Chapter 1
Entering the Digital Realm

1.1 Introduction

In 1999 when I finished the book *Wide-Field Astrophotography* the field of astrophotography was on the threshold of change. The century-old technique of processing film images and printing them in a home darkroom was moving toward electronic film scanners and photo editing using computer software. Trays full of foul-smelling chemicals for print making were in the process of being replaced by a desktop covered with inexpensive, yet sophisticated, ink jet printers and home computers. While this was happening, consumer digital cameras that bypassed film development and directly produced images in electronic form, were gaining market acceptance. These early cameras were expensive and produced pixilated low-resolution images, but there were a few professional cameras that heralded the future direction of the market that we now see today.

Although I have spent half a century following amazing advances in space technology and electronics, I was not prepared for the lightning speed at which digital photography overtook film-based imaging. It is true that some film-based astrophotography will remain with us for the foreseeable future because it is a complementary tool for the astroimager. But there is also no denying that digital imaging has leapfrogged film into mainstream astrophotography. Today’s larger and higher resolution sensors with lower electronic noise that enable longer exposures, along with powerful image processing techniques, have established digital imaging as a widely accepted and powerful tool in astronomy.

The popularity of digital imaging is readily apparent from the large numbers who discuss it on various Internet forums. Film astrophotography attracts about 500 adherents to the *Astrophoto* mailing list. But in a few short years the *digital_astro* mailing list has grown to include thousands of subscribers. Indeed, as Figure 1.1 demonstrates, amateurs using off-the-

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1 In this book I will, from time to time, mention web sites. Since the web is a dynamic medium, specific addresses are listed in Appendix A. Further, an updated list will be available at my publisher’s web site (www.willbell.com) in the section devoted to this book.
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Shelf consumer digital cameras can achieve results on par with, or better than, they used to with film cameras. In no uncertain terms, digital astrophotography is now an established branch of astronomy. I believe that it has evolved to the point that it deserves its own formal book on the subject. The field has grown beyond what can be done by merely updating an existing astrophotography book, so this one was designed from the start to address that need and acquaint both the novice and the experienced film astrophotographer with the new world of digital astrophotography.

Electronic imaging using cooled charged-coupled device (CCD) cameras has been in widespread use for several decades and still reigns as the highest resolution and most sensitive medium for recording faint celestial objects. However, a scientific grade CCD camera lacks the familiarity of conventional photography equipment. There is a big jump in user-friendliness between standard cameras and specialized CCDs. However, the advent of high-quality sub-$1000 digital single-lens reflex (DSLR) cameras now presents the astrophotographer with a more familiar alternative. Up

Fig. 1.1 Today's digital single lens reflex cameras have unprecedented sensitivity to faint light. This image of the Rossette Nebula was taken with a Canon 10D at ISO 1600 through an Orion 80ED refractor with an f/6.3 focal reducer, and shows faint hydrogen-alpha emission extending to the lower left that is not recorded by the author's 8-inch f/1.5 Schmidt camera. The image is a combination of 42 separate three-minute exposures, 11 four-minute exposures, and 7 five-minute exposures for a total of 3 hours and 35 minutes combined exposure. Photo by Michael Howell.
Section 1.2: Is Digital Good Enough for Astrophotography?

The introduction of high-quality sub-$1000 DSLR cameras marked a true turning point in the acceptability of digital astrophotography. Prior to their appearance, the debate about the viability of digital cameras in astrophotography was a polarizing subject with believers of film astrophotography in one camp and digital devotees in the other. The Canon EOS DSLR models—beginning with the 30D, 60D, 10D, 20D—have convincingly proven that consumer digital cameras do have the sensitivity to be effective astroimagers. The acceptance has accelerated as prices have dropped.

Jay Ballauer took up the digital challenge and compared the performance of the Canon Digital Rebel to the output of a top-of-the-line Santa Barbara Instrument Group ST-10XME CCD astrocamera. Both instruments were coupled to his Takahashi FSQ-106, that operated at f/5. Jay shot a triple exposure of the Orion Nebula, M42, with the ST10XME for 20 minutes each through a red, blue and green filter, then combined them into a color composite with a total exposure time of 60 minutes. He then imaged M42 with a Digital Rebel, taking 18 separate 5-minute exposures, and then digitally combine them into a single 90-minute exposure. The resulting images are shown in Figure 1.2.

