Juno at Perijove-6 (2017 May 19): What the JunoCam images show

--John Rogers (British Astronomical Association), 2017 June 3

(Miniature figures are at the end. Full-size figures are in a separate ZIP file.)

At perijove-6 (PJ6), JunoCam returned a large number of superb images, thanks to the fact that this was a 'Gravity science' orbit in which the spacecraft was pointing continuously at Earth for optimum tracking, so it was able to transmit extra images live.

Images were taken at close intervals as Juno passed over the northern and southern polar regions, with the intention that a movie could be produced, and this has been achieved by Gerald Eichstädt (who processed the images) and Seán Doran (who further enhanced Gerald's images and merged them into a continuous movie). The movie is stunning, and enhanced further by György Ligeti's music as used in '2001: A Space Odyssey'. It is at:
https://www.youtube.com/watch?v=3kQbTBt418o
(and doing the rounds in the press and social media).

The quality of the JunoCam images in mid-latitudes is now astonishing, surpassing the Voyager close-ups, and they reveal new aspects of the cloud textures.

The most outstanding discovery at PJ6 was the plethora of **tiny bright clouds casting shadows**, widespread over many regions of the planet. Dr Candy Hansen reported these at the recent Juno press conference and said that they are about 50 km across (i.e. a few pixels). Cloud shadows have rarely if ever been reported before on Jupiter, except for the high-altitude haze bands which JunoCam discovered at PJ1. (There are also rafts of small clouds over the EZ, known since the Voyager encounter, which were imaged casting shadows at PJ4). But these tiny white clouds casting shadows were noted across the whitened STB and STZ at PJ5, and a few examples can be discerned in earlier JunoCam images (see Fig.A6 in accompanying report). The main reason for their widespread detection at PJ6 seems to be improved image quality (and the turbulent northern latitudes were not closely imaged at PJ5).

In the PJ6 closeups of the northern hemisphere, we see them most commonly as lines of clouds within bright strips in cyclonic folded filamentary regions (FFRs); also, over smaller cyclonic turbulence; over an anticyclonic oval in the N3 domain; as small orange-tinted clusters in the orange NTB(S); and scattered across the white NTropZ. In the southern hemisphere, they can be seen in turbulence on the SEBs, and widely across the STropZ and whitened STB and STZ and S3TZ, although the resolution in high southern latitudes is lower.

The images also hint at other novel cloud properties. In a few places one can see cloud or haze bands crossing, presumably at different levels (e.g. on the S edge of the bright white patch in the northern NTB) [such cross-cutting was also observed in Voyager images].

In the northern mid-latitudes [Figures 5 & 6], at this resolution, **dark belts appear diffuse** (notably a sector of NNTB, as well as dark bands in NTZ and NNTZ), whereas adjacent bright strips in FFRs have very sharp edges, and the NNTB-FFR appears to overlie the adjacent dark NNTB. But one also gets a strong impression that the dark belts may actually be diffuse dark haze that may partially mask underlying features.

In the SSTB, the dark belt structures generally seem much more sharply defined, but there is a striking view of bright white strips of a FFR over-riding the edge of a red-brown 'barge' [which was only starting to form at PJ5]. [Voyager 2 observed a similar phenomenon on a NEB barge.]

These indications of **high altitude for white strips in FFRs** are consistent with JunoCam's images of the polar regions, where the bright strips in high-latitude FFRs are routinely methane-bright, and they sometimes appear as high-altitude haze bands at the terminator.

Specific features: I did not expect any important named features to be in view, as perijove-6 was over what some people have called "the boring side" of the planet (though I would never admit that Jupiter has such a thing). However, several notable circulations did in fact appear. Anticyclonic ovals included a new vortex in the NEBn; southern red oval S4-LRS-1; and two white ovals (AWOs) in the S2 domain, with dynamic cyclonic structures betwen them. Even more impressive were the close-ups of cyclonic turbulent regions ('folded filamentary regions', FFRs) in the north, esp. long-lived ones in the NNTB and NTB.

