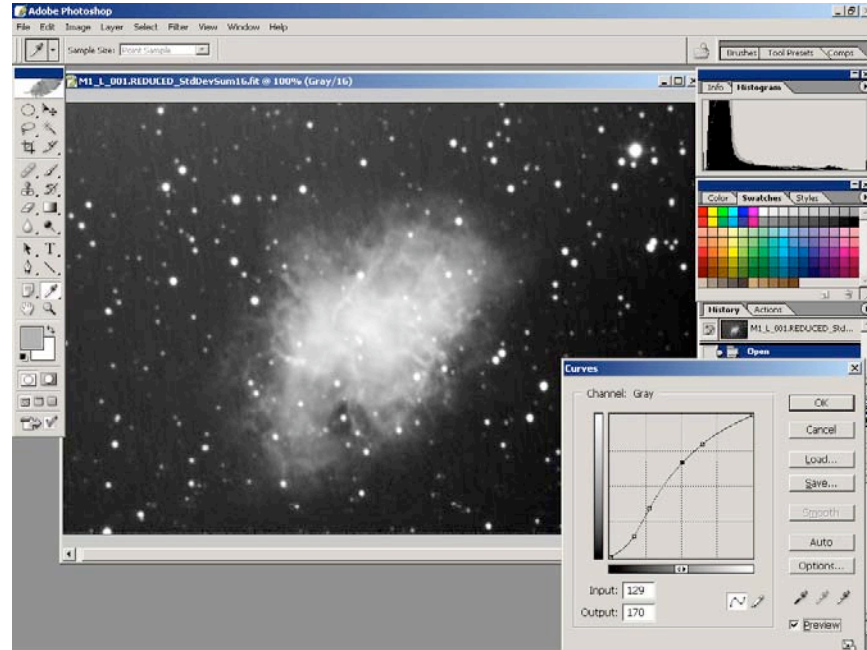
Photoshop itself can't read the FITS format directly, to import into Photoshop, there's a very good import filter provided by NASA which allows you to do some powerful preliminary histogram manipulations right as you import the FITS data:

http://www.spacetelescope.org/projects/fits_liberator/

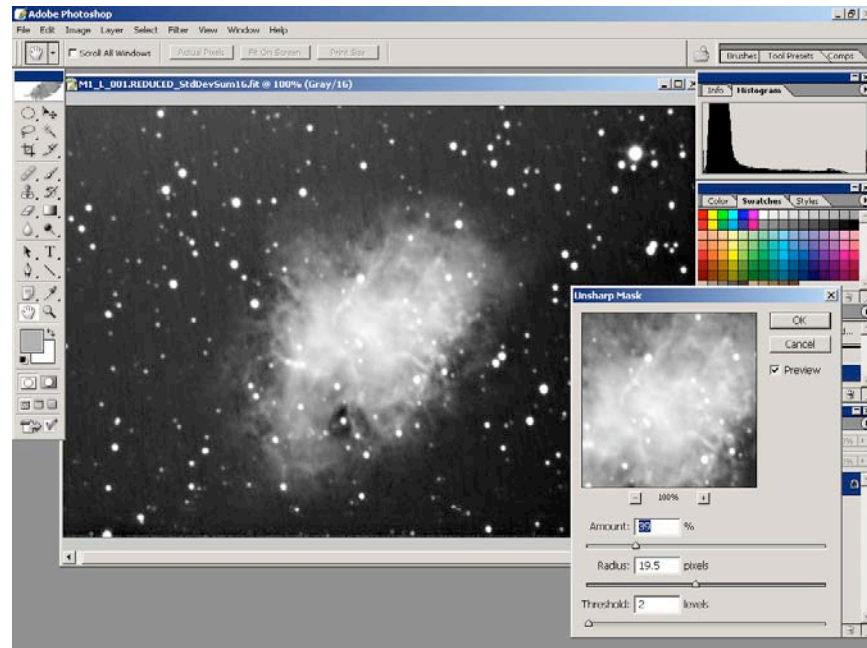
Here's the image of M1 being imported into Photoshop. I'm using the "log" histogram stretch and set the black and white clip points to import all the data and not clip anything – I want to retain as much of the picture information as possible. One of the nice features of Photoshop CS, compared to earlier versions, is the ability to manipulate 16-bit data, so make sure you have the 16-bit option set as below:



Upon import into Photoshop, I “curved” the image to bring up some mid-tone detail:



Finally, a mild Unsharp Mask with a large radius brings out some of the large scale detail in M1 without making the star edges look excessively sharp and unnatural:



And the final result:



Here's a comparable photo taken with a Meade DSI on the same telescope setup, with a stronger reducer (0.375x):



For about the same amount of exposure (actually, significantly less given that the SBIG shot M1 at about f8 versus the DSI shooting M1 at about f5), the SBIG goes deeper, because of the lack of obscuring noise courtesy of the active cooling. There's also greater detail in the nebula itself. In absolute terms the SBIG clearly gives the better image, but considering the DSI's price of \$299, the DSI is clearly a terrific bargain.

