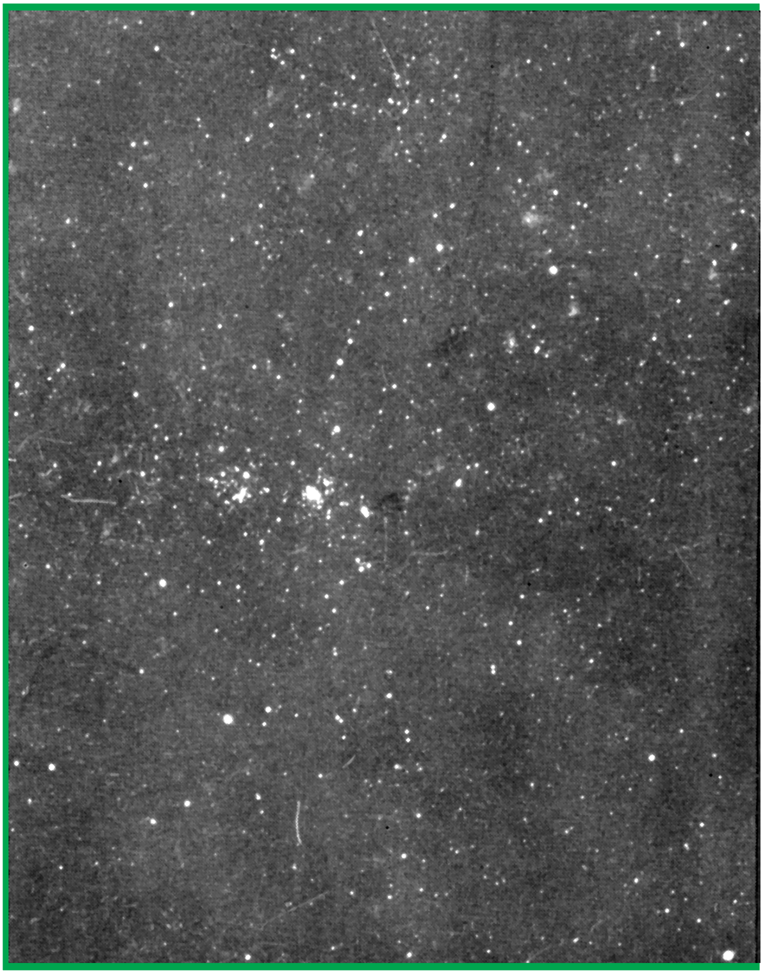
Handbook of
Astrophotography
for Amateur Astronomers



G. N. Patterson

Handbook of

Astrophotography

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SECOND EDITION

G. N. Patterson

Saskatoon Centre, R.A.S.C.

Compiled for use as reference material in a course in
Astrophotography

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The Author

Gordon N. Patterson, DFM CD BE, was born in Woodrow, Saskatchewan, received his B.Sc. in Engineering Physics from the University of Saskatchewan, served 26 years in the Royal Air Force and Royal Canadian Air Force during and after World War II, retiring in 1966 with the rank of Squadron Leader. Although he had an early interest in astronomy, he did not become actively involved until the formation of the Saskatoon Centre, R.A.S.C. in 1969, when he was elected as Secretary of the Centre. He has been active in various roles in the Centre ever since that date, and started, and continues to give training to new members in fundamentals of astronomy and astrophotography. He was given a Life Membership in the Royal Astronomical Society of Canada in 1979 by the Saskatoon Centre, and was awarded the Society's Service Medal at the annual R.A.S.C. General Assembly held in Saskatoon in 1982. He has recently retired from the Physics Department of the University of Saskatchewan.

FORWARD

Most persons with a hobby interest in astronomy will eventually attempt astrophotography. This initially may be no more than photographing the moon and lunar eclipses. Success with these inevitably lead to more ambitious projects — photographing the sun and solar eclipses, and some of the more distinctive planets and constellations. The problems are varied and numerous. They include attachment of a suitable camera to a telescope, focusing the camera, selection of suitable film or plates and filters, choice of exposure time and the processing of the exposure. All these and more, Mr. Gordon Patterson has outlined in sufficient detail in this *Handbook* so that the amateur, by following the information which is provided, can anticipate success with a minimum of trial-and-error attempts. This is particularly important in the photography of infrequent phenomena like eclipses.

The information provided by Mr. Patterson is particularly useful to the amateur astronomer, since he started as an amateur and acquired his knowledge of astrophotography by consulting the technical literature on the subject, and through experimentation with the actual photography. While some technical detail is included, the descriptive material is presented in such a way as to be directly useful to a person attempting astrophotography for the first time. Reference to it will help avoid numerous disappointments, even though, as Mr. Patterson emphasizes, detailed notes on film, filters, exposure times and so on are necessary so that these can be used to improve the procedures followed for subsequent photography. It is a pleasure to recommend this *Handbook* for use by the amateur astrophotographer, and also for those who have already acquired some experience.

Dr. Balfour W. Currie, C.C., Ph.D., FRSC.

PREFACE

This *Handbook of Astrophotography for Amateur Astronomers* was originally prepared as a series of hand-outs for use in a course on astrophotography given to members of the Saskatoon Centre, R.A.S.C. by Mr. Gordon N. Patterson.

The material contained in this *Handbook* is not necessarily original, but has been gleaned from a variety of sources, ie, University courses, articles published from time to time in astronomy and science publications, photographic publications, etc., but is largely a condensation of data proven out by trial-and-error techniques over a lengthy period of time. Because of this, a compilation of a bibliography would be extremely difficult.

Numerous graphs are used since they are more inclusive of data than tables of figures — it is possible to pick off a precise point on a graph instead of extrapolating data from figures given in a table. Tables are used, however, where that form of presentation is preferable.

No attempt is made in this *Handbook* to cover data that is readily available in other publications, such as developing and printing, types of films, etc., except where this information is unique to the process or method being described. Recommended publications that should be used to complement this *Handbook* are *Kodak's Darkroom Guides*. Other publications are mentioned as their use arises.

This *Handbook* has been subject to several revisions, and no doubt, will be subject to more later. Astrophotography is an on-going subject, with new techniques and methods being developed all the time, and the author would be the last to indicate that this *Handbook* was the "final answer." It is only a start in the right direction to becoming a good amateur astrophotographer.

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SECTION 1 — INTRODUCTION

Astrophotography is, literally, the taking of photographs of astral or sky objects such as the sun, moon, planets, stars and deep sky objects. It has also come to mean taking photographs of atmospheric phenomena such as aurora, meteor showers, parahelia, etc. A good astrophotograph is the result of experience, knowledge of the equipment to be used, and an element of luck. The good luck element can be largely, but not totally, eliminated by a good understanding of the various factors involved, and the use of proper techniques. The object of this *Handbook* is to summarize many of the techniques, some of which are unique, used in astrophotography.

Astrophotography differs from normal, routine photography in that:

a. The object to be photographed is usually very distant.
b. With the exception of the Sun, most objects are so poorly illuminated that a normal "built-in" light meter, or an external light meter are of no value in determining the exposure times required.
c. Focusing in a TTL (Through The Lens) camera is very difficult due to the poor illumination and size of the object, so special techniques are required to obtain a precise focus; the normal ground-glass screen built into a camera requires too much light to give a sharp image at focus.
d. Due to the small size of the object, some pre-magnification is usually needed ahead of the film plane, resulting in a long exposure time.
e. Long exposure times can only be obtained by accurate tracking of the object being photographed. This requires special ancillary equipment.
f. Long exposure times can result in film fogging. This can be minimized by correct selection of film and the proper use of filters.
g. Long exposure times result in low-intensity reciprocity failure. Proper techniques can minimize the effect of this failure but cannot nullify it completely. With colour film only the use of a cold camera (below freezing point) can produce satisfactory results.

h. Absolute precision in polar alignment and mounting rigidity are mandatory due to the extremely long focal lengths used. Even the slap of the focusing mirror can introduce unacceptable vibrations.
i. Atmospheric refraction, and air and light pollution cause special problems. The newer nebular filters can minimize some of the effect of light pollution, but the other forms must be tolerated and worked around.

The above lists some, but not all, of the problems encountered by the budding astrophotographer. Don't lose hope and give up. Most can be minimized using proper techniques coupled with trial-and-error methods. What may work ideally for one individual does not necessarily produce the same results with someone else. Experience is gained by making mistakes — do not discard the data that gave an unacceptable picture; store it away so that you know what not to do the next time. This is what experience is all about. Further, do not be ashamed to use someone else's ideas. An experience shared is another form of learning, and it will add up to your own fund of experience in this fascinating hobby.

SECTION 2 — GENERAL CONSIDERATIONS

2.1 LOCATION

One of the primary conditions for good astrophotography is the location of the telescope. While good photographs can be taken of some of the brighter astronomical objects in built-up urban areas, (usually with special filters), the preferred location is one well away from urban areas and their resultant air and light pollution problems. A dark area will permit longer exposures without film fogging, and is practically mandatory when photographing Deep Sky Objects. Other aspects should also be taken into account such as:

a. Accessibility, particularly in wintertime. It is no good having the perfect site if you cannot get to it when you need to. Also covered under this heading is the distance that has to be travelled to get to the site. If you have to travel several hours to get to the site, this is so much time taken away from useful photographing time.
b. Shelter availability. This is most important during winter, when even a mild breeze at −20°C can be insufferable. This, of course, is why so many private observatories get built.
c. Horizon Masking — if you are interested in planetary work, a good clear horizon is essential. A grove of trees or brush in the wrong place can seriously inhibit the usefulness of a site.
d. Freedom from vandalism — in this day and age, a site that is quite free from wanderers in summertime may be inundated with powered recreation vehicles in wintertime. It is often preferable to relax on some of the other requirements to ensure this criteria is met — usually an obliging farmer can be found who will provide some safeguards against unauthorized entry and vandalism.

2.2 THE TELESCOPE

An accurately tracking, equatorial-mounted telescope, fitted with a variable frequency drive, rigidly mounted and accurately oriented for correct latitude and true north, is essential for long exposure photographs. If a refracting-type telescope is used, it should normally not be faster than f/15 to minimize achromatic aberration. For a reflector-type telescope, speed should normally not exceed f/8, although excellent photographs have been taken with reflectors with faster speeds than this, ie, f/4.5 The main reason for this is to minimize coma. Special type astro-cameras, such as the Schmidt Camera can have speeds as fast as f/0.5. Provision has to be made for visually "tracking" a nearby star during the exposure time. This is best provided by an ancillary telescope that is accurately collimated with the main telescope, and is equipped with a reticle using lighted crosshairs. Tracking power is dealt with later, but roughly averages about 5-power per inch of focal length of the "camera" objective, or camera effective focal length. Further, a wind-proof shelter around the telescope is almost essential, both from the point of view of the photographer's comfort, and to prevent wind vibration of the telescope.

2.3 RECORDING

A very essential feature to successful astrophotography is the keeping of accurate records of all photos taken, including all dates and times, exposure times, films used, seeing conditions, objects photographed, etc. These data will provide the tyro and experienced astrophotographer with a fund of information that will act as a "yardstick" for future photographs. A simple method that the author has used on occasion is to use a small battery-operated cassette recorder while at the telescope, and transcribing the information later to the back of the finished print, or a proper log sheet, for a permanent record. Further, transcribing this basic information onto prints used for display of competitive purposes gives everyone a chance to see how it was "done" and provides a "share-the-wealth" concept with new and budding astrophotographers.

SECTION 3 — THE CAMERA

The best camera to use for astrophotography is one that has been especially designed for this type of photography. Such a camera is designed to mount directly onto a telescope, has provision for changing the degree of magnification of the image on film, is fitted to take the special filters used in astrophotography, has a shutter free from any vibration, and has provision for precise focusing.

Such cameras are available, and are not necessarily as expensive as one might think. A type used professionally is diagrammed below.

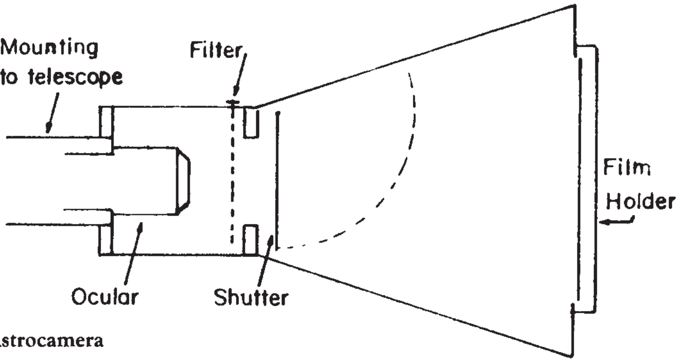


Figure 3.1 - Astrocamera

The camera shown above is designed to use sheet or plate glass film. The ocular provides a method of changing magnification by using the projection method (q.v.), and the shutter is operated by a pneumatic bulb or electrical release. In the more professional cameras some provision is made for chilling the film plates to cryogenic or dry ice temperatures to minimize the problem of reciprocity failure (q.v.). Notice that the camera is not equipped with a light meter as it is of little or no value for this type of usage.

The ideas shown above have been incorporated in some 35-mm format cameras, and can be seen advertised in various astronomy magazines. In these cameras, focusing is done in free air — not on a ground-glass screen — by means of an ocular focused on to a clear glass focusing screen on which a cross-hair has been engraved.

The camera within the price range of the average amateur that can be readily adaptable for astrophotography is the 35-mm through-the-lens (TTL) focusing camera, preferably with a removable lens. The built-in light meter is of no value for astrophotography, but can be used for normal snap-shots. If possible, it is desirable to obtain a camera where the focusing mirror can be locked out of the way. This will prevent the so-called "mirror-slap" that can make a camera vibrate when a picture is taken on the average telescope mounting. It is also desirable if the focusing screen can be removed and a special clear screen installed, together with a special focusing ocular that can be adjusted to focus precisely on the clear glass screen.

When the camera lens is removed, a plastic T-compatible adapter fits into the camera in place of the lens, and a metal T-adapter screws into the T-compatible adapter, and onto the telescope. In some cases a special fitting is used to screw into the T-compatible adapter, and is inserted into the ocular focusing assembly in place of the ocular. This permits using the telescope as a "telephoto" lens. On the other hand, the camera lens can be left on the camera, and the camera mounted onto the telescope. This will give a wider format picture when the telescope is guided to follow the sky.

A permanent lens camera can be used for astrophotography, but its application is limited to the Afocal Method (q.v.), or wide angle, piggy-back type photos.

SECTION 4 — ASTROCAMERA SYSTEMS

This section outlines briefly the various "systems" in use for taking astrophotos. Details on each system will be described in later sections.

4.1 - THE MOUNTED CAMERA

All astrocameras should be mounted, either on a sturdy tripod, or piggy-back onto a telescope. The camera, in either case, uses its own lens, either wide-angle, normal, or telephoto, depending upon the coverage desired. When mounted on a tripod, the sky "moves" with relation to the camera, and the picture will show "star-trails" which have the true North Pole as their center. The length of the trail will depend upon the length of the exposure. The same technique is used during a meteor shower, where the camera shutter is left open for some time in hopes that a meteor will flash past through the center of view of the camera.

Where the camera is mounted "piggy-back" on the telescope body, and the telescope aligned to north and either driven or tracked correctly, excellent constellation pictures are obtained without trailing images.

4.2 - DIRECT OBJECTIVE or PRIME FOCUS SYSTEM

In this system, the camera lens is removed and a T-adapter is used to couple the camera body to the telescope. No eyepiece or ocular is used in the camera system. The camera is focused using the telescope focusing rack-and-pinion until the camera film plane is at the focal point of the telescope Objective. Essentially, the Objective becomes the camera lens, and is a telephoto lens equalling the effective focal length of the telescope Objective, ie, the image on the film plane is the First Image or Direct Objective at the Objective Prime Focus, hence the name.

4.3 - THE AFOCAL SYSTEM

In this system, the camera lens remains on the camera, and an ocular or low-powered eyepiece is used in the telescope. This is the only coupled system that can be used with a fixed-lens camera or with fixed-eyepiece telescopes (binoculars). Magnification results as long as the camera lens has a greater focal length than that of the ocular.

4.4 - PROJECTION SYSTEMS

In these systems, an eyepiece or special projection lens is placed between the telescope and the film plane to project a magnified image onto the film plane. Two such systems are used, a Positive Projection System (one using a positive projection lens), and a Negative Projection System, where a negative projection lens is used. In either case the result is the same, the Prime or First Image is projected in an enlarged format on the film plane. In both systems, the lens used for projection should have a flat field or stars at the outer edges of the field will be out-of-focus when the central stars are in focus. The only alternative to using a flat-field lens is to use a curved film plane which can be extremely difficult to fabricate.

SECTION 5 — THE DIRECT OBJECTIVE or PRIME FOCUS SYSTEM

This telecamera system is so named because the film plane is at the prime focus of the telescope Objective, lens or mirror. Of all coupled systems, this is optically the fastest, resulting in the shortest exposure time, but with the smallest image.

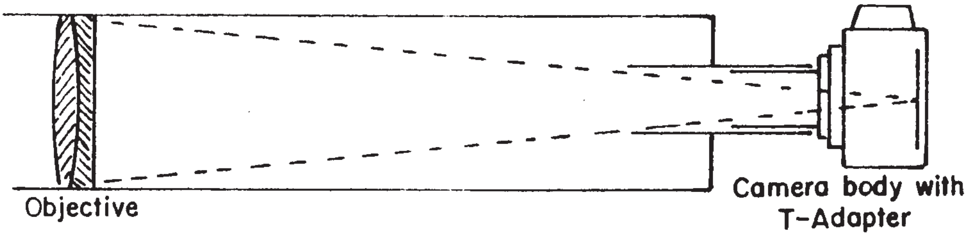


Figure 5.1 - Prime Focus System

Mechanically, the system is simple. The camera lens is removed and replaced with a T-compatible adapter ring into which is mounted a telescope-to-adapter unit which fits directly in place of, or in, the telescope eyepiece tube. No additional mounting struts or braces are required. Focusing is done using the telescope focusing unit. The camera-to-adapter unit can be obtained for a variety of cameras, to adapt directly to the 2-inch Celestron fitting, the 1¼-inch OD ocular fitting, or to the Japanese telescopes with 0.960-inch OD fitting.

In a refractor-type telescope, there is usually plenty of focus travel so there is no problem in positioning the camera film at the prime focus of the Objective. This same situation does not hold with most reflector (Newtonian) telescopes, as the focus travel is limited and the prime focus is located inside the eyepiece tubing. In such a case, the only practical solution is to position the Objective mirror forward about 2 or 3 inches until the prime focus is outside the eyepiece tube. An extension tube, such as an empty Barlow Lens tube, can be used to move the ocular out to the new position of the prime focus. One disadvantage of moving the mirror is that the diagonal does not reflect all of the light rays into the camera (vignetting), so the effective aperture is reduced. It should be noted that only the reflector-type telescope gives a colour-pure image as there is no achromatic aberration with a mirror. The speed of the system is given by the f/number:

$$f/\# = \frac{\text{Effective Focal Length of Objective}}{\text{Effective Aperture of the Objective}}$$

SECTION 6 — THE AFOCAL SYSTEM

The afocal system is the only coupled system that can be used with a fixed-lens camera, or a fixed ocular telescope (binocular). The major problem in using this system is mounting the camera so that its optical axis coincides exactly with that of the telescope, but incorporating into the mounting a feature whereby the camera can be easily swung out of the way for telescope focusing.

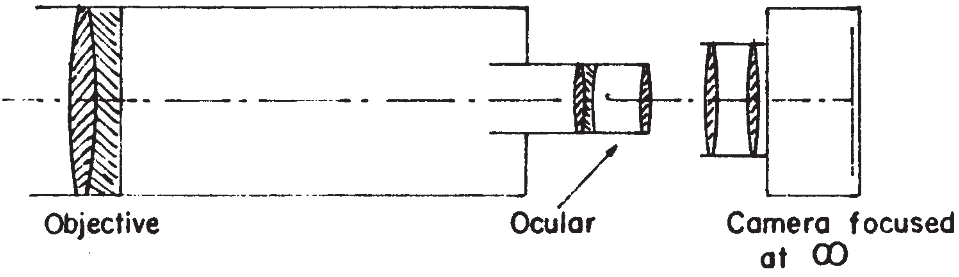


Figure 6.1 - The Afocal System

The telescope, complete with eyepiece, is first focused visually so the sky object appears in sharp focus. This means that the rays of light leaving the eyepiece are parallel, or the object appears to be at Infinity. The camera lens is then set at Infinity focus, with the aperture wide open (lowest f/number). The camera lens is placed close to the eyepiece, and may have to be enclosed to prevent outside light from entering the camera lens. The best separation distance between the camera lens and the eyepiece is found by experimenting to minimize any vignetting (cutting-off-corners) of the film image. To obtain any magnification of the prime image, the eyepiece must have a smaller Effective Focal Length than that of the camera lens.

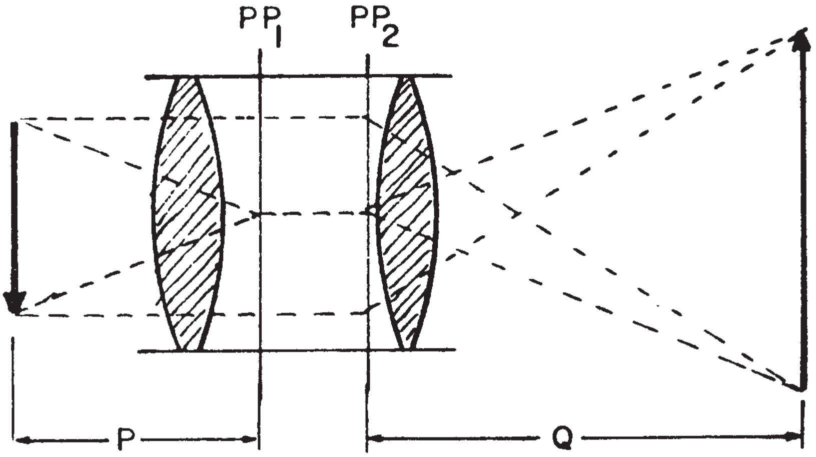
The following mathematical relationships apply to the Afocal System and will assist in determining the kind of image to be expected:

$$\text{Projection Magnification (M)} = \frac{\text{E.F.L. of Camera Lens}}{\text{E.F.L. of Eyepiece}}$$

$$\begin{aligned}\text{E.F.L. of System} &= \text{E.F.L. of Telescope Objective} \times \text{M}\\ &= \text{Power of Telescope} \times \text{E.F.L. of Camera Lens}\end{aligned}$$

$$\begin{aligned}\text{f/\#} &= \frac{\text{Power of Telescope}}{\text{Usable Aperture}} \times \text{E.F.L. of Camera Lens}\\ &= \frac{\text{E.F.L. of Objective} \times \text{E.F.L. of Camera Lens}}{\text{E.F.L. of Eyepiece} \times \text{Usable Aperture of Objective}}\\ &= \text{f/number of Telescope} \times \text{Projection Magnification}\end{aligned}$$

The Afocal System has one major advantage — it is very easy to achieve a sharp focus, unless you have other trouble with your eyes, such as astigmatism, etc. The major drawback is the mechanical system needed for mounting the camera. While very short exposures can be taken while manually holding the camera lens to the telescope, it is very difficult to maintain the stability needed to obtain a clear photo. For longer time exposures, the mechanical system to hold the camera becomes absolutely mandatory. It does, however, get away from the need for moving the primary mirror in a Newtonian reflector, and might prove the preferred method for someone who does not want to take on the task of moving his mirror, then re-collimating his telescope. It is also the method to use at Star Nights, where some enthusiastic viewer wants to take a picture of the Moon through your telescope and you do not have the adapter for his camera, or his lens does not come off. It is also the only method that can be used to couple a camera to your binoculars where you cannot remove the eyepiece.



Principal Planes of Dual Lens Ocular

SECTION 7 — PROJECTION SYSTEMS

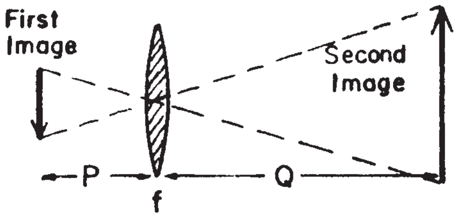
Projection systems are the most versatile of all tele-optical systems in that they allow a wide variation of image magnification and give a reasonably sized image that does not require too much enlargement to produce an acceptable print. They do, however, have one major drawback — they are difficult to focus accurately, with the degree of difficulty increasing with magnification. In addition, exposure time increases with the square of the f/number, so a very stable, accurate tracking system becomes essential. The mechanical system is, however, relatively simple and rugged.

Magnification in Projection Systems is dependent on two things: the effective focal length of the Projection Lens, and the Projection Distance between the lens and the film plane.

The terms of "Positive" or "Negative" projection come from the type of projection lens used. Positive projection uses a projection lens with a positive focal length (+), ie, convex, whereas Negative projection uses a projection lens with a negative focal length (−), ie, concave, such as the traditional Barlow Lens.

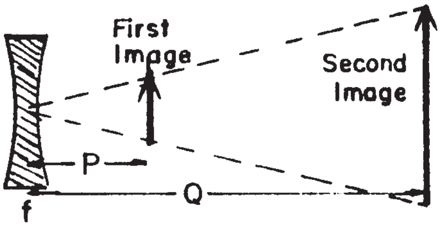
7.1 - PROJECTION SYSTEM GEOMETRY

POSITIVE



$$M = \frac{Q - f}{f}$$

NEGATIVE



$$M = \frac{Q + f}{f}$$

P = distance from first image to Principal Point$_1$ of lens
Q = distance from film plane to Principal Point$_2$ of lens
M = Projection Magnification = Q/P
f = effective focal length of projection lens

SECTION 8 — POSITIVE PROJECTION SYSTEM

The projection lens is usually a good quality, colour-corrected standard ocular with, of course, a positive focal length.

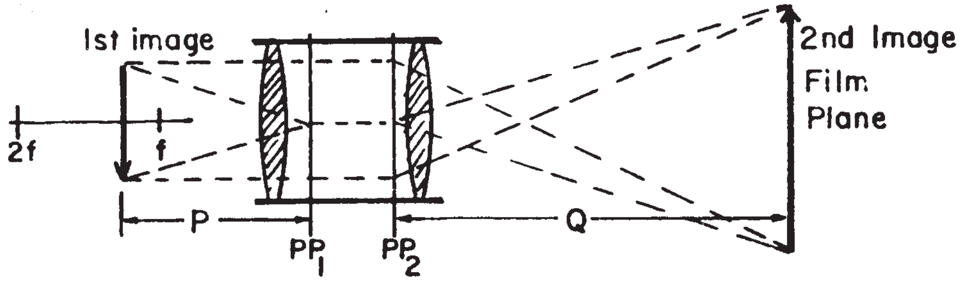


Figure 8.1 - Positive Projection System

The distances, P, and Q, are measured from the Principal Planes of the Projection Lens. Where a simple convex lens system is used, these distances are measured from PP_1 and PP_2, the front and rear Principal Planes. As these positions are very difficult to determine, the author has devised a different method to obtain magnification, which will be discussed later in this book. The distance, P, is always greater than one focal length of the ocular, but less than two focal lengths. Note: if $P = 2 \times f_1$, the Projection Magnification is equal to unity or 1.

From lens formulae, $\frac{1}{f} = \frac{1}{P} + \frac{1}{Q}$; *or* $f = \frac{P \times Q}{P + Q}$; *and* $M = \frac{Q}{P}$

$$Q = f(M + 1) = P \times M = \frac{P \times f}{P - f}$$

$$P = f + \frac{f}{M} = \frac{Q}{M} = \frac{Q \times f}{Q - f}$$

$$M = \frac{f}{P - f} = \frac{Q}{P} = \frac{Q - f}{f}$$

$$f = \frac{P \times M}{1 + M} = \frac{Q}{1 + M} = \frac{P \times Q}{P + Q}$$

For the entire telecamera system:
$\text{E.F.L.}_{\text{system}} = \text{E.F.L.}_{\text{objective}} \times$ Projection Magnification; and,
$\text{f/number} = \text{f/\#}_{\text{objective}} \times \text{Projection Magnification} = \frac{\text{E.F.L. of System}}{\text{Objective Aperture}}$

SECTION 9 — NEGATIVE PROJECTION SYSTEM

In the Negative Projection System, the projection lens should be a good quality achromatic negative lens. For most purposes a good achromatic Barlow lens is adequate, and if it is adjustable in its mounting, a variety of projection magnifications can be obtained by varying the projection distance, so that one lens will take the place of several to provide changes in magnification.

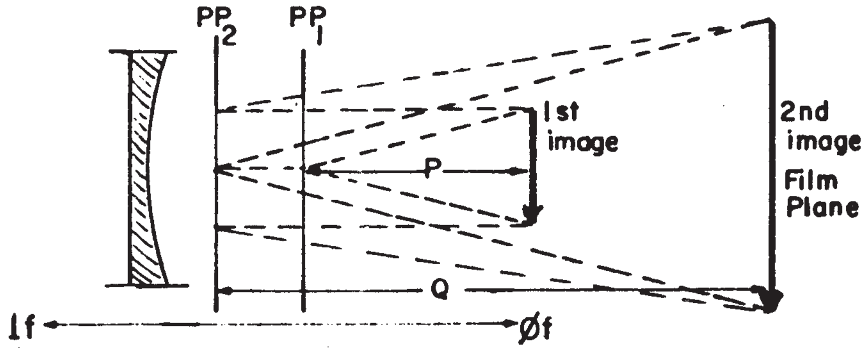


Figure 9.1 - Negative Projection System

The distances P and Q are measured from the principal planes of the negative lens, but since "f" is negative, the point P is on the same side of the lens as the point Q and the film plane. The distance P may be considered negative in the conventional system of designating positions. The distance P must be greater than zero but less than one focal length of the negative lens.

The following lens formulae apply for negative projection:

$$Q = f(M - 1) = P \times M = \frac{f \times P}{f - P}$$

$$P = f - \frac{f}{M} = \frac{Q}{M} = \frac{f \times Q}{f + Q}$$

$$M = \frac{f}{f - P} = \frac{Q}{P} = \frac{f + Q}{f}$$

$$f = \frac{P \times M}{M - 1} = \frac{Q}{M - 1} = \frac{P \times Q}{Q - P}$$

For the entire telecamera system:

$$\text{E.F.L.}_{\text{system}} = \text{E.F.L.}_{\text{objective}} \times \text{Projection Magnification}$$

$$\text{f/number} = \text{f/\#}_{\text{objective}} \times \text{Projection Magnification} = \frac{\text{E.F.L. of System}}{\text{Objective Aperture}}$$

SECTION 10 — IMAGE SIZE ON FILM

It is always useful to be able to determine the size of the photographic image on the film since, with a fixed size of film the required projection magnification to fill the film, or to give an acceptable size image, can be determined beforehand. This will assure that too high a projection magnification is not used, ensuring that all desired objects will be in the film frame size chosen. The image size can be calculated from the following formula, provided the angular size of the object being photographed is known:

$$\text{Image Size} = \frac{\text{Angular Size of Object in Arc-seconds} \times \text{E.F.L. of System}}{206{,}265}$$

The measurement units of the Image Size and the E.F.L. are the same, ie, if one is given in millimeters, so is the other. The number, 206,265, is the number of arc-seconds in one Radian.

The Angular size of some astronomical subjects is given in the following Table I:

10.1 - TABLE I - ANGULAR SIZES

Object	Minimum	Maximum	Object	Size
Sun	31.42’	32.50’	M1 - Crab Nebula	6’ × 4’
Moon	29.46’	32.88’	M8 - Lagoon	60’ × 35’
Mercury	4.60”	12.20”	M13 - Globular Cluster	23.2’
Venus	9.57”	65.56”	M27 - Dumbbell	8’ × 7’
Mars	3.53”	23.44”	M31 - Andromeda Nebula	158’ × 50’
Jupiter	30.58”	49.57”	M42 - Orion Nebulae	85’ × 50’
Saturn (Disc)	15.07”	20.77”	M44 - Beehive	90’
Saturn (Rings)	35.10”	48.35”	M45 - Pleiades	120’
Uranus	3.07”	3.75”	M51 - Whirlpool	10.7’ × 7’
Neptune	2.24”	2.44”	M57 - Ring Nebulae	1.4’ × 1’
Pluto	0.15”	0.27”	M97 - Owl	3.3’

Two charts, Chart I(a), and Chart I(b), have been prepared to show image sizes for various angular width objects at different effective focal lengths. Chart I(b) also has two horizontal lines drawn on it to represent the length and width of the standard 35-mm frame.

10.2 - USABLE FILM SIZE (35-mm)

Most amateur astrophotographers, and even some professionals, will use a 35-mm format camera, and it is of value to know the usable size of the film frame so that projection magnification may be determined. Plate film sizes are given with the film.

Width	×	Length
0.94 inch	×	1.40 inches
24.00 mm	×	36.00 mm

10.3 - SAMPLE CALCULATIONS ON IMAGE SIZES AND PROJECTION LENSES

PROBLEM: Given a telescope with an Objective E.F.L. of 2,000 mm and a Positive Projection distance of 160 mm, what should be the minimum E.F.L. of the Projection Lens to take a photo on 35-mm film of the Crab Nebula, 4' × 6', or 240" × 360"?

a. Determine E.F.L. of System required $= \dfrac{\text{Width of Film} \times 206{,}265}{\text{Angular Width of Object in Arc-seconds}}$

$$= \frac{24\text{ mm} \times 206{,}265''}{240''} = 20{,}626.50\text{ mm}$$

b. Determine Projection Magnification M $= \dfrac{\text{E.F.L. of System}}{\text{E.F.L. of Objective}} = \dfrac{20{,}626.50}{2{,}000} = 10.31\times$

c. Determine E.F.L. of the Projection Lens E.F.L. $= \dfrac{Q}{1 + M} = \dfrac{160}{1 + 10.31} = 14.14$ mm

The correct answer is to use a projection lens with an E.F.L. of 14.14 millimeters. The odds are such a lens would be hard to obtain, so use a lens nearer to that calculated figure, but ensure it has a longer focal length than that calculated. A 16-mm positive projection lens would be preferred in this case.

