Jupiter in 2021: Report no.5

The South Temperate domain in 2021

John Rogers (BAA) (2021 Dec.18)

This domain has been of great interest in 2020-2021, with the cyclical birth and transformation of STB structured sectors, proceeding partly as before but partly in a new way; and with v-hi-res observations of these events, from both amateur images and spacecraft images.

We have not posted a substantial report on this domain since our 2020 Report no.4 (2020 July), but there were no major changes from then until this year, and our reports on Juno perijoves (elsewhere on our web site) give updates on subsequent developments. Now, this report describes amateur observations in the 2021 apparition from early April to late November, plus information from JunoCam perijoves throughout the year, and from Hubble imagery on 2021 Sep.4.

Thanks are due to many people, beginning with all the observers. Analysis depended on work by the ALPO-Japan (esp. Shinji Mizumoto), and the JUPOS team (esp. Gianluigi Adamoli, Rob Bullen, and Michel Jacquesson who made the routine measurements, while Adamoli also did extra analysis, and Bullen made regular maps). Andy Casely also made maps, esp. at Juno perijoves. The JunoCam data come from the NASA JunoCam team (Candy Hansen, Glenn Orton, Tom Momary) with citizen scientist Gerald Eichstädt.

Background

From 2000 to 2020, the S. Temperate domain has been arranged as follows. There is one large anticyclonic oval (oval BA), which always has a short dark segment of STB (STB segment A) f. it [f. = following = westward]. There are always one or more additional structured sectors, which are cyclonic regions that drift faster (eastwards) than BA and therefore periodically catch up with it, colliding with STB segment A and producing a longer, more turbulent STB segment, which then slowly contracts. The remaining longitudes of the domain are largely undisturbed and pale, the STB being almost white.

In late 2019 the additional structured sector was the 'STB Spectre', a pale, quiescent, closed cyclonic circulation that was rapidly expanding in longitude. In early 2020, its p. end [p. = preceding = eastward] caught up with the f. end of STB segment A and disappeared [see our 2020 Report no.2, & our PJ25 report]. In contrast to previous such collisions, the Spectre did not change; but by 2020 March, STB segment A began to grow longer and more active, leading to acceleration of oval BA and extensive outbreaks of dark spots or streaks p. BA on the STBn jet and f. (along the S edge of the Spectre) on the STBs jet. Thus the usual sequels of the collision did occur [2020 Reports nos.2 & 4, & PJ32 report].

This left the f. end of the former Spectre as an isolated cyclonic hemi-circulation (from STBs to STBn), which maintained its identity & drift [2020 Reports nos.2 & 4, & PJ28 report]. JunoCam closeups at PJ28 (2020 July 25) confirmed that it was still a well-established structure with cyclonic recirculation, and had a small methane-bright anticyclonic vortex on its S side (still present at PJ30). This is a type of structure not previously examined by spacecraft.

It was therefore expected that a new structured sector would arise, probably in the form of a small cyclonic spot some tens of degrees p. BA [Rogers JH (2019), 'Jupiter's South Temperate Domain, 2015-2018': https://britastro.org/sites/default/files/STempR_2015-2018_Report-text.pdf]. JunoCam images showed several small, low-contrast cyclones in this region, and Ricardo Hueso [paper submitted for publication] has tracked these using Hubble and ground-based images. In

2020, two of them turned into notable dark spots which we called DS6 and DS7. DS6 was a very dark compact oval spot, closely examined by JunoCam at PJ26 (2020 April 10).

DS7, further p. BA, had an interesting story. A small pale streak, tracked in amateur images, was identified as a probable cyclone of interest. On 2020 May 31, just after it passed the GRS, Clyde Foster noticed a new, very methane-bright spot at that location, and two days later, JunoCam closeup images at PJ27 showed it as a bright high-altitude cloud that had erupted within a well-formed pale cyclone. Although this bright convective plume was short-lived, it initiated continuing disturbance at this point, in the form of an irregular, variable dark spot called Clyde's Spot or DS7. [For more details see: our 2020 Report no.4 and links therein, including Clyde Foster's abstract for EPSC2020; our PJ27 report; & a paper submitted for publication by Ricardo Hueso and colleagues, analysing the development and dynamics of the spot in detail.]

