Astrophotography Without A Telescope

A Frugal Approach

Anthony Galván III

Astrophotography Without A Telescope

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Dos Gatos
252 Old Ranch Dr.
Goleta, CA 93117
www.dosgatos.com/no-scope-ap

For my wife, Joan, for her patience as I go in
and out of the house at various hours of the night to
image the night sky.

Astrophotography Without A Telescope

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Preface – Astrophotography Without A Telescope

In May of 2000 I made a presentation at the Riverside Telescope Makers Conference entitled Astrophotography Without a Telescope. The presentation was well received and I told myself I needed to turn the slide presentation into a book. Now, 17 years later, the book is here and updated to reflect today's technology – which has made astrophotography not only more accessible but affordable.

I hope the examples and tips found here will guide you and add to your imaging skills.

The goal of this book is to start you out on the road to astrophotography without investing large sums of money. Digital cameras have made imaging celestial targets much easier than with film. Plus, digital cameras have some characteristics that outperform film's ability to render an image and that is my objective, to point you to the frugal way of imaging the sky.

Astrophotography is the area of astronomy that sooner or later catches a visual amateur astronomer's interest. Observers decide they would like to capture a significant event in the sky such as a solar or lunar eclipse or perhaps an occultation of a planet or star by the moon.

Imaging sunspots often starts a solar observer down the path of solar astrophotography. Some solar observers will image the sun using filters to view our closest star in different wavelengths of light for more unusual views in the hydrogen alpha or calcium K wavelengths.

Capturing images of the planets, the sun and moon is simple. The equipment needed is basic and with time and practice good images are produced. A camera, a wide-angle lens, a telephoto lens and a sturdy tripod are the most basic items needed to begin astrophotography, whether one is using film or imaging digital without the need of an equatorial mount (GEM); in other words by being frugal.

Being frugal means imaging the sky with general photographic equipment to make an astrophotograph. Make yourself a frugal astrophotographer. Even though a low-cost low-power telescope can be useful, you will read later a scope is not a necessity to start.

The range of subjects you can image in the sky without a telescope are numerous.

What this book is not.

One thing this book will not discuss in length are the processes and techniques of manipulating digital images with the many software applications currently available. The software that allows us to make astrophotographs without a GEM use a technique known as stacking. Stacking involves taking a series of short exposures and stacking them together to create an exposure composed of the total exposure time. An introduction to stacking software warrants a book on its own and there are several already available for you to improve your photographic skills.

Image manipulation allows you to enhance digital images, correct exposure shortcomings and even enhance the image from the original "out of the camera" file.

At the end of this book you will find a list of software applications which are useful in manipulating and correcting images. In addition, a list of books dealing with this subject is also included.

The other area of digital astrophotography I will not discuss in detail is webcam or video imagining. Again, like image manipulation, there books and websites that discuss in detail the equipment and software needed to accomplish this type of imaging.

Think of this book as an introduction to the Zen of the Chip.

Introduction

In the early 1990s if you wanted to image deep-sky objects you needed a clock drive or equatorial mount with an accurate polar alignment, fast film, a dark sky and plenty of time to expose film to capture a nebula or other faint deep-sky object. A motor drive mount was essential if you were going to photograph deep-sky objects because exposure times needed to be long, 20 minutes to over an hour, for some targets.

Capturing images of the planets or the sun also required good seeing, a long focal length refractor, a steady mount for the telescope and the ability to shoot many frames to compensate for less than ideal atmospheric conditions in order to pick the best negative or slide to print.

Astrophotographers in those days shot many frames during an evening session because they did not know if camera shake would find its way into the exposure. Sometimes an aircraft would fly into your point of view or someone walking by in the dark would trip on the tripod and ruin the shot at the last minute of your 60-minute exposure!

The advent of digital cameras has helped astronomers capture and create more successful images than has been done in the past. It is not so much the immediacy of the digital image that has transformed the processes required to produce a good image of an astronomical object. Rather, digital cameras are able to produce images that are not plagued by the restrictions and limitations of film and the darkroom.

Low-cost digital video cameras, originally used for video conferencing over the internet, became a tool well suited to image planets. The web-cam, as it is known today, is connected to a computer and modified to replace an eyepiece on a telescope to create video files. The images are then “stacked” and “flattened” to produce high-quality images of the sun, the moon, Jupiter and Saturn. Many of these images often rival images taken from observatories with sophisticated telescopes and cameras decades earlier.

The digital camera choices for today’s budding astrophotographer are many. There are Digital Point and Shoot (DPS) models which can be attached to a telescope and produce excellent images of the moon or sun, the planets and even some deep-sky objects, depending on the camera being used.

The number of digital single lens reflex (DSLR) on the market capable of producing high-resolution images has also increased in the past few years as well. The DSLR camera is a good choice for photographers who may already have the interchangeable lenses from their older film cameras which will fit the newer DSLR camera.

Digital video cameras have also improved over the past ten years. These newer web-cams produce better than average images when coupled with an image processing program such as Registax or K3CDDTools.

Regardless of which camera type you may start out with, the basic processes are the same. Let us look at what makes these cameras types similar in one respect and quite different in another. Once you understand the differences among the various digital camera designs, you will be able to decide what type of camera works best for you to image the sky, day or night.

Remember, being frugal is to use what you have on hand to be as cost effective as possible. There are times when least is best and we will work towards that goal.

Chapter 1 - Astrophotography, The Beginning

Analog Imaging

In 1839 John William Draper created the first documented astrophotograph. Shooting through a 12 inch Newtonian scope he exposed a daguerreotype plate for 20 minutes to produce the first detailed image of the moon, Figure 1-1.

Figure 1-1 John William Draper's daguerreotype

In 1880, Draper's son, Henry, imaged the Orion Nebula through an 11-inch Alvan Clark refractor with an exposure of 51 minutes on a more modern dry plate, Figure 1-2.

Figure 1-2 First photographic image of the Orion Nebula, 1880.

John Draper’s medium was a daguerreotype plate. The plate is a sheet of silvered copper placed in a fuming box and sensitized with a halide (usually iodine). After the plate is exposed in the camera the plate is developed by exposing the plate to fumes from heated mercury. The image is always a mirrored image.

Henry Draper’s dry plate was the forerunner of modern film. Henry Draper used a glass plate coated with silver bromide. The glass plate was developed with a solution of iron sulfate and acetic acid turning the silver-halide grains into metallic silver. The result is what we modern folks call a film negative. Draper’s plate was made of glass, not celluloid.

Since Henry Draper’s day things have changed considerably in the field of astrophotography. Film speeds (sensitivity to light) were constantly being improved. The methods to process the film were improved including techniques which required placing the film in a special environment to make it more sensitive to light.

Early astrophotographs were black and white images. A variety of methods to produce color images were employed by inventors and photographers from the mid-1800s to the mid-1900s. These methods were labor and equipment intensive, in other words, not practical for most users. However, James Clerk Maxwell made the first color astrophotograph in 1861 using a three-filter additive process employing a red, green and blue filter. This three-color process is still used by astrophotographers with modern Charged Couple Device (CCD) cameras.

Kodak’s Kodachrome changed how color images would be created for general photography. Kodak created a single strip of film known as a tri-pack composed of three light-sensitive emulsions to record one of the three additive primary colors, red, green, and blue. Despite the “slowness” (sensitivity to light) of the film color, photography was to become an important tool for astronomers in the years to come.

Film manufacturers worked to produce faster films (more sensitive to light) to the delight of astrophotographers. However, the faster films did come at a price; grain (the textured look of high-speed film) and low resolution were more evident in these high-speed films.

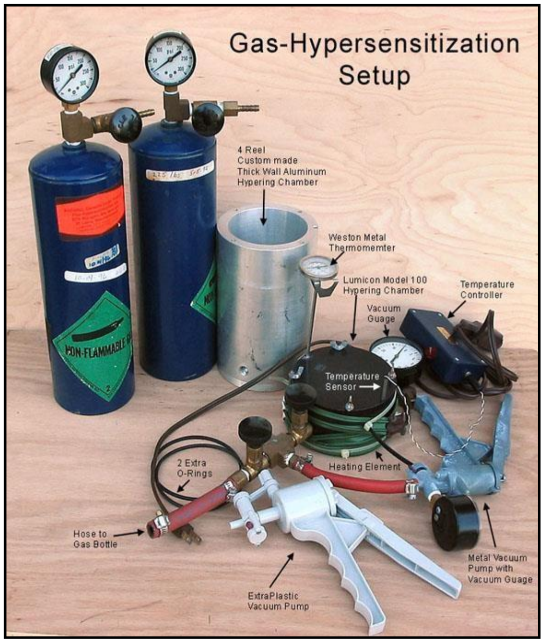


Figure 1-3 Film Hypering components

By the late 1980s astrophotographers took to hypering film to make it more sensitive to light in an effort to use short exposure times, especially for deep-sky objects. Hypering was one of those magical things that required special equipment, making it seem even more special.

Film was placed in a chamber; pressure and heat was added to the chamber and then exposed to hydrogen or a mixture of hydrogen and nitrogen gas. The premise behind this was to remove moisture form the film base which made it more sensitive to light. This procedure required a miniature pressure chamber and was time consuming and labor intensive.

In the late 1980s film manufacturers had improved their films, especially color films with characteristics which made them suitable to deep-sky objects without any special preparation or processing. Change, however , was just around the corner. Figure 1-3 shows the various pieces of equipment needed to hyper film.

Chapter 2 - Digital Imaging

Charged-Coupled Device Chip (CCD)

The charged-coupled device or CCD was introduced by Bell Labs in 1969. The silicon detector converted light photons to an electrical signal that was transmitted to a computer for viewing, storage and postproduction manipulation.

Like the analog methods of exposing photographic film to light and then processing the film in chemicals to produce a negative or positive image, a CCD chip also captures light. However, the manner in which images are viewed does not require a darkroom. The analog photographic process would change in the decades to come.

The advantages of the CCD camera became apparent to astrophotographers immediately to early users of this technology.

- Images were seen almost instantly on a computer screen
- Sensitivity of the device or chip was much greater than film
- The image could be manipulated with software to produce a better image or correct problems with the image in ways a darkroom technician could not.

The extended sensitivity was important to astronomers, who often exposed film for over an hour to image deep-sky objects. However, the CCD chip brought along limitations and problems similar to those astrophotographers faced using photographic film.

- Film, especially color film, suffered from reciprocity failure. Simply put, the longer film was exposed to light the greater the color shift within the film's emulsion layers. Reciprocity failure also meant that a 10 minute exposure compared to a five minute exposure was not going to capture twice as much information as the five minute exposure. Instead, the exposure might need to be 15 or 20 minutes to capture twice the detail but at the cost of experiencing a color shift and increase film grain.

- The CCD chip, while able to image fainter objects with less exposure time, suffered from electronic noise. Long exposures on a CCD chip produce artifacts on the frame. This "noise" is an inherent trait in the electronic chip. Think of noise as electronic grain in the image. While it is impossible to remove grain from an image made on film, noise can be managed in the digital frame produced with a CCD chip using several techniques:

  shorter exposures combined into one exposure can reduce noise (stacked images)

  the CCD chip can be cooled to reduce noise

- Early CCD chips were expensive and they required a computer to operate the camera and create the images, which needed to be viewed on a monitor. These early devices, however, were not for the frugal astrophotographer. There were few commercially available digital cameras on the market at the time available to astrophotographer and they were expensive.

Despite the issues and equipment requirements needed to image with a CCD chip, photographers were ready to use these new devices.

In the early 1990s, *The CCD Camera Cookbook* by Viekko Kanto, John Munger, and Richard Berry provided instructions and a list of components needed to build your own CCD camera. Using a Texas Instrument TC 245 chip, the builder would have a camera that could image a 378x242 pixel frame. It is estimated over 8,000 astrophotography pioneers built a Cookbook CCD camera. The cookbook camera was capable of competing head on with some of the commercial cameras such as Santa Barbara Instrument Group's ST-5 or ST-6. It's not known how many of these cameras were constructed but they numbered in the hundreds.

However, the use of a CCD camera for astrophotography was dependent on other items the astrophotographer had to take to the fields:

- Computer – the camera unit is operated by a computer program. Prior to the small laptops found today, early astrophotographers often used desktop computers to operate their CCD cameras. The camera did not have a shutter but relied on a computer application to "take" the photo.
- Power supply – CCD cameras require a large amount of power. Field users often found themselves needing several large deep-cycle marine batteries for power.
- Telescope with a clock drive – since the camera did not have a lens, attaching it to a telescope mounted on a clock drive or equatorial mount was the most common imaging platform.

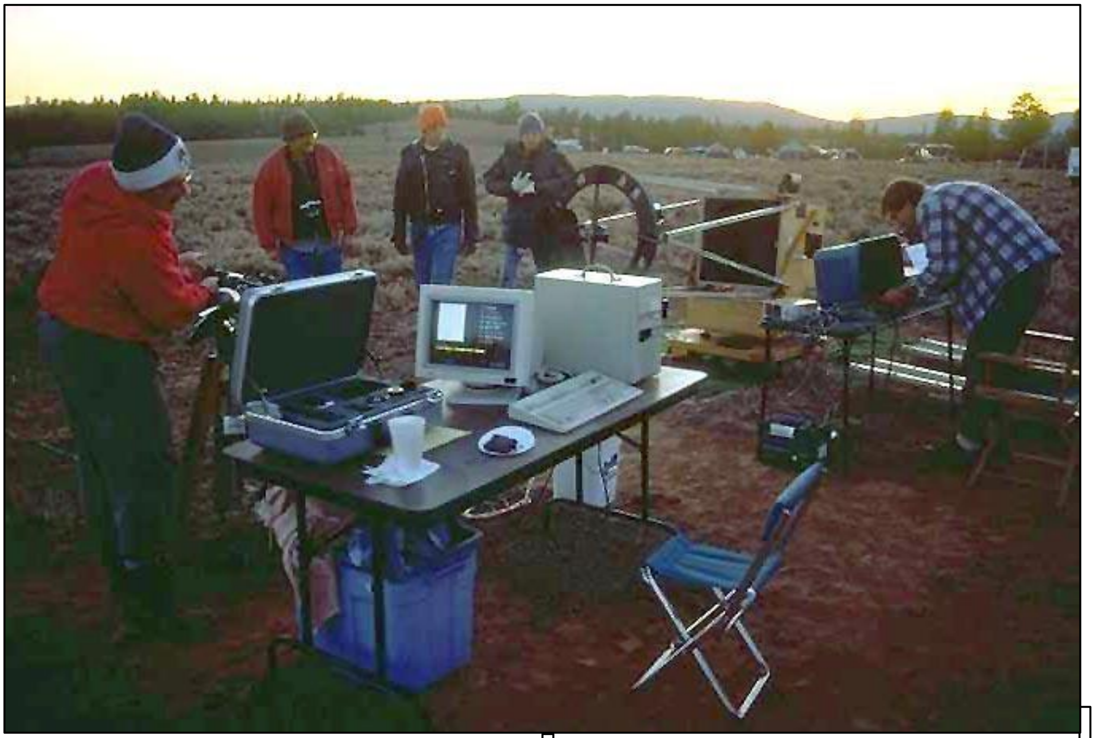


Figure 2-1 CCD imaging equipment in the 90s

Figure 2-1 shows astrophotographers setting up for a night of imaging. Notice the desktop computer and 15 inch monitor. The camera is in the metal case and the photographer is preparing the equatorial mount to attach the telescope and then the camera. These digital rigs were not for the faint of heart!

For the frugal astrophotographer, less is best. So, if you don't want to burden yourself with a heavy clock drive mount, computer and deep-cycle batteries for power, using a CCD based camera may not be the best approach to imaging the night-time sky.

Complementary Metal-Oxide Semiconductor Chip (CMOS)

The development and introduction of the complementary metal-oxide semiconductor or CMOS chip in the 1990s for consumer digital cameras opened up astrophotography to a wider audience of users. While the initial CMOS chips were not suitable for serious imaging, over time the chip and cameras using this chip were improved. Today's CMOS based digital cameras have evolved from the early CMOS point and shoot camera to cameras able to image deep sky objects without the need of a clock drive or telescope.

CMOS chips have characteristics that make them ideal for any frugal astrophotographer. Unlike the CCD chip, their power requirements are less. They are cheaper to manufacture but tend to produce more noise at long exposures. Over the past 20 years the quality and capability of CMOS chips is now comparable to the CCD chip.

The first consumer Digital Point and Shoot (DPS) cameras on the market were CMOS based cameras. Nothing more than point and shoot cameras, they did, however, change the way photographers would image the world around them.

Because a CMOS image sensor can contain various camera circuits on the same chip CMOS cameras can be quite small. This was one factor which made the consumer digital camera so popular after it was introduced. The low power consumption of a CMOS camera that allows for a smaller camera body also made them more appealing to users.

The fact that a photograph could be seen on a computer made the early cameras a big success commercially. However, they were nothing more an electronic Instamatic type cameras. You powered up the camera, pointed the camera and tripped the shutter. Focusing was not an issue because these cameras used fixed-focus lenses; making them so easy to use that many children received a DPS camera as a first camera present.

These first digital cameras had sufficient Pros and Cons to warrant improvements that would make them better for astrophotography.

Pros

- Easy to use
- Fixed focus lens
- Inexpensive

Cons

- Limited sensor sensitivity (ISO settings)
- Difficult to attach to a telescope
- No capacity for remote control
- Little or no ability to manually adjust ISO, shutter, aperture or focus
- CMOS chips were noisy at low light levels
- None were available as Single Lens Reflex (SLR) cameras to take advantage of existing lenses and other accessories

Figure 2-2 Early Nikon Coolpix camera

Figure 2-2 is the Nikon Coolpix 100, one of the first digital point and shoot cameras on the market. It had the following features:

- 1 MB built in storage – 21 images at fine resolution.
- 512X480 pixel resolution
- Fixed focus lens
- 4 AA batteries for power
- Images transferred to computer via a PCMCIA interface
- No preview screen

This was cutting-edge technology at the end of the last century but not very useful for astrophotography. But, later cameras, especially later Nikon Coolpix and Canon Powershot models, appeared and they were well-suited to learn the basics of astrophotography.

