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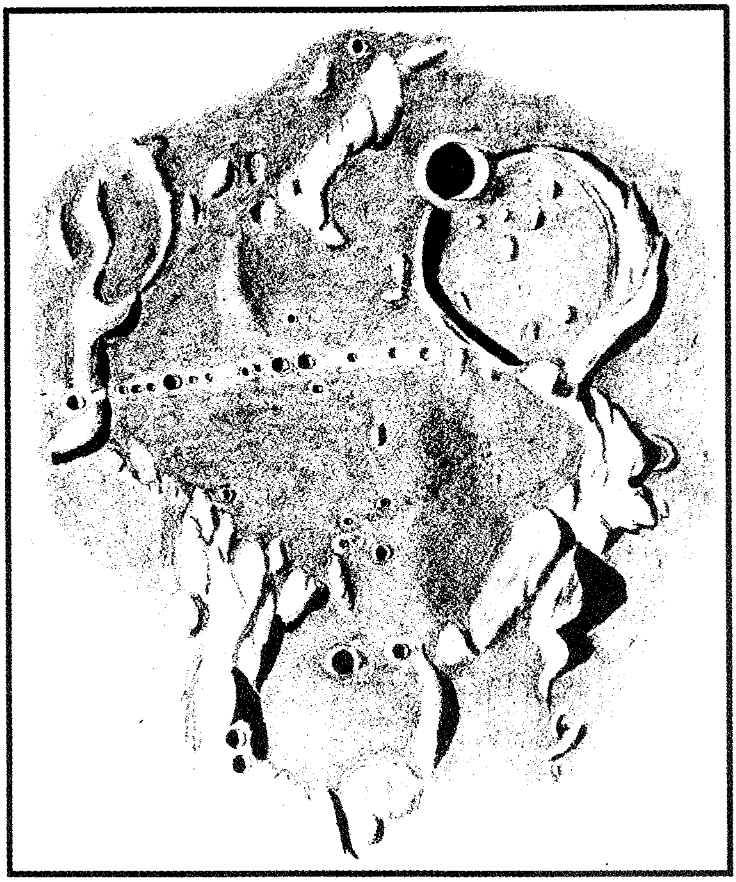

The lunar crater chain Catena Davy, drawn by Alika K. Herring on 1958 May 27, 04h15m UT, using a 12.5-in reflector at 228x-310x. Lunar south is at the top; the crater Davy is at upper right, and the large enclosure containing Catena Davy is called Davy Y. The crater chain has been described as composed of secondary, or alternatively volcanic, craters. Now it is thought possible that it resulted from the impact of a fragmented comet as happened when Comet Shoemaker-Levy 9 struck Jupiter in 1994. A tribute to Mr. Herring appears on pp. 30-31 of this issue.

E ASSOCIATION OF LUNAR AND PLANETARY OBSERVERS

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ASSOCIATION OF LUNAR & PLANETARY OBSERVERS
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IN THIS ISSUE

OBSERVATIONS OF SATURN DURING THE 1994-95 APPARITION

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

ABSTRACT

A.L.P.O. Saturn Section observers throughout the World contributed visual, photographic, and CCD data on Saturn for the 1994-95 Apparition, covering the period from 1994 APR 22 through 1995 JAN 23. Telescopes that were used ranged in aperture from 7.6 cm (3.0 in) to 40.6 cm (16.0 in). Several observers described vague dark spot activity in the Northern and Southern Hemispheres of Saturn during the apparition, as well as dusky festoons and other wispy dark features among the planet's belts and zones. Although professional astronomers in Spain and France announced the detection of a diffuse white area near Saturn's South Pole during 1994 August, no A.L.P.O. observers reported seeing this feature. The major highlight of the 1994-95 Apparition was an outburst of a moderately prominent white spot in the Equatorial Zone (EZ) of the planet, first reported by A.L.P.O. observers on 1994 AUG 23, and persisting at least into 1994 December. Saturn observers attempted central meridian (CM) transit timings to try to establish rotation rates for the spot. During the 1994-95 Apparition, the inclination of the Rings to our line of sight, B, reached a maximum value of + 8°.127 on 1994 NOV 08. The Northern Hemisphere of Saturn's Globe and the north face of the Rings were visible during 1994-95, with the substantially diminished inclination of the Rings to our line of sight affecting the appearance of features near Saturn's extreme northern limb. Much of the Southern Hemisphere of the planet was visible during 1994-95 as the inclination of the ring plane decreased. Accompanying this report are references, drawings, photographs, graphs, and tables.

INTRODUCTION

Extremely good observer participation during 1994-95 resulted in a useful collection of visual, photographic, and CCD observations of the planet Saturn and its Ring System. This analytical summary, which is supplemented by several drawings, photographs, and CCD images, is based upon data received for the observing season (period of actual observations) 1994 APR 22 - 1995 JAN 23. All dates and times in this report are in Universal Time (UT).

Table 1 (below) provides geocentric data in Universal Time for the 1994-95 Apparition of Saturn. Throughout the observing season the numerical value of B, the Saturnicentric latitude of the Earth referred to the ring plane (positive when north), ranged between the extremes of +4°.863 (1994 JUN 17) to +8°.127 (1994 NOV 08). The value of B', the saturnicentric latitude of the Sun, ranged from +8°.312 (1994 APR 22) down to +4°.412 (1995 JAN 23).

Table 1. Geocentric Phenomena for Saturn During the 1994-95 Apparition.

Conjunction	1994 FEB 21, 17h UT
Opposition	1994 SEP 01, 17
Conjunction	1995 MAR 06, 02
Opposition Data:	
Visual Magnitude	+0.5
B	+6°.640
B'	+6°.460
Declination of Saturn	-10°.02
Globe	
Equatorial Diameter	19".00
Polar Diameter	16".99
Rings	
Major Axis	43".32
Minor Axis	5".01

Table 2 (below and p. 2) lists the 30 individuals who submitted a total of 203 observations to the A.L.P.O. Saturn Section for the 1994-95 Apparition, along with their observing sites, number of dates of observations, and descriptions of their telescopes.

Table 2. Contributing Observers, 1994-95 Apparition of Saturn.

Observer & Location	No. of Dates	Telescope Data*
Benton, Julius L., Jr.	12	15.2 cm (6.0 in) R
Wilmington Island, GA	12	25.4 cm (10.0 in) S
Bosselaers, Mark	3	40.6 cm (16.0 in) N
Berchem, Belgium		
Cole-Arnal, Oscar	11	25.4 cm (10.0 in) S
Waterloo, Ontario, Canada		
Cuppens, Wim	1	20.3 cm (8.0 in) R
Genk, Belgium		
Dobbins, Thomas A.	1	25.4 cm (10.0 in) N
Coshocton, OH		
French, Alan & Sue	1	25.4 cm (10.0 in) N
Scotia, NY		
Graham, David L.	5	15.2 cm (6.0 in) R
North Yorkshire, UK	3	40.6 cm (16.0 in) N
Graham, Francis G.	1	33.0 cm (13.0 in) R
East Pittsburgh, PA		
Haas, Walter H.	1	20.3 cm (8.0 in) N
Las Cruces, NM	8	31.8 cm (12.5 in) N
Hargreaves, Gary S.	1	7.6 cm (3.0 in) R
Mission, British Columbia, Canada	8	12.7 cm (5.0 in) R

– Table 2 continued on p. 2 –

Table 2—Continued.

Observer & Location	No. of Dates	Telescope Data*
Heath, Alan W.	12	30.5 cm (12.0 in) N
Nottingham, UK		
Hill, Richard	2	35.6 cm (14.0 in) N
Tucson, AZ		
Lehman, David J.	8	25.4 cm (10.0 in) S
Fresno, CA		
Liu, Joseph	1	20.6 cm (8.1 in) R
Salinas, CA		
Melillo, Frank J.	1	20.3 cm (8.0 in) S
Holtsville, NY		
Niechoy, Detlev	1	10.2 cm (4.0 in) R
Gottingen, Germany	35	20.3 cm (8.0 in) S
	4	30.5 cm (12.0 in) N
Pearsall, James E.	1	20.3 cm (8.0 in) N
McMinnville, TN		
Plante, Phil	1	15.2 cm (6.0 in) N
Poland, OH	6	20.3 cm (8.0 in) R
	3	40.6 cm (16.0 in) C
Sabia, John D.	1	23.0 cm (9.0 in) R
Scranton, PA		
Schmude, Richard W.	5	9.0 cm (3.5 in) R
Barnesville, GA	4	35.6 cm (14.0 in) S
Stryk, Ted	4	25.4 cm (10.0 in) N
Bristol, VA		
Teichert, Gérard	1	28.0 cm (11.0 in) S
Hattstatt, France		
Vandenbohede, Alexander	1	20.3 cm (8.0 in) R
Beisbroek, Belgium		
Viens, Jean-Francois	3	25.4 cm (10.0 in) N
Quebec, Canada		
Verwichte, Erwin	4	15.2 cm (6.0 in) N
Genk, Belgium	5	20.3 cm (8.0 in) R
	1	25.4 cm (10.0 in) N
Warell, Johan	9	16.0 cm (6.3 in) R
Uppsala, Sweden		
Wasiuta, Myron A.	1	25.4 cm (10.0 in) N
Fredericksburg, VA		
Whitby, Samuel R.	15	15.2 cm (6.0 in) N
Hopewell, VA	1	17.8 cm (7.0 in) R
Will, Matthew	4	20.3 cm (8.0 in) N
Springfield, IL		
Wouter, Krznaric	1	11.0 cm (4.3 in) R
Genk, Belgium		
Total Observations	*203*	
Total Observers	*30*	

Notes: C = Cassegrain, N = Newtonian, R = Refractor, S = Schmidt-Cassegrain.

Figure 1 (p. 3), a histogram, gives the distribution of observations by month throughout the observing season. Most of the data were amassed during the months of 1994 JUL-DEC (89.7 percent). Of the submitted observations, 32.0 percent were made before opposition (1994 SEP 01), 0.5 percent on that date, and 67.5 percent after opposition. While an intense scrutiny of Saturn in the months nearest, and including, the date of opposition is very gratifying, it remains our objective to achieve, as much as possible, continuous coverage of the planet throughout each apparition. Therefore, we strongly encourage observers to begin following the planet when it first appears in the eastern sky before dawn and to continue their investigations until Saturn approaches conjunction with the Sun.

Figure 2 (p. 3) graphs the number of observations by instrument type. Telescopes of classical design (refractors, Newtonians, and Cassegrains) were used for 68.5 percent of the 203 observations in 1994-95. Their excellent image contrast and resolution makes them the instrument of choice of many individuals seeking a telescope purely for detailed planetary work. Also, 92.0 percent of the observations were made with instruments equal to or greater than 15.2 cm (6.0 in) in aperture.

Because of their reputation for inferior image contrast, Schmidt-Cassegrain telescopes have often been looked upon with some derision by many planetary observers, but about a third of the observations submitted in 1994-95 were made with such instruments, which ranged in aperture from 20.3 cm (8.0 in) to 35.6 cm (14.0 in). In recent years, there has been a growing percentage of larger apertures employed for A.L.P.O. Saturn observations. Based on the testimony of a number of regular planetary observers, there appears to be more emphasis now on aperture when acquiring a telescope than there is on any specific design. The writer takes no unyielding position in matters of instrument choice because he has experienced completely satisfactory views of Saturn through high-quality instruments of virtually every design, including Schmidt-Cassegrains. Simply put, optical quality should be the main prerequisite for any lunar and planetary telescope, and proper alignment of optical components will help insure optimum performance.

Figure 3 (p. 4) depicts the international base of 30 observers and 203 observations of the A.L.P.O. Saturn Section for 1994-95. During the observing season, the United States was responsible for 46.3 percent of the submitted observations and 56.7 percent of the participating observers. Valuable international participation in our programs continued during the 1994-95 Apparition, as demonstrated by a substantial percentage of individuals and observational reports from outside the United States. It is always the desire of the A.L.P.O. Saturn Section to enlist as many dedicated observers throughout the World as possible.

Seeing conditions during the 1994-95 apparition averaged 5.5 on the A.L.P.O. Seeing Scale (where 0.0 is the worst possible seeing and 10.0 denotes perfect seeing). Atmospheric transparency (usually defined as the magnitude of the faintest star just barely visible to the unaided, dark-adapted eye near the object being observed) averaged about +4.2 during the 1994-95 observing season.

The writer is grateful to all the dedicated A.L.P.O. Saturn observers mentioned in *Table 1* who contributed data to our programs during 1994-95, and observers in the United States and elsewhere are cordially encouraged to join us in coming apparitions as we attempt to realize our primary objective of maintaining comprehensive international surveillance of Saturn.

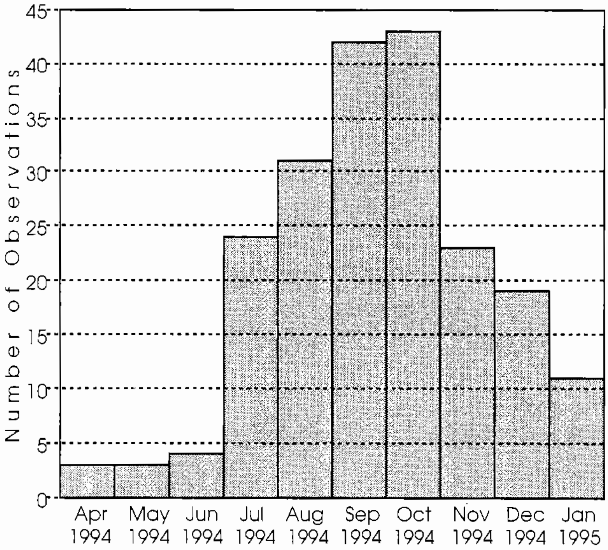

Figure 1. Distribution by month of the 203 observations submitted for the 1994-95 Apparition of Saturn. Note that 32.0 percent of the observations were made prior to opposition (1994 SEP 01), 0.5 percent on the date of opposition, and 67.5 percent after that date.

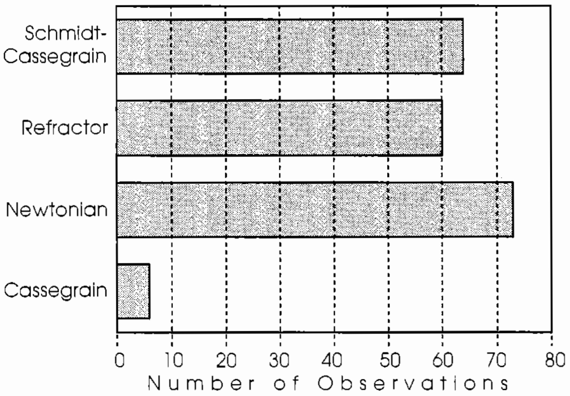

Figure 2. Number of observations by type of instrument, 1994-95 Apparition of Saturn.

THE GLOBE OF SATURN

This discussion is derived from 203 observational reports for the 1994-95 Apparition that were contributed to the A.L.P.O. Saturn Section. Except when the identity of an individual is pertinent to the discussion, the names of observers are not included in the text. Drawings, photographs, and CCD images accompany this report (see *Figures 5-14* on pp. 12-13), and we suggest that readers refer to them as they study this analysis. Features on the Globe of Saturn are described in north-to-south order and can be identified by the nomenclature diagram in *Figure 4* (p. 5).

Our summary of Saturn's global atmospheric features compares data between apparitions, as in previous Saturn observing reports, in order to help the reader to appreciate the delicate yet perceptible variations that may be occurring both in terms of Saturn's seasons and over a much longer span of time.

Intensities of Global Features.—Evidence suggests that the constantly changing inclination of Saturn's rotational axis relative to the Sun and Earth may affect recorded variations in belt and zone intensities, which are given in *Table 3* (p. 6) for 1994-95. Recent photoelectric photometry of Saturn indicates that the planet may exhibit oscillations of about ±0.10 visual magnitude with time, beyond those attributable to changing aspect and distance from the Sun and the Earth, and this finding has prompted some investigators to suggest that transient and long-lived atmospheric features in the belts and zones of Saturn may contribute to such brightness fluctuations. Routine photoelectric photometry of Saturn, conducted in conjunction with visual intensity estimates, would be a valuable project for suitably-equipped observers. [Conventional photoelectric photometry would be useful for whole-disk magnitude measurements, while CCD images could be used for photometry of specific Globe and Ring features. Ed.]

The intensity scale used here is the A.L.P.O. Standard Numerical Relative Intensity Scale, where 0.0 is total black and 10.0 is

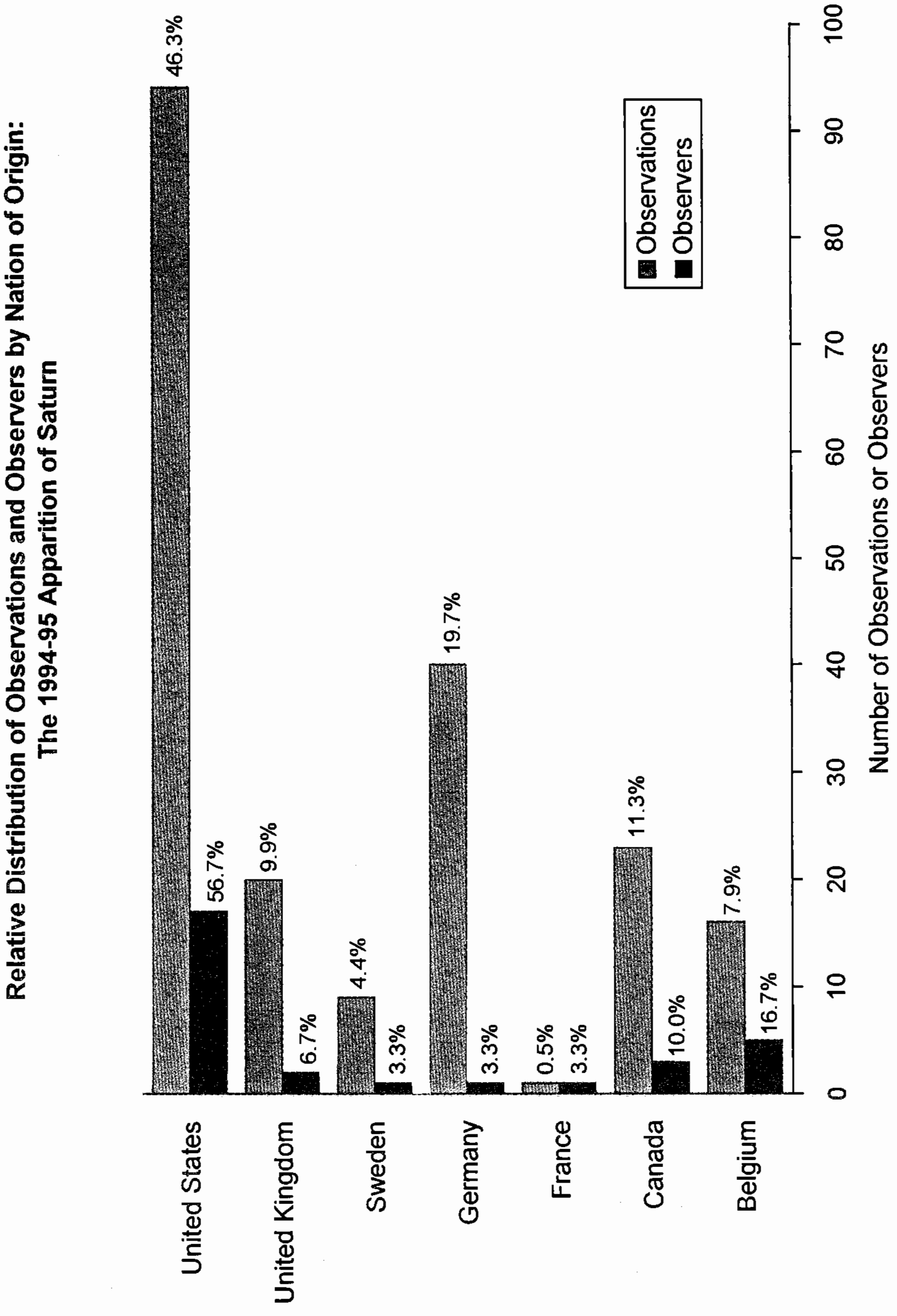

Figure 3. Number and percentage of observers and observations by nation, 1994-95 Apparition of Saturn.

the brightest possible condition. This scale is normalized by setting the outer third of Ring B at a standard brightness of 8.0. The arithmetic sign of an intensity change is found by subtracting a feature's 1993-94 intensity from its 1994-95 intensity. A change of only ±0.1 mean intensity points is considered to be of no real consequence, nor is a variation truly noteworthy unless it exceeds about 3 times its standard deviation.

Nomenclature of Saturn's Rings and Globe

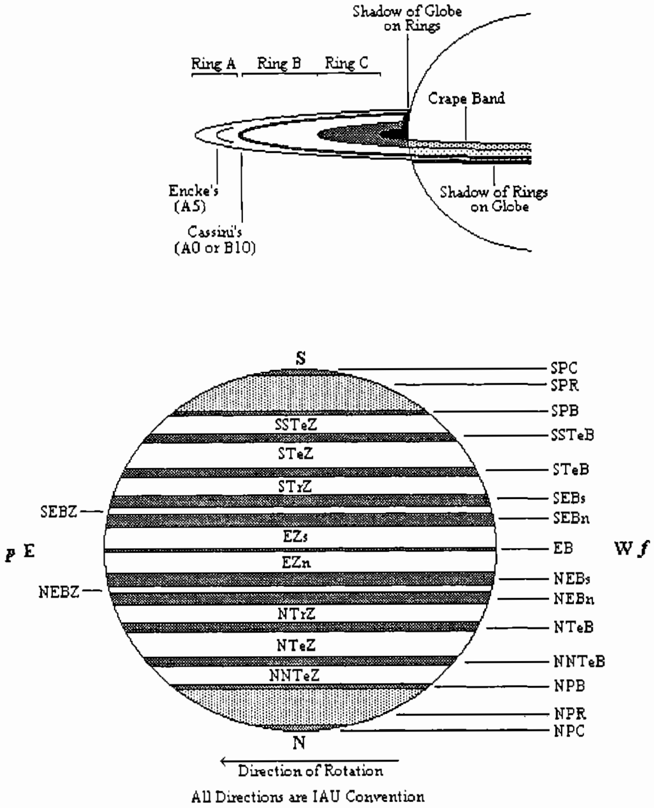

Figure 4. Nomenclature of features of Saturn's Rings and Globe. Letter abbreviations are: B = Belt, C = Cap, E = Equatorial, *f* = Following, N = North, n = North Component, P = Polar, *p* = Preceding, R = Region, S = South, s = South Component, Te = Temperate, Tr = Tropical, and Z = Zone. Mentioned in *Table 3* but not shown above is the Terby White Spot (TWS), located on the Rings adjacent to the Shadow of the Globe on the Rings.

Latitudes of Global Features.—With respect to the latitudes of Saturn's global features, observers used the visual method developed and introduced by Haas during the 1960's. Employing this method, one estimates the fraction of the polar semidiameter of the planet's disk that is subtended on the central meridian (CM) between the limb and the feature whose latitude is sought. This procedure is extremely easy to use; and with care in its execution, the results from this method compare very favorably with similar values derived with a bi-filar micrometer. After mathematical reduction, the resulting latitudes of Saturn's global features are given in *Table 4* (p. 7). It must be remembered, however, that it is often risky to place extreme confidence on data from only a few observers. Worth noting, however, is the fact that Haas has been employing this technique for many years with excellent and reliable results. Use of this method continues to grow among our observers, and it is strongly recommended that individuals use this very simple procedure whenever possible, even if a bi-filar micrometer is available. This advice is given because data from both the visual and the micrometrical methods would be useful for comparison. [Note also that positions can easily be measured directly from CCD images or even from digitized photographs. Ed.] A full discussion of this visual technique can be found in the Saturn Handbook. In discussing each feature on Saturn's Globe, notes regarding latitude data are incorporated into the text where appropriate.

Table 3. Visual Numerical Relative Intensity Estimates and Colors: Saturn, 1994-95.

