Twisting of Earth's Neutral Sheet and its Response to Changes in the IMF B_y Component

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1. Introduction

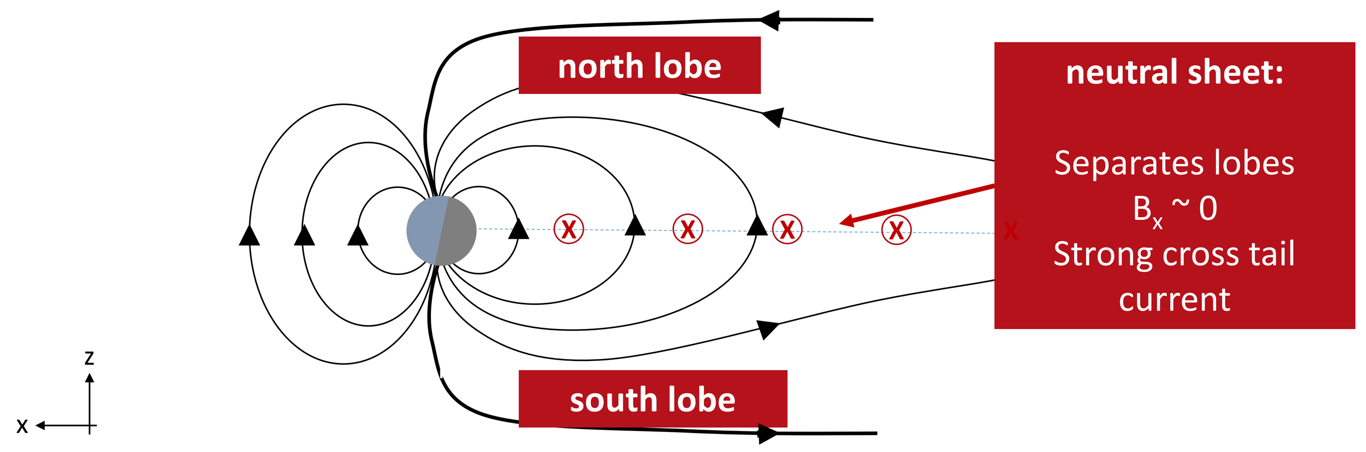
We have collated over 25 years of magnetic field, electric field, and velocity data from the Geotail, Cluster, Double Star, and Themis spacecraft missions to elucidate large-scale patterns in the terrestrial magnetotail, particularly those relating to magnetospheric asymmetries.

In this work, we analyze the twisting of Earth's magnetotail, driven by the interplanetary magnetic field (IMF) B_y component. By filtering the spacecraft data to the region where the tailward directed field and the returning earthward field are at their closest, known as the neutral sheet, we can determine the twist of the tail using *in situ* measurements of the local magnetic field. Furthermore, by then filtering these data by IMF orientation, we can determine the effect of the IMF on the tail twisting.

