



“Before fiddling with the Wolf Moon, Learn to How!”

A Rookies Guide to Astrophotography

By Larry Kilgore

Astrophotography Workshop

What is Astrophotography?

Astrophotography, also known as astronomical imaging, is photography of astronomical objects, celestial events, and areas of the night sky. **The focus of this Workshop is on SLR Astrophotography, but telescopes and other devices will be mentioned.**

Astrophotography Warning

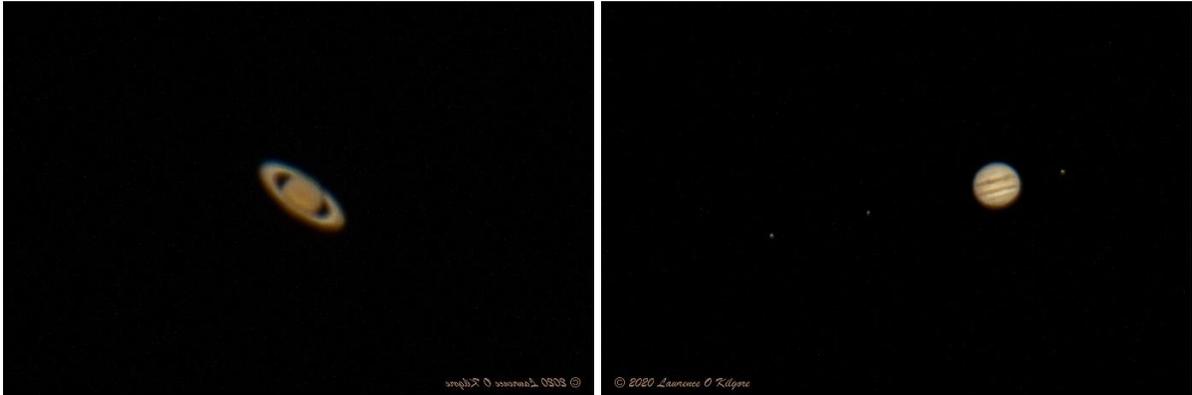
Astrophotography can lead to insanity. This is an easy hobby to do poorly and an extremely difficult hobby to do well. I strive to do well but have done poorly AND gone a little insane.

Astrophotography Can Be Rewarding

YOU TOO can simply point your camera to the heavens and take an image of planets, stars, and deep sky objects. By putting your camera on a tripod and shooting with the right settings, you can take simple images such as this. Here is the night sky, a tree on the right, the Milky Way galaxy, and the arrow is pointing to the Andromeda Galaxy, which is a “deep sky” object.



Fuzzy images of planets are easy to take simply using your camera and tripod. This is Saturn and Jupiter taken with a Nikon SLR and a 500 mm lens, and no tracker.



Types of Astrophotography Equipment

- **Refractor Telescopes** - a telescope that uses lenses to amplify light (can get large)



- **Reflector Telescopes** – a telescope that uses a mirror to amplify light (much smaller)



- **SLR Cameras** – 35 mm cameras with lenses are essentially refractors with amplifying sensors.



- **Digital Telescope Cameras** – When using a telescope, you can insert a small CCD camera into the view finder and download images to an iPad or computer.



- **SLR Cameras on Telescopes** – A simple T-Ring is an SLR “bolt on” adapter that allows an SLR camera to be inserted into the view finder of a telescope. They are model dependent.



- **Star Tracker mounts for SLR and Tripod** – Motorized mounts to keep your camera pointing at an object.



- **Solar HA Telescopes** Hydrogen-Alpha (Ha) solar scopes are dedicated Ha or Quark Telescopes used exclusively for Solar observing. You get the granulation on the Solar chromosphere, along with views of flares and prominences on the Solar limb. They restrict the bandpass of light to the Hydrogen-Alpha emission line only (656 nm wavelength), which is the spectrum in which the Sun shows much of its activity.



- **Auto guided Trackers and Telescopes** – Tracker motors are not perfect, and they are not really “tracking anything”, they are just a very precise motor that turns the mount at the same rate as the Earth’s rotation. Minor tilt in your tripod will still allow drift on a centered object. So, the trackers usually have a port to plug into to send guidance corrections. You then buy a small auto guider telescope that has a built-in camera. You align it to any bright star, and it optically keeps the star centered by sending correction instructions to your tracker. They can dramatically extend exposure times out to many minutes, or even longer.



- **Cell Phone Apps** – Inexpensive and even free, apps like “Skyview” allow a real-time display of sky objects, superimposed upon where you point in the sky. It even works below the horizon so you can tell when objects will rise.



- **Observatory Rental** – Some observatories have idle time when their big telescopes are not being used, and/or older observatories that are not in demand for leading edge research; sometimes they will rent time to the public. You can tell them what to point to, how long an exposure to take, and you get the image, and it belongs to you since you purchased the time on a telescope.

What Is Skynet University?



Star trails, including the Large and Small Magellanic Clouds, over Skynet's 32-inch diameter PROMPT-C7 telescope at Cerro Tololo Inter-American Observatory in the Chilean Andes.

