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MEMORANDUM
RM-6262-NASA
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OBSERVATIONS OF THE 1969 INFERIOR CONJUNCTION AND GREATEST WESTERN ELONGATION OF VENUS: DATA CATALOG AND PRELIMINARY ANALYSIS

G. E. Kocher, G. F. Schilling, R. C. Moore and M. Turner

PREPARED FOR:
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The RAND Corporation
SANTA MONICA • CALIFORNIA

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PREFACE

This Memorandum catalogs the reduced observational data obtained during the inferior conjunction and greatest western elongation of Venus in 1969. The research objectives and the scientific results of the program are summarized in a companion Memorandum RM-6261-NASA: *Venus Cusp Observations During 1969: Synopsis of Results*. The work was performed in partial fulfillment of Contract NASw-1762, "Telescopic Observations of Venus Cusp Phenomena," for the Office of Space Science and Applications, National Aeronautics and Space Administration.

SUMMARY

This Memorandum includes a catalog of telescopic and photometric information on Venus obtained in 1969. Two specific celestial phenomena were investigated: inferior conjunction (April 3 to 22) and greatest western elongation (June 14 to 21). The latter was observed simultaneously from observatories some eleven degrees apart in longitude. Along with each photographic observation, many of which were in daylight or twilight, photometer readings of the sky, near Venus and elsewhere, were recorded. This program was the observational follow-up of a theoretical study that suggested that the Venus cusp extension angle measured was dependent on the brightness of the terrestrial sky around it. Now it is suggested that additional factors also play a role -- factors associated with the earth's atmosphere and with the characteristics of the observing equipment. The interplay of two parameters, sky brightness and film exposure time, is examined.

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I. INTRODUCTION

The program described in Venus Cusp Observations During 1969: Synopsis of Results* centered on telescopic observations of the angular extent of the Venus crescent near the periods of inferior conjunction (April 1969) and greatest western elongation (June 1969). Surface brightness of the terrestrial sky was shown to have an important effect upon results. The principal scientific objectives were the acquisition and use of data for gaining additional knowledge about the atmosphere of Venus, based on a theory that explained quantitatively the Venus cusp extension phenomena and that revealed the causative roles played by the atmospheres of Earth and Venus. This theory was published in The Twilight Atmosphere of Venus.**

The observational information gathered represents a heretofore non-existent data base for scientific studies of the Venus cusp phenomena. In this Memorandum, we tabulate the data reduced to date and show some of the relationships found. We have attempted to catalog the data here in such form that they may be readily usable by other investigators in conjunction with information given in the two other Memorandums referenced above.

The observational programs were conducted at the Table Mountain Observatory (TMO) of the Jet Propulsion Laboratory, California Institute of Technology, near Wrightwood, California, and at the observatory of New Mexico State University (NMSU) near Las Cruces, New Mexico.

Observations of the inferior conjunction of Venus (15:00 UT 8 April 1969) were conducted at TMO from 3 April to 22 April 1969. Useful photographic, visual, and photometric data were obtained.

Observations of the greatest western elongation of Venus (17:00 UT 17 June 1969) and of geometric dichotomy (07:00 UT 18 June 1969) were

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*RM-6261-NASA, The RAND Corporation, Santa Monica, California, March 1970.

**RM-5386-PR, The RAND Corporation, Santa Monica, California, July 1967.

conducted at both TMO and NMSU between 14 June and 21 June 1969. Photographic, visual, and photometric data were obtained.

We have been able to complete the reduction and preliminary analysis of only part of the observational material to date. There is much additional information in the data; it is hoped that further scientific analysis will be supported.

II. OBSERVING PROGRAMS

SCHEDULE OF OPERATIONS: INFERIOR CONJUNCTION

The schedule called for morning and evening twilight observations of Venus before inferior conjunction, round-the-clock observations near inferior conjunction (8 April), and morning twilight and forenoon observations after inferior conjunction. Unfavorable weather conditions, including two brief snowstorms, required some deviations from this plan. Successful photographic data, visual data, or photometric measurements were obtained at TMO during the periods listed in Table 1.

Table 1

SUCCESSFUL OBSERVING PERIODS DURING THE INFERIOR CONJUNCTION OF VENUS IN APRIL 1969

Date (PST)	Time Periods (PST)
3 April	10:55 - 14:58; 17:15 - 18:57
4 April	05:22 - 07:00; 10;59 - 11:01; 17:11 - 18:40
7 April	07:08 - 08:54; 10:51 - 11:29; 14:20 - 15:03
8 April	04:35 - 07:30; 10:21 - 10:58; 15:30 - 18:26
9 April	04:50 - 05:35; 07:06 - 07:14; 17:48 - 18:45
10 April	10:24 - 11:16
11 April	04:27 - 05:33; 12:53 - 12:56
12 April	04:45 - 05:21; 20:25 - 21:07
13 April	04:35 - 05:26
14 April	04:19 - 05:09
15 April	04:16 - 05:12; 08:59 - 09:50
16 April	04:00 - 05:12; 09:22 - 09:39
17 April	04:06 - 05:12; 09:18 - 09:39
19 April	03:54 - 05:21; 08:31 - 10:10
20 April	03:51 - 05:17; 09:45 - 10:16
21 April	04:01 - 05:19; 09:40 - 10:21
22 April	03:54 - 05:14; 09:40 - 10:17

A total of 26 III-F plates with an average of 16 images on each, and 12 strips of 35-mm film (II-F, III-F, and Tri-X) with an average of 25 images on each, were obtained with the 16-in. Cassegrain reflector. In addition to Venus exposures, the plates and films recorded star trails for precise angular reduction, and images of Jupiter or the Moon for photometric comparisons.

The complementary and precisely timed photometric measurements consist of values of the brightness of the terrestrial sky at the zenith, at the horizon, and around Venus.

Supplementary visual observations were conducted with a 6-in. guide refractor at various magnifications.

SCHEDULE OF OPERATIONS: GREATEST ELONGATION

In order to understand better the effect of telescope size on the measured value of the Venus cusp extension angle and the related date of apparent dichotomy, a program of observations at greatest western elongation was carried out simultaneously at the two sites. In addition, the geographic separation of Table Mountain Observatory and the New Mexico State University Observatory permitted simultaneous images of Venus to be obtained under different sky brightness conditions. The observing periods are listed below:

Table 2

SUCCESSFUL OBSERVING PERIODS DURING THE GREATEST WESTERN ELONGATION OF VENUS, JUNE 1969 (UT)

(June)	TMO	NMSU
14		09:39-12:52
16		11:19-12:37
17	09:30-13:31	09:34-13:35
18	09:59-13:30	09:32-12:46
19	09:58-13:30; 20:12-23:00	11:03-12:29
20	10:17-13:30; 20:03-23:00	11:07-12:43
21	10:30-13:30; 19:42-20:20	05:51-06:13

At TMO 25 strips of 35-mm film (III-F with no filter) with an average of 19 images per strip were obtained with the 16-in. Cassegrain reflector. For photometric comparison, images of Saturn and Mercury also were included. Supplementary visual observations were made with the 6-in. guide refractor at various magnifications.

At NMSU 22 plates (III-F with no filter) with an average of 25 images on each plate were obtained with the 24-in. Cassegrain reflector. In addition, again for photometric comparison, images of Jupiter and Mars were included.

At both locations, the complementary and precisely timed photometric measurements consisted of values of the brightness of the terrestrial sky in the vicinity of Venus and at the zenith.

INSTRUMENTATION

Inferior Conjunction

The April 1969 data on inferior conjunction were obtained at the Table Mountain Observatory. Most of the observations were taken with the 16-in. telescope, the remainder with an auxiliary 6-in. refractor. The instrumental particulars are listed below.

Telescope Location:

Latitude	34° 22' 54."02 N
Longitude	117° 41' 51."22 W
Altitude	7503 ft (2287 m)

Optical parameters:

Optical type	Cassegrain reflector with quartz elements	guide refractor
Aperture, D	16 in.	6 in.
Effective focal length, F	803 in.*	90 in.
Focal ratio, F/D	50*	15
Plate scale	10."2/mm*	...
Magnification (power)	993× (20-mm eyepiece)	100 to 300×

*Figures vary slightly with placement of camera and secondary.

While visual estimates of crescent extent were made with both telescopes (principally the refractor), all photographs were made with the reflector. The two cameras used were

(a) Plate camera, including diagonal pivoting mirror and guiding eyepiece. Plate size, 3 1/4 in. × 4 1/4 in. It was focused by using a ground glass at the focal plane. Shutter speeds available were B, and 1 to 1/100 sec.

(b) Film camera: Nikon 35-mm camera body using standard cartridges. Shutter speeds available were T, B, and 1 to 1/1000 sec.

Neither camera used an amplifying lens such as a Barlow.

A variety of Kodak emulsions was employed, but most were of the spectroscopic film and plate series.

	Number Reduced	
Emulsion type	Plates	Films
II-F		2
III-F	18	9
Tri X		1

Processing was carried out in UFG 1:1, 8 minutes @ 70°F for plates (and 14 minutes @ 70°F for films), followed by a 30-sec stop bath, a 5-min fix, a 2-min hypo clear, and a 20-min wash.

Measurements of sky brightness were made with the two photometers described below.

Manufacturer	Asahi Optical	Mekano
Model	Honeywell 1°/21°	Spotron
Sensor	CdS	CdS
Spot diameter	1°	2°
Serial number	33137	12 514

In addition, to prevent off-scale readings, the Honeywell meter was occasionally fitted with a Kodak Wratten neutral density filter (ND 1.0, 10 times reduction) when the telescope was pointed near the sun. Meter calibration data are shown in Figs. 1 and 2.

The two photometers were compared by simultaneous measurements of a specific area of relatively clear sky; the comparison is plotted

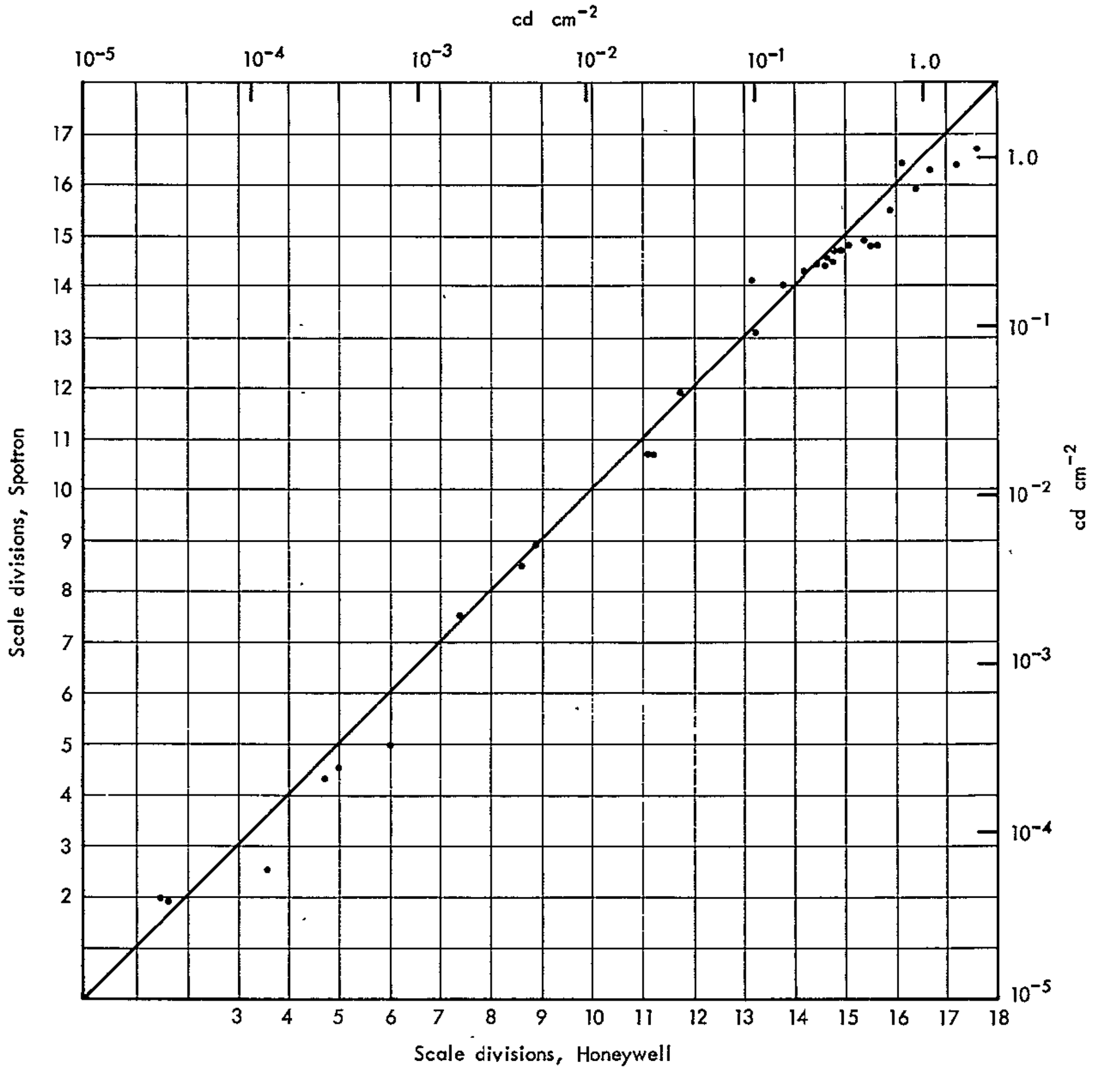

Fig. 1 -- Comparison of photometers (sky source).

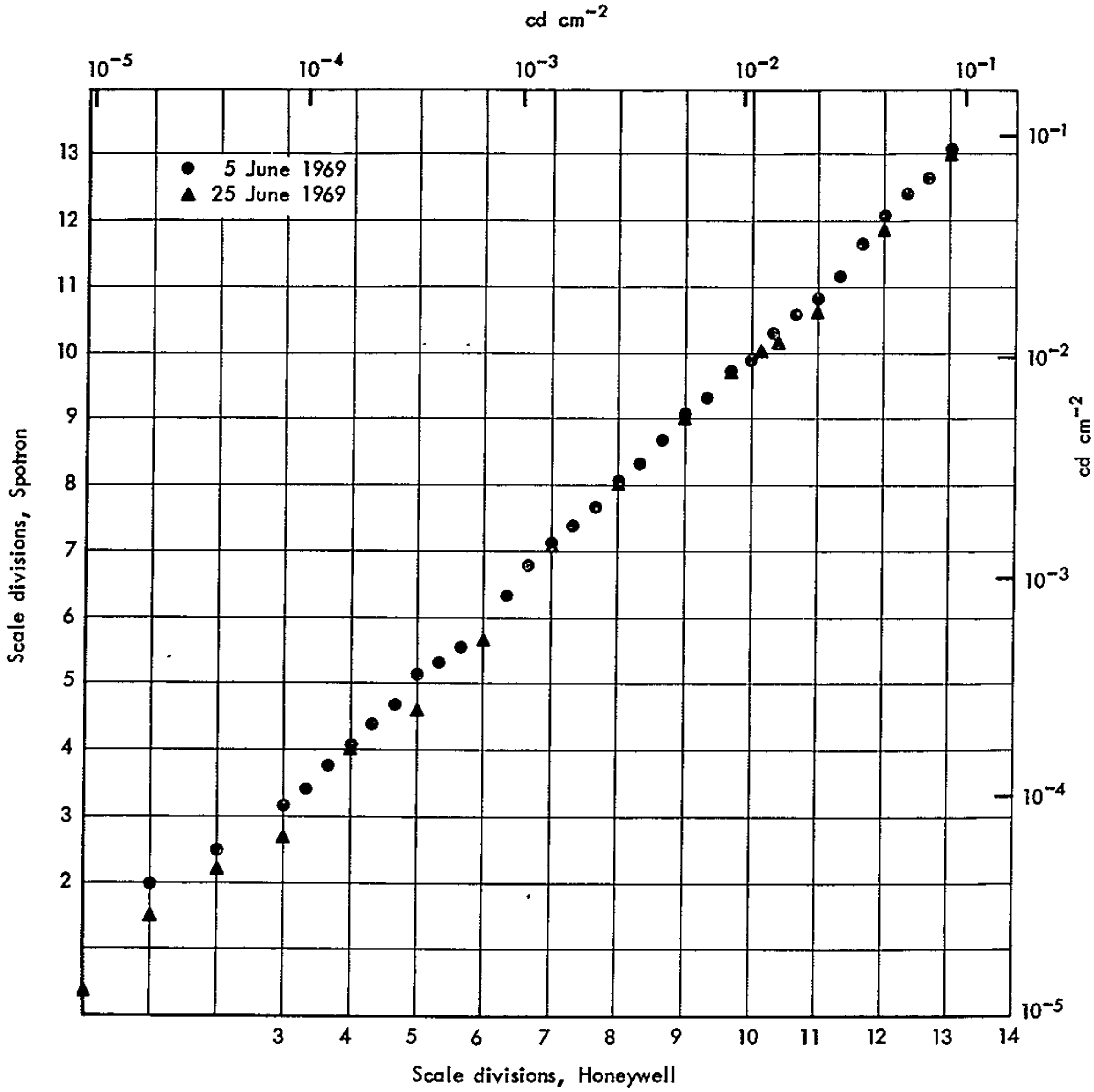

Fig. 2 -- Comparison of photometers (incandescent-light source).

in Fig. 1. The sample of data shown was taken at one sea-level and two mountain locations. They were compared also in the laboratory through sequential measurements of an artifically illuminated, translucent screen; the comparison is plotted in Fig. 2. Within the accuracy of visual readings of the photometer scales, the meters provided comparable and stable measurements between ambient light levels of 10^{-4} and 1 candle per square centimeter. Outside this range, at very low and very high light levels, it was difficult to read the scales accurately. As can be noticed in Fig. 1, occasional differences occur between the readings of the two meters. This resulted from nonuniform sky conditions; the fields of view of the two meters were different (acceptance angles of one degree versus two degrees).

The meters indicated surface brightness, or luminance, in instrumental SD units (SD ≡ scale divisions), where an increase by one scale division represents a doubling of brightness. Scale divisions and absolute units of surface brightness are related as follows:

$$[\text{cd ft}^{-2}] = 10 \times 2^{(SD-10)}$$

$$[\text{cd cm}^{-2}] = 1.05 \times 10^{-5} \times 2^{SD}$$

Table 3 is provided to facilitate conversion from scale divisions to candles per square centimeter. Under field conditions, reading accuracy was degraded by scale parallax and scale interpolation uncertainties. The combined uncertainty is estimated to be not more than 0.2 scale division.

Unfortunately, the available photometers did not have the range we would have preferred. We generally began exposures before the meters responded. Photometers sensitive to lower levels of surface brightness, i.e., below 10^{-5} cd cm^{-2}, however, would have required an investment very much out of proportion to the added capability. As work along these lines proceeds, one would like ultimately to extend the data base to the lowest possible levels of sky brightness. But for our purposes the meters used were at least very convenient, quite reproducible in response, and reliable.

