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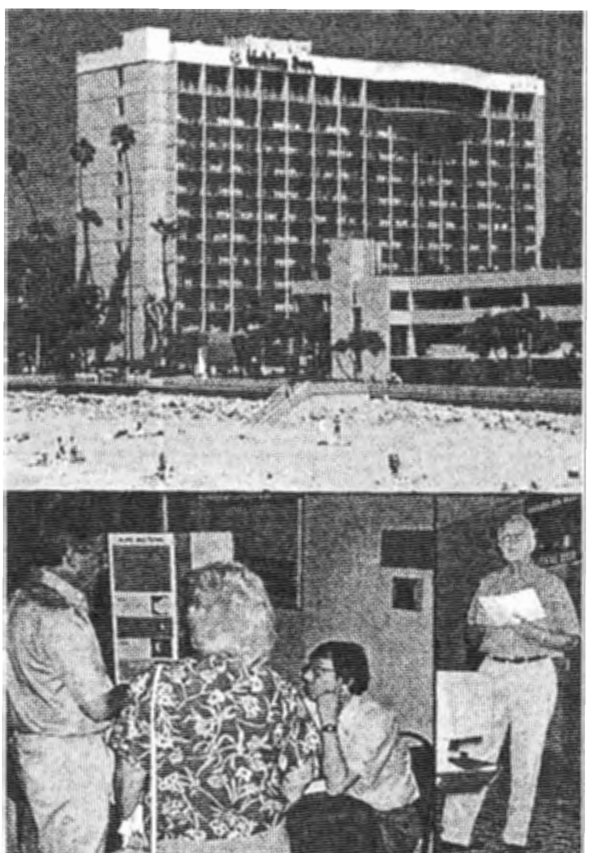

Three scenes from the A.L.P.O.-ASTROCON 2000 Convention in Ventura, California, July 19-22, 2000, reported on in pages 89-91 of this issue. On the left is the convention site, the Holiday Inn Ventura Beach Resort. In the lower left is the A.L.P.O. information desk, staffed by Matthew Will (seated). Professional historian Thomas R. Williams is in the lower right, reporting on "A History of the A.L.P.O. Lunar Meteor Project."

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In This Issue

A.L.P.O. OBSERVATIONS OF VENUS DURING THE 1996-97 WESTERN (MORNING) APPARITION

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ABSTRACT

This report is a synopsis of visual and photographic observations contributed to the A.L.P.O. Venus Section by observers in the United States, Canada, and Germany during the 1996-97 Western (Morning) Apparition, including instrumentation and data resources utilized in making those observations. Comparative studies deal with observers, instruments, and visual and photographic data. The report includes illustrations and a statistical analysis of the categories of features in the atmosphere of Venus, including cusps, cusp-caps, and cusp-bands, seen or suspected at visual wavelengths, both in integrated light and with color filters, as well as in a few ultraviolet photographs. Terminator irregularities and the apparent phase are discussed, as well as coverage based on results from continued monitoring of the dark hemisphere of Venus for the Ashen Light.

INTRODUCTION

A total of 120 drawings and photographs of Venus were received by the A.L.P.O. Venus Section during the 1996-97 Western (Morning) Apparition. Geocentric phenomena in Universal Time (UT) for the 1996-97 Apparition are presented in *Table 1* (to right), while *Figure 1* (below) illustrates the distribution of observations by month during the observing season.

Observational monitoring of Venus was reasonably good throughout the 1996-97 Apparition. In what continues to be a

Table 1. Geocentric Phenomena in Universal Time (UT) for the 1996-97 Western (Morning) Apparition of Venus.

		1996	
Inferior Conjunction		Jun 10^d	16^h
Initial Observation		Jun 15	11
Greatest Brilliancy (m_v = -4.7)		Jul 17	09
Greatest Elong. West (45°.8)		Aug 20	02
Dichotomy (predicted)		Aug 22	19
		1997	
Final Observation		Mar 11	11
Superior Conjunction		Apr 02	14
Observed Range			
Apparent Diameter, d:	57".12 - 9".76	(1996 Jun 15) (1997 Mar 11)	
Phase Coefficient, k:	0.007 - 0.995	(1996 Jun 15) (1997 Mar 11)	

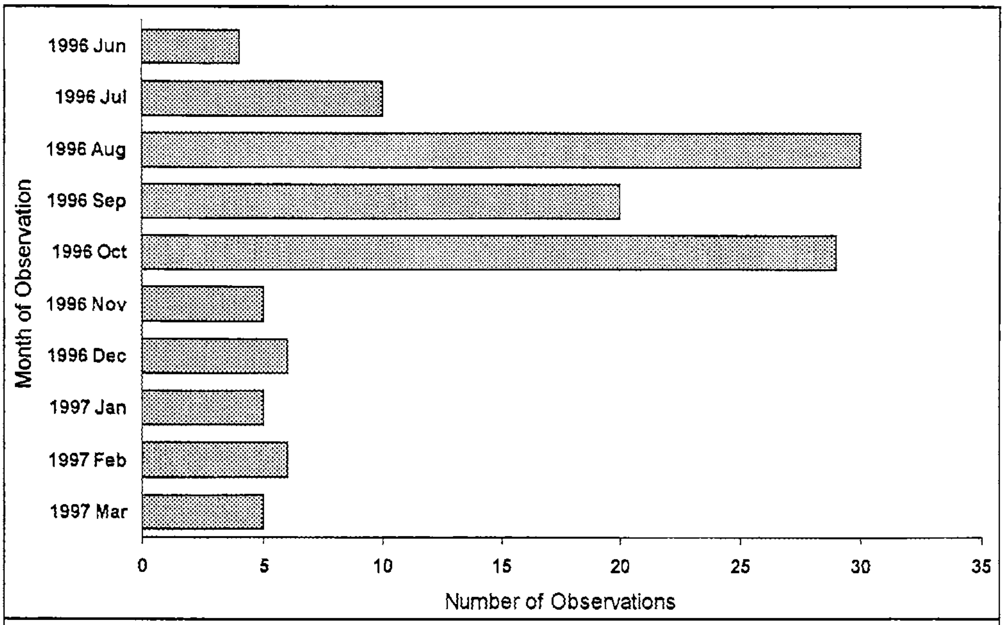

Figure 1. Distribution of observations by month during the 1996-97 Western (Morning) Apparition of Venus.

Table 2. Participants in the A.L.P.O. Venus Observing Program During the 1996-97 Western (Morning) Apparition

Observer and Observing Site	No. Obs.	Telescope(s) Used
Benton, Julius L. ; Wilmington Island, GA	26	15.2-cm (6.0-in) Refractor
Cole-Arnal, Oscar; Belwood, Ontario, Canada	6	15.2-cm (6.0-in) Refractor
Hargreaves, Gary S.; Mission, British Columbia, Canada	1	7.6-cm (3.0-in) Refractor
	1	12.8-cm (5.0-in) Refractor
	9	15.2-cm (6.0-in) Newtonian
Melillo, Frank J.; Holtsville, NY	7	20.3-cm (8.0-in) Schmidt-Cass.
Niechoy, Detlev; Göttingen, Germany	65	20.3-cm (8.0-in) Schmidt-Cass.
Schmude, Richard W. ; Barnesville, GA	1	9.0-cm (3.5-in) Maksutov
	1	25.4-cm (10.0-in) Newtonian
	1	50.8-cm (20.0-in) Newtonian
	1	61.0-cm (24.0-in) Newtonian
Viens, Jean-Francois; Charlesbourg, Quebec, Canada	1	11.5-cm (4.5-in Newtonian
Total Number of Observers	7	
Total Number of Observations	120	

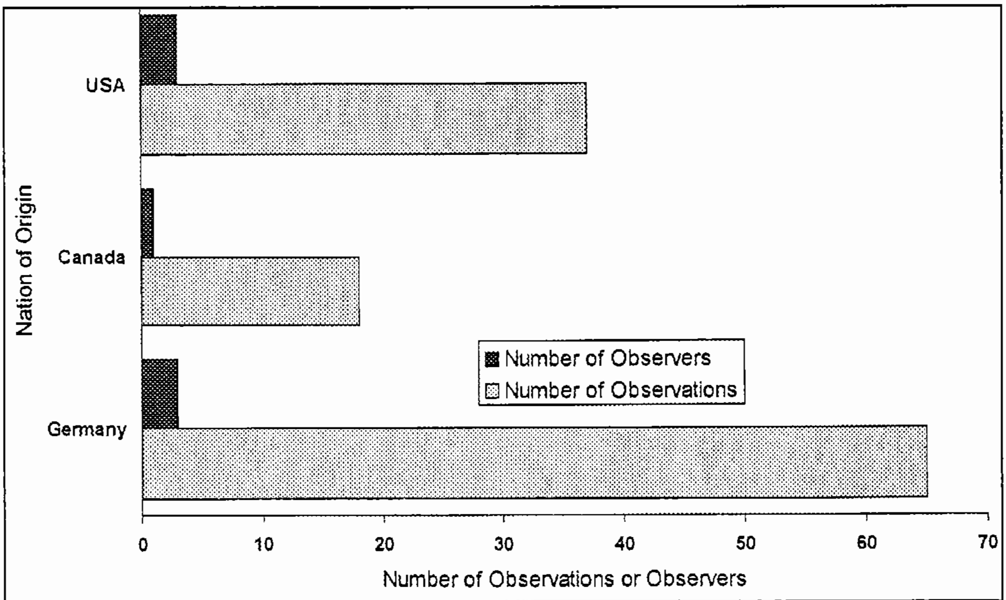

Figure 2. Distribution of observations and observers by nation of origin during the 1996-97 Western (Morning) Apparition of Venus.

welcome trend, individuals began their observing programs soon after Venus emerged from Inferior Conjunction on 1996 JUN 10. They continued to follow the planet up to about three weeks before Superior Conjunction on 1997 APR 0 2. The "observing season," or observation period, ranged from 1996 JUN 15 to 1997 MAR 11, with nearly two-thirds of the observations (65.8%) submitted for the period from 1996 August - October. Peak observational activity in 1996-97 followed soon after the time Venus reached greatest brilliancy and maximum elongation from the Sun.

Seven individuals contributed visual and photographic observations of Venus during the 1996-97 Apparition, and *Table 2* (at top) gives their observing sites, number of observations, and instruments used.

Figure 2 (above) shows the distribution of observers and contributed observations by nation of origin for the 1996-97 Apparition. About two-fifths of those taking part in A.L.P.O. Venus programs (42.9%) resided in the United States and accounted for nearly one-third (30.8%) of the total observations received. Thus, during 1996-97, as in recent previous apparitions, international participation in our programs continued, supporting our efforts to foster increased cooperation among lunar and planetary observers worldwide.

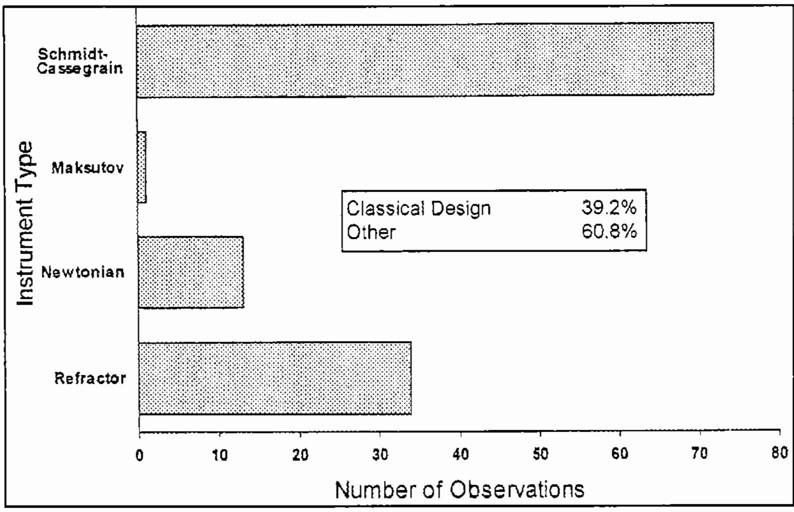

Figure 3. Types of telescopes used during the 1996-97 Western (Morning) Apparition of Venus. "Classical Design" consists of refractors and Newtonian reflectors.

The types of telescopes employed to perform observations of Venus in 1996-97 are shown in the graph in *Figure 3* (above). Also, the vast majority (96.7%) of the observations were made with telescopes of 15.2-cm (6.0-in) aperture or greater. Classical designs (e.g., refractors and Newtonians) were used in about two-fifths (39.2%) of the observations, while most of the remaining (60.8%) Venus observations were generated using Schmidt-Cassegrains (one observation was made using a Maksutov). During 1996-97, most observations (97.9%) occurred under light sky conditions—quite a few even in broad daylight—as more individuals tried to locate and follow Venus after sunrise to avoid the overwhelming glare normally associated with the planet. Also, viewing Venus higher in the sky helped minimize the effects of atmospheric dispersion and image distortion near the horizon, at least until solar heating by late morning deteriorated images.

The A.L.P.O. Venus Section Coordinator is most grateful to the seven individuals mentioned in this report who persevered during early morning hours to submit observations during 1996-97. Readers interested in learning more about the planet Venus are urged to become regular contributors to our observational pursuits in forthcoming apparitions.

Observations of Venusian Atmospheric Details

Procedures and techniques for conducting visual studies of the vague and elusive "markings" in the atmosphere of Venus are thoroughly outlined in *The Venus Handbook*. Readers who have access to earlier issues of this Journal may find it of benefit to consult to previous apparition reports for a historical perspective on A.L.P.O. Venus studies.

The great majority of observations utilized in this analysis were made at visual wavelengths, and several examples of these observations in the form of drawings and photographs appear in this report to assist the reader in interpreting the phenomena reported in the atmosphere of Venus in 1995-96 (*Figures 6-16*, pp. 56-57). One observer, Frank Melillo, continued his very welcome and ambitious photography of Venus at ultraviolet (UV) wavelengths, and some of his photographs are included in this report (*Figures 9*, *11*, and *14*, pp. 56-57).

The visual and photographic data for the 1996-97 Apparition represented all of the traditional categories of dusky and bright markings in Venus' atmosphere, as described in the literature referenced previously in the report. *Figure 4* (p. 52) illustrates the frequency in which the specific forms of markings were seen or suspected. Most observations called attention to more than just one category of marking or feature, and consequently totals exceeding 100 percent are possible. Readers should recognize that there is an inherent subjectivity that exists when visual observers made attempts to describe the highly elusive atmospheric markings of Venus, undoubtedly affecting the data in Figure 4. Nevertheless, it is believed that conclusions deduced from these data appear reasonable.

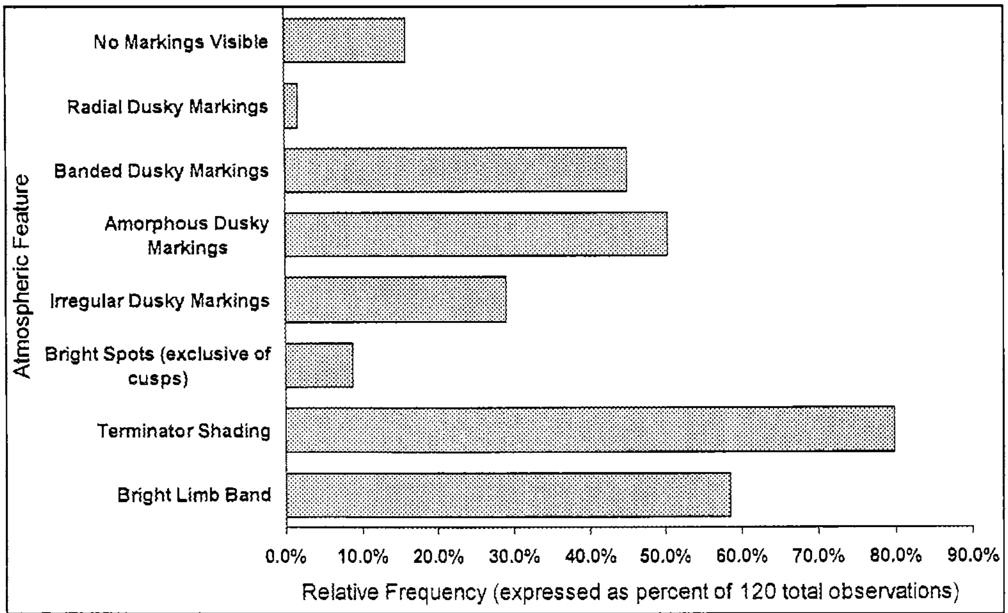

Figure 4. Relative frequency of specific forms of atmospheric markings on Venus during the 1996-97 Western (Morning) Apparition.

The dusky markings in the atmosphere of Venus are notoriously hard to detect visually, which is a characteristic of the planet that is mostly independent of the experience of the observer. Using color filters and variable-density polarizers helps reveal subtle cloud phenomena on Venus at visual wavelengths, but the A.L.P.O. Venus Section strongly encourages observers to attempt regular UV photography. The morphology of features revealed at UV wavelengths is usually quite different from what is seen in visual regions of the spectrum, particularly radial dusky patterns.

Figure 4 shows that a small percentage (15.9%) of the observations of Venus in 1996-97 referred to a brilliant disk completely devoid of markings, in contrast with what was reported during several previous apparitions of the planet. When dusky features were seen or suspected, most fell in the categories of "Banded Dusky Markings" (45.1%), "Amorphous Dusky Markings" (50.4%), and "Irregular Dusky Markings" (29.2%). Only a very few sightings of "Radial Dusky Markings" (1.8%) were reported during the 1996-97 Western (Morning) Apparition. In a few of Melillo's photographs taken at ultraviolet wavelengths vague dusky atmospheric features appear to be present.

Terminator shading was apparent during much of the 1996-97 observing season, reported in 79.8 percent of the observations, as shown in Figure 4. The terminator shading usually extended from one cusp region to the other, and the shading seemed to lighten (i.e., take on a higher intensity) as one progressed from the region of the terminator toward the bright limb of the planet. This gradual variance in brightness ended in the Bright Limb Band in most accounts. No photographs in 1996-97 clearly showed any hint of terminator shading.

The mean relative intensity for all of the dusky features on Venus in 1996-97 ranged from 7.9 to 8.5, using the A.L.P.O. Relative Intensity Scale that runs from 0.0 for black to 10.0 for the brightest possible feature. In addition, the A.L.P.O. Scale of Conspicuousness (which runs sequentially from 0.0 for "definitely not seen" up to 10.0 for "certainly seen") was used regularly during 1996-97. On this scale, the dusky markings in Figure 4 had a mean conspicuousness of approximately 3.5 during the apparition, which suggests that these features fell within the range from very indistinct impressions and fairly good indications of their actual presence on Venus.

Figure 4 also shows that "Bright Spots or Regions," exclusive of the cusp areas, were seen or suspected in only 8.9 percent of the total submitted observations, and these areas had a derived mean relative intensity of 9.0 to 9.5. In drawings made at visual wavelengths, observers called attention to such bright areas by sketching in dotted lines around such features. Although these features were completely absent on photographs in integrated light, one or two of Melillo's near-ultraviolet photographs appeared barely to capture them.

Observers regularly used color-filter techniques during the 1996-97 Apparition, and when results were compared with studies in integrated light, it was clear that color filters and variable-density polarizers enhanced the visibility of elusive Venusian atmospheric phenomena.

THE BRIGHT LIMB BAND

Figure 4 reveals that in 58.5 percent of the submitted observations in 1996-97 reference was made to a "Bright Limb Band" on Venus' illuminated hemisphere. When the Bright Limb Band was reported, it appeared as a continuous, brilliant arc extending from cusp to cusp 85.4 percent of the time, and interrupted or only partially visible along the limb of Venus in 14.6 percent of the positive reports. The mean numerical intensity of the Bright Limb Band was 9.9, becoming more obvious when color filters or variable-density polarizers were employed. Despite the dazzling brilliance of this feature to visual observers, it was not apparent in any photographs of Venus submitted in 1996-97.

TERMINATOR IRREGULARITIES

The terminator is the geometric curve that divides the sunlit and dark hemispheres of Venus. Observers described an irregular or asymmetric terminator in slightly more than one-third (37.2%) of the observations in 1996-97. Amorphous, banded, and irregular dusky atmospheric markings appeared to blend with the shading along the terminator, possibly contributing to reported deformities. Filters enhanced the visibility of terminator irregularities and dusky atmospheric features closely associated with it during the 1996-97 Apparition. Because of irradiation, bright features adjacent to the terminator may occasionally look like bulges, and dark features may look like dusky hollows.

CUSPS, CUSP-CAPS, AND CUSP-BANDS

For the most part, when the phase coefficient, k, lies between 0.1 and 0.8 (the phase coefficient is the fraction of the disk that is illuminated), the features on Venus having the most contrast and prominence are repeatedly sighted at or near the planet's cusps. These features, called "cusp-caps," are sometimes bordered by what are described as dark, usually diffuse, cusp-bands. *Figure 5* (below) shows the visibil-

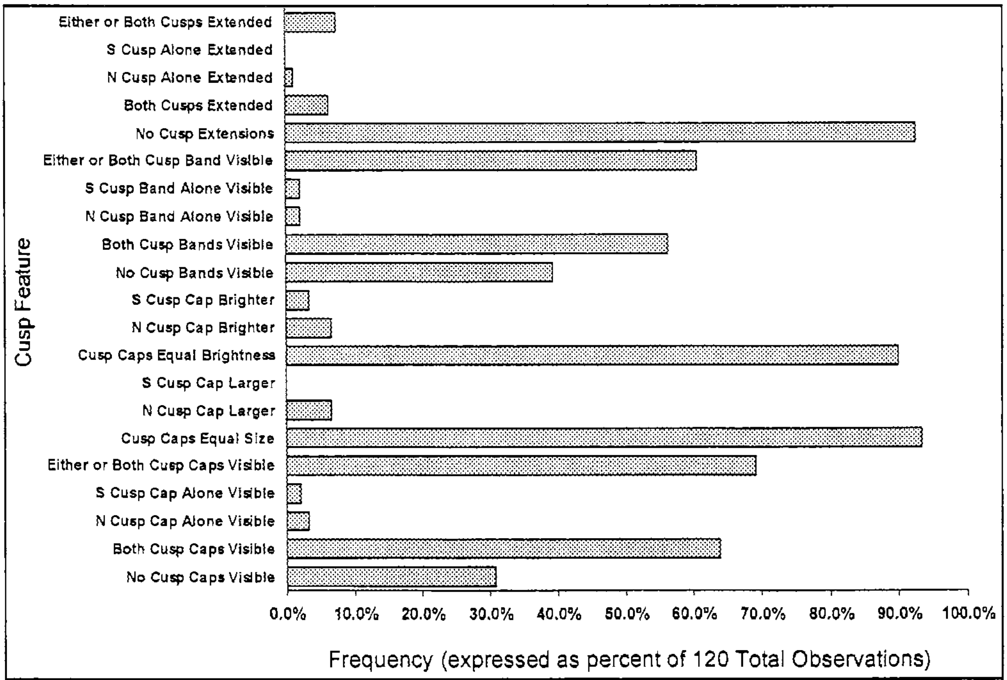

Figure 5. Visibility statistics of cusp features of Venus during the 1996-97 Western (Morning) Apparition.

ity statistics for Venusian cusp features in 1996-97.

