Jupiter in 2020, Report no.2: Changes in the South Temperate Domain

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Introduction & Summary

Since 2000, Jupiter's South Temperate domain has contained only one large anticyclonic oval (oval BA), with a STB dark segment (here called A) on its following (f. = west) side, and one or two other structured sectors, which are often visually inconspicuous. These evolve in cycles in which a structured sector appears tens of degrees longitude preceding (p. = east [of]) oval BA, prograde relative to BA, and after several years catches up with BA from the f. side. When it collides with the STB dark segment A, it transforms into a dark, turbulent extension of that segment, and several other consequences occur: (i) oval BA accelerates eastward; (ii) BA acquires a dark collar; (iii) an outbreak of dark spots prograde Np. BA on the STBn jet; (iv) an outbreak of dark spots or streaks emerges Sf. BA on the retrograding jet or in the STZ, forming a 'Sf. tail'. Three of these cycles have been documented in our long-term reports [refs.1-4].

In recent months we have been anticipating the culmination of the latest cycle, and the start of another. The former refers to the arrival of the structured sector known as the STB Spectre at the f. side of oval BA; the latter refers to the origin of putative new cyclonic circulations on the p. side of oval BA. Recent developments suggest that both processes are occurring now.

In summary: The p. end of the Spectre caught up with STB segment A in mid-Feb., 2020, or somewhat earlier. There has been no noticeable change in the Spectre itself, which has remained invisible to ground-based imaging except at its f. end. However, from early March, segment A itself has been expanding again and remains turbulent, and all the other expected sequels of such a collision have occurred: the acceleration of oval BA, the dark collar around BA (which already existed), the outbreak of dark spots Np. BA in the STBn jet (which started in Dec.), and the outbreak of dark spots Sf. into the 'tail'.

On previous occasions it was suspected that all these phenomena could be due to the turbulence in segment A, which was renewed each time another structured segment merged with it. In 2020, the STB Spectre had become so long that one could not confidently forecast whether its collision would have the same consequences. The result seems to have been that it has not undergone any transformation itself (at least, not yet), but since the collision segment A itself has expanded with renewed activity, thus producing the same consequences around it.

Sources of data: For detailed reports and maps of the region around oval BA in 2019, see our 2019 Report no.9 [ref.5] and our report on PJ24 (which was on 2019 Dec.26 at solar conjunction). Here I describe the situation from JunoCam images during solar conjunction, and from amateur observations. Thanks are due to the observers who have produced excellent images, mainly in Australia and South Africa and the Philippines. Thanks are also due to Shinji Mizumoto of ALPO-Japan, who maked regular maps that are an invaluable resource [ref.6]; and to the JUPOS team, whose data have provided drift rates for the features (here expressed as DL2 (deg/mth), i.e. degrees in System II longitude per 30 days). JunoCam obtained good views of the region of interest at PJ26 on April 10, which will soon be described in a separate report.

I. Following Oval BA: Arrival of the STB Spectre

The STB Spectre is a cyclonic circulation that began as a small very dark spot ('DS5') in 2014 Dec. From 2016 to 2019 inclusive, it was visually inconspicuous (though always identifiable in v-hi-res amateur images or spacecraft images), consisting of an oblong whitish core surrounded

by a pale bluish loop. It often had a slightly darker patch at each end, and the whole of it was dark in methane-band images. I designated it more formally as STB structured sector F. Previous similar structures were the STB Remnant (sector C) and the STB Ghost (sector E). [refs. 1-4, and several of our reports on JunoCam images].

Unlike its predecessors, the Spectre elongated extremely rapidly, by ~7.5 deg/mth throughout 2019 [ref.5]. Its ends are plotted on the JUPOS chart (Figure 1). The f. end was quite well defined. The p. end was not, after 2019 April, because it was in a very disturbed region p. the GRS, but it appeared intact and closed in Juno's PJ23 images (2019 Nov.3). The p. end maintained a very rapid average drift rate (DL2 ~ -21 deg/mth in 2019), but seems to have been repeatedly associated with features in the STZ marking the f. end of the 'tail' Sf. STB segment A [ref.5]. One of these, a small AWO that it probably encountered in July, accelerated to the same speed as the Spectre's p. end, probably merged with another small AWO p. it on 2019 Sep.20, and has remained as a distinct small AWO thereafter (Figure 1). This AWO was still adjacent to the p. end of the Spectre in JunoCam maps at PJ23 (2019 Nov.3), PJ24 (2019 Dec.26, at solar conjunction), and PJ25 (2020 Feb.17).

