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A HIGH-VELOCITY OUTBREAK ON THE NORTH TEMPERATE BELT

At certain latitudes on Jupiter there are very rapid jet streams, which climatic models[1] attribute to material flowing off the bright zones into the dark belts. The jet streams are normally observed only during violent outbreaks, and 1975 witnessed two such events in different latitudes. Although that in the South Tropical region was the more spectacular[2], one in the North Tropical region was equally sudden, and spots created in it had the fastest velocities ever observed on Jupiter.

Fifteen observers provided material for this report; a list of them will appear in the final report on the apparition.

Description of the Disturbance

The outbreak took place in the North Tropical Zone (NTropZ) and on the south edge of the North Temperate Belt (NTBs), and consisted of white spots separated by dark projections or spots.

The first group of three white spots was discovered on September 23–24, by M. Foulkes, P. B. Withers, and T. Broadbank. The region had been clear, apart from the usual white spots in the North Tropical Current (NTropC), two and three nights earlier. The white spots, about 8° long, were involved with the narrow, disturbed south component of the NTB [NTB(S)]. At high resolution, the dark spots between them were seen to be very dark chunks of NTB(S), and very small oval white spots could be detected just north of the NTB(S) (e.g. fig. 1).

The main disturbance moved at – 13° per day in System 2 (fig. 5 and Table I). Spots 1 and 4, some 74° apart, marked its outer limits at first, but by late October minor humps and holes further preceding extended it to a length of some 170°.

There was also a secondary disturbance, first seen as a single black spot on the NTBs by Broadbank on September 23–24. A typical white spot (spot 6) soon appeared, but faded by October 5: a thinning of NTB(S) may or may not have represented it thereafter. Preceding the spot was a disturbed stretch of NTB(S), which moved like the main disturbance.

The main disturbance revived briefly in early December, with several new white spots, but by late December all but a few vague dark spots had faded out. Most of the NTropC white spots had also gone. The NTropZ, which had been bright white before the outbreak, was then left unevenly but strongly shaded, and deficient in blue. It was lighter again in early 1976 but still yellowish. The NTB as a whole remained dark and neutral in colour throughout, but P. J. Young's observations show that the NTB(S) ended up much stronger than before.

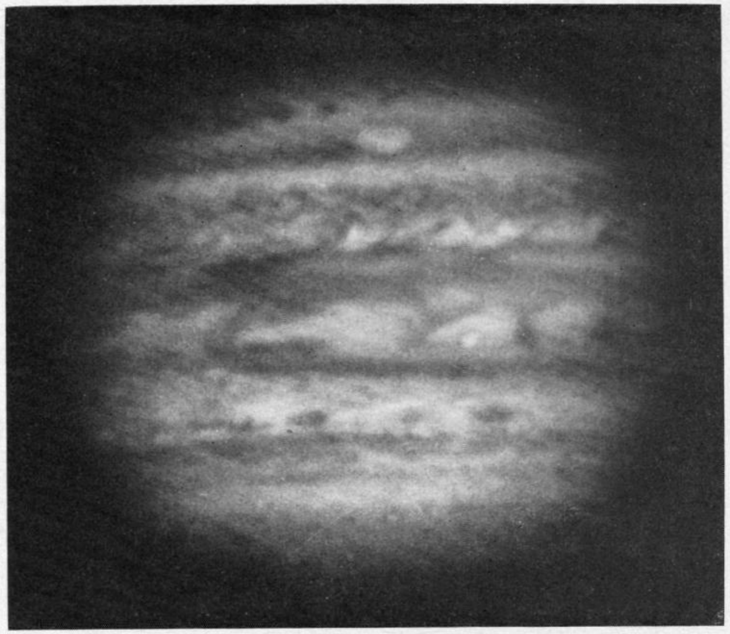

FIGURE 1. 1975 Oct. $2^d\,22^h\,40^m$ UT. $\omega_1 = 314°$, $\omega_2 = 186°$. 1070 mm Spec., yellow filter. Photograph by C. Boyer.