Did the ST-10XME outperform the Digital Rebel in Jay’s comparison? Of course it did. The cooled CCD chip in the ST-10 camera, using three exposures each through a different filter (tri-color imaging), has far more dynamic range than the Digital Rebel’s single exposure complementary metal oxide semiconductor (CMOS) sensor that images all colors at once. The ST10XME’s CCD was also far more sensitive to the important hydrogen-alpha wavelength present in emission nebulae than the Digital Rebel which performed more like a film camera using a red insensitive “four-layer” color film.

But look closely at the two images. Consider that the ST10XME image was obtained with a camera that is dedicated only to telescopic astrophotography, while the Digital Rebel image was obtained by a camera that
Fig. 1.2 Jay Ballauer took these comparison photos of M42 to demonstrate the amazing image quality possible with today’s DSLR cameras. The upper image was taken with a Santa Barbara Instrument Group ST10XME specialized astronomical CCD camera. The lower one was taken on the same telescope with a Canon Digital Rebel camera. The diffraction spikes around bright stellar images in the lower photograph were added for aesthetic appeal by placing two crossed strings in front of the refractor objective lens. Photos by Jay Ballauer.
Section 1.3: Is Digital Astrophotography Hard to Master?

We have all admired the great astrophotography displayed in magazines like *Sky and Telescope* and *Astronomy*. We have also known that producing such images requires the three “Ps”; that is, practice, patience and persistence. Celestial imaging is not like taking ordinary snapshots and digital astrophotography differs in some ways from film astrophotography. In this endeavor we are chasing dim objects, often invisible to the naked eye, that are literally millions of light years away. To image these elusive objects, we have to rely on basic knowledge of astronomy and telescopes to navigate our way to the target, acquire the image using established principles of technical photography, and then finally apply computer image processing techniques to “develop” the image for display. For some, this might require a lot of expensive new equipment.

Fortunately, most amateur astronomers already have a majority of the high-priced items needed to begin digital astrophotography. The fact that you are reading this book means it’s likely that you already have a telescope. You probably have a digital camera, or plan to get one soon. It is also likely that you have a home computer that has some sort of image processing software already in it. If this is the case, you are essentially ready; there are only small details like adapters to mount the camera to the telescope to deal with.

We have all heard the story of an astrophotographic novice who simply hand-held a digital camera to the eyepiece of a telescope and snapped a fantastic close-up image of the Moon. But what about more advanced and challenging deep-sky imaging through a telescope? Is that hard to do? Peter Langsford found that it was not if he properly chose an object that is almost guaranteed to be a success—a bright globular cluster. Using his alt-azimuth mounted Meade 8-inch LX-90 f/6.3 and his Canon 300D, Peter took the stunning image of Omega Centauri shown in Figure 1.3 on his first deep-sky astrophotography attempt.

Langsford’s image of Omega Centauri would be the envy of any film astrophotographer—indeed, one of my fondest memories is spending an
Fig. 1.3 Peter Langsford’s first astrophoto attempt resulted in this excellent Omega Centauri image. It is a combination of 4 nineteen-second exposures at ISO 800 using a Canon 300D and an 8-inch f/6.3 Schmidt-Cassegrain telescope. Peter achieved this success by applying techniques that are only possible with digital astrophotography. Photo by Peter Langsford.

Fig. 1.4 Peter Langsford’s Meade alt-az mounted LX-90 is typical of most beginner’s astrophotography set up. His telescope features some handmade wooden accessories such as a laptop stand, refractor mount, and counterweight bar. Photo by Peter Langsford.
evening with Jack Newton, a premier expert in celestial imaging, as he photographed Omega Centauri at the 1984 Texas Star Party. I can attest that Jack, a master at film astrophotography, worked hard with advanced film camera equipment to capture an image of Omega that was no better than the one Langsford digitally captured from his own backyard.

So how did Langsford capture Omega Centauri? The key was a digital camera and the rapid feedback it provides. Here is how he went about it: Using an inexpensive but very useful software program called DSLRFocus, he took a rapid series of images with his 300D set at ISO 800 that were downloaded via a cable connected to his laptop computer. The software sequentially displayed the images on his laptop as he adjusted the focus of the telescope. Once proper focused was achieved, Peter shot a sequence of four 19-second images of his target. Longer exposures would have been possible with an equatorially-mounted telescope, but Langsford’s LX-90 was driven only in altitude and azimuth. Thus the image seen through it experienced field rotation. By using a series of short exposures, he eliminated visible field rotation in each separate image. Next, using one of several astronomical image processing programs perfected for digital photography (ImagesPlus), he slightly rotated and aligned the successive images to counter the effects of field rotation. Then, he digitally combined all four images into a single one that simulates just over a minute’s exposure. Other standard image processing techniques such as contrast and sharpness enhancement were applied to create the final result: a stunning deep-sky image on his first attempt.

