# Astrophotography Basics

Kodak thanks the Astronomical Society of the Pacific (ASP) and the American Astronomical Society (AAS) for their help in preparing this booklet.
The **American Astronomical Society** is the major organization of professional astronomers in the United States, Canada, and Mexico. Its basic objective is to promote the advancement of astronomy and closely related branches of science. Its membership includes physicists, mathematicians, geologists, and engineers whose research interests lie within the broad spectrum of subject matter that non comprises contemporary astronomy. The Society's activities include publishing journals, holding national meetings, operating research and travel grant programs, and encouraging and supporting astronomy education.
The **Astronomical Society of the Pacific** is an international, nonprofit scientific and educational organization whose main aim is to increase public understanding and appreciation of astronomy. The Society is unique in bringing together, in its membership and through its programs, professional astronomers, educators, amateur astronomers, and thousands of interested lay people.

Man has wondered and speculated about the universe through the ages. Now that space exploration is a reality, public interest in astronomy has increased enormously. People the world over are combining their own ingenuity with the capabilities of modern optics and photographic materials in order to increase their knowledge of astrophotography. Besides being educational, astrophotography is an entertaining hobby, ideal for experimentation.

So that you can enjoy the fun of astrophotography and take rewarding pictures of celestial objects, we want to help you become familiar with the principles of astronomical picture-taking. This pamphlet will give you a good understanding of this fascinating field of photography.

## GETTING STARTED

### Stationary Camera

You can start taking astrophotographs with a minimum of equipment. All you need is a camera that can make time exposures, a cable release and rigid tripod, and film. A small penlight with a red filter over it will come in handy to check camera settings in the dark.

Since many of your pictures will be time exposures, one of the most important requirements for astrophotography is a steady camera support. Therefore, place your camera onto a rigid tripod before taking pictures. Also use a cable release. This will help you get sharp pictures by keeping camera vibration to a minimum when you open and close the shutter

To determine the best exposure for your equipment, make test pictures. If you are using an autofocus SLR camera or an autoexposure camera, if possible, set the focus and exposure manually. Automatic focus and automatic metering generally do not work well for astrophotography.

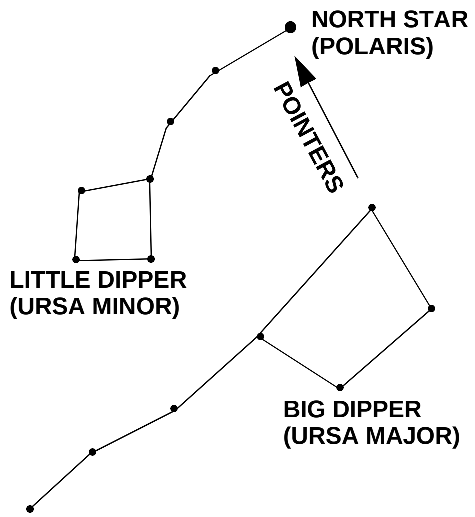
**Star Trails.** Bright stars are good subjects for your first astronomical picture-taking experience because they are easy to photograph. Stars do not remain stationary in the sky. They appear to rise and set because of the rotation of the Earth. When you take time exposures of stars, you will discover that stars create interesting lines called star trails on your film.

So let's take some pictures. Load your camera with a fast film such as KODAK PROFESSIONAL T-MAX 400 Film. Set the camera lens at its maximum opening and the focus at infinity.With your camera on a tripod, aim it toward a group of stars and open the shutter for a 4-minute exposure. At the end of the exposure, close the shutter.

After your film has been processed, you will find that the stars have been recorded as a series of streaks or star trails. From these star trails you can determine the next exposure. If the trails are needle-sharp, you know that your lens is in sharp focus at the infinity setting. If the trails are straight and not jagged, you know that your camera support is sufficiently rigid.

You can use longer exposures and get the best pictures on dark, moonless nights away from the bright lights of cities. Moonlight and city lights produce a general background light in the night sky. This skylight limits the maximum exposure time that you can use without overexposing the background areas of your pictures.

Be sure to keep your camera lens free of dew from the night air. A lens cap is helpful in keeping dew off the lens between exposures. If you don't have a lens cap, you can make one from cardboard. When dew gets on the lens, wipe the lens surface with a clean, soft lintless cloth or KODAK Lens Cleaning Paper. However, don't clean the lens while you're making an exposure.




You can obtain interesting circular star trails by photographing the sky area around the North Star in the Northern Hemisphere and around the Southern Cross in the Southern Hemisphere. The North Star, called Polaris by astronomers, and the Southern Cross, called Crux, are located near the Earth's celestial pole-points. The Earth rotates around the celestial pole-points at the rate of 15 degrees per hour, or 1 degree every 4 minutes. This causes the stars to appear to rotate around the pole-points. (To find Polaris, see the diagram above. Turn the diagram, if necessary, in order to orient it correctly with the stars in your sky.) Polaris is the star at the end of the handle of the Little Dipper constellation called Ursa Minor.

If you make a time exposure of 5 minutes or more of the area of the sky that includes a pole-point, your photograph will show circular star trails made by the stars revolving around it. Since Polaris is about 1 degree away from the true celestial pole-point, your photograph will show that Polaris has also made a short trail.

For other fascinating picture-taking possibilities, try some pictures of constellations such as the Big Dipper, Orion, or Cassiopeia in the Northern Hemisphere or the Magellanic Clouding the Southern Hemisphere. Try exposures of 5, 10, or 15 minutes, with the lens wide open. You can add interest and dimension to your astronomical photographs by including silhouettes of objects such as trees, your home, a church, or a landscape in the foreground of your pictures.

You can take beautiful pictures of celestial objects in color or in black-and-white. Since your eyes have low sensitivity to color when they become adapted to the dark, you may not realize that the stars have different colors. You can capture the colors of the stars with color film, such as KODAK EKTACHROME 400X Professional Film for color slides or KODAK MAX Versatility Film for color prints. Set your camera's lens wide open and expose for 1 to 30 minutes or more. The longer the exposure, the longer the star trails will be on your film. If you wish to avoid recording trails, use an exposure less than 30 seconds.

To make constellations stand out more when you project color slides, put a tiny needle-prick through the beginning of the trail of each star that makes up the constellation.

**Comets.** You can photograph comets by making a time exposure with a 35 mm SLR camera mounted on a rigid tripod. Use a fast lens with a large maximum aperture—*f*/1.4, *f*/2.0, or *f*/2.8. The normal 50 mm camera lens usually has a large aperture as do some telephoto lenses. Use a fast film. For color prints, use KODAK MAX Versatility Film or KODAK ROYAL GOLD 1000 Film. For color slides, use KODAK EKTACHROME 400X Professional Film or KODAK EKTACHROME P1600 Professional Film. For black-and-white prints, use KODAK PROFESSIONAL T-MAX 400 Film or KODAK PROFESSIONAL T-MAX P3200 Film.

On the first frame of the roll take an ordinary picture of anything bright. You do this to establish a reference frame for the photofinishing equipment that will be cutting your roll into frames (unless you process it yourself). Since subsequent frames will appear to be nearly blank, the reference frame will give automatic printers and slide mounters a starting point and hopefully prevent them from cutting frames in half. Alternatively and perhaps preferably, you can ask for the film back uncut and then cut it yourself.

Attach a cable release to the camera, and mount the camera on a sturdy tripod. Make a series of exposures to ensure a satisfactory photo. Since the comet should be available for many nights, reshooting should be possible. Make the exposure series in seconds, doubling the time for each successive exposure: 1, 2, 4, 8, 16, 32, 64, 128, and 256 seconds. The long exposures will result in a blurred trail caused by the Earth's rotation (see "Guided Cameras," for guided photography).

**Meteors.** The glowing trail of vaporization that flashes as a piece of cosmic debris burns up in the atmosphere is called a meteor. Photographing meteors is a challenge and takes a great deal of patience. Although they appear much more often than comets, the position of meteors in the sky is unpredictable; they appear in all parts of the sky. You can take pictures of meteors in the same way as you photograph star trails, closing the shutter after a bright meteor has crossed the camera field of view.

