NO. 178 INITIAL DEVELOPMENT OF THE JUNE 1971 SOUTH EQUATORIAL BELT DISTURBANCE ON JUPITER

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ABSTRACT

Photographs taken with the Catalina 61-inch reflector from June 21 through July 10, 1971 have enabled the author to study and measure the early developments of a major South Equatorial Belt (SEB)disturbance. High-resolution photographs of the disturbance were obtained on seven nights during the 19-day interval. Our first photograph at 04:38 UT on June 21 recorded the initial outbreak at $79\overset{\circ}{.}5$ longitude (System II), and -14° Zenographic latitude. From this point, dark spots moved along the SEBs towards increasing longitude, and white spots a short distance along the SEBn towards decreasing longitude. The preceding white spot in Figure 18 had an initial period of $9^h54^m32\overset{s}{.}5 \pm 3\overset{s}{.}5$, and retrograding dark spots on the SEBs a mean period of $9^h58^m30\overset{s}{.}5 \pm 7^s$. The feature from which all the spots emerged had a rotation period of $9^h55^m29^s \pm 2\overset{s}{.}5$, and is close to the System III radio period of $9^h55^m29\overset{s}{.}73 \pm 0\overset{s}{.}04$ derived by Carr.

1. Introduction

Major South Equatorial Belt (SEB) disturbances have been recorded about a dozen times beginning in 1919 (Chapman and Reese, 1968). They are recognized by their common characteristics. Initially, a small white or dark spot, or a faint wisp is seen within the SEB Zone (SEBZ). From this point, the seat of the disturbance, dark spots move along the S component of the SEB (SEBs) towards increasing longitude in System II. These are known as the "retrograding dark spots". Also, white and dark spots leave the seat of the disturbance and move along the SEBn towards decreasing longitudes. The SEBn is in System I, but during a disturbance, the change in longitude is usually expressed relative to System II. The SEBZ becomes filled with many spots, wisps, columns, and loses its conspicuousness when the retrograding dark spots reach its vicinity. The June 1971 disturbance was a major one with above-average activity, although the Red Spot has failed to fade.

2. Observations

Mr. W. E. Fox, Director of the Jupiter Section of the B.A.A. was probably the first person to see and recognize the importance of a small white spot located in the SEBZ of Jupiter, June 21, 1971. (E. J. Reese discovered a second disturbance on July 18, 1971 near $\lambda_2 = 144°$). As a guest and consultant of the Lunar and Planetary Laboratory, using the Catalina 61-inch telescope, Fox estimated the time of Central Meridian (CM) passage of the spot, made a sketch, and alerted the photographic team to its nature and importance. Previous photographs, taken with the 24-inch reflector on Mauna Kea on June 18, indicate that a white spot was present then near the limit of visibility in blue light, but invisible in red light (Baum,1971). Our 61-inch photos of June 16 fail to show anything unusual near the longitude of the outbreak.

At Catalina Observatory on June 21, 04:38 UT, the white spot was seen and photographed at longitude 79°.5 (System II) and latitude -14°. When near the CM it was the brightest feature on the disk at all observed wavelengths (3100-8800Å). However, its contrast against the SEBZ became less as it approached the preceding limb. It was faintly recorded June 21, 06:00 UT in blue light, and just barely at 06:10 UT in infrared. There were no "irradiating" spots (Peek, 1958) photographed during the interval of June 21 to July 10, 1971.

On June 28 and July 10, Jupiter was photographed with the 61-inch in the 8860Å methane band. The white spots preceding the center of the disturbance were much brighter on the methane photo than on the infrared photo, 6550-8800Å (10% passband limits). This indicated they were relatively high in the Jovian atmosphere, but the lack of irradiation suggests they were not extremely high. Examination of color and black-and-white photographs consistently revealed the SEBZ spots preceding the center of the disturbance as *white*, the oblique column bridging the SEBn and SEBs as *red*, the seat of the disturbance as *red*, and the retrograding dark spots as *blue*.

Table I lists the observational records for the 17 composites here shown, including the number of images combined in each composite. These composites were prepared and measured by the author. The increase in contrast permitted recognition and measurement of features barely seen on original negatives. The summer rains prevented observations much beyond the 19 days here covered.

