No. 102 VENUS PHOTOGRAPHS

PART I:
PHOTOGRAPHS OF VENUS TAKEN WITH THE 82-INCH TELESCOPE AT McDONALD OBSERVATORY, 1950–56

by G. P. KUIPER, J. W. FOUNTAIN, AND S. M. LARSON

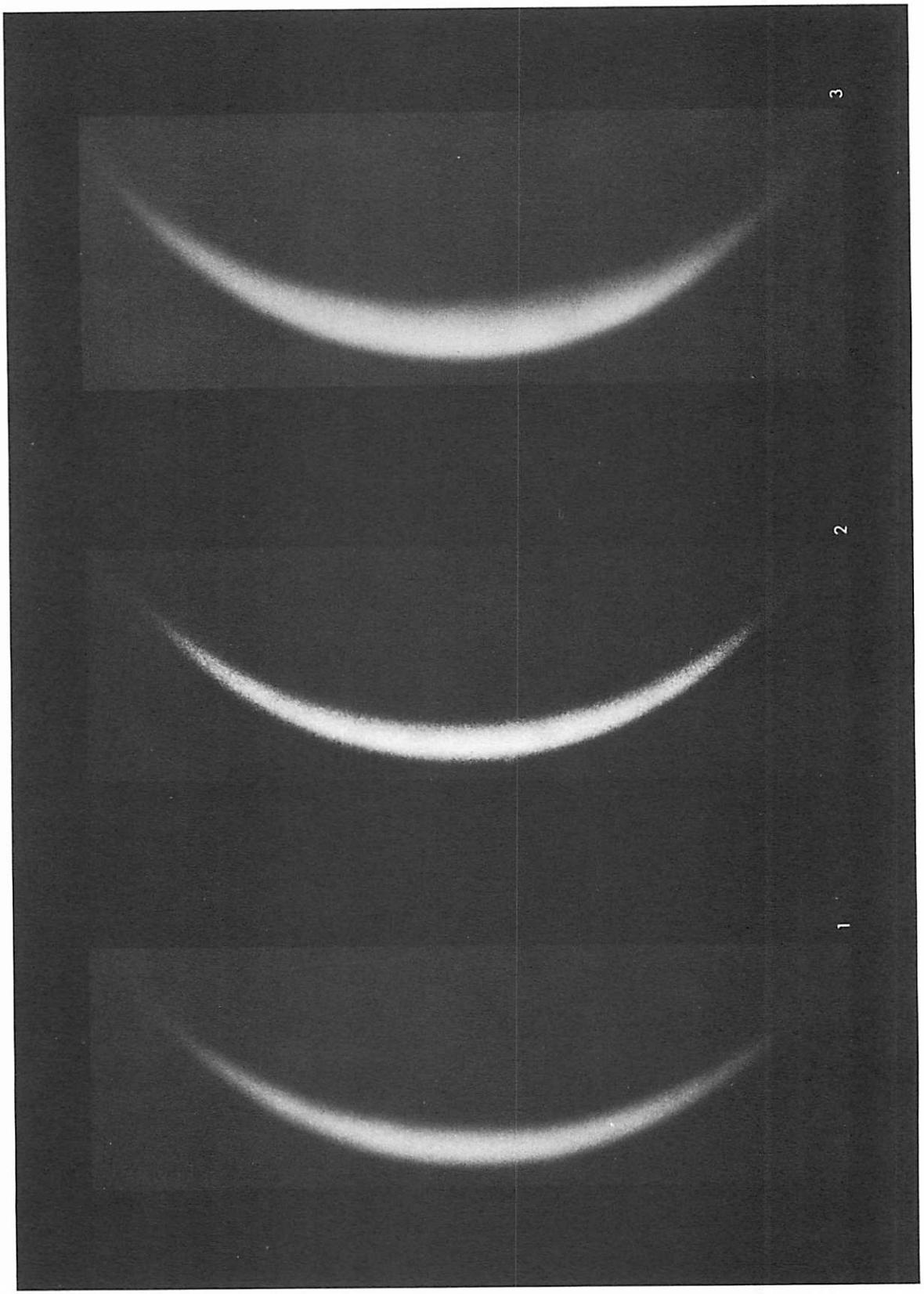
September 27, 1968

ABSTRACT

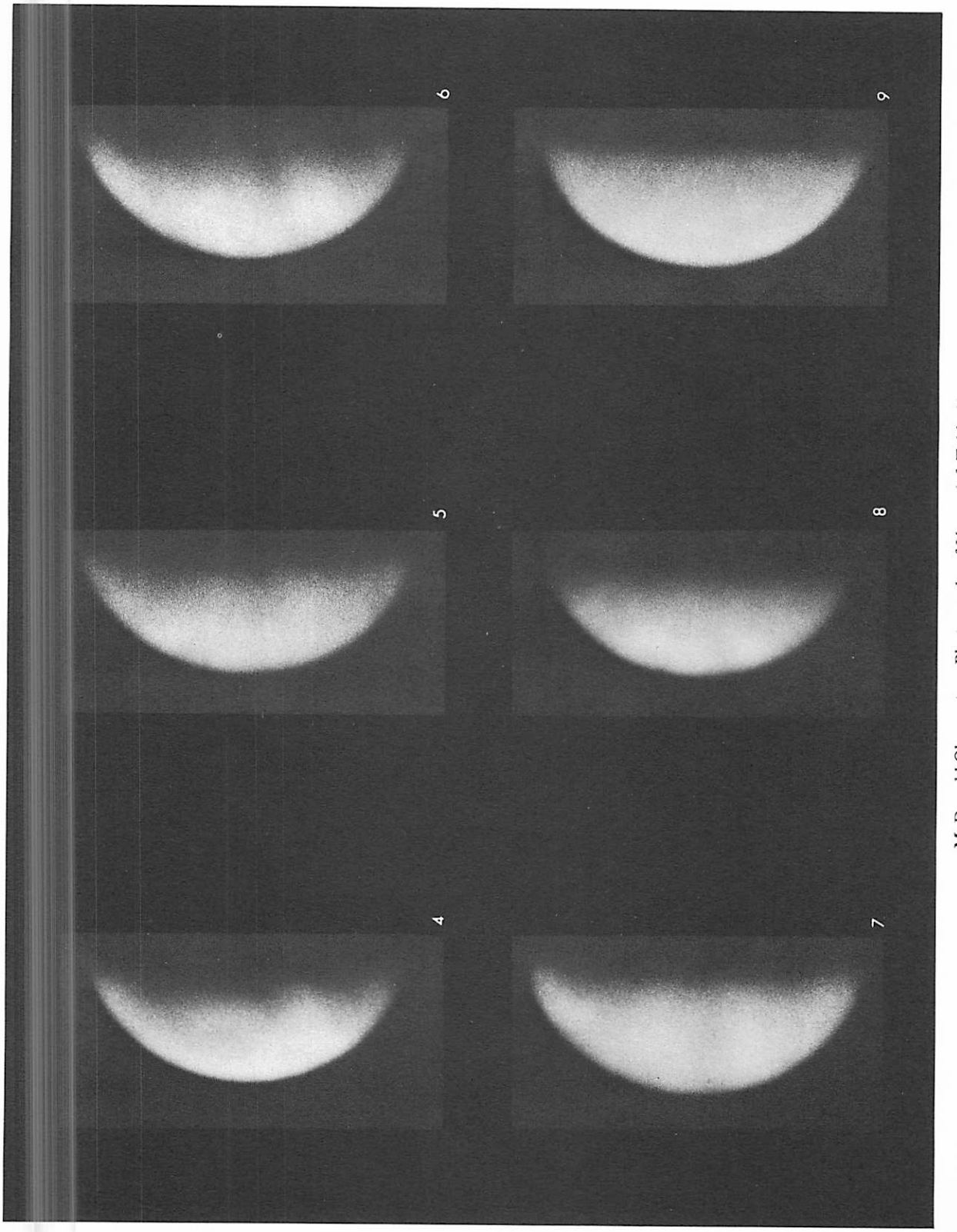
In this *Communication* are collected three series of Venus photographs, taken in our continuing planetary program: one at the McDonald Observatory 82-inch telescope (discussed in Part I); one with the Steward Observatory 36-inch telescope (Part II); and one with the 61-inch NASA telescope at the Catalina Observatory (Part III). North is up in all reproductions. Most photographs reproduced here were taken in the UV, but some at longer wavelengths, 5500 and 8700 Å. Parts I and II state some conclusions on the wavelength dependence of the visibilty of the cloud markings: indistinct markings are at times visible in both the yellow and the near IR but they are of much lower contrast than those observed in the UV. The UV cloud pattern varies not only from day to day, at times in a cycle of 4–5 days as has been noted before; but also over a period of a decade or two as is seen by comparison of Parts I and III.

After Dr. Kuiper's return from Europe late 1945, where he had the opportunity of frequently visiting with Dr. B. Lyot in Paris, he started a program of planetary photography with the 82-inch telescope in early 1946. This program was continued intermittently until 1956, at which time some 478 plates had been taken, each carrying about eight exposures. In 1966 this material was made available to the Planetary Data Center at Lowell Observatory for copying. It was nevertheless deemed of interest, in the context with our other studies of the planet Venus, to make composite enlargements of the better originals and publish the results here. Most of the Venus photographs were made on Eastman IV-O without filter, but occasionally a UV filter centered at 3600 Å was used. Also, some exposures were made on Eastman IV-G (visual) and IV-N, the latter with a Corning 2550 filter which made the effective wavelength around 8700 Å.

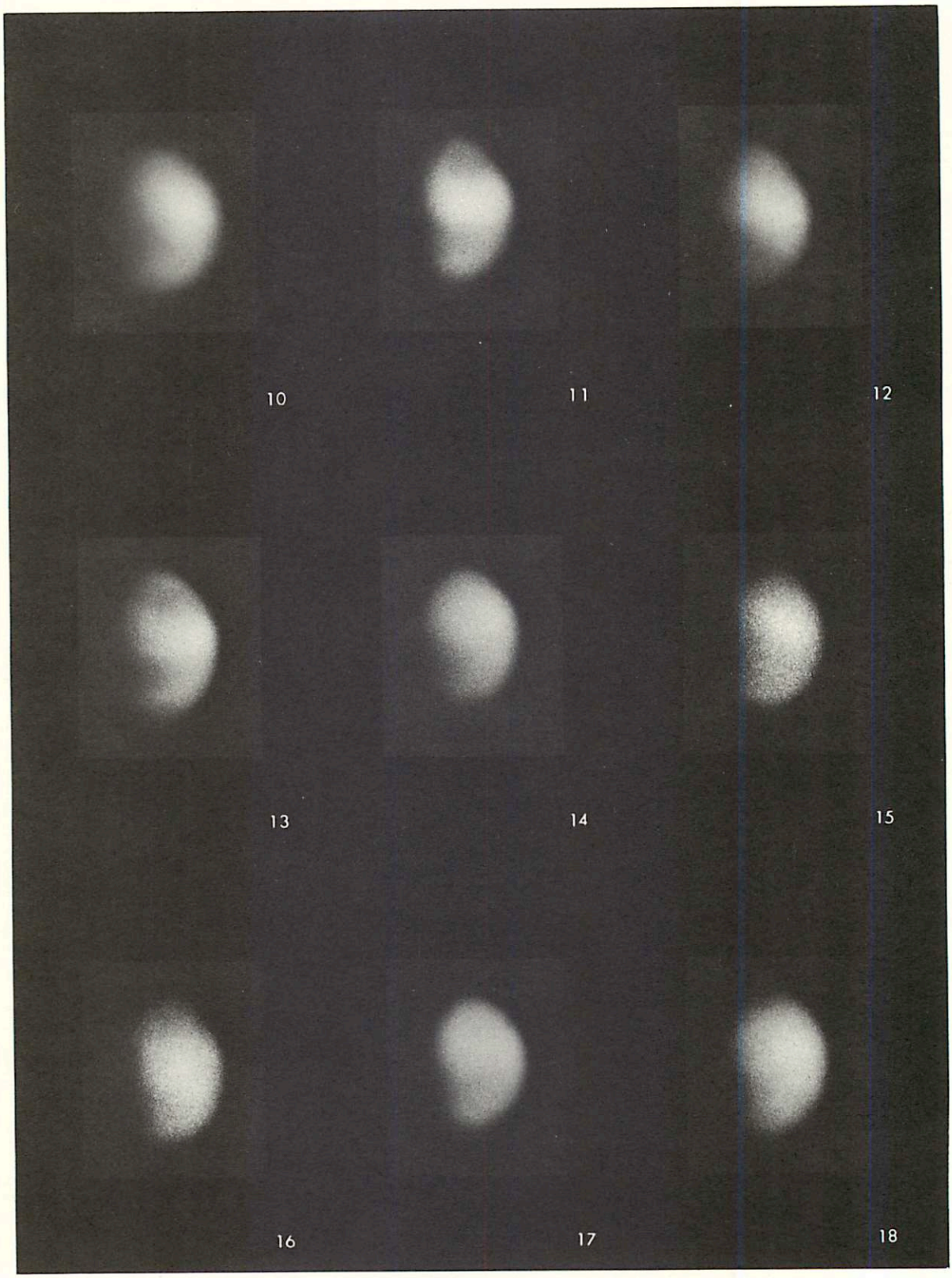
All exposures were taken with a planetary enlarging camera at the Cassegrain focus using an equivalent focal length of about 300 ft (90 m.).



