Jupiter in 2001/2002

Part II: Local features and drifts

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A report of the Jupiter Section (Director: John H. Rogers)

[Note that this paper forms a continuation from Part I (*J. Brit. Astron. Assoc.,* **118**(2), 75–86 (2008 April). The numbering of figures, tables and references is continuous from Part I where Figures 1–9, and Tables 1–3, may be found.

All the spots and streaks are listed in Tables 4–8 (this paper), and many are identified on Figures 4–6 (Part I).]

S. Polar region

The white spots at 59°S and 50°S may have been the long-lived ones tracked for several years, but they have had wildly varying drift rates, so the identification of the 59°S spot is uncertain. For the 50°S spot (S^3TC no.1 in Table 4) the identification seems more secure, and while its speed still varied, its latitude was correlated with its speed (Figures 10a, 11a, 13g).

Although it lay just S of the chain of SSTB-AWOs, its fluctuations were unrelated to them.

S. S. Temperate region

There was still an array of seven anticyclonic white ovals (AWOs) at 40–41°S, occupying 160° of longitude at opposition; we have named them A1 to A7. The last four were still only 10–20° apart, sometimes converging and rebounding, as in the previous apparition (Table 4; Figures 4, 10c, 11).

In 2002 March, the last pair of them (A6 and A7) converged rapidly and merged (Figure 10b,c). This is the first time such a merger has been directly observed. This merger was anticipated by AC and H–JM, and was followed intensively by all observers who could, especially AC. In spite of often bad seeing conditions across Europe and America, the observers succeeded in obtaining a detailed record of the event. These results have been presented and discussed in detail elsewhere.[14,15] Here we give only a summary of this merger.

It happened during a series of interactions between anticyclonic ovals in the jovian southern hemisphere, while oval BA was overtaking the GRS (see below), and the SSTC-AWOs were in turn overtaking oval BA. While AWO-A7 gradually accelerated, A6 rapidly decelerated around March 10–14, meanwhile drifting N of its typical latitude, until the two ovals came into contact. The final steps of interaction and merger were very rapid, lasting only a week (Figure 10b). The two ovals orbited round each other anticlockwise through at least 360° over March 21–28, and were definitely a single AWO thereafter. Meanwhile a cyclonic white oval between the two AWOs brightened (March 21) (SSTC no.8 in Table 4, labelled C1 on Figure 10b), then it disappeared or became unresolvable from the merging AWOs; then a cyclonic white oval appeared Nf. the merged oval (March 25) (no.9, labelled C2), moving much more slowly. This may have been the same cyclonic oval, ejected in the merger.

▸ *Superhump periods in the dwarf nova SDSS J0824 (continued)*

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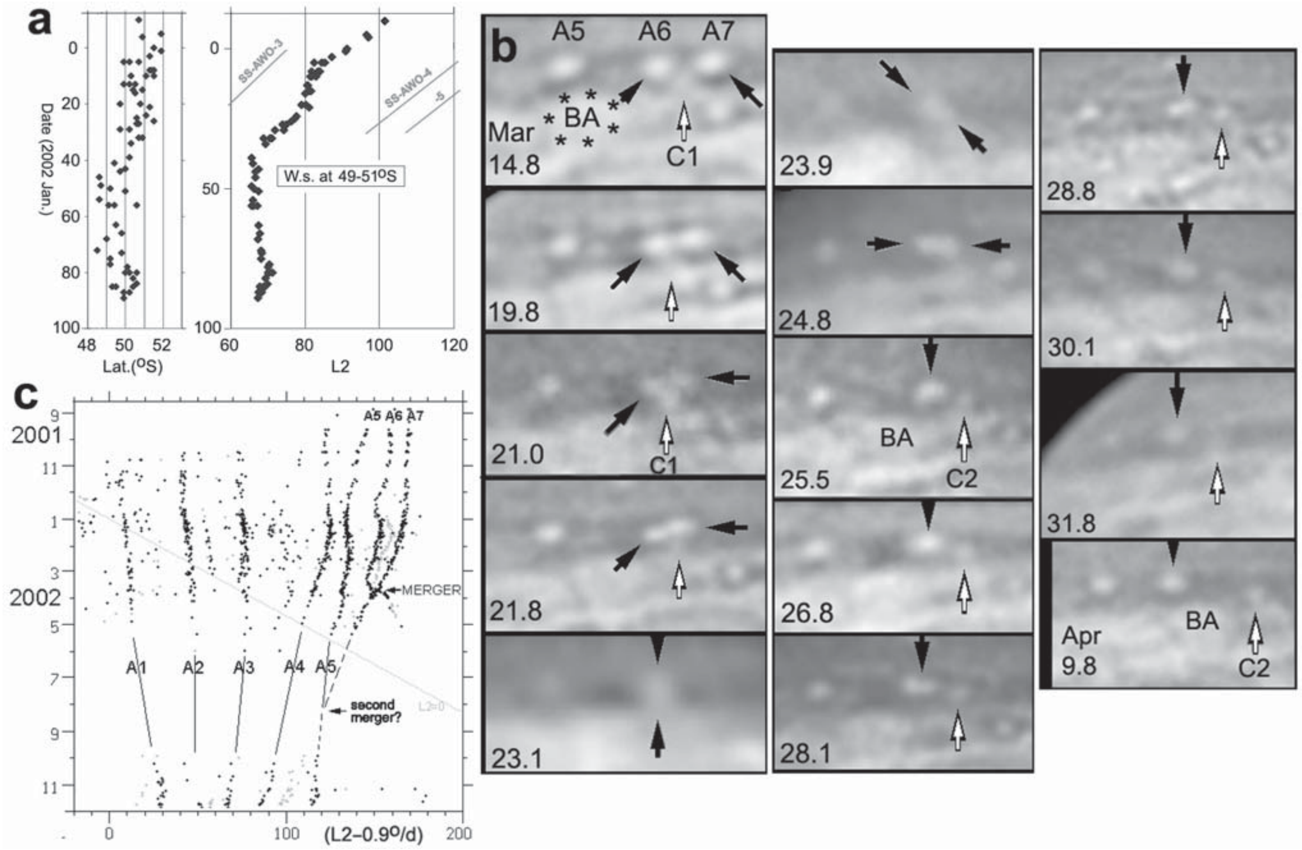

Figure 10.
(a) Latitude and longitude variations of the white spot at 49–51°S. The tracks of SSTC ovals A3 to A5 are shown for comparison.
(b) Merger of SSTC ovals A6 and A7. The two AWOs are indicated by black arrows; cyclonic white spots by white arrows (C1 = no.8 in Table 4, C2 = no.9, possibly the same oval). After 2002 March 24 a single AWO is marked but it is clearly still double on April 28–30. These AWOs were passing oval BA which was passing the GRS (see Figures 6 & 11 for context).
Images were taken by the following observers: 2002 March 14.8, 19.8, 21.0, Cidadão; March 21.8, Cidadão (similar by Coelho), with I-band image by Peach; March 23.1, Sherrod (in bad seeing); March 23.9, Coelho (similar by Peach); March 24.8, Peach; March 25.5, Tan; March 26.8, Cidadão (similar by Coelho); March 28.1, Grafton; March 28.8, Cidadão (similar by Peach); March 30.1, Parker; March 31.8 and April 9.8, Cidadão.
(c) Longitude chart of the SSTC white ovals. Black, latitudes –43 to –40° (anticyclonic, A1 to A7); grey, –40 to –37° (cyclonic). A7 merged with A6 in March, and probably with A5 during the subsequent solar conjunction.

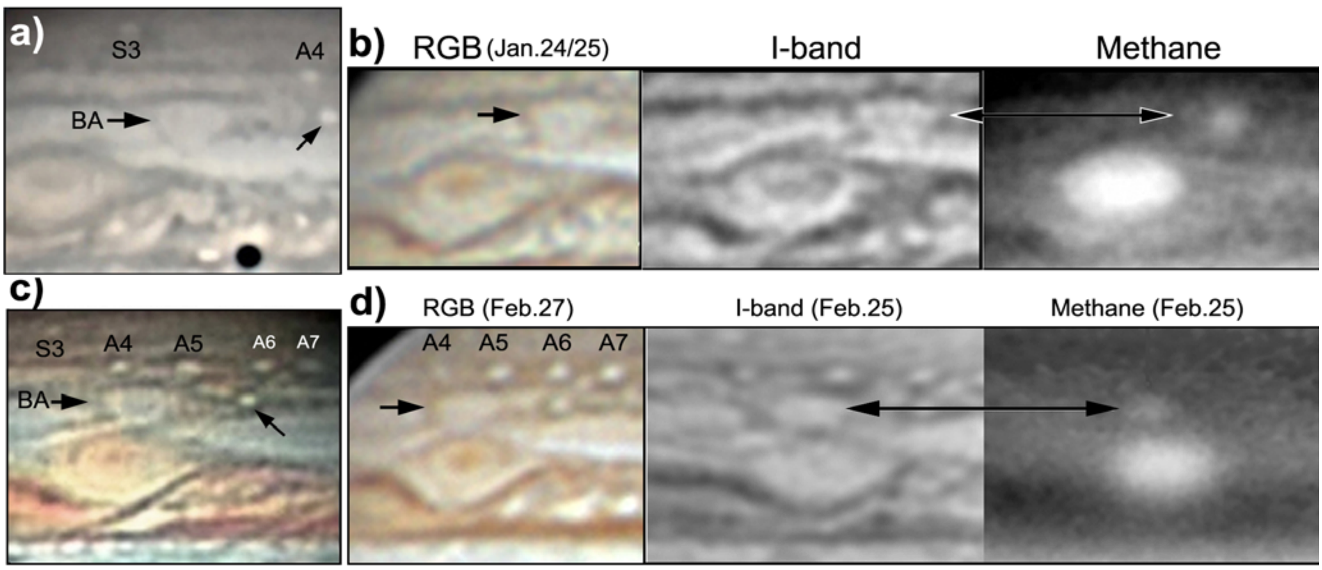

Figure 11. Detailed views of oval BA passing the GRS, with other AWOs. For full-disk colour images see Figures 5 & 6 in Part I. These images show anticyclonic ovals in four consecutive domains: the GRS, oval BA (arrowed; and smaller AWO no.3 f. it), SSTC ovals A4 to A7, and the S^{3}TC AWO (labelled S3 below it).
(a) 2002 Jan 6 (Legault); also shows Io and shadow in transit on SEBn.
(b) Jan 24/25 (Cidadão). Three wavebands: (L) white light, (C) I-band, (R) methane.
(c) Feb 15 (Grafton).
(d) Feb 25–27 (Cidadão); three wavebands as in (b).

