Chapter 1

Welcome to DSLR Astrophotography

Digital single-lens reflex (DSLR) cameras are an unusually cost-effective way to photograph the sky. The lower-cost DSLRs marketed to amateur photographers perform almost identically to the high-end professional models.

Unlike compact digital cameras and smartphones, the DSLR is designed for versatility and performance. It has a larger sensor, giving higher sensitivity to light and lower noise; interchangeable lenses, with the ability to couple to telescopes and other optical instruments; and full manual control.

Besides ready-to-view JPEG files, DSLRs also deliver "raw" image files that indicate the number of photons that reached each pixel. With raw files, you can subtract out the brightness of the sky background, correct for measured irregularities in the sensor, and combine multiple exposures of the same subject. These capabilities make the DSLR a powerful tool for photographing faint celestial objects.

By accumulating faint light, DSLRs can capture views of the sky that cannot be seen by human eyes in any telescope. Consider for example Figure 1.1. This is a six-minute exposure of the Andromeda Galaxy, with the contrast and brightness adjusted in *Photoshop* as if it were a daytime photograph; no special processing of raw files was done.

No telescope can give you that view. The reason is that the human eye cannot accumulate light. The outer parts of the galaxy are too dim for the eye to see, and telescopes don't make extended objects (surfaces) brighter. (If they did, sailors would hurt their eyes using telescopes to view distant ships on a sunny day.) Even with a telescope, the eye can see the spiral arms of the galaxy only faintly, under ideal conditions. By accumulating light and subtracting out the background glow of the suburban sky, the DSLR made the spiral arms clearly visible under conditions that were far from ideal.

As you move past the beginner stage, you can do just as much computer control and image enhancement with a DSLR as with an astronomical CCD camera. Some astrophotographers bring a laptop computer into the field and run their

Canon's nomenclature can confuse you. The EOS Digital Rebel, EOS Kiss, and EOS 300D are the same camera (one of the first good, affordable DSLRs), but the EOS 300 and EOS Rebel are film cameras from an earlier era. The EOS 200D, on the other hand, is one of the newest DSLRs, much newer than the 300D. The EOS 30D is a good DSLR from about a decade ago, but the EOS D30 is an early DSLR from before Canon developed sensors suitable for astronomy. And so on. If you want to buy a secondhand camera, pay attention to the names.

Pentax, Sony, Olympus, and other DSLR makers are highly respected but have not achieved as large a following among astrophotographers, and I have not tested their products. Sony makes the sensors for Nikon and several other brands (not Canon), although of course the firmware and internal image processing are different. Pentax K-series DSLRs reportedly have better deep-red (hydrogen-alpha) sensitivity than other non-astronomical DSLRs, though I have not tested this; also, Pentax has an interesting feature called the Astrotracer (see below) for fixed-tripod star-field images. Before buying any camera, you should search the Web and get astrophotographers' opinions of it; also make sure its file formats and camera interface are supported by astrophotography software.

1.3.2 Camera Features

Live View: *Practically Essential*

The most important feature to look for in a DSLR is **Live View** (live focusing), the ability to view the image on the screen while you focus the camera. Normally the live view image can be magnified ×5 and ×10, so you can judge it very carefully.

Live View was introduced experimentally on the Canon 20Da (not 20D) in 2005 and soon became standard on almost all DSLRs. It made a lot of other focusing techniques obsolete. Before then, we did our best to focus in the viewfinder, usually with a magnifier such as the Canon Angle Finder. Then, to confirm focus, we took 5-second test exposures and viewed them magnified or downloaded them to a computer. We put various kinds of masks in front of the telescope to exaggerate the effect of focusing error so we could judge it more easily. No more! Viewing an actual star image at pixel resolution is all we need.

Flip-out (Vari-angle) Screen: *Useful*

Although professional DSLRs don't have it because it's not considered rugged, a **flip-out screen** is very handy to have. It enables you to focus and adjust a DSLR that is aimed up at the sky without having to crouch under it. The alternative is to view the screen with a small hand-held mirror (Figure 3.5).

