So, you want to do long exposure astrophotography?

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Introduction

So what exactly is long exposure astrophotography? Normally this is considered exposures longer than thirty seconds at a very far away and dim object such as a nebula (brightly colored gas cloud in space). All those really cool Hubble telescope images are all in this category.

Let's start by scaring the heck out of you, long exposure astrophotography starts with at least $2000 assuming you already have a camera and can have you out in the freezing cold dead of night for 8+ hours dripping wet from dew to get one little picture that some people won't believe you took anyway. If that freaks you out, stop reading and stick with visual. Still with me? Then let's move on!

Astrophotography and other forms of photography have much in common. Both can be done by anyone with enough money for a body/lens or body/scope combination, and both can be improved with the right skills and right equipment.

Let me start this by saying that as of this writing I have been doing photography over twenty years, many of those as a pro, and astrophotography for about six months. I do not consider myself an expert at either, but given my equipment and level of experience, I don't think I stink either.

With either type of photography you have to ask yourself what you want to accomplish before you just jump in. There are many different levels and tons of different specializations you can master. The bulk of people I hear talk about wanting to do astrophotography want to do a few things including the moon, Jupiter, Saturn, the Orion nebula, the Horsehead nebula, and a few other galaxies and nebulas to show their friends and impress their family.

Planets are usually done with a video camera (mainly webcams) and are stacked from there. Some nebulas like Orion and galaxies like Andromeda *can* be done with some form of success using short exposures on an Alt/Az mount (more on that later). I stress the word can because technically, you *can* perform brain surgery with common household tools, but would you really *want* to? Since this article is aimed at long exposure AP, and since I have no desire to do short exposure work and so know very little about it, we will ignore it for the moment.

Mostly today what you see is done for the web, or low resolution, however most people I hear talk about wanting to do this want to print out the images to show to people as well as post the images online. This requires a little resolution, say 3000x2400 pixels, or 7.2MP after cropping for an 8"x10" print. The higher resolution camera you use, the more you can crop. I would recommend using at least a 10MP camera, preferably a DSLR (more on that later) for Deep Space Objects (everything except the planets basically).

Section 1: The Mount

So on to the basics, the mount. The single most important thing in astrophotography is the mount. This is also where you will spend the single biggest block of your money. If the mount is not solid enough, and accurate enough, your images will look like blurry little blobs. Do you want to take pictures of blurry little blobs? I didn't think so.

There are two types of mounts for telescopes, Alt/Az, and EQ. Alt/Az mounts move up and down, and left and right. Unfortunately the stars appear to rotate around the earth instead of move up/down left/right. If you use an Alt/Az mount for long exposure the object you have in the center of your eyepiece will stay in the center, and everything will rotate. Think of it this way, point your camera at the center of a windmill, now watch as the center of the windmill stays in the center of the frame, but the blades rotate around in a circle. With an Alt/AZ mount you would only be able to take the picture by moving the camera up, down, left or right, you could not rotate it so the outside of the windmill would always be blurry from motion. With this type of mount you can not do long exposure astrophotography. Alt/Az mounts are typically found on scopes used primarily for visual use such as Dobsonians and many other reflectors. Figure (1) shows an illustration of what happens when you try to do long exposure AP with an Alt/Az mount. Note in the image below that the blurring gets worse the farther away from the lower left it gets, that is because Polaris is close to the bottom left of the image so everything rotates around that corner.

Figure (1). Illustration of what happens using an Alt/Az mount for long exposure AP.

This brings us to the EQ mount. On an EQ mount the scope rotates on two axes, this allows for it to not only keep the centered object in the center, but to keep the framing correct by rotating the camera with the scope as the stars rotate. Again with the windmill, you can now rotate the camera at the same speed as the blades of the windmill spin, so the image is nice and sharp and everything is stopped as shown in figure (2).

Figure (2). Same image as figure (1) but on an EQ mount.

The ideal mount for AP work starts with the HEQ-5 such as the Orion Sirius. Anything smaller will most likely not drive your AP scope with all the accessories accurately enough to get you what you want. The next step up is the EQ-6 like the Orion Atlas. The only difference in these two is the amount of weight you can put on them, and of course how much they weigh. Other manufacturers make comparable mounts but as of 01/01/2012 you can expect to pay roughly $1000+ for an AP mount. That is the mount alone, no scope, no camera, no adapters, nothing.

There are devices called EQ wedges which can convert some forked Alt/Az mounts into something that works much like an EQ mount. This may be sort of a solution if you already have a good deal invested in an Alt/Az mount. There are however several issues with this starting with the bearings that connect the fork to the optical tube which were not designed to carry the weight of a heavier camera or guidescope. Then the fork mount is not as stable as a EQ mount even when wedged because of the distance from the mount axis to the telescope being greater. Next, the scope is pretty much integrated with the fork mount, making upgrading the scope practically impossible.

In addition, weird as it may seem, the fork Alt/Az mount even without a $400-$800 wedge can be more expensive than about the same setup with an EQ mount. Case in point would be the Celestron C8 S-GT XLT for $1529 while the Celestron CPC 800 XLT is $1999. It also weighs 7lbs more even without the wedge!

Section 2: The telescope

Next up comes the scope. There are two basic types of scopes, reflector and refractor. You can use either for AP work and the choice is usually a personal one although most AP people I know use refractors.