As Figure 5 shows, when the northern and southern cusp-caps of Venus were observed in 1996-97, these features were equal in size and brightness most of the time. There were a very few instances when either the northern or southern cusp-cap was the larger, the brighter, or both, and in a little less than one-third of the observations submitted (30.8%), neither cusp-cap was visible. The mean relative intensity of the cusp-caps was about 9.9 during the 1996-97 Apparition. Dusky cusp-bands bordering the bright cusp-caps were not reported in 39.4 percent of the observations when cusp-caps were visible, and the cusp-bands displayed a mean relative intensity of about 7.0 (see Figure 5).

Cusp Extensions

Again as shown on Figure 5, there were usually no cusp extensions reported beyond the 180° expected from simple geometry in 92.5 percent of the observations (in integrated light and with color filters). However, early in the apparition, as Venus passed through its crescentic phases following inferior conjunction in 1996-97, several observers recorded cusp extensions that ranged from 2° to 10°. Just after inferior conjunction, two or three observers witnessed the cusps joining along the planet's unilluminated limb, forming a beautiful halo encircling the dark hemisphere of Venus. Cusp extensions were shown on drawings, with their appearance enhanced by color filters and polarizers, but none were photographed successfully. Experience has shown that cusp extensions are very difficult to document on film due to the fact that the sunlit regions of Venus are so much brighter than the faint extensions. Observers are encouraged to try their hand at recording cusp extensions using CCD cameras, video cameras, or both in future apparitions. [Refer also to the article on Venusian cusp extensions by Walter H. Haas on pp. 58-66 of this issue.]

Estimates of Dichotomy

A discrepancy between the predicted and the observed dates of dichotomy (half-phase), known as the "Schroeter Effect" on Venus, was reported by observers during the 1996-97 Apparition. The predicted half-phase occurs when k = 0.500, and the phase angle, i, between the Sun and the Earth as seen from Venus equals 90°. The observed-minus-predicted discrepancies for 1996-97 are given in *Table 3* (above).

Table 3. Observed versus Predicted Dichotomy of Venus, 1996/96 Western (Morning) Apparition.

	Observer		
	Benton	Hargreaves	Niechoy
a. UT Dates (1966 Aug. days).			
Observed (O)	26.55	27.46	26.13
Predicted (P)	19.79	19.79	19.79
Difference (O-P, days)	+6.76	+7.67	+6.34
b. Phase (k).			
Observed (O)	0.500	0.500	0.500
Predicted (P)	0.536	0.540	0.534
Difference (O-P)	-0.036	-0.040	-0.034
c. Phase Angle (i, degrees).			
Observed (O)	90.0	90.0	90.0
Predicted (P)	85.9	85.4	86.1
Difference (O-P)	+4.1	+4.6	+3.9

Dark Hemisphere Phenomena and Ashen Light Observations

The Ashen Light, first reported by G. Riccioli in 1643, refers to an extremely elusive, faint illumination of Venus' dark hemisphere. Although it does not have the same origin, the Ashen Light resembles Earthshine on the dark portion of the Moon. Most observers agree that Venus must be viewed against a completely dark sky for the Ashen Light to be seen, but such circumstances occur only when the planet is very low in the sky where adverse terrestrial atmospheric conditions contribute to poor seeing. Also, substantial glare in contrast with the surrounding dark sky influences such observations. Even so, the A.L.P.O. Venus Section continues to hear from observers who say they have seen the Ashen Light when Venus was seen against a twilight sky.

During 1996-97, there were practically no instances (97.9% of the observations) when the Ashen Light was suspected in integrated light, color filters, and variable-density polarizers. On the very rarest of occasions, a few observers reported vague suspicions of the phenomenon, but there was no confirmation of their impressions. There were no instances during the 1996-97 Apparition when observers described a dark hemisphere of Venus that appeared darker than the background sky; when seen, this phenomenon is almost certainly a contrast effect.

Conclusions

The results of our analysis of visual and photographic observations contributed to the A.L.P.O. Venus Section during the 1996-97 Western (Morning) Apparition suggested limited activity in the atmosphere of the Venus. It has already been mentioned in this report that it is very troublesome to differentiate between what constitutes real atmospheric phenomena and what is merely illusory on Venus at visual wavelengths. A greater level of confidence in our results will improve as the number of observers and incidence of simultaneous observations increases. The Venus Section is making a special effort to organize and implement a simultaneous observation schedule so that observers near to one another can set aside times to follow Venus with others using similar methods and equipment to view the planet at the same time. The simultaneous observing schedule is expected to appear on the A.L.P.O. Website at www. lpl.arizona.edu/alpo. In addition to routine observations, the Venus Section desperately needs more ultraviolet photographs of Venus, as well as CCD images of the planet at different wavelengths. We are attempting to standardize and improve observational techniques and methodology so that comparison of our results with those of previous morning observing seasons, as well as with evening apparitions of Venus, is more reliable.

A.L.P.O. studies of the Ashen Light, which peaked during the Pioneer Venus Orbiter Project, are continuing every apparition. Constant monitoring of the planet for the presence of this phenomenon by a large number of observers, ideally participating in a simultaneous observing program, remains important as a means of improving our chances of capturing confirmed dark-hemisphere events.

Active international cooperation by individuals making regular systematic, simultaneous observations of Venus remains our main objective, and the A.L.P.O. Venus Section invites interested readers to join us in our projects and challenges ahead.

References

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The drawings and photographs that follow (Figures 6-16) have had their contrast enhanced and are oriented with the South Pole of Venus at top. Any that were originally drawn reversed have been rectified, as noted in their captions. Unless otherwise stated, Seeing (*S*) is in the Standard A.L.P.O. Scale (0 = worst, 10 = perfect) and Transparency (*Tr*) is the limiting visual stellar magnitude in the vicinity of Venus. *k* is the phase coefficient and *d* is the angular diameter. Ephemeris data from *The A.L.P.O. Solar System Ephemeris,* and *The Astronomical Almanac,*1996 and 1997 editions for both.

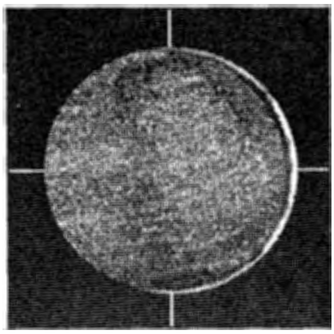


Figure 6. Drawing of Venus. 1996 JUN 17, $05^{h}58^{m}$ UT. D. Niechoy. 20.3-cm (8.0-in) Schmidt-Cassegrain, 225X, integrated light. S = 2.0, Tr = +2.5 (daytime). k = 0.016, d = 56".3. Original reversed. Observer noted, "Impression of a darker night side between the cusps of the disc! I think it could be an illusion."

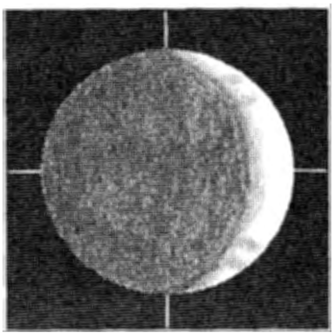


Figure 7.Drawing of Venus. 1996 JUL 07, $06^{h}35^{m}$ UT. D. Niechoy. 20.3-cm (8.0-in) Schmidt-Cassegrain, 225X, W47(blue) Filter. S = 2.5, Tr = +2.5. k = 0.181, d = 43".5. Original reversed.

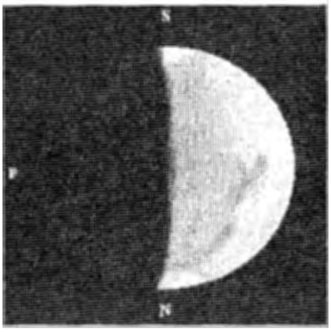


Figure 8. Drawing of Venus. 1996 AUG 14 $10^{h}06^{m}$-$10^{h}16^{m}$ UT. R.W. Schmude, Jr. 50.8-cm (20.0-in) Newtonian, 350X, integrated light and W80A (blue) Filter. S = 6.0, Tr = +4.5. k= 0.4697, d = 25".2. Observer notes: k estimated as 0.46, dark-side illumination suspected (relative intensity 1/2).

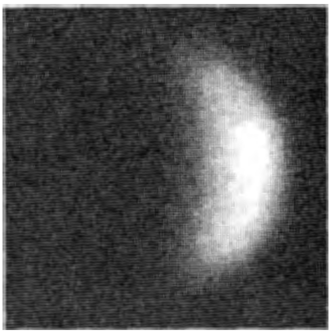


Figure 9. Photograph of Venus. 1996 AUG 18, $14^{h}10^{m}$ UT. F.J. Melillo. 20.3-cm (8.0-in) Schmidt-Cassegrain, 10-mm eyepiece projection with 2X Barlow lens, 7-s exposure, Schott UG-1 UV filter, Kodak Technical Pan 2415 Film. S = 8, daylight. k = 0.493, d = 24".0. k estimated as 0.49.

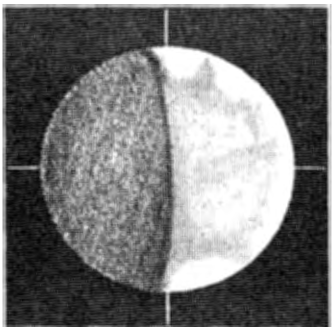


Figure 10. Drawing of Venus. 1996 AUG 19 $03^{h}32^{m}$ UT. D. Niechoy. 20.3-cm (8.0-in) Schmidt-Cassegrain, 225X, W25 (red) Filter. S = 2.5, Tr = +2.0 (twilight). k = 0.496, d = 23".9. Original reversed. Observer noted that the night side was possibly visible.

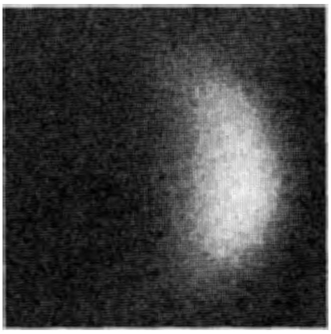


Figure 11. Photograph of Venus. 1996 AUG 31, $14^{h}10^{m}$ UT. F.J. Melillo. 20.3-cm (8.0-in) Schmidt-Cassegrain, 10-mm eyepiece projection with 2X Barlow lens, 7-s exposure, Schott UG-1 UV filter, Kodak Technical Pan 2415 Film. S = 7.0, daylight. k= 0.561, d = 21".1. k estimated as 0.53.

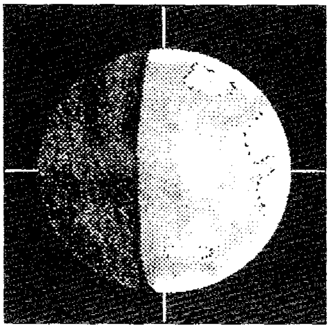
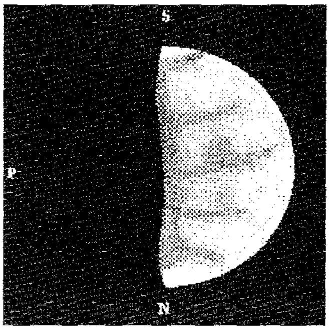


Figure 12. Drawing of Venus. 1996 SEP 05, 04^h57^m UT. D. Niechoy. 20.3-cm (8.0-in) Schmidt-Cassegrain, 225×, W25 (red) Filter. S = 2.0, Tr = +2.0 (daylight). k= 0.582, d = 20".1. Original reversed.

Figure 13. Drawing of Venus. 1996 SEP 06, 11^h12^m-11^m30m UT. R.W. Schmude, Jr. 61.0-cm (24.0-in) Newtonian, 500×, integrated light and W47 (blue) Filter. S = 6.0, Tr = +5.0. k= 0.588, d = 19".8. k estimated as 0.48.



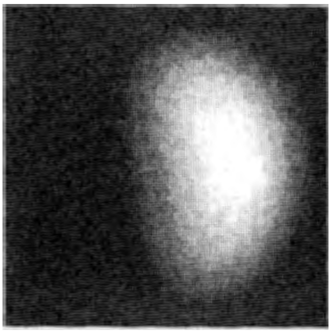
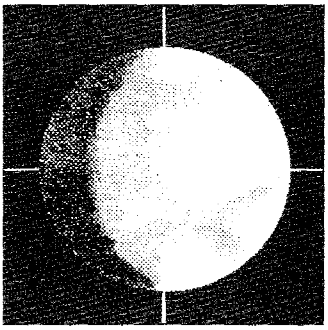


Figure 14. Photograph of Venus. 1996 OCT 05, 14^h00^m UT. F.J. Melillo. 20.3-cm (8.0-in) Schmidt-Cassegrain, 10-mm eyepiece projection, 8-s exposure, Schott UG-1 UV filter, Kodak Technical Pan 2415 Film. S = 5, Tr = +4.5 (daylight). k= 0.708, d = 15".8.

Figure 15. Drawing of Venus. 1996 OCT 20, 03^h36^m UT. D. Niechoy. 20.3-cm (8.0-in) Schmidt-Cassegrain, 225×, W25 (red) Filter. S = 3.0, Tr = +2.5. k= 0.757, d =14".5. Original reversed.



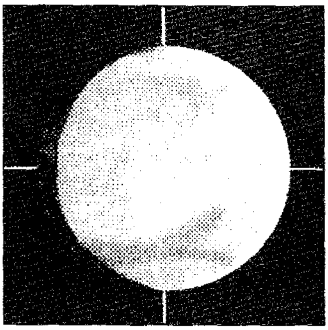


Figure 16. Drawing of Venus. 1997 JAN 14, 11^h44^m UT. D. Niechoy. 20.3-cm (8.0-in) Schmidt-Cassegrain, 225×, integrated light. S = 3.0, Tr = +3.0. k= 0.948, d =10".6. Original reversed.

A Visual Observational Study of the Extensions of the Cusps of Venus, 1937-1998

By: Walter H. Haas, Founder, A.L.P.O.

Abstract

It has long been known that the atmosphere of Venus prolongs the cusps of that planet when it is a narrow crescent and even exhibits Venus as a ring of light when very close to Inferior Conjunction. Clearly, less striking cusp-extensions must exist at other phases. While the sources of observational errors in measuring the very thin and very dim extensions are numerous, the author did undertake such a study over the interval 1937-1998 with telescopes ranging from 8 to 46 cm in aperture and including both refractors and Newtonian reflectors. Most of the some hundreds of measures obtained between a Greatest Eastern or Western Elongation and the related Inferior Conjunction were simple visual estimates of the angular perimeter of the illuminated limb, usually in white light but sometimes with Kodak Wratten filters. In addition, the angular perimeter was measured at the telescope with a filar micrometer on 34 occasions and also upon 17 Venus drawings.

An analysis was made of the white-light visual estimates and the micrometer measures to see how the perimeter varies with the phase angle, the angle at Venus between the directions to the Sun and the Earth. A simple approximate formula was derived from spherical trigonometry to compute the breadth of the twilight arc produced by the planet's atmosphere. It must be realized that we are dealing only with the atmosphere above the visible surface and with cusp extensions bright enough to be seen on a daytime of twilight sky. A tentative value for the breadth of this twilight zone, in which refraction, diffuse reflection, or both occur, is 4.0 degrees, from which we need to subtract 0.37 degrees because the Sun illuminates slightly more than half of the globe of Venus. Occasional marked inequalities in the lengths of the two cusp-extensions and variations in the visibility of the aforementioned complete ring of light suggest that values much greater than 4 degrees frequently occur.

Note: This paper was delivered on July 16, 1999 at the annual convention of the A.L.P.O., held in conjunction with the Astronomical League in Cheney, Washington.

Introduction

It has long been known that the cusps of the narrow crescent of Venus are extended well beyond their geometric positions. Indeed, the planet may even become a complete ring of light near Inferior Conjunction [1]. The effect is correctly attributed to the planet's atmosphere.

Now what is so very evident at a particular phase of Venus must actually exist all the time. We readily note, for example, the striking atmospheric dispersion of the light of a star near the horizon and the lovely colors; but actually this effect occurs all over the sky, except at the zenith, to a less obvious extent. Thus I became interested early in my observing career in the presumed relationship between the phase angle i of Venus, the angle at Venus between the directions to the Sun and to the Earth, and the observed angular perimeter p of the illuminated part of the planet. If Venus lacked an atmosphere, this p would always be close to 180°. At first it even appeared possible that such observations might help determine the height of the atmosphere of Venus, or at least of that por-

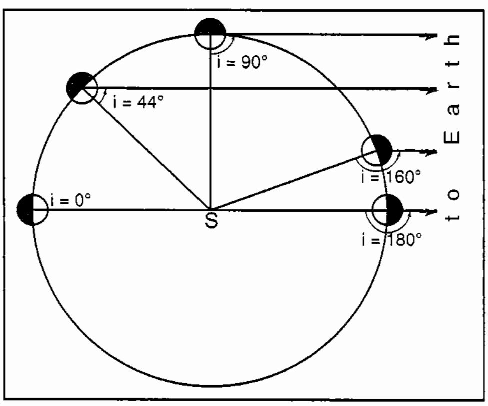


Figure 1. The phase angle, i, of Venus. S designates the Sun. The phase angle is the Sun-Venus-Earth angle, which is between 0° and 90° when Venus is gibbous, very close to 90° at Greatest Elongation, and between 90° and 180° when Venus is a crescent.

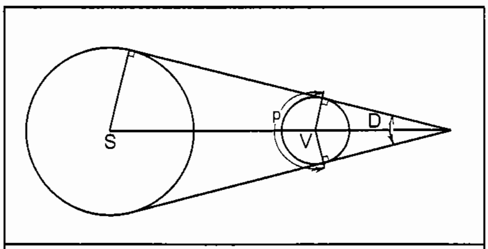
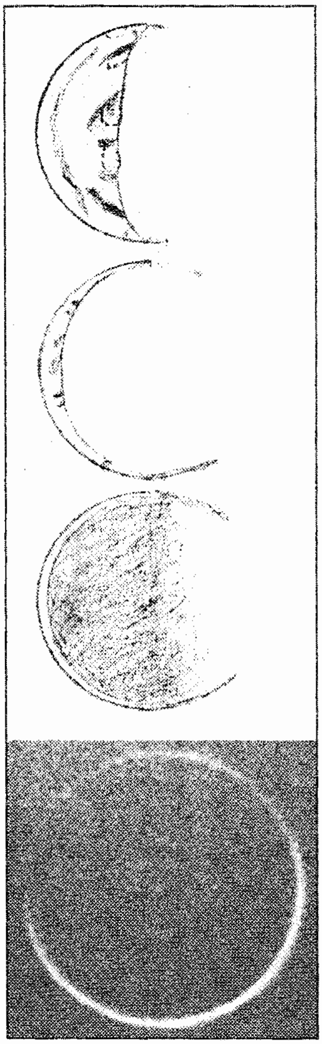


Figure 2. Correction for the finite distance of the Sun. S is the Sun, V is Venus. The angle D is the apparent angular diameter of the Sun as seen from Venus. At Greatest Elongation, i = 90°, the perimeter p is 180° + D. Diagram not to true scale!

Figure 3. Sample Views of Venus Cusp Extensions.



a. Drawing by Walter H. Haas, 1949 Dec 26, $23^h 10^m$ UT. 15-cm reflector, 141×. Seeing bad, sky clear. Phase angle 118°.9. South at top in all views.

b. Drawing by Walter H. Haas, 1937 Apr 01, $00^h 25^m$ UT. 15-cm reflector, 188×. Seeing poor. Phase angle 143°.1.

c. Drawing by Walter H. Haas. 1996 Jun 03, $20^h 16^m$ UT. 32-cm reflector, 101×. Seeing bad. Phase angle 165°.0.

d. Photograph by A.S. Murrell, Research Center, New Mexico State University. 1964 Jun 20, $17^h 18^m$ U, 18^h after Inferior Conjunction. Venus 2°.33 from center of Sun, phase angle, i = 176°.3. Seeing 6, Transparency 6 or better (both on a 0-10 scale). Photograph in red light, IV-E Eastman spectroscopic plate, OG-2 Filter. Exposure 0.2 sec. 12-in (30.5-cm) Cassegrain reflector, f/66.

tion above the visible surface and detectable on the bright sky against which the planet must usually be viewed. In 1943 some early results were reported [2]. In recent years the observations have been added to the A.L.P.O. Venus Files. We shall in 1999 hardly compete with the many recent discoveries of space probes; but perhaps this long-term project may still possess some historical interest and may be an interesting example of a simple amateur observing program. The geometry of the varying phase-angle is shown in *Figure 1* (p. 58).

We pause to call attention to a minor correction. Note *Figure 2* (p. 58). The Sun is larger than Venus, and they are separated by a finite distance. It follows that the angular perimeter would slightly exceed 180° even if the planet lacked any atmosphere. The angular diameter (*D*) of the Sun as seen from Venus is readily computed from the known diameter of the Sun and the known mean radius of the orbit of Venus. We find D = 0°.737 = 0° 44'.2. Note in Figure 2 that at greatest elongation, or half-phase, each cusp will be prolonged by D/2 degrees. We shall eventually need to subtract D/2 from the breadth ℓ of the "twilight zone" on Venus, the illuminated area bordering the geometric exact hemisphere.

Figure 3 (left) shows some sample views of the extensions of the cusps. Note particularly that the ring of light was photographed clearly at a phase angle of 176°.3.

The Observations

Unless the reverse is stated, all observations discussed here are by the author. I do know of a few observations by others, but their inclusion would have little effect on the analysis. Also, all observations were made when the phase-angle exceeded 90° (i.e., Venus was a crescent), with one trivial exception. All dates mentioned are by Universal Time. The observations made are of three types.

First, drawings. The angular perimeter was measured on 17 *original* drawings.

Second, micrometer measures. A filar micrometer was used to measure the perimeter directly rather than, as is the usual practice, to measure some distance defined by the extended cusps. The method I usually employed was to place a wire successively tangent, as estimated, to the two cusps, reading off the involved angle of rotation. On a few occasions a wire was instead placed successively perpendicular, as estimated, to the ends of the two cusps. A few of the micrometer measures were made with red or blue color filters. The micrometer measures secured are as follows:

1. Measures on 7 dates from 1938 Dec 11 to 1939 Jan 28, i =137°.6 to 91°.3, with the Case School 23-cm refractor (telescopes described below).

2. Measures on 3 dates from 1940 Apr 02 to 1940 Apr 22, i = 80°.5 to 92°.8, with the Ohio State University 30-cm refractor.

3. Measures on 6 dates from 1943 JUL 01 to 1943 AUG 19, i = 92°.7 to 142°.6, and on 15 dates from 1945 MAR 13 to 1945 JUN 23, i ranging from 91°.2 to 165°.4, with the Flower Observatory 46-cm refractor.

Third method, simple angular perimeter estimates. If the cusp-ends define a perfect hemisphere, p is 180°. If, for example, their extensions fill two-thirds of the whole circular limb, p is 240°. The complete ring clearly is 360°. The method is quick and easy to use and may even be more accurate than one would expect.

In the years 1937-98 I made 217 perimeter estimates of this kind without a color filter, i.e., in white light. There were also 80 estimates in red light with Eastman Kodak Wratten Filter 25 or 25A, 70 estimates in blue light with Wratten Filter 47, and 28 estimates in green light with Wratten Filter 58. A very small number of estimates was made with other color filters.

It would occasionally happen that two or more estimates would be made on the same date of the same type and in the same color. For example, the cusps might look more prolonged as the sky darkened. In such cases an average value was taken, and considered to be a single observation.

