John Westfall

The Strolling Astronomer

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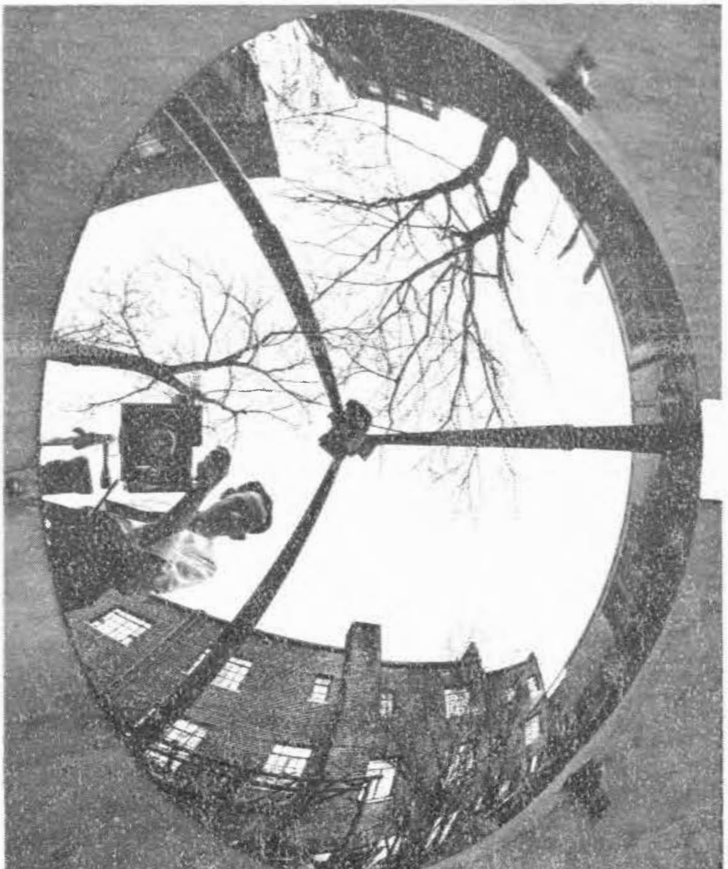

All-sky camera constructed by Mr. Charles Cuevas, New York City, for observations during total solar eclipse on July 20, 1963. Apparatus consists of a 12-inch condensing lens aluminized on convex surface, over which is mounted a Kine Exacta Camera. Camera will be used to photograph moon's shadow projected against earth's atmosphere. Photograph taken by Charles Cuevas, seen in camera view of sky; contributed by William H. Glenn. See article on pages 55-59 of this issue.

THE STROLLING ASTRONOMER

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ASSOCIATION OF LUNAR & PLANETARY OBSERVERS
ALPO

IN THIS ISSUE

THE ART OF LUNAR DRAWING

By: Clark R. Chapman, A.L.P.O. Lunar Recorder

Introduction. Amateur astronomers have made many thousands of drawings of lunar features, done in all sizes, by all methods, and with varying degrees of success. Sometimes the drawings bear some likeness to the actual lunar features, but more often they do not. In any case, the drawings are mailed in to the lunar recorders and coordinators of various astronomical organizations, including the A.L.P.O. They also are submitted for publication in various popular journals, and they are mailed to professional selenographers. Nearly all of them eventually end up within a dusty folder of worthless material, never to be seen, published, or analysed. A few drawings are occasionally used as filler material in a magazine or as illustrations in descriptive books about the moon. Whenever some optimistic enthusiast attempts to do a scientific evaluation of the drawings, he soon discovers that it is a hopeless task, unless he uses only the works of a very few select observers. Most drawings are so exceedingly inaccurate that absolutely nothing useful can be learned from them.

For these reasons, most selenographers regard lunar drawings as scientifically worthless. With the publication of the Kuiper Photographic Lunar Atlas and the even more outstanding photographs taken recently with the Lick 120-inch reflector, drawings seem even more worthless. The latest photographs show with complete objectivity detail well below the resolving power of any amateur telescope so that even if a drawing were to be completely accurate, it would still be inferior to the photographs.

Until recently there were a few areas of study where careful and systematic studies by drawings would have been useful, principally because of the lack of professional interest in the moon and because of the relative dearth of top-quality photographs throughout all solar lightings and lunar librations. The need for these studies (including cartography of limb regions, depiction of low maria features near the terminator, and studies of very low contrast tonal shadings) is now rapidly disappearing.

There are a number of amateurs who are attempting to work in these few remaining areas of study who could greatly improve their results if their drawings were more accurate. For a few years, at least, there will also be a demand for accurate and realistic drawings of lunar features to serve as illustrations in popular journals. Also, the amateur who just wishes to make a drawing for the fun of it would probably be happier if his drawing were a good representation. Finally, making drawings of lunar features serves as very good training for the beginning lunar observer. Nothing is better than making systematic drawings for a beginning observer to become famaliar with the lunar surface and with the important interpretational problems.

Methods of drawing. Drawings fall into various broad categories depending upon their purposes. Some of the more common types of drawings are the line drawing, the notational sketch, and the artistic drawing. The line drawing is done with either pencil or ink and records topographical features only (hills, craterlets, or streaks but not shadows or tonal differences) by means of various solid and broken lines. The notational sketch is best characterized as an inartistic or incomplete sketch supplemented profusely with written notes and numbers on the face of the sketch. These two methods, along with other types (such as drawing on photographs as done by Krieger), are all subject in more limited ways to the pitfalls encountered by observers using the most familiar method, the artistic drawing, which I will discuss in detail.

Artistic drawings attempt to show accurately and realistically lunar features exactly as they appear. The principal purpose is to make a "photographic" drawing: a drawing that shows everything the way a photograph would but makes use of the eye's greater resolving power, contrast perception, and (to a limited extent) interpretational ability. These drawings are generally done in pencil, but sometimes in ink, paints, or a combination of the three. Paints are very difficult to work with except for such uses as whitening very bright features or blackening shadows. The only satisfactory use of ink alone is in stippling; this method of drawing, when learned well, has a number of advantages as far as objectivity and realism are concerned because it best duplicates the actual method the eye or the camera uses in seeing. It is a rather tedious method and is not at all easily performed at the telescope so that more will be lost than gained by an inexperienced observer using it.

Supplies necessary. The beginning observer should use pencil for his drawings. There are two methods of pencil drawings, both of which are used successfully by accomplished lunar artists. Using either method, the observer should first have a variety of pencils of various hardnesses with some sharpened and some blunted. He should also have a few erasers, some of which are sharpened to a point. One very useful tool is an artist's stump which is a "pencil" made entirely of paper tightly rolled. This can be purchased for a dime at an artist's supply store, or it can be made easily from a sheet of porous paper. Although drawings can be made on practically any type of paper, comparatively smooth paper which is as white as possible and takes pressure well is the best. I have found that regular duplicating paper meets these conditions sufficiently. A better quality paper would be some improvement, and several American lunar artists recommend Pinehurst Tablet paper. Finally, the observer should have a well-placed light and a smooth hard surface on which to draw.

Procedure. If the drawing is to have any scientific value, the outline of the feature to be observed plus the location of other prominent objects within or near it should be prepared before the observation. Outlines may be traced carefully from photographs. If the feature is near the limb, try to use a photograph with a similar libration. The Kuiper Photographic Lunar Atlas is an excellent source of photographs from which to trace outlines. If necessary, photographs may be enlarged by the use of photographic enlarging equipment, opaque projectors, and graphical enlarging means. Outlines of some interesting craters are being issued for interested persons by the A.L.P.O. Lunar Training Section, which the writer directs.

The two methods of making pencil lunar drawings might be called the "sketching" method and the "shading-erasure" technique. The "shading-erasure" technique was well outlined in Sky and Telescope for June, 1959. The paper is first shaded by lightly rubbing it with pencil shavings or by some other method before the observation. Lighter areas are depicted by erasing the shading, darker areas are made by rubbing with the stump, and very dark areas are depicted with pencil.

The "sketching" method is probably the most common. The observer starts by making essentially a line drawing on white paper showing the outlines and positions of all features seen, beginning with the largest and working down to the smallest. After most of this work is completed, the observer shades in the areas in the proper relative tones leaving the brightest areas white.

Both methods have their advantages and disadvantages. Often the drawings done with the "shading-erasure" technique are more artistic, but certain types of features (such as faint maria shadings) are much more difficult to depict clearly. Using either method of drawing, the observer should try to use the entire tonal range available to him. The brightest features should be left white, and the darkest features (not shadow) should be very dark grey. It is difficult to represent with pencil the innumerable variations in tone visible to the perceptive eye. Drawings should show only features definitely and accurately seen. The observer should adopt a style of drawing that makes it very clear what marks he has intended to show and which ones are extraneous. (Impressionistic lunar drawings can be very artistic but are impossible to analyse objectively.) Wavy lines drawn to indicate a general impression of waviness should be avoided.

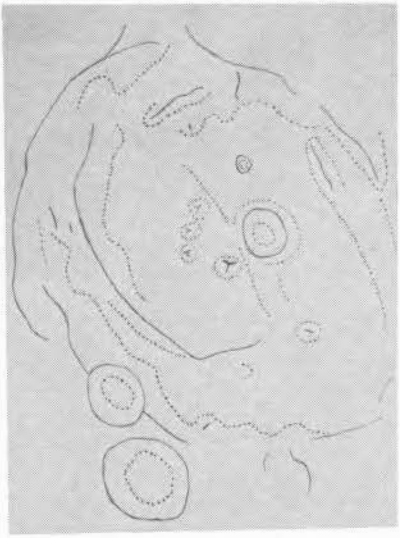

FIGURE I. First of four stages in the construction of a drawing of the lunar ring-plain Posidonius by Clark R. Chapman. A standard outline has been traced from a large scale photograph.

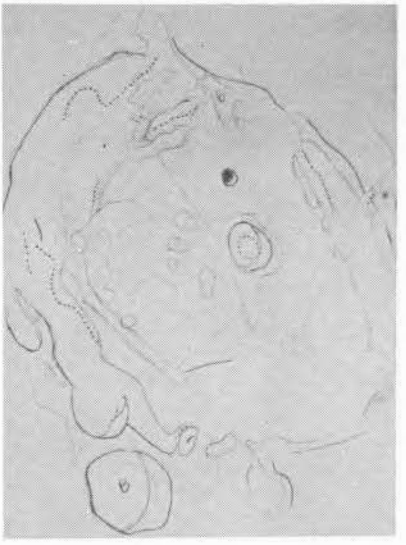

FIGURE 2. Second stage. The standard outline has been altered to conform to the solar lighting and libration at the time. Boundaries of shadows and major topographical features have been sketched.

FIGURE 3. Third stage in the drawing of Posidonius. The shadows have been filled in, and general shading has been added to the floor.

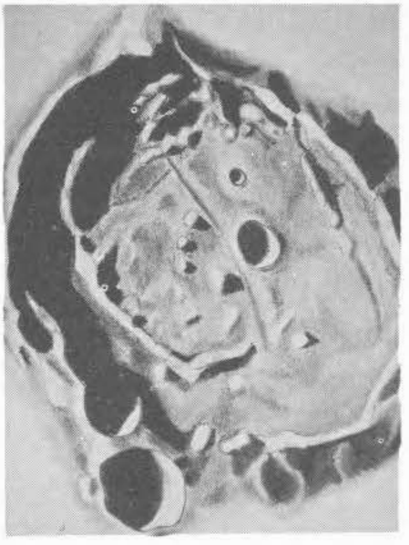

FIGURE 4. Fourth stage, the completed drawing. The original was about $5\frac{1}{2}$ by $4\frac{1}{2}$ inches. See also text of Mr. Chapman's article.

Every wiggle should be meaningful. Avoid pencil-thin lines or boundaries if possible. A boundary can only be resolved down to the resolving power of the telescope. If a drawing is made to the usual scale of about ten miles to the inch, it is obvious that only under exceptional circumstances can the diameter of a craterlet or the breadth of a line or boundary be less than a sixteenth of an inch.

It takes considerable practice and some talent to make a realistic drawing. One of the key elements in realism is the three-dimensional effect. The moon, unlike any of the planets, has detail which is primarily in relief. The eye tends to take many things for granted that are important in producing the relief effect. There is a big difference between the appearance of a bright spot and a bright mountain on the moon; yet on many drawings they appear drawn the same. The addition of a few shadings, which are there but which the eye tends to take for granted, will transform a featureless spot into a three-dimensional mountain. Similar three-dimensional shadings set off slopes, hills,and crater-rims.

Most important in making a good lunar drawing is accuracy. Be sure that relative <u>positions</u> are correct. Be especially careful with <u>shapes</u> of large objects. One of the most serious failings of many lunar drawings occurs in <u>relative sizes</u>. Continually compare smaller objects within the crater to the size of the crater itself. Be careful not to fall into the trap of systematically drawing interior detail too large or too small. There are two other ways in which systematic size errors may be avoided. Avoid using too little magnification. Also avoid using scales much smaller or much larger than ten miles to the inch on your drawings. For accurate drawings be sure to check and recheck features already drawn as you work on new parts of the crater.

When you think that you are finished, check all regions again, making sure that you have left nothing out. Compare the general appearance of your drawing with the object itself and see if your drawing really looks the same. If not, decide why not and correct the drawing. Be sure to leave plenty of time for an observation. A drawing must be thorough. It also cannot take too long or the lighting will change too much, so do not draw too large a region or you will be unable to finish the drawing. A crater the size of Plato should be about the largest feature that an amateur with a good telescope should attempt to draw.

If it is at all possible, the entire drawing should be finished at the telescope (with the possible exception of erasing stray marks and smoothing things up a bit with the stump). At times, however, observing conditions are so poor (winter weather, mosquitoes, cramped observing position, too little light, etc.) that it is really quite impossible to do accurate shading at the telescope. Under these conditions it may be permissible to come inside and <u>immediately</u> finish the drawing, but a note should be made of the fact. After all, there is nothing magical about standing next to the telescope, and your drawing might be less inaccurate drawn inside your house than if you tried to shade with frozen fingers; but if you are away from the telescope for any length of time, memories fade and the drawing cannot be compared again with the moon itself. It is worthless just to make notes or a hasty sketch at the telescope and then come inside to make the drawing.

Be sure to estimate seeing and transparency conditions while at the telescope. Record the magnification and filters used (a neutral density filter can be helpful for reducing glare) and any other factors which might have an effect on the accuracy of the drawing. Record the Universal Time of the drawing to within at least ten minutes. (This time should refer to the time at which the major shadows were drawn.) If possible, look up the sun's selenographic colongitude from the <u>American Ephemeris</u>, or some other source, as well as the librations if the object is not near the center of the moon.