After solar conjunction, JunoCam closeups at PJ33 on 2021 April 15 showed what had become of these spots. DS6 had drifted close to BA and faded, becoming an orange oval -- which was bright white in amateur images, henceforth called WS6. DS7 was still a turbulent spot and had expanded into a miniature FFR, apparently emitting disturbance Np. and Sf. [For more details see our PJ33 report, & Clyde Foster's abstract for EPSC2021]. PJ34 images on 2021 June 8 confirmed this picture, and showed that the DS7 FFR was still expanding. So Clyde Foster had observed (for the first time) an outbreak that initiated a turbulent structure that is likely to continue expanding to form the next structured sector, to be called (in historical sequence) STB segment G.

2021: Summary

Strip-maps of the domain are shown in Figures 1-4: Fig.1, a selection from ground-based observers; Fig.2, from JunoCam at PJ33-PJ35; Fig.3, from amateur observers at PJ36 on Sep.1-3; Fig.4, from HST (OPAL) on Sep.4 (& see animation Anim-2). The JUPOS chart, showing the tracks of all the features described is in Fig.5. All these figures have north up and System 3 longitude (L3). Supplementary Figures S1 to S4 present maps and JUPOS charts with south up and System 2 longitude (L2). **Table 1** summarises the drift rates and latitudes of the main features discussed. Our standard abbreviations are used.

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In 2021, all the S. Temperate features present in 2020 have persisted, transformed, and converged to occupy a darkened, disturbed sector spanning ~130° longitude.

STB segment A has remained turbulent and gradually lengthened (with a few fluctuations) until it reached a length of 60° in 2021 Nov.

At its f. end is a small but very bright AWO, several years old.

Further f. segment A is a long stretch of very dark STZ Belt (STZB), that emerged from segment A in 2019, but in 2021 is largely undisturbed. Its f. end has been fixed at a feature that we call spot 8 (see below), until last month.

Oval BA has been 'off-white', with a slight warm tinge throughout the apparition (stronger in JunoCam and Hubble images). Its dark rim faded away in May but reappeared during June. It had suddenly accelerated in 2020 March following the STB Spectre collision, and has retained a rapid average drift since then, DL2 ~ -17 deg/30d (Fig.6). However there have been large non-periodic fluctuations in the drift rate, ranging from -18.5 deg/30d in 2020 Aug-Sep. to -12.5 deg/30d in 2021 May to -18.3 deg/30d from July to October.

WS6 remains next to BA, though oscillating in in distance from it, and remains bright white.

Clyde's Spot (DS7) is a short turbulent dark streak, appearing as a FFR in JunoCam images, and it has been emitting disturbance both Np and Sf. it, so that the whole sector from oval BA to the F-Spectre has been somewhat darkened and disturbed. This is not (yet) a definitive revival of the STB in this sector but could become so. Many small spots have been tracked retrograding out of DS7, and some of them merged with other small dark spots to create a very dark anticyclonic spot here called d1, which ended up adjacent to WS6.

STBn jet spots (ignoring the S. Tropical Band) were sparse up to July, but a few were arising just p. BA/WS6, and about one per month just p. DS7 up to July. From late August onwards, more appeared at both locations, and from early Sep. when the F-Spectre arrived at DS7, this became the source of an intense STBn jet outbreak which is now streaming past the GRS.

Another site of activity appeared on August 7, with a convective plume outbreak in a small cyclone that we call Spot 8, exactly like the Clyde's Spot outbreak the previous year. This also generated some spots on the STBn jet; but its activity may now be waning.

Thus we can now compare two or three turbulent STB structured sectors in different stages of development: segment A, Clyde's Spot/DS7 (segment G), and potentially spot 8. All of them have intermittently emitted disturbance and small dark spots both eastward on the STBn jet, although modulated by the adjacent large circulations, and westward on the STBs jet and STZ The westward disturbances, which we have previously called the 'South-following tail' of such sectors, took various forms in 2021: Sf. segment A, it has been a quiescent, very dark STZB; Sf. DS7, the spots mostly either merged into the growing, very dark spot d1, or disappeared there; and Sf. spot 8, only a few spots were tracked in a short-lived disturbance. We have not recorded systematic recirculation in these regions this year.