2. Motivation

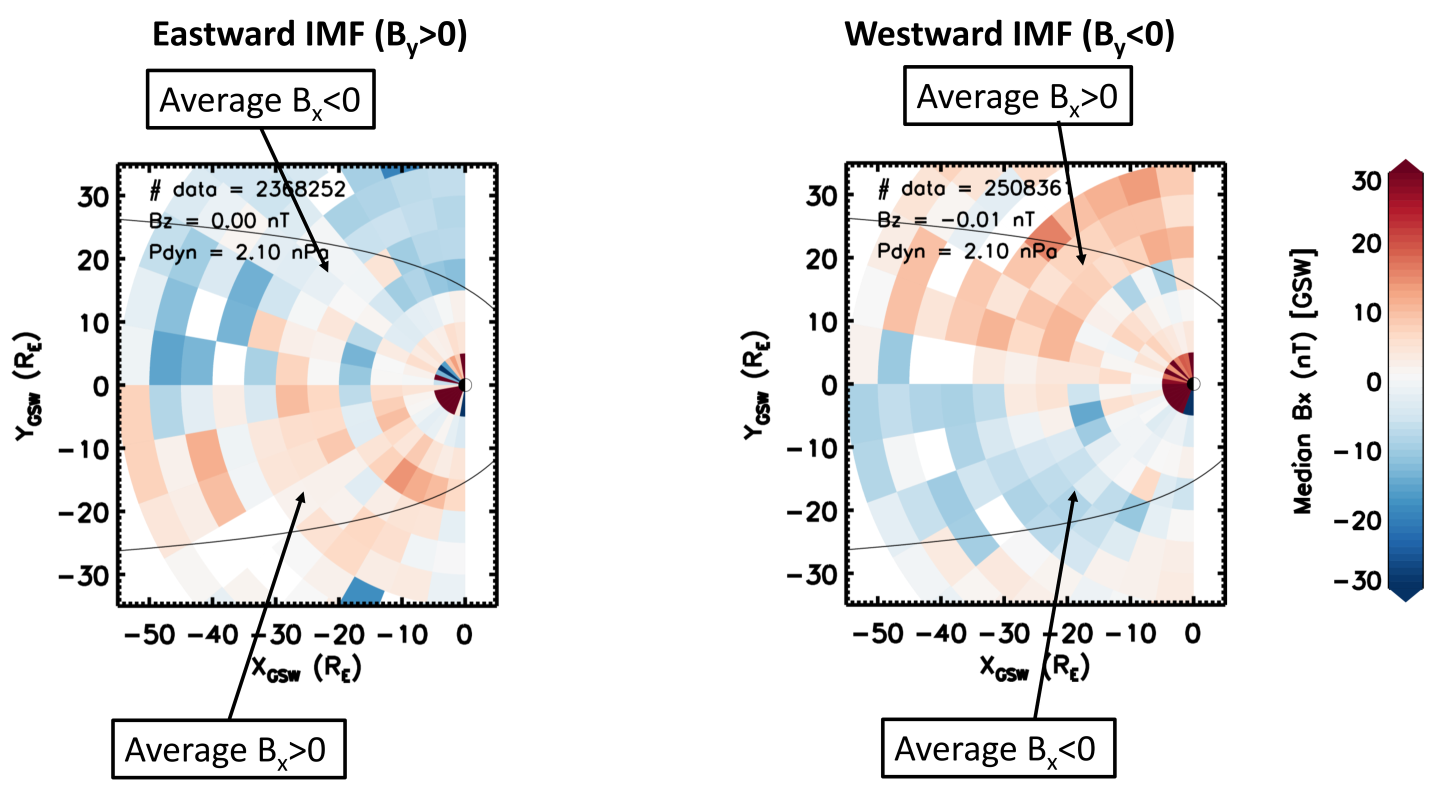
One of the biggest challenges in predicting the influence of the solar wind, and the embedded IMF, on the dynamics of the magnetosphere is derived from the inherent time dependence of the coupled system. For example, previous studies have shown that the IMF introduces asymmetries in the tail (e.g. Cowley et al., 1981), and these are particularly driven by coupling with a B_y dominated IMF (e.g. Nishida et al., 1998). Yet significant uncertainty remains as to the extent and timeframe over which IMF B_y influences magnetospheric dynamics, including control over auroral morphology.

3. Earth's neutral sheet

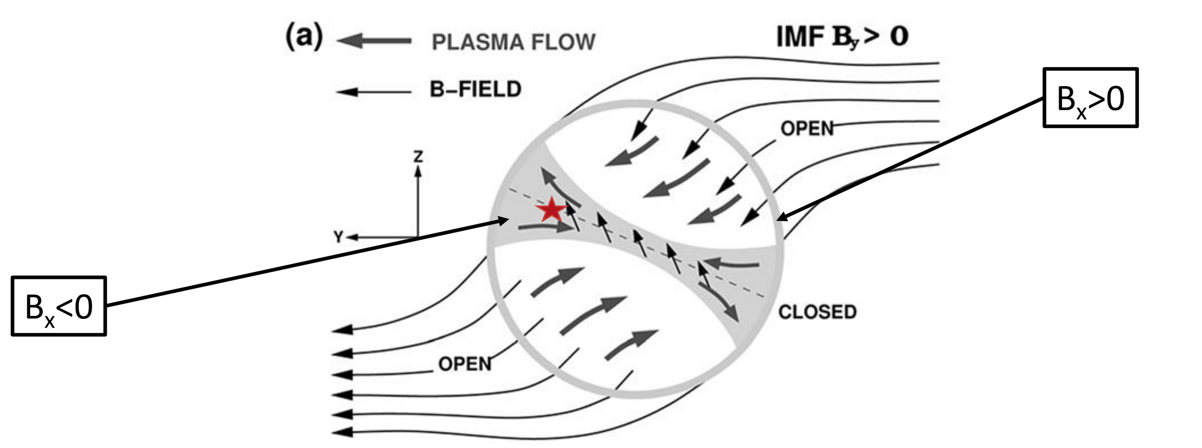


4. 60min average magnetotail B_x [$|Z_{GSW}| < 3R_E$]

