

AN INTRODUCTION TO ASTROPHOTOGRAPHY

**A Comprehensive guide for learning
the basic skills used in astrophotography**

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WHAT DO YOU NEED TO KNOW BEFORE GETTING INTO ASTROPHOTOGRAPHY

You Don't Have To Be A Millionaire

If you've ever paged through any astronomy magazine on the market and you turn to the pages at the back where they show the images submitted by the readers, a quick sum will tell you that the average cost of the equipment used well exceeds US\$ 10,000. Knowing that you may tell yourself that you will never be able to afford to do any astrophotography or that you will never achieve results like that? Well, don't despair because you don't have to be a millionaire to start the great hobby of astrophotography. Modest equipment is very affordable from many of the astronomy equipment manufacturers and yes, results like in the magazines are achievable, the only difference is that with modest equipment you have to work harder to achieve those results, but they are possible. This guide will refer to equipment with which you can achieve very good results without having to break the bank.

City Dwellers

Any astronomer who lives in a city will know that light pollution is our worst enemy, it prevents us from seeing 50% of the viewable objects in the night sky and in some cities it even limits us to just viewing the moon and bright planets.



The image on the left above shows what a typical person could see in the night sky from their backyards approximately 50 years ago and the image on the right shows what the effect light pollution has on our night sky and what an astronomer living in the city generally has to contend with today. Lucky for astronomers we now have access to some very good filters that can block out most of this light pollution and although this isn't always evident when doing visual astronomy, it becomes an astrophotographer's best friend in the city. So, although you might live a city and think there is no way you can do any sort of astrophotography, it is astrophotography that makes doing astronomy in the city worthwhile. With the use of some filters and even without, you will be able to

get fairly decent results, at least far better results than looking through an eyepiece and just seeing an orange glow. So don't let the bright orange glow in your backyard discourage you, grab that telescope and camera and you will be surprised as to what you can achieve.

The Three P's Of Astrophotography: Preparation, Patience and Perseverance

It took about two years of doing astrophotography before learning the secret ingredient to making most nights out successful. By success, we mean producing images of which 90% can be used for processing. This secret is the three P's of astrophotography, namely preparation, patience and perseverance. Like most things in life, the more we are prepared for an event, the better the event is handled especially when something happens that we didn't plan for, the same applies to astrophotography. When you see that the weather forecast for the evening looks promising you could load up the [Starry Night Pro software](#) which contains the current and future positions of 16 million stars and 1 million deep-sky objects. Identify an object you wish to photograph that night and the software will tell you exactly where it will be located at the time you plan to go out. Take your equipment out early if you don't have an observatory and set everything up and let your telescopes start the cooling process. This covers the preparation process.

The patience comes in when you have to do the polar alignment of your mount, focus your camera and take the images. If any of these three processes are rushed, it generally ends in you having to throw out half your exposures for the evening.

The most important of all the P's is perseverance. Trust me, when you've spent the better part of three nights out in the freezing cold and have nothing to show for it, it takes a special something to convince you to go out again the next evening and try again. In conclusion, don't let the excitement of the night's imaging prospects make you rush through the process; it's just not worth it. Take your time, enjoy it and make sure it's right and you will see what a huge improvement will be evident in your images.

Various Types of Astrophotography

There are a number of ways of imaging the night sky; it all depends on what you would like to image and what you can afford. Although there are more ways, let's classify astrophotography into three main categories:

1. Video Astrophotography

The introduction of cheap video webcams used with personal computers led to the birth of this form of astrophotography. It is predominantly used to photograph the moon and planets by taking streams of video of the object and then using software like Registax to break this video stream up into individual frames. These individual frames are then calibrated and stacked (explained later in the article) using software to create the final image. Since the start of this type of astrophotography, many astronomy equipment manufacturers have started developing their own

form of video CCD cameras that produce amazing results. The [Orion Star Shoot Solar System Colour imager](#) is an example of this type of camera.



NEW!

2. DSLR (Digital Single Lens Reflex) Astrophotography

The first popular form of amateur astrophotography was done using film camera's that were connected to telescopes and the shutter then opened to collect light. The astrophotographer had no clue what the image would look like or if he had even focused the camera perfectly until he developed the night's images. Can you imagine how frustrating this form of astrophotography must have been?

Luckily, as technology advanced and CCD chips became more affordable, so too did the digital SLR. Today, you can use every day DSLR's from popular manufacturers like Canon (<http://www.canon.com>) and Nikon (<http://www.nikon.com>) to take the most amazing images of the night sky with the advantage of being able to view your images as they are taken, giving you the opportunity to correct any mistakes in your setup without wasting an entire evening. Also, a DSLR camera can be used for day-time photography when you're not using it photograph the night sky.

The disadvantage of using this type of camera for astrophotography is that almost all the stock cameras have low pass, long wave length filters built in that make them poor at recording hydrogen alpha light in red emission nebula. There is a solution to this problem as well, you can modify your DSLR camera and remove the standard filter and replace it with a filter that allows the transmission of this particular wavelength, but then you sacrifice the ability to use the camera for day-time photography.

DSLR astrophotography is probably the easiest and most affordable way to start off with your deep-sky astrophotography endeavours. Almost all astrophotographers make their start here where they acquire and refine their skills before moving to dedicated CCD astrophotography. You'll need to get some sort of device to attach your camera to your telescope. This [Orion SteadyPix Deluxe Camera Mount](#) does the job quite well.



3. Dedicated CCD (Charged Coupled Device) Astrophotography

Dedicated CCD Astrophotography involves the use of CCD camera's specifically designed for taking images of the night sky. The CCD's used in these cameras are generally far more sensitive than CCD chips used in normal DSLR cameras.

This type of camera generally comes in various forms, namely monochrome and colour CCD cameras. The monochrome CCD camera is more sensitive to light than colour CCD cameras due to the fact that the monochrome CCD cameras do not have a Bayer matrix covering the CCD chip. The Bayer matrix is what differentiates a monochrome CCD chip from a colour CCD chip and allows a CCD chip to produce colour images. Most serious amateur and professional astrophotographers use monochrome CCD cameras to produce stunning

images. They produce colour images by taking individual images through different colour filters and then combining these images to produce a single final colour image.

Besides the above mentioned variations of CCD cameras, there are two additional variations, namely actively cooled CCD cameras and standard uncooled CCD cameras. Why have a cooled CCD camera? Cooled CCD cameras produce better images than uncooled CCD cameras because cooled CCD cameras produce less noise in the image and hence the image is clearer and contains more detail compared to images taken with an uncooled camera.

An example of this type of camera is the [Orion Star Shoot Pro Deep Space CCD Camera](#). This type of astrophotography is generally the most technical and most expensive type of astrophotography requiring many hours of capturing to produce a single image. This type of astrophotography also produces the best results for the time spent imaging compared to other forms of astrophotography.



ASTROPHOTOGRAPHY BASICS

From here on, we will start looking at what you need to know and what equipment you will need to start taking your own images of the night sky. Let us first start by looking at some of the basics of astrophotography. If we had to complete this section with everything there is to know and consider about astrophotography, then we would need to dedicate the next 100 pages to this section, but the purpose of this article is to provide you with what you need to know to get started and here they are:

Signal to Noise Ratio (S/N)

If you have ever read any article on astrophotography, you will notice that the author always refers to the signal to noise ratio. The greater the signal to noise ratio of a given image, the better the image quality will be and therefore the better your resulting image will look.

An explanation in very simple terms is that signal is the data collecting on the CCD chip, whether you are doing video, DSLR or CCD astrophotography. This is the data or image information we want to collect and we want to collect as much of it as we possibly can. In the case of signal, more is always better.

Noise is the data collecting in the image that we don't want and is caused by many factors. You can find noise being caused by the CCD chip itself, by the heat and light that find their way into the camera, from light pollution and from the process of reading the data from the chip just to name a few.

Another simple way to illustrate the concept is as follows: Pretend you're watching a good hockey game and someone is doing dishes near by. The "signal" you want to capture is the images and sounds coming from your TV. The "noise" you want to filter out is the loud clanging of the dishes. In other words, more signal and less noise means a better hockey game viewing experience.

