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Distant magnetotail dynamics of Earth-like planetary magnetospheres

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1. Introduction

Solar/stellar wind plasma flows compress planetary magnetospheres on the dayside and stretch the field lines into comet-like long-tail configuration on the night side. During disturbed times both the dayside magnetosphere and the magnetotail play a key role in mass- and energy-loading and circulation processes in the Earth's magnetosphere. In-situ measurements in the near-Earth and mid-magnetotail have revealed that the formation of thin current sheets and magnetic reconnection in the tail is associated with system wide substorms and enhanced connectivity between the magnetotail and auroral regions. The distant magnetotail was studied by single spacecraft missions or occasionally during fortuitous rare alignment of two spacecraft constellations only. The recent two-probe NASA mission ARTEMIS provides the first opportunity for systematic studies of distant magnetotail dynamics and its connectivity to near-Earth space. Using ARTEMIS data we will present occurrence statistics of reconnection processes in the distant tail and compare it to auroral, near-Earth and mid-tail occurrences available from ground-based measurements or previous space missions. This allows us to evaluate the connectivity of the distant tail to near-Earth magnetosphere and auroral ionosphere. In this contribution we also present ARTEMIS observations of large-scale motions of the distant magnetotail under varying conditions in the solar wind. More general situations, including stellar wind - exoplanetary magnetosphere interactions, can be understood by comparison of the distant magnetotail data with numerical simulations. To this end we will use GUMICS-4 global MHD simulations, allowing to reveal the behavior of magnetosphere-ionosphere system under varying external forcing.

2. Reconnection statistics in the distant tail

Magnetic reconnection (MR) represents a multi-scale physical process in laboratory, space and astrophysical plasmas. It is associated with large-scale (system- and fluid-scale) reorganizations of the magnetic field topology and localized kinetic (ion- and electron-scale) processes, leading to particle energization, intense energy bursts and flows. MR plays a crucial role in understanding the non-steady interaction of stellar winds with planetary magnetospheres and in explaining the bursty response of magnetosphere-ionosphere system during disturbed times.
On the basis of previous statistical studies in the case of Earth [e.g. 1] it is suggested that, MR is preferentially initiated in the mid magnetotail (between X = 15 and 30 *RE* tailward, where *RE* is the Earth's radius). Occasional distant tail observations of the Geotail probe beyond 30 *RE* have revealed a highly dynamic, turbulent plasma sheet, characterized by complex 3D structures, multiple X-lines, appearance and dynamical evolution of acceleration centers [2]. Here we concentrate on electron acceleration and bulk flow signatures of MR in the distant tail.
Statistical analysis has shown that near MR sites the flux of 5 keV electrons (eflux(5 keV)) is higher than the flux of 1 keV electrons (eflux(1 keV)) [1]. We use the ratio r = eflux(5 keV)/eflux(1 keV) as a proxy for the occurrence of highly accelerated electron events and MR, providing that r>1.9. Figure 1a shows that at downtail distances between X = 40 and 75 R_E accelerated electrons over the threshold r are observed together with MR associated high speed tailward – Earthward flows (± Vx) in high plasma beta regions (Figure 1b). The trajectories of ARTEMIS P1 and P2 probes are indicated in Figure 1c, together with the positions of observed MR signatures (triangles). Circles indicate MR events observed by both probes [3,4].
We will show that the occurrence of MR signatures in this deep-tail region is comparable to that in the mid-tail. In order to test the connectivity of the dynamic tail to near-Earth region, we will compare

MR occurrence in the distant tail with auroral indices data.

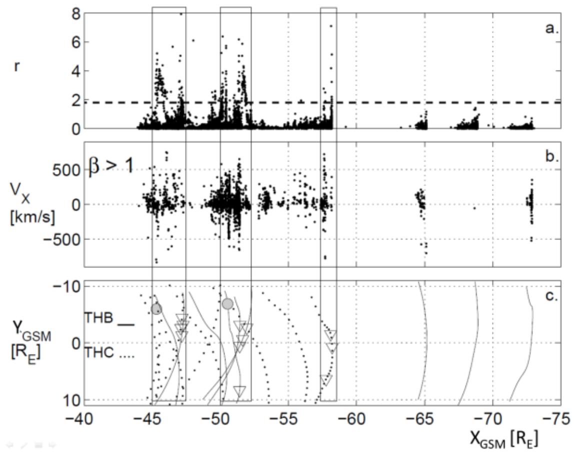

Figure 1: Reconnection statistics in the distant magnetotail [3,4]

3. Large-scale motions of the magnetotail

As an example of large-scale distant tail motions we will show ARTEMIS two-probe plasma and magnetic field observations on 19-20 November 2010, when the orientation of the interplanetary magnetic field changed. Moreover, magnetopause motions were associated with increased kinetic/static pressures and directional changes of the solar wind speed.

ARTEMIS observations compared to Geotail and Cluster data in the post-terminator magnetosheath provided evidence for successive large-scale motions of the distant magnetotail accompanied by the motion of magnetopause boundary over the ARTEMIS spacecraft. The trajectories of the spacecraft are shown in Figure 2. The consecutive events lasted ~ 18 hours, during which time repeatedly reappearing strahl electrons indicated the crossing of open/closed magnetic field lines. The thick white lines in Figure 2 indicate time intervals when the magnetopause moved over ARTEMIS spacecraft P1 and P2, then the probes suddenly appeared in the magnetosheath. We will present the results of large-scale MHD model (GUMICS-4 code) with the actual solar wind input, which confirm the motion of the distant magnetotail mainly in X-Y GSM plane.

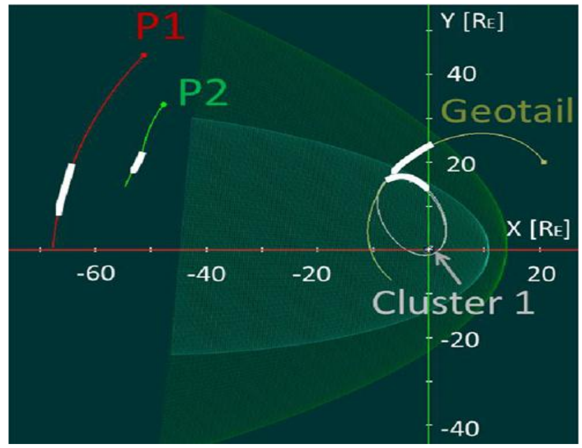

Figure 2: Trajectories of ARTEMIS P1, P2 and Geotail, Cluster 1 probes on 19-20 November 2010. Thick white lines indicate time intervals of large-scale motions of the distant magnetotail.

4. Summary and Conclusions

1. MR statistics associated highly accelerated electron events suggest that the distant tail region is rather active and plays a more important role in global magnetosphere-ionosphere couplings than previously believed.
2. The observed and simulated large-scale motions and the long-term ARTEMIS measurements provide an opportunity to understand better the details of the interaction of distant magnetotails of the Earth-like planets with the solar/stellar wind.
3. The general knowledge about the large-scale magnetotail motions might be of importance for the observations of similar effects during exoplanet transits.

Acknowledgements

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References

[1] Nagai, T., et al., J. Geophys. Res., 110, A09208, 2005.
[2] Angelopoulos, V., et al., J. Geophys. Res., 101, 24599, 1996.
[3] Vörös, Z., Nonlin. Proc. Geophys. 18, 861, 2011.
[4] Vörös, Z., et al., Astrophys.Space Sci. Proc., in press.