Haze bands in JunoCam's images of the south polar region

--John Rogers, 2017 Nov.23

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The JunoCam images of the south polar region (SPR) always show some bands of haze, sometimes brightly lit at the terminator, sometimes dimly visible on the sunlit side. The bands are linear or arcuate, and may be dark (brown) or bright (white or rainbow-coloured), similar to those in the northern N5 and N6 domains. One long curved ('bow-shaped') band has been seen in a similar position, tangential to CPCs-4 & 5, at several recent perijoves; I will call this "the long band". It has actually been present from PJ5 to PJ9, with an interesting relationship to the pentagon of CPCs; previously, only shorter bands were present in this region.

To establish the positions of these bands, we need use Gerald's polar projection maps, with the terminator region enhanced, including plenty of outbound images so as to cover a range of terminator longitudes; and we need to assemble these into animations or composites favouring the near-terminator regions so as to trace haze bands over some distance. Both Gerald and I have previously assembled some of these for some perijoves; I have made a few more from Gerald's maps for this report. I have also traced the positions of the visible bands onto our best current maps of the SPR at each perijove, in the attached figure. These assemblies are not complete for all perijoves. Bands would not have been detectable over the whole SPR at each perijove, because of the limited range of illumination and resolution available even in the most complete sequences of outbound images.

These haze maps are all preliminary, for several reasons: (i) They use many different techniques for illumination adjustment near the terminator (Gerald has used a succession of explicit algorithms, and I then apply gradients and blend versions arbitrarily). (ii) The individual image maps are merged in an ad-hoc manner to preserve the regions where haze bands are visible. (iii) The maps still have residual projection anomalies, so registration may not be perfect.

Results: General description

Here I will only describe haze bands between ~65-85ºS (planetocentric), i.e. south of the highest prograde jet. Just to the north, many haze bands are sometimes seen in the S4 and S5 domains, esp. in the S4 domain where they tend to be ⊃-shaped, aligned with the zonal wind profile (ZWP) of the domain. These have similar properties to those in the SPR but I have not carefully studied them. Near the south pole, haze bands are not usually seen over the CPCs except for the long band over the outer edges of CPCs-4 & 5.

Almost all the bands in this region are oriented obliquely, from SW to NE, consistent with a smooth ZWP between the prograde flow of the outer edges of the CPCs, and the retrograde jet at ~71ºS. Some of them curve northwards across this retrograde jet in accordance with the ZWP. [I call this a retrograde jet although it is probably discontinuous, existing only in the flow of the FFRs which form an almost complete ring around the SPR.]

The long band was not seen as such until PJ5 (see below), though at PJ1 to PJ4, multiple shorter bands slightly further north, not overlapping the CPCs, might be seen as precursors of it. The PJ1 images showed a particularly dense carpet of haze bands on the opposite side of the SPR,

extending thinly over some of the CPCs. Was the haze especially dense at PJ1, or was it better seen because of the longer exposures and different colour balance compared to subsequent perijoves? In the PJ4 maps, only a few weak bands were visible in the SPR. This could be because we only have lo-res maps at present, but they do show dense swathes of haze bands in the S4 domain, and inspection of the images does not add any more in the SPR, so I suspect the deficiency of haze bands was genuine.

Results: The long band

The long band has been seen consistently from PJ5 to PJ9. At all except PJ7 it is tangential to CPC-4 & 5, slightly overlapping the outer part of one or both. It has a shorter 'arm' east of CPC-5, running NE (absent at PJ7); and it has a longer 'arm' west of CPC-5, running NW (like most other bands), extending into one or more ⊃-shaped bundles of bands which bend tightly across the 71ºS retrograde jet (at L3 ~ 100-140) and then run NE across the FFRs, consistent with the ZWP. (This curved extension is often especially prominent at the terminator, and at PJ5 it was the 'crazy band' which appeared almost black at dawn but a bright rainbow band at dusk. It could not be viewed at PJ6.) All these components are often seen as bundles of both brown and white bands, and some sectors are 'rainbow bands' [see below].

The largest AWO at ~72ºS (provisionally marked 'R1' on the figure) has retrograded past the long band. At PJ7 [Figure below] it was partially overlapped by the most northerly extension of the long band, probably a rainbow band overlying the white oval. At PJ8 it lay directly underneath the ⊃-shaped extension of the long band, which was visible as a dark brown band overlying the white oval. The bands did not appear to be at all perturbed by the AWO, so they must be above its circulation.