All these events parallel the merger of homologous ovals BE and FA in the S. Temperate region exactly two years earlier:[15–18] the rapid convergence, orbiting, and merger; the fact that the merged oval initially had the same rapid drift as the f. parent; and, most unexpectedly, the appearance of a more slowly moving cyclonic oval at the point of merger. In fact, this agrees with a prediction from a theoretical model of the atmosphere by Youssef & Marcus.[19,20]

While ovals BE and FA were merging, there was dissociation between their cloud patterns at different levels, represented by images in visible light, I-band, and methane band.[16,18] During the present merger, both visible and I-band images were taken on many dates, and they generally looked similar, except on March 21, when Peach's I-band image showed them as an east-west streak;[15] however this was unconfirmed. Cidadão's methane-band images faintly detected the pair on March 19 and 21, but it was unresolvable; as these SSTB AWOs are so small, it is rare for amateur methane images even to detect them.

South Temperate region

Oval BA

The last surviving great AWO on the STB, oval BA, varied in visibility during the apparition, but persisted throughout (Figures 5 & 6, 2–11). Before conjunction the most conspicuous feature in this region was the dark spot or streak (a short sector of dark STB: STC no.2 in Table 4) between oval BA and the smaller AWO f. it (STC no.3). Oval BA itself was present but not conspicuous, and in December it was completely invisible in white light. Then in January it suddenly brightened as it was about to pass the GRS. At this time it sometimes had a puzzling tripartite or lobed appearance, as in the previous apparition, but this was probably because the dark STB was liable to break up around the oval, which remained coherent (Figure 11).

Through all these visible changes, oval BA remained consistently bright in methane images. Cidadão's composites

Table 4. Longitudes and drifts, 2001/2002. S. Temperate and Polar regions

Current	*Spot no.*	*Description*	*Lat.*	*L2(O) (Jan.1)*	*DL2*	*Dates*	*Previous L2(O) (2000 Nov 28)*	*Notes*
SPC	1	WS	−59.0	161	0	Dec–Feb	—	Not the old long-lived one?
S^3TC	1	WS	−50.8	91	(−20)v	Dec–Jan	6	Tracked Oct–Apr; DL2
			−49.7		+3	Feb–Mar		Range −32 to +3, oscillating
			−50.0		(−9)	late Mar.		
SSTC	A1	AWO	(nd)	9	−25.5	Nov–Apr	15	
	A2	AWO	−40.3	43	−27.5	Sep–Nov	31	
					−25.5	Nov–Jun		
	A3	AWO	−40.4	76	−26	Aug–May	50	
	A4	AWO	−40.7	124	−26.5	Sep–Jan	104	
					−32	Feb–Apr		
	A5	AWO	−40.4	134	−30	Aug–Dec	132	
					−26	Jan–Feb		
					−30	Feb–May		
	A6	AWO	−40.7	152	(−29)v	Aug–Mar	150	Oscillating. Merged with A7
	A7	AWO	−40.8	168	−27.5	Aug–Jan	166	in March (see text)
					−35	Feb–May		Before & after merger with A6
	8	Cyc.WS	−38.2	158	(v)	Dec–Mar	—	Oscillating between A6 and A7
	9	Cyc.WS	−39.0	—	−19	Mar.25–Apr.21	—	Emerged from A6–A7 merger
	10	WO	−40.5	240	−25	Nov–Mar	—	
	11	WO	(v)	270	−27.5	Dec–Mar	—	
	12	F.dk (S)SSTB	−41.1	265	−27	Dec–Feb	—	
	mean	AWOs	−40.55		−28.3	(N=11m/6s)*		DL2 range −25.5 to −35
STC	1	AWO-BA		—	−13.2	Sep–Dec	270	
			−32.3	102	−11.3	Dec–Jan		Approaching GRS.
				—	−13.7	Feb–May		Passed GRS in late Feb.
	2a	Small v.d.s.	(nd)	—	−12	Aug–Dec	—	Smaller than space bet.1 and 3
	2b	Dark streak	(nd)	115	−7.5	Dec–Jan	—	Filling STB space bet.1 and 3
	3	AWO	—	—	−15	Oct–Dec	287	
			−33.4	123	−9	Jan		
			−33.7	—	−18	Jan–Feb		Approaching GRS.
			−33.8	—	−12	Mar–Apr		Passed GRS in April.
	4	f.end dk STB(S)	(nd)	(110)	0	Feb–Apr	—	
	5	d.s.in faint STB	−29.2	234	−15	Sep–May	96	Old DS1b.WS a few deg. Sp.it
	6	p.dk STB(S)	−33.7	248	−15	Dec–Apr	—	
	7	p.dk STB	−31.2	278	−14.5	Aug–Apr	131	Old dark streak DS2.
	8	f.dk STB	(nd)	308	−14.5	Sep–Apr	156	Old dark streak DS2.
	mean	AWOs & belt	−29 to −34		−13.75	(N=11m/6s)*		DL2 range −9 to −15.
STC (cont.)	9–13	5 d.ss.STB(S)	−33.0	310–360	av. −3	Nov–Jan		DL2 range −1 to −8

Columns in this and subsequent tables include: Lat., zenographic latitude; L2(O), L2 at opposition on 2002 Jan.1; DL2, drift in L2 in degrees longitude per 30 days.
Abbreviations: AWO, anticyclonic white oval; cyc., cyclonic; d.s., dark spot; n.d., not determined; WS, white spot; v, variable.
*(11m/6s) means N = 11 measurements for 6 spots. v. variable.

(Figures 3, 11) showed that the methane-bright spot was smaller than the visible spot but always in its centre; the visible periphery was quite large and variable.

Oval BA decelerated in mid-December as it approached the GRS, then accelerated again at the end of January just as the passage began. The conjunction was in late Feb with no further change in speed. After passing the GRS, oval BA was again difficult to see, having no dark rim, and the dark streak f. it was also much reduced (Figure 13g–i).

The small AWO f. it (no.3) decelerated soon after oval BA, but did not reproduce BA's behaviour thereafter: it accelerated again before encountering the GRS, so it was back on its original track by the time of its GRS conjunction in early April.

From March onwards, a dark STB(S) segment developed f. AWO no.3, elongating alongside the GRS with its f. end stationary at L2 ~ 110.

STB

The other long-lived STB segment also persisted, and again had a series of slow-moving STB(S) dark spots f.it. Its core was called DS2 in previous apparitions (STC no. 7–8 in Table 4) (Figure 4). But it acquired a new p. end, 30° further p., from Dec onwards (STC no.6). Preceding it, a long-lived small dark spot (STC no.5) had a new bright white oval on its S edge. Although this appeared to be a new AWO in STZ, it was not methane-bright.

STBn jetstream

Three small dark spots were detected in the STBn jetstream (Table 5); two of them (DL2 = –102 and –110°/mth) ran up to the GRS in early Jan.

South Tropical region

STropZ p.GRS

There were several features of interest in the STropZ p. the GRS (Table 5; Figures 12 & 13). A new South Tropical Band (STropB) started emerging from the p. end of the GRS around Nov 2, rapidly extending in the p. direction. Meanwhile, a new anticyclonic brown oval merged with another one f. it in Dec and remained a stable object. For reasons explained below, we call it oval Q4. A very similar STropB and oval had existed in the previous apparition, but the present examples were new. In more detail, their history was as follows.