The telescopes used in this study, ignoring a few used very seldom, were:

1. Two 15-cm f/7.9 Newtonian reflectors over the entire span of years.

2. The 24-cm refractor in the Clarke Observatory of Mount Union College at Alliance, Ohio in 1937-40.

3. The 23-cm refractor in the Warner and Swasey Observatory of the Case School of Applied Science at East Cleveland, Ohio in 1938-39.

4. The 30-cm refractor in the McMillin Observatory of the Ohio State University at Columbus, Ohio in 1940.

5. The 46-cm Brashear refractor in the Flower Observatory of the University of Pennsylvania at Upper Darby, PA. in 1942-45.

6. A Cave 32-cm f/8.1 Newtonian reflector in 1957 and later.

7. A Criterion 20-cm, f/8 Newtonian reflector (Dynascope) in 1988 and later.

8. Another 20-cm, f/10 Newtonian reflector in 1998, owned by Mr. Cecil Post.

When were the observations made, and under what circumstances? The great majority of them were secured at eastern (evening) apparitions either soon before sunset or on a bright twilight sky. A smaller number were made at western (morning) apparitions near sunrise. A still smaller number were obtained with Venus seen on a dark sky and necessarily at a low altitude. A few observations, chiefly near an Inferior Conjunction, were made in bright sunshine, with the planet high above the horizon. As Venus observers will know, the seeing or atmospheric steadiness was usually poor, and sometimes terrible. The transparency varied greatly, though one tried to observe in clear skies. In observations near Inferior Conjunction, and hence with Venus close to the Sun in the sky, very low magnifications became necessary just to find the planet on the brilliant sunlit background. Otherwise, the higher powers preferred by planetary observers, say 20 to 30 per inch of aperture or more, helped to dim the brilliant crescent and to assist the visibility of the very faint extensions of the cusps.

Observational Difficulties

All measures are subject to errors, and these efforts to determine how much the cusps are extended surely have their share! The notes accompanying the observations stress again and again that the extensions are extremely faint and very thin. Of course, if they were otherwise, the effect would be better known. Some sources of errors are:

1. The brightness of the sky surrounding Venus varies with the planet's elongation from the Sun, from 0° to 47°, and also with the particle and water vapor content of the air.

2. The atmospheric transparency varies, in part with changing altitude above the horizon. Presumably longer extensions are recorded in clearer skies.

3. The seeing, or atmospheric steadiness, varies. Presumably the cusps look longest in the best seeing. But be wary: atmospheric tremors may produce false cusp extensions.

4. There may well have been changes in the sensitivity of the one observer's eye during the 61 years covered by this study.

5. The brightness of the image of Venus, and hence the observed extensions of the cusps, must vary with changes in aperture and magnification.

6. The following suggested effect will be more controversial. Near Inferior Conjunction the unilluminated hemisphere of Venus is sometimes reported to be visible, much like the Earthshine on the crescent Moon. It is easy to imagine a bright rim to the Earthshine—try looking next time—and perhaps observers of Venus cusp extensions are sometimes misled by a similar effect.

Analysis of the Observations

The perimeters measured on drawings are too few and too inconsistent to be considered further. Some observers might be more accurate artists than I have been.

Thinking of the role of color filters in Martian research, we might well expect changing perimeter values with the red, blue, and green filters. Nevertheless, the estimated perimeter was usually the same with all of these filters and also the same as in the non-filtered (white-light) view. We shall hence attempt no analysis of the visual estimates made with the three color filters. The results could differ little from those in white light.

Nevertheless, there may be some basis for thinking that filters affect the data. On 1940 Apr 02, 21, and 22, $i = 80°.5$ to $92°.8$ and thus near half-phase, micrometer measures of the perimeter were made in both red and blue light. The blue perimeter exceeded the red perimeter by 9°.4, 3°.6, and 6°.7, a mean difference of 6°.6. On 6 dates from 1958 Jan 7 to 22, the estimated blue perimeter surpassed the white light perimeter by 34° to 70°, giving a mean of 52°, while i ranged from 136°.7 to 162°.7. Curiously, no difference was later found on 1958 Jan 23, 24, 25, and 26, with $i = 164°.2$ to $168°.9$. Also curiously, this difference was not found in other apparitions of Venus under apparently similar conditions.

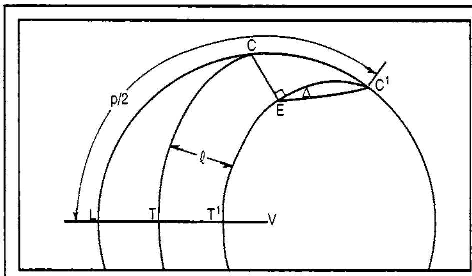


Figure 4. Phase angle, observed perimeter, and twilight arc. Let V be the center of the globe of Venus, C a cusp, and L the center of the illuminated limb. The theoretical terminator is TC, assuming no atmosphere and the Sun infinitely distant and a point source. The observed terminator is T^1EC^1, where point E is found by dropping a perpendicular from C upon the observed terminator. Small circle T^1EC^1 is separated from great circle TC by a twilight arc of breadth ℓ. Let Δ denote the angle between great circle arc EC^1 and small circle EC^1.

We next consider *Figure 4* (lower left) and want to derive a formula for expressing ℓ, the width of the twilight are, in terms of the observed perimeter p and the phase angle i. In the spherical triangle CEC^1, arc $CC^1 = p/2 - 90°$, since C is a theoretical cusp and L is at mid-limb. Arc CE is the ℓ we want, and angle CEC^1 is $90° + \Delta$. At C^1 a tangent to the limb of Venus is clearly normal to the direction to the Earth, and a tangent to small circle arc C^1E along the *observed* terminator is clearly normal to the direction to the Sun. The angle between the two tangents must be the phase angle i, and in Figure 4 the interior angle CC^1E is then $180° - i + \Delta$. In spherical triangle CEC^1 we have by the Law of Sines:

$$\frac{\sin (CE)}{\sin (\text{angle } CC^1E)} = \frac{\sin (CC^1)}{\text{Sin} (\text{angle } CEC^1)}.$$

With the values noted above this relation can be reduced to:

$$\sin \ell = - \sec A \cos p/2 (\sin i \cos \Delta - \cos i \sin \Delta). \quad (1)$$

Since it is often true that Δ is very small so that, approximately, $\sin \Delta = 0$ and $\cos \Delta = \sec \Delta = 1$, we get as a simpler and useful approximate equation:

$$\sin \ell = - \sin i \cos p/2. \quad (2)$$

It may be interesting to use Calculus to see how the perimeter p varies with changing i. Equation (2) may be rewritten as:

$$\cos p/2 = - \sin \ell \csc i. \quad (3)$$

We can differentiate and write:

$$-1/2 \sin p/2 * dp/di = \sin \ell \csc i \cot i, \text{ or:}$$

$$dp/di = -2 \sin R \csc p/2 \csc i \cot i.$$

If we are a little past an evening Greatest Elongation, with p a little more than 180°, p/2 a little more than 90°, and i a little more than 90°, we see from this equation that perimeter p is changing very slowly as phase angle i increases. But if we are approaching an Inferior Conjunction, with p nearing 360°, p/2 nearing 180° and i nearing 180°, then p is increasing very rap-

Table 1. Visual Observations by Walter H. Haas of Angular Perimeter p of Venus.

Phase Angle i	Visual White-Light Estimates				Micrometer Estimates			
°	No.	Mean °	S.E. ±°	ℓ °	No.	Mean °	S.E. ±°	ℓ °
80.5	0	-	-	-	2	184.0	4.7	1.97
90.0-94.9	11	181.6	0.3	0.80	8	187.8	1.6	3.90
95.0-99.9	13	181.5	0.6	0.80	2	185.6	5.1	2.77
100.0-104.9	11	184.2	1.2	2.05	1	193.5	-	6.59
105.0-109.9	12	183.2	0.7	1.52	2	186.2	0.5	2.96
110.0-114.9	13	184.3	1.2	2.03	1	190.0	-	4.62
115.0-119.9	14	188.2	1.8	3.64	0	-	-	-
120.0-124.9	10	188.3	1.3	3.54	3	192.4	4.5	5.23
125.0-129.9	12	186.9	1.8	2.70	3	191.4	5.0	4.52
130.0-134.9	5	183.0	2.0	1.11	0	-	-	-
135.0-139.9	14	192.5	2.8	4.18	3	186.7	2.6	2.26
140.0-144.9	15	195.6	4.0	4.74	3	189.5	2.8	2.89
145.0-149.9	15	192.6	2.6	3.38	0	-	-	-
150.0-152.9	7	227.4	8.4	11.06	1	186.2	-	1.48
153.0-155.9	9	210.1	3.9	6.40	0	-	-	-
156.0-158.9	9	217.5	5.2	7.09	2	198.4	7.2	3.51
159.0-161.9	11	226.8	14.1	7.62	1	210.3	-	5.00
162.0-164.9	6	236.2	12.0	7.69	1	202.0	-	3.11
165.0-167.9	16	251.2	12.4	7.81	1	204.5	-	2.84
168.0-170.9	11	243.3	14.7	5.48	0	-	-	-
171.0-173.9	2	250.0	30.1	4.30	0	-	-	-
177.3	1	360.0	-	-	0	-	-	-

Note: S.E. = standard error (standard deviation of mean).

idly as i increases (note that cot i is negative).

We are finally ready to look at the data, the filar micrometer measures and the white-light estimates. The observations are clearly very sensitive to the phase angle; e.g., a given change in brightness along a thinning, extended cusp will cause a far larger error in the measured perimeter when i = 165° than when i = 95°. It was hence decided to divide the observations into intervals of phase angle: at 5° intervals from i = 90° to i = 150° and at 3° intervals from i = 150° to 174°. (The only observations with i more than 171° were at 171°.3, 173°.1, and 177°.3.) In *Table 1* (above), the phase angle or phase-angle interval is the leftmost column. Under "Visual White Light Estimates" there are four columns. The leftmost one is the number of observations for that phase angle. The next column to the right is the average value of the estimated perimeter, the arithmetic mean of all the observations for that phase angle. Next to the right is the standard deviation of the arithmetic mean [standard error] with its usual statistical meaning. Of course, we need at least two observations to compute a standard deviation. The rightmost column is the value of ℓ for that average perimeter and that phase-angle, as computed from equation (2) above. The four columns are then repeated under the heading "Micrometer Measures."

We now seek to evaluate ℓ, the width of the twilight arc. The 20 values tabulated for visual estimates in Table 1 give us for the mean and the standard deviation of the mean:

$$\ell = 4°.40 \pm 0°.63.$$

The 15 values tabulated for micrometer measures supply:

$$\ell = 3°.58 \pm 0°.36.$$

It may be worthwhile to reduce the micrometer data in other ways. If we consider the 34 individual measures of the perimeter and the angle i associated with each one, the mean and the standard deviation of the mean become:

$$\ell = 3°.58 \pm 0°.38.$$

This difference is nil, justifying the first method.

Noting that the standard deviations of the visual estimates are much smaller soon after Greatest Elongation, we might like to use only the 16 micrometer measures in the phase-angle interval 80°.5 - 111°.5. There results:

$$\ell = 3°.62 \pm 0°.58.$$

If we finally select only those measures in the interval above made in white light and also made with the micrometer wire tangent to the cusps, we get from 9 measures:

$$\ell = 3°.45 \pm 0°.67.$$

The visual estimates of the perimeter in Table 1 are plotted in *Figure 5* (p. 63), and the micrometer measures are plotted in *Figure 6* (p. 64). There is also shown for comparison the perimeter for ℓ = 4°, computed from cos p/2 = -sin 4° csc i. Vertical error bars one standard deviation long are plotted above and below all observed points (provided, of course, that the point represents more than one measure). For example, take the micrometer measure at 97°.5, the mid-point of the interval 95°.0-99°.9. The mean value is 185°.6, and the standard deviation is ±5°.1. The error bar extends from 180°.5 (185°.6 - 5°.1) to 190°.7 (185°.6 + 5°.1).

It will be noted on both plots that a twilight arc 4° wide fits the observations reasonably well from, roughly, i = 115° to 150°. For i = 80° to 115° there is still a good fit to the micrometer measures, but the visually estimated perimeters are consistently too small. One might conjecture that the dimly lit extensions of the cusps cannot then be detected very close to the far brighter illuminated cusps. Many observers record the two cusp-caps as the

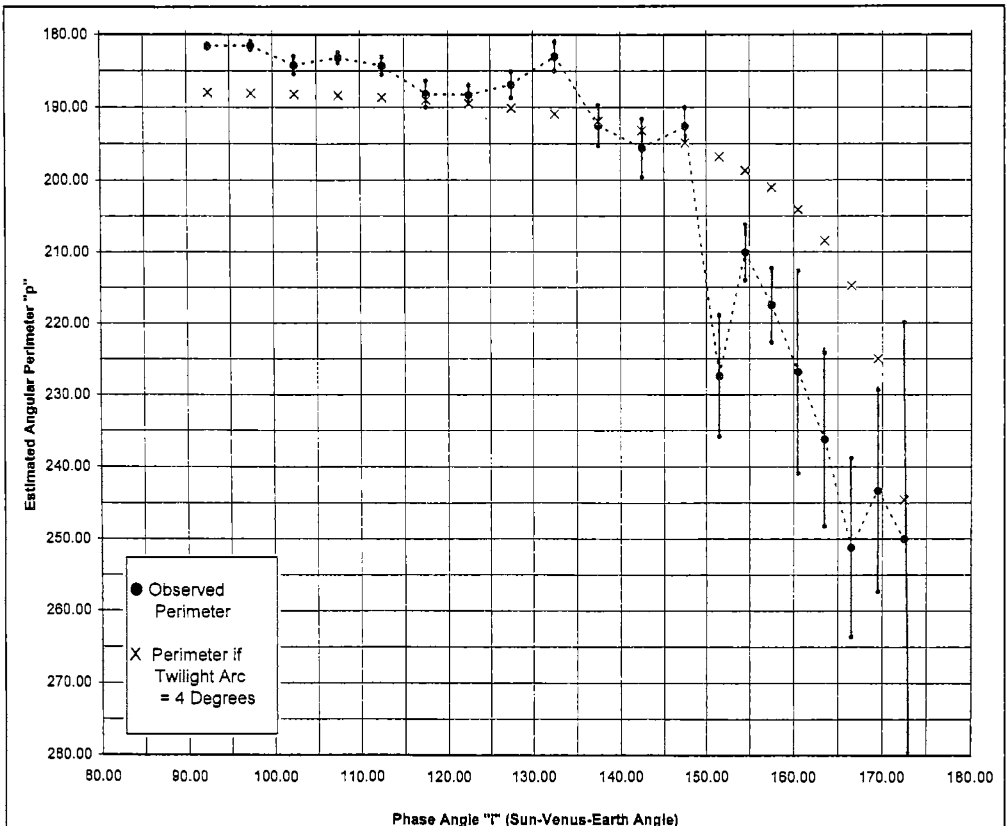


Figure 5. Visual white-light estimates of angular perimeter "p" of Venus.

brightest parts of the disk of Venus [6], and they are occasionally present on photographs. For i more than 150° the micrometer measures still give a fair fit to ℓ = 4° but the visual estimates are now too large, and also clearly subject to large random errors. Some possible explanations are:

1. The visual estimates are simply too large, and do include very large errors.

2. The very dim cusp extensions vanish when adjacent to a conspicuous dark micrometer wire so that the measured perimeter is systematically too small.

3. Fainter extensions are seen as Venus is closer to Inferior Conjunction (and closer to the Sun in the sky). Truly doubtful!

4. Perhaps the main reason, the approximate equation (2) should be replaced by the exact equation (1) with a proper value of Δ.

In conclusion of this analysis, I would suggest that we adopt as the width of the twilight arc:

$$\ell = 4°.0 \pm 0°.5,$$

from which we should subtract 0°.37 to allow for the finite distance of the Sun (Figure 2).

It must always be borne in mind that we are dealing only with that part of the atmosphere of Venus above the visible, cloud-covered surface. The cusp extensions must also be bright enough to be seen here against the bright sky around Venus. We make no attempt here to explain the extensions of the cusps by either refraction or diffuse reflection [3]. Their extreme faintness would suggest reflection, but it must also be recognized that very thin refraction-caused extensions well below the resolving power of the telescope can appear to be very faint. Probably both reflection and refraction play a role.

An Alternate Approach: The Ring of Light

Referring to *Figure 7* (p. 64), let i_0 be that value of i when the tips of the advancing cusp extensions first join at the midpoint L of the normally unilluminated limb. Of course, the observed perimeter is then

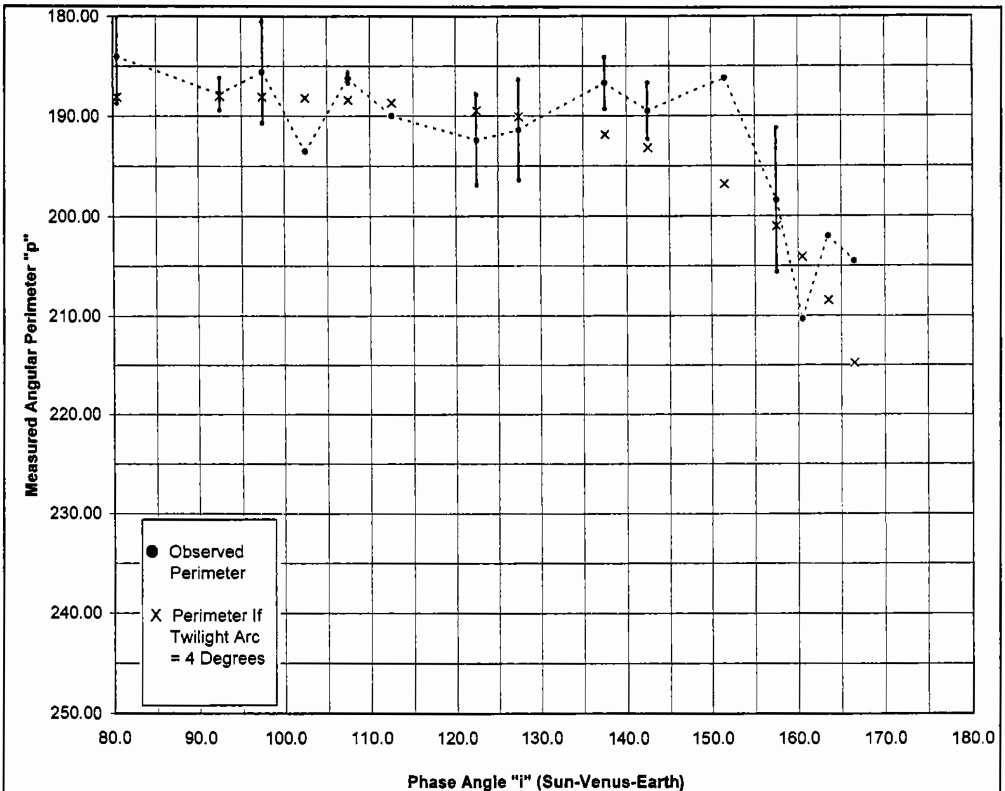


Figure 6. Micrometer measures of angular perimeter of Venus.

360° and remains so when i exceeds i_0. (At morning apparitions the critical value i_0 would be the time when the ring of light is first broken.) Arc SL, the distance of the mid-limb point from the subsolar point, is clearly 90° + ℓ. Glancing at Figure 7, we note that this distance is also 360° - i_0 - 90°, or 270° - i_0. If, then, 270° - i_0 = 90° + ℓ, it follows that:

$$\ell = 180° - i_0. \quad (4)$$

Can we hope to evaluate ℓ by making useful determinations of i_0? Among our visual estimates are 5 examples where the angular perimeter was estimated to be 360°. All were recorded with a 15-cm reflector.

1. 1951 SEP 01. i = 167°.0. Ring complete, seen better with green and blue filters. Sky very clear.

2. 1951 SEP 02. i = 167°.8. Sky very clear.

3. 1951 SEP 03. i = 168°.0. Ring very dim, perhaps brightest in blue. Sky very clear.

4. 1951 SEP 09. i = 161°.5. Ring very faint, perhaps brightest in blue.

5. 1964 JUN 19. i = 177°.3. Complete ring very definite.

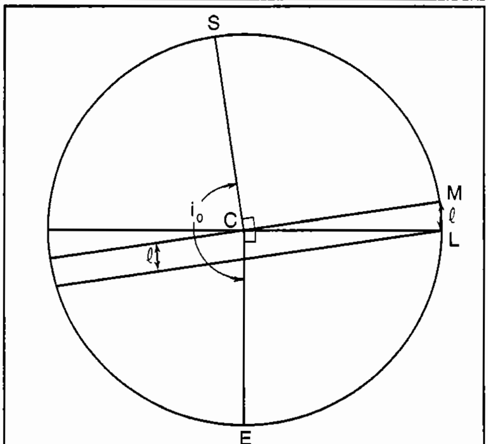


Figure 7. Phase angle and ring of light. Looking down on a cusp of Venus from a great height, we note the sub-Earth point E, the sub-Sun point S, and the center L of the usually unilluminated limb. CM is normal to CS, and the twilight arc ML is of width ℓ.

There can be no serious question of the validity of the 1964 JUN 19 observation; and indeed the complete ring was photographed on 1964 JUN 20, i = 176°.3 [4]. See also Figure 3. It follows from equation (4) that our much-discussed twilight arc breadth must be 3°.7 or more.

For the other 4 records of a complete ring it is hard to accept the resulting values of ℓ, namely, 13°.0, 12°.2, 12°.0, and 18°.5. There are 12 perimeter estimates with i greater than 168°.0 in which the cusps formed *no* complete ring. There are 33 perimeter estimates and 2 micrometer measures with i greater than 161°.5 in which the ring was *not* seen. Many of these negative observations were with apertures larger than 15 cm, though probably never with as clear skies as prevailed on 1951 SEP 01-03. My observing notes sometimes clearly state that no complete ring was present.

An accurate observation of the ring or its absence on the bright daytime sky near the Sun is indeed not easy. Thus on 1937 APR 16, with i = 170°.0, Richard C. Hildner, then Head of the Mathematics Department at Mount Union College, found that blinking his eye showed the horns extended nearly the whole way around but later thought that this effect was probably illusory. On 1951 AUG 16, with i = 141°.7, several experienced amateurs at a Convention of the Western Amateur Astronomers observed Venus with 15- to 25-cm telescopes. Everyone noted greatly extended cusps, and a few observers even thought that the ring of light was occasionally complete. Finally, when we take all of the observed perimeters for phase angles of more than 160° and plot p against i, the result is a classic "scatter diagram"— it is *hard* to see a trend.

Nevertheless, it might be worthwhile to test whether these observations at large phase angles can be correlated with the sunspot cycle or flare solar activity and their presumed effect upon the upper atmosphere of Venus.

AN ODDITY: UNEQUAL CUSP EXTENSIONS

We have so far supposed in this discussion that everything is symmetric on Venus and that the north and south cusps are always prolonged by the same amount. In reality they are frequently found to be unequal. Indeed, there appears to be some tendency for a given inequality to persist for days. Thus the north horn was regularly the more prolonged, the more conspicuous, or both from 1977 MAR 22 to APR 03, i = 146°.0 to 166°.9. The north horn was again the more extended on 1990 JAN 01 and 02, i = 143°.9 to 146°.7. The south cusp was the more prolonged on 1996 JUN 01 and 03, i = 159°.1 and 165°.0. On 1945 MAR 24, i = 135°.2, another observer independently confirmed my opinion that the south horn was thinner than the north horn. However, there were also many times when the two extensions were explicitly said to be alike.