10.3.2 PROBLEM

What is the maximum angular arc in seconds that can be covered on a 35-mm film using the Prime Focus System with a telescope having an Objective Lens with an E.F.L. of 2,000 mm?

NOTE: Normally, 35-mm film is 24 × 36 mm.

$$\text{Angular Size in Arc-seconds} = \frac{\text{Image Size} \times 206{,}265}{\text{System E.F.L.}}$$

$$\text{i. Angular Width} = \frac{24 \times 206{,}265}{2{,}000} = 2{,}475.18'' = 41.25' = 0.69^\circ$$

$$\text{ii. Angular Length} = \frac{36 \times 206{,}265}{2{,}000} = 3{,}712.77'' = 61.88' = 1.03^\circ$$

Therefore, the sky coverage with this system is:

$= 2{,}475'' \times 3{,}713''$; or
$= 41.25' \times 61.88'$; or
$= 0.69^\circ \times 1.03^\circ$

10.4 - GENERAL

The two charts included in this section will provide a quick and ready reference to determine the coverage that can be obtained with different systems. They will also assist in selecting the proper system to provide the range you need to photograph any particular object. It is usually advisable to make your own tables to cover the equipment that you will normally be using for astrophotography so that the figures you specifically require are always at hand.

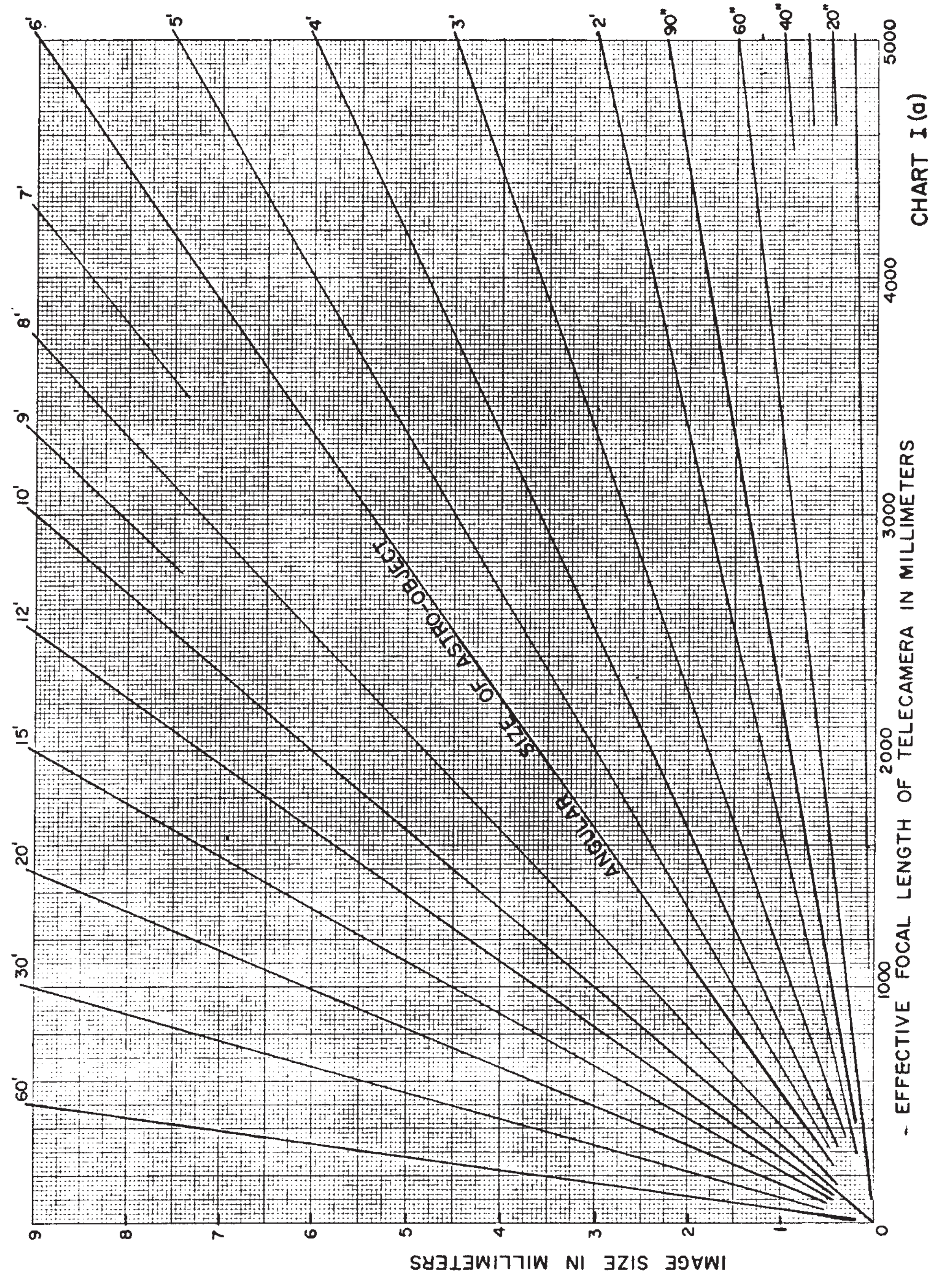


IMAGE SIZE IN MILLIMETERS
0
1
2
3
4
5
6
7
8
9
EFFECTIVE FOCAL LENGTH OF TELECAMERA IN MILLIMETERS
0
1000
2000
3000
4000
5000
ANGULAR SIZE OF ASTRO-OBJECT
60'
30'
20'
15'
12'
10'
9'
8'
7'
6'
5'
4'
3'
2'
90"
60"
40"
20"

CHART I (a)

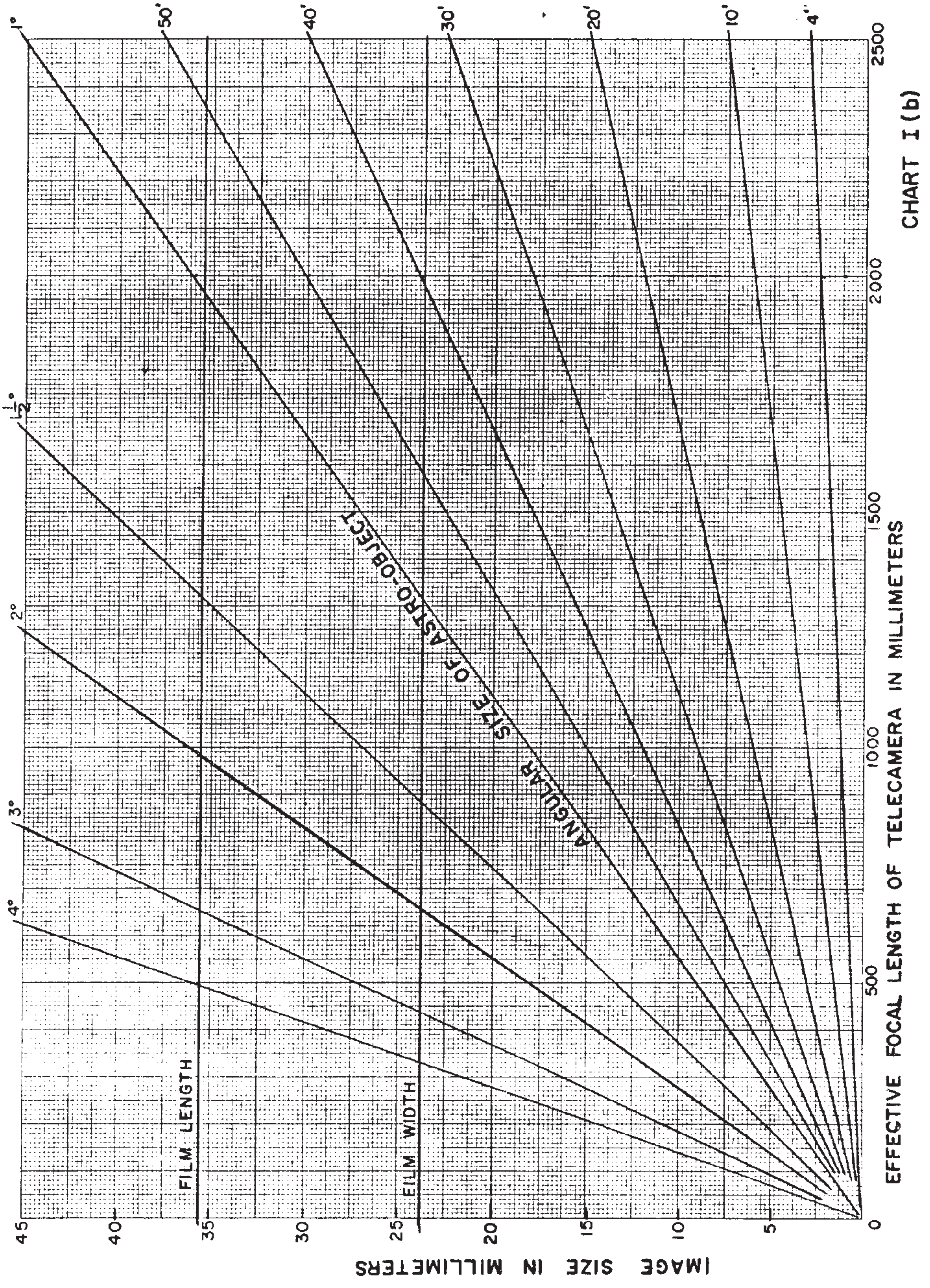


CHART I (b)

EFFECTIVE FOCAL LENGTH OF TELECAMERA IN MILLIMETERS
0
500
1000
1500
2000
2500
IMAGE SIZE IN MILLIMETERS
0
5
10
15
20
25
30
35
40
45
FILM LENGTH
FILM WIDTH
ANGULAR SIZE OF ASTRO-OBJECT
4°
3°
2°
1½°
1°
50'
40'
30'
20'
10'
4'

SECTION 11 — EXPOSURE TIMES

One of the major questions asked of any astrophotographer is, "What exposure did you use to get that picture?" There is no simple answer to such a question as there are too many variables to be considered, but it is possible to understand the effect of the different variables and make allowances for them, such that the "Exposure Time" can be reduced to a very good "guestimation."

The first consideration in resolving this topic is to realize that there are at least three major or basic situations to be looked at. These are:

a. Solar System Photography (Moon, Planets, Comets, etc.)
b. Stellar Photography (Stars and Star-like Objects)
c. Solar Photography (Sun)

11.1 - SOLAR SYSTEM PHOTOGRAPHY

All solar system objects, with the exception of the sun, shine by reflected light, and are subject to the same form of treatment as are normal terrestrial photographs. A light meter, so useful to the ground-oriented photographer, becomes of no value in planetary photography because there is insufficient illumination to measure, (except for very expensive meters), so some other technique has to be employed to determine exposure times.

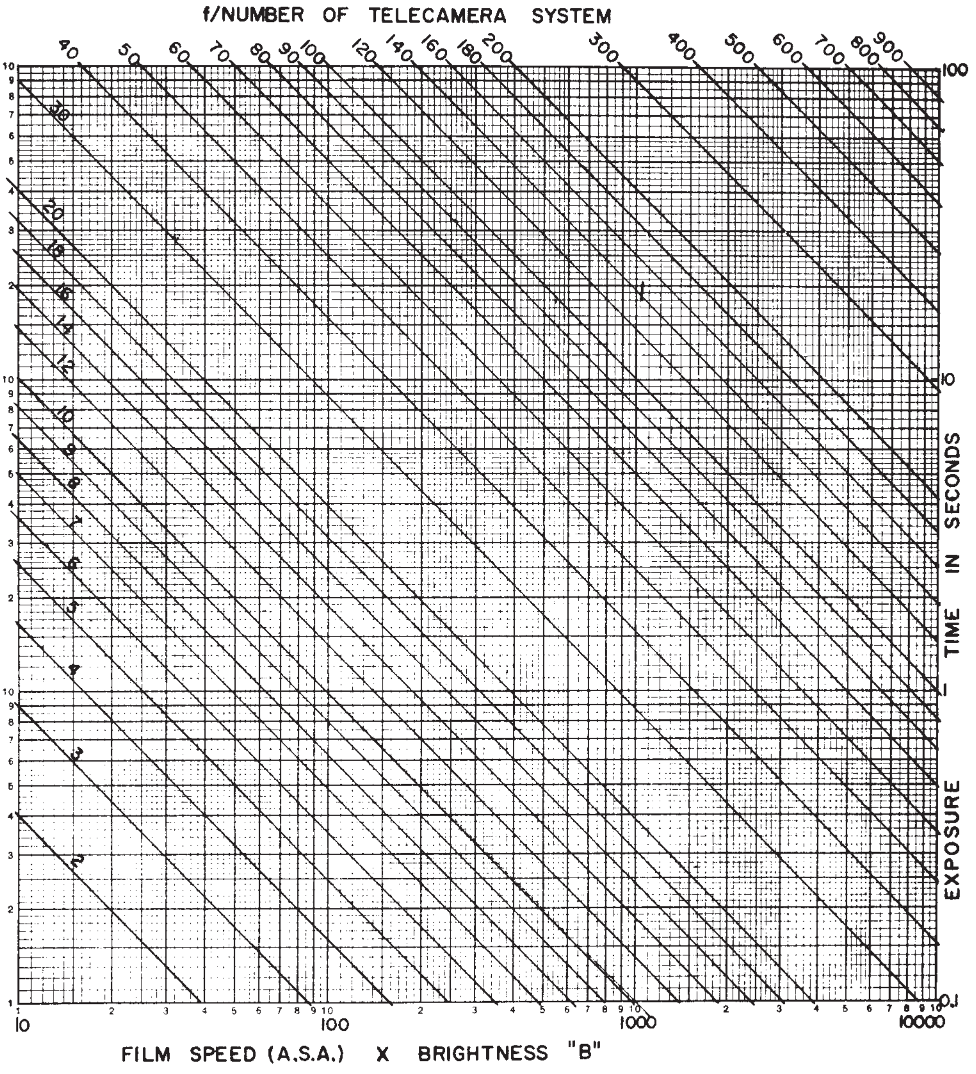
Exposure time is related to the speed, (f/#), of the telecamera system, the film speed (ASA), and the Brightness, (B), of the object in accordance with the following formula:

$$T = \frac{f^2}{S \times B}$$; where T = Exposure Time in Seconds
f = f/# of Telecamera System
S = ASA, Speed of Film
B = Brightness of the Object

This formula holds regardless of the clear aperture of the telescope so that two telescopes with differing apertures but the same f/number would require the same exposure time, other things being equal.

CHART II

$$T = \frac{f^2}{S \times B}$$



It would be nice if this was all that was involved. Unfortunately, this is not the whole picture. Vagaries of the atmosphere cause additional problems that have to be considered. One major problem in this category is refraction attenuation. As an object becomes closer to the horizon, its light has to pass through thicker layers of atmosphere which in turn reduce the brightness level of the object.

A further atmospheric problem is created by air turbulence, and by air pollution (dust, pollen, smoke, light, etc.) All these items have to be considered in the calculations to determine the correct exposure time.

One last problem — camera shutter speed. When your exposure time works out to be less than, or more than those fixed shutter settings, what do you do? Obviously some compromise is needed. Also, when the calculated speed exceeds one second, a time exposure is needed, and this leads to a further problem, called Reciprocity Failure.

I shall now attempt to deal with each of these problems in turn, and show how their effects on exposure time calculations can be minimized.

11.2 - EQUATION EXPOSURE TIMES

Chart II has been prepared based on the formula given in paragraph 11.1. This is a graph drawn on log-log paper, showing the product of the film speed (ASA) and object brightness (B) along the bottom axis, and the exposure time (T) along the vertical axis. The speed of various telecamera systems (f/#), is shown by various slanting straight lines. To use, determine the f/number of your telecamera system, and the product of the S and B. Follow the vertical line upwards that corresponds to the S × B until it meets that for the f/#, then read the exposure time off the right vertical axis.

It should be pointed out that in a later section of this book, I have included a circular slide rule that obviates the use of this chart, but astrophotographers should understand where and how such information is obtained. Special charts can be drawn up for each film speed, leaving only the Brightness Factor (B), along the bottom line. These are handy, but slightly restrictive, so I have not repeated them in this revised edition of this *Handbook*.

11.3 - CAMERA SHUTTER SETTING VS. TIME - CHART III

As mentioned earlier, calculated exposure times very seldom equal the speed designations marked on your camera dial. Obviously, some compromise is necessary as we cannot alter the speeds built into the camera. A graph has been made up showing the actual time in seconds or parts thereof. After calculating an exposure time, and assuming it is less than one second, check along the base of this graph, find the calculated time, follow the line upwards until it meets the diagonal line. Use the shutter speed that is nearest to your calculated speed.

CHART III

CAMERA SHUTTER SETTING vs TIME

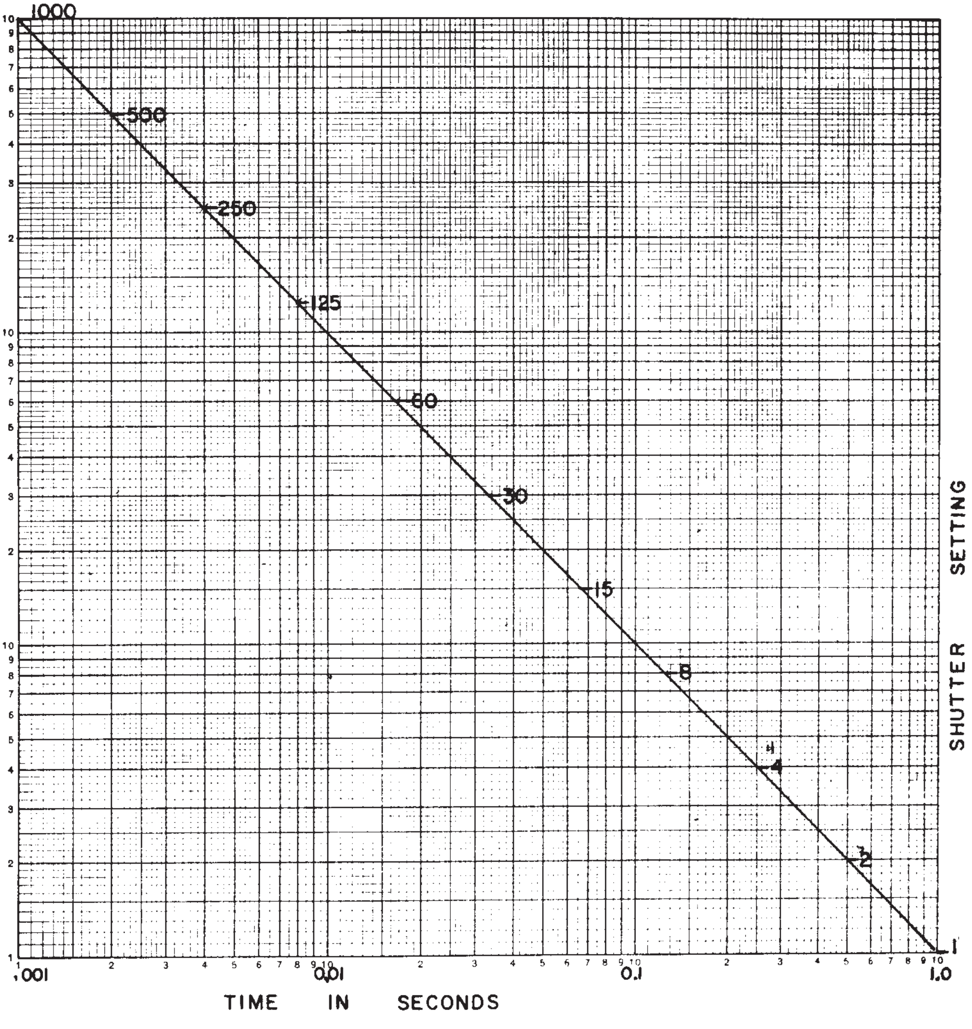


CHART IV(a)

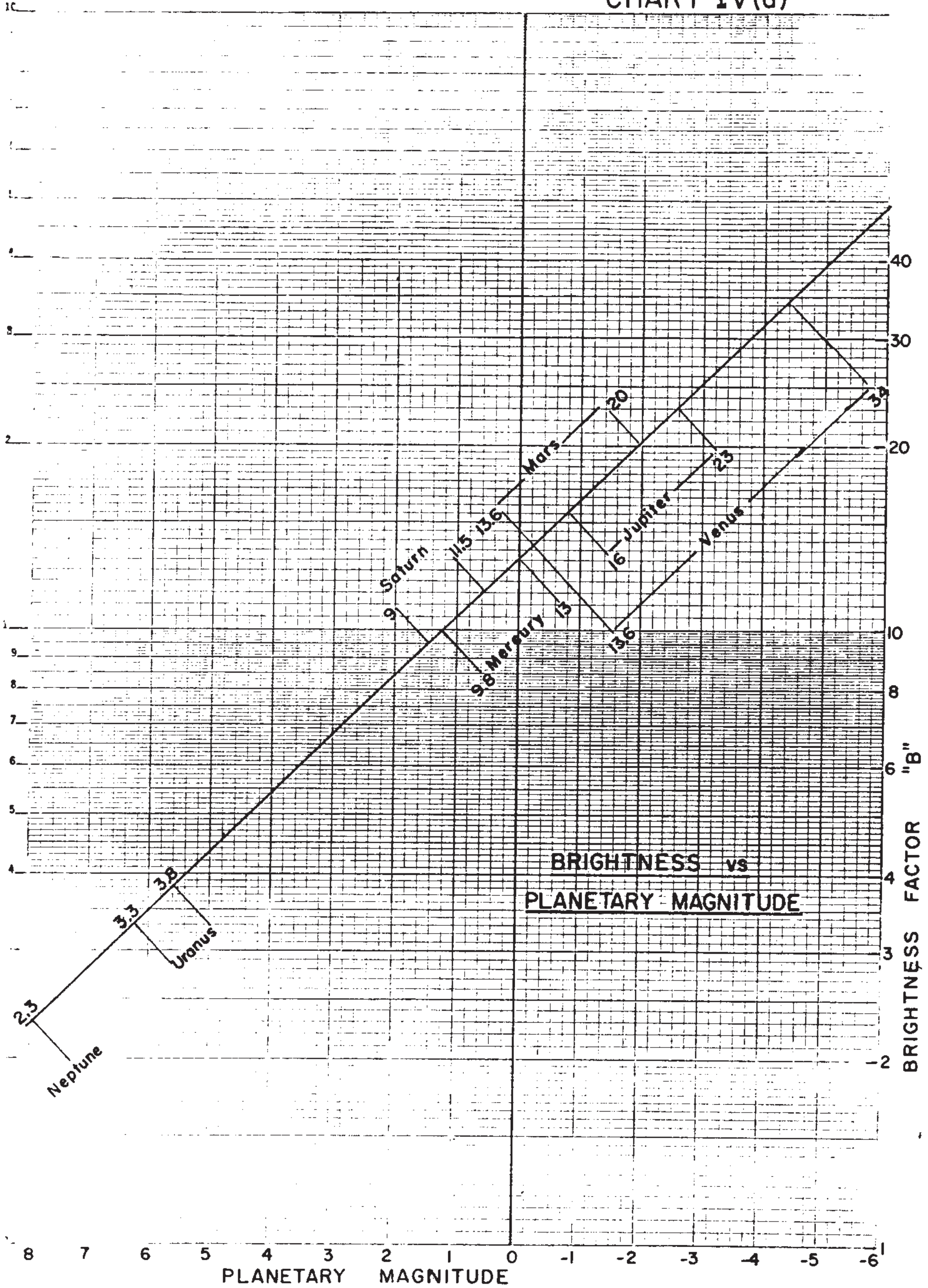
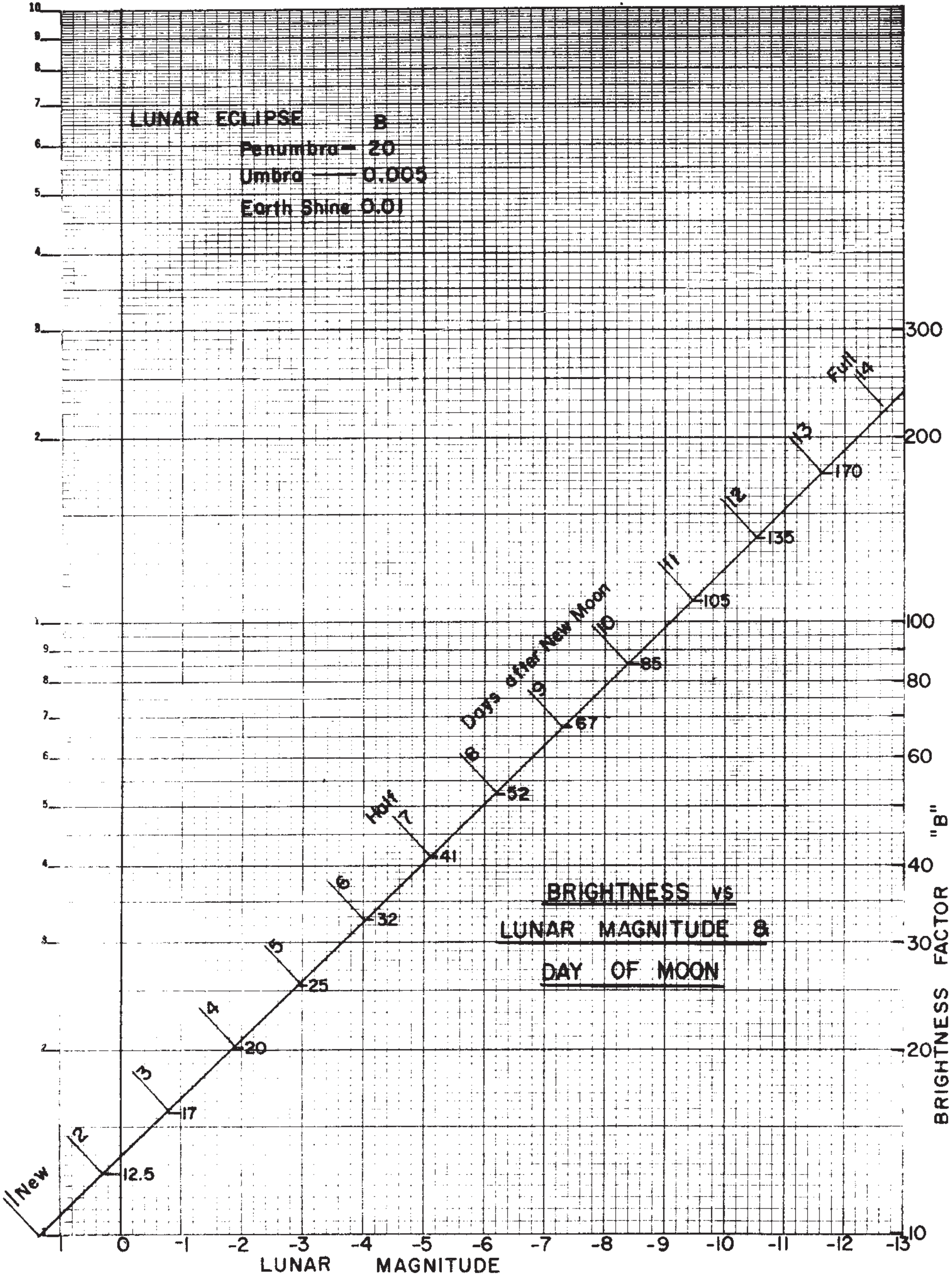

BRIGHTNESS vs
PLANETARY MAGNITUDE
PLANETARY MAGNITUDE
BRIGHTNESS FACTOR "B"
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
40
30
20
10
8
6
4
3
2
1
Neptune
2.3
Uranus
3.3
3.8
Saturn
9
11.5
Mercury
9.8
13
13.6
Mars
13.6
20
Jupiter
16
23
Venus
34

CHART IV(b)


LUNAR ECLIPSE
B
Penumbra — 20
Umbra —— 0.005
Earth Shine 0.01
BRIGHTNESS vs
LUNAR MAGNITUDE &
DAY OF MOON
Days after New Moon
1 New
2
3
4
5
6
7 Half
8
9
10
11
12
13
14 Full
12.5
17
20
25
32
41
52
67
85
105
135
170
10
9
8
7
6
5
4
3
2
1
9
8
7
6
5
4
3
2
300
200
100
80
60
40
30
20
10
BRIGHTNESS FACTOR "B"
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
LUNAR MAGNITUDE

11.4 - BRIGHTNESS FACTORS

The word "Brightness" has been mentioned several times so far in this section. Where does one obtain these magic figures? I found two figures in an old pamphlet on the Brightness of the First Quarter Moon (20) and for the Full Moon (220). As Brightness relates directly to Magnitude, which is logarithmic, I plotted these values on semi-log graph paper as a straight line, divided that line into even parts for day intervals, and read off the individual values for each day. This basic graph, (somewhat improved), is shown as Chart IV(b). By relating Brightness to Magnitude, and extending the graph to lower values, I was able to include all the planets, as in Chart IV(a). Pluto is not shown to keep the graph on the page. I have tried out the various Brightness values, and they work very well. A shortened version is shown in Table II.

TABLE II — ACCEPTED BRIGHTNESS FACTORS

MOON	DAY	BRIGHTNESS	PLANET	BRIGHTNESS
New	1	10.0	Mercury	9.8 to 13.0
	2	12.5	Venus	13.6 to 34.0
	3	17.0	Mars	13.6 to 20.0
¼	4	20.0	Jupiter	16.0 to 23.0
	5	25.0	Saturn	9.0 to 11.5
	6	32.0	Uranus	3.3 to 3.8
½	7	41.0	Neptune	2.3
	8	52.0	Pluto	0.32 to 0.48
	9	67.0		
	10	85.0		
¾	11	105.0		
	12	135.0		
	13	170.0		
Full	14	220		

11.5 - ATMOSPHERIC ABSORPTION

One factor that must be considered in all exposure calculations is the lowering of the brilliance factor due to the position of the object from the zenith. For all practical purposes, this factor can be ignored if the subject is at least 45° or higher from the horizon. If the object is lower than 45°, the light coming from that object has to traverse more atmosphere due to the lower angle, and therefore there is a lowering of brightness. Table III gives the apparent loss of magnitude and brilliance for any astro-object below 45° from the horizon. To use the Table, multiply the given brightness, B, of the object by the figure listed in the Brightness Loss Factor column to obtain the corrected brightness figure to be used in the formula.

11.6 - TABLE III - LOSS OF BRIGHTNESS WITH ALTITUDE FROM HORIZON

Apparent Altitude in Degrees	Dimming in Terms of Magnitude	Brightness Loss Factor
1	3.0	0.063
2	2.5	0.100
4	2.0	0.158
10	1.0	0.398
13	0.8	0.478
15	0.7	0.525
17	0.6	0.575
19	0.5	0.631
21	0.4	0.692
26	0.3	0.759
32	0.2	0.832
43	0.1	0.912
45	0.0	1.000

11.7 - OTHER FACTORS

Under this heading come all those little unknowns that crop up from time to time to ruin what should have been a good picture. Such things as light pollution, dust and dirt in the air, turbulent atmosphere, etc. figure in this grouping. Some items have no easy cure, except don't take the picture, but there are times when the picture MUST be taken. When such situations arise, bracket your photographs. Consider your calculated time at "T"; take additional pictures at ¼T, ½T, 2T and 3T. These pictures may not be ideal, but usually one of them should be usable.

11.8 - STELLAR PHOTOGRAPHY

Photography of Stars and Deep-Space Objects differ in several respects from Lunar and Planetary photography;

a. The Planets and the Moon shine by reflected light from the Sun, and may be considered as an extension to normal terrestrial photography in that the prime consideration governing exposure time is the speed, or f/number of the telecamera system. (See formula on page 23.) This is not the case with stars and deep-space objects which are basically self-illuminating. Here the primary consideration governing the exposure time is the clear aperture of the telecamera system. Note: this does not apply to those objects classed as nebulosities.

b. The limiting magnitude obtainable with a telescope is governed by the aperture. The formula for the limiting *visual* magnitude is given by:

$M_V = 9.1 + 5 \log_{10}A$; where A = clear aperture given in inches.

Photographic magnitudes will usually exceed the visual values because of the film's ability to retain and store photon energy. One formula given for limiting *photographic* magnitude is:

$M_p = 6.0 + 5 \log_{10}A + 2.15 \log_{10}E$; where A is as above, and
E = the Exposure Time in Minutes.

Telescopes with special coatings on their mirrors may provide up to an additional magnitude or even two. Note: Most normal film emulsions are more sensitive in the blue-green range, so the red-yellow stars may not conform too closely to the above formula, more exposure being required to register them on film. Notice that film speed does not enter the above formula which indicates only the "limiting" magnitude obtainable.

c. While most lunar and planetary exposures vary from 1/1,000 second to a few seconds, stellar exposures require from several minutes to several hours to get good pictures. Such exposures require precise tracking for extended periods of time, necessitating a good, controllable variable frequency drive and some means of visually tracking a star in the area being photographed.

d. Nebulosities, being reflective and luminescent, have to be treated as if they were both planetary objects and stellar objects at the same time. This is where your experience comes to the force. Use what works for you.

A good method for determining the capability of any telecamera system is to take several exposures at increasing time intervals of a subject like M45, The Pleiades. This is a very good astro-object as there are numerous stars of very accurately determined photographic magnitudes in a relatively small sky area. Compare each photograph with a Photographic Magnitude Chart, (Page 42 of Hans Vehrenberg's *Atlas of Deep Sky Splendors*), and this will establish a good "yardstick" of your telecamera system in that you can determine beforehand what exposure time will be required to capture any particular star. A chart can then be made, plotting exposure time versus magnitude for any future photography of other stellar objects. Such a chart will be of particular value to someone who plans to photograph a Messier Object, etc., where the magnitudes can be obtained from various sources, hence the time of exposure can be determined directly from your own chart and used as a guide.

In Table IV, I have included a comparison of stellar magnitudes and the comparable brightness ratio of each magnitude. This brightness ratio has no relationship to the "Brightness" (B) used in the formula on page 23.

