Composition of upstream ion events during time of high speed solar wind streams: Geotail and WIND measurements compared

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Abstract

We compare simultaneous observations within the magnetosphere, the magnetosheath and the upstream region from the spacecraft Geotail and WIND, during two periods of corotating interaction regions (CIRs) strongly interacting with the magnetosphere (9 Jan., 1992 – Feb. 18, 1992). The Geotail energetic particle observations provide evidence that, under conditions of a highly disturbed magnetosphere, the seed ion population was accelerated within the plasma sheet of the magnetosphere and leaked upstream from the bow shock. The upstream ion events have been reported (Mason et al., 1996) to show a composition close to that observed in the outer magnetosphere and in CIRs at much higher energies. We interpret these observations as suggesting that the magnetosphere acts as an accelerator of the seed CIR ions, and that these ions after their acceleration leak to the interplanetary space, where make a strong contribution in upstream ion events.

1 Introduction

During times of substorm activity, magnetospheric particles leak outside the Earth's bow shock and propagate in the interplanetary space (Scholer et al., 1981; Anagnostopoulos et al., 1998 and references therein). Recent statistical studies have shown that, in particular, at times of a highly disturbed magnetosphere, as indicated by the magnetospheric index Kp, magnetospheric particles leak almost permantly from the magnetosphere in the magnetosheath and from there in the interplanetary space (Anagnostopoulos et al., 1998, 1999, 2000; Karanikola et al., 1999).

In this study we compare multispacecraft observations and we examine the possible leakage of magnetospheric particles during the period Jan. 20, 1995 – Feb. 19, 1995, when two CIRs associated with high speed solar wind streams ($\geq$700 km/sec) highly disturbed the magnetosphere at a level of K_p>4–5.5, and the WIND spacecraft (s/c) observed upstream ion bursts with a composition similar to that of the CIR population (Mason et al., 1996).

2 Observations

Figure 1 displays the positions of the spacecraft Geotail and WIND during the periods Jan. 29, 1995 – Feb. 5, 1995 (A) and Feb. 12, 1995 – Feb. 16, 1995 (B). We see that during these periods, when WIND was far upstream from the bow shock, Geotail explored the Earth's magnetosphere, the magnetosheath and the near Earth interplanetary space.

Figure 2a presents interplanetary and magnetospheric data for the time period between Jan. 20, 1995 – Feb. 19, 1995. In particular, Figure 2a displays solar wind speed from the WIND s/c and the values of the magnetospheric index K_p (two upper panels), ion spectrogram and electron flux-time profile from Geotail observations (two panels in the middle), and 30–60 keV/n CNO observations obtained

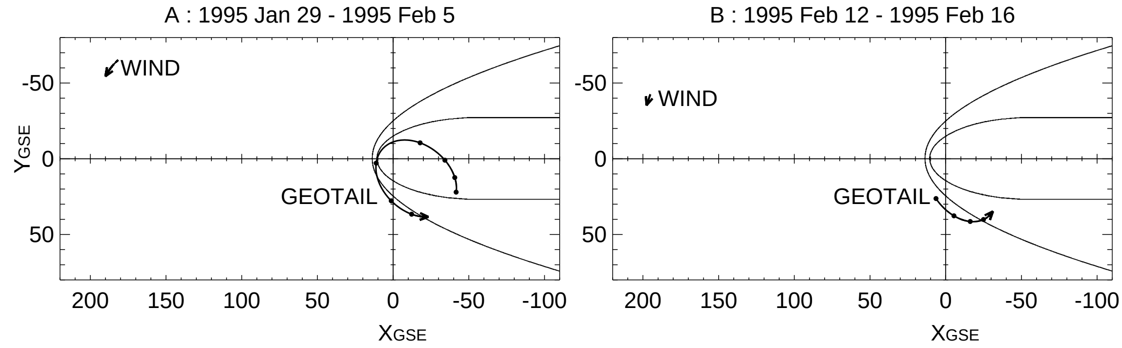

Figure 1. The projection of the positions of the spacecrafts Geotail and WIND in the X-Y plane, during the periods Jan. 29, 1995 – Feb. 5, 1995 (A - left panel) and Feb. 12, 1995 – Feb. 16, 1995 (B - right panel)

by the WIND (bottom panel). At Periods A and B, the Earth's magnetosphere was highly disturbed, with a Kp index to be in most of the time >4–5, due to the incident of high speed solar wind streams (∼600–700 km/sec), which are signatures of CIRs (Mason et al., 1996; Anagnostopoulos, 1998).

From Figures 1 and 2a, we see that the Geotail s/c observed numerous very intense bursts of energetic ions and high energy electrons within the magnetosphere and its environment, which were evidently produced by acceleration / transport processes within the magnetosphere and escaped to the magnetosheath and the upstream region. During these times, the WIND s/c also observed CNO burst activity far upstream from the bow shock.