Electronic First-curtain Shutter: *Useful for Lunar and Planetary Work*

Considerably less essential, but useful if you have it, is **electronic first-curtain shutter** (EFCS), a vibration-saving feature that is very helpful with still pictures

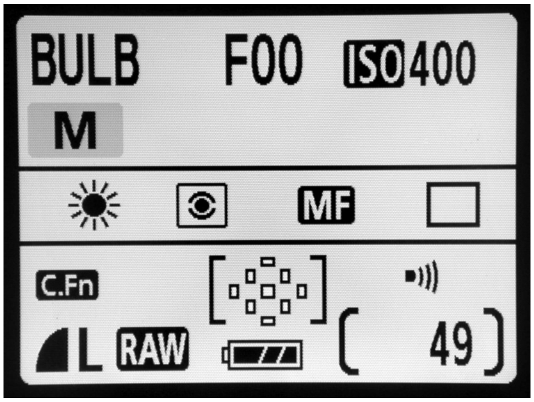


Figure 3.1. Display panel of a Canon XTi (400D) set up for deep-sky photography. *F00* means the lens is not electronic and the camera cannot determine the *f*-stop. *C.Fn* means custom functions are set.

Figure 3.2. For manual control of shutter and aperture, set mode dial to M.

set the aperture. It will generally be displayed as $f/0$ or F00. Nikons may also display a blinking question mark indicating a lack of electronic communication with the lens. You can still take pictures; the computer inside the camera just doesn't know what the aperture is.

3.1.2 Manual Focusing

In astrophotography, you must always focus manually; autofocus doesn't work on celestial objects. You must also *tell* the camera you want to focus manually,

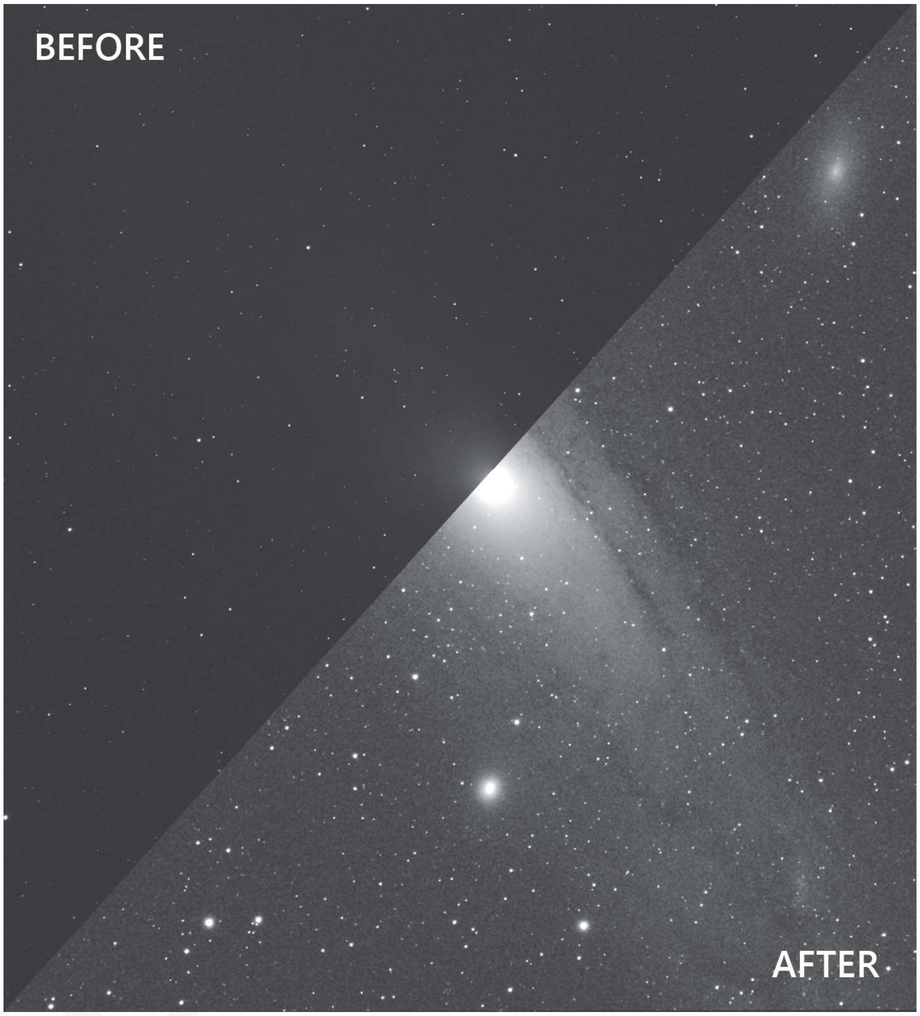


Figure 4.5. Stretching is often necessary to make an astronomical image viewable. (Telescope image of M31, before and after stretching.)

