New findings bring physicists closer to understanding the formation of planets and stars

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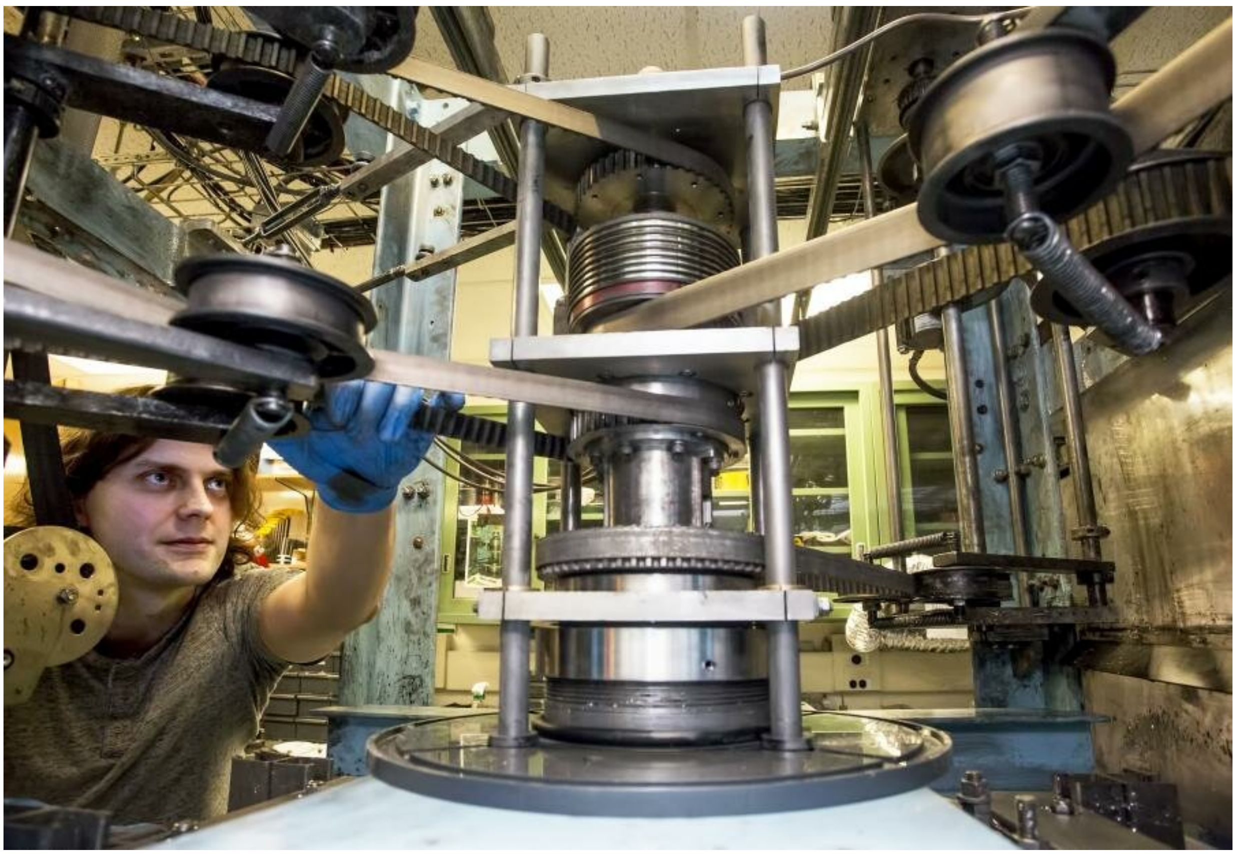


PPPL physicist Kyle Caspary tending to the Magnetorotational Instability Experiment. Credit: Elle Starkman

