White spot Z: its history and characteristics, 1997-2013

John Rogers (British Astronomical Association) (Dec. 2013)

Summary

White spot Z (WSZ) is a prominent, long-lived anticyclonic white oval (AWO) at ~19ºN, in the North Tropical domain. It first appeared in 1997 and is the only feature in the domain to have lasted more than a few years. It has claimed attention in autumn 2013 because it has become unusually methane-bright and now is developing slight reddish colour. Here we summarise the previous history of WSZ, from our previous reports and from JUPOS data, and provide illustrations of its recent behaviour.

To a first approximation, WSZ is a great AWO at 19ºN, and it appears thus when the N. Equatorial Belt (NEB) is broadened to encircle it with dark material. However, when the NEB is narrowed so that WSZ is in the N. Tropical Zone, its oval form is often obscured by a faint grey streak, whereas a tiny, bright white spot appears on its N edge at 20.2ºN. During the great NTBs jetstream outbreaks in 2007 and 2012, WSZ became dark grey.

WSZ almost always has a faster drift than other stable spots in the domain (AWOs and cyclonic barges), and lies slightly further north than other AWOs. In its early years, it eliminated other spots preceding it; later it became more likely to accelerate them to its own speed, 'pushing' them ahead of it and sometimes causing them to merge with other spots further ahead. In exceptional circumstances in 2007 and 2009, it failed to accelerate barges preceding it and almost halted its drift, but only temporarily. Conversely, after the great northern upheaval of 2012, it accelerated to a rapid speed which was unprecedented and anomalous for its latitude, and collided with an AWO preceding it in early 2013. Collisions between AWOs in this domain are uncommon and lead to only partial merger; a remnant of the leading oval always persists for a short time.

These ovals are not usually methane-bright, but WSZ became modestly methane-bright after the 2013 merger, and by 2013 Sep. the whole oval was strongly methane-bright. In visible light, the aspect of a grey streak and a northerly bright spot was notable. The grey area acquired slight brown tint during Oct., then in late Nov. more distinct reddish colour appeared around the northerly bright spot. We wait to see whether WSZ will now transform itself into a Little Red Spot.

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Introduction

WSZ appeared in 1997 as one of an array of AWOs that developed in the aftermath of the NEB expansion event of 1996 [ref.1]. Although we have covered it frequently in our reports over the past 16 years, we have only given brief summaries of its nature and early history [refs.2 & 3]. So in this article, I give a more extensive overview of WSZ, from these reports and from the JUPOS database. The Appendix includes more detailed notes on it from our existing reports (1998-2013), plus the complete JUPOS charts for these years. It also includes new compilations of images from 2011-2013 to document the recent developments.

This is not a final report, as we still need to complete the analysis of the images and JUPOS data for many apparitions. However, it is sufficient to document the reproducible characteristics of

WSZ over its long history – some of which have previously only been noted as passing phenomena.

Thanks are due to all observers, who are listed on the JUPOS website (http://jupos.org) and in our final apparition reports. Many images are reproduced in the figures in the Appendix. Although I have selected the best hi-res images to illustrate this report, images of more modest quality are also valuable and have contributed the bulk of the JUPOS measurements used for tracking WSZ and other spots. I also thank the JUPOS team (Hans- Jörg Mettig, Gianluigi Adamoli, Michel Jacquesson, Marco Vedovato, and Grischa Hahn), especially Hans-Jörg Mettig who produced the charts, and Gianluigi Adamoli who did extra measurements or analysis for some apparitions which had not yet been analysed, including full reports for the apparitions of 2006 and 2011/12 (in preparation).

All illustrations herein have south up, and all longitudes are System II, unless otherwise stated. However a chart in System III is provided [Appendix Fig.5B] to facilitate identification of WSZ in professional images. Drifts (DL2) are in degrees longitude per 30 days, and latitudes are zenographic. P. means preceding (eastward), f. means following (westward).

Fig.1 is a compilation from cylindrical-projection maps made in each apparition from 2000 onwards, showing WSZ. It also shows the changes in appearance of the NEB. The NEB has undergone expansion events with a period of 3-5 years [ref.4]; they occurred in 1996, 2000, 2004, 2009, and a full NEB Revival in 2012. The other grand-scale phenomena affecting this domain are NTBs jetstream outbreaks, which occurred in 2007 March and 2012 April.

Appearance & latitude

To a first approximation WSZ is a great AWO, often little different from others in the domain, though always one of the largest and brightest. It always appears as an oval, surrounded by dark NEB material, when the NEB is broad after a NEB expansion event, and the mean latitude is 19.2ºN for the complete oval (Appendix Table 1).

When the NEB is narrower, the latitudes of spots remain unchanged, but AWOs including WSZ are less obvious against the bright NTropZ; so it is often recorded as a bay in NEBn, and the corresponding JUPOS latitudes average 17.2ºN, presumably for its south part or edge.