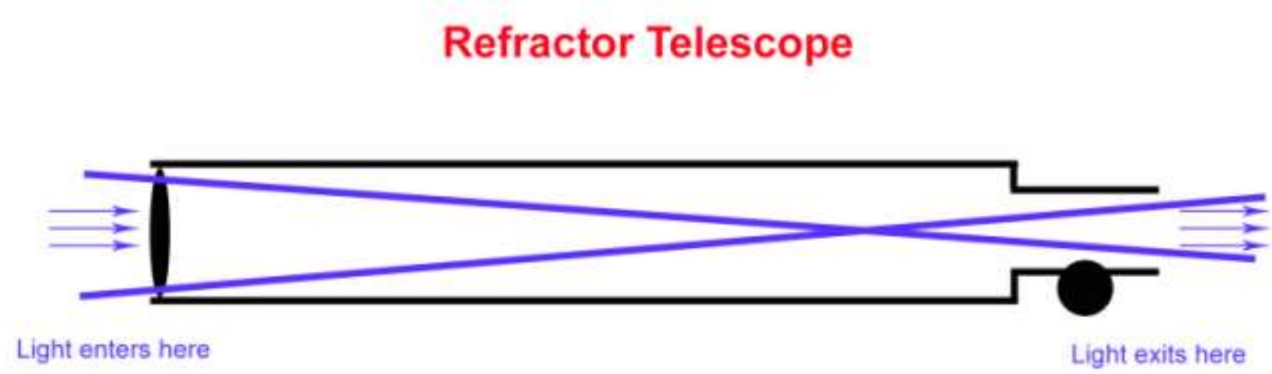


Figure (3). Diagram of a refractor telescope.

Refractors can be good for AP work because they have no central obstruction, do not suffer from coma, do not usually need to be collimated, require virtually no cool down time, offer low wind resistance, and a smaller area for their mass (makes it easier for the mount to drive them). The down side for a refractor is that inch for inch, they are the most expensive type of telescope. They also generally have a shorter focal length which is neither good nor bad, but is a consideration. Figure (3) shows a refracting telescope. Note that the light just passes straight through, this maximizes the amount of light gathered per millimeter of aperture and minimizes problems inherent with bouncing light all over the place.

Figure (4) on the left. A refracting telescope with a smaller refracting telescope mounted on top as a guidescope. Figure (5) on the right. A reflecting telescope. Both scopes are on EQ mounts.

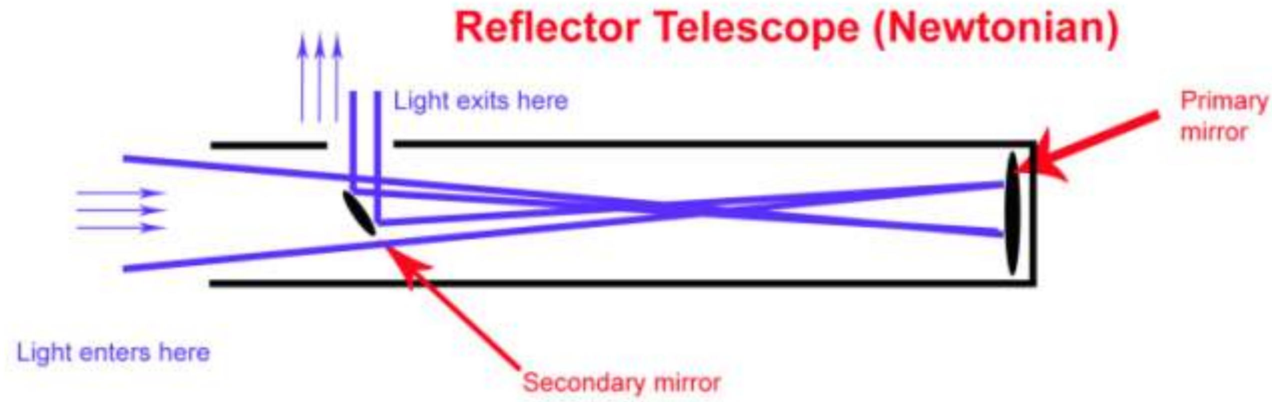


Figure (6). Diagram of a Newtonian reflector telescope.

Reflectors can be good for AP work because they can offer longer focal lengths and are less expensive per inch. Some can also be much more compact than a refractor. Note that in a Newtonian reflector, which is the most common type, the light has to bounce off of two mirrors which have to be precisely aligned and since one end is wide open, this allows in dust, dirt, spiders, dew and other things we don't want to talk about. When you hear about collimation, this is the alignment of the two mirrors has needs to be done frequently.