A few minutes of playing with this adjustment will teach you more than I could by writing ten more pages. For best results, do it in several steps rather than trying to get everything exactly right at once. Don't be afraid to move the middle slider a *long* way to the left to bring out deep-sky detail. To color-balance your image, you can adjust red, green, or blue separately from the other colors. Once you've mastered stretching, you'll find yourself using it (more subtly, of course) in your daytime photography too.

If you're going to do substantial stretching, it's best to start with a raw image from the camera, rather than a JPEG file, because of its greater bit depth, but if all you have is a JPEG, you can still use stretching effectively.

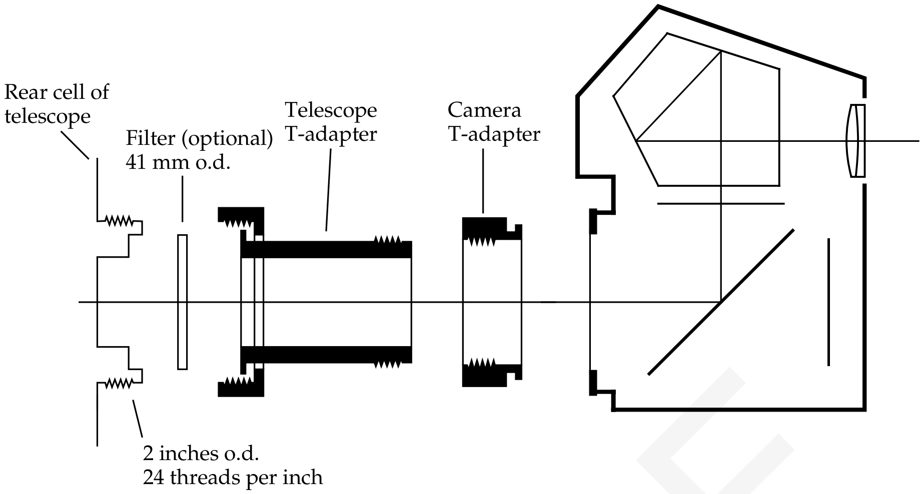


Figure 6.11. Schmidt–Cassegrains have a threaded rear cell and accept a matching T-adapter.

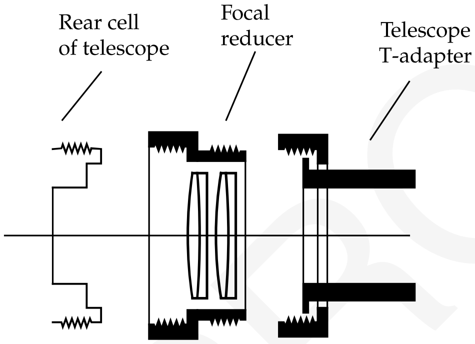


Figure 6.12. Meade or Celestron focal reducer screws onto rear cell of telescope.

the outer part; do this if your camera ends up upside down or tilted and there is nowhere else to make the correction.

You can get a simple eyepiece-tube adapter that screws into the T-ring (Figure 6.10) or a telescope T-adapter for other types of telescopes (Figure 6.11). Here you'll encounter the other screw coupling that is common with telescopes, the classic Celestron rear cell, which is 2 inches in diameter and has 24 threads per inch. Meade adopted the same system, and telescope accessories have been made with this type of threading for over 30 years. In particular, that's how the Meade and Celestron focal reducers attach to the telescope (Fig. 6.12).

Besides these common adapters, there are also adapters for many other configurations; check the catalogs or web sites of major telescope dealers. In particular, there are 48-mm T-rings for cameras with full-frame sensors, and other adapters that fit them.