Luckily, there are various ways to decrease the noise in an image. This can be achieved by doing one or all of the following depending on your individual circumstances:

1. Do your imaging under dark skies
2. Take longer exposures
3. Cool your CCD chip as much as possible
4. Combine multiple images by stacking your images (explained later)

If you live in a city where you are plagued by light pollution of which you can do nothing about, you can reduce the noise in your images by taking longer exposures and by using a [quality light pollution filter](#). If you own a cooled CCD camera, set the CCD camera temperature to as low as it can go and take many images of your target which you will then combine using various methods discussed later in the article to provide you with an image with low noise hence increasing your signal to noise ratio.

One important aspect to note is that you will never be able to completely remove all the noise in your images, it will always be there, all you can do is try and minimise it as much as possible. How you reduce the noise in your images will depend largely on your circumstances. Not having one or more of the noise reducing factors only means that you need to maximise the use of the other factors in order to produce low noise images. At the end of the day, the lower you can get the noise in your images to be, the easier it will be to process your image to get most of the captured detail out of it.

Why are the Objects you Imaged so Small?

So, you've gone outside and taken some images and when you finally finish processing them you notice that the object you imaged is very small in the frame. You might ask yourself that when you looked at the object through your eyepiece it seemed quite big, why is it so small now?

Well, the answer is quite simple. Every eyepiece you own has a certain focal length and the focal length of your telescope divided by the focal length of the eyepiece gives you the current magnification you're viewing at.

With a CCD camera the situation is completely different. Essentially, a CCD camera doesn't have a focal length; the image size on the frame is determined by the size of the field of view. To determine the field of view for your telescope and CCD camera combination, you need to know what the dimension of your CCD chip is in millimetres as well as the focal length of your telescope in millimetres. The formula used to calculate this is as follows: $FOV \text{ (Degrees)} = 57 \times \text{CCD Chip Dimension (mm)} \text{ divided by focal length of telescope (mm)}$. Therefore, from the formula we can deduce that if you want the object you're imaging to be larger in the image you're taking, you need to increase the focal length of your telescope. Below is a comparison of two images taken with the same CCD camera; the image on the left is taken with a telescope with a focal length of 500mm and the image on the right is taken with a telescope with a focal length of 1200mm.



500mm Focal Length



1200mm Focal Length

There is a downside to increasing the focal length of your telescope to get the object in the image to appear larger and that is that you are decreasing the image scale. The effects of decreasing the image scale will be explained in a later section.

How Long Should My Exposures Be?

You've now set up your equipment, you've got your computer running and you've decided on the object you wish to image that night, now how long should your exposures be?

The length of your individual exposures can depend on a variety of things but the two most important things to consider is light pollution and the focal ratio of your telescope. Light pollution plays a role because if you live in an area of high light pollution and you're exposures are too long, then your image will be washed out by a red and orange glow. So, the trick is to figure out what the longest exposure is you take before the image is completely washed out by this red and orange glow, because after all, in order for us to minimize the amount of noise in our images we need to take as long as exposures as we possibly can.

The other factor that influences the length of your exposures is the focal ratio of your telescope. The higher the focal ratio of your telescope, the longer your exposures need to be and vice versa. Despite what you may think, the aperture of your telescope has no influence on the length of the exposures. If you have two telescopes of different apertures but the same focal ratio, the exposure length for both telescopes will be exactly the same, even if one telescope has a sixteen inch aperture and the other an eight inch aperture. The only difference between the images taken is that the image taken with the sixteen inch telescope will give you a lower image scale compared to the image taken with the eight inch telescope. The advantage of shorter exposure times gained with using a low focal ratio telescope is why many astrophotographers employ the use of focal reducers with their high focal ratio SCT's. Here's an [example of a focal reducer](#) that was designed for the [ED100 telescope](#).



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Given the factors above, remember that our goal is always to take exposures that are as long as possible in order for us to minimise the amount of noise in our images. The advantages of short focal ratio telescopes are that more detail is captured in a shorter time compared to telescopes with a longer focal ratio.

Image Scale

Measuring the image scale helps you determine how well your camera and telescope are matched to each other. Image scale is measured in arcseconds per pixel, in other words how much of the sky is captured on every pixel of your CCD chip.

High resolution images are images where the arcseconds per pixel is a very low value, namely, a very small part of the sky is captured per pixel on the CCD chip. Low resolution images are the exact inverse of this, low resolution images are created when the arcseconds per pixel is a higher value, and hence you are capturing a larger section of the sky per pixel.

You might be thinking that the higher the resolution of your images the better the image, this is not always true for the following reasons:

1. The seeing conditions on any given night limit the image scale. In order to take high resolution images, namely images with an image scale less than 1 arcsecond per pixel, the seeing conditions have to be near perfect or your images will not be sharp and crisp.
2. The capabilities of your mount may also be a limiting factor when wanting to image at a high resolution. A mount that tracks the night sky poorly will not deliver sharp and crisp images.
3. Another item to consider is the optical quality of your telescope. A lack of sharpness and contrast from your telescope optics will lower the resolution of the image you're able to image at.
4. Many telescopes such as SCT's provide smaller fields of view due to higher focal lengths, but these telescopes very often also have high focal ratios requiring longer exposures.

The general consensus amongst astrophotographers is that unless you live in an area or regularly travel to a location where the seeing conditions are exceptional and allow for imaging at a high resolution and image scale of less than 1 arcsecond per pixel, the best image scale to aim for is an image scale between 1.5 and 3 arcseconds per pixel. This range of image scale provides the best combination for imaging at a reasonable resolution and not being so heavily influenced by the factors listed above. Remember that image scale is determined by the camera and telescope you use, not just the one or the other. A great tool for calculating your image scale for a specific CCD chip and telescope focal length can be found here:

http://www.newastro.com/book_new/camera_app.php

Guided Or Unguided Astrophotography

If you've done visual astronomy in the past, you will know that if you haven't aligned your telescope correctly and even when you do for that matter, the object being viewed never stays perfectly still in the field of view of the eyepiece. Here are some of the reasons why this happens:

1. Inaccurate polar alignment. This will cause a slow drift of the field of view as well as causing a rotation in the field of view. How much this movement is depends on how inaccurate your polar alignment is.
2. Every mount contains some degree of periodic error. Periodic error is caused by imperfections in the telescope's worm gear. Many modern mounts contain a feature called periodic error correction. This allows the telescope to learn where the imperfections are and correct for them when they occur.
3. Incorrect settings in the mount itself such as backlash settings.

If your mount suffers from any of the above symptoms, you will not be able to take long unguided exposures because the problems listed above will cause star trails in your images and these images are then unusable.

To correct for the problems above astrophotographers employ guiding in their setup. Guiding can be described as using the same or a different telescope and camera to take images of a star every few seconds. If the star changes position, software on your computer or in the camera itself sends signals to the mount to correct for this movement.

If you wish to take long exposures of the night sky and possess an average mount, you will inevitably have no choice but to use guiding in obtaining your images. The equipment required to do this will be explained in the following section.

RECOMMENDED ASTROPHOTOGRAPHY EQUIPMENT

In this section of the article we are going to look at the various equipment options available to amateur astrophotographers. Please note that the equipment listed here are only recommendations for people taking on astrophotography for the first time, what you end up wanting to buy will largely depend on your available budget.

Mount

Ask any astrophotographer and they will tell you that the mount is the most important part of your astrophotography equipment. Without a good mount with decent tracking abilities and low periodic error, your images will never be as good as you would like them to be. It has been recommended by many astronomers that you should spend at least 60% of your available budget on the mount and the rest of the funds on the telescope, camera and other accessories.

Two main types of mounts are available to amateur astronomers today, the German Equatorial mount and the fork mount. Many mounts available in both these variations have been designed primarily for visual astronomy; they are generally compact and light weight in nature. If at all

possible these are the type of mounts you should try and avoid for astrophotography as they tend to provide you with the most problems when it comes to getting a well tracked image. Although almost all astronomers will recommend a German Equatorial mount for astrophotography this does not mean that a fork mount cannot be used for astrophotography. The addition of an equatorial wedge to your fork mounted telescope will convert it into an equatorial mount and make it very useful for astrophotography.

A very important thing to consider when purchasing a mount for astrophotography is the load capacity of the mount. Remember that the average entry level astrophotography gear could easily weigh in at in between 15lb and 25lb and it is recommended that you never exceed 75% of your mounts load capacity when it comes to astrophotography as the heavier the equipment on the mount, the harder the mount has to work to track correctly, even when you are guiding.

The image below and on the left is a good example of a good entry level German Equatorial mount for astrophotography. The image on the right is a bigger heavier German Equatorial mount with a greater load capacity which is even better suited to astrophotography. The price of these German Equatorial mounts range from \$750 to \$1500. They may look the same, but when you go through the specs, they are quite different.