These inequalities imply differing atmospheric conditions for refracting light, diffusely reflecting light, or both at the two areas on Venus where near-tangential rays illuminate the cusp extensions. If, then, the *mean* atmosphere-caused twilight arc is about 3°.6, as discussed above, there must be places on the planet which sometimes produce greater extensions. It may accordingly be that the smaller phase-angle values noted above for the complete ring of light, i =161°.5 to 168°.0, are acceptable even if also unusual.

NOTES FOR THE FUTURE

The alert reader will surely think of ways of bettering the observational data here used. The more intensive use of color filters and carefully controlled photography are obvious improvements. One may also think of an occulting bar to hide the illuminated crescent and thus to make the faint cusp extensions more evident. The application of CCD imaging to supply quantitative data on the brightness of a prolonged cusp at a specified position would be a major improvement.

The period February-May, 2001, centered on the inferior conjunction occurring on 2001 MAR 30, will be a good time to investigate these cusp extensions. Some guidelines are given in *Table 2* (below) [5].

When Venus transits the Sun on 2004 Jun 08, we may expect that new technologies will make the contents of this paper very obsolete.

I wish to thank Mr. J.O. Hughes of Las Cruces for considerable help in preparing Figures 5 and 6.

Table 2. Recommended Period to Investigate the Cusp Extensions of Venus.

UT Date	UT	Phase Angle i	Remarks
2001	h		
FEB 24	00	119°.1	Venus east of Sun.
MAR 08	00	134°.8	
MAR 20	00	155°.0	
MAR 30	04	168°.9	Inferior Conjunction; Venus 8° 01' north of Sun.
APR 01	00	168°.4	Venus west of Sun.
APR 13	00	149°.7	
APR 25	00	130°.7	
MAY 07	00	116°.2	

Note: Prof. Haas described and tabulated the recommended period for 1999 in his talk, given on July 16, 1999. In the text and this table, the Editor has substituted data centered around the next inferior conjunction of Venus, on 2001 MAR 30, using *The Astronomical Almanac for the Year 2001.*

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Fifty Years Ago: A Selection from The Strolling Astronomer, May 1, 1950 (Vol. 4, No. 5), "Some Lunar Affairs," p. 9.

Figure 1 on pg. 1 [below, left] may be regarded as typical of Mr. E. J. Reese's many excellent drawings of the crater Conon. Referring to the map of Conon on pg. 1 of the February issue [lower right], the reader will see that Reese has here represented Fault B, Cleft V, and Streaks V, A, and Z. It will be noted that Reese on this date found Fault B dark, conspicuous, and unbroken. At the position indicated by the star Reese remarked a dark shading on the inner west wall of a craterlet, a shading seen well by L.T. Johnson on November 30, 1949 at colongitude 26°.8. (Colongitude is the eastern [now western, Ed.] longitude of the sunrise terminator.) The dark spot indicated by the pair of stars in Figure 1 was observed also by T. Cragg on the same date (December 30). On March 29, 1950, Conon was drawn independently under mediocre conditions by Cragg and W.H. Haas only 30 minutes apart; each used a 6-inch reflector, and the colongitude was about 36°.1. Haas saw Fault B; continuous and very dark, it impressed him as being the shadow of a ridge (as Hare has seen it with his excellent 12-inch reflector). Cragg probably drew the southwestern half of Fault B; he also depicted several dark streaks on the floor itself, all of which escaped Haas. One of these might be Cleft V. Both observers saw Q and O (refer to map) as white areas on the floor.

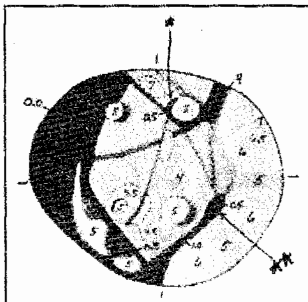
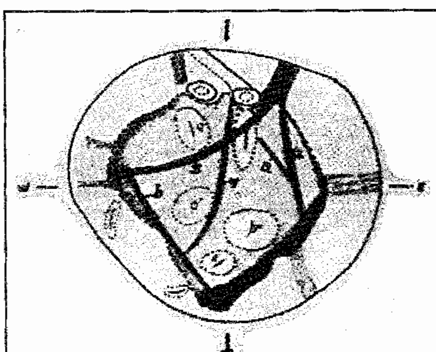


Fig. 1. Crater Conon
E. J. Reese. 6-in. Refl.
Dec. 30, 1949. 1^h 30^m.
240X.
Colong. = 31°.0

To right: Figure 1 from page 1 of the February 1, 1950, issue of The Strolling Astronomer (the first issue to contain illustrations) with the caption:

"The accompanying chart is a preliminary map of the lunar crater Conon prepared by E.J. Reese in November, 1949. It is based upon a large number of observations and drawings by himself and other members of the A.L.P.O., chiefly in 1947-49."



WIDEBAND PHOTOMETRY OF JUPITER: 1999-2000

By: Richard W. Schmude, Jr. and Heidi Lesser, Gordon College, 419 College Drive, Barnesville, GA 30204

ABSTRACT

An SSP-3 solid-state photometer and a 0.51-m Newtonian telescope (stopped down to an aperture of 0.05 m) was used along with filters that were transformed to the Johnson B, V, R and I System to measure the brightness and color of Jupiter. The normalized magnitudes of Jupiter are: B(1,0) = -8.53±0.02; V(1,0) = -9.40±0.01; R(1,0) = -9.89±0.02 and I(1,0) = -9.76±0.02. The measured solar phase-angle coefficients are as follows: c_B = 0.0104±0.0026, c_V = 0.0076±0.0021, c_R = 0.0082±0.0026 and c_I = 0.0056±0.0024. These results show that Jupiter is brightest through the red filter.

INTRODUCTION

In 1961 Harris [1961, 280] wrote: "Accurate photometric data for Jupiter are quite limited and it is not possible to give a completely satisfactory description of its brightness variations." It appears that this quote is still valid almost four decades later. It is for this reason that we have carried out photoelectric measurements of Jupiter during the 1999-2000 Apparition. It is well known [Peek, 1958; Rogers, 1995] that Jupiter undergoes visible changes from time to time. We hope to be able to correlate precise brightness and color measurements with visible changes on the Jovian disk and to perhaps even detect Jovian brightness changes due to the solar cycle and the changing inclination of Jupiter's axis. A thorough knowledge of Jupiter's photometric constants may also enable astronomers to learn more about extrasolar planets in the future; for example, Seager, [1999, 1408] has presented a theoretical photometric light curve of the extrasolar planet 51 Peg b which is a Jupiter-sized planet 0.05 astronomical units from its primary star. [An astronomical unit, or AU, is the mean distance from the Earth to the Sun; 149,597,870 km. *Ed.*]

In this paper we report new B, V, R and I [blue, visual, red, and infrared] photoelectric magnitude measurements of Jupiter at different phase angles [i.e., angles at Jupiter between the Sun and the observer]. These data are used in computing the normalized magnitudes [i.e., magnitudes were Jupiter 1 AU from the Sun and the Earth], solar phase-angle coefficients and color indices of Jupiter during the 1999-2000 Apparition.

METHOD AND MATERIALS

An SSP-3 solid-state photometer, along with filters that have been transformed to the Johnson B, V, R and I System, were used in collecting all photoelectric measurements. A 0.51-m Newtonian telescope with a focal length of 2.29 m was also used in collecting the magnitude measurements. The telescope was stopped down to an aperture of 0.05 m to prevent saturation of the detector. The comparison star used in all photoelectric measurements was α Arietis, whose 1999.5 coordinates are 02^h07^m, +27°28′ [United States Naval Observatory, 1998, H32]. This star was selected to be a comparison object because it is relatively bright, it has a color similar to that of Jupiter and because this is one of the UBVRI standard stars listed in *The Astronomical Almanac*. The magnitudes of α Arietis used in the evaluation of photoelectric data are: B = +3.15, V = +2.00, R = +1.16 and I = +0.54.

All measurements were corrected for both atmospheric extinction and transformation. Extinction coefficients were measured on all dates except for the R- and I-coefficients on 1999 SEP 05. In these two cases, extinction coefficients (in magnitudes/air mass) of 0.19 (R-filter) and 0.16 (I-filter) were assumed based on the measurements in Schmude, 1994 [15]. The average difference in air mass between Jupiter and α Arietis for the R- and I-filters on 1999 SEP 05 were 0.10 and 0.01 air masses respectively, and so possible errors from the assumed extinction coefficients are expected to be small. The transformation coefficients were measured using the star-pair method [Hall and Genet, 1988, 200]; the two stars used in the evaluation of transformation coefficients were γ Pegasi and χ Pegasi. These two stars were selected because they have a wide difference in (B-V) values and because they are listed as UBVRI standard stars in *The Astronomical Almanac* [United States Naval Observatory, 1999, H32]. The resulting transformation coefficients are: ε_B = +0.091, ε_V = -0.019, ε_R = -0.072 and ε_I = -0.107. The value of k_B'' was assumed to equal -0.03 while the value of k_V'' was assumed to equal zero. [Hall and Genet, 1988, 195]. The values of k_R'' and k_I'' were also assumed to equal zero [Hall, 1999]. Magnitudes were calculated from equation 13.10.1 of Hall and Genet, 1988 [199]. An initial value of (B-V) = +0.85 was assumed for Jupiter and was used in computing the transformation and k_B'' corrections. The transformation and k_B'' corrections were subsequently modified to reflect the measured (B-V) value which was usually slightly higher than +0.85. The check star used in the Jupiter measurements was α Persei. The measured magnitudes of α Persei were: B = +2.31±0.03, V = +1.79±0.01, R = +1.38±0.01 and I = +1.08±0.03. The literature magnitudes of the check star are: B = +2.28, V = +1.80, R = +1.35 and I = +1.02 [Iriarte *et al.*, 1965, 25]. There is satisfactory agreement for the B, V and R filters but the measured I magnitude is 0.06 magnitudes fainter than the literature value.

Results

There are two common ways of calculating the normalized magnitude at a solar phase angle of zero degrees and the solar phase-angle constant. Both methods rely on the equation:

$$X(1,0) = X - 5 \log [r\ \Delta] + 2.50 \log k - c_X\alpha \quad (1),$$

where X(1,0) is the normalized magnitude at a solar phase angle of zero degrees, X is the apparent magnitude, r and Δ are the Jupiter-Earth and Jupiter-Sun distances in astronomical units, k is the fraction of the disk that is illuminated, c_X is the solar phase-angle coefficient and α is the solar phase angle in degrees. In Method I, the quantity X - 5 log [r Δ] + 2.50 log k is plotted (on the vertical or Y axis) against α, the solar phase angle; the slope equals c_X and the Y-intercept equals the normalized magnitude at a solar phase angle of zero degrees. The value of c_X in method I includes only changes due to the shadows of haze particles and clouds. In Method II, however, the quantity X - 5 log [r Δ] is plotted (on the vertical axis) against α and the slope includes both the changes due to shadows and changes in the fraction of Jupiter's disk that is illuminated. In the case of Jupiter there will be a 10-20 percent difference in slopes between Method I and Method II, but a negligible (<0.01 magnitude) change in the normalized magnitudes; however for Mars, Venus and the Moon, the difference in solar phase angle coefficients and normalized magnitudes will be much greater. The authors have used Method I in computing the solar phase-angle coefficients and normalized magnitudes because the 2.50 log k term does not change in a linear way with increasing α. Others, however, have more frequently used Method II.

The measured magnitudes of Jupiter corrected for extinction and transformation are listed in *Table 1* (p. 69). The first column in this table gives the UT date/time of the measurement, the second column gives the filter, the third and fourth columns give the apparent and X(1,α) magnitudes. The X(1,α) value is the normalized magnitude at a solar phase angle equal to α. The X(1,α) magnitude is calculated from:

$$X(1,0) = X - 5 \log [r\ \Delta] + 2.50 \log k \quad (2,)$$

where X is the apparent magnitude (in column 3), and the other terms are the same as in equation (1). The fifth and sixth columns give the mean air mass of Jupiter and the comparison star at the time of measurement, the seventh column gives the air temperature at the time of measurement and the eighth column gives the solar phase angle of Jupiter on the date of measurement. Each magnitude listed in the third column of Table 1 is a mean of three measurements. The measurements were made in the sequence SJSJSJCS where S is the three 10-second integration-time comparison star readings, C is three 10-second check star readings and each J is three 10-second Jupiter readings, or in a few cases ten 1-second readings. It sometimes became necessary to take 1-second integration time readings because the 10-second readings went off the photometer scale. All S, C and most of the J readings were preceded and followed by three 10-second sky brightness readings. A typical SJSJSJCS sequence took 30 minutes and so the times of measurement are reported only to a precision of 0. 01 day.

Table 1. Photoelectric Magnitude Measurements of Jupiter and Other Related Parameters,

Date	Filter	Magnitude Meas.	Magnitude Norm. (1,α)	Air Mass Planet	Air Mass C. Star	T(°C)	α(°)
(1999)							
Sep 05.24	B	1.77	8.41	1.58	1.38	15	9.3
Sep 05.26	V	2.68	9.32	1.37	1.23	15	9.3
Sep 05.28	R	3.16	9.80	1.25	1.15	15	9.3
Sep 05.30	I	3.05	9.68	1.18	1.09	15	9.3
Sep 25.15	B	1.94	8.46	1.89	1.63	9	6.1
Sep 25.17	V	2.86	9.38	1.61	1.42	9	6.1
Sep 25.20	R	3.34	9.87	1.42	1.28	8	6.1
Sep 25.22	I	3.20	9.73	1.29	1.18	7	6.1
Oct 23.05	B	2.06	8.52	1.41	1.31	9	0.2
Oct 23.07	V	2.93	9.39	1.54	1.43	8	0.2
Oct 23.09	R	3.40	9.87	2.07	1.86	8	0.2
Oct 23.11	I	3.29	9.76	1.78	1.61	7	0.2
Nov 04.05	B	2.05	8.53	1.67	1.55	-2	2.6
Nov 04.07	V	2.90	9.38	1.46	1.37	-4	2.6
Nov 04.10	R	3.39	9.87	1.27	1.20	-5	2.6
Nov 04.12	I	3.28	9.76	1.19	1.13	-6	2.6
(2000)							
Jan 06.07	B	1.59	8.44	1.18	1.04	-1	11.2
Jan 06.09	V	2.46	9.31	1.25	1.78	-1	11.2
Jan 06.11	R	2.94	9.79	1.37	1.14	-2	11.2
Jan 06.14	I	2.87	9.72	1.51	1.22	-2	11.2

Discussion

The normalized magnitude at a phase angle of zero degrees is related to X(1,α), through:

$$X(1,0) = X(1,\alpha) + c_X\alpha \qquad (3),$$

where X(1,α) is calculated from Equation 2, c_X is the solar phase-angle coefficient and α is the solar phase angle in degrees. Equation (3) is in the form of the linear equation y = mx + b where m = slope = cX and the y-intercept is X(1,0). A plot of X(1,α) (y-axis) versus α (x-axis) should therefore yield a straight line with a slope equal to c_X and an intercept equal to X(1,0). Such plots were done for each filter and are presented in *Figure 1* (right). The resulting X(1,0) and c_X values are summarized in *Table 2* (p. 70). Uncertainties were calculated in the same way as in Schmude, 1998 [179].

The results in Table 2 compare well with available previous results. The B(1,0) value in Table 2, -8.53±0.02, compares well with the value of-8.55±0.01 listed in Irvine *et al.*, 1968a [826]. The (V-R) value at a phase angle of 0° is +0.49, which is close to the value of +0.50 listed in Harris, 1961 [299]. Our mean (R-I) value, -0.13, is slightly different from the value of -0.03 listed in Harris, 1961 [299], but is consistent with the trend in Figure 5 of Irvine *et al.*, 1968b [262], which shows Jupiter being brighter in R compared to I. One of

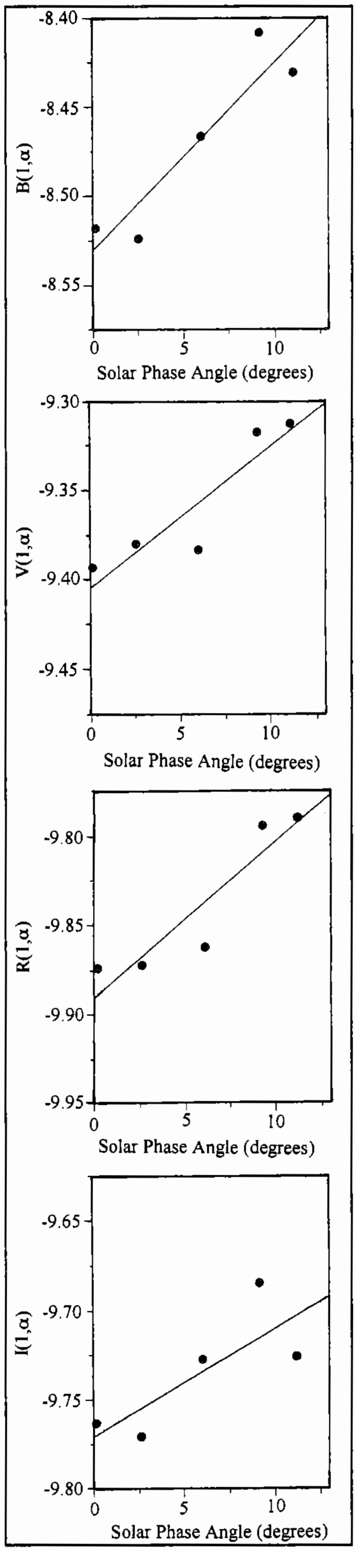


Figure 1. Plots of X(1,α) versus the solar phase angle (a) for the B, V, R and I Filters based on data collected during the 1999-2000 Apparition of Jupiter.

Table 2. Selected Photometric Constants for Jupiter in the 1999-2000 Apparition.		
Filter	Solar Phase-Angle Coefficient	Normalized Magnitude
B	c_B = 0.0104±0.0026	B(1,0) = -8.53±0.02
V	c_V = 0.0076±0.0021	V(1,0) = -9.40±0.01
R	c_R = 0.0082±0.0026	R(1,0) = -9.89±0.02
I	c_I = 0.0056±0.0024	I(1,0) = -9.76±0.02

the authors has measured a 0.1-0.2 magnitude change in the I-filter brightness of Saturn between 1996-98 [Schmude, 1999, 244] and a similar change may be taking place on Jupiter.

A summary of the V(1,0) and c_V values collected over the last 138 years is given in *Table 3* (below), along with pertinent explanations.

The measurements in 1951 and 1952 are much brighter than the values in Irvine *et al.*, 1968a [826] and in this study; this may be due to the faintness of the South Equatorial Belt of Jupiter during 1951-1952 [Rogers, 1995, 177]. The South Equatorial Belt also grew faint when the 1989-90 data were collected but had returned when the 1991 data were collected, which is consistent with the photometric measurements. We conclude that Jupiter became about 0.07 magnitudes brighter when the South Equatorial Belt disappeared in 1951-1952 and 1989. The normal South Equatorial Belt covers about 14 percent of Jupiter's disk according to images taken by Don Parker [Dobbins and Sheehan, 1999, 120-121]; this fact, along with the 0.07-magnitude brightening of Jupiter just mentioned, leads us to believe that the albedo of the South Equatorial Belt is about half that of the Equatorial Zone through the V-Filter.

The eye-based magnitude estimates of Zollner and Muller were corrected by Harris using "modern values of V for the comparison stars and modern phase functions" [Harris, 1961, 277]. Stanton [1999, 111], however, points out that for the average observer, eye-based magnitudes are related to Johnson V-filter magnitudes through:

$$m_V = V + 0.210\ (B\text{-}V) \qquad (4)$$

where m_V is the eye-based magnitude, V is the Johnson V-filter magnitude and (B-V) is the Johnson (B-V) color index. If a value of (B-V) = +0.85 is taken for Jupiter, based on Irvine *et al.* 1968a [826], and assuming that Zollner and Muller were "average observers" then a correction factor of -0.18 magnitudes must be added to their eye-based magnitudes to bring them in line with Johnson V-filter magnitudes. This correction factor was added to the normalized eye-based magnitudes and the results are listed in Table 3. The values are consistent with the selected V(1,0) value to within 0.05 magnitude.

Table 3. Summary of Magnitude Measurements of Jupiter, 1862-2000.

Apparition(s)	Filter	Normalized Magnitude	c_V	Method[a]	Source
1862-1864	eye-based	-9.44[b]	---	---	[Harris, 1961, 281]
1878-1890	eye-based	-9.35[b]	0.005	---	[Harris, 1961, 281]
1917	c	---	0.015	II	[Harris, 1961, 281][d]
1928	c	---	0.009	II	[Harris, 1961, 281][d]
1951	V	-9.46	---	---	[Harris, 1961, 281]
1952	V	-9.48	---	---	[Harris, 1961, 281]
1954	V	-9.39	---	---	[Harris, 1961, 281]
1963-1965	V	-9.40	0.008	II	[Irvine *et al.* 1968a, 826-827]
1989-1990	V	-9.44	0 0048	I	[Westfall, 1991, 49][e]
1989-1990		-9.44	0.0056	II	[Westfall, 1991, 49]
1991	V	-9.38	---	---	[Schmude, 1993, 136]
1994	V	-9.41	---	---	[Schmude and Bruton, 1995, 261]
1999-2000	V	-9.40	0.0076	I	this work
1999-2000	V	-9.40	0.0086	II	this work

[a]Method I and method II are explained in the text.
[b]Recalculated based on equation (4) in the text and assuming that the (B-V) value of Jupiter is +0.85.
[c]Filters other than the Johnson V filter were used.
[d]Calculated from Figure 3 in [Harris, 1961, 281].
[e]Recalculated by Schmude using Method I.

The V-filter magnitudes in Table 1 compare well with predicted values in the *Astronomical Almanac* [1998, E70; 1999, E68]; the mean discrepancy being less than 0.01 magnitudes. A minimum magnitude (i.e., maximum brightness) of V = -2.93 was measured for Jupiter on opposition day, 1999 Oct 23. Since Jupiter reached perihelion on May 20, 1999 [Bishop, 1998, 171] and was very close to perihelion in October, 1999, it was near the brightest that it could be on the day of opposition.

CONCLUSIONS

A series of photoelectric measurements of Jupiter were made between 1999 SEP 05 and 2000 JAN 06. The selected normalized magnitudes computed from Method I are: $B(1,0) = -8.53 \pm 0.02$, $V(1,0) = -9.40 \pm 0.01$, $R(1,0) = -9.89 \pm 0.02$ and $I(1,0) = -9.76 \pm 0.02$ while the corresponding solar phase angle coefficients are: $c_B = 0.0104 \pm 0.0026$, $c_V = 0.0076 \pm 0.0021$, $c_R = 0.0082 \pm 0.0026$ and $c_I = 0.0056 \pm 0.0024$. It is also concluded that eye-based magnitudes estimated between 1862 and 1890 are consistent with Johnson V-filter magnitudes to within 0.05 magnitudes. Finally we conclude that Jupiter increased in brightness by about 0.07 magnitudes when the South Equatorial Belt faded completely in 1951-1952 and 1989.

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WHOLE-DISK PHOTOMETRY OF JUPITER: 1991 AND 1994

By: John E. Westfall, Editor, J.A.L.P.O.

Dr. Schmude's immediately preceding article gives an opportunity for the Editor to report his unpublished photometry of Jupiter in 1991 and 1994. As with Dr. Schmude's observations, an SSP-3 photometer with wide-band filters was used throughout. In this brief report, the notation of his report is used whenever possible.

