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Magnetospheric dynamics under variable solar wind conditions

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Undoubtedly, the MHD approximation is well established on a larger scale such as the Sun and the Earth's magnetosphere. Several groups have developed MHD models of the global planetary magnetosphere over the past 40 years. Different schemes and meshes were developed according for each model. These models aimed to succeed in physical coupling with various regions, including the inner magnetosphere model. Until now, the global MHD models have been a valuable research tool for investigating the 3D magnetic field topology and magnetospheric dynamics of near-Earth space environments.

The global MHD simulation showed that vortex-like structures are generated in the inner boundary of the magnetopause with quasi-periodic behavior at an interval of 9-11min during weak and steady solar wind conditions. [1,2] They found that dayside magnetic reconnection played a role in generating vortices with a periodicity in the magnetopause boundary. At the center of the vortices, the bipolar magnetic field perturbation and the total magnetic field intensity increased. The velocity was low at the vortex centers with variations in the V_x and V_y components approximately 90 degrees out of phase. Density and plasma pressure were low at the center of the vortices, but the current was high.

We observed at least seven coronal mass ejections (CMES) from the Sun, which passed through the Earth's magnetosphere for three days on May 10 to 12, 2024. During this period, the Dst index reached a minimum of -412 nT at 03 UT on May 11. The AL index was below -1500 nT for about ten times. A very strong magnetic storm and several substorms occurred. To investigate how the strong solar winds impact the Earth's magnetosphere, an MHD simulation was performed. When a large southward IMF passes through the magnetosphere, a small plasmoid is generated near the tail region. Additionally, a vortex forms in the inner boundary magnetosphere even when the strong southward IMF has a finite B_y component, and the dipole tilt exists.

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References

[1] Park KS, Front. Astron. Space Sci. 8:758241(2021)
[2] Park *et al*, J. Astron. Space Sci. 37 (2), 77–84 (2020)

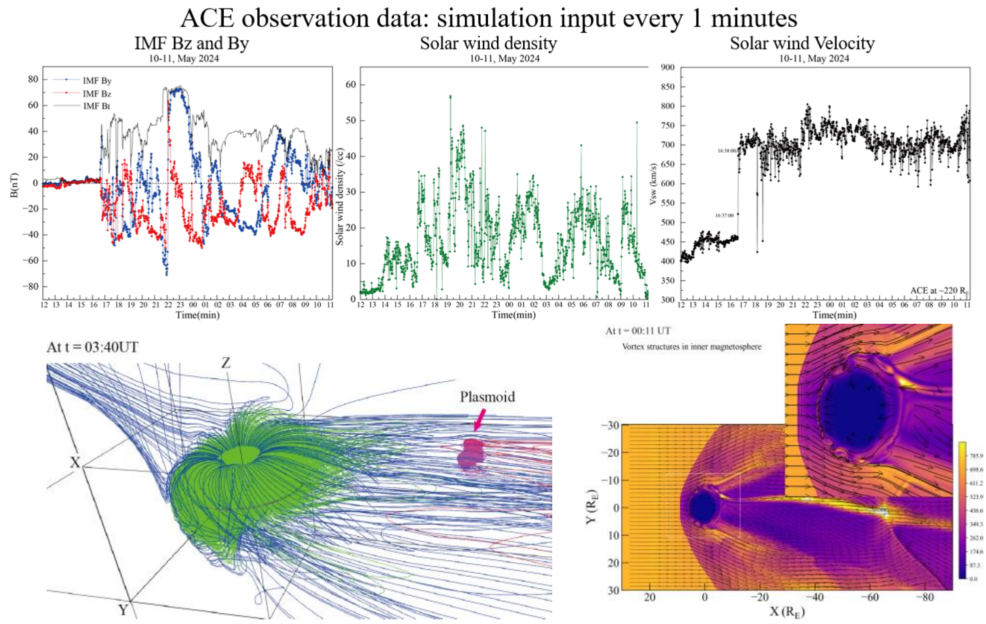

Figure 1. The simulation input parameter are shown in upper panels. IMF B_z turned southward at 16:40UT, decreasing to -50nT at 21:52UT during a sharply dawnward IMF. IMF By reached 73nT. The solar wind density was 56/cc with a strong velocity ranging from 450 to 800 km/s. The simulation results show the 3D magnetic field structure (bottom left) and plasma flow (bottom right) in the magnetosphere. Magnetic reconnection occurred in the dayside magnetopause and tail region. The plasmoid was generated in plasma sheet region. The vortex formed in the inner boundary of the magnetopause.