In Oct–Nov, oval Q4 and another one f. it appeared as dark humps or 'blobs' in the STropZ, at L2 ~ 25 and 40. The few hi-res images then showed that they were ovals with white cores and extensive dark rims (Figures 12 & 13; Ref.3). Around Nov 2, the new STropB started to emerge from the p. end of the GRS rim (Figure 12), prograding at DL2 ~ –24°/mth, and soon contacted the S rim of the second oval. Between Nov 19 and Dec 17, the STropB seems to have extended very rapidly

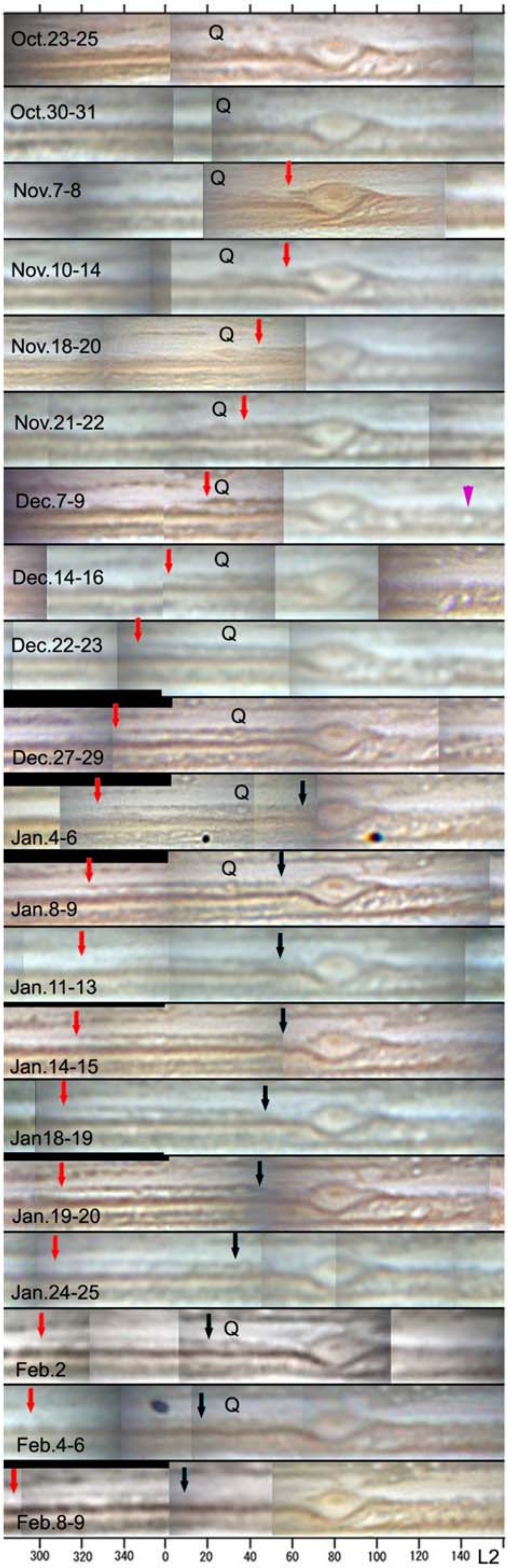

Figure 12 *(right)*. Strip-maps of the S. Tropical region, 2001/'02, from all available images, prepared by Y. Iga. These show the origin and evolution of the S. Tropical Band (p. and f. ends marked by arrows) and oval Q4 (label 'Q' above).

Table 5. Longitudes and drifts, 2001/2002. S. Tropical region

Current	*Spot no.*	*Description*	*Lat.*	*L2(O) (Jan.1)*	*DL2*	*Dates*	*Notes*
STBn jet	1–3	3 small d.ss.	–26.8	—	av. –99	Dec–Jan	DL2 = –85, –102, –110
	4	p. end STropB	–25.0	338	–39	Dec–Jan	After passing oval Q4
	5	D.s. p. GRS	–24.3	63	(–40)	Jan	
STropC	6a	Dark oval in STropZ	–23.7	(25)	(+4.5) –> 0	Aug–Dec	Oval Q4: before STropB
	6b	W.oval in STropZ	–22.9	30	+1 –> +6	Jan–May	Oval Q4 (after STropB & merger)
	7	GRS	–21.6	79	+0.6	Aug–May	17° long. (L2 =75 on 2000 Nov 28)
	8	D.s.	–22.5	(320)	+6	Mar–May	
	mean		–21.6 to –23.7		+3.0	(N=6m/3s)	DL2 range 0 to +6
(STropZ)	—	5 d.ss.	–22.7	(126–165)	av.+22	Jan–Feb	DL2 range +17 to +27
SEBs jet	—	10 d.ss. SEBs	–19.8	in range 140–340	av. +111	Oct–Mar.	DL2 range +98 to +123
	—	pair of d.ss.	(nd)	in range 140–340	+45	Mar–Apr	
STropC (mid-SEB)	9	p. end d.streak	–16.5	178	(+4)	Oct–Apr	Dark streaks in SEB which merged
	10	f. end d.streak	–16.4	204	+2.5	Oct–Apr	
	11	reddish-brown v.d.s.	–16.7	(257)	+7.5	Sep–Dec	(L2 ~181 in 2000 Nov.)
	mean	dk.streaks	–16.5		+4	(N=3)	DL2 range +2.5 to +7.5
Mid-SEB	—	w.ss. f. GRS:	–11 to –16	90–140	av. –38.1	Nov–Apr	DL2 range –20 to –63
Mid-SEB		Spots elsewhere:		*L2(T)*$			
	12	w.s. p. GRS	(nd)	~0	–63	Jan	
	13	w.s. p. GRS	–14.7	~61	–29	Jan–Mar	
	14	d.s. f. dist. region	(nd)	~163	–55	Jan	
	15	d.s.	–12.3	~240	–130	Jan	

$ (T is approx. Feb 1 for spot 13, early Jan for the others.)

to the p. side of the ovals (in the same way that the Great South Tropical Disturbance used to do when passing the GRS), and the two ovals began moving towards each other. They apparently merged between Dec 9 and 17. The resulting white oval remained embedded in the north edge of the STropB. Meanwhile the STropB continued to elongate at DL2 = –39°/mth, until the end of Jan. The STropB detached from the GRS in mid-Jan, then during March it faded away, leaving oval Q4 again as an isolated bright oval with a narrow brown rim.

Oval Q4 was methane-bright, though not strongly so. It was not detectable in Akutsu's images, but was always weakly visible in Cidadão's images, and also in IRTF images on Sep 14 and in Jan–Feb.

Discussion: The 'Oval Q' phenomenon

Oval Q4 behaved exactly like one during the previous apparition (no.4 in ref.6), in its interactions with other smaller spots and with the STropBand, its alternate brown or white aspects, its intermittent brightness in methane, and its slow retrograde motion typical of the STropC. These anticyclonic brown ovals have now become a regular feature of the STropZ p. the GRS, so we propose to call such a spot 'Oval Q', with individual stable ones numbered in order of appearance. In earlier decades, these longitudes were frequently occupied by South Tropical Disturbances or Dislocations, but since the 1990s, these ovals have become common. One was observed during the *Voyager 1* encounter;[11] there was a long-lived one from 1987 to 1997 (here named Q1); another in 1998–'99 (Q2), and another from 1999 to 2001 (Q3). Possibly these ovals now appear more frequent because of the improved observations. Or possibly the GRS, which is still shrinking,[21,22] is now less able to inhibit growth of other anticyclonic ovals in the same latitude.

SEBs jetstream

Distinct retrograding spots were quite sparse but several spots or groups of them were tracked well, with typical speeds for the jetstream.

South Equatorial Belt

There were a few dark streaks in the characteristic latitude of 16.5°S (the S edge of the SEBZ), which were interesting because they were long-lived. One, a well-defined reddish-brown dark spot (STropC no.11 in Table 5) was tracked from 2000/'01. Some less well defined dark streaks (nos.9–10) merged, and persisted as a reddish-brown streak in 2003/'04.

The 'post-GRS disturbance' of turbulent bright spots existed as usual (Figures 5 & 6). A new extension of it began with a new white spot on Dec 7 at L2 = 140. By Dec 11 it was rapidly growing bigger and strikingly brighter. On Dec 15 it had moved down to L2 ~ 130 with a second spot appearing at L2 ~ 140. On Dec 19 these white spots had developed into elaborate rifting abutting the previous post-GRS disturbance. Activity dwindled to smaller scale in January, but burst out again with a new white spot at L2 = 135 on Feb 18, and continued energetically here through March (Figure 6).

The bright spots in the new extension had prograding drifts similar to others in the post-GRS disturbance (Table 5). Although individual drifts were often imprecise as the spots only lasted 1–2 weeks, at least eleven were well-observed, and many other less well-tracked spots showed similar drifts.