Chapter 3 - Which Digital Camera to Choose?

Digital cameras

There are two types of digital cameras an astrophotographer can use. The most affordable is the Digital Point and Shoot (DPS) camera. DPS cameras can be a no-frills unit with very simple controls or expensive with lots of features, some of these features being useless for astrophotography. The more expensive Digital Single Lens Reflex (DSLR) camera offers more controls to the photographer but comes at a higher price and some restrictions.

Digital point and shoot camera (DPS)

There are key features a DPS camera must have to be useful for astrophotography. The essential features needed on a DPS camera are:

- Ability to change ISO settings – this allows the user to change the camera's sensitivity to light. ISO 400 to 1600 are the sensitivity settings most often used. Higher ISO settings are good but they produce more image noise.
- Manual adjustment for shutter speed, aperture and focus – these features are essential in astrophotography. Auto focus is generally not useful for astrophotography.
- Remote control capability to trip the shutter – remote control of the camera reduces camera movement when the shutter is activated. Some cameras have infrared control systems and some cameras can be controlled using a Palm Pilot or similar pocket PC. Some point and shot cameras have provision for a mechanical cable release or wireless shutter release systems. Newer cameras offer Wi-Fi or USB connectivity to a Smartphone or tablet to control the camera.

Other features which are useful on a DPS camera include:

- A swiveling or tilting LCD screen – this is helpful when the camera is pointed close to vertical. A tilting screen also helps in focusing the camera.
- Mounting collar to attach the camera to a scope or add auxiliary lenses.
- Video capability – many DPS offer basic video capability which can be useful on certain astronomical targets.
- Can be powered from an AC power supply if needed. This is useful for time-lapse projects.
- Capability for the camera to perform noise reduction internally after a long exposure.
- Ability to switch between black and white and color modes.

Figure 3-1 Canon A70 Powershot camera

Figure 3-1 is the Canon Powershot A70. It was a big improvement over the Coolpix 100 with the following features useful to an astrophotographer:

- LCD preview screen
- Manual and Auto shutter controls
- Auto focus On or Off
- Compact Flash Memory card
- Video recording
- Ability to accept auxiliary lenses
- 3.2 megapixels
- ISO range: 100 - 400

Figure 3-2 Control dial for Canon A70

A DPS for astrophotography needs to have adjustable shutter speed controls as well as be able to switch to manual focusing.

Figure 3-2 shows the shooting mode ring on the Canon A70. The letters M, Av, Tv, P and Auto allows the photographer to configure the camera in a certain shooting mode.

The icons indicate specific shooting conditions. For astrophotography these are not used. However, this camera exposure ring shows the camera can also produce video, a feature useful in certain conditions. Letters indicate more specific camera exposure controls as noted below.

- **M** – Manual setting. The photographer can select the shutter speed, aperture, ISO speed and focus the camera manually. This is the most useful for the astrophotographer.
- **Av –** Aperture value. This setting allows the photographer to select a certain aperture, the camera then selects the appropriate shutter speed.
- **Tv –** Time value. This setting allows the photographer to select a certain shutter speed, the camera then selects the appropriate aperture setting.
- **P –** Program. The camera selects the appropriate shutter speed and aperture setting based on the ISO setting.
- **AUTO** – Automatic. The camera selects the ISO setting and the appropriate shutter speed and aperture based on the light conditions, the least useful to the astrophotographer.

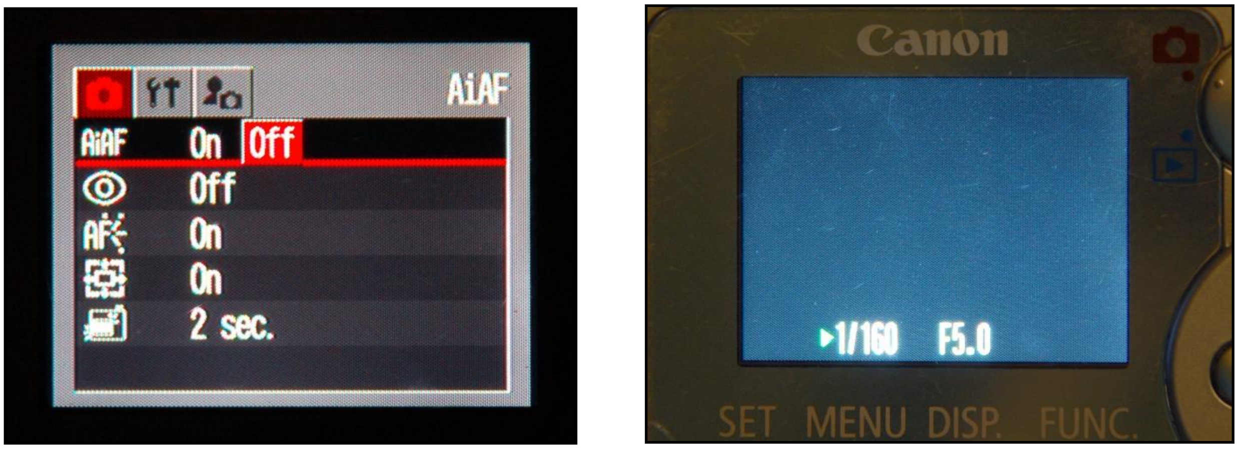


Figure 3-3 The Canon A70 controls are monitored and set using information displayed on the LCD screen

In manual mode, as seen in Figure 3-3, the photographer can select and make changes to shutter speed, aperture and focus. Your camera's manual will have information on how to set and use the manual controls.

Digital Single Lens Reflex Camera (DSLR)

The most popular DSLR brands currently used by astrophotographers are made by Canon, Fuji and Nikon. As the designation implies, these are single lens reflex cameras which use a CMOS chip instead of film to create an image. The features found on these cameras give the photographer more control in creating an image than the typical point and shoot digital camera.

Figure 3-4 Canon EOS 20D DSLR

Figure 3-5 Nikon D80 DSLR

Figure 3-4 shows an early Canon EOS 20D which can still be found at reasonable prices and a Nikon D80 (Figure 3-5) which is also a suitable DSLR for astrophotography.

A DSLR camera allows the photographer to select a shutter speed, aperture and ISO settings. Other features which make a DSLR well-suited for astrophotography are:

- Ability to attach the camera to a telephoto lens or scope for prime focus astrophotography
- Remote shutter control – all models have infrared, USB or hard cable shutter control capability. Some can be controlled by a computer, a smart phone , or a hand-held computer with the appropriate software
- Video – some models now offer HD quality video
- Live view focus – certain models provide a live view of the image, allowing the photographer to focus properly while looking through the lens
- Noise control – certain models allow the photographer to remove noise (signal interference) directly in the camera when high ISO settings are used
- AC power capability
- Ability to switch color modes: color, black and white or infrared (when modified)
- Ability to change lenses – the DSLR offers the photographer a wide choice of lenses, from wide angle to telephoto. However, not all lenses are suitable for astrophotography.

> *It should be noted that older Nikon lenses (pre-digital days) can be attached to the newer Nikon/Fuji DSLRs. As can be expected, these older lenses will not communicate with the DSLR's metering system but are used with the camera in Manual mode and manually focused. This point alone makes some of the older and fast Nikon and Nikkor lenses very desirable for astrophotography since the older lenses can be purchased at reasonable prices.*
>
> *On the other hand, not all Canon DSLRs are backward compatible with many of the older Canon lenses like the Nikons. However, Nikon lenses can be mounted to a Canon body with an adapter which has been designed for this purpose.*

Using a Canon DSLR offers the advantage of using both Canon and Nikon lenses. In addition, one older model, the Canon EOS 20D is suitable for astrophotography because it offers high sensitivity to the red wavelengths in deep sky objects. Other Canon models can be modified by having the Infra-Red filter removed, making them more sensitive to red wavelengths as well. This modification, however, makes the camera useful strictly for astrophotography work.

To date, there are no similar modifications for Nikon DSLRs. However, the Fuji S series (S1, S2, etc.) are Nikon based DSLRs which use Fuji's CMOS chips. These chips are different from the Sony chips found in the Nikons and offer a better response to the red wavelengths than the Sony chips.


Figure 3-6 Fuji S2 DSLR based on the Nikon D80

The Fuji S series cameras are based on Fuji's Super CCD chip. On the S2 it is a 6 megapixel chip that can also produce a 12 megapixel image. Based on the Nikon N80 body, S series cameras also use a film camera type cable release shutter design.

The one major drawback of the Fuji S1 and S2 is that they use two battery types, AA and CR123. The newer S3 use just the AA battery and the S5 uses a newer Li-on battery, which is not compatible with Nikon's EN-EL3e battery.

Figure 3-6 illustrated the larger size of the Fuji S series DSLRs. Over time DSLR models have become smaller with more features.

DSLR: DX versus FX

The image sensor size or format dictates whether the DSLR camera is a DX or FX camera. The two formats use a digital sensor but the diagonal of each is different and that difference affects the actual effective focal length of the lens being used on the camera.

A 35mm film camera produces an image in a frame 24mm high and 36mm wide. The DX sensor, or APS-C, as it is known for film formats, is much smaller, producing an image 15.7mm high and 23.6mm wide. This crop factor of 1.5 is for good for photographers who want to get more image on the frame and bad for those photographers who want a view as wide as possible.

The DX sensor, being smaller, creates an image from a 300mm lens as if the lens was a 450mm lens (300 X 1.5 = 450). The aperture remains the same. If you have a 300mm f/2.8 lens and attach it to a DX sensor DSLR, your images will be appear to be taken through a 450mm f/2.8 lens.

For wildlife photographers and astrophotographers, the DX sensor is not a bad thing. However, if you need to image wide views keep in mind a 18mm wide angle lens on a DX camera will produce an image that will produce a view as if the lens were a 27mm lens (1.5 factor). To get the true 18mm coverage wide angle coverage you would need to use a camera with a FX sensor.

Being frugal, the DX sensor makes much more sense!

There is no need to go crazy and buy a $1000 Digital Single Lens Reflex camera (DSLR) to begin imaging the sky. A good used Digital Point & Shoot (DPS) camera with certain basic features is sufficient to keep you busy as you learn to use the camera, its various features and become familiar with the software used to enhance your images.

It is possible to purchase a good DPS camera in the $100-$200 range on the Internet on sites such as eBay or Craigslist. Better yet, there may be members of your local astronomy club who have a camera they haven't used since they upgraded and will be happy to sell it for a reasonable price, just to reduce their equipment inventory (they will use the money to buy another accessory).

The Nikon Coolpix series cameras are good cameras to start your astrophotography experience.

Figure 3-7 Early Nikon CoolPix 995

The Coolpix cameras, like the Coolpix 995 in Figure 3-7, are available used on the Internet for less than $100. While most models produce images of less than six megapixels they offer features which are quite suitable for any frugal astrophotographer:

- Manual exposure and focusing options
- Swivel screen
- Remote control option
- Ability to attach to a telescope or eyepiece
- Limited video capture

If you own a Nikon SLR film camera which is gathering dust and you have a fast lens laying around, you might consider purchasing a used Nikon D80 or D90 to get started. Figure 3.5 shows a Nikon D80.

The Fuji S2 and S3 DSLR models are good used cameras to start with as well. Not only do they use Nikon lenses but the shutter release button is tapped to take a traditional cable release. Unfortunately, while the Canon DSLRs are better suited for astrophotography work because of their infrared characteristics, they are not completely backward compatible with older non-digital Canon lenses as the Nikon system is. Still, used Canon Rebel DSLRs are also available for under $400 from eBay or Craigslist as well.

Figure 3-8 Nikon to Canon lens adapter

On the plus side for Canon DSLR owners, Nikon/Nikkor lenses can be attached to a Canon camera with an adapter. However, there is no adapter to mount a Canon lens to a Nikon body due to the Canon lens design. The adapter may not provide all the electronic controls you may want but it gives the astrophotographer more options for lenses.

Figure 3-8 is a Nikon to Canon lens adapter. These can be found online in prices ranging from $35 to $100.

Video Cameras

An overview.

Using a low-cost video camera is another way to get started in astrophotography. However, using video to image does require the addition of a computer to control the camera and a lens or telescope to focus an image. This does require a drive to keep the scope aligned with the object. However, the tracking requirements for video imaging is not as crucial as for still images.

There are several USB video cameras which are suited for astrophotography and are worth considering. Keep in mind, a laptop is needed to run the camera and to save the images to the laptop's hard drive. Think of the video camera as a digital eyepiece connected to a computer or tablet. After the video is saved it can be manipulated/processed (stacked) to produce useable image.

Early Video Cameras

Webcams (digital video cameras) opened up imaging the planets, moon and sun with the ease of plugging the camera into a computer, installing the software and attaching the camera to a telescope or camera lens and capturing images.

One of the first commercially available webcams in the late 1990s, which were computer-based video cameras modified for astronomical use, was Connectix's QuickCam, Figure 3-9. The computer's printer port provided the connection and power to these early digital video cameras.

A modification required the removal of the camera's lens and the Infra-red filter. This camera was for the frugal astrophotographer who did not want to build a Cookbook CCD camera. Simple and easy to tear apart, it was the "do it yourself – DIY" junkie's dream.

Resolution was rated at 320X240 pixels with an imaging rate of 15 frames per second (fps) in video mode. The black and white camera could also take a snapshot which was controlled by software on the computer.

Figure 3-9 Connectix Quick Cam before modifications

Figure 3-10 Quick Cam prime focus images

Figure 3-10 shows Saturn imaged through a Celestron C8 and the moon imaged through a Celestron C78, a 300mm short refractor.

Celestron, Meade and Orion sell CMOS video camera models suitable for planetary, lunar and solar imaging. These cameras are connected to a computer and controlled by the software that comes with the camera. They do require an objective lens and are attached to a scope like an eyepiece for prime focus videography. Adapters can be made to mate certain cameras to a normal photographic lens as well.

Newer video astronomy designed cameras are now identified as Lunar Planetary Imagers (Meade) or Neximage Solar Imager (Celestron). Similar camera models are sold by Orion Telescope Company as well as other makers, Figure 3-11.

Figure 3-11 Current video cameras made for astrophotography

The downside of these cameras is that you are tethered to a computer. If you want to experiment with video, keep in mind that most new DSLR and DPS cameras have video capability. This would be a frugal way to test the waters for video imaging.

What Do I Need?

Astronomy is one of those hobbies that dwells on accessories. Astrophotography is no different.

Remember when you purchased your first telescope?

Suddenly you found it necessary to purchase additional eyepieces. Along with the additional eyepieces came filters, diagonals, Barlow lenses, a better clock drive and more. Astrophotography follows the same rules in that more is better, or so we think.

Once you have a camera for astrophotography and decide you want to image astronomical targets you will find yourself needing additional items and equipment to help make the imaging process easier. Many of these items do make the process easier and do help produce better images. Manufactured accessory items can be costly and this is where the frugal astrophotographer can have fun making their own accessories, when possible.

Besides the camera, the following two items are essential.

Tripod – the heavier the better! Why heavy? A heavy tripod will remain steady, even when the wind is blowing.

Shutter release cable/connector – for digital cameras that have a threaded shutter button, a shutter cable is the cheapest option. Shutter release cables can be obtained from any camera store. Newer cameras can be also controlled via Infra-Red, a USB cable or through Bluetooth/Wi-Fi to a Smartphone or tablet to trip the shutter.

Depending on the camera additional items would include the following:

Camera/telescope attachment rings. DPS cameras require an adapter to mate the camera with an eyepiece or lens. Lenses can be changed on a DSLR.

- DSLR – lenses for prime-focus photography
- T-Ring – to attach a camera body to a scope/eye piece
- Eyepieces – for eyepiece projection photography

Telescope – short focal length for:

- Prime-focus photography
- Eyepiece Projection lens photography

Software for remote control – for tablet or smartphone to:

- Control the shutter on the camera
- Create time-lapse videos

Flashlight
Notepad
Barndoor – a DIY clockdrive? – more on this item later

What You Really Need to Know Before You Start

The most important concept to understand is the basic principles of exposure. The concept is the same whether one is exposing film or using a CCD or CMOS chip to create a digital image.

An exposure consists of an amount of time to expose light to film or the chip combined with a fixed unit of light passing through a lens which will fall on the film or chip. These two items are referred to as the shutter speed or exposure time and the aperture or lens opening which creates an exposure. The more common reference for these two items is the shutter speed and f/stop.

Two other variables have an impact on how the image will appear on film or chip. These variables are the focal length of the lens and the lens' maximum aperture or speed. The focal length of the lens determines whether you produce a wide angle view (short focal length) or a magnified (telephoto) view (long focal length).

A lens has a maximum aperture or f/stop. The lens' aperture can also referred to as focal ratio, f-ratio, or relative aperture. The aperture is the maximum diameter of the lens. Aperture is referred to as f/1.2, f/2.8, f/8 or f/22 etc. The ratio for each stop is half or twice of the adjacent stop. As an example, f/1.2 will let in twice as much light as f/2.8. The aperture setting f/3.5, on the same lens will pass one-fourth the light of f/1.2.

An exposure then consists of combining a shutter speed and f/stop to properly expose film or capture an image on a chip. Shutter speeds on mechanical cameras are set in fractions of a second, such as 1/30, 1/60 or 1/125 and B for bulb or T for Time. These last two settings keep the shutter open for as long as the shutter button or cable release keeps the shutter open. The bulb setting is the most frequently used shutter setting used by astrophotographers.

