

## **Beginner's astrophotography**

One of the most rewarding challenges to amateur astronomers is to record images of celestial objects on film. There are many pitfalls and obstacles that tend to discourage many would-be-astrophotographers. The information in this fact sheet will help those who are interested in astrophotography to hurdle these many obstacles and learn to take good astrophotos.

Astrophotography can develop and grow over time. There is something new to learn each time you go outside and take photos of the night sky. There are many good books available on the subject, and a list of a few books appear at the end of this fact sheet. The most important thing to remember is that practice makes perfect, so do not be afraid to go outside often and try your hand at astrophotography. When you get good results, there is nothing more satisfying!

### **1. The Astrophotographer's Camera**

Your choice of camera depends on the type of astrophotos you want to take. For fixed tripod and piggyback shots, just about any camera will do, as long as it has a B or bulb setting allowing for time exposures. For prime focus and eyepiece projection photography, the best camera is a single-lens reflex (SLR) camera. The SLR camera is the preferred type of camera for most amateurs. An SLR camera should have the following features for taking astrophotographs.

- The lens should be removable.
- The camera must have a bulb or time exposure setting.
- The camera must have a cable-release attachment.
- The focusing screen should be as clear as possible.
- The camera should operate smoothly, with little shutter slap and minor vibration.

It also helps if the SLR camera is a manual type, i.e., you do not need to turn it on to take a picture. For example, Olympus used to make the OM-1 model, which was (and still is) a splendid camera for astrophotography. It has all the features required, and also is very easy to use. You can still find these cameras quite often at second-hand photography stores and if you get a chance to buy one, do it! Any SLR camera, however, will do as long as it meets the above requirements.

### **2. Types of Astrophotography**

There are basically four types of astrophotography, with each specifically suited for recording a particular type of photo. The four types are,

- Camera fixed on a tripod or other stationary support with no drive provision.
- Piggybacked on a telescope or equatorial drive.
- Prime focus, where the telescope is used as a huge telephoto lens.
- Projection, where an eyepiece is inserted between the telescope and camera body.

## 2.1 Fixed (tripod mounted) photography

Advantages	Disadvantages	Use	Maximum exposures
Speed	Star trails after 25 sec.	Bright comets	Comets: 5 min.
Wide field	Limited magnifications	Circumpolar shots	Circumpolar: 1 hour
Small investment	Limited light cumulation	Meteors	Meteors: 10 min.
Easy to do	Short exposures	Constellations	Constellations: 1 to 3 min.

This is the easiest way to get started in astrophotography and to take many stunning and different photos. All you need is a dark sky, a good tripod, and a decent camera. Aim your camera at a particular area of the sky you wish to photograph, set the f-stop to the fastest speed on the lens (usually f/1.2 to f/2.5) and let fly. Try to use a fast film in the 250 to 800 ASA range, and with a 50-mm normal lens (for a SLR camera) take a 5 to 30-second exposure. Remember that any exposure longer than about 25 seconds with a 50-mm lens will cause star tails to appear on the film. If you are taking a circumpolar shot, stop down the lens to f/2.5 to f/4 so that the light reaching the camera does not saturate the film, and to prevent reciprocity failure (the falling off of the film's sensitivity to light after a short time, thereby causing it to fail and causing extensive fogging on the film).

Be sure to focus carefully on the stars and frame the desired area prior to starting each image to ensure pinpoint star images and sharp star trails. Do not assume that the infinity setting is correct on your camera – manually check! Remember the larger the camera lens, the quicker the stars will trail. A 200-mm telephoto lens will generate star trails in about eight seconds.

The fixed camera method is the best way to take pictures of meteor showers. The camera can be pointed at an area of the sky where the radiant is known, and the lens opened for 20 to 30 minutes. Again, a fast film is necessary, and any of the major brands (Konica, Fuji, Kodak) will work quite well. Remember to monitor the sky area you are photographing, and after one or two meteors appear in the area, stop the exposure and start another. The reason for this is that the dimmer meteors picked up on film can be washed out by background skylight if you expose the film for a long time after the passage of the meteor.

It is very important to keep a log of your exposures. By recording the date, film type and speed, exposure time, seeing conditions, etc., you will be able to get better shots over the long run.

## 2.2 Piggyback astrophotography

Advantages	Disadvantages	Use	Maximum exposures
Longer exposures	Increased investment	Comets to mag. 10	Comets: 1 hour
Great light cumulation	Clock drive required	Deep-sky objects	Deep sky: 1 hour
Magnitude gain	Darker sky needed	Milky Way	Milky Way: 45 min.
Increased resolution with telephoto lens		Planetary conjunctions	Conjunctions: 5 min.
Guiding not always necessary		Meteors	Meteors: 10 min.

