Future Exploration of Ice Giant Systems

Royal Society, London, January 20-22 2020

#IceGiants2020
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https://ice-giants.github.io

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In January 2020, the international Ice Giants community met in London for a three-day meeting to review the scientific potential, mission concepts, and future strategy for coordination on the exploration of these distant worlds. With more than 200 attendees, this was one of the largest discussion meetings hosted by the Royal Society in recent memory, filling their Wellcome Trust lecture theatre. It was also the largest gathering of Ice Giant scientists, engineers, mission planners, policymakers, and industry to date, highlighting the increasing momentum and enthusiasm for an ambitious new mission to Uranus and/or Neptune. The participants made clear their overwhelming excitement and optimism for exploring the Ice Giants as the next logical step in our exploration of the Solar System.

The following memorandum outlines the key findings of the meeting and is split into two halves – (i) our notes on the path ahead in the coming years; and (ii) our notes on the meeting format. We stress that this is a grassroots effort led by the community, and does not represent the thoughts of either national or international space agencies. This document does not attempt to review the scientific discoveries and discussions that were presented in London, but we note that, while important research on the Ice Giants continues today, an ambitious new mission is now required to dramatically advance our understanding of these enigmatic objects. Even if we were to launch at the end of the 2020s, more than half a century will have elapsed since humankinds' first and only encounters with these worlds (Voyager 2). The Ice Giant systems (encompassing the planet interiors, atmospheres, rings, satellites, and magnetospheres) fundamentally challenge our understanding of the formation, evolution, and habitability of planetary systems. We hope that the #IceGiants2020 meeting served to unite this community towards the goal of a paradigm-shifting mission of discovery to the Ice Giants, which will contribute to shaping planetary science for a generation.

Notes on the Path Ahead:

1. **Cross-Disciplinary Relevance of an Ice Giant Mission – the "Elevator Pitch":** Presentations throughout the meeting made an excellent case for the scientific potential of an Ice Giant System mission, but whilst the breadth and wealth of scientific questions argues for a flagship/large-class mission, the community lacks a focussed and cohesive central theme. Such a unifying theme is sorely needed to engage the wider scientific community (e.g., exoplanetary science, heliophysics, planetary formation, etc.), and to create an easily-articulated "elevator pitch" for an Ice Giant mission that might appeal to policymakers, industry, and member states. Many suggestions were proposed but need significant additional refinement: using the exploration of the Ice Giants to unlock the secrets of the most common outcome of planetary formation (e.g., Neptune-sized exoplanets); understanding the formation history of our solar

[1] Christopher Arridge was also a co-convenor of this meeting but is also co-chairing ESA's Voyage 2050 activity, to which Ice Giant whitepapers were submitted, and so recuses himself from co-signing this document. This document also benefitted from discussions with Olivier Mousis and Olivier Witasse.

system; searching for icy oceans in the distant solar system; etc. We urge the community to work to better-articulate these central themes, focussing on a core message.