Electronic shutters on digital cameras will produce shutters speeds outside the traditional 1/30 or 1/60 of a second. If the digital camera determines 1/28 is appropriate, it sets 1/28 of a second for an exposure time (another advantage of digital over analog/mechanical systems). Like the aperture settings, each shutter speed is twice as fast or twice as long as the adjacent setting (analog cameras). Your camera's manual will have more details on whether your camera is capable of producing variable shutter speeds.

For astrophotography purposes we must also add the ISO setting or sensitivity to light of the film or chip and the maximum aperture of the lens when imaging. Selecting a fast film (with a high ISO number such as 800 or 1600) or setting the digital camera's sensitivity to the same ISO number (800 or 1600) indicates the subject is not reflecting much light. In order to create a good image we must help the medium being used by increasing its sensitivity to light.

- The increased sensitivity, coupled with a fast lens then allows us to expose the film for a shorter period of time. There is a trade-off, however, when using film with a high ISO number. The images will be grainy, the resolution is less than using a slower film setting and the image will tend to look soft. To have sharper images you select a slower film but then must expose it for a longer period of time because of its lower sensitivity.

- With a digital chip, there is also a trade-off. High ISO settings will produce noise in the image. Noise is seen as a salt and pepper-like grain in the image. Some of the noise is caused by dead pixels in the chip and as the chip becomes hotter (from the longer exposure time) more noise becomes evident.

There are computer processes which allow the photographer to reduce the amount of noise in a digital frame but it is one element which must be kept in mind when imaging. Like all photographers, we must then make some decisions while imaging.

The decisions will be based on several things:

1. **Subject** – is it bright or dim?
    a. the moon, sun and planets are bright
    b. constellations are dim
    c. eclipses will start out bright and then become dim
    d. meteor showers – the longer exposure (timed exposure) needed to capture any meteors requires a low ISO setting
2. **Lens aperture** – is it fast (f/1.4) or slow (f/5.6)?
    a. DSLRs offer more choices for fast lenses which allows for more options with regards to ISO settings
    b. DPS camera lenses tend to be in the f/3.5 range, not fast and not slow
3. **Lens focal length** – short (wide angle) or long (telephoto)?
    a. 18mm – 35mm wide angle images will show less star movement during exposure, allowing a lower ISO setting and longer exposure
    b. 105mm to 400mm telephoto images increase star movement requiring a higher ISO setting to allow for a shorter exposure as well as camera movement.
    c. DSLRs offer more choices of fast short and long focal length lenses
4. **ISO setting**
    a. based on the above conditions you select an ISO setting that will allow you to create an image that will satisfy you, the photographer

To put all these elements into perspective think about cooking steak or chicken. Some meats, such as steak, can be cooked quickly on a hot grill. The result is a rare steak which is tasty. Other meats, such as chicken, require just a bit more time to cook and using a hot grill is not necessarily the best way to cook chicken. Chicken will require more cooking time and less heat than steak, or you end up with burnt offerings to the Gods.

Exposure is simply cooking the film or chip with the right amount of light (aperture) for an optimum time (shutter speed) based on what you are imaging and with what equipment you have at hand.

> *The hotter the cooking temperature (high ISO) the less cooking time (shorter exposure time). The lower the cooking temperature (low ISO) the longer the cooking time (longer exposure time).*

The 400 Exposure Rule

This rule is used to find the longest exposure that will produce pin-point stars without trailing for a given lens focal length. A short focal length lens (wide-angle) has a wider field of view than a long focal length lens (telephoto) and will allow a longer exposure before stars begin to trail. The rule is divide 400 by the focal length to get the exposure time, in seconds. The reason I recommend 400 over the older 600 rule is that this rule needs to work with cameras having a full-size sensor or an APS-C sensor, which captures 2/3 more field of view, resulting in a need of a slightly shorter exposure since stars will begin to trail faster.

Example: 18mm lens	**Full Frame Sensor**	**APS-C sensor (1.5X factor)**
	400 ÷ 18 = 22.22 or 20 seconds	**400 ÷ 27 = 14.8 or 15 seconds**

This is a starting point with a lens wide open and with an ISO which will give the best image without too much noise. Stars near the pole will move slower than stars near the equator. If you stop down you will need to increase the time or the ISO setting. Now you are ready to start imaging the skies

Chapter 4 – How To Image Without an Equatorial Mount

An equatorial mount is not necessary to start imaging the sky. However, a long focal telephoto lens or a short focal length spotting scope can be used when used in certain configurations, as listed here.

1. *Astrophotography without a telescope (DPS and DSLR) – just the camera*

Celestial events such as planetary conjunctions, star trails, eclipses, meteor showers, sun halos, sun dogs, sunsets, auroras, rocket launches and planetary transits are subjects which can be imaged with just the camera. The basic items needed are the camera, a tripod and a cable release or remote control device. These images will be wide-field views of images, depending on the focal length set with the DPS camera or the lens which is attached to the DSLR.

A webcam or CCD camera is not suited for this approach since it must have a primary lens to be able to focus.

2. *Afocal/Eyepiece projection astrophotography with a DPS camera*

Afocal or eyepiece projection astrophotography involves imaging through the eyepiece of a telescope or spotting scope. The earliest application of the DPS camera in astrophotography was using this approach. Cell phone cameras can also be used to create afocal images through a spotting scope or telescope's eyepiece. Remember, all you need is a steady tripod to start with; forget the GEM.

Any camera which has a viewing screen to view, compose, and focus the image can be used for this method. This is one technique where a DPS camera's autofocus can be used, with some success, depending on the camera.

This technique is referred to as digi-scoping and is favored by birders, who use their spotting scopes and a DPS camera to image through the spotting scope's eyepiece. The use of a DSLR camera for this technique is not as popular or convenient as using a DPS camera.

Hand-held Afocal/Eyepiece projection (DPS)

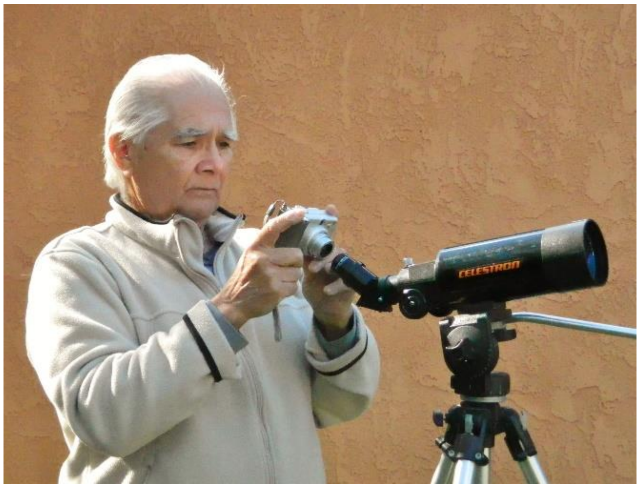


Figure 4-1 Very frugal imaging technique

There are drawbacks, though, to simply hand-hold a camera to the eyepiece. You must be aligned with the eyepiece or the image will be vignetted. Vignetting is when dark edges are created in an image because the taking lens is not optically aligned with the projection lens or eyepiece. If the focal length of the camera's lens is too short (zooming back to the wide angle setting) Vignetting will also occur as well as zooming in too far.

A DPS camera has the edge over the DSLR camera with this approach because the lens can be zoomed in and out and you can see the results on the camera's viewing screen. With the newer "Live Image" DSLRs, this is not a problem, but, the larger, heavier DSLR is bulky to use in a hand-held manner.

Another problem with the hand-held technique is camera movement. While the scope is stationary on a mount or tripod, you are holding the camera to make the exposure. Blurry images are common when using the hand-held approach to imaging because there will be camera movement.

Figure 4-1 illustrates how awkward handholding the camera to a scope can be. Handholding a camera to image through an eyepiece, while quick and simple, will not consistently produce sharp images. However, there are clips and brackets for certain DPS and smartphones which allow good alignment between the eyepiece and the camera.

Afocal/Eyepiece Projection Adapters (DPS)

In order to align the DPS camera to the eyepiece some form of attaching device is needed. Camera and eyepiece adapters for various cameras and Smartphones are available from many manufacturers. Some adapters are made for specific cameras while other adapters are universal models.

Figure 4-2 Canon A70 with eyepiece projection components

Figure 4-2 shows a Canon A70 Powershot camera with a Scopetronix eyepiece and Canon camera adapter. The camera's lens ring is removed and replaced with the eyepiece adapter mount. The eyepiece is held in the adapter with six set screws. An extended eyepiece adapter is screwed into the camera and the eyepiece is then attached to the telescope. This rig allows the photographer to image through the eyepiece without the hassles of trying to hold the camera steady while shooting through the eyepiece.

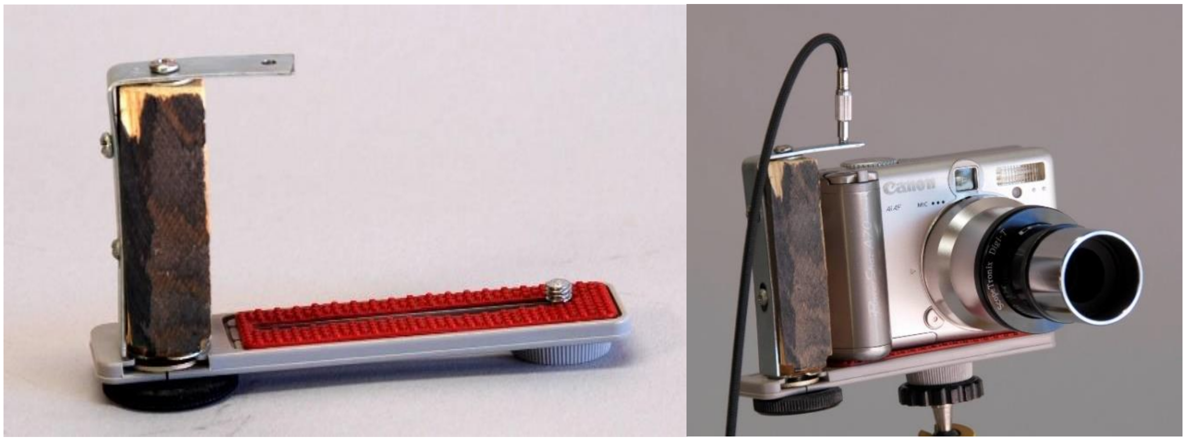


Figure 4-3 A shutter release frame for a Canon A70

A shutter release cable is essential to open and close the shutter with no camera movement. For older cameras that do not have a remote cable thread on the shutter button a Do It Yourself (DIY) shutter release rig can be made to trip the shutter. Figure 4-3 shows a home-made shutter release cable rig and the camera. Newer DPS cameras may have Wi-Fi or Bluetooth capability allowing the use of a Smartphone or tablet to trip the shutter.

The DIY approach is one way of being frugal.

Figure 4-4 Coolpix 995 with eyepiece and remote unit

Some DPS cameras have lenses which do not retract. Eyepieces are easier to attach to this type of lens with an eyepiece adapter collar that attaches around the lens. A common lens diameter is 25mm. On this type of camera, adapters are easy to find.

In Figure 4-4 a Scopetronix Digi T-ring is attached to a 1.25 inch eyepiece. The eyepiece is secured with three set screws. The Digi-T-ring unit is screwed into the camera's lens. This Coolpix is using a remote cable made specifically for the camera.

This type of eyepiece adapter is simple to assemble and set up on the camera. The eyepiece is then mounted to the telescope. Older Coolpix cameras are well suited for afocal photography because the LCD screen swivels, making it easier for the photographer to compose and focus the image.

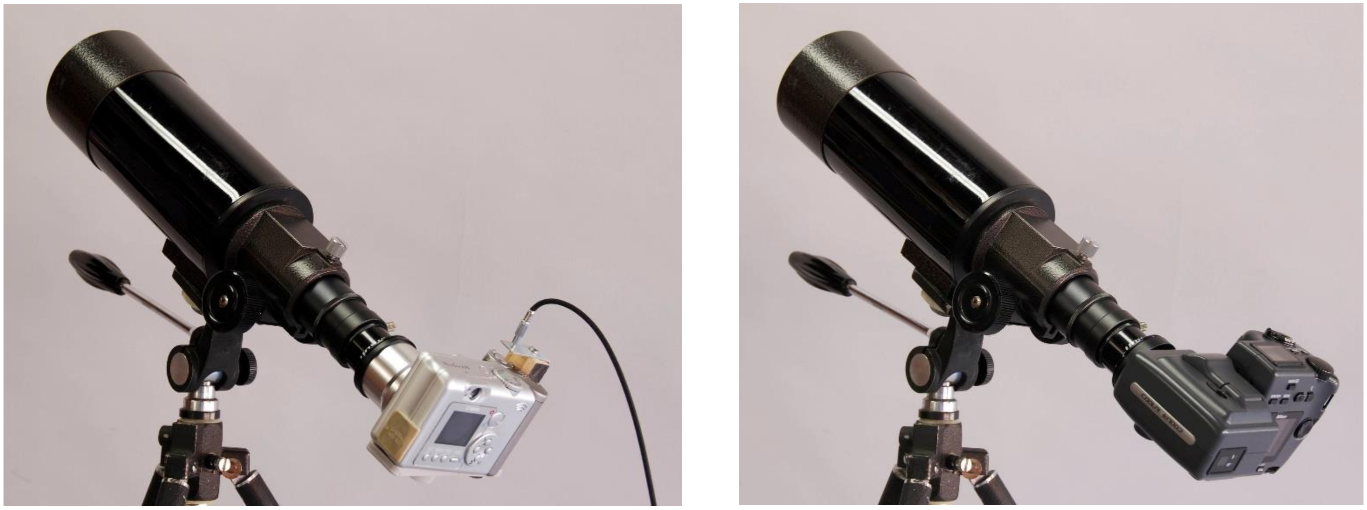


Figure 4-5 Eyepiece projection setups

Using a DPS camera to image through a scope with an eyepiece is the most frugal way to get started in astrophotography. Figure 4-5 shows a Canon A70, and a Nikon Coolpix 995 setup up for eyepiece projection on a Fixed tripod.

However, there are limitations on what can be photographed based on the DPS. It is important to remember that the autofocus function of the DPS camera should not be used unless you are employing the hand-held method.

Still, there are certain DPS models which provide a great deal of flexibility to the photographer to manipulate shutter speed, aperture and ISO settings. Check with members of your local astronomy club on which DPS camera models astrophotographers in the club use to image.

3. *Prime Focus Astrophotography – DSLR*

Prime focus astrophotography is where a camera body uses a telescope as the primary lens to image. The DSLR is the best-suited camera to use for this technique. Short focal length refractors offer a reasonable apertures (f/stop) which will allow exposure times of ten seconds or less, they are portable and within the price range of all frugal astrophotographers. I suspect many potential frugal astrophotographers probably have one of these scopes somewhere in their cache of unused goodies.

Once the lens is removed from the DSLR, you must be able to attach the camera to the telescope. For prime focus work you will need two items, a T-ring and a telescope T-adapter, depending on the scope you have.

T-rings are made to fit specific camera mounts. One end will match the bayonet mount of the camera (Nikon, Canon, Olympus, etc.) The other end is threaded to accept a range of accessories. Figure 4.6 shows a T-ring made for Minolta camera. The T-ring telescope adapter screws into the camera adapter and then allowing the camera to be mounted to the scope through the eyepiece opening.

T-ring telescope adapters are available in 1.25 inch and 2 inch diameter sizes. This allows using a small refractor or a large Schmidt-Cassegrain scope if needed.

Figure 4-6 T-ring with 1 ¼ inch eyepiece adapter. The adapter would allow you to attach a DSLR directly to a scope.

Figure 4-6 T-ring and adapter

A short focal length telescope such as an 80mm diameter 400mm focal length wide field refractor is a good scope to use to learn prime focus astrophotography. This type of refractor has a reasonable aperture of f/5. While not in the range of being a fast “taking” lens, the aperture size is sufficient to image the moon or sun without the need of a clock drive and these scopes are available at a reasonable cost.

Think of this scope as your 400mm f/5 telephoto lens, which can also be used for terrestrial objects. The downside is that the camera’s metering system cannot be used so you must set the camera to Manual and test to find the best exposure for your images. Focusing is accomplished by viewing through the viewfinder of the camera and using the scope’s focusing knob to focus the image.

If you don’t have a short focal length telescope an inexpensive telephoto lens which uses a T-adapter is another way to get started.

This type telephoto lens is cheap and very common. Keep your expenses down by starting out with this type of long focal length lens if you have a DSLR camera.

Figure 4-7 Spiratone 400mm f/6.9 pre-set manual focus lens

Figure 4-7 Spiratone 400mm f/6.3 preset telephoto lens. Notice the camera end is threaded for a T-ring adapter.

These older pre-set lenses (the f/stop must be manually opened and closed) are inexpensive and can be found at garage sales and thrift shops for less than $20. With the correct T-mount they can be attached to any DSLR camera and used with the camera's manual setting for shutter speed control. Since they are also manually focused they make excellent lens to image the moon and the sun (with the appropriate solar filter).

On a DSLR camera with a chip aspect of 1.5:1 this 400mm lens becomes a 600mm telephoto and with a 2X teleconverter (works like a Barlow lens –doubles the focal length) will have a focal length of 1200mm; but with a very slow f/12 lens aperture speed. This lens is best suited for lunar work and with the appropriate filter, solar imaging.

4. Projection Eyepiece Astrophotography

We can take the prime focus approach (where the DSLR is attached to a telescope) one step further and add an eyepiece to the equation. This technique is not the same as the hand-held DPS technique because you are not imaging through the camera's prime lens. Instead, the eyepiece will produce its own magnified image on the camera's film plane or sensor. The DSLR camera is best suited for this technique. DSLRs with LiveView features are ideal since they allow you to see the image live and focus precisely. DPS cameras with LCD screens are also ideal for this technique since they do provide a live view on the LCD screen.