TABLE I

Observational Data on Photographs

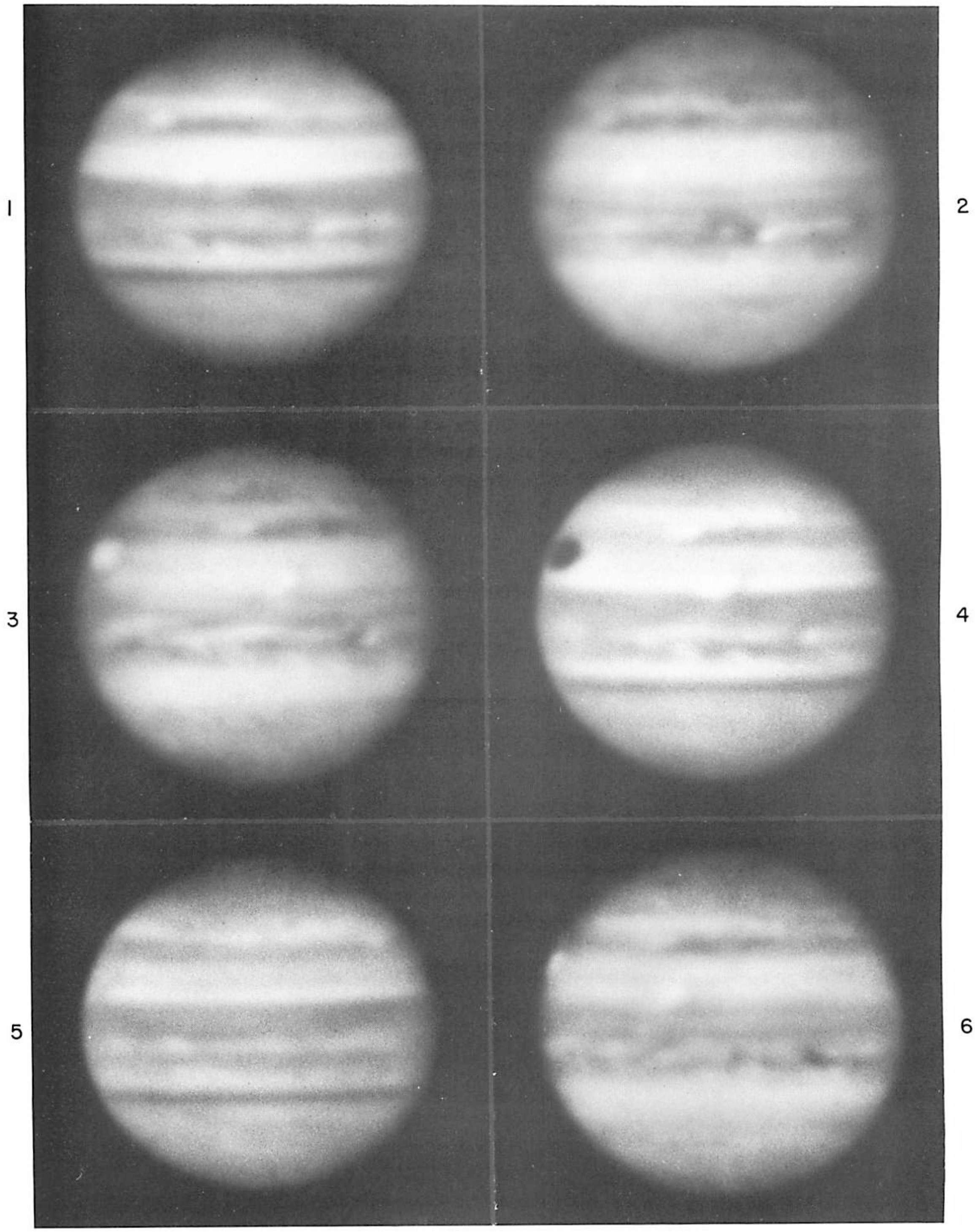
Fig.	Date 1971	UT	Color	Film	Filter	Roll #	Compos.	No.
1	21 June	04:50:30	B	103-0	NF	1399	1286	7
2	21 June	05:01:34	IR	HSIR	GG-14	1400	1305	10
3	23 June	05:43:34	IR	HSIR	RG-5	1407	1306	6
4	23 June	05:49:03	B	103-0	NF	1408	1287	4
5	26 June	05:08:00	UV-B	103-0	NF/UG-5	1418	1288	3
6	28 June	05:10:44	IR	HSIR	GG-14	1423	1289	4
7	28 June	05:16:39	UV	103-0	UG-5	1424	1290	4
8	6 July	03:45:51	B	103a-0	NF	1442	1292	5
9	6 July	04:01:08	IR	HSIR	GG-14	1443	1291	5
10	7 July	07:00:43	UV-B	103-0	NF/UG-5	1453	1285	12
11	7 July	07:06:26	IR	HSIR	RG-5	1454	1293	7
12	10 July	04:16:21	B	103-0	NF	1457	1294	6
13	10 July	04:24:39	IR	HSIR	RG-5	1458	1295	6
14	10 July	04:38	8990Å	HSIR	8900Å	1459	1301	3
15	10 July	05:14:39	G	Plus-X	GG-14	1462	1297	6
16	10 July	06:05:42	IR	HSIR	GG-14	1467	1298	5
17	10 July	06:27:24	UV-B	103-0	NF/UG-5	1469	1299	5