<u>The Lunar Training Program</u>. In starting his program of learning how

to draw the moon, the beginning lunar observer should pick out several rather prominent moderate-sized craters such as Atlas, Cassini, and Herodotus and perhaps another feature like the Hyginus Cleft. He should make at least half a dozen drawings of each feature under varying illuminations while keeping these instructions in mind. Not until he is confident that he has developed considerable skill with these few objects should the beginner branch out on a drawing program of his own. As Recorder of the Lunar Training Program of the A.L.P.O., I will be glad to offer criticism and suggestions to learning lunar observers if sample drawings are submitted to me.

Once the observer has reached a state of considerable skill and has really learned the appearance of the moon, he is ready to work on more advanced projects. It would be hoped that he would devote his time to a scientifically worthwhile activity which practically precludes the making of individual drawings. A systematic series of drawings of a single feature under all illuminations, if carefully done, can still be of some value; but random single drawings of many craters are quite worthless scientifically, although they may be pretty pictures to show to friends.

When submitting drawings to the Lunar Section, it is best to submit the original drawing. If you do not wish to part with the original, a carefully traced copy will suffice. Half an hour should be spent in copying a good lunar drawing. A photographic copy of the original is fine, but some of the other copying processes which reproduce greys poorly should be avoided. Be sure to include all relevant data about the drawing when it is submitted.

Drawing the moon is practically a lost art. With just a little patience and ingenuity and keeping this article in mind, the beginning observer can become an accurate lunar observer in a relatively short time. The A.L.P.O. Lunar Training Program will be glad to assist any interested beginning lunar observer.

A SUGGESTED CLASSIFICATION FOR LUNAR TOPOGRAPHY

By: L. J. Robinson

The conventional categories for the lunar topography have grown slowly and haphazardly through several centuries of use in the lunar literature. Rigorous definitions of properties and classes of lunar formations are lacking and, as a result, many descriptive terms now used have lost (or for that matter, never had) any precise meaning. A. V. Khabakov makes this point clear when he states in The Moon: A Russian View, "The problem of further ordering and improving of the names, nomenclature, and classification of different land forms of the Moon remains an important one, . . ."

A classic example of this confused terminology is found in the words "cleft" and "rille". For many years the two words have been used more or less as synonyms to denote cracks in the lunar crust. Of late, however, the Kuiper Lunar and Planetary Laboratory, in particular, in the explanatory handbook to the Photographic Lunar Atlas proposes that the term "rille" be exclusively used since "cleft" connotates cleavage, an assumption not warranted in the light of current knowledge. Irregardless of the semantic merits or demerits of such a change, it is a welcome simplification of a rather nasty enigma. However, this single instance serves only to point out one aspect of the whole problem.

Fundamentally, one might ask, "What are the bases for a useful classification of the lunar surface?" Primary considerations require that an accepted system should:

(1). be complete enough to provide definitions for all genetic formations. Such definitions should consider only the physical type of feature and should not imply an assumed mode of origin.

(2). be established on a small number of easily recognizable properties.

(3). be in concert with contemporary thinking, using common notation and terminology wherever possible.

(4). subdivide certain genetic classes to show morphological differences.

(5). provide an abbreviated notation for wholesale application.

Of course, meeting fully all of these criteria is problematical at best. The lunar surface does not lend itself well to categorical description - there will always be variants to any class one may establish. On the other hand, photographic or visual inspection should serve to classify any particular feature: there is a sufficient diversity of physical characteristics among the genetic lunar formations to allow each to be unique in at least one respect.

Taking into consideration the aforementioned objectives, the descriptive summaries given in: Alter, An Introduction to the Moon, Baldwin, The Face of the Moon, Grabau, Principles of Stratigraphy, Kuiper (Editor), Photographic Lunar Atlas, Markov, (Editor), The Moon: A Russian View, and Moore, "The Classification of Lunar Walled Formations", J.B.A.A., Vol. 72, No. 5, as well as the oft used glossology of the B.A.A. and the A.L.P.O., this writer arrives at the following scheme. It is doubtful that these classifications and definitions will receive the total subscription of all workers, but it is hoped that this paper will stimulate further endeavors on this problem.

The Classification

Object Class*	Abbreviation	Examples **
Classic Crater	C	Copernicus (C1). Arzachel (C2). Conon (C1). Maurolycus (C Pec). Alpetragius (C Pec).
Crater Bay	CB	Fracastorius (CB1). Julius Caesar (CB2). Sinus Iridum (CB1). Gassendi (CB2).
Crater Ghost	CG	Ring N. of Flamsteed. Fra Mauro. Guericke. Yerkes.
Crater Mare	CM	Clavius (CM2). Plato (CM1). Deslandres (Hell Plain) (CM3). Cassini (CM2). Ptolemaeus (CM1). Grimaldi (CM1).
Crater Pit	CP	On Kies' dome. On the central peak in Alpetragius.

* See Figure 5.
** See supplementary notation and definitions.

Object Class	Abbreviation	Examples
Dome	D	Inside Darwin. S.E. of Kies. N. of Hortensius.
Dome Complex	DC	Domes E. and N. of Arago. Rümker.
Fault Scarp	F	Straight Wall. In Lacus Mortis In Boscovitch.
Hill	H	On extreme W. portion of Plato's floor. Between Cassini A and Cassini B.
Mare	M	Mare Crisium. Mare Serenitatis.
Mountain Range	MR	Leibnitz Mountains. Caucasus.
Nimbus	N	Posidonius Gamma. Linné.
Peak	P	Piton. Pico. Leibnitz Alpha.
Plateau	PL	Wargentin. Between Kant and Zöllner. N.- N.E. of Linné.
Ridge	R	Serpentine Ridge. Between Plato and Piazzi Smyth. Along W. shore of Mare Humorum.
Rille	RI	Byrgius-Sirsalis system. Hyginus Rille. In Posidonius. Triesnecker system.
Saucer	S	In Ptolemaeus. N. of Wollaston.
Trough	T	S.E. from Bullialdus. S.E. of Triesnecker.
Valley	V	Alpine Valley.

Supplementary Notation

Abbreviation	Definition
	Prefixes
U	object located in uplands: the bright mountanous regions of the Moon.
W	object located in mare: the dark regions.
X	object is member of a chain, range, rim, or complex.
Y	object is a parasite crater or other secondary feature.

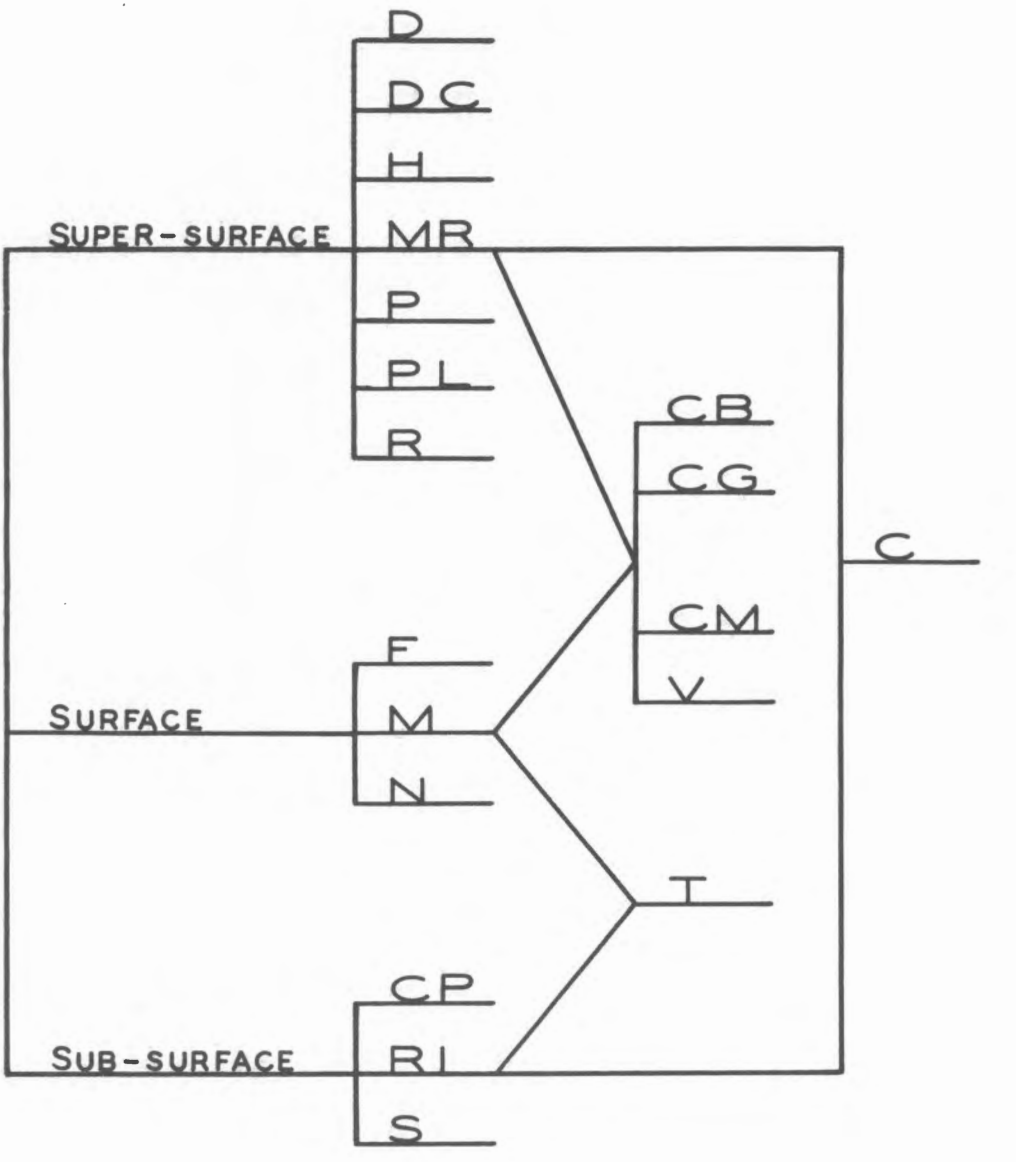

FIGURE 5. A proposed classification of lunar topography by L. J. Robinson. See his article in this issue for abbreviations and detailed explanations.

Calling All Observers! Every A.L.P.O. member is urged to take part in our new Simultaneous Observation Program. The schedule for June, July, and August is given on pages 81 and 82 of this issue. The assistance of both beginning and experienced observers is needed if results of the greatest attainable value are to be secured.

Class Suffixes

1. crater which has no parasite craters of significance on rim, wall, or floor.

2. crater which exhibits a number of parasite craters but which still retains, to a high degree, the earmarks of a crater, i.e. walls in good condition, minimal internal destruction, etc.

3. crater which is barely recognizable as such due to great internal and/or external destruction: rim almost absent, floor filled or broken, many prominent parasite craters on floor, rim, or walls.

Pec object which markedly departs from the object class with which it is most closely associated.

Suffixes

p polygonal crater.
c convex floor.
b bright crater.
n dark or light material on floor and/or walls.
r ray center.
m major mountain mass (es), relative to crater's diameter, within crater.

Format to be Used with the Classification

Format (complete):

Name, (Orthographic coordinates of center of object), Prefix - Class, Class Suffix - Suffix.

Format (abridged):

Name or Designation, Class, Class Suffix.

Examples

Complete:	Aristarchus, (-.677,+.403), W-C1-bnr.
Abridged:	Aristarchus, C1, or (-.677,+.403), C1.
Complete:	Kunowsky, (-.537,+.055), W-CM1-pm.
Abridged:	Kunowsky, CM1, or (-.537,+.055), CM1.
Complete:	(-.472,+.125), WX-D.
Abridged:	(-.472,+.125), D.
Complete:	Stadius Rille, (-.276,+.270), WX-RI.
Abridged:	(-.276,+.270), RI.

Definitions

Classic Crater is any closed mountain cirque having a diameter of less than 190 miles. This cirque shall exhibit internal walls leading to a floor which lies below the level of the surrounding environs; evidence of external walls should also be present. The floor of the crater shall compose less than one-half of the crater's rim-to-rim diameter; objects having floors of a larger proportion than one-half shall be considered Crater Maria.

Crater Bay	is any cirque fundamentally of crater form which has had a substantial portion of its "seaward" wall broken or otherwise destroyed. The remainder of the cirque's wall shall,in the greater part, be contiguous with an upland mass.
Crater Ghost	is any cirque found within a mare or the floor of another crater. These craters shall appear obliterated to one degree or another. Such objects shall differ from Crater Bays in that they shall not connect to any major upland mass.
Crater Mare	is any closed cirque less than 190 miles in diameter which exhibits a smooth, mare-like floor that is greater than 50% of the crater's rim-to-rim diameter.
Crater Pit	is a small crater having no visible rim, to the limits of observational resolution. Such objects differ from Saucers in that they can occur anywhere on the lunar surface: the Saucers are confined to the mare-like areas.
Dome	is a single, regular swelling on the lunar surface whose major axis: minor axis ratio shall not surpass 1.5:1. The surface of a Dome shall appear dark under a low sun and shall become invisible under high illumination. Domes may exhibit secondary features such as pits, clefts, or other minor markings.
Dome Complex	is any object similar to a Dome but which has two or more contiguous uplifts or an irregular vertical profile.
Fault Scarp	is a fracture in the lunar crust along which one side has been vertically displaced with respect to the other side.
Hill	is a low mountain mass, usually isolated but sometimes occurring in small associations. A Hill will appear bright and visible under both high and low illumination.
Mare	is a large, generally circular depression which is dark in tone; all known maria have heretofore been officially designated.
Mountain Range	is an association of at least five major mountain masses which are not part of any other formation (such as a crater rim). All peaks of a Mountain Range should have their bases joined by connecting lowland areas. Associations having less than five members or whose members are not connected by lowlands shall be considered as a group of isolated peaks.
Nimbus	is a generally small light spot showing no relief; these spots usually exhibit a small crater at or near their centers.