Meteors vary greatly in brightness and frequently in color. These small bits of matter enter our atmosphere at about 25 miles per second and burn at only 50 to 70 miles above the Earth's surface.

On a clear, dark night away from city lights, you may see 5 to 10 meteors an hour. Moonless nights are best for observing and photographing meteors.

There are certain periods of the year when meteor showers occur. The showers may last for several hours or a few days, but each meteor will be visible for only a few seconds. If you find out when meteor showers are due and where to look in the sky, you may have a chance to photograph them. When a spectacular meteor shower is expected, your local newspaper may publish the date in advance. The table below indicates the times of the year when meteors are most likely to appear. The best time is after midnight because then we are on the leading side of the Earth. Because we are traveling faster, the probability of seeing meteors is higher.

**Some prominent meteor showers**

| Name of meteor shower | Occurrence |
|---|---|
| Quadrantids | January 1-4 |
| Lyrids | April 19-23 |
| Eta Aquarids | May 1-6 |
| Delta Aquarids | July 26-31 |
| Perseids | August 9-15 |
| Orionids | October 18-23 |

**Aurorae.** Usually visible only from high latitudes, the Northern Lights (or the Southern Lights) vary greatly in form, intensity, color, and height. Often faint and flickering, they are difficult to photograph. To photograph an auroral display, set your camera lens at its widest opening, and use a fast film such as KODAK PROFESSIONAL T-MAX 400 Film or KODAK PROFESSIONAL T-MAX P3200 Film for black-and-white prints, KODAK EKTACHROME P1600 Professional Film for color slides, or KODAK MAX Versatility Plus Film or KODAK ROYAL GOLD 1000 Film for color prints.

Since an auroral display has such a wide range of intensity and brightness, exposure times can vary from 1 second to 2 minutes. In order to increase your chances of getting a good picture, take pictures at several different exposure times. Some aurorae move faster than others and require shorter exposure times. Blurring will occur if the light pattern moves during exposure, so the shorter exposures will yield sharper pictures.

**Manmade Satellites.** The appearance of satellites is very predictable, since they orbit the Earth every 90 minutes or so.

You won't get any detail in photographs of satellites when you use a telephoto lens or a telescope because satellites are too small and far away. Pictures of satellites will be better if you use a normal-focal-length lens on your camera because they will include more of the satellite path. This will make it easier for you to aim your camera toward the passing satellite. In addition, you can use longer exposures, since it takes longer for the satellite to move across the camera’s field of view. Finally, a normal-focal-length lens minimizes the effects of camera vibration.

To take pictures, load your camera with a fast film and set the lens wide open. When the satellite comes into view, point your camera toward the satellite path. (It will be too dark to use your viewfinder.) Open the shutter on B (Bulb) and wait until the satellite passes out of your camera field of view. Then close the shutter. You can make your picture even more impressive if you plan the timing so that you take the picture as the satellite passes through or near a prominent constellation.

**The moon.** Since the moon is our closest celestial neighbor, it presents exceptional opportunities for astrophotography. The full moon requires the same exposure as a sunlit subject here on Earth. The gibbous moon (between half and full) requires two times as much exposure as a full moon (1 stop more); the half moon requires 2 stops more exposure; and a crescent moon (less than half) requires 3½ stops more exposure than a full moon.

Although the moon appears large to your eye, it is a very small subject to photograph. For example, with a 50 mm camera lens, the image of the full moon will be less than 1⁄50 inch (0.5 mm) on your film, hardly more than a speck. But you can take excellent pictures that will show some surface detail if you use a lens of at least 12 inches (305 mm) focal length and make a photographic enlargement to gain additional magnification.

You can determine in advance the approximate diameter of the moon's image that you'll get on your film by dividing the focal length of your camera lens by 110. Use the same units—inches or millimetres—for both image diameter and the focal length.

## Sky Charts and Astronomical Tables

Sky charts, such as those published in *Sky and Telescope, Astronomy,* and other magazines each month and in many local newspapers each week, indicate the positions of celestial objects and the times that they are visible. When you use a sky chart, imagine that the chart is pasted on the ceiling so that the compass directions agree with your location. The stars on the chart will then appear in their correct positions.

A *Rotating Star and Planet Locator is* a helpful guide for locating celestial objects. When the dial is set for the month, day, and hour, the dial indicator shows all of the constellations overhead for a particular latitude.

## Sky Mapping

You can make a sky map by using your 35 mm SLR camera on an ordinary (but very stable) tripod. The high speed of KODAK PROFESSIONAL T-MAX P3200 Film will enable you to make fairly short exposures. Except for critical results, the exposure time is short enough to minimize star streaks caused by the Earth's rotation. The star streaks can be further hidden by the combined effects of the small image size and film grain. The fine grain and excellent sharpness of T-MAX P3200 Film will enable you to enlarge your series of negatives to make a large sky atlas. Depending on the maximum lens aperture and focal length of your lens, you will be able to record stars to as faint as magnitude 10 before exposures become too long and the star streaks become apparent. You can use your atlas to supplement published star charts, or to record nova, asteroids, or other transient events.

The table below provides useful information on lens coverage to make a sky map. Expose T-MAX P3200 Film at EI 3200 and develop it according to the instructions provided with the film. You can also vary the exposure index and development to suit your equipment and local skies. To minimize camera vibration, use a locking cable release and lock up the camera mirror if your camera has this control.

The camera's normal 50 or 55 mm lens is well suited to sky mapping. Its large maximum aperture allows for a fairly short exposure time. Its field of view is broad enough to cover a moderate area of sky. Set the lens to *f*/2 or /2.8, and start out with an exposure of 30 to 50 seconds (testing may show that your equipment and local sky conditions require a different exposure). If you use a 100 or 200 mm lens its narrower view will require more exposures to make the map. Single-focal length lenses (as opposed to zoom lenses) will generally allow larger maximum apertures and give better results at those apertures.

Using exposure times no longer than the maximum times shown in the table, you should be able to make 8 x 10-inch prints that do not show star streaks. You can make bigger prints if your exposure times are significantly shorter than the maximum times in the table.

To better reveal the faintest stars, copy the negatives to obtain positive transparencies and then make a set of enlarged paper prints that show black stars on a grey background. For more information, see pages 108-109 in *Star Gazing With Telescope and Camera,* (Amphoto, 1967).

**Lenses for Sky Mapping with a 35 mm Camera**

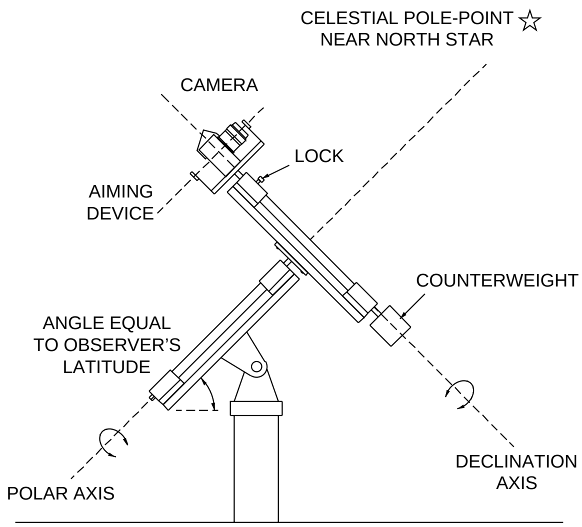
| Focal length mm | Field degrees | Frame area sq. deg. | Area -10% sq. deg. | Number of frames Area -10% | | Maximum exposure* (seconds) |
|---|---|---|---|---|---|---|
| | | | | All sky | +90° to -30° | |
| 35 | 38 x 54 | 2052 | 1847 | 23 | 18 | 50 |
| 50 | 28 x 40 | 1120 | 1008 | 41 | 31 | 40 |
| 100 | 14 x 20 | 280 | 252 | 164 | 123 | 20 |
| 200 | 7 x 10 | 70 | 63 | 655 | 491 | 10 |

* To avoid star streaks at a declination of 45°.