Langsford did nothing extraordinary to achieve his fine image of Omega Centauri. In fact, he used the same tools available to most amateur astronomers and quickly produced an image that anyone would be proud to display. The digital camera, software, and techniques used are available to anyone who can afford moderately-priced equipment, and is willing to learn some new twists to the old art of astrophotography.

However, I do not want you to conclude from this description that imaging deep-sky objects with a digital camera shooting through a telescope has become point-and-shoot imaging. Peter chose a target that exploited the strengths of his camera. He took a series of images that were short enough to overcome his tracking problems and then combined them digitally using an image processing program. Langsford’s results represent, in a sense, a “best case scenario” for novice digital imaging success. But what are the typical beginner’s results more likely to be like? To find out, Richard Berry purchased a Nikon D70 DSLR and took a series of photographs to determine what the novice will see with a single, relatively short expo-
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sure. Here is what he had to say:

The common theme is that these are “first light” images with the Nikon D70. I didn't bother guiding or anything fancy—it was bad enough trying to find the little buttons, focus on dim stars, and start and stop exposures. I used a speed of ISO 1600 with noise reduction and normal JPG compression for every exposure. While the Byers 812 mount normally tracks well if it's properly polar aligned and you're in the right part of the sky I did not fiddle with it. It was also a chilly night and everything got wet.

Figures 1.5 through 1.8 show Richard’s pictures, and the captions provide background material on how they were shot and processed. These are the kind of exposures you are likely to try your first night out. It is quite possible to be disappointed if you are not forewarned. While imaging the Sun, Moon and planets is relatively easy because of the abundance of light, deep-sky objects like gaseous nebulae, galaxies and planetary nebulae

Fig. 1.5 Richard Berry writes: This is the first astro-picture I took with my new Nikon D70 camera. Since it was late in the season, the Lagoon (M8) was nearly in the trees when I started this 60-second exposure, and the sky was not yet fully dark. I used an ISO setting of 1600 with noise reduction on. Both tracking and focus are poor, but the nebula is clearly visible. For processing, I loaded the image into Astronomical Image Processing for Windows (AIP4Win), split it into RGB color channels, applied AIP’s Rolling Pin Tool to fix vignetting, and reassembled the channels using the Join Colors Tool.

\(^2\) However, if you are an old timer who tried film based astro-imaging in the past and were frustrated with the first results which were usually rather poor, you probably will be amazed and pleased.
Section 1.3: Is Digital Astrophotography Hard to Master? 9

Fig. 1.6 Richard Berry writes: This is a five-minute exposure of M31 with my 6-inch f/5 Newtonian on the Byers 812 mount, at an ISO setting of 1600 with noise reduction on, saved as a JPG. The clock drive was running, but I did not guide the telescope, so the stars are trailed. This image is straight out of the camera with no processing, and the corners are dark from vignetting. This is the real McCoy—a completely honest example of “first light” with my new DSLR.

Fig. 1.7 Richard Berry writes: The last-quarter Moon was shining brightly, and the eastern sky was starting to brighten when M42 finally cleared the trees, so this is the last picture I took the first night I had my Nikon D70. The camera was on my 6-inch f/5 Newtonian on a Byers 812 mount. I focused on Betelgeuse, so I had a nice bright star that was easy to see in the viewfinder. The ISO was 1600.
have never been “easy” targets whether you use a film camera, astronomical-grade CCD, or a consumer digital camera. One of the facts of life with digital camera imaging is that the hardware limits exposure times, and to build up a nice image you will have to take a number of short exposures and combine them. With the proper processing, you will get very pleasing results that will compare very favorably with film. At least for now, the laws of physics prevent digital cameras from head-to-head competition with dedicated astronomical CCD cameras. As I wrote at the beginning of this section, successful imaging takes practice, patience and persistence. If you like the pictures you see in this book and are willing to purchase a good mount and spend the time, you too can successfully image “faint fuzzies.”

