THE ASSOCIATION OF

LUNAR AND PLANETARY OBSERVERS

JUPITER HANDBOOK

AN

A L P. O

OBSERVING MANUAL

F O R W A R D

The following pages were written and prepared by Mr. Elmer J. Reese, whose accomplishments in the field of amateur lunar and planetary observing are well known to veteran ALPO members. As a serious student of Jupiter he has done much original and valuable work; particularly on the problem of determining the rotation period of the solid ball of the planet. In addition, he spends countless hours preparing " drift charts " of Jovian features - and, somehow, still finds time to make those detailed and carefully reported observations with his own instruments for which he is so widely admired.

Because it comes from so exemplary a source, we therefor recommend this Jupiter Handbook without reservation to all those amateur astronomers who are sincerely interested in making truly valuable studies of the Giant Planet.

[illegible]

OBSERVING JUPITER AND ITS SATELLITES

The amateur astronomer who possesses a telescope of good optical quality will find Jupiter a fascinating world to study. Its large, bright disc; its ever-changing pattern of colorful belts and zones; its great variety of markings; its four bright satellites -- all these and more await the observer who will gaze "hour after hour on the glories of the giant planet, gathering fresh delight as feature after feature is revealed beneath his scrutiny". Good observational work has been done with apertures as small as three inches, but apertures from six to twelve inches and larger afford a much better view of the planet.

In this pamphlet we hope to supply the beginner with detailed instructions for observing Jupiter and its satellites. Emphasis will be placed on recording and reporting observations in an efficient and abbreviated manner. A limited amount of general information of particular interest to the observer will also be given; however, space limitations do not permit the inclusion of much information to be found in easily available textbooks and handbooks (1,2,3,4,17).

A. General Information

Belts and Zones. The observer should be thoroughly familiar with the names and abbreviations of the dark belts and bright zones which are characteristic features of Jupiter's disc (Figs. 1 and 2). The appearance of the belts and zones varies considerably from time to time. A belt may sometimes be wide and dark, while at other times it may be thin and faint, or invisible. Occasionally a belt may appear double being divided into two components by a bright rift or zone. The South Equatorial Belt is especially susceptible to this doubling action, and its two components are indicated by the suffix n or s (SEBn, SEBs) and its brighter interior can be referred to as the SEB Interior Zone (SEBZ).

Rotation of Jupiter and Systems of Longitude. Jupiter rotates on its axis more rapidly than any other planet, completing one rotation in about $9^h 55^m$. The rotation period, as determined by the observation of well-defined spots on the disc, is found to vary in different latitudes -- indeed, different spots in the same latitude commonly yield slightly different results. It has also been found that the rates of rotation vary from year to year. It is evident that the detail which we observe on Jupiter belongs not to the solid surface of the planet, but rather to an extensive, cloud-laden atmosphere containing many sharply bounded currents moving in a direction parallel to the equator. The rotation period is generally shortest in the equatorial regions and longer in higher latitudes; however, the variation with latitude is irregular, and there are marked differences between the northern and southern hemispheres.

The mean rotation periods found in various latitudes are given in Table 2. The great equatorial current has a mean period of $9^h 50^m 26^s$ which is about five minutes shorter than the remainder of the visible surface where the periods range from about $9^h\ 55^m$ to $9^h\ 56^m$. Because of this, it has been found convenient to use two systems of longitude for the planet.

Since there are no permanently fixed markings visible on Jupiter from which longitudes can be measured, astronomers use two arbitrary meridians adopted by Marth in 1896. System I longitude, which is measured from an arbitrary meridian rotating uniformly in a period of $9^h\ 50^m\ 30^s.003$, is used for the Equatorial Zone, the south edge of the North Equatorial Belt, and the north edge of the South Equatorial Belt. System II longitude, which is measured from an arbitrary meridian rotating in a period of $9^h\ 55^m\ 40^s.632$, is used for the remainder of the planet. The American Ephemeris and Nautical Almanac gives the longitude of the central meridian of the illuminated disc of Jupiter in each system for 0^h Universal Time of each day when the planet is observable. (The central meridian is the imaginary line or meridian extending from pole to pole and bisecting the disc.) The longitude of the central meridian at any other time can easily be found with the aid of Table 1 which gives the change of longitude in intervals of mean time. The symbols λ_1 and λ_2 are used to represent, respectively, longitudes of System I and System II.