Table 3

CONVERSION OF SCALE DIVISIONS TO CANDLES PER SQUARE CENTIMETER

SD	cd cm^{-2}	SD	cd cm^{-2}	SD	cd cm^{-2}	SD	cd cm^{-2}	SD	cd cm^{-2}
0.0	1.05-05	4.0	1.68-04	8.0	2.69-03	12.0	4.31-02	16.0	6.89-01
0.1	1.13-05	4.1	1.80-04	8.1	2.88-03	12.1	4.61-02	16.1	7.38-01
0.2	1.21-05	4.2	1.93-04	8.2	3.09-03	12.2	4.95-02	16.2	7.91-01
0.3	1.29-05	4.3	2.07-04	8.3	3.31-03	12.3	5.30-02	16.3	8.48-01
0.4	1.39-05	4.4	2.22-04	8.4	3.55-03	12.4	5.68-02	16.4	9.09-01
0.5	1.49-05	4.5	2.38-04	8.5	3.81-03	12.5	6.09-02	16.5	9.74-01
0.6	1.59-05	4.6	2.55-04	8.6	4.08-03	12.6	6.53-02	16.6	1.04 00
0.7	1.71-05	4.7	2.73-04	8.7	4.37-03	12.7	6.99-02	16.7	1.12 00
0.8	1.83-05	4.8	2.93-04	8.8	4.69-03	12.8	7.50-02	16.8	1.20 00
0.9	1.96-05	4.9	3.14-04	8.9	5.02-03	12.9	8.03-02	16.9	1.29 00
1.0	2.10-05	5.0	3.36-04	9.0	5.38-03	13.0	8.61-02	17.0	1.38 00
1.1	2.25-05	5.1	3.61-04	9.1	5.77-03	13.1	9.23-02	17.1	1.48 00
1.2	2.41-05	5.2	3.86-04	9.2	6.18-03	13.2	9.89-02	17.2	1.58 00
1.3	2.59-05	5.3	4.14-04	9.3	6.63-03	13.3	1.06-01	17.3	1.70 00
1.4	2.77-05	5.4	4.44-04	9.4	7.10-03	13.4	1.14-01	17.4	1.82 00
1.5	2.97-05	5.5	4.76-04	9.5	7.61-03	13.5	1.22-01	17.5	1.95 00
1.6	3.19-05	5.6	5.10-04	9.6	8.16-03	13.6	1.31-01	17.6	2.09 00
1.7	3.42-05	5.7	5.46-04	9.7	8.74-03	13.7	1.40-01	17.7	2.24 00
1.8	3.66-05	5.8	5.86-04	9.8	9.37-03	13.8	1.50-01	17.8	2.40 00
1.9	3.92-05	5.9	6.28-04	9.9	1.00-02	13.9	1.61-01	17.9	2.57 00
2.0	4.20-05	6.0	6.73-04	10.0	1.08-02	14.0	1.72-01	18.0	2.76 00
2.1	4.51-05	6.1	7.21-04	10.1	1.15-02	14.1	1.85-01		
2.2	4.83-05	6.2	7.73-04	10.2	1.24-02	14.2	1.98-01		
2.3	5.18-05	6.3	8.28-04	10.3	1.33-02	14.3	2.12-01		
2.4	5.55-05	6.4	8.88-04	10.4	1.42-02	14.4	2.27-01		
2.5	5.95-05	6.5	9.51-04	10.5	1.52-02	14.5	2.44-01		
2.6	6.37-05	6.6	1.02-03	10.6	1.63-02	14.6	2.61-01		
2.7	6.83-05	6.7	1.09-03	10.7	1.75-02	14.7	2.80-01		
2.8	7.32-05	6.8	1.17-03	10.8	1.87-02	14.8	3.00-01		
2.9	7.85-05	6.9	1.26-03	10.9	2.01-02	14.9	3.21-01		
3.0	8.41-05	7.0	1.35-03	11.0	2.15-02	15.0	3.44-01		
3.1	9.01-05	7.1	1.44-03	11.1	2.31-02	15.1	3.69-01		
3.2	9.66-05	7.2	1.55-03	11.2	2.47-02	15.2	3.96-01		
3.3	1.04-04	7.3	1.66-03	11.3	2.65-02	15.3	4.24-01		
3.4	1.11-04	7.4	1.78-03	11.4	2.84-02	15.4	4.54-01		
3.5	1.19-04	7.5	1.90-03	11.5	3.04-02	15.5	4.87-01		
3.6	1.27-04	7.6	2.04-03	11.6	3.26-02	15.6	5.22-01		
3.7	1.37-04	7.7	2.19-03	11.7	3.50-02	15.7	5.60-01		
3.8	1.46-04	7.8	2.34-03	11.8	3.75-02	15.8	6.00-01		
3.9	1.57-04	7.9	2.51-03	11.9	4.02-02	15.9	6.43-01		

Greatest Western Elongation

Data during June of 1969 were obtained at Table Mountain Observatory and at New Mexico State University Observatory. The instrumental particulars are compared below:

Site	TMO	NMSU
Telescope location		
Latitude	34° 22' 54".02 N	32° 17' 17".12 N
Longitude	117° 41' 51".22 W	106° 41'.8 W
Altitude	7503 ft (2287 m)	4767 ft (1453 m)
Optical parameters		
Optical Type	Cassegrain reflector	
Aperture, D	16 in.	24 in.
Effective focal length, F	803 in.*	1780 in.
Focal ratio	50*	74
Plate scale	10".2/mm*	4".56/mm
Magnification (powers)	993×	
Camera parameters		
Description	Contarex 35 mm	3 1/4 × 4 1/4 plate
Amplifying lenses	None	None
Shutter speeds	T, B, 1 to 1/1000 sec	T, 6 to 1/20 sec
Filters	None	NG-4

Kodak spectroscopic emulsions type III-F were used in both cameras. At TMO 25 strips of film were used, averaging 19 planetary images each. At NMSU 22 plates were used, each having 25 planetary images. Each plate was provided with a photometric calibration strip.

Measurements of sky brightness were made with the two photometers described earlier. Sky brightness was such that neither was used with any kind of filter.

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*Figures vary slightly with placement of camera and secondary.

METHOD AND TECHNIQUE: INFERIOR CONJUNCTION

In order to obtain data over the widest possible range of sky brightness, it was necessary to resort to practices that are unorthodox in ordinary astronomical work. This was especially true during inferior conjunction, with Venus very close to the Sun. In particular it was also necessary to observe the planet as near the horizon as possible as the sky was darkest then.

For a typical observing run, for example on a few days after inferior conjunction, preparations were made to begin observations at Venus rise. The exact time and azimuth of the planet's rising were computed in advance to assist in anticipating the planet's appearance (see Appendix). Starting at planet rise, photographs were taken frequently with simultaneous readings of the brightness of the sky surrounding Venus. Since one of the objectives was to determine the exposures at which both Venus and the sky become visible on the photographs, a range of exposures was used, each series being started when the sky brightness had changed sufficiently. The data in Section III reveal the exact plan used. Photography was continued until the sky reached its daytime brightness. Toward the end of each day's run, Venus was not visible through the photometer eyepiece because of the high brightness of the sky. It was then necessary to establish the Venus location by sighting along the telescope tube. Between each series of exposures, visual observations of the Venus crescent arc length were made by all observers present to establish the relationship between visual and photographic observations.

The use of color filters on the camera would have permitted sharper pictures, to be sure, but our lack of knowledge of the variations of apparent brightness with wavelength, both of Venus and of the terrestrial sky, particularly at large zenith distances and at sunrise, would have complicated greatly the interpretation of results. Ultimately, of course, such work is desirable, but knowledge has not yet progressed to that point.

Some other consequences of our interest in the brightness rather than the spatial resolution of the Venus images were (a) no need for many exposures to capture the few fleeting moments of outstanding atmospheric clarity and (b) the use of the same film or plate sometimes for hours, because of the desirability of getting as many data as possible on one plate to minimize variations due to processing and to emulsion sensitivity.

METHOD AND TECHNIQUE: GREATEST ELONGATION

For observations near dichotomy, the methods used were similar to those described above. However, since Venus was farther from the Sun, it was possible to make observations against a much darker sky.

The procedures at NMSU were somewhat different because of the different equipment. For example, the shutter on the 24-in. telescope did not operate reliably at speeds shorter than 1/20 sec. In order to obtain photographs under bright-sky conditions, it was necessary to use a neutral-density filter in the camera. The NG-4 filter used reduced the intensity of light at the plate by a factor of ten. Also, the time of each exposure was automatically recorded when the shutter was operated. Since a sensitometer was available at NMSU, each plate was given a photometric calibration strip.

III. CATALOG OF TELESCOPIC DATA

The reduced telescopic data are collected in catalog form in three functional tables.

PLATE MEASUREMENTS

Table 4 presents the data collected on spectroscopic plates type III-F, exposed in the 16-in. telescope at TMO. The purpose was to determine the apparent size of the Venus crescent under widely varying conditions of sky brightness and exposure duration.

Date is the Universal day on which the observation was made.

Plate Number is the TMO serial number, 16-in. telescope series.

Image designates which of the many images on each plate was used. The images are numbered sequentially, so the first exposure is Image 1, and so on.

UT is the Universal Time of the start of the exposure. Hours and minutes are indicated to the left of the colon, seconds to the right.

Photometer is the surface brightness of the terrestrial sky around Venus. The tabulated values are readings of the photometer, in scale divisions, at the instant of exposure. Venus was centered in the photometer's field of view. (Even at the lowest measurable levels of sky brightness, the contribution by Venus was imperceptible with the meters.) The values can be converted from scale divisions to candles per square centimeter by reference to Table 3.

Exposure is the duration of shutter opening, in seconds.

Angular Extent is the arc length of the Venus crescent as it appears on each image. It is expressed in degrees. A description of the measuring process is given in Section V.

Venus Altitude is the angular height of Venus (90° -zenith distance) above the horizon. These values were computed from knowledge of the exact time and place of observation. The computer program used for these calculations is in the Appendix. The program also gives the altitude and azimuth of the Sun. In the interests of economy, only representative values are given; more detailed data can be generated at any time from the program.

FILM MEASUREMENTS

Table 5 is a collection of photographic data obtained on films exposed through the 16-in. telescope at TMO.

Date and UT are the Universal date and time of each observation.

Film Number is the TMO serial number identifying the film (16-in. telescope series).

Type specifies the emulsion type used (all Kodak).

Image designates the serial number of the exposure on a given plate.

Photometer gives the measured sky brightness around Venus at the instant of exposure in scale divisions (refer to Table 3). An entry of "L" indicates a barely noticeable meter response below 1 scale division.

Exposure is the duration of shutter opening, in seconds.

Angular Extent is the measured arc length of the Venus crescent on the photographic negative, in degrees. The technique of measurement is described in Section V.

Venus Altitudes are representative values determined by the computer program in the Appendix.

VISUAL ESTIMATES

Table 6 lists the visual estimates of the extent of the Venus crescent, as determined by several observers at TMO.

Date and UT are the Universal day and time of observation.

Photometer gives the surface brightness, in scale divisions, of the sky around Venus at the time of observations. The values can be converted to candles per square centimeter by means of Table 3.

Observer identifies the source of the data:

K: G. E. Kocher

M: R. C. Moore

S: G. F. Schilling

Y: J. Young

Angular Extent is the estimated arc length of the Venus crescent in degrees. All observations were made with the 6-in. refractor attached to the 16-in. telescope unless otherwise indicated. Removal of the camera was necessary to use the 16-in. telescope visually.

Venus Altitude tabulates a few representative values of the angular height of Venus above the horizon. Details of the computation are given in the Appendix.

Table 4

ANGULAR EXTENT OF VENUS IMAGE OBTAINED FROM III-F PLATE MEASUREMENTS

Date	Plate No.	Image	UT	Photometer	Exposure (sec)	Angular Extent	Venus Altitude
4 April	5425	4	1350:12	17.3	.1	155-160	5° 27'
		5	1429:20	17.7	.01	165	13 23
		6	:42	17.7	.02	170	13 29
		9	59:30	17.3	.01	160	19 34
		14	1900:02	16.3	.01	185	66 03
5 April	5426	1	0124:00	18.0	.01	175	16 38
		2	34:43	18.0	.01	165	
		3	43:29	17.9	.01	165	
		4	49:20	18.0	.01	160	
		8	0216:10	13.7	.02	175	
		9	:20	13.7	.02	170	
		10	:30	13.6	.02	170	
		11	:55	13.5	.02	185	
		12	0217:55	13.4	.04	180	5 30
7 April	5428	11	1653:31	17.9	.01	160	46 13
		12	:41	17.9	.01	160	
		14	54:28	17.9	.02	160	46 25
7 April	5429	1	1855:56	17.2	.01	160	66 58
		3	57:11	17.2	.01	160	
		8	1901:35	17.0	.01	165	
		13	05:59	17.8	.01	160	68 07
8 April	5430	7	1346:43	17.4	.01	175	8 55
		9	1400:37	17.7	.01	170	11 46
		11	01:12	17.7	.01	175	11 54
		14	02:03	18.0	.01	175	12 04

Table 4 -- continued

Date	Plate No.	Image	UT	Photometer	Exposure (sec)	Angular Extent	Venus Altitude
8 April	5431	3	1446:18	17.6	.01	180	21° 10'
		4	:33	17.6	.01	180	21 14
		5	49:54	17.6	.01	180	21 56
		9	1509:48	17.4	.01	180	26 00
		15	30:18	17.4	.01	175	30 18
		16	:34	17.4	.02	160-170	30 20
8 April	5432	2	1821:58	17.3	.01	185	63 00
		6	24:18	17.3	.01	185	63 12
		7	:37	17.3	.02	175	63 24
		8	28:12	17.0	.02	180	63 56
		10	29:31	16.9	.02	180	64 07
		12	32:48	17.1	.1	185	64 33
		14	57:28	16.9	.01	180	67 28
9 April	5435	6	0029:08	17.7	.01	165	22 04
10 April	5440	8	1903:59	17.0	.1	160	68 10
		9	04:18	17.0	.04	160	68 11
11 April	5442	15	1300:35	8.9	.5	180	2 38
		16	:55	9.0	1.0	195	2 44
11 April	5443	5	1303:38	9.7	.5	200	3 14
		6	04:53	10.2	.5	210	3 30
		7	05:07	10.5	.2	195	3 40
		14	07:47	11.1	.2	205	3 50
		15	08:00	11.2	.5	200	4 10
		16	:11	11.3	1.0	220	4 11

Table 4 -- continued

Date	Plate No.	Image	UT	Photometer	Exposure (sec)	Angular Extent	Venus Altitude
11 April	5444	3	1309:56	11.6	.1	195	4° 32'
		4	10:09	11.6	.2	195	
		5	:26	11.7	.5	195	
		6	11:38	11.9	.5	205-215	
		7	:53	11.9	.2	200	
		8	12:10	12.1	.1	195	4 57
		13	13:36	12.3	.1	195	5 15
		14	:52	12.3	.2	190	
		15	14:05	12.3	.5	195	
		16	:16	12.5	1.0	180	5 23
11 April	5445	2	1317:18	12.9	.04	180	5 58
		3	:29	13.0	.1	200	
		4	:40	12.9	.2	190	
		5	:56	13.1	.5	180	
		8	19:23	13.2	.1	185	
		13	20:27	13.6	.1	185	
		14	:40	13.6	.2	190	6 42
11 April	5446	12	1332:44	15.5	.04	165	9 00
		14	33:17	15.7	.2	180	9 16
13 April	5450	15	1309:24	12.7	.04	180	6 22
14 April	5452	17	1309:22	12.7	.04	180	7 20
15 April	5453	6	1247:09	6.2	1.0	180	3 40
		8	50:30	6.8	1.0	185	4 23
		9	52:51	7.5	1.0	180	4 47
		13	1302:23	10.9	.2	185	6 50
15 April	5454	2	1724:30	15.8	.01	170	58 20
		10	38:12	15.8	.01	165	61 40
		16	50:03	15.8	.04	150	62 04

Table 5

ANGULAR EXTENT OF VENUS IMAGE OBTAINED FROM FILM MEASUREMENTS

Date	Film No.	Type	Image	UT	Photometer	Exposure (sec)	Angular Extent	Venus Altitude
16 April	5459	II-F	6	1225:05	0	1	160-170	0° 07'
			7	27:39	L	1/2	130-150	
			8	28:30	L	1/8	too faint	
			9	29:00	1.0	1/30	invisible	
			10	:43	1.5	1/125	invisible	
			11	36:15	3.8	1	190	
			12	:37	3.9	1/8	130-150	
			13	37:00	4.0	1/125	invisible	
			14	47:45	6.5	1	205-215	
			15	48:03	6.6	1/8	175	
			16	:32	6.6	1/125	invisible	4 53
16 April	5460	Tri-X	3	1310:47	12.8	1/8	180	9 26
			4	11:07	12.8	1/125 ?	195	
			5	13:45	13.1	1/8	185	
			6	14:06	13.1	1/60	180	
			7	:19	13.2	1/500	170	
			8	18:10	13.6	1/1000	invisible	
			9	:25	13.7	1/500	165	
			10	:43	13.7	1/250	invisible	
			11	:52	13.7	1/125	170	
			12	19:00	13.8	1/60	185	
			13	:09	13.8	1/30	185	
			14	:17	13.8	1/15	190	
			15	:27	13.8	1/8	180	
			16	:35	13.8	1/4	175	
			17	:42	13.9	1/2	155	
			18	:49	13.9	1	160	
			19	20:45	14.0	1 ?	160	
			20	21:06	14.2	1/125	170	
			21	:14	14.2	1/125	170	11 35

Table 5 -- continued

Date	Film No.	Type	Image	UT	Photometer	Exposure (sec)	Angular Extent	Venus Altitude
16 April	5466	II-F	1	1723:57	16.2	1/500	165	58° 51'
			2	24:22	16.2	1/250	170	
			3	25:22	16.2	1/8	too dark	
			4	:43	16.2	1/30	140	
			5	26:17	16.2	1/125	160	
			7	:44	16.2	1/250	165	
			8	28:07	16.2	1/500	165	
			9	31:52	16.0	1/8	too dark	
			10	32:05	16.0	1/30	160	
			11	:22	16.0	1/125	170	
			12	:30	16.0	1/250	185	
			13	:40	16.0	1/500	180	
			14	33:07	16.0	1/2	too dark	
			15	:20	16.0	1/250	185	
			16	:28	16.0	1/250	185	
			18	36:28	16.2	1/8	too dark	
			19	38:32	16.2	1/30	155	
			20	:45	16.2	1/125	160	60 57
17 April	5467	III-F	6a	1226:09	0	1	130	1 12
			7a	:37	0	1/8	invisible	
			8a	:55	0	1/60	invisible	
			7	34:15	1.7	1	175	
			8	:31	1.7	1/8	too faint	2 54
			9	:44	1.7	1/60	invisible	
			10	38:15	3.5	1	180	
			11	:25	3.5	1/8	155	
			12	:35	3.6	1/60	invisible	
			13	45:45	5.5	1	195	
			14	:52	5.6	1/8	130	

Table 5 -- continued

Date	Film No.	Type	Image	UT	Photometer	Exposure (sec)	Angular Extent	Venus Altitude
17 April	5467 (cont'd)	III-F	15	1246:02	5.7	1/60	invisible	5° 12'
			16	51:50	7.2	1	205	
			17	52:00	7.3	1/8	165	
			18	:10	7.3	1/60	too faint	6 30
			19	57:45	9.0	1	210	
			20	:55	9.0	1/8	175	
			21	58:02	9.1	1/60	too faint	
			22	1302:15	11.0	1/8	185	
			23	:25	11.0	1/60	140	
			24	:34	11.1	1/125	invisible	8 25
			25	06:40	11.9	1/8	200	
			26	:47	12.0	1/60	135	
			27	:55	12.0	1/125	too faint	
			28	12:25	13.0	1/8	195	10 40
17 April	5469	III-F	1	1721:30	16.2	1/2	too dark	
			2	22:10	16.2	1/8	170	58 58
			3	:32	16.2	1/30	180	
			4	:47	16.2	1/125	180	
			5	23:15	16.2	1/250	180	
			6	:42	16.2	1/500	170	
			7	25:32	16.2	1/8	170	
			8	:45	16.2	1/30	185	
			9	:57	16.2	1/125	180	
			10	26:15	16.2	1/250	165	
			11	:42	16.2	1/500	170	
			12	28:45	16.2	1/8	180	
			13	:58	16.2	1/30	190	
			14	29:11	16.2	1/125	190	
			15	:48	16.2	1/250	175	

Table 5 -- continued

Date	Film No.	Type	Image	UT	Photometer	Exposure (sec)	Angular Extent	Venus Altitude
17 April	5469 (cont'd)	III-F	16	1730:09	16.2	1/500	165	
			18	32:46	16.2	1/30	170	
			19	:57	16.2	1/125	190	
			20	33:03	16.2	1/250	175	
			21	:13	16.2	1/60	180	
			22	34:37	16.2	1/8	165	
			23	:47	16.2	1/30	175	
			24	:54	16.2	1/60	190	
			25	35:02	16.2	1/125	180	
			26	:23	16.2	1/250	170	
			27	:27	16.2	1/1000	150 faint	
			28	:59	16.2	1	too dark	
			29	36:54	16.2	1/60	190	
			30	37:04	16.2	1/60	185	61° 06'
19 April	5470	III-F	5	1217:44	0	1	165	1 11
			7	30:04	3.6	1	185-195	3 41
			8	:13	3.7	1/8	140	3 43
			9	40:08	5.8	1	190	5 45
			10	:17	5.8	1/8	160	5 47
			11	48:35	7.5	1	200	7 29
			12	49:05	7.6	1/8	165	7 35
			13	53:30	8.95	1	195	8 30
			14	:52	9:05	1/8	185	8 34
			15	58:30	10.5	1	205	9 31
			16	:48	10.6	1/8	180-185	9 35
			17	1304:25	12.4	1	190	10 44
			18	:38	12.45	1/8	185-190	10 47
			19	10:30	13.1	1	180-185	12 00
			20	:38	13.2	1/8	180	12 02

