Jupiter's S2 (S.S. Temperate) domain, 2012-2023:

Appendix 3: Our principal reports, 2012-2023

S2 jet

2013/14 no.4:
https://britastro.org/jupiter/2013_14report04.htm

Several SSTBn jet spots have been recorded, mostly prograding up to the dark spots in STZ Sf. the dark STB segment, where they decelerate and are lost. One pair prograded up to the STB Ghost, where one disappeared, while the other reversed its drift to retrograde (with oscillations) in the STZ (Figs.2 & 3).

2014/15 no.12 (Final report):
https://britastro.org/jupiter/2014_15report12.htm

S2 jet: Only a few spots were tracked, for only a few weeks each. Some disappeared at the STB Ghost, and others in the tail of the STB dark segment. (Inc. global ZDP)

2015/16 no.13 (Final report): Full description & charts, inc. global ZDP.
https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2015-16/2015-16-report-no-13-final-report

The SSTBn (S2) prograde jet carried an unusually large number of small dark spots. One of them arose shortly p. oval BA in Nov. and passed DS5. Thereafter, when DS5 had pulled ahead of BA and evolved into the STB Spectre, the SSTBn jet spots arose at or just p. the Spectre. They had initial speeds of DL2 = -116 (±7) deg/mth (n=5), which is faster than all previous measurements for this jet except by New Horizons. (We have previously observed mean peak speeds averaging -110 (±2), with a maximum of -114 in 2011/12. The peak speed was -94 from Cassini and -126 from New Horizons. --Ref.22). They all decelerated after 2-3 weeks, en route to the STB Ghost; as they did so, two of them crossed and some others merged. They drifted slightly northward at this time although the ZDP was unusually shallow [see JUPOS chart & Fig.20]. None of them got past the STB Ghost. [Many of them recirculated to retrograde in STZ at the f. end of the STB Ghost or STB Spectre. These events are shown in [JUPOS chart & Figs.17 & 21]..... Throughout, all these spots changed their latitude along with their drift rate, adhering to the Cassini ZWP [Fig.20]. These set up the recirculation loops.]

2015/16 no.13 (Final report): Full description & charts, inc. global ZDP.
https://www.britastro.org/node/8263
[Much activity on S2 jet, at its peak & N side (STZ).]

The SSTBn and STBs jets and recirculation at the STB Ghost and Spectre:
These events confirm that the STB Ghost and Spectre, like the earlier STB Remnant, block the passage of all SSTBn jet spots, and cause most of them to recirculate. Indeed we recorded more such recirculations in this apparition than in any previous one. But it is notable that all the recirculated spots, f. the STB Ghost and Spectre, retrograded for only a few tens of degrees before they either disappeared or reversed their drift again to join the STC. (This was also typical for spots recirculated from the STB Remnant and Ghost in earlier years [refs.18 & 19].)

2016/17, Report no.10: Interim report (2017 May)
https://britastro.org/node/10328

STZ & SSTBn jet: The STB Spectre, with evidence for more coherent recirculation:

The STB Spectre, a cyclonic circulation like the STB Ghost, is ~3.5º long internally, and ~10-11º long externally. Its drift rate is unchanged at -15.5 deg/mth. It was beautifully imaged by JunoCam at Perijove-5, especially its p. end.

Once again we find that prograding spots from the S2 (SSTBn) jet are halting or recirculating south of the Spectre, as shown in Figure 9. In fact (as described in detail on Fig.9), these spots seem to be travelling around an elongated 'recirculation loop' – which can be seen as a pale grey line around an orange oblong in some v-hi-res images, esp. by Olivetti. It is ~20-27º long with its p. end due south of the Spectre. The JunoCam closeup images at Perijove-5 on March 27 actually covered

the p. end of this recirculation loop (Fig.9), although it was not recognised at the time. The loop can also explain observations from last apparition. It remains to be seen whether this loop is now a permanent structure, or will gradually become one. If so, it could be the start of the next generation of great white ovals in the S. Temperate domain.

The SSTBn (S2) jet shows few spots except that, from Feb. to April, several quite prominent dark spots have been prograding with various speeds over tens of degrees both p. and f. oval A5a. Speeds have ranged up to DL2 = -68. As shown in Appendix 4 (Fig.1), they are within a densely disturbed stretch of SSTBn f. A5a, and encounter a prominent dark spot (probably anticyclonic vortex) almost fixed just Np. A5a; a few spots, with DL2 ~ -50, continue prograding on SSTBn p. this spot.

2018 no.6 ("Draft final report"): General description & charts.

https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2017-18/jupiter-in-2018-report-no-6

STZ and SSTBn (S2) jet: The following features have all appeared tens of degrees p. oval BA, which could be further consequences of the transformation of the STB Ghost.

(1) The only spots recorded in the SSTBn (S2) jet this year were a pair of dark spots that were tracked from late March until mid-May, with DL2 increasing from (-66,-69) to -89 deg/mth.

(2) A dark spot in southern STZ (34ºS) appeared in late May (33 --> 40 p. BA; DL2 ~ -19)...

2022/23 no.8 (Final report on S.hemis.):

https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2022-23/jupiter-in-2022-23-report-no-8

[Full description & charts, inc. JunoCam maps PJ41-PJ49: Fig.13].

SSTBn (S2) jet: Only a few inconspicuous, short-lived dark spots were tracked in this jet. One in June had DL2 = -134. Another in Oct. had DL2 = -125. From Nov-Jan., a dark spot was tracked with DL2 = -55.

S3 jet

2013/14 no.4 [not accessible online, formerly on ALPO-Japan]:

In the S3 prograde jet (formerly called S3TBn jetstream), there have been 5 exceptionally prominent white spots, and one dark spot. The 5 white spots were sometimes almost as bright as the S2 AWOs, which they were passing [Fig.4]. These 5 white spots existed as early as 2013 Sep., and Dennis Put first drew attention to one on Oct.6, though no.5 did not become prominent until early Dec. Nos.1 & 2 merged in Nov., and nos.3 & 4 in Jan., and they may have disappeared in Feb. These spots had mean latitude 43.9ºS (+/-0.2), mean speed DL2 = -98 deg/mth, with a range of DL2 from -85 to -102 deg/mth, following a cyclonic gradient on the S side of the S3 jet peak [Fig3C], exactly like S3 jet spots in previous years [ref.2].