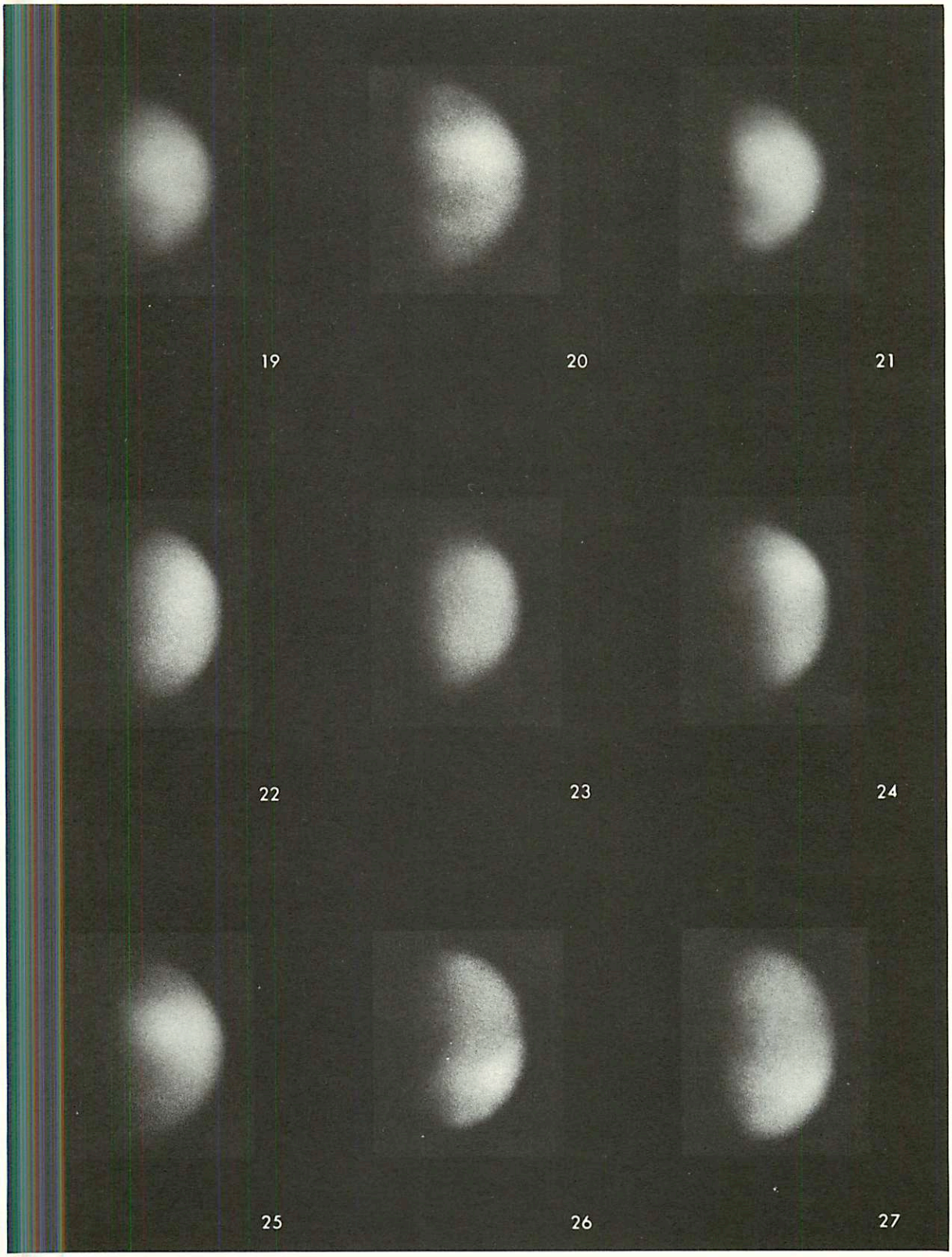
McDonald Observatory Photographs of Venus (cf. Table 1).



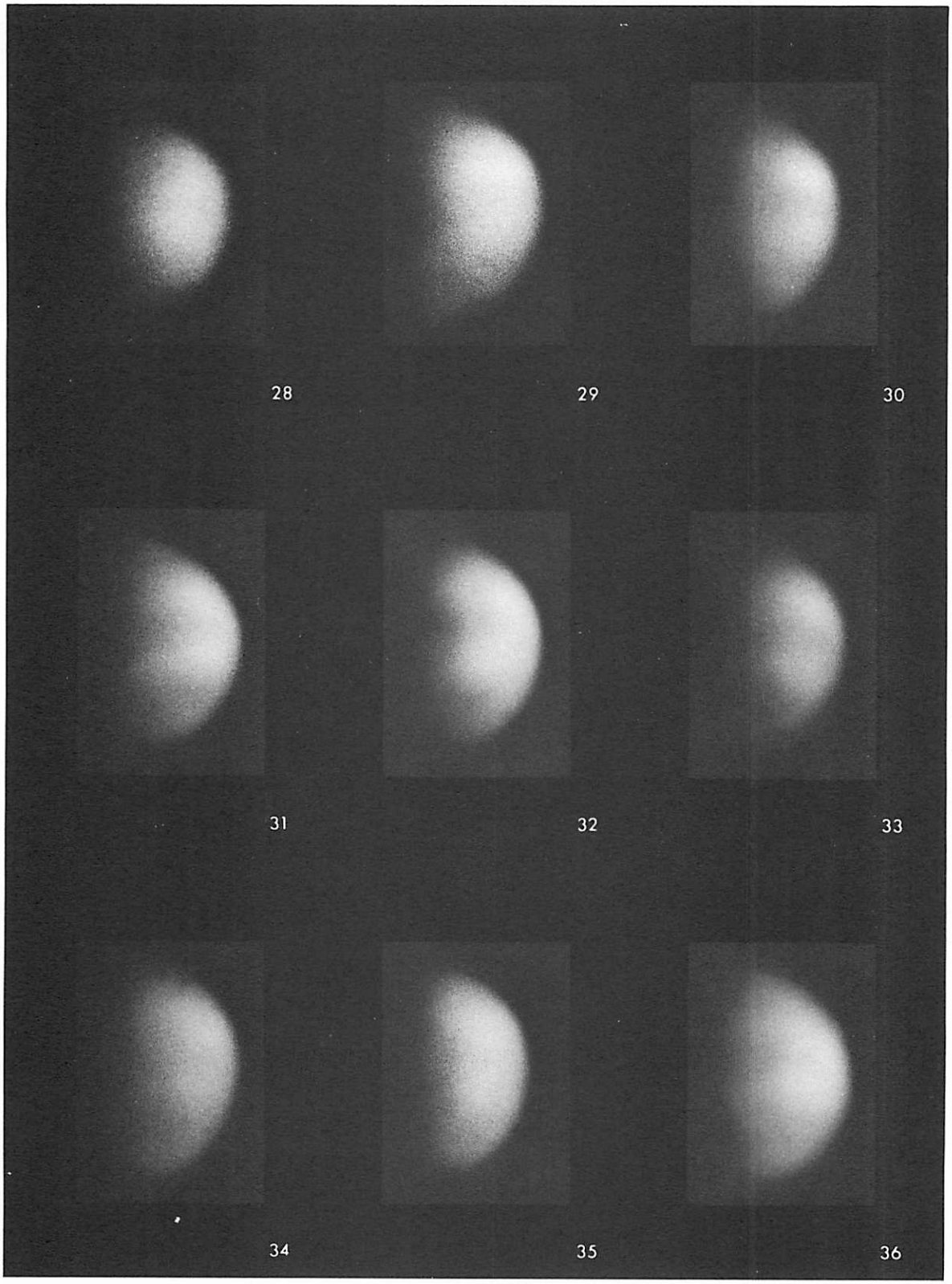
McDonald Observatory Photographs of Venus (cf. Table 1).