Table 5 -- continued

Date	Film No.	Type	Image	UT	Photometer	Exposure (sec)	Angular Extent	Venus Altitude
19 April	5470 (cont'd)	III-F	21	1310:44	13.3	1/30	175	12° 03'
			22	:52	13.4	1/125	135	12 04
			23	14:24	13.65	1/8	185-190	12 48
			24	:39	13.7	1/125	150	12 51
			25	16:15	13.9	1/8	185	13 11
			26	:25	14.0	1/125	140	13 13
			27	18:02	14.1	1/8	185	13 33
			28	:15	14.1	1/125	150	13 36
			29	19:12	14.2	1/8	185	13 48
			30	:19	14.2	1/125	150	13 49
			31	20:30	14.3	1/8	180	14 04
19 April	5471	III-F	4	1648:13	15.2	1/8	175	54 48
			5	:34	15.2	1/60	180	
			6	:55	15.2	1/125	175	
			7	1700:02	15.0	1/8	170	
			8	:18	15.0	1/60	185	
			9	:28	15.0	1/125	185	
			10	10:35	15.1	1/8	175	
			11	:45	15.1	1/60	180	
			12	:56	15.1	1/125	190	
			13	20:03	15.1	1/8	185	
			15	:23	15.1	1/125	190	
			16	30:12	15.0	1/8	175	
			17	:38	15.0	1/60	180	
			20	31:37	15.0	1/60	180	
			21	40:30	15.0	1/8	185	
			22	:40	15.0	1/60	175	
			23	:55	15.0	1/125	170	
			24	50:20	14.9	1/8	185	

Table 5 -- continued

Date	Film No.	Type	Image	UT	Photometer	Exposure (sec)	Angular Extent	Venus Altitude
19 April	5471 (cont'd)	III-F	25	1750:28	14.9	1/60	180	
			26	:32	14.9	1/125	185	
			27	1800:40	15.0	1/8	180	
			28	:50	15.0	1/60	185	
			29	:56	15.0	1/125	180	
			30	04:04	14.8	1/2	160	64° 10'
20 April	5472	III-F	2	1205:00	0	4.5	165	-0° 36'
			3	10:56	0	4.5	205	+0 36
			3a	--	--	--	160	
			4	14:38	0	4.5	200	
			5	26:20	3.0	1	190	
			6	:31	3.0	1/8	165	
			7	34:55	4.8	1	190	
			8	35:00	4.8	1/8	165	
			9	38:25	5.4	1	195	
			10	:31	5.4	1/8	180	
			11	44:18	6.7	1/8	175	
			12	:28	6.7	1	195	
			13	49:37	8.1	1	200	
			14	:43	8.1	1/8	175	
			15	56:15	9.7	1	200	
			16	:23	9.7	1/8	180	
			17	59:20	11.1	1	195	
			18	:28	11.1	1/8	185	
			21	1302:15	12.0	1	190	
			22	:27	12.0	1/8	190	
			23	:32	12.0	1/8	190	
			24	:40	12.0	1/30	165	
			25	09:20	13.0	1/8	185	

Table 5 -- continued

Date	Film No.	Type	Image	UT	Photometer	Exposure (sec)	Angular Extent	Venus Altitude
20 April	5472 (cont'd)	III-F	26	1309:29	13.0	1/30	175	
			27	12:30	13.6	1/8	180	
			28	:38	13.6	1/30	170	
			29	15:40	14.0	1/8	185	13° 55'
21 April	5477	III-F	3	1208:43	0	1	175	0 56
			4	11:47	0	4	195	1 33
			5	12:13	0	1	180	1 39
			6	18:19	0	1	180	2 54
			7	:31	<1	1/8	155	2 56
			8	29:02	3.0	1	195	5 06
			9	:18	3.0	1/8	165	5 09
			10	38:18	5.2	1	200	7 00
			11	:39	5.2	1/8	175	7 04
			12	48:04	7.4	1	205	9 01
			13	:23	7.5	1/8	180	9 05
			14	59:25	11.4	1	205	11 20
			15	:38	11.45	1/8	185	11 23
			16	:50	11.5	1/60	145	11 26
			17	1307:34	12.8	1/8	190	13 02
			18	:50	12.8	1/60	175	13 06
			19	15:00	13.8	1/8	190	14 35
			20	:07	13.8	1/60	175	14 36
			21	17:27	14.0	1/2	175	15 05
			22	:38	14.0	1/500	too faint	15 07
			23	:59	14.0	1/8	185	15 12
			24	18:13	14.0	1/60	170	15 15

Table 5 -- continued

Date	Film No.	Type	Image	UT	Photometer	Exposure (sec)	Angular Extent	Venus Altitude
22 April	5482	III-F	1	1757:38	15.2	1/30	175	63° 39'
			2	:57	15.2	1/60	170	
			3	58:12	15.2	1/125	175	
			4	59:55	15.2	1/30	170	
			5	1800:17	15.3	1/60	180	
			6	:36	15.3	1/125	175	
			7	01:06	15.3	1/30	180	
			8	:18	15.3	1/60	180	
			9	:27	15.3	1/125	185	
			10	02:29	15.3	1/30	180	
			11	:46	15.3	1/60	175	
			12	03:17	15.3	1/125	170	
			13	06:10	15.3	1/2	160	
			14	:29	15.3	1/500	160	
			15	:52	15.3	1/30	175	
			16	07:01	15.3	1/60	185	
			17	:40	15.3	1/125	170	
			18	08:45	15.3	1/30	180	
			19	09:13	15.3	1/60	170	64 07

Table 6

VISUAL ESTIMATES OF THE ANGULAR EXTENT OF THE VENUS CRESCENT

Date	UT	Photometer	Observer	Angular Extent	Venus Altitude
16 April	1234:30	~ 3	K; M; S	>180	2° 02'
	43	~ 5.5	S; K	225±10	
	50	~ 7	M	220	
	1301	~10	M; S	200-205	
	24	~14	K; M; S	190	12 10
	1738	16.2	S	160	60 50
17 April	1229	~ 1.0	S	220	1 47
	30	1.0	K	210	
	32	~ 1.5	M	225	
	36:30	2.5	Y	200	
	40:30	4.0	S	225	
	43:20	5.0	Y	240	
	45	5.3	K	225	
	45	"	Y	240	
	45	"	M	230	
	45	"	S	230	
	51	7.0	Y	225	
	53:30	7.5	Y	220	
	55:37	8.3	Y	220	
	58:45	9.0	Y	215	
	59	9.5	Y	225	
	1301	10.0	Y	215	
	02	11.0	Y	210-215	
	03:30	11.4	S	200-205	
	04	11.5	Y	210	
	06:15	11.8	Y	200	
	07	12.0	Y	200	
	08	12.2	Y	190	
	09:10	12.4	Y	190	
	10	12.5	Y	190 (16")	
	11:00	12.6	Y	>180	
	11:45	12.6	Y	190	
	13:00	13.0	Y	185	
	13:45	--	Y	190	
	14:22	--	S	195	
	21:30	13.5	Y	>180	
	25	13.5	Y	>180	
	26	13.5	Y	190	
	26	13.5	S	180-190	13 28
19 April	1216	0	Y	200-210	51
	24:30	2.3	Y	200	
	26:45	3.0	Y	200	3 01
	30:30	3.7	Y	200	
	31:45	4.0	S	210	4 02
	33	4.3	K	195	4 18

Table 6 -- continued

Date	UT	Photometer	Observer	Angular Extent	Venus Altitude
19 April (cont'd)	1236	5.0	Y	200	4° 55'
	37:10	5.2	S	210-215	
	38:40	5.5	M	215	5 27
	39:35	5.7	K	200	
	41	6.0	Y	205	
	41:45	6.1	S	220	
	42:50	6.3	M	215	6 19
	44	6.5	K	205	
	46:30	7.0	Y	210	7 04
	49	7.6	Y	220-225	7 35
	51	8.1	S	215	
	53	--	Y	280 (16")	8 24
	54:15	--	Y	250 (16")	
	55:10	9.5	Y	230	8 50
	56:00	--	K	220 (16")	
	56:00	--	K	220	
	56:55	10.0	S	220	
	58:15	--	Y	240-250 (16")	
	58:50	10.6	Y	215	9 35
	1301:40	11.7	Y	210	10 10
	02:45	12.0	S	205	
	03:30	12.2	Y	220 (16")	10 33
	04:20	12.4	Y	210	10 44
	07:35	--	Y	190 (16")	11 20
	07:35	12.9	Y	200	
	09:15	13.0	S	200	11 44
	11:15	13.3	Y	200	
	11:35	--	Y	190 (16")	
	12:10	13.5	S	190-195	
	12:50	13.6	M	190	12 29
	13:20	13.6	K	170	
	13:52	--	K	185 (16")	
	15:05	13.8	Y	180	
	15:05	13.8	K	170	
	15:32	13.8	Y	190	
	16:09	13.9	K	180	13 11
	16:53	14.0	Y	190	
	17:05	--	Y	180 (16")	
	17:43	14.1	K	180	
	18:30	14.1	Y	170	
	19:05	14.2	Y	185	13 47
	19:35	14.2	K	175	
	20:10	14.3	Y	180	
	20:55	14.3	K	175	14 09
	21:10	--	Y	160 (16")	
	21:20	14.4	Y	180	
	21:30	14.4	S	180	
	22:22	14.4	M	185	14 27

Table 6 -- continued

Date	UT	Photometer	Observer	Angular Extent	Venus Altitude
19 April (cont'd)	1635	15.4	S	160	52° 46'
	35	"	K	170	
	35	"	M	175	
	1701	15.0	S	160	
	01	"	K	170	
	01	"	M	170	
	1711	15.1	S	160-165	
	11	"	K	170	
	11	"	M	170	
	1721	15.1	S	165-170	
	21	"	K	165	
	21	"	M	180	
	1731	15.0	S	170	
	31	"	K	170	
	31	"	M	170	
	1741	15.0	S	175-180	
	41	"	K	170	
	41	"	M	175	
	1751	14.9	S	170	
	51	"	K	175	
	51	"	M	170	
	1801	15.0	S	170-175	
	01	"	K	165	
	01	"	M	165	
	1804	14.8	S	180	
	04	"	K	170	
	1811	14.8	S	175	64 37
	11	"	K	165	
	11	"	M	170	
20 April	~1220	1	Y	210	2 27
	22:15	1.5	S	225-230	
	24:15	2.5	Y	215	
	27	3.0	Y	240	
	27	"	M	225	
	33	4.2	Y	225	
	36	5	Y	230	
	36	"	M	230	
	41	6.0	Y	230	
	42	6.0	K	225	
	47	7.5	Y	220	
	48	7.7	S	215	
	50	8.2	Y	230	
	52	8.6	K	220	
	52	"	M	220	
	53	9.1	S	215-220	
	55	9.5	Y	220	
	58	10.6	Y	220	

Table 6 -- continued

Date	UT	Photometer	Observer	Angular Extent	Venus Altitude
20 April (cont'd)	1300	11.5	Y	220	
	02	12.0	Y	230	
	05	12.4	S	210	
	07	12.6	M	220	
	10	13.0	Y	220	
	13	13.6	Y	200	
	13:30	13.6	S	195	
	14:20	13.8	M	190	
	15	14.0	Y	195-200	
	17:30	14.2	Y	190	14° 17'
	1747	14.3	K	170	62 53
	47	"	S	160	
	47	"	M	180	
	56	14.4	K	175	
	56	"	S	170	
	56	"	M	180	
	1808	14.3	K	175	
	08	"	S	170	
	08	"	M	180	
	16	14.3	K	175	64 41
	16	"	M	180	
21 April	1209:35	0	K	225	1 08
	09:45	0	S	230	
	12:55	~ .3	K	220	
	17:50	.6	M	220	
	19:05	1.0	K	215	
	26:30	2.0	S	225	
	30	3.0	K	215	
	31	3.2	M	225	
	32	3.5	S	220	
	39	5.2	K	220	
	39	"	S	220	
	41	6.0	M	220	
	49	8.0	K	215	9 13
	49	"	S	215-220	
	49	"	M	215	
	1301	11.6	K	210	
	01	"	S	210	
	01	"	M	210	
	08	12.8	K	195	
	08	"	M	200	
	16	13.8	K	185	14 47
	16	"	S	195	
	16	"	M	195	

Table 6 -- continued

Date	UT	Photometer	Observer	Angular Extent	Venus Altitude
21 April	1744	15.5	K	170	62° 42'
(cont'd)	44	"	S	160-170	
	44	"	M	170	
	51	15.8	K	165	
	51	"	S	165	
	51	"	M	165	
	56	15.8	K	165	
	56	"	S	160	
	56	"	M	160	
	1800	15.8	K	165	
	00	"	S	165	
	00	"	M	165	
	06	15.8	K	160	
	06	"	S	150	
	06	"	M	155	
	11	15.8	K	155	
	11	"	S	160	
	11	"	M	150	
	16	15.8	K	155	64 30
	16	"	S	140	
	16	"	M	145	
22 April	1207	0	Y	195	1 22
	07	0	S	190-240	
	07	0	K	195-220	
	09:45	0	Y	220	
	14:50	0	Y	220	
	17	>0	S	225	
	19	1.0	Y	230	
	19	"	K	215	
	19	"	M	210	
	23	1.5	Y	225	
	26	2.0	S	210	
	32:30	4.0	Y	215	
	35:45	4.6	Y	225	
	39:30	5.6	S	205-210	
	39:40	"	M	200	
	41:30	6.2	Y	220	
	42:45	6.4	K	225	
	43:15	6.5	S	220	
	48:30	8.0	Y	230	
	48:40	"	S	215-220	
	49:30	8.5	K	215	
	49:40	"	M	215	
	52:30	9.5	Y	220	
	57:30	11.0	Y	200	
	58:05	11.2	S	205	
	59:00	11.5	K	205	
	59:10	"	M	200	

Table 6 -- continued

Date	UT	Photometer	Observer	Angular Extent		Venus Altitude
22 April	1301:35	12.0	Y	200		
(cont'd)	04:10	12.3	Y	200		
	07:45	12.9	K	190		
	08:30	13.0	M	190		
	11:30	13.5	Y	180		
	13:36	13.7	M	185		
	14:40	13.8	S	185		15° 18'
	1750	15.2	S	170		63 13
	50	"	K	165		
	50	"	M	175		
	59	15.2	S	160-170		
	59	"	K	170		
	59	"	M	170		
	1801	15.3	S	160-170		
	07	15.3	S	160-170		
	09	15.3	M	175		
	18	15.3	S	175-180	(16")	
	18	"	K	170	(16")	
	18	"	M	170	(16")	
	20	15.3	S	165-170		64 19
	20	"	K	165		
	20	"	M	175		

IV. CATALOG OF PHOTOMETRIC DATA

INFERIOR CONJUNCTION

Table 7 presents the photometric data other than those measurements at the instant of photographic exposure or visual observation, which are given in Tables 4, 5, and 6. The objective was to determine the brightness variation of selected parts of the sky under varying conditions of solar position. The measurements were made with the meters described in Section II.

The first column, UT, specifies the Universal day and time of observation, to the nearest minute. The absence of an entry means that the value (hours, or minutes, or both) is the same as the preceding one.

The second column gives the measured brightness, converted to candles per square centimeter. The first entry, for example, should be read as

$$4.5 \times 10^{-1} \text{ cd cm}^{-2}$$

The third column gives the direction of the reading:

z means the meter was pointed to the zenith.

V means Venus was centered in the field of view.

WH means the western horizon.

EH means the eastern horizon.

In some cases the brightness varied only slightly over long periods; the data were then condensed from the many entries in the log as follows: "Period" means the time interval referred to, and "Range" means the limit of variation in brightness during that period.

GREATEST ELONGATION

The data in Tables 8 and 9 were obtained at TMO and NMSU Observatory, respectively. They are photometric measurements of the surface brightness of the terrestrial sky near the period of greatest western elongation of Venus. The first column, UT, gives the Universal date and time of each observation. The next two columns give the measured brightness of the sky surrounding Venus (V) and at the zenith (z). The meter readings in scale divisions have been converted to candles per square centimeter by means of Table 3. For example, the first entry in Table 8 is a brightness of 4.2×10^{-5} cd cm^{-2}.

Table 7

SKY BRIGHTNESS (TMO)

UT	cd cm^{-2}	
3 April		
1855	4.5 -1*	z
1919	5.2 -1	z
38	4.9 -1	z
2002	3.2 -1	z
27	3.7 -1	z
45	2.6 -1	z
2100	2.4 -1	z
30	2.0 -1	z
46	2.8 -1	z
2258	1.5 -1	z
4 April		
0115	1.1	V
	5.7 -2	z
0200	9.1 -1	V
	2.5 -2	z
15	2.0 -1	V
	4.1 -3	z
30	3.8 -2	V
	2.7 -4	z
36	1.5 -5	z
45	6.7 -4	WH
50	3.4 -4	WH
55	1.3 -4	WH
57	8.4 -5	WH
1348	1.7	V
	3.0 -2	z
1400	1.8	V
	5.0 -2	z
	1.5	WH
29	2.2	V
	5.7 -2	z
	1.7	WH
32	1.2	V
	4.6 -2	z
59	1.7	V
	7.0 -2	z
	2.6	WH
1818	2.3 -1	z
38	6.9 -1	V
	2.6 -1	z
49	7.4 -1	V
	2.6 -1	z
59	8.5 -1	V
1900	2.3 -1	z
01	7.4 -1	V

UT	cd cm^{-2}	
5 April		
0111	2.4	V
	6.5 -2	z
24	2.8	V
	7.0 -2	z
34	2.8	V
	5.3 -2	z
43	2.6	V
	4.0 -2	z
49	2.8	V
	3.5 -2	z
59	1.0	V
	2.5 -2	z
0205	4.5 -1	V
	1.4 -2	z
10	3.2 -1	V
	7.1 -3	z
16	1.4 -1	V
	3.8 -3	z
17	1.1 -1	V
	3.3 -3	z
19	8.6 -2	WH
	2.3 -3	z
24	8.0 -2	WH
	1.2 -3	z
26	6.1 -2	WH
	7.2 -4	z
27	5.3 -2	WH
	5.9 -4	z
28	4.3 -2	WH
	3.6 -4	z
31	1.6 -4	z
33	1.3 -4	z
35	9.7 -5	z
36	8.4 -5	z
7 April		
1512	9.2 -2	z
17	9.2 -2	z
25	1.1 -1	z
1610	1.3 -1	z
50	2.6	V
	1.6 -1	z
52	2.6	V
	1.4 -1	z
53	2.9	V

UT	cd cm^{-2}	
7 April (cont'd)		
1654	2.6	V
	1.4 -1	z
1851	1.3	V
	3.2 -1	z
54	1.5	V
	3.2 -1	z
57	1.6	V
	3.4 -1	z
1900	1.3	V
	3.4 -1	z
08	2.2	V
	3.2 -1	z
2220	3.2 -1	z
27	1.7	V
31	2.2	V
42	6.9 -1	z
43	1.5	V
2303	1.6	V
8 April		
1301	4.4 -4	EH
04	8.4 -5	z
05	9.5 -4	EH
08	1.7 -3	EH
	1.8 -4	z
10	2.9 -3	EH
	2.6 -4	z
15	5.4 -3	EH
	6.3 -4	z
17	8.7 -3	EH
	1.7 -3	z
19	1.6 -2	EH
	2.2 -3	z
22	2.3 -2	EH
	3.6 -3	z
24	3.3 -2	EH
	5.0 -3	z
30	5.7 -2	EH
	1.2 -2	z
31	2.8 -1	V
37	2.1 -1	EH
	2.2 -2	z
40	2.5 -2	z
	1.1	V
45	3.0 -2	z
	1.7	V

*Absence of an exponent means that the exponent is zero.

