

Jupiter's high-latitude northern domains: Dynamics from Earth-based and JunoCam imaging

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1. Introduction and Summary

Jupiter's troposphere is divided by eastward (prograding) jets into dynamical domains, which we number sequentially ([Figure 1](#)) so the highest-latitude northern domains are N4, N5 and N6 ([Figure 2](#)). Here we describe characteristics of these domains with short- and long-term tracking of features that can be identified in JunoCam images. Anticyclonic white ovals (AWOs) and cyclonic folded filamentary regions (FFRs) were tracked in 2021 and earlier years, using amateur images (analysed in the JUPOS project; e.g. [Figure 3](#)) and JunoCam maps (from the imager on NASA's Juno orbiter; e.g. [Figure 4](#)) and several Hubble maps (from the OPAL project: [ref.1](#)).

The N6 domain is narrow and corresponds to a largely bland zone in JunoCam maps; all features in it are rapidly prograding. The N4 and N5 domains are broad and chaotic with numerous large FFRs and smaller vortices. Their zonal wind profiles (ZWPs) are dominated by the drifts of AWOs and FFRs, but faster retrograde winds exist in the FFRs. Northerly AWOs have rapid prograde drifts, but these often change suddenly, sometimes due to interactions with FFRs or with other AWOs. Most remarkably, in 2021-22 we have one or (very likely) two examples of AWOs moving south to cross prograde jets: one from the N4 domain and one from the N3 domain.

2. Zonal drift profiles

Previous spacecraft ZWPs have revealed the overall pattern of the domains: in both N4 and N5, the ZWP is 'blunt' with a broad retrograde flow ([Figure 1](#)). The Cassini polar movie, and our long-term ground-based analysis [[ref.2](#)], suggested that this represents the bulk motion of the rapidly-changing FFRs, and this is confirmed by tracking features in 2021. The mean speeds in L3 are: in N4, +14 deg/30d; in N5, +20 deg/30d. Faster retrograde winds exist in the FFRs. Conversely, AWOs have fast prograding drifts when in the northern part of each domain, but steady retrograding drifts in the southern part, where they often wander in latitude (especially in N4). The largest AWO, in N5, has probably been tracked for at least 3 years and often progrades with the N6 jet. Some smaller AWOs are also long-lived, while others appear and disappear within months.

3. Influences on the zonal drifts

In both N4 and N5, AWOs often undergo sudden large changes in their latitude and drift rate ([Figure 3](#)) – just as in the N2, S3 & S4 domains. Decelerations are sometimes due to the AWO encountering a FFR, according to examples in the Cassini polar movie and long-term

ground-based analysis combined with Hubble maps [ref.2]. Accelerations may sometimes be due to the AWO encountering a smaller white spot. AWOs sometimes pass each other in different latitudes unperturbed, but sometimes their mutual interactions can lead to mergers, or cause one or both to change latitude and speed. In 2021, a pair in N5 rebounded exchanging tracks, and other interactions may have propelled a N4 and a N3 AWO southwards to cross the jet.

4. AWOs crossing prograde jets

Coherent circulations almost never cross prograde jets on Jupiter, but ground-based data has demonstrated two previous instances where a N4 AWO crossed the N4 jet into the N3 domain, and in 2021-22 there was probably a third such event, captured in JunoCam images. N4-AWO-A swung rapidly southwards after it approached N4-AWO-B (Figures 3 & 4), and was last seen at PJ39, straddling the N4 jet and split into two lobes (Figure 4).

Likewise, a N3-AWO swung southwards and crossed the N3 jet into the NNTZ – the first time that a spot has been seen to cross a prograde jet other than the N4 jet.

5. Cloud textures

JunoCam provides unprecedented resolution on the cloud-tops in this region, revealing features such as ‘pop-up clouds’; these are small, very bright white clouds only ten(s) of km across, projecting above the main cloud deck [ref.3], seen in many locations including AWOs, FFRs, and linear white cloud bands outside the main circulations (Figure 5). AWOs have thick white cloud cover with spiral streaking and scattered pop-up clouds. There are also much smaller vortices, both anticyclonic and cyclonic; the latter include well-formed orange-brown spiral cyclones, and ovals with quiescent dark brown cloud-covered interiors. FFRs have a variety of white, grey and orange clouds and hazes that appear to be at different levels. Dense rows of pop-up clouds are commonly seen on the white strips in FFRs, possibly representing the uppermost layer of convection. These white strips are probably thunderstorms, as FFRs in N4 are the most frequent location on the planet for lightning strikes [ref.4].