## Guided Camera

So far we have been talking about stationary cameras. You can improve your astrophotographs by using your camera on an equatorial mount in order to follow the motion of astronomical subjects. This compensates for the rotation of the Earth and keeps the images stationary on your film during the long exposures that may be necessary for pictures of faint objects. An equatorial mount provides a heavy, firm support and orients your camera for convenient tracking of celestial objects. You can purchase an equatorial mount, without motorized drive, reasonably from scientific-supply firms. A motorized drive, however, works better.

**Equatorial Mount for Guided Camera**




**How to use an equatorial mount.** (Refer to figure above.) For the Northern Hemisphere, set the polar axis parallel to the Earth's axis by pointing it at the celestial pole-point near the North Star. When you do this, the angle between the polar axis and the horizontal will be equal to the latitude of your location (published in almanacs and atlases). You can measure this angle with a protractor and a level. Once you have properly aligned the polar axis, you won't have to change it unless you move the telescope to another latitude.

Next mount the camera at the end of the declination axis as shown in the figure above. Point the camera toward the object you want to photograph and lock the declination axis. Now by rotating only the polar axis (usually with a knob attached to a gear drive), you can follow the motion of an astronomical subject accurately. An aiming device aligned parallel to your camera lens axis will help you center your camera on the subject. You can use a simple aiming device made from two screw eyes available from hardware stores, but a small telescope or binocular attached near the camera will be much more satisfactory.

If you guide your camera carefully, stars will appear as points of light of very small diameter. The brighter stars, however, will produce larger images because of light spreading in the film. You cannot magnify star images with long-focal-length lenses because stars are much too far away from us. However, the moon and planets do have definite image diameters. When you photograph these subjects, you can obtain larger images by using a telephoto or long-focal-length lens on your camera.

## Telescope

To photograph astronomical subjects in greater detail, you will need a telescope. There are two major classes of telescopes: refracting and reflecting. The refracting telescope forms an image of an object by transmitting the light rays through a lens system similar to camera or binocular lenses. The reflecting telescope collects the light rays with an accurately curved mirror which forms the image. With both telescopes, the primary image is magnified by an eyepiece. Reflecting telescopes are less expensive and are generally better at focusing different colors in the same plane. This feature is important in obtaining sharp images

Astronomers use the term objective lens or objective when they refer to the telescope main or primary lens which collects the light from the subject. The objective may be either the objective (front) lens of a refracting telescope or the mirror of a reflecting telescope. When we discuss telescope lenses in more detail, we will use these terms*.

**Telescope mounting and drive system.** An equatorial mounting with motorized drive system will allow you to use the long exposures that are necessary for astrophotography of many interesting objects far out in space. This equipment will permit the recording of planets, nebulae, galaxies, and star clusters. Equatorial mounts with clock drives are available reasonably from scientific supply firms.

Operating a motorized mount is similar to operating a simple equatorial camera mount. Turn the telescope about the declination axis to the desired position, and lock the declination axis. The motor drive will rotate the telescope and declination axis about the polar axis in order to keep the desired object in view and stationary on your film. You can take pictures of brighter objects without using a drive system, but a drive system is almost a necessity for photographing faint objects.

* Some modern telescopes, especially models popular with amateurs, combine mirrors and correcting lenses to produce a compact, portable unit.

When you use a drive system, set it to rotate the polar axis one revolution per day. Professional astronomers rotate the polar axis of their telescopes once every sidereal day (23 hours, 56 minutes, and 4 seconds of clock time), which is the true rotational period of the Earth. However, even their guiding mechanisms are not perfect. Refraction by the Earth's atmosphere changes the apparent position of celestial objects; therefore, slight guiding corrections are required. An ordinary 24-hour clock drive is good enough for most astrophotography; you can correct for the slight guiding discrepancy manually, if necessary.

To observe the tracking accuracy of your drive system, you can view the object relative to the cross hairs of a reticle used with an illuminated eyepiece on your telescope, or you can use a guide telescope aligned with the main scope. In addition, a small finder telescope is often necessary to help you locate celestial objects because the field of view of the high-power main scope is extremely small.

**Telescope and camera.** The four basic telescope-camera systems are (1) eyepiece-camera lens, (2) eyepiece projection, (3) prime focus, and (4) negative-lens projection (figure 2, page 10). The system you use depends primarily on your equipment and on the desired image size.

The *eyepiece-camera lens system* is probably the most convenient for those who are new to astrophotography because you don't need a special camera or a camera with a removable lens. You can take astrophotographs with an ordinary camera positioned close to the eyepiece of your telescope. However, when using this system you may find it difficult to check alignment and focus. Image contrast may be reduced by reflections from the many lenses, in the light path.

There are several kinds of optical instruments that you can use for the telescope part of your eyepiece-camera system. These include binoculars and spotting scopes as well as astronomical telescopes with eyepieces. To take pictures with your camera and telescope, you'll need a simple mounting device to attach the two units. The mounting device should provide both precise alignment of your camera lens with your telescope eyepiece and a rigid, vibration-free support of your camera. Although the mount should furnish a lighttight guard between the two units, this guard is not absolutely necessary. A black, lintfree cloth will do. You can purchase mounting devices inexpensively from optical supply firms.

With the other three telescope-camera systems, you do not use your camera lens. Therefore, you'll need a camera with a removable lens and shutter that's built into the camera body. The camera body you use should have some provision for focusing on a substitute film plane. (See the following section on focusing.) Cameras that do not fulfill these requirements must be altered.

An excellent camera for astrophotography with a telescope is the single-lens reflex camera with a removable lens. You can use this type of camera with all four telescope-camera systems by using the camera with or without its lens, depending on the system you employ. When you look through the viewfinder of a single-lens reflex camera, you are looking through the lens system. This enables you to position the image and focus your telescope-camera system conveniently and accurately.

You can also purchase specially built astrocameras from telescope manufacturers.

With the *eyepiece-protection system*, you attach your camera, with its lens removed, to the telescope eyepiece. The eyepiece projects the image directly onto the camera film plane. Since you don't use the camera lens, there are fewer lenses for the light to pass through. As a result, less light is absorbed and there are fewer lens aberrations to affect the image.

Also, with the eyepiece-projection system you can increase magnification by moving the film plane farther from the eyepiece. However, as you do this, the image-forming light is spread over a larger area. This fainter image requires a longer exposure.

To focus the image on the film plane, it's necessary to move the eyepiece outward slightly from the setting for visual use. See Focusing procedure.

In the *prime-focus system*, the objective of the telescope focuses the image directly on the camera film plane, thus eliminating extra lenses. Consequently, this system yields small images of maximum contrast, sharpness, and brightness.

The *negative-lens projection system* is similar to the prime-focus method, but a negative achromatic lens, usually referred to as a Barlow lens, is placed inside the focus of the objective. This lens magnifies the image without greatly increasing the length of the telescope. This principle is used in telephoto lenses.

**Focusing procedure and camera alignment.** The way in which you check for alignment and sharp focus of your telescope and camera will depend on the type of camera you use.

With a single-lens reflex camera and a suitable mount, line up your camera so that the film is centered at right angles to the optical axis of your telescope. If you use the camera lens, place it close to the eyepiece of the telescope. Next put a piece of tracing paper or tissue paper over the front of the main tube of your telescope, and illuminate it evenly with a 100-watt light bulb in a reflector about 2 feet away. Set the camera lens at its smallest opening. Then move the camera back and forth slightly to obtain the most uniform illumination in your viewfinder. If the camera lens is either too close or too far from the eyepiece of the telescope, the corners of the viewfinder will be dark.

For focusing, take the paper off the end of the telescope and point the telescope toward a bright astronomical subject, such as the moon or a bright star, NOT THE SUN! If you use the camera lens, open the lens to its maximum opening and set the lens for infinity. Then adjust the focus with your telescope (or binocular). When the image looks sharp on the ground glass of your viewfinder, it will be sharp on your film.

With a nonreflex camera, use the same mounting setup and alignment procedure. To align and focus this type of camera, you will need a piece of ground glass to fit the film plane of your camera. Ground glass is available through your photo dealer or from scientific-supply firms. You can use a piece of wax paper or matte acetate (thin plastic sheeting which has a matte surface) as a substitute, but be careful not to bend it; the wax paper or matte acetate must be flat in the film plane.