Multispectral imaging:

These various features show distinct properties in the near-ultraviolet (UV) and methane band (CH4, 889 nm), as shown in the HST maps (Fig.4) and ground-based images (Figures 7-9):

Oval BA is very bright in CH4 (as usual for large anticyclonic ovals), and dull in UV, indicating its slightly 'warm' tinge.

WS6, by contrast, is very bright in UV, but uneven in CH4; its core is quite methane-dark but its periphery uneven. (A similar, larger cyclonic circulation just Sp. it, in the SSTB between AWOs A5 and A4, is likewise bright in UV, but variable in CH4.)

Clyde's Spot (DS7) appears dark and disturbed in CH4, and dull in UV. Some of the disturbances around it appear similar.

The F-Spectre is still the f. end of a slightly methane-dark sector, as it was when the Spectre was a complete circulation.

The tiny AWO just S of the F-Spectre, remarkably, is not methane-bright, but is very UV-bright.

Following oval BA

STB segment A expanded to ~25° in longitude in 2020 May; the length increase stalled but resumed, reaching 38° in 2020 Nov, then 45° at PJ32 (2021 Feb.21) & PJ33 (2021 April 15). It then stalled again, as oval BA was slow-moving during May; also BA lost its dark rim in May, and all these changes suggest that STB segment A had reduced activity in that month. But thereafter, BA accelerated again and segment A slowly lengthened, reaching 60° long in November.

At its f. end is a small but very bright *AWO*, several years old, similar in size to some of the familiar AWOs in the S2 domain.

The STZ f. segment A has been occupied by a very dark belt (STZB) throughout the year. Although it emerged Sf. the disturbed segment A in 2019, this year it has been undisturbed

along most of its length. Its spread westwards appeared to be blocked, some time in 2020, at a position that was later recognised as the cyclonic 'spot 8' (see below). Its f. end was well defined from late 2020 onwards, and in 2021 from early May we can see the slightly oblique grey streak N of it that evolved into spot 8, sometimes with a small white spot (AWO?) between them. The methane-bright plume of spot 8 erupted within it on Aug.7, and from that time onwards, the STZ f. spot 8 became very bright white (see below). In Sep., spot 8 accelerated and the f. end of the STZB decelerated, so they were no longer linked.

Two tiny AWOs have developed within the STZB, making a series of AWOs with spacings of ~55-65 deg from oval BA to the second AWO to these tiny ones. (A fifth track on the JUPOS chart, alongside the GRS in Oct., was actually a tiny cyclonic white spot, displaced south to 31°S as it passed the GRS, like the precursors of Clyde's Spot and spot 8; but it has not undergone any such convective outbreak.)

Preceding oval BA

WS6 has been a very bright white cyclonic oval throughout this apparition. After solar conjunction we expected to see DS6, but when JunoCam imaged the region close up at PJ33 (2021 April 15), DS6 had been replaced by an orange cyclonic oval adjacent to oval BA (Fig.2), which must have been the same feature. Reddish colours always appear stronger in JunoCam images, and the colour was somewhat weaker at PJ34 (2021 June 8), and even weaker in the HST OPAL images on Sep.4 (Fig.4). It generally appeared bright white in amateur images; however, the very best amateur images close to opposition (e.g. many of those in Fig.9) did resolve the slightly redder inner oval from the bluer outer annulus. WS6 was in contact with oval BA in March-April, but its relative position has oscillated slowly since. It drifted slightly away from BA in May-June, returned to contact in July-Aug., and has subsequently separated again. These changes in drift rate corresponded to changes in its latitude, in accordance with the ZWP, as shown by JUPOS data in the alternating green and cyan tracks in the JUPOS chart (Fig.5), and in the analysis below (Fig.S3).

STBn jet activity: There had been an intense outbreak of dark spots on the STBn jet p. BA in 2020 Jan-Mar., around the time of the STB Spectre collision [2020 Report no.2], but it then ceased and few spots were recorded here subsequently. In 2021 April-July, the STB(N) p. BA was combined with a strong S. Tropical Band (STropB) from the GRS, making a dark belt in which no spot activity was visible; moreover, any STBn jet disturbance might have been blocked by WS6. (However, smallscale turbulence was discernible in July p. WS6. In this account, we ignore many STBn jet spots at <26°S, related to the STropB.) In August, the STZB faded away.