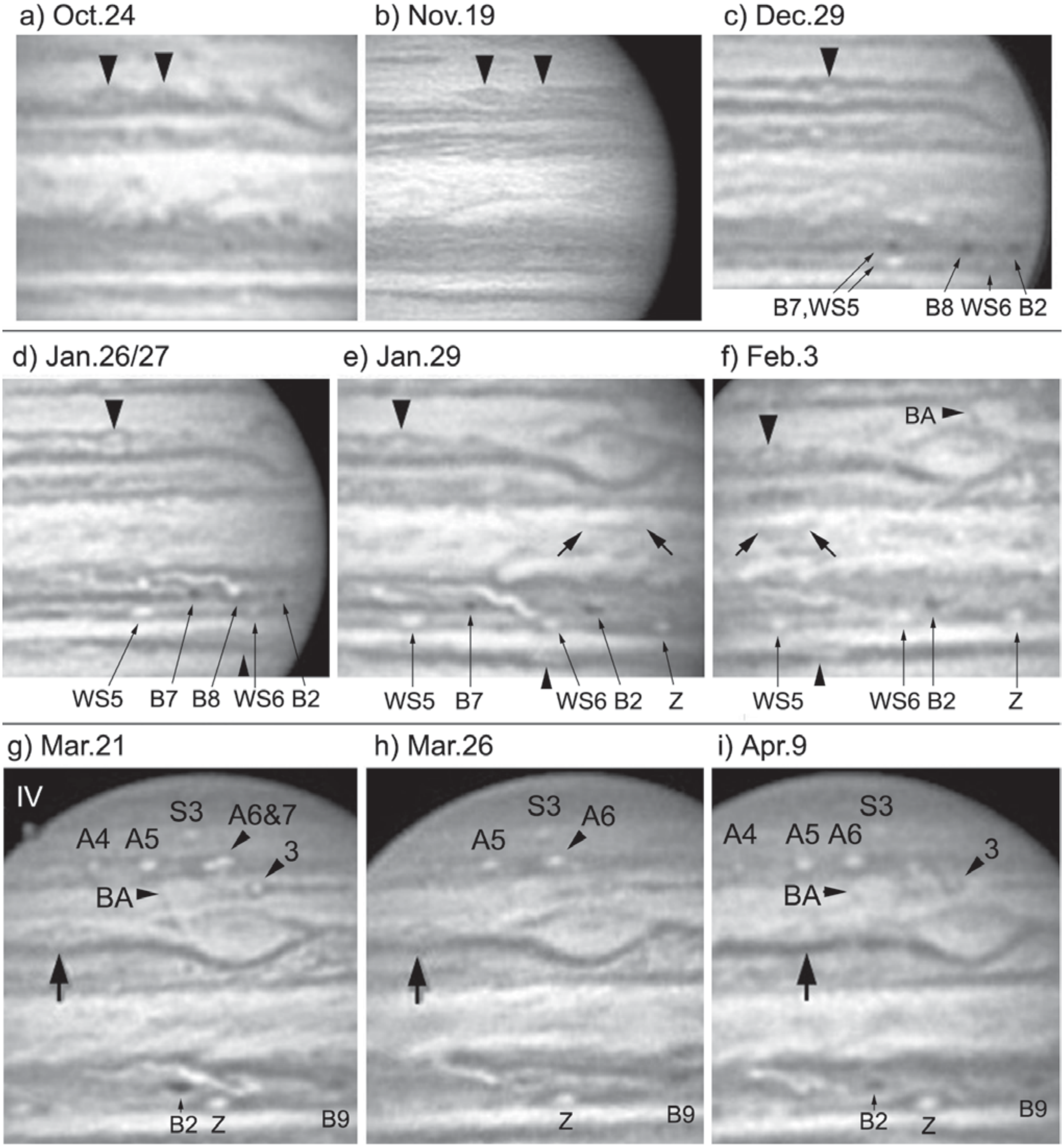

Figure 13.

Detailed views of features p. the GRS (for wider views see Figures 5, 6, 12, 14). Includes: Oval Q4, before merger (top row: two arrowheads); after merger (middle row: arrowhead, with STropB); and later (bottom row: arrow below). SED main complex indicated by bright streak and dark (bluish) streak in EZ(S) on Jan 29 (alongside GRS) and Feb 3 (oblique arrows). NEB barges and portholes; note B7 and WS5 in conjunction on Dec 29, and bright rift over-riding B8 on Jan 26–29, with northerly streamer encircling it cyclonically on Jan 29. NEB rifts, Jan 26–Feb 3, & Mar 21–Apr 9. Rift in NTB, paralleling the NEB rift (middle row, arrowhead below); as in Figure 14b.

Images are as follows:

(a) 2001 Oct 24, 07h 09m (Parker), CM1=68, CM2=35.

(b) Nov 19 (Grafton), CM1=239, CM2=8.

(c) Dec 29, 01h 00m (Cidadão), CM1=193, CM2=18.

(d) 2002 Jan 26, 23h 50m (Cidadão), CM1=52, CM2=16.

(e) Jan 29, 02h 21m (Parker), CM1=100, CM2=48.

(f) Feb 3, 21h 57m (Cidadão), CM1=167, CM2=70.

(g) Mar 21 (Cidadão);

(h) Mar 26 (Cidadão);

(i) Apr 9 (Cidadão).

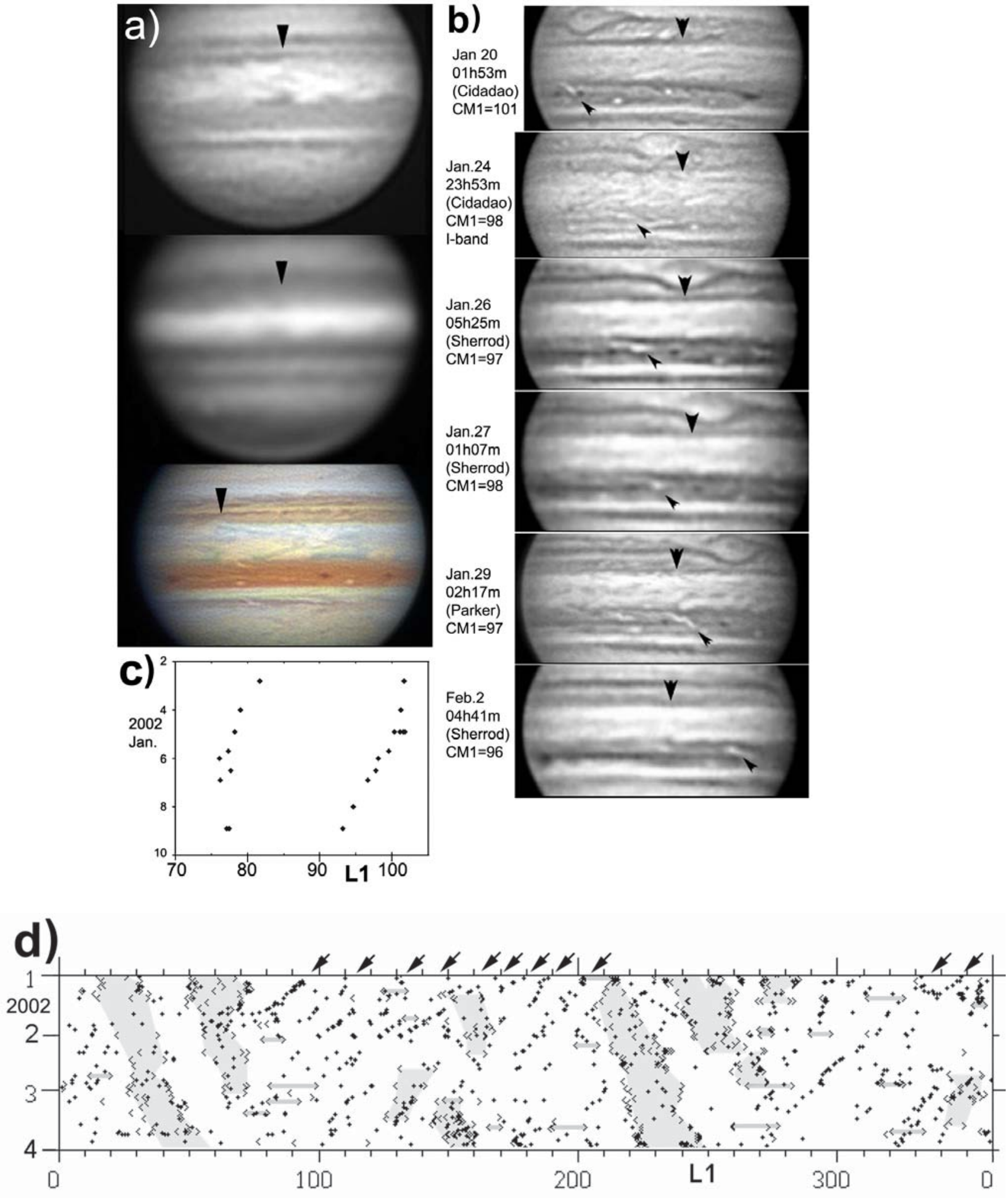

Figure 14.

(a) S. Equatorial Disturbance (main complex) in 2001 Nov, at L1 ~ 53, in multispectral images. (Top) I-band (>820nm), Nov 16, 15h 33m UT (Akutsu), CM1=50, CM2=198. (Middle) Methane band (893nm), 3 min later: there is still a discontinuity in this methane image, albeit diffuse. (Bottom) White light, Nov 18, 07h 47m (Grafton), CM1=81, CM2=217. The last image also shows clearly that a long faint sector of NTB is a set of oblique rifts.

(b) Images showing features in the equatorial region, 2002 Jan 20 to Feb 2, passing the GRS. All have CM1 ~ 97 (except the first). All in white light except Jan 24/25 which is in I-band. This set shows miniature NEBs festoons prograding in L1; the large arrowhead points to one. The SED main complex is on the right side of each disk, detectable only by a bright streak and dark streak in EZ(S) (passing the GRS around Jan 29–31). The oblique arrowhead points to a bright rift in mid-NEB, which brightens then covers and destroys barge B8 (see also Figure 13). At back of arrowhead, a rift in NTB moves at similar speed (NTC-B).

(c) The fastest bright spots in the NEBs jet at 6°N: chart in L1.

(d) All dark features from 4–10°N: chart in L1. Tracks of major dark plateaux are indicated by grey shading; < > p. and f. ends; DL1 ~ +12°/mth. Numerous smaller dark features, indicated by points, move towards lower left at DL1 ~ –14 to –36°/mth.