2015/16 no.13 (Final report): Full description & charts, inc. global ZDP.
https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2015-16/2015-16-report-no-13-final-report

The S3 jet was visualised by just 5 short-lived white spots, four of them having DL2 = -102.8 (±1.2), mostly at latitude 43.8ºS.

2016/17, Report no.10: Interim report (2017 May)
https://britastro.org/node/10328

The S3 jet displays a large outbreak of exclusively white spots: there are 12 of them spaced 7-15º apart (mean 10.5º), with DL2 = -98 (±1.5) deg/mth.

2018 no.6 ("Draft final report"): General description & charts.
https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2017-18/jupiter-in-2018-report-no-6

S3 jet: Exceptionally, only two spots were tracked in the S3 jet, both white, with DL2 = -96 and -97.

2019 no.9 ("Draft final report"): Full description & charts.
https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2019/jupiter-in-2019-report-no-9
[Includes ZWPs by Marco Vedovato, from amateur images in April [Report no.1] & from the Hubble OPAL images on June 26-27 (Figure 4).]

S3 jet: Only one dark spot was tracked in this jet, for the month of April, with DL2 = -98 deg/mth.

2022/23 no.8 (Final report on S.hemis.):
https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2022-23/jupiter-in-2022-23-report-no-8
[Full description & charts, inc. JunoCam maps PJ41-PJ49: Fig.13].

S3 jet: This jet was quite active. It carried six small round white spots in June-July, with mean DL2 = -95.6 (±3.7; N=6) (range -89 to -98) at 43.9 (±0.2)°S, i.e. on the anticyclonic side (see ZDP in Figure 16). And from June to Jan. it carried numerous small dark spots, which were tracked in a single 70°-long longitude band that moved with the SSTC. This band was f. SS-AWO-A8, as far as the FFR p. A1, a sector in which the SSTZ was unusually clear and white, apart from the small slow-moving spots described above. So these S3 jet spots, possibly emanating from the FFR p. A1, were more visible here than they would have been elsewhere. They had mean DL2 = -97.8 (±6.5; N=15) (range -85 to -104) at 42.9 (±0.1)°S, i.e. on the cyclonic side. There were a few short-lived dark spots with similar drifts in other sectors.

& Appendix: Zonal drift profile for S2 domain *[NEW, 2024 Sep.28].*

S2 domain

2012/13 no.9.
https://britastro.org/jupiter/2012_13report09.htm
Includes: **Appendix 5**: ZWP by G. Hahn, from amateur images, 2012 Sep-Oct.

2013/14 no.4:
https://britastro.org/jupiter/2013_14report04.htm

There are now ten AWOs forming stable arrays around the circumference. V-hi-res images have revealed details in the cyclonic regions between them.

Between A3 and A4, a cyclonic white oval developed in early Nov., which was reported by Manos Kardasis on Nov.9 as a methane-bright spot. This was unusual if not unprecedented, as cyclonic spots are always dark in methane unless undergoing a vigorous convective outburst; but even more remarkably, it has remained methane-bright into Dec. (Fig.4). This perhaps demonstrates what new phenomena can be uncovered now that image derotation allows observers to obtain such hi-res methane-band images.

& no.6 *[not accessible online, formerly on ALPO-Japan which has changed]*:
The ten AWOs remain in three stable arrays, with spacings of 13-24º [Figs.1&4], moving with mean DL2 = -27 deg/mth. AWO A7a was new in 2013 August.

Between A3 and A4, a cyclonic white oval developed in early Nov., which was surprisingly methane-bright and remained so into Dec. In recent methane images [Figs.2 & 6], it is not quite so bright, though still brighter than its surroundings. It is still very bright at visible wavelengths. From its appearance, nestled between AWOs A3 and A4, observers are calling it "the Mickey Mouse spot".

& no.8 *[not accessible online, formerly on ALPO-Japan which has changed]*:
"New cyclonic ovals in SSTB" *[report text copied below]*
[& note oscil'n of AWO A0 with P ~ 45d, much less than period in previous apparitions, Ref.2]

& no.10 "ZWPs from ground-based and Hubble images, 2014 February and April" (with G. Hahn).

2013/14 no.8: New cyclonic ovals in SSTB (2014 April 12)
--John Rogers (BAA) & Michel Jacquesson (JUPOS team).

Recent images are showing some interesting changes in the SSTB: more cyclonic light ovals may be developing there, between the long-lived anticyclonic white ovals (AWOs).

For several months observers have been watching the 'Mickey Mouse spots', which comprise a new, bright white cyclonic oval between AWOs A3 and A4 (see our Reports no.4 & 6, and Figure 1). Recently observers have noticed the cyclonic oval flattening, and it may be lengthening, as persistent cyclonic white oblongs do.

The second feature is between AWOs A7a and A8 (see Figure 2 – set of images). It started as a dark brown 'barge' in October, which became very dark, but has recently shrunk rapidly within a pale reddish outline, and in lo-res images it has already disappeared, leaving a light reddish oval behind. Meanwhile a third feature developed between AWOs A0 and A1: a more complex, poorly resolved cyclonic area, which also seems to be becoming light reddish now. Possibly one or both of these will develop into cyclonic white ovals.

A JUPOS chart of this sector is in Figure 3. The AWOs seem to play ping-pong with the cyclonic formations! It may be significant that in each case, the cyclonic oval developed as the AWOs were converging rapidly. In the case of A3-A4 (the 'Mickey Mouse spots'), they have continued to converge and are now only 15 deg. apart, even though the bright cyclonic oval is not shrinking; indeed it is probably already expanding, and will continue to do so, so the AWOs flanking it will move apart. In the case of A7a-A8 and A0-A1, the AWOs began to move apart at about the time that the cyclonic cell appeared, and may have been pushed apart by it. Indeed A0 and A1 had approached to only 11 deg., so the new cyclonic oval may have prevented an imminent merger.

