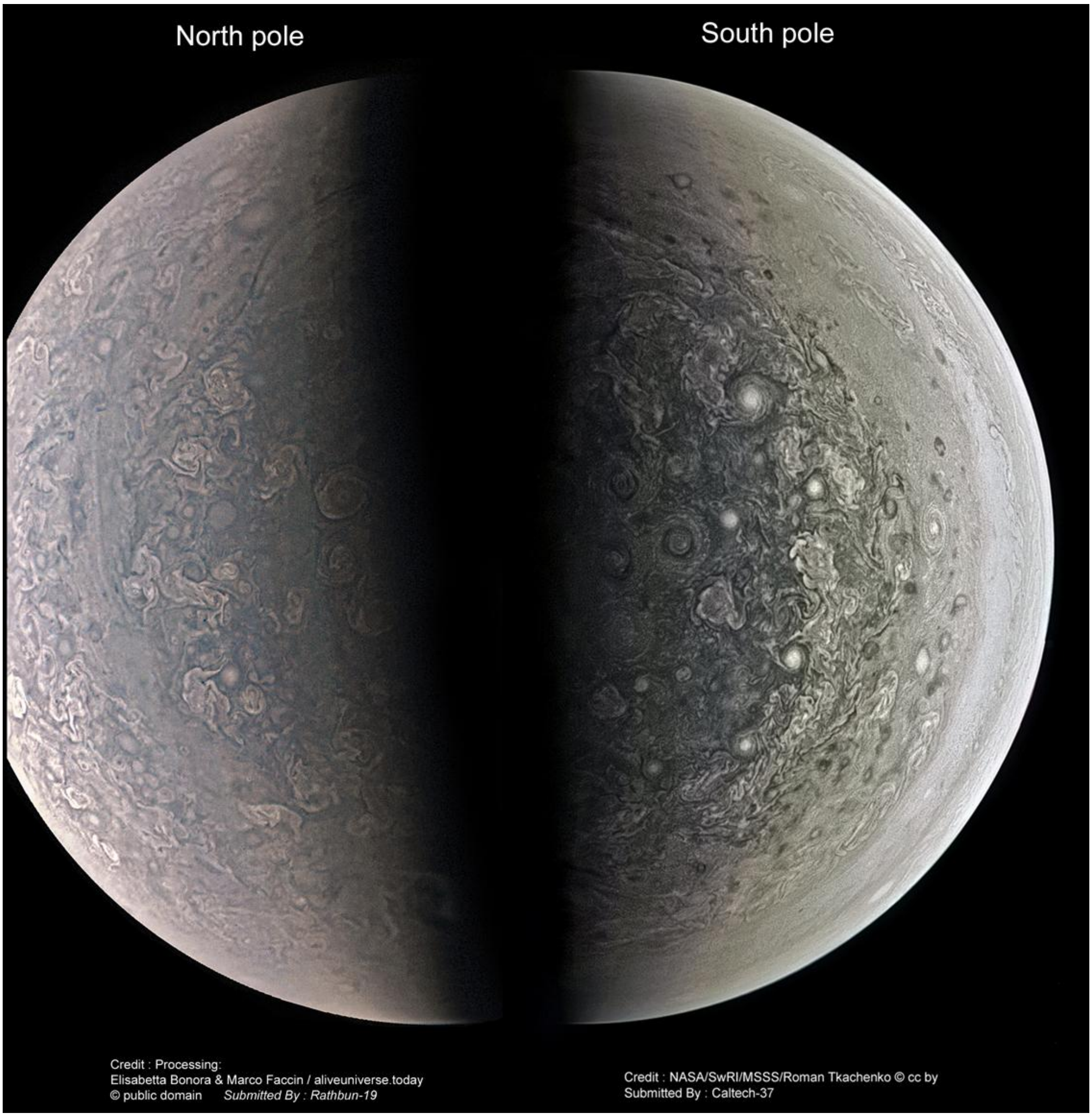
Juno at Perijove-1: What the JunoCam images show

--John Rogers (BAA)

This PDF is a compilation of several items that were posted on the JunoCam and BAA Jupiter Section web pages in 2016 Sep. Full-size versions of the pictures can be found in those posts.

The Juno spacecraft made its first operational flyby of Jupiter (Perijove-1) on 2016 Aug.27.
The JunoCam images were released on the JunoCam Image Processing web page over the following few weeks. Here I present annotated compilations of the images to identify the features that they show.

Highlights of the JunoCam images include:
--Discovery of clusters of storms which look like cyclones around each of the poles.
--Best-ever views of the widespread turbulent cyclonic regions at high latitudes.
--The perijove track passed close to an important circulation called the 'STB Ghost', showing vortices and turbulent clouds adjacent to it.
--Changes are occurring in the S.S. Temperate domain; notably, two of the nine long-lived white ovals are very close and likely to merge soon.



Introduction

Apart from the public release images of the north and south polar regions, the JunoCam images were posted in the form of raw images (sets of alternating red, green & blue strips, scanned as the spacecraft flies rapidly from north to south) plus 'Level 1' products – i.e. consecutive strips map-projected and combined so as to produce a single colour image. No adjustments were made to colour or brightness. Amateurs are invited to try their hands at processing all the images; improved versions have already been posted on the JunoCam web site. *[Figure 1 (above): Images taken directly above the north and south poles, processed by E. Bonora, M. Faccin, and R. Tkachenko.]*

JunoCam is operating in difficult lighting conditions because the plan for the (non-imaging) mission required that the spacecraft flies directly above the terminator. This means that lighting is dim, with a strong gradient of illumination from day to night side, and contrast may be much reduced by high-level haze. (Imagine flying over a terrestrial landscape close to sunset; with a light haze above, it can be difficult to see anything of the darkened terrain below.) Moreover, perijove-1 was intended for testing the equipment, including exposure times, and data compression for transmission; so some of the images are deliberately of suboptimal quality. *[There were artefactual colour bands parallel to the terminator; their origin would be elucidated at perijove-3 and fully corrected at perijove-4.]*

Here I have processed some of JunoCam's original images in Adobe Photoshop, adjusting gradients, contrast, and unsharp masking to enhance detail over most of the image. This was not done systematically nor optimally – no doubt others can do a better job. But the products show enough detail that we can recognise some interesting features, whether previously known or not.

