NO. 175 NARROW-BAND PHOTOGRAPHY OF JUPITER AND SATURN

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ABSTRACT

Jupiter and Saturn were photographed with narrow-bandwidth interference filters ($\lambda/\Delta\lambda \sim 30$) from 3000 to 9200Å and in the 1-2μ region with an infrared-sensitive vidicon. Changes with wavelength are noted in the limb darkening and surface detail.

Photography of Jupiter and Saturn through wide-bandwidth filters (~1000Å) has been pursued with the 61-inch Catalina reflector for the past six years with gratifying results. The occasional use of narrower-bandwidth filters has sometimes yielded interesting features which remain unnoticed through broader filters. Three sets of wheel-mounted interference filters (14 per wheel) used for a 42-filter photometer were adapted for direct photography of the planets.

1. The Photography

The filters have effective wavelengths spacings of 100Å from 3000 to 4000Å, with bandwidths also of 100Å; from 4200 to 8000Å the spacing is 200Å and the bandwidth 200Å; while longward of 8000Å the spacing is 300Å and bandwidth 300Å. Not all of the filters were used since those with transmission above 9200Å would have required the use of an infrared emulsion with too-low sensitivity. The emulsions used are: Kodak Spectroscopic III-0 for ultraviolet and blue light; Kodak High Contrast Copy, Type 5069, for visual light; and Kodak High Speed Infrared, Type 2481, for the infrared. The films were developed to gammas of approximately 3.5, 3.6, and 1.6, respectively.

Enlarged positive copies of the originals were made, composited with other frames whenever practical. Printing negatives were prepared from these positives and processed to a gamma which approximately equalized their effective contrast. No attempt was made to correct for the variation in film gamma with wavelength. Contact prints were made on the same contrast-grade paper, with no dodging or shading applied, and processed identically. The images are reproduced here, North up, at a constant scale of about 1.0 arc sec per mm.

The filters, described by W. Wamsteker in *LPL Communication No. 167*, have a clear aperture of 12mm and could conveniently be mounted in a filter-wheel assembly which placed the film plane about 75mm from the filter. Although the image diameter of Jupiter on the film was only 4.2mm, the beam at the filter was 9.8mm, and required precise centering in the 12mm filter. For some frames a slight decentering has caused some vignetting: on the North limb of the Jupiter images 10-12, and on some images of the Rings of Saturn. In addition, variations in the thicknesses of the filters caused small displacements of the focal plane which could not easily be corrected, especially at the extreme wavelengths, so that some images are slightly out of focus. (The assembly is currently being modified and improved filters are being selected).

2. Infrared Vidicon Imagery

In order to record Jupiter and Saturn at still longer wavelengths, a Hamamatsu TV-Type 156/157 IR Vidicon was used. A Schott RG-1000 filter cut out wavelengths shortward of 1μ, making the response of the system nearly constant from 1.0 to 2.1μ and near zero elsewhere. The sensitivity of the vidicon was not completely constant over the field, which was detected by shifting the image between exposures. The TV imaging system introduced geometric distortion causing the planet image to appear stretched. It was not practical to calibrate the picture intensities so that the contrast is somewhat uncertain.