Since the autumn, **the p. end of the Spectre** has only been clearly identifiable in JunoCam maps (Figure 2). The length of the Spectre was 120º at PJ23, 135º at PJ24, and 163º at PJ25. The p. end (and associated AWO) had mean DL2 ~ -22 deg/mth (2019 Aug. to 2020 Feb.). Some time during solar conjunction, they caught up with STB segment A. The JUPOS chart (Figure 1) suggests that this may have been only just before PJ25 (2020 Feb.17), when they were in contact, and the p. end of the Spectre was tapered so it was not clear whether it still maintained cyclonic circulation.

Considering the structures f. oval BA in order of increasing longitude:

(i) STB segment A. This had remained ~20-22° long from 2019 March to Sep., not showing its expected shrinkage [ref.5]. At PJ24 (Dec.26) it was only 16º long, having resumed shrinking, and at PJ25 (2020 Feb.17), only 10º long. This was its minimum: since early March it has grown again, expanding to 17º long by April 12. The intense turbulence in segment A is visible in an animation (Figure 5).

(ii) The STZ AWO was described above. It reached its minimum distance f. BA at PJ25, and has remained in contact with the f. end of segment A since then. Thus its arrival at segment A reduced its DL2 from -22.3 deg/mth (mean, 2019 Aug. to 2020 Feb.) to -9 deg/mth (Feb-April), and it is moving away from BA.

(iii) The dark 'tail' in the STZ, Sf. segment A. This was variable in 2019, then virtually absent during solar conjunction (PJ24, PJ25), except for one or two dark spots. In early March, 2020, more small dark spots retrograded to repopulate this tail – i.e. they were travelling along the S edge of the Spectre. The best-tracked of them had DL2 = +12 deg/mth (March-April).

Oval BA is still white, and still has a dark rim, which it had throughout 2019.

The average drift rate of BA from 2019 March to Oct. was DL2 = -14.2 deg/mth, with some fluctuations -- still in the fast range. From 2019 Oct. to 2020 Feb. it was almost unchanged at -13.6 deg/mth. (I think that both the dark rim and the fairly rapid drift rate were due to the continuing turbulence in the STB segment A, despite its short length.)

BA accelerated dramatically in early March, 2020, having DL2 = -18.0 from then to mid-April.

II. Preceding Oval BA: STBn outbreak and origins of new circulation(s)

STBn jet outbreak:

Volleys of dark spots or streaks on the STBn jet Np. BA have occurred intermittently in recent years: there was one volley in 2019 Sep. [ref.5]. (It may be relevant that BA accelerated strongly, but temporarily, around Oct.1; and that segment A has remained turbulent although small in 2019, which might explain these events.) In JunoCam maps, there was no substantial outbreak at PJ23 (2019 Nov.3) but a new one was under way at PJ24 (2019 Dec.26).

In maps of ground-based images (S. Mizumoto: ref.6), this outbreak was well under way at the start of 2020 Feb., as the apparition began. It proceeded throughout Feb. and March. In mid-March, a prominent chain of irregular dark spots extended all the way from BA to the GRS. The ALPO-Japan chart (S. Mizumoto) shows the leading edge with DL2 = -92 deg/mth, while the JUPOS chart shows tracks with DL2 = -81, -77, and -64 deg/mth (Feb.-April). The leading edge encountered the GRS on March 21-22, but only faint remnants survived p. the GRS. In late March, the whole chain was fading, and in April no further dark spots are appearing.

Thus, although such outbreaks had occurred intermittently last year, this particularly prominent one coexisted with the other consequences of STB sectors colliding as noted above.