Skynet is a global network of fully automated, or robotic, telescopes serving professional astronomers, students of all ages — graduate through elementary school — and the public over the internet.

Headquartered at the [University of North Carolina \(UNC\)](#) and funded primarily by the [National Science Foundation](#), [NASA](#), and private donations, Skynet's [telescopes](#) span four continents. They have taken over 16 million images for tens of thousands of users.

For the most part, access to Skynet is limited to the institutions that have contributed the telescopes (each ~\$100K or more). However, Skynet is also open to anyone who takes our tuition-free, self-paced **Astronomy with Skynet courses** through Skynet University!

Skynet University offers the same introductory astronomy courses that we have developed for our students at UNC to everyone everywhere. These courses are taken by both science and non-science students, and are now offered at [other institutions](#) as well.

Differences Using the Various Devices

Here are some differences in the results from some of the different devices versus an SLR Camera.

Nikon D850 versus 8" Reflector Telescope (500 mm versus 2000 mm)



Nikon D850 versus a Solar Ha Telescope



Nikon D850 versus an Observatory Shot (the Orion Nebula)



Nikon D850 versus a shot by a good Refractor Telescope (Jupiter/Saturn Conjunction)



Nikon D850 single shot of the Milky Way versus a shot with an SLR Tracker



Nikon D850 single shot of Comet Neowise versus an SLR Tracker



Nikon D850 on a Star Adventurer “tracker” versus an SLR on a Reflector Telescope with a T-Ring



Cell Phone App Called “Skyview” that lets you point to an object in the sky and it tells you what it is. It is free and for a couple of bucks you get the “Pro Version”. Here’s Uranus and Mars above the constellation Cetus. As you move the circle over objects it identifies them.



Issues Related to Astrophotography

- **Star Trails** Streaks from long exposures is the biggest issue with amateur astrophotography
- **Satellites** There are currently around 6,000 satellites and you will “discover” them in your images
- **City Lights** Regardless of what you do, unless you travel to a “dark park” you will get light pollution
- **Clouds** An extra level of challenge is present in the Midwest. If it is cloudy you get nothing.
- **Nighttime** You are photographing at night, in the dark and your subject is essentially black
 - **Everything is BLACK!** - An essentially black subject rarely has anything to focus on (and Infinity is not necessarily in focus)
 - **I Cannot Even See My Camera!** - Unless your camera lights up the dials and settings, it can be difficult to adjust in the dark. If you even touch the camera, you cause shake or possibly misalignment. The most frequent adjustments I make are to the ball head my camera sits on and that usually gets my polar alignment off.
- **Temperature** Clear nights come with cold fronts and you can get physically chilled. Also, the cold can allow condensation to form on the lens. Bitter cold can affect your electronics.
- **Atmosphere** Even when the night is “clear looking” you get constant atmospheric distortion.
- **Moon** If the moon is in the sky it will affect your shots.
- **Time** If you get serious about Astrophotography, you will sit for perhaps 20 minutes, sometimes hours, and even all night in some cases. All while your camera is taking images, and you do nothing, just to get a single celestial image. Add calibration and you spend even more time outdoors. You had better not be out of focus!
- **Image Orientation** Depending on your equipment, you may not see what you’d see through binoculars. You may be looking at something that’s reversed or upside down.
- **Power** How many batteries do you have, and do you really want to change one in the middle of a long shoot?
- **Budget** Solving the problems above usually requires more gear and more money.

Solving Issues Related to Astrophotography

Star Trails and Satellites – Below is an example of both Star Trails as well as a Satellite streak.



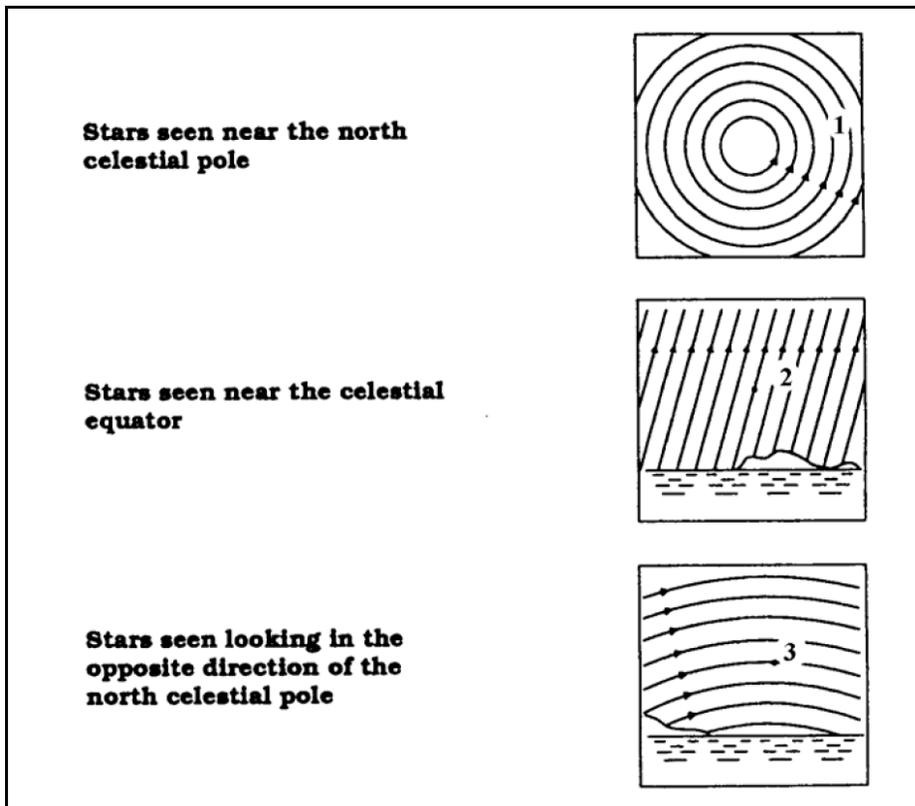
Some Satellites are Interesting (Nikon D850 single shot of the International Space Station)



