Report no.22 (final, 2011 April 6):

Jupiter's SEB Revival in 2010/11: Analysis of the early stages of the southern branch

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Summary

We present a preliminary analysis of the retrograding spots in the SEB(S) in the early phase of the 2010 SEB Revival. Before the Revival there was a continuous chain of small white spots separated by dark projections along the SEB(S) with rather slow speed compared to the normal jet. ('Slow' and 'fast' here refer to speeds in the westward, retrograding, direction.) At the start of the Revival, the first dark spots in the southern branch appeared to form from a few of these projections which suddenly darkened and accelerated to full jet speed as they passed the source, without decrease in latitude. Then, larger dark spots appeared from the turbulent region close to the source, which also moved with nearly the full jet speed even though they were up to 2 degrees south of the canonical jet peak, and they did not appear to be vortices. Thus, the normal zonal gradient was violated as a band on the S side of the jet peak suddenly accelerated. This band became the revived SEB(S). Some of the dark spots drifted to the S edge of it and had slower speeds more consistent with the usual zonal gradient. Subsequently, the previous chain pattern re-established itself at the leading edge of the SEB(S), still travelling more slowly than a dark spot that shifted from one projection to the next. Similar behaviour was probably occurring within the reviving SEB(S), where chains of small bright spots like the pre-outbreak chain again developed, probably with similar low speed, in spite of the dark material retrograding more rapidly in the same latitude. Thus, there are several surprising results from this analysis: the normal zonal gradient was changed, there was no evidence for vortical motion, but there was sudden acceleration of a broad band including pre-existing cloud-top features. This suggests that the initial outbreak caused a sudden massive perturbation of the normal zonal winds.

Introduction

The jet on the SEBs edge is the fastest retrograde jet on the planet, with a peak at ~19.5 deg.S according to profiles from spacecraft [***see box***]: the peak speed is up to DL2 = +133 deg/month according to spacecraft and ~+120 deg/month for visible spots. These dark jetstream spots were initially recorded by visual observers during SEB Revivals, and then during episodes of long-running normal activity. Images from Voyager and Cassini during normal activity showed that they were anticyclonic vortices, and so were spots produced in the 2007 SEB Revival. Therefore, the present paradigm is that these jetstream spots are vortices 'rolling' along the southern side of the SEBs jet [Ref.1].

In 2010, we have the first opportunity to find out whether this paradigm still holds true during a complete SEB Fade and a very energetic Revival. How would the initial outbreak lead to the formation of new dark spots and to the revival of the SEB(S)? We have now tracked the spots in the southern branch of the Revival from 2010 Nov. to mid-January, 2011, aiming to establish accurate speeds, latitudes, and life histories.

Measurements

All these results are from analysis of amateur images, and we are very grateful to all the observers, including those whose images are used in Figs.4-7.

This analysis uses the JUPOS database up to 2011 Jan.15, plus additional measurements by JHR. The JUPOS team is Hans-Joerg Mettig, Gianluigi Adamoli, Michel Jacquesson, and Marco Vedovato. Up to Jan.15 they had made nearly 100,000 measurements of spots on images of Jupiter in the 2010/11 apparition! However, the raw JUPOS charts gave only a partial view of the SEB(S) activity, as the spots are too complex and numerous to be measured comprehensively. Therefore I have also identified major persistent spots visually on image compilations (Figs.4-7), and combined existing JUPOS measurements of these with manual measurements on additional images, to produce detailed tracks for individual spots **(Table 1).**

In this report on the SEB(S), unlike reports on all other latitudes, 'fast' and 'slow' refer to speeds in the retrograding direction, i.e. towards increasing longitude.

Results: Before the Revival

The faded SEB(S) carried a remarkable regular chain of small bright spots separated by faint grey projections, with a spacing of 5-6 deg. This 'chain' or 'sawtooth pattern' has been seen in other years when the SEB(S) was completely faded. We have reported an analysis of this chain from 2010 June to Sep. [Ref.6], showing that its mean speed (DL2) varied from +75 to +57 deg/month, and its latitude was -20.9 deg. The speed was about half the usual SEBs jet speed, but consistent with the speed in spacecraft profiles for this latitude, ~1 degree south of the jet peak (within the uncertainties of measurement and the width of the spots).

