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Article

Observations of the step-like accelerating processes of cold ions in the reconnection layer at the dayside magnetopause

Qinghe Zhang [a,*], Michael Lockwood [b], John C. Foster [c], Qiugang Zong [d], Malcolm W. Dunlop [e], Shunrong Zhang [c], Jøran Moen [f], Beichen Zhang [g]

[a] *Shandong Provincial Key Laboratory of Optical Astronomy and Solar-Terrestrial Environment, Institute of Space Sciences, Shandong University, Weihai 264209, China*
[b] *Department of Meteorology, University of Reading, Reading RG6 6BB, UK*
[c] *MIT Haystack Observatory, Westford, MA 01886, USA*
[d] *School of Earth and Space Sciences, Peking University, Beijing 100087, China*
[e] *Space Sciences Division, SSTD, Rutherford Appleton Laboratory, Didcot OX11 0QX, UK*
[f] *Department of Physics, University of Oslo, Blindern 0316, Oslo, Norway*
[g] *SOA Key Laboratory for Polar Science, Polar Research Institute of China, Shanghai 200136, China*

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ABSTRACT

Cold ions of plasmaspheric origin have been observed to abundantly appear in the magnetospheric side of the Earth's magnetopause. These cold ions could affect the magnetic reconnection processes at the magnetopause by changing the Alfvén velocity and the reconnection rate, while they could also be heated in the reconnection layer during the ongoing reconnections. We report *in situ* observations from a partially crossing of a reconnection layer near the subsolar magnetopause. During this crossing, step-like accelerating processes of the cold ions were clearly observed, suggesting that the inflow cold ions may be separately accelerated by the rotation discontinuity and slow shock inside the reconnection layer.

1. Introduction

Cold ions (few eV) of plasmaspheric origin are often observed in the outer magnetosphere and the magnetospheric side of magnetopause, which are in the form of drainage plumes mainly driven there by convection electric field during the high geomagnetic activity [1–7], and are carried there by plasmaspheric wind via combinational consequence of corotation and convection electric field during quiet geomagnetic activity [6–11]. Cold ions from the polar ionosphere can also directly reach the dayside magnetopause along the magnetic field lines via outflow [12]. When the cold ions reach the dayside magnetopause, they may be involved in, and influenced by, magnetic reconnection in the magnetopause current sheet [5,13–17]. On reaching the magnetopause, it has long been thought to be lost to interplanetary space as the field lines are opened by reconnection [13,18–22].

The operation of MR is expected to result in a reconnection layer with characteristic ion and electron diffusion regions and an X-line of the central, null (zero) field and associated bundles of reconnected flux (flux tubes, moving in predictable ways from the magnetic merging line) during periods of ongoing or intermittent reconnection [23–27]. Previous theories and simulations predicted that there are several boundaries within the reconnection layer, which can accelerate the ions at the associated area [28,29]. Different models, however, predicted different boundaries [28,29]. In the ideal MHD simulation, rotational discontinuities (RD), slow shocks or slow expansion fan (SS/SEF), and contact discontinuity (CD) are present in the reconnection layer [28], while in the hybrid simulation, the contact discontinuity cannot be identified due to the mixing of ions from the magnetosheath and magnetosphere, and slow shocks and slow expansion waves are modified [29]. At the magnetopause, the Alfvén wave is an intermediate wave or shock and transmitted through RD, thus, people often talk about RD and Alfvén wave together [30]. Observations confirmed the existence of the RDs and SS/SEF [31,32]. Recent laboratory experiments and particle-in-cell simulations also suggested that the Hall effects can produce a strong electric field in the reconnection plane that is strongest across the separatrices, which separates the incoming field line region from the exhaust of reconnected field lines [33,34]. Dipolarization fronts and flux ropes in the reconnection region of the magnetotail can also accelerate the particles, especially the electrons [35–39]. Clear separated acceleration signatures are difficult, despite recent access to multi-point sampling

* Corresponding author.
E-mail address: zhangqinghe@sdu.edu.cn (Q. Zhang).

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on small and meso-scale, owing to the fact that most of the encounters are highly dynamic. We report here one of the first, clear partial transitions through a reconnection layer near the subsolar magnetopause, which shows clear accelerations of the cold ions in the reconnection layer.