11.9 - TABLE IV - MAGNITUDE/BRIGHTNESS RELATIONSHIP

Magnitude	Brightness Ratio	Remarks
−2	1,584.9	Sirius = −1.42 (Brightest Star)
−1	631.0	
0	251.2	
1	100.0	
2	39.811	
3	15.849	
4	6.310	
5	2.512	
6	1.000	Normal Limit for Eye
7	0.39811	
8	0.15849	
9	0.06310	
10	0.02512	
11	0.01000	Visual Limit for 3"
12	0.0039811	
13	0.0015849	Visual Limit for 6"
14	0.0006310	Visual Limit for 12"

11.10 - SOLAR PHOTOGRAPHY

WARNING: DIRECT PHOTOGRAPHY OF THE SUN THROUGH A TELESCOPE OR CAMERA CAN BE VERY DANGEROUS, BOTH TO THE PHOTOGRAPHER AND THE CAMERA, UNLESS PROPER PRECAUTIONS ARE TAKEN AT ALL TIMES.

The Sun is one star where insufficient illumination is not a problem: on the contrary, the problem is to reduce the amount of radiation, from the infra-red through to the ultra-violet, to a level safe enough to avoid damage to the camera and/or the photographer. To understand some idea of the "Brightness, B" of the Sun, consider its magnitude of $-26.^{m}73$ and compare that to the Full Moon with a magnitude of $-12.^{m}70$. There is a difference of 14.03 magnitudes. A difference of five magnitudes represents a difference in Brightness of 100, that of ten magnitudes, of 100 × 100, or 10^4, while that of 14.03 magnitudes means a difference in Brightness of 40.93×10^4, or 4.093×10^5. This shows the difference only in its brightness relative to the Moon. In absolute terms it is 220 (Full Moon's Brightness) $\times 4.093 \times 10^5 = 9.004 \times 10^7$, nearly one hundred million times brighter than the Full Moon.

It can be seen that extreme care must be taken when trying to look at anything this bright — in fact, if one tried it, it is likely blindness would shortly result. Proper filters are required, and a desired feature is a telescope with a variable aperture, (don't laugh, they can be found!) which would help to reduce the usable aperture to a safer size.

A refractor is the preferred telescope for the amateur for solar photography, or viewing, as the glass lenses effectively stop all the ultra-violet rays, and it is relatively simple to make an Objective mask and fit with suitable gelatine filters ahead of the Objective lens. It should be remembered that infra-red rays still pass through glass, so there will be considerable heat at the Prime Focus — enough to melt a filter, crack a glass filter, and burn out a camera shutter unless the brightness level is considerably reduced.

Neutral Density filters (gelatine) can be mounted in front of the Objective to reduce this high level of illumination. Normally, a Neutral Density filter of 6 (ND6) will cut down the brightness to an acceptable camera level if the telescope aperture is not too great. It should also be kept in mind that ND filters do not stop the ultra-violet completely, so additional precautions should be taken during eye-ball focusing.

So-called ocular solar filters — sold in some of the "toy" telescopes, should be removed and destroyed so they can never be used. They cannot stop enough light, and are at the very center of the hottest part — the prime focus — so they can shatter suddenly, resulting in instant blindness. Smoked glass filters also should never be used. Table V lists the various ND filters, cross referenced to welding filters to show their characteristics and usage. Welding filters are seldom free from distortion, so are not preferred for photography.

A good method of checking safe limits on heating is to place a thermometer at the Prime Focus to determine the temperature level of the Prime Image. If this is a normal or near normal value, it is safe to mount a camera for Prime Focus photography. (Normal value is about 20°C).

11.11 - TABLE V - TRANSMISSION CHARACTERISTICS OF NEUTRAL DENSITY FILTERS

ND Filter Number	Welding* Filters		Transmission Percent	Times Diminished	General Rating
	Density	Shade			
2.5	—	—	0.32	300	All too bright for direct usage.
—	2.96	8	0.11	900	
3.0	—	—	0.10	1,000	
—	3.40	9	0.04	2,500	
3.5	—	—	0.03	3,300	
—	3.82	10	0.015	6,600	
4.0	—	—	0.010	10,000	Satisfactory for up to 2" aperture
—	4.22	11	0.006	17,000	
4.5	—	—	0.003	33,000	

* Welding filters are designed to permit the welder to see the piece he is welding without being "blinded" by the electric arc from his welding equipment. Usually, the length of time the welder spends "looking" is short, and a filter with less loss of light is permissible. Only the heaviest of industrial arc-welding, requiring a Number 14 Filter, approaches a washed-out Sun, (not full brilliance). This means that only a Number 14 Welding Filter could be used for solar viewing, and then only for short periods of time. The "normal" Welding Filter, used for gas welding and light arc-welding is a Number 10. At least two of these filters would be needed for minimal solar viewing.

ND Filter Number	Welding* Filters		Transmission Percent	Times Diminished	General Rating
	Density	Shade			
—	4.70	12	0.002	50,000	Satisfactory for 2" to 3" aperture
5.0	—	—	0.001	100,000	
—	5.10	13	0.0008	125,000	
5.5	—	—	0.0003	330,000	Comfortable for 3" aperture
—	5.52	14	0.00028	333,000	
6.0	—	—	0.0001	1,000,000	Dim for 3"

It can be seen from the above that many "Welding Filters" are not suitable for viewing on their own. Note that Neutral Density Filters can be added, ie, a ND2 + ND4 = ND6.

11.12 - SOLAR ECLIPSE PHOTOGRAPHY

Photography of the Sun during the eclipse phases, ie, pre-eclipse, totality, and post-eclipse, is quite detailed and will be covered in a separate section (see section 21).

SECTION 12 — RECIPROCITY FAILURE

Reciprocity failure is a factor that all astronomers, both amateur and professional, have to contend with at some time or other if they ever expect to be able to take reasonably good astrophotographs with any degree of consistency. The end effect of reciprocity failure is a negative with contrast reduced from what it should be for an average negative, provided the measured or calculated time of exposure was used, ie, the negative is under-exposed even though it was given the theoretically correct exposure time. As far as astronomers are concerned, this effect takes place at any exposure time longer than one-tenth of a second, (unless special astronomy film 103a[-] is used), and is referred to as "Low-Level Reciprocity." There is also failure at the other end of the exposure scale, referred to as "High-Level Reciprocity," but we do not concern ourselves with this latter effect in astrophotography.

Briefly, the Law of Reciprocity states that the density of the exposure is equal to the exposure time multiplied by the intensity of the light hitting the film, or, the longer the exposure, the darker the negative. Exposure time is a logarithmic function, and the Law is written mathematically as:

$E = I \times T^p$; where E = Density of the Exposure
I = Intensity of the light on the film
T = Exposure Time
p = a constant (Schwarzschild coefficient)

When we examine the so-called constant "p", we find that it is dependent upon a variety of other factors, some of which are:

a. Type of film emulsion
b. Intensity of the light
c. Wavelength of the light
d. Temperature, and
e. Kind of developer and development time

As can be seen, "p" is anything but a fixed constant, other than under a specific set of conditions; it can even differ between different batches of the same film.

The fact that temperature plays a part in determining this constant "p" is taken into account by professional astrophotographers. Lowering the film temperature can considerably reduce the effect of Low-Level Reciprocity, and professional astronomers freeze their film to eliminate, or greatly reduce this effect during the several hours exposure needed for faint stars. Freezing film does have the effect of reducing the film speed (ASA), but this is more than off-set by the reduction in exposure time to allow for reciprocity failure, so, in essence, exposure time is reduced.

Cold cameras are on the market for amateurs, and many have made their own, with surprisingly good results. Also, the effect of Low-Level Reciprocity can be off-set by longer exposures, and shorter development times.

In the Kodak Professional Data Book, F5, titled, *Kodak Black-and-White Films*, there are published tables for each film under a heading of Reciprocity Effect Adjustments. These are different for each type of film, and an example for Tri-X Pan film is given below:

Exposure Time In Seconds	**Exposure Adjustments f/Stop**	**Development Adjustments**
1/1,000	none	none
1/100	none	none
1/10	none	none
1	½ Stop more	none
10	1½ Stops more	10% less
100	2½ Stops more	10% less

The amateur astrophotographer cannot vary his stops, at least not normally, so the change in stops would have to be translated into a change in exposure time. A much more realistic table has been devised by Mark Hilburn, who has done considerable experimentation with low-level reciprocity failure using a variety of B & W films, and his table is listed on the following page as Table VI.

All the above applies to B & W film. Colour film is a different proposition entirely. There are three emulsion layers in colour films, and each layer has its own failure rate, so low-level reciprocity in colour film not only causes a loss in density, but also causes a colour shift — the film colour no longer appears correct. This end effect cannot be corrected for by using longer exposures as was the case with B & W films. It is possible to use colour correcting filters, but this technique is very much a hit-or-miss proposition, and the correction is seldom complete and satisfactory. The only satisfactory solution for colour film is the Cold-Camera technique where the film is kept at below freezing temperatures. To some degree, and with certain colour films, satisfactory results can be obtained by photographing with a normal camera in winter-time with temperatures below −20°C.

12.1 - TABLE VI - MARK HILBURN'S RECIPROCITY COMPENSATION TABLE FOR B & W FILMS

Calculated Exposure Time	Actual Exposure Time	Development Adjustments
½ second	1 second	93%
1 second	3 seconds	90%
2 seconds	8 seconds	87%
4 seconds	20 seconds	84%
8 seconds	48 seconds	81%
15 seconds	105 seconds	78%
30 seconds	240 seconds	75%
60 seconds	540 seconds	72%
120 seconds	1,200 seconds	70%

Example: If your calculation indicates an exposure time for 15 seconds at the f/number of your telecamera system, expose the film for 105 seconds and develop it for 78% of the time you would normally use.

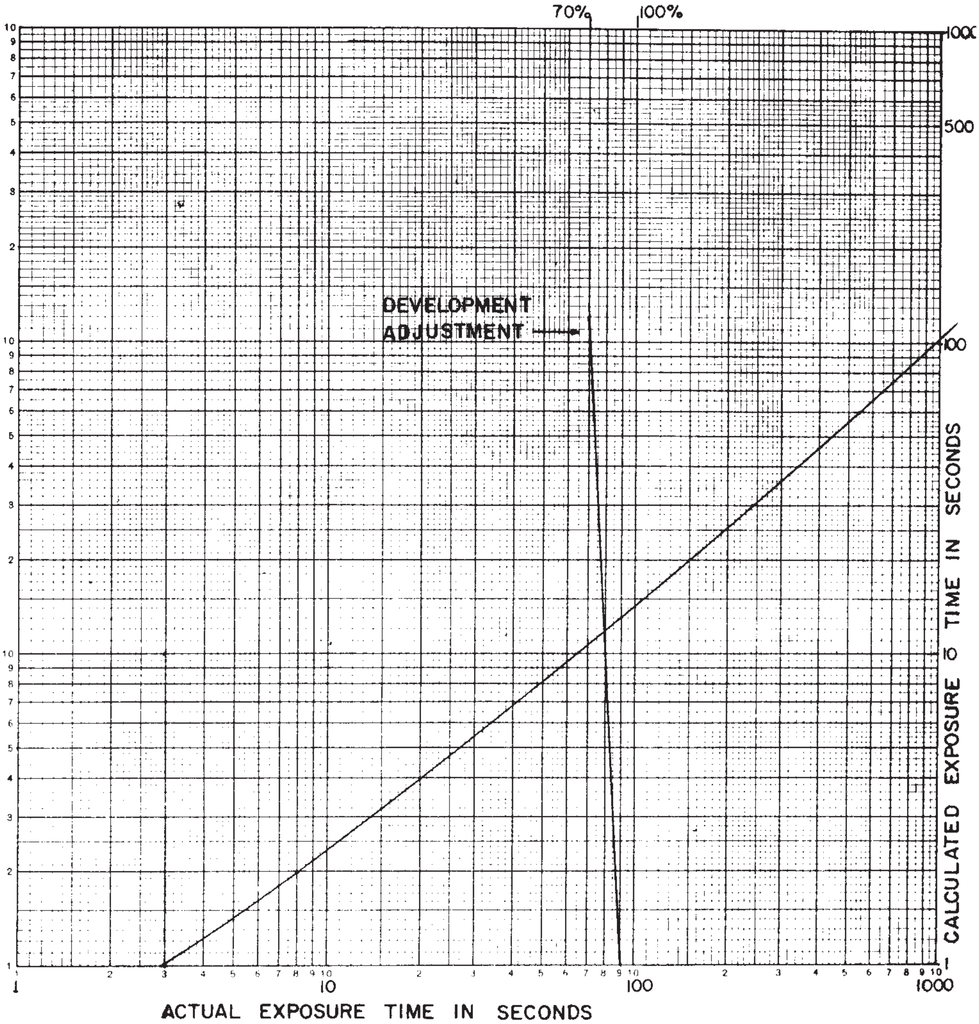
The above figures in Table VI, when plotted on a logarithmic graph, show a nearly straight line curve, which will permit a quick determination for any other figure than those given in the table. Such a chart is shown in Chart V (page 38).

All astrophotographers should also remember that printing paper, being a photographic emulsion, also suffers from low-level reciprocity failure, and if long exposures are used, there will be a speed loss, and a change in the degree of contrast. Here the only solution is making test strips until the desired result is obtained.

A last thought on reciprocity failure — always keep full records of your exposures, etc. This will help you develop your own table that you can refer to for future photographs, and will gradually help to reduce future trial-and-error attempts.

CHART V

MARK HILBURN'S RECIPROCITY COMPENSATION TABLE



SECTION 13 — FOCUSING

The difficulty of obtaining an accurate focus is one of the major problems that all astrophotographers run into, and determines whether a photograph is good or mediocre, ie, how much enlargement it will accept before detail is lost.

The major problem in achieving accurate focus is the very low level of illumination and small size of the object. With the exception of the Moon, it is not possible to determine the precise focus using the normal ground-glass screen in the average TTL 35-mm camera, and even lunar photographs will be improved using a separate focusing device.

Two different methods of focusing are required: one for planetary and lunar photography, and one for stellar photography. In one instance, planetary photography, we are dealing with a disc-like object, whereas with stellar photography we are looking at a point source of coloured light.

The stellar focusing unit was very adequately described in an article by Mr. R. E. Cox, entitled, "A simple knife-edge focusing attachment," in the October 1971 issue of *Sky and Telescope* q.v.

A knife-edge works well for point source objects like stars but is not as effective with disc-like objects. If the knife-edge is replaced with an ocular spaced back so it focuses exactly at the same plane as the knife-edge, the focusing device can be attached to the telescope as if it were an ocular, the telescope focused normally for a good clear image in the ocular. Remove the focusing attachment and replace with a camera. Take a picture, knowing it is in accurate focus.

A diagram of a suitable focusing device that has been found very effective is shown on the next page in Figure 13.1. This device, instead of being designed to fit into the standard 1¼-inch ID ocular tube, is designed to fit into the standard T-adapter. This makes it more versatile in that it will fit on to any telescope that a 35-mm camera can be mounted on, and, with interchangeable back plates, ie, knife-edge or ocular, can be used for both stellar and planetary photography.

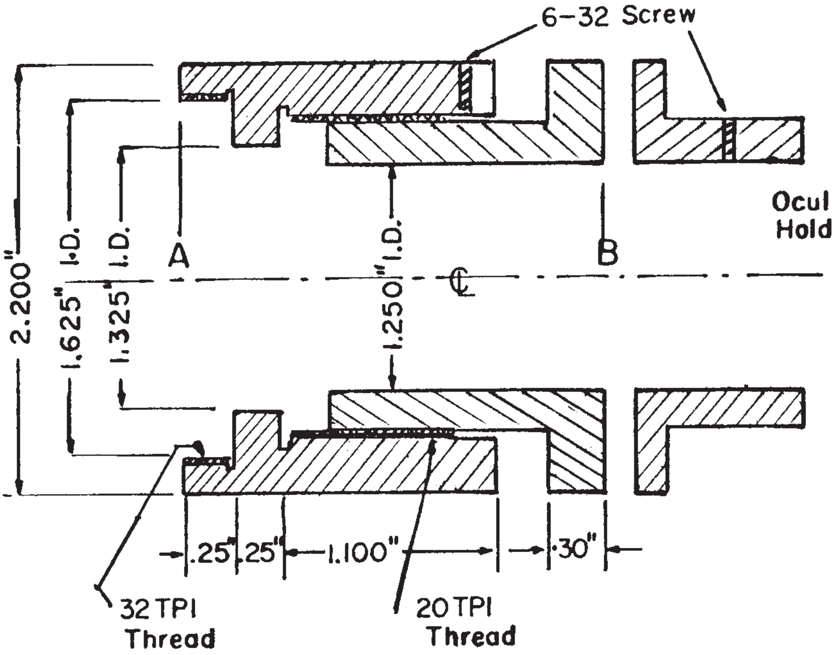


Figure 13.1 - Focusing Unit for Planetary & Lunar Photography

DETAIL

a. The front thread, (32 TPI) mates with the standard T-Adapter.
b. The internal thread is 20 TPI so that one turn moves the focusing adjustment by 0.050-inch. The rear of the outer sleeve is indexed into 50 divisions to enable calibrating the focusing movement to 0.001-inch.
c. Distance, AB, is adjusted to equal the distance from the film plane, B, of the camera to the front of the T-adapter when mounted on the camera in place of the normal lens.
d. The ocular holder internal diameter mates with the ocular to be used. An Allen screw, 6-32, is used to secure the ocular once it has been focused to point B.

USE

a. Use a low-power ocular, 25 to 40 mm E.F.L.
b. Screw T-adapter into front of focusing unit, or if using Celestron fittings, screw directly onto camera adapter or extension tube, and mount on telescope in place of normal ocular.
c. Focus object precisely, just as you would using a normal ocular. Lock telescope focusing control, if possible, to prevent further movement.
d. Remove focusing head, and mount camera in its place.
e. Proceed to take your picture without any further focusing.

13.2 - ASTROPHOTOGRAPHY CAMERAS

Some cameras are available on the market, (35-mm), that have either a built-in focusing ocular with diopter adjustment, or have an attachment that can be added to the normal camera. When such an attachment is used, the normal ground-glass focusing screen is removed, and replaced with a clear screen that has a cross-hair etched into the flat surface. The ocular is adjusted, (diopter adjustment), until the etched cross-hair is in sharp focus. This cross-hair is optically at the precise focal plane, so focusing the telescope to have a sharp image, using the focusing ocular, of the object being photographed, automatically assures a sharp image at the focal plane on the film.

This technique of focusing is especially desirable when focusing on dim objects, or objects that are being magnified using projection photography. No light is lost due to a ground glass screen, so much dimmer objects may be clearly seen.

SECTION 14 — TRACKING

The long exposures required for stellar photography highlight the necessity for some means of accurately keeping the telecamera pointing precisely at the stellar object being photographed. This means an equatorially mounted telecamera with a clock drive, and equipped with fine adjustments in both Right Ascension and Declination. For Right Ascension, very fine control of a Variable Frequency Power Supply (VFPS) is a necessity, with the VFPS accurately holding whatever frequency it is set to. Experience has shown that most VFPS's will not hold a stable freequency in cold weather — even touching the remote hand control, (which contains resistors, hence frequency-determining elements), can cause a wide frequency variation leading to erratic tracking. The only solution to this problem is to place *ALL* frequency determining elements inside the VFPS, mount the VFPS in a temperature controlled environment, and control by means of relays mounted inside the VFPS that are operated by switches in the hand control. For fixed observatories, the VFPS, relay controlled, can be removed into a warm environment, eliminating all temperature problems.

Maintaining a stable frequency alone is also not completely adequate for good tracking, due primarily to variable atmospheric refraction which will change with the position of the star in the sky. An accurately positioned telecamera, aligned to true North and the precise latitude, will still require some adjustments in Declination on a long exposure due to refraction, hence the Declination axis also requires some form of fine control. For a telecamera that is only approximately aligned in RA and Dec., constant variation of both axes will be mandatory.

Experience has shown that it is preferable to use a RA Drive frequency slightly slower than a sidereal, and use the coarse-fast control for "catch-up" rather than setting the RA Drive exactly at sidereal and alternating from coarse-fast to coarse-slow, etc. The latter practice introduces the possibility of uneven drive due to backlash in the drive gears. This uneven drive is particularly noticeable where spur gears are used instead of worm gears for the RA Drive assembly.

It should be noted that a telecamera system that is not properly balanced will throw an abnormal loading on the RA Drive Motor, resulting in erratic drive and uneven tracking. Always balance the telecamera system for the area of the sky being covered. The less corrections required in guiding, the better the detail in the photograph.

14.1 - OFF-AXIS TRACKING

Off-Axis Tracking is the term used to indicate that the telecamera is being guided by a star that is not the one that is being photographed in the center of the picture. A right-angled prism is mounted within the cone of view of the telecamera and the light from this prism is directed to a tracking ocular. A tracking ocular is one having an illuminated reticle, usually cross-hairs (see Figure 14.1). Here the Off-Axis Tracking Unit consists of a tube, usually about 2 inches in diameter, coupling the camera (without lens), to the telescope. In the tube, near its outer edge, a right-angled prism is mounted so that some of the cone of light from the telescope objective is intercepted and bent 90° to focus at a lighted cross-hair reticle which is at the focal point of a tracking ocular. This ocular has a diopter adjustment to accurately focus the cross-hairs for the individual using the unit.

In use, the ocular is precisely focused on the lighted reticle, (diopter adjustment), and the object being photographed is brought to a sharp focus at the filmplane of the camera. Now the tracking ocular-reticle assembly is adjusted to focus on a star at the edge of the field seen by the telescope. Use the parallax method for focusing. When properly focused, the star will not move from its position on the reticle when the eye is moved slightly sideways. At the same time, ensure the cross-hairs are oriented to

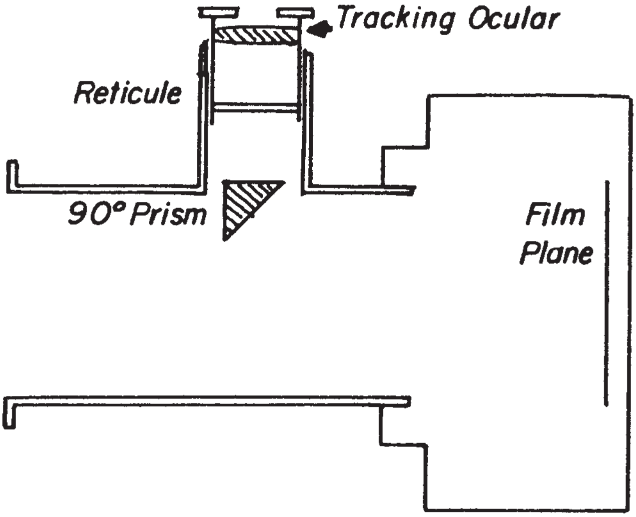


Figure 14.1 - Off-Axis Tracking Assembly

coincide with the Right Ascension and Declination Axes of the telescope. This way, it is possible to see which direction or axis needs correction when the star moves away from center.

Possibly the most difficult task in using off-axis tracking is finding a suitable star within the area being photographed. Remember the total field seen by a 2,000 mm objective on 35-mm film is small, 39' × 59', and it is usually necessary to off-set the desired object from the center of the film plane to find a suitable tracking star. Additionally, the position of the tracking ocular is limited to a position where the object can be viewed with some degree of comfort. In some instances it is just not possible to find a suitable star in the area desired, and some other method of tracking has to be employed.

Tracking should be done at as high a power as possible. The quality of the stellar image of the tracking star is immaterial so long as it can be seen, ie, it may be slightly blurred, but still remain usable. In any event, tracking* power should be at least 5× per inch of focal length of the telecamera, ie, if the E.F.L. of the telecamera equals 80 inches, tracking power (minimum) should be 5 × 80 = 400×. Experience has shown that a tracking power of 400× enables corrections to be applied before any loss of image quality results in a Prime-Focus photography taken with a Celestron 8 telescope.

Practice tracking for some time before attempting a photograph. Tracking requires a lot of practice before one can consider himself/herself reasonably adept at it.

14.2 - ON/OFF AXIS TRACKING

This form of tracking is given this name because it is possible to use it to track precisely on the object being photographed, or on some object displaced from the one being photographed. A second telescope is mounted on the telecamera system on a special base that can be moved laterally and up and down with relation to the main optical axis of the telecamera. This allows the telescope to be sighted on the same object being photographed, or if this object is nebulous, then on a nearby star. This is basically the same system used by many amateurs whose only telescope is a small aperture refractor, and they mount a camera, probably with a telephoto lens on it, and follow the object by tracking visually with the refractor.

To be effective, the tracking telescope must be equipped with an illuminated cross-hair reticle and be capable of being used at high power. Remember that tracking power should be 5-power per inch of effective focal length of the telecamera lens or objective. Where the tracking telescope is fitted to a larger telescope, it is preferred to have the tracking scope mounted on a tangent-arm coupling unit making it possible to off-set the telescope to a suitable tracking star. The cross-hair reticle should be oriented to coincide with the Right Ascension and Declination Axes of the telecamera system. This aids in determining in which direction any correction should be applied.

*(5× per inch = 1× per 5 Millimeter)

It is usually much easier to find a suitable tracking star with this type of tracker, consequently this is the preferred tracking system for many amateur astrophotographers. There is, however, one possible drawback to this method of tracking — telescopes tend to flex slightly as they move, and unless both telescopes flex identically, (an impossibility), there is a possibility of faulty tracking between what is seen visually, and what appears on film. Further, any looseness in the tracking telescope mounting will totally ruin any attempts at tracking. These faults usually occur when one telescope is a refractor and the other is a reflector, and is more likely to be noticeable as the telescopes pass through the zenith line where there is liable to be a possible change in balance. On small telescopes where all optical components are securely fastened, and the telescope tubes are solid, ie, not frame-construction, this problem is minimal.

14.3 - TRACKING RETICLE

For accurate tracking, the viewer must have some reference point within his optical system to which the star being tracked can be located. This is usually a reticle with cross hairs, (two wires or lines crossing at right angles on the optical axes), located at the prime focus of the objective lens of the tracking telescope, and also the focal point of the tracking ocular. As this cross-hair needs to be seen in the dark, some provision must be made to illuminate it.

There have been many articles written on how to obtain a suitable lighted reticle for use in tracking. Some reticles are actually fine wires or spider web, crossing at the center of the field of view; others project the image of cross-hairs onto a glass reticle plate, while a common type uses a solid circle of thin glass or clear plastic with the cross-hairs etched or scribed on one surface, and edge-lighting is used to illuminate the lines.

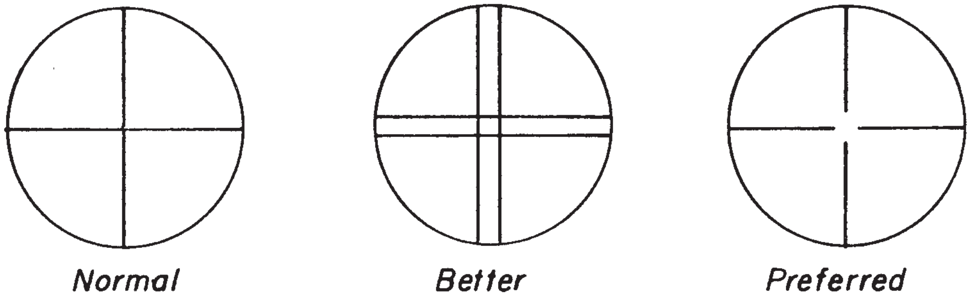

Normal *Better* *Preferred*

Figure 14.2 - Types of Cross-Hairs

In the author's opinion, any type of cross-hairs that physically cross at the center of the reticle are not considered ideal, as the central point is obscured, and the track-star has to be off-set from center to be seen clearly.

If actual thin cross-wires are used, there should be two in each direction, spaced about 1 to 2 millimeters apart, forming a small clear square at the axis of sight. The tracked star is then placed at the center of this square and kept there. One of the main disadvantages of actual wires is the difficulty of obtaining even illumination across the entire field of view covered by the wires.

The author has experimented with many forms of reticles, and in his opinion, the ideal cross-hair reticle is where the etched or scribed lines on the reticle surface do not quite meet at the center, ie, do not cross over. The gap is about 1 to 2 millimeters. An unmarked portion is left at the reticle center. Good, even illumination is obtained across the entire field of view with edge lighting, and the tracking star can be clearly seen and positioned at the center of the reticle. The eye automatically establishes the center point where the lines would cross over and where the star should be, and the slightest movement from this position is immediately noticeable. The clear center also allows tracking on much fainter stars. (Note: To the best of the author's knowledge, this recticle is not available commercially — the author had to make his own.)

Regardless of the type of cross-hairs, some provision must be made to adjust the level of illumination, and in addition, provision has to be made to adjust the tracking ocular relative to the cross-hairs (diopter adjustment) to enable the viewer to bring the cross-hairs to a sharp focus. Red light is preferred for illumination to avoid diminishing one's night vision. Cross-hairs should be just discernable, not brightly lighted; the lower the brightness you can live with the better the tracking and the lower the eye fatigue.

14.4 - TRACKING TECHNIQUES

Accurate tracking of a star is an art that can only be acquired by continual practice. Regardless of how many aids the amateur has available to him there still remains the human factor of fallibility. The object of this section is to outline some of the things to watch out for, based on the combined experiences of the Saskatoon Centre, RASC, Astrophotography Group. It is by no means a total coverage of this subject:

a. Ensure the telecamera system is properly balanced. An unbalanced system tends to move in jerks, and cannot be driven or corrected smoothly. This problem is particularly noticeable as the system passes through the zenith line where a sudden jump may result due to any imbalance in the system.

b. Personal comfort is essential, particularly where tracking is required for an extended period, or in cold weather. This involves suitable clothing, and a comfortable viewing position to minimize fatigue.

c. Viewing should be carried out with both eyes open to avoid eye fatigue. This also permits alternate viewing with either eye, but does require a fair amount of practice.

d. Use the lowest level of illumination of the tracking reticle that still permits the lines to be seen. As this level will change as one's eyes become dark adjusted, provision must be made for reducing this level. Also, a low level of illumination will permit using fainter stars without losing them in overly bright cross-hairs.

e. Always adjust the tracking ocular to bring the cross-hairs into sharp focus. (Note: focus with both eyes open.) Then focus the telescope to bring the tracking star into sharp focus on the cross-hairs. Use the parallax method to check focus, ie, when the star is accurately focused on the cross-hairs, sideways movement of the eye will not cause the star to move from its position on the cross-hair. At the same time, orient the cross-hairs to coincide with the Right Ascension and Declination Axes — when the star drifts from the center, it is immediately apparent which axis has to be corrected, and which way.

f. Know your telescope tracking system thoroughly. Remember, you will be working in the dark which is no time to be fumbling about for controls. Know which switch or button to press to increase or decrease drive speed, or to adjust declination up or down.

g. Use the highest tracking power available so that any tracking drift is magnified and noticed immediately. Never let the star drift for any length of time. Correct immediately, but avoid over-correction. It is this action that requires skill and knowledge, and can only be acquired by frequent usage and practice.

h. When photographing the planets or the moon — usually quite short exposures — adjust the RA drive speed to hold the image at the center of the cross-hairs. Do this at a very high power — this will normally be the only tracking possible due to the very short exposure times.

i. When photographing stellar or deep-space objects, adjust the RA drive speed to be very slightly slow, and use the coarse-fast control in a "catch-up" mode. This provides for correction to always be in the same direction and helps to minimize any backlash that can occur when the RA speed alternates between coarse-fast and coarse-slow controls. Avoid using any fine-frequency adjustment during picture taking — any adjustment of this control should be carried out before starting the photography.

j. Wherever possible, keep all illumination near the telecamera system, other than reticle lighting, off or very dim. If light is needed, ensure only dim red light is used to avoid loss of night vision.

k. This part has been reserved for last because it is possibly the most important technique of all. BEFORE TAKING A PHOTOGRAPH, PRACTICE TRACKING THE STAR FOR SEVERAL MINUTES TO ENSURE THAT:
   - the RA drive speed is correct for the object being photographed.
   - you know which correction to apply when the star drifts in any direction, and how much correction is needed to keep the star centered on the cross-hairs.
   - illumination of the cross-hairs is properly adjusted.
   - all backlash is removed from the system.
   - the camera film has been advanced ready for the photograph to be taken.
   - the camera shutter is at the correct setting. If you are using bulb or time position, ensure the locking mechanism on your cable release is properly set.
   - for planetary photography, if the camera is fitted with a lock-up mirror, ensure this is in the locked position.
   - after you have been all through this check phase, do it all over once more, just to make sure nothing has been forgotten. It is very frustrating to spend an hour or so tracking for a photograph just to find out that you forgot to set the camera shutter to the "Bulb" position.

SECTION 15 — PHOTOGRAPHIC FILM FOR ASTROPHOTOGRAPHY

"What kind of film should I use to take a picture of this astro-object?" This question, or one like it has plagued all astrophotographers at some time or other. The answer is not a simple one as there are too many variables to be considered, such as:

a. Subject Matter
b. Telecamera system in use
c. B & W or Colour film
d. Local environment — background lights, etc.
e. Availability of film
f. Ultimate use of picture — personal, competitive, etc.
g. and many others.

Normally, the film should be fast enough to keep the exposure time to a minimum, thereby reducing the problems associated with prolonged tracking periods and reciprocity failure. On the other side of the problem is the need for fine-grained film to permit a high degree of enlargement before the grain starts to show. The two requirements are directly contradictory as high-speed film is invariably coarse-grained, whereas fine-grained film has a slow speed. Obviously, any solution has to be a compromise, so each situation has to be considered separately. In each instance, B & W film is considered first, followed by the use of coloured slide film. Coloured negative film is not considered as it works out to be more expensive, and requires extra processing, ie, printing, before the final image can be evaluated.

15.1 - LUNAR PHOTOGRAPHY

Normally, the light available in lunar photography is adequate for short exposures, so a slow-speed, fine-grained film such as Pan-X, ASA 32, or Kodak 2415, or their equivalents are ideal selections. If the photograph is accurately exposed and precisely focused, a very high degree of enlargement is possible. Even projection photography, with its magnified image and higher f/number, can be excellent, but does require a high degree of precision focusing because of the greater E.F.L., and f/number.

When the moon is less bright, ie, a thin crescent, so that the exposure time has to be increased, a faster film, such as Plus-X at ASA 125, or equivalent is preferred. This film still has fine enough grain to permit a fair degree of enlargement, but is fast enough to avoid time exposures.