Mean B_x component of the local magnetic field in the neutral sheet region ($|Z_{GSW}| < 3R_E$), under IMF B_y dominated intervals. Assuming no twisting of the tail, one should expect a mean $B_x \sim 0$. However, under B_y dominated intervals:



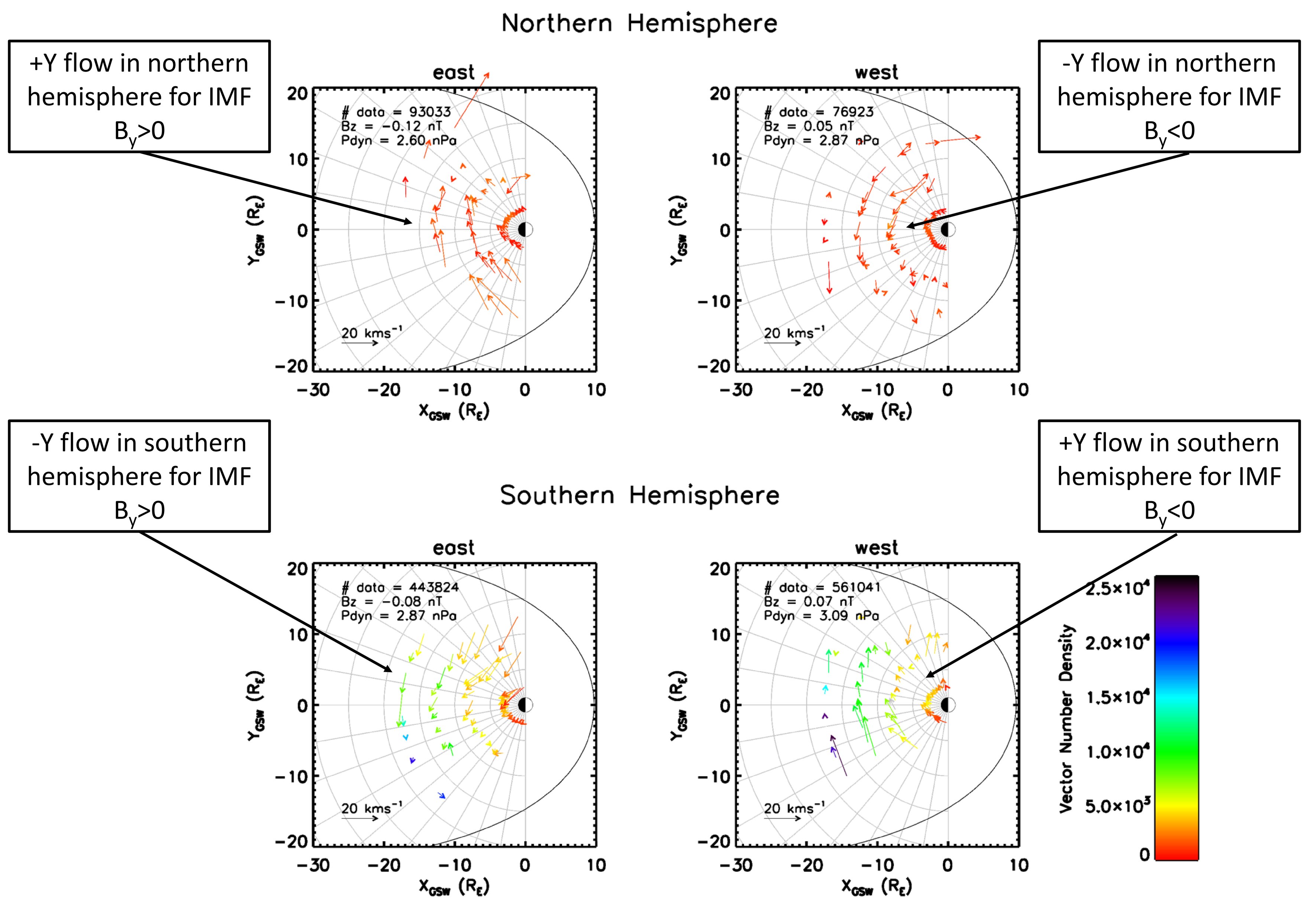
This result is consistent with past studies (e.g. Tenfjord et al., 2016) and suggests that asymmetric flux loading drives a twisted magnetotail.