This technique produces large scale images and is best for planetary, lunar or solar detail. Planets can be imaged because they are bright enough to be seen through the viewfinder to focus and provide sufficient light to use a reasonable shutter speed. However, the final image size may not be sufficient to provide usable detail. Craters on the moon and sunspots are good targets for this technique as well. ***Remember to always use a solar filter whenever you image the sun.*** Eyepiece projection is not for deep sky objects (DSO) since they are faint to begin with and would offer problems in focusing and exposure.

Eye Piece Projection – what you will need

In addition to the camera you will need a 1.25 inch or 2 inch eyepiece, T-mount adapter and either a T-ring telescope adapter or an eyepiece projection adapter. If you plan to use a 2 inch eyepiece you will need to use a 2 inch telescope adapter and a 2 inch eyepiece projection adapter. Two inch hardware is much more expensive than the more common 1.25 inch items but the decision is up to you as to how frugal you wish to be. The two inch equipment is best suited with a DSLR.

- Eyepiece – any focal length will work. However, any eyepiece less than 10mm will vignette the image and have more image fall off around the edges. The best eyepiece focal range is

25mm to 18mm. Some eyepieces have been designed for eyepiece projection. They include the Pentax XP series and the Baader Hyperion series. For a basic eyepiece design, start with a Plossl eyepiece.

- T-mount adapter – the appropriate adapter for your camera.
- Eyepiece projection adapter – an eyepiece adapter threads into the T- mount adapter. The eyepiece is mounted in the adapter and held in place with a set screw. Some adapters allow you to adjust the eyepiece to change the magnification of the image.

Figure 4-8 Nikon D90 with T-ring, eyepiece and 1.25 inch eyepiece holder

Figure 4-8 shows a DSLR camera with the basic items needed for eyepiece projection. A T-ring, which attaches to the camera, an eyepiece and the eyepiece adapter which holds the eyepiece and then screws into the T-ring.

5. Webcam/DPS/DSLR Video Astrophotography (the short course)

Video imaging is another process which can be accomplished with a DPS, DSLR camera or webcam. Keep in mind the webcam will require a computer to capture the images. A video-capable DPS or DSLR camera does not have to be connected to a computer which offers a bit more flexibility to the photographer. Instead, you can record the images directly into the camera and then transfer the images by connecting the camera directly to the computer or inserting the camera’s storage card into the computer for manipulation and enhancement of the images.

Webcams and video eyepieces are attached to a scope or can use a photographic lens with the appropriate mounting adapter. These cameras do not produce an image but must be connected to a computer or video recording device to capture the image. For the frugal photographer this is a good way to start and use the camera and video capture software.

DPS and DSLR cameras that have video capability offer more flexibility because these cameras will record the video image onto the camera’s storage card. Working the video files is simplified by transferring the files to a computer with a cable or removing the storage card and inserting it into the computer to transfer the video files. Some photographers find this approach easier and less equipment-intensive.

Video Format

The video format a webcam will produce is dependent on the camera’s video codec. DPS or DSLR cameras produce video files in several formats as well. There is no set standard format but all these formats are compatible with current PC and Mac computers and image processing software. The most common video formats produced by digital cameras are AVI, ASF, WMV or MOV.

This type of astrophotography lends itself to lunar, solar and planetary imaging because these targets are bright and do not require the need for a clock drive or tracking device, *per se*. In addition, when used with stacking software, excellent images can be produced.

Chapter 5 - Getting Started

From this point on, document every shot you take. Create a logbook as you start imaging the sky. A journal will help you create better images as you gain experience photographing the sky and learning to use your camera. As is expected, later you will probably want to upgrade the camera and other equipment, perhaps to image deep-sky objects and these notes will be invaluable as you go along that new path.

What should you enter in your logbook?

- Date/Time – the day and time you make the image
- Location – urban or rural
- Target – the target or event
- Shutter speed – in fractions of a second or the length of the exposure
  - Exposure time is also used to create a dark frame for image manipulation.
- Aperture/Lens – f/stop setting and focal length of lens used
- ISO – film or chip sensitivity setting
- Results/Comments – note how the image came out. List whether it's acceptable or needs to be reshot due to whatever looks wrong. This is where you need to write down what was correct or wrong.
- The image is out of focus or blurry. What did you do to make it so?
  - Camera shake
  - Camera power dies during the exposure
  - The image is under or over exposed. What were your exposure settings?
  - Why is it over or underexposed
  - The location: urban or dark sky area?
  - Next time do a better job of scouting the location. Maybe a street light was there and you didn't notice it until after you had made the exposure.
- What went right – this is important because it will help with subsequent shooting sessions
- This is your image. Did you accomplish what you set out to do or not? If not, write down what needs to be better to improve the image.
- Post-shooting image manipulation – what software and technique was used to improve the image
- Any surprises that you find in your image. These will help you see better each time you have a shooting session.

Celestial Targets

The following targets and events are easy subjects to image without the need of a telescope:

- Star Trails
- Meteor Showers
- The Sun
- The Moon
- Eclipses – Lunar and Solar
- Conjunctions and Occultations
- Rocket Launches
- Auroras
- Sun Dogs
- Sun Pillars
- Comets
- Rainbows

Chapter 6 - Star Trails and Meteor Showers

The easiest astrophotograph to make is a star trail image.

The earth rotates 360° in a 24 hour period or 15° in one hour. When you leave the shutter of the camera open for any amount of time the light from a star or stars will create a streak of light or a star trail on film or the camera chip as a result of the rotation. The longer the exposure the longer the trails will appear in the frame. Leave the shutter open for 15 minutes and you will get a streak of light across the film or digital chip plane.

Figure 6-1 Star trails around Polaris

Figure 6-2 Star trails and meteor shower (camera pointing south, trails are streaks instead of circular).

Figure 6-1 is a 15 minute timed exposure with the camera pointed towards Polaris, which is hidden by the branches of the tree. The earth's rotation becomes more evident with this type of orientation as the stars create concentric circles around the celestial pole star during the exposure. The diagonal line running from the upper right to the lower left corners of the image are the lights from a passing aircraft which flew across the field of view during the time the shutter was held open.

Sometimes these intrusions may ruin a shot or they can also become an additional visual element to the shot. This is the easiest astrophotograph to make.

Figure 6-2 is a 20 minute exposure, taken from Figueroa Mountain, California, which captured the light from stars as they moved across the film plan to create the star trails. The image also shows meteors from the 2001 Leonid Meteor Shower which were falling during the 15 minute exposure.

Star trail images will also show the various colors of stars which are used to identify the type of star in the image. The color is an indication of the star's temperature. How many meteor trails can you see in the image in Figure 6.2?

How To Image Star Trails:

1. Set the camera* on a tripod. Attach a cable release or remote control unit to trip the shutter without moving the camera.
2. Set the shutter speed to "B" for Bulb. This will leave the shutter open for as long as the shutter is held open (Some DPS cameras may not have a Bulb setting). The lens aperture is set to its widest setting (the lower number such as f/2.8 or f/3.5).
3. Focus is manually set to infinity (∞). Both the DPS and DSLR camera must be taken off the Automatic mode and changed to Manual to set the Bulb setting. DPS cameras must also be in the Manual focus mode to set the focus to infinity (∞). Autofocus is not used in astrophotography.
4. Compose the shot by looking for objects in the foreground which will add interest to the image and look through the camera's viewfinder or screen.

* Always use fresh batteries if using a digital camera. Bulb exposures will drain a camera's batteries faster than normal shutter speed usage and you don't want the camera powering off during a long exposure.

Software which allows you to stitch exposures is useful for producing long star trails by stitching short exposures into one long exposure.

Stars With No Trails

The frugal astrophotographer should push the envelope when possible and creating star images without trails is quite inside the envelope. Star trails require a location that will provide a good background, a clear nighttime sky and practice. After you have created star trail images that you are satisfied with, you are ready to start imaging stars without trails.

The star trail images are produced because the earth is rotating at 15 ° per hour and by leaving the shutter open for any length of time the result is light of the stars is trailed in the image. There are two approaches to produce pin-point star images.

1. Use a clock-drive (German Equatorial Mount –GEM) – expensive and not what a frugal astrophotographer would consider to use in the first place, or maybe?

2. Use an exposure that allows sufficient light to create the pinpoint without a drive mechanism. Use the 400 Rule to calculate exposure times.

Approach number two is the most acceptable, but it does come with several *caveats*. The camera must have a lens with a large aperture. A short exposure time or shutter speed is needed to minimize the star's movement and the ISO setting will need to be high in order to capture the star's light with the short exposure time, hence the need for a large aperture or f/stop.

Star images without trails are best suited to a DSLR camera. The few DPS cameras which offer the Bulb setting cost as much as a used DSLR but their lens apertures are usually in the f/3.5 range. These cameras, unfortunately, do not allow you to change lenses like a DSLR camera.

Consider purchasing a used DSLR and look for a fast short focal lens to complete the set. The lens does not have to be an Auto-Focus (AF) lens because the AF feature is seldom used in astrophotography.

The focal length of the lens also contributes to the length of a star trail. When using a DSLR change to a wide angle lens (18mm to 28mm focal length). The short focal length helps minimize star trails and allows you to use a longer exposure time as well without producing star trails.

Figure 6-3 Orion Constellation, 8 X 4 second exposures.

Figure 6-3 Pin-point stars in the Orion Constellation

The ISO setting was 3200 and the focal length of the lens was 18mm with an aperture of f/3.5. The exposure was four seconds. The problem with the image is the amount of noise or grain evident in the frame. This is an inherent problem when using high ISO settings.

Eight exposures were stacked and blended to produce the final image using DeepSky Stacker as noted in Chapter 11. Stacking exposures helps remove some of the noise due to the high ISO setting.

Older manual focus Nikon lenses (Figure 6-4) with apertures in the f/1.2, f/1.4 or f/1.8 range are well suited for this and they can also be attached to Canon DSLRs with an adapter as well as a Nikon or Fuji S series DSLR camera. These lenses allow you to use ISO 800 or lower and faster exposure times to minimize noise and still produce good sharp star images.

Photography is a series of compromises and astrophotography has more compromises than normal photography. As a frugal astrophotographer you will chart your path with the tools (equipment) you have on hand and the targets you will image.

Figure 6.4 – Nikkor 50mm, f/1.4 manual lens

Chapter 7 - The Moon and the Sun

The moon and sun are ideal targets to begin learning astrophotography. Both are bright and large objects which makes them easy to find and focus in a viewfinder or LCD screen. As you practice imaging the moon and sun you will become more familiar with the camera and where the various controls are as well. As you advance to other targets you will be able to use and control the camera without having to think about how to change settings. The moon can also be imaged during the day and I would suggest some daytime imaging sessions to become familiar with the camera.

Equipment needed to image the moon can be as minimal as the camera you have on hand and a long telephoto lens or small telescope and combined with an eyepiece projection set up to obtain detail images of craters on the moon and a tripod.

Lunar images include full moon, lunar phases, lunar craters, earthshine, conjunctions, occultations and eclipses. Each requires a different approach and in some cases, additional equipment besides the basic camera. Starting out by imaging a full moon will help you identify some of the problems faced when imaging the moon.

Solar imaging always requires the need of a solar filter! Solar filters block most of the sunlight to avoid any damage to the eyes. They are usually made from a durable material which transmits 1/100,000th of the light. They are used for visual observation and photography. More information on solar filters will be discussed in the solar section of this chapter.

Solar events that can be imaged are eclipses, transits, sunspots, prominences and surface granulation. Each of these will require a special solar filter in order to view these solar events.

Warning: Always use a solar filter when viewing and imaging the sun.

Getting Started - The Moon

The moon goes through phases every 29 days, 12 hours, 44 minutes (from new moon to new moon). The major moon phases are:

- New Moon
- Waxing Crescent
- First Quarter
- Waxing Gibbous
- Full Moon
- Waning Gibbous
- Last Quarter
- Waning Crescent
- New Moon

Waxing/Waning Crescent Moons

The challenge with the end or beginning of the new moon phase is to image the earliest waxing crescent or latest waning crescent as the moon rises or sets during these phases. This will require timing and patience, plus you will need to bracket the exposures to get the most detail on the moon’s surface.

Figure 7-1 Waning moon, fixed tripod

Figure 7-1, taken early in the morning, shows not only the waxing moon but a Great Horned Owl flying back to its roost after hunting during the night.

Images like this require luck and also some knowledge of other events occurring at the same time.

I had seen the owl on other mornings as I fetched the newspaper from the driveway. I decided to keep the camera on a tripod in case I saw the owl again. In this particular morning I saw the waxing moon and took the camera to capture the thin crescent. The owl just happened to fly overhead then.

The key to an interesting image is to frame the subject with foreground or background material. In this instance, the owl was an added bonus.

Earthshine

Earthshine is a good target to image during the thin crescent phases as well. The camera's exposure meter may be useful to establish a starting point. However, you will want to bracket the exposures to ensure imaging the detail in the moon's dark or shadow side. The trade off for this detail is that the moon's crescent or sun light side will be overexposed. Figure 7-2 shows detail on the moon's surface from reflected earthshine, Venus and the star 28 Sagittarii to the right of Venus, all captured with a zoom lens and tripod.

Figure 7- 2 Earthshine, Venus and star 28 *Sagittarii*

Imaging earthshine on the moon provides you with an opportunity to try different exposures.

Try various exposure settings using the matrix, center-weight and spot meter settings on the camera. Change the metering to Manual and add your own shutter and exposure settings and see which is best.

Compose the shot with something in the foreground to add depth to the shot. This image was taken with a zoom lens.

First/Last Quarters

First and last moon quarters and the phases in between offer good opportunities to image using the eyepiece projection technique. The moon's features are more visible as sunlight falls across the moon surface at an angle creating shadows in and around craters. In addition, mountains and valleys are side lighted or backlighted during any phase up to or after a full moon. This type of side illumination reveals surface texture and details that make for interesting images.

Moon features along the terminator line are excellent targets to image as the moon transitions from a waxing moon to a waning moon. These features are hard to see during the full moon phase because sunlight is falling directly on the surface of the moon.

Figure 7-3 Lunar views at prime focus and with eyepiece projection

Figure 7-3 illustrates a prime focus image of the moon and detail using eyepiece projection as discussed in Chapter 4.

Full Moon

Figure 7-4 Full moon on full from a CMOS chip.

Figure 7-4 shows a full moon taken with Fuji S1 camera and 400mm telephoto lens with a 2X teleconverter.

Even though the effective focal length is 1200 mm it is not enough to fill the frame with the moon's disc.

The fact that the moon is not filling the frame allows you to find and center the object easier than if it was filling the frame because you can move the scope to center the target in the viewfinder.

Figure 7-5 Moon cropped

Figure 7-5 shows the same image, but this time it has been cropped. Even with some cropping the image is static and boring.

Unless a full moon image is being used to describe features such as craters and *mares* try to add some other visual elements to the shot.

Use the full moon time to practice focusing. Autofocus will not work perfectly so you must focus manually through the viewfinder or screen. Work on tripping the shutter as smoothly as possible. Any camera movement will result in a blurred image, regardless of how well you have focused.

Lunar Eclipses

Figure 7-6 Total lunar eclipse at totality

Imaging lunar and solar eclipses (with the appropriate filter) is easy and can often lead the photographer to unusual locations, especially to image solar eclipses.

A lunar eclipse occurs when the earth passes between the moon and the sun, blocking the sun’s light and dimming the view of the moon. During a lunar eclipse the moon passes through the earth’s shadow resulting in surreal views of the moon. Lunar eclipses only occur during a full moon.

Figure 7-6 shows a total lunar eclipse taken with a DSLR and long focal length telephoto lens. The only necessary equipment to image a total lunar eclipse is a sturdy tripod and cable or shutter release for the camera.

There are three types of lunar eclipses one can image:

1. Penumbral Lunar Eclipse
    The moon passes through earth's penumbral shadow.
    A penumbral lunar eclipse is subtle and difficult to observe.
2. Partial Lunar Eclipse
    Part of the moon passes through earth's umbral shadow.
    Partial eclipses are easy to observe.
3. Total Lunar Eclipse
    The entire moon passes through earth's umbral shadow.
    A total lunar eclipse produces vibrant views of the moon during totality.

Like any celestial event that takes place over a certain period of time, it helps to know the exact times the event will start and the best locations to view the event. Planning your location and testing the equipment before the eclipse is always a “must do.”

Figure 7-7 Partial lunar eclipse under cloudy skies.

Figure 7-7 shows a partial eclipse of the moon. A partial lunar eclipse occurs when just part of the moon passes through just the part of the earth’s umbral shadow.

The result is part of the moon darkens and takes on a crimson color while the other remains in sunlight. The result is very dramatic depending on your location. Even with a cloudy sky you can produce some dramatic lunar images.

Making the Image

It is important to be familiar with your equipment for any eclipse. However, unlike a solar eclipse, the lunar eclipse occurs at a slower pace and you will not be rushed by the event. Still, it is important you know your equipment. Again, practice by taking various moon shots during different phases of the moon.

Determine which exposure settings work best with the various lenses you have available. Because the moon is bright, using ISO settings of 100 to 400 work best.

Using The DSLR For A Lunar Eclipse

At the beginning of a lunar eclipse the full moon will be bright. The camera's meter can read properly when set to spot meter. However, as the moon begins to dim you will need to make adjustments to the point where the full eclipse has occurred and then change the exposure settings as the moon leaves the earth's shadow and begins to become brighter again.

A tripod is essential, as is a cable release or remote control for the camera. A telephoto of at least 400mm with a teleconverter, which gives you an effective focal length of 800mm, is sufficient to photograph a lunar eclipse. However, if you wish to create a wide-angle scene, zoom lenses offer you the ability to change the field of view throughout the eclipse.