1.4 The Digital Advantage

As someone who has exposed countless rolls of film over 50 years, I think. “What’s not to love about digital imaging?” Digital imaging is quick, giving new meaning to the term “instant gratification.” You see the results immediately on the camera’s own image-viewing screen and know immediately if you have a “keeper.” Digital images are versatile—they can be printed, archived to storage media, transmitted via E-mail or displayed.
on a web site. Digital is inexpensive (after the initial equipment investment). With 35-mm film, you may get one (if that!) good high-resolution lunar image out of 36 exposures on a roll. Counting the cost of the film and developing, followed by the time to scan the negatives in search of the best image, that one roll can cost up to $10 and consume an entire evening of time, possibly without yielding a good image. With digital, that same imaging session costs literally pennies—just the price of the electricity to recharge the camera’s batteries and run the computer to view the images. Expenses only accumulate with successful images that deserve to be archived on a recording medium and/or printed. The sub-par images go away with a tap of the computer’s delete key. Digital imaging also provides the ability to instantly correct problems. If an image is out of focus, underexposed, suffering from camera shake or any other correctable problem, you will know it now instead of after wasting an entire imaging session. Digital techniques open up a whole new spectrum of possibilities for the astrophotographer. After all, there is no photo lab to send you back a dark, overexposed print because they didn’t know what an astrophoto was. When you move to digital you can be in complete control of the image from shutter snap to finished print.

Experienced film imagers know that digital is not ready to entirely replace film photography. There are certain applications where the latter is...
still superior, such as ultra-high resolution wide-field Schmidt camera work. But digital has certainly matured to the point where it takes its place alongside film in a majority of celestial applications. Indeed, digital is now superior to film in telescopic lunar and planetary work, and is equal to film in deep-sky imaging and wide-field work in all areas except recording emission nebulae that shine in the far red end of the spectrum. However, as we shall see in later chapters, astrophotographers are finding ways around this inherent limited sensitivity to red light by performing modifications to their digital cameras.

1.5 Comparing Digital and Film Cameras

Digital cameras are also electronic devices, and in some cases this leads to an unconventional appearance. They all have a lens in front and a viewfinder with which to frame the image. Some digital models have fixed lenses that cannot be removed while other models are of the conventional single-lens reflex design and have interchangeable lenses. Additionally, digitals have a liquid crystal display (LCD) screen on the back of the camera that can act as a viewfinder with fixed-lens cameras or be used to preview any of the images stored in the camera’s memory. Some camera models like the Olympus Camedia series strongly resemble small conventional 35-mm cameras. Others, such as older Nikon Coolpix models, have a two-piece body where the camera body and LCD display can swivel at an angle to the lens and imaging head, giving it a decidedly futuristic look. What separates digitals from film cameras is the fact that instead of opening the back of the camera and threading a roll of film onto the take-up spool, you insert a reusable memory card to record your images.

Since digital cameras use no film, you do not face one of the major practical problems in film astrophotography—which film to use? Another digital advantage is that all images can be in color, although some cameras have an option for recording images in pseudo-black and white. These black-and-white images appear to be monochrome, but are recorded as color images whose red, blue and green components combined to create all whites, blacks and grays. But the default selection of only a single imaging sensor has drawbacks for certain types of astrophotography. Most digital camera sensors are covered with an infrared filter that makes them insensitive to the far-red region of the spectrum where emission nebulae shine in the red hydrogen-alpha wavelength.

With film cameras, the type of film used governs the exposure’s sensitivity to light and the extent to which colors can be perceived. A fine-grained high-resolution film may be used, but at the expense of low sensi-
Section 1.5: Comparing Digital and Film Cameras

Digital cameras can have a conventional appearance like the early model Olympus Camedia C-2040 (left), or their optics and electronics can be separated, leading to radical-looking camera designs such as the Nikon Coolpix 995 (right). Photos courtesy of Olympus and Nikon.

Activity to light. A faster film more sensitive to dim light may be used, but at the disadvantage of having coarser-grained lower-resolution images. Film speeds are gauged by their ISO speed rating, with the doubling of the ISO number indicating a doubling of the film’s apparent sensitivity to a given amount of light. 200-speed film is twice as fast as 100-speed, 400-speed is twice as fast as 200-speed, and so forth. Practical film speeds range from ISO 100 to ISO 1600. Digital cameras carry over the concept of ISO speed with their imaging sensors, but the same sensor is adjustable between ISO 100 and 400, and even up to ISO 6400 on some, by making electronic adjustments with the camera’s controls.