The JUPOS chart tracked a few STBn jet spots up to August (see Adamoli's analysis, below), mostly arising just p. BA/WS6. In late August more appeared, some just p. WS6, and some just p. the F-Spectre, and some p. spot 8 (a series of 7 or 8 that appeared between Aug.20—Sep.2 and prograded for a long way – viewed by JunoCam at PJ37 on Oct.16). The JUPOS chart showed few distinct jet spots coming from DS7, but more detailed study (below) showed that some were emerging just p. DS7: about one per month up to July, and more thereafter. After DS7 met the F-Spectre in early Sep., many emerged there -- an increasing jumble of dark spots running up to the GRS. As of late Nov., they are an intense STBn jet outbreak streaming past the GRS.

DS7 (Clyde's Spot): (I am still using this term to refer to the growing FFR, although it is now called the Clyde's Spot Remnant by some authors; I expect it will soon be sufficiently well established to be named STB segment G.) It is a short turbulent dark streak, appearing as a FFR in JunoCam images (most recently at PJ34: Fig.2), and it has been emitting disturbance both Np and Sf. it, so that the whole sector from oval BA to the F-Spectre has been darkened and disturbed (see below). As the F-Spectre maintained an unusually slow drift rate, DS7 caught up with it in early Sep. Since then, DS7 retained its consistent drift rate, and seems to have become larger, ~17° long

in Nov. – although its boundaries are unclear in ground-based images. It is certainly a vigorous turbulent region now. From Sep. onwards, intense disturbance was emitted p. from it on STBn (see above), but the activity f. it subsided; the sector back to WS6 seemed to be quieter in Oct.

Earlier, many small spots were tracked retrograding out of DS7, and some of them merged with other small dark spots to create a dark spot, here called d1. This was very dark in July and August, converging on WS6, and was then adjacent to WS6 up to late Oct. (However in Nov., after the analysis reported here, it recirculated to the SSTBn, shifting south and prograding away from WS6.)

The F-Spectre was indistinct at the start of the apparition, and its identity uncertain in the absence of closeup images to verify its circulation (no JunoCam closeups of it since PJ30). But it became more distinct from April to July, as the space between it and DS7 became increasingly shaded and spotty. Its cyclonic curve was not obvious, except where highlighted by a white oval during May; but its circulation was eventually confirmed by the HST maps on Sep.4 (Fig.4 & Anim-2). There is a tiny AWO (UV-bright) just S of the F-Spectre, which is probably the same one that existed here in 2020. The F-Spectre arrived at DS7 in early Sep. and its subsequent fate is unclear, as DS7 retained its drift and became larger.

Clyde's Spot and surroundings (from BA to the F-Spectre): Detailed investigation

(Collaboration with Gianluigi Adamoli & Shinji Mizumoto)

To elucidate what was happening in this sector, we used a series of maps made every few days (by Shinji Mizumoto, April to August; e.g. Figure S1), and extended JUPOS measurements and analysis of spots (by Gianluigi Adamoli, late March to early Sep.). The JUPOS chart is shown in Figure S2. This analysis, with Figures S1-S4, was done in our historic convention using System 2 longitude (L2) and south up, rather than the L3/north-up convention used in the other figures.

Figure S1 shows excerpts from Mizumoto's series of maps, selected to encompass the JunoCam maps from PJ33, PJ34 & PJ35, so the tracked spots can be identified in those maps. In the southern STZ and alongside the SSTBn, there are several compact dark spots (vertical light-blue arrows), with speeds fairly close to the S.Temperate Current (STC) that governs the major features of this domain. Several of them may have arisen independently of Clyde's Spot. These include d1 and d2 (already present on May 2); in late May they converge closely, together with a spot f. them that recirculated from the retrograding STBs in mid-May, and two of them merge around June 1. On July 4-6, the remaining two merge, producing one larger dark spot that we still call d1. It persists thereafter, becoming fixed just Sp. WS6 from mid-August onwards (until late Oct.).

