Ground-Based Science to Enable Ice Giant Missions

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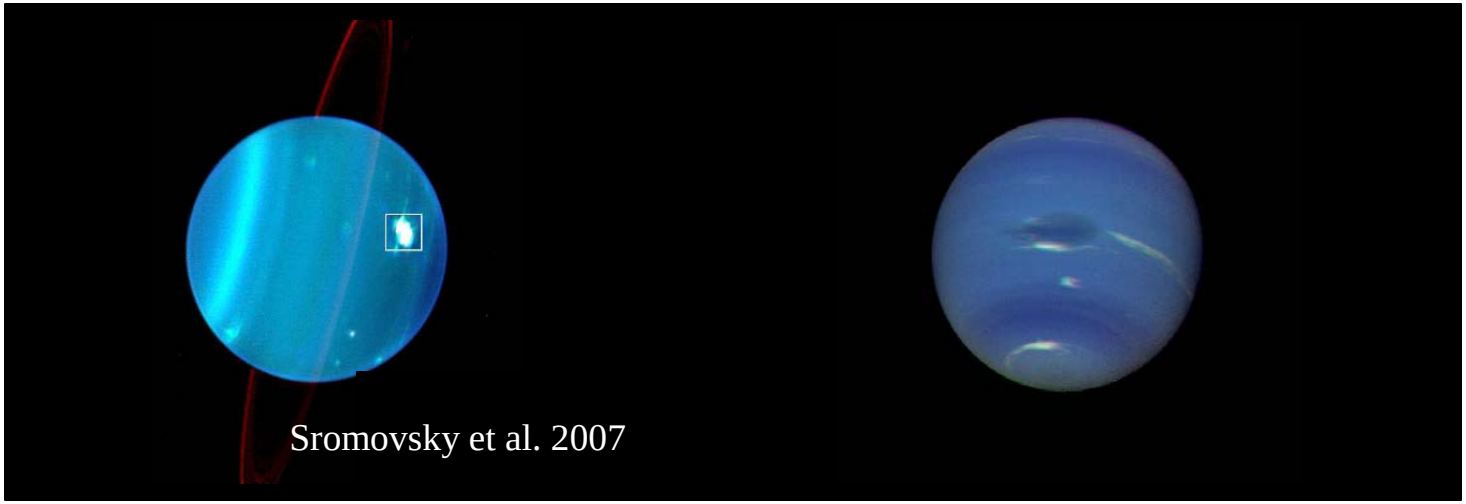


The Problem

There are some mission ideas for the Ice Giants which require a key bit of knowledge to make them viable. Often, however, that bit of knowledge requires a mission to acquire the information. How can we break this “chicken and egg” problem?

What we Found

We did not identify any magic-bullet ground-based work that would **enable** a mission. We did identify some useful things to do.

Looking for Problems and Solutions

In December 2013 posed the issue via e-mail to ~170 Ice Giant fans. Over the next month, 20 people contributed to the discussion.

Discussions and presentation at the January 2014 OPAG meeting in Tucson. Minor refinements immediately after the meeting.

People Engaged

Parul Agrawal
Sushil Atreya
Martin Burgdorf
Shawn Brooks
Ted Dunham
Jim Friedson
Jeff Hall
Mark Hofstadter
Steve Miller
Julie Moses
Glenn Orton
Abigail Rymer
Evgeniy Sklyanskiy
Tom Stallard
Matt Tiscareno
Zibi Turtle
Daniel Wenkert
Padma Yanamandra-Fisher
Eliot Young
Leslie Young

Candidate Questions Identified (1 of 2)

"What is the atmospheric density of Uranus and/or Neptune in the 10 mbar to 1 µbar region (~100-300 km above the 1-bar level)?"

- Needed for aerocapture missions if wish to use flight-proven entry body shapes.
- Ideas discussed include measurements (IR spectrosopy for the low-altitude region, stellar occultations and H3+ emission for the high altitudes) and modeling (atmospheric dynamics, seasonal effects, upper atmospheric heating mechanisms).