Performance of the ST402 is comparable to the SBIG ST2000 (not shown), the chief difference being overall field-of-view due to the much bigger chip in the ST2000.

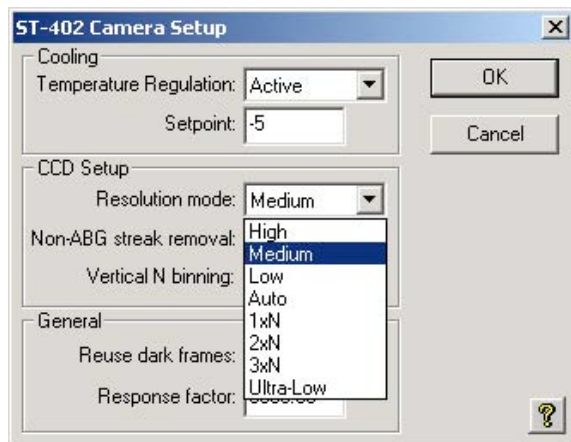
Second Astro Light – Adding RGB to “L”

There are various ways to shoot color images. Standard tri-color imaging takes exposures through red, green, and blue filters and combines them to create an RGB image. One of the disadvantages of the standard RGB method is that the filters reduce the amount of light reaching the sensor, so exposure times have to be increased dramatically over an unfiltered greyscale image to get an equivalently low signal to noise ratio. For example, a total of 1 hour of exposure was taken to get a smooth image of M1 above. To get an equivalently low signal to noise ratio in RGB would have taken approximately 9 hours of exposure. The reason is that each R, G, B filter transmits approximately a third of the available light, so each channel needs to be shot for 3 hours to get the same amount of signal. Then there are three channels each, for a total of 9 hours. That's at least 2 nights of shooting, probably more like 3.

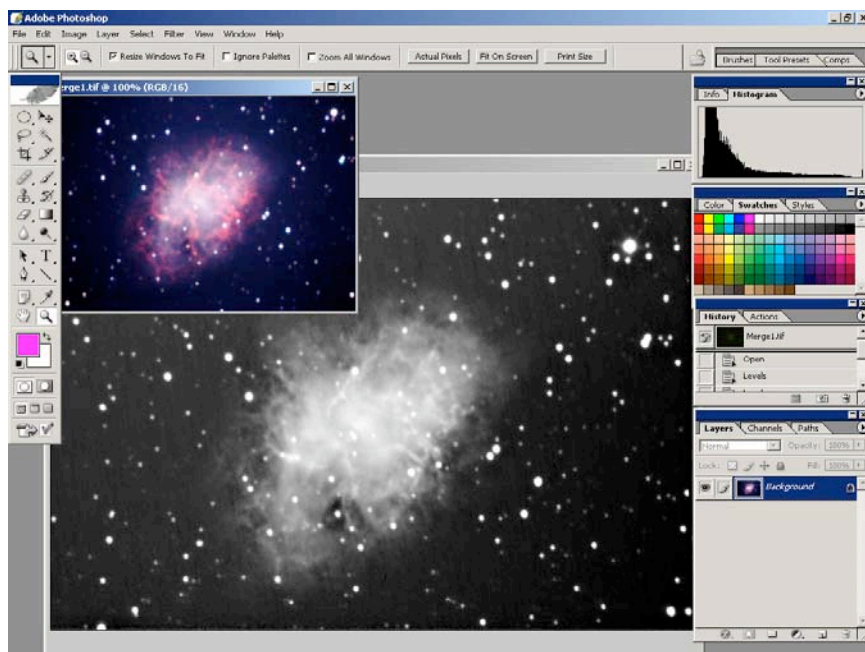
An alternate method, LRGB, takes advantage of a peculiarity of the human visual system to dramatically reduce the amount of time needed to create a color picture.

In the LRGB method, a very high quality “L”, luminance, picture is taken. Then a lower resolution, lower signal to noise ratio set of R, G, and B pictures, chrominance, are taken. The reason that the R, G, and B channels can be lower resolution is that the human visual system is very sensitive to brightness variations, but relatively insensitive to variations in color. So, instead of shooting 9 hours of pure RGB, we can take the 1 hour of “L” already captured, and then add about 20 minutes each of R, G, and B, shot at lower resolution. The lower resolution, called binning, combines the light from several pixels into one. The result is lower resolution, but higher sensitivity.

