Reconstruction of a bipolar magnetic signature in an earthward jet in the tail: Flux rope or 3D transient reconnection?

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Southward-then-northward magnetic perturbations are often seen in the tail plasma sheet, along with earthward flows, but the generation mechanism of such bipolar signatures (magnetic flux rope resulting from multiple X-line reconnection, transient reconnection, or else) has been controversial. At ˜2313 UT on 13 August 2002, the Cluster spacecraft encountered a bipolar signature at the leading edge of an earthward jet, with one spacecraft (Cluster 3) in close proximity of the current sheet center. Application to this bipolar structure of Grad-Shafranov (GS) reconstruction technique for recovery of two-dimensional (2D) magneto-hydrostatic structures (Sonnerup et al., JGR, 2006) suggests that a flux rope with diameter ˜2 Re was embedded in the flow. To investigate the validity of the GS result, we tested the method, using synthetic data from a 3D MHD simulation in which a bipolar field can be produced, without invoking multiple X-lines, through localized reconnection under the presence of guide-field By (Shirataka et al., JGR, 2006). A flux rope-like (closed field loop) structure, which does not really exist in the simulation, was erroneously produced from the GS method, but with a shape elongated in the flow direction. Unambiguous identification of which (flux rope or 3D transient reconnection) leads to an observed bipolar structure thus seems difficult. However, we infer that a flux rope was responsible for the bipolar signature in the Cluster event, because the magnetic structure reconstructed is nearly circular, suggesting a relaxed minimum-energy state. Our results also suggest that one needs to be cautious about interpretation of some (e.g., force-free, or magneto-hydrostatic) model-based results.