Introduction

Welcome to *Nebulosity*. *Nebulosity* is designed to be a powerful, but simple to use capture (Artemis/Atik16, Canon DSLR (DIGIC II), CCD Labs Q8, Fishcamp, Meade DSI, Orion StarShoot, SAC10, SAC7/long-exposure webcam, SBIG, or Starlight Xpress SXV) and processing (just about anything) application for your CCD camera. Its goal is to suit people ranging from the novice imager who wants to create his or her first images and the advanced imager who wants a convenient, flexible capture application for use in the field. As such, an emphasis has been placed on easy access to commonly-used camera controls, as nobody wants to navigate through many menus in order to simply capture a series of images.

An emphasis has also been placed on compatibility with other applications. For more advanced imagers who already use more sophisticated astronomical image manipulation software (e.g., *AstroArt*, *ImagesPlus*, *Iris*, or *Maxim DL*, to name but a few), *Nebulosity* might serve as a suitable capture application and provide a few processing tools. *Nebulosity* supports a wide range of output formats under the FITS standard, so that your images can be easily imported into whatever software you use. Finally, a targeted emphasis has been placed on image processing. For many imagers, the tools provided here will be well-suited to produce images that are ready to be touched up in a graphics editing package (e.g. *Adobe Photoshop* or the freeware application GNU's *GIMP*). The tools provided are the tools most of us want and need to make great images.

What *Nebulosity* is not designed to do is to be an all-inclusive, general-purpose, full-powered astronomical imaging and analysis package. There are several of these on the market already and all are excellent packages. All are very large, place more substantial demands on your computer, and, by virtue of being large and all-inclusive, do not typically present a simple, clean, interface for basic image capture control. The author of *Nebulosity* routinely stands in cold, dark fields with a laptop and a camera taking pictures. Under these situations, when gloves must be removed to operate the computer, simple, dedicated user interfaces are exceptionally welcome.

That said, the author is also a stickler for power and accuracy. You get quite a few "serious" tools in *Nebulosity*. The ones you get are purpose-built — tools that you will want for processing raw DSO images into beautiful pictures.

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Features

- Simple, but powerful interface

    1. All basic controls are present on the main screen. No need to navigate through lots of menus during an imaging session. *Nebulosity* was designed to be easily operated in the field by someone who actually operates it in an actual field.
    2. By default, all displays are auto-scaled. Any scaling (including inverted) of the data onto the display possible using easy sliders.
    3. Histogram gives a quick view of how much of the valid data range is being used during each capture.
    4. Pixel statistics / area statistics pop-up window
    5. Zoom button lets you rescale the displayed image quickly.
    6. Versitile *Image Preview / Rename* tool to quickly sift through large sets of images.
    7. Measure Distance tool lets you measure the distance (CCD pixels, arc-seconds, or arc-minutes) among up to 3 points.
    8. Can act as a FITS, PNG, BMP, JPG, or TIFF file viewer for Windows (double-click or drag/drop).
    9. Can write / run scripts to automate captures (interactive and unattended)
    10. Unlimited undo/redo (0, 3, or unlimited levels of undo).
    11. Small clock to show local time, UTC, GMST, local sidereal, Polaris RA, or current CCD temperature

- Capture control

    1. All basic capture parameters present on main screen. Duration of exposure, number of exposures per captured series, delay between captures, name of series, camera gain and camera offset all in one simple panel.
    2. Times may be specified in either seconds or milliseconds
    3. Quick *Preview* button captures one frame with current settings and displays it on the screen without saving. Helps in focus, composition, and tuning of capture parameters.
    4. *Frame and Focus* mode: Loops a quick, binned image to assist in rapid initial focus and framing.
    5. *Fine Focus* mode: Loops a very quick image around a selected star in full resolution and provides running statistics (and linegraphs of the history of the statistics) to assit in fine-tuning focus.

6. Capture one-shot color in RAW CCD format or reconstruct color on the fly — your choice.
7. Automatic setting of camera offset
8. Capture status able to be shown in large red display for easy viewing when away from computer.

- Multiple file formats supported
    1. Read virtually any FITS file to process images from virtually any camera (RGB color, black and white, compressed or uncompressed, any bit depth)
    2. Process data from FITS, PNG, TIFF, BMP, or JPEG.
    3. Captured data saved in FITS as 16-bits (0-65,535) per color channel, 32-bit floating point, or in 15-bits (0-32767) per color channel.
    4. One-shot color data captures may be saved in RAW CCD format or as reconstructed full-color images in an RGB FITS format (Maxim / AstroArt style or ImagesPlus style) or 3 separate FITS files (the latter only for capture and subsequent use in other programs).
    5. Captured data saved in either lossless compressed FITS according to the FITS standard or uncompressed FITS
    6. These same save formats available for any loaded image, making *Nebulosity* serve to convert between many FITS formats (just select your output format using the settings on the Preferences menu).
    7. Save current displayed image in BMP or JPG format (24-bit color) *as displayed*
    8. Save current image in 16 bit/color (48-bit color) uncompressed TIFF, compressed TIFF, or PNG (compressed) format
    9. Load 8/24 bit PNG, TIFF, JPG, and BMP (scaled to 16/48-bit) or 16/48-bit PNG and TIFF.
    10. Load Canon CR2 format RAW (Rebel XT, 20, 20Da, 5D, etc) and Canon CRW format as pure Bayer-matrix RAW data.
    11. Batch convert from FITS to 16/48-bit PNG or compressed TIFF
    12. Batch convert from CR2, CRW, PNG, TIFF, JPG, and BMP to FITS
- Camera support (capture - Windows-only unless noted)
    1. Atik 16/16IC/16HR series / Artemis 429/285 cameras
    2. Canon DIGIC II DSLRs (Windows and OS X): EOS 1D/1Ds Mk II/Mk IIN, 1Ds Mk II, 20D/20Da, 350D / Rebel XT, 5D, 30D, 400D / Rebel XTi). Captures are to FITS files with pure Bayer-matrix data extracted on the fly (or ultra-fast color JPEGs - your choice). Bulb-mode exposures via ShoeString DSUSB adapter, serial port adapters, or parallel port

adapters.

3. CCD Labs Q8-HR (Windows)
4. Fishcamp Starfish (Windows and OS X)
5. Meade DSI, DSI Pro, DSI II, and DSI II Pro (Windows and OS X).
6. Opticstar DS-335 and DS-335 ICE
7. Orion StarShoot Deep-Space Color Imager
8. SAC10
9. SAC7 / SC1 long-exposure modified webcams / Atik 1&2 – all via the either a parallel port or via the ShoeString LXUSB adapter for all-USB (no parallel port) long-exposure imaging.
10. SBIG (Windows and OS X)
11. Starlight Xpress SXV / SXVF USB cameras (Windows and OS X)
12. Simulated camera (Windows and OS X)
13. **Virtually any camera's images can be processed in *Nebulosity***.

- Internal calculations

1. All data stored internally in 32-bit floating point *per color channel*. For B&W or RAW images, this equates to 32-bits and for color images, this equates to 96-bits in all math routines. You will never have overflow (saturation) or overflow or quantization issues as a result.
2. Critical math routines computed in double-precision (64-bit per channel) floating point.
3. Since all captures even from one-shot color cameras can be done in B&W mode (RAW CCD data) and since memory for color images is only allocated when viewing in color, memory requirements can be reduced by capturing one-shot color data in RAW format for machines with less RAM.
4. All calculations done using pointer arithmetic for high-speed operation.

- Image processing

1. Dark / flat / and bias frame pre-processing of B&W, RAW one-shot color, and RGB one-shot color sets of images.
2. Auto-scaling of dark frames to compensate for differences in exposure time or temperature.
3. Create and apply *Bad Pixel Maps* as an alternative way of removing hot pixels.
4. Versatile *Levels / Power Stretch* tool lets you apply not only simple linear stretching of your images, but non-linear stretches as well. Pre- and post- stretch histograms interactively

displayed.

5. *Digital Development Processing* (DDP). A technique to make CCD images look more like film images by using a hyperbolic scaling of the data. Here, the basic technique is enhanced to allow easy darkening of the background at the same time.

6. *Star Tightening*. A technique to sharpen stars using an edge-detection algorithm (does not leave the artifacts found in "unsharp mask" techniques).

7. Traditional and Laplacian image sharpening

8. Grade a series of images to determine the sharpest / best of the set

9. Versitile *Image Preview / Rename* tool to quickly sift through large sets of images.

10. Align a series of images using simple translation (for equatorially mounted telescopes).

11. Align a series of images using sub-pixel level accuracy and translation + rotation and (optional) scaling (equatorial or alt-az telescopes)

12. *Drizzle* alignment and resolution enhancement for either equatorial (translation only) or alt-az (translation + rotation).

13. *Colors in Motion*: Simultaneous over-sampling alignment and De-Bayer of one-shot color images to significantly decrease color error and increase resolution. For one-shot color imagers, this improves resolution and reduces color error.

14. Average a series of images without alignment (e.g., for combining darks, flats, bias frames, etc.)

15. Standard-deviation based stacking of aligned frames to reduce noise in final stack.

16. LRGB color synthesis (RGB, traditional LRGB, and color-ratio LRGB)

17. *Line filter reconstruction for one-shot cameras*. Optimized reconstruction of RAW images taken using line filters. General mode plus modes optimized for H-alpha and O-III/H-beta on CMYG arrays

18. Adaptive scaling of combined data (stacks) to use full 16-bit range (gives you the best features of adding and averaging frames).

19. Image normalization to balance intensity across images.

20. Tools to set the minimum of an image to zero (useful if a computation has taken it above 65,535 and you wish to save the image) and to rescale the intensity of an image (multiply each pixel by a constant).

21. Color balance adjust (offset and scaling) with real-time 3-color histograms for easy, accurate balancing. Luminance extraction provided as well.

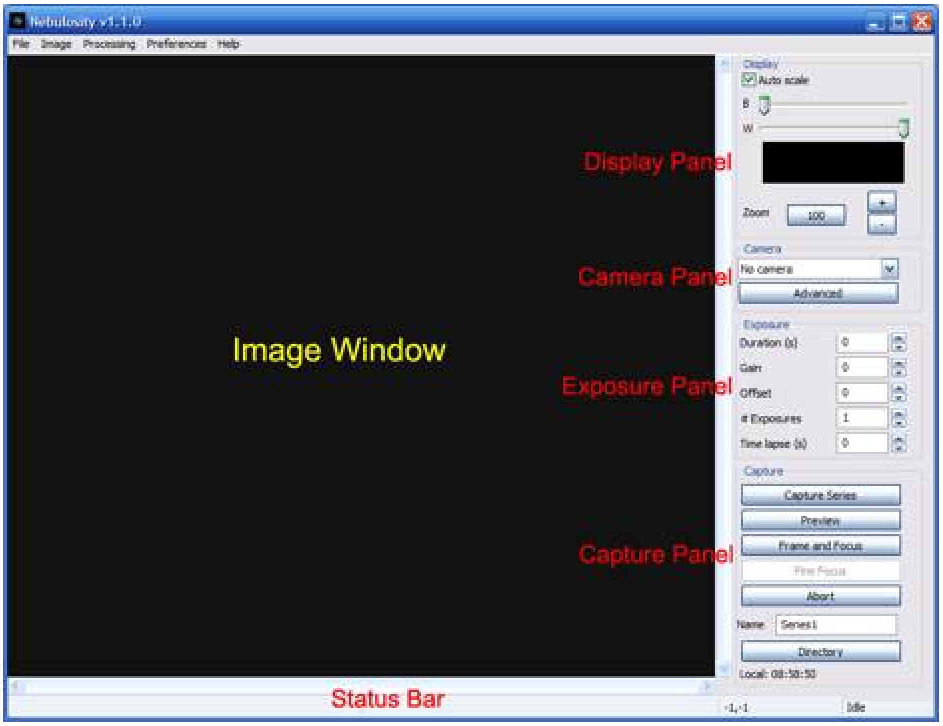
22. De-mosaic a RAW one-shot color image using a very high quality debayer routine (VNG).

Both interactive and batch-mode supported. Pixels become square in the process if native pixels were not square.

23. White blance on Canon DSLR settings for both stock and extended-IR cameras
24. Square pixels for images from B&W cameras.
25. 2x2 binning of images: addition, averaging, adaptive, and low-noise 2x2 for one-shot color sensors.
26. Blurring of images (3 levels)
27. Vertical smoothing / deinterlacing
28. Rotation / mirror imaging of images
29. Resampling / resizing of images using a choice of 6 algorithms: Box, Bilinear, B-Spline, Bicubic (Mitchell & Netravali), Catmull-Rom spline, & Lanczos sinc
30. Crop tool

Main Screen

When you open *Nebulosity*,you are presented with a screen that looks like this:



It has 5 main sections:

- Image Window
- Display Panel
- Exposure Panel
- Capture Panel
- Status Bar

Image Window

The image window is where your images will be displayed. Itstarts off at a default size (optimized for 1024x768 displays), but is easilyresized by simply resizing or maximizing *Nebulosity* itself. If an image is too big to fit into thewindow, the scrollbars will allow you to navigate around the image. Alternatively,the Zoom button, located in the Display panel, will resize the image to helpmake it fit your screen.

Display Panel

Here, you have several controls that affect how the image isdisplayed in the Image Window. Keep in mind that your data are often in 16-bit(or 48-bit aka 16-bit/color) format. That means that you can have 65,536shades of grey in the image. But, your monitor can most likely only displayabout 256 shades of grey (24-bit color). Thus, the data need to be scaled todisplay well on your screen. That's the purpose of the first three controlshere.

These are the **B** and **W** sliders, and the **Auto scale** checkbox. The B and W sliders set the level inyour data to assign to black and white respectively. Slide the B slider to theright and your image gets darker. You've told *Nebulosity* that ahigher image intensity equals black, meaning more of your data should be dark. Slide it to the left and the image gets brighter. Likewise, slide the W sliderleft and the image gets brighter as more of your data should be white. Putthem closer and you have a higher contrast image. Put them further apart andyou have a lower contrast image. Flip sides (white below black) and you'llinvert the image. If you don't want to mess with any of this or if the imagegets way out of whack, select **Auto scale**(it's set by default). The Auto scale checkbox tries to set the B and Wsliders automatically by using data from the **Histogram.**

Keep in mind that these tools only affect the way the image is displayed. They do not affect the actual data. If you save the image, adjust the sliders or zoom control and save it again under a new name, you'll have two identical copies of the same data. (NOTE: There is one exception to this rule. The Save BMP As Displayed uses the values in the sliders to help get your data from 48-bits into 24-bits)"

Below the sliders is a **Histogram** display. When you first start *Nebulosity*it is black, but if you load an image or capture an image (use the CameraSimulator if you don't have one) you'll see a red display in this window. Thisbox intentionally lines up with the sliders, for the left of the boxcorresponds to intensities near zero in your image and the right corresponds tointensities near the maximum (65,535 for 16-bits) in your image. So, if yousee a small area of red on the left side of the histogram and you're not seeinganything on the screen, it means that you have a faint signal in the image. Slide the W slider to the left to come near that small area of red and you'llsee your faint image.

The Histogram is a very powerful tool in image capturing,for it tells you a lot about your image. Are all of the data far to the left? If so, your entire image is faint and you should increase your exposure or gainif possible (see below). Do you see a nice curve that trials off to the rightjust before you get to the edge of the Histogram? If so, you've got a niceexposure and are making the most of your data. Do you see that instead oftrailing off smoothly near the right edge, the curve ends abruptly at the rightedge? If so, you're saturating a lot of the pixels in your image and shouldlikely use a shorter exposure or less gain. Are you cutting of hard on theleft edge? If so, use more gain, more offset, or a greater exposure duration.

Finally, the panel has the **Zoom** button (marked "100%" by default). Repeated clickson the Zoom button will cycle through several zoom modes (25%, 33%, 50%, 100%,200%, & 400%) to get a better view of your image. Next to this, you'll see+ and – buttons that let you zoom in and out respectively. Note again,this only affects how you see your image, it does not change the underlying imageitself.

For a more detailed inspection of your image, try activatingthe **Pixel Stats** pop-up window (underthe *Image* menu).

Camera Panel

The Camera panel contains a pull-down to select your cameramodel. When you pull down your camera model, *Nebulosity* attempts to connect to the camera. Success offailure will be noted in the left-hand panel of the Status Bar.

If you're new to CCD imaging and don't have a camera yet orwant to explore some of *Nebulosity*without attaching your camera, a **Camera Simulator** is provided asone of the camera choices. The camera is always aimed at the same patch of sky(that happens to have 20 stars of different brightness) but the mount isn'tperfect, so you'll notice the stars move a bit from image to image. The camerahas noise, and responds to all the controls in the **Exposure Panel**,letting you get a feel for what to expect and how to use the program.

Here, you will also find an **Advanced** tab. *Nebulosity* picks default valuesof a number of camera options that are optimal for most DSO imaging. However,if you want to select any of these yourself, you can do so in the dialog boxthat appears when you click this button.

Exposure Panel

Here, you have controls for all basic exposure options.

- **Duration**: How long (in seconds) per image?
- **Gain**: How much CCD amplifier gain should be used during A/D conversion? (Think of gain as a volume knob for the signal coming off the CCD). Numbers range from 0-63.
- **Offset**: What offset should be added to the signal during A/D conversion? (The offset adds signal into every pixel to help you keep the pixels from having zero values anywhere). Numbers range from 0-255. (See Automatic Offset on p. 16)
- **# Exposures**: How many images do you want to take?
- **Time lapse**: How much time (seconds) should be inserted between each image?

Most of these are fairly self-explanatory, but Gain andOffset deserve a bit of attention. They get this in the Section TakingGood Images. For now, you can leave them at their defaultvalues.

Capture Panel

In this panel, you'll find the **Preview** button. This button takes a single image atwhatever Duration, Gain, and Offset you've specified and shows it on thescreen. It does not save the image. This lets you fine-tune the compositionof your image and hone in on correct focus of your telescope. It also lets youdetermine the optimal Duration, Gain, and Offset. (Use the handy **Frameand Focus** button for rough focus andcomposition).

There are three controls used in capturing a **Series**. A text entry box near the bottom lets you set thedefault **Name** for the series anda button lets you select the **Directory** the data will be saved in. Finally, at the top ofthe panel is the **Capture Series**button. This starts the sequence acquisition process. For example, if you'vesetup for 10 exposures of 20 seconds to be stored in MyDocuments\Nebulosity\August_20_2005 and called M51, *Nebulosity*will loop and take all 10 exposures. The first will be called M51_1.fit, thesecond M51_2.fit, etc. At the end of the capture, you'll hear the Windows *Ta-Da!* sound play. (To abort a sequence, press the **Abort**button).

The default directory is located in "My Documents" in a folder called "Nebulosity". If you use the default directory and it doesn't exist, Nebulosity will attempt to create it. If you forget to set the directory you actually want to use and capture a night's worth of data, this is where it is. If you use a different directory and pull down Save Preferences from the Preferences menu, the current directory will be saved as the default

Three things to note concerning series captures:

1. If you provide a name that already exists (e.g., you hit Capture Series again without changing the name), *Nebulosity* will create a new name to use in saving the series. Here, it would be M51-1_1.fit, M51-1_2.fit, etc. Hit it again and you'll get M51-2_1.fit, etc.

2. If you need to abort a series during the capture, press the Abort button in the Camera panel (or click the mouse inside the Image Window and press the ESCAPE key.)

3. The format the files are saved in is based on your choice in the *Preferences* menu.

Finally, you will also see three buttons: **Frame and Focus**, **Fine Focus**, and **Abort**. Frame andFocus is a useful tool for composition of images and for obtaining rough focus. Press this button and the camera will enter its most-sensitive, fastest modeand continually loop exposures. This gives something of a "live video" display, showing you an image as quickly as possible (it may still take severalseconds to update, depending on the camera). Adjust your focus, move yourtelescope, etc. until you have a reasonable image and then press **Abort** to cancel the automatic looping.

Note: The Abort button works in a number of places – during capturing, frame/focus, fine focus, alignment, etc. On several cameras (e.g., the SAC10) aborting can take several seconds to clear and reset the camera.

Tip: During Frame and Focus and Fine Focus, you can adjust a number of parameters on the fly. You can alter the exposure duration, gain and offset and you can also turn on and off Auto-Ranging and adjust your sliders. The effect of each won't be seen until the next image appears, though.