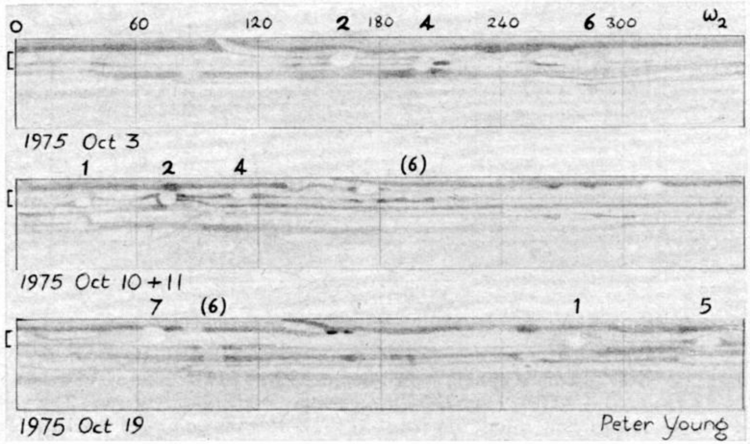

FIGURE 2. Maps of northern hemisphere, with NTropZ indicated. 220 mm OG, ×200. P. Young.

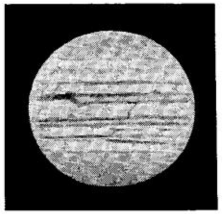

FIGURE 3 (*left*). 1975 Sept. $23^d 22^h 15^m$ UT. $\omega_1 = 317°$, $\omega_2 = 257°$. 254 mm Spec., ×195. M. Foulkes.

FIGURE 4 (*right*). 1975 Nov. $13^d 21^h 08^m$ UT. $\omega_1 = 54°$, $\omega_2 = 326°$. 390 mm Spec. Photograph by H. Dall.

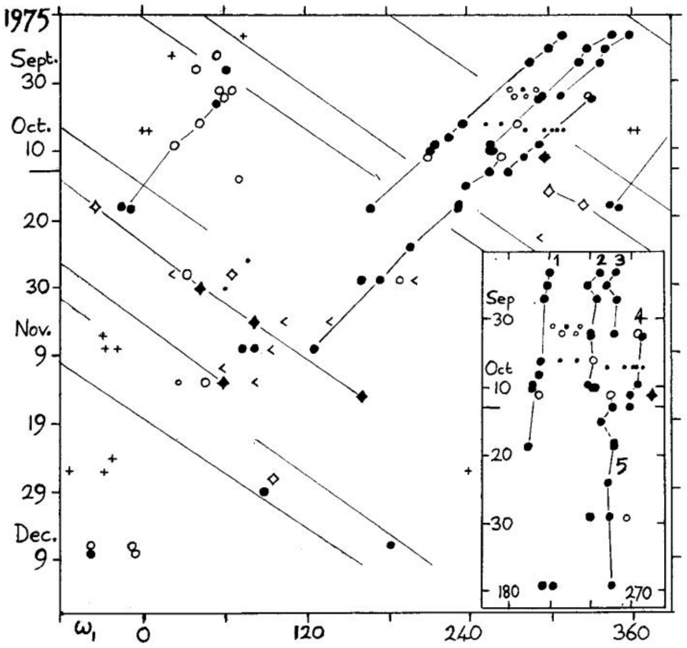

FIGURE 5. Chart of the disturbance in System 1. Circles, white spot in northern NTropZ or NTBs bay. Diamonds, white spot in southern NTropZ: diagonal lines indicate others, moving with NTropC. NTBs projections (crosses) and preceding ends of NTB(S) (ticks) are shown where there are no white spots to define the disturbance. The inset shows the same features in a system moving at −5° per day relative to System 1 and coincident with it on the night after opposition (Oct. $13^d 24^h$).

TABLE I

OBSERVATIONS OF WHITE SPOTS

Spot	*Dates observed and no. of reliable longs ( )*	*ω_1 when first observed*	*ω_1 at opp. (Oct. 13/14)*	*Change in ω_1 per 30d*	*Period*
1	Sept. 23 – Oct. 19 (8)	310	197	−169	$9^h 46^m 43^s$
2	Sept. 23 – Oct. 11 (7)	348	(238)	−158	$9^h 46^m 58^s$
3	Sept. 23 – Oct. 2 (4)	359	(254)	–	–
4	Oct. 2 – Oct. 14 (4)	330	270	–	–
5	Oct. 11 – Nov. 9 (7)	264	256	−150	$9^h 47^m 08^s$
6	Sept. 27 – Oct. 19 ? (4)	74[c]	10	–	–
7	Oct. 16 – Dec. 9 (3)	270[a,b]	(279)[b]	+219[b]	$9^h 55^m 27^s$

NOTES: a Large white spot on Oct. 13/14, also identified as spot 4.
b Corresponding ω_2 values are: 58, (67), −10.
c Dark spot on Sept. 23/24.