Clyde's Spot (DS7) is seen as a dark, disturbed streak, corresponding to the FFR shown in the JunoCam maps. It emits much smallscale disturbance on the STBs retrograding jet f. it, including frequent distinct dark spots (2-3 per month; oblique cyan arrows). These retrograding spots are first seen either at the f. end of Clyde's Spot (the first 2) or ~10-15° f. it where they emerge from a chaotic strip (later ones); examples are in the PJ34 and PJ35 maps. On reaching d1, they either disappear (five examples up to July) or merge with it (two in August). A typical one is labelled d3 (July 2-17): its speed and latitude (DL2 = +26 deg/30d, 32.4°S) were representative. It was last imaged on July 21, stretched into a > shape just after passing d1, both in ground-based and in JunoCam (PJ35) images.

From the JUPOS analysis, these retrograding spots had DL2 ranging from +5 to +34 deg/30d, and adhered well to the Cassini ZWP (whose peak speed was +31 deg/30d) (Figure S3). In comparison, retrograding dark spots f. STB segment A had, on average, lower latitudes, as

did one f. the outbreak of August 7 [d17, only 5 days track], whereas two in the undisturbed sector [d4, d5] had higher latitudes. We have previously found altered ZWP in different sectors of this domain and this may be a further case of this.

STBn jet (Figure S4): Many spots were tracked in this broad, double-peaked jet, all around the planet, and they generally clustered around the Cassini ZWP but with considerable scatter. Some of this is attributable to their habit of drifting northwards between the jet components without change of speed. We did not find any definite variations of ZWP between different sectors. Only a few of the tracked spots were within the sector considered here, and they were close to the general ZWP.

Although the shaded STB between DS7 and the F-Spectre was generally quiescent, the maps showed several spots prograding in this sector (oblique orange arrows in Figure S1). They appeared in the same latitude as DS7 (~30°N), at or near its p. end, and moved N as they prograded towards the F-Spectre (a distinct oblique albedo boundary). In this sector, there were 4 such spots from late April to early July. (There were also one or two more in mid-July as the sector became very short.)

The next three spots tracked, in July-August, did not come from DS7, but appeared further north at ~26°N, in a disturbed patch of STBn just p. WS6, and passed DS7 and F-Spectre without major effect.

As noted above, more STBn jet activity developed after this detailed analysis was completed.

The outbreak of 2021 Aug.7 (Spot 8)

This is a cyclonic feature that developed exactly like Clyde's spot, starting as a faint streak with a tiny light spot within it, then undergoing a methane-bright plume outbreak (on 2021 Aug.7) just after it had passed the GRS, and then developing into a turbulent, largely dark spot emitting disturbance p. and f.

The methane-bright outbreak was discovered by Christopher Go, so it could be named "Christopher's Spot", but in view of the varying appearance of other such features over time -- DS6/WS6 and DS7/Clyde's Spot – I am referring to this feature simply as 'spot 8', in succession to them.

The first sign of spot 8 as a suspected cyclonic feature was a slightly oblique grey streak, from early May onwards (Fig.1). It was adjacent to the f. end of the STZB throughout this time, suggesting that it was already a bigger dynamical feature than just a cyclonic eddy. Within this grey streak a small white spot brightened noticeably as it passed the GRS from 2021 June to early August (Fig.11).

In the first few days of August it appeared bright white, but still not methane-bright (Fig.11). The first two images in Fig.11B showed that it was especially bright near the limb, suggesting that it was quite high up even though not methane-bright. It was compact on Aug.4, but seemed to have extended white haze in Damian Peach's v-hi-res image on Aug.5. Perhaps the bright white spot in early August was a combination of weak convective pulses that did not become methane-bright, and rather diffuse haze overlying the cyclonic feature. The last CH4 image showing no outbreak was on Aug.5 at 23:18 (J. Camarena).

On Aug.7, Eric Sussenbach produced an amazing RGB image sequence from one rotation before "Christopher's Spot" erupted. (There was no CH4 image at that time.) He got a sequence at superb resolution lasting 100 minutes, and changes can be seen between the start and end of this sequence (Fig.11A & Anim-1). (Eric and John Sussenbach processed two image batches near the start and two image batches near the end, so the changes were confirmed.) The images showed less bright material than earlier – perhaps it was stripped away by incipient turbulence? As I interpret these images, the earlier ones show an elongated white spot in the southern part of the "grey streak"; in the later images this is less bright, but there is a new, brighter spot on its Np. edge (orange arrow). This was closer to where "Christopher's Spot" appeared 9 hours later (red arrowhead), but not exactly coincident, so it was probably not the upwelling plume. Nor are these positions likely to record circulation, because it would be anticlockwise, contrary to the cyclonic circulation of this latitude and subsequent observations. So there seem to be 3 possible explanations for the change recorded during Eric's sequence:

(1) It could be a sign of increasing disturbance just before the plume erupted;
(2) It could be a continuation of random variations as seen in previous days;
(3) It could be due to the changing viewing angle as the spot crosses the disk from the morning to late-afternoon side. (The sequence also clearly shows the SEBn jet and the GRS circulation.)