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References:

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2. Rogers J et al., (2017), ‘Jupiter’s high northern latitudes: patterns and dynamics of the N3 to N6 domains.’ <https://britastro.org/node/11328>
3. Hansen C et al. (2019), ‘JunoCam images of castellanus clouds on Jupiter.’ AGU abstract #P44A-05.
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Fig.1. Zonal drift profile for N3–N6 domains
from ground-based images, 2021: measurements
by JUPOS team, analysis by G. Adamoli

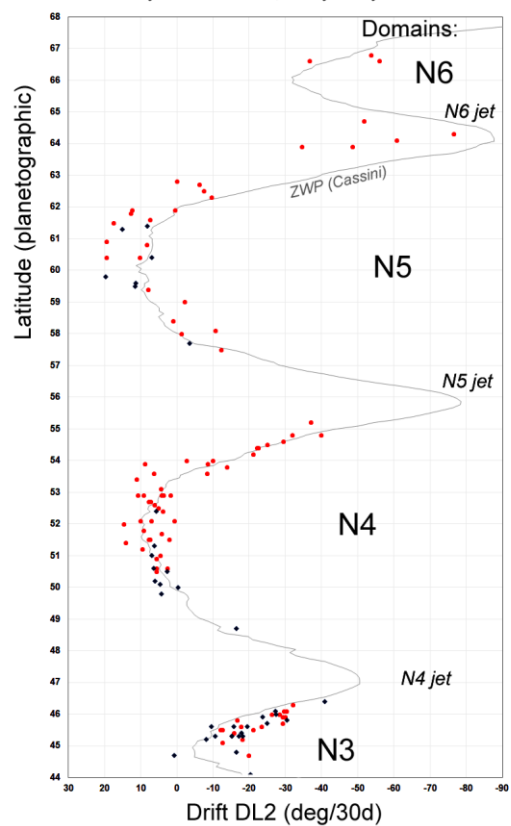


Fig.2.
The high northern domains
(numbered) from JunoCam
PJ24 image 23. Red curves indicate
approximate latitudes of prograde jets.

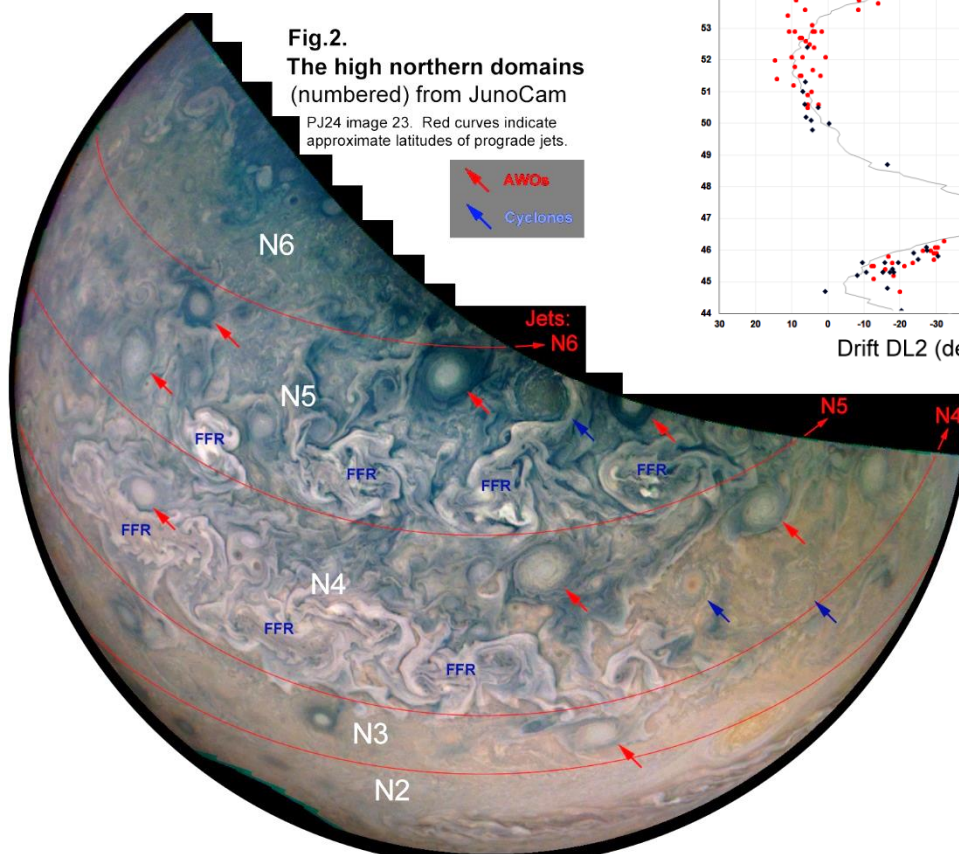


Fig.3. Tracking of white and dark spots in the N4 domain from amateur images, 2021-22 (JUPOS project)
(Larger, darker points are from JunoCam maps)

