Probing a 100-Year-Old Theory of Plasma Motion with MMS

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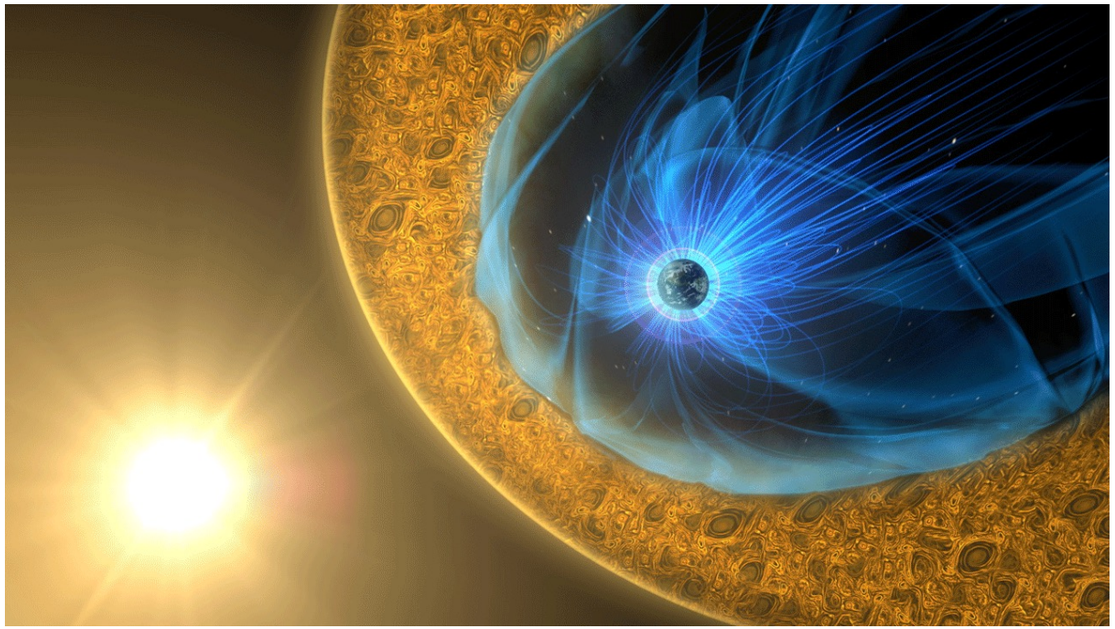
Plasma – a gas where particles have split into charged ions and electrons – is somewhat rare on earth, but makes up 99% of normal matter in the universe. Despite its prevalence, scientists haven't been able to observationally verify a fundamental theory describing how plasma moves in response to electric and magnetic forces. Until now.

With its ultraprecise measurements, NASA's Magnetospheric Multiscale mission – MMS – has finally measured plasma's movement on the small scales necessary to see if plasma collectively interacts with electromagnetic fields in the way the theory predicts, which is described mathematically by the so-called Vlasov equation. Since the beginning of plasma physics research nearly 100 years ago, the Vlasov equation has often been assumed to be valid for many kinds of plasmas in space. The new MMS results, published in *Nature Physics* on July 5, 2021, enabled scientists to see the fundamental plasma variations described in the theory for the first time in nature.

Measuring the basic interactions of space plasmas with electric and magnetic fields helps scientists better understand different mechanisms that fuel energetic space weather events, from auroras to plasma ejections off the Sun, which can interfere with satellites and communications on Earth.



The thin boundary in Earth's protective magnetic field, or magnetosphere, shown here between the blue and yellow regions, is where NASA's Magnetospheric Multiscale mission measured terms of the Vlasov equation. The new measurements help scientists better understand how supersonic solar wind plasma particles penetrate the magnetosphere where they can produce auroras and damage communications satellites. **Credits: NASA's Goddard Conceptual Image Lab**

Shuster, Jason (UMD/673), Gershman, Dan (673), Dorelli, John (673), Giles, Barbara (673), Wang, S. (UMD), Bessho, Naoki (UMD/673), Chen, Li-Jen (673), Cassak, P. (WVU), Schwartz, S. (CU Boulder), Denton, R. (Dartmouth), Uritsky, Vadim (CUA/673), Paterson, William (673), Schiff, Conrad (580), Viñas, Adolfo (CUA/673), Ng, Jonathon (UMD/673), Avanov, Lev (UMD/673), da Silva, Daniel (USRA/673), Torbert, R. (SwRI/UNH), 2021: "Structures in the Terms of the Vlasov Equation Observed at Earth's Magnetopause," Nature Physics, doi:10.1038/s41567-021-01280-6