[Orion SkyView Pro Equatorial GoTo Telescope Mount](#)



[Orion Atlas EQ-G Computerized GoTo Telescope Mount](#)

Primary Imaging Telescope

The question of what telescope to purchase as your first astrophotography telescope has been a debate that has and still is ranging on. There are 3 main [types of telescopes](#) today; the refractor, the reflector and the catadioptric.

The refractor telescope is probably the oldest design of telescope and today, price per inch they are the most expensive types of telescopes as well. We get 2 types of refractors, achromatic and apochromatic telescopes. The difference between the two is that apochromatic refractors correct for the chromatic aberration present in achromatic refractors. Chromatic aberration occurs when the individual wavelengths of light don't focus at the same point causing colour halos around bright objects in your image. For the purpose of astrophotography the best type of refractor to use is the apochromatic refractor and these can vary in price from a few hundred dollars to several thousands of dollars.

The reflector telescope is our next telescope for consideration. Price per inch they are probably the cheapest type of telescope available today. Another advantage of the reflector type of telescope is that they generally have low focal ratios making them perfect for astrophotography and they come in many sizes ranging from 4 inches right up to 50 inches. One disadvantage of this telescope is the tendency of reflectors to produce images containing a lot of coma, but don't despair this can be corrected by purchasing a coma corrector. Nowadays you can purchase a fairly good sized and good quality reflector for under \$1000.

Catadioptrics telescopes are the final category of telescopes we will be looking at. Telescopes that fall into this category are telescopes like the Schmidt Cassegrain, Maksutov Cassegrain and Ritchey-Chretien telescopes. These telescopes use a combination of mirrors and corrector plates to focus the image into the CCD chip. They are also characterised as having long focal lengths and high focal ratios. These telescopes range in sizes from 4 inches to 24 inches. The most expensive of these types of telescopes is the Ritchey-Chretien which boasts some of the best image quality available to amateur astronomers today and another advantage of the Ritchey-Chretien is that it has an almost perfectly flat field of view, something that the other types of telescopes in this category generally suffer from. Prices range from a few hundred dollars to well over \$100,000.

So now that we know what types of telescopes are available, which one do we choose? Well, it all depends on what your budget is, but if we can give you some advice, start with a short focal length, low focal ratio wide field of view telescope. The reason we suggest this is that short focal length telescopes makes your reliance on a perfect high end mount less as well as allows you to image almost every clear night because seeing has a lesser effect on short focal length scopes. This is a great place to start. Below are affordable telescopes to use ranging from a short focal length refractor on the left to a long focal length Ritchey-Chretien on the right.



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[Orion ED80T CF Apochromatic Refractor Telescope](#)



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[Orion 8" f/4.0 Newtonian Astrograph Reflector](#)



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[Orion 8 f/8 Ritchey-Chretien Astrograph Telescope](#)

Guide Scope Telescope

As discussed in the previous section, guiding is the process whereby you use the same or different telescope and camera to monitor the movement of a star using software and then using the software to send corrective signals to the mount. This ensures that your resulting image is free of star trails.

Generally speaking, the guide telescope doesn't have to be a brilliant telescope, it just needs to be a telescope that you can connect a camera to and that can bring the camera to focus. The general rule of thumb when it comes to guide telescopes is that you want a telescope that has a fairly low focal ratio and a small to moderately sized aperture. A standard 70-100mm short tube refractor is perfect for this application. Along with your guide telescope, you will want to purchase a set of guide telescope rings to fit your guide telescope. Guide telescope rings allow you to mount the guide telescope to your mount but still allows you to adjust the orientation of the guide telescope to match up to your imaging scope and to be able to adjust where your guide telescope is pointing when searching for a guide star. When you decide to employ guiding in your setup, you will require the use of a computer to control the software and communication to your mount.

A great starter kit is the [refractor package deal](#) from Orion which includes the guide telescope, guide telescope rings and Orion Starshoot Autoguider camera on the right. This package **saves you about \$300!**



Imaging Camera

Now that you have selected a steady mount and telescope with which to take your images, you now have to decide what camera to purchase.

The first decision you have to make regarding this process is what type of astrophotography are you planning on doing, will it be video astrophotography, DSLR astrophotography or CCD astrophotography.

The second decision you need to make is how much money you want to spend on your CCD camera. A very important aspect to bear in mind is that if you decide to do video or CCD astrophotography, you will require a computer of some sort with you while you carry out your imaging. Video astrophotography is by far the cheapest form of astrophotography but mostly limits you to imaging the moon and bright planets.

CCD cameras vary greatly in price depending on the type of CCD camera you want and the class (grade) of CCD chip it contains. You will also need to decide between getting a monochrome CCD camera or a colour CCD camera. Remember as mentioned in the beginning of this article that although the monochrome CCD chip is more sensitive than the colour CCD chip, you will need to spend additional money on [colour filters](#) in order to produce colour images with your monochrome CCD camera. Prices for CCD cameras range anything from \$500 to well over \$10,000.

DSLR cameras are great for astrophotography because they are cheapest type of camera in terms of dollar per pixel value. As discussed previously, the disadvantage of a DSLR is that it is not sensitive to wavelengths of light in the red band. This however can be corrected by purchasing a replacement filter. Many other modifications are also available for DSLR owners. DSLR prices range from \$600 to \$3000 for some really top class cameras.

When choosing your camera, remember to check the image scale you will obtain with the selected camera and imaging telescope. The most practical and useful image scale value range is between 1.5 and 3 arcseconds per pixel.

Below are some of the cameras we recommend to someone wanting to start astrophotography.



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[Orion StarShoot Solar System Color Imager IV](#)



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[Orion StarShoot Pro V2.0 Deep Space Color CCD](#)



[Orion Parsec 8300C Astronomical Imaging Camera](#)



[Canon EOS t2i DSLR](#)





Guide Camera

In the previous section we discussed the options of doing guided or unguided astrophotography. If you plan on taking exposures longer than a minute or two, this is something you will have to consider.

There are 2 main forms of guiding, the one form involves the use of an additional telescope and camera which monitors the star movements and send corrections via your computer to the other telescope doing the imaging. The other form of guiding is when your CCD camera contains two CCD chips, one for imaging and one for guiding. This type of guiding does not require additional telescopes as the guiding and imaging is all done from the same machine. SBIG, QSI and other CCD camera manufacturers can provide you with this type of CCD camera but beware, they are expensive.

In the event of you using the traditional method of another telescope and camera, you will require a guide camera. This type of camera doesn't have to be as specialised or as expensive as your main imaging camera, you could in fact use a standard computer webcam as a guide camera. This has been done by many astrophotographers. The alternative is to purchase a camera specifically designed for autoguiding your mount from Manufacturers like Orion and SBIG. The price of guide cameras range from about \$250 to \$1500. An entry level guide camera is the [Orion Starshoot Planetary Imager and Autoguider](#).

Below is an example of a great imaging setup for beginners that will cost you just under \$3800.

 <p>FREE SHIPPING!</p>	 <p>FREE SHIPPING!</p>	 <p>FREE SHIPPING!</p>	 <p>FREE SHIPPING!</p>
<p>Orion SkyView Pro Equatorial GoTo Telescope Mount</p>	<p>Orion ED80T CF Apochromatic Refractor Telescope</p>	<p>Autoguider Refractor Package</p>	<p>Orion StarShoot Pro V2.0 Deep Space Color CCD</p>

TIME TO DO SOME ASTROPHOTOGRAPHY

Setting Up For a Nights Imaging

Great, now that you've got yourself some really cool equipment, what now? How do you set it up and how do you take some images? Remember in the beginning of this article we discussed the three P's of astrophotography; Preparation, Patience and Perseverance? This is where they come into play. In this section we will talk about setting up your equipment and how to get yourself ready for a great nights imaging and not a night where you want to throw your equipment in the nearest dumpster. Due to the fact that so many types of equipment are available on the market today and there is no way to write an article for everything, we will provide you with a general guideline on what to do that will apply to most astrophotography setups. We assume that you at least have some form of equatorial mount, be it a German Equatorial mount or a fork mount with an equatorial wedge. We will also be assuming that you have a main imaging telescope and that you have a separate guide telescope and guide camera. Due to the nature of self-guiding CCD camera's and the various forms of software that comes with them, we will not be making reference on the basic use of self-guiding CCD cameras.