3. The Measures

The longitude measures were made on 65-mm diameter composites using a milimeter scale, aligned parallel to the equator, and with estimates to the nearest 0.2 mm. Measures of the same features on different composites were generally consistent to within 1° near the CM and 3° near the limb. A least-squares analysis of all longitude measures indicates that the mean standard deviation of a longitude determination is $0\overset{\circ}{.}9$. Latitudes were similarly determined, but only near the CM. Measures were reduced by an IBM 1130 computer with a program written by H. Gordon Solberg. His measures of a few of the more prominent features on a digitized Mann measuring machine provided a check.

Figure 18 shows a drift chart of the features measured. On June 26 they were so near the limb that only their separations were measured. Their absolute longitudes were located by a visual best fit. The Red Spot was measured near the CM and drawn with its following end at System II (λ_2) longitude 20° for the entire interval. No interaction with the disturbance was noted.

Of the two major and other minor preceding white spots in the SEBZ, the brightest (marked WS in Fig. 18) was also the longest lived, and can be identified as the June 21 white spot representing the initial outbreak. From June 21 to July 7 it remained near -14° latitude, with a period of $9^h54^m32\overset{s}{.}5 \pm 3\overset{s}{.}5$. On July 10, however, its latitude was -12°, placing it in apparent contact with