An example illustrating the ease with which the longitude can be found follows: The center of the Red Spot was estimated to be on the central meridian at 10:31 PM, EST on the evening of August 30, 1949. What was the longitude in System II of the center of the Red Spot? First, we convert EST into UT: 3:31 UT, August 31, 1949. From the ephemeris we find that the longitude (II) of the central meridian at 0^h on August 31 was 116°.7. From Table 1, herein, we find that the longitude (II) of the central meridian increased 127°.5 in 3 hours and 31 minutes. Adding 127°.5 to 116°.7 we obtain 244°, the longitude (II) of the center of the Red Spot.

General Description. The telescope reveals much structural detail in the belts and zones. Dark projections and bright indentations or bays are frequently seen along the edges of the belts. In recent years the south edge of the North Equatorial Belt has been particularly active. Thin dusky wisps or festoons are sometimes seen in the zones -- especially the Equatorial Zone. A festoon may appear in the form of a loop terminating at two dark spots on the same belt edge, or it may extend obliquely across a zone connecting dark spots on the adjacent belts. A variety of small, bright and dark areas may usually be seen on the belts and zones. These lesser markings are more or less transient features in the Jovian atmosphere. Some of them change in appearance from night to night and disappear after a few days or weeks; others are more quiescent and endure for many months.

Amid all the turmoil in Jupiter's atmosphere, the Great Red Spot has maintained its identity for over a hundred years--perhaps much longer. This famous feature has displayed many different aspects since it became prominent in 1878; however, these changes do not seem to be progressive and the various aspects have recurred frequently. In recent years the Red Spot has sometimes

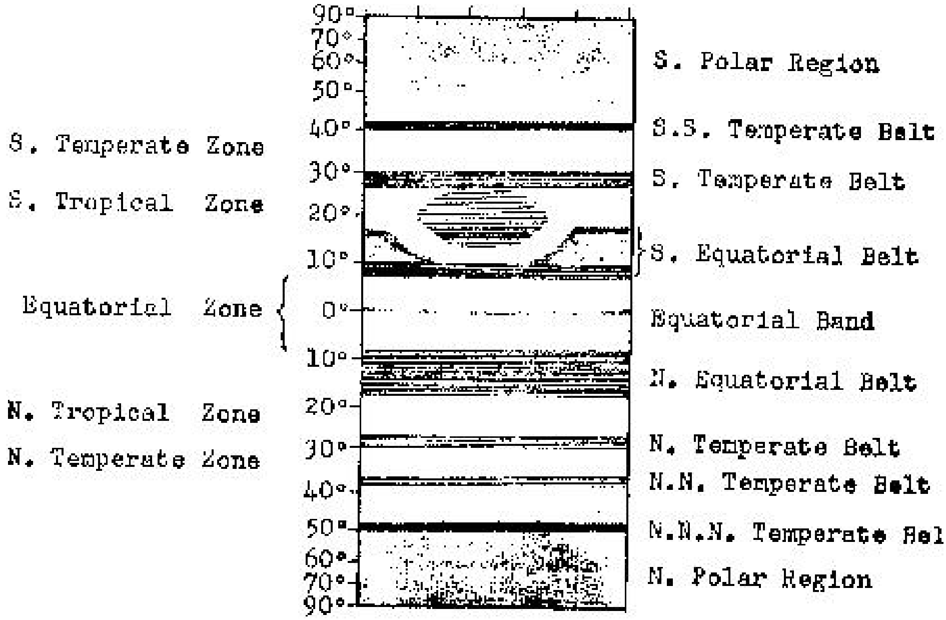


Figure 1. The names of Jupiter's Belts and Zones. (A scaled diagram showing zenographic latitudes and ten degree intervals of longitude.)

Table 1. Change of Longitude in Intervals of Mean Time.

System I

HOURS	DEGREES	MINUTES	DEGREES	MINUTES	DEGREES
1	36.58	10	6.10	1	0.61
2	73.16	20	12.19	2	1.22
3	109.74	30	18.29	3	1.83
4	146.32	40	24.39	4	2.44
5	182.90	50	30.48	5	3.05
6	219.48			6	3.66
7	256.06			7	4.27
8	292.64			8	4.88
9	329.22			9	5.49
10	5.80				

System II

HOURS	DEGREES	MINUTES	DEGREES	MINUTES	DEGREES
1	36.26	10	6.04	1	0.60
2	72.52	20	12.09	2	1.21
3	108.79	30	18.13	3	1.81
4	145.05	40	24.18	4	2.42
5	181.31	50	30.22	5	3.02
6	217.57			6	3.63
7	253.83			7	4.23
8	290.10			8	4.84
9	326.36			9	5.44
10	2.62				

Table 2. Mean Rotation Periods of Some of the More Important Jovian Currents.

