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MEASUREMENTS OF SATURN IN 1969

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May 1970

*TN-701-70-33 is supported by NASA Grant NGL-32-003-001

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INTRODUCTION

Some recent measurements of Saturn and its rings are summarized in this note. The results are based on measurements of good quality photographs with a Mann measuring machine. The photographic plates were exposed at the f:75 Cassegranian focus of the NMSU 61-cm reflector.

Photographs of Saturn used in measuring the latitudes of the belts and the dimensions of rings A and B were taken in orange light. Standard exposures produced images of the planet having an optical density of about 0.65 above the plate background. Images of Saturn having an optical density of 0.9 above the background were selected for measuring the equatorial and polar diameter of the planet, and 1.2 above the background for measuring the inner edge of ring C.

The measurements reported here involved a slight change in our usual technique. Diffraction at the edges of the cross wires in the measuring machine impairs definition as a wire approaches the edge of a feature such as a delicate belt. This uncertainty in the measurements has been eliminated by using as a reference an exceedingly small, well-defined black spot on the reticle having a diameter of about 10 microns. This reference spot is comparable in size to the grain in the emulsion of our plates and, although easily visible at all times, the spot does not appear to modify delicate detail in its vicinity.

LATITUDES OF SATURN'S BELTS

The latitudes of the edges of Saturn's belts were measured on nine photographic plates of excellent quality taken in orange light between 30 September and 5 November (Fig. 1). The results of these measurements are tabulated in Table I, while the adopted nomenclature of the belts is explained in Fig. 2.

It is inconvenient that different kinds of latitude are in general use for Saturn and Jupiter. Planetographic latitude is so generally used for Jupiter that a change would not appear to be desirable. In the case of Saturn, however, planetocentric latitude is more commonly used in the belief that it is more significant from the terrestrial observer's point of view. Actually, as pointed out by B. M. Peek (1958), mean eccentric latitude is more convenient than either of the other two kinds of latitude. Not only is the sine of the mean eccentric latitude the measured fraction of the polar semidiameter when the Earth is overhead at the planet's equator, but the cosine of the mean eccentric latitude multiplied by the equatorial radius of the planet gives the radius of rotation at that latitude. The three kinds of latitude mentioned above are computed as follows:

Mean eccentric latitude: $\beta' = \theta + D'$

Planetocentric latitude: $\tan \beta = \tan \beta' \div R$

Planetographic latitude: $\tan \beta'' = R \tan \beta'$

where θ is the angle whose sine is the measured fraction of the polar semidiameter, R is the ratio of equatorial diameter to polar diameter, and

D' is the angle whose tangent is equal to R times the tangent of the planetocentric declination of Earth at the time of observation.

Table I gives our results in all three kinds of latitude.

The aspect of Saturn's belts was considerably different in ultraviolet light (Fig. 3) where the Equatorial Zone was very dark and extended southward to Saturnigraphic latitude -15°.3. There was a dark shading in the South Polar Region which extended northward to latitude -64°. Between these two dark shadings were two conspicuous belts, the STB extending from -27°.8 to -36°.4 and the SSTB extending from -41°.9 to -49°.4. A remarkable feature in ultraviolet light was the excessive brightness of the northern hemisphere of the planet north of the rings. We might speculate that the shadow of the ring system to the south of this brilliant zone, and perpetual night in the North Polar Region to the north might chill the upper atmosphere and produce a highly reflecting cloud layer near the tropopause.

DIAMETER OF SATURN (OPPOSITION, 1969)

	Equatorial diameter		Polar diameter		
Wavelength	Unit distance	Kilometers	Unit distance	Kilometers	Oblateness
6200 Å (orange)	165".997	120,393 ±220	148".306	107,562 ±193	0.1066

DIAMETER OF SATURN'S RINGS (30 SEP 69-5 NOV 69)

Object	Number of measurements	Diameter at unit distance	Diameter in kilometers
Ring A, outer edge	49	377".137	273,527 ± 68
Ring A, inner edge	38	336.066	243,739 ± 94
Cassini's Division	66	329.783	239,182 ± 44
Ring B, outer edge	43	324.557	235,392 ± 55
Ring B, inner edge	40	252.770	183,327 ± 83
Ring C, inner edge	15	206.883	150,046 ±175

Photographs used in measuring rings A and B were taken in orange light and given standard exposures. Measurements of ring C, however, were made only on photographs taken in blue light and given three times the standard exposure (Fig. 4). From these measurements the width of Cassini's Division is 4,174 km.

BRIGHT SPOT IN SATURN'S SOUTHERN HEMISPHERE

Only on rare occasions does a discrete marking in Saturn's atmosphere become conspicuous enough to provide a good reference for determining the rotation period of the planet (Dollfus, 1963). The 1969-70 apparition of Saturn was made unusually interesting by the appearance of a small but well-defined bright spot at Saturnigraphic latitude 57°S. which persisted for several months.