For background info about the features that we have tracked from Earth, including a predictive map for perijove-1, please see our 'Jupiter in 2015/16' page at: https://www.britastro.org/node/6809
--and particularly Report no.9.

North and south poles

The main revelation from the images is at the north and south poles: around each pole there is a tightly-packed cluster of circular storms which, from their spiral patterns, appear to be cyclones. On the illuminated side of the south pole, at least four are visible; at the north pole, at least three, and they are reddish (though we cannot see the exact north pole as it is currently in shadow). No such well-defined circular cyclones occur anywhere else on Jupiter. On Saturn, Cassini has revealed that there is a single mega-cyclone precisely at each of the poles. On Jupiter, Juno now suggests that there are multiple cyclones clustered around the poles. Hopefully, future images from JunoCam or from JIRAM will tell us more about them.

In the **south polar region (Fig.2, below)**, we can see several of the anticyclonic white ovals (AWOs) that we have tracked, in the S2, S3 and S4 domains. Surprisingly there are two AWOs close to the expected position of long-lived S4-AWO-1, and I can't tell which is it as we were not able to track it so close to solar conjunction. We cannot track many features at >53ºS from ground-based images, but the Juno images reveal that the higher latitudes are largely packed with cyclonic turbulent regions ('folded filamentary regions', FFRs). Previous spacecraft images suggested that these occupied only part of the south polar region, but here it is almost filled with them. There is a particularly dense band of them around 72ºS and just further north; this seems to be the location of a distinct retrograde (westward) jet because the images also show 4 AWOs just south of this latitude.

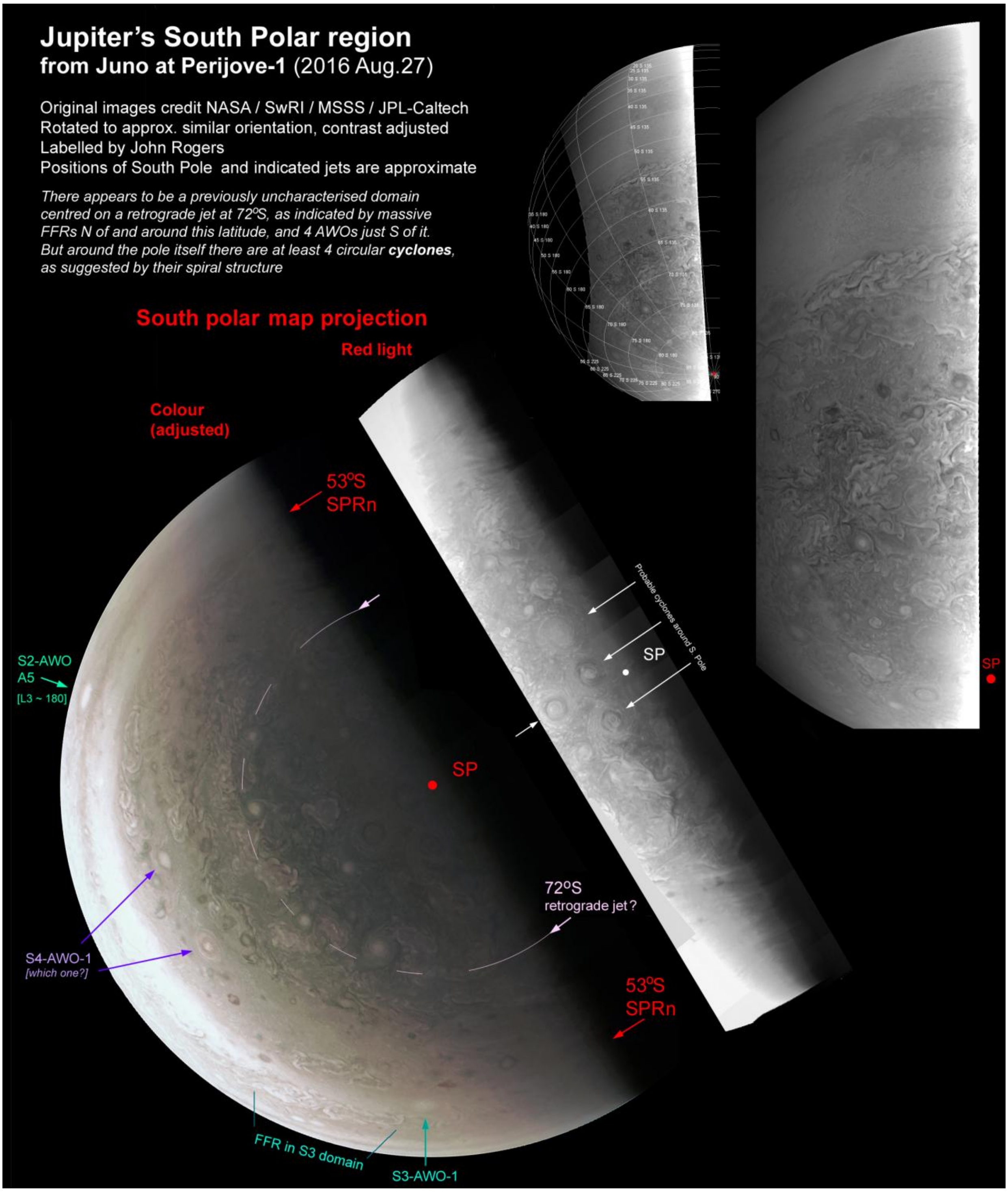


Figure 2.

