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In situ exploration of Icy Giant Planets with entry probe

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Abstract

A comprehensive exploration of the Uranus and/or Neptune system is essential to understand the formation of the giant planets in particular and the solar system in general. Noble gases are key, and they can only be acquired by entry probes. Complimentary data on orbiter, especially gravity and magnetic field will help constrain the formation models even more robustly.

1. Introduction

The icy giant planets are also important for understanding the nature and workings of roughly 40 per cent of the 4000 confirmed exoplanets that are mini-Neptune to Neptune in size (2-5 times larger than Earth). While Jupiter and Saturn have been explored extensively by flyby, orbiter, and a probe (Jupiter) missions, only brief flyby observations of Uranus by Voyager 2 in 1986 and Neptune in 1989 have been done so far. Observations from 1 AU are also quite limited in scope. Considering their importance of the icy giants to the solar system and the extrasolar systems, an orbiter-probe mission is needed to carry out detailed investigation of the atmosphere, charged particle environment, satellites and rings, and to understand the formation of the icy giant planets. This presentation focuses on the science critical to the question of planet formation, whose implementation requires *in situ* measurements by entry probes.

2. What's known?

Abundances of the heavy elements and their isotopes are required to address the formation question. In Uranus and Neptune, the only heavy element determined to date is carbon (C/H) from ground-based observations of methane, whereas in Jupiter abundances of most heavy elements have been determined as a result of the Galileo entry probe measurements, and Juno is determining the ammonia and water abundances (Figure 1, [1]).

3. Entry probe

Because of their very cold atmospheres, the cloud levels in the Icy Giants are much deeper and there are potentially other greater sinks for water and ammonia below the clouds, so the determination of the oxygen and nitrogen elemental abundances is unlikely. On the other hand, the noble gases and their isotopes provide equally compelling constraints on the planet formation and volatile delivery scenarios [2]. Moreover, being chemically inert and primordial, noble gases are going to be uniform all over the planet, and not affected by local dynamics or meteorology of the probe entry site, unlike the condensibles, methane, ammonia, hydrogen sulfide and water. Noble gases can only be measured in situ with entry probes.

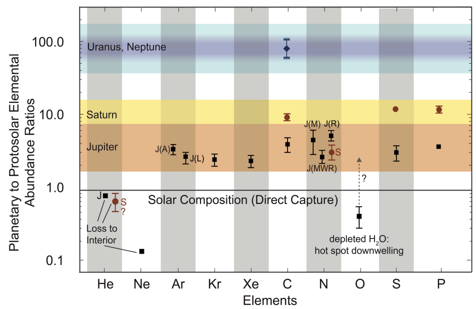
Besides the heavy noble gases, Ar, Kr and Xe, helium and neon ratios (He/H, Ne/H) are extremely important to measure, as they provide an insight into the planet's energy balance and interior processes. They can be measured only *in situ*. Stable gas isotopes including D/H, carbon, nitrogen and possibly sulfur isotopes also inform of the origin, evolution and the volatile delivery. Entry probes only can make those measurements. For context and modeling, precise pressure-temperature profile from the exosphere to probe depth is required. That can be done only by entry probe using an atmospheric structure instrument.

4. Orbiter

Gravity and magnetic field measurements by orbiter are very important complement to the probe data on composition. Feasibility of carrying out a measurement of depth profile of ammonia and water by a Juno-like microwave radiometer on orbiter needs to be studied. Though the measurement of the

O/H and N/H elemental ratio in Uranus and Neptune seem unlikely by MWR also, a depth profile of water and ammonia can provide valuable insight into the tropospheric dynamics.

Fig. 1. Elemental abundances in the giant planets (Atreya et al. 2019).



4. Implementation

An orbiter-probe mission to the icy giants requires no new mission enabling technology. Certain advanced technology developments, such as cryopropulsion, enhanced radioisotope power sources, and availability of Space Launch System (SLS) may enhance the science return, however.

References

[1] The Origin and Evolution of Saturn, with Exoplanet Perspective" S. K. Atreya et al., in *Saturn in the 21st Century* (K. H. Baines et al., eds.), pp. 5-43, Cambridge University Press, 2019. [2] Mousis, O. et al. O. Mousis, et al., Scientific rationale for Uranus and Neptune in situ explorations. *Planet. Space Sci*. 155 (2018) 12-40.