Our first record of the bright spot is on a photograph taken by A. S. Murrell on 25 October 1969 (Fig. 5) which indicates that the spot was on the planet's central meridian at 0743 UT. Photographs taken during the next few months (Fig. 6) revealed the spot to be nearly fixed in latitude and rotating once every 0.4421 days. Little change was observed in the size or brightness of the spot: measurements gave it a mean length of 6000 km and a mean width of 8000 km. Photographs taken in orange, green, and blue light indicate that the spot was yellowish in color. Our last record of the spot was on 7 February 1970 when the spot was on Saturn's central meridian at 0219 UT. Even on this last date of observation, the spot still appeared very much as it did three months previously; however, the S.S.S. Temperate Belt apparently was fading during the interval of observation. It was in the south edge of this belt that the bright spot produced a small notch or gap.

Although the bright spot required only slightly better than average seeing to be recorded photographically with the 24-inch reflector, it proved to be a very elusive object for visual observers. R. B. Minton was unable to see it with an 8-inch reflector in very good seeing, the writer was unable to see it with a 16-inch reflector in good seeing, and J. C. Robinson could not see it visually with the 24-inch reflector even though he knew where the spot should be and described the view as one of the best he had ever had of Saturn. Clyde Tombaugh, however, was able to see the spot by glimpses with his 16-inch reflector during moments of very good seeing. Photographically the spot was ideal for measuring since it was very small, completely isolated, and well-defined when seeing was good.

The longitude of the bright spot was measured and computed in a special system of longitude which we call System III. System III was given an arbitrary sidereal rotation period of exactly 10^h38^m, and an ephemeris was constructed using the formula and epoch suggested by M. B. B. Heath (1953). The longitude of the spot gradually decreased with time as shown in Table II and Fig. 7.

A weighted linear least squares analysis indicates that the spot drifted from longitude 148°9 on 25 October 1969 to 322°8 on 7 February 1970 with a rotation period of $10^h36^m36^s.53 \pm 0^s.48$.

A second degree polynomial curvefit indicates that the spot drifted from longitude 148°4 on 25 October 1969 to 321°6 on 7 February 1970 with a mean rotation period of $10^h36^m36^s.20 \pm 0^s.47$. The parabolic solution gives the following equation for the longitude of the spot in System III.

$$\lambda = 148^\circ.89 - 1^\circ.72825\ T - 0^\circ.00052\ T^2$$

where T is the time in days from 25 October 1969 at 0^h UT. The indicated acceleration relative to System III corrected for latitude was 8.5×10^{-8} m/sec^2. It can be shown that statistically the standard deviation of the residuals for the parabolic solution is not significantly better than that for the linear solution.

SUPERIOR GEOCENTRIC CONJUNCTIONS OF TITAN

Photographs of Saturn were taken by Thomas B. Kirby near the times of four superior geocentric conjunctions of Titan (Fig. 8). The observed time of each conjunction was obtained by measuring the distance of the satellite from the extension of the planet's central meridian.

Since the orbital plane of Titan was inclined about 17° to our line of sight, the satellite was nearly one minute of arc south of the center of

Saturn's disk at the time of conjunction. An error of one half degree in setting Saturn's central meridian on the photographic plate parallel to the y-axis of the measuring machine would result in an error of 8.6 minutes in the observed time of conjunction. By measuring the position angle of a fixed fiducial line relative to many equatorial star trails, the position angle of the fiducial line was determined with a standard deviation of 1.4 minutes of arc.

The central meridian of Saturn was found by measuring the outer edge of Ring A or the center of Cassini's Division in each ansa. This method should give a much more accurate value for the position of the central meridian than could be obtained by measuring the east and west limbs of the planet and applying a correction for phase.

The result of the measurements are tabulated below:

Date	Observed UT of conjunction	Standard deviation	Number of measurements	Corrected UT of conjunction	Deviation (O-C)
14 Dec 69	$5^h\ 4^m.32$	$\pm 0^m.25$	31	$5^h\ 3^m.48$	$+0^m.84$
15 Jan 70	2 10.30	±0.30	27	2 9.48	+0.82
31 Jan 70	1 25.37	±0.27	36	1 26.23	-0.86
16 Feb 70	1 9.11	±0.44	17	1 9.94	-0.83

The corrected times of conjunction represent the best fit which can be obtained from the four observed times making allowances for changes in light time and the planetocentric right ascension of Earth, but ignoring perturbations. The sidereal period of Titan was assumed to be 15.945448 days.