3. Jupiter

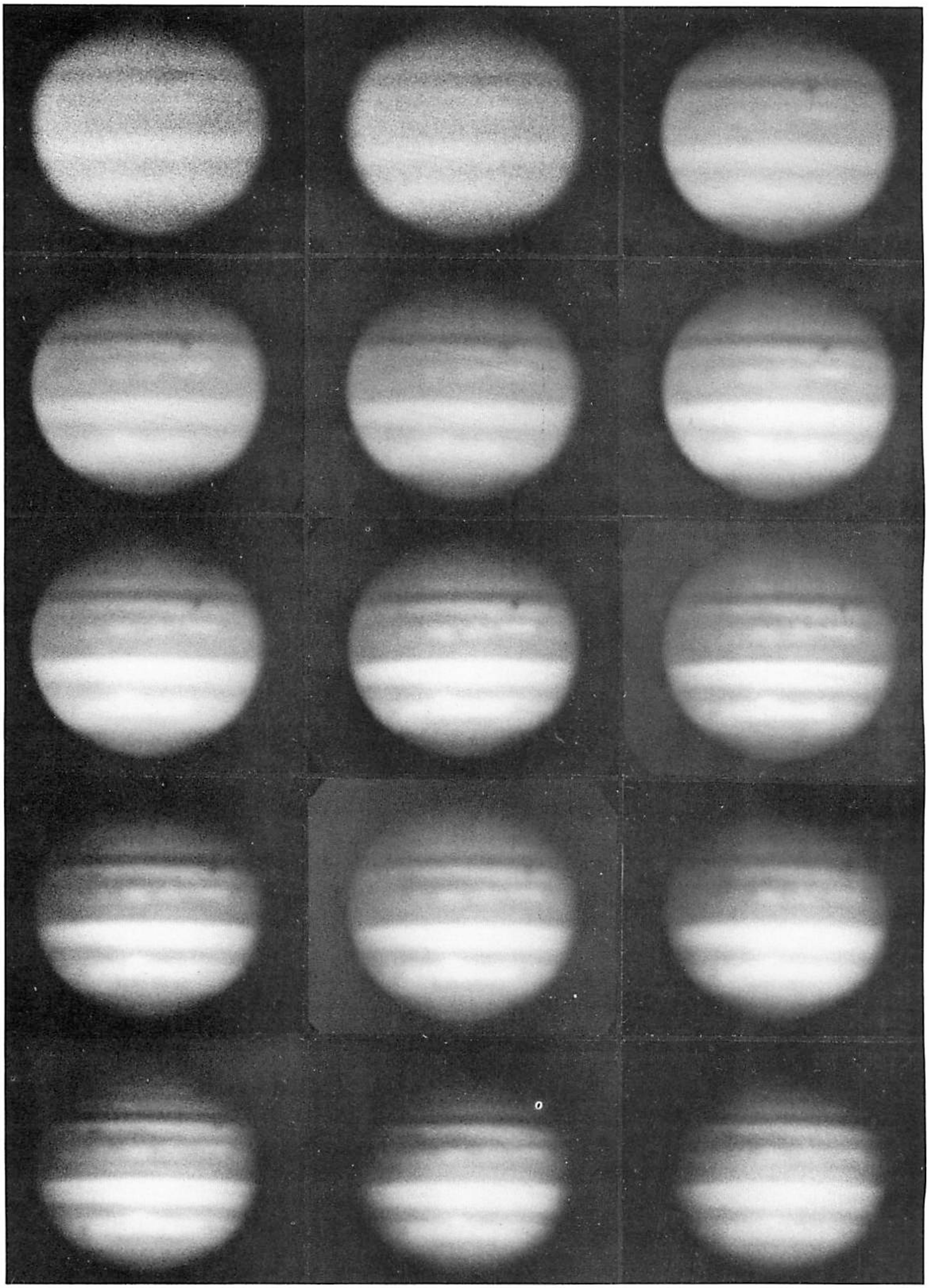
Two nights were required to record the planet with all the filters. The results here presented are considered preliminary because of the low declination of the planet, 20°S. The rapid rotation of the planet resulted in noticeable displacement of features from frame to frame. It is therefore not possible from our data to compare features at a particular longitude for all wavelengths. However, the change with wavelength in the general appearance may be seen, since aside from the persistent spots and equatorial fine structure, the planet on these dates had a rather similar appearance at all longitudes. Data for the Jupiter photographs are found in Table I. Two prints are included of the 3000Å image, the second one printed precisely as all following images; the first print with slightly enhanced contrast.