Before loading this type of camera with film, open the camera back and place the ground glass over the film plane of the camera, with the ground surface toward the lens. Make sure that the glass is resting on the film-plane frame or rails; then fasten it in place with tape.

Open the camera shutter on B (Bulb). Use a locking cable release to keep the shutter open. Then with the camera lens wide open and set on infinity, adjust the focus with your telescope and observe the image on the ground glass with a magnifier, such as the KODAK Achromatic Magnifier, 5X. When the image appears in sharp focus on the ground glass, it will be sharp on your film.

After focusing, lock all adjustments and remove the ground glass. Then load your camera with film. Be careful not to disturb the focus.

**Lens speed.** The lens speed of a telescope-camera system indicates its light-gathering capability. This is expressed by *f*-number or objective diameter, depending on the subject you are photographing.

In astrophotography there are two kinds of subjects—extended objects and point-source objects. Extended objects appear large enough so that their images cover an appreciable film area. For example, the moon, sun, planets, and large nebulae are extended objects. Point-source objects, such as stars, make a tiny image the size of which is nearly independent of lens *f*-stop or focal length.

When you photograph extended objects, as in conventional photography, the light reaching the film in your telescope-camera system compared to another telescope-camera system is inversely proportional to the ratio of their f-numbers squared. For example, the image from an *f*/4 telescope-camera system is 4 times brighter than the image from an *f*/8 system;

$$\left(\frac{8}{4}\right)^2 = 4$$

This means that a picture taken at *f*/4 requires an exposure time 1/4 as long as a picture taken at *f*/8.

However, when you take pictures of point-sources (stars), the image intensity that reaches your film depends upon the diameter of the telescope or binocular objective, *not the f-number*. In this situation the lens speed of telescope objectives is directly proportional to the ratio of the squares of their diameters. A 3-inch diameter objective transmits 2.25 times as much light as a 2-inch objective;

$$\left(\frac{3}{2}\right)^2 = 2.25$$

Your exposure time will be 1/2.25 as long with the 3-inch objective.

**The *f*-number of your telescope-camera system.** The *f*-number of your system is determined by your telescope (or binocular). When you take pictures through a telescope and you use your camera lens, set the camera lens at its widest opening.

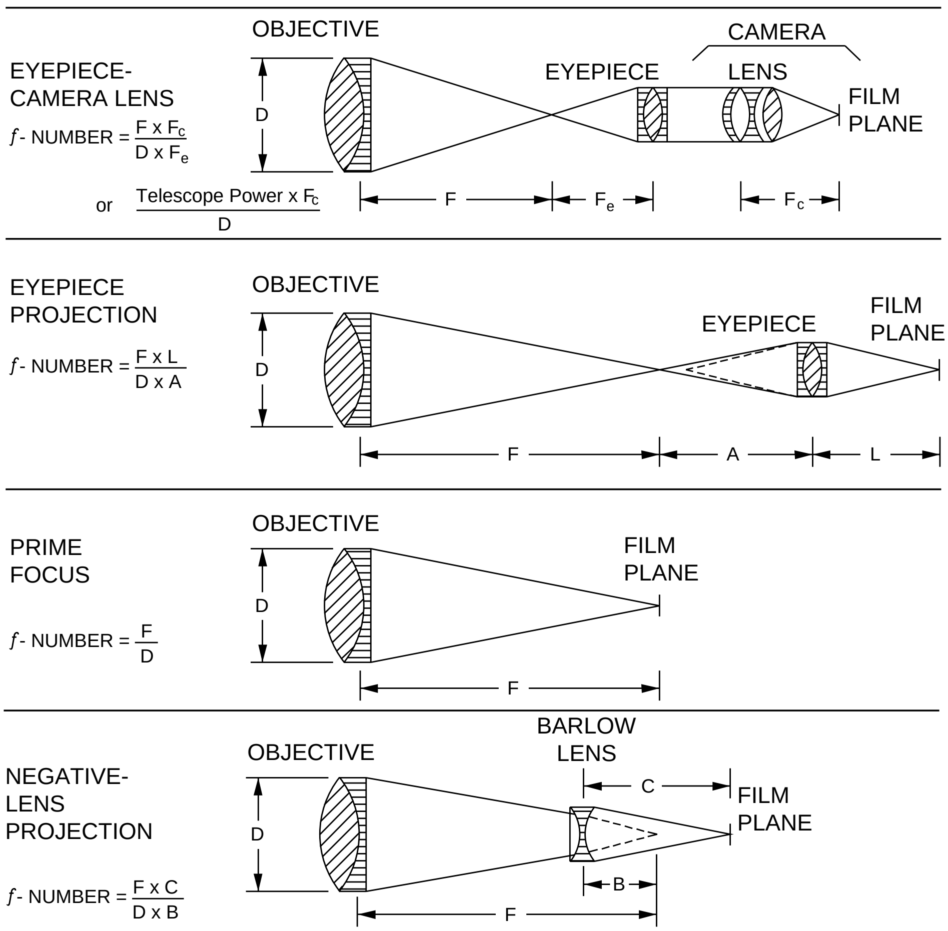
The formulas and diagrams in the figure below will help you determine the effective f-number of each of the telescope-camera systems. With the eyepiece camera lens system, you can use the formula that includes telescope power if you don't know the focal length of your telescope objective or eyepiece but you do know the power of your telescope, spotting scope, or binocular.

**Formula 1**

$$\frac{(f\text{-number for your system})^2}{(f\text{-number for example})^2} = \text{exposure compensation}$$

**Formula 2**

$$\frac{(\text{objective diameter for example})^2}{(\text{objective diameter for your system})^2} = \text{exposure compensation}$$




**Where**

| | | |
|---|---|---|
| F | = | focal length of the telescope objective |
| $F_e$ | = | focal length of the eyepiece |
| $F_c$ | = | focal length of the camera lens |
| D | = | diameter of the telescope objective |
| L | = | distance of eyepiece from the film (eyepiece projection only) |
| A | = | distance of eyepiece from normal focus of the telescope objective (eyepiece projection system only) |
| C | = | distance of Barlow lens from film |
| B | = | distance of Barlow lens from normal focus of telescope objective |
| Telescope power | = | printed on the telescope eyepiece, on the binocular; or given in the instruction manual for the equipment. |

**Note:** Use the same units for all dimensions.

## Apparent Brightness of Astronomical Subjects

The Greek astronomer Hipparchus devised a system of classifying stars according to degree of brightness, which is still in use today. He designated the 20 brightest stars as *first magnitude;* the next 50, in order of brightness, as *second* magnitude; and so on. Stars that are barely visible to the normal, unaided eye are sixth-magnitude stars. The sun, moon, and some planets are brighter than first-magnitude stars and have negative magnitudes. For example, the brightness of the sun is -26.7.

This brightness relationship is useful because it can help you determine exposure time. Each magnitude difference of 1.0 indicates a brightness difference of 2.5. For a given astrophotographic setup, this means that fourth-magnitude stars will require 2.5 times the exposure time of third-magnitude stars, and so on. Books on astronomy in your public library contain tables of relative magnitudes for various celestial objects. You can estimate magnitude classification to a high degree of accuracy by comparing the object of interest with objects of known magnitude.

## Estimating Exposure

General exposure recommendations are given in the table on page 13. Since there are so many variables in taking astrophotographs, such as equipment, speed of the film, and atmospheric conditions, the table gives exposure ranges to serve as a basis for your own pictures.

You may find exposure data with astrophotographs in books and magazines. You can relate these data to your own astrophotography setup. For example, assume that the exposure for a photograph of the moon is given as 1/250 second at f /8 with KODAK PROFESSIONAL T-MAX 100 Film. If your telescope-camera system has an effective f-number of f/32 and you are using KODAK PROFESSIONAL T-MAX 400 Film, what should your exposure time be?

Since the moon is an extended object, the normal f-number relationship is valid. Therefore, to determine the exposure compensation for the smeller f-number of your system, use formula 1 on page 8.