The shift in the position of Titan relative to Saturn's central meridian caused by atmospheric refraction was negligible at the greatest hour angle at which a photograph was taken.

ACKNOWLEDGMENTS

The writer wishes to express his thanks to R. L. Fritz for his work in composing and printing images of Saturn, and to Mrs. E. M. Ingraham for her work in preparing some of the figures. The work reported here was supported by the National Aeronautics and Space Administration under Grant NGL-32-003-001.

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TABLE I

MEAN LATITUDES OF SATURN'S BELTS IN ORANGE LIGHT
(30 Sep 69-5 Nov 69)

Feature	Number of Measurements	Standard deviation	Saturnicentric β	Mean Eccentric β'	Saturnigraphic β''	$\cos \beta'$
N. edge dark cap	9	±0°.3	-71°.8	-73°.5	-75°.2	.284
S. edge SPB	8	±0.3	-64.7	-67.1	-69.3	.389
N. edge SPB	8	±0.3	-57.5	-60.3	-63.0	.495
S. edge SSSTB	5	±0.2	-50.6	-53.7	-56.7	.592
N. edge SSSTB	5	±0.2	-45.3	-48.5	-51.6	.663
S. edge SSTB	4	±0.4	-39.9	-43.0	-46.2	.731
N. edge SSTB	4	±0.4	-35.0	-38.1	-41.2	.787
S. edge STB	5	±0.1	-31.0	-33.9	-36.9	.830
N. edge STB	5	±0.5	-25.8	-28.3	-31.1	.880
S. edge SEB	6	±0.2	-21.7	-24.0	-26.4	.914
N. edge SEB	5	±0.4	-10.7	-11.9	-13.3	.979
S. Edge EB	6	±0.2	- 5.0	- 5.6	- 6.2	.995
N. edge EB	6	±0.2	+ 1.5	+ 1.7	+ 1.9	.999

TABLE II

LONGITUDE AND LATITUDE MEASUREMENTS OF A BRIGHT SPOT IN SATURN'S SOUTHERN HEMISPHERE

Date	Longitude (System III)			Deviation from least squares position: weighted linear	Deviation from least squares position: unweighted parabolic	Saturnigraphic Latitude	
1969							
Oct 25.29	149°5	±0°4	(9)	+0°5	+1°1	-57°3 ± 1°4	(3)
29.29	142.5	±0.9	(7)	+0.7	+1.0		
31.10	140.1	±0.7	(2)	+1.5	+1.8		
Nov 1.39	134.3	±0.8	(5)	-2.1	-1.8		
3.17	131.5	±1.0	(2)	-1.7	-1.5		
5.37	128.0	±0.3	(14)	-1.3	-1.2	-57.8 ± 0.3	(6)
7.14	126.0	±0.9	(3)	-0.2	-0.1		
10.23	119.9	±0.8	(7)	-0.8	-0.9	-56.8 ± 0.4	(6)
17.28	107.0	±0.9	(7)	-1.1	-1.4		
21.28	102.1	±0.4	(8)	+1.1	+0.7	-57.9 ± 0.4	(4)
22.18	99.1	±1.1	(2)	-0.4	-0.7		
25.26	98.1	±0.8	(4)	+4.1	+3.7		
Dec 2.29	84.0	±2.7	(3)	+2.5	+2.0		
7.20	70.8	±0.7	(2)	-2.0	-2.5		
12.05	65.7	±0.8	(8)	+1.5	+1.0	-57.1	(1)
15.16	59.5	±1.1	(5)	+0.9	+0.3		
16.07	56.9	±1.0	(6)	-0.1	-0.6		
20.03	50.3	±0.5	(5)	+0.4	-0.1	-56.8 ± 0.8	(2)
22.24	44.6	±1.7	(3)	-1.4	-1.9		
1970							
Jan 8.04	16.9	±0.4	(6)	+0.7	+0.6		
15.11	2.5	±1.1	(3)	-1.2	-1.0		
19.09	356.7	±0.8	(5)	+0.1	+0.4		
27.05	344.0	±0.9	(3)	+1.6	+2.2		
Feb 7.10	320.2	±0.8	(6)	-2.6	-1.4	-56.7 ± 0.8	(2)
	standard deviation =			± 1°53	±1°50		

Note: The standard deviation of the mean, and the number of images measured (in parentheses) are included. The mean Saturnigraphic latitude of the bright spot from 24 measurements was -57°3 ± 0°3.

Fig. 1. Saturn in orange light, 5 November 1969, 0358 UT. Photograph by Claude Knuckles. All of the Photographs in this report were taken at the f:75 focus of the 61-cm reflector and are oriented with south at the top.

