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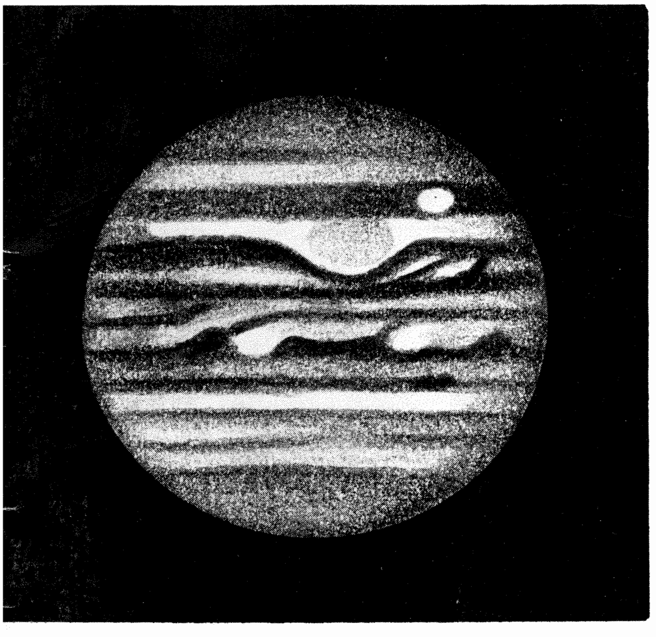

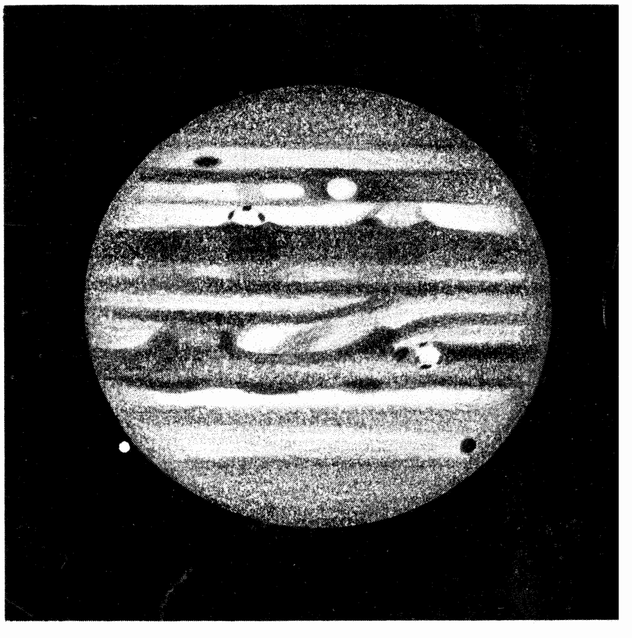

Two drawings of Jupiter by Mark S. Daniels with a 20-cm. (8-inch) f/7 Newtonian reflector at 191X. Simply inverted views with south at top. Seeing fairly good (6 or 7), transparency good. Left drawing: July 26, 1983, 1 hr., 45 mins., Universal Time, CM(I) = 331°, CM(II) = 34°. Right drawing: July 30, 1983, 3 hrs., 11 mins., Universal Time, CM(I) = 295°, CM(II) = 327°. Some descriptive notes on page 82.

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IN THIS ISSUE

GALILEAN SATELLITE ECLIPSE TIMINGS: 1975 - 1982 REPORT

By: John E. Westfall, A.L.P.O. Assistant Jupiter Recorder, Eclipse Timings

I. Introduction

The four large satellites of Jupiter were the first Solar System satellites to be discovered beyond our own Moon. Since Galileo's discovery of them in 1610, their orbital motions have fascinated astronomers for a variety of reasons. First, their independent motion about Jupiter was immediately recognized as a proof of the Copernican theory. Second, apparent discrepancies in the geocentric times of satellite phenomena provided the first practical method for the determination of the speed of light, by Roemer in 1675. Then, before the invention of the chronometer, the timing of Galilean satellite phenomena was one of the most popular methods for determining terrestrial longitudes.

It was early recognized that Jupiter's satellite system is a Solar System in miniature, almost a laboratory example of celestial mechanics in which revolution periods are measured in days rather than years. Laplace's publication of Mecanique Celeste in 1805 began a series of studies of these satellites' motions which still continues, involving astronomers such as E.C. Pickering, Sampson, Andoyer, de Sitter, and Lieske. Amongst other reasons, we are now interested in the orbital dynamics of these bodies in order to plan space missions such as the Voyagers and Galileo.

Theoretical studies of their orbits require observations of the positions of these satellites. The most accurate Earthbased means of determining satellite positions is through the timing of their eclipses in Jupiter's shadow. For example, the observations of Io analyzed here have produced positional uncertainties of 49 - 83 kilometers--equivalent to an Earthbased angular accuracy of 0.01 - 0.02 arc-seconds!

The late Dr. Joseph Ashbrook, then editor of Sky and Telescope magazine, recognized that amateurs could conduct accurate Galilean satellite eclipse timings using relatively small telescopes and, in an article in the October, 1976, issue of that magazine, invited its readers to participate (Ashbrook 1976). Subsequently, seven separate listings of observed eclipse timings appeared in Sky and Telescope in 1977 - 1980 (Ashbrook 1977a, 1977c, 1978a, 1978b, 1979a, 1979b, 1980). In 1977, Dr. Ashbrook became an Assistant A.L.P.O. Jupiter Recorder and extended this program to the A.L.P.O. membership (Ashbrook 1977b). With his death in 1980, the Sky and Telescope program ended; but the present writer is continuing the A.L.P.O. observational program, now in cooperation with the (Australian) National Association of Planetary Observers and the Royal Astronomical Society of New Zealand.

The efforts of Dr. Ashbrook and others spurred an extraordinary observational effort. The present report analyzes some 1321 timing observations made from 1975 to 1982. The analysis of Galilean satellite eclipse timings is complex because many separate factors can influence the apparent time of eclipse disappearance or reappearance. This report is concerned with only four such variables--the apparition, the satellite itself, the type of event, and telescope aperture. Further, more specialized, reports will investigate other factors, including the effects of angular proximity to Jupiter, the visual magnitudes of eclipse disappearance and reappearance, and the timing of satellite transits and occultations as well as eclipses. Naturally, we hope that this program will continue, and it is planned to publish reports similar to this one following each future Jupiter apparition.

II. Methodology

A. Observations

Making a Galilean satellite eclipse timing is a relatively simple observation--one times, to the nearest U.T. second, when the satellite is either last visible (in an eclipse disappearance) or first becomes visible (for a reappearance). Even given uncertainties in the predicted times, and the finite duration of shadow ingress or egress, such an observation typically takes only a few minutes. Besides a telescope (apertures in the range 5 - 76 cm. have been used), one needs an accurate time source, such as WWV time signals, and a table of predicted eclipse times, such as is given in The Astronomical Almanac (A.A.) for each year. For a timing observation to be of use, the observer should also record telescope aperture, magnification, seeing, transparency, and moonlight and twilight conditions. (The last two items can be computed later from the time and the known position of the observer.)

Given the simplicity of making such observations, together with the large readership of Sky and Telescope magazine, a large number of such timings were made during 1975 - 1980. For the 1980/81 and 1981/82 apparitions, when the program had been discontinued by that magazine, the number of observations fell off. At present, the Association of Lunar and Planetary Observers, the (Australian) Association of Planetary Observers, and the Royal Astronomical Society of New Zealand are the sources of the eclipse timings which are analyzed here. The number of timings, by apparition and satellite, are given in Table 1, below.

Table 1. Number of Eclipse Timings by Apparition and Satellite

Apparition	Dates[a]	No. Timings by Satellite[b] I	II	III	IV	Total
1975/76	03/22/75-04/27/76	14	10	0	0	24
1976/77	04/27/76-06/04/77	151	64	63	0	278
1977/78	06/04/77-07/10/78	116	69	60	9	254
1978/79	07/10/78-08/13/79	173	94	66	52	385
1979/80	08/13/79-09/13/80	70	32	19	21	142
1980/81	09/13/80-10/14/81	40	27	20	0	87
1981/82	10/14/81-11/13/82	72	41	38	0	151
Total	03/22/75-11/13/82	636	337	266	82	1321[c]

[a]Dates of conjunction of Jupiter with the Sun.
[b]I = Io, II = Europa, III = Ganymede, IV = Callisto.
[c]544 disappearances and 777 reappearances.

Most of the differences among the numbers of observations for the four satellites is due to the differences in their periods of revolution, and thus in the frequencies of their eclipses. Also, Callisto undergoes eclipses only about half the time (for periods of about 3 years, separated by 3-year gaps). With the exception of 1975/76, there were sufficient timings every apparition for a statistical analysis. However, the results for 1979-82 are more uncertain than for 1976-79 because of the post-1979 falloff in the number of observations. Likewise, results for Io are more certain than for Europa and Ganymede, and are least certain for Callisto. The Appendix at the end of this report references the observations which have been published before, and summarizes those that have not.

B. Sources of Error

An individual eclipse timing is subject to two general forms of error, random and systematic. Purely random errors are probably relatively small, compared with the systematic ones, but are unpredictable and can be reduced only by averaging groups of observations. Systematic errors are attributable to identifiable causes, and can theoretically be reduced by grouping similar observations (e.g., by observer) and/or by formulating mathematical models that predict the error's effect as a function of a known quantity (e.g., the aperture-effect model used in this report). Unfortunately, the number of factors which can influence eclipse timings is large enough so that even the apparently large number of observations used here is insufficient to group the data into all possible combinations, particularly after they must first be grouped by satellite, event type, and apparition.

Besides accidental errors in timing, a major source of random error is unpredictable variations in the heights of Jupiter's cloud tops, which cast the shadow that causes the eclipses. There may also be variations in the transparency of Jupiter's atmosphere above the cloud layer. On the other hand, there are a large number of systematic effects:

1. Satellite (orbital, albedo, and diameter differences);
2. Aperture (affecting limiting magnitude; type of telescope may also have some effect);
3. Magnification;
4. Observer ("personal equation");
5. Seeing (atmospheric steadiness/turbulence);
6. Transparency (atmospheric clearness/obscuration); along with the effects of twilight, moonlight, and Jupiter's altitude above the horizon;
7. Angular proximity of satellite to Jupiter at time of observation;

8. Size and intensity of shading of Jupiter's penumbra (varies with satellite);
9. Jovicentric latitude of eclipse (related to satellite's angle of entry into the shadow cone);
10. Psychological differences between perceived eclipse disappearance and reappearance ("first speck" versus "last speck");
11. For Io, possible short-term and long-term changes in albedo.

One other possible source of error is the fact that observations are grouped by entire apparitions.* This would obscure any short-term deviations of a satellite from its ephemeris. Such deviations are probably small for the E-2 ephemeris, but may be significant over the course of an apparition when using the A.A. ephemeris.

C. Method of Analysis

After grouping observations by apparition and by satellite, the method of analysis used here also groups by eclipse disappearance and reappearance because several of the systematic effects listed above should be approximately symmetric with event type. For example, poor transparency should make an eclipse disappearance about as many seconds early as it would make a reappearance late. In fact, averaging disappearance and reappearance timings should have some "cancelling-out" effect with factors 2 - 9 as listed above. Unfortunately, it is the exception, rather than the rule, that an observer can make disappearance and reappearance timings for the same eclipse. Thus, the two types of events are averaged for whole-apparition groups of timings.

Although it would be possible to do so, this analysis does not attempt to derive independently the satellites' orbital parameters. Instead, the observations are studied in terms of their time residuals (observed - predicted) from existing ephemerides. The two ephemerides so used are:

1. "A.A.", the ephemeris used to generate the satellite phenomena predictions published annually in The Astronomical Almanac. These are computed by the Service des Calculs, Bureau des Longitudes, Paris, and are based on the tables of R.A. Sampson (1910, themselves based on eclipse timings made by E.C. Pickering in 1878-1903), using methods developed by H. Andoyer (1915). They are currently published to 1 minute precision.

2. "E-2", the ephemeris developed by Dr. Jay H. Lieske (1980) of the Jet Propulsion Laboratory for the NASA Voyager missions. The predictions cover 294,233 eclipses (167,624 visible) for the period 1610-2000 and are given to 1 second E.T. precision (Lieske, 1981).

Except for the "cancelling-out" effect for factors 2 - 9 noted above, and for differences among individual satellites (factor 1), the only factor explicitly considered in this analysis is telescope aperture, measured in centimeters. Unfortunately, most other factors are not easily analyzed statistically. One such is atmospheric conditions (factors 5 and 6), which, for the period studied, were most often reported simply as "g", "f", or "p" (good, fair, or poor).

The statistical model used here is a linear least-squares regression equation of the form:

$$y_{(s,e,a,t)} = A_{(s,e,a,t)} + B_{(s,e,a,t)}\, x, \text{ where:}$$

y = estimate of (observed - predicted) residual in seconds;
x = 1/aperture (cm.);
A, B = regression coefficients;
s = satellite (I, II, III, IV);
e = ephemeris (A.A., E-2);
a = apparition;
t = event type (disappearance, reappearance).

Probably the most debatable aspect of this model is the assumed linear relationship between the time residual and the reciprocal of telescope aperture. The form of this model was investigated using 8 aperture-grouped means of 524 timings of Io made during 1976-81, with their residuals from the E-2 ephemeris. First, a scatter diagram was drawn, plotting residuals against reciprocal of aperture, which appeared to give a reasonable fit. Second, using the same set of data, the reciprocal-aperture and two alternate linear models were computed, with the results given in Table 2.

*It would be quite possible to group observations by other time intervals, for example, three- or six-month periods. It would be necessary for a successful analysis that observations be numerous enough in whatever time intervals are selected. Observations will always be rare when Jupiter is near conjunction with the Sun, for example.

Table 2. Comparison of Time Residual: Aperture Linear Regression Models

Model No.	x	y	R^2	s_E
1	1/Aperture	Residual	0.9623	$\pm 2^s.1$
2	log(Aperture)	Residual	0.8528	± 4.2
3	log(Aperture)	log(Res.)	0.8252	± 4.7

Notes: Aperture is in cm.; y is in sec., based on the E-2 ephemeris. R^2 is the "coefficient of determination" and expresses the proportion of the variance of y that is removed when the model is used. s_E is the "standard error of estimate," which is the root-mean-square deviation of the observations from the model.

It appears fairly clear that the reciprocal-aperture model gives a good fit between aperture and time residual, with a standard error one-half or less that of the other two models. Another advantage of the reciprocal-aperture model is that it easily allows extrapolation to estimate the value of the residual for an "infinite" aperture (i.e., x = 0), which is an approximation of the time when the satellite's limb is internally tangent with the umbra.

Because the above model explicitly considers only aperture, the remaining factors (numbers 3 - 11) are effectively random in nature. To reduce the effect of these unconsidered variables, any individual observation was rejected if it deviated from the regression model at a 1-percent level of significance (i.e., were the model correct, only 1 percent of the observations would deviate from it by so large an amount). When this happened, the regression was recomputed omitting the anomalous observation(s); sometimes, this computing had to be done iteratively several times. Overall, 20 (1.5 percent) of the observations were rejected when using their residuals from the A.A., compared with 49 (3.7 percent) for the E-2 ephemeris. The greater number rejected when using the E-2 ephemeris is a result of the greater precision of its predictions.

When there were relatively few observations of a particular type of event in an apparition, the value of the (1/Aperture)-coefficient B became quite uncertain. In some cases, it even had the incorrect algebraic sign. When this happened, it appeared best to abandon the linear regression method and instead to calculate the satellite's residual as the simple (unweighted) mean of the mean disappearance and reappearance residuals.

The second stage of analysis involved finding the time residual for each satellite as based on its disappearance and reappearance residuals. Following the symmetry argument given earlier, the satellite's residual should be given by simply averaging its predicted disappearance and reappearance residuals as estimated for some standard aperture. At first glance, it would appear that the particular aperture used should not matter, except that a value near the mean of the apertures might give less uncertainty than others. However, this assumes that the (1/aperture)-coefficient B should have the same absolute value for disappearance as for reappearance (i.e., $B_d = -B_r$; the signs should differ because large apertures should detect disappearance later, but reappearance earlier, than small apertures, and B should be negative for disappearance and positive for reappearance). Actually, the absolute disappearance and reappearance values of B were found to differ rather consistently. Of the 20 cases studied, the mean of B_d and B_r, rather than being near 0, was positive 13 times and negative only 7 (at a 95-percent significance level positive 4 times and negative only once). This result appears most likely to be a consequence of "factor 10"--psychological differences between perceived disappearance and reappearance. The effect hypothesized here is that the observer can follow a satellite deeper into Jupiter's penumbra during disappearance because he/she knows the satellite's location, while, with a reappearance, the satellite's position can only be anticipated. The disappearance: reappearance discrepancy tended to be smaller for larger apertures, as shown in Table 3, which uses the same group of observations as were employed to derive Table 2.

Table 3. Predicted Eclipse (Disappearance+Reappearance) Discrepancy by Aperture

	Satellite			
Aperture (cm.)	Io	Europa	Ganymede	Callisto
6.1 (2.4 in.)	$+16^{s}.0 \pm 4^{s}.1$**	$+31^{s}.6 \pm 6^{s}.3$**	$-28^{s}.2 \pm 14^{s}.2$*	$+132^{s}.2 \pm 46^{s}.7$**
10.2 (4.0 in.)	$+7.5 \pm 1.5$**	$+16.0 \pm 3.3$**	-15.4 ± 5.5*	$+74.2 \pm 21.2$**
15.2 (6.0 in.)	$+4.8 \pm 1.5$**	$+8.3 \pm 3.4$*	-11.2 ± 5.1*	$+45.9 \pm 17.6$*
20.3 (8.0 in.)	$+3.3 \pm 1.7$	$+4.4 \pm 4.0$	-9.1 ± 5.9	$+31.4 \pm 20.4$
25.4 (10.0 in.)	$+2.5 \pm 2.0$	$+2.1 \pm 4.5$	-7.8 ± 6.5	$+22.7 \pm 23.2$
35.6 (14.0 in.)	$+1.5 \pm 2.2$	-0.6 ± 5.1	-6.3 ± 7.4	$+12.7 \pm 27.0$
60 (24.0 in.)	$+0.5 \pm 2.5$	-3.3 ± 5.7	-4.8 ± 8.4	$+2.7 \pm 31.4$
"Infinite"	-0.9 ± 3.0	-7.2 ± 6.7	-2.6 ± 9.9	-12.0 ± 38.2

*, ** These symbols indicate significant difference from 0 at 5- and 1-percent confidence levels respectively, and are used in this manner for the remainder of this report.

Thus, it appears best to extrapolate to an "infinite" aperture (i.e., x = 0) as a standard in order to minimize any asymmetry between disappearance and reappearance timings. This "infinite" aperture value is simply equal to the A coefficient in the regression model.

Another advantage of using residuals extrapolated for "infinite" aperture is that the difference between the disappearance and reappearance residual should approximately give the time interval taken by the satellite to traverse Jupiter's shadow edge. This is, of course, an approximation because of the finite width of Jupiter's penumbra (i.e., 754, 1200, 1915, and 3367 km. for satellites I-IV respectively). If this time interval is multiplied by the orbital speed of the satellite (17.326, 13.736, 10.877, and 8.214 km./sec. for satellites I-IV respectively), and then by the cosine of an eclipse's jovicentric latitude (to allow for the oblique passage of the satellite through the shadow edge), one then obtains an estimate of the diameter of the satellite. Naturally, we now can measure the diameters of the Galilean satellites more accurately by using Voyager-1 and -2 imagery. However, eclipse-derived diameters can be compared with Voyager-derived diameters as a rough check on the accuracy of the eclipse timings and the aperture:residual model.

D. Format of Results

The results of the analyses of eclipse timings are presented in the next four sections, one section for each satellite. These results are mainly tabular, although the final part of each section consists of a verbal summary and apparition:residual graph. For each satellite, independent comparisons are made first with the A.A. ephemeris and then with the E-2 ephemeris. The format used for each ephemeris is identical. First, the coefficients of determination and of regression and their uncertainty ranges are given for each apparition. Throughout this report, uncertainty ranges will be preceded by the "±" symbol, which will indicate ± 1 standard error. Second, predicted residuals and uncertainty ranges are given for each of several commonly-used apertures, by apparition. Third, the orbital residuals and uncertainty ranges of the satellite are given, also by apparition, in seconds of time, orbital arc, and kilometers. Finally, satellite diameters and uncertainty ranges are given and are compared with Voyager-mission values, by apparition, along with the means for the entire period. The "preliminary" diameters are not corrected for the oblique passage of the satellite through Jupiters' shadow; the "corrected" diameters have been adjusted for this effect by multiplying by the mean cosine of the eclipses' jovicentric latitudes for each apparition. (The "standard" satellite diameters are 3640, 3066, 5216, and 4890 km. for satellites I-IV respectively; Lieske 1981.) The writer has previously published results for the 1980/81 apparition (Westfall 1982); these are repeated here to provide continuity.

