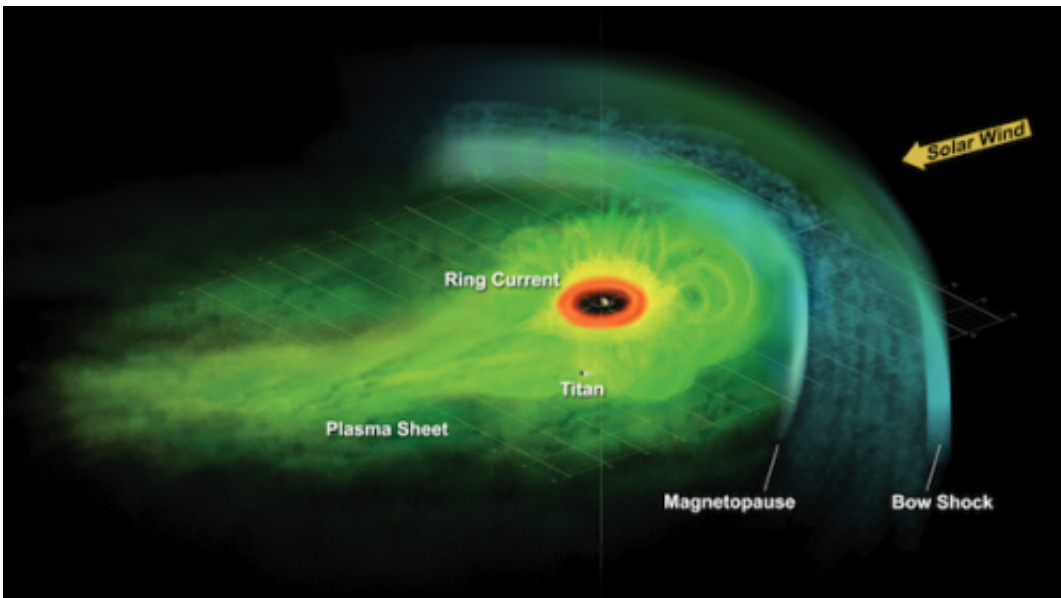


Magnetic shielding of exomoons: to be or not to be

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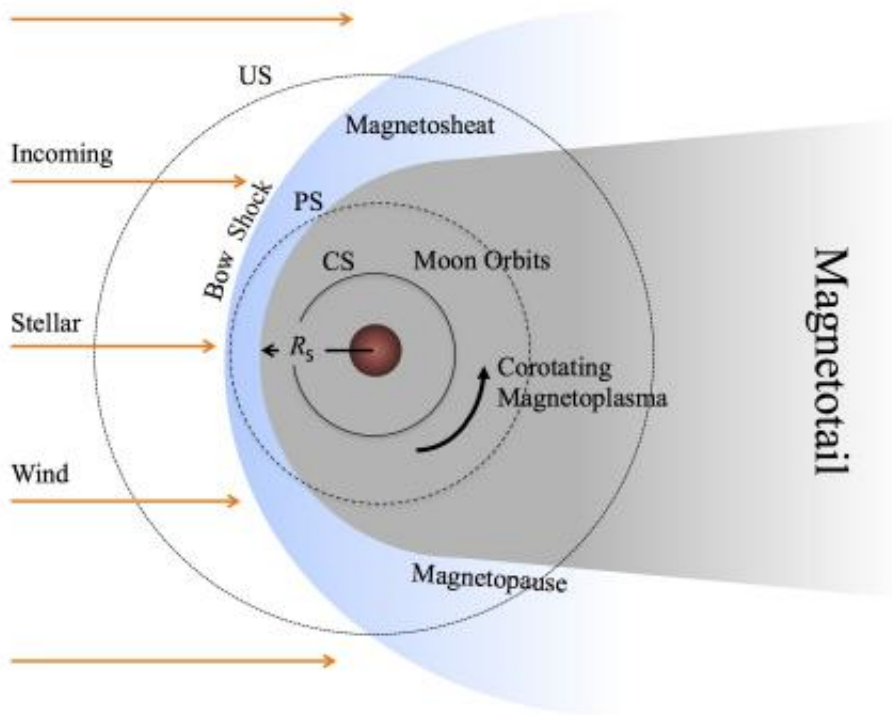