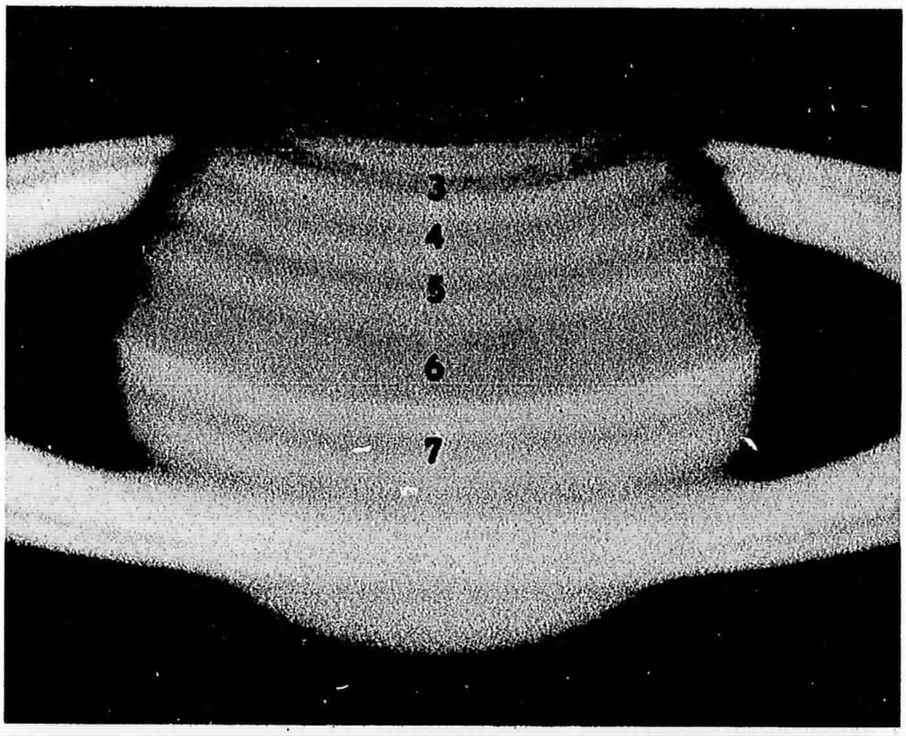

Fig. 2. Diagram of Saturn indicating the nomenclature of the belts used in this report. South is at the top, and rotation is from right to left.

1. South Polar Cap
2. South Polar Belt (SPB)
3. S.S.S. Temperate Belt (SSSTB)
4. S.S. Temperate Belt (SSTB)
5. South Temperate Belt (STB)
6. South Equatorial Belt (SEB)
7. Equatorial Band (EB)