The 'Mickey Mouse spots' have just passed the GRS (L2 = 210), and the cyclonic oval between A7a-A8 is predicted to be at the following longitudes: L2 = 42 (April 12), 37 (April 18), 31 (April 24), 26 (April 30).

2014/15 no.3: [see Fig.6, JUPOS chart]:
https://britastro.org/jupiter/2014_15report03.htm

There are now 11 AWOs in the S.S. Temperate domain! Two new ones are labelled A7a and A7b (A7a and A7ab on Marco's latest maps). A7a and A8 passed oval BA in 2014 Dec.

In 2013/14, two reddish cyclonic ovals were recorded between pairs of AWOs [see our 2013/14 report no.8], and not surprisingly, both of these became cyclonic white ovals. They can be seen in Fig.2, labelled CWO, although both are now small.

2014/15 no.12 (Final report):
https://britastro.org/jupiter/2014_15report12.htm

[Inc. global ZDP: mean positions for S2 AWOs & CWOs fit well on Cassini ZWP]

S2 domain [JUPOS chart S2]: There were 11 AWOs in the S.S. Temperate domain, including two new ones named A7a and A7b. They had been gathering closer in longitude, now forming a single array spanning 230º long. Their mean DL2 ranged from -25 (A6 at the p. end of the array) to -30 (A4 and A5, at the f. end). However, in 2015 March, A5 decelerated to DL2 = -26.6, due to expansion of the cyclonic white oblong p. it.

Also, the cyclonic white ovals (derived from red ovals in the last apparition) persisted between AWOs A7a & A8, and between A0 & A1. The cyclonic ovals sometimes bounced to and fro between the flanking AWOs.

Another cyclonic white oblong present in 2013/14, between A3 and A4, had broken up in late May, 2014, just before solar conjunction. Then a new cyclonic white oblong developed between A4 and A5 during solar conjunction, between 2014 May and Aug.; it was very bright in late Aug. when the apparition began. In 2015 March it started to expand, as such oblongs normally do.

2015/16 no.13 (Final report): Full description & charts, inc. global ZDP.
https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2015-16/2015-16-report-no-13-final-report

There were *nine long-lived AWOs* here, which continued to follow the general rules described in our long-term report [ref.22]: "There have always been between 6 and 9 long-lived AWOs in this domain from 1986 to 2013,..... In contrast, transient AWOs also appear (...the recent frequency has been about one every two years), but do not last more than 1-2 years." Of the 11 AWOs that were present in 2014/15 [ref.3], A7a and A7b were new and small and disappeared again. The 9 long-lived ones (numbered A0 to A8 for historical reasons) continued to converge into a tightly spaced array (A6- - -A0- - -A5), except that A5 (at the f. end) increasingly separated from the others [Fig.22 & JUPOS chart]. This was initially because of the white cyclonic sector between A4 and A5, which was rapidly expanding as they do, but this became less bright during April-May (see below), leaving A4 and A5 almost 60º apart. The other eight ovals continued to converge until they occupied only 133º longitude (centre to centre, for a mean spacing of 19.0º) at the start of August. However, a new light (though not white) oblong appeared between A1 and A2 during April-May; then a new white oblong appeared between A3 and A4 in August [IR image by Miles, Aug.28], and A3 and A4 began to move apart again.

For the long-lived AWOs, the mean DL2 was -28.4, at 40.6ºS. There was also a new, small AWO remote from the others, oscillating with irregular periods of 0.8—2.3 months. On June 20 it was apparently merging with an even newer and smaller AWO p. it (Fig.21).

In cyclonic latitudes, the AWOs are usually separated by various cyclonic structures, especially FFRs, as revealed by the Voyager images. The best amateur images are now sufficiently good to resolve these structures, and the arrangement in 2016 Jan.-June [Fig.22] was:
--between A6-A7-A8-A0: FFRs;
--between A0-A1: cyclonic white oval, oscillating;
--between A1-A2: off-white oblong developing (pale fawn colour);
--between A2-A3: FFR;
--between A3-A4: short bland section [Jan-March?] in which a narrow belt segment became increasingly dark (to June) before turning white (August);
--between A4-A5: long white oblong until March-April, but then more disturbed and encroached upon by a dark belt in SSTZ with slow-moving dark spots or waves along the boundary;
--f. A5: large FFR (Jan.-May); seems quieter in June.
The chronicle can be extended to late August with the JunoCam images [Appendix 3], in which there was still a large FFR f. A5, and the only notable change was the new white oblong between A3-A4.

In comparison with the arrangement in 2015 March [ref. 3], some of these sectors were of the same cyclonic type, but about half had changed. Given these frequent changes and the limitations on resolving FFRs, we cannot say definitely whether FFRs persisted through solar conjunction.

Several slow-moving dark spots or streaks were recorded, in the now-shaded interval between A4-A5, and f. the new oscillating AWO: mean DL2 for the best 3 tracks was -13.9, at 40.6ºS. Hi-res images in late April suggested that in both these sectors, the slow-moving features may have been waves on the retrograding jet separating a whitened 'SSTB' from darkened 'SSTZ' [Figs.3 & 17].

2016/17 no.4.

https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2016-17/2016-17-report-no-4-the-apparition-up-to-2017-january

Major changes here were revealed by Juno's perijove-1 images in late August, including the close approach of two long-lived AWOs (A8 and A0), which led to the prediction that they would soon merge.* This indeed happened on Nov.18-23, just as they passed oval BA (Fig.7); the images show them moving around each other until there was only a single oval on Nov.23 (which we call A8).

*Ref: our 'Results from Juno' page (https://www.britastro.org/node/8004) or Appendix 3 to our final report for 2015/16 (https://www.britastro.org/node/8263).

Discussion: This was a rare event – the first merger of long-lived SS-AWOs since 2002. (In contrast, smaller short-lived ones merge quite often.) As the merged oval has settled down into an evenly-spaced chain with the others, I do not expect any more mergers. However it is notable that most of this chain, from A6 to A3, now have an unusually high speed, DL2 = -30.5 deg/month. Whether this is cause or effect, it is associated with the expansion of the whitened sector of SSTB between A3 and A4 (which was viewed by Juno at perijoves-1 and -3, showing the typical outline of a cyclonic circulation). This expansion is expected to continue.