In this instance $\frac{32^2}{8^2} = 16$

therefore, your system requires 16 times as much exposure. However, your film is 4 times as fast as the film used in the example, so it requires l/4 of the exposure. Combine both factors by multiplying l/4 X 16=4. This calculation indicates that you need 4 times as much exposure as was used in the example. To determine your exposure time, multiply the exposure time used in the example by 4. Since 4 x 1/250 second= 1/60 (approximately), the exposure time for your setup is 1/60 second.

In star photography the diameter of your telescope or binocular objective, not the f-number, determines the intensity of the light that reaches your film. Consequently, exposure data for photographs of point-source objects should include objective diameter rather than f-number. To compute the exposure compensation for differences in objective diameter, use formula 2.

Then multiply the exposure time used in the example by the exposure compensation. Also compensate for differences in film speed, if any.

## Film Selection

Film speed is an important consideration in astrophotography as a high-speed film requires less exposure time. Shorter exposures minimize the effects of guiding errors and atmospheric shimmer, factors that reduce image sharpness. The film speed is listed on the instruction sheet which comes with the film or is printed on the film box.

The response of a film is directly proportional to its film speed. For example, a film with a speed of ISO 400 is 4 times as fast as a film with a speed of ISO 100;

$$\frac{400}{100} = 4$$

Consequently, the exposure time for the 400-speed film would be l/4 as long as the exposure time for the 100-speed film.

Speeds of film for pictorial photography are based on average exposure times used in taking conventional pictures. If your calculated exposure time is much longer than 1/10 second, you should regard your exposure estimate as the basis for trial only. So make a series of test exposures at ¼, 1, 4 and 16 times the calculated exposure. Corrections for very long exposures are required to compensate for reciprocity effect. To obtain these corrections for Kodak films, call Kodak at 1-800-242-2424.

Film graininess is also an important factor to consider in selecting a film for astrophotography. Graininess is the salt-and-pepper appearance or sand-like pattern that is sometimes evident in enlarged photographs. Usually, slow-speed films have the finest grain. If you plan to enlarge your astrophotograph, it is best to use the finest-grain film you can. However, the film you select should have not only fine grain but also adequate speed for your picture-taking situation. KODAK PROFESSIONAL T-MAX 100 Film is an excellent choice. See other film suggestions on page 15.

## KODAK Technical Pan Film

The versatility of KODAK PROFESSIONAL Technical Pan Film makes it especially useful for advanced or professional astrophotography. Its extremely fine grain and extended-red spectral sensitivity enable it to resolve close double stars, reveal veiled nebulosity, and record fine details. You can expose Technical Pan Film at varying exposure indices and develop it to a wide range of contrasts to suit different needs. Common for pictorial use, it is readily available at many photo dealers.

Astrophotographers can also make specialized use of Technical Pan Film. To learn more about KODAK PROFESSIONAL Technical Pan Film, call Kodak at 1-800-242-2424, extension 19, and ask for KODAK Publication No P-255, *KODAK PROFESSIONAL Technical Pan Films.*

## Camera Filters

You can take excellent astrophotographs without using filters, but sometimes filters may help reduce the effect of the background light. Moonlight scattered by the Earth's atmosphere produces a predominantly blue skylight. If your exposure time is long enough, this light causes overexposure in the sky areas of your picture. You can use filters to reduce the effect of background light. With panchromatic black-and-white film use a No. 8 yellow filter or a No. 15 deep-yellow filter over the camera lens. This will permit you to use longer exposure times without overexposing the background areas of your picture. Since filters decrease the intensity of the light reaching your film, increase your exposure time by the filter factor listed on the instruction sheet that comes with the film or the filter. Camera filters are generally not used with color films.

## Film Processing

When you have your film processed, you can request that it be returned to you uncut and unprinted or unmounted. This is usually preferable to having the photofinisher do the cutting. The photofinisher may think that star images are just dust spots or have difficulty locating the picture areas and cut right through pictures without realizing it.

If the photofinisher will be cutting and printing or mounting your film, use the first frame to take a picture of an ordinary subject in bright light. This will provide a reference frame for automatic printers or slide mounters and hopefully prevent them from cutting through images.

After your film has been processed, you can draw frame lines across the film with a KODAK Negative Pencil or an equivalent to show the negative areas to be printed. You can cut apart the frames from your transparency films by hand and mount them in KODAK READY MOUNTS, available from photo dealers.

**Exposure Guide for Basic Astrophotography**

| Subject | Instrument | Mount | Objective | *f*-number | Films | Exposure |
|---|---|---|---|---|---|---|
| Star trails and comets | Camera with time exposure | Rigid support | Any lens | Wide open | High speed, B & W and color | Up to 30 min or more |
| Meteors | Camera with time exposure | Rigid support | Good wide-field lens | *f*/6.3 or wider | High speed, B & W and color | 10 to 30 min |
| Aurorae | Camera with time exposure and fast lens | Rigid support | Fast lens | *f*/4.5 or wider | High speed, B & W and color | 1 sec to 2 min |
| Manmade satellites | Camera with time exposure and fast lens | Rigid support | Fast lens | *f*4.5 or wider | High speed, B & W and color | Hold shutter open for duration of pass |
| Moon | Camera or camera with telescope | Rigid or equatorial with or without drive | 1" diameter or larger | *f*/4.5 or slower | Medium speed, B & W and color | 1/125 sec to 0 sec |
| Stars and comets | Camera or camera with telescope | Equatorial with guiding sights | 1" diameter or larger | *f*/6.3 or wider | High speed, B & W and color | 1 min to 1 hr |
| Star clusters, nebulae, and galaxies | Camera or camera with telescope | Equatorial with sights and drive | 1" diameter or larger | About *f*/6.3 | High speed, B & W and color | 10 min to 1 hr |
| Planets | Camera with telescope | Equatorial preferably with drive | 1" diameter or larger; for detail, 6" and up | Use *f*-number determined by your system | High speed, B & W and color | ½ to 15 sec |
| Sun* (Never look at the sun through any optical device without adequate protection!) | Camera or camera with telescope | Rigid or equatorial with or without drive | Neutral density filters 4.0—6.0 over 1 to 4" main objective | *f*/11—*f*/32 | Low speed, B & W and color | 1/30 to 1/1000 sec with neutral density filters 4.0—6.0 over main optical objective, not behind the eyepiece! |

* For protection in observing the sun, see section "Solar Eclipse.".

## SOLAR ECLIPSE

**Warning**

Protect your eyes! Don't look at the sun directly during a partial solar eclipse!

BLINDNESS will result from looking at the sun, either directly or through a viewfinder. Never look at the sun without adequate protection. Protecting your eyes adequately will reduce exposure to ultraviolet and infrared radiation, which can severely burn your eyes instantaneously without your immediately being aware of it. Also, adequate protection will increase eye comfort by reducing the intensity of the visible sun rays. NO FILTER IS USED DURING THE TOTAL ECLIPSE.

### Viewing filter for partial phases

Always use a filter that will absorb *sufficiently* the ultraviolet, visible, and infrared energy of the sun. Special solar filters for viewing or photography are available.

If you are observing a total eclipse, during the few minutes of totality you do not need a viewing filter. However, as soon as totality ends, begin using the viewing filter again.

**Do not use color film, KODAK WRATTEN Neutral Density Filters, or crossed polarizing material as a viewing filter. These items will not protect your eyes as they do not absorb the ultraviolet and infrared rays sufficiently.**

### Focal Length of Lens

The high light intensity of the sun even during an eclipse permits you to use any camera. However, the size of the sun or moon image depends on the focal length of the camera lens. You can estimate the actual image size on the film by dividing the focal length by 110. For example, with a camera lens having a focal length of 4 inches (100 mm), the image size would be about 4/110 inch (1 mm) in diameter—the thickness of a dime. However, many good pictures of eclipses have been made with 35 mm cameras equipped with lenses of 2-inch (50 mm) focal length. So don't put your camera away because you don't have a long-focal-length lens.

In movies of the eclipse, the image will be enlarged when projected on the screen. Assuming a magnification of 110 diameters on projection, the diameter of the image of the sun on the screen will be approximately equal to the focal length of your camera lens.