Under light-polluted skies, digital cameras have an advantage: the skyglow can be subtracted through image processing. If the sky is too bright, the color image can be converted to a grayscale black-and-white image to allow deeper processing that will reveal faint objects that would ordinarily be lost in the glow of light pollution. Under dark skies digital cameras show another great advantage: their system of electronic imaging records light linearly; that is, there is no “reciprocity law failure” as there is with chemical-based film. Doubling the exposure produces an image that is twice as bright.

The end result of the photographic process is similar with the two types of cameras—an image printed on paper, or a “picture” is produced. With a film camera, photosensitive chemicals on the film react to incoming photons during the exposure. The exposed film is developed in a succession of chemicals to produce either a negative image or a positive transparency. This is in turn printed onto photographic paper with an enlarger and developed chemically, or it is scanned electronically for computer processing and printing with an ink jet or other appropriate printer. With a digital camera, incoming photons strike an electronic detector that converts the
image into electronic signals. These signals are then processed and recorded electronically on the memory card, then downloaded to a computer or printer in order to produce the final picture. More detail on how a digital camera works is presented in Chapter 3.

1.6 Expectations

The digital beginner would naturally ask, “How good can my astronomical images be?” Unfortunately, there is no clear-cut answer. Many factors enter the photo quality equation, and most of them are beyond the immediate control of the photographer. Different cameras vary greatly in capabilities, usually in direct proportion to their price. The type of astrophotography being done and the size of the telescope used also set limits on what can be achieved. Of course, environmental factors play a big role. Long-exposure deep-sky imaging is very difficult from light-polluted areas, and high-resolution telescopic images are equally difficult to achieve if wind is shaking the telescope. But digital cameras by their very nature offer the user an ar-

Fig. 1.11 Heavily light-polluted sky inhibits backyard astrophotography of diffuse nebulae, but bright star clusters will shine through light pollution. Convert the image to grayscale to eliminate excess color shifts caused by light pollution, and image starry objects like globular cluster M3 in black and white. This image is composed of 4 stacked thirty-second exposures at ISO 800 with a Canon 10D and a 200-mm lens stopped to f/5.6. Photo by Robert Reeves.
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ray of capabilities that in some cases allows them to achieve images that would not be possible with conventional film cameras.

Among the factors governing final image quality, perhaps the most important is the camera itself. Almost any digital camera is capable of taking breathtaking images of the Sun, Moon and planets. Indeed, you will find that a digital model can often take better lunar images than a film camera. But most of point-and-shoot digital cameras have limited long-exposure capability usually between to 16 to 30 seconds—due to the camera’s internal operating system; and digital processing must be used for imaging dim deep-sky objects. More advanced interchangeable lens DSLR cameras are capable of longer exposures, but they are also more expensive.

The resolution, or number of pixels, used to form the image in a particular camera, also sets a limit on how much detail can be recorded. A threshold past which a digital camera has enough pixels to produce 4 by 5-inch, “film-like” photographic prints is usually considered to be 3 megapixels. However, today even entry-level point-and-shoot models now easily exceed this threshold. We will discuss this in detail in Chapter 3.

A 35-mm film camera has a fixed imaging size: 24 by 36 mm. We have grown accustomed to gauging our field-of-view with a particular lens or calculating the size of the target’s image on the focal plane using these numbers. However, digital cameras usually have a much smaller imaging surface. This presents us with puzzling lens focal length “equivalency factor” charts in camera advertisements. The smaller imaging detector means that the field-of-view with a given lens focal length is smaller with a digital camera. On fixed-lens models this is no problem as they come already equipped with shorter focal length lenses, sometimes of less than 10-mm focus, to provide normal or wide-angle views on their smaller imaging surfaces. Interchangeable lens DSLR cameras, such as the Canon 10D, 20D, 300D, or Nikon D70, use lenses originally designed for 35-mm film cameras and one quickly finds that the smaller imaging chip on the DSLR changes the expected image scale by quite a bit. For the Canon models above, the ratio is 1.6; that is any lens previously used on 35-mm film cameras now seems to have 1.6 times greater focal length when used on digital ones. In some cases this is a bonus. Our moderate 200-mm focal length f/4 lens used on a 35-mm camera now behaves like a whopping 320-mm focal length lens with the same f/ratio. But there is a down side. Our existing 35-mm camera wide-angle lenses are now merely “normal” lenses with the DSLR. We will have to purchase a 20-mm focal length lens to get the same digital field-of-view we used to have with 35-mm focal length lenses on film cameras.