TABLE I

Jupiter Photographs

Frame	Date 1971	Time UT	Film	Å	No. images	Exp. Sec.	CM λ(I)	CM λ(II)
1	Apr 7	11:23:02	III-0	3000	1	330	74°.9	216°.0
2	"	11:23:02	III-0	3000	1	330	74.9	216.0
3	"	11:32:48	III-0	3090	3	60	80.9	221.9
4	"	11:36:13	III-0	3200	5	20	82.9	223.9
5	"	11:38:41	III-0	3325	5	15	84.5	225.5
6	"	11:41:09	III-0	3420	5	15	86.0	227.0
7	"	11:43:06	III-0	3530	6	7	87.2	228.2
8	"	11:44:33	III-0	3625	5	7	88.0	229.0
9	"	11:50:45	III-0	3720	4	5	91.9	232.8
10	"	11:51:41	III-0	3800	5	3	92.4	233.3
11	"	11:52:31	III-0	3940	5	2	92.9	233.8
12	"	11:53:31	III-0	4000	5	1.5	93.5	234.4
13	"	11:54:30	III-0	4260	5	1	94.1	235.0
14	"	11:54:59	III-0	4440	5	1	94.4	235.3
15	"	11:55:39	III-0	4600	3	1.5	94.8	235.7
16	"	10:27:27	HCC	5000	1	25	41.1	182.4
17	"	10:29:40	HCC	5200	1	6	42.4	183.8
18	"	10:31:35	HCC	5400	1	7	43.6	185.0
19	"	10:33:19	HCC	5600	1	7	44.6	186.0
20	"	10:46:27	HSIR	5800	4	1.5	52.7	193.9
21	"	10:47:13	HSIR	6060	5	1	53.1	194.3
22	"	10:47:51	HSIR	6200	5	1.5	53.5	194.7
23	"	10:48:55	HSIR	6400	5	1.5	54.2	195.4
24	"	10:49:47	HSIR	6620	5	1.5	54.7	195.9
25	"	10:50:30	HSIR	6775	5	1.5	55.1	196.3
26	Apr 7	9:40:34	HSIR	8964	3	90	12.4	154.0
27	Apr 8	9:28:39	HSIR	7000	1	1.5	163.2	250.6
28	"	9:13:44	HSIR	7200	5	2	154.1	288.2
29	"	9:13:01	HSIR	7400	4	2	153.7	287.8
30	"	9:04:22	HSIR	7600	3	2	148.4	282.6
31	"	9:03:24	HSIR	7800	2	1	147.8	282.0
32	"	9:03:00	HSIR	8000	3	1	147.6	281.8
33	"	9:02:30	HSIR	8300	3	1	147.3	281.5
34	"	9:01:48	HSIR	8600	3	2	147.0	281.1
35	"	9:00:32	HSIR	8900	5	8	146.0	280.3
36	Apr 8	8:56:14	HSIR	9200	2	120	143.4	277.6
37	Jan 21	3:06:00	IR Vidicon	1-2μ	8	1/4	10.7	14.4

It is seen that there are no major changes for λ<4600Å. From 4600 to 5000Å the change is rapid, with festoons and other fine structure becoming prominent. From 6000 to 9200Å, again little change is seen with the exception of the 8900Å frame which includes a strong methane band. The planet was also photographed through a filter with effective wavelength 8964Å, bandwidth 190Å, which has a transmission more nearly corresponding to the methane band and is less contaminated by the continuum (see *LPL Comm. No. 174*).