However, sometimes it shows more complex structure which suggests that it is more than a simple oval. In several years, a tiny bright spot has been recorded in v-hi-res images in the northern part of WSZ. This northerly white spot (N.w.s.), at 20.2ºN, was first seen in 1998, interrupting the bluish N.Trop.Band in that year. It was recorded again in 2008, 2009, and now 2011/12 and 2013, at the same latitude. In all those years, WSZ was in a broad NTropZ preceding a NEB expansion event, so I looked at the best images in a similar year, 2003, which we had not thoroughly analysed – and indeed the N.w.s. was obvious in that year as well.

In some of these years, the appearance of WSZ was also unusual as the white oval was largely filled with a grey 'eye' shape, with the N.w.s. on its N edge. Although this appearance was not generally noticed until autumn 2013, review of earlier images shows it clearly in 2011/12 and in 2003. (Hi-res images from 2011/12 are shown in Appendix Figs.6 & 7.) At the smallest scale that we can resolve, the N.w.s. shows rapid variability as tiny irregularities on the N.Trop.Band prograde past it, and appears to emit tiny bright streaks p. it along the N.Trop.Band.

WSZ had an even more unusual appearance for several months in 2007 and 2012, during and after the NTBs outbreaks of those years. In each case it became dark grey! (See interim reports reprinted in Appendix.) Then it revived, spasmodically, starting with short-lived eruption of a bright white spot within it (lat.18.7ºN on 2007 August 7; similar on 2012 July 8), then gradually lightening over subsequent weeks.

The latitudes are plotted against drift rate in **Fig.2B**, showing the zonal drift profile (ZDP). For the white oval aspect, all points except for 2012 are consistent with a typical ZDP for a large anticyclonic oval, matching the zonal wind profile for fast speeds but not extending to slow (retrograding) speeds. (Other AWOs in this domain follow almost the same ZDP, according to analysis of the 2006 apparition: G. Adamoli, in preparation.) The point for the grey oval in 2007, when it decelerated after the NTBs outbreak, is consistent with the same profile. However the point for 2012, when it accelerated after the concurrent violent outbreaks in the NTBs and NEB, is completely inconsistent. This suggests that the acceleration in 2012 was a unique consequence of the NEB Revival – even though we found no overall change in the ZDP for other spots in this domain.

Discussion:
The varied appearance and behaviour of WSZ has given rise to some uncertainty about its true nature. I think we can be sure that it is basically an AWO like others, centred at 19ºN -- this latitude also being consistent with the central white spot eruption in 2007, and the methane-bright oval in 2013. However, there are several unsolved puzzles concerning the nature of WSZ. Why is it faster-moving, longer-lived, and centred further north, than other AWOs in the domain? Why does it lose its white cloud cover during NTBs outbreaks, and why does the revival of the white oval begin with a small bright outburst near its centre? And what is the N.w.s.? It is unlikely to be the dynamical centre of WSZ, given the regular shape and latitude of the oval in many years. But it also seems unlikely to be merely a cloud condensation near the N edge, as it is so compact, and there is no reason to think the dynamics would be exceptional here. The appearances in 2011/12 [see Figs.6 & 7 in Appendix] suggest that it may be a small convective plume, not unlike the one that sometimes appears on the N edge of the GRS [see our 2009 reports].

High-level haze

AWOs in the NTropZ, unlike those in other domains on the planet, are not usually bright in methane-band images (889 nm), indicating that they do not have high-level haze caps. Sometimes they are very weakly methane-bright, sometimes not at all. We have not noticed anything special about WSZ in this regard, except that hi-res images in 2011/12 showed the N.w.s. to be methane-bright [Appendix Fig.7]. As it is so small, the N.w.s. would not have been resolved in earlier methane-band images. However, the whole of WSZ became somewhat more methane-bright in early 2013, as described below.

Longitudinal drift, history and interactions

WSZ was the fastest-moving (eastward) stable spot in the domain when it first appeared in 1997, and remained so for many years thereafter (ignoring a few minor or transient features). The other stable spots are other AWOs, and cyclonic dark 'barges'. Here is a brief summary of its history: see the JUPOS charts and the interim reports in the Appendix for further details. A chart of the speed over time is in **Fig.2A**.

In late 2000, WSZ caught up with a dark barge and 'pushed it along' just p. it. In late 2001, WSZ and the barge suddenly accelerated even further, causing the barge to merge with another one p. it (2001 Nov.), after which they accelerated even further to DL2 = -18.5 deg/month. The barge merged with yet another one in 2002 Dec., and decelerated; then when WSZ caught up with the merged barge again in 2003 Feb., it too decelerated, to DL2 = -7, marking the first time it showed a sustained speed that was less than some other spots in the domain. Nevertheless, these other spots did not persist to the next apparition, when new spots created during the 2004 NEB expansion event were all moving slower than WSZ. By 2005 these had developed into a full array of barges and ovals, including two barges and two ovals just p. WSZ which were moving along with it, causing the leading barge to merge with another barge p. it in 2005 May.