Since Sep., the chain persisted with little change until the onset of the Revival -- indeed, until the dark spots of the reviving SEB(S) actually over-ran it at any given longitude. The complete chart is **Fig.1,** and speeds and latitudes for various sectors are given in **Table 1.** In July, the mean speed had been +75 at all longitudes; then in August a sector of slower speeds, ~+57, gradually spread westwards from the GRS (which was centred at L2 ~ 155), covering all longitudes by early Sep. Then in Sep., faster speeds of ~+74 reappeared f. the GRS and spread westwards, covering all longitudes by the start of Nov. The latitudes did not change significantly in the sector from L2 ~ 10-150 (20.9 S in July, 20.65 S in Nov.). However, at lower L2, both bright and dark spots in the chain had slightly lower latitudes, averaging 20.4 S, and as low as 20.2 S around L2 ~ 240-300. This was the sector where the Revival outbreak began, though there is no apparent connection. Overall, provisionally, we can assign a mean speed of -69 deg/mth and mean latitude of 20.7 (+/-0.25) for this chain of spots, both bright and dark.

In addition, there were several short gaps in the chain which moved with DL2 = +134 deg/mth in July-Sep. These were still evident up to Nov., with DL2 ~ +132 to +140 deg/mth. Remarkably, this is the peak speed of the jetstream as established by spacecraft [New Horizons, +133 deg/mth: Ref.3], indicating that the peak jet wind speed still existed even though no distinct features could be seen on it.

Results: During the Revival

The longitude-vs-time charts for the dark spots in the southern branch are shown in different versions in **Figs.1-3**, and the images are compiled in **Figs.4-7**. The spots are labelled by still-provisional letters.

The Revival started with a brilliant plume erupting at L2 = 288, lat. 17.1 S, on Nov.9. The southern branch began on Nov.14, when a pre-existing projection (P1) darkened as it passed the source. It suddenly accelerated to full jet speed (Nov.15-16) and split into two (P1, P2).

Subsequently, the pre-existing projections were indistinguishable as they passed the disturbed source region, so we cannot identify them individually with subsequent dark spots in the southern branch (P3, DS1, etc.), but the morphology and the JUPOS chart suggest that they did develop in the same way, with the pre-existing projections accelerating, splitting (to maintain the spacing), and darkening, as they passed the very dark spot at the source. Thus, P2 and P3 also darkened and accelerated, but by mid-Dec. only P1 remained.

By mid-Dec., P1 again appeared to be just one in a long chain of little projections, as before the outbreak, except that it was darker than the others and rather southerly. The chain all had DL2 ~ +68 to +75 deg/mth in this sector, but P1 retained a faster speed, DL2 = +110. Detailed analysis of images on Dec.11-14 **[Fig.3b & Fig.5]** shows that P1 was a southerly patch that actually shifted from one slower-moving projection to the next. But it disappeared around Dec.24, leaving only the pre-existing chain.

More substantial dark spots began with DS1, formed on Nov.20-21 when a new, very dark spot at the source extended Sf. to darken and accelerate the next projection in the chain. DS2 to DS5 formed similarly from Nov.24-27, all with DL2 ~ +108 to +120. They never adopted the oval form of vortices. Their shapes and arrangements were changing very rapidly; however some of the best images showed they were separated by and curled around small white ovals at ~20.1 deg.S, separated by 7-9 deg. – possibly the same ovals that formed the pre-outbreak chain?

In Dec., DS1-DS5 diverged in their appearance. DS2 quickly disappeared; later, so did DS4.
DS3 became bigger and darker until it was very large and dark.
DS1 became concentrated on the S edge of the belt [SEB(S)s] and decelerated, becoming a streak which disappeared into the ever-expanding DS3. However, it then re-emerged on the Sp. side of DS3, as the small spot B. DS1/B was the first of several spots located on the SEB(S)s at 21.9 S, all with much slower (though variable) speeds compared to the jet peak.
DS5 became a large, very dark spot on the S edge of the reviving belt, and decelerated accordingly in early Dec. It continued to be very prominent throughout Dec.
More very dark spots were emerging from the chaotic region Sf. the source, of which DS6 was the most substantial. It caught up with DS5 and actually passed it, remaining dark until late Dec.

