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Transport of Ions at Earth's Collisionless Bow Shock

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Earth's bow shock is a well-known example of collisionless plasma shocks. The bow shock has been extensively studied since it was first observed by a spacecraft[1]. It is widely accepted that the solar wind ions are fully thermalized as they cross the bow shock and the reflected ions at the shock play a substantial role on heating of ions[2]. However, recent observations showed that in some cases solar wind ions transport the bow shock without significant thermalization[3]. In this study, we present new findings about the thermalization of ions when the ions transport across the bow shock.

Fig. 1 shows the summary plot of the shock crossing event on 17 January 2003 observed by the Cluster 1 spacecraft. Cluster 1 crossed the bow shock at ~1348 UT from the magnetosheath. The estimated shock normal angle is ~79°. The Alfvén and magnetosonic Mach numbers are ~12.2 and ~4.75, respectively. Thus, the bow shock is a supercritical, quasi-perpendicular shock. There are some variations of magnetic field around the shock crossing, but they do not affect the kinetic properties of ions as they cross the bow shock.

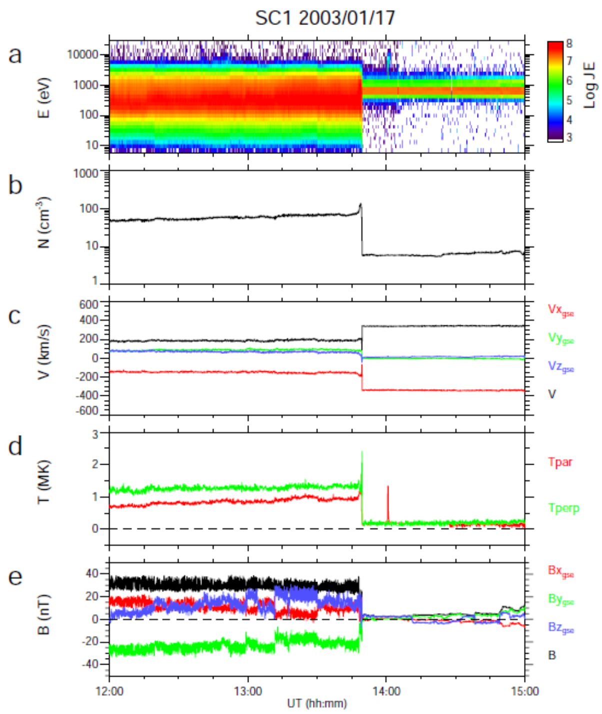

Fig. 1. Summary plot of the shock crossing event on 17 January 2003 observed by *the* Cluster 1 *spacecraft*. From top to bottom shown are (a) the spectrogram of ion energy flux, (b) ion density, (c) ion bulk velocity, (d) ion temperature, and (c) magnetic field. The velocity and magnetic field are presented in the geosynchronous solar ecliptic (GSE) coordinates.

Fig. 2 shows the examples of the velocity space distribution functions of the ions in the solar wind at 1351:42 UT and in the magnetosheath at 1345:04 UT. The 2-dimensional distribution function in the magnetosheath (Fig. 2(d)) looks almost isotropic and fully thermalized as expected in the downstream region of a shock. However, the 1-dimensional cuts of the distribution function (Fig. 2(e) and (f)) show that the distribution consists of two components: a cold core component, which is similar to the solar wind, and a hotter component. Both components well fit into the Maxwellian distributions, which suggests that the components are thermalized independently. The results suggest that the transport process of ions across a collisionless shock should be reexamined.

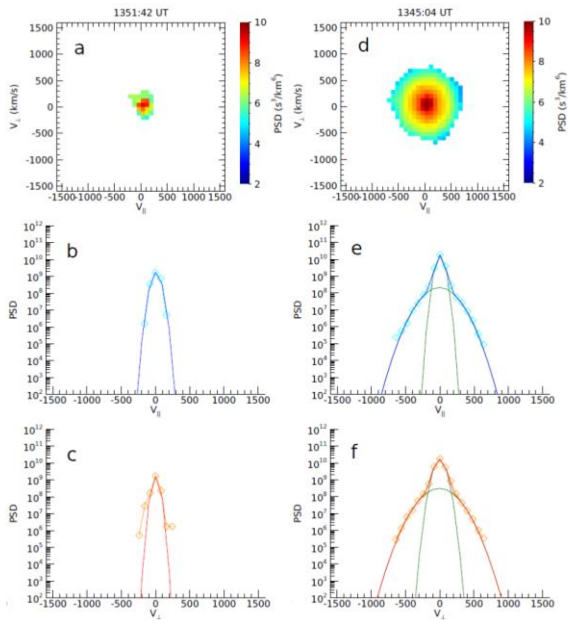

Fig. 2. Ion velocity space distribution functions on the $V_{\parallel}$-$V_{\perp}$ plane (a) in the solar wind at 1351:42 UT and (d) in the magnetosheath at 1345:04 UT. In (b) and (c), the blue and red solid lines show the fitting curves into a Maxwellian distribution function for the distribution function in (a) along the $V_{\parallel}$ and $V_{\perp}$ directions, respectively. (e) and (f) present the same plots for the distribution function in (d).

References

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