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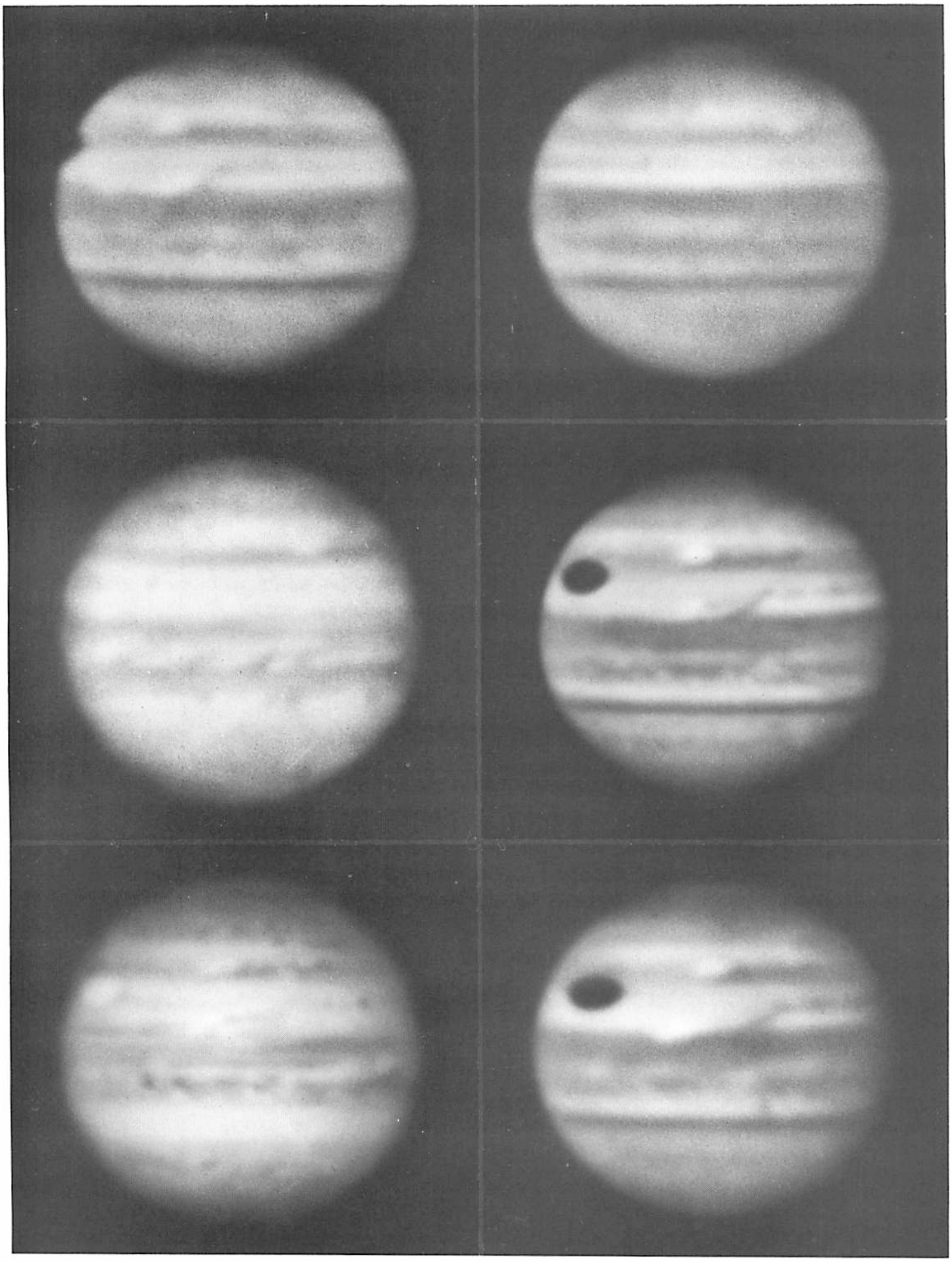
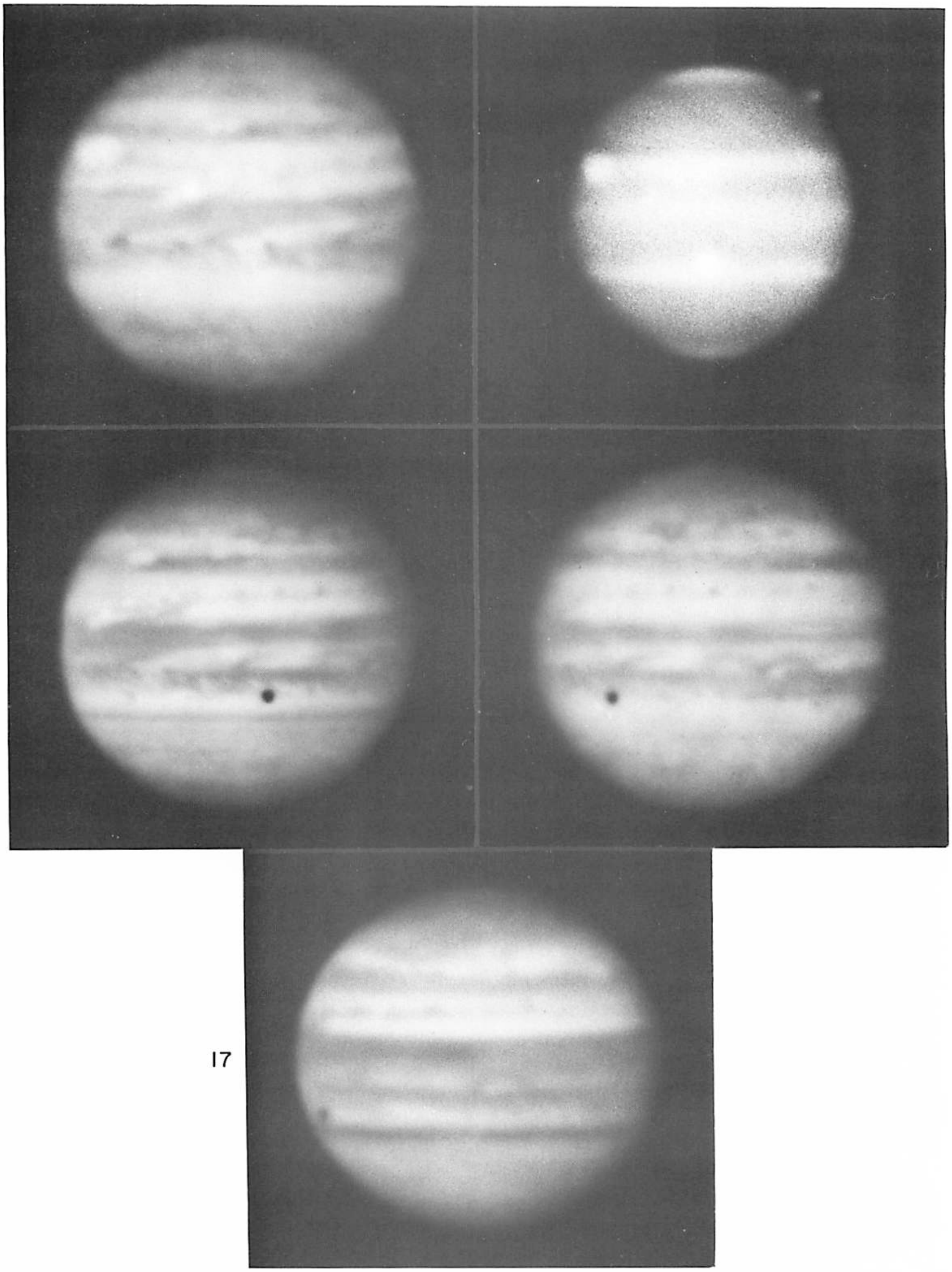


