JunoCam at PJ39: What the pictures show

John Rogers (BAA) (2022 March 2)

Appendix A
Ground-based tracking of the ovals in N4 domain prior to PJ39

[This is an excerpt from our eventual report on the high northern domains in 2021-22, in preparation.]

To elucidate the behaviour of the AWOs in the N4 domain, throughout 2021 and leading up to PJ39, we have combined measurements from our JunoCam maps with tracking from amateur images performed by the JUPOS team [Gianluigi Adamoli, Rob Bullen, Michel Jacquesson, Hans-Joerg Mettig, & colleagues]. Figure A1 shows part of the JUPOS chart of the domain. Figure 7 in the main report shows our JunoCam maps of the high northern domains, from PJ36 to PJ39. Detailed analysis of the JUPOS data is still in progress, but we can give an overview of the results. Latitudes given herein are planetocentric unless otherwise stated.

Long-lived white ovals in this domain are very likely to be anticyclonic (invariably so for high-latitude ones) [ref.1], and their identity as AWOs was confirmed whenever JunoCam imaged them. Three AWOs in Figure A1 (labelled A,B,E) were well tracked throughout the apparition, and several others for shorter periods, despite their large changes of speed.

Most white spots and other features in the domain were retrograding, with DL3 = +14 (±2) deg/30d. But some of the higher-latitude AWOs were rapidly prograding, with DL3 ≈ -16 to -30 deg/30d. These speeds are entirely typical of the N4 domain [ref.1, & our final report on 2020]. The retrograding speed is the zonal slow current for the domain, and is likely to apply to the FFRs as well, although they have not been systematically tracked.

Ovals A and B were of special interest because of their interactions between PJ38 and PJ39. Although the JUPOS chart does not show their interaction clearly, the original ground-based images in Dec. (Figure A2) show that **AWO-B** did prograde steadily past AWO-A in Dec. (conjunction on Dec.16), so its identity in the JunoCam maps is confirmed; it was at 50°N at PJ38 and PJ39. **AWO-A** was steadily prograding throughout 2021, and from Nov-Jan. it had DL3 = +10 deg/30d, in the range 44-48°N [48-52°N planetographic]. On the JunoCam maps it was at 49°N (PJ38) then 46°N (N lobe of hourglass) at PJ39.

PJ39 was too late in the apparition for hi-res ground-based coverage, but some good images were obtained (Figure A3). The best image, on Jan.10 (T. Olivetti in Figure A3) shows both AWOs (B at 49°N, A at 45°N), but it doesn't show clearly what happened to A. Nevertheless, the JunoCam and ground-based tracking together indicate that this long-lived AWO moved south until it was crossing the N4 jet at PJ39.

Cyclonic lozenge C was not tracked by JUPOS. It could be the same feature at PJ37, PJ38 and PJ39 (Figure 7).

I suggest that A interacted first with C (as seen at PJ38, in spectacular closeup images shown in our report), sending it south, then interacted with B, which sent A south in turn. If so, the interaction with B must have been under way in early Dec., when JUPOS indicates that A moved below 48°N [52°N ’graphic]; only then did B accelerate to pass north of A.

Ref.1: Rogers J, Adamoli G, Jacquesson M, Vedovato M, & Mettig H-J (2017), ‘Jupiter’s high northern latitudes: patterns and dynamics of the N3 to N6 domains.’ https://britastro.org/node/11328

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Figures (Appendix A):

