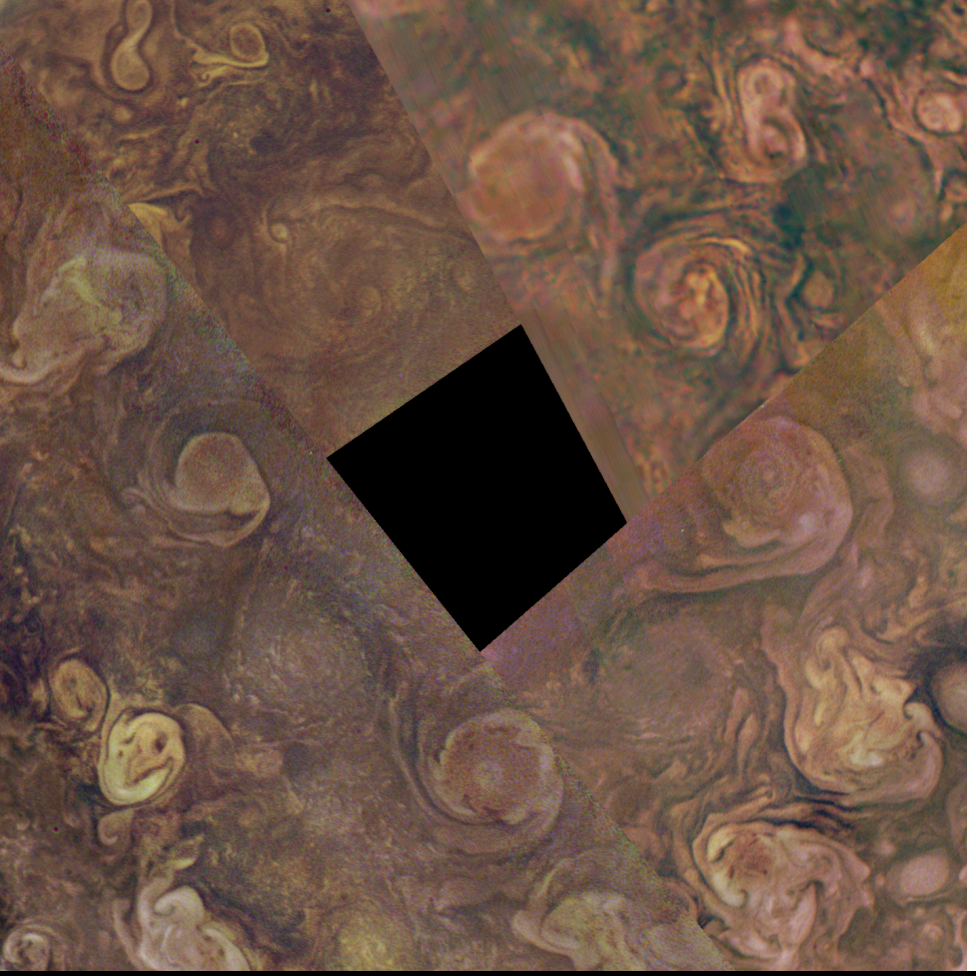

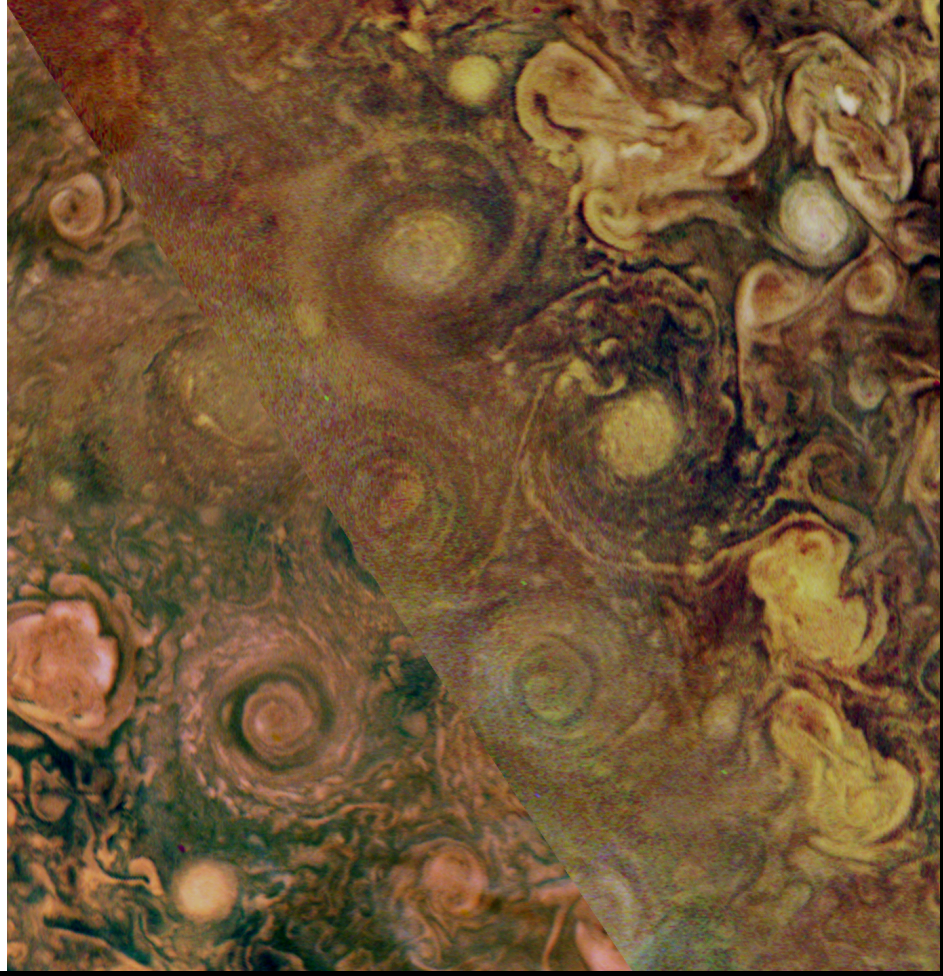

Long-term evolution of Jupiter's circumpolar cyclones with Juno

Fachreddin Tabataba-Vakili[1], J.H. Rogers[2], G. Eichstädt[3], G.S. Orton[1], C.J. Hansen[2], J.A. Sinclair[1], R.S. Giles[1], M.A. Caplinger[5], M.A. Ravine[5], S.J. Bolton[6]

1: Jet Propulsion Laboratory, 2: British Astronomical Association 3: Independent scholar 4: Planetary Science Institut
Systems 6: Southwest Research Institute, San Antonio, Texas, USA

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JUNO

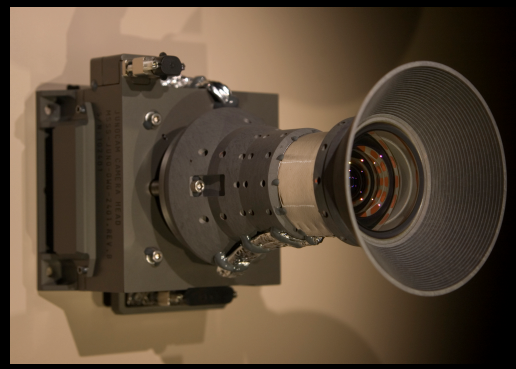
Jet Propulsion Laboratory
California Institute of Technology

JunoCam

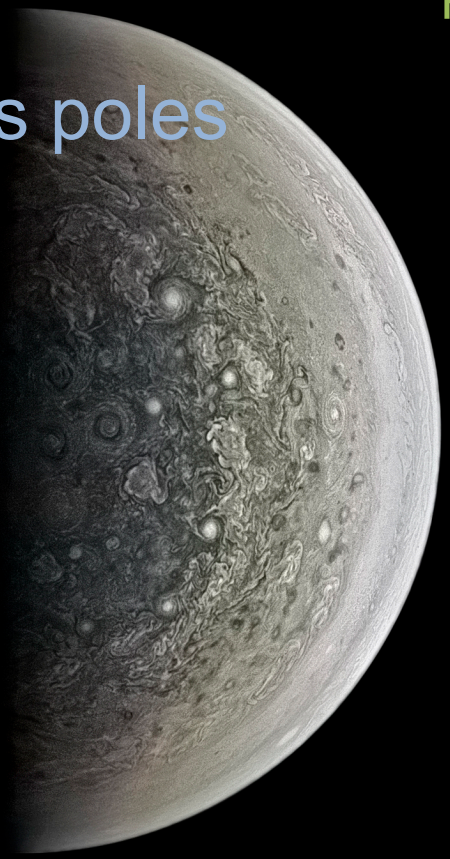
JunoCam is on the Juno payload to give the public an opportunity to participate in a planetary mission

Unique views of Jupiter's poles

Drove the camera design



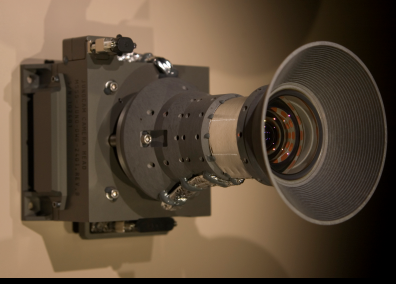
PJ1



South Pole

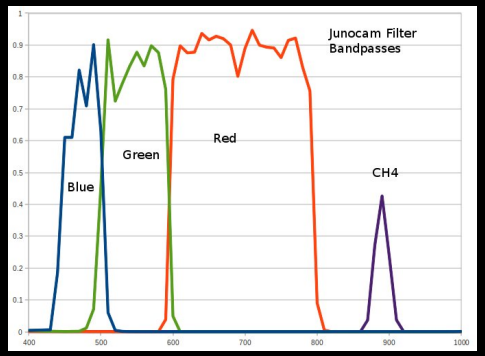
North Pole

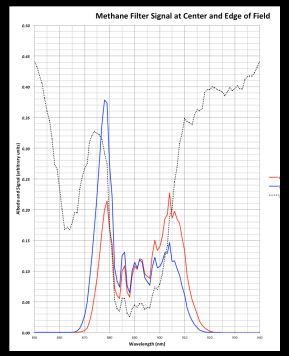
NASA / JPL / MSSS / Roman Tkachenko



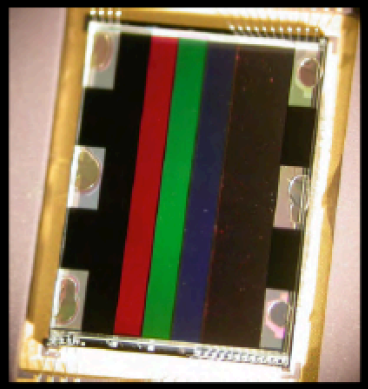
JunoCam Description

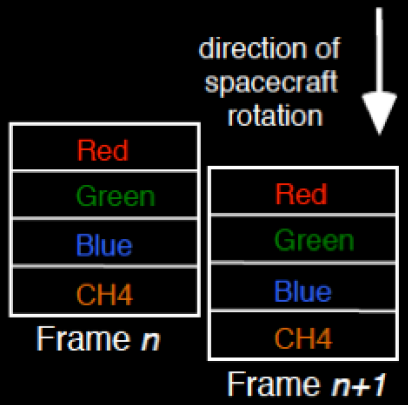
- JunoCam is a fixed-mounted, fixed field of view push-frame visible camera that images in four color bands
  - Broadband blue, green and red
  - Narrow methane band filter centered at 889 nm





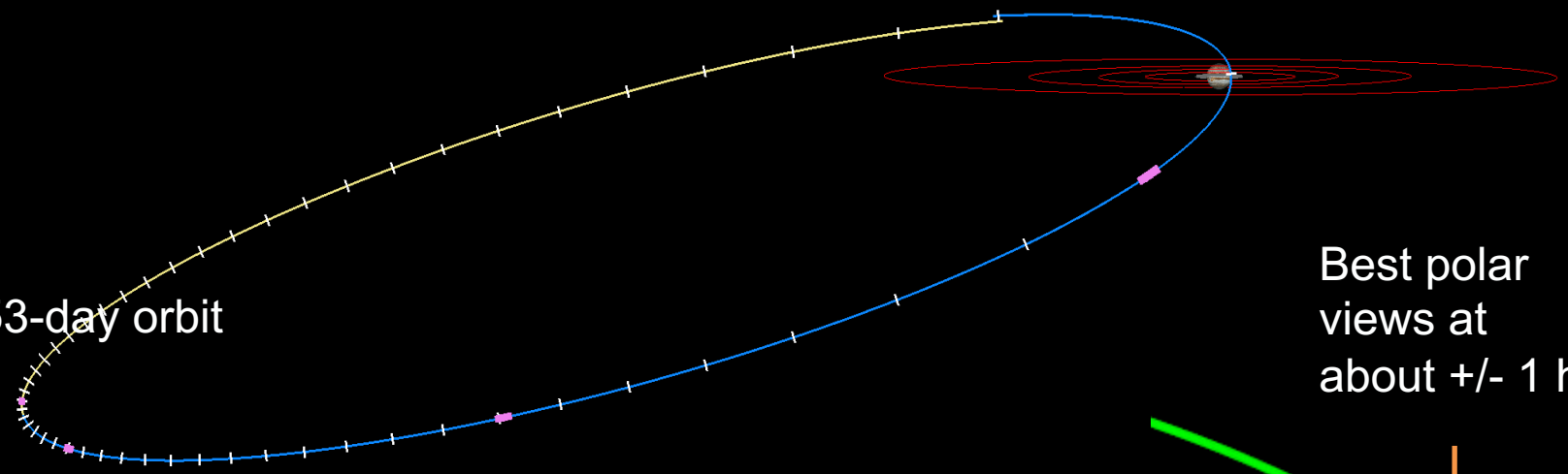
- *A JunoCam image is acquired as S/C rotation sweeps the 1600 pixel, 58° wide FOV across Jupiter*



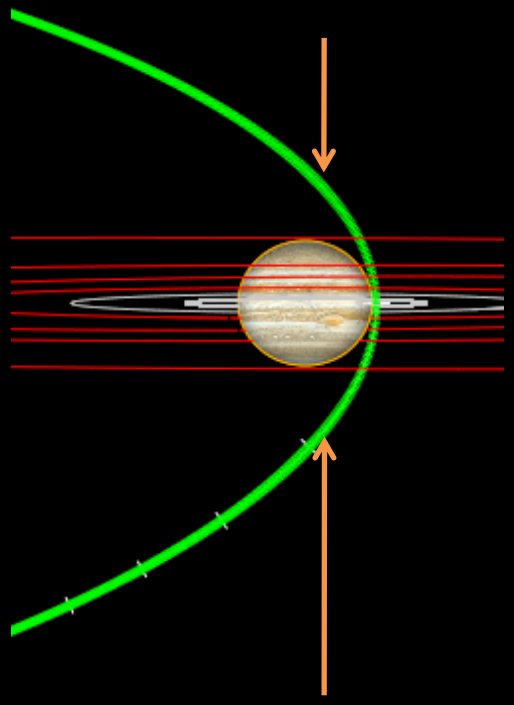


- Time-delayed integration (TDI) used to build up SNR
- Built and operated by Malin Space Science Systems