Proper filters (see section 16) will markedly improve image quality on B & W film. Usually a No. 8 or No. 9 (yellow) filter is used to minimize the sky-blue haze, and allows more detail to show on the Moon's surface.

For photographing the Moon in colour, any colour slide film will do. Even Kodachrome can be used as the exposure times are usually short enough, normally less than $1/8$-second, to avoid reciprocity failure. Filters will also help, but should be limited to a No. 6, or a clear haze filter to avoid undesired colouring on the film. Where exposures will exceed $1/8$-second, use Ektachrome 64 or Fujichrome R100, or some other colour film with an equivalent ASA to avoid colour shift due to any reciprocity failure.

15.2 - PLANETARY PHOTOGRAPHY

In planetary photography, the image on film is quite small and usually less bright than that of the Moon. A higher film speed is desirable, but one must keep in mind that a high degree of enlargement will be required to obtain an image with any detail, so the situation arises where projection photography comes into play. Do not make the mistake of using too high a magnification as this will seriously hamper your ability to obtain an accurate focus, and of course, will cause longer exposures, ie, a magnification 5× will increase exposure time by a factor of 25, reduce the light at any place in the image to $1/25$ of its original value, and increase the focusing problem by the same factor of 25. Still, with your telecamera system, such a magnification may be acceptable. B & W film to be used should be one like Plus-X, Kodak 2415, or FP-4, all with an ASA of 125. In some instances it may be permissible to use a higher ASA rating such as Tri-X at ASA 400, provided the print enlargement is kept to a minimum. Again, filters may be used to provide special emphasis to particular planetary features desired.

When photographing the planets in colour, use a colour slide film that has a low reciprocity failure rate. Kodachrome has no place here; try using High Speed Ektachrome, ASA 200-400, Fujichrome, ASA 100-400, or some other equivalent. GAF 500 should not be used here because of severe reciprocity failure. Filters may help, but will depend upon the type of film, the astro-object, and the telecamera system, so some experimentation may be needed to get best results.

15.3 - DEEP-SPACE PHOTOGRAPHY

For deep-space photography, long exposures are the order of the day, even with high speed film. This will mean, of course, careful tracking for extended periods of time, so, if one wants to keep these times to a minimum, very high speed film is needed, with a minimal reciprocity failure rate. B & W films are available to fit these requirements, and are known as Kodak 103a(—). The "a" indicates astronomy, and the dash in the parentheses is a capital letter indicating the spectral range of the film. This film is expensive, but can be obtained by amateurs, and gives excellent results. Fair results can be obtained using Tri-X film, but reciprocity failure makes for very long exposure times, and does not give as good a result as 103a(—).

High speed film is invariably coarse-grained, making any direct enlargement undesirable. However, some astrophotographers have found that by making contact prints directly from the 103a(—) or Tri-X film onto a fine-grained B & W film, such as Pan-X or Kodak 2415, enlargement can be greatly increased. Of course, this is a positive "negative" or B & W slide, but that is no real handicap as the process can be repeated to obtain a proper negative. Recent experimentation with hypersensitizing film using a forming mixture of 8% Hydrogen and 92% Nitrogen has shown marked increase in film sensitivity. In particular, hypersensitized Kodak 2415 appears to match the characteristics of 103a(—) film. (See section 22).

Coloured slides are preferred for deep-space photography, usually using a film like High Speed Ektachrome, Fujichrome or other transparency film with an ASA of 400. Do not use GAF 500 (see above). The above films suffer from reciprocity failure, but are not too severe. If the film can be frozen, the effect of reciprocity failure can be minimized, hence the Cold Camera.

15.4 - NEAR SPACE PHENOMENA: COMETS, METEORS, AURORA, PARAHELIA

- Comets are usually slow moving objects, but to obtain photographs with good detail, a reasonably long exposure, tracked on the head of the comet, is necessary. Use Plus-X, High Speed Ektachrome, or Fujichrome R100. Try various speeds, ie, 5-minutes, 10-minutes, etc., to capture various aspects.
- Meteors are normally bright, fast moving objects, but require the camera be set for time exposures as one never knows when they will appear. Use a tripod-mounted camera equipped with a very wide-angle lens, and loaded with a high-speed film such as Tri-X or High Speed Ektachrome 400.
- Aurora may be both fast or slow moving; fast moving aurora will require short exposures with fast film, whereas the slow variety can be captured with slower film and exposures. One of the better films is High Speed Ektachrome, chilled. A wide angle lens is preferred as aurora can be widely dispersed.
- Parahelia. For the benefit of anyone unfamiliar with this term, it is the name given to such phenomena as "Sun-Dogs", etc.; phenomena that are Sun-related, but are the result of a specific concentration of particulate in the atmosphere. One form of parahelia is the well-known Rainbow, but how many have a good photograph of a Double-Rainbow? Another, and much more spectacular parahelia, occurring when the near atmosphere is heavily laced with ice crystals, can be extremely spectacular. A sketch is shown in Figure 15.1 - Parahelia Phenomena, showing the type of phenomena that can occur. The diagram indicates the so-called "perfect" parahelia which is an extremely rare event. Every effort should be made to try and capture such an event on colour film even though, to the purists, it may not seem to be astronomical in nature. In this parahelia, the Sun is surrounded by two Rainbows, with a white line traversing through the Sun and the Double Sun-Dog positions, continuing completely around the horizon. Inverted Rainbow Arcs, high above the

Sun, the larger arc just touching the outer Rainbow, add to the beauty of this spectacle. Two white pillars are spaced about 120° away from each side of the Sun along the "white line."

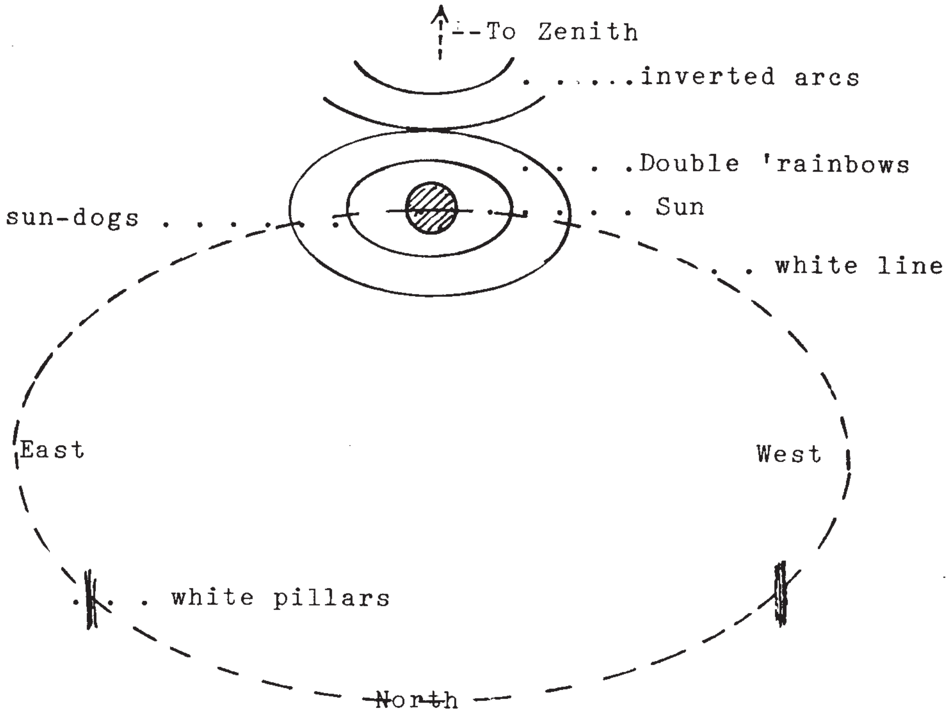


Figure 15.1 - Parahelia Phenomena

The above Figure shows the idealized parahelia. It is very seldom that all the features listed will be seen — the double rainbows usually are truncated by the horizon, and only an even distribution of ice-crystals, with no air movement, will allow the "parahelia" to form.

To photograph this, use Kodachrome 64 or Fujichrome R100, in a camera fitted with a very wide angle lens, ie, 50 - 60°. Mount the camera on a tripod, and interpose an obstruction to prevent the image of the Sun itself from appearing in the camera view finder. Use the light exposure meter, but bracket at least three stops or speeds on either side of that indicated by the meter.

15.5 - FILM HANDLING - A POTPOURRI

Every astrophotographer should be able to process his/her own films, both B & W and colour. The author came to this conclusion after losing some prized comet film by a commercial agency where each slide was cut down through the comet head, despite the fact that the film had been sent with instructions, "Develop Only, Do Not Cut or Mount." The result was two weeks of irreplaceable photography totally destroyed.

Frequently, better detail, particularly with lunar and/or planetary photographs, can be obtained if the film is developed using a Fine Grain Developer, such as Acufine, Microdol-X, etc. These are more expensive developers, but give excellent results.

Many photographers are unaware that Panatomic-X can be developed as a B & W slide. Instead of using the conventional negative developer, such as D-76, use the Kodak Direct Positive Developing Kit. Full directions for use come with the kit.

Although it is not normally apparent to the eye, there is a wide range of beautiful coloured objects in the heavens, but it is necessary to resort to colour film to capture these objects in full colour. A personal preference to use colour transparency film as opposed to colour negative film is based on the following reasons:

a. Transparency films are available with wider ranges of ASA speeds.
b. Transparency film may be easily "push-processed" by leaving it in the First Developer for a few extra minutes, then processing the remaining steps normally. No extra costs are involved. This cannot be done to the same degree with colour negative film.
c. Processing is all done at the same time, ie, in the development phase. No costly colour print enlarger is needed before the photo can be analyzed.
d. Prints can now be made just as easily from a slide as from a negative.

Nearly all colour film will show a shift in colour if the exposure time is lengthy, ie, more than one second, if the photo is taken in warm weather. This is the major reason that professional astronomers resort to freezing their film in a "Cold-Camera." The colour imbalance is due to differing reciprocity failure rates for the three colours, red, green and blue. However, when the film is frozen, the reciprocity curves tend to stabilize together, and better colour balance is obtained, even though the film ASA speed is reduced. This same effect can be approximated by the amateur when he photographs in cold weather at about −20° or lower, provided the film and camera have been cooled to these temperatures.

It is possible to obtain an excellent colour picture of an astro-object using a totally different technique. Type 103a(—) film (B & W) is used, (three kinds, each having a different spectral response area), with appropriate filters. The same picture is taken three times, each time with a different film and filter. The three B & W negatives are then processed, and during the printing stage, each negative is used with its appropriate filter for a partial exposure on the same sheet of coloured negative paper. When the printing paper is processed, a coloured print is the result. The process is extremely complex and expensive, and only the experienced astrophotographer should try this technique. Details on this and similar processes have been published in various astronomy magazines (See Section 23).

It is not generally known that there are some special B & W Developers that will automatically "Push-Process" a film during normal development. One such developer is Diafine, a two-solution developer that automatically push-processes a B & W film to six times its normal ASA rating, ie, Tri-X at ASA 400 would be pushed to an ASA rating of 2400. While this does increase the effective film speed, it also has the effect of increasing the grain size on film.

Recently, hypersensitizing film in various gaseous atmospheres, particularly hydrogen, has resulted in higher ASA ratings of film and shorter exposures.

SECTION 16 — PHOTOGRAPHIC FILTERS

Filters are used in photography to improve the contrast between different coloured objects, or between an object and its background. A filter is a selective device which, when placed between the source of the light or object and the film permits a selective gradation of light wavelengths or colour to register on the film, resulting in differing contrast levels. It should be noted that there is invariably a loss of light or illumination onto film when a filter is introduced into the path of the light waves, and as a result, the exposure time will be increased. The major problem in the use of filters is to select the one that will achieve the contrast gradation required with the minimum of increase in exposure time.

Kodak publishes an excellent information source on filters, entitled, *Kodak Filters for Scientific and Technical Use, Publication No. B-3,* which is recommended reading for everyone interested in the general use and care of filters.

In astrophotography, the problem is to select the proper filter to reduce the effect of background illumination without causing loss of detail of the astro-object being photographed. Generally, panchromatic film covers all visible colours but seems to be more sensitive in the blue-green end of the spectrum. This is the end of the spectrum where the background light and haze predominate, so the primary object is to use a filter that will eliminate or generally reduce the blues, unless it is the blues you want.

With certain exceptions, filters generally pass best the light that is the same colour as the filter appears, ie, a yellow-coloured filter will pass yellow light best, cutting down on the strength of blues and reds. Table VII gives a listing of some of the filters of use in astrophotography, together with their filter factor, etc. The Filter Factor is a number that is multiplied by the calculated exposure time without filter, to give the corrected exposure time when the filter is used. It should be noted that the Filter Factor listed is an average given for the use of that filter in normal circumstances. Its use in astrophotography can hardly be termed normal, and the Factor given should be considered a guide only. In fact, the Filter Factor may change depending upon which astro-object it is being used on. It is here that very careful records should be kept to find out which factor works best with which subject.

Filters may be glass, acetate or gelatine. Glass is preferred as it is less easily damaged, but the choice of colours available in glass is limited, and the cost is high. Any filter placed between the objective and the film must be clean and free from distortion, or these defects will appear on the negative. Proper care of filters is detailed in the above-listed Kodak publication.

CC or Colour Correction Filters may be used with certain colour transparency films to attempt to minimize the shift in colour balance due to reciprocity failure, but these can only be determined by experimentation.

WARNING: Never use an ocular-mounted filter for solar photography unless a proper Neutral Density filter is in use over the telescope objective.

Table VII does not cover all the filters that can be used but does give some idea where to start. Results will depend upon many factors such as whether the telescope optics are coated or not, seeing conditions, object being photographed, type of film, etc. This is one of the areas where experience is the best teacher. It should be noted that the filters have two identifications — the Wratten number and the Kodak number. Generally speaking, the Kodak number is the one in more common usage. Neutral density filters are not shown in Table VII as they will have already been covered in Table V, shown in paragraph 11.11, page 33.

16.1 - FILTERS USEFUL IN ASTROPHOTOGRAPHY - TABLE VII

WRATTEN NUMBER	KODAK NUMBER	COLOUR	FILTER FACTOR	ACTION OF FILTERS
K1	6	Light Yellow	1.5	Absorbs some UV and blue, but not too effective with achromatic lenses. Lunar work near New Moon.
K2	8	Yellow	2.0	Better than #6 in absorbing blues. Minimizes haze. Good for lunar and planetary photography.
K3	9	Deep Yellow	2.0	Removes more blue than #8. Very good through haze. Lunar & Planetary use.
X1	11	Yellow Green	3.0	Absorbs violet, some blue and some red. Planetary use.
X2	13	Dark Yellowish Green	5.0	Similar to #11 but absorbs more red. Use for high green-sensitive film.
G	15	Deep Yellow	3.0	Almost complete elimination of blue. Excellent with haze. Lunar, Planetary and InfraRed.

WRATTEN NUMBER	KODAK NUMBER	COLOUR	FILTER FACTOR	ACTION OF FILTERS
A	25	Red Tricolour	8.0	Transmits red, absorbs blue and green. Penetrates haze. Stars and Planets. Contrasts.
C5	47	Blue Tricolour	5.0	Transmits blue, absorbs red, yellow and green. Increases haze. Stars and Planets.
B	58	Green Tricolour	8.0	Absorbs violet, most blue and most red. Transmits green and yellow. Use for contrast effect. Stars.

As can be seen, the above list is only a few of the filters that are available for use in astrophotography. The choice of filter size will depend upon whether the filter is to be used with projection photography or for prime focus photography. Filters used for projection photography should be able to screw into the front threads of your projection ocular. Filters used for prime focus must be large enough to cover the T-adapter without vignetting any of the picture.

SECTION 17 — COLD WEATHER ASTROPHOTOGRAPHY

Before commenting adversely on the type of individual who is "nuts" enough to want to take photographs in cold weather, stop and realize some of the benefits of such a practice:

a. Some of the best astro-objects are only visible in the winter skies, so if these objects are going to be photographed, it can only be done in cold weather, at least in the Northern Hemisphere.
b. Skies in wintertime are usually cleaner, ie, free from wind-blown dust, etc., although the amateur may have to contend with ice crystals from time to time, plus the occasional aurora.
c. Winter gives longer periods of darkness, giving longer periods for photography in darker skies.
d. Colour film reciprocity tends to stabilize for all colours, (red, green and blue), at cold temperatures, so colour photographs taken at −20°C or colder show better colour balance, hence the "cold-camera." Note that the ASA speed of film usually decreases with decrease in temperature, so exposures will be slightly longer.

17.1 - REQUIREMENTS

a. Clothing — obviously, if one is going to take winter astrophotos, personal comfort is essential. Warm clothing that is not too bulky is a necessity. A personal preference is a good "skidoo suit" with felt-lined skidoo boots, or the popular "Moon-boots." If possible, use silk-lined thin leather gloves as flexibility of the fingers is essential and only silk-lined gloves will provide both warmth and flexibility. A portable hand-warmer is also a desired feature. A face mask to keep off the wind is a good idea, but care should be taken to avoid directing one's breath up towards the eyes — it fogs up the oculars very quickly.
b. The Site — a location sheltered from any wind or breeze is highly desirable to minimize chill factor. Even a mild breeze at sub-zero temperatures can be very chilling after a short while with no movement permitted. An open top igloo-type

circular low wall can provide very good wind protection in the open country. Obviously, a domed-top Observatory is the preferred location, if it is at a Dark Site.

c. Power — any variable frequency power supply (VFPS) that uses solid state devices will behave erratically at very low temperatures. Also, if the hand-control contains any frequency-determining elements, ie, resistors, etc., even the warmth of one's hand will introduce a marked change in Drive Frequency. The only solution found by the author is to remote all frequency-determining elements into the VFPS, which itself is then located into a temperature-controlled environment. Operation is carried out by two single pole-double throw-center off spring-loaded switches in the hand control which operates relays inside the VFPS box. One set of relays control the coarse-fast and coarse-slow function of the RA, while the other set of relays control the polarity of voltage supplied to the Declination motor. For use in the author's home Observatory, the VFPS is remoted into the house basement, with all control and drive voltage leads passing underground in conduit. For field use, the VFPS is mounted inside an insulated box that can be temperature controlled by a battery warmer.
d. The telescope must be fitted with an extended Dew-cap to prevent condensation on the optics. Some dew-cap heating may be provided, but to date, the author has never needed this feature even at −30°C.
e. The normal bulb-type shutter release with a black air tube, has a habit of stiffening up in the cold, and will transmit vibration and movement to the telecamera, just as will the more solid wire sheathed cable release. Replace the black rubber hose on the bulb-type release with one made of latex. Latex will remain fully flexible even down to −50°C, but I for one, am not going out to take pictures at that temperature. A simple spring-type hose clamp will hold the shutter open for time exposures.

17.2 - THE CAMERA

Modern 35-mm cameras are precision pieces of equipment and may not operate properly at very cold temperatures. Before using a camera on a telescope in cold temperatures, check it out. This can be done by wrapping the camera in thin plastic to keep all humidity out, and then leaving the camera in a freezer for a day to cool down before checking to see if the shutter will work. DO NOT FORCE MOVEMENT as this may damage the camera. Most cameras will operate at temperatures much colder than one would like to use them. If a camera fails to operate outside, ie, seizes, wrap it tightly in thin plastic to exclude all air and humidity, and bring it inside to warm up. NOTE: *Always wrap a cold camera tightly in plastic before bringing it to a warm environment to prevent condensation on the film and camera parts, ie, lenses, shutter, etc.* Let the tightly wrapped camera come to room temperature before removing the plastic. It is possible to get any camera lubricated for cold-weather operation, and this will avoid a lot of trouble in future.

17.3 - FILM

In cold weather, film can become brittle and break easily if moved or bent. The teeth on the film advance ratchet in the camera can easily tear out the perforations on the film, stopping further film advance. If you have any doubt about how any particular film will behave in cold weather, it is advisable to experiment before-hand with the film to determine its temperature limitations. Normally, the thinner the film, the more flexible it will be at cold temperatures, but this may not always be true. To test, load the film in your camera, wrap the loaded camera in plastic, then place in a freezer to cool down. When it has reached freezer temperature, try to advance the film DO NOT FORCE. If it will not advance, this does not mean you cannot use the film. What it does mean is that you will have to wrap the loaded camera up after each photo, bring it in and let it warm up in the refrigerator, advance the film and go back out to take another photograph. By placing the wrapped, loaded camera in the fridge, neither camera nor film gets so warm that they have to be re-cooled before use outside again.

When a roll of film is completed outside in cold weather, rewind the film back into its cassette while still outdoors in the cold, remove from the camera and wrap both the film cassette and camera tightly in plastic. Allow both to come up to room temperature before removing the plastic wrapping. Only after the film is completely warmed to room temperature is it safe to develop. Failure to properly warm up the film will result in severe condensation on the film surface which will cause streaking on the developed negative.

One problem that frequently crops up in cold weather is static bursts of "lightning flashes" on the developed film. This appears to have a variety of causes, dependent upon the camera used, type of film, etc. Static is always generated when humidity is very low, and of course this is the case on cold winter nights. While not being a cure-all, the author's suggestion is to avoid fast film movement, ie, advance the film slowly, load the film slowly into the cassette, rewind the film very slowly back into the cassette, etc. Fast movement of the film past the felt surfaces inside the loader, the cassette, or within the camera may be the major cause of this problem.

NOTE: If you bring your telescope inside during cold weather, it too should be tightly wrapped in plastic to prevent any condensation on the telescope optics due to indoor humidity.

SECTION 18 — POLAR ALIGNMENT BY TRANSIT

18.1 - TIME

Before any alignment is carried out, an understanding of time is mandatory. Time plays a very essential part in astronomy and astrophotography, particularly Local Sideral Time (LST). By determining the LST at a site, one can accurately adjust the telescope RA Setting Circle (if it has one). Conversely, and of much more importance, is aligning the telescope axis for True North, an absolute necessity for long astrophotos. It is possible to obtain a very accurate, (within 20") polar alignment on a good sunny day by using a "solar transit," if one has a good solar filter and access to the *American Almanac*, the book that has replaced the *Nautical Almanac & American Ephemeris.* At night time, polar alignment can be carried out using a "stellar transit," but it is necessary to convert between clock time, local time, and sidereal time. The next subsection will deal with determining sidereal time.

18.2 - DETERMINING LOCAL SIDEREAL TIME

Several methods of determining Local Sidereal Time have been devised, some using conventional methods, while others rely on electronic calculators. I use both, but have found the following method easy to use, and it gives quite good accuracy. Items required are:

i. Current copy of *The Observer's Handbook*, and
ii. Accurate longitude of location.

Method:

a. Determine the Longitude Difference from the Zone Setting Longitude, ie,
   Assume Longitude of Location = 103° 07' 10" W
   Nearest Time Zone Longitude (CST) = 90° 00' 00" W
   Longitude Difference = 13° 07' 10"

b. Determine Longitude Time Correction (15° = 60 minutes)

$$\frac{(13^\circ\ 07'\ 10'')}{15} \times 60 = 52^{\text{min.}}\ 28.67^{\text{sec.}}$$

c. Determine the Apparent Right Ascension of the Sun for the date from *The Observer's Handbook*, page 9. Assume October 18, 1980; Gives App RA = $13^h\ 31^m\ 46^s$.

d. Determine the Correction to the Sun Dial for the same day from the same page of *The Observer's Handbook*. For October 18, 1980; Sun Dial Correction = $-14^m 51^s$.

NOTE: When the day falls between those listed in the *Handbook*, interpolation between two dates will be required.

Calculations for LST for 7:30 p.m. CST, October 18, 1980:

a. Change Zone Time to 24-hour clock. 7:30 p.m. CST	=	$19^h\ 30^m\ 00.00^s$
b. Subtract Longitude Correction	=	$00^h\ 52^m\ 28.67^s$
Result is Local Mean Time (LMT)	=	$18^h\ 27^m\ 31.33^s$
c. Add Vernal Equinox Correction	+	$12^h\ 00^m\ 00.00^s$
	=	$30^h\ 27^m\ 31.33^s$
d. Add Apparent RA of Sun	+	$13^h\ 31^m\ 46.00^s$
	=	$43^h\ 59^m\ 17.33^s$
e. Subtract Sun Dial Correction	−	$[-14^m\ 51.00^s]$
[Note correction is negative]	=	$44^h\ 14^m\ 08.33^s$
f. Deduct Whole Day Intervals	−	$24^h\ 00^m\ 00.00^s$
Local Sidereal Time	=	$20^h\ 14^m\ 08.33^s$

So the Local Sidereal Time that corresponds to 7:30 p.m. CST at the location listed on October 18, 1980 is $20^h\ 14^m\ 08^s$ LST.

18.3 - POLAR ALIGNMENT BY SOLAR TRANSIT

A Solar Transit is easily carried out, and has one distinct advantage — the target is large and easily seen. The disadvantages are that a solar filter is required, (an Objective Filter), the weather must be clear so the sun can be seen, and the transit can only be carried out at *LOCAL* Noon. Further, both solar and stellar alignments require a telescope mounting head that may be levelled, and turned without the pier or tripod legs turning. Fine adjustment to the turning motion are a distinct advantage. Such a mounting head is described in Section 20.

Method:

a. From the *American Almanac* determine:
   i.) the transit time of the sun for the day
   ii.) the semi-diameter of the sun for the same day.

b. Determine the Longitude Time Correction (see paragraph 18.2).

c. Translate the semi-diameter of the Sun from minutes of arc into seconds of time, ie, 15.31 minutes of arc is equal to 15.31 × 4.0 seconds = 61.24 seconds. (Note that it is not possible to accurately determine where the center of the Sun is, so the transit is carried out on the west and east solar rims. Further, Ephemeris Transit Time is given as Local Time, and has to be changed to Clock or Zone Time.)

Calculations:

Assume Ephemeris Transit Time for October 18, 1980 = $12^h\ 06^m 22.50^s$

a. Convert to Zone Time, CST, by adding the Longitude Time Correction + $00^h\ 52^m\ 28.67^s$

   Transit Time for Center of Sun (CST) = $12^h\ 58^m\ 51.17^s$

b. Transit of West Limb = Transit Time of Sun minus the solar semi-diameter = $12^h\ 58^m\ 51.17^s - 01^m\ 01.24^s$

   Transit West Rim = $12^h\ 57^m\ 49.93^s$

c. Transit for East Rim = $12^h\ 58^m\ 51.17^s + 01^m\ 01.24^s$

   Transit East Rim = $12^h\ 59^m\ 52.41^s$

Transit Technique

As noted earlier, the telescope must be equipped with a solar filter over the Ojective, and an ocular equipped with black-line crosshairs for positioning the Sun. The telescope head and the Declination Axis have to be perfectly horizontal. (Use an accurate level — note that this implies some method of levelling the head, ie, either levelling feet on the tripod or levelling screws on the telescope head.) Ensure the Declination Axis remains in this position for the entire transit by locking the RA Axis with the motor drive OFF. The declination axis may be moved in elevation only, to keep the image of the sun centered in the ocular. The only other moving part is the head of the telescope, where it mounts on the pier or tripod, and this is a movement in azimuth only. Shortly before transit time, move telescope head and the declination axis vertically to pick up the solar image. Have the crosshairs vertical and horizontal, and centre the solar image on the horizontal crosshair by ajustment of the declination axis vertically. Now move the telescope head in azimuth so the vertical crosshair just touches the western limb of the sun. Use an accurate time signal, WWV or CHU, to give precise time — an assistant here can be invaluable, clock-watching, and calling off time. Hint: I normally use an accurate stop-watch that is started precisely five minutes before transit, and have an assistant give me a count-down to the five-minute mark. At the precise instant of transit, stop moving the telescope head, and lock it into position. Keep the stop-watch going, stopping it at the precise instance of the East Rim Transit. This should agree with your calculated value, and will give you an idea of how accurate your transit was. This will have aligned your telescope in azimuth only. An additional technique will be required to align it in elevation, and this will be described in Section 19. However, if your telescope was already aligned in elevation, you are now all ready for that star party or short-duration (15 minutes) astrophotography.

18.4 - POLAR ALIGNMENT BY STELLAR TRANSIT

Stellar or star transit is almost identical to a solar transit with the exception that there is only one transit, and it is necessary to change the Right Ascension of the star into Zone or Clock Time. A stellar transit is an ideal way for setting up a telescope for a Star Party. Additionally, one gets more than one chance — there are plenty of stars.

The method used is to first determine the approximate time in the evening when the telescope is to be set up — determine the Local Sidereal Time for this set-up, then look in *The Observer's Handbook* for a star near that particular Right Ascension. Using the Right Ascension for the star selected, work backwards from the method shown in paragraph 18.2 to determine the Clock or Zone Time for that star's RA. Using the same example cited for finding Local Sidereal Time, we have a Sun of $13^h\ 31^m\ 46^s$, and a Longitude Time Correction of $52^m\ 28.67^s$. We note from the previous example that 7:30 p.m. CST was equal to a Local Sidereal Time of $20^h\ 14^m\ 08.33^s$. Select a star near this RA. Looking in *The Handbook*, there is a dearth of bright stars in this RA, other than Deneb, and this is too high to give a really accurate transit. However, Beta Aquarius at RA $21^h\ 30^m\ 30^s$; Dec. −05° 40' at 2.86 magnitude is ideal.

Calculations:

a. Enter Right Ascention of Star	=	$21^h\ 30^m\ 30^s$
b. Add one whole day interval	+	$24^h\ 00^m\ 00^s$
	=	$45^h\ 30^m\ 30^s$
c. Add Sun Dial Correction	+	$[-14^m\ 51^s]$
	=	$45^h\ 15^m\ 39^s$
d. Subtract Apparent RA of Sun	−	$13^h\ 31^m\ 46^s$
	=	$31^h\ 43^m\ 53^s$
e. Subtract Vernal Equinox Correction	−	$12^h\ 00^m\ 00^s$
	=	$19^h\ 43^m\ 53^s$
f. Add Longitude Time Correction	+	$00^h\ 52^m\ 28.67^s$
Stellar Transit Time	=	$20^h\ 36^m\ 21.67^s$
	=	8:36:22 pm CST

Transit Technique

As with the solar transit, the RA is locked with the declination axis in a horizontal position, and the drive motor OFF. No filter is required, but an ocular with a lighted cross-hair is needed to center the star. Move the entire telescope head to follow the star until the precise transit time, then lock up the head, and the telescope is ready for use. As noted earlier, this technique only aligns the telescope in azimuth.

The two methods of polar alignment listed here, solar and stellar transits, are usually sufficiently accurate for a long evening's viewing or short duration astrophotography, if the elevation has been previously set. However, neither method alone has sufficient accuracy for long period astrophotography, or for a permanent pier. Only photographic alignment can achieve the precision of alignment required for that, and this is outlined in Section 19.

SECTION 19 — POLAR ALIGNMENT FOR A PERMANENT SITE

When long exposures are required in astrophotography, accurate polar alignment is essential. If this alignment is not accurate, the star images at the outer edge of the negative will show some trailing, regardless of how accurate the tracking was carried out. For much shorter exposures, the same effect is present, but is minimal due to the shorter exposure length and can be "lived-with." Obviously, such precise alignment is only justified where the pier location is permanent, ie, an Observatory or a pier that is anchored to the ground at some remote site of backyard, where only the telescope is removable.

The first step to obtaining an accurate alignment is to carry out either a solar or stellar transit as outlined in Section 18. This means, of course, that some provision has been made on the pier to ensure that the Head is level, can be moved in Azimuth with very slow motion, and that some similar provision has been made for minute adjustments in the Elevation Axis. A pier incorporating all these features is presented in Section 20.

How can you tell if your telescope is properly aligned? One very simple check is to note the amount of Declination corrections needed to track a star. Very little, if any, Declination corrections are needed in a properly-aligned and levelled telescope — only corrections in Right Ascension to compensate for inaccurate motor-drive speed. The only Declination adjustments should be to compensate for refraction, and such corrections should be minimal.

A more positive (and quantitative) technique is to site your telescope on Polaris, using an eyepiece with lighted cross-hairs, with the cross-hairs oriented so that one set is parallel to the horizon. Have the telescope driven, but make no attempt to track. Center Polaris on the cross-hairs, and let the telescope run for 15-20 minutes, then note the position of Polaris. If the star is still centered on the cross-hairs, the telescope is accurately aligned. If it has drifted either sideways or up or down, or a combination of both, the polar alignment is incorrect.

The problem now is to interpret, from the movement of Polaris, just which axis, Azimuth or Elevation, or both, is misaligned, and by how much, and which way. The problem is further complicated by the introduction of secondary mirrors and/or right-angle prisms into the optical path, resulting in a change of orientation in one or more axes of the image.

In a conventional refractor, or Cassegrain-type telescope, the image is "normal," ie, both axes are turned so the image appears true, but rotated 180 degrees. With this type of image, if the star has drifted to the right, the Elevation axis is too high; if the drift is to the left, the Elevation axis is too low. If the drift is upwards from the horizon, the Azimuth axis is too far to the West; if the drift is down toward the horizon, then the Azimuth axis is pointing too far to the East. This is diagrammed in Figure 19.1 below.