In the **north polar region (Fig.3, below)**, the images do not show any specific features that we have tracked, as they do not happen to be in this longitude range. We can see that the north polar region is almost filled with FFRs, as we knew from previous spacecraft, but now we see them in more detail and closer to the pole. (Three examples are marked on the images.) There is one bland zone, and the Juno images show a novel type of feature within it: long, very narrow cloud lanes, not fixed in latitude. [This bland zone may be the same as in the Cassini map at ~61ºN zenocentric = 64ºN zenographic, close to the N6 jet.]

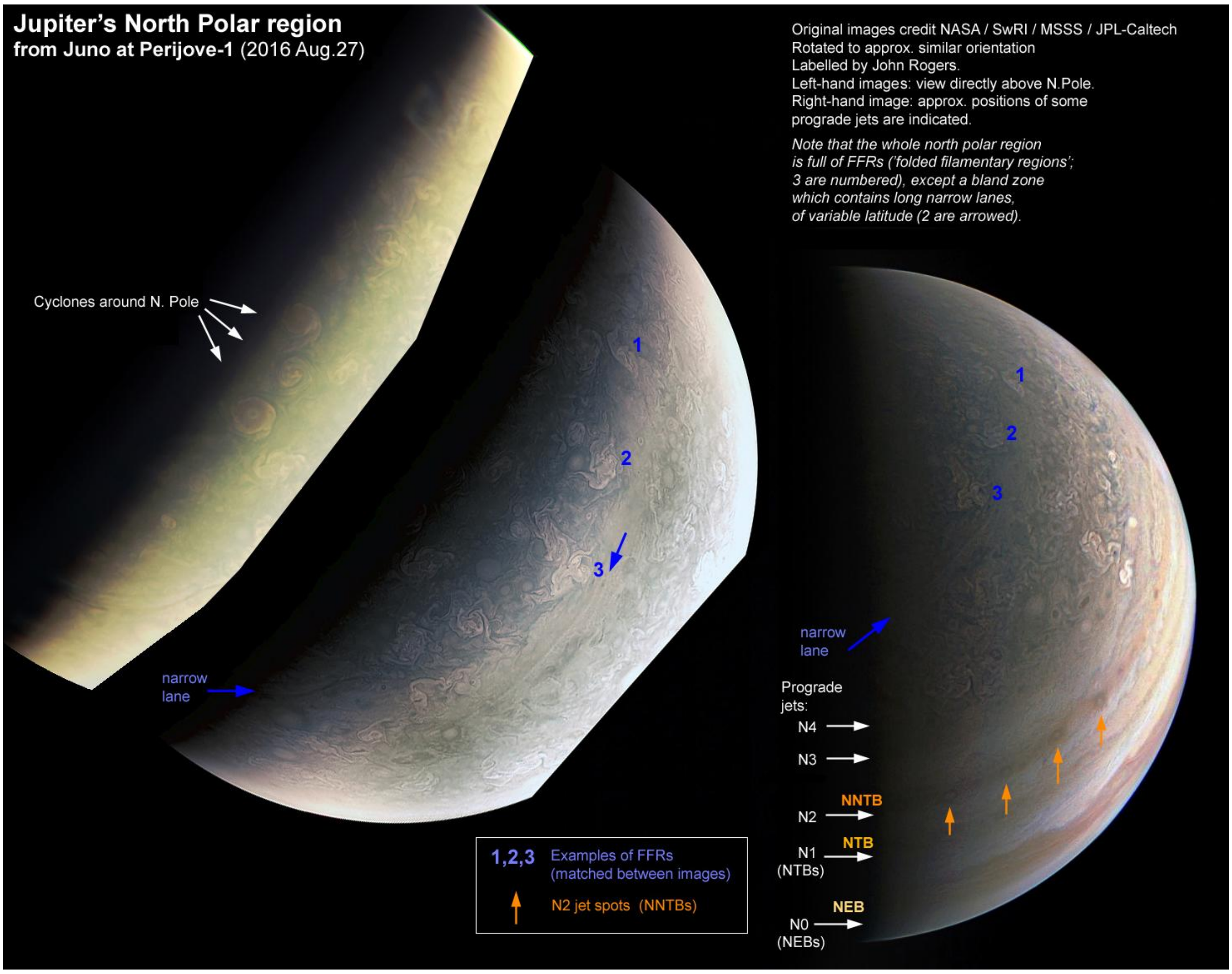
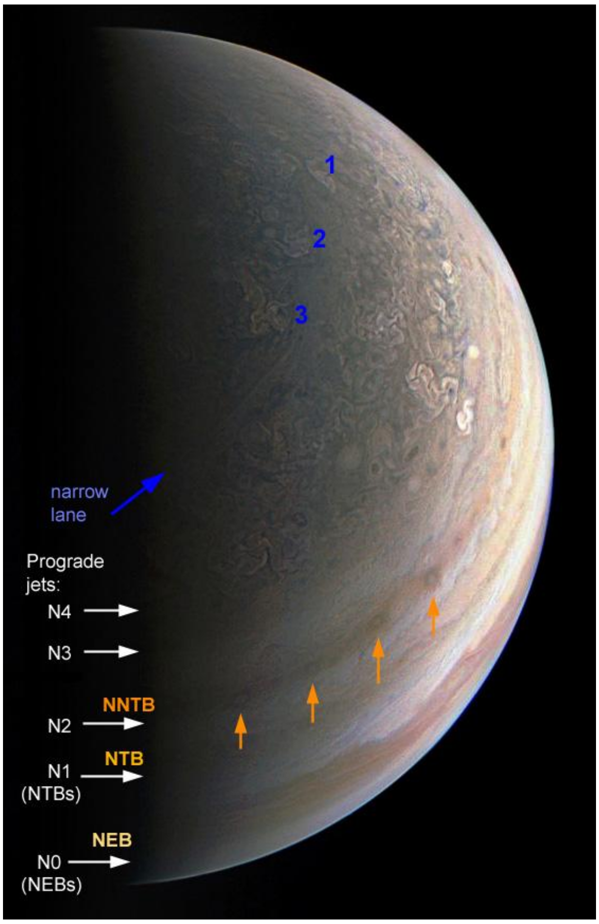


Figure 3 (above & right).