	1994-95 Relative Intensities			
Globe/Ring Feature	Number of Estimates	Standard Deviation	Change Since 1993-94	"Mean" Derived Hue in 1994-95
Zones and Other Bright Areas:				
NPC	8	5.48 ±0.41	+0.77	Dusky Yellowish-Grey
NPR	24	5.56 ±0.70	+0.76	Yellowish-Grey
NTeZ	6	6.58 ±0.45	+0.78	Dull Yellowish-White
NTrZ	8	6.79 ±0.23	+0.99	Yellowish-White
EZn	39	7.59 ±0.92	-0.01	Pale Yellowish-White
Globe N of Rings (entire)	13	5.33 ±1.10	-0.07	Dusky Yellowish-Grey
Globe S of Rings (entire)	14	5.65 ±0.79	+ 0.05	Dusky Yellowish-Grey
EZs	16	6.59 ±0.72	-------	Dull Yellowish-White
STrZ	8	6.71 ±1.31	-------	Yellowish-White
STeZ	10	6.72 ±0.68	+0.52	Yellowish-White
SPR	15	5.97 ±0.91	-------	Yellowish-Grey
SPC	1	5.50 ------	-------	Dusky Yellow-Grey
Belts:				
NTeB	2	6.25 ±0.25	+0.75	Very Pale Grey
NEB	37	4.64 ±1.17	+0.94	Light Greyish-Brown
EB	1	3.70 ------	-2.30	Dark Grey
SEB (entire)	19	4.64 ±0.96	+0.74	Greyish-Brown
STeB	13	5.03 ±1.24	+0.33	Greyish
Rings:				
A (entire)	35	6.99 ±0.60	+0.79	Dusky White
A0 or B10 (ansae)	15	2.03 ±1.54	+0.83	Greyish-Black
B (outer 1/3)	---	8.00 (standard)	---	White
B (inner 2/3)	23	6.81 ±0.74	-0.59	Yellowish-White
C (ansae)	15	2.32 ±1.22	+1.22	Dark Greyish-Black
Crape Band	19	2.20 ±1.10	-0.80	Dark Grey
Sh G on R	18	0.62 ±1.02	+0.32	Dark Greyish-Black
Sh R on G	4	1.00 ±1.22	+0.80	Dark Greyish-Black
TWS	5	7.28 ±0.37	-0.52	White

Notes: For nomenclature see text and *Figure 4* (p. 5). A letter with a digit (e.g. A0 or B10) refers to a location on the Ring in units of tenths of the distance from the inner edge to the outer edge. 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 most brilliant possible condition. The adopted scale for Saturn uses a reference standard of 8. 0 for the outer third of Ring B, which appears to remain stable in intensity for most Ring inclinations. All other features on the Globe or in the Rings are compared systematically using this scale, described in the *Saturn Handbook*, which is issued by the A.L.P.O. Saturn Section. The "Change Since 1993-94" is in the sense of the 1993-94 value subtracted from the 1994-95 value, "+" denoting an increase in brightness and "-" indicating a decrease (darkening). When the apparent change is less than about 3 times the standard deviation, it is probably not statistically significant.

NORTHERN PORTIONS OF THE GLOBE

During 1994-95, observers were rewarded by what seemed to be an apparent slight elevation in activity in the Northern Hemisphere of Saturn when compared with the immediately preceding apparition, although this impression may have been in part due to the tendency to use larger instruments in 1994-95 than earlier. A number of short-lived and rather vague, wispy festoons, together with subtle dusky mottlings, characterized several of the planet's northern belts and zones during the apparition, including the sporadic appearance of a few transient, diffuse light patches. Also, on the basis of their mean intensities, one is tempted to conclude that the belts and zones of the Northern Hemisphere were all slightly brighter than they had been in 1993-94. Complications affect our interpretations, however, when one compares the mean intensity of the Globe North of the Rings (see *Table 3*, above) in 1994-95 with that of 1993-94, where no discernible brightness variation is indicated. Furthermore, comparing the estimated brightness of the Globe north of the Rings versus that of the Globe south of the Rings, the former was the darker of the two hemispheres by -0.32 mean intensity points.

By far the most noteworthy feature reported in the Northern Hemisphere of Saturn in 1994-95 was a moderately brilliant white spot that emerged in the Equatorial Zone (EZ), first detected in late 1994 August and persisting at least into 1994 December; this feature will be discussed more in the later section dealing with Saturn's Equatorial Zone. Observers also detected variations in the appearance, bright-

Table 4. Saturnian Belt Latitudes in the 1994-95 Apparition.

	Form of Latitude (Change from 1993-94 in Parentheses)					
Saturnian Belt	Planetocentric		Eccentric		Planetographic	
	° °	°	° °	°	° °	°
N edge NEB	+17.6 ±1.3	(-3.0)	+19.5 ±1.5	(-3.4)	+21.7 ±1.6	(-3.6)
S edge NEB	+14.0 ±2.0	(-1.2)	+15.6 ±2.2	(-1.3)	+18.9 ±2.4	(-1.5)
N edge SEB	-19.5 ±7.7	(......)	-21.6 ±8.2	(......)	-23.8 ±8.6	(......)
S edge SEB	-23.1 ±8.4	(......)	-25.4 ±1.3	(......)	-27.9 ±1.4	(......)
Center STeB	-39.3 ±2.8	(-1.0)	-42.5 ±2.9	(+0.6)	-45.7 ±5.5	(-1.0)

Notes: For nomenclature see text and *Figure 4* (p. **). Latitudes are calculated using the appropriate geocentric tilt, B, for each date of observation. Planetocentric latitude is the angle between the Equator and the feature as seen from the center of the planet. Planetographic latitude is the angle between the surface normal and the equatorial plane. Eccentric, or "Mean," latitude is the arc-tangent of the geometric mean of the tangents of the other two latitudes. The change shown in parentheses is the result of subtracting the 1993-94 latitude from the 1994-95 latitude.

ness, or both, of different belts and zones in the Northern Hemisphere of Saturn during 1994-95.

North Polar Region (NPR).—The yellowish-grey NPR was uniform in overall appearance in 1994-95 and showed what might have been a slight increase in brightness (+0.76 in mean intensity) since 1993-94. The dusky yellowish-grey North Polar Cap (NPC), just a little darker than its immediate environment, was seen periodically during the apparition. Situated in the extreme north, since 1993-94 the NPC exhibited a small rise in brightness (a mean intensity change of +0.77). The North Polar Belt (NPB) was not reported by A.L.P.O. observers during the 1994-95 observing season.

North North Temperate Zone (NNTeZ).— This feature was not mentioned in observational reports submitted during 1994-95.

North North Temperate Belt (NNTeB).—Observers did not report this feature during the 1994-95 Apparition.

North Temperate Zone (NTeZ).—In 1994-95 the dull yellowish-white NTeZ showed a small increase in brightness since the immediately preceding apparition (a change in mean intensity of +0.78). The NTeZ was not frequently reported during the apparition, but when it was seen, observers suspected short-lived and diffuse light and dark features associated with the NTeZ, all at the threshold of vision. The NTeZ and STeZ exhibited nearly the same mean intensity during the 1994-95 observing season.

North Temperate Belt (NTeB).—The light-greyish NTeB was extremely ill-defined during 1994-95, more so than in 1993-94, and only barely discernible from its surroundings. On the few dates when it was detected, the NTeB extended uniformly across the Globe from limb to limb, but always was very diffuse. Possibly contributing to the poor contrast of the NTeB with adjacent zones on Saturn was the suspected increased brightness of the belt in 1994-95 (cautiously based on only two estimates, it appeared lighter by +0.75 mean intensity points than in 1993-94).

North Tropical Zone (NTrZ).—The yellowish-white NTrZ was second only to the Equatorial Zone (EZ) in being the brightest zone on Saturn's Globe in 1994-95. The NTrZ was brighter during 1994-95 by +0.99 mean intensity points over what it had been in 1993-94, and observers described it as a dull yellowish-white zone with only an occasional suspected bright area or festoon as it extended across the Globe from limb to limb.

North Equatorial Belt (NEB).—The most common aspect of the greyish-brown NEB during 1994-95 was as a single feature, only rarely suspected of being differentiated into an NEBn and NEBs; where "n" refers to the North Component and "s" to the South Component, separated by an NEBZ (North Equatorial Belt Zone). Numerous and considerably diffuse dark spots and dusky projections, sometimes barely extending into the EZn, could be detected in better seeing conditions during the apparition, but none of these features had enough longevity to permit repeated CM transit timings. On the basis of intensity estimates in 1994-95, the NEB was not quite as dark as it had been in 1993-94 (lighter by +0.94 mean intensity points). The NEB was equal in mean intensity to its southern counterpart, the SEB. Aside from an isolated glimpse in 1994-95 of what may have been the Equatorial Band (EB), the NEB joined the SEB in being the darkest belts on Saturn during the apparition.

Equatorial Zone (EZ).—With Saturn's Rings nearing the time of edgewise orientation (in 1995-96), during 1994-95 the EZ could be seen as two components: the EZn (the region of the EZ between where the Rings cross the Globe and the NEB) and the EZs (the portion of the EZ between where the Rings cross the Globe and the SEB). The pale yellowish-white EZn was virtually the same brightness in 1994-95 as it was in 1993-94 (a negligible mean intensity change of -0.01), and the EZn was always the most brilliant zone on Saturn during the 1994-95 Apparition, closely approaching the intensity of the outer third of Ring B. The rather conspicuous brightness of the EZn during the apparition was attributed somewhat to periodic sightings of transient bright, diffuse areas and sporadic white-spot activity in the region.

The most significant feature in the EZn, however, was undoubtedly the bright white spot that was sighted initially in mid-July of 1994 by astronomers in Spain, at Pic du Midi in France, and in Japan. The first A.L.P.O. observation of the EZn white spot was by Thomas A. Dobbins on 1994 AUG 23 using a 25.4-cm (10.0-in) Newtonian. Dobbins described the feature as a bright oval about 3-4 arc-seconds across near System I longitude 206°. [System I longitude uses a sidereal rotation period of 10h 14m 00s and is applied to NEBs, EZ, and SEBn. Ed.] From the date of Dobbins' observation in 1994 August until well into 1994 December, A.L.P.O. observers all over the world followed the evolution of the EZn white spot. The mean intensity of the white spot was 8.4, suggesting that it was slightly brighter than the outer third of Ring B, and clearly the brightest Saturnian feature during 1994-95. Although drawings by several observers depicted the white spot as an increasingly diffuse feature as the apparition progressed, rapidly spreading out longitudinally along the EZn, CCD images made by James E. Pearsall on 1994 SEP 10 with a 20.3-cm (8.0-in) Newtonian most dramatically revealed the morphology of the feature [see *Figure 8*, p. 11]. Pearsall's CCD images showed that the EZn white spot also contributed to the brightening of the EZs in the same longitude, and had the ring system been edge-on during 1994-95, the latitudinal extent of the disturbance within the entire EZ could have been more precisely evaluated. A few observers suspected that, by late 1994 November, the white spot had differentiated into two diffuse areas of equal brightness, but confirming data were lacking. Hubble Space Telescope (HST) images in visible, ultraviolet, and near infrared wavelengths on 1994 DEC 01 revealed considerable structure within the white spot, and even though they were more detailed, the view looked very similar to Pearsall's CCD images in early September.

The white spot outburst in 1994-95 was considerably less turbulent than the Great White Spot of 1990, yet it rated as a moderately large disturbance, persisting much longer than most Saturnian atmospheric phenomena of the apparition. CM transit timings of the 1994-95 EZ white spot were unfortunately too scattered to derive reliable rotation periods. [This feature is shown on Figures 7-8, 10-12 and 14. These suggest a drift rate of approximately 9°.5/day in System I, with a corresponding rotation period of 10h 07m 09s. Ed.]

Sightings of wispy festoons projecting from the NEBs, some associated with the preceding and following edges of the bright white spot, occurred during the 1994-95 Apparition, but capturing CM transits of any of the vague bright and dark features in the EZn proved fruitless.

The Equatorial Band (EB) was suspected only once during the 1994-95 Apparition as a dark grey, poorly-defined linear feature running across Saturn's Globe. Although a lone intensity estimate hinted that the belt was much darker in 1994-95 than in 1993-94 (by -2.30 mean intensity points), probably no confidence can be placed in this impression.

The dull yellowish-white Equatorial Zone–South Component (EZs) was darker by -1.00 mean intensity points than the EZn, but is it conceivable that observers viewed much of the EZs through portions of the very tenuous Ring E where it crossed in front Saturn's Globe? Perhaps the shadow of the rings on the Globe contributed to the darker appearance of the EZs as well.

Shadow of the Globe on the Rings (Sh G on R).—This feature was occasionally seen as a dark greyish-black feature on either side of opposition during 1994-95, regular in form; any deviation from an actual black (0.0) intensity was due to scattered light and poor seeing.

Shadow of the Rings on the Globe (Sh R on G).—This feature was sometimes seen in 1994-95 as dark greyish-black south of the Rings where they crossed the Globe. Any variation from the true black (0.0) intensity occurs for the same reasons as noted in the preceding paragraph.

SOUTHERN PORTIONS OF THE GLOBE.

As the plane of the Rings and Equator of Saturn continued to decrease its tilt to our line of sight in 1994-95, increased areas of the Southern Hemisphere of the planet were open for our inspection, while correspondingly the Northern Hemisphere was less visible. Belts and zones of the Southern Hemisphere were visible, and comparisons with their counterparts in the Northern Hemisphere became possible. As a whole, the Globe of Saturn south of the plane of the Rings was slightly brighter than the portion of the Globe north of the ring plane in 1994-95, an impression that was also noted in 1993-94.

Astronomers at Pic du Midi Observatory in France announced the discovery of a bright, diffuse white spot on Saturn, occupying about 5° to 12° of longitude, at an approximate latitude of -60° in the planet's Southern Hemisphere (in the SPR) on 1994 AUG 13, seen also by observers at the Black Birch Station of the U.S. Naval Observatory in New Zealand on 1994 AUG 20. A.L.P.O. Saturn Section observers, however, did not report this feature during 1994-95.

South Equatorial Belt (SEB).—The SEB was observed during 1994-95 as a single, greyish-brown feature with the same mean intensity as the NEB, with no reported differentiation into SEBn or SEBs components. The SEB was the darkest and most obvious belt in the Southern Hemisphere of Saturn in 1994-95, and it was lighter by +0.74 mean intensity points than it was in 1993-94. The SEB was equal in mean intensity to its northern counterpart, the NEB. And, as mentioned previously, apart from a solitary view in 1994-95 of an apparent Equatorial Band (EB), the SEB and NEB were the darkest belts on Saturn's Globe during the observing season. A few dark spots were sighted along the SEB during 1994 July, but they did not endure long enough for CM transit timings.

South Tropical Zone (STrZ).—The yellowish-white STrZ was a fairly bright zone during 1994-95, of about the same overall intensity as the STeZ, and only slightly darker than the NTrZ. It was stable in brightness and apparently devoid of activity throughout the entire apparition.

South Temperate Belt (STeB).—The STeB was described during the 1994-95 Apparition as greyish in color, extending uninterrupted across the Globe from one limb to the other. The STeB was darker than its Northern-Hemisphere counterpart, the NTeB, by -1.22 intensity points. No activity was reported in the STeB in 1994-95.

South Temperate Zone (STeZ).—The yellowish-white STeZ was essentially equal in mean intensity to the STrZ, and the STeZ and STrZ together were the third brightest zones on Saturn in 1994-95, with uniform intensity throughout the apparition and no clearly defined activity. The STeZ was +0.52 mean intensity points brighter in 1994-95 than it was in 1993-94, and when compared with the NTeZ, the STeZ was +0.14 mean intensity points brighter during the apparition.

South Polar Region (SPR).—The SPR was a uniform yellowish-grey during the 1994-95 Apparition, without any discernible activity, according to A.L.P.O. Saturn observers, but recall that a diffuse white spot was seen in this region during 1994 July and August by professional astronomers. Somehow, the SPR white spot escaped the view of A.L.P.O. observers. There was one sighting in 1994-95 of the South Polar Cap (SPC), ill-defined and slightly brighter than its surroundings, but the South Polar Belt (SPB) was not reported at all throughout the apparition.

SATURN'S RING SYSTEM

This section focuses on investigations of Saturn's Ring System that were contributed in 1994-95, along with a continuing comparative study of the mean intensity data as has been done for previous apparitions. The northern face of the Rings was presented less favorably to our view in 1994-95 than in 1993-94 because of the significantly diminished tilt of the Ring System to our line of sight.

Ring A.—Taken as a whole, Ring A was dull white throughout the 1994-95 Apparition, seemingly a little brighter than in 1993-94 (by only +0.79 mean intensity points). No reports of Encke's Division (A5) at the Ring ansae were received during the apparition, not were there any other intensity minima recognized in Ring A in 1994-95. On perhaps one or two occasions, Ring A was noted to have distinct outer and inner halves in terms of brightness, but no comparative intensity estimates were made.

Ring B.—The outer third of Ring B is the adopted standard of reference for the A.L.P.O. Saturn Intensity Scale, with an assigned value of 8.0. For the duration of 1994-95, this region of Ring B appeared white, stable in intensity, and unquestionably the brightest feature on either Saturn's Globe or Rings, except for the brilliant EZn white spot (of mean intensity 8.4) that persisted from 1994 August into December. In 1994-95, the inner two-thirds of Ring B, which was yellowish-white in color and uniform in intensity, displayed a small decrease in brightness since the immediately preceding observing season (a brightness decrease of-0.59 mean intensity points).

Cassini's Division (A0 or B10).—Cassini's Division was regularly visible at the ansae in 1994-95, but even in excellent seeing, observers had little success in seeing the feature elsewhere in the Rings because of the small value of B during the apparition. Cassini's Division was described as greyish-black during the 1994-95 Apparition, apparently of a lighter intensity when compared with 1993-94 (a difference of +0.83 mean intensity points); an impression largely attributable to the small inclination of the Ring System to our line of sight. Normally, any deviation from a true black appearance for this feature is due to such causes as scattered light or poor seeing. [Except when the sunlit Globe can be seen through the Division. Ed.}

Ring C.—Seen mostly as a greyish to greyish-black component at the ansae, Ring C was of a lighter intensity (+ 1.22 mean intensity points) during 1994-95 when compared with 1993-94. As a common rule, faint or narrow Ring features are easier to see, and they typically appear darker, at greater ring inclinations.

The Crape Band (Ring C as projected onto the Globe) had a darker overall intensity in 1994-95 than in 1993-94 (by -0.80 mean intensity points). Observers agreed that this feature was uniform in intensity and extremely dark grey in color. Except when they are near the plane of the Rings, the Saturnicentric latitudes of the Sun and Earth conspire to bring about the partial coincidence of the Crape Band with the shadow of Ring C on the Globe, making the Crape Band appear somewhat darker as happened in 1994-95.

Ring Components Other than A, B or C.—Ring D (inside Ring C) nor Ring E (outside Ring A) were reported in 1994-95, although it is remotely possible that the presence of the tenuous Ring E in front of Saturn's Globe during the apparition could have contributed to a duskier appearance of the EZs. Normally, investigations of these Ring components are well beyond the scope of most visual work because they are difficult to detect, requiring the best possible seeing conditions and relatively large aperture.

Terby White Spot (TWS).—The TWS is an occasionally seen brightening of the Rings immediately adjacent to the Sh G on R. A small number of observers in 1994-95 reported a bright TWS (of mean intensity 7.28), and as in 1993-94 and other recent apparitions, this feature appeared not nearly so conspicuous as it had been in the early to mid-1980's. The TWS is of no significance in terms of the Rings themselves, since it is most certainly a spurious contrast phenomenon, not an intrinsic Saturnian feature. It is of interest, however, to try to ascertain whether there is any correlation between the brightness of the TWS and the varying tilt of the Ring, as well as its appearance and prominence in different color filters and polarizers.

Bicolored Aspect of the Rings.—This phenomenon is a reported difference in color between the two ansae of the Rings. Several individuals made regular attempts to see if they could detect the bicolored aspect in 1994-95. Their efforts resulted in the detection of variations in the brightness of the East and West ansae (IAU system) when compared with W47 (Wratten 47) or W80A (both blue) and W25 or W23A (red) Filters. *Table 5* (below) lists the circumstances of these observations. There were two instances of searches for the bicolored aspect within a few hours of

Table 5. Observations of the Bicolored Aspect of Saturn's Rings During the 1994-95 Apparition.

Observer	UT Date and Time (entire observing Period)	Telescope Type and Aperture	Magnification	Seeing	Transparency	Filter B	Filter IL	Filter R
Plante	1994 May 28 08:40-08:54	R 20.3 cm (8.0 in)	176X	4.5	+2.5	E	E	=
Hargreaves	1994 Jun 02 10:30-11:14	R 12.7 cm (5.0 in)	190X	3.0	---	W	=	E
Hargreaves	1994 Jun 23 10:25-10:45	R 12.7 cm (5.0 in)	190X	3.0	---	W	=	E
Hargreaves	1994 Jul 06 09:30-10:45	R 12.7 cm (5.0 in)	190X	---	---	W	=	=
Hargreaves	1994 Jul 10 09:15-10:45	R 12.7 cm (5.0 in)	190X	---	---	=	=	=
Hargreaves	1994 Jul 13 10:18-10:56	R 7.6 cm (3.0 in)	200X	8.0	+5.0	E	=	W
Whitby	1994 Jul 15 08:35-08:50	N 15.2 cm (6.0 in)	310X	7.0	+4.0	=	=	=
Hargreaves	1994 Jul 28 07:30-08:45	R 12.7 cm (5.0 in)	228X	---	+4.0	W	=	W
Schmude	1994 Aug 04 07:00-07:14	S 35.6 cm (14.0 in)	325X	9.0	+5.0	=	E	=
Hargreaves	1994 Aug 04 10:00-11:30	R 12.7 cm (5.0 in)	228X	5.0	+3.0	=	=	=
Whitby	1994 Aug 13 08:55-09:07	N15.2 cm (6.0 in)	310X	7.0	+4.0	=	=	=
Hargreaves	1994 Aug 30 09:00-10:00	R 12.7 cm (5.0 in)	190X	7.0	---	=	=	=
Plante	1994 Sep 01 02:50-03:11	R 20.3 cm (8.0 in)	428X	5.0	+4.0	W	=	=
Will	1994 Sep 04 06:50-07:10	N 20.3 cm (8.0 in)	270X	4.5	+4.0	E	E	W
Lehman	1994 Sep 06 05:20-06:10	N 25.4 cm (10.0 in)	250X	5.0	+5.0	E	E	E
Hargreaves	1994 Sep 07 07:13-09:15	R 12.7 cm (5.0 in)	228X	4.0	+3.0	=	=	=
Lehman	1994 Sep 14 05:20-06:10	N 25.4 cm (10.0 in)	250X	4.0	+4.8	E	E	E
Whitby	1994 Sep 20 01:33-01:48	N 15.2 cm (6.0 in)	310X	7.0	+5.0	=	=	=
Lehman	1994 Sep 20 05:40-06:05	N 25.4 cm (10.0 in)	250X	5.0	+5.5	W	=	E
Dobbins	1994 Sep 21 04:53	N 25.4 cm (10.0 in)	Video Recording (W12 [yellow] Filter) W > E in video frame?					
Heath	1994 Sep 26 22:10	N 30.5 cm (12.0 in)	190X	---	---	=	=	=
Whitby	1994 Sep 27 00:45-00:55	N 15.2 cm (6.0 in)	205X	6.0	+5.0	=	=	=
Heath	1994 Sep 27 21:10	N 30.5 cm (12.0 in)	190X	---	---	=	=	=
Whitby	1994 Sep 30 23:45-23:55	N 15.2 cm (6.0 in)	205X	4.0	+3.0	=	=	=
Lehman	1994 Oct 03 03:45-04:30	N 25.4 cm (10.0 in)	250X	6.0	+5.0		=	
Heath	1994 Oct 09 21:15	N 30.5 cm (12.0 in)	190X	---	---	E	=	=
Will	1994 Oct 10 04:00-04:20	N 20.3 cm (8.0 in)	270X	6.0	+5.0	E	W	W
Heath	1994 Oct 13 21:00	N 30.5 cm (12.0 in)	190X	---	---	E	=	=
Heath	1994 Oct 17 21:00	N 30.5 cm (12.0 in)	190X	---	---	=	=	=
Haas	1994 Oct 19 01:41-01:54	N 20.3 cm (8.0 in)	231X	5.0	+2.5	E	=	=
Whitby	1994 Oct 22 01:10-02:00	N 15.2 cm (6.0 in)	310X	9.0	+4.0	E	=	=
Lehman	1994 Oct 28 03:55-04:30	N 25.4 cm (10.0 in)	310X	4.0	+4.5	E	W	E
Whitby	1994 Nov 12 01:45-02:00	N 15.2 cm, (6.0 in)	205X	6.0	+5.0	=	=	=
Will	1994 Nov 24 01:26-01:41	N 20.3 cm (8.0 in)	270X	5.0	+5.0	W	W	W
Whitby	1994 Dec 01 23:05-23:15	N 15.2 cm (6.0 in)	310X	7.0	+5.0	=	=	=
Haas	1994 Dec 04 00:49-01:39	N 31.8 cm (12.5 in)	366X	4.0	+3.0	E	=	=
Haas	1994 Dec 17 01:30-02:22	N 31.8 cm (12.5 in)	366X	4.0	+3.0	=	=	=
Haas	1994 Dec 18 00:38-02:55	N 31.8 cm (12.5 in)	366X	3.5	+4.0	E	=	=
Haas	1994 Dec 22 00:32-01:09	N 31.8 cm (12.5 in)	366X	3.0	+3.5	W	=	=
Will	1994 Dec 26 00:26-00:45	N 20.3 cm (8.0 in)	270X	3.5	+4.0	E	E	E
Haas	1995 Jan 01 00:27-01:06	N 31.8 cm (12.5 in)	366X	4.0	+3.5	E	=	=
Haas	1995 Jan 14 00:59-01:40	N 31.8 cm (12.5 in)	366X	3.5	+4.0	E	=	=
Haas	1995 Jan 23 00:58-01:18	N 31.8 cm (12.5 in)	366X	3.0	+3.5	E	=	=

Notes: Telescope types are as in *Table 2* (pp. 1-2). Seeing is in the 0-10 A.L.P.O. Scale, and Transparency is the limiting visual magnitude in the vicinity of Saturn. Under "Filter," B refers to the blue W47 or W80A filters, IL to integrated light (no filter), and R to the red W25 or W23A filters. E means the East ansa was brighter than the W, W that the West ansa was the brighter, and = means that the two ansae were equally bright. East and West directions are as noted in the text.

each other, on 1994 AUG 04 and SEP 20, but with contradictory results. To better understand what is the nature of the bicolored aspect of the Rings, there remains a great need for observers to strive to conduct simultaneous observing programs which stress, among other projects, a systematic study of this phenomenon. The greater the number of persons taking part in this effort, making independent, systematic visual estimates with color filters and doing CCD work and photography in the corresponding wavelengths, all at the same time, the better will be the chances of shedding some new light on this intriguing and poorly understood phenomenon.