### Camera Protection

**The sun can burn holes in focal-plane shutters, warp the leaves of between-the-lens shutters, and melt composition shutter blades.** Use neutral density filters that are made *for photographic use*. These will help you take properly exposed photos but will not protect your equipment. If your camera must be pointed toward the sun throughout the eclipse, shade it between exposures. It is wise to shade the camera from direct sunlight at all times to avoid overheating film and camera.

### Aiming Your Camera

NEVER LOOK AT THE SUN THROUGH A CAMERA VIEWFINDER WITHOUT SUITABLE FILTERS EVEN FOR A BRIEF TIME. This is especially important with single-lens reflex cameras. The best policy is to aim your camera without using its viewfinder. If you must use the viewfinder, use solar filters, as noted before, held *in front of the viewfinder or, with a single-lens reflex camera, in front of the camera lens.*

FILTERS MADE FOR PHOTOGRAPHIC USE GIVE NO VISUAL PROTECTION. Therefore, use the solar filters for visual aiming and photography. If you don't have a solar filter, aim without using the viewfinder and change to neutral density filters made for photographic use to take pictures of the eclipse (see below) Once you have changed to neutral density filters for use on your camera, do not look through the viewfinder.

### Exposure

The light from the sun's surface is so intense that in order to photograph the partial phases of the eclipse, you must reduce the sun's light by 10,000 to 100,000 times. Neutral density filters (ND) provide the most convenient way of cutting down the light to allow normal camera exposures. **During the partial phases, the light intensity of the surface of the sun is the same as it is when there is no eclipse**.

Here is a simple formula for determining the correct exposure for the partial phases:

$$f^2 = S \times t \times 10^2 - D$$

where

| | | |
|---|---|---|
| *f* | = | lens opening |
| S | = | ISO speed of the film |
| t | = | shutter speed in seconds |
| D | = | density of the neutral density filter in use |

For example, with a neutral density filter of 5.0, KODACHROME 64 Film, and a shutter speed of 1⁄125 second, you would use a lens opening of *f*/8; with a shutter speed of 1/30 second, you would use a lens opening of *f*/16.

Additional exposure information is given in the table "Solar Eclipse—Approximate Exposures for Still Cameras." If you are taking pictures with a simple nonadjustable camera, use KODAK PROFESSIONAL T-MAX 100 Film and a 5.0 ND (neutral density) filter during the partial phases. Remove the ND filter only during totality.

The brightness of the sun does not change during the eclipse (except when it is total), so your exposure during partial phases should remain constant as long as sky conditions remain constant. Most camera exposure meters average the reading over some area. If the visible portion of the sun does not cover all this area, the meter will indicate more exposure than needed.

If you have a camera with automatic exposure control, consult your camera manual to override the automatic exposure system; or see your local camera dealer.

## What to Photograph During a Solar Eclipse

**Partial phases.** Beginning about 1 hour before totality, you can see the moon gradually encroaching on the sun's disk; for about 1 hour after totality, the shadow gradually retreats. You can obtain an interesting record of the eclipse by mounting your camera onto a firm support and making a series of exposures at 5-minute intervals on the same frame of film, starting a half hour before totality and continuing for a half hour after. For this technique, you'll need to use a camera which will let you take more than one exposure on the same frame of film. Check your camera manual to see if you can do this with your camera.

The period over which you can make such a record on a single frame depends on the angle of view of your camera lens. The position of the sun will change about 15 degrees per hour. A normal-focal-length camera lens will cover a sufficient angle for exposures over a 2-hour period. Watch your local newspaper for the timing of the progress of the moon across the sun disk; then plan your camera position and exposure schedule accordingly. Better yet, practice the day before.

**Shadows under trees.** All during the partial phases, the sunlight filtering through the leaves of trees forms images of the eclipsed sun on the ground. You can photograph these crescents easily with normal exposures for the film you're using.

**Shadow bands.** During the last few seconds before totality, you may see wave-like shadows called shadow bands moving over the ground. They average from 1 to 2 inches in width and are 5 or 6 inches apart. They are most easily visible on a white background, such as a bed sheet.

This phenomenon is *very difficult* to photograph because of the low illumination and the speed of movement. With a white sheet on the ground to obtain as high reflectance as possible, you can expose T-MAX 400 Film at 1/125 second with a lens opening of *f*/2. If the largest lens opening on your camera is *f*/3.5, to record the shadow bands you can use T-MAX P3200 Film for a camera that accepts 135-size film or T-MAX 400 Film (pushed 1 or 2 stops) for a camera that accepts 120-size film.

**Landscape during totality.** The intensity of the available illumination varies rapidly during the minute just before, and the minute just after, totality. At the darkest period (during totality), an exposure of about 1/4 second at *f*/8 on KODAK PROFESSIONAL EKTACHROME Film E200 should give good results for landscape photography.

During totality, you may not be able to see the settings on your camera. Carry a pocket flashlight so that you can check or change your camera settings.

**Total eclipse.** Totality usually lasts less than 5 minutes. Therefore, it is a good idea to go through a few practice runs and time yourself so that you can take several pictures during this brief period.

**Baily's beads.** For an instant just before totality and again just as the sun emerges, light breaks through the valleys on the rim of the moon, forming what looks like a beaded necklace along the edge of the moon. This brief display is very spectacular.

Use a shutter speed of 1/500 second, no filter, and the same lens opening recommended for partial phases in the table "Solar Eclipse—Approximate Exposures for Still Cameras."

The diamond-ring effect can be photographed by adjusting exposure for the prominences without the neutral-density filter.

**Warning**

Do **NOT** remove the filter too soon! If you do, severe eye damage can result.

**Corona.** At totality, the corona appears around the sun as a beautiful halo, decreasing in brightness from the moon's rim outward. Points of interest to observe and photograph in the outer corona are the equatorial streamers, which may extend several diameters from the sun. Superimposed on the inner corona are solar prominences, scarlet, tongue-like jets shooting outward from the sun surface.

Since the intensity of the corona fades rapidly away from the solar limb (edge of the sun's apparent disk), the distance to which the photograph will show the corona depends on the exposure—the longer the exposure, the greater the extension. However, if you attempt to record the faint outer streamers, then the inner corona will be overexposed. The most colorful results are often obtained with a shorter exposure gauged to record the inner corona. As an aid in capturing both effects on the same piece of film, use color negative film and selective printing.

## Telescope or Binocular

You can use a small telescope or binocular in conjunction with an ordinary camera. The image size obtained with such a combination will be equal to that obtained with your camera alone multiplied by the power of the telescope or binocular. It is best to build some type of rigid support to hold your telescope and camera in alignment.

You can arrive at the best focus and exposure for the partial phases experimentally by photographing the sun prior to the eclipse. Make an approximate focus setting by focusing the telescope or binocular on an object at a great distance. Then set your camera lens at infinity, and focus at the largest lens opening. Join the camera and telescope, covering the space between the camera lens and the eyepiece of the telescope with a black cloth to cut out stray light. See section entitled "Telescope."

## Camera Support

For a series of pictures of the partial phases, mount your camera on a tripod or other rigid support to prevent movement between exposures. Also, with long-focal-length lenses, a telescope or a binocular, a solid support is essential to avoid loss of definition due to camera motion.

Because of the Earth's rotation, solar images 1 inch in diameter or greater will show significant movement on the film during exposures of 1/6 second or more. For these and longer exposures, use an equatorial mounting with a clock drive. If your exposures exceed 1 second and no drive mechanism is available, the diameter of the solar image should be proportionately smaller as exposure times are increased.

## Filters

**Warning**

Filters made for photographic use give **NO VISUAL PROTECTION**. Do not try to observe a solar eclipse through such filters because they transmit infrared energy which can burn your eyes.

The use of neutral density filters is a convenient way of reducing the excessive light intensity for photography during the partial phases. You can quickly remove the filters from in front of the lens at totality.

The KODAK WRATTEN Neutral Density Filter No. 96 (gelatin) is available in the following densities: 0.10, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 1.00, 2.00, 3.00, and 4.00. You can obtain intermediate densities or higher densities, such as 5.0 and 6.0, by combining two of the standard filters. However, if you use more than two at one time, image sharpness will be reduced. These filters are available through photo dealers.