High northern latitudes

Fig. 3 (this page) & Fig.4 (below) show some of the huge FFRs (folded filamentary regions) at high latitudes; two of them were numbered on the images of the north pole in the previous post. These images also show narrow cloud lanes at the terminator (arrowed) – at various latitudes and orientations. These are probably the features which the Juno team referred to in their first press release as clouds casting shadows – something which has never before been recorded on Jupiter. The accompanying methane-band image (not shown here) is very dim, but at least one of these cloud lanes may be methane-bright; so it is possible that they are features of the high-altitude North Polar Hood.

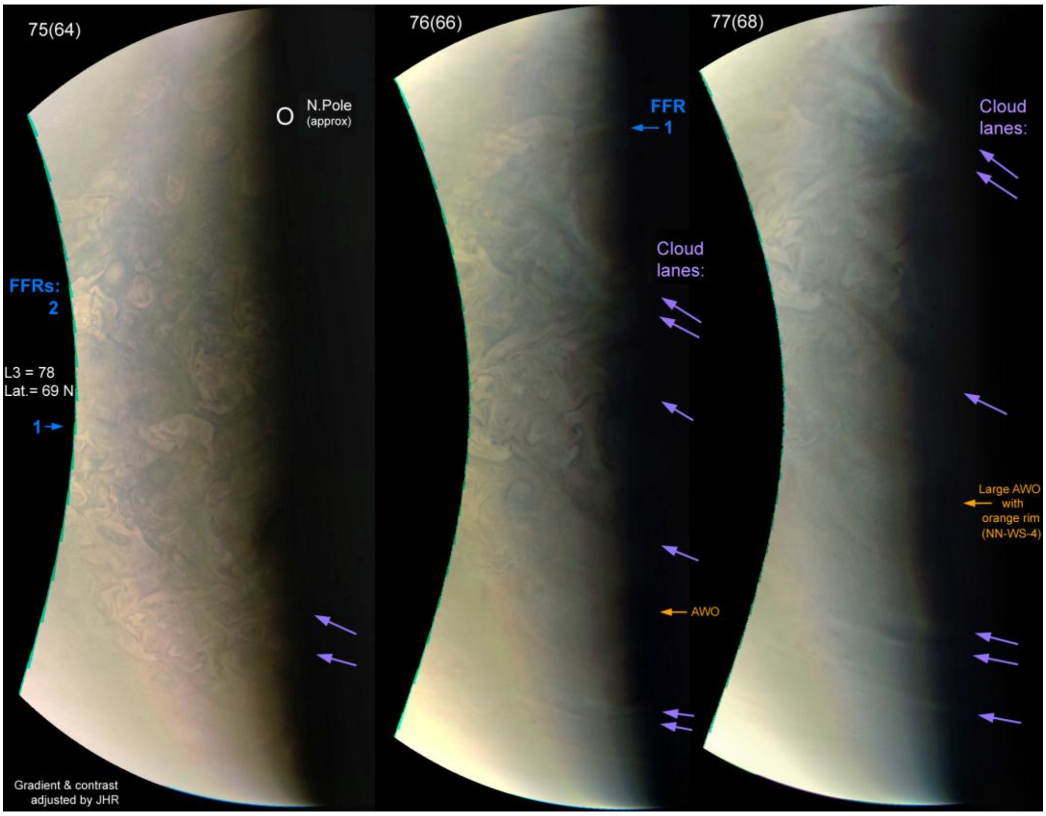
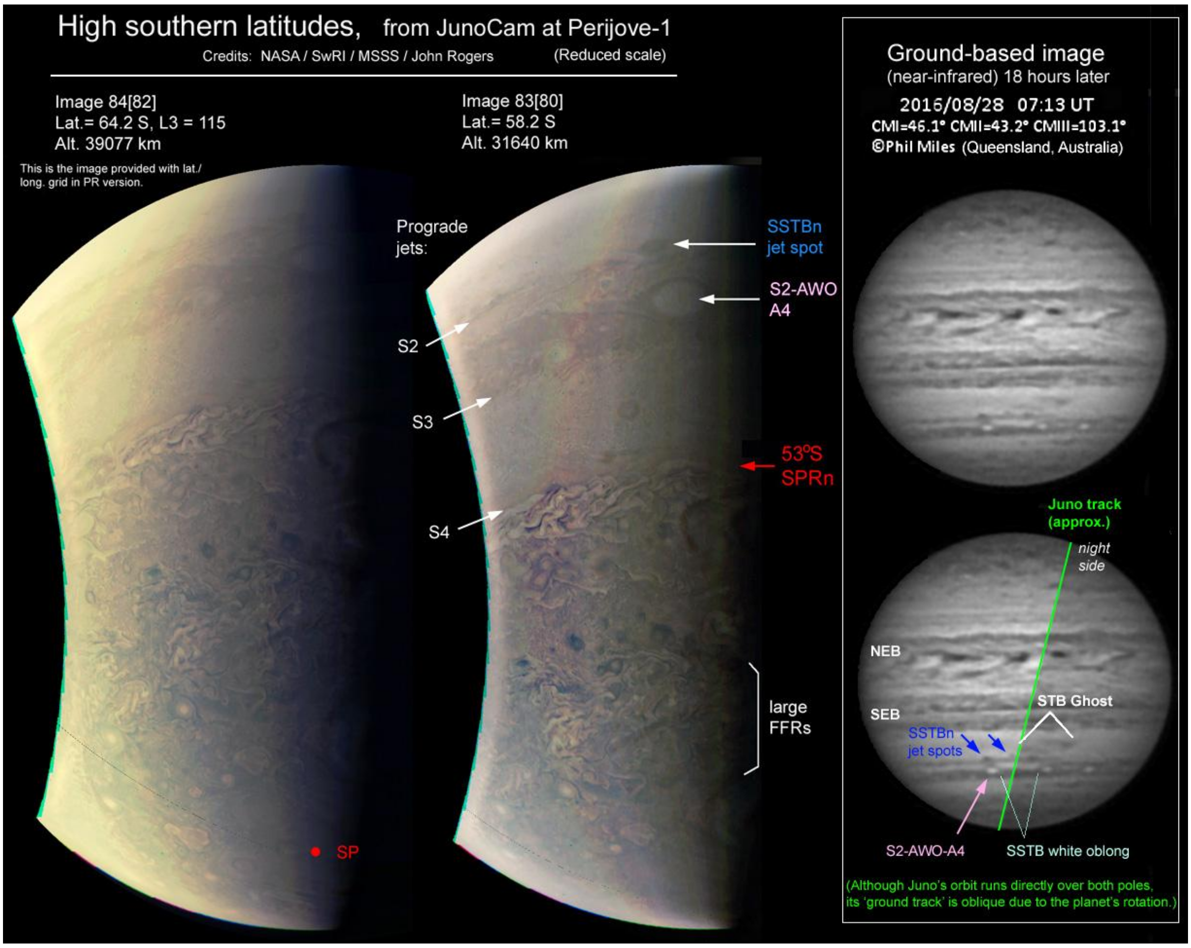