You'll likely now want to use the **Fine Focus** button to fine-tune your focus (not available onall cameras).

When you click on this button, you're asked to click on a star. This can be either from the last Preview or from the last exposure in the Frameand Focus routine. When you do so, the image will now continually display thearea centered on that star in full resolution. Use this to fine-tune yourfocus.

Focus can be achieved visually by looking for the sharpest image while adjusting your telescope's focus or by using the focus aids provided. Best focus will be achieved when the maximum intensity recorded from a star is highest and when the star appears sharpest. Next to the small window with the star, you'll see three numbers. One (M) indicates the maximum intensity recorded in the window around the star. As focus converges, this number will go up and peak. The second (m) indicates the average of the three most intense pixels. By combining several pixels, noise in our estimate of brightness (focus) is reduced. Finally, the third (S) indicates an estimate of the sharpness of the image. This is especially useful when more than one star appears in the window.

Below the image of the star and the readout of the current frame's focus measures is a line graph showing the history of these values. The most recent 100 samples are plotted so you can watch how the focus quality changes as you adjust you telescope's focus knob. This graph will auto-scale itself if the range is too large or too small for the display. Finally, also shown on here are the best values achieved during this Fine Focus run for all three measures (horizontal dotted lines).

Finally, you'll likely want to use the **Preview** button to set exposure durations, etc.

Status Bar

At the very bottom of the screen is the **Status Bar**. *Nebulosity* gives you a lot ofinformation down there. The Status Bar is divided into 4 panels. Theright-most panel always tells you what *Nebulosity* is doing. It may read "Idle" (it's not doing anything), "Capturing","Processing", etc. Next to that, is a panel that shows you the X and Ylocation of your cursor and the intensity of the image at that pixel (see thePixel Stats pop-up window under the Image menu to provide more detail).

The left two panels are used for information andinstructions concerning what *Nebulosity*is doing. Load an image and you'll see its dimensions and the name come uphere. Start an image alignment process and you'll get instructions and progresshere. Start an image capture and you'll also see your progress down here,along with what file was just saved. When in doubt about what's going on,check the Status Bar.

Capturing Images

Most of what you need to know to capture images was coveredin the previous section on the Exposure panel. There are a few topics worthconsidering on their own, however.

- Monochrome vs. Color?
- One-shot color: RAW vs. RGB?
- File formats
- Automatic Offsets

Monochrome vs. Color

G	B	G	B
R	G	R	G
G	B	G	B
R	G	R	G

Monochrome cameras have CCD pixels that have no filterplaced in front of them. Light simply hits the CCD array and the intensitygets recorded and saved. The CCD and *Nebulosity* don't care in the slightest whether you have no filter in place, an IRfilter in place, a red filter, an Ha filter, or any combination thereof. Tothe camera and to *Nebulosity*,it's all black and white data that comes straight off of the CCD as every pixeloperates just as every other pixel.

One-shot color cameras like the SAC10 or StarShoot are adifferent story altogether. One-shot color cameras have tiny color filtersplaced over each CCD pixel. Typically, red, green, and blue filters are used(although other options for filter sets exist). For example, if one looked ata small 4x4 pixel patch of the CCD, one might see the arrangement shown on theright. Each pixel in on the chip codes for only one color. So, if you have 1million pixels, you have 500,000 green, 250,000 red and 250,000 blue pixels (CCDmakers over-emphasize the green since our eyes are most sensitive to green). This is why you may hear people say that one-shot color imagers have lessresolution than monochrome imagers.

To some degree, this is true. Yet, when you look at adigital photograph from a digital camera, you don't see this array of colorsand you don't see a low-resolution shot. Digital cameras use this same kind ofone-shot color CCD but produce crisp, full-color images with as many pixels inthe output (each pixel having values for red, green, and blue) as they havepixels on the chip.

Whether the way this works is black magic or math is up foryou to judge, but there are very good techniques for turning images from this"Bayer" matrix into a full-resolution, full-color image. This conversion iscalled "De-Bayering" or "De-Mosaicing" the raw CCD image. Depending upon thesophistication of the technique, the end result can be as poor as havingresolution of one fourth the pixel count or as good as having nearly as goodresolution as the full pixel count. In general, the "luminance" or"brightness" resolution is almost as good as a monochrome CCD, whilethe color resolution (the ability to rapidly change between red, green, andblue) is not as good, with techniques differing in just how much is lost. Fortunately, while intensity in both daylight and astronomical images canchange very suddenly in an image (as we go from a black background to a star),the hue (or color) changes much more gradually. Thus, we can "get away" withhaving less color resolution than we have intensity resolution.

It is for this very reason that even when using monochromeCCDs, imagers often shoot a luminance channel at full resolution and colorchannels at lower resolutions (by "binning" their CCDs to increase thesensitivity but decrease the resolution). Thus, low color resolution but highintensity resolution is often chosen by monochrome CCD imagers, narrowing thepotential difference between the quality of the output between the two CCDtypes.

One-shot color: RAW vs. RGB?

Nebulosity lets youcapture and save images from one-shot color cameras either in the RAW formatfrom the CCD (where pixels still follow the Bayer pattern or whatever patternis on your CCD) or in full-color RGB format. RAW format is simply a monochromeformat. Just as with a monochrome camera, the CCD and *Nebulosity* cared not whether a filter was in place, the same istrue for RAW.

For full-color RGB, *Nebulosity* first captures this raw data from the CCD and then applies a De-Mosaicfunction to convert it into a full-color image. This full-color image is thensaved and the raw data are lost.

On-the-fly conversion to RGB is the default in *Nebulosity*, as it is perhaps the simplest and most intuitiveformat for the user. You ask for a full-color image and you get it. Many fineimages are created this way, but it does have a few drawbacks. First, eachimage is 3x as large as a RAW image, taking up 3x as much space on your harddisk and 4x as much space in your computer's memory (a separate luminance iscalculated and kept in memory as well). Second, on-the-fly De-Mosaic takessome amount of time for each image. Thus, if your capture machine is alower-end machine, you may want to capture in RAW and convert to RGB later.

Finally, RAW capture has one more advantage. Dark frame,bias frame, and light frame pre-processing is somewhat more accurate at fixingimages in RAW mode than in RGB mode. In addition, if you capture in RAW formatyou can use the powerful Bad Pixel Map tool, which must be used prior to theDe-Mosaic process (see 5.3 Bad Pixel Mapping). **For these reasons, it isbetter to capture your one-shot color data in RAW format and convert it later.**

If you do choose to save the data in RAW format and notconvert on the fly, you will pre-process your images in B&W / RAW mode andDe-Mosaic all of the pre-processed images prior to stacking (otherwise, you'llput red pixels atop green pixels, etc. and loose all hope of making a finalcolor image).

File formats

Nebulosity can readjust about any valid FITS image file out there (it makes extensive use ofNASA's FITS library) and can write images in a range of useful FITS formats. The format it will write in is set by your choices in the Preferences menu. This is true not only for captures but for any time you pull down "Save" fromthe File menu (thus letting *Nebulosity* act as a FITS format converter).

> Note: By default, *Nebulosity* will acquire images from one-shot color cameras like the SAC10 and StarShoot, converting the RAW data to full-color data on the fly as quickly as possible. When saving, its default is to save in RGB FITS files of the style supported by Maxim DL and AstroArt. **If you want your color imager to save in RAW format (see above as to why you likely will want to do this), select RAW acquisition from the Preferences, Color acquisition mode submenu.**

For color images, you have several options. RGB FITS is thedefault. Here, a single file holds the red, green, and blue data after theimage has been converted into a full-color image (De-Mosaic). Unfortunately,there are two ways in which other programs have chosen to implement RGB data inFITS files. The differences are esoteric to most (and concern using 3 HDU'svs. using 3 axes) until one realizes that programs using one standard don'tgenerally like files written by the other standard. So, *Nebulosity* will not only read both formats just fine, but it'llwrite either of them. They're labeled *RGB FITS: ImagesPlus* and *RGB FITS: Maxim / AstroArt*.

> **Tip**: Right click on a .fit file in Windows and select "Open With" and "Choose Program". Browse to Nebulosity (c:\Program Files\Nebulosity\Nebulosity.exe) and select "Always use the selected program". Now, double-clicking on .fit file will automatically start Nebulosity and load the image.

In addition to this, *Nebulosity* will write three separate FITS files for afull-color image if you so desire. One will have the red data, one the green,and one the blue. [Note, this is an output-only format currently]

Nebulosity can savein a compressed FITS format to save space. The compression algorithm used isnative to FITS and is a lossless one. You're doing no harm to your data byusing it. If you don't wish to use compression (e.g., you wish to use aprogram that doesn't support it), simply uncheck this in the Preferences menu. [Note: Maxim DL uses a "compressed FITS" format that is proprietary and not thestandard FITS compression. Nothing outside of Maxim DL can read this formatand Maxim doesn't seem to always like FITS' native compressed format.]

If space is not a concern and you want to absolutely maximize the quality of the saved data, you can choose to save the data in 32-bit floating point format. This is the native format used internally. Data files will be twice as large and, in truth, will likely show little more than the default of saving in 16-bit integers.

Finally, you can choose to rescale your data to 15-bitsrather than the full 16-bits possible. Thus, your data will be scaled into therange of 0-32767 rather than 0-65535. This is an option to support severalprograms.

Suggested settings if you plan to use other applications as well	
AstroArt	16-bit, RGB FITS Maxim/AstroArt, uncompressed
ImagesPlus	16-bit, RGB FITS ImagesPlus, compressed
Iris	15-bit, 3-separate files, uncompressed or PNG/TIFF.

Maxim DL	16-bit, RGB FITS Maxim/AstroArt, no compression
	Note: Select Save Settings in the Preferences menu and these will become the defaults.

FITS is used as a standard not only because it is so commonin the astronomical community, but also because it allows for arbitraryinformation to be stored along with the image. So, *Nebulosity* stores information such as the time the image wascaptured, what camera was used, what exposure duration, gain and offset wereused, etc. along with the image.

That said, many graphics programs do not support reading ofFITS images. Here, you have two options. First, you can save an image *asdisplayed* (i.e., taking into account the Band W slider positions) in 24-bit BMP format. If you do this, try to do mostof your processing beforehand as this format will allow for only 8-bits ofinformation for each color channel. Subtle gradations will be lost when you dothis (but remember, your monitor will only display 8-bits per color anyway).

Second, you can save in 16-bit/color (aka 48-bit color) TIFFor PNG format. Both compressed (LZW) and uncompressed TIFF formats aresupported (PNG format is always compressed). These options all provide ways ofsaving your data without any loss or degradation for use in other programs. *Thesealso are excellent ways to get color images into Iris v5.* (Note, you may wish to ensure that your data arewithin the range of 0-65535 before saving this way.)

Tip: You can drag and drop any supported image (FITS, JPEG, BMP, TIFF, PNG, etc) from Windows into *Nebulosity* and *Nebulosity* will automatically open that image. You can also associate *Nebulosity* with any of these file types (Right-click, Open With, browse to Nebulosity.exe) so that double-clicking on them will launch *Nebulosity*

Finally, you can load both 8-bit/color (24-bit) and 16-bit/color (48-bit) images from a number of formats. 8-bit JPEG, BMP, TIFF, PNG, and TGA files can be loaded and will be automatically stretched to 16-bits/color. 16-bit TIFF and PNG can be loaded as well.

Automatic Offset

To get the most out of your data, you should never, everhave a pure black background with zeroes anywhere in the image. Stretch zeroall you like and it'll always be zero. The camera's "offset" parameter letsyou ensure that this won't happen by adding a small bias signal as it digitizesthe image. However, what value do you pick?

Nebulosity picksdefaults based on your camera, but every individual camera is a bit different. An offset of 40 may be perfect for one StarShoot but maylead to zeros in the background at short exposures for another StarShoot. Anoffset of 40 may be great if your gain is 30 but be too much if your gain is60. *Nebulosity* gives you a way to calibrate your camera so that theprogram can determine what offset to use automatically (it will aim to have aminimum of 1000 in your image).

To do this, you first need to takeseveral calibration frames. *Nebulosity*will guide you through the process and it's quite automatic, but you do need tomake sure that these are dark frames and that the camera's cooler (TEC) isturned on and stable (leave it going for several minutes prior to calibration). If you do the calibration indoors, make sure that no light is getting to thecamera (wrapping the front in tin foil is great for this – black plasticlenscaps are quite "clear" to near IR light).

Once the camera is cooled andsetup for dark frames (and connected), simply pull down *Calibrate forauto-offsets* from the *File* menu. When prompted to ensure you're setup, press OK andwait while several frames are captured. Once done, ensure that *Auto Offset* is selected in the *Preferences* menu (you may want to Save Preferences) and that's it! You'll notice the text in the Control Panel now indicates that the offset isautomatically set. As you change the gain, you'll notice this valueautomatically update.

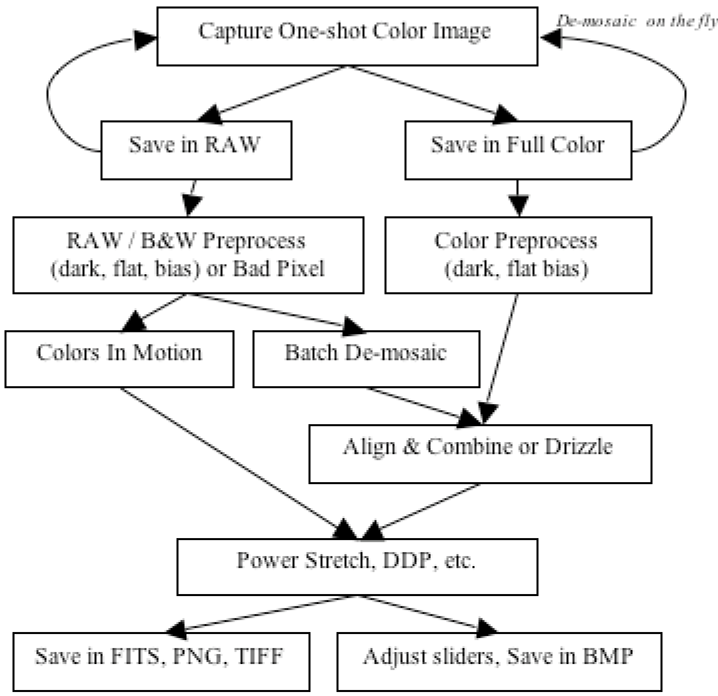
If you want to manually set theoffset, simply change the value to whatever you would like. To revert back tothe automatically-set value, simply adjust the gain and it will automaticallyreset the offset.

Image Pre-Processing

The following sections walk you through what to do with your data once captured. Traditional pre-processing (artifact removal with dark, bias, and flat frames) is covered first. A second method of removing hot pixels, known as Bad Pixel Mapping is then covered. For many cameras, especially cooled cameras with Sony chips, this method is perferable to traditional dark frame subtraction.

- Pre-processing: Theory
- Pre-processing: How-to
- Automatic dark frame scaling
- Bad Pixel Mapping

Pre-processing: Theory



Our CCD images have a number of artifacts in them. Typicalartifacts include *hot pixels* (brightdots that appear in the same place on the image and that get worse withincreased exposure duration or temperature), *vignetting* (un-even illumination of the field), *dustspots* (large blobs or donuts that appearsuperimposed on the image, looking a bit like a watermark), and *noise* (a static-like or grainy appearance to the image). The first three and one source of noise related to the *bias* or *offset*in the image are addressed during pre-processing.

Our goal here is to apply the following formula to ourimage:

NewImage = (RawImage- DarkImage - BiasImage) / (FlatImage - DarkImage - BiasImage)

Both **Dark Frames** and**Bias Frames** are taken with nolight hitting the camera. Dark frames are to be taken under the samecircumstances as your **Light Frames**(e.g., the RawImage pictures of your DSO). Use the same duration of exposureand try to have the CCD at the same temperature (e.g., if you use the TEC inyour DSO shots, use it in the Dark frames. Often, these are taken in the sameimaging session or a collection of "master" dark frames for various imagingsituations is compiled. Always take a number of dark frames (somewhere between10 and the number of exposures used in your light frames) and combine them(average or median) to create a suitable dark frame to be used duringpre-processing.

Bias frames can be taken at any time simply by covering thetelescope or putting a lenscap on the camera and taking a series of shortexposures (e.g., 10 ms). Take a good number of these some day when you'rebored and combine them (average or median) to create a master bias frame.

In contrast to Bias and Dark frames, **Flat Frames** are taken with light hitting the camera, but withthe light coming from an even field of illumination (e.g., aiming yourtelescope at a white wall, defocused at the sky at dusk bouncing the scopearound, putting a diffuser over your telescope, etc). The exposure duration ofFlat frames does not matter *per se*, but should be long enough toensure no pixels are at or near zero and no pixels are near saturation (*Nebulosity* will automatically scale the intensity of the imageto have a mean of 1.0, so don't worry how bright it is overall). Again, takeseveral of these and combine them.

Nebulosity's Pre-processroutine will subtract any Dark frame provided from each image, subtract any Biasframe provided from each image, and divide the result by the flat Frame. Youmay notice that this is leaving off part of the equation, as the denominatordoes not include the part about subtracting the Dark frame and Bias frame fromthe flat frame. This is because the Flat frame is typically taken at adifferent duration (usually much shorter) than the Light frames, meaning adifferent Dark frame is needed to remove the hot pixels from the Flat frame. What this means is that for best results, you should pre-process your Flatframe by treating it like a Light frame and applying a suitable Dark frame andBias frame to create the "master flat" image used to correct your Light frames.

Pre-Processing: How To

You've taken your images and are now comfortably inside. Now what? How do you get all those raw frames to look like a nice pretty stack? Just what the heck is Bad Pixel Mapping? Should I try Drizzle?

The rest of the manual provides answers to many individual questions and documents each of the tools. The goal of this section is to let you see how all of these fit together and to give you the necessary information to choose a path through the initial processing of your data. This alone won't give you a full understanding of how each tool works (see the individual section for each tool), but it should help put all the pieces together.

The basic steps are as follows:

1. Prepare any sets of darks, flats or bias frames for use by stacking them
2. Take care of hot pixels (dark subtraction or Bad Pixel Mapping), bias signals, and/or vignetting (flats)
3. (optional) Normalize the images
4. Convert RAW images into color via Demosaic (if one-shot CCD used and captured in RAW, which you really should do) and square-up your pixels (if needed)
5. (optional) Grading and Removing Frames
6. Stack the images (Align and Combine)
7. Crop the image to clean it up
8. (color only) Run the Adjust Color Offset tool to remove skyglow hue
9. Stretch the image (Levels, DDP, etc)

1. Preparing the darks, flats, and biases

If you've taken darks, flats, and/or bias frames for this imaging session, you'll need to put them together to form "master" darks, flats, and/or bias frames. If you've not got a new set of these, simply skip to the next step as there's nothing to do here. Assuming you do have some, what we need to do is take the set of them (e.g. 20 bias frames) and combine them so that you can use them to remove artifacts in your light frames. Having more than one dark, flat, and/or bias frame is a good thing as each individual frame has both the artifact you want to remove from your lights and random noise. Stack a bunch of these together and the random noise goes away leaving you with a clean image of the artifact you want to remove. Use just one and you remove the artifact and whatever random noise that one frame had. *Since it's random noise won't be the same as the random noise in your image, using just one dark, flat, or bias will actually inject noise into your light frame and make it noisier.* This is why people take a good number (20-100) of each of these.

When stacking these, we *don't want the frames to move*. That is, since there isn't a star whose motion we want to track, we don't want to align these images. We just want them stacked on top of each other as-is. To do this:

1. Pull down Processing, Align and Combine

2. Select "None" for the Alignment method and keep it set to "Save stack" and "Average / Default"
3. Click OK and then select all of your dark frames (or bias frames, or flat frames)
4. When all are stacked, give the resulting combined dark frame a name like "master_dark" or "master_dark_1m" (1m being a code for 1 minute - something to let you know what kind of master dark this is)
5. Repeat for any other types you have (flats and/or biases)

Ugly Details

At this point, you've got nice stacks of each and the stacks can be ready to use. If you want the absolute cleanest pre-processing and, it's worth considering the following issue. *Nebulosity*'s pre-processing just does the basic math for you. It subtracts the dark and bias from the image and divides this by the flat. It does not do anything to the bias, dark, and flat you pass in during Pre-processing. It just uses them.