(1946 to 1960, A.L.P.O.)

CURRENT	MEAN PERIOD
S.S. Temperate Current (SSTB, SSTeZ)	$9^h\ 55^m\ 6^s$
S. Temperate Current (S. edge STB, STeZ)	9 55 10
S. Tropical Zone Disturbances	9 55 24
Great Red Spot	9 55 42
South Equatorial Belt, South Component	9 55 41
S. Equatorial Current (S. part EZ, N. edge SEB)	9 50 37
N. Equatorial Current (N. part EZ, S. edge NEB)	9 50 24
N. Tropical Current (N. edge NEB, NTrZ)	9 55 28
N. Temperate Current (N. edge NTB, NTeZ)	9 56 4
N.N. Temperate Current (NNTB, NNTeZ)	9 55 40
N.N.N. Temperate Current (NNNTB)	9 55 20

More complete information on the mean rotation periods of the various Jovian Currents can be found in the following references:

The Planet Jupiter, B. M. Peek, 1958, pgs. 189, 190.
Rev. T.E.R. Phillips: Jupiter. Encyclopaedia Brittanica, 1943
J.B.A.A., Vol. 64, No. 7, pg. 292.

been visible as a dusky, orange-ochre ellipse about 22,000 miles long and 8,000 miles wide (Figure 3, left). At other times the Red Spot itself has been quite invisible, but its position has been clearly marked by the Red Spot Hollow (Figure 3, right). The Hollow is a large, white, oval-shaped area in the South Tropical Zone in which the Red Spot may or may not be visible. The apparent repelling action of this white oval gives rise to the familiar appearance of the Red Spot Bay in the south edge of the South Equatorial Belt. The physical nature of the Red Spot remains a profound mystery. Unquestionable changes in its rotation period preclude the possibility that it is the visible result of a more or less constant eruption from the solid nucleus of the planet. An excellent summary of the complex inter-relations between the Red Spot and the South Tropical Disturbance (another long-enduring dark area in the South Tropical Zone first seen in 1901 and last definitely seen in 1939) has been given by Phillips (5).

B. Observing Programs

Full-Disc Drawings and Sectional Sketches. Drawings of Jupiter, if made with care, form a valuable record of the changing appearance of the planet. The earliest records of many great disturbances in the Jovian atmosphere are to be found on such drawings.

Standard forms for making full-disc drawings of Jupiter can be obtained on request from the A.L.P.O. Jupiter Recorder. These forms contain blank discs of the correct oblateness for Jupiter. The black background around the discs contribute to a more realistic appearance of the finished drawing, and simplify the job of reproducing drawings in the Strolling Astronomer. The forms provide space for recording all pertinent data and notes.

When making a full-disc drawing of Jupiter, the observer must work rapidly, otherwise his finished drawing will be distorted by the rapid rotation of the planet. First, lightly sketch in the more prominent belts giving close attention to their widths and latitudinal positions. There is no great hurry here since rotation has little effect on the latitudes of the belts. Next, note the time to the nearest minute and rapidly sketch in a half-dozen or so of the more prominent spots on various portions of the disc. This should take only a minute or two. With this done, the lesser details can be drawn at greater leisure in their proper places relative to the prominent details already positioned. Each completed drawing should include the date and time (preferably by Universal Time), seeing conditions, aperture and magnification. The observer will also want to compute the longitude of the central meridian in each system (CM_1 and CM_2). Much useful information on the making of drawings can be found in an article by William K. Hartmann in The Strolling Astronomer, Volume 14, pgs. 2-11.

Large scale drawings of small portions of the planet can be made at considerable leisure and the finer details can be shown to advantage. A strip sketch of a particularly active belt or zone, or group of belts and zones, may be extended as the planet rotates and thereby reveal a much greater range of longitudes than can be seen at any one time. Very careful drawings of active portions of the planet made on closely adjacent dates is a promising method of investigating such problems as the nature and relative levels of the Jovian markings and their influence on each other. Each sectional drawing should have all the depicted belts identified, and the times of transit of some of the more interesting markings should be indicated. The longitudes of these markings can be computed and entered on the drawing at a later time. Figure 1 shows the proper relation of latitude to longitude for strip or sectional sketches of Jupiter.

