Jupiter in 2019: Report no.4

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This interim report is, as always, the result of work by many amateur observers, whether illustrated here or not. Many of their images are now of superb quality, especially those taken from Australia, South Africa, Brazil, and the Philippines. When images are lo-res or absent on a particular date, it is not for want of trying; the most assiduous observers often report that bad seeing or bad weather has impeded their efforts. The report also depends on the work of the JUPOS team (Gianluigi Adamoli, Michel Jacquesson, Marco Vedovato, Rob Bullen, Hans-Jörg Mettig), who produced a new set of charts up to April 21. I have not made an annotated set for this report (please refer to the set posted with report no.3) but they are the source for drift rates quoted herein. Marco Vedovato (JUPOS team) and Shinji Mizumoto (ALPO-Japan) are now posting regular maps of the planet, and I am also grateful to them and to Andy Casely, Clyde Foster, and Chris Go, for pointing out and tracking interesting phenomena, especially around the GRS.

Juno's perijove 19 (PJ19) was on 2019 April 6, returning images of southern latitudes only.

As usual, this report mostly uses System II longitude (L2), although L3 scales are given on some maps, and L1 is used for the equatorial region. Drift rates in L1 or L2 (DL1, DL2) are given in degrees per 30 days (deg/mth). DL3 = DL2 + 8.0 deg/mth. P. = preceding (east), f. = following (west). Latitudes are planetographic. North is up in illustrations unless otherwise indicated. Uncropped and unlabelled versions can be provided if needed.

Some of the highest-resolution images from 2019 March to May are shown in Figure 2. (Note that most were taken with telescopes larger than a C14: size still matters, if the seeing is good!) Most of this set show oval BA, p. the GRS; two show the f. end of the STB Ghost, f. the GRS. Methane-band images (including structure in the polar hoods) are in Figure 10.

Zonal wind profile (ZWP)

Marco Vedovato produced a ZWP from two pairs of amateur images taken on April 19-21 (Figure 1). It's particularly interesting, in view of our recent publications on speed variations in the major jets, to see that:

--The NTBs jet speed is u_3 = +155 m/s (DL1 = -128 deg/mth); so we can predict that a new NTBs jet outbreak will occur in 2021.

--The NEBs jet speed is u_3 ~ +110-115 m/s (DL1 ~ -9 to -20 deg/mth), so there must be a lot of small-scale features in the 'fast' range, not just the well-tracked large dark formations in the 'normal' range.

--The SEBs jet speed appears to be u_3 ~ -27 to -34 m/s (DL2 ~ +51 to +67 deg/mth): this is much less than the retrograding speed of the jet peak or of typical retrograding rings (see below), so it may be the speed of the small-scale wave-trains that were prominent earlier in many v-hi-res images, and/or, of irregular dark patches around the jet.

Maps of the planet

Maps of the planet are shown in Figure 3 (April 5-6: including PJ19), Figure 4 (April 9-10: best resolution for the PJ19 track), and Figure 5 (April 19-21).

Northern hemisphere

North polar region

The only conspicuous feature is an unusually large white oval at 61°N (Figures 2,4,5); this must be an anticyclonic white oval (AWO) in the N5 domain. It had DL2 = +17 deg/mth from March 22 to April 10, and has been at L2=56 since then. Juno may see it at PJ20.

N2 domain

NNTZ ovals: As shown by the updated JUPOS chart (Figure 6), the three long-lived ovals all decelerated since Feb. and were near-stationary in L2 in March, but then developed different drifts. Here I list (i) L2 on April 20, and recent drift; (ii) appearance in RGB images; (iii) apearance in methane-band images:
NN-LRS-1: L2=84, stationary; pale grey, barely visible; very methane-bright.
NN-WS-4: L2=130, retrograding; pale grey like NN-LRS-1; moderately methane-bright.
NN-WS-6: L2=334, prograding; bright white; weakly but consistently methane-bright.

