Project Details

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Program Element: Focused Science Topic

Topic: Fast Reconnection Onset

Project Title:
Magnetotail reconnection: Understanding and quantifying onset conditions using kinetic theory, simulations and data mining

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Summary:
Science goals and objectives: Magnetotail reconnection is inherently unsteady. Its onset, which is thought to be the cause of substorms, critically depends on the strength of the northward magnetic field Bz and its distribution along the tail. Onset may be permitted by demagnetization of electrons or ions in that field. It is preceded by the formation of ion-scale thin current sheets (TCS) embedded into a thicker plasma sheet. Unsteady regimes and mechanisms of reconnection depend on the tail geometry and the solar wind driving strength and are poorly constrained by observations because of extreme data paucity. The goal of this project is to understand the mechanisms of magnetotail reconnection onset during magnetospheric substorms. The objective is to quantify the onset conditions, regimes and their uncertainties using a combination of kinetic particle-in-cell (PIC) and magnetohydrodynamic (MHD) models, as well as data-mining (DM) algorithms to address the following Science Questions:
1) What are the critical conditions for reconnection onsets, enabled by demagnetization of electrons and ions, taking the observed pre-onset geometry of the tail, realistic external driving conditions and 3-D non-reconnection motions into account?
2) How does the magnetotail stability picture based on isotropic plasma equilibria change in the presence of TCS?
3) How unsteady is the magnetotail reconnection and what is the distribution of the reconnection electric field?
Methodology: To reproduce unsteady reconnection regimes it is proposed to use 3-D particle-in-cell (PIC) simulations covering ~10 earth radii (RE) along the tail and a few RE across the tail. Initialization of PIC runs will be done using new classes of weakly anisotropic 2-D TCS equilibria that describe embedded TCS with the observed aspect ratios and Bz profiles. To describe the global configuration of the tail prior to the onset we employ DM processing of space magnetometer data. The DM approach enables visualizing the global geometry of the tail at the moment of interest by mining big historical data. It resolves tailward Bz gradients, critical for the ion-demagnetization mediated onset, and embedded TCSs. It allows one to assess the unsteady component of the reconnection electric field, while its steady component will be assessed independently from the solar wind and interplanetary magnetic field data using a global MHD model.
Proposed Contributions to the Focused Science Team Effort: This study will determine the roles of global and local features of the magnetotail in reconnection onset: TCS, Bz profiles, ion and electron demagnetization processes as well as ideal MHD regimes. It will extend existing tearing stability picture going beyond isotropic current sheet models and single-scale TCS. It will help better understand not only the magnetotail onset physics but also similar processes in other space plasmas, where in situ observations are more limited or impossible. The potential contributions to the FST s team effort will be DM-enabled models of the magnetotail reconnection onset, its quantitative criteria and their observational constraints. Reconnection electric field distributions will help define the reconnection rate. Metrics of the proposed study will include predictive onset parameters, such as the critical TCS thickness and aspect ratio, tailward Bz gradient, strength of the driving electric field, roles of non-reconnection motions, electron and ion demagnetization parameters. The milestones will be determined by different classes of DM tail reconstructions and driving field strength. Error measures will include validation results for individual events and statistical bias of the DM data bins, estimates of impact of artificial parameters used in PIC codes, simulation and observation constraints in the assessment of ion and electron demagnetization parameters.

Publication References:

no references