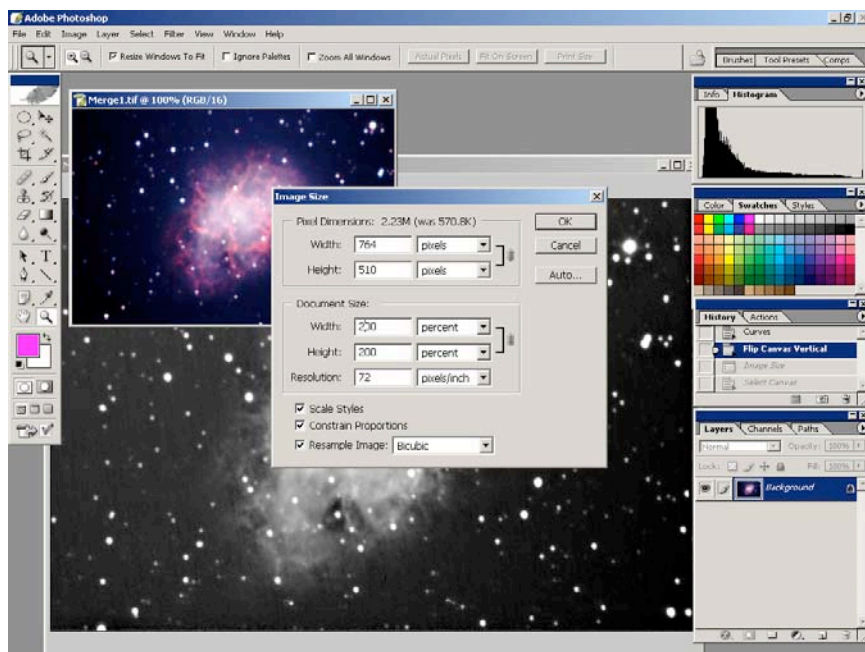
To change the resolution mode to 2x2 binning, go back to “Setup” in CCDOPS and select “medium” resolution mode:



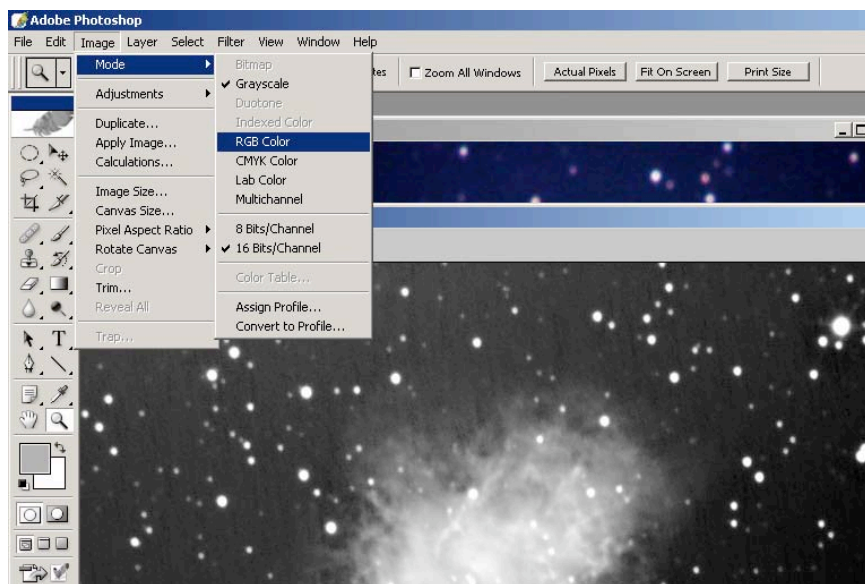
Using the “ColorGrab” option in the “Grab” menu, I collected 4 x 5minutes of exposure for each of R, G, and B. These were processed and merged together in CCDSoft to create the initial low-resolution RGB image. Initial color balancing and curving in Photoshop gave this result (RGB is shown at the same scale as the L image):