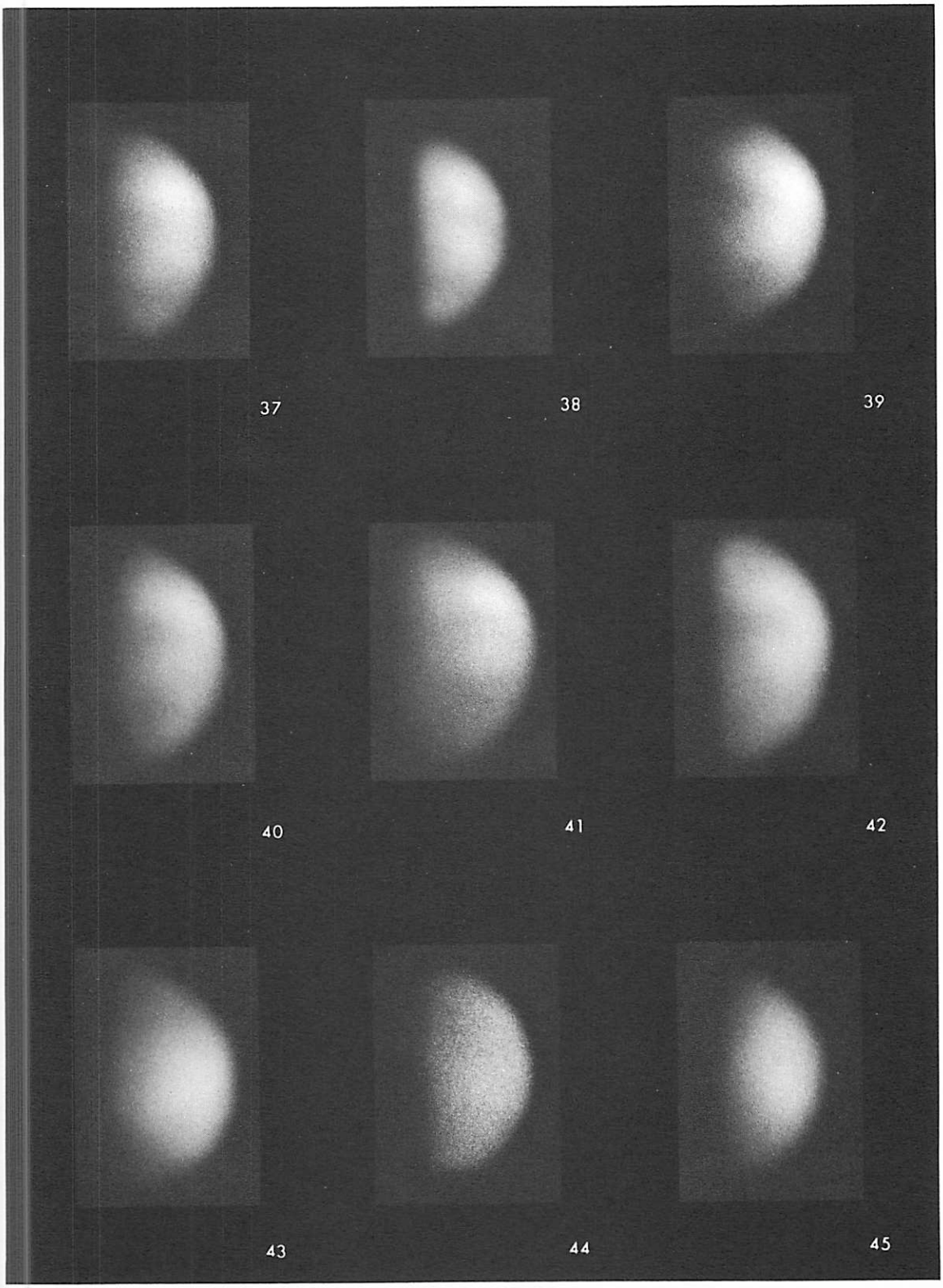
McDonald Observatory Photographs of Venus (cf. Table 1).



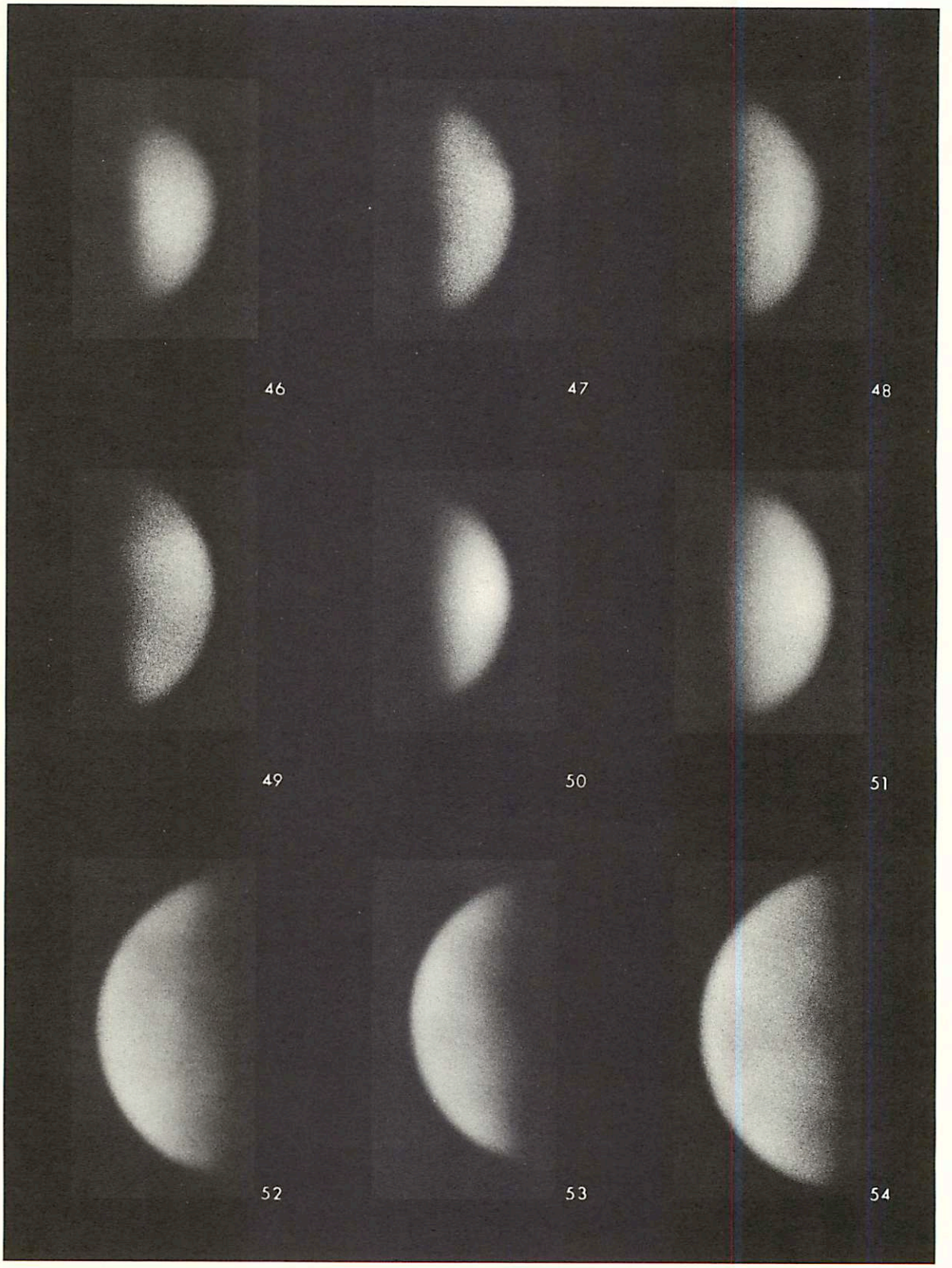
McDonald Observatory Photographs of Venus (cf. Table 1).



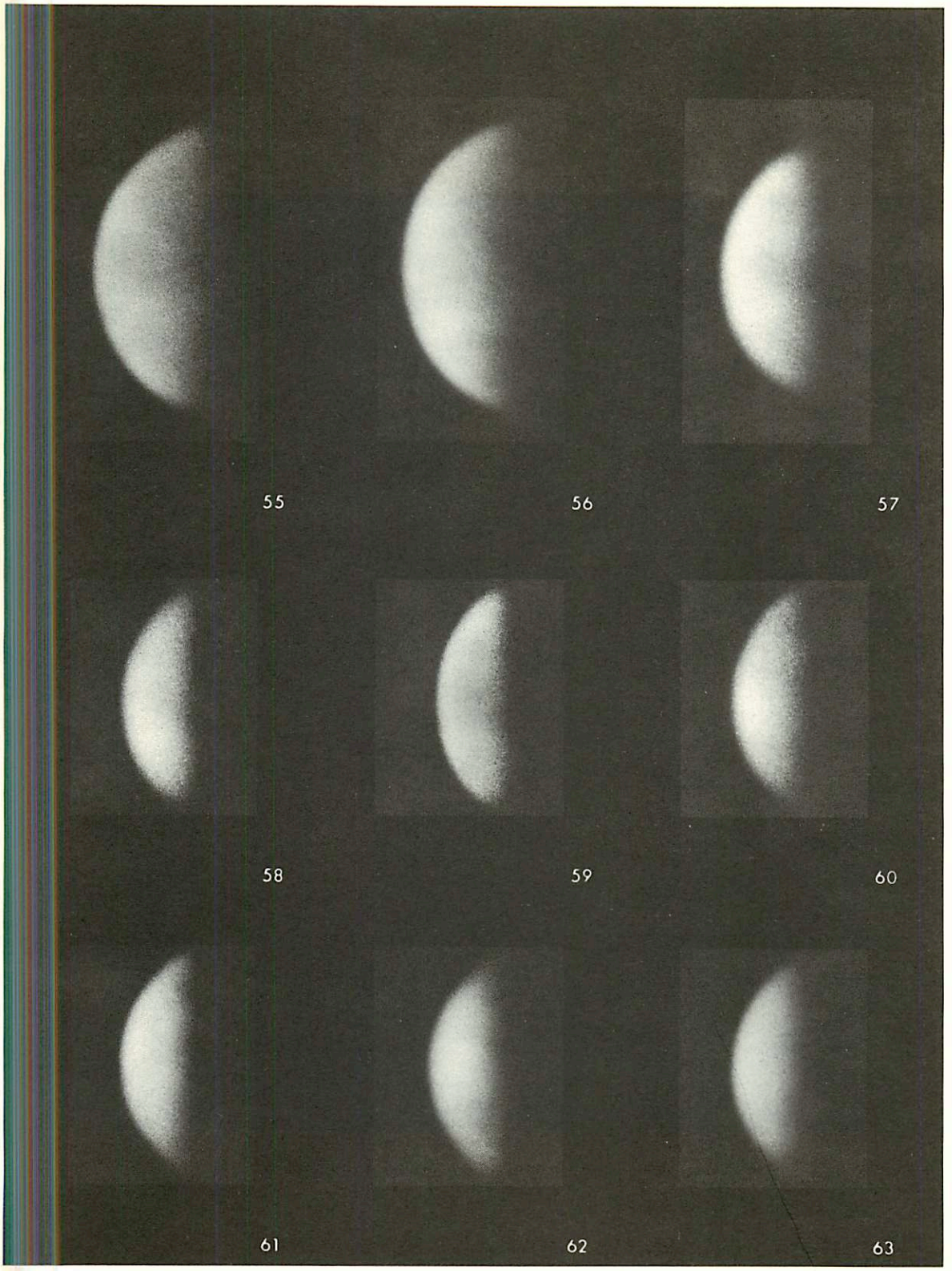
McDonald Observatory Photographs of Venus (cf. Table 1).