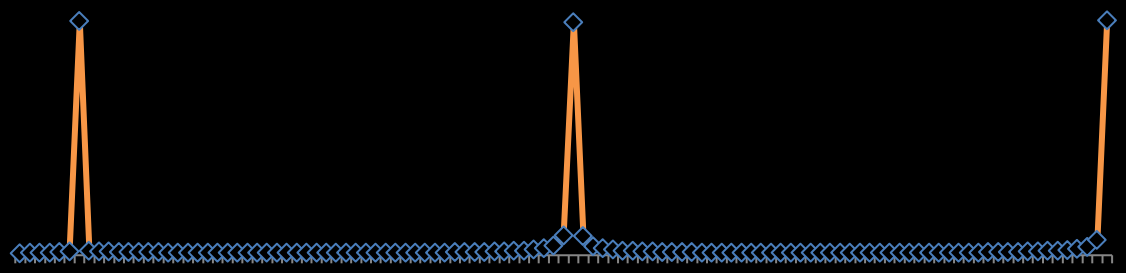
Juno's Elliptical Polar Orbit



Best polar views at about +/- 1 hr

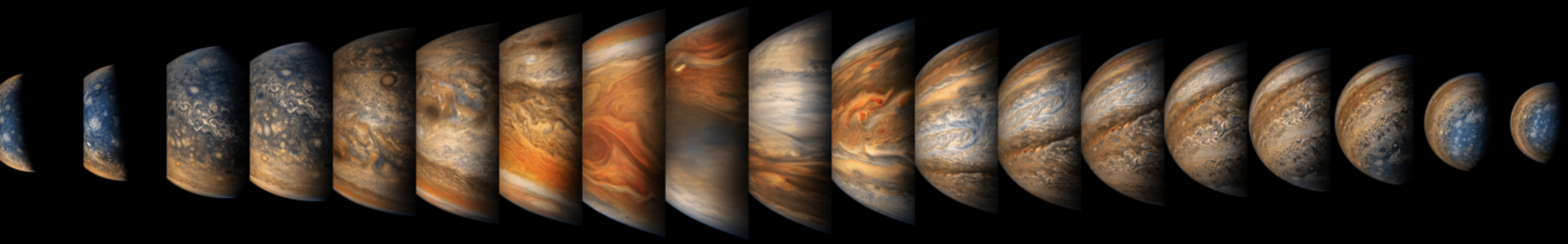


Jupiter is <50 pixels for most of Juno's orbit

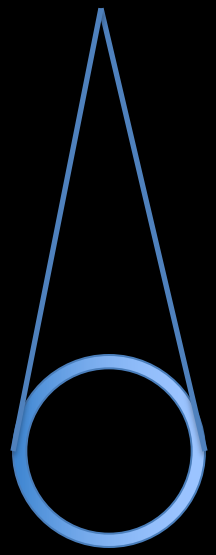


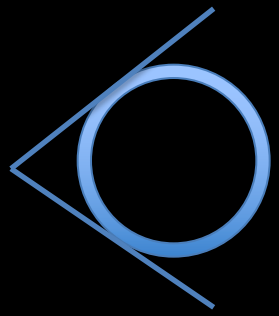
- Perijove swath begins ~1 hr before closest approach
- ~2h from north pole at minimum emission angle to south pole at minimum emission angle

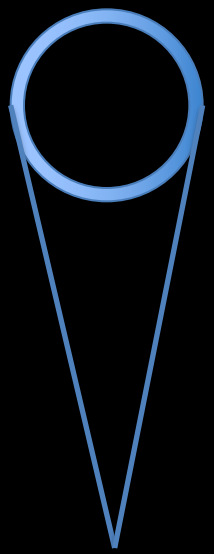
PJ8 Perijove Pass



NASA / JPL / MSSS / Gerald Eichstädt / Sean Doran





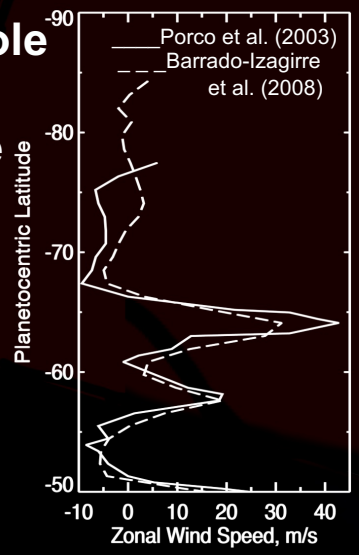


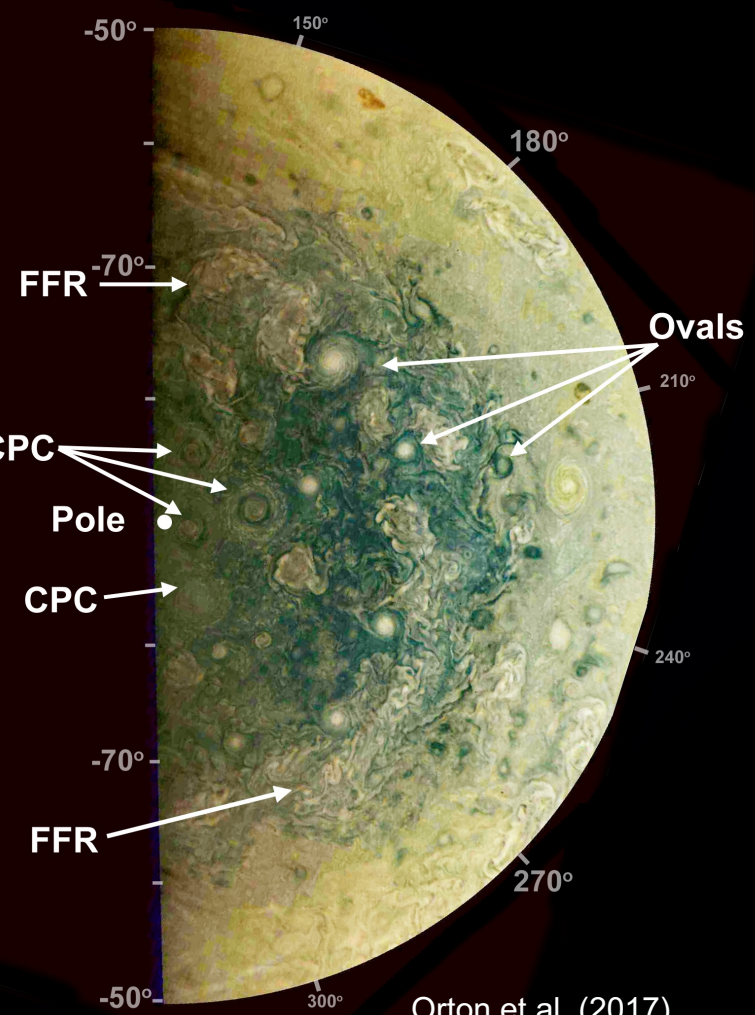
Polar Observations with Juno

JunoCam: South Pole

Perijove 1 (PJ1)

- FFR: Folded Filamentary Regions
  - Longest reaches across 10000 km
  - Colocated with eastward jet near 65°S
- Oval vortices
  - Largest is anticyclonic
- **CPC: Circum-polar Cyclones**
  - **Cyclonic vortices**
  - **Clustered around the pole**
  - **Central cyclone is slightly offset from pole**



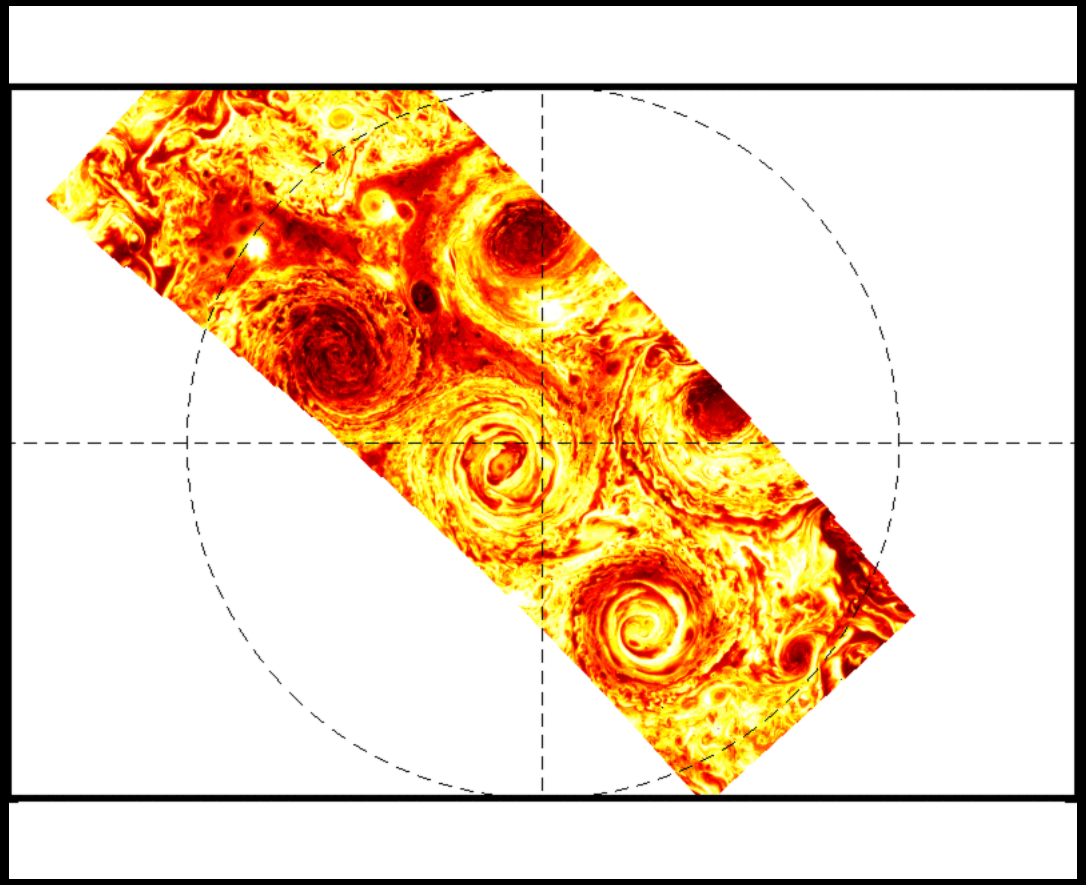


Orton et al. (2017)

Polar Observations with Juno

JIRAM (Jovian Infrared Auroral Mapper)