Table 6. Longitudes and drifts, 2001/2002. Equatorial region

Current	*Spot*	*Description*	*Lat.*	*L1(O) (Jan 1)*	*DL1*	*Dates*	*Previous L1(O) (2000 Nov 28)*	*Previous DL1 2000/'01*
SEC	1	Tiny dark proj. SEBn	–7.4	~233	–114	Jan		
	2	Tiny dark proj. SEBn	–7.4	~315	–100	Dec–Jan		
	—	13 tiny dark projs.	–7.6	(~330–100)	–60	Jan	(DL1 range –50 to –75)	
	—	6 tiny w.ss	–6.2	(~330–100)	–60	Jan–Feb		
	4	Inflexion in SEBn (SED main complex)	–7.9	108	+37	Oct–Jan.	7	+37
	5	P.end dark blue streak*	–3.4	97	+33	Jan–Mar		
	6	F.end dark blue streak*	–4.0	108	+33	Jan–Mar		
		*(in EZ(S) at SED main complex)						
CEC	1	Dark streak	+1.6	—	+22	Mar–Apr		
	2	Pair of d.ss.	+0.7	288	+30	Dec–Jan		
NEC	1	Long plateau	(nd)	—	(+17)	Sep	232	+8 (var.)
				20	+12	Sep–Mar		
	2	Long plateau	(nd)	—	(+20)	Sep–Oct	296	+9 (var.)
				60	+6	Oct–Mar		
	3	Long plateau	(nd)	—	(+15)	Sep–Nov		
		ibid., p.end		206	+7	Jan–Mar	12	+13
		ibid., f.end		217	+11	Dec–Apr	27	+13
	4	Long plateau	(nd)	247	+9	Oct–Mar	76	+12
	mean				+12	(N = 8m/4s)	(DL1 range +6 to +20)	
NEC (fast)	5	W.s.	+5.8	—	–56	Jan		
	—	10 small d.spots	+7.6	—	–26	Dec–Mar	(DL1 range –14 to –36)	

Equatorial region

EZ(S) & South Equatorial Disturbance

From 1999 to 2001 there had been a remarkable South Equatorial Disturbance (SED) affecting the SEBn and EZ(S).[8,17] The main complex of the SED remained feebly, intermittently detectable in both visible and methane bands in late 2001 (Figure 14a). It continued to move at DL1 ~ 37°/mth (SEC no.4 in Table 6). In visible light, it was little more than a discontinuity between sectors of SEB(N). In methane bands, it still showed a dark EZ(S) on the p. side, but this was now a band separate from the methane-dark SEB and had a tapered f. end, so it was less distinct than before.

The main complex passed the GRS around Dec 5 (L1 ~ 75), without becoming any more conspicuous. After early Jan it ceased to be detectable in visible light, though it remained a very ill-defined feature in methane images. It passed the GRS again around Jan 31, and again there was no more than a slight bright 'bay' in SEBn in visible light (Figure 13e,f), and a long tapering f. end in methane images.

However, inspection of the *JUPOS* charts revealed that a dark streak in EZ(S), with a uniquely slow drift, still marked the main complex of the SED (SEC nos.5–6: DL1 = +33 from start of Jan to end of March; Figures 5, & 13e,f). A similar bluish streak had existed earlier in the heyday of the SED.

In mid-March, the SED produced one more visible feature on SEBn, though ~30° p. the previous track of the main complex. This was the f. end of a dark segment of SEB(N), at L1 ~190, f. the GRS. It developed from March 9 onwards (Figure 6), and was first spotted visually on March 14 by Tom Dobbins – who 2.5 years earlier had discovered the SED, in very similar circumstances, as it perturbed the SEB on its runup to the GRS. The main complex passed the GRS again in late March but still did not become any more visible as a result.

At other longitudes on SEBn, remarkably fast drifts were recorded, similar to those recorded in recent apparitions but even more extreme. (For illustrations see Refs.8 & 26.) Hi-res images revealed many tiny bluish projections separated by tiny bright bays, and separate charts for the dark features on SEBn and bright spots in EZ(S) agree in showing at least eight tracks in each chart with DL1 ~–60°/mth, over short intervals; many other such features were too short-lived to give reliable drifts. These drifts were seen between ~30° and 170° p. the main complex. Further p., there were even faster spots. The fastest speed was DL1 =–114°/mth (SEC no.1 in Table 6: a small bluish-grey projection, initially ~160° f. the main complex, last seen only 50° f. the main complex). This was the fastest speed ever recorded in this latitude in ground-based observations, amounting to +160 m/s in System III, and it represents the maximum speed of the jetstream.[24,25]

Discussion: The SEBn jetstream and the SED

It is now clear that we are tracking the same features that are tracked by spacecraft images, up to the peak speed of the jet; and that these speeds vary systematically with longitude relative to the SED. For the third apparition running, we observed greater speeds at greater distances p. the main complex of the SED. The SED is a large-scale wave that affects many aspects of the SEBn,[17,8,24] and we now conclude that it affects the observed speed of the jet itself. Further details and discussion of these results are presented elsewhere.[26]

Streaks in EZ

There was a sharp boundary at 2.5°S between the narrow, bright white EZ(S), and the broad, dusky yellowish EZ(N). Both parts contained bluish-grey streaks, all with positive DL1 though moving independently. The main one in the EZ(S) was associated with the main complex of the SED. Several isolated grey streaks just N of the boundary represented the slow, seldom-observed Central Equatorial Current (e.g. two in Table 5). Further N in the EZ(N) were weak fragments of festoons associated with the NEBs plateaux.

EZ(N)/NEBs

The chart for EZn/NEBs was quite extraordinary (Figure 14d & Table 6). There were only 4–5 large dark features, continuing the trend of the previous apparition: they were long low plateaux, ~15-25° long, each with a thin festoon at the f. end, and they still had unusually slow drifts (mean DL1 = +12°/mth, equivalent to 99.7 m/s in System III). Meanwhile, from late Dec onwards, the chart also showed numerous small spots moving exceptionally fast (mean DL1 =–26, or 117.9 m/s). They were both bright spots and dark projections, typically lasting ~3–6 weeks. Examples are visible in Figure 14b.

Finally, one white spot in EZ(N) moved even faster (DL1 = –56°/mth, or 132 m/s: Figure 14c). This exceeds the previous visual record of DL1 ~ –50°/mth in 1942/'43 (ref. 11, pp.136 and 146).

Discussion: The NEBs jetstream and its visible wave patterns

Thus on the NEBs, as on the SEBn, we have detected faster motion than ever before. However, even our record-breaking speed of 132 m/s is not the peak speed of the jet. Normally the visible features on NEBs move with speeds near System I, even in hi-res spacecraft images, but the *Galileo* Probe showed that the jet was much faster at deeper levels (170 m/s, or DL1 ~ –135°/mth).

It is thought likely that the dark NEBs projections are Rossby waves whose phase speed (the observed drift) is much less than the underlying wind speed.[27–29] If so, their phase speed should vary with their spacing, and this appears to be so.[28,30] In 2001/'02 we have recorded two concurrent sets of NEBs projections which extend this relationship to even more extreme values: the large slow projections (99.7 m/s, with spacings of ≥35°), and the small rapid projections (117.9 m/s, with a fairly regular spacing of ~13°). These values are consistent with the correlation established by Arregi et al.,[30] and suggest that the small rapid projections are also Rossby waves.

Such rapid features are not commonly observed on the NEBs, but could perhaps arise as a consequence of the weakening of the long-lived larger projections. The situation may have been similar in 1986–'87, when large dark plateaux on NEBs 'collapsed' then disappeared, and their p. ends moved at similar speeds, DL1 = –18 to –29°/mth.

North Tropical region

Following the NEB expansion event in 2000, there was a typical array of dark cyclonic 'barges' and bright anticyclonic 'portholes' (AWOs). Unusually, most of the barges and one of the portholes (the famous white spot Z: WSZ) had persisted for several years, dating from the previous cycle of NEB expansion. However, more portholes were developing. There was also a turbulent 'rifted region' trapped between two of the oldest, most stable spots – WSZ and barge B4 – emitting bright rifts which prograded past WSZ. These features are listed in Table 7, and many are labelled in the colour plates. The *JUPOS* chart is Figure 15.

NEB rifts

For the first time in many years, conspicuous bright rifts were arising in a slow-moving rifted region, which was trapped between WSZ and barge B4. This rifted region moved with DL2 = –5°/mth, accelerating to –19 during the apparition (NTropC no.8 in Table 7). Three major volleys of rapidly prograding rifts arose from it, in late Dec, early Feb, and mid-

Table 7. Longitudes and drifts, 2001/'02. N. Tropical region

Current	*Spot no.*	*Description*	*Lat.*	*L2(O) (Jan 1)*	*DL2*	*Dates*	*Previous L2(O) (2000 Nov 28)*	*Notes*
NIC	*mean*	W.streaks in rifts	+11 to +14 (av.+12.4, ±0.9)		–44 to –85 (av. –68)	(N=6)		
NTropC	1	barge B7	15.0	43	(var)	Sep–Jan	—	see text
	2	WS5	18.9	45	(–8)var	Nov–Mar	—	crossed track of B7!
	3	barge B8	15.3	64	(–4)var	Aug–Jan	106	see text
	4	WS6	18.8	72	(–8)var	Nov–Feb	112?	
	5	barge B2	15.3	(100)	–2	Aug–Nov	148	merged with B3
	6a	barge B3	14.3	(79)	–15	Aug–Nov	195	
	6b	merged barge	15.2	82	(–7)var	Nov–Apr	—	see text
	7	WS1=WSZ	19.0	102	–10.5	Aug–May	205	
	8a	rifted region	15.3	130–140	(–5)	Sep–Jan	—	same trapped rifted region,
	8b	rifted region	(±0.9)	—	(–19)	Jan–Mar	—	accelerating
	9	new barge B9	14.8	138	–14	Jan–May	—	arose at f. end of rifted region
	10	new WS7	19.0	(147)	–10	Jan–May	—	arose at f. end of rifted region
	11	barge B4	15.9	162	–4.5	Aug–May	211	stable
	12	WS2	18.3	199	(–1.5)var	Sep–Apr	—	
	13	barge B5	15.8	236	–0.5	Aug–May	267	fairly stable
	14	WS3	18.5	247	0	Oct–May	—	var. drift earlier
	15	barge B6	15.9	261	(–2.5)var	Oct–May	307	var. drift earlier
	16	WS4	18.7	310	–6	Sep–May	—	with fluctuations
	17	barge B1	15.9	320	–6	Aug–May	37	
	18	d.s.	18.6	0	+7	Dec–Apr	—	
	mean	Barges & AWOs	+14 to +19		–6.2	(N=17)		DL2 range 0 to –15