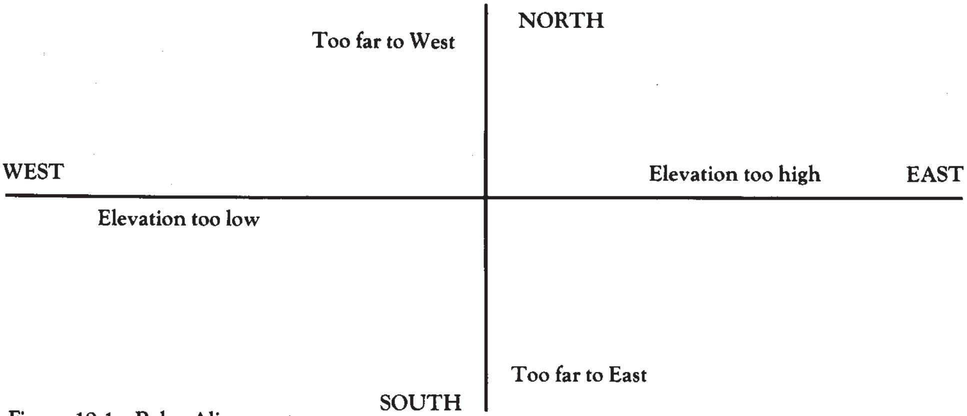


Figure 19.1 - Polar Alignment

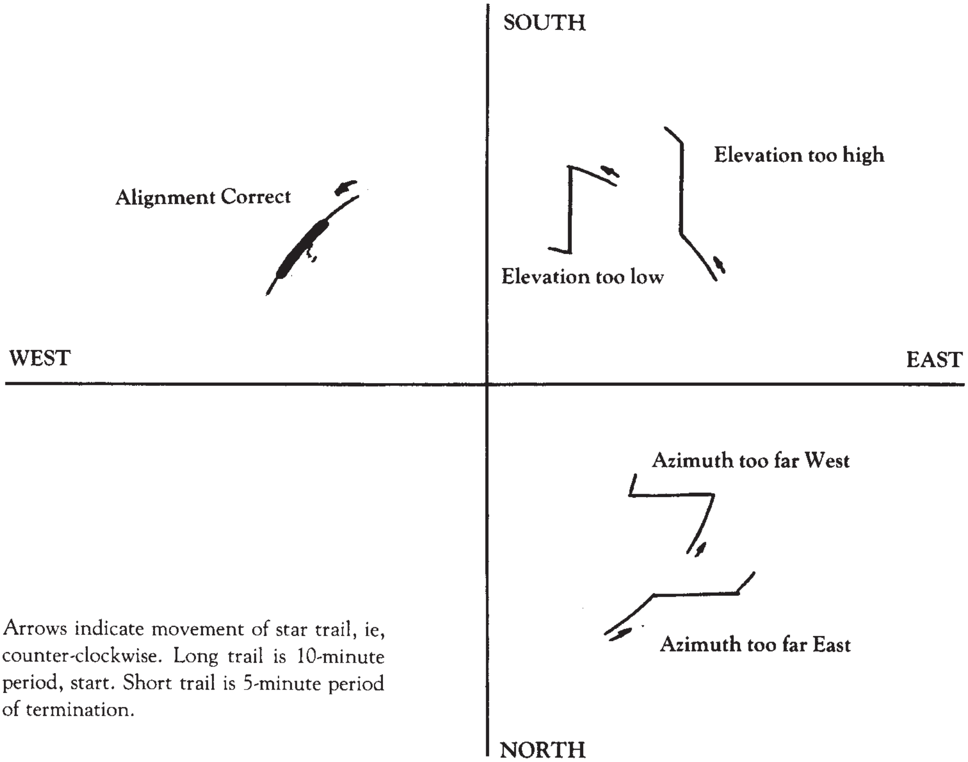
If the image is inverted in one plane due to a right-angle prism or secondary mirror, the movement of Polaris in that plane will be reversed, so the indications would be directly opposite to those indicated in Figure 19.1 for that particular plane. If there is more than one partial reversal in the image planes, this gives rise to lots of head-scratching to try and resolve which way is which. A simpler method may be to try a correction and note the result — if the drift is increased, the correction has been applied the wrong way. Apply a correction to the particular axis at fault, center Polaris on the cross-hairs, and repeat the run. If the same time interval is used for each test, it will quickly become apparent how the corrections are affecting the alignment, and by how much, ie, you can calibrate your adjustments.

Where a secondary mirror is involved, reason out which axis is not reversed. This can be difficult if the secondary is in a right-angled viewer that is not oriented with one of the major axes. In any case, apply a correction and note the effect. It soon becomes apparent which axis has to be corrected. If both axes are out, the usual case, correct one at a time. Trying to speed things up by correcting both axes simultaneously can lead to much greater problems plus wasted effort and time. If your adjustments are made by the turning of a threaded bolt, it is possible to "calibrate" the bolt thread to assist in judging the right amount of correction to apply.

After both axes have been corrected so Polaris does not drift visually over a period of 20 minutes, confirm your alignment by photography. Several articles have been written about this method of alignment, so this method is not an original for me — it is the method I have used with quite good success.

Couple a camera to your telescope in the Prime Focus configuration with the camera base parallel to the horizon or ground. Use Tri-X or other fast B & W film. Focus on Polaris, and try and set the image of Polaris in the center of your viewfinder. This will be a time exposure of about 35 minutes with no tracking. Start your photograph with the drive-motor OFF, and let the star trail for 10 minutes. Then turn ON the drive-motor, without tracking, for 20 minutes. At the end of the 20-minute drive period, turn OFF the drive-motor, and let the star trail for 5 minutes, then terminate the exposure. Make a note of the clock-time when the photograph was started.

Develop the film and analyze the picture. If you are precisely aligned, the paths of the two trail-periods and the one "track" period will form one smooth curve, with the "track" well "burned-in" due to overexposure. If this is the case, consider yourself extremely fortunate — you are properly aligned. Unfortunately, this is seldom the case. The usual picture shows two trail periods, one long (10-min.), one short (5-min.), joined by a straight line, the "track" period, making something like a "Z" or its inverse. This is where the clock times of the photograph are required. Determine the Local Sidereal Time for when the photograph was started, and from this determine the position of Polaris in its circular path around the North Celestial Pole. Orient your photo to fit the Polaris circle, and you can now determine which way, if any, the star drifted, hence which axis needs to be corrected. (See Figure 19.2) Apply a small correction to the proper axis and repeat the photographic sequence until a smooth curve configuration, shown in Figure 19.2 is obtained.



Arrows indicate movement of star trail, ie, counter-clockwise. Long trail is 10-minute period, start. Short trail is 5-minute period of termination.

Figure 19.2 - Photographic Polar Alignment

As can be deduced, accurate polar alignment can be a very lengthy procedure, but it is well worth the effort and time taken by ensuring high-quality astrophotos showing no trailing at the outer edges due to frequent Declination corrections. Further, if it is worth all the time and trouble to make an Observatory to house your telescope, it should be worth the extra effort required to ensure that your telescope is accurately aligned to the True North Celestial Pole.

There is one further advantage of an accurate polar alignment. If an accurately measured solar transit or stellar transit is taken from the "accurate" site, it is possible to determine the exact longitude by a reverse calculation, ie, you determine the Longitude Time Correction, and from this you can determine the correct Longitude to the nearest second of arc.

SECTION 20 — CONSTRUCTION OF AN ADJUSTABLE TELESCOPE HEAD

Most amateur telescopes are usually mounted on either a portable pier with three low-mounted feet, or on a three-legged tripod. These mounting "platforms," while adequate for short term viewing, have no provisions built-in for the adjustment of either the Azimuth or Elevation planes to permit fine settings necessary for astrophotography of any astro-object other than the Moon, where a very short exposure is adequate. Where a longer exposure is required, as in star fields or nebulosities, precise alignment is necessary, and the above noted "platforms" are totally inadequate. The author has designed a type of telescope platform which he refers to as a telescope head, and which is described in detail, with the help of drawings, in this section. With few exceptions, no dimensions have been included as the design is a concept that can be adapted to whatever materials are available. Fine adjustments are available in both Azimuth and Elevation, and enable the "head" to be set to precisely true north. The author has built his mount from basics and has also modified some existing mountings to incorporate the necessary features to provide the fine adjustments needed. Two versions are shown, one for a portable pier, Figure 20.1, and one for a permanent pier, Figure 20.2.

20.1 - A PORTABLE PIER

All references in this subsection will be to Figure 20.1. Obtain a section of thick-walled steel or iron pipe, the wall thickness being at least ¼-inch. Diameter will depend upon the size and weight of the telescope to be mounted, but for an 8-inch telescope, the author used iron pipe of 4½-inches outside diameter. A section about two feet long is adequate. Cut the pipe into two sections, one about 9 inches long, the other 15 inches long. The shorter piece will be the Rotatable Head, (b), in the Figure, and the longer piece will be the Pier Base, (d). Mount each piece in a lathe, and face off the ends of the pipes so they are square. Obtain some hardwood of sufficient dimensions to form a solid cylinder about 6 inches long, or two cylinders 3 inches long each, of suitable diameter to be a drive-in fit into the end of each section of iron pipe.

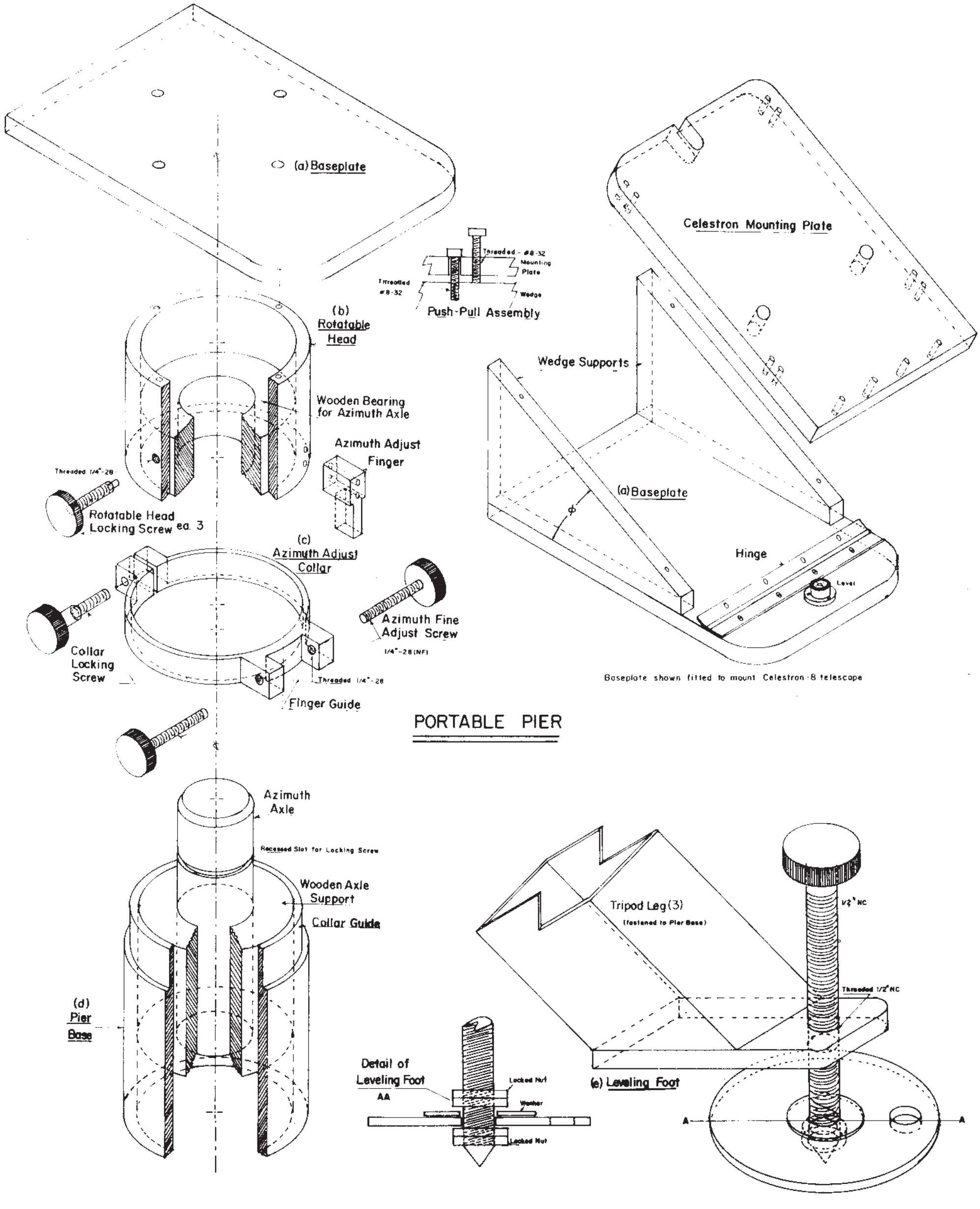


Figure 20.1 - A Portable Pier Head

Now remount the Pier Base, (d), in the lathe so the wooden cylinder faces the tailstock. Use a support to hold the pipe true. Drill a hole through the wooden cylinder to take the Azimuth Axle, which can be a piece of steel or aluminum rod at least one inch in diameter. Drill the hole in the wood so that the Azimuth Axle has to be driven in, ie, it is a very tight fit. Use a centering drill in the lathe tailstock to make a center hole in the Azimuth Axle to take a tail cone lathe center. With this center in place, the surfacing of the Pier Base can be carried out.

First turn down the Azimuth Axle until it runs true to the pier axis. Take the least amount of material off this Axle as possible. It should be noted that the Azimuth Axle should project from the Pier Base approximately three inches. After turning down the Axle, face off the Wooden Axle Support so it is at right-angles to the Axle. Now, cut out the Collar Guide on the upper surface of the Pier Base. This should be about ¾-inch high (along the surface of the Base), and about ⅛-inch deep. This is used to retain the Azimuth Adjust Collar, (c). A slot, about ³⁄₁₆-inch deep, and ⁵⁄₁₆-inch wide, is now cut in the Azimuth Axle, about 1½-inches from the wooden surface. This slot serves to seat the Rotatable Head Locking Screws, which prevents the removal of the Rotatable Head, and serves as an azimuth lock once the Head has been aligned. Before removing the Pier base from the lathe, champher off the upper edge of the Azimuth Axle to permit easy assembly into the Rotatable Head.

Now mount the Rotatable Head, (b), in the lathe, after driving in the second wooden cylinder — mount so the wooden cylinder faces the tail stock. Use the support to ensure the pipe runs true to the pier axis. Drill out a hole in the wooden cylinder to form a bearing for the Azimuth Axle. This should be a loose fit as it is only intended as a central guide — the centering will eventually be the Rotatable Head Locking Screws, (3). Also, the wood may swell slightly when damp and make turning the Rotatable Head difficult. Make sure the wooden cylinder is faced off to match the edge of the metal pipe of the Rotatable head. When the "Head" and the "Pier Base" are mated, they should turn smoothly on the wood and metal.

NOTE: If the lathe is fitted with an Indexing Head, it would be desirable to mark off 120° intervals along the outer circumference of both the Head and Base, the positions for the holes to be drilled in the Head for the Locking Screws, these holes being drilled with a Number 7 Wire Drill for the Locking Screws that will be ¼-inch diameter, threaded 20-threads-per-inch, NC. The Screws to mount the three legs for the Pier are not shown in the diagram, as the legs may be made from many different materials. Two holes, in-line vertically, should be drilled for each leg, below the Collar Guide. The author drilled ⁵⁄₁₆-inch holes, tapped to take ⅜-inch NC Bolts. Use V-Blocks and a Drill Stand to ensure all holes are drilled true toward the pier central axis.

The Azimuth Adjust Collar is made from ⅛-inch thick brass stripping, ¾-inch wide. Use a circular bending jig to obtain a good circle, and cut the length just long enough so both ends meet when mounted in the Collar Guide. Silver-solder a ¾-inch square brass block, about one inch long, over the junction seam of the Collar. Ensure the block is centered lengthwise over the seam. A second piece of brass, ¾-inch by 1-inch, and about 2 inches long, is filed out to fit on the outside of the Collar, and cut out as shown in the diagram of the Finger Guide. This is then silver-soldered to the Collar, diametrically opposite the block over the seam. A hole, using a Number 3 Wire Drill, is drilled lengthwise, as shown, through the two protruding portions of the Finger Guide. Note that all holes should be first drilled under-size, then "reamed" out to the correct size. These two holes are tapped with a ¼-inch, National Fine tap, 28-threads-per-inch. A similar hole is drilled through the other block on the Collar. The Collar is now cut with a hacksaw through the smaller block at the seam of the Collar. On one side of this split block, the hole is re-drilled, (enlarged), with a ¼-inch drill; the other side of the block is tapped with the ¼-inch, NF tap. This hole takes the Collar Locking Screw which is made from ⅜-inch brass rod, with one inch of its length turned down in a lathe to ¼-inch diameter, and threaded 28-turns per inch. The threaded portion passes through the clear ¼-inch hole into the threaded portion, and when screwed up, tends to tighten the Locking Ring in the Collar Guide. If the Collar has been made correctly, it will turn relatively smoothly in the Collar Guide when the Locking Screw is loose, but cannot be turned, ie, is rigidly locked on the Collar Guide, when the Locking Screw is tightened. A suitable knurled knob should be silver-soldered on the other end of this Locking Screw to make handling the Screw easy. This Collar provides a coarse adjustment of the head when loose, and a Fine Adjustment when tightened.

Two additional brass screws, complete with knurled knobs, threaded ¼-inch, 28 TPI, are made to fit into the two holes of the Finger Guide. These are the Azimuth Fine Adjust Screws.

NOTE: Brass has been specified for use in various places in this design. The main reasons for this are that brass can be readily silver-soldered, and does not rust, so the threads of the various adjustment screws should never seize up due to rusting — a common problem for a pier left out in the weather.

The Azimuth Adjust Finger is a small, finger-like piece of metal that is mounted at the bottom of the Rotatable Head with the "finger" projecting into the Finger Guide when the Head and Base are assembled. The Azimuth Fine Adjust Screws bear upon this "finger" and cause the Head to rotate with respect to the Base when the Collar is locked and the Fine Adjust Screws are turned — this is the Fine Adjustment of the Azimuth Axis. The 28-threads-per-inch of the screws permit fine control of this movement, and the Screws are intended to work against each other to hold the Finger securely in position once the desired setting has been achieved. The other locking mechanism of the Head is the three Rotatable Head Locking Screws, made of ¼-inch brass rod, threaded 20 TPI, to mate with the three holes tapped at 120° in the Head. The end of each bolt meshes into the recessed slot cut into the Azimuth Axle. When the Screws are loosened, the Head may be turned with respect to the Pier Base. When these Screws are tightened, the Head cannot turn, nor can it be removed from the Pier Base.

To carry a telescope, a flat metal baseplate, ½-inch aluminum, is fastened by four countersunk bolts, #8-32, to the top of the Rotatable Head. Shown in the Diagram is the author's mounting used to carry his Celestron-8 telescope. Any other mounting could be used in place of the one shown, ie, tailor-made for your own telescope.

All parts of the mounting are made from ½-inch aluminum plate. The Baseplate, (a), is secured to the Rotatable Head. On the Baseplate are two angled Wedge Supports, cut so the angle is about two degrees less than that needed for the local Latitude. A piano hinge is mounted on the Baseplate to carry the telescope Mounting Plate. #8-32 screws are used throughout. The Wedge Supports are secured to the Baseplate with countersunk #8-32 bolts. Holes, #8-32, are drilled along the edges of the Mounting Plate, and in the Wedge Supports, so that of each pair of screws, one screw is pulling the Mounting Plate down towards the Wedge, whereas the other screw is pushing the Mounting Plate away from the edge. Four sets are used to ensure no play in the Mounting Plate. These Screws provide the Fine Adjustment in the Elevation Angle, and the author prefers to have screws with Allen Heads to facilitate fine adjustments using Allen wrenches.

A good-quality spirit level, bubble-type, was mounted to the Baseplate to level the telescope Head.

While no provision is shown for the legs for the Pier, the system the author uses for telescope levelling is shown. Each telescope leg terminates in a ½-inch thick stainless steel plate that is securely fastened to the tripod leg, and projects out beyond it for about one and one-half inches. A hole is centered in this projected area and drilled and tapped for ½-inch National Coarse thread. A stainless steel bolt, threaded throughout its length, has a knurled knob on one end for manual turning. The other end is tapered to a coarse point, and has a large diameter, 4 to 6 inches diameter, ¼-inch aluminum plate, mounted. The hole in the plate is larger than ½-inch, ie, about ⅝-inch diameter, to allow free movement of the plate on the bolt. The plate is held on the end of the bolt by locking nuts. These nuts were made by cutting two nuts in half, facing them off in the lathe, then turning two of them against each other to provide a tight lock. The plate bears against the ground, but does not let the bolt sink into the ground, so turning the bolt raises or lowers that leg. Again, stainless steel and aluminum were used to avoid the rusting caused by iron or normal steel.

It is appreciated that there is a lot of machining involved in the making of this portable pier. If you are mechanically inclined, and have access to a machine shop, the job is simple. If, on the other hand, you do not have access to these facilities, you could give these instructions and Diagram to a mechanically inclined friend who could make the pier for you.

I have had occasion to modify other mounts, ie, Edmund Scientific mounts. It was easy enough to fit levelling feet to the three legs, but the pier pipe is not thick-walled. What was done in this case was to cut the pipe about five inches from the top and drive in wooden cylinders as was noted in the article. In fact, proceed identically with the previous instructions with the exception that the pipe cannot be cut to take a Collar Guide. What is done is to make an extra ring to mount over the pipe that slides down and acts as a support for the Collar Ring. This extra ring can be fastened to the pier base with three small screws which will hold it securely.

NOTE: The diagram shows a hole, ⅝-inch in diameter, in the plate of the levelling foot. This was added to provide the capability of locking the pier to the ground with long (3 feet), ½-inch diameter rods with a nut mounted at the top end. This permits removing the telescope from the mount without the danger of disturbing the mount and the polar alignment remains accurately set.

20.2 - A PERMANENT PIER

A permanent pier is one that is rigidly fixed to the ground. Usually, such piers are like an iceberg — a large portion is underground, probably reinforced concrete, to provide a base for a larger type telescope, that may or may not be mounted in an Observatory. To gain the maximum benefit from such a base, the Telescope Head needs to have the capability for very accurate, fine adjustment in both the Azimuth and Elevation Axes for polar alignment.

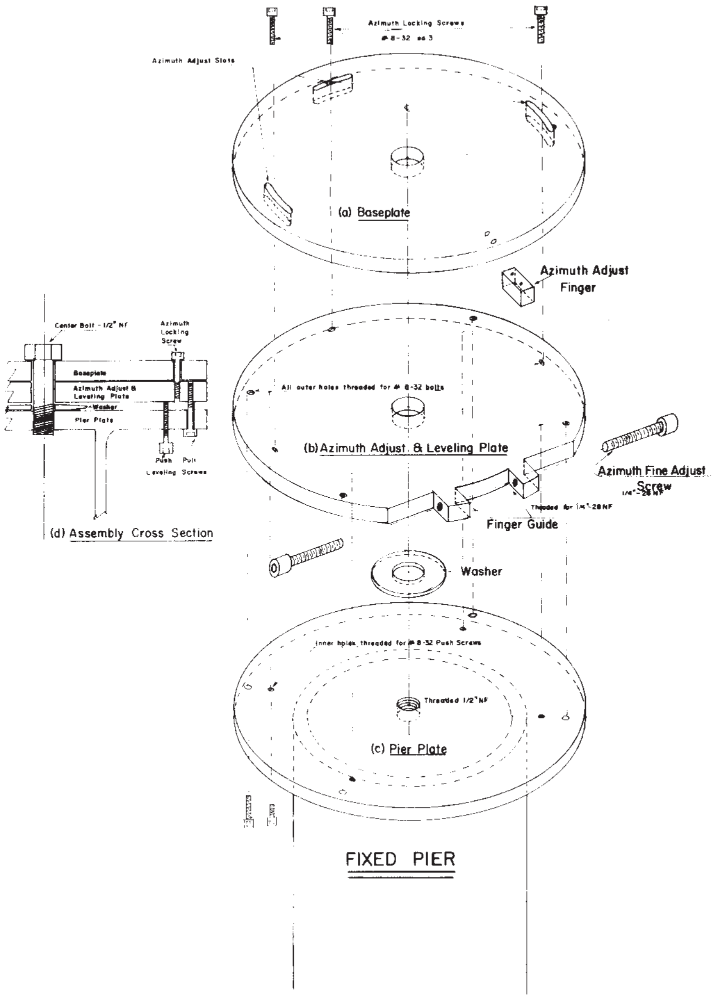


Figure 20.2 - Head For A Permanent Pier

All references in this subsection will be to Figure 20.2 on page 73. It should be noted that in this diagram, no attempt is made to show the internal construction of the pier; this is left up to the individual as such construction will depend upon the terrain, size of telescope, etc. It is assumed that such a base is provided, and a metal pedestal is mounted on the pier to support the Pier Head.

In the diagram, the metal pedestal has a circular metal plate, the Pier Plate, (c), welded or otherwise fastened to the pedestal top. See detail in Assembly Cross Section, (d). This Plate should be mounted to the pedestal in as level a configuration as possible. The center of the Plate is drilled and tapped to take a ½-inch, NF bolt. In addition, four sets of holes are drilled as shown in (c), the inner holes drilled and tapped for #8-32 bolts — the outer drilled to clear such bolts, ie, No. 19 wire drill.

Two additional metal plates, at least ½-inch thick, are made to mount above the Pier Plate. Both have a ½-inch hole drilled in their centers to mate with the threaded hole in the Pier Plate. The middle plate, Azimuth Adjust and Levelling Plate, (b), has a portion cut out, as shown in the diagram, to provide the Finger Guide. Holes are drilled through the two protruding sections, and tapped to take the Azimuth Fine Adjust Screws, ¼-inch, 28-threads-per-inch, NF. These bolts have Allen Heads so adjustment can be made with an Allen Wrench. Additional holes (7) are shown in this plate, but these are not drilled at this stage.

The top plate, Baseplate (a), has a small Azimuth Adjust Finger, a small block, ½-inch square by about ¾-inch long, is fastened with two bolts to the underside of the Baseplate to mate with the slot of the Finger Guide. Three other curved slots are cut as shown, to take #8-32 bolts, which when loose, will allow the Baseplate to turn on the surface of the Azimuth Adjust and Levelling Plate, with the Azimuth Adjust Finger centered in the Finger Guide.

A washer, shown between the bottom and middle plates, is filed so that its surface tapers towards its outer edges. This allows the middle plate to be tightened by the Center Bolt, but the plate can still be raised or lowered at its edges by the Push-Pull Levelling Screws, (d).

The three plates and washer are assembled, with the Center Bolt holding them together as shown in (d). The "Push" #8-32 levelling screws only (4), are used to level the two upper plates. It is assumed that a telescope Head Mounting and telescope have been fitted to the Baseplate. After the Baseplate has been levelled, carry out a Solar Transit as outlined in Section 18, by moving the two upper plates with relation to the Pier Plate. It should be noted that the Azimuth Fine Adjust Screws should be tightened on the Azimuth Adjust Finger, which should be approximately centered in the Finger Guide Gap. When this Transit, which need not be of high precision, is completed, without dismantling the Plates, drill upward, through the outer four holes in the Pier Plate, the holes for the "Pull" levelling screws. These holes are drilled and tapped for #8-32 bolts. NOTE: the screw holes only need to be started — they can be drilled out after the plates are disassembled. Also, before disassembly, mark the positions on the Azimuth Adjust Plate for the Azimuth Locking Screws. These, too, can be drilled out and tapped #8-32 after disassembly. In the assembled configuration, the position of these holes should be central in the Azimuth Adjust Slots.

When all construction details have been completed, the Pier Head can be assembled as shown in detail (d), and the alignment of the Head started.

First, very carefully level the Baseplate, (a), by adjusting the Push-Pull Levelling Screws, with the Center Bolt snug. Use as much precision here as is possible, ie, obtain a good precision level.

Mount the Telescope Head to be used on the Baseplate, and carry out an accurate Solar Transit, this time using the Azimuth Fine Adjust Screws. Note that during this adjustment, the Azimuth Locking Screws should be loose, and the Center Bolt should be snug, but not torqued tight. After the Transit, the Locking Screws can be snugged down, but again, not too tightly — photographic Fine-Adjust still remains. Only after the completion of the photographic alignment, can the Azimuth Locking Screws and the Center Bolt be tightened down to prevent any further movement of the Azimuth Polar Alignment. The Elevation Polar Alignment feature should be incorporated in the Telescope Head.

Once again, in this article, access to a machine shop is desirable for manufacturing the Pier Head.

SECTION 21 — ECLIPSE PHOTOGRAPHY

This section developed as a result of the author's active interest in the February 26, 1979 Eclipse. In preparation for the eclipse, the author scanned many publications, looking for some definitive information on taking pictures during the various phases of a solar eclipse, but was unable to find anything that could be considered as applicable to any such situation. As a last resort, he went through several years of *Sky & Telescope*, *Astronomy*, and other technical publications where any solar photo gave any information on exposure times, type of telescopes in use, size, f/number, film, filters, etc. He ended up with a wide range of information, very little of which seemed to correlate with any other. Some information on photos taken during totality did relate, but other than that, it was strictly by-guess-and-by-God. Finally, he ran a series of solar exposures using various films and various filters, and arrived at some agreement within the full solar phase. It is the result of all this research that has been included in this Section, and the author cannot guarantee everything stated is completely correct — it did work for him during the eclipse.

Photography of a solar eclipse can be divided into two separate phases — the partial phase, and the totality phase. The partial phase is visible over a wide area, whereas the totality phase is visible only to those located within a narrow path along which the Moon completely obscures the Sun. During the partial phase, heavy filtering will be required to limit the brilliance of the Sun to a safe value for viewing and photography. During the totality phase, no filtering is required. The transition between the two phases, one at the start of totality, and the other at the termination of totality are extremely sudden, and extreme care must be taken to prevent damage to the eyes and/or camera during these transition phases, and yet some of the desirable photographic events, such as the Diamond Ring, and Bailey's Beads, only occur during these transition phases.

21.1 - SOLAR BRIGHTNESS

Let us first look at the brightness of the Sun. We know that its magnitude is $-26.^{m}73$, whereas that of the Full Moon is given as $-12.^{m}70$, a difference of 14.03 magnitudes. We know from Chart IV(b), and Table II, that the Brightness of the Full Moon is listed as 220 units. We also know that a difference of five magnitudes gives a difference of 100 times in brightness, each magnitude increasing the brightness product by indices of 2.512, (Table IV).

The representative increase in brightness of the Sun over the Full Moon is given by:

$$\begin{aligned} 2.512^{14.03} &= 409{,}520.34 \text{ times the Full Moon} \\ &= 409{,}520.34 \times 220 \\ &= 90{,}094{,}475.39 \text{ Brightness Units.} \end{aligned}$$

A figure of this size is rather difficult to understand, and the only way to bring it down to a useful unit is to limit it severely. This is done by the use of Neutral Density Filters (see Table V, page 34). If we use an ND-6 filter, this will bring the above Solar Brightness figure down to 90.09, a useable value for our Exposure Formula. It should be noted that the Exposure Formula was developed for photographing an object reflecting light, not one producing light, but it will serve as a rough starting point to determine exposure times. However, trial exposures of the sun with various film speeds, f/numbers and Neutral Density Filters, lead to a Brightness Factor of 400 Brightness Units when using an ND-6 filter. Why the discrepancy between 90 and 400 is not known, but if the figure of 400 is used in the Exposure Formula when using an ND-6 filter, the Exposure Times will be more nearly correct. Note that this applies only for the full Sun, ie, the uneclipsed Sun. To determine the Exposure Time for any period where the solar disc is partially obscured due to eclipsing, it is necessary to know how much of the disc is eclipsed to determine what "B" to use in determining exposure times.

21.2 - PARTIAL PHASES OF SOLAR ECLIPSE

Anyone intending to photograph a solar eclipse, or a partial solar eclipse, should be aware of the various key time intervals of an eclipse.

a. First Contact — This is the time, in any one area, when the edge of the Moon first makes contact with the edge of the Sun.
b. Second Contact — This is the time when the Sun is just totally eclipsed. The period between First and Second Contacts is one of the two partial phases of the eclipse for those persons located within the path of totality.
c. Third Contact — This is the time when the edge of the Sun first re-appears after totality. The period between Second and Third Contacts is the duration of the totality portion of the eclipse in that area.
d. Fourth Contact — This is the time when the disk of the Moon just completely uncovers the Sun. It is the end of the Eclipse in that area, with the period between Third and Fourth Contacts being the second portion of the partial eclipse phase in that area.

Persons to one side of the path of totality will not see Second and Third Contacts; the entire eclipse will remain a partial eclipse in those areas.

21.3 - SOLAR PHOTOGRAPHY

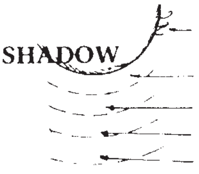
If one is serious about keeping a running photographic record of an entire eclipse, publications about the eclipse, its path, the times that certain events will be happening, the degree of obscuration should be obtained. This information can usually be obtained from the *American Almanac, The Observer's Handbook*, astronomy publications, etc. Even meteorologists help to provide educated guesses as to the chances of good weather and seeing conditions. Whatever is decided, do your planning early, and obtain any materials you may need before the rush starts. Above all, ensure you have a guaranteed location to set up your equipment. It is usually better to go as a team, and try and cover a variety of projects. Each one helps out the others and makes for an enjoyable excursion.

Using the technical information on Contact Times and Degree of Obscuration, work out ahead of time, the number of photos you want to take, the time they are to be taken, the Brightness Factor, "B", and hence the Exposure Times, "T". It is always good to bracket exposures — film is cheap. Just be sure and husband your time so you can change cameras, or films, and not be caught at a crucial moment with an empty camera.

Remember that two very critical periods are Second and Third Contacts, when the Bailey's Beads and Diamond Ring effects are present, and extremely short-lasting.

21.4 - PHOTOGRAPHY DURING TOTALITY

During totality, ensure your Neutral Density filters are removed. Based on my research of other peoples' successful totality pictures, I have prepared the Brightness Chart shown in Figure 21.1 below.



	Brightness, "B"
Prominences	160
Inner Corona	80
Middle Corona	4.75
Outer Corona	0.64
Extreme Corona	0.08

Figure 21.1 - Coronal Brightness Levels

Exposure Time may be calculated from the Exposure Formula given earlier in the *Handbook*, ie, $T = f^2/(A \times B)$.

As can be seen from the above Brightness Figures, the brightness levels vary greatly across the Corona, and a photo of the Outer Corona will result in an over-exposure of all the Inner Corona Area, whereas, correct exposure of the Inner Corona will show none of the Outer Corona. The idea is to take a series of exposures of differing lengths, and try to capture as much of the Corona and Solar detail as possible.

Table VIII has been prepared, listing exposure times for various f/numbers, films and Coronal areas. These were used during the 1979 Total Eclipse and worked well.