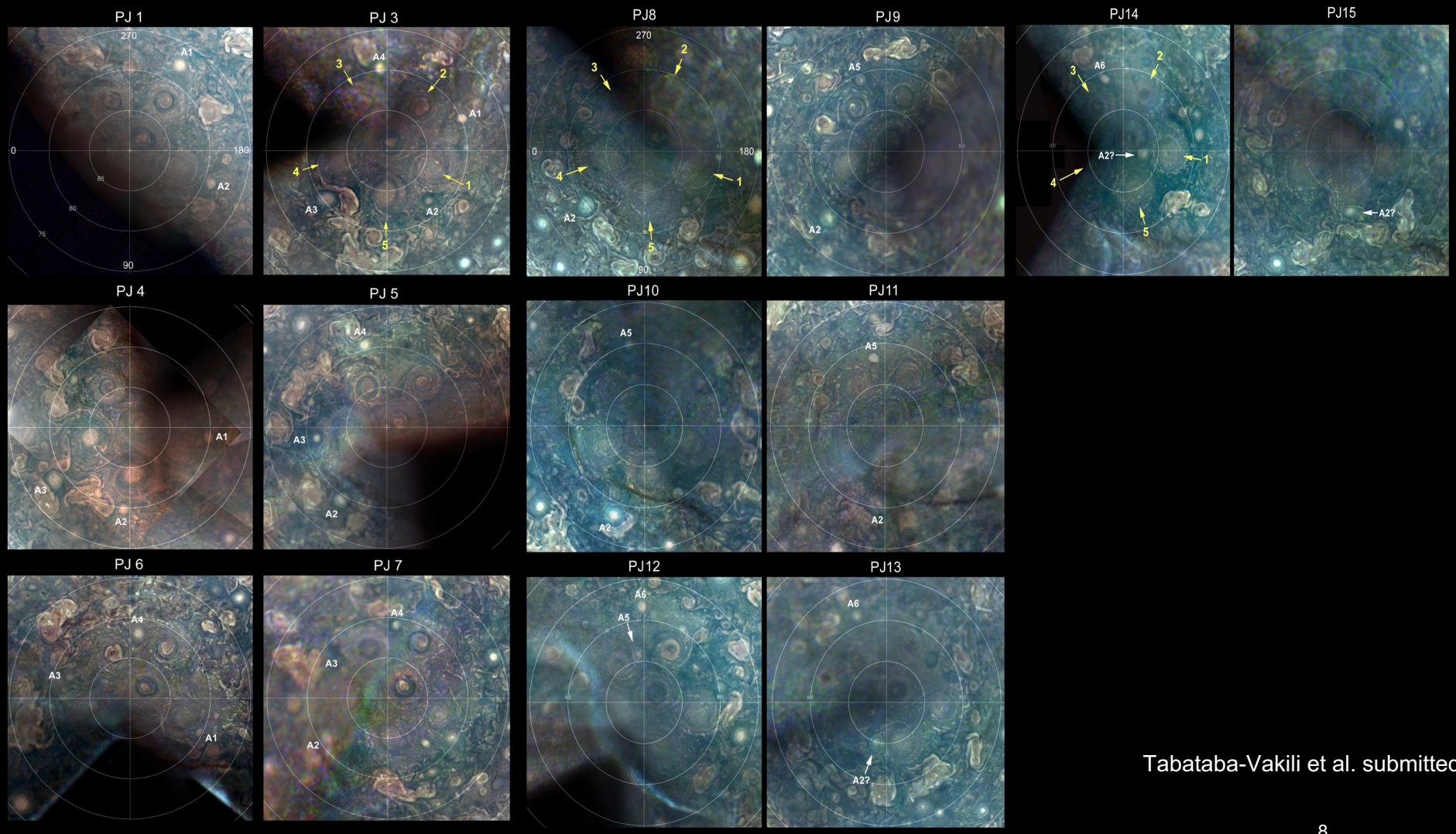
- Perijove 4
- South pole



Adriani et al. 2018

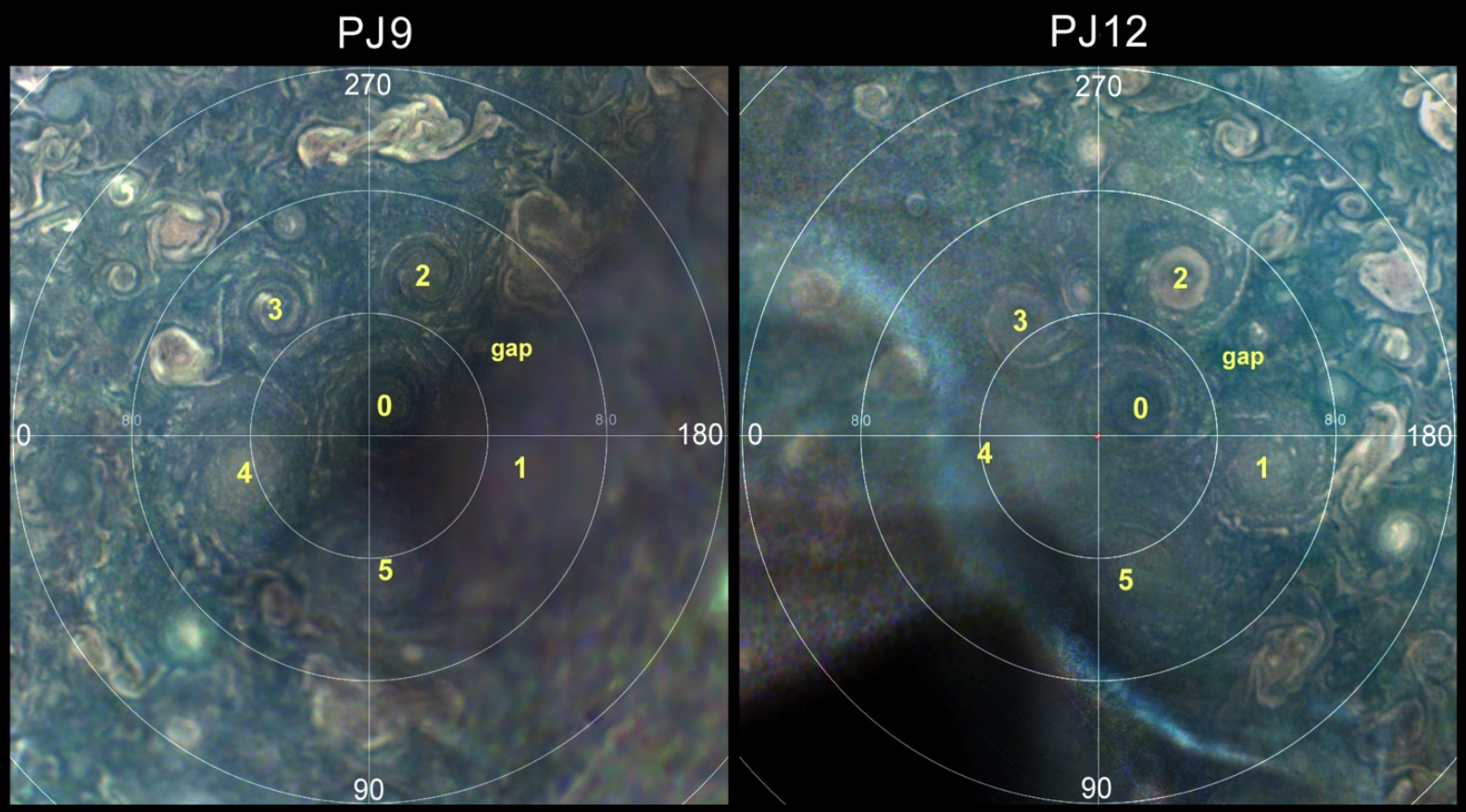
Polar Observations with Juno

South Pole: Long-term evolution



Tabataba-Vakili et al. submitted

South Polar CPCs



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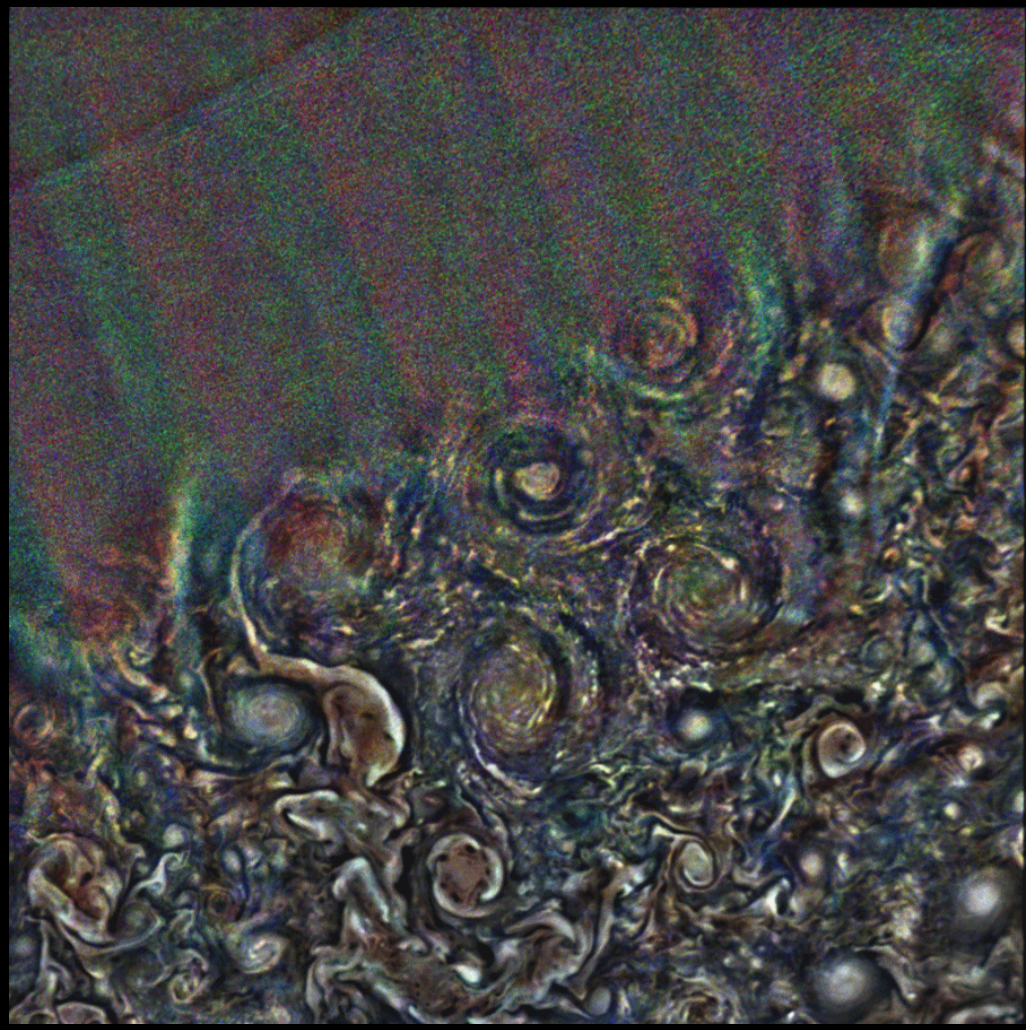
Polar Observations with Juno

South Pole: Long-term evolution



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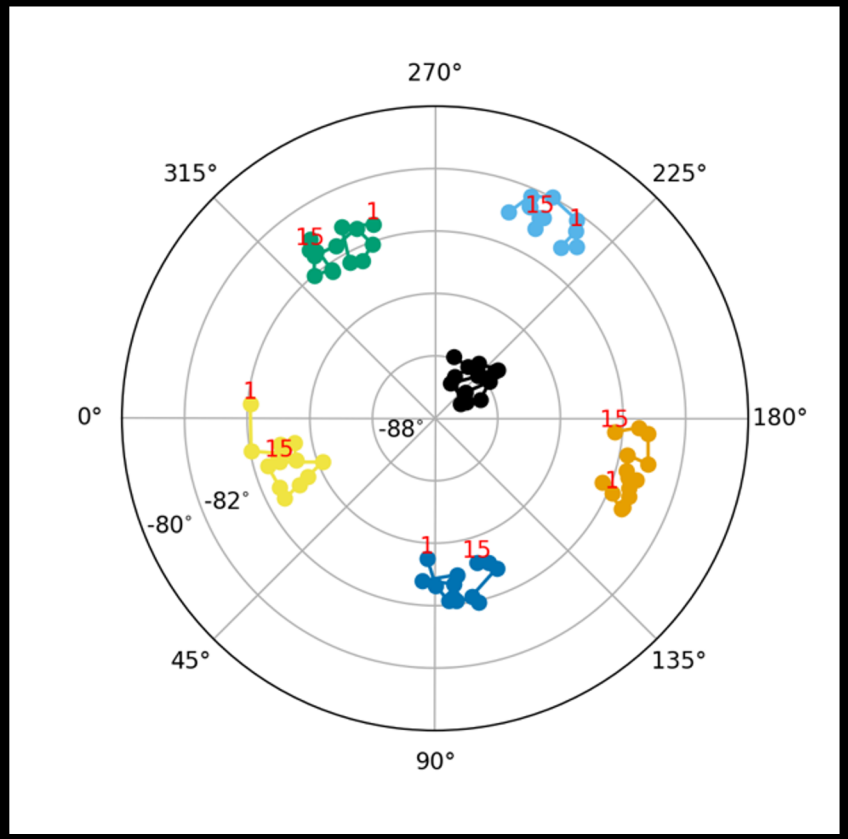
Polar Observations with Juno

South Pole: Long-term evolution



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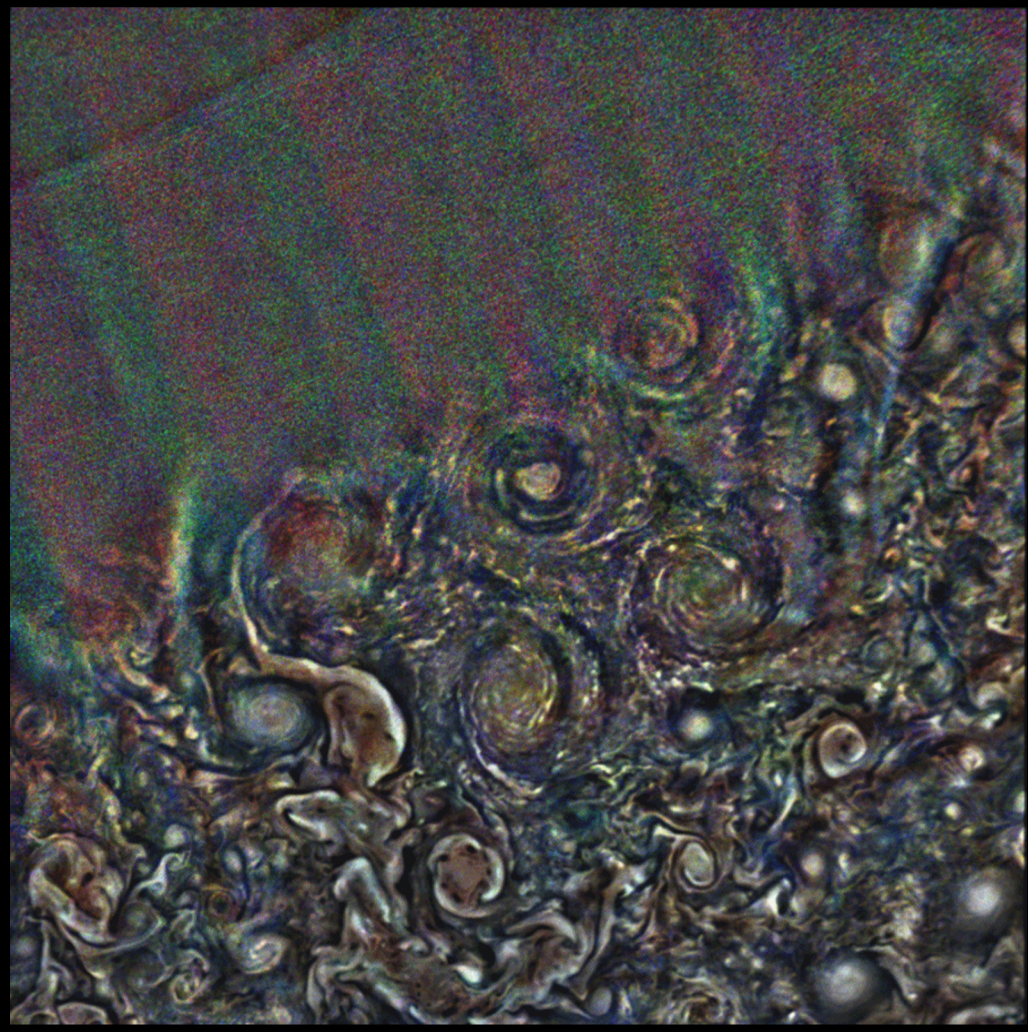
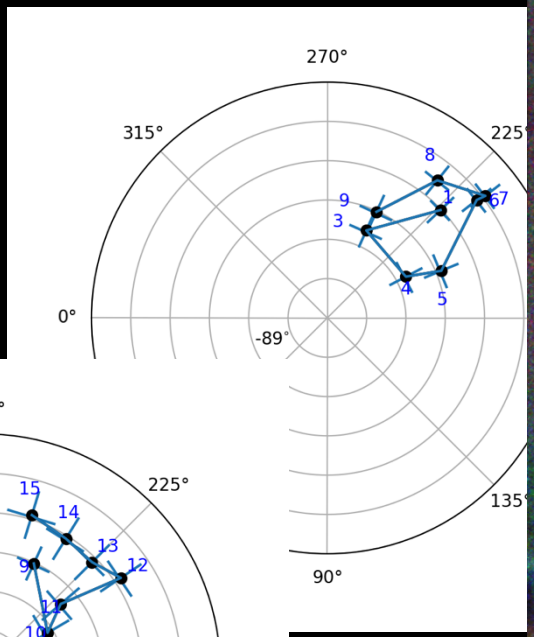
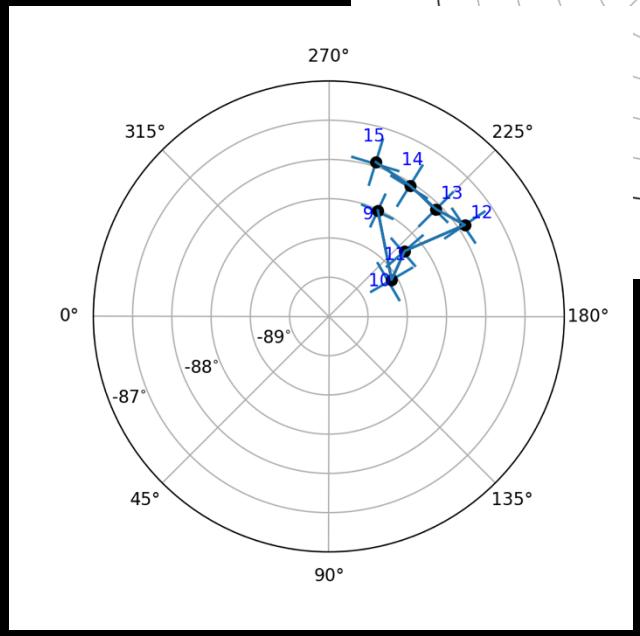
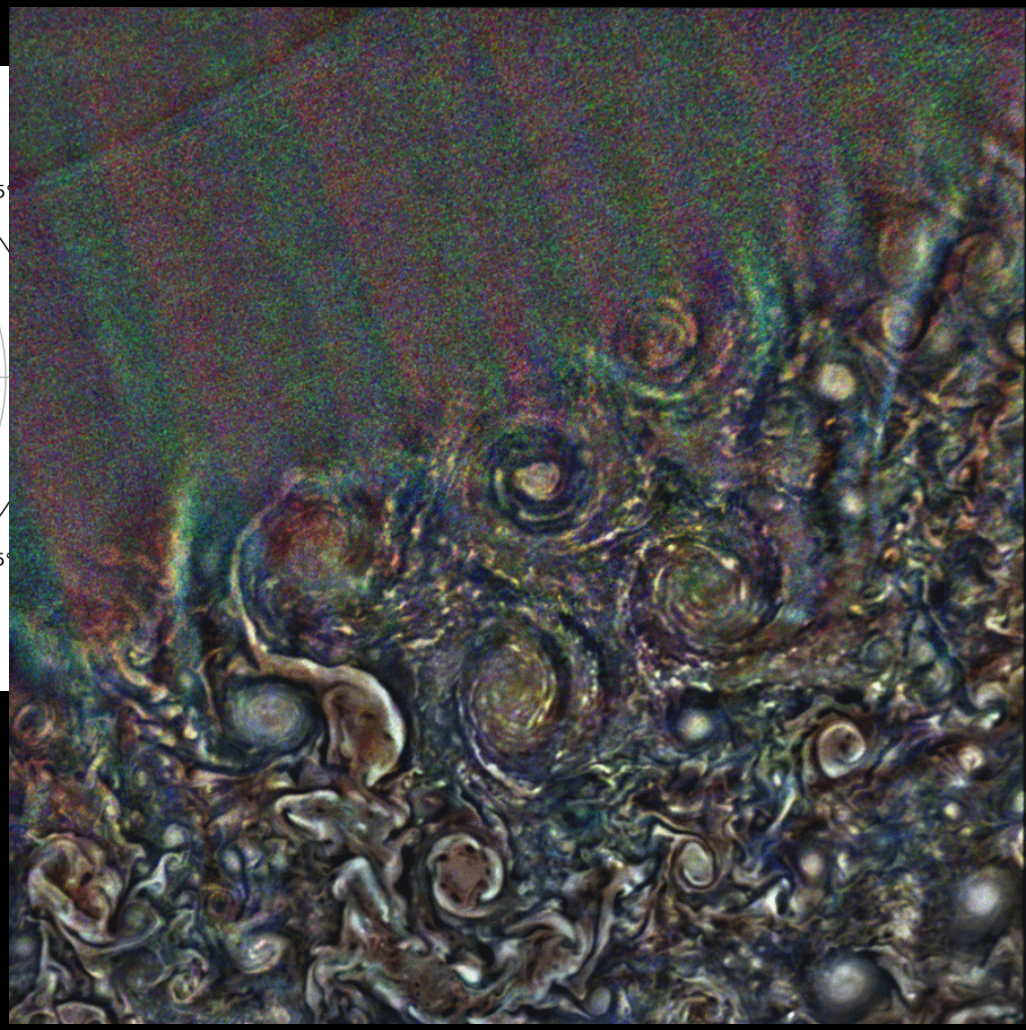


