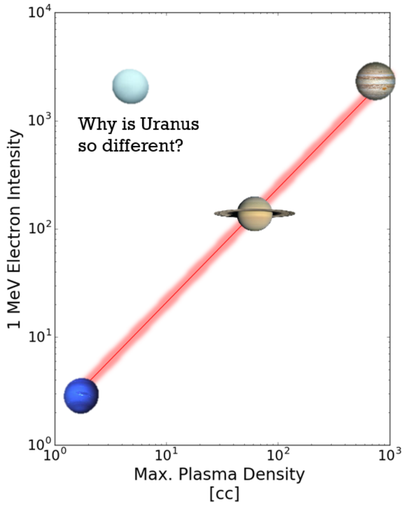
White Paper draft:

Magnetospheric measurements are important for a future Ice Giant mission

P. Kollmann (Peter.Kollmann@jhuapl.edu), I. Cohen, R. C. Allen, G. Clark, S. Vines, W. Dietrich, J. Wicht, I. dePater, M. Gkioulidou,
A. Masters, K. D. Runyon, A. Rymer, B. Mauk, R. McNutt Jr., P. Brandt, E. Roussos, R. Cartwright, V. Hue

Space physics mysteries

Radiation and plasma is found throughout the universe where it can exist under a wide variety of conditions, many of which are impossible reproduce here on Earth. This is why it is useful to use our solar system as a natural laboratory to study plasma and radiation.



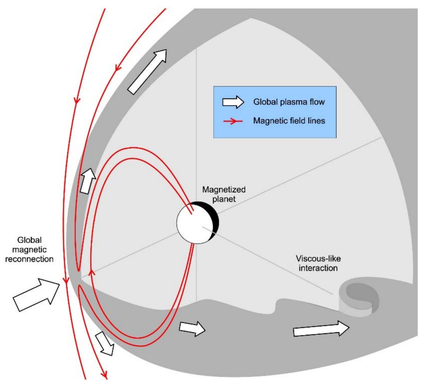
Uranus has strong electron radiation belts (Mauk+2014) **even though it lacks a strong source population** (Selesnick+84)**.** How can this be?

Radiation is are accelerated from plasma. Its intensities are balanced for example by atmospheric absorption. We do not seem to understand that balance at Uranus.

Our current knowledge from the inner planets appears insufficient to understand the Ice Giants. How do we then want to ever understand exoplanets?

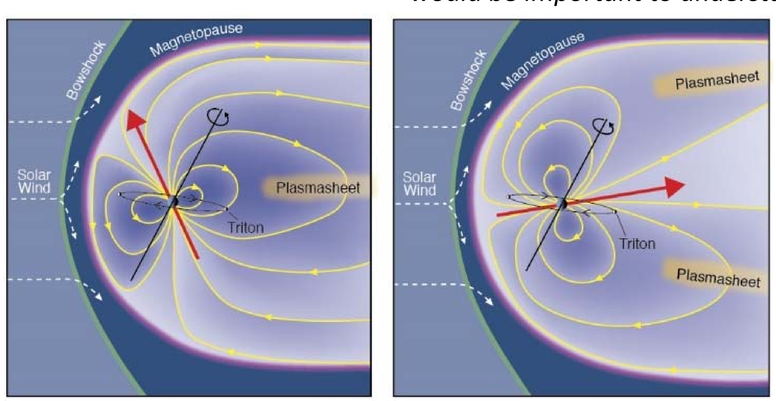
Uranus may be the best prototype for a solar wind driven magnetosphere (Selesnick+87), **yet it shows no evidence for solar wind plasma** (Mauk+87). What drives plasma flows in Uranus' unique magnetic configuration?

Earth is often called solar wind driven, yet its plasmasphere is rotationally driven. Uranus on the other hand does not have a plasmasphere (Selesnick+86).



Triton releases material (Richardson+91) **but we did not observe Neptune's magnetosphere shedding this plasma** (Mauk+91). How do magnetospheres far from their host star balance mass budgets?

