Research Article

Correlation of core field polarity of magnetotail flux ropes with the IMF B_y: Reconnection guide field dependency

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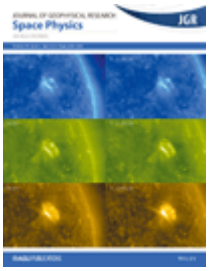

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Key Points:
- Correlation between core field and IMF By is guide field dependent
- Reconnection guide field dependency can explain previous controversial results
- Results are crucial to studying core field generation for weak guide field

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Correlation of core field polarity of magnetotail flux ropes with the IMF B_y: Reconnection guide field dependency

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Abstract The relationship between the core field and the interplanetary magnetic field (IMF) B_y has been addressed by spacecraft observations in the magnetotail, but it is not yet fully clear since observations by Slavin et al. (2003) and Borg et al. (2012) show controversial results. In this study, we examine 13 flux ropes from the Cluster observations to show for the first time that the correlation between the core field B_{core} and the IMF B_y depends on the guide field B_{g}. For large guide fields ($>$ 20% of the reconnecting field), we show that the B_{core} is found to correlate with the IMF B_y. However, for weak guide fields ($<$ 10% of the reconnecting field) we show that the core fields have either a positive or negative polarity, irrespective of the IMF B_y. This result indicates that for weak guide field reconnection the core field generation of the magnetotail flux rope is not governed by the external IMF B_y. We can explain the previous controversy in terms of the guide field dependency. We also confirm earlier suggestions that for weak guide field reconnection the flux ropes can have a significant core field whose polarity agrees with the ambient quadrupole Hall field. In addition, the Grad-Shafranov reconstruction results suggest that the axis of the flux rope may have been kinked. Our findings are crucial and can help advance theoretical simulations of the core field generation for weak guide reconnection. Discussions of the possible core field generation for weak guide field will be given in terms of 3-D reconnection.

1. Introduction

Magnetic reconnection is an important mechanism for energy conversion in the Earth's magnetotail where the magnetic energy is transformed into the plasma kinetic and thermal energy. Observational evidence was found for collisionless reconnection in the magnetotail, for which the quadrupole Hall magnetic field and the bipolar Hall electric field [*Sonnerup*, 1979] were confirmed [e.g., *Nagai et al.*, 2001; *Øieroset et al.*, 2001; *Borg et al.*, 2005; *Nakamura et al.*, 2006; *Eastwood et al.*, 2007; *Wang et al.*, 2012].

Magnetic flux ropes are of a helical magnetic field structure, which typically has a significant core field (i.e., the component of the magnetic field along the axis of the flux rope) and a field strength enhancement at the center of the flux rope and is considered as the by-product of the reconnection. For a nominal magnetotail plasma sheet, the core field of the flux rope is oriented in the dawn-dusk direction. Recent observations have revealed that the magnetotail flux ropes can be generated by collisionless reconnection with a small or large guide field in the dawn-dusk direction [e.g., *Eastwood et al.*, 2007, 2010b; *Retinò et al.*, 2008; *Wang et al.*, 2012].

Using ISEE 3 observations in the distant tail between $-50\ R_E$ and $-250\ R_E$, *Moldwin and Hughes* [1992] found that for 87% of 39 flux ropes the core field B_{core} had the same polarity as the interplanetary magnetic field (IMF) B_y. Using Geotail observations between $-10\ R_E$ and $-30\ R_E$, *Slavin et al.* [2003] found that 15 flux ropes with an earthward outflow had a correlation coefficient of 0.67 between the B_{core} and the IMF B_y, while it was 0.37 for 13 flux ropes with a tailward outflow. Recently, using Cluster observations between $-15\ R_E$ and $-20\ R_E$, *Borg et al.* [2012] found that 27 flux ropes had, however, no significant correlation with the IMF B_y. These controversial results between *Slavin et al.* [2003] and *Borg et al.* [2012] have not been explained so far. In this paper, we will explain this disagreement in terms of guide field dependency.

In this study, two criteria are used to select the magnetotail flux ropes seen by the Cluster spacecraft for examinations. First, the field strength and the core field are enhanced at the center of the flux rope. Second, only