In the tables which give coefficients of determination and regression, the first entry under "No.Ob." gives the number of observations submitted, followed in parentheses by the number actually used in the regression. In the tables of orbital residuals, the "Sig." column indicates whether the satellite deviated significantly from the ephemeris, with the same symbols as in Table 3.

III. IO

A. Io: Astronomical Almanac Ephemeris

Table 4. Io (A.A.): Coefficients of Determination and Regression

	Disappearance				Reappearance			
Appar.	No.Ob.	R^2	A	B	No.Ob.	R^2	A	B
1975/76	0(0)	------	-----	-----	14(14)	.021	$-157^{s}.5 \pm 17^{s}.0$	+ 77±152
76/77	87(86)	.135**	$+34^{s}.0 \pm 5^{s}.6$	-231± 64	64(64)	.314**	-211.3± 6.4	+323± 61
77/78	38(36)	.047	+ 4.6± 8.5	-116± 88	78(78)	.098**	-201.1± 6.0	+203± 70
78/79	53(53)	.002	-24.8± 7.7	+ 31± 92	120(117)	.125**	-192.4± 5.1	+220± 54
79/80	36(35)	.239**	+ 2.6± 7.7	-261± 81	34(34)	.332**	-211.7± 8.5	+370± 93
80/81	9(9)	.654**	+25.7±12.7	-511±141	31(30)	.138*	-203.5± 8.4	+211± 98
81/82	26(26)	.035	+ 0.0±12.4	-194±209	46(41)	.493**	-229.3± 7.5	+628±102

Table 5. Io (A.A.): (Observed - Predicted) Residuals by Aperture

	Disappearance				Reappearance			
Appar.	s_E	6 cm.	10 cm.	20 cm.	s_E	6 cm.	10 cm.	20 cm.
1975/76	-----	-----	------	-----	$\pm 26^{s}.5$	-145 ± 12^{s}	-150 ± 7^{s}	-154 ± 11^{s}
76/77	$\pm 24^{s}.4$	-4 ± 6^{s}	$+11 \pm 3^{s}$	$+22 \pm 3^{s}$	±25.5	-158± 5	-179±3	-195± 4
77/78	±23.7	-14± 8	- 7± 4	- 1±5	±22.7	-171± 7	-184±3	-194± 3
78/79	±24.7	-20± 9	-22± 4	-23±4	±27.6	-156± 5	-170±3	-181± 3
79/80	±21.5	-40± 7	-23± 4	-10±5	±24.9	-151± 9	-175±5	-193± 5
80/81	±20.4	-58±14	-25± 8	0±8	±25.8	-169±10	-182±5	-193± 5
81/82	±26.7	-32±24	-19±11	-10±5	±26.1	-126±11	-167±6	-198± 4

Table 6. Io (A.A.): Orbital Residuals[a]

Appar.	Time	Orbital Arc	Kilometers	Sig.
1976/77	$-88^{s}.7 \pm 4^{s}.2$	$-0^{\circ}.209 \pm 0^{\circ}.010$	-1537± 73	**
77/78	- 99.8±5.2	-0.235±0.012	-1729± 90	**
78/79	-108.6±4.6	-0.256±0.011	-1882± 80	**
79/80	-104.5±5.7	-0.246±0.013	-1811± 99	**
80/81	- 88.9±7.6	-0.209±0.018	-1540±132	**
81/82	-114.6±7.3	-0.270±0.017	-1986±126	**

[a]Overall means not given because individual apparitions differ significantly from each other.

Table 7. Io (A.A.): Estimated Diameters

	(D-R) Time	Diameter (km.)		
Appar.	Difference	Prelim.	Corrected	Diff. from Std.
1976/77	$245^{s}.3 \pm 8^{s}.5$	4250 ± 147	4031 ± 139	+391 (+10.7 %)**
77/78	205.7 ± 10.4	3564 ± 180	3473 ± 175	-167 (- 4.6 %)
78/79	167.6 ± 9.2	2904 ± 159	2897 ± 159	-743 (-20.4 %)**
79/80	214.3 ± 11.5	3713 ± 199	3694 ± 198	+ 54 (+ 1.5 %)
80/81	229.2 ± 15.2	3971 ± 263	3859 ± 256	+219 (+ 6.0 %)
81/82	229.3 ± 14.5	3973 ± 251	3772 ± 238	+132 (+ 3.6 %)
Mean	------------	----------	3621 ± 163	- 19 (- 0.5 %)

IO: ORBITAL RESIDUALS BY APPARITION.

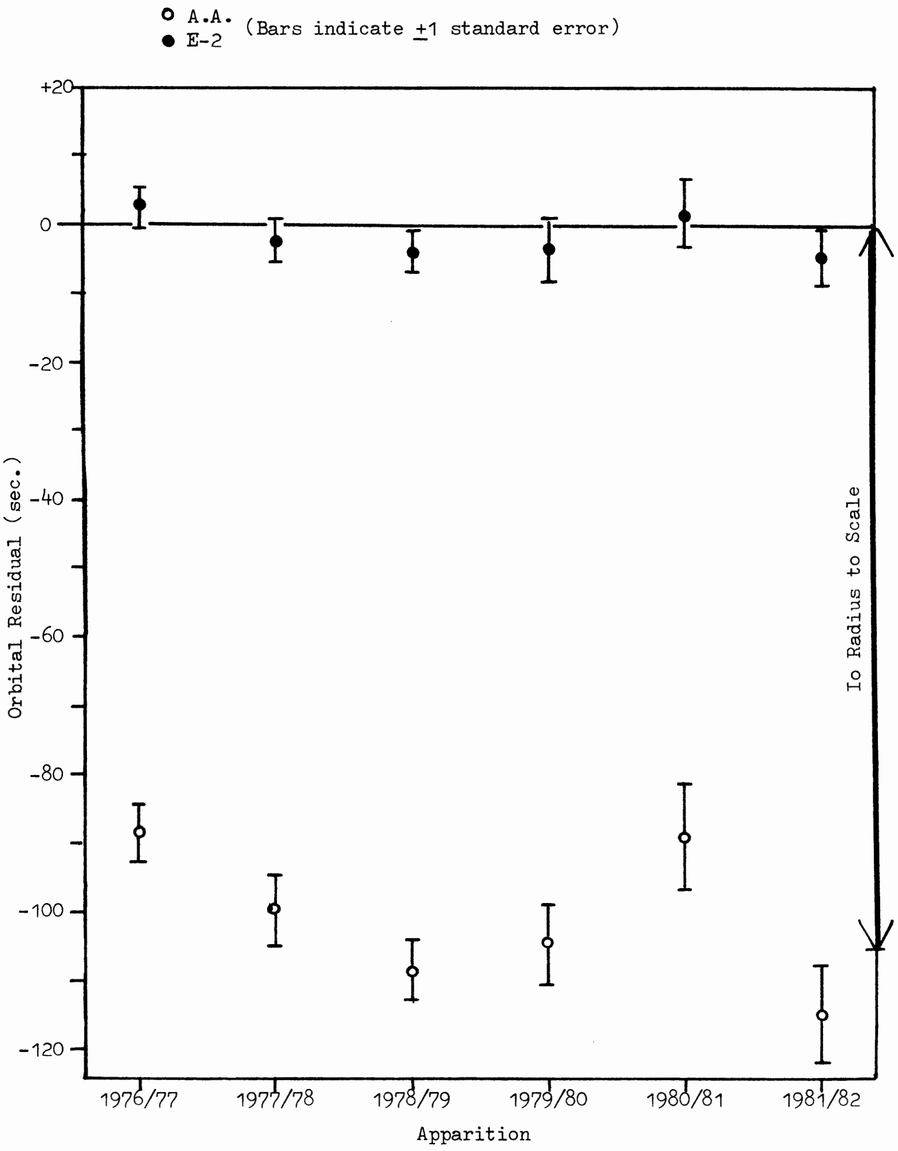

Figure 1

B. Io: E-2 Ephemeris

Table 8. Io (E-2): Coefficients of Determination and Regression

	Disappearance				Reappearance			
Appar.	No.Ob.	R^2	A	B	No.Ob.	R^2	A	B
1975/76	0(0)	------	-----	-----	14(14)	.124	- 91^{s}4±18^{s}8	+220±169
76/77	87(83)	.251**	+106^{s}4±2^{s}9	-178± 34	64(61)	.432**	-101.7± 4.9	+312± 47
77/78	38(35)	.209**	+ 96.8±4.8	-145± 49	78(75)	.332**	-102.5± 4.0	+268± 44
78/79	53(50)	.001	+ 83.8±5.2	- 10± 61	120(113)	.257**	- 91.9± 2.9	+196± 32
79/80	36(35)	.315**	+ 94.1±6.9	-284± 73	34(33)	.404**	-101.4± 6.6	+337± 73
80/81	9(9)	.637**	+110.5±8.8	-341± 97	31(30)	.686**	-107.0± 3.8	+336± 43
81/82	26(25)	.007	+ 93.9±6.6	- 43±109	46(40)	.226**	-103.1± 4.8	+230± 69

Table 9. Io (E-2): (Observed - Predicted) Residuals by Aperture

Appar.	Disappearance s_E	6 cm.	10 cm.	20 cm.	Reappearance s_E	6 cm.	10 cm.	20 cm.
1975/76	-----	-----	------	-------	±29^{s}4	-55^s±14^s	-69^s±8^s	-80^s±12^s
76/77	±12^{s}6	+77^s± 3^s	+89^s±2^s	+98^s±2^s	±19.0	-51± 4	-70±3	-86± 3
77/78	±13.1	+73± 4	+82±2	+90±3	±14.9	-59± 4	-76±2	-89± 2
78/79	±16.3	+82± 6	+83±3	+83±3	±15.8	-60± 3	-72±2	-82± 2
79/80	±19.4	+47± 7	+66±3	+80±4	±19.3	-46± 7	-68±4	-85± 4
80/81	±14.2	+53±10	+76±5	+93±5	±11.2	-51± 5	-73±3	-90± 2
81/82	±13.9	+87±12	+90±6	+92±3	±16.1	-65± 8	-80±4	-92± 3

Table 10. Io (E-2): Orbital Residuals

Appar.	Time	Orbital Arc	Kilometers	Sig.
1976/77	+2^{s}4±2^{s}8	+0°006±0°007	+42±49	--
77/78	-2.8±3.1	-0.007±0.007	-49±54	--
78/79	-4.1±3.0	-0.010±0.007	-71±52	--
79/80	-3.7±4.8	-0.009±0.011	-64±83	--
80/81	+1.7±4.8	+0.004±0.011	+29±83	--
81/82	-4.6±4.1	-0.011±0.010	-80±71	--
Mean	-1.8±1.3	-0.004±0.003	-31±23	--

Table 11. Io (E-2): Estimated Diameters

Appar.	(D-R) Time Difference	Diameter (km.) Prelim.	Corrected	Diff. from Std.
1976/77	208^{s}0 ± 5^{s}7	3604 ± 99	3418 ± 94	-222 (- 6.1 %)*
77/78	199.2 ± 6.2	3451 ± 107	3363 ± 104	-277 (- 7.6 %)**
78/79	175.6 ± 6.0	3042 ± 104	3034 ± 104	-606 (-16.6 %)**
79/80	195.4 ± 9.5	3386 ± 165	3369 ± 164	-271 (- 7.4 %)
80/81	217.5 ± 9.6	3768 ± 166	3662 ± 161	+ 22 (+ 0.6 %)
81/82	197.0 ± 8.1	3413 ± 140	3240 ± 133	-400 (-11.0 %)**
Mean	------------	----------	3348 ± 85	-292 (- 8.0 %)*

C. Io: Summary

Io was the most often-timed Galilean satellite, chiefly because it experiences eclipses more frequently than the others. However, we cannot observe both disappearance and reappearance for the same eclipse of Io, which probably contributed to the fact that there were only about two-thirds as many disappearance timings as reappearance timings. Compared with the other satellites, the fading or brightening of Io is unusually rapid, so that the variation among observers' timings is comparatively small. The mean standard error using the A.A. ephemeris was ± 25 seconds, which was reduced to ± 16 seconds when the E-2 ephemeris was used.

The effect of aperture was statistically significant in 19 of the 26 cases studied (a "case" is a particular event type for a particular apparition for a particular ephemeris). Nonetheless, there were sizeable differences in the magnitude of the aperture effect (B) between disappearance and reappearance and between apparitions. In the former case, some of this difference may be due to psychological differences between the perception of a visible object vanishing and of a previously invisible object appearing. However, at present, there is no complete explanation for the large variation of the B-coefficient from apparition to apparition, although much of this change may be due to random error.

It is quite clear that Io's observed position deviated markedly from the predictions of The Astronomical Almanac; Io was significantly "early" for every apparition studied. In complete contrast, Io's position never deviated significantly from that predicted by the E-2 ephemeris. Likewise, in every apparition, there was a significant difference between the A.A. and the E-2 residuals. The observed deviations from each ephemeris are graphed by apparition in Figure 1. When time-series regression was used, neither set of residuals showed a consistent trend over time. However, it is interesting that the apparent changes in the Io residuals, based on the E-2 ephemeris, seem to be reflected, with greater amplitude, in the A.A.-residuals. Indeed, there was a highly-significant correlation of +0.955 between the two sets of residuals, and the deviation of Io from the A.A. ephemeris can be predicted from its deviation from the E-2 ephemeris with a standard error of only ± 3.5 seconds [Dev. (A.A.) = $-94^{s}.8$ + 3.26 Dev.(E-2)]. Were this correlation between the two sets of residuals due to observation error, one would expect them to have the same amplitude. Thus, it appears likely that there is some consistent factor influencing Io's motion which is unaccounted for in the A.A. ephemeris and is partially accounted for in the E-2 ephemeris.

Using the results of the analyses of eclipse timings to calculate Io's diameter is a check of the accuracy of the timings and of the analysis. Although the 6-apparition mean diameter for Io using the A.A. ephemeris (3621 km.) was very close to the Voyager value (3640 km.), this result appears due to luck, because the E-2-derived mean was 292 km. too small. Indeed, in half the cases, the calculated diameter differed significantly from the standard. Most frequently, the calculated diameter tended to be too small.

(to be continued)

JUPITER SATELLITE ECLIPSE EPHEMERIS FOR 1984

By: John E. Westfall, A.L.P.O. Assistant Jupiter Recorder, Eclipse Timings

The table of Galilean satellite eclipse times which follows on pages 54 and 55 is a condensed version of the "E-2" ephemeris, kindly furnished to the A.L.P.O. by Dr. Jay H. Lieske of the Jet Propulsion Laboratory. Originally in Ephemeris Time (E.T.), the eclipse predictions given here have been converted to Universal Time (U.T.) and have been rounded to 1 minute in order to prevent observer bias. Each event's entry is given in the following order:

Event Type--Satellite number ("1" = Io, "2" = Europa, "3" = Ganymede, "4" = Callisto, followed by "D" for eclipse disappearance, "R" for eclipse reappearance, and "C" for a close approach to the shadow, meaning a possible partial eclipse.

Month number (2 digits) and day number (2 digits).
Hour (2 digits) and minute (2 digits), U.T.
Apparent distance of satellite from Jupiter's limb in Jovian radii.

Observers should note that the observed time of eclipse may differ from the predicted by up to several minutes. The difference depends partially on telescope aperture, and mean differences for the last several apparitions are given below (where positive values mean that the observed event is later than predicted, and negative values mean earlier than predicted):

Event	Aperture, cm. (in.)		
Type	6 (2.4")	10 (4")	20 (8")
1D	+ $1^{m}.2$	+ $1^{m}.4$	+ $1^{m}.5$
1R	- 0.9	- 1.2	- 1.4
2D	+ 1.1	+ 1.5	+ 1.8
2R	- 0.7	- 1.2	- 1.5
3D	+ 3.4	+ 4.4	+ 5.1
3R	- 4.0	- 4.6	- 5.2
4D	+ 3	+ 4	+ 5
4R	- 1	- 3	- 5

The times for satellite 4 (Callisto) are uncertain for the reason that Callisto last underwent an eclipse in January, 1981. Because eclipses of this satellite are fairly rare, observers are urged to time them whenever possible. Eclipses of Callisto are predicted for the following dates in 1984:

Jupiter Galilean Satellite Eclipse Ephemeris for 1984

3D 0101 0146 0.5	3R 0220 0824 0.6	4C 0405 1816 4.1	1D 0520 0632 0.7
1D 0101 1110 0.3	1D 0221 1856 0.9	2R 0405 1855 0.0	2D 0521 2113 1.1
1D 0103 0539 0.3	2D 0223 0054 1.4	1D 0406 0045 1.1	1D 0522 0101 0.7
2D 0104 0656 0.4	1D 0223 1325 0.9	1D 0407 1913 1.1	3D 0523 0906 1.7
1D 0105 0008 0.3	1D 0225 0753 0.9	2D 0409 0539 1.7	3R 0523 1207 0.1
1D 0106 1836 0.3	2D 0226 1411 1.4	1D 0409 1341 1.1	1D 0523 1929 0.7
2D 0107 2013 0.5	1D 0227 0221 0.9	3D 0410 0919 2.6	2D 0525 1031 1.0
3D 0108 0805 0.8	3D 0227 0933 2.3	3R 0410 1215 1.1	1D 0525 1358 0.7
1D 0108 1305 0.4	3R 0227 1224 0.8	1D 0411 0810 1.1	4D 0525 2338 2.4
1D 0110 0733 0.4	1D 0228 2050 0.9	2D 0412 1856 1.7	4R 0526 0101 1.9
2D 0111 0930 0.6	2D 0301 0328 1.5	1D 0413 0238 1.1	1D 0527 0826 0.6
1D 0112 0202 0.4	1D 0301 1518 0.9	1D 0414 2106 1.0	2D 0528 2349 0.9
1D 0113 2030 0.4	1D 0303 0917 1.0	2D 0416 0814 1.6	1D 0529 0254 0.6
2D 0114 2247 0.7	2D 0304 1645 1.5	1D 0416 1535 1.0	3D 0530 1304 1.4
3D 0115 0945 1.0	1D 0305 0415 1.0	3D 0417 1317 2.6	1D 0530 2123 0.6
1D 0115 1459 0.4	3D 0305 1331 2.4	3R 0417 1614 1.0	2D 0601 1307 0.9
1D 0117 0927 0.5	3R 0305 1622 0.9	1D 0418 1003 1.0	1D 0601 1551 0.5
2D 0118 1204 0.7	1D 0306 2243 1.0	2D 0419 2132 1.6	1D 0603 1019 0.5
1D 0119 0356 0.5	2D 0308 0602 1.5	1D 0420 0431 1.0	2D 0605 0226 0.8
1D 0120 2224 0.5	1D 0308 1712 1.0	1D 0421 2259 1.0	1D 0605 0448 0.5
2D 0122 0121 0.8	1D 0310 1140 1.0	4C 0422 1217 3.8	3D 0606 1703 1.1
3D 0122 1343 1.3	2D 0311 1920 1.6	2D 0423 1050 1.6	1D 0606 2316 0.5
1D 0122 1653 0.5	1D 0312 0608 1.0	1D 0423 1728 1.0	2D 0608 1544 0.6
1D 0124 1121 0.6	3D 0312 1729 2.5	3D 0424 1715 2.5	1D 0608 1745 0.4
2D 0125 1437 0.9	3R 0312 2021 1.0	3R 0424 2013 0.9	1D 0610 1213 0.4
1D 0126 0550 0.6	1D 0314 0037 1.0	1D 0425 1156 1.0	4D 0611 1729 1.2
1D 0128 0018 0.6	2D 0315 0837 1.6	2D 0427 0007 1.6	4R 0611 1914 0.6
2D 0129 0354 0.9	1D 0315 1905 1.0	1D 0427 0624 1.0	2D 0612 0502 0.5
3D 0129 1741 1.5	1D 0317 1333 1.0	1D 0429 0053 1.0	1D 0612 0641 0.3
1D 0129 1847 0.6	2D 0318 2154 1.6	2D 0430 1325 1.5	3D 0613 2102 0.8
3R 0129 2028 0.1	1D 0319 0802 1.0	1D 0430 1921 1.0	1D 0614 0110 0.3
1D 0131 1315 0.7	3D 0319 2126 2.6	3D 0501 2113 2.4	2D 0615 1820 0.4
2D 0201 1711 1.0	4C 0320 0015 4.0	3R 0502 0012 0.8	1D 0615 1938 0.3
1D 0202 0744 0.7	3R 0320 0019 1.1	1D 0502 1349 0.9	1D 0617 1407 0.2
1D 0204 0212 0.7	1D 0321 0230 1.0	2D 0504 0243 1.5	2D 0619 0739 0.3
2D 0205 0628 1.1	2D 0322 1112 1.6	1D 0504 0818 0.9	1D 0619 0835 0.2
1D 0205 2041 0.7	1D 0322 2058 1.1	1D 0506 0246 0.9	3D 0621 0100 0.4
3D 0205 2138 1.7	1D 0324 1527 1.1	2D 0507 1601 1.4	1D 0621 0304 0.2
3R 0206 0026 0.3	2D 0326 0029 1.7	1D 0507 2114 0.9	2D 0622 2057 0.2
1D 0207 1509 0.7	1D 0326 0955 1.1	3D 0509 0111 2.2	1D 0622 2132 0.1
2D 0208 1945 1.1	3D 0327 0123 2.6	3R 0509 0410 0.6	1D 0624 1600 0.1
1D 0209 0937 0.8	3R 0327 0417 1.1	4D 0509 0552 3.3	2D 0626 1016 0.1
1D 0211 0406 0.8	1D 0328 0423 1.1	4R 0509 0643 3.0	1D 0626 1029 0.1
2D 0212 0903 1.2	2D 0329 1346 1.7	1D 0509 1542 0.9	1D 0628 0457 0.0
1D 0212 2234 0.8	2R 0329 1620 0.0	2D 0511 0519 1.3	3D 0628 0458 0.1
3D 0213 0136 1.9	1D 0329 2251 1.1	1D 0511 1011 0.9	4D 0628 1123 0.0
3R 0213 0425 0.5	1D 0331 1720 1.1	1D 0513 0439 0.8	1R 0630 0140 0.0
1D 0214 1703 0.8	2D 0402 0304 1.7	2D 0514 1837 1.3	2R 0630 0213 0.0
2D 0215 2220 1.3	2R 0402 0538 0.0	1D 0514 2307 0.8	1R 0701 2009 0.0
1D 0216 1131 0.8	1D 0402 1148 1.1	3D 0516 0508 2.0	1R 0703 1437 0.1
1D 0218 0600 0.8	3D 0403 0521 2.7	3R 0516 0808 0.4	2R 0703 1532 0.1
2D 0219 1137 1.3	3R 0403 0816 1.1	1D 0516 1736 0.8	1R 0705 0906 0.1
1D 0220 0028 0.9	1D 0404 0616 1.1	2D 0518 0755 1.2	3R 0705 1203 0.3
3D 0220 0534 2.1	2D 0405 1621 1.7	1D 0518 1204 0.8	1R 0707 0334 0.2

March 20
April 5, 22
May 9, 25/26

June 11, 28
July 15, 31/Aug. 1
August 17

September 3, 20
October 6/7, 23
November 9, 26
December 12/13, 29

The Callisto events of March 20, April 5, April 22, and May 9 may be partial eclipses. Callisto should be watched for at least an hour before and after mid-event on those dates, and its brightness periodically compared with the other satellites. It would be very rewarding if observers equipped with photoelectric photometers made frequent, accurately-timed measures at these times; to the best of this writer's knowledge, no one has ever photoelectrically recorded a partial eclipse of Callisto.