This method of astrophotography is the most widely used and is extremely versatile way of getting beautiful astrophotos. A camera with a lens is attached to a telescope or guiding apparatus and the film is exposed for long periods of time while a motor drive enables the telescope to track the sky. Good film to use for this method is Kodak 1000 (very blue sensitive), Konica 800 and 1600 (very red sensitive), and Fuji 800 and 1600 (good all round film). Good slide film is anything that is fast, i.e. 800 or above and preferably something that can be pushed processed. As with the tripod method, the shutter is kept open by using the camera's B or bulb setting and a cable-release clamp. This method is great because any size (focal length) lens can be used on the camera, from 18 mm to 600 mm and larger.

There are several things to consider when taking piggyback photos. The most important point to consider is that the better the polar alignment of the camera, the better the tracking, which means there is less likelihood of having to guide using a 50-mm or smaller lens. Also, a sturdy mount is required and the telescope must be able to track accurately. The longer the focal length of the lens, the more precise polar alignment and guiding needs to be.

Simply lining up Polaris (i.e. the North star) is usually fine for wide angle shots and for 50-mm or smaller lenses, but guiding is essential to get good results when using 135 to 200-mm or larger lenses. A guiding eyepiece used with the telescope is preferred. Guiding is when the telescope is used to keep a guide star centered in the cross hairs of the guiding eyepiece. This will prevent the starlight from trailing on the film. For example, with a 40.6-cm diameter telescope, a 9-mm guiding eyepiece provides about 400 magnification for guiding. For camera lenses that are 135-mm or larger, about 150 magnification is required for guiding. After polar aligning, centre the camera on the area of the sky to be photographed. Next, find a star in or near the area of the sky to be photographed and center this star on the cross hair of the guiding eyepiece in the telescope. The cross hairs in the guiding eyepiece should run the direction as the corrections that will be made in right ascension and declination. Next, adjust the position of the camera so the field is again centered. Make sure the tube of the telescope is not in the picture. Use a cable release to expose the film. Keep the selected guide star centered on the cross hairs or in the bull's-eye, depending on the type of guiding eyepiece. Make corrections in right ascension and declination as required for the duration of the exposure. Typically, with 800 to 1600 speed film, near some light pollution from city lights, use exposure times ranging from 8 to 15 minutes. My experience has been with 800 Konica, M31 at f/5 with a 200-mm lens for 10 minutes is perfect, whereas M31 at f/3.5 with a 135-mm lens is too much with a 10-minute exposure. Experiment!

The following formula is good to know to determine the field coverage in degrees for any focal length lens for a 35-mm camera.

$$\begin{aligned}\text{vertical degrees} &= 57.3/\text{lens effective focal length (in mm)} \times \text{film frame size} \\ \text{horizontal degrees} &= 57.3/\text{lens effective focal length (in mm)} \times \text{film frame size}\end{aligned}$$

The film frame size for a 35-mm camera is 24 mm vertical and 36 mm horizontal. A 135-mm camera lens would give:

$$\begin{aligned}57.3/135 \times 24 &= 10.19 \text{ degrees vertical} \\ 57.3/135 \times 36 &= 15.28 \text{ degrees horizontal}\end{aligned}$$

or a field that is about 10 by 15 degrees of the sky.

### 2.3 Prime focus photography

Advantages	Disadvantages	Use	Maximum exposures
Great resolution	Guiding is essential	Comets close up	Comets: 30 min.
Large image scale	Problem in the wind	Deep-sky objects	Deep sky: 2 hours
Extremely accurate	Very difficult for novices	Double star	Double star: 10 min.
		Planets and moons	Planet and moons: 2-5 min.
		Lunar disk	Lunar disk: 1/250 to 1 sec.

Prime focus photography can be extremely frustrating. A little care and a lot of patience are required. Remember that any mistakes made using prime focus are often not noticeable with piggyback photography. First use fast film that is not too grainy such as Konica 800 or 1600, Kodak 1000, or Fuji 1600, as these films are extremely good for this type of photography. For slide film, use as fast as you can obtain. Ektachrome 400 pushed to 800 is good, as is Fuji and Konica slide film.

