

## Icy Giant Planet Exploration

\*Sushil K Atreya<sup>1</sup>, Mark D. Hofstadter<sup>2</sup>, Amy Simon<sup>3</sup>, Kim R. Reh<sup>2</sup>, Olivier Mousis<sup>4</sup>, Krista Soderlund<sup>5</sup>

1. University of Michigan Ann Arbor, 2. Jet Propulsion Laboratory, 3. Goddard Space Flight Center, 4. Laboratoire d'Astrophysique de Marseille, 5. University of Texas at Austin

Giant planets hold the secrets of solar system formation, and there is much interest in their exploration. They also serve as analogs for the giant planets in extrasolar systems. While Saturn-Jupiter sized exoplanets number about 500, mini-Neptune and Neptune sized objects (2-5 times Earth) comprise nearly half of approximately 4000 confirmed exoplanets to date. Since the early 1970's, spacecraft have explored the gas giants, Jupiter and Saturn, extensively using flybys, orbiters and an entry probe (at Jupiter). Voyager 2 is the only spacecraft ever to visit the two icy giants, with a flyby of Uranus in 1986 and Neptune in 1989. Though the Voyager instruments were optimized for observations of Jupiter and Saturn, tantalizing data were collected at Uranus and Neptune as well. Those data have raised such fundamental questions as: did Uranus and Neptune form in the same manner as the gas giants, did they form at their present orbital locations or not, what role did migration play in their formation and evolution, why (and how) does Neptune generate internal heat, whereas Uranus does not, what is responsible for their intrinsic magnetic fields in the absence of a metallic hydrogen phase, why are the rings of Uranus different from Neptune's rings and what's maintaining them, why does Neptune's moon Triton possess an atmosphere of nitrogen and methane, etc. To address these questions and others requires a comprehensive exploration of the icy giant planet systems by an orbiter-probe spacecraft at Uranus or Neptune or both [1], like the Galileo orbiter-probe mission at Jupiter. International partnership is most desirable for maximizing the science return of such a mission. [1] M. Hofstadter, A. Simon, K. Reh, J. Elliott, and the NASA Ice Giants Science Definition Team, Ice Giants Pre-Decadal Survey Report (2017) NASA-JPL-ID-100520, [https://www.lpi.usra.edu/icegiants/mission\\_study/Full-Report.pdf](https://www.lpi.usra.edu/icegiants/mission_study/Full-Report.pdf)

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