Jupiter Galilean Satellite Eclipse Ephemeris for 1984 (continued)

2R 0707 0450 0.2	2R 0822 0956 1.5	3D 1006 1253 1.0	3D 1118 1254 0.2
1R 0708 2203 0.2	1R 0823 2226 0.9	3R 1006 1610 2.8	1R 1118 1600 0.8
1R 0710 1630 0.2	3D 0824 1252 0.7	4D 1006 2320 3.4	3R 1118 1616 2.0
2R 0710 1810 0.3	3R 0824 1605 2.4	4R 1007 0238 4.7	2R 1119 0637 1.2
1R 0712 1100 0.3	1R 0825 1657 0.9	1R 1007 0428 1.1	1R 1120 1029 0.8
3R 0712 1603 0.6	2R 0825 2314 1.5	2R 1007 1458 1.7	1R 1122 0458 0.7
1R 0714 0529 0.3	1R 0827 1125 1.0	1R 1008 2257 1.1	2R 1122 1955 1.2
2R 0714 0728 0.5	1R 0829 0554 1.0	1R 1010 1726 1.1	1R 1123 2327 0.7
4D 0715 0519 0.3	2R 0829 1233 1.6	2R 1011 0417 1.7	1R 1125 1755 0.7
4R 0715 0739 1.1	1R 0831 0023 1.0	1R 1012 1154 1.1	3R 1125 2016 1.8
1R 0715 2357 0.3	3D 0831 1652 0.8	3D 1013 1653 1.0	4D 1126 0527 1.5
1R 0717 1826 0.4	3R 0831 2006 2.5	3R 1013 2010 2.7	4R 1126 0911 3.0
2R 0717 2047 0.6	1R 0901 1852 1.0	1R 1014 0623 1.1	2R 1126 0913 1.1
1R 0719 1254 0.4	2R 0902 0152 1.6	2R 1014 1735 1.7	1R 1127 1224 0.7
3R 0719 2003 1.0	4D 0903 1116 3.2	1R 1016 0052 1.1	1R 1129 0653 0.7
1R 0721 0723 0.4	1R 0903 1320 1.0	1R 1017 1921 1.0	2R 1129 2230 1.0
2R 0721 1006 0.7	4R 0903 1414 4.4	2R 1018 0654 1.6	1R 1201 0122 0.6
1R 0723 0152 0.5	1R 0905 0749 1.0	1R 1019 1350 1.0	1R 1202 1951 0.6
1R 0724 2020 0.5	2R 0905 1511 1.6	3D 1020 2053 0.9	3R 1203 0016 1.5
2R 0724 2325 0.8	1R 0907 0218 1.0	3R 1021 0012 2.6	2R 1203 1148 0.9
1R 0726 1449 0.5	3D 0907 2052 0.9	1R 1021 0829 1.0	1R 1204 1419 0.6
3R 0727 0004 1.3	3R 0908 0006 2.7	2R 1021 2012 1.6	1R 1206 0848 0.6
1R 0728 0915 0.6	1R 0908 2047 1.1	1R 1023 0247 1.0	2R 1207 0106 0.9
2R 0728 1243 0.9	2R 0909 0429 1.7	4D 1023 1722 3.0	1R 1208 0317 0.5
1R 0730 0346 0.6	1R 0910 1516 1.1	4R 1023 2049 4.4	1R 1209 2146 0.5
1R 0731 2215 0.6	1R 0912 0944 1.1	1R 1024 2116 1.0	3R 1210 0418 1.3
4D 0731 2317 1.5	2R 0912 1748 1.7	2R 1025 0930 1.6	2R 1210 1423 0.8
4R 0801 0150 2.5	1R 0914 0413 1.1	1R 1026 1545 1.0	1R 1211 1615 0.5
2R 0801 0203 1.0	3D 0915 0053 1.0	3D 1028 0053 0.7	4D 1212 2330 0.5
1R 0802 1643 0.7	3R 0915 0408 2.7	3R 1028 0413 2.5	4R 1213 0322 2.0
3D 0803 0054 0.0	1R 0915 2242 1.1	1R 1028 1014 1.0	1R 1213 1043 0.5
3R 0803 0404 1.6	2R 0916 0707 1.7	2R 1028 2248 1.5	2R 1214 0341 0.7
1R 0804 1112 0.7	1R 0917 1711 1.1	1R 1030 0443 1.0	1R 1215 0512 0.5
2R 0804 1521 1.1	1R 0919 1140 1.1	1R 1031 2312 0.9	1R 1216 2341 0.4
1R 0806 0541 0.7	2R 0919 2026 1.7	2R 1101 1207 1.5	3R 1217 0818 1.1
1R 0808 0010 0.7	4D 0920 0517 3.5	1R 1102 1741 0.9	2R 1217 1659 0.6
2R 0808 0440 1.2	4R 0920 0826 4.7	3D 1104 0454 0.6	1R 1218 1810 0.4
1R 0809 1838 0.8	1R 0921 0608 1.1	3R 1104 0814 2.3	1R 1220 1238 0.4
3D 0810 0454 0.3	3D 0922 0453 1.1	1R 1104 1209 0.9	2R 1221 0616 0.6
3R 0810 0805 1.9	3R 0922 0809 2.8	2R 1105 0126 1.4	1R 1222 0707 0.4
1R 0811 1307 0.8	1R 0923 0037 1.1	1R 1106 0638 0.9	1R 1224 0136 0.3
2R 0811 1759 1.3	2R 0923 0944 1.7	1R 1108 0107 0.9	3R 1224 1220 0.8
1R 0813 0736 0.8	1R 0924 1906 1.1	2R 1108 1443 1.4	2R 1224 1934 0.5
1R 0815 0204 0.8	1R 0926 1335 1.1	4D 1109 1124 2.3	1R 1225 2005 0.3
2R 0815 0718 1.3	2R 0926 2305 1.7	4R 1109 1500 3.8	1R 1227 1434 0.3
1R 0816 2033 0.9	1R 0928 0804 1.1	1R 1109 1936 0.9	2R 1228 0851 0.4
3D 0817 0853 0.5	3D 0929 0853 1.1	3D 1111 0854 0.4	1R 1229 0902 0.2
3R 0817 1205 2.2	3R 0929 1209 2.8	3R 1111 1215 2.2	4R 1229 2131 1.0
4D 0817 1716 2.5	1R 0930 0233 1.1	1R 1111 1405 0.9	1R 1231 0351 0.2
4R 0817 2002 3.6	2R 0930 1221 1.7	2R 1112 0401 1.3	3R 1231 1620 0.5
1R 0818 1502 0.9	1R 1001 2101 1.1	1R 1113 0834 0.8	2R 1231 2209 0.3
2R 0818 2036 1.4	1R 1003 1530 1.1	1R 1115 0302 0.8	
1R 0820 0930 0.9	2R 1004 0140 1.7	2R 1115 1719 1.3	
1R 0822 0359 0.9	1R 1005 0959 1.1	1R 1116 2131 0.8	

Note by Editor. The purpose of these tables on pages 54 and 55 is to help observers plan their studies of future eclipses of the Galilean satellites. Unless the tables are so used, this space has not been well used. It will be noted that the tables include all eclipses and hence are fully as useful to our readers overseas as to the ones in the United States. A fairly accurate clock drive is just about essential to the successful observation of eclipse disappearances and reappearances. The experienced observer will develope his own techniques for detecting the "first speck" and "last speck" of a satellite at the edge of the umbra. Your variable star observing friend may have some good suggestions. With reappearances it is essential to know where to look for the initial visibility of the satellite. Diagrams like those in the 1983 Astronomical Almanac, pg. F17 et seq., may be most helpful.

THE OCCULTATION OF 1 VULPECULAE BY THE MINOR PLANET PALLAS: A REPORT

By: William T. Douglass, Past President, Southern Cross Astronomical Society,
Donald C. Parker, MD and Jeff D. Beish, A.L.P.O. Mars Recorders,
Institute for Planetary Research Observatories, and
James O. Martin and Donald R. Monger, Astronomers,
U.S. Naval Observatory Time Service

Abstract

On May 29, 1983 the minor planet Pallas occulted the 4.8-magnitude star 1 Vulpeculae. This event was observed by the authors with the aid of a photoelectric photometer, a precision strip chart recorder, and a Cesium beam frequency standard ("atomic clock"). In addition to obtaining very precise timings of the occultation and later reappearance, the authors found good evidence for the existence of a companion for 1 Vulpeculae. Based on the data derived from the photometer tracing and published magnitude, spectral type, and parallax values, the authors present calculations of the stars' magnitudes, separation, and diameters.

Shortly before 05:00 hrs., U.T. on May 29, 1983 the 4.8-magnitude star 1 Vulpeculae was occulted by the minor planet Pallas. This rare event was visible over South Florida. In addition to more precisely defining Pallas' orbit, observing this occultation could yield other important information: whether the star (a spectroscopic binary) could be resolved and the separation of the components measured and whether a possible satellite of Pallas could be found. It was essential, therefore, that the observations be as quantitative as possible. The following report not only presents the results of these observations but also reveals the high degree of accuracy that can be achieved with today's amateur instruments and professional cooperation.

Methods and Materials

Photoelectric observations were made at the observatory of William T. Douglass in S. Miami, Fla. (N 25° 42' 37", W 80° 18' 02"; Elevation 3 meters). The primary instrument was a permanently mounted, well-aligned 35.6-cm. f/10 Schmidt-Cassegrain. Guiding and visual timings were made through a 12.7-cm. Schmidt-Cass.

Light intensity was measured with an Optec SSP solid state photoelectric photometer set on "fast" response time (0.05 sec.). The specially ordered photodiode had an improved blue response. Recordings were made on a Heathkit strip chart recorder at 10 inches per minute. When travelling at maximum speed, the recorder's pen takes 0.5 seconds to traverse the full width of the chart paper (10 ins.). The height of the tracing of the occultation was approximately 5 inches (13 cms.).

Timing was accomplished by means of a PC118 Cesium beam frequency standard ("atomic clock") which was kindly furnished and operated by U.S. Naval Observatory astronomers James Martin and Donald Monger. When the clock was connected to the recorder, a sharp blip was marked on the chart each second. The Cesium clock printed 67 consecutive one second time blips on the chart paper 5 minutes before, and again 4 minutes after the occultation. These signals and the chart paper itself were then carefully measured by Mr. Martin, and a least squares analysis was performed to determine the uniformity of the paper feed and the accuracy of the chart lines. The actual times of the various parts of the occultation were then determined from chart readings applied to the slope resulting from this regression line according to the formula:

$$T = T_0 + Bx, \qquad (1)$$

where "T" is the U.T. of the event, "T_0 is the y-intercept, or reference time (4^h 50^m $00^s.000$ U.T.), "B" is the slope, and "x" is the chart reading on the time axis. Thus, we are regarding time as a function of distance measured on the chart.

The star was centered on the photometer's diode by slow motion slewing in R.A. and declination until a maximum deflection occurred on the photometer's output. It was kept there by careful guiding with the auxiliary telescope. A visual timing of the event was also made through the guide scope, using a modified Cronos electronic stopwatch synchronized with the Cesium clock.

Results

I. CHART ACCURACY

The 67 consecutive time marks on either side of the occultation were plotted against the chart time scale. The resultant slope was 5.993 seconds per inch. The least squares analysis yielding this slope had a correlation coefficient of 1.0000. Thus the strip recorder and paper had sufficient accuracy to time the events of the occultation by using the method described in the previous section.

II. PHOTOELECTRIC TIMES

The tracing of the occultation was analyzed by Mr. Martin, who divided the event into eight parts (T1-T8), each corresponding to a sudden change in direction of the pen. These are depicted in Figure 2. They can be seen on a copy of the actual recording. These times are referenced to the baseline time T_0, which was $04^h\ 50^m\ 00^s.000$ U.T.

The star's disappearance occurred at $04^h\ 55^m\ 43^s.18$ (TI); it reappeared at $04^h\ 56^m\ 19^s.65$ U.T. (T5). The duration was thus 36.47 seconds.

TABLE I

Event	Chart(in.)	T (sec)	RMS (sec.)	U.T. Event
T1	58.115	343.179	0.033	$04^h\ 55^m\ 43^s.18$
T2	58.160	343.449	.033	$04^h\ 55^m$ 43.45
T3	58.200	343.689	.033	$04^h\ 55^m$ 43.69
T4	58.260	344.048	.033	$04^h\ 55^m$ 44.05
T5	64.200	379.647	.033	$04^h\ 56^m$ 19.65
T6	64.260	380.006	.033	$04^h\ 56^m$ 20.01
T7	64.280	380.126	.033	$04^h\ 56^m$ 20.13
T8	64.300	380.246	.033	$04^h\ 56^m$ 20.25

(RMS = root mean square)

The time required for complete disappearance on the chart (T1-T4) was 0.87 sec., while that for reappearance (T5-T8) was 0.60 secs. These are significantly longer than the time normally required for the pen to move 13 cms. The reason for this difference appears to be the two brief leveling-off periods T2-T3 (0.24 sec.) and T6-T7 (0.12 sec.). These two features appear to represent a real phenomenon. They display remarkable similarities. For example, the times from first disappearance or reappearance to resumption of rapid slope (T1-T3 and T5-T7) are 0.51 and 0.48 seconds respectively. Also, if one includes the baseline or "zero" on the chart, the vertical distance from the point of slope interruption to the point where vertical pen motion stops (T5 and T8) are identical on disappearance and reappearance. Possible reasons for these slope interruptions will be discussed later.

III. VISUAL TIMING

While guiding on the star, Dr. Parker made the following visual timings: disappearance at $04^h\ 55^m\ 43^s.83$; reappearance at $04^h\ 56^m\ 20^s.47$; duration 36.64 secs. While observers at other sites reported gradual fading, Parker observed the brightness changes to be quite sudden. He was, however, observing the out-of-focus image in order to guide accurately.

IV. OTHER EXTINCTIONS

The star was observed continuously either visually or photometrically from 4:50 to 5:08 U.T. Although 1 Vulpeculae was occasionally dimmed by passing clouds, it was in view all during this time; and no secondary occultations were noted.

V. ATMOSPHERIC CONDITIONS

Seeing: Quite variable due to rapidly moving nearby cumulus. Scintillation was, however, not excessive.

Transparency: During the observation period a "hole" opened in the clouds. The transparency was quite good in this area. J. Beish reported being able to see 1 Vulpeculae with the unaided eye. This would represent a transparency of 4.5-5.0 on the A.L.P.O. scale. Inspection of the chart, especially just before and after the occultation, will reveal variations in transparency, with marked improvement occurring after the event.

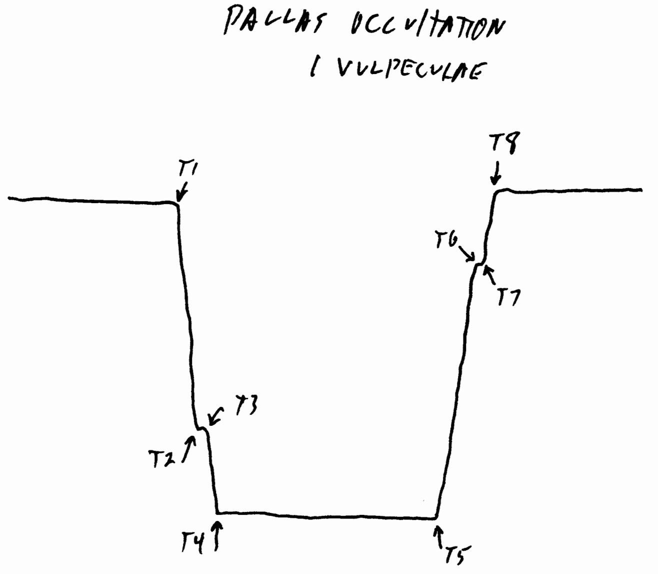

Figure 2. A schematic of the photoelectric tracing obtained during the occultation of 1 Vulpeculae by Pallas. The events, T-1 through T-8, are described in the text. Time increases to the right; brightness increases upward. Contributed by Donald C. Parker.

Discussion

Aside from the timings, the important finding in this report is the plateau during the star's trace in disappearance and reappearance. The authors are confident that these features in the curves result from a fainter companion star's being occulted 0.51 seconds after the primary and reappearing 0.48 seconds after the brighter star. The closeness of these times, especially in view of a small ink skip on the brightening curve, is highly suggestive of a binary star. Furthermore, on the vertical scale the brightness of this alleged companion measures nearly the same on fading (0.32 of the total light) as it does on brightening (0.33 of the total).

While these arguments strongly favor evidence for the presence of a companion, the plateaus in our curves could conceivably be due to scintillation or to dark features on the surface of the star. To investigate these alternatives, we made some rough calculations. The star 1 Vulpeculae is known to be quite distant; its parallax is listed as 0.01 arc-sec.[1] This value would place it 326 light-years from the Earth. At that distance, 1 Vulpeculae would have an absolute magnitude, M, of -0.22. (This result agrees well with an extinction-corrected published value of -0.4[1].) The star's spectral type is B5.[2] The authors compared 1 Vulpeculae's luminosity to those of other B-type stars such as Zeta Aurigae B and Rigel and found that 1 Vulpeculae should have a diameter of approximately 3 x 10^6 Km. Even if the star had twice this diameter, at a distance of 100 parsecs its disk would subtend an angle of only 0.0003 arc-seconds. Since Pallas had a rate of apparent motion of 0.0061 arc-seconds per second, it would then take only 0.05 seconds completely to occult the star. Since the plateaus occur approximately 0.3 seconds after the initial fading or brightening, they are most likely not caused by light from the primary star; nor are they due to scintillation.

It is of interest that a number of visual observers reported a gradual fading of the star. This result is most likely due to the 0.5-second delay in the occultation of the fainter component: the eye and brain fused the fading into a smooth curve rather than a stepwise event. While the brain is capable of detecting the flashing of a high intensity light at rates of up to 60 times per second, it has much less ability to discern flickering of low intensity illumination. This fact is actually due to a persistence of excitation of the retinal rods, which leads to flicker fusion at rates as low as 5-6 times per second.[3] It would be interesting to learn whether observers using large aperture instruments, with a resulting brighter star image, were able to detect a stepwise fading or brightening.