So what's the problem? The problem is that that dark frame has the bias error in it already. The flat frame has the bias error and some amount of thermal noise in it (which will lead to hot pixels). So, if you use all of these as-is, you're going to do things like subtract out the bias error twice, which will actually inject the reverse of the bias error (still noise) back into your image. Oops.

The solution is to pre-process your pre-processing frames. You can, for example, apply the bias frame as the only pre-processing step for pre-processing your "master dark" and "master flat" frames. You can also have a dark frame taken at about the same exposure durtation as your flats and apply this to the flats. Before fully going down this route, consider the following recommendations:

Recommendations

- If you are using normal dark subtraction and not Bad Pixel Mapping to address the hot pixels, your darks already have the bias error in them. Do not collect extra bias frames and do not use any bias frames during pre-processing. Just use the darks and both the dark current and the bias error will be removed.
- If using flats, it is worth knowing that *Nebulosity* passes a mild smoothing filter over your flat in any case (a 2x2 mean filter). This will help remove hot pixels in the flat if your exposure duration was long enough to put them in there and will also remove some of the bias error. You may still remove the bias from this if you like, or simply pass something like the 3x3 median filter over your flat to smooth it out prior to applying this to your light frames.
- If using Bad Pixel Mapping, consider using bias frames as well. There is no need to clean up your dark frame (i.e. remove it's bias error) as with BPM, only the very hot pixels are touched. The bias error in your dark frame is ignored completely. If your camera has a strong bias error, grab a stack of bias frames once (shortest exposure possible) and grab and stack a bunch of these (you only need to do this once). Call it a "master bias" or "uber-master-bias" or whatever you like and apply this during pre-processing (below).

2. Taking care of hot pixels, bias signals, and/or vignetting

At this point, you should have "master" darks, flats, and/or bias frames. If you don't and you're processing without these, skip this step. Keep in mind, you can use as many of these as you want (or don't want). You can use darks but nothing else, flats and biases but not darks, etc. It's up to you and what type of pre-processing images you actually have. If you've got a stack of darks to use, you have a choice to make. Dark subtraction or Bad Pixel Mapping?

Dark subtraction vs. Bad Pixel Mapping

Both of these techniques are designed to deal with the thermal noise inherent in your images and the resulting "hot pixels" that show up in the same spot on the image in each frame. Dark subtraction is the traditional way of doing this. It works by simply subtracting the value for each pixel in your "master dark" from the value of that pixel in each light frame. If your light frames and dark frames were taken with the same exposure duration and at the same temperature, dark subtraction will remove the hot pixels (and "luke-warm" pixels as well - any thermal noise, not just the brightest). This can work very well *if you control the temperature, exposure duration, and take a lot of dark frames*. If you don't do these, you can end up with "holes" in the image (black spots where the hot pixel used to be), incomplete hot pixel removal, and you can inject noise into your light frames (see above).

Bad Pixel Mapping works differently. You first create a "Bad Pixel Map" (Processing, Bad Pixels, Make Bad Pixel Map) using a dark frame or stack of dark frames. A slider appears to let you set a threshold (feel free to use the default). Values in the dark frame that are above the threshold say "this pixel is bad". Bad pixels, and only bad pixels are fixed in your light frames by using surrounding good pixels to help fill in what this pixel should have been. For many cameras (in my experience, the cooled cameras with Sony sensors work best), this is an exceptionally powerful technique as the hot pixels are removed effectively with no noise being injected. It's also very flexible as you can use the same "master dark" from night to night and from exposure duration to exposure duration just by adjusting the slider and making new maps as needed.

Note: If you use Bad Pixel Mapping you will not use Dark Subtraction and vice versa. One or the other but no need for both. If you use Bad Pixel Mapping you can still use flats and bias frames and it doesn't matter whether you apply BPM before or after your other pre-processing.

Applying Bad Pixel Mapping

To apply BPM to your light frames:

1. Create a Bad Pixel Map if you don't already have one. Processing, Bad Pixels, Make Bad Pixel Map. Select a dark frame or stack and start off by just hitting OK to use the default threshold.

2. Pull down Processing, Remove Bad Pixels, selecting the one for the kind of image you have. If you have a one-shot color camera that is still in the RAW sensor format and looks like a greyscale image and not color (another reason to capture in RAW and not color...), select RAW color. If it's a mono CCD, select B&W. If it's already a color image, you can't use Bad Pixel Mapping.

3. A dialog will appear asking you for your Bad Pixel Map. Select it.

4. Another dialog will appear asking you for the light frames. Select all of them (shift-click is handy here).

5. You will end up with a set of light frames that have had the bad pixels removed. They will be called "bad_OriginalName.fit" where OriginalName is whatever it used to be called.

Applying Darks, Flats and Biases

Here, you get to apply traditional dark subtraction, flats, and biases in any combination you wish. To do this:

1. Pull down Processing, Pre-Process Color images or Pre-Process BW/RAW images. Color images are already full-color. BW/RAW images were either taken on a monochrome camera (BW) or taken on a one-shot color camera but have not yet been converted into full-color via the Demosaic process.
2. A dialog will appear that will let you select your various pre-processing control frames (darks, flats, and/or biases). Select whichever you have by pressing the button and telling Nebulosity which file to use here.
3. If you are using dark subtraction and you doubt your exposure and/or temperature control was perfect, select the "Autoscale dark" option.
4. Click OK and you will be asked to select the light frames you wish to pre-process.
5. When all is done, you will have a set of files called "pproc_OriginalName.fit".

3. Normalize Images (optional)

All things being equal, your 50 frames of M101 should all have the same intensity. They were taken on the same night one right after the other and all had the same exposure duration. So, they should be equally bright, right? Yes, but there's that nagging "all things being equal" we supposed and, well, all things aren't always equal. For example if you start with M101 high in the sky and image for a few hours it starts picking up more skyglow as the session goes on, brightening the image up. That thin cloud that passed over did a number on a frame that still looks good and sharp, but isn't the same overall intensity as the others, etc. All things are not always equal.

If you're doing the Average/Default method of stacking, you need not worry about this issue unless the changes are really quite severe. If you're using standard-deviation based stacking, Drizzle, or Colors in Motion, it is a good idea to *normalize* your images before stacking. What this will do is to get all of the frames to have roughly the same brightness by removing differences in the background brightness and scaling across frames. To normalize a set of images, simply:

1. Pull down Processing, Normalize images
2. Select the light frames you want to normalize
3. In the end, you'll have a set of images named "norm_OriginalName.fit"

4. Converting RAW images to Color and/or Pixel Squaring (aka Reconstruction)

The last step before stacking your images is to convert them to color (if they are from a one-shot color camera and you captured in RAW) and square them up as needed. Some cameras have pixels that are not square and this will lead to oval rather than round stars. The process of demosaic'ing (color reconstruction) and/or pixel squaring is called *Reconstruction* in *Nebulosity*.

Note, you can tell if your images need to be squared up by pulling down Image, Image Info. Near the bottom you will see the pixel size and either a (0) or (1). If it is (1), the pixels are square. Of course, the pixel dimensions will be the same in this case too.

To reconstruct all of your light frames, simply:

1. Pull down Processing, Batch Demosaic + Square (if images are from a one-shot color camera) or Batch Square (if images are from a monochrome camera or you just feel like squaring up a color cam's but keeping the image as monochrome for some reason).

2. Select your frames

3. In the end, you'll have a set of images named "recon_OriginalImage.fit"

5. Grading and Removing Frames (optional)

Sometimes bad things happen. The tracking goes awry, a breeze blows, you trip over the mount, etc. This is a good time to find those "bad" frames and pretend they never happened. There are two tools to help you here.

Grade Image Quality

This will look at a set of frames and attempt to automatically grade them as to how sharp they are relative to each other. The idea here being that you'll not use the least sharp frames. Pull down Processing, Grade Image Quality and point it to your light frames. It will rename them (or copy them with a new name) denoting how sharp each frame is.

Image Preview

This will let you easily go through your images one by one to examine them, (optionally) rename them, and/or (optionally) delete them. File, Preview Files. If you've not tried this, try it. It's quick, easy, and immensely useful.

6. Stacking: Align and Combine

It's now time to Align and Combine (stack) your light frames. Here, there are a large number of options as to how to proceed. We'll start with the basic version first and then detail the other paths you can take.

1. Pull down Processing, Align and Combine Images

2. If you're not on an alt-az mount, hit OK, keeping the defaults of saving the stack, using Translation, and Average / Default stacking. If you're on an alt-az mount, you'll need to include rotation, so change the Alignment Method to Translation + Rotation.

3. Select your light frames

4. Find a star in your image that's not ultra faint and not big and bloated. Move your mouse over it to make sure that the core of the star isn't all 65535 (the max possible value). Click on that star and *Nebulosity* will advance to the next image. If your mount's tracking is at all decent, the same star on the next frame should be circled. If the circle is on the right star (don't worry about centering), just hit Ctrl-click (or Command-Click on the Mac) to tell Nebuolsity "yes, that's the right star and I want to use this frame". If it missed the star, just click on it (don't worry about being precise). If the frame is a bad one and you'd like to skip it and not include it, hit Shift-click.

5. If you're doing Translation + Rotation (or Drizzle), you'll need to find a second star and run through each frame again. Try to pick one that's not very close to the first star.

6. When you're done (the Status Bar will show you your progress), *Nebuolsity* will align and combine all the images and pop up a dialog asking you for a filename to save the resulting stack in.

There you have it! Basic stacking. There are some more advanced options you can try:

- Translation + Rotation (+ Scale): The normal Translation alignment will only shift images by whole pixels and does not account for any rotation across frames. Running these will shift the images by fractional pixels (interpolating them as needed), rotate them as needed and, if selected, scale them as needed to co-register the images.
- Drizzle: Drizzle is a powerful technique that will align, combine, and increase the resolution of your images during stacking. It is suitable for alt-az mounts as rotation is included in the alignment. You will therefore need to select two stars during alignment. Make sure you have Normalized your images at some point first.
- Colors in Motion: This tool is only available for images from one-shot color cameras that have not been converted into color yet. It will align the images and convert them into color at the same time. It is a translation-only based alignment.
- Standard Deviation (SD) stacking: Instead of taking the average value for each pixel (across images), take the average but toss out "outliers" or values that are atypical. Thus, if a hot pixel "crosses over" a pixel in the aligned image (the hot pixel didn't move but the frame did when the stars were aligned), this bright hot pixel will be an atypical sample and will be tossed out before averaging. To use this technique, you must first do your alignment, saving each frame first and then pass these aligned frames ("align_OriginalName.fit") into Align and Combine again, selecting "None (fixed)" as the alignemnt method (and one of the Std. Dev. thresholds in the Stacking Function). Make sure you have Normalized your images at some point.

7. Crop off the edges

After stacking, odds are you've got a dark border around your image as *Nebulosity* tried to make an output image big enough to hold everything from every frame (an exception here is in rotation where you will have bits cut off at times). Odds are you don't want this bit and it'll just make the histograms look funky when you're stretching. Use the mouse to define a rectangle that has the good part of the image and pull down Image, Crop. Save this with a new name.

8. Remove the Skyglow Color: Adjust Offset tool

If you're shooting in color (one shot or having combined frames), odds are the background sky is not a nice neutral gray, but rather something rather unpleasant (green, pink, and orange are common). This comes from the color of your skyglow. Fortunately, it's easy to remove. Simply pull down Image, Adjust Color Offset. Unless you've got a reason, accept the default values. Save this with a new name.

9. Stretching

Now, the fun begins as it's time to see what you really have in that shot. Sitting atop that skyglow should be the faint galaxy or nebula you were shooting and stretching is how we bring this out. There are two main tools for stretching in *Nebulosity*. The first is the Levels / Power Stretch and the second is Digital Development Processing (DDP).

The goal in both of these is to pull your image's intensity profile (histogram) and stretch it so that very low contrast differences are made more apparent. Thus, you are pulling your faint galaxy arms away from the skyglow and doing things like sending the skyglow down to a nice dark background. When doing this:

- Keep your eye on the histogram. The histogram is your friend.

- Until the very last steps of stretching, don't let the left edge of the histogram get cut off and don't bang too much (e.g. the core of your galaxy) into the right edge of the histogram. Once they hit the edges (0 and 65535), you'll never resolve details in there again.
- Turn off auto-scaling (or let *Nebulosity* do this for you) so that what you're seeing on the screen is the full 16-bit data in all it's glory. This will help you use the full range of intensities your image can take. Remember, the B and W sliders are just there to make the image prettier on the screen (they do a stretch for display but don't really affect the underlying image). So, have them at full left and full right and then start to stretch. (If you're in auto-scale when you enter Levels, it will turn it off and set these at the extremes for you).
- Don't try to do everything in one pass. Make several passes over the image to slowly pull it into the condition you want it.
- Save often

Levels / Power Stretch

The Levels tool in *Nebuolsity* does the same math to your image as tools like PhotoShop's Levels tool. You're setting a black point (top sider), a white point (middle slider) and a midpoint or "power" (bottom slider). With several passes over the data you can do the same thing that a "Curves" tool will do for you. In general, for the first few passes, have the "power" slider be less than one (try values like 0.6) as this will help accentuate the low-contrast details and pull them out. Start getting the details to pull apart from the background before you work too hard on pushing the background to being dark. You can always darken the background later.

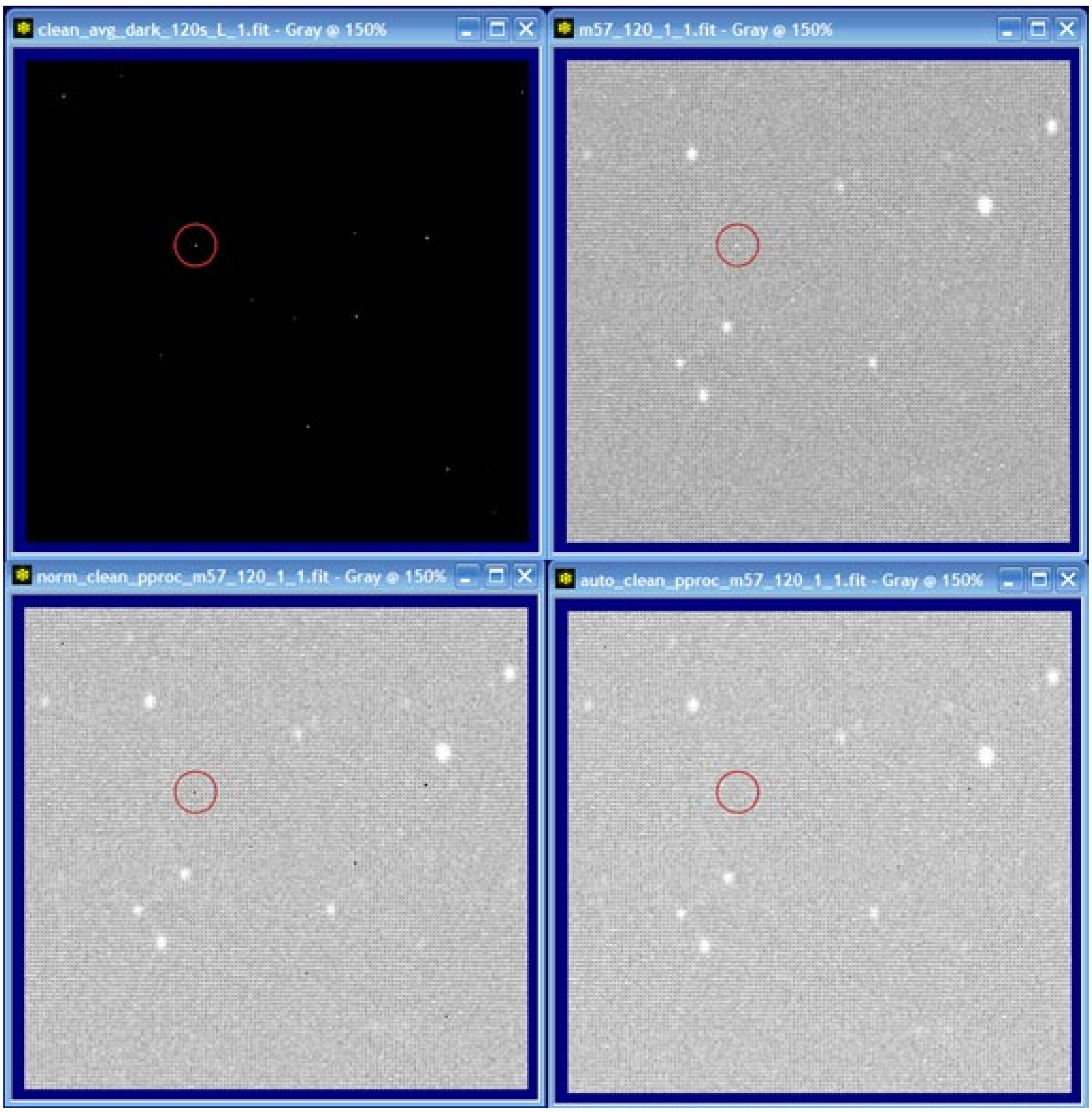
Digital Development Processing

If you use DDP, do it first or without using the Levels tool much beforehand as the math behind it expects you to have not altered the linear response of your CCD's image. I find that DDP works best if the skyglow is not too bright to begin with. Feel free to use the Levels tool and adjust the black-point (first) slider to bring the histogram nearer to the left edge before running DDP. Just don't start adjusting the Power (aka midpoint, aka 3rd slider) in the Levels tool before using DDP.

Automatic Dark Frame Scaling

You may find after processing your images that the hotpixels have not been fully removed or that they were removed "too much" andwhere bright spots used to appear, there are now black holes (no, you didn'timage a black hole...). This happens if the *dark current* recorded in your dark frames doesn't match the darkcurrent recorded in your light frames. Typically, this happens if the exposuredurations were different, if the gain/offset was different, or if the CCDtemperature was different.

Nebulosity has theability to compensate for these differences automatically. It does so when the"Autoscale dark" box is checked during dark / bias / flat frame selection. *Nebulosity* begins by finding 30-300 hot pixels in your darkframe and then finding those same pixels in each light frame. Bymathematically modeling the relationship between the intensity of these hotpixels in the two sets of images, *Nebulosity* can determine how much "hotter" or "colder" the hotpixels are in the light frame than in the dark frame. It then scales the darkframe accordingly. The picture below shows it in action.



In the upper-left, we have a section of a dark frame,stretched to show the hot pixels. In the upper-right, we have a raw lightframe showing our stars and the hot pixels (e.g., the dot inside the redcircle). In the lower-left, we have the result of a standard dark subtraction. Note the "black hole" inside the circle. In the lower-right, we have theresult of the autoscaled dark subtraction.