2016/17 no.8 ("Mergers of small ovals in the S2 domain") = No.10 Appendix 4:

Describes how vortices emerging f. a large FFR merge into new AWO A5a.

https://www.britastro.org/node/9378

[Not copied here; please see online version.]

2016/17, Report no.10: Interim report (2017 May)

https://britastro.org/node/10328

There are now 8 long-lived AWOs (Fig.1), and a smaller, newer one provisionally named A5a (see below). Six of the 8 are still in a close array, with mean DL2 ~ -30 deg/mth, even though A6, A7 & A7 have been wandering to and fro within it. A4, A5 and A5a had mean DL2 ~ -27 deg/mth in April.

The main cyclonic features are as follows:
--A FFR p. A6.
--A small dark spot between A6-A7 in Dec-Feb., which became a brown streak in Feb. then faded away.
--FFRs between A7-A8-A1 and between A2-A3 (in April).
--A whitish oblong between A3-A4, which had expanded to be 40º long in March and April; but in April it contains some thin grey streaks which reduce its brightness.
--The giant FFR f. A5 [still impressive in Go's images on April 20 (Fig.7b) & 22-25 (Fig.N5)].

F. the giant FFR, v-hi-res images over the past 2 years have shown 2 or 3 very small AWOs. The furthest f.(W.) of these, and the largest, currently called A5a, may be becoming a ninth long-lived AWO. The JUPOS chart and recent hi-res images show that the tiny AWOs are forming in the wake of the giant FFR, and successively merging into A5a. Thus we may be observing the formation of a new large AWO in detail for the first time. All this is described in Appendix 4 = Report no.8 (expanded).

Also see: **2016/17 no.14, & PJ1 report**.

2018 no.2. [A5a is shrinking. Inc. JunoCam maps PJ1-PJ10.]
https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2017-18/jupiter-in-2018-report-no-2

The 8 long-lived AWOs are still present although the distances between them continue to vary. But AWO A5a, which had been growing slowly during 2017 as it absorbed mini-AWOs that developed in the wake of a long FFR, has now shrunk again. This is best shown in the JunoCam maps (Figure 9). Will it disappear, as most other new AWOs in this domain do within 2 years? It has been passing a very long FFR in the S3 domain, and is approaching the long FFR in the S2 domain; are these now draining it of energy?

2018 no.5. [Merger of A6 & A7]
https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2017-18/jupiter-in-2018-report-no-5

The most interesting event was the merger of 2 AWOs (called A6 and A7) in the SSTZ, which happened simultaneously with the similar merger in the NNTZ. The AWOs converged rapidly until in contact on May 24 (shown in Juno's outbound images) and 25. They were spiralling together on May 26 (excellent image by Go), and on May 28 the merged oval was elongated at 13:30 (Wong, Go) but rounded up at 23:30 (Pereira). Animated maps of this merger (from May 14-28) have been posted by Marco Vedovato:
http://pianeti.uai.it/images/A6-A7-merging.gif or
http://alpo-j.asahikawa-med.ac.jp/kk18/j180601r.htm

2018 no.6 ("Draft final report"): General description & charts [see Figure 11]:
https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2017-18/jupiter-in-2018-report-no-6

AWOs: Since the merger of AWOs A6 and A7 in May (see Report no.5), the count is seven large AWOs plus the younger, smaller AWO A5a. As described in Report no.2, A5a has stopped growing as it approa-ched the long FFR p. it. They came into contact in April, and A5a remained at the f. end of the FFR in May-June. This may be why A5a changed its drift suddenly in late May, from DL2 -31.5 to -21.0.

Drift rates of AWOs from Feb. onwards: A8 and A1 to A5 had steady mean DL2 values ranging from -26.8 to -28.3 (though with a few faster track segments up to -31). A6 and A7 accelerated suddenly in March, from ~-27 to ~-38 (A6) and from ~-32.5 to -40 (A7), as a new FFR appeared and expanded alongside them, possibly pushing them p. away from A8. They passed BA in April, then merged in late May (Report no.5). (A7 attained DL2 = -48 before the merger.)

Cyclonic features: There were no whitened sectors of SSTB until April, when a pale fawn-coloured cyclonic circulation between A8 and A1 gradually brightened [Figures 11 & 12]. It was brilliant white by late May, and expanding, and surprisingly methane-bright (even up to Aug.16 [Casely]). A cyclonic dark spot f. A5a shrank and turned reddish in March, then light fawn-coloured in May.

Thus we have in this domain several instances of phenomena that we suspect or know to be general: two where a FFR probably excluded AWO(s) from the same longitude sector; one where a cyclonic white segment expanded; and one where a cyclonic dark spot turned red before fading away.

2019 no.4:
https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2019/jupiter-in-2019-report-no-4
This report covers activity on Jupiter up to early May. It includes a zonal wind profile made by Marco Vedovato from amateur images on 2019 April 19-21.

2019 no.9 ("Draft final report"): Full description & charts.
https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2019/jupiter-in-2019-report-no-9
[A5a is still present. Inc. JunoCam maps PJ17-PJ23.]

Zonal wind profile (ZWP) from Hubble data

Report no.4 presented a ZWP made by Marco Vedovato from amateur images in April. He has also produced one from the Hubble OPAL images on June 26-27 (Figure 4).

Sector 1: L3 = 205-305 (p. GRS). Sector 2: L3 = 130-240 (further p. inc. oval BA)
The new ZWP shows good agreement with the April ground-based ZWP in the prograding range, but for all the retrograding jets, the April ground-based profile was blunted, the retrograding speeds being less extreme or zero. Thus the ground-based profile was similar to the zonal drift profiles that we routinely obtain by tracking of small spots, whereas the HST profile is more sensitive to true wind speeds.

S2 domain
[See JUPOS chart, & strip-maps from JunoCam (Figure 17) and from amateur data (Figure 18).]