Another problem with the smaller imaging sensors in digital cameras
is that even if yours has a sufficient number of pixels to produce detailed images that does not mean it will necessarily work well for long exposures. As the size of the sensor gets smaller, or more pixels are packed onto the same size sensor, the chip’s full-well capacity is decreased. Since the full-well capacity is smaller, the readout noise becomes a more significant part of the overall signal, because the smaller pixel cannot be exposed as long as a larger pixel before it saturates. This is the digital camera’s electronic corollary to the dreaded reciprocity law failure that makes certain 35-mm films less efficient with increasing exposure length. This phenomenon creates speckles, or hot pixels, that dot the image like snow and grow worse as exposure time increases. It also worsens at higher temperatures, doubling in amount for every seven-degree Centigrade increase. However, again, the digital world has ways to minimize the effects of noise in long-exposure images as will be discussed in Chapter 14.

Even the very best digital camera will not ensure good astrophotos if the telescope is not up to the task. Sharp optics are a must for high-resolution lunar and planetary imaging and a large aperture is necessary for capturing dim, deep-sky objects. Good polar alignment and accurate tracking by the telescope’s mount are is also needed for successful long-exposure imaging. The telescope and camera mounting and how the camera is adapted to the telescope also play a critical role in the resulting image quality.

Since a majority of digital cameras have a fixed lens, telescopic photography with these models must be done by the afocal-projection method, which often introduces the problem of vignetting of the image. Vignetting is the effect where the edges of the field-of-view are darkened because the camera’s sensor is not viewing the entire cone of light exiting the eyepiece. Fortunately, there are methods for controlling vignetting with the creative use of a fixed-lens digital camera’s built-in zoom features and the careful selection of eyepieces. We will discuss this in more detail in Section 4.6.

Image processing is the vital link in the chain of events that ultimately produces the finished print. Just as computer image processing became an integral part of film astrophotography after the popularization of film scanners, digital astrophotography—through its electronic character—naturally lends itself to image enhancement with various image-processing techniques. But again, the details of these concepts will be explored in Chapter 14.

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3 But even here, digital astrophotography can compensate for less than perfect alignment and tracking to a surprising degree if you are willing to take many short exposures and combine them.
Before we dive into the specific details of digital astrophotography, as a confidence building exercise, let’s jump right in and actually do some imaging of an object that is easily viewed from almost anywhere—the Moon. Large amounts of skyglow have no affect on the Moon and bright planets. These targets can be imaged from almost any location so long as there is not a light source shining directly into the telescope that would reduce image contrast.

Over a period of four decades, I have exposed thousands of frames of Plus-X, Panatomic-X and Technical Pan film through various telescopes seeking the ultimate lunar image. Often I achieved reasonably good results, but at great expense in both time and money. Now, by utilizing the inherent traits of lightweight digital cameras—high sensitivity, autoexposure, autofocus, reusable memory cards, the ability to quickly detect and delete substandard images, and digital-image processing software—the success ratio is near 100%. I am not exaggerating when I say that I can now take better Moon pictures by accident with a simple digital camera than I previously did on purpose with top-of-the-line film cameras and exacting darkroom work. Let’s see how you can start doing this right now.

To image the Moon, one only needs tripod-mounted binoculars or a telescope and a digital camera. A clock drive to track the Moon is not required. Low-magnification scenes of the entire lunar globe can be photo-

Fig. 1.12 The most common mistake made by novices and veterans alike during afocal lunar photography is forgetting to turn off the camera’s built-in flash. Photo by Becky Ramotowski.
graphed by simply holding the camera to the eyepiece. The exposure times are so short, just hundredths of a second, that movement from unsteady hands, and the orbital movement of the Earth and Moon, will not be noticeable. Only when higher-magnification views are attempted through a telescope will a clock drive or means of holding the camera steady be required.