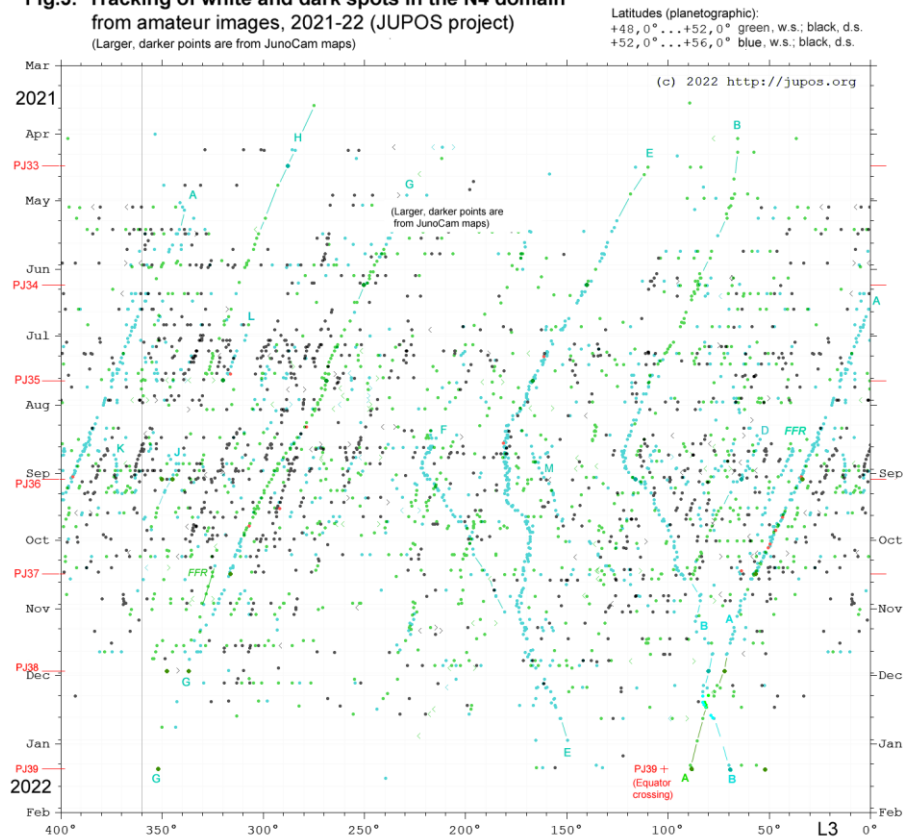


Fig.4. Maps from JunoCam showing AWOs in N4 & N5 at PJ38 & PJ39.

In N5, a is probably an AWO that lasted throughout 2021; e is the largest AWO.

In N4, A & B are AWOs that interacted sending A south to the N4 jet;

C is a cyclonic oblong; arrows indicate their deduced motions.

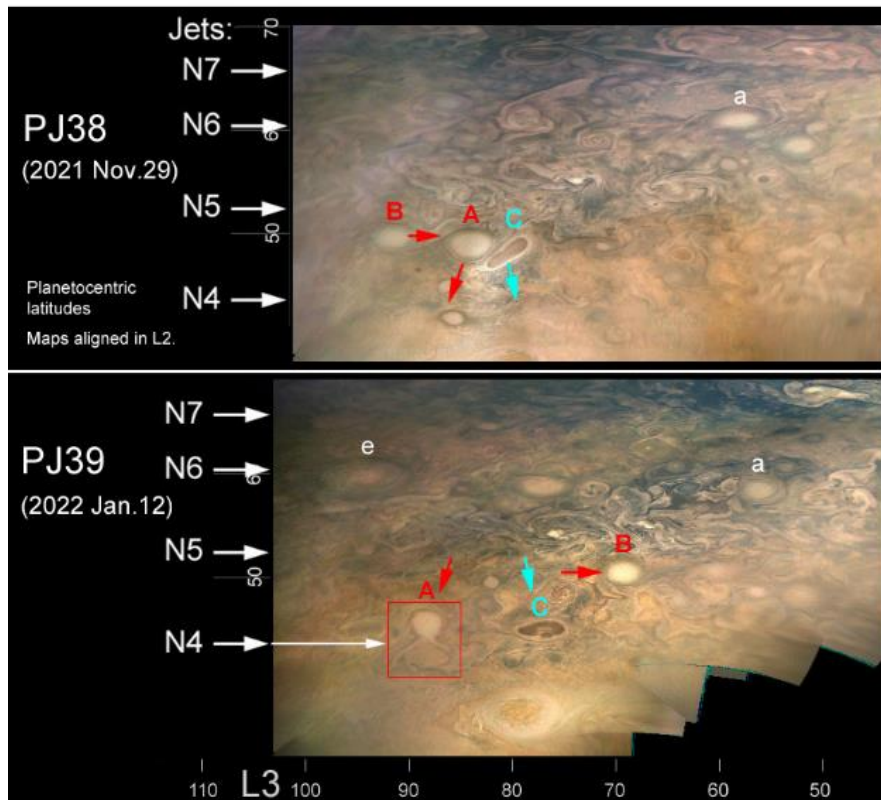


Fig.5. Typical features of northern domains,
in a JunoCam image (PJ39 image 22). A large N5 FFR fills 2/3 of the frame;
below it is a N4 AWO. Enlargements below show popup clouds in these features.