TABLE II

OBSERVATIONS IN MID-OCTOBER
(ws = white spot)

Date	*Observer*	*Spot 2*	*Spot 3 (5)*	*Spot 4*
Oct. 10	PY	ws breaking disturbed NTB(S)	(Absent)	Gap in NTB(S)
Oct. 10/11	TB	*Very large, very bright ws*		
Oct. 11/12	DG	(NTB(S) thin: no ws)	*Flattened ws breaking NTB(S)*	Slight bay in NTB(S)s
Oct. 13/14	DH, RP, TB	(Active but no ws)	Bright ws in NTropZ between bridges	*Large ws in NTropZ*
Oct. 15/16	DH	(Active but no ws)	Small brilliant ws in NTBs	

OBSERVERS: T. Broadbank, 220 mm Spec.; D. Gray, 250 mm Spec; D. Hitchens, 220 mm Spec.; R. Paterson, 320 mm Spec.; P. Young, 230 mm OG.

INDIVIDUAL SPOTS

Of the three initial spots, spot 1 was the brightest and longest-lived, and spot 3 the shortest-lived (fig. 5 and Table I). A fourth spot, which appeared after September 27–28, was distinctly white only at its first presentation.

In mid-October a dramatic burst of activity affected the main disturbance. It appears that each spot in turn was re-ignited, starting with spot 1 which had disappeared around October 2 but revived by October 6–7. Table II shows that new white spots were then observed in the positions of spots 2, 3 (previously absent), and 4, although it should be borne in mind that almost every event in this sequence depends on a single observation only.

From this activity only two spots persisted. One, spot 5, most likely came from the revived spot 3, and was recorded as bright on every occasion until November 9, when it was just a gap in the NTB(S). The other, remarkably, was a large white area moving with the NTropC—spot 7. This generally lay further north than the other NTropC spots, often spanning the NTropZ. It may even have emerged from the revived spot 4 of October 13–14 (Table I), but as with spot 5 the early identifications are not entirely secure.

Discussion

The outbreak described here, like previous ones on the NTBs, clearly belongs to the North Temperate Current C (NTC-C), which is the fastest current on the planet. However, the 1975 rotation period of $9^h 46^m 56^s$ (mean of spots 1, 2 and 5) is far shorter than the current's mean period ($9^h 49^m 07^s$, 1926–43)[3]. The only previous feature with a comparable period ($9^h 47^m 03^s$) was a solitary NTBs white spot in 1970[6].

The 1975 outbreak was also unusual in being dominated by white spots. Previous outbreaks have consisted mainly of small dark spots, although small white spots were sometimes seen between them[4, 5], perhaps analogous to the smaller more northerly ones of 1975. Fig. 1 shows some of these persisting where spots 1 and (perhaps) 3 had temporarily disappeared, and it seems possible that they were the sources of the more complex main spots.

The appearance of spot 7 in the NTropC is without precedent in NTBs outbreaks, although spots do diverge on different currents in SEB outbreaks. Spot 7 may originally have been an NTBs spot, which survived the violent shearing between the currents that is illustrated in fig. 1. The overall changes in the NTropZ, which became dusky yellow, are typical of these outbreaks. Despite its energy, the 1975 outbreak was less extensive and less long-lived than those of 1929–31 and 1939–43[4, 5].

Similar outbreaks occur on the NNTBs, usually a few months after a NTBs outbreak (see Appendix). None had been observed this time up to 1976 February. One may also expect to see an intermediate rate of drift within the NTB itself, the NTC-B, about two years after the NTBs outbreak.

APPENDIX

History of Global Upheavals

The close coincidence of the 1975 outbreaks on the SEB and NTBs prompts enquiry into any relationship between them. Wacker[10] has proposed that outbreaks in both regions occur as parts of organized global upheavals, which typically progress according to the following scheme (modified from ref. 10):

T = −1 yr	SEB(S) is very faint and GRS prominent. GRS rotation period increases. EZ becomes dusky orange with active white spots in the north.
T = 0	SSTC invades STB. SEB outbreak, causing GRS to fade and (in some years) spots on STBn.
T = +1 to 2 yr	NEB outbreak. NTBs and NNTBs outbreaks. EZ quietens and becomes more bluish.
T = +3 to 4 yr	NTC-B appears in NTB.