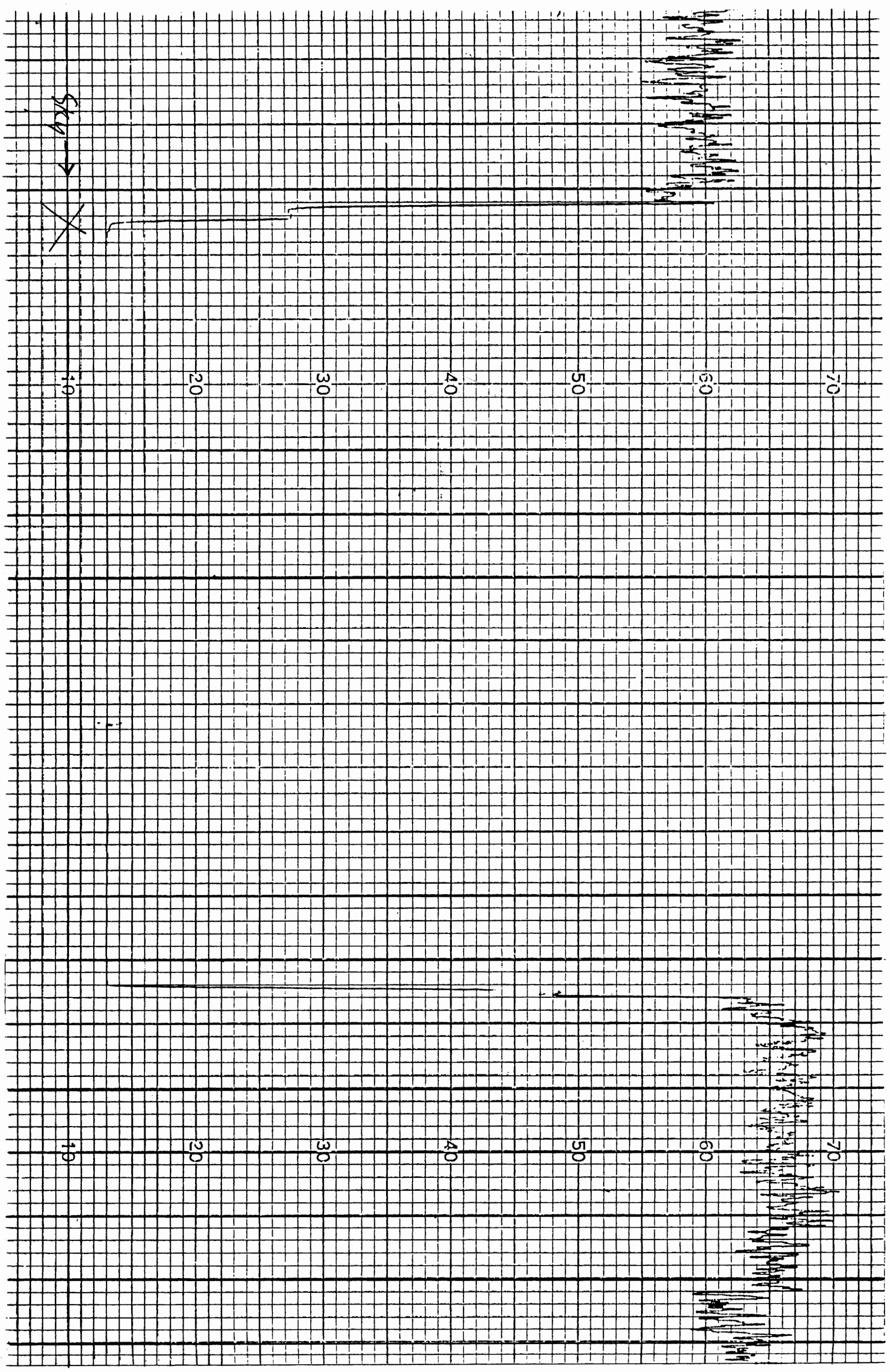

Figure 3. This is a Xerox copy of that portion of the photoelectric tracing showing the actual occultation of 1 Vulpeculae by Pallas. The "X" represents the level of background sky illumination. Contributed by Donald C. Parker.

From the tracing one can calculate the magnitudes of the two components of 1 Vulpeculae. While some star catalogues list slightly brighter visual magnitudes,[1,2] the authors adopted 4.8 for the star's total magnitude since that was the value published by I.O.T.A.[4] Also, the author's previous photometric measurements of other stars of known magnitude and color yielded an unfiltered corrected magnitude of close to 4.8 for the star. Measurement of the chart revealed that the fainter component (b) had about 1/3 the luminosity (L) of the whole system. Thus star "a" is twice as bright as star "b", or:

$$L_a/L_b = 2 \tag{2}$$

The difference in stellar magnitudes (Dm) will be:

$$Dm = 2.51 \log(L_a/L_b) = 0.75 \text{ magnitudes} \tag{3}$$

To find the magnitude of each component, one uses a 0 magnitude star for comparison:

$$m_{(a+b)} - m_0 = 2.51 \log(L_0/(L_a+L_b)) \tag{4}$$

$$\text{Then, since } L_a = 2L_b,\ L_b = (L_a+L_b)/3 \tag{5}$$

A 0 magnitude star is 82.9 times brighter than one of 4.8 stellar magnitude. Substituting this value for L_0 in equation (4) and using equation (5) yields:

$$m_b - m_0 = 2.51 \log(L_0/L_b) = 2.51 \log(82.9 \times 3)$$

Then <u>b = 6.0 magnitude</u>.

From equation (3) $m_a = 6.0 - 0.8$, so:

<u>a = 5.2 magnitude</u>.

Another data item which can be calculated from the results of the occultation is the diameter of each component of 1 Vulpeculae. Assuming a distance of 100 parsecs, the absolute magnitudes (M) of each component would be:

$$M_a = +0.24 \qquad M_b = +0.99$$

The authors selected Zeta Aurigae B as a comparison star since its spectral type (B7) is close to that of 1 Vulpeculae, and its size and luminosity are fairly accurately known.[5] This star's M is -1.6, and its radius is approximately 2.8×10^6 Km. From the absolute magnitudes, the luminosity ratios (DL) were calculated:

$$L_{zeta}/L_a = 5.44; \qquad L_{zeta}/L_b = 10.8$$

Then the radius (r) of each of 1 Vulpeculae's components was derived from the following relation:

$$r^2 = (2.8 \times 10^6)^2/DL$$

<u>Diameters: 1 Vul. a = 2.4×10^6Km; 1 Vul. b = 1.7×10^6Km</u>

Finally, one may calculate the angular separation of the two components in the direction perpendicular to Pallas' motion. (Since the stars' position angle is not known, the actual separation cannot be determined from the data.) The average time delay of star b's disappearance or reappearance was 0.50 seconds. Since the asteroid was moving across the sky at a rate of 0.0061 arc-seconds per second, the angular separation was 0.003 arc-seconds! At 100 parsecs this would represent a distance of 4.6×10^7 Km. This reveals the enormous one-dimensional resolution that can be obtained in occultation work.

It should be mentioned that the light contributed by Pallas was not included in the above calculations. Clouds prevented the accurate calibration required for Pallas' magnitude determination since a shift to a more sensitive scale on the photometer would have been required. It can be seen from Fig. 3, however, that the asteroid made a very small contribution to the total light (less than 6%). Since the calculations are presented for demonstrative purposes, the authors took the liberty of disregarding the small amount of light from Pallas. Inclusion of this factor would increase the length of this paper, cause confusion, and not significantly change the results.

Summary

The occultation of 1 Vulpeculae by the minor planet Pallas yielded some interesting findings. The authors hope that the measurement of accurate disappearance and reappearance times will help astronomers refine the asteroid's orbital elements and lead to better determinations of its size and shape. Another result was confirmation that 1 Vulpeculae is a double star. Many of the calculations performed in the previous section are based on published values for "m", spectral type, and parallax which have uncertain accuracy. The authors presented these calculations in order to point out the value of observing occultations. Perhaps the most important result of this occultation observation is a demonstration of what can be achieved with cooperation between amateur and professional astronomers.

Addendum

After completion of this paper, the authors were delighted to receive an International Astronomical Union telegram (Circular No. 3825) which reported the results of a photoelectric observation of the occultation of 1 Vulpeculae by Pallas. Observing near Presidio, Texas, W.B. Hubbard and H.J. Reitsema, of the Lunar and Planetary Laboratory, noted a two-step disappearance, with the brighter component occulted approximately 0.5 seconds before the fainter. They note that this interval corresponds to a separation of 0.003 arc-seconds. These workers measured a difference in brightness of 0.9 stellar magnitudes at 470 nm (0.470 microns) and 0.6 magnitudes at 800 nm. The photometer used in the present study employed an unfiltered diode with a maximum response at 850 nm. However, this detector has an extended blue sensitivity, with 50% peak response at 510 nm. Since it was unfiltered for the occultation observation, the magnitude difference calculated in this paper agrees well with those obtained by Hubbard and Reitsema.

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LUNA INCOGNITA: 1982-83 OBSERVATIONS AND 1984 OBSERVING SCHEDULE

By: John E. Westfall, A.L.P.O. Lunar Recorder

1982-83 Observations

The A.L.P.O.'s Luna Incognita program continued to collect and to analyze members' drawings and photographs of this lunar region during 1982-83. Our goal is to survey and map the lunar south and southwest limbs, an area of about 270,000 square kilometers which was not adequately photographed by the Lunar Orbiter and Apollo Missions in the 1960's and 1970's.

Thus, we are engaged in mapping the only remaining unmapped area on the Moon. One cause of interest in this region is due to the belief of some space scientists that the portions of it which are in perpetual shadow, due to high mountains and a continually-low Sun angle, may contain water ice--a valuable resource for a manned lunar base! Our project uses such sources as the "Watts Limb Profile Charts," Soviet Zond-8 and U.S. Orbiter-4 and -5 photographs, and previous and current Earth-based maps, drawings, and photographs. Despite this "historical" information, many gaps remain to be filled in by A.L.P.O. members' visual and photographic observations. Since the last report (JALPO, 29, Nos. 9-10 (Dec., 1982), pp. 180-183) was written, the following persons have contributed observations:

(text continued on page 64)

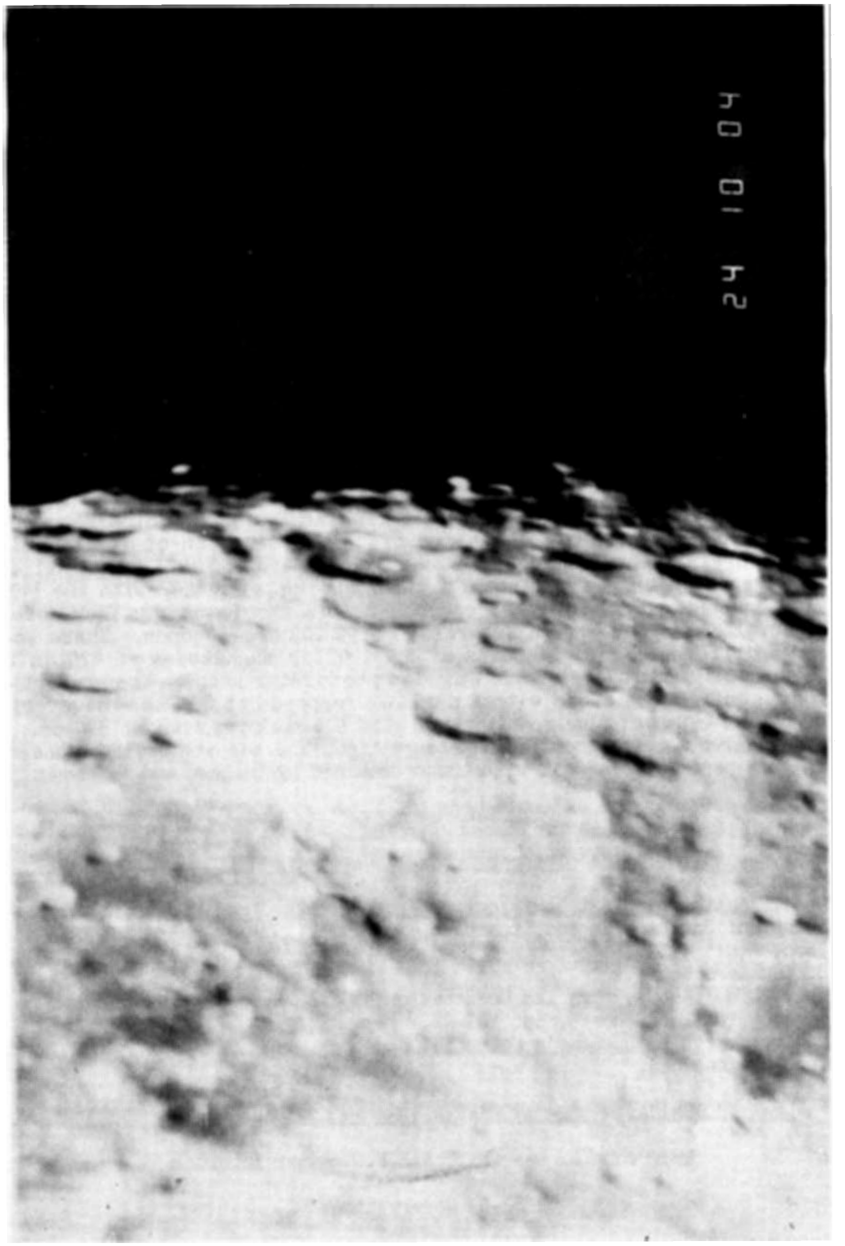

Figure 4. The southern limb of the Moon ("Zone A" of Luna Incognita), photographed by the French observer Michel Legrand on May 24, 1983, at 22:04 U.T. He used a 21-cm. telescope at Eff. f/80, exposing 2 seconds on Kodak 2415. South is at the top, the Sun to the left. Below center is the large walled-plain Clavius. Above center is Casatus, with a crater on its floor; and to the left of Casatus is the deep crater Newton. South of these two last craters are the peaks of the Leibnitz Mountains. (Lunar Data: Colong. 062°7; Solar latitude - 0°6; Geocentric librations 5°1 E/4°7 S.)

Note by Editor. On pg. 63 and elsewhere the term colongitude may be unfamiliar to many of our readers. It is the lunar western (IAU sense) longitude of the sunrise terminator, measured at the equator from the center of the Moon at mean librations. Colongitude is approximately 270° at New Moon, 0° at First quarter, 90° at Full Moon, and 180° at Last Quarter. The Sun's Selenographic Latitude, in the table on page 63, may be thought of as the tilt of the Moon's axis to the Sun. It has a maximum numerical value of about a degree and one-half, as compared to 23°27' for the Earth.

THE VISIBILITY OF "LUNA INCOGNITA" IN 1984

1984 U.T. Date	Solar Selenograph. Colong.	Lat.	Form(s)
JAN 19	097°9*	-1°1	B(-2/-4)
20	110.0*	-1.1	A(0/-6);B(0/-6)
21	122.2	-1.1	A(0/-6);B(+2/-6)
22	134.3	-1.1	A(+5/-6);B(+4/-6)
23	146.4	-1.2	A(+5/-6);B(+4/-6)
24	158.6	-1.2	A(+5/-6);B(+6/-6)
25	170.7	-1.2	B(+6/-4)
26	182.9*	-1.2	B(+6/-4)
FEB 16	078°5	-1°4	A(-5/-6)
17	090.6*	-1.5	A(0/-6);B(-2/-6)
18	102.8*	-1.5	A(0/-6);B(+2/-6)
19	114.9*	-1.5	A(+5/-6);B(+4/-6)
20	127.1	-1.5	A(+5/-6);B(+6/-6)
21	139.2	-1.5	B(+6/-4)
22	151.4	-1.5	B(+8/-4)
MAR 14	047°3	-1°5	A(-5/-6)
15	059.4	-1.5	A(-5/-6)
16	071.6	-1.5	A(0/-6)
17	083.7	-1.4	A(0/-6)
18	095.9*	-1.4	A(0/-6);B(+2/-6)
19	108.0*	-1.4	B(+4/-4)
20	120.2	-1.4	B(+6/-4)
APR 10	016°4	-1°2	A(-5/-6)
11	028.6	-1.1	A(-5/-6)
12	040.8	-1.1	A(-5/-6)
13	052.9	-1.1	A(0/-6)
14	065.1	-1.1	A(0/-6)
15	077.2	-1.0	A(0/-6)
MAY 07	345°8	-0°6	A(-5/-6)
08	358.0	-0.6	A(-5/-6)
09	010.2	-0.5	A(-5/-6)
10	022.4	-0.5	A(0/-6)
11	034.6	-0.4	A(0/-6)
12	046.8	-0.4	A(0/-6)
JUN 03	315°5	+0°1	A(-5/-6)
04	327.8	+0.2	A(-5/-6)
05	340.0	+0.2	A(0/-6)
06	352.2	+0.2	A(0/-6)
07	004.4	+0.3	A(0/-6)
08	016.7	+0.3	A(0/-6)
09	028.9	+0.3	A(0/-6)
JUN 27	248°6*	+0°7	B(-6/0)
JUL 01	297°7	+0°8	A(-5/-6)
02	309.9	+0.8	A(0/-6)
03	322.2	+0.9	A(0/-6)
04	334.4	+0.9	A(0/-6)
05	346.6	+0.9	A(0/-6)
06	358.9	+1.0	A(+5/-6)
JUL 24	218°6*	+1°3	B(-6/0)
25	230.8*	+1.3	B(-6/-2)
26	243.1*	+1.3	B(-6/-2)
JUL 30	292°1	+1°3	A(0/-6)
31	304.3	+1.3	A(0/-6)
AUG 01	316.6	+1.4	A(0/-6)
02	328.8	+1.4	A(+5/-6)
AUG 20	188°5*	+1°5	B(-6/0)
21	200.7*	+1.5	B(-8/-2)
22	212.9*	+1.5	B(-8/-2)
23	225.2*	+1.5	B&C(-8/-4)
24	237.4*	+1.5	B&C(-6/-4)
25	249.6*	+1.5	A(-5/-6);B&C(-6/-6)
AUG 29	298°6	+1°5	A(+5/-6)
SEP 16	158°1	+1°4	B(-6/0)
17	170.3	+1.4	B(-6/0)
18	182.5*	+1.4	B(-8/-2)
19	194.7*	+1.4	B&C(-8/-4)
20	206.9*	+1.4	B&C(-8/-4)
21	219.1*	+1.3	A(-5/-6);B&C(-6/-6)
22	231.4*	+1.3	A(-5/-6);B&C(-6/-6)
23	243.6*	+1.3	A(-5/-6);B&C(-4/-6)
OCT 14	139°6	+1°0	B(-6/0)
15	151.7	+1.0	B(-6/-2)
16	163.9	+0.9	B(-6/-4)
17	176.1	+0.9	B&C(-8/-4)
18	188.3*	+0.9	A(-5/-6);B&C(-8/-6)
19	200.5*	+0.8	A(-5/-6);B&C(-6/-6)
20	212.6*	+0.8	A(-5/-6);B&C(-6/-6)
21	224.8*	+0.8	A(-5/-6);B&C(-4/-6)
22	237.1*	+0.7	A(0/-6);B(-2/-6)
23	249.3*	+0.7	A(0/-6);B(0/-6)
NOV 10	108°4*	+0°3	B(-4/0)
11	120.6	+0.3	B(-6/-2)
12	132.7	+0.2	B(-6/-4)
13	144.9	+0.2	B(-6/-4)
14	157.0	+0.2	A(-5/-6);B&C(-6/-6)
15	169.2	+0.1	A(-5/-6);B&C(-6/-6)
16	181.3*	+0.1	A(-5/-6);B&C(-6/-6)
17	193.5*	+0.1	A(-5/-6);B&C(-4/-6)
18	205.7*	+0.0	A(-5/-6);B&C(-4/-6)
19	217.9*	+0.0	A(0/-6);B(-2/-6)
20	230.1*	-0.0	B(0/-4)
21	242.2*	-0.1	B(+2/-2)
DEC 09	101°2*	-0°5	B(-4/-2)
10	113.4*	-0.6	B(-6/-4)
11	125.5	-0.6	A(-5/-6);B&C(-4/-6)
12	137.6	-0.6	A(-5/-6);B&C(-4/-6)
13	149.8	-0.6	A(-5/-6);B&C(-4/-6)
14	161.9	-0.7	A(-5/-6);B&C(-4/-6)
15	174.0	-0.7	A(-5/-6);B(-2/-6)
16	186.2*	-0.7	A(0/-6);B(-2/-6)
17	198.4*	-0.8	B(0/-4)
18	210.5*	-0.8	B(0/-4)
19	222.7*	-0.8	B(+2/-2)

(text continued from page 61)

Name	Instrument(s)*	Number Contributed: Drawings	Photographs
Patrick Abbott	32 cm. RL	9	-
Charles Cyrus	32 cm. RL	3	-
James Fox	20 cm. RR	1	-
Francis Graham	15 cm. RL, 33 cm. RL	3	23
Francis & Charmaine Graham	15 cm. RL, 33 cm. RL	3	5
Francis Graham & Mary Benson	33 cm. RL	-	4
Francis Graham & Theresa Guzik	20 cm. RL, 33 cm. RL	5	36
Francis Graham & Daniel Potemra	33 cm. RL	2	11
Francis Graham, Robert Wamsley, & Douglas Ramey	33 cm. RL	-	4
Francis Graham, William Hall, Barton Levenson, & Theresa Guzik	33 cm. RL	-	2
Michel Legrand	21 cm. RL	-	3
John Westfall	25 cm. RL	1	-
1982-83 Total		27	88
Project Total		105	281

*RL = Reflector, RR = Refractor.