Some DSLRs will also allow you to create time-lapse multiple exposures on one frame to show the moon as it enters the earth's shadow and begins to dim. In creating a multiple exposure of a lunar eclipse, you will need to change exposure settings throughout the eclipse.

The photographer can also create a multiple exposure composite of a lunar eclipse. The multiple images will show the various phases of the eclipse as the moon enters the earth's shadow or prenumbra, is centered in the umbra, the darkest portion of the shadow and then leaves the earth's shadow. Multiple exposure images are normally shot with a wide-angle lens because the moon's path across the sky is large.

Figure 7-8 Lunar eclipse sequence (NASA)

Figure 7-8 shows a multiple exposure sequence of a lunar eclipse, from the start to finish.

To create such an image with a DPS or DSLR camera, you will set the camera on a tripod and shoot a series of images over a given time period. Be consistent on the interval; every five minutes will produce a good series. You will need to increase the exposure as the moon approaches totality (preview the image to check the exposure) and then decrease the exposure as the moon leaves the earth's shadow.

Once you have imaged the complete eclipse, you will use an editing program such as Photoshop or GIMP to combine the images and create the collage of all the images.

Caution – Objects Are Smaller Than They Appear

While the moon and sun are some of the largest objects in the sky to image, not every camera and lens combination will produce an image size large enough to produce detail. This is not so much a problem when using a DSLR with a long focal length lens such as a 400mm telephoto lens or attaching the camera to a telescope with a focal length of 1000mm or more.

Using a DPS to obtain detail images of the moon or sun will require the afocal or eyepiece projection method. Do no rely on the optical zoom feature if the camera has it. Optical zoom is an electronic interpolation of the scene or object that actually reduces the resolution and sharpness of what is being imaged.

Using a 400mm telephoto lens on a DSLR to shoot the sun will not fill the image frame with sun. At 400mm the effective focal on a DSLR with an older sensor chip produces an image that is magnified1.5 due to the chip's smaller size. This means the 400mm lens is producing an image as if the actual lens was a 600mm focal length lens. Using a 2X teleconverter changes the actual focal length to 800mm but the effective focal length is now 1200mm. At such a long focal length, using a sturdy tripod and cable release are a necessity to reduce camera shake. Remember to give the camera time to settle down before actually making the exposure after you have touched the camera. If you don't have a shutter release set, the camera's timer to make the exposure. It will be smoother than using the shutter button.

Using A DSLR To Image the Sun

Our closest star is an easy target to image and one which will also help you become more familiar with your imaging tools. **Before you start any solar imaging session ensure you are using the correct solar viewing filter on the camera lens or telescope.**

Like the moon, to the naked eye, the sun appears as a large object in the sky. However, despite its large size in the sky, a long focal length is best to produce an image of the sun that will produce sufficient detail. Figure 7.8 shows the sun imaged with an 800 mm lens on a Fuji S2 DSLR camera with an aspect ratio of 1:1.5 and a frame size of 3024X2016 pixels. Effective focal length is now 1200mm. The use of a shorter focal length will result in a smaller image of the sun.

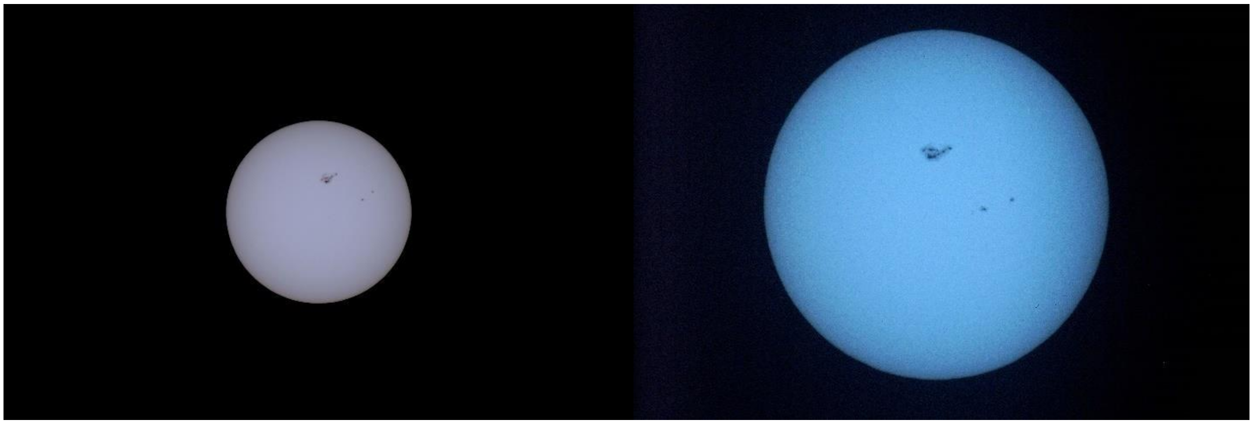


Figure 7-9 White light solar images, full frame and cropped

Figure 7-9 also shows a full frame and cropped image of the sun that has been enlarged to fit the 3024X2016 pixel frame. Enlarging the image allows you pull out detail not seen in the original imaged frame.

A DSLR camera allows you to use lenses with various focal lengths. These examples show 400mm is a good focal length to start with for solar images. When coupled with a 2X tele-converter you end up with an 800mm focal length lens. Since most DSLRs have a magnification factor of 1.5 the effective focal length of the lens becomes 1200mm.

Filters for Solar imaging

Various types of solar filters photographers can use to image the sun. Selecting the correct filter depends on what type of image you want to produce. The most important thing to remember is **NEVER** look at the sun through the camera's viewfinder without the appropriate filter.

Neutral density (ND) filters are NOT safe filters to view or image the sun.

The role of the solar filter is not only to reduce the intensity of visible light but also filter out ultraviolet and infra-red radiation which can damage the eye or produce complete blindness and to bring the light level down to a level where the well-exposed image can be created.

The most common type of filter used for solar imaging is one that simply reduced the intensity of the sunlight and filters out the damaging UV and infra-red radiation. They are made of glass, such as the Thousand Oaks filters or aluminized mylar such as the Solar Skreen filters. There is also a black polymer filter which filters out the appropriate wavelengths and reduces the intensity of the light.

Differences in cost are one aspect to consider. Thousand Oaks filters are expensive but are made to fit over the tube assembly. These filters produce a yellow-orange image. The Solar Skreen filters produce a white image of the sun and the Black Polymer filters produce a greenish image of the sun. Which you select is a personal preference and how you will be using or manipulating the image later on.

For the frugal astrophotographer the Solar Skreen or Black Polymer filters are the first choice. These filters come in sheets and the user will cut to size and make a frame to hold the plastic sheets together in front of the camera’s lens or telescope.

White Light Filters

Figure 7-10 Venus 2004 transit

The image of the June, 2004 Venus transit in Figure 7-10 was taken using a Solar Skreen filter, a Mylar filter which has been aluminized. A white solar image is produced using a filter that reduces the intensity of the sunlight to 0.001%. A white light filter also transmits the entire visible spectrum, making it easy to see sunspots. The filter allows the photographer to image the sun’s surface, or photosphere, hence the term “white light.”

Do It Yourself (DIY) Solar Filters

Urban myths abound about DIY solar filters made from materials found around the house. This is one instance where you should **<u>NOT</u>** be a frugal astrophotographer.

These items should not use for the simple fact that if you don't know their light transmission characteristics in the ultraviolet and infrared spectrum are safe. The goal of a solar filter is to filter out the IR and UV wavelengths and reduce the intensity of the light. Do not use these items to construct a solar filter:

- Polaroid film sheets
- color film base (of any type, no matter how exposed or processed)
- dye-based black-and-white film strips
- magnetic floppy disk medium
- Compact Discs (CD) or DVDs
- non-optical grade aluminized Mylar (e.g., Pop-Tart wrappers)
- smoked glass or welders glasses because they are not consistent in blocking levels

White light filters made of a polymer material (film-based) fit over the front objective of a scope or they can be made to fit in front of a telephoto lens. Sheets of aluminized mylar for solar viewing can be purchased from companies such as Thousand Oaks, Solar Rainnbow Symphone, Baader Planetarium or Daystar. The sheets can then be cut down and placed in a holder to fit a lens.

While the Thousand Oaks filter produces a yellow-orange view and the Solar Skreen filters produce a grey view, they are both considered white light filters because they block out the full spectrum and reduce the intensity of the sun to pass through the filter. Thousand Oaks filters are made of glass instead of aluminized mylar and will cost more. Another filter is the R-G Solar filters which are made of black polymer. These filters will also produce a yellow-orange image and are available in glass or film.

These filters are for visual use and can be used for photographic purposes to image the surface of the sun. There is one type of mylar filter which is designed specifically for photographic purposes but must be used with a Neutral Density filter to protect your eyes. This filter is made by Baader Planetarium of Germany and is intended for use on a telescope, not a camera lens. Known as Baader AstroSolar Photofilm, this filter provides a netural density of 3.5 and is useful for eyepiece projection photography and **not intended for visual use on telephoto lens for a DSLR.**

The use of a Thousand Oaks or film-based solar filter allows you to produce images of the sun at all wavelengths. To view specific wavelengths such as the hydrogen-alpha (Ha) range or Calcium K and Calcium H, special blocking filters are used. These filters and their associated blocking filters are expensive and put them out of the frugal astrophotographer league. However, if you have the funds to purchase one of these filters you will be able to image views of the sun in wavelengths the human eye and a camera normally do not see.

Hydrogen Alpha Filters

Hydrogen-alpha (Ha) solar filters transmit only one specific wavelength, 656.3nm. This wavelength is the reddish light produced by hydrogen atoms. And, like the white light filters mentioned previously, the Ha filter also reduces the intensity of sunlight to 0.001% to protect the viewer. Hydrogen-alpha filter components consist of a tuning filter, which allows the viewer to tune the range of red light and a blocking filter, which is orients the narrow cone of light passed by the front or etalon filter.

There are several manufacturers of Hydrogen-alpha solar filter sets. Companies such as Coronado, Daystar, Thousand Oaks, Lunt and Baader Planetarium sell these filter sets. For those wanting to be as frugal as possible and still wanting to image in the Hyrdogen-alpha range, then consider purchasing the Coronado PST or Personal Solar Telescope (now labeled Meade).

Figure 7-11 Coronado PST with Nikon Coolpix 995

The PST is a dedicated 40mm telescope with the two filter units built into the telescope unit for under $700. Figure 7-11 shows a Nikon Coolpix 995 attached to the PST with an eyepiece attachment. For an inexpensive way to image the sun in the Hydrogen-alpha (Ha) wavelength, the Coronado PSTs is one of the easiest ways to do so.

You can decide whether you want to invest in a Ha setup after working with light solar filters and experimenting with white light solar filters. Figure 7-12 shows the difference between the two wavelengths of light from the sun.

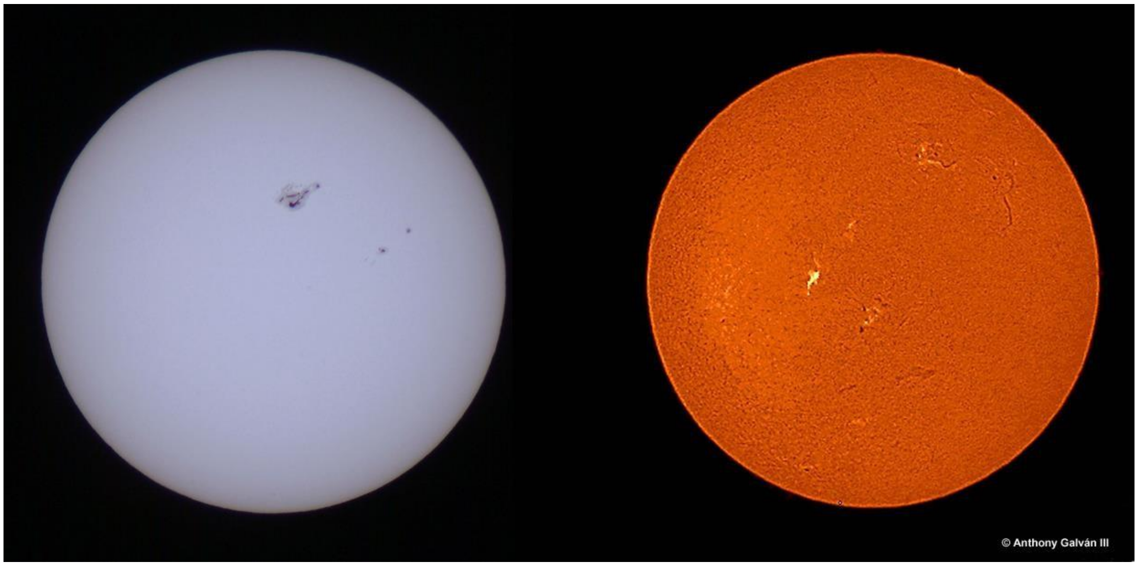


Figure 7-12 The sun in white light and Hydrogen-Alpha wavelengths

You can also start out simple and make your own solar filter using a Thousand Oaks or Baader filter insert. The choice will be up to you whether you purchase a filter or make your own filter mask.

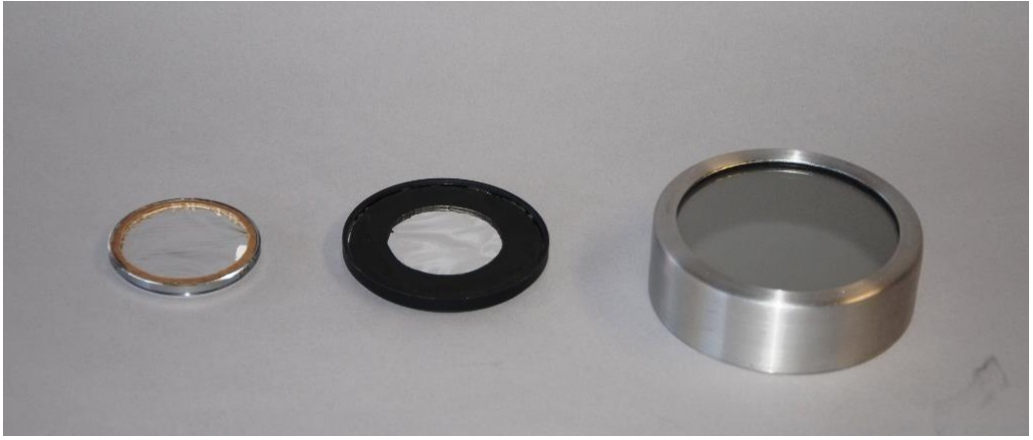


Figure 7-13 DIY solar filters for telephoto lens and telescope

Figure 7-13 shows three solar filters. From left to right, a film-based filter fitted into a metal filter ring that no longer had a glass filter. The center filter shows the film-based material fitted to the lens cap of a lens and on the right, a Thousand Oaks solar filter made to fit over a 90mm telescope.

Using a DSLR to Image a Total Solar Eclipse

Solar eclipses are one of the most spectacular celestial events to see. However, they do pose a problem in that the initial and final stages of imaging a solar eclipse require the use of a solar filter. Any appropriate solar filter will do for these stages of the eclipse.

There are five stages to a solar eclipse. (Figures 7-14 and 7-15)

- First contact – this is when the moon first touches the outside perimeter of the sun, a visual indication the transit of the moon across the face of the sun has started. **A solar filter is needed.**
- Second contact – this is when the outside edge of the moon is just touching the first inside edge of the sun after first contact. **A solar filter is needed.**
- Totality – this is when the moon is in the center of the sun. Just before totality a bright flash appears. This is when the solar filter can be removed, but you must keep it handy to replace it after totality. Totality time varies but it is just a **FEW MINUTES! After totality the solar filter must be replaced and remain on the lens or scope for the duration of the event!**
- Third contact – as the moon continues moving across the face of the sun it will touch the edge of the sun towards the end of the event. **A solar filter is needed.**
- Fourth contact – This is the last point where the moon touches the outside edge of the sun, ending the eclipse. **A solar filter is needed.**

These contact terms are also used for planetary transits across the face of the sun. In one respect an eclipse is a transit of the sun by the moon.

Figure 7-14 Solar eclipse just after first contact and headed for second contact

Figure 7-15 Solar eclipse just before totality and Bailey's beads (before third contact) –no filter is needed.

Chapter 8 - Conjunctions, Occultations and other sky events

Conjunctions & Occultations

Astronomical conjunctions occur when two astronomical objects are seen close together on the same right ascension. A conjunction can consist of two solar system bodies or one solar system object and a distant object such as a star appearing close to each other. Conjunctions are the result of perspective because the two objects are never close to each other.

The best thing about imaging conjunctions is that they are easy to see and require nothing more than a camera and a good location. A tripod and shutter release or remote control will make imaging the conjunction easier and reduce camera shake. Make your conjunction images interesting by framing the conjunction with interesting objects in the background or foreground.

Figure 8-1 Conjunction of Venus, Saturn and Mercury

Figure 8-1 shows a sunset conjunction of Venus, Saturn and Mercury with Pollux off to the right. Conjunctions are best imaged during sunrise or sunset. Framing the scene with a background adds depth to the image.

Occultations occur when one body passes in front of another body. Eclipses and transits can be considered a form of occulation as well.

The most common occultations are those of the moon occulting a star or planet. Figure 8-2 shows the star Aldebaran just before being occulted by the moon.

For both of these images the camera was mounted on a tripod and a shutter release was used to trip the shutter. The occultation image required the use of a telephoto lens with a 2X teleconverter to increase the size of the object.

Figure 8-2 Moon occulting Aldebaran

Other Sky Events

There are a number of astronomical events that can be imaged with nothing more than a camera, a telephoto lens, tripod and shutter release or remote control. In some instances the use of a fast lens (a lens faster than f/2.8) is useful.