New circulation(s) p. BA:

There is often evidence for some recirculation in the S. Temperate domain some tens of degrees p. BA, and it is in this region that all the previous STB structured sectors have arisen. So I have been expecting a new one to appear here for some time. JunoCam images have shown small, low-contrast cyclonic eddies at PJ19, PJ20, and PJ24; and there are often broad low projections north from SSTBn.

But only now, with the first ground-based images of 2020, we see new features of which one or more could be precursors of a new structured sector. In fact there are three such features (Figures 2 & 3):

(1) A very dark spot ~42º p. BA. This has been present since Feb., sometimes a very dark compact spot, sometimes more variable. It has DL2 = -17 (Feb-April). The pale cyclone imaged by JunoCam at PJ24 was 37º p. BA so this is likely the same feature, now darkened.

(2) An oblique streak or pair of light blue-grey spots, ~80-90º p. BA. This has been present since Feb., and is now starting to pass the GRS. Though not well resolved, this could be a feature with a central white spot, reminiscent of the early STB Ghost or Spectre after the dark spot had faded. Like them, it is methane-dark (Figure 3).

(3) Between (1) and (2), the latest maps (Figure 2) and images (April 14-18: Figure 3) suggest that a much longer structure resembling the earlier STB Spectre may have already formed, ~20º long!

If the dark spot (1) persists, I suggest calling it DS6, as the spots that initiated the Ghost and Spectre happened to be called DS4 and DS5 respectively. And if a duplicate of the earlier Ghost and Spectre does emerge out of this, it will need a name; perhaps STB Wraith or Phantom?

III. F. end of the STB Spectre

The f. end of the Spectre is on now the other side of the planet from oval BA etc., with DL2 = -11.4 deg/mth (Feb-April) (Figure 1).

In 2019 it had low contrast, but was fairly distinct after April in hi-res images. It was closely imaged by Juno at PJ21 & PJ22, showing a well defined cyclonic circulation, and passed the GRS in October [ref.5].

In 2020 it has accumulated more dark material (Figure 4). In Feb. & March this consisted of streaks largely outlining the curve of the f. end, and there was a small bright white spot (possible AWO) immediately S of the f. end. In April, this white spot has been replaced by a large dark mass extending further Sf. from the f. end (possibly the 'recirculation loop' defined in previous reports on the Spectre and Ghost; refs.2&3), and there are also narrow streaks extending along the retrograding jet f. the Spectre and the prograding jet on its N edge. The shape has not been changing rapidly and does not yet reveal visible dynamics, but this structure is worth watching during 2020.

References:

1. Rogers J (2016), 'Jupiter's South Temperate domain....' https://www.britastro.org/node/7230
2. Rogers J (2015) 'Jupiter's South Temperate Domain, 2012-2015'. http://www.britastro.org/jupiter/2014_15report08.htm
3. Rogers J (2019), 'Jupiter's South Temperate Domain, 2015-2018'. https://britastro.org/node/17283 (esp. Appendix A).
4. P. Iñurrigarro, R. Hueso, J. Legarreta, A. Sánchez-Lavega, G. Eichstädt, J. H. Rogers, G. S. Orton, C.J. Hansen, S. Pérez-Hoyos, J. F. Rojas, & J. M. Gómez-Forrellad (online, 2019). 'Observations and numerical modelling of a convective disturbance in a large-scale cyclone in Jupiter's South Temperate Belt.' Icarus 336 (2020), paper 113475. [STB Ghost & its transformation]

5. Rogers J (2019), Jupiter in 2019: Report no.9. https://www.britastro.org/node/20350
6. Mizumoto S [ALPO-Japan: Regular maps from amateur images]: http://alpo-j.sakura.ne.jp/Latest/j_Cylindrical_Maps/j20_Cylindrical_Maps_L3.htm

Drift rates (DL2, degrees per 30 days)
measured from JUPOS charts, as in main text:

Oval BA	(Oct-Feb.)	-13.6 (mean)
	(Mar-Apr.)	-18.0
P. end Spectre)	(Aug-Feb.)	-22.3 (mean)
& small AWO)	(Feb-Apr.)	-9
D.s. in Sf. tail	(Mar-Apr.)	+12
D.ss. in STB(N) p. BA	(Feb-Apr.)	-81, -77, -64
D.s. p. BA	(Feb-Apr.)	-16.8
F. end Spectre	(Feb-Apr.)	-11.4