Note that *Table 5* uses Saturnian or IAU directions, where West is to the right in a normally inverted telescope image (observer located in the Northern Hemisphere of the Earth) which has South at the top.

SATURN'S SATELLITES

As in the immediately preceding apparition, no observers in 1994-95 contributed systematic visual estimates of Saturn's satellites using the methods outlined in *The Saturn Handbook*. We strongly encourage photoelectric or CCD photometry and systematic visual magnitude estimates of Saturn's satellites in future apparitions.

SIMULTANEOUS OBSERVATIONS

A few simultaneous, or near-simultaneous, observations of Saturn were submitted during 1994-95, where "simultaneous observations" are those in which individuals work independently of one another but observe at the same time and on the same date. As in the 1993-94 Apparition, the occurrence of simultaneous observations was entirely fortuitous, and the A.L.P.O. Saturn Section would like to receive reports from individuals who participate in a routine simultaneous observing effort. Simultaneous observations provide much-needed verification of ill-defined phenomena on Saturn's Globe and in the Ring System, greatly strengthening the confidence level in the interpretation of the data. Readers are urged to inquire about how to pursue simultaneous observations in future observing seasons.

CONCLUSIONS

Based on our analysis of the submitted observations of Saturn in 1994-95, atmospheric activity had increased somewhat since the immediately preceding observing season. Whether the slight apparent brightness increase for most global features was related to any Saturnian seasonal effect remains unclear, particularly because an assessment of such phenomena requires gathering and comparing data over at least one orbit of the planet around the Sun, which spans a period of 29.5 years. This opportunity will arise at the conclusion of the 1995-96 Edgewise Apparition of Saturn, when the A.L.P.O. Saturn Recorder will initiate a detailed comparative analysis of visual numerical relative intensity estimates going back to 1965-66 (one Saturnian year ago). We hope that this study will shed some light on possible seasonal effects as they might apply to the prominence of belts and zones on Saturn's Globe as well as Ring features. The results of this investigation will be published in a later issue of this Journal.

We cordially invite our readers to join us in contributing to our observing programs in order to help us accomplish our observational objectives in the years ahead. Systematic observations of Saturn are necessary for the success of our pursuits, and we need as many dedicated observers as possible.

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Figures 5-14 (pp. 12-13). Unless otherwise stated for these illustrations: **Seeing** is given on the 0-10 A.L.P.O. Scale, where 0 is the worst and 10 is perfect; **Transparency** is the limiting naked-eye visual magnitude in the vicinity of Saturn; **CM(I)** is the central-meridian longitude in rotational system I (844°.3/day, applying to the NEBs, EZ, and SEBn); **CM(II)** is the same in rotational system II (812°.0/day, applying to the remainder of the Globe); **B** is the saturnicentric latitude of the Earth; and **B'** is the saturnicentric latitude of the Sun. Saturnicentric south is at the top in all views, with celestial east (following) to the right (Figure 12 was initially reversed left-to-right and has been rectified, while a black background has been added to Figures 7, 11, 13, and 14.) Contrasts have been exaggerated for reproduction.

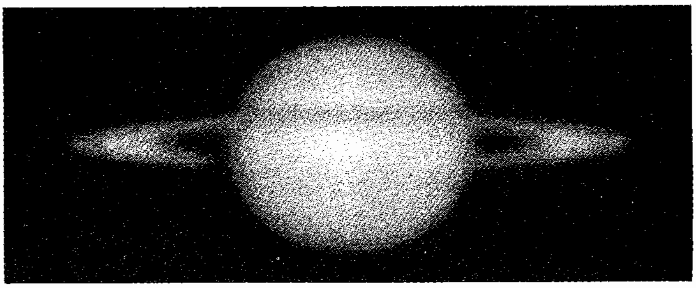

Figure 5. Photograph by Richard W. Schmude, Jr. 1994 Aug 07, 07h55m UT. 35.6-cm (14.0-in) Schmidt-cassegrain, f/200, 5 sec (color original). CM(I) = 283°.0, CM(II) = 176°.2, B = +5°.7, B' = +6°.8.

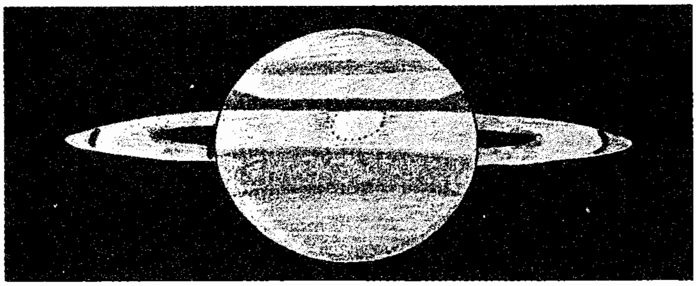

Figure 6. Drawing by Erwin Verwichte. 1994 Aug 11, 00h01m-00h12m UT. 15.0-cm (5.9-in) Newtonian, 111X, no filter. Seeing = Antoniadi I-II (Excellent-Good), Transparency = Good, with clouds. CM(I) = 142°.6-149°.0, CM(II) = 277°.3-283°.5, B = +5°.9, B' = +6°.8.

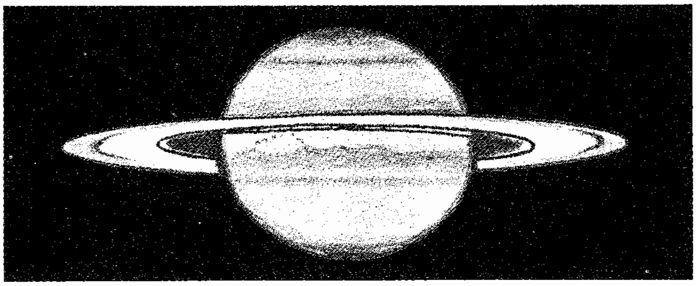

Figure 7. Drawing by Phil Plante. 1994 Sep 01, 02h50m-03h11m UT. 20.3-cm (8.0-in) refractor, 250X & 428X, no filter. Seeing = 5, Transparency = +4.0. CM(I) = 333°.7-346°.0, CM(II) = 146°.3-158°.1, B = +6°.6, B' = +6°.5. Observation made 14 hours before opposition. Note EZn White Spot to left of CM.

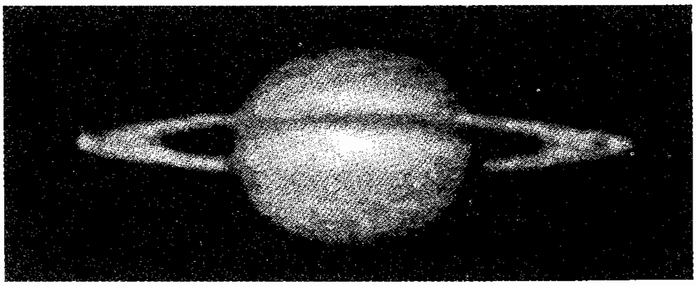

Figure 8. CCD image by James Pearsall. 1994 Sep 10, 04h07m UT. 20.3-cm (8.0-in) Newtonian, f/58, 2 sec., no filter. Spectrasource Lynzz PC camera, processed with AstroIP and QwikPIX software. Seeing = 6, Transparency = +4. CM(I) = 058°.1, CM(II) = 298°.2, B = +6°.9, B' = +6°.3. Note EZn White Spot immediately to right of CM.

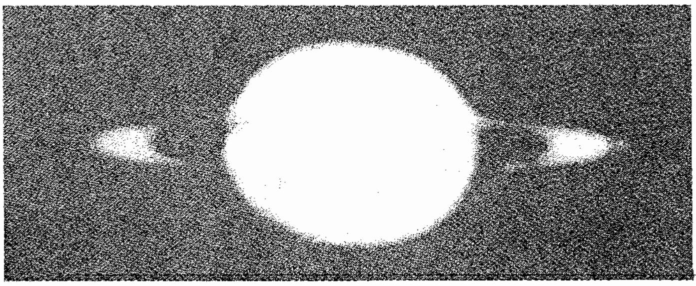

Figure 9. Video image by Tom Dobbins. 1994 Sep 21, 04h53m UT. 25.4-cm (10.0-in) Newtonian, W12 (yellow) filter. CM(I) = 012°.8, CM(II) = 256°.7, B = +7°.3, B' = +6°.2. Processed to enhance visibility of Ring A and B ansae; note greater brightness of following (right) ansae.

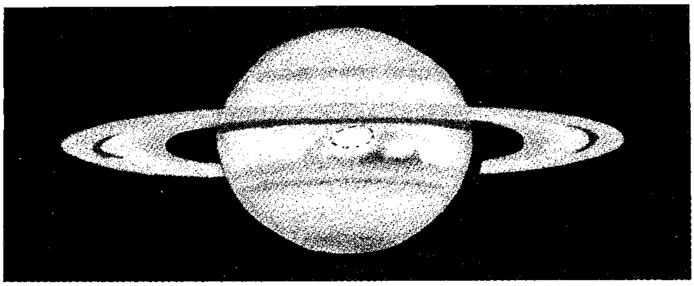

Figure 10. Drawing by David Graham. 1994 Oct 10, 22h10m UT. 40.6-cm (16.0-in) Newtonian, f/5, 286X, no filter. Seeing = Antoniadi III (Fair). CM(I) = 102°.8, CM(II) = 069°.7, B = +7°.8, B' = +6°.0. Note EZn White Spot on CM.

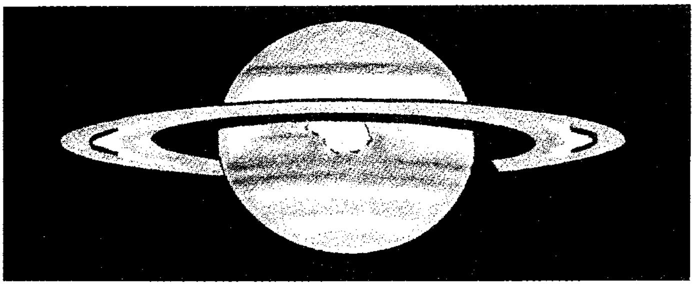

Figure 11. Drawing by Samuel R. Whitby. 1994 Oct 22, 01h27m UT. 15.2-cm (6.0-in) Newtonian, 205X & 310X, no filter. Seeing = 9, Transparency = +4. CM(I) = 145°.4, CM(II) = 112°.6, B = +8°.0, B' = +5°.7. Note EZn White Spot on CM.

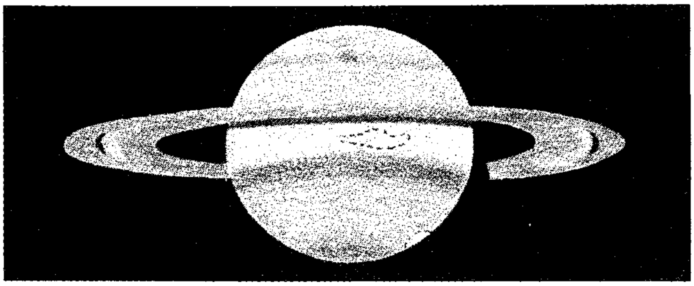

Figure 12. Drawing by Richard W. Schmude, Jr. 1994 Nov 09, 01h18m-01h57m UT. 9.0-cm (3.5-in) refractor, 250X, integrated light and W82 Filter. Seeing = 7.5, Transparency = +4. CM(I) = 216°.5-239°.3, CM(II) = 322°.5-344°.5, B = +8°.1, B' = +5°.5. Note EZn White Spot immediately to right of CM.

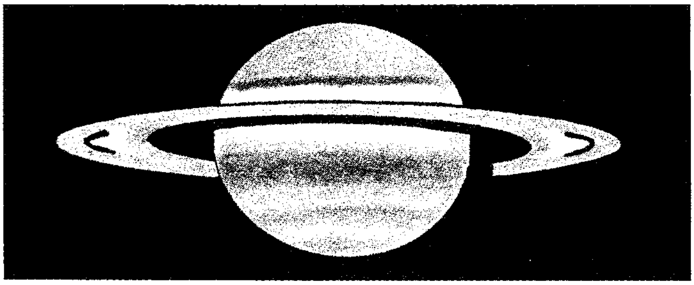

Figure 13. Drawing by Samuel R. Whitby. 1994 Dec 01, 23h05m-23h15m UT. 15.2-cm (6.0-in) Newtonian, 205X & 310X, no filter. Seeing = 7, Transparency = +5. CM(I) = 115°.2-121°.1, CM(II) = 201°.4-207°.1, B = +7°.9, B' = +7°.7.

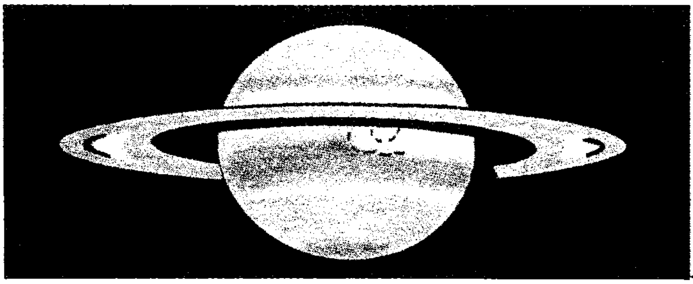

Figure 14. Drawing by Samuel R. Whitby. 1994 Dec 08, 23h45m UT. 15.2-cm (6.0-in) Newtonian, 205X & 310X, no filter. Seeing = 7 - 5, Transparency = +4. CM(I) = 287°.9, CM(II) = 147°.2, B = +7°.7, B' = +5°.1. Note EZn White Spot to right of CM.

GALILEAN SATELLITE ECLIPSE TIMINGS: THE 1992/93 APPARITION

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ABSTRACT

The A.L.P.O. Jupiter Section received 696 visual timings of the eclipses of Jupiter's four Galilean satellites from 70 observers for the 1992/93 Apparition. For each satellite, eclipse visual disappearance and reappearance timings were adjusted for telescope aperture and were then combined for comparison with the Jet Propulsion Laboratory's "E-2" Ephemeris.. Io appeared to be about 5 seconds, and Europa about 18 seconds, "early" in their orbits; both statistically significant differences. The observed position of Ganymede fitted the ephemeris well (only one event of Callisto was observed, insufficent for analysis).

INTRODUCTION

The 1992/93 Apparition of Jupiter was the seventeenth studied by the A.L.P.O. Jupiter Section's Galilean Satellite Eclipse Timing Program. The satellites timed were Io (*1*), Europa (*2*), Ganymede (*3*); and Callisto (*4*). Visual observers timed the "first speck" visible when the satellite reappeared from Jupiter's shadow (*reappearance*), or the "last speck" seen when the satellite disappeared into the shadow (*disappearance*). Reports for previous apparitions are listed under "References" (p. 20). [Westfall 1983-84, 1986a, 1986b, 1987, 1988, 1989, 1991, 1992, 1994, and 1996]

Table 1 (below) lists some significant dates for the 1992/93 Jupiter Apparition.

Table 1. 1992/93 Jupiter Apparition Chronology.

			d	*h*
Conjunction with the Sun	1992	SEP	17	19
First Eclipse Timing	1992	OCT	14	06
Opposition to the Sun	1993	MAR	30	12
Closest Approach to Earth	1993	MAR	31	07
Aphelion (farthest from Sun)	1993	JUN	15	--
Last Eclipse Timing	1993	SEP	17	09
Conjunction with the Sun	1993	OCT	18	10

An *apparition* is the period between successive conjunctions; an *observing season* is the period of actual observation. The observing season began 27 days after conjunction, with Jupiter 20° west of the Sun; it ended 31 days before the next conjunction, at solar elongation 24° east. The jovicentric declination of the Sun was such that eclipses of Callisto ended early in the apparition.

At closest approach, Jupiter's distance from the Earth was 4.4542 AU [astronomical units; 1 AU = 149,597,870 km], with an equatorial diameter of 44".20, and a visual magnitude of -2.40. Its geocentric declination at opposition was -2°.4, so that observers in the Earth's Southern Hemisphere began to be favored over those in the Northern Hemisphere during this apparition.

OBSERVATIONS

The timings received for 1992/93 bring our 17-apparition total to 7675 visual timings. Less than half the timings were submitted to the A.L.P.O. directly, or by a coordinating individual (283; 41 percent of the total of 696). We were fortunate to also receive 324 timings (47 percent) by 17 New Zealand and Australian observers coordinated by Brian Loader of the Royal Astronomical Society of New Zealand and 89 timings (13 percent) by nine Spanish observers from the Agrupación Astronòmica de Sabadel. A total of 70 persons made observations. The timings themselves are listed in *Table 10*, followed by the list of observers (pp. 21-25). We wish here to single out those observers for the 1992/93 Apparition who have contributed observations for at least five apparitions. *Table 2* (below) gives their names, nations and number of apparitions.

Table 2. Long-Term Participating Observers, Galilean Satellite Eclipse Timing Program.

William Abrahams (Australia, 8)
Colin Bembrick (Australia, 7)
J.L. Blanksby (Australia, 6)
Paul H. Bock (United States, 5)
Henk Bulder (Netherlands, 9)
Ricard Casas (Spain, 7)
Joaquim Garcia (Portugal, 6)
Martin George (Australia, 5)
Rui Gonçalves (Portugal, 6)
Nuno Gracias (Portugal, 5)
Walter Haas (United States, 9)
Robert Hays (United States, 7)
Alfred Kruijshoop (Australia, 7)
Brian Loader (New Zealand, 12)
Malcolm MacDonald (New Zealand, 6)
Craig MacDougal (United States, 8)
Harry Moller (Australia, 5)
Jens Østergaard Olesen (Denmark, 6)
R. Parmentier (United States, 6)
John Priestly (New Zealand, 9)
Dennis Rowley (United States, 6)
Benita Ruiz Ruiz (Spain, 6)
Charlie Smith (Australia, 6)
Joaquim Vidal (Spain, 6)
John Westfall (United States, 16)

Timings for the 1992/93 Apparition were made by observers in 15 countries in five continents, as shown in *Table 3* (below). However, there remain longitude gaps in our coverage, such as most of the Pacific Basin and Asia. Observers from five countries were more active than the average and are commended; the countries were Australia, New Zealand, Portugal, Italy, and Canada. It is, however, disappointing that the average American observer timed only a few events.

Table 3. Nationalities of Observers and Observations, 1992/93 Apparition.

Nation of Residence	Number of Observers	Number of Observations	Observations per Observer
United States	14	68	4.9
Australia	12	254	21.2
Spain	9	89	9.9
Hungary	6	23	3.8
New Zealand	5	70	14.0
Portugal	4	49	12.2
Denmark	4	36	9.0
Israel	4	16	4.0
The Netherlands	4	11	2.8
Italy	2	27	13.5
P. R. of China	2	18	9.0
Canada	1	16	16.0
India	1	9	9.0
Argentina	1	6	6.0
Poland	1	4	4.0
Mean	*4.7*	*46.4*	*9.9*

A significant factor in the observations was the size of telescope used. Most observers used a single telescope, but 29 used two or three instruments. The 103 telescopes used are tallied by aperture in *Table 4* (below); instruments have been grouped by aperture range (gaps indicate no telescopes in those ranges).

The most popular aperture continues to be 20 cm, which was also the median size. Thirteen small telescopes, 5.0 to 6.3 cm in aperture, were used, comprising 13 percent of the instruments. The twelve fairly large telescopes, 32 cm or larger in aperture, constituted 12 per cent of those used. The range of apertures continues to be large; from 5.0 to 91 cm, showing that almost any size of telescope can be used in our program.

Table 4. Number of Telescopes Used, By Aperture, 1992/93 Apparition.

Aper. (cm)	No.Tele.	Aper. (cm)	No.Tele.
5.0	3	25.0-25.4	7
6.0-6.3	10	28.0-31.8	7
8.0-8.4	3	32.0	3
9.0-10.0	5	40.0-41.0	5
11.0-12.7	12	46.0	1
13.0	2	65.0	1
15.0-17.8	16	75.0	1
20.0-20.6	24	91.0	1
21.0-23.0	2	*Total*	*103*

Table 5 (below) gives summary statistics for the timings in terms of the satellite and the type of event. Note that the "Number of Events Total" refers to events that occurred during the observing season only.

Table 5. Summary Statistics By Event Type, 1992/93 Apparition.

(1 = Io; 2 = Europa; 3 = Ganymede; 4 = Callisto; D = Disappearance; R = Reappearance)

Event Type	Number of Timings	Number of Events* Total	Timed	
1D	138	96	59	(61 %)
1R	207	96	68	(71 %)
1	345	192	127	(66 %)
2D	70	54	29	(54 %)
2R	117	47	35	(74 %)
2	187	101	64	(63 %)
3D	86	42	25	(60 %)
3R	77	41	25	(61 %)
3	163	83	50	(60 %)
4D	0	2	0	(0 %)
4R	1	2	1	(50 %)
4	1	4	1	(25 %)
D	294	194	113	(58 %)
R	402	186	129	(69 %)
TOTAL	696	380	242	(64 %)

* During observing season.

As always, the closer a satellite is to Jupiter, the greater the number of timings made of its eclipses because the frequency of satellite eclipses decreases outwards from Jupiter. Reappearances comprised the majority of timings for all satellites but Ganymede. About two-thirds of the eclipses that occurred for all four satellites were actually timed, which is a rough indicator of our longitude distribution's effect on our "efficiency" in covering events.

As is usual, the number of timings varied considerably from month to month, as shown in *Table 6* (below) and *Figure 1* (p. 16).

Table 6. Number of Timings by Month, 1992/93 Apparition.