**Neutral density filters**

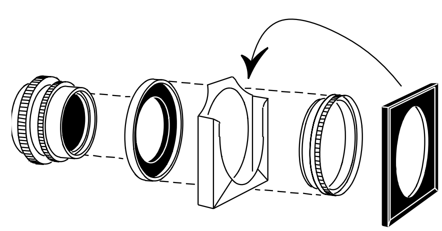
| Neutral Density Value | Filter Factor | Reduces Exposure by (*f*-stops) |
|---|---|---|
| 0.1 | 1¼ | ⅓ |
| 0.2 | 1½ | ⅔ |
| 0.3 | 2 | 1 |
| 0.4 | 2½ | 1⅓ |
| 0.5 | 3 | 1⅔ |
| 0.6 | 4 | 2 |
| 0.7 | 5 | 2⅓ |
| 0.8 | 6 | 2⅔ |
| 0.9 | 8 | 3 |
| 1.0 | 10 | 3⅓ |
| 2.0 | 100 | 6⅔ |
| 3.0 | 1,000 | 10 |
| 4.0 | 10,000 | 13⅓ |
| 5.0 | 100,000 | 16⅔ |
| 6.0 | 1,000,000 | 20 |

When you use neutral density filters, be sure you don't confuse their density values. For example, a 0.50 neutral density filter reduces the light by approximately 3 times while a 5.0 neutral density filter reduces the light by 100,000 times.

Some neutral density filters are identified as 2X, 4X, 8X, and 10X. These designations indicate the filter factor and are equivalent to the following densities: 2X = 0.30, 4X = 0.60, 8X = 0.90, and 10X = 1.00. The filter factor indicates how many times the filter reduces the light. For example, a filter factor of 4 means that the filter reduces the light by 4 times.

*Be sure of terminology when ordering neutral density filters. Obtain a 4.0 filter, not a 0.40 or 4X filter.*

Although gelatin-film neutral density filters are protected by a thin lacquer coating, you should handle these filters only by the edges or at the extreme corners. The KODAK Gelatin Filter Frame, a two-part metal frame, is a convenient accessory for handling gelatin filters. You can use the filter frame with the KODAK Gelatin Filter Frame Holder, which you attach to your camera lens with an appropriate adapter ring. The filter frame holder is convenient to use because you can change filters rapidly, but it's not a necessity. You can attach the filter frame, or even the filters alone, to the lens with small strips of pressure-sensitive tape.



## Exposure Table

The exposure recommendations in the table entitled table "Solar Eclipse—Approximate Exposures for Still Cameras." are based on results obtained in actual solar eclipse photography with clear viewing conditions. So much depends on atmospheric conditions, however, that you should regard these exposures only as approximate guides.

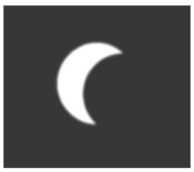
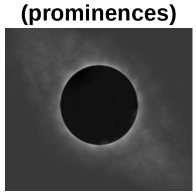
Exposure for each phase of the eclipse, especially during totality, can vary over a wide range and still produce good photographs. If you take several pictures at different exposure times and settings, each picture should show different details of the eclipse. Therefore, for the best coverage, bracket the suggested exposure. Take pictures at the estimated exposure and at 1, 2, and 3 stops less exposure and more exposure than the estimate.

You can calculate exposure times for lens openings other than those given in the table. Suppose the effective lens opening of your lens is *f*/32 and the table suggests *f*/8. Divide 32 by 8 and square the answer:

$$\frac{32}{8} = 4 \quad \text{and} \quad 4^2 = 16$$

Therefore a lens opening of *f*/32 will require an exposure 16 times as long as that required at *f*/8.

**Solar Eclipse—Approximate Exposures for Still Cameras**

| ISO Speed | Partial Phases  | Totality (prominences)  | Totality (inner corona)  | Totality (outer corona)  |
|---|---|---|---|---|
| 25—32 | *f*/5.6<br>5.0 ND<br>1/125 | *f*/3.5<br>No Filter<br>1/125 | *f*/3.5<br>No Filter<br>1/15 | *f*/3.5<br>No Filter<br>1/2 |
| 40—50 | *f*/6.3<br>5.0 ND<br>1/125 | *f*/4.5<br>No Filter<br>1/125 | *f*/4.5<br>No Filter<br>1/15 | *f*/4.5<br>No Filter<br>1/2 |
| 64—100 | *f*/8<br>5.0 ND<br>1/125 | *f*/5.6<br>No Filter<br>1/125 | *f*/5.6<br>No Filter<br>1/15 | *f*/5.6<br>No Filter<br>1/2 |
| 125—160 | *f*/11<br>5.0 ND<br>1/125 | *f*/8<br>No Filter<br>1/125 | *f*/8<br>No Filter<br>1/15 | *f*/8<br>No Filter<br>1/2 |
| 200—250 | *f*/16<br>5.0 ND<br>1/125 | *f*/11<br>No Filter<br>1/125 | *f*/11<br>No Filter<br>1/15 | *f*/11<br>No Filter<br>1/2 |
| 400—650 | *f*/16<br>5.0 ND<br>1/250 | *f*/16<br>No Filter<br>1/125 | *f*/16<br>No Filter<br>1/15 | *f*/16<br>No Filter<br>1/2 |
| 1000—1250 | *f*/16<br>5.0 ND<br>1/500 | *f*/16<br>No Filter<br>1/250 | *f*/16<br>No Filter<br>1/30 | *f*/16<br>No Filter<br>1/4 |

**Note:** ND indicates neutral density filter. Equivalent exposures may be used: 5.0 ND at *f*/11, 3.0 + 2.0 ND at *f*/11, or 4.0 ND at *f*/32 approximately.

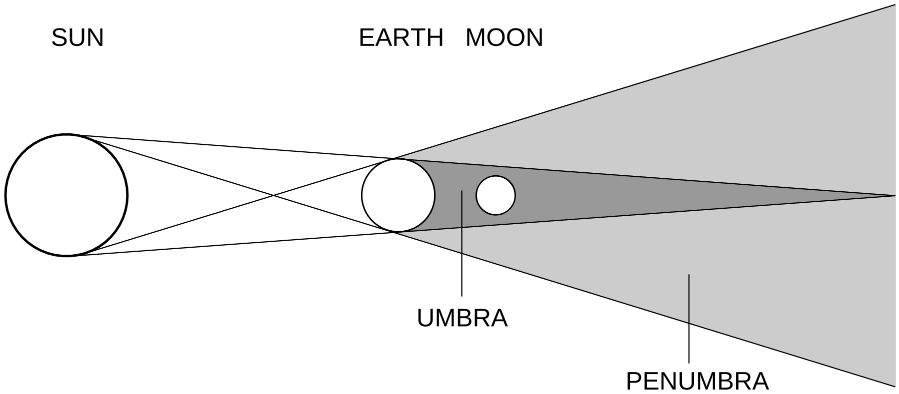
## KODAK Films

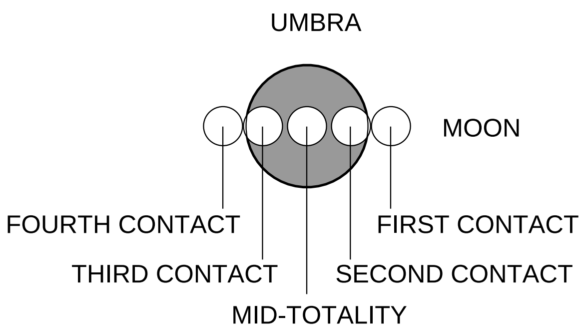
For the partial phases, you can use any film for general photography. For the most interesting phases of an eclipse, those occurring during totality, a high-speed film is desirable. The following films are suggested for photographing the eclipse. You can use the ISO speeds with the exposure table on page 14 and with the formula on page 11.

