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PHOTOGRAPHIC OBSERVATIONS OF JUPITER IN 1968-1969

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INTRODUCTION

A number of interesting events took place on Jupiter during the apparition of 1968-69. The South Equatorial Belt faded considerably (Figs. 1 and 2). Near the end of the apparition the south component of that belt was thin and faint, while the South Tropical Zone and the interior of the South Equatorial Belt combined to form a very wide and bright zone reminiscent of the appearance in 1963. Numerous small bright spots surrounded by dark penumbral-like shadings were observed in the southern part of the South Temperate Zone (Figs. 3 and 4). A highlight of the apparition was the apparent formation of numerous dark spots on the south edge of the N. N. Temperate Belt in a localized area nearly stationary in System II.

LATITUDE MEASUREMENTS

A total of 992 measurements were made of the latitudes of Jovian belts and 22 selected features. Nearly all of the plates measured were taken in blue light since the limb of the planet is best defined in this color. Table I, which summarizes the measurements of belt latitudes, divides the apparition into two parts so that any short term changes in latitude might become apparent.

Gradual changes in the latitude of the belts during the last six apparitions are shown graphically in Fig. 5. There appears to be a tendency for certain belt edges in a given hemisphere to move in unison. An example of this might be the north edge of the North Equatorial Belt, the south edge of the North Temperate Belt, and the N. N. Temperate Belt.

A comparison of recent measurements of the latitudes of Jovian belts with earlier measurements made by members of the British Astronomical Association (Peek, 1958) and the Association of Lunar and Planetary Observers is given in Table II. The mean latitudes of both the STB and the SSTB have been a degree or two higher during the last twenty years than they were from 1908 to 1947.

Latitude measurements of selected spots will be summarized in the following sections which deal with the longitudes and rotation periods of those spots.

ROTATION PERIODS OF INDIVIDUAL SPOTS

Bright Spots in Southern Part of STeZ (S. S. Temperate Current)

Mean zenographic latitude of spots 1, 3, 6 = -38°.8 (9 dates)
spots 2, 4 = -40°.6 (9 dates)
spot 5 = -41°.3 (3 dates)
Mean width in latitude of spots 1, 3, 6 = 5°.8 (9 dates)
spots 2, 4, 5 = 3°.6 (10 dates)
Mean length in longitude of spots 1, 3, 6 = 9°.7 (31 dates)
spots 2, 4, 5 = 4°.5 (20 dates)

Object	Limiting Dates	Limiting Longitudes	N	$\Delta\lambda_2$/day	Rotation Period	S.D.
1	Feb 10-Apr 26	146°.1- 74°.0	12	-0°.9607	$9^h55^m1^s.2$	$\pm0^s.4$
2	Mar 28-Jul 5	199.0-115.3	9	-0.8449	9 55 6.0	±0.3
3	Mar 28-Jul 5	207.8-126.1	8	-0.8247	9 55 6.8	±0.3
4	Apr 21-May 18	199.8-175.7	4	-0.8940	9 55 4.0	±1.0
5	Mar 27-Jun 21	266.5-186.0	7	-0.9359	9 55 2.2	±0.4
6	Mar 17-Jul 15	285.5-178.8	12	-0.8890	9 55 4.2	±0.2

Mean drift rate relative to System II = -0°.8915 deg/day = -10.04 m/sec.
Mean rotation period = $9^h55^m4^s.1$

Spots 1, 3, and 6, which were larger and more diffuse than spots 2, 4 and 5, were situated about 2° nearer the equator than the other spots. All of the spots had very nearly the same rotation period and their drifts were quite linear. Most of the spots in the group more distant from the equator were surrounded by a dark border which remained symetrically placed relative to the enclosed bright spot for many months. Spots 2, 3, and 4 are shown preceding the large oval DE in Fig. 4, while spots 5 and 6 follow DE.

The Long-Enduring South Temperate Ovals (S. Temperate Current)

Object	Limiting Dates	Limiting Longitudes	N	$\Delta\lambda_2$/day	Rotation Period	S.D.
FA	Oct 29-Aug 16	119°.6-299°.2	57	-0°.6198	$9^h55^m15^s.2$	±0^s.1
BC(part 1)	Oct 25-Jan 18	221.8-164.5	7	-0.6764	9 55 12.9	±0.9
BC(part 2)	Jan 18-Aug 24	164.5- 25.9	54	-0.6353	9 55 14.6	±0.1
DE(part 1)	Oct 28-Dec 11	336.9-302.6	5	-0.7728	9 55 8.9	±0.9
DE(part 2)	Dec 11-May 17	302.6-199.6	34	-0.6576	9 55 13.6	±0.1
DE(part 3)	May 17-Aug 15	199.6-135.2	12	-0.7151	9 55 11.3	±0.4

Mean rotation period of BC = $9^h55^m14^s.1$
Mean rotation period of DE = $9^h55^m12^s.2$
Mean rotation period of all = $9^h55^m13^s.8$
Mean drift rate of all = -0.6532 deg/day = -8.06 m/sec.