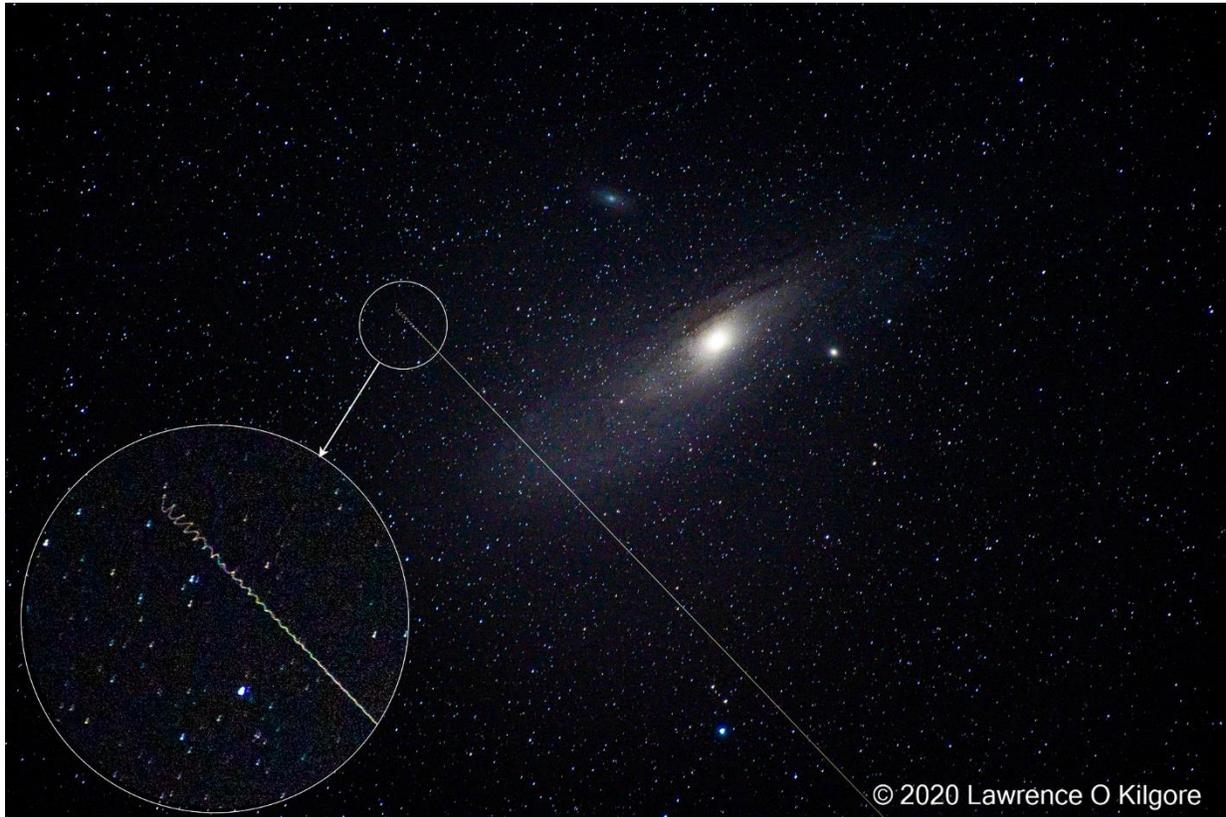
Star trails will differ based on where you are pointing your imaging device. You have probably seen the photographs of star trails that follow a circular path around the north star.



If you point to the North Star, the celestial equator, or toward the South Pole, star trails appear differently:



Satellites - There is not much you can do about satellite streaks until you get to post-processing. Post-processing has software techniques to remove these often-unwanted streaks. In one Andromeda shot, I was excited to see what I thought was a meteor streak where it burned out in a spiral of death. Astrophotography experts said this is common and it is a Satellite, and that is the start of the streak not the end of it, and the spiral was a vibration from my tracking motor.



Star Trails – Instead of perfect round dots, stars turn into short lines of the same color when you are not tracking earth rotation and/or your shutter speed is too long. In post processing when merged with “good round star images”, they can produce “pedestals” which make the stars look like a wine glass (see prior image with the Satellite streak).