<u>Visual Color and Intensity Observations.</u> A continuous record of the variations in the color, intensity, and latitude of the belts and zones is as important in the study of Jupiter's atmosphere as are the daily records maintained by weather observers in the study of the earth's atmosphere. While all such observations may not have immediate scientific value, it seems possible that they may be of great value to future investigators.

Lengthly word-descriptions of colors and intensities should be avoided since they are difficult to combine and analyze. A good method of recording these observations at the telescope is to list the belts in a vertical column in the order of their decreasing conspicuousness. The color and intensity of each belt is then listed beside its name. A similar list is made for the zones. Tabular forms for reporting these observations to the Jupiter Section may soon be available.

Simplicity in word-descriptions of colors is desirable and the use of abbreviations will save much time and space. Some of the colors commonly seen on Jupiter, together with suggested abbreviations, follow:

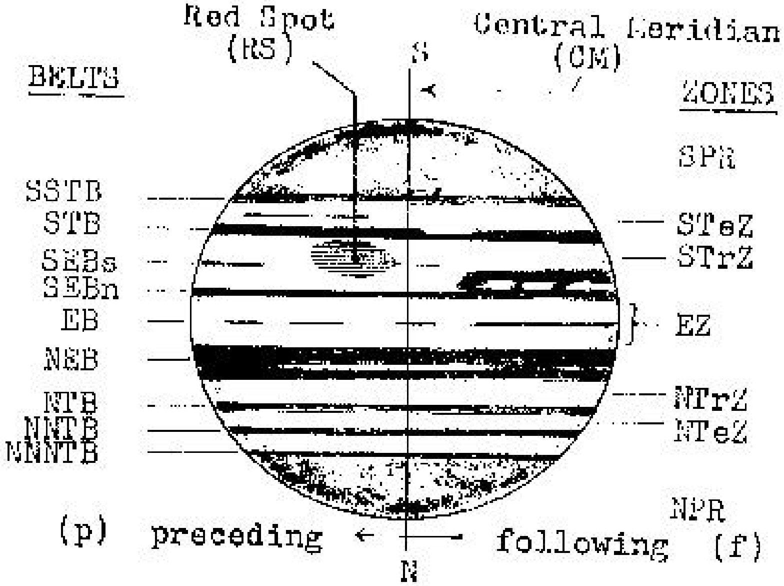
white	W	yellow	Y
gray	G	orange	O
brown	Br	ochre	Oc
red	R	bluish-gray	Bl-G
blue	Bl	reddish-brown	R-Br

Observations of color should be made when the planet is high above the horizon and the sky is clear and dark (6). It might be mentioned, however, that some experienced observers have found planetary colors more pronounced on a twilight sky than on a dark sky. The observer must always be on guard against atmospheric dispersion (7) and off-axis eyepiece dispersion which produce spurious colors at the limb of the planet and along the edges of the belts. Reflectors equipped with achromatic eyepieces show colors more reliably than refractors, and large apertures are much superior to small ones.

Estimates of the relative intensities of the belts and zones are easier to make and analyze if a numerical intensity scale is used instead of word descriptions. A convenient scale is given in Table 3. The numbers represent certain descriptive

Table 3. Intensity Scale

10	Unusually brilliant	10.0
9	Extremely bright	Very bright zone 9-8
8	Very bright	
7	Bright	Ordinary bright zone 8-6
6	Slightly shaded	Dull zone 6-5
5	Dull	
4	Dusky	Polar Region 4.5-3.5
3	Dark	Ordinary dark belt 3.5-
2	Very dark	Very dark belt 2.5-1.5
1	Extremely dark	Darkest of condensations
0	Black, shadow	-- Shadow of a satellite 0.0



B : Belt, Band.
E : Equatorial.
N : North
S : South.

R : Region
T : Temperate (or Te)
Tr: Tropical
Z : Zone

Figure 2. Abbreviations of Jupiter's Belts and Zones.

Jupiter
July 16, 1949
$15^h 43^m$ U.T.
CM_1 307°
CM_2 251°
Drawing by Shiro Ebisawa

Jupiter
December 4, 1949
$8^h 15^m$ U.T.
CM_1 67°
CM_2 277°
Drawing by Sadao Murayama

Figure 3. Two views of Jupiter showing the Red Spot (left) and the Red Spot Hollow (right).

words. On this scale, the usual intensity of the brighter zones is 7 or 8; the darker belts, 2 or 3; the polar regions, 4. After the observer has had some experience using intensity numbers, he will automatically associate certain observed intensities with certain numbers. Eventually, his results will become quite reliable.