The most obvious features of this domain, as always, are the *AWOs – currently 8 of them*. This year they had DL2 ranging from -28 to -34 deg/mth (when steady over several months). A1 is the largest and A5a the smallest. A5a approached to within 10° of A7 in Sep., but rebounded and survived.
[Since A6 and A7 merged, Marco Vedovato has called the resulting oval A6, whereas I am calling it A7, in case A5a ever grows large enough to deserve redesignation as A6.]

In the intervals between the AWOs, as usual there were a variety of *cyclonic structures*: white oblongs, dark bars, and FFRs.

Two intervals had white oblongs, which had persisted from 2018: the A8-A1 and A1-A2 intervals. A8-A1 was a white oblong 23° long in Jan., elongating as the AWOs moved apart. In Feb. it became duller, and up to Oct. it remained dull white, while the ovals moved to a maximum of 80° apart in Sep. In June, a dark strip of 'southerly SSTB' developed as a tapered 'tail' f. A8, becoming a distinct dark segment of (S)SSTB, elongating (f. end DL2 = -17, July—Oct.) until it covered almost all the southern half of this sector, while the north half remained dull white. Images by Hubble (June 26-27) and JunoCam (PJ21, July 21) clearly showed the braided border of the narrow white strip. A1-A2 was a bright white oblong from Feb. to the end of May. In June it elongated and became duller, so it was dull white up to Oct. (JunoCam viewed it closeup at PJ22 in Sep. and showed it was disturbed.)

The interval A7-A8 initially included two short dark bars. As the AWOs converged, in May these bars merged into one, 13° long, which was very dark brown from June to August. It faded in Aug. and disappeared in Sep.

FFRs can be seen in the best amateur images and maps, and more systematically in spacecraft maps from Juno and Hubble (Figure 17). They were present between A2-A3 (small and intermittent); p. A4 (intermittent); between A4-A5; p. A5a (see below); and between A5a-A7 (up to June, then this interval was less disturbed). Note that some transformed into less turbulent structures, for a shorter or longer time. The FFR p. A5a has existed for several years, sometimes 'feeding' this small AWO with smaller vortices but sometimes threatening to weaken it; this year it was in contact with the AWO; it was a FFR (though variable) up to early July, but thereafter it was absent (mid-July to Sep.) (Figure 15).

In the longer intervals between AWOs, lacking well-defined cyclonic structures, we tracked several *slow-moving features*. These were dark spots or streaks (i.e. (S)SSTB segments) at 40-41°S, the same latitude as the AWOs, diffuse and grey in spacecraft images – similar to the 'tail' commonly seen in the STZ Sf. S. Temperate structures, as described above. Such features were recorded f. A3 in Feb.-March, f. A5 in Feb.-April, and f. A8 in July-Oct.; plus a cyclonic white oval f. A5 in May-July. Typical speeds were from DL2 = -17 (the f. end of dark (S)SSTB f. A8) to -19.5 (the cyclonic white oval f. A5).

[& see PJ24 (2019 Dec.26), *among JunoCam reports listed below***]**

2020 no.4: General description & charts.

[A5a merged with A7 on 2019 Dec.26, imaged by Juno at PJ24.]

https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2020/jupiter-in-2020-report-no-4

Figure 16 is a set of maps which include the S2 domain from 2020 March to June. There are still seven AWOs, as described in our 2020 Report no.1: "The SSTB is marked by the usual array of AWOs on its S edge. They are numbered A1 to A8, but lacking A6. A6 merged with A7 in 2018 May, then A5a, the small AWO that had replaced it, was fortuitously imaged merging likewise with A7 at PJ24 (2019 Dec.26)."

There are no white oblongs now. Two were present in 2019 Sep-Oct. (an old one between AWOs A1-A2, and a new one between A2-A3). But in 2020, in the PJ25 map (Feb.17) and subsequent ground-based maps (Figure 16), those sectors are very short and appear to be FFRs. FFRs have also been recorded in some other sectors. The long sector between A8-A1 (part of which has been alongside STB Segment A) was mostly white up to early June apart from a narrow SSTB(N); but in June and July it is more shaded.

2020 no.10 ("The S2 domain in 2020").

[NEW REPORT. No big changes in S2, but origin of a small FFR observed.]

Here we summarise the domain's features, with a set of ground-based maps (Fig.1), a set of JunoCam maps (Fig.2), and the JUPOS chart (Fig.3). In fact, there were no notable changes during the year, apart from the appearance of one small FFR (Figs.4&5) and possible late quiescence of two others.

Anticyclonic white ovals (AWOs):

JunoCam had spotted AWOs A7 and A5a merging at PJ24 on 2019 Dec.26, when they were adjacent to oval BA (see our PJ24 report). This left seven long-lived AWOs (A1-A5, A7, A8). A1 to A3 were closely spaced throughout the year, their centre-to-centre distances generally being between 13º and 22º. A4 and A5 also gradually converged on them until by late December (the end of the apparition) the array of five spanned only 83º – nicknamed the "string of pearls" by the JunoCam team.

Mean drift rates (DL2, deg/30d): A1 to A3, -27; A4, -28; A5, -32; A7, -37*; A8, -32*.

*These speeds are from June to Nov. A7 drifted faster from early March to mid-April (-39) then slower from late April to late May (-28), before adopting almost constant drift from early June until Nov. (-32). A8 underwent synchronised variations though less extreme. The cause of these variations is not known, although we note that they passed oval BA in Feb-March, then passed the GRS in May-June.

Cyclonic features:

from Report no.4 (2020 July): "There are no white oblongs now. Two were present in 2019 Sep-Oct. (an old one between AWOs A1-A2, and a new one between A2-A3). But in 2020, in the PJ25 map (Feb.17) and subsequent ground-based maps, those sectors are very short and appear to be FFRs. The long sector between A8-A1 (part of which has been alongside STB Segment A) was mostly white up to early June apart from a narrow SSTB(N); but in June and July it is more shaded."

Folded Filamentary Regions (FFRs): The cyclonic sectors can be completely documented now that ground-based maps (hi-res for ~6 months around opposition) are complemented by JunoCam maps (every 53 days, though not always covering all longitudes well), and by a Hubble map on 2020 Aug.25. As there were no white oblongs nor large dark circulations, the only large cyclonic features were FFRs, all but one of which existed throughout the apparition, at least up to Sep. as follows. (SSTB sectors are referred to the flanking AWOs.)