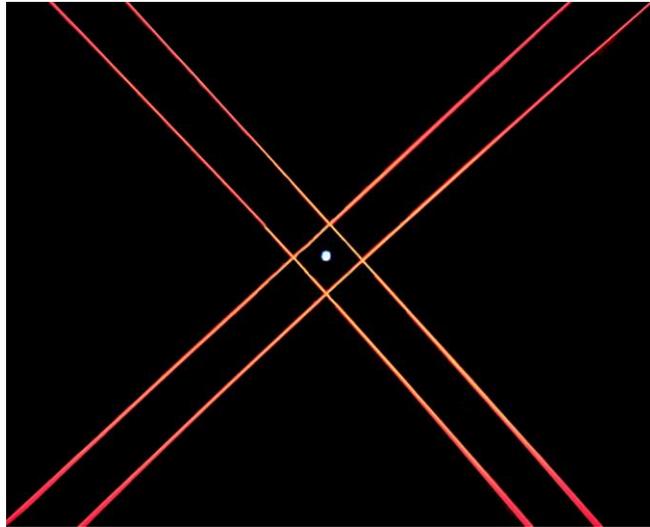


You can see the lower image taken for 30 seconds has nice round stars, but the upper image of 90 seconds has star trails that appear as short “lines”. The best thing to do with Star Trails is to not produce them to begin with.

There are two basic approaches to solving this:

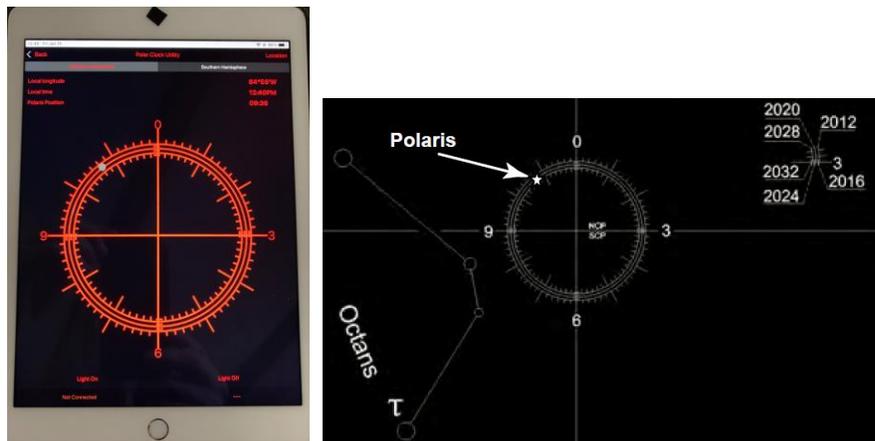
- **Use a Tracking Device** – Telescopes often come with a built-in motor that moves the telescope to exactly match the rotation of the earth, so you can take a series of images without getting star trails. There are two basic types of “trackers”:
 - **Altitude-azimuth Alignment** (also called Alt-az, as called azimuth-elevation) uses a motor to track both compass direction (azimuth) as well as altitude above the horizon. Often easier to align to planets and stars but although the scope can stay fixed on a celestial object, the object itself will slowly turn like a rotating clock as you take images.

Here is what an alignment prism on a telescope looks like, with an illuminated target cross hair. You get close to an alignment star, then as it drifts to the center, you press an Alignment button.



- **Polar Alignment** (also called an equatorial mount or a wedge mount) only needs to be rotated about a single axis, at a constant rate, to follow the rotation of the night sky (called diurnal motion), so although it initially needs constant attention to maintain tracking, it settles down and tracks fine. The added advantage is the celestial object will NOT rotate during a long series of images.

It is much easier to attain Polar Alignment. For example, the Sky Adventurer Tracker comes with a Cell Phone or iPad app. It connects to the tracker and allows for BULB controlled long exposures. To perform alignment, it also uses your location, date, and time to show you exactly where the North Star (Polaris) should be on a little clock display (below, left image). This is real-time and it moves as the night progresses. Initially, you adjust knobs on the tracker until a Polaris is in the same location while viewing it's small, built-in telescope. The big difference is Polaris barely moves so you can easily adjust until you get it right:



- **Use the “500 Rule”** – Without a tracker you can still shoot with your SLR and avoid star trails. In celestial imaging we usually want perfect points of light to represent how we see the stars with our eyes. So even if you do not have a fancy telescope or tracker you can still achieve points of light by use of a simple rule that is often called the “500 Rule”: **500** divided by the Focal Length (**FL**) of your lens equals the longest shutter speed (**SS** is in Seconds) to avoid star trails where **CF** is your crop factor.

$$500 / CF \times FL = SS$$

FL is a fixed value with an **FX** lens, because the crop factor of an **FX** lens is 1 so **1 x FL = FL** but for **DX** lenses **FL** becomes crop factor (**CF**) times Focal Length (**FL**). So, **FL** is replaced by **CF x FL**. So,

$$500 / 1 \times FL = SS \quad \text{(for full frame sensors)}$$

or

$$500 / \text{Crop-Factor} \times \text{Focal Length} = SS \quad \text{(for DX sensors)}$$

Here is an example of the formula used with a Canon EOS 60Da (APSC-C sensor) camera and a 50mm F/1.8 camera lens:

$$500 / 1.6 \text{ (Crop-Factor)} \times 50 \text{ (focal length of my lens)} = 6.25 \text{ seconds max}$$

Here is an example using an FX Nikon D850 and a 500 mm lens:

$$500 / 500 = 1 \text{ second max}$$

Do not confuse which is the mm of your lens with the “500 Rule” constant. The above example just happened to be for a 500 mm lens. The two 500’s are not related to each other.