For another year, we are very appreciative to Mr. Francis Graham and his associates, who have contributed the bulk of our drawings and photographs. Mr. Graham has also helped provide us with historical data. We also welcome three new participants--Dr. Abbott, Mr. Cyrus, and Mr. Legrand. A recent Luna Incognita photograph by Mr. Legrand is reproduced here as Figure 4.

Observing Luna Incognita in 1984

Particularly because this region will be well-presented in 1984, additional observers are invited to participate in our project. Located as it is in the Moon's "marginal zone," Luna Incognita is best observed when lighting and libration conditions are optimal. The table, "The Visibility of 'Luna Incognita' in 1984," on page 63 gives those dates when these conditions are favorable.

Generally speaking, observers with at least 10-cm. (4-in.) refractors or catadioptics, or 15-cm. (6-in.) Newtonians can make useful drawings, particularly if they have experience in observing "easier" lunar areas. With slightly larger apertures (say, 20 cms. or more), there is also the potential for high-resolution photography.

Interested observers can obtain a "Luna Incognita Observer's Kit" from the writer; to do so, please send $1.50 (stamps preferred) to his address as given on the inside back cover. This kit contains a brief set of instructions, a graph to help select the appropriate outline chart for each date (the charts vary as to area and libration), and a map of the region as seen under optimum libration. Also included is a set of 34 outline charts for making drawings, each chart for a particular "Zone" and longitude/latitude libration combination.

The table on page 63 gives those dates in 1984 when Luna Incognita will be visible from the Earth. Whether a date is judged suitable for observing this region depends on both libration and solar lighting. In particular, no dates are given for the colongitude range 250°-290° because the Moon then appears too near the Sun. Also, in the table:

1. All data are for 0 hours, Universal Time (U.T.)
2. The "Forms" column indicates which of the set of outline charts is to be used on that date. The letters refer to the three Zones of Luna Incognita: "A" = south polar; "B" = intermediate (Hausen-Drygalski); "C" = northernmost portion. The numbers in parentheses give the chart's longitude/latitude librations, expressed in degrees.
3. Asterisked (*) colongitudes indicate a medium-to-low Sun angle for Zones B and C (i.e., colongitudes 090°-120° and 180°-250°). Note that the Sun angle is always low for Zone A.

As the observing schedule shows, Luna Incognita can be observed in every lunation, indeed for a total of 103 dates in 1984. Librations are quite favorable for some of these dates, exposing "Zone C" for the first time in several years (i.e., on 22 dates, 15 with a medium or low Sun angle). Zone B will be observable on 68 dates, 42 with a medium or low Sun. Zone A will be well-presented on 66 dates.

Particularly favorable dates are as follows:

Zone A--Favorable due to southerly solar latitude: JAN 20-24, FEB 16-20, MAR 14-18, and APR 10-15.

Zones B and C--Favorable longitude/latitude libration combination and a medium or low Sun angle: AUG 23-25, SEP 19-23, OCT 17-21, and NOV 16-18.

A.L.P.O. members who wish to take advantage of the favorable Luna Incognita observing opportunities in 1984 are invited to contact the writer.

THE 1980-1981 APPARITION OF SATURN

By: Julius L. Benton, Jr., A.L.P.O. Saturn Recorder

Abstract

Visual and photographic studies of the planet Saturn, its satellites, and its ring system were carried out with telescopes ranging in aperture from 8.3 cm (3.25 in.) to 32.0 cm. (12.5 in.) from 1980, November 26 through 1981, August 12. A total of 108 observations was amassed. Observational data suggest that only very marginal activity was apparent on the globe of Saturn, fairly consistent with the apparitions of 1978-79 and 1979-80. Eleven individuals contributed observations to the A.L.P.O. Saturn Section in 1980-81.

Observations of Saturn's northern hemisphere could be carried out more advantageously than in 1979-80, and the northern face of the rings came under close scrutiny throughout the apparition as well. For the subsequent years, on into the 1990's, Saturn will present to observers on Earth its northern regions for systematic investigation.

Numerous references are cited at the conclusion of the report for additional reading; and within the body of text are illustrations, tables, and graphs to clarify the analytical material.

Introduction

The present report deals with visual and photographic observations of the planet Saturn, its satellites, and its ring system for the period 1980, November 26 through 1981, August 12. Although substantial regions of the planet's southern hemisphere remained visible in 1980-81, it was the northern hemisphere of the globe and the north face of the rings which became increasingly open to our inspection during the 1980-81 apparition. Such will, of course, be true in the next several years as the rings continue to open up, providing better views of the northern global and ring features and associated phenomena. For the period given above, the numerical value of B, which denotes the planetocentric latitude of the Earth referred to the ring plane (positive when north), varied between +4.°189 and +7.°329. The rings were open to their maximum amount on 1981, January 12, while maximum closure took place on 1981, June 1, all for the period of observation just noted.

Opposition to the Sun took place on 1981, March $27^{d}05^{h}$ U.T.; and the apparent visual stellar magnitude of Saturn on that date was +0.6. The major axis of the ring system was then 43.″85 while on the same date the minor axis was 4.″25. Also on March 27th, the equatorial diameter of Saturn's globe was 19.″47; the polar diameter was 17.″42. At opposition the numerical value of B was +5.°561.

The contributing observers were as follows:

Observer	Location	No. Observations	Instrumentation*
Benton, Julius L.	Warrington, PA	3	8.3-cm. (3.25 in.) RR 10.2-cm. (4.0 in.) RR 30.0-cm. (12.0 in.) MAK
Boisclair, Norman J.	S. Glens Falls, NY	30	15.0-cm. (6.0 in.) S-C
Buczynski, D.G.	Lancaster, England	1	15.0-cm. (6.0 in.) RR
Copeland, Bennett	Baxley, GA	1	15.0-cm. (6.0 in.) NEW

Observer	Location	No. Observations (Continued)	Instrumentation*
Heath, Alan W.	Nottingham, England	31	30.0-cm. (12.0 in.) NEW
Hernandez, Carlos E.	Miami, FL	3	20.0-cm. (8.0 in.) S-C
Laureys, Roger	Vliermaalroot, Belgium	2	25.0-cm. (10.0 in) NEW
Pierce, William	Memphis, TN	2	20.0-cm. (8.0 in.) NEW
Robotham, Robert	Springfield, Ontario, Canada	20	8.3-cm. (3.25 in.) RR 20.0-cm. (8.0 in.) S-C 32.0-cm. (12.5 in.) NEW
Sabia, John D.	Scranton, PA	7	23.0-cm. (9.0 in.) RR
Troiani, Daniel M.	Chicago, IL	8	25.0-cm. (10.0 in.) NEW
	Total No. of Observers:	11	
	Total No. of Observations:	108	

*RR-Refractor; NEW-Newtonian; S-C-Schmidt-Cassegrain; MAK-Maksutov.

The distribution of observations by month in 1980-81 is presented in Figure 5 in the form of a histogram, the inspection of which indicates that the largest percentage of observations came in during the months of 1981, March through 1981, June (76.85% of the total received for the apparition). A decline in the number of submitted reports took place on either side of the peak period just mentioned. Considering the dates prior to and following opposition, it is noticed that 30.56% of the data were received up to 1981, March 27; and 69.44% were received after that time. As has been noted in past apparitions, similar percentages are common prior to and following opposition, suggesting that observers favor studying Saturn when the planet is conveniently placed in the evening sky.

The 1980-81 apparition came to a close as the planet Saturn entered the solar domain, conjunction taking place on 1981, October 06^d04^h U.T.

The author would like to express his sincere thanks to those colleagues mentioned in this report who faithfully participated in the observing programs of the A.L.P.O. Saturn Section. The continued meaningful observational work by such individuals is vital to the success and continuation of our systematic efforts, and all who share an interest in studies of the planet Saturn are welcome and are encouraged to join us in the years to come. New observers especially are urged to contact the writer, who will be pleased to discuss potential programs with them.

Section I. The Globe of Saturn

The descriptive, analytical report which follows has been derived from an exhaustive reduction of the total mass of observational data submitted to the A.L.P.O. Saturn Section throughout the 1980-81 apparition. The names of observers have been purposely omitted in the interest of brevity, except where the identities of individuals is pertinent to the data.

The instrumentation employed during 1980-81 ranged from 8.3 cm. (3.25 in.) to 32.0 cm. (12.5 in.) in aperture, with inherent differences understood in optical design, functional capability, and quality, together with a varying incidence of practical observational experience among participants in the program. A total of 108 observations reduces to the following percentages with respect to aperture categories:

90.74%.......Apertures 15.0 cm. (6.0 in.) and greater.
9.26%........Apertures ranging from 8.3 cm. (3.25 in.) to 10.2 cm. (4.0 in.).

Numerical tables, illustrations, and graphs accompany the present report; and reference to these is encouraged for increasing one's understanding of Saturnian phenomena in 1980-81. Refer to Figure 6 for the nomenclature of the belts, zones, and ring features used in this report.

Northern Portions of the Globe. Beginning with the immediately preceding apparition when Saturn's rings were edgewise to our line of sight, progressively more and more of the northern hemisphere of the globe could be seen to advantage by observers. As the rings continue to open up to their maximum extent over the next several years, the northern hemisphere can be studied effectively with varying apertures. In our discussions henceforth, at least until the next edgewise

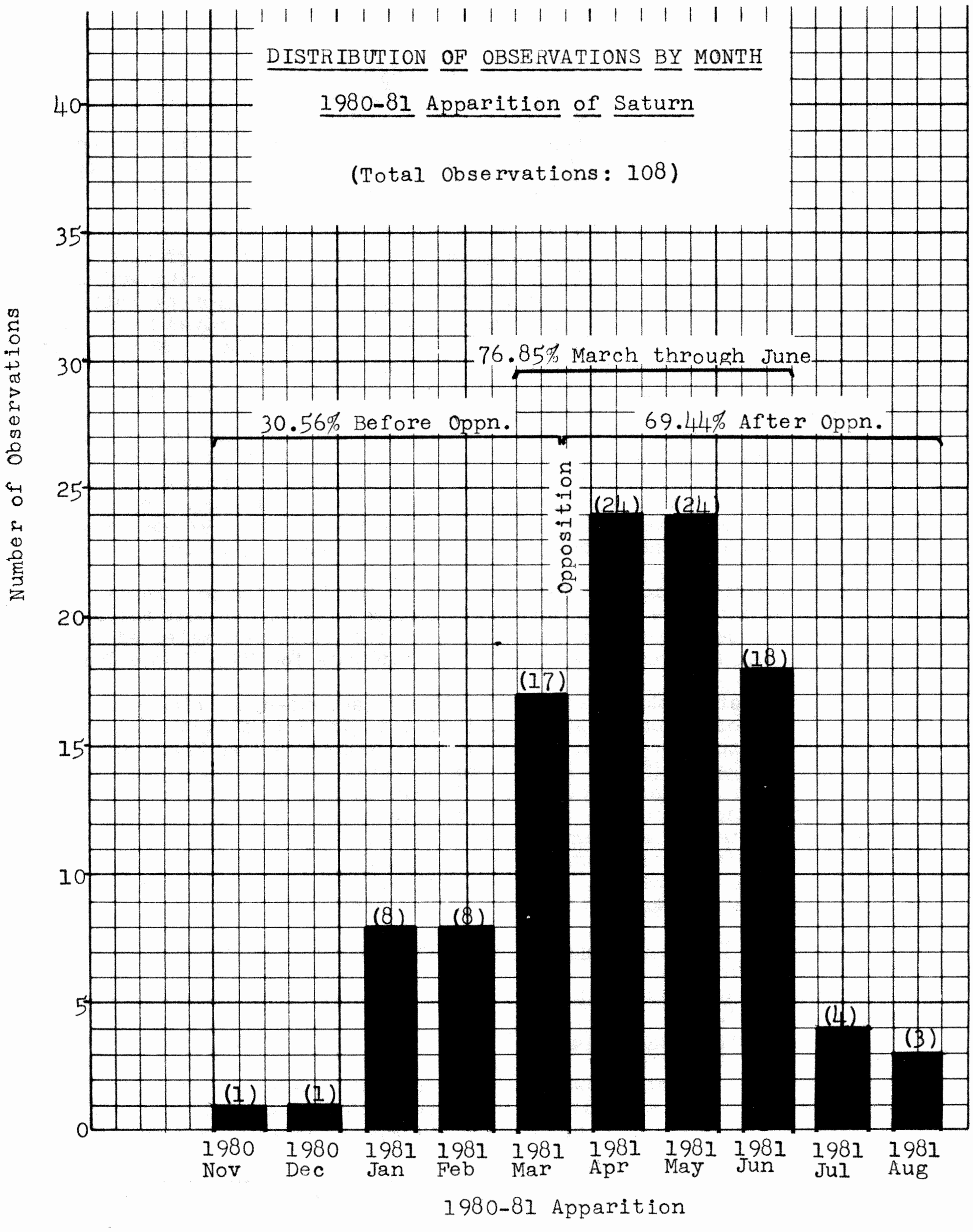

Figure 5

orientation of the rings in the 1990's, we shall proceed to describe global phenomena starting at the extreme northern polar limb of Saturn progressing southward toward the southern polar limb.

There was only a limited degree of activity reported in Saturn's northern hemisphere in 1980-81 when compared with the 1979-80 apparition. Atmospheric phenomena were manifest only as dark spots or elongations along the southern edge of the North Equatorial Belt (NEB) late in the apparition, with all other areas apparently devoid of the brightenings, elusive mottlings, and diffuse festoon patterns generally suspected in 1979-80. Consequently, one is led to the supposition that the northern hemisphere of Saturn was less active in 1980-81 when compared to the 1979-80 period.

In summation, all of the reported zones of Saturn's northern hemisphere were slightly increased in brightness in comparison to the 1979-80 apparition, with the exception of the North Tropical Zone (NTrZ). The Equatorial Zone (EZ) in 1980-81 was brighter than in 1979-80 by a mean intensity factor of 0.4 units, followed by the North Polar Region (NPR) (brighter by a mean factor of 0.3), and the North Temperate Zone (NTeZ) (brighter by an insignificant mean factor of 0.1). The North Tropical Zone (NTrZ) showed a diminution in overall brightness since 1979-80 by a mean factor of 0.2, not really a substantial variation.

The only belt of Saturn's northern hemisphere which could be compared with the previous observing season was the North Equatorial Belt (NEB), brighter in 1980-81 by an almost meaningless overall factor of 0.1 units on the intensity scale.

From 1979-80 to 1980-81, the northern hemisphere region exhibiting the greatest, although quite subtle, brightness elevation (as derived from the mean numerical relative intensity data shown in Table I) was the Equatorial Zone's northern component (EZ_n) (by a mean factor of 0.4). The feature showing the greatest mean diminution in brightness was the North Tropical Zone (NTrZ), with a mean factor of 0.2, practically insignificant.

It is worth mentioning that the globe between the North Equatorial Belt (NEB) and the north polar limb was darker by a mean intensity factor of 0.4 when compared to the global region between the southern edge of Ring A (terminus at the outer edge of Ring A in front of the globe) and the southern polar limb. Generally, the data show that the above northern regions brightened since 1979-80, while the southern areas maintained about the same overall intensity as in the preceding apparition.

The information which has been outlined in the foregoing paragraphs has been derived from an intensive comparative investigation of Saturnian belt and zone mean intensity data beginning with the 1979-80 apparition for selected Northern Hemisphere global features and extended to include data for 1980-81 (see Tables I and II).

A representative sketch of Saturn with its accompanying ring system for a numerical value of B equal to +5°000 is included. On it is depicted the standard accepted nomenclature for belts, zones, and ring components (see Figure 6).

North Polar Region (NPR). The NPR was somewhat brighter (by a mean intensity factor of 0.3 units) throughout 1980-81 than it had been in the immediately preceding apparition, although some individuals noted a possible darkening trend for the region late in the observing season. Also, the NPR exhibited virtually the same mean intensity as the South Polar Region (SPR) in 1980-81 and was generally uniform in overall intensity, very dusky yellowish-grey in coloration, and devoid of any presence of the North Polar Cap (NPC) or North Polar Belt (NPB) during the apparition.

North North Temperate Zone (NNTeZ). No observational reports of the NNTeZ were received during 1980-81.

North North Temperate Belt (NNTeB). The NNTeB was not recorded by observers throughout 1980-81.

North Temperate Zone (NTeZ). The yellowish-white NTeZ was equal in mean intensity to the South Temperate Zone (STeZ) in 1980-81, and examination of the available comparative data shows no change in overall intensity since the 1979-80 period. The NTeZ was completely uniform in intensity along its linear extent from limb to limb, second only to the EZ_n in brightness in 1980-81 (by a mean intensity factor of 0.5).

North Temperate Belt (NTeB). The very difficult and intermittently visible NTeB was the lightest of the Northern Hemisphere belts during 1980-81; and with the exception of the NEB, it was the only belt reported in the Northern Hemisphere. Having not been seen in 1979-80, it could not be compared with the last apparition. The NTeB was lighter than the South Temperate Belt (STeB) by a mean intensity factor of 0.3, but the darker STeB was apparently less conspicuous to observers than was the NTeB!

North Tropical Zone (NTrZ). The dusky yellowish-grey NTrZ was slightly darker in 1980-81 than it had been in 1979-80 (by a mean intensity value of 0.2); and comparing the region to the EZ_n and NTeZ, the NTrZ was third in order of conspicuousness. The narrow NTrZ was usually uniform along its full extent across the globe of Saturn, quite inconspicuous, and darker than its southern counterpart (i.e., the STrZ) by a mean factor of 0.4 units in 1980-81.

North Equatorial Belt (NEB). In 1980-81 the NEB was undifferentiated into components, without any indication of a dividing NEB Z (North Equatorial Belt Zone). The NEB was greyish to greyish-brown in coloration, and it was the darkest belt in the Northern Hemisphere of Saturn. In fact, the NEB was the darkest belt on the planet's globe in 1980-81; it was fairly wide (in close agreement with the impressions of individuals in 1979-80); and aside from a suspected fading late in

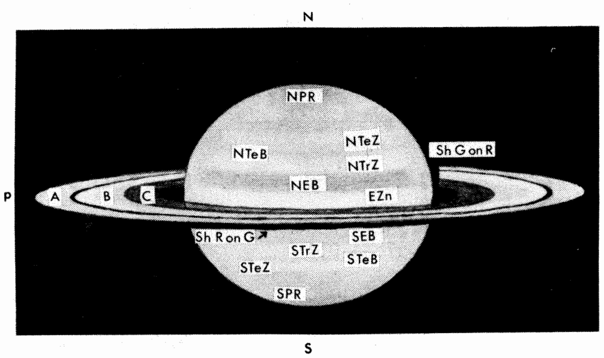

Figure 6. Imaginary sketch of Saturn to show representative appearance during the 1980-81 apparition and to give standard nomenclature of belts, zones, and ring features. Simply inverted view with north at top. B, planetocentric latitude of Earth, = +5°.0. The two shadows changed as the Sun-Earth-Saturn geometry varied. Surface features on Saturn may also have varied slightly during the apparition. Sketch contributed by Julius Benton.

the apparition, observers noted some vague dark spots along the southern border of the NEB in May and June of 1981. The spots were apparently transient phenomena, not persisting long enough for transit data to be amassed. Comparing the NEB in 1980-81 to 1979-80, it showed about the same overall intensity. The NEB was much darker than the SEB (by a mean factor of 1.7), showed more activity than the SEB, and was considerably wider than the SEB, all in 1980-81.

Equatorial Zone (EZ) (chiefly the EZ_n). By a fairly significant amount (mean intensity factor of 0.5), the EZ_n was the brightest zone on Saturn's globe throughout the 1980-81 apparition. In a more general view, the EZ_n was second only to the outer third of Ring B in being the brightest Saturnian feature in 1980-81; and many observers remarked that the EZ_n was about equal to the inner 2/3 of Ring B in intensity during much of the apparition. The pale yellowish-white EZ_n exhibited an overall uniformity in intensity, showing a brightening trend since 1979-80 (by a mean factor of 0.4). Although the EZ_n was devoid of detail in 1980-81, some individuals suspected a roughly linear and discontinuous Equatorial Belt (EB) on occasion; and this EB was described as having a dark yellowish-grey hue, intermediate between the NTeB and NEB in brightness.

Shadow of Rings on the Globe. The projected shadow of the rings on the globe was reported by observers during the 1980-81 apparition as a uniform greyish-black feature, geometrically regular, and most commonly seen in the month of May, 1981. Its aspect naturally varied with the changing geometry of the Sun-Earth-Saturn system.

Shadow of Globe on the Rings. The shadow of the globe on Saturn's ring system was reported by observers as a very dark greyish-black feature of regular geometric form throughout the 1980-81 period. It was naturally least conspicuous near opposition.