Figure 2b displays, from top to bottom: (a) CNO, proton and electron fluxes from the Geotail s/c and (b) CNO data from the WIND s/c (adapted from Mason et al., 1996), for the days 30 and 31 of Jan. 1995. We see that CNO events were observed by WIND during the periods marked I, II and III in Figure 2b, and that they well correspond to CNO, electron and proton bursts at the position of the s/c Geotail within the magnetosphere, which started a little earlier. Magnetic field and plasma data (not shown in the figure) suggest that Geotail moved in most of the time examined in Fig. 2b in or near the plasma sheet.

In the rest, we concentrate on the time period marked III in Figure 2b, which was reported by Mason et al. (1996) as a time with a typical ion event of their 9-month study of upstream CNO bursts. During period III, Geotail crossed several times the current sheet and detected bursts in the flux of energetic CNO ion, protons and electrons. Notice that WIND detected a CNO event a little later.

3 Discussion

Mason et al. (1996) reported characteristics of short duration heavy ion enhancements observed by the WIND spacecraft upstream from the bow shock during times of high-speed streams. Mason et al. (1996) presented CNO observations for the period Jan. 20, 1995 – Feb. 19, 1995, and in particular for a typical event on January 31, 1995. These authors analyzed data obtained far (∼180–200 R_E) upstream, from the bow shock for the period Jan. 20, 1995 – Feb. 19, 1995 and they could not directly compare their observations with predictions of bow shock acceleration and of leakage models. However, they found more attractive that the CIRs provided the seed population, which was further accelerated in association with the bow shock, and then was observed in the upstream region by WIND.

Anagnostopoulos (1998) analyzed and discussed the WIND observations presented by Mason et al. (1996) and he found the characteristics of upstream ions consistent with the characteristics of energetic ions leaking from the magnetosphere