For the big 500 mm lens, you are zoomed in on the stars, and that magnifies any movement such as bumping your tripod or in our case, the stars moving. So, in this case, I cannot shoot over 1 second. I have tested both 1 second and 2 second exposures with my 500 mm lens, and in fact, 1 second exposures had no star trails but the 2 second exposure did.

500 Rule Table - You can make your own table ahead of time and carry it with you as a quick reference. No need to worry about lenses you do not even own. Here is an example of various lens focal lengths, FX and DX crops, and the max seconds with each:

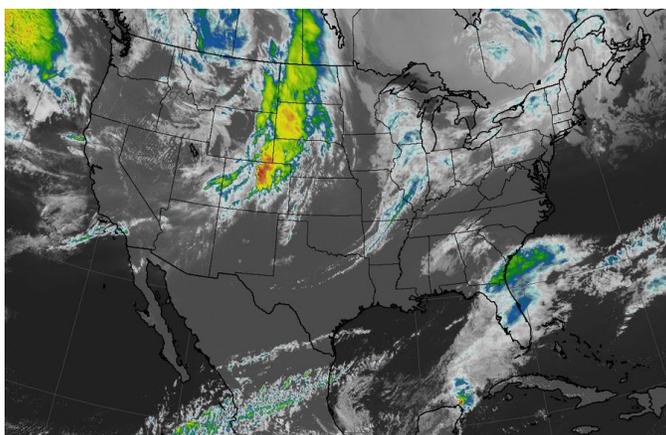
Focal Length	Seconds Before Stars Blur		
	Full Frame	Nikon 1.5 Crop	Canon 1.6 Crop
10	n/a	33	31
14	36	24	22
16	31	21	20
20	25	17	16
24	21	14	13
28	18	12	11
35	14	10	9
50	10	7	6
70	7	5	4
85	6	4	4

City Lights - Regardless of what you try, unless you travel to a “dark park” you will get light pollution. You can dramatically improve your images later to remove light pollution, so do not worry too much about it. I always use a lens hood while shooting Astrophotography, so I do not get light from passing cars, neighbors nighttime lighting, or my headlamp.

Clouds - The only solution for clouds is to not shoot when its cloudy. I use the US Infrared Satellite radar with animation so you can see if it is starting to clear for the evening:

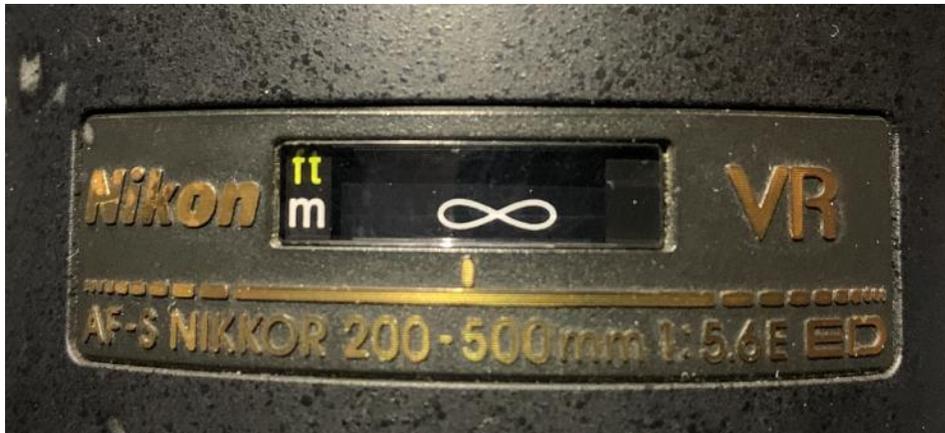
<https://www.wunderground.com/maps/satellite/regional-infrared>

My experience is if you have the darkest grey color over your area, it is clear. (See Arkansas, North Carolina, South Carolina, and Northern Mexico in this image for the dark grey):



Nighttime - Everything is BLACK! You are photographing at night, in the dark and your subject is essentially black, so there is little to focus on. Here is what you can do to improve that:

1. The rear image display screen is essential for Astrophotography and checking your focus.
2. Crank your ISO to max (for me that is 25,000 ISO), then Switch to Live View.
3. If you have a bright planet or the moon, autofocus on it
4. Switch your lens to MANUAL.
5. Make a note on the EXACT location the focus indicator line is on the Infinity Symbol. You do NOT want to just crank your lens to Infinity, its rarely the proper focus:



6. Always start from the position shown with autofocus on a star or planet or the moon.
7. Open your lens aperture as wide as it will go (f/5.6 in this case), then switch to 1/100th second shutter speed. The faster shutter speed lets you review focus test shots quickly.
NOTE: Raising your f/stop to gain depth of field does not gain you much when shooting essentially at infinity. Open your f/stop to allow as much light in as possible.
8. Take a test shot of your celestial object.
9. Using the camera's magnify button, zoom in on each test image to check the focus.
10. Repeat this making minor manual adjustments to focus. When it is perfect make a note of its new location on the infinity symbol, leave it alone. (your lens should already be on MANUAL).
11. Take a cell picture of your focus indicator for future reference.
12. Return your shutter speed to the proper number of secs (or BULB)
13. LOWER YOUR ISO BACK TO YOUR ORIGINAL OR YOU WILL REGRET IT, I DID!!