Table 7 -- continued

UT	cd cm^{-2}	
8 April (cont'd)		
1346	3.0 -2	z
	1.8	V
48	2.2	V
53	2.2	EH
	4.3 -2	z
	2.4	V
59	5.0 -2	z
	2.2	V
1400	5.3 -2	z
01	2.8	EH
	4.6 -2	z
	2.8	V
03	1.7	EH
	5.3 -2	z
	2.1	V
24	1.5 -2	z
Period: 1445 to 1530		
Range of z: 6.5 -2 to 1.1 -1		
Range of V: 1.7 to 2.2		
Period: 1817 to 1858		
Range of z: 2.1 -1 to 4.5 -1		
Range of V: 1.3 to 1.7		
2356	2.1 -1	z
	2.1	V
9 April		
0014	1.5 -1	z
	2.1	V
29	1.1 -1	z
	2.2	V
44	9.9 -2	z
	2.4	V
	2.6	WH
59	8.6 -2	z
	2.1	V
	2.8	WH
9 April (cont'd)		
0114	7.2 -2	z
	2.1	V
	1.7	WH
0130	5.7 -2	z
	2.1	V
	1.8	WH
45	4.6 -2	z
	1.7	WH
51	3.8 -2	z
	1.4	WH
55	1.0	WH
57	6.9 -1	WH
58	2.7 -2	z
	6.0 -1	WH
1250	1.3 -4	EH
52	1.8 -4	EH
53	3.4 -4	EH
55	6.7 -4	EH
56	9.5 -4	EH
58	1.4 -3	EH
59	1.9 -3	EH
1301	2.5 -3	EH
02	2.9 -3	EH
04	4.1 -3	EH
	6.6 -3	V
05	8.2 -3	V
06	1.6 -4	z
09	1.6 -2	V
	4.1 -4	z
20	6.1 -2	V
	3.6 -3	z
23	1.1 -1	V
Period: 1506 to 1514		
Range of z: 1.1 -1 to 1.3 -1		
10 April		
Period: 1824 to 1916		
Range of z: 2.8 -1 to 4.0 -1		
Range of V: 1.4 to 1.7		
11 April		
1245	8.4 -1	EH
47	1.3 -4	EH
49	2.4 -4	EH
	2.7 -4	V
50	3.4 -4	V
51	4.4 -4	V
52	5.5 -4	V
53	8.3 -4	V
54	9.5 -4	V
55	1.6 -3	V
56	1.9 -3	V
57	2.3 -3	V
58	3.3 -3	V
59	4.1 -3	V
1300	4.7 -3	V
01	7.1 -3	V
02	7.6 -3	V
03	8.7 -3	V
05	1.5 -2	V
06	1.8 -2	V
07	2.2 -2	V
08	2.5 -2	V
09	3.0 -2	V
10	3.3 -2	V
11	4.0 -2	V
12	4.6 -2	V
13	5.0 -2	V
14	5.3 -2	V
17	7.5 -2	V
18	9.2 -2	V
19	9.9 -2	V
20	1.1 -1	V
21	1.4 -1	V
29	3.0 -1	V
30	3.2 -1	V
31	3.4 -1	V
32	4.0 -1	V
33	5.2 -1	V
34	6.0 -1	V
2053	9.1 -1	V
54	7.9 -1	V
55	2.8 -1	z
56	3.0 -1	z

Table 7 -- continued

13 April

UT	cd cm^{-2}	
1248	1.1 -3	V
49	1.2 -3	V
51	2.7 -3	V
53	3.3 -3	V
54	4.7 -3	V
55	5.4 -3	V
56	7.6 -3	V
57	8.2 -3	V
59	1.5 -2	V
1300	2.0 -2	V
02	2.7 -2	V
08	5.7 -2	V
09	7.0 -2	V
12	9.2 -2	V
26	3.4 -1	V

14 April

UT	cd cm^{-2}	
1232	1.5 -5	V
35	8.4 -5	V
38	1.4 -4	V
41	2.7 -4	V
43	3.4 -4	V
48	8.3 -4	V
49	1.0 -3	V
51	1.4 -3	V
54	2.5 -3	V
56	3.8 -3	V
58	6.6 -3	V
1300	1.8 -2	V
02	2.8 -2	V
04	3.5 -2	V
06	5.0 -2	V
07	5.3 -2	V
08	5.7 -2	V
11	8.0 -2	V

15 April

UT	cd cm^{-2}	
1235	4.2 -5	V
37	8.4 -5	V
39	1.1 -4	V
41	1.7 -4	V
42	2.4 -4	V
44	3.4 -4	V
45	4.8 -4	V
47	6.7 -4	V
48	8.9 -4	V

15 April (cont'd)

UT	cd cm^{-2}	
1250	1.2 -3	V
53	1.9 -3	V
55	3.3 -3	V
58	5.4 -3	V
1300	9.4 -3	V
02	2.0 -2	V
05	3.3 -2	V
08	5.7 -2	V
12	9.2 -2	V

Period:
1720 to 1750
Range of V:
5.6 -1 to 6.4 -1

16 April

UT	cd cm^{-2}	
1227	1.1 -5	V
29	2.1 -5	V
30	3.0 -5	V
36	1.5 -4	V
37	1.7 -4	V
47	9.5 -4	V
48	1.0 -3	V
57	5.4 -3	V
1304	3.0 -2	V
09	6.5 -2	V
10	7.5 -2	V
11	7.5 -2	V
13	9.2 -2	V
14	9.2 -2	V
18	1.3 -1	V
20	2.0 -1	V
	1.2 -2	z

Period:
1722 to 1728
Range of V:
7.9 -1
Range of z:
2.3 -1

Period:
1731 to 1739
Range of V:
6.9 -1 to 7.9 -1

17 April

UT	cd cm^{-2}	
1229	2.1 -5	V
33	3.0 -5	V
34	4.2 -5	V
36	6.0 -5	V
37	8.4 -5	V
38	1.2 -4	V
40	1.7 -4	V
43	3.4 -4	V
45	4.8 -4	V
46	5.5 -4	V
47	6.7 -4	V
51	1.4 -3	V
52	1.7 -3	V
55	2.7 -3	V
56	3.8 -3	V
57	5.4 -3	V
58	5.8 -3	V
1301	1.5 -2	V
02	2.2 -2	V
04	3.0 -2	V
06	4.0 -2	V
07	4.6 -2	V
08	5.0 -2	V
09	5.7 -2	V
12	7.0 -2	V
22	1.2 -1	V

Period:
1718 to 1739
Range of V:
7.9 -1
Range of z:
2.4 -1

19 April

UT	cd cm^{-2}	
1220	3.0 -5	V
24	4.2 -5	V
26	8.4 -5	V
29	1.2 -4	V
30	1.4 -4	V
31	1.7 -4	V
33	2.1 -4	V
34	2.7 -4	V
36	3.4 -4	V
38	4.8 -4	V
40	5.9 -4	V
41	6.7 -4	V

Table 7 -- continued

UT	cd cm^{-2}	
19 April (cont'd)		
1242	8.3 -4	V
44	1.0 -3	V
46	1.4 -3	V
48	1.8 -3	V
49	2.0 -3	V
50	2.7 -3	V
52	3.8 -3	V
53	4.4 -3	V
54	6.6 -3	V
55	7.6 -3	V
56	9.4 -3	V
57	1.4 -2	V
58	1.6 -2	V
59	2.2 -2	V
1300	3.0 -2	V
01	3.5 -2	V
03	5.0 -2	V
04	5.7 -2	V
05	6.1 -2	V
07	7.0 -2	V
09	8.6 -2	V
10	1.1 -1	V
12	1.3 -1	V
14	1.4 -1	V
16	1.6 -1	V
18	1.9 -1	V
19	2.0 -1	V
20	2.1 -1	V
22	2.3 -1	V
Period: 1631 to 1810		
Range of V: 3.0 -1 to 4.5 -1		
Range of z: 1.5 -1 to 2.1 -1		
20 April		
1220	2.1 -5	V
23	4.2 -5	V
26	8.4 -5	V
33	2.1 -4	V
35	2.9 -4	V
38	4.4 -4	V
44	1.1 -3	V
	3.0 -5	z
48	2.2 -3	V
	8.4 -5	z

UT	cd cm^{-2}	
20 April (cont'd)		
1249	2.9 -3	V
	1.0 -4	z
53	5.8 -3	V
	2.2 -4	z
55	7.6 -3	V
	3.6 -4	z
56	8.7 -3	V
57	1.6 -2	V
	5.9 -4	z
59	2.3 -2	V
	8.9 -4	z
1301	3.5 -2	V
	1.3 -3	z
02	4.3 -2	V
05	5.7 -2	V
	2.3 -3	z
07	6.5 -2	V
	2.7 -3	z
08	8.6 -2	V
09	3.6 -3	z
10	3.8 -3	z
11	4.4 -3	z
12	1.3 -1	V
	5.4 -3	z
13	5.8 -3	z
14	6.6 -3	z
15	7.1 -3	z
16	2.0 -1	V
	8.2 -3	z
17	8.7 -3	z
Period: 1745 to 1815		
Range of V: 2.4 -1 to 4.2 -1		
Range of z: 2.1 -1 to 2.4 -1		
21 April		
1218	1.5 -5	V
20	2.1 -5	V
24	3.0 -5	V
29	8.4 -5	V
37	3.4 -4	V
38	3.9 -4	V
48	1.8 -3	V
49	1.2 -4	z

UT	cd cm^{-2}	
21 April (cont'd)		
1253	4.4 -3	V
	2.1 -4	z
57	2.3 -2	V
	4.8 -4	z
1300	3.0 -2	V
	8.3 -4	z
02	3.8 -2	V
	1.4 -3	z
07	7.0 -2	V
08	7.5 -2	V
09	8.6 -2	V
11	1.1 -1	V
12	1.2 -1	V
15	1.5 -1	V
	7.6 -3	z
18	1.7 -1	V
	1.5 -2	z
Period: 1744 to 1821		
Range of V: 4.2 -1 to 6.4 -1		
Range of z: 2.4 -1 to 4.0 -1		
22 April		
1218	2.1 -5	V
27	6.0 -5	V
29	8.4 -5	V
31	1.3 -4	V
33	1.7 -4	V
35	2.4 -4	V
36	2.9 -4	V
38	4.8 -4	V
	2.1 -5	z
40	6.7 -4	V
43	9.5 -4	V
44	1.1 -3	V
45	1.4 -3	V
	4.2 -5	z
46	1.7 -3	V
	8.4 -5	z
47	1.9 -3	V
48	2.7 -3	V
	1.2 -4	z
49	3.8 -3	V
51	5.4 -3	V
	2.4 -4	z

Table 7 -- continued

UT	cd cm^{-2}	
22 April (cont'd)		
1253	1.1 -2	V
54	1.4 -2	V
	5.1 -4	z
56	2.2 -2	V
57	2.3 -2	V
	7.7 -4	z
1300	3.3 -2	V
01	4.3 -2	V
	1.9 -3	z

UT	cd cm^{-2}	
22 April (cont'd)		
1303	5.0 -2	V
	2.5 -3	z
04	5.3 -2	V
06	7.0 -2	V
07	7.5 -2	V
	4.4 -3	z
08	8.6 -2	V
11	1.2 -1	V
12	1.3 -1	V

UT	cd cm^{-2}	
22 April (cont'd)		
1313	1.3 -1	V
14	1.4 -1	V
	1.2 -2	z
Period:		
1743 to 1817		
Range of V:		
4.0 -1 to 4.2 -1		
Range of z:		
2.4 -1 to 2.6 -1		

Table 8

SKY BRIGHTNESS (TMO)

UT	V* ($cd\ cm^{-2}$)	z* ($cd\ cm^{-2}$)
17 June		
1156:00	4.2 -5	-
1200:00	3.7	-
06:30	5.6	-
10	1.5 -4	5.2 -5
13	2.6	9.7
14:30	3.4	1.1 -4
15:00	3.9	1.4
:33	4.2	
:44	4.4	
20:00	1.4 -3	2.9
:23	1.6	
24:15	-	5.9
25:00	3.3	-
:20	3.8	-
:35	4.0	1.0 -3
30:00	7.1	1.7
:08	7.6	-
:37	8.2	2.2
35:00	1.6 -2	3.3
:37	1.8	3.8
37:15	2.2	5.0
40:00	2.5	1.1 -2
:36	2.6	
45:00	3.5	1.3
:23	3.8	-
:36	3.9	1.4
50:00	5.0	1.8
:23	5.3	-
55:00	5.7	2.2
:37	6.1	
1300:00	7.0	2.6
:36	7.5	2.6
13:30	1.1 -1	3.8
18		
30:00	1.3	5.0
18 June		
1154:30	4.2 -5	-
1200:00		1.0 -5
07:45	1.3 -4	4.2
11:40	2.6	-
15:00	5.1	1.3 -4
:50	5.5	

UT	V ($cd\ cm^{-2}$)	z ($cd\ cm^{-2}$)
18 June (cont'd)		
1220:00	1.8 -3	3.0 -4
:27	1.9	-
:40	2.0	-
:55	2.2	3.9
25:00	4.1	8.3
:16	4.4	-
:24		1.1 -3
30:00	8.7	1.9
:26	9.4	-
:56		2.2 -3
31:15	1.3 -2	-
35:00	1.9	3.6
:37		3.9
40:00	2.6	6.2
:35		6.6
45:00	4.0	8.7
:20	4.3	-
:44		1.5 -2
50:00	5.7	1.9
:31		2.0
55:00	6.1	2.3
:33	6.1	2.5
1323:25	1.1 -1	5.0
30:00	1.3	
19 June		
1200:00	3.7 -5	1.0 -5
:35	4.2	
04:20	5.2	4.2
09:18	1.9 -4	6.0
15:00	5.5	1.1 -4
:24	5.9	-
:29	6.3	1.3
20:00	1.9 -3	3.0
:34	2.0	3.6
25:00	4.1	8.3
:19	4.4	-
:29	4.7	-
26:00	5.0	1.3 -3
30:00	8.2	1.9
:13	1.2 -2	-
:34	1.2	2.3
35:08	1.9	3.8

UT	V ($cd\ cm^{-2}$)	z ($cd\ cm^{-2}$)
19 June (cont'd)		
1235:40	2.0 -2	
40:00	2.6	1.1 -2
:47	2.8	-
:59		1.2
45:00	4.0	1.4
:30	4.3	1.5
50:00	5.3	1.8
:31		1.9
55:50	6.5	2.2
1300:00	7.5	2.5
:57		2.6
25:20	1.1 -1	4.3
30:00		4.6
2012	-	8.5 -1
45	-	4.2
2100	-	3.4
15	-	3.0
30	-	3.4
45	-	3.2
2200	-	2.8
30	-	3.0
47	-	2.6
2300	-	2.4
20 June		
1158	4.2 -5	-
1200:00	3.7	-
10	2.1 -4	6.0 -5
15	4.8	1.1 -4
:42	4.5	1.3
20:00	1.7 -3	2.7
:28	1.9	-
:36	2.0	3.4
25:00	3.8	6.3
:21	4.1	-
:34	4.4	8.9
28:30	6.2	1.6 -3
30:00	1.1 -2	1.8
:22	1.2	-
:49		2.2
31:50	1.3	-
32:30	1.4	2.6
34:10	1.5	3.1

*Absence of an exponent means that the exponent is the same as the preceding entry.

Table 8 -- continued

UT	V (cd cm^{-2})		z (cd cm^{-2})	
20 June (cont'd)				
1235:00	1.6	-2	3.3	-3
:26	1.8		-	
:33			3.6	
40:00	2.5		5.4	
:19	2.6		-	
:35	2.8		1.2	-2
45:00	3.5		1.3	
:35	3.8		-	
:49	4.0		1.4	
50:00	5.0		1.5	
:33			1.9	
55:00	5.7		2.2	
1300:00	6.1		2.6	
01:08	6.5			
:47	7.0			
30:00	9.9		4.3	
2003	-		1.3	0
06	-		9.4	-1
10	-		9.1	
12	-		8.5	
15	-		6.9	
20	-		7.4	
30	-		6.0	
45	-		6.2	

UT	V (cd cm^{-2})		z (cd cm^{-2})	
20 June (cont'd)				
2100	-		3.2	-1
16	-		2.6	
45	-		2.3	
2200	-		1.8	
15	-		1.7	
30	-		1.6	
45	-		1.4	
2300	-		1.1	
21 June				
1156	4.2	-5	-	
1200:00			3.0	-5
15:	4.8	-4	1.2	-4
:13	5.5		-	
:31	5.9		1.4	
20:00	1.7	-3	2.7	-4
:37	1.9		-	
21:13	2.0		3.9	-4
25:00	3.8		7.2	
:20	4.1		-	
:30	4.4		9.5	
26:00	4.7		-	
:15	4.8		-	
:30	5.0		-	
:45	5.2		-	

UT	V (cd cm^{-2})		z (cd cm^{-2})	
21 June (cont'd)				
1227:00	5.4	-3	-	
:15			1.3	-3
30:00	1.2	-2	1.7	
:44			2.0	
32:45	1.4		2.5	
33:53	1.5		3.1	
35:00	1.6		3.3	
:29	1.8		3.6	
40:00	2.5		1.1	-2
:29	2.6			
45:00	3.8		1.3	
:39	4.0		1.4	
50:00	5.1		1.6	
:31	5.3		1.8	
56	6.5		2.3	
1300:00	7.5		2.8	
:24	7.8		2.8	
30:00	1.1	-1	4.3	
:17	1.2		-	
:27	1.3		-	
:49	1.4		5.0	
1942	-		9.7	-1
52	-		1.0	0
2007	-		1.2	
15	-		1.1	

Table 9

SKY BRIGHTNESS (NMSU)

UT	V* (cd cm^{-2})	z* (cd cm^{-2})
14 June		
1125	1.7 -4	-
27	2.4	-
29	3.1	-
30	3.4	-
34	5.5	1.8 -4
35	7.2	2.1
36	9.5	2.7
38	1.4 -3	3.9
39	1.7	4.4
40	2.2	5.5
41	2.7	6.3
42	3.3	7.7
43	3.8	8.3
44	4.4	1.0 -3
46	5.4	1.1
47	6.6	1.4
48	7.6	1.8
49	8.7	2.2
51	1.1 -2	2.9
54	2.7	4.1
56	3.0	5.0
58	3.5	6.2
1201	4.3	8.7
05	5.7	2.3 -2
06	6.1	2.7
09	7.0	2.8
13	8.6	3.3
20	1.1 -1	4.6
39	1.5	5.7
52	1.7	7.0
16 June		
1119	2.1 -5	-
23	4.2	-
25	8.4	-
28	1.2 -4	2.1 -5
29	1.7	2.1
31	2.1	3.0
32	2.4	3.0
32	2.7	4.2
33	3.4	6.0
34	4.8	1.0 -4
35	5.5	1.3

UT	V (cd cm^{-2})	z (cd cm^{-2})
16 June (cont'd)		
1137	6.7 -4	1.5 -4
38	8.3	2.1
38	9.5	2.4
39	1.1 -3	2.9
41	1.4	4.1
41	1.7	4.4
42	1.9	5.1
43	2.2	6.3
43	2.7	7.2
44	3.3	8.3
45	3.8	9.5
45	4.4	1.2 -3
47	5.4	1.4
48	6.6	1.7
49	7.6	2.0
50	1.1 -2	2.7
51	1.2	2.7
53	1.4	3.8
55	1.8	4.4
57	2.2	5.8
59	2.7	7.1
1202	3.0	1.2 -2
03	3.5	1.3
06	4.3	1.5
10	6.1	2.3
13	7.0	2.7
18	8.6	2.8
27	1.2 -1	4.0
33	1.4	5.0
37	1.5	5.7
17 June		
1109	1.1 -5	-
19	2.1	-
23	4.2	-
26	8.4	-
28	1.2 -4	1.5 -5
30	1.7	2.1
31	2.1	3.0
33	2.7	3.0
34	3.4	4.2
35	4.1	6.0
36	4.8	8.4

UT	V (cd cm^{-2})	z (cd cm^{-2})
17 June (cont'd)		
1136	5.5 -4	1.0 -4
38	6.7	1.4
38	8.3	1.7
39	9.5	1.9
40	1.1 -3	2.4
41	1.4	2.9
42	1.7	3.9
43	1.9	4.4
43	2.2	5.5
44	2.7	6.3
45	3.3	7.2
46	3.8	8.3
46	4.4	9.5
48	5.4	1.2 -3
49	6.6	1.4
50	7.6	1.8
51	1.1 -2	2.0
52	1.2	2.3
53	1.4	3.1
54	1.5	3.3
55	1.8	3.8
57	2.2	4.7
59	2.7	5.8
1201	3.0	7.1
03	3.5	1.2 -2
07	4.3	1.5
11	5.3	1.9
15	6.1	2.3
19	7.0	2.7
27	8.6	3.3
42	1.1 -1	4.6
1320	1.2	6.1
18 June		
1108	1.5 -5	-
18	2.1	-
23	4.2	-
26	8.4	1.3 -5
29	1.2 -4	1.5
30	2.1	2.1
31	2.4	2.1
32	2.7	3.0
32	3.4	4.2

*Absence of an exponent means that the exponent is the same as in the preceding entry.