Southern Portions of the Globe. Saturn's Southern Hemisphere, now slowly disappearing from our view as the rings open up to expose more of the planet's Northern Hemisphere, showed very little activity in 1980-81. From a collective point of view, the visible zones of the Southern Hemisphere were equal to, or only slightly brighter than, their appearance in the 1979-80 period. The visible zones in the south, limited by the current ring inclination, were (in order of decreasing brightness) the South Temperate Zone (STeZ), the South Tropical Zone (STrZ), and the South Polar Region (SPR); and when it is noted (from Table II) that the mean intensity change factors for the STeZ and STrZ amounted to only 0.1 from 1979-80 to 1980-81, there is no true significance to any increases in brightness. Only the SPR could be said to have shown any apparent brightness increase, by a mean factor of 0.4.

The belts of the Southern Hemisphere of Saturn were fairly inconspicuous in 1980-81, especially the SEB. Curiously, the SEB was the lightest of the Saturnian belts, almost in the league with the various zones in intensity (e.g., the SPR), and had increased in brightness by a mean intensity factor of 1.4 units since 1979-80. Apparently, there was some confusion and difficulty among observers in actually discerning the SEB as a distinct feature in 1980-81, mainly because the rings passed almost in front of the approximate latitude on the globe where the SEB is situated.

(text continued on page 71)

Table I. Visual Numerical Relative Intensity Estimates of Major Global and Ring Features for the Planet Saturn During the 1980-81 Apparition with Accompanying Absolute Color Data.

Global or Ring Feature	Relative Intensity: No. of Visual Estimates	Mean Intensity and Std. Deviation	Derived Absolute Color
ZONES:			
EZ_n	56	7.230±0.750	Pale yellowish-white
NTeZ	38	6.742±0.250	Yellowish-white
STeZ	42	6.576±1.051	Light dusky yellowish-white
STrZ	2	6.100±0.000	Dusky yellowish-white
NTrZ	3	5.733±0.100	Dusky yellowish-white
Globe between S terminus Ring A and S polar limb	2	5.700±0.000	Yellowish-grey
NPR	57	5.528±0.187	Dusky yellowish-grey
SPR	44	5.352±0.899	Very dusky yellowish grey
Globe between NEB and N polar limb	2	5.250±0.249	Very dusky yellowish grey
BELTS:			
SEB	5	5.240±1.050	Very light bluish-grey
NTeB	37	4.646±0.255	Dark yellowish-grey
STeB	2	4.400±0.000	Dark yellowish-grey
EB	2	4.000±0.000	Dark yellowish-grey
SPB	2	3.800±0.000	Dark yellowish-grey
SSTeB	9	3.567±0.155	Very dark yellowish-grey
NEB	28	3.518±0.725	Grey to greyish-brown
RINGS:			
Ring B (outer 1/3)	Standard	8.000	White
Ring B (inner 2/3)	38	7.384±0.288	Yellowish-white
Ring A (whole)	55	6.729±0.500	Yellowish-grey
Crape Band	8	2.938±0.919	Dark yellowish-grey
Ring C (ansae)	31	1.971±0.010	Dark grey
Shadow Rings on Globe	15	1.740±0.281	Greyish-black
Cassini's Division (B10 or A0)	32	0.847±0.925	Dark greyish-black
Shadow Globe on Rings	33	0.418±1.101	Very dark greyish-black

Visual numerical relative intensity estimates (visual surface photometry) are based upon the A.L.P.O. Intensity Scale, where 0.0 denotes complete black (shadow) and 10.0 refers to the greatest brilliant white condition (very brightest Solar System reflectivity). The adopted scale utilized employs (for Saturn) a reference standard of 8.0 for the outer third of Ring component B, which appears to be usually stable in intensity with time and most ring inclinations. All other global and ring features are estimated relative to this reference standard, and details as to the procedures for conducting such visual estimates are given in The Saturn Handbook.

Table II. Comparative Mean Intensity Data For Saturnian Global Belts and Zones*

Saturnian Feature	Average Intensity 1979-80	1980-81	Mean Intensity Change and Notes
1. The Northern Hemisphere: Zones			
EZ_n	6.8	7.2	Brighter (0.4)
NTeZ	6.6	6.7	Brighter (0.1)
NTrZ	5.9	5.7	Darker (0.2)
NPR	5.2	5.5	Brighter (0.3)
II. The Northern Hemisphere: Belts			
NTeB	---	4.7	No comparison possible
EB	---	4.0	No comparison possible
NEB	3.4	3.5	Brighter (0.1)
III. The Southern Hemisphere: Zones			
STeZ	6.5	6.6	Brighter (0.1)
STrZ	6.0	6.1	Brighter (0.1)
SPR	5.0	5.4	Brighter (0.4)
IV. The Southern Hemisphere: Belts			
SEB	3.8	5.2(?)	Brighter (1.4); dubious?
STeB	---	4.4	No comparison possible
SPB	---	3.8	No comparison possible

*Data on the ring system are omitted because of the lack of comparative intensities from 1979-80, when the rings were edgewise to our line of sight.

Other belts reported in the Southern Hemisphere of Saturn during 1980-81 were the South Temperate Belt (STeB) and the South Polar Belt (SPB), the former being brighter than the SPB by a mean intensity factor of 0.6 throughout the period. Since the STeB and SPB were not reported in 1979-80, no comparative data are available.

The globe between the southern terminus of the outer edge of Ring A (where it crosses in front of the globe) and the southern polar limb was brighter than the corresponding region between the NEB and north polar limb (by a mean intensity factor of 0.4). We have already noted that the above southern regions of Saturn's globe remained fairly stable in intensity compared to 1979-80, while the aforementioned northern areas brightened since 1979-80.

South Equatorial Belt (SEB). The SEB was generally inconspicuous, fairly diffuse, and often confused by observers with the rings as they passed in front of the globe in 1980-81. The coloration ascribed to the SEB was a very light bluish-grey, the belt showing no differentiation into components or any distinct South Equatorial Belt Zone (SEB Z). The SEB was devoid of activity and uniform in intensity throughout, and as mentioned earlier, unusually bright for a Saturnian belt. Even though it was hard for observers to discern the full extent or width of the SEB, the collective opinion was that the SEB was seen to greatest advantage just south of the ring shadow on the globe in late April and May of 1981.

South Tropical Zone (STrZ). The uniform and dusky yellowish-white STrZ was seen only with considerable difficulty and very infrequently in 1980-81, exhibiting very little change in brightness since the 1979-80 apparition. Compared with the STeZ, the STrZ was darker by a mean intensity factor of 0.5, while the NTrZ was darker than the STrZ by a mean factor of 0.4 in 1980-81. Observers remarked that the STrZ was not nearly so easy to see as the STeZ or the NTrZ; but it was the second brightest zone of the Southern Hemisphere, behind the STeZ.

South Temperate Belt (STeB). The STeB was detected by observers in 1980-81 only with difficulty as a dark yellowish-grey, roughly linear feature, interrupted along its global extent from limb to limb. Since it was not reported in 1979-80, no comparative data were available for analysis. The STeB was slightly darker than its northern counterpart, the NTeB, by a mean intensity factor of 0.3; but it was far less frequently observed.

South Temperate Zone (STeZ). With the exception of the SPR, the STeZ was the most commonly reported and brightest zone in the Southern Hemisphere of Saturn during 1980-81. The STeZ was described during the apparition as a light dusky yellowish-white feature, uniform in brightness, almost equal in overall intensity to the NTeZ, and devoid of detail or activity of any kind. The STeZ was brighter

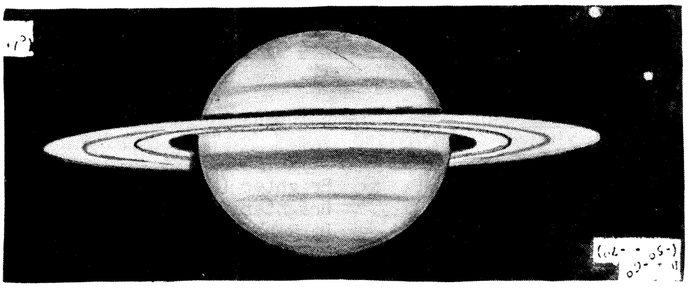

Figure 7. Drawing of Saturn by Carlos E. Hernandez on May 6, 1981, 4^h0^m-4^h40^m, U.T. 20-cm. Celestron reflector, 335X. Seeing 7 (scale of 0 to 10 with 10 best), transparency 8(?). Simply inverted view with south at top. <u>B</u> = +4°4.

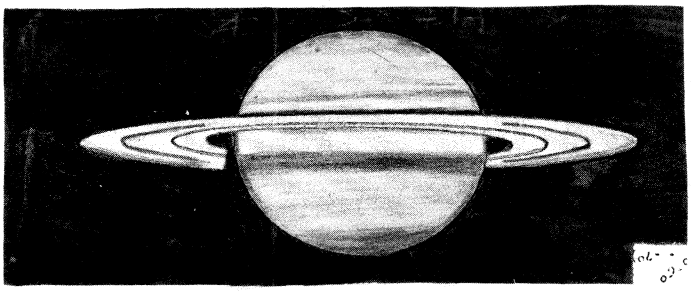

Figure 8. Drawing of Saturn by Carlos E. Hernandez on May 29, 1981, 4^h30^m-5^h0^m, U.T. 20-cm. Celestron reflector, 380X. Seeing 5, transparency 7(?). <u>B</u> (Saturnicentric latitude of Earth) = +4°2. South at top.

than the nearby STrZ by a mean intensity factor of 0.5 units in 1980-81, but the STeZ remained virtually unchanged in mean intensity since 1979-80.

<u>South South Temperate Belt (SSTeB)</u>. The very dark yellowish-grey SSTeB, although very narrow and often discontinuous along its length, was the most frequently seen Southern Hemisphere belt in 1980-81. Observers did not record the SSTeB in 1979-80.

<u>South South Temperate Zone (SSTeZ)</u>. The elusive SSTeZ was not reported in 1980-81 by participating observers.

<u>South Polar Region (SPR)</u>. Reported in 1980-81 as a very dusky yellowish-grey feature, undifferentiated and diffuse, the SPR was the darkest of the Southern Hemisphere zonal areas. It had about the same mean intensity as the NPR throughout the apparition, and the SPR showed an increase in brightness by a mean factor of 0.4 since 1979-80. The ill-defined South Polar Belt (SPB) was seen on a few occasions during 1980-81, having a dark yellowish-grey coloration and being generally uniform in intensity throughout. It was about halfway between the brighter EZ and SSTeB in intensity; and due to the lack of intensity data from 1979-80, no comparisons are possible.

<u>Latitude Data</u>. Visual and other quantitative latitude data were lacking in 1980-81, a situation also true for the immediately preceding apparition. Because of the great importance of these estimates and measurements, all observers who have some experience in viewing Saturn with moderate apertures are fervently urged to pursue such work. Details for carrying out latitude studies can be found in <u>The Saturn Handbook</u>.

Section II. The Ring System

For several years now, discussions of global and ring phenomena have embodied, and have relied upon in part, a continuing comparative analysis of mean intensity data from apparition to apparition. In the foregoing section dealing with Saturn's global phenomena for 1980-81, we extended our comparative studies to include data for the current apparition. Intensity data for Saturn's ring components and phenomena were lacking in 1979-80 because of the edgewise orientations during that period. Also, in 1979-80 observers saw the southern face of the ring system for the last time for many years to come. Beginning with this 1980-81 apparition, we shall proceed to amass intensity data for subsequent comparative investigations of features and phenomena of the northern face of Saturn's ring system.

<u>Ring B</u>. The outer third of Ring B is the reference standard for the A.L.P.O. Visual Numerical Relative Intensity Scale, with an assigned value of 8.0. It is commonly known that when the numerical value of <u>B</u> equals or exceeds about 5 degrees, the intensity of the outer third of Ring B remains rather stable with

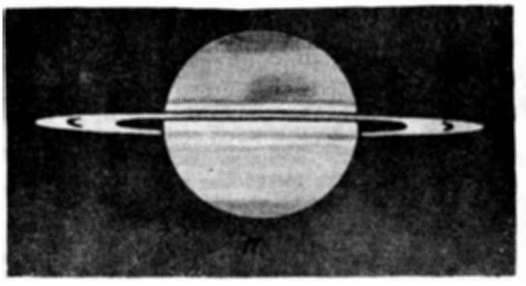

Figure 9. Drawing of Saturn by Roger Laureys, Belgium on March 21, 1981 at 23^h46^m, U.T. 25-cm. Newtonian reflector at 250X. Seeing 5 (scale of 0 to 10 with 10 best), transparency 3 (scale of 0 to 10 with 10 best). Simply inverted view with south at the top. $\underline{B}$ = +5°8. Saturn 6 days before opposition, and shadow of globe on rings not visible.

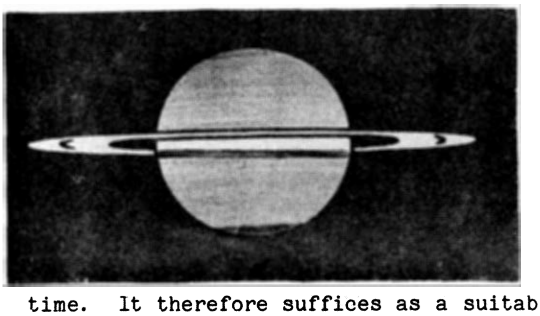

Figure 10. Drawing of Saturn by Roger Laureys, Belgium on March 26, 1981 at 22^h0^m, U.T. 25-cm. Newtonian reflector at 250X. Seeing 6, transparency 8. $\underline{B}$ = +5°6. South at top. Saturn 1 day before opposition.

time. It therefore suffices as a suitable reference standard for pursuing intensity estimates of Saturn's global and ring features.

The outer third of Ring B remained nearly constant in appearance during the whole of 1980-81, displaying a distinct and uniform whitish appearance, and remaining throughout the apparition the brightest Saturnian feature. The inner two-thirds of Ring B, only slightly brighter than the Ez_n throughout 1980-81, was dimmer than the outer third of Ring B by a mean intensity factor of 0.6 units; and it was described as having a uniform yellowish-white tone.

Cassini's Division, denoted in the literature as A0 or B10, could be seen with ease at the ansae in good seeing. It was described as a fine curvilinear, dark greyish-black feature, easiest to detect at the ansae. Of course, when the numerical value of $\underline{B}$ becomes small or zero, all divisions or "intensity minima" in the rings are more difficult to perceive and appear deceptively less dark. No other such "intensity minima" were reported in Ring B in 1980-81.

Ring A. As a whole, Ring A was yellowish-grey in hue. It was generally undifferentiated into component structure, and exhibited about the same intensity (mean) as the NTeZ (the second brightest feature on Saturn's globe). Generally uniform in intensity throughout, Ring A showed no sign of Encke's Division (denoted in the literature as A5) or any other "intensity minimum."

Ring C. When seeing cooperated, the dusky, dark grey Ring C could be seen at the ansae with ease. The intensity across the visible portion of Ring C (at the ansae) was uniform during 1980-81.

The Crape Band (where Ring C crossed the globe of Saturn) was seen with some difficulty in 1980-81, being described as a dark yellowish-grey feature and more or less linear in appearance.

Ring D. Observations of the ring component internal to Ring C, now denoted in the literature as Ring component D, were apparently lacking in 1980-81. The elusive innermost ring component, confirmed by the Voyager missions, has been suspected by some individuals in the past as it passed in front of the globe (or perhaps it was the shadow of Ring D).

Ring E. External to Ring A is very broad, tenuous ring component denoted as Ring E, confirmed by the Voyager missions of 1980 and 1981. The initial Earth-based observations of the faint, elusive Ring E date back to the 1907-08 apparition when the rings were edgewise to our line of sight. Observers have, from time to time, suspected seeing Ring E (or a ring external to Ring A) over the years; but no suspected observations were forthcoming in 1980-81. Presumably, this faint component should be easier to see near edgewise presentations.

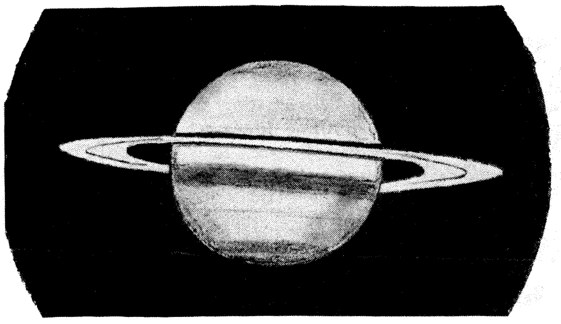

Figure 11. Drawing of Saturn by Carlos E. Hernandez on April 14, 1981, 1^h0^m-1^h10^m, U.T. 20-cm. Celestron reflector, 335X. Seeing 5, transparency 8(?). Simply inverted view with south at top. B = +5°.0. Compare to Figures 7 and 8 by the same observer.

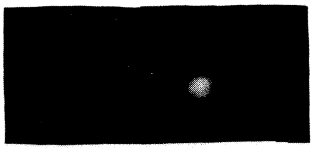

Figure 12. Photograph of Saturn by D. G. Buczynski, England on May 31, 1981 at 23^h0^m, U.T. 15-cm. f/19 refractor. Exposure 7 seconds. Kodak 2415 HC-110, 10X enlargement.

Terby White Spot (TWS). No observations were forthcoming of a Terby White Spot in 1980-81. (It lies on the rings and borders the shadow of the globe there.)

Bicolored Aspect of the Rings. No suspected differences in the brightness of the east and west ansae, either in integrated light (no filter) or with color filters, were reported in 1980-81.

Section III. Saturn's Satellites

Because of the small numerical value of B during the 1980-81 apparition, it was still possible for individuals to observe occultations and eclipses of SIII (Tethys), SIV (Dione), and SV (Rhea). Predictions for such phenomena were available in the literature. Generally, larger apertures are required to view these phenomena to advantage; but smaller instruments have produced good results in the past as well. During 1980-81, no observations were submitted where timings of occultation or eclipse events took place.

Magnitude estimates of the satellites were also lacking in 1980-81, although one or two individuals mentioned that SVI (Titan) usually appeared brighter when viewed in a W47 (blue) filter. Also, when Titan was near eastern elongation, it appeared nearly equal when viewed alternately with W25 (red) and W47 (blue) filters. Titan was distinctly red in early June of 1981, according to A. Heath in England, an opinion supported by filter observations.

No other satellite observations were submitted in 1980-81, and observers are encouraged to pursue these programs in future apparitions. Details for carrying out satellite observations can be found in The Saturn Handbook.

Conclusions

During 1980-81, the apparition which succeeded the edgewise orientation of the ring system to our line of sight in 1979-80, observers followed Saturn fairly well in a collective effort to monitor global and ring phenomena. It is obvious from the foregoing report that the Northern Hemisphere of Saturn, as well as the north face of the rings, received the greatest emphasis in 1980-81; and in subsequent years more and more of these northern regions of Saturn will be open to our inspection. For 1980-81 activity in the northern areas was not so pronounced as in 1979-80, and the southern areas were generally devoid of activity during the apparition.

Observers are encouraged to continue to pursue general studies of Saturn, as in 1980-81; and such support as highly essential and instrumental in assisting in the long-term acquisition of data. In addition, several areas which have been largely neglected in the past, but particularly in recent years, are satellite observations and latitude estimates. It would be meaningful if individuals would direct attention to these programs as well, and the writer will be pleased to assist those interested in such pursuits by providing guidance and other information. Simultaneous observations of Saturn are also sought in all areas, and individuals are encouraged to undertake these endeavors.

Again, and in conclusion, an expression of thanks must go out to all those who faithfully participated in our programs through 1980-81.

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OUTLINE OF THE LUNAR AND PLANETARY TRAINING PROGRAM, 1983 - 1984

By: Jose Olivarez, A.L.P.O. Lunar and Planetary Training Program Recorder

The Lunar and Planetary Training Program is open to all members of the A.L.P.O., novice or experienced, with the goal to help members become proficient observers. The program consists of learning the techniques of useful lunar and planetary observing, the proper method of recording the observations, and the development of a drawing skill. The learning process consists mainly of practice at the telescope and a constant effort to improve the observations by the training of the eye and the improvement of drawing and recording techniques. The Program outline follows:

A. The student should have a minimum of a 4-inch refractor (f/15) or a 6-inch (f/8) reflector.
   The Training Program Recorder will advise on optical instrumentation, accessories, and other practical aspects of observing the Moon and planets. Students wishing such guidance should contact the Recorder.
B. The student will gather the supplies recommended. These include publications, drawing supplies, A.L.P.O. Observing Forms, etc. See section below on "Observing Supplies Recommended."
C. Understand the meaning and use of the "Ephemerides for Physical Observation" as given in the current annual Astronomical Almanac for the Moon and each of the bright planets.
D. Learn how to estimate seeing conditions (1 to 10) and transparency of the air (faintest star seen by the unaided eye).
   For an understanding of seeing and transparency and their effects on lunar and planetary images, consult the papers listed below under "Modern Papers on Seeing and Transparency."
E. Learn how to compute the longitude of the central meridian of Jupiter and Saturn for any time.
   Consult The Jupiter Observer's Handbook and The Saturn Handbook for detailed instructions.
F. Learn procedures and develop skill in making timings of the transit of features across the central meridians of Jupiter and Saturn.
   Consult The Jupiter Observer's Manual and The Saturn Handbook for detailed instructions.
G. Learn how to figure the Moon's selenographic colongitude.
   Consult The Astronomical Almanac for the Sun's selenographic colongitude as given for every day of the year for zero hours, Universal Time. The colongitude advances by approximately 0.01 degrees per minute, 0.08 degrees per 10 minutes, 0.25 degrees per 30 minutes, and 0.51 degrees per hour.
H. Develop skill in lunar and planetary drawing.
   This skill may be achieved mainly by continuous practice and by following the advice of experienced observers.