Liou and Newell (2010)

5. Magnetotail lobe flow measurements

To test the hypothesis that asymmetric flux loading is responsible for the tail twist, we analysed the flow in the magnetotail lobes during eastward and westward IMF intervals.



The plots demonstrate that the average flow direction in the lobes is opposite for the two hemispheres, introducing a twist into the tail. Additionally, this twist direction changes based on IMF B_y orientation.

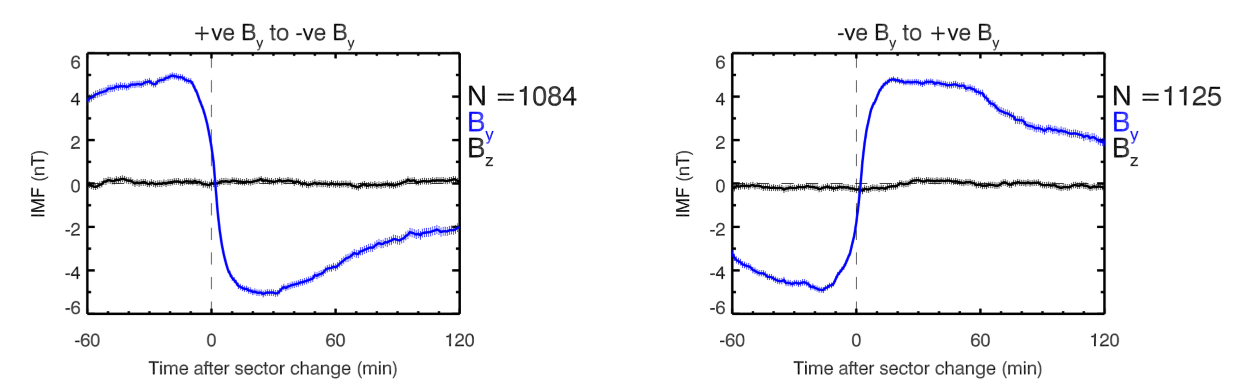
6. IMF B_y switching

Using a method similar to Tenfjord et al. (2016), we identify intervals where the IMF B_y switches polarity (e.g. +ve B_y to –ve B_y) and where the B_y component switches between "on" and "off" modes (e.g. +ve B_y to $B_y \sim 0$).

For a switch to have taken place we require that the both the 60 min and 20 min average IMF B_y component was >2nT (or <-2nT) before the switch and both these averages were <-2nT (or >2nT) after the switch. For the "off" states, the average |By| < 0.5 nT for both averaging lengths.

Using two averaging lengths ensures a quick transition and period of sustained orientation.

Example of +ve to –ve and –ve to +ve IMF B_y are shown.



8. Unanswered questions and future study

Using a large collated data set, we have shown the statistical effect of the IMF B_y component in creating a twisted magnetotail and have shown how the neutral sheet twist can be identified in local magnetic field data. By combining the data from many example cases, we aim to address the statistical response time of the neutral sheet twist to changes in the orientation of the IMF B_y component.

By utilising data from multiple spacecraft in different orbits to perform superposed epoch type analyses, we will isolate temporal variations in the magnetosphere to elucidate the timescales of the solar wind influence. In addition, interpretation of our results in the context of MHD model simulations, will aid in the derivation of a 4-D picture of the magnetosphere and feed into development of the MHD models.