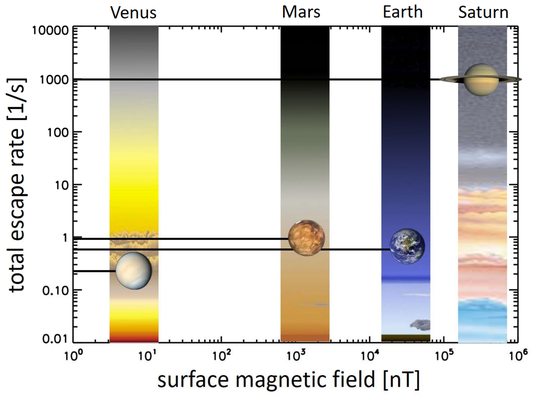
It has been suggested that the solar wind-magnetosphere interaction changes its nature fundamentally (from reconnection to Kelvin-Helmholtz) with distance to the Sun (Masters+18), which would be important to understand exoplanets. But is that true?



Neptune's plasma sheet changes every day from planar to cylindrical, unlike any other planet. Does this extreme difference reveal gaps in our basic understanding of magnetospheric physics?

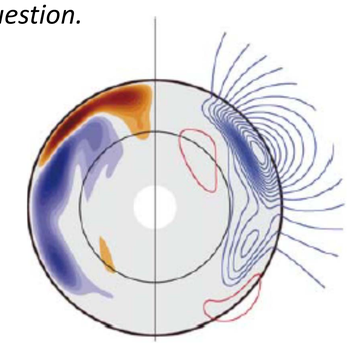
Magnetospheric measurements are essential to other disciplines

Radiation and magnetic measurements revealed the Enceladus plume (Dougherty+06), the Europa gas torus (Lagg+03), and the G ring arc (Hedman+07). Radiation leaves clearly visible patterns on moon surfaces (Schenk+11). Magnetic, plasma, and radiation measurements are used to infer subsurface oceans (Saur+10). Magnetic field measurements have been used to constrain planetary interior (Stanley+04, Connerney+18).

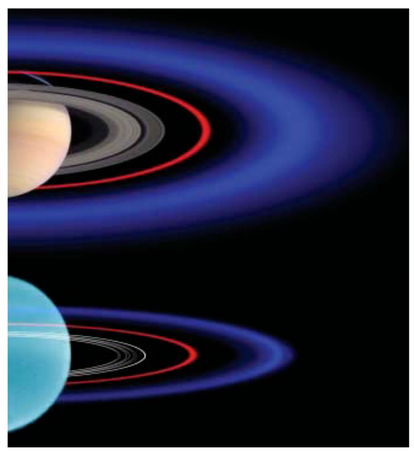


The magnetic fields of Ice Giants resemble Earth's during reorientation of its magnetic field (Glassmeier+10). **Do planetary magnetic fields affect atmospheric escape**, as it is commonly assumed (Moore+07, Wei+14)?

Differences between terrestrial planets appear to be in the noise, differences to Saturn and Jupiter might be too extreme. The Ice Giants may be the sweet spot to advance this question.



The magnetic fields of the Ice Giants are unlike those of other planets and may be explained with a dynamo driven by ionically conducting ice (Stanley+04). Yet, **we currently lack constraints to further study this theory.**



Uranus' μ-ring is blue from micron-sized grains (similar to Saturn's E-ring), even though Uranus lacks a geologically active moon. Can electromagnetic forces help understand the ring formation and evolution?

Plasma and radiation charge up ring grains, making them susceptible to magnetospheric fields. These may also explain the large time dependence of some Ice Giant rings.

Most of the Ice Giants' moons have dark surfaces (Cartwright+18). How is the weathered uppermost surface layer of these satellites related to their pristine composition?

The Icy Moons of the Ice Giants seem to have their subsurface oceans being frozen out. **What is the timeline for habitability of Ice Giant moons?**

A flyby is insufficient

Magnetospheres are highly dynamic. Therefore at least one orbiter is required if we want to disentangle trajectory/spatial/temporal effects.
Flybys and Earth-based observations were unable to determine that Enceladus is geologically active and the source for Saturn's E-ring, one of the major discoveries of the Cassini orbiter.