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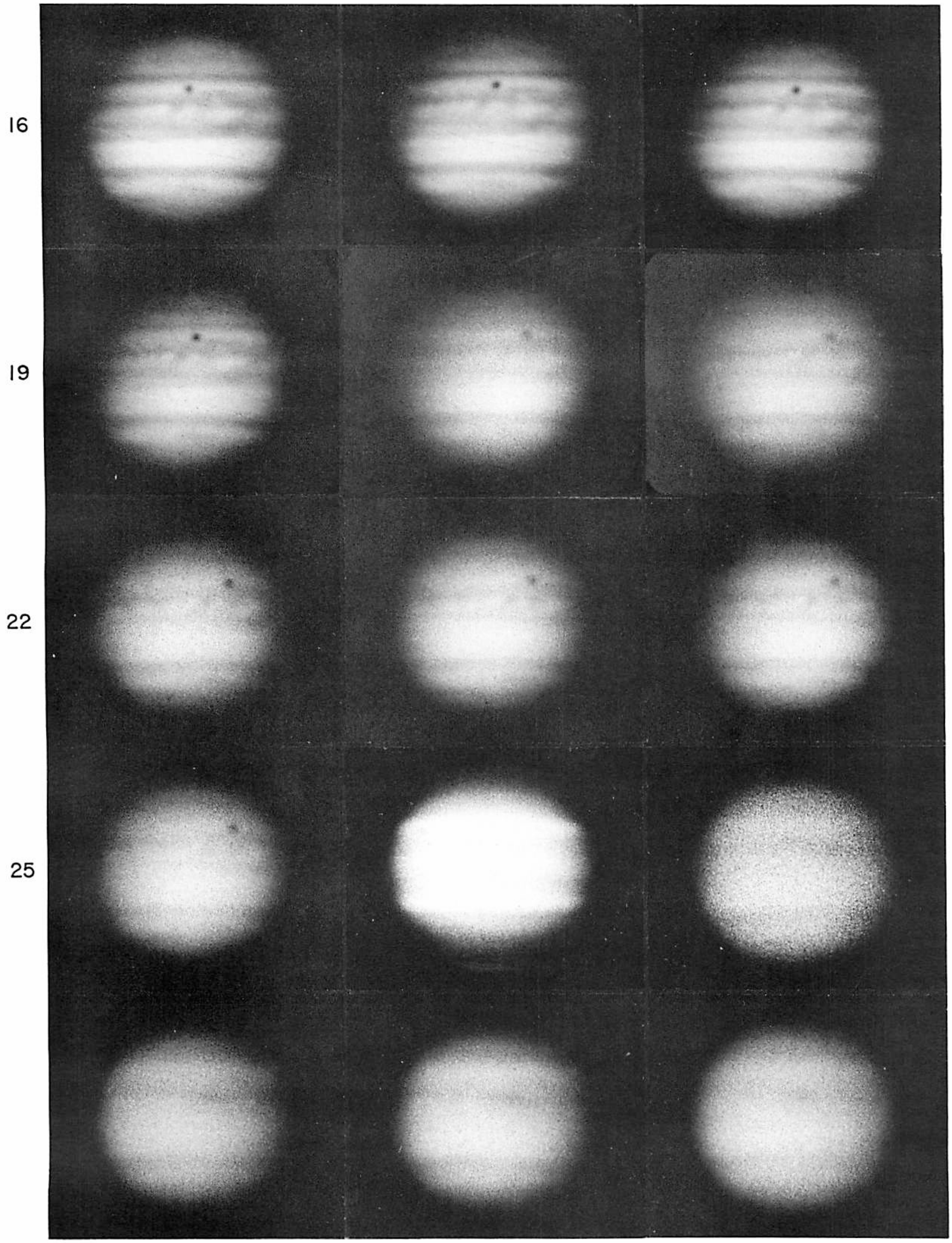
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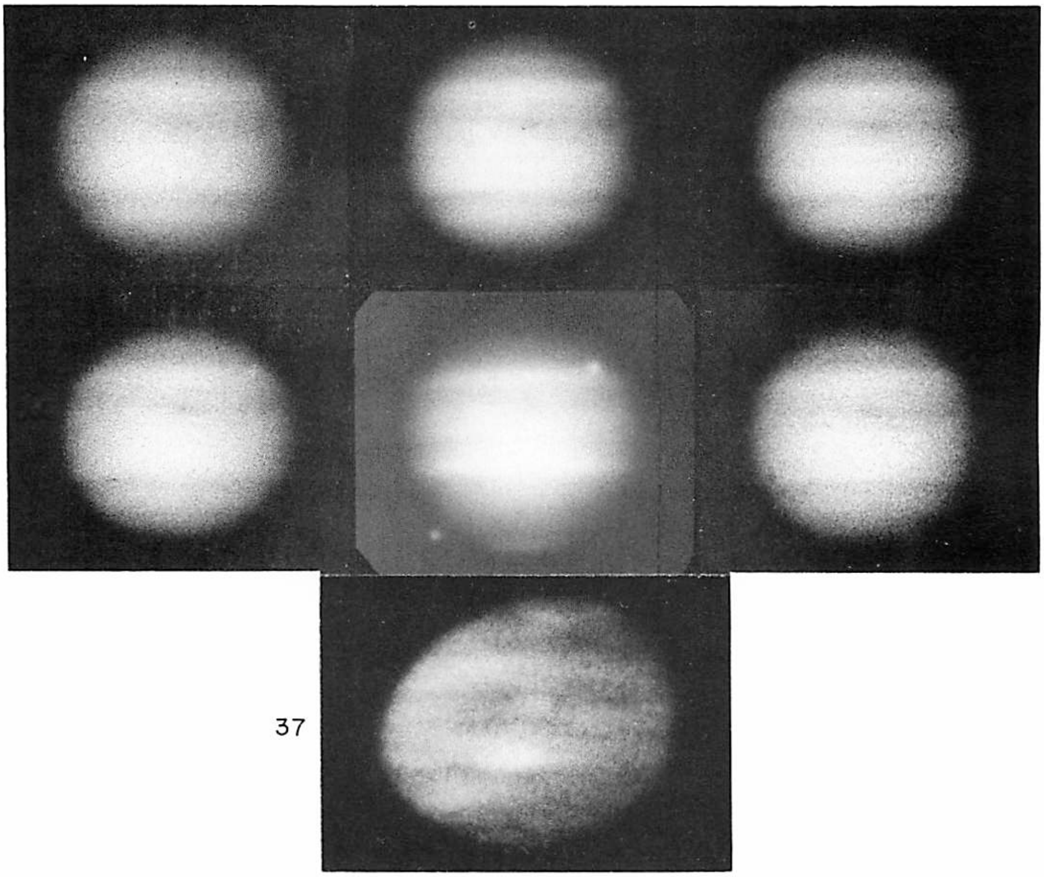