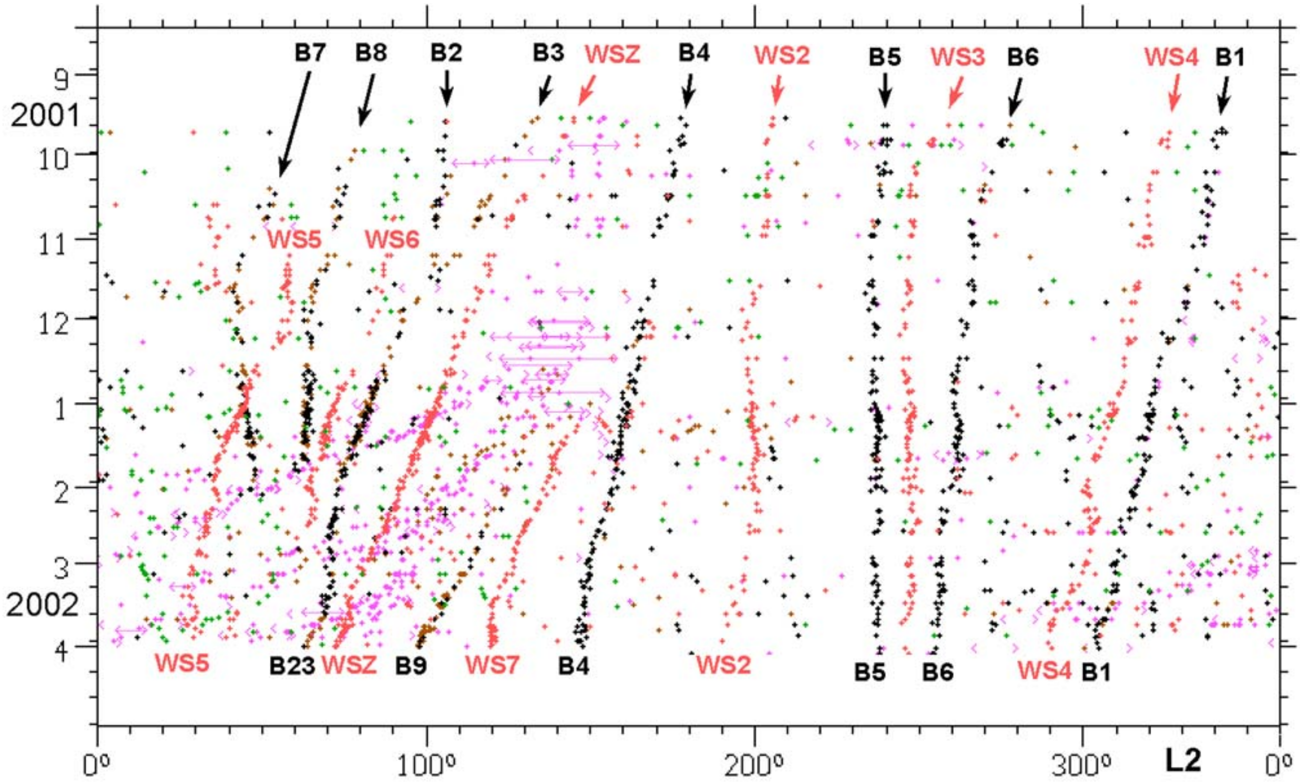

Figure 15. Longitude chart of the N. Tropical Current, latitudes 10–20°N, showing the barges (including merger of B2 and B3 and disappearance of B7 and B8), portholes (including first appearance of WS5, 6, and 7), and trapped rifted region emitting bright rifts.

Pink, white spots, 10–16°N, including < > ends of bright rifts, 10–20°N. *Red*, white spots, 16–20 °N (portholes/AWOs). *Brown*, dark spots 12–15°N; *Black*, dark spots 15–18°N (barges); *Green*, dark spots 18–20°N (minor features).

March. These rifts had speeds ranging from DL2 ~ –44 to –85 (NIC in Table 7). The rifted region is well shown in Figures 5, 6, 13, 14b, and in the longitude chart, Figure 15.

The rifted region was already present in 2001 September, and throughout October it consisted of an oblique rift centred on a very bright irregular spot at L2 = 153. Thereafter the oblique rift accelerated, and in late Dec it appeared splendidly dynamic, with a dramatic dark oblique streak along its Sf. side running into B4.

The rapidly prograding rift which broke out from it in late Dec was a small bright spot as it passed the S edge of WSZ on Jan 7, and then became spectacularly bright, and continued to evolve. It left a new, very dark grey, NEB(N) segment around WSZ (especially dark in I-band images, Jan 25–29). This bright rift revived on Jan 20 alongside WS6, intruding between B8 and B2/3, then prograding slowly past B8. On Jan 26 it erupted a new bright white spot, and by Jan 29 it almost completely covered B8 (Figure 13 & 14b); in fact the rift seems to have erupted a new northerly extension which whipped cyclonically around the barge on Jan 29. By Feb 2–3 only a tiny remnant of B8 remained, almost in contact with WS6, and then it disappeared – destroyed by the rift and the white oval. The same rift then went on to destroy barge 12 in turn (Figure 15).

Meanwhile the trapped rifted region was again active. Two similar volleys of prograding rifts, likewise accelerating from DL2 ~–44 to ~–80°/mth, produced equally spectacular views in Feb and March.

NEBn/NTropZ

There were eight dark barges in autumn. Preceding the rifted region, where turbulent rifts were passing, two barges merged (B2 & B3) and two were destroyed by rifts (12 & 13), while on the f. edge of the rifted region, a new barge appeared (B9). Thus there were six barges by the end of the apparition. Meanwhile new white spots (portholes) were appearing, the number increasing from four to seven during the apparition.

The merger of barges B2 and B3 was eagerly watched. Mergers of these cyclonic dark ovals are not uncommon, but have never been observed in such detail. It was probably the approach of WSZ which impelled barge B3 into the rapid prograde drift that caused it to merge with B2. This event was predicted from our charts on Nov 6 and actually began on Nov 7. It was most thoroughly covered in images by Sherrod, together with other American observers. The merger was described and illustrated in Refs.2 & 15. Here we give only a brief summary, with some illustrations in Figure 5.

The two barges converged without change of speed, B3 travelling faster and being ~0.8° further south than most barges. They appeared to merge smoothly into a single complex by Nov 12, but over the following week this still contained two small dark nuclei and it deformed as if they were still sliding past each other. From Nov 20 onwards, there was just a single merged barge, longer than either parent, which persisted as a conspicuous dark streak prograding past the longitude of the Great Red Spot.

The merged barge survived, despite a prominent rift erupting close to it around Jan 21 (Figure 5). The merged barge was again nearly destroyed by a major NEB rift on March 26, but it reappeared, although very small. Earlier in March, the merged barge had approached again to within only 10° of WSZ, and after a brief rebound, the two established a stable pairing maintaining the rapid drift of WSZ.

The merged barge was initially at 14.8°N (Nov–Dec) but then increased over the next two months until it was at 15.6°N in Feb, simultaneously decelerating. Curiously, other new barges as well as the merged barge were at lower latitudes than the older barges (Table 7). However, there was no correlation of age with speed this year. One may speculate that this was because the barges were now all linked to planetary-scale waves in the NEBn jet, rather than developing f. a local active region as in previous apparitions.

Preceding WSZ and the merged barge, we have already noted that two AWOs appeared (WS5 and WS6) while two barges were destroyed (B8 and B7) (Figures 13 & 14b). One other remarkable event was that WS5 and 12 actually passed each other, at the New Year, instead of remaining stably aligned as usual (shown in Figures 13c & 15). Finally, in late March 2002, WS5 and WS6 converged until 10° apart. The p. one (WS5) was indistinct after April 4, apparently disappearing rather than merging. All these changes p. WSZ may have been related to turbulence and bright rifts that were prograding from the trapped rifted region.

Elsewhere, there were lesser short-term fluctuations in DL2, which sometimes applied over extended longitude sectors (Figure 15). 10, WS3, and 11, initially with varying drifts, converged to form a stable triplet; minor fluctations in their drifts tended to occur to all 3 synchronously. WS4 and B1 also formed a stable pair.

Meanwhile the expanded NEBn gradually cleared at many longitudes, so some barges stood out more as the NEB largely returned to its normal width.

Table 8. Longitudes and drifts, 2001/'02. N. Temperate and Polar regions

Current	*Description*	*Lat.*	*Mean DL2*	*N*	*DL2 range*
NTC-C (NTBs jet)	Humps on NTBs	25.1	–293.1	7	–291.5 to –295.5
NTC-B	P. or f. ends of rifts	27.2	–60	7	–60 to –62
	Light sector NTB	27.2	–95	1	—
NTC-A (NTBn jet?)	Small d.ss.	30.6	+28.4	7	+23 to +33
NNTBs jet	Small d.ss.	35.0	–79	2	both accel. from –76 to –82
N^3TBs jet	Small d.ss.	41.5	–28	3	–25 to –30 (irreg.)