Figure 4 (above); Figure 5 (below).



High southern latitudes

Fig.5 overlaps with the images of the south pole in the previous post, and shows some of the huge FFRs at high latitudes. I have marked the positions of some of the known jets, and long-lived white oval A4 in the S2 domain. The accompanying ground-based image, taken by Phil Miles in Australia, shows the same features 18 hours later.

South Temperate latitudes

The two images in **Fig.6** captured either the following (west) end of the STB Ghost or, more likely, the region immediately following it. The whole region seems to be exceptionally turbulent. The Ghost is a cyclonic circulation, and on its south side, spots arriving on the prograde S2 (SSTBn) jet recirculate to return in the opposite direction. One such spot can be seen here, and it appears to be a vortex. (These two images are not of high quality, because their titles indicate that they were intended for 'compression comparison' – i.e. testing the effect of reducing file sizes for transmission.)

The accompanying ground-based image by Phil Miles shows the same features 18 hours later.

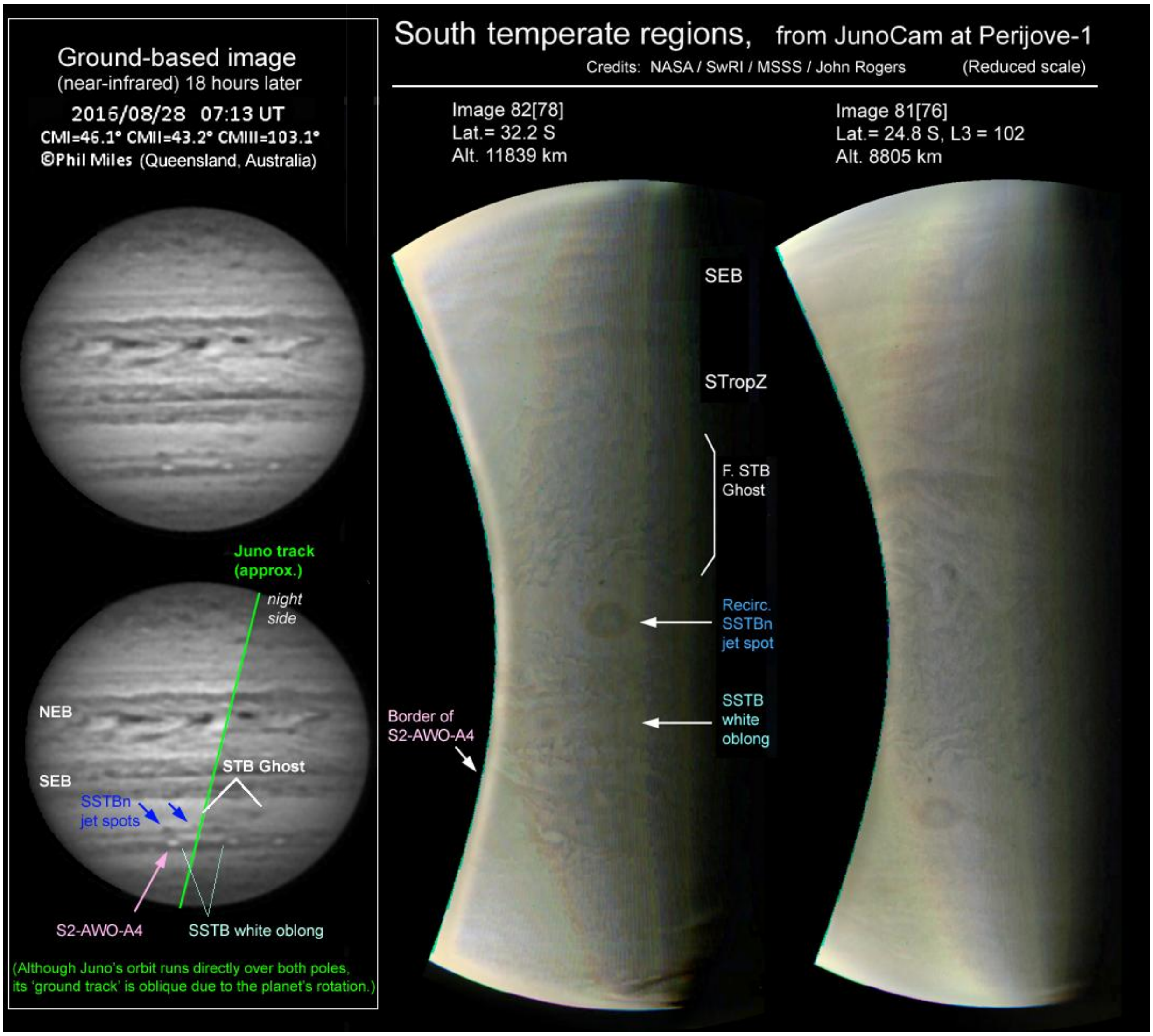
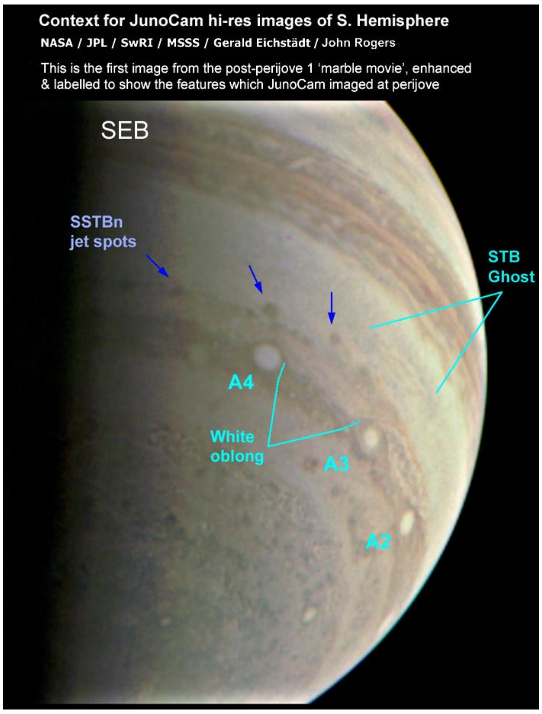