1991 JOVIAN PHOTOMETRY

The results of the 1991 FEB-APR photometry are given in *Table 1* (below). The instrument used was a 10.-2-cm (4.0-in) f/10 refractor, using a 1-second integration time with the Johnson V Filter only. Differential extinction and satellite-contribution corrections were applied, but not transformation corrections. The comparison star used was β Geminorum, a K0 star with (B - V) = +1.00 [USNO, 2000, H11] and with an assumed V = +1.139. Observations were timed so that the altitudes of Jupiter and the comparison star were nearly equal. In Table 1, the median altitudes are the altitudes of Jupiter and the comparison star, respectively.

The normalized, $V(1,\alpha)$, magnitudes were reduced as were this writer's 1990 measurements [Westfall, 1991], using two models that gave the results:

$$V(1,0) = V(1,\alpha) + (.0049\pm.0016)\,\alpha \qquad (1)$$

$$V(1,0) = V(1,\alpha) + (-12.31\pm3.35)\log k \qquad (2)$$

Table 1. Whole-Disk V-Photometry of Jupiter in 1991.

1994 UT Date (Mean)	Phase Angle °	C.M. (I) °	C.M. (II) °	Median Altitude ° °	Jovian Magnitude V	Jovian Magnitude V(1,α)
FEB 07.330	1.98	132	067	71.2/72.1	-2.521±.005	-9.320
13.319	3.22	350	239	70.8/71.0	-2.525±.003	-9.334
MAR 08.263	7.31	344	049	69.8/69.8	-2.415±.002	-9.319
09.257	7.46	127	193	70.3/70.7	-2.391±.002	-9.299
30.192	9.77	145	052	71.3/71.7	-2.269±.004	-9.308
APR 03.191	10.14	055	292	69.8/69.9	-2.216±.004	-9.282
09.173	10.49	266	097	70.1/70.4	-2.172±.003	-9.278
Mean						-9.305 ±0.009

The effect of phase angle (α) or phase (k) in both models was significant at the 5-percent level. The value of V(1,0) (i.e., $V(1,\alpha)$ with $\alpha = 0°$) and the standard errors (S.E.) of the two models were:

Model	V(1,0)	S.E.
(1)	-9.341±.013	±.013
(2)	-9.331±.008	±.012

Thus these models indicate that Jupiter was indicated as brighter than Schmude's 1991 measurements by 0.04 and 0.05 magnitudes, respectively.

1994 JOVIAN PHOTOMETRY

The writer conducted Jovian photometry in 1994 JUN-AUG, which included the July 16-22 period of impacts of fragments of Comet Shoemaker-Levy 9 with Jupiter, in order to investigate possible brightness changes due to those impacts. [Chodas and Yeomans, 1996, 12-16]. Unfortunately, this timing meant that the measurements had to be made when Jupiter was relatively low in the sky.

All measurements were made with a SSP-3 photometer and 9.0-cm f/11 Maksutov telescope, using Johnson V- and B-Filters. The results are summarized in *Table 2* (p. 73), where: SF = San Francisco (122°.5 W/37°.7 N, 25-m elevation, extinction coefficients: k_V = -0.30 mag./airmass; k_B = -0.35 mag./airmass; SB = Sierra Brooks, 120°.2 W/39°.6 N, 1606-m elevation, extinction coefficients: k_V = -0.25 mag./airmass; k_B = -0.30 mag./airmass. The comparison star used throughout was κ Virginis, a K2.5 star with V = +4.19 and (B - V) = +1.33 [USNO, 2000, H19]. As in 1991, differential extinction and satellite-contribution corrections were applied, but not transformation corrections.

Table 2. Whole-Disk V- and B-Photometry of Jupiter in 1994.

1994 UT Date (Mean)	Station	Phase Angle °	C.M. (I) °	C.M. (II) °	Median Altitude ° °	Jovian Apparent Magnitude V	B	(B - V)	Normal. Mag. V(1,0)	B(1,0)
JUN 07.230	SF	7.00	081	098	40.1/42.0	-2.325±.012	-1.433 ±.024	+0.892 ±.027	-9.310	-8.418
08.210	SF	7.14	227	237	40.1/42.0	-2.343±.009	-1.508 ±.030	+0.835 ±.031	-9.336	-8.501
09.222	SF	7.29	030	033	40.1/41.9	-2.335±.014	-1.449 ±.016	+0.886 ±.021	-9.335	-8.449
10.230	SF	7.43	195	190	40.0/41.6	-2.319±.024	-1.306 ±.035	+1.013 ±.042	-9.323	-8.310
24.230	SF	9.11	245	133	37.1/38.3	-2.255±.004	-1.379 ±.019	+0.876 ±.019	-9.335	-8.459
JUL 05.216	SB	10.04	169	333	32.4/33.5	-2.182±.008	-1.304 ±.034	+0.878 ±.035	-9.327	-8.449
11.242	SB	10.38	059	177	25.0/25.6	-2.134±.017	-1.263 ±.047	+0.871 ±.050	-9.318	-8.447
12.233	SB	10.43	209	320	27.1/27.9	-2.135±.024	-1.261 ±.039	+0.874 ±.046	-9.324	-8.450
13.241	SB	10.48	013	016	25.0/25.8	-2.094±.004	-1.230 ±.111	+0.868 ±.108	-9.290	-8.426
14.230	SB	10.52	162	257	26.7/27.5	-2.125±.006	-1.336 ±.239	+0.790 ±.245	-9.327	-8.518
15.235	SB	10.56	324	052	24.6/25.2	-2.067±.022	-1.199 ±.002	+0.868 ±.022	-9.274	-8.106
18.235	SB	10.66	077	142	23.5/24.3	-2.092±.008	-1.116 ±.026	+0.986 ±.031	-9.320	-8.344
19.237	SB	10.68	237	294	22.5/23.4	-2.100±.007	-1.110 ±.161	+0.828 ±.002	-9.331	-8.502
23.224	SB	10.76	137	164	22.9/23.7	-2.074±.023	-1.180 ±.034	+0.894 ±.041	-9.332	-8.438
24.227	SB	10.78	297	316	21.8/22.4	-2.061±.029	-1.187 ±.117	+0.874 ±.121	-9.326	-8.432
25.217	SB	10.79	086	098	23.3/24.0	-2.040±.008	-1.220 ±.038	+0.820 ±.039	-9.312	-8.492
AUG 06.201	SB	10.72	164	085	20.2/20.2	-1.951±.004	-1.035 ±.021	+0.913 ±.025	-9.295	-8.379
07.201	SB	10.70	322	235	19.6/19.6	-1.951±.080	-1.016 ±.154	+0.935 ±.174	-9.303	-8.368
Mean								+0.883 ±.015	-9.318 ±.004	-8.435 ±.014

It is clear from Table 2 that the B magnitudes show considerable scatter, primarily because the comparison star was comparatively faint in B. For this reason, the following analysis is confined to the V measurements.

As he did for 1990 and 1991, the writer used two models, which gave:

$$V(1,0) = V(1,\alpha) + (.0039\pm.0028)\ \alpha \qquad (3)$$

$$V(1,0) = V(1,\alpha) + (-6.68\pm4.78)\ \log k \qquad (4)$$

The effect of phase angle (α) or phase (k) in both models was not significant at the 5-percent level. nonetheless, the indicated value of V(1,0) (i.e., V(1,α) with α= 0°) and the standard errors (S.E.) of the two models were:

Model	V(1,0)	S.E.
(3)	-9.355±.028	±.017
(4)	-9.339±.016	±.017

Note that these models give a V_0 for Jupiter brighter than Schmude and Bruton's 1994 values by 0.05 and 0.07 magnitudes, respectively.

The finding that phase angle was not a significant factor for Jupiter's magnitude in mid-1994 may be due to the limited range of phase angle observed, but could also be due to changes in Jupiter's magnitude caused by the Comet Shoemaker-Levy 9 impacts. *Figure 1* (to right) shows the V(1,α) values for the observing period, plotted against time. Given the scatter among the measurements, and their limited number, there appears to be no evidence for a global V-magnitude change attributable to those impacts.

REFERENCES

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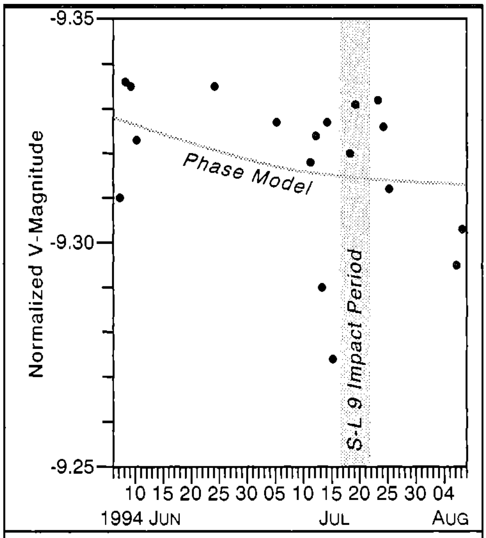

Figure 1. Normalized V-magnitudes measured for Jupiter near the period of the Comet Shoemaker-Levy 9 impacts.

Galilean Satellite Eclipse Timings: The 1994/95 Apparition

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Abstract

The A.L.P.O. Jupiter Section received 407 visual timings of the eclipses of Jupiter's Galilean satellites Io, Europa, and Ganymede from 45 observers for the 1994/95 Apparition (Callisto underwent no eclipses during this 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 was found to differ significantly in position from the E-2 Ephemeris, being 6.1±2.6 seconds "early" in its orbital position, while Europa and Ganymede did not differ significantly from the E-2 Ephemeris.

Introduction

The 1994/95 Apparition of Jupiter was the nineteenth studied by the A.L.P.O. Jupiter Section's Galilean Satellite Eclipse Timing Program. The satellites timed were Io (1), Europa (2), and Ganymede (3); Callisto (4) was not eclipsed in 1994/95. 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. 80). [Westfall 1983-84, 1986a, 1986b, 1987, 1988, 1989, 1991, 1992, 1994, 1996, 1998 and 1999]

Table 1 (below) lists some significant dates for the 1994/95 Jupiter Apparition. All dates and times in this report are in Universal Time (UT); also, an *apparition* is the period between successive conjunctions, while an *observing season* is the period of actual observation. The 1994/95 observing season began 55 days after conjunction, with Jupiter 43° west of the Sun; it ended 30 days before the next conjunction, at solar elongation 25° east.

Table 1. 1994/95 Jupiter Apparition Chronology.
[Meeus, 1995; U.S. Naval Observatory, 1993 and 1994]

		d	h
Conjunction with the Sun	1995	Nov 17	20
First Eclipse Timing	1995	Jan 11	16
Opposition to the Sun	1995	Jun 01	01
Closest Approach to Earth	1995	Jun 02	23
Last Eclipse Timing	1995	Nov 18	09
Conjunction with the Sun	1995	Dec 18	22

At closest approach, Jupiter's distance from the Earth was 4.32470 AU [astronomical units; 1 AU = 149,597,870 km], with an equatorial diameter of 45".54. At opposition, Jupiter had a visual magnitude of -2.6 and a geocentric declination of -21°.2 so that observers in the Earth's Southern Hemisphere were favored over those in the Northern Hemisphere for this apparition.

Observations

The 407 timings received for 1994/95 bring our 18-apparition total to 8644 visual timings, but represent a 28-percent drop from the 1993/94 Apparition. A total of 45 persons made observations and are listed in *Table 2* (p. 75) along with their nationalities, telescope apertures and number of timings. The timings themselves are given in *Table 8* (pp. 81-82), the observers and their telescope apertures identified by the numbers given in the left-hand column of Table 2.

Contributing to this total were 290 timings (71 percent) by 17 New Zealand and Australian observers coordinated by Brian Loader of the Royal Astronomical Society of New Zealand. As Jupiter moved farther south, the Australia-New Zealand observers' contribution became increasingly significant. Five new contributors joined our program in 1994/95, but 15 of the contributors from the last previous apparition were not heard from. The 1994/95 observers were fairly productive, averaging 9.0 timings per observer; the 19-apparition

Table 2. Participating Observers, Galilean Satellite Eclipse Timings, 1994/95 Apparition.

Ob. No.	Observer	Nationality	Tele. Aper. cm	No. of Timings
1	Abrahams, W.	Australia	6.	1
2	Allely, T.	N. Zealand	10.	3
3	Bembrick, C.	Australia	7.	17
3a	"	"	10.	3
4	Blanksby, J.	Australia	15.	32
5	Bock, P.	USA (VA)	12.7	3
6	Brylowski, Z.	Poland	15.	2
7	Busa, S.	Hungary	20.	9
8	Castaño, J.	Spain	8.0	3
9	Chen, D.-h.	P.R. China	11.4	18
10	Dickie, R.	N. Zealand	20.	10
10a	"	"	25.	2
11	Garcia, J.	Portugal	40.0	3
12	George, M.	Australia	13.	3
12a	"	"	20.	1
13	Gonçalves, R.	Portugal	15.0	1
14	Haas, W.	USA (NM)	31.75	1
15	Hays, R.	USA (IL)	15.	9
16	Keszthelyi, D.	Hungary	5.0	3
17	Kruijshoop, A.	Australia	20.	11
18	Larkin, P.	Australia	20.	40
19	Loader, B.	N. Zealand	20.	13
20	Mac Donald, M.	N. Zealand	25.	19
20a	"	"	30.	7
21	MacDougal, C.	USA (FL)	15.	6
22	Maluf, W.	Brazil	60.	5
23	Matthews, T.	Australia	10.	37
24	Moller, H.	Australia	20.	36
25	Nyári, S.	Hungary	5.75	5
26	O'Yiang, T.-j.	P.R. China	10.0	12
27	Pan, X.-q.	P.R. China	6.3	2
28	Patak, A.	Hungary	30.5	3
29	Priestley, J.	N. Zealand	20.	2
30	Samolyk, G.	USA (WI)	32.	1
30a	"	"	65.	2
31	Shi, Q.-D.	P.R. China	8.	1
31a	"	"	10.	3
32	Skilton, P.	Australia	6.	1
32a	"	"	15.	11
33	Smith, C.	Australia	25.	14
34	Stubbings, R.	Australia	25.	11
35	Sullivan, M.	Canada	11.4	7
36	Szabó, S.	Hungary	6.3	2
37	Szöllosi, A.	Hungary	6.	1
37a	"	"	11.4	4
38	Testa, L.	Italy	20.	1
39	Thienpont, E.	Belgium	25.4	1
40	Van Gestel, J.	Belgium	20.	1
41	Waraczynski, S.	USA (WI)	25.4	2
41a	"	"	31.75	1
42	Westfall, J.	USA (CA)	27.8	2
43	Wolf, G.	N. Zealand	6.	2
43a	"	"	12.	14
44	Yiang, H.-t.	P.R. China	7.5	2
45	Zhang, X.-j.	P.R. China	8.	1

Number of Observers and Observations by Nationality

Nationality	Observers	Timings	Timings per Observer
Australia	11	218	19.8
Belgium	2	2	1.0
Brazil	1	5	5.0
Canada	1	7	7.0
Hungary	6	27	4.5
Italy	1	1	1.0
New Zealand	6	72	12.0
Poland	1	2	2.0
Portugal	2	4	2.0
P.R. China	6	39	6.5
Spain	1	3	3.0
United States	7	27	3.9
TOTAL	45	407	9.04

Table 3. Long-Term Participating Observers, Galilean Satellite Eclipse Timing Program (through 1994/95).

(The first number is the number of apparitions; the second the number of timings.)

William Abrahams (10; 46)
Colin Bembrick (9; 97)
J.L. Blanksby (8; 220)
Paul H. Bock (7; 41)
Chen Dong Hua (6; 120)
Ross Dickie (6; 77)
Joaquim Garcia (8; 189)
Martin George (6; 21)
Rui Gonçalves (8; 156)
Walter Haas (11; 73)
Robert Hays (9; 101)
Alfred Kruijshoop (9; 155)
Patricia Larkin (6; 176)
Brian Loader (14; 299)
Malcolm MacDonald (8; 120)
Craig MacDougal (10; 115)
Terry Matthews (5; 129)
Harry Moller (7; 269)
John Priestly (11; 104)
Gerry Samolyk (5; 17)
Charlie Smith (8; 168)
Luigi Testa (5; 62)
John Westfall (18; 340)

average is only 8.1 timings per observer per apparition. We wish here to recognize those observers for the 1994/95 Apparition who had contributed observations for at five or more apparitions. *Table 3* (to left) gives their names, number of apparitions and number of timings.

Timings for the 1994/95 Apparition were made by observers in 12 countries in 5 continents. There continue longitude gaps in our coverage, such as much of the Pacific Basin and Asia. Also, it is disappointing that less than one-sixth of the observers were from the United States and that the Americans averaged relatively few timings per observer.

The size of telescope used significantly affected the timing results, as will be shown later. Most observers used a single telescope, but ten used two instruments. The 56 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, although the median size was 15 cm; both values typical for recent apparitions. Eight small telescopes, 5.0 to 7.5 cm in aperture, were used, comprising 14 percent of the instruments. The seven fairly large telescopes, 31.75 to 65 cm aperture, constituted 12 per cent of those used. The range of apertures continues to be large, showing that almost any size of telescope can be used in our program.

Table 4. Number of Telescopes Used, by Aperture, 1994/95 Apparition.

Aperture (cm)	No. of Teles.	Aperture (cm)	No. of Teles.
5.0-5.75	2	20.0	10
6.0-6.3	6	25.0-25.4	6
7.0-7.5	2	27.8	1
8.0	3	30.0-30.5	2
10.0	5	31.75-32.0	3
11.4	3	35.6	1
12.0	1	40.0	1
12.7-13.0	2	60.0	1
15.0	6	65.0	1

Table 5. Summary Statistics By Event Type, 1994/95 Apparition.	
(1 = Io; 2 = Europa; 3 = Ganymede; D = Disappearance; R = Reappearance)	
Event Type	Number of Timings
1D	93
1R	118
1	211
2D	42
2R	64
2	106
3D	46
3R	44
3	90
D	181
R	226
Total	407

Table 5 (left) gives the number of timings by satellite and type of event. As always, the closer a satellite is to Jupiter, the more the timings made of its eclipses because the frequency of eclipses decreases outward from Jupiter. As with all previous apparitions, there is a bias toward reappearance timings; in this case with 56 percent of the timed events being reappearances.

As is usual, the number of timings varied by month, as shown in *Table 6* (upper right) and *Figure 1* (below).

The most frequent observing was for the five months nearest opposition, when Jupiter was above the horizon for most of the night. There is the usual bias toward post-opposition timings. Observers should make more pre-opposition timings in the future, even though this means observing after midnight.

The pattern in Figure 1 reflects the visibility chronology for the different eclipse phenomena for the different satellites. Eclipse disappearances of Io are usually visible only before opposition, and reappearances visible only after. This is usually true for Europa as well; but when Jupiter is near aphelion both the disappearance and reappearance events of the same eclipse can be seen near quadrature, as was observed for the 1995 Mar 14 eclipse. Disappear-ances and reappearances for the same eclipses of Ganymede can be observed for most of an apparition except near opposition or conjunction.

Table 6. Number of Timings by Month, 1994/95 Apparition.

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

1995	Jan	(043°-061°W)	11
	Feb	(061°-086°W)	17
	Mar	(086°-115°W)	35
	Apr	(115°-146°W)	53
	May	(146°-178°W)	55
	Jun	(178°W-148°E)	55
	Jul	(148°-117°E)	65
	Aug	(117°-089°E)	51
	Sep	(089°-063°E)	44
	Oct	(063°-039°E)	19
	Nov	(039°-025°E)	2
Before Opposition		171	(42.0 %)
After Opposition		236	(58.0 %)

Reduction

Reduction began by grouping the timings by satellite and by whether they were of a disappearance or a reappearance. The reported times 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

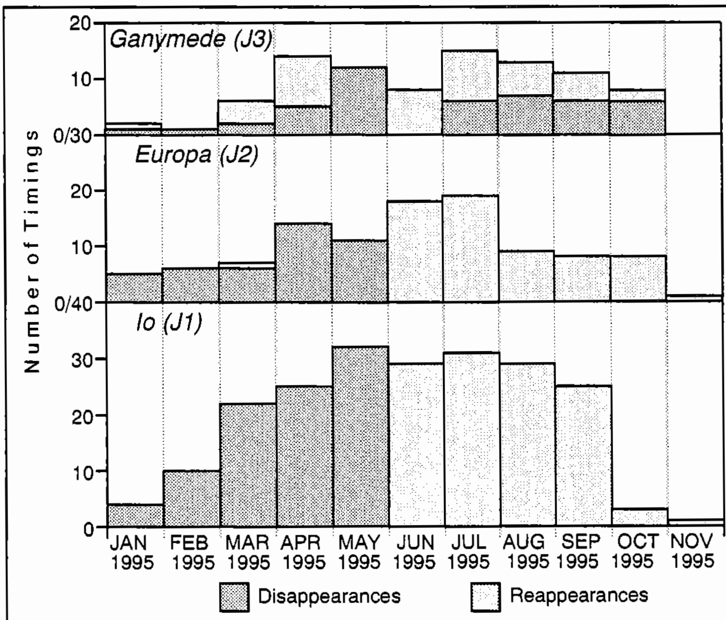

Figure 1. Number of timings of Galilean satellite eclipses by month, satellite, and type of event, during the 1994/95 Apparition of Jupiter.

from the observed time; a positive residual meant that an event was "late"; a negative residual, These residuals are given in the right-hand column in Table 8. The next step was to correct for aperture with a linear regression model in which the dependent variable (y) was the residual in seconds and the independent variable (x) was the reciprocal of the telescope aperture in centimeters. The form of the model is:

$$(1) \quad y_{est} = A + Bx,$$

where A and B are the regression coefficients.

A total of 50 timings, or 12.3 percent, were not used; 15 had obvious blunders in recording the correct time, while 35 were deleted because of differences from the regression model that were significant at the 5-percent level (i.e., would occur by chance under 5 percent of the time) as measured by the standard error (given in *Table 7*, p. 78). For each satellite and type of event this 5-percent significance criterion was applied twice in succession. The timings not used for the 1994/95 Apparition are shown by italicized residuals in Table 7.

Two statistics describe how well Equation (1) fits the observed residuals. One, the standard error (S.E.), is the root-mean-square difference between Equation 1 and each observation. The other statistic, R^2, measures what proportion of the variance (squared differences among the residuals) is removed by Equation (1).

To check the reduction method described above, the writer estimated the diameter of each satellite by taking the differences between its predicted disappearance and reappearance residuals to approximate 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.

1994/95 Results

Details for the 1994/95 Apparition follow in *Table 7* (p. 78). This table gives results for each of the three 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 entry is the mean residual for the timings that were retained, followed by the coefficient of variation (R^2), 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 orbital residual, which measures the amount the satellite is "behind" (positive) or "ahead of" (negative) its predicted position is given in seconds, kilometers, and degrees of orbital arc in Table 7.

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" Galileo-derived satellite diameter (Io, 3638 km; Europa, 3130 km; and Ganymede, 5268 km [United States Naval Observatory, 2000, p. F3]).