NOTE: There can sometimes be a little "slack" when adjusting the focus on a lens manually. In other words, as you start to turn the focus ring, nothing happens for a fraction of an inch. For this reason, you cannot always count on a visual examination of "your spot" on Infinity. Start there, but always do a focus check before each session.

I Cannot Even See My Camera! - Unless your camera has lighted dials, it can be difficult to adjust settings. Not all my buttons and dials light up. I have most buttons memorized and I can find them in the dark, but the only thing to do is to buy a headlamp. You will need it anyway, so you do not trip over your tripod, stumbling around in the dark, during a 20-minute stacking session.

Headlamps are critical since it leaves both hands free. I use a Surefire that can be made very dim. But I also carry around a Black Diamond head lamp as a back-up. The Black Diamond is interesting because it has a “red light led” you can switch to. After your eyes adjust, the red light is enough to find anything on your camera in the dark and has the added benefit of not affecting your vision when reviewing images on the rear screen. It is also much safer than white light when the headlamp inadvertently flashes the lens.

Surefire LED Headlamp with White Fresnel lens versus and LED Headlamp with red illuminators.



Temperature Clear nights come with cold fronts so you may get physically chilled. Also, the chill can bring condensation to the lens, which is deadly for Astrophotography (all images will be blurry):

- For starters, **dress appropriately**. On cold nights, my best defense is shell pants to cover my sweats, or even ski bibs under your jacket. Also, good warm boots help a LOT.
- **Wear a good jacket and cap** if it is cold. Wind can be a real chill so a shooting location out of the wind helps.
- **Invest in an inexpensive lens heater**. I have one and it really works. I shot one night, and everything was covered with frost except my lens. I got at CooWoo USB powered Lens heater on Amazon for less than \$20. I use a USB Power brick to power it. It has 3 different temp settings. It fits my 500 mm lens snugly with its built in Velcro. **One caveat** is it is not long enough to wrap around the barrel of my telescope. I stuffed it into the mounting rail, and it seemed to still work. So, if you need to use it on a telescope, get a longer one. I power it with a USB Power brick, which provides USB power for days. You can also power other USB devices with it.



- For cold nights I **use a propane heater**. It warms the immediate area up enough to make it comfortable and reduces condensation. (Also encourages your favorite squeeze to hang with you!). **Carry a foam stadium cushion to kneel on**. I find myself checking alignment and making adjusting on my knees a lot and a cushion really helps.

Portable Propane heater and a closed cell phone pad for kneeling and sitting on:



- Use a **lawn chair with a thin cushion** on it so wind does not go through the back of the chair.

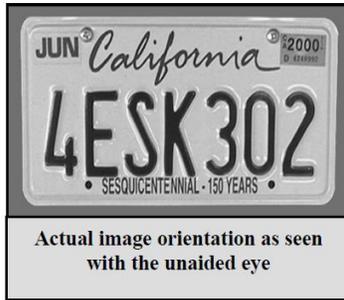
Atmosphere Other than checking the Infrared Radar (previously discussed) and simply not shooting when it is not clear, even when the night is clear looking you will get constant atmospheric distortion. The best approach is to take a lot more exposures. If for example you **take 60 shots**, the stacking and post processing software will fix most sky distortion for you. So, do not worry about it.

Moon - If the moon is in the sky it will affect your shots. I have been shocked how a $\frac{3}{4}$ moon in another area of the sky, totally blew out my images. For me, **it is not worth it to shoot** when a significantly bright moon is in the sky. (Consider moon photography instead)

Budget Solving the Astrophotography problems usually requires more gear and more money. If you want to do some decent SLR Camera Astrophotography, you can do it for less than \$500 by buying a star tracker. They are not perfect but can extend your "500 Rule" from a few seconds out to 30 seconds or more.

Time If you get serious about Astrophotography, you may sit for minutes to many hours while your camera is taking images, all for just one celestial image. Add calibration and you spend even more time outdoors. Plan other activities. I often join my wife in a lawn chair while I am shooting, and we look at the sky. In my driveway, I will simply go back inside the house to warm up, catch a bite to eat, or watch TV. I set a timer for when my session will end, then go back out for the next session.

Image Orientation Depending on your equipment, you will see how an object looks as if you were looking through binoculars (normal orientation), or the image could be upside or backwards. This is not much of an issue in Astrophotography because we can flip or rotate the image later.



Power How many batteries do you have?

- When I am at home, I run an extension cord out to my photography location.
- I use an A/C converter for my camera to replace my battery. Otherwise, the battery may fail in the middle of the shoot. If you have a tracker it will need power and you also do not want it to fail in the middle of a shoot.