Peak	is a mountain mass, either an individual member of a range or isolated; it exhibits a large exterior slope, appears bright under all angles of illumination, and has an apex whose minimum cross-section is small compared to its base.
Plateau	is a generally flat, usually dark area whose upper surface lies above the level of its environs. Such objects have diameters greater than their height above said environs.
Ridge	is a low, gently sloped swelling on a mare surface or the surface of a crater floor. It is invisible as a relief feature under a high sun and has the tone and physical appearance of the Mare. Its major axis: minor axis ratio shall surpass 1.5:1.
Rille	is a long, narrow fissure in the lunar crust having steeply sloping sides. The tops of the sides of Rilles show no exterior walls but may exhibit either regular or serrated edges.
Saucer	is a more or less circular, very shallow depression within a Mare or a crater. These objects are rimless and have smooth, regular bottoms of a tone scarcely distinguishable from their environs.
Trough	is a long, rather narrow depression (relative to its surroundings) which exhibits a smooth bottom and low, exterior walls. The surface of these objects is normally quite mare-like in tone.
Valley	is a pronounced cut through a Mountain Range or other mountainous complex. Its floor may be smooth or may exhibit secondary detail.

Postscript by Editor. We express our thanks to Mr. Robinson for an ambitious and needed attempt to clarify lunar terminology. A subject of this kind can be discussed at length, and readers are invited to comment. Perhaps some of these comments can be published in a future issue or can even be developed into a paper for the approaching A.L.P.O. Convention at San Diego. Mr. Robinson will be glad to receive thoughtful and constructive criticism of the proposed terminology; his address is P.O. Box 147, Cambridge 38, Massachusetts.

OBSERVING THE MOON'S SHADOW AND THE DEGREE OF DARKNESS AT THE TOTAL SOLAR ECLIPSE OF JULY 20, 1963

By: William H. Glenn

Any observer in or near the path of totality at the solar eclipse of July 20, 1963, can contribute observations of scientific interest by observing the appearance of the moon's shadow projected against the earth's atmosphere as it appears in the sky just before, during, and just after totality, and by observing the degree of darkness occurring during the total phase. Very little attention has been paid to these phenomena in the past, largely because observers have been so intent on making observations of the corona that they have overlooked other phenomena visible at eclipse time. Any capable observer, however, by allotting a small amount of his observing time to these phenomena, can help fill these gaps in the records of eclipse observations.

At the time of a total eclipse, the shape of the moon's shadow on the ground is that of an ellipse, with its major axis directed towards and away from the sun's azimuth. For an observer witnessing the total phase, the moon's shadow overhead appears dusky blue, if there are no clouds; and the light from outside the shadow appears as a bright border around the horizon. Since air transmits the long wavelengths of light more readily than the short ones, the light from outside the shadow tends to be yellowed or reddened, the exact color depending on the distance of the shadow edge from the observer. According to Dr. John Q. Stewart,[1] when the shadow edge is 50 miles or more from the observer, the reddening is pronounced and the horizon glow has a tawny hue. The bright horizon glow does not extend upward very far before it meets the shadow edge. As the distance from the observer to the shadow edge decreases, the color becomes less yellowish; and the horizon glow extends higher into the sky. If the shadow edge is only five miles away, the horizon glow extends high into the sky and may be expected to be bluish white. Since the shadow edge is constantly moving with respect to the observer, the distance of the observer from the shadow edge is constantly changing,and with consequent rapid variation in the appearance of the shadow in the sky during the eclipse. Careful descriptions of these moment-to-moment changes in the appearance of the sky during totality are of interest. Observations are of particular interest just before and after totality, when the moon's shadow projected against the atmosphere can be seen approaching toward, and receding from, the observer.

Observers in northern Japan, near the beginning of the path, where the moon's shadow strikes the earth almost tangentially, will first see the shadow in the sky above them, as it falls through the atmosphere. During totality the shadow will stand like a truncated V in the eastern sky, with the eclipsed sun placed within it, similar to the cover photograph of the November,1959, issue of Sky and Telescope. After totality, the shadow will seem to "drop to earth", quickly disappearing as it races eastward. Any observers who happen to be aboard ship in the Atlantic Ocean near the end of the eclipse path on July 20, 1963 will see a reversal of the effects noted at sunrise. The truncated V will be visible in the western sky during totality at sunset, and the shadow will appear to rise as it leaves the earth tengentially. The shadow will not be conspicuous before totality.

In eastern Quebec and Maine the shadow first strikes the earth obliquely from the west and may not be readily observable before second contact. After third contact, however, the shadow will become conspicuous as it appears to "rise from earth", moving upward and away. Observers at other locations along the path of totality will see phenomena similar to those described above, the exact appearance depending on their location in the path.

Observers outside the path of totality along its entire length should attempt to observe the shadow projected against the atmosphere, even though they may be some distance from the nearest location where the eclipse is total. At the total eclipse of July 9, 1945, the moon's shadow was seen near the horizon from Portland, Oregon, 320 miles west of where the eclipse was first total at sunrise[2]; and at the eclipse of October 2, 1959, which was total in Massachusetts, the shadow was seen on the northeastern horizon by an observer only 15 miles northeast of New York City.[3] Observers closer to the path of totality, of course, have a much greater chance of seeing the shadow.

Observers within the path of totality should record the entire sequence of events, from the first appearance of the shadow before totality, through the changes in sky brightness and appearance during totality, to the disappearance of the shadow after totality. Observers outside the path should observe the sky and horizon in the direction of the path of totality,

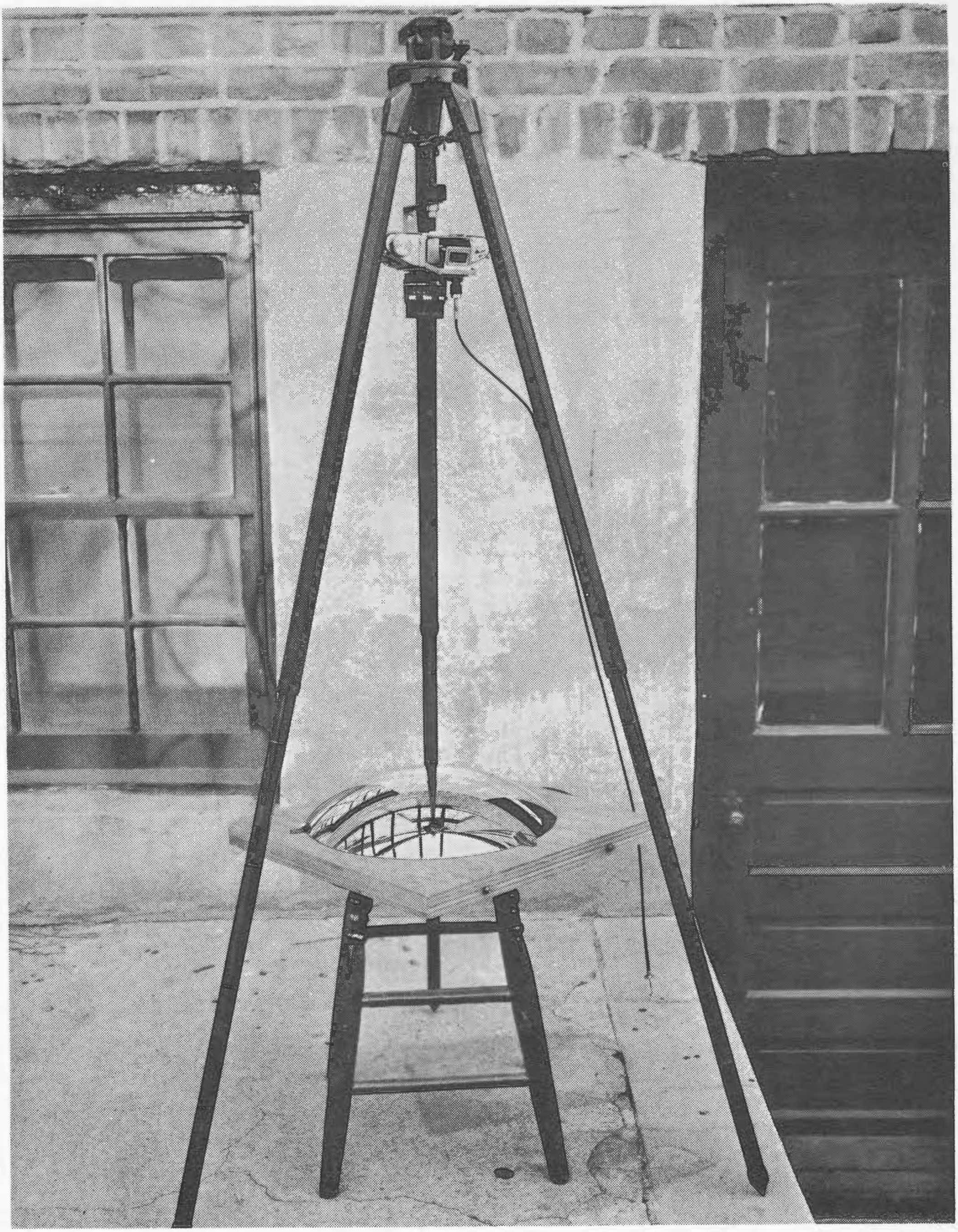

FIGURE 6. All-sky camera constructed by Mr. Charles Cuevas. Photograph by Charles Cuevas, contributed by William H. Glenn. A Kine Exacta camera is mounted above a 12-inch condensing lens aluminized on the convex side. See text of Mr. Glenn's article.

looking for the shadow in the sky near their horizon, for a few minutes just before, during, and after the time when totality is due to occur at the point in the path nearest them. Careful descriptions of the time, color, and general appearance of whatever is observed should be made.

Observations of the degree of darkness during the total phase should also be made by persons within and near the path of totality. One way of doing this is to record the smallest size newsprint readable during totality. Another way is to record the faintest stars visible during the total phase. The first procedure can be carried out even when the sky is overcast, but care should be taken to record the extent and type of cloud cover if observations are made under these conditions. Some clues to the degree of darkness experienced can also be obtained by recording the visibility of landmarks and the figures on the dial of a watch, but these procedures do not lend themselves to control as readily as the newsprint procedure.

Visual observations of the appearance of the shadow and of the degree of darkness should not be considered substitutes for good photographs and photoelectric observations. All-sky cameras should be useful for recording the appearance of the shadow projected against the atmosphere. At the suggestion of the writer, Charles Cuevas, of the Amateur Astronomers Association, constructed three all-sky cameras for use during the total eclipse of October 2, 1959. The cameras consisted of 8" and 14" diameter condensing lenses aluminized on their convex surfaces, over which were mounted still cameras and motion picture cameras. Rain during totality prevented their use in 1959, but it is hoped to employ them again this year to obtain photographs of the shadow.

The attention of readers is directed to Figure 6 and the front cover photograph. Others are encouraged to construct and operate such all-sky cameras. Exposure meter readings can be taken close-up from the mirror. Negatives or transparencies should be flipped over since the mirror gives a mirror image of the sky. Focusing is best done with a single lens reflex camera. Of course, motion picture or still cameras can be used in all-sky cameras; and the diameter of the mirror can vary, Charles Cuevas suggesting that even 6-inch condensing lenses can be used.

At the eclipse of July 9, 1945, Dr. John Q. Stewart employed a series of photocells directed at the zenith and at four points of the horizon to record the moment-to-moment changes of sky brightness during the total phase.[2] The zenith readings obtained during totality were about 0.2 foot candles; and the horizon readings were, of course, higher. A similar arrangement, constructed for the 1959 eclipse by Victor Gogolak, failed to operate properly because of rain during the total phase, but it is hoped to use a revised setup this year. Observers who attempt photoelectric observations should carry out their program even if the sky is totally overcast.

Another type of visual observation that can be made is an estimate of the color of the moon during totality. Since the moon always reflects earthshine to the observer, it should not be totally black during the total phase; and estimates of its color and of the degree of darkness as compared to the sky near the corona are of interest.

The writer will attempt to collate and summarize all observations made of the appearance of the shadow and degree of darkness during this eclipse. The writer has revised the questionnaire used at the eclipse of July 9, 1945, by Dr. John Q. Stewart, and will send copies to persons requesting them. Observations are particularly wanted from observers in northern Japan, Alaska, and western Canada, as well as from those in Quebec and Maine. The writer's address is 3235 Parkside Place, New York 67, New York.

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FOUNDATIONS OF VISUAL PLANETARY ASTRONOMY. I.[1]

By: Charles H. Giffen

Introduction

The methods of visual planetary astronomy have been born in ignorance, bred in misunderstanding, and matured in obstinacy. Early planetary observers were quite ignorant of most principles of optics and vision: they learned to observe by trial and error. Later observers misunderstood newly learned (and often conflicting) facts and fiction about observing technique. Recent history has seen the stubborn adherence to old methods in spite of sound evidence and reasoning which show them to be amiss.

The visual observing technique of both professionals and amateurs has followed this course. Very few of either rank have extricated themselves from this froth of malpractice. Because of the preoccupation of professionals with instrumental techniques, visual planetary astronomy has fallen largely to amateur astronomers. Observing technique has been developed at the hands of amateurs, and the present problems are a result of this fact. More pointedly: amateurs are basically non-scientists, in comprehension, in thinking, and in attitude. Consequently, observing technique has suffered in its development. A reasonable basis upon which to work out observing technique includes some acquaintance with physical optics, with sight phsiology and psychology, and with the optical characteristics of the planets. But rarely have these considerations been made. Moreover, amateurs seldom think analytically or logically about their observing technique. Their evaluation of the methods used and the results secured has been much more subjective than objective. And this clearly leads to a general attitude towards visual planetary studies that is patently wrong and that misrepresents woefully the intentions of the serious amateur astronomer.

To visual observing technique, professionals have added little. They have, particularly in the United States, used the same ill-founded techniques as amateurs and have made no attempts to ascertain whether these methods are valid. It seems their rationale is that, no matter how visual observations are made, they are of the same, essentially nil value. With this as an unwritten bylaw, professionals have employed some of the worst observing methods known, not occasionally, but flagrantly. It is a misfortune that visual methods have developed so haphazardly with amateurs -- it is a miscarriage of the scientific method that these have been perpetrated in terrible forms by professional astronomers.

Yet the necessary rudiments for working out suitable observing technique have not gone undiscovered. Many of them have become buried in the literature, but ferreting them out and using them should offer no real problems at all. There has never been a systematic assemblage of these rudiments into a rigorous study of visual planetary technique. In the current and succeeding chapters of this paper, we present the results of such an investigation in an effort to bridge partly this unfortunate gap. Because of space limitations and this serial presentation of only the results of this work, full details will be published elsewhere under the same title as a unified, complete edition.

We take the trouble to describe here some of the principles used in making this investigation. These principles may not be evident in the bare, final results. Nevertheless, they should be acknowledged so as to better understand these results and their significance. Therefore, we have occasionally succumbed in this report to working through a few of the more interesting approaches in a very sketchy manner. The final edition reveals the use of these principles in a great many places -- some in minute detail.

