'It Takes a Village.' Collaborative Outer Planet Missions. A. M. Rymer[1], E. P. Turtle[1], M D. Hofstadter[2], A A. Simon[3], and G B. Hospodarsky[4]
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Introduction: A mission to one or both of our local Ice Giants (Uranus and Neptune) emerged as a high priority in the most recent Planetary Science Decadal Survey [1] and was also specifically mentioned supportively in the Heliophysics Decadal Survey [2]. In 2016, NASA convened a science definition team to study ice giant mission concepts in more detail [3]. Uranus and Neptune represent the last remaining planetary type in our Solar System to have a dedicated orbiting mission. The case for a Uranus mission has been made eloquently in the Decadal Surveys. Here we summarize some of the major drivers that lead to enthusiastic support for an Ice Giant mission in general, and use the example of a Uranus Mission concept to illustrate opportunities such a mission might provide for cross-division collaboration and cost-sharing.

Context and Motivation: The Cassini spacecraft has been able to make unprecedented observations of the heliosheath during its tour of the Saturnian system, due to a fortuitous combination of the capabilities of its instrumentation and the vision of a small group of plasma physics experts who recognized the opportunity post launch [4]. Future missions might not include such a comprehensive instrument suite without deliberate prior planning.

Opportunity: A mission to the outer solar system provides numerous opportunities for cross-disciplinary science and collaboration, including, but not limited to:

1) Heliophysics. Studies of the heliosphere via inclusion of energetic neutral atom (ENA) imaging technology could be performed during cruise and, like Cassini, make observations of both planetary and heliospheric ENA emission during an orbital tour.

2) Exoplanets. Exoplanetary studies would certainly benefit from *in situ* study of Uranus and Neptune since the majority of exoplanets that have been discovered are also Ice Giants [*e.g.,* 5]. Measurements at infrared to millimeter wavelengths of dust in the inner solar system, looking inward from the outer solar system, could also be compared with what is seen when looking at proto-planetary and planetary disks around other stars to help put observations of distant solar systems in context.

3) Interstellar Probe. It is conceivable to combine an Ice Giants mission with the long desired follow up to the two Voyager spacecraft in the form of an "Interstellar Probe" to investigate the structure of the furthest reaches of our solar system and its interaction with the interstellar medium [6]. In this scenario, Ice Giant orbiter(s) and probe(s) could be dropped off en route to the intergalactic medium.

4) Astrophysics. Instrumentation could be specifically designed to make useful long-wavelength radio observations of the cosmic microwave background during interplanetary cruise to an Ice Giant planet and then to perform deep sounding of the atmosphere and satellites of the Ice Giant itself.

5) Interagency collaboration. Other agencies (*e.g.,* ESA, JAXA) are pursuing many of the same overarching goals [*e.g.,* 7] and there is much that a combination of agencies could achieve that a single agency alone cannot. However, different timelines and mission development processes can hamper coordination. As an example of one strategy to foster collaboration, NASA missions of opportunity have helped US participation in missions being developed by other agencies. The 'directed good fortune' represented by NASA MoOs is an excellent model which we suggest can be more broadly applied.

These examples highlight how cooperation across NASA Divisions and between space agencies furthers the specific goals the Planetary Science Division has identified for this workshop. Most strongly, the "Origins" theme is addressed, using observations of solar system planets and the Sun's magnetosphere to connect our mature solar system to young and forming exoplanetary systems. (Cosmological studies would also address "Origins" in the most inclusive sense.) And interagency collaborations can enhance or enable investigations in all the Workshop's themes, by either expanding the scientific payload possible compare to a NASA-only mission, or in the extreme by enabling a mission that would not be feasible for budgetary or other programmatic reasons.

Recommendation: Future missions, including a long anticipated voyage to Uranus and Neptune should consider not just the directed mission, but also ways to make the most of other logistical and scientific opportunites along the way. In this presentation we will provide examples of what has been achieved through both fortuitous and directed collaboration and suggest strategies to enable cross-division collaboration and cost-sharing to improve collaboration over the upcoming decades.

References:

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