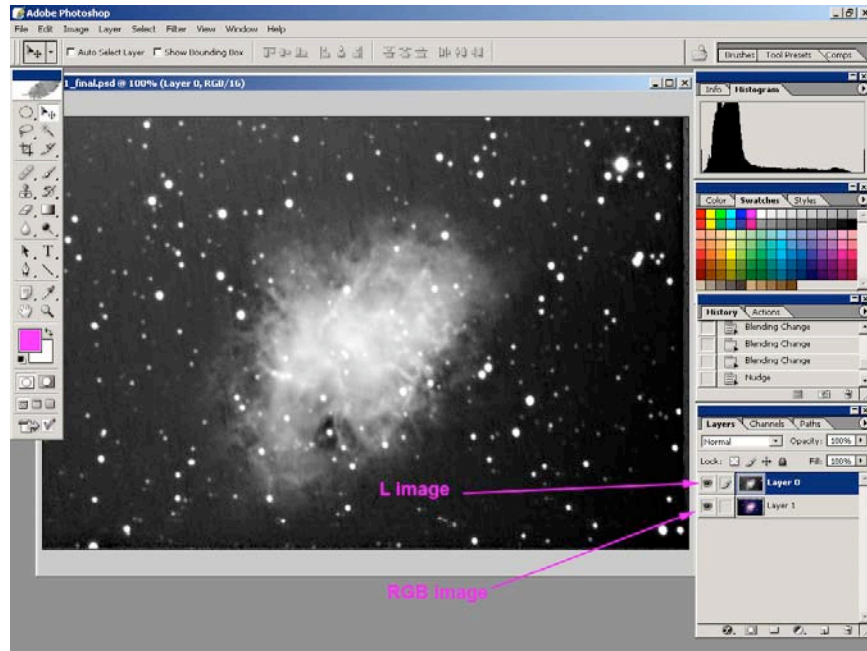
You can clearly see that the RGB image is half the size of the L image. The next step to creating the LRGB composite is to double the size of the RGB image:



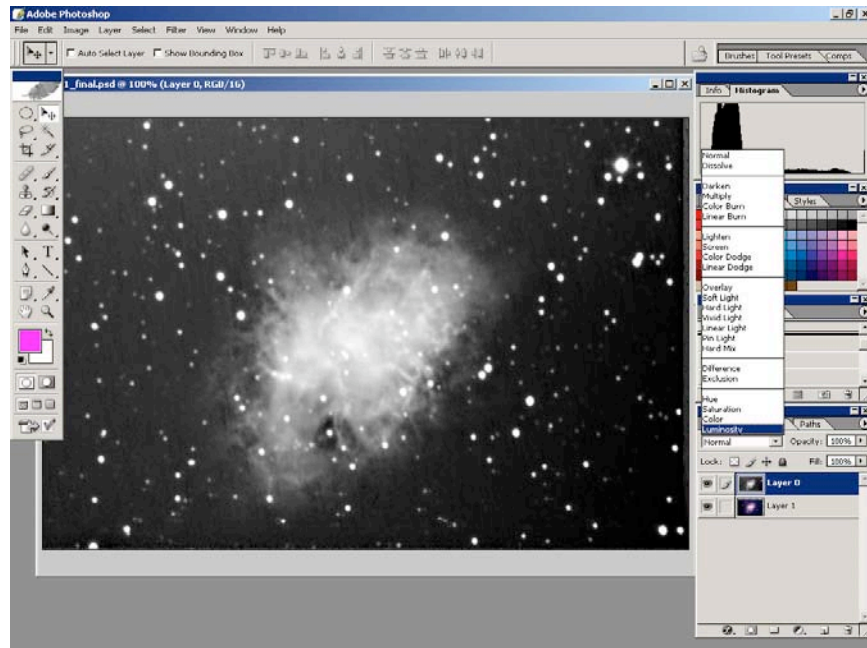
The RGB image is a 16-bit “RGB” file. The L image is a 16-bit greyscale, it has to be now converted to an “RGB” file also. Select the L image and change it to “RGB”:



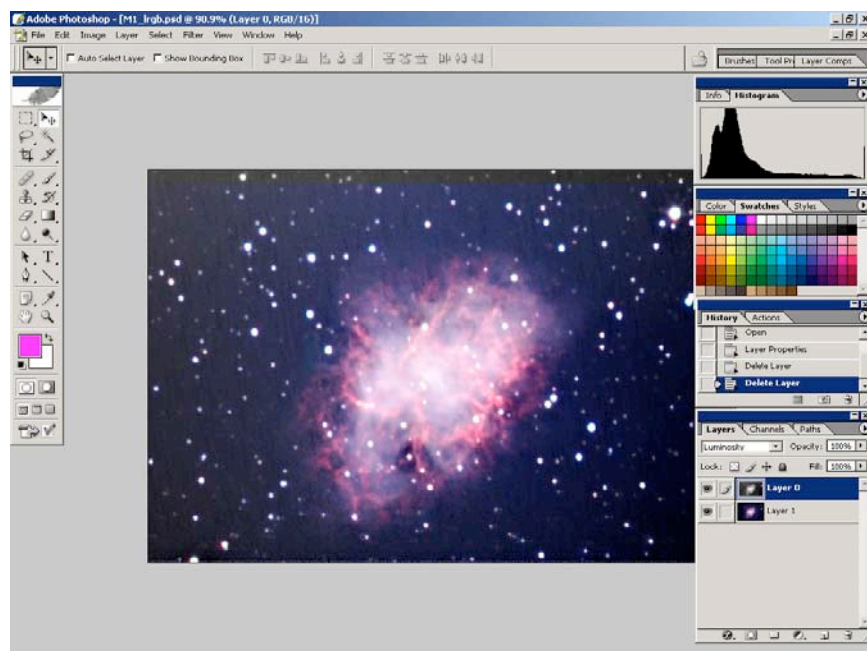
Go back to the RGB image, “Select All” and paste it into the L image. Rearrange the layers so that the L image is on top of the RGB image:



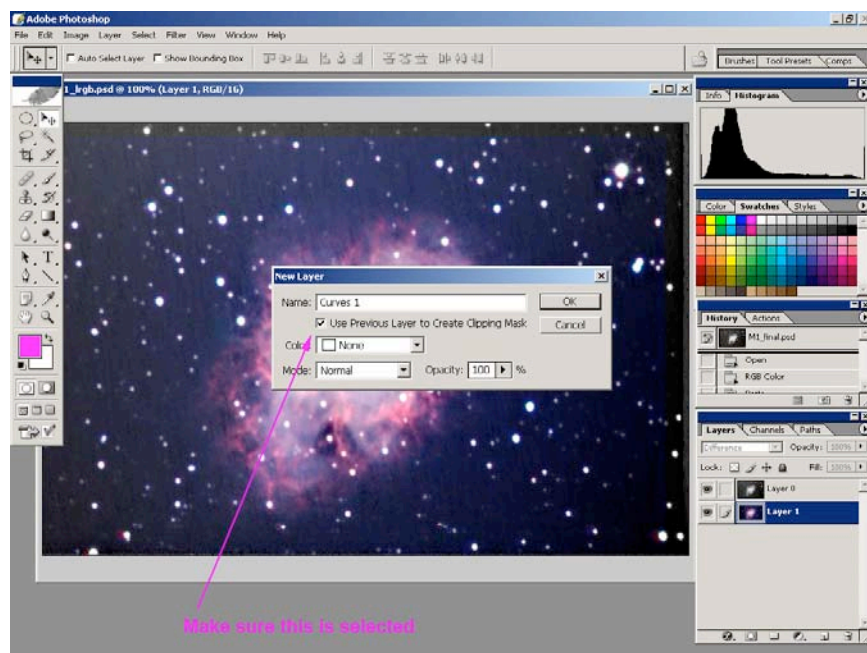
Switch the mode on the top layer from “Normal” to “Luminance”:



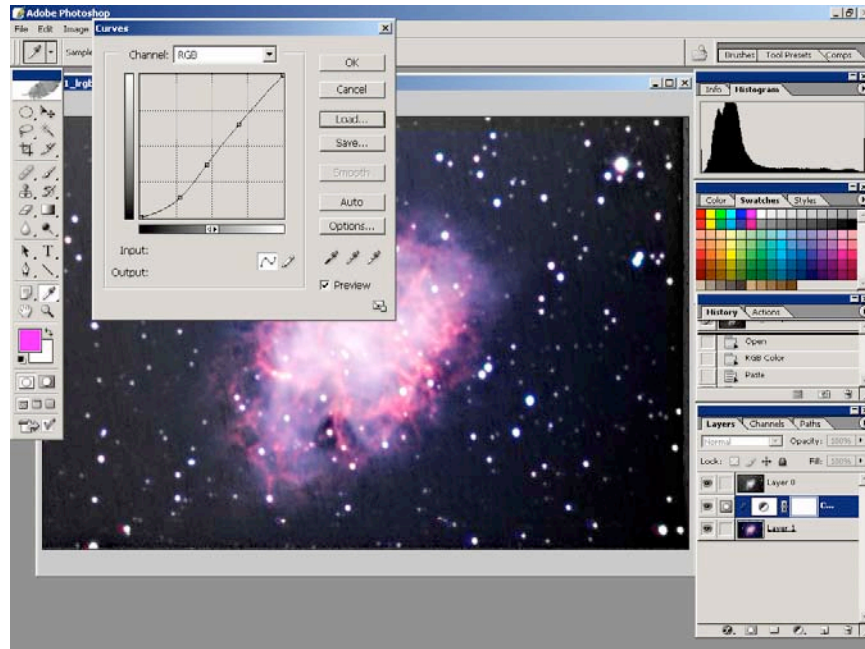
The result is an LRGB composite:



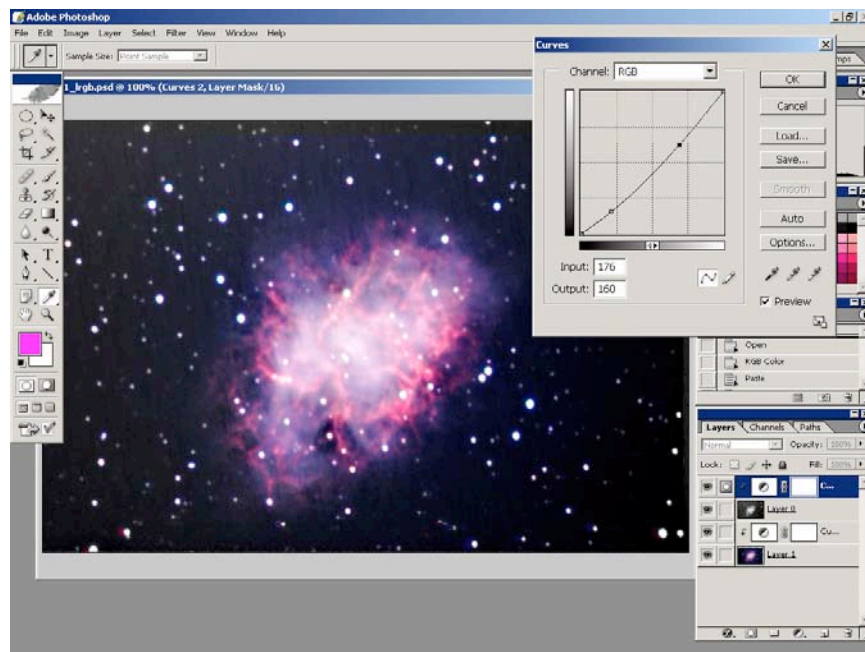
Often, as in this case, adding the color makes background noise in the L layer visible, and also the color balance in the RGB layer may result in an overly saturated looking picture. One of the features of the LRGB compositing method is the ability to control the characteristics of the L and RGB layers separately, through individual curves. I usually start by adjusting the RGB layer, reducing overall brightness to bring down the saturation in the composite. Add a “Curves” adjustment layer operating on just the RGB layer:



Curve the RGB layer to bring down the overall brightness and in particular to bring down the dark areas which are mainly noise:



The color cast in the background is now gone, but the overall brightness is excessive. This is handled by adjusting the brightness of the L layer. Select the L layer and add another "Curves" adjustment layer and adjust to taste:



Here's the final result:



It's a LOT more work than with the DSI, but the results are significantly better.

ST402 as an autoguider

Unlike the other cameras in the SBIG line, the ST402 is not a "self-guiding" camera i.e. it has only one CCD. However it does have the relays built into it to control a mount, so it can be used as either a camera, or an autoguider, but not both at the same time.

To autoguide, the camera is connected via "standard ST-4" port to the mount. Losmandy, Astrophysics, Software Bisque mounts (and others) all support this port and will direct connect to the camera. Aside from the hardware support (relays), most of the smarts of autoguiding are in the software package that is used to drive the ST402 – a PC must be connected. For the review I used CCDOPS, but commercial third party programs such as CCDSoft or Maxim DL/CCD will drive the ST402 as well (and, frankly, more easily than CCDOPS).

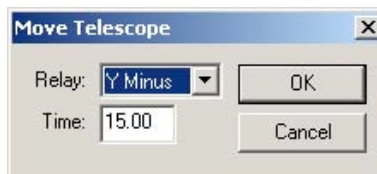
Autoguiding consists of the following steps:

- find a guide star
- calibrate the mount i.e. have the camera/software figure out the scale of "how many seconds of driving the mount results in how many pixels of image movement, and in what direction"
- start tracking and fine-tune autoguiding behavior

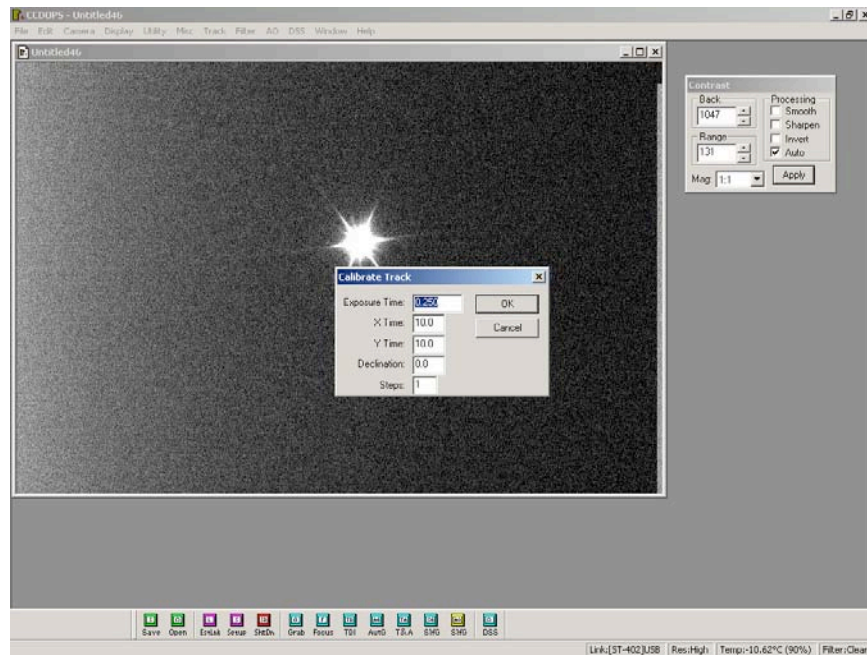
Autoguiding is quite an art – although in theory the electro-mechanical feedback system that consists of the star, the atmosphere, the telescope, and the mount is a closed loop system, it's full of non-linearities which means you have to develop a “feel” for your system based on your specific setup.