We begin at the very bottom by investigating the limits to which visual planetary astronomy can be taken and the methods by which these limits may be attained. The procedure is quite straightforward in that the calculation of the limits indicates the methods of attaining them. We shall also see that certain factors affecting these limits are variable and that we ought to measure them. Entirely analogous methods will usually show how this may be done effectively.

The general strategy involves a consideration of various factors contributing to the problem. These factors will usually be regarded as (perhaps variable) <u>proto-quantities</u>. In this general context, the "value" of a proto-quantity is merely the characterization of it through relations and operations defined among these objects. Hence, in a given problem, the proto-quantities need not be numerical. It is the variable aspect of the factors which we must analyze in a problem. Some of the factors will be subject to our direct control; these are called <u>free variables</u>. Others will be controlled by the conditions under which we must work and are called <u>parameters</u>; always-fixed parameters may be called <u>constants</u>. And those factors which vary only as a result of all the others are called <u>dependent variables</u>.

The general problem becomes, then, essentially the expression of the relations and operations for factors entering into consideration together with an instruction that tells one what to do with this expression. Some examples of instructions are: find all possible values of the dependent variables; find all values of the free variables which, for given parameters, produce (specified) optimum values of the dependent variables; calculate values of the dependent variables for given free variables and parameters. The solution to the problem is quite simple in essence: follow instructions.

In this form, however, the general problem is usually much too intractable. The usual course of subdivision and simplification is taken in such cases. In each of the component "exercises" of this process,one works for a reduction in the complexity of factors and relations for the expression of the problem. The general characteristic of tractable exercises is a type of homogeneity or compatibility which appears among the factors and relations. Often they become essentially numerical; but others, such as combinatorial or enumeration types, may occur.

One non-arithmetic type of relation which appears repeatedly in analyses of this sort is a <u>tolerance</u> relation. A tolerance relation imposes a kind of indistinguishability among certain objects which are perhaps otherwise distinct without the tolerance. Thus, resolving power of a telescope defines a tolerance on the field of view. Family names place a tolerance on people: after all, a McCoy is a McCoy! Numerical quantities are often given with a superimposed tolerance in the form of mean deviations or probable errors. By analyzing tolerances placed on the visual field of the eye and on the brain, an interesting study of visual perception, which we shall have occasion to use and enlarge, has been initiated by E. C. Zeeman (1)[2].

In the first chapter, we investigate the two most important limiting factors in visual planetary observing: resolution and contrast. We are able to find specific values of our free variables which optimize these factors for given observing circumstances. In addition, we are able to determine what the optimum circumstances should be and what values for resolution and contrast result in these cases. We turn our attention to planetary seeing and transparency in the second chapter, as these most strongly influence resolution and contrast. We seek evaluations of seeing and transparency which allow us to determine the values of optimum resolution and contrast over a wide range of the parameters involved. With this done, the combined results of the first two chapters enable one to determine the limits he is reaching with his methods and to adjust these methods so as to take these limits to their logical extremes.

Thereafter, in immediately succeeding chapters, we attack the real problems of the planets themselves -- what types of data are desired, how these may be secured, how the results are interpreted. Thus, in the third chapter, we consider the problem of determining intensity differences on the planets. The problem is not unlike that of the first chapter, and we actually proceed along lines which are a continuation of that study. Instead of finding the limits of contrast perceptibility between adjacent areas, we wish to determine the actual contrasts among several areas on the planets. Similar approaches will be used for subsequent problems, and from time to time we shall have to investigate new limiting factors, such as color perception.

The 1961 A.L.P.O. Simultaneous Observation Program introduced by Chapman (2, 3, 4) has shown that, while a great many observations are quite discordant, some types can produce remarkably good results and that certain observers have apparently consistent technique which produces uniformly good results. The causes of these phenomena will become quite apparent in this study. It is not our aim to refute or vindicate the many different techniques employed by observers. Nevertheless, the fact is that we must evaluate our methods in these pursuits if we are to get anywhere at all. And in the end, we must choose and adjust our methods carefully in order to yield the most feasible and efficient study of the planets. In doing this, we shall have to realize that both large and small scale changes may be required, that we may have to settle with less than ideal methods in some cases, that no improvement of methods will make different types of observations have equal merit, and that we can never hope to reach the end of improvement in ourselves. Fortunately, an organism or organization with a sense of honor, sincere purpose, and unbigoted attitude is unashamed to meet these realizations.

The author wishes to thank the several members and officials of the A.L.P.O. who have urged, helped, and encouraged him in this project. Hopefully, this assistance will continue, for we should be as thorough and accurate as possible in this endeavor. Any criticisms or opinions would be very much appreciated. These and other comments should be sent to the author, care of the Mathematics Department, Princeton University, Princeton, New Jersey.

I. Resolution and Contrast.

Abstract. Resolution and contrast have long been recognized as the main limitations of planetary astronomy. It is the variability of resolution and contrast with observing conditions that make them so important.

Sato (5) has pointed out this variability qualitatively and has illustrated its great dependence upon seeing and transparency, even while other conditions remain fixed. Following lines similar to those of Danjon and Couder (6), we develop the subject quantitatively, and in greater detail than Dollfus (7).

From planet to eye, the factors which we must consider include: the planet, the earth's atmosphere and its state, the telescope and its properties, and the observer's visual capabilities. The only factors that may be construed as freely variable are: magnification, aperture (restricted by the maximum available), and transmission (which may be reduced by the interposition of filters in the optical path). The rest we may treat as parameters, although we make further restrictions for specific calculations by assuming a reasonable quality for the telescope and by taking average visual capabilities for the observer. There is here no real loss of generality, as these rarely affect the values of the free variables which optimize resolution and contrast. Moreover, the formulae involved may be used to make specific calculations by merely changing the appropriate values of these parameters, since they may be determined for individual observers and telescopes.

We take the course of least resistance and greatest efficiency by treating contrast first and resolution second. In this way, we may eliminate seeing conditions from our initial contrast considerations and use seeing conditions and our results on contrast to handle resolution. Not only is the problem more tractable in this form, but the final results are expressible in a very nice way. We tabulate specific calculations and conclude with a discussion of our results and their applications.

1. Contrast. Intuitively, contrast may be defined as the fractional difference in brightness between two objects. Thus, suppose two areas of surface brightnesses B and $'B$, respectively, are given with $B \geqslant {}'B$ as measured, say, in stilbarnes (candles/cm^2). Then the contrast c between the two areas is defined as the quotient $B - {}'B$ by B:

$$c = \frac{B - {}'B}{B} .$$

When $c = 0$, then $B = {}'B$, and the two areas are of equal brightness; when $c = 1$, then $'B = 0$, and that area is perfectly "black".

A detector has contrast sensitivity $\overline{c}(B)$, or simply $\overline{c}$, at the brightness level B, if $\overline{c}$ is the minimum detectable value of c in the above expression. If the detector is the eye, we use the special notation $\overline{c}^*(B^*)$, or simply $\overline{c}^*$, for the visual contrast sensitivity at the apparent brightness B^*. A plot of visual contrast sensitivity is given in Figure 7 (see 6, p. 50). These values are only typical; the actual contrast sensitivity at its minimum has been known to vary by a factor of three. Nevertheless, the shape of the curve is very much the same for all people. The minimum value of $\overline{c}^*$ is about 0.017 and is reached when B^* is about 0.01 stilb. For B^* between 0.0005 and 0.4 stilb., $\overline{c}^*$ is nearly constant and less than 0.020. Outside this interval, $\overline{c}^*$ increases rapidly and the eye quickly becomes rather insensitive to contrast. Clearly then, we should like the apparent brightness of a planet being observed visually through a telescope to be inside this interval and as near to 0.01 stilb. as possible.

We consider a planet with brightness B. When the light from the planet passes through the optical train up to the eye, B will be altered to an apparent brightness B^* according to the steps to be outlined below. Surface brightnesses of the planets and the Moon are listed in Table 1. For the planets beyond Mars, B is practically constant, and the values listed will serve for most purposes. For the others, the changes in B are quite significant, and the values listed are only typical. The average surface brightness of a planet may calculated from the

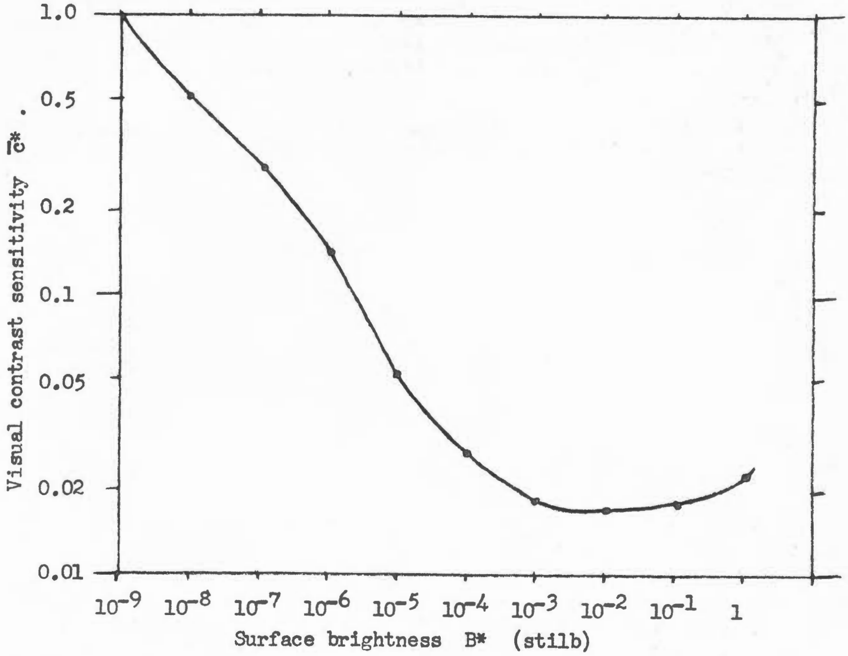

FIGURE 7. Visual contrast sensitivity as a function of apparent surface brightness. See discussion in text of article by Charles H. Giffen in this issue.

following formula:

$$B = \frac{4(10^{-0.4(M)})}{ks^2},$$

where B is in stilbarnes, M is the magnitude, s is the semidiameter in seconds of arc, and k is the fraction of the disk illuminated.

Table 1. Surface Brightnesses of the Planets and Moon.

Planet	B (stilb.)
Mercury	0.6 :
Venus	2. :
Mars	0.2 :
Jupiter	0.070
Saturn	0.028
Uranus	0.0054
Neptune	0.00037
Moon:	
1-2 days from new	0.03 :
quarters	0.1 :
full	0.6 :

When light passes through a medium, a certain fraction of it is lost by absorption, obscuration, etc. To that fraction which travels on through the medium are added amounts of light which are due to local scattering of light from the object in question and to extraneous scattering of other light in the medium. This happens twice in our case, once as the light travels through the atmosphere and once as the light travels through the telescope. If the light is passed through a filter before entering the eye, this happens once more; but we can agree to include any scattering of either type (which will normally be alomst zero) in ths scattering terms for light passing through the telescope. Lastly, because we are dealing with extended objects, there must be a final correction which takes care of the difference in light grasp between the telescope and eye and which allows for the change in scale due to the magnification employed. The apparent surface brightness B* may then be calculated with the following sequence of formulae:

$$B_1 = u_1 B + S_1 + H_1 \qquad (1)$$

$$B_2 = u_2 B_1 + S_2 + H_2 \qquad (2)$$

$$B' = uB_2 \qquad (3)$$

$$B^* = \frac{p^{*2} B'}{p^2}\ , \ p \geqslant p^* \qquad (4a)$$

$$B^* = B'\ , \ p \leqslant p^*. \qquad (4b)$$

In equation (1), u_1 is the atmospheric transmission, S_1 is the local atmospheric scattering due to B, and H_1 is the sky brightness. In equation (2), u_2 is the instrumental transmission, S_2 is the local instrumental scattering due to B_1, and H_2 is the extraneous instrumental brightness. In equation (3), u is the transmission of the filter being employed. In equation (4), p* is the equipupillar power per unit aperture, and p is the power per unit aperture being employed. The equipupillar power per unit aperture is that value of p for which the exit pupil of the eyepiece is the same as the pupil of the eye. The two parts of equation (4) result from the manipulation of the following two relations:

$$d = \frac{D}{P} = \frac{1}{p} \qquad (5)$$

$$d^* = \frac{D}{P^*} = \frac{1}{p^*}\ ,$$

where d is the diameter of the exit pupil of the eyepiece, D is the aperture of the telescope, P is the power being employed, d* is the diameter of the pupil of the eye, P* is the equipupillar power, and p, p* are as before.

The apparent contrast c* may now be calculated using the above formulae together with the following:

$$c_1 = cu_1 B B^{-1} \qquad (1')$$

$$c_2 = c_1 u_2 B_1 B_2^{-1} \qquad (2')$$

$$c' = c_2 \qquad (3')$$

$$c^* = c'\ . \qquad (4')$$

Note that by working backwards through these equations by substituting for c* the value $\bar{c}^*$ of the visual contrast sensitivity, one obtains as a solution for c the value $\bar{c}$ of the actual contrast sensitivity being realized on the planet. Note further that the filter and magnification being employed do not change contrast, although they do change the brightness; hence, they also change the contrast sensitivity. The same happens for other parameters, although they are involved in a much more complicated way. It is fortunate that the free variables are involved in so simple a way.