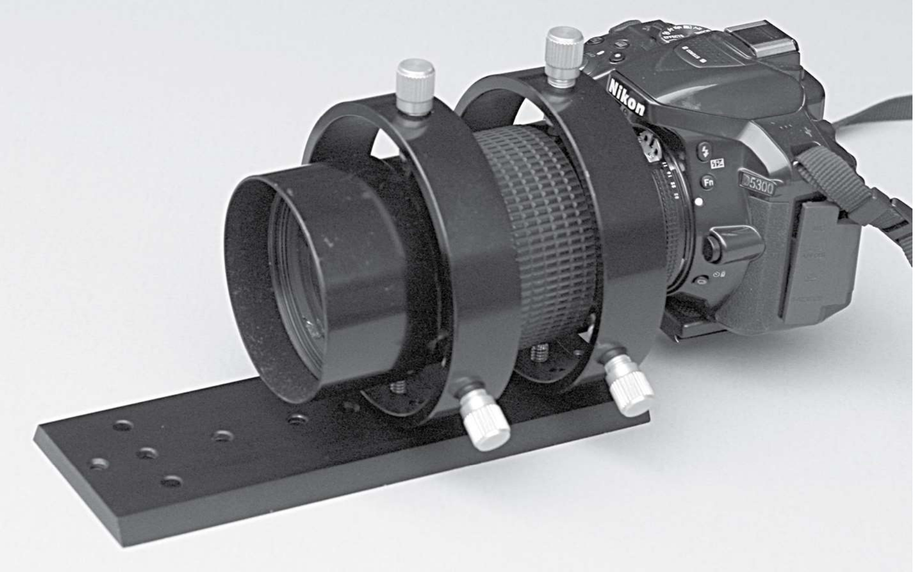


Figure 7.10. Some lenses can be mounted in rings like a small refractor. With this lens, the front ring screws cannot be tightened until after focusing. Take care not to de-center the front of the lens.

Figure 7.11. Homemade tripod collar for Nikon 180/2.8 AF lens consists of wooden block with large round hole, slot and bolt to allow tightening, and a 1/4″-20 threaded insert on the underside.