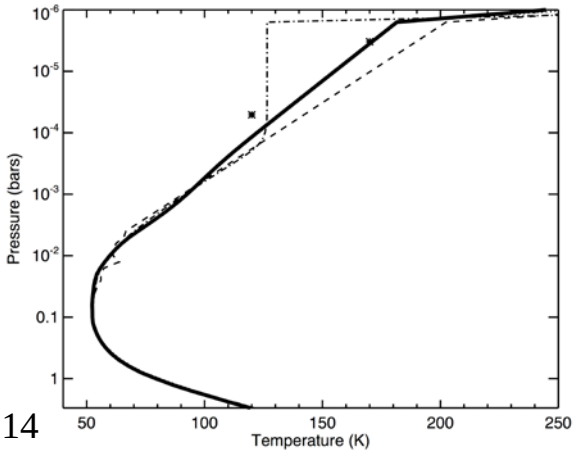
But keep in mind there are also technology work-arounds.

- Having a higher lift-to-drag ratio (L/D) on the entry body compensates for trajectory and atmospheric uncertainties.
- High entry velocities (with tougher thermal protection requirements) can partially mitigate uncertainties.

Current Assessment: Upper Atmospheric Density

Valuable measurements can be made and models improved, but they are unlikely to eliminate the need for a new entry shape.

- Visible and UV stellar occultations (e.g. Young et al. 2001).
  - Potentially covers 1 microbar to 1 millibar.
  - Uncertainties in average density can be small (5%), but absolute vertical structure not well constrained.
  - Limited opportunities in both time and lon/lat space.
- Mid-IR spectroscopy (e.g. Orton et al. 2014).
  - Covers <1 millibar to >1 bar.
  - Uncertainties in density 5% at pressures > 1 mbar, but >>30% and model-dependent at pressures << 1 mbar.
  - Limited vertical resolution.
- Atmospheric modeling required to
  - Extrapolate occultation lon/lat/season to aerocapture location.
  - Estimate fine-scale atmospheric vertical structure deep, large-scale at high altitudes.

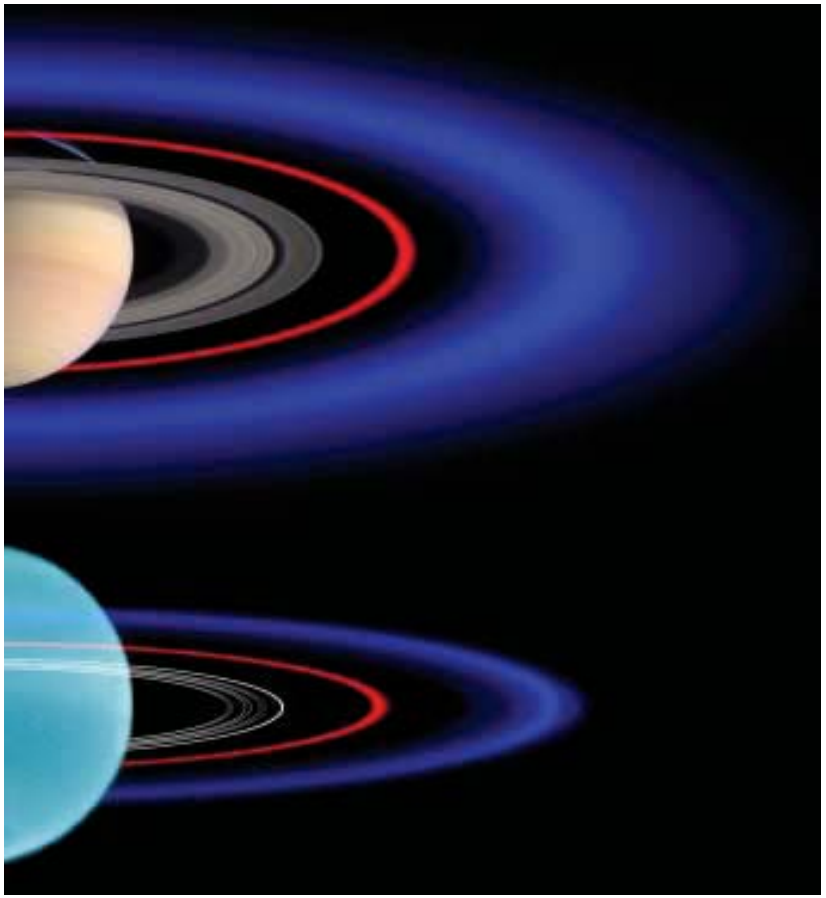


Orton et al. 2014

Candidate Questions Identified (2 of 2)

"What is the distribution of ring particles between 1-bar and the innermost of the known rings?"