Object	Mean Latitude	Mean Width	Mean Length	Longitude II at opposition
FA	-33°.4 ±0.1 (17)*	6°.0 ±0°.2 (17)*	11°.3 (64)*	35°.1
BC	-33.4 ±0.1 (17)	6.5 ±0.2 (17)	12.5 (65)	124.3
DE	-33.6 ±0.1 (16)	5.9 ±0.2 (16)	12.5 (50)	236.4
Mean	-33°.5	6°.1	12°.1	

*NOTE: Numbers of dates on which observations were made are given in parentheses.

The oval FA underwent a small, constant acceleration throughout the apparition. Conjunction with the Red Spot took place on 9 April

1969 at longitude (II) 23°.7. A least squares solution gives the following equation for the motion of FA:

$$\lambda_2 = 119°.6 - 0°.5538T - 0°.00023T^2$$

where T is the time in days from 29 October 1968. The rotation period decreased from $9^h55^m17^s.9$ to $9^h55^m12^s.5$ during the interval of observation. The acceleration relative to System II corrected for latitude was 6.48×10^{-8} m/sec^2.

Dark Spots on North Edge South Temperate Belt ($\beta'' = -26°.2$)

Object	Limiting Dates	Limiting Longitudes	N	$\Delta\lambda_2$/day	Rotation Period	S.D.
1	Mar 17-May 10	325°.6-119°.6	7	-3°.8152	$9^h53^m 4^s.6$	± 1^s.4
2A	Apr 6-Apr 20	288.1-230.2	6	-4.1525	9 52 50.9	± 2.1
2B	Apr 20-May 20	230.2-118.3	10	-3.7162	9 53 8.7	± 1.1
2C	May 25-Jun 16	100.9- 38.9	7	-2.7918	9 53 46.3	± 1.0
2D	Jun 17-Jun 23	36.5- 6.1	4	-5.3391	9 52 2.7	±14.7
2E	Jun 23-Jul 4	6.1-332.0	4	-3.0148	9 53 37.3	± 2.7
3	Apr 10-May 1	279.6-195.4	6	-4.0115	9 52 56.6	± 3.3
4A	Apr 3-Apr 23	319.1-235.6	10	-4.1907	9 52 49.4	± 1.3
4B	Apr 23-May 20	235.6-133.3	9	-3.7922	9 53 5.6	± 0.8
4C	May 25-Jun 27	116.0- 39.7	15	-2.3116	9 54 6.0	± 1.3
4D	Jun 30-Jul 4	34.8- 10.7	3	-5.9681	9 51 37.2	± 2.7
4E	Jul 4-Jul 23	10.7-328.5	5	-2.2223	9 54 9.6	± 1.7
5	Apr 13-May 1	287.7-213.0	5	-4.1511	9 52 51.0	± 3.0
6	Apr 18-May 25	276.2-130.1	8	-3.9471	9 52 59.3	± 1.3
7	May 2-Jun 13	239.5- 78.8	9	-3.8260	9 53 4.2	± 1.6
8	Apr 30-May 18	260.3-191.4	6	-3.8294	9 53 4.1	± 2.8
9A	May 11-Jun 23	236.3- 72.0	7	-3.8064	9 53 5.0	± 1.1
9B	Jun 23-Jul 4	72.0- 36.8	5	-3.2524	9 53 27.6	± 5.4
10A	May 18-Jun 9	239.0-151.8	4	-3.9627	9 52 58.6	± 1.7
10B	Jun 23-Jul 16	101.2- 29.7	9	-3.1065	9 53 33.5	± 2.7
11	May 21-Jul 5	250.0- 76.4	7	-3.8572	9 53 2.9	± 1.2
12	May 9-Jul 5	186.9- 84.7	4	-3.9341	9 52 59.8	± 0.5

Mean rate and rotation period= -3.9280 deg/day, -51.51 m/sec, $9^h53^m0^s.0$
Mean width in latitude = 3°.8 (21 measurements)
Mean length in longitude = 4°.1 (157 measurements)

Rapidly moving spots were observed on the north edge of the South Temperate Belt for the fourth consecutive apparition (Fig. 4). The mean rate and rotation period given above are for drifts 1, 2A, 2B, 3, 4A,

4B, 5, 6, 7, 8, 9A, 10A, 11, and 12 which did not appear to be influenced by proximity to the Red Spot. As the spots approached or receded from the Red Spot (drifts 2C, 2E, 4C, 4E, 9B, 10B) their mean drift rate decreased to -2.7832 deg/day (-36.50 m/sec) which corresponds to a rotation period of $9^h53^m46^s.7$. Two spots were observed to pass along the south edge of the Red Spot (drifts 2D and 4D) at the very rapid rate of -5.6536 deg/day (-72.8 m/sec) which corresponds to a rotation period of $9^h51^m50^s$.

From 25 May 1969 to 16 June 1969 spot 2 underwent a constant deceleration of 1.11×10^{-5} m/sec^2 as it approached the Red Spot. A least squares solution gives the following equation for the drift of the spot in System II:

$$\lambda_2 = 101^\circ.5 - 3^\circ.6179T + 0^\circ.03665T^2$$

where T is the time in days from 25 May 1969. Thus the rotation period increased from $9^h53^m13^s.1$ to $9^h54^m19^s.6$ and the drift rate decreased from -47.3 to -25.9 m/sec during the interval of deceleration.