Below is a general guideline and steps you can take to ensure that everything is setup correctly for your nights imaging. Remember, take your time when performing these steps and make sure they are done as accurately as you can as this will make everything you have to do the rest of the evening a lot simpler.

Setting Up Your Equipment:

1. The first thing you need to do when you start to set up your equipment is to place your tripod on the ground with the leading leg pointing in the direction of true north if you're in the northern hemisphere and true south if you live in the southern hemisphere.

If you are using a compass to determine the direction of true north or south, remember to factor in the specific magnetic declination for your location. The magnetic declination for your location can be found on the following website: <http://www.magnetic-declination.com/>

Once you have your tripod pointing in the general direction of true north or south, make sure you level your tripod by using a spirit level or something similar. Why do we level the tripod with a spirit level when my mount has a built in bubble level? The reason is because the bubble levels found on many mounts have proven to be inaccurate, so we prefer to level the tripod with a spirit level before placing the mount on the tripod.

2. Place the mount on top of the tripod with the right ascension access pointing in the direction of true north or south. Secure all the bolts that you need to fix the mount to the tripod with.
3. Adjust the latitude setting on your mount to the approximate latitude of where you live.
4. Placing your imaging telescope and your guiding telescope on your mount can be done in two ways, namely a side by side configuration like the image below on the left or you can piggyback your guide scope on top of your imaging telescope as indicated by the image below on the right. Mounting your telescopes side by side will require an [Orion Wide Side-by-Side Plate](#). Special plates and adaptors can also be purchased if you wish to mount your guide scope on top of your imaging scope. Which way is the best way? Honestly this is one thing people will probably always argue about! There is much debate on the astronomy forums on the internet with regard to which is better, my advice to you is to go read through the forums and decide which method will be best for your equipment and setup.

Side By Side Mounting



Piggyback Mounting



5. Now that you have your mount set up and your telescopes firmly in place on your mount, you have to balance the mount and your telescopes. Performing this step correctly is extremely important and it's even more important that you try and get your telescope as balanced as possible. Take your time when performing this step as it will prolong the life of your motors and worm gears and will make your guiding far more accurate. Remember that you will need

to balance your telescope with all your telescope diagonals, finder scopes and cameras in place. As they would be when you are imaging.

Here is a general guideline on how to balance your telescopes and mount, there is however more detailed explanations on the internet:

- There are also screws to hold the two major axis' tight. Make sure the screw that holds the axis with the weight is tight, and then loosen the screw that will allow the scope to turn. Next, move the scope back and forth in its mounting rings until you can move it to any position, and it stays where you leave it. You have now balanced the Declination Axis.
 - Next, we want to tighten the Declination Axis screw, and loosen the other one, for balancing the Right Ascension Axis. The Right Ascension is the one that your weight is screwed into or attached to. Once we have loosened the screw holding this axis, we want to get the weight adjusted so that the scope can swing from side to side, again, staying in place wherever you place it.
6. Once you have completed the balancing process, you now have to try and polar align your telescope as accurately as you can. Here is a brief explanation on how to do this. Due to the fact that all scopes' latitude adjustment scales are not accurate, with the weight pointing straight down, both axis' locked at this point, simply move the Latitude adjustment until the Polaris is centred in the scope. You may have to move the base of the mount, or the whole tripod to one side or the other now to centre the Polaris. The closer you can get Polaris to the centre of the eyepiece, the better the mount will track. Once you have set the Latitude, it's a good idea to set this stop screw so that the scope doesn't "creep down" during your observing session.
 7. Now that the telescopes and the mount are balanced and roughly polar aligned, set your right ascension and declination axis' back into their starting/default positions. Power up your telescope and enter all the initial information such as the date and time and your location. Depending on your make of mount, you must perform a two star alignment in order to get your mount calibrated to the date, time and location you have entered. Once you have successfully completed the initial alignment process, it's always a good idea to add a view calibration stars to your alignment stars to improve the tracking, however first check the mounts manual to see if this is a feature offered by your mount. After completing this step, it is highly recommended that you perform a drift alignment on your mount to improve the accuracy of your polar alignment. I'm not going to explain the process here but there are many websites that give detailed information on how to perform a drift alignment on your telescope.

8. Now that your mount is aligned and tracking correctly, attach your imaging camera and guide camera's to your telescopes and turn on your computer and start the software supplied with your guide camera and imaging camera. DSLR users will not have to start software for their DSLR unless you have specific software you want to use with your DSLR. Point your imaging telescope to a fairly bright star. Centre the star in your finder scope and then take some short exposures with your CCD camera or DSLR to make sure that the selected star is in the centre of the field of view of the camera. Once you have completed this, adjust your guide telescope until the same star is in the centre of your guide camera's field of view.

Once you have completed the above steps, then we need to move onto the next section which is the most important section in this article, focusing your cameras.

Focus, Focus and Focus

Out of all the information provided in this article, if you choose to only remember one thing about it, this section would be the one to remember. There is almost nothing else as important in astrophotography than correctly focusing your cameras and there is no worse feeling in the world than spending an entire evening imaging your favourite object only to find when you start to process your images that the focus wasn't 100% accurate. An entire evening of clear skies wasted.

There is no full proof method of making sure you get your images 100% right, it's always a matter of trial and error. Start of your focusing routine by pointing the telescope to a fairly bright star, but not too bright that it will make it difficult to judge an in focus image from an out of focus image. Once you have the star in the centre of the field of view start by taking a short exposure of about 10 seconds (This step applies to both DSLR and CCD cameras). Examine the image carefully and then adjust the focus slightly in either direction. Take another 10 second image and compare the new image from the previous image, if the image is worse, then adjust the focus in the opposite direction, if it's better then continue to adjust the focus in the same direction, taking another 10 second image for comparison after every adjustment. Continue this process of going back and forth with the focus until you are convinced that you have reached optimal focus.

A good way of ensuring that you have reached optimal focus is to zoom in on the image and check the sharpness of the star. Most DSLR's have a nice feature of being able to zoom in on an image while it is in preview mode and some DSLR camera's today even come with a "Live View" mode which enables you to carefully focus the image while the camera displays a streaming video of the target. Some CCD camera software has a focus mode which instructs the camera to take an exposure of the target every couple seconds automatically which means you can stand at your telescope and see the changes in the images as you adjust the focus. Once you have achieved optimal focus and you own a refractor or reflector telescope with a Crayford focuser, make a small mark on the draw tube of the focuser as this will serve as an excellent place to start your focusing routine the next time you setup. This will also save you a lot of time and energy rather than starting the process from scratch every time. Please note that if you are using a monochrome CCD camera with various filters, you will need to refocus your camera every time you change the filters.

As stated above, there is no simple recipe for making sure you get the best focus every time, you have to be patient and get make sure you get it right by following silly routines as described above. There is however other tools that you can use to help you achieve optimal focus faster.

One of these tools is the Bahtinov Mask. The Bahtinov Mask consists of a disk made of opaque material fitted over the telescope objective with slots cut out in a specific pattern devised by amateur astrophotographer Pavel Bahtinov. What this mask does is create diffraction lines when the target or star being imaged is out of focus. So, when you don't see the diffraction lines anymore, it means that your image is in good focus and all you need to do is make the finer adjustments to bring the image into perfect focus.

Other great tools to use in helping you to achieve optimal focus come in the form of software tools you can load onto your computer. Software packages like ImagePlus (<http://www.mlunsold.com/>) have great focusing routines for DSLR and CCD cameras and if you have a motorised focuser, software like this can almost automate the entire focusing procedure for you ensuring you get perfect focus every time.

Calibration Frames

It was mentioned in previous sections of this article that the main purpose of imaging is to obtain the highest signal to noise ratio in our images. we explained that the sources of noise could come from the camera itself amongst other things. The purpose of calibration frames is to remove as much noise and imperfections from the image as possible which have been caused by the camera itself and the imperfections in the camera and telescope optical train.

There are three main types of calibration frames:

- Dark Frames
- Bias Frames
- Flat Frames

1. Dark Frames

Dark Frames are images taken with no light falling on the CCD, so that the only values present in the pixels are due to Bias and Dark Current. Typically, Dark Frames are acquired by placing a light-proof dust cap over the telescope objective and making a series of exposures with the same settings (**exposure and temperature**) as for the Light Frames to be calibrated. You must take at least as many dark frames as you have taken light frames. We will later combine these images to produce a master dark frame.