Thus, in the second half of Dec., most of the dark spots had faded, leaving just P1 (rapidly fading), DS3 (very large and dark, spanning the whole SEB(S)), DS5 (very dark and southerly), and residual activity near the source. Between these widely-separated dark spots, the revived SEB(S) was still chaotic but on a small scale, and it appeared to be resolving into a chain of small white ovals at -20.1 deg. This became a widespread pattern of small white cells separated by dark bridges, just like the pre-outbreak chain, reappearing between the surviving big dark spots (P1, DS3, DS5). This surprising development is discussed further below.
The edges of the revived SEB(S) are at 19.4 and 21.6 (+/-0.3) deg.S. The N edge is close to the canonical latitude of the jet peak.

In late Dec., the sector from the source to DS5, rifted by small white ovals, generated another series of very dark spots. Apart from the chain of small dark spots in mid-SEB(S) (which were striking in A. Wesley's infrared image on Dec.31), there were prominent dark streaks on the south edge, including DS5. These all resolved into conspicuous dark spots, but they did not show long steady tracks, possibly because the large spots were actually transient assemblies of central and southerly spots with different speeds. Continuing to emerge closer to the source were more small dark spots, some of which became southerly and thus had slower (but variable) retrograding drifts.

All these dark spots were still changing rapidly at the end of this analysis in mid-January; the large ones were generally becoming smaller, and the 'chain of light ovals' pattern was re-asserting itself across most of this sector, as elsewhere.

With the apparent reappearance of the old chain pattern, along most of the revived SEB(S), it is of great interest to know what its speed is. This is difficult to determine for the same reasons as before the Revival, compounded by the rapid variability of dark streaks that may be moving around the white ovals, and the decreasing frequency of hi-res images. I have not yet attempted it generally, because we will soon have more complete data from January. However, dark spots a,b,c were probably representative of this pattern: they were small northerly dark spots projecting between tiny light ovals, just like the pre-outbreak projections, in the sector between DS3 and DS5, and they had DL2 ~ +51 deg/mth. This suggests that the cloud-top layer of the SEB(S) had resumed a drift rate, as well as a morphology, similar to the pre-outbreak state.

To summarise, as soon as the southern branch started, pre-existing projection(s) accelerated up to peak jet speed [see box]. All the major dark spots at 20.0 to 21.3 S showed speeds in the peak range (+114 to +134 deg/mth), except for DS5 which soon decelerated and moved S (but not including less conspicuous spots). All the more southerly dark spots (21.4 to 21.9 S) moved more slowly, most of them with DL2 ~ +44 to +60, which is consistent with the spacecraft gradient. Meanwhile several small northerly spots (20.0 S) had a much slower speed, DL2 ~ +51, which probably applies to the small white ovals that were forming a renewed chain within the revived belt; this speed does not represent the jet peak which is normally evident at this latitude, but it may have co-existed with faster-moving dark material. (This question will be investigated further when the January data are complete.)

Table 1. Latitudes and speeds of retrograding dark spots on SEBs.