Polar Observations with Juno

South Pole: Long-term evolution







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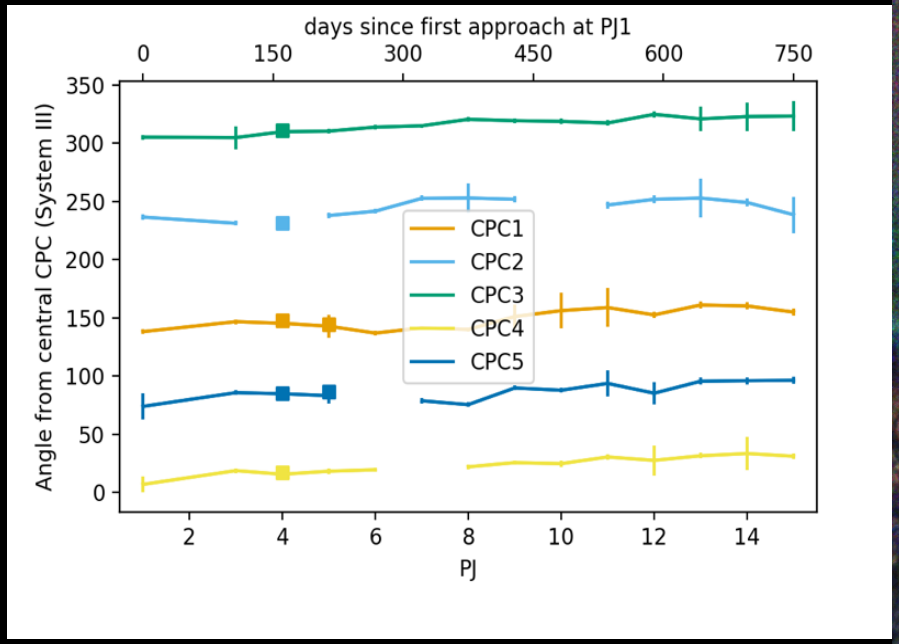
Polar Observations with Juno

South Pole: Long-term evolution



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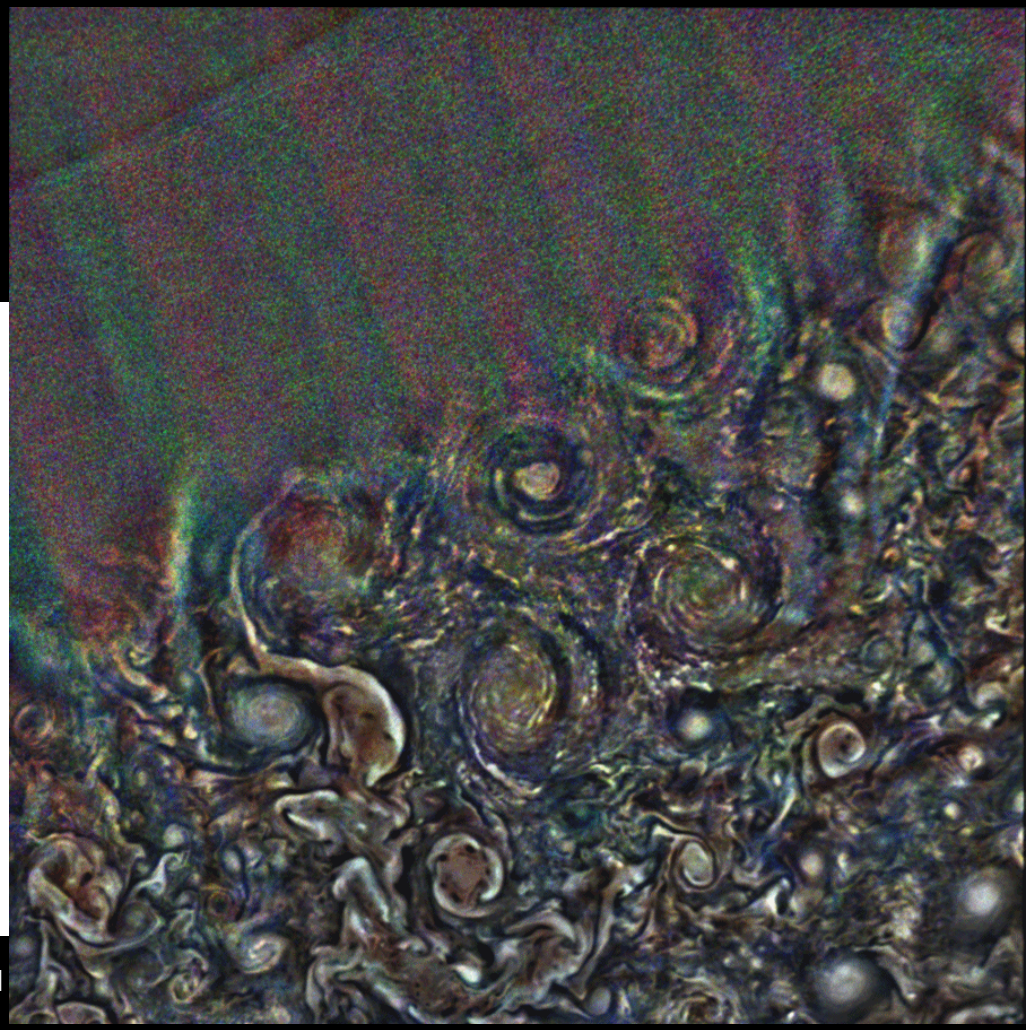
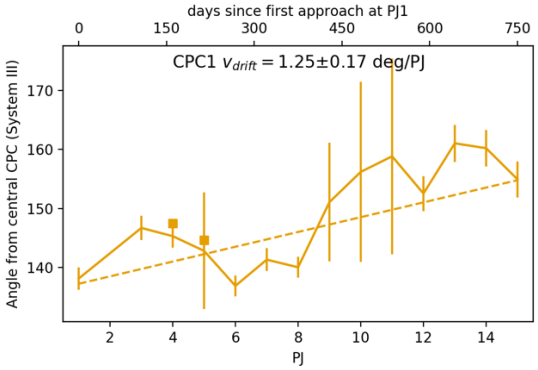
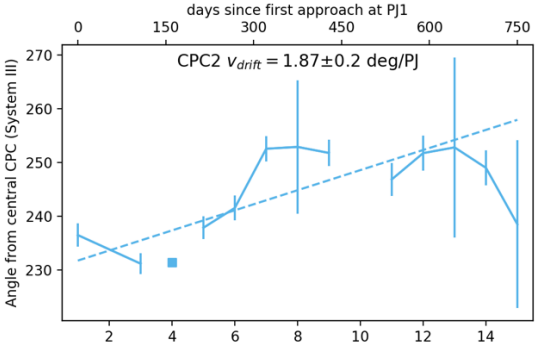
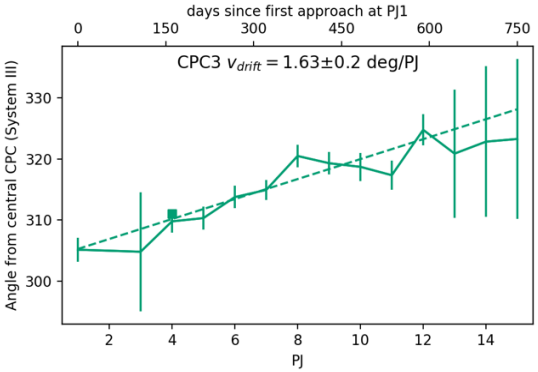