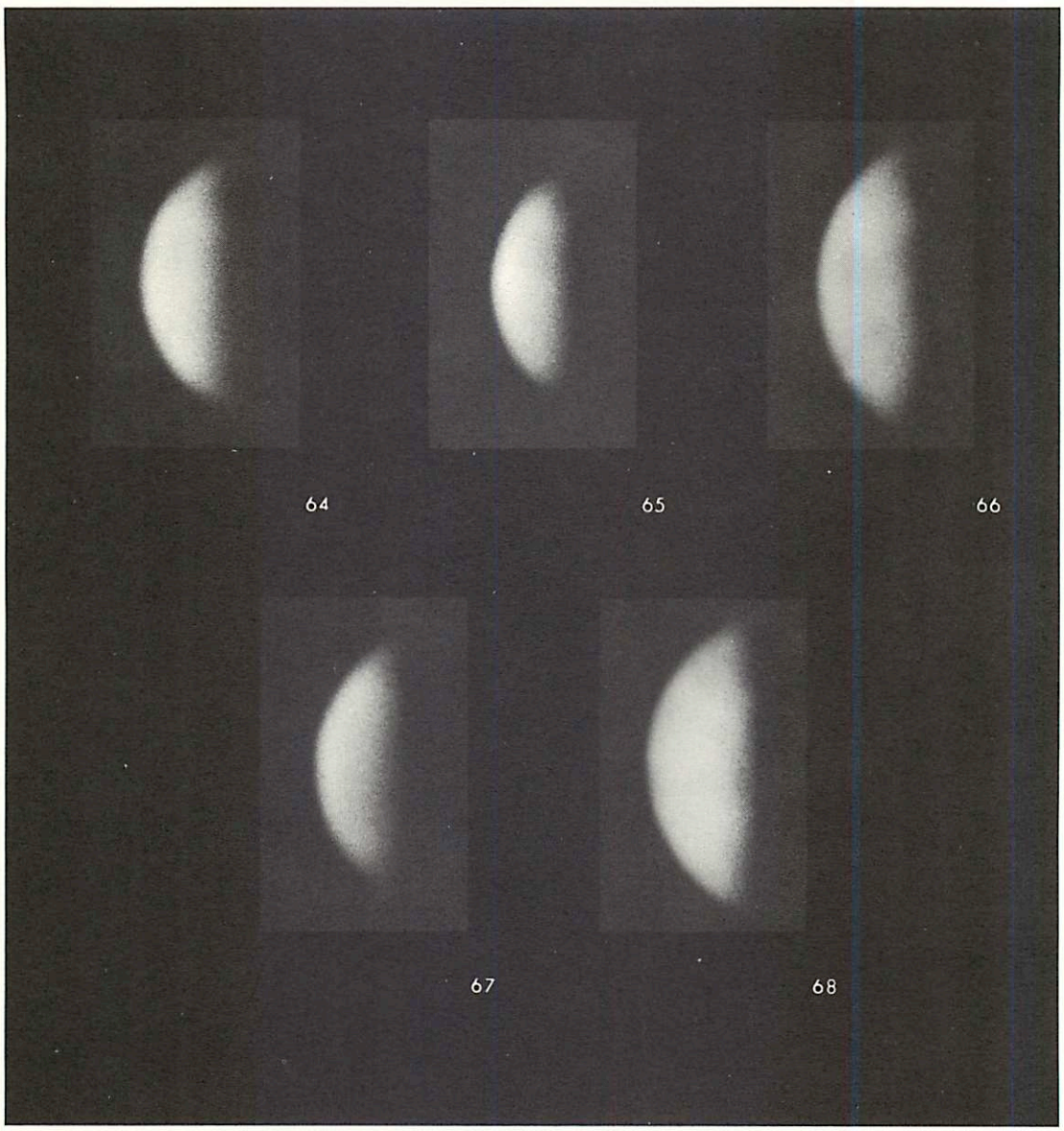
McDonald Observatory Photographs of Venus (cf. Table 1).



McDonald Observatory Photographs of Venus (cf. Table 1).



McDonald Observatory Photographs of Venus (cf. Table 1).



McDonald Observatory Photographs of Venus (cf. Table 1).

TABLE 1

OBSERVATIONAL DATA ON MCDONALD OBSERVATORY VENUS REPRODUCTIONS

No.	McD.	Date	UT	Emul.	Corning Filter	No. of Images	k	Semi-diameter
1	200	1950 Feb 17	16:11	IV-N	2550	5	0.103	26″.9
2	201	Feb 17	16:37	IV-N	2550	2	0.103	26.9
3	202	Feb 17	17:00	IV-N	2550	5	0.103	26.9
4	299	1950 Apr 8	13:33	IV-O	none	1	0.479	12.8
5	301	Apr 8	13:56	IV-O	none	1	0.479	12.8
6	302	Apr 8	14:10	IV-O	none	1	0.479	12.8
7	304	Apr 8	14:43	IV-O	none	4	0.479	12.8
8	305	Apr 8	14:53	SB Pan	>5300 Å	4	0.479	12.8
9	306	Apr 8	15:10	SB Pan	>5300 Å	1	0.479	12.8
10	341	1954 Jun 15	22:40	IV-O	none	3	0.813	6.5
11	342	Jun 15	22:59	IV-O	none	4	0.813	6.5
12	343	Jun 15	23:19	IV-O	none	2	0.813	6.5
13	344	Jun 15	23:39	IV-O	none	1	0.813	6.5
14	345	Jun 15	23:55	IV-O	none	1	0.813	6.5
15	346	Jun 16	00:02	IV-O	none	2	0.813	6.5
16	347	Jun 16	00:08	IV-O	none	2	0.813	6.5
17	348	Jun 16	00:13	IV-O	none	3	0.813	6.5
18	350	Jun 16	00:20	IV-O	none	4	0.813	6.5
19	354	Jun 16	01:40	IV-O	none	3	0.813	6.5
20	356	Jun 16	01:50	IV-O	none	1	0.813	6.5
21	357	Jun 16	01:55	IV-O	none	4	0.813	6.5
22	359	Jun 25	22:50	IV-O	none	2	0.780	6.8
23	360	Jun 25	22:57	IV-O	none	2	0.780	6.8
24	361	Jun 25	23:04	IV-O	none	4	0.780	6.8
25	362	Jun 25	23:09	IV-O	none	3	0.780	6.8
26	363	Jun 25	23:45	IV-O	5860, 5970	2	0.780	6.8
27	364	Jun 26	00:08	IV-O	5970	3	0.777	6.9
28	369	Jun 26	22:26	IV-O	none	2	0.777	6.9
29	382	Jul 18	21:59	IV-O	none	3	0.701	7.9
30	383	Jul 18	22:05	IV-O	none	3	0.701	7.9
31	387	Jul 18	23:59	IV-O	none	3	0.701	7.9
32	389	Jul 19	00:30	IV-O	none	4	0.699	7.9
33	391	Jul 19	00:44	IV-O	none	4	0.699	7.9
34	392	Jul 19	00:49	IV-O	none	3	0.699	7.9
35	393	Jul 19	00:54	IV-O	none	3	0.699	7.9
36	394	Jul 19	00:57	IV-O	none	3	0.699	7.9
37	395	Jul 19	01:08	IV-O	none	3	0.699	7.9
38	397	Jul 19	01:14	IV-O	none	3	0.699	7.9
39	398	Jul 19	01:19	IV-O	none	4	0.699	7.9
40	399	Jul 19	01:22	IV-O	none	4	0.699	7.9
41	400	Jul 19	01:25	IV-O	none	3	0.699	7.9
42	401	Jul 19	01:29	IV-O	none	3	0.699	7.9
43	402	1954 Jul 20	01:23	IV-O	none	4	0.697	8.0
44	403	Jul 20	01:26	IV-O	none	3	0.697	8.0
45	406	Jul 20	01:39	IV-O	none	4	0.697	8.0
46	419	1956 Mar 15	22:10	IV-O	none	4	0.643	9.0
47	421	Mar 17	21:33	IV-O	none	2	0.635	9.2
48	422	Mar 17	21:58	IV-O	none	3	0.635	9.2
49	424	Mar 17	22:20	IV-O	none	3	0.635	9.2
50	425, 426, 427	Mar 17	22:52	IV-O	none	8	0.635	9.2
51	428	1956 Mar 17	23:05	IV-O	none	4	0.635	9.2
52	433	Sep 9	12:53	IV-O	none	4	0.548	10.9
53	437, 438	Sep 9	13:11	IV-O	none	8	0.548	10.9
54	441	Sep 9	13:22	IV-O	none	4	0.548	10.9
55	442	Sep 9	13:24	IV-O	none	3	0.548	10.9
56	443, 444	Sep 9	13:30	IV-G	none	7	0.548	10.9
57	447	Sep 10	11:46	IV-G	none	3	0.552	10.8
58	450	Sep 10	12:00	IV-G	none	4	0.552	10.8
59	451	Sep 10	12:04	IV-G	none	3	0.552	10.8
60	454	1956 Sep 16	11:50	IV-G	none	4	0.582	10.2
61	456, 457	Sep 16	11:58	IV-G	none	8	0.582	10.2
62	458, 459	Sep 16	12:03	IV-G	none	8	0.582	10.2
63	460, 461	Sep 16	12:08	IV-G	none	8	0.582	10.2
64	462	Sep 16	12:13	IV-G	none	4	0.582	10.2
65	463	Sep 16	12:16	IV-G	none	4	0.582	10.2
66	464	Sep 16	12:18	IV-G	none	4	0.582	10.2
67	465	Sep 16	12:20	IV-G	none	4	0.582	10.2
68	467	Sep 16	12:46	IV-G	none	3	0.582	10.2

The frames to be reproduced were selected by Dr. Kuiper; the copying and printing were done by Messrs. J. Fountain and S. Larson, with the assistance of Miss D. Miller, using the same methods used in Part III of this *Communication*.

The observational data are found in Table 1, giving for each print the identification number shown here on the reproduction, the original McDonald Observatory plate number, the date and time (UT), the emulsion and filter used, the number of images used in the composite, the fraction k of the disk illuminated, and the semi-diameter of the planet, taken from the *Nautical Almanac*.

The faint "notches" noted on the infrared exposures of the crescents (1, 2, and 3) are regarded real, as are the delicate detail shown on some of the IV-G exposures (56–68) and the two panchromatic frames, 8 and 9. It is seen that the 1950 UV exposures (4–7) tend to show a belt-like structure of the Venus haze layer, with No. 7 showing a distinct north-polar enhancement. The 1956 violet exposures show only the most delicate structure, not appreciably stronger than that shown in the yellow on IV-G. In addition to some runs of about one hour, two longer runs are included: one (frames 10–21) of $3^h\ 15^m$ taken on June 15–16, 1954; and one (frames 29–42) of $3^h\ 30^m$ taken on July 18–19, 1954. Some *retrograde motion* in the clouds is noted between frames 10–12 compared to frames 19–21. Frames 16–18 are affected by inferior seeing. Likewise, a retrograde cloud motion is indicated between frames 30–33 compared to 40–42. If in each case the displacement is estimated to be roughly 10°, a motion corresponding to a rotational period of 4–5 days is indicated. Clearly, this subject must be pursued with a greatly intensified effort under the best possible seeing conditions.

Photographic copies of the Venus records reproduced in this *Communication* can be supplied by this Laboratory for research purposes.

Acknowledgments. The program on planetary photography at this Laboratory is supported by NASA Grant NsG 161-61. We are indebted to Miss D. Miller for her able assistance in making the composites; to Mrs. A. Agnieray for the composition of the plates and the retouching of minor defects; and to the Director of the McDonald Observatory for the continued loan of the originals.

PART II:
MULTICOLOR PHOTOGRAPHY OF VENUS, 1962

by WILLIAM K. HARTMANN

March 30, 1968

Gehrels and Samuelson (1961) suggested that the polarization of Venus at 3140 Å shows anomalous variations. In 1962, Gehrels encouraged the writer to make a series of photographs with his liquid filter at this wavelength and filters at other wavelengths, to search for possible anomalous markings that might be associated with the observed anomalous polarization. A number of liquid filters, constructed by S. F. Pellicori and having bandwidths of about 360 Å, were used. The photography was carried out with the 36-inch reflector of Steward Observatory, at that time located on the University of Arizona campus.

Photographs were obtained on 31 dates during the 1962 apparition. Three examples are shown in Figure 1. It was found that the markings become prominent within a rather short wavelength interval near 3700 Å. Within the contrast limitations imposed by the (Panatomic X) film, there was no evidence of a continued inverse fourth-power increase in visibility of the markings toward shorter wavelengths, indicating that differential Rayleigh scattering is not dominant in producing the markings. This is consistent with the failure of Rayleigh scattering to satisfy the Venus scattering function (Kuiper 1957). Because of the poorer seeing at shorter wavelengths, 3500–3700 Å appears optimum for photography of the ultraviolet markings.