A new study on magnetic fields around extrasolar giant planets sheds first light on the magnetic environment of extrasolar moons. The work, authored by René Heller of the Department of Physics and Astronomy at McMaster University (Canada) and Jorge I. Zuluaga of the FAcOm group in the Institute of Physics of the University of Antioquia (Colombia), is the first to explore the complex magnetic environment of exomoons and its impact on the habitability of these peculiar bodies. Regrettably the results are not completely encouraging. Even the most

massive moons that can be expected from a formation point of view will be small compared to Earth. Thus, the only possibility these moons can be magnetically protected from the stellar and cosmic high-energy radiation is that they are encased by their giant planet's magnetosphere. Yet, in orbits close to the planet, these moons can be subject to enormous tidal heating, potentially making them uninhabitable. These results represent just the beginning of an interesting research branch, which introduces a new key factor for the habitability of those "Pandora"-like environments.

Probably the first image that comes to our minds when thinking of an inhabited extrasolar moon shows the beautiful landscapes of Pandora, the hypothetical moon of James Cameron's movie *Avatar*. But the environments of extrasolar moons seem to be less favored than the idealized version shown on the big screen. Even if located around planets in the stellar "habitable zone," where the amount of incoming light allows for the existence [liquid water](#) and hence life, exomoons are subject to a number of other perturbing effects making things harsher for life than previously thought.

In a paper accepted for publication in the *Astrophysical Journal Letters* (arxiv.org/abs/1309.0811), Prof. Jorge I. Zuluaga and Dr. René Heller have studied the relationship among the magnetic field of extrasolar [giant planets](#) in the stellar habitable zone and the so-called "habitable edge" around those planets. This edge defines the minimum distance to the planet at which a moon would just avoid to undergo a runaway greenhouse effect—an uninhabitable state similar to that on Venus. Heller and Zuluaga studied moons having a mass and size similar to that of Mars orbiting planets with masses and compositions ranging from that of Neptune to Jupiter. Larger moons, with masses similar to that of Earth, are unlikely to have formed even around the largest planets, while moons lighter than Mars will not be easily detected in the near future.

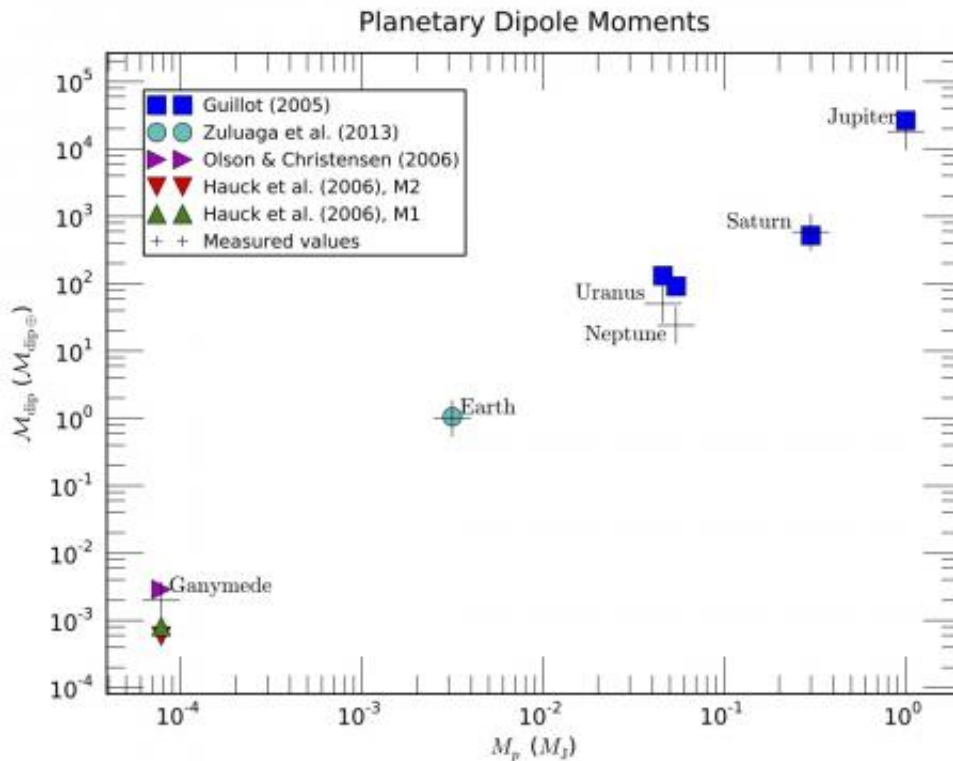


Structure of the magnetosphere. Dashed lines represent the orbits of moons which are completely shielded (CS), partially shielded (PS) and unshielded (US)