Comets

Comets can be imaged with nothing more than a fast lens, a high ISO setting and a tripod.

Figure 8-3 Comet Machholtz with 300mm f/2.8 telephoto lens

Figure 8-3 shows Comet Machholtz taken with a 300mm f/28 telephoto lens. This comet was unusual in that it brightened as it approached the earth.

The camera was mounted on a tripod. The camera was set to ISO 1600 which allowed a short shutter speed of four seconds (note the stars start to trail).

As noted in Chapter 6, the earth rotates 15º in one hour. Even with a fast f/2.8 lens the shorter the shutter speed the less chance to have an image with blurred stars. Using a faster ISO would have allowed a faster shutter speed but would have also produced more image "noise." Noise is one of the trade-offs when using a fast ISO setting.

Figure 8-4 Comet Hale-Bopp with no drive

Figure 8-4 shows Comet Hale-Bopp shot on film during its appearance in 1997.

This photo was made with a 50mm f/1.4 lens, transparency film and hand-powered clock drive known as a "Barn Door" mount.

Barn Doors are discussed at length in Chapter 9.

The barn door mount can produce pinpoint stars as seen in Figure 8-4 as long as the focal length of the lens is short.

Transits

Transits of the sun involve one of the inner planets, Mercury or Venus, moving across the face of the sun. Unfortunately the last transit of Venus for this century occurred on June 5, 2012. The next transit of Venus will be December 10, 2117. However, transits of Mercury, while not as spectacular, will still occur in the 21st century. The next transit of Mercury will be November 11, 2019.

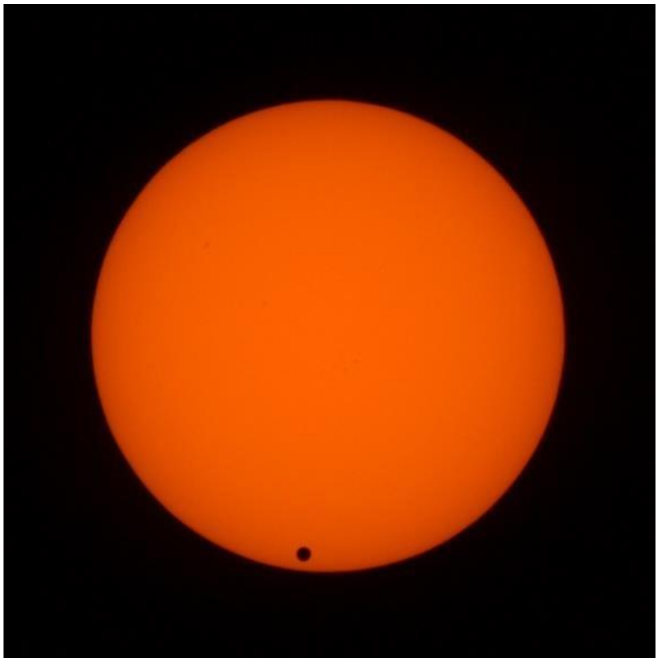


Figure 8-5 Transit of Venus

Imaging a transit requires a telephoto lens, a solar filter and a tripod for good results.

Figure 8-5 shows the planet Venus as it begins its June, 2004 transit across the sun. A 400mm lens with a 2X teleconverter and Solar Skreen filter was used to make the image.

The inner planets are much smaller than the moon so their transits do not occult or cover the sun completely.

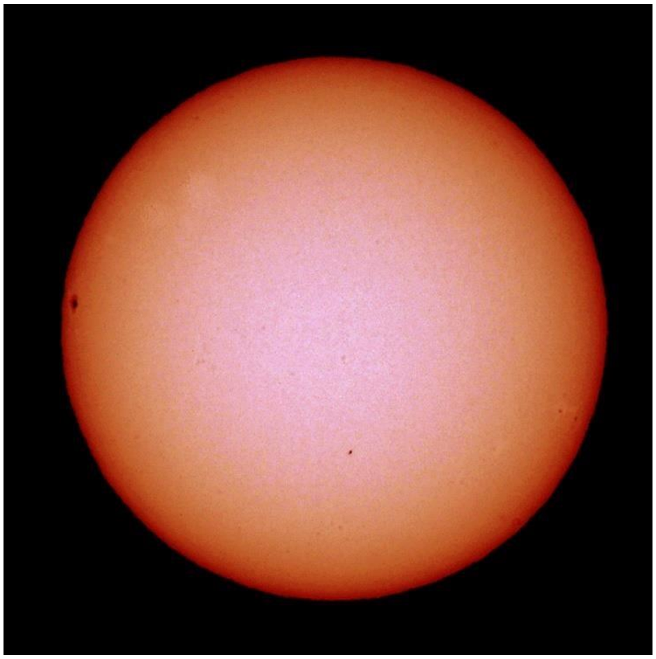


Figure 8-6 Transit of Mercury

Figure 8-6 shows the planet Mercury (the small dot in the lower portion of the image). Notice the sunspot at the 9 o’clock position.

When comparing the two images notice how much smaller the planet Mercury is compared to the planet Venus.

While there will be no more transits of Venus this century, get ready for Mercury’s transit on November 11, 2019

Sky Phenomena

There are other celestial events which are not only easy to image but interesting to search and witness. Many of these events require nothing more than the time to seek them, a camera and a tripod. Even when traveling you may find a perfect location to image sky phenomena or a celestial event.

Crepuscular Rays

Crepuscular rays are rays of sunlight that appear to radiate from a point in the sky where the sun is located. These rays, which stream through gaps in clouds or between other objects, are columns of sunlit air separated by darker cloud-shadowed regions. Despite seeming to converge at a point, the rays are in fact near-parallel shafts of sunlight, and their apparent convergence is a perspective effect (similar, for example, to the way that parallel railway lines seem to converge at a point in the distance).

Figure 8-7 Crepuscular rays

Figure 8-7 shows crepuscular rays can be found indoors as well as outdoors.

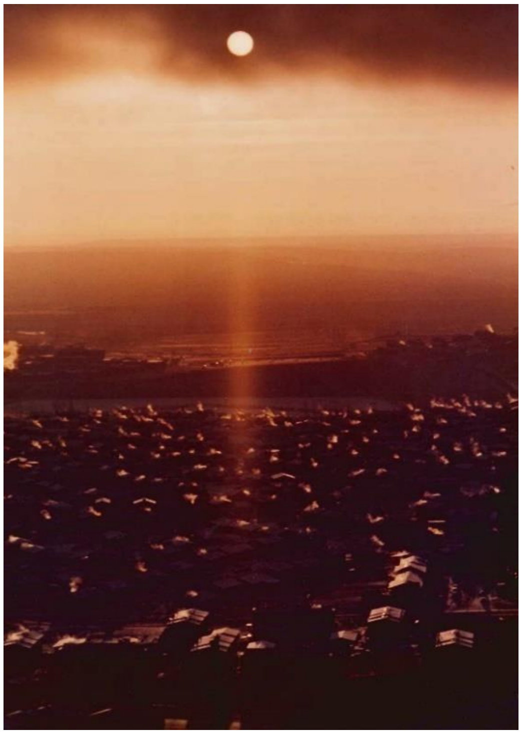
Sun Halos

A Sun halo, sometimes called an icebow, is an optical phenomenon created by ice crystals creating colored or white arcs and spots in the sky. These halos often appear near the sun or moon but can sometimes be seen in the opposite part of the sky. They can also form around artificial lights in very cold weather when ice crystals known as diamond dust are floating in the air.

Figure 8-8 shows a sun halo using a lamp post to reduce the glare of the sun and allow the ice particles in the air to be seen. Many times you'll see these events while traveling. Keep your camera handy.

Figure 8-8 Sun Halo in Morocco

Sun Pillars



Sun pillars are optical phenomenon formed by the reflection of sunlight or moonlight from ice crystals present in the earth's atmosphere. They are also referred to as the crystal beam phenomenon.

The light pillar looks like a thin column that extends vertically above and/or below the source of light. The light pillar is prominently visible when the sun is low or lies below the horizon. It normally forms an arc that extends from five to ten degrees beyond the solar disc. Light pillars can also be seen arising from the moon.

Light pillars are formed by reflection from ice crystals with roughly horizontal faces. Figure 8-9 shows a sun pillar over Boulder, Colorado.

Figure 8-9 Sun Pillar

Auroras

Auroras occur when areas of the earth’s magnetosphere are struck by solar wind particles, causing ionization of particles in the atmosphere. They occur in the polar regions and visually are stunning and mysterious.

As noted in previous examples, location, location, location will make for an interesting aurora image. The equipment needs are simple. A camera on a tripod and the ability to open and close the shutter are all you need to image the Aurora Borealis, and being at the right latitude.

Figure 8-10 Aurora Borealis in Canada (NASA)

Rocket Launches

Rocket launches are as easy to image as star trails. It is important you are close to a launch facility in order to see the rocket fly into the sky. However, close can be up to a hundred miles away from the launch facility because the rockets will fly into the earth's atmosphere.

In the United States, the major rocket launch sites are Cape Canaveral/Kennedy Space Center, Florida, Vandenberg Air Force Base, California, Poker Flats, Alaska and Wallops Flight Facility, Virginia.

Not all U.S. launch schedules are posted by these facilities. Contacting their operations centers will help you find out when there is a launch. Vandenberg Air Force Base does not have a public viewing area but any location within 100 miles of the launch site will allow you to watch a launch and image it.

There are launch sites around the world. If you live outside the U.S. keep in mind that most launch facilities are part of that country's military network and information and access to launch areas may be difficult to obtain or may even be prohibited.

Equipment needs are simple: a camera, tripod and the ability to make a time exposure. In the case of a rocket launch it also helps to know the trajectory of the rocket in order to orient the camera for the best view.

Figure 8-11 Alaskan rocket launch with an aurora (NASA)

Sometimes it's possible your image may contain more than one celestial target or event. Figure 8-11 shows a rocket launch from Poker Flats in Alaska at the same time an aurora is in the night sky.

Pre-planning can provide you with some spectacular images.

Figure 8-12 Delta IV launch VAFB

Night launches are generally made as time-exposures. The camera's shutter is held open and as the rocket flies across the sky, the glare of the rocket engines leaves a streak of light. Figure 8-12 is a 90-second time exposure of a Delta IV rocket launched from Vandenberg Air Force Base, California. The long exposure is also showing star trails.

Launches require a tripod and shutter release/remote control. A variable for rocket launches is whether the night sky is illuminated by the moon or not. Most time exposures are 60 seconds or longer so you should run a test exposure at ISO200, 400 and 800 to see how much ambient light the camera will pick up.

Figure 8-13 Delta IV at sunset

The other important thing to remember is the flight path. A wide-angle lens will produce a better image as well as objects in the foreground to give scale to the image.

Launches can occur during the day or evening. While night launches are the most spectacular some launches, especially those at day break or sunset, offer unusual photo opportunities.

If the moon is in the field of view the rocket launch image will be improved as well.

Figure 8-13, taken at sunset, not only shows the rocket climbing but the moon as well. Because there is sufficient light a shorter exposure is needed. Even so you can still see the glow of the rocket's engines just behind the rocket and exhaust plume as the rocket climbs to altitude into the light of the sun, which is below the horizon.

Chapter 9 – Tracking the Night Sky for Pennies

We have been looking at ways to use the shortest possible exposure to image a celestial image. However, there are times when an exposure longer than one to five seconds is needed. The trade-off is we also don't want star trails in the image.

The most obvious solution is to use an equatorial mount or clock drive to track the night sky. Again, another trade-off appears, clock drives are expensive. Some clock drives are expensive and some are not. Let's look at those which are affordable. The first affordable drive is the barn door.

Barn Door

A barn door tracker, also known as a Haig or Scotch mount, is a device used to cancel out the earth's rotation when making a photographic image. It is a very simple alternative to a motorized equatorial mount.

Figure 9-1 Barn door mount

Figure 9-1 shows components of a barn door mount. Two pieces of wood, a door hinge, hardware to mount the camera to the mount and a turning screw to move the top board make a barn door mount.

Figure 9-2 Scorpius rising, 10 minute barn door exposure

Figure 9-2 is a ten minute exposure of the constellation Scorpius made with the barn door shown in Figure 9-1 exposed on film. The scopes in the foreground were "painted" with a red light to give depth to the image.

The important thing to remember when using a barn door is to align the hinge as closely as possible to the North Star.

The closer the alignment, the better the tracking will be with the barn door.

Constructing a Barn Door or Scotch Mount

The barn door mount was designed by G.Y. Haig. An eccentric Scotsman and inventor of unusual astronomical engines, his plans were published in the April, 1975 issue of *Sky and Telescope*. When Haig was asked why he named the mount a Scotch drive he answered, “Scots are frugal so why not a frugal or Scotch Mount?”

How does it work?

- **The earth turns 360 ° in 24 hours. (15 °/hr. or 5 °/20 min.).**
- **A 1/4 X 20 screw (1/4 in. dia. w/20 threads/in.), when turned @ 1 RPM (revolution per minute), travels one inch in 20 minutes.**
- **When a 1/4 X 20 screw is 11.42 inches from a pivot point and turned 1 rpm, the triangle's hypotenuse will move at the same rate as the sky.**
- **When a camera is attached to the hypotenuse, it will also move at the same rate as the sky.**

Some plans include the use of an electric motor but a simple mechanical model works well. Most of the materials needed may already exist in a garage or basement. With the exception of the ball swivel head for the camera, all items can be found at a hardware store. Expect to pay less than $15 for all needed hardware. The swivel head will cost anywhere from $25 to over $200, depending on your tastes.

Materials

- 2 - 12 X 4 X 3/4 inch boards (particle board or solid wood)
- piano hinge cut down to 4 inches or a door hinge
- 1 - 1/4 X 20 X 4 tangent bolt w/ wing nut at one end
- 1 - 1/4 X 20 X 1 bolt
- 2 - 1/4 X 20 T- nuts, internal threads
- 2 - small nails
- rubber bands
- 1 - tripod swivel head

Construction

Mark one board **Top** and the other board **Bottom,** Figure 9-3. The top board will have one 1/4 inch hole drilled. Center the hole on the board. The swivel head will attach to the top of this board with the 1/4 X20 bolt.

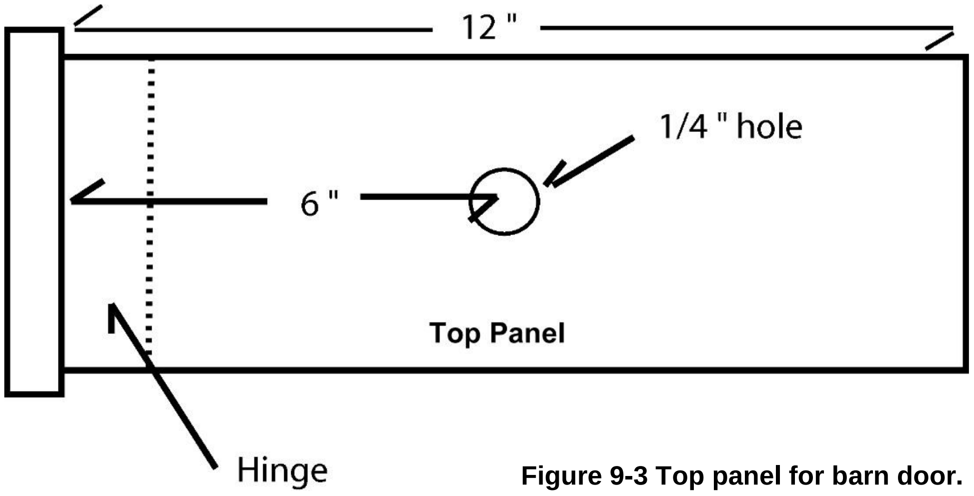


Figure 9-3 Top panel for barn door.

Next, take the **Bottom** board and drill a ¼ inch hole centered on the board and attach a 1/4X20 T-nut. Ensure the smooth side is facing the bottom. A tripod will attach to this side, Figure 9-4.

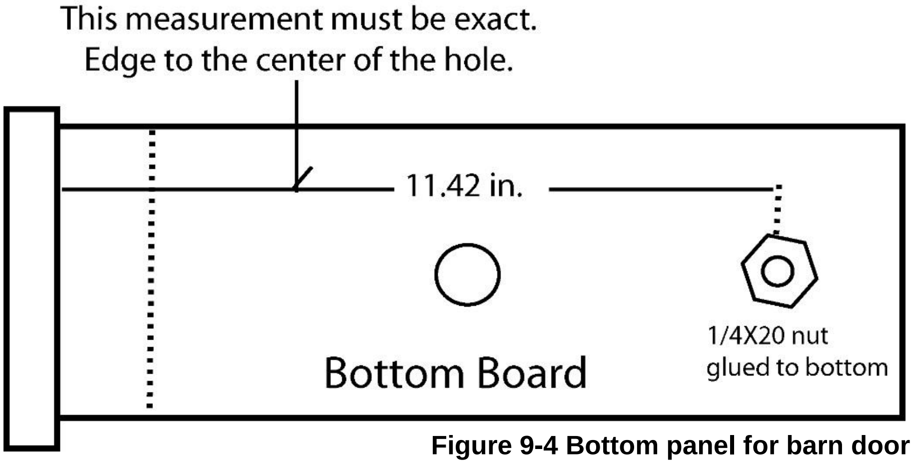


Figure 9-4 Bottom panel for barn door.

Measure from the end of the bottom board 11.42 in. (11.7/16 in.). This is the distance from the edge of the board to the center of the hole. Place a 1/4 X 20 T-nut or 1/4 X 20 nut for the tangent bolt to travel in the hole. If you use a nut, glue or epoxy it in place. Ensure it is perpendicular to the surface of the board, Figure 9-5.