We find that, for the most part, u may also be treated as a parameter—

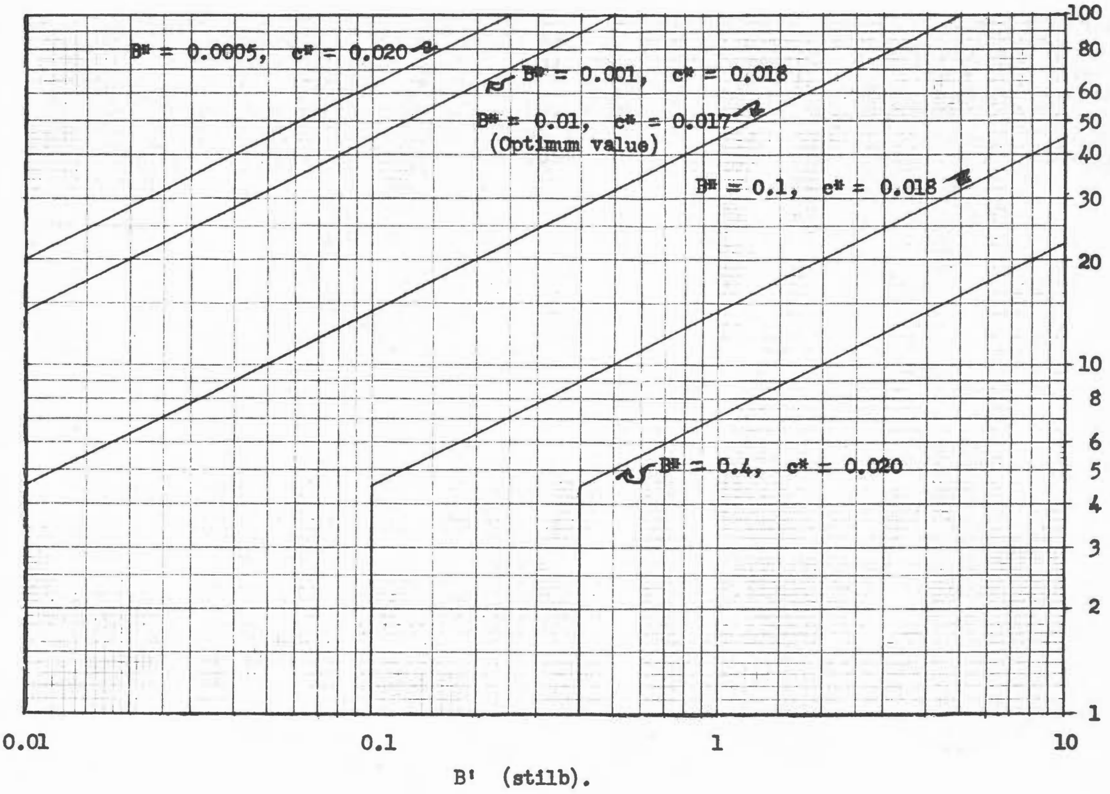

FIGURE 8. Apparent brightness B* and apparent contrast sensitivity c* as functions of B' and power per inch aperture p . Both scales are logarithmic. See also discussion in text.

as indeed it will be if the filter is being used for purposes other than just brightness reduction. For this reason, we shall be mostly interested in the variation of B* with B' and the power per unit of aperture being employed. This variation is shown in Figure 8, where we have plotted p against B' (both logarithmically) for the various contours of equal apparent brightness B* . These contours are drawn for B* equal to 0.0005, 0.001, 0.01, 0.1, and 0.4 stilb.; and they correspond to values of $\bar{c}^*$ of 0.020, 0.018, 0.017, 0.018, and 0.020, respectively, thus covering the region which gives the optimum visual contrast sensitivity (i.e., that region between the contours). The units of p are power per inch of aperture, and the value of p^{*2} which we take is 20, corresponding to a diameter of the pupil of the eye of about 5.7 mms.

We must now investigate the various things contributing to the equations (1) and (2). The atmospheric transmission u_1 is a function of the transparency, given by:

$$u_1 = 10^{0.4(T_r - 6)} ,$$

where T_r is the value of the transparency defined in the second chapter of this paper (essentially the same T_r as that introduced by Robinson in reference 8). The local atmospheric scattering S_1 is usually insignificant, especially in conditions of high transparency. The sky brightness H_1 is normally about 10^{-8} on clear, moonless, city-lightless nights and about 10^{-4} to 10^{-3} on equivalent days; these values may increase enormously when conditions are worse. Instrumental transmission u_2 is about 0.6 for large refractors and about 0.7 for small refractors; it is about 0.8 for standard aluminized reflectors and about 0.9 for freshly silvered reflectors. As with S_1, the local instrumental scattering S_2 should be quite insignificant, especially when optical surfaces are in excellent condition. The extraneous instrumental scattering H_2 will also be very small normally; however, daylight or other light falling on the optics can increase this to a rather large amount.

The effect of u_1 and u_2 is to decrease brightness, while the effect of the scattering terms is to increase brightness, usually by very small amounts compared to the transmission. Meanwhile, the effect of u_1 and u_2 on contrast is normally rather small compared with that of the scattering terms, which may be considerable. From the overall effects, we conclude that we would like the scattering terms to be as small as possible and the transmission factors to be generally as large as possible. Under the "best" conditions, we may assume that the scattering terms are actually set equal to zero. This will generally give a good approximation to the values of B' and c', the formulae of which become very much simplified:

$$B' = uu_2u_1B ,$$

$$c' = c .$$

With B' easily computable in this form, we may readily find the range of powers per inch of aperture which produce optimum contrast sensitivity from this and equation (4) above. Moreover, under the conditions which allow the approximation $c' = c$, we have $c^* = c$ from equation (4'). Therefore, <u>the visual contrast sensitivity at apparent brightness B^* is just the actual contrast sensitivity at actual brightness B</u>:

$$\bar{c}^*(B^*) = \bar{c}(B) .$$

To illustrate the use of these results in practical situations, we give in Table 2 the optimum power range on the various planets for different values of uu_2u_1. A comparison of these values with those values that have been used in the past will show, in part, why visual planetary work is so often useless. In particular, note the maximum permissible powers per inch with Jupiter, Saturn, and the outer planets; also, note the minimum permissible values for Venus and Mercury at typical brightnesses. It is clear that <u>far too many observers are employing the wrong powers for observing detail of low contrast</u>. In at least two cases, Venus and Saturn, this had led to the rather hasty conclusion that little detail exists at all. With Venus, the tendency has been to use powers too low or no dimming filter, especially when seeing (as in twilight) is not very remarkable; with Saturn, the opposite has happened, namely the tendency to use powers far too high to have adequate contrast sensitivity. Much the same problems often occur with Mercury and Jupiter, respectively.

We conclude from our study of contrast that <u>we are limited in our choice of magnifications for observing a given planet by several factors</u>, if we are to obtain optimum contrast sensitivity at that time. These limitations should be adhered to if at all possible. It is important to note here that resolution criteria, treated in the next section, place further restrictions on the lower limit of powers per inch aperture which observers should use.

<u>2. Resolution</u>. Unfortunately, the problem of resolution is not so uncomplicated as that of contrast, principally because of the problem of defining resolution correctly. Actually, several definitions can be given. Of the many definitions that have been devised, several are quite restrictive as to the type of objects considered; however, these usually can be treated in a convenient form with relatively uncomplicated tools (e.g., diffraction theory applied to point sources of light). The con-

Table 2. Optimum Power Per Inch Ranges, for Optimum Contrast Sensitivity.

Planet	$uu_2u_1 = 0.6$			$uu_2u_1 = 0.8$			$uu_2u_1 = 1.0$		
	Lo	Opt	Hi	Lo	Opt	Hi	Lo	Opt	Hi
Mercury	8.5	27.	85	9.8	31.	98	11.	35.	110
Venus	16.	49.	156	18.	56.	180	20.	63.	200
Mars	4.9	16.	49	5.6	18.	56	6.3	20.	63
Jupiter	—	9.2	28	—	10.6	33	—	12.	37
Saturn	—	5.8	18	—	6.7	21	—	7.5	24

The values under the columns labelled Lo, Opt, and Hi represent apparent brightnesses of 0.001, 0.01, and 0.1 stilb, respectively. The maximum permissible values (corresponding to a value for the apparent brightness of 0.0005 stilb) are 40% greater than the Hi values given; the three maximum values for Saturn are therefore 26, 30, and 34 for $uu_2u_1 = 0.6$, 0.8, and 1.0, respectively.

sideration of more complicated objects and shapes leads to more complex definitions, many rather incompatible with numerical manipulations. And in visual planetary studies, the particular behavior of the eye must be taken into account.

From these complications in the definition and the investigation of resolution, we should like to choose a road which is both accurate and efficient for our purposes of exhibiting how to calculate and how to attain the limits of resolution. To a very great extent, this can be done in a way that represents other approaches to resolution. I.e., many types of resolution can be derived from each other, and the optimum values of the free variables coincide under given initial conditions for each type. Therefore, we make no attempt at a comprehensive treatment of all types of resolution. Instead, we need only develop those types which are necessary for our analysis -- a few others being mentioned in passing to indicate where they fit in.

Certain applications of tolerance relations, mentioned in the introduction, provide a very unified, although rather novel, approach to resolution. This is the approach we take, because it is also extremely natural and certainly well-motivated. A lack of the necessary geometric and topological foundations undoubtedly explains its not being discovered and used before. For our studies, a further advantage to this approach is its applicability to other considerations, such as the representation and interpretation of the visually perceived planetary image -- to be taken up in later chapters of this work.

Consider the visual field X of the right eyeball and two images A' and B' on X. If the eye cannot tell A' from B', we say that A' and B' are <u>indistinguishable</u> and write $A' \sim B'$; if A' and B' are not indistinguishable, we say A' and B' are <u>distinguishable</u> and write $A' \nsim B'$. By the very definition of the relation symbol $\sim$, it is <u>reflexive</u> (i.e., $A' \sim A'$, for any image A' on X) and <u>symmetric</u> (i.e., $A' \sim B'$ and $B' \sim A'$ mean the same thing). Any relation among pairs of elements of a set which is reflexive and symmetric is called a <u>tolerance relation</u>. If we let //X// be the set of all images on the <u>right visual field</u> X, then we see that the relation just defined for //X// is a tolerance relation completely characterizing the resolution of the right eyeball. This tolerance relation is called the resolution tolerance of the right eyeball; of course, it varies for different specimens of right eyeballs. Moreover, given an arbitrary tolerance of the images on a visual field, we can imagine an idealized right eyeball which has this tolerance for its resolution tolerance, although practical realization seems next to the impossible. Observe also that we do not have to restrict this type of consideration to the eye; any other light detector will serve just as well for these definitions. We shall call any tolerance relation for images on an optical field a resolution tolerance, or simply either "tolerance" or "resolution", used more or less interchangeably. Similarly, "indistinguishable" and "distinguishable" are interchangeable with "unresolvable" and "resolvable", respectively.

We have managed, at this point, to embed the problem of studying visual resolution in the problem of studying tolerance relations for images on an optical field -- the latter being somewhat larger and more mathematical. By utilizing the abstract mathematical nature of an image on an optical field (i.e., a non-negative, real-valued function) in terms of the brightness of an image at each point of the field, we are in a position to formulate a mathematical problem, which, restricted to the study of vision, is precisely our problem of discussing resolution and its role in visual planetary astronomy. We can go no further in this note than to outline a few of the results of such a mathematical study.

In later chapters we shall be concerned with what types of objects we can resolve. Just now we are more concerned with finding some sort of "measure" of resolution which tells us (in some sense) just how much we can resolve. In particular, we wish to define the concept of a resolution character (a numerical quantity, depending upon resolution) in order to indicate its useful properties, and then to find such a function which we can use. The main property of a resolution character is given by its definition: it is a number, some power of which gives a direct relative measure of the quantity of objects which can be resolved in a homogenous image. There is a further restriction that, for objects distributed in just one dimension, the resolution character itself should measure the quantity of these objects discernible. Hence, if the image were a series of randomly spaced parallel lines, and two observers were realizing resolution characters of 3 and 2, respectively, then the second would resolve 3/2 times as many lines as the first. If, on the other hand, the image were made up of randomly spaced points, a dimensionality argument shows that the second observer would see $(3/2)^2 = 9/4$ times as many points as the first. For homogenous distributions of other objects, the second observer would detect $(3/2)^r$ times as many objects as the first, for some real number r . In the cases we meet, r will generally be no greater than 2 and no less than 1 (as might be reasonably expected). That it is possible to have a function that is a resolution character which is stable (i.e., which works for all configurations coming into consideration) for visual planetary work is a rather lengthy mathematical exercise.

Strictly speaking, resolution is a function of things other than just the image: apparent brightness, contrast sensitivity, contrast of markings, aperture, seeing conditions, transparency conditions, etc. We have managed to eliminate transparency conditions (for our purposes) by including them in apparent brightness and contrast sensitivity limitations; at least for our purposes, this causes no difficulty and more than a little simplification. Also, in the first section of this chapter, we have tried to force the brightness and contrast sensitivity to a uniform value for the various planets -- the uniform value being, generally, the optimum value or at least in an optimum range. This procedure also results in our not having to worry about these considerations in studying resolution, provided that we stay within the limits given by the last section. Under the assumption that the contrast of markings on the various planets is constant, we could drop that restriction; however, this does not seem to be the case -- even at first glance. Nevertheless, since an image is made up of continuous tones and not just light and dark tones, it is best not to try to include directly the contrast of markings on the image in the formulation of a resolution character; further justification for this is the variability of the contrast among markings. Also, what is more useful for later considerations, the elimination of the dependence of a resolution character upon the contrast of markings enables us to use the resolution character in the study of the markings themselves (to be shown in a succeeding chapter).

From this rather brief discussion (it can be rigorized), we see that the effects on resolution with which we are most concerned are those due to the aperture of the telescope and to the seeing conditions at the time of observation. In particular, we should want any resolution character that we define to vary only as a function of aperture and seeing conditions -- provided that the other conditions in the above paragraph are met with. To do this, we shall have to impose some further restrictions on the magnification being used in order to obtain optimum resolution -- just as we had to do for optimum contrast.

We now proceed to the definition of a resolution character which best fits our purpose. Note that if we let s' be the smallest angular separation discernible between two points of light at apparent magnitude 6, then s' is just one of the classical definitions of (numerical) resolution. In fact, if we let $S' = 1/s'$, then S' is essentially a resolution character. Also, from diffraction theory and assuming perfect seeing conditions, s' is inversely proportional to D, the diameter of the telescope objective; and hence D is directly proportional to S', Dawes' criterion giving $4''.56(S') = D$. For these conditions of perfect seeing D is also a resolution character. This observation concerning the relation of S' and D under perfect conditions motivates our own definition of a resolution character which we will use exclusively. The <u>standard resolution character</u> D^* is defined as the diameter a telescope <u>would have</u> (i.e., the <u>apparent diameter</u>) under perfect conditions of seeing in order to produce an image equivalent to the one being observed in the given situation. Thus, an observer may be observing with a 10" telescope but only resolving all that a 6" telescope under perfect conditions can resolve and no more; according to our definition, the apparent diameter $D^* = 6$ even though the actual diameter $D = 10$. It is clear that the quantity D^* defines a resolution character for all conditions. Note also that the apparent brightness B^*, the apparent contrast c^*, and the visual contrast sensitivity $\bar{c}^*$ are <u>not</u> functions of D^*, but of D.