2. Bias Frames

The bias frame is a representation of the noise that occurs during the download process, making the zero level of each pixel fluctuate slightly. It can be a small source of noise in the image but adds noise none the less. To create a bias frame you need to take an exposure using your camera with an exposure length of zero seconds, or as close to zero seconds as

the camera will allow. It is a good idea to take at least twenty of these. We will then combine them later to produce a master bias frame.

3. Flat Frames

The flat frame is a representation of the imperfections found in your optical train. These imperfections can come in the form of dust on the telescope lens or dust on the CCD chip. Imperfections are also caused by the light coming from the telescope not completely covering the CCD chip, hence causing vignetting. To take a really good flat frame is very difficult and requires some patience. Many explanations can be found on the internet explaining how to take a good flat frame, here is just one method. To get a proper flat frame you must take a short exposure of an evenly illuminated object. Some suggest using the evening sky; others prefer to use their laptop screen. Start by setting up your laptop computer with the screen brightness set to its minimum. Then open an application such as notepad and maximize it on the screen, and be careful that nothing casts a shadow onto the screen. Next point your telescope at the laptop screen and wrap a plain white t-shirt over the objective lens of the telescope to diffuse the light coming from the laptop's LCD screen. For some cameras if you're in full resolution mode, take a 6 to 8 second exposure with an automatic dark subtraction (don't forget to dark subtract these - that's a big source of noise). Always try to take at least twenty of these flat frames which you'll later combine to produce a master flat frame.

Regardless of whether you are using a DSLR or a CCD camera to acquire your images, you will need to take calibration frames if you want to produce really great images. Also, once you have taken your bias and flat frames, you won't need to take them again unless something in your optical train changes. Dark frames unfortunately have to be taken every time you acquire your images as your dark frame has to be at the same exposure and temperature as your light frames in order for them to work. As stated, there are many ways to take these images and it is extremely important that you take really good calibration frames, for more information on this, run search on the internet as there is a wealth of information on this topic.

Exposure Time And Number Of Exposures

In-order for us to capture the most details of our target and to reduce the noise in the image, we need to take exposures as long as we possibly can. As discussed previously, the length of exposures you will be able to take will be dependent on the amount of light pollution at your imaging site as well as the tracking ability of your mount if you're not using guiding to correct for errors in your mount.

To determine the maximum length of the exposures you can take is going to take some experimentation. DSLR users must remember that the length of your exposures will also be determined by the ISO setting you plan to use on the camera. Also bear in mind that the higher the ISO setting, the more noise will be evident in your images. I've found that with most DSLR camera's that the best ISO setting to use is ISO800. Start your experimentation off by taking a single five minute exposure of your target. If the image is completely washed out by a red and orange haze then unfortunately the light pollution in your area is too high for five minute exposures. Try decreasing your exposure time to four minutes and re-evaluate your results. Also, you need to check your images for star trails, if after a five minute exposure your image starts to show star trails then your mount is not able to track accurately enough for the set exposure time. Again, try decreasing your exposure time to four minutes and then re-evaluate your results.

Continue to do this until you have an image which isn't washed out by the light pollution and where you have perfectly round stars not showing any signs of star trails. This is the optimal exposure time for your specific camera settings and location.

As for the number of exposures you should take, in this case more is always better and more than that is best. Always try and take as many exposures as you possibly can because not only does taking multiple images and combining them reduce the noise in your image, but stacking these images which will bring out even more details in your image. The more images we can stack the better the details in the image will look.

BASIC IMAGE PROCESSING

Software Requirements

Since camera and astronomy equipment has become more affordable and with that amateur astrophotography becoming more and more possible for ordinary people to do, there has been an explosion in terms of the types and numbers of software packages that can be obtained to not only process your images but capture them as well.

A lot of amateur astronomers prefer to have two separate applications for capturing their images and processing their images. Others again prefer to have one package that does everything. The choice is yours at the end of the day and it all depends on which software packages you are more comfortable to work with as some of the image processing applications can be very difficult to understand and use.

Below are a list of readily used astrophotography software applications and some image processing applications used by amateur astrophotographers:

- | | | |
|--------------------|--------------------------------|-------------------------------------------------------------------------------|
| 1. Image Plus | (Image Capture and Processing) | (http://www.mlunsold.com) |
| 2. Deepsky Stacker | (Image Processing) | (http://deepskystacker.free.fr) |
| 3. CCDStack V2 | (Image Processing) | (http://www.ccdware.com) |
| 4. CCDSoft | (Image Capture and Processing) | (http://www.bisque.com) |
| 5. MaximDL | (Image Capture and Processing) | (http://www.cyanogen.com) |
| 6. Adobe Photoshop | (Image Processing) | (http://www.adobe.com) |

If you did not receive any software with your camera that can be used for the image capture and processing, any one of the above mentioned applications are exceptionally good and there are demo versions available for many of them. You need to decide which application you are more comfortable working with and which application makes the most sense to you.

Calibrating Your Images

We have finally come to the point where we can start processing our images and seeing the fruits from the previous night's hard work.

The first step in processing your images is to go through your images from the previous night (these are referred to as your light frames) one by one and check each image for any defects. The defects can be any abnormalities in the image such as a streak from a passing aeroplane or meteor, or perhaps there is one image that is blurred because you bumped the camera or mount by mistake. If you identify any of the images as having abnormalities, either delete these images or rename them so that you don't include them in your main processing.

The second step of processing your images is to calibrate the light frames with the calibration frames you also acquired the previous night or that you have acquired on a previous occasion. Many of the astrophotography software applications listed above automates the entire process of creating your master calibration frames and then calibrates your light frames using the master calibration frames all in one step.

Due to the fact that each software package works differently, we will give you an explanation below of what your software package is doing when it calibrates your light frames using your calibration frames:

1. Create master dark frames,
 - For master dark frames of the same exposure time as the light frames, the software makes a median combined master dark frame.
 - If the exposure time for the dark frame was different to the light frame, this is referred to as using or creating scalable darks,
 - First create a master bias frame using the median combined method,
 - Subtract the master bias from each dark frame,
 - Median combine all dark frames to create a scalable master dark frame.
2. Create master flat field frames using the median combined method.
3. Apply master bias frames to light frames if using scalable master dark frames.
4. Apply master dark frames to matching light frames.
5. Apply master flat field frames to matching light frames.

At the end of the above process, you will have a complete set of calibrated light frames. The below images show what a difference calibrating your light images make to your images:

Uncalibrated



Calibrated



Stacking Your Images

Aligning Your Images

Now that we calibrated our images, we can now move onto the process of aligning and stacking our images before we start with final processing.

Aligning our images is the process where the software package evaluates each image against your initial reference image and then determines what adjustments need to be made to the other images in order to align all the stars with the initial reference image.

Typically how the software works is that you need to select a reference image. Once you have selected a reference image the software will generally require you to select a number of stars on the reference image to use as reference stars on the other images. Once you have selected your reference stars and tell the computer to align the images, it will align all the other images with your reference image using the reference stars you selected.

Below is an example of what a stacked image will look like if the images haven't been aligned with one another:



Stacking Your Images

Image stacking is the process of combining two or more images so that the overall detail is more intense. This makes the final image a lot more eye-popping. Stacking makes it possible for astrophotographers to produce a similar quality image from ten one minute exposures as compared to one ten minute exposure image. Stacking has really helped astronomers who live in really light polluted areas and astronomers who do not own \$10 000 mounts that track perfectly for hours.

There are several methods that can be used to stack your images; here are just some of those methods:

1. Sum Stacking

A new image is created from the weighted sum of the pixel values of all the images

2. Mean Stacking

A new image is created from the weighted mean of the pixel values of all the images

3. Median

A new image is created from the weighted median of the pixel values of all the images

4. Minimum

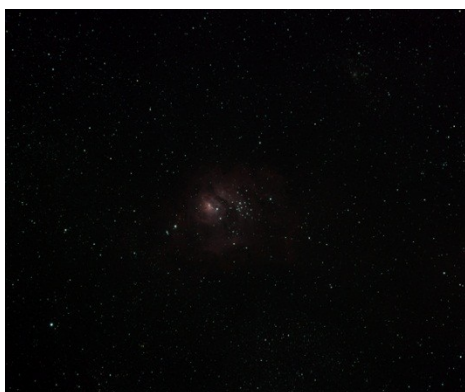
A new image is created from the minimum pixel values of all the images

5. Maximum

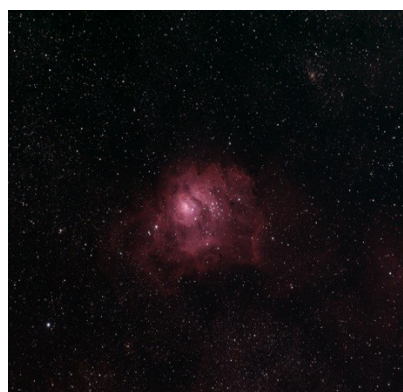
A new image is created from the maximum pixel values of all the images

Below on the left is an example of a single light frame of the Orion Nebula compared to stacked image of 10 light frames (Images were stacked using the Sum method):

Single Light Frame



Stacked Image (10 Light Frames)



Unfortunately due to the fact that all the software packages have their own methods and procedures for stacking, you will have to consult the manual that accompanied your software for instructions on how to stack your calibrated images.