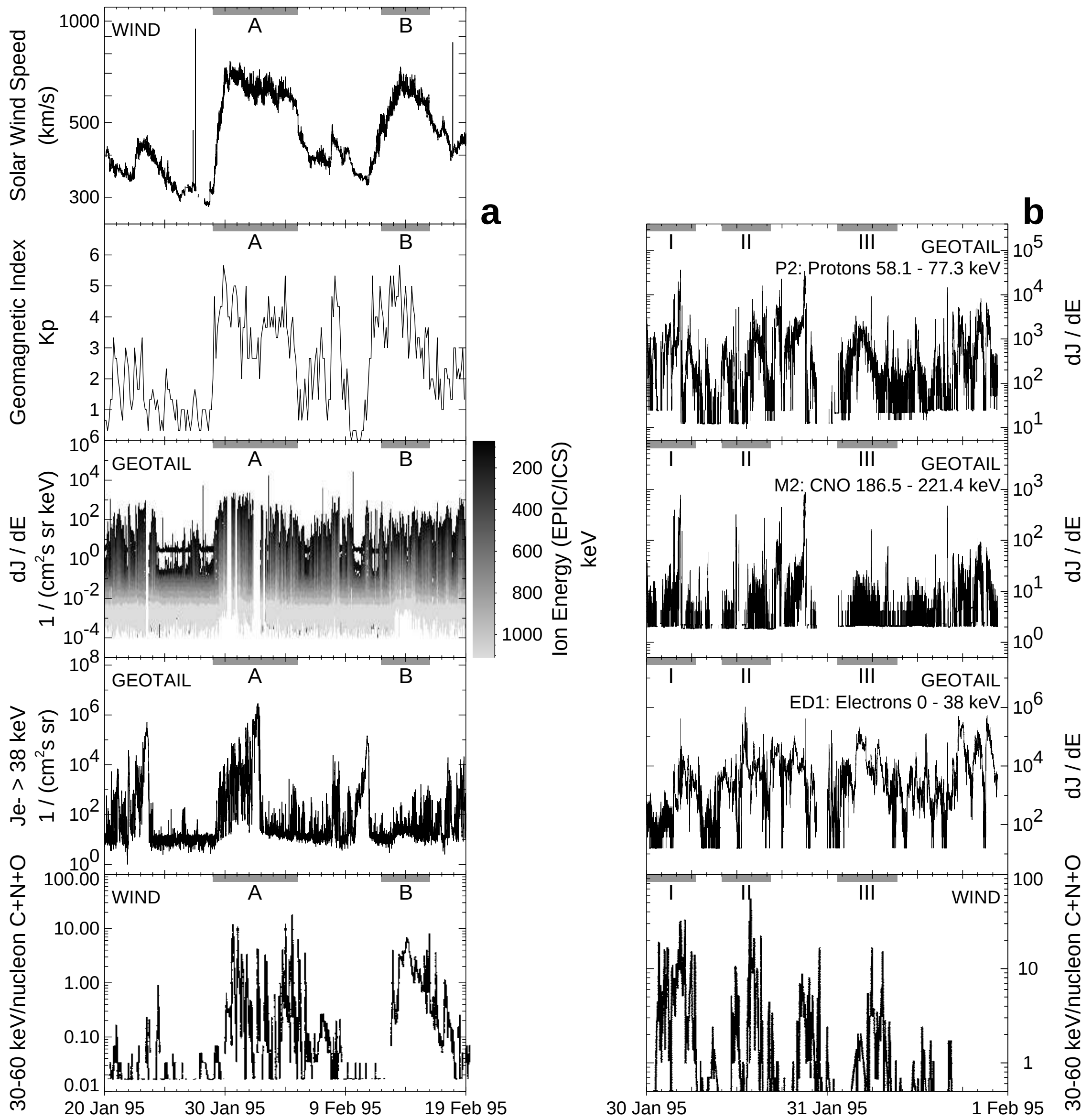

Figure 2. **(a)** Solar wind speed from the WIND spacecraft and the magnetospheric index Kp (two upper panels), ion spectrogram and electron flux-time profile from Geotail observations (two panels in the middle), and 30-60 keV/n CNO fluxes measured by the WIND spacecraft (bottom). The observations suggest that the magnetosphere was a rich source of energetic ions and electrons during periods A and B. **(b)** Geotail and WIND energetic particle observations for the days 30 and 31 of Jan. 1995. The multispacecraft observations suggest that the magnetosphere was a rich source of CNO ions and magnetospheric electrons during period III, when an upstream CNO event was detected by WIND. The upstream ion event III considered to be a typical one in studies of upstream heavy ion events (Mason et al., 1996).

(Anagnostopoulos et al., 1998, 2000). For instance, he noted the negative correlation of the peak-to-background flux values pb^{-1} with the background flux b. Mason et al.(1998) responded that the parameters AB^{-1} and B show a negative correlation, for two whatever sets of independent parameters A and B. However, this statement supports (rather than opposing) our argument. The negative correlation of the peak-to-background flux values pb^{-1} with the background flux b is consistent with the leakage model and with previous observations of magnetospheric ions leaking to the upstream region, and confirm that the peak flux p of upstream ion events is independent from the background flux b of the CIR population. Mason et al. (1996) assumed the CIR ion population to be the ambient population of bow shock acceleration. If the CIR energetic ion population was actually the seed population for bow shock acceleration, the two parameters, the background flux of the CIR population and the peak flux p of the bow shock accelerated ions, would not be independent.

In this paper, we analyzed multispacecraft data from the spacecraft Geotail and WIND in order to further examine the origin of the CNO events observed by WIND. The Geotail observations suggest that the magnetosphere was highly disturbed during the periods Jan. 29, 1995 – Feb. 5, 1995 and Feb. 12, 1995 – Feb. 16, 1995, due to the interaction with two CIRs (Figs. 2a and 2b); rich CNO, electron and proton burst activity was observed by Geotail at or near the current sheet, within the magnetosheath and in the upstream region. The observations shown in Figures 2a and 2b strongly suggest that the magnetosphere was an abundant reservoir of energetic ions, and that provided the magnetosheath and the upstream region with magnetospheric CNO ions, protons and electrons. These ions, under some conditions, could propagate and reach the position of the WIND s/c.

In particular, during the time period III (Figure 2b) for which intense production of CNO, electrons and other particle species was detected in the current sheet, Mason et al (1996) reported a CNO burst at the position of WIND spacecraft. Based on the good time correspondence of CNO, proton and electron bursts observed by Geotail within the plasma sheet, and the bursts observed in the upstream region by WIND, we infer that the magnetosphere was the source of the upstream ion event C.

At this time, WIND was 195 R_E upstream from the bow shock, and observed strong field aligned anisotropies and ion (HE, C, O, Fe) spectra suggesting a composition He:C:O:Fe = 86:1.46:1:0.12 (near 45 keV/neucleon) that is similar to that that observed in the outer magnetosphere and in CIRs (at much higher energies). We interpret these observations as probably suggesting that the magnetosphere acted as an accelerator of the seed CIR ions, and that these ions after their acceleration leaked to the interplanetary space, where made a strong contribution in upstream ion events.

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References

Anagnostopoulos, G.C., 1998, Geophys. Res. Lett., 26, 1523.

Anagnostopoulos, G.C., A.G. Rigas, E.T. Sarris, and S.M. Krimigis, 1998, J. Geophys. Res., 103, 9521.

Anagnostopoulos, G.C., G. Kaliabetsos, G. Argyropoulos, and E.T. Sarris, 1999, Geophys. Res. Lett., 26, 2151.

Anagnostopoulos, G.C., G. Argyropoulos, and G. Kaliabetsos, 2000, Ann. Geophysicae, 18, 42.

Karanikola, I., G.C. Anagnostopoulos, and A.G. Rigas, 1999, Ann. Geophysicae, 17, 650.

Mason, G.M., J.E. Mazur, and T.T. von Rosenvinge, 1996, Geophys. Res. Lett., 23, 1231.

Mason, G.M., J.E. Mazur, and T.T. von Rosenvinge, 1998, Geophys. Res. Lett., 25, 1527.

Scholer, M., F. M. Ipavich, G. Gloeckler, and D. Hovestadt, 1981, J. Geophys. Res., 49, 186.