Modeling Fluid Dynamics and Magnetic Fields on the Outer Planets

Understanding how convection influences the dynamics and magnetic field generation in planets directly supports the science objectives of NASA's Planetary Atmospheres and Outer Planets research programs to characterize and understand the dynamical processes and circulation of planetary atmospheres and interiors.

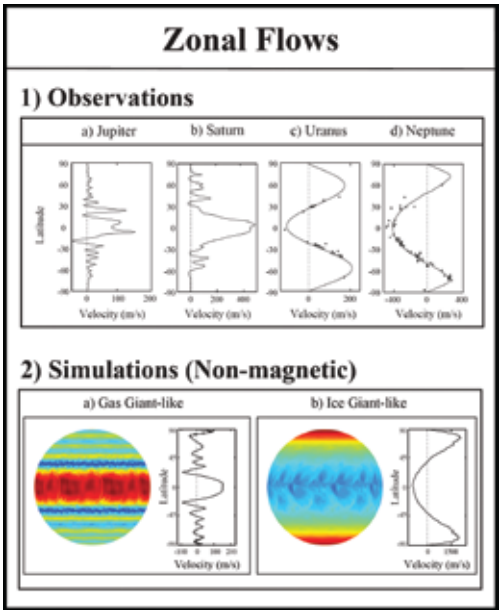
We seek to understand zonal flow and magnetic field generation in planetary interiors by simulating convection and dynamo action in rotating spherical shells. The Giant Planets of our solar system are a natural application for this work, as there is a sharp dichotomy in zonal flows (east-west winds) and magnetic fields between the Gas Giants (Jupiter and Saturn) and the Ice Giants (Uranus and Neptune) that cannot yet be explained.

The Gas Giants are characterized by multiple, latitudinal wind jets and dipolar magnetic fields, while the Ice Giants have only three jets and non-dipolar magnetic fields. Toward the ultimate goal of explaining why the Ice Giants are fundamentally different from the Gas Giants, the objectives of this project are to:

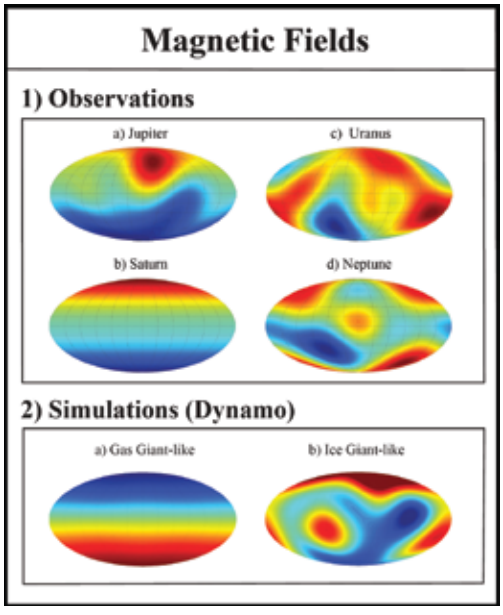
- Understand what drives Gas Giant-like and Ice Giant-like zonal flows in non-magnetic convection simulations (top figure)
- Determine under what conditions non-dipolar magnetic fields are generated in dynamo simulations (bottom figure)
- Predict when these dynamical regimes may be applicable to planets
- Couple the zonal flow and magnetic field generation processes in a single model for each planetary regime

This research will also provide detailed models to be compared with data returned by the Voyager, Galileo, Cassini, New Horizons, and upcoming Juno missions.

Our simulations would not be possible without super-computing capabilities. The Schirra supercomputer (IBM POWER5+, 320 dual-core processors) at the NASA Advanced Supercomputing facility is an ideal platform for our numerical experiments, as it scales well using OpenMP parallelization and is well suited for data-intensive computations.



1) Observed profiles of zonal velocities in the cloud layers of the Giant Planets. 2a) Gas Giant-like and 2b) Ice Giant-like simulations. Left panels: outer boundary zonal flow. Red (blue) indicates eastward (westward) flows. Right panels: corresponding azimuthally-averaged profiles.



Surface radial magnetic fields of the 1) Giant Planets, 2a) Gas Giant-like simulation, and 2b) Ice Giant-like simulation. The colors represent field intensity where red (blue) indicates outward (inward) directed field; each planet is plotted with its own color scale.

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