Having defined the resolution character D^*, we should like to be able to compute it. For this, we must note that the principal sequence of obstacles light rays meet in their journey from planet to eye are, in order, the earth's atmosphere, the telescope objective, the eyepiece, and the observer's eye. It is a mathematical exercise to check that D^* is proportional to $a/(a+t)$, where a is the radius of the diffraction disk of a point of light and is simply the familiar $a = 5''.5/D$, and where t is the <u>turbulence</u> and is equal to the radius (in seconds of arc) of the seeing disk caused by deformation of light from a point source. Since this constant $a/(a+t)$ of proportionality is just equal to 1 in conditions of perfect seeing (i.e., when the turbulence $t = 0$), then, except for limitations that might be given by the magnification being used and the observer's eye, we have:

$$D^* = \frac{a}{a+t} \cdot D = \frac{5.5(D)}{5.5 + tD} . \qquad (7)$$

The effect of magnification and of the resolving power of the eye may be treated together as follows:

First, let us suppose our "telescope" is the eye itself, and that we can vary its diameter (with diaphragms). Since the optics of the eye are not so good as those of a telescope, we should expect, even under perfect conditions, that D_e^* (the apparent or effective diameter of the eye) would vary in a different manner with D_e (the actual diameter of the entrance pupil into the eye). This is in fact the case, as is shown

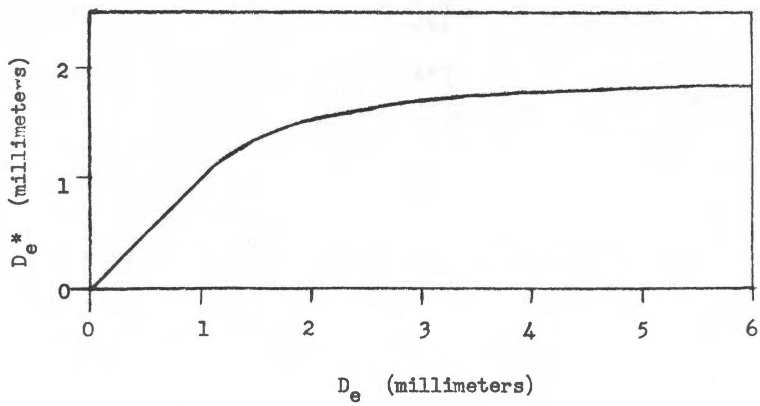

FIGURE 9. Resolving power of the eye of Charles Giffen shown as the variation of the effective diameter D_e* of the eye with the actual diameter D_e. These values were determined experimentally with the writer wearing glasses -- as he does when he observes. Always in making such a graph, the observer should correct for myopia or hyperopia; and if he wears glasses that correct for astigmatism when observing, he should correct for astigmatism as well. See also text of Mr. Giffen's article.

in Figure 9, where the variation of the writer's eye is shown. For $D_e \leqslant 1$ mm., almost all eyes have equivalent sensitivity, given by $D_e^* = D_e$ in this range. For a few people, this relation holds for slightly greater values of D_e (up to about $1\frac{1}{2}$ mms.); but imperfections in the optics of the eye and the discontinuous structure of the retina impose an upper limit on the value which D_e* can assume -- usually about 2 mms. Always, $D_e^* \leqslant D_e$.

Just as before, the employment of magnification results in the eye's being diaphragmed, so that $D_e = 1/p$ (p being the power per unit of aperture). Manipulation of formulae (5), (6), and (7) gives the following <u>general formula for the resolution character</u> D* :

$$D^* = \frac{aD}{(a+t)} = \frac{5.5(D)}{5.5 + tD} \text{ , when}$$

$$\frac{a}{a+t} = \frac{5.5}{5.5+tD} \leqslant \frac{D_e^*}{D_e} \; ; \qquad (8a)$$

$$D^* = \frac{D_e^* D}{D_e} \text{ , when}$$

$$\frac{a}{a+t} = \frac{5.5}{5.5+tD} \geqslant \frac{D_e^*}{D_e} . \qquad (8b)$$

Now, in perfect seeing, t = 0, and the ratio a/(a+t) = 1; since neither a/(a+t) nor D_e^*/D_e ever exceeds 1, and since the first ratio in conditions of perfect seeing is 1, then formula (8b) gives us the value of the resolution character. And, under these perfect conditions, (8b) reaches its maximum only when $D_e^*/D_e = 1$; therefore, <u>under perfect conditions we must choose a magnification high enough for</u> $D_e^* = D_e$. Choosing the conservative value of 1 mm. (which holds for almost all observers), and converting to inches, we see that a D_e no greater than 1/25 inch will give the complete resolution possible in perfect conditions. I.e., a typical person observing in perfect seeing conditions must use at least 25 power per inch of aperture (since $p = 1/D_e$) to resolve all detail possible.

At any rate, <u>for given observing conditions</u>, $a/(a+t)$ <u>is determined</u>, <u>and we must employ a low enough</u> D_e <u>so that</u> $D_e{*}/D_e$ <u>is greater than or equal to</u> $a/(a+t)$, <u>if we are to maximize</u> D^* <u>and hence obtain maximal resolution for the conditions</u>. This means that for given values of $a/(a+t)$, there are minimum values for the power per inch which one can employ. For a typical specimen of the eye, these minimum permissible values of p are given in Table 3; for a given specimen of the eye, one may plot $D_e{*}/D_e$ against D_e and solve the equation $D_e{*}/D_e = a/(a+t)$ for D_e using this graph - then the reciprocal of D_e (taken in inches) gives the minimum power per inch $\bar{p}$ which should be used.

<u>Table 3. Resolution Powers per Inch for</u>

<u>Given Impersonal Efficiencies</u> $a/(a + t)$

$a/(a + t)$	$\bar{p}$
0.30	4.2
.35	4.9
.40	5.8
.45	6.7
.50	7.7
.55	8.6
.60	9.5
.65	10.6
.70	12.0
.75	13.8
.80	15.6
.85	18.1
.90	20.4
.95	22.7
1.00	25.0

Based on a typical eye, somewhat worse than that in Figure 9.

From the identity $a/(a + t) = 5.5/(5.5 + tD)$, we see that we need only to calculate the turbulence in order to obtain this critical ratio. Actually, in the next chapter, our considerations of seeing allow us to calculate this ratio directly and at the same time to determine the minimum permissible value $\bar{p}$ for p . This value $\bar{p}$ is called the <u>resolution power per inch</u> for the given conditions; in a similar manner, $\bar{P} = \bar{p}D$ is the <u>resolution power</u> for a telescope of aperture D . The most comfortable ranges which observers usually find range from $\bar{p}$ to $3\bar{p}$ for the power per inch being employed. Note that with Saturn, especially in good conditions, one is limited to staying near $\bar{p}$ (which in good conditions is nearly 25) by contrast considerations (see Table 2 and Figure 8); to a lesser extent, the same holds for Jupiter.

Footnotes

[1]The first two chapters are an amplification of a paper, "Resolution, Contrast, and Seeing in Visual Planetary Astronomy", presented in popular form at the Tenth A.L.P.O. Convention in Montreal on September 3, 1962. The introduction has been prefixed as useful background material, as an editorial on the present status of visual planetary observing technique, and as an exposition of the approaches to, and goals of, this series of articles, more of which are forthcoming. A more complete edition of the entire manuscript will be made available in the future, as it is beyond the limits of reason to use excessive space in this journal.

[2]Numbers in parentheses refer to the bibliography at the end of the paper.

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(to be continued).

MERCURY'S LIBRATION IN LONGITUDE

By: Dale P. Cruikshank

Owing to the eccentricity of the orbit of Mercury (amounting to 0.20563 at January 0, 1956, but the value is slowly changing), the planet undergoes a libration in longitude as seen from the earth. This libration now amounts to $\pm 23^\circ 40' 46''.6$ and alternately exposes the east and west limb regions. These libratory regions are of great importance in evaluating drawings of Mercury and in the construction of planispheres.

Lowell gave an adequate derivation of the formulae for this libration in his "New Observations of the Planet Mercury", Memoirs of the American Academy of Arts and Sciences, Vol. XII, No. IV, p. 433, 1898. M. B. B. Heath published the same derivation in The Journal of the British Astronomical Association, Vol. 69, No. 1, p. 46, 1959, and gave a table of libration versus days past perihelion. This relation is to be prefered over libration versus heliocentric longitude because of the precession of the perihelion of Mercury's orbit. Perihelion passages are listed each year in The American Ephemeris and Nautical Almanac.

Figure 10 was constructed from Heath's table. I have found it very useful for my own work. Its accuracy is probably limited to about $0^\circ.5$ in longitude and one day in time.

The nomenclature has caused some confusion in the past. A positive libration means that the mean center of the disk is displaced toward the positive direction, and the opposite limb is exposed. On planispheres,

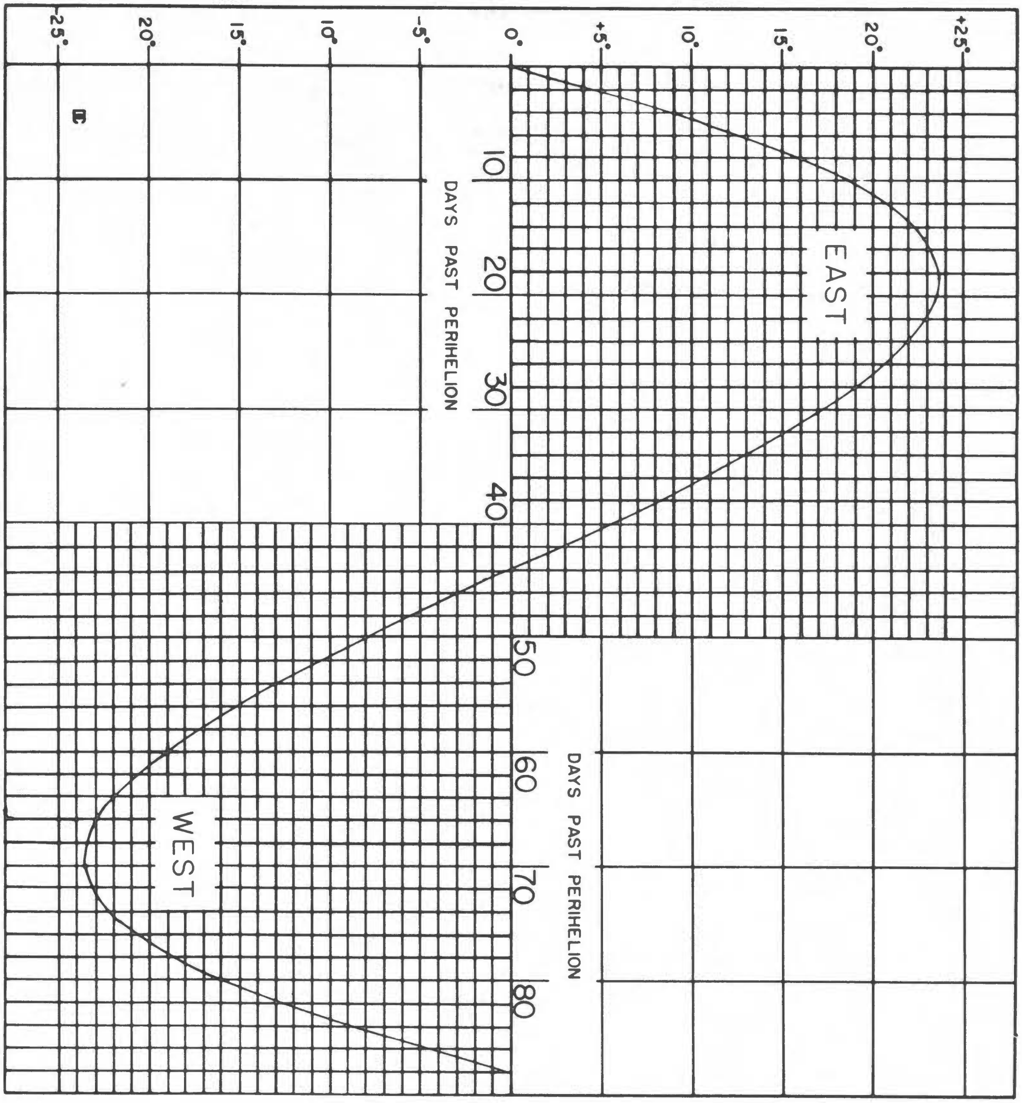

FIGURE 10. The libration in longitude of Mercury expressed graphically as a function of days past perihelion. A positive sign denotes a western libration which exposes the east limb, where west is the direction of increasing longitude. Contributed by Dale P. Cruikshank. See text of his article.

positive is west, the direction of increasing longitude. Therefore, a positive libration exposes the east limb and negative libration exposes the west limb. [The terminator is west of the mean center of the disk during evening apparitions of Mercury. - Editor]

Note to July 20, 1963 Total Eclipse Observers. Mr. William Glenn, 3235 Parkside Place, New York 67, New York has available a form for recording observations of the moon's shadow in the atmosphere (see pp. 55-59). Interested persons who expect to see the eclipse should write to Mr. Glenn at once.

BOOK REVIEWS

The System of Minor Planets, by Günter D. Roth. Translated from German to English by Alex Helm. London: Faber and Faber, Ltd., 1962. 128pp. Price 25 shillings.

Reviewed by Richard G. Hodgson

Most of the literature of astronomy runs to extremes. It is either of the elementary, general survey type, or else is the advanced technical essay of professional research. The need for works on an intermediate level which will pull together the findings of research scattered in many sources on a carefully delimited subject is apparent. The books by Peek on Jupiter and by Alexander on Saturn are invaluable for this reason; this book by Roth proposes to do much the same thing on the subject of the minor planets. Originally published in German as one in the series of Orion books, this English translation has been revised and enlarged.

Roth's book is valuable for three reasons. First, for those of historical bent, it presents a good summary history of the discovery of the minor planets. Second, it provides a good deal of information on minor planets, scattered through its pages and in three appended tables. The organization of this material could have been better. For example, the diameters of the minor planets are discussed in both chapters 6 and 15, and might better have been placed in chapter 9 on physical data. Orbital data, set forth in five brief chapters, might have been consolidated into one of greater length. The third, and perhaps most valuable, aspect of the book is its detailed account of equipment within amateur means which can be used to undertake serious work. The description of the multi-purpose astrograph of A. Güttler and W. Strohmeier is well illustrated, and should be of great interest. There is also helpful material on visual work with micrometers, and for photography.