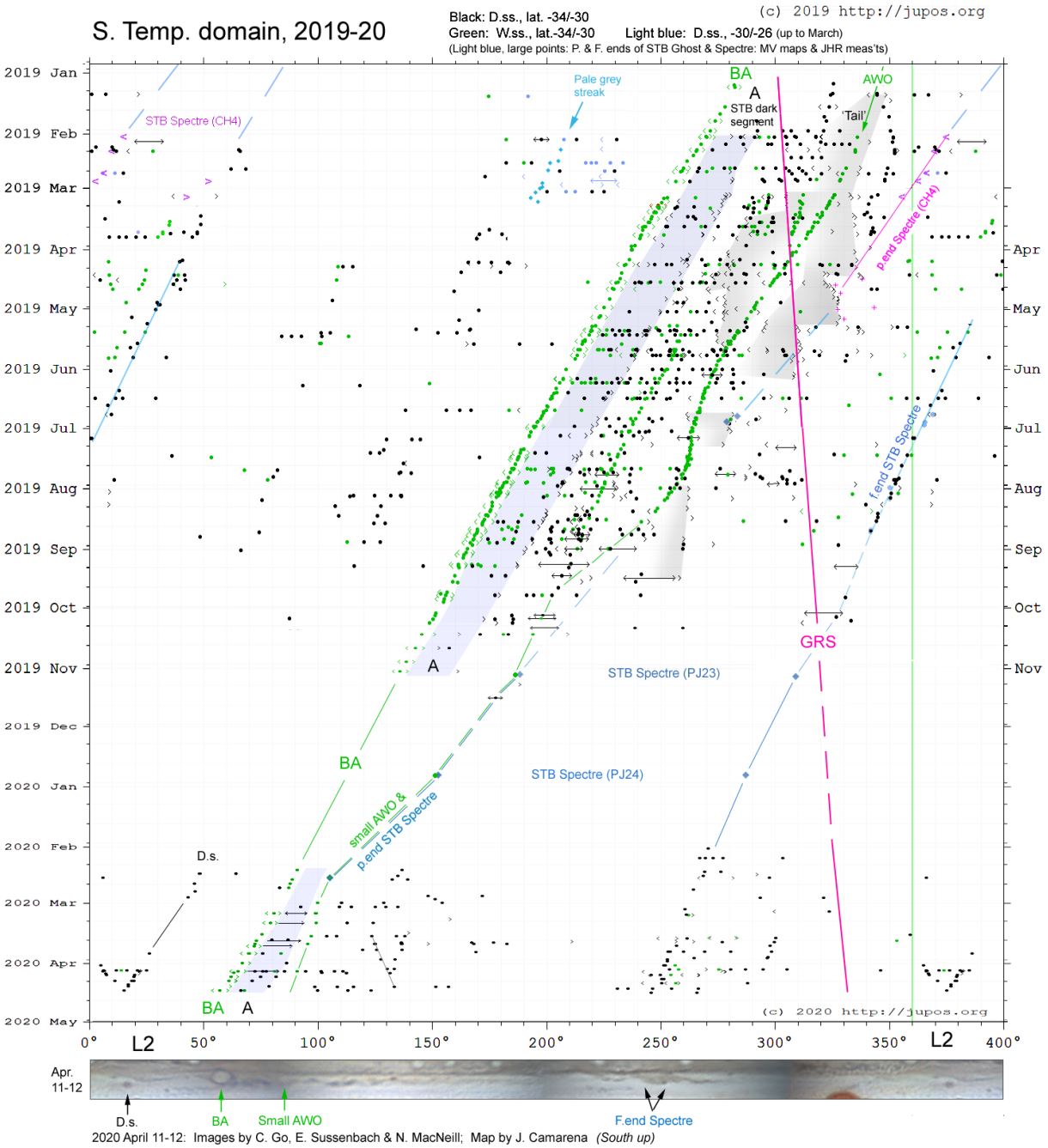

Figure 1. JUPOS chart for the S. Temperate domain in 2019-2020. Note that this has the traditional orientation with longitude increasing to the right, and thus, opposite to the maps and images in subsequent figures.