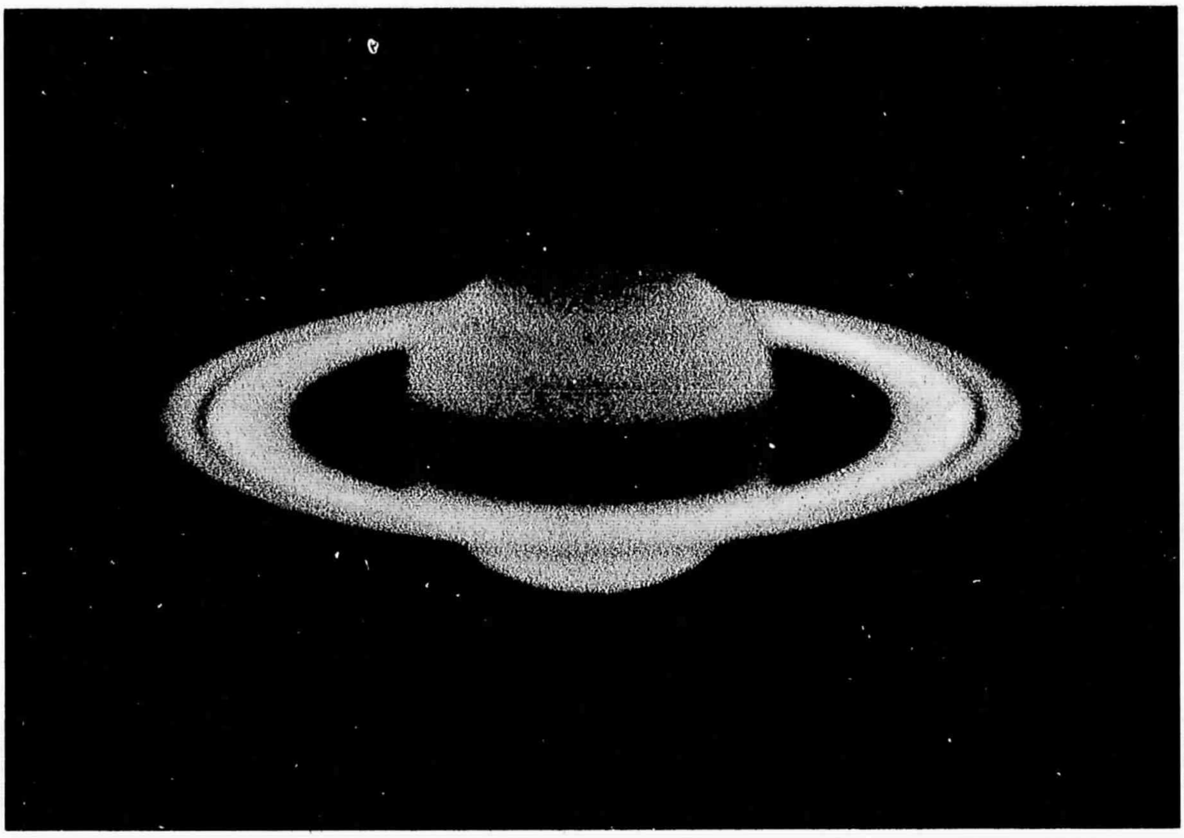

Fig. 3. Saturn in ultraviolet light, 5 November 1969, 0440 UT, showing a very dark Equatorial Zone and a brilliant north limb. Photograph by Claude Knuckles.

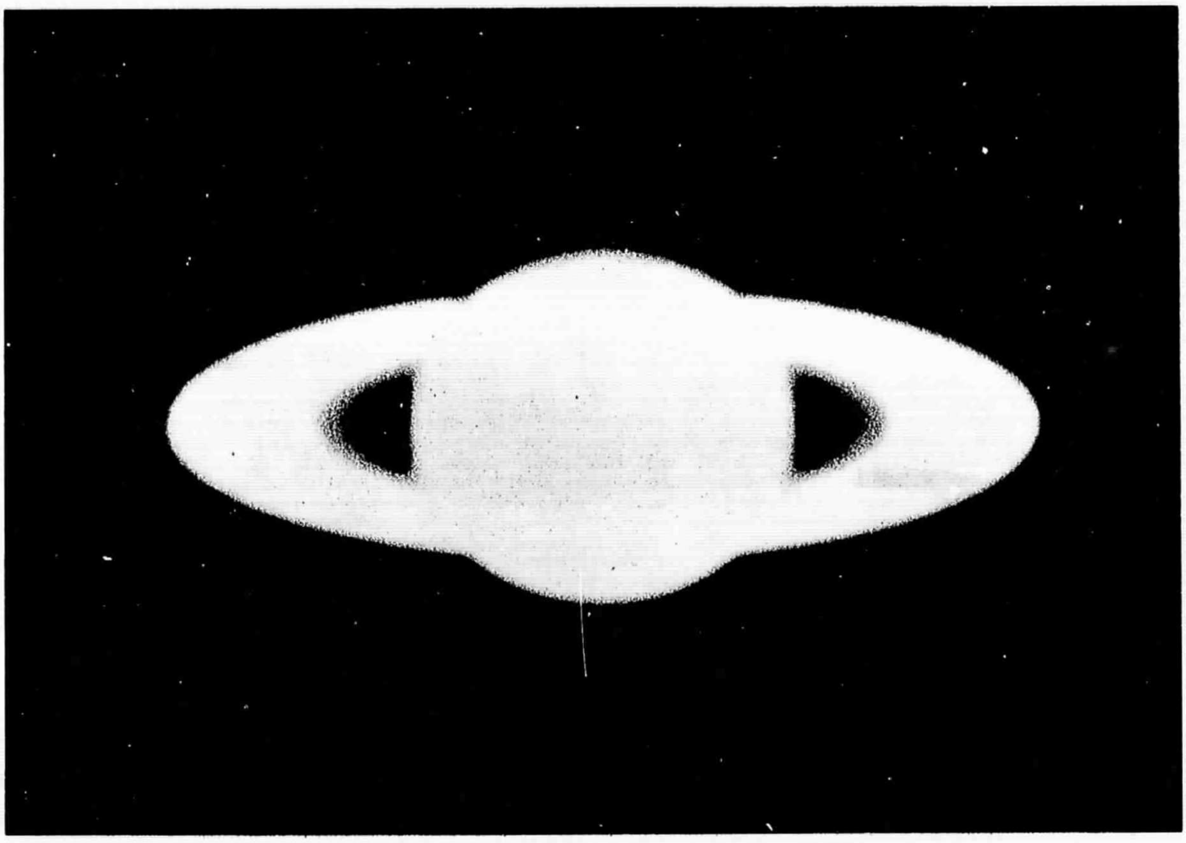

Fig. 4. Saturn in blue light, 25 October 1969, 0720 UT, with three times standard exposure to show ring C. Photograph by A. S. Murrell.