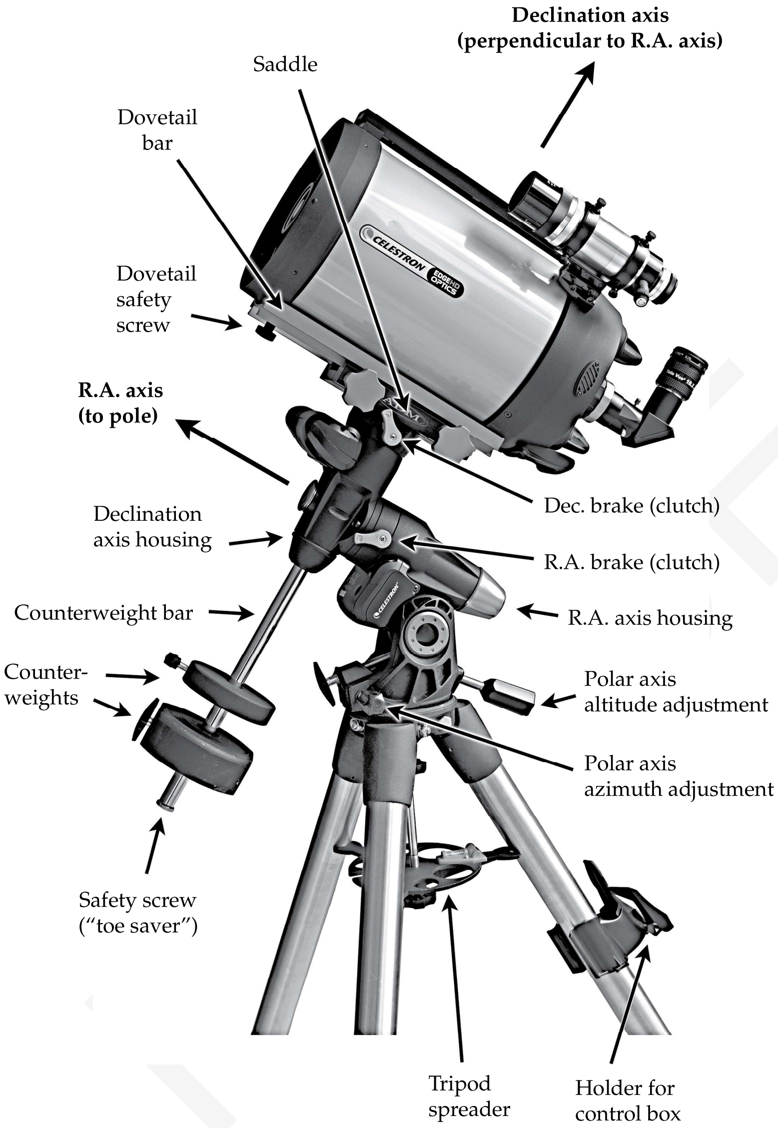
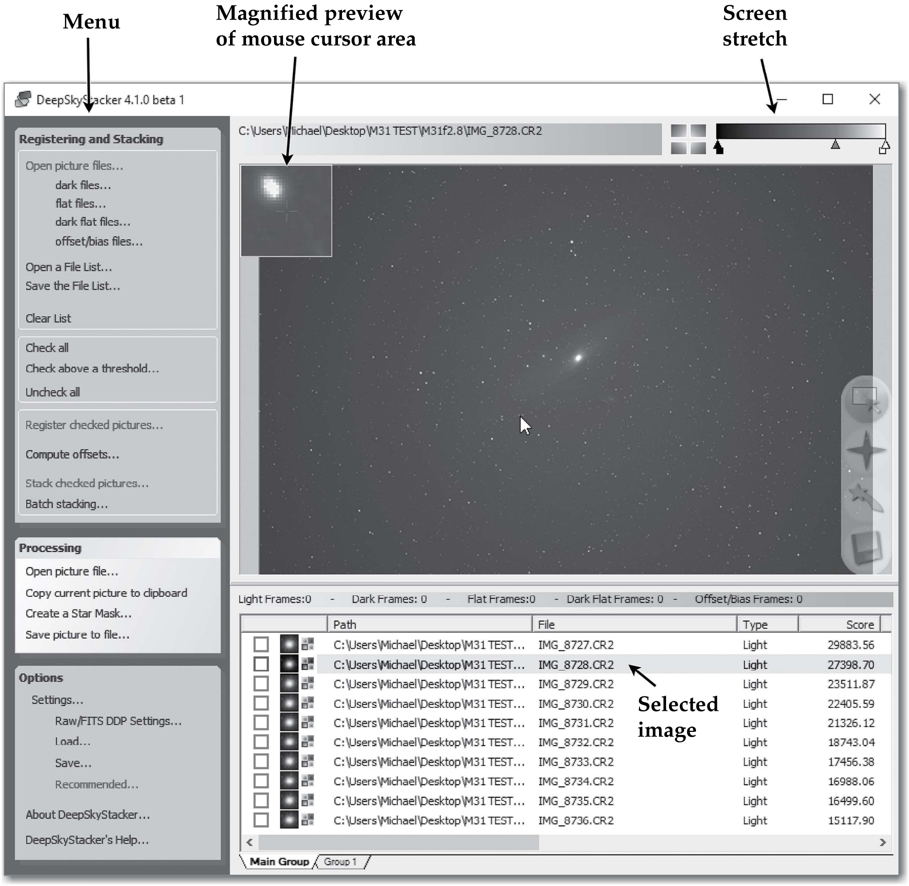


Figure 8.6. One of the author's present setups, with Celestron AVX mount, ADM saddle, and Celestron and iOptron counterweights. Cables and control box omitted for clarity. This is a visual configuration; for guided photography, this telescope requires a larger mount.

with it, it cannot swing around to cover the entire sky without bumping into the tripod or pier. In particular, it cannot track a celestial object across the meridian for more than a short distance (maybe as much as an hour's worth of terrestrial rotation, but not more). The solution is to "flip" the telescope by aiming it at the pole, rotating 180° eastward in right ascension, and then aiming it at the object again. When this is done, pictures will be upside down relative to the way they were before the flip. Computerized mounts usually do not perform meridian