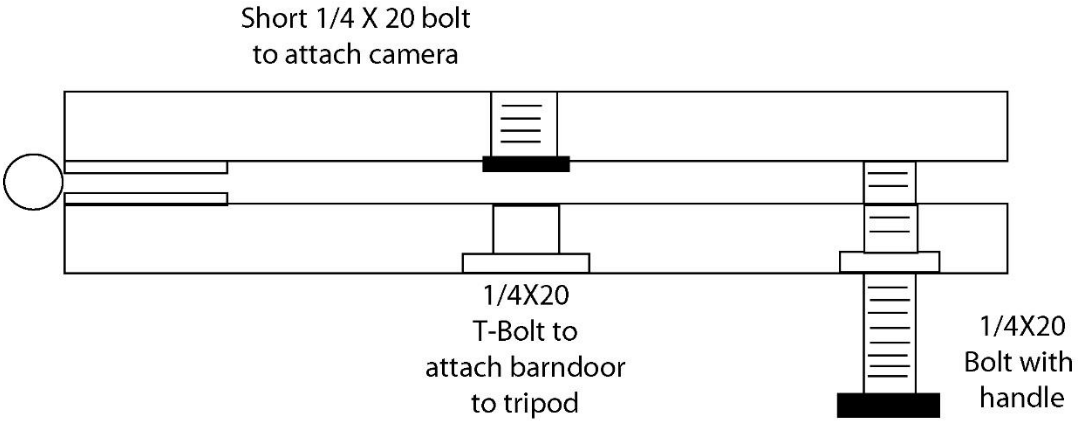


Figure 9-5 Side view of barn door.

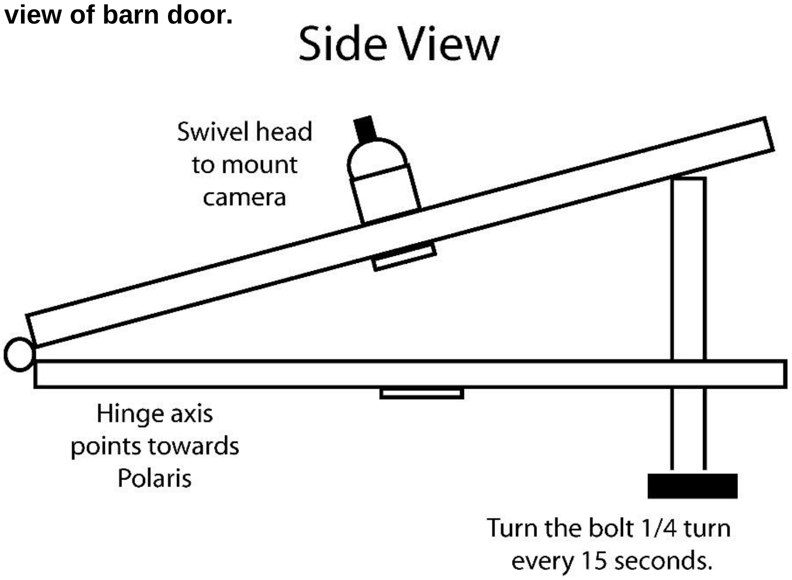
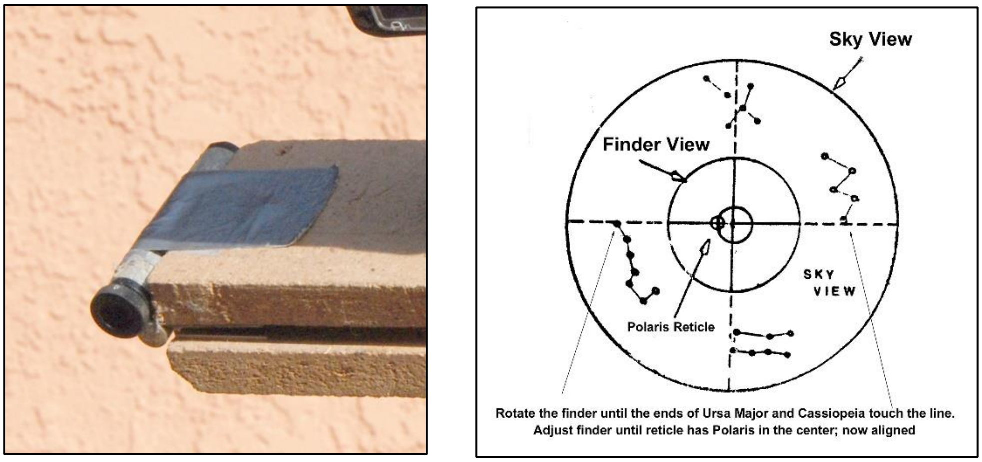


Figure 9-6 Barn door open.

Aligning the Barn Door Mount

Attach the barn door to a tripod, preferably a tripod with elevation control. Sight along the axis of the door hinge toward Polaris. Once you have the hinge aligned with Polaris, you are ready to begin exposing. The use of a polar alignment scope helps make a more precise alignment.

Older Celestron polar alignment scopes are inexpensive and attach easily to the hinge on the barn door. Figure 9-7 shows a polar scope taped to the hinge of the barn door and the reticle view of the scope.



Rotate the finder until the ends of Ursa Major and Cassiopeia touch the line. Adjust finder until reticle has Polaris in the center; now aligned

Figure 9-7 Celestron Polar Alignment Scope in place and alignment picture through scope.

Once the hinge is aligned with Polaris, use the ball mount to move the camera to find your target. Remember, a digital camera needs to be set to Manual, not Automatic (including the focus setting).

Figure 9-8 Camera mounted on barn door.

1- Set the Focus to infinity. Some camera models will allow you to set the focus to infinity within the setup menu. Read your camera's manual to perform this function.

2- Set the lens (f/stop) to the maximum aperture (f/1.4 to f/2.8 are considered fast apertures).

3- Set the shutter speed to **B** for Bulb. Open the shutter with a cable or remote unit and keep the shutter open.

4- Begin turning the tangent screw one-quarter turn every 15 seconds.

Open the shutter as smoothly as possible. The use of a shutter release cable, an Infra-red device or Smart Phone with a DSLR device known as a Smart Trigger will accomplish this.

Once you open the shutter, begin counting or start a timer you can see in the dark.

You must not jar or move the mount while turning the tangent bolt.

Make a range of exposures, three minutes, five minutes, 10 minutes, etc. Mark the handle of the tangent screw at quarter intervals to help you mark off the quarter sections. To ensure the tangent screw turns smoothly file down the head to a round radius. Figure 9-8 shows how the barn door is aimed at Polaris.

The exposure time is limited by the focal length of the lens. Short focal length lenses (18mm – 35mm) are considered wide-angle lenses and will provide the best images . They will not show mount movement as much as a longer focal length lens at short exposure times (400 Rule).

There are several types of barn door designs. Some plans include the use of an electric drive motor. Once you have made the simple hinge model, you might consider making a more elaborate model.
For those of you who want something more modern consider some of the newer sky drive tracking devices. While not in the spirit of frugal astrophotography, they do provide a reliable and cheaper alternative to purchasing a German Equatorial Mount.

One of the more popular current sky drives is the iOptron Sky Tracker. Another alternative is to shop around for some of the older sky drives, which can be purchased for less than $200 from the various online astronomy classified sites.

Figure 9-9 iOptron and Vista Sky Tracker

Figure 9-9 shows one of the newer sky trackers on the left and a circa 1990s analog style tracker. The iOptron tracker, on the left, and the Vista Sky Tracker on the right, both employ a polar alignment scope and provide movement only in the Right Ascension (RA) direction.

These portable trackers, like the home-made barn door mount, attach to a standard tripod. With accurate alignment 20 minute exposures are possible with these portable units.

For the best results when using a barn-door or sky tracker, keep the focal length of the lens short. These portable trackers are useful for wide field imaging, are quick to set up and can be purchased for less than $400.

Chapter 10 - Putting It All Together

Okay, now what do you do?

First of all, many pages ago I wrote that this book is not about image manipulation (using software to improve the digital image). That subject and those skills require time and practice to hone so I leave that portion of learning to you after you have become proficient with your camera and equipment.

What do you need to start imaging the night sky or other celestial targets?

The first thing to do would be to see whether the camera or cameras you currently own have the following features or capabilities:

- Manual shutter control (does it have a "B" Bulb setting?)
    - Some cameras will only allow a long exposure of less than one minute
- Manual aperture (f/stop) control
- Manual focusing capability
    - The ability to disable Autofocus
- Ability to change the ISO settings to 1600 or higher
    - Built-in noise reduction (**NR**) is also a good feature
- Ability to trip the shutter with a cable or remote unit (this is an important feature)
    - Wireless remote or cabled remote
    - Shutter activation via a smartphone, iPad or Android Tablet App
- For a DPS model attachment rings to mount to a small scope or for eyepiece projection
- Video capability is a plus feature for eyepiece projection work of planets

Once you have determined your camera has these features, you are ready to start imaging. Or, you may discover your present camera does not have the basic features and it will be time to purchase a new camera. Armed with what you know now you will be able to find and purchase the right camera for astrophotography.

Some additional items that will make your imaging work more efficient.

- A sturdy tripod
- For a DSLR
    - Live View – the ability to view through the lens in real-time
    - Right angle finder – makes focusing and composing easier
    - 2X teleconverter
- For a DPS
    - Live View
    - Camera to scope attachment accessories
- Appropriate Cables for the camera and any Android device you may have for remote control operation of the camera
- Lenses
    - Wide-angle – f/3.5 or better – remember a DX chip will increase the foca length
    - Telephoto – faster is better, F/2.8, no longer than 400mm

Tonight go out and look at the moon. If you have a telephoto lens with a focal length of 200mm to 400mm, you will be ready to start work as a frugal astrophotographer! Get the tripod ready and start imaging!

Your DPS or DSLR will give you instant gratification with your first shots. Now you know what you need to work on.

Chapter 11 – Software for Astrophotography

As mentioned in the Preface, this work does not address how to use software to improve or enhance a digital image in detail. This chapter, though, provides an overview on software used not only to correct or manipulate and image but also to assist in controlling the camera and capturing still and video images from a camera.

Digital Imaging Software

Photoshop is one of the most used image processing applications used by photographers for image enhancement and manipulation. In fact, the term “photoshop” something implies the image has been altered or manipulated for good or bad. However, for an astrophotographer, Photoshop is often used to help enhance an image due to some of the physical limitations of the chip, be it a CMOS or CCD chip, exposure issues or to enhance the image creatively.

Simple enhancements can be making an image lighter or darker, increasing the contrast or decreasing contrast and even converting a color image to a black and white image (often done with solar images). In addition, image software can add or remove unwanted color from an image or add color, as needed. Remember those photos you took years ago under fluorescent light? They came out a bit green or yellow and not very flattering. With image software you can remove the unwanted color and improve the image.

Another way software is used is to “stack” images or frames to replicate a longer exposure. Going the frugsal route with a barn door or fixed tripod exposure we know we are limited to short exposures if we don’t want star trails. Stacking software allows you to take a series of short exposures and stack them to generate an image that will appear as if it had been made with a long exposure to begin with (simple explanation).

> Take 20 4-second exposures and stack them and you produce an image “almost” equivalent to an 80-second exposure. There are some other factors swhich play into this process, but in simple terms the software stacks each exposure on top of the other to produce a master.

Stacking, when combined with a fast lens can produce decent images of some deep sky objects without the need for a German Equatorial Mount (GEM).

Another technique involving the stacking process is to shoot video of an object and have the software stack each frame to produce a better still image. The stacking process is one favored by planetary imagers and works on the same principle as stacking a series of still images. However, with video, you will find a range of cameras using CCD or CMOS chips with resolution ranging from 640 X 480 pixels to 1280 X 960 pixels. The down side of using these cameras is often the cost for some of the cameras and the fact that you will be tethered to a computer to record the video.

Still, if planetary, lunar and solar images are what you want to work with, some of the CMOS video cameras, as described in Chapter 3, are a good way to start.

The learning curve is steeper once you start working with imaging software but you have to start some where. I recommend you start with the moon and planets or the sun (with the appropriate and safe filters) to see if working with video images is something you want to pursue further.

Finally, some DPS and DSLR cameras have video capability, so you may already have a video capture device on hand. The only limitation, especially with a DPS camera, is the video record time. Some cameras will only record ten seconds and others more, depending on the resolutions size selected in the camera.

More recent software applications allow for remote control of the camera to trip the shutter, set exposure setting and even create time-lapse files of an event. Controlling a camera with a tablet or smartphone helps the astrophotographer control how and when they take an image. Add to this Wi-Fi or Bluetooth connectivity and the photographer is no longer tethered to the camera but can still control the camera to make an exposure.

Software

There is a wide range of software to choose from, whether one works on a PC, Mac or Linux computer or Android device. The following is a short list of some well-known applications currently used by astrophotographers. These applications range from being free (freeware) to fee based such as Adobe's Photoshop.

Please note some shareware downloads are limited in what they do or they may be evaluation versions which work for an evaluation period. After the evaluation period the application will no longer function unless you register and/or pay a fee to use the program.

Adobe Photoshop: post image processing (fee based) – http://www.adobe.com

DeepSkyStacker: image calibration, aligning and stacking specific for deep space astrophotography (freeware) - http://deepskystacker.free.fr/english/index.html

Envisage: image acquisition, calibration, aligning and stacking for Meade DSI cameras. http://www.meade.com/support/software-firmware/

Focus magic: improves images focusing and contrast. http://www.focusmagic.com/download.htm

GIMP: Post image processing software and cross platform - Mac, Windows, Linux and GNU (Open source freeware) - https://www.gimp.org/downloads/

IMerge: makes astrophotography mosaics (freeware) - http://jaggedplanet.com/imerge.asp

Iris: image calibration, aligning, stacking and post-processing (freeware) http://www.astrosurf.com/buil/us/iris/iris.htm

K3CCDTools: photo and video acquisition, planetary image processing (trial version, must register) http://www.pk3.org/Astro/index.htm?k3ccdtools_download.htm

MaxIm DL: image acquisition, calibration, aligning, stacking and post-processing. (free trial version) http://maxim-dl.software.informer.com/5.1/

PixInsight LE: image post-processing (freeware version) - https://pixinsight.com/download/index.html

RegiStax: image calibration, aligning and stacking specific for planetary astrophotography. It can also be used for deep space astrophotography (freeware) - http://www.astronomie.be/registax/

StarTrails: blending software to merge short timed-exposure to extend the overall time of the actual exposures, good for producing longer star trails – (freeware) http://startrails.de/html/software.html

Tawbawares Image Stacker: blends short exposure to create an image based on a longer exposure time, good for producing longer star trails - http://www.tawbaware.com/imgstack.htm

Camera Control Software

Other camera software applications are camera control applications and apps. Depending on the operating system of your device there are applications to remotely trip the shutter, provide LiveView to help in focusing on the device screen instead of using the camera‘s viewfinder and the ability to set time intervals for time-lapse photography. There are apps for Mac, Linux and Android handheld devices such as tablets and smartphones. These camera control apps allow the astrophotographer to control their camera without touching it. Some apps will work in a wireless mode utilizing Bluetooth or Wi-Fi connectivity while others may require an On-The-Go (OTG) cable to connect the device with the camera.

While the majority of camera control apps are written for Canon model cameras, other camera brands such as Nikon, Sony, Casio and Fuji are able to be configured to work with these applications. Most cameras manufacturers also provide software to control a camera, though they are generally written for use on a computer.

This is a short list of Android camera control apps that work with a smartphone or tablet.

CamCap: fee based – works with most camera brands

http://fullapkdownload.com/Full_CamCap-DSLR-Controller_APK.html

DSLR Controller: fee based - Canon cameras -

https://play.google.com/store/apps/details?id=eu.chainfire.dslrcontroller&hl=en

DSLRDashboard: free - http://download.cnet.com/DslrDashboard/3000-7240_4-75964251.html

Helicon Remote: free – overall, works well with Canon and Nikon DSLRs – including wi-fi connections

http://www.heliconsoft.com/heliconsoft-products/helicon-remote/

qDSLR Dashboard:fee based – Canon http://dslrdashboard.info/qdslrdashboard-download/

The Dark Side of Digital Imaging

In addition to learning how to use digital imaging software, you will need to learn to identify and take care of problems inherent when using CMOS or CCD chip cameras and inherent optical problems with your lenses. The following are problems and corrections, for some of the problems that are part of digital imaging, especially when taking a frugal approach to astrophotography.

Bias Frame – an exposure is made, with the lens covered, at the fastest speed and temperature that will be used for imaging. Up to ten exposures are made and kept as bias frames in order to remove the chip’s read out signals from the frame. This is often called an off-set frame and is needed if you will be stacking images.

Chromatic Aberration (CA) – chromatic aberration, also known as color fringing, is the result of a lens not able to focus all color wavelengths at the same point. Fast lenses, such as an f/1.2 or f/1.4 lens, will show CA and coma but when stopped down to f/2.8 or f/3.5 will reduce the amount of CA seen.

Coma – a lens aberration that reproduces pinpoints of light, such as stars which are off-axis, into glowing highlights with a comet-like tail. For the frugal astrophotographer, coma will be seen mostly in the corners of the image frame while the central part of the image has little or no comaic aberration. Centering your target and stopping down the lens to f/2.8 or f/3.5 will reduce the effect.

Dark Frame – an exposure with the same speed and ISO setting as the light frame exposure (actual image) with the lens covered to remove noise from the frame. Normally the dark frames are made after the initial exposures, with up to ten dark frames that will be used to subtract the noise when the images are stacked. Some cameras have noise reduction features to help reduce chip noise.

Flat Frame – flat frames or flat fields are exposures made of a plain background to create a frame which will show artifacts such as dust spots or vignetting resulting from imperfections of the chip. Flat frames, like dark frames, are used subtracted from the light frame to remove the artifacts from the frame.