- Needed to identify safe trajectories for orbit insertion, probe insertion, gravity measurements.
- Ideas include stellar occultations, theoretical work, and re-analysis of Voyager data.



de Pater et al. 2006

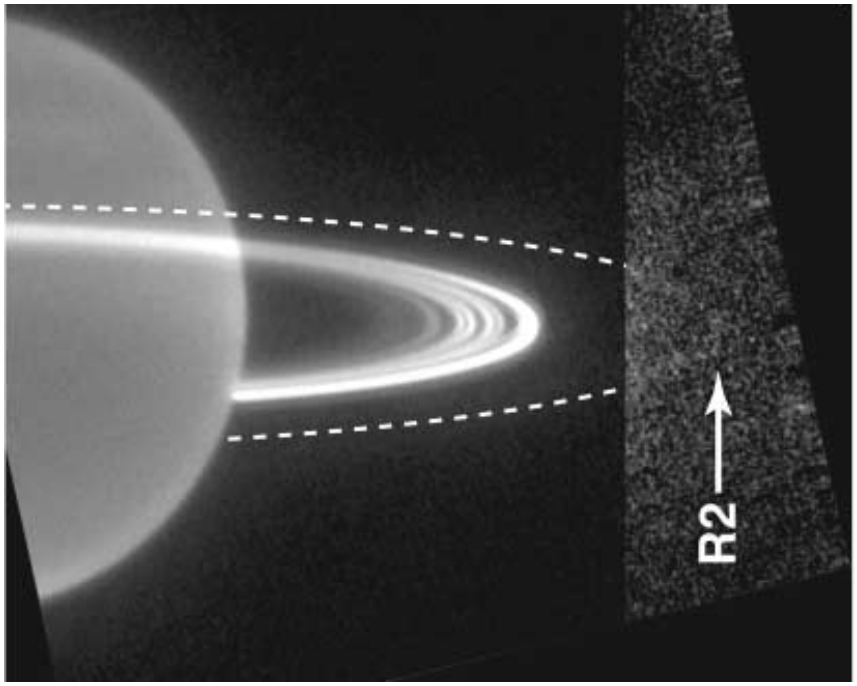
Current Assessment: Ring Hazard

No "magic bullet" observation to make from the ground or near-Earth with current assets that can confidently minimize the risk.

- Just a few small particles can ruin your day.
- Existing instruments do not meet the demanding sensitivity and stability requirements (photometry to 1 part in 10^7).

Will learn from the Juno and Cassini Proximal missions.

A specially-designed instrument might do it (Kepler achieves precision of better than 10 ppm).



de Pater et al. 2006

Possible Next Steps

For upper atmospheric structure:

Iterate with engineers to determine how valuable the measurements/modeling we envision will be. Can ground-based work bring us across a tipping point that makes it much easier to find a workable entry body shape?

Advocate for occultation observations and mid-IR spectral imaging, along with upper atmospheric modeling, to help future aerocapture missions.

For assessing the ring hazard:

Reconcile our estimates with what New Horizons has done.

Await knowledge gained from Juno and Cassini and see how it impacts ring models.

Think about a dedicated instrument/mission.

Website:

http://www.hou.usra.edu/meetings/icegiants2014/

This workshop is designed to review the current state of knowledge of the ice giant atmospheres, satellites, rings, magnetospheres, and interiors, identifying science priorities, and providing traceability to future missions. Topical discussions will be broad, with an eye toward big-picture questions, including exoplanet science and the need for supporting observations, laboratory work, and modeling. The expected outcomes of this workshop include raising awareness on the importance of ice giant planet system science and prioritizing the discipline-specific science goals. We envision the results of this workshop will guide future Decadal Survey, Cosmic Vision, and other mission studies.