Light Frames:0 - Dark Frames: 0 - Flat Frames:0 - Dark Flat Frames: 0 - Offset/Bias Frames: 0

	Path	File	Type	Score
☐	C:\Users\Michael\Desktop\M31 TEST...	IMG_8727.CR2	Light	29883.56
☐	C:\Users\Michael\Desktop\M31 TEST...	IMG_8728.CR2	Light	27398.70
☐	C:\Users\Michael\Desktop\M31 TEST...	IMG_8729.CR2	Light	23511.87
☐	C:\Users\Michael\Desktop\M31 TEST...	IMG_8730.CR2	Light	22405.59
☐	C:\Users\Michael\Desktop\M31 TEST...	IMG_8731.CR2	Light	21326.12
☐	C:\Users\Michael\Desktop\M31 TEST...	IMG_8732.CR2	Light	18743.04
☐	C:\Users\Michael\Desktop\M31 TEST...	IMG_8733.CR2	Light	17456.38
☐	C:\Users\Michael\Desktop\M31 TEST...	IMG_8734.CR2	Light	16988.06
☐	C:\Users\Michael\Desktop\M31 TEST...	IMG_8735.CR2	Light	16499.60
☐	C:\Users\Michael\Desktop\M31 TEST...	IMG_8736.CR2	Light	15117.90

Figure 12.2. *DeepSkyStacker*'s user interface is straightforward, with the menu always visible at the left.

