On the Relationships between Low-Latitude Pi2 Pulsations, Auroral Brightenings, and Plasma Sheet Fast Flows

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ABSTRACT

Since the timing relationships between nightside Pi2 pulsations, auroral brightenings, and fast flows in the plasma sheet differ among previous studies, it is still not well certain about what is exactly their occurrence sequence that is essential for determination of their cause and effect. In this study, their relationships are examined with 11 events of fast flows perpendicular to the ambient magnetic field observed by Geotail at -14.8 *Re* < *Xgsm*< -30.0 *Re* and by comparing to low-latitude Pi2s sensed by the SMALL array and Polar UVI images respectively. The main results are as follows. These selected fast flows do not have a clear preference of preceding or following the onsets of auroral brightening and ground Pi2. For at the same onset time sector, the delay time of ground Pi2 to the fast flow is from -11 (ahead) to +11 (lag) min. Moreover, the delay time of auroral bulge to the fast flow is from -1 to +22 min. Consequently, these suggest that the selected fast flows in the plasma sheet do not directly result in auroral brightenings and low-latitude Pi2s. Instead, they could result from the same impulsive sources initiated in the near Earth region and in the distant Earth region in the plasma sheet.

Introduction

Since Pi2 pulsations (the geomagnetic perturbations with a period 40-150 s) are widely used as a substorm indicator, they are used to compare to other substorm signatures for investigation of the timing relationships. Recently, Nagai and Machida (1998) found that flow bursts in the middle magnetotail preceded low-latitude Pi2 pulsations by 1-3 min. Liou et al. (2000) found that auroral arc brightening also preceded low latitude Pi2 pulsations by 1-3 min. However, Kepko et al. (2004) showed that the onsets of both nightside Pi2 pulsations and magnetic bay variations were simultaneous with auroral arc brightening. They argued that these are driven by the flow bursts in the magnetotail occurring with 1-3 min before.

On the other hand, Shue et al. (2003) found that all tailward fast flows in the plasma sheet are associated with enhanced auroral power. Moreover, they found that half of earthward fast flows are associated with decreasing auroral power, indicating that earthward fast flows are not necessarily associated with enhanced auroral power.

Thus the question is if earthward flow bursts lead to the onsets of auroral brightenings and nightside Pi2s, why not all earthward flow bursts are found to be associated with enhanced auroral power. Namely, the causal link between the flow bursts in the magnetotail, nightside Pi2s, and auroral brightenings is not well certain. To find out their spatial and temporal relationships is still an important issue in space physics. In this study, we examine the relationships between the plasma sheet fast flows, identified by Shue et al. (2003), Polar UVI images and low-latitude Pi2s at the SMALL array.

Data Presentation

To study the quantitative relationship between plasma sheet fast flows and auroral power, Shue et al. (2003) have selected 149 events in the years of 1997 and 1998 with a strict criteria that the *x* component of the fast flow perpendicular to the ambient magnetic field is larger than 300 km/s, the ratio of the ion pressure to the magnetic pressure more than 0.5 and the Geotail locations about $-20\ Re < Ygsm < 20\ Re$. Since the SMALL array was in the test operation in late 1997 and formally deployed in November 1998, there are only 11 events of Pi2 pulsations observed at the Beijing station (BJI, corrected magnetic latitude 34.2^{o}, corrected magnetic longitude 188.7^{o} and L=1.46) available for comparison with auroral brightenings and plasma sheet fast flows studied by Shue et al. (2003).

Panel 1 shows an example of auroral brightenings displayed with Polar UVI images from 1233:55 UT to 1332:11 UT on 7 December 1997. In Panel 1, one can find that auroral activations (blue brightening) began at 1243:07 UT and persisted through 1322:59 UT. In addition, two distinct auroral intensifications (red and white breakups) appeared at 1246:11 UT and 1310:43 UT, respectively. To discern auroral activations, red breakup is termed as auroral brightening (AB) and more intensified breakup as auroral bulge (BG). But the red breakup with a lifetime less than 3 min is called pseudobreakup. Figure 1 shows an example of the magnetic *Bz* component and the *Vx* component of the flow velocity detected by Geotail, the ground magnetometer data at BJI and the *AL* index from 1230 UT to 1330 UT on 7 December 1997. In Figure 1, the vertical dashed line denotes auroral bulge, the vertical dash-dotted line for the plasma sheet fast flow (FF) and the vertical line for the Pi2 onset most adjacent to the plasma sheet fast flow (MAP). Moreover, the thick horizontal line marks the time period of auroral brightenings during the time of interest in Figure 1. Figure 2 shows the comparison of ground Pi2 onsets and auroral bulges to plasma sheet fast flows for all selected events. In Figures 2a and 2b, the star denotes the ground Pi2 onset and auroral brightening related to the earthward fast flow and the diamond for the tailward one. Figure 2a shows ground Pi2 onsets and auroral bulges versus magnetic local time. Figure 2b displays the location of fast flows in the plasma sheet. Figure 2c shows the delay time of ground Pi2 onsets and auroral bulges to the fast flow at the same onset time sector. The positive delay time denotes the time of ground Pi2 onset and auroral bulge lagging behind the fast flow onset and the negative delay time for those occurring ahead of the fast flow onset.