A1-A2 and A2-A3: FFR in each sector, from 2019 Dec.26 (PJ24) to 2020 Aug.25 (HST), and from April to August (amateur); not well viewed after August.

A3-A4 and A4-A5: FFR in each sector, from Dec.(PJ24) or Feb.(PJ25) to Sep.(PJ29) (not viewed thereafter); and from March or April to Sep. (amateur), but not recorded as active in Oct-Nov.

A5-A7: The p. half of this long sector was not well viewed by JunoCam. Amateur maps showed it as a reddish-brown segment from Feb. to April, then dark (May-Nov.); also dark in HST map (Aug.25). The f. half was a large FFR (2019 Dec.—2020 Dec., JunoCam; & April-Nov., amateur).

A7-A8: This sector was undisturbed up to May, but amateur images show a new small FFR developed: it first appeared as a small white spot on April 26-28, which became an expanding turbulent region (Figure 4). Unlike "Clyde's Spot" in the STB, which erupted nearby on May 31, it was not methane-bright when it appeared, except for a small methane-bright spot on May 3-5 – probably a small short-lived convective plume that initiated the transformation. Tiny weakly methane-bright spots were recorded within the complex in early June. JunoCam maps showed this small FFR on June 2 (PJ27), containing tiny bright white spots, one of which was methane-bright (Figure 5). This FFR gradually expanded as AWOs A7 and A8 moved apart, up to Nov.8 (PJ30), but amateur images suggest that it was smaller again in Nov., and it was small on Dec.30 (PJ31).

A8-A1: This long sector was remarkably quiet and pale, except for a narrow dark SSTB(N). It contained some slow-moving small dark spots.

Slow-moving dark spots: The JUPOS chart shows a number of tracks for such spots at 40ºS in the A8-A1 sector from June to Oct., and only a few short or indistinct tracks for them elsewhere. Speeds (DL2) ranged from -10 to -16 deg/30d; mean DL2 = -11.6 (±4.2; N=6). We speculate that these could have formed in disturbance streaming past A8 from the new FFR p. A8.

There was also a slow-moving, very dark *cyclonic spot*, at ~38ºS, which was alongside oval BA when it first darkened in late June; it may have developed from a much fainter spot as it passed BA. JunoCam showed it as a small dark oval (PJ30, similar to STB-DS6 nearby); perhaps paler reddish-brown on Dec.30 (PJ31). It was well tracked by JUPOS from July 1 to Nov., with DL2 = -20.9 (July 1 – Aug.20) then -24.4 (Aug.23 – Nov.7).

2021/22 no.10 (Final report):

https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2021-22/jupiter-in-2021-22-report-no-10-final

[Full description & charts, inc. JunoCam maps PJ32-PJ39 (Fig.17). Inc. account of new AWO "A0", probably formed from vortices from a FFR like A5a, 2021 Aug., but disappeared (merged with A1?) by PJ39 in 2022 Jan.]

Maps from April to Nov. were presented in Fig.1 of our Report no.5. Maps in Dec.-Jan. are in Figs.2 & 3; images of the chain A1-A5 in Dec. are in Fig.16. Fig.17 is a collection of all the JunoCam maps from 2021. Fig.18 is the JUPOS chart of the domain.

Anticyclonic ovals:

There are still seven stable AWOs in this domain. At the start of the apparition, AWOs A1 to A5 had closed up together to form a single chain, mostly separated by FFRs. The other two (A7 & A8) were widely separated. Their drifts ranged from DL2 = -27 to -32 deg/30d, with A3 (the steadiest) having DL2 = -28.7.

A much smaller AWO, referred to here as A0, was tracked 20-30° p. A1 from August onwards. It is also shown in the JunoCam map at PJ36 (Sep.2) and the Hubble OPAL maps (Sep.4) (Fig.5). It seems likely that A0 was created or sustained by mergers of smaller anticyclonic vortices emerging from a large FFR just p. it, just as we reported for a small AWO known as A5a from 2015-2019 [see our 2016/17 Report no.8]. Blinking of the OPAL maps (posted with 2021 Report no.5 as Animation-2) reveals a row of three such vortices leading from the cyclonic FFR to the AWO A0; also, at PJ38 (2021 Nov.29), we noted a chain of four anticyclonic vortices likewise (Fig.17). But by PJ39 (2022 Jan.12), the FFR had moved closer to A1 and the chain of vortices had diminished, while A0 had disappeared; the JUPOS chart suggests it merged with A1.

Cyclonic features:

FFRs were all documented in the JunoCam maps (Fig.17) and most of them also in the amateur maps. An isolated FFR was present ~40-60° p. A1 at least from April to Oct. (and later still in JunoCam maps), although it may have been weaker in June. There was also a large FFR p. A7 and another p. A8, although their level of disturbance may also have varied. AWOs A1,A2,A3,A4 were initially all separated by small FFRs (PJ32 & PJ33, Feb. & April), but the one between A1-A2 became less turbulent at PJ34 (June), leaving only the other two.

A white oblong developed between A4 and A5 at the start of the apparition. This was a small FFR at PJ29, then a dull grey-brown oval in JunoCam images at PJ31 & PJ32 (2021 Feb.21) during solar conjunction, and slightly lighter at PJ33 (April 15). Amateur images from March 14 to April 9 showed it very light, slightly reddish, and by May it was fully white. It remained bright white thereafter, but did not expand: it was 9° long in June-July, and only 7-8° long in Nov.-Dec.

A very small, very dark spot was first seen just Nf. A7 in June, drifting f. from it. In August it turned brown and faded, then was lost as it encountered a FFR p. A8.

Slow-moving dark spots and streaks were present 20-50° f. A8 from July onwards, some with DL2 = -20.1 (±1.9), others with DL2 = -13.3 (±1.4).

2022/23 no.8 (Final report on S.hemis.):

https://britastro.org/section_information_/jupiter-section-overview/jupiter-in-2022-23/jupiter-in-2022-23-report-no-8

[Full description & charts, inc. JunoCam maps PJ41-PJ49: Fig.13].