Autosave.tif, in the folder with the light frames) and also to generate an HTML file describing the processing run. These settings will be remembered for the next processing run.

The first time it reads each set of calibration frames, *DeepSkyStacker* creates a master frame (master dark, master flat, etc.) and stores it in the same folder. On subsequent runs, it uses the master frame to save time.

12.2.4 Viewing and Selecting Images to Stack

You don't have to check all the images, of course; you can stack only the good ones. To preview an image, click on it in the list of files, wait a moment for it to load, and look at it on the screen (Figure 12.2). Screen stretch is at the upper right. To see a star magnified, move the mouse cursor over it and look at the upper left of the picture.

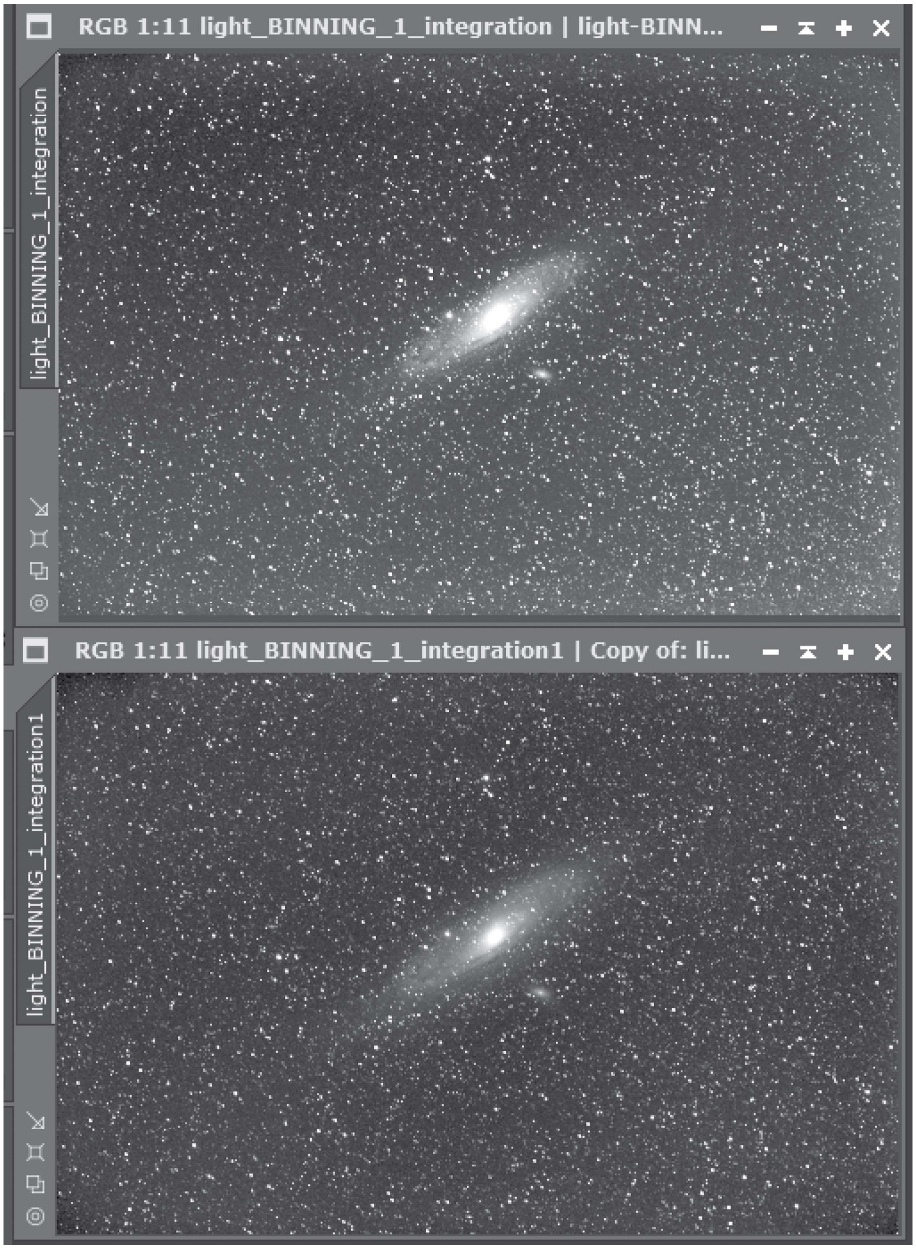
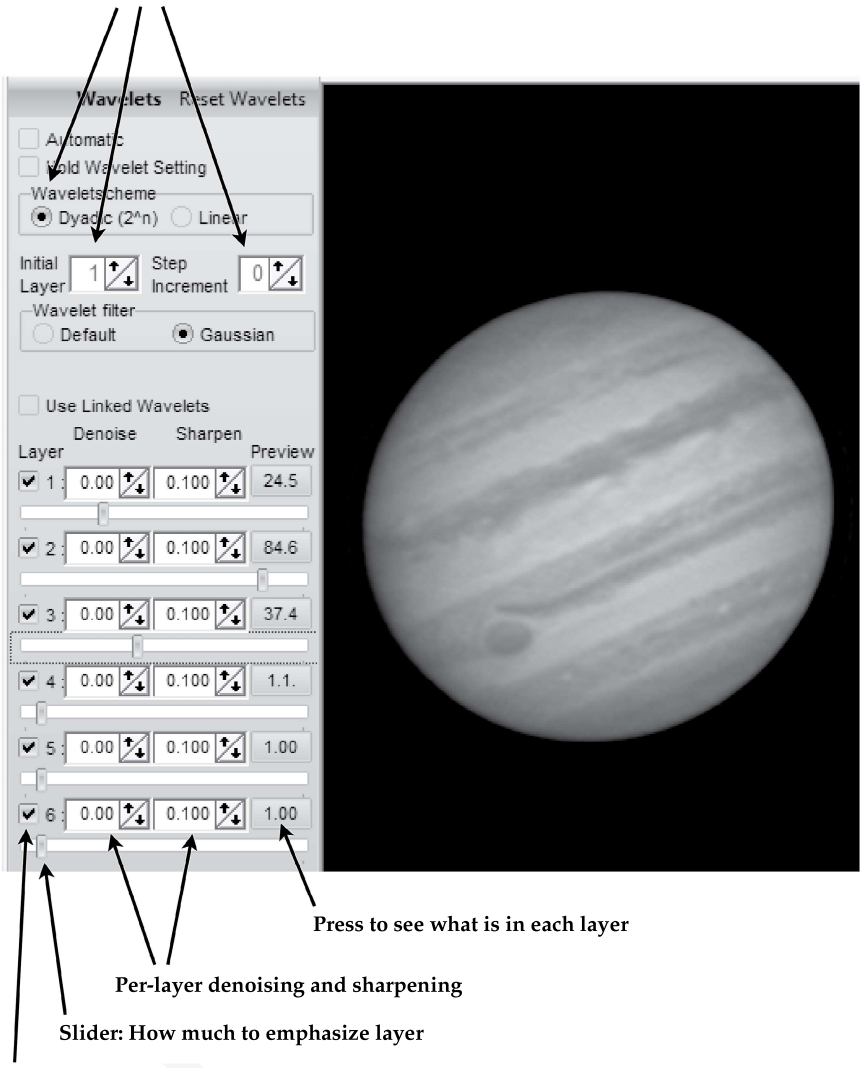


Figure 13.1. (Top:) Even after flat-fielding, this image still is lighter at the bottom and at the upper right than elsewhere because of city lights. (Bottom:) Background flattening removes the gradients.