A special adapter, called a T-adapter or T-ring, is required to mount a camera to the telescope. These adapters may be purchased at any camera store, and you need to obtain the proper adapter that will work with your particular camera body. Essentially what you are doing is attaching a camera body directly to a telescope, and the telescope becomes a large telephoto lens. You need to know the focal ratio of your telescope. The focal ratio is needed to determine the length of exposure. The smaller the focal ratio, the faster the system, and the smaller the image. The larger the focal ratio, the slower the system, the larger the image, and the longer the exposure time. Focal reducers can be placed between the telescope and the camera body, and this effectively speeds up the system, but also reduces the image size, and can cause vignetting at the edges due to lens aberration, which can not be helped.

Good polar alignment is required, and any of the methods described in the literature will work. However, the star-drift method will generally give the best results. Make sure the tripod is sturdy and the telescope with attached camera are balanced. Next, the telescope will have to be guided while taking a picture. Guiding is required for a variety of reasons, including inconsistency in the atmosphere, clock drive inaccuracies, and power spikes. Keep in mind that the more accurate the polar alignment, fewer corrections that will be required. For Schmidt-Cassegrain telescopes, the easiest way to guide is to use an off-axis guider. An off-axis guider is placed between the telescope and the camera body. Off-axis guiders have a small prism that rotates and allows starlight to reach the guiding eyepiece, which is placed in the off-axis guider tube. The other methods for guiding are with a guide scope, which is the easiest, or with a CCD camera. The latter method can be quite difficult.

Focusing is CRITICAL with prime focus photography. First, focus on a bright star. It helps if there are two or three other stars in the field of view. Other objects that work well to focus on are the moons of Jupiter. Make sure to re-check the focus after each exposure.

There are four things with prime focus photography that can affect any given system and the way it records celestial objects:

- The size of the primary mirror or lens.
- The focal ratio of the telescope.
- The focal ratio of the system.
- The length of time the film is exposed.

The larger the mirror or lens of the telescope, generally the more that can be recorded on film. However, attention needs to be paid to the focal ratio of the system because a faster system can record more light from an extended field object, such as a nebula, than a slower system. For example, a 15.2-cm, f/5 system can record more light than a 20.3-cm, f/8 system using the same exposure time. The light recording power of any system is directly proportional to the square of the radius of the objective, and inversely proportional to the square of the focal ratio. Also, a system with a larger focal ratio is able to resolve more detail. So it is a compromise between system speed and resolution power.

## 2.4 Eyepiece projection

Advantages	Disadvantages	Use	Maximum exposures
Optimum resolution	Perfect tracking needed	Lunar images	-
Largest image scale	Excellent optics needed	Planets	-
Short exposures	High quality eyepieces needed External vibrations Excessive film (bracketing)	Double stars	-

This method, also called positive projection, uses a camera body without a lens, and is mounted on a telescope with an eyepiece fitted in a special adapter, called a projection tube. The projection tube is fitted between the telescope and camera body. A T-ring is needed to fit the camera body to the projection tube.

The effective focal length (EFL) of an eyepiece projection system is defined as:

$$\text{EFL} = \text{magnification (by projection)} \times \text{objective focal length (in mm)} / \text{objective diameter (in mm)}$$

$$\text{Magnification (by projection)} = \text{distance from eyepiece to film plane (in mm)} / \text{focal length of the eyepiece (in mm)}$$

For example, let's say a 20-mm eyepiece is used for eyepiece projection in a Schmidt-Cassegrain telescope, which has a 40.6 cm (406 mm) mirror, with a focal length of 4000 mm. Assume the distance from the eyepiece to the film plane is 76 mm. Therefore,

$$\begin{aligned} \text{Magnification (by projection)} &= 76 \text{ mm} / 20 \text{ mm} = 3.8 \\ \text{EFL} &= 3.8 \times 4000 / 406 = 37.44 \text{ (round to 37)} \end{aligned}$$

Therefore, the focal ratio of the system in the above example is f/37. Using these formulae will allow you to accurately calculate the f-ratio of any eyepiece projection system.

When taken pictures, it is a good practice to bracket exposures in sets of four to get your image. This may mean obtaining one in four images that are correct, which is a good ratio of pictures taken as keepers. A downside to the eyepiece projection method is that a lot of film can be used. Slide film is great, because slide images can be projected onto a large screen to view good detail. Any film from 50 to 200 speed is good for the Moon, keeping in mind that the slower the film, the longer the exposure time. A good 200 to 800-speed film is good for photographing Mars, Jupiter, and Saturn. Good results depend on how accurate the f-ratio is determined, the film speed, and the quality of the polar alignment. Eyepiece projection has two major enemies: 1) vibration in the system, and 2) atmospheric turbulence.