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On the images taken at 3000-3300A a *hood is seen over the South Pole* which is somewhat lighter than the rest of the dark South Polar Region (SPR)*. The North Polar Region (NPR) is darker than the SPR and only a slight hint of a corresponding hood is seen there. The South Temperate Belt (STeB), flanked by the bright South Temperate Zone (STeZ) and the South Tropical Zone (STrZ), is clearly seen. From the South edge of the North component of the South Equatorial Belt (SEBn) to the North Temperate Belt (NTeB) there is an almost uniform appearance except for light features near the equator. *Slight limb brightening* from Rayleigh scattering is seen, especially along the bright (East) limb. The North Equatorial Belt (NEB) is dark. From 3400 to 4000Å the brightness of the STeZ and the STrZ increases, and the visibility of the Polar hood and limb brightening decreases. *Limb darkening* is seen in the dark regions for $\lambda > 3600$Å.

The contrast between belts and zones diminishes somewhat from 4200 to 4600Å, and limb darkening becomes strong. The North Tropical Zone (NTrZ) and the Equatorial Zone (EZ) become somewhat lighter. From 4800 to 5600Å the NTeB lightens

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* The nomenclature used here is explained on p. 352.

with respect to the STeB. Festoons and fine structure are seen in the EZ. The STeB,SEBn, and the NEB all have approximately the same brightness. From 5800 to 8600Å there is no substantial change in the appearance of the planet. The 7200Å image appears unaffected by the 7250Å methane band which does affect the Saturn image.

The 8900Å filter includes the strong methane absorption band, so the image is strongly influenced by the variation in the methane absorption over the planet. Strong limb darkening is seen in the belts. The NTeZ, EZ, and STrZ are very bright. The South Polar hood is much brighter than the adjacent SPR and extends to about the same latitude, -68°, as the Polar hood seen around 3000Å. A weaker hood is just visible at the North Pole. The negative planetocentric declination of the Earth may be responsible for the southern hood appearing stronger than the northern one. This hood has been interpreted as a haze of moderate density (Owen, 1969), since weak bands show little variation over the disk (Münch and Younkin, 1964). Polarization data (Gehrels *et al*, 1969) and the bright hoods in the deep ultraviolet also indicate conditions at the Jovian poles different from the remainder of the planet. The 9200Å image appears much the same as the 8600Å image, so that the singular appearance of the planet at 8900Å can safely be attributed to the methane distribution above the clouds. The belts tend to appear dark and the zones light on the methane image, but not in the same proportion as the visual image. Interestingly, the relation to the visual brightness is opposite for the Saturn belts and zones (p. 337).

The 1.0-2.1μ TV image shows characteristics of both the normal infrared and methane images. This region has strong ammonia and methane absorptions as well as islands that approach the continuum. A hint of the South Polar hood is visible and the STeB,NEB, and NTeB are dark. The centrally-placed Red Spot is the brightest feature on the planet. Because of inadequate sensitivity of the detector, it was not possible to image separately the spectral ranges corresponding to the ammonia, methane, and continuum, so this image is a composite of all of these and is not uniquely informative about any.

4. Saturn

Color differences on Saturn are far less apparent than on Jupiter; however, certain colors can be reliably observed with a large telescope. The color of the South Polar Region (SPR)* may vary from blue-green to grey; the Equatorial Zone (EZ) is often a deeper yellow than the South Temperate Zone (STZ), and the Rings appear a paler yellow than the ball; but since the greatest change in the appearance of the planet is from the blue to the ultraviolet, the most striking color differences escape visual detection.