Go's images one rotation later on Aug.7 showed the start of the convective outbreak: a very small white spot in RGB, brighter in IR continuum, and very bright in CH4. (Several other observers, in Australia, Japan and Thailand, also recorded the outbreak at about the same time, e.g. Fig.11B.) It faded rapidly in CH4, and was never conspicuous in visible light, but initiated continuing disturbance at that site (Figs.11B & 12, & HST image in Fig.4) – developing exactly like Clyde's Spot in 2020. E.g. on Aug.10, Andy Casely noted that the plume in CH4 was somewhat larger and more structured, although fainter, and in RGB there were several condensations surrounded by new bluish material, with the disturbance spread out NE-SW.

Fig.12 shows v-hi-res images of the outbreak in late August, in which it was enlarged, and had vigorous smallscale activity internally (note changes within a few rotations on Aug.26-27). Disturbance from it was spreading in the Np. and Sf. directions on the STBn and STBs jets. JunoCam got a good view of it at PJ36 (Sep.2) (Fig.13A), which showed white cloud lobes reminiscent of those in Clyde's spot at PJ27 (Fig.2), as well as a long series of eddies and spots prograding from the outbreak on the STBn jet. A volley of 7 or 8 STBn jet spots that arose Np. it in late August persisted through October (Fig.10), and a few spots were tracked retrograding Sf. it (Figs.5 & S2).

In Sep., spot 8 became less visibly active, and accelerated eastwards. It has become less and less conspicuous since then, and I thought it might be fading away. However, JunoCam's closeups of it at PJ38 (Nov.29) show that it is still a turbulent little feature, roughly the same size as at PJ36 (Fig.13B). (The STBn jet spots seen passing it were initiated by disturbance from Clyde's Spot, and had passed the GRS.)

The future of spot 8 is uncertain. As it appeared in a long undisturbed sector of the domain, it could persist and expand as the precursor of another structured segment. On the other hand, as it did not appear in the sector p. oval BA, it could just fade away. Another similar cyclonic feature has been noted in 2021 – brightening as it passed the GRS in Oct. – but there was no methane-bright outbreak within it.

It is also possible that all these disturbances will become part of a more widespread revival of the STB. There was a precedent for this in 1993, which is all described in our report:
[Rogers JH (2016), 'Jupiter's South Temperate domain: Evolution 1991-1999 and dynamics of cyclonic structured sectors as seen in Hubble maps.' https://www.britastro.org/node/7230]

But observations this year are far better than those in the 1990s.

Hubble (OPAL) maps, 2021 Sep.4

The Hubble Space Telescope (HST) takes comprehensive sets of images once a year in the OPAL project [NASA / ESA / STScI / A. Simon, G. Orton & M. Wong: maps posted here: https://archive.stsci.edu/prepds/opal/]*. From the images taken on 2021 Sep.4, global maps ~10 hours apart were posted, which can be blinked to give an excellent overview of the morphologies and dynamics in this domain, at a time when Juno perijoves were not covering the most interesting sector (Fig.4 & Anim-2). It confirms the processes described above:

--Cyclonic circulation and eddying in STB segment A, DS7 (Clyde's Spot), and Spot 8.

--Dark spots prograding on the STBn p. WS6 and continuing alongside DS7.

--Dark patches retrograding f. DS7, as far as WS6, where they squeeze between WS6 and the anticyclonic d1.

--Cyclonic recirculation from STBs to STBn at the F-Spectre, and a tiny AWO just S of it.

--Structures around Spot 8, viz. the boundary between dark STZB p. it and very bright STZ f. it, with signs of anticyclonic recirculation there; and rather faint spots prograding from Spot 8 on the STBn jet.

*"This work used data acquired from the NASA/ESA HST Space Telescope, associated with OPAL program (PI: Simon, GO13937), and archived by the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-26555. All maps are available at http://dx.doi.org/10.17909/T9G593."