Processing Your Images

This is the most exciting part of the entire astrophotography process. This is where you see whether your hard work in terms of setting up your equipment correctly, making sure that your camera is focused as accurately as you can get it and getting as many good exposures as you can has paid off.

After stacking your individual images as explained in the previous section, you already get to see some of the fruits of your labour, but you might be thinking that you haven't managed to get as much detail in your images as you expected you would get. Don't worry, because we are not done yet. This part of the image processing is where you will extract even more data from your image by applying various functions to it.

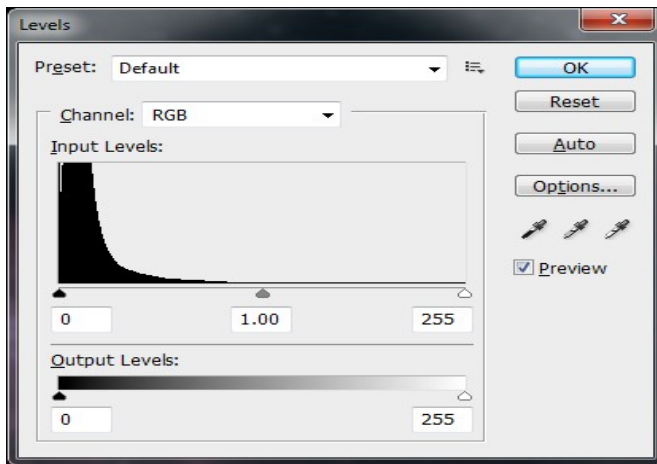
Some of the standard functions that astronomers apply are functions like Levels, Curves and Colour Correction. Besides the mentioned functions, there are many other techniques to get the most out of your image but you will have to consult the user manual of the software you are using to discover what other functions your software might contain for getting the most out of your images. The internet is also a great resource for discovering what tools other astrophotographers are using to process their images.

Due to the fact that the functions mentioned above are pretty standard across all image processing software, I'll be demonstrating the effect of each of these functions through the use of Adobe Photoshop.

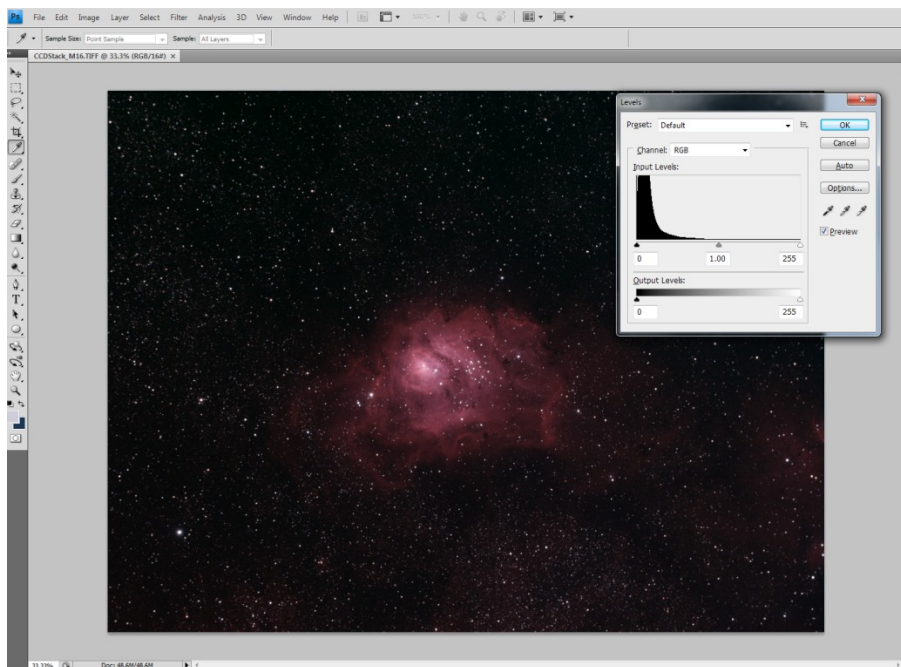
1. Levels

The first step we take when we start processing our images is to adjust the levels of the image. Levels is a tool in Photoshop and other image editing programs which can move and stretch the brightness levels of an image histogram. It has the power to adjust brightness, contrast, and tonal range by specifying the location of complete black, complete white, and midtones in a histogram. Since every image's histogram is unique, there is no single way to adjust the levels for all your images.

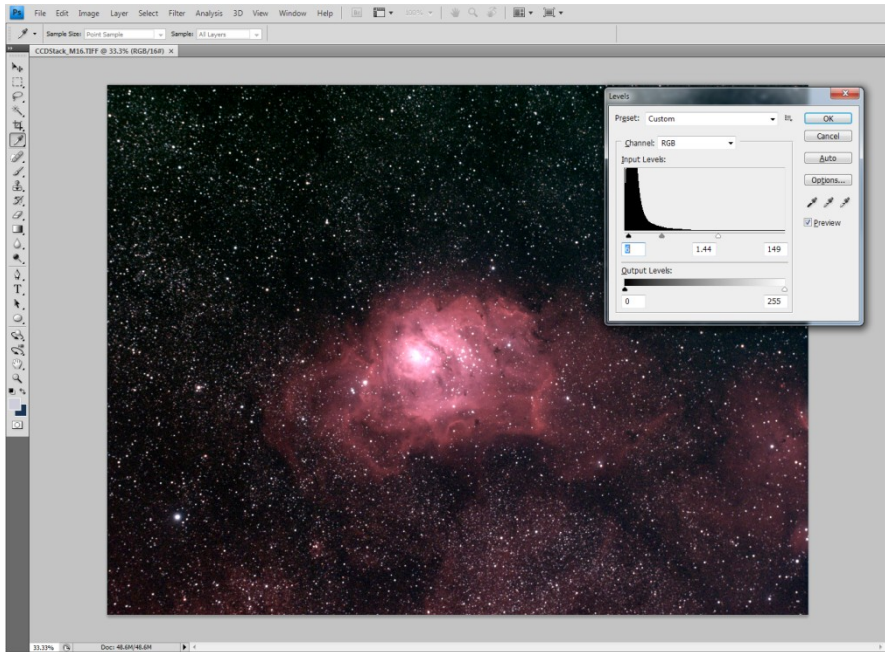
Below is an image of what the Levels tool looks like in Adobe Photoshop. We adjust our image by moving the black and white sliders of the input range to either brighten or darken details in the image. The grey point in the middle is used to adjust the midtones in the image.



Below is an image before we adjusted the white point on the Levels tool.



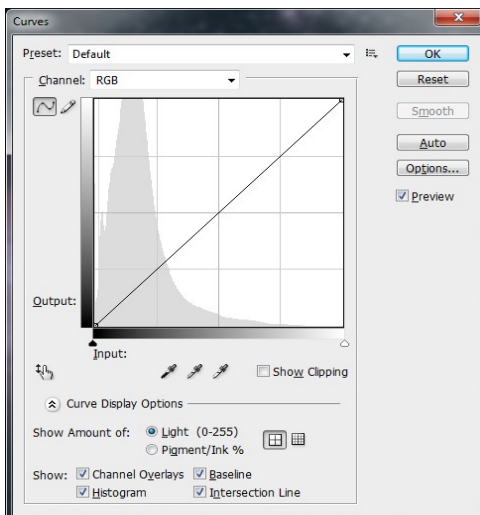
Here is an image after we adjusted the white point on the Levels tool. Notice how much brighter the image appears and how subtle details start to come through.



You don't have to make all your Levels adjustments in one iteration. You can make several iterations of Levels adjustments in order for you to incrementally improve your image, that way, if you take it a step too far you don't have to start all over again, you only have to undo the last iteration.