The NNTB is fragmentary, and the pale sectors include 2 or 3 folded filamentary regions (FFRs: cyclonic rifted regions). Dark segments of NNTB have DL2 ~ 0; but the two most prominent ones faded away, rather rapidly, in April.

The NNTBs jet still carries many dark spots, all with DL2 ~ -81 deg/mth.

N1 (N. Temperate) domain

The NTB is now all faint, but still contains a substantial rifted sector (Figures 2&10). On April 29-30 this was N of the GRS, spanning L2 ~ 300-350 (L3 ~ 250-305). But there is no longer a substantial dark sector (NTD) f. it.

North Equatorial Belt (NEB)

The N. Tropical Zone has almost completely cleared, and the NEB is still as described in report no.3. There are now 3 small barges in it as well as many bays or AWOs on NEBn. In methane images, there are no significant methane-dark waves.

Equatorial region

Not much has changed since our previous report. There is still an array of NEBs dark projections, some quite complex, with positive drift in L1. The ochre coloration of the EZ is intense, all around the planet. This is the most impressive coloration episode since 1990-91. It is most intense between +4 and -4 deg latitude, but also covers most of the EZ north of that, blending with the grey of the festoons from NEBs and the whiter shade of the plumes between them. Only a narrow strip of EZ(S) is still white, although not as bright as it was before.

Figure 7 shows the EZ sector which Juno passed over at PJ19, for several days around the perijove, with the point of equator crossing at L1=216 marked by a cross. Juno flew over a complex region of bright spots and festoons in EZ(N) similar to the one described in Report no.3. Figure 8 shows maps of the whole EZ over the same time-span. Two of the bright spots (plumes) in EZ(N) show rapid changes within a few days.

Southern hemisphere

South Equatorial Belt (SEB)

The SEB still consists of three fairly narrow dark components: SEB(N) at 9°S, SEB(C) at 13°S (absent for some distance f. the GRS), and SEB(S) at 18-19°S (broad and disturbed f. the GRS, narrow and dark p. the GRS). The broad white 'SEB Zone' f. the GRS is still prominent. Indeed, we have the strange situation in which the northern half of the belt is largely quiet and whitened, while the southern half shows normal activity of the post-GRS rifting and SEBs jetstream spots. In the past, intense EZ coloration events have often been associated with SEB Fades, so I speculate that the paleness of the northern half is a compensatory response to the EZ coloration, but it has not (yet?) developed to a Fade encompassing the whole belt.

The long-lived barge described in report no.3 has remained at L2 = 224, 16°S. Throughout 2019 it has been only light brown, with a bright halo, in the increasingly light zone between SEB(C) and SEB(S).

The SEB sector f. the GRS had multiple new bright outbreaks in Feb. (Report no.3), which continued in March. but died out in early April. However, typical bright white spots reappeared immediately f. the GRS on April 28 and were also methane-bright (Figures 10&11).

Although the post-GRS rift activity is limited, the SEB(S) has recently become very disturbed. F. the GRS, it is complex with a long dense chain of dark spots (Figure 10). At other longitudes, there are now many oval rings retrograding with DL2 ranging from +94 to +120 deg/mth (Figure 9D); these are typical SEBs jetstream spots, i.e. vortices.

Great Red Spot (GRS) and surrounding area

The GRS is still small (14° long) and very red. There has been much interest in the emergence of red, methane-bright 'flakes' or 'blades' that detach from the f. (west) end of the GRS (Figures 9-11) – a phenomenon that has been prominent in recent JunoCam images (PJ17, PJ18, PJ19) and also observable in amateur images, as described in our 2019 Reports nos. 1 and 2, although it was apparently rare until 2017 (see Box 2).

Maps made by Shinji Mizumoto, posted on ALPO-Japan (http://alpo-j.asahikawa-med.ac.jp/Latest/j_Cylindrical_Maps/j_Cylindrical_Maps.htm), implied that these flakes were induced by the arrival of retrograding rings (vortices) on the SEBs jet. He found that each of three successive flakes in early 2019 was formed within a few days after a retrograding ring entered the Red Spot Hollow (RSH), suggesting that these vortices were disrupting the periphery of the GRS, and this has been confirmed by more recent examples. The red flakes last for more than a week, detaching from the f. end of the GRS and extending in the f. direction within the SEB(S). Their reddish colour is often difficult to distinguish from the brown of the belt but they can be identified as methane-bright.