<u>Transit Observations</u>. Central meridian transit observations have supplied most of our present knowledge of the motions of the various currents in the atmosphere. Few observing programs are at once so easy and so useful. The observer merely records the time, to the nearest minute, when each Jovian spot appears to be on the central meridian. As the planet rotates on its axis, the spots move from right to left across the disc, as seen in an inverting telescope from the northern hemisphere. An obvious shift in the position of a spot near the central meridian can be detected in five minutes, and the probable error of a visual transit observation is not greater than two or three minutes (8,9).

Each transit observation must include the date, time of transit, a brief description of the object observed, and its location with regard to the belts and zones. The only accessories needed are pencil, notebook or observing form, and a watch. The observer may prefer to use the standard time adopted by his locality when recording observations at the telescope; however, it is desirable that Universal Time be used when reporting observations to the Section. Standard observing forms for reporting transits are available on request.

Practically all Jovian spots can be classified as either dark markings (D) or bright markings (W). The time of transit can refer to the center (c), preceding end (p), or following end (f) of a marking. Thus, if the observer will begin his description of a transit with the capital letter (W) or (D) with the proper subscript (p, c, or f), the all-important part of the description will have been recorded. If these letters are followed by an abbreviation indicating the type of marking observed, the Recorder is frequently aided considerably in identifying the marking from day to day. A suggested nomenclature of the more frequently observed surface details on Jupiter can be found in the article, "Jovian Nomenclature and Transit Observations" (<u>The Strolling Astronomer</u>, Vol. 14, pgs. 18-21).

The following abbreviations are commonly used in recording transit observations:

D	: dark marking	Sm.	: small
W	: bright marking	proj.	: projection
c	: center	cond.	: condensation
p	: preceding or preceding end	elong.	: elongated
f	: following or following end	conspic.	: conspicuous
N	: north	indef.	: indefinite
S	: south	sect.	: section
v	: very	RS	: Red Spot
L	: large	RSH	: Red Spot Hollow

Thus, the following end of a darker section of the North Temperate Belt can be recorded as follows: Df (sect.), NTB. (A careful study of the sample list of transits to be found in the article, "Jovian Nomenclature and Transit Observations" should be helpful to the beginner. All of the markings recorded in this sample list can be found in the accompanying full-disc drawing.)

Small sketches of portions of the planet on which one or more transit objects are indicated by their numbers are very useful. Such sketches should have the depicted belts identified.

The portion of an object which is chosen for timing a transit should be that portion which is most likely to be timed by other observers. If a condensation is rather small, the center of the object should be chosen in preference to one of its ends.

If for one reason or another a transit time is uncertain, a question mark should be placed after the recorded time. If a transit time is an estimate, the abbreviation (est.) should be placed after the recorded time.

The observer is encouraged to compute the longitude of each spot whose transit he has timed. The longitudes thus obtained are very useful in the study of the visible surface of Jupiter. Spots seen on successive nights can be identified with greater certainty. Such identification is especially important when we are studying the changes in appearance of very active areas on closely adjacent dates.

If a spot is observed for some weeks or months, its rotation period can be determined with considerable accuracy from the changes in its longitude. Rotation periods are best determined by plotting the observations on squared graph paper with the dates arranged vertically and the degrees of longitude horizontally. A convenient scale is 1/10th inch to 5° of longitude, and 1/10 th inch to 2 days. From an examination of these graphs, markings seen on successive dates can be identified, their drifts in longitude established, and their rotation periods determined. It will be found that the markings drift in various directions. If the drift-line is straight and constant in longitude, the rotation period is constant and identical with that of the system used. However, if the drift-line is curved or irregular, the period is variable. When the drift in longitude has been established, the rotation period can be found with the aid of the conversion tables in appendix IV of B. M. Peek's <u>The Planet Jupiter</u>. The rotation period also can be computed by one of the following formulas:

For markings in System I : $\text{Period} = 9^h50^m30^s.003 + (1.345^s)(\pm D_1)$

For markings in System II : $\text{Period} = 9^h55^m40^s.632 + (1.369^s)(\pm D_2)$

Here, D_1 is the number of degrees a marking drifts in 30 days in System I longitude; D_2 refers to System II. Also, D_1 and D_2 are positive when the markings drift towards increasing longitudes, negative when towards decreasing longitudes.