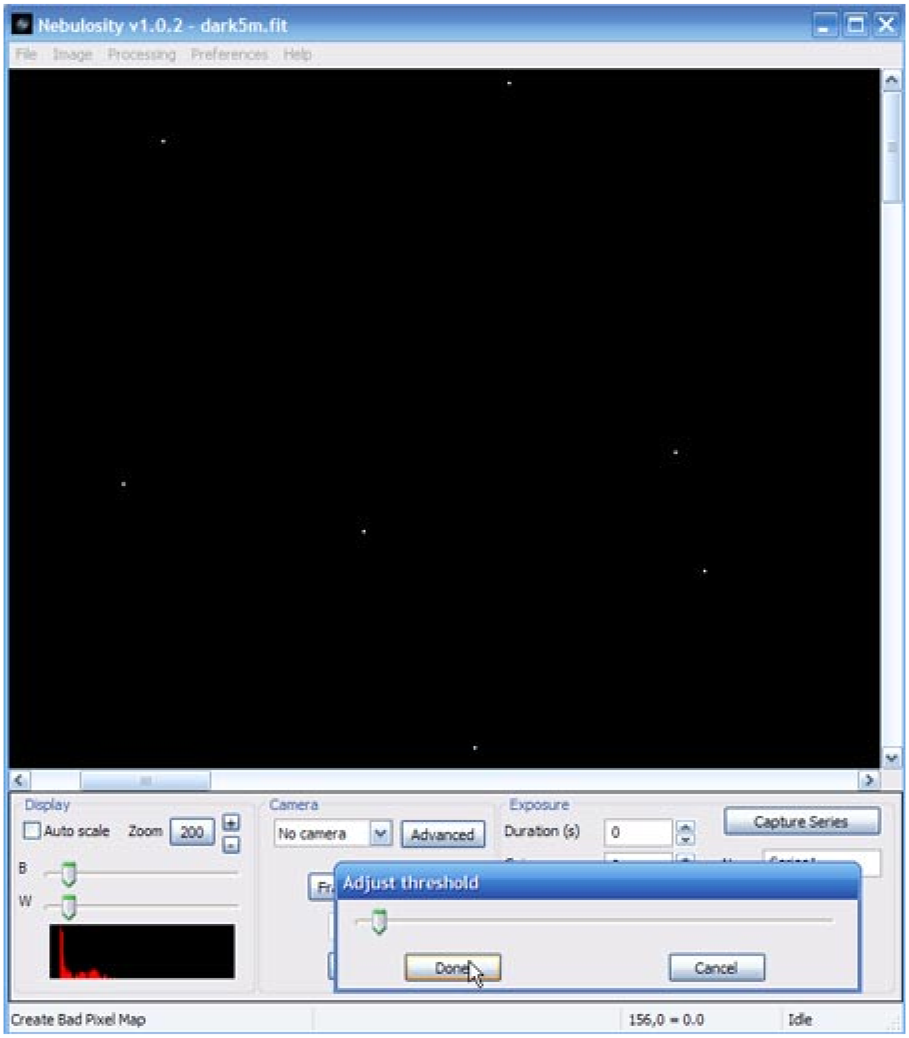
Bad Pixel Mapping

Removal of hot pixels using the typical (orautomatically-scaled) dark frame subtraction technique does have one realdrawback. Your dark frame contains not only information about the hot pixels,but it contains other kinds of noise as well. Stretch the dark frame andyou'll see the same kind of "readout noise" you see in a bias frame along withother noise components. If you average many of these frames (some suggesttwice as many dark frames as light frames), much of this noise will disappear,but it may take a lot of dark frames to have it go away (and some will never goaway unless you cleanly bias-correct your dark frame). Therefore, while darkframe subtraction will remove hot pixels, *it can actually add noise intoyour image!*

An alternative method for removing hot pixels is called *BadPixel Mapping*. In this technique, youfirst identify those pixels on your CCD that are prone to problems – yourhot pixels. Once you've identified those pixels, only those pixels in yourlight frames are touched. We don't really know what the value in that pixelshould be, but the software can make an educated guess and fill in for the badvalue. This can work very well as the images below show. First is azoomed-in frame from a one-shot camera that was de-mosaiced without anycorrection.

Next is the same area when the bad pixel map was appliedprior to the de-mosaic process.

Using Bad Pixel Maps is quite easy but does require thatyou are either using a black and white camera or, if using a one-shot colorcamera, that you capture in RAW mode (Bad Pixel Mapping must be performed priorto converting the image into full-color). The first step is to generate themap. For this, you need a dark frame or an average of several dark frames. Ideally, this will be a combination of several frames taken at the longestexposure duration you expect to use. Pull down *Bad Pixels*, *Make bad pixel map* from the Processing menu and load the dark framewhen prompted. A slider will now appear and the display will show you your hotpixels. *Nebulosity* attempts tocome up with a reasonable position of the slider for you. Here, wehave the default setting and display for creating the Bad Pixel Map used in theexample above.



At this point, you can adjust the slider and you'll see thenumber of bad pixels identified change. Move it to the left and more pixelsappear and move it to the right and fewer appear. What you are doing is movinga threshold – saying that anything above this intensity is a bad pixeland anything below it is a good pixel. When you like your map, click on Doneand you will be prompted for a name to give this Bad Pixel Map. Give it ameaningful name, as you may well want to create several maps. If you used a5-minute dark frame, you could use that dark frame to make several maps –one for ~5-minute exposures, one for ~1-minute exposures, and one for~20-second exposures for example by using different values of the threshold(letting fewer hot pixels show for the shorter exposure maps). There is no"exact right value" here. You're simply telling *Nebulosity* which pixels not to trust.

Once you have your map, you can now process your lightframes. In the *Bad Pixels* menu, selectthe *Remove bad pixels* optioncorresponding to the kind of images you have (images from a one-shot colorcamera in RAW format prior to the de-mosaic process OR images from a black andwhite camera). It'll prompt you for the map to apply and then for the set oflight frames you want to process (shift-click or ctrl-click to select multipleframes).

When done, you can *Batch De-mosaic* the images if they were from a one-shot color cameraand then go on to Alignment and Stacking.

Reconstruction: Demosaicing and Pixel Squaring

If you capture in RAW format from a one-shot color imager, you will at some point need to "Debayer" or "Demosaic" your images. (If you capture doing color on the fly, this happens immediately after image capture automatically). This converts the RAW image from the camera into a full-color frame (see One-shot color: RAW vs. RGB). This can be done either before or after pre-processing (although results will be best if you do it after pre-processing - see Pre-Processing. In addition, whether you use a color or monochrome imager, you will often need to convert the camera's native pixel dimensions into square pixels prior to stacking your images as many cameras have pixels that are natively not square.

Nebulosity provides tools to do this on both an individual image (on the Image menu) and in a batch mode for a series of images (on the Processing menu). If *Nebulosity* is able to determine the needed information about the image and where it came from, this will happen automatically. If not, a dialog will appear and prompt you to enter in several parameters about your camera so that the processing can go on accurately.

It is important to note that *Nebulosity* will automatically square the pixels during the debayer process for one-shot color images. Any color image is assumed to therefore have square pixels.

It is also important to note that if you use a Canon DSLR, ideal color balance in *Nebulosity* will be accomplished if you select the appropriate setting under "DSLR White Balance / IR Filter" in the Preferences dialog.

Previewing and Grading Images

Let's face it. Some images just don't look good. Some of your shots may look great and some may look horrible. Maybe the tracking failed, maybe dew started to form, maybe you hit the scope or the wind blew. Who knows what, but some shots just aren't as good as others.

When stacking images you have the chance to skip any frame you don't like but this can be a bit too subjective at times. *Nebulosity* provides two ways to do this beforehand.

The first is to use the Preview Files command in the File menu. You can use this to load up a set of images and rename or delete ones you do not wish to use. The second is a way to automatically grade each image in your set **relative to each other image in the set** to let you pick the best frames. In the **Processing** menu, you'll find an entry for **Grade Image Quality**. Select it and you'll be asked to choose the frames you want to grade.

It is important to note that the quality estimate will always grade each image relative to the other images you select. It is not any estimate of *absolute quality*, rather it is an estimate of *relative quality*, or how sharp one image is relative to all of the others in the set. When run, an algorithm is used to determine how sharp each image is and those sharpness scores are then tabulated with some basic statistics. The net result is a score for each image relative to all the others in the set. This score is such that the average quality in the set will always be given a value of 50. The closer the score gets to 100, the sharper this one frame is relative to all the others. The closer it gets to 0, the fuzzier it is relative to the others. (Technically, this is a "normal curve equivalent score", a transformation of a z-score).

LRGB Color Synthesis

Nebulosity allows you to synthesize a color image from separate frames. For example, users of monochrome cameras must take a set of images through red, green, and blue filters to create a color image. Users might also want to combine a full-color image from a one-shot color camera with a "luminance" frame taken from a monochrome camera, or to combine images taken through separate line filters. *Nebulosity* provides a tool for this.

To use the tool, you must first align all your images and save each frame (rather than the whole stack) using the Align and Combine tool. Co-register the images using any version of the Translation (+Rotation +(Scale)) tool you wish.

Located in the Processing menu, the LRGB Color Synthesis tool can then be activated. Select your mode (RGB, Traditional LRGB, and Color Ratio LRGB) and frames. If you have a full-color file, you can load all 3 color planes at once using the "RGB frame" button. This will overwrite any red, green, or blue data you have already loaded. (You can load these first and then replace any color plane by loading another file into that color plane directly.) If you know ahead of time you wish to scale the color channels relative to each other, you can do so using the sliders.

Modes

RGB

In RGB mode, 3 color channels are used and directly create a color image. It is the simplest mode.

LRGB: Traditional HSI

This implements the traditional LRGB technique. The red, green, and blue frames are used to calculate a hue and saturation value at each pixel. The luminance (or intensity) value is replaced by the value provided by the luminance frame. The resulting HSI (or HSL) data are converted back into RGB in the output image. This is the traditional method, but can lead to a loss of saturation.

LRGB: Color Ratio

This technique gives an alternative method of luminance layering that avoids the loss of color saturation by the traditional method. The RGB data are used to create R:L, G:L, and B:L ratios (L derived from RGB). The L component is then replaced by the value in the luminance frame and the image converted back to RGB.

Image Normalization

Ideally, all frames taken under the same circumstances of the same target should all have the same intensity. Often, this is not the case as changes in light level, cloud cover, etc. can change the intensity from frame to frame. Further, if changes are made in the capture settings (e.g., different exposure durations), you're certainly going to have differences in overall image intensity across frames.

If you're doing the Average/Default method of stacking, you need not worry about this issue unless the changes are really quite severe. If you're using standard-deviation based stacking, Drizzle, or Colors in Motion, it is a good idea to *normalize* your images before stacking. What this will do is to get all of the frames to have roughly the same brightness by removing differences in the background brightness and scaling across frames.

The *Normalize* entry in the Processing menu will go through all selected frames and attempt to put them all in a common intensity range by taking care of offset and scaling differences across frames. After normalization, all frames should have their minimum at ~100 and their maximum at ~65535. Do this *before* you do any alignment of the frames (it can be done before or after pre-processing, but you don't want the black borders surrounding the image that can come in during alignment to throw off the normalization process.)

Stacking Images

Stacking multiple exposures is a fantastic thing to do foryour images. If you can stack your images, you don't need to hold perfecttracking as long (making life easier) and you reduce any noise in your imagethat is not consistent from exposure to exposure (much of the noise is not). Thus, a stack of images will look less grainy (less noisy) than any oneindividual image. This lets you stretch and process the image more to bringout fainter details. All in all, stacking is a very good thing.

In *Nebulosity*, stacking can be done with or without alignment. For light frames (where stars are apt to move between each frame), you will want to align the images either prior to stacking or during stacking (see below). For things like dark frames, bias frames, and flat frames, you will not want to align the frames first.

Alignment

Few of us have perfect mounts that track or guide so wellthat there is no drift whatsoever across images. (In fact, it turns out to bebetter to have a bit of drift between images, as your image isn't alwaysaligned with whatever consistent noise is in your camera, but this is a ratherlong topic not worth going into at the moment.) The net result of this is thatif we were to stack a series of images atop each other as they came off thecamera, we would end up with a blurred or streaky looking image. Each star wasnot in the same place in each image (the whole field of stars moved betweenimages), so the result is quite poor.

In *Nebulosity*, this process is called "Align and Combine" and there are various options available to you (see below). In each, you are asked to find a star (or sometimes two) that is the same in each image. You will be asked to left-click on this common star (it is best to use a somewhat isolated and non-saturated star) in each image. Don't worry about being perfect in your clicking. *Nebulosity* will always search around the area where you clicked to find the star's centroid (i.e., it will refine your click automatically). In addition after the first image, *Nebulosity* will attempt to find the same star in each image for you and place a circle around that star. If you wish to keep *Nebulosity's* location, simply Ctrl-click (Command-click on the Mac) anywhere in the image (if it gets it wrong, just click on the correct star). Finally, if you want to skip an image (e.g., if it was blurred), simply Shift-Click anywhere in the image and it will not be used in the stacking process.

Nebulosity provides several waysto align a series of images prior to or during stacking to take out this overallmovement in the image. In the simplest method (Translation), *Nebulosity* will take out shifts between your images (a.k.a. *translations*) and average the aligned data. You do this bypicking a common star in each image, and *Nebulosity* takes care of the rest, shifting each frame (by whole pixels, without "resampling"). This works very well forequatorially-mounted telescopes (including fork-mounted scopes on a wedge). This does not work for Alt-Az mounted scopes. This style of mount makes starsnot only move left/right and up/down but the entire field rotates as well.

A more complex technique, Colors in Motion, is also used for stacks that have shifts betweenimages. Unlike the other techniques provided, Colors in Motion simultaneouslyaligns RAW images, stacks them, and reconstructs color information fromone-shot color cameras. It cannot be used on RGB data or on black and white data.

To align and combine images using alt-az mounted scopes (or equatorially- mounted scopes), *Nebulosity* provides three other techniques. The first is similar to the above but allows for rotation and sub-pixel alignment. It is called Translation + Rotation. Related to this is Translation + Rotation + Scaling in which frames are allowed to be resized to align atop each other. To let *Nebulosity* know about the possible rotation, you must pick two stars in each image. Each image will be shifted and rotated to align them all prior to averaging the data.

The final technique that works on both equatorial and alt-az mounted scopes is called Drizzle (Alignand Combine: Drizzle). Drizzle can notonly combine images from alt-az (or equatorial) scopes, but it also enhancesthe resolution very well. To do this, you will again have to pick twostars in each image, and *Nebulosity*will do the rest.

Combination methods

In all of these, you have the option of using either strict averaging or adaptive stacking. In several (the Translation (+Rotation) (+Scaling)) you also have the option of saving each individual file post-alignment rather than saving the stack. This can be very useful, for example, in preparing frames taken through different filters for (L)RGB color synthesis or for using the Standard Deviation method of stacking.

Averaging vs. Adding vs. Adaptive Stacking

During any of the Align and Combine methods, *Nebulosity* can mathematicallystack images in one of two ways. By default, an Adaptive Stacking techniqueis used (see Preferences menu). Some people worry a great deal about whetherto add (sum) or average their frames during the stacking process. Each techniquehas its ups and downs. If you have 3 images in which the same pixel reads 100,100, and 101, summing gives you 301, whereas averaging gives you 100. Internally, in *Nebulosity*, theaverage would be 100.33333 (as it should be), but when saved, it would become100 as the images are saved in "integers" (aka whole numbers, not "floats"which let you have fractional bits as well). This makes one think that addingis best, but another example shows the problem there.

Let's now say that abright pixel reads 32000, 32010, and 32100 in our three images. The sum is 96110here where the average is 32036.666. When saved, this would become 65535 ifsumming were used and 32037 if averaging were used. Let's have another pixel– even brighter – reading 64000, 64010, and 64100 in the image. Once saved, the sum would make this 65535 and the average would make it 64037. Here, we see the problem with simple summing. You can saturate the imagepretty easily, especially if you start with 16-bit images. Here, one pixelshould be twice as bright as the other and yet it ends up equally bright(65535) if adding is used, since this is the highest possible value.

Nebulosity uses anAdaptive Stacking technique that avoids the weaknesses of both. It can beviewed as always being somewhere in between adding and averaging your data. The output (the stack) will always have a maximum value of ~65535 so that youare always using the full range of your data. This is enabled by default andfor most uses will be optimal. (Note, it is not used when the Fixed Combine isselected as this tool is often used for dark frames). Unless you have a realreason to, you should leave this on (see Preferences menu). If you turn itoff, *Nebulosity* will compute astraight average when stacking.

Standard Deviation Based Stacking

If you were to take a perfect image of a target, each pixel would have its "ideal" or "true" value - how much intensity there is from that part of the target. The trouble is, each time we sample the target (take an image of the target), we record both that true value and some noise.

Averaging helps to get rid of this noise. It should tell us the central tendency and therefore estimate the truth. The more samples we have, the better the estimate is. But, if some samples are really abnormal ("outliers"), the average can get thrown off. For example if a hot pixel drifts into a patch of background sky, the average value will go up considerably and the hot pixel will show up in the stack (technically, of course, the stars and sky moved, not the hot pixel).

Standard Deviation based stacking gives us a way to identify these outliers and eliminate them prior to computing the average. To do this, we calculate not only the mean (average) of each pixel's value in the dataset but also a second statistic that describes how much variability there is around that mean. We calculate the standard deviation (the square root of the variance) and use this to filter out "bad" samples.

If we assume the data are "normal", about 70% of all samples will lie within one standard deviation of the mean (that is, 70% are less than one standard deviation above or one standard deviation below the average). About 95% like within 2 SD of the mean.

During SD stacking each (aligned) pixel, has the mean and standard deviation calculated across all of the images in the stack. If your SD threshold is at 1.5, any samples of that pixel that have an intensity beyond 1.5 SD from the mean are removed and a new average, excluding these samples, is calculated. This is why hot pixels are often eliminated using SD stacking - those hot pixel values are very abnormal and lie far away from the mean.

With the filter set at 1.75, it takes a more extreme or "outlying" intensity value to be counted as "bad" than at 1.5. At 2.0, it takes even more abnormal a value to be excluded. Thus, more samples go into the final image using a higher threshold (and more noise as well). Typically, filtering values at 1.5 or 1.75 will yield the best results.

How-to

To use Standard Deviation stacking, you must first Normalize your frames. Then, you must align your images using any of the Translation (+Rotation (+Scaling)) routines. Do this to all of your images and save each file rather than saving the average stack. Then, select "None" for alignment method and the various SD stacking choices will appear. Try 1.75 or 1.5 initially before using any more extreme values.

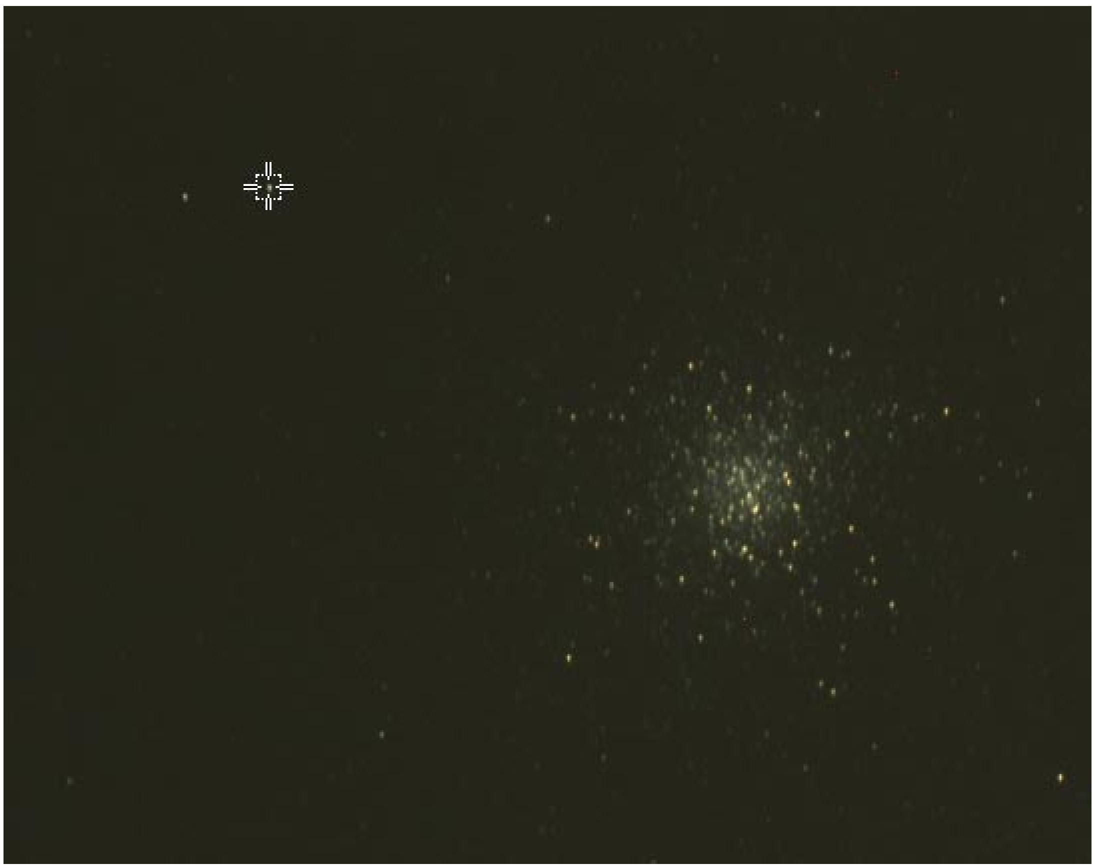
Note, that this requires a lot of memory. If you are using DSLR images, 1Gb of RAM would be considered a minimum for this kind of technique.

