A statistical study of magnetospheric plasma mass loading using the Cluster spacecraft

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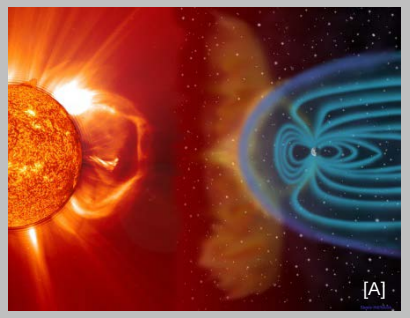
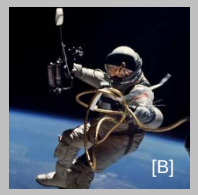
Aim of Study

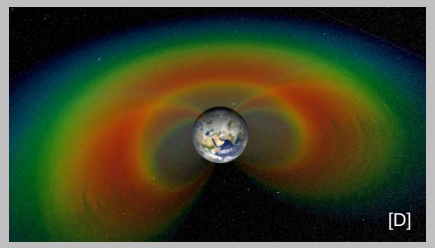
Obtain a 3D map of how magnetospheric plasma varies based on in-situ observations from Cluster. The empirical model provides an understanding of how the mass density in the magnetosphere responds to changes in solar wind plasma and internal variations. This is of significant importance, in terms of space weather affecting the multitude of satellites orbiting the Earth.

1. What is a magnetosphere?

A magnetosphere is defined as the region of space around the planet where the motion of charged particles is dominated by the planet's magnetic field. As illustrated in the figure on the right, the Earth's magnetosphere is strongly coupled to the solar wind (a constant outflowing plasma from the Sun).

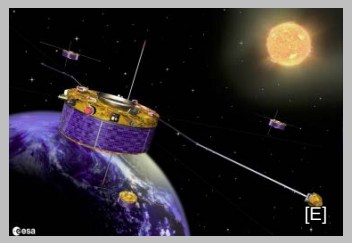






2. Why is the Earth's magnetosphere of interest?

The Earth's magnetosphere exhibits detailed structure and highly variable dynamics. A region of trapped energetic charged particles, referred to as the radiation belts, pose a threat to spacecraft and astronauts in the region. Therefore, the features and changes in the "space weather" of this environment is of high importance.

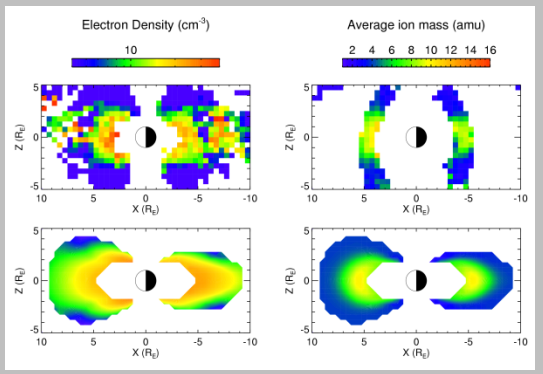


3. The Cluster spacecraft

Cluster consists of four identical spacecraft orbiting Earth in a tetrahedral configuration, with identical instruments on each spacecraft. This study utilises measurements obtained by Cluster over the mission so far (spanning approximately 2000-2012), providing a comparatively large dataset with good spatial and temporal coverage, as well as high statistical reliability.

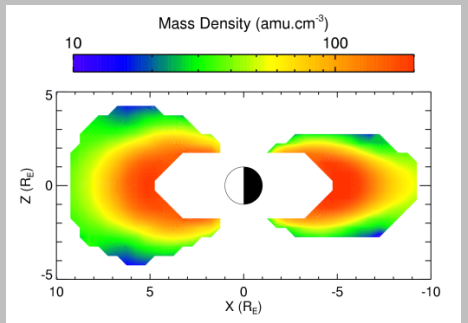
4. Data

Data from the WHISPER instrument, which measures electron density, and the CIS instrument, which measures ion composition, are used in the study (upper panels). These datasets provide information on how many plasma particles are in a region, as well as how heavy they are.



5. Results

By quantifying spatial dependences in the data, empirical models for the electron density and average ion mass in the magnetosphere are obtained (lower panels). A key result of the analysis is an observed enhancement in electron density at low latitudes. This feature is unaccounted for by previous models.



6. Mass density model

By combining the electron density and average ion mass models, an empirical model for the plasma mass density is inferred. The model provides information on how the solar wind and magnetosphere interact, as well furthering our knowledge of the various dynamical processes that take place within the magnetosphere.

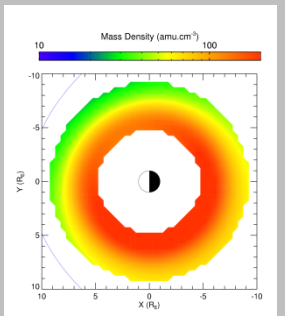


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Image credit: [A] Steele Hill, NASA; [B,C] NASA; [D] NASA/Goddard Space Flight Center Scientific Visualization Studio; [E] ESA/Cluster

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