The core of this new work is in the calculation of the size of the magnetospheres of giant planets that are located in the habitable zones of their host stars. Planetary magnetospheres are "bubbles" made of fields and plasma created by the shock between the stellar wind and the intrinsic magnetic field of the planet. These bubbles separate the immediate magnetic environment of the planet from the very different environment of the interplanetary space. Magnetospheres could be really huge. In the solar system, for example, Jupiter is surrounded by a magnetosphere that ends at distances up to 50 times the size of the planet (3.5 million of kilometers or almost 10 times the distance from the Earth to the Moon) on the dayside and stretches out almost as far as the [orbit](#)

of Saturn in the night or trailing side, creating an "invisible" plasma tail. Although the magnetosphere and its elongated tail could cover billions of kilometers, the most important part in terms of permanent moon coverage is restricted to a region the size of the dayside radius, or "standoff radius."

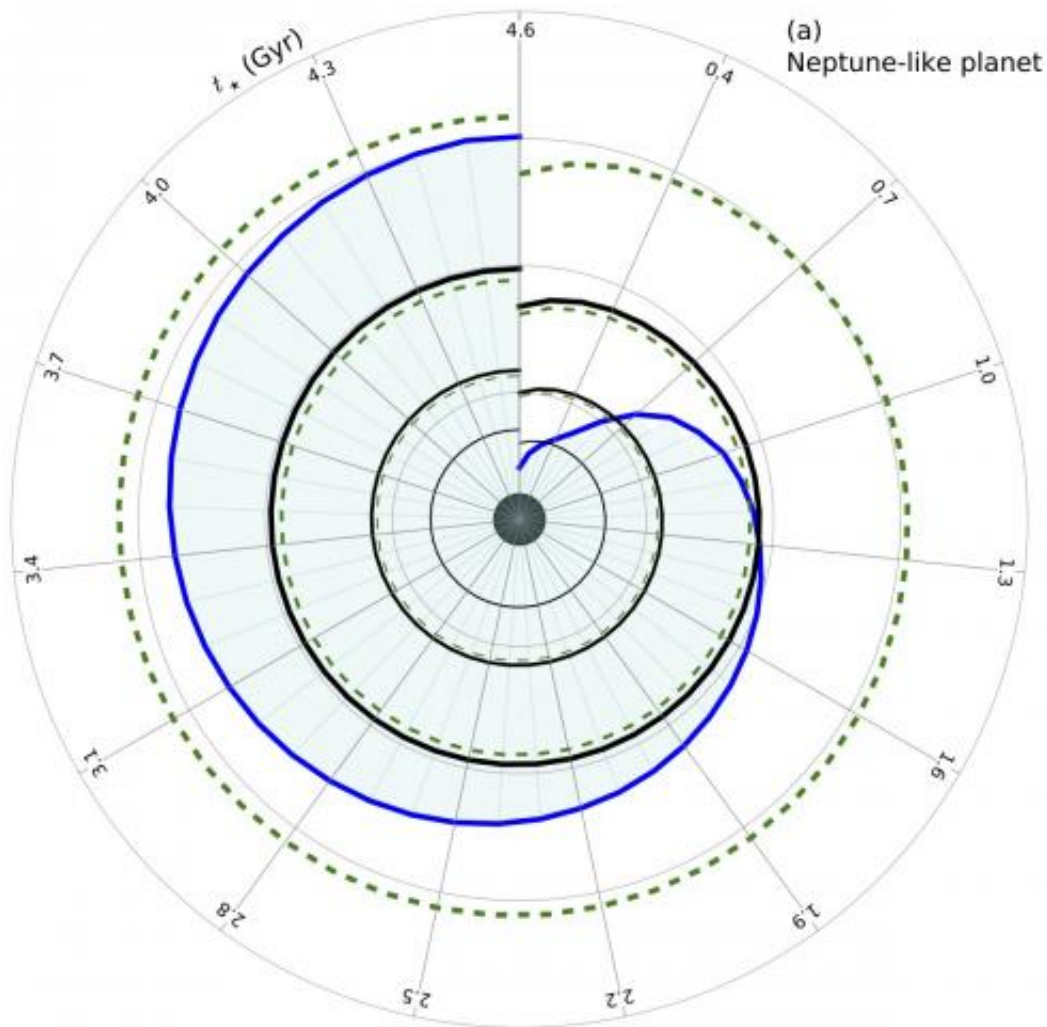
But, how can you know or predict the magnetosphere size of extrasolar planets? This is a field on which Prof. Zuluaga has specialized in the last couple of years. He and his team at the University of Antioquia have gathered knowledge about the generation and maintenance of magnetic fields in terrestrial and giant planets and use it to predict the intensities of those magnetic fields. This knowledge was recently applied to predict magnetic fields of small Earth-like planets as part of a work that was published in the *Astrophysical Journal* (arxiv.org/abs/1304.2909). Calculating the magnetic field of giant planets requires knowledge about the bulk properties and interior structure of those planets. For that purpose Heller & Zuluaga dug in to the well known models by Jonathan Fortney and collaborators at the University of California and used the properties of planets with different sizes and compositions to estimate their magnetic properties. How reliable could these results be? Applied to the already known solar system bodies, the methods developed by Zuluaga and his team are able to predict the so-called magnetic dipole moment of bodies ranging from Ganymede to Jupiter to the right order of magnitude. This is sufficient to predict magnetospheric sizes within a factor of 2.