Spot 4 also decelerated as it approached the Red Spot. Its rotation period increased from $9^h53^m15^s$ on 25 May 1969 to $9^h54^m57^s$ on 27 June 1969, as its drift rate decreased from -46.7 to -14.0 m/sec. The equation of motion during this interval follows:

$$\lambda_2 = 116^\circ.5 - 3^\circ.5705T + 0^\circ.0378T^2$$

Dark Spots on Belt in South Tropical Zone

Object	Limiting Dates	Limiting Longitudes	N	$\Delta\lambda_2$/day	Rotation Period	S.D.
1 (Dp)	Mar 27-Apr 10	335°.2-320°.3	5	-1°.0621	$9^h54^m57^s.1$	$\pm5^s.3$
2 (Df)	Mar 27-Apr 20	355.4-325.9	10	-1.2286	9 54 50.2	
3 (Dp)	Mar 27-Apr 20	362.9-330.4	11	-1.3534	9 54 45.1	
4 (Df)	Apr 8-Apr 20	368.3-349.8	6	-1.5473	9 54 37.2	±5.1
5 (Dp)	May 24-Jun 10	357.0-337.0	5	-1.1765	9 54 52.4	
6 (Dc)	Apr 22-May 2	262.1-248.8	3	-1.3300	9 54 46.1	

Mean rate and rotation period = -1.2830 deg/day, -17.0 m/sec, $9^h54^m48^s.0$

These dark streaks were located on a thin belt apparently originating at the preceding tip of the Red Spot at latitude -22°.6 and then angling southward to latitude -24°.6 some twenty degrees preceding the Red Spot. The dark streaks themselves appeared to originate at the preceding tip of the Red Spot and to move away from that feature at the rate of 17 m/sec. Spots 2 and 3 were accelerated as they moved away from the Red Spot. Least squares solutions give the following equations of motion for spots 2 and 3:

$$\lambda_2 = 355°.4 - 0°.7233T - 0°.02106T^2$$

$$\lambda_2 = 362°.9 - 0°.7163T - 0°.02654T^2$$

where T is the time in days from 27 March 1969.

Red Spot

Photometric measurements made on selected plates taken near the oppositions of 1968 and 1969 indicate that the brightness of the Red Spot in 1968 was 0.77 times greater in blue light, and 0.89 times greater in green light, than it was in 1969. An apparently stable portion of the South Polar Region was assumed to be of unit brightness during each apparition. This assumption seems to have been justified since the brightest zone during each apparition was found to be about 2.1 times brighter than the South Polar Region. The behavior of the Red Spot and associated activity in the South Tropical Zone has been discussed elsewhere (Reese, 1969).

Dark Spots on North Edge SEBs ($\beta'' = -16°.1$)

Object	Limiting Dates	Limiting Longitudes	N	$\Delta\lambda_2$/day	Rotation Period	S.D.
1	Jan 7-Jun 6	75°.6- 81°.0	39	+0°.0360	$9^h55^m42^s.1$	$\pm0^s.1$
2	Jan 14-Mar 3	94.9-101.2	6	+0.1314	9 55 46.0	±0.7
3A	Jan 14-Mar 3	126.4-128.3	6	+0.0417	9 55 42.4	±1.3
3B	Mar 3-Apr 14	128.3-143.8	7	+0.3647	9 55 55.6	±0.8

Mean rate and rotation period = +0.1205 deg/day, +1.68 m/sec, $9^h55^m45^s.6$

The three spots tabulated above were quiescent spots located on the north edge of the SEBs. Similar spots having very nearly the same rotation period were observed at this latitude from 1959 to 1962. Spot 1, which is shown near the central meridian in Fig. 6, gradually decreased in length from 13°.4 to 4°.1 during the interval of observation. Spot 2 had a mean length of 7°.8, and spot 3 decreased in length from 9°.6 to 6°.2 during the interval of observation. The average measured width of the spots was 2°.6 in latitude.

No rapidly retrograding spots were observed on the south edge of the SEBs during the apparition.

Dark Area in SEB Interior Zone ($\beta'' = -12°.6$)

Object	Limiting Dates	Limiting Longitudes	N	$\Delta\lambda_2$/day	Rotation Period	S.D.
Prec. end	Jan 14-Feb 12	203°.0-129°.7	4	-2°.5269	$9^h53^m57^s$	$\pm 12^s$
Fol. end	Jan 14-Feb 10	257.6-194.8	4	-2.3231	9 54 5	± 4

Dark Spots on North Edge North Temperate Belt (N. Temp. Current A) ($\beta''=+30°.2$)

Object	Limiting Dates	Limiting Longitudes	N	$\Delta\lambda_2$/day	Rotation Period	S.D.
1	Nov 12-Apr 5	103°.8-175°.3	22	+0°.4968	$9^h56^m 1^s.1$	$\pm 0^s.2$
2(Dp)	Dec 29-Apr 10	234.3-272.9	13	+0.3792	9 55 56.2	±0.6
3(Dc)	Dec 29-Mar 27	243.9-282.8	12	+0.4412	9 55 58.8	±0.4
4(Df)	Dec 29-Apr 10	253.5-306.5	14	+0.5199	9 56 2.0	±0.5

Mean rate and rotation period = +0.4593 deg/day, +5.82 m/sec, $9^h55^m59^s.5$

The North Temperate Belt faded almost to invisibility during the apparition after having been quite dark and conspicuous since 1964. The belt, which was divided into two faint components, displayed several dark streaks on the north component during the first half of the apparition.