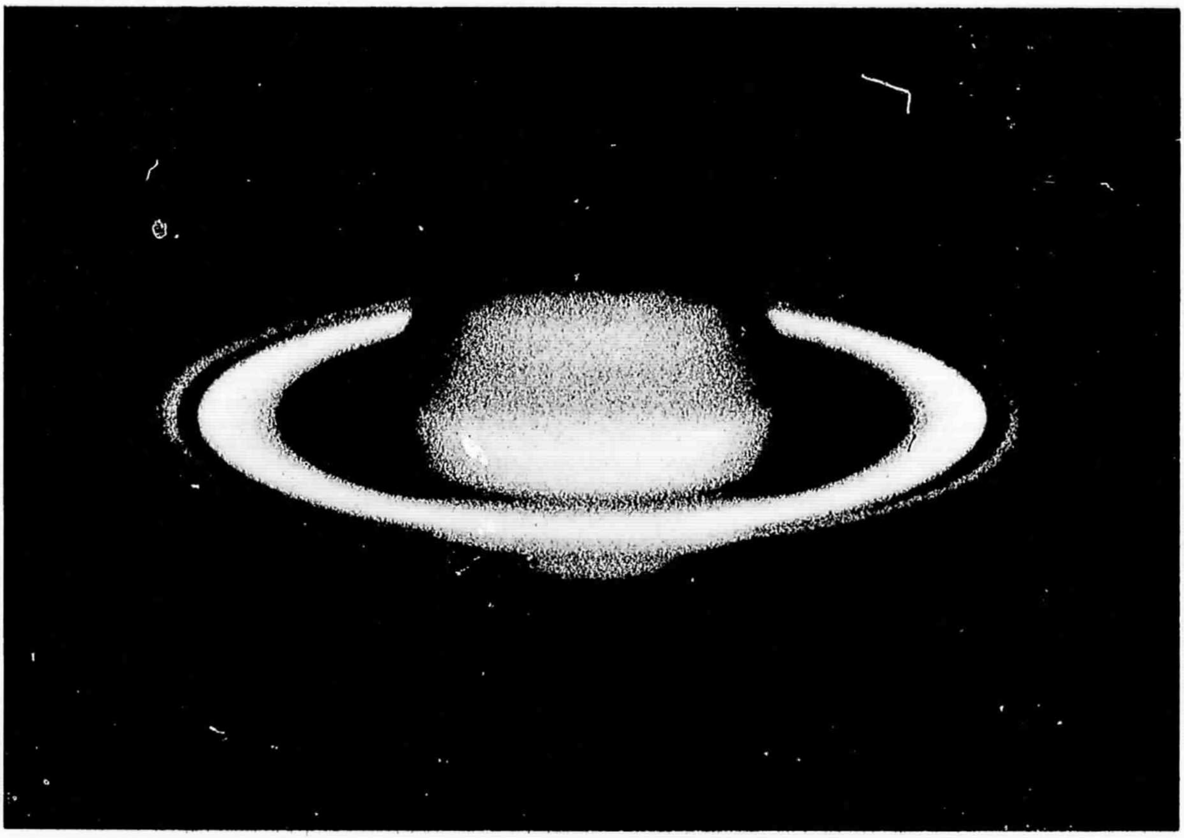

Fig. 5. Saturn in green light, 25 October 1969, 0708 UT, discovery photograph of a small bright spot in the southern hemisphere which persisted for several months. Photograph by A. S. Murrell.

