Dynamics of Jupiter's polar cyclones

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Description

The *Juno* spacecraft has recently revealed shortcomings in our understanding of Jupiter's atmosphere. In particular, the planet's poles host regularly-spaced cyclonic vortex structures, whose configuration should be unstable yet they remain persistent over long periods. This PhD project will study these cyclonic structures at Jupiter's poles using a General Circulation Model, to try to understand the physical processes driving these strange phenomena.

Nearly fifty years on from the first spacecraft fly-by of Jupiter in 1973, many aspects of its atmosphere remain poorly understood. As NASA's *Juno* spacecraft unlocks the secrets of Jupiter's deep interior, and with future missions such as ESA's *JUICE* and potential missions to the ice giants in mind, the coming years will be crucial for our understanding of giant planet atmospheres. Jupiter and the other giant planets in our Solar System are archetypes for gaseous planets around other stars, and are some of the best natural examples of 2D turbulence on a rotating sphere. Important phenomena not yet fully understood about the giant planets include the energy sources for large scale circulation, moist convective processes, the relationship between flow on different scales, the vertical structure below the clouds and into the deep interior, the evolution of large-scale flow, the source of small-scale waves and equatorial stratospheric oscillations, Saturn's polar hexagon, the cyclones at Jupiter's poles, the distribution of lightning and ammonia, large storms, and the effects of impacts and other events.

Numerical simulations are key to further advances in these areas. They help test ideas in the absence of complete observations, identify the smallest set of processes that explain particular phenomena, and allow the effects of particular physical processes to be isolated. In recent years significant progress has been made simulating giant planet atmospheres using numerical simulations of varying complexity. The Jason GCM, based on the MITgcm and developed at the University of Oxford, simulates Jupiter's upper troposphere and lower stratosphere. It qualitatively reproduces several of the major features of Jupiter's weather layer, such as the banded jet structure, eastward equatorial jet, typical zonal jet speeds, and a variety of turbulent vortices.

To study Jupiter's polar atmosphere, this project is likely to include the following stages:

- Technical work to convert the Jason GCM's horizontal grid from longitude-latitude to cubed-sphere. This will solve the "polar convergence problem", where grid cells become very small near the pole, requiring artificial damping of the flow. This change will allow the polar regions to be simulated properly.
- A series of high-resolution simulations will then be carried out to explore Jupiter's polar cyclones. We shall run simulations starting from the observed cyclone configuration, and also study whether the model can spontaneously generate these cyclones.

- We shall also explore how more idealised configurations of cyclones behave, evolve, and interact, varying the number of cyclones, distance from the poles, size, depth, and whether there is a central cyclone.
- Moist convection is an important process in giant planet polar regions. The Jason GCM includes moist convection, but several improvements could be made to the scheme. In particular, water clouds are generally too thick, probably because precipitation is not included, so this shall be added to the model.
- This work will require Juno polar wind measurements to compare the model against. Raw images are available via NASA's Planetary Data System. Time permitting, this project may also involve selecting appropriate images and retrieving polar winds, using a technique previously used to map Jupiter's global wind structure.

This project will suit a keen theoretical/computational person who is excited about using state-of-the-art numerical simulations and some of the most recent spacecraft observations of the giant planets. There may be opportunities for collaboration with colleagues in the UK, France, and the USA.

Recommended reading

A. Adriani et al. (2018), "Clusters of cyclones encircling Jupiter’s poles", Nature, 555, 216-219, 10.1038/nature25491.

A. R. Vasavada & A. P. Showman (2005), "Jovian atmospheric dynamics: an update after Galileo and Cassini", Rep. Prog. Phys., 68, 1935-1996, 10.1088/0034-4885/68/8/R06.

R. M. B. Young et al. (2019) "Simulating Jupiter's weather layer. Part I: Jet spin-up in a dry atmosphere", Icarus, 326, 225-252, 10.1016/j.icarus.2018.12.005.

Candidate Profile

Masters in Physics, Mathematics, or similar.

A good grade in advanced calculus is essential. A candidate who has also taken courses in atmospheric physics, fluid dynamics, or computational physics will be particularly attractive.

An aptitude for computer programming is essential, and experience would be highly beneficial. Any experience with Fortran will be looked upon very favourably.