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Study of a Flux Transfer Event with Cluster Spacecraft

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Cluster multipoint measurements are used to study a magnetosheath Flux Transfer Event (FTE), with a typical magnetic signature. A large negative By (GSE) component is observed before, during and after the event. Cluster data demonstrate that the FTE is a force free configuration, with a current flowing essentially in the Y (GSE) direction. The current density is filamented, and it shows reversals from parallel to antiparallel to **B**. Energetic electron and ions, escaping from the magnetosphere (antiparallel to **B**), are observed during the magnetic signature of the FTE, as expected.

These escaping energetic electrons and ions continue to be observed about 2 minutes after the passage of the magnetic structure of the FTE. Surprisingly, during the magnetic signature of the FTE, energetic electrons are also observed in the parallel (to **B**) direction, with fluxes comparable to the antiparallel direction, and larger than in perpendicular direction. These enhanced energetic electron fluxes in parallel and antiparallel directions indicate that field lines are closed inside the FTE, at least during its early phase.

During the same time interval the density is about 4 times less than in the adjacent magnetosheath, which is also consistent with being on closed field lines (magnetospheric). When the 4 S/C cross the magnetopause, a tangential discontinuity (TD), it remains in the closed magnetosphere for about 30 sec. No compelling evidence for a boundary layer (BL) is found during this first crossing. 35 sec later, the 4 S/C cross a second TD: the boundary between the magnetosphere and a turbulent magnetopause boundary layer (MPBL). Just after, and during $\sim$ 25 sec, field lines are alternatively open & closed, as inferred from signatures on energetic electrons. The ion flow velocity is then accelerated, during the crossing of a third discontinuity; a rotational

discontinuity (RD), corresponding to an open magnetopause. While crossing this RD the modulus of the ion flow velocity is multiplied by 2.

Thus the acceleration of the ion flow is observed on open field lines, as expected from the standard FTE model (see for instance Paschmann et al., 1982). Yet the ion flow velocity is continuous across the second TD, thus the accelerated ion flow is found to penetrate on closed field lines, through a TD, which is unexpected. Our observations demonstrate that the accelerated flow of ions is not limited to open field lines, which indicates that an efficient anomalous transport of the plasma occurs. It is suggested that the anomalous transport, through the inner edge of the MPBL, is due to a fast spatial diffusion associated with large amplitude electromagnetic ULF fluctuations observed simultaneously.

A simple cartoon is proposed to help visualize results: a magnetic pressure pulse, as it propagates along the MP, acts as a zipper: it leaves behind it opened field lines. Then the opening of the field lines is not limited to a remote reconnection site (e.g. equatorial); it occurs all along the motion of the zipper.

Others FTE events are also studied in the same way.