Astrophotography Basics

Cameras, Acquisition, and Processing

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April, 2018

Art, Science, Hobby

Astrophotography ingredients.

The focus of astrophotography can be as an art form, or it can be for a science project, or it can just be a hobby - something to spend your money on. I've been pretty successful with astrophotography as a hobby. It is keeping me broke, but well entertained.

In this presentation I'm going to focus the information for beginners. For those of you who are already past that stage, your comments as we go through this are welcome. For those of you who are considering astrophotography, please interrupt with your questions as we go through this presentation.

Getting Started

Telescope

Mount

Camera

Pointing Software

Guiding Software

Image Capture Software

Image Processing Software

This list shows the basics of what is needed. I'll go through each item in turn and explain what I think are essential factors for each item.

Your Telescope

- Reflectors
  - Celestron
  - Meade
  - Orion
- Refractors
  - Televue
  - Stellarvue

Astrophotography needs a good telescope. Shown here are many models to choose from. A reflector will give you a bigger aperture at a lower price than a refractor, but bigger isn't always better. Refractors provide sharp and bright images, and to get the equivalent in a reflector means getting a really big one with special lenses.

The main factor for astrophotography is not especially size, but in how well the red, green, and blue wavelengths are focused into the camera. Refractors with three aperture lenses, called a triplet, is the best in that class. Reflectors with specially designed aperture lenses, called an SCT (Schmidt-Cassegrain), is the best in that class.

The focal length of the telescope determines the size of the object that you want to image. For very small objects, like a planet, you need a long focal length - greater than 8. For very large objects, like the Andromeda Galaxy, you need a short focal length - less than 4. There are adapters for one focal length to take you to the other, such as a doubler for increasing the focal length and a reducer for decreasing the focal length, but the price you pay is loss of light because of the extra glass that is introduced.

A focal length of around 5 to 7 will accept focal reducers and doublers to get to the other focal lengths with ease.

Your Mount

- Alt-Az (Altitude-Azimuth)

- GEM (German Equatorial Mount)

Each type of mount has its advantages and disadvantages.

The Alt-Az mount is commonly found in universities. A disadvantage of this mount is that it has to be driven in both axes simultaneously in order to track an object. Another disadvantage is that the camera has to be rotated as the mount is driven in Right Ascension to avoid elongation of stars for long expusres. Another disadvantage - specifically for fork type mounts - is that it if the camera is mounted in the rear of the OTA, then it is possible to run the camera into the mount as the mount approaches the Zenith. An advantage of this mount is that there is no need to perform a pier flip at the Meridian.

An advantage of the GEM is that if it is properly aligned and configured, then it only needs to be driven in the Right Ascension. Another advantage is that the camera doesn't have to be rotated while tracking - except when doing a pier flip. A disadvantage is that when the mount tracks past the Meridian, it is necessary to do a pier flip and a 180º rotation of the camera. Another disadvantage is that it is possible to run the OTA into the pier.

You can convert an Alt-Az mount to an Equatorial Mount with a wedge. This removes the need to rotate the camera and also only needs to be driven in Right Ascension. For fork mounts, you still have to be aware that a rear-mounted camera doesn't make contact with the mount.

Imaging Cameras

- Web Cam: Philips ToUcam

- Smart phone

- DSLR: Canon, Nikon

- CCD: Meade, Orion, Atik, Mallincam, SBIG

I've seen some really excellent images coming from a simple web cam that was modified to fit a 1.25" eyepiece holder. Thinking about doing that modification is enough to put many people off, but for any tinkerer, it is a breeze. The main appeal of this camera is that it is really, really cheap.

The only thing you need for a smart phone or other handheld camera is a steady hand. You can also purchase adapters that will supposedly hold your device up to the eyepiece. Lots of luck with that.

The next step up is to use a DSLR. There is software for both the Canon and the Nikon that will automate the exposure process for you. A DSLR is cheaper than many CCD cameras having the same size imaging chip, and almost everyone has one, so that's a good way to start. The downside is that it isn't cooled, it's heavy and bulky, and you probably don't want to modify your camera if you also use it for other purposes.

Using a CCD camera is considered the ultimate way to go. Many of them are cooled, and that's just one of the best features to have in an astrophotography camera. There are so many vendors and models to choose from that you really need to be looking around a lot before you jump into any one camera - because each camera type is designed for specific objects and works best with a given OTA. For example, you wouldn't use a full frame CCD on a telescope that doesn't have a 2" or bigger focuser, and using a near real time video camera definitely isn't best for long exposures. The factors for selecting a CCD camera are many, so learn about them before jumping into this arena. Bigger isn't always better.

Planetarium Software

» DSO Browser (dso-browser.com)

» Stellarium

» SkySafari

» Starry Night

To help you plan what you're looking for, a planetarium program is extremely useful.