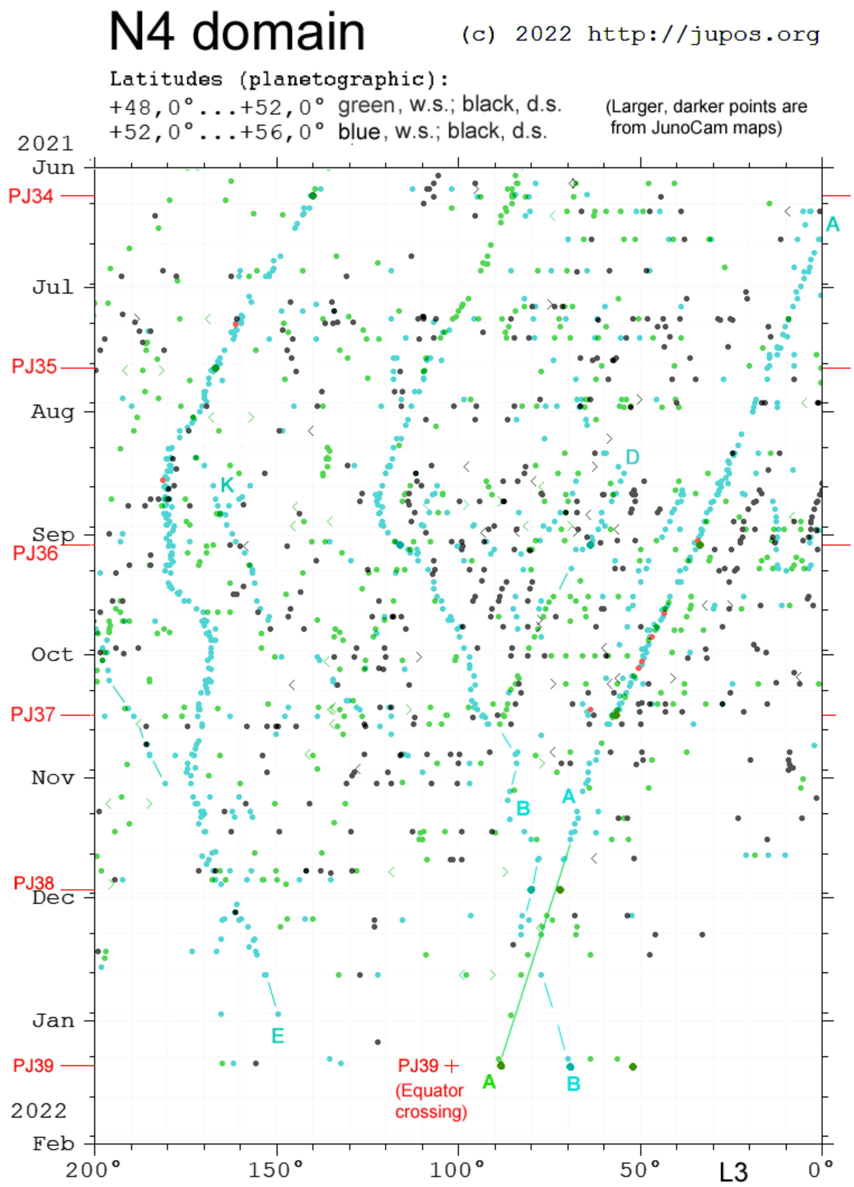

Figure A1. Excerpt from the JUPOS chart showing the positions of spots in the N4 domain in 2021-22, with positions from the JunoCam maps added as larger symbols. The JUPOS chart is now plottrf in L3 with longitude increasing to the left, consistent with the format of the JunoCam maps, contrary to our previous conventions.