Align and Combine: Translation

This is the most straightforward method of stacking. Each image is shifted up, down, left, and/or right by whole pixels prior to align it with all the other images prior to combining.

Once your images have been pre-processed, select **Align and Combine: Translation** from the Processingmenu. You will then be presented with a dialog asking you what frames you wishto align. Select all of your pre-processed frames, even if you think a few youmay not want to keep and press OK.

At this point, you'll notice the cursor has changed to across-hair (see below). You may also notice all of the menu items have gonegrey, as you are now in alignment mode. The status bar shows your progress,telling you how many frames you've selected to align and how many you've doneso far. Feel free to adjust the display levels or zoom factor here to get agood view.



Your goal now is to identify the same star in each image. Pick a star that is fairly isolated and that is not saturated. Big, bloatedstars need not apply nor should ultra-faint ones near the level of thebackground. Opening up the Pixel Stats window can help in selecting a suitablestar. Put the cursor over this star (and remember which one it is) and clickthe left mouse button. In so doing, you're saying "The star is here" to *Nebulosity*.

In truth, you're actually saying, "The star is about here." None of us can click perfectly all the time and doing so would be a very timeconsuming process as we would obsess over whether it the click should be hereor one pixel over. So, *Nebulosity* neverassumes you got it 100% on target. Instead, it looks in a small area (5pixels) to see if there's a better candidate for the center of that star. Thatis, it refines your click. So, get close, but don't obsess over being perfect. *Nebulosity* assumes you're notperfect and will try to fix it anyway. After the first image, you will notice a circle appear around a star - hopefully, the same star you've been using in prior images. To keep the current location (i.e. to say "yea, you got the right star, there Nebulosity), Ctrl-Click (Command-Click on the Mac).

Tip: If you want to abort the whole process, simply press the Abort button.

If there is an image you don't want to include in the stack(e.g., a plane flew through your DSO, the mount mistracked, you moved the scopeto re-center the target during imaging, the wind blew, a cop shined a spotlightat your scope – all of which have happened to me), just Shift-Left-Clickanywhere in the image. That frame will be ignored. (The FWHM specified in thePixel Stats window can help here, too).

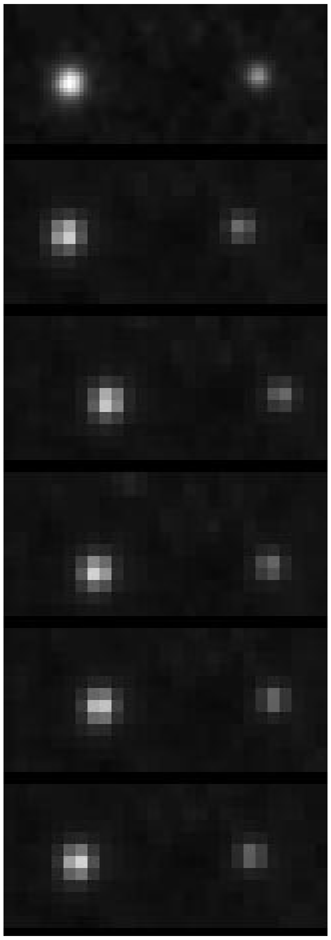
Once you've selected the same star in each image (at least for each image youplan to use), *Nebulosity* then goes aboutaligning the images and combining them into one composite image. Depending onhow many images you're aligning and how big they are, this could take sometime. *Nebulosity* shows you itsprogress in the Status Bar. After all images have been combined, *Nebulosity* prompts you for a name to save the composite imageas. Give it a name and press OK and you're done. The image now displayed onthe screen is this composite image.

Align and Combine: Translation + Rotation (+ Scaling)

Using this method, images are shifted (translation), rotated, and optionally scaled by sub-pixel amounts in order to optimally align images prior to combining them. The process is very similar to that used in Align and Combine: Translation. The only difference in what you do is to pick two stars in each image.

Once you have gone through and picked the first star (which *Nebulosity* uses to gauge the translation), you will go back through all images and be asked to pick a second star (used to gauge rotation). As before, feel free to keep the current best guess of the star's location (Ctrl-Left-Click or Command-Left-Click on the Mac), to skip any image you don't like by Shift-Left-Clicking or to abort by hitting the Abort button.

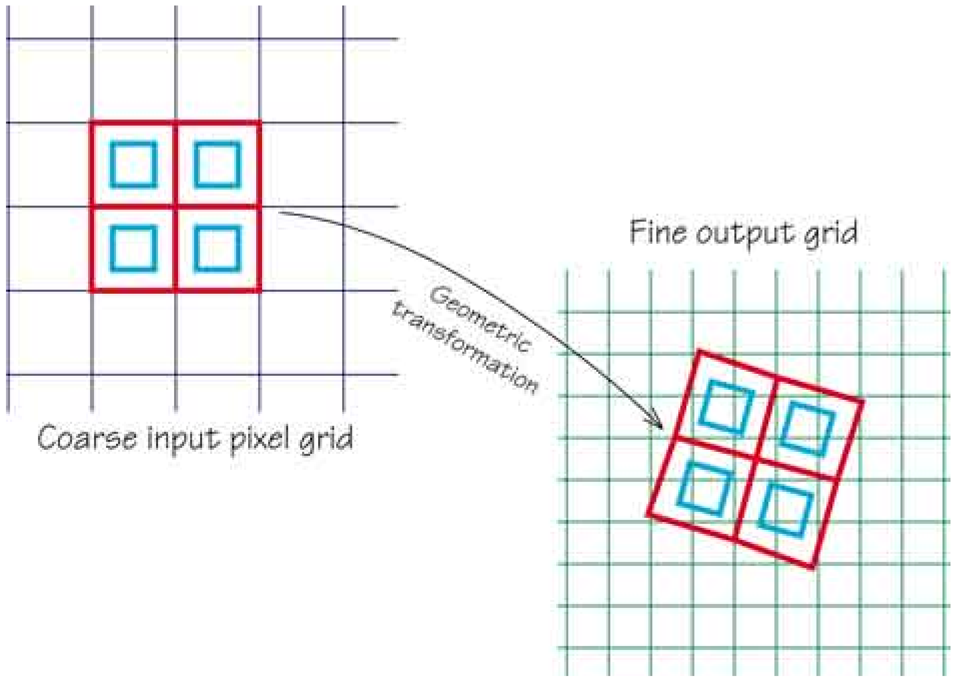
Drizzle alignment (Translation & Rotation + Resolution enhancement)



Drizzle is a technique developed by Andy Fruchter (Space Telescope Science Institute) and Richard Hook (Space Telescope European Coordinating Facility) to make the most of images from the Hubble Deep Field's WFPC2 camera. Their insight stemmed from the idea that images from the Hubble were *undersampled*. The optics were able to resolve a lot more detail than the size of the CCD pixels would allow. So, a star that hit the dead center of a pixel would have some spread over adjacent pixels but would still look blocky. Small motions of the star on the CCD could keep it on the same pixels, but the relative brightness of the pixels would alter slightly based on exactly where the star was centered.

That effect can be seen here. On the top is a well-sampled shot taken from the Digitized Sky Survey and below are several undersampled versions in which the stars moved a bit prior to being sampled (on a simulated camera). Drizzle uses this information to not only align images, but also to create a higher resolution stack than you find in any individual image.

Here is a diagram from Andy Fruchter's page on Drizzle showing the technique. Each pixel in the original image is first reduced (from the red pixel size to the blue pixel size – this is the "pixfrac" or "pixel reduction factor" term). The pixels are then translated and rotated so that they will all be in the same position in the output image. You'll notice two things about the output image. First, the pixels in the output image are smaller than the original pixels. This is the "up-sample factor" – how much higher the output resolution is than the input resolution.

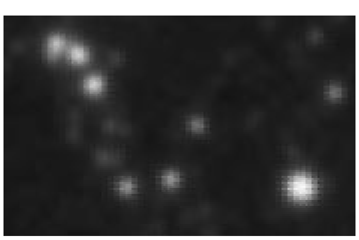


Second, these pixels will usually not line up perfectly with a pixel in the output image. Key to Drizzle is the fact that these "drops" (the blue pixels) fall onto the output pixels to the degree that they overlap. The value dropped by a blue pixel will fall a lot on one output pixel, a little on another, less still on a third, etc. Think of the output grid as having little wells (or spots on an ice-cube tray) for each output pixel and the water drop landing on a spot that hits multiple wells. As multiple images rain pixels down onto the output image, the output pixels fill up to the degree that input pixels line up with the output pixels.

That's the theory behind Drizzle. How does it work in *Nebulosity*? Images must be black and white or full-color (but not RAW) and pre-processed. There should also be some movement between images (e.g., if *Fixed combine of images* would make a blurry average). You'll also want to have a minimum of 8-10 images to work with as well and you should most likely have Normalized your images prior to stacking.

Drizzle requires two stars to be found in each image. First, find one star (left-clicking as in Align and Combine: Translation) in all the images (shift-left-click to skip an image, ctrl/command-left-click to keep the current guess). This first one will serve to let *Nebulosity* know how much translation is in each image. After you have selected the same star in each image, *Nebulosity* will loop back and ask you to find a second star in each image. A red target will appear over the first star to let you know what you picked the first time. Don't pick a star that's too close to the first one, as the second star lets *Nebulosity* know how much rotation is present. The further away it is, the more "leverage" you have.

Once the stars are picked, you'll be presented with a dialog asking you for a few parameters to give to Drizzle. It asks for the "Pixel Reduction" factor (how much smaller the pixels become before being transformed to the output grid) and the "Up-sample" factor (how much bigger the output image is than the input images).

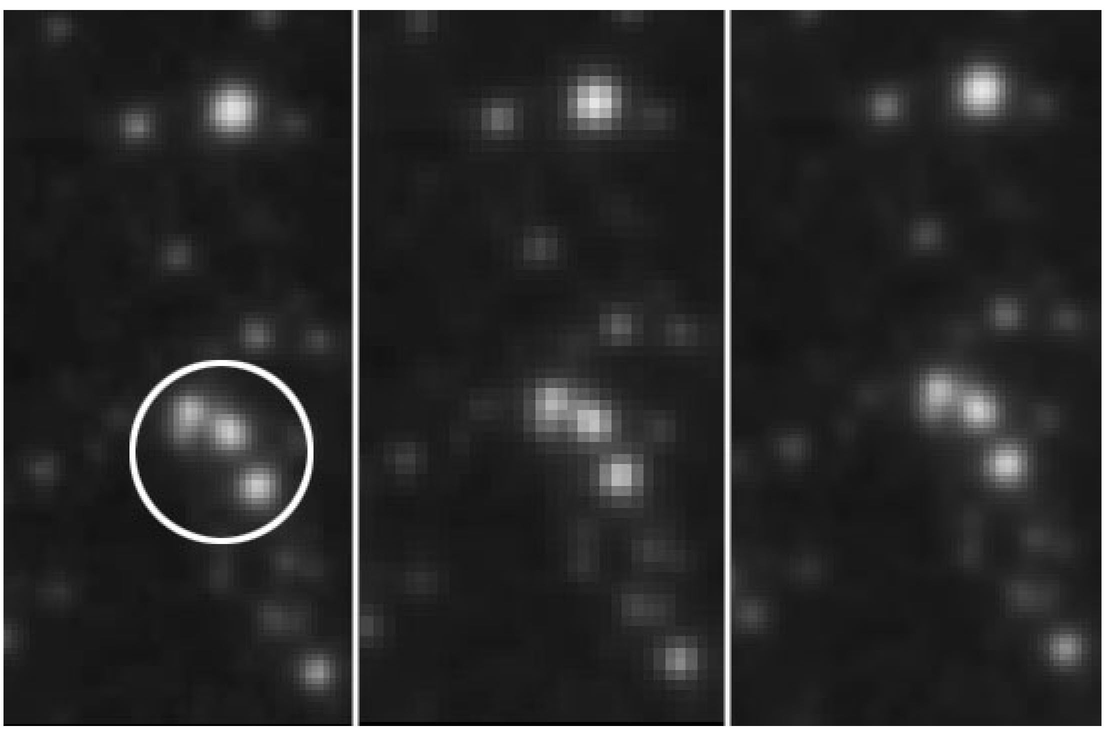


Typical pixel reduction factors range from 0.5-0.8 (0.6 is the default) and typical up-sample factors range from 1.2-2.5 (1.5 is the default). If you try to use very small pixel drops (e.g. a pixel reduction factor of 0.2) or very large up-sampling factors (e.g., 3.0), you risk leaving "holes" in the output image where no pixels dropped from an input image to the output image or other artifacts (right).

Finally, you'll be asked for an "Atomizer" value (default value of 2). This parameter lets you trade off speed and accuracy of the Drizzle process. Think of it as how fine a "mist" is being made out of each "drop". 1 is the fastest but is a bit less accurate and should not be used if you have a small number of images. 3 is the slowest but most accurate. 2 represents a good trade-off (and will rarely look any different than 3).

Be warned – Drizzle is computationally intensive. Be prepared to find something else to do for awhile after you've picked your stars.

Here is a shot of a small portion of a test image used to evaluate Drizzle. On the left, we have a single raw frame taken from the DSS again. This frame was shifted randomly and undersampled to create a stack of frames that where then aligned with either translation (middle) or Drizzle (right). For display here, each image is shown at the same scale. Note the separation of close stars recovered by Drizzle and its overall increase in resoution.



Colors in Motion (Simultaneous translation align + Color reconstruction)

Colors In Motion (CIM) is a tool developed for *Nebulosity* that combines the process of color reconstruction from one-shot color images, the alignment process, and the stacking process in one step. This is done not as a convenience to the user but to achieve a more accurate and higher resolution final image by doing these steps at the same time.

To use CIM you must have captured data in RAW format and *you need to have a sizable number of frames*. In addition, you should most likely have Normalized your images prior to stacking. Ten frames is the absolute minimum and it wants as many as possible (30-50 frames would be reasonable starting points). Data should be pre-processed first but not De-Mosaic'ed. Finally, your tracking should not be perfect. Good or excellent is fine, but perfect is not. If you can make a sharp image by stacking your frames without any alignment, don't bother trying CIM. If such a stack makes a blurry image, you're in great shape for CIM.

Using CIM is much like using the normal alignment process (see section 5.5). You will be asked to locate the same star in each of the images you wish to align (Ctrl-click after the first image to keep the star Nebulosity chose - Command-click on the Mac). Here too, you can skip any individual image by simply Shift-Left-Clicking anywhere in the image. After picking a common star in each, you are then prompted for a "CIM Threshold" (if you have at least 10 images). This threshold marks the dividing line between "Full CIM" and "Partial CIM" (Partial CIM blends a standard debayer version of the image with the CIM version of the image). 10 is a reasonable value (lower numbers will force more pixels to be Full CIM and higher numbers will force more pixels to be Partial CIM).

CIM is computationally intensive, so be prepared to wait awhile once you've told it where the common star is in each image. When it's done, you'll be asked for a file to save the results in.

Image Adjustment

While *Nebulosity* is notdesigned to be an advanced image processing application like PhotoShop or the GIMP, it does supply a number of purpose-built and very useful tools for adjusting your images (usually the result of stacking). These tools are located under the Image menu.

For any of these, if you decide you don't like the results, simply press ***Cancel*** or use the ***Undo*** command in the Image menu (or Ctrl-Z). By default you have 3 steps of Undo available, but with a quick trip to the Preferences menu, you can have unlimited Undos and Redos.

- Demosaic
- Reconstructing Images from One-shot Color Cameras and Line Filters
- Scale Intensity and Zero Min
- Bin / blur
- Vertical smoothing (deinterlacing)
- Crop
- Adjust Color Offset
- Adjust Color Scaling
- Discard Color
- Levels / Power Stretch
- Digital Development (DDP)
- Tighten Star Edges
- Show Pixel Stats and Image Info
- Measure Distance

Demosaic Image

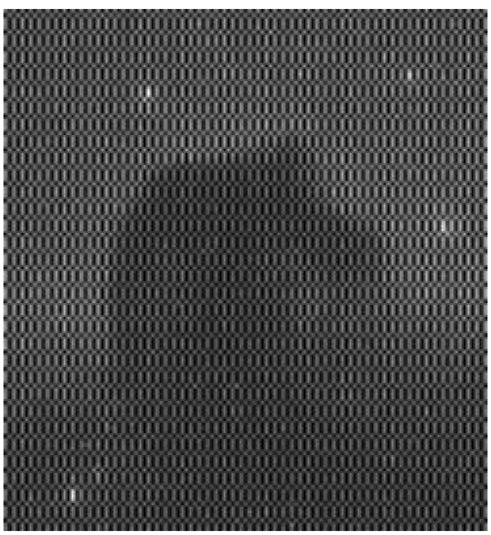
If you captured a one-shot color image in RAW format andwish to see it in full-color, use this tool. It will reconstruct the Raw imageand turn it into a full-color image for viewing or saving. There is also a **Batch** version of this tool that will allow you toDe-Mosaic a series of files. (Note, this should be done if you capture in RAWformat *after* pre-processing but *before* alignment).

It is also important to note that if you use a Canon DSLR, ideal color balance in *Nebulosity* will be accomplished if you select the appropriate setting under "DSLR White Balance / IR Filter" in the Preferences dialog.

Reconstructing Images from One-shot Color Cameras and Line Filters

In a previous section (see Monochromevs. Color?) a typical color filter array was shown for a one-shot colorcamera that uses red, green, and blue filters. If we place a "line filter" infront of such a camera, what happens? For example, suppose we placed anH-alpha filter in front of this array? Such filters pass light in a verynarrow range, centered on 656nm of "Hydrogen alpha". Emission nebulae emitlight specifically at this wavelength (and several others), so passing thislight and block all else can lead to an excellent way to image nebulae amidlight pollution and can lead to stunning images of these nebulae. Whenmultiple lines are imaged separately (e.g. one frame of Ha, one of O-III, etc)they can be combined into beautiful "false color" images.

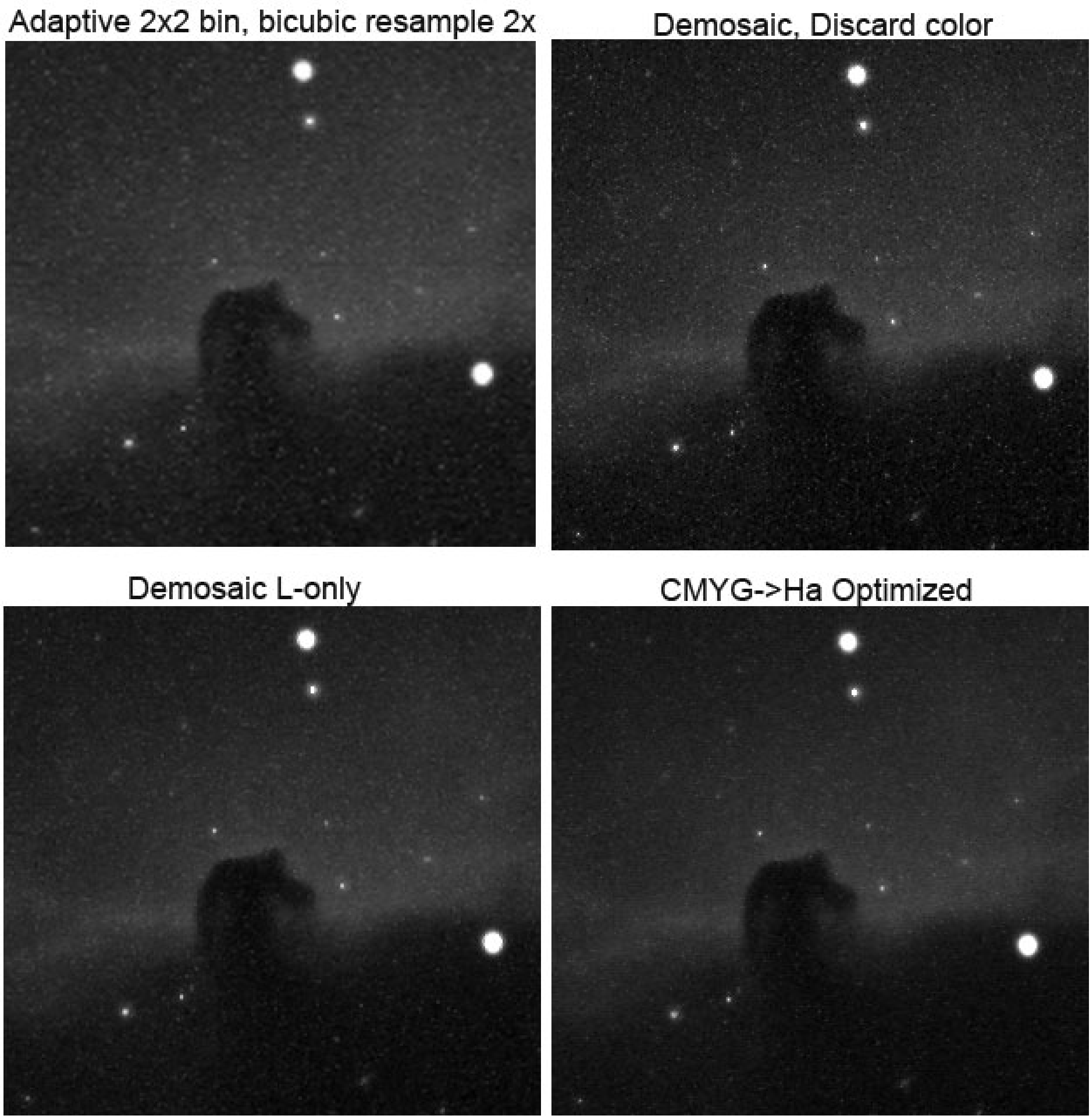
Typically, such imaging has been reserved for monochromecameras. The reason can be seen in that Bayer array. Photons that passthrough the Ha filter are well into the red area of the spectrum. As such,only the red pixels will get any light. The green and blue pixels will bedark. Thus, we have only 25% of our pixels doing anything and the others aremerely contributing noise. So, when reconstructing RAW data, one could takethe RAW data and use the Low Noise 2x2 Bin or Adaptive 2x2 Bin tools. This would create an imagehalf the size but would remove all evidence of the Bayer pattern. The onevalid red pixel would be averaged with the three invalid pixels in a local 2x2area and the result would be dominated by the red signal. One could also usethe normal debayer routine and simply use the Discard Color tool. This is acommon approach, but one that may not be optimal (see image below).