Table 9 -- continued

UT	V ($cd\ cm^{-2}$)	z ($cd\ cm^{-2}$)
18 June (cont'd)		
1134	4.1 -4	6.0 -5
34	4.8	8.4
35	5.5	1.0 -4
36	6.7	1.3
37	8.3	1.6
38	9.5	1.8
39	1.1 -3	2.2
39	1.4	2.6
40	1.7	3.1
40	1.9	3.9
41	2.2	4.1
42	2.7	5.1
43	3.6	6.7
44	3.8	7.2
45	4.4	8.9
46	5.4	1.2 -3
48	6.6	1.6
49	7.6	1.9
51	1.1 -2	2.3
52	1.3	3.1
53	1.4	3.3
55	1.8	4.1
57	2.2	4.7
59	2.7	6.2
1201	3.0	7.1
03	3.5	8.2
06	4.3	1.3 -2
10	5.3	1.8
14	6.1	2.0
18	7.0	2.7
25	8.6	3.3
34	1.1 -1	4.0
46	1.2	5.0
19 June		
1103:30	1.1 -5	-
16:15	2.1	-
23:20	3.0	1.1 -5
25:10	4.2	1.1
26:25	8.4	1.1
27:37	1.0 -4	1.1
28:10	1.2	2.1
29:28	1.4	2.1
30:11	1.7	2.1

UT	V ($cd\ cm^{-2}$)	z ($cd\ cm^{-2}$)
19 June (cont'd)		
1131:09	2.1 -4	2.1 -5
:58	2.4	3.0
32:46	2.7	3.0
33:36	3.4	3.0
34:38	4.1	4.2
35:26	4.8	6.0
36:09	5.5	9.0
:58	6.7	1.1 -4
37:57	8.3	1.4
38:35	9.5	1.7
39:10	1.1 -3	2.1
40:00	1.4	2.4
:58	1.7	2.9
41:30	1.9	3.4
42:12	2.2	4.1
43:04	2.7	4.8
44:17	3.3	6.3
45:08	3.8	7.2
46:06	4.4	8.9
47:40	5.4	1.2 -3
49:20	6.6	1.6
50:27	7.6	1.9
51:32	1.1 -2	2.2
:55	1.2	2.3
53:10	1.3	2.9
54:15	1.4	3.3
56:11	1.8	4.1
58:00	2.2	5.0
1200:00	2.7	6.2
02:10	3.0	7.1
04:55	3.5	1.2 -2
08:00	4.3	1.4
12:25	5.3	1.9
16:17	6.1	2.3
20:35	7.0	2.7
27:15	8.6	3.3
38:50	1.1 -1	4.0
20 June		
1107:00	1.1 -5	-
21:05	2.1	-
23:10	3.0	-
25:51	4.2	-
27:07	8.4	1.3 -5

UT	V ($cd\ cm^{-2}$)	z ($cd\ cm^{-2}$)
20 June (cont'd)		
1128:14	1.0 -4	1.3 -5
:50	1.2	1.3
29:35	1.4	2.1
30:25	1.7	2.1
31:19	2.1	2.1
32:10	2.4	2.1
:50	2.7	3.0
33:45	3.4	3.0
34:39	4.1	4.2
35:27	4.8	6.0
36:04	5.5	9.0
:55	6.7	1.1 -4
37:48	8.3	1.3
38:30	9.5	1.6
39:05	1.1 -3	1.9
:58	1.4	2.4
40:54	1.7	2.9
41:35	1.9	3.6
42:15	2.2	4.1
43:15	2.7	5.1
44:40	3.3	6.7
45:20	3.8	7.2
46:21	4.4	8.9
47:57	5.4	1.2 -3
49:30	6.6	1.7
50:55	7.6	2.0
52:20	8.7	2.3
53:39	1.4 -2	3.3
54:10	1.5	3.6
56:43	1.8	4.1
58:40	2.2	5.0
1200:35	2.7	6.2
02:28	3.0	7.6
04:45	3.5	1.2 -2
08:02	4.3	1.4
12:00	5.3	1.8
16:10	6.1	2.3
19:10	7.0	2.5
25:10	8.6	3.0
27:35	9.2	3.1
29:15	9.9	3.5
33:10	1.1 -1	3.8
40:00	1.1	5.0
43:00	1.2	5.0

V. DATA REDUCTION AND ANALYSIS

In our theoretical study published in 1967,* we suggested that, for Venus, the cusp extension angle measured depends on the brightness of the terrestrial sky at the moment of observation as well as on the height of the scattering atmosphere above the surface of Venus. In addition, an exploratory test program carried out about the same time indicated that varying the length of exposure time would artificially alter the brightnesses of the planet relative to the sky surrounding it. Other factors such as astronomical seeing, size of telescope, atmospheric extinction, plate sensitivity, and type of filter also affect the apparent angular extent of the crescent.

During the 1969 Venus inferior conjunction particular emphasis was given to two of the parameters, namely, sky brightness and duration of exposure.

The discussion of the observational material is presented in three parts: photographic material, photometric material, and sky brightness effects.

PHOTOGRAPHIC MATERIAL

The photographic material, obtained through the telescopes, is concerned principally with the angular extent of the Venus crescent. (Photometric information in the pictures is also available, and is discussed in the final part of this section.) The information sought is the positional relationship of terminator and cusps to the bright limb. In the inferior conjunction observations, these quantities are rather easily obtained from the Venus images, mainly because the phase is a thin crescent.

The angular extent of the Venus crescent (from which cusp extension angles can be deduced) was determined by using an optical comparator whose reticle was placed directly against the emulsion. (The

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*RM-5386-PR; see footnote on p. 1.

photograph was illuminated from below.) Since no commercially available reticle had the necessary graduations, we prepared our own according to the design shown in Fig. 3.

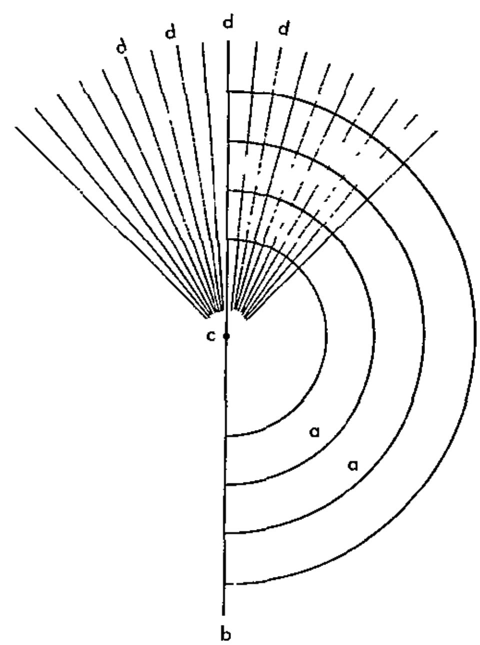

Fig. 3 — Reticle design.

Because the size of the Venus image varied with the date of observation and telescope focal length, it was necessary to have several circular arcs (a, Fig. 3). The comparator was positioned by fitting the bright limb of the Venus image to the appropriate arc (a). This centered the reticle on the image. Then the comparator was rotated until the line (bc) just touched the lower cusp. The angular extent was then apparent from the location of the other cusp. The radial lines (dc) were 5° apart. Measurements made by two observers are compared in Fig. 4. The scatter of points arises in deciding just where the image of the cusp becomes distinct from the background. This typifies a well known problem in astronomy, encountered, for example, when deriving integrated magnitudes of galaxies or the angular diameters of planets. Images that were very lightly or very heavily exposed presented more severe problems in positioning the reticle.

The measurements of the angular extent of the Venus crescent are presented in Tables 4 and 5.

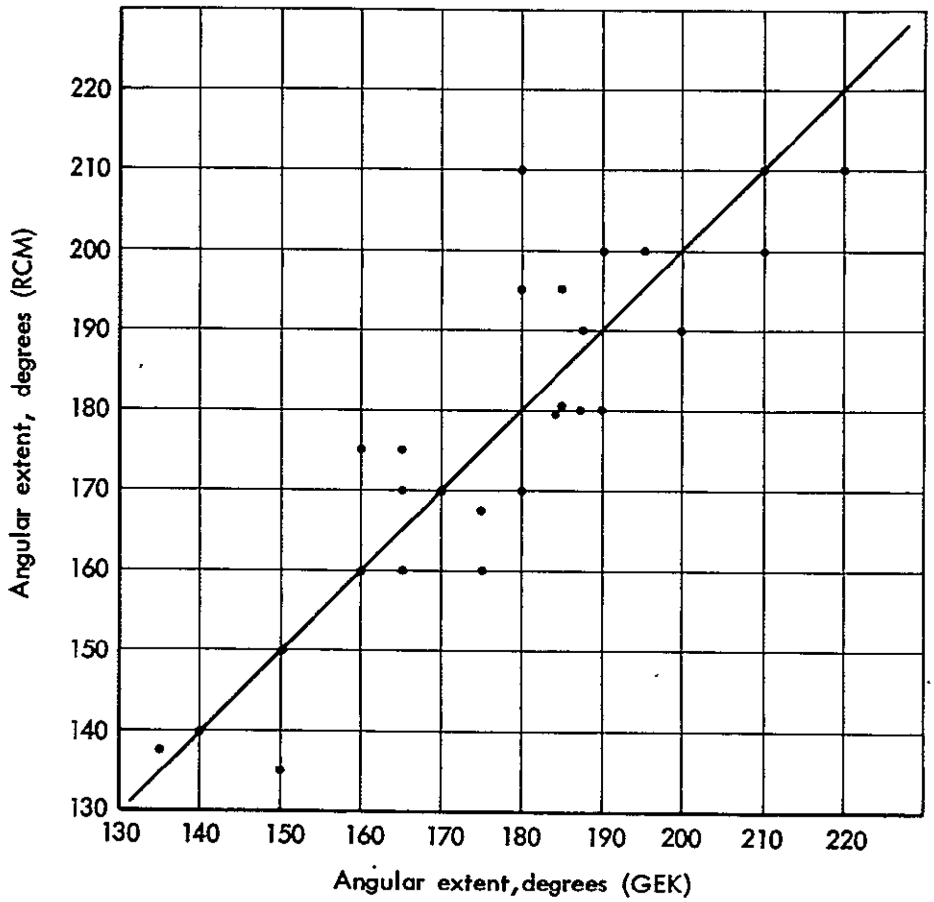

Fig. 4 -- Comparison of measurements of angular extent of the photographic image of the crescent.

In the case of the elongation data, the planet is very close to quarter phase. The precise relationships of the various parts of the image can be measured only on a measuring engine. This very time-consuming task was beyond the scope of our project, but could, of course, be performed at any later time.

PHOTOMETRIC MATERIAL

The photometric data are available in both the direct meter readings of sky brightness and in the density of the photographic images. The latter data are discussed in the last part of this section. The sky-brightness data obtained with the meters are tabulated in Sections III and IV. In Section III only those measurements of sky brightness around Venus at the time of an exposure are listed. All other measurements of sky brightness are collected in Section IV. As may be seen in the discussion of their characteristics in Section II, the photometers were stable, functional instruments.

Representative data are plotted in Figs. 5 through 9; they show the brightness of the sky at Venus and at the zenith. The lower part of each figure is a plot of the celestial altitude of the Sun and Venus to aid in interpreting the photometric data. April 8 was the date of inferior conjunction.

SKY-BRIGHTNESS EFFECTS

The brightness of the terrestrial sky affects the observed extent of the Venus crescent. This is demonstrated quite clearly in Fig. 10. Here the angular extent of the Venus crescent is plotted against shutter speed on two days. The data from 17 April, represented by circles, show that the maximum extent of the Venus crescent is observed at exposures of about 0.0125 sec. When the sky was half as bright (data of 22 April) we see that not only was the optimum exposure greater (about 0.02 sec.) but also the maximum size of the measured Venus crescent was smaller.

Figures 11 through 14 are plots of measured angular extent of the Venus crescent under various conditions of sky brightness. The data

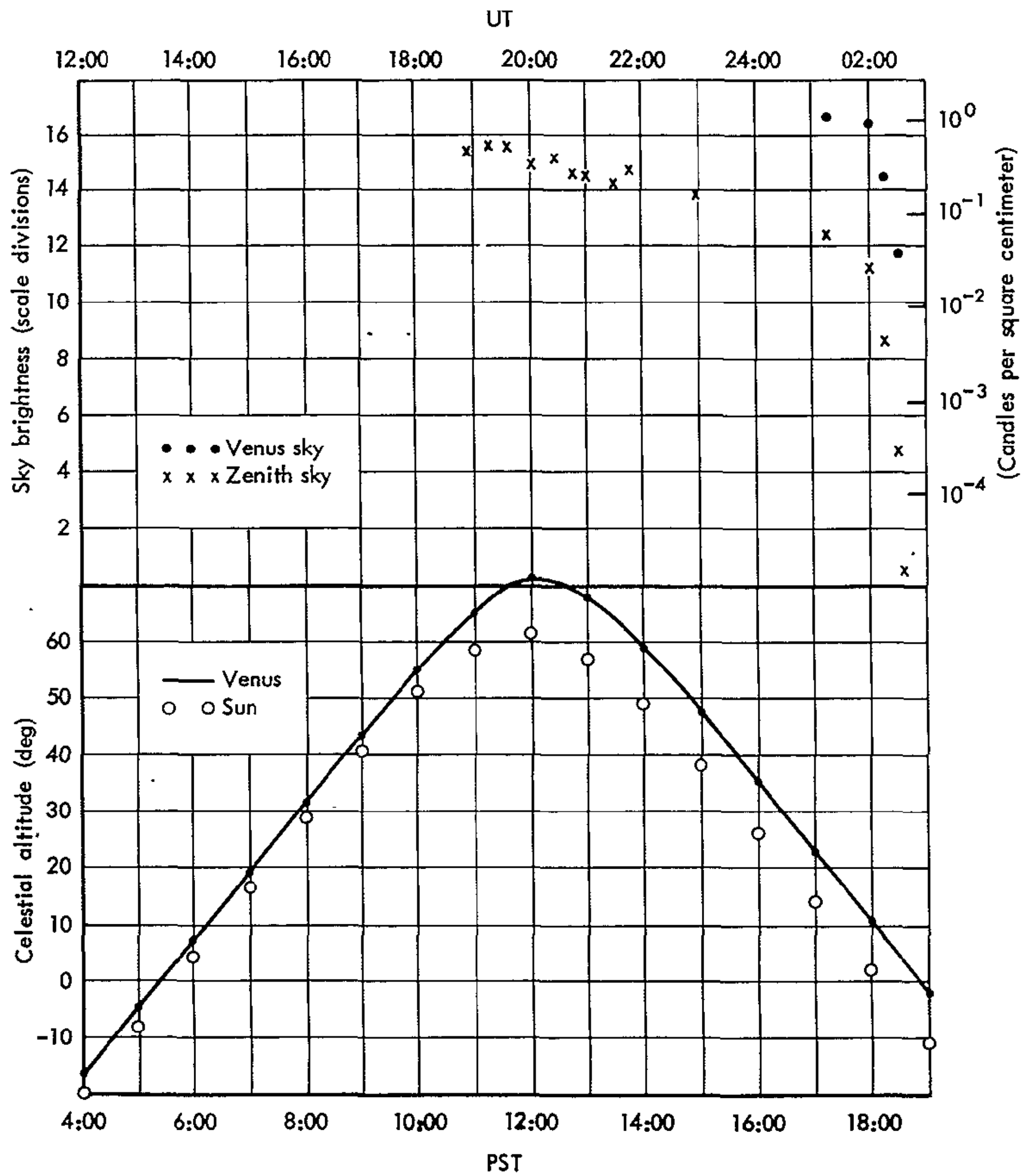

Fig. 5 -- Sky brightness and celestial altitudes, 3 April 1969, Table Mountain Observatory.

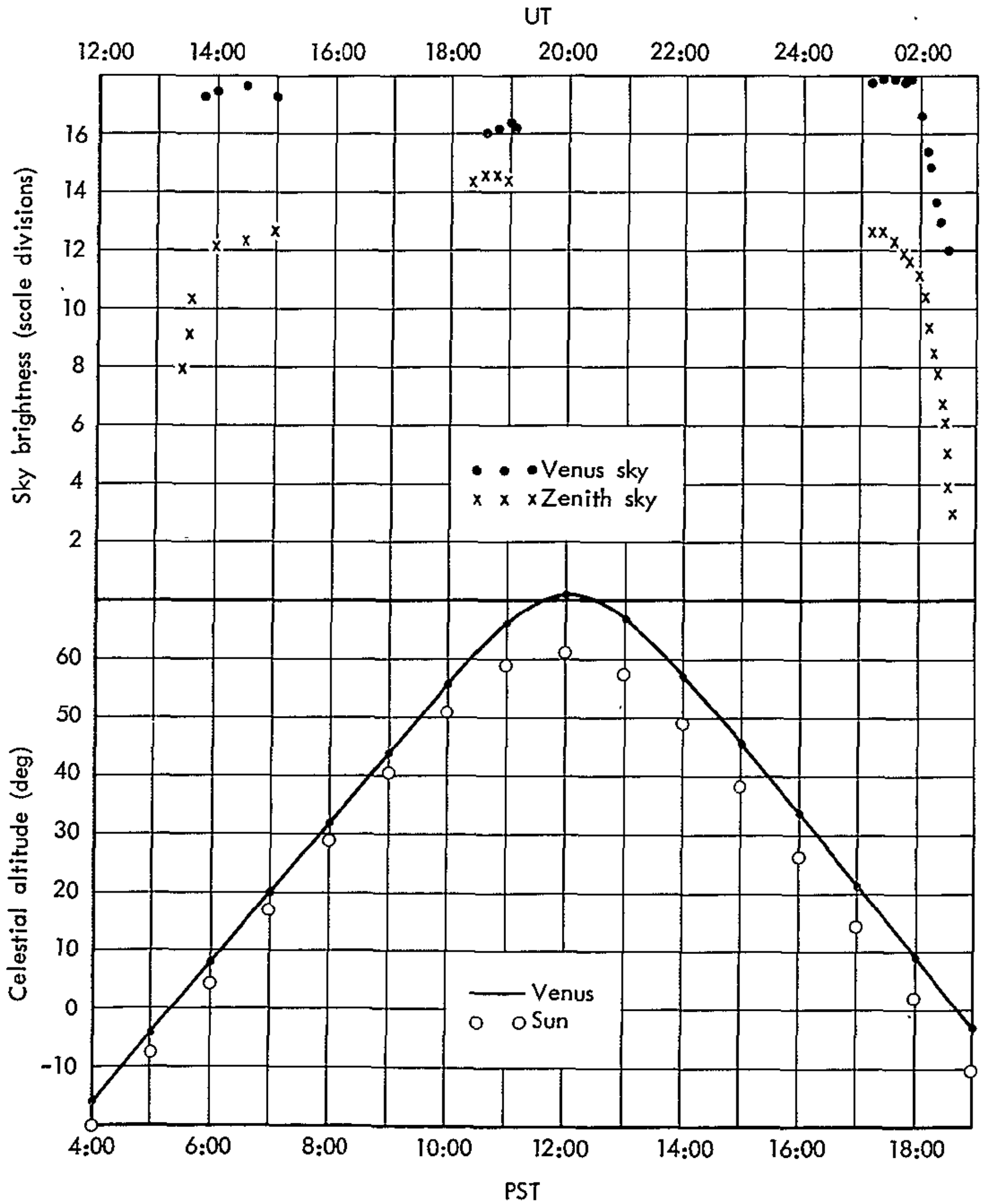

Fig. 6 -- Sky brightness and celestial altitudes, 4 April 1969, Table Mountain Observatory.

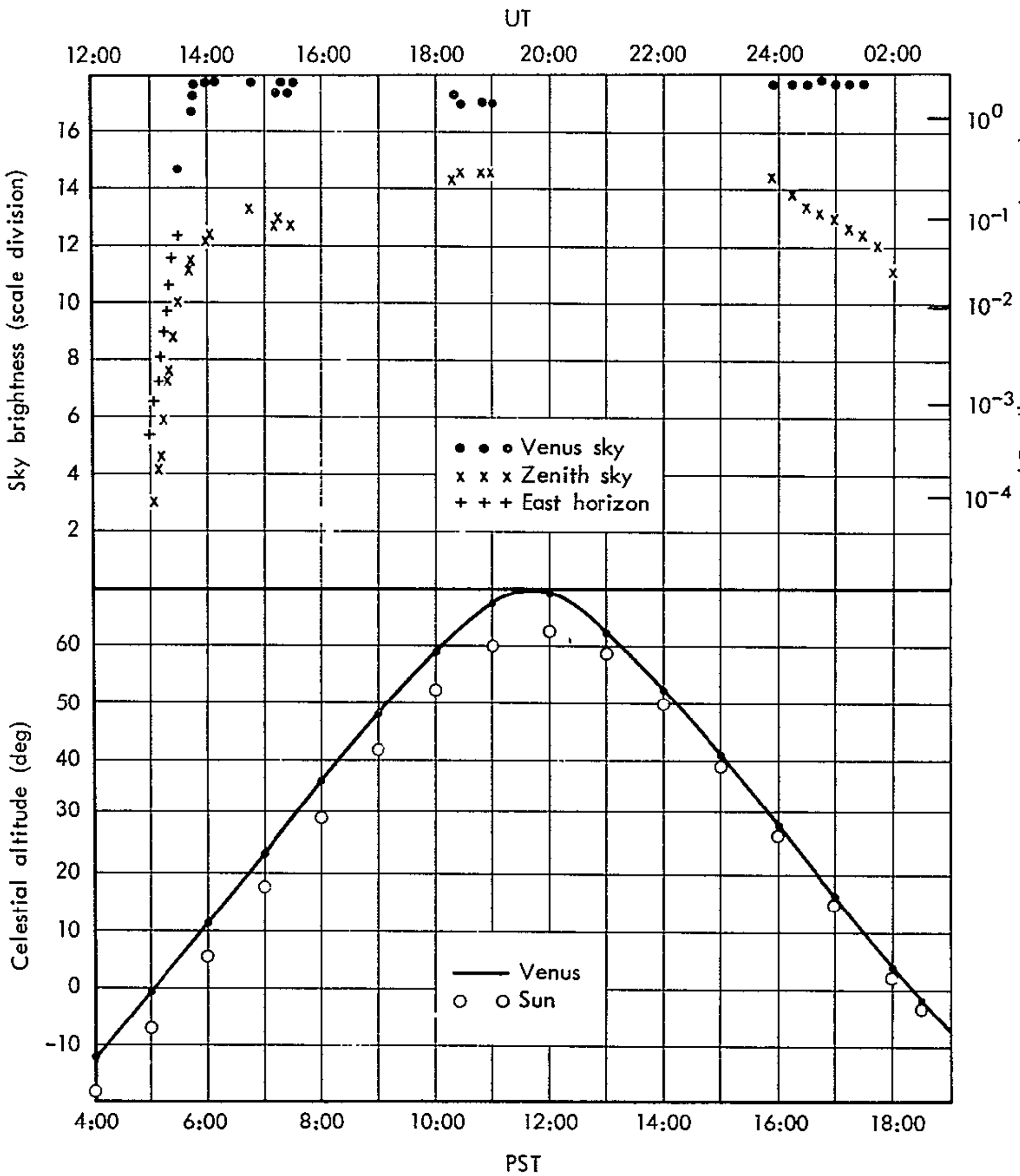

Fig. 7 -- Sky brightness and celestial altitudes, 8 April 1969, Table Mountain Observatory.