When I am home, I prefer an A/C + USB style power strip for everything:



- Trackers often use a cell phone or iPad app to control it. You will not want to run out of USB power on them either. When I must go portable, I use my Celestron Power tank. Even with that, camera power using an A/C inverter, the power tank still only lasts 2-3 hours. One advantage of the power tank is the large flashlight and red light to illuminate your photography area. It comes with 2 USB ports and 2 x 12 Volt car plugs.



Post Processing

Post processing is as important a part of Astrophotography as taking the images to begin with. Post processing can give stunning results from seemingly nothing.

Stacking

Stacking multiple images is the fundamental underpinnings of all amateur Astrophotography. Imagine a series of transparent sheets with stars printed on them. As you stack more and more on top of each other, then hold up the entire stack to a light, the accumulation of all the printed stars will multiply and make a much richer brighter star image. You will also find that you have to shift the transparent sheets, so the stars line up with each other. Those are the two fundamental aspects of stacking.

Stacking Is Not Enough

Stacking can involve more than just your camera exposures of the celestial object, and you can improve your results by using what is called Calibration frames (discussed later).

I shot 7 x 60 second exposures of the Andromeda Galaxy, stacked them, and got a few stars and a fuzzy blob.



Software not specific for Astrophotography has limitations

Using all the tools available within Lightroom and Photoshop, I was able to enhance it to look like this. Even though it brightens Andromeda tremendously, it also brightens all the stars and whether you can see it or not, it also brightens the background noise.



Using Software Written Specifically for Astrophotography

Spending a few hours in a software program called PixInsight, and using no calibration frames, I was able to turn a fuzzy background into what looks more like a distant, mysterious galaxy in space:



Where Did All This Detail Come from?

So, I went from the stacked image on the left to the PixInsight enhanced image on the right. It is not hard to see how tremendously powerful Astrophotography specific software can be.



Even though the left image seems to contain nothing more than a few faint stars and a few fuzzy smudges, your camera has recorded a rich variety of information that you cannot see. It is all squeezed down into a band of low light that, to your eyes looks almost black.

What is needed is software that knows you are trying to enhance the night sky and provides tools to let you pick out the interesting elements and suppress the unwanted light and noise, while affecting nothing else.

Stacking with Calibration Frames

Camera exposures when combined in the stacking process can dramatically improve your results. By removing unwanted camera artifacts and allowing the software to use both bright and dark examples from the camera, background noise can be removed and eye-popping results may be obtained.

Calibration Terms

Once all calibration frames are stacked with the source images, they are referred to as “Main Subs” (I do not make this stuff up!)

Types of Calibration Frames

- Subs or Lights These are your main camera exposure at a celestial object
- Flats White balance shots that help remove vignetting (a pain to remove later)
- Darks Taken with lens cap on at end of each session to remove background noise
- Bias Put lens cap on and shoot at highest shutter speed, removes electronic noise
- Dark Flats Immediately after shooting flats, repeat with lens cap on

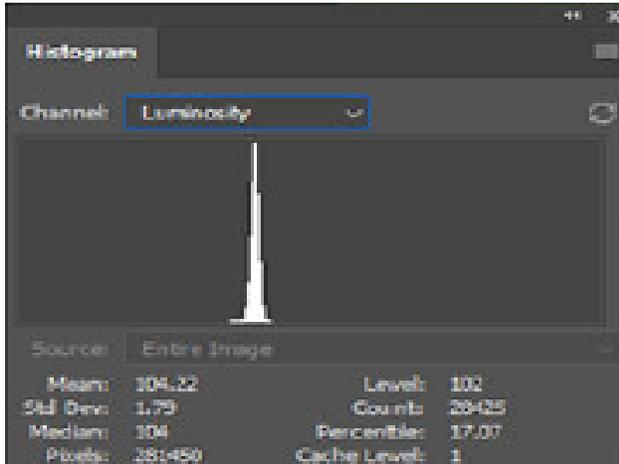
Subs (or Lights) Main Exposures – These are the unedited and unstacked images you take with your camera or telescope. They can be rather boring before being post-processed.



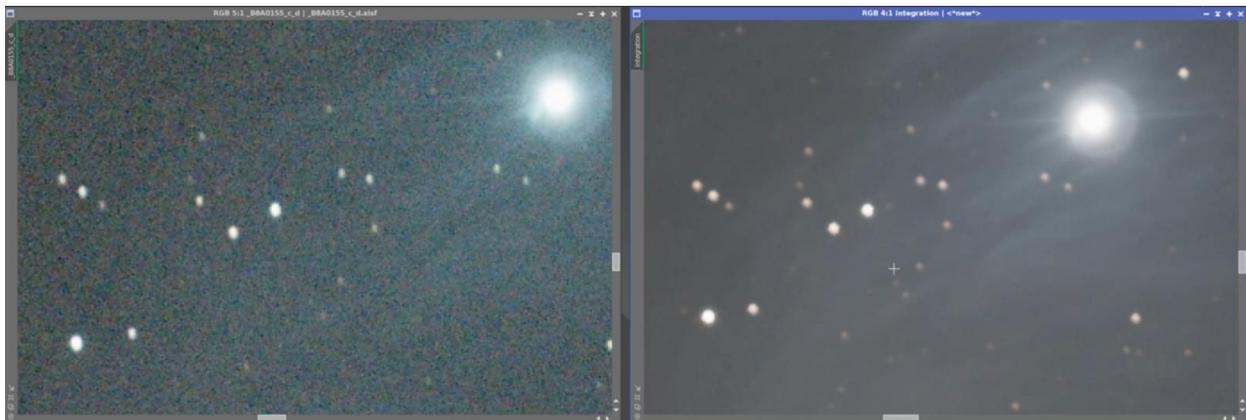
Flats (cover your lens with a white T-Shirt, illuminate during daytime sky or with a light box and shoot at the same ISO and focus as your Subs (take 15-20). Flats allow smoothing of the overall image balance and reduces vignetting.