Table 7 gives the statistical significance of the differences of the following values from zero: R^2, the orbital residual (in seconds of time only), and the difference between the estimated and the standard satellite diameters. Statistical significance is shown by "(ns)" for not significant, "*" significant at the 5-percent level, and "**" 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^2 values, in five of the six cases the aperture-regression model significantly reduced the variance among the timings. Nonetheless, only with the eclipse reappearances of Ganymede was the majority of the variance among the timings accounted 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

Table 7. Galilean Satellite Timings Compared With E-2 Ephemeris, 1994/95.

	Satellite		
	Io	Europa	Ganymede
Disappearance			
Number of Observations	93 (84)	42 (37)	46 (41)
Mean Residual (seconds)	+80.2 ±1.7	+97.5 ±3.3	+382.8 ±9.9
Coefficients:			
R^2	0.0373 (ns)	0.2594**	0.1318*
A (seconds)	+86.9 ±4.1	+121.7 ±7.5	+418.7 ±24.8
B	-93 ±52	-330 ±94	-877 ±361
Standard Error (seconds)	±15.3	±17.4	±59.9
Aperture Residual (seconds):			
6-cm	+71 ±5	+67 ±9	+272 ±38
10-cm	+78 ±2	+89 ±4	+331 ±16
20-cm	+82 ±2	+105 ±4	+375 ±11
40-cm	+85 ±3	+113 ±5	+397 ±17
Reappearance			
Number of Observations	118 (99)	64 (59)	44 (37)
Mean Residual (seconds)	-87.6 ±1.5	-93.4 ±4.1	-325.8 ±12.7
Coefficients:			
R^2	0.1363**	0.2668**	0.5254**
A (seconds)	-99.0 ±3.2	-125.7 ±7.9	-427.5 ±18.6
B	+171±44	+453 ±100	+1234 ±198
Standard Error (seconds)	±14.1	±27.4	±54.0
Aperture Residual (seconds):			
6-cm	-71 ±5	-50±10	-222 ±19
10-cm	-82 ±2	-80 ±5	-304 ±10
20-cm	-90 ±2	-103 ±4	-366 ±11
40-cm	-95 ±2	-114 ±6	-397 ±14
Orbital Residual			
Seconds	-6.1 ±2.6*	-2.0 ±5.4 (ns)	-4.4 ±15.5 (ns)
Orbital Arc (degrees)	-0.014 ±.006	-0.002 ±.006	-0.003 ±.009
Kilometers	-105 ±45	-27 ±75	-48 ±169
Diameter			
Seconds	186.7 ±5.2	247.3 ±10.9	846.1 ±31.0
Kilometers	3100 ±87	3023 ±133	6059 ±222
Compared with Standard (km)	-205 ±87** (-14.8%)	-107 ±133 (ns) (-3.4%)	+791 ±222 ** (+15.0%)

and phase angle of Jupiter, apparent 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 standard error gives the uncertainty of the timings, which increased with distance from Jupiter as follows (the standard error of disappearance is given first, followed by that of reappearance): 15 and 14 seconds for Io, 17 and 27 seconds for Europa, and 60 and 54 seconds for Ganymede. This trend is expected as the satellites move more slowly, and Jupiter's shadow penumbra becomes broader, with increasing distance from the planet.

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 differed significantly from the E-2 Ephemeris only for Io, which appeared to be 6.1±2.6 seconds "early" in its orbit, a difference significant at the 5-percent level.

The accuracy of our method of analysis was roughly assessed 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 Galileo Mission. There were significant difference for Io and Ganymede; Io too small and Ganymede too large. Europa's estimated diameter did not differ significantly from the standard values. The signs of the 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 outward in the satellite system.

Comparison with 1993/94 Apparition

The apparent changes in satellite position between the 1993/94 and 1994/95 apparitions were found by subtracting the former from the latter, giving:

Io	-2.9 ±3.6 s
Europa	+2.2 ±7.7 s
Ganymede	+19.5 ±24.9 s

None of these apparent changes is statistically significant; there was no "acceleration" or "decelleration" of any satellite between one apparition and the next.

Long-Term Results

The orbital residuals for Io, Europa, Ganymede, and Callisto for the 18 apparitions from 1976/77 through 1994/95 are graphed in *Figure 2* (below; there were insufficient observations for 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 equal at least about ±2 standard errors.

The diagram hints at cyclical variations for some of the satellites, particularly Europa and Ganymede, perhaps in a 12-year cycle reflecting Jupiter's orbital period. We hope that sufficient timings for enough future apparitions will reveal such long-term patterns in the deviations.

Conclusion

We encourage suitably-equipped observers to use their CCD or video cameras to time the eclipses of Jupiter's four major satellites and report their results to the program headed by Anthony Mallama [E-mail: tmallama@stx.com ; Mallama, 1991; Mallama *et al.*, 1994]; 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.

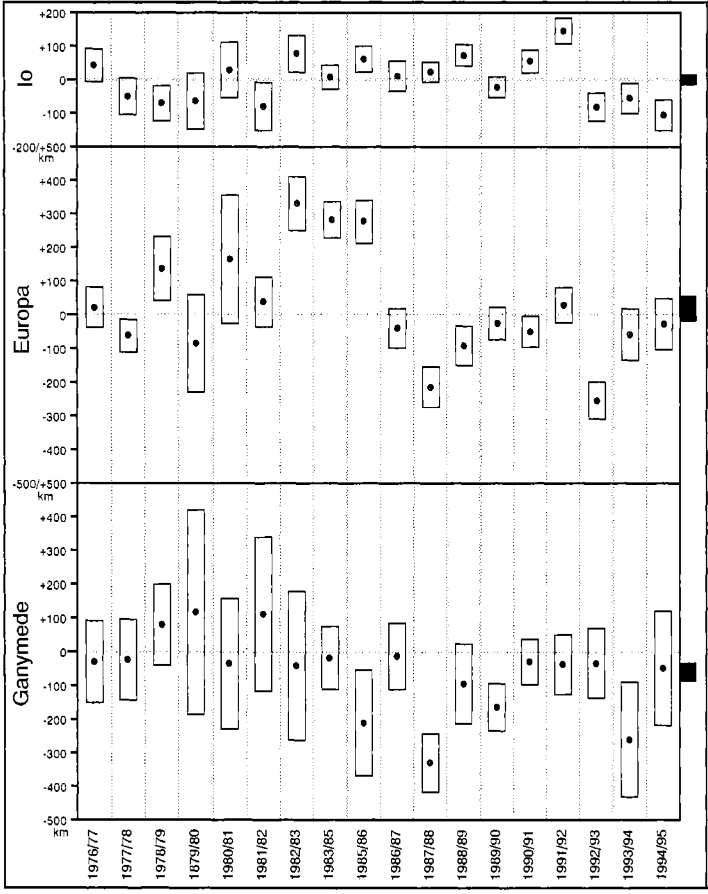

Figure 2. Deviations in kilometers of the Galilean satellites Io, Europa and Ganymede from the JPL E-2 Ephemeris for the 1976/77 - 1994/95 Apparitions. The black dot for each apparition represents the estimated deviation of each satellite, while the height of each open bar represents the ±1-standard deviation range of the estimate. The black rectangles on the right edge of the graph represent the ±1-standard deviation range of the 18-apparition mean deviation; none of the three long-term means are significantly different from 0 at the 5-percent level of confidence. (Callisto is not included because it undergoes eclipses by Jupiter in only 3 years out of 6, and was not eclipsed during the 1994/95 Apparition.)

We hope that both recent and long-term participants 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 (inside back cover). He can send you instructions,with 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 *The Handbook of the British Astronomical Association*, as well as every month in *Sky & Telescope* magazine.

We thank the many observers who participated in this A.L.P.O. project for the 1994/95 Apparition of Jupiter. Remember that your timings become more accurate as you accumulate experience, and also that, the more visual timings that are made, the more accurate our results.

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(Table 8 follows on pp. 81-82.)

Table 8. Galilean Satellie Eclipse Timings, 1994/95 Apparition.

Io Disappearances

1995

UT Date mmdd	Geometry r °	Obs. No.	Cond. STB	Res. sec.
0111	0.7-18	2	002	+90
0115	0.7-18	7	—	+75
0125	0.8-18	24	011	+70
		23	000	+87
0203	0.9-18	18	000	+90
0210	1.0-18	24	020	+78
		23	000	+91
		18	010	+98
0217	1.0-18	23	001	+95
		24	012	+96
0223	1.0-18	7	—	+77
0224	1.0-18	24	112	*+37*
		23	002	+54
0226	1.0-18	2	101	+81
0302	1.0-18	8	—	*+26*
0305	1.0-18	23	000	+83
		4	000	+91
		33	010	+107
		17	000	+109
		9	221	*+138*
0307	1.0-18	10	100	+92
0311	1.0-17	7	—	+70
0312	1.0-17	24	011	+82
		23	000	+99
		26	211	+109
0314	1.0-17	19	100	+90
		33	101	+110
0316	1.0-17	15	100	+94
0318	1.0-17	8	—	*+20*
0319	1.0-17	23	000	+87
		24	012	+90
0321	1.0-17	19	101	+83
		23	001	+87
		33	101	+102
0323	1.0-17	19	200	+79
0330	0.9-17	18	000	+90
0403	0.9-17	7	—	*+36*
0404	0.9-17	24	010	+82
		23	000	+88
0406	0.9-17	18	010	+66
		23	000	+74
		24	010	+83
		1	100	+87
		33	100	+99
		17	000	+105
0411	0.8-17	23	000	+86
		24	012	+86
0413	0.8-17	20a	000	+69
		24	022	+81
0415	0.8-17	32	010	+39
		20a	000	+79
		43	001	+91
		18	001	+94
0422	0.7-17	4	110	+72
		32a	000	+87
		18	000	+90
0427	0.6-17	4	112	+76
		18	000	+95
0429	0.6-17	24	010	+77
		3a	000	+83
		23	000	+87
0501	0.6-17	43a	010	+77
0504	0.5-17	23	010	+74
0506	0.5-17	27	011	+53
		20	000	+56
		26	100	+74
		31a	011	+90
0508	0.5-17	43a	010	+42
		19	020	+49
0508	0.5-17	20	000	+57
		4	100	+68
		18	000	+88
0513	0.4-17	44	010	*-10*
		9	000	+60
		20	001	+73
		10	100	+77
		33	012	+85
0515	0.3-17	3	000	+73
		24	112	+81
0520	0.2-17	9	211	+76
0522	0.2-17	4	110	+52
		24	020	+71
		18	010	+81
0524	0.2-17	20	000	*+45*
		35	010	+81
		20	000	+83
0526	0.1-17	15	102	+59
		21	211	+82
0527	0.1-17	11	22–	*+25*
		28	—	+70
0529	0.1-17	3	100	*+24*
		23	000	+54
0531	0.0-17	23	000	+40

Io Reappearances

1995

UT Date mmdd	Geometry r °	Obs. No.	Cond. STB	Res. sec.
0602	0.0-17	18	000	-88
0605	0.1-17	11	2—	*+97*
0607	0.1-17	26	101	-73
0609	0.2-17	43a	010	*-2964*
0611	0.2-17	15	101	-93
0614	0.3-17	24	112	-63
0616	0.3-17	24	110	-72
0621	0.4-17	18	010	-87
0623	0.4-17	10a	010	-95
		18	000	-95
		4	120	-62
		31a	011	-57
		20	000	*-45*
0625	0.5-17	17	100	-103
		18	000	-97
		4	100	-96
		32a	000	-96
		34	001	-96
		20	000	-94
		35	100	-88
		43a	110	*+139*
0627	0.5-17	22	000	-108
0628	0.5-17	6	121	-101
		40	001	-94
		36	—	-75
		38	100	-69
		25	—	*-17*
0630	0.6-17	9	000	-86
		31	211	-68
0702	0.6-17	32a	000	-98
		23	000	-94
		4	100	-93
		3	000	-76
0704	0.6-16	15	000	-103
0705	0.6-16	22	000	-90
0707	0.7-16	9	010	-78
		3	000	-66
0709	0.7-16	18	000	-109
		26	001	-109
		4	002	-92
		43a	100	*+135*
0711	0.7-16	35	001	*-187*
		10	101	*-155*
		20a	010	*-136*
0713	0.7-16	22	000	-100
0716	0.8-16	9	000	-92
		3	000	-71
0718	0.8-16	18	000	-94
		34	000	-94
		4	010	-88
		3	000	-86
0720	0.8-16	41a	110	-106
		21	221	-98
		30	111	-78
0721	0.9-16	11	00–	-83
		16	—	*-3*
0725	0.9-16	19	000	-111
		23	000	-98
		43a	000	*+224*
0728	0.9-16	22	000	-88
0801	1.0-16	10a	000	-101
		34	000	-101
		23	000	-97
		3	000	-87
		43a	010	*+131*
0803	1.0-16	10	001	-107
0806	1.0-16	7	—	-122
		6	122	*-31*
		25	—	*+26*
0808	1.0-16	9	000	*-129*
		26	120	-56
0810	1.0-16	20	000	-89
		3	000	-74
		12	010	-58
0812	1.0-16	41	111	-103
		15	000	-99
0817	1.0-16	17	000	-114
		12	000	-94
		4	100	-91
		3	000	-85
0824	1.1-16	4	100	-88
		9	000	-79
		26	100	-79
		20	020	-59
		12	200	*-47*
0826	1.1-16	19	000	-102
		20	000	-67
0831	1.1-16	18	000	-86
		26	100	-78
0902	1.1-16	18	000	-100
		32a	000	-98
		4	001	-95
		34	110	-92
		20a	000	-79
		43a	110	*+114*
0904	1.1-16	14	210	-118
0909	1.1-16	34	000	-106
		18	100	-102
		4	001	-94
		20a	000	-78
0916	1.0-16	34	000	-96
		18	010	-86
		4	100	-84
		24	110	-77
		9	222	-64
		26	100	-57
		23	000	-53
0918	1.0-16	10	101	-92
0923	1.0-16	24	110	*-130*
0925	1.0-16	32a	000	-103
		18	000	-94
		4	100	-87
		20	020	*+7*
0927	1.0-16	42	000	-84
1011	0.9-15	20a	020	-71
1018	0.8-15	20	100	-67
1025	0.7-15	23	010	-72
1110	0.5-15	4	221	-61

Europa Disappearances

1995

UT Date mmdd	Geometry r °	Obs. No.	Cond. STB	Res. sec.
0116	1.2-31	2	202	+81
0123	1.3-31	4	100	+79
		33	101	+132
0130	1.4-31	23	000	+85
		24	010	+118
0217	1.6-30	20a	010	+137
0224	1.6-30	23	100	+75
		4	000	+95
		18	000	+105
		24	210	+108
		17	000	+129
0314	1.6-30	19	200	+110
0318	1.6-30	37a	—	*+33*
0321	1.6-30	19	101	+118
		33	101	+133
0325	1.6-30	37a	—	+87
0328	1.5-29	4	020	+80
0404	1.4-29	4	001	+74
		23	000	+88
		24	010	+94
0411	1.3-29	23	001	+60
		24	112	+76
0415	1.3-29	4	201	+89
		43	001	+95
		18	001	+115
0422	1.1-29	4	010	+93
		18	010	+107
		32a	000	+110
0429	0.9-29	24	010	+92
		3a	000	+113
		23	000	+115
0503	0.9-29	21	111	+115
0506	0.8-28	27	011	+62
		26	000	+97
		31a	011	+97
0510	0.7-28	20	000	+98
0517	0.5-28	4	011	+71
0524	0.2-28	20	000	*+45*
		24	020	*+50*
0531	0.0-28	23	000	*+39*
		24	010	*+39*
		9	221	+76

Europa Reappearances

1995

UT Date mmdd	Geometry r °	Obs. No.	Cond. STB	Res. sec.
0314	0.0-29	33	101	-46
0604	0.1-27	19	000	-96
		34	100	-51
0607	0.2-27	7	—	-69
0611	0.3-26	24	222	-67
		23	012	-30
0615	0.4-26	37a	—	-61
0618	0.5-26	24	010	-126
		9	211	-53
0625	0.7-26	18	000	-133
		3	000	-91
		4	010	-86
		9	101	-86
		19	200	*-41*
		45	000	-34
		43a	110	*+115*
0629	0.8-26	35	001	-139
		22	000	-115
		21	211	-112

Table 8—*Continued.*

UT Date mmdd	Geometry r	Geometry °	Obs. No.	Cond. STB	Res. sec.
0702	0.9	-26	24	210	-115
0706	1.0	-26	43a	000	*+141*
0709	1.1	-26	28	——	-136
			7	——	-107
			25	——	-36
			16	——	+10
0713	1.2	-25	33	102	-133
			10	001	-111
0720	1.2	-25	34	000	-119
			3	000	-106
			4	010	-105
			9	100	-86
			18	010	-75
0724	1.4	-25	5	000	-123
			41	011	-122
			21	021	-115
0727	1.4	-25	9	222	-90
			26	120	-54
0731	1.5	-25	35	100	-120
0807	1.6	-25	20	010	-112
0810	1.6	-24	13	00–	-87
0814	1.6	-24	17	000	-142
			29	100	-141
			4	000	-121
			23	000	-120
			20	000	-90
			3	000	-89
0821	1.7	-24	12a	100	-113
0915	1.6	-23	18	000	-125
			34	000	-115
			32a	010	-103
			23	002	-72
			20	020	*-43*
0922	1.6	-23	18	010	-91
			9	111	-90
			26	110	-44
1010	1.4	-22	19	001	-109
			20	000	-87
1017	1.3	-22	18	010	-123
			34	110	-97
			32a	000	-94
			19	100	-91
			20	110	-53
1024	1.1	-22	23	000	-92
1118	0.7	-21	18	102	-32
Ganymede Disappearances					
1995					
0117	1.7	-53	24	102	+334
0222	2.4	-52	35	111	+318
0301	2.4	-52	4	020	+376
			18	010	+381
0406	2.1	-51	23	000	+407
			24	110	+447
			18	000	+452
			17	100	+459
			33	100	+491
0512	0.8	-50	15	101	+374
0519	0.5	-50	43a	010	*+44*
			24	110	+372
			4	000	+383
			32a	000	+420
			18	000	+426
			17	000	+448
			33	101	+469
0526	0.2	-50	24	110	+260
			23	000	+329
			18	000	+354
			33	200	+392
0701	0.2	-48	3	000	+302
			24	010	+329
0723	0.8	-48	5	000	+235
			15	000	+391
0730	1.0	-47	35	010	+323
			19	000	+395
0806	1.1	-47	23	010	+327
			10	001	+415
0813	1.2	-47	3	000	+289
			23	000	+351
			4	101	+371
			34	000	+388
			17	100	+392
0904	1.3	-46	5	001	+318
			15	100	+366
			30a	111	+397
0918	1.2	-45	43a	111	*+50*
			18	020	+260
0925	1.1	-46	24	010	+265
1002	0.9	-44	7	——	+297
1031	0.7	-43	3	000	*+127*
			32a	220	*+157*
			4	110	*+193*
			18	102	+264
			17	100	+308
Ganymede Reappearances					
1995					
0117	0.7	-54	24	112	-316
0316	1.3	-52	8	–1–	-214
0323	1.2	-52	21	111	-370
0330	1.1	-52	18	010	-381
			42	000	-377
0406	1.0	-52	33	100	-458
			17	000	-427
			18	000	-390
			24	010	-378
0406	1.0	-52	23	000	-372
0421	0.6	-51	37a	——	-321
			36	——	-320
			25	——	*+161*
			7	——	*+662*
0603	0.0	-50	39	001	*-108*
0617	0.7	-49	32a	020	-441
0624	1.0	-49	10	000	-392
			18	110	-349
			3a	000	-343
			4	200	-342
			9	111	-300
			43a	010	*+224*
0701	1.3	-49	3	000	-351
			24	010	-276
0708	1.6	-49	28	——	-325
			37	——	-253
			25	——	-196
			16	——	-107
0730	2.2	-48	19	000	-389
			10	000	-365
			43a	011	*+146*
0806	2.4	-47	10	101	-370
			26	102	-334
			23	020	-256
			20	000	*-216*
			9	222	*-98*
0813	2.5	-47	23	020	-202
0911	2.5	-46	29	000	-410
			18	011	-341
			3	000	-264
0918	2.5	-46	9	111	-263
			44	100	-178
1010	2.1	-45	30a	111	-347
			15	100	-336

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. *Obs. No.:* Observer number as listed in the first column in Table 2 (p. 75).

D. *Cond.:* Conditions of observation; in order, seeing (S), transparency (T), and field brightness (B). 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 +61 seconds prior to 1995 Nov 05, and +62 seconds thereafter. Italicized residuals denote timings that were not used in the regression analysis because either they were obviously in error or because they differed from the regression model at the 5-percent significance level.

The Domes of the Rima Birt Region

By: P.G. Salimbeni, R. Lena, G. Mengoli, E. Douglass and G. Santacana; Geologic Lunar Research Group (GLR)

Abstract

In this paper we study three domes that have been observed in the Rima Birt region. Two of them are bisected by the Rima itself. One of the bisected domes lies to the west of the dome located at ξ = -.155/η = -.347(9°.51 W/20°.30 S) and shows the same appearance and dimensions as -155-347. The approximate location is ξ = -.161/η = -.349 (9°.89 W/20°.43 S) and it appears to need very specific lighting conditions for its observation, indicated by the fact that it has been described by few observers until now and has appeared only twice in the reports of the A.L.P.O. Lunar Dome Survey of the last 30 years.

Introduction: General Geology of Lunar Domes

Lunar domes are gentle swellings between 3 and 60 km across, and are at most a few hundred meters in height. Most have very low angles of inclination, only a few degrees at most. This makes domes similar to Earth's shield volcanoes. Many have a central "pit crater", which occurs upon magma withdrawal with collapse about the vent.

The distribution of domes on the lunar surface favors the Western Hemisphere [IAU directions] of the Moon. The large cluster of 28 domes in the well-studied Hortensius-Milichius-Tobias Mayer region, along with a greater expanse of maria accounts for the greater number of domes in the Western Hemisphere.

Domes probably formed in the latter stages of volcanism on the moon. Early-stage lavas were very fluid, due to their high heat, massive volumes, and mineralogy. Mineral composition was particularly important, as lunar lavas are mafic in composition (low silica content, high metal oxide content) which tend to be very fluid (low viscosity). Because of this, the original lavas on the Moon flowed from eruptive fissures and did not produce 'volcanoes'. An example of this kind of volcanic activity on earth is the 'Great Crack' fissure eruption of 1823 in the Hawaiian volcanoes. The vast majority of these eruptive fissures were covered over by their lavas, and so cannot be seen. This is as opposed to felsic lavas (high silica content), which on Earth produce steep-sided, rhyolitic domes with short lava runs. Over time, the erupting lavas cooled, decreased in flow rate, and began to crystallize. This changed the characteristics of the lava, decreasing its fluidity so that it began to 'pile up' around its vent, forming low shield-like volcanoes. This is the source of our lunar domes.

Geology of the Rima Birt Section

The Rima Birt Section of the Moon represents a vast lava field in the Mare Nubium region. The rima itself occurs within a massive flooded crater, somewhat over 200 km in diameter. While the outline of the eastern half of this crater can been seen in the adjoining highland region, the western half can only be visualized by the mare ridges, which mark the rim. It is likely that the faults created by this impact produced the conduits for lavas in this region. Rima Birt itself is a rille just over 50 km in length, with small craters at each end. From photographs, both of these craters appear to occur in domes. The rille itself is unique in that it has an offset in its mid-section. This rules against its origin as a flow feature such as a lava tube. Rather, our sense is that it represents extension and faulting due to dike intrusion. There is a complex of three domes at the north end of Rima Birt, further supporting our notion that all these features have a volcanic origin. There is also a general "darkening" about these domes which likely represents a late-stage lava flow with slightly different metal content, which produces the color differences of lava on the Moon. However, another explanation could be that this feature represents lava fountaining. The age of this dome complex is difficult to estimate, as we lack high-resolution imagery of this region. However, a general age estimate would put it at 2-3 billion years [i.e., during the Eratosthenian Period. *Ed.*]. As a final note, it is of interest that dome complexes often occur on gentle rises, as is the case with the Marius Hills and Mons Rümker, and we suspect that just such a rise might exist here.