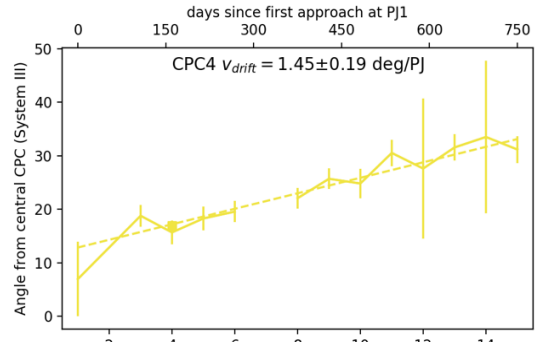
Polar Observations with Juno

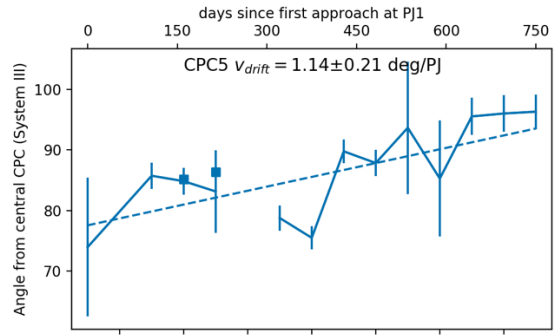
South Pole: Long-term evolution

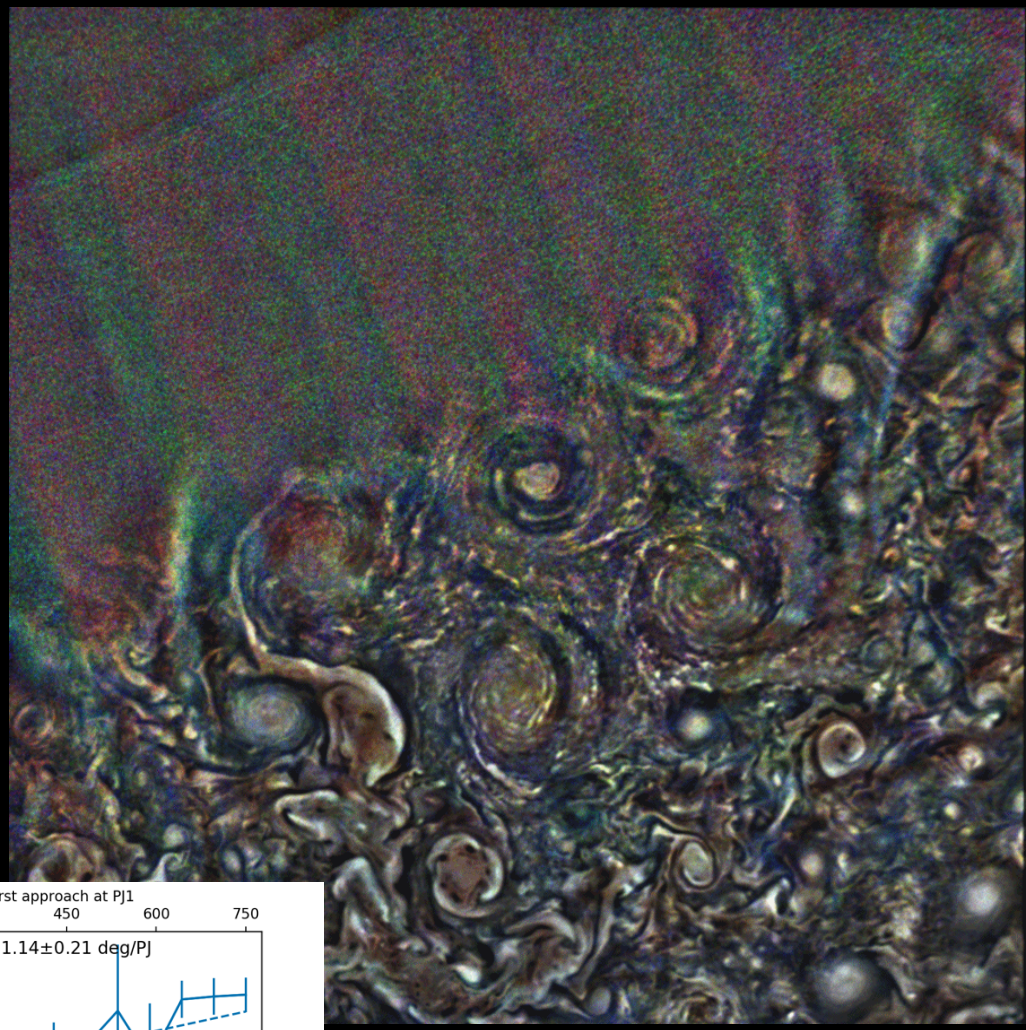












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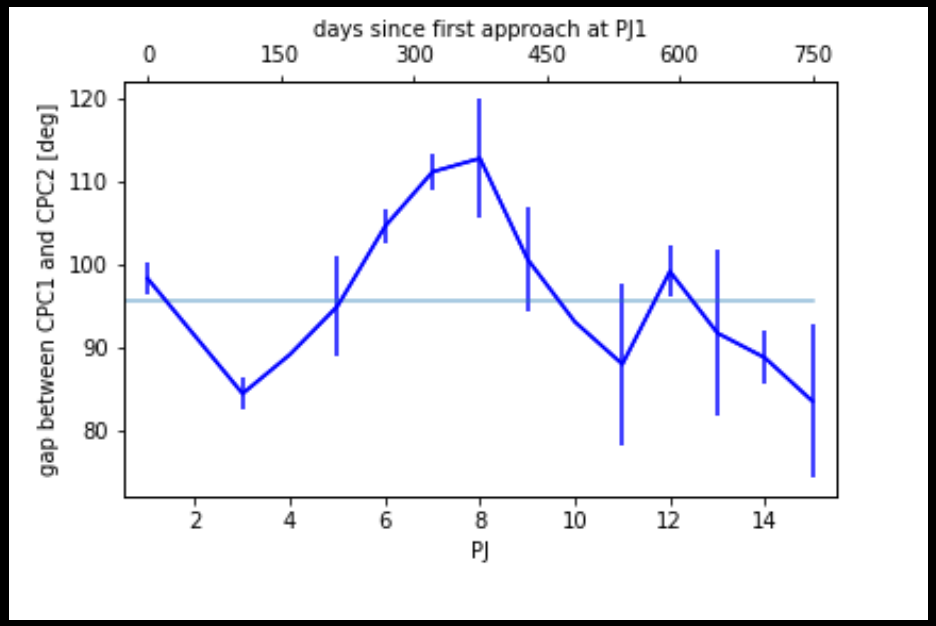
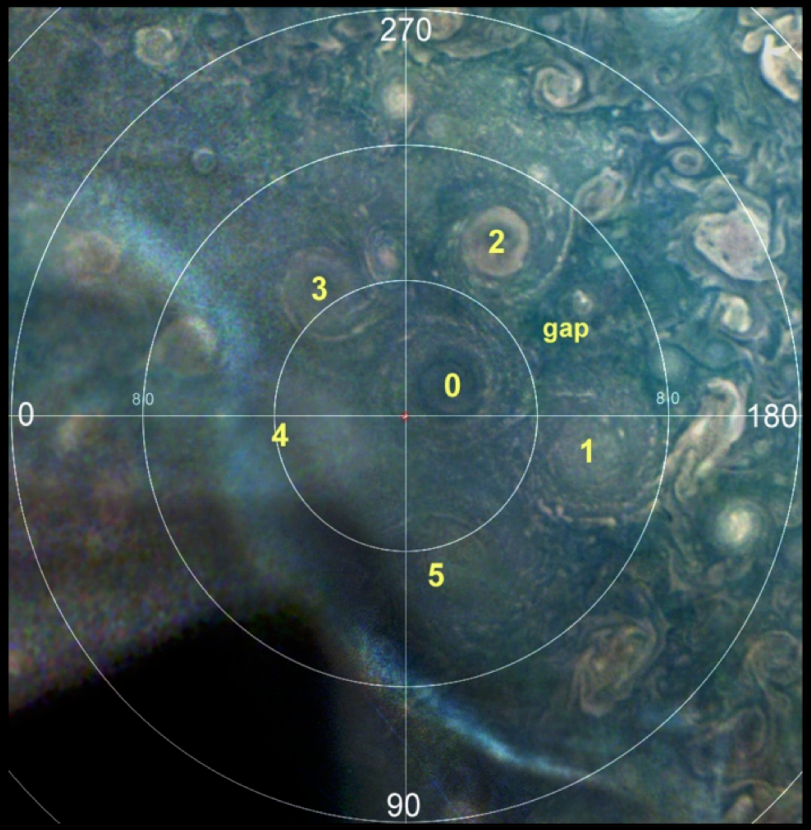
Polar Observations with Juno

South pole: Long-term evolution

Gap width



CPC (south pole)	1-2 (gap)	2-3	3-4	4-5	5-1
Mean gap width [deg]	97	71	67	63	63



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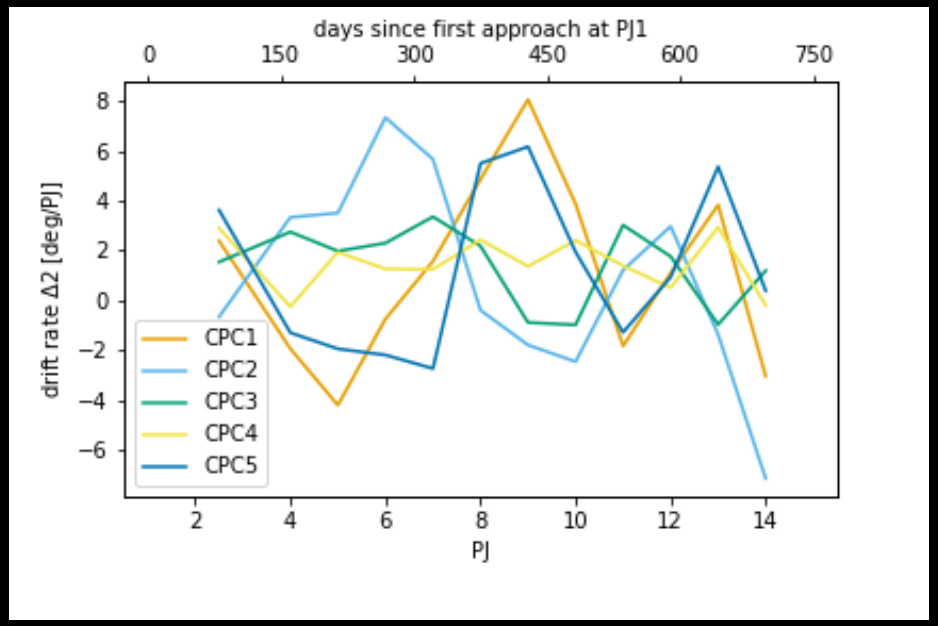
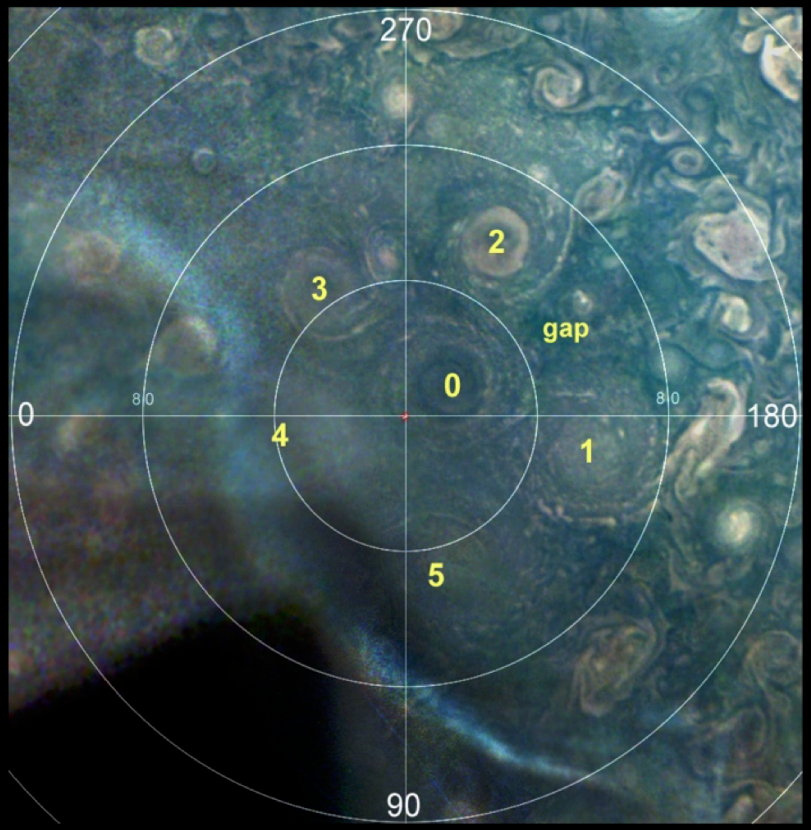
Polar Observations with Juno

South pole: Long-term evolution

Instantaneous drift rate



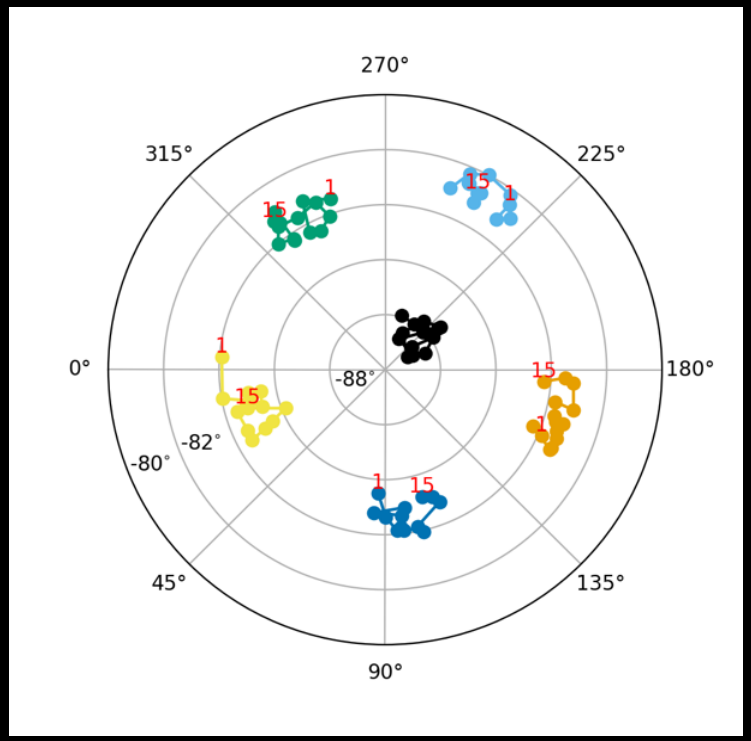


Tabataba-Vakili et al. submitted

Polar Observations with Juno

South Pole: Cyclone Structure

- 5-point outer structure appear to be centered about the central cyclone rather than the rotational pole
- Rotation rate of the pentagon is 1.5+/-0.2 degrees per perijove.
- Outer cyclones do not revolve around the pole uniformly, instead they “wobble” back and forth in longitude
- Central cyclone has a circular motion with a period of 8 PJs



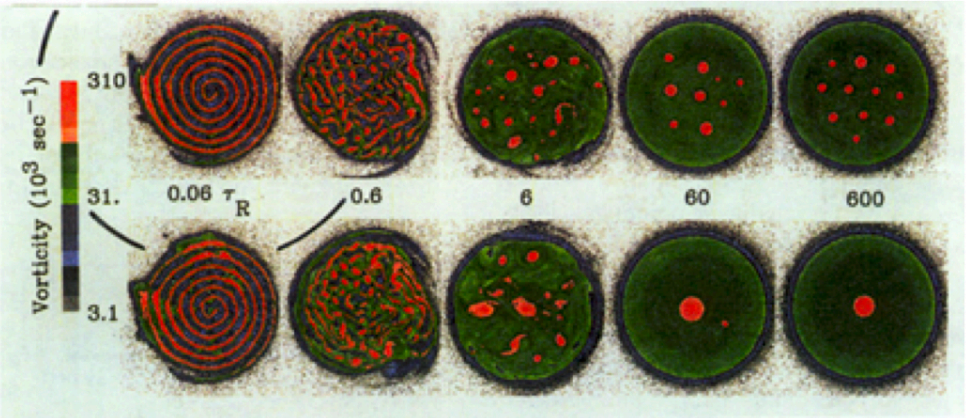
Tabataba-Vakili et al. submitted

Comparison with Theory

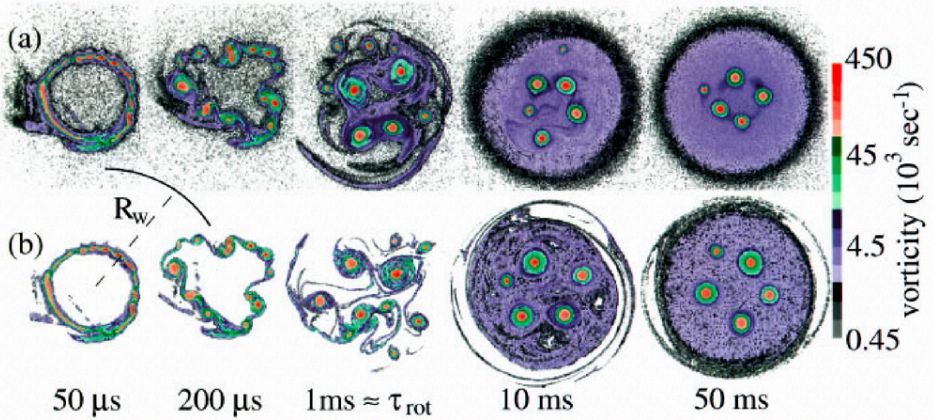
Vortex Crystals

- Constellations of vortices as rare stable solution for initial turbulence.
- Observed in magnetized plasma columns and rotating superfluids to represent 2d turbulence.
- Effect is described by 2d Euler equations.
  - No friction
  - Only positive vorticity
- Formation to achieve maximum entropy.
- In lab and models: stable for around 400 rotations, after which minute frictional effects cause dissipation.