This domain is narrow, so the cyclonic and anticyclonic features differ only a little in latitude, and they typically all move with the same zonal slow current, the SSTC (Figure 12 = JUPOS chart; Figure 13 = JunoCam maps).

AWOs: There are still 7 large long-lived AWOs at ~40.6°S, numbered A1-A5, A7 & A8. AWO-2 had no rim and so was hard to detect in late-apparition ground-based images, but the PJ48 maps confirmed its continued existence. The 7 AWOs had mean speeds throughout the apparition ranging from DL2 = -27.8 to -31.8; over 2-month intervals the range was -26.9 to -36.0. The overall mean was -29.8 (±1.4; N=7).

There were two cyclonic white oblongs (CWOs), p. A5 and p. A2. Both were methane-dark (esp. in JunoCam maps). The CWO p. A5 was well-defined and bright white throughout, growing in length from 10° to 14°. The one p. A2 had begun as a small light spot in 2021 Dec, and was still dull in JunoCam images at PJ39 & PJ40, but was a distinct white oblong from 2022 April (PJ41) to August. But it was only dull white again in Sep. & Oct., and disappeared in Nov.

There were FFRs just p. the three isolated AWOs (A1, A7 & A8), and small ones trapped between A2-A3-A4, as marked on the JUPOS chart. All lasted throughout the apparition. except for the FFR just p. A1, which ceased to be visibly active in Oct. in ground-based images, though a remnant was visible in Junocam maps.

A tiny AWO existed p. A8 from June to Sep., wandering to and fro on the S edge of the FFR there. The Sep.29 map shows it in contact with both the FFR and A8, and it may have then merged with A8.

Dark features were as follows (see JUPOS chart in Fig.12):

There were plenty of well-defined slow tracks, for small dark spots influenced by the 'retrograding jet' of the S2 domain (as in the S1 domain) [although in S2 there is only a velocity minimum, not a jet with positive DL2]. These occurred in the sectors f. A1 and f. A8, from June to the end of Oct., with some residual activity f. A8 thereafter. They may have consisted of dark material emanating from the FFRs p. each of these AWOs, as in the 'Sf. tail' of a turbulent STB segment. Their average speed was DL2 = -15.3 (±3.4; N=8) (range -10.5 to -20.8).

F. A8 there was a long, very dark 'SSTZB' from May to July, which may have been a 'Sf. tail' of the FFR p. A8. In July it broke up into the slow-moving dark spots mentioned above, and also a spot we call ds1, which had an interesting history.

ds1 was a small, very dark brown, cyclonic spot with typical SSTC drift (DL2 = -27.6 --> -30.8 --> -26.1). JUPOS analysis shows that its latitude ranged from 38.2 to 38.5°S in accordance with the cyclonic gradient. (see Figures 13 & 14). It first developed in early July as it was about to pass oval BA (Fig.14A). At the end of Oct. it collided and probably merged with a very small cyclonic white oval f. it (Fig.14B, & Report no.5). Then it was fading in Dec., and during Jan. it dwindled to become a small, light brown spot with a white collar (see Report no.5, Fig.4, where it is indicated by a pink arrowhead, just south of STB WS6). By late Jan. it was a dull white cyclonic oval (Fig.14C), as also shown in the PJ49 map (March 1). So this was a typical example of a dark spot fading through reddish to white.

A second very dark brown spot was Nf. A7 in June-Sep. (well viewed by JunoCam at PJ44). It was red-brown at the end of Sep.(Figure 2), fading in early Oct., and then lost into the adjacent FFR p. A8.

& NEW [2024 Sep.28]:

2022/23 no.8: Appendix: Zonal drift profile for S2 domain

The JUPOS data has now been analysed by Gianluigi Adamoli to produce a zonal drift profile (ZDP). The data are plotted in Figure 21, and compared with the ZWP from Cassini. We note that the Cassini ZWP does have a retrograde jet in the middle of the S2 domain, unlike previous spacecraft ZWPs which showed only a velocity minimum with little or no retrograde wind (Table 1).

The points all cluster around a smooth ZDP curve, which is the same as the Cassini ZWP at >40ºS, but blunted at 39-40ºS [all latitudes planetographic] (vel.min. DL2 ~ -10 deg/30d instead of +14 deg/30d from Cassini, but similar to the ZWP from Voyager), and systematically 0.8º further S than Cassini on the cyclonic side at <39ºS. There is little difference between dark and bright spots, or between longitude sectors.

There may be a slight difference between large and small spots, but this could be an artefact. The JUPOS measurers sometimes use the AWOs in this domain as a latitude standard, checking that they are measured close to 40.5ºS, although their latitudes do vary and the mean latitude could be slightly higher. The points for the AWOs on this chart do show variations which parallel the ZWP, and suggest that the AWOs are at slightly lower latitude than smaller spots with the same drift rates (consistent with what we have found for some other domains, due to large ovals deflecting the retrograde jet in the middle of the domain: ref. our long-term reports on N2, S1, etc?), but this could be an artefact of the adopted standard. The points for the other large feature, the cyclonic white oblong, also lie slightly off the mean ZDP, by ~0.2º.

The smaller spots are of interest, most of them being dark spots moving more slowly than the AWOs. One group [ds10-ds22, except ds17] were in the A8-A1 sector (f. A8), very small dark spots in a clear SSTZ, almost all at 40-41ºS and slow-moving; thus, on the south flank of the "retrograde jet". (A few exceptions [ds15 & ds16, & ds17 in the A1-A2 sector] were further south and rapidly prograding under the influence of the S3 jet.)

The other groups were in the A1-A2 sector (f. A1), where there was a long pale fawn sector, though it did not clearly have a closed circulation [so is not marked on our synoptic EPSC2024 chart]. They were either on the S edge [ds23-ds29: 40-41ºS, anticyclonic] or the interior [ds3-ds9: 38-39ºS, cyclonic] of this pale fawn sector, and those on the S edge corresponded to dark wave-like bulges; as at PJ26, these waves probably marked the track of the retrograde jet (see JunoCam images at PJ41 & PJ43: Figure 22). Both groups of spots [except ds3] all had track segments with DL2 between -8 and -28, and those in the interior had approximately the same drift rates as those on the S edge, showing how a zonal slow current such as the SSTC can operate over both cyclonic and anticyclonic latitudes separated by a wavy retrograde jet.