Observation of Lunar Domes

The observation of lunar domes is a challenging activity that requires dedication and good timing along with good observing conditions. All observations of domes must be carried out near the lunar terminator where the solar altitude does not exceed approximately 8°. Domes may come in many shapes and sizes but the most common ones are hemispherical in shape with a high profile, a low rounded shadow, and sometimes with a central crater on the top. The crater is a good indication of the volcanic origin of these structures but it is not necessarily present at all times. In 1964 John Westfall created a dome classification scheme that is widely used by the Association of Lunar and Planetary Observers Lunar Dome Survey. Basically the classification takes into account the size of the dome, the shape, location, surface detail, surroundings and profile. Each category is given a letter or number and their combination provides a clear encoded description of the dome in question.

Observations of The Rima Birt Domes

On 1999 May 23, 22^h00^m UT, P.G. Salimbeni and P. Ricciardi of the Geologic Lunar Research group observed three domes to the north of the Rima Birt. This observation was carried out independently by both observers. The telescopes used were a 200-mm Schmidt-Cassegrain and a 10-cm f/10 refractor. *Figure 1* (upper right) shows the aspect of the region as drawn by Salimbeni.

As depicted in Figure 1, there are two bisected domes that follow closely in the same line as the Rima Birt itself.

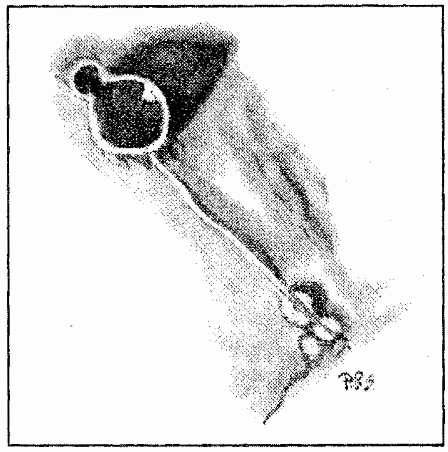

Figure 1. Drawing of Birt (upper left) and the Rima Birt by P.G. Salimbeni. 1999 May 23, 22^h00^m UT. Colong. 013°.3. [Colongitude is the longitude of the sunrise terminator; sunrise at Birt is near Colong. 009°, noon near 099°, and sunset near 189°.] South at top.

Forming a triangle with these two bisected domes lies a third dome to the east (lower left in the drawing). The more difficult dome is the one observed on the northern tip of the Rima. The drawing was carried out under very favorable observing conditions with a seeing of II on the Antoniadi scale [i.e., "good." *Ed.*].

Raffaello Lena did another observation of this region, on 1999 May 24 using a 100-mm refractor at f/15 and 250×. The seeing was also estimated at II on the Antoniadi scale. The drawing below *(Figure 2)* shows the region as observed by Lena.

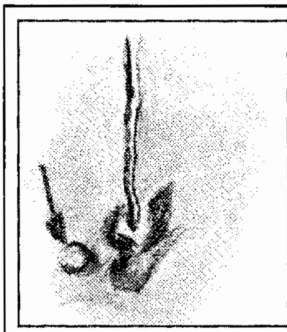

Figure 2. The northern portion of the Rima Birt with the Rima Birt Domes, drawn by Raffaello Lena, 1999 May 24, 21^h10^m UT. Colong. 025°.1. 10-cm f/15 refractor, 250×. Seeing II (Antoniadi Scale; good). South at top.

The two bisected domes can be readily observed to the north of the Rima Birt with the more northerly dome clearly bisected by the Rima. This dome is not as clear in Lena's drawing as in that of Salimbeni but its bisected nature is clearly suggested in this drawing as well. The dome appears to be a hemispherical one with a central cleft that bisects it right in

Figure 3. CCD image of Birt and surroundings by Giorgio Mengoli, 1999 JUL 21, 19^h55^m UT. Colong. 013°.3. South at top. The Rima Birt extends to the lower right, with the Rima Birt domes at its lower end. 15.2-cm refractor.

the center and forms a continuous line with the Rima Birt. The central cleft needs good seeing conditions in order to be observed clearly.

A CCD image obtained by Giorgio Mengoli on 1999 JUL 21 at 19^h 55^m UT also shows this dome (see *Figure 3*, above). The image was taken with a 15.2-cm ED refractor and HX5 Starlight Express CCD camera (16-bit) coupled to a Celestron Ultima Series 2X Barlow lens. The integration time was 0.12 seconds with a 2X unsharp masking adaptive filter and degauss filter (sigma 0.8, coefficient 1.0), Zoom hardware (1.5X). The software used was Astroart and Pix Win 4.

Previous observations of the dome at $\xi = -.161/\eta = -.349$ (9°.89 W/20°.43 S) were reported to the A.L.P.O. by one observer; Marvin Huddleston detected the dome in an observation made on 1972 FEB 23 at 02^h47^m UT (see *Figure 4*, below). Huddleston reported a position of $\xi = -.162/\eta = -.348$ (9°.95 W/20°.37 S). Ours is the third observation of the dome reported to the A.L.P.O., including CCD imaging.

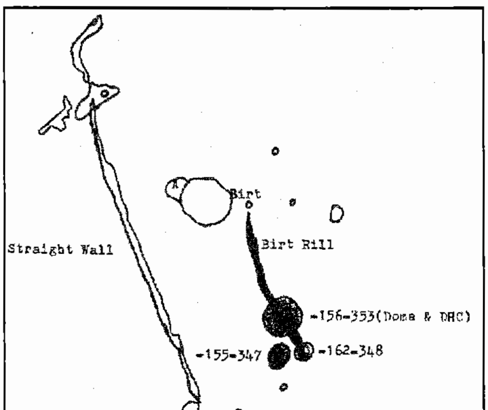

Figure 4. Marvin Huddleston's sketch map of the Rima Birt ("Birt Rill") domes, observed on 1972 FEB 23, 02^h47^m UT. Colong. 013°.2. South at top. "DHC" stands for dark-haloed crater.

This dome has been observed by Harold Hill and appears in his splendid book of lunar drawings. Although not specifically described as in the other three observations, it is definite that Hill also observed three domes during his study of this region.

This dome was also observed by Massimo Giuntoli on 1991 APR 22, at 19^h50^m UT using a 10.0-cm refractor at f/10 and 166X to 250X. Giuntoli's drawing does not include the dome's position or its bisected nature. See *Figure 5* (below) for Giuntoli's drawing.

A hint of this dome is also present in a single video frame sent to the GLR group by F. Badalotti. The image was made using a video camera and a 25.0-cm f/10

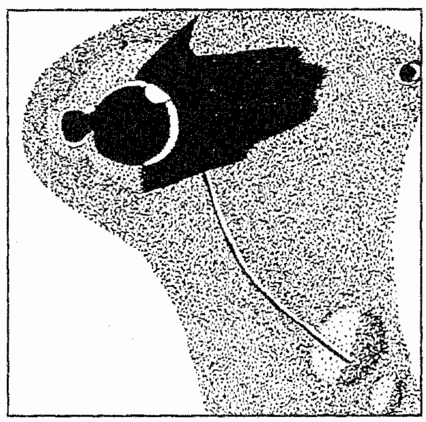

Figure 5. Stipple-type drawing of the Rima Birt domes (lower right) by Massimo Giuntoli, 1991 APR 22, 19^h50^m UT. 10.0-cm refractor, 166X and 250X. Colong. 012°.4. South at top.

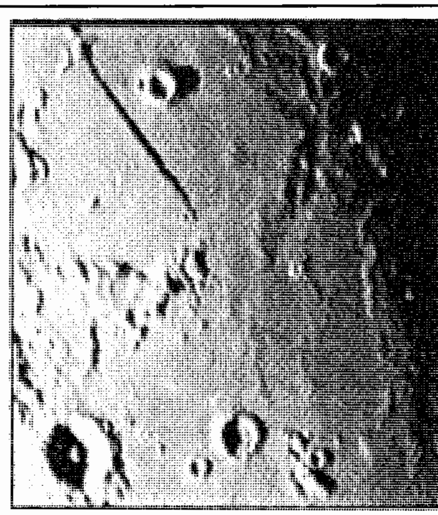

Figure 6. Video frame of the Birt region (upper left) by F. Badalotti, 1999 MAY 23, 19^h10^m UT. 25.0-cm Schmidt-Cassegrain. Colong. 011°.9. South at top.

Schmidt-Cassegrain. It was obtained on the same night as Salimbeni's observation, 1999 May 23, at 19^h10^m UT. *Figure 6* (p. 85) shows Badalotti's observation.

Using both Salimbeni's and Lena's drawings plus Mengoli's CCD image, this dome may be classified according to the Westfall classification scheme as DW/2a/6f/9j. Huddleston classifies it as DW/2a/4f/7j .The fact that there have been only two previous reported observations of this dome strongly suggests that this may be a very difficult object requiring specific lighting conditions in order to be clearly defined. G. Santacana observed this region several times from 1994 to 1997, finding domes only in the coordinates $\xi = -.155/\eta = -.347$ (9°.51 W/20°.30 S) and $\xi = -.156/\eta = -.353$ (9°.60 W/20°.67 S) using both a 20.0-cm Schmidt-Cassegrain and 20.3-cm Newtonian.

Using Mengoli's CCD images, Lena has been able to measure both the heights and the diameters of the three domes in the Birt region. The measurement process consisted of enlarging the images and measuring the size of known objects like the crater Birt and Rupes Recta in millimeters to produce a conversion factor to kilometers on the Moon. Then measurements are made of the domes and converted to kilometers. For height measurement the same process was followed to measure the shadow length of the domes. Using the *Lunar Toolkit* program, written by Harry Jamieson, the heights of the three domes were then calculated. *Table 1* (below) summarizes diameter and heights of the three domes in the Birt region.

Due to the fact that foreshortening is not being considered in the calculations, they must be regarded as close approximations rather than strictly accurate.

Table 1. Diameters and Heights of the Rima Birt Domes.

Dome	Diameter	Height
-161-349	10 km	200 meters
-155-347	12 km	200 meters
-156-353	10 km	250 meters

Conclusions

The appearance of the three domes so close together is a definite indication that at some time in its geologic history, the north end of the Rima Birt was an area with a high level of volcanic activity.

Three independent observations confirm the presence of a bisected dome at $\xi = -.161/\eta = -.349$ (9°.89 W/20°.43 S). The position is based on measurements from plate D6-a of the *Orthographic Atlas*, carried out by Harry Jamieson, at that time the Coordinator of the Lunar Dome Survey for the A.L.P.O. More observations of this dome structure are needed to establish its exact position, height and other surface features. It is also important to note that in this region two bisected domes appear in line with each other.

This report also demonstrates that lunar domes are difficult features for the lunar observer. They require extreme patience, specific conditions of lunar solar altitude, and good seeing. The observations of the Rima Birt region clearly show that the study and classification of these volcanic structures on the moon is far from being complete. More observations and observers are needed worldwide in order to observe these important lunar geologic formations.

If observers wish further information, the Web page of the GLR group is at http://digilander.iol.it/gibbidomine

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Note on Lunar Coordinates: The A.L.P.O. Lunar Dome Survey and the preceding paper catalog domes using a shorthand version of their rectangular coordinates ξ and η (also called *direction-cosines*) on the widely used orthographic projection of the Moon at mean libration. ξ is the east-west coordinate, and η is the north-south coordinate, both expressed in units of the mean lunar radius. Dome positions are in units of thousandths of the lunar radius; thus dome -161-349 is at position $\xi = -.161/\eta = -.349$. A feature's latitude, $\beta = \sin{-1}\ \eta$; and its longitude, $\lambda = \sin{-1}\ (\xi/\cos\ \beta)$. *Ed.*

Additional Views of the Rima Birt and the Rima Birt Domes.

Figure 7 (left). Lunar Orbiter-4 High-Resolution Frame 113 showing Rupes Recta (the "Straight Wall") on the left, Birt to the left of center, the Rima Birt extending to the lower right, and the Rima Birt domes at the lower end of the rima. South at top. Taken 1967 MAY 19, $17^h21^m06.71^s$ UT. Colong. = 030°.5. The solar lighting is too high for a clear view of the low-profile domes, but brings out well Rima Birt, which has been interpreted as a collapsed lava tube or a graben (fault depression). To give an indication of scale, the crater Birt has a diameter of 16.8 km and is 3470 m in depth.

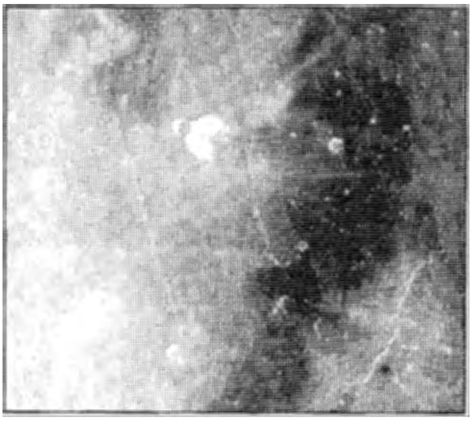

Figure 8 (right). Clementine view of the Birt area, composed of digital image mosaic frames BI17S351.IMG and BI24S351.IMG. Near-Infrared (750 nm); taken at local noon. 0.5-km pixel size. The high lighting shows the Rima Birt as a bright line. The domes are not visible as relief features, but rather are coincident with a dark patch, interpreted as "dark-halo material"; pyroclastic volcanic ejecta, perhaps from the crater at the north end of the rima (i.e., the "DHC" mentioned in Figure 4). South at top.

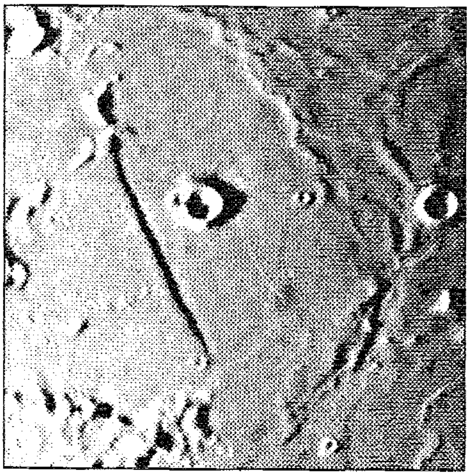

Figure 9 (left). CCD image of Birt and vicinity. Taken by J. Westfall, 1993 MAR 02, 04h46m UT. 28-cm Schmidt-Cassegrain, f/21, 0.15-sec exposure. 0.5-km pixel size. Colong. = 014°.6. South at top. At a smaller scale than Figure 7, this shows the western outline of the basin roughly centered on the crater Birt. Compare Figures 6, 3, 9 and 7 as an example of how rapidly the appearance of this area changes with increasing solar elevation.

Aims of the Comets Section

By: Gary Kronk, Acting A.L.P.O. Comets Coordinator

Introduction

Members of the A.L.P.O. Comets Section have a long history of providing high-quality comet observations. In turn, the section coordinators have done an excellent job in publishing analyses in the *Journal, A.L.P.O.*

My personal membership first began in 1976, while Dennis Milon was the Coordinator (then called "Recorder"). Early in that year I had watched Comet West burst into the morning sky. West was only the third comet I had ever seen, but, with over 110 observed comets up to the present year, it still ranks as perhaps the most spectacular comet I have ever seen.

My very first issue of *The Strolling Astronomer* was that of May, 1976. It contained an article titled "Drawings and Photographs of Comet West (1975n)." Since I knew no one else locally who was interested in astronomy, not to mention comets, this article was a thrill to read just to see how others saw the comet. Later issues continued coverage of Comet West and, very quickly, I found my interest in comets increasing.

I began sending every observation I made to Dennis, and imagine my surprise when I saw an article on periodic comet d'Arrest in the April, 1978 issue that had my name in it. This was a very important moment for me, as it probably is for every comet observer; to see one's name listed as a contributor to the understanding of a comet. My desire to observe comets went to new heights thereafter, as did my need to learn more about comets. The former has led to over 1500 comet observations, while the latter has led to the publication of two books on comets and one on meteor showers. I even manage a website, called "Comets and Meteor Showers," which I began in 1995 (http://comets.amsmeteors.org).

The Future of the A.L.P.O. Comets Section

Over the years I watched Dennis, Milon, David Levy, and Don Machholz do excellent jobs filling the role of Coordinator, and I certainly hope to continue to maintain the quality of the Section. After being asked to become the new Coordinator I began thinking of what I could contribute personally to the Section.

I certainly wish to continue collecting and analyzing observations sent in by members of the A.L.P.O. Comets Section. As I am in the middle of a four-book contract with Cambridge University Press, which is bringing me to analyze every comet seen throughout history, I have acquired the tools and even written a few programs over the years that help me with the analysis of comets.

An area that I think will be unique during my upcoming time as Coordinator will be the use of the World Wide Web. Although I liked David's newsletter and Don's "Comet Comments" that were sent out to inform observers of comet information, I think most people today rely on the WWW for up-to-date information, and that the days of newsletters are dwindling. Ultimately, however, I would like to conduct a survey of all active members of the Comets Section to find out how many use the WWW.

One way I hope to use the WWW will be to link the A.L.P.O. Comets Section page to the "Current Comet" section of my Comets and Meteor Showers site. This will help provide observers with discovery information, up-to-date observations, images, and ephemerides for comets moving through, or soon to move through, our skies.

Another use of the WWW will be for education. As a member of the St. Louis Academy of Sciences and St. Louis Astronomical Society I give several talks to clubs and schools each year on comets. I would like to bring that educational aspect of my life to the Section through the use of the WWW. I already have the basic tools on my existing site and I would like to either create a more complete educational comet area on the A.L.P.O. site or enhance my existing site with obvious pointers helping to promote the A.L.P.O. This WWW section could help enhance the interest of would-be comet observers and perhaps help draw more observers to the Comets Section, via membership in the A.L.P.O.

What do I expect from A.L.P.O. observers? Most important will be careful observations. I am still very interested in receiving magnitude estimates of the coma and nucleus condensation. It is also important to give the diameter of the coma and the degree of condensation in the condensed area of the coma. If there is a tail, measure the length and determine the direction it is pointing. General descriptions of the comet are always valuable. And, most important, please include details about the instrument that made the observations. The form published by David Levy in the March, 1988 issue of *The Strolling Astronomer* is still quite valuable as an orderly guide to marking down the details described above. I hope to place this form on the web within the next couple of months.

I would also like to receive contributions of photographs and CCD images from members to help illustrate the "Current Comets" section on the WWW or to be put directly on the A.L.P.O. Comets Section web site. In addition, there is always a place for such images in *The Strolling Astronomer*.

CONCLUSION

I look forward to working with the members of the A.L.P.O. Comets Section and, in particular, Jim Scotti, who has been the Assistant Coordinator for years. I hope you will all be patient with me as I take on this new job. I think that, together, we can maintain the quality of the section at the level it has been for years, and maybe improve upon it through the use of the WWW.

THE A.L.P.O. MEETS ON THE SHORES OF THE PACIFIC: ASTROCON 2000

The Ventura Conference

Fig. 1. Tim Robertson, conference host

The national amateur astronomy convention for the year 2000 was held on July 16-19 in the Holiday Inn Ventura Beach Resort in the Southern California coastal city of Ventura [see front cover], where the Sun shone every day of the meeting. The convention ran smoothly, as one would expect when an A.L.P.O. staff member coordinated affairs: Timothy L. Robertson of the sponsoring group, the Ventura County Astronomical Society (VCAS). Not counting the VCAS, no less than ten organizations participated: the Association of Lunar and Planetary Observers, the Astronomical League, the Western Region of the Astronomical League, *Sky & Telescope* Magazine, the Search for Extraterrestrial Intelligence Institute, the International Dark Sky Association, the American Association of Variable Star Observers, the International Occultation Timing Association, the Astronomical Society of the Pacific, and the American Association of Amateur Astronomers. Corporate sponsors included the Bushnell, Boeing, and Budweiser Corporations. The featured speakers were Jimmy Doohan ("Scotty" of *Star Trek*) and Don Yeomans (JPL). The banquet speaker was a very special planetary science pioneer—Galileo Galilaei!

Fig. 2. Galileo, complete with telescope.

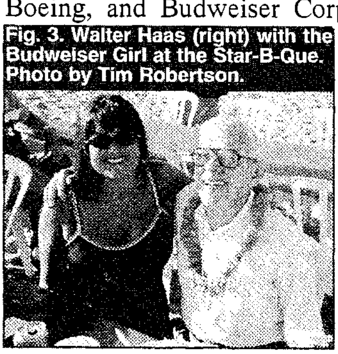

Fig. 3. Walter Haas (right) with the Budweiser Girl at the Star-B-Que. Photo by Tim Robertson.

Convention activities took several forms: Business meetings of several of the participating groups; paper sessions and workshops; displays and vendors' booths; tours to Mount Pinos, Mount Wilson Observatory, and the Jet Propulsion Laboratory; door prizes; a Star-B-Que on the beach; and the traditional Banquet.


Fig. 4. The JPL tour; the Mission Control Center.

A.L.P.O. Activities


Figure 5. Banquet scene with (l. to r.) John and Beth Westfall and Phil Plante. Photo by Rik Hill.

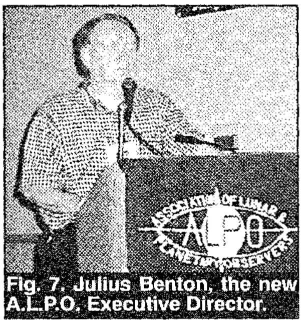
Fig. 7. Julius Benton, the new A.L.P.O. Executive Director.


Fig 6. At the same table, left to right: Walter Haas, Tom Cave and Dan Joyce. Photo by Rik Hill.

The Association of Lunar and Planetary Observers took part in the conference in several ways, among which were paper sessions, presenting two awards, and holding a two-session Board meeting. Matt Will deserves special credit for manning an A.L.P.O. Information Booth [see front cover]. Other A.L.P.O. members and staff contributors to our displays were: Gary Cameron (A.L.P.O. history), Rik Hill (information on constructing spectroscopes)Harry Jamieson (A.L.P.O. membership information), Dan Joyce (Solar-System body videos), John McAnally (Jupiter Transit Display), Derald Nye (Minor Planets Section), Don Parker (Observations of Mars), Tim Robertson (Training Program handouts), and Richard Schmude (Remote Planets Section).


Fig. 8. New Acting Assistant Meteors Coordinator Robin Grey. Photo by Rik Hill.

Worthy of mention is the fact that our group did quite well with the door prizes; among the more significant items A.L.P.O. members walked away with were an 8-inch Meade Schmidt-Cassegrain telescope, *two* Bushnell Voyager 4.5-inch telescopes, and a copy of the lunar coffee-table book *The Full Moon*, by Michael Light.


Fig. 9. Don Parker (left) introducing Steve O'Meara. Photo by Rik Hill.


Fig. 10. Dan Troiani, speaking about Mars observing. Photo by Rik Hill.