21.5 - TABLE VIII - TOTALITY EXPOSURE TIMES, NO ND FILTER

	FILM SPEED	f/NUMBER OF CAMERA LENS (SYSTEM)								
	25	1.4	2.0	2.8	4.0	5.6	8.0	11	16	22
	64	2.0	2.8	4.0	5.6	8.0	11.0	16	22	32
	100	2.8	4.0	5.6	8.0	11.0	16.0	22	32	44
	160/200	4.0	5.6	8.0	11.0	16	22	32	44	—
	400	5.6	8.0	11.0	16	22	32	44	—	—
EXPOSURE TIMES	Prominences B = 160		1000	500	250	125	60	30	15	8
	Inner Corona B = 80	1000	500	250	125	60	30	15	8	4
	Middle Corona B = 4.75	60	30	15	8	4	2	1	2s	4s
	Outer Corona B = 0.64	8	4	2	1	2s	4s	8s	16s	32s
	Extreme Corona B = 0.08	1s	2s	4s	8s	16s	32s	64s	128s	—

As can be seen, some of the figures for the Outer and Extreme Corona are extremely lengthy although these can be reduced by using faster films and lower f/numbers.

The main thing about photographing a total solar eclipse is to go prepared for any eventuality. It is an event that does not take place often in one's area, and when it does occur, planning must precede the actual event by some months. Take everything you will need, and take spares for those items as well. Even then, you will find something has been left behind — Murphy's Law — and it will always be the one thing that you cannot manage without.

21.6 - A WORD OF CAUTION

Solar eclipses can be dangerous if not viewed correctly, and it is possible to get so interested in taking photos during totality that one loses track of time, and gets caught by the full blast of the Sun, without a filter. Set up a warning system that will alert everyone at least 10 seconds before Third Contact, then everyone will have fond memories of an unforgettable event.

21.7 - LUNAR ECLIPSES

A lunar eclipse is not the spectacular event that a solar eclipse is, but it is, nevertheless, a very colourful event that is worth photographing.

Unlike the solar eclipse that is restricted to a relatively narrow band across the Earth's surface, the lunar eclipse is usually seen over at least half the Earth's surface, and many more people have the opportunity to photograph this event.

To understand the reason for the "colour" in a total lunar eclipse, one should be aware how the eclipse is caused. The Moon enters the dim or penumbral shadow first, at which time its brilliance decreases, but aside from this, there is little change in the Moon's appearance. All surface features are still visible but fainter. After a period of time, a darker shadow is seen creeping across the Moon's surface, the umbral shadow. When this completely covers the Moon, totality for the lunar eclipse starts. This phase will last quite some time, then the dark edge of the umbral shadow is seen slowly leaving the Moon, followed later by the penumbral shadow.

During the totality phase, the Moon is "illuminated" by light that is "bent" or refracted by the Earth's atmosphere. The longer wavelengths of the spectrum are bent towards the Moon, and result in giving the Moon a reddish or coppertone colour. If the Moon is centered exactly at the centre of the umbral shadow, all the Moon will appear reddish. This is an event that does not happen often, so the edge of the Moon nearest the penumbral shadow will assume a silvery cast. During the entire eclipse, the Moon will be changing colour over its surface, and is a very photogenic subject.

Refer back to Chart IV(b) for Brightness figures, "B", for lunar eclipses. It is recommended that Fujichrome R400 film be used as this is more sensitive in the red. Using a telecamera speed of f/10, exposures for penumbra will be 0.0125 second, (1/80), for Earth Shine exposure will be 25 seconds, and for the umbra the exposure time will be 50 seconds. Obviously, the latter two exposures will be subject to reciprocity failure. Some provision should be made for the telecamera to follow the Moon.

SECTION 22 — HYPERACTIVATION OF FILM

22.1 — RESEARCH BACKGROUND

For many of the past years professional astronomers have been experimenting with ways to minimize the exposure times required to get acceptable photos of stars and nebulosities with very low brightness levels, ie, high magnitude values. Most of their photos were taken with B & W plate film and, initially, most efforts were directed to reducing the effect of reciprocity failure.

The major manufacturers such as Kodak concentrated on improving their plate films since these were the films used in laboratories and observatories for spectroscopy. The outcome of this research was the now well-known spectroscopic films designated as 103a(-). This is a group of films where the "(-)" indicates the spectral region where the film was most sensitive. The "a" indicates "astronomy," and these films had little or no reciprocity failure, the film continues to record evenly over a long period of time. Such films are, however, not considered high speed, and are quite coarse grained, therefore research continued to improve the speed so that exposure time could be reduced. Some gain was achieved by the use of special developers, and such developers are still in use, ie, Diafine, etc.

None of these techniques were considered the complete answer, so research continued. Much of this research was carried out by professional astronomers and their assistants in major observatories. It was noted that some speed improvement could be obtained if the film emulsion was "flashed" for an extremely short period with a bright light — tending to overcome the initial latency of the emulsion to recording, but this was not considered a suitable technique as the film had to be used immediately after "flashing," and the method had too many variables to be reliable. During this period of research it was noted that if the emulsion was exposed to certain gasses, ie, fumes from formaldehyde, ammonia, etc., just prior usage, film speeds were greatly increased.

It was this latter technique that was later developed into the present method that we refer to as "hypering," or hyperactivating the film emulsion. The most effective gas appeared to be hydrogen gas. The hypering effect varies with the type of emulsion, and will give good results with both B & W and colour film.

There is, however, a problem. Hydrogen is a very explosive gas — witness the Hindenberg-Zeppelin that used hydrogen — so the use of pure hydrogen is considered quite hazardous. Further experimentation showed that very little hydrogen was required, so to reduce the "Hindenberg Effect," the explosive hydrogen gas was diluted with nitrogen gas. It should be noted that film soaked in nitrogen gas alone did show some increase in speed and, as it is inert, was the logical gas to mix with hydrogen. Further experimentation showed that a mixture of 8% Hydrogen with 92% Nitrogen gave excellent results. Such a mixture is now referred to as "forming gas."

Numerous articles have been written about the use of forming gas, and one agency that has been foremost in making it available to amateur astrophotographers is Lumicon. This company not only manufactures Hyperactivating Kits, including pressurized containers of forming gas, but also gives detailed instructions for the use of such kits.

It should be noted at this time that hyperactivation itself is relatively simple, using the proper kits, but care in the use of the kits should always be exercised. While there is little risk, if any, due to the hydrogen gas, once it is properly mixed with nitrogen, there is still an explosive risk due to the high pressure of the gas in its storage tank — any tank containing gas at high pressure can rupture and explode if handled improperly. Care should always be exercised when opening the various valves to ensure pressure in the hypering tank does not change too abruptly.

22.2 HYPERING PROCEDURE

The results or effects of hypering will differ quite markedly between different brands of films. Each of these films will give differing results depending on the length of exposure to the forming gas, the gas pressure inside the hypering tank, and the temperature of the gas, tank, and film during the hypering process. This process is normally termed "soaking."

Dr. Jack B. Marling of Lumicon has devoted considerable time and funds researching the preferred times and temperatures needed to "soak" various films. Such information comes with each Lumicon Hypering Kit, and such proprietary information cannot be included in this article.

As I use the Lumicon kit myself, I hope they will excuse me as I describe the methods that I use. The negative film itself can be hypered without removing it from its cassette, or if you have the larger hypering tank that I use, the film can be pulled out of its cassette but still attached to its reel, and threaded into a developing reel (all in total darkness naturally), then the loaded reel, with cassette attached, can be placed in the hypering tank and the light-tight top sealed. The tank is equipped with an electrical heating coil wrapped around it. This is now turned on to warm the tank to the recommended temperature. The tank is then completely evacuated, (I use an electric-motor-driven vacuum pump), and after the pressure gauge shows the best vacuum, the tank valve is slowly switched over from the vacuum pump to the tank holding the pressurized forming gas. Once the recommended pressure of the gas has been reached, the valves on both the forming gas tank and the hypering tank are closed. The film is now allowed to soak for the recommended period of time. Soaking time may be reduced to some extent by a slight increase in temperature and/or pressure, but these measures should only be tried after experience has been obtained from the results of the photos taken. It is quite easy to over-do the hypering and end up with a grossly over-exposed negative and a ruined film. I would seriously suggest that anyone trying hypering for the first time carefully adhere to the instructions that come with the kit.

NOTE: A film that has been spooled onto the developing reel, ie, that is open to the forming gas, will take less time to soak compared to a film that is inside its cassette. However, if time is not too important, and you have the larger soaking tank that I use, it is possible to "hyper" several cassettes at the same time, and save on the use of forming gas.

22.3 - ASTROPHOTOGRAPHY FILMS

There are many films, both B & W and colour, that may be hypered and used for astrophotography. However, some films react better to hypering than others, and will give much better results. As a general rule, colour films do not give as good a result as do B & W films. This is probably because B & W films have only one photosensitive emulsion whereas colour films have three.

For colour film, depending on which colour emulsion is nearest to the surface, ie., closest to the forming gas, the end result means that that surface gets more hypering. The end result may be a dominating tint on the final photo.

Some colour films may show a dominant bluish tint, and such colour films are preferred for photographing nebulae that are predominantly blue. One such film is High Speed Ektachrome, but many other films also show this characteristic. On the other hand some colour films show an increasing sensitivity in the red region of the spectrum, and of course, such films will have an advantage when photographing nebulae with a dominant reddish colour. One such film that I use is Fuji 100, but again, many other films are red-sensitive. One factor noted is that hypered colour film appears to be grainier that non-hypered film of the same make.

As a general rule, the very high speed colour films are not recommended for hypering although this is a personal view of the author — other astrophotographers may have different views. The only true way to decide which film is best for each subject is the old method of try-and-find-out.

22.4 - DURATION OF HYPERING EFFECT

A drawback to the use of hypered colour film is that the effect has a relatively short duration, and such film should be used as soon as possible after being hypered. Normally, the hypered colour film should be used within two weeks to a month after being treated. Also, as the author has found out, hypering can be over-done. The final effect is a grossly over-exposed negative.

One little technique that I use with colour film is to divide a newly-purchased colour film into four (in the darkroom, of course), and load each quarter film into separate cassettes. Each cassette is hypered later as needed, letting me take only a few exposures at one time and develop immediately. When more film is required, a second (quarter) cassette is hypered. While this requires more hypering, I can usually combine the colour film with some B & W in the same hypering tank, and thereby not waste forming gas.

B & W film, generally, lends itself very well to being hypered, possibly because there is only the one layer of emulsion to be treated, but again, some films are better than others. One of the preferred films, in my opinion, is Kodak SO-2415. This film evolved from two earlier films, SO-410 and SO-115. These films were produced by Kodak for use, one for Solar Patrol work and the other for Microphotography. Both films had almost identical characteristics, and now SO-2415 has replaced both of them. This film is very fine-grain, better than Pan-X, but with a normal ASA speed of ASA-80 to ASA-160. The two speeds are given to cover the different developers normally used. These developers are Kodak D-19, and HC-110 (dilutions D and F). Without hypering, this film is ideal to catch fine detail and allow excellent enlargement without indication of grain in the print. Use of D-19 makes the film work almost like High Contrast Copy film. The HC-110 developers also allow for high contrast but also act as a moderating developer.

When SO-2415 is hypered, the speed increase is almost phenomenal. Lab measurments have indicated an ASA speed increase many times normal. This speed increase does not appear to be at the expense of the fine-grain. In other words, hypered 2415 may give a speed of, say, 20 times, or 20 x 180 or ASA-3600 without any increase in graininess. Results from this film have been compared to 103a film, and in certain applications, 2415 is considered to be superior to 103a, due possibly to the much finer grain. This makes it ideal for the amateur astrophotographer.

One further advantage of the use of hypered B & W film is its storing capability. Whereas colour film appears to have unacceptable loss, as far as hypering improvement is concerned, after storage for a month, hypered B & W film will store for at least six months. My own experience is that 2415 is still showing good hypered capability after storage in excess of six months.

I should point out that all storage of hypered film should be done in a freezer. I make it a general practice to encase each hypered film, in its cassette and plastic holder case, in a small plastic sandwich bag which is wrapped tightly around the film holding case to remove any air, and is then kept tight around the case with an elastic band. When I intend to use the film it is removed from the freezer, still tightly wrapped and allowed to slowly warm to room temperature before being loaded into the camera. This will prevent any possibility of condensation getting on the film surfaces.

22.5 - STATIC

One problem I have noticed with hypered film is static-like "lightening" marks on exposed film. As I live in a relatively low humidity climate, the air is normally "dry." It would appear that hypering the film has the effect of reducing the relative humidity even further than normal. The effect, however, can be minimized to some extent by ensuring the film is loaded in the camera with a grounding strap clipped to the camera; that the camera has a grounding strap attached when it is mounted onto the telescope; and that the film is advanced very slowly in the camera. Similar precautions should be taken when loading the film from the camera into the developing reel.

22.6 - REFERENCES

Numerous articles have been written on the subject of hypersensitizing film, and several of these articles have appeared in periodical magazines such as *Astronomy* and *Sky & Telescope*. In addition several Photo-Bulletins on this subject have been published by the American Astronomical Society (AAS) specifically dealing with this subject.

SECTION 23 - ASTROPHOTOGRAPHY USING INDIRECT COLOUR

23.1 - BACKGROUND

Normally when one thinks of colour photography, whether normal ground-based or astral, one thinks of using colour film and/or slides. However, when colour film is used for exposures exceeding a second or more the effect of Reciprocity Failure and the resultant colour-balance shift must be considered. Reciprocity Failure can, to some extent, be minimized by the use of hypered film and the use of cold-cameras or cold weather techniques (see Section 17). Such methods do provide some relief from the colour-balance shift due to Reciprocity Failure, but are not the total answer. Another technique, when properly applied, will give much better colour rendition. This technique is termed "Indirect Colour." This section is included only to let the amateur know that this technique exists.

Anyone who is watching a colour TV set is watching indirect colour, where the three basic light colours, red, green, and blue are being combined to give any colour desired from black to white, and any colour in between. Another example is the beautiful colour photos we have seen of the planets sent back to Earth by the various satellites such as Explorer, Voyager, etc. These pictures were sent back to Earth in electronic black and white, then changed to the correct colour by a properly programmed computer. The same type of program can be used to "enhance" a picture, similar to the use of a tone control on an audio program that will augument particular tones.

23.2 - TECHNIQUE

The technique listed in 23.1 was to take three photos of the same object, each time using a complementary filter, ie, Cyan, Magenta, and Red. These photos were recombined into one picture to give the true colour of the original scene. In these cases the photos were electronic images. However, a similar method may be employed using negative film and appropriate filters.

The film used is spectroscopic film such as Kodak 103a(-), the bracketted space being a capital letter which indicates the film's spectral range. While Kodak is not the only manufacturer of such spectroscopic film, they are the ones best known to the author.

The choice of filters to be employed will depend on where you live, ie, North America or Europe. Several articles have been written on this subject, and have appeared in popular periodical magazines such as *Sky & Telescope*, *Astronomy*, and various AAS Photo-Bulletins. This of course is where I have obtained such information, from articles by Hans Vehrenberg, Eckhard Alt, Ernst Brodkorb and Jurgen Rusche, all from West Germany. Their articles recommend the following films and filters:

For Red - use 103a(E) film with Wratten 25 or Schott OG 590 filter.
For Green - use 103a(G) film with Wratten 61 or Schott KV 470 filter.
For Blue - use 103a(O) film with Wratten 2B or Schott KV 389 filter.

As stated, three separate exposures are taken of the object. The exposure time for each colour, according to Vehrenberg, is based on the ratio of 1:1.3:2, where 1 is for Blue, 1.3 for Green, and 2 for Red. The exposures must, of course, be taken from the exact same spot with the same camera lens system, in other words they are identical with the exception of the film and filter used. Other sources have indicated that different ratios were used but the listed ones are a good place to start.

Taking the exposures are, however, only the first step. The rest is all in the darkroom. The next step is to develop the individual negatives in D-19 developer, usually for about 4 minutes. The next step is to make internegatives, ie, make prints on negative plate film, using a very fine-grained film such as Pan-X. After developing and fixing, each negative is bleached as if it were a colour film. Bleaching is continued until all the metallic black silver is completely converted into silver bromide, (white colour), after which the films are thoroughly washed to ensure all the bleaching agent is removed. The internegatives are now dyed to produce the desired colours in the areas where the silver bromide remains — this is probably the most critical part of the process. The Blue light exposure is dyed Yellow, the Green to Magenta, and the Red to Cyan. As can be seen, these are the complementary colours of the originals.

To make a coloured print, the three internegatives are "sandwiched" together to make one negative to be used to make the colour picture. To do this, the three internegatives are mounted between two pieces of optically-flat glass to ensure minimum negative thickness and precise registration. As the "negative" is very thick in comparison to a normal colour negative, the enlarger must be equipped with a long-focus projection lens to minimize parallax.

An alternative method that has been used is to expose each unbleached negative separately, with its appropriate filter, on to the same colour print paper. Use a Red filter for the Red internegative, Green with Green, and Blue with the Blue negative. The major problem with this technique is to ensure accurate registration of each negative on to the colour print paper. To achieve this, both the print paper easel, and the enlarger must be rigidly mounted to prevent any movement once the printing exposure has started.

At this stage, most amateur astrophotographers will throw up their hands and decide to find another hobby. I should point out that to date my results have been lamentably poor. Considerable experimentation is required, in addition to a well-equipped photo-lab and a lot of patience. However, having seen some of the results using this technique, I think the method is worth the effort.

23.3 - REFERENCES

"More About Indirect Colour Astrophotography," *Sky & Telescope*, November 1984.

"Photographs of Deep-Sky Objects," *Sky & Telescope*, April 1978.

APPENDIX “A”

ASTROPHOTOGRAPHY EXPOSURE GUIDE

The author has designed, and copyrighted, an Astrophotography Exposure Guide in the form of a circular slide rule. This guide has been found very useful for calculations of the exposure times for lunar and planetary photographs, given the age of the Moon, or the magnitude of the planet, information which is readily available from *The Observer's Handbook*. It is, of course, necessary to know the speed of your astrocamera system, ie, the f/number, and the ASA speed of the film being used. The exposure guide is based on the formula:

$$T = \frac{f^2}{A \times B}; \text{ where}$$

T = Exposure Time in seconds,
f = speed of telecamera system,
A = ASA speed of film, and
B = Brightness of Object.

Brightness of the object is quickly determined. In the case of the Moon, it is only necessary to know the age of the Moon from New Moon; in the case of the planets, the magnitude. As stated, this information is available in *The Observer's Handbook*. Also included on the guide is the Reciprocity Equivalent times, where exposure time, T, is in excess of one second. A separate table on the guide lists the loss of magnitude when the desired object is below 45° from the horizon.

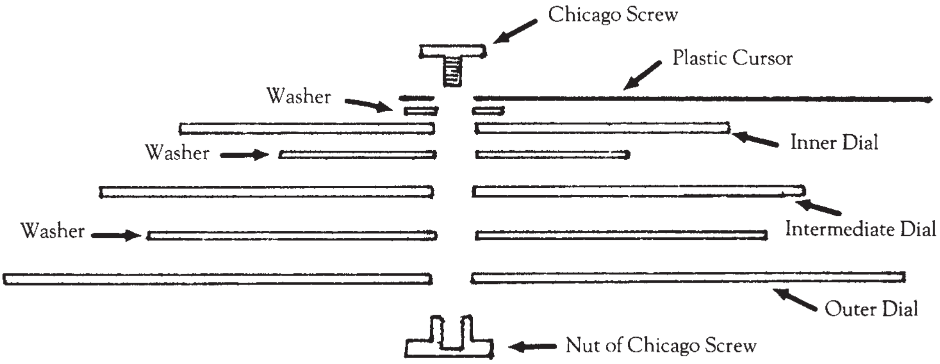
The guide is made up from three circular logarithmic charts, each on a separate page. These charts are mounted, then joined through the centre with a Chicago Screw. The “wheels” each turn independently, and a cursor indicates the final result, the Exposure Time.

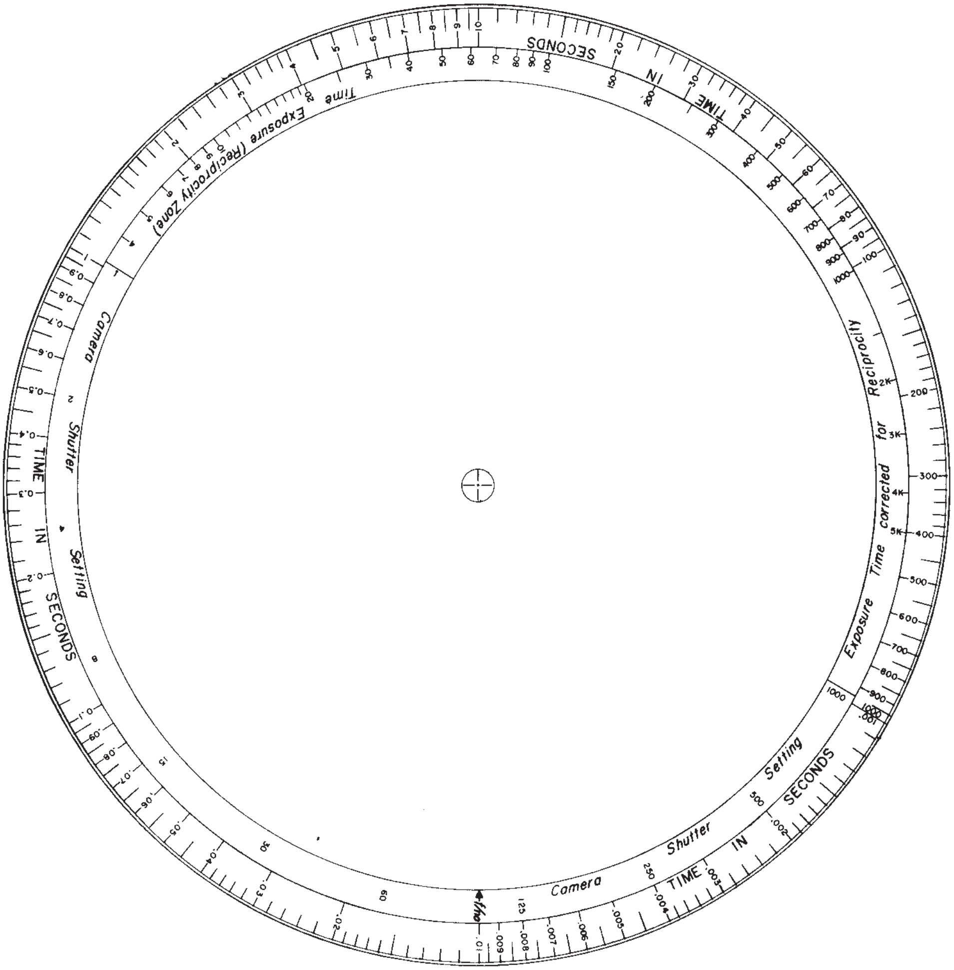
ASSEMBLY INSTRUCTIONS FOR THE ASTROPHOTOGRAPHY EXPOSURE GUIDE

1. Remove each Graph Sheet page and the Instruction Sheet page very carefully from the book to prevent any ripping or tearing.
2. Using two-inch or wider double-sided tape (the kind used to fasten down carpets, etc.) cover the back of each sheet without any overlapping of the strips. Be sure the tape is mounted smoothly, with all air bubbles removed.
3. Obtain a reasonably stiff but thin base to mount the Graph Sheets on. Suggestions are 6-ply poster-board, thin but rigid, (1/32-inch), aluminum sheeting, or thin plastic sheet. To ensure a good bond between the base material and the graph sheets, make sure that the backing sheeting is clean and free from any oil or grease. Where poster-board is selected as the backing, use extra blank white sheets with double-sided tape mounted on them, to be mounted on the reverse side of the backing, ie, the side away from that holding the graph sheets.
4. Working with one sheet at a time, remove the covering paper from the double-sided tape on the graph sheets (not the Instruction Sheet), and lower each sheet down gently onto the backing material, ensuring that no air bubbles are present, and that the surface of the graph sheets is perfectly smooth when mounting is finished. Use a hard rubber roller. On the two smaller graph sheets, mount the blank white sheets to the reverse side of the backing.
   NOTE: mounting the blank sheets on the reverse side of the poster board provides equal pressures on both sides of the backing, and helps to avoid warping of the dials later due to humidity.
5. After mounting the largest graph sheet, obtain a 3/16-inch punch or roto-bore drill, and carefully drill out the center hole on this and the Direction Sheet. Make up a jig of a flat piece of plywood, about a foot square, and mount in the center of this plywood a short vertical "axle" made from 3/16-inch rod. Lay the largest graph sheet on this plywood, face downward, with the axle passing through the center hole in the sheet. Remove the paper covering from the double-sided tape at the back of the Direction Sheet and gently lower the sheet, sticky-side down, onto the graph sheet, with the 3/16-inch axle passing through the center hole in the Direction Sheet. Once mounted, remove from this jig and roll this Direction Sheet to remove all air bubbles.
6. This next step is not essential to the immediate operation of the guide, but will ensure that the guide will have a much extended life-time or usable period. Obtain some Book-Lon, a clear adhesive plastic sheeting, and cover both sides of all three sheets or dials. Work out all air bubbles to ensure a good bond between the plastic and the surface of the dials. This material forms a permanent bond with the paper in 24 hours, and will greatly reduce the effect of wear on the surfaces of the dials. When the dials are all covered, drill out the center hole on all three dials with the 3/16-inch punch or roto-bore. Also, drill out the center hole in the clear plastic cursor.

7. Using scissors, or tin shears, carefully cut around the outer edges of all three dials, so that they now become circular dials. If the backing material is metal, use a fine file to lightly file the edges of the backing material so there are no snags or sharp points.
8. Make up two washers, about 2-inches in diameter, with a $^{3}/_{16}$-inch center hole, from posterboard. These will be mounted between each dial pair to prevent the dials from rubbing on each other.
9. Cut out the plastic cursor.
10. Assemble the exposure guide, as shown below, using a Chicago Screw to fasten the assembly together.

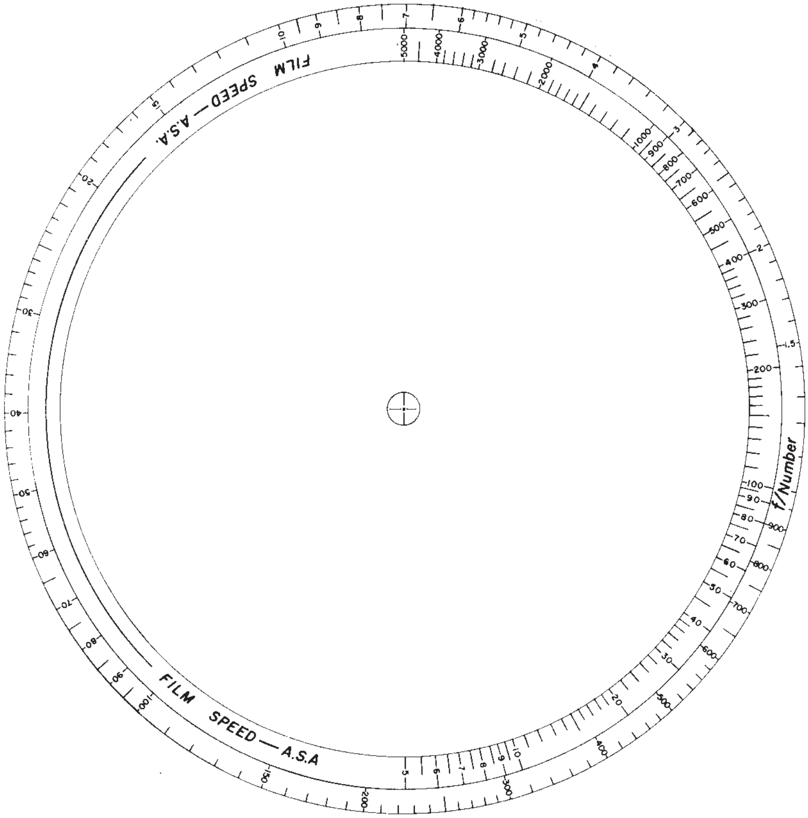
ASSEMBLY DIAGRAM





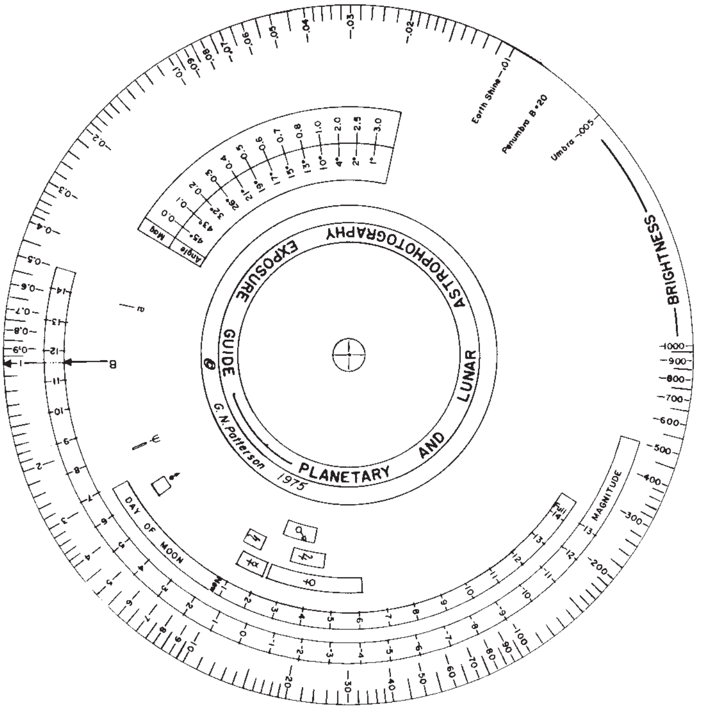
APPENDIX "A", PLATE I

This is the Outer or Exposure Dial for the Planetary and Lunar Astrophotography Exposure Guide. This is the dial that shows the exposure time. At a time of 0.01-second, at the bottom of the dial as shown above, is the f/# Fixed Cursor. In use, the film speed on the Intermediate Dial, Outer Scale, is set to this cursor. Between 0.001-second and 1 second, the outer scale registers the exposure time, "T", with the inner scale registering the nearest camera shutter speed setting. From 1 second to 1000 seconds, the outer scale shows the basic calculated time, the inner scale, the time corrected for reciprocity failure.



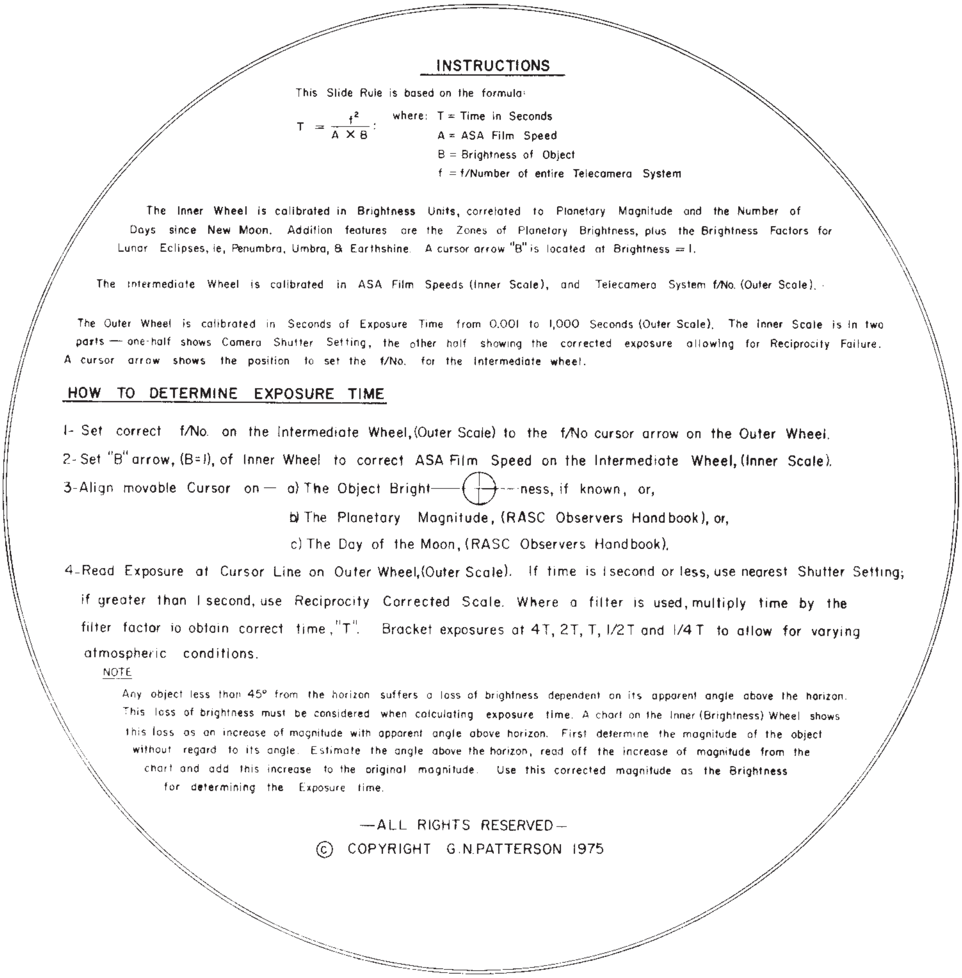
APPENDIX "A", PLATE II

This is the intermediate dial which registers astrocamera speed ratings on its outer scale in the traditional f/numbers, with the inner scale registering the film speed in ASA ratings. In practice, the f/# cursor of the outer dial is set to the astrocamera speed or f/number as listed on the outer scale of this dial. The "B" line cursor on the inner dial is set to the film ASA number on the inner scale of this dial.



APPENDIX "A", PLATE III

This is the inner dial of the astrophotography exposure guide. The outer scale shows the brightness, "B", ratings, and at "B" = 1, the "B" cursor line is shown. In use, this "B" cursor line is set to the film ASA number on the inner scale of the intermediate dial. In addition to the brightness values, scales showing magnitude, day of the moon, and planet brightness zones are added coincident with the brightness. A small scale showing the relationship between angle above the horizon, and loss of magnitude, is included to determine loss, if any, of any object that is closer than 45° from the horizon. The brightness values for earth shine and umbra are correctly positioned — penumbra is listed as a value only.