Spot 1, which had a mean length of 9°.6 and width of 3°.0, had a constant deceleration of 4.32×10^{-7} m/sec^2 which increased its rotation period from

$9^h55^m52^s.3$ to $9^h56^m9^s.8$ during the interval of observation. A least squares solution gives the following equation for the position of the spot in System II:

$$\lambda_2 = 103^\circ.8 + 0^\circ.2849T + 0^\circ.00147T^2$$

where T is the time in days from 12 November 1968.

Spots 2, 3, and 4 refer to the preceding end, center, and following end of a dark streak which increased in length from 20° to 30° during the interval of observation. The streak broke into two parts and dissipated in April.

Dark Spots on South Edge of N. N. Temperate Belt (N. N. Temp. Current B)

Object	Limiting Dates	Limiting Longitudes	N	$\Delta\lambda_2$/day	Rotation Period	S.D.
1	Dec 11-Jan 13	413°.4-317°.2	4	-2°.9158	$9^h53^m41^s.3$	±2s.5
2	Feb 10-Mar 17	417.3-319.7	7	-2.7883	9 53 46.5	±1.3
3A	Mar 17-May 2	378.8-252.2	12	-2.7535	9 53 47.9	±1.1
3B	May 4-Jun 23	247.5-132.8	8	-2.2925	9 54 6.7	±0.8
4A	Mar 18-May 16	386.9-241.2	18	-2.4700	9 53 59.5	±1.2
4B	May 18-Jul 5	235.4-123.5	9	-2.3313	9 54 5.2	±0.6
5A	Apr 3-May 28	371.0-224.7	21	-2.6607	9 53 51.7	±0.5
5B	Jun 9-Jun 28	192.7-148.7	3	-2.3159	9 54 5.8	±3.1
6	Apr 4-May 26	380.9-240.1	11	-2.7064	9 53 49.8	±1.2
7	Apr 4-Jun 21	402.6-182.2	17	-2.8264	9 53 44.9	±0.4
8	Apr 21-Jun 21	400.2-239.1	15	-2.6405	9 53 52.5	±0.9
9	May 1-Jul 13	403.8-203.2	8	-2.7477	9 53 48.1	±0.8
10	May 1-Jul 13	423.4-243.9	10	-2.4587	9 53 59.9	±1.8
11	May 25-Jun 24	419.3-335.3	4	-2.7973	9 53 46.1	±1.0
12	Jun 18-Jul 23	420.7-324.8	7	-2.7388	9 53 48.5	±2.7

Mean rate and rotation period = -2.7087 deg/day, -32.44 m/sec, $9^h53^m49^s.7$

The south edge of the N. N. Temperate Belt was very active during the apparition with numerous dark spots forming near longitude (II) 60° and then drifting rapidly in the direction of decreasing longitude. This non-random distribution in the longitude at which the spots first appeared suggests a subsurface source rotating in a period nearly the same as that of System II

The mean zenographic latitude of these spots was +35°.8, and the mean length and width were both 4°.7. Spots 3B, 4B, and 5B were not included in the mean rate and rotation period.

Dark Spot on South edge of N. N. N. Temperate Belt (N. N. N. Temp. Current)

Object	Limiting Dates	Limiting Longitudes	N	$\Delta\lambda_2$/day	Rotation Period	S.D.
1	Jan 12-Jun 21	239°.3-174°.9	18	-0°.4025	$9^h55^m24^s.1$	$\pm 0^s.5$

The mean zenographic latitude of this spot was +42°.8, the mean length was 5°.7, and the mean width was 5°.4. The spot is shown following the central meridian in Fig. 3, and preceding the central meridian in Fig. 4. There was an oscillating component in the motion of the spot having an amplitude of about 3° in longitude and a period of about 75 days.