2. **ESA's Council of Ministers (CMIN19):** We are extremely grateful to the ESA Director of Science, Günther Hasinger, for highlighting the value of Ice Giant exploration as one of the "four pillars" of the science proposal to ESA's Council at Ministerial Level (CMIN19, or #Space19plus). We recognise that the timing of the "M*" (medium-class) mission request, before the outcome of the US Decadal Survey is known in 2022, meant that it could not be properly proposed and developed during the November 2019 meeting. After initial discussions between ESA and its Member States prior to CMIN19, it was considered better to leave the M* concept for a later CMIN. Nevertheless, the small investments that have been made by ESA (three CDF studies over the past 18 months; participation in the joint NASA-ESA science study team in 2017) have proven to be invaluable to the European community, and we would warmly welcome continued ESA support for Ice Giant mission concept studies between now and the next CMIN (expected in 2022), when the outcome of the US Decadal will be known. The community stresses that ongoing ESA support will be necessary, even at a low level, to develop a robust proposal ahead of the next Council of Ministers meeting (~2022), if a US-Europe partnership mission is to remain viable.
3. **Importance of European Member State Advocacy:** There is a misleading perception that European scientists should be solely "lobbying ESA" to push forwards an Ice Giant mission to the next phase. Whilst there is a place for such advocacy (e.g., the Voyage 2050 process), grassroots focus should be equally weighted towards national funding agencies, who ultimately prepare a package of recommendations for their Ministers. Mission/instrument teams must acknowledge that funding is scarce and must be prioritised: for example, national funding agencies are unlikely to be able to fund instrument development for multiple ESA missions simultaneously, with the end of the 2020s being particularly tight (ATHENA, LISA, ARIEL, M5, etc.). National funding agencies will be seeking to balance the scientific excellence, hardware development opportunities, and industry investments across multiple projects, in addition to their contributions to ESA's science budget. It is therefore imperative that European consortia emphasise the extreme value of Ice Giant exploration to their own countries at every opportunity, so that the agencies might compel Ministers to respond positively at such a time when a future Ice Giant mission is proposed to ESA's Science Programme Committee (SPC) and CMIN (hopefully in 2022). Furthermore, we encourage strong involvement with commercial and industrial partners to create positive momentum within ESA member states. Both the clarity of the mission theme (point 1) and the value to an individual country should be important considerations during this advocacy.
4. **Timescales:** Numerous studies have now shown that the window of opportunity to utilise a Jupiter gravity assist (GA) for Neptune (2029-30) is more challenging for a partnership mission (i.e., ESA, NASA, and other national agencies working together) than a mission to Uranus. Opportunities to reach Uranus with a GA are plentiful between 2030-34, with continued possibilities extending into the mid- and late-2030s. As a consequence of these planetary alignments, partnership mission concept studies that target Uranus, rather than Neptune, are deemed to have a more realistic chance of success/funding in the coming decade. However, we note that this absolutely does not discount NASA-led missions at an earlier date (if supported by the upcoming US Decadal and successful in competitive mission selections), or ESA-led missions as part of Voyage 2035-2050 (if supported by the Senior Survey Committee and approved by the SPC). Furthermore, whilst we fully support and encourage the exploration of alternative launch systems (and trajectories that do not require a GA) for an Ice Giant mission as a game-changing technology, we emphasise that trajectories with gravity assists are available with today's launch capabilities.
5. **US Planetary Decadal Survey:** The US Decadal Survey process is starting in earnest, and is a key "decision gate" for an ambitious mission to an Ice Giant System. The breadth of the science, and

the clarity of message, must be emphasised via the submission of white papers to the Survey Committee. However, we also urge all Ice Giant scientists to respond to any and all requests from the Decadal Panels (e.g., provide information, presentations, and representation whenever you are asked). Furthermore, white papers that reach beyond the "usual" planetary science themes and explore cross-cutting opportunities (exoplanets, heliophysics, planet formation, small bodies, the use of the cruise phase for astronomy, etc.), as well as preparatory laboratory experiments, will be extremely valuable, particularly if they help to identify *core themes* for the Decadal and emphasize why an Ice Giant System explorer can address many of those themes. In summary – it is likely that no missions (either partnership or independent) could proceed unless the Ice Giant community successfully makes its case to the US Decadal with a clear message in 2020-22. At the time of writing, we expect white papers to be due in summer 2020, with a draft report prepared by October 2021, for release in March 2022. A preliminary list of proposed white papers is available here.