Data for the Saturn images are found in Table II. The photographs taken from 3000 to 3200Å show the EZ dark, with the Equatorial Band (EB) somewhat lighter. The STZ is bright and the SPR is dark. *Limb brightening* is seen except within the SPR. From 3300 to 3500Å the EB fades, the contrast between the STZ and the SPR increases, and the South Temperate Belt (STB) and South South Temperate Belt (SSTB) become visible because of improved resolution. The contrast between the

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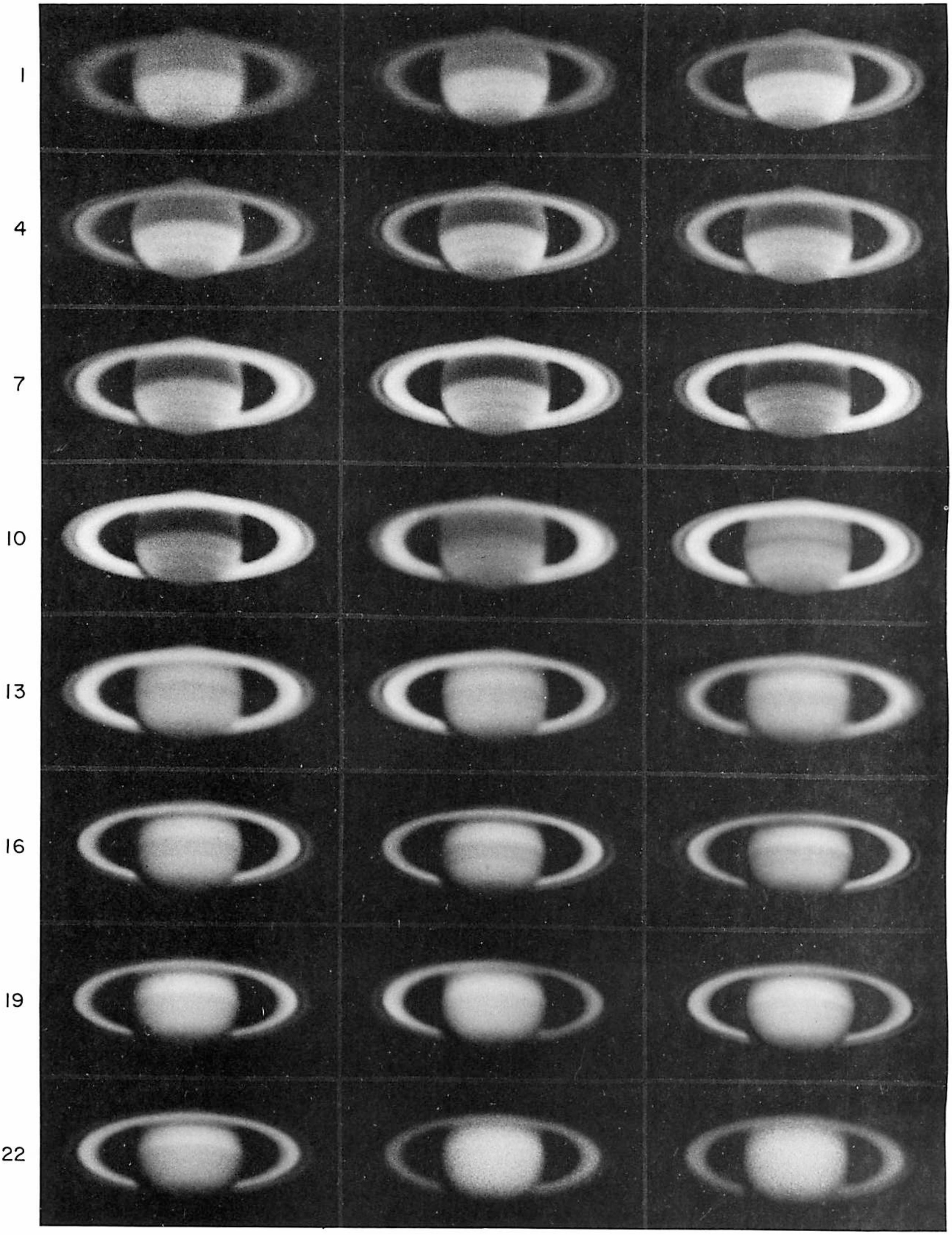
* The system of nomenclature used here follows that of Alexander (1962).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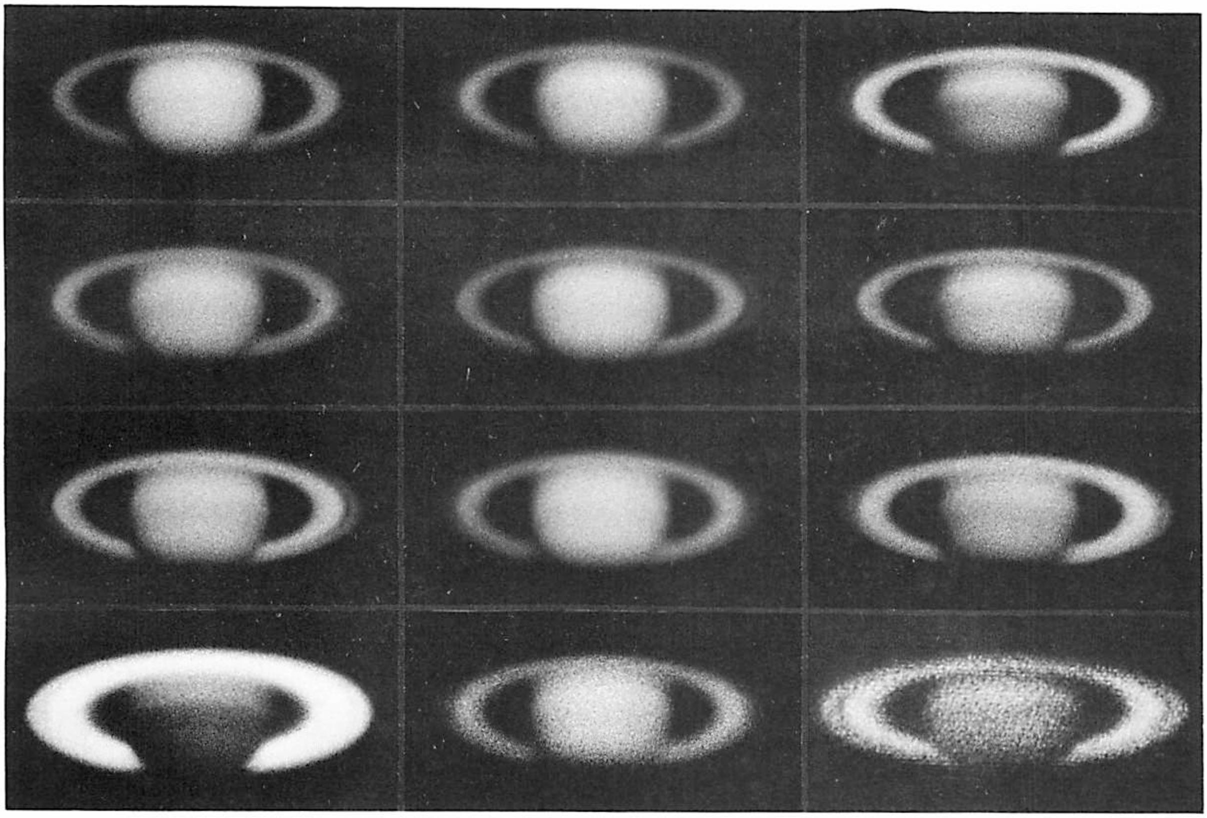