<u>Photography</u>. Photographs of Jupiter provide an accurate and permanent record of the position, width, and intensity of the various belts and zones. The latitudes of the belts and th longitudes of individual spots can be measured from good photographs. Longitudes determined in this manner form a valuable supplement to the longitudes from transit observations. Reliabl values for the intensities of Jovian features could be obtained by measuring original negatives with a photoelectric microphotom eter. Such measures could serve as a check on the accuracy of visual intensity estimates, and many such measures over a period of years might uncover certain empirical laws governing the appearance and behavior of the Jovian cloud belts. A photometer adaptable to this work and costing less than fifteen dollars to construct (excluding a microscope) has been described by S. Archer (18).

A comparison of photographs taken in succession through different color filters will reveal the colors of the belts and zones. If a belt is predominently red, it will appear much darker on a photograph taken with violet light than on one taken with red light.

A fine millimeter scale is satisfactory for measuring photographs for belt latitudes providing certain precautions are taken. The most serious source of error is encountered in determining the true limb of the planet on a photograph. Since the image of the planet on the original negative is usually too small to be measured accurately without a measuring machine, the most satisfactory procedure is to enlarge the negative onto another sheet or plate of "wide-latitude" negative material thereby obtaining an enlarged positive transparency. If an enlarged paper print is to be measured, it is advisable to trans a strong light through the back of the print when measuring the polar diameter and locating the center of the disc. For this reason, nothing should be written on the back of a print in the vicinity of any of the images of the planet.

Most planetary photographers agree that more will be gained by enlarging the telescopic image of the planet considerably and using a fast film. It seems that the high resolution of very fine-grain films is paid for at much too high a price in respect of low sensitivity and consequent increase of exposure time or diminution of image size (19). H. E. Dall, however, has found that a medium speed, medium fine-grain film gives optimum results on the planets because it has better contrast than the very fast films (20).

Information on planetary photography useful to the amateur can be found in many recent issues of various journals (21,22,23)

Latitudes of Belts. Latitudes can be measured visually with a filar micrometer attached to the telescope, or they can be measured from good photographs with a fine scale. The measurements required are the polar radius (r) and the distance (d) from the center of the disc to the edge (or center) of each belt. The distance (d), which is measured along the central meridian, is positive if it extends northward from the center of the disc, and negative if it extends southward. The zenographic latitude (B") can then be computed from the following formulas:

$$\sin \theta = d/r$$

$$B' = \theta + 1.07\ D$$

$$\tan B'' = 1.07 \tan B'$$

Here, the constant 1.07 is the ratio of the equatorial and polar diameters for an assumed oblateness of 1/15.4. The zenocentric declination of the earth (D) is given in The American Ephemeris and Nautical Almanac under the heading De.

The mean zenographic latitudes of Jupiter's belts for two intervals of time follow:

Belt	Mean Latitude 1908-1947	Mean Latitude 1948-1960	
SSTB, center	41°.6	42°.4	S.
STB, center	29.0	31.0	S.
SEB, S. edge	18.9	20.7	S.
SEB, N. edge	7.1	7.7	S.
NEB, S. edge	7.2	6.9	N.
NEB, N. edge	17.3	17.7	N.
NTB, center	27.8	27.0	N.
NNTB, center	36.4	35.4	N.

The mean latitudes for the interval from 1908 to 1947 are based on data published in reference (10) and various other Reports of the B.A.A. Jupiter Section. The mean latitudes for 1948 to 1960 are based on various Reports of the A.L.P.O. Jupiter Section. The B.A.A. results are based on measurements with a filar micrometer. The A.L.P.O. results are based on measurements of photographs.

Color and Brightness of the Four Bright Satellites. Photometric observations by Guthnick (1914) and Stebbins (1926) have established the existence of small variations in brightness dependent upon the orbital positions of the satellites. These periodic variations indicate that the periods of revolution and rotation of each satellite are identical, and that the surface of each is unevenly marked. However, large and irregular variations (11) in the color and brightness of the satellites have been reported from time to time, and these may indicate that the satellites possess atmospheres. A long series of measurements with a photoelectric or visual photometer is neede Photoelectric photometry, despite recent advances (12,13), is still expensive and complicated; however, a good visual photometer (14) is within the means of the advanced amateur.