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TABLE I

MEAN ZENOGRAPHIC LATITUDES (β") OF JOVIAN BELTS IN 1968-69

N = Number of dates on which observations were made

	4 Nov 68-26 Mar 69 Pre-opposition			28 Mar 69-7 Jun 69 Post-opposition			Mean for 1968-69	
Belt	β"	S.D.	N	β"	S.D.	N	β"	N
s/SPB	-67°.7	---	1	-68°.0	±0°.2	8	-68°.0	9
SPB	-64.3	---	1	-65.4	±0.3	7	-65.3	8
SSSTB	-55.4	±0°.2	4	-54.5	±0.2	3	-55.0	7
SSTB	-43.2	±0.5	8	-43.8	±0.3	9	-43.5	17
STeZB	-38.7	±0.4	3	-37.3	---	1	-38.4	4
s/STB	-33.8	±0.2	15	-33.4	±0.3	10	-33.6	25
n/STB	-26.8	±0.2	16	-26.2	±0.4	10	-26.6	26
STrZB	-25.0	±0.6	5	-24.5	±0.6	5	-24.8	10
s/SEBs	-20.7	±0.2	17	-20.1	±0.1	10	-20.5	27
n/SEBs	-14.5	±0.1	17	-14.6	±0.2	9	-14.5	26
s/SEBn	-10.7	±0.1	15	-10.5	±0.1	9	-10.6	24
n/SEBn	- 7.4	±0.1	15	- 7.2	±0.1	9	- 7.3	24
s/EB	- 4.5	±0.1	13	- 4.5	±0.1	9	- 4.5	22
n/EB	+ 2.9	±0.2	13	+ 2.3	±0.3	9	+ 2.7	22
s/NEB	+ 7.0	±0.2	15	+ 6.6	±0.1	9	+ 6.9	24
n/NEB	+20.7	±0.1	15	+21.0	±0.2	9	+20.8	24
s/NTBs	+24.4	±0.2	14	+24.1	±0.2	7	+24.3	21
n/NTBs	+26.6	±0.2	5	+26.5	±0.2	7	+26.5	12
n/NTBn	+30.8	±0.2	13	+31.7	±0.4	6	+31.1	19
NNTB	+37.2	±0.2	19	+36.7	±0.3	9	+37.0	28
NNNTB	+44.6	±0.2	13	+44.6	±0.2	8	+44.6	21

TABLE II

MEAN ZENOGRAPHIC LATITUDES OF JOVIAN BELTS, 1908-1969

	1960-1969 (N.M.S.U. Observatory)			1949-1962 (Assn. Lunar & Planetary Obs.)			1908-1947 (British Astron. Assn., B. M. Peek)			
Belt	Mean latitude	Latitude range	Number of apparitions	Mean latitude	Latitude range	Number of apparitions	Mean latitude	Latitude range	Number of apparitions	Mean of all
SSTB	44°.4	43°.1-46°.3	9	44°.9	42°.1-47°.1	7	41°.6	37°.0-45°.4	20	43°.0 S
STB	30.0	29.4-31.0	9	31.0	29.8-32.7	12	29.0	26.7-30.5	36	29.6 S
s/SEB	20.9	19.9-21.7	9	20.8	18.2-22.6	11	18.9	16.4-22.6	30	19.7 S
n/SEB	6.8	5.8- 7.6	7	7.3	5.5- 7.9	9	7.1	4.4- 9.0	33	7.1 S
s/NEB	7.4	6.6- 8.6	9	6.8	4.1- 7.9	12	7.2	4.5- 9.0	34	7.1 N
n/NEB	19.9	16.9-21.4	9	17.9	13.7-21.3	12	17.3	12.7-22.0	34	17.9 N
NTB	28.0	27.5-28.7	5	26.7	23.6-30.0	8	27.8	24.5-32.2	33	27.6 N
NNTB	37.3	36.8-38.0	6	36.3	33.7-41.0	10	36.4	33.1-39.5	17	36.5 N
NNNTB	44.9	44.5-45.9	6	45.3	44.8-45.7	2	--	------	--	45.0 N