7 8 9 10 11 12



13 14

15 16

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the SEBn, which was rotating close to that of System I. Its longitude increased by 6° in this 3-day interval over what was projected, yielding an approximate period of $9^h54^m19^s$. This rapid decrease in period, as the SEBn is approached, is well illustrated by the increasing curvature of the dark (in blue light) column joining the SEBn and SEBs, as time progresses. The other minor SEBZ white spots were evidently torn into invisibility upon reaching the SEBn, as none were photographed proceeding toward decreasing longitudes. Three factors indicate that the long-lived WS was higher in the Jovian atmosphere than any other SEBZ white spots. First, the others were swept into invisibility upon reaching the SEBn. Second, WS is the more prominent one shown in the July 10 methane photograph (Fig. 14). Third, and most important, shortly after July 10, WS crossed *over* the SEBn into the Equatorial Zone (Reese, personal communication). This suggests that this cloud, some 5,000 km in diameter, was not attached to the visible cloud deck. The fact that WS accelerated toward decreasing longitudes upon reaching the latitude of the SEBn, suggests the presence of an atmospheric current above the SEBn cloud deck rotating in the same direction, but with a longer period. Scarcity of observations prevents more quantitative interpretation. In past disburbances, dark spots advanced along the SEBn by 4-9° per day, and white spots"retrograded"along the SEBs 3-5° per day (Peek, 1958), which may be compared with the drift rates found in Table II.