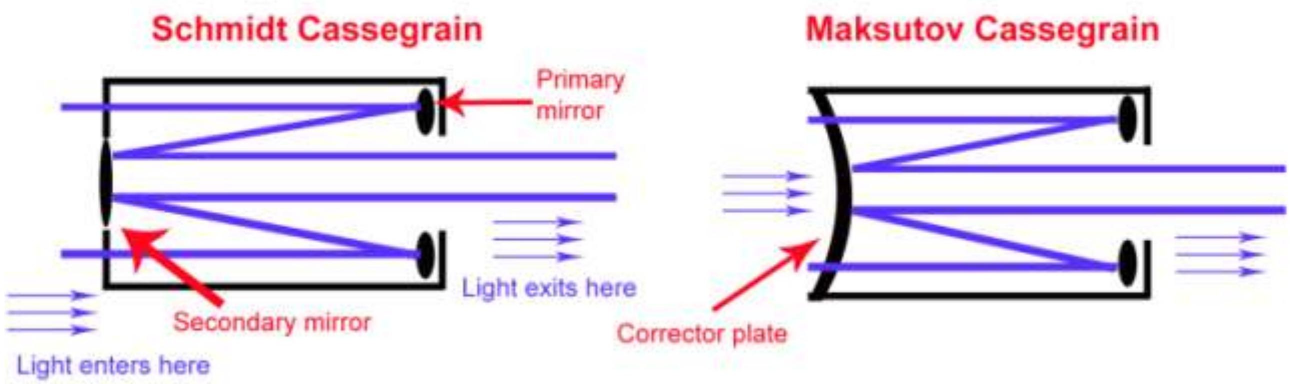


Figure (7) on the left, diagram of a Schmidt Cassegrain telescope & Figure (8) on the right of a Maksutov Cassegrain telescope.

There are also hybrid scopes such as Maksutov-Cassegrains and Schmidt-Cassegrains which combine some of the qualities of both a refractor (being sealed and sometimes lenses) and a reflector (multiple mirrors). These typically have the advantage of being much smaller than Newtonians, and are sealed against dust. They still retain the disadvantages of being slow scopes, having to be frequently collimated and having long cool down times.

Once you pick the type of scope, there are other factors to consider. For refractors you should pick an ED APO scope for imaging (ED is enhanced dispersion, APO is Apochromatic, these make sure that all wavelengths of light converge at exactly the same place preventing the blue/violet "glow" you see on many bright objects through a telescope). You can even go one step further and get an ED APO triplet which uses three elements of glass instead of two for the standard doublet to do an even better job reducing those halos. For reflectors you need to make sure they are designed for astrophotography. The reasoning is that some reflectors such as Newtonians can not focus with a camera attached and need to have the primary mirror moved forward. Astrographs are a type of reflector telescope specifically made to be able to focus with a camera attached.

Next thing to consider is the scope's f-ratio. Scopes are usually listed as, for example, a 110mm f7 scope, this means that the opening on the front is 110mm (aperture), and that it has a focal length of 770mm (110 x 7 = 770). This is important because the lower the f-ratio, the shorter exposures you can use, and this is called a faster scope. So, a f5 scope is faster than a f7 scope which is faster than a f12 scope which is slower than a f10 scope. This also means a faster scope has a shorter focal length and less magnification (actually larger field of view) than a slower scope given the same aperture.

One other important consideration with your choice of scopes is the focuser size. Many starter scopes come with a 1.25" focuser. This is a problem because if you hook up a camera such as a DSLR to this you are likely to get some vignetting of the image. Vignetting is where the center is nice and bright but the outside edges are darker, especially the corners. It is much better to get a 2" focuser right off the bat. Many scopes designed just for astrophotography have 2.5", 3" and even 4" focusers to ensure this is not a problem. Since I shoot a crop sized DSLR sensor 2" is more than enough. You can expect some very slight vignetting using a full framed DSLR with a 2" focuser but nothing a couple of flat frames will not fix quite easily, however a 1.25" focuser will lose too much light to fix well with flat files. Larger focusers also provide more stability to the image train with lots of things like cameras, field flatteners, filters, etc attached.

For scopes you can expect to pay anywhere from $500 up just for the optical tube. My refractor I believed to be the best bang for my buck when I bought it at about $1000, it is a 110mm f7 ED APO Orion Premium.

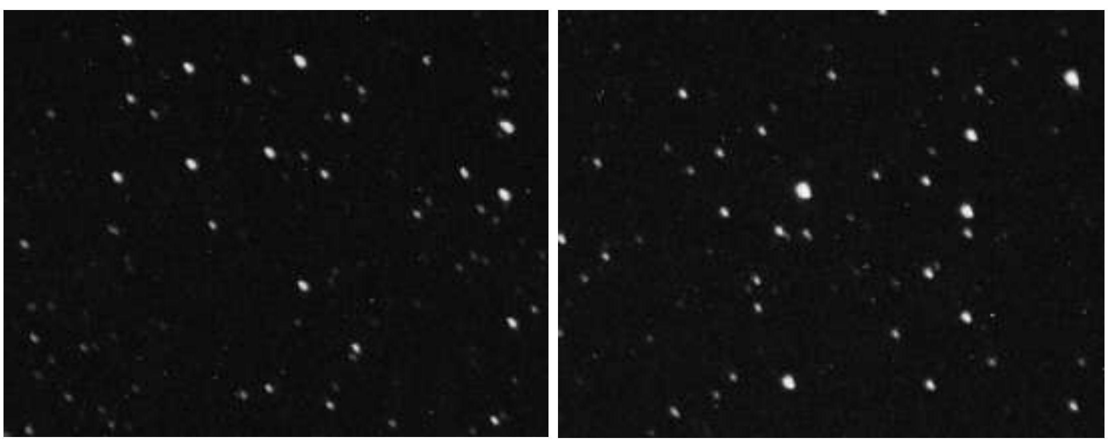
Your choice of scope will also determine your mount. You need a mount that can easily hold your scope. Mounts have maximum load specifications such as 30lbs. This means that the scope can accurately drive up to 30lbs of payload not including the counterweights. Most people say that for AP work you should never exceed 75% of the mount's rated capacity. I disagree with such a broad statement and get a little more technical with it.