Histogram – a histogram is a graph showing the distribution of light and dark pixels in the frame. Most digital cameras will show a histogram when viewing an image. Dark pixels will be on the left and light pixels on the right.

Noise – every chip produces noise, every chip! In the digital image the goal is to capture the most and best light signals (photons) using the shortest amount of time to reduce the amount of noise. Unfortunately, unwanted signals generated by the chip as it heats up, even during the exposure results in noise. When you start subtracting the hot pixels with a dark frame, a bias frame and flat frame you eventually reduce much of this unwanted noise.

Signal to Noise Ratio (SNR) – SNR is a fancy way to say more signal photons on the chip with less unwanted noise photons from the same chip. The higher the signal to noise ratio the less post imaging work that needs to be done to the image or images.

Vignetting – a frame with a bright center and dark edges is the result of vignetting. For the astrophotographer vignetting is the result of optical issues. Optical vignetting is more common when using zoom lenses over fixed focus lenses. Digital vignetting occurs because the light striking the center pixels is coming in a direct angle while light striking pixels on the edges of the chip are striking at an oblique angle. The result, then, is often an uneven look, the center being bright and the edges dark.

The 400 – 600 Rule

Remember the 400-600 rule is a starting point for exposure. The focal length of the lens, aperture setting, the type of sensor the camera has and your location, high or low latitudes, will determine the best exposure without star trails. If you want star trails don’t follow the 400-600 rule.

Conclusion

The learning curve to use post-imaging software is steep but the rewards are worth the effort. The most basic post-imaging tasks you will undertake will be making an image lighter or darker. Regardless of which software you start with keep notes of what you have done, what was right and what was wrong.

Now, begin you frugal astrophotography journey by learning the ins and outs of your camera.

Read the camera’s instructions manual. Again, read the instruction manual, You will be surprised how much information a manual contains.

At this point it’s time to go outside and capture some photons.

So much technology has entered the astrophotography field since 2000. Deep-sky objects can be made without a GEM. Wi-fi cameras and devices have replaced shutter release cables and help see and focus better. Take advantage of these advancements and enjoy the night sky.

Tony Galván – Goleta, California

References

Buick, Tony. 2006. *How to Photograph the Moon and Planets with your Digital Camera.* London, UK: Springer-Verlag.

Dragesco, Jean. 1995. *High Resolution Astrophotography.* Melbourne, Australia: Cambridge University Press.

Lodriguss, Jerry. *A Beginner's Guide to DSLR Astrophotography*. CD-ROM

Martinez, Patrick. 1987. *Astrophotography II.* Richmond, Virginia: Willmann-Bell, Inc.

North, Gerald. 1997. *Advanced Amateur Astronomy.* Cambridge, UK: Press Syndicate of the University of Cambridge.

Seip, Stefan. 2006. *Digital Astrophotography.* Santa Barbara, California: Rocky Nook.

Credits

Figure 1-1 Reference (No Author) – [Online image]. John Draper Moon photograph (1839).
From http://www.fotoart.gr/photography/history/historyphotos/onephotoonestory/thefirstphotoofthemoon.htm

Figure 1-2 Referenece (No Author) – [Online image] Henry Draper Orion Nebula Photograph (1882).
From http://www.saburchill.com/HOS/astronomy/033.html

Figure 1-3 Lodriguss, Jerry. Catching the Light. [Online image]. Film hyperization components.
From http://www.astropix.com/HTML/I_ASTROP/FILM/HYPERING.HTM

Figure 7-8 Reference (No Author) – [Online image]. http://www.penny4nasa.org/category/moon/

Figure 8-10 Aurora Borealis. From:
https://www.google.com/search?q=aurora+borealis+wallpaper+1&rlz=1C1CHHJ_enUS682US682&source=lnms&tbm=isch&sa=X&ved=0ahUKEwiy0evy0v7RAhVklVQKHZIUBVoQ_AUICCgB&biw=1600&bih=770

Figure 8-11 – Poker Flats rocket launch and aurora borealis.
From https://www.nasa.gov/feature/wallops/2017/nasa-sounding-rocket-successfully-launches-into-alaskan-night

Glossary

Afocal photography – holding a camera over the eyepiece to make an image. Afocal photography can be hand-held or with the use of a frame. -

Aperture- the opening of the lens' diaphragm calibrated as "f/stop." The lower the number the larger the opening. A lens will have a focal length and aperture designation such as 50mm, f/1.4. A large aperture lets in more light but may produce coma.

CCD – camera sensors known as charged-couple devices. Cameras designed strictly for astrophotography are designed around a CCD chip. CCD cameras require the use of a computer.

Chromatic aberration (CA) – also known as color fringing, occurs when a lens is not able to focus all color at the same point in a lens due to the range of light wavelengths in the scene. CA can often be corrected by using a Minus Violet filter to reduce the color fringing.

CMOS – camera sensors known as complementary metal-oxide-semiconductor devices. CMOS chips are found in most consumer digital cameras and do not require a computer to be used.

Coma – a lens aberration that produces bright spots with a comet-like tail pointing away from the center of the frame.

Eyepiece – a lens housing that acts as a magnifying glass to produce an image on the focal plane of the telescope. Scope magnification is determined by dividing the focal length of the scope by the focal length of the eyepiece.

Eyepiece projection – a focal plane image magnified by placing an eyepiece between the telescope and the camera's focal plane. The eyepiece further magnifies the image to the sensor or film plane.

Focal length – distance from a scope's objective lens or mirror to the focal point where light (the image) is focused.

ISO (International Standard Association) – a standard used to set specific sensor sensivity to light. Lower number are not as sensitive to light as high ISO numbers. There is a point, though, where a high ISO setting also produces more than normal noise.s

Noise – unwanted signals and electronic signals produced by a camera chip or the camera's circuit. It can appear as off-color pixels in the image or produce a grainy looking image.

Prime focus photography – the camera's sensor is located on the focal point of the scope. The scope is acting as the camera's lens.

Shutter speed – the amount of time light strikes the sensor. On film cameras shutter speeds where generally set as fractions of a second such as 11/25 or 1/8 of a second. While those shutter speeds are still used some digital cameras can produce a speed to match the ISO and aperture selected.

How The Photos Were Made

The following list provides technical information on the illustrations in the book. Some of the images were made on film and some are digital. Use this information as a guide for creating your own images.

Figure 6-1 – Star Trails around Polaris:

- Exposure: 15 minutes
- Media: Film, ISO 400
- Lens: Tamron 28-200 f/3.5 zoom
- Camera: Nikon F
- Mount: Fixed tripod, camera pointed towards Polaris from my backyard. Ambient light illuminated the tree in the foreground.

Figure 6-2 – Meteor Show

- Exposure: 20 minutes @ f/3.5
- Media: Film, ISO 400
- Lens: 80mm f/3.5
- Camera: Yashica Twin Lens Reflex
- Mount: Fixed tripod, Perseus meteor shower, 2005 with the City of Lompoc, California in the background.

Figure 6-3 – Milky Way

- Exposure: 4 seconds @ f/1.4
- Media: Digital, ISO 800
- Lens: Nikkor 50mm f/1.4
- Camera: Nikon D80
- Mount: Fixed tripod, note no star trails at this short exposure using a fast lens.

Figure 7-1 – Waxing Moon and Owl

- Exposure: 1/10 second @ f/3.5
- Media: Digital, ISO 400
- Lens: Tamron 28-300 f/3.5 @ 28mm
- Camera: Fuji S1
- Mount: Fixed tripod, an accidental shot. I was imaging the crescent moon when the owl flew into the frame. I managed to get three shots with the owl. This was the best of the three.

Figure 7-2 – Earthshine, Venus and 28 Sagittarii

- Exposure: 1/4 second @ f/3.5
- Media: Film, ISO 100
- Lens: Tamron 28-200 f/3.5 @ 28mm
- Camera: Fuji S1
- Mount: Fixed tripod. I took several exposures, varying the shutter speed to obtain the best shadow detail on the moon’s surface.

Figure 7-3 – Moon Craters

- Exposure: 1/100 second
- Media: Digital, ISO 100
- Lens: 400mm telescope with 28mm eyepiece projection.
- Camera: Nikon Coolpix 950
- Mount: Fixed tripod. Because the moon is bright, a lower ISO setting can be used and still use a shutter speed fast enough to minimize movement.

Figure 7-4/7-5 – Full Moon (full frame and cropped)

- Exposure: 1/180 second @ f/11.2
- Media: Digital, ISO 200
- Lens: Tokina 400mm f/5.6 with a 2X teleconverter
- Camera: Fuji S2
- Mount: Fixed tripod. 400mm lenses are not expensive and when coupled with a 2X teleconverter they provide reasonable images with a DSLR. Figure 24 shows how cropping a full frame image will improve the image.

Figure 7-6 – Lunar Eclipse at Totality

- Exposure: 1/20 second @ f/5.6
- Media: Digital, ISO 800
- Lens: Nikkor 300mm f/2.8 with 2X teleconverter
- Camera: Fuji S1
- Mount: Fixed tripod. Even a 300mm lens with a 2X teleconverter will provide a detailed image of the moon. However, at totality the amount of light from the moon diminishes. As a result, at totality it is necessary to increase the ISO rating.

Figure 7-7 – Partial Lunar Eclipse

- Exposure: 1 second
- Media: Digital, ISO 800
- Lens: Nikkor 300mm f/2.8
- Camera: Fuji S2
- Mount: Fixed tripod. This full frame view of the moon shows the relative size of the moon with a telephoto lens without a 2X teleconverter. In this case clouds add interest to the image.

Figure 7-8- Lunar Eclipse sequence

- Exposure:
- Media:
- Lens:
- Camera:
- Mount:

Figure 7-9 – Solar sun spots (full frame)

- Exposure: 1/4000 second
- Media: Digital, ISO 100
- Lens: Tokina 400mm f/5.6
- Camera: Fuji S2
- Mount: Fixed tripod. Baader Solar filter coupled with an orange filter. The filter was attached to the telephoto’s lens cap. The Baader filters are white light filters but with an orange filter you can add color to the white light image.

Figure 7-9 – Solar sun spots -cropped

- Exposure: 1/4000 second
- Media: Digital, ISO 100
- Lens: Tokina 400mm f/5.6 with 2X teleconverter
- Camera: Fuji S2
- Mount: Fixed tripod. Baader Solar filter coupled with an orange filter. The filter was attached to the telephoto’s lens cap. Cropping the frame allows you to direct the viewer’s interest to the sunspots.

Figure 7-10 – Venus Transit across the Sun

- Exposure: 1/4000 second
- Media: Digital, ISO 100
- Lens: Tokina 400mm f/5.6 with 2X teleconverter
- Camera: Fuji S2
- Mount: Fixed tripod. Baader Solar filter. This is the same filter as used for Figure 29. This time, however, no orange filter was added to the solar filter.

Figure 7-12 – White Light and H-Alpha Solar views

- Exposure: White light, 1/4000 second; H-Alpha 1/213 second
- Media: Digital, ISO 100
- Lens: White Light: 400mm; H-Alpha 400mm
- Camera: White Light: Fuji S2; H-Alpha Nikon Coolpix 995
- Mount: Fixed Tripod, White Light Baader Solar Filter; H-Alpha Coronado H-Alpha setup.

Figure 7-14 – Solar Eclipse: second and fourth contacts

- Exposure: 1/30 second
- Media: Kodak Ektachrome, ISO 160
- Lens: Nikkor 300mm f/2.8
- Camera: Nikon 8008
- Mount: Fixed tripod, Thousand Oaks Solar Filter

Figure 7-15 – Solar Eclipse - totality

- Exposure:1/250 second
- Media: Kodak Ektachrome ISO 160
- Lens: Nikkor 300mm f/2.8
- Camera: Nikon 8008
- Mount: Fixed tripod, no filter

Figure 8-1 – Conjunction of Venus, Saturn and Mercury

- Exposure: 2 seconds
- Media: Digital, ISO 400
- Lens:18-200 Tamron Zoom
- Camera: Fuji S2
- Mount: Fixed Tripod

Figure 8-2 - Occultation

- Exposure: ½ second
- Media: Kodak Tri-X film
- Lens: 400mm telephoto
- Camera: Nikon 8008
- Mount: Fixed tripod, 2X converter on lens

Figure 8-3 – Comet Machholtz

- Exposure: 4 seconds
- Media: ISO 1600
- Lens: Nikkor 300mm f/2.8
- Camera: Fuji S2
- Mount: Fixed tripod. The short exposure is possible because of the fast f/2.8 lens.

Figure 8-4 – Comet Hale-Bopp

- Exposure: 15 second
- Media: Ektachrome 160
- Lens: Nikkor 50mm f/1.8
- Camera: Nikon 8008
- Mount: Barn door mount

Figure 8-5 – Venus Transit

- Exposure: 1/4000 second
- Media: ISO 400
- Lens: 400mm
- Camera: Fuji S2
- Mount: Fixed tripod, Solar Skreen filter and 2X teleconverter.

Figure 8-6 – Mercury Transit

- Exposure: 1/4000 second
- Media: ISO 200
- Lens: 400mm
- Camera: Fuji S2
- Mount: Fixed tripod, Solar Skreen filter and 2x teleconverter.

Figure 8-7 – Crepuscular Rays at sunset

- Exposure: 1/51 second
- Media: ISO 80
- Lens: 12 mm
- Camera: Nikon Coolpix 950
- Mount: Handheld

Figure 8-7 – Crepuscular Rays in building

- Exposure: 1/50 second
- Media: ISO 400
- Lens: Nikon 18-200 VR
- Camera: Nikon D90
- Mount: Handheld

Figure 8-8 – Sun Halo

- Exposure: 1/4000 second
- Media: ISO 400
- Lens: Nikon 18-200 VR
- Camera: Nikon D90
- Mount: handheld

Figure 8-9 – Sun Pillar

- Exposure: 1/30 second
- Media: Ektachrome 160
- Lens: Nikon 35mm
- Camera: Nikon F
- Mount: handheld

Figure 8-12 – Rocket Launch at night

- Exposure: 80 seconds
- Media: ISO 400

- Lens: Tamron 18-200
- Camera: Fuji S2
- Mount: Fixed tripod

Figure 8-13 – Rocket Launch at sunset

- Exposure: 1/45 second
- Media: ISO 400
- Lens: 18mm wide angle
- Camera: Fuji S2
- Mount: Fixed tripod

Figure 9-2 – Deep sky

- Exposure: 30 seconds
- Media: Film, ISO 800
- Lens: Nikkor 50mm f/1.8
- Camera: Nikon 8008
- Mount: Barn door mount

This information should be used as a guide for imaging specific celestial targets. Keep in mind you may need to experiment with exposure settings depending on your equipment.

Finally, remember, there are many items you can make or adapt to use with your camera. Don't be afraid to experiment.

Shooting Log

The Frugal Astrophotographer’s Shooting Log

Photographer ____________________________________ Date ______________________________

Location ____ Time______________________________

Object ____

Camera ____

Lens ___________________________ Focal Length_________________ Aperture _______________

ISO ____ Color Temperature ___________________

Camera Lens _____ Prime Focus _____ Eyepiece Projection ______

Tripod _____ Barndoor _____

Filter ____

Video ___

ISO ______________ Frames per second _______ Resolution ________________

Weather Conditions ____

Notes____

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Problems/Corrections____

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Resources

The following companies and websites offer equipment and information to help your frugal astrophotography remain frugal. This is not a complete list so I leave it to you to add more resources as you progress.

Anacortes Telescope & Wild Birds - http://www.buytelescopes.com/ online source for a range of optical items.

Astronomy Magazine – www.astronomy.com online source for the latest celestial events, products and tips.

AstroSolar - http://astrosolar.com/en/ online source for various solar viewing accessories including the polymer solar filter sheets.

Baader Solar Filters - http://www.baader-planetarium.de/com/sofifolie/bauanleitung_e.htm online source for a range of solar viewing accessories including DIY solar filter housings.

Cloudy Nights – www.cloudynights.com online source covering a range of astronomy topics and tips. A very good classified section where you can find new and used equipment,

Craigslist – www.craigslist.com online source base on your location. Again, search using key words such as Celestron, Meade, telescope, camera, Nikon, Canon and so forth.

Ebay – www.ebay.com online source for any astronomy related item. Remember when using Ebay to expand your search with more than one key, i.e. telescope/refractor/Schmidt-Cassegrain/eyepiece/eyepiece filter etc.

Rainbow Symphony Filters -https://www.rainbowsymphony.com/ a range of solar viewing filters and accessories.

Sky & Telescope Magazine - www.skyandtelescope.com/ online source for the latest celestial events, products and tips.

Thousand Oaks Optical Filters - http://www.thousandoaksoptical.com/ a complete range of solar filters and solar view accessories

Telescope Adapters/CNC Supply - https://www.telescopeadapters.com/ online source of adapters and accessories for just about any camera and smartphone. The Scopetronix line is now made and marketed by this company. If you need a camera adapter they will probably have it.

Finally, check your local astronomy club. Ask around, you never know what someone may have for sale.

About the author –

Anthony (Tony) Galván III began his photographic career at the age of 10. From his first camera, a Sabre 620 box camera to a Nikon D3200 today, Tony continues to "take pictures" of the unusual. His photos have taken first place in competitions such as the All-Army Photo contest and the Professional Photographers of America competitions and have also been featured in newspapers and magazines internationally. His astrophotographs have been published in *Astronomy* and *Sky & Telescope* magazines and featured in NASA's Astro Photo of the Day. His technical skills were honed during his tenure as a staff photographer for the National Center for Atmospheric Research (NCAR) in Boulder, Colorado. His desire to simplify astrophotography for everyone is the basis for this book.

Tony's blog, no-scope-astrophotography is the place to see what readers have imaged and for tips on making better "no scope" astrophotographs.