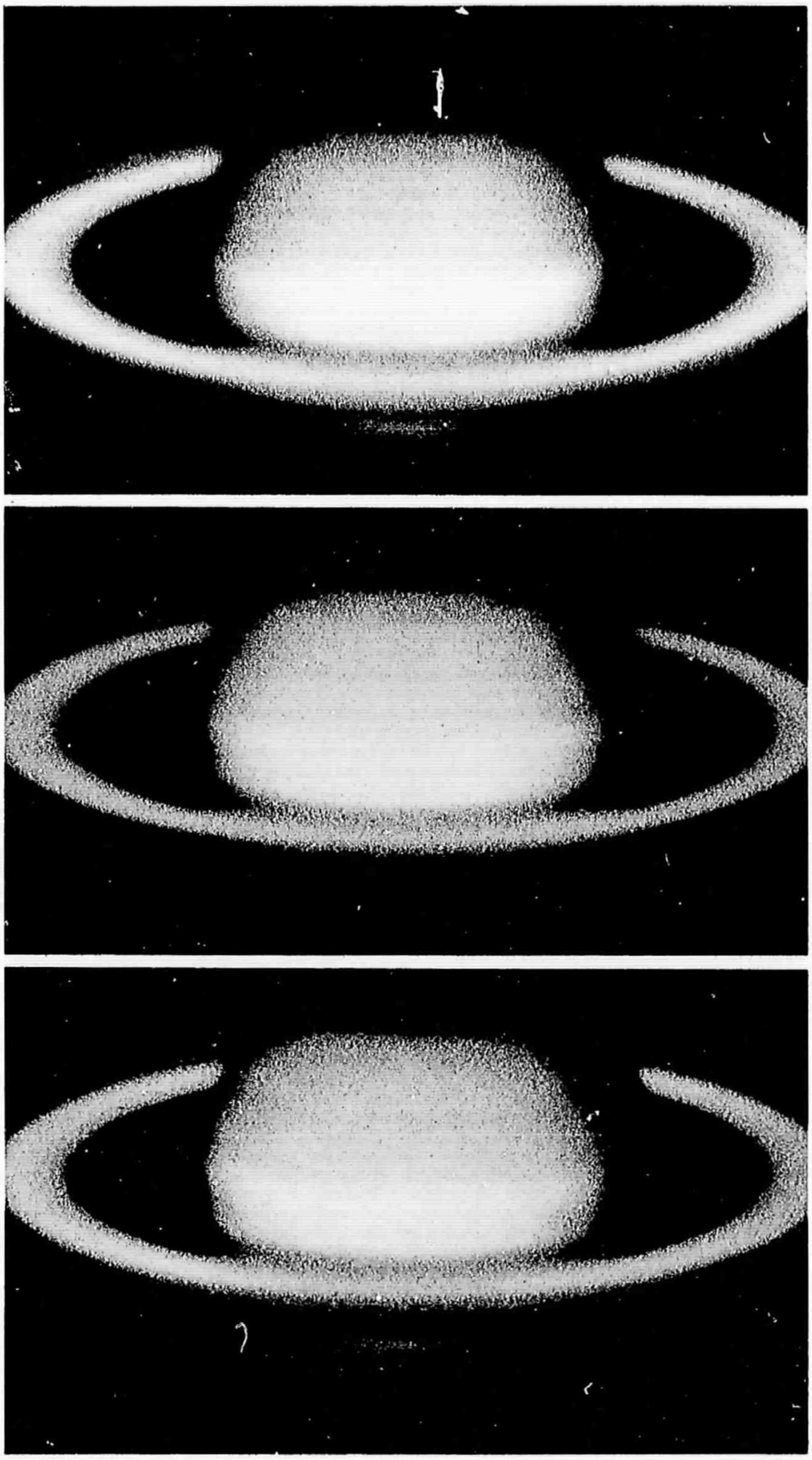

Fig. 6. Three photographs of Saturn in orange light showing later views of a small bright spot in the southern hemisphere. Top, 5 November 1969, 0812 UT, photograph by J. C. Robinson showing bright spot to right of central meridian. Center, 16 December 1969, 0135 UT, photograph by Claude Knuckles showing bright spot to left of central meridian. Bottom, 7 February 1970, 0226 UT, photograph by J. C. Robinson showing bright spot near central meridian.