Table III

Date of First Observation of each Episode of Activity on the Rapid Jet Streams, plus each comparable outbreak on SEB or NEB

The table includes all recorded episodes except for SSTC extensions in 1887–88, 1911, and 1956; NEB outbreaks of 1896–1915; SEB outbreaks of 1946-58; and CC(S) in 1969. Years in which EZ was especially shaded, outside 1894–1916 and 1944–59, are also indicated. Outbreaks falling outside the standard sequence are shown in italics.

Jet stream	–	SSTC	CC(S)	CC(N)	–	NTC-C	NNTC-B	NTC-B
Location	EZ/EB	SSTBn	STBn	SEB	NEB	NTBs	NNTBs	NTB
Event	Shading	Extension to STBs	Spots	Great outbreak	Outbreak	Outbreak	Outbreak	–
1	1881–86	–	–	1882[a,c]	–	*1880 Oct. 17*	–	–
2	–	–	–	(1892 early)[a,c]	1893 Aug.	*1891 July 11*	–	–
3	1919–20	1919 Dec.	1919–20	1919 Dec. 8	–	–	–	–
4	1925–27	–	–	–	1926[a]	1926 June 15[b]	(1926 July ?)[e]	1928 Aug.
5	1927–29	1928 Nov.	*1931*	1928 Aug. 10	–	1929 Sept. 27	1929 Oct.	1931 Dec.
6	1936–40	1938	1938	(1937 Aug. 5 ?)[a]	1939–41[c]	1939 Sept. 23	1940 Oct.	1941 Dec.
7	1942–44	*1940*	–	1943 Feb. 7	–	*1942 Oct. 5*[d]	d	d
8 }	1961–65	–	{ *1962*[b]	1962 Sept. 23 }	1963 Dec.	1964 July 7[b]	{ 1965 Dec.	–
9 }		–	{ 1965–66	1964 June 10[c] }			{ 1968 Jan.	1969 Feb.
10	1968–72	–	–	1971 June 21	1971–72[c]	*1970 Aug. 12*[b]	1972 Apr.	–
11	1972–	–	–	1975 July 5	–	1975 Sept. 23	–	–
Refs.[f]	–	12	–	13	11	4–7	4, 5, 8	9

Notes:
a Belt revived between apparitions, no drifts recorded.
b Only one spot observed.
c Atypical slow and/or quiet revival.
d Activity remained from 1939–41.
e Disturbance seen but no rapid drifts recorded.
f See also ref. 3 and contemporary reports.

NOTE: Nomenclature of belts, zones and currents is that of ref. 3. T = Temperate, Trop = Tropical, CC = Circulating Current, GRS = Great Red Spot.

This Appendix offers evidence that:

1 almost every outbreak on the rapid jetstreams fits in with this scheme;

2 the character of the upheavals has varied systematically during the past century;

3 the two outbreaks of 1975, with the continued darkness of the southern EZ, represent the latest global upheaval.

Table III lists the occasions on which the various outbreaks have been observed. It includes those of the NEB[11], which, unlike the SEB, does not have a tropical jetstream. The most striking element in the upheaval is the SEB outbreak, but the most consistent is the colour and/or darkening in the EZ and EB. This was present in about 30 of the 56 apparitions since 1878, omitting 1894–1916 and 1944–1959 whose different character is explained below. These 30 apparitions witnessed 9 of the 10 SEB events in Table III, and the 30 following them witnessed 7 of the 9 NTBs outbreaks. Two other dramatic types of disturbance, the South Tropical Disturbances (7 since 1888) and STB Fades (5 since 1961), seem unrelated to the upheavals.

Table III shows that the past century can be divided into five eras according to the varying pattern of the upheavals.

In the *first era*, roughly 1878–94, the present north–south asymmetry was different, with the SEB bearing equatorial projections and the NEB undergoing violent revivals. There were no violent SEB outbreaks, but the two drastic fadings of the GRS, the first being during a quiet SEB revival, did follow closely after the two NTBs outbreaks.

The *second era* had NEB outbreaks, or at least marked revivals, about every three years from 1893 to 1915 inclusive, but no other outbreaks and only occasional EZ activity. The great South Tropical Disturbance appeared and the present north–south asymmetry developed.

The *third era* was that of the four great SEB outbreaks. Each was part of a major global upheaval, with outbreaks elsewhere, major equatorial colouring, and slowing of the GRS.

