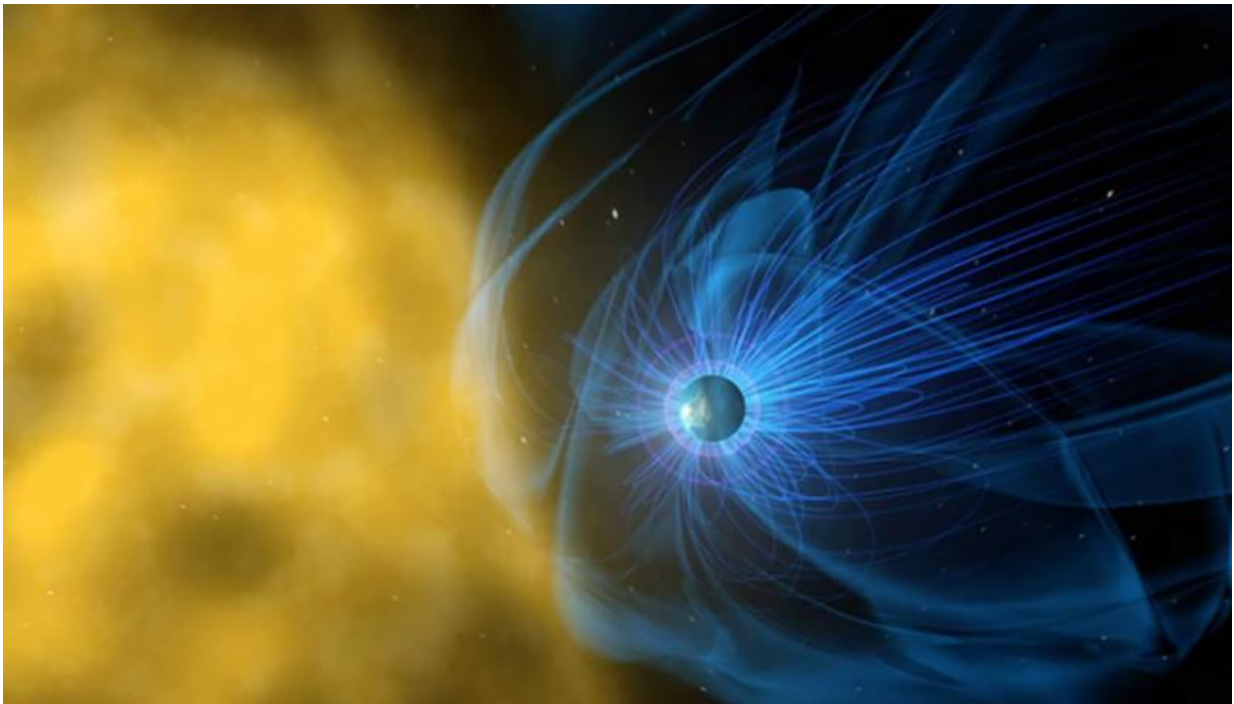


# Probing the possibility of life on super-Earths

June 19 2017, by Charlie Osolin

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Earth is surrounded by a giant magnetic bubble called the magnetosphere, which is part of a dynamic, interconnected system that responds to solar, planetary and interstellar conditions. Credit: NASA

Along with its aesthetic function of helping create the glorious Aurora Borealis, or Northern Lights, the powerful magnetic field surrounding our planet has a fairly important practical value as well: It makes life possible.

By deflecting harmful charged particles from the sun and the cosmic rays that constantly bombard the planet, and preventing the solar wind from eroding the atmosphere, Earth's [magnetic field](#) has allowed multi-cellular life forms up to and including humans to develop and survive.

And now, with the discovery of thousands of planets beyond the solar system known as exoplanets, scientists are eager to learn if rocky "super-Earths," up to 10 times more massive than Earth, might also be able to harbor life.

"Finding habitable exoplanets is one of the top three goals of the planetary science and astronomy communities," said Lawrence Livermore National Laboratory physicist Rick Kraus. "With these discoveries come many questions: What do these planets look like? Is our solar system unique? Is Earth unique? Or more specifically, is Earth uniquely habitable?"