Several stable configurations of vortex crystals. (Fine et al. 2005)



The evolution of two vortex experiments with slightly different viscosities. (Fine et al. 2005)

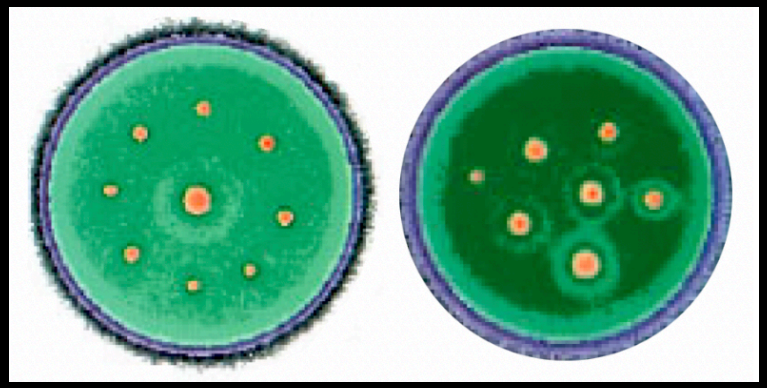


Experiment (a) and simulation (b) of vortex crystal evolution with the same initial conditions. (Schecter et al. 1999)

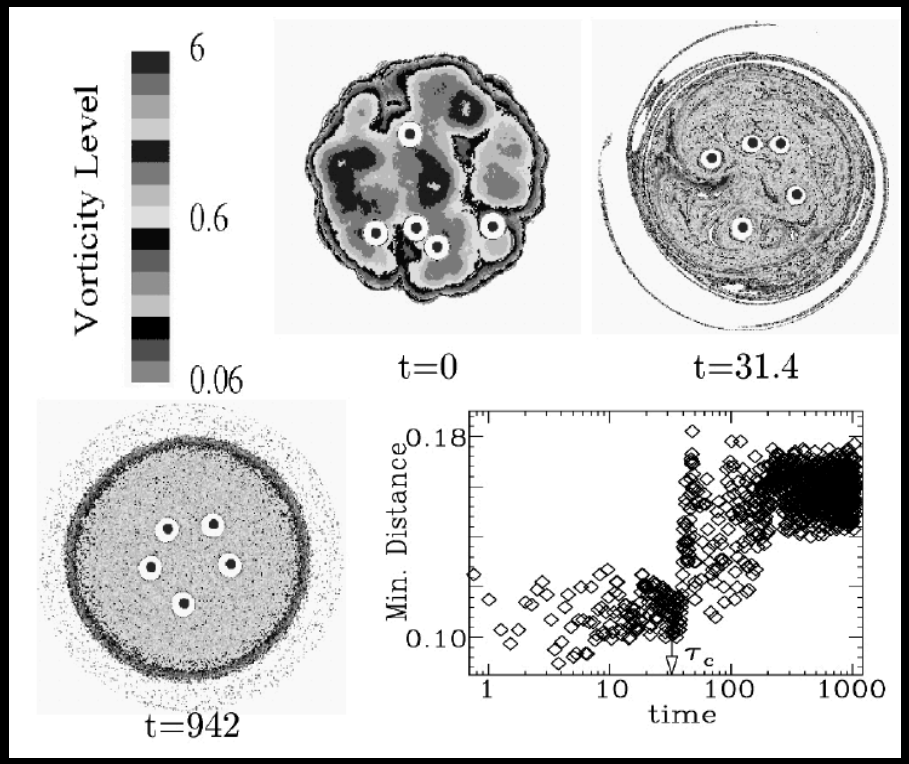
Comparison with Theory

Vortex Crystals

- CPCs and Vortex Crystals compare well in terms of
  - Shape
  - Time evolution



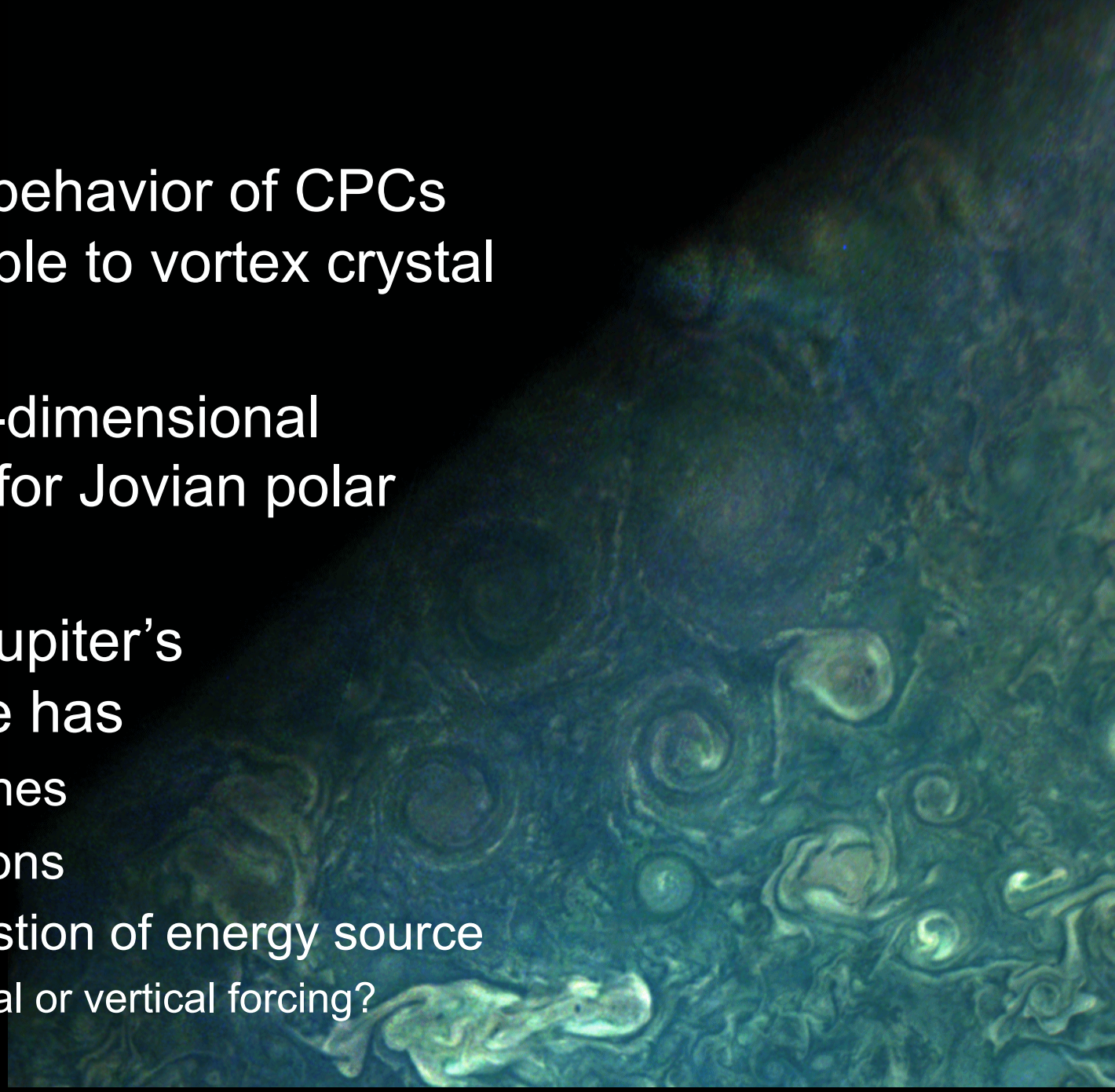
Fine et al. (1995)



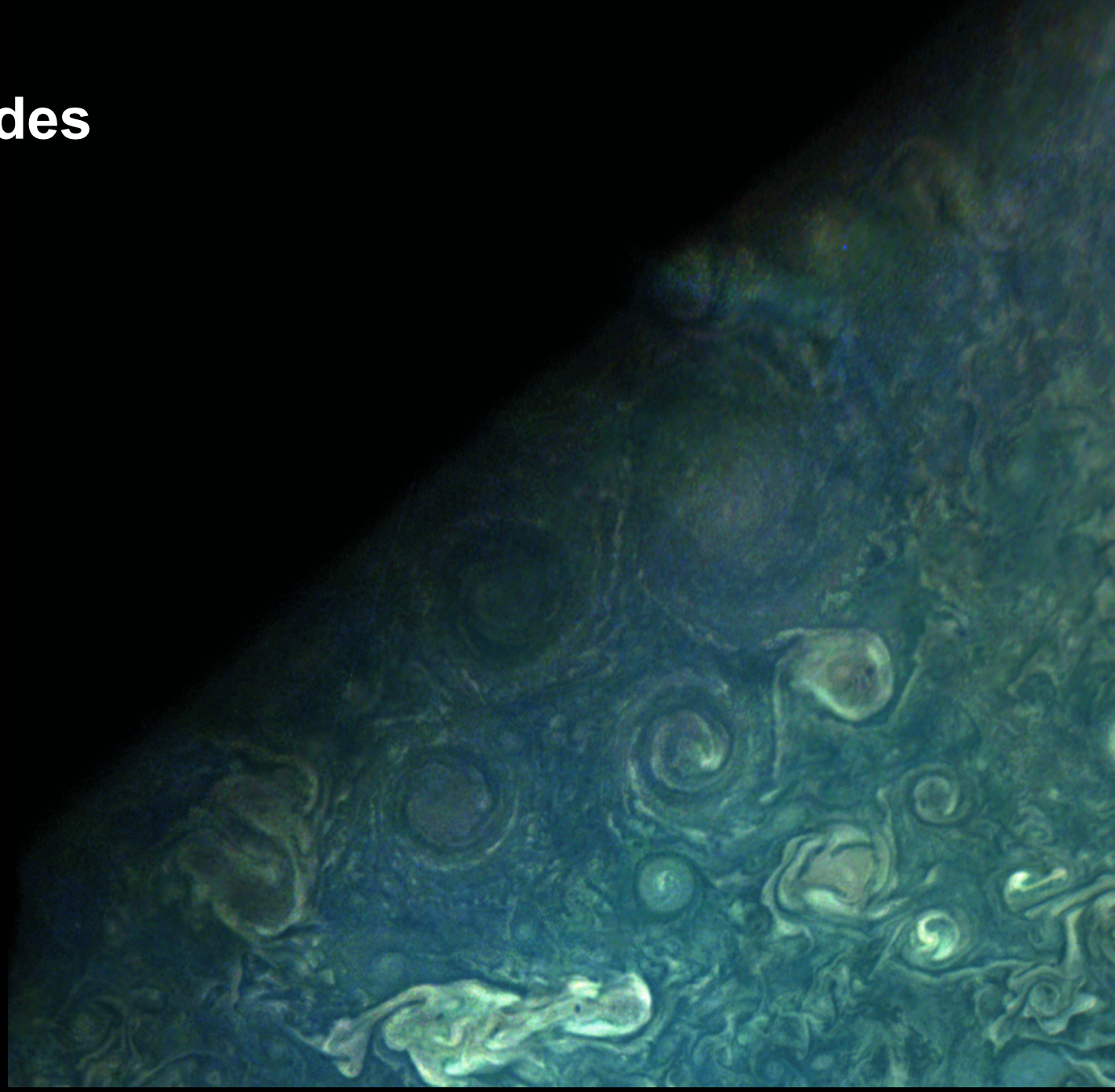
Jin and Dubin (2000)

Summary

- Long-term behavior of CPCs is comparable to vortex crystal theory
- Supports 2-dimensional turbulence for Jovian polar region
- However, Jupiter's atmosphere has
  - Anti-cyclones
  - 3 dimensions
  - Open question of energy source
    - Horizontal or vertical forcing?



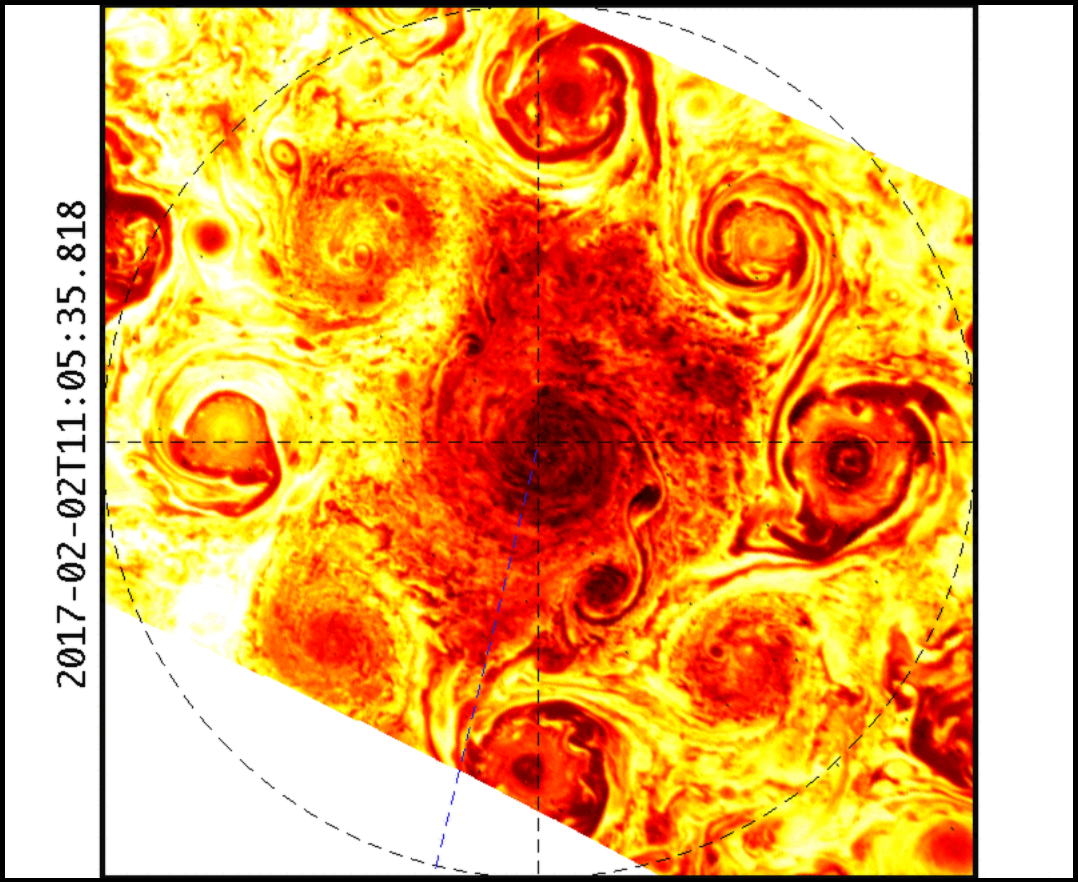
Backup slides



Polar Observations with Juno

JIRAM (Jovian Infrared Auroral Mapper)