Section 3: Configuring your setup

To figure the maximum load for your mount you should start with 50% of the rated maximum, then add and subtract based on factors such as how large the load is, how long it is, etc. For example, a short refractor weighing 75% of the maximum load will actually provide better results than a large Newtonian at 50%. Why? Think of it this way, which is easier to carry around, a 15lb bag of dog food or a 10lb 4'x8' sheet of ¼" plywood? The plywood is huge, turns into a kite in the slightest breeze, and because of its size makes it very hard to control quickly and accurately. Even though the dog food is heavier, it is much easier to control and wind does not affect it.

So I say up to 75% of the maximum payload for refractors, and up to 50% for reflectors, as a general rule. This means with a payload (including scope, camera, adapters, guidescope, etc) of 20lbs you can use a HEQ-5 rated at 30lbs for a refractor, or if you want to use a reflector you need to use an EQ-6 rated at 40lbs.

In order to take long exposures, even with a great mount, you need to align it correctly. EQ scopes need to be polar aligned, or aligned with the north celestial pole. This is just about pointed to the star Polaris in the northern sky. In fact, if you are doing visual you can just point the mount towards Polaris and be done, unfortunately with AP you need to be a little more accurate. See figures (9) and (10) for examples of incorrect alignments. Note that since it is an alignment problem figure (9) which is the top left corner of the image, and figure (10) which is the lower left, show the exact same problem.



Figures (9) & (10). Results of bad alignment

Your nicer EQ mounts have what is called a polar scope built into them, this is a small scope actually in the mount itself. Looking through the polar scope you may see something similar to figure (11).

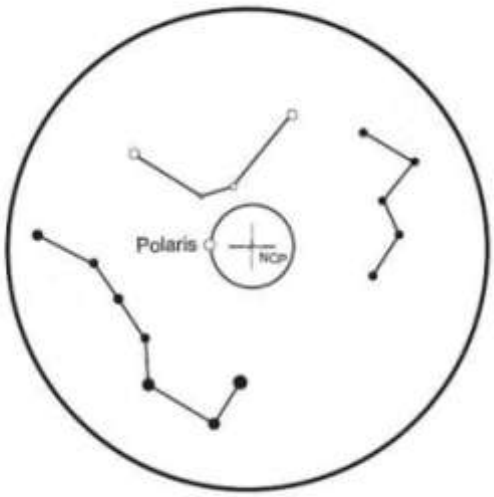


Figure (11). View through a polar scope.

The little circle next to the word Polaris is where you want to adjust the scope so that the star Polaris is visible in the center of that circle. Use the images of the constellations Big Dipper and Cassiopeia to align it correctly with those constellations in the sky at the time you are setting up. Note that the images (and the circle to put Polaris in) rotates as the scope rotates, line up the constellations and center Polaris.

The other thing you need to check before you start imaging is the balance of the scope. There are two axes you need to balance on an EQ mount, the first is shown here in figure (12):

Figure (12). Scope balancing

In the image above I have turned the scope on it's side by loosening the right ascension release then locking it at 90 degrees. I can then loosen the declination release and pivot one end of the scope up and down to see if it is balanced. To balance it, I loosen the scope ring knobs and slide the scope towards the lighter end and recheck. Once finished, I tighten the scope ring knobs back down and move to the front of the scope.

Figure (13). Balancing the scope tube.

Now we need to balance the other axis just like we did to the last one. This time, loosen the right ascension lock and pivot the scope and weight up and down. You can slide the weight left and right (as it appears in figure (13) above) until it balances the scope. Lock everything down, return the scope to it's home position and you are done.

Next up is the guiding. Long exposure work requires that the telescope follow the stars exactly. If it does not, you get odd shapes for the stars instead of round, or you get streaks, or some other weird things. For this we use an autoguider which watches a star and send minute corrections to the scope computer to make sure it is dead on accurate. One thing to note is that the larger the field of view a telescope has (smaller f-ratio, less magnification) the easier and more forgiving the guiding is. The most popular guider I know of is the Orion Starshoot Autoguider (SSAG for short).

Now that we have the guider, you have to have some kind of scope to put the guider into so it too can see the stars. You can use an "off axis" mount which basically splits the light from the scope into two paths, one for the camera and another for the guider. I prefer the second method which mounts a second telescope onto the main scope for the guider, look back at figure (4) to see what this setup looks like. This allows me to have a wider field of view for the guider so I have more guide stars, and also allows me to do whatever I want to the optical path without having to worry about the guiding.

Orion sells the guider in two packages like the ones I recommend, the mini autoguider package and the awesome autoguider package. The difference is the scope size. I run the awesome package so I get the larger 80mm guide scope which collects more light than the little one meaning I can guide on a wider selection of stars. These two guider packages run $349 and $399 respectively. If you choose to go with an off axis solution, that runs about $409.