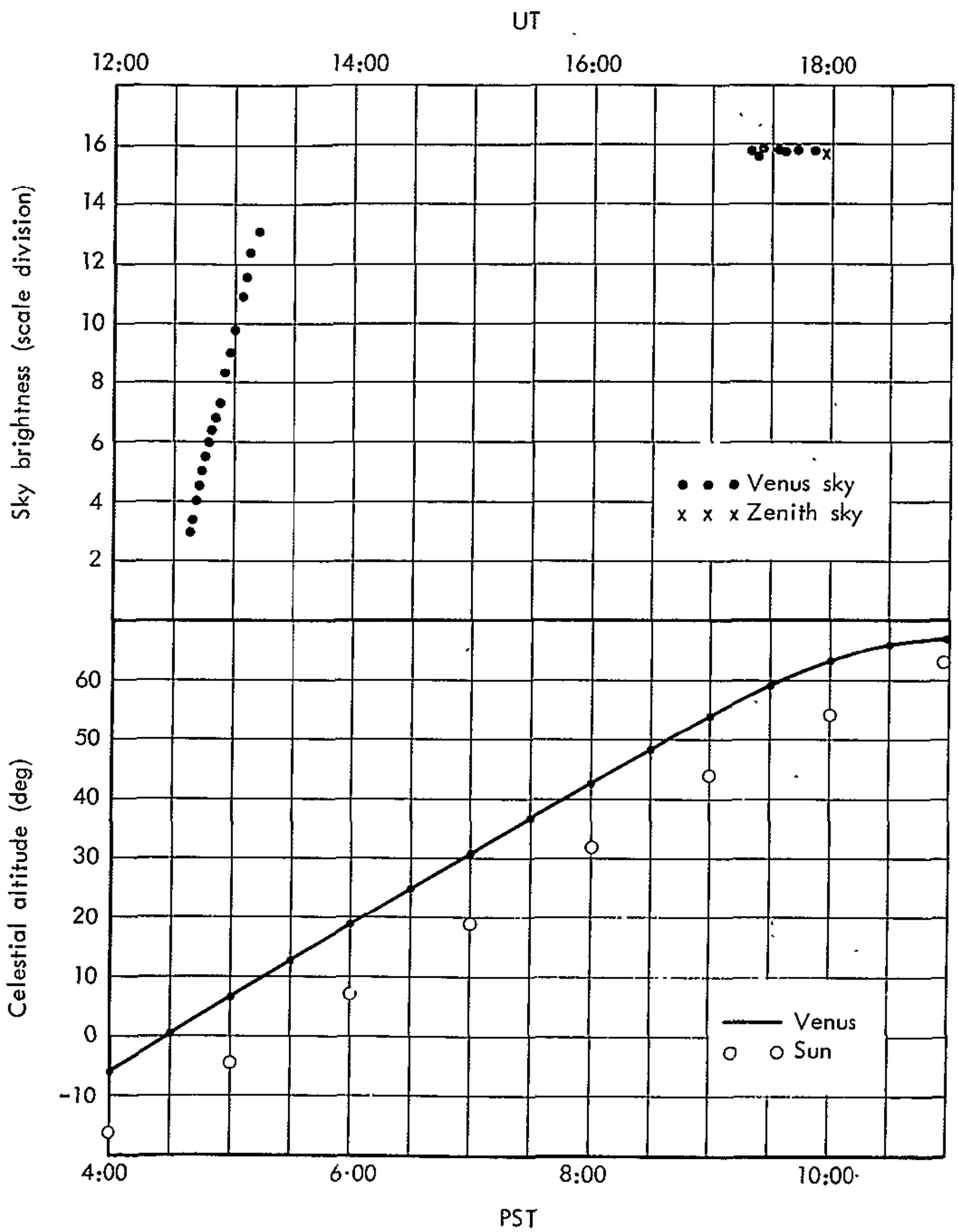

Fig. 8 -- Sky brightness and celestial altitudes, 15 April 1969,
Table Mountain Observatory.

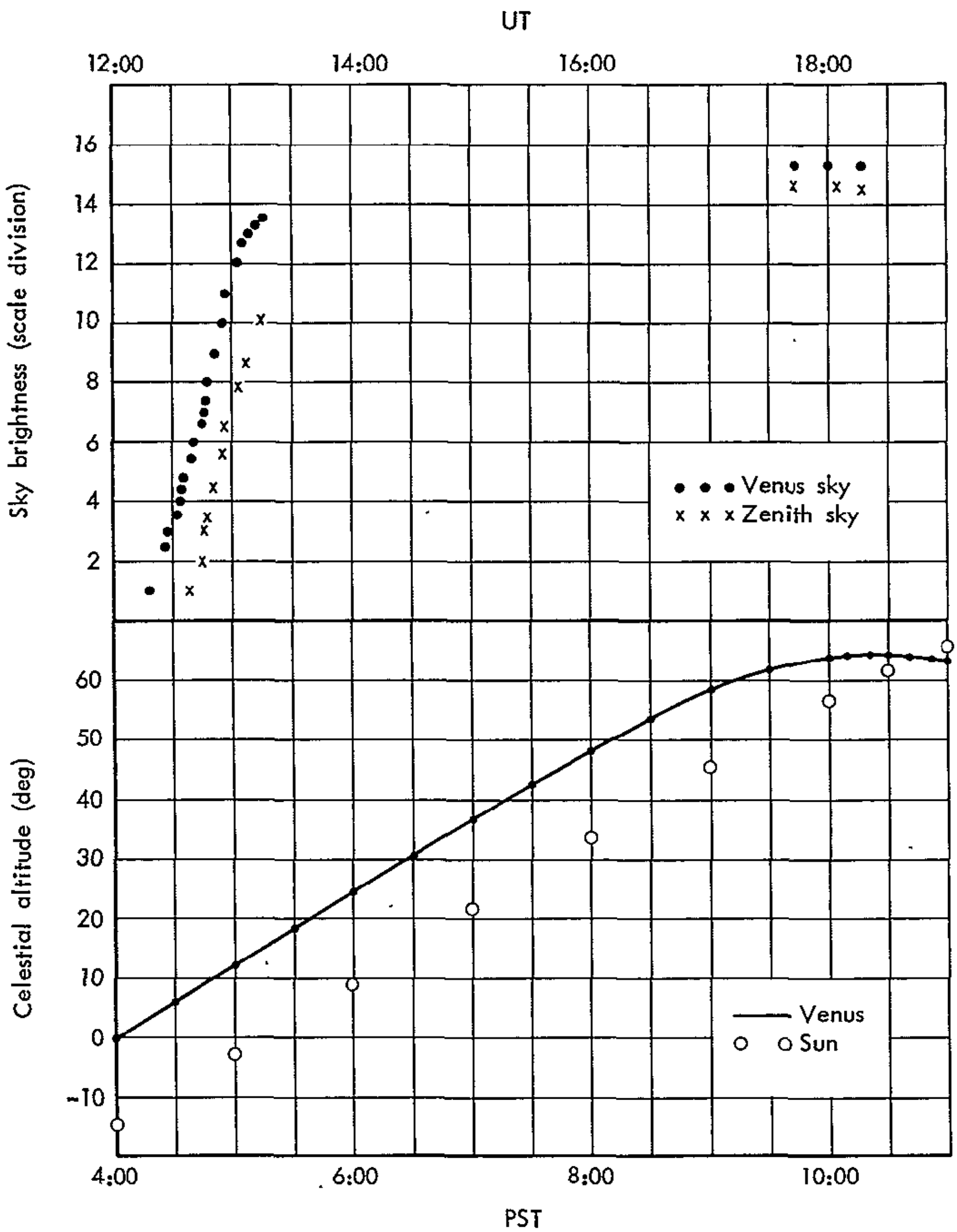

Fig. 9 -- Sky brightness and celestial altitudes, 22 April 1969, Table Mountain Observatory.

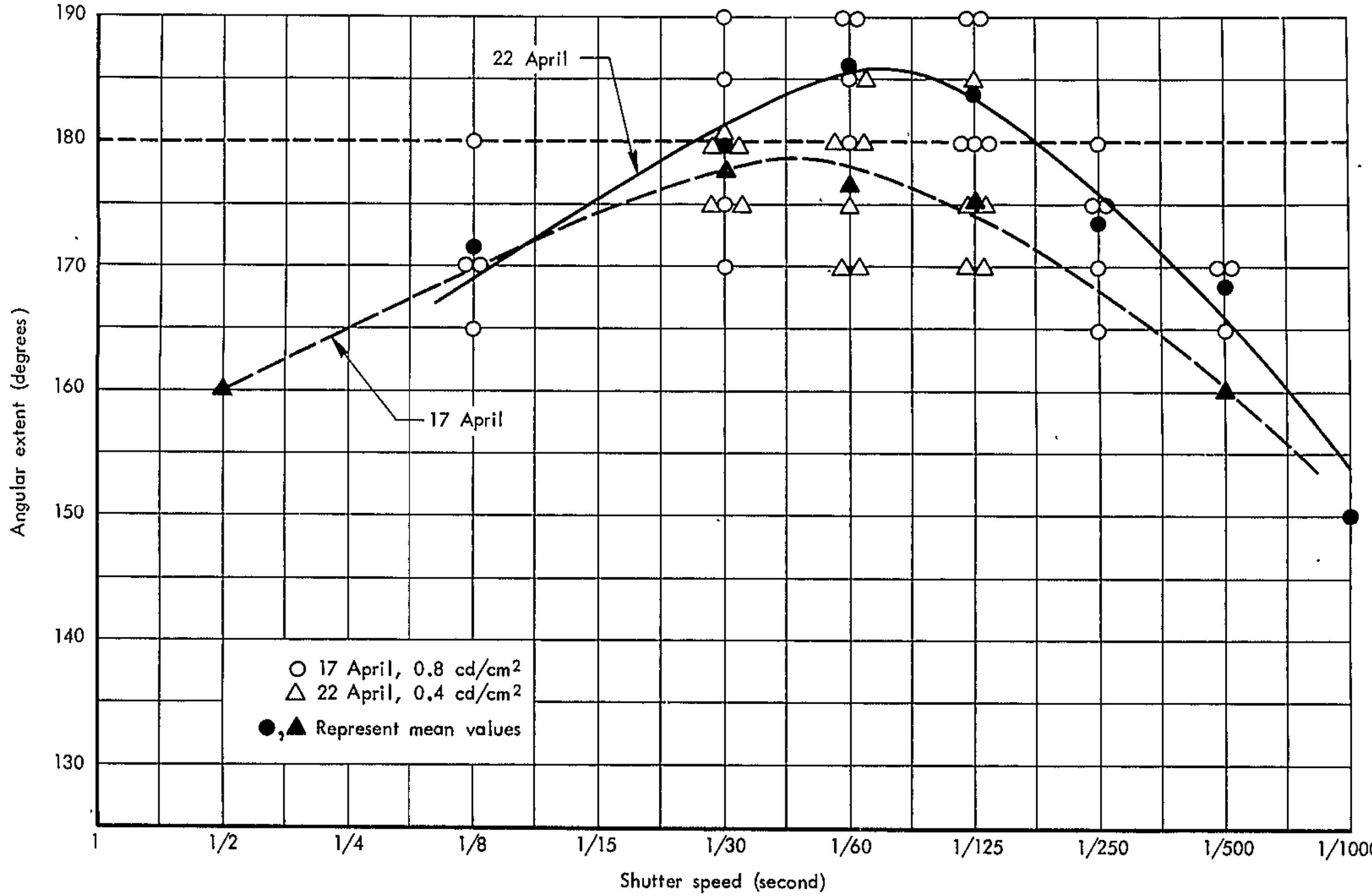

Fig. 10 -- Effect of exposure (the product of sky brightness and exposure time) on the angular extent of the Venus crescent.

are parameterized in exposure times. The curves clearly show the effect of sky brightness on the measured size of the Venus crescent. Furthermore, the evolution of the curves due to the changing angular distance between Venus and the Sun is apparent.

Finally, Fig. 15 is an example of the effect of a specific combination of telescope and emulsion properties in determining the minimum exposure needed to obtain a detectable image. The data shown are for June conditions at TMO. Elongation photographs were examined to determine which exposures were sufficient to show the sky or Venus. The triangles and circles represent combinations of exposure times and brightness that resulted in barely detectable images of the sky and Venus respectively. The limiting relationship for the upper curve was approximately

$$B \times t = 10^{-4} \text{ sec cd cm}^{-2}$$

where B is the surface brightness and t is the duration of the shutter opening. This relationship was needed for the interpretation of data of the kind shown in Figs. 11 through 14.

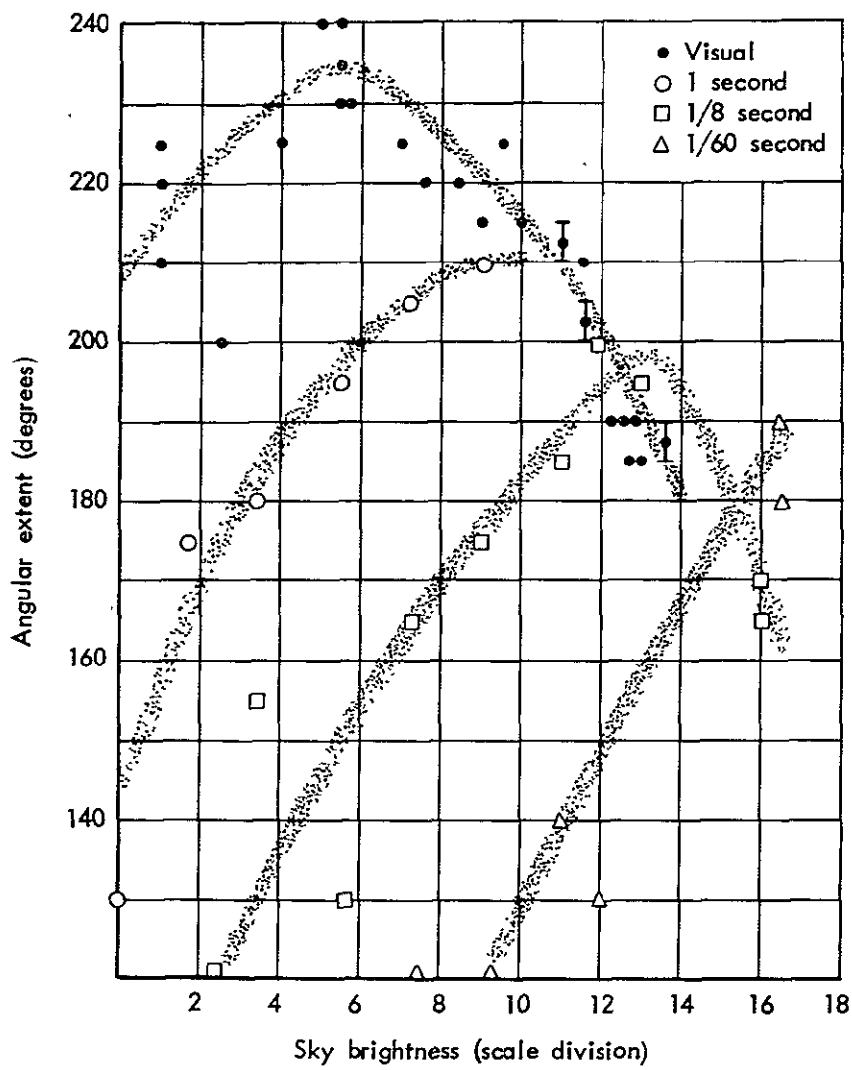

Fig. 11 -- Apparent angular extent of Venus crescent as a function of sky brightness and exposure time, 17 April 1969.

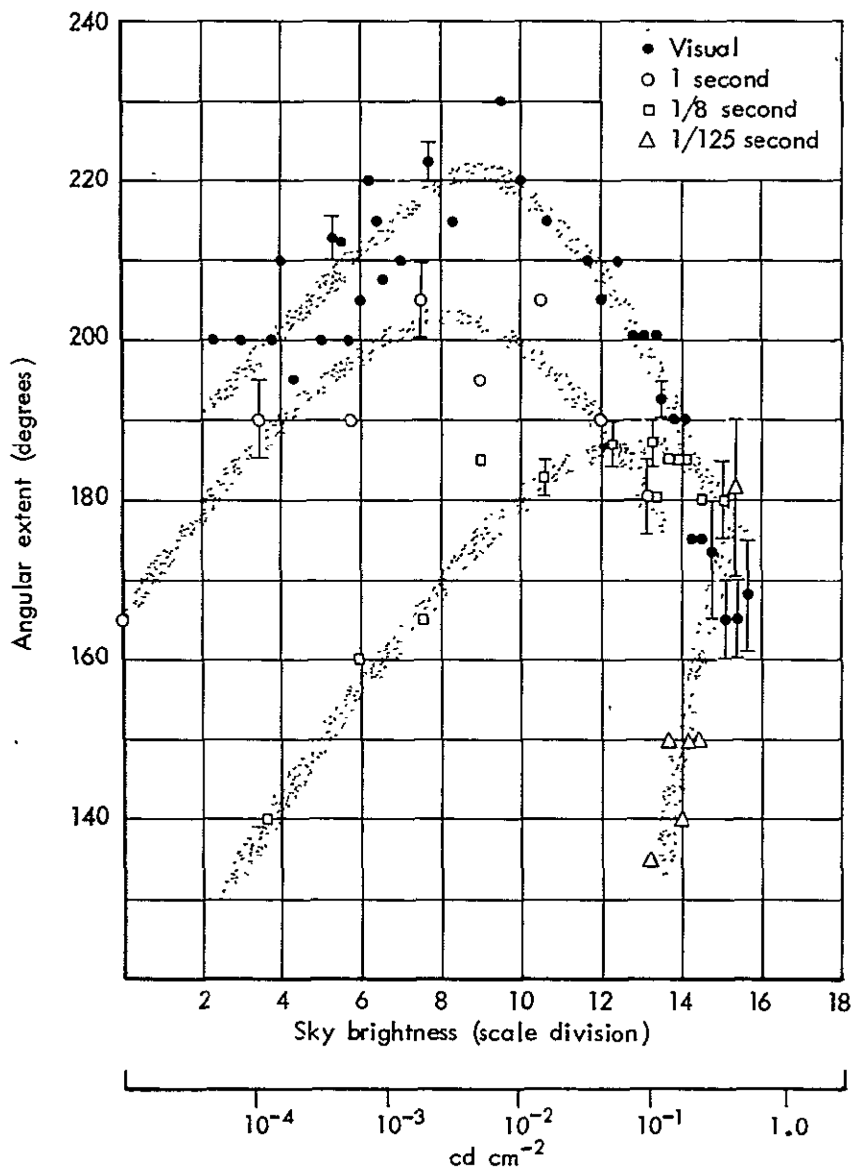

Fig. 12 -- Apparent angular extent of Venus crescent as a function of sky brightness and exposure time, 19 April 1969.

