The magnetotail current sheet movement detected by Cluster

Weijie Sun [1], Quanqi Shi [1], and Ting Xiao [1]

[1]Shandong Provincial Key Laboratory of Optical Astronomy and Solar-Terrestrial Environment, School of Space Science and Physics, Shandong university at Weihai, Weihai, 264209, China. Email:sqq@sdu.edu.cn

Abstract

Using Cluster four spacecraft data, we have made a statistical research on the motion properties of the magnetotail current sheets of the year 2004 and 2005 with various methods. We find that most of the current sheets are propagating from the midnight tail region to dawn and dusk flanks which is consistent with previous studies. Most of the current sheets are propagating with the velocities smaller than 100 km/s, and the exceptions account for 6.5 % of all events. We have also found that 'Enter/Retreat' current sheets more favorably occur during the southward interplanetary magnetic field (IMF).

1. Introduction

The magnetotail current sheet was discovered by Ness in 1965 [1]. There are many dynamic processes which have a great influence on the earth are occurred near the current sheet [2]. Many studies have been carried out on the relationship between the current sheet feature and the solar wind [3,4]. Speiser and Ness claimed that the spacecraft's multiple crossings of the current sheets might because of its flapping movement, and they also mentioned that the flapping movement might caused by the inhomogeneous solar wind [5]. Lui et al. pointed out that the current sheet might exist dusk and dawn waves [6].

With the multi-point observations of the Cluster, it's possible to calculate the velocity of current sheet flapping movement. Sergeev et al. calculated the velocities of current sheet crossings which are located in the $8R_e < |Y| < 15R_e$ region during Cluster 2001 tail season [7]. Their results showed that most magnetotail current sheets propagated from the midnight tail region towards dawn and dusk flanks. Also see in [8, 9]. Zhang et al. found a same magnetotail current sheet propagated from the midnight tail region toward the dawn flank with TC-1 and Cluster, and his result implied that the flapping movement of current sheet could stretch in a large scale (5Re) along X direction [10]. Runov et al. also found a longer event (7Re) observed by THEMIS [11]. The flapping movement of current sheet prefer moving up and down in the midnight tail region [9, 12].

Sun et al. found that the way of current sheets propagating toward midnight ($Y = 0$) is significantly different from the ones propagating toward flanks [9]. The current sheets propagating towards flanks often appear as a pair of current sheets traversed the spacecraft one by one, while current sheet propagating towards midnight ($Y = 0$) often show that one current sheet traversed spacecraft and traverse them again in the opposite direction. See figure 5 and 6 in [9]. In this article, we will make investigation of current sheet crossings in 2004 and 2005. We will make a further investigation of current sheets propagating toward midnight.

2. Analytical methods

The MDD (minimum directional derivative method) and STD (spatio-temporal difference method) methods are employed to analyze the crossings of magnetotail current sheet in 2004 [13-16], and the crossings in 2005 were analyzed by Timing method [17, 18]. The criteria we used to select crossing events in this article is the same as that used by Sun et al. [9], i) the sign of B_x change at least for one spacecraft; ii) $|\Delta B_x| > 10nT$ in 300 s. We get 183 events in 2004 and 164 events in 2005 in total. We first use the MDD method to determine the dimension and variable direction of the structure, and then use the STD method to calculate the velocity of the structure. More details can be found in the references [13-16].

3. Observations

3.1 Distribution of the motion velocities

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Figure 1 shows the positions of magnetotail current sheet crossings in 2004 and 2005. From this figure, we can find that the current sheet crossings in the dawn side could be found in bigger negative Z position than crossings in the dusk side, while the crossings in the dusk side were found in bigger positive Z position. We have calculated the velocities with MDD and STD methods for the 2004 crossings and Timing method for the 2005 crossings, and displayed their projections on the GSE X-Y plane in Figure 2. We get the similar results as Sergeev et al. and Sun et al., that is, most current sheets in the dawn side propagated towards dawn flank and most current sheets in the dusk side propagated towards dusk flank [7, 9]. This feature is much obvious in the $|Y_{GSE}|>8R_e$ region. Statistical results also show that most current sheets are moving with velocities smaller than 100 km/s, and current sheets with velocities larger than 100 km/s are only take account for 6.5 % of all the events.