(Solar elongation range in parentheses; restricted to observing season)

1992	OCT	(020-034°W)	3	Timings
	NOV	(034-059°W)	18	
	DEC	(059-086°W)	15	
1993	JAN	(086-118°W)	62	
	FEB	(118-147°W)	66	
	MAR	(147°W-178°E)	103	
	APR	(178-145°E)	119	
	MAY	(145-114°E)	135	
	JUN	(114-087°E)	91	
	JUL	(087-061°E)	56	
	AUG	(061-037°E)	20	
	SEP	(037-024°E)	8	
Before Opposition			265	(38.1 %)
After Opposition			431	(61.9 %)

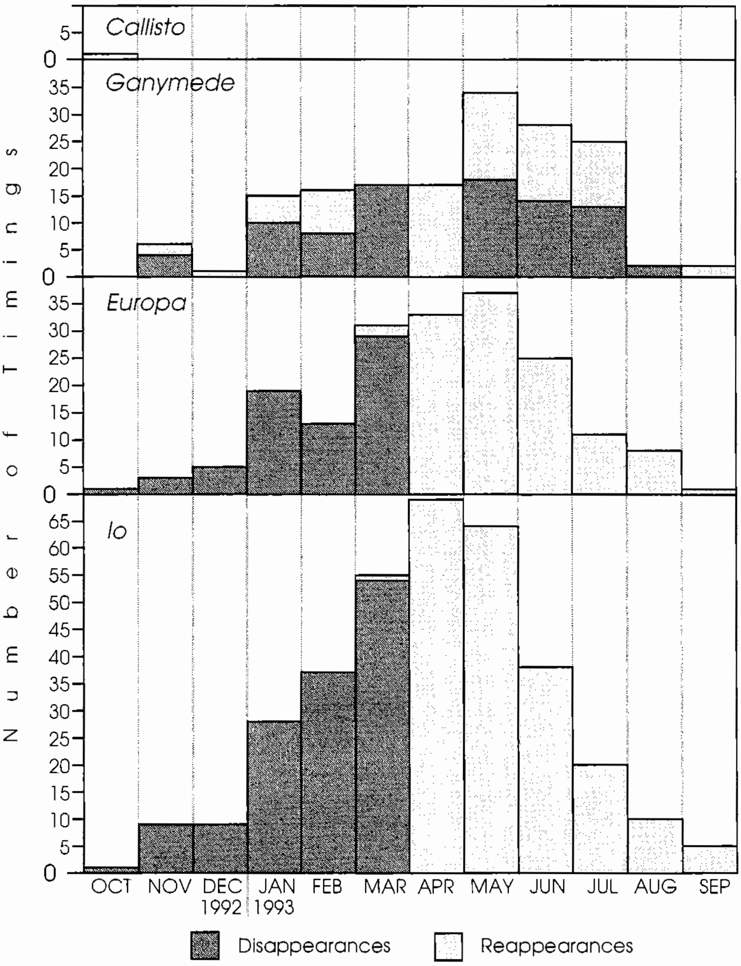

Figure 1. Histogram of the number of eclipse timings by type and month for the 1992/93 Apparition of Jupiter, where: 1 = Io, 2 = Europa, 3 = Ganymede, 4 = Callisto, D = Disappearance, and R = Reappearance. The bars at the bottom show when eclipse events of each type occurred.

The most intensive observing was for the three months including and after opposition, when Jupiter was easily viewed in the evening sky. We have an ongoing bias toward post-opposition timings; observers should make more pre-opposition timings in the future, even though this means observing after midnight.

REDUCTION

The first step in reduction was to segregate the timings by satellite and by whether of a disappearance or a reappearance. Observations were compared with the predictions of the "E-2" Ephemeris developed by Jay H. Lieske of the Jet Propulsion Laboratory. [Lieske, 1981] The predicted time of each event was then subtracted from the observed time; a positive residual meant that an event was "late"; a negative residual, that it was "early." These residuals are given in the right-hand column in *Table 10*. The next step was to correct for aperture with a linear regression model in which the dependent variable was the residual (**y**) and the independent variable was the reciprocal of the telescope aperture, measured in centimeters (**x**). The form of the model is:

$$\mathbf{y = A + Bx}, \qquad (1)$$

where **A** and **B** are the regression coefficients. The final residual for each satellite is equal to the mean of its disappearance and reappearance regression models' predictions of the residual for an "infinite" aperture (i.e., with the reciprocal of the aperture equal to zero).

Two statistics describe how well equation (1) fits the observed residuals. One, the *standard error* (S.E.), measures how different the average residual was from that predicted. The other, *R-Square*, measures what proportion of the variance (squared differences among the residuals) is removed by equation (1).

Three timings were not used because they differed by many minutes from the predictions and could not be reconciled, and the single Callisto timing could not be used because it was too small a sample. A number of timings were rejected because of differences from the regression model that were significant at the 5-percent level (i.e., would occur due to chance less than 5 percent of the time) as measured in terms of the standard error (given in *Table 7*, p. 18). For the 1992/93 Apparition, 65 timings (9.4 percent) were rejected, and are shown by italicized residuals in *Table 7*.

To check the method described above, the writer estimated the diameter of each satellite by taking the differences between its predicted disappearance and reappearance residuals, which should give the amount of time it took Jupiter's shadow edge to cross the satellite's disk. Then, taking into account each satellite's velocity and mean angle of entry or exit from the shadow, the diameter in kilometers was calculated and is shown in *Table 7*.

The method of analysis is described in more detail in our 1975-82 report [Westfall, 1983-84], and the criteria for the rejection of timings are in the report for 1985/86 [Westfall, 1987].

LONG-TERM RESULTS

The orbital residuals for Io, Europa, Ganymede, and Callisto for the sixteen apparitions from 1976/77 through 1992/93 are graphed in *Figure 2* (below; there were too few timings made in the 1975/76 Apparition to determine its orbital deviations). In the figure, the error bars represent a ±1 standard-error range, and a deviation from the ephemeris significant at the 5-percent level would have to be at least about ±2 standard errors.

The diagram shows that the widths of the error bars have tended to diminish over time, chiefly due to the greater accuracy caused by an increasing number of timings submitted to the program. There are hints of cyclical variations for some of the satellites, particularly for Europa and Ganymede, perhaps in a 12-year cycle associated with Jupiter's orbital period. We hope that we will receive sufficient timings for enough future apparitions to investigate this question.

1992/93 RESULTS

Details for the 1992/93 Apparition follow in *Table 7* (p. 18). This table gives results for each of the three inner Galilean satellites in a separate column. Each column is divided into four parts, "Disappearance," "Reappearance," "Orbital Residual," and "Diameter." For both disappearances and reappearances, the number of timings is given first, followed in parentheses by the number finally used in the regression analysis after aberrant timings had been deleted. The next item is the mean residual for the timings that were retained, followed by the coefficient of variation ("R-squared"), which is the proportion of the variance among the timings that is explained by the aperture model. Fourth, the two regression coefficients are given with their 1-standard error uncertainty ranges; in *Table 7*, all such uncertainty ranges are preceded by the "±" symbol. Next is the standard error of estimate for the regression model. Following this are the predicted residuals for four commonly used telescope apertures.

The disappearance and reappearance data are combined in order to give the orbital residuals, expressed as how far "ahead" (negative) or "behind" (positive) the satellite was in terms of the E-2 Ephemeris. This value and its 1-standard error uncertainty range are given in seconds of time, degrees of orbital arc, and kilometers.

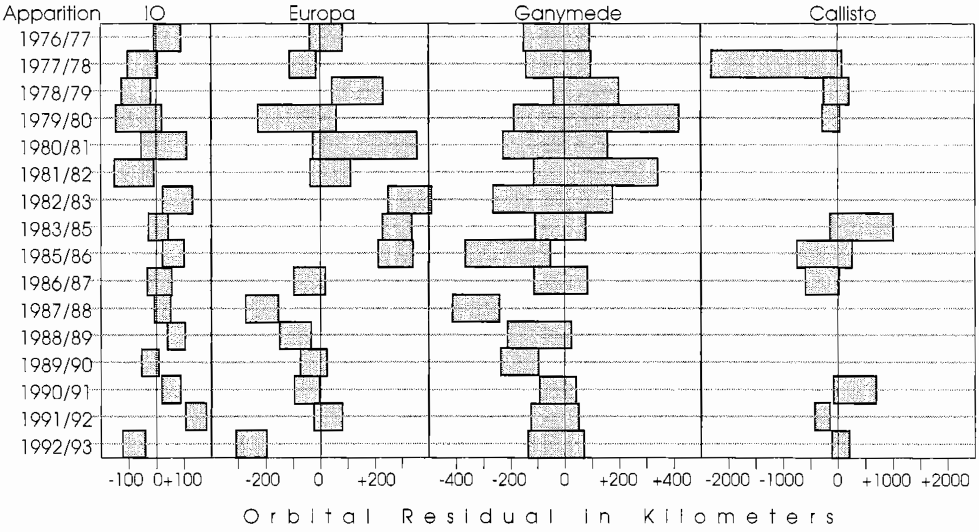

Figure 2. Graph of deviations of the Galilean satellites from the E-2 Ephemeris for the 1976/77 through the 1992/93 Apparitions. Units are in kilometers. The width of each bar represents ±1 standard error. Note the different scale for Callisto, which was not eclipsed in every apparition.

Table 7. Galilean Satellite Timings Compared With E-2 Ephemeris, 1992/93.

Satellite:	Io	Europa	Ganymede
Disappearance			
Number of Observations	138 (124)	70 (64)	86 (80)
Mean Residual (seconds)	+76.9±1.6	+74.3±3.2	+257.9±6.3
Coefficients:			
R-squared	.0038 (ns)	.1062**	.1562**
A (seconds)	+78.8±3.3	+88.6±6.1	+293.6±11.1
B	-30±44	-214±79	-496±131
Standard Error (seconds)	±17.9	±24.6	±52.4
Aperture Residual (seconds):			
6-cm	+74±5	+53±8	+211±14
10-cm	+76±2	+67±4	+244±7
20-cm	+77±2	+78±3	+269±7
40-cm	+78±2	+83±4	+281±8
Reappearance			
Number of Observations	207 (185)	116 (104)	75 (70)
Mean Residual (seconds)	-71.6±2.0	-100.4±3.2	-276.1±7.8
Coefficients:			
R-squared	.1472**	.2201**	.0431 (ns)
A (seconds)	-88.3±3.5	-125.6±5.5	-299.6±15.5
B	+252±45	+369±69	+383±219
Standard Error (seconds)	±24.6	±29.0	±64.1
Aperture Residual (seconds):			
6-cm	-46±5	-64±7	-236±24
10-cm	-63±2	-89±4	-261±11
20-cm	-76±2	-107±3	-280±8
40-cm	-82±3	-116±4	-290±11
Orbital Residual			
Seconds	-4.8±2.4*	-18.5±4.1**	-3.0±9.5 (ns)
Orbital Arc (degrees)	-0.012±.006	-0.022±.005	-0.002±.006
Kilometers	-82±41	-254±56	-33±103
Diameter			
Seconds	167.1±4.8	214.1±8.2	593.2±19.0
Kilometers	2798±80	2583±99	5053±162
Compared with Standard (km)	-832±80** (-22.9 %)	-555±99** (-17.7 %)	+253±162 (ns) (+5.3 %)

The results of the satellite diameter estimation described above are given at the bottom of each column, where the calculated satellite diameter is given in seconds of time and in kilometers. The latter value is corrected for the mean cosine of the angle of entrance into or out of Jupiter's shadow. This quantity is then compared with the "standard" Voyager-derived satellite diameter (Io, 3630 km; Europa, 3138 km; Ganymede, 5262 km; and Callisto, 4800 km).

Table 7 also shows the statistical significance of the differences of the following values from zero: "R-squared," the orbital residual (in seconds of time only), and the difference between the estimated and the standard satellite diameters. The statistical significance is shown by "(ns)" for not significant, "*" for significant at the 5-percent level, and "**" for significant at the 1-percent level (these percentages give the probability of such results having occurred due solely to chance).

There are six event types listed in *Table 7*; eclipse disappearances and reappearances for each of the three satellites analyzed. As shown by the R-square values, in four of the six cases the aperture-regression model significantly reduced the variance among the timings. Nonetheless, the majority of the variance among the timings remained unaccounted for in our simple residual-aperture model. Naturally, the uncertainties in our timings represent the combined effect of many variables that are not considered in our analysis, for example: type of instrument, magnification, optical quality, atmospheric conditions, distance and phase angle of Jupiter, distance of the satellite from Jupiter's limb, keenness of the observer's eye, or possible use of an occulting bar (an object placed at the focus of a positive eyepiece to block out Jupiter itself). Clearly, only some of these variables are quantifiable, and for some we have no data at all. Nonetheless, with the large number of timings we are now receiving each apparition, a more complex statistical analysis is possible, which might reduce the amount of uncertainty.

The average uncertainty of the timings is indicated by the standard error, which was roughly the same for disappearance and reappearance timings, but increased going outward in distance from Jupiter; about 18-25 seconds for Io, 25-29 seconds for Europa, and 52-64 seconds for Ganymede. This trend is not surprising because the satellites move more slowly, and Jupiter's shadow penumbra becomes broader, as one moves away from the planet. These factors also are reflected in the mainly increasing numerical values of the B-coefficients with distance from Jupiter; these values measure the effect of aperture variations on the reported times of events.

The orbital residuals, expressed in seconds of time, are the simple means of the disappearance and reappearance A-coefficients of each satellite. These values have also been converted to degrees of orbital arc and to kilometers.

The timing results for two of the three satellites differed significantly from the E-2 Ephemeris; Io was reported as being eclipsed about 5 seconds earlier than predicted. The difference was 2.00 times the standard error of that value, just significant at a 5-percent level. However, note that the regression of disappearance timings for Io did not give a statistically significant result (although the algebraic signs of both coefficients were as expected). This condition makes Io's orbital residual uncertain, and indeed the simple mean of the disappearance and reappearance means of Io gives a marginally statistically significant *positive* residual (+2.6±1.3 seconds).

Likewise, the reappearance regression of Ganymede did not yield statistically significant results (although the algebraic signs of both coefficients were as expected). However, the small orbital residual for that satellite was not statistically significant, and indeed the simple mean of the disappearance and reappearance means of Ganymede gives a result that is not statistically significant (-9.1±5.0 seconds).

It is clear that Europa's position did not conform with the E-2 Ephemeris during 1992/93, this satellite being -18.5±4.1 seconds early in respect to the ephemeris, a highly significant result. This conclusion was confirmed by another group's CCD photometric timings (see below).

The accuracy of our method of analysis can be assessed approximately by using the A-coefficients to estimate the diameters of the satellites, and then to compare these estimates with the diameters that were derived from the Voyager Missions. In the cases of Io, Europa, and Callisto there were significant differences, but of different signs. Io and Europa were estimated as too small, but the estimated diameter of Ganymede did not differ significantly from the standard values. These diameter differences follow the trend found for most previous apparitions and may be an effect resulting from the increase in the size of Jupiter's penumbral shadow zone as one moves outwards in the satellite system.

COMPARISON WITH 1991-92 APPARITION

Io was significantly "late" in 1991/92 (+8.4±2.2 seconds), but apparently significantly "early" in 1992/93. Io's orbital change from 1991/92 to 1992/93 was a statistically significant -13.2±3.3 seconds.

Europa was a non-significant +2.1±3.8 seconds late in 1991/92, changing to -18.5±4.1 seconds early in 1992/93; a statistically significant acceleration of -20.6±5.6 seconds.

Finally, Ganymede's position was estimated to be -3.4±8.1 seconds early in 1991/92 and -3.0±9.5 seconds early in 1992/93. The small relative change of +0.4±12.5 seconds was not statistically significant. (Note that Callisto was analyzed only for the earlier apparition.)

In a personal communication, Brian Loader of New Zealand pointed out that the estimated diameters of all four satellites were smaller in our 1991/92 report [Westfall, 1996] than in that for the 1990/91 Apparition [Westfall, 1994]. *Table 8*, below, shows the changes in the estimated satellite diameters within the last three apparitions.

Table 8. Changes in Estimated Satellite Diameters; 1990/01, 1991/92, and 1992/93 Apparitions.*

Satellite	1990/91 - 1991/92	1991/92 - 1992/93
Io	-265±100**	-141±109 (ns)
Europa	-361±136**	-24±141 (ns)
Ganymede	-466±214*	+11±233 (ns)
Callisto	-129±378 (ns)	----------

* Units are kilometers. Changes are defined by subtracting the earlier apparition from the later. Statistical significance is shown as in Table 7.

Thus, from 1990/91 to 1991/92, the apparent diameters of the inner three Galilean satellites shrank significantly. Mr. Loader suggested that this could be due to terrestrial atmospheric extinction caused by aerosols created by the Mount Pinatubo volcanic eruption, citing changes in photometric extinction coefficients. This appears a likely explanation, and would have caused eclipse disappearances to occur earlier than normal, and reappearances later, making apparent satellite diameters appear too large. No significant changes in apparent diameters occurred from 1991/92 to 1992/93, so whatever factor that caused the original changes appears to continue in effect.

PARALLEL STUDIES

Two other groups of observers are timing and analyzing the eclipses of Jupiter's satellites, using methods different than the writer's, and thus have the potential of confirming or falsifying the results reported here.

The group headed by Anthony Mallama uses CCD images to measure the changing brightnesses of the Galilean satellites as they enter and leave Jupiter's shadow [Mallama *et al.*, 1994]. They analyze their measures using a theoretical model of brightness change, adjusted for albedo variations on the surfaces of the satellites themselves. One important difference between their technique and the writer's is that the CCD-based approach can in theory obtain accurate results for a single event, while the method used in this report aggregates data for an entire observing season.

To make the Mallama *et al.* results more comparable with ours, we have taken simple means of their disappearance and reappearance timings for each satellite during the 1992/93 Apparition, reversing the signs of their E-2 residuals to conform with ours, and give them in *Table 9* (below).

Table 9. Summary of Mallama *et al.* Galilean Satellite Timings, 1992/93 Apparition.

Satellite	Mean Residual (sec.)
Io	+1.4±2.0
Europa	-21.5±5.3
Ganymede	-4.3±3.7

The CCD-based timings for Io differ significantly from ours based on regression, but not from the simple mean of our Io disappearance and reappearance timings, suggesting that our non-significant regression result for Io disappearances did affect the accuracy of our Io regression result.

We are pleased, however, that the Mallama *et al.* results for Europa did not differ significantly from ours, indicating that this satellite actually was significantly ahead of the E-2 Ephemeris.

For Ganymede the results of the two methods did not differ significantly from each other. Both the writer's visual-timing method and the CCD-photometry method indicate that Ganymede's position conformed well with the predictions of the E-2 Ephemeris.

Although not applicable to the 1992/93 Apparition, we wish to point out that a Spanish group is experimenting with a more complex method of analyzing visual timings that takes into account the satellites' apparent distances from Jupiter [Barba and Castaño, 1996]. They also use visual photometry of the brightness changes near disappearance and reappearance, analogous to the method used by Mallama *et al.* with CCD photometry. The Barba-Castaño method promises to reduce somewhat the uncertainties in the results obtained from visual timings.

CONCLUSION

We encourage suitably-equipped observers to use their CCD or video cameras to time the eclipses of Jupiter's four major satellites [Mallama, 1991]; conventional photometers are difficult to use accurately because of the effect of scattered light from Jupiter. However, we need also to continue the visual timings which remain the mainstay of our program and provide comparability with the body of similar visual timings that goes back to the Seventeenth Century.

Naturally, we hope that the present observers will continue and new ones will join us. For information on this program, please contact the writer, whose address is given in the A.L.P.O. staff listing (pp. 46-47). Along with instructions, he can send you a timing report form, which should be returned at the end of each apparition (*not* of the calendar year). You will also need predictions of these events, which are published each year in the *Astronomical Almanac*, *Observer's Handbook of the Royal Astronomical Society of Canada*, and in *The Handbook of the British Astronomical Association*, and each month in *Sky & Telescope*.

We thank the many observers who participated in our project for the 1992/93 Apparition of Jupiter. Remember that your timings become more accurate as you accumulate experience. Likewise, the more visual timings that are made, the more accurate our results. Thus we hope to hear from you again!

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Table 10. Galilean Satellite Eclipse Timings, 1992/93 Apparition.

UT Date	Geometry		Ob. No.	Con.	Res.
mmdd	r	°		stb	sec.
-------- Io Disappearances -------					
1992					
1014	0.4	-12	24b	212	+54
1106	0.5	-12	40a	101	+57
			24b	112	+78
			27	102	+78
1116	0.8	-13	41	002	*-11*
1122	0.8	-13	64	110	+44
			24b	122	+55
			28a	000	+66
1125	0.8	-13	17	010	*+26*
			5	210	+43
1202	0.9	-13	42	010	+54
1204	0.9	-13	61	000	+47
1206	0.9	-13	53	21 -	+46
1209	0.9	-13	12	002	+60
1211	0.9	-13	18	101	+64
1213	1.0	-13	39	101	+93
1220	1.0	-13	30	000	+79
1225	1.0	-13	42	010	*-110*
1231	1.0	-13	11	101	+54
1993					
0103	1.0	-13	17	001	+60
			58a	000	+62
			36	100	+90
0105	1.0	-14	61	121	+62
0107	1.0	-14	20a	- - -	+66
			64	100	+103
			24	022	*+142*
0110	1.0	-14	36	001	+71
			5	001	+73
			58a	000	+93
			42	122	+99
0112	1.0	-14	61	001	+74
0114	1.0	-14	10a	- - -	+75
			24b	022	+113
0116	1.0	-14	24b	222	+106
0117	1.0	-14	42	011	+93
0119	1.0	-14	5	100	+70
			58a	000	+70
			36	000	+78
			35	200	+84
			60	211	+97
0123	1.0	-14	52	000	+76
0124	1.0	-14	42	112	+50
			46	001	+108
0130	0.9	-14	52	020	*+27*
			20a	- - -	+43
			28a	000	+106
0131	0.9	-14	8a	220	+91
0202	0.9	-14	58a	020	+37
			12	000	+80
			60	100	+107
0204	0.9	-14	17	000	*+1*
			30	000	+92
0206	0.9	-14	52	000	*+134*
0208	0.8	-14	40a	001	+91
0209	0.8	-14	12	000	+68
			42	012	+84
			46	001	+85
0211	0.8	-14	42	221	+74
			60	102	+102
0215	0.8	-14	64	010	+71
0215	0.8	-14	52	000	+100
0216	0.7	-14	46	001	+76
			43a	001	+89
			12	000	+93
0218	0.7	-14	5	000	+73
			36	010	+77
			42	010	+83
0220	0.7	-14	70a	100	+63
			18	100	+87
0222	0.7	-14	62a	122	+53
			64	100	+55
			44	000	+72
			28a	002	+87
			52	000	+88
			24b	111	+94
0223	0.6	-14	52	100	+69
			15	010	+76
			64	100	+83
			8a	000	+108
0225	0.6	-14	17	110	+61
			42	010	+90
0227	0.6	-14	5	220	+42
			38	000	+72
			35	120	+75
0301	0.6	-14	52	000	+110
0303	0.5	-14	40a	201	+47
			52	000	+86
			7	111	+90
0304	0.5	-15	42	020	+76
0306	0.5	-15	17	000	+80
			60	112	+100
0308	0.4	-15	38a	102	*-46*
0310	0.4	-15	20a	- - -	+62
			13	202	+66
			52	010	+91
			19	222	+92
			39	202	+93
			43a	222	*+151*
0311	0.4	-15	22	000	*+21*
			44	000	+54
			45	- - -	+62
			20a	- - -	+69
			10a	- - -	+89
			64a	100	+90
0313	0.3	-15	38	000	*+33*
			36	010	+78
			58a	000	+78
			5	100	+79
			42	011	+80
			35	100	+99
0315	0.3	-15	50	000	+95
0317	0.3	-15	52	000	+91
0318	0.2	-15	52	020	+49
			28	110	+57
			10a	- - -	+89
			8a	110	+90
			15	000	+92
			64a	100	+95
			67	- - -	+105
0320	0.2	-15	17	000	+60
			36	100	+77
			58a	000	+83
			60	010	+95
0322	0.2	-15	17	000	+74
			60	200	+92
0324	0.1	-15	61	000	+36
			52	001	+76
0326	0.1	-15	44	000	*-22*
			26a	101	+73
			52	001	+81
			15	100	+84
0327	0.1	-15	17	000	*+34*
			64	101	+87
0329	0.0	-15	42	010	+46
			17	000	+56
			60	200	+60
			1a	001	+77
0331	-0.0	-15	61	110	*-30*
-------- Io Reappearances -------					
1993					
0331	0.0	-15	917	000	-121
0402	0.1	-15	61	111	-28
			52	001	-18
0404	0.1	-15	52	010	-4
0405	0.1	-15	64a	101	-76
			56	002	-58
0407	0.2	-15	35	100	-86
			4	000	-71
			36	010	-69
			5	122	-66
			37a	200	-61
			38	000	-31
			17	000	-14
0409	0.2	-15	18	201	-27
0411	0.2	-15	33a	000	-100
			68	100	-81
			18	112	-64
			15	022	*+6*
0412	0.3	-15	11a	010	-98
			43a	000	-89
			28a	121	-56
			24b	002	-31
			44	000	-27
			40	200	-22
			20a	- - -	*+16*
0414	0.3	-15	17	000	-98
			35	000	-91
			5	020	-80
			36	010	-77
0416	0.3	-15	17	000	-129
			37a	010	-91
			35	000	-86
			58a	000	-84
			38	000	-23
			70	110	*+71*
0418	0.4	-15	47a	000	-104
			19a	210	-100
			33	100	-90
0419	0.4	-15	52	000	-79
			40a	012	-67
			15	010	-60
			7	122	-53
			44	000	-41
0421	0.4	-15	36	010	-67
			17	000	-11

Table 10. Galilean Satellite Eclipse Timings, 1992/93 Apparition—Continued.