INSTRUCTIONS

This Slide Rule is based on the formula:

$T = \frac{f^2}{A \times B}$; where:

T = Time in Seconds
A = ASA Film Speed
B = Brightness of Object
f = f/Number of entire Telecamera System

The Inner Wheel is calibrated in Brightness Units, correlated to Planetary Magnitude and the Number of Days since New Moon. Addition features are the Zones of Planetary Brightness, plus the Brightness Factors for Lunar Eclipses, ie, Penumbra, Umbra, & Earthshine. A cursor arrow "B" is located at Brightness = 1.

The intermediate Wheel is calibrated in ASA Film Speeds (Inner Scale), and Telecamera System f/No. (Outer Scale).

The Outer Wheel is calibrated in Seconds of Exposure Time from 0.001 to 1,000 Seconds (Outer Scale). The Inner Scale is in two parts — one-half shows Camera Shutter Setting, the other half showing the corrected exposure allowing for Reciprocity Failure. A cursor arrow shows the position to set the f/No. for the Intermediate wheel.

HOW TO DETERMINE EXPOSURE TIME

1- Set correct f/No. on the Intermediate Wheel, (Outer Scale) to the f/No cursor arrow on the Outer Wheel.

2- Set "B" arrow, (B=1), of Inner Wheel to correct ASA Film Speed on the Intermediate Wheel, (Inner Scale).

3- Align movable Cursor on — a) The Object Bright—⊕—ness, if known, or,
b) The Planetary Magnitude, (RASC Observers Handbook), or,
c) The Day of the Moon, (RASC Observers Handbook).

4- Read Exposure at Cursor Line on Outer Wheel, (Outer Scale). If time is 1 second or less, use nearest Shutter Setting; if greater than 1 second, use Reciprocity Corrected Scale. Where a filter is used, multiply time by the filter factor to obtain correct time, "T". Bracket exposures at 4T, 2T, T, 1/2T and 1/4T to allow for varying atmospheric conditions.

NOTE

Any object less than 45° from the horizon suffers a loss of brightness dependent on its apparent angle above the horizon. This loss of brightness must be considered when calculating exposure time. A chart on the Inner (Brightness) Wheel shows this loss as an increase of magnitude with apparent angle above horizon. First determine the magnitude of the object without regard to its angle. Estimate the angle above the horizon, read off the increase of magnitude from the chart and add this increase to the original magnitude. Use this corrected magnitude as the Brightness for determining the Exposure time.

APPENDIX "A", PLATE IV

This is the instruction dial that is mounted on the outer side of the outer or exposure dial, after the exposure dial has been mounted onto some stiff backing plate.

Follow assembly instructions carefully, and ensure your exposure guide is not left outside in humid or wet weather. If treated properly, this guide will last a long time and give good service.

APPENDIX "B"

ASTROPHOTOGRAPHY EXPOSURE GUIDE

The author's son, who is an ardent calculator "addict," has devised a calculator program for the astrophotography exposure guide, using a programmable calculator. The first program was devised to use an HP-67 calculator with programmable cards. The program involves two phases, due to the limit imposed by the cards, so he worked out a program to determine the brightness factor, "B", for the various days of the moon, then converting it into a magnitude. This value is then used in the second phase in conjunction with the other parameters of the formula, ie, f/number, film speed, elevation angle, etc., to give an exposure time, which is corrected for reciprocity failure if the exposure exceeds one second.

The entire program requires two magnetic program cards, and the entire program is shown, step by step, in this Appendix for anyone who has a similar calculator. Note that this same program will work with the HP-97, and the HP-41, although my son has re-written the programs for the HP-41 to include a demand feature from the calculator when it requires additional information. Both these programs have been registered with Hewlett-Packard, and can be obtained from that source. They are included in this *Handbook* as an interest item.

Program Description

Program Title LUNAR DAY CONVERTER

Name JAMES P. PATTERSON **Date**

Address DOE/AES UPPER AIR, P.O. BOX 106

City CAMBRIDGE BAY **State** N.W.T. **Zip Code** XOE OCO

Program Description, Equations, Variables, etc. Equations for this program were derived using the relation of lunar day verses brightness and then converting brightness to stellar magnitude. Following formulas were used.

Lunar day = brightness $B = ae^{bx}$ - where "a" & "b" are constants and "x" is the lunar day

Constants for this formula were broken down into thirteen pairs.

Brightness = stellar magnitude $M = \frac{LN\ x/a}{b}$ - where "a" & "b" are constants and "x" is the brightness

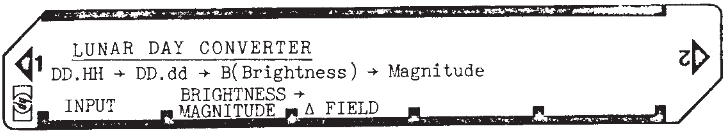
Constants are: "a" = 13.237

"b" = -0.2222

Operating Limits and Warnings Input should not be greater than 28.00 days as this represents a new moon.

DO NOT USE THIS SPACE

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Load both sides of program card				0.00
2.	Load both sides of data card				0.00
3.	Input lunar day(0 to 28) either as DD(days) or	DD(.HH)	A		DD.dd
	as DD.HH(days & hours)				Brightness
					Magnitude
4.	If brightness is known and magnitude is wanted	Brightness	B		Brightness
					Magnitude
5.	If above information is used in conjunction				
	with 'Astrophotography Guide' program, stellar	DD(.HH)	A		DD.dd
	magnitude derived will only apply if camera				Brightness
	field of view is larger or equal to angular				Magnitude
	diameter of moon. Should field be smaller than				
	lunar diameter, compute data as per step 3,	Brightness	ENT↑		Brightness
	then input brightness, lunar diameter, and	Lunar Dia	ENT↑		Lunar Dia
	field diameter(NOTE: both diameters must be	Field Dia	C		Brightness
	input ed in same units, ie - seconds or minutes				Magnitude
	of arc, not both)				
6.	NOTE: Magnitude derived from above steps can	Brightness	ENT↑		Brightness
	only be used if moon fill's entire field of view	Ratio	÷		ΔBrightness
	Use inverse rule against new brightness(- ie -	ΔBrightness	B		Brightness
	if moon only in 1/2 of field, divide brightness				Magnitude
	by 4; if only in 1/3, divide by 9, etc.)				

STEP	KEY ENTRY	KEY CODE	COMMENTS
001 A	f LBL A	31 25 11	INPUT
	f INT	31 83	
	h LST X	35 82	
	g FRC	32 83	
	EEX	43	
	2	02	
	x	71	Converts Days & hours to DD.dd
	2	02	
	4	04	
010	÷	81	
	+	61	
	1	01	
	4	04	
	h x↔y	35 52	
	g x≤y?	32 71	Is it a full moon?
	GTO 0	22 00	
	2	02	Converts days > 14 days to < 14 in order to compute brightness and mag.
	8	08	
	h x↔y	35 52	
020	-	51	
0	f LBL 0	31 25 00	
	DSP 2	23 02	DD.dd
	f -x-	31 84	
	2	02	
	h x↔y	35 52	
	g x≤y?	32 71	If ≤ 2 days
	GTO 0	22 00	
	4	04	
	h x↔y	35 52	
030	g x≤y?	32 71	If ≤ 4 days
	GTO 1	22 01	
	6	06	
	h x↔y	35 52	
	g x≤y?	32 71	If ≤ 6 days
	GTO 2	22 02	
	8	08	
	h x↔y	35 52	
	g x≤y?	32 71	If ≤ 8 days
	GTO 3	22 03	
040	1	01	
	0	00	
	h x↔y	35 52	
	g x≤y?	32 71	If ≤ 10 days
	GTO 4	22 04	
	1	01	
	2	02	
	h x↔y	35 52	
	g x≤y?	32 71	If ≤ 12 days
	GTO 5	22 05	
050	GTO 6	22 06	
0	f LBL 0	31 25 00	= 2 days
	2	02	
	h x↔y	35 52	
	g x≠y?	32 81	If ≠ 2 days
	GTO 7	22 07	
	RCL 1	34 01	
	g GSBf a	32 22 11	
	RCL 0	34 00	
	GTO fe	22 31 15	
060 1	f LBL 1	31 25 01	= 4 days
	4	04	
	h x↔y	35 52	
	g x≠y?	32 81	If ≠ 4 days
	GTO 8	22 08	
	RCL 3	34 03	
	g GSBf a	32 22 11	
	RCL 2	34 02	
	GTO fe	22 31 15	
2	f LBL 2	31 25 02	= 6 days
070	6	06	
	h x↔y	35 52	
	g x≠y?	32 81	If ≠ 6 days
	GTO 9	22 09	
	RCL 5	34 05	
	g GSBf a	32 22 11	
	RCL 4	34 04	
	GTO fe	22 31 15	
3	f LBL 3	31 25 03	= 8 days
	8	08	
080	h x↔y	35 52	
	g x≠y?	32 81	If ≠ 8 days
	GTO fb	22 31 12	
	RCL 7	34 07	
	g GSBf a	32 22 11	
	RCL 6	34 06	
	GTO fe	22 31 15	
4	f LBL 4	31 25 04	= 10 days
	1	01	
	0	00	
090	h x↔y	35 52	
	g x≠y?	32 81	If ≠ 10 days
	GTO fc	22 31 13	
	RCL 9	34 09	
	g GSBf a	32 22 11	
	RCL 8	34 08	
	GTO fe	22 31 15	
5	f LBL 5	31 25 05	= 12 days
	1	01	
	2	02	
100	h x↔y	35 52	
	g x≠y?	32 81	If ≠ 12 days
	GTO fd	22 31 14	
	RCL B	34 12	
	g GSBf a	32 22 11	
	RCL A	34 11	
	GTO fe	22 31 15	
6	f LBL 6	31 25 06	>12 → ≤14 days
	RCL D	34 14	
	g GSBf a	32 22 11	
110	RCL C	34 13	
	GTO fe	22 31 15	
7	f LBL 7	31 25 07	>0 → <2 days

REGISTERS

0 7.9999 99995	1 0.2231 43552	2 10.440 12535	3 0.1325 18920	4 7.2759 57533	5 0.2468 60080	6 7.7668 95951	7 0.2376 71640	8 7.8700 51986	9 0.2379 58660
S0 6.7582 17988	S1 0.3074 84700	S2 8.1919 99686	S3 0.2231 43560	S4 7.2334 70574	S5 0.2478 36160	S6 6.8459 15376	S7 0.2534 48940	S8 10.273 42068	S9 0.2113 09120

A	B	C	D	E	I
6.616071818	0.251314400	5.953751291	0.257829000	8.490892428	0.230523400

Program Listing

EP	KEY ENTRY	KEY CODE	COMMENTS
	f P↔S	31 42	
	RCL s1	34 01	
	g GSBf a	32 22 11	
	RCL s0	34 00	
	f P↔S	31 42	
	GTO fe	22 31 15	
8	f LBL 8	31 25 08	>2 → <4 days
	f P↔S	31 42	
	RCL s3	34 03	
	g GSBf a	32 22 11	
	RCL s2	34 02	
	f P↔S	31 42	
	GTO fe	22 31 15	
9	f LBL 9	31 25 09	>4 → <6 days
	f P↔S	31 42	
	RCL s5	34 05	
	g GSBf a	32 22 11	
	RCL s4	34 04	
	f P↔S	31 42	
	GTO fe	22 31 15	
b	g LBLf b	32 25 12	>6 → <8 days
	f P↔S	31 42	
	RCL s7	34 07	
	g GSBf a	32 22 11	
	RCL s6	34 06	
	f P↔S	31 42	
	GTO fe	22 31 15	
c	g LBLf c	32 25 13	>8 → <10 days
	f P↔S	31 42	
	RCL s9	34 09	
	g GSBf a	32 22 11	
	RCL s8	34 08	
	f P↔S	31 42	
	GTO fe	22 31 15	
d	g LBLf d	32 25 14	>10 → <12 days
	h RCI	35 14	
	g GSBf a	32 22 11	
	RCL E	34 15	
e	g LBLf e	32 25 15	Subroutine
	x	71	
	DSP 2	23 02	
B	f LBL B	31 25 12	Brightness→ Mag
	f -x-	31 84	Brightness
	ENT↑	41	
	.	83	
	2	02	
	2	02	Constant
	2	02	
	2	02	
	CHS	42	
	h 1/x	35 62	
	1	01	
	3	03	
	.	83	
	2	02	Constant
	3	03	

STEP	KEY ENTRY	KEY CODE	COMMENTS
	7	07	
170	7	07	
	h R↑	35 54	
	h R↑	35 54	
	h x↔y	35 52	
	h R↓	35 53	
	h x↔y	35 52	
	÷	81	
	f LN	31 52	
	x	71	
	DSP 2	23 02	
180	f -x-	31 84	Magnitude
	h SPACE	35 84	
	h RTN	35 22	
a	g LBL fa	32 25 11	Subroutine
	x	71	
	g e^x	32 52	
	h RTN	35 22	
C	f LBL C	31 25 13	Δ FIELD
	2	02	
	÷	81	
190	g x^2	32 54	
	h π	35 73	
	x	71	Area of moon
	h x↔y	35 52	
	2	02	
	÷	81	
	g x^2	32 54	
	h π	35 73	
	x	71	Area of field
	h x↔y	35 52	
200	÷	81	Ratio of field
	÷	81	Δ Brightness
	GTO B	22 12	-
210			
220			

LABELS					FLAGS	SET STATUS		
NPUT	B B→Mag	C Δ Field	D	E	0	FLAGS	TRIG	DISP
broutine	b >6 <8	c >8 <10	d >10 <12	e x DSP 2	1	ON OFF 0 ☐ ☑ 1 ☐ ☑ 2 ☐ ☑ 3 ☐ ☑	DEG ☑ GRAD ☐ RAD ☐	FIX ☑ SCI ☐ ENG ☐ n 2
= 2	1 = 4	2 = 6	3 = 8	4 = 10	2			
= 12	6 >12 ≦14	7 >0 <2	8 >2 <4	9 >4 <6	3			

Program Description

Program Title ASTROPHOTOGRAPHY EXPOSURE GUIDE
Name JAMES P. PATTERSON **Date**
Address DOE/AES UPPER AIR, P.O. BOX 106
City CAMBRIDGE BAY **State** N.W.T. **Zip Code** XOE OCO

Program Description, Equations, Variables, etc. Exposure time is based on the following formula: $T = \frac{f^2}{A.B}$ where - f = f/no. of telecamera system; A = ASA of film; & B = Brightness To determine brightness of any stellar object, given it's stellar magnitude, the following formula is used: $B = ae^{b\chi}$ - where χ = stellar magnitude; & "a" & "b" are constants - a = 13.23542635 & b = -0.22233214

Correction for atmospheric absorption vs elevation angle is approximated by: $M_\Delta = a + b\text{LN}\chi$ - where χ = elevation angles $<33^\circ$; a = 2.995551676; & b = -0.819135677 NOTE: For elevation angles from $33^\circ \rightarrow 44^\circ$, a correction of +0.1 is used as above formula breaks down with these angles. For angles less than 33°, the fit is very good(+0.1-0.0)

Reciprocity rate is based on "Mark Hilburn's Reciprocity Compensation Table" which only applies when using B & W film. When using color film, a cold camera should be used using the uncorrected times as computed(Time_u). This is because the color bases react differently to long exposures. The formula used in this program is approximated by $T_c = a\chi^b$ - where χ = uncorrected exposure time(Time_u); and values for "a"&"b" are constants divided into eight(8) pairs, each set being determined by the value of Time_u. The range covered by this program is from 0.5 secs to 400 secs(uncorrected). It was felt that anything greater than 400 sec(uncorrected) was meaningless as this time, corrected, becomes 5195 secs, almost 1½ hrs.

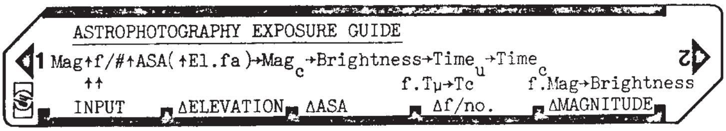
When applying the above times to actual photography, one should realize that these values are based on perfect conditions, something which rarely happens. In order to ensure a useable photograph, bracketing should be done based on $\text{Time}_u(T_u)$. Until one has gained enough experience in knowing the right values to use, times of ¼T, ½T, T, 2T, & 4T should be included in your calculations, using step #6.

By keeping records of all exposures, you will beable to better determine which values will fit best under varing conditions.

Operating Limits and Warnings Any times(T_u) which results in a value greater than 400 secs, will not have any reciprocity calculated and T_c will be the same as T_u.

DO NOT USE THIS SPACE

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1.	Load both sides of program card.				0.00
2.	Load both sides of data card.				0.00
3.	Data input is determined by value of elevation	Magnitude	ENT↑		Magnitude
	angle. Use only if less than 45°.	f/no.	ENT↑		f/no.
	NOTE. All inputs are read back before data	ASA	A		A,f,M
	computed - ie A,f,M or E,A,f,M(fa) where M=				Mag(c)
	magnitude; f= f/no.; A= ASA; & E= elevation				Brightness
					Time$_u$
	For elevation angles less than 45, input as	Input Mag,			Time$_e$
	follows	f/#,&ASA	ENT↑	ENT↑	
		as above	ENT↑		
		Elevation	f	a	E,A,f,M
					M_e,B,T_u,T_e
4.	Any of the above input values can be changed	Elevation	B		Elevation
	separately without effecting the others.				M_c,B,T_u,T_c
		ASA	C		ASA
					M_e,B,T_u,T_e
		f/no.	D		f/no.
					M_c,B,T_u,T_c
		Magnitude	E		Magnitude
					M_c,B,T_u,T_c
5.	If magnitude known and brightness only needed.	Magnitude	f	e	Magnitude
					Brightness
6.	Because the atmosphere is never constant, the				
	above times should be bracketed to cover best	$\frac{1}{4}T_u$	f	d	$\frac{1}{4}T_u$, T_e
	time which is usually different each time.	$\frac{1}{2}T_u$	f	d	$\frac{1}{2}T_u$, T_c
	Using "Time$_u$"(T_u), using following values, find	$2T_u$	f	d	$2T_u$, T_e
	corresponding "Time$_e$"(T_e): $\frac{1}{4}$T,$\frac{1}{2}$T,2T,&4T	$4T_u$	f	d	$4T_u$, T_e
	NOTE: Abreviations used in above examples				
	E= Elevation angles; A= ASA of film; f= f/no.				
	of telecamera system; M= Stellar magnitude;				
	M_c = M corrected for absorption; B= Brightness;				
	T_u = Exposure time(secs)uncorrected for				
	reciprocity; T_c = Exposure time(secs)				
	corrected for reciprocity(Black&White film)				
	Also, note that T_u = 400 secs is largest that				
	can be computed as T_e = 5195 secs.				

Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS
	h x↔y	35 52	
	g x≤y?	32 71	If ≤ 120 secs
	GTO 7	22 07	
	4	04	
	0	00	
	0	00	
	h x↔y	35 52	
20	g x≤y?	32 71	If ≤ 400 secs
	GTO 8	22 08	
	GTO 9	22 08	> 400 secs
1	f LBL 1	31 25 01	> 0.5 ≤ 8 secs
	RCL 3	34 03	
	h y^x	35 63	$T_c = ax^b$
	RCL 2	34 02	
	x	71	
	GTO 9	22 09	
2	f LBL 2	31 25 02	> 8 ≤ 20 secs
30	RCL 5	34 05	
	h y^x	35 63	$T_c = ax^b$
	RCL 4	34 04	
	x	71	
	GTO 9	22 09	
3	f LBL 3	31 25 03	>20 ≤ 31 secs
	RCL 7	34 07	
	h y^x	35 63	
	RCL 6	34 06	$T_c = ax^b$
	x	71	
40	GTO 9	22 00	
4	f LBL 4	31 25 04	> 31 ≤ 47 secs
	RCL 9	34 09	
	h y^x	35 63	$T_c = ax^b$
	RCL 8	34 08	
	x	71	
	GTO 9	22 09	
5	f LBL 5	31 25 05	> 47 ≤ 60 secs
	f P↔S	31 42	
	RCLs1	34 01	
50	h y^x	35 63	$T_c = ax^b$
	RCLs0	34 00	
	x	71	
	f P↔S	31 42	
	GTO 9	22 09	
6	f LBL 6	31 25 06	> 60 ≤ 85 secs
	f P↔S	31 42	
	RCLs3	34 03	
	h y^x	35 63	$T_c = ax^b$
	RCLs2	34 02	
60	x	71	
	f P↔S	31 42	
	GTO 9	22 09	
7	f LBL 7	31 25 07	> 85 ≤ 120 secs
	f P↔S	31 42	
	RCLs5	34 05	
	h y^x	35 63	$T_c = ax^b$
	RCLs4	34 04	
	x	71	

STEP	KEY ENTRY	KEY CODE	COMMENTS
	f P↔S	31 42	
170	GTO 9	22 09	
8	f LBL 8	31 25 08	> 120 ≥ 400 secs
	f P↔S	31 42	
	RCLs7	34 07	
	h y^x	35 63	$T_c = ax^b$
	RCLs6	34 06	
	x	71	
	f P↔S	31 42	
9	f LBL 9	31 25 09	
	f -x-	31 84	$Time_c$(secs)
180	h SPACE	35 84	
	h CF 0	35 61 00	
	h CF 1	35 61 01	
	h CF 2	35 61 02	
	h RTN	35 22	
B	f LBL B	31 25 12	Δ Elevation input
	4	04	
	4	04	
	h x↔y	35 52	
	g x≤y?	32 71	If ≤ 44°
190	h SF 0	35 51 00	
	h SF 2	35 51 02	
	STO A	33 11	
	f -x-	31 84	Elevation angle
	h SPACE	35 84	
	GTO 0	22 00	
C	f LBL C	31 25 13	Δ ASA input
	h SF 2	35 51 02	
	STO B	33 12	
	f -x-	31 84	ASA
200	h SPACE	35 84	
	GTO 1	22 01	
D	f LBL D	31 25 14	Δ f/no. input
	h SF 2	35 51 02	
	STO C	33 13	
	f -x-	31 84	f/no.
	h SPACE	35 84	
	GTO 1	22 01	
E	f LBL E	31 25 15	Δ Magnitude input
	STO D	33 14	
210	h ST I	35 33	
	h SF 2	35 51 02	
	f -x-	31 84	Magnitude
	h SPACE	35 84	
	GTO 1	22 01	
e	g LBLf e	32 25 15	Magnitude → Brightness
	RCL 1	34 01	
	x	71	
	g e^x	32 52	
	RCL 0	34 00	$B = ae^{bx}$
220	x	71	
	DSP 2	23 02	
	f -x-	31 84	Brightness
	h SPACE	35 84	
	h RTN	35 22	

LABELS					FLAGS
INPUT	B ΔELEVATION	C Δ ASA	D Δ f/no.	E Δ MAG	0 ELEVATION
INPUT ELEVATION	b	c	d TIME → TIME u	e MAG → BRIGHTNESS	1 MAGNITUDE CORRECTION
BEGIN	1 USED(2)	2 USED(2)	3 USED(2)	4 USED(2)	2 DATA IN
USED	6 USED	7 USED	8 USED	9 USED	3

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☑	DEG	☑	FIX	☑
1	☐	☑	GRAD	☐	SCI	☐
2	☐	☑	RAD	☐	ENG	☐
3	☐	☑			n 2	

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001 a	g LBLf a	32 25 11	Input with elevation		RCL D	34 14	
	STO A	33 11			DSP 2	23 02	
	f -x-	31 84	Elevation angle		f -x-	31 84	Magnitude(corrected
	h SF 0	35 51 00	Indicating input	060	RCL 1	34 01	
	h R↓	35 53			x	71	$B = ae^{bx}$
A	f LBL A	31 25 11	INPUT(M,f/#,ASA)		g e^x	32 52	
	STO B	33 12			RCL 0	34 00	
	f -x-	31 84	ASA		x	71	
	h R↓	35 53			h ST I	35 33	
010	STO C	33 13			f -x-	31 84	Brightness(B)
	f -x-	31 84	f/no.		RCL B	34 12	
	h R↓	35 53			x	71	$T_u = \frac{f^2}{A.B}$
	STO D	33 14			RCL C	34 13	
	h ST I	35 33		070	g x^2	32 54	
	h SF 2	35 51 02	Indicating inputs		h x↔y	35 52	
	f -x-	31 84	Magnitude		÷	81	
	h SPACE	35 84		d	g LBLf d	32 25 14	$Time_u \rightarrow Time_c$
0	f LBL 0	31 25 00	Beginning		STO E	33 15	
	h F 0?	35 71 00			f -x-	31 84	$Time_u$(secs)
020	GTO 1	22 01			.	83	
	4	04			5	05	
	5	05			h x↔y	35 52	
	STO A	33 11			g x≤y?	32 71	If ≤ 0.5 secs
1	f LBL 1	31 25 01	Compute atmospheric	080	GTO 9	22 09	
	RCL A	34 11	absorption		8	08	
	4	04			h x↔y	35 52	
	4	04			g x≤y?	32 71	If ≤ 8 secs
	h x↔y	35 52			GTO 1	22 01	
	g x>y?	32 81	If > 44°		2	02	
030	GTO 4	22 04			0	00	
	3	03			h x↔y	35 52	
	2	02			g x≤y?	32 71	If ≤ 20 secs
	h x↔y	35 52			GTO 2	22 02	
	g x>y?	32 81	If > 32°	090	3	03	
	GTO 3	22 03			1	01	
	f LN	31 52			h x↔y	35 52	
	f P↔S	31 42	$\Delta M = a + bLNx$		g x≤y?	32 71	If ≤ 31 secs
	RCLs9	34 09			GTO 3	22 03	
	x	71			4	04	
040	RCLs8	34 08			7	07	
	+	61			h x↔y	35 52	
	f P↔S	31 42			g x≤y?	32 71	If ≤ 47 secs
	GTO 2	22 02	Magnitude correction		GTO 4	22 04	
3	f LBL 3	31 25 03		100	6	06	
	.	83			0	00	
	1	01			h x↔y	35 52	
2	f LBL 2	31 25 03	$Magnitude_c$		g x≤y?	32 71	If ≤ 60 secs
	RCL D	34 14			GTO 5	22 05	
	+	61			8	08	
050	h ST I	35 33			5	05	
	h SF 1	35 51 01	Indicating correction		h x↔y	35 52	
	h CF 2	35 61 02	applied to magnitude		g x≤y?	32 71	If ≤ 85 secs
4	f LBL 4	31 25 04			GTO 6	22 06	
	h F 1?	35 71 01	Flags determine from	110	1	01	
	h RC I	35 34	which register is to		2	02	
	h F 2?	35 71 02	be recalled		0	00	

REGISTERS

0 13.235 42635	1 -0.2222 33214	2 2.8834 95158	3 1.3731 07580	4 4.1547 81156	5 1.1963. 93259	6 5.0126 71187	7 1.1381 34576	8 4.2885 27552	9 1.1847 20603
S0 5.4362 62314	S1 1.1232 02596	S2 5.6682 87223	S3 1.1150 65909	S4 3.7321 31253	S5 1.2092 69216	S6 4.2883 02466	S7 1.1849 39780	S8 2.9955 51676	S9 -0.8191 35677

A ELEVATION ANGLE	B FILM ASA	C TELECAMERA f/no.	D STELLAR MAGNITUDE	E UNCORRECTED EXPOSURE TIME	I (MAGNITUDE) BRIGHTNESS

RECIPROCITY COMPENSATION TABLES

T_u	T_c	T_{HP}	ΔT	T_u	T_c	T_{HP}	ΔT
0.5	1	1	0	29	231	231	0
1	3	3	0	30	240	241	−1
2	8	7	1	32	260	260	0
3	14	13	1	34	280	280	0
4	20	19	1	36	300	299	1
5	27	26	1	38	320	319	1
6	34	34	0	40	340	339	1
7	41	42	−1	42	360	359	1
8	48	50	−2	44	380	380	0
9	57	58	−1	46	400	400	0
10	65	65	0	48	420	420	0
11	73	73	0	50	440	440	0
12	82	81	1	52	460	460	0
13	90	89	1	54	480	480	0
14	98	98	0	56	500	500	0
15	105	106	−1	58	520	520	0
16	114	115	−1	60	540	540	0
17	123	123	0	65	600	596	4
18	132	132	0	70	650	647	3
19	141	141	0	75	700	699	1
20	150	150	0	80	750	751	−1
21	160	160	0	85	800	803	−3
22	170	169	1	90	860	861	−1
23	179	178	1	95	920	920	0
24	188	187	1	100	980	978	2
25	196	195	1	120	1200	1220	−20
26	204	204	0	200	2300	2285	15
27	213	213	0	300	3750	3695	56
28	222	222	0	400	5000	5195	−195

ABSORPTION FACTOR

θ	ΔMag	ΔMag_{HP}
45	0.0	0.0
43	0.1	0.1
32	0.2	0.2
26	0.3	0.3
21	0.4	0.5
19	0.5	0.6
17	0.6	0.7
15	0.7	0.8
13	0.8	0.9
10	1.0	1.1
4	2.0	1.9
2	2.5	2.4
1	3.0	3.0

APPENDIX “C”

DETERMINING THE SPEED OF A TELECAMERA SYSTEM

The formula for determining exposure time depends entirely upon knowing your telecamera f/number or speed. While it is easy enough to determine the f/number of a simple prime focus telecamera, the problem becomes more difficult when one has to consider projection systems.

PRIME FOCUS TELECAMERA

$$\text{The f/number, } f/\# = \frac{\text{Objective Effective Focal Length}}{\text{Objective Aperture}}$$

Magnification = Unity = 1.

PROJECTION SYSTEM TELECAMERA

In most projection systems, the projection lens is not a simple lens, but is composed of many lenses. As a result, it is difficult to know where one should measure the projection distance, Q (Figure 8.1 or 9.1) from in order to determine the speed of the system. Rather than resort to tricky, and quite likely, inaccurate measurements from “Principal Planes,” it is better to determine the f/number experimentally.

First, roughly determine the projection distance for each projection lens to be used, ie, measure from the center of the ocular length to the film plane of the camera. Then, using the formula listed calculate a rough f/# for each projection lens:

$$f/\#_{pr} = f/\#_{pf} \times \frac{\text{Projection Distance} \times \text{EFL of Projection Lens}}{\text{EFL of Projection Lens}}$$

where $f/\#_{pr}$ = Projection f/number, and

$f/\#_{pf}$ = Prime Focus f/number.

Mount a black & white steel measuring tape (metric) on a post or side of a house, far enough away that an accurate focus can be obtained in the telecamera at prime focus. Determine the exposure time at prime focus using the built-in light meter, and take a good photograph of the tape at prime focus. Set the f/# of the prime focus on the exposure guide, with the "B" cursor set on the film speed used. Set the movable cursor to the camera shutter speed used and read off the brightness, "B" of the tape from the inner dial. Use this "B" factor and determine the rough exposure times for all projection oculars using the rough f/numbers determined initially. As these exposures are only approximate, bracket at least two stops or two speeds either side of that calculated.

Make a good enlargement for each projection ocular combination, and for the photograph taken at prime focus. Using a travelling microscope, or other accurate device, carefully measure each print, and determine the magnification of scale for each ocular combination. Remember, the magnification at prime focus is equated to unity, ie, 1. All other photo measurements and scales are referred to that at prime focus to determine the degree of magnification. Once this has been carried out, it is quite easy to determine the speed or f/number of each projection system from the following formula:

$$f/\#_{\text{projection}} = f/\#_{\text{prime focus}} \times \text{Magnification Factor}$$

Similarly, the equivalent focal length of each projection combination can be found by multiplying the Objective EFL by the Magnification for that projection system.

It is a good idea to make up a chart to show these values at a glance for future reference. Additionally, once the Projection EFL is known, the angle of coverage for each system can be added to this chart to assist in determining what projection ocular to use when any particular object is to be photographed.

APPENDIX "D"

COMPUTER PROGRAM

This Appendix offers a Computer Program, written for the Commodore C-64 Computer in Basic which should be readily adaptable to any computer capable of using Microsoft programming.

The program is a combination of several shorter programs. It has been written to carry out the various calculations listed in Sections "5" to "9" inclusive, pertaining to determining the Effective Focal Lengths of the various Astrocamera Systems, a most important requirement in determining the Speed or f/number of the camera system in use. In addition to this function, the program also determines the size of the image on film, calculations listed in Section 10. This part of the program includes the Object Size Table listed in Section 10.1.

Also included in the program are tables listing brightness values for various stellar objects, the moon, planets, solar and lunar eclipses plus suggested values for some galactic objects. The values listed in these tables will be used in the program to determine the exposure times for the astrocamera values worked out earlier in the program.

A further table is included to determine the corrected value of exposure time, taking into account the altitude above the horizon of the object being photographed.

