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Direct observation of magnetosheath plasma penetrating the magnetopause

Herbert Gunell (1), Hans Nilsson (2), Gabriella Stenberg (2), Maria Hamrin (3), Tomas Karlsson (4), Rickard Lundin (2), and Mats André (5)

(1) Belgian Institute for Space Aeronomy, Brussels, Belgium (herbert.gunell@physics.org, +32 2 374 8423), (2) Swedish Institute of Space Physics, Kiruna, Sweden, (3) Umeå University, Umeå, Sweden, (4) Royal Institute of Technology, Stockholm, Sweden, (5) Swedish Institute of Space Physics, Uppsala, Sweden

Plasma structures with higher density and momentum than the surrounding plasma can penetrate magnetic field barriers through self-polarisation. As the electrons and ions gyrate in opposite directions, space charge sheaths form on the edges of the structure, and this causes a polarisation electric field $\vec{E} = -\vec{v} \times \vec{B}$ to be set up inside. Thus, the plasma is able to continue moving with its initial velocity by means of an $\vec{E} \times \vec{B}$-drift, as described theoretically by *Schmidt* (Phys. Fluids, vol. 3, p. 961, 1960).

This process has been studied rather extensively in laboratory experiments with flowing plasmas (*e.g. Baker and Hammel*, Phys. Fluids, vol. 8, p. 713, 1965; *Lindberg*, Astrophys. Space Sci., vol. 55, p. 203, 1978; *Ishizuka and Robertson*, Phys. Fluids, vol. 25, p. 2353, 1982; *Hurtig*, et al., Phys. Plasmas, vol. 11, p. L33, 2004). Similar behaviour has been observed for laser produced plasmas in magnetic fields (*Ripin, et al.*, Phys. Rev. Lett., vol. 59, p. 2299, 1987; *Mostovych, et al.*, Phys. Rev. Lett., vol. 62, p. 2837, 1989).

In the 1970s Lemaire suggested that inhomogeneities in the solar wind can penetrate the magnetopause as plasma filaments through a process called impulsive penetration (*Lemaire*, Planet. Space Sci., vol. 25, p. 887, 1977). Satellite based measurements have shown evidence of magnetosheath plasma inside the magnetosphere (*Woch and Lundin*, J. Geophys. Res., vol. 97, p. 1431; *Lundin, et al.*, Annales Geophysicae, vol. 21, p. 457, 2003).

We present data from the Cluster spacecraft showing in situ observations of magnetosheath plasma penetrating the dayside magnetopause. First, we observe structures of magnetosheath plasma when the spacecraft are located on closed field lines in the dayside magnetosphere. Then, as the spacecraft cross the magnetopause, a transition region is observed in which the plasma flux is directed inwards throughout the spacecraft crossing. Thus the penetrating plasma structure is directly observed at the magnetopause during the penetration process. The measured plasma flux across the magnetopause was a few per cent of the solar wind flux at the time of penetration.