UT Date mmdd	Geom- etry r	°	Ob. No.	Con. stb	Res. sec.
--- Io Reappearances-Cntd. ---					
1993					
0423	0.5	-15	50	000	-99
			35	010	-96
			18	010	-86
			1	000	-77
			36	010	-75
			38	000	-60
			5	020	-49
0427	0.5	-15	24b	001	-82
			15	010	-72
			52	000	-65
			28a	010	-38
			44	010	-34
0428	0.6	-15	43a	001	-87
			48	121	-70
			62	111	-67
			23a	001	-61
			9	120	-47
0430	0.6	-15	17a	010	-131
			35	000	-102
			60	111	-95
			36	000	-92
			5	000	-87
			18a	000	-80
			59a	000	-79
			58	000	-72
0502	0.6	-15	50	100	-102
			60	112	-96
			17a	000	-64
			37	000	-56
			70	111	*+222*
0504	0.6	-15	19	021	-106
0505	0.7	-15	8a	001	-107
			10a	211	-81
			15	000	-74
			52	001	-73
			64	000	-72
			20a	111	-69
			20	111	-57
			28a	100	-57
			9	121	+13
0507	0.7	-15	17a	010	-85
0509	0.7	-15	18a	100	-102
			35	010	-95
			58a	000	-88
			17a	000	-83
			36	000	-78
			5	020	-61
			70	111	*+126*
0511	0.7	-15	39	101	-105
			30	010	-102
			68	210	-94
0512	0.8	-15	52	000	-73
			15	001	-67
			28a	220	*+149*
0514	0.8	-16	57	- - -	-22
0516	0.8	-16	60	101	-108
			42	010	-85
			17a	000	-75
0518	0.8	-16	61	221	-79
0520	0.8	-16	27	100	-61
0521	0.9	-16	9	121	-39
0523	0.9	-16	17a	000	-117
			60	101	-105
			36	010	-97
			35	100	-95
			42	010	-95
			5	000	-89
			58a	000	-85
			46	002	*+7*
			70	112	*+93*
0525	0.9	-16	60	101	-97
			36	001	-90
			35	100	-87
			17a	000	-71
			38a	000	-37
0527	0.9	-16	33	100	-89
			52	020	*+94*
0528	0.9	-16	52	000	*-101*
			24a	- - -	-100
			40a	000	-94
			63	121	-91
			20a	122	-84
			27	100	-70
			22	021	-68
			20	122	-65
			65	221	-41
			9	210	-13
			64	110	*-2*
0530	0.9	-16	42	012	-89
0601	1.0	-16	17a	000	-121
0603	1.0	-16	39	011	-99
			69a	100	-83
			55	222	-82
			69	000	-60
0604	1.0	-16	26b	101	-98
			24b	001	-84
			54	011	-68
			22	000	-49
			52	020	*+71*
			51	001	*+84*
0606	1.0	-16	57	111	0
0608	1.0	-16	60	201	-112
			1a	100	-95
			17a	000	-63
			46	001	-53
0610	1.0	-16	18	200	-90
			70	211	*+201*
0612	1.0	-16	52	000	-68
0615	1.0	-16	17a	000	-26
0617	1.0	-16	50	000	-99
			18	100	-81
			36	110	-73
			17a	000	-52
			5	020	-39
			70	111	*+79*
0619	1.0	-16	53	00 -	-88
			2	110	-44
0620	1.0	-16	10a	211	-91
			44	001	-58
			22	201	-46
0622	1.0	-16	42	220	-75
			57	221	*+107*
0624	1.0	-16	58a	000	-90
			70	011	*+115*
0626	1.0	-16	61	122	-92
0627	1.0	-16	14	012	*+147*
0629	1.0	-16	43	002	-85
0701	1.0	-16	35	100	-101
			36	000	-92
			58a	100	-87
			5	211	-64
0706	1.0	-16	64	001	-58
0708	1.0	-16	12	000	-68
0710	1.0	-16	38a	000	-57
0712	1.0	-16	30	100	-89
			31	211	-86
			55b	211	-86
0713	1.0	-16	21a	220	-73
			24b	211	-52
			52	020	-38
0717	1.0	-16	58a	000	-88
			36	010	-87
0726	0.9	-16	38a	000	-78
			70	210	*+210*
0729	0.9	-16	49	221	-63
			48	020	-41
			9	101	-15
0802	0.9	-16	17a	100	-83
0805	0.9	-16	52	000	-53
0809	0.8	-17	17a	110	-58
0816	0.8	-17	42	211	-44
0818	0.8	-17	38a	010	*-9*
0825	0.7	-17	5	001	-73
			58a	100	-69
			17a	000	*+2*
			18	201	*+21*
0828	0.6	-17	52	200	-55
0901	0.6	-17	41	000	-92
0917	0.4	-17	36	100	-54
			35	212	-42
			58a	200	-35
			5	201	-1
---- Europa Disappearances ---					
1992					
1021	0.7	-24	24b	112	+65
1118	1.2	-25	17	011	*-157*
1122	1.3	-25	64	101	+53
			24b	122	+75
1202	1.4	-26	46	011	+49
1217	1.5	-26	24b	112	+71
			40a	201	+72
1227	1.6	-26	41	200	+60
			42	110	+66
1993					
0103	1.6	-27	57	- - -	*+111*
0114	1.6	-27	61	011	+46
0118	1.6	-27	62a	222	+76
			40a	001	+94
0121	1.5	-27	5	000	+44
			42	211	+72
			58a	000	+90
			36	000	+91
			35	100	+103
0125	1.5	-27	55a	221	+25
			20a	- - -	+67
			26a	100	+103

Table 10. Galilean Satellite Eclipse Timings, 1992/93 Apparition—Continued.

UT Date	Geom-etry		Ob. No.	Con.	Res.
mmdd	r	°		stb	sec.
Europa Disappearances–Cntd.					
1993					
0125	1.5	-27	24b	101	+116
0128	1.5	-27	57	- - -	+10
			46	011	+67
			5	011	+68
			42	010	+97
			58a	000	+104
			17	000	+120
0201	1.4	-27	39	211	+102
0204	1.4	-27	57	- - -	*-32*
			46	020	+55
0208	1.3	-28	37	200	+47
			61	001	+50
0211	1.2	-27	24b	112	+92
0215	1.2	-28	61	100	+48
			35	010	+103
0219	1.1	-28	40a	001	+67
			26a	000	+99
			52	000	+100
0222	1.0	-28	42	010	+94
0226	0.9	-28	64	000	+60
0301	0.8	-28	60	101	+106
			17	110	+120
0305	0.7	-28	52	000	+89
			39	101	+102
0308	0.6	-28	22	122	*-41*
			7	001	+61
			42	112	+91
			8a	201	+97
			64a	100	+97
0312	0.5	-28	58a	200	*-149*
			70	110	+41
			33	010	+60
0315	0.4	-28	54	211	+34
			64	100	+60
			52	001	+69
			8a	100	+112
0319	0.3	-28	42	210	+56
			36	020	+84
0323	0.2	-29	2a	110	*-13*
			10a	- - -	+46
			52	000	+70
			33	100	+88
0326	0.1	-29	5	000	+25
			25	100	+49
			58a	000	+58
			36	000	+95
			17	110	+113
0330	0.0	-29	52	020	+39
			39	101	+75
---- Europa Reappearances ----					
1993					
0330	0.0	-29	61	100	-25
			47	100	*-5*
0402	0.1	-29	8	020	-96
			32	020	-62
			66	112	*-26*
			34	112	*-16*
0406	0.2	-29	17	101	-179
			60	202	-124
			37a	000	-111
0406	0.2	-29	5	102	-91
			4	000	-72
0409	0.3	-29	23a	011	-121
			52	000	-100
			56	001	-100
			28a	010	-98
			15	000	-74
			44	000	*-20*
0413	0.4	-29	60	100	-147
			18a	100	-128
			17	000	-110
			38	000	-50
0417	0.5	-29	33	100	-126
			18	212	-95
			52	000	-84
			23a	210	-62
			43a	210	-42
0420	0.6	-29	5	020	-113
			36	010	-109
0424	0.7	-29	39	211	-126
			33	000	-105
			18	011	-85
			52	000	-71
			2	110	-66
0427	0.8	-29	17a	010	-181
			23	001	-114
0501	0.9	-29	33	000	-119
			18a	201	-115
			70	111	*+193*
0504	1.0	-29	8a	202	-137
			10a	222	-128
			7	222	-124
			20a	211	-120
			26a	102	-114
			15	000	-98
			44	000	-93
			45	111	-87
			28	001	-66
0508	1.1	-29	37a	000	-129
			17a	000	-78
			58	100	-70
			70	111	+10
0511	1.1	-29	15	000	-89
			44	000	-87
0515	1.2	-29	35	000	-133
			60	101	-131
			5	000	-126
			42	010	-125
			36	000	-114
			58a	000	-114
			17a	000	*+36*
			59	020	*+42*
0519	1.3	-29	52	000	-102
			2a	100	-35
0522	1.3	-29	60	120	-115
			36	010	-110
			57	110	-54
			38	000	-48
0526	1.4	-30	68	111	-135
			30	100	-132
			29	10 -	-97
			2	110	-74
			52	100	-56
0602	1.5	-30	18a	101	-128
			61	001	-107
0605	1.5	-30	43a	101	-133
			63	212	-115
			64	001	-101
0609	1.5	-30	17a	000	-93
0612	1.6	-30	26b	100	-132
			24a	100	-126
			10a	211	-120
			21a	110	-105
			9	200	-19
0616	1.6	-30	17a	000	-196
			50	100	-136
			58a	000	-129
			35	100	-119
			37a	100	-119
			5	000	-115
			36	110	-100
			38a	000	-68
			70	111	*+79*
0620	1.6	-30	52	000	*-164*
0623	1.6	-30	42	110	-113
0627	1.6	-30	68	101	-128
			33	000	-124
0630	1.6	-30	57	111	*+32*
0711	1.6	-30	50	210	-122
			58a	000	-110
			38a	000	-91
0714	1.5	-31	24b	211	-74
			14	000	*+261*
0718	1.5	-31	42	110	-126
			36	010	-103
0725	1.5	-31	42	211	-58
0729	1.4	-31	19	121	-137
			30	200	-117
			68	211	-106
0812	1.2	-31	50	200	-135
			17a	000	-93
			58a	111	-64
			5	202	-58
			70	111	*+155*
0815	1.2	-31	52	000	-70
0819	1.1	-31	58a	100	-97
			36	010	-74
0916	0.6	-32	52	002	-35
- Ganymede Disappearances -					
1992					
1106	1.6	-29	27	001	+201
			40a	101	+257
			24b	111	+272
			26a	101	+278
1993					
0109	2.5	-33	36	001	+271
			5	101	+279
			42	012	+296
			60	020	+305
			4	000	+333
0116	2.5	-33	42	012	+180
0124	2.4	-34	26	201	+154
			43a	122	+296
0131	2.3	-34	52	020	+265
			6	201	+276

Table 10. Galilean Satellite Eclipse Timings, 1992/93 Apparition—Continued.

Ganymede Disap.–Continued.

UT Date mmdd	Geom- etry r	°	Ob. No.	Con. stb	Res. sec.
1993					
0207	2.1	-34	13	201	+304
			33	001	+315
0214	1.9	-35	37a	010	+311
0221	1.6	-35	60	120	+301
			42	010	+308
0228	1.4	-35	28	110	+144
			62	021	+177
			42	111	+317
0308	1.1	-36	54	201	+250
			20a	- - -	+270
0315	0.7	-36	6	010	+288
			33	010	+301
			55b	221	+304
			52	000	+308
			39	201	+317
			24b	001	+323
			30	000	+327
0322	0.4	-37	17	011	*+64*
			38a	000	+185
0329	0.1	-37	17	000	+160
			5	100	+170
			25	200	+185
			42	010	+214
			60	100	+275
			1a	201	+323
0504	0.1	-39	17a	000	+181
			60	022	+249
0511	0.4	-39	59	100	+136
			46	002	+159
			12	022	+180
			5	100	+226
			17a	000	+254
			58a	100	+290
			35	000	+311
			36	000	+314
			60	101	+324
0525	0.8	-40	65	110	+146
			22	100	+213
			10	222	+228
			64	000	+248
			62	020	+270
			48	010	+279
			52	000	+286
0602	0.9	-40	33	000	+254
			26b	201	+294
			52	000	+300
0609	1.0	-41	69	100	+198
			69a	200	+322
0616	1.1	-41	38a	000	*-74*
			70	111	*+53*
			5	100	+260
			58a	100	+276
			36	100	+301
			35	100	+322
			50	000	+325
0623	1.1	-41	12	000	+187
0630	1.1	-42	57	221	*-145*
0707	1.1	-42	9	110	*-77*
			14	000	+155
			21a	110	+202
			20	112	+208
0707	1.1	-42	20a	111	+262
			52	000	+280
			10a	211	+302
0729	0.9	-43	70	100	*+94*
			5	201	+235
			17a	000	+255
			36	100	+278
			58a	100	+289
			35	101	+318
0805	0.7	-43	12	100	+146
0819	0.4	-44	52	001	+231

- Ganymede Reappearances --

UT Date mmdd	Geom- etry r	°	Ob. No.	Con. stb	Res. sec.
1992					
1120	0.4	-30	17	010	*+146*
1127	0.5	-30	42	122	-148
1212	0.8	-31	64	000	-182
1993					
0102	1.0	-32	60	101	-295
0109	1.0	-33	42	012	-228
0131	0.7	-34	61	110	-228
			6	100	-220
			30	200	-209
0207	0.6	-34	33	001	-260
			13	201	-256
			38	101	*+86*
0214	0.4	-35	37a	000	-329
			42	010	-226
			12	000	-153
0221	0.2	-35	3	001	-185
			42	010	*-75*
0405	0.3	-37	56	002	-300
			26a	101	-292
			64a	001	-274
			24b	001	-272
			40a	012	-222
			62	121	-198
0412	0.6	-38	11a	000	-365
			20a	- - -	-290
			52	000	-276
			44	000	-237
			2a	110	-178
0420	0.9	-38	39	210	-341
			61	111	-317
			29a	11 -	-249
0427	1.3	-39	60	102	-350
			17a	001	-269
			61	221	*-44*
0504	1.5	-39	60	102	-349
			5	012	-331
			17a	010	-287
			36	020	-210
0511	1.8	-39	35	000	-363
			5	000	-301
			36	010	-282
			58a	000	-277
			17a	110	-148
0518	2.0	-40	20a	221	-316
			44	001	-290
			64	100	-289
			20	221	-281
			65	212	-226
			40a	012	-148
0518	2.0	-40	28	112	-118
0602	2.3	-40	39	201	-372
			29	10 -	-316
			47	111	-312
0609	2.4	-41	17a	000	-299
0616	2.5	-41	50	100	-366
			35	120	-360
			37a	100	-358
			58a	000	-347
			36	100	-333
			5	020	-290
			38a	000	-241
			17a	000	-209
			70	111	*+80*
0630	2.5	-42	9	121	-214
0707	2.5	-42	52	000	-313
0715	2.4	-42	68a	110	-308
0722	2.3	-43	50	100	-385
			37a	000	-369
			18	120	-190
			17a	000	*-114*
			70	010	*+168*
0729	2.2	-43	35	201	-358
			58a	000	-354
			36	010	-320
			5	201	-312
			17a	010	-296
0910	1.1	-45	41	000	-296
			42	211	-247

--- Callisto Disappearances ---

(None)

---- Callisto Reappearance ----

UT Date mmdd	Geom- etry r	°	Ob. No.	Con. stb	Res. sec.
1992					
1017	0.8	-72	24b	112	-540

The Key to the above table and List of Observers follow on p. 25.

Key:

A. *UT Date:* the Universal Time year, month number, and day of the event.

B. *Geometry:* The apparent distance of the satellite from the nearest Jovian limb in units of the Jovian equatorial semidiameter (**r**); followed by the jovicentric latitude (as projected onto the shadow), in degrees, of the center of the satellite in relation to the shadow center.

C. *Ob.No.:* Observer (or team) number as listed below. In that list, the first figure in parentheses represents the aperture of the telescope used in centimeters; the second the number of timings submitted using that telescope.

D. *Con.:* Conditions of observation; in order, seeing, transparency, and field brightness. The code is: 0 = condition not perceptible with no effect on timing; 1 = condition perceptible with possible minor effect on timing; 2 = condition serious with definite effect on the accuracy of the timing. A dash indicates that the observer did not report that particular condition.

E. *Res.* (residual): The time difference in seconds, found by subtracting the eclipse UT as predicted by the E-2 Ephemeris from the observed eclipse UT. The former, originally given in Ephemeris Time, was converted to UT using an assumed ΔT value of +58 seconds prior to 1992 OCT 06, +59 seconds from 1992 OCT 06 to 1993 JUN 10, and +60 seconds thereafter. Italicized residuals denote timings that were not used in the regression analysis because they differed from the regression model at the 5-percent significance level.

Participating Observers, 1992/93 Apparition

(In Parentheses: Aperture in cm followed by number of timings)

1	Abrahams, W. (8.0; 1)
1a	" (20.0; 3)
2	Barroso, N. (12; 3)
2a	" (20; 3)
3	Barry. R. (15; 1)
4	Bembrick, C. (8.0; 3)
5	Blanksby. J.L. (15.0; 33)
6	Bock, P.H., Jr. (12.7; 3)
7	Brylowski, Z. (15; 4)
8	Bulder, H. (25; 1)
8a	" (30; 7)
9	Busa, S. (8.4; 8)
10	Campos, F. (12.5; 1)
10a	" (20.6; 9)
11	Casas, R. (20.3; 1)
11a	" (40.0; 2)
12	Chen, D.H. (11.4; 9)
13	Coucke, M.G. (20; 3)
14	Crespo, M.A. (11.4; 3)
15	Darnell, P.B. (17.8; 11)
16	Davis, M.A. (6; 3)
17	de Rosamond, A. (20.0; 23)
17a	" (32.0; 30)
18	Dickie, R. (20.0; 8)
18a	" (25.0; 5)
19	Dillon, W.G. (28; 3)
19a	" (91; 1)
20	Fernandez, D. (11.0; 4)
20a	" (15.8; 13)
21	Fernandez, M.V. (6.0; 1)
21a	" (8.0; 2)
22	Foglia, S. (11.4; 6)
23	Gabzo, O. (20.3; 1)
23a	" (25.4; 3)
24	Garcia, J. (10; 1)
24a	" (20; 2)
24b	" (40; 20)
25	George, M. (13.0; 2)
26	Gonçalves, R. (5; 1)
26a	" (5; 6)
26b	" (20; 3)
27	Gracias, N. (13; 4)
28	Grunnet, C. (6.3; 4)
28a	" (25.4; 8)
29	Haas, W.H. (20.3; 1)
29a	" (31.75; 2)
30	Hays, R.H., Jr. (15; 8)
31	Hesseltine, C. (32; 1)
32	Hilt, F. (10; 1)
33	Himes, D. (30; 12)
33a	" (40; 1)
34	Kroon, G. (15; 1)
35	Kruijshoop, A. (20.0; 23)
36	Larkin, P. (20.0; 35)
37	Loader, B. (10.0; 2)
37a	" (20.0; 9)
38	MacDonald, M. (20.0; 8)
38a	" (30.0; 10)
39	MacDougal, C. (15; 11)
40	Marques, R. (20.0; 1)
40a	" (25; 11)
41	Matthews, T. (20.0; 4)
42	Moller, H. (20.0; 37)
43	Ofek, E. (15; 1)
43a	" (20.0; 7)
44	Olesen, J.O. (20; 12)
45	Otazu, X. (10.0; 2)
46	O'Yiang, T.-J. (15.0; 9)
47	Parmentier, R. (15; 2)
47a	" (75; 1)
48	Patak, Á. (11; 3)
49	Presits, P. (5; 1)
50	Priestley, J. (20.0; 10)
51	Rasmussen, A. (11.4; 1)
52	Roque Barretto, M.J. (6.0; 47)
53	Rowley, D.A. (20.0; 2)
54	Ruiz Ruiz, B. (11.5; 3)
55	Samolyk, G. (15; 1)
55a	" (32; 1)
55b	" (65; 2)
56	Shemmer, O. (20; 3)
57	Singh, J.E.S. (6; 9)
58	Skilton, P. (6.0; 2)
58a	" (15.0; 27)
59	Skilton, R. (6.0; 2)
59a	" (15.0; 3)
60	Smith, C. (25.0; 26)
61	Sullivan, M.W. (11.43; 16)
62	Szabó, S. (6.3; 4)
62a	" (11; 2)
63	Szöllösi, A. (15; 2)
64	Testa, L. (20; 16)
64a	" (40; 5)
65	Tizedes, C. (5; 3)
66	van der Werf, A. (46; 1)
67	Vidal, J. (41.0; 1)
68	Waraczyski, S. (25.4; 5)
68a	" (31.75; 1)
69	Westfall, J. (9; 2)
69a	" (28; 2)
70	Wolf, G. (6.0; 16)
70a	" (21.0; 1)
70b	" (23.0; 1)

Observer Identification Numbers by Country

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Australia: 1, 4, 5, 17, 25, 35, 36, 41, 42, 58, 59, 60

Canada: 61

Denmark: 15, 28, 44, 51

Hungary: 9, 48, 49, 62, 63, 65

India: 57

Israel: 3, 23, 43, 56

Italy: 22, 64

Netherlands: 8, 32, 34, 66

New Zealand: 18, 37, 38, 50, 70

People's Republic of China: 12, 46

Poland: 7

Portugal: 24, 26, 27, 40

Spain: 10, 11, 14, 20, 21, 45, 52, 54, 67

United States: 6, 13, 18, 19, 29, 30, 31, 33, 39, 47, 53, 55, 68, 69

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By: Michael Mattei

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SUBJECT INDEX

A LETTER FROM THE FOUNDER OF THE A.L.P.O.

My interview with *Sky & Telescope*, as reported on page 82 of the November, 1997 issue of that magazine, appears to have created an impression that I am unconcerned about the less "advanced" members of the A.L.P.O. except as providing needed financial support. At least such was the reaction of a couple of our members. If my 50-odd years of trying to encourage amateur observations with ordinary telescopes and accessories do not refute this impression, nothing I say here is likely to do so. The published interview is not word-for-word what I said, or rather wrote; but there are probably no serious changes in meaning, and the resemblance to the original was very close for *Sky & Telescope*.

However, it is true that the very great majority of the members of the A.L.P.O. do *not* contribute in any way beyond paying dues. A conservative estimate might be that 80 percent of them do not submit any observations to the Section Coordinators, do not correspond with any of the staff members, and do not participate in any of our programs and projects.

Are we failing to give them an opportunity to do more than pay dues and carry a membership card? I definitely think not. Many of the articles in the *Journal, A.L.P.O.* concern such matters as drawings of Venus, sketches of lunar domes, visual intensity estimates of features on Saturn and its rings, integrated visual magnitude estimates of the brightness of comets, and central meridian transits of the surface features on Jupiter. These are not the modern, "cutting edge technology" which we admire in the work of such "advanced" observers as Parker, Westfall, and Troiani. The great majority of professional astronomers would surely consider the kinds of observations listed above to be of very limited scientific value compared to what Parker *et alii* are doing. Indeed, an "advanced" planetary observer, who has sometimes been an A.L.P.O. member, accuses us of looking far more to the Nineteenth Century than to the Twenty-first. He considers that our Mars Section is the only part of the A.L.P.O. doing work of real scientific value.