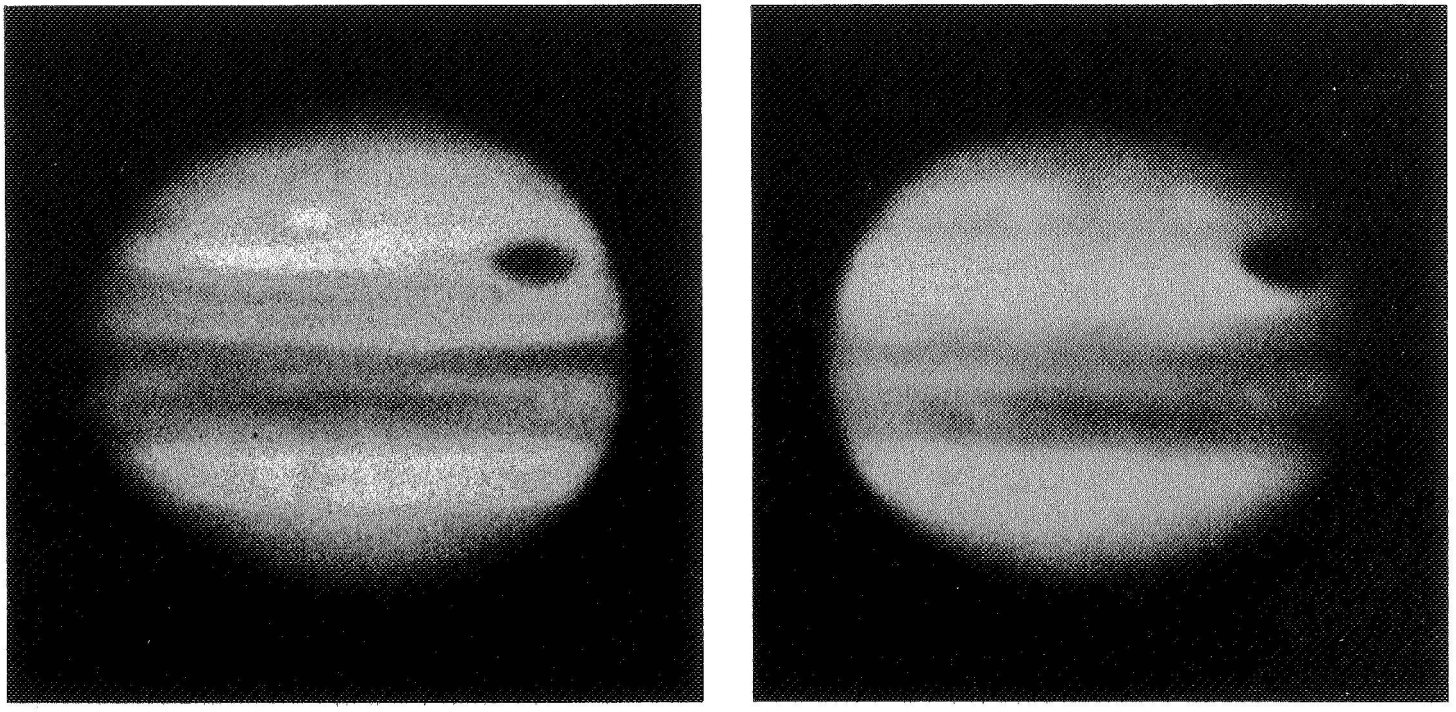

Fig. 1. Two photographs of Jupiter in blue light showing a notable brightening of the southern part of the South Equatorial Belt during the apparition. Left, 4 November 1968, 1306 UT, ω_2 341°, showing the bright oval DE preceding the Red Spot. Right, 16 July 1969, 0259 UT, ω_2 341°. South is at the top and the direction of rotation is from right to left. All of the photographs in this report were taken with a 61-cm reflector.

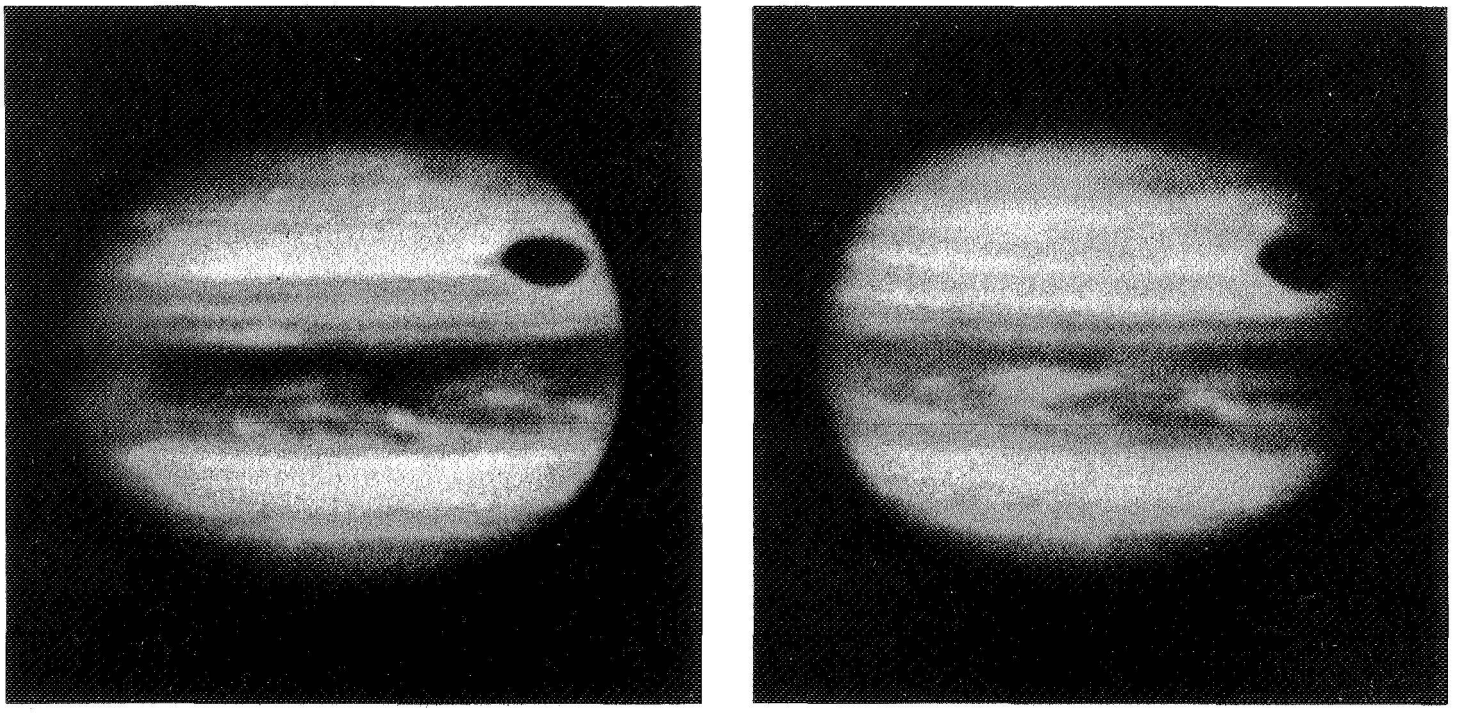

Fig. 2. Two photographs of Jupiter in blue light showing a fading of the south component of the South Equatorial Belt. Left, 13 January 1969, 1050 UT, ω_2 335°; right, 23 April 1969, 0310 UT, ω_2 334°. Dark spots shown on south edge of N. N. Temperate Belt.