Once you have an autoguider you may need to tweak it, using guiding software such as PHD Guiding you can get a graph that shows you exactly how the mount is moving (see figure (14)), then tweak the settings to get smoother guiding. As a general rule you want the two numbers on the far lower left, Osc-Index and RMS to be as low as possible and the graph to be as smooth as possible.

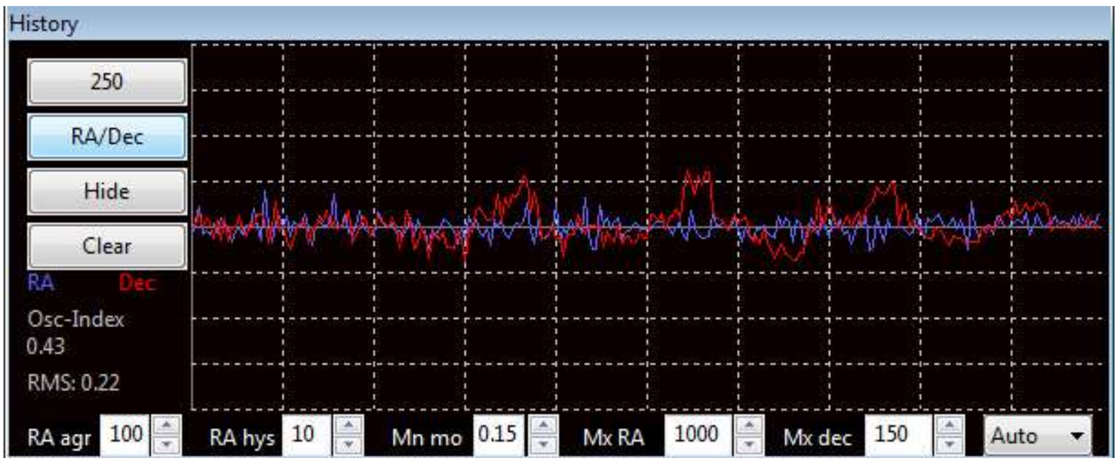


Figure (14). A graph showing the guiding characteristics of my mount using PHD Guiding.

Section 4: The camera

The next concern is cameras. If you are just starting out I recommend you use a DSLR such as the Canon Rebels or Nikon D5100/7000. If you already have a DSLR, use it, even if it is a Pentax, Sony, Fuji, whatever. Canon has probably the widest array of software available to control the camera (which you will need) of any brand. You can however use pretty much any of them, I for example use a Nikon D7000 and it does a fantastic job.

When choosing a DSLR if you do not already have one I would suggest a few things. Get one that is at least 10MP, one that you feel comfortable using (feel it in your hand, check out the controls, play with it and see what you do/don't like about each one), one that shoots in RAW, and silly as it may seem, get one that is at least partially weather sealed (the D7000 is). Why weather sealing? One word, dew. If you choose the D7000 or something comparable expect to pay $1000-$1500 for the body alone. Now some people will scream and say you can get a much cheaper body that will do just fine, and it will, right up until the dew forms on it, the scope rotates, and the runoff seeps into the camera shorting it out.

Now one thing you notice I did not mention with cameras is their maximum ISO. Having higher ISO performance is good, but not because you want to use it. My D7000 captures outstanding daylight or nighttime images at ISO1600, and quite good images at ISO3200. ISO6400 is usable in a pinch. The problem is, you will be stretching the image so you need the latitude offered by the lower ISOs which is why the vast majority of my imaging is at ISO800. If I need more light I just extend the exposure time.

Eventually you will hear of people "modding" their DSLRs for better response to red. Let me first dispel a myth about DSLRs. Some people say that they are completely insensitive to high wavelength red such as Hydrogen Alpha (Ha for short), this is absolutely not true, see figure (15). Ha is at about 656nm in the visible spectrum and a standard DSLR will capture it just as well as anything else in the visible spectrum. The problem comes because there are some very dim Ha nebulas which are just too dim to do easily with a standard DSLR. You can then "mod" your DSLR and have the UV/IR filter removed which as the added benefit of increasing the red sensitivity substantially. Keep in mind that when you do this, it massively increases the red in your images making everything very very red (including things that should not be red) and totally useless for normal photography without additional filters or heavily tweaking the custom white balance feature of your camera. Both Nikon and Canon cameras can be modded. I am currently still using an unmodded camera.

Figure (15). NGC2244 shot using a Hydrogen Alpha filter and an unmodded DSLR with the same exposure settings as would be used without the filter.

You could also consider a dedicated CCD imaging camera built just for astrophotography. The down side here is that you can't use this kind of camera for anything but astrophotography. The advantages are that they are usually internally cooled which can dramatically reduce noise, they are more sensitive to the full spectrum of light, they can have filter wheels built in, and they can have guiders built in. They can also get very expensive in a big hurry. A basic CCD for astrophotography can start at $1500.

Section 5: Other important equipment

Depending on where you live you might be like me down here in Texas where you have a real problem with dew. I have come home from the dark site and literally used five or six towels to wipe off my equipment before taking it inside. When I lift the lid to one of my equipment cases at the dark site, water runs off and splashes on the ground (not drips, not trickles, literally splashes). So unless you just want to image for an hour or two and then pack it up, you need dew control.