In spite of some organizational weaknesses and some parts which may be rather elementary, Roth's The System of Minor Planets is a valuable book which should be in the library of every serious amateur astronomer.

Star Gazing with Telescope and Camera, by George T. Keene. Chilton Books, Philadelphia, 1962. Paper, $1.95. Cloth, $2.95.

Reviewed by J. Russell Smith

If you have ever made a telescope or if you are interested in making or using a telescope, you will be interested in this small volume of 128 pages. It is filled with basic information and is written for the amateur astronomer by one well experienced in the field of telescope making and of amateur astronomy in general. The excellent figures, diagrams, and photographs, used for illustrating the principal facts and concepts, will be helpful to the beginner. The following divisions will be found in the contents: Introduction, Choosing Telescopes and Binoculars, Making a telescope, Using a Telescope, Objects and Visual Techniques, Lenses and Cameras for Astrophotography, and Skyshooting. The appendices are composed of a number of titles as follows: Solar System Data; Clusters, Nebulae, and Galaxies: Double Stars for Testing Telescope Resolution; Bright Stars for Use with Setting Circles; Meteor Showers; Sources of Supplies; and Suppliers.

In the data about the Solar System on page 117, this reviewer found that the author lists 11 moons for the planet Jupiter instead of 12, which is the correct figure. One excellent point that was noted about the listing of clusters, nebulae, and galaxies on page 118 is that they are arranged in order of right ascension. Thus, the author's listing groups objects visible on a particular night. This plan is very commendable.

Der Sternhimmel 1963: Edited by Robert A. Naef, Arrau, Switzerland. H. R. Sauerländer & Co., 134 pp. Available in the United States from Albert J. Phiebig, P.O. Box 352, White Plains, New York.

Reviewed by Klaus R. Brasch

This small but comprehensive astronomical handbook undoubtedly ranks among the finest of its kind, along with the handbooks of the British Astronomical Association and the Royal Astronomical Society of Canada. In a clear and concise manner, it presents a monthly summary of astronomical events, pointing out and describing in detail the highlights among these. For example, the July 20 solar eclipse of this year over the U.S. and Canada is described in considerable detail and is illustrated with accurate maps.

For planetary observers, along with standard information and diagrams showing the planets' positions throughout the year, a detailed map of Mars, a schematic representation of Jupiter's belts and zones, and aspects of Saturn's ring system in the past and future are given. These are to mention but a few of the more outstanding features. Comets, minor planets, meteor showers, fixed and variable stars, the Sun, the Moon, and so forth are all dealt with through tables, diagrams, and special description where necessary. The book concludes with a list of definitions of more common astronomical terms and symbols.

The only weak point found by this reviewer appeared not to be in the context but in the binding of the book, which is unnecessarily flimsy, especially for a handbook which is intended to receive frequent handling. Aside from this, however, nothing but praise can be allotted to this fine book, now in its 23rd year of publication. Although written in German, Der Sternhimmel is easily understood by the interested reader; and no serious amateur should be without it.

A Hold Fizikája (The Physics of the Moon) by P. Hédervári. "Gondolat" Publisher, Budapest. 1962. pp. 126, 31 figs. In Hungarian.

Reviewed by G. Tóth, Geophysical Institute "Roland Eötvös", Budapest, Hungary

In Hungary several books have been published on astronomical subjects during the past few years. These have been mostly works of a general character, dealing with some extended parts of astronomical science such as the Solar System as a whole, with the galaxy or other galaxies, etc.

The book under review, on the other hand, might be looked upon as being of a new type since it is dealing only with one celestial body, the Moon. No such book has previously been published in Hungary. Despite the rather restricted extent of the book, it was the aim of the author to give a fairly complete account of researches concerning the Moon. Its leading viewpoint is geophysical, and he intended to clear up the similarities and connections between phenomena on the Earth and the Moon. The internal structure of the Moon is dealt with in great detail since - as the author sees it - internal processes have played the most important role in forming the surface of the Moon, too. In the frame of the discussion, a theory of the expansion of the Moon - based on a similar theory of the Hungarian geophysicist, L. Egyed, concerning the Earth- is given.

We may mention on this occasion that in the meantime the theory has been extended by the author; upon his recent standpoint one may suppose that in the last phase of expansion the core of the Moon - which had been once in a metallic phase - reached a state of instability, thus resulting in giant explosions and crater-forming. The energy needed for the forming of the Moon's surface was easily available from the internal transforming processes. We may calculate the energy needed for the formation of the individual craters, using vulcanological considerations (see the article of the author on pages 275-277 of Volume 16, Numbers 11-12 of The Strolling Astronomer).

The first chapter of the book deals with ancient views and beliefs connected with the Moon; then follows the discussion of the Moon as a celestial body as well as a description of the features of the surface. Most interesting is chapter four, where the views and theories put forward in connection with the development of the Moon are discussed. A minor gap felt by the present reviewer is that the meteor-theory of the craters is but briefly mentioned; it may have deserved a somewhat more complete treatment. The internal structure of the Moon is treated in chapter five, together with the expansion theory; chapter six deals with the influences exerted by the Moon.

When discussing the radioactivity of the Moon, the author mentioned only the investigations made by Kuiper and MacDonald, while the pioneering works of Professor Urey remained unrecorded. In a new edition or in publication in some foreign language, this omission must be remedied.

Solar Research, by Giorgio Abetti. Edited by Colin A. Ronan and Patrick Moore, Macmillan, 1963. 172 pages. $3.95.

Reviewed by Patrick S. McIntosh

This book is the fourth in a series called A Survey of Astronomy, edited by Ronan and Moore; and like its predecessors, it is intended to bridge the gap between the elementary texts and the highly mathematical advanced books. It is written with a minimum of equations, and most of these are in footnotes. The language is simple and is readily understood by the high school student and the amateur astronomer. It is not a beginner's book on the sun since it assumes some previous knowledge of the sun, and some physics and math. It is recommended for presenting a very up-to-date account of our present knowledge of the sun in a concise and readable manner. Many of the paragraphs are condensations of research papers of the last five years. Not only does the book bring the reader right up to the latest frontiers of solar research, but it also presents a glimpse of problems yet to be solved.

Unfortunately, in comparison to previous books on the sun, this book rates low on several counts. The illustrations and photographs, while excellent, are far too few and certainly should have been distributed throughout the chapters instead of being put in a center section. There seems to be some inconsistency in the first chapter in the use of equations. Several equations are omitted which are usually included even in elementary books, while some rather advanced equations are included in the footnotes. The terminology is often confusing and inconsistent and is not in keeping with the professional designations for features on the sun. This may well be the fault of the translator and not the author. Dr. Abetti is a much better astronomer and writer than this book indicates. A few facts that are erroneous may also be due to the translation. It is stated that the time for the sunspot numbers to rise to a maximum in the solar cycle is longer than the time for them to fall to minimum. This is the reverse from fact. The description of the evolution of a sunspot group is misleading in suggesting that the pores which result from the dissolution of a group grow again into another mature group. This is not true. The organization of the material is often poor. The chapter on total eclipses contains as much detailed description of sunspots as the chapter entitled "Photosphere of Sun and Sunspots". In other sections, the material on a specific subject is often scattered among other facts, creating some discontinuity.

The book could benefit from the inclusion of references to the books and papers containing the original research quoted in the text. The reader who is ready to step beyond the elementary text should be introduced to the use of references. Many of these readers could benefit from reading the original papers. Certainly some of the errors in this book could be corrected by using the references. There is a page of bibliography at the end of the book; but it was disappointing to see that it did not include the best elementary book on the sun, which, in the reviewer's opinion, is to be preferred to Abetti's Solar Research.

Soviet Science of Interstellar Space, by S. Pikelner. Philosophical Library, New York, 1963. pp. 230. Price $7.50.

Reviewed by Fred C. Trusell

The scope of this book is much broader than its title would indicate, for the author cites the works of Western astronomers as frequently as he does those of his Soviet colleagues. It is, then, a review of man's knowledge of interstellar space and the means by which he acquired this knowledge. After an introductory chapter on stars and the galaxy, and an excellent discussion on the atom and its spectroscopic properties, the chapters proceed in logical order from planetary nebulae, through diffuse nebulae, to interstellar gas. A study of magnetic fields in our galaxy precedes the concluding chapter on stellar and galactic evolution.

This is not an easy book to read. The author, as one finds in many Russian publications, has skimmed off the cream; and it is pretty thick. However, the book is self-contained, presenting all of the background necessary for understanding its contents, and will yeild up its information to the serious reader.

OBSERVING PROGRAMS OF THE A.L.P.O. SATURN SECTION

By: Joel W. Goodman, A. L. P. O. Saturn Recorder

Foreword by Editor. This article was originally written by Dr. Goodman as a set of instructions for beginning observers of Saturn and as needed and helpful reference material for amateur observers in general. Though it will be available from Dr. Goodman as mimeographed pages, perhaps not exactly as here published, it is also our thought that publishing this material here and now will assist readers in planning more useful Saturn studies during the favorable summer observing season. The planet will reach opposition on August 13, 1963 and can be observed to advantage before midnight by late June.

The nomenclature for the ball and rings of Saturn can be found, for example, in Figure 5 on pg. 127 of the July-August, 1961 Str. A. (Vol. 15, Nos. 7-8).

I. Introduction

There are few celestial objects more picturesque and fascinating than the planet Saturn. The great yellow globe girdled by its perfectly symmetrical system of rings, to our knowledge unique in the universe, and attended by its cortege of satellites is immediately captivating and perenially rewarding. In addition to its aesthetic qualities, Saturn has numerous features requiring constant and careful observation.

Second only to Jupiter among the planets in mass and volume, Saturn lies at a mean distance of about 793×10^6 miles from Earth. At opposition, its globe subtends an angle of about 17" of arc while the major axis of the ring system spans about 42" of arc. Thus, the disc of Saturn requires more than twice the magnification needed by Jupiter for comparable apparent size.

Regarding the question of minimum effective apertures, it is hazardous categorically to fix an inflexible lower limit in view of the extraordinary results achieved by numerous skilled observers with small telescopes. However, it may be stated with some confidence that possessors of small telescopes accustomed to observing Jupiter will find Saturn relatively barren and changeless. Almost any optical assistance will reveal the ring system; and apertures as small as three inches may show the principal features of the planet, including one or two of the most conspicuous belts on the globe and the major division in the rings. However, six inches or more, while perhaps not essential, is certainly desirable for serious work. For some of the more advanced programs, at least ten or twelve-inch instruments are required, and even at this level the optics will be severely challenged.

The primary consideration in any aperture range is the selection of a sensible, realistic observing program within the capabilities of available equipment. This article is intended as a guide for the amateur embarking on, or experienced in, the observation of Saturn. Programs which can yield significant, meaningful results, eventuating hopefully in a fuller comprehension of the planet, are detailed and emphasized in the hope that observers will thereto direct their efforts. The list is by no means comprehensive but does include programs considered of major importance.

II. The Globe

Saturn, like Jupiter, has a system of dark belts and brighter zones crossing its globe roughly parallel to the equator. The nomenclature attached to these features, too, is similar to that applied to the Jovian system. It is of paramount importance for the observer to familiarize himself with this nomenclature since confusion will be inevitable if different observers refer to the same features by different terms.

A. Intensity Estimates

The belts and zones vary in intensity, and some belts even disappear entirely for periods of time. A project of fundamental importance in the program of the Saturn Section is the visual estimation of the intensities of the belts and zones relative to the intensity of the outer half of Ring B (see the later Section III). A direct scale of 0-10 has been adopted, with 0 deep black and 10 brilliant white. The intensity of the outer half of Ring B, normally the brightest part of the Saturnian system, is arbitrarily fixed at 8.0; and the intensities of all other features are estimated relative to it. Estimates are made in tenths of a unit; and, with practice, gratifying consistency may be achieved.

Example: Suppose, in a given view, the Equatorial Band (EB), Equatorial Zone (EZ), North Equatorial Belt (NEB), North Tropical Zone (NTrZ), North Temperate Belt (NTB), North Temperate Zone (NTZ), and North Polar Region (NPR) are seen. Intensity estimates of these features might be tabulated as follows:

Feature	Intensity
EB	3.8
EZ	7.2
NEB	3.0
NTrZ	5.9
NTB	3.4
NTZ	5.2
NPR	2.8

The interpretation of these values is as follows: The EZ was the brightest part of the visible portion of the globe, though quite perceptibly duskier than the primary standard, the outer section of Ring B. The NTrZ was considerably darker than the EZ but somewhat brighter than the NTZ, while the darkest area was the NPR. Of the belts, the NEB was darkest and the EB brightest, with the NTB midway between. Variations in intensity of features during the course of an apparition and from one apparition to another will also be revealed by these records.

Intensity estimates may be made with telescopes less than 6 inches in aperture, although the number of features visible in such instruments will necessarily be small. Several of the belts are sometimes resolvable into multiple components in larger instruments. When seen thus, the intensity of each component should be estimated separately.

B. <u>Central Meridian Transits</u> - Occasionally, discrete detail is visible in the belts or zones of Saturn. This detail is similar in form to, but is generally much less distinct than, detail seen on Jupiter. Projections or appendages from the belts sometimes leading to extended festoons, or bright spots in the zones comprise the most commonly recorded types. It is noteworthy, however, that such detail is rare and often, when present, is accessible only to relatively large apertures. It is therefore inadvisable for observers with ordinary equipment to adopt the recording of such features as a sole or principal observing project. However, when features of this kind are seen, central meridian transits of them should be timed unfailingly, and an attempt should be made to follow them from night to night for the duration of their visibility. The rarity of such markings makes relentless tracking worth the effort. Rotation rates of latitude zones on Saturn are infirmly established precisely because detail amenable to transit timing is uncommon.

The simplest procedure for timing central meridian transits is simply to estimate to the nearest minute the time when the feature is exactly midway between the limbs of the planet. A more accurate method involves making three estimates: (1) The last minute when the feature is definitely on the following side of the central meridian, (2) the minute when the feature is precisely on the central meridian, (3) the initial time when the feature is definitely on the preceding side of the central meridian. Reports of central meridian transits should include: (1) A description of the feature, (2) latitudinal position of the feature, (3) date and time of the transit(s).