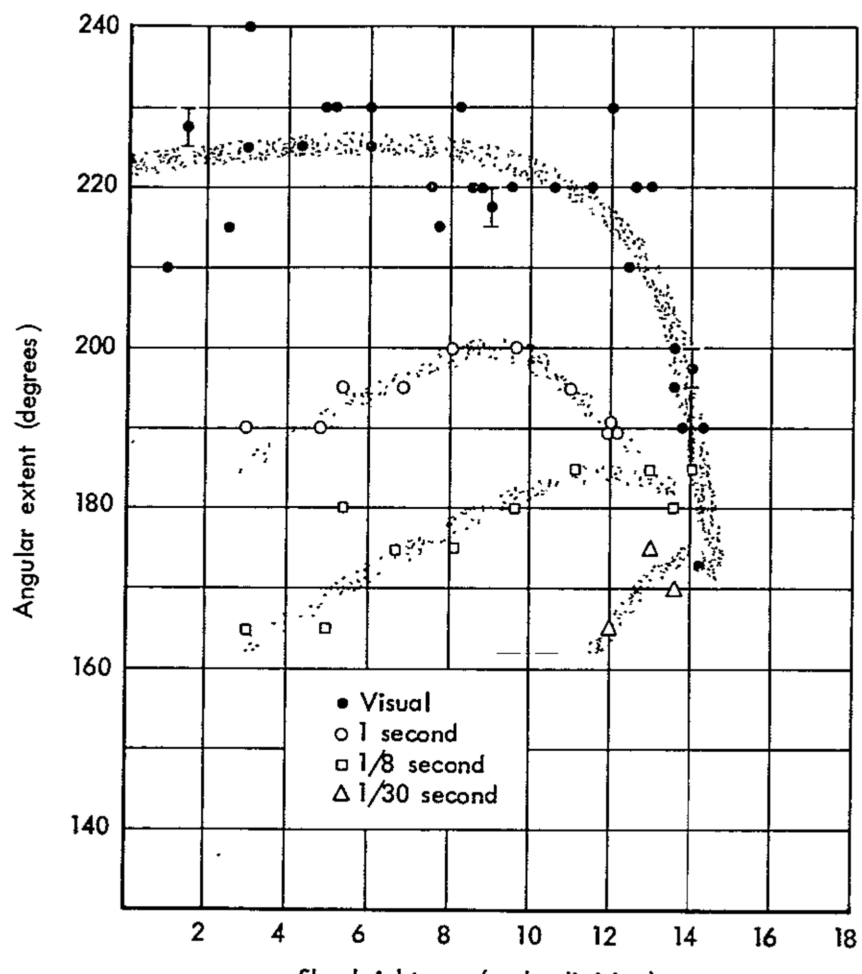

Fig. 13 -- Apparent angular extent of Venus crescent as a function of sky brightness and exposure time, 20 April 1969.

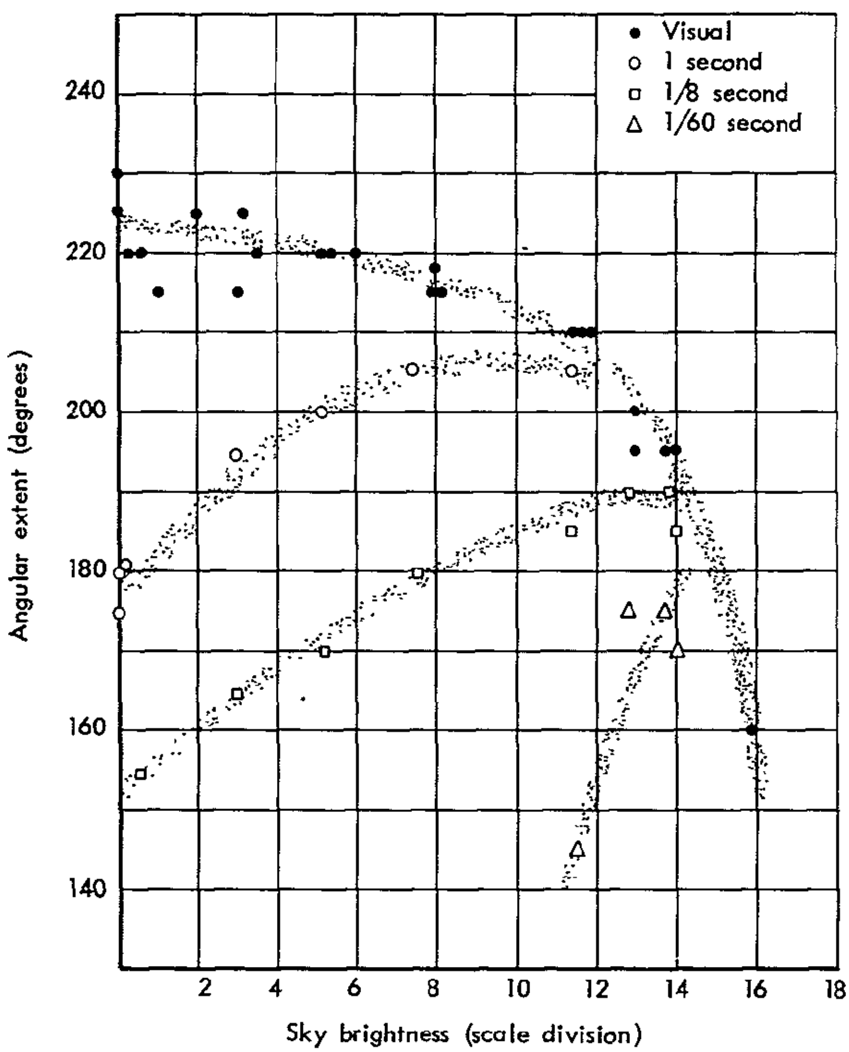

Fig. 14 -- Apparent angular extent of Venus crescent as a function of sky brightness and exposure time, 21 April 1969.

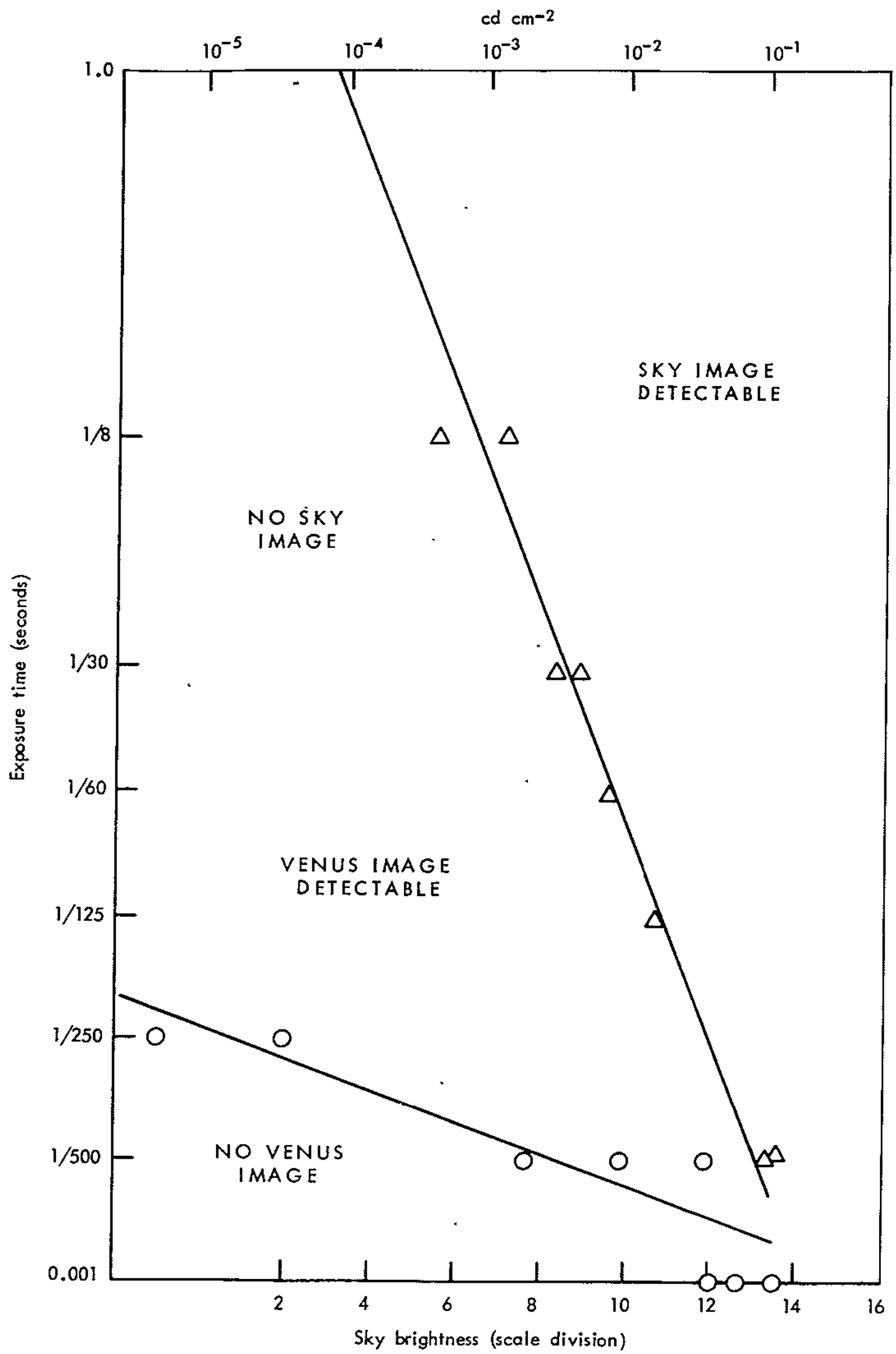

Fig. 15 -- Limiting conditions relating exposure time and object brightness at Table Mountain Observatory, June 1969.

Appendix

COMPUTER COMPUTATIONS

A major factor contributing to the success of the observational program was the development of a number of on-line JOSS* computer programs. These permitted the precise preplanning of observational details as a function of the expected celestial configurations and terrestrial sky conditions at the observing sites. In addition, computer programs were used for the processing, reduction, and analysis of the data. Copies of the major programs and examples of the output are reproduced in this Appendix.

Page 63: Ephemeris Program

The program input consists of the distances Earth to Venus, Earth to Sun, and Sun to Venus, as tabulated in the American Ephemeris and Nautical Almanac. The output consists of tables of Elongation, Phase Angle (i), and Exterior Orbit Angle (α). Time intervals of output can be called for as desired. Examples of program output are shown on the following pages.

Page 64: Ephemeris Program Output for April 1969 (Summary)

Page 65: Ephemeris Program Output for 8 and 9 April 1969

Page 66: Ephemeris Program Output for June 1969 (Summary)

Page 67: Ephemeris Program Output for 17 and 18 June 1969

Page 68: Look-Angle Program for TMO

The program input consists of the hourly values of GHA and declination of Venus and Sun as tabulated in the Nautical Almanac. The output consists of tables of celestial look angles for specific location, at any desired time interval.

Page 70: Look-Angle Program for NMSU Observatory

Page 72: Example of look angles for TMO, 4 April 1969

Page 73: Example of look angles for TMO, 19 June 1969

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*JOSS is the trademark and service mark of the Rand Corporation for its computer program and for services using that program.

Page 74: Example of look angles for NMSU Observatory, 19 June 1969

Page 75: Plate-Analysis Program

The program input consists of a series of plate-micrometer readings such as diameter and cusp positions, and ephemeris data. The output is a complete analysis in terms of the parameters described in RM-5386-PR.

Page 78: Example of plate analysis for two images, giving cusp extension angles of 10° and 15° respectively.

```
Type all.

1.05 * Ephemeris (every 1/10 of a day and SUMMARY).
1.2 Set e=[S(j)*2+v(j)*2-l(j)*2]/[2•S(j)•v(j)].
1.3 Set E=d(arg[e,sqrt(1-e*2)]).
1.4 Set i=[v(j)*2+l(j)*2-S(j)*2]/[2•v(j)•l(j)].
1.5 Set I=d(arg[i,sqrt(1-i*2)]).
1.8 Set A=d[r(180)-r(I)].
1.89 Line if fp(j/10)=0.
1.9 Type j/10,E,A,I in form 1.

2.1 Set a=a.
2.2 Do part 3 for b=0(1)9.

3.1 Set j=(10•a)+b.
3.2 Set S(j)=b•([S(a+1)-S(a)]/10)+S(a).
3.3 Set l(j)=b•([l(a+1)-l(a)]/10)+l(a).
3.4 Set v(j)=b•([v(a+1)-v(a)]/10)+v(a).
3.5 Do part 1.

5.5 Set l(m+1)=l(m)-[[l(m)-l(m+2)]/2].

9.1 Demand S(j).
9.2 Demand l(j).
9.3 Demand v(j).

10.1 Delete S(n).
10.2 Delete l(n).
10.3 Delete v(n).

Form 1:
Apr __.__:  Elongation: ___.___"  Alpha: ___.___"  i: ___.___"

      D(r,c):  ip(r•c)+.01•ip[60•fp(r•c)]+.006•fp(60•r•c)
      R(d,c):  [ip(d)+ip(100•fp[d])/60+fp(100•d)/36]/c
        d(x):  D(x,45/arg(1,1))
        h(x):  R(x,3/arg(1,1))
        r(x):  R(x,45/arg(1,1))
      s(x,y):  d(r(x)+r(y))
        t(x):  D(x,3/arg(1,1))
```

Do part 1 for j=4(1)23.

Apr	4.0:	Elongation:	10.4407"	Alpha:	14.5842"	i:	165.0118"
Apr	5.0:	Elongation:	9.3929"	Alpha:	13.2746"	i:	166.3214"
Apr	6.0:	Elongation:	8.4302"	Alpha:	12.0832"	i:	167.5128"
Apr	7.0:	Elongation:	7.5807"	Alpha:	11.0539"	i:	168.5421"
Apr	8.0:	Elongation:	7.2847"	Alpha:	10.2440"	i:	169.3520"
Apr	9.0:	Elongation:	7.1821"	Alpha:	10.1008"	i:	169.4952"
Apr	10.0:	Elongation:	7.2823"	Alpha:	10.2415"	i:	169.3545"
Apr	11.0:	Elongation:	7.5713"	Alpha:	11.0442"	i:	168.5518"
Apr	12.0:	Elongation:	8.4141"	Alpha:	12.0709"	i:	167.5251"
Apr	13.0:	Elongation:	9.3733"	Alpha:	13.2547"	i:	166.3413"
Apr	14.0:	Elongation:	10.4128"	Alpha:	14.5600"	i:	165.0360"
Apr	15.0:	Elongation:	11.5042"	Alpha:	16.3406"	i:	163.2554"
Apr	16.0:	Elongation:	13.0315"	Alpha:	18.1723"	i:	161.4237"
Apr	17.0:	Elongation:	14.1742"	Alpha:	20.0354"	i:	159.5606"
Apr	18.0:	Elongation:	15.3300"	Alpha:	21.5218"	i:	158.0742"
Apr	19.0:	Elongation:	16.4823"	Alpha:	23.4133"	i:	156.1827"
Apr	20.0:	Elongation:	18.0318"	Alpha:	25.3056"	i:	154.2904"
Apr	21.0:	Elongation:	19.1718"	Alpha:	27.1953"	i:	152.4007"
Apr	22.0:	Elongation:	20.3003"	Alpha:	29.0757"	i:	150.5203"
Apr	23.0:	Elongation:	21.4118"	Alpha:	30.5450"	i:	149.0510"

Do part 2 for a=8,9.

Apr	8.0:	Elongation:	7.2847"	Alpha:	10.2440"	i:	169.3520"
Apr	8.1:	Elongation:	7.2745"	Alpha:	10.2314"	i:	169.3646"
Apr	8.2:	Elongation:	7.2643"	Alpha:	10.2147"	i:	169.3813"
Apr	8.3:	Elongation:	7.2541"	Alpha:	10.2021"	i:	169.3939"
Apr	8.4:	Elongation:	7.2439"	Alpha:	10.1854"	i:	169.4106"
Apr	8.5:	Elongation:	7.2336"	Alpha:	10.1727"	i:	169.4233"
Apr	8.6:	Elongation:	7.2233"	Alpha:	10.1559"	i:	169.4401"
Apr	8.7:	Elongation:	7.2131"	Alpha:	10.1432"	i:	169.4528"
Apr	8.8:	Elongation:	7.2028"	Alpha:	10.1304"	i:	169.4656"
Apr	8.9:	Elongation:	7.1924"	Alpha:	10.1137"	i:	169.4823"
Apr	9.0:	Elongation:	7.1821"	Alpha:	10.1008"	i:	169.4952"
Apr	9.1:	Elongation:	7.1922"	Alpha:	10.1134"	i:	169.4826"
Apr	9.2:	Elongation:	7.2023"	Alpha:	10.1259"	i:	169.4701"
Apr	9.3:	Elongation:	7.2123"	Alpha:	10.1425"	i:	169.4535"
Apr	9.4:	Elongation:	7.2224"	Alpha:	10.1550"	i:	169.4410"
Apr	9.5:	Elongation:	7.2324"	Alpha:	10.1714"	i:	169.4246"
Apr	9.6:	Elongation:	7.2424"	Alpha:	10.1839"	i:	169.4121"
Apr	9.7:	Elongation:	7.2524"	Alpha:	10.2003"	i:	169.3 57"
Apr	9.8:	Elongation:	7.2624"	Alpha:	10.2127"	i:	169.3833"
Apr	9.9:	Elongation:	7.2724"	Alpha:	10.2251"	i:	169.3709"

Do part 1 for j=15(1)29.

Jun	15.0:	Elongation:	45.4527"	Alpha:	87.5403"	i:	92.0557"
Jun	16.0:	Elongation:	45.4626"	Alpha:	88.3240"	i:	91.2720"
Jun	17.0:	Elongation:	45.4657"	Alpha:	89.1050"	i:	90.4910"
Jun	18.0:	Elongation:	45.4703"	Alpha:	89.4836"	i:	90.1124"
Jun	19.0:	Elongation:	45.4642"	Alpha:	90.2555"	i:	89.3405"
Jun	20.0:	Elongation:	45.4558"	Alpha:	91.0252"	i:	88.5708"
Jun	21.0:	Elongation:	45.4449"	Alpha:	91.3925"	i:	88.2035"
Jun	22.0:	Elongation:	45.4318"	Alpha:	92.1537"	i:	87.4423"
Jun	23.0:	Elongation:	45.4124"	Alpha:	92.5126"	i:	87.0834"
Jun	24.0:	Elongation:	45.3910"	Alpha:	93.2656"	i:	86.3304"
Jun	25.0:	Elongation:	45.3633"	Alpha:	94.0204"	i:	85.5756"
Jun	26.0:	Elongation:	45.3336"	Alpha:	94.3654"	i:	85.2306"
Jun	27.0:	Elongation:	45.3019"	Alpha:	95.1124"	i:	84.4836"
Jun	28.0:	Elongation:	45.2643"	Alpha:	95.4536"	i:	84.1424"
Jun	29.0:	Elongation:	45.2248"	Alpha:	96.1930"	i:	83.4030"

Do part 2 for a=17,18.