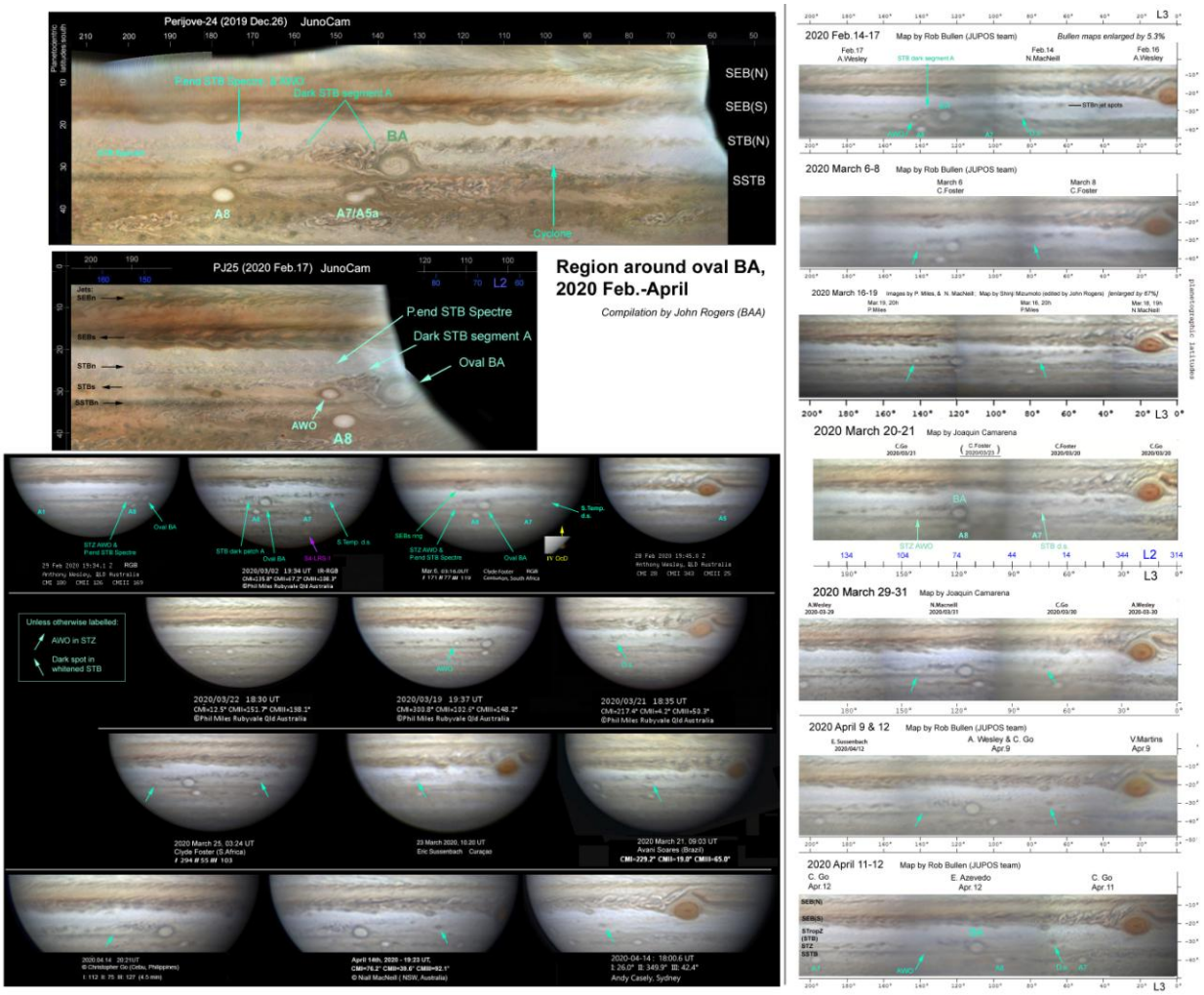

Figure 2. A collection of JunoCam maps, ground-based maps, and images, showing the region centred on Oval BA in 2020.