Recent policies and actions would surely show that we do not share his opinion. The content of the *J.A.L.P.O.* has already been cited. Efforts have been made in recent years to improve and to streamline the Training Program–and yet a report at the 1997 Convention said that only three or four persons had enrolled themselves in it. There ought to be dozens! Some years ago the Journal included a series of "For the Beginner" articles. More recently, and in large part thanks to Harry Jamieson, the volunteer staff and the number of Sections have been increased. There should now be some project or program for just about everyone! For example, Historical Section and Computing Section buffs can do research at home or in a library, far from a telescope. We are always glad to hear from members about how to improve these services. In brief, members unable to do CCD imaging, micrometer measurements, high-resolution studies with large apertures, and so forth certainly have available other opportunities; they and we should be honest enough to admit that these activities will often be of less scientific value. It is disappointing to us when a member finds nothing to do beyond paying his or her dues, but surely we are trying to provide projects from which to choose.

It is not news that in many volunteer organizations (e.g., science clubs, churches, and fraternities) a small portion of the membership does almost all of the work. They have problems finding members willing to be officers. Thus the moral and financial support of the idle many makes possible the efforts of the productive few. It has been so in the A.L.P.O. over the years. We are certainly an important contributor to the success of an organization when we use our money to promote activities we consider important and valuable.

It is no pleasure to suspect that the A.L.P.O. will split in the future, considering the diversity of skills and interests. It will require a wise leadership to provide services considered valuable and worth supporting by both the few semiprofessional and the many less skilled, less affluent others. It may be worth remembering that the Compromise of 1850 held together a Union composed of badly disparate parts for only ten years. Finally, the Italian (U.A.I.) practice of regular bimonthly Bulletins by Section Coordinators is excellent. Worth imitating?

It would be wonderful to be able to say honestly in a future interview that every member does *more* than pay dues!

Walter H. Haas

A.L.P.O. Director Emeritus
October 4, 1997

IN MEMORIAM: ALIKA K. HERRING

By: Walter H. Haas, A.L.P.O. Director Emeritus

It is rare to find among astronomers a person both skilled in making excellent telescope optics and outstanding in carrying out high-quality visual observations. William Herschel demonstrated both abilities in the past, and many readers will think of Clyde Tombaugh as a conspicuous example in the current century. Another such person was Alika K. Herring, who died early in 1997.

This short biographical sketch will indicate something of his extensive activities and interests. He was born in Hawaii of missionary parents, and his wife Trene was also a native of that island. He graduated from the University of Oklahoma at Norman in 1932. He worked as a mailman and a musician during the Great Depression, and then enlisted in the Navy after Pearl Harbor. He served as a Sonar Man during World War II. After subsequent employment as a musician and a machinist, while also making several telescope mirrors, he went to California in 1951. He met Tom Cave and worked for the Cave Optical Company until 1961. There he made several thousand astronomical mirrors. There next followed a professional career at the Lunar and Planetary Laboratory of the University of Arizona at Tucson, the Director being Gerard P. Kuiper. Alika observed and photographed the Moon, along with others, culminating in the production of the excellent *Consolidated Lunar Atlas* in 1967. Seeking a site for Dr. Kuiper, where atmospheric steadiness would allow large telescopes to study the very finest lunar and planetary details, he conducted seeing tests near Tucson, in Hawaii, in Chile, in Baja California, and elsewhere. He used for these tests a 12.5-inch mirror he had made himself and had brought to what he considered a unique degree of perfection through many loving hours of the most critical testing. With the decline of federal support of astronomy research and space programs, Alika left the Lunar and Planetary Laboratory in 1970 and returned to the Cave Optical Company, where he was employed until his retirement in 1979. He now made and sold mirrors, with the knowledge of Tom Cave, and continued briefly to do so after retirement. His mirrors acquired a strong reputation for excellence, and it is even said that the market led to the production of some counterfeit "Herring mirrors" –a high compliment in its way.

He was a modest and retiring man, who found public speaking a terrible embarrassment. This trait was unfortunate, for he had far more to say than many who are fluent. He was very friendly, a genial host in his home to all who shared his interests. When there was an A.L.P.O. Convention where he lived, my wife and I could expect to escape from formal activities for some treasured hours with Alika and Trene. On a clear evening, his telescope was at the disposal of his guests.

His chief contribution to science was surely the site-testing which led to the selection and development of Mauna Kea in Hawaii as a major center of astronomical research. Alika tested both Haleakala and Mauna Kea at some length and found slightly better seeing at Haleakala. However, Mauna Kea was chosen because it rose above the top of the frequent cloudy inversion layers, and Haleakala didn't. Even so, Mauna Kea is an amateur observer's dream come true; Herring regularly used 619× to observe the Moon with a 12.5-inch aperture and could regularly elongate the double star $\gamma 2$ Andromedae–its separation was only 0.4 arc-seconds at the time. He found there periods of perfect seeing with intervals of many seconds between any visible atmospheric tremors.

This site-testing on mountaintops required considerable resourcefulness and dedication. Alika once commented to me on the contrast between how he lived under sub-Arctic conditions 10,000 feet or more above sea level and the popular vision of Hawaii as a lush tropical paradise. On one occasion he had to be rescued by helicopter from a mountaintop in Baja California in the teeth of an approaching storm. He took his responsibility very seriously, as a published comment (O. Richard Norton, "Master Optician, Master Observer."*Sky & Telescope*, May, 1995, pp. 81-86) shows: "I shudder now when I think of the responsibility I had. Millions and millions of dollars hung in the balance, and it all was pretty much on my say-so. It scared me."

Some good lunar and planetary observers make drawings of indifferent quality. Contrariwise, Alika was among the best lunar artists of our times. Selected lunar drawings by him appeared in *Sky & Telescope* and the *Journal, A.L.P.O.* over a period of many years, and our front cover and *Figure 1* on p. 31 are samples in this issue. He came to regard drawing lunar features with Earth-based telescopes as of limited scientific value in our Space Age but as an interesting art form. As for his general skill in visual observations, I recall one time when he and I were observing Saturn at his home, and Alika was identifying several of the satellites. I was unable to see all that he described, but reference to the *American Ephemeris and Nautical Almanac* showed him to be exactly right.

Alika was always very supportive of the A.L.P.O. He served as a valued Lunar Recorder from 1957 to 1961. He was in charge of the A.L.P.O. Exhibit at one of our early conventions–collecting, arranging, and returning the display items. He was a delightful astronomical correspondent in those pre-e-mail days, and his thoughts were always helpful and scientifically reliable.

Like William Herschel, Alika was deeply interested in music as well as astronomy. He was a master of the Hawaiian steel guitar, and was even said to be the best performer in the United States on this instrument for several years. Late in his life he produced five albums or more of Hawaiian music.

Alika Herring photographed Halley's Comet during its 1985-86 appearance. He wrote on his annual Christmas card that the photographs would be mementos for his descendants when the comet returned in 2061. Later years brought him macular degeneration in both eyes, and he had to abandon making mirrors and observing the sky. He could retain his love of music and make tapes of romantic Hawaiian melodies. The very special 12.5-inch mirror reposed in a box in his study. He preserved a remarkably cheerful spirit and was interviewed by O. Richard Norton for Sky and Telescope in 1995. It was a sad day when his son telephoned to say that Alika had passed away, and that he specially wanted me to know.

I wish to thank Tom Cave of Long Beach, California, and Cecil Post of Las Cruces, New Mexico, for help in collecting some of the material in this article.

Aloha, dear friend!

Some Comments by the Editor:

To elaborate slightly on Walter Haas' tribute above, Alika Herring's lunar work while with the Lunar and Planetary Laboratory in Tucson included preparing a series of sketch maps of the lunar limb areas, based on rectified lunar photographs and personal telescopic observations. These were published during 1961-65 in the *Communications, Lunar and Planetary Laboratory* in the form of six articles, which represented the culmination of Earth-based mapping of those portions of the Moon.

Also, the lunar drawings published in *Sky & Telescope* magazine came to contain 40 separate drawings, typically published every third issue between 1958 and 1967. Alika's lunar drawings were always attractive; their accuracy became clear only when space-probe images produced views of the Moon with detail sufficient to check against his drawings. We are happy to have the chance to republish two of his lunar depictions here; a view of Davy Y and Catena Davy on the front cover, and another of Ramsden and part of its rille system in *Figure 1* (below).

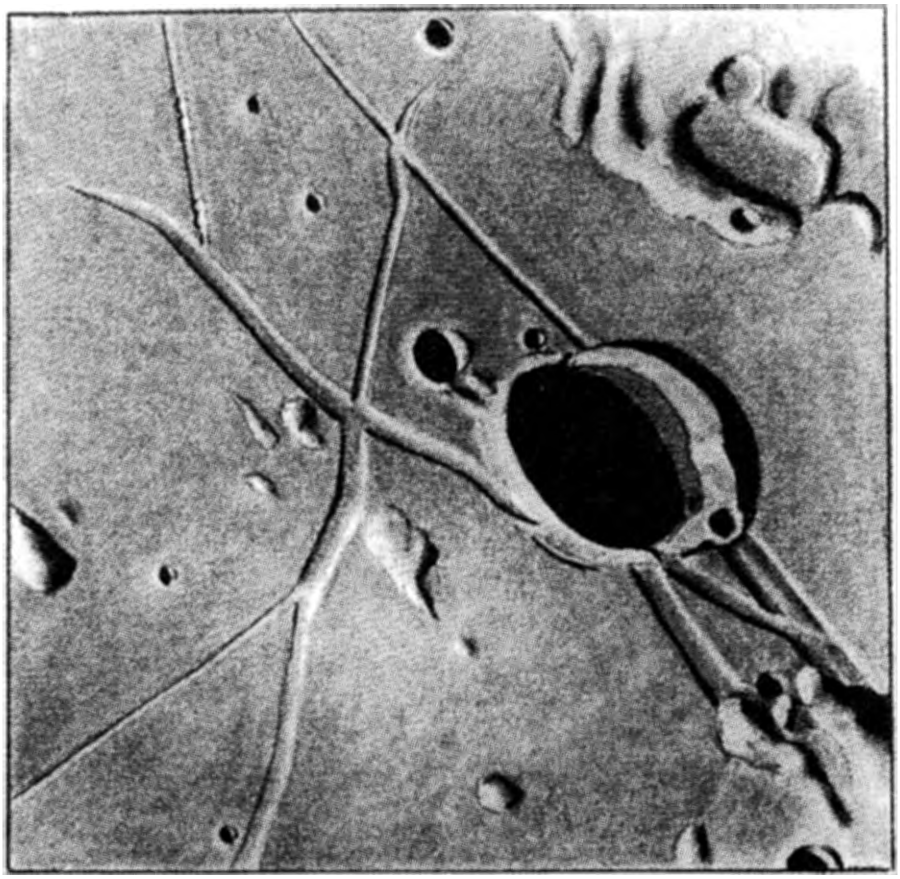

Figure 1. Ramsden and part of its rille system, drawn by Alika K. Herring on 1962 Sep 10, 02h40m UT. 12.5-in (31.75-cm) Newtonian, 208X. Seeing 5-7 on the A.L.P.O. Scale (0 = worst, 10 = perfect), Transparency 5 on the A.L.P.O. Scale (0 = worst, 5 = best). Solar colongitude 041°.6. South at top.

ACCURACY OF THE SHADOW METHOD OF LUNAR HEIGHT DETERMINATION

By: William F. Davis III

ABSTRACT

The accuracy of the shadow method of lunar height determination developed by Wilhelm Olbers is tested at the telescope by comparing calculated heights to plotted heights as drawn on lunar topographic orthophoto maps. A database of 119 measurements is analyzed to evaluate typical amounts and sources of error.

INTRODUCTION

The method of elevation determination that is the subject of this paper uses the lengths of the shadows cast by lunar features to determine their elevations. It began with Johann Hieronymus Schroeter (1745-1816), who in 1791 published *Selenotopographische Fragmente sur genauern Kenntniss der Mondflache* (Fragments of Lunar Topography). Working just outside Bremen, Germany, with a 19-in telescope at 300×, he used a device which functioned much like a micrometer (though not as accurate) to introduce a new method of height calculation called the "shadow method" [1]. His early results with this new method were disappointing, giving elevations far too high. He then turned to his good friend Wilhelm Olbers (1758-1840), a medical doctor and astronomer, who developed the version of the shadow method which, with some modification, is still in use today [2].

Typically a discussion of lunar height measurements requires some explanation of the various methods employed, both past and present. Gilbert Fielder offers a good explanation of the light-tangent, shadow, photometric, comparative, eclipse, occultation, photogrammetric, and absolute methods of height determination [3]. This paper will focus on the shadow method only, and more specifically on the shadow method as it relates to direct "at-the-telescope" micrometer work. [Although the reduction techniques involved are equally applicable to the measurement of shadows on photographs or CCD images. Ed.]

Olbers' method was used in this study to determine the relative heights of objects from micrometric measurements of the shadows they cast in the lunar morning or afternoon. Perhaps the clearest explanation of the method is by Thomas L. MacDonald, director of the Lunar Section of the British Astronomical Association from 1937-1945. His 1931 paper, "On the Determination of Relative Altitudes," [4] is the basis of the height calculation subprogram contained in the *Lunar Observer's Tool Kit* (also called Tools), a computer program developed by Harry D. Jamieson [5]. Tools is the source of the ephemeris data used in this study and, in my opinion, is currently the single best source for accurate height determination based on telescopic, micrometric shadow length measurement.

THE SHADOW METHOD TESTED

The Lunar Topographic Orthophoto (LTO) map series [6] was used to evaluate the magnitude of the cumulative errors inherent in the shadow method of height determination. There are approximately 200 maps in this 1:250,000-scale series. They cover the flight paths of Apollo Missions 15-17 and represent only a small portion of the lunar surface. Each map is in a Transverse Mercator Projection and covers an area extending four degrees in latitude and five degrees in longitude.

Height determined from the shadow method is relative, being simply the height difference between a peak and the tip of its shadow. Terrain which slopes downward from a peak will yield a higher elevation than terrain which slopes upward. Because the LTO maps show peak elevations and contain contour lines at 100-meter intervals, they offer a way to compare the height measured by the shadow method to the actual height plotted on an LTO map, and thus to evaluate the accuracy of the shadow method itself.

This comparison is done by first measuring the shadow length of a peak and calculating the height in the usual manner. The calculated solar azimuth is converted to shadow azimuth (180° different) and the projected shadow length is drawn to scale on the LTO map, using the peak as the starting point. The elevation of the shadow tip is read from the closest contour line and then subtracted from the peak elevation. This plotted elevation is compared to the calculated elevation and the difference is expressed as a percentage. Eighteen elevations were selected for analysis and are listed in *Table 1* (p. 33).

These elevations were selected because of their height, position, and appearance on the LTO maps. Bennett Hill and Hill 305 are located on the eastern shore of Palus Putredinis; they were named during the Apollo 15 Mission. The Delisle α elevations are three peaks of the same mountain. Mons Undest was formerly Lambert γ. Mons Vinogradov was formerly Euler β. Mons Vinogradov (α) is the author's designation for an unnamed elevation located close to Mons Vinogradov.

The mean height of all these features from 119 measurements was 1599.6 meters. *Figure 1* (p. 33) shows the range of measured peak elevations at 500-meter intervals.

Table 1. Elevations Selected for Measurement.

	Position			
Name of Elevation*	ξ	η	Longitude	Latitude
Albategnius α CP	+.065	-.196	3°.80E	11°.30S
Archerusia Prom.	+.358	+.289	21°.96E	16°.80N
Bennett Hill	+.042	+.437	2°.68E	25°.91N
Delisle α (east)	-.522	+.509	37°.33W	30°.60N
Delisle α (south-west)	-.531	+.504	37°.94W	30°.26N
Delisle α (west)	-.531	+.509	38°.09W	30°.60N
Delisle β	-.512	+.485	35°.84W	29°.01N
Hadley Mons	+.064	+.448	4°.11E	26°.62N
Hadley δ	+.059	+.432	3°.75E	25°.89N
Harbinger Montes β	-.587	+.445	40°.96W	26°.42N
Harbinger Montes δ	-.581	+.471	41°.20W	28°.10N
Harbinger Montes ζ	-.591	+.452	41°.49W	26°.87N
Hill 305	+.047	+.446	3°.01E	26°.49N
Lahire Mons	-.382	+.463	25°.53W	27°.58N
Theophilus φ CP	+.436	-.198	26°.41E	11°.42S
Undest Mons	-.284	+.446	18°.50W	26°.49N
Vinogradov Mons	-.497	+.380	32°.50W	22°.33N
Vinogradov Mons (α)	-.496	+.362	32°.15W	21°.22N

**Prom. = Promontorium; CP = central peak.*

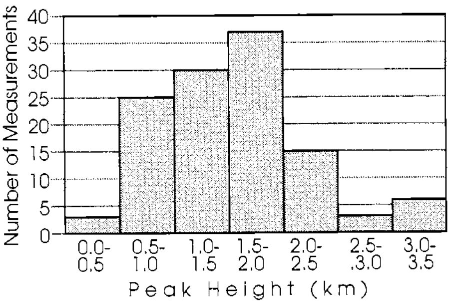

Figure 1. Distribution of measurements by height of peak.

A Microsoft Works database was created to archive the variables of each individual measurement. Jamieson's Tools program was used to generate ephemerides for the moment of observation. This information was entered into the appropriate cells of the database, which was programmed to use the ephemerides and micrometer measurement to calculate measured height, projected shadow length, and shadow azimuth. The formulae and methods used were identical to those used in Tools. The projected shadow was then plotted on the appropriate LTO map and the height of the shadow tip determined from the contour line closest to it. This height was entered into the "shadow tip height" database cell, allowing the program to complete the comparison of measured height to plotted height and to express the difference as a percentage error, with the convention that an error was positive for a measured height which exceeded the plotted height and negative for a measured height less than plotted height.

The data in the first screen of a typical three-screen record are given in *Table 2* (to right).

For the 119 measurements made of the 18 peaks, the mean error in measured height compared to plotted height was only -77.3 meters or just -3.7 percent. Positive measuring errors tend to cancel out negative ones; in short, the more measurements made, the greater the accuracy. This is not surprising, as the reliability of the shadow method was never in question. Rather, the purpose of this study is to evaluate the potential errors inherent in an individual measurement, and unfortunately, they abound. A fairer way to investigate error is to examine the absolute value of the percent error, which averaged 11.0 percent, close to Fielder's estimated error for heights determined from the shadows on photographs [7]. Absolute percent errors ranged from 0 to 33.2 percent. *Figure 2* (p. 34) graphs seven error ranges and shows the number of measurements which fell into each range.

ANALYSIS OF RESULTS

Peak Coordinates.—"Evaluated horizontal and vertical accuracy of the LTO series at 90% probability generally ranges form 160-500 meters and 30-115 meters respectively relative to the Apollo 15 (April 1973) Datum." [8] Because of the importance of peak longitude in calculating solar altitude, an error in this coordinate will cause more inaccuracy in height determination than a like error in latitude. The maximum probable LTO horizontal error of 500 meters is 0°.017 of longitude at the lunar equator and 0°.019 at latitude 31°. Latitude 31° is the position of Delisle α (east); of the 18 peaks measured, this elevation has the highest latitude and therefore potentially the greatest possible magnitude of east-west positional error.

Table 2. Sample Partial Elevation Record.
(reformatted to fit column)

OBJECT: Albategnius alpha CP

MEASURED HEIGHT (m): 1704.8
PLOTTED HEIGHT (m): 1703
% ERROR: 0.1%

DATE: 6/30/94 UT HR: 8 UT MIN: 55

PROJEC SHA (km): 17.3
SHADOW AZIMUTH: 90.0

RISE: SET: 1 OT: 3

OBSERVER: Bill Davis

OBJECT LONG: 3.8 OBJECT LAT: -11.3
EARTH LONG: 4.62 EARTH LAT: -5.06
SUN COLONG: 170.406 SUN LAT: 1.154
MOON ALT: 44.94 SUN ALT: 5.908
GEO D: 62.6848893 ARC SEC: 9.083
OBSERVATION #: 104
TRUE H (m): 7503 SHA TIP H (m): 5800

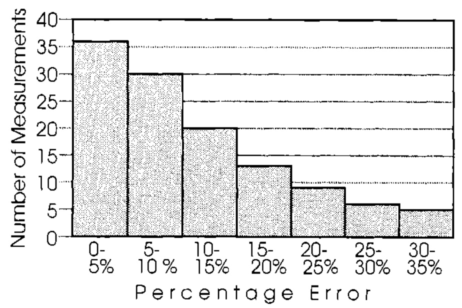

Figure 2. Distribution of measurements by percentage error.

Assuming a positive error in longitude of 0°.019 (giving longitude -37°.31), the four measurements of Delisle α (east) were recalculated allowing for new solar altitudes and final height determinations. Compared to the original measurements (-37°.33 longitude), the mean error for the four new height determinations was only 0.6 percent; a mean difference of only four meters from the originals. It is probable that vertical errors in the LTO maps are responsible for more discrepancies in this study than horizontal errors; however, there is no way to analyze this effect.

Seeing.—Due to limited observing opportunities, the mean lunar altitude at the observer's position was only 48°.3. Although measurements were taken only when seeing was good (II, on the Antoniadi Scale; ranging from I = perfect to V = very bad, scarcely allowing for the making of a rough sketch), viewing through the additional atmosphere that lower altitudes impose certainly increased shadow length uncertainties. Because of local atmospheric conditions and traffic vibrations, most measurements (67 percent) were made during the early morning hours (usually 3 a.m. to 6 a.m., local time). The mean absolute error for these 80 measurements was 9.6 percent; the other 39 measurements made during early evening hours (usually 6 p.m. to midnight local time) had a mean absolute error of 14.0 percent.

Slope.—The effect of slope should not be a factor in this error analysis, since the shadow tip elevation was taken directly off an LTO map, presumably accurate to 100 meters. The observed fact was that shadow tips which fell on rapidly changing topography made accurate height determination difficult. This is because of slight errors in shadow length measurement, which cause the shadow tip to fall on the "wrong" contour line. Because of the small areal coverage of the LTO maps, some peaks were chosen despite the topography of their surroundings.

One example of this problem is the central peak Albategnius α. The shadows of eight lunar afternoon measurements fell within the crater floor and the mean absolute error was 7.3 percent. However, three sunrise shadows climbed the walls of Klein and Klein A where elevation changes rapidly; the mean absolute error was 23.4 percent. One shadow of Mons Hadley ran into Hill 305, causing a -29-percent error. A shadow of Delisle α (south-west) did not clear its own base and produced a 33.2-percent error. On the other hand, four lunar afternoon shadows of Mons Vinogradov fell on terrain which does not vary in height by more than 100 meters for at least 60 kilometers from the peak base; here the mean absolute error was only 5.5 percent.

Foreshortening.—The mean phase angle (also known as the auxiliary angle) was 87°.8 and ranged from 35-130°. *Figure 3* (below) shows six ranges of phase angle, the mean arc second shadow length for each range, and the percent of that shadow length which was

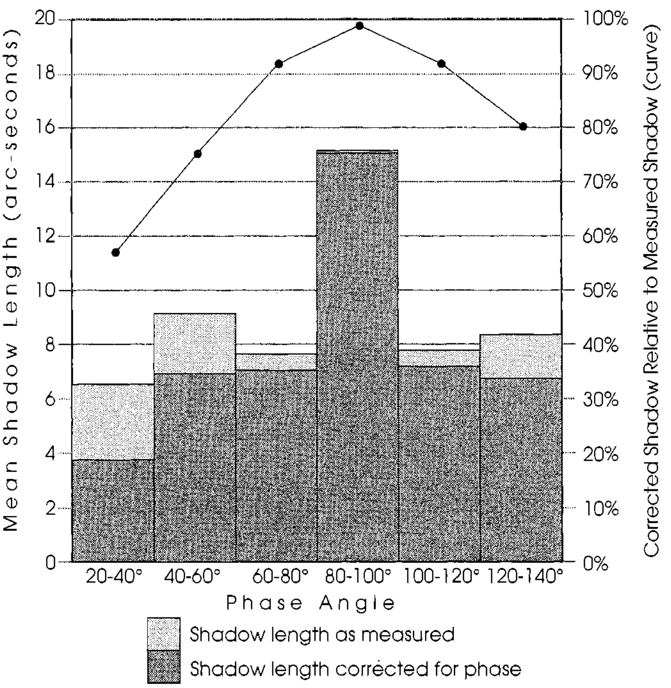

Figure 3. Relation of measured shadow length to corrected shadow length as a function of phase angle.

visually measured. The mean shadow length in arc-seconds for each range is further distinguished as that portion that was visually measured (light tone) and that portion that was the result of the phase angle foreshortening correction (dark tone).