2. Curves

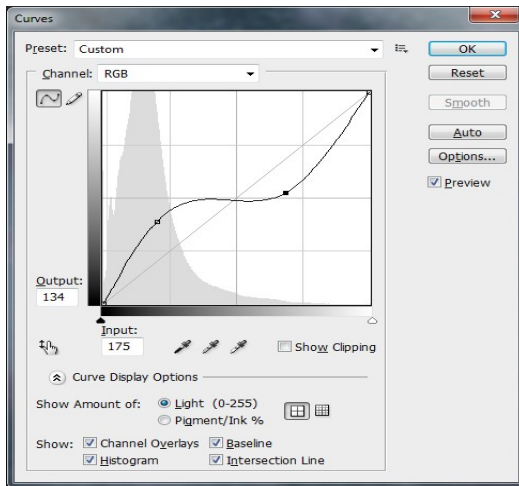
The idea behind Curves is all about re-mapping values. A pixel starts out at a certain brightness, and you change it to be brighter or darker.



The curves box opens as a straight line because you haven't made any changes yet. That means that the brightness values before and after are the same. You will effect a change by changing the shape of the curve.

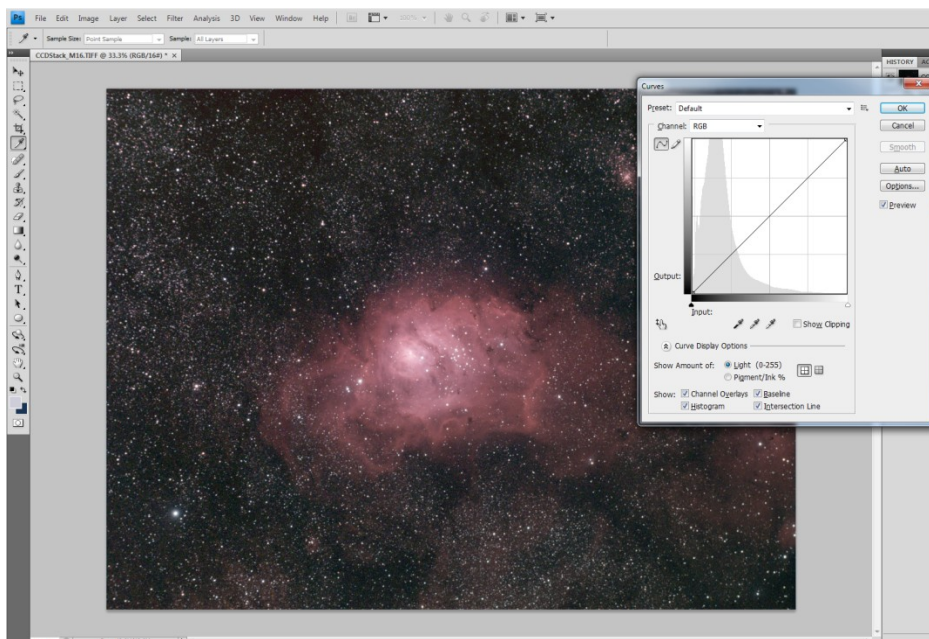
You begin altering the brightness values by clicking once somewhere on the line. This will establish a “point”; this point can now be dragged to a different place within the grid, which causes that tonal value to change, either lighter or darker depending on whether you drag it up or down. The reason it’s a curve is so that the change blends smoothly throughout the image. It’s important to note, however, that you can’t increase contrast in one region without decreasing it in another. The curves tool redistributes contrast.

Below is an example of an adjusted Curve line.

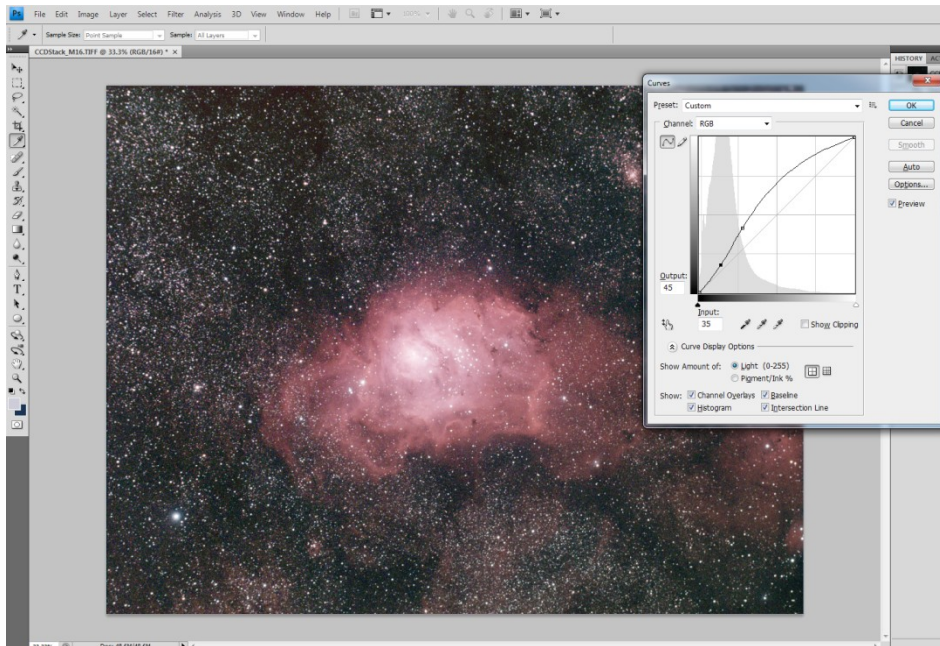


Just like with the Levels tool, you can perform many iterations of the Curve adjustment hence allowing you to make small adjustments at a time until you get the image looking exactly the way you want it.

Below is an example of our image before making any Curves adjustments:



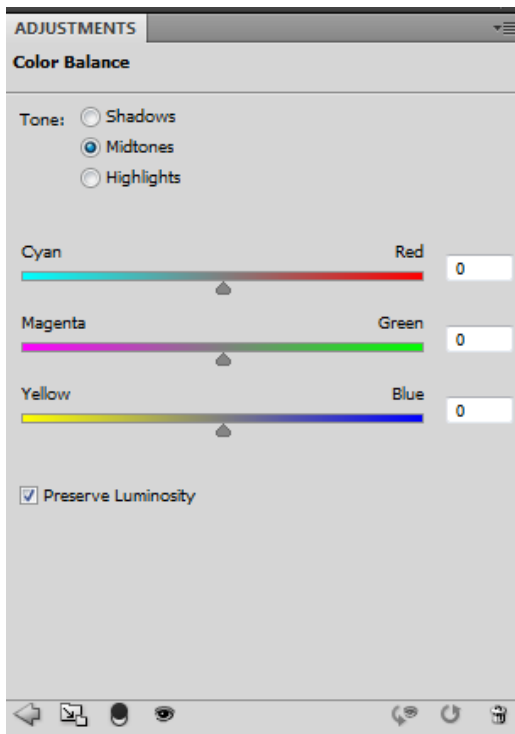
Here is an image after we have adjusted the Curves:



3. Colour Correction

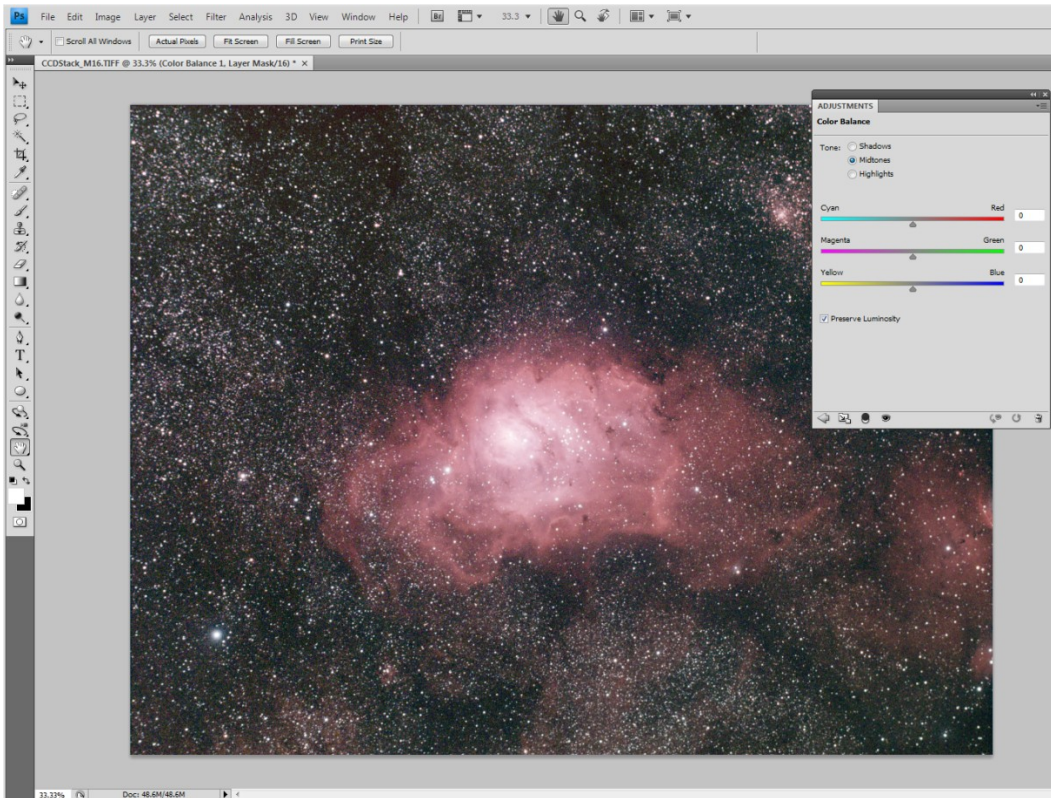
It sometimes happens that when we adjust our image with tools like the Levels and Curves adjustment demonstrating above, the colour turns out to not quite be the way we want it.

To correct this we can perform some colour adjustment to our image using the Colour Balance tool shown below:

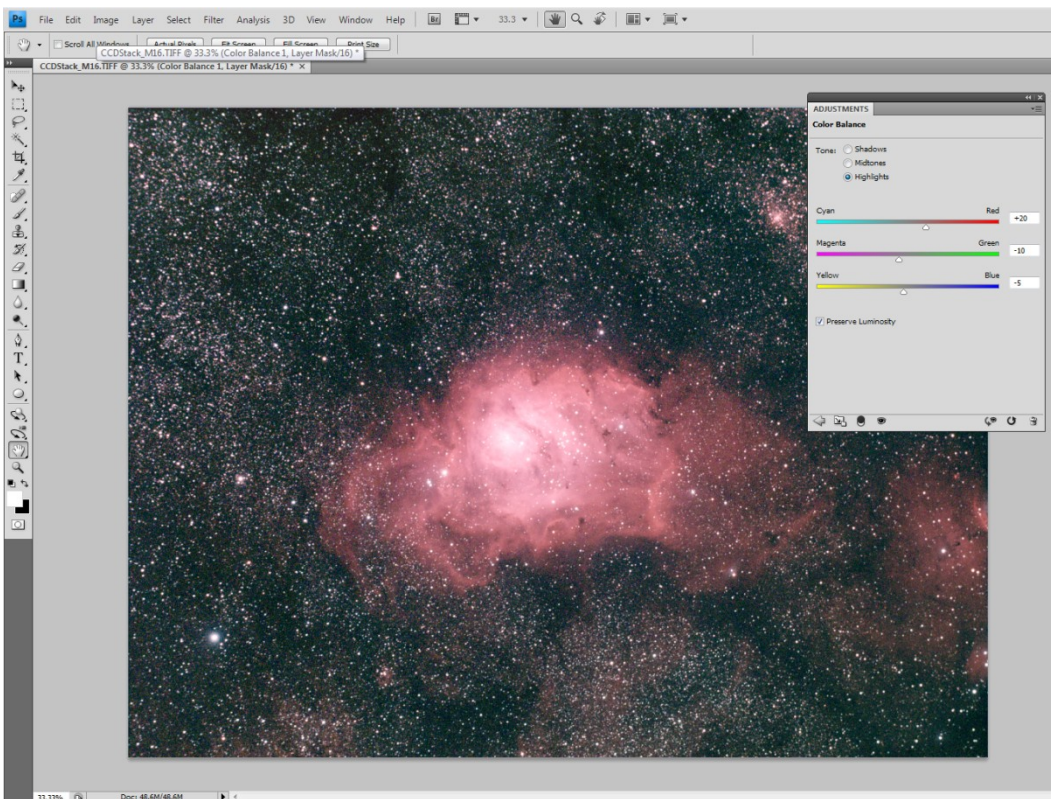


Adobe Photoshop allows you to adjust the colour balance of our image on all three individual tones, namely Shadows, Midtones and Highlights. On each of these tones you can adjust the colour on three levels, namely your red, green and blue channels. Adjusting the colour balance on your images makes very subtle changes, be sure to look at your entire image to see the whole effect of the colour change; you don't want an image with a beautiful red nebula but a green starry background. Adjusting the colour balance on each image will be different, it all depends on what you've imaged and what you think the correct colour for the image should be.

Below is an image before any colour balance adjustments:



Here is an image after colour balance adjustments:



EASY ASTROPHOTOGRAPHY TARGETS TO GET STARTED WITH

As with anything in life, we first need to learn to crawl before we can learn to walk. So with that, here are some beautiful and bright objects in the night sky which we recommend you start your astrophotography endeavours with. Due to the fact that they are bright objects, they will be easier to photograph than items that are very dim and it will provide you with a great starting point to learn how to process your images using the software you have.

Object Name / Catalogue Number	Constellation	Best Time Of Year To Image Northern Hemisphere / Southern Hemisphere
Orion Nebula (M42)	Orion	Winter / Summer
Pleiades Cluster (M45)	Taurus	Winter / Summer
Andromeda Galaxy (M31)	Andromeda	Winter / Summer
Great Globular Cluster in Hercules (M13)	Hercules	Spring / Autumn
Lagoon Nebula (M8)	Sagittarius	Summer / Winter
Trifid Nebula (M20)	Sagittarius	Summer / Winter
Swan Nebula (M17)	Sagittarius	Summer / Winter
Beehive Cluster (M44)	Cancer	Winter / Summer
Butterfly Cluster (M6)	Scorpius	Summer / Winter
Triangulum Galaxy (M33)	Triangulum	Autumn / Spring

SUGGESTED BOOKS AND WEBSITES

Books and DVD's

Title	Author	ISBN Number / Web Site
Digital SLR Astrophotography	Michael A. Covington	0521700817
Video Astronomy	Eric J. Douglass	1931559090
The New CCD Astronomy	Ron Wodaski	0971123705
Zone System for Astro Imaging	Ron Wodaski	0971123756
The 100 Best Astrophotography Targets	Ruben Kier	1441906029

Astrophotography For The Amateur	Michael A. Covington	0521627400
A Guide To Astrophotography with Digital SLR Cameras	Jerry Lodrigus	0972973753
Making Every Pixel Count- Powerful Processing in Photoshop (DVD)	Adam Block	http://www.astrophotography-tonight.com/photoshop-astrophotography-dvd/
Making Beautiful Deep-Sky Images: Astrophotography with Affordable Equipment and Software	Greg Parker	B000SIQQA2

Web Sites

Web Site	Web Site URL
TelescopeKing.com	http://www.telescopeking.com
Astronomy Forum	http://www.astronomyforum.net
Astrophotography Tonight	http://www.astrophotography-tonight.com
Andy's Shot Glass	http://www.andysshotglass.com
Russel Croman Astrophotography	http://www.rc-astro.com
Astronomy For Beginners	http://www.astronomyforbeginners.com/astrophotography/
Noel Carboni Photoshop Tools	http://www.prodigitalsoftware.com/
Astrophotography Tools	http://www.ideiki.com/astro/

Final Words

As you probably noticed, astrophotography is not exactly super easy. But guess what, it's not super hard either. Thanks to the availability of affordable quality equipment, astrophotography is accessible to everyone. If you're considering astrophotography as a hobby, then this guide was written specifically for you! We want to get started on the right track and we hope we've made it easier for you.

We would also like to give a special thanks to Brandon Webb who has supplied us with some of his images used in this ebook, including the image used on the cover.

If you would like to leave feedback about this guide, please visit our [Facebook page](#) and write a little message on our wall. If you think others might benefit from this guide, we'd love it if told them about it. Our web address is <http://www.telescopeking.com>. Thank you for taking the time to download and read this guide. Please visit our site for all your telescope equipment need.

The TelescopeKing.com team.