| **KODAK Black-and-White Films** | **Film Speed** |
|---|---|
| KODAK PROFESSIONAL T-MAX 100 Film | 100 |
| KODAK PROFESSIONAL PLUS-X 125 Film | 125 |
| KODAK Black & White + 400 Film | 400 |
| KODAK PROFESSIONAL T-MAX 400 Film | 400 |
| KODAK PROFESSIONAL TRI-X 400 Film | 400 |
| KODAK PROFESSIONAL PORTRA 400BW Film | 400 |
| KODAK PROFESSIONAL T400 CN Film | 400 |
| KODAK PROFESSIONAL T-MAX 3200 Film | EI 1000 to 25,000 |
| KODAK PROFESSIONAL Technical Pan Film | EI 25 to 200 |
| **KODAK Color Print Films** | |
| KODAK Bright Sun Film | 100 |
| KODAK ROYAL GOLD 100 Film | 100 |
| KODAK PROFESSIONAL SUPRA 100 Film | 100 |
| KODAK PROFESSIONAL PORTRA 160VC Film | 160 |
| KODAK Bright Sun and Flash Film | 200 |
| KODAK MAX Versatility Film | 400 |
| KODAK PROFESSIONAL SUPRA 400 Film | 400 |
| KODAK PROFESSIONAL PORTRA 400VC Film | 400 |
| KODAK MAX Versatility Plus Film | 800 |
| KODAK PROFESSIONAL SUPRA 800 Film | 800 |
| KODAK PROFESSIONAL PORTRA 800 Film | 800 |
| **KODAK Color Slide Films** | |
| KODACHROME 64 Film | 64 |
| KODAK EKTACHROME 64 Professional Film | 64 |
| KODACHROME 64 Professional Film | 64 |
| KODAK ELITE Chrome 100 Film | 100 |
| KODAK ELITE Chrome Extra Color 100 Film | 100 |
| KODAK PROFESSIONAL EKTACHROME Films E100S, E100SW, and E100VS | 100 |
| KODAK EKTACHROME 100 Plus Professional Film | 100 |
| KODAK EKTACHROME 100 Professional Film | 100 |
| KODAK ELITE Chrome 200 Film | 200 |
| KODAK PROFESSIONAL EKTACHROME Film E200 | 200 |
| KODAK ELITE Chrome 400 Film | 400 |
| KODAK EKTACHROME 400X Professional Film | 400 |
| KODAK EKTACHROME P1600 Professional Film | EI 1600 |

# LUNAR ECLIPSE

## General Procedures




A lunar eclipse occurs when the moon passes through the shadow of the Earth. When the moon is within the umbra (or darkest) part of the Earth's shadow (see illustration), it is illuminated only by the light refracted through the Earth's atmosphere. This light is usually orange or brick-red. Totality, the length of time the moon is totally within the umbra, may last as long as 1 hour and 40 minutes. Before the moon moves into the umbra, it passes through an area of partial illumination, called the penumbra. In the penumbra, the moon appears nearly the same as when it's in the full light of the sun.

It's easy to photograph a lunar eclipse. However, because the moon is so dim during totality, you should use high-speed film. During totality, use the largest lens opening possible. This allows you to use shorter exposure times to stop the moon's motion in your photographs.

The moon may appear large to you, but when photographed through a lens of normal focal length, it will be a very small spot on the film. See "Sky Mapping."

Use the lens with the longest focal length available for your camera, and support the camera on a steady tripod. To record details on the moon, take your pictures through a telescope, spotting scope, or a binocular. See "Getting Started."

By making multiple exposures of the moon at regular intervals, you can obtain an interesting sequence showing the progression of the eclipse all in one photograph. To try this technique, you can either use a camera that allows you to make multiple exposures on the same frame of film; or you can alternately cover and uncover the lens. Check your camera manual. You should use a normal-focal-length lens so that you can get the whole series in one picture. Aim your camera so that the picture will include the path of the moon as the Earth's rotation moves it across the sky from east to west.

To capture the sequence, begin taking pictures as the moon moves into the umbra. Make exposures at 6-minute intervals so that the images of the eclipse will be evenly spaced across the film frame. A normal-focal-length lens will cover an angle of view sufficient for about a 2-hour series of exposures. Since the images of the moon will be quite small, you may want to have an enlargement made.

### Lunar Eclipse Exposures

Lunar eclipses vary in duration and differ greatly in apparent brightness and color. Variations in atmospheric conditions and in the distance of the moon above the horizon may affect the moon's apparent brightness, making exact recommendations impossible. Use the exposures suggested in the table “Lunar Eclipse Exposure Recommendations” as guides only. If the sky is hazy or if the moon is low in the sky, try doubling the recommended exposure time.

When you’re taking single pictures of the moon, it’s a good idea to bracket the estimated exposure for more assurance of properly exposed pictures. Try 1 and 2 stops more and less exposure than that recommended in the table “Lunar Eclipse Exposure Recommendations.”

When the moon is partially in the umbra, where you can see a definite shadow line across its surface, select the exposure for either the umbra portion or the penumbra portion. The film cannot properly record both areas at the same time.

Gradually increase the exposure from the second contact to mid-totality; decrease the exposure from the second contact to the third contact. (See "Lunar Eclipse Exposure Recommendations" table.)

You can calculate exposure times for f-numbers other than those given in the table. Suppose your largest lens opening is *f*/5.6 and the table suggests *f*/2.8. Divide 5.6 by 2.8 and square the answer: 5.6 / 2.8 = 2, and $2^2 = 4$. This means the *f*/5.6 lens opening will require an exposure 4 times as long as that required with a lens opening of *f*/2.8. For example, if the table suggests 1 second at *f*/2.8, you can use 4 seconds at *f*/5.6.

The moon appears to move a distance equal to approximately half its diameter in 1 minute. If the exposure time with a normal-focal-length lens is longer than 10 seconds, the moon motion is likely to be evident in the photograph. If you use a telephoto lens or a telescope with your camera, the maximum exposure time must be even shorter.

You can use the following formula to determine the approximate maximum exposure time for sharp pictures of the moon with a telephoto lens or telescope.

$$\frac{\text{Focal length of normal lens}}{\text{Focal length of telephoto lens (or telescope)}} \times 10 = \text{Maximum exposure time in seconds}$$

For example, suppose the normal lens for your 35 mm camera has a focal length of 50 mm and you want to use a telephoto lens of 400 mm

Then $\frac{50}{400} \times 10 = 1.25$

The answer, 1.25, means that the maximum exposure time for sharp pictures of the moon with 400 mm lens is about 1 second.

Of course, longer exposure times can be used if you put your camera onto an equatorial telescope mounting that is driven to compensate for Earth's rotation.

**Lunar Eclipse Exposure Recommendations**

| **Stage of Eclipse** | **ISO Film Speed** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **25–32** | **64–80** | **100–125** | **200** | **400** | **800–1000** | **1250–1600** | **3200** |
| Full moon, clear sky | 1/250 *f*/5.6 | 1/250 *f*/8 | 1/250 *f*/11 | 1/250 *f*/16 | 1/250 *f*/22 | 1/500 *f*/22 | 1/1000 *f*/22 | 1/2000 *f*/22 |
| Moon deep in penumbra up to FIRST contact and after FOURTH contact | 1/60 *f*/5.6 | 1/60 *f*/8 | 1/60 *f*/11 | 1/60 *f*/16 | 1/125 *f*/16 | 1/250 *f*/16 | 1/500 *f*/16 | 1/1000 *f*/16 |
| At SECOND and THIRD Contacts | 2 *f*/2 | 1 *f*/2 | 1 *f*/2.8 | 1 *f*/4 | 1/4 *f*/2.8 | 1/8 *f*/2.8 | 1/15 *f*/2.8 | 1/30 *f*/2.8 |
| MID-TOTALITY | 8 *f*/2 | 4 *f*/2 | 2 *f*/2 | 2 *f*/2.8 | 1 *f*/2.8 | 1/2 *f*/2.8 | 1/4 *f*/2.8 | 1/8 *f*/2.8 |

See section " KODAK Film."

**Note:** All exposure tines are in seconds or fractions of a second. With color negative films, use 1/2 stop larger lens opening than indicated in the table.

Consumer Imaging
**EASTMAN KODAK COMPANY • ROCHESTER, NY 14650**





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