2. Observations and results

Fig. 1 summarizes conditions on 17 January 2013, where the IMF and solar wind data come from the NASA OMNIWeb and has been shifted 5 min from the nose of bow shock to the subsolar day-

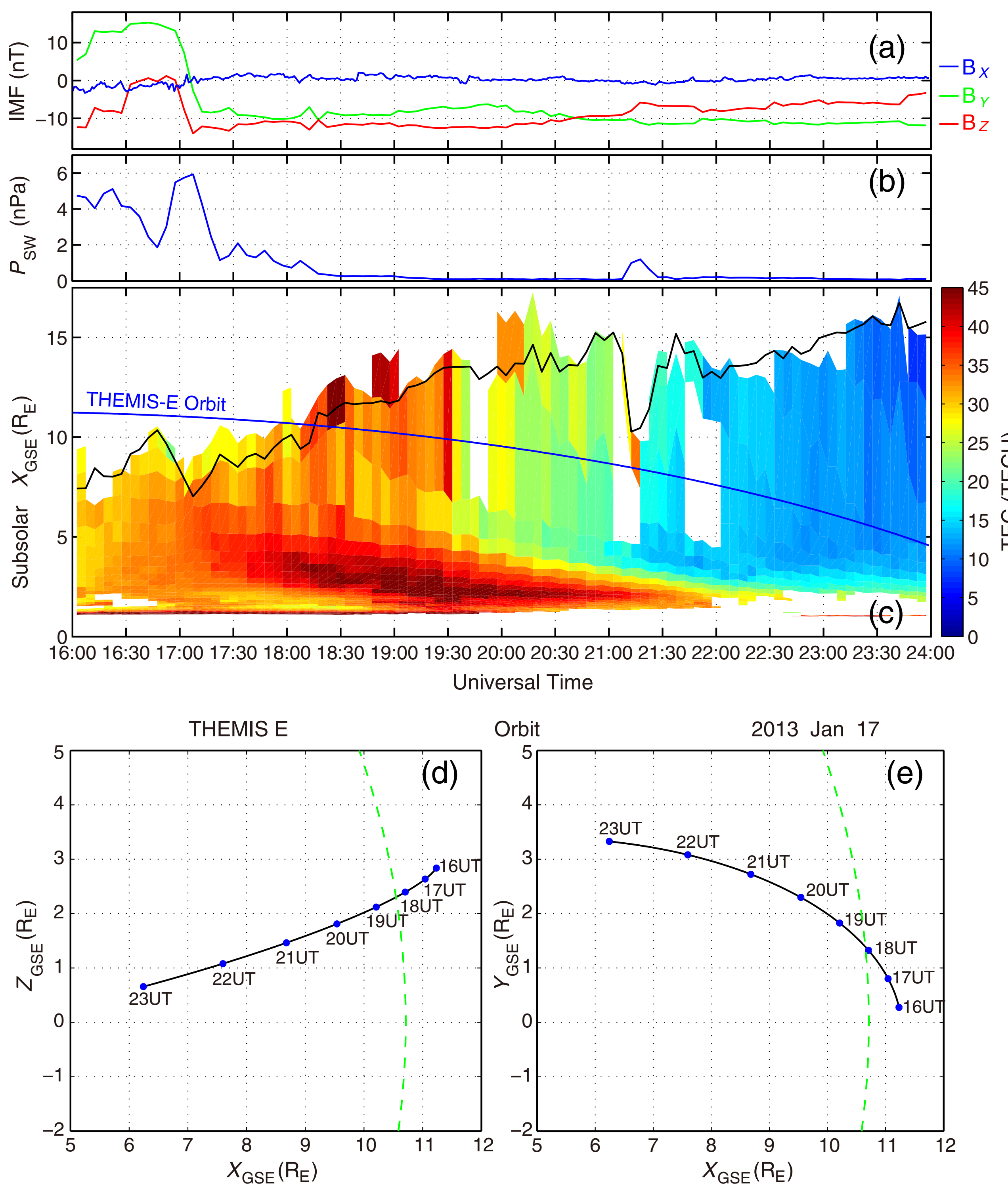

Fig. 1. Data from 17 January 2013. (a) The interplanetary magnetic field *X*, *Z* and *Y* components (in the GSM frame). (b) The solar wind dynamic pressure P_{SW}. (c) A keogram showing total electron content mapped from the noon meridian to the equatorial plane using the Tsyganenko T96 model [41], as a function of time. The black line shows the magnetopause position from a different model [42] and the blue line the path of THEMIS-E. (d) and (e) The orbit tracks of THEMIS-E relative to the modelled magnetopause position in XZ_{GSE} and XY_{GSE} plane (GSE is geocentric solar ecliptic coordinate system).