While we cannot escape the loss of resolution entirely,there are ways of improving how images are reconstructed on one-shot colorcameras when line filters are used. For example, when CMYG color arrays areused instead of RGB arrays, more pixels respond to Ha light (as is shown bythis shot with an Ha filter of the Horsehead nebula, courtesy of MichaelGarvin). Knowing this, and knowing how the pixels respond to this light canlet us optimize this reconstruction.

Nebulosity gives youseveral tools to do the reconstruction in addition to using the binning tools or the Discard Color tool. One is a "Generic" method that will do agood job on any line filter with any camera but is not optimized for anyspecific combination. A second is a reconstruction optimized for "nebula"filters and O-III filters that leak light in the Ha and beyond regions (e.g.,Televue, Meade, and Lumicon filters). This is also a rather genericreconstruction that will work well with a wide range of setups. Finally, forCMYG arrays, there are optimized reconstructions for Ha and pure O-III filters(e.g., Astronomik, Orion, and Custom

Scientific) that do not leak light in Haor higher wavelengths. A comparison of these techniques on the data from theHorsehead nebula taken on an Orion StarShoot's CMYG array is shown below.



Scale Intensity

You may find times at which your image does not take up thefull range the data provides or that you wish to re-scale the brightness of animage. For example, if you use the Adaptive Stacking (see Preferences)technique and have stacks taken with two different exposure durations, youmight want to rescale the intensity of one before combining them. Or, youmight simply want to brighten or darken the image. The Scale Intensity toollets you multiply each pixel by a value you specify. Enter 0.5 and your imageis half as bright. Enter 2.0 and it's twice as bright. When you pull downthis tool, several suggestions for scaling factors are given (e.g., to ensureyour data fits into 16-bits).

Zero Min

If the lowest pixel value in your image is at 20,000(resulting from a bright sky), why would you want to let the rest of your dataonly use the remaining 44,535 possible values when you save? You could have alot more "room" for a range of intensities if you shifted the whole imageintensity down by 20,000. This tool will do that automatically for you, by makingsubtracting the current minimum value from each pixel.

Binning

Images from some cameras (e.g., the SAC10) are quite largeand it can be useful to cut their size down (e.g., to post to the Web). *Nebulosity* lets you bin images 2x2, thus cutting the image sizein half. An added benefit of binning is that by combining data from 4 pixelsinto one, noise is reduced (much in the same way it is with stacking). Finally, one additional use of binning 2x2 is to remove all color informationfrom a RAW frame off a one-shot color camera. This turns the one-shot color camerainto something a lot closer to a monochrome camera.

Nebulosity gives you3 ways to bin your image. You can sum all 4 pixels (which will brighten theimage considerably), average all 4 pixels (which will keep the same brightness)or perform an adaptive bin. The adaptive bin will combine the data in a waybetween the summation and averaging, optimizing the combination so that thefull 0-65535 range is used.

Blurring

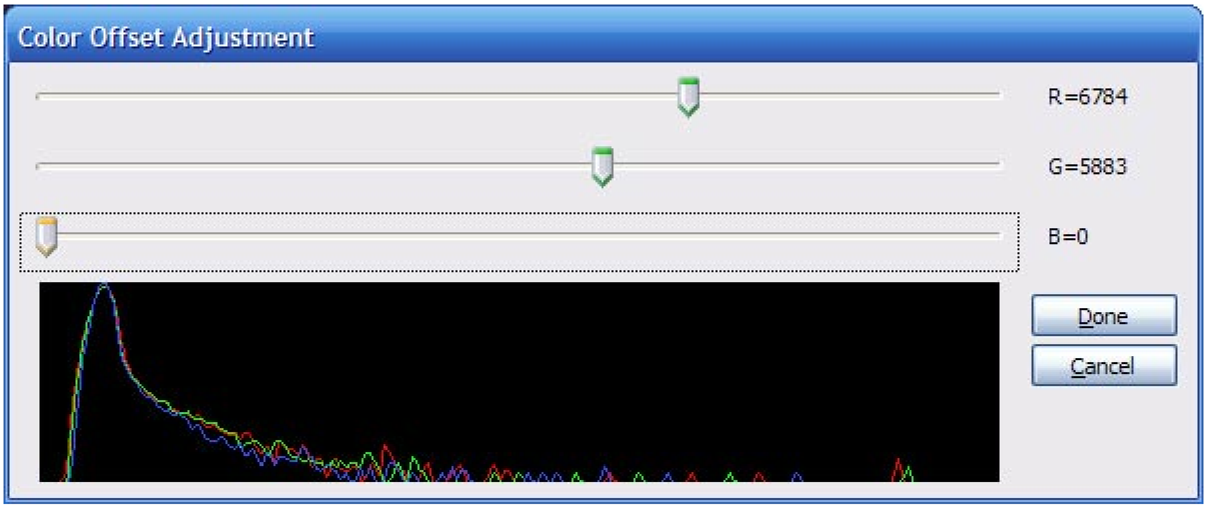
Nebulosity lets you apply a Gaussian blur to your image. This is another nice way of reducing noise. For example, prior to applying a flat frame to your image it can be useful to blur the flat first to reduce noise in the image. Three levels of blur are provided for.

Cropping

Usually, after stacking a series of images, you end up witha dark border in your stacked frame. This is because *Nebulosity* had to move all the images around to get them toline up and some needed to be moved further than others. To get rid of theseborders (or just to recompose your image), you can crop the image. To do so,simply drag a selection using the left mouse. Start in one corner and hold the mouse button down to create a selection box and let go when the box is the desired size. Once happy with the box, pull down *Crop* from the *Image* menu and you'll have cropped in on just that area.

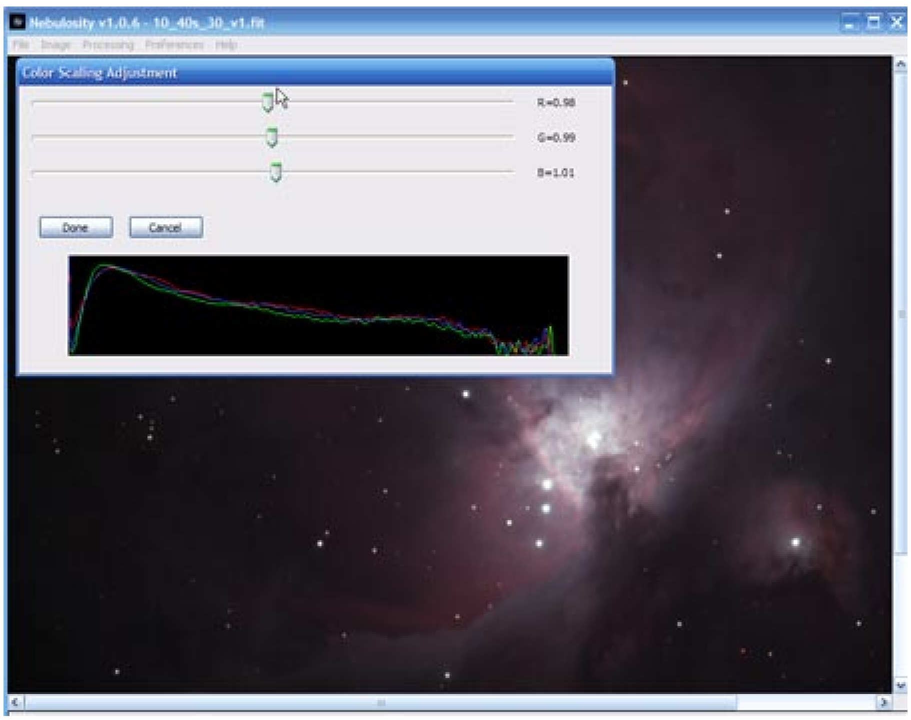
Adjust Color Offset

When taking images in color, it is often the case that thebackground has a slight color hue rather than being a neutral grey. This canbe the result of a color "bias" in the image – the minimum value in eachcolor channel not being the same. This can be fixed by subtracting a constantnumber from one or two of the color channels. The Adjust Color Offset toollets you do this. A dialog box will appear with sliders for red, green, andblue. *Nebulosity* will attempt todetermine reasonable values for the sliders when the dialog opens. The valuesyou enter here will be subtracted from the specified color channel(s). Forexample, sliding the Red slider to 1100 will not affect the green and blue databut will make every red value 1100 less than it was previously. A 3-colorhistogram is shown below the sliders to help in getting the offset just right. Aim to have the left edge of the histograms similar for all three colors. PressingCancel will revert back to the original image.



Adjust Color Scaling

In color imaging, it is often the case also that your colorchannels are not balanced in their scaling either. This is particularly truein using separate color filters in a black and white camera (if one does notperfectly adjust exposure duration to compensate for the varying transmissionof color filters and for the CCD's varying sensitivity to different colors) butcan occur in a one-shot color camera as well. The Adjust Color Scaling toollets you rescale the intensity of individual color channels much like the ScaleIntensity tool lets you rescale the intensity of the entire image. Setting theGreen slider to 1.05 would, for example, multiply the intensity of each pixel'sgreen component by 1.05. A 3-color histogram is shown below the sliders tohelp in getting the offset just right. Aim to get the histograms similar insize to color balance the image. Pressing Cancel will revert back to theoriginal image.



Discard Color

At times, one may want to take a color image and strip it ofall color information. This can be useful, for example, if you want to make aluminance (L) channel for image processing outside of *Nebulosity*. This tool does just that, converting your colorimage into a monochrome image (the average RGB value is used).

Levels / Power Stretch

The Levels / Power Stretch tool is a very versatile anduseful tool. Once you have combined a number of images, you'll likely noticethat your sky is still bright and the DSO is quite possibly still dim. Overall, the combined shot looks little like the wonderful shots you see postedon the Internet, even by others with the same camera. The problem is that eventhough you've combined many images, your skyglow and DSO are still at the samebasic levels they were at initially. Combining images does not make the resultany brighter than the original. What it does, though, is to make the result *cleaner* than the original. So, if your skyglow had been at10,000 ± 2,000 it may now be at 10,000 ± 100. If the faint bits of your DSOwere at 11,000 ± 2,000, they may now be at 11,000 ± 100. If we were to set theblack level of the image (just with the slider) up to 10,000 the sky would goquite black and your DSO would remain.

The **Levels / Power Stretch** tool lets you do this and quite a lot more. When run, it presents youwith three sliders and a window showing your image histogram (see below). One slidersets the black level and another sets the white level. The third sets the"power" (or middle slider in a "levels" tool). Leaving the power at 1.0 performs a "linear stretch" of the data. Setting the power below 1.0 will tend to brighten the fainter bits of theimage. Setting it above 1.0 will tend to darken the fainter bits and brightenthe already brighter bits. What it is doing is computingfor each pixel:

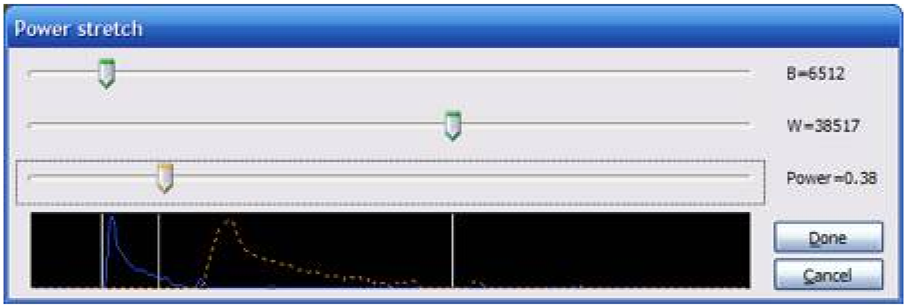
$new\_value = original\_value^{power}$

At the same time, it is stretching the data so that theoutput ranges between the values set by the black and the white level sliders. You can see its effect in the histogram window. Here, the initial histogram isshown in blue and the output, or resulting histogram is shown as a dashedorange line. In the example shown below, you can clearly see the histogrambeing stretched to pull out interesting bits in the data.

Many users are more familiar witha Levels tool. Infact, it is mathematically identical to a Levels tool. Here, the "power"setting is directly related to the "midtone" setting in a typical Levels tool. (In fact, the industry-leading Adobe® PhotoShop® reports a value in its Levelstool between the black and white points that varies with the midtone level andthat is 1/power). To assist in using it this way, the black-point, midtone,and white-point lines are superimposed on the histogram. As is typically shownin a Levels tool, these lines show where in the original histogram (blue line)the black (left line), midtone (middle line) and white (right line) points lie. You will note that as you move the power slider, the midtone's positionrelative to the white and black points will move, but that it often won't beplaced directly under the slider. This is entirely normal. If you wish tothink in terms of setting the midtone level of the image, adjust the powerslider until the middle line (slightly darker than the other two) is at thedesired place in the histogram.

There are a few things to note. First, if Auto-Scale is turned on prior to entering the Levels tool, it will be turned off and the B and W sliders set at their full extent. This is to show you how much of the full data range you are using and to encourage you to stretch the image to use that full range. (If not in Auto-Scale mode, the sliders are not moved).

Second, the Levels tool can be quite computationally taxing on your computer, especially if you are working with very large images. To make the adjustments more responsive, try defining a region of interest (ROI) with the mouse (just as when cropping) before entering Levels. You will preview the adjustments on this region only. When you hit OK, the same adjustment will be done to the whole image.



Note: The histogram shown here is based on the luminance values of the image. This may lead to clipping of the data if you have not already balanced the color channels. Balance reasonably before stretching and/or keep an eye on the histogram shown in the main window (which is computed based on all color values).

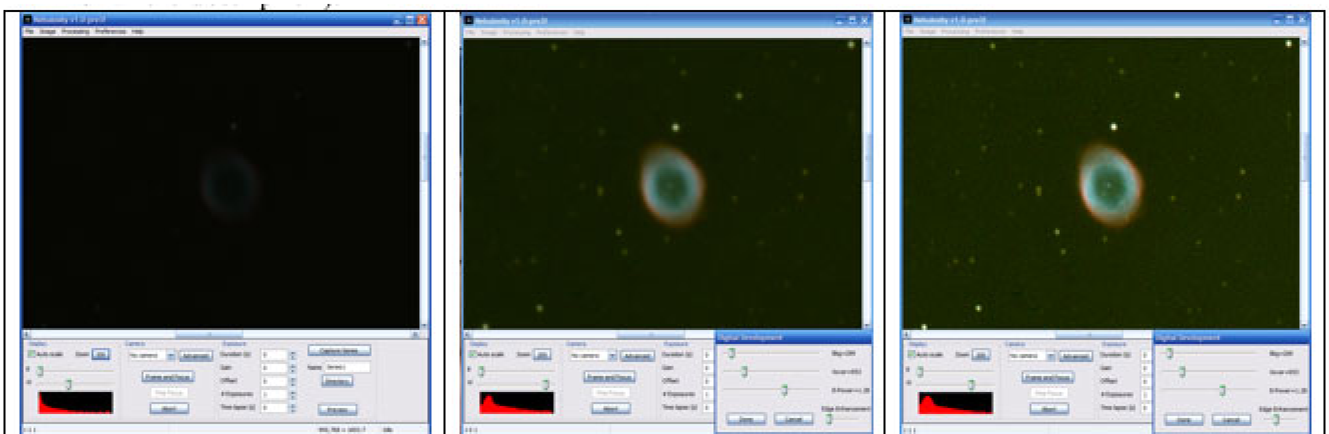
Take your shot and try setting the power to 0.3 – 0.8and then sliding the white and black levels. You should notice that the faintbits of your DSO start to appear and become a lot more prominent. Quite often,optimal results are obtained by using this tool multiple times. Each time,make only moderate adjustments to the image and don't worry about getting yourbackground very dark the first time or so through. Gradually hone in on yourdesired image. Don't worry about the fact that you're doing this multipletimes and that it might cause problems with the image range or values. Remember, *Nebulosity* does everything in32-bit floating point numbers(96-bits per pixel total) internally. Adjust and re-adjust as you see fit.

Digital Development Processing (DDP)

DigitalDevelopment Processing (DDP) is a technique developed by K. Okano to makeCCD images look more like film images. Like the Power Stretch tool, it helpsbring out faint detail in the image and helps suppress skyglow. Okano'stechnique passes a hyperbolic function to the data to make the linear CCDresponse much more like the S-shaped "gamma" response of film.

When you select Digital Development, four sliders arepresented. Default parameters for each are pre-selected.

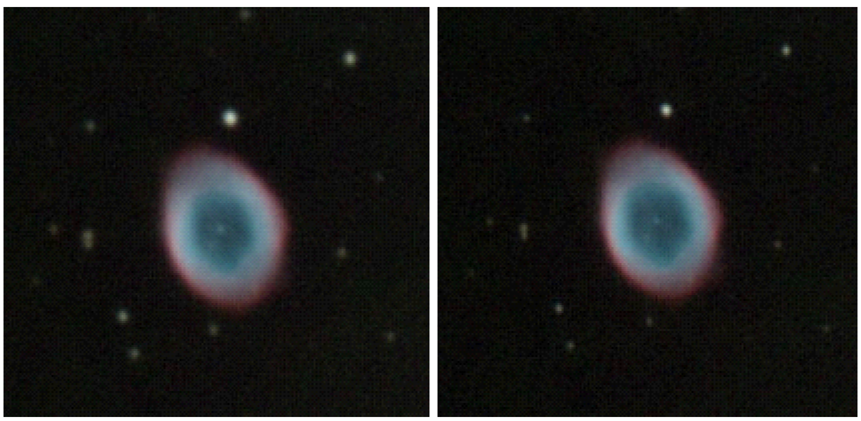
The first slider, labeled *Bkg* sets a level for the background in the output image (Okano's *b* parameter). The second slider, labeled *Xover* sets the cross-over point (where the transformationshifts from a linear to a curved one – Okano's *a* parameter). The third slider, labeled *B-power* provides a method for darkening the backgroundduring the DDP process (not in Okano's description but may be set to 0 for apure DDP processing). Finally, the fourth slider, labeled *EdgeEnhancement* controls the amount ofsharpening done during the DDP process (part of Okano's description).



