Part I
DSLRs for Astrophotography

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Excerpt
More Information

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

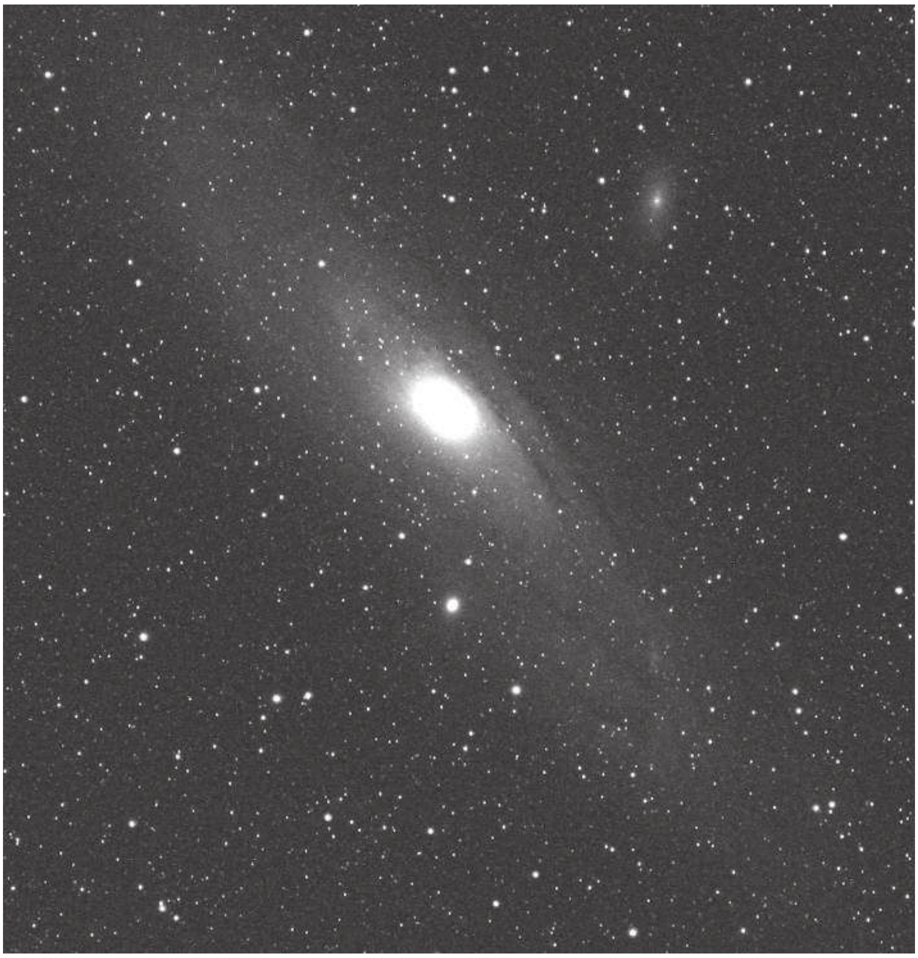

Figure 1.1. The galaxy M31 as the image came from the camera, with no processing except adjustment of brightness and contrast. Canon Digital Rebel (300D); single 6-minute exposure through a 300-mm lens at *f*/5.6, captured as JPEG.

DSLR under continuous computer control. Others, including me, prefer to use the camera without a computer and do all the computer work indoors later.

1.1 What is a DSLR?

1.1.1 Digital Single-Lens Reflex Cameras

A DSLR is a digital camera that is built like a film SLR (single-lens reflex) and has the same ability to interchange lenses. You can attach a DSLR to anything that will form an image, whether it's a modern camera lens, an old lens you have adapted, or a telescope, microscope, or other instrument.

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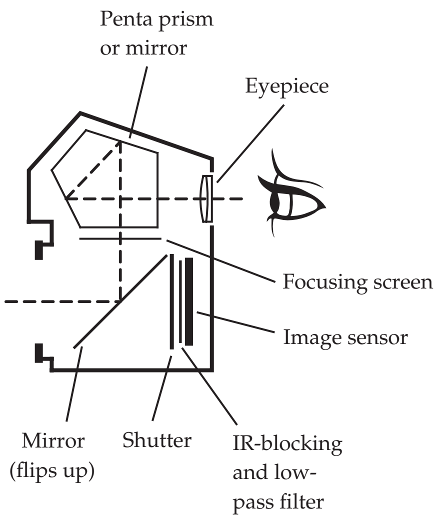

Figure 1.2. A DSLR is a single-lens reflex camera with a digital image sensor. Mirror and eyepiece allow you to view the image that will fall on the sensor when the mirror flips up and the shutter opens.