6. **Unity of Message:** The 2020 workshop largely avoided a discussion of whether Uranus or Neptune should be explored first, and echoed previous statements that both worlds are compelling and wholly deserving of orbital exploration. The decision between the two will likely come down to programmatic considerations, risk, and the urgency of the launch timeline. The conference attendees were keen to emphasise that, whichever target is chosen, the unity of the community must be strong and resolute, backing whichever destination is chosen. We hope that the international community will respond with a unity of message and purpose when an Ice Giant System explorer becomes a reality.
7. **Ongoing European Study Activities:** With this in mind, we strongly urge ESA and European member states to continue their active mission concept development, recognising that Uranus is the more realistic prospect for launch opportunities in the 2030s. This will be of considerable importance if ESA's Voyage 2050 survey were to prioritise a science theme relevant to Ice Giant exploration in the near future. We particularly urge mission and instrument concept developments that are adaptable to different mission flavours (ESA-led, NASA-led, NASA-ESA partnership missions). The European community are keen to develop robust, feasible, and properly costed proposals for partnership missions that could proceed quickly after 2022, should the US Decadal Survey favour an Ice Giant mission in the near term, so that this could be presented to ESA's SPC and Council of Ministers. We emphasise the strong risk of delaying any activities until 2022, given the lengthy development timescales for previous missions, and urge ESA and European member states to initiate this work as soon as possible.

Notes on the London Meeting:

1. **Meeting Structure and Organisation:** The Royal Society meeting was split into four distinct phases: (i) plenary reviews and discussion, dealing with high-level science and mission ambitions, favourable to policymakers, stakeholders, and industry without delving into the detail of each science theme; (ii) mission and instrument-themed posters so that the full range of ideas could be represented; (iii) two parallel splinter meetings on the final day (at two of London's Learned Institutions at Burlington House: the Royal Astronomical Society and Geological Society), when more technical scientific discussions could be held with a smaller audience; and (iv) a series of review papers to be published in Philosophical Transactions of the Royal Society A, summarising both the plenary reviews, and the cutting-edge science presented during the splinter sessions. The organisers and attendees felt that this worked extremely well, and would like to extend their gratitude to all the staff at the Royal Society, Royal Astronomical Society, and Geological Society, for enabling the success of this meeting.
2. **Allowing Discussion Time:** The organisers experimented with having 2-3 review talks back to back, before having the speakers return to the stage for an extended Q&A session. This allowed audience members time to think of discussion points, whilst also digesting material from

multiple (related) topics. This style appeared to go down well and encouraged active discussion, and we would certainly recommend it for future meetings of this nature.

3. **Increasing Diversity:** The science organising committee worked to ensure that gender and career stage were well balanced throughout all stages of this meeting, and we feel that the high quality of the presentations were a consequence of this careful planning. We are also extremely grateful that the Royal Society offered to cover childcare arrangements for some of our organisers and plenary speakers, which further enabled wide participation. However, we recognise that racial diversity was strongly lacking at this meeting, primarily as a consequence of the lack of diversity within our community. We are keen to highlight this failing, in the hope that it can be improved in forthcoming community meetings, and so that we can have the best scientific leaders for these future missions.
4. **Meeting Outputs:**
    a. Invited speakers will be writing short review-style articles for Philosophical Transactions of the Royal Society A. We are also open to any participants who may wish to submit their work as an outcome of this meeting. All reviews will be made open-access as soon as they are available, with final publication intended in the autumn of 2020. We hope these detailed reviews will aid authors of future white papers for the US Decadal Survey.
    b. Presentations from the meeting will be made permanently available via our website: https://ice-giants.github.io/ [Preliminary locations for presentations here: https://github.com/ice-giants/papers/tree/master/presentation]
    c. Photographs from the event are being hosted here, including a group photograph taken on Tuesday 21st January in the Marble Hall of the Royal Society: https://www.flickr.com/photos/186601760@N03/
    d. The meeting organisers used social media in attempt to generate wider excitement for proposed missions to the Ice Giants. You can view some of the conversations here: https://twitter.com/hashtag/IceGiants2020
    e. Audio recordings of presentations will be collated by the Royal Society, and will be hosted alongside the conference programme here: https://royalsociety.org/science-events-and-lectures/2020/01/ice-giants/

Finally, we wish to thank all the participants at the 2020 workshop for their optimism and enthusiasm, which contributed to a successful meeting. We thank the Royal Society for funding and hosting the discussion meeting, and the members of the science organising committee for developing the programme. We hope that this meeting will be seen as an important stepping stone towards our vision of seeing an ambitious Ice Giant System explorer in the coming decades.

Warm Regards,
The #IceGiants2020 SOC

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