Mizumoto's maps include a constantly updated set centred on the GRS, with relevant features marked, including the reddish flakes ('blades') that detach from the f. end of the GRS, and the retrograding rings on SEBs that arrive at its p. end. The only examples of these features from 2019 Jan. to March were: (1) A pair of retrograding rings entered the Red Spot Hollow on Jan.21 & 24; a red flake commenced on Jan.25. (2) A retrograding ring entered the Red Spot Hollow on Feb.8; a red flake probably commenced around Feb.9, too small to be well resolved but well shown in Juno's PJ18 images on Feb.12. (3) A retrograding ring entered the Red Spot Hollow on March 23; a red flake commenced around March 27. This had become very elaborate f. the GRS by the time JunoCam imaged it (near the limb) at PJ19 on April 6 (Figure 9). Red material also emerged at the p. end of the GRS (April 1-6); the PJ19 methane map suggests that this also derived from the same red flake, which had flowed ~270 deg around the GRS by April 6.

In early April, another pair of retrograding rings was observed approaching the RSH. They entered it on April 12 & 15. Indeed they triggered the emergence of a pair of red blades from the GRS (April 17-20) (Figure 10). However, the interaction became more complex. A large dark hook-like structure developed on the southern edge of the SEB immediately following the GRS. (This was reminiscent of the South Tropical Disturbance (STrD) that was passing the GRS in early 2018, although it did not have the circulation pattern of a true STrD.) Some of the dark material in the hook-like structure streamed around the south edge of the GRS, forming a very dark grey collar around the GRS (which looked like a giant red eye!), and thence prograded as a S. Tropical Band preceding the GRS. This was a dynamic stream with multiple concentrations and extensions, again reminiscent of the STropD. Meanwhile, as shown in Figure 11, the red material did persist in the SEB f. the dark collar, and red material was also discernible in a diffuse fringe tracking around inside the collar from May 1-5 until it emerged as a red, methane-bright streak p. the GRS on May 6-7. Marco Vedovato's animation suggests that this circulating red fringe may have been a relic of the earlier interaction with a SEBs spot, having circulated completely around the GRS.

Box 1. Animated maps of the GRS region showing these phenomena have been posted by:

(1) Shinji Mizumoto:
http://alpo-j.asahikawa-med.ac.jp/Latest/j_Cylindrical_Maps/j_Cylindrical_Maps.htm

(2) Marco Vedovato: **http://pianeti.uai.it/images/J_Map_L2_2019_GIF.gif**

(3) Andy Casely: **https://photos.app.goo.gl/3fk3ESpwnNBUXsc39**
(He says: This is an animation of maps only from April 14-20, but has as many frames as possible. It shows the entrance of the two SEBs retrograding rings into the RSH, being disrupted and stretched, and peeling off flakes of red material from the GRS. Two bright spot outbreaks grow on the NEB too.

& Here is the Voyager 1 'blue movie':
https://commons.wikimedia.org/wiki/File:790106-0203_Voyager_58M_to_31M_reduced.gif

Box 2. Previous examples of these phenomena at the GRS:

This behaviour has rarely been observed until 2018-2019. It may have been under-reported as high resolution is needed to detect the 'flakes' Nevertheless, it is possible that this behaviour has only recently started, with the shrinkage of the GRS.

In the Voyager 1 movie (URL above), SEBs retrograding rings were swinging round the GRS with vigorous interactions but not usually causing obvious disruption of the GRS itself as at present. However, one such 'flake' was visible in an image on 1979 Feb.25 [P-21151].