I use a four port, dual channel dew controller with four dew strips (heated strips with velcro that warm the air around my optics to keep them dry). One strip goes near the front of the optics on both my main and guide scopes, one on my finder scope, and one on my main scope's focusing tube. Without these it would be more trouble to set up and tear down than it would be worth imaging for an hour or two. Expect to pay $100-$300 for this setup.

Now you may think, scope, mount, guiding, camera and dew, that should do it! Not even close.

Next we need at least one computer to run the shutter and guide the scope (the autoguider plugs into a computer to run software that does the actual guiding). Most imagers use a laptop or netbook for this. I actually use two, one netbook for shutter and guiding, and one laptop for image transfers (images show up complete with histograms on the screen immediately after taking each frame), remote control of the scope and session planning. To preserve your night vision you can get red rubylith sheets off of eBay and cut them to fit over the screen. I actually have dedicated one netbook and one laptop to astrophotography so I mounted the rubylith under the bezel so it appears factory.

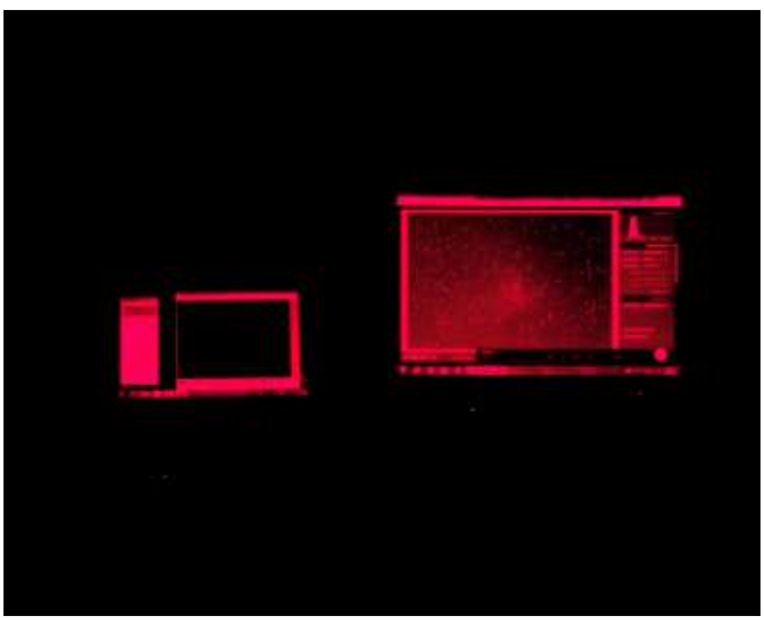


Figure (16). My two computers at a dark site covered with rubylith.

Now we need to be able to focus accurately. I start by pointing the scope at a bright star, something like Vega or Rigel. Then using the live view on the camera zoomed all the way in I make the star as small as possible using my focusing knobs and then lock the focus. Once that is done I place a Bahtinov focusing mask over the front of the scope and shoot a four second exposure at ISO800 to make sure my focus is perfect, adjusting the focuser forward and backward in small increments until the central line is centered in the cross as in figure(17). If I am using a narrowband filter such as Ha, I double the exposure time to eight seconds.

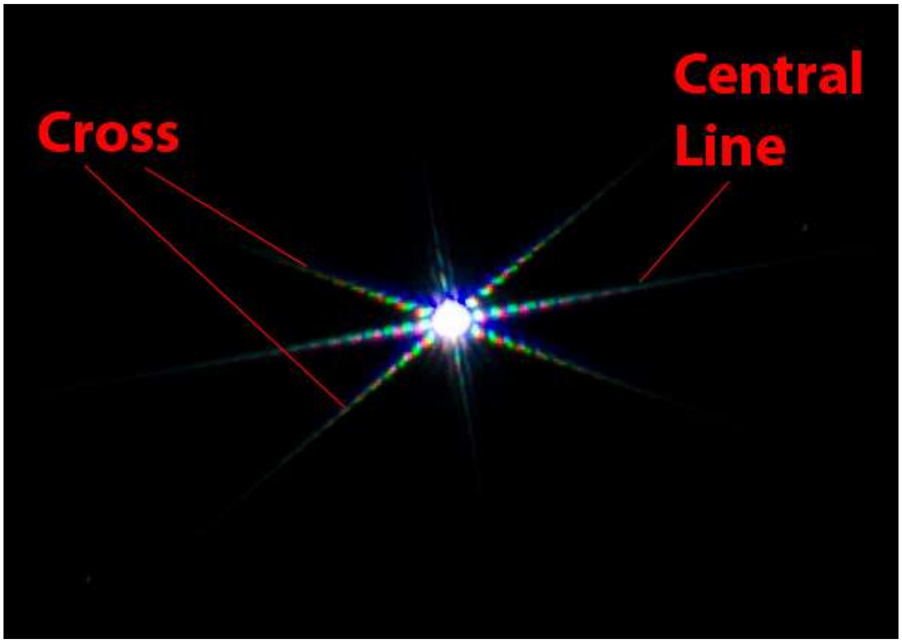
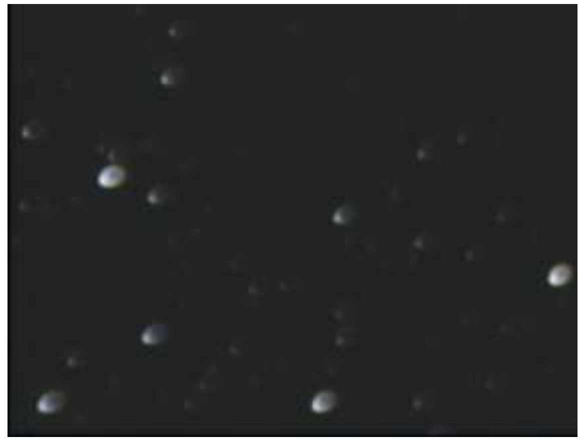


Figure (17). Focusing with a Bahtinov mask

Figure (18). A typical Bahtinov Focusing Mask that fits over then end of the telescope.

