The State of Knowledge of Ice Giant Interiors.

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Introduction: Uranus and Neptune belong to a distinct class of planets called the "Ice Giants". This name was developed to distinguish them from the "Gas Giant" planets, Jupiter and Saturn, because Uranus and Neptune possess much smaller gaseous envelopes (10-20% of their mass as H_2 and He) than their Gas Giant cousins.

Ice Giant planet interiors are far-less understood due to their lack of study by spacecraft – Voyager 2 remains, to this day, the only spacecraft to visit these planets. In addition, their much more distant locations in the solar system and cooler temperatures make them difficult objects to study from facilities located in the vicinity of Earth.

State of Knowledge: In order to determine the bulk composition of these planets we need knowledge of the ice-to-gas and ice-to-rock ratios in addition to the absolute abundances of the Noble gases and water. These are required to deduce the conditions in the planetary nebula and the planet formation process [1]. The extent to which gas and the heavier components are segregated or well-mixed will provide clues about when they were incorporated and how much mixing occurred. Deducing these components provides clues as to their chemical and thermal evolution.

To determine the interior density profile of these planets the gravitational moments must be measured to good accuracy. These values can be measured by a spacecraft coming close to the planet. Currently J_2 and J_4 are known but J_6 has not been determined. The known gravitational moments impose that the bulk density of Uranus and Neptune is composed of heavier elements "ices", namely -- oxygen, carbon, nitrogen, and sulfur that were incorporated at the protoplanetary stage either as solids or as gases trapped in a water-ice clathrate [2].

Uncertainties in the gravity field, shape, and rotation period affect the inferred planetary interior because modifying the solid-body rotation periods for these planets greatly alters their derived internal structures [3].

Differences: Uranus and Neptune have significant differences. Neptune has a larger mean density in comparison with Uranus. This requires that there must be slightly different composition between the two and Neptune must have either more heavy elements (compared to H_2 and He) or a larger rock-to-ice ratio.

These planets possess hot interiors and a large amount of energy has to be transported from the interior to the top of the atmosphere by radiation, conduction and convection [2]. However, Uranus is known to have a annomolously low internal heat flux especially in comparison to Neptune. Uranus is famous for its large obliquity (98°**)** and models that assume homogeneity of each layer and adiabatic temperature profiles fail in reproducing the gravitational moments. Is the interior of Uranus not homogeneously mixed? If so, heat would not be able to escape by convection but would have to go through a much slower diffusive process. This could therefore be the reason for the low internal heat flux of Uranus. Could the obliquity of Uranus be causing this stratification and be part of the reason for its inability to release heat?

Conclusion: A clear understanding of the interior structure of the Ice Giants is needed to deduce the conditions in the planetary nebula and the planet formation process [1]. The great advances in exo-planet discoveries from Kepler have also brought to light the importance of our Ice Giants at home. A class of exoplanets similar in size to our Ice Giants is continuing to grow due to the highly successful Kepler mission [4] and the more we investigate the interior of our own planets the more we may reveal about these worlds beyond our solar system.

In this presentation the state of knowledge of the interior structure and thermal balance of both Uranus and Neptune will be reviewed. This will set the ground-work for discussion of spacecraft requirements in order to build on the knowledge in this field.

References:

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