	L2	Dates	DL2	Lat. (DS)	(Lat) SD	(Lat) n	Lat. (WS)	(Lat) SD	(Lat) n
FROM ANALYSIS IN SEP:									
Pre-existing sawtooth projections:									
	fast sector (av.)	July-Aug.	**75**	-20,84	0,46	628	-20,88	0,48	295
	slow sector (av.)	Aug.-Sep.	**57**	-20,84	0,48	280	-20,98	0,5	183
	fast sector (range)	July-Aug.	+70 to +82						
	slow sector (range)	Aug.-Sep.	+51 to +66						
(Speeds & latitudes have not been accurately analysed for Sep-Oct. yet; they were much the same as July and Nov.)									
FROM ANALYSIS IN DEC:									
Pre-existing sawtooth projections:									
	20-140	Nov.1 - Dec.3	**74**	-20,65	0,37	321			
	230-380	Nov.1-8	**72**	-20,49	0,43	73	-20,38	0,46	65
	320-380	Nov.9-29	**72**	-20,51	0,40	83			
	290-330	Nov.10-15	**70**	-20,08	0,53	53	-20,16	0,33	16
	310-360	Nov.16-25	**70**	-20,48	0,53	24	-20,54	0,40	38
mean of these 4:	230-380 (undist.)	Nov.1-25	**71**	**-20,39**	**0,47**	233	-20,36	0,40	119
including the actual projs. w became P1-P3:									
	260-300	Nov.1-9	**70**	-20,20	0,31		-20,32	0,29	
The first 2-3 dark spots in S. branch (sawtooth projections):									
	P1-P3	Nov.16-25	**132**	-20,74	0,60	41			
	P1-P3	Nov.27-Dec.4	**117**	-20,75	0,40	11			
Larger dark spots in main S. branch (revised from orig. report):									
	DS1	Nov.24-Dec.6	**118**	-21,23	0,24	13			
	DS3	Nov.28-Dec.6	**120**	-20,01	0,45	9			
	DS5	Nov.27-Dec.6	**108**	-20,63	0,40	9			
	Z1,Z2	Dec.4-13	40	-19,58	0,30	11			
FROM ANALYSIS IN FEB [Dec. data remeasured):									
	P1	Dec.3-23	110	-20,76	0,32	7			
	DS3	Dec.3-31	114	-20,23	0,50	4			
	DS4	Dec.3-7	114	-20,10	0,30	3			
	DS5	Dec.7-26	45	-21,93	0,55	4			
	DS6-7	Dec.5-19	116	-20,03	0,59	3			
FROM ANALYSIS IN FEB [Jan. data remeasured):									
	A (DS3)	Dec.31-Jan.8	118	-21,3	0,20	3			
	B (DS1)	Dec.19-Jan.12	60	-21,9	0,68	3			
	a,b,c	Jan.0-8	51	-20,0	0,33	8			
	E,F,G	Jan.0-12	44	-21,8	0,54	13			
	k	Jan.4-8	134	-21,0		1			
	m	Jan.2-12	86	-21,9	0,50	7			
	p	Jan.2-12	72	-21,4	0,62	4			
	t	Jan.4-12	56	-21,9	0,50	4			

Notes:	B	Remnant of DS1 after passing DS3. DL2 oscillates +40 to +80.
	G	Spot G moved faster till Jan.6, not included.
	p	Prob. DL2 declining +83 to +55, lat.-21 to -22.

Thus, there were three remarkable aspects to the speeds: the pre-existing chain of spots whose speed was slightly slow for its latitude; the dark spots in the Revival which showed the peak jet speed spread over a much broader latitude range than normal; and apparently the re-establishment of a chain of spots with exceptionally slow speeds within the revived belt.

Discussion

Were there any changes to the zonal wind profile during the Fade and Revival of the SEB?

In the faded state, the chain of spots on the faded SEBs was initially quite close to the normal latitude for its speed (20.9 deg.S; DL2 ~ +75 deg/month) [Ref.6]. However there are now several reasons to think that this chain was indeed moving significantly more slowly than the standard zonal winds. First, subsequent JUPOS measurements in early Nov. showed lower latitudes for the chain although the speed was still DL2 ~ +71 deg/mth (Table 1 & **Fig.8d**). Second, a zonal wind profile obtained by Grischa Hahn in 2010 Sep. suggests a reduction in the jet peak speed ***(see box below)***. Third, JUPOS measurements in 2006 (as the normal activity was ending prior to the 2007 Fade; recently analysed by G. Adamoli) appear to show a similar deviation from the standard profile at that time **(Fig.8b):** the last spots all moved slightly slower than the Cassini profile, as they retrograded slowly along SEBs and then recirculated in the STropZ (that is, reverted their drift to prograde (in L2) while shifting to higher latitude), during a brief final stage of their evolution.

