Geophysical Research Abstracts, Vol. 9, 01895, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-01895

Two-fluid collisionless reconnection: transition to a vortex turbulent regime

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We consider a two-fluid, collisionless model with full electron inertia effects in Ohm’s law ($m_p = 100 \, m_e)$. The length scale of the initial sheared magnetic field is of the order of the ion skin depth d_i and we take a guide field of the same order of the shear field, as typically observed in the terrestrial magnetotail. After the spontaneous growth of the reconnection instability ($k \, d_i \simeq 1$) we observe a transition to a super-Alfv\’enic regime of the electron flow with a corresponding magnetic field spectrum in the inertial range extending now well above $k \, d_i \sim \sqrt{m_p/m_e}$ (whistler range) with a $-5/3$ power law distribution. The electrons flow along the island magnetic isolines in layers of alternating sign. On the other hand, the ion flow is destabilized by the development of Kelvin-Helmholtz like instabilities leading to the formation of vortices that propagate inside the magnetic island. A model of the observed ion flow configuration (after the saturation of the reconnection instability) reproduces the main features and the time scale of the observed hydrodynamic transition to the vortex regime.