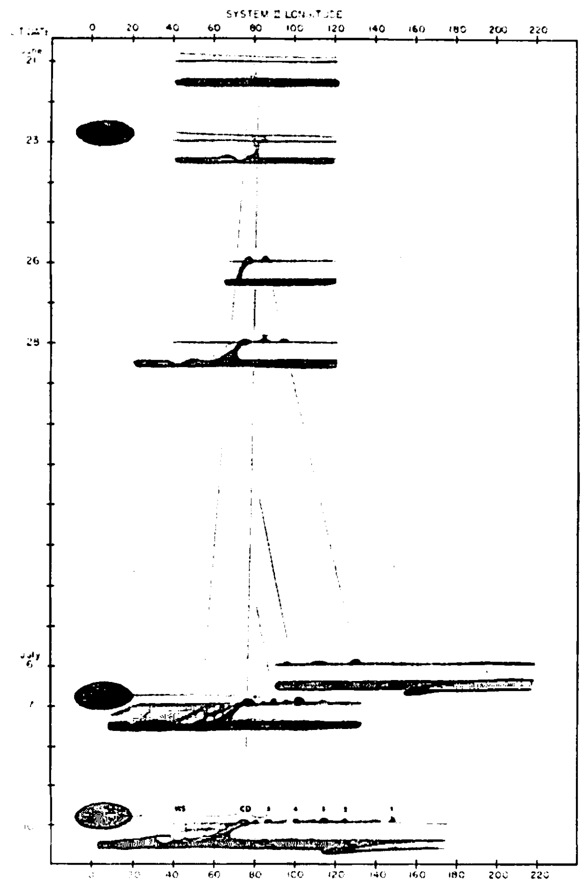

Fig. 18 Drift chart of June 1971 SEB disturbance from June 21 to July 10. Each day tick mark also represents -18° Zenographic latitude in the sketches, with their vertical scale 2° per small square in both coordinates

The most interesting result of the measures is that the seat of the disturbance had a period of $9^h55^m29^s \pm 2\overset{s}{.}5$ between June 21 and July 10, 1971. This period is quite close to the System III radio period of $9^h55^m29\overset{s}{.}73 \pm 0\overset{s}{.}04$ (Carr, 1970). In 1953, Reese suggested that the observed longitudes of the *initial* outbreaks of SEB disturbances might be consistent with one or two Jovian surface features rotating with one *uniform* period (Reese, 1953). It had also been observed by Reese and others that in the course of a disturbance, spots appear to erupt from a point rotating closely with that of System II ($9^h55^m40\overset{s}{.}643$). The seat of the June 1971 disturbance rotating at nearly that of System III strengthens the 1953 Reese hypothesis. Very recently, Reese has plotted the outbreaks of the twelve disturbances in System III, and has found an even closer fit than the 1968 determination (Chapman and Reese, 1968; Reese 1972). Of the three indicated source longitudes, the outbreak of June 18, 1971 was less than 1 degree from the longitude of the primary source. The longitude of this source is given by $\lambda_2 = 353\overset{\circ}{.}1 - 0\overset{\circ}{.}25627$ (JD - 2435839.5).

By July 10, five dark spots were retrograding along the SEBs. The first had the longest period, consistent with some past disturbances. Its period was $9^h58^m46^s \pm 2^s$. Spot No. 3, the darkest, had a period of $9^h58^m18^s \pm 10^s$; and No. 4 a period of $9^h58^m18^s \pm 10^s$. Spots Nos. 2 and 5, which were only measured once, were assumed to rotate with the period of Nos. 3 or 4 in order to estimate their dates of formation. This date of formation was determined by a least-squares analysis of the longitude of the spot versus the longitude of the seat of the disturbance. The mean interval between formations was 2.8 days. This regular spacing of SEBs spots is well illustrated in Slipher (1964, p. 97, lower left). By July 10, 1971, each dark spot had one or more white spots associated with it. In some cases their Northerly latitude produced apparent breaks in the SEBs, or at least a reduction in its width. The dark SEBs spots retrograded at a maximum of 135° per 30 days. At this rate of drift, it was calculated that the first spot would be N of the preceding edge of the Red Spot near August 24, 1971. Photographs at Catalina Observatory at this longitude and date were not obtained, but subsequent photographs show the SEBs curving to the N, avoiding the Red Spot. As of October 14, 1971 our photographs show the Red Spot as prominent as ever during the 1970-71 apparition.