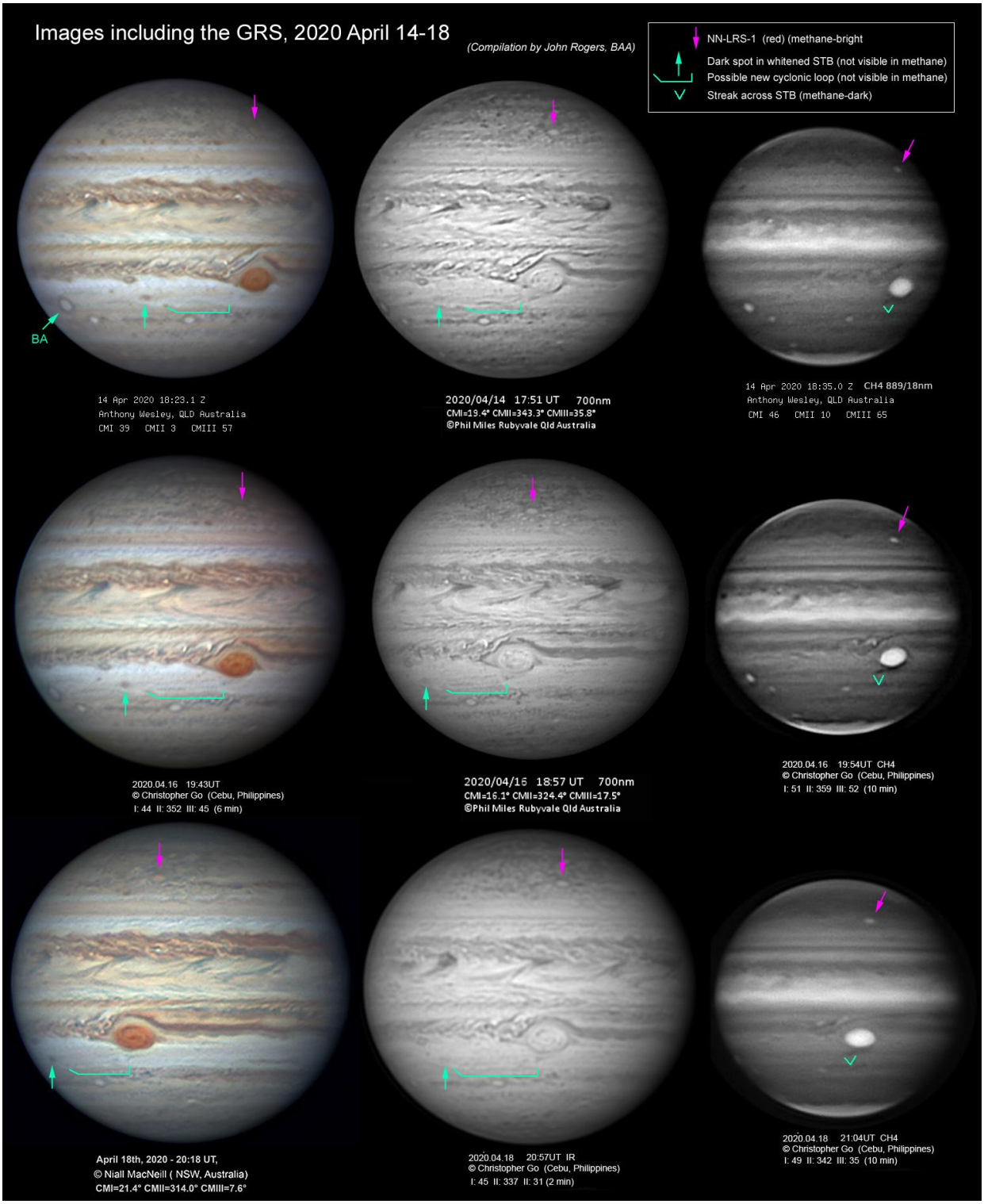

Figure 3. V-hi-res images from April 14-18 showing the region just f. the GRS, in which several cyclonic structures may be forming.