I. Study past reports and papers showing observational methods used by A.L.P.O. contributors.
J. Purchase handbooks and other guides (of your choice) produced by the A.L.P.O. Recorders.
Write to A.L.P.O. Recorders for handbooks available and prices.
K. Submit your lunar and planetary drawings to the Lunar and Planetary Training Program Director (address listed on inside back cover of this issue) for evaluation and improvement suggestions (if needed).
All correspondence MUST include a self-addressed stamped envelope for the Director's reply.
L. When a student has demonstrated that he has the knowledge and skill successfully to participate in the A.L.P.O. observing programs, he will be certified to that effect by the Training Program Director and will have one of his observations published in the "Observations and Comments" section of the A.L.P.O. Journal.

Although a fair amount of study is essential, there is no prescribed number of observations which a student must make in order to complete the program. The amount of work done is entirely up to the student's interests and the degree of proficiency he may wish to attain. Also, a student may concentrate only on lunar or only on planetary observing. The program is flexible and is geared to make an A.L.P.O. membership more enjoyable by helping the student to prepare to participate in the A.L.P.O.'s exciting Lunar and Planetary Observing Programs.

Observing Supplies Recommended

1. DRAWING SUPPLIES - The beginning observer should use pencil for his drawings. For lunar drawings, he should 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 at an artist's supply store for 25 cents or less. 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. Regular duplicating paper meets these conditions sufficiently and may be used for lunar drawings or planetary strip sketches. For Venus, Mars, Jupiter, and Saturn disc drawings done on the A.L.P.O. recording forms, a 2 1/2 pencil is recommended.
2. A.L.P.O. RECORDING FORMS - These official recording forms are available from the Recorders. The Mars Observing Forms are available from the Mars Recorder in lots of 20 at cost. Observing forms for either Saturn or Venus are available from the Venus and Saturn Recorder in lots of 25. Jupiter recording forms are also available from the Jupiter Recorders at cost.
3. THE ASTRONOMICAL ALMANAC - This book is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Most libraries will have a copy on reserve.
4. A.L.P.O. OBSERVING HANDBOOKS - The A.L.P.O. Handbooks published by the Recorders are invaluable aids in lunar and planetary observing.
5. WRATTEN COLOR FILTERS - If desired, filters may be acquired for planetary observing as recommended by the A.L.P.O. Recorders.

Modern Papers on Seeing and Transparency

The following papers are listed in order of readability and value to the beginning visual observer.

1. Gordon, Rodger, "Seeing and Transparency," Star and Sky, Vol. 1, No. 6, June, 1979, pp. 18-20.
2. Vaughn, Frank, "Astronomical Seeing," Sky and Telescope, Vol. XIX, No. 1, November, 1959, pp. 37-38.
3. Norton, O.R., "Seeing Through the Sea of Air," The Review of Popular Astronomy, Vol. LVIII, No. 526, Feb.-March, 1964, pp. 24-29.
4. Sato, T., "Effects of Observational Conditions," Strolling Astronomer, Vol. 16, Nos. 7-8, July-August, 1962, pp. 162-165.
5. Gordon, Rodger, "Poor Seeing and Telescope Efficiency," Star and Sky, Vol. 1, No. 7, July, 1979, pp. 38-39.
6. Young, A.T., "Seeing and Scintillation," Sky and Telescope, Sept., 1971, Vol. 42, No. 3, pp. 139-141 and 150.

THE NEW A.L.P.O. METEOR SECTION

By: David H. Levy, A.L.P.O. Meteor Recorder

Time!
Magnitude? --Second. No! 2.5!
Shower? --Perseid.
That's Meteor No. 66!

And with activities like this gearing up all across the continent, the A.L.P.O. is happy to announce that its new Meteor Section has been established. It is a section meant to introduce new meteor observers to the joy of this exciting activity. It is a section designed to coordinate visual observations of meteor showers. And it is a section that we hope will act as a link between professional needs and amateur enthusiasm.

In 1982 the A.L.P.O. asked its members whether a Meteor Section should be established, and the written response was one of approval by a significant margin. Further, a great majority of those who answered were interested in the traditional work of meteor counts and radiant determination by visual means. Meteor photography, telescopic observation, and radio counts also sparked some interest.

There is a need for the collection of archival data on meteors, their showers, and their radiants. During the IGY this work was very popular, especially in Canada, where many observers participated in a government-sponsored visual meteor program which was so successful that it was extended until late in the 1960's. Initially, the A.L.P.O. Meteor Section will seek to recreate that interest; but of course, as interests of both amateur observers and professional research change, the Section will try to grow and to satisfy these interests.

The first step towards uniformity of intent and style in visual meteor observing should be the publication of a handbook for meteor observers. This project has already begun, and we hope to complete it within a year. But don't wait that long to start watching! For each meteor, record its magnitude, shower status, and any unusual behavior. And remember that meteor observing can be an immensely satisfying group activity for your astronomy club. It requires practically no instrumentation, and brings your members together. Observations collected over long periods can be valuable; but possibly most important for amateurs, meteor observing is fun.

The writer will be glad to hear from readers interested in the work of the Meteor Section. Please write to him at Jarnac Observatory, Route 7, Box 414, Tucson, Arizona 85747, USA.

A PHOTO-FINISH: TIPS ON SOLAR PHOTOGRAPHY

By: Brad Timerson, A.L.P.O. Solar Section

The techniques used by individuals in taking solar photographs will certainly be different. However, to be successful, these techniques must be consistent, with the goal of improving each photograph foremost. With this goal in mind, I would like to describe some of the procedures I use in taking photographs of the Sun.

Unlike photographers of other objects through a telescope, solar photographers do not have to worry about lack of light. It is this abundance of light which does, in fact, present other problems. One of them is the need to decrease the intensity of the light to a level that is both safe for viewing, and, at the same time, within the range of films that are presently available. A second problem is actually a consequence of the first. The energy of the Sun causes a great deal of atmospheric turbulence which can spoil photographs. Fortunately, both of these problems can be lessened through the use of a special solar filter. For the past several years, I have been using a Tuthill Solar Skreen filter. This filter cuts down on the intensity of sunlight before it enters the optical system of the telescope. At the same time the filter is reducing the intensity of the light so as to allow safe visual observations to be made, it is also allowing enough light to pass through so that exposure times can be as short as possible in order to subdue atmospheric distortions.

In addition to the Solar Skreen filter, the equipment I use includes a 32 cm, f/4-f/15 Newtonian-Cassegrain, and a Minolta SRT-101 SLR. The telescope is stopped down to 11 cm with an aperture over which the solar filter has been taped. Thus, the telescope performs as an 11 cm, f/11 Newtonian reflector for prime focus photography.

The first thing that I do once everything is set up is to observe the Sun visually. It's important to get some idea of what the seeing conditions are like and thus what kind of results can be expected in photographs. It is very difficult to approach the same resolution in photographs as that which can be seen through the eyepiece. Strive for that result as a goal, but don't be too disappointed if it is not attained. Be sure to record the seeing conditions using the scale outlined in the A.L.P.O. Solar Section Handbook. Other data are also required on the observing forms - be sure you write down everything. If you expect to improve, these data will be crucial in analyzing your techniques (right or wrong) and in modifying them accordingly. Take out the eyepiece, and attach the camera in its place. Be sure that the camera fits snugly against the eyepiece holder and has been firmly tightened into position. Center the Sun's image in the viewfinder, and roughly focus the camera. At this point, I spend a few minutes to align the Sun's image in the viewfinder so that the north pole of the Sun is at the top. This aligning can be done by moving the Sun back and forth in right ascension and checking the viewfinder to see if this motion is parallel with either the top or bottom edge of the viewfinder screen. Rotate the camera in the eyepiece holder until the alignment is complete. While the results of this alignment are not exact, they should be satisfactory. Be sure to check again and to tighten the camera in the eyepiece holder.

What I believe to be the hardest--and most crucial--step comes next, and that is the careful focusing of the Sun's image in the viewfinder. Unless you have one of the special low-light viewfinder screens in your camera (I don't), you will probably find the Sun's image to be dimmer than you would like for easy focusing. What was a comfortable light level for viewing is not the optimum for focusing. I have found one technique to be quite useful in these difficult situations. Center the limb of the Sun or a sunspot in the clearest part of the screen. Rack the camera in and out of focus while slowly moving closer to the proper focal point as you go. At some point, the limb or sunspot should appear to be sharply defined, or at least much better than in other positions. Most of the time, I am able to see the difference between the umbral and pneumbral regions of sunspots using this technique and careful viewing through the camera. If you find that your photographs are still out of focus, try taking several exposure sequences at very slightly different focal positions. Start at a position you feel is just inside of exact focus, and take several exposures while racking the camera toward exact focus and then a little beyond. Keep careful records; and, upon your later examination, one negative should stand out as being much better than the others. This one should be the proper position at which to focus the camera. One other technique that may have to be used when all else fails is to place a small piece of ground glass on the focusing rails in place of the film. This will allow you to find exact focus without using the camera's viewfinder. It also allows you to check up on your viewfinder's focusing accuracy from time to time.

To calculate the proper exposure, I use the formula:

$$\text{Exposure time} = (f/\text{stop})^2/[\text{ASA} \times 10^{(7-d)}],$$

where d is the neutral density of the filter used. In the case of the Solar Skreen, this value is about 4. As an example, with my telescope working at f/11 and using 2415 Technical Pan (ASA 100), my exposures should be 1/826 second. I usually take a sequence of exposures with the calculated value near the middle. My exposure sequence is therefore: 1/1000, 1/500, and 1/250 second. The idea behind the exposure sequence is to compensate for high clouds, excellent transparency, and possible inconsistencies in negative processing. The ideal exposure time would be at or near the fastest shutter speed the camera allows. This choice helps eliminate vibrations (usually from the wind) or tracking errors if the telescope is not driven. More importantly, it helps to freeze the turbulence present in the atmosphere so that any detail which can be seen will not be smeared. If your camera has a mirror lock-up feature, be sure to use it. After last touching the camera, I allow at least 10 seconds for all vibrations to cease before taking any photographs. If it is windy, wait for a calm period before tripping the shutter. Always use a cable release or self-timer. When using a cable release, push it slowly. You can cause vibrations by jabbing the cable release during an exposure.

With each exposure, I record the time to the nearest second using WWV time signals. Times to the nearest minute would be sufficient. Other data concerning the exposure as outlined on the data forms in the Handbook should also be recorded at this time. Leave nothing to memory. Be sure to mark the roll of film and your notes so that you can match negatives with data later on. Magic marker (permanent) or specially made film stickers could be used for this purpose.

Next comes film processing. Although satisfactory results can sometimes be provided by a commercial photofinisher, it is best to do your own processing. In doing so, you can use the newest film emulsions like 2415 Technical Pan (highly recommended) and have them processed properly. I develop the film in a solution made up from scratch. It is probably similar to Kodak's Tech Pan developer except that the mixed developer is much cheaper, lasts longer, and keeps the speed of the film up near ASA 100. The developer formula and procedure used in the film processing are given below:

Developer-modified POTA	Technique:
800 ml warm water	water pre-rinse 1 minute at 75°F
4 gr phenidone	developer 8 minutes at 75°F
45 gr sodium sulfite	5 sec. agitation each 1/4 min.
1 ml 0.1% benzotriazole	water rinse-instead of stop bath
water to make 1000 ml	fix and wash as per film instructions

When the film is dry, inspect the negatives looking for one which has good exposure latitude. Details on the Sun's surface should stand out easily against the solar disk, but be wary of a negative that may be too dense. To make prints, I use Polycontrast RC paper developed normally in Dektol 1:2. Whole disk prints are made with a diameter of 18 cm on 8x10 paper through a #3 polycontrast filter. The exposure through the enlarger should be adjusted so that full development yields a properly exposed print. Don't be tempted to pull a print from the developer early in order to compensate for over-exposure under the enlarger. Pulling a print early is a technique which is sometimes used when printing an excessively contrasty negative. Once the print is dry, attach the completed data sheet to the back of the print, and mark the north point on the front of the photograph.

Much more information on solar photography can be found in the A.L.P.O. Solar Section Handbook.* I hope that this short discussion of some of my techniques will be useful to those engaged in solar photography. Any specific questions will be gladly answered by me, but please include a self-addressed stamped envelope for reply. My address is Brad Timerson, 623 Bell Road, Newark, New York 14513.

Addendum to Developer for 2415 Tech Pan

A new developer for Tech Pan 2415 has recently come to my attention. Although I have not yet had a chance to try this formula, the source has been very reliable in the past.

The formula is:

sodium sulfite	25 gr
vitamin C (crystals)	0.25 gr
phenidone	0.6 gr
Photo-Flo 200	1 ml
water to make	1000 ml

Developing times:

EI 100: 12.5 minutes at 68°F for high contrast subjects
EI 125: 13.75 minutes at 68°F for medium contrast subjects
EI 160: 15.75 minutes at 68°F for low contrast subjects

(To the uninitiated, EI is the abbreviation for exposure index. It is similar to, though not exactly like, the ASA rating of film speed. Camera meters should be set to this value when taking pictures, and any exposure calculations with the formula above should be done with the EI in place of the ASA.)

After loading the film and the developer in the tank, agitate for 10 seconds and let stand for the remainder of the first minute. Then agitate 2 inversions every 30 seconds for the rest of the developing time. Stop, fix, and wash as usual for 2415.

The reason this developer works is that ascorbic acid (vitamin C) and phenidone form one of those mysterious developing combinations which transform the two components into a third developer that has properties all its own. In this developer, the phenidone is energized enough to handle higher EI's while keeping the fog level low enough to stabilize the density range at a level to maintain the contrast within reason. The developer rates Tech Pan at an honest EI of 125, maybe

*This Handbook is reviewed elsewhere in this issue.

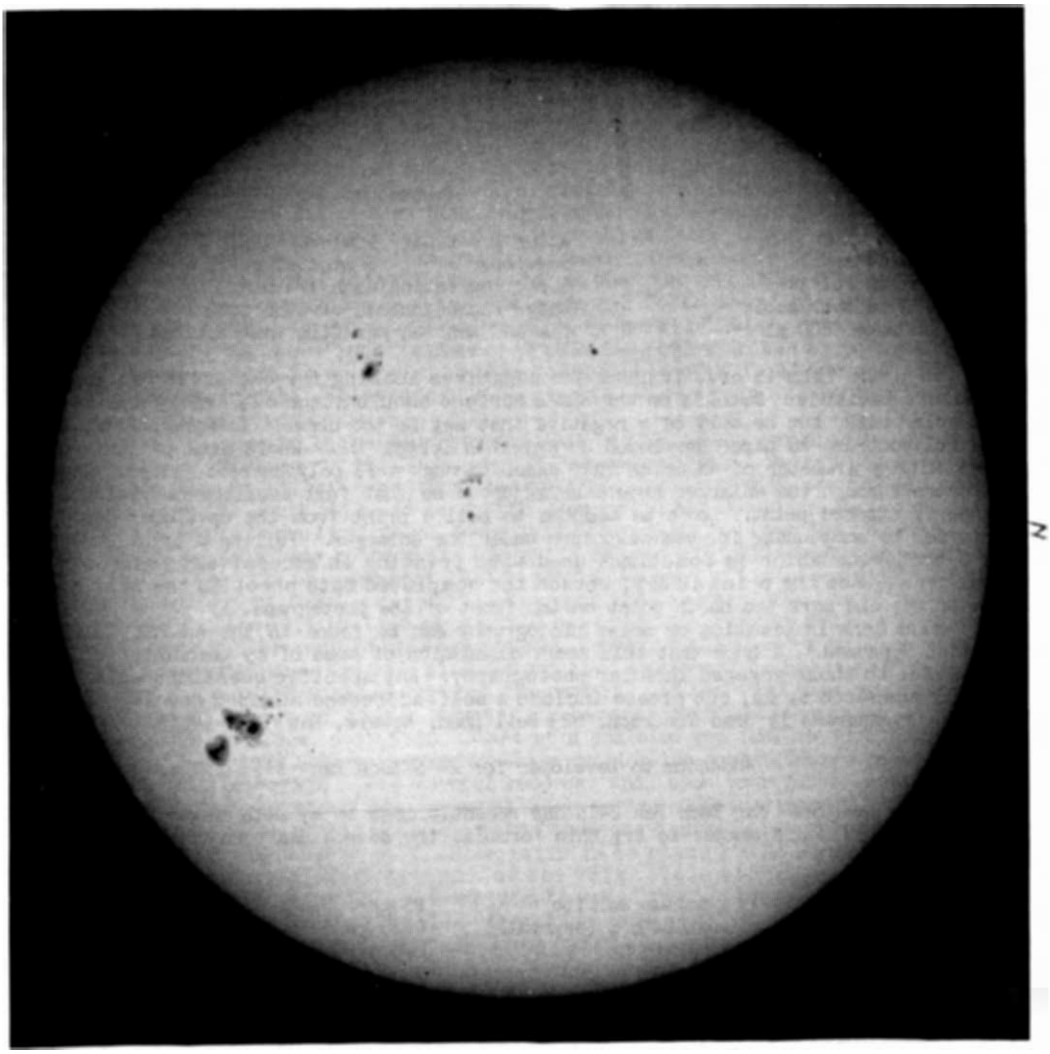

Figure 13. Photograph of whole disc of Sun by Brad Timerson on May 12, 1983 at $19^{h}49^{m}45^{s}$, Universal Time. 11-cm. reflector at F/11 (stop on larger Newtonian). Exposure 1/125 second on 2415 film, developed in modified POTA for 8 minutes at 75°F. North direction marked. Estimated visual resolution 1".

higher. The devloper is very soft working, highly compensating, and relatively dilute. This may produce a tendency to uneven development and staining, thus the addition of the Photo-Flo. An alternate procedure would be to pre-soak in a working strength solution of Photo-Flo 200 for 1.5 minutes with just 10 seconds initial agitation. (I prefer the pre-soak method because the dye present in the film base is dissolved by the pre-soak solution and removed before the developer is added. Thus, the developer doesn't become discolored. When using a pre-soak, the Photo-Flo should be eliminated from the developer.)

Figure 14. High resolution photograph of part of Sun by Brad Timerson on May 12, 1983 at $19^h57^m20^s$, U.T. 11-cm. reflector at effective F/33 (stop on larger Newtonian). Exposure 1/15 second on 2415 film, developed in modified POTA for 8 minutes at 75°F. North direction marked. Estimated visual resolution 1". Compare detail to whole disc photograph on page 80.

If you prefer working from stock solutions and then diluting just before use, here's how they could be mixed and used:

Part A		Part B	
boiling water	900 ml	hot water	800 ml
sodium sulfite	12 gr	sodium sulfite	160 gr
vitamin C	2.5 gr	Photo-Flo	6.7 ml
phenidone	6 gr	water to make	1 liter
water to make	1 liter		

For a working solution:

Part A	1 part
Part B	1.5 parts
Water	7.5 parts

I hope that this new developer proves to be useful to those amateurs who like to experiment. I know I'm always playing around with developer formulas looking for something better.

SOME RECENT OBSERVATIONS OF JUPITER

Those readers who were studying Jupiter last summer may be especially interested in the two drawings of the Giant Planet on the front cover. The quality of these drawings is excellent. The notes which follow use the standard nomenclature of the belts and zones, which is given in Figure 1 on page 222 of Journal A.L.P.O., Vol. 29, Nos. 11-12, March, 1983.

The July 26, 1983 drawing shows the Great Red Spot as a dusky ellipse in the South Tropical Zone and near the central meridian of the planet. There is the familiar bay to the north of the Spot, where the South Equatorial Belt South is deflected from its normal latitude.

The observer, Mr. Mark Daniels, calls attention on the July 26 drawing to how the Equatorial Band is attached to the South Equatorial Belt North in the longitudes preceding (left of) the Red Spot. Just following this EB segment there is a large dark projection from the south edge of the North Equatorial Belt into the Equatorial Zone. Note the movement of this projection in the four days between the July 26 and July 30 drawings. (Of course, the projection and its neighbors near the equator are moving in System I, while the rest of the planet follows the slower System II.) The July 26 drawing further shows South Temperate Zone oval DE approaching conjunction in longitude with the Red Spot, though still at a larger longitude (to the right of the Spot).