Check the camera histogram of your Flats before producing a set of images. The histogram should be relatively centered and be between 1/3 and 2/3 of the exposure maximum and minimum. If you have "clipping" (e.g., the histogram line is squished to one side or the other) it is too bright or too dark. Increase or decrease your light source accordingly. Here is an example of a good Histogram.



Darks (immediately after your shooting session, put the lens cap on and shoot the same settings, take at least 5). Darks help eliminate noise in the background. Each of the calibration frame does something to enhance certain aspects of your original image stack. On the left is a sky image without using Darks versus the one on the right using Darks. This is VERY zoomed in and the right image may not be very impressive, but when pulling back to normal size, the sky and background will be much clearer and more dramatic.



Bias (put lens cap on and set camera to fastest shutter speed). It is not temperature dependent and can be done later. A bias frame is essentially the shortest exposure time possible on the camera, with the shutter closed. We are interested in the fixed noise pattern of the electronics, therefore keeping the exposure short prevents other noise from creeping in. It is simply recording the cameras electronic signals and no image, take 50-100.



Dark Flats (lens cap on immediately after Flats, same settings, same number as Flats). I have never taken Dark Flats and they are not mentioned in my software of preference (PixInsight under "Weighted Batch Processing"). Be aware of them and that they may be needed in other software.

WARNING: Using the built in "High ISO Noise Reduction" or "Long Exposure Noise Reduction" can double the time of each exposure. If this is not considered when using a Tracker iPad application or a timer interval, you can over run your exposures. Some shots will be the right number of seconds, but others will be shortened. It will diminish your stacking or even make it impossible.

If you are trying to do cumulative North Pole circular trails, the additional NR time can leave your star trails as dashed lines. If you are time-constrained, turn off your camera's noise reduction during Astrophotography, otherwise it will double your shooting time.

NOTE: One interesting feature the Star Adventurer is the ability for the tracker to run at 12 times earth rotation. This is a trick to let you do an entire night's worth of North Pole Circular Trails in just a couple of hours. You can also use it to do moving time lapse videos during daytime as well.

Astrophotography Software

There are literally hundreds of types of Astrophotography software. They range from Camera control, focusing, Image Acquisition automation, Plate Solving, Autoguiding, Photo Utilities, Filters, Planetary specific software, and much more. Since this Workshop focuses on what you can do with your SLR, the focus of this section is on.

Items in [Blue](#) I have used and recommend:

Image Calibration, Aligning and Stacking

Deepsky Stacker	Free	Image calibration, alignment, stacking
Regim	Free	Image calibration, alignment, stacking
IRIS	Free	DSLR control, image acquisition automation
RegiStax	Free	Stacking planets / webcams, no support
Nebulosity	\$ 95	Acquisition automation, calibration, and processing
APT	€18.70/\$22.59	Image calibration, correction, enhancement
Images Plus	Free	Image calibration, correction, enhancement
AstroArt	€135/\$165	DSLR and CCD control and image processing
PixInsight	€230/\$281	Image calibration, correction, enhancement, stacking
Maxim DSLR	\$199	DSLR control and image processing
Prism Pro and Advanced	\$349/\$499	Automation and real time monitoring. Subscription.
Sequator	Free	Good star stacking software, easy to use

Image Correction and Enhancement (not listed above)

GIMPshop	Free	Photoshop clone with stacking and astro features
Paint Shop Pro	\$79.99	Photoshop clone with curves and some astro
Picture Window Pro	Free	Photo editing, some stacking and astro features
Photoshop Elements	\$99.99	Photoshop "light"
Photoshop CS5 Retail	\$239	For 12 Month Subscription

Planetarium Programs and Atlases

Stellarium	Free	You can see alignments and orientation in the future
Cartes du Ciel	Free	Open-source planetarium, Linux, macOS, and Windows
Virtual Moon Atlas	Free	Moon observation, survey, lunar formations database
MegaStar	\$129.99	Deep sky observing data on more than 200,000 objects
SkyMap Pro	Free Trial	Sophisticated star charting and planetarium program
The SkyX	\$329	Pro Astronomy Software, deep space, adv. features
Starry Night Pro	\$249.95	Telescope control, Deep sky database, 3D

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www.kilgorski.com