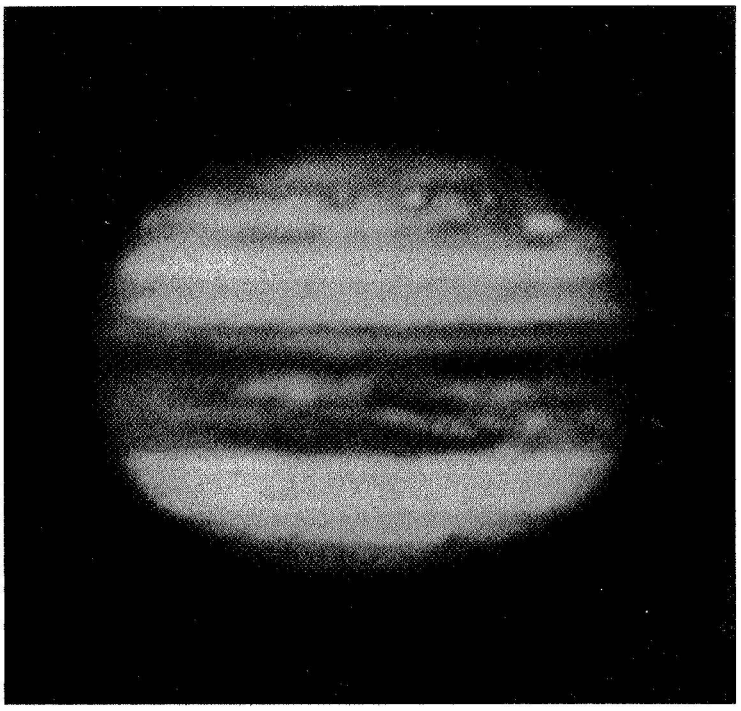

Fig. 3. Jupiter in blue light, 26 March 1969, 0606 UT, ω_2 190°, showing three bright spots in the South Temperate Zone preceding the oval DE. Dark spot number 1 is shown on south edge of N. N. N. Temperate Belt.

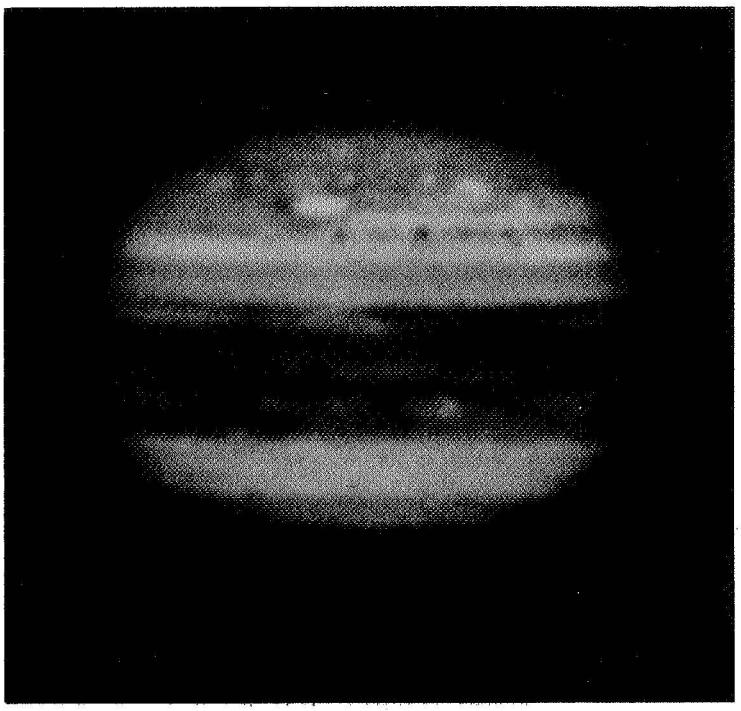

Fig. 4. Jupiter in blue light, 22 April 1969, 0427 UT, ω_2 230°, showing great activity in the South Temperate Belt and South Temperate Zone.

