Astrophotography on the Cheap[1]

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Teaching introductory astronomy means discussing celestial objects that are beyond most students' experience. Simply talking about them is usually not sufficient to convey their size, distance, complexity, and beauty.[2] One way that we introduce our students to celestial objects is through observing sessions,[3,4] but we have also extended these observing sessions to include astrophotography (AP). This approach relies on recent advances in the field of astrophotography. New computerized tracking and autoguiding mounts and digital still and video photography have made it easier[5,6] and cheaper to take high-quality astrophotographs. While it is easy to spend $15,000 or more on a single astrophotography setup or even a single device (telescope, camera, and mount), taking simple, short-exposure photos can cost anywhere from $50 to a few hundred dollars depending on how much equipment you already have.

Perhaps the biggest revolution in AP is the use of digital cameras and video cameras. While most high-end AP applications use dedicated cooled CCD cameras, digital cameras represent a reasonable and inexpensive alternative. One can use point-and-shoot digital cameras (see the "Afocal astrophotography" section below), including cellphone cameras. For those with a digital single lens reflex (DSLR), the options increase (see the "Afocal astrophotography," "Eyepiece projection," "Wide-angle astrophotography," and "Prime focus astrophotography" sections below). Most recent DSLRs can be controlled from a laptop computer via a USB cable.[7] Once connected, they can then acquire images "hands free," which improves image quality since one is not touching the camera to take an exposure. In addition, these cameras also have a large LCD screen to preview images and set the correct focus. Finally, many of these cameras can take movies (some older Canon cameras can be "tricked" into taking movies via software[8]).

For bright objects, such as the Moon and planets, instead of taking single exposures, another option exists. It is actually preferable to use a digital video camera, a webcam, to capture a movie of the object. While there are specialized video cameras for astronomy, a simple modified webcam such as the Phillips ToUcam (<$100) has been used by astrophotographers to acquire lunar and planetary images (the Celestron NexImage is based on the now discontinued Phillips ToUcam). This method requires a connection to a laptop. There are numerous benefits of movies. For example, a video image on a laptop can be shared with more students at once than a telescope eyepiece. From an astrophotography point of view, free software (such as RegiStax[9]) can be used to convert the movie to individual frames, align the frames, pick the best frames, and stack them together into a single final image. This method allows the taking of multiple (hundreds to a thousand) images and then only keeping the best of the bunch when the atmosphere (seeing) behaves.

Fig. 1. The first quarter Moon taken with a Canon S30 through a 26-mm eyepiece on a Meade 10-in LX200 telescope.

Afocal astrophotography

Afocal astrophotography is perhaps the quickest and easiest way to capture an image through a telescope. Once the object of interest is centered and focused in the telescope eyepiece, it is only a matter of pointing a camera (with a lens) into the eyepiece and taking a picture. Changing the eyepiece, therefore, changes the magnification. Although it is possible to get decent pictures of bright objects like the Moon without a camera mount, in most cases one is necessary. The SteadyPix mount by Orion Telescopes clamps to the outside of 1.25-in and 2-in eyepieces, providing a steady platform on which to mount digital or film cameras for afocal astrophotography. Even the deluxe model, which is sturdy and has some useful additional features, is priced less than $50. The image shown in Fig. 1 was taken through the eyepiece of a Meade 10-in LX200 using a deluxe SteadyPix to hold a Canon S30 camera. It is the result of stacking eight images taken in rapid succession using RegiStax software to "beat" the seeing. Wavelet sharpening further enhances the image quality. Recently Orion has introduced an iPhone holder similar to its SteadyPix platform; see this issue's cover photo of the Venus Transit taken with an iPhone using this technique. In addition, several vendors offer low-cost optical zoom lenses for iPhones and iPads that can be purchased for less than $50.

Eyepiece projection

Eyepiece projection is the next easiest method of astrophotography. In this method a camera with a removable lens is used to take a picture of the image in an eyepiece. Again, changing the eyepiece changes the magnification. With this technique an eyepiece projection adapter tube is used to couple a DSLR camera to the eyepiece. The adapter tube has

 DOI: 10.1119/1.4767479

Fig. 2. Eyepiece projection setup. On the left the eyepiece projection adapter and a T-ring are shown. On the right the completed connection is shown (the eyepiece is inside the adapter and cannot be seen).

a 1.25-in nosepiece at one end and T-threads at the other end. The eyepiece is placed in the adapter tube and locked into place with a thumbscrew. The end with the eyepiece and 1.25-in tube nosepiece is connected to the telescope (either directly or via a diagonal), and the other end is connected to the DSLR via a T-ring adapter appropriate for the brand of camera, as seen in Fig. 2.

One of the benefits of this method and the afocal method is that the effective magnification of the telescope-eyepiece-camera system can be changed by changing the eyepiece and the separation between the eyepiece and the camera. In addition, recent DSLRs can take movies, but even older DSLRs such as certain older Canon cameras can be tricked into taking movies with the freeware EOS Camera Movie Record program, as shown in Fig. 3.

Wide-angle astrophotography

Some of the most interesting astronomical images are wide-field photographs of the night sky that show star clustering and nebulosity on a large scale. There are a number of approaches that can be used to capture images, and we outline a few below.

One less expensive approach is to make use of a digital camera and a sturdy (fixed) tripod. Most point-and-shoot digital cameras will take time exposures with maximum times of 15 seconds to 1 minute. But, once set up, they can take many exposures relatively quickly. Combining a large number of short-exposure images with stacking software averages out noise and enhances the visibility of dim stars and

Fig. 3. Eyepiece projection image of Jupiter and Io taken with a Canon 450 DSLR, a 15-mm eyepiece, and an 8-in Celestron Schmidt-Cassegrain telescope. Movie acquired with the EOS Camera Movie Record and individual frames stacked in RegiStax.

nebulae. The number of exposures that can be combined is usually limited only by the patience of the observer. Relatively inexpensive DSLR cameras can also be used to take very long time exposures with minimal accessories. For example, one can use a remote shutter control with a Canon Rebel on the bulb setting to take exposures only limited in length by battery life, usually more than three hours, an example of which is shown in Fig. 4.