In 2006 Feb., just as it induced another barge merger p. it, WSZ underwent another sudden, unexplained acceleration, soon reaching DL2 = -19 (which would be its fastest speed ever until 2012). This led to its first definite collisions with other AWOs p. it: one in 2006 June, which was well observed, and one in 2006 Sep. which was not.

In early 2007 it progressively decelerated again, most dramatically in 2007 April when it came up against a barge p. it and decelerated suddenly from DL2 = -11 to -1.5 (its slowest speed ever), so that it formed a triplet with the barge and another AWO p. it. This group picked up speed again in late 2007, and in early 2008 the leading AWO collided with another one p. it, and another barge joined the leading edge of the group, destroying smaller, slower-moving barges which it encountered.

In 2009 July, two months after the NEB expansion event began, WSZ suddenly decelerated again to DL2 = -5 on encountering an AWO associated with the source region of the expansion event. In 2010 these still formed a stable group, with a barge between them, but WSZ was no longer the fastest spot in the domain. It regained this title in late 2011, along with a barge pushed along p. it. Then in summer 2012, immediately after the spectacular concurrent NEB and NTB Revivals, it progressively accelerated to speeds far beyond anything seen before, peaking at DL2 = -42 in autumn 2012. A new AWO p. it was moving almost as fast, and merged with another AWO in 2012 Nov., then this in turn collided with WSZ in 2013 Feb. [see Appendix Fig.8].

Discussion:
The reasons for these dramatic speed changes remain unknown. They do not show any correlation with NEB expansion events. Two of the most extreme speed changes occurred immediately after the two NTBs outbreaks, which also radically changed the appearance of WSZ (see above); however, the change in 2007 was a sudden deceleration, whereas the change in 2012 was a massive acceleration. As noted above, the latter event may have been a unique consequence of the NEB Revival.

Collisions with other ovals and barges

WSZ often encounters slower-moving spots p. it, usually barges (dark cyclonic circulations). The typical outcome of these encounters has changed over the years. In its early years (1997-1999), WSZ was destroying slower-moving barges p. it as it overtook them. Since then, rather than destroying the next barge, WSZ has often impelled it to accelerate to the same speed, forming a group (2000, 2005-2006, 2008); and sometimes entraining another AWO and barge p. it as well. In these groupings, the leading barge often merged with slower-moving barges which it encountered (2001, 2002, 2005, 2006, 2008; see refs. below). More recently still, WSZ has sometimes failed to destroy or accelerate spots which it encountered, but has decelerated to their speed: this happened in 2007 (up against a barge, shortly after the NTBs outbreak) and in 2009 (up against an AWO associated with the ongoing NEB expansion event). These episodes may indicate that the influence of WSZ has been weakening over the years, or they may have been exceptional circumstances.

Mergers between barges have turned out to be quite common. The first three were reported in detail in ref.[3] (as well as our interim reports). Others have occurred since [ref. 5], and typically followed much the same course, with the two barges in slightly different latitudes sliding together with initial overshoot but without obvious disturbance, although sometimes a small white spot appears briefly.

Collisions of WSZ with other AWOs have occurred in 2006 (twice) and in 2012/13, always when WSZ was moving exceptionally fast. We have also recorded collisions between other pairs of AWOs in this latitude on 5 occasions (2007 Feb., 2008 April, 2010 Aug. & Sep., 2012 Nov.) [ref. 5, & see reports in Appendix]. Six of these 8 events have been fairly well observed, and in each case there seems to have been no more than a partial merger. The leading (Sp.) oval shrinks as it squeezes along the S edge of the following (Nf.) oval; then they usually can be seen to spiral together, but only partially; in every case, part of the Sp. oval continues or re-emerges Sf. the surviving oval, as a slow-moving small white cloud which only lasts for a few days or weeks before disappearing. The surviving (originally Nf.) oval sometimes shows signs of instability or methane-brightness in the days during and after the interaction.

Discussion:

The great strength of WSZ is evident from the powerful effects which it has on (cyclonic) barges and (anticyclonic) ovals which it approaches. When it approaches a barge, WSZ usually accelerates it as if to 'push' it forward. This does not require a direct eastward force from WSZ; it may occur because streamlines (including the retrograding NEBn jet) are diverted southwards and compressed around the S edge of WSZ, so a barge affected by this distortion is pushed southwards into a faster prograding flow.

WSZ rarely comes into contact with another AWO. Usually, this is because AWOs are separated by barges. Thus, as in other domains, AWOs do not readily merge. The three collisions involving WSZ all occurred when it was prograding exceptionally fast. Two other collisions were between pairs of ovals just p. WSZ; but the other three were far away, and it is not clear what impelled them into contact.

It is also striking that none of the interactions led to a complete merger; although there are usually clear signs of the ovals spiralling together, at least part of the Sp. partner always escapes, though it does not last long. Of course, we cannot say how much of the energy and vorticity of the Sp. oval is transferred to the surviving one. [See the 2006 interim report, copied in Appendix, for a discussion.] Further study will be needed for a complete assessment of these events.