In general, I like to guide my mount every 5 seconds: too much longer and the mount will wander off the star at long focal lengths; too much shorter and you're chasing seeing. With a 5 second exposure, the ST402 can go quite deep, so you'll always have a wide selection of guide stars to choose from.

To calibrate the mount for the first time, get a bright star isolated on the screen. CCDOPS gives you the ability to control the mount by specifying which relay to activate, and how long to activate it at:



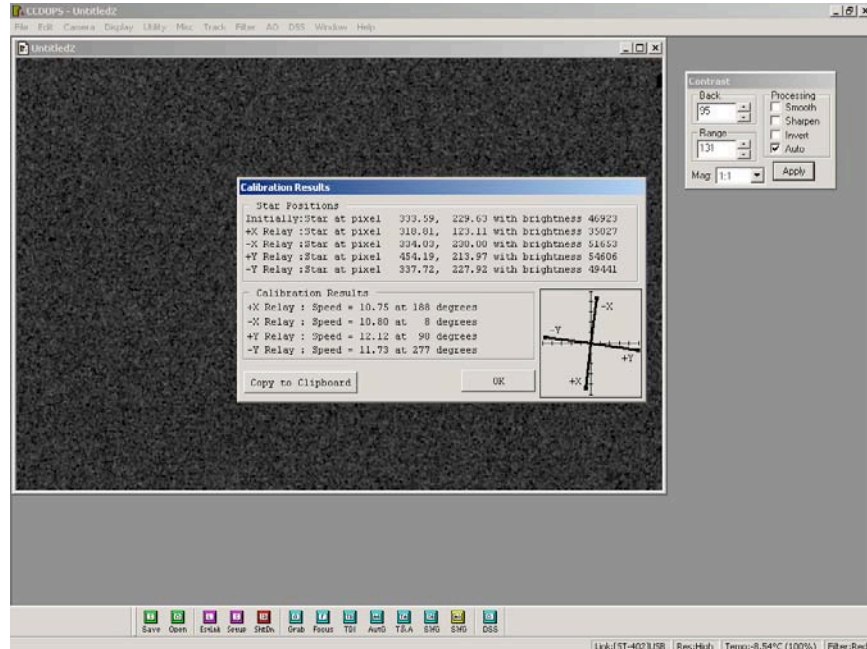
With CCDOPS it's best to have one star much brighter than any other in the field so that it doesn't get confused during the calibration process. To start calibration, select Track -> Calibrate...



In the dialog you specify the exposure time, and the number of seconds to move the mount in each direction. The software will then take a reference photo, measure the location of the star, move the mount and re-measure for each direction. The length of

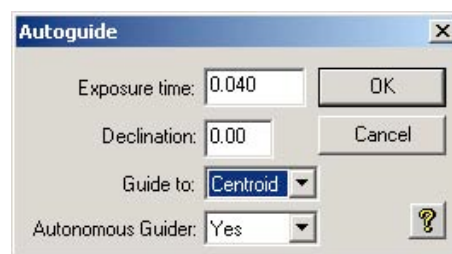
time to move the mount depends on the image scale, which is a function of the focal length. To determine how long to move the mount, check the help file in CCDOPS.

If everything goes well, you will get the following:

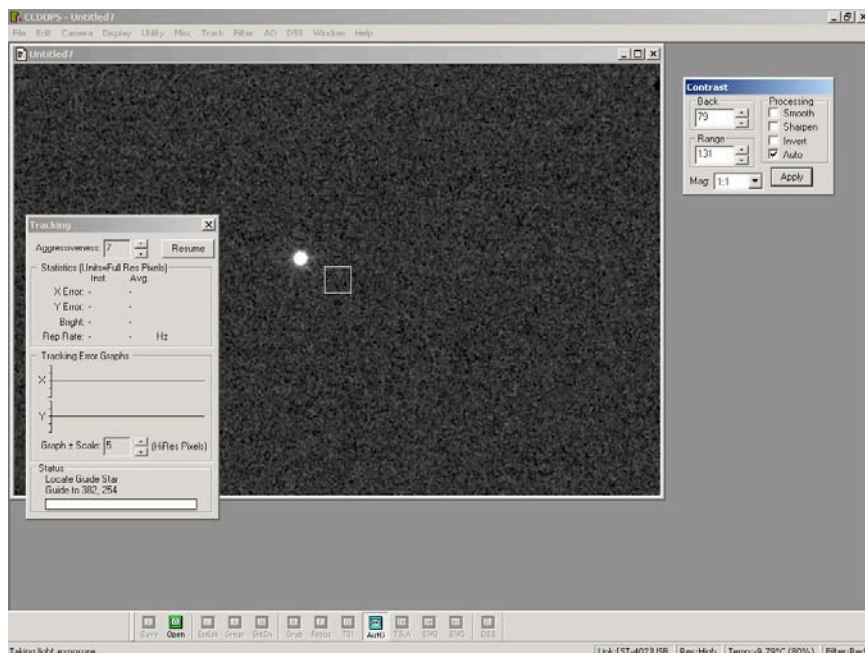


The dialog shows where the star initially was and where it ended up after each move and the orientation of movement with respect to the axes of the camera.

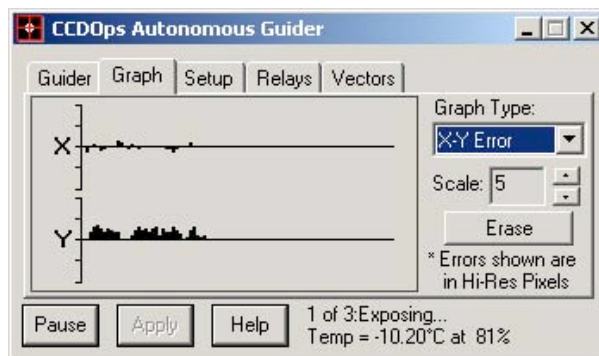
Once calibration has successfully passed, autoguiding is started by selecting Track -> Autoguide...



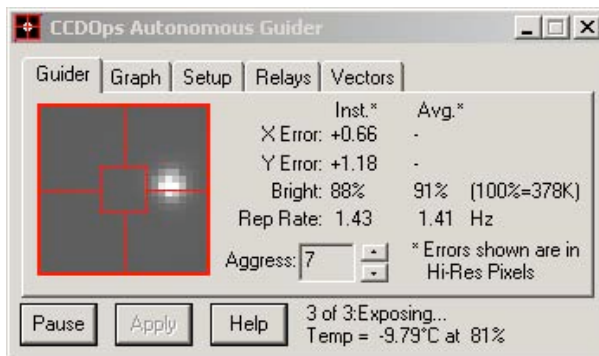
Set up the exposure time to make sure the guide star is not saturated, that you're guiding to the centroid of the star image, and enable the autonomous autoguider mode. The following dialog box will show up and you will get a cursor to identify your guide star:



Click on the guidestar you want and hit “Resume” and the standalone guider will start guiding:



Clicking on the “Guider” tab allows you to watch the star/mount interactions, which is very helpful in initial debugging of your autoguide setup. Here you can see that the star has moved off center and the autoguider is moving the star back...



Summary

Pros

- “Pro” level photographic capabilities
- Very complete product package – comes with everything you need
- High quality physical packaging
- Small CCD size lends itself to good DSO imaging scale with short refractors
- Optional built-in RGB filter wheel is very convenient
- Without the RGB filter wheel, makes for a relatively inexpensive autoguider
- CCD generates less shot noise than other CCD cameras, making post-processing easier
- Good price/performance ratio

Cons

- Not a self-guiding camera and so relatively narrow application range
- Autoguiding requires an attached computer
- Small CCD size leads to high magnifications with typical SCT focal lengths – need to use a 0.63x reducer
- CCDOPS software not as full-featured or convenient as CCDSoft or Maxim DL/CCD – buyer should be prepared to buy that additional software

Several years ago, a camera like the ST-402 would be a slam dunk decision. Since then, new technology has appeared on the market that makes the decision more complex.

DSLRs, particularly ones “modded” to remove the IR filter can approach the capabilities of the ST-402, except for the dimmest objects, at the same price point or lower, with a much wider field of view due to the significantly larger sensor. The advantage the ST-402 has over a DSLR is the ability to go almost arbitrarily deep due to the actively cooled and temperature regulated sensor.

Webcams and freeware such as Registax 2 enable very high resolution planetary imaging (not specifically reviewed here) at a 10x lower price point.

The new Meade DSI gives *somewhat* comparable images to the ST-402. The advantage of the ST-402 here is that it’s a great beginning camera to learn the image acquisition and processing techniques that would be used with larger and more expensive CCD cameras. The ST-402 can be seen as a low price point entry to the SBIG family of cameras.

The bottom line is that the ST-402 is a highly capable camera, whether you decide on it is probably a function of whether you see this as your last camera, or the beginning of your astrophotography journey.

Happy Imaging!