As soon as the Revival began, there was a remarkable change in the wind profile **(Fig.8d)**. The first dark spot in the southern branch was a pre-existing projection which accelerated suddenly as dark material from the Revival source was injected into it. Subsequent spots may have arisen in the same way (but in a more confused setting). These spots were in the same latitude as the pre-existing chain but with almost double the speed. So there was a massive acceleration of the southern flank of the jet, i.e. a broadening of the jet to the south: the peak jet speed (+114 to +134 deg/mth) extended over the whole latitude sector south to 21.3 S (almost identical with the latitude band which became the revived dark SEB(S).)

We reported a similar phenomenon in the 2007 Revival, when the first 4 large spots in the southern branch were likewise unusually far S for their speeds – in contrast to later spots which fitted onto the Cassini profile [Ref.1 & **Fig.8c**]. Those early spots appeared to be vortices, as they were very dark round spots within 10 days of their appearance, and later circulated as vortices; so were the later spots. Thus they differed from the non-vortical spots of 2010. However, there was a similar anomaly in the speed profile in both SEB Revivals.

How significant are these deviations from the Cassini gradient? In some normal years, the distinct vortices on the SEBs jetstream are likewise further south than the gradient would indicate, probably because they are entrained by interaction with the jet peak at their northern edge [**Fig.8a**]. However, the early spots in the 2007 Revival systematically differed from the later spots. It is even more anomalous in the 2010 Revival that dark spots right up to 21.3 deg.S have accelerated to near-peak jet speeds, even though they do not appear to be vortices.

Thus the paradigm of a fixed zonal wind pattern, with circulations moving along with it, is clearly violated by these events. This is the first time that a definite increase in zonal winds has been demonstrated by modern observations. (The SEBs has moved even faster in the past, and I attributed this to S.Tropical Disturbances –see the book.) In other cases where a jet has apparently increased in speed – the NEBs and NTBs – this turned out to be due to a permanent deep super-fast jet emerging at the surface. That is not the case here: the peak jet speed has not increased, but broadened to the south.

This was probably not due to deep, fast-moving disturbances breaking through to the surface, as the existing cloud-top pattern appeared to accelerate. I suggest that the SEBs jet broadened at depth – either as part of the buildup to the outbreak, or as an immediate reaction to it – and was then able to accelerate the existing cloud-top structures immediately downstream of the outbreak source. This source, arising from a deep level, was such a large and powerful storm that it was able to deflect the jet.

Yet another surprise was the reinstatement of the chain of white ovals within long sectors of the revived SEB(S), probably with the same slow speed range that it had before the Revival. This was clearly the case in the leading sector where P1 was the only surviving dark spot in mid-Dec.: the chain was again moving with its original slow speed, and the faster-moving P1 was superimposed on it, migrating from one projection to the next. The same duality probably exists within long sectors of the revived SEB(S), if our speed for spots a,b,c turns out to apply generally. It is possible that dark material was flowing around the slowly-retrograding ovals to form the faster-retrograding spots in the same latitude.

To explain this strange duality of speeds, two possibilities can be considered. Perhaps the chain is a wave pattern with a phase speed which is slower than the material wind speed, while the dark spots move with the true wind speed. Or, perhaps the chain moves with the cloud-top wind speed while the dark spots are driven by a faster wind speed at a deeper level. Either explanation raises further difficulties, mentioned below, which have yet to be resolved. Further analysis of images in January may clarify this puzzling situation.

What were the dark spots in the southern branch?

The nature of the slowly-retrograding chain of spots is still mysterious. If they were slow-moving waves, it is strange that they were not disrupted by the outbreak. If they were moving with the zonal wind, it is strange that the colocalised dark spots could move faster – although this might be possible if, for example, the ovals in the chain were small superficial vortices, while the dark spots were gaps in the cloud cleared from below.

The first dark spots in the Revival appeared to be projections in the pre-existing chain that filled up with dark material flowing from very dark spot(s) at the source. This origin suggests that the darkening was superficial, and indeed, most of these projections soon faded again. Whether the ‘dark material’ was a genuinely dark aerosol (soot, as in Kevin Baines’ hypothesis for Saturnian spots), or a thinning of the cloud layer, may be determined by professional mid-infrared observations.

Later SEB(S) spots, being larger and darker, may have represented more extensive changes to the cloud layers; but they appeared to be amorphous dark streaks and patches.