The July 30 drawing shows Jupiter II (Europa) just off the preceding (left) limb of Jupiter and its shadow just inside the following limb. Mr. Daniels invites attention to the very dark small oval in the South Temperate Zone preceding oval BC (near the central meridian) by about 40 degrees in longitude. The observer had never before seen a similar feature in this latitudinal portion of Jupiter.

Students of Jupiter will doubtless note several other features of interest.

BOOK REVIEWS

The Physics of Stars, by S.A. Kaplan. John Wiley & Sons, New York, 1982. 158 pages. Hardbound, Price $34.95. Translated from the Russian original.

Reviewed by Dale P. Cruikshank

Here is an excellent little book about stars, their properties, and the physical processes occurring within them. It is especially good in that it bridges the gap between very elementary popular books and the more rigorous texts on astrophysics. With only high-school algebra and elementary physics, the reader can gain a clear and exciting picture of modern knowledge and front-line research in the study of the stars, including pulsars and black holes. Thermonuclear energy sources in stars are explained clearly, and the chapter on stellar evolution is particularly lucid. Exponential notation is used throughout, and American readers should note that the term "milliard" means billion! There are frequent references to the work of Soviet astronomers which is often little known to Western readers. This book is recommended for amateur astronomers as well as for undergraduate students desiring an authoritative, concise, and highly readable overview of stellar astronomy. The price for the hardbound copy is very high, and readers may wish to wait for a possible soft-cover edition.

* * * * *

The McGraw-Hill Encyclopedia of Astronomy, edited by Sybil P. Parker, Consulting Editor Professor George O. Abell. McGraw-Hill Company, N.Y. 10020, 1983. 450 pages. Price $44.50.

Reviewed by Walter Scott Houston

Encyclopedias are usually dust-dry reading. This one is quite different. It is a compilation from the 1982 edition of the McGraw-Hill Encyclopedia of Science and Technology with no indication of any revisions. The alphabetically ordered articles are followed by brief modern bibliographies and are signed by the authors. We see such names as George Abell, Helen Hogg, Lawrence Aller, Bart Bok, Arthur Code, Jessie Greenstein, Paul Herget, Allen Hynek, Gerald Kuiper, Allan Sandage, and Peter van de Kamp. An index in the back locates items not listed in the main sequence, and another list identifies the authors.

The articles are beautifully written in a style quite comfortable to the non-professional. The editor deserves recognition for the uniformly lucid presentations. The graphics are exciting. It is a real pleasure merely to scan through them. A few random points will buttress these remarks.

While most books talk about two of the libration points of the Earth-Moon system, this book shows the classical five. The sensitivity to exact language shows in the M 31 account, where the major axis is specifically limited to a specific photographic density, avoiding discussion about M 31's ultimate length. It is refreshing to find Roche's limit confined to a liquid planet and not applied to a solid planet.

Tectites are accepted as splashes from meteorite impacts on the Earth, and the discovery of Pluto is assigned without question to Tombaugh. An added note gives both Lowell and Pickering equal credit for the computational sector of the discovery.

The account of SS 433 is a gem of lucid presentation of a complicated phenomenon that can be easily followed and understood by any amateur.

A few of the articles fall short. The variable star account mentions the AAVSO but fails to suggest the modern importance of the organization. We have been unable to find mention of the American Meteor Society; and the ALPO, despite the striking justification of its ground-based work by the NASA fly-bys, is not mentioned either. The weakest section is the advice on how to hunt for meteorites from a tracked-down fireball. The advice is useless. Fortunately these weak patches are rare. The remainder of the encyclopedia reads like a novel. One can dip at random and quickly become intrigued.

The articles do one more thing. They fit together to build a coherent multi-dimentional model of the cosmos as astronomers know it today. In this mode it may be the best path to a full understanding of how the NASA space programs have infused astronomy with the shining new life it revels in today.

* * * * *

<u>The Visibility of Deep-Sky Objects</u>, by Fred Klein. Klein Publications, 12225 Magdalena Ave., Los Altos, CA 94022. 1981. Five paper back pamphlets with a total of 283 pages. Vol. 1 \$6.95, Vols. 2 and 3 \$11.95, Vols. 4 and 5 \$11.95. All five for \$27.95.

Reviewed by Walter Scott Houston

This book is essentially a catalog of some 2497 objects including double stars, Barnard black nebulae, and red stars, in addition to the usual galaxies, planetaries, clusters, and diffuse nebulae. Two things are unique about it. The master list was taped. After that it was cheap and easy to print out lists on any basis--e.g. by right ascension, by visibility, or by location on the plates of the Tirion Atlas. We will see more of this kind of publication.

The second innovation is a system for classification of the difficulty of seeing the objects. It is based on equations the author has derived, and Volume 1 contains graphs illustrating the system which plots size against magnitude and then adds a third grid indicating visibility. Sample objects are plotted on the graph, and based on results obtained from the author's 8-inch telescope. Only a large number of amateur observations will properly test Klein's Object Visibility values.

Book 1 contains the explanation for the tables, a list of some 500 most interesting objects of all types by right ascension. The list is then repeated by type of object and listed in order of object visibility. A list of 50 best objects for star parties ends the book. Book 2 covers everything but galaxies, which are handled in Book 3. Objects are listed by right ascension only. Books 4 and 5 group all the 2497 objects by the number of the Tirion chart and by right ascension within that heading.

This book is an intersting attempt to break the bonds of tradition and exploit the advantages of computer data manipulation. Whether it will prove useful enough to set a new style of catalog form cannot be decided from an armchair. Much will depend on how much promotion the publisher can organize.

* * * * *

Comets, Laurel L. Wilkening, editor. University of Arizona Press, Box 3398, Tucson, AZ 85722. 1982. 766 pages. Price $29.95, hardcover.

Reviewed by Derek Wallentinsen

This book consists of the proceedings of IAU Colloquium No. 61, "Comets: Gases, Ices, Grains and Plasma," held in 1981 at Tucson, Arizona. There are 29 articles in seven parts, which are marshalled around the structure of a comet: Overview; Nucleus; Dust; Coma; Ion Tails and Solar Wind Interactions; Origin, Evolution, and Interrelations; and Appendix. There is also a Glossary of terms used in the text.

Papers of special interest to A.L.P.O. comet observers include the general review articles by Susan Wyckoff (observations) and Ľubor Kresák (statistics) in Part I; papers on the rotation (Fred Whipple) and splitting (Zdenek Sekanina) of nuclei in Part II; the paper "Comet Head Photometry: Past, Present, and Future" by David Meisel and Charles Morris (both authors have been active participants in the A.L.P.O. Comets Section) in Part IV; and John Brandt's "Observations and Dynamics of Plasma Tails" in Part V. Evolution of comets into asteroids is reviewed by Johan Degewij and Edward F. Tedesco (a member of the A.L.P.O. Minor Planets Section) in a paper in the sixth part of the book. The appendix article by Brian Marsden and Elizabeth Roemer gives very useful information on reporting discoveries of comets, astrometry, ephemeris calculation, cometary brightness, and abbreviated tables of cometary orbital elements.

Comets is a "state of the art" compendium of cometary science as of its publication date, and will stand as a current source until P/Halley's apparition in the mid-1980s. Theories and data are presented both as an introduction for newcomers (including adept amateurs) and as a reference volume for professional astronomers who are cometary specialists. The volume is put together in the thorough style of other books in the University of Arizona Press' Space Science Series, and it is written in a clear technical prose which is accessible to informed amateurs. This book is for those seeking more substance than is given in Calder's The Comet is Coming or in an introductory astronomy text. It is also suggested reading for those who desire information on the latest cometary research. I strongly recommend this book to anyone in the A.L.P.O. who is seriously interested in comets and their observation.

* * * * *

Catalog of Cometary Orbits, by Brian G. Marsden, Enslow Publishers, Bloy Street and Ramsey Avenue, Box 777, Hillside, NJ 07205. 1983. 96 pages. Price $10.00, paperbound.

Reviewed by Derek Wallentinsen

The Catalog of Cometary Orbits (CCO) is the latest compilation of cometary data by the Central Bureau for Astronomical Telegrams of the I.A.U. It is intended to be complete for observed comets through May, 1982 and contains information on 1109 apparitions of 710 comets.

The CCO is in two parts: the basic catalog (pp. 7-62) and statistical tables (pp. 63-96). First is the general catalog, a listing of 1109 orbits by time of perihelion passage. Given are the standard orbital elements (T, q, e, P, and i), the epoch of osculation for the orbit, the number of observations used and their timespan, and the number of planets whose perturbations were included in the numerical integration of the orbit. For periodic comets the orbit may be predicted, in which case the correction in days to the predicted perihelion time is given in place of the number of observations. Next come tables of names and observational intervals, references and notes, and a cross-reference for periodic comet apparitions. Nongravitational force parameters are given for the approximately 350 orbits where they have been determined.

The last one-third of the book is devoted to low-precision statistical tables to supplement the general catalog. Ecliptic longitude (L) and latitude (B) of perihelion are added here, as well as aphelion distances where they are appropriate. One hundred and twenty-one periodic comets ($P \lesssim 200$ yr.) of single and multiple apparitions are listed with orbital elements to one or two decimal places. For nearly parabolic orbits ($P > 200$ yr.) there are tables of elliptical and hyperbolic elements of 273 comets listed in order of 1/a, the reciprocal of the semimajor axis. These are not the "original" and "future" orbits which are almost always elliptical when referred to the center of mass of the Solar System, well before or after passing inside of Neptune's distance. Five hundred and eighty-nine long-period comets are tabulated in four ways: in order of longitude of perihelion, inclination, longitude of the ascending node, and perihelion distance. The listing by orientation of perihelion allows identification of comet groups and separate apparitions of the same comet. The Kreutz sungrazers are conspicuous at L=282°, B=+35°.

Earlier editions of the CCO were published at the Smithsonian Astrophysical Observatory. This first commercial edition is generally similar--not surprising as it was prepared from a computer-generated copy at the Central Bureau for Astronomical Telegrams. The switch to a trade printer replaced a staple binding with a glued spine; however, the inconvenient format of the catalog (from left to right along the long axis of the page) would be much more compatible with a spiral wire binding like those found in some technical manuals.

The Catalog of Cometary Orbits is useful to anyone working on the celestial mechanics of these objects at a level beyond computation of a current ephemeris from elements on the IAU Circulars. It should also prove interesting to those who are investigating characteristics of cometary orbits for historical or physical purposes. Informed amateurs fascinated by cometary statistics will find a source here. The book is recommended to persons in any or all of these three categories.

* * * * *

Handbook for the White Light Observation of Solar Phenomena, by Richard E. Hill. Available from Richard E. Hill, 4632 E. 14th St., Tucson, AZ 85711. 1983. 47 pages. Price $4.00, softbound.

Reviewed by David H. Levy

Richard Hill has written a much-needed guide to observing the Sun. For many years observers of the daytime star have struggled along without any central guide to their work, as amateur groups have had the apparent idea that proper solar observing techniques could be acquired instinctively, like breathing and walking. Possibly this misconception is a good reason that solar observing has not captured the imagination of more observers before now.

The A.L.P.O. Solar Handbook is just that--an observing handbook that is designed to be used at the telescope. It is informational only to the point that its users can now observe their star with confidence. Readable in one setting, its various sections discuss the Sun's morphological features, the rotation, and the solar cycle. Instructions for observing, photographing, and reporting are concise and uncomplicated. The report forms Rik Hill has designed are simple and can be completed quickly, and the inclusion of the Stonyhurst disks completes the materials that solar observers will need. The handbook is useful to beginners, helpful to people already familiar with solar observing, and filled with updates and reminders which may assist even the most experienced watchers of the Sun.

Unfortunately, the readability of this guide is marred and the clarity is limited by frequent lapses of grammar and sentence structure. If this shortcoming can be corrected in a second printing, then the book will truly be a success.

* * * * *

The Lighter Side of Gravity, by Jayant V. Narlikar. W.H. Freeman and Company, 660 Market Street, San Francisco, CA 94104. 1982. 224 pages. Hardbound, price $17.95. Paperbound, price $8.95.

Reviewed by Joel W. Goodman

This is an instructive and enjoyable book about a "force" that we take for granted in our everyday lives, but about which most of us have very little real perception. The author, a professor of astrophysics in India, takes the reader on a delightful journey through the concepts of Aristotle, Galileo, Newton, and Kepler to the curved space-time of Einstein's general relativity and the large-scale structure of the universe as we perceive it today. Black holes, with their strange gravitational effects, are treated extensively; and the newer concept of "white holes," which are "time-reversed" versions of objects undergoing gravitational collapse, is discussed at length. According to the definition, the entire expanding universe would constitute a gigantic white hole! All this is presented in an eminently readable style with abundant use of familiar similies to make complex points crystal clear, and with minimal use of mathematical equations. Indeed, one need have no mathematical background whatever in order to understand the text, an extraordinary testimony to Professor Narlikar's success in composing a book on this subject for the general reader.

As a novice in this field I hesitate to fault the book; but if pressed, I would point to the somewhat disproportionate amount of space devoted to black and white holes, which, though admittedly fascinating, are still really theoretical phenomena (but are apparently special interests of Professor Narlikar), as contrasted to a very cursory treatment of the significance of relating gravity to other physical forces such as electromagnetism. This effort unsuccessfully occupied the latter part of Einstein's life and continues to elude the best minds in the field. Unfortunately, the casual reader would gain little sense of the importance of a "unified field theory" to contemporary physics from this book. However, the slender volume does excel at explaining in lucid graphic fashion the role of gravity in astronomical phenomena and can be heartily recommended on that strength.

NEW BOOKS RECEIVED

Handbook of Model Rocketry, by G. Harry Stine. Arco Publishing, Inc., 215 Park Avenue South, New York, NY, 10003. 1983. Fifth Edition. 367 pages. Price $10.95, paperbound. Notes by J. Russell Smith.

The author of this book founded the National Association of Rocketry back in 1957. He is certainly well qualified to write in the field of rocketry. There are 18 chapters followed by a Bibliography, eight Appendices, and an Index. If you are interested in rocketry, you will certainly want this book on your book shelf.

* * * * *

Frame of the Universe, by Frank Durham and Robert Purrington. Columbia University Press, New York. 284 pages, illustrated. 1983. Price $24.95, hardbound. Notes by Gail O. Clark.

Two capable astrophysicists delve into a well-researched history of cosmological thought, putting major emphasis upon archeo-astronomy, medieval belief, and the contributions of Copernicus, Galileo, Newton, and Einstein. A significant portion of the volume examines modern cosmology and concludes with that ultimate construct of relativity: the black hole.

ANNOUNCEMENTS

Best Solar System Images Available from the Astronomical Society of the Pacific. The most dramatic and informative spacecraft views of our Solar System have been assembled into two special slide sets by Dr. David Morrison. Each set of 50 slides is accompanied by detailed captions. The first set includes the best images from the Voyager, Viking, Mariner, Apollo, and other missions, together with a complete list of planetary probes and a full table of data about all the known planets and satellites. The second set complements and extends the images in the first set. The two sets together are both a very beautiful display and an important educational tool. Each set can be purchased for $34.95 plus $2.00 for postage and handling from the Astronomical Society of the Pacific, Selectory Department, 1290-24th Avenue, San Francisco, CA 94122.

Updated Guide to Aerospace Literature. The new Seventh Edition of The Aerospace Bibliography lists books published between 1971 and 1980. Like earlier editions, it provides educators with an annotated, graded guide to reference materials dealing with aerospace topics. The new volume consists of three parts: a subject index, an annotated bibliography, and listed reference books. International Standard Book Numbers are used. The 140-page Aerospace Bibliography-Seventh Edition is available for $6.00 from Superintendent of Documents, Dept. 36-AU, Washington, DC 20402. Orders should include payment and should reference stock number 033-000-00866-0.

Staff Address Changes and New Section. Three members of our volunteer staff have new addresses. These are effective at once. (1) Phillip W. Budine, P.O. Box 450, Sidney, NY 13838-0450. Mr. Budine is a Jupiter Recorder. (2) Charles F.

Capen, Solis Lacus Observatory, Route 2, Box 262E, Cuba, MO 65453. Mr. Capen is a Mars Recorder. (3) Julius L. Benton, Jr., Associates in Astronomy, P.O. Box 147, New Hope, PA 18938. Dr. Benton is involved with the Saturn Section, the Venus Section, and the lunar Selected Areas Program.

We have also started a new Meteor Section under the leadership of David H. Levy, Route 7, Box 414, Tucson, AZ 85747. Mr. Levy's ideas about the new Section and its work are briefly presented on page 77.

Sustaining Members and Sponsors. The persons listed below support the work of the A.L.P.O. by voluntarily paying higher dues, $40 per volume for Sponsors and $20 per volume for Sustaining Members. Their generous assistance and meaningful support are here gratefully acknowledged. This financial aid is especially valued in the present period of inflation and increasing costs. If there are errors in the lists, the fault is wholly the Editor's--and he would like to be told about them.

Sponsors - Philip and Virginia Glaser, Dr. John E. Westfall, Dr. James Q. Gant, Jr., Ken Thomson, Darryl J. Davis, Dr. A.K. Parizek, Raleigh Crausby, James H. Fox, and Dr. Howard W. Williams.

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Our Thanks to the Kansas Astronomical Observers. We gladly welcome several new members from the Kansas Astronomical Observers in Wichita, Kansas. Mr. Jose Olivarez, who is in charge of the A.L.P.O. Lunar and Planetary Training Program (see pages 75 and 76), writes that the K.A.O. pays a portion of the subscription fees in order to encourage its members to join the A.L.P.O. Other societies might like to imitate this plan. We enjoy repeated correspondence from astronomy societies who plan to have numbers of their members join our studies, but these good intentions seldom later become actual memberships.

Invitation to Study Earthquake Light Phenomena. Dr. Péter Hédervári, Georgiana Observatory, H. 1023 Budapest, II., Árpád fejedelem útja 40-41, Hungary on March 23, 1983 wrote in part as follows:

"In the name of the Subcommission on Earthquake Prediction Research of the European Seismological Commission I take the liberty to ask your [i.e., all A.L.P.O. members and friends] help in creating and developing a worldwide net of observers of earthquake light (EQL) phenomena and other strange precursory events of impending earthquakes. The newly established EQL Project was formed by the decision of the subcommission mentioned above during its last international meeting at Leeds, England in August, 1982; and I was asked to take the necessary steps toward the creation of the net. The EQL Project now has many members and co-workers from many parts of the world, mainly geoscientists. I wish to cooperate, however, with astronomers as well, since they are very well educated and serious observers who work in the night when the different luminous phenomena, related to impending shocks, can be seen relatively easily and perhaps can also be photographed. . . . It would be particularly important [if J.A.L.P.O. readers would help] to collect data from the Pacific Coast of the United States, and especially from Washington, California, and New Mexico, as well as from Japan, where earthquakes are frequent natural events.

"EQL's are rather usual precursory signs of earthquakes, particularly stronger ones. Their true nature is, however, very obscure. Literally thousands of reports on them are available, but nobody knows their origin. There are many different kinds of lights: glow on the surface, illumination of the sky, brilliant moving objects over the soil or between the clouds in the heaven, like slow meteors or ball-lightning, phosphorescence of the water of the sea, lights and flames from the soil or on the crest of arriving normal or tsunami (tidal) waves, brilliancy of the slopes of a mountain, sparks in the air, etc. Since--as mentioned above--the EQL many times appeared some minutes, hours, or even days prior to an earthquake (and not only during or after the shock), this phenomenon really is an important precursor. Hence, the collection and publication of such data appear to be indispensable. As regards publication, short notes can be published in the Circulars of the EQL Project, and longer papers in some of the internationally known geoscientific periodicals, such as the newly established Earth Evolution Sciences. All the data of new (as well as old, historically known) events will be collected and analyzed by the Georgiana Observatory [address above].

"Reports on other strange events related to earthquakes (e.g., unusual fog, mist, air-shock, abrupt change in air pressure, sudden cooling or warming of the atmosphere, gas and mud eruptions, strange odor, occurrence of earthquake-fountains, visible waves on the ground, magnetic disturbances, and above all, restless, unusual behavior of the different animals prior to the shock) would also be very much appreciated.

"In the reports on EQL the following data should by all means be mentioned: time of the shock (year, month, day, hour, and minute), epicentral coordinates, epicentral intensity in terms of the 12-degree Richter scale (M) or body wave magnitude (m) if known, focal depth if known, the position of the EQL in terms of its distance and direction relative to the epicenter, exact time of occurrence of the EQL relative to the time of the shock, the place of the light relative to the surroundings (e.g., along the slope of a hill, near to an earthquake fault, high in the air, on the crest of a tsunami wave, etc.), duration of the luminous phenomenon as measured or estimated, and the color and intensity of the EQL. Every kind of information may be very important!

"Readers of these notes are requested to call them to the attention of their colleagues."

Bargains for Solar Observers. Solar Recorder Richard E. Hill, 4632 E. 14th St., Tucson, AZ 85711 writes of a special offer available to members of the A.L.P.O. Solar Section. A well-known dealer in astronomical items will sell them a solar screen at a 20 percent discount and an H-Alpha filter at a discount. Interested persons should contact Mr. Hill for more details.

The Strolling Astronomer

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