Useful observations of the relative brightness of the Jovi satellites can be made without a photometer by listing the satellites in the order of their decreasing brightness and estimating the number of steps of one-tenth magnitude between them. The observer can become quite proficient in judging differences in brightness corressponding to a few tenths of a magnitude by practising on stars of known magnitude. More useful results can be obtained if a star of the fifth or sixth magnitude happens to be visible in the same field with the Jovian satellites. The star (or stars) is then included in the step estimates. This method has one very serious weakness: Th apparent brightness of a satellite is considerably affected by its proximity to the brilliant planet. The results are most reliable when the satellites are clustered together at nearly the same distance from their primary. The observations can be recorded at the telescope by means of a crude sketch without knowing the identity of the satellites. An example follows:

	II		I	III	IV
July 6, 1949 3:35 UT					
S4, T4	•	⊖	•	•	•
6-in. refl. 60X	3(2)		2(2)	1(3)	4

The number on the left, below each satellite, indicates the ord of brightness, while the number on the right (in parentheses) indicates the estimated number of steps between that satellite and the next fainter one. After the observations have been mad the satellites can be identified from tables in the Ephemeris. When reporting the observations, it is convenient to list the estimated magnitudes of the satellites in tabular form (24). Unless a suitable star of known magnitude happens to be include in the step estimates, it will be necessary to assume that one satellite's magnitude is constant. For this purpose the magnit of satellite III may be assigned an arbitrary magnitude of 5.1. The magnitudes of I, II, and IV in the above example then become 5.4, 5.6, and 5.8 respectively.

With good seeing, a magnification of not less than 200X, and an aperture of 6 inches or larger, an experienced observer can usually recognize each satellite from the brightness, color, and size of its disc. The relative albedo (reflecting power per unit area) of the satellite as compared with that of Jupiter can be determined by observing the appearance of the satellites when they are in transit across the disc of Jupiter. When seen against the dusky limb of Jupiter, all the satellites except IV appear bright. The third and fourth satellites usually appear dark at mid-transit; the first satellite, dusky against a bright zone, and bright against a dark belt; the second satellite, bright against a dark belt, and quite invisible against a very bright zone. Variations in the appearance of the satellites when in transit have been reported frequently (15). Such anomalous appearances tend to confirm the irregular variations in the magnitudes of the satellites already mentioned.

Phenomena of the Satellites. The transits of the satellites and their shadows across the disc of Jupiter, and occultations and eclipses of the satellites by Jupiter are very interesting phenomena to observe with even a small telescope. The times of occurrence of all these phenomena are given in the *Ephemeris*. These predicted times refer to the centers of the satellites. In recent years most observers have found a very persistent systematic difference between the predicted times and the observed times for these phenomena. B. G. Marsden has found that if an empirical correction of -1.2 minutes is applied to all the predicted times the calculations will be more in agreement with the observations (25). The times should be recorded to the nearest tenth of a minute. Since the satellites have discs, there are two contacts at each ingress, egress, disappearance or reappearance. It is advisable to record the time of each contact. The mean of these two times can then be compared with the predicted time given in the ephemeris.

Once in about every six years the plane of the orbits of Jupiter's satellites passes near the sun and earth. For some months around these times the Jovian satellites can mutually occult and eclipse each other. The times of these phenomena are predicted in the *Handbook of the B.A.A.* Certain aspects of these occultations and eclipses require a very large telescope to be observed satisfactorily. An excellent discussion of these mutual phenomena can be found in Chapter 32 of B. M. Peek's *The Planet Jupiter*.

Markings on the Satellites. Markings have been seen on all of the large satellites. The spots on the third satellite are the easiest, while those on the second are extremely vague. Observations of these markings are useful in determining the rotation periods of the satellites, constructing maps of the surface features, and determining the nature of the spots. It is possible that some of the markings may be transient atmospheric features.

This program requires excellent seeing and an aperture of at least 12 inches. The satellites should be scrutinized under the highest practical magnification in all of their orbital positions. Antoniadi found that the markings are seen to advantage when the satellites are in transit on the disc of Jupiter (16).

C. Recording Observations at the Telescope

After the beginner has become familiar with the names of the belts and zones (Section A) and has acquired some idea of the kinds of observations needed (Section B), he is ready to make some of the most fascinating observations in the realm of astronomy. He will need much patience and perseverence however. No department of observational astronomy is more beset with obstacles than the study of planetary markings. Many intending observers have abandoned this field because the markings seemed so difficult and the seeing so poor. Those who persist soon discover that their ability to perceive delicate planetary markings increases greatly with practise. They also learn to take full advantage of intermittent moments of fine seeing (24).