Comparison between the dipole moments observed (crosses) in selected solar system bodies (especially giant planets) and those predicted with the models by Zuluaga et al. (2013)

So where do the exomoons enter this story? Well, they enter with the expertise of René Heller. As an expert in exomoon [habitability](#), he and his colleague Rory Barnes published a paper in January 2013 in the journal *Astrobiology* ([arxiv.org/abs/1209.5323](#)), which showed that exomoons cannot not be arbitrarily close to their host planets due to the illumination coming from the planet and the heat released by tidal dissipation. They defined a minimum distance at which exomoons will be too hot for liquid surface water and called it the "habitable edge." Actually, there are two edges, defined by two different criteria: the closer (and more optimistic) one is determined by the maximum amount of heat the exomoon atmosphere could absorb before going into a

runaway greenhouse state. Further outside, there is a more pessimistic edge, defined by the tidal heat similar to that observed on the surface of Jupiter's moon Io. Under this condition, the exomoon could be so geologically active, having for example volcanoes and large magmatic events, that life will find it hard to thrive.



Evolution of the standoff distance (blue spiral) and the habitable edges (black and green spirals, black for the runaway greenhouse edge and green for the Io edge)

Once combined, the estimation of the magnetospheric size and that of the habitable edges produced very interesting results concerning the conditions for habitability of exomoons. Heller & Zuluaga found that exomoons orbiting planets similar to Neptune, Saturn or Jupiter in the [habitable zone](#) of a 0.7-solar-mass star and with eccentricities typical for solar system moons will be shielded by the planet's magnetic field only if they are closer than the runaway greenhouse edge. In other words, either such an exomoon will be magnetically shielded or habitable, but not both. This is bad. These results will, however, depend on the composition of the planets. For example, a Neptune-like planet that instead of having almost half of its mass in hydrogen would be composed almost completely of heavy elements could have some chances to shield its habitable moons already in the very early phase of the system's life, when the stellar wind is strong.

What are the implications and future developments of this work? Heller & Zuluaga point to a really interesting and previously overlooked aspect of exomoon habitability. The issue should be explored in depth, something that the researchers announce for their upcoming work. Although it is hard to predict the outcome of their ongoing research, there is something Heller & Zuluaga have been able to establish: Pandora's inhabitants will face hard time reading their compasses.

Provided by FACOM

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