On Thursday, July 20, A.L.P.O. members delivered a grand total of fourteen papers, for the most part each lasting 30 minutes. We anticipate that most of these will be published over the next year in the J.A.L.P.O.; the authors and titles are given in the table below.

The A.L.P.O. needs to have at least one face-to-face (non-virtual) Board of Directors' Meeting each year; because of a lengthy agenda we had two in 2000: the evenings of July 19 and 20. The rather lengthy minutes of this meeting will be published in the next issue

A.L.P.O. Paper Session at ASTROCON, July 20, 2000.

Julius L. Benton, Jr., "The Planet Saturn: Recent A.L.P.O. Observations and Program Notes."
Thomas Cave, "Mars: *Le Gran Illusion.*"
Thomas A. Dobbins and William Sheehan, "Project 'Delta Luna:' A Proposal to Search for Impact Features of Recent Origin on the Moon."
Walter H. Haas, "Those Unnumbered Reports of Lunar Changes—Were They All Blunders?"
Richard Hill, "The Value of Synoptic Observations of the Sun: Are Your Observations Useful?"
Robert D. Lunsford, "Video and Audio Presentation of the Leonid Meteors Seen From Europe."
John McAnally, "Jupiter 1999-2000: Chaos in the South Temperate Zone."
Stephen J. O'Meara, "Moon Watching—It's a Blast: Correlating Volcanic Eruptions with Lunar Cycles."
Richard W. Schmude, Jr., "Wideband Photoelectric Photometry of the Jan 20/21, 2000 Lunar Eclipse" *and* "Magnitude Measurements and Other Studies of the Remote Planets and Their Satellites."
Daniel M. Troiani and Daniel Joyce, "Mars 1999: Summary of A.L.P.O. Observations. Looking Forward to Mars in 2001."
John E. Westfall, "A Preliminary Report on the November 15, 1999, Transit of Mercury."
Matthew Will, "Believing is Seeing."
Thomas R. Williams, "A Short History of the A.L.P.O. Lunar Meteor Project."

Fig. 11. The A.L.P.O. Board Meeting—Second Session. At the table, from left to right, are: Julius Benton, Beth Westfall, Harry Jamieson, Matt Will, Rik Hill, Walter Haas, Richard Schmude, and Don Parker.

of our Journal, although the staff changes approved by the Board are given in the "Announcements" section of this issue (p. 92). Also, to help in advance planning, we can divulge that our organization will meet next in Frederick, Maryland, on July 24-28, 2001, with the Astronomical League.

Fig. 12. A.L.P.O. Meteors Coordinator Robert Lunsford.

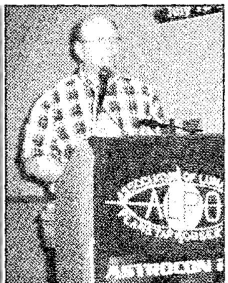

Fig 13. Assistant Jupiter Coordinator John McAnally.

Although the A.L.P.O. itself did not organize any excursions, it certainly contributed members to trips to the Mount Pinos star party held at the famous dark-sky site at 8826 feet above sea level in the Los Padres National Forest, and to the Jet Propulsion Laboratory in Pasadena. Additional tours went to Griffith Observatory and Mount Wilson.

This year, the A.L.P.O. presented two awards at the convention Banquet. One was our annual Walter H. Haas Observing Award, which was presented to Gordon Garcia, a prolific observer of our Solar Section; Gordon was unable to attend, and the award was accepted for him by Rik Hill, Solar Coordinator. The second award, not presented every year, was the Peggy Haas Service Award, going to retiring Comets Coordinator Don Machholz for his many years of discovering comets and encouraging, making, and analyzing Comets observations.

Fig. 14. Retiring Executive Director Don Parker (left) with Membership Secretary Harry Jamieson, clowning with a Mars T-shirt.

Fig. 15. An animated presentation on lunar photometry by Richard Schmude.

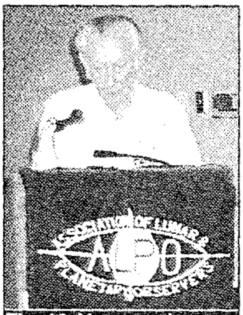

Fig. 16. Veteran observer Tom Cave speaking on "Mars: *Le Gran Illusion*."

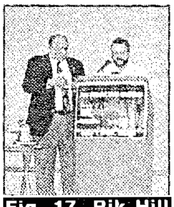

Fig. 17. Rik Hill (right) accepting the Walter Haas Observing Award for Gordon Garcia. Photo supplied by Rik Hill.

Fig. 18. Don Machholz (left) receiving the Peggy Haas Service Award from Don Parker.

Fig. 19 (left). The lobby of the Holiday Inn Ventura Beach Resort during ASTROCON 2000. The registration table is to the left. To the right are booths operated by participating groups and vendors.

THE ASSOCIATION OF LUNAR AND PLANETARY OBSERVERS

Founded by Walter Haas in 1947, the A.L.P.O. now has about 500 members. Our dues include a subscription to our quarterly Journal *(J.A.L.P.O.), 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.

Our advertising rates are $85.00 for a full-page display advertisement, $50.00 per half-page, and $35.00 per quarter-page. Classified advertisements are $10.00 per column-inch. There is a 10-percent discount for a three-time insertion on all advertising.

All payments should be in U.S. funds, drawn on a U.S. bank with a bank routing number, and payable to "A.L.P.O." All cash or check dues payments should be sent directly to: A.L.P.O. Membership Secretary, P.O. Box 171302, Memphis, TN 38187-1302. When you write to our staff, please provide a stamped, self-addressed envelope. Note that the A.L.P.O. maintains a World-Wide Web homepage at: http://www. lpl.arizona.edu/alpo/

Keeping Your Membership Current.—The top line of your *J.A.L.P.O.* mailing label gives the volume and issue number when your membership will expire (e.g., "42.2" means Vol. 42, No. 2). We also include a First Renewal Notice in that issue, and a Final Notice in the next one. Please let the Membership Secretary know if your address changes. Dues payments should be made directly to the Membership Secretary.

A.L.P.O. ANNOUNCEMENTS

RECENT BOARD DECISIONS

Staff and Section Changes**—Tony Grigsby** has left the Solar Section staff; **Brad Timerson** is now permanent *Assistant Solar Coordinator.* **James Bell** has resigned as *Assistant Mars Coordinator.* **Lawrence Garrett** has been appointed a permanent *Assistant Minor Planets Coordinator*, the "Acting" prefix removed. **Damian Peach** has been made a permanent *Assistant Jupiter Coordinator*; no longer "Acting." **Mark Davis** is no longer serving as Assistant Meteors Coordinator; **Robin Gray** has been appointed *Acting Assistant Meteors Coordinator* (P.O. Box 547, Winnemucca, NV 89446; e-mail: SevenValleysEnt@HotMail.com). **Gary Cameron** is no longer Acting Historical Coordinator; **Richard Schmude** is now *Acting Historical Coordinator*; the **Historical Section** itself has become permanent and is no longer "Provisional."

Julius L. Benton, Jr. is now *A.L.P.O. Executive Director*, **Donald C. Parker** having stepped down. **Harry D. Jamieson** has replaced Dr. Benton as *A.L.P.O. Associate Director.*

A.L.P.O. Convention. in 2001.—The A.L.P.O. Board of Directors has accepted the invitation of the Astronomical League and the Mid-East Region of the Astronomical League to participate in ALCON 2001, our 52nd convention and the first of the new century/millennium. Our 2001 Convention will be held at the Holiday Inn and Francis Scott Key Conference Center in Frederick, Maryland, on July 24-28. Tours are being planned to the Space Telescope Science Institute in Baltimore, and the National Air and Space Museum and the U.S. Naval Observatory in Washington, DC. For further information, contact Frank Moon, Chair, ALCON 2001, 7210 E. Sundown Court, Frederick, MD 21702 (E-mail: ALCON2001Chair@aol.com). Convention rates at the Holiday Inn are $89/night single or $99/night double; call 301-694-7500 or 800-868-0094 for reservations and mention the "2001 Astronomical League Conference" to obtain convention rates.

(Other Board decisions made at our 2000 meeting will be reported in the next issue.)

OTHER A.L.P.O. NEWS

Staff Address and Address Changes.—The postal address of **Brian Cudnik**, *Acting Lunar Coordinator*, was incorrectly given in the previous issue, and should be changed to: 5800 Hollister Road, #1616, Houston, TX 77040. **Thomas A. Dobbins,** *Acting Assistant Historical Coordinator*, now has a postal address: 305 Northern Spy Circle, Howard, OH 43028. **William Sheehan,** *Acting Assistant Historical Coordinator*, now has postal and e-mail addresses: 2105 Sixth Avenue SE, Willmar, MN 56201; e-mail: sheehans@tds.net. *Executive Director* **Julius L. Benton's** *secondary* e-mail address is now jlbaina@msn.com; his primary e-mail address remains unchanged as jlbaina@aol.com.

A.L.P.O. Awards for the year 2000.—At our recent Convention, the A.L.P.O. issued two awards to well-deserving recipients: The *Peggy Haas Service Award* was presented to retiring Comets Coordinator **Don E. Machholz**, while the annual *Walter H. Haas Observing Award* went to solar observer and Assistant Coordinator **Gordon W. Garcia**.

Other Amateur and Professional Announcements

Deadline for NSF Planetary Science Proposals—The next deadline for submitting planetary science proposals to NSF is September 25, 2000, 5 PM submitter's local time. All proposals must be submitted electronically via FastLane. For more information, contact Vernon Pankonin, Division of Astronomical Sciences, Suite 1045, National Science Foundation, 4201 Wilson Blvd., Arlington, VA 22230 (E-mail: vpankonin@nsf.gov; Tel.: 703-292-4902; FAX: 703-292-9034).

Roster of Upcoming Meetings

September 22-23, 2000: Nightfall. Dark-sky observing at Palm Canyon Resort, Borrego Springs, California. [Fox & Stephens, CPAs, 8300 Utica Ave., Suite 105, Rancho Cucamonga, CA 91730; Telephone: 909-948-2205; E-mail: rstephens@foxandstephens.com]

September 22-24, 2000: MERAL/VAAS Convention and Star Party 2000. Convention of the Mid-East Region of the Astronomical League at Charlottesville, Virginia. [Ed Walendowski. Telephone: 804-975-2888; E-mail: mewalen@rlc.net; Website: http://www.cvilleastro.org/]

September 28-October 1, 2000: Enchanted Skies Star Party. At Socorro, New Mexico. [Chamber of Commerce, P.O. Box 743, Socorro, NM 87801. Telephone: 505-835-0424; E-mail: chamber@socorro-nm.com; Website: www.socorro-nm.com, click on "events"]

October 14-15, 2000: Solar Eclipse Conference 2000. An International Solar Eclipse Conference will be held at the Congress Centre Elzenveld, Antwerp, Belgium on October 14-15, 2000. Three days of lectures will discuss predictions, mathematics, solar physics, weather forecasting, eye safety, diameter measurement, edge and central observing,ancient eclipse research, five years of SOHO, the solar maximum; and the August, 1999, July, 2000, and June, 2001 eclipses. [Patrick Poitevin, 7A The Drift, Rowlands Castle, Havant, Hampshire, PO9 6DG England. Telephone: +44 (0)97901 514 097. E-mail: Patrick_Poitevin@hotmail.com; Webpage: http://www.eclipsechasers.net]

October 23-27, 2000: 32nd Division for Planetary Sciences Meeting. At the Pasadena Convention Center, 3000 E. Green Street, Pasadena, California. [Website: http://www.aas.org/dps2000/]

November 8-10, 2000: Conference on the Earth-Moon Relationship. At Padova, Italy. [Cesare Barbieri, Department of Astronomy, University of Padova, Vicolo Osservatorio 5, 35122, Padova, Italy. Telephone: +39-049-829343; FAX: 39-049-8293507; E-mail: cbarbier@uxl.unipd.it *or* barbieri@pd.astro.it]

November 13-16, 2000: Annual Meeting of the Geological Society of America. At Reno, Nevada. [GSA Meetings Department, P.O. Box 9140, Boulder, CO 80301-9140. Telephone: 303-447-2020 or 800-472-1988; FAX: 303-447-0648; E-mail: meetings@geosociety.org; Website: http://www.geosociety.org]

December 5-7, 2000: ISCO 2000, International Conference on Space Optics. At Toulouse Labège, France. [Agence DAG-25, rue Saint Guilhem, 31400 Toulouse, France. Telephone: 33-05-61-25-15-00; E-mail: isco@dag.fr; Website: http://www.cnes.fr/colloque]

January 4-8, 2001: Small-Telescope Astronomy on Global Scales. IAU Colloquium 183. At Kenting National Park, Taiwan. The conference is intended to foster international cooperation on variability or wide-field survey/monitoring projects for telescopes of 1 m or less. [Ms. Kelly Chen, c/o IAUC183, Graduate Institute of Astronomy, National Central University, Chung-Li 32054 Taiwan. Telephone: +886-3-426-2302; FAX: +886-3-426-2304; E-mail: iauc183@joule.phy.ncu.edu.tw; Website: http://www.astro.ncu.edu.tw/iauc183]

June 25-30, 2001: Conference on Jupiter—Planet, Satellites and Magnetosphere. At the Harvest Regal Hotel, Boulder, Colorado. [Fran Bagenal, Professor of Astrophysical & Planetary Sciences, CB 391, University of Colorado, Boulder. Telephone: 303-492-2598; FAX: 303-492-6946; E-mail: bagenal@colorado.edu; Website: http://dosxx.colorado.edu/JupMeet.html]

July 24-28, 2001: ALCON 2001. Astronomical League-A.L.P.O. Convention, hosted by the Astronomical League and the Mid-East Region of the Astronomical League. At the Holiday Inn and Francis Scott Key Conference Center. [Holiday Inn reservations: telephone 301-694-7500 or 800-868-0094. Meeting information, contact Frank Moon, Chair ALCON 2001, 7210 E. Sundown Court, Frederick, MD 21702; E-mail: ALCON 2001Chair@aol.com]

PUBLICATIONS OF THE A.L.P.O.

A.L.P.O. MONOGRAPH SERIES

A.L.P.O. monographs are publications that we believe will appeal to our members, but which are too lengthy for publication in our Journal. They should be ordered from our Editor (P.O. Box 2447, Antioch, CA 94531-2447 U.S.A.) for the prices indicated, which include postage. Checks should be in U.S. funds, payable to "A.L.P.O."

Monograph Number 1. ***Proceedings of the 43rd Convention of the Association of Lunar and Planetary Observers. Las Cruces, New Mexico, August 4-7, 1993.*** 77 pages. Price: $12.00 for the United States, Canada, and Mexico; $16.00 elsewhere.

Monograph Number 2. ***Proceedings of the 44th Convention of the Association of Lunar and Planetary Observers. Greenville, South Carolina, June 15-18, 1994.*** 52 pages. Price: $7.50 for the United States, Canada, and Mexico; $11.00 elsewhere.

Monograph Number 3. ***H.P. Wilkins 300-inch Moon Map.*** 3rd Edition (1951), reduced to 50 inches diameter; 25 sections, 4 special charts; also 14 selected areas at 219 inches to the lunar diameter. Price: $28.00 for the United States, Canada, and Mexico; $40.00 elsewhere.

Monograph Number 4. ***Proceedings of the 45th Convention of the Association of Lunar and Planetary Observers. Wichita, Kansas, August 1-5, 1995.*** 127 pages. Price: $17.00 for the United States, Canada, and Mexico; $26.00 elsewhere.

Monograph Number 5. ***Astronomical and Physical Observations of the Axis of Rotation and the Topography of the Planet Mars. First Memoir, 1877-1878.*** By Giovanni Virginio Schiaparelli, translated by William Sheehan. 59 pages. Price: $10.00 for the United States, Canada, and Mexico; $15.00 elsewhere.

Monograph Number 6. ***Proceedings of the 47th Convention of the Association of Lunar and Planetary Observers, Tucson, Arizona, October 19-21, 1996.*** 20 pages. Price $3.00 for the United States, Canada, and Mexico; $4.00 elsewhere.

Monograph Number 7. ***Proceedings of the 48th Convention of the Association of Lunar and Planetary Observers. Las Cruces, New Mexico, June 25-29, 1997.*** 76 pages. Price: $12.00 for the United States, Canada, and Mexico; $16.00 elsewhere.

Monograph Number 8. ***Proceedings of the 49th Convention of the Association of Lunar and Planetary Observers. Atlanta, Georgia, July 9-11, 1998.*** 122 pages. Price: $17.00 for the United States, Canada, and Mexico; $26.00 elsewhere.

OTHER PUBLICATIONS OF THE A.L.P.O.

(Checks must be in U.S. funds, payable to an American bank with bank routing number.)

Order from: A.L.P.O., P.O. Box 2447, Antioch, CA 94531-2447, U.S.A:

An Introductory Bibliography for Solar System Observers. Free for a stamped, self-addressed envelope. A 4-page list of books and magazines about Solar System bodies and how to observe them. The current edition was updated in October, 1998.

Order from: A.L.P.O. Membership Secretary, P.O. Box 171302 Memphis, TN 38187-1302 U.S.A:

A.L.P.O. Membership Directory. $5.00 in North America; $6.00 elsewhere. Continuously updated list of members on 3.5-in MS-DOS diskette; either DBASE or ASCII format. Make payment to "A.L.P.O." Also available as an e-mail downloaded file, given the requester's e-mail address. Provided at the discretion of the Membership Secretary.

Order from: Walter H. Haas, 2225 Thomas Drive, Las Cruces, NM 88001, U.S.A.
(E-mail: haasw@zianet.com):

Back issues of ***The Strolling Astronomer (J.A.L.P.O.).*** Many of the back issues listed below are almost out of stock, and it is impossible to guarantee that they will remain available. Issues will be sold on a first-come, first-served basis. In this list, volume numbers are in italics, issue numbers are in plain type, and years are given in parentheses. The price is $4.00 for each back issue; the current issue, the last one published, is $5.00. We are always glad to be able to furnish old issues to interested persons and can arrange discounts on orders of more than $30. Make payment to "Walter H. Haas."

$4.00 each: *1* (1947); 6. *8* (1954); 7-8. *11* (1957); 11-12. *21* (1968-69); 3-4 and 7-8. *23* (1971-72); 7-8 and 9-10. *25* (1974-76); 1-2, 3-4, and 11-12. *26* (1976-77); 3-4 and 11-12. *27* (1977-79); 3-4 and 7-8. *31* (1985-86); 9-10. *32* (1987-88); 11-12. *33* (1989); 7-9. *34* (1990); 2 and 4. *37* (1993-94); 1, 2 and 3. *38* (1994-96); 1, 2, and 3. *39* (1996-97); 1, 2, 3 and 4. *40* (1998); 2 and 4. *41* (1999); 1, 2, 3, and 4. *42* (2000), 1.

Current Issue [*42*, 2]; $5.00.

PUBLICATIONS OF THE SECTIONS OF THE A.L.P.O.

Order the following directly from the appropriate Section Coordinator; use the address in the staff listing (next two pages) unless another address is given below.

Lunar and Planetary Training Program (Robertson): *The Novice Observers Handbook,* $15.00. An introductory text to the Training Program. Includes directions for recording lunar and planetary observations, useful exercises for determining observational parameters, and observing forms. To order, send a check or money order made out to "Timothy J. Robertson."

Lunar (Benton): (1) *The ALPO Lunar Section's Selected Areas Program (SAP),* $17.50. Includes a full set of observing forms for the assigned or chosen lunar area or feature, together with a copy of the *Lunar Selected Areas Program Manual.* (2) *Observing Forms Packet,* $10.00. Includes observing forms to replace the quantity provided in the Observing Kit above. Specify the Lunar Forms. (See note for Venus.)

Lunar (Dembowski): *The Lunar Observer,* a monthly newsletter, is available online at the A.L.P.O. Homepage, http://www. lpl.arizona.edu/alpo/ . Hard copies may be obtained by sending a set of self-addressed stamped envelopes to Bill Dembowski at his address in our staff listing.

Lunar (Jamieson): *Lunar Observer's Tool Kit,* consisting of a 3-1/2-in. MS/DOS diskette containing an observation-planning program and a lunar dome data base with built-in instructions. Price $25.00.

Venus (Benton): (1) *The ALPO Venus Observing Kit,* $17.50. Includes introductory description of A.L.P.O. Venus observing programs for beginners, a full set of observing forms, and a copy of *The Venus Handbook.* (2) *Observing Forms Packet,* $10.00. Includes observing forms to replace the quantity provided in the Observing Kit above. Specify the Venus Forms. (To order the above, send a check or money order made out to "Julius L. Benton, Jr." All foreign orders should include $5.00 additional for postage and handling; for domestic orders, these are included in the prices above. Shipment will be made in two to three weeks under normal circumstances. NOTE: Observers who wish to make copies of observing forms have the option of sending a SASE for a copy of forms available for each program. Authorization to duplicate forms is given only for the purpose of recording and submitting observations to the A.L.P.O. Venus, Saturn, or Lunar SAP Section. Observers should make copies using high-quality paper.)

Mars (Troiani): (1) *Martian Chronicle;* send 8-10 SASEs; published approximately monthly during each apparition. (2) *Observing Forms;* send SASE to obtain one form which you can copy; otherwise send $3.60 to obtain 25 copies (make checks out to "J.D. Beish").

Mars (Astronomical League Sales, P.O. Box 572, West Burlington, IA 52655 U.S.A.): *ALPO's Mars Observer Handbook,* $9.00.

Jupiter: (1) "Jupiter Observer's Start-Up Kit" is available for $3.00 from David J. Lehman. (2) *Jupiter,* the newsletter of the Jupiter Section is available on the Internet at the Jupiter Section Web page or by mail: send SASEs to David J. Lehman. (3) To join the Jupiter Section's E-mail network, "J_Net," send an E-mail message to David J. Lehman at DLehman111@aol.com, write "subscribe J_Net" in the subject field. (4) *Timing the Eclipses of Jupiter's Galilean Satellites;* send a SASE with 55 cents in stamps to John Westfall. This is the project "Observing Kit" and includes a report form.

Saturn (Benton): (1) *The ALPO Saturn Observing Kit,* $20.00. Includes introductory description of A.L.P.O. Saturn observing programs for beginners, a full set of observing forms, and a copy of *The Saturn Handbook.* (2) *Observing Forms Packet,* $10.00. Includes observing forms to replace the quantity provided in the Observing Kit above. Specify the Saturn Forms. (See note for Venus.)

Meteors (Astronomical League Sales, P.O. Box 572, West Burlington, IA 52655 U.S.A.): (1) The pamphlet, *The A.L.P.O. Guide to Watching Meteors* is available for $4.00 (price includes postage). (2) The *Meteors Section Newsletter* is published quarterly (March, June, September, and December) and is available free of charge if you send 33¢ in postage per issue to Coordinator Robert D. Lunsford, 161 Vance Street, Chula Vista, CA 91910 U.S.A..

Minor Planets (Derald D. Nye, 10385 East Observatory Dr., Corona de Tucson, AZ 85641-2309 U.S.A.): Subscribe to: *The Minor Planet Bulletin;* quarterly, $9.00 per year for the United States, Mexico and Canada; or $13.00 for other countries (air mail only).

Computing Section (McClure): A Computing Section Newsletter, *The Digital Lens,* is available via e-mail. To subscribe or to make contributions, contact the editor, Mike W. McClure, at: MWMCCL1@POP.UKY.EDU .

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