Since a majority of digital cameras have a fixed lens, we will be using the afocal-projection method whereby the telescope eyepiece projects the Moon’s image directly into the camera’s infinity-focused lens. Choose a low-power eyepiece with the widest apparent field-of-view. The wide field-of-view is necessary to prevent the vignetting problem previously mentioned. Focus the telescope carefully on the Moon using corrected vision—that is, if you wear glasses, use them while focusing the telescope. Now, just for fun, simply hold the camera to the eyepiece and aim using the LCD image preview screen. If the Moon fills a majority of the field-of-view, let the camera’s autoexposure and autofocus functions control the exposure. Make sure the camera lens is square with, and perpendicular to, the eyepiece. Use the camera’s optical zoom to help frame the image or reduce vignetting. Now press the shutter release.

If you are typical, and I also made the same mistake, you just had your first lesson in digital astrophotography with a point-and-shoot camera … turn off the flash! Now try it again. Aim squarely into the eyepiece and press the shutter. Congratulations! Now the LCD viewfinder is displaying your first lunar photograph, and it is probably better than the vast majority of amateur film-based Moon pictures from decades past. Now continue to take images through the eyepiece until you fill the camera’s entire memory card. There is strength in numbers; take a long series of images, because a few will always be sharper than others due to variables such as camera movement and atmospheric turbulence. Remember, you can later delete all but the best ones.

Higher-magnification views of the Moon will require a steadier camera mounting to allow the longer exposures necessary with higher-power eyepieces. The easiest way to do this without first purchasing special adapters to mount the camera onto the telescope is to use an ordinary camera tripod. Now that the camera is stable and not in our hands, we have more control over the image. Using the LCD preview monitor on the back of the camera, we can detect focus, composition, and exposure errors and correct them on the spot.

1.8 Improving Your Moon Shots

Now that you see celestial imaging is possible with your camera, let’s look
Section 1.8: Improving Your Moon Shots

at some basic techniques to improve on what you just did. The following is a list of pointers to insure digital success on your digital lunar voyage.

1. Be sure the camera’s battery is fully charged before an imaging session. Keep a spare set of batteries handy in case it becomes depleted. A digital camera with a dead battery is little more than an expensive paperweight.

2. Set the camera to the full-manual control setting that allows you to select the aperture and shutter speed. If the camera has an auto-off option, be sure to disable it so the camera will not shut down after a period of inactivity while you are working with the telescope. Shoot with the lens wide open. If the camera is allowed to automatically stop down the lens, it will vignette the image at smaller f/stops. Find the proper shutter speed by experimenting and viewing the results on the camera’s LCD monitor. Once the proper exposure is found, delete the misexposed test shots.

3. If the camera is attached to the telescope with an adapter, make sure it will not strike any portion of the mount when the telescope is slewed from one part of the sky to another. This is especially important with motorized computer-controlled Go-To mounts.

Fig. 1.13 An option for camera stability during afocal astrophotography is to mount the camera on a separate tripod. This eliminates telescope shake during the exposure, but it is inconvenient to constantly shift the camera to keep up with the moving eyepiece as the telescope tracks the sky. Photo by Robert Reeves.
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4. Focus the telescope by eye, with corrective eyeglasses if needed, then let the camera’s autofocus option refine the focus.

5. Turn off the flash!

6. When shooting the full disk of the Moon at low magnification, such as with a 32-mm Plössl through a common 8-inch f/10 SCT, the camera can actually be hand-held because the shutter speed will be in the $\frac{1}{500}$- to $\frac{1}{800}$-sec. range at ISO 200 or 400 settings, (see Figure 1.14).

7. At slightly higher magnifications—say, using a 25-mm eyepiece on the same 8-inch SCT—the camera can still be hand-held, but only half the

Fig. 1.14 At low magnification it is possible to take great Moon pictures by simply holding the camera to the eyepiece. Photo by Robert Reeves.
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shots will be acceptable because of camera shake. With still higher magnification, a tripod, or some means to attach the camera to the telescope is necessary as the shutter speeds drop to between about $\frac{1}{40}$- and $\frac{1}{8}$-sec. At slower shutter speeds, it may be necessary to use the camera’s self-timer option to trigger the shutter without vibration if the camera does not have remote-control options.

8. When aiming the camera into the eyepiece, either by hand or on a tripod, make sure the lens is square with the eyepiece. If it is not, the edges of the photo will be out of focus. If you are holding the camera by hand, remember that not all models fire the shutter as soon as the shutter button is pushed. Some have up to a two-second delay while the autofocus routine completes its operation before exposing.