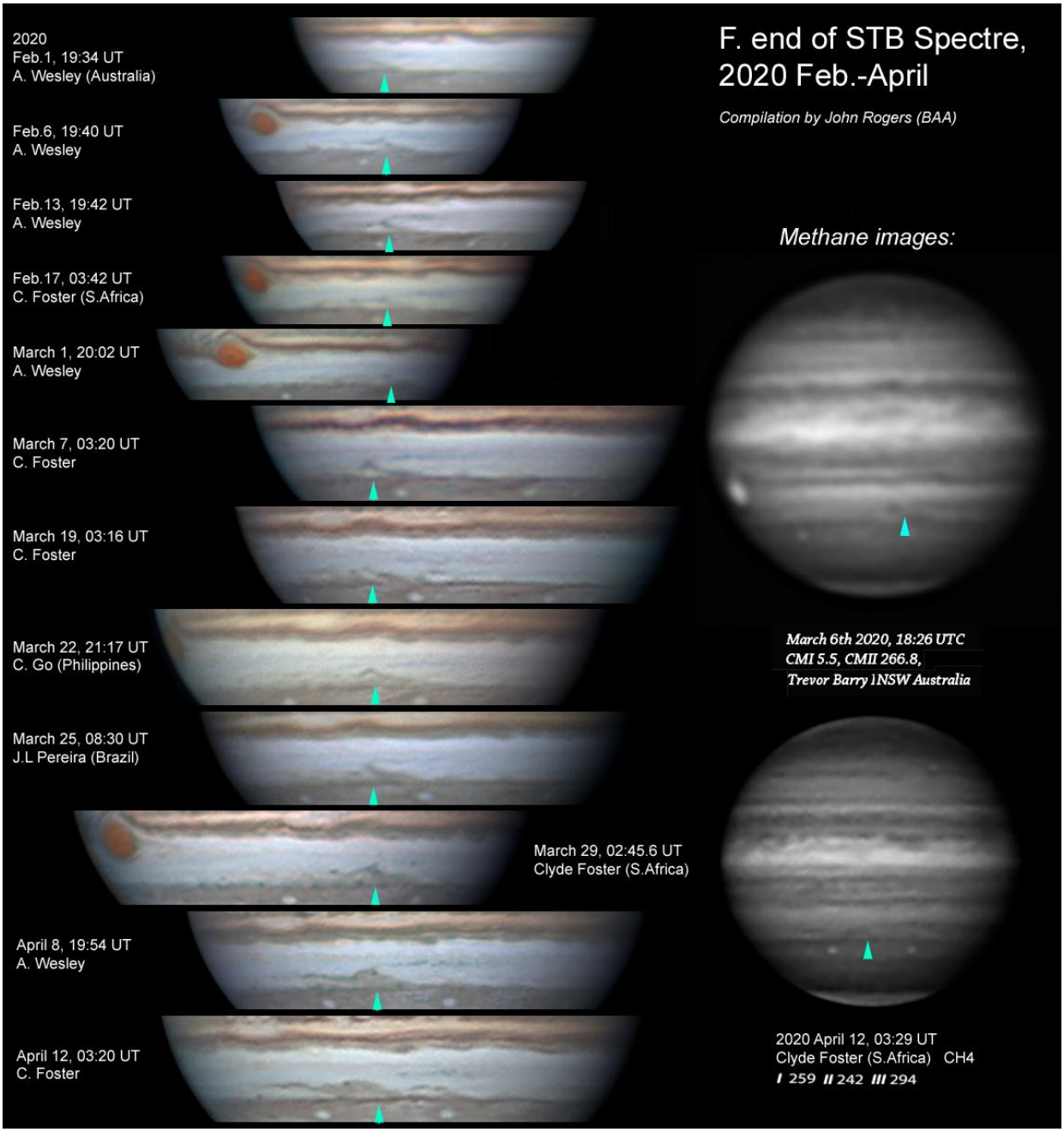

Figure 4. Images showing the f. end of the STB Spectre in 2020.

Figure 5 [*posted separately*]. Animation of two images taken 10 hours apart on 2020 April 14, showing the region centred on Oval BA; images and animation by Christopher Go (Philippines) and E. Sussenbach (Curaçao).