Note that the closer the phase angle is to 90°, the greater is the shadow length visually measured relative to the corrected length. Longer shadows can be measured more accurately than shorter ones. Despite this fact, there was no correlation between phase angle and absolute percent error. Except for a small phase angle error, never more than 1°.25 (because geocentric libration values were used), foreshortening errors are mathematically eliminated except in limb regions. Since no peak had an absolute longitude greater than 40°, other variables such as solar altitude, shadow length, and slope had much more effect on error.

Micrometer Use and Magnification.—Shadow measurements were taken using a 20-cm, f/10 Schmidt-Cassegrain telescope. A microscope filar micrometer with an eyepiece focal length of 23 mm was modified to fit a 1.25-in drawtube, and was used in two optical trains over the course of the study:

- The first optical train achieved a magnification of 315X and consisted of a 2.8X telenegative amplifier inserted into the visual back of the telescope, followed by a star diagonal and micrometer. Seventy-five measurements (63 percent) were made with this arrangement.
- The second optical train had a magnification of 525X and consisted of a 25-mm orthoscopic ocular inserted into the visual back of the telescope in eyepiece projection fashion, followed by a 4.75-in extension tube, star diagonal, and micrometer. Forty-four measurements (37 percent) were made with this arrangement.

As expected, the 525X optical train produced greater accuracy. Its mean absolute error of 9.7 percent compares favorably with an 11.8-percent absolute error for the 315X optical train.

The procedures for calibration and use of a filar micrometer were taken from Chapter 15 of *Observing and Photographing the Solar System* [9], with one notable exception. The authors recommend that the optics of a catadioptric telescope be fixed and that a rack-and-pinion focuser be installed in the visual back to prevent changing the effective focal length by movement of the primary mirror during long-term micrometer work. This approach was tried, but it rendered the telescope useless for lower-power observing. Since this study was to span several years, the rear focuser was abandoned. This no doubt introduced additional error, although much care was taken to focus sharply before each set of measurements. The screw constants were also periodically recalibrated during the study and found to agree closely.

The effect of personal error must also be considered. Theoretically, the number of positive error and negative error measurements should be about the same. This was not the case. A negative error was recorded in 76 measurements, 63.9 percent of the total. This suggest that the author has a tendency to underestimate shadow length. It is interesting to note however, that the absolute error in the two groups differed by only 1.4 percent, being slightly greater for the negative error measurements.

Shadow Length.—The mean solar altitude was 6°.8. *Figure 4* (below) shows the six ranges of solar altitude which account for all observations. The vertical columns represent the number of observations which fell into each range. An evaluation of how solar altitude affected accuracy is difficult because of the additional variables of measured height and projected shadow length for each of the 18 elevations studied.

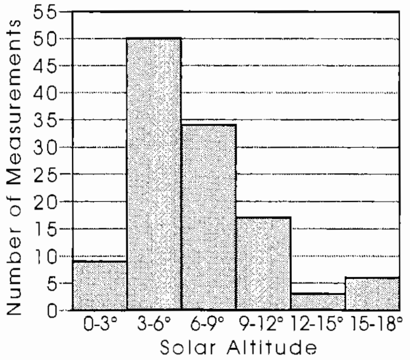

Figure 4. Distribution of measurements by range of solar altitude.

For measurements of the same feature, increased solar altitude, which results in decreased shadow length, should introduce more error. A more meaningful analysis can be seen in Figure 5 (p. 35), which shows four ranges of solar altitude for the 12 measurements of Harbinger Montes β. The vertical columns depict the mean projected shadow length for each solar altitude range. The line in the upper portion of the graph shows the mean percentage absolute error for each range. Note the increase in percentage error as solar altitude increases and projected shadow length decreases.

Perhaps the best way to achieve an understanding for the value of making multiple measurements is to give an example. A typical case is the 16 measurements made of Harbinger Montes δ. The mean absolute percent error was 9.9 percent, mean measured height 1,773 meters, and mean solar altitude 9°.3. The greatest absolute percentage error was -32 percent but the median was just ±7 percent (i.e., half the measurements had this error or less). This pattern was typical for most of the 18 elevations measured. [Note that, statistically, the error of the *mean* of a group of measurements should decrease in proportion to the

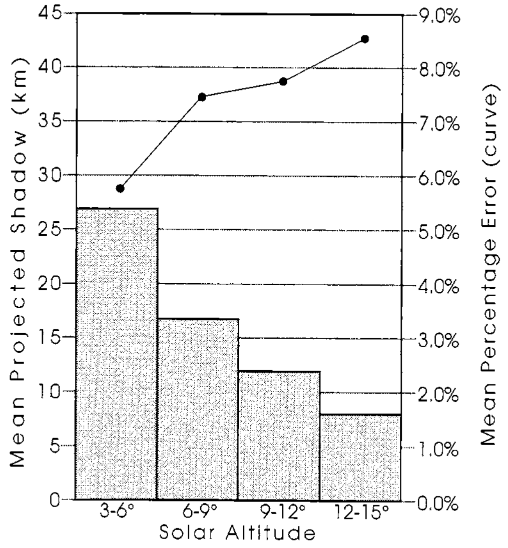

Figure 5. Harbinger Montes β: Mean projected shadow length (columns; left scale) and mean percentage error of measurement (line in upper portion; right scale); both in terms of solar altitude.

square root of the number of measures that went into that mean. Thus the mean of 16 measures should be four times as accurate as a single measurement. Ed.]

CONCLUSION

It is probable that multiple measurements of a peak will average an absolute error of 10 percent or less if the following statements are true:

- The peak coordinates are accurately known.
- The seeing is excellent.
- The lunar terrain adjacent to the peak is reasonably level.
- The peak is some distance from the lunar east or west limb.
- The micrometer is well calibrated.
- The magnification is large.
- The solar altitude is below 10°.

This degree of error is well within the limits of accuracy for other lunar elevation-measuring techniques, even the photometric method.

Those who enjoy the challenge of micrometer work at the telescope can make a valuable contribution to selenography by taking multiple measurements of elevations and recording the height, shadow length, and solar azimuth of each observation.

ACKNOWLEDGEMENT

This paper was born of the inspiration of John Westfall, who conceived its scope, and Harry Jamieson, who made the numbers crunch properly. Without their continuous advice and encouragement, this project would have remained in my backyard. If the study is found to have merit, it is due to their experienced mentorship; if not, it is despite their best efforts with a novice investigator.

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METEORS SECTION NEWS

By: Robert D. Lunsford, A.L.P.O. Meteors Coordinator

JANUARY-JUNE, 1996, METEOR ACTIVITY SUMMARY

Observations were sparse during the first half of January, when moonlight wiped out the Quadrantids. The last half of the month was dominated by the Alpha Crucids, which are unfortunately invisible from the Northern Hemisphere. As the Alpha Crucid activity waned, the Alpha Centaurids replenished the southern sky with activity. Overall activity was low during the second half of February and throughout most of March.

The April Lyrids were well seen with 25 different observers reporting activity. Rates of 5 to 20 per hour were reported, depending on the sky conditions at each observer's site. Two weeks later the Eta Aquarids were not well seen due to the intense moonlight present during this shower.

We express many thanks to Mr. Tim Cooper of South Africa, who shared his data with us. The many radiants active during May and June are located low in North American skies but pass overhead as seen from South Africa. Tim's counts indicate what can truly be seen from these far southern radiants during this time of year.

Table 1. Recent A.L.P.O. Meteor Observations; January - June, 1996.

1996 UT Date	Observer and Location	Universal Time	Number and Type* of Meteors Seen	Comments (+N = Limiting Magnitude)
JAN 04	George Zay, CA	07:38-13:51	6 COM, 2 DCA, 26 QUA, 8 SPO	+5.0
18	George Zay, CA	06:03-08:44	2 COM, 6 DCA, 3 SPO	+5.9
	Graham Wolf, New Zealand	09:00-14:00	14 ACR, 17 SPO	+4.5
19	Robyn Freedman, CA	02:12-07:15	1 DCA, 9 SPO	+5.8
	George Zay, CA	02:12-07:15	2 DCA, 9 SPO	+5.9
	Graham Wolf, New Zealand	09:00-12:00	14 ACR, 11 SPO	+6.5
	Graham Wolf, New Zealand	14:00-16:00	9 ACR, 7 SPO	+6.6
20	Mark Davis, SC	01:00-05:00	10 SPO	+5.2
	Graham Wolf, New Zealand	09:00-13:30	7 ACR, 14 SPO	+6.4; 10% cloudy
21	Mark Davis, SC	01:20-05:20	8 SPO	+5.3
	Graham Wolf, New Zealand	09:00-16:00	4 ACR, 27 SPO	+6.3; 5% cloudy
23	Mark Davis, SC	02:00-05:00	8 SPO	+5.3
	Robert Lunsford, CA	09:00-14:00	1 DCA, 17 SPO	+5.3
29	Graham Wolf, New Zealand	09:00-14:00	2 ACN, 19 SPO	+4.5
30	Graham Wolf, New Zealand	09:00-12:00	4 ACN, 10 SPO	+4.6; 10% cloudy
31	Graham Wolf, New Zealand	09:00-12:00	7 ACN, 12 SPO	+4.5; 10% cloudy
FEB 01	Graham Wolf, New Zealand	09:00-16:00	2 ACE, 23 SPO	+4.5
09	Graham Wolf, New Zealand	09:00-14:00	10 ACE, 1 VIR, 19 SPO	+4.4
10	Graham Wolf, New Zealand	09:00-16:00	13 ACE, 5 VIR, 26 SPO	+4.4
13	Mark Davis, SC	00:18-03:18	13 SPO	+5.2
14	Mark Davis, SC	01:12-02:18	3 SPO	+5.2
16	Graham Wolf, New Zealand	08:30-14:00	18 ACE, 8 DLE, 22 SPO	+5.8
17	Graham Wolf, New Zealand	13:00-16:30	5 ACE, 2 DLE, 15 SPO	+6.0
23	George Zay, CA	04:11-08:50	3 DLE, 2 VIR, 11 SPO	+6.0
	Graham Wolf, New Zealand	08:30-10:00	8 DLE, 6 VIR, 17 SPO	+4.4
24	Mark Davis, SC	04:30-07:50	1 DLE, 1 VIR, 13 SPO	+5.2
	Graham Wolf, New Zealand	08:30-10:10	3 DLE, 2 VIR, 5 SPO	+5.6
	Graham Wolf, New Zealand	11:00-16:00	12 DLE, 9 VIR, 24 SPO	+4.5
25	Graham Wolf, New Zealand	08:30-14:00	14 DLE, 8 VIR, 17 SPO	+4.7
26	Graham Wolf, New Zealand	08:30-16:00	12 DLE, 6 VIR, 30 SPO	+4.4
27	Graham Wolf, New Zealand	08:30-16:00	10 DLE, 6 VIR, 29 SPO	+4.6
28	Graham Wolf, New Zealand	08:30-12:00	3 DLE, 3 VIR, 9 SPO	+4.5
	Graham Wolf, New Zealand	12:00-16:00	7 GNO, 17 SPO	+4.7

Table 1 continued on pp. 38-40 with notes on p. 40.

Table 1—Continued.

1996 UT Date	Observer and Location	Universal Time	Number and Type* of Meteors Seen	Comments (+*N* = Limiting Magnitude)
Mar 13	Mark Davis, SC	01:01-04:01	8 SPO	+5.5
14	Mark Davis, SC	01:36-03:36	5 SPO	+5.5
15	Mark Davis, SC	03:15-04:15	3 SPO	+5.3
18	George Zay, CA	04:43-12:53	4 DLE, 3 VIR, 14 SPO	+5.9
	J. Kenneth Eakins, CA	06:00-08:00	2 VIR, 1 SPO	+5.3
	Robert Lunsford, CA	10:00-13:00	7 VIR, 17 SPO	+6.3
19	George Zay, CA	04:45-12:45	1 DLE, 1 VIR, 16 SPO	+5.9
	Robert Lunsford, CA	09:45-12:45	5 VIR, 11 SPO	+6.5
23	Mark Davis, SC	04:40-08:40	3 VIR, 16 SPO	+5.6
24	Pierre Martin, Ontario	05:50-06:53	1 VIR, 4 SPO	+5.4
	Michael Morrow, HI	12:05-13:05	2 SPO	+6.0
25	J. Kenneth Eakins, CA	05:30-07:30	*(none seen)*	+5.2
	Robert Lunsford, CA	11:15-12:15	1 VIR, 3 SPO	+6.2
27	Robert Lunsford, CA	10:15-11:45	5 SPO	+6.3
28	George Zay, CA	09:19-12:41	3 VIR, 13 SPO	+5.8
	Robert Lunsford, CA	10:30-12:30	12 SPO	+5.8
Apr 09	Graham Wolf, New Zealand	08:00-12:00	3 VIR, 13 SPO	+4.3
13	George Zay, CA	05:33-13:19	3 VIR, 25 SPO	+5.9
	Pierre Martin, Ontario	06:11-06:43	1 VIR, 3 SPO	+5.7
15	Robert Lunsford, CA	09:30-12:30	18 SPO	+6.3
	Graham Wolf, New Zealand	11:00-18:00	1 VIR, 31 SPO	+4.5
16	Robert Lunsford, CA	08:00-12:00	4 LYR, 2 SAG, 35 SPO	+6.6
	Graham Wolf, New Zealand	08:00-18:00	1 PPU, 40 SPO	+4.6
17	Graham Wolf, New Zealand	08:00-18:00	2 PPU, 1 SAG, 47 SPO	+4.6
18	Mark Davis, SC	06:20-08:20	2 LYR, 11 SPO	+5.5
	Graham Wolf, New Zealand	08:00-14:00	1 PPU, 1 SAG, 25 SPO	+4.5
19	Doug Kniffen, MO	03:10-04:10	4 SPO	+5.7
	Michael Morrow, HI	11:45-12:45	6 SPO	+6.5
20	Pierre Martin, Ontario	06:15-07:26	3 SAG, 4 SPO	+6.0
	Phyllis Eide, HI	11:45-13:00	2 LYR, 5 SPO	+6.0
	Michael Morrow, HI	11:55-13:00	2 LYR, 7 SPO	+6.5
21	Richard Schmude, GA	02:57-04:28	1 LYR, 2 SPO	+5.0
	Richard Taibi, MD	06:37-07:57	1 LYR, 2 SPO	+5.3
	George Gliba, MD	07:18-09:18	6 LYR, 5 SPO	+5.1
	Robert Lunsford, CA	09:00-12:00	29 LYR, 31 SPO	+6.6
	Michael Morrow, HI	11:10-12:40	4 LYR, 10 SPO	+6.0
	Phyllis Eide, HI	11:10-12:40	1 LYR, 6 SPO	+6.0
22	Belinda Atkins, GA	01:10-01:40	*(none seen)*	+4.0
	Carrie Brooks, GA	01:10-01:40	*(none seen)*	n.a.
	Alex Cain, GA	01:10-01:40	2 LYR, 1 SPO	+4.0
	Brenda Evans, GA	01:10-01:40	2 SPO	+4.5
	Jayne Figueroa, GA	01:10-01:40	1 LYR	+4.0
	Kim Gray, GA	01:10-10:40	*(none seen)*	+4.0
	Scott Hanson, GA	01:10-01:40	*(none seen)*	+4.0
	Aaron Hayes, GA	01:10-01:40	*(none seen)*	+4.0
	Troy McDaniel, GA	01:10-01:40	*(none seen)*	+4.5
	Scott Mitchell, GA	01:10-01:40	1 LYR, 1 SPO	+4.0
	Erika Mitchem, GA	01:10-01:40	*(none seen)*	n.a.
	Gavin Porter, GA	01:10-10:40	*(none seen)*	+4.0
	Richard Schmude, GA	01:10-01:40	1 SPO	+4.5
	Kim Tucker, GA	01:10-01:40	*(none seen)*	+4.0
	Nancy Turner, GA	01:10-01:40	1 SPO	+4.5
	Bree Wright, GA	01:10-01:40	*(none seen)*	+4.5
	Lewis Gramer, MA	04:00-07:20	26 LYR, 16 SPO	+5.8
	Pierre Martin, Ontario	04:22-08:50	44 LYR, 2 SAG, 16 SPO	+5.8
	V. Giovannone, NY	04:50-05:50	3 LYR	+4.0
	Wayne Hally, NJ	05:03-06:03	5 LYR, 2 SPO	+5.5
	George Zay, CA	05:27-12:08	2 ETA, 46 LYR, 30 SPO	+6.0

Table 1 continued on pp. 39-40 with notes on p. 40.

Table 1—Continued.

1996 UT Date	Observer and Location	Universal Time	Number and Type* of Meteors Seen	Comments (+*N* = Limiting Magnitude)
APR 22	Wayne Hally, NJ	06:35-06:55	1 ABO, 3 LYR, 2 SPO	+5.5
(Cntd.)	V. Giovannone, NY	07:30-08:00	1 LYR, 1 SPO	+5.0
	Ron Rosenwald, TX	08:00-09:00	*(none seen)*	n.a.; 100% cloudy
	Robert Lunsford, CA	08:00-12:00	1 ETA, 54 LYR, 37 SPO	+6.5
	Peter Detterline, PA	10:00-12:00	12 LYR, 2 SPO	+5.4
	Graham Wolf, New Zealand	12:00-18:00	5 ETA, 1 SAG, 22 SPO	+4.5
23	George Zay, CA	06:53-12:04	19 LYR, 25 SPO	+6.0
	Ron Rosenwald, TX	08:00-09:00	*(none seen)*	n.a.; 100% cloudy
	Robert Lunsford, CA	08:30-12:15	23 LYR, 1 ETA, 33 SPO	+6.3
	Graham Wolf, New Zealand	15:00-18:00	6 ETA, 16 SPO	+4.7
24	George Zay, CA	07:07-12:01	1 ETA, 5 LYR, 1 SAG, 13 SPO	+6.0
	Ron Rosenwald, TX	08:00-09:00	*(none seen)*	n.a.; 100% cloudy
	Robert Lunsford, CA	08:00-12:00	1 ABO, 5 LYR, 2 SAG, 17 SPO	+6.6
	Michael Morrow, HI	13:15-14:30	12 SPO	+5.5
	Graham Wolf, New Zealand	15:00-18:00	6 ETA, 15 SPO	+4.5
25	Pierre Martin, Ontario	06:23-07:49	1 ETA, 8 SPO	+5.9
	Robert Lunsford, CA	08:00-12:00	6 LYR, 1 SAG, 21 SPO	+6.5
26	Graham Wolf, New Zealand	15:00-18:00	8 ETA, 15 SPO	+4.7
28	Richard Taibi, MD	07:36-08:36	1 SPO	+5.4
MAY 05	George Zay, CA	08:40-11:50	7 ETA, 6 SPO	+5.0
06	Mark Davis, SC	07:03-09:03	2 ETA, 5 SPO	+4.8
	George Zay, CA	08:44-11:46	5 ETA, 4 SPO	+5.0
07	Lewis Gramer, MA	04:45-06:30	1 ETA, 1 SAG, 9 SPO	+5.3
10	Mark Davis, SC	02:29-05:29	2 SAG, 15 SPO	+5.7
11	Mark Davis, SC	03:17-06:17	1 ABO, 1 IAA, 21 SPO	+5.7
14	Robert Lunsford, CA	07:30-11:30	7 ETA, 3 SAG, 16 SPO	+6.8
15	Robert Lunsford, CA	07:30-11:30	5 ETA, 4 SAG, 23 SPO	+6.6
16	Robert Lunsford, CA	08:45-11:45	2 ETA, 3 SAG, 21 SPO	+6.4
17	Mark Davis, SC	03:41-05:11	1 SAG, 6 SPO	+5.6
18	Mark Davis, SC	02:34-05:04	2 SAG, 14 SPO	+5.6
	Phyllis Eide, HI	06:30-07:30	4 SPO	+6.0
	Michael Morrow, HI	06:30-07:30	6 SPO	+6.0
19	Doug Kniffen, MO	07:36-08:48	14 SPO	+5.3
20	Lew Gramer, MA	04:40-06:20	2 SAG, 5 SPO	+5.4
	Robert Lunsford, CA	08:30-11:30	9 SAG, 15 SPO	+6.4
22	Robert Lunsford, CA	07:30-11:00	1 ETA, 2 SAG, 18 SPO	+6.7
24	Michael Morrow, HI	11:10-12:40	10 SPO	+6.0
25	Wayne Hally, NJ	04:36-06:57	1 SAG, 4 SPO	+5.2
	Lew Gramer, MA	05:08-06:25	1 SAG, 9 SPO	+5.5
26	Lew Gramer, MA	07:45-08:15	4 SPO	+5.4
	Michael Morrow, HI	11:40-13:10	9 SPO	+6.0
27	Robert Lunsford, CA	09:00-11:30	4 SAG, 21 SPO	+6.4
JUN 04	Tim Cooper, South Africa	16:45-18:15	1 OSC, 3 SPO	+5.7
05	Amy Andrews, GA	01:57-02:27	*(none seen)*	+5.0
	Alex Cain, GA	01:57-02:27	3 SPO	+5.0
	Fletcher Carey, GA	01:57-02:27	*(none seen)*	+5.0
	Brenda Evans, GA	01:57-02:27	*(none seen)*	+5.0
	Jayne Figueroa, GA	01:57-02:27	1 SPO	+5.0
	Scott Hanson, GA	01:57-02:27	1 SPO	+5.0
	Jermaine Harvey, GA	01:57-02:27	1 SPO	+5.0
	Rebecca Hendrix, GA	01:57-02:27	*(none seen)*	+5.0
	Ben Leeds, GA	01:57-02:27	1 SPO	+5.0
	Tamika McKenzie, GA	01:57-02:27	2 SPO	+5.0
	Scott Mitchell, GA	01:57-02:27	*(none seen)*	+5.0
	Gavin Porter, GA	01:57-02:27	2 SPO	+5.0
	Richard Schmude, GA	01:57-02:27	1 SPO	+5.0
	Kim Tucker, GA	01:57-02:27	1 SPO	+5.0

Table 1 continued on p. 40 with notes .

Table 1—Continued.