Unprocessed	DDP, No edge enhancement	DDP with Edge enhancement

Sharpening and Tighten Star Edges

Often, lack of precise focus or seeing will end up makingyour images slightly blurry. There are numerous techniques astro-imagers haveused to fix this. Standard "sharpen" or "unsharp mask" techniques can beuseful, and two such techniques are included. These can be prone to over-sharpening the image, highlightingnoise, and leaving black halos around stars. *Nebulosity* provides a tool that takes a different approach to the problem. TheTighten Star Edges tool first examines your image and performs an edgedetection analysis using a modified version of the Sobel Edge Detector (modified to work better with our round stars than the traditional Sobel).These edges are then subtracted from your image to yield tighter stars andenhanced edges. Note, this is not the same kind of edge enhancement doneduring DDP processing.



This is a shot of M57 as acquired (left) and afterthe Tighten Star Edge tool using the default parameters. Using the slider thatappears when you run this tool (located in the Image menu), you can adjust thedegree of edge enhancement applied.

Measure Distance

Knowing how far apart several stars are can be quite useful. You can use it to calculate the effects of focal reducers (measuring thedistance between stars in prime-focus and reduced images) or to say, "Hey isthis pair of stars on my image really that pair of stars in the atlas?" TheMeasure Distance tool lets you do this.

First, select up to 3 stars in your image by simplyright-clicking on them in the image. The first will get a red circle aroundit, the second a green, and the third a blue. If you make an error, eitherShift-R-Click to erase all points or keep selecting stars (you'll cycle back tored after blue). Next, pull down *Measure Distance* from the *Image* menu. You'll be asked for the resolution of the image in arc-secondsper pixel. (If you don't know, simply use 1.0 as a value and all values willbe in CCD pixels or see *Your Telescope*). A window will then appear showing you thedistance from red to green and, if three points were selected, green to blueand red to blue.

Supported Cameras

Nebulosity supports a wide range of cameras on both Windows and OS X. They are:

- Canon DIGIC II DSLRs: EOS 1D/1Ds Mk II/Mk IIN, 1Ds Mk II, 20D/20Da, 350D / Rebel XT, 5D, 30D, 400D / Rebel XTi). See here for more details.
- Fishcamp Starfish
- Meade DSI, DSI Pro, DSI II, and DSI II Pro.
- SBIG (see below)
- Starlight Xpress SXV / SXVF USB cameras (see below)

In addition, on Windows, the following cameras are supported

- Atik 16 series (all) / Artemis 429/285 cameras
- CCD Labs Q8-HR
- Opticstar DS-335
- Orion StarShoot Deep-Space Color Imager
- SAC10
- SAC7 / SC1 long-exposure modified webcams / Atik 1 and Atik 2 cameras. See here for more details

Camera-specific notes

Canon DSLRs

See here.

SBIG

All SBIG cameras should be supported by SBIG's Universal Driver. This must be installed first (see SBIG's website if you have not already used SBIG's software on your computer). On Windows and OS X, USB and Ethernet versions are supported. On Windows, but not OS X, parallel port models are supported. Note, however, that if you SBIG is a dual-chip model, the guide chip will not be available to any other program when the camera is in use in *Nebulosity*. Also, only 2x2 binning is supported.

Long-exposure webcams and SAC7

See here

Starlight Xpress

USB-based "SXV" and "SXVF" cameras are supported. Earlier SX USB-based cameras may work, but may require updates to the camera's firmware or driver from the Starlight Xpress website.

The "Fast" mode available on the M (and MX) cameras is enganged whenever "High Speed mode" is selected in the Advanced Panel. On these cameras, short exposures are done via the "Interlaced" mode and longer exposures (generally ~1s or longer) are done via the "Progressive" mode. 2x2 binning is supported, but other bin modes are not.

Canon DIGIC II DSLRs

The Canon DIGIC II-based DLSRs are supportedin *Nebulosity* on both the Windows and Mac OS X platforms. These include the following models:

- EOS 1D / 1Ds Mk II and Mk IIN
- EOS 20D / 20Da
- EOS 350D / Rebel XT
- EOS 5D
- EOS 30D
- EOS 400D / Rebel XTi

Note, older DIGIC I-based cameras (D30/60, 1D, 10D, and 300D) are currently not supported (a different Canon driver is required for these cameras).

The supported DSLRs act much as any one-shot color astronomical camera would in *Nebulosity*. Via the Preferences, you can opt to acquire images in pure RAW (Bayer-matrix images that have not been converted to color yet), or in RGB, choosing whether you wish to optimize speed (high-quality JPEG images are downloaded from the camera) or quality (the RAW image is downloaded, the Bayer matrix extracted, and *Nebulosity's* Demosiac routines are applied). RAW Bayer-matrix images are the best choice when the highest quality is desired as they allow you to pre-process the images *before* conversion into color, and the color conversion (Demosaicing) is done using *Nebulosity's* best routines.

Likewise, features such as Frame and Focus and Fine Focus are fully supported as well. Gain conrol is supported (ISO values reported), but note that Offset is not adjustable on thse cameras. Whether RAW or RGB images are collected, data are saved in FITS format (color images are linearly stretched to 16-bits, while RAW Bayer-matrix data are kept as 12-bits).

There are several key things to note about the Canon DSLRs, however.

White balance

One cannot read a setting on the camera that lets you know if the camera uses a stock IR filter or if it has been modified to have an extended-IR response (e.g. using a Baader IR filter or a Huetech filter). Color reconstruction must be done differently if an extended-IR filter is used, however. To ensure accurate color, make sure you have made the appropriate selection in the Preferences, Processing, DSLR White balance / IR filter section. *Note, that if you see pink cores to saturated areas, try the Straight Color Scale option.*

Long exposures / bulb triggers

The Canon DLSRs are limited to 30s exposures when the camera's internal timing is used. If you connect the USB cable to the camera and your computer and this is your only connection, you will be limited to 30 seconds of exposure. To achieve longer exposures, some form of "bulb adapter cable" is required . Various forms of this exist to drive the camera's "bulb" setting from USB, serial, or parallel ports on your computer. ***If you use one of these to allow you longer exposures you must also keep the USB data cable connected*** (i.e. you will have two cables connected).

In the Preferences menu, you will find options to let you choose your long-exposure cable setup. Nebulosity supports the following:

- ShoeString DSUSB USB adapter (PC and Mac)
- Serial port adapters (COM1-8) such as Hap Griffen's (PC and Mac)
- Parallel port adapters (Pin 2 or Pin 3 on ports 0x378, 0x278, and 0x3BC) such as Hap Griffen's (PC only)

Note: Not all USB->Serial adapters will work as we need direct control over several data pins on the serial port. Generally, those that require a driver disk will be more likely to work (tested with inexpensive Prolific-based adapters and Keyspan adapters).

Note: Select your long-exposure adapter prior to connecting to the camera. *Nebulosity* attempts to connect to the long-exposure adapter when it connects to the camera itself.

Mirror lockup

The DIGIC II cameras all support a mirror-lockup mode. When enabled, pressing the shutter button once lifts the mirror and pressing it a second time triggers the exposure. Enabling this mode involves entering your camera's Tools menu and finding the appropriate Custom Function (CFn) - usually either 12 or 7, selecting and enabling this prior to connecting to the camera in *Nebulosity*. *Nebulosity* has no way to set this mode itself, but it can detect if the camera is in mirror-lockup mode and, if so, will send the appropriate shutter pulse prior to the main exposure.

Note: For Mirror-Lockup mode to be used, you must have a long-exposure cable selected and attached. Mirror-lockup cannot be used in USB-only mode.

Troubleshooting Connections

There are several steps to take to ensure *Nebulosity* will connect to your camera.

1. Ensure that the USB data cable is connected (in addition to any long-exposure "bulb" cable) and that the camera did not decide to shut itself off from inactivity (once connected, *Nebulosity* will keep it turned on)
2. Ensure that your camera drivers (from the Canon CD) have been installed on your computer.
3. Verify that the EOS utility is installed and that it connects to the camera and can be used to control the camera.
4. Ensure that the camera is set to communicate (Menu, Tools, Communication) to the computer in "PC Connection" mode.

SAC7 and Long Exposure Webcams

The SAC7 and other cameras based on long-exposuremodifications to webcams according to the work of Steve Chambers (otherwiseknown as "SC-modified" webcams) are supportedin *Nebulosity*. There are a few thingsto note, however.

First, these cameras can either be used directly when attached to a parallel port (you'll need to know the "port number") or via a USB port. Many modern computers lack a parallelport or only include one that is derived from an internal USB-Parallel adapter. Unfortunately, these adapters do not make the right signals for the cameras tooperate. ShoeStringAstronomy has devised an excellent solution with their "LXUSB" product. This plugs into a USB port and, when controlled by *Nebulosity*, will make signals that can be used to fully controlthese cameras. Thus, cameras like the SAC7 can now be used on machines thatonly have USB ports and that do not have a parallel port at all!

Second, these cameras typically have two modes – a"short exposure" mode and a "long exposure" mode. In short exposure mode, thecamera's own controls adjust the exposure duration (typically 1/25thof a second or shorter) via a pop-up window. In long exposure mode, theprogram (such as *Nebulosity*) controlsthe exposure duration.

In *Nebulosity*, shortexposure mode is selected by setting the exposure duration to 0. Anythinggreater than zero will put the camera into long exposure mode. In shortexposure mode, the shutter speed is controlled via a pop-up window. Press theAdvanced button in the Camera panel and you'll get a slightly different versionof the Advanced dialog described above. You'll find *Setup* and *Format* buttons that let you configure the resolution, shutter speed, gain,frame rate, etc.

Note: For the best images in both short and long exposure modes, always set the frame rate to a low setting such as 5 FPS. This minimizes the amount of compression your images undergo. Do this in the Advanced Dialog using the Setup and Format buttons

In addition to these buttons, the Advanced Dialog has oneadded section for these cameras. A "Read delay" can be entered. The defaultvalue should work on most systems but if you find you are dropping frames, tryadjusting this value (5 ms increments will be good). System speed andspecifics of your camera may dictate a slightly different value (10ms –30ms for a typical range).

Camera Advanced Panel

If you click on the **Advanced** button in the Camera panel, a dialog box will appear that lets you setvarious advanced controls on the camera. Some of the options may be grayedout. If so, this means either that the current camera does not support thisfeature or that some other feature is preventing it from being activated. Below is a description of the available options.

- *Amp off*: Checking this box will have the CCD camera's amplifier turned off during the exposure. This amplifier, when on causes "amp glow" – a brightening usually in one corner of the image. Rarely would you ever want to uncheck this box.
- *Double Read*: This option enables a feature designed to fix the "interlacing artifact" found on interline transfer CCDs like the SAC10 and Orion StarShoot. You'll notice each exposure takes twice as long but that you end up with a smoother image. This option is particularly useful for shorter exposures where the problem is worse (4 seconds of read time is a lot in comparison to a 2 second exposure but not much in comparison to a 5 minute exposure). If you're working with bright objects or short exposures, you'll want to use this or the VBE option.
- *High speed read*: If selected, the camera will read the image off the CCD more rapidly but at the expense of increasing the noise. This is enabled by default during Frame and Focus but is not to be used for DSO imaging. *Selecting both* High speed read *and* Double Read *is an excellent way to take good planetary or lunar shots.*
- *Binning*: Selecting this option will put the camera into a binned mode whereby pixels are combined during the CCD readout itself. This increases sensitivity at the cost of resolution and, at times, at the cost of color on one-shot color cameras.
- *Oversample*: If selected the camera will sample and convert the information from the CCD twice. The net result is a less noisy image, but one that takes a bit longer to read and process.
- *VBE balance color exp times: (SAC10 only)* This feature attempts to fix the same problem addressed by the Double Read option (the problem is sometimes called the Venetian Blind Effect), but to do so with a single exposure. It intelligently balances the intensity of the odd and even lines and can be quite useful for shorter exposures.

Taking Good Images

You didn't buy a camera to take dim, noisy, fuzzy images,yet chances are quite decent that's what you could get your first night out. How do those pros make such good images? This guide won't make you a pro, butit will at least get you started in the right direction. For help on any ofthese, consider joining the SAC Yahoo Group.

Your Telescope

CCD cameras are not as forgiving as your eye and can be usedto reveal any flaws you have in your telescope. It's time to make sure it's ingood shape by checking:

1. Is it well collimated?
2. Can yourigidly mount the camera to it or is there play in the focuser or attachment?
3. Have yougot a good handle on dew prevention? (The author has more than once taken along series of exposures only to realize he was shooting through a solid layerof due on the telescope objective.)
4. Is itwell-matched to the camera?

This last is, in and of itself, a rather lengthy topicwith some disagreement as to what is the absolute best match, but a few thingscan be agreed on. The most critical aspect of this is to determine just howmuch sky each pixel covers using your telescope. That can be done with thefollowing simple formula:

Arc-secondsper pixel = 206,265 * *pixel_size* / *focal_length*

For maximum resolution, withperfect tracking (see below) and excellent seeing, a value of 1"/pixel is agood target (some pros go to smaller values still). For more typicalconditions with good seeing and good tracking, 2"/pixel is another fine target. Larger amounts of sky covered per pixel will let you cover more sky and willnot stress your mount's guiding accuracy as much (see below), making values of3-6"/pixel quite reasonable for many situations. In so doing, you are tradingoff extreme resolution for wider swaths of sky and less difficulty guiding.

From this formula, you can seethat there are two ways to adjust the final resolution in your image. You caneither adjust the pixel size of the camera or you can adjust the focal lengthof your telescope. Neither seem trivial at first glance and, while they can beadjusted, it is only to a limited degree. (Telescope focal length can beshorted with a focal reducer and lengthened with a Barlow. CCD pixel size canbe effectively increased by binning.) Thus, determining what telescope to usefor a given camera or *vice versa* isoften best done before purchase.

So, what telescope focal length isgood for a SAC camera? That depends on the camera. The SAC9 has an effectivepixel size of 0.01 mm and the SAC10 has a pixel size of 0.0034 mm. Put the2000mm focal length of an 8" f/10 in there and you see the SAC9 is at1.04"/pixel and the SAC10 is at 0.36"/pixel. Put a 650 mm focal lengthtelescope in there and the SAC9 is at 3.2"/pixel while the SAC10 is at1.1"/pixel. The SAC10 clearly favors shorter focal length telescopes. Ifyou've got an SCT, go get a focal reducer.

Your Mount

A number of aspects about your mount will affect the qualityof your images. Here, we'll talk about accurate polar alignment and aboutperiodic error and guiding.

Note: To see how much your mount is moving betweenimages, right-click on a star to lay down a "target" circle around it. Thistarget will remain in the same place on the image across captures, and let yousee how far that star has moved.

Polar Alignment

If you've got an equatorial mount, aiming at Polaris withthe RA and DEC zeroed will get you somewhat close to polar alignment but notclose enough for imaging. Using a polar alignment scope on yourequatorial mount or using your GOTO mount's alignment procedure will get youcloser. But, neither will get you spot-on enough for long-exposurework. To do that, you've got two main options:

1) Drift alignment. In this technique, you watch howstars drift through the field and adjust your mount accordingly. For astandard equatorial mount, this is your best bet. It takes a bit ofpractice, but, once you know what you're doing, it'll take about 30 minutes toget a decent drift alignment – decent enough for the kind of exposuresyou'll be able to do without guiding anyway. Others have done a good jobdescribing the technique, including a site by Bruce Johnston orone by Scott Tucker.

2) Iterative alignment. If you have a GOTO scope, youowe it to yourself to learn how to do this. I can get a nice alignmentthat won't drift (well, periodic error of course, but no overall drift) for anhour worth of imaging in about 5-10 minutes of work. There are several sitesthat go over the method (e.g. Bradley Hope's, Philip Perkins', MichaelCovington's, etc), but the basic idea is very simple.

First, do a "one star" alignment – the kind in whichthe scope aims itself towards where Polaris should be (using the Kochab clockif that makes sense to you) and then asks you to adjust the mount physically tocenter Polaris. After centering Polaris, the scope slews over to a singlestar and asks you to use the keypad controls to center that other star. At this point, you're close and have done the standard "one star" alignment.

Now, tell the scope to GOTO Polaris. Adjust the mountphysically to remove about half the error between where it ended up and wherePolaris actually is (i.e., have it aim to the spot about halfway between theGOTO and Polaris). Now, do a GOTO back to your alignment star, center,and SYNC to that star. Repeat a few times until your GOTOs on Polaris endup without any error and you're good to go!

Periodic Error and Guiding

Now that your scope is polar aligned, the stars won't driftacross the field *on average*. You'llstill notice that they will rock back and forth a bit – sometimes veryslowly and sometimes in abrupt jumps. This is called *periodic error* and caused by minor imperfections in your mount's *wormgear* – a cylindrical gear thatactually turns the telescope to counteract the earth's rotation. No worm gearis perfect, but some have bigger problems than others. If you don't choose toguide your telescope during imaging, these imperfections will limit how longyou'll be able to expose each image. Exactly how long you can go will dependon the size of the periodic error and the amount of sky covered by each CCDpixel. Wide-angle shots with 10"/pixel are a lot more tolerant of periodicerror than zoomed-in shots at 1"/pixel.

Many amateurs run shots unguided and end up stacking many15-40s long exposures into one long image. With enough images, and with theright exposure settings (see below), this can be used to make very nice images.

But, what can you do to lengthen this time or to fix theproblem entirely? Several mounts offer *Periodic Error Correction (PEC)*. On these mounts, you train the telescope to knowwhat the error is like by following a single star and correcting the errorsusing the telescope's controller. The mount then learns these corrections andapplies them automatically. This can reduce the error quite a bit.

A second technique, often used on its own or in conjunctionwith periodic error correction is guiding. Here, an image of a star is sent toeither an eyepiece (*manual guiding*) or asecond camera (*autoguiding*) whileyour main imaging camera collects pictures. Two approaches are taken. In one,an *Off-Axis Guider* is used tosplit some of the light away from the main camera and towards this eyepiece orsecond camera. A small prism is placed so that the light split off is lightthat would not have fallen on your main imaging camera anyway. In a second,another telescope (a *guide telescope*)is attached to the imaging telescope. In both, this second view of a star isused to determine when the telescope is drifting slightly off target and tocorrect this problem by sending very small movement commands to the mount.

Many packages are out there to help you autoguide your mount. A free one from Stark Labs, *PHD Guiding* , works well on a wide range of cameras and mounts and is designed to be "Push Here Dummy" simple. Its goal is to make it so that you have little excuse for not trying autoguiding.

Focus

Getting your camera sharply focused is critical to takinggood pictures. The Frame and Focus routine will get you close, but will oftennot get you to as sharp a focus as you could get. For this, you'll want tomake sure you're using the full Preview mode or the Fine Focus mode, makingonly small adjustments to your focus between each shot.

You can evaluate your focus by simple visual inspection orby calculating several statistics about a star. In particular, when a star isin focus, it will get more of its light on a central CCD pixel than when out offocus. The Fine Focus tool offers an excellent focus aid that will help you achieve critical focus.

In addition to these techniques, there are a few others youcan try. One technique is to build or buy a Hartman Mask, a diffraction mask,or a modification of the Hartman Mask. They're not tough to build – manyconsist of cutouts in pieces of cardboard and one is assembled out ofTinkerToys (no, really). All work by having you place something in front ofthe scope during focusing. When the star is nice and sharp, the artifactsinduced by each disappear (e.g., the multiple circles you'd see with theHartman mask converge into one).

A second technique to try is to use the fact that in focusstars get more of their light on the CCD than out of focus stars. When in focus,you'll be able to see stars in the Preview or even Frame and Focus that woulddisappear when out of focus. Adjust the exposure duration or gain until youcan just barely see a star. Adjust the focus to see if you can make itbrighter or if it disappears on either side of where you are right now (or, ifyou know you're a bit out, make the star disappear with the duration or gainand reappear with the focus knob).

Exposure settings

When taking images, there are a few simple rules to followthat will let you collect frames that can be used to make a nice final picture.

Rule #1: Use the Histogram to keep your background abovethe floor and bright bits below the *ceiling.*

First, you should always try to expose images so that thebackground sky is "off the floor" and the stars (or at least the cores of theDSOs) are "off the ceiling". What this means is that you don't want largeparts of your image to have values of zero or of 65535 (the minimum and maximumpossible values). Any time a pixel has either of these values, we've lostinformation. For example, let's say a star is at 65535 and one next to it isreally twice as bright. Both get recorded at 65535 and the final image doesn'tshow a difference between the two. Once we've reached this maximum, we simplycan't go any higher and so important details (such as the difference betweenthese stars) are lost.