How to scale wavelets (filter radii)



☐ Automatic
☐ Hold Wavelet Setting

Waveletscheme: ● Dyadic (2^n) ○ Linear

Initial Layer: 1 Step Increment: 0

Wavelet filter: ○ Default ● Gaussian

☐ Use Linked Wavelets

Layer	Denoise	Sharpen	Preview
☑ 1 :	0.00	0.100	24.5
☑ 2 :	0.00	0.100	84.6
☑ 3 :	0.00	0.100	37.4
☑ 4 :	0.00	0.100	1.1.
☑ 5 :	0.00	0.100	1.00
☑ 6 :	0.00	0.100	1.00

Press to see what is in each layer

Per-layer denoising and sharpening

Slider: How much to emphasize layer

Whether to include layer

Figure 14.13. Multiscale sharpening adjustments in *Registax,* the classic software package for this purpose.

there is rarely any need to emphasize any of the layers with larger filter radii. However, multiple layers with a radius of 1 can be useful; they are not redundant, because each one works on the residue from the previous one, and quite often, the first one traps almost all the noise. That is why *Registax* allows you to specify a starting radius of 1 and an increment of 0.

Along the way, you can denoise and/or sharpen individual layers. In *Registax,* be sure to press Do All after making the settings, so they will be applied all over the image.

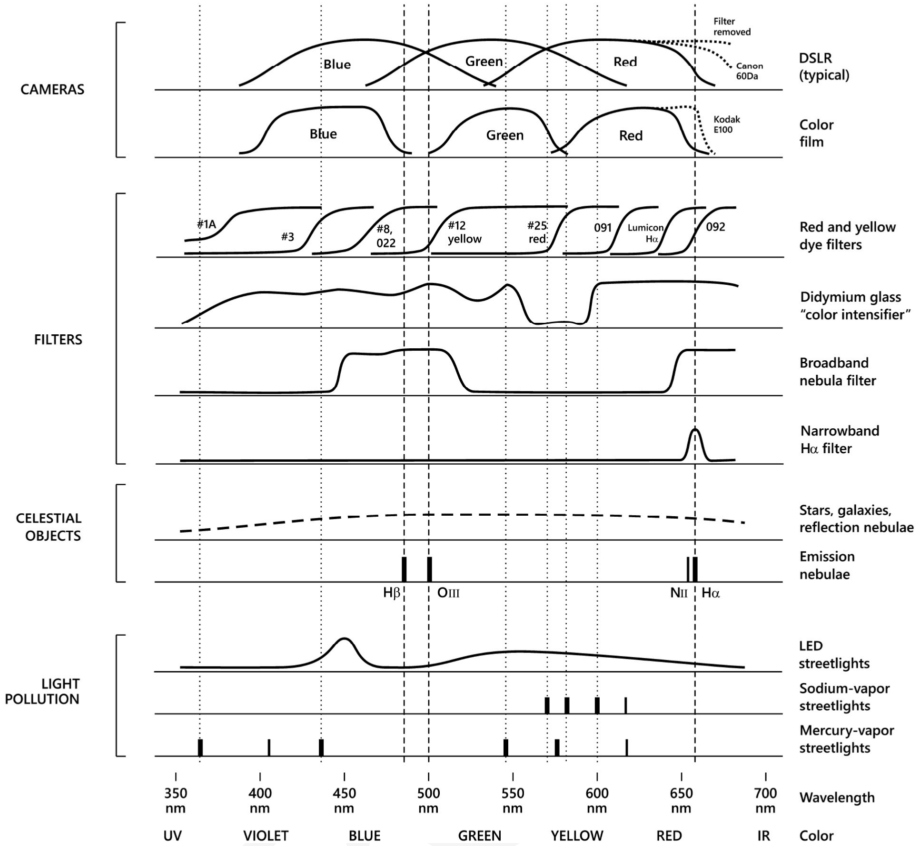


Figure 17.1. The visible spectrum as it relates to cameras, filters, celestial objects, and sources of light pollution. Data are approximate; consult actual specification sheets when possible.

17.2 Filter Modification

17.2.1 What Filter Modification Achieves

Many astrophotographers use DSLRs that have been modified to extend their response to the deep red end of the spectrum. This serves two purposes. One is that it enables the camera to pick up the strong hydrogen-alpha (Hα) emission from nebulae at 656.3 nm. The other is that working in deep red light, with filters blocking out the rest of the spectrum, is a good way to overcome skyglow from city lights.

Canon's EOS 20Da and EOS 60Da and Nikon's D810A, as well as some Fuji DSLRs, have been manufactured with extended red response. Usually, though, astrophotographers rely on third parties to modify their cameras. Reputable purveyors of this service include Hutech (www.hutech.com), Hap Griffin