TABLE II: Bright SEBZ and Dark SEBS Spots

Spot	Period	Drift per day	Nm	Np	Dates Measured	Date Formed	Formation Interval
WS	$9^h54^m32\overset{s}{.}5 \pm 3\overset{s}{.}5$	$-1\overset{\circ}{.}67$	4	4	Jun 21-Jul 7	--	--
WS	9 54 19 ±4	-3.7	2	2	Jul 7-10	--	--
1	9 58 46 ±2	+4.5	3	4	Jun 28-Jul 10	Jun 24.6	--
2	9 58 43*	+4.4*	1	2	Jul 10	Jun 28.1	$3\overset{d}{.}5$
3	9 58 43 ±10	+4.4	3	3	Jul 6-10	Jul 1.8	1.7
4	9 58 18 ±10	+3.8	2	2	Jul 7-10	Jul 4.6	2.8
5	9 58 18*	+3.8*	1	1	Jul 10	Jul 7.7	3.1

Nm: Dates measured; Np: Dates photographed; * Assumed, not calculated

5. Conclusions

The basic 1953 Reese hypothesis, of *constant* rotation period of the SEB sources, together with his 1972 revised source rotation period, is strengthened by two facts. The longitude of the initial outbreak was 1 degree from the predicted longitude of the primary source, and the seat of the disturbance drifted $-8.^{\circ}23 \pm 2.^{\circ}2$ per 30 days or moved nearly with System III. The Kuiper hypothesis of the recurrent nature of the SEB disturbances is that because the meteorology of Jupiter is internally driven, a temperature inversion builds up and eventually breaks through the visible cloud deck (Kuiper, 1972). The period of this meteorological relaxation time is calculated to be about 8 years. Both hypotheses are satisfied if one assumes that a surface feature *triggers* the outbreak near the longitude of this feature. The simultaneous display of two SEB disturbances would seem to favor the meteorological explanation; otherwise one is faced with the improbability of two nearly simultaneous volcanic-type eruptive processes occurring some 120° of longitude apart. However, an eruptive process is not vital to the validity of the Reese hypothesis. On the other hand, the properties of WS suggest a violent ejection and transport in the higher atmosphere. Kuiper (1972) points out that a deep solid surface of Jupiter probably exists. The three source longitudes determined by Reese have remained fixed and retained their identities for 52 years.

A thorough search of observational material may show whether prior disturbances rotated closely with that of System III. This period may have existed for a fraction of the lifetime of the 1928 SEB disturbance. According to observations by the Jupiter Section of the B.A.A., the seat of eruption "showed accelerated motion in the direction of diminishing longitude", and over a 17-day interval, had a drift of -19° per 30 days (Phillips, 1935). In addition, the center of eruption of the 1958 disburbance had a period of $9^h55^m33^s$ from April 19 to 30, 1958 (Reese, personal communication). The need exists for additional investigations by Jupiter observers and meteorologists.

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REFERENCES

Baum, W. A. 1971, "Observations of New Major Disturbances on Jupiter", *Sky and Telescope*, *42*, 176-180.
Carr, T. D. 1970, "The Twelve-Year Periodicities of the Decametric Radiation of Jupiter", *Radio Science*, *5*, 495-503.
Chapman, C. R. and Reese, E. J. 1968, "A Test of the Uniformly-Rotating Source Hypothesis for the South Equatorial Belt Disturbances on Jupiter", *Icarus*, *9*, 326-335.
Kuiper, G. P. 1972, *Sky and Telescope*, Jan,,Feb issues; *LPL Comm. No. 173*.
Peek, B. M. 1958, THE PLANET JUPITER (London: Faber and Faber).
Phillips, T. E. R. 1935, "Twenty-Seventh Report of the Section for the Observation of Jupiter", *Mem. of the B. A. A.*, *30*,213.
Reese, E. J. 1953, "A Possible Clue to the Rotation Period of the Solid Nucleus of Jupiter", *J. Brit. Astron. Assoc.*, *63*, 219-221.
Reese, E. J. 1972, "Jupiter: Its Red Spot and Disturbances in 1970-71", New Mexico State University Observatory TN-72-40.
Slipher, E. C. 1964, A PHOTOGRAPHIC STUDY OF THE BRIGHTER PLANETS (Lowell Obs. and NGS).