In order to avoid star trails from the rotation of the Earth, a tracking mount of some type is necessary, though. If a telescope with a tracking system is available, a piggyback mount allows the camera to be attached to the telescope tube to facilitate tracking. Piggyback mounts, a small piece of hardware that attaches to the telescope using existing screw holes, are available for most commercial telescopes. If a telescope isn't available, a "barn-door type" mount will provide photographs of similar quality, provided it is properly aligned. An example of a piggyback image is shown in Fig. 5. Barn-door mounts, or double barn-door mounts, can be constructed from scraps of wood and supplies typically available in physics departments (like a 1.0 rpm motor and threaded rod) for very low cost. The Internet is a good source for plans.

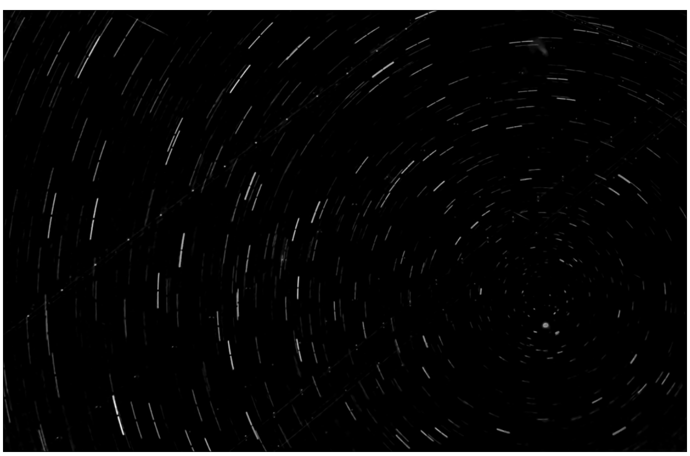

Fig. 4. Two 10-minute exposures of the region around Polaris taken with DSLR (70-mm lens) on a fixed tripod. The straight-line streaks are the trails of two airplanes.

Fig. 5. Unguided image of the North America nebula in the constellation Cygnus. The image above is the result of stacking 50 20-second exposures taken with a Canon 85mm lens attached to a DSLR camera.

Fig. 6. Orion nebula image (cropped) composed of 35 10-second exposures taken via prime astrophotography with a Canon DSLR and a 66-mm apochromatic refractor on a $750 Celestron equatorial mount (unguided).

Fig. 7. Orion nebula image (cropped) composed of nine 180-second exposures taken via prime astrophotography with a modified Canon DSLR ($1000) and a 90-mm apochromatic refractor ($1000) on a $1500 Celestron equatorial mount guided with a 70-mm telescope ($750), Orion Autoguiding Camera ($350), and controlled by Craig Stark's PHD[10] guiding program (free).

Prime focus astrophotography

Prime focus astrophotography is exactly like wide-angle astrophotography except that the camera is directly connected to a telescope. There are two ways to view this direct coupling of the camera and telescope: the telescope behaves like a massive telephoto lens for the camera or the camera behaves like the eyepiece for the telescope.Unlike afocal, eyepiece projection, and wide-angle astrophotography, this method yields a fixed magnification based on the camera's sensor size (its effective focal length) and the telescope's focal length (magnification = focal length of telescope/effective focal length of camera). With this method one can either use a video camera, a DSLR, or a dedicated CCD coupled to the telescope.

Typically this approach uses an equatorial telescope mount that tracks the sidereal rotation as precisely as possible. However, no matter how accurate the tracking, alignment and mount errors will limit exposure times to 10–60 seconds unless periodic corrections are made. Video cameras are therefore ideal for this approach in that they take multiple short exposures. Even with drive errors, short exposures, such as shown in Fig. 6, can be taken.

The modern way around these errors is to use a mount that can be guided with correction signals from a separate telescope and camera (called a "guide scope" and "guide camera," respectively). While these techniques are not difficult with modern computer programs, cameras, and mounts, they are not cheap (an autoguiding mount, telescope, and camera will easily set you back over $1000), as shown in Fig. 7.

Conclusion

The first time students (or adults) see the Moon or Jupiter in the eyepiece of a telescope, they usually become very excited. When they realize that they can take a picture of what they see, the level of excitement increases further. In most cases, this excitement will transfer to other aspects of the course, including the lecture and other laboratory components, and student performance will be enhanced. Cheap still and video cameras and the ubiquitous cell phone camera make it possible for every student to experience the excitement, whether a telescope is available or not. With a telescope, almost anyone can take good pictures of objects seen in textbooks and on the Internet, although it takes a certain amount of patience and perseverance. But the satisfaction gained from taking your own picture of the Moon, a planet, or a deep-sky object makes it worthwhile.

References

1. "Cheap" is a relative term in astronomy and astrophotography. The goal of this paper is to introduce techniques that are inexpensive for a typical physics program without a dedicated observatory.
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7. For a comparison of recent Canon and Nikon cameras, see "Catching the Light" by Jerry Lodriguss at www.astropix.com/HTML/I_ASTROP/COMPARE.HTM.
8. EOS Camera Movie Record, freely available for download at sourceforge.net/projects/eos-movrec/.
9. RegiStax, freely available for download at www.astronomie.be/registax/.
10. PHD, which stands for "Push Here Dummy," is freely available for download at www.stark-labs.com/phdguiding.html.

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