9. If using a tripod, position it so that the clock drive will move the eyepiece either directly away from, or toward, the camera, not across the camera’s field-of-view. This allows about two minutes of shooting before the camera needs to be nudged either closer or further away. Preferably, place the tripod so the eyepiece will be moved away from the camera. However, depending on where the telescope is aimed, this may not be practical. If the eyepiece must approach the camera, monitor it closely to avoid a slow collision.

10. Cameras with a fixed lens assembly that does not automatically extend outward when the camera is turned on can be attached directly to the telescope eyepiece using various adapters that screw into the lens’ filter thread. WARNING: If your camera lens automatically extends when the camera is turned on, you cannot attach the camera with the threads at the end of the lens. You must use a camera-to-eyepiece mounting system (see Section 8.5 for examples). This adapter threads into the fixed barrel surrounding the extendable portion of the lens assembly. These are the same threads that the camera’s lens cap attaches to. The reason it is critical to use this type of camera-to-telescope adapter is that the motor-driven extendable lens elements are retained with small plastic tabs that can break very easily when a side load is applied to them.

11. Do not trigger the shutter on a scope-mounted camera by hand. This will induce vibration that is magnified by the telescope and will blur the image. If a remote trigger, either electric cable operated or wireless, is not available, start the exposure using the selftimer option. By the time the camera shutter trips after the 10-second delay, any telescope vibrations will have damped out.

12. Use the widest field-of-view eyepieces possible to avoid vignetting. My Meade Series 4000 32-mm Super Plössl covers the camera’s entire field-of-view, but my Brandon eyepieces cause progressively greater vignetting with each decrease in focal length. Use the camera’s optical zoom to increase detail or eliminate vignetting. Avoid using digital zoom because
it merely enlarges the image by resampling the central pixels in the field-of-view and enlarges that portion of the image over more pixels. There is no increase in detail with digital zoom.

13. If you do not have an external power source to run the camera during extended sessions at the telescope, use nickel metal hydride (NiMH) rechargeable batteries in the camera. These last several times longer than
regular alkaline batteries, which will allow you to use the camera’s LCD monitor screen as needed to monitor the telescope’s aim, without worrying about battery depletion.

14. Use the highest quality JPG setting with the largest pixel-size image available. Although the image counter will show you have a certain number of exposures for a given size memory card, you will get more images per megabyte on the Moon and planets than with normal daylight imaging. My Olympus 3020Z indicates I should get 34 maximum resolution JPG images on a 64-Mb memory card. But in practice, I get about 60 lunar, and over 100 planetary, images because the JPG algorithm in the camera compresses the black background more efficiently than for normal fully-illuminated daylight snapshots.

15. Take as many shots as the camera’s memory card will allow—there is strength in numbers. Out of a series of 50 repetitive lunar images, at least one will be great even if atmospheric turbulence is blurring most of them. It is possible to take over 100 lunar images in a half-hour imaging session. Just delete the substandard ones.

16. When processing the JPG images saved from a photo session, first convert them to TIF format to prevent losing any image quality as happens with repeated “saves” of JPGs that have been processed and changed. Once lunar images are processed and adjusted to your liking, you can convert them to grayscale (black and white) to reduce the file size by two-thirds. If no further changes in the image are expected, the TIF file can be converted back to a JPG to further reduce the file size for archiving.

17. Depending upon what type of telescope you use, and whether you use a star diagonal or not, the orientation of the resulting image may be normal, reversed, or both upside down and reversed. The image will have to be rectified in an image processing program before it can be viewed and printed normally.

18. Advanced image processing programs such as Photoshop are not required to process your lunar images. The necessary conversion from JPG to TIF format, the inversion or reversal of the image, contrast manipulation, conversion to grayscale, sharpening, and printing the image can all be done with the freeware program Irfanview.

19. A useful accessory to have is a memory-card reader to download images into the computer. This allows downloading the contents of the memory card without having to remove the camera from the telescope. Once the card is erased, it can go back to the telescope for more imaging. A second memory card will also prove useful as lunar and planetary imaging can produce a massive amount of exposures in a short time.

In a nutshell, it is fun to be able to do astrophotography from the
driveway at home with a digital camera. Try your hand at this the next time the Moon is available and follow the tips listed above to get your first digital astrophoto experience. As you gain confidence in your ability and in your camera’s capability, follow the tips and advice in the following chapters and join the legions of new astrophotographers who are imaging the universe with a digital camera.