7. References:

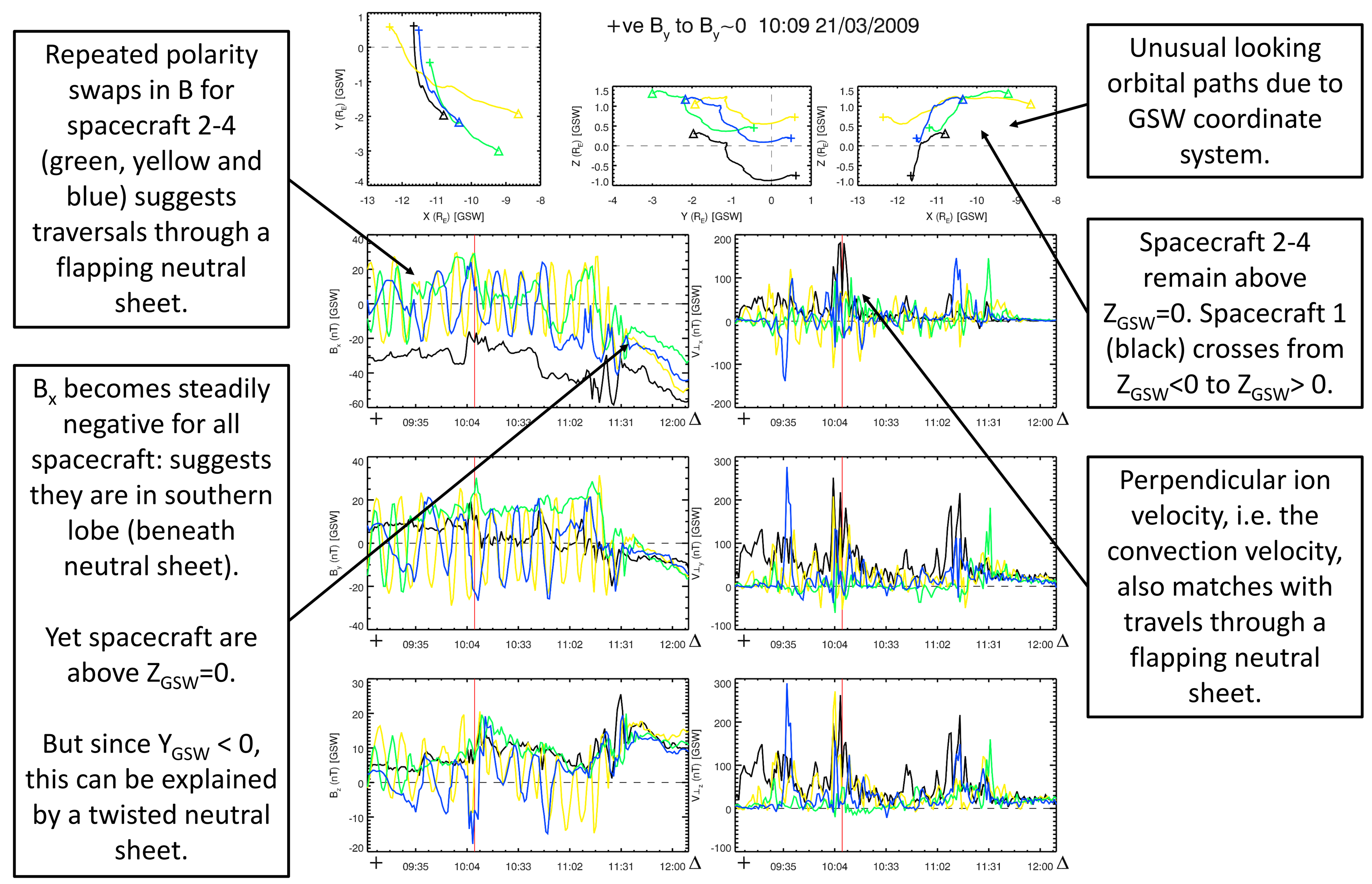
Cowley, S. W. H. (1981), *Planetary and Space Science* 29.1 : 79-96.
Nishida et al. (1998), *J. Geophys. Res.*, doi:10.1029/97JA01617.
Liou and Newell (2010), *Geophys. Res. Lett.*, doi: 10.1029/2010GL045537.
Tenfjord et al. (2016), *J. Geophys. Res.*, doi:10.1002/2016JA023018