1996 UT Date	Observer and Location	Universal Time	Number and Type* of Meteors Seen	Comments (+*N* = Limiting Magnitude)
JUN 05	Nancy Turner, GA	01:57-02:27	1 SPO	+5.0
(Cntd.)	Tim Cooper, South Africa	18:50-19:35	1 LSA, 1 TOP, 2 SPO	+5.6
06	Tim Cooper, South Africa	18:55-20:40	1 TOP, 7 SPO	+6.1
07	Tim Cooper, South Africa	18:25-20:30	1 CSC, 1 GSA, 1 ISC, 2 TOP, 5 SPO	+6.1
08	Tim Cooper, South Africa	18:20-20:00	1 ASC, 1 OSC, 3 TOP, 4 SPO	+5.9
09	George Zay, CA	05:11-11:24	2 SAG, 22 SPO	+5.0
10	George Zay, CA	05:02-11:22	2 SAG, 26 SPO	+5.9
	Michael Morrow, HI	07:00-08:00	4 SPO	+6.5
11	Robert Lunsford, CA	07:30-11:30	1 JLY, 8 SAG, 31 SPO	+6.3
	Tim Cooper, South Africa	18:54-21:00	4 TOP, 2 SPO	+5.6
12	George Zay, CA	05:00-11:30	7 SAG, 41 SPO	+6.0
	Lew Gramer, MA	05:15-06:20	1 SAG, 5 SPO	+5.5
	Robert Lunsford, CA	07:30-11:30	2 JLY, 5 SAG, 44 SPO	+6.3
	Michael Morrow, HI	07:45-09:15	1 JLY, 8 SPO	+6.0
	Tim Cooper, South Africa	18:00-20:00	3 CSC, 1 LSA, 2 TOP, 5 SPO	+5.8
13	Robert Lunsford, CA	07:30-11:30	3 JLY, 6 SAG, 32 SPO	+6.5
	Tim Cooper, South Africa	18:30-20:45	2 CSC, 1 LSA, 3 SPO	+6.0
14	Robert Lunsford, CA	07:30-11:30	1 JLY, 29 SPO	+6.6
	Tim Cooper, South Africa	18:30-19:30	2 TOP, 5 SPO	+5.7
	Tim Cooper, South Africa	19:45-21:45	2 CSC, 4 LSA, 2 TOP, 8 SPO	+5.8
15	Lew Gramer, MA	05:45-07:50	16 SPO	+6.6
	J. Kenneth Eakins, CA	09:15-10:15	2 JLY	+5.3
	Tim Cooper, South Africa	19:00-20:05	1 ASC, 1 ISC, 4 SPO	+5.8
16	Pierre Martin, Ontario	03:24-07:36	4 JLY, 7 SAG, 18 SPO	+5.9
	Wayne Hally, NJ	04:21-05:30	1 SAG, 3 SPO	+5.0
	George Zay, CA	04:55-11:27	4 SAG, 33 SPO	+6.0
	Peter Detterline, PA	05:00-06:00	1 JLY, 4 SAG, 2 SPO	+5.2
	Lew Gramer, MA	05:40-07:43	1 JLY, 3 SAG, 19 SPO	+6.7
	George Gliba, MD	05:45-07:53	3 JLY, 3 SAG, 11 SPO	+6.2
	J. Kenneth Eakins, CA	08:05-10:05	3 JLY, 4 SPO	+5.3
	Tim Cooper, South Africa	18:15-21:15	1 CSC, 3 GSA, 1 ISC, 5 LSA, 1 TOP, 13 SPO	+6.0
17	Mark Davis, SC	04:17-07:53	3 SAG, 26 SPO	+5.7
	Robert Lunsford, CA	08:30-11:30	2 SAG, 28 SPO	+6.7
	Tim Cooper, South Africa	18:57-21:00	2 GSA, 2 ISC, 3 LSA, 3 TOP, 9 SPO	+6.0
18	Mark Davis, SC	03:40-05:22	1 SAG, 13 SPO	+5.8
	J. Kenneth Eakins, CA	08:25-09:25	2 JLY, 2 SPO	+5.4
22	George Zay, CA	05:10-11:26	7 SAG, 26 SPO	+6.0
23	Mark Davis, SC	01:15-02:33	8 SPO	+5.7
26	Pierre Martin, Ontario	05:57-07:41	1 SAG, 2 TCE, 10 SPO	+5.8

***Meteor Shower Abbreviations**

ABO	Alpha Bootids	ETA	Eta Aquarids	PPU	Pi Puppids
ACE	Alpha Centaurids	GNO	Gamma Normids	QUA	Quadrantids
ACN	Alpha Carinids	GSA	Gamma Sagittarids	SAG	Sagittarids
ACR	Alpha Crucids	IAA	Iras-Araki-Alcockids	SPO	Sporadics
ASC	ALpha Scorpids	ISC	Iota Scorpids	TCE	Theta Centaurids
COM	Coma Berenicids	JLY	June Lyrids	TOP	Theta Ophiuchids
CSC	Chi Scorpids	LSA	Lambda Sagittarids	VIR	Virginids
DCA	Delta Cancrids	LYR	Lyrids		
DLE	Delta Leonids	OSC	Omega Scorpids		

THE LATEST MAPS OF MARS

By: Daniel M. Troiani, A.L.P.O. Mars Coordinator

The three maps below show Mars during the 1996-97 Apparition. Mars' South Pole is at the top, with the white clouds seen over the South Polar region during most of the observing season. The North Pole is at the bottom, with the small bright white North Polar Cap (NPC) as seen close to opposition date displaying the NPC outliers. The left and right edges are the 0° Meridian; the map is on a cylindrical equidistant projection. The albedo map (*Figure 1*) was produced by Dan Troiani using the computer program "PhotoStyler," and was produced using all the data (CCDs, drawings, and photographs) from the A.L.P.O. Mars Section during the 1996-97 Apparition. This map took over 30 hours of computer time to produce, plus many hours of preparation work.

Most of the white areas in *Figure 2* were clouds, with the "Syrtis Blue Cloud" over Syrtis Major. Fog occurred in the Hellas region, while Chryse had a mixture of white clouds with a little dust. Finally, orographic clouds were observed over the great volcanoes in the Tharsis region.

In *Figure 3,* the extent of the dust storms that were observed is show by dotted lines. [These were drawn by the Editor; in the original map they were shown in yellow.]

Figure 1. Martian Albedo Map, 1996-97 Apparition.

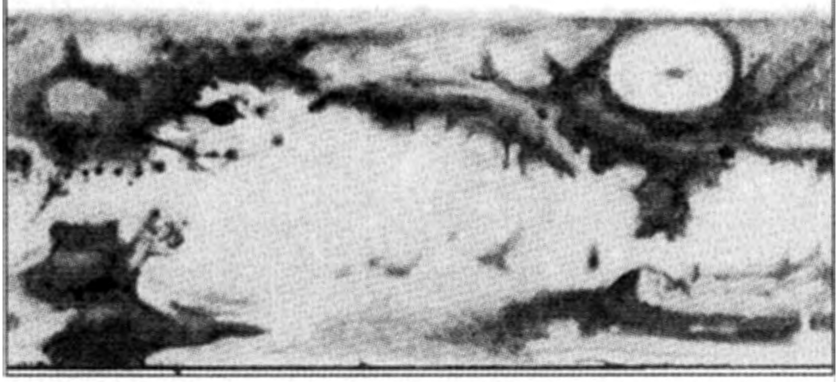


Figure 2. Martian Cloud Map, 1996-97 Apparition.

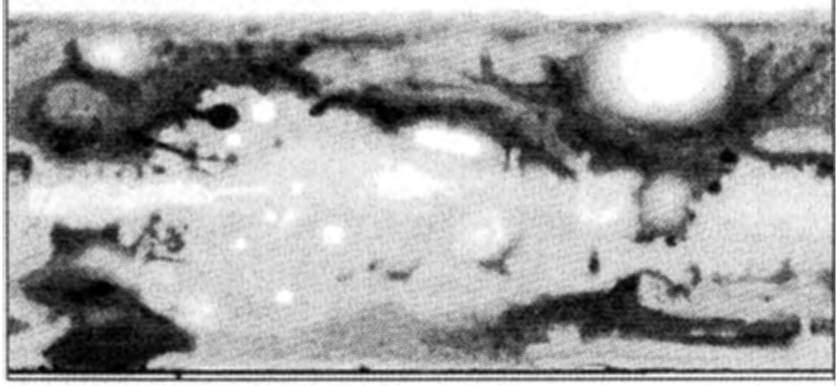
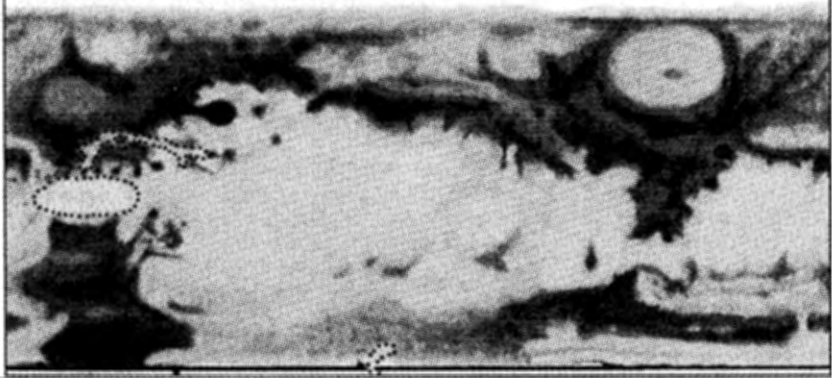


Figure 3. Martian Dust Storm Map, 1996-97 Apparition.



ON THE SEAS OF THE MOON

By: Bill Dembowski, Coordinator of General Lunar Programs

ABSTRACT

This report presents a brief overview of the various types of features which can be found on the lunar maria, some of the methods which can be utilized to observe them, and the A.L.P.O. programs that can benefit from those observations.

The dark areas on the visible surface of the Moon, considered by the ancients to be seas, have long since proven to be vast lava plains. Because they originated more recently than the highlands that constitute the remainder of the Moon, these lava flows contain relatively few large craters. Many craters that are prominent on the maria would go relatively unnoticed if located in the jumble of the highlands. The sharp contrast of small bright craters on dark maria surfaces makes them ideal markers for the study of lunar eclipses. Since no two lunar eclipses are the same, using these craters to time the passage of the Earth's shadow across the Moon's surface can provide valuable data about the Earth-Moon relationship. This isolation of features also makes the maria favorite hunting grounds for amateur observers who pursue the time-honored practice of sketching lunar formations.

The sketching of lunar features has more value than just the esthetics of the finished drawing. It has been proven many times that sketching an object forces us to observe it more closely and, therefore, to see features that might otherwise go undetected. By making gray-scale drawings of craters we also gain experience and skill in estimating the relative brightness of the observed details. David Lehman's sketch of Gassendi (*Figure 1*, below), on the shores of Mare Humorum, exhibits the entire range of tones from black shadow (0) to brilliant white (10). Once acquired, this skill in recording light intensities forms the basis of the Selected Areas Program, which records and plots changes in the albedo of various features over time, particularly under high-sun conditions.

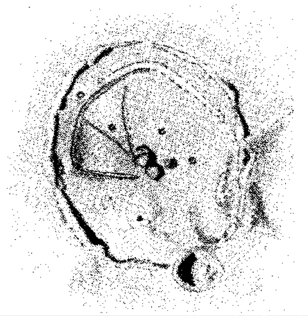


Figure 1. Drawing of lunar crater Gassendi by David Lehman. 1994 Nov 15. 25-cm (10-in) reflector, 207X. Lunar south at top.

Sketching also allows one to become intimately familiar with the topography of the Moon, especially if the same feature is sketched repeatedly under various lighting conditions. A knowledge of the appearance of a feature under normal circumstances is vital to the study of Lunar Transient Phenomena (LTP). These are short-lived lights, glows, flashes, mists, and obscurations occasionally reported on the Moon. One can hardly know if something out of the ordinary is occurring without a baseline knowledge of what is ordinary. Although found in virtually all regions of the Moon, LTP appear to occur most often on, or around, the maria. The area within Oceanus Procellarum around Aristarchus, Herodotus, and Vallis Schröteri is perhaps the most active on the entire Moon. Other LTP areas include Gassendi on Mare Humorum and the entire southern half of Mare Imbrium. Perhaps there is a relationship between the LTP and the relative youth of some features found in these regions. The work of the LTP Program will go a long way in proving or disproving such a relationship.

In addition to isolated craters, the maria contain low-profile features not often found in other regions of the Moon. Wrinkle ridges are exclusively a marial feature. These gently sloping ridges present a rope-like appearance in the eyepiece and seldom achieve a height of more than 200 meters above the surrounding terrain. The most likely origin of these ridges lies in compression caused by the periodic subsidence of the marial lavas. The most famous of the wrinkle ridges is the Serpentine Ridge (now called Dorsa Smirnov) on the Mare Serenitatis but wrinkle ridges appear on all of the major seas.

Another class of low-relief feature is domes. Although sometimes found within the walls of large highland craters, domes are most frequently associated with the maria. These blister-like formations tend to form in clusters such as those in the central region of Mare Tranquillitatis and the vicinities of Marius, Tobias Mayer, Milichius, and Hortensius in Oceanus Procellarum. The sketch by Robert Hays, Jr., (*Figure 2*, p. 43) shows the dome complex of Mons Rümker in Oceanus Procellarum. The exact nature of domes is not entirely understood but is almost certainly volcanic in nature. Domes show poorly on the medium-sun angle photographs by the Lunar Orbiters because they require a low Sun to be visible. Therefore, the ongoing Lunar Dome Survey continues to detect, classify, and map the locations of these unique features with ground-based telescopes.

Manually sketching surface features is the most common form of recording lunar observations, but film and electronic imaging are both becoming increasingly popular. One of the advantages of imaging the Moon is the ability to record positional data with great accuracy. Whether it is the position of a lunar dome or the shadow of a mountain peak, the accuracy of imaging is difficult to duplicate with a sketch. The photograph of the western shore of Mare Nectaris (*Figure 3*, lower right) is still usable for determining the heights of the features recorded, despite being taken under less-than-ideal seeing conditions. Vertical studies can also be pursued using a micrometer, recticle eyepiece, or by simply timing the passage of the shadow across the crosshair of an eyepiece. When the shadow measurement and other basic information are fed through the software of the *Lunar Observer's Tool Kit*, available from Lunar Coordinator Harry D. Jamieson, accurate heights can be found for the feature observed. The resulting value is the height of the feature relative to the ground. Therefore, if a mountain peak is measured under different lighting angles, we are not just determining the height of the peak, but also plotting the profile of the surrounding terrain. Beyond mensuration and positional studies, imaging of LTP events is extremely valuable.

The maria cover approximately 31 percent of the visible surface of the Moon and are distributed in such a manner than there is always a marial region on the terminator. This makes them ideal for work on the A.L.P.O. Lunar Dome Survey. Of course one can also perform useful work under a high Sun, with the A.L.P.O. Eclipse, LTP, and Selected Areas Programs being prime examples. Regardless of the areas studied or the methods employed, you are encouraged to participate in one or more of the aforementioned programs and contribute to the ongoing effort to do science with the Moon. Further, observations that are not a part of one of our regular structured programs are also welcome, which include vertical studies [see the article by William Davis, "Accuracy of the Shadow Method of Lunar Height Determination" on pp.32-36 of this issue] and high-sun observations of ray systems and of bright and banded craters. The enjoyment and training that these can provide an observer make them worthwhile in themselves, and there is always a chance that they may prove to be of serendipitous value to science.

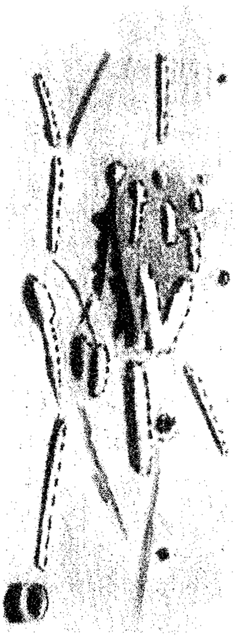


Figure 2. Drawing of the Mons Rümker dome complex in Oceanus Procellarum by Robert Hays, Jr. 1997 FEB 20, 15-cm (6.0-in) reflector, 170X. Lunar south at upper left.

[Notes by Editor. The "official" programs of the A.L.P.O. Lunar Section are given in the staff listing on pp. 46-47 of this issue, together with the Coordinators responsible for these programs and their postal and e-mail addresses.

Note also that observers, whether they sketch or image the Moon, should always record supporting data such as are given in the illustration captions in this article, *together with* the Universal Times of the beginning and end of the observation to 1-minute precision as well as the Seeing and Transparency in the standard A.L.P.O. Scales. It is also useful to include the solar colongitude and latitude and the librations, which may be computed with the *Lunar Observer's Tool Kit*, referred to in the article above.]

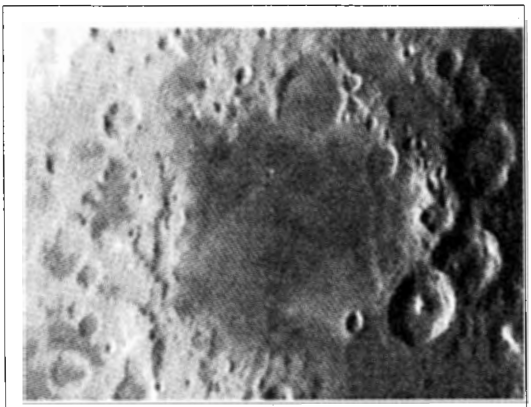
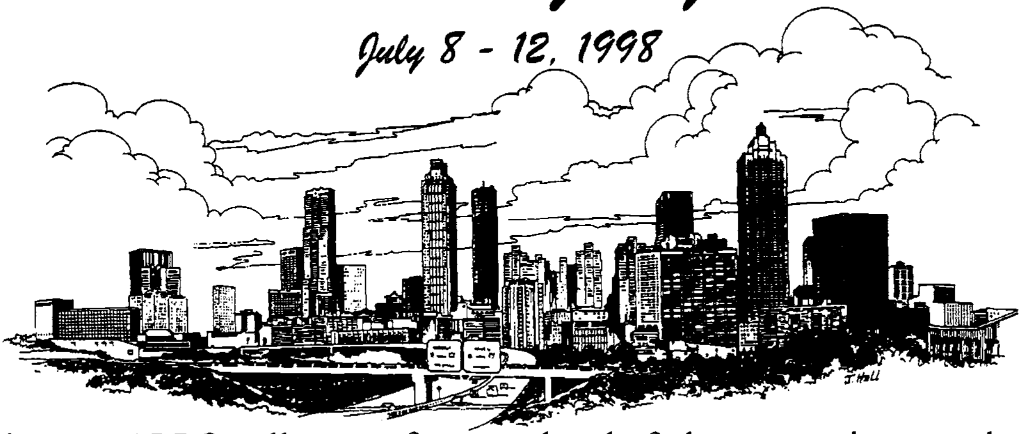


Figure 3. Photograph of Mare Nectaris by Bill Dembowski. 1997 JUL 10. 12.7-cm (5.0-in) refractor, f/76, 1 sec on Kodak TP2415 Film. Lunar south at top.

Atlanta, Georgia

July 8 - 12, 1998



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THE A.L.P.O. PAGES

THE ASSOCIATION OF LUNAR AND PLANETARY OBSERVERS

Founded by Walter Haas in 1947, the A.L.P.O. now has about 600 members. Our dues include a subscription to the quarterly Journal, *The Strolling Astronomer*, and are $23.00 for one year ($40.00 for two years) for the United States, Canada, and Mexico; and $30.00 for one year ($54.00 for two years) for other countries. One-year Sustaining Memberships are $50.00; Sponsorships are $100.00. There is a 20-percent surcharge on all memberships obtained through subscription agencies or which require an invoice.

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A.L.P.O. ANNOUNCEMENTS

Changes in Jupiter Section Staff.—Two new Acting Assistant Coordinators have been appointed to our Jupiter Section. The first is **David J. Lehman**, who will be in charge of the Section's Internet communications, including the development of a Section newsletter. David's address is: 6734 N. Farris, Fresno, CA 93711, Internet: DLehman111@aol.com . The second new person will help to analyze central-meridian transit timings and is: **John McAnally**, 2124 Wooded Acres, Waco, TX 76710; Internet: CPAJohnM@aol.com . Note that observers should continue to send reports of central-meridian transit times to Coordinator Phil Budine. Finally, Acting Assistant Coordinator Carl W. Keller has resigned due to time pressures.

Solar Section Changes<—As part of a reorganization of the Solar Section, **Rik Hill** (address in staff listing on p. 46) is now **Acting Solar Coordinator**, following the resignation for personal reasons of **Tony Portoni**. Two new Assistant Recorders have been added to the Section (their addresses are in our staff listing on p. 46): **Jeff Medkeff,** who will aid Mr. Hill in preparing reports, material for the web page, and the SolNet e-mail information service; **Gordon W. Garcia** will be responsible for cooespondence and new observers.

Staff in Motion.—**Ken Poshedly**, the A.L.P.O. Publicist, has a new e-mail address: ken.poshedly@mindspring.com . Note that his nine-digit postal ZIP code is 30078-2784. Two members of the **Jupiter Section** have new postal addressese: (1) **Sanjay Limaye**, *Assistant Coordinator; Scientific Advisor;* University of Wisconsin, Space Science and Engineering Center, Atmospheric Oceanic and Space Science Bld. 1017, 1225 W. Dayton St., Madison, WI 53706. (2) **Wynn Wacker**, *Coordinator;* 2109 McKenna Blvd., Madison, WI 53711.

Expansion of Publications Section.—As announced in the previous issue, the A.L.P.O. now has a Publications Section, initially with John Westfall as Editor and Julius L. Benton., Jr. as Acting Asssitant Editor. **Julius Benton**'s title has now been changed to **Acting Distributing Editor**; *effective immediately all manuscripts submitted for publication in J.A.L.P.O. should be sent to him* (his address is given in our staff listing on p. 46). In addition, the Section will now be aided by. **Klaus R. Brasch**, whose address is also now given in our staff listing. Dr. Brasch has already been of help in editing manuscripts. In addition, we wish also to thnak two A.L.P.O. staff who, although not formally members of the Publications Section, have recently contributed their time to helping with our editing: Harry D. Jamieson and Ken Poshedly.

Termination of International Solar System Observers' Fund.—This A.L.P.O. program has been intended to solicit gifts of observational instruments, accessories, and related supplies to be donated to active solar-system observers who reside in countries where foreign exchange is hard to come by. Begun in 1991, this program has been coordnated throughout its existence by Paul H. Bock, Jr. Mr. Bock has recently written to us, resigning from his post due to time constraints on his part and a general lack of membership interest in the program. We are following his recommendation that the program be terminated, but wish to thank Mr. Bock for his years of service in this post, which did suceeed in furnishing several deserving amateurs with needed equipment.

Retirement of Instruments Section.—During the several months that the position of Coordinator of the Instruments Section has remained vacant nobody has come forward to volunteer for this function. Thus we are forced to close the Instruments Section until, we hope, increased interest warrants reopening it.

EXTRA-A.L.P.O. ANNOUNCEMENTS

Peach State Star Gaze.—The fifth annual Peach State Star Gaze, sponsored by the Atlanta Astronomy Club, will be held on March 26-29, 1998, and will feature presentations by the A.L.P.O.'s Mike Mattei and Richard Schmude and by A.A.V.S.O. Director Janet Mattei, along with workshops. Onsite lodging is included. The location will be Camp McIntosh, at Indian Springs State Park, Jackson, Georgia. For information, contact: Ken Poshedly, 1741 Bruckner Court, Snellville, GA 30078-2784; Telephone (770) 979-9841; E-Mail ken.poshedly@mindspring.com

ALCON'98.— The Astronomical League's next Convention is to be held at the French Lick Springs Resort in southern Indiana, July 21-26, 1998. The planned rogram includes amateur and professional speakers, workshops, the Star-B-Que, Awards Banquet, and much more. Individual registration is $50, family $90, prior to March 15. More information can be had via e-mail at alcon98@gsl.revnet.com or on their webpage, http://ourworld.compuserve.com/homepages/sconner . To make reservations at the French Lick Springs Resort, call 1-800-457-4042; mention ALCON'98 to get the $79 nightly room rate (up to two adults per room).

UNIVERSE'98.—Once again, the Astronomical Society of the Pacific and *Astronomy* magazine are sponsoring an astronomical exposition. UNIVERSE'98 will be held as part of the 110th Annual Meeting of the ASP, and will be at the Hyatt Regency in Albuquerque, New Mexico, June 27-28.. The expo charge is $20 for both days, $12 for one day, with children under 12 free. For information, please contact: Annual Meeting (General Info.), Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112 (Telephone: 415-337-1100, X-109. Fax: 415-337-5205. Internet: lkeechler@aspsky.org . Webpage: www.aspsky.org .)

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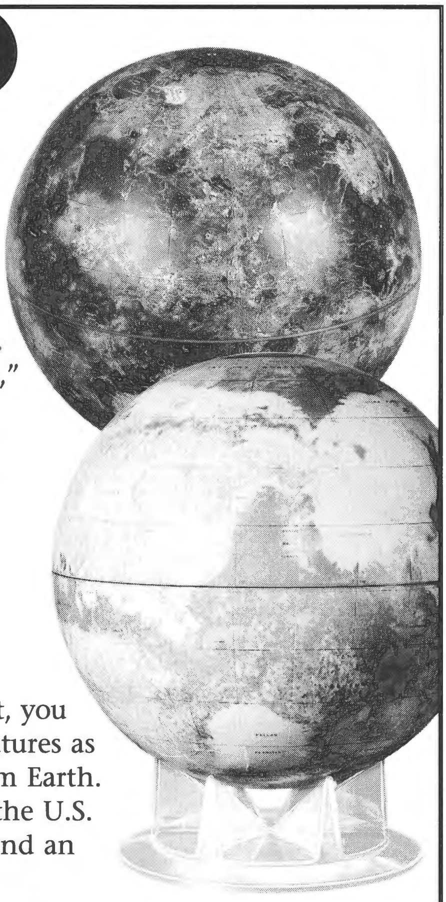

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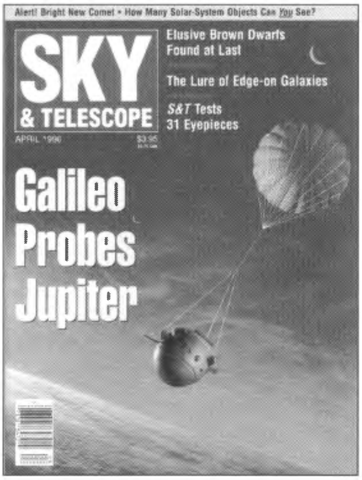

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