As with the prime focus method, focusing is of utmost importance. One suggestion is to focus on one of the bright moons of Jupiter or on a moderately bright star. Then move to the object to be photographed. Make sure there is detail in the camera and fine focus if required. Then, get ready to shoot. Try to use the hat trick and not the camera mirror lock. Put a dark piece of paper or card in front of the lens, open the camera's shutter, wait three seconds to allow any vibrations to stop, and then remove the card to expose the film. When the exposure is completed, put the card back in front of the camera and close the shutter. This eliminates any shutter vibration, and is a good way to take pictures. Remember the rule for this type of astrophotography, take lots of shots and hope a few of them are good to keep.

### **3. A Note on Film**

There are many types of film that are excellent for astrophotography, such as black and white, colour, print film, and slide film. Konica, for example, used to make an extremely good red and blue sensitive film at ASA 3200, which was fast and not too grainy. Konica 800 print film is exceptionally good in the red range, and Konica 1000 is very good in the blue range. As for slide film, Ektachrome 200 and 400 are good for planets, and Kodak 50 is good for the Moon and solar images. There is Agfa black and white print film that is ASA 3200, but can be pushed to 9600! When it comes to film for astrophotography - experiment! There are four things to look for in a film for astrophotography:

- Speed: Measured by ASA number. The higher the number, the faster the film and the shorter the exposure time.
- Grain: Fine grain is usually desirable.
- Contrast: High contrast is better.
- Colour sensitivity: Panchromatic for planets; experiment with deep sky images.

Always use a reputable firm to develop your hard-earned shots. Always let the developer know that the film contains astrophotos. Something else to remember is to make the first exposure on a roll of film a normal, daylight shot so the developer can see where the exposures start on the film.

Finally, always check your camera before taking any photographs. Is the f-stop set correctly? Is the film in camera correctly? If using lenses, is the lens focused to infinity? Above all, try and have fun with it. Astrophotography is hard to do, but the results can be very rewarding.

### **4. Polar Alignment Methods**

#### **4.1 Star drift polar alignment**

- Initially, do a quick, visual alignment on Polaris.
- Point the scope to a fairly bright star that is near the meridian passing overhead and very near the celestial equator. Example stars include: Altair, Spica, Regulus, Procyon, Betelgeuse, Mintaka, and Rigel.
- Using high magnification, drift will be noticed in declination if the telescope is not aligned to the north celestial pole. All drift in right ascension should be ignored. If the star drifts south, the polar axis is too far east; if the star drifts north, the polar axis is too far west. Make sure the direction of drift is the direction in the sky.
- Adjust the telescope in azimuth, and keep monitoring and adjusting as necessary until all drift is eliminated.

- Next, centre a bright star close to the east horizon, at an elevation of 15 to 20 degrees, and close to the celestial equator.
- Monitor the drift as before, ignoring any drift in right ascension. If the star drifts south, the polar axis is too low; if the star drifts north, the polar axis is too high.
- Adjust the elevation until there is no longer any drift.
- You are now accurately aligned to the north celestial pole.

#### 4.2 Alternative method using a finder scope

- Turn the telescope to declination of 90 degrees (assuming setting circles are properly set).
- Make sure the mechanical axis of a fork-mount telescope is aligned with the line extending from the end star of Ursa Major through Polaris and into Cassiopeia.
- In a 8-by-50 finder (field of view = 5 degrees) the celestial north pole is only 0.36 the distance of the field offset from Polaris. Move the mounting of the telescope toward the end star of Ursa Major until Polaris is one-third away from the centre to the edge in the telescope. Remember, the finder will be reversed (left to right) from what is seen with the eye. Make sure the telescope is physically moving away from Polaris and toward the last star of the handle in Ursa Major.

#### 4.3 Setting the declination circles

- Point the telescope away from the base and set the declination to 90 degrees.
- Put a low power eyepiece in the telescope and focus on a star field.
- Leaving the declination clamped, rotate the telescope about the right ascension axis while observing the star field. If the declination is true to 90 degrees, the star field will appear to rotate in concentric circles around a point in the centre of the eyepiece. If the image is moving in arcs, and not circles, the declination is not set correctly.
- Move the scope in declination slightly, and repeat until the star field circles about the centre. At that point, the declination is exactly 90 degrees, and the setting circles should be adjusted to read this position.

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