Before beginning an evening's work, the observer will want to have within easy reach various eyepieces, a watch accurate to the nearest tenth of a minute, an assortment of pencils, an observing notebook or standard forms, and a dim white light for illuminating the notebook. When the giant planet glides into the field of view, the observer should first scan the central meridian of the planet. If there is a well-defined spot on that meridian, he should note the time to the nearest minute and record it in the notebook together with a brief description of the appearance and location of the spot. If no other spots are about to transit the central meridian, the observer might list the belts and zones in the order of their decreasing conspicuousness and then estimate their colors and intensities. As the hours go by, new detail becomes visible near the east limb and other detail disappears near the west limb. Markings are rarely noticed when more than 50 or 60 degrees from the central meridian because of Jupiter's hazy atmosphere. The observer will want to make sectional sketches of some of the more interesting portions of the planet, and, if time permits, a full-disc drawing. However, these other programs should not be allowed to interfere with the timing of transits.

The best magnification to use when observing Jupiter depends on such factors as aperture, eye-training, and the nature of the observation. Observers accustomed to relatively high powers will find the low power image so bright that delicate colors and details are lost in the resulting glare. Observers accustomed to low powers will find the high power image pale and lacking in contrast. Magnifications most frequently used in planetary work range around 30X or 40X per inch of aperture (except for very large telescopes where atmospheric tremors seldom permit magnifications greater than about 900X). After the observer has decided upon the best magnification for each observing program, he should use that magnification consistently.

D. Reporting Observations

Observations of Jupiter should be sent to the Recorder of the Jupiter Section of the Association of Lunar and Planetary Observers. The name and address of the Recorder can be found in the current issue of The Strolling Astronomer. Transit observations and drawings should be reported once a month; tabular lists of color and intensity estimates can be reported at the end of the apparition.

References

1. Astronomy, Volume I, Russell, Dugan and Stewart, 1926.
2. Earth, Moon and Planets, Fred L. Whipple.
3. The Handbook of the British Astronomical Association.
4. Rev. T.E.R. Phillips: Jupiter. Encyclopaedia Brittanica, 1943.
5. Memoirs B.A.A., Vol. 34, Part 2, 1939.
6. W.H. Haas: Colors on Jupiter. J.R.A.S.C., Vol. 33, p. 283.
7. J.B.A.A., Vol. 47, p. 106, 1937.
8. B.M. Peek: The Observatory, Vol. 59, p. 272, 1936.
9. W.H. Haas and H.M. Johnson: J.R.A.S.C., Vol. 37, p. 365.
10. Memoirs B.A.A., Vol. 29, Part 3, 1930.
11. The Strolling Astronomer, Vol. 2, No. 9, 1948.
12. Sky and Telescope, Vol. 6, p.7, 1947.
13. Sky and Telescope, Vol. 8, p. 169, 1949.
14. J.R.A.S.C., Vol. 35, p. 261, 1941.
15. Telescopic Work for Starlight Evenings, W.F. Denning, 1891.
16. E.M. Antoniadi: J.R.A.S.C., Vol. 33, p. 273, 1939.
17. The Planet Jupiter, B.M. Peek, 1958.
18. S. Archer: Photoelectric Photometer. J.B.A.A., Vol. 70, p. 183.
19. F.J. Hargreaves: Photography of Planets. J.B.A.A., Vol. 59, p. 178.
20. R.E. Dall: Factor of Merit of Films. J.B.A.A., Vol. 70, p. 159.
21. T.W. Rackham: A Lunar Camera. J.B.A.A., Vol. 66, p. 61.
22. P.R. Lichtman: Planetary Photography. Str. A., Vol. 10, p. 73.
23. J. Eastman: Planetary Photography. S.&T., Vol. 18, p. 510.
24. The Strolling Astronomer, Vol. 8, p. 137.
25. B.G. Marsden:Satellite Phenomena. J.B.A.A., Vol. 68, p. 60.
26. W.H. Haas: Training of the Eye. P.A., Vol. 54, No. 9, 1946.

A.L.P.O JUPITER RECORDER
PHILIP W. BUDINE
R.D. #3, BOX 145C
WALTON, NY 13856 U.S.A