Following WSZ, new barges and ovals are created, with slower speeds. This process also deserves further study. They seem to develop from small beginnings over some distance. It is conjectured that they arise from instability of the NEBn retrograding jet, but it is not clear whether this is specifically in the 'wake' of WSZ, or merely in a sector where no stable spots yet exist.

The changes in 2013

The first methane-band images of the present apparition, starting with Chris Go's on 2013 Aug.31, revealed that WSZ had become remarkably methane-bright, even brighter than NN-LRS-1 (**Fig.3** & Fig.9 in Appendix). The methane-bright oval, centred at 18.9 (+/-0.3) ºN, coincided with the expected outline of the visible oval. Visibly, WSZ had very low contrast and was hard to make out, apart from the bay in the NEBn. Hi-res images showed that this was because the oval was partly occupied by a diffuse grey streak, as in 2011/12; the N.w.s. was faintly present in some hi-res images. (At this time, WSZ was advancing rapidly on a pair of dark barges, which were impelled toward each other, but the f. (smaller) one disappeared on 2013 Sep.16 just as they made contact.). The grey area in WSZ developed a very faint brownish tint during the autumn, and the N.w.s. was on its N edge. Latitude measurements in Nov. placed the grey-brown area at 18.4ºN and the N.w.s. at 20.2ºN (G. Adamoli; Appendix Table 1).

On 2013 Nov.24, Chris Go reported a more distinct reddish colour in his image. This colour had developed within the previous 1-2 days: the reddish colour can be seen developing from Nov.23 (Rozakis) to Nov. 24 (Morales Rivera, Go), in the N half of the oval centred on the N.w.s., still half-encircled by the grey streak on its S side. (**Fig.3**, and Appendix Fig.10.)

As of early Dec., the colour is still very weak – much the same as many dull brownish regions on the planet -- but it has persisted for several weeks, so we wait to see how it will develop.

Discussion:
The reddish colour and the complete methane-bright cap are new for WSZ. Why have they appeared now, and what is their significance?

Reddish anticyclonic ovals on Jupiter are always very methane-bright, probably because the reddish colour is itself in a high-altitude haze. So the exceptional methane-brightness of WSZ from 2013 Aug. was apparently a precursor of the reddish colour that appeared in Nov. How did this begin? One clue may be the series of interactions in 2012/13, when two other large AWOs partially merged, and the resulting oval went on to partially merge with WSZ. This was probably the largest merger to affect WSZ in its history, and occurred in the unique circumstances of the NEB Revival. After this event, WSZ was weakly methane-bright (Appendix Fig.8); so one hypothesis is that the merger intensified the circulation of WSZ, leading to a thickening of its cloud cap, which progressed gradually over the following 6 months, and ultimately led to red colour appearing as well.

Whereas white colour in AWOs clearly represents a thick cloud layer, the nature of grey or red colours is still uncertain. Grey colour usually coincides with clearings of the clouds (bright in professional 5-micron images), but it is conceivable that grey clouds also exist; K. Baines and colleagues [ref.8] have proposed that transient vortices on Saturn are dark grey from lightning-generated soot. Red colour is also unexplained but is usually present on features with very fast winds and/or vigorous disturbance. The prevailing hypothesis is that it represents some compound dredged up from the depths in anticyclonic ovals, which is either red itself or becomes red on exposure to sunlight.

Why did the reddish colour appear in the N part of WSZ? One hypothesis is that the N.w.s. is a convective plume and the red material emerged from it. An alternative is that the red material was distributed around the oval but, as in the GRS, internal dynamics tends to concentrate it on the high-latitude side.

The reddish colour is still very weak and we don't know whether it will last. However, as Chris Go has proposed, WSZ could well develop into a proper red oval or 'Little Red Spot' (LRS). LRSs in this domain have only been definitely observed in four apparitions, and each time there were 2 or possibly 3 of them [ref.6, pp.117 & 398]. These apparitions were 1895/96, 1919/20, 1973, and 1976/77. On each occasion, one of them was the fastest-moving spot in the domain. The LRSs of 1973 had DL2 = -23 and -26 and were at 19.2 N [BAA report], and one was imaged by Pioneer 10. Those of 1976 had DL2 = -20 and -13, and one of them was imaged professionally and was also at 19.2 N [ref.7]. Thus their speeds and latitude were similar to those of WSZ, and it would only take an intensification of the present reddish colour to convert WSZ into a Little Red Spot.