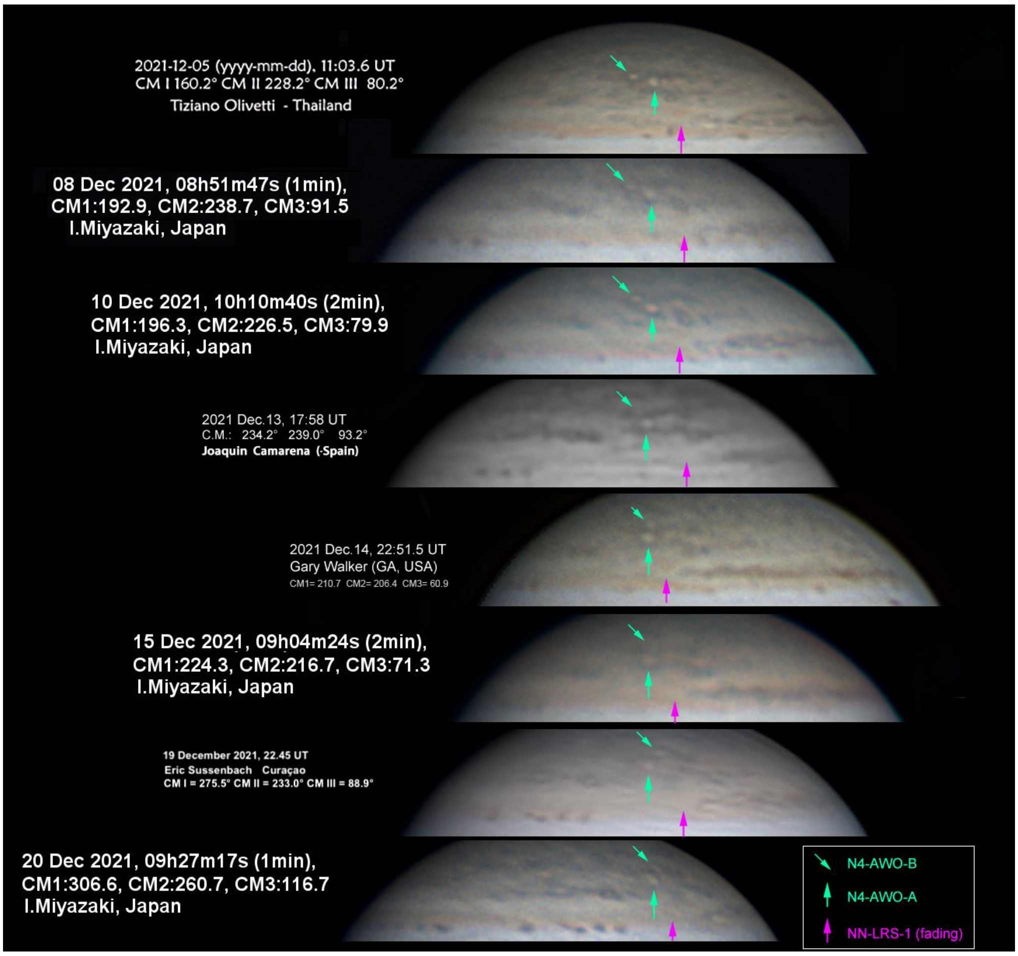

Figure A2. Images showing N4 AWOs A & B passing each other in 2021 Dec.

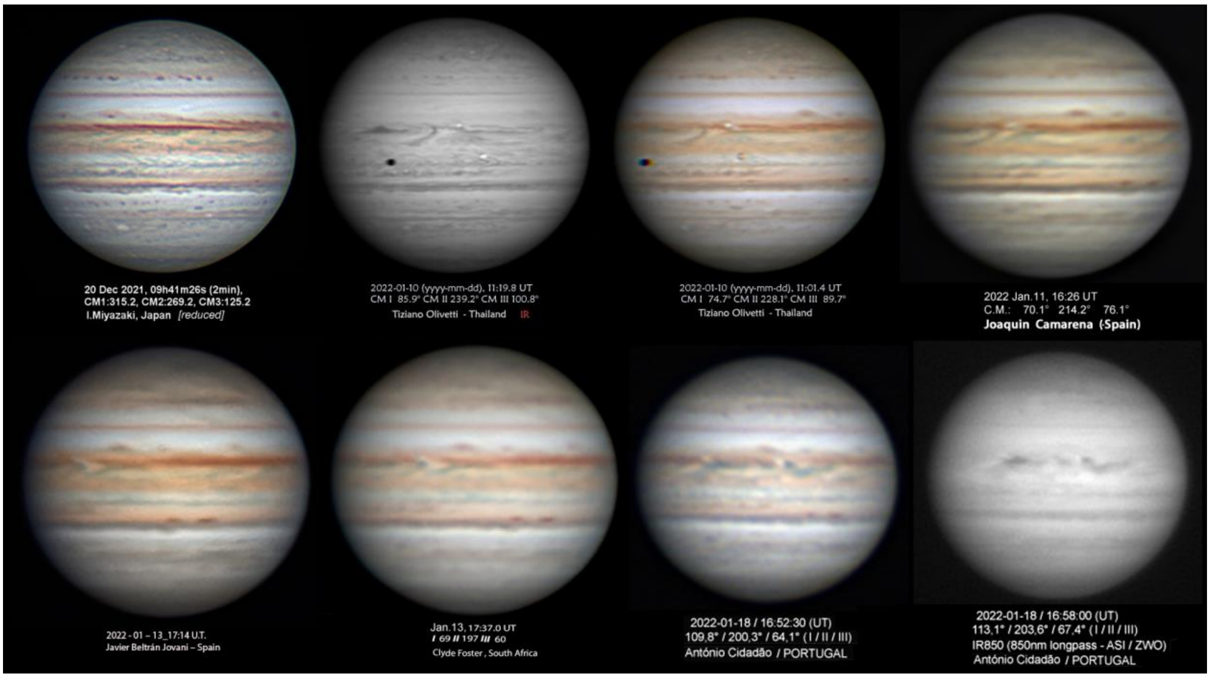

Figure A3. The best amateur images around the time of PJ39.