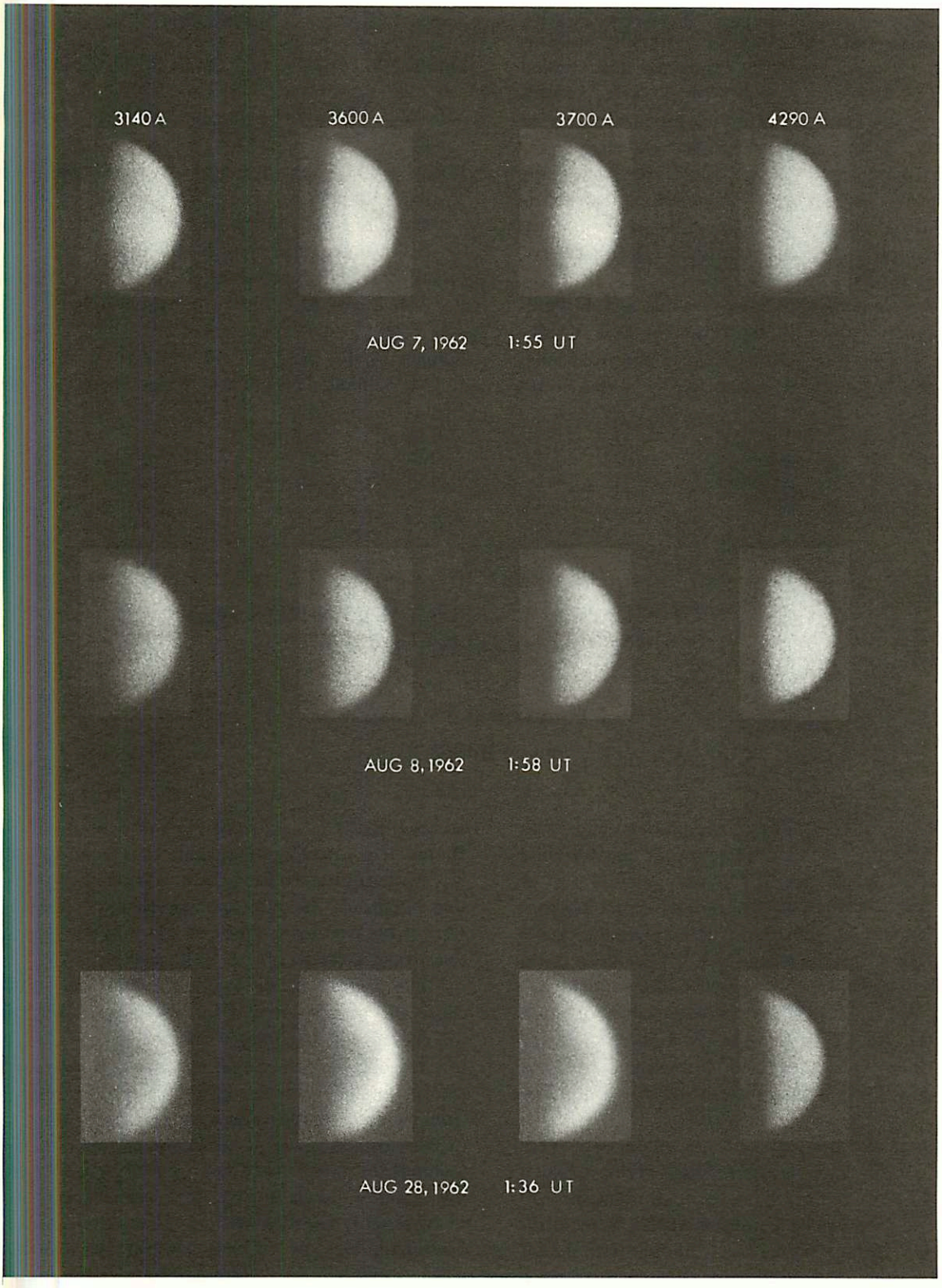


Fig. 1 Four-color photography of Venus on three dates. Passband wavelengths are given at the top. Each photograph is a composite of two or three images. No evidence was found for variation of structure markings with wavelength.

No anomalous markings were found with the 3140 Å filter, indicating that the variability in ultraviolet polarization (recently confirmed and studied in detail by Coffeen, to be published) is not accompanied by any changes in the apparent structure of the cloud markings observed at that wavelength.

The photographs of the 1962 program, being part of an international patrol effort, were forwarded to A. Dollfus and a number of them have been analyzed by him and published (Dollfus, 1964, 1965; Focas, 1967).

Acknowledgments. Thanks are due to S. F. Pellicori who constructed the filters, and to D. P. Cruikshank and T. Owen who assisted in the observing. Part of this program was supported by NASA Grant NsG 161-61.

REFERENCES

Dollfus, A. 1964 *Trans. I. A. U.* XIIB, Commis. 16, 200.

———. 1965 "The Planets," *Endeavour,* XXIV, 87.

Focas, J. H. "Contribution des Observations Effectuees depuis la Terre à l'exploration directe des Planetes," *Moon and Planets,* ed. A. Dollfus, (Amsterdam: North-Holland).

Gehrels, T. and Samuelson, R. E. 1961 "Polarization Phase Relations for Venus," *Ap. J.,* **134,** 1022.

Kuiper, G. P. 1957, *The Threshold of Space,* ed. M. Zelikoff, (New York: Pergamon).

PART III:
UV PHOTOGRAPHS OF VENUS TAKEN WITH THE 61-INCH NASA TELESCOPE, 1967

by J. FOUNTAIN AND S. LARSON

July 13, 1968

Ultraviolet photography of the planet Venus with the 61-inch NASA telescope at the Catalina Observatory was begun in January 1967 as part of the general Observatory program of direct photography of moon and planets. Several systematic efforts to photograph this planet in the UV have been made in the past 40 years, following the independent discoveries by Wright (1927) and Ross (1928) of cloud markings in the UV and the publication of an extensive, excellent series of UV photographs by Ross (1928). The present series is part of this continuing effort.

Most of the photographs presented here were taken at the F/45 Cassegrain focus of the 61-inch telescope (plate scale 3″/mm), diaphragmed to 50 inches. Light baffles were used near the focus to reduce stray light. Kodak spectroscopic 103-0 and III-0 emulsions were used most often with either a 1-mm Schott UG-11 or a 2-mm Schott UG-5 filter. The transmissions of these filters are shown in Figure 1. At times when the F/45 secondary was not accessible, the F/13.5 secondary was used with the Barlow lens to enlarge the image by a factor of about 3. This lens absorbs the shorter ultraviolet light and thus increases the effective wavelength. The films were processed to gammas of 1.0 to 3.0. Exposure times ranged from 1/4 to 1/30 second.

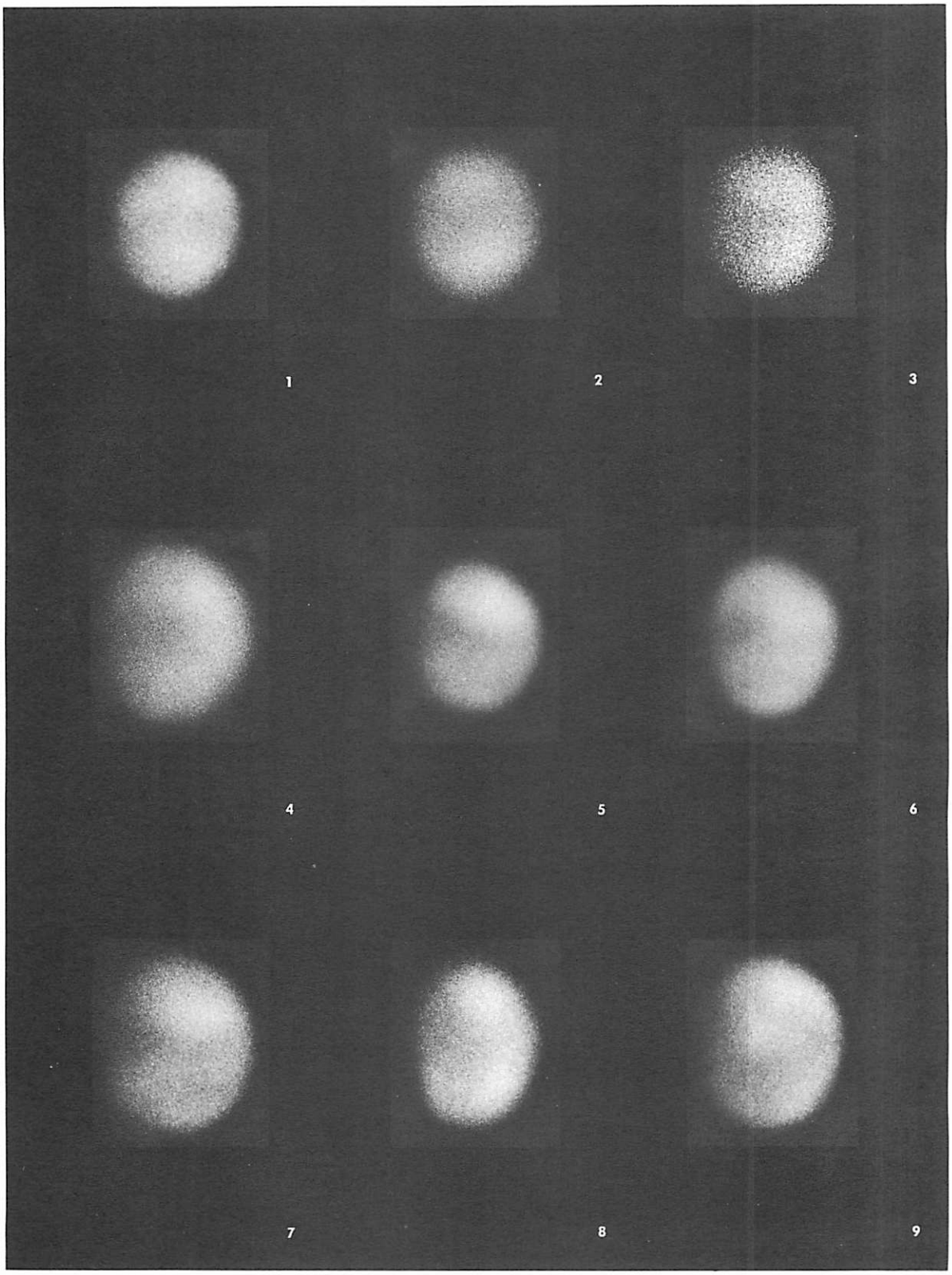
The contrast of the Venus clouds is low and because the photography is usually done in daylight, the contrast in the image will be even lower. For this reason, the contrast of the images has been increased in the reproductions and composites have been made to reduce the effects of plate grain and to increase the reliability of the cloud detail shown. Composites were made from every roll of Venus photographs taken during 1967 containing images of reasonably good resolution. This was done in the customary way by copying several images, taken within a short interval, with careful registration. The improvement of the composites arises from the averaging of densities in the grain distribution and, therefore, increases with the square root of the number of