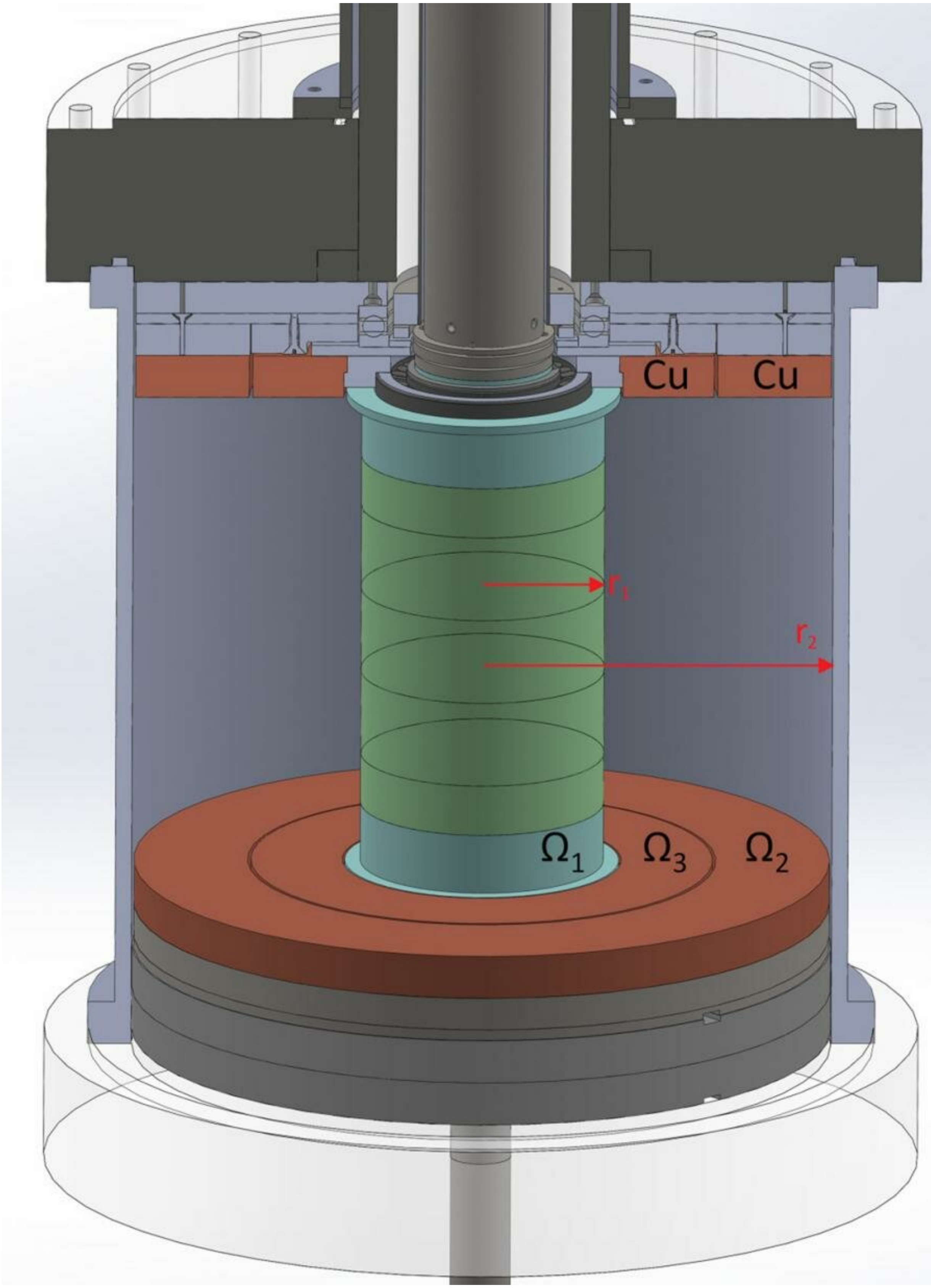
Down a hallway in the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL), scientists study the workings of a machine in a room stuffed with wires and metal components. The researchers seek to explain the behavior of vast clouds of dust and other material that encircle stars and black holes and collapse to form planets and other celestial bodies.

New findings reported in *Physical Review E* further the understanding of a machine known as the magnetorotational instability (MRI) experiment, which is named for and brings us closer to detecting the source of the instability that causes the material to collapse into such bodies. The phenomenon has long been conjectured but never definitively shown to exist.

The results of the PPPL experiment focus on the effect of copper endcaps that form artificial boundaries in place of nature's gravity on the top and bottom of the main vessel of the lab's machine. The device houses two nesting cylinders with the space between them filled with a liquid-metal alloy known as Galinstan.

"We're trying to recreate the conditions found in outer space in the laboratory, but we have to deal with these endcaps," says PPPL physicist Kyle Caspary, lead author of the paper. "In order to deal with them and discover the MRI in our apparatus, we have to fully understand the effects of the endcap boundaries. If we can understand this layer better, we could operate the machine in a way that would allow us to discern the fluctuations that we see from the MRI."

The nested cylinders rotate at different speeds, creating regions of Galinstan that rotate in the cylinders at different rates. This rotation mimics the differential rotation rates of dust and other material swirling in so-called accretion disks around cosmic objects like stars and black holes.


Cu
Cu
r1
r2
Ω1
Ω3
Ω2

Schematic of the magnetorotational experiment. Credit: Kyle Caspary

As the liquid in the nested cylinders turns, instabilities arise in the region between the two cylinders, just as storms develop between different masses of air. PPPL scientists scrutinize these fluctuations to find evidence of the magnetorotational instability, which is thought to cause the matter in accretion disks to collapse more quickly than current models predict.

"Astrophysicists have hypothesized that if there were turbulence in the flow of material in accretion disks, that could explain the discrepancy between theory and observation," said Erik Gilson, the PPPL physicist in charge of the MRI experiment. "Turbulence would lead to a larger viscosity of flowing material, and that would mean a higher accretion rate."

While endcaps are essential for operation of the MRI experiment to prevent the liquid alloy from splashing out, there are no endcaps in space. Understanding precisely how the endcaps affect the behavior of the Galinstan would therefore let scientists translate the data gathered by the MRI experiment into a form that would match what occurs in nature.

The data gathered by Caspary indicate that the copper endcaps, which conduct electricity, seem to make certain instabilities more likely to occur. In addition, the conducting endcaps cause the instabilities to transition from one to many frequencies, like symphonies with multiple lines of sound. The multiple frequencies are evidence that the endcaps affect the magnetic fields in the liquid metal. That interaction between the endcaps and the magnetic fields preserves the separation of the fastand slow-moving regions of Galinstan.

Caspary and Gilson now feel that they are closer to detecting the magnetorotational instability in space. "We gained some very useful insights into how the boundaries affect the stability of the flow, and some insights into how we can change our rotation rates and how we can spin the machine to avoid instabilities, while still being in a realm in which we can find the MRI," Caspary said.

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