Current	*Spot no.*	*Description*	*Lat.*	*L2(O)*	*DL2 (Jan.1)*	*Dates*	*Previous L2(O) (2000 Nov.28)*	*Notes*
NNTC (NNTB)	1a	p.end dk NNTB 1	39.1	51	(+12)	Dec–Jan	—	Omitted from mean.
	1b	p.end dk NNTB 1	39.1	(62)	0	Feb–Mar	—	*
	2a	p.end dk NNTB 2	38.0	(144)	(+3)	Aug–Oct	(133)	Present from 2000 Dec
	2b	f.end dk NNTB 2	37.8	(162)	–2	Sep–Oct	(170)	Turned red in 2002 Jan
	3	p.end dk NNTB 3	38.6	290	0	Aug–Apr	287	
	4	p.end dk NNTB 4	40.6	334	(0)	Aug–Feb	—	
	mean	NNTB segments	38.8		0	(N=5)		DL2 range –2 to +3
		* NNTC nos.1a and 1b were the same feature, which decelerated.						(exc.no.1a)
		Its f. end was at NNTC no.5/6 (AWO). No.5 merged with no.6 in late Feb. (see text).						
NNTC (NNTZ)	5	ws(AWO)	40.9	94	~+2 var	Dec–Feb	104	Merged with no.6
	6	ws	40.7	110	~–6 var	Dec–May		
	7	ds	40.2	98	–2 to +15	Dec–Apr		
	8	Little Red Spot	41.0	166	–1.8	Sep–Apr	203? 280?	
	9	ds	41.0	261	+2.5	Sep–Apr		
	mean	w.ss.,d.ss.	40.7		+2.3	(N=5)		DL2 range –6 to +15
N^3TC	1	ws	46.0	333	–24	Dec–Jan		
	2	ws	44.0	34	–22	Nov–Mar		
	3	ws	45.5	(84)	–15	Jan–Feb		
	4	ws	46.2	197	–31	Dec–Jan		
	5	ws	43.9	252	–22	Sep–Jan		
	mean	w.ss.	45.1		–22.5	(N=5)		DL2 range –15 to –31
N^4TC	*mean*	(6 spots)	51.1	60-150	+1.5	Dec–Feb		DL2 range –3 to +6
		(w.ss., d.ss.)	(range 50.7 to 51.6)					(see text)
	1	ws	50.0	(27)	+1	Oct–Dec		
	2	ws	52.2	210	+11	Jan		
	3	ds	53.4	116	+5, –20	Jan		
	mean	w.ss., d.ss.	50.0 to 53.4		+0.6	(N=9)		DL2 range –20 to +11
NPC	1	ws	57.2	132	–25	Jan–Feb		Then halted at L2 = 94
	2	ws	60.1	60	+8	Jan–Feb.	282	
	3	ws	59.5	257	+10	Oct–Mar	148	

North Temperate region

Seven NTBs jetstream spots were still present (the same seven that have existed for several years: N. Temperate Current C in Table 8), though they were usually ill-defined, as in the previous apparitions.

The NTB was generally a very dark grey belt, but several oblique bright rifts were recorded, moving with the N. Temperate Current B. (e.g. Figures 6, 13, 14a,b, 17). Their p. and f. ends were tracked for 1–3 months each. Six of these p. or f. ends had DL2 = –60°/mth. Also, a faster-moving disturbance gave rise to two more compact pale sectors of the belt in Jan–Feb, each ~12° long. The first had DL2 = –95, and the second initially had DL2 ~ –70 but then decelerated to ~ –50 and stabilised at ~ –60.

The slow N. Temperate Current A was even slower than usual: many small dark spots were tracked on NTBn at all longitudes with very slow speeds, DL2 ~ +23 to +33, obviously influenced by the NTBn jetstream, although not quite as slow as the spot that we detected in the previous apparition. (Figure 16a & Table 8).

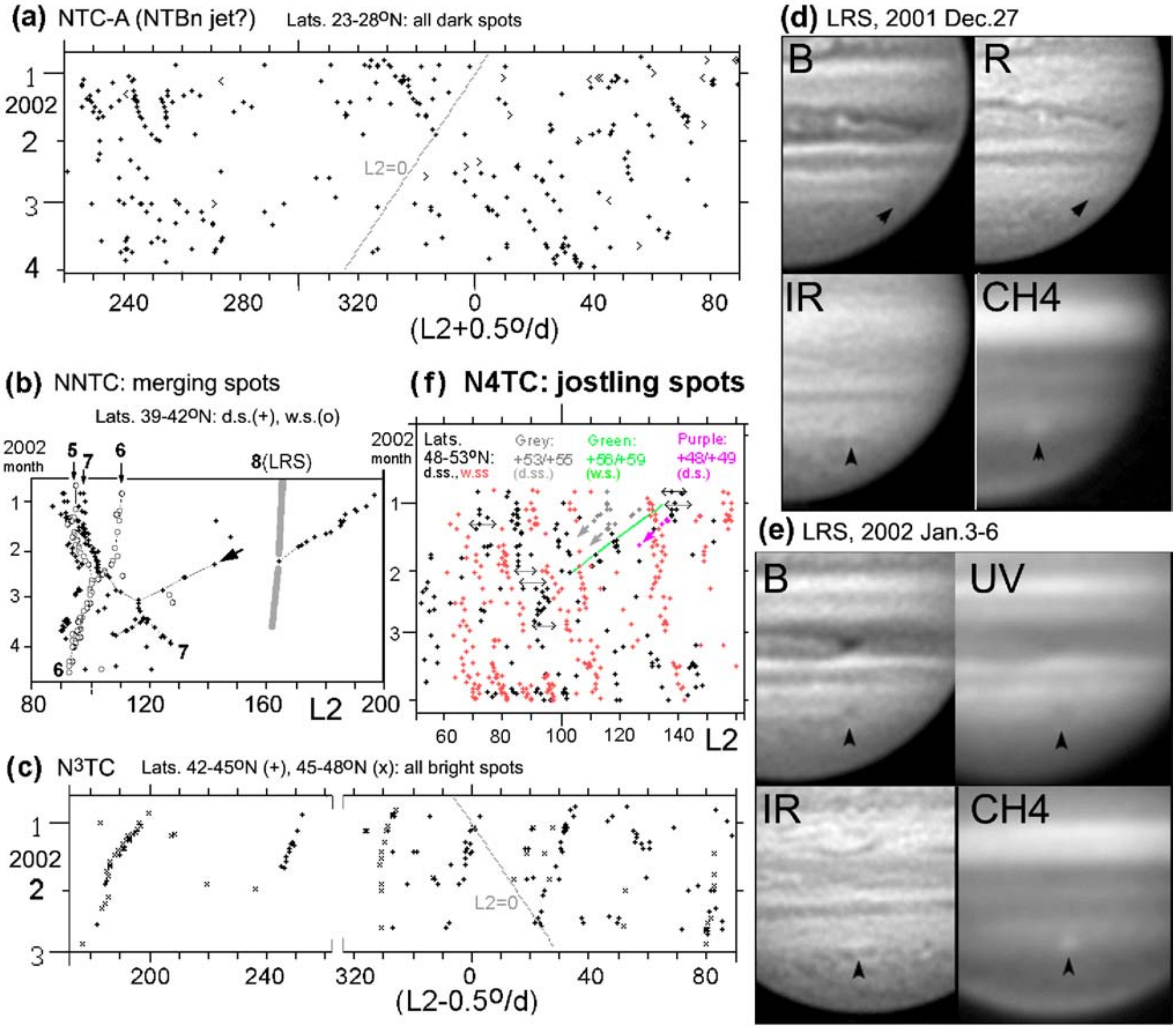

Figure 16. (a–c) Longitude charts in northern latitudes.
(a) NTC-A: latitudes 23–28°N, dark spots; scale moves +0.5°/day in System II. (Diagonal grey line is L2=0 in all charts.)
(b) NNTC: latitudes 39–42°N; scale is System II. Black points, dark spots; open circles, bright spots. This shows the merger of AWOs 5 and 6; ejection of dark spot 7 f. the merged AWO; two rapidly-moving tiny dark spots (indicated by arrows), which terminated at dark spot no. 7 and Little Red Spot no.8 respectively.
(c) N3TC: Latitudes 42–48°N, bright spots; scale moves –0.5°/day in System II.
(d–e) The Little Red Spot in NNTZ, in multispectral images, showing that it is dark in blue and UV, bright in I-band and methane, and still conspicuous when near the limb. It is N of NEB barge B4. All images by Cidadão.
(d) 2001 Dec 27: Blue, 02:00 UT, CM2=133; Red, 5 min earlier; I-band, 02:43 UT, CM2=139; CH_4 (methane), 10 min later.
(e) 2002 Jan 3–6: Blue, Jan 6, 01:00 UT, CM2=141; UV, 10 min later. I-band, Jan 4, 00:08 UT, CM2=169; CH_4 (methane), 13 min earlier. (Also see Figures 9a,b & 17.)
(f) Longitude chart of N.N.N.N. Temperate domain, 48–53°N, and further north, where spots of different speeds were jostling each other. Black, dark spots, 48–53°N; red, white spots, 48–53°N; purple, one dark spot, 48–49°N; grey, dark spots, 53–55°N; green, white spot, 56–59°N. The purple, grey, and green tracks have DL2 ~ –25°/mth, as have very short segments of red tracks, but most of the spots are nearly stationary.