Appendix B
Ground-based observations of the NEB(S) outbreaks in 2021 Dec.--2022 Jan.

--John Rogers (BAA) & Shinji Mizumoto (ALPO-Japan) (2022 Feb.22)

[This is an excerpt from our report:
'Jupiter in 2021/22, Report no.7: Equatorial Region Update: Part II [revised]':]
https://britastro.org/node/26505

The outbreaks in 2022 Jan. (up to PJ39):

These events have all been thoroughly documented by co-author Shinji Mizumoto, whose sets of maps are posted on the ALPO-Japan web site (http://alpo-j.sakura.ne.jp/Latest/j_Cylindrical_Maps/j_Cylindrical_Maps.htm). His chart and maps covering the outbreak longitudes in January are reproduced here with further annotation. Figure B1 plots longitudes (L1) against time. Figure B2 presents the maps from Jan.1-20, labelled around PJ39 to identify the features seen by JunoCam, including superfast projection(s) and a methane-dark patch. Figure A3 in Appendix A shows the original images around the time of PJ39.

Outbreak no.7 began as a tiny white spot on Dec.18, and was brighter on Dec.21. It behaved just like its predecessors. It initially had positive DL1, and after about a week, a dark bluish, very methane-dark spot formed adjacent to it. The growing white spot then moved south to break thru into the EZ and changed to negative DL1 (~-1.7 deg/day), i.e. in the same super-fast range exhibited by other features on NEBs at this time. Meanwhile the extremely methane-dark spot persisted for over a month, at 9°N, and retained its positive DL1 (+1.7 deg/day), which would be normal for a latitude of 10°N [planetographic].

Outbreak no.8 appeared close to plume no.7 on Jan.6, becoming bright on Jan.9. It again had positive DL1 (+2.0 deg/day), so it passed north of plume 7 on Jan.11, then continued along the increasingly disturbed sector between plume no.7 and its retrograding methane-dark spot. Around Jan.19-23, as usual, plume 8 moved south and reversed its drift, meanwhile generating a very methane-dark spot which continued to retrograde at +2.0 deg/day.

PJ39 was on Jan.12, passing over longitudes close to the PJ38 track, both in L1 and in L3. (Coincidentally, L1=L3 on the date of PJ39.) Although the planet was sinking into the evening twilight, ground-based observers managed to get good enough images to track the features that appeared in Juno's images (Figures B2 & A3).

Figure 12 in our main PJ39 report shows the JunoCam map. The plumes and projections marked were tracked in amateur images (Fig.B2) as follows:

Plume 8 had appeared around Jan.9 [yellow arrowhead in Fig.B2] and is still a very bright compact white spot in the NEB(S). It is retrograding with DL1 ≈ +2.1 deg/day (Fig.B1).

Plume 7 had appeared in Dec. and moved south to span the NEBs and change its speed to prograding, around Jan.1 [red arrowhead in Fig.B2]. At PJ39 it is a whitish area in EZ(N), prograding with DL1 ≈ -1.7 deg/day.

Proj. a (L1 $\geq$ 104): This is the p. end of a long dark bluish formation which was elongating. The p. end was not methane-dark, and was virtually stationary in L1 up to Jan.11, but then began prograding at ~-1 deg/day. Further f., it includes the extremely methane-dark patch created in association with plume 7 in Dec., still retrograding (see above); but being at L1 = 120 on Jan.12, this patch is hardly visible to JunoCam.

Proj. b (L1 = 91): This well-defined mini-projection formed in early Jan. at the f. edge of plume 7. It is prograding at ~-1 deg/day (Jan.6-13). It is not notably methane-dark [A. Cidadão, Jan.11], though a methane-dark patch would develop nearby on Jan.18.

Proj. c (L1 = 82): This is the p. end of plume 7, though it was not a distinct mini-projection until Jan.10. It is prograding at ~-1.7 deg/day (Jan.11-18), like plume 7.

Discussion:

The visible appearance suggests that each outbreak begins with the eruption of a convective plume, and vigorous updraft in the plume leads to adjacent downdrafts (creating a clear deep hole that is very methane-dark) and a disturbed wake (white streaks and reddish-brown belt). The initial retrograding speed for the plume is fairly close to that expected for the latitude of ~10°N [‘graphic] from the usual ZWP.