- Perijove 4
- North pole

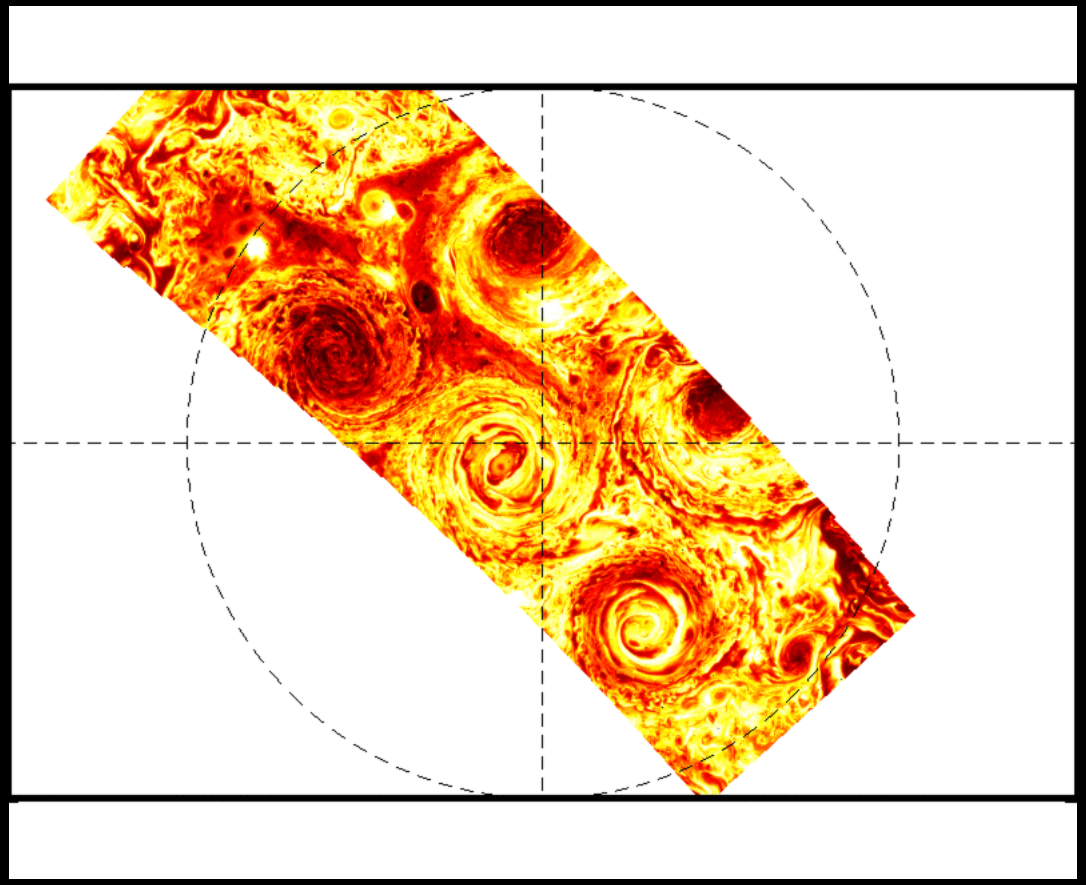


Adriani et al. 2018

Polar Observations with Juno

JIRAM (Jovian Infrared Auroral Mapper)