TABLE 1

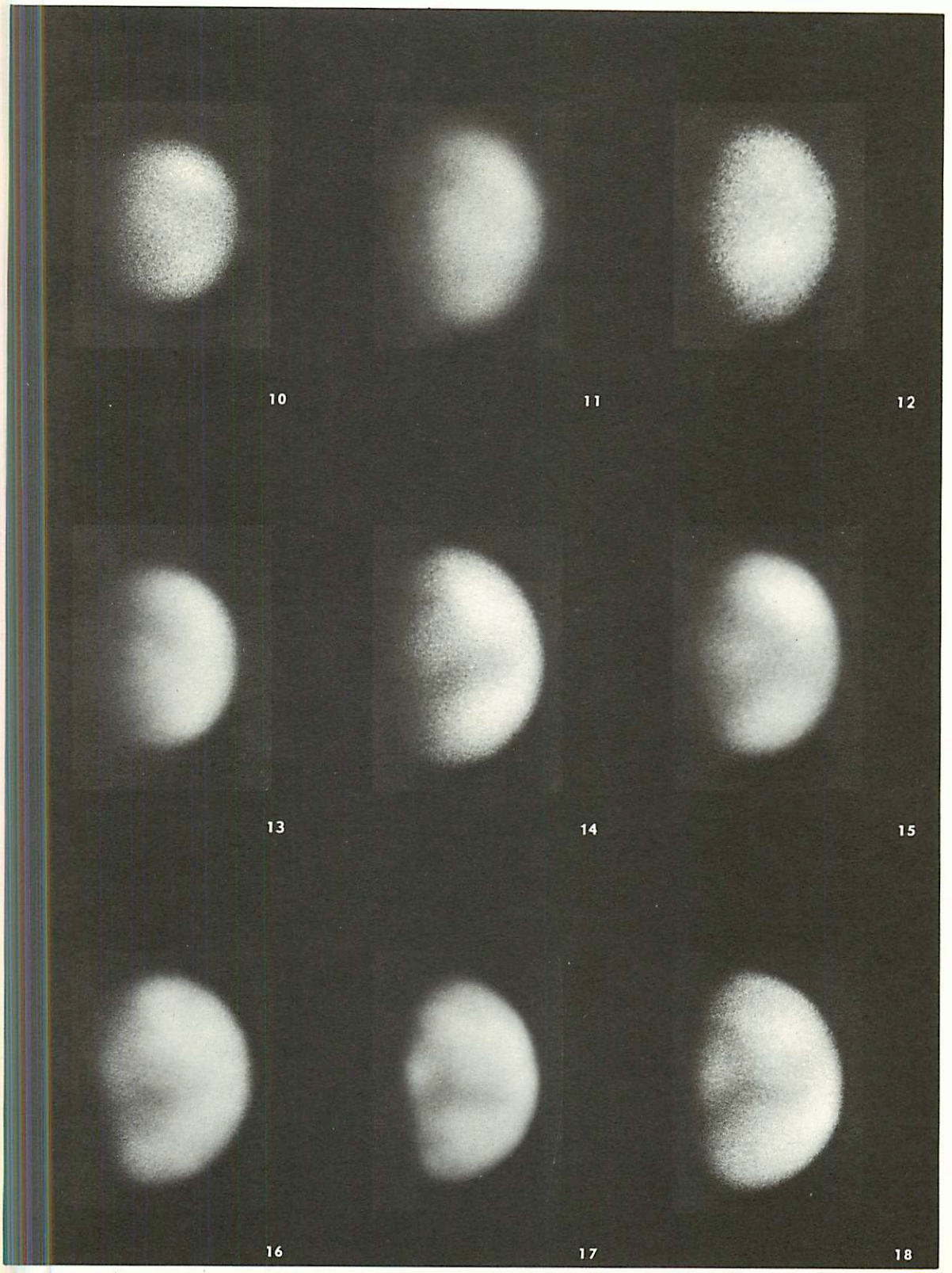
OBSERVATIONAL DATA ON CATALINA OBSERVATORY VENUS REPRODUCTIONS

No.	1967 Date	Mid. Exp. UT	Film	UG Filter	No. of Images	k
1	Jan 21	23:51.5	103-0	11	3	.96
2	Feb 18	00:55.9	103-0	11	4	.92
3	Feb 18	22:12.6	103-0	5	2	.92
4	Mar 14	21:47.8	103-0	5	5	.87
5	Mar 15	00:14.3	III-0	11, 5	24	.87
6	Mar 15	00:37.6	103-0	5, 11	11	.87
7	Mar 15	00:38.2	103-0	5 (11)	3	.81
8	Mar 16	23:47.3	III-0	5	4	.86
9	Mar 17	20:33.2	III-0	5	6	.85
10	Mar 17	20:47.3	103-0	5	7	.85
11	Mar 22	22:06.0	103-0	5 (11, No filt.)	12	.85
12	Mar 23	22:15.1	III-0	No filt. (11)	3	.85
13	Mar 24	00:04.1	III-0	11 (No filt.)	6	.84
14	Apr 25	23:40.6	103-0	5	25	.74
15	Apr 25	22:00.1	103-0	5	8	.74
16	Apr 26	00:09.6	103-0	5	11	.74
17	Apr 26	01:55.8	103-0	5	19	.74
18	Apr 26	02:11.0	III-0	5	1	.74
19	Apr 26	02:11.2	III-0	5	5	.74
20	Apr 26	02:10.1	III-0	5, 11	11	.74
21	Apr 26	23:46.0	III-0	5	6	.74
22	Apr 27	00:14.7	III-0	11, 5	12	.74
23	Apr 27	01:14.6	III-0	11, 5	4	.74
24	Apr 27	01:14.8	III-0	11, 5	12	.74
25	Apr 27	02:05.6	III-0	11, 5	13	.74
26	May 2	23:21.8	III-0	11, 5	11	.72
27	May 3	01:15.7	III-0	11, 5	10	.72
28	May 3	02:41.5	III-0	11, 5	14	.72
29	May 4	01:05.3	III-0	11, 5	13	.71
30	May 4	01:44.0	III-0	11, 5	15	.71
31	May 4	02:00.8	III-0	11, 5	16	.71
32	May 4	22:33.4	III-0	5	8	.71
33	May 5	00:52.6	III-0	5, 11	15	.71
34	May 5	01:42.3	III-0	5, 11	20	.71
35	May 9	23:02.1	III-0	5, 11	8	.69
36	May 10	00:04.8	III-0	5, 11	14	.69
37	May 11	00:49.7	III-0	5, 11	8	.68
38	May 11	01:52.6	III-0	11	5	.68
39	May 14	23:56.4	III-0	5, 11	14	.67
40	May 15	00:42.5	III-0	5 (11)	8	.67
41	May 15	23:01.7	III-0	5 (11)	10	.67
42	May 22	00:06.6	III-0	5	7	.64
43	May 22	00:14.5	III-0	11	11	.65
44	May 22	01:25.8	III-0	5, 11	17	.65
45	May 22	02:10.3	III-0	5, 11	13	.65
46	Jun 13	02:35.4	III-0	5	5	.54
47	Jun 21	02:07.0	103-0	11	10	.49
48	Jul 5	01:08.9	103-0	11	12	.40
49	Jul 11	01:44.7	103-0	11	9	.37
50	Jul 26	00:51.6	FGP*	5	1	.23
51	Oct 9	12:57.6	III-0	11	6	.28
52	Oct 10	13:29.7	III-0	11	20	.29
53	Oct 10	13:08.9	III-0	11	8	.29
54	Oct 11	12:54.6	III-0	11	10	.32
55	Oct 13	11:52.5	III-0	11	11	.35
56	Nov 8	13:34.3	III-0	11	2	.50
57	Nov 8	13:34.1	III-0	11	10	.50
58	Nov 9	13:25.2	III-0	5	12	.50
59	Nov 9	13:25.3	III-0	5	5	.50
60	Nov 10	13:41.1	III-0	5, 11	14	.51
61	Nov 10	17:11.6	III-0	11	10	.51
62	Nov 11	13:12.1	III-0	5, 11	6	.51
63	Nov 11	13:21.8	III-0	5, 11	9	.51

*Eastman Fine Grain Positive



Catalina Observatory Photographs of Venus (cf. Table 1).



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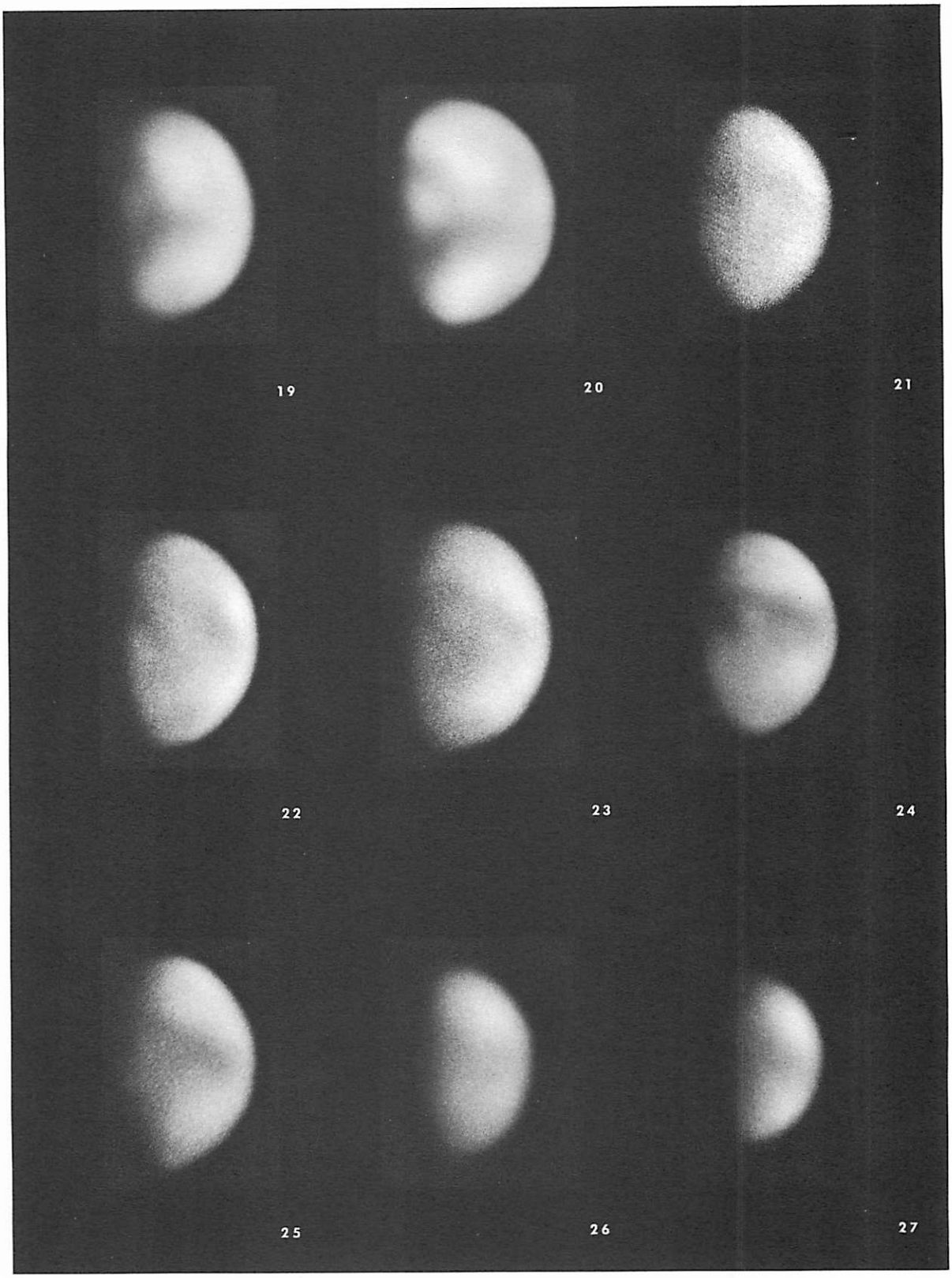