The JunoCam images at PJ38 and PJ39 fortunately captured all the types of feature in these outbreaks:

Bright active outbreaks were captured at maximal resolution at PJ38 (plume 6) & PJ39 (plume 8). Each was a thick mass of bright white clouds, with a hint of cyclonic structure, surrounded by thinner whitish veils, consistent with these being the top of powerful convective outbreaks with hazes expanding from them. Plume 6 was partly overlaid by orange hazes. In both cases, wakes of whitish haze were seen, containing mesoscale waves at PJ39.

NEBs festoons with super-fast speed, possible or definite, were recorded at both perijoves, showing long blue-grey and whitish streaks, and orange haze bands sometimes cutting obliquely across them, consistent with super-fast features being deep-seated, overlaid with hazes. However, whether these aspects are significantly different from normal times need further study.

Methane-dark spots were ill-defined blue-grey patches (PJ38): they were only imaged at lo-res near the limb, but were probably partly overlaid with whitish or orange haze bands, consistent with these too being deep features.

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Figures (Appendix B):

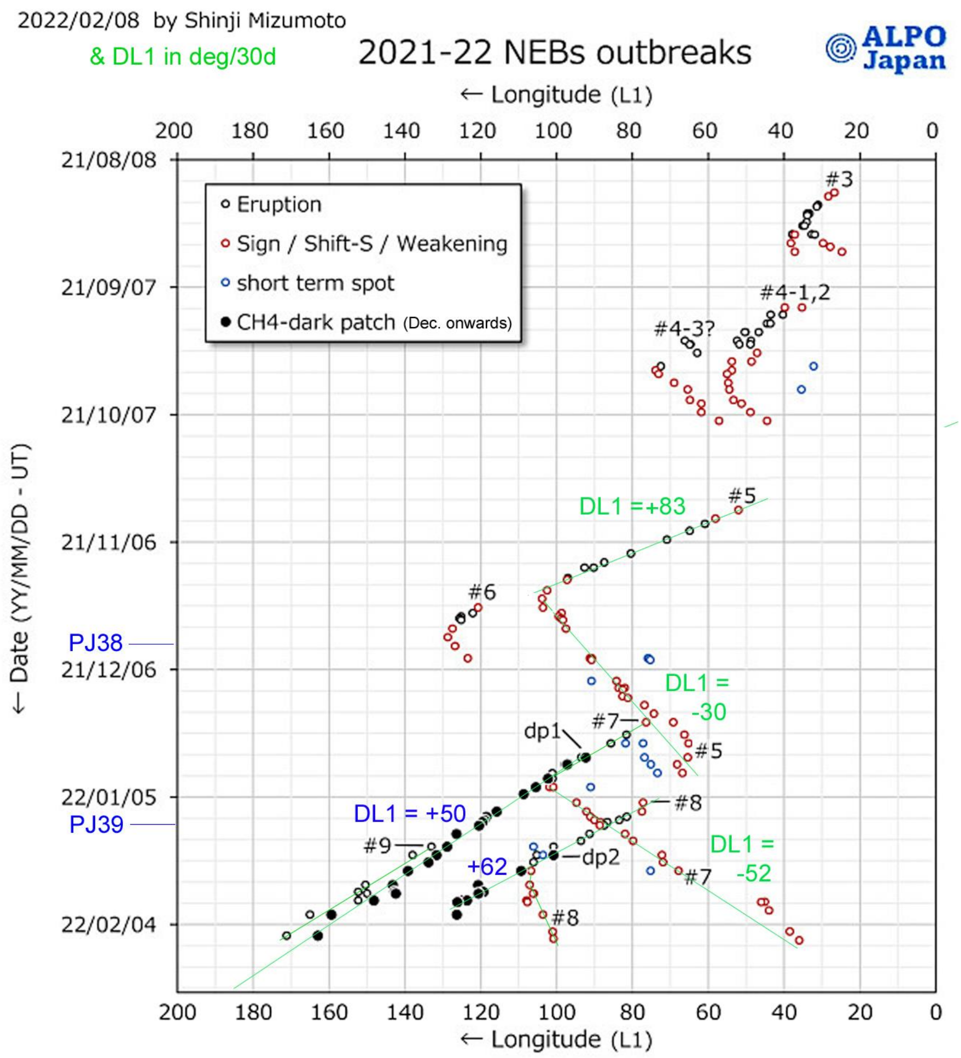

Figure B1. Charts of the NEB(S) outbreaks, with drift measurements.

Figure B2. Maps (Jan.1-20), including JunoCam at PJ39, including superfast projections (narrow black lines) and a methane-dark patch (black arrows).