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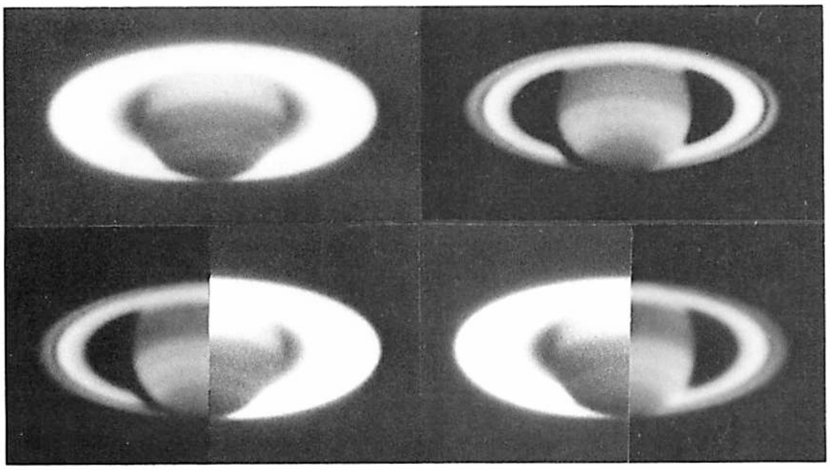