The same holds true on the dim end. Let's say a faint armof a galaxy is just barely brighter than the skyglow around it (a very commonsituation). If your background sky is recorded as zero, quite possibly thefaint bit of the galaxy is at zero as well. No matter how many images youstack, if they all have zero in them, you'll never be able to find that dimgalaxy arm in your image.

How do you do this? The exposure duration is the mostobvious method. Longer exposures will brighten the image (moving the histogramto the right). In addition, the increasing the gain and offset controls willalso brighten the image. Both will add more noise into the image, but a littlebit more noise is a lot better to have than ultra-black backgrounds. If you'rerunning unguided images, you'll likely use higher values of gain and offsetthan those running guided.

Rule #2: Take lots of images

Every image you take has noise in it. So, adding imagestogether adds noise into the image, right? Yes and no. If you compare a stackof 20 exposures of 30-second each to one exposure of 10 minutes, the singlelonger exposure will quite probably be a cleaner looking shot. But, if youcompare one of the 30-second long images to the combination of all 20exposures, the combination or "stack" of images will have a lot less noise init than the single frame.

Why is this? Much of the noise in our images is *uncorrelated* or *white*noise. What this means is that each time we sample something (e.g., each timewe take an image), we get some noise added into the image that has nothing todo with the amount of noise added in the last time we took the image. (Hotpixels and readout noise are examples of *correlated* noise and are addressed in dark frames and biasframes respectively).

When we combine multiple images, this uncorrelated noisestarts to disappear. Four 30-second exposures will have half the noise of asingle 30-second exposure (noise follows a 1/sqrt(N) function where N is thenumber of images you combine). One hundred such frames will have one tenth asmuch noise (and therefore 10x the SNR). Reducing the noise allows one to"stretch" the image to make a very fine distinction between dim portions of aDSO and the skyglow that is just the tiniest bit darker than the DSO (this willalways be the case – its just a question of how small that differenceis.)

Rule #3: Don't over-tax your mount

If your mount can only take exposures of 30-seconds beforeshowing tracking errors on most exposures, don't try going any longer than30-seconds until you can guide your mount (*PHD Guiding* from Stark Labs is free and tries to make this as painless as possible). Take Rule #1 and Rule #2 to heart and gathermany noisier shots. Each one may look pretty bad and it may look like you'llnever get a good image out of your efforts. Don't despair. I've had many niceshots come out of raw frames that look like noise with barely a hint of any DSOin there much less a nice smooth one.

Menu Reference

File Menu

- *Open File*: Loads any FITS (color or B&W, compressed or not, 8-64 bits, integers, floating points, you name it), PNG, TIFF, JPG, or BMP file into memory and display. 8-bit/color files are automatically stretched to full range.
- *Save current file (FITS)*: Saves the currently displayed image in FITS format using 16-bit integers (0-65,535). Compression set by *Preferences*, *Save as compressed FITS.*
- *Preview Files*: Opens a dialog that lets you preview a set of files, deleting and renaming them as desired. Useful for filtering images and for quick looks at files.
- *Save BMP file as displayed*: Saves the currently displayed image in Windows BMP (bitmap) format. The values of the black and white sliders set the black and white levels in this, since BMP format is only 8-bits / color. How it looks is how it will save.
- *Save JPG file as displayed*: Like Save BMP, but in JPEG format. Any JPEG quality / compression (0-100) factor possible.
- *Save 16-bit/color TIFF*: Saves the current image in TIFF format (lossless compressed or uncompressed) at full 16-bit/color (aka 48-bit color) bit depth. This preserves all information in your image for use in graphics programs
- *Save 16-bit/color PNG*: Saves the current image in PNG format (always lossless compression) at full 16-bit/color (aka 48-bit color) bit depth. This preserves all information in your image for use in graphics programs
- *Save Color Components*: Saves the current color frame as three separate FITS files corresponding to the the red, green, and blue components of the image.
- *Batch convert FITS to PNG*: Convert multiple files from FITS format (color or B&W) into 16/48-bits PNG format for use in other programs.
- *Batch convert image files to FITS*: Convert multiple graphics image files (PNG, TIFF, BMP, JPG) to FITS format for processing in *Nebulosity*.
- *Edit / Create Script:* Open a window that allows you to create a capture script and load / edit an existing script.
- *Run Script*: Run a capture script, automating the image capture process
- *Calibrate for auto-offsets*: Calibrate your camera so that *Nebulosity* can automatically set the optimal offset value. See Automatic Offset.
- *Preferences*: Set various preferences. See Preferences.
- *Exit*: Exit the program

Image Menu (see also the Image Adjustment section)

- *De-Mosaic*: Convert a single RAW CCD image currently displayed from a one-shot color camera into a full-color image. Faster and better quality modes available.
- *Square B&W pixels*: Squares pixels from black and white images.
- *One-shot color with line filters*: Tools for reconstructing a RAW image taken with line filters (e.g., Ha, Hb, OIII) from a one-shot color camera are provided along with a special Low Noise 2x2 bin optimized for these cameras.
- *Scale Intensity*: Multiply each pixel in an image by a user-specified constant to shift the overall intensity.
- *Zero Min*: Add or subtract a constant from the current image so that its minimum will be zero.
- *Bin/Blur Image*: Perform 2x2 binning using simple summation, simple averaging, or an adaptive algorithm. These reduce your image size by 2x. Or, blur your image with your choice of 3 levels of blur (Gaussian kernel sigma=1-3).
- *Sharpen Image*: Three tools are provided. Traditional and Laplacian sharpen tools based on 3x3 kernels are provided along with the *Tighten Star Edge* tool. This applies an edge-detection routine (not a typical "sharpen" or "unsharp mask") to tighten stars and enhance edges in your image.
- *Mirror/Rotate Image*: Tools are provided for 90 and 180 degree rotation and for mirroring an image horizontally or vertically.
- *Resize Image*: Resample the image to change its size using any one of 6 different resampling algorithms (Box, Bilinear, B-Spline, Bicubic (Mitchell & Netravali), Catmull-Rom spline, & Lanczos sinc)
- *Crop*: Resize the image by removing or trimming unwanted edges.
- *Adjust Color Offset*: Subtract user-specified values from the red, green, and blue color channels to balance the color of the background in the image.
- *Adjust Color Scaling*: Apply a user-controlled scaling to the red, green, and blue color channels separately to help balance the image.
- *Discard Color*: Remove all color information from an image (extract the luminance data)
- *Levels / Power Stretch*: Apply a user-controlled stretch routine to the current image. You can use this much in the same way a Levels tool is used to bring out details in the image.
- *Digital Development*: Apply a user-controlled stretch routine to the current image designed to make CCD images look more like film images. An excellent way to bring out faint detail in your images.
- *Show Pixel Stats*: Opens a pop-up window that shows the intensity (I), red (R), green (G), and blue (B) values under the current pixel, the min, mean, and max in a box 21x21 pixels big (+/- 10 pixels) around the current pixel, and the min, mean, and max of the entire image. If there is a star near the

cursor, it will also report the FWHM of the star (how wide it is) and any shift between the peak value of the star and the center based on the FWHM. You can keep this dialog up as long as you like and continue to work in *Nebulosity*. As the mouse moves around or as new images are acquired, the window will update itself.

- *Show Image Info*: Shows information about the current image including its size and the various capture parameters that either were stored in the FITS header or will be stored when the image is saved.
- *Measure Distance*: Measure the distance in CCD pixels, arc-seconds, and arc-minutes among up to 3 points in the image (right-click to set points first).
- *Undo*: Undo the last change to your image. Undo will let you step back from any changes made by tools in the Image menu. By default, you can take 3 steps back. You can opt to disable Undo in the Preferences menu (to run a bit faster) or to have virtually unlimited undo capability.
- *Redo*: Think you liked it better with that processing you just undid? Redo.

Processing Menu (see also the Pre-Processing section)

- *Batch Demosaic + Square RAW Color* and *Batch Square BW*: Batch versions of the tools found in the Image menu.
- *Grade Image Quality*: Grade a set of images to determine the sharpest (and fuzziest) of the set.
- *Normalize Intensities*: Normalize all images in a set to remove offset and scaling differences.
- *Pre-process color images*: Apply traditional dark frame, flat frame, and bias frame corrections to correct for typical CCD artifacts. Apply these corrections to a series of full-color images (RGB FITS files).
- *Pre-process BW/RAW images*: Apply traditional dark frame, flat frame, and bias frame corrections to correct for typical CCD artifacts. Apply these corrections to a series of either black and white (monochrome CCD) images or to RAW images from a one-shot color camera (e.g., the SAC-10) prior to De-Mosaic color reconstruction.
- *Bad Pixels*: Create a map of the bad pixels on your CCD and/or apply that map to remove hot pixels.
- *Align and Combine*: Align and (optionally) combine a series of images. A dialog will appear to let you control the method. Methods include: Fixed (no alignment), Translation ("one star", full-pixel shifts), Translation + Rotation (subpixel, including rotation such as with an alt-az mount), Translation + Rotation + Scaling (same, but including a scaling term), Drizzle, and Colors in Motion. For Fixed alignment, Standard Deviation based stacking is an option.
- *LRGB Color Synthesis*: Create a color image from separate files using RGB, traditional HSI-based LRGB, or Color Ratio based LRGB

Help Menu

- *About*: Display program and version information
- *Show Help*: Display this manual
- *Check web for updates*: Connect to the Stark Labs website and check for updates. If an update is available, the Release Notes will be shown and you will be given the opportunity to visit the Stark Labs website to download the new version.

Preferences

Capture

- *Use msec not seconds*: All times specified in milliseconds rather than seconds
- *Use auto-offset if available*: Use a camera-specific set of measurements taken during the Automatic Offset calibration if such measurements are available.
- *Enable Big Status Display during capture*: During series captures, the progress will be displayed in a pop-up dialog for easy viewing if you've left the computer unattended.
- *Color acquisition mode*: When taking images with a one-shot color camera, what should be done about converting them to full-color?
    - *RAW CCD data*: Do no reconstruction and keep the data as RAW CCD data. When saved, one FITS file with the raw data from the CCD (effectively a black and white image that contains the color information) will be saved. You will likely want to De-Mosaic the image prior to alignment and stacking or use Colors in Motion.
    - *RGB Optimize speed*: Do color reconstruction on the fly during image acquisition and try to go for the fastest good color reconstruction at the expense of a bit of quality.
    - *RGB Optimize quality*: Do color reconstruction on the fly during image acquisition and try to go for the highest quality color reconstruction at the expense of a bit of speed.
- *DSLR Long Exposure Adapter*: Without a "bulb" adapter cable ("USB only, 30s max"), you will be limited to 30 second exposures. Here, select which long-exposure adapter you have. Please make this selection before connecting to the camera.

Output

- *Save as compressed FITS*: FITS files are saved in lossless compressed FITS format to save space with no loss of data integrity (default). Note, however, that some applications do not support this aspect of the FITS standard.
- *Save in 32-bit floating point*: FITS files are saved in the 32-bit floating point format used internally to ensure no possible loss of data resolution at a cost of files being twice as large
- *Use 15-bits (0-32767) instead of 16-bits*: FITS files are saved in data ranging from 0-32767 rather than 0-65,535 if this is selected. Some programs (e.g., Iris) require this format.
- *Color file format*: When saving full-color data from a one-shot color CCD camera (e.g., the SAC-10), this preference controls how the color data are to be saved.
    - *RGB FITS - ImagesPlus*: One FITS file with red, green, and blue components of a reconstructed (de-mosaic'ed) full-color image stored inside in the style expected by ImagesPlus (separate "HDU" per color) (default).
    - *RGB FITS – Maxim / AstroArt*: One FITS file with red, green, and blue components of a

reconstructed (de-mosaic'ed) full-color image stored inside in the style expected by Maxim DL and AstroArt (a "3-axis" or "3D" image with color along the third axis).

  - *3 FITS files*: Reconstruct the full color image and save the red, green, and blue data in three separate files. This should only be used if *Nebulosity* is not to be the primary pre-processing application and if the application to be used does not support RGB FITS (e.g., Iris).

Processing

- *Use adaptive stacking*: For the stacking techniques that you use on your light frames (Translation, Drizzle, Colors in Motion), the image will automatically have the intensity scaled to use the full range of the 16-bit file format used. Adding images and averaging images each have their strengths and weaknesses. The Adaptive stacking technique side-steps the weaknesses of each and lets you get the most out of your data. The only downside is that a stack of 30s images and a stack of 3m images would appear equally "bright" after stacking this way.
- *Undo / Redo settings*: You can opt for either no undo capability (to run faster and save hard disk space), 3 steps worth of undo (default), or virtually unlimited undo capacity.
- *Manually override color reconstruction*: Typically, Nebulosity will attempt to determine what kind of camera a one-shot color file comes from and set the various demosaic options automatically. At times, you may wish to override this automatic behavior and specify offsets, array types, color mixing, etc. manually. Enabling this preference will bring the manual color reconstruction dialog up each time so that you can override any automatic behavior.
- *DSLR White Balance / IR filter*: Ideally, the pixels are white balanced prior to actually implementing the demosaic of a RAW image. For most cameras, this white balance is known *a priori*, but DSLRs can be stock or modified. Choose the setting here that best corresponds to your camera setup. Note, that at times, if there are severely saturated areas, this may lead to a pink area in the saturated zones. If this occurs, the Straight Color Scale option can be used.

Misc

- *Clock settings*: In the control panel, *Nebulosity* can display a small clock that will show the current time in a range of time formats or show the CCD's current temperature. The time formats all use your computer's internal clock as the starting point and convert that into other times. Note that local sidereal time and Polaris RA depend on *Nebulosity* knowing your longitude.
  - *No clock:* Hide the clock
  - *Local time*: The current local time
  - *UT/GMT time*: The current Universal Time (or Greenwich Mean Time)
  - *GMT Sidereal*: GMST or Greenwich Mean Sidereal Time
  - *Local sidereal*: The current local sidereal time (useful in finding objects with setting circles)
  - *Polaris RA*: Polaris' current right ascension (useful in using polar alignment scopes)

    - *CCD Temperature*: Current temperature of the CCD in centigrade. Will display "N/A" during image capture.

- *Longitude*: Local sidereal and Polaris RA require knowing your current longitude. Enter it in decimal notation (e.g., -77.1 not H:M:S) with west (e.g., USA locations) being negative.

Scripts

Nebulosity providesyou with the ability to automate your capture process by using scripts. Scripts are simple text files that list a series of commands for *Nebulosity* to perform in sequence. For example, the scriptshown here would set the output directory to be \ccd\Oct22_05 on your "C" drive(usually the letter associated with your hard drive). If the directory didn'texist, Nebulosity would attempt to create it. It would set the output filename to be "m27", the duration to be 2s (2000 ms), the gain to be 18, theoffset to be 28 and then capture 10 images in a series (m27_1.fit, m27_2.fit,etc). It would then pause and alert the user to "Setup for darks" (i.e., placethe lenscap over the telescope). After the user hits OK, it would then capture10 dark frames (dark_1.fit, etc.)

```
SetDirectory c:\ccd\Oct22_05SetName m27SetDuration 2000SetGain
18SetOffset 28Capture 10PromptOK Setup for darksSetName darksCapture 10
```

Nebulosity 's scripts can be created dynamically using the clipboard's operating system. If commands are placed on the clipboard and *Nebulosity* is in a special "Listen" mode, it will suspend reading commands from the script file and instead read them from the clipboard. This allows other programs to dynamically control *Nebulosity's* actions. Full list of Commands

You can write scripts in any text editor (save in "ASCIItext" format) or in *Nebulosity's*built-in editor. Simply pull-down Create / Edit Script from the File menu. Here, you can start typing commands or load an existing script. When done,you'll likely want to save your script (Save button) and then press Done. Standard Windows shortcuts for copy (Ctrl-C), cut (Ctrl-X), and Paste (Ctrl-V)work within the editor window.

When you're ready to execute the script, simply pull downRun Script from the File menu. *Nebulosity*will then first verify that it's a valid script. Then, it will go through lineby line, executing each command until it reaches the end of the file. As itdoes so, the Status bar will keep you apprised of what *Nebulosity* is currently doing. Pressing the Abort button willcancel the script at any time.

Note: Commands act just as if you were to do them in the GUI. So, if you've already set something in the GUI or if it is the default, there is no need to enter it in the script. For example, since the default is to have the CCD amplifier control enabled (so that the amp is off during exposure), there is no need to write "SetAmplifierControl 1" *in every script you write.*

Tip: Script files can contain extra spaces or blank lines if you want to make them look cleaner when writing them. Nebulosity will simply skip any extra spaces or lines it finds.

Tip: If you want to place a "comment" to yourself in a script, simply put a "#" character at the beginning of the line. Nebulosity will ignore that whole line. For example:

```
   # Script used to capture data on 10/22/05      SetName         M51
      ...
```

Tip: You can execute scripts at startup by passing the script name as a command-line argument. For example "nebulosity script.neb" will automatically execute script.neb

Full Command List

The following is the list of commands recognized by *Nebulosity*. They are presented here capitalized to help showyou the meaning of the command, but *Nebulosity* ignores the case of all commands. So, "SetName" isthe same as "setname" and "SeTNAme".

Each command must be placed on aseparate line and each line must have a command and a parameter with at leastone space between the command and the parameter. When the list shows theparameter to be N, it means a number should be provided as the parameter. Whenthe list shows the parameter to be S, it means a string (aka text) should beprovided as the parameter.

Capture Setup Commands

These commands mirror the controls present in the ControlPanel and several of the settings available in the Preferences menu.

- **SetName** S - Sets the base filename to be S
- **SetDirectory** S - Sets the capture directory to be S
- **SetGain** N - Sets the camera gain to be N
- **SetOffset** N - Sets the camera offset to be N
- **SetDuration** N - Sets the exposure duration to N milliseconds
- **SetTimelapse** N - Sets the time lapse to be N milliseconds
- **SetColorFormat** N - Sets the color file format used when (and if) full-color images are written. 0: RGB FITS in ImagesPlus format. 1: RGB FITS in Maxim / AstroArt format. 2: 3 separate FITS files.
- **SetAcqMode** N - Sets the color acquisition mode. 0: RAW or BW images. 1: RGB Optimize speed. 2: RGB Optimize quality.

Control Commands

These commands control the capturing process itself and letyou interact with the user.

- **Capture** N - Captures a series with N images according to the current settings.
- **PromptOK** S - Displays S on the screen and prompts the user to hit OK or Cancel. If OK is hit, the script continues. If Cancel is hit, the script is stopped.
- **Delay** N - Pause execution for N milliseconds
- **SetBLevel** N and **SetWLevel** N - Sets the B and W slider levels to N. If N = -1, auto-scaling is turned on.
- **Connect** N - Connect to camera N

1. None
2. Simulator
3. StarShoot
4. SAC10
5. LE Webcam (LXUSB)
6. LE Webcam (Parallel)
7. Artemis 285 (Atik 16HR)
8. Artemis 285C (Atik 16HRC)
9. Artemis 429 (Atik 16)
10. Artemis 429C (Atik 16C)
11. Canon DSLR
12. Reserved
13. Meade DSI
14. Fishcamp Starfish
15. Starlight Xpress SXV
16. SBIG
17. CCD Labs Q8-HR
18. Atik 16IC
19. Atik 16IC Color

- **Listen** N - Enable (1) or disable (0) listening to commands from the clipboard. Each command on the clipboard must start with "/NEB". For example, "/NEB Listen 0" on the clipboard will return processing to the script file.
- **Exit** N - Wait N milliseconds and then exit the program

Advanced Camera Control Commands

These commands have the same function as the Advanced cameradialog box, allowing you to override the current settings shown in the dialog. See Section 6 (Camera Advanced Panel) for more details on each. If the camerais not capable of the command given in the script, the command is ignored.

- **SetAmpControl** N - 1: Amplifier control is enabled and the CCD amp is off during exposures. 0: Amplifier control is disabled and the CCD amp is on during exposures.

- **SetHighSpeed** N - 1: Enable high speed readout mode. 0: Disable high speed readout mode.
- **SetBinning** N - 1: Enable binning. 0: Disable binning.
- **SetOversample** N - 1: Enable CCD oversampling. 0: Disable CCD oversampling.
- **SetDoubleRead** N - 1: Enable double-read mode. 0: Disable double-read mode