Were any vortices present? The small white ovals might have been small vortices, with the dark material of the Revival flowing around them. And some dark spots were quite compact and could have been vortices: spots B and DS5 on the SEB(S)s edge, and a series of small, very dark ones that appeared around Dec.30. But they were not the predominant elements of the southern branch.

Interaction with the GRS

In early Jan., the leading end of the southern branch arrived at the Red Spot Hollow. By this time the large, dark brown DS3 (A) was the leading spot, but some residual dark material must have persisted from the vanished spots ahead of it, as the RSH rim already started to darken by Jan.5. DS3 arrived on Jan.17, and its dark brown material flowed Np. around the RSH over the next few days, creating a mess at the northernmost point where it met the very dark spot from the SEB(N). There was no indication that DS3 persisted any longer; however, material from it may have spread around the f. side of the GRS and combined with the very dark rim that apparently arose from the SEB(N), both of which could have contributed to the disturbance that circulated around the S side of the GRS in late Jan.

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References: *See box below.*

BOX: The profile of the SEBs jet.

The zonal wind profile is the relationship between mean east-west speed and latitude, which has hitherto been determined only by spacecraft observations, because it requires measurement of the motion of the smallest possible cloud features. Generally, the profile comprises a distinct peak speed for each jet, and a smooth gradient of speed between the jets. This box gives some background information on the profile of the SEBs jet.

This jet, with a peak at ~19.5 deg.S according to profiles from spacecraft [Refs.2,3], is the fastest retrograde jet on the planet. The peak speed is typically DL2 ~ +120 deg/mth for visible spots, and the best estimate of the peak from spacecraft is +133 deg/mth [Ref.1]. This speed has actually only been recorded in the admittedly less-robust data set from New Horizons [Ref.3], but an independent analysis of the same images by Grischa Hahn, while obtaining a slower mean speed overall, confirms a speed of ~+130 deg/mth in some sectors [Ref.5]. It probably applies in many years, as other spacecraft profiles appear to be truncated (even Cassini's in Fig.8), and we have independent evidence for a peak speed of ~+133 deg/mth in 2007 [Ref.1] and 2010 [this report].

Images from Voyager and Cassini during normal activity showed that the dark jetstream spots were anticyclonic vortices; so were spots produced in the 2007 SEB Revival [Ref.1]. Therefore, the present paradigm is that these jetstream spots are vortices 'rolling' along the southern side of the SEBs jet [Ref.1].

However there are other 'normal' periods when the SEBs appears more chaotic or streaky, and few if any distinct spots can be tracked. This was the case in the late 1990s, and in 2006. The nature of the features on the SEBs at these times has not been investigated in detail, but the wind profile from Hubble Space Telescope data in the late 1990s [Ref.4] was similar to the Cassini profile but with the peak of the SEBs jet truncated at DL2 = +104 deg/mth, suggesting that the true peak may have been masked by overlying features.

In 2010, Grischa Hahn has determined the zonal wind pattern over most of the planet from ground-based (amateur) images for the first time, using a new correlation analysis program which he has written for WinJUPOS, and posted his resulting charts [Ref.5]. He analysed sets of images taken 10 hours apart on 2010 Sep.4 by Don Parker and Tomoyuki Yoshida. At 20.9 deg.S, on the flank of the jet, he confirmed the speed of DL2 = +75 deg/mth (u_3 = -38 m/s) that we recorded for the chain. The peak of the jet was located at 20 deg.S, with DL2 = +94 (u_3 = -46.6 m/s). Preliminary correlations on other pairs of images confirm this speed over a range of latitudes, -19 to -21.5 deg.S [G. Hahn, personal communication]. This peak speed is lower than normal, similar to the HST value in the 1990s, and likewise could represent a truncation of the usual jet peak at cloud-top level. However, it is clearly not due to masking by the visible chain of spots (the speed was different), and the speeds that we recorded for gaps in that chain proved that the normal peak jet speed did still operate, but possibly at a deep level.

1. Rogers J & Mettig H-J (2008), 'Jupiter in 2007: Final numerical report' (Part 3, inc. box & Figs.13 & 14): http://www.britastro.org/jupiter/Jup_2007_Part3_STropR-sm.pdf
2. Porco C. et al., Science 299, 1541-1547 (2003) [Cassini profile]
   Data provided by A. Vasavada.
3. Cheng A. et al., Astron.J.... (2008) [New Horizons profile]
   Data provided by A. Cheng & A. Simon-Miller.
4. Garcia-Melendo E & Sanchez-Lavega A, Icarus 152, 316 (2001)] [HST profile]
5. Hahn G., 'Longitudinal drift determination from image pairs with WinJUPOS' (text in German): http://www.grischa-hahn.homepage.t-online.de/astro/winjupos/LongDrifts/index.htm .
6. Rogers J, Mettig H-J, Adamoli G, Jacquesson M & Vedovato V (2010). Report no.8: 'Jupiter in 2010: Interim report: Southern hemisphere' (Appendix: 'The motion of the chain of spots on SEBs in 2010'): http://www.britastro.org/jupiter/2010report08.htm

Figures:

JUPOS charts of longitude vs time:

Fig.1. JUPOS chart [from H-J.M.] showing the motion of the chain of spots on SEBs before and during the Revival. All dark spots (black) and bright spots (red) on the SEBs (latitude band -22.5 to -19.0 deg.S), in a longitude system moving at +2.0 deg/day relative to System II. Grey lines indicate tracks of the dark projections. (The chart is not fully annotated for July-August as this was shown in our earlier report.) The grey area is the slow-moving sector with DL2 ~ +50 to +68; in other sectors the chain had DL2 ~ +70 to +75. Green lines indicate fast-moving gaps with DL2 ~ +132 to +140. Blue lines and labels indicate the first dark spots in the southern branch of the SEB Revival, after the initial outbreak (SEBO).

Fig.2. JUPOS data – Enlargement of the SEB Revival region using same data as Fig.1, re-plotted by JHR using Excel, in a longitude system moving at +3.0 deg/day relative to System II. Spots are colour-coded by latitude, allowing spots in slightly different latitudes to be distinguished. *[This figure has been transferred to report no.21.]*

Fig.3. Charts of identified dark spots, consisting of selected JUPOS data plus additional measurements as indicated on the images, plotted by JHR using Excel. This allows all the spots to be tracked (and identifications to be checked). (a) Dark spots in Dec. (b) Enlarged sector in mid-Dec. showing dark spot P1 and the complete chain of grey projections. (For greater accuracy, CM longitudes were corrected based on measurements of 4 stable large ovals in other latitudes.) (c) Dark spots in Jan.(and a few white spots, shown yellow).

Image sets of the southern branch in 2010, with spots labelled:

Fig.4. Images of the source and S branch, 2010 Nov.14-Dec.3.

Fig.5 . Images of the S branch, 2010 Dec.3-31.

Fig.6. Images of the S branch, 2011 Jan.1-10.

Fig.7. Images of the S branch, 2011 Jan.11-22 (not yet measured).

Fig.8. Charts of speed (DL2) vs latitude (zenographic) for SEB(S) spots.
(Scale of wind speed u_3 is calculated for 20.8 deg.S.)
(a): Mean values for vortices during normal years of SEB activity (JUPOS/BAA data, brown; Cassini data, blue):
--1928-1991 (mean from Rogers book; inc. SEB Revivals as well);
--1999-2002 (BAA reports, from JUPOS data)
--2000 (Cassini: approx. centre & N-S extent of vortices, estimated from publicly released maps).
Blue line: Cassini zonal wind profile (Ref.2); plus 2 additional points from New Horizons (Ref.3).
(b) 2006, when normal activity was ending (JUPOS data analysed by G-L.A., unpublished, plotted by J.H.R.)
(c) 2007: The SEB Revival: data already published on our web site [Ref.1]. (Green:) The first substantial spots (recently re-analysed by JHR, confirming the original results with greater precision). (Brown:) Later spots.
(d) 2010: The SEB Revival and pre-existing chain: data from Table 1. (Green, left:) Average values for the chains of pre-existing projections, including the small group which became the first dark spots in the SEB Revival (small point); (right:) The same group after they darkened early in the SEB Revival (at right; data mostly for P1 at different times). (Brown:) Later spots.