C. <u>Latitude Measurements</u> - Latitudes of belts and zones on Saturn have been known to vary, sometimes over quite short periods. Latitudes of features may be measured by one of three techniques, depending on the sophistication of the observer's equipment. These techniques are considered in order of increasing reliability as follows:

1) Measurement of features from sketches of Saturn made at the telescope. The observer must position features on the sketch as accurately as possible. The saturnicentric latitudes of features may be calculated by applying the Crommelin formulae:

> Get B, the saturnicentric declination of the Earth, from <u>The American Ephemeris and Nautical Almanac</u>. From $\tan B' = 1.12 \tan B$, get angle B'; then from $\sin (b' - B') = y/r$, where r is the polar radius of Saturn and y is the distance of the feature from the center of the disk, find $(b' - B')$, hence b'; finally, from $\tan C = \tan b'/1.12$, find C, the required saturnicentric latitude.
> The only measurements required are the parameters (r) and (y), where y is positive when north.

2) Measurement of features on photographs of Saturn. This method will yield more accurate positions than the preceding technique but is limited by the sparsity of detail ordinarily visible on photographs made with even very large telescopes. Good quality pictures made with amateur instruments often show one or two conspicuous belts, but their outlines may be indistinct due to the long exposures required and/or graininess of the film emulsion. Thus, positions of features on photographs, as a rule, are difficult to measure very accurately.

3) Measurement of features with a filar micrometer. This is without question the most desirable method of making latitude determinations but requires an extremely well mounted telescope equipped with a very accurate clock drive and smooth slow motions. Additionally, it

requires, of course, a filar micrometer. Very few amateurs are so richly endowed, but those who are should include latitude determinations as a routine part of their program.

D. Color Estimates - Definite hues may be perceived in the belts and zones of Saturn, particularly by those abnormally sensitive to color. Colors in white light are often reported along with intensity estimates, but color estimates assume greater value if made with color filters. Eastman Kodak Wratten filters are very suitable for this purpose. A blue filter should make features with a bluish hue appear relatively bright while the opposite would be true with a red filter. Colors are often clues to the chemical composition of substances and, in this context, could be of considerable value in studies of Saturn. Overinterpretation of such manifestations, which may be influenced by a multitude of variables, should be guarded against, however.

III. The Rings

This ring system is the hallmark of Saturn's magnetism. Without it, the planet would be a smaller, dimmer, and very quiescent replica of Jupiter. The rings have fascinated astronomers for generations, and much about them remains a mystery. There are three principal rings girdling Saturn. The outermost, Ring A, is separated from the central, Ring B, by a dark gap called Cassini's Division, which is visible in 3-inch telescopes when the plane of the rings is oblique enough to our line of sight. The innermost, Ring C, or the Crepe Ring as it is sometimes designated, is by far the faintest of the three and requires at least 4-inch apertures to be seen with certainty. A fourth very tenuous ring beyond Ring A has been suspected by some observers, but the evidence for its existence is at present very controversial. This feature, referred to as Ring D, is therefore not considered to be an established member of the Saturnian system.

A. Intensity Estimates - Intensity estimates of the rings are made in much the same way as are those of global features. With telescopes above 3 inches in aperture the rings will clearly be non-uniform in intensity. The outer part of Ring B is usually the brightest part of the entire Saturnian system and is very perceptibly brighter than the inner portion. With steady atmospheric conditions and sufficient aperture Ring A may be seen to vary in intensity over its breadth. When distinctly seen, such variations should be reported. Remember that all intensity estimates are made relative to the outer section of Ring B, which is fixed at a value of 8.0.

B. Color Estimates - On several occasions in the past, observers have noted a bluish hue in Ring A. This phenomenon has been detected both with and without the use of filters, although filters should markedly enhance the effect. Observations supporting this phenomenon are scant, and a concerted study is certainly warranted. The program involves making intensity estimates of Ring A, relative to the outer portion of Ring B, using a series of color filters. Eastman Kodak Wratten filters # 48 (blue), # 58 (green), and # 25 (red) comprise a complementary assortment since they transmit almost mutually exclusive portions of the visible spectrum. The outer part of Ring B for this project is fixed at a standard intensity of 5.0 on the direct scale of 0 (dark) to 10 (bright) in all filters. The intensity of Ring A is then compared to that of Ring B in all filters.

C. Intensity Contour of the Rings - The rings of Saturn are not uniform in brightness but appear to be interrupted by a number of ripples or intensity minima. The most conspicuous of these is Cassini's Division, which separates Ring A from Ring B and may be a true gap. The other intensity minima are much more difficult to perceive and, at best, require moderately large apertures. The characterization and positioning of such minima is of great interest, particularly since there is some basis for believing that they vary both with respect to prominence and position. Several studies employing large visual telescopes and photometric techniques have established the existence of about half a dozen minima in addition to

Cassini's Division. Only observers with telescopes in excess of 12-inches aperture should devote much effort to a search for these minima, since such apertures are required for results of appreciable significance. Amateurs in possession of suitable equipment should attempt to measure the positions of intensity minima seen with respect to the edges of the ring, preferably with a filar micrometer but otherwise by careful sketching.

D. <u>Occultations of Stars by the Rings</u> - Occultations of stars by Saturn's rings present unusual opportunities for detecting and determining positions of intensity minima. Variations in the brightness of stars during passage behind the rings can reveal intensity differences which would not otherwise be perceptible with the same aperture. Unfortunately, only reasonably bright stars can successfully be observed during occultation by most amateur instruments. Six-inch telescopes can be applied with optimism to the observation of occultations of 7th magnitude stars; but 8th magnitude stars probably require at least 12-inch apertures to be seen through Ring A, which on the whole is much less dense than Ring B. This is not intended to imply that observers with smaller telescopes should overlook occultations of such stars, since even determinations of the times of contact with globe and rings are very valuable. Furthermore, although the star may be lost much of the time while behind the rings, it may suddenly brighten sufficiently when behind an area of lesser density to be detected in small telescopes. When reporting observations of occultations, accurate coordinates of the observer's position should be included. Timings of events should be as precise as the observer's equipment will permit.

IV. The Satellites

Saturn is attended by nine known satellites, seven of which can be seen with quite modest equipment. Little worthwhile, however, can be done with them using ordinary instruments. It has been common practice to estimate the stellar magnitudes of the satellites, with reference to standard stars of calibrated brightness when the planet is passing through a variable star field or with reference to Titan, the most conspicuous satellite, at other times. The object of this project is the detection of brightness variations of the satellites during the course of their orbital passage. Visual estimates are very unreliable, however, since the apparent brightness of a satellite will be a function of its distance from the bright image of Saturn as well as of its actual brightness. Such estimates, therefore, have limited value. When using Titan as the reference standard, a magnitude of 8.3 is assumed for it, and the magnitudes of the other satellites are estimated in steps of 0.1 magnitudes.

A. L. P. O. SIMULTANEOUS OBSERVATION PROGRAM
SCHEDULE, JUNE - AUGUST, 1963

Date 1963	Planet	Observing Period	Project and Notes
18 Jun.	Mercury	Sunrise - A.M.,L.T.	Special.
19 Jun.	Mercury	Sunrise - A.M.,L.T.	Special.
20 Jun.	Mercury	Sunrise - A.M.,L.T.	Special.
22 Jun.	Mercury	Sunrise - A.M.,L.T.	Special.
22 Jun.	Saturn	08:00 - 09:00 U.T.	Standard. D at 08:30.
23 Jun.	Saturn	06:00 - 07:45 U.T.	Standard. D at 07:00.
23 Jun.	Jupiter	08:00 - 09:00 U.T.	Standard. D at 08:30; S at 08:25.
30 Jun.	Saturn	06:00 - 10:00 U.T.	Standard. D at 06:30, 08:00, 09:30.
1 Jul.	Jupiter	06:30 - 10:30 U.T.	Standard. D at 07:00, 08:30,10:00; S at 06:43, 07:15, 07:36, 08:58, 09:37, 09:47, 09:47, 10:02.
6 Jul.	Saturn	06:00 - 08:00 U.T.	Standard. D at 06:30, 07:30.
14 Jul.	Saturn	08:00 - 10:00 U.T.	Standard. D at 08:30, 09:30.
19 Jul.	Jupiter	03:30 - 05:00 U.T.	Standard. D at 04:00; S at 03:52, 04:12, 04:29, 04:42.
27 Jul.	Saturn	05:00 - 09:00 U.T.	Standard. D at 05:30, 07:00,08:30.
2 Aug.	Jupiter	06:00 - 08:00 U.T.	Standard. D at 06:30, 07:30; S at 06:18, 06:50, 07:34.

Date	Planet	Observing Period	Project and Notes
11 Aug.	Saturn	02:00 - 08:00 U.T.	Standard. D at 02:30, 04:00, 05:30, 07:30.
17 Aug.	Jupiter	08:00 - 09:00 U.T.	Standard. D at 08:45; S at 08:33.
24 Aug.	Saturn	07:00 - 10:00 U.T.	Standard. D at 07:30, 09:30.
31 Aug.	Saturn	03:00 - 07:00 U.T.	Standard. D at 04:00, 06:30.
31 Aug.	Jupiter	07:15 - 10:00 U.T.	Standard. D at 07:45, 09:30; S at 07:30, 08:43, 09:00.

The schedule above was communicated by the Director of the present Simultaneous Observation Program, namely Mr. Charles H. Giffen, Dept. of Mathematics, Princeton University, Princeton, New Jersey. (His temporary summer address is Van Vleck Hall, University of Wisconsin, Madison 6, Wisconsin.) Observations of Jupiter made in this program should be mailed at once to Mr. Glaser, the Jupiter Recorder; other observations in this program on the selected dates should be mailed directly to Mr. Giffen. The program is drscribed fully on pp. 29 - 34 of our Jan.-Feb., 1963 issue. There the abbreviations and the words standard and special are explained. We note briefly here that D is for drawing and S for a satellite phenomenon.

All readers are very strongly urged to participate fully in this program. They should follow carefully Mr. Giffen's instructions laid down in the Jan.-Feb. issue.

THE COMING SAN DIEGO CONVENTION OF THE A.L.P.O.

By: Walter H. Haas

The Eleventh Convention of the Association of Lunar and Planetary Observers and the Fifteenth Convention of the Western Amateur Astronomers will be held jointly at the U.S. Grant Hotel in San Diego, California on August 22 - 24, 1963. A very cordial invitation is hereby extended to all A.L.P.O. members to attend. A special feature of this meeting will be a guided tour of the Palomar Observatory, in northern San Diego County. The co-hosts are the Palomar Amateur Astronomers and the San Diego Astronomer Associates. The General Convention Chairman is Martin Sloan, Route 3, Box 840, Escondido, California. Special Arrangements have been made with the Grant Hotel for a meeting room (their Royal Palm Room) and for the display of astronomical exhibits. Mr. Sloan writes that all committees are hard at work and that prospects are excellent for a truly outstanding astronomical meeting.

Mr. Clark Chapman will again be in charge of the A.L.P.O. Exhibit. Material for display should be mailed as soon as possible to Mr. Chapman's temporary summer address:

Clark R. Chapman
% Dale Cruikshank
1422 E. 6th St.,
Tucson 11, Arizona.

Experience has shown that A.L.P.O. Exhibit items are best limited to drawings, photographs, and charts. Please help the A.L.P.O. by submitting suitable material - and please do so soon to give Mr. Chapman time enough to arrange our display, as he did so well at Montreal in 1962 and at Detroit in 1961.

The A.L.P.O. program of papers is being integrated with the W.A.A. program, as was done very successfully at the 1961 Long Beach Convention. A.L.P.O. papers have so far been promised by Klaus Brasch, Tom Cave, Charles Giffen, Joel Goodman, Charles Capen, Frank Manasek, George Rippen, H. M. Hurlbury, and Takeshi Sato. Subjects include the meteorology of Venus, recent observations of Mars, latitudes of features on Saturn, concepts of lunar crater development, intensity measurements on planets, and color photography of the moon and planets. More papers are needed - qualified members are invited to contribute suitable papers, and again there is a need for haste before the Convention.

To find out more about the San Diego Convention, COME AND ENJOY IT. There will be several delightful features we're not mentioning here!

ANNOUNCEMENTS

New Address for Uranus-Neptune Recorder. Mr. Leonard B. Abbey's address is now Box 22236, Emory University, Atlanta 22, Georgia.

Request for July-August, 1962 Issue. The Pan American College Library would like a copy of this issue to complete their file of Volume 16. This issue is out of stock. Persons interested in furnishing this issue should correspond with Professor Paul R. Engle, Director, Pan American College Observatory, Edinburg, Texas.

A.L.P.O. Activities at League Convention. Although the A.L.P.O. has no official role in the Astronomical League National Convention at Orono, Maine on July 18 - 20, 1963, the League has graciously invited attending A.L.P.O. members to participate on an individual basis. Persons having papers to read should send them directly to Mr. Ralph K. Dakin, 720 Pittsford-Victor Road, Pittsford, New York. Persons having drawings, charts, and photographs to exhibit should make arrangements with Mr. John E. Welch, 107 Lower Beverly Hills, West Springfield, Massachusetts. They should naturally inform Mr. Welch how much space their material requires. There is, of course, a need for great haste with both papers and exhibit materials.

We wish our friends in the Astronomical League a very successful Convention and a splendid view of the total solar eclipse.

Acknowledgment. We want to thank all those who have commented in correspondence on the "open letter" on pp. 40 and 42 of the Jan.-Feb., 1963 issue. It is always helpful to receive the opinions of our readers. We want to thank even more those who have reacted by sending stamped, self-addressed envelopes for the use of our Recorders. It is true, however, that our two Canadian Recorders cannot use United States postage stamps.

East and West on the Moon. We also very much appreciate the correspondence received from members about the usage of lunar east and west (see pp. 35-36 of Jan.-Feb., 1963 issue). Clark Chapman, Dr. Seville Chapman, Alika Herring, James Bartlett, David Barcroft, J. Russell Smith, and a few others have expressed their opinions. After some thought, we have come to these conclusions:

1. It is recommended that A.L.P.O. members follow the usage of the I.A.U. resolution of 1961, which names these directions so that the moon rotates from west to east. Thus, Mare Crisium is in the moon's east hemisphere; Oceanus Procellarum, in the west hemisphere. Whatever the merits or demerits of this terminology, it is now in wide usage and will continue to be widely employed. The A.L.P.O. wants to follow that usage which will create least confusion and will help most in lunar studies.

2. It is very strongly urged that all writers in The Strolling Astronomer clearly and adequately describe how they are applying east and west on the moon. This plan is obligatory while two contradictory systems are both in use.

Lunar Training Program. All new members of the A.L.P.O. and also older members who have never done much systematic observing are especially invited to join Clark Chapman's Lunar Training Program. His article "The Art of Lunar Drawing" elsewhere in this issue will be helpful to them.

The Strolling Astronomer

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