"Reflex" means that the camera has a mirror that enables you to view the image formed by the lens (Figures 1.2 and 1.3). The mirror directs the image to a focusing screen and eyepiece. When you take the picture, the mirror flips up, the view in the eyepiece goes dark, the image sensor is turned on, and the shutter opens.

With a film SLR and some early DSLRs, focusing through the eyepiece is your only option. Most newer DSLRs, however, offer Live View (live focusing) as an alternative: you can turn on a continous display of the image, and even view it magnified, on the screen on the back of the camera.

For astronomy, Live View is almost indispensable. There is no substitute for viewing a star image, highly magnified, as actually captured by the sensor, while you refine the focus.

1.1.2 DSLRs without Mirrors: MILCs

If you have Live View, do you need a mirror and focusing screen? No, say the makers of mirrorless interchangeable-lens cameras (MILCs), which work like DSLRs but rely on electronic previewing to frame and focus the image.

MILCs are gaining popularity with serious photographers. Figure 1.4 shows one, an Olympus OM-D. Another, the Sony α7S (A7S), has impressed astrophotographers with its high sensitivity to dim light, though it has also reportedly had problems with a "star eater" (Section 3.7.2).

MILCs are a less mature technology than conventional DSLRs, with more difference in performance from model to model. That is partly because some of

Figure 1.3. A more elaborate view of what's inside a DSLR. Note computer circuitry ("DIGIC II") at right. (Canon USA)

Figure 1.4. A mirrorless interchangeable-lens camera (MILC) is like a DSLR without mirror and focusing screen. Eyepiece, if present, shows an internal electronic display. (Grant George Buffett)

them were conceived of as cut-down DSLRs, and others, with smaller sensors, as scaled-up compact digital cameras. If you are contemplating using one for astronomy, I recommend checking online astronomy forums to find out how well it performs; the situation is changing rapidly.

The shallower body design of an MILC allows the lens to be closer to the sensor than in a DSLR, so that the MILC's wide-angle lenses perform better than lenses of comparable focal length for a DSLR. The shallow body also allows room for adapters so that one MILC can take lenses designed for several brands of DSLRs.

A drawback of MILCs for astronomy is that the sensor is normally operating all the time, to allow for image previewing. This tends to heat it up, increasing noise in the image. (The original rationale for the DSLR, in fact, was that the sensor would operate only for brief moments when taking pictures, and this would keep it cool.) The best MILCs compensate for the problem to some extent by using especially good heat sinks on their sensors; besides, you can always turn the camera off and let it rest when you are neither focusing nor exposing a picture.

For the rest of this book, I'll consider MILCs a type of DSLR even though they lack the reflex mirror. Practically everything I say about DSLRs applies to them; all the image processing techniques are exactly the same.

1.2 DSLRs versus Other Cameras

1.2.1 Dedicated Astrocameras

Should you be using a DSLR or a camera designed just for astrophotography, a dedicated astrocamera? The question takes on new urgency now that DSLR-like, multi-megapixel sensors are available in dedicated astrocameras (Figure 1.5) that operate connected to a separate computer and power supply. Astrocameras with large sensors used to be a lot more expensive than DSLRs, but the price gap is narrowing. Adapters are available to use astrocameras with camera lenses as well as telescopes.

Compared to a DSLR, an astrocamera is vibrationless (no shutter or mirror) and better at keeping the sensor cool to avoid thermal noise; many of them have thermoelectric cooling, and all have large heat sinks. Although newer DSLRs have much less thermal noise than those of ten years ago, cooled astrocameras still have an advantage, particularly in warm weather and for longer exposures.

Not all astrocameras produce color images directly. Those that do are called one-shot color (OSC) cameras; like DSLRs, they have alternating red, green, and blue pixels on the sensor. The rest are inherently monochrome but can still produce high-quality color pictures by taking separate exposures through red, green, and blue filters (R, G, and B), often accompanied by an unfiltered luminance (L) exposure to pick up more faint detail.

Figure 1.5. A dedicated astrocamera with thermoelectric cooling (ZWO ASI1600MM-Cool, 16 megapixels, monochrome). (ZWO Company photo.)

The disadvantage of the astrocamera is that it has to be tethered to a computer; you can't use it by itself. If you already use a computer with your telescope for telescope control or autoguiding, that is not a serious drawback. It does mean that the astrocamera cannot be used for daytime snapshots.