In publicly posted maps from the Hubble Space Telescope, no such feature was recorded in 2014, 2015 or 2016; but the paired maps of 2017 Feb.2 showed a similar red 'blade', and revealed its dynamics over 10 hours, although it was not as substantial as this year's examples. Another such flake can be seen on 2017 May 18-19 in professional IR images by Dr Glenn Orton (https://www.jpl.nasa.gov/news/news.php?feature=6889) and images and animation by Chris Go, in our 2016-17, report no.13 (https://www.britastro.org/node/10663). (In early 2017 there were only a few SEBs retrograding rings, but the SEBs was rather chaotic.) We also observed a distinct example of a red, methane-bright flake induced by an incoming SEBs ring on 2015 Feb.26 (see our 2014-15 Final Report, Fig.6: http://www.britastro.org/jupiter/2014_15report12.htm), although we interpreted it differently at the time; we had an animation of it over 10 hours.

The GRS periphery has also appeared 'ragged' in other Hubble and JunoCam images since 2017 Feb., although the recent 'blades' appear more substantial. Possibly the small size of the GRS has made it susceptible to disruption by incoming vortices in a way that did not commonly occur previously.

GRS drift rate:
Figure 12 is the JUPOS chart, updating the predictive chart from Report no.3, showing that the GRS has continued to decelerate (move towards more positive longitudes). The present mean drift rate, DL3 = +10.1 deg/30d, is similar to its rate in 2017. I don't see any reason for it to change further, but it could, esp. in view of the dynamic activity taking place around it. The deceleration is good news for Juno: at PJ21 on July 21, it will fly over the GRS at L3=298, which is now predicted to be just 2 deg from the centre of the GRS at L3=296 (+/-2 deg).

S. Temperate domain

Oval BA is still white, with a dark grey rim. It had rapid drift in 2019 Jan-March (DL2 = -17 deg/mth), but suddenly and unexpectedly decelerated around March 20, to DL2 = -13 deg/mth. The drift rate mainly depends on the state of the dark STB segment on its f. side, and this is still present with small-scale turbulence, presumably responsible for BA's dark rim. However, this dark segment had become quieter recently, with no dark material being emitted p. on the STBn jet nor f. in the STBs jet, so perhaps this could explain the deceleration.

Further f., the dark sector of STZ is still present, with one or more tiny rings (AWOs) embedded in it. Two of these merged around April 1, due S of the GRS, as noted by Chris Go and shown in Figure 9B&C (including the PJ19 map which suggests the merger was not yet complete then). The merger can be seen in the GRS animations listed above. These also show the opposite motions of the principal tiny AWO (prograding with the STC) and dark condensations (retrograding with the STBs jet) on opposite sides of the 'STZ Belt'.

The STB Spectre is still almost invisible in visible light, but detectable in the best images (Figures 2 & 10), and its f. end has become more distinct since mid-April. It is still dark in methane images, which enabled its p. end to be tracked, and showed it to have grown to ~70 deg long on April 18-19. This may have been its maximum extent, because positions for the p. end since late April have been scattered and indistinct as it approached the GRS. The p. end may have stalled or changed ~11 deg. f. the f. end of the GRS. Possibly it has been truncated or constricted by the prominent dark collar that has extended around the GRS, and/or by the STB dark segment which is adjacent (Figure 11).

P. oval BA, we noted 1 or 2 faint oblique streaks across the whitened STB (Report no.3). This feature is unchanged up to early May, with drift similar to BA. This region was captured by JunoCam at PJ19, revealing the streak(s) to be 3 contiguous cyclonic vortices.

S2 (S.S. Temperate) domain

The 8 AWOs persist. A8 and A1 have moved apart as the whitened sector of SSTB between them lengthened; as of April 30 it was ~45 deg long and not very bright. The adjacent whitened sector between A1 and A2 is shorter and very bright white, but not methane-bright (C. Go, April 16 & 21).

S. Polar region

S4-LRS-1, which apparently merged with S4-AWO-2 during solar conjunction, has had mean DL2 ~ -18 deg/mth since 2018 Sep. It still has DL2 ~ -17 deg/mth, with small fluctuations.

A white oval near 70°S has been tracked in Feb.-March with DL2 = +14 deg/mth.