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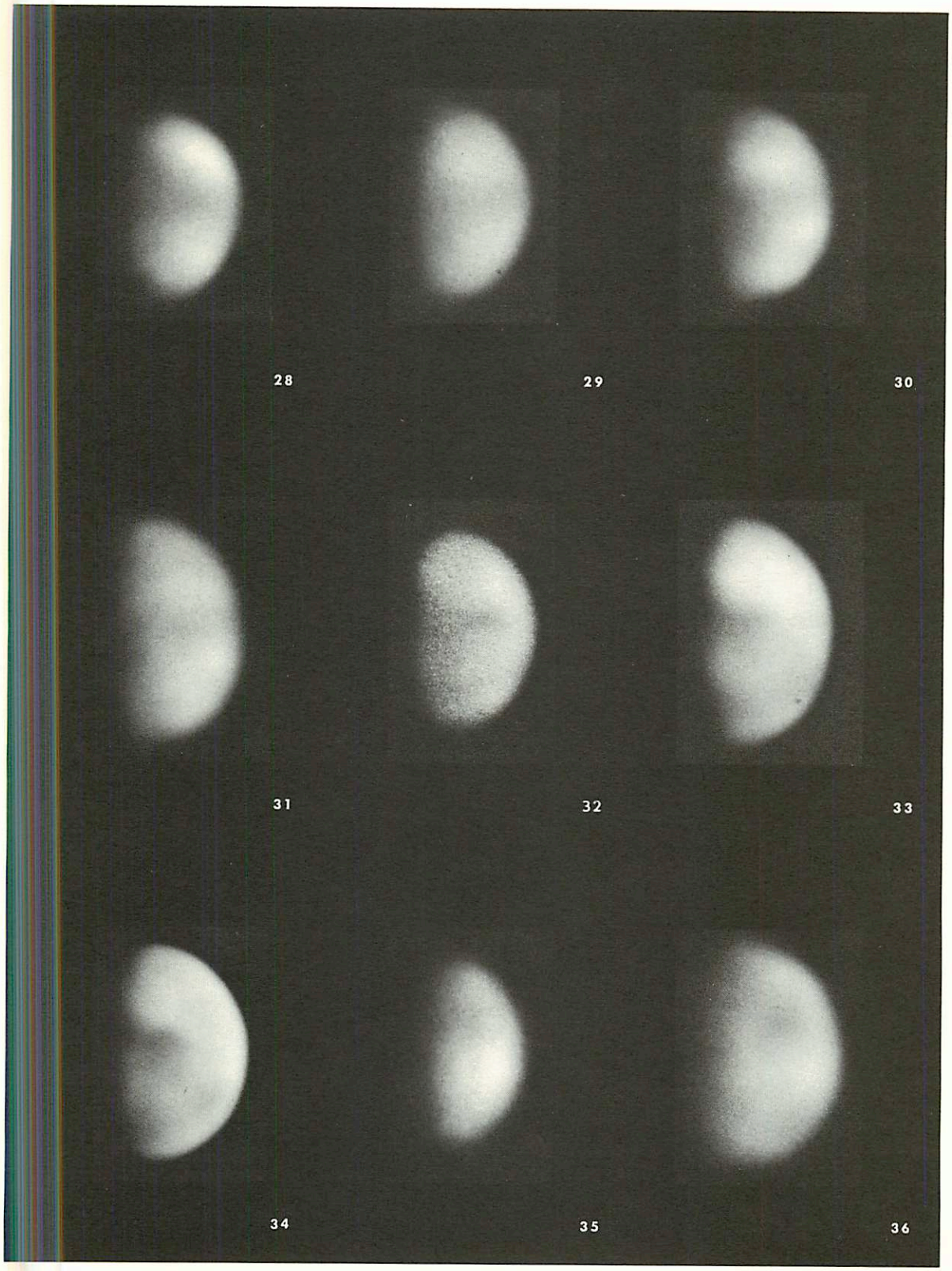
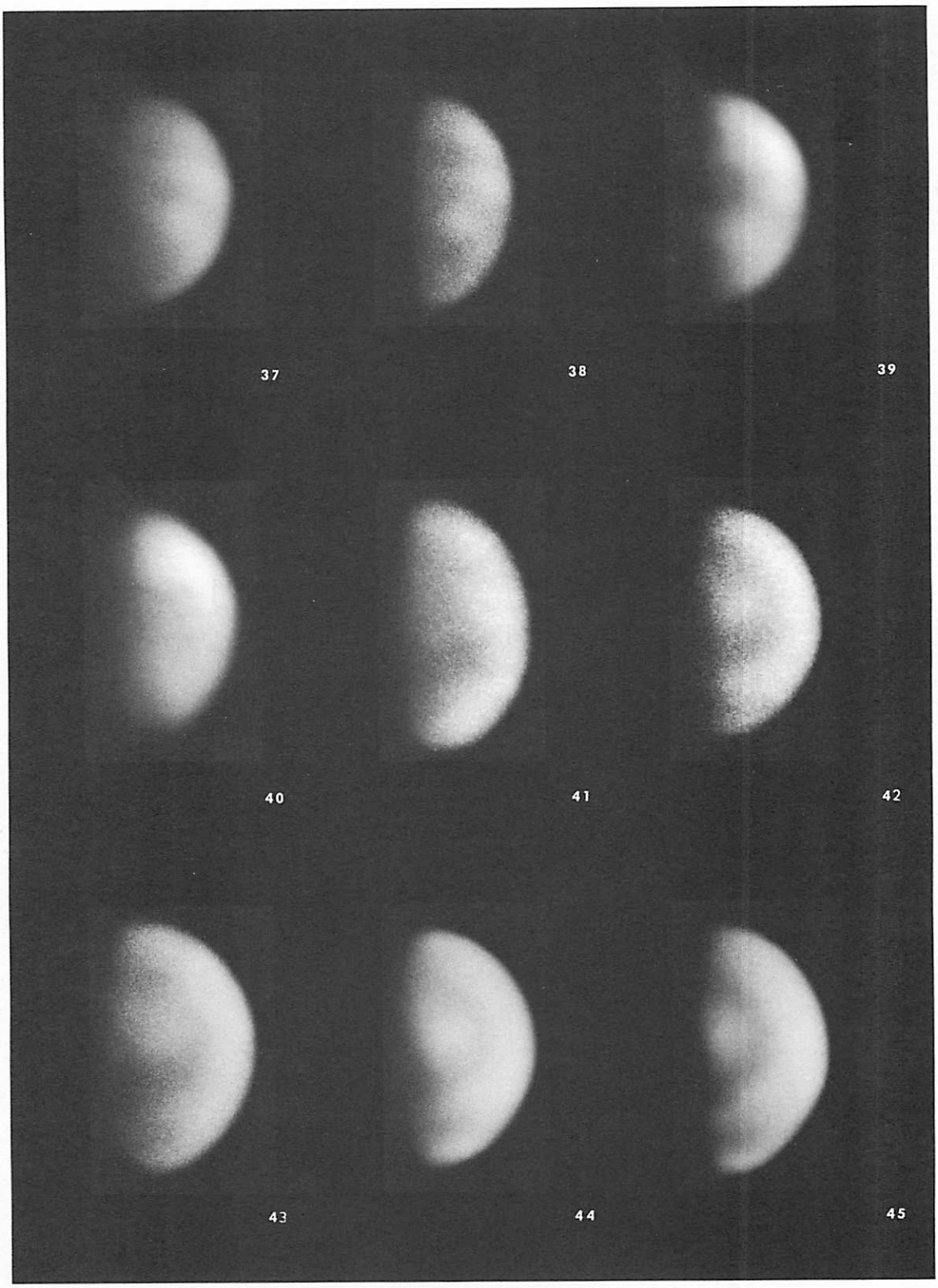


Catalina Observatory Photographs of Venus (cf. Table 1).