TABLE II

Saturn Photographs

Frame	Date	Time UT	Film	Å	No. images	Exp. Sec.
1	Dec 14 1970	5:04:30	III-0	3000	2	300
2	"	4:56:20	III-0	3090	5	60
3	"	4:48:13	III-0	3200	5	30
4	"	4:45:05	III-0	3325	5	30
5	"	4:42:02	III-0	3420	5	28
6	"	4:38:55	III-0	3530	5	20
7	"	4:36:52	III-0	3625	5	15
8	"	4:35:02	III-0	3720	5	15
9	"	4:32:09	III-0	3800	5	8
10	"	4:29:09	III-0	3940	5	8
11	"	5:25:30	HCC	4000	1	130
12	"	5:29:27	HCC	4260	1	45
13	"	5:31:19	HCC	4440	1	45
14	"	5:33:04	HCC	4600	1	45
15	"	3:52:40	HCC	4810	1	60
16	"	3:54:22	HCC	5000	1	45
17	"	3:57:55	HCC	5200	1	12
18	"	4:00:40	HCC	5400	1	20
19	"	4:02:07	HCC	5600	1	15
20	"	4:03:27	HCC	5800	1	15
21	"	4:05:36	HCC	6060	1	12
22	"	4:08:40	HCC	6200	1	60
23	"	6:08:13	HSIR	6400	5	4
24	"	6:09:29	HSIR	6620	5	4
25	"	6:10:20	HSIR	6775	5	3
26	"	6:17:14	HSIR	7000	5	3
27	"	6:25:31	HSIR	7200	5	4
28	"	6:26:12	HSIR	7400	5	4
29	"	6:27:04	HSIR	7600	5	3
30	"	6:27:43	HSIR	7800	5	3
31	"	6:30:52	HSIR	8000	4	2.5
32	"	6:34:17	HSIR	8300	5	2
33	"	6:34:58	HSIR	8600	5	4
34	"	6:35:57	HSIR	8900	2	24
35	"	6:42:52	HSIR	9200	2	240
36	Oct 21	6:48:00	Plus X	10,000-21,000	5	0.25
37	Jan 25 1972	2:51:44	HSIR	8964	12	90
38	"	3:31:24	103-0	4000	8	1

SPR and the lighter STZ diminishes between 3600 and 3900Å; and at 4000Å the EZ begins to lighten, especially at the North end, and the limb brightening diminishes. At 4200Å the EZ has lightened to equality with the STZ except for the extreme South edge which remains dark. Neither limb brightening nor darkening is apparent here. Slight *limb darkening* is seen at 4400Å and the North part of the STZ darkens, while the South part gets lighter. Between 4600 and 5200Å the North part of the STZ forms a dark band consisting of two dark components separated by a lighter one; further, the EZ brightens, and the ball and the Rings achieve approximate equality of brightness. From 5400 to 5600Å the SPR becomes darker and limb darkening increases. The two dark components of the SEB become brighter, and from 5800 to 6200Å they continue to brighten until they blend with the light zone separating them, making the region between the SPR and the EZ fairly uniform in brightness. Limb darkening increases and the SPR is seen to be divided into an outer, lighter ring and the darker polar cap. At 7200Å the EZ is very bright and the SEB is noticeably darker than the STZ. This is probably due to the 7250Å band of methane which lies within the bandpass of the filter. In the 7400 to 8600Å region the SEB appears about the same brightness as the STZ.

In the 8900Å image, which includes the strong methane band, the EZ is bright and the rest of the planet quite dark, especially the SPR which is the darkest part of the disk. Considerable limb darkening is seen overall. Frames 37 and 38 show recent 8964Å methane and UV images taken by S. M. Larson; Frames 39 and 40 show the match of the two. The methane picture is undodged. The STB, the SSTB, and the northern edge of the SPR, as well as the prominent EZ, are light in the methane image and dark at 4000Å, though the polar cap is dark on both. Hence, the EZ reaches high altitude while the polar cap contains no high layer of condensed material. Also, the STB, SSTB, and the North edge of the SPR may be rather higher than other regions on the planet. Polar haze, present on Jupiter, is absent on Saturn. The Saturn Rings are, of course, very bright in this image. At 9200Å the appearance of the planet is similar to the 8600Å image, so no important color change takes place around the methane band. The Saturn image taken with the infrared vidicon in the 1-2μ region is similar in appearance to the 8600Å image, with strong limb darkening, bright EZ, somewhat darker STZ, and dark SPR.

5. The Rings of Saturn

There is nothing in the images taken to indicate a change with wavelength in the appearance of the Rings. Differences among these images may all be attributed to vignetting by the small filters.

Acknowledgments: I wish to thank Dr. Kuiper for providing the interference filters and the infrared vidicon, and for guidance in the observations with the vidicon. The Jupiter composites were prepared by J. Barrett; and the Saturn composites, by R. B. Minton. S. M. Larson, J. Barrett, and R. B. Minton participated in some of the observations. The work of this project is supported by NASA Grant NGL-03-002-002.

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