The long band, like others in the SPR, is very weak or invisible in methane images. In the PJ8 image (in my posted report), it can be faintly seen as a slightly methane-dark band. In the PJ7 image (Figure below), it is not visible at all.

The position of the long band suggests a dynamical relationship to the cluster of CPCs, since its inflexion is at CPC-5, opposite the gap in the pentagon. Perhaps both the gap and the long band are features of a systematic flow around and through the pentagon, which is not yet understood? The apparent absence of the long band at early perijoves is unlikely to be related to cyclic motion relative to the pole, since the centre of the pentagon was at approx. the same position at PJ3 as at PJ9; however, it could perhaps be related to the progressive widening of the gap.

Could there also be a relationship to the southern auroral oval? Its standard position is plotted on the PJ9 map in the figure. The long band itself runs diametrically across the middle of the oval, but bands associated with its ⊃-shaped curve, and its NE extension near ~70ºS, do appear to be close to the auroral oval.

Discussion: Brightness, colours, and altitudes of the bands
(summary of previous comments, esp. those made in my PJ4 report)

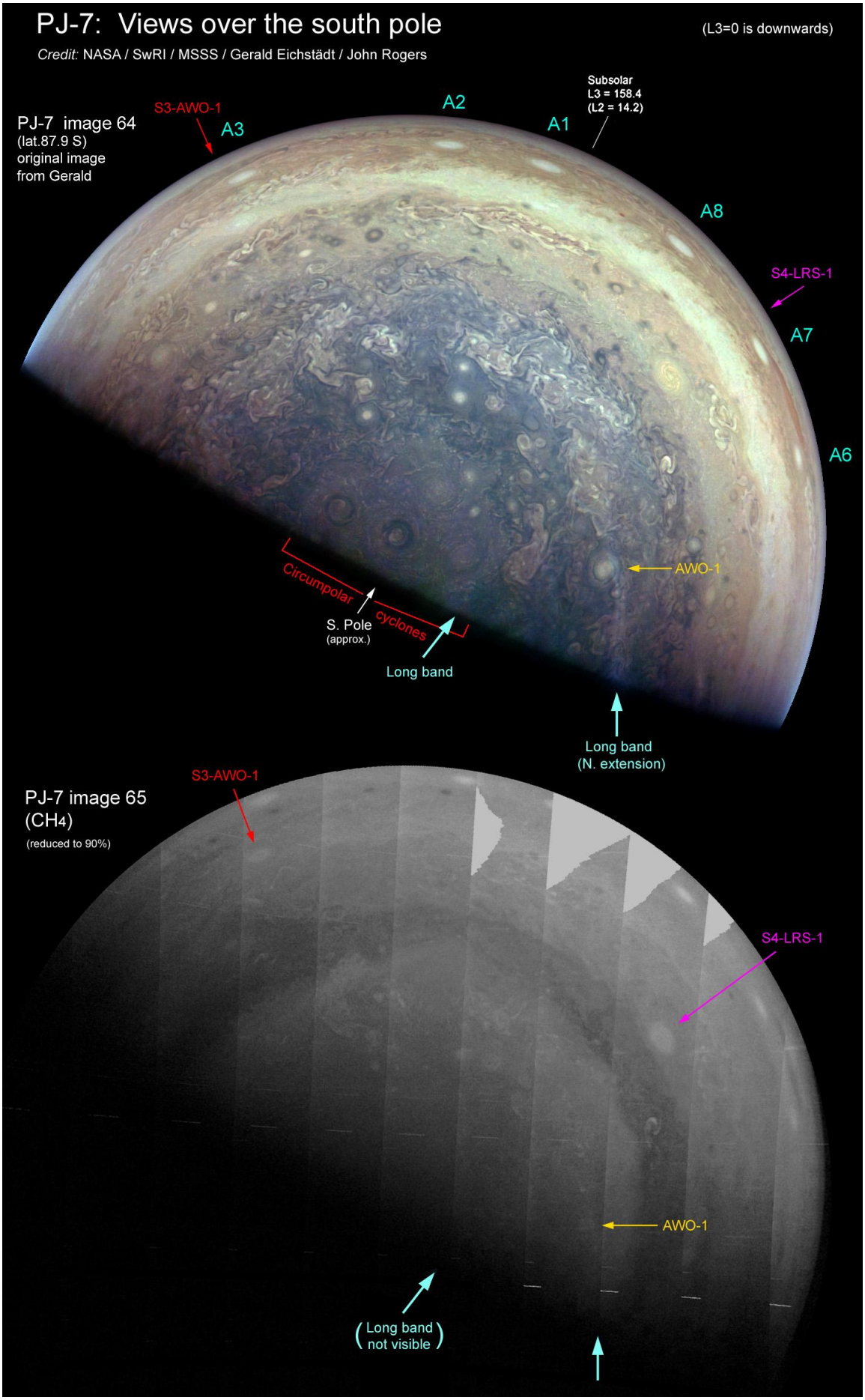
The bands described in this report are not evidently related to the methane-bright S. Polar Hood (SPH) which covers the same region, and can be discerned as a faint bluish haze in many colour images. They are also distinct from the white strips in FFRs, which are methane-bright [Figure below] – but these are not always highlighted in visible light at the terminator. The following comments apply to the bands in both north and south hemispheres.