There is also a smaller kind of astrocamera used mainly for video and short-exposure imaging (Figure 1.6). These originated as cheap webcams with an eyepiece tube substituted for the lens; indeed, I imaged the 2003 apparition of Mars with a modified webcam. A small video astrocamera can complement a DSLR by serving as an autoguider (Chapter 9) and by enabling you to do planetary work beyond the DSLR's capabilities (Chapter 14). Video astrocameras are inexpensive, and you will probably end up with one.

There are even astrocameras made out of DSLRs and MILCs by adding cooling and other modifications. These are offered by CentralDS (www.centralds.net) and other firms. I classify them as dedicated astrocameras because they require a computer connection and cannot be used handheld for daytime photography.

1.2.2 Fixed-Lens Digital Cameras?

Digital cameras other than DSLRs and MILCs are usually not very suitable for astrophotography because the lenses are not removable, the sensor is small and

Figure 1.6. A video astrocamera (ImagingSource DMK series).

hence less sensitive, the lens is small (a disadvantage where starlight is concerned, regardless of *f*-ratio), and the camera does not deliver raw files suitable for calibration and stacking.

There are two exceptions to what I just said. One is that some of the best fixed-lens digital cameras are almost like DSLRs whose lenses cannot be removed, and they can be used as such, within the limits of the lens. Even so, DSLRs offer more for the money.

The other exception is that any digital camera, even a smartphone, can be aimed into the eyepiece of a telescope. This technique, called afocal photography (Figure 6.6), is suitable only for single exposures of the moon and possibly bright planets. Because its lens is the same size as the human eye or even smaller, a compact digital camera works well with an eyepiece and can even be handheld; the moon seen through a telescope is like a daytime terrestrial scene. Surprisingly good results have been obtained this way, and pushing a limited camera past its limits can be a satisfying challenge, but it is beyond the scope of this book.

1.2.3 What about Film?

Although film photography lives on as an art form (and I practice it as such), there is, as far as I can determine, no longer any situation in which film outperforms digital imaging for astrophotography.

Film is nonlinear; that is, its response is not proportional to the number of photons, so calibration and subtraction of sky fog are not practical. (Film images can still be digitized and stacked.) What's worse, film suffers reciprocity failure, so that most of the photons in a long exposure are forgotten; that's why the typical deep-sky exposure takes 30 minutes or more, rather than one or two minutes as with a DSLR. Further, my experiments have shown that the smallest points of light that register on fine-grained film are about five times as large as the pixels of a modern DSLR. That is, the DSLR is five times as sharp as film.

1.3 Choosing a DSLR

1.3.1 Canon vs. Nikon vs. Others

New models of DSLRs are introduced every few months, and the major manufacturers compete with each other so closely that their products perform very much alike. See Chapter 16 for the details of how DSLR image sensors are evaluated. Here I will not recommend specific models but only give general guidelines.

Most DSLR astrophotographers use Canon or Nikon cameras, not because other brands don't work, but because there's safety in numbers. Canon and Nikon are the two manufacturers that have made cameras specifically for the astronomy market (the Canon 20Da and 60Da and Nikon D810A). That doesn't mean you have to buy one of those models, but it does show that the makers care about astronomy, as well as other kinds of scientific photography.

Further, Canon and Nikon both have large astrophotographic user communities, and the cameras and their file formats are supported by numerous astronomical software packages and special accessories.

Canon and Nikon differ in design philosophy. The Canon EOS system is very consistent. Canons all work alike, except for documented differences in features, and all take the same lenses (except that some lenses only fit cameras with APS-C sensors, and of course the MILCs have a different line of lenses). Nikon, on the other hand, pursues somewhat different design philosophies in different cameras, and even the set of Nikon lenses that you can use differs slightly from one DSLR to another. The lens mount dates back to the 1959 Nikon F but has undergone many variations (see Section 7.3).

You can use Nikon lenses on Canon bodies, with an adapter, but not vice versa, because the Canon DSLR body is shallower, so the lens can still be the right distance from the sensor even though space is taken up by the adapter. MILC bodies are even shallower and can take a wide range of DSLR lenses. For more about lens adapters, see Section 7.3.3.

One final difference is that with Canon DSLRs, you can use the exposure meter and aperture-priority auto exposure with any lens or telescope. This capability is handy for daytime photography and for taking flat fields for calibration. Nikon DSLRs can only meter and auto-expose with newer Nikon lenses that contain electronics; if you attach other optics, even old Nikon lenses, you can expose manually but cannot use the meter.