National Aeronautics and Space Administration

FY24 Strategic Initiatives Research and Technology Development (SRTD)

Using Microwave Radiometers and Gravity Science to Probe Uranus's Deep Atmospheric Circulation and Interior Structure

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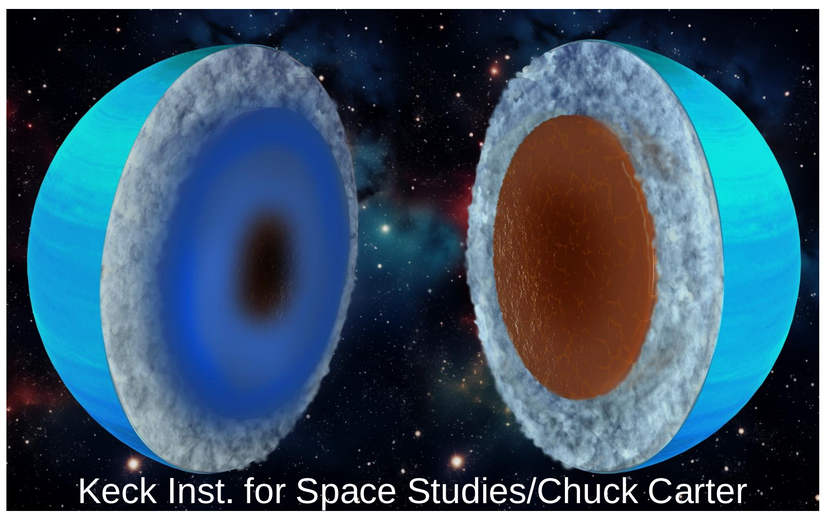
Strategic Focus Area: Ice Giant Science Leadership | **Strategic Initiative Leader:** David H. Atkinson/Leslie Tamppari


Keck Inst. for Space Studies/Chuck Carter

Is Uranus mostly water or rock? If water, is it liquid or solid? We are developing techniques and designing the mission to answer these and other compelling questions about Uranus.

Objectives:

- Develop innovative ways to use Doppler tracking of a Uranus orbiter to study the interior structure of the planet.
- Use ground-based microwave observations to determine the composition and dynamics of the atmosphere and the extent to which the observable atmosphere exchanges mass and energy with deeper levels.

Background:

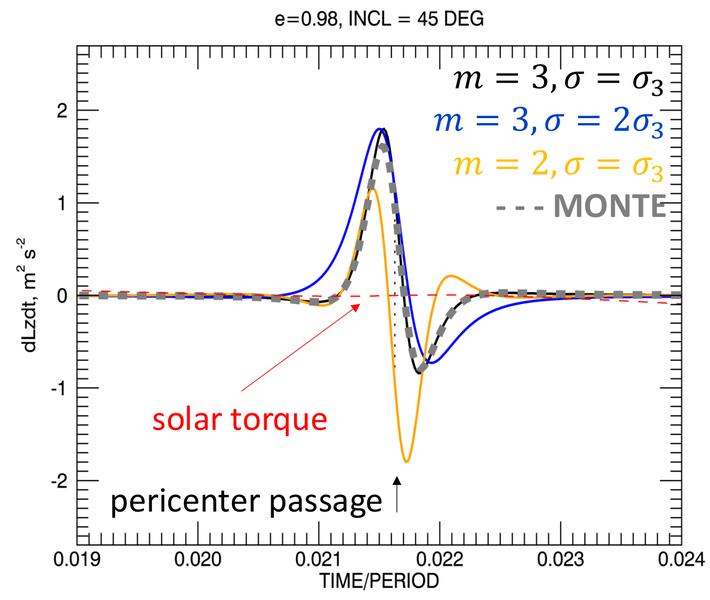
For the SR&TD: To maximize the science return from the expected Uranus Flagship mission and to enhance JPL's ability to assume leadership positions, we developed new techniques and performed new observations that advance our understanding of Uranus and that set mission and instrument requirements.

For gravity science: Planets have resonant frequencies at which they preferentially oscillate and moons raise tides on the planet. Both alter the mass distribution in ways that depend on the overall interior structure, and the changes can be detected via spacecraft Doppler tracking.

For microwave observations: A new ground-based radio telescope enables the first long-wavelength (~1 meter) studies of Uranus's deep atmosphere. Similar observations by the Juno spacecraft have revolutionized our understanding of Jupiter (Bolton et al. 2017, *Science* **356**).

Approach and Results:

- Traditional Doppler analyses are not able to identify specific planetary oscillations (Markham et al. 2020, *PSJ* **1**). We used orbital simulations to determine that retrieving the torques on a spacecraft's orbit does allow one to identify the frequency and amplitude of oscillations that reveal interior structure. We also find that typical giant-planet orbital tours could detect tides and distinguish between solid and fluid interiors.
- Making the first observations of Uranus at wavelengths of 45 and 85 cm, we found the composition and temperature of the atmosphere at pressures from ~1 to ~100 bars does not accurately predict conditions in the ~100 to 1000 bar range. This suggests our models of atmospheric chemistry and the temperature lapse rate are incorrect or there is limited exchange between upper and lower troposphere.
- Observations at wavelengths from 0.7 to 20 cm between 1981 and 2023 have allowed us to identify seasonal changes in atmospheric circulation, characterize the small-scale banding seen, and to confirm via spectral identification the presence of H_2S in the upper troposphere of Uranus.



We can distinguish among oscillations with similar frequencies by the differing torques placed on a spacecraft (solid lines). Using JPL's MONTE orbit simulation software we retrieve frequency and phase to ~0.5%, amplitude to 16%.

Significance/Benefits to JPL and NASA:

- Our new method for detecting planetary oscillations allows a determination of interior structure while placing minimal demands on spacecraft resources.
- Our ground-based radio observations have made fundamental scientific discoveries and allow us to set instrument requirements for a future orbiting microwave radiometer.
- We have successfully proposed to NASA's ROSES program, bringing new funds to JPL and attesting to the scientific value of our work.

Acknowledgements:
Drs. J. Fuller (Caltech) and C. Mankovich (JPL) made contributions to this effort.

National Aeronautics and Space Administration

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RPD-170 Clearance Number: CL#24-5133

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Publications:

A. Akins, M. Hofstadter, B. Butler, A.J. Friedson, E. Molter, M. Parisi, and I. de Pater, "Evidence of a Polar Cyclone on Uranus from VLA Observations," *GRL* **50**, e2023GL102872 (2023).

M. Parisi, A.J. Friedson, C. Mankovich, M. Hofstadter, A. Akins, R. Karimi, and D. Landau, "Uranus Orbiter and Probe: A Radio Science Investigation to Determine the Planet's Gravity Field, Depth of the Winds, and Tidal Deformations," *Plan. Sci Jour.* **5**:116

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