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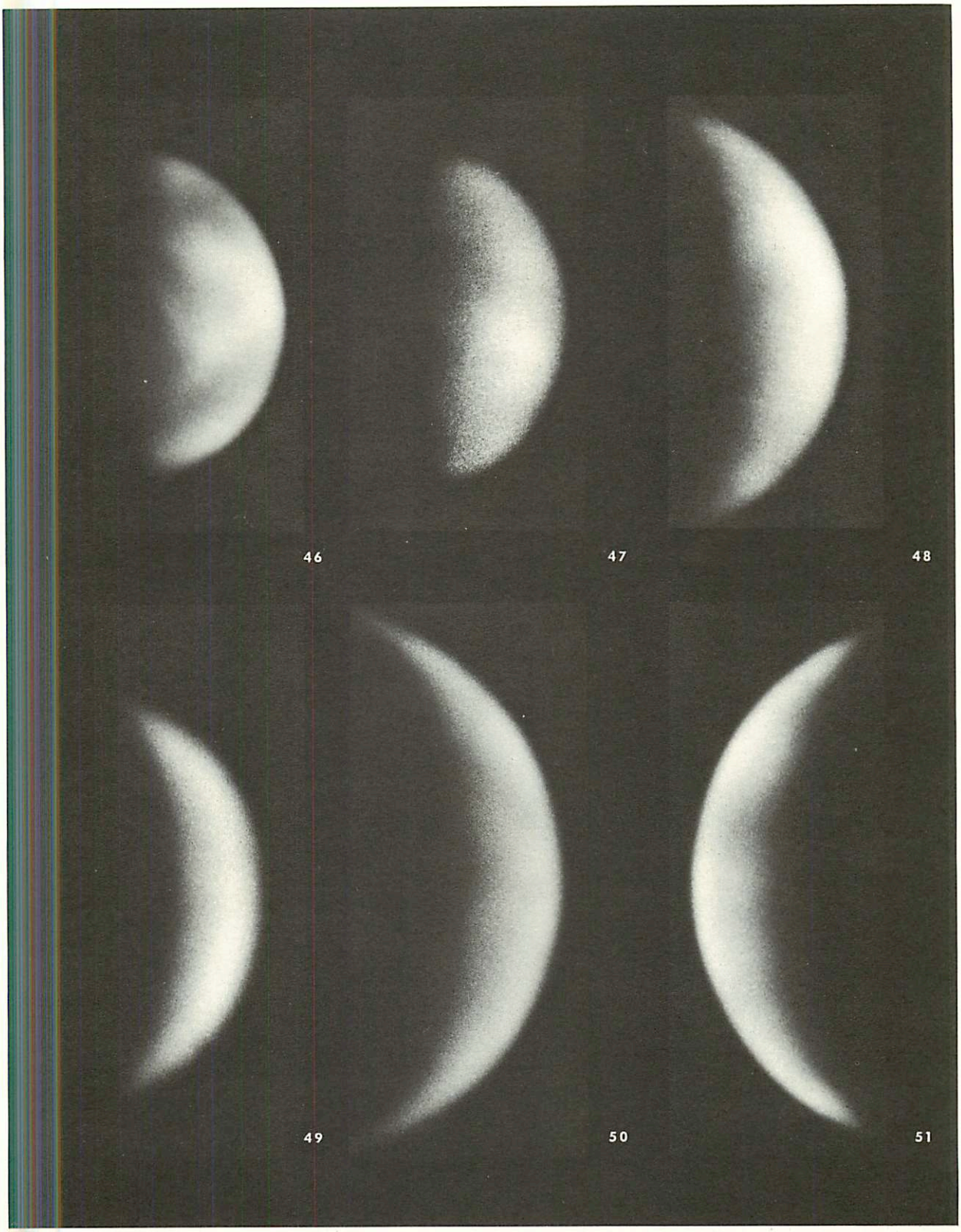
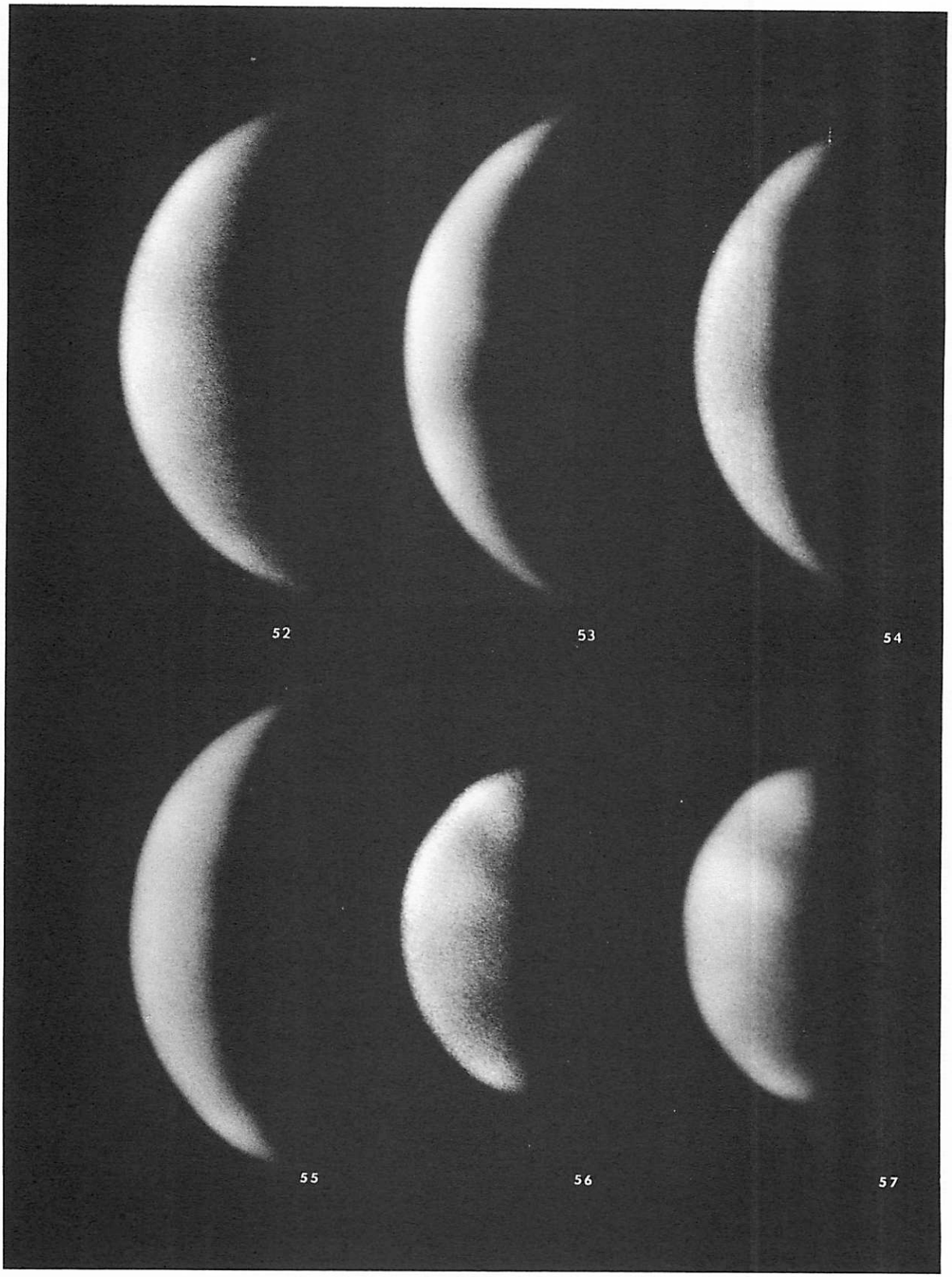
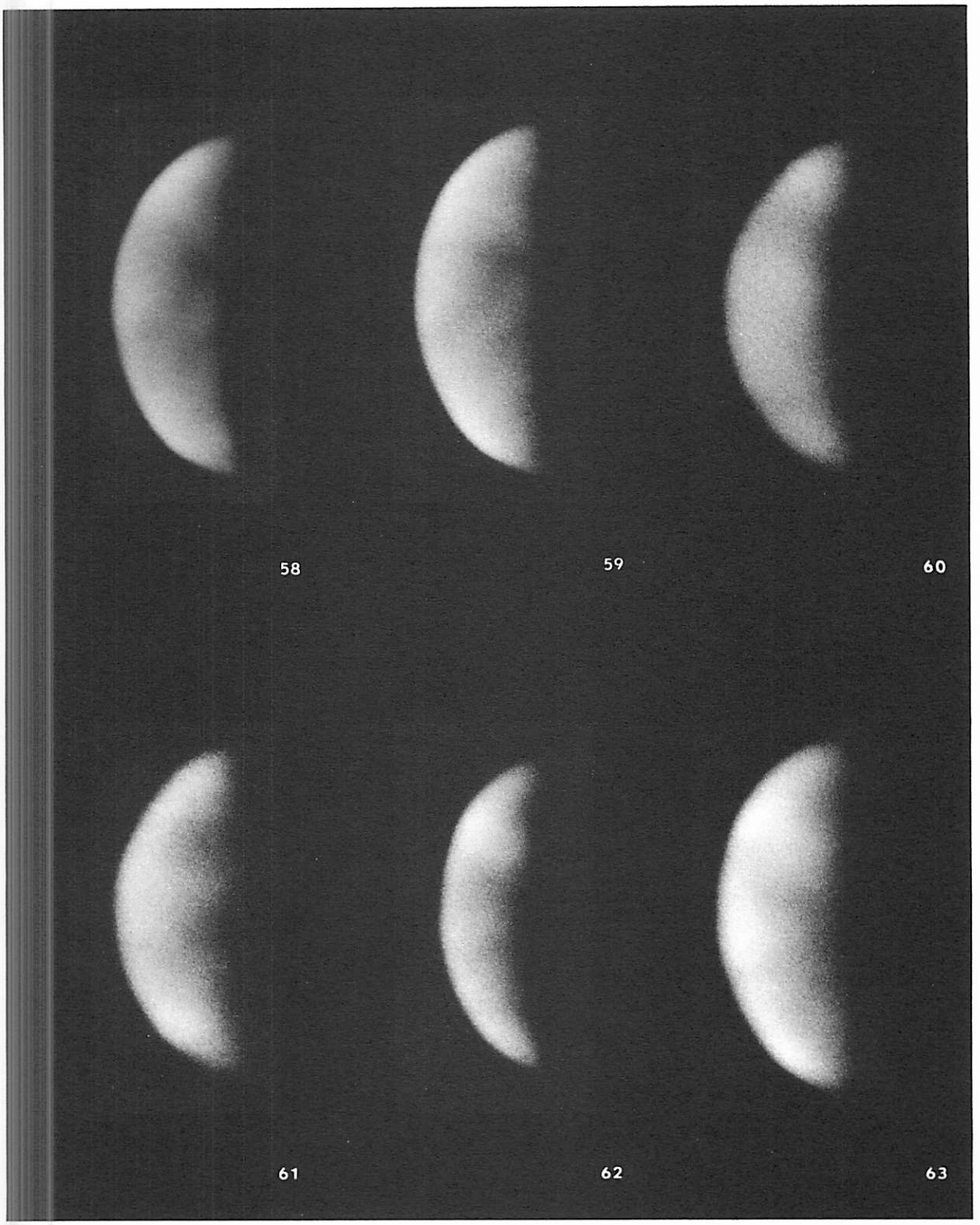


Catalina Observatory Photographs of Venus (cf. Table 1).



Catalina Observatory Photographs of Venus (cf. Table 1).



Catalina Observatory Photographs of Venus (cf. Table 1).

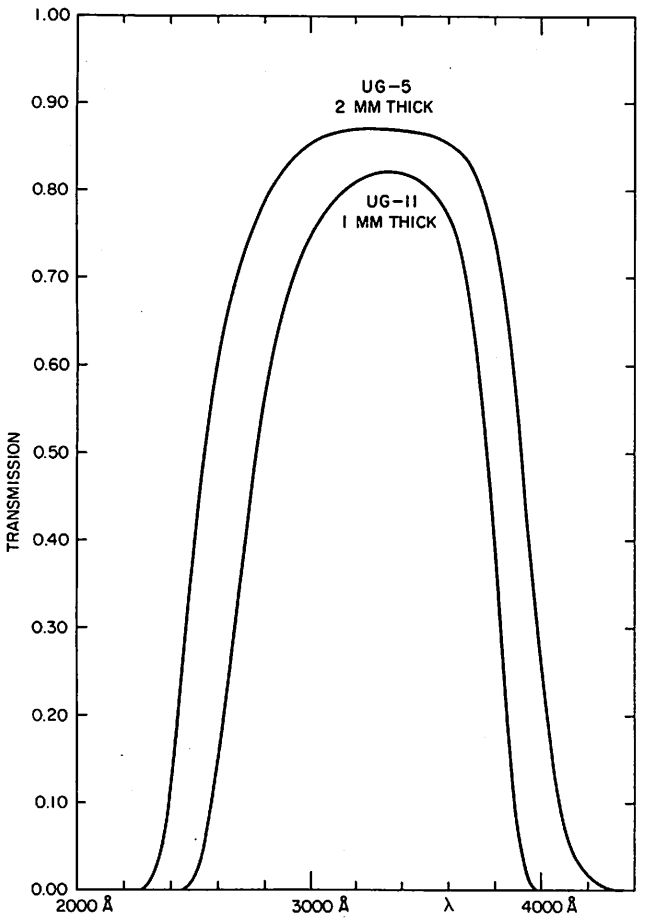


Fig. 1

originals used. This allows recognition of low-contrast clouds difficult to detect on the originals. However, the use of many images may slightly degrade the angular resolution.

Upon completion of the composite positive copies, over 60 in number, undodged negatives were made. In copying these in turn on paper, the intensity gradients toward the terminator were reduced through manual dodging. Therefore, on the positive prints, photometric comparisons of features, normal to the terminator, cannot be made directly. Dust-specks and minor filter marks have been retouched in the prints. Finally, each print was critically compared with the corresponding positive film composite to ensure that all detail was accurately represented. The prints are reproduced at a scale of about 2.5 mm per arc second.

Table 1 lists for each print the identification number, the date and time (U.T.), the number of images combined in the composite, and the fraction k of the disk illuminated. The following special cases are noted. Frame 7 contains the best 3 images used in the composite No. 6. Similarly, 18 and 19 contain the best 1 and 5 of 20; 23 contains the best 4 of 24; 56 contains the best 3 of 57; 59 contains the best 5 of 58. No. 15 precedes in time No. 14 and No. 53 precedes No. 52, as given in the Table.

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REFERENCES

Ross, F. E. 1928 "Photographs of Venus" (Contri. of Mt. Wilson, No. 363) *Ap. J.*, 68, 57–92.

Wright, W. H. 1927 "Photographs of Venus Made by Infrared and by Violet Light", *Pub. A.S.P.*, 39, 220–221.