References:

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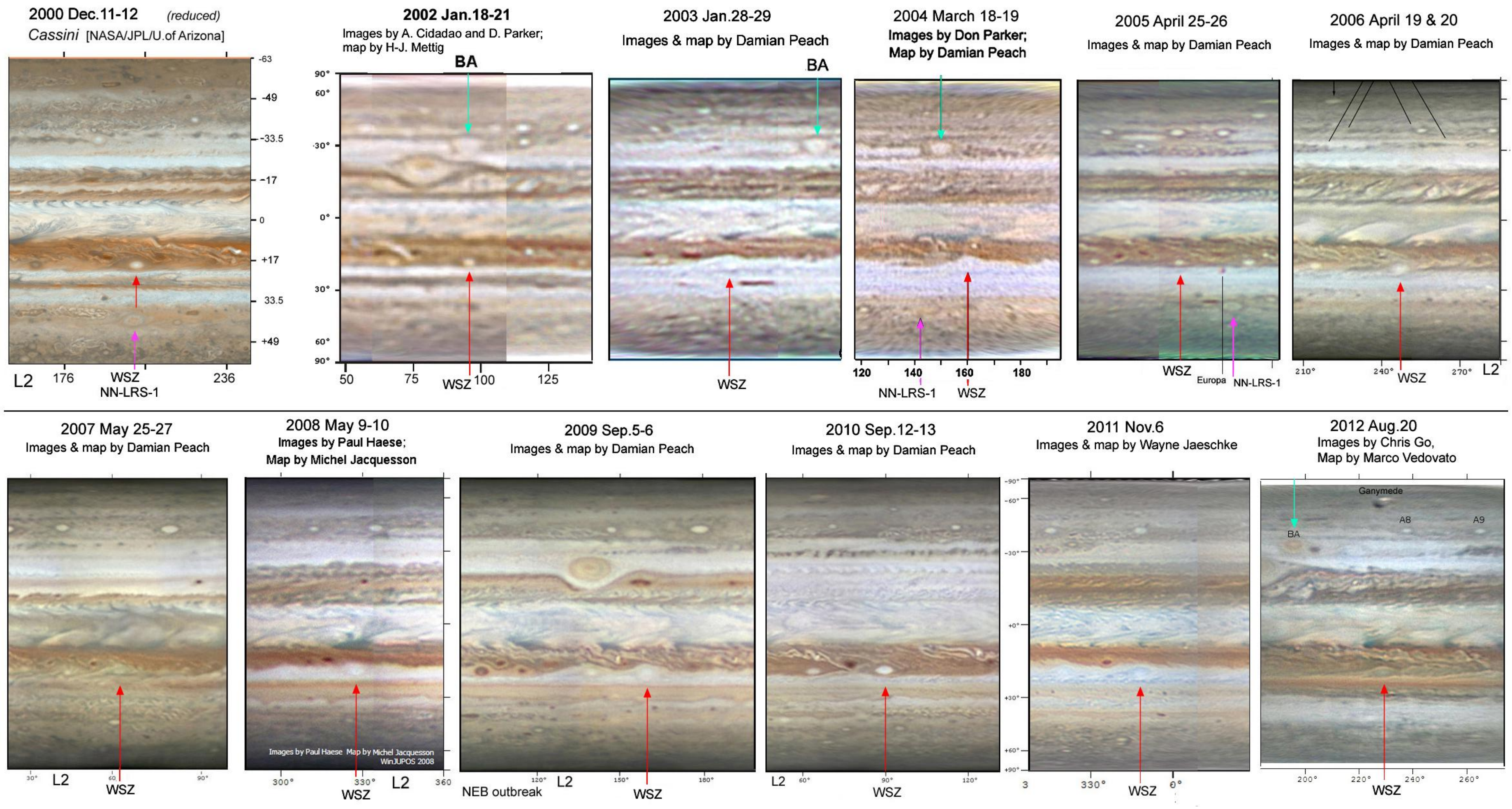
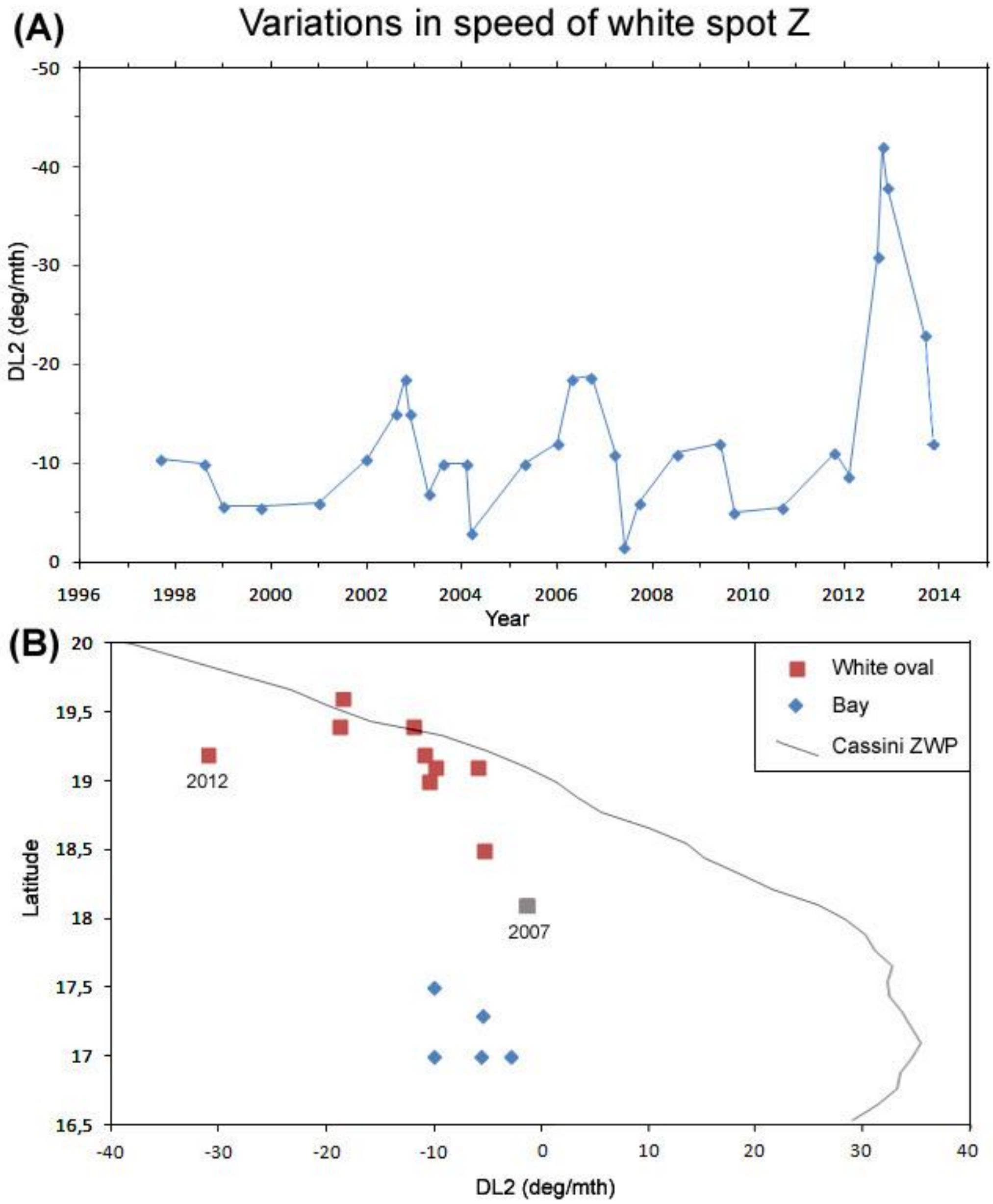
Figures:

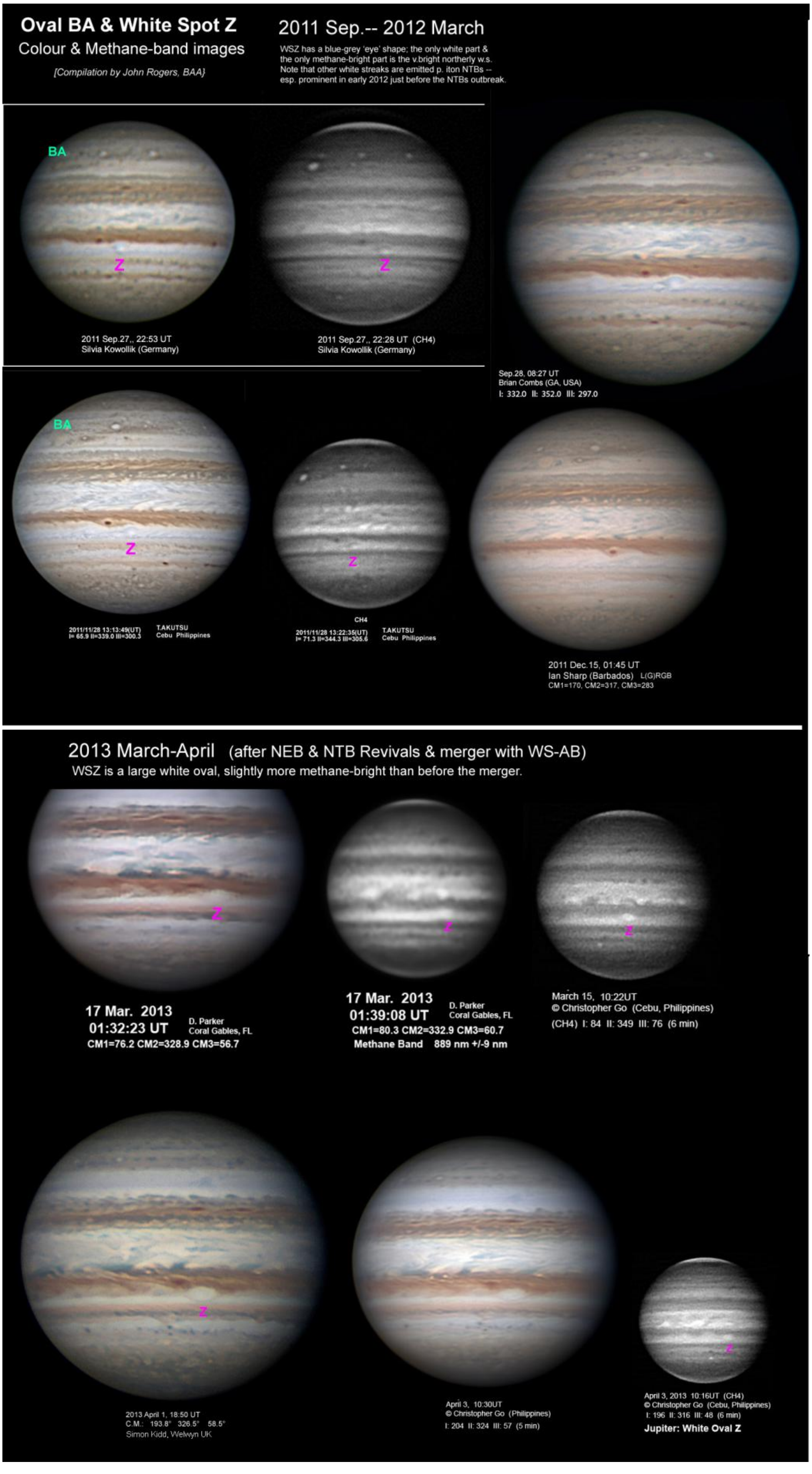
[next page:]
Figure 1. Excerpts from maps for each apparition from 2000 onwards. All are cylindrical projection maps, except for the first which is an equirectangular projection map from Cassini. WSZ is indicated as well as two other large anticyclonic ovals, BA and NN-LRS-1.