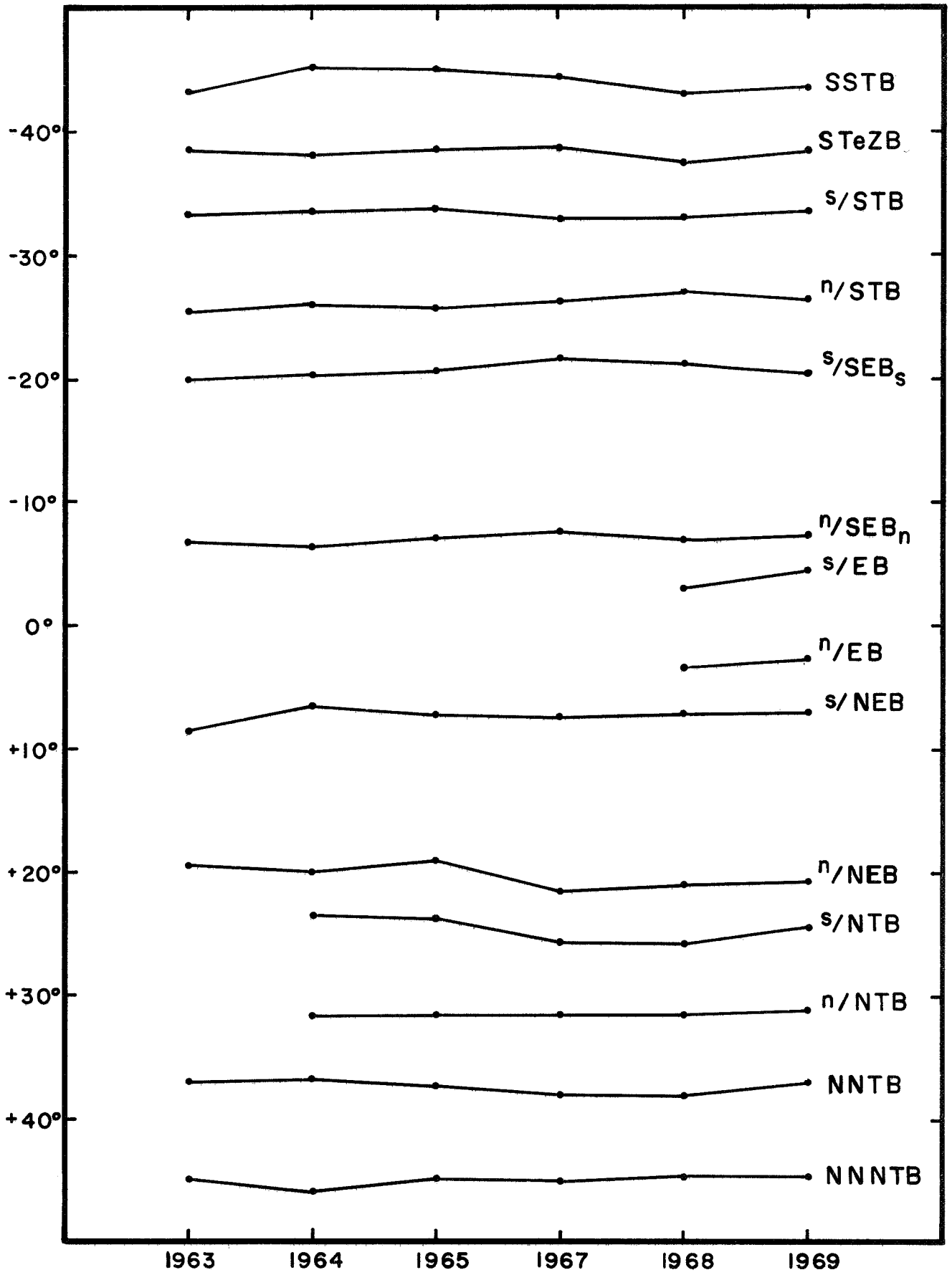

Fig. 5. Gradual changes in the zenographic latitude of Jupiter's belts during the last six apparitions.

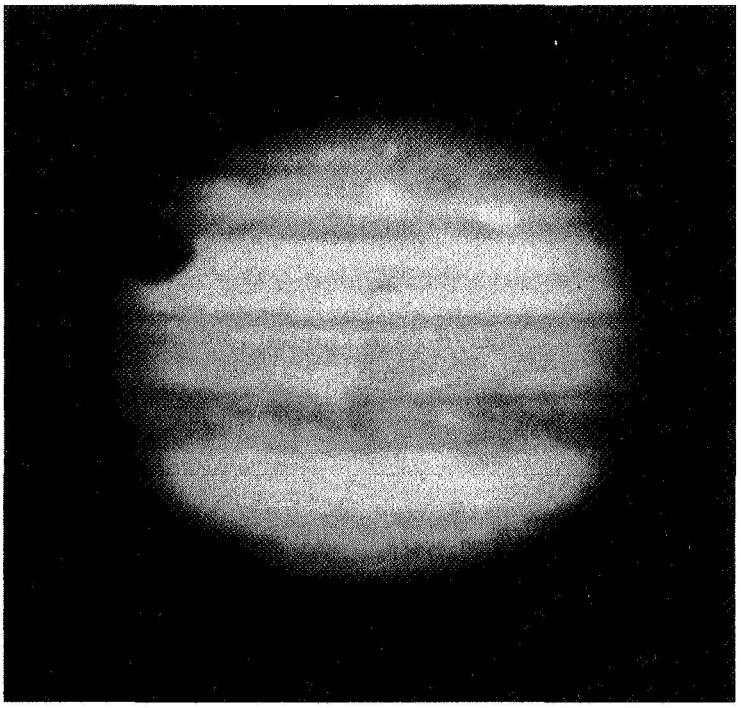

Fig. 6. Jupiter in green light, 21 April 1969, 0427 UT, ω_2 80°, showing a solitary dark spot which persisted for several months in the South Equatorial Belt about 40° following the Red Spot.