Figure 6.

Fig.7 is a set of ground-based images from April, when Jupiter was much more observable. They show the STB Ghost and some of these SSTBn spots interacting with it, as well as a S2-AWO to its south; but note that all these spots have moved so they are not the same ones that are shown in the JunoCam images. (An extended version of this figure, tracking individual SSTBn spots recirculating at the Ghost, will be included in our final report on the 2016 apparition.)



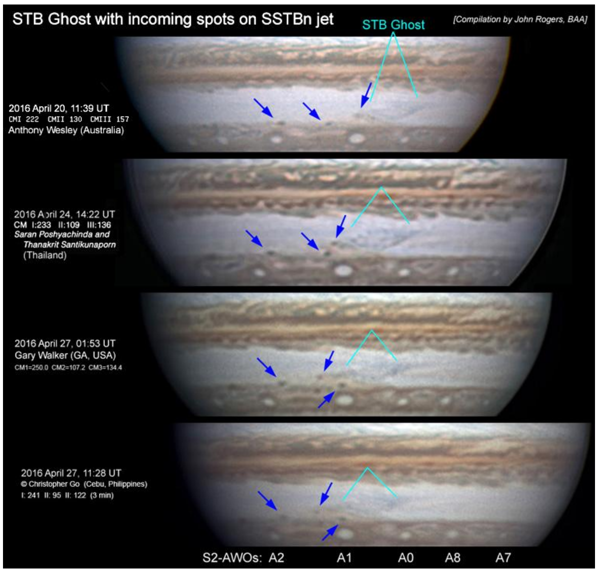


Figure 7 (above): Ground-based images in April.
Figure 8 (left): This first image in the post-perijove sequence ('marble movie'), which Gerald Eichstädt has processed, provides the best context for the features which were labelled above.

A global survey of Jupiter

Before and after its first perijove on Aug.27, Juno's camera was taking frequent shots of the whole planet, nicknamed 'marble movies'. Within a day or so either side of perijove, the planet was close enough to show many details, covering the northern hemisphere for a whole rotation in the day before perijove, and the southern hemisphere for a whole rotation in the day after. The resolution was comparable to the best ground-based images (better at high latitudes), and much better than ground-based images at that time. Gerald Eichstädt has kindly provided processed versions of all the raw images. In the attached compilations, I have further enhanced a selection of them, and identified the features which we were following in amateur images, so that we can give an update on the development of these atmospheric features.
Here follows a summary of the features that are labelled in these two image sets. The most unexpected is at the end: two long-lived white ovals appear likely to merge.

Northern hemisphere (Fig.9):
Here there have been no substantial changes over the past half-year.
The four ovals labelled in red (WS-4, 6, 8, and LRS-1) are anticyclonic ovals in the NNTZ.
There are still many little round spots (vortices) on the prograding NNTBs jet. They may be induced by a large turbulent sector ('FFR') in the NNTB.
There is also still a large turbulent ('rifted') sector in the NTB, which gives rise to a darkened sector of the zone following [west of] it, the North Temperate Disturbance (NTD). Both these sectors are now of considerable length.
The principal spots along the NEB north edge are also unchanged: four small 'barges' (labelled B-1 to B-4 on the image set), and the very bright oval, White Spot Z.