Figure 1 [not copied here] is a set of amateur images of the PJ6 target areas. **Figure 2** shows the locations of the PJ6 track and images on a near-simultaneous ground-based map, and **Figure 3** shows the PJ6 images all projected onto a cylindrical map (compiled from Gerald Eichstädt's maps)*. Subsequent figures present annotated sets of the projected images from the JunoCam team* (with further contrast adjustment to some), as they give an excellent overview with reduced image distortion and uniform colour and brightness. These do not have full resolution, but they provide an index to the bewildering features shown in the full images, which other people are processing to being out maximum detail. I also present panels of clips from some of the complete images (contrast-enhanced from Gerald's versions). As the cloud textures are of particular interest, no sharpening has been applied to any of these pictures.

Footnote: Image products available:

The JunoCam images are now routinely produced in the following formats.

1) from the JunoCam team, on their web site:

--Raw images (in ZIP files), consisting of many strips alternately in red, green and blue. These are scans taken while the spacecraft moves rapidly at low altitude over the planet, which require complex processing to convert to seamless images.

--'Map-projected' images (processed by Mike Caplinger), with the strips and colour channels combined, brightness level rendered uniform across the image, and the image projected as if seen looking down from a single point on Juno's trajectory. However, they do not have full resolution. I use these for overviews because they have uniform brightness level and reduced compression near the horizon.

2) from Gerald Eichstädt:

--Unprojected images, with the strips and colour channels combined. These retain the original geometry such that features near the horizon are very foreshortened. I use these for viewing details as they have full resolution and high image quality.

--Maps from the colour images in cylindrical and polar projections, with two different levels of processing. However, they do not have full resolution. These are invaluable for establishing the positions and patterns of features.

North polar region (Figure 4):

These views confirm the now-familiar features, as reported at previous perijoves.

With Gerald's polar projection maps, we can locate the latitudes of the known jets, even where they are not obvious from cloud textures. (All latitudes are planetocentric.)

The 'bland zone' lies between 59-60ºN and 64-65ºN, approximately coinciding with the N6 domain. The long narrow haze bands within it have now proliferated into dense bundles which fill the bland zone (as seen near the terminator) and also veer further south, spanning the N5 and N4 domains down to ~48ºN. In the methane image, again, while some of these white bands are

weakly methane-bright, it is more notable that the brown bands are methane-dark, suggesting that they are clear lanes in the diffuse methane-bright north polar hood.

Two large AWOs are prominent, one at 59ºN (N5 domain), and one at 49ºN (N4 domain). Each is the product of a merger of a pair of AWOs that were imaged at PJ5 [as described in our 2016-17 Report no.9, recently updated].

High northern temperate latitudes (Figures 5 & 6):

The glorious chaos of these turbulent latitudes is shown in stunning detail – including tiny bright clouds casting shadows, as shown in all four hi-res clips (Figure 6).

Knowing the mean latitudes of the jets, it seems possible to identify the N2, N3 and N4 jets in the cloud textures, although they are complex. I still cannot see cloud textures to locate the N5 jet. As the Cassini polar movie showed, these jets only emerge from the jostling and shuffling of many chaotic features.

The most spectacular feature is a large FFR in the N2 domain, replacing a sector of NNTB. This is probably the same large FFR that we tracked during the 2015/16 apparition. Its bright white strips visibly obtrude over an adjacent diffuse dark grey sector of NNTB, as described above.

The NTB image also shows part of a large FFR – a long-lived rifted sector which persisted through the great NTB jet outbreak last autumn. So this sector is not typical of the whole NTB. The vivid orange NTB(S) persists and now has a sharp southern boundary with the white NTropZ. Further south, the image unexpectedly captured a new anticyclonic vortex in the expanded northern NEB. This feature had not previously been recorded, but it is just visible in Chris Go's image on May 17 (Figure 5). (The NTB and NEB are also shown in the accompanying report comparing images from all perijoves.)

Low-latitude belts (NTB, NEB, SEB, & whitened STB):

As the PJ6 images did not target known major features in these belts (and the NEB and EZn images were of low quality), the images are best appreciated in comparison with those from previous perijoves, as shown in the accompanying report.