DSO Browser is a website that contains all that you need to decide what to look for because it gives you a full list of objects in the sky for a given night and lets you set up a plan for what to observe - and it's free. The downside is that you probably don't have an Internet connection where your telescope is - unless you also have a smartphone configured to provide an Internet connection to your laptop using a Personal Hotspot.

Stellarium is an excellent - and free - planetarium software. You can search for almost any object in the night sky and get a small amount of technical information on it, and often also see a reasonable image of the object. Stellarium can also control your telescope - with the appropriate adapter. This app works on Windows, the Mac, tablets, and smartphones.

SkySafari comes in three version from basic to pro. The basic version can't control your telescope from a computer, but the other versions can - with the appropriate adapter. The amount of technical information that it provides goes well beyond what Stellarium provides, with lots of excellent images for many popular objects. You can also find objects in the sky using various search factors and set up an observing list. This app works on Android and iOS and the Mac, but not on Windows.

One step up from SkySafari is Starry Night from the same developer. This is the premier planetarium application at an affordable price with several versions suitable for beginners and professionals.

There are many features of both Stellarium and SkySafari that make either one a winner for the beginner, but SkySafari is definitely for the serious astronomer.

Autoguiding

- There's only one: PHD 2
- Dithering
- Drizzle

PHD 2 (Push Here Dummy) is probably the best app for autoguiding. The sample time for autoguiding is dependent on how well your mount tracks. This can be from fractions of a second to several seconds.

If the seeing is really bad - causing the stars to jump around a lot - a short sample time can actually make things worse because then the mount would not be able to keep up with the dancing stars.

PHD 2 has a dither feature that moves the telescope a few pixels for every snapshot taken. Dithering is important because it aids in removing hot pixels in the pre-processing phase. So even if your mount can track perfectly for up to 20 minutes, dithering is still useful for all images.

Some apps can take advantage of the dithering feature to turn square stars into round stars using a drizzle technique. Drizzling was developed for processing data from the Hubble Telescope. Up to 30 frames are required for drizzle to work properly.

More Serious Stuff

- TheSky X

- MaximDL

- Sequence Generator Pro (SGP)

For more serious astronomy work to automate your image capture task, you need to look into TheSky X, MaximDL, and Sequence Generator Pro. Any of these apps give you advanced features for controlling the mount, the imaging camera, the electronic focuser, and the autoguider. But for beginners, stick with the easy stuff until you get a feel for taking astrophotos that are worth keeping.

My personal favorite is SGP. Many others prefer TheSky X. The people at Starizona will get you started with MaximDL.

Image Capture

- Lights:
  - Exposure Duration
  - Gain/ISO
- Flats
  - To remove lens and sensor artifacts
- Darks
  - To remove hot pixels
- Bias
  - To remove sensor noise

Although you can get by with a single shot for some bright objects (there's a Facebook site for sharing single shot DSLR Astrophotography), it is best to take at least 10 and up to 50 exposures of the target object. The light accumulates as you stack images, so a dim object will come to life by stacking many frames, and detail in bright objects will pop out.

For best results, you also need from 10 to 20 Darks - and these should be taken with the same ISO/gain, the exposure duration, and the temperature as the Lights.

To remove dust bunnies and vignette from the image, you need from 10 to 20 Flats. These are taken by covering the aperture with a white cloth, pointing the telescope at a clear, bright spot in either the morning or evening twilight hours, and adjusting the exposure to produce an image equivalent to a 50% gray - the histogram will show the data between 25% and 50%. The ISO/gain should be the same as for the Lights, but you might be forced to adjust this to get the right exposure - depending on your camera's feature.

Finally, to get the very best background possible, take up to 100 Bias frames. This is done with the same ISO/gain, but the shortest possible exposure time.

The Darks, Flats, and Bias all have to be retaken periodically as conditions with the camera change. For example, it is next to impossible to prevent dust from getting onto any camera sensor, and hot pixels creep in without warning.

So now notice that all of these images are taken with the same ISO/gain. For some targets, you need to adjust the ISO/gain different than for others. For example, bright objects can use a lower ISO/gain than dim objects. The higher the ISO/gain, the more noise you inject into the image. For some DSLRs, the noise actually increases below and above a sweet spot, usually between 800 and 1200 ISO. The newer DSLRs with really high ISO settings can be pushed up to 3600 ISO or more to achieve a shorter exposure time or to pull out more light from very dim objects. The trade-off here is the sky. The higher the ISO, the more likely it is that you will be capturing sky

Image Processing

- AstroToaster

- RegiStax

- CCDStack/RegiStar

- PixInsight

These applications are listed in order of complexity, with the simplest one first. I actually started with RegiStax. Others may have started with something different. I got reasonably good images with RegiStax. However, AstroToaster made things a little simpler with very little image post-processing needed.