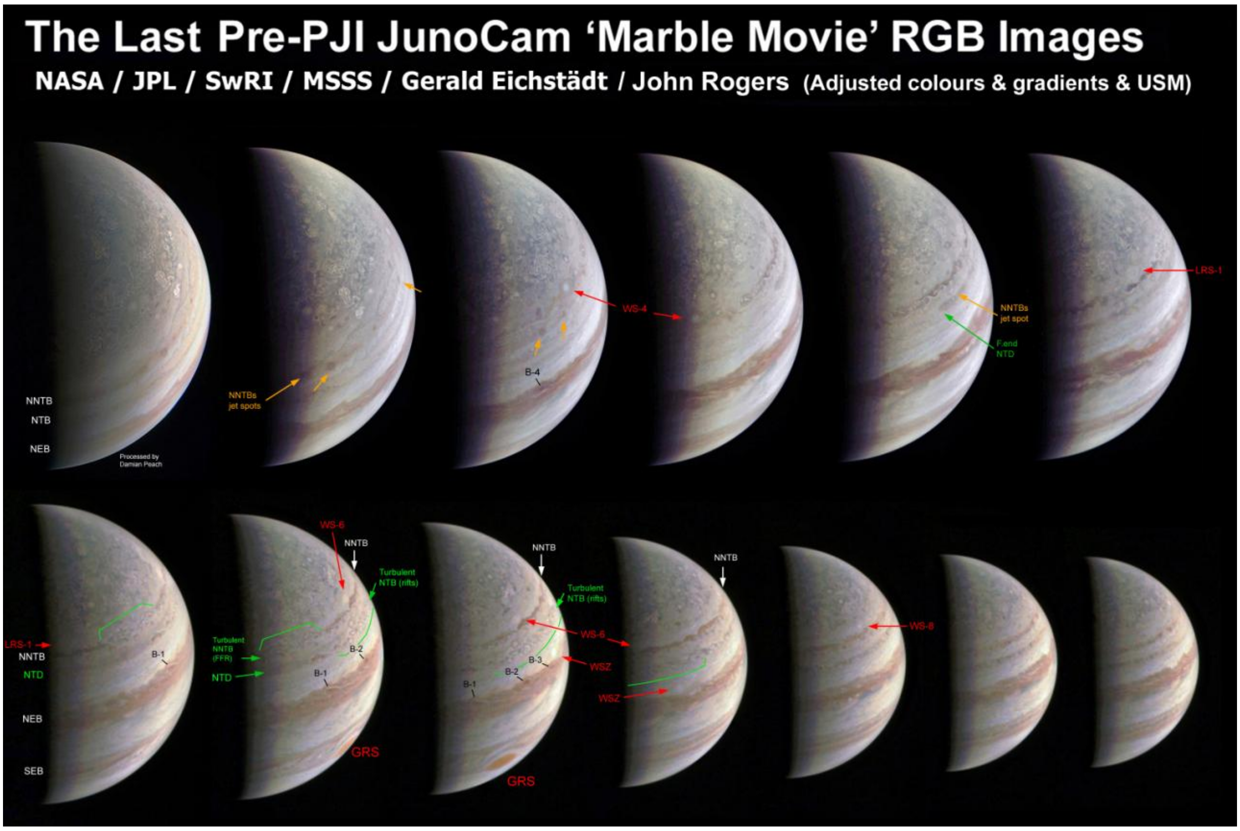


Figure 9.

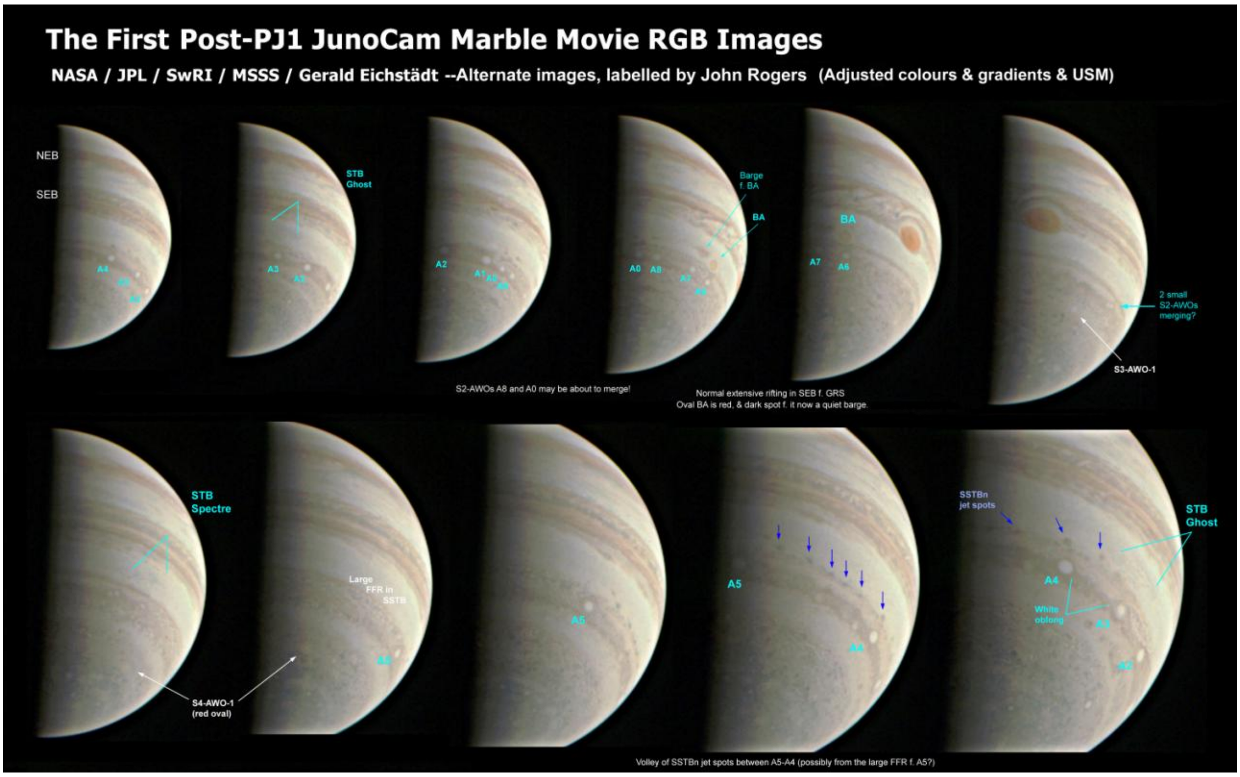


Figure 10.

