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RESEARCH NEWS STORY

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Chiba University
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Using X-Rays as a New Diagnostic Tool for Monitoring Space Weather

Scientists propose a new approach to detect and measure breaches in Earth's protective magnetic barrier

Earth's magnetosphere protects us from charged particles constantly emitted by the Sun, but intense conditions can breach it through a process called magnetic reconnection. Now, researchers from Japan propose a novel method using soft X-ray imaging to remotely measure the reconnection rate, a key parameter in magnetic reconnection. This study showcases a powerful tool for forecasting hazardous space weather events, paving the way to safer near-Earth space applications and exploration.

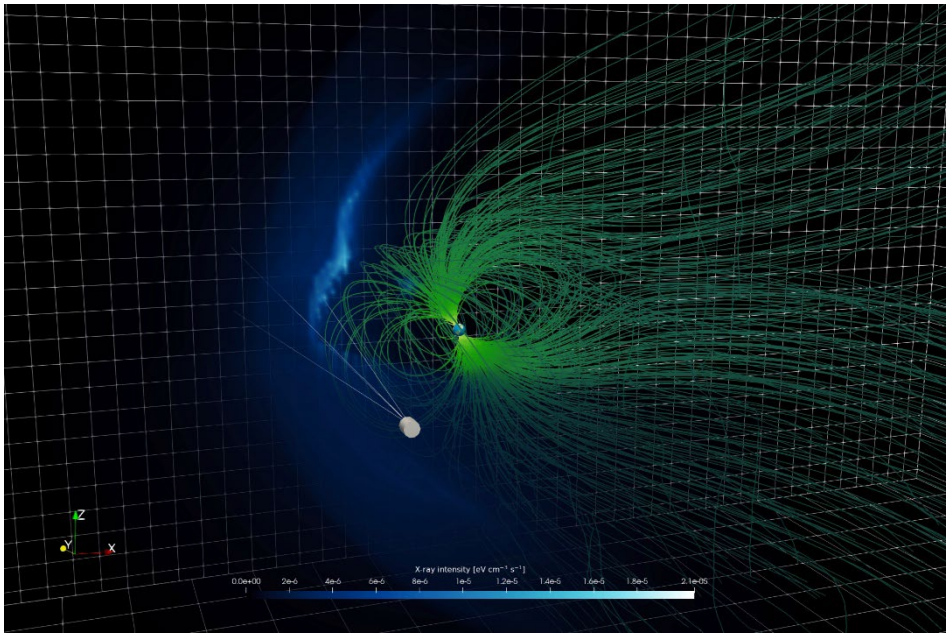

Image title: Simulating interactions between solar wind and Earth's magnetic field
Image caption: This image depicts the X-ray emission intensity distribution (keyed in colors) calculated by the proposed model and Earth's magnetic field (lines). The sphere in the center of the figure represents the Earth, and the left-hand side of the figure is the sun side.
Image credit: Dr. Yosuke Matsumoto from Chiba University, Japan
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The magnetosphere, formed by the Earth's magnetic field, acts as a protective shield that deflects solar wind—the flow of charged particles constantly streaming from the Sun toward our planet. This magnetic barrier protects our atmosphere and the technology we increasingly depend on in the near-Earth space, such as communication satellites. However, the magnetosphere isn't impenetrable, as a fundamental process called 'magnetic reconnection' can temporarily strip this barrier during intense solar wind and cause violent energy fluctuations in the near-Earth space. As human activity in this region increases, understanding and forecasting such space weather becomes critical.

A key to understanding these breaches lies in measuring what's known as the 'reconnection rate,' which quantifies energy efficiency in magnetic reconnection processes. For decades, scientists have attempted to measure this rate using various methods, including spacecraft flying directly through reconnection zones and observations of solar flares by remote imaging. However, these traditional approaches provide only local snapshots of the magnetic reconnection process or are limited by specific, often unsteady conditions. Obtaining a comprehensive and consistent picture that bridges the gap between local and global reconnection rates remains a challenge.

Against this backdrop, a research team led by Associate Professor Yosuke Matsumoto from the Institute for Advanced Academic Research at Chiba University, Japan, is testing an innovative approach using soft X-ray imaging to measure the reconnection rates. The study, co-authored by Mr. Ryota Momose from Chiba University and Prof. Yoshizumi Miyoshi from Nagoya University, was made available online on June 23, 2025, and was published in Volume 52, Issue 12 of the journal *Geophysical Research Letters* on June 28, 2025.

Soft X-ray emission occurs through a charge exchange process between the heavy ions in the solar wind and the hydrogen neutral atoms originating from the Earth. In this study, the researchers propose leveraging the soft X-rays that are naturally emitted when solar wind particles interact with the boundaries of the magnetosphere to remotely measure reconnection rates across much larger regions than previously possible.

The team conducted advanced computer simulations on the Fugaku supercomputer, combining high-resolution global magnetohydrodynamic simulations of Earth's magnetosphere with a model of soft X-ray emission. From the simulations, they analyzed how reconnection-related X-rays can be viewed from a satellite positioned at a lunar distance during intense solar wind conditions. This vantage point roughly matches that of an upcoming X-ray imaging satellite like GEO-X, which is scheduled for launch in the near future.

After analyzing the simulation results, the researchers found that the brightest X-ray emissions form distinct cusp-shaped patterns that directly reflect the magnetic field structure around reconnection zones. By measuring the opening angle of these bright regions, they calculated the global reconnection rate to have a value of 0.13, which closely matches theoretical predictions and previous laboratory measurements. Therefore, the results demonstrate that the geometry of bright X-ray features correlates with the reconnection rate, offering a new method to estimate this important parameter. "*Imaging X-rays from the sun-facing magnetospheric boundary can now potentially quantify solar wind energy inflow into*

the magnetosphere, making X-rays a novel space weather diagnostic tool," highlights Dr. Matsumoto.

By providing a new way to measure and understand magnetic reconnection, this research contributes directly to improving space weather forecasting. Being able to predict how solar activity influences the near-Earth space is vital for protecting astronauts and ensuring the reliability of communication systems and space missions, especially in the face of potentially devastating events like magnetic storms.

Notably, this study also has broader scientific implications for understanding magnetic reconnection in other contexts, as Dr. Matsumoto explains, "*Magnetic reconnection is not only responsible for breaching Earth's magnetic shield but is also the underlying process behind explosive events in plasma devices, the Sun, and black holes. Understanding this process is essential for advancing technologies like plasma confinement in fusion reactors and investigating the origin of high-energy cosmic rays.*"

As humanity prepares for an era of space exploration and commercial space activities, this newly proposed method could pave the way to accurate space weather predictions, helping ensure the safety and success of our ventures beyond Earth's atmosphere.

About Associate Professor Yosuke Matsumoto from Chiba University
Dr. Yosuke Matsumoto joined Chiba University in 2011. Since 2022, he has been serving as an Associate Professor at the Institute for Advanced Academic Research. He specializes in space and planetary science, as well as theoretical studies related to cosmic rays and astrophysics. He has published over 70 research papers on these topics and received multiple awards, including the NASA Group Achievement Award to the MAVEN Mission Team. He has professional memberships in multiple academic societies, including the Society of Geomagnetism and Earth, Planetary and Space Sciences.

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Reference:
Title of original paper: Estimation of Reconnection Rate From Soft X-Ray Emission at the Earth's Dayside Magnetopause
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