Summary and Conclusion

The comparison results are summarized as follows. (1) These selected fast flows do not have a clear preference of preceding or following the onsets of auroral brightening and ground Pi2. (2) Auroral brightenings occur with a likelihood of three in seven for the earthward fast flow events and three in four for the tailward ones. (3) The occurrence number of the earthward fast flows preceding ground Pi2 onsets is higher than that of the ones following ground Pi2 onsets by five to one. For the tailward fast flows, the occurrence number is the same for both. (4) For at the same onset time sector, the delay time of ground Pi2 to the fast flow is from -11 to +11 min. Moreover, the delay time of auroral bulge to the fast flow is from -1 to +22 min.

While at the same onset time sector, the plasma sheet fast flow does not always precede the onsets of ground Pi2 pulsation and auroral bulge. Our findings are different from those in the previous studies. Thus, these suggest that the selected fast flows in the plasma sheet do not directly result in auroral brightenings and low-latitude Pi2s. One may argue that Geotail may be not close to the impulsive source and miss the fast flows responsible for the onsets of ground Pi2 and auroral bulge. From Figure 2b, however, one can see that Geotail is in the plasma sheet and around the midnight time zone for all events. Additionally, the earthward fast flow occurs at $Xgsm > -17$ Re and the tailward fast flow at $Xgsm < -17$ Re. Likewise, this phenomenon reappears around $Xgsm \sim -28$ Re. Furthermore, the fast flow moves earthward with the northward magnetic field at $Xgsm > \sim -28$ Re and tailward with the southward magnetic field at $Xgsm < \sim -28$ Re. These features imply that there can be magnetic reconnection (or neutral line) close to Geotail in the near Earth region and in the distant Earth region as well. Hence, low-latitude Pi2s, auroral brightenings, and plasma sheet fast flows could result from the same impulsive sources initiated in the near Earth region and in the distant Earth region in the plasma sheet.

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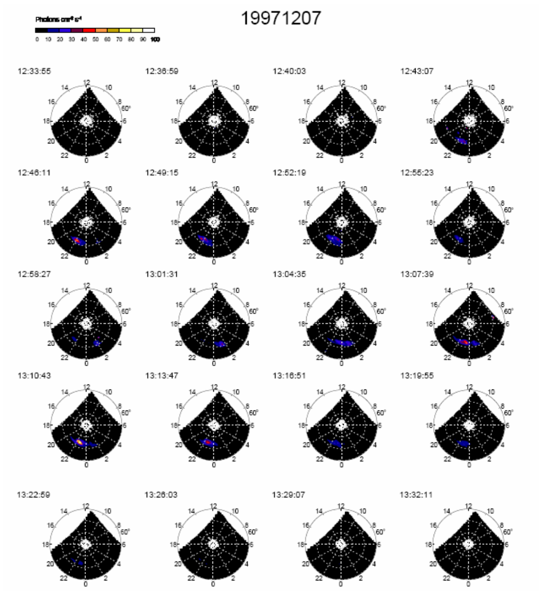

Panel 1. See text for detail.

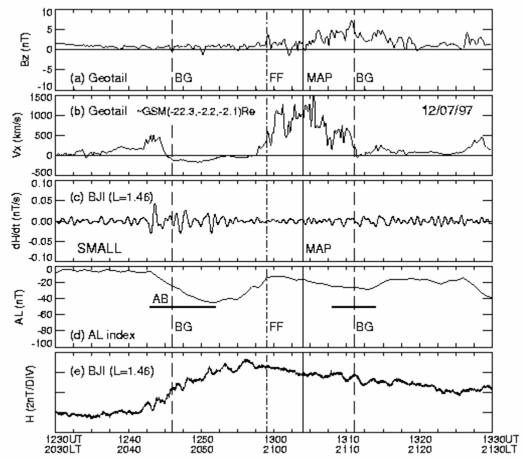

Figure 1. See text for detail.

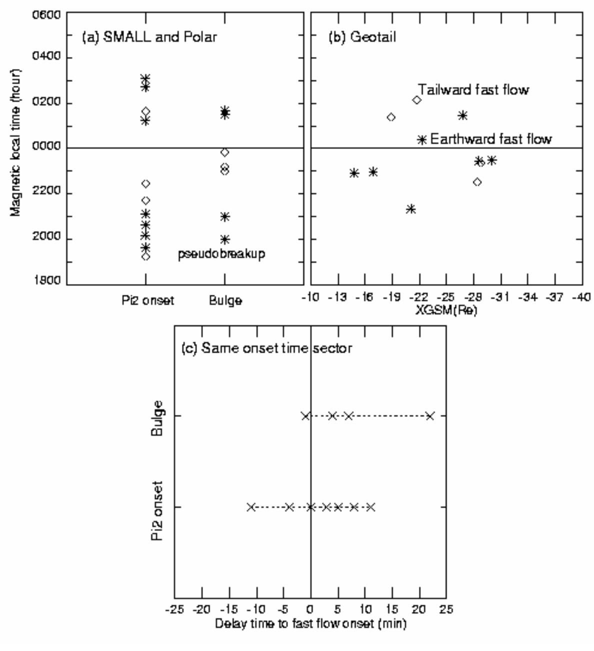

Figure 2. See text for detail.