In the *fourth era*, there were SEB outbreaks every three years from 1943 to 1958 inclusive (assuming one during the 1946 conjunction). There was also some irregular EZ activity, but the GRS decelerations and other outbreaks stopped again until 1958.

The *present era* began with the 1962 SEB outbreak, which was a year late and abortive, and was soon followed by an atypical one which developed slowly during 1964–66. Neither these outbreaks, nor the next in 1971, produced the usual drastic fading of the GRS, which did not occur until the 1975 outbreak. Meanwhile, EZ activity increased again. Small outbreaks also started again in the north, although their frequency makes them difficult to correlate. (This is partly due to the excellent photographic coverage now maintained, without which the NTBs white spot of 1970[6], for instance, would probably have been missed. This spot may have presaged a further unobserved outbreak in early 1971, as the NTB had revived, bright red, by the next apparition, and photographs then show a few small NTBs projections.)

So what will happen next? One could interpret the five eras as displaying systematic migration of the locus of activity, from global to NEB to global to SEB to global. The present era also resembles the first and third in that NTBs outbreaks have been getting increasingly extensive during it. But in many respects each era has been unique.

Since 1962, outbreaks of the SEB, like those of NTBs, have been getting more energetic: in 1975 the SEB outbreak had a record number of sources (four), while the NTBs one had more prominent spots and a faster jetstream than ever before. The past 100 years still offer no sure guide to the outcome of the present crescendo of activity.

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References

1 Williams, G. P. and Robinson, J. B., *J. Atmos. Sci.*, **30,** 684 (1973).
2 Fox, W. E., *J. Brit. astr. Ass.*, **86** (2), 162 (1976).
3 Peek, B. M., *The Planet Jupiter*, London, 1958.
4 Phillips, T. R. S., *Mem. Brit. astr. Ass.*, **32,** Part IV (1937).
5 Peek, B. M., *ibid.*, **35,** Parts I, III, IV (1947).
6 Reese, E. J., *Icarus*, **14,** 343 (1971).
7 Reese, E. J. and Smith, B. A., *ibid.*, **5,** 248 (1966).
8 Minton, R. B., *Commun. Lunar Plan. Lab.*, **9,** 397 (no. 182) (1973).
9 Budine, P. W., *Strolling Astronomer*, **24,** 228 (1974).
10 Wacker, W. K., *ibid.*, **25,** 145 (1975).
11 Wacker, W. K., *ibid.*, **24,** 136 (1973).
12 Reese, E. J., *Icarus*, **17,** 704 (1972).
13 Reese, E. J., *ibid.*, 57.

This paper was republished in the BAA Memoir (vol.43, no.1) 'Jupiter 1973-1977: The Pioneer Years' with the following addendum:

An independent account of the NTBs outbreak has been published by Sanchez-Lavega & Quesada,[5] based on and illustrated by detailed photographs such as Fig. 26. According to these authors, the two outbreaks on opposite sides of the planet began with white spots only on Sep 14. White spot no. 1 was also observed by the Unione Astrofili Italiani from Sep 16 onwards.[8] The speeds given for the white spots by Sanchez-Lavega and Quesada[5] agree with ours, but they also identified slower motions in the disturbed NTB(S) as follows:

White spot no. 1: $\Delta\lambda_1 \approx -173$, *decelerating to* -153.
Dark spots f no. 1 (average of 4): $\Delta\lambda_1 \approx -41$
(P = 9h 49m 35s).
Secondary disturbance (2 bright and 3 dark spots):
$\Delta\lambda_1 \approx -125$ *to* -61, *average* -98 *(P = 9h 48m 19s).*
Two tiny white spots at lat. 26.5°N: $\Delta\lambda_1 \approx +81$
(P = 9h 52m 19s).

These drift rates were approximate (≃±30° per month) but clearly show that a great range of speeds was in operation. Spot no. 1 and some other white spots moved at the unprecedentedly fast rate, while the dark spots trailed behind them at the less extreme rate typical of NTC-C before 1970.[18] All these features were centred at latitudes 22.5°N to 24°N. The tiny white spots at 26.5°N, between NTB(S) and NTB(C), moved with a much slower speed characteristic of the so-called NTC-B. This speed was observed in the NTB about two years after historical NTC-C outbreaks,[18] but was not evident to visual observers either during or after the 1975 outbreak.