

## Scientific rationale for Uranus and Neptune in situ explorations

\*Olivier Mousis<sup>1</sup>, David H. Atkinson<sup>2</sup>, Thibault Cavalié<sup>3</sup>, Leigh N. Fletcher<sup>4</sup>, Michael J. Amato<sup>5</sup>, Shahid Aslam<sup>5</sup>, Francesca Ferri<sup>6</sup>, Jean-Baptiste Renard<sup>7</sup>, Thomas Spilker<sup>8</sup>, Ethiraj Venkatapathy<sup>9</sup>, Peter Wurz<sup>10</sup>

1. Aix Marseille Université, CNRS, LAM (Laboratoire d' Astrophysique de Marseille) UMR 7326, 13388, Marseille, France, 2. Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA, 91109, USA, 3. LESIA, Observatoire de Paris, PSL Research University, CNRS, Sorbonne Universités, UPMC Univ. Paris 06, Univ. Paris Diderot, Sorbonne Paris Cité, 5 place Jules Janssen, 92195, Meudon, France, 4. Department of Physics & Astronomy, University of Leicester, University Road, Leicester, LE1 7RH, UK, 5. NASA Goddard Space Flight Center, Greenbelt, MD, 20771, USA, 6. Università degli Studi di Padova, Centro di Ateneo di Studi e Attività Spaziali "Giuseppe Colombo" (CISAS), via Venezia 15, 35131, Padova, Italy, 7. CNRS-Université d' Orléans, 3a Avenue de la Recherche Scientifique, 45071, Orléans Cedex 2, France, 8. Solar System Science & Exploration, Monrovia, USA, 9. NASA Ames Research Center, Moffett field, CA, USA, 10. Space Science & Planetology, Physics Institute, University of Bern, Sidlerstrasse 5, 3012, Bern, Switzerland

The ice giants Uranus and Neptune are the least understood class of planets in our solar system but the most frequently observed type of exoplanets. Presumed to have a small rocky core, a deep interior comprising ~70% heavy elements surrounded by a more dilute outer envelope of H<sub>2</sub> and He, Uranus and Neptune are fundamentally different from the better-explored gas giants Jupiter and Saturn. Because of the lack of dedicated exploration missions, our knowledge of the composition and atmospheric processes of these distant worlds is primarily derived from remote sensing from Earth-based observatories and space telescopes. As a result, Uranus's and Neptune's physical and atmospheric properties remain poorly constrained and their roles in the evolution of the Solar System not well understood. Exploration of an ice giant system is therefore a high-priority science objective as these systems (including the magnetosphere, satellites, rings, atmosphere, and interior) challenge our understanding of planetary formation and evolution. Here we describe the main scientific goals to be addressed by a future in situ exploration of an ice giant. An atmospheric entry probe targeting the 10-bar level, about 5 scale heights beneath the tropopause, would yield insight into two broad themes: i) the formation history of the ice giants and, in a broader extent, that of the Solar System, and ii) the processes at play in planetary atmospheres. The probe would descend under parachute to measure composition, structure, and dynamics, with data returned to Earth using a Carrier Relay Spacecraft as a relay station. In addition, possible mission concepts and partnerships are presented, and a strawman ice-giant probe payload is described. An ice-giant atmospheric probe could represent a significant ESA contribution to a future NASA ice-giant flagship mission.

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