

Disruption Process of Accumulated Northward Interplanetary Magnetic Fields Ahead of the Dayside Magnetosphere

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Magnetic Fields Ahead of the Dayside Magnetosphere
(昼側磁気圏前面に蓄積された北向き惑星間空間磁場の解消プロセスに関する研究)

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論 文 内 容 の 要 旨

The Interplanetary Magnetic Field (IMF) constantly continuing to blow toward the Earth interacts with the Earth's magnetic field. One of the interactions is the magnetic reconnection, allowing solar energy to flow into the Earth when the IMF connects to the Earth's magnetic field. The amount of energy injection into the Earth changes depending on the IMF direction, affecting the location and efficiency of the magnetic reconnection. It is important to understand the presence or absence of the reconnection associated with the IMF condition because a change in the plasma distribution in the ionosphere and the magnetosphere is triggered by the magnetic reconnection.

We focused on situations where the IMF direction changed discontinuously from northward to southward. Previous models and observations suggested that the IMF direction discontinuity (DD) led to the magnetic reconnection between northward and southward IMF when the DD reached the bow shock. However, there was little research on this reconnection because reconnected magnetic field lines did not directly connect with the Earth's magnetic field line. Then, the plasma and magnetic field structure changes associated with the IMF reconnection, as well as a quantitative assessment of its effects, is poorly understood. The purpose of this thesis is to simulate and visualize the effects on plasma and magnetic field structures and provide a quantitative interpretation through a comparison with the observation results by satellite data when IMF DD moves from the dayside to the nightside of the magnetosheath. We implemented the Reproduce Plasma Universe (REPPU) 3D Magnetohydrodynamic (MHD) code.

First, we elucidated the change in the magnetic field structures associated with the magnetic reconnection that occurred during the movement of the DD between the dayside and nightside magnetosphere. As shown by the previous work, we indicated the occurrence of the reconnection when the IMF DD reached the bow shock. We called the magnetic field lines

created by this reconnection the “U-shaped magnetic field line”. The U-shaped magnetic field lines with both ends extending to the solar wind region were transported to the high-latitude magnetopause, where they reconnected with the lobe magnetic field.

We also conducted a quantitative study of the IMF reconnection outflow. Reconnected magnetic field lines are greatly bent and have curvature, it is known that the Ampère force generates the plasma acceleration as reconnection outflow. In the GEOTAIL observations, the plasma velocity accelerated toward the exhaust direction from the IMF reconnection region, by approximately 75 km/s, in response to the arrival of the IMF DD. We also obtained a similar variation from our simulation results. The representation of reconnection outflow increased by 20 km/s relative to the background magnetosheath flow velocity in the exhaust direction. However, this acceleration appeared to be slow as compared with the accelerated reconnection outflow in the nightside plasma sheet or the dayside magnetopause. A slow reconnection outflow velocity was due to the weak incoming IMF strength. Furthermore, the magnetic field lines after the IMF reconnection did not immediately move downstream from the reconnection region. Consequently, the IMF reconnection occurred intermittently, confirmed by the plasma flow perpendicular to the magnetic field after IMF reconnection.

We revealed the current circuit generated by the effects on the DD. The center plane of the DD had an extremely weak magnetic field, with the magnetic field gradient present away from this DD. This magnetic field gradient interacted with the magnetic field, generating the perpendicular current circuit the vicinity of the DD. This current circuit was divided into Earthward and anti-Earthward sides by the DD, and each current circuit flowed between along the DD and the bow shock.

The relationship between the timescale for the complete disruption of accumulated northward IMF in the dayside magnetosheath and the southward IMF parameters was also investigated. It was found that when the velocity, density, and magnetic field strength of the southward IMF were varied, the timescale varied widely, between 5 and 12 minutes. Three major factors were found to change the timescale: (i) fluctuations in the background magnetosheath flow velocity, (ii) changes in the reconnection outflow velocity, and (iii) compression and expansion of the accumulated region due to the dynamic pressure.