Sometimes a band appears white when illuminated from one side and dark when illuminated from the other (notably the 'crazy band' in the SPR at PJ5, but there are other examples), but as white and brown bands often form tight bundles, and it is difficult to be certain whether maps of the terminator region are accurately aligned, we cannot exclude the possibility of differential visibility of adjacent bright and dark bands.

We have various hypotheses for the multiple colours, some or all of which may be true, but no agreed conclusion yet. *White bands* are seen mainly near the terminator, sometimes projecting across it, demonstrating their high altitude. Sometimes they are bright bluish on one side and reddish on the other side (*'rainbow bands'*): Several of these have now been confirmed in two successive images (at PJ8 and PJ9 – and also one at PJ1; so these are not camera artefacts). I suspect the bluish colour (usually on the sunlit side) may be due to wavelength-dependent scattering in the thin outer fringe of the band, whereas the reddish colour (usually on the shadowed side) could be due to any of the following explanations for brown bands.

Brown bands can sometimes be seen right across the sunlit part of the region, and can be very dark near the terminator. (In methane images, those in the northern bland zone are notably methane-dark, but those in the south polar region are not.) The following possible explanations have been proposed, and some or all could be true:
--Alongside the terminator, they may be shadows cast by the white bands, with diffusely scattered red light (like a volcanic sunset on Earth);
--They may be clear lanes within the methane-bright polar hoods (which are diffuse and pale bluish-white, not usually noticed in close-up images), exposing the browner atmosphere below;
--As brown bands are usually adjacent to white bands, these may be waves of alternating thinner and thicker haze, and/or, waves in which particles are tilted at slightly different angles;
--They may be bands of brown aerosols, which is strongly indicated by cases where a brown band is seen lying across a white oval (AWO) (in the SPR at PJ8, and in the N5 domain at PJ9). If so, there is a puzzle as to how multiple white and brown bands can lie in bundles if they are chemically different. Perhaps brown aerosol might be descending from above due to auroral-induced chemistry, while white aerosol might be wafted upwards due to tropospheric turbulence, and the two streams could avoid mixing?

There is still a major paradox regarding the methane images, which is difficult to reconcile with the usual paradigm that methane-bright = high-altitude. It is always notable that the white bands in the SPR are weak or absent in methane images. (This region is all within the methane-bright SPH. I have not done a systematic survey of other latitudes but there too, the bands are not as methane-bright as might be expected.). If the bands lay below the SPH, they should not appear visibly bright at the terminator; but if they lay above the SPH, they should appear methane-bright on the sunlit disk. (The SPH does not obscure other methane-bright features below it, viz. the FFRs and AWOs.) Could their particles be highly reflective in white/blue light but not at all in the methane band, either because they do not scatter near-IR, or because they actually absorb in the methane band? (But I understand they cannot be methane-ice as the SPR is not cold enough.)


PJ-7: Views over the south pole
Credit: NASA / SwRI / MSSS / Gerald Eichstädt / John Rogers
(L3=0 is downwards)
PJ-7 image 64
(lat.87.9 S)
original image
from Gerald
S3-AWO-1
A3
A2
A1
Subsolar
L3 = 158.4
(L2 = 14.2)
A8
S4-LRS-1
A7
A6
AWO-1
Circumpolar
cyclones
S. Pole
(approx.)
Long band
Long band
(N. extension)
PJ-7 image 65
(CH4)
(reduced to 90%)
S3-AWO-1
S4-LRS-1
AWO-1
(Long band
not visible)