2000 Dec.11-12 (reduced)
Cassini [NASA/JPL/U.of Arizona]
-63
-49
-33.5
-17
0
+17
33.5
+49
L2 176 WSZ 236
NN-LRS-1
2002 Jan.18-21
Images by A. Cidadao and D. Parker;
map by H-J. Mettig
BA
90° 60° 30° 0° 30° 60° 90°
50 75 WSZ 100 125
2003 Jan.28-29
Images & map by Damian Peach
BA
WSZ
2004 March 18-19
Images by Don Parker;
Map by Damian Peach
120 140 160 180
NN-LRS-1 WSZ
2005 April 25-26
Images & map by Damian Peach
WSZ
Europa
NN-LRS-1
2006 April 19 & 20
Images & map by Damian Peach
210° 240° WSZ 270° L2
2007 May 25-27
Images & map by Damian Peach
30° L2 60° 90°
WSZ
2008 May 9-10
Images by Paul Haese;
Map by Michel Jacquesson
Images by Paul Haese Map by Michel Jacquesson
WinJUPOS 2008
300° 330° L2 360
WSZ
2009 Sep.5-6
Images & map by Damian Peach
NEB outbreak 120° L2 150° 180°
WSZ
2010 Sep.12-13
Images & map by Damian Peach
L2 60° 90° 120°
WSZ
2011 Nov.6
Images & map by Wayne Jaeschke
-90° -60° -30° +0° +30° +60° +90°
3 330° WSZ 0°
2012 Aug.20
Images by Chris Go,
Map by Marco Vedovato
Ganymede
A8
A9
BA
200° 220° 240° 260°
WSZ

[Below:]
Figure 2. Variations in speed of WSZ. (Data are in Table 1 in Appendix.) (A) Variation of speed over its history. (B) Variation of speed with latitude.



[Next 2 pages:]
Figure 3. Images in colour and in methane band (889 nm), showing WSZ from 2011 to 2013. (See Appendix for more images covering these periods, & see attached ZIP file for full-size versions of all figures.)
(a) 2011/12 , showing a blue-grey 'eye' shape with only the N.w.s. bright.
(b) 2013 March-April, after the NEB Revival and two partial mergers of AWOs were completed. (c) 2013 Sep: WSZ strongly methane-bright for the first time)
(d) 2013 Nov: WSZ begins to show reddish colour.