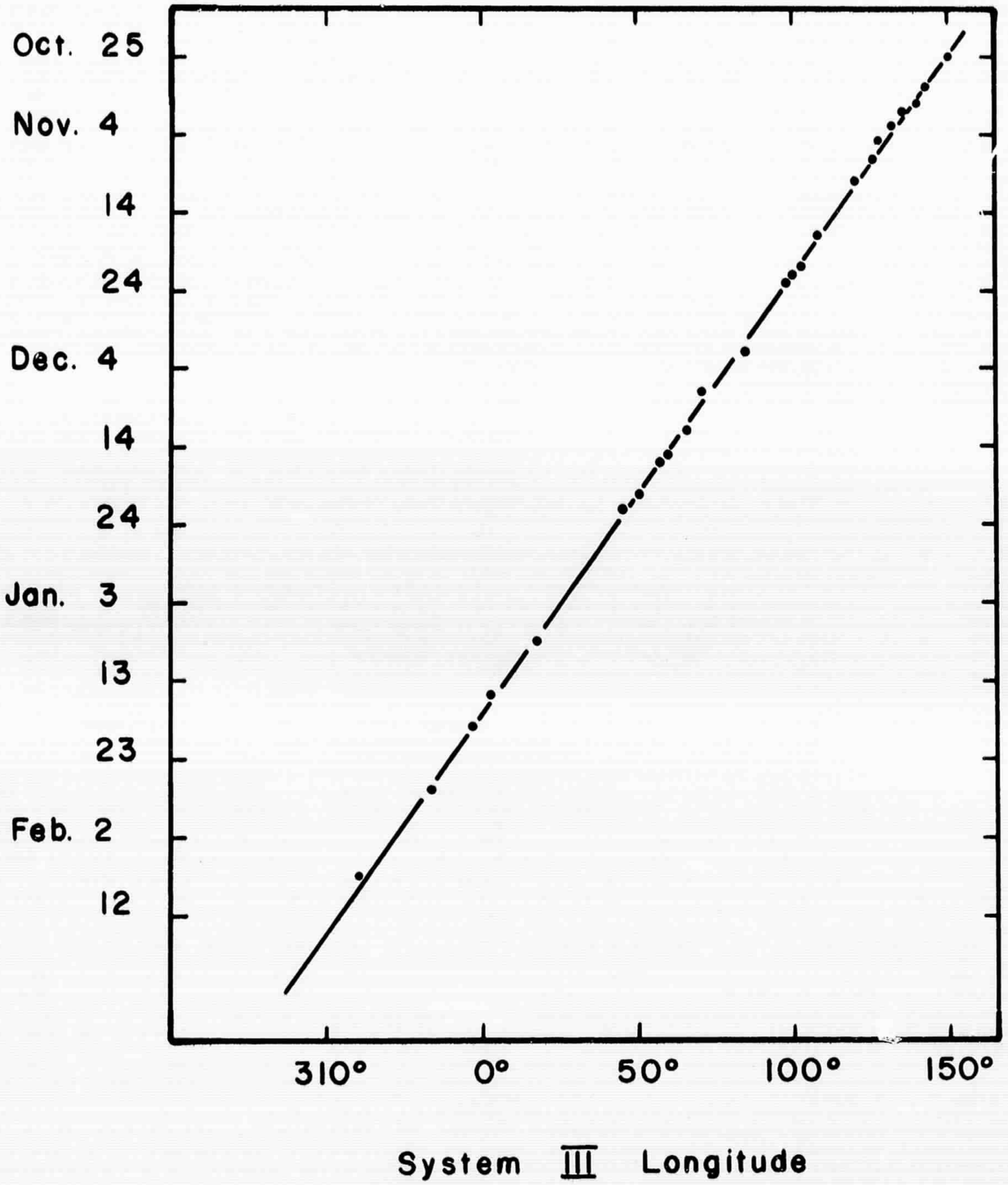

Fig. 7. Motion of a small bright spot in Saturn's southern hemisphere in an arbitrary system of longitude from 25 October 1969 to 7 February 1970.

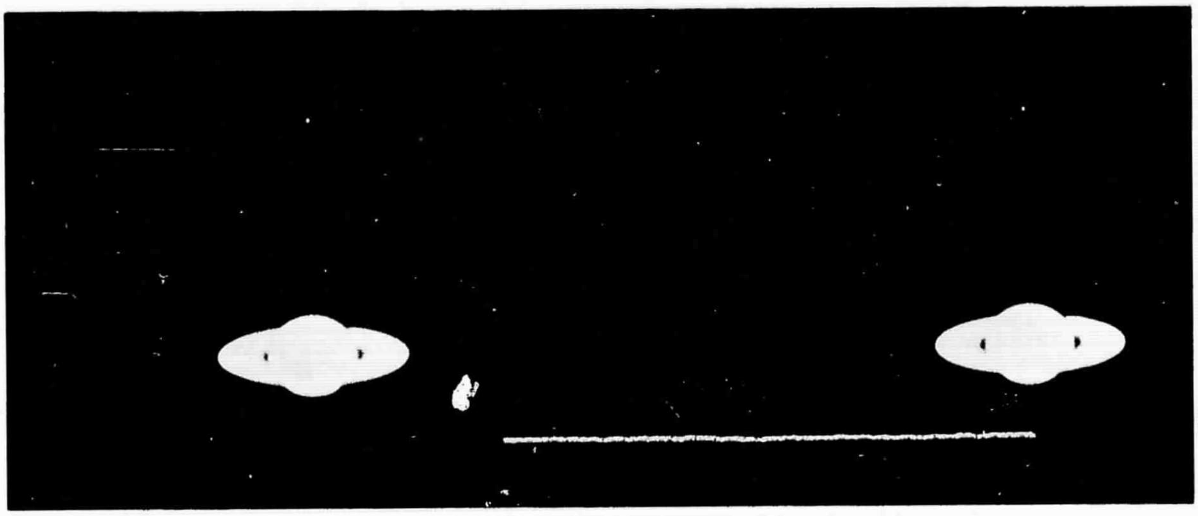

Fig. 8. Portion of one of the photographic plates used to measure the distance of Titan from superior geocentric conjunction. A star trail, fiducial lines, and the satellites Titan, Rhea, Tethys, and Dione are shown. Photogtaph by Thomas B. Kirby on 15 January 1970.