Taking all the track segments for dark spots between 40.0 and 40.6ºS, the mean DL2 is -15.8 (±4.3; N=20), with a range from -7.9 to -27.1 deg/30d.

In our JunoCam perijove reports, *the following include significant notes on the S2 domain, copied here:*

PJ1 (2016 Aug.27):
There is an unusually dense outbreak of small dark spots on the prograding *SSTBn jet,* between a large turbulent sector in the SSTB ('FFR'; this may be inducing them), and the cyclonic 'STB Ghost', where we have observed such spots to recirculate into the STZ (this region was imaged by JunoCam at perijove).

The most notable changes are affecting the S.S. Temperate anticyclonic white ovals *(S2-AWOs).* Two small ones appear to be merging in these images; such small-scale events are not uncommon and we observed one earlier this year. However, the nine numbered AWOs are very stable, and yet two of those – A0 and A8 – have rapidly converged to only 9º apart and therefore are likely to merge in the coming weeks or months. They have always been smaller than most, while their neighbour, A1, has become the largest. Indeed it is possible that an A0-A8 merged oval could then merge with A1 in turn. In October they will start passing oval BA (which will itself be passing the GRS in November), and this passage may trigger a merger if it has not happened before....

PJ8 (2017 Sep.1):
S2 domain: The same sequence of images (e.g. Figures 6 & 11 & S2) shows the sector of SSTB f. the giant FFR f. AWO-A5. ... The f. end of the giant FFR is in view, and the beautiful patterns f. it support what we have inferred from ground-based observations: that small anticyclonic vortices arise from the turbulence of the FFR, and drift gradually westwards relative to it, eventually merging into the recently developed AWO-A5a [see our recent reports esp. 2016/17 Report no.8].
The global map (Fig.2) also shows that AWOs A1 and A2 are now only 9º apart, so they are likely to merge soon, possibly before PJ9.

PJ10 (2017 Dec.16):
S2 domain: All the AWOs persist, along with several FFRs. On the map, a box encloses two tiny AWOs which have probably developed in the wake of the largest FFR and will soon merge with each other and/or with oval A5a.

PJ11 (2018 Feb.7):
In the S2 domain, the long-lived AWOs (A1 to A8) have been joined by a new small one [p.A4, immed. f. FFR]. Between this one and A4, due S of the GRS, the map shows a brilliant white point (white arrow; also methane-bright), likely to be a new convective plume. Indeed, ground-based images show this was absent up to Feb.5 and first recorded on Feb.7 (by David Carlish, one rotation before the PJ-9 map). On subsequent days it seemed to be less bright.

In the SSTB, the large FFR is splendidly shown (Fig.8), and a small grey anticyclonic vortex is just the sort of thing that I think has been emerging from it and evolving into mini-AWOs which eventually merge with AWO A5a.

PJ24 (2019 Dec.26):
S2 domain: There is also a remarkable feature just south of oval BA: two S2-AWOs are merging! (Figs.14 & 15) They are A5a and A7. A5a was a small AWO which appeared in 2015; many mini-AWOs merged with it as it grew, one such merger being imaged at PJ1 [see our 2016/17 reports nos.8,10,14]. A7 was a full-size AWO which had been tracked for many years. A6 merged with A7 in 2018 May, and I wondered whether A5a would grow to replace it, but instead it is following the same fate. It is fortunate that JunoCam captured the merger, which takes only a few days. And it is unexpected, as the two ovals converged closely in Sep., but rebounded. This merger is occurring adjacent to oval BA – like some previous mergers of S2-AWOs. However, as the AWOs had not actually passed BA, I am not sure if this is an adequate explanation. Perhaps a better explanation is renewal of the large FFR p. A5a, which had been present (variably) for several years, then absent from mid-July to Sep., 2019, but is large and turbulent in the PJ24 images. Possibly this revived FFR pushed A5a towards A7, leading to the merger.

Another change is in the interval between A7 and A8: this sector of SSTB has turned into a whitish cyclonic circulation during solar conjunction.

PJ26 (2020 April 10):

S2 domain: The same maps (Figure 12) and animations (A-D) show fine details of structures in the S2 domain, including AWOs A7 and A8. The SSTB between them is a pale, closed cyclonic circulation (similar to the former STB Spectre). The retrograding jet along its S side traces out substantial waves.

South of STB segment A there is a small, very bright spot which looks like a new convective outbreak; will this develop into a FFR?* Almost due S of that, in the S4 domain, there is another such outbreak but bigger and brighter.

**The bright outbreaks in S2 and S4 domains: ground-based follow-up:*

Despite their small size, the bright outbreaks in the S2 and S4 domains could both be followed in amateur images, but up to April 26, neither had produced any notable structure. A compilation of the best images from April 14 to 26 is in our Report no.3 [ref.1]. The S2 outbreak was followed by expanding small-scale bluish-grey granularity, perhaps an FFR but much smaller than some that are detected in this domain.

PJ38 (2021 Nov.29):

Another interesting feature in Figure S1 is the chain of anticyclonic eddies following the S2-FFR. These appear to be a specially clear example of vortices being emitted in the retrograde flow west of a FFR. The global map (Figure N4) shows that they lead up to a fifth, larger vortex [then named A0] that is just preceding AWO-A1, suggesting that these small vortices may end up merging into a larger vortex and perhaps into AWO-A1 itself. We followed just such a phenomenon in this domain a few years ago, which led to the formation of a medium-sized AWO that we called A5a, although it eventually broke up on encountering another FFR.

PJ39 (2022 Jan.12):

The chain of anticyclonic vortices noted at PJ38 p. AWO-A1 has diminished, as the FFR from which they were emitted has moved closer to A1; but two very small, dark brown cyclonic ovals are still present alongside (like miniature versions of STB spot 8).

PJ44: [Posted animation showing circulations on FFRs]

(Since PJ47, the S2 domain has only been imaged at resolution comparable to ground-based.)