As long as we are talking about round stars, the spacing of the camera, type of telescope and options used can really cause some strange problems. For example, a refractor typically needs what is called a field flattner to make sure the stars at the outer edges are just as round as in the center. When you do not have one, you can get images with the corners looking like figures (19) and (20). Note that the stars elongate in different directions between the two figures, that is because figure (19) is the top left and figure (20) is the bottom left, they elongate towards the center of the image.



Figures (19) & (20). Elongated stars caused by not having a field flattner on a refracting telescope, upper left and lower left corners of the same image.

Section 6: Acquiring and processing images

What some people forget at this point is that almost nothing you take a picture of will look the way you want it to, you need to do some processing. For that we need to stack the images first. Stack you say? Stack what? Glad you asked!

Astrophotography is not one image. Back in the film days it could be, but even then you could stack multiple images in the darkroom to make one image. To see what stacking and processing can do to an image, see figures (21) and (22). There are four types of images we can use to stack, in order of importance they are…

Figure (21). A single light frame, unstacked and unstretched.


Figure (22). The same image as figure (21) but stacked, stretched, cropped and processed.

Light frames. These are normal pictures just like you would take in the daytime. Each one we try to get as close to the final product as possible as we are taking them. The more lights you take, the more detail you can get out of an image, to a point. Once you pass 20 or so the returns diminish quickly. The formula is simple, use the inverse square law. For example, if you take one image, you can get a 100% improvement by taking two, then a 50% increase by taking four, then 25% increase by taking sixteen, then a 12.5% increase by taking thirty two, then a 6.25% increase by taking sixty four, and so on. The additional detail is gained by increasing the signal to noise ratio of the image.

Dark frames. These are taken using the same ISO and shutter speed as above, at the same temperature (this is important), except they are taken with the lens cap, scope cap, or body cap on so that the frame is completely black. The same rules for number of images applies as above. We take these images so that they show us how hot pixels the camera generates at a given temperature, given exposure time, and given ISO, which we then subtract from the lights to get cleaner images.

Bias frames. These frames are taken at the same temperature, the same ISO, but at the fastest shutter speed your camera can do with the lens cap on. This shows us the electrical noise the camera generates so that we can subtract it from the lights. The same rules for number of images applies as above.

Flat frames. These are taken with even lighting over the front of the scope. An example would be during daylight, drape a white t-shirt over the front of the scope, then adjust the camera to take a correct exposure through the scope. The same rules for number of images applies as above. These are used to correct vignette and other optical defects in your optical train such as dust.

Technically darks already contain bias information so bias frames are not really required, and if you have no vignette or other optical defects you can skip flats as well. Lights and darks however are pretty much required.

Once you have these images you can use a program such as Deep Sky Stacker (freeware, download) to combine them into a single image you can then process using something like Photoshop.

Now after reading all of that people still ask, how many should I take? The short answer is take 20, that way you are covered for 16 plus some in case some do not turn out as well as you expected. Using this number you will get the “best bang for the buck”, or “most return for your investment”, or whatever you want to call it.

Exposure time is something that a lot of people have trouble understanding. There are no magic exposure settings for any particular type of object. Some things like M42 need a combination of images at different exposures which can range from ISO800 15 seconds, to ISO800 200 seconds. Most of your targets however will use one setting for all the images (unless you decide to shoot with different filters and combine them).

The way I do exposures for nebulas and galaxies is I start with something like ISO800 300 seconds and look at the resultant image. There are two particular things I look at (besides framing of course) which starts with the histogram as shown in figure (23).

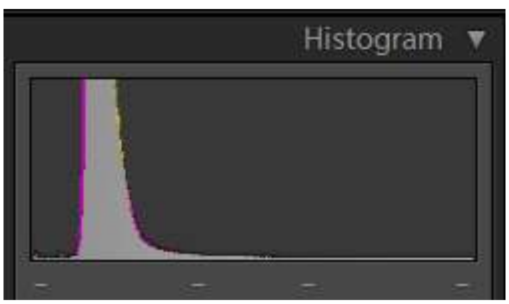


Figure (23). Typical histogram of a single light frame.

What I am looking for in the histogram is clear separation from the left hand side of the image. This tells me that I have clear definition in my image. Next I look at the background, it should be dark gray. The background turning lighter means you are capturing more sky fog, which is light pollution.

In the two figures below note that in figure (24) not only is the background darker, but there is much more contrast between the nebula and the background than in figure (25). You want to get as much detail out of the nebula as possible which requires as much exposure as possible, but keep in mind in the final image you want the black of space to be dark (I prefer almost black) and there to be clear separation between that and the nebula.