7. Example neutral sheet data

Example 1: a flappy neutral sheet fly-through

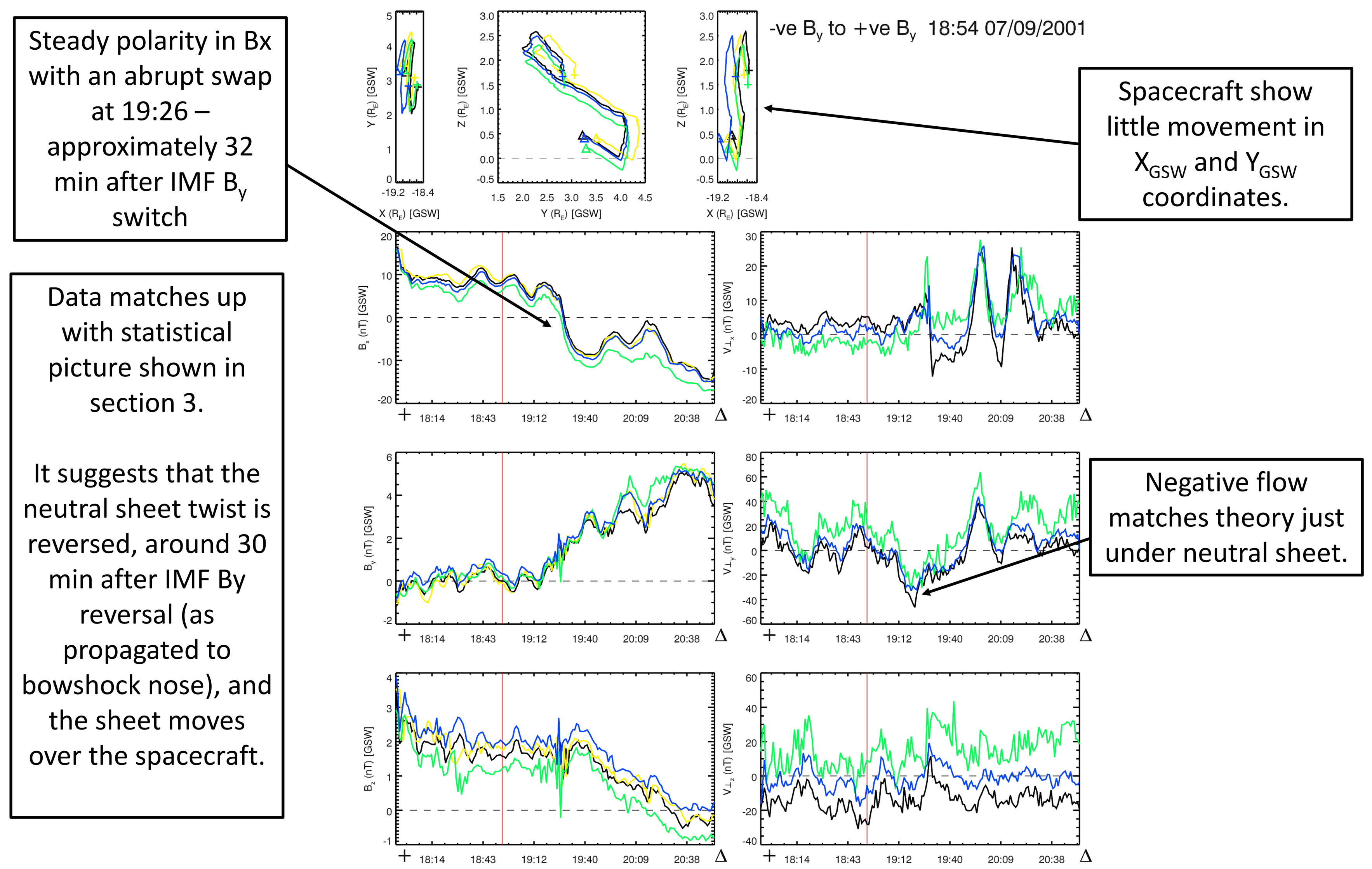
In this first example, we provide an example of a spacecraft crossing into the different lobes. Associated with this crossing is a reversal in orientation of the local B_x component.

All data are 1 min resolution and are centred around an IMF B_y switch (details at the top of the plot). The red vertical line indicates the time of the unpropagated IMF B_y switch.



Example 2: a sudden switch

In this second example, the spacecraft is expected to have remained in the same lobe (based on its coordinates) yet we see a reversal in orientation of the local B_x component.



This strongly suggests that the spacecraft have recorded the neutral twisting over them. See red star on flow diagram in section 4.