The origin of bifurcated current sheets explained

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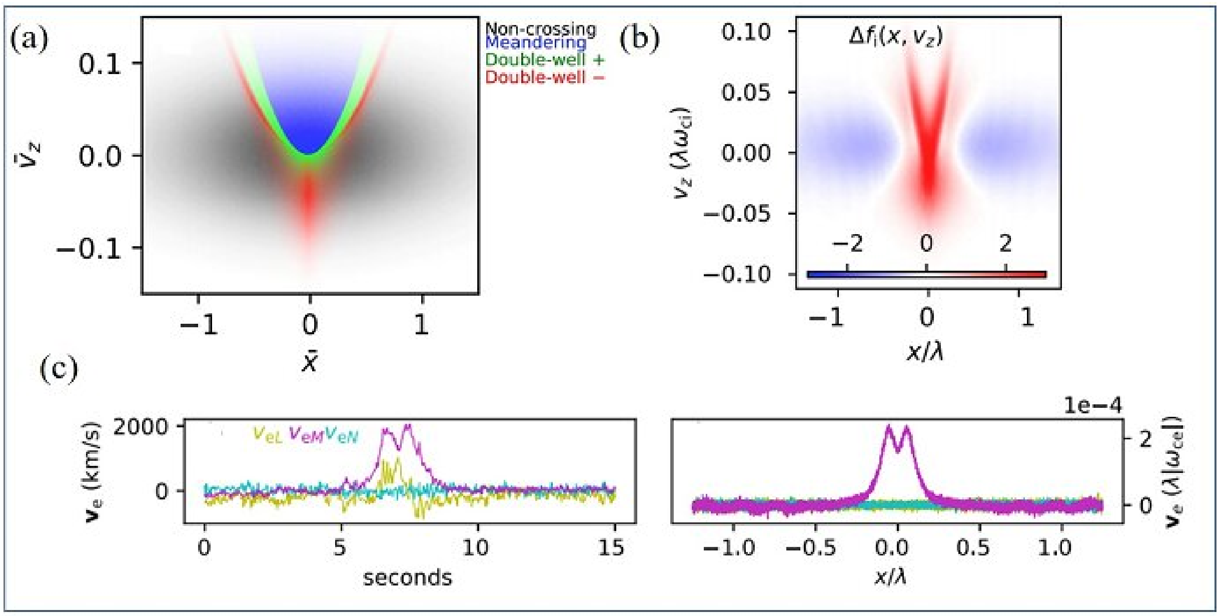

The orbit class phase-spatial distribution of particles was theoretically derived and confirmed by particle simulation, and the bifurcated current sheet data was compared with the satellite data from NASA (USA).

Credit: Pohang University of Science & Technology (POSTECH)

A Korean research team has identified the origin of bifurcated current sheets, considered one of the most unsolved mysteries in the Earth's magnetosphere and in magnetized plasma physics.

A POSTECH joint research team led by Professor Gunsu S. Yun of the

Department of Physics and Division of Advanced Nuclear Engineering and Dr. Young Dae Yoon from the Pohang Accelerator Laboratory has theoretically established the process of collisionless equilibration of disequilibrated plasma current sheets. In addition, by comparing this with particle simulations and satellite data from NASA, the origin of the bifurcated current sheets—which had remained largely unknown—has been revealed.

In the Earth's magnetosphere, a sheet-shaped plasma is observed that is trapped between two regions of opposing magnetic fields. Because current flows inside it, it is also called a current sheet. According to the conventional theory, the current sheet exists as a single bulk in which the magnetic pressure due to the magnetic field generated by the current and the thermal pressure of the plasma balance one another, thereby forming an equilibrium. However, in 2003, the European Space Agency's Cluster mission observed a bifurcated current sheet in Earth's magnetosphere. Since then, similar phenomena have been observed.

On the other hand, extensive research has been accumulated on the condition in which the magnetic force and thermal pressure are perfectly balanced with each other in the current sheet. But the process through which a disequilibrated current sheet equilibrates remains largely unknown. Since plasma systems generally do not start from an equilibrium state, comprehension of the equilibration process is desired to better understand the current sheet plasma dynamics.

The joint research team thoroughly analyzed the process in which the disequilibrated sheet achieves equilibrium by considering the orbit classes and phase-space distributions of particles that constitute the current sheet and found that the current sheets can naturally bifurcate during the equilibration process. It was then confirmed that these theoretical predictions were consistent with the particle-in-cell simulation results performed by the KAIROS supercomputer at the

Korea Institute of Fusion Energy. In addition, the simulation data were compared and verified with NASA's Magnetospheric Multiscale (MMS) measurements.

This achievement has enhanced the comprehension of magnetized plasma dynamics by incorporating theoretical analyses, supercomputer simulations, and satellite observations. Since the Earth's magnetospheric plasma has similar characteristics as other magnetized plasmas such as nuclear fusion plasmas in various ways, it is anticipated to contribute to a wide range of fields.

"This study has a significant academic value in that it simultaneously resolved two mysteries: the process through which disequilibrated current sheet equilibrates and the origin of bifurcated current sheets," explained Professor Gunsu S. Yun of POSTECH who participated as a co-corresponding author in the study. "We are trying to extend the analysis framework for plasmas with strong guide fields and hope to understand similar phenomena that occur in fusion plasmas."

More information: Young Dae Yoon et al, Collisionless relaxation of a disequilibrated current sheet and implications for bifurcated structures, *Nature Communications* (2021). DOI: 10.1038/s41467-021-24006-x

Provided by Pohang University of Science & Technology

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