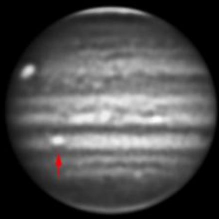


Oval BA & White Spot Z
Colour & Methane-band images
[Compilation by John Rogers, BAA}
2011 Sep.-- 2012 March
WSZ has a blue-grey 'eye' shape; the only white part & the only methane-bright part is the v.bright northerly w.s. Note that other white streaks are emitted p. iton NTBs -- esp. prominent in early 2012 just before the NTBs outbreak.
BA
Z
Z
2011 Sep.27,, 22:53 UT
Silvia Kowollik (Germany)
2011 Sep.27,, 22:28 UT (CH4)
Silvia Kowollik (Germany)
Sep.28, 08:27 UT
Brian Combs (GA, USA)
I: 332.0 II: 352.0 III: 297.0
BA
Z
Z
2011/11/28 13:13:49(UT)
I= 65.9 II=339.0 III=300.3
T.AKUTSU
Cebu Philippines
CH4
2011/11/28 13:22:35(UT)
I= 71.3 II=344.3 III=305.6
T.AKUTSU
Cebu Philippines
2011 Dec.15, 01:45 UT
Ian Sharp (Barbados) L(G)RGB
CM1=170, CM2=317, CM3=283
2013 March-April (after NEB & NTB Revivals & merger with WS-AB)
WSZ is a large white oval, slightly more methane-bright than before the merger.
Z
Z
Z
17 Mar. 2013
01:32:23 UT
D. Parker
Coral Gables, FL
CM1=76.2 CM2=328.9 CM3=56.7
17 Mar. 2013
01:39:08 UT
D. Parker
Coral Gables, FL
CM1=80.3 CM2=332.9 CM3=60.7
Methane Band 889 nm +/-9 nm
March 15, 10:22UT
© Christopher Go (Cebu, Philippines)
(CH4) I: 84 II: 349 III: 76 (6 min)
Z
Z
2013 April 1, 18:50 UT
C.M.: 193.8° 326.5° 58.5°
Simon Kidd, Welwyn UK
April 3, 10:30UT
© Christopher Go (Philippines)
I: 204 II: 324 III: 57 (5 min)
April 3, 2013 10:16UT (CH4)
© Christopher Go (Cebu, Philippines)
I: 196 II: 316 III: 48 (6 min)
Jupiter: White Oval Z

White spot Z, 2013 Sep:

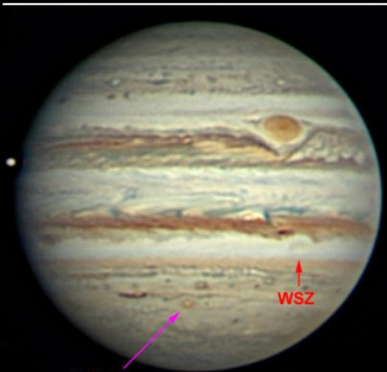
WSZ has become unusually methane-bright, like NN-LRS-1.
Visibly it has low contrast but stretched images
show a diffuse grey streak within the bay, and
narrow bright northerly white strip.

3 Sept. 2013
10:06.1 UT
D. Parker
Coral Gables, FL
Derotate 2 images: 10:00-10:12
CM1=196.7 CM2=229.6 CM3=2.8

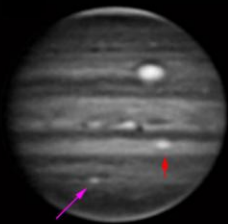


3 Sept. 2013
10:45.2 UT
D. Parker
Coral Gables, FL
Methane Band 889 nm +/-9 nm
CM1=220.6 CM2=253.2 CM3=26.4

2013 Sep.4, 04:43.5 UT
Damian Peach (UK)



28 Sept.2013, 4:14.6 UT
Manos Kardasis

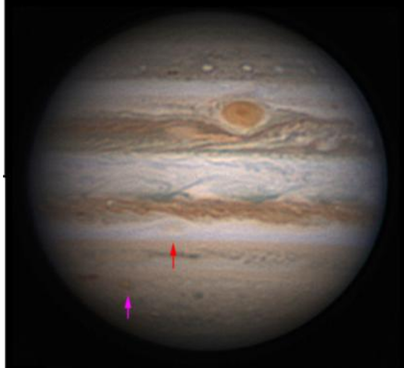


2013 Sep.28, 04:29 UT (CH4)
Manos Kardasis (Greece)

2013 Sep.29, 10:42.6 UT
Gary Walker (GA, USA)
(11 mins derotation)
CM1=2.6 CM2=196.9 CM3=337.1

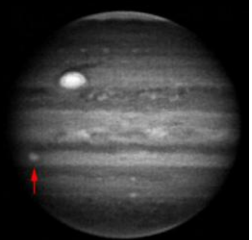
2013 Nov.

The grey streak had a slight brown tint, and on Nov.23-24, light reddish tint develops in N part



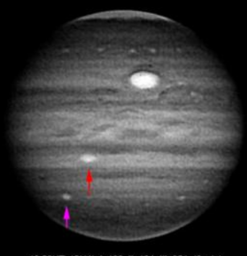
2013 Nov.23, 02:59.5 UT John Rozakis Athens Greece

2013 Nov.24, 07:14 UT
Efrain Morales Rivera (Puerto Rico)
I: 79.6, II: 207.6, III: 359.



November 24, 2013 17:47UT (CH4)
© Christopher Go (Cebu, Philippines)
I: 106 II: 230 III: 26 (6 min) (5 min)

December 3, 2013
© Christopher Go (Cebu, Philippines)
19:00UT I: 132 II: 188 III: 346 (5 min)



19:09UT (CH4) I: 138 II: 194 III: 351 (6 min)
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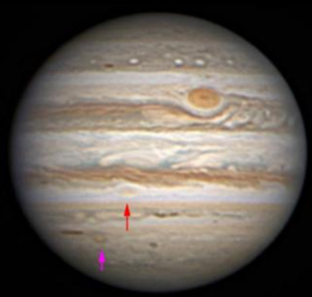

2013 Dec.9
03H58.4 UT I : 170.9° II : 185.5° III : 344.5°
Jean-Jacques Poupeau (France)