- Perijove 4
- South pole

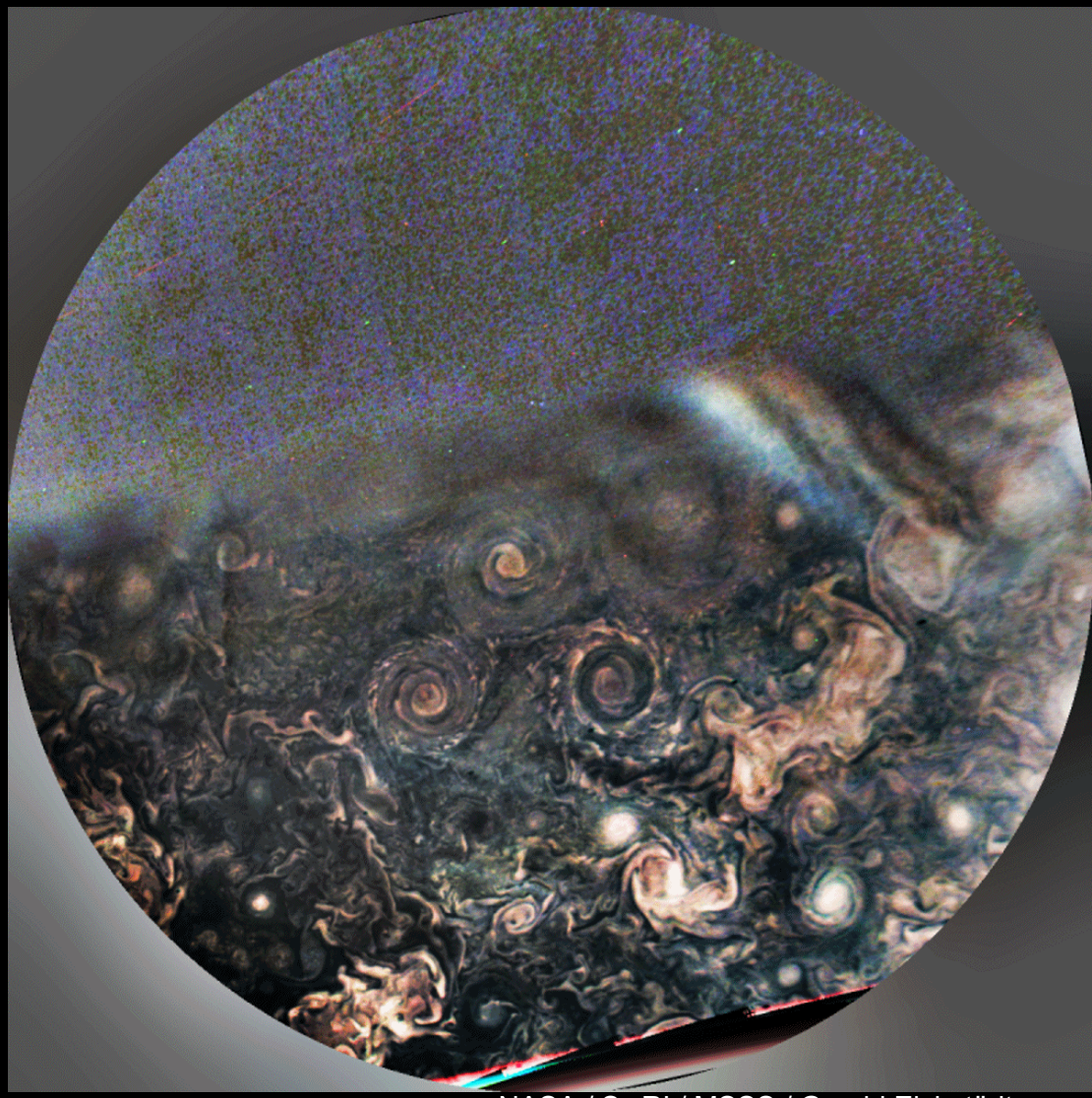


Adriani et al. 2018

Polar Observations with Juno

South Pole: Animations

- Perijove 5

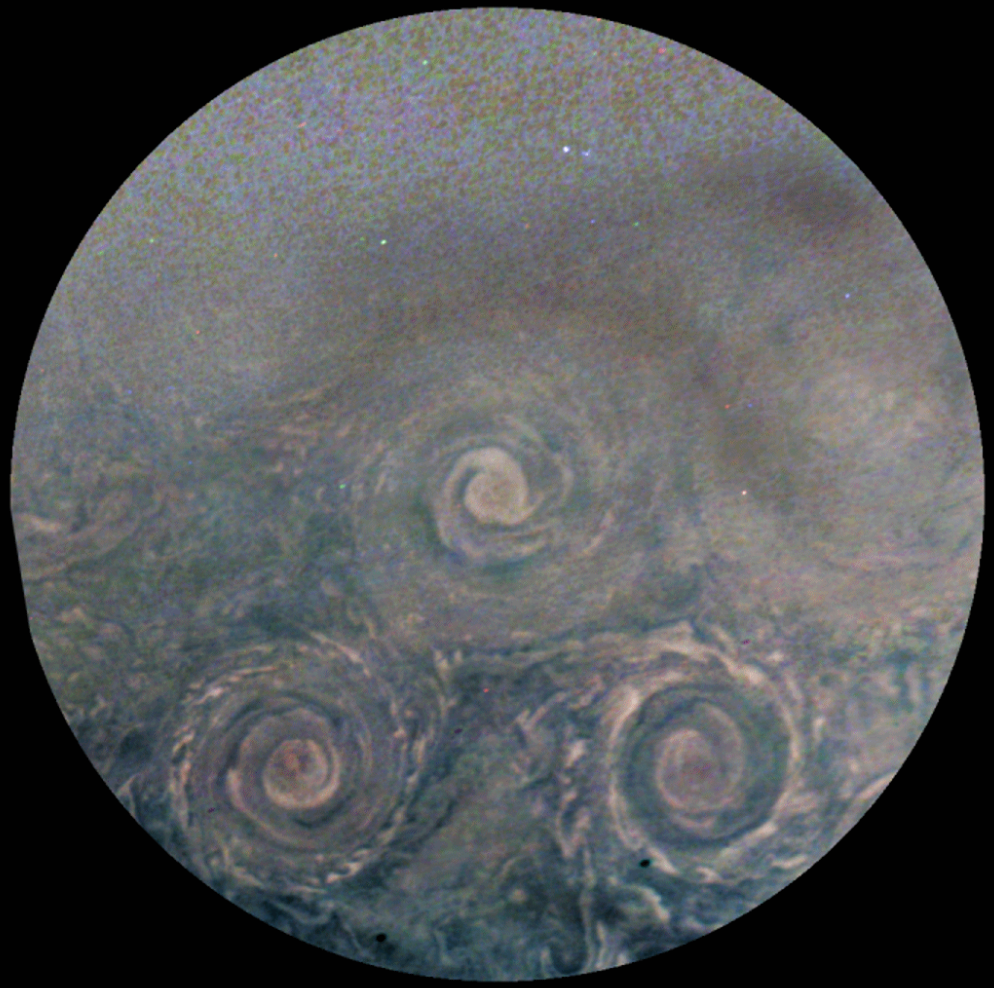


NASA / SwRI / MSSS / Gerald Eichstädt

Polar Observations with Juno

South Pole: Animations

- Perijove 5

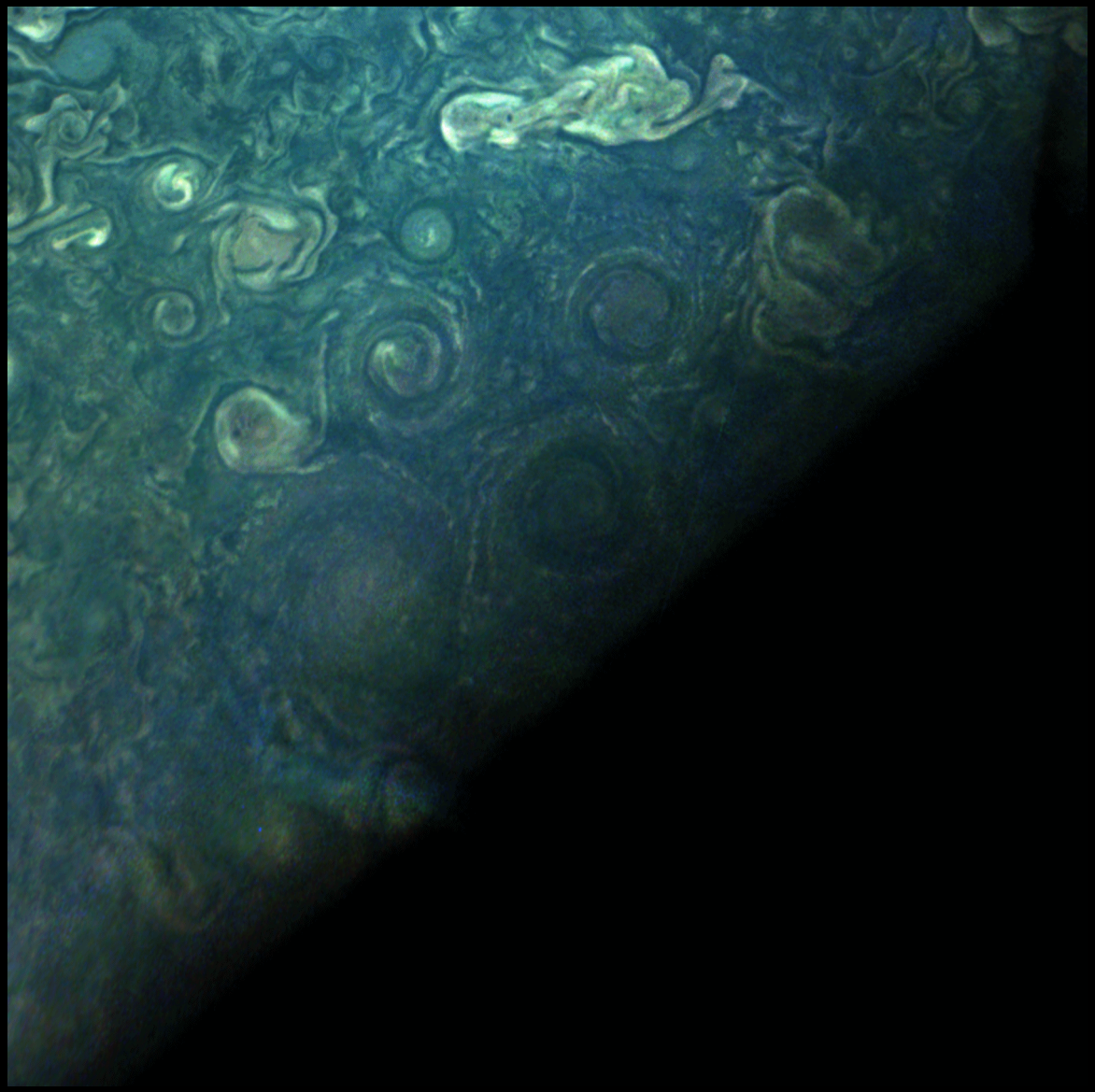


NASA / SwRI / MSSS / Gerald Eichstädt

Polar Observations with Juno

South Pole: Animations

- Perijove 9



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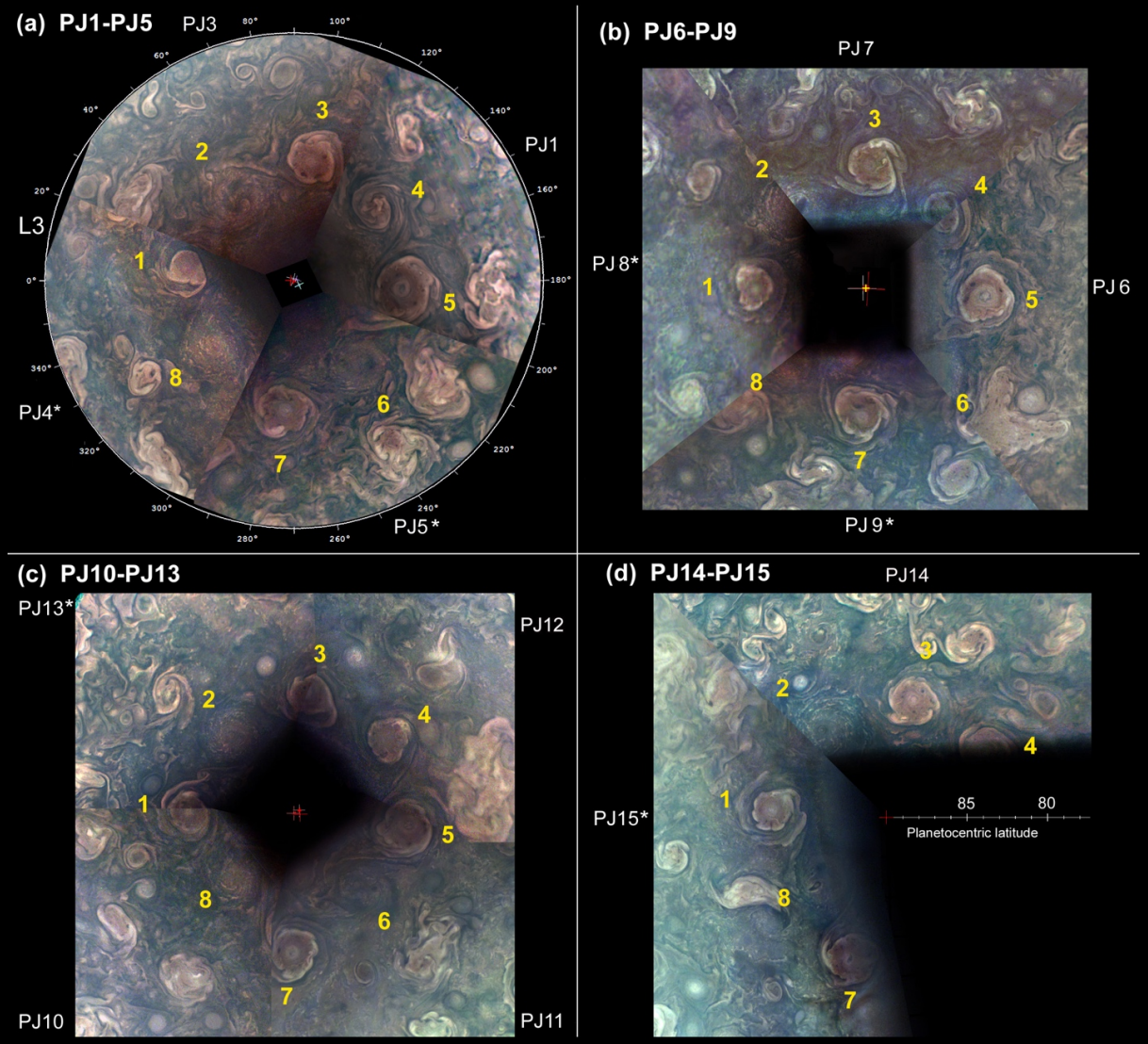
Polar Observations with Juno

North pole: Long-term evolution



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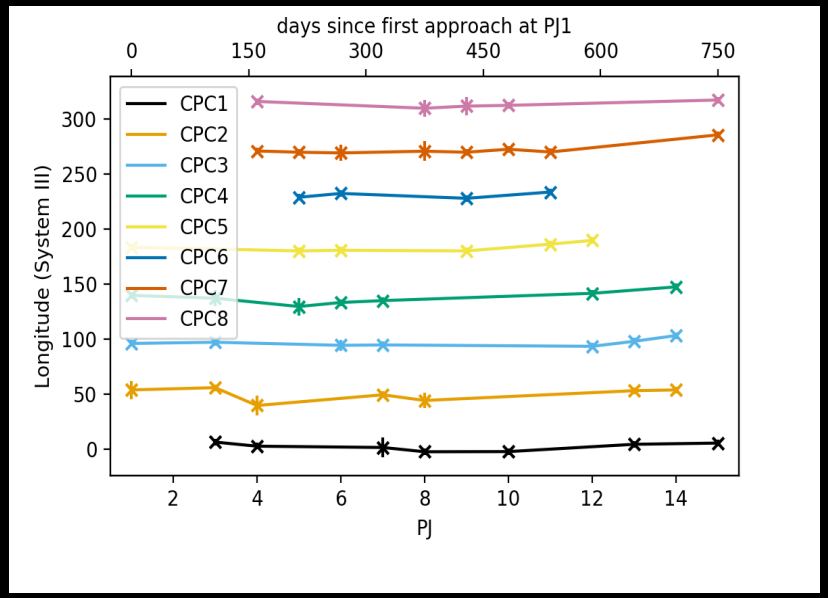
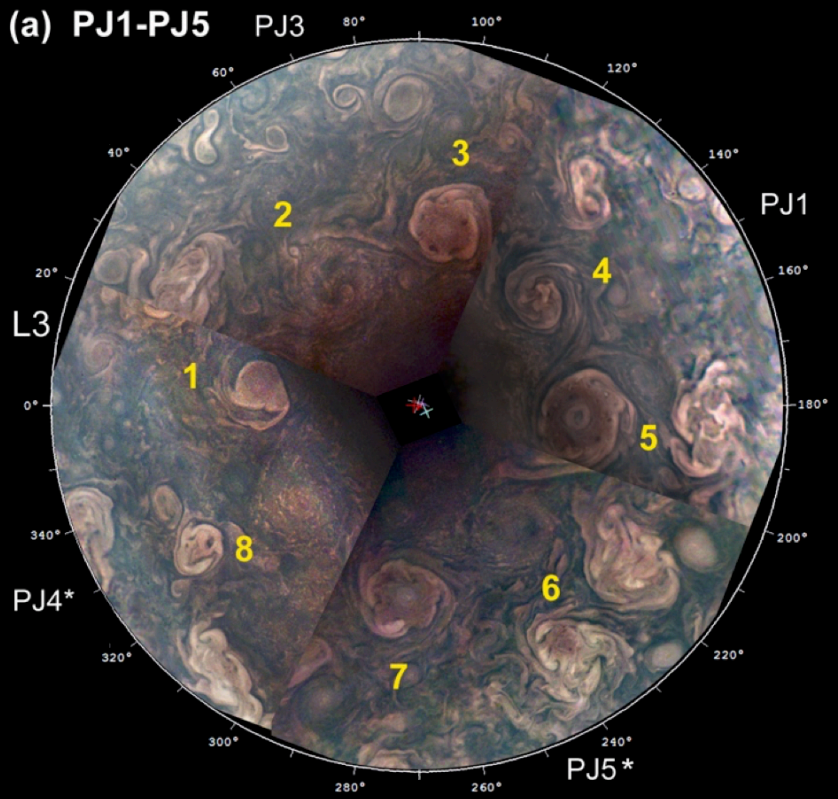
North pole: Long-term evolution





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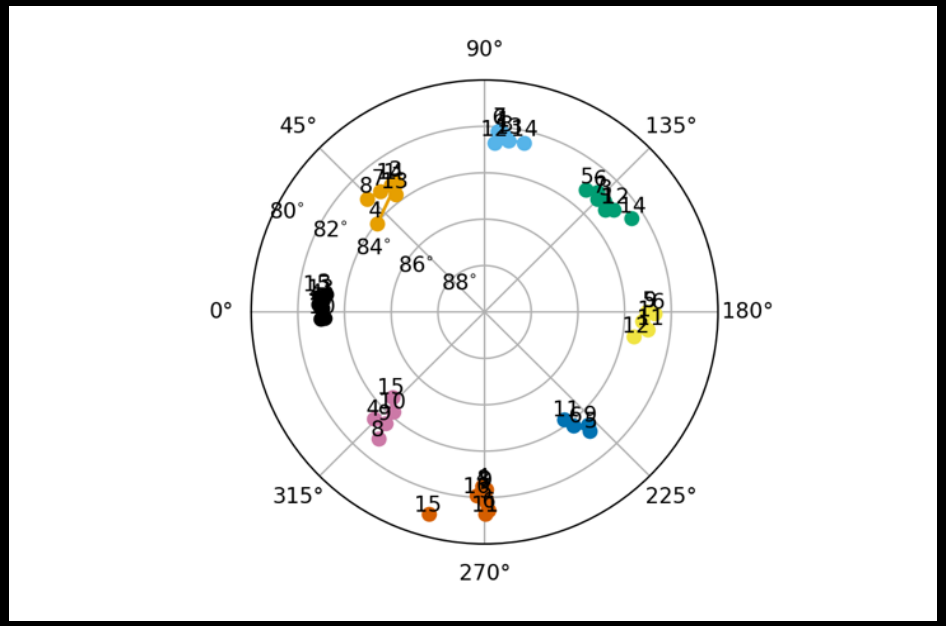
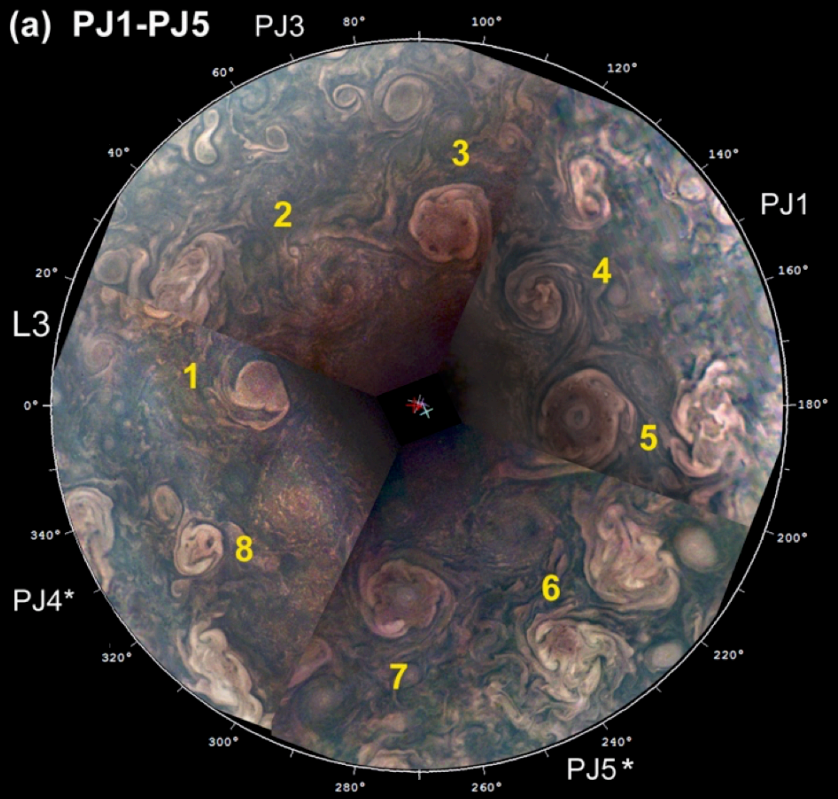
North pole: Long-term evolution





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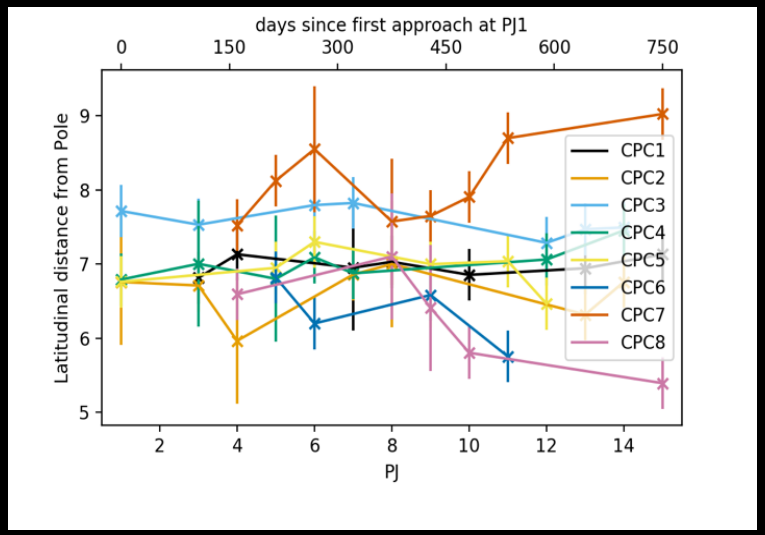
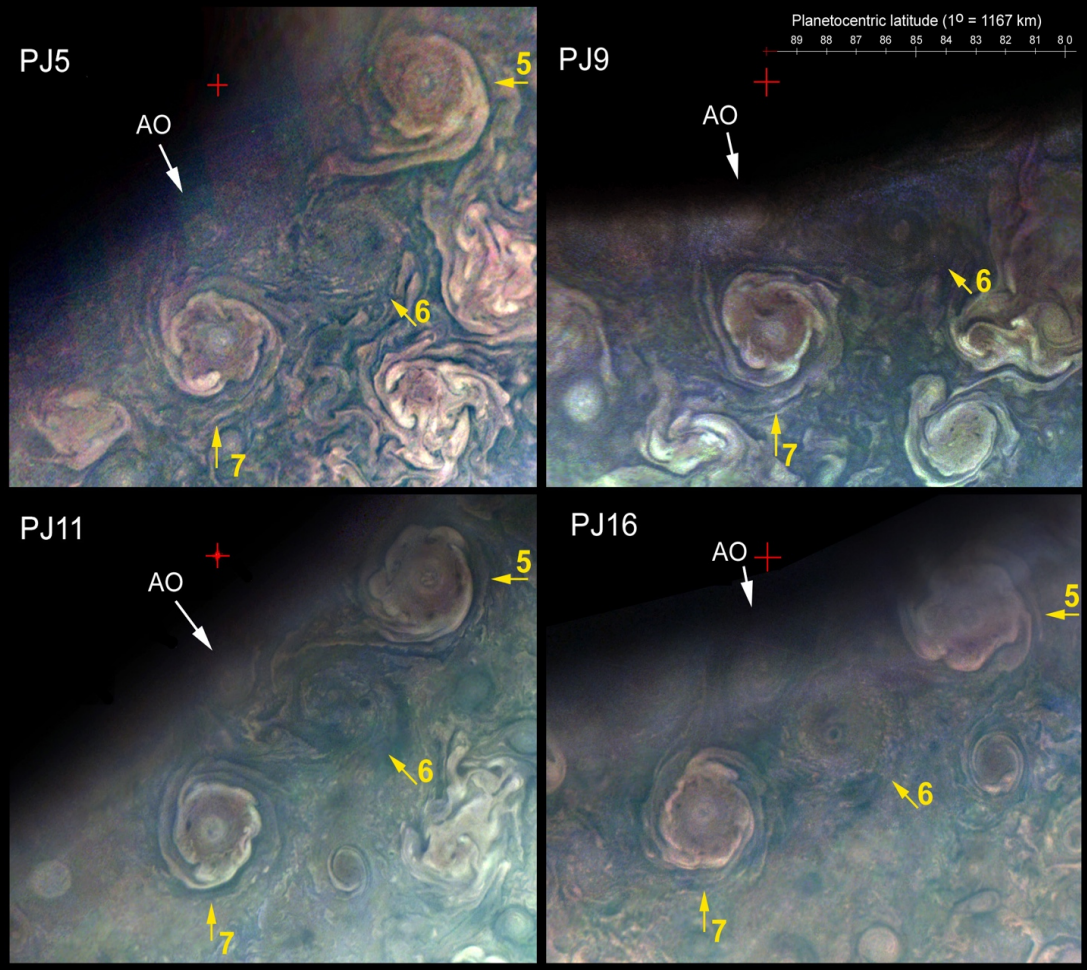
North pole: Long-term evolution





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