A listing at the end of the program gives those five characters that are used to highlight titles in the program, and to move the cursor to various positions. These may be omitted without affecting the working of the program. The last one listed, "CLR/HOME," should not be omitted. It may be replaced by CHR$(19). If it is omitted, the various explanatory statements will tend to remain on screen as the program proceeds. There are many PRINT statements, used primarily to separate the lines of various statements.

```
100 REM ASTRO PROGRAM APPENDIX 'D' HANDBOOK
110 PRINT"▜";"▓▓▓▓▓"
120 PRINTTAB(4)"****************************"
130 PRINTTAB(5)"*";TAB(10)"▚ASTROCAMERA DATA■";TAB(30)"*"
140 PRINTTAB(5)"*";TAB(9)"▚AND EXPOSURE TIMES■";TAB(30)"*"
150 PRINTTAB(5)"*";TAB(30)"*"
160 PRINTTAB(5)"*";TAB(12)"▚PROGRAM BY■";TAB(30)"*"
170 PRINTTAB(5)"*";TAB(12)"▚GN PATTERSON■";TAB(30)"*"
180 PRINTTAB(5)"*";TAB(30)"*"
190 PRINTTAB(5)"*";TAB(13)"▚SASK.CENTRE■";TAB(30)"*"
200 PRINTTAB(5)"*";TAB(14)"▚SASKATOON■";TAB(30)"*"
210 PRINTTAB(4)"****************************"
220 FOR I=1TO2500:NEXT
230 REM ASTROCAMERA PARAMETERS
240 PRINT"▜"
250 PRINTTAB(2)"THIS PROGRAM CALCULATES THE SPEED"
260 PRINT
270 PRINTTAB(2)"OF THE SYSTEM,THE 'F/NUMBER', AND"
280 PRINT
290 PRINTTAB(2)"ALSO DETERMINES THE SIZE OF THE"
300 PRINT
310 PRINTTAB(2)"IMAGE ON FILM.  YOU WILL BE ASKED"
320 PRINT
330 PRINTTAB(2)"TO INPUT THE FOCAL LENGTHS OF THE"
340 PRINT
350 PRINTTAB(2)"VARIOUS LENSES, THE APERTURES"
360 PRINT
370 PRINTTAB(2)"AND THE PROJECTION DISTANCES OR"
380 PRINT
390 PRINTTAB(2)"POWERS AS NEEDED"
```

```
400 PRINT
410 INPUT"■■■PRESS < RETURN > TO CONTINUE ";Z$
420 PRINT"■"
430 PRINT"■ASTROCAMERA SYSTEMS AND EXPOSURE VALUES■"
440 PRINTTAB(2)"--------------------"
450 REM SELECT SYSTEM IN USE
460 PRINTTAB(3)"■1■.PRIME FOCUS"
470 PRINT
480 PRINTTAB(3)"■2■.TELESCOPE AFOCAL"
490 PRINT
500 PRINTTAB(3)"■3■.BINOCULAR AFOCAL"
510 PRINT
520 PRINTTAB(3)"■4■.PROJECTION"
530 PRINT
540 PRINTTAB(3)"■5■.MENU FOR EXPOSURE TIMES"
550 PRINT
560 PRINTTAB(3)"■6■.OBJECT SIZE TABLE"
570 PRINT
580 PRINTTAB(3)"■7■.BRIGHTNESS LOSS/ALTITUDE"
590 PRINT
600 PRINTTAB(3)"■8■.END"
610 PRINT:INPUT"SELECT DESIRED TOPIC BY NUMBER ";A$
620 A-VAL(A$)
630 PRINT:PRINT"■"
640 ON A GOTO 650,740,850,950,1100,3220,3590,3860
650 REM PRIME FOCUS SYSTEM
660 INPUT"ENTER OBJECTIVE EFL IN MM ";F1
670 PRINT:INPUT"ENTER OBJECTIVE APERTURE IN MM ";D1
680 PRINT:PRINT
```

```
690 PRINTTAB(3)"F/NUMBER= ";F1/D1
700 PRINT:INPUT"ENTER OBJECT SIZE IN ARCSEC ";S1
710 PRINT:PRINT"IMAGE SIZE= "(S1*F1)/206265;"MM"
720 PRINT:INPUT"████PRESS < RETURN > TO CONTINUE ";Z$
730 GOTO 420
740 REM TELESCOPE AFOCAL SYSTEM
750 INPUT"ENTER OBJECTIVE EFL IN MM ";F1
760 PRINT:INPUT"ENTER OBJECTIVE APERTURE IN MM ";D1
770 PRINT:INPUT"ENTER EYEPIECE EFL IN MM ";F2
780 PRINT:INPUT"ENTER CAMERA LENS EFL IN MM ";F3
790 PRINT
800 PRINT:PRINT"F/NUMBER= ";(F1*F3)/(F2*D1)
810 PRINT:INPUT"ENTER OBJECT SIZE IN ARCSEC ";S1
820 PRINT:PRINT"IMAGE SIZE= ";(S1*F1)/206265;"MM"
830 PRINT:INPUT"████PRESS < RETURN > TO CONTINUE ";Z$
840 GOTO 420
850 REM BINOCULAR AFOCAL SYSTEM
860 INPUT"ENTER BINOCULAR POWER ";P1
870 PRINT:INPUT"ENTER BINOCULAR APERTURE IN MM ";D2
880 PRINT:INPUT"ENTER CAMERA LENS EFL IN MM ";F3
890 PRINT:PRINT
900 PRINT"F/NUMBER= ";(P1*F3)/D2
910 PRINT:INPUT"ENTER OBJECT SIZE IN ARCSEC ";S1
920 PRINT:PRINT"IMAGE SIZE= ";(S1*P1*F3)/206265;"MM"
930 PRINT:INPUT"████PRESS < RETURN > TO CONTINUE ";Z$
940 GOTO 420
950 REM PROJECTION SYSTEMS
960 INPUT"ENTER OBJECTIVE EFL IN MM ";F1
970 PRINT:INPUT"ENTER OBJECTIVE APERTURE IN MM ";D1
980 PRINT:INPUT"ENTER PROJECTION LENS EFL IN MM ";F4
```

```
990 PRINT:INPUT"ENTER PROJECTION DISTANCE IN MM ";Q
1000 PRINT:PRINT
1010 PRINT"PROJECTION MAGNIFICATION= ";(Q-F4)/F4;"X"
1020 PRINT:PRINT"EFL OF SYSTEM= ";F1*(Q-F4)/F4;"MM"
1030 PRINT:PRINT"F/NUMBER= ";F1*(Q-F4)/(D1*F4)
1040 PRINT:PRINT
1050 INPUT"ENTER OBJECT SIZE IN ARCSEC ";S1
1060 PRINT:PRINT"IMAGE SIZE= ";(S1*F1*(Q-F4)/F4)/206265;"MM"
1070 PRINT:INPUT"■■■■PRESS < RETURN > TO CONTINUE ";Z$
1080 GOTO 420
1090 PRINT"■"
1100 PRINT"■":GOSUB 3040
1110 PRINT"■"
1120 PRINT TAB(13)"■M E N U■"
1130 PRINT
1140 PRINT"THESE ARE YOUR OPTIONS:"
1150 PRINT
1160 PRINT TAB(5)"■1■.A TABLE WHICH LISTS 'B'-VALUES"
1170 PRINT TAB(5)"FOR COMMONEST CELESTIAL OBJECTS"
1180 PRINT
1190 PRINT TAB(5)"■2■.EXPOSURE TIMES LISTED IN"
1200 PRINT TAB(5)"A TABLE OF COMMON F-STOPS."
1210 PRINT
1220 PRINT TAB(5)"■3■.THE EXPOSURE TIME FOR A"
1230 PRINT TAB(5)"SINGLE F-STOP"
1240 PRINT
1250 PRINT TAB(5)"■4■.RETURN TO PROGRAM"
1260 PRINT
1270 PRINT:INPUT"ENTER THE NUMBER OF YOUR CHOICE";N
```

```
1280 IFN<1 OR N>4 THEN PRINT"PLEASE RE-ENTER WITH A NUMBER FROM 1 TO 4:GOTO1210
1290 ON N GOTO 2170,1420,1800,420
1300 PRINT "⊐":PRINT"YOU HAVE TWO OPTIONS:"
1310 PRINT
1320 PRINT TAB(5)"■1■.EXPOSURE TIMES LISTED IN A"
1330 PRINT TAB(5)"TABLE OF COMMON F-STOPS."
1340 PRINT
1350 PRINT TAB(5)"■2■.THE EXPOSURE TIME LISTED FOR"
1360 PRINT TAB(5)"AN F-STOP OF YOUR CHOICE."
1370 PRINT
1380 PRINT:INPUT"ENTER THE NUMBER OF YOUR CHOICE ";O
1390 PRINT TAB(15)"DAY 12";TAB(31)"135"
1400 IF O<1 OR O>2 THEN PRINT"PLEASE RE-ENTER WITH A 1 OR A 2.":GOTO 1380
1410 ON O GOTO 1420,1800
1420 PRINT"⊐"
1430 PRINT TAB(13)"■EXPOSURE TIMES■"
1440 PRINT
1450 REM F=F-STOP OF LENS,E=ASA OF FILM,B=BRIGHTNESS VALUE OF OBJECT.
1460 PRINT"TO EXIT PROGRAM ENTER 0 FOR ASA"
1470 PRINT
1480 PRINT"⊐"
1490 INPUT"ENTER SPEED (ASA) ";E
1500 IF E=0 THEN 1110
1510 IF B<>0 THEN GOTO 1530
1520 INPUT"ENTER B-VALUE OF OBJECT ";B
1530 A$="M":Q$="N"
1540 PRINT CHR$(19):PRINT"---------------------------------------"
1550 PRINT"■ASA= ";E; TAB(13)"EXPOSURE TABLE";TAB(32)"B= ";B"■
1560 PRINT"---------------------------------------"
1570 PRINT"F/STOP";TAB(9);"MINUTE(S)";TAB(20);"SECOND(S)";TAB(31);"FRACTION"
```

```
1580 PRINT
1590 FOR I=1 TO 13
1600 READ F
1610 IF F=0 THEN 1700
1620 GOSUB 1750
1630 IF G<2001 THEN 1660
1640 PRINT
1650 PRINT"■VALUES NO LONGER PRACTICAL (LOWER ASA)■"
1660 IF T<=60 THEN 1680
1670 T=0
1680 PRINTF;TAB(9) INT(M); TAB(20) INT(T); TAB(31)"1/"INT(G)
1690 NEXT I
1700 PRINT"---------------------------------------"
1710 RESTORE
1720 GOSUB 2120
1730 DATA 22,16,11,8,5.6,3.5,2.8,2,1.8,1.4,0
1740 PRINT:GOTO1490
1750 REM M=MINUTES T=SECONDS G=FRACTION OF SECONDS
1760 T=F↑2/(E*B)
1770 M=T/60
1780 G=1/T
1790 RETURN
1800 PRINT"■":PRINT TAB(14)"■EXPOSURE TIME■"
1810 PRINT"TO EXIT PROGRAM ENTER 0 FOR ASA."
1820 INPUT "ENTER EXPOSURE VALUE(ASA) ";E
1830 IF E=0 THEN 1110
1840 PRINT
1850 IF F<>0 GOTO 1890
1860 PRINT"■"
```

```
1870 INPUT"ENTER F-STOP ";F
1880 PRINT"■":PRINT
1890 IF B<>0 GOTO 1910
1900 INPUT"ENTER B-VALUE ";B
1910 A$="S":Q$="N"
1920 GOSUB 1750
1930 PRINT CHR$(19)
1940 PRINT "ASA= ";E
1950 PRINT "F-STOP = ";F
1960 PRINT "B-VALUE= ";B
1970 IF G<2001 THEN 2000
1980 PRINT
1990 PRINT"■EXPOSURE NOT PRACTICAL (LOWER ASA)■"
2000 IF T<60 THEN 2020
2010 T=0
2020 PRINT"---------------------------------------"
2030 PRINT TAB(13)"■EXPOSURE TIME■"
2040 PRINT"---------------------------------------"
2050 PRINT"MINUTE(S)";TAB(14)"SECOND(S)";TAB(24)"FRACTION";
2060 PRINT
2070 PRINT INT(M);TAB(14)INT(T);TAB(28)"1/ "INT(G)
2080 PRINT"---------------------------------------"
2090 RESTORE
2100 IF G<2001 THEN GOSUB 2120
2110 PRINT: GOTO 1820
2120 PRINT:INPUT"■■■■PRESS < RETURN > IF YOU WISH TO CONTINUE ";Z$:GOTO420
2130 IF A$="M" THEN GOTO 1540
2140 IF A$="S" THEN GOTO 1930
2150 PR# 0
2160 RETURN
```

```
2170 PRINT"⊐"
2180 PRINT TAB(10)"▚BRIGHTNESS VALUES■"
2190 PRINT"FOR WHICH CELESTIAL OBJECT WOULD YOU"
2200 PRINT"LIKE VALUES? "
2210 PRINT:PRINT "1.MOON"
2220 PRINT:PRINT "2.PLANETS"
2230 PRINT:PRINT "3.SUN"
2240 PRINT:PRINT "4.DEEP SKY OBJECTS"
2250 PRINT:PRINT:PRINT
2260 INPUT"ENTER THE NUMBER OF YOUR SELECTION. ";N
2270 IF N<1 OR N>4 THEN 2320
2280 IF N=1 THEN 2350
2290 IF N=2 THEN 2580
2300 IF N=3 THEN 2760
2310 IF N=4 THEN 2870
2320 PRINT"PLEASE RE-ENTER WITH A NUMBER BETWEEN"
2330 INPUT"1 AND 4 ";N
2340 GOTO 2270
2350 PRINT"⊐":PRINT TAB(15)"▚MOON■"
2360 PRINT
2370 PRINT"LUNAR PHASES"
2380 PRINT"AGE OF MOON";TAB(15)"NEW";TAB(32)"10"
2390 PRINT TAB(15)"DAY 2";TAB(32)"12.5"
2400 PRINT TAB(15)"DAY 3";TAB(32)"17"
2410 PRINT TAB(15)"DAY 4";TAB(32)"20"
2420 PRINT TAB(15)"DAY 5";TAB(32)"25"
2430 PRINT TAB(15)"DAY 6";TAB(32)"32"
2440 PRINT TAB(15)"QUARTER MOON";TAB(32)"41"
2450 PRINT TAB(15)"DAY 8";TAB(32)"52"
```

```
2460 PRINT TAB(15)"DAY 9";TAB(32)"67"
2470 PRINT TAB(15)"DAY 10";TAB(32)"85"
2480 PRINT TAB(15)"DAY 11";TAB(31)"105"
2490 PRINT TAB(15)"DAY 12";TAB(31)"135"
2500 PRINT TAB(15)"DAY 13";TAB(31)"170"
2510 PRINT TAB(15)"FULL MOON";TAB(31)"220"
2520 PRINT TAB(4)"EARTHSHINE";TAB(32)"0.01"
2530 PRINT"LUNAR ECLIPSE FEATURES."
2540 PRINT TAB(4)"EDGE OF UMBRA";TAB(32)"0.05
2550 PRINT TAB(4)"MID TOTALITY (VARIES)";TAB(32)"0.005"
2560 GOSUB 3010
2570 GOTO 1300
2580 PRINT "■":PRINT TAB(14)"■PLANETS■"
2590 PRINT TAB(6)"MERCURY";TAB(27)"9.8-13"
2600 PRINT
2610 PRINT TAB(6)"VENUS";TAB(26)"13.6-34"
2620 PRINT
2630 PRINT TAB(6)"MARS";TAB(26)"13.6-20"
2640 PRINT
2650 PRINT TAB(6)"JUPITER";TAB(26)"16.0-23"
2660 PRINT
2670 PRINT TAB(6)"SATURN";TAB(27)"9.0-11.5"
2680 PRINT
2690 PRINT TAB(6)"URANUS";TAB(27)"3.3-3.8"
2700 PRINT
2710 PRINT TAB(6)"NEPTUNE";TAB(27)"2.2-2.4"
2720 PRINT
2730 PRINT TAB(6)"PLUTO";TAB(27)"0.3-0.5"
2740 GOSUB 3010
2750 GOTO 1300
```

```
2760 PRINT "▞":PRINT TAB(16)"▨SUN■"
2770 PRINT TAB(6)"SOLAR DISC";TAB(20)"10,000,000"
2780 PRINT"SOLAR ECLIPSE FEATURES:"
2790 PRINT TAB(4)"PROMINENCES";TAB(27)"100"
2800 PRINT TAB(4)"INNER CORONA";TAB(28)"50"
2810 PRINT TAB(4)"MIDDLE CORONA";TAB(29)"5"
2820 PRINT TAB(4)"OUTER CORONA"; TAB(29)"0.5"
2830 PRINT TAB(4)"ECLIPSE SKY";TAB(29)"0.01"
2840 PRINT TAB(4)"HORIZON(ECLIPSE)";TAB(29)"0.5"
2850 GOSUB 3010
2860 GOTO 1300
2870 PRINT"▞":PRINT TAB(10)"▨DEEP SKY OBJECTS■"
2880 PRINT TAB(2)"PERFECT COUNTRY SKY";TAB(27)"0.000002"
2890 PRINT
2900 PRINT TAB(2)"MIDDLE OF ORION NEBULA";TAB(27)"0.001"
2910 PRINT
2920 PRINT TAB(2)"MOST NEBULAE";TAB(27)"0.0001"
2930 PRINT
2940 PRINT TAB(2)"MIDDLE OF M-31";TAB(27)"0.0001"
2950 PRINT
2960 PRINT TAB(2)"MOST GALAXIES";TAB(27)"0.0001"
2970 PRINT
2980 PRINT TAB(2)"MILKY WAY";TAB(27)"0.00001"
2990 GOSUB 3010
3000 GOTO 1300
3010 PRINT:PRINT"ENTER THE B-VALUE OF THE OBJECT WHICH"
3020 INPUT"YOU WANT TO PHOTOGRAPH ";B
3030 RETURN
3040 PRINT TAB(10)"▨EXPOSURE PROGRAM■"
```

```
3050 PRINT
3060 PRINT"THIS PROGRAM PROVIDES THE USER WITH"
3070 PRINT:PRINT"EXPOSURE TIMES FOR PHOTOGRAPHING COMMON"
3080 PRINT:PRINT"CELESTIAL OBJECTS. THE USER MAY"
3090 PRINT:PRINT"CHOOSE THE OPTION OF HAVING EXPOSURE"
3100 PRINT:PRINT"TIMES LISTED IN A TABLE OF COMMON"
3110 PRINT:PRINT"F-STOPS, OR THE EXPOSURE TIME FOR A"
3120 PRINT:PRINT"SINGLE F-STOP"
3130 PRINT:INPUT"████PRESS < RETURN > TO CONTINUE ";Z$
3140 PRINT"▟":PRINT:PRINT"IN ORDER TO PHOTOGRAPH AN OBJECT, ITS"
3150 PRINT:PRINT"BRIGHTNESS VALUE (B-VALUE) MUST BE"
3160 PRINT:PRINT"KNOWN. IF AN OBJECT'S B-VALUE IS UN-"
3170 PRINT:PRINT"KNOWN, A TABLE IS PROVIDED WHICH LISTS"
3180 PRINT:PRINT"THE B-VALUE OF MANY COMMON OBJECTS."
3190 PRINT:PRINT:PRINT
3200 INPUT"PRESS <RETURN> TO CONTINUE ";Z$
3210 RETURN
3220 PRINTTAB(3)"█TABLE OF OBJECT SIZES IN ARCSECONDS█"
3230 PRINTTAB(1)"--------------------------------------"
3240 PRINTTAB(1)"OBJECT";TAB(20)"MINIMUM";TAB(31)"MAXIMUM"
3250 PRINT"---------------------------------------"
3260 PRINTTAB(1)"SUN";TAB(18)"60*31.42'";TAB(29)"60*32.50'"
3270 PRINTTAB(1)"MOON";TAB(18)"60*29.46'";TAB(29)"60*32.88'"
3280 PRINTTAB(1)"MERCURY";TAB(22)"4.60''";TAB(32)"12.20''"
3290 PRINTTAB(1)"VENUS";TAB(22);"9.57''";TAB(32);"65.56''"
3300 PRINTTAB(1)"MARS";TAB(22);"3.53''";TAB(32);"23.44''"
3310 PRINTTAB(1)"JUPITER";TAB(21)"30.58''";TAB(32) "49.57''"
3320 PRINTTAB(1)"SATURN(DISC)";TAB(21);"15.07''";TAB(32)"20.77''"
3330 PRINTTAB(1)"SATURN(RINGS)";TAB(21)"35.10''";TAB(32)"48.35''"
3340 PRINTTAB(1)"URANUS";TAB(22)"3.07''";TAB(33)"3.75''"
```

```
3350 PRINTTAB(1)"NEPTUNE";TAB(22)"2.24''";TAB(33)"2.44''"
3360 PRINTTAB(1)"PLUTO";TAB(22)"0.15''";TAB(33)"0.27''"
3370 PRINT
3380 INPUT"■■■■PRESS < RETURN > TO CONTINUE ";Z$
3390 PRINT"--------------------------------------"
3400 PRINT"■"
3410 PRINTTAB(12)"■DEEP-SKY OBJECTS■"
3420 PRINT"--------------------------------------"
3430 PRINTTAB(3)"OBJECT";TAB(28)"SIZE"
3440 PRINT"--------------------------------------"
3450 PRINTTAB(1)"M1-CRAB NEB.";TAB(26)"6'*4'"
3460 PRINTTAB(1)"M8-LAGOON";TAB(25)"60'*35'"
3470 PRINTTAB(1)"M13-GLOBULAR";TAB(26)"23.2'"
3480 PRINTTAB(1)"M27-DUMBBELL";TAB(26)"8'*7'"
3490 PRINTTAB(1)"M31-ANDROMEDA NEB.";TAB(24)"158'*50'"
3500 PRINTTAB(1)"M42-ORION NEB.";TAB(25)"85'*50'"
3510 PRINTTAB(1)"M44-BEEHIVE";TAB(27)"90'"
3520 PRINTTAB(1)"M45-PLEIADES";TAB(26)"120'"
3530 PRINTTAB(5)"1";TAB(14)"3.0";TAB(25)"B*";TAB(30)"0.063"
3540 PRINTTAB(1)"M57-RING NEB";TAB(25)"1.4'*1'"
3550 PRINTTAB(1)"M97-OWL NEB.";TAB(26)"3.3'"
3560 PRINT
3570 INPUT"■■■■PRESS < RETURN > TO CONTINUE ";Z$
3580 GOTO 420
3590 PRINT"■"
3600 PRINT"■BRIGHTNESS LOSS/ALTITUDE ABOVE HORIZON■"
3610 PRINT"--------------------------------------
3620 PRINT
3630 PRINT"ALTITUDE";TAB(11)"MAGNITUDE";TAB(28)"BRIGHTNESS"
```

```
3640 PRINTTAB(1)"DEGREES";TAB(12)"DIMMING";TAB(27)"LOSS FACTOR"
3650 PRINT"-----------------------------------------"
3660 PRINTTAB(4)"1";TAB(14)"3.0";TAB(26)"B*";TAB(30)"0.063"
3670 PRINTTAB(4)"2";TAB(14)"2.5";TAB(30)"0.100"
3680 PRINTTAB(4)"4";TAB(14)"2.0";TAB(30)"0.158"
3690 PRINTTAB(3)"10";TAB(14)"1.0";TAB(30)"0.398"
3700 PRINTTAB(3)"13";TAB(14)"0.8";TAB(30)"0.478"
3710 PRINTTAB(3)"15";TAB(14)"0.7";TAB(30)"0.525"
3720 INPUT"████PRESS < RETURN > TO CONTINUE ";Z$
3730 PRINTTAB(3)"17";TAB(14)"0.6";TAB(30)"0.575"
3740 PRINTTAB(3)"19";TAB(14)"0.5";TAB(30)"0.631"
3750 PRINTTAB(3)"21";TAB(14)"0.4";TAB(30)"0.692"
3760 PRINTTAB(3)"26";TAB(14)"0.3";TAB(30)"0.759"
3770 PRINTTAB(3)"32";TAB(14)"0.2";TAB(30)"D.832"
3780 PRINTTAB(3)"43";TAB(14)"0.1";TAB(30)"0.912"
3790 PRINTTAB(3)"45";TAB(14)"0.0";TAB(30)"1.000"
3800 PRINT
3810 PRINTTAB(2)"OBTAIN 'B' VALUE FROM TABLE 5 ,THEN "
3820 PRINTTAB(2)"MULTIPLY BY APPROPRIATE LOSS FACTOR"
3830 PRINTTAB(2)"TO OBTAIN CORRECTED BRIGHTNESS."
3840 INPUT"████PRESS < RETURN > TO CONTINUE ";Z$
3850 GOTO 420
3860 PRINT"■":PRINT TAB( 6)"▣▣▣▣▣▣▣▣▣▣▣▣▣ GOOD LUCK WITH YOUR PHOTOS"
3870 END
```

— NOTES —

— NOTES —

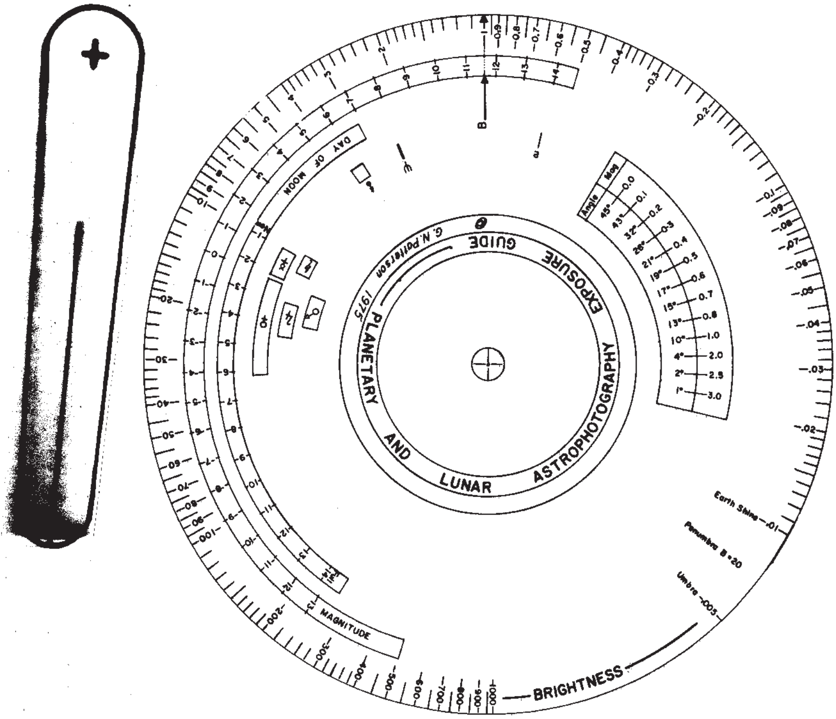
— NOTES —

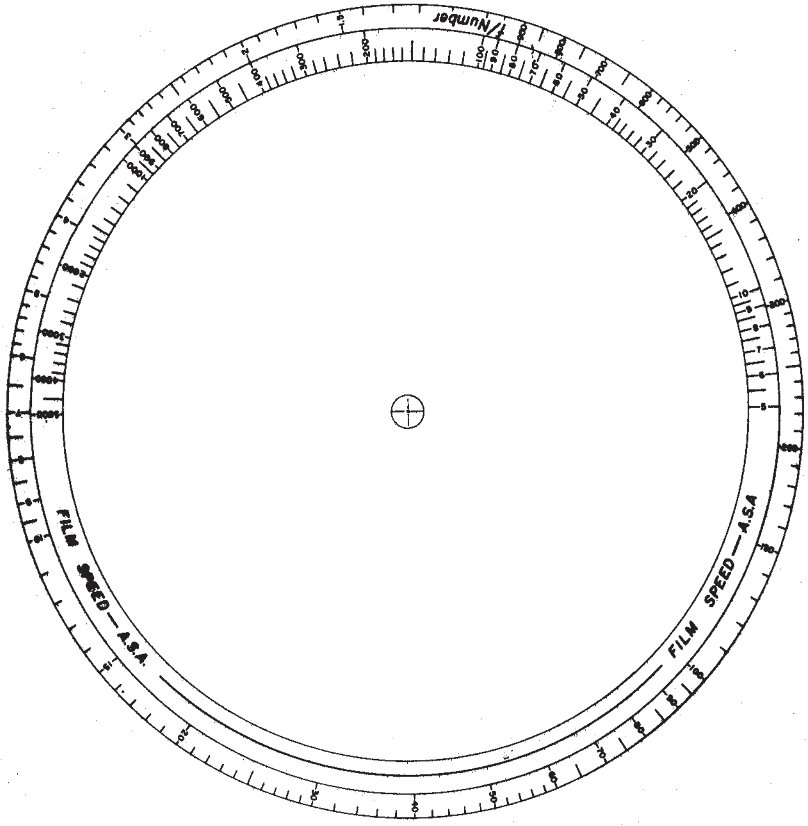
— NOTES —

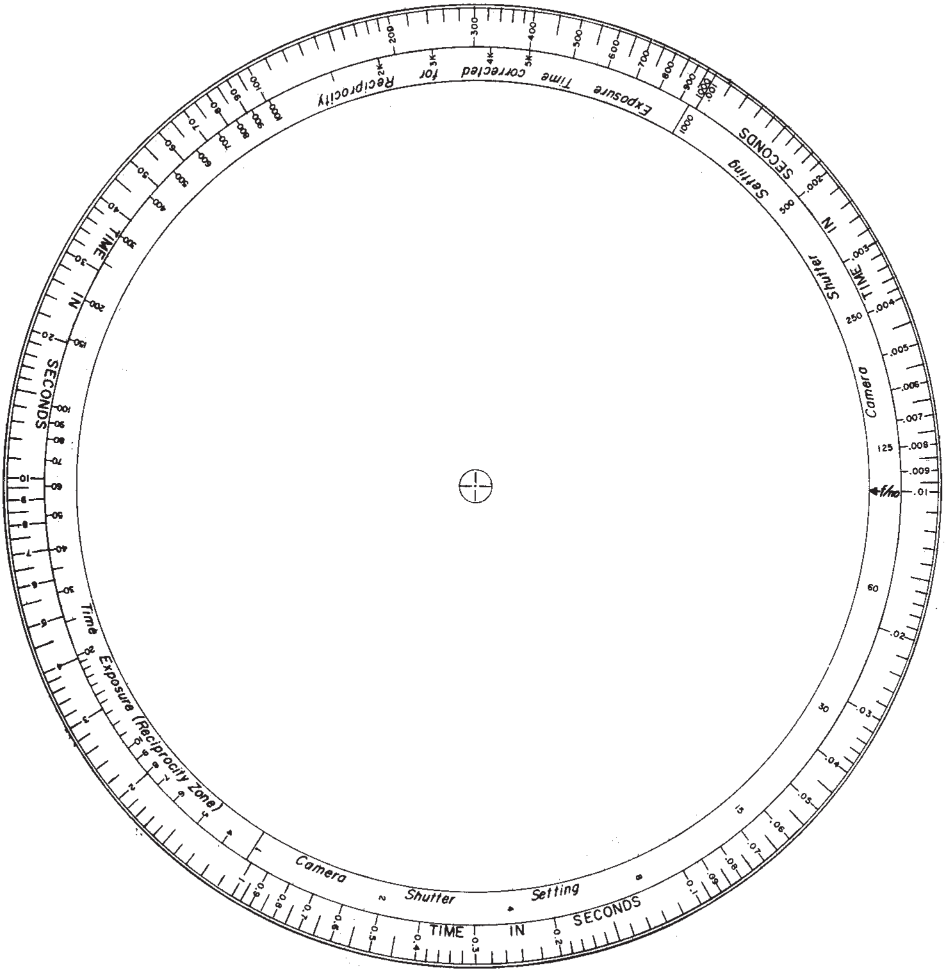
— NOTES —

— NOTES —

— NOTES —


PLANETARY AND LUNAR ASTROPHOTOGRAPHY EXPOSURE GUIDE
G.N. Patterson 1975
BRIGHTNESS
MAGNITUDE
DAY OF MOON
B
Angle Mag
45° 0.0
43° 0.1
32° 0.2
26° 0.3
21° 0.4
19° 0.5
17° 0.6
15° 0.7
13° 0.8
10° 1.0
4° 2.0
2° 2.5
1° 3.0
Earth Shine .01
Penumbra B=20
Umbra .005


f/Number
FILM SPEED — A.S.A.
FILM SPEED — A.S.A



Exposure Time corrected for Reciprocity
TIME IN SECONDS
Camera Shutter Setting
TIME IN SECONDS
Camera Shutter Setting
TIME IN SECONDS
Time Exposure (Reciprocity Zone)
f/no
1000
500
250
125
60
30
15
8
4
2
1K
2K
3K
4K
5K

INSTRUCTIONS

This Slide Rule is based on the formula:

$$T = \frac{f^2}{A \times B}:$$

where:
T = Time in Seconds
A = ASA Film Speed
B = Brightness of Object
f = f/Number of entire Telecamera System

The Inner Wheel is calibrated in Brightness Units, correlated to Planetary Magnitude and the Number of Days since New Moon. Addition features are the Zones of Planetary Brightness, plus the Brightness Factors for Lunar Eclipses, ie, Penumbra, Umbra, & Earthshine. A cursor arrow "B" is located at Brightness = 1.

The Intermediate Wheel is calibrated in ASA Film Speeds (Inner Scale), and Telecamera System f/No. (Outer Scale).

The Outer Wheel is calibrated in Seconds of Exposure Time from 0.001 to 1,000 Seconds (Outer Scale). The Inner Scale is in two parts — one-half shows Camera Shutter Setting, the other half showing the corrected exposure allowing for Reciprocity Failure. A cursor arrow shows the position to set the f/No. for the Intermediate wheel.

HOW TO DETERMINE EXPOSURE TIME

1- Set correct f/No. on the Intermediate Wheel, (Outer Scale) to the f/No cursor arrow on the Outer Wheel.

2- Set "B" arrow, (B=1), of Inner Wheel to correct ASA Film Speed on the Intermediate Wheel, (Inner Scale).

3-Align movable Cursor on — a) The Object Bright—⊕—ness, if known, or,
b) The Planetary Magnitude, (RASC Observers Handbook), or,
c) The Day of the Moon, (RASC Observers Handbook).

4-Read Exposure at Cursor Line on Outer Wheel, (Outer Scale). If time is 1 second or less, use nearest Shutter Setting; if greater than 1 second, use Reciprocity Corrected Scale. Where a filter is used, multiply time by the filter factor to obtain correct time, "T". Bracket exposures at 4T, 2T, T, 1/2T and 1/4T to allow for varying atmospheric conditions.

NOTE

Any object less than 45° from the horizon suffers a loss of brightness dependent on its apparent angle above the horizon. This loss of brightness must be considered when calculating exposure time. A chart on the Inner (Brightness) Wheel shows this loss as an increase of magnitude with apparent angle above horizon. First determine the magnitude of the object without regard to its angle. Estimate the angle above the horizon, read off the increase of magnitude from the chart and add this increase to the original magnitude. Use this corrected magnitude as the Brightness for determining the Exposure time.

COVER PHOTO:

Subject: λ & χ Perseus
Date: September 14, 1985
Film: Pan 2415, Hypered
Exposure: 20 minutes
200 mm, f/5.6
Nikon Piggy-Back, C-8

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