Jun	17.0:	Elongation:	45.4657"	Alpha:	89.1050"	i:	90.4910"
Jun	17.1:	Elongation:	45.4659"	Alpha:	89.1438"	i:	90.4522"
Jun	17.2:	Elongation:	45.4700"	Alpha:	89.1825"	i:	90.4135"
Jun	17.3:	Elongation:	45.4701"	Alpha:	89.2213"	i:	90.3747"
Jun	17.4:	Elongation:	45.4702"	Alpha:	89.2559"	i:	90.3401"
Jun	17.5:	Elongation:	45.4703"	Alpha:	89.2946"	i:	90.3014"
Jun	17.6:	Elongation:	45.4703"	Alpha:	89.3333"	i:	90.2627"
Jun	17.7:	Elongation:	45.4704"	Alpha:	89.3719"	i:	90.2241"
Jun	17.8:	Elongation:	45.4704"	Alpha:	89.4105"	i:	90.1855"
Jun	17.9:	Elongation:	45.4703"	Alpha:	89.4450"	i:	90.1510"
Jun	18.0:	Elongation:	45.4703"	Alpha:	89.4836"	i:	90.1124"
Jun	18.1:	Elongation:	45.4702"	Alpha:	89.5221"	i:	90.0739"
Jun	18.2:	Elongation:	45.4701"	Alpha:	89.5606"	i:	90.0354"
Jun	18.3:	Elongation:	45.4659"	Alpha:	89.5950"	i:	90.0010"
Jun	18.4:	Elongation:	45.4657"	Alpha:	90.0334"	i:	89.5625"
Jun	18.5:	Elongation:	45.4655"	Alpha:	90.0719"	i:	89.5241"
Jun	18.6:	Elongation:	45.4653"	Alpha:	90.1102"	i:	89.4858"
Jun	18.7:	Elongation:	45.4651"	Alpha:	90.1446"	i:	89.4514"
Jun	18.8:	Elongation:	45.4648"	Alpha:	90.1829"	i:	89.4131"
Jun	18.9:	Elongation:	45.4645"	Alpha:	90.2212"	i:	89.3748"

```
Type all.

1.0 Set X=57.295779.
1.05 * Table Mt. Venus Angles (every 10 minutes).
1.1 Type form 15 if $≤4.
1.2 Do part 3 for b=0(1)5.

2.2 Set m=sin(E)•sin[r(34.22)]+cos(E)•cos(U)•cos[r(34.22)].
2.25 Set M=sin(e)•sin(r[34.22])+cos(e)•cos(u)•cos(r[34.22]).
2.3 Set a=d(arg[sqrt(1-m*2),m]).
2.35 Set k=d(arg[sqrt(1-M*2),M]).
2.4 Set n=-cos(E)•sin(U)/cos[r(a)].
2.45 Set N=-cos(e)•sin(u)/cos[r(k)].
2.5 Set A=d(arg[sqrt(1-n*2),n]).
2.55 Set K=d(arg[sqrt(1-N*2),N]).
2.6 Set p=(sin(E)•cos[r(34.22)]-cos(E)•cos(U)•sin[r(34.22)])/cos[r(a)].
2.65 Set P=d(arg[p,sqrt(1-p*2)]).
2.66 Set q=(sin(e)•cos[r(34.22)]-cos(e)•cos(u)•sin[r(34.22)])/cos[r(k)].
2.665 Set q=-1 if q<-1.
2.67 Set Q=d(arg[q,sqrt(1-q*2)]).
2.8 Line if b=0.
2.91 Set P=d(r[360]-r[P]) if n≤0.
2.93 Set Q=d(r[360]-r[Q]) if N≤0.
2.95 Set Z=d(r[P]-r[Q]) if Q≥P.
2.96 Set Z=d(r[P]-r[Q]-r[360]) if Q<P.
2.965 Set Z=d(r[360]+r[Z]) if r[Z]<r[-180].
2.97 Do part 11 if i≥7.
2.98 Do part 12 if i<7.

3.2 Set U=b•([V(i+1)-V(i)]/6)+V(i) if V(i+1)≥V(i).
3.24 Set U=b•([V(i+1)+r[360]-V(i)]/6)+V(i) if V(i+1)<V(i).
3.3 Set E=b•([F(i+1)-F(i)]/6)+F(i).
3.41 Set u=b•([W(i+1)-W(i)]/6)+W(i) if W(i+1)≥W(i).
3.43 Set u=b•([W(i+1)+r[360]-W(i)]/6)+W(i) if W(i+1)<W(i).
3.51 Set e=b•([f(i+1)-f(i)]/6)+f(i).
3.9 Do part 2.

9.0 Type i in form 2.
9.1 Demand v(t,i) as "GHA-Venus".
9.2 Demand G(t,i) as "DEC-Venus".
9.3 Demand w(t,i) as "GHA-SUN".
9.4 Demand g(t,i) as "DEC-SUN".
9.5 Line.

11.05 Do part 15 if $>47.
11.1 Type i,10•b,i-7,10•b,a,P,k,Q,Z in form 1.

12.1 Type i,10•b,i+17,10•b,a,P,k,Q,Z in form 1.

15.1 Page.
```

15.2 Type form 15.
15.3 Line.

Form 1:
__:__ __:__ ___.__' ___.__' ___.__' ___.__' ____.__'

Form 2:
GMT __:00

Form 15:
GMT PDT Venus alt. Az. SUN alt. Az. Bearing

```
D(r,c):  ip(r•c)+.01•ip[60•fp(r•c)]+.006•fp(60•r•c)
  F(i):  [ip[G(t,i)]+fp[G(t,i)]/.6]/X
R(d,c):  [ip(d)+ip(100•fp[d])/60+fp(100•d)/36]/c
  V(i):  [ip[v(t,i)]+fp[v(t,i)]/.6]/X-r[117.41]
  W(i):  [ip[w(t,i)]+fp[w(t,i)]/.6]/X-r[117.41]
  d(x):  D(x,45/arg(1,1))
  f(i):  [ip[g(t,i)]+fp[g(t,i)]/.6]/X
  r(x):  R(x,45/arg(1,1))
```

Recall item 17.
Done.
Type t.
t = 19

Do part 1 for i=15.

15: 0	8: 0	58.08'	126.11'	26.29'	78.36'	47.34'
15:10	8:10	59.46'	129.42'	28.31'	79.49'	49.53'
15:20	8:20	61.18'	133.32'	30.33'	81.02'	52.30'
15:30	8:30	62.45'	137.44'	32.35'	82.16'	55.28'
15:40	8:40	64.05'	142.18'	34.38'	83.30'	58.48'
15:50	8:50	65.16'	147.16'	36.41'	84.46'	62.31'
GMT	PDT	Venus alt.	Az.	SUN alt.	Az.	Bearing

Delete all.

```
Type all.

1.0 Set X=57.295779.
1.05 * New Mexico Venus Angles (every 10 minutes).
1.1 Type form 15 if $≤4.
1.15 Set L=32.1717.
1.2 Do part 3 for b=0(1)5.

2.2 Set m=sin(E)•sin[r(32.1717)]+cos(E)•cos(U)•cos[r(32.1717)].
2.25 Set M=sin(e)•sin(r[32.1717])+cos(e)•cos(u)•cos(r[32.1717]).
2.3 Set a=d(arg[sqrt(1-m*2),m]).
2.35 Set k=d(arg[sqrt(1-M*2),M]).
2.4 Set n=-cos(E)•sin(U)/cos[r(a)].
2.45 Set N=-cos(e)•sin(u)/cos[r(k)].
2.5 Set A=d(arg[sqrt(1-n*2),n]).
2.55 Set K=d(arg[sqrt(1-N*2),N]).
2.6 Set p=(sin(E)•cos[r(L)]-cos(E)•cos(U)•sin[r(L)])/cos[r(a)].
2.65 Set P=d(arg[p,sqrt(1-p*2)]).
2.66 Set q=(sin(e)•cos[r(L)]-cos(e)•cos(u)•sin[r(L)])/cos[r(k)].
2.665 Set q=-1 if q<-1.
2.67 Set Q=d(arg[q,sqrt(1-q*2)]).
2.8 Line if b=0.
2.91 Set P=d(r[360]-r[P]) if n≤0.
2.93 Set Q=d(r[360]-r[Q]) if N≤0.
2.95 Set Z=d(r[P]-r[Q]) if Q≥P.
2.96 Set Z=d(r[P]-r[Q]-r[360]) if Q<P.
2.965 Set Z=d(r[360]+r[Z]) if r[Z]<r[-180].
2.97 Do part 11 if i≥6.
2.98 Do part 12 if i<6.

3.2 Set U=b•([V(i+1)-V(i)]/6)+V(i) if V(i+1)≥V(i).
3.24 Set U=b•([V(i+1)+r[360]-V(i)]/6)+V(i) if V(i+1)<V(i).
3.3 Set E=b•([F(i+1)-F(i)]/6)+F(i).
3.41 Set u=b•([W(i+1)-W(i)]/6)+W(i) if W(i+1)≥W(i).
3.43 Set u=b•([W(i+1)+r[360]-W(i)]/6)+W(i) if W(i+1)<W(i).
3.51 Set e=b•([f(i+1)-f(i)]/6)+f(i).
3.9 Do part 2.

9.0 Type i in form 2.
9.1 Demand v(t,i) as "GHA-Venus".
9.2 Demand G(t,i) as "DEC-Venus".
9.3 Demand w(t,i) as "GHA-SUN".
9.4 Demand g(t,i) as "DEC-SUN".
9.5 Line.

11.05 Do part 15 if $>47.
11.1 Type i,10•b,i-6,10•b,a,P,k,Q,Z in form 1.

12.1 Type i,10•b,i+18,10•b,a,P,k,Q,Z in form 1.
```

15.1 Page.
15.2 Type form 15.
15.3 Line.

Form 1:
__:__ __:__ ___.__' ___.__' ___.__' ___.__' ___.__'

Form 2:
GMT __:00

Form 15:
GMT MDT Venus alt. Az. SUN alt. Az. Bearing

```
D(r,c):  ip(r•c)+.01•ip[60•fp(r•c)]+.006•fp(60•r•c)
  F(i):  [ip[G(t,i)]+fp[G(t,i)]/.6]/X
R(d,c):  [ip(d)+ip(100•fp[d])/60+fp(100•d)/36]/c
  V(i):  [ip[v(t,i)]+fp[v(t,i)]/.6]/X-r[106.4148]
  W(i):  [ip[w(t,i)]+fp[w(t,i)]/.6]/X-r[106.4148]
  d(x):  D(x,45/arg(1,1))
  f(i):  [ip[g(t,i)]+fp[g(t,i)]/.6]/X
  r(x):  R(x,45/arg(1,1))
```

Recall item 17.
Done.
Type t.
t = 19

Type form 15.
GMT MDT Venus alt. Az. SUN alt. Az. Bearing
Do part 1 for i=15.

GMT	MDT	Venus alt.	Az.	SUN alt.	Az.	Bearing
15: 0	9: 0	66.13'	141.29'	35.12'	82.32'	58.56'
15:10	9:10	67.27'	146.49'	37.18'	83.41'	63.08'
15:20	9:20	68.31'	152.40'	39.24'	84.51'	67.49'
15:30	9:30	69.23'	159.01'	41.30'	86.03'	72.58'
15:40	9:40	70.02'	165.49'	43.37'	87.16'	78.32'
15:50	9:50	70.25'	172.56'	45.44'	88.31'	84.24'

Delete all.

GMT	PDT	Venus alt.	Az.	SUN alt.	Az.	Bearing
1: 0	18: 0	22.50'	273.42'	14.14'	266.59'	6.43'
1:10	18:10	20.46'	275.03'	12.11'	268.25'	6.38'
1:20	18:20	18.42'	276.24'	10.07'	269.50'	6.34'
1:30	18:30	16.38'	277.44'	8.03'	271.15'	6.29'
1:40	18:40	14.35'	279.04'	5.60'	272.39'	6.25'
1:50	18:50	12.33'	280.24'	3.56'	274.03'	6.20'
2: 0	19: 0	10.31'	281.44'	1.53'	275.28'	6.16'
2:10	19:10	8.29'	283.04'	-.10'	276.52'	6.12'
2:20	19:20	6.28'	284.25'	-2.12'	278.17'	6.08'
2:30	19:30	4.28'	285.47'	-4.14'	279.43'	6.04'
2:40	19:40	2.29'	287.10'	-6.16'	281.10'	5.60'
2:50	19:50	.31'	288.34'	-8.17'	282.38'	5.55'
3: 0	20: 0	-1.26'	289.59'	-10.18'	284.08'	5.51'
3:10	20:10	-3.23'	291.26'	-12.17'	285.39'	5.47'
3:20	20:20	-5.18'	292.55'	-14.16'	287.12'	5.42'
3:30	20:30	-7.12'	294.25'	-16.14'	288.47'	5.37'
3:40	20:40	-9.04'	295.57'	-18.10'	290.25'	5.32'
3:50	20:50	-10.55'	297.32'	-20.06'	292.05'	5.27'

GMT	PDT	Venus alt.	Az.	SUN alt.	Az.	Bearing
14: 0	7: 0	47.11'	110.01'	14.32'	71.19'	38.42'
14:10	7:10	49.06'	112.16'	16.30'	72.33'	39.43'
14:20	7:20	51.00'	114.39'	18.28'	73.46'	40.53'
14:30	7:30	52.51'	117.13'	20.27'	74.59'	42.14'
14:40	7:40	54.40'	119.58'	22.27'	76.12'	43.47'
14:50	7:50	56.26'	122.57'	24.28'	77.24'	45.33'
15: 0	8: 0	58.08'	126.11'	26.29'	78.36'	47.34'
15:10	8:10	59.46'	129.42'	28.31'	79.49'	49.53'
15:20	8:20	61.18'	133.32'	30.33'	81.02'	52.30'
15:30	8:30	62.45'	137.44'	32.35'	82.16'	55.28'
15:40	8:40	64.05'	142.18'	34.38'	83.30'	58.48'
15:50	8:50	65.16'	147.16'	36.41'	84.46'	62.31'
16: 0	9: 0	66.18'	152.39'	38.44'	86.02'	66.37'
16:10	9:10	67.10'	158.26'	40.48'	87.21'	71.05'
16:20	9:20	67.49'	164.34'	42.52'	88.42'	75.52'
16:30	9:30	68.15'	170.59'	44.56'	90.06'	80.54'
16:40	9:40	68.28'	177.35'	46.59'	91.32'	86.02'
16:50	9:50	68.26'	184.13'	49.03'	93.02'	91.11'

TMO, 19 June 1969

GMT	MDT	Venus alt.	Az.	SUN alt.	Az.	Bearing
14: 0	8: 0	56.24'	118.28'	22.45'	75.49'	42.39'
14:10	8:10	58.14'	121.27'	24.48'	76.56'	44.31'
14:20	8:20	60.00'	124.42'	26.52'	78.02'	46.40'
14:30	8:30	61.42'	128.18'	28.57'	79.09'	49.08'
14:40	8:40	63.19'	132.15'	31.01'	80.16'	51.59'
14:50	8:50	64.50'	136.38'	33.06'	81.24'	55.14'
15: 0	9: 0	66.13'	141.29'	35.12'	82.32'	58.56'
15:10	9:10	67.27'	146.49'	37.18'	83.41'	63.08'
15:20	9:20	68.31'	152.40'	39.24'	84.51'	67.49'
15:30	9:30	69.23'	159.01'	41.30'	86.03'	72.58'
15:40	9:40	70.02'	165.49'	43.37'	87.16'	78.32'
15:50	9:50	70.25'	172.56'	45.44'	88.31'	84.24'
16: 0	10: 0	70.33'	180.13'	47.50'	89.50'	90.24'
16:10	10:10	70.25'	187.31'	49.57'	91.11'	96.20'
16:20	10:20	70.00'	194.37'	52.04'	92.36'	102.00'
16:30	10:30	69.21'	201.23'	54.10'	94.06'	107.17'
16:40	10:40	68.29'	207.43'	56.17'	95.42'	112.00'
16:50	10:50	67.24'	213.32'	58.23'	97.25'	116.07'

NMSU, 19 June 1969

```
Type all.

1.1 Do part 10.
1.11 Line.
1.12 Type "Page".
1.13 Type i in form 1.
1.2 Do part 2 for o=1(1)f.

2.0 Line.
2.1 Set j=J(o).
2.2 Do part 3.
2.4 Do part 4.
2.5 Do part 5.
2.6 Do part 6 for a=1(1)3.
2.7 Do part 7.

3.1 Set k=z(o).
3.2 Set O=|sum[g=1(1)k:[G(j,g)-F(j,g)]/2]/k|.
3.3 Set M=|sum[g=1(1)k:[U(j,g)-W(j,g)]]/k|.
3.4 Set N=|sum[g=1(1)k:[E(j,g)-W(j,g)]]/k|.
3.5 Set S=|sum[g=1(1)k:[C(j,g)-W(j,g)]]/k| if C(j,g)≠0.
3.55 Set S=0 if C(j,g)=0.
3.6 Set v=|sum[g=1(1)k:[V(j,g)-W(j,g)]]/k|.
3.8 Type j,A(o) in form 2.
3.85 Type form 5.
3.9 Type O,M,N,v,S in form 3.

4.2 Type M/O,N/O,v/O,S/O in form 4.
4.4 Set e=1-cos[r(A(o))+r(.22)].
4.5 Set L=[M/O]-e.
4.6 Set u=[[M/O]-e]/sin[r(A(o))+r(.22)].
4.7 Set l=d(arg[1,u]).
4.8 Type e,L,l in form 8.

5.1 Set X=arg[sqrt(1-[(N/O)-1]*2),(N/O)-1].
5.21 Set b=(sin(X)·sin[r(A(o))])-sin[r(.22)].
5.215 Set p(1)=b/(cos[r(.22)]+cos[r(A(o))]).
5.22 Set t(1)=sin(X)·sin[r(A(o))].
5.23 Set q(1)=b/(cos[r(.22)]-cos[r(A(o))]).
5.3 Set Y=arg[sqrt(1-[(v/O)-1]*2),(v/O)-1].
5.31 Set b=(sin(Y)·sin[r(A(o))])-sin[r(.22)].
5.315 Set p(2)=b/(cos[r(.22)]+cos[r(A(o))]).
5.32 Set t(2)=sin(Y)·sin[r(A(o))].
5.33 Set q(2)=b/(cos[r(.22)]-cos[r(A(o))]).
5.5 Set Z=arg[sqrt(1-[(S/O)-1]*2),(S/O)-1].
5.51 Set b=(sin(Z)·sin[r(A(o))])-sin[r(.22)].
5.515 Set p(3)=b/(cos[r(.22)]+cos[r(A(o))]).
5.52 Set t(3)=sin(Z)·sin[r(A(o))].
5.53 Set q(3)=b/(cos[r(.22)]-cos[r(A(o))]).
```

```
6.2 Set P(a)=d(arg[1,p(a)]).
6.3 Set T(a)=d(arg[sqrt(1-t(a)*2),t(a)]-r(.22)).
6.4 Set Q(a)=d(arg[1,q(a)]).

7.1 Line.
7.15 Do part 8 if S=0.
7.2 Type d(X),d(Y),d(Z) in form 6.
7.3 Type sin(X),sin(Y),sin(Z) in form 7.
7.4 Type P(1),P(2),P(3) in form 9.
7.5 Type T(1),T(2),T(3) in form 10.
7.6 Type Q(1),O(2),O(3) in form 11.

8.1 Set Z=0.
8.3 Set P(3)=0.
8.4 Set T(3)=0.
8.5 Set Q(3)=0.

9.1 Line.
9.2 Type "Page".
9.3 Type i in form 1.
9.4 Do part 2 for o=1(1)f.

10.2 Demand i as "PLATE No.".
10.3 Demand f as "Number of Images measured".
10.5 Do part 11 for o=1(1)f.

11.0 Line.
11.1 Demand J(o) as "IMAGE No.".
11.2 Demand z(o) as "Number of Measurements".
11.25 Demand A(o) as "Alpha".
11.3 Do part 13 for g=1(1)z(o).

13.0 Line.
13.05 Set j=J(o).
13.1 Type j,g in form 13.
13.2 Demand W(j,g) as "West".
13.3 Demand U(j,g) as "Terminator".
13.4 Demand V(j,g) as "Southern".
13.5 Demand C(j,g) as "Long South".
13.6 Demand E(j,g) as "Northern".
13.7 Demand F(j,g) as "SOUTH".
13.8 Demand G(j,g) as "NORTH".

Form 1:
   PLATE No.: ____

Form 2:
IMAGE No.: __                                        Alpha:__.___"

Form 3:
  __.___  __.___    __.___   __.___  __.___

Form 4:
       /P: _.____    __.____   __.____ __.____
```

Form 5:
Radius N North Cusp South Cusps

Form 6:
PI: ___.___" ___.___" ___.___"

Form 7:
sin(PI): ___.___ ___.___ ___.___

Form 8:
m/R: ___.___ L: _.___ SIG: __.___"

Form 9:
Sigma-P: ___.___" ___.___" ___.___"

Form 10:
Sigma-T: ___.___" ___.___" ___.___"

Form 11:
Sigma-Q: ___.___" ___.___" ___.___"

Form 13:
IMAGE No.: __ Measurement _

D(r,c): ip(r·c)+.01·ip[60·fp(r·c)]+.006·fp(60·r·c)
R(d,c): [ip(d)+ip(100·fp[d])/60+fp(100·d)/36]/c
d(x): D(x,45/arg(1,1))
r(x): R(x,45/arg(1,1))
s(x,y): d(r(x)+r(y))

*** EXAMPLE ***

Do part 9.

```
   PLATE No.: 9139

IMAGE No.:  2                                              Alpha: 88.3836"
    Radius     M        North Cusp   South Cusps
    1.434    1.507        1.686      1.607      .000
         /R: 1.0508       1.1757     1.1207     .0000
        m/R:  .9827                                        L: .0681  SIG: 3.5343"

        PI:        10.0701"     6.5551"      .0000"
    sin(PI):         .1757       .1207       .0000
   Sigma-P:         9.2310"     6.2204"      .0000"
   Sigma-T:         9.4450"     6.3344"      .0000"
   Sigma-Q:         9.4957"     6.4026"      .0000"

IMAGE No.:  8                                              Alpha: 88.3440"
    Radius     M        North Cusp   South Cusps
    1.481    1.801        1.885      1.880      .000
         /R: 1.2165       1.2728     1.2696     .0000
        m/R:  .9816                                        L: .2349  SIG:13.1321"

        PI:        15.4947"    15.3831"      .0000"
    sin(PI):         .2728       .2696       .0000
   Sigma-P:        14.3358"    14.2404"      .0000"
   Sigma-T:        15.2729"    15.1614"      .0000"
   Sigma-Q:        15.1626"    15.0605"      .0000"
```