So to recap, start off with something like ISO800 and 300seconds, then look at the histogram. If the hump is either touching the left side, or right next to it, increase your exposure. If the hump has clear separation, check the sky fog and see if it is too light, and if so, reduce the exposure to balance it out.

These guidelines are to give you something to start with, only your experience and trial and error will get you where you need to be to create great images.

Figure (24). A well exposed light frame.

Figure (25). An overexposed light frame.

One thing is really important when you go to edit the image, you must use a photo editing program that can work on 16bit. TIFF files for good results. One popular free program, GIMP, I believe will not work with 16bit files, so is not suitable. I also believe that the cheaper versions of Photoshop called Elements will not work with 16bit files. I hate to say it but you really should consider the full Photoshop CS5 package for this at about $600.

Why 16bit files? Because you are going to “stretch” the image to make things more visible. Stretching needs a lot of latitude in the image colors or you get banding. Each of the colors Red, Blue and Green in an 8bit image has 256 shades of that color to work with. So for example there are 256 shades of red, 256 shades of blue, and 256 shades of green that can be blended together to make one of 16.7 million colors.

In comparison a 16bit image has 65,536 shades of each color for a total of 281 trillion colors! Now this is important because a faint nebula might be so dim in your image that if the image is 16bit and black is 0,0,0 that red may be 100,0,0 out of 65536, 65536, 65536. If that same image was 8bit it would have to round to 0,0,0 out of 255, 255, 255 since 100 is so low. This would have the effect of erasing any data you captured!

One thing that always seems to pop up on forums is the use of light pollution filters. Do they work? What are the pros and cons? Lets start with do they work….

Figure (26). Lagoon nebula without light pollution filter.

Figure (27). Lagoon nebula with light pollution filter.

Figure (26) & (27) were taken minutes apart, same scope, same settings, same everything, except figure (27) was taken with a light pollution filter. So do they work? You betcha! Unless I am shooting narrowband I always have a light pollution filter on my setup.

Of course if I lived somewhere where I had no light pollution (the middle of the ocean, the middle of the desert in West Texas) then I probably wouldn't use it as it does block some light I might want. Some versions also tend to make the blue/violet halos around bright stars worse (the Orion Astrophotography LPF I had was much worse at this than the new Baader Moon & Skyglow filter I currently use).

Next up is focal reducers. These are often combined with field flatteners although both items can be purchased separately. The focal reducer does two things, it increases the field of view (reduces the magnification) of your scope, and it increases the amount of light hitting the sensor of the camera since you have a wider field of view. This means you can use shorter exposures but trade off size of the object in your frame. Where this comes in really handy is larger targets like the North American nebula which would normally be impossible to fit completely in the frame of all but the smallest focal length scopes, and when you use a really slow scope such as an f10 SCT telescope.

Now we have covered the most important items, although there is still a lot to consider, AC adapters, USB cables, barlows, eyepieces for visual, and much more.

Here is a complete list of my basic imaging kit:

Orion Premium 110mm f7 ED APO refractor (main scope)
Orion 80mm shorttube guidescope (scope for guiding)
Rings for guidescope (attach the guidescope to the rail below)
Rail for guidescope (attach the rings above to the main scope)
Orion Star Shooter Auto Guider (the acutal guider)
Celestron Laser Pointer finder (finderscope)
Orion Red Dot Finderscope (finderscope)
Dew Not 2 channel 4 port controller box (to control the strips)
4 - Dew Not heater strips for both scopes and red dot finder (to preven dew)
AC to DC converter 6A for dew system (to power the dew system from AC)
HoTech field flattner 2" (to make the stars on the edge of the frame round)
Badder Moon & Skyglow filter 2" (to remove light pollution)
Orion 2" Nikon T-Ring (attaches to the camera)
Orion 2" 5mm T-Ring spacer (provides extra spacing between camera and field flattener)
Nikon D7000 body
Orion Sirius EQ Go-To mount and tripod
AC adapter for mount (not included with mount purchase)
Extra 11lb counterweight for Sirius mount (to bring everything into balance)
Case for optical tube (for transportation)
Netbook to control guiding and shutter
two USB cables for guiding and shutter
two USB stalk red LED lights to light up keyboards
Shoestring Astronomy USB controller for Nikon (allows for shutter computer control)
Laptop running Lightroom for tethered image capture and star maps
USB cable for tether
2x 3-element Orion APO barlow (to get closer to objects)
2" Extention tube (needed to focus when using barlow)
Baader 2" 32nm Ha filter (for taking Ha images)
Orion Stratus 5mm 2" eyepiece
Orion Stratus 8mm 2" eyepiece
Orion Stratus 13mm 2" eyepiece
Orion Stratus 24mm 2" eyepiece
Orion 2" Dieelectric 90 degree diagonal
Orion 24mm lit chrosshair eyepiece
Bahtinov Mask (for focusing)
Binoculars (for keeping an eye on seeing conditions)
Portable table (for laptops)
Portable chair (for my rear end)
Lightroom for general processing and cropping
Photoshop CS5 for serious processing
DSS for stacking
AstroPlanner for planning imaging sessions
Stellarium for general star charts
Powerstrip and extention cord
Red Flashlights (2 in case one dies)
Two cases to carry all the accessories in
One case for laptop, netbook, log book, pens, etc
Rags for whiping off dew
Clear paper sleeves to keep dew off target lists

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