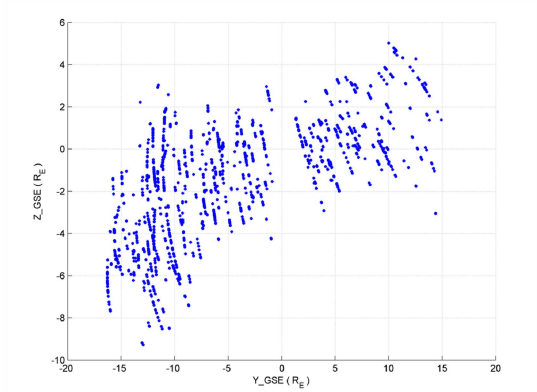

Figure 1. The distribution of the locations of magnetotail current sheet crossings in 20004 and 2005 in Y-Z plane. The current sheet crossings in the dawn side could be found in bigger negative Z position than crossings in dusk side, while the crossings in the dusk side were found in bigger positive Z position.

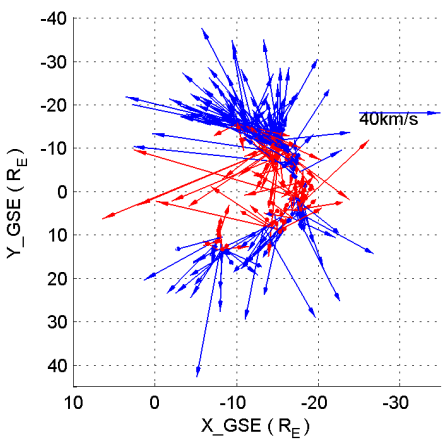

Figure 2. The the magnetotail current sheet velocities distribution in the X-Y plane of GSE coordinate system of 2004 and 2005. The red arrows represent the velocities of current sheets which were moving toward midnight (Y=0), and the blue arrows represent the velocities of current sheets which were moving toward flanks.

3.2 The current sheet propagating way and their possible sources

Sun et al. mentioned the way of current sheets propagating toward midnight ($Y=0$) is significantly different from the ones propagating toward flanks [9]. The current sheets propagating towards flanks often appear as a pair of current sheets traversed the spacecraft one by one, while the current sheets propagating towards midnight ($Y=0$) often show that one current sheet traversed spacecraft and traverse them again in the opposite direction, see figure 5 and 6 in

[9]. We call the first case 'Pass Through' effect and the second case 'Enter/Retreat' effect [15]. In this section, we try to investigating their possible source.

We first pick out the current sheets which are propagating towards midnight, and check out their corresponding IMF conditions. Figure 2 is the distribution of the IMF B_z and current sheet propagating velocity V_x. From Figure 3, we find that the amount of current sheets corresponding southward IMF is about twice of current sheets corresponding northward IMF. It seems that the 'Enter/Retreat' current sheets more favorite occur during the southward IMF.

4. Conclusion

We have made a statistical research on the flapping movement of magnetotail current sheets in 2004 and 2005. We got the velocities distribution in the GSE X-Y plane. Most current sheets in the dawn side propagated towards dawn flank and most current sheet in the dusk side propagated towards dusk flank which is similar to those got by Sergeev et al. and Sun et al. [7, 9]. Most of the current sheets are propagating with velocities smaller than 100 km/s, and the exceptions are only take account for 6.5 % of all the events. We have also checked the relationship between the 'Enter/Retreat' current sheets and IMF conditions. It's found that the 'Enter/Retreat' current sheets occur during the southward IMF period are twice of northward IMF period.

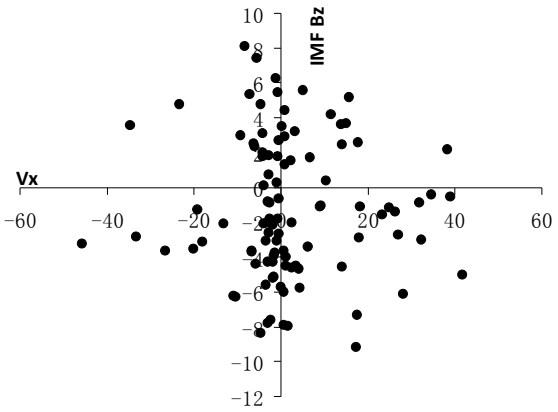

Figure 3. The distribution of IMF B_z and current sheet propagating velocity V_x. Every solid circle in this figure denotes a current sheet crossing event.

5. Acknowledgments

The work is supported by NNSFC 41031065, 41074106, 40874086, 40890162, and 40604022, the Shandong Natural Science Foundation (Grant No. 2009ZRB01352), and by the Project Supported by the Specialized Research Fund for State Key Laboratories in China. Thanks to FGM and CIS teams for providing the Cluster data.

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