Figures

Figure 1. A selection of strip-maps of the S. Temperate and adjacent domains from images by amateur observers in 2021. All figures (except the Supplementary Figures S1 to S4) have north up and System 3 longitude (L3), though L2 is added for some maps. In addition to S. Temperate features, AWOs A1-A8 in the S. S. Temperate domain are labelled.

Figure 2. Strip-maps from JunoCam images at PJ33-PJ35. Diagonal green arrows indicate spots retrograding from DS7 as indentified in our ground-based analysis (Fig.S1).

Figure 3. Strip-map from images by amateur observers at PJ36 on Sep.1-3. This map can be compared with maps on Sep.4-5 by amateurs (Fig.1) and by Hubble (Fig.4).

Figure 4. Strip-maps from HST (OPAL) on Sep.4, in RGB & UV & CH4, aligned. Also see the blink animation of two RGB maps ~10 hours apart: Anim-2). On this date, DS7 and the F-Spectre were close to coming into contact.

Figure 5. JUPOS chart of longitude vs time, showing the tracks of all the features described in this report. (For an equivalent chart in L2 in reverse orientation, see Suppl.Figs. S2 & S3.)

Figure 6. JUPOS chart of longitude vs time for oval BA over 4 years, in a longitude system moving at DL3 = -8.5 deg/30d. Blue and green marks indicate its p. and f. ends.

Figure 7. Some of the highest-resolution images in RGB, with companion images in CH4: May 17-29 & June 1. (Please see Fig.1 for annotations.)

Figure 8. Selected multispectral images in the 889 nm methane band (CH4), near-ultraviolet (UV), and RGB or IR continuum: May 24-28 & June 5-6. All are by Clyde Foster except for the last row. (Please see Fig.1 for annotations.)

Figure 9. Some of the highest-resolution images in RGB in August, with some companion images in CH4 and UV. (Please see Figs.1&4 for annotations.)

Figure 10. JUPOS chart for spots in the STBn jet (black points), in a longitude system moving at DL3 = -90 deg/30d. Bright spots in the same latitude band appear as cyan points, and tracks of major features are overlaid.

Figure 11. Spot 8: The precursor cyclone (July 31 to Aug.7: yellow arrowhead in (A), arrow in top row of (B), enclosed in red oval in central enlargements in (B)) and the methane-bright outbreak on Aug.7 (red arrowhead in (A)) and its evolution over the next few days. (A) Cylindrical map projections by E. & J. Sussenbach (upper left enlargements) and S. Mizumoto (all others). (B) Unprojected images. In the enlargements, dark blue arrows indicate a STBn jet spot being deflected around the S edge of the GRS,

Figure 12. Spot 8 (red arrowhead): V-hi-res images showing its further development around the time of opposition (Aug.19/20). Images are ~10 hrs apart on Aug.19 and ~10-20 hrs apart on Aug.26-27; rapid changes can be seen.

Figure 13. JunoCam closeups of Spot 8 at PJ36 (A: Sep.2) and PJ38 (B: Nov.29). [Also see Hubble image in Fig.4.] Red arrows indicate STBn jet spots.

Supplementary Figures S1 to S4 include maps and JUPOS charts with south up and System 2 longitude (L2).

Figure S1. Maps by Shinji Mizumoto: three excerpts from his much longer series, selected to encompass the JunoCam maps from PJ33, PJ34 & PJ35 (shown larger in Fig.2). Diagonal green arrows indicate spots retrograding from DS7. Diagonal orange & red arrows indicate spots prograding in the STBn jet, from DS7 or from the WS6 region respectively.

Figure S2. JUPOS chart for the S2 domain. (A chart in L3 in opposite orientation is in Fig.5.)

Figure S3. Chart of drift rate vs latitude for spots in this domain (Zonal Drift Profile: ZDP) compared with the Zonal Wind Profile (ZWP) from Cassini in 2000. Some spots are represented by multiple points for track segments with different drift rates.

Figure S4. (A) JUPOS chart for dark spots in the STBn jet, in L2. Different colours denote different latitude ranges. (See also Fig.10.) (B) ZDP from these data. Symbols with a vertical bar denote spots which were decreasing in latitude without change of speed.