EPSC Abstracts
Vol. 12, EPSC2018-74, 2018
European Planetary Science Congress 2018

A Joint NASA/ESA Mission Concept for In Situ Probe Explorations of the Ice Giants

D.H. Atkinson[1], O. Mousis[2], T.R. Spilker[3], A. Coustenis[4], M. Hofstadter[1], J.-P. Lebreton[5], K. Reh[1], A.A. Simon[6]

[1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109 USA (David.H.Atkinson@jpl.nasa.gov), [2]Aix Marseille Université, CNRS, Laboratoire d'Astrophysique de Marseille, UMR 7326, 13388 Marseille, France, [3]Independent Consultant, [4]LESIA, Observ. Paris-Meudon, CNRS, Paris Univ., France, [5]CNRS-Universitè d'Orlèans, 3a Avenue de la Recherche Scientifique, 45071, Orlèans Cedex 2, France, [6]NASA Goddard Space Flight Center, Greenbelt, MD, USA

Abstract

1. Introduction

The top-listed goal in the NASA 2018 Strategic Plan is to "Expand Human Knowledge through New Scientific Discoveries", with a key Strategic Objective to *Understand the Sun, Earth, Solar System, and Universe*. The outer solar system comprises many unexplored bodies within which exists evidence of solar system origin, formation, and processes central to the evolution of the solar system. The ice giants Uranus and Neptune are a largely unexplored class of planet that has received only the briefest of glimpses by the Voyager 2 spacecraft. The value of further studying the ice giants as essential to understanding the solar system is reflected in the Planetary Sciences Decadal Survey Vision and Voyages 2013-2022 recommendation of a Uranus orbiter and probe as the highest priority new start Outer Planet flagship mission [1]. Following up on that, a joint NASA-ESA study of potential ice giant missions was recently completed [2]. Preliminary planning for the ESA Cosmic Visions 2050 prioritizes an M-class mission contribution to a possible future NASA flagship ice giant mission, utilizing a unique planetary alignment in 2028-2032 [3].

The ice giant planets fill the gap in size between the larger gas giants and the smaller terrestrial planets including Earth. Aside from the initial reconnaissance by Voyager 2, to date much of our knowledge of ice giant cloud-top composition and atmospheric processes arises from distant observations from space-based telescopes and observatories on Earth. However, whether from Earth or from a local spacecraft, remote observations cannot directly provide unambiguous measurements of the abundances of noble gases and key isotopes, as well as the altitude profiles of atmospheric thermal and energy structure, stability and dynamics, composition, and cloud properties. [4]

Due to the physical limitations of remote sensing and the lack of *in situ* measurements, many of the most important physical and atmospheric properties of the ice giants are poorly constrained and the ultimate role of the ice giants in the evolution of the Solar System is currently impossible to ascertain. Only *in situ* exploration by a single or multiple descent probes can reveal the secrets of the deep, well-mixed atmosphere that contains clues from the epoch and location of ice giant formation. Of particular importance are the chemically inert noble gases. With no detectable radio signature and therefore requiring direct sampling, the noble gases reflect the processes of ice giant origin, formation, and evolution, including the delivery of heavy elements, and evidence of possible giant planet migration.

A mission concept for a flagship mission to one of the ice giants includes a NASA-provided spacecraft that would carry and deliver a European probe to the ice giant atmospheric entry interface point, and would subsequently act as a relay receiving station for the atmospheric probe science telemetry. The primary goal of the European ice giant atmospheric probe would be to measure the well-mixed abundances of the noble gases He, Ne, Ar, Kr, Xe and their isotopes, the altitude profile of the heavier elements C, N, S, and P, key isotope ratios $^{15}N/^{14}N$, $^{13}C/^{12}C$, $^{17}O/^{16}O$ and $^{18}O/^{16}O$, and D/H, and disequilibrium species CO and PH_3 which act as tracers of internal processes. The atmospheric probe would sample well into the cloud-forming regions of the troposphere where many cosmogenically important and abundant species are expected to be well mixed, far below regions directly accessible to cloud top remote sensing.

Throughout the atmospheric descent, the probe would measure pressure and temperature to provide valuable context for the composition measurements, the vertical thermal and energy structure and static stability, the location, density, and composition of the upper cloud layers, as well as direct tracking of the planet's atmospheric dynamics including zonal winds, waves, convection and turbulence.

It is important to recognize that a single probe can make the most critical measurements of noble gases and isotopic ratios, as atmospheric weather and circulation do not significantly alter those abundances in the troposphere. Multiple probes are most valuable for studying horizontally varying conditions due to weather, seasonal, and circulation-driven processes.

The ice giant planets represent the last unexplored class of planets in the solar system and along with super-Earth sized planets (up to 2x Earth diameter), Uranus-Neptune sized planets are the most frequently observed exoplanets. Extended studies of one or both ice giants would include interiors, moons, rings, magnetospheres, origins, and atmospheres. In particular, detailed studies of atmospheric structure, processes, and composition, noble gas abundances require *in situ* measurements from an entry probe to further constrain models of solar system formation, chemical, thermal, and dynamical evolution, the formation and evolution of atmospheres, atmospheric processes, and to provide further ground-truth for many exoplanetary systems.

Additionally, the ice giant planets offer laboratories for studying the dynamics, chemistry, and processes in other planetary atmospheres including that of Earth. By extending the legacy of the Galileo Jupiter probe mission and possibly a future Saturn entry probe mission, an ice giant probe or probes would further discriminate between and help refine theories addressing the formation, and chemical, dynamical, and thermal evolution of all the giant planets, the solar system including Earth and the other terrestrial planets, and lend significant insight into the formation and structure of exoplanetary systems.

Acknowledgements

This research was carried out in part at the Jet Propulsion Laboratory, California Institute of Technology, under contract with NASA. Government sponsorship acknowledged. O. Mousis acknowledges support from CNES.

References

[1] Squyres, S., et al., "Visions and Voyages for Planetary Science in the Decade 2013-2022," National Academies Press (2011).

[2] Hofstadter, M.D., Simon, A.A., Reh, K., Elliott, J., and the ice giant study team. Ice Giants Pre-Decadal Survey Mission Study Report. JPL Document number 100520 (2017). Available at http://www.lpi.usra.edu/icegiants/mission_study/

[3] Hasinger, Gunther, "Cosmic Vision – Exploration of the Universe," European Geosciences Union Annual Meeting, Vienna, Austria, 2018.

[4] Mousis, et al., Scientific rationale for Uranus and Neptune in situ explorations Pl. Sp. Sci., 2017. In press https://doi.org/10.1016/j.pss.2017.10.005