High southern temperate latitudes (Figures 7 & 8):

As is often the case in these latitudes, the visible belts and zones are not in register with the jets. The canonical STB is all white, so there is a broad bright zone spanning the canonical STropZ-STB-STZ. Then there is a very broad 'SSTB' covering the S2 and part of the S3 domain, then a 'S3TZ' covering the rest of the S3 domain.

In the S2 domain, because of its rapid drift, the same sector is seen at PJ6 as at PJ5, with AWOs A6 and A7. But a dark streak between them at PJ5 has grown into a striking red-brown barge at PJ6, with bright strips from an adjacent FFR overlapping it.

In the S3 domain, there are many small circular cyclones of different colours. Similar cyclones have also been seen here at previous perijoves, including a beautiful red one at PJ3. (They are much smaller than the circumpolar cyclones: see Figure 9.) The S3 domain is unusual in producing these little cyclones.

South polar region (Figure 9):

These views confirm the now-familiar features, as reported at previous perijoves.

Figure A5:

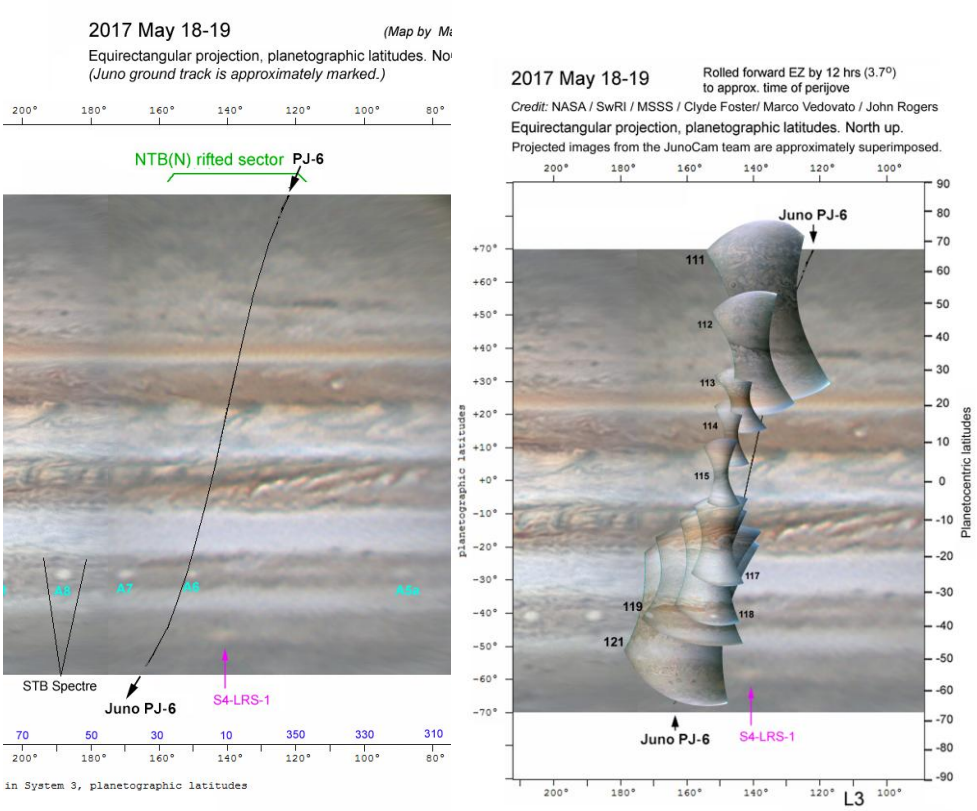

Figure 2:

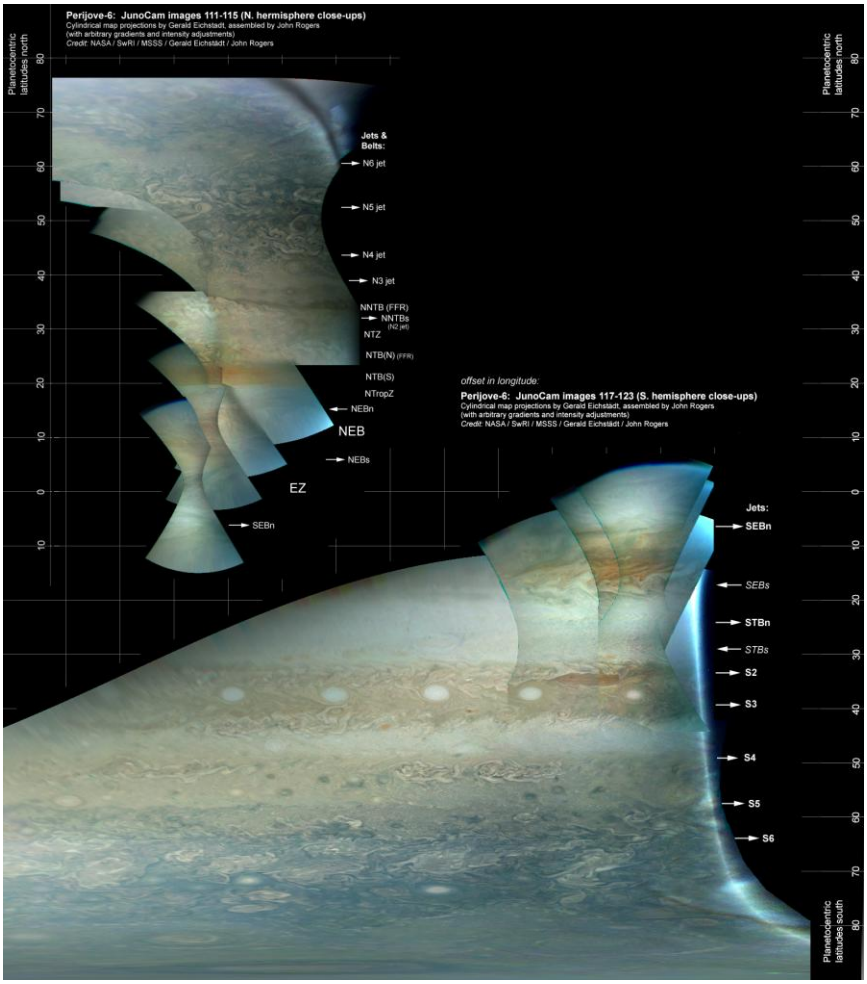

Figure 3:

Figure 4:

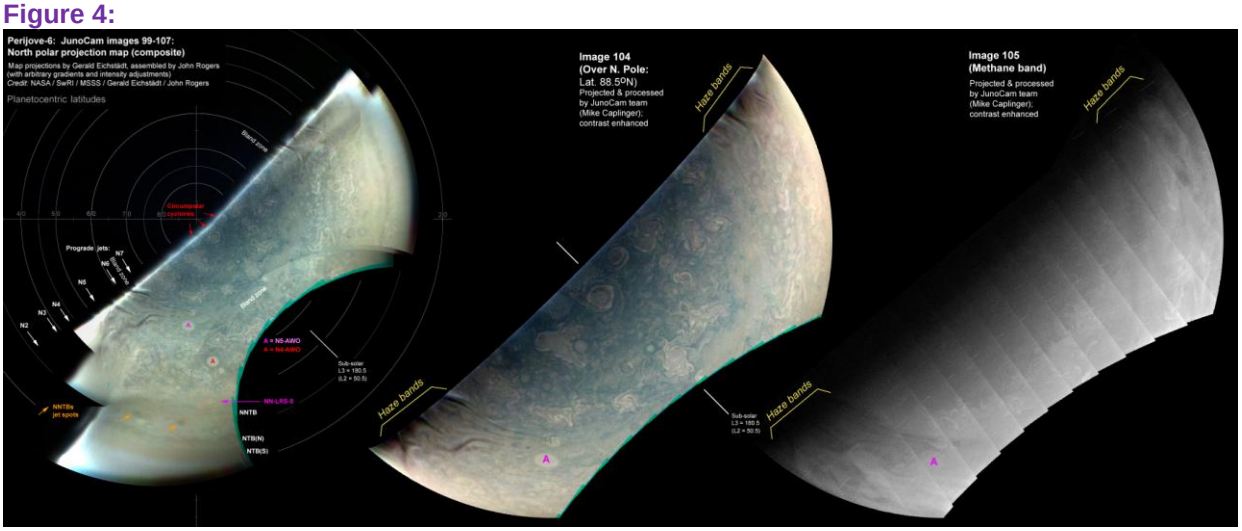

Figure 5:

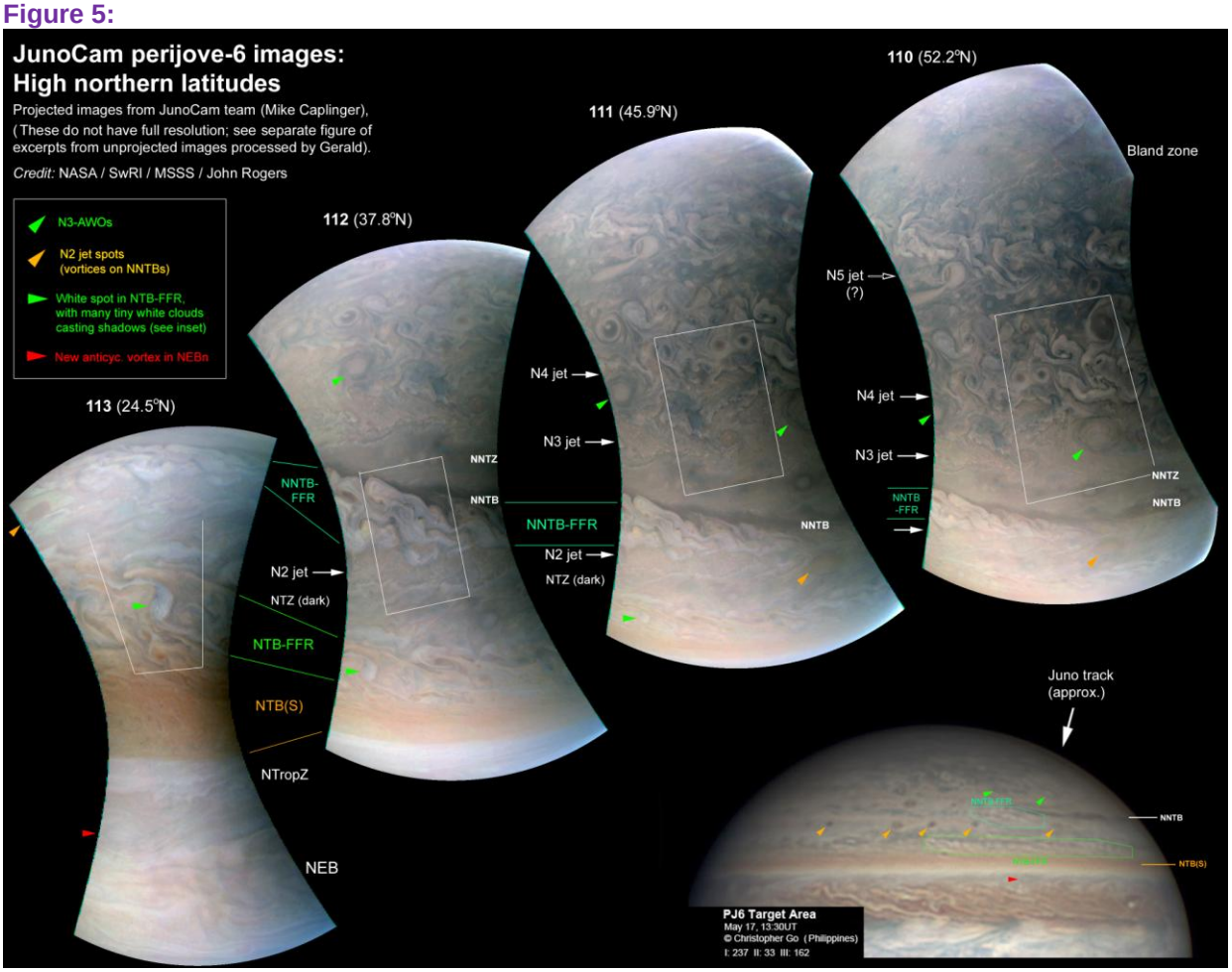

Figure 6:

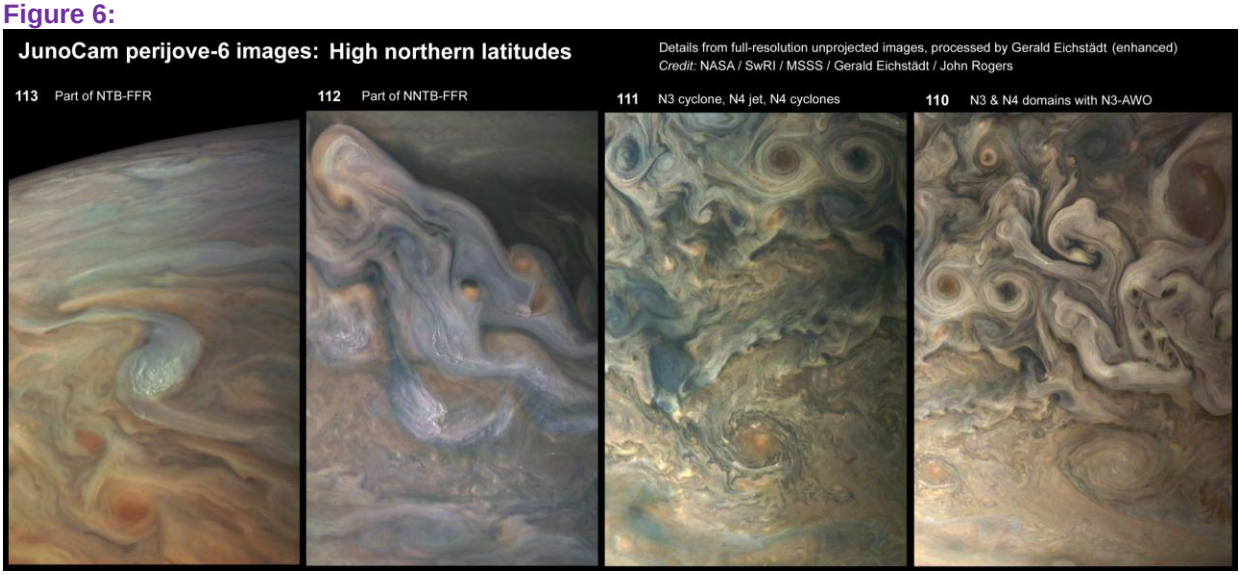

Figure 7:

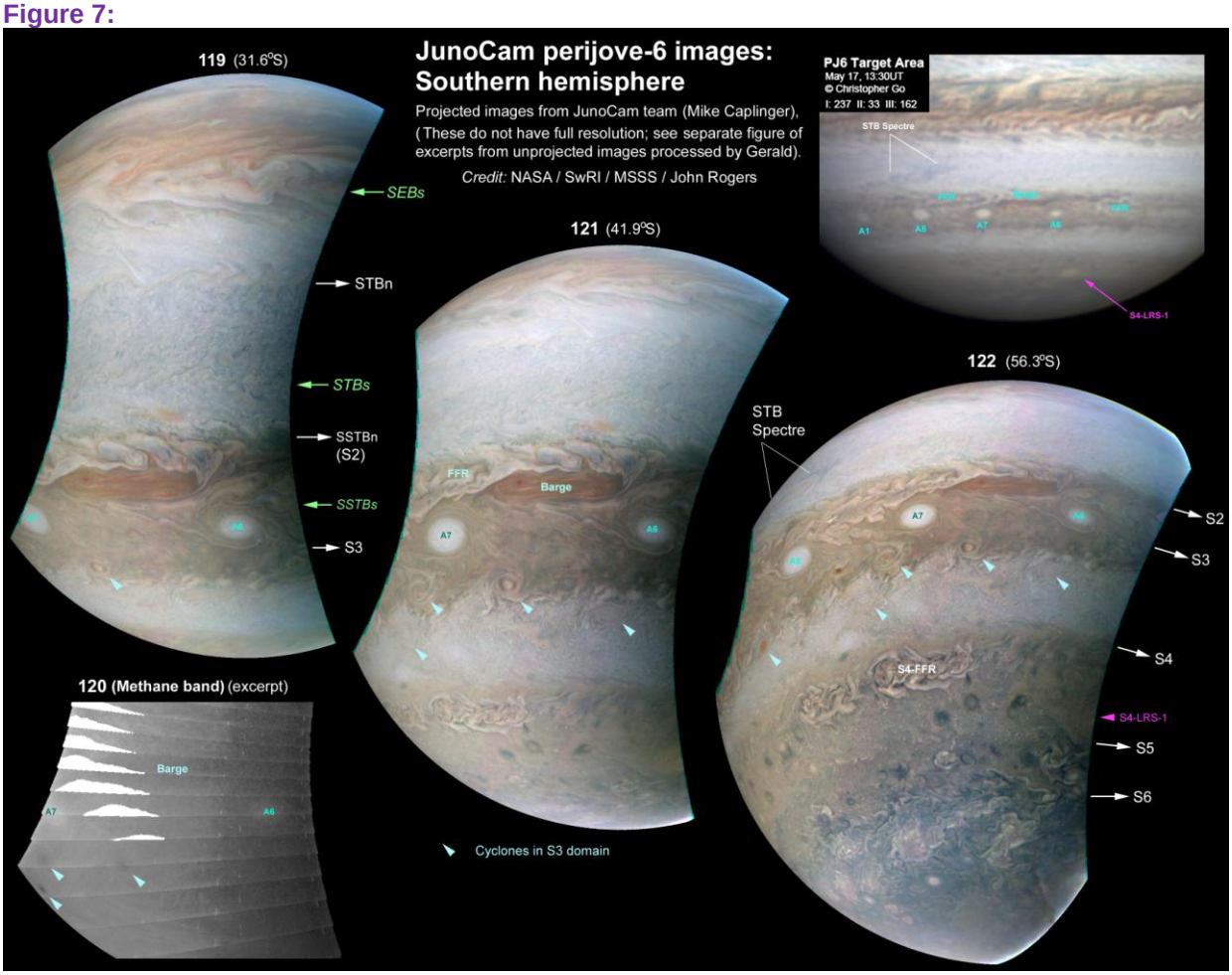

Figure 8:

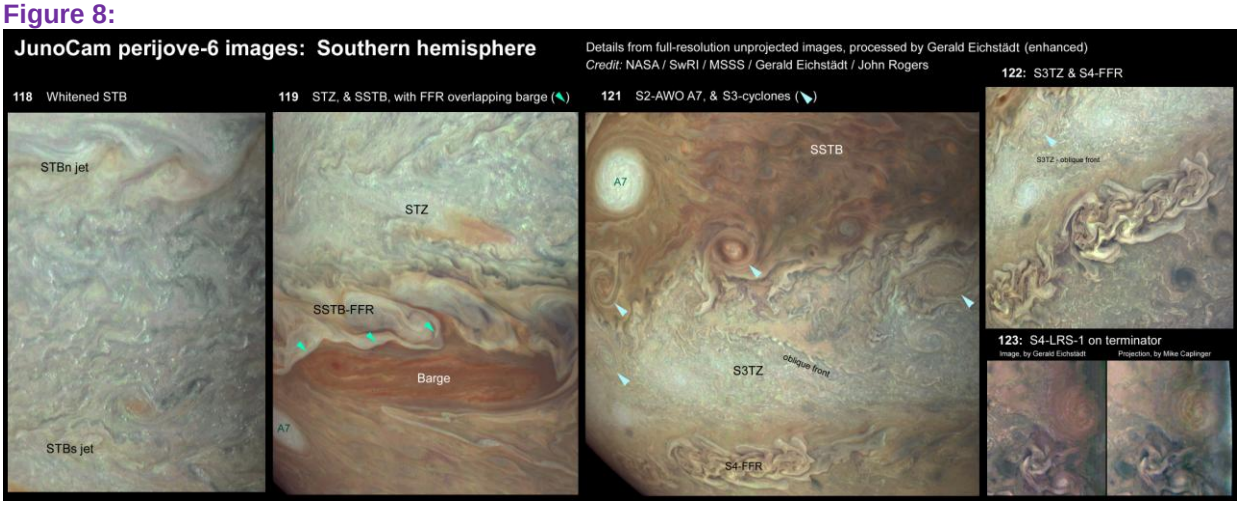

Figure 9: