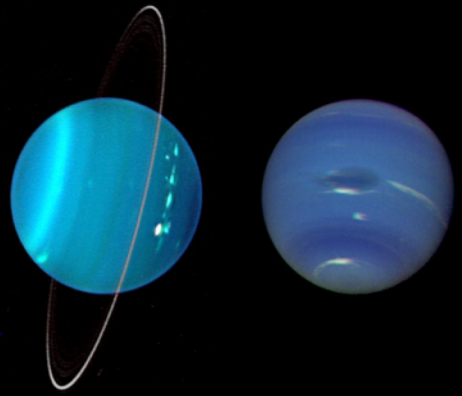


Uranus (left, Sromovsky et al. 2007) and Neptune (right, Voyager)

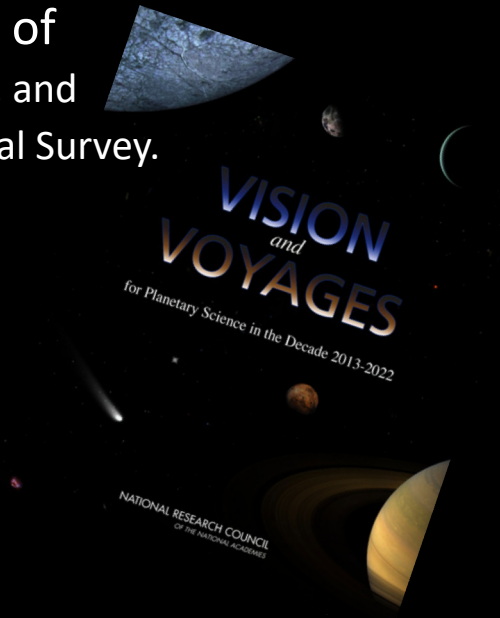
~~U.S.~~ A U.S. Scientist's Perspectives on Ice Giant Missions

Ice Giant Systems 2020
Scientific Discussion Meeting of the Royal Society, London

Mark Hofstadter (JPL/Caltech)

I. My perspective is...

- My own opinion, shaped by conversations with many of you in this room.
- Not coming from a place of disappointment, in spite of
  - IG's not prioritized after the recent ESA Ministerial Meeting, and
  - NASA not initiating the 3rd Flagship of the 2013-2022 Decadal Survey.
- Rooted in optimism!
  - I believe an IG mission will happen in the coming decade.
  - It is our job to ensure the mission achieves as much as possible.



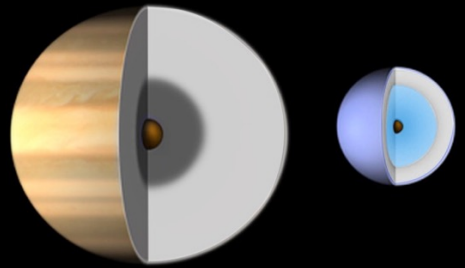
II. The case for an IG mission (1/2)

The science is compelling! As we're hearing at this workshop

- The Ice Giant *systems* are unexplored and very different from the Gas Giants.
- They challenge our understanding of planet formation, evolution, and physics.
- An ice giant flagship would engage all planetary science disciplines, as well as the heliophysics and exoplanetary communities.

Community support is strong

- Endorsement by NASA's Outer Planets Assessment Group (OPAG) every year since 2016.
- International Ice Giant workshops in 2013, 2014, 2019, and 2020.
- White Papers to the Heliophysics, Astrophysics, and Planetary Decadal Surveys.
- Mission proposals to ESA (M- and L-Class) and NASA (PMCS).



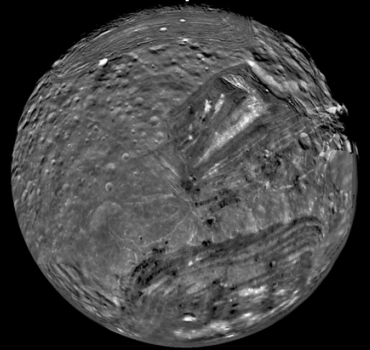
II. The case for an IG mission (2/2)

NASA, ESA, and other National Agencies have shown interest

- NASA's first and largest Pre-Decadal study was for IG missions, and it added a PMCS study.
- ESA has recently completed three studies: flight elements it could contribute to a NASA-led IG mission, a stand-alone probe mission, and a follow-up probe study.

There is a scientific need to initiate a mission soon

- Typical development times for a Flagship mission are ~10 years.
- Flight times (unless one commits to launch on an SLS) are ~10 years.
- Optimal launch windows are near 2030 and 2045 (particularly important for orbiters).
- BUT...launching to Uranus in the 2040's would mean not seeing the unexplored Northern Hemispheres of the satellites, while launching to Neptune would not arrive in time to test a leading model for Triton's plumes.

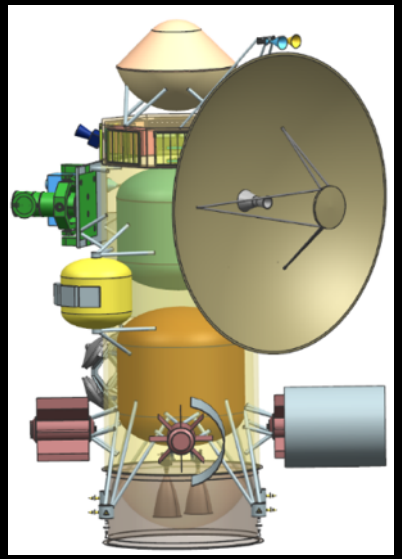


III. Missions: Science vs. Cost (1/4)

What we want: A fully instrumented orbiting spacecraft with atmospheric probe. This is required for addressing priority science goals across all elements of an IG system (interior, atmosphere, rings, satellites, and magnetosphere). Such a mission will put it in NASA's "Flagship" cost category (most likely $2 to $2.5B).

Missions focused on a subset of the desired science objectives can be much less expensive, even fitting in the Discovery cost cap (<$0.5B). An optimist might view these as a way to get a second spacecraft to an IG. But what if that's all we get?

International cooperation, allowing cost sharing among agencies, is an opportunity to maximize the science return.



Notional design from the 2017 NASA study

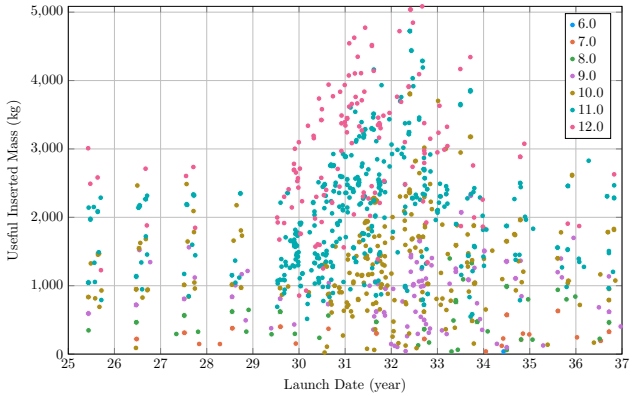
III. Missions: Launch Dates (2/4)

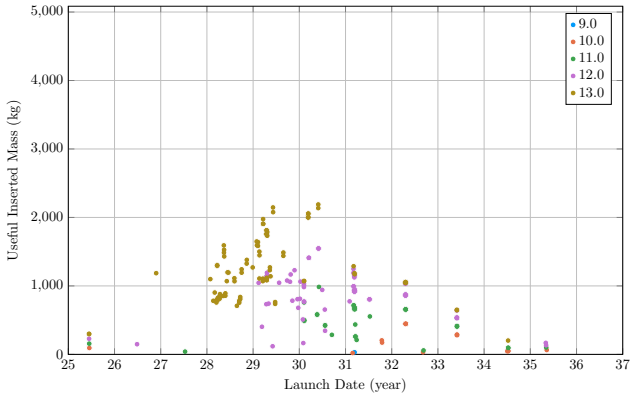
The greatest mass can be delivered utilizing a Jupiter gravity assist with a launch around 2029 for Neptune and 2031 for Uranus. The next opportunities are ~15 year later.

Figures below (from 2017 NASA study) highlight the value of Jupiter *for orbital missions.*

Launch year is less critical if you are doing a flyby (e.g. the Trident Discovery proposal) or if you are willing to commit to using the SLS (Space Launch System) under development for sending humans beyond Earth orbit.

Uranus





Neptune

III. Missions: Programmatic Factors (3/4)

Programmatic considerations are important factors in choosing future missions.

- Schedule
  - In the 2023-2032 time frame, optimal Neptune trajectories occur earlier than Uranus trajectories. If NASA starts a non-IG Flagship after Europa Clipper, it becomes difficult to get to Neptune. Smaller, competed missions would be less directly affected.
- Cost
  - In the last Decadal Survey, the IG mission was the least expensive Flagship recommended for flight.
  - It is less expensive to perform a given mission at Uranus than at Neptune.
- Risk
  - Studies indicate IG missions can be flown without any new technology efforts, though completion of a new, longer-lived radioisotope power supply is needed for a Flagship orbiter and completion of HEEET (thermal protection) is desired for an atmospheric probe.
  - New technologies can enhance an IG mission (see talks tomorrow and various posters).
  - Note that NASA's plutonium production plan assumes an Advanced RTG will be available for a Flagship launched around 2030.

III. Missions: Uranus or Neptune? (4/4)

To first order, Uranus and Neptune are equally compelling as science targets.

The planets are, however, not equivalent! Each has things to teach us the other cannot.

- Uranus has native satellites, Neptune a captured KBO.
- They appear to have different internal structures...which is the “normal” Ice Giant?
- Different processes are acting in their atmospheres, rings, and magnetospheres.

The Ocean World communities’ interest in Triton led OPAG to make Neptune its preferred target.

From the standpoint of understanding Giant Planets, some argue Uranus is the preferred target.

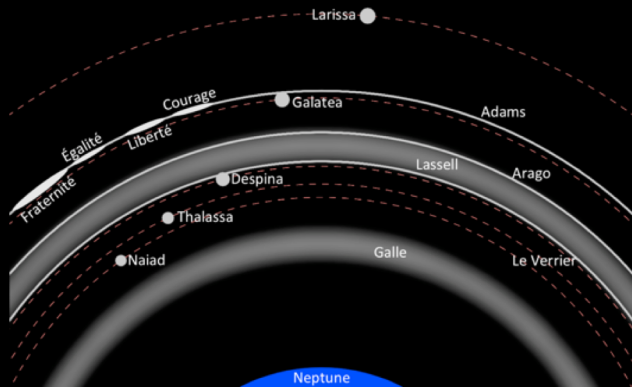
The science community would love to explore both Ice Giants.

- The planets are not aligned, so two spacecraft are required.
- ESA has studied options to fly an independent spacecraft.
- Cost, and the potential requirements for Plutonium, are limiting factors.

IV. The Importance of the Decadal Survey

The NASA Planetary Science DS will determine what, if any, U.S. mission is flown to an Ice Giant in the next decade.

- If an IG Flagship is chosen as the top priority, one is likely to fly.
  - To target Neptune, an early start is required or reliance on an advanced launch vehicle.
  - Would allow all aspects of an IG system to be explored, and ensures arrival early enough to either see the uranian satellite Northern Hemispheres or test Triton plume models.
- If an IG Flagship is selected at a low priority, a Neptune mission is particularly at risk.
- If there is no IG Flagship but the New Frontiers program is open to IG's
  - Many groups will propose, and I think their case is strong.
  - A limited set of science objectives will be targeted.
- If the DS does not specifically call for an IG mission
  - Additional Discovery proposals are likely and their case is strong.
  - Only one element of an IG system will be targeted.



IV. The Importance of ESA

While NASA and the DS controls the fate of the mission we *really* want to see flown, ESA is a critical player.

- ESA contributions can make a mission affordable to NASA and significantly enhance the science. In ESA's L-2/L-3 competition the SSC stated that ESA participation in a U.S.-led mission was the preferred path to IG's.
- ESA's desires can influence NASA's priorities/schedule in Flagship missions and in the specifics of competed missions.
- Can ESA fly a limited lifetime stand-alone mission to Uranus?

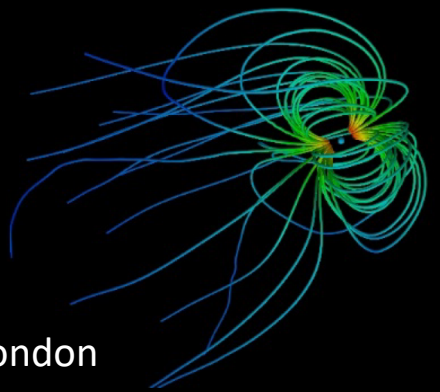


Image: Lars Majnertsen, Imperial College London

Key points

- Either planet is worthy of having a fully-instrumented Flagship orbiter doing system science, plus a probe.
- ~2030 is the right time to launch.
- Community support and the U.S. Decadal Survey are critical to making it happen.
- Write or endorse White Papers, continue doing science!

Uranus (left, Sromovsky et al. 2007) and Neptune (right, Voyager)

Questions/Comments?