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Reconstruction of time-evolving, two-dimensional, quasi-magnetohydrostatic structures from single-spacecraft data

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We present an extension of Grad-Shafranov (GS) reconstruction [Hau and Sonnerup, 1999], a data analysis tool for the recovery of two-dimensional (2D), time-independent plasma structures from data recorded as the structures move past an observing probe. The new development allows us to incorporate slow time evolution of 2D structures whose force balance at every moment can be approximated by the GS equation. The spatial initial values for time steps before and after the actual measurements are obtained by advancing them backward and forward, respectively, in time based on the Faraday's law and equation of motion for an incompressible plasma (incompressibility is a straightforward consequence of the GS model); they are then used for the conventional spatial integration of the GS equation. The consequence is multiple field line maps, which can be used to investigate temporal development of the observed structures. The technique is benchmarked by use of 2D magnetohydrodynamic simulations of magnetic reconnection, and then is applied to a flux transfer event (FTE) seen by the Cluster spacecraft at the dayside high-latitude magnetopause, studied earlier by Hasegawa et al. [2006]. The application shows that the associated flux rope was in an approximate equilibrium, but its cross-section was slowly contracting in its direction of motion under the presence of weak poleward convective flow on the equatorward side of the FTE.

Hasegawa, H., B. U. O. Sonnerup, C. J. Owen, B. Klecker, G. Paschmann, A. Balogh, and H. Reme (2006), The structure of flux transfer events recovered from Cluster data, Ann. Geophys., 24, 603-618.
Hau, L.-N., and B. U. O. Sonnerup (1999), Two-dimensional coherent structures in the magnetopause: Recovery of static equilibria from single-spacecraft data, J. Geophys. Res., 104, 6899-6917.

Keywords: Grad-Shafranov equation, magnetohydrostatic equilibrium, magnetopause, magnetic reconnection, flux transfer event, inverse problem