Southern hemisphere (Fig.10):
In the SEB following the GRS, there are now large bright 'rifts', i.e. the convective activity there has returned to normal, and the SEB will not fade in the next few months.

Oval BA (strongly reddish) is approaching the GRS. The small dark patch following it seems, at last, to have rounded up to form a quiescent small dark brown barge.
There is an unusually dense outbreak of small dark spots on the prograding SSTBn jet, between a large turbulent sector in the SSTB ('FFR'; this may be inducing them), and the cyclonic 'STB Ghost', where we have observed such spots to recirculate into the STZ (this region was imaged by JunoCam at perijove).

The most notable changes are affecting the S.S. Temperate anticyclonic white ovals (S2-AWOs). Two small ones appear to be merging in these images; such small-scale events are not uncommon and we observed one earlier this year. However, the nine numbered AWOs are very stable, and yet two of those – A0 and A8 – have rapidly converged to only 9º apart and therefore are likely to merge in the coming weeks or months. They have always been smaller than most, while their neighbour, A1, has become the largest. Indeed it is possible that an A0-A8 merged oval could then merge with A1 in turn. In October they will start passing oval BA (which will itself be passing the GRS in November), and this passage may trigger a merger if it has not happened before. Merger(s) will no doubt perturb the relative drifts of the AWOs, which will also be disturbed by expansion of the white oblong that developed in August between A3 and A4. Therefore, predicting the positions of these AWOs will be less reliable than usual – but all of them will be of interest.

Map of the planet from JunoCam images, 2016 August 27 (Fig.11)

This map of Jupiter on August 27 was produced from the JunoCam images just before and after perijove-1, mainly by Gerald Eichstädt. The northern hemisphere is from inbound images from 03:45 to 13:58 (UTC at the spacecraft), and the southern hemisphere is from outbound images from Aug.27, 19:15 to Aug.28, 04:45. The map has been generated by collaboration of many amateurs using the data from NASA's Juno team. Gerald Eichstädt processed and projected the JunoCam images and converted them into maps. Because images of this oblate planet taken from such high latitudes and phase angles had never before been used to make a map, it was difficult to achieve accurate coordinates, so I checked the longitude scale of the map by reference to amateur data: charts from the JUPOS team up to August, and a map made by Marco Vedovato from infrared images taken by Phil Miles on Aug.26-28. The latter images (and those by Anthony Wesley) were especially important for accurate alignment. Gerald and I then re-compiled the map and adjusted the colours and intensities to enhance visibility of features.

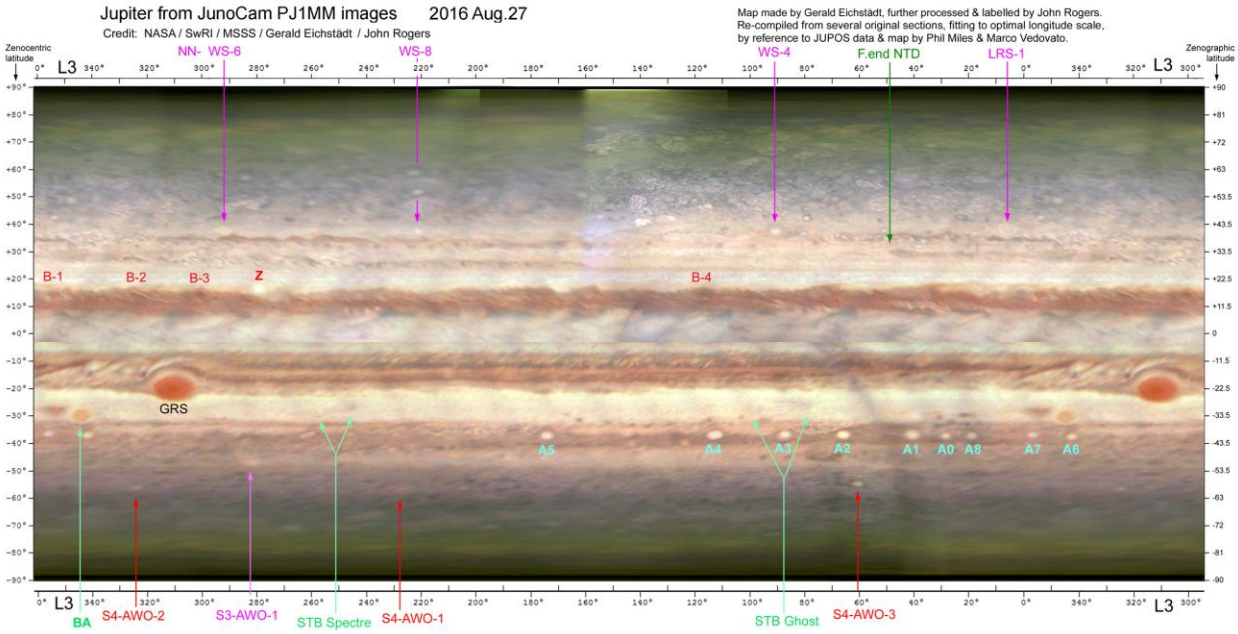


Figure 11.