In situ evidence of firehose instability in multiple magnetic reconnection

Alexandra Alexandrova¹, Alessandro Retinò¹, Andrey Divin², Lorenzo Matteini³, Olivier Le Contel¹, Hugo Breuillard¹, Filomena Catapano⁴, Giulia Cozzani⁵, and Jan Deca⁶,⁷

¹Laboratory of Plasma Physics, Ecole Polytechnique, Paris, France
²Saint Petersburg State University, Saint Petersburg, Russia
³Department of Physics, Imperial College London, London, UK
⁴Department of Earth Observation, European Space Agency, ESRIN, Frascati, Italy
⁵Swedish Institute of Space Physics, Uppsala, Sweden
⁶Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, USA
⁷Institute for Modeling Plasma, Atmospheres and Cosmic Dust, NASA/SSERVI, USA

Energy conversion via reconnecting current sheets is common in space and astrophysical plasma. Frequently, current sheets disrupt at multiple reconnection sites, leading to the formation of plasmoid structures between the sites, which might affect energy conversion. We present in situ observations of multiple reconnection in the Earth's magnetotail. The observed highly accelerated proton beams parallel to magnetic field and the ion-scale wave-like fluctuations of the whistler type imply the development of firehose instability between two active reconnection sites. The linear wave dispersion relation estimated for the measured plasma parameters, indicates a positive growth rate of the firehose-related electromagnetic fluctuations. The detailed time-space evolution of the plasmoid is obtained by reconstruction of observations with the 2.5D implicit particle-in-cell simulations. In course of time, plasma on the periphery of the plasmoid becomes anisotropic and as it overcomes the firehose marginal stability threshold, the corresponding magnetic field fluctuations arise. The results of observations and simulations suggest that the firehose instability operating between reconnection sites, converts plasma energy of the proton temperature anisotropy to the energy of magnetic field fluctuations, counteracting with the conversion of magnetic energy to the energy of plasma in reconnection sites.