It didn't take long for me to want to do more, and that's when my savings account started depleting rapidly - as if buying new cameras and new telescopes and new mounts and building an observatory and making everything automated from inside my house wasn't enough.

AstroToaster will process all your images on the fly or after the fact. If you like seeing how your images develop as they are being taken, this is a fun way to spend a few hours while watching the equivalent of paint drying. Or you can just come back to it after all the images have been taken to be surprised. It kind of reminds me of the Pepsodent toothpaste commercial: you wonder where the yellow went. But in this case it could be, "So where's the image?" That's when you discover that your telescope was pointing someplace else.

RegiStax is a bit more complicated to use than AstroToaster - it has six steps. The last step takes a bit more ingenuity to figure out what a wavelet is and how to make those adjustments. PixInsight goes into excruciating detail on wavelets, but it also has dozens of tools that I haven't even gotten to yet. The results from RegiStax just might be enough, but further image processing can be done, whereas with PixInsight it does everything.

Between RegiStax and PixInsight there is CCDStack - and that can be just as expensive as PixInsight with the add-ons. A CD tutorial is available for $96.99. CCDStack is primarily for stacking your images and getting them ready for image editing with something like Photoshop. Similar to CCDStack is RegiStar.

I'm not going to go into any detail about how to use these applications because I think the user manual is more than adequate for an IQ greater than 130.

Workflow

- ⇨ Pre-Processing
  - ⇨ Create Master Darks, Master Flats, Master Bias
  - ⇨ Star alignment
  - ⇨ Calibration and Integration
  - ⇨ Crop

- ⇨ Post-Processing (linear)
  - ⇨ Stretching, Background, Deconvolution, Color & Noise

- ⇨ Post-Processing (non-linear)
  - ⇨ Stretching, Noise reduction, HDR, Contrast, Color

In my experience, the minimum number of steps to process astronomy images is around 14, although using AstroToaster does all of those steps in one automated process. Granted, some of these 14 or so steps contain detail that effectively increases the number of steps. Some steps may be repeated several times. The actual tweaking that one does at each step is dependent on the quality of the images, the result you're looking for, and the amount of time one wants to put into post-processing.

Pre-processing is broken up into three phases. In the first phase, the collected images are combined into masters. Then the stars in the Light frames need to be aligned. Calibration is necessary to ensure that all frames are made equal. And then they are all integrated into one Master image. Cropping the final Master is just trimming off the edges where the integrated images overlapped.

There are two major steps in post-processing. This is the image editing phase. In the first step, we do an initial stretch of the image to get a look at what the result might look like. We do our best to create a clean, dark background. The stars might need to be trimmed, called deconvolution. We need to minimize the noise in the image and do an initial color adjustment. In the second step, we finalize the stretching, make an attempt to get as much final contrast and detail as possible, and tune the colors to our liking.
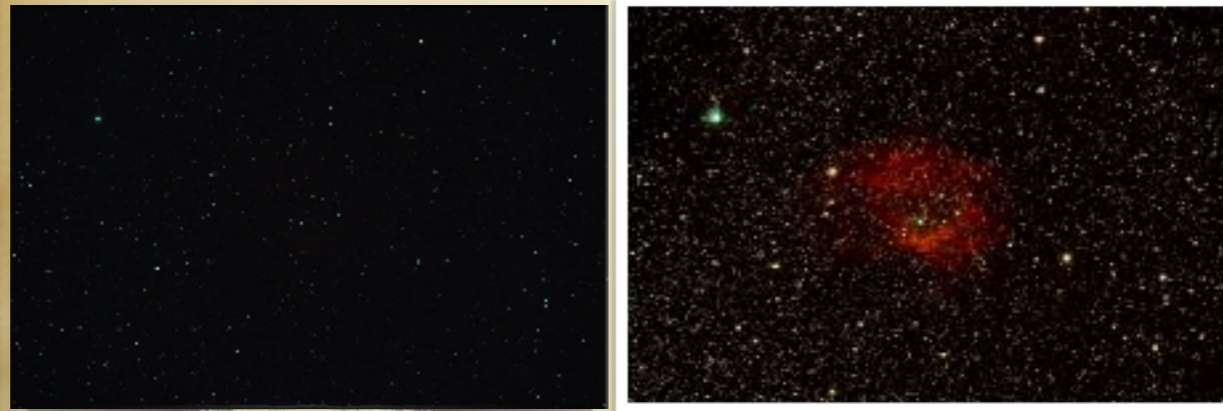
So here's what can be done. The initial, unstretched image of a stacked, calibrated, and integrated set of Light frames doesn't seem to show anything. But after applying the post-processing image editing, we are rewarded with something that hopefully made the lost sleep and thousands of dollars worth taking the dive into astrophotography.

References

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