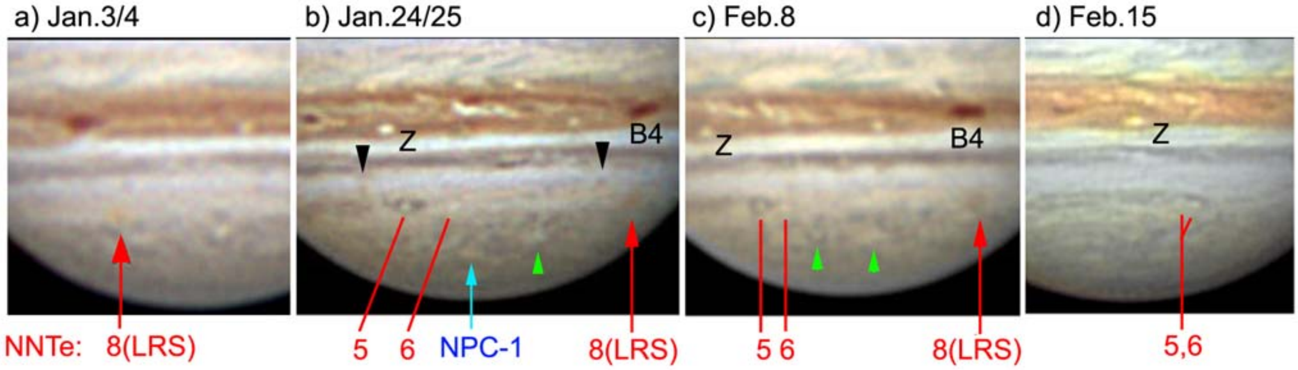

Figure 17. Details of spots in N.N. Temperate region.
N.N. Temperate spots are labelled in red: AWOs nos. 5 and 6, which approach (b,c) and merge (d).; dark spot no.7, initially the dark rim of no.5, which swaps places with AWO no.6 during the merger (d); and the Little Red Spot, no.8, pure red in Jan (a) but dark brown in Feb (c). In (b), also note two dark spots on NNTBs jetstream (arrowheads), and a pale reddish strip between them where NNTB is absent; this was formerly a dark bar which turned red.
Further north, many spots were tracked in the N^4TC: green arrowheads indicate two white ovals.
(a) 2002 Jan 3/4, 00h 39m UT (Cidadão), CM1=48, CM2=187.5.
(b) Jan 25, 00h 57m UT (Cidadão), CM1=137, CM2=116.
(c) Feb 8, 22h 39m UT (Cidadão), CM1=262, CM2=127.
(d) Feb 15, 02h 26m UT (Grafton), CM1=267, CM2=86.

N. N. Temperate and Polar regions

NNTB

The NNTB was represented by just a few dark segments, all about 15–40° long although the f. ends were usually irregular. NNTC features 1–4 in Table 8 were mostly p. ends of these segments, with typical slow NNTC speeds.

Two of these dark brown segments of NNTB turned into red streaks before fading away:

1) A dark bar at L2 ~135–165 in Sep became reddish in Oct (Figure 5); thereafter there was only a pale diffuse reddish haze around that region.
2) A dark bar in Oct–Dec (NNTC no.2a–2b in Table 8) turned into red streaks of NNTB(S) at L2 ~ 0–25 in Jan (Figure 4).

Discussion: Dark bars reddening before disappearing

These events seem to be examples of a general phenomenon, as other very dark cyclonic bars or barges have turned red before disappearing: in the NEB (1890–'91;[31] in the STB ('Morphing Spot', 1994–'95,[32,33] and 'DS1', 2000),[6] in the SSTB (2004: BAA report in preparation); and in the NNTB again (2006).[34] As red colour on Jupiter is associated with regions of high wind speeds or strong turbulence, this phenomenon might indicate stormy weather leading to the breakup of dark cyclonic circulations.

NNTZ

Around L2 ~ 100–120, two probable mergers of small spots were indicated by the *JUPOS* chart (Figure 16b). The first event involved a dark-rimmed little AWO on NNTBn (NNTC no.5 in Table 8) (Figures 5, 6, 17). A smaller AWO f. it (no.6), converged on it in Feb, and although they virtually disappeared from images, they apparently merged in late Feb. Details are given in Ref.15. The result was a single white oval, on the track of no.6 with DL2 = –4, but looking like no.5. During the merger, the dark NNTB streak (no.7) squeezed past AWO no.6 and developed increasing retrograde motion plus a tiny transient white spot in the NNTB latitude (37°N): probably a cyclonic white spot created in the merger. Thus this event was similar to the merger of AWOs in the SSTZ.[15]

Further f. there were several minor dark spots rapidly prograding at 41.5°N, presumably influenced by the N^3TBs jetstream (nominally 42.2°N). The second merger was between one of these obscure spots and the prominent dark spot (NNTC no.7) (Figure 16b). They apparently merged in early March, and hi-res images on March 14–16 showed no.7 partly double with rapid rotation. Around this time, it split again, producing another prograding spot with DL2 = –28, while no.7 retrograded with DL2 = +15.

The NNTZ-LRS

There was a single methane-bright spot in the NNTZ, which in visible light was a Little Red Spot (LRS) at 41°N (NNTC no.8 in Table 8), with steady motion. It was present at the start of the apparition: it was already both methane-bright (from Sep 23 onwards) and red (from Oct 8 onwards). The best colour images showed it as a brick-red rimless oval within the NNTZ (Figures 5, 6), while filter images showed it very dark in blue, invisible in red, and bright in I-band (Figures 7d, 9a,b, 16d,e, 17). These aspects were even stronger when it was near the limb, consistent with the reddish spot being at high altitude (especially Cidadão's images in Jan & Feb, e.g. Figure 7d when it is visible near the limb in methane (bright) and UV (dark)). These aspects persisted throughout 2002 Feb, and it was still distinct in March, although by then its colour was more brown as it darkened in green filter images. (It was not visible in colour images by some other observers, probably because of insufficiently selective blue channel.)

It may be identical to long-lived NNTC ovals no.8 and/or 9 in the previous apparition. Then, no.8 had been methane-bright but only feebly reddish; no.9 had ceased to be either methane-bright or reddish.[6] Their tracks would have intersected in mid-2001 during solar conjunction, so they could then have merged, initially maintaining the rapid drift of no.9 (as with other mergers of AWOs).[15] This would be consistent with both the position of the present LRS (having decelerated to the normal NNTC speed) and its strong colour (the reddish cloud-cap being rejuvenated by the merger).

Higher latitudes, to North Polar region

According to HST data,[25] prograde jets are at latitudes 42.2°N (N^3TBs), 46.5°N (N^4TBs), 55.1°N (N^5TBs), and 63.5°N (N^6TBs). These can be used to define the domains in the high northern latitudes.

At least five white ovals were tracked in the N^3TC, with a real spread of latitudes from 44 to 46°N (Figure 16c; & Table 8). The two most conspicuous in Figure 4 (N^3TC-1 and 4) were also the fastest moving and the furthest north.

At latitudes 50 to 54°N, many dark and bright spots were almost stationary in L2, representing the typical N^4TC (Figures 16f & 17). However a few of them, especially one at 53.4°N, showed signs of more rapid drift over short intervals, DL2 ~ –20°/mth (Figure 16f), possibly influenced by a prograding AWO at 57.2°N in the next domain to the north (NPC no.1). In these high latitudes the *Cassini* polar movie[35] showed that spots or turbulent regions are quite large compared to the widths of the alternating jets in which they move, and so they jostle one another like people in a crowded railway station. Our chart apparently reveals this jostling, between slow-moving spots (51°N, nominally in the 'N^4TZ' anticyclonic domain) and spots influenced by the prograde N^5TBs jet (55°N) (Figure 16f).

Even further north, two white spots at 60°N with slow positive DL2 had been tracked with similar speed since the previous apparition (Table 8). These may represent a retrograding N^5TBn jetstream.

Discussion: Mergers of ovals

In this apparition we have recorded or inferred an exceptional number of mergers of spots. This report describes mergers of AWOs in the SSTZ and the NNTZ, and also infers mergers of anticyclonic ovals in the STropZ (oval Q4 and another) and the NNTZ (the Little Red Spot possibly formed from two predecessors). There was also a merger of two barges in the NEB, and of two tiny dark spots in the NNTZ.

It has long been known that large, long-lived AWOs very rarely merge.[11] However, smaller anticyclonic vortices observed by spacecraft very commonly merge. So the large number of mergers discussed in this report reflects the fact that amateurs can now routinely resolve smaller ovals than before.

A major conclusion, presented in detail elsewhere,[15] is that cyclonic and anticyclonic mergers proceed in characteristically different ways. The two cyclonic barges, prior to merger, showed little change in their drift rates or latitudes; during the merger, there was no sign of mutual circulation, but they just slid past each other before merging smoothly to form a longer barge. We have subsequently observed two other mergers of barges in the NEB, which happened in the same way.[15] In contrast, in anticyclonic mergers in the STZ (2000) and SSTZ and NNTZ (this apparition), the AWOs accelerated towards each other and then circled rapidly round each other, before merging to form a slightly larger oval.[15] The appearance of a cyclonic white spot f. the merging pair in each case supports theoretical modelling.[19,20]

However, the view that mergers between larger AWOs are not common seems to be supported by interactions in the NEBn. In this apparition, WS5 and WS6 approached each other, but it seems that one disappeared rather than merging. Even more strikingly, in 2006, WSZ rapidly approached another AWO in the NEBn, but as they came close the convergence suddenly slowed, then the smaller AWO shrank and squeezed round the S side of WSZ before disappearing, without visibly merging with it. With lower temporal and spatial resolution, a merger would have been inferred, but in fact the interaction was not so straightforward. Thus, interactions between large AWOs are not yet fully understood.

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Erratum

In Figure 5c of Part I of this paper [*J. Brit. Astron. Assoc*., **118**(2), 75–86 (2008 April)] the correct longitudes of the image taken on Nov 7 were CM1= 255, CM2= 84.