Those questions have inspired a current National Ignition Facility (NIF) Discovery Science campaign aimed at determining if giant rocky planets could have Earth-like magnetic fields. An atmosphere, mild climate and liquid water are usually considered the bare essentials for life as we know it to evolve, but the presence of a magnetic field is equally important, Kraus said. "Active plate tectonics and a magnetosphere are both considered requirements for a habitable exoplanet," he said. "A stable surface environment free of ionizing radiation is one of the most important qualities of a planet that are considered a requirement for habitability."

Earth's magnetic field is generated as convection currents in the planet's liquid [iron](#) outer core are twisted by the planet's spin, creating a magnetodynamo that produces the magnetosphere (dynamoes convert mechanical energy into electric energy or in this case, magnetism). A planet with only a solid core may not have a magnetic field, and thus be unlikely to

harbor life as we know it.

"We need to understand the melting transition of the iron cores in order to determine if it is even possible to have a liquid outer core and a solid inner core within a super-Earth," Kraus said.

### **Melting curve is critical**

"The interior pressures of super-Earths are so extreme, up to 35 million times (Earth's) atmospheric pressure, that we have very little information about how materials might actually behave within them," he added. "The melting curve of iron is critical to addressing the question of whether a super-Earth could have a protective magnetosphere. It is the pressure-induced solidification of iron that releases the latent heat that drives the complex convective flow within a planet's core."

The research team is using a NIF experimental platform called TARDIS (target diffraction in situ) to study the melting curve of iron at pressures ranging from five to 20 megabar (five to 20 million Earth atmospheres). The TARDIS X-ray diffraction diagnostic is designed to shed light on the phase changes, or structural transitions between states of matter, that occur in materials under such extreme pressures and temperatures (see ["NIF's TARDIS Aims to Conquer Time and Space"](#)).

The campaign builds on a novel experimental technique developed at the Omega Laser Facility at the University of Rochester. The researchers shock an iron sample so it liquefies at 2.5 Mbar and then use ramp (shockless) compression to compress it to 10 Mbar. In situ X-ray diffraction, currently the most accepted means for measuring melting and solidification, is used to confirm that the first shock melted the material and the subsequent ramp-compression wave caused it to re-solidify (unlike shock compression, ramp compression keeps sample temperatures low and allows the study of matter compressed to extreme

densities).

"The experiments also represent a significant advance over what can be explored about the melting of iron using static compression experiments," said the campaign's principal investigator, Russell Hemley of the George Washington University, director of the Carnegie/DOE Alliance Center (CDAC). "Those experiments to date have been limited to pressures of about three Mbar—or the pressures of Earth's core—and have been controversial. Hence the new results also will improve our understanding of the core of our own planet as well as provide crucial information about the nature of super-Earths and their potential habitability. "

"One way to think about this experiment," Kraus said, "is that we use the shockwave to create a warm dense thermal state in the iron similar to that within the liquid iron outer core of a super-Earth. Then, by subsequently shocklessly compressing the iron we simulate the thermodynamic path that would be experienced by a parcel of iron convecting deep within the liquid [core](#) of a super-Earth. With X-ray diffraction, we can directly answer the question of whether that parcel of iron would solidify as it reaches a prescribed depth."

NIF is the only facility capable of achieving and probing these extreme states of matter. The experiments require the high and sustained energy intensity only achievable on NIF, and the laser's unique pulse-shaping capability enables ramp compression of iron from 5 to 20 Mbar. The campaign was awarded six shot days in fiscal years 2016 to 2018, enough for 12 experiments.

"If we observe solidification—diffraction from solidified iron—on the much shorter timescale of a laser experiment," Kraus said, "then we know the melting curve is steep enough to have a [solid inner core](#) and [liquid outer core](#), which could enable a magneto-dynamo within super-

Earths. Then, our goal is to explore the different entropy states, or temperature profiles, that can be achieved in the cores of super-Earths and probe the thermodynamic path taken by a descending liquid iron parcel. This discovery would be a critical step forward in determining the types of extra-solar planets that could be habitable."

Provided by Lawrence Livermore National Laboratory

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