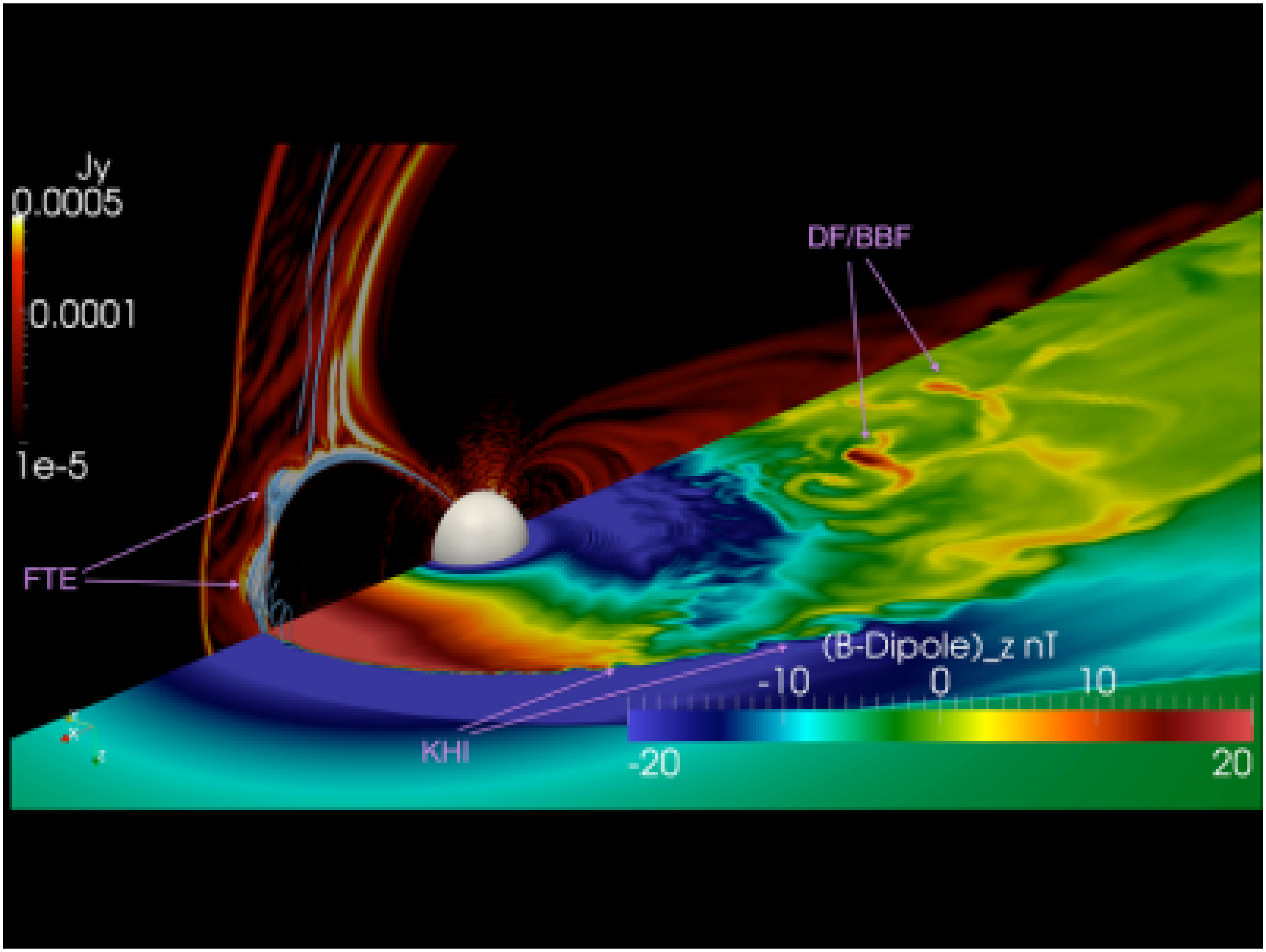
Great Mysteries of the Earth's Magnetotail

Workshop on Magnetotail Reconnection Onset and Dipolarization Fronts; Laurel, Maryland, 16–18 September 2015



Dipolarization fronts (DFs), bursty bulk flows (BBFs), flux transfer events (FTEs), and Kelvin-Helmholtz instability (KHI) in a high-resolution simulation of an idealized substorm. The simulation was performed using the Lyon-Fedder-Mobarry global magnetosphere model. Credit: Viacheslav G. Merkin

By Mikhail I. Sitnov, Viacheslav G. Merkin, and Joachim Raeder 21 March 2016

Charged particles trapped by Earth's magnetic field form its plasma environment, the magnetosphere. The solar wind, the flow of plasma emanating from our star, stretches the magnetosphere on the nightside—the magnetotail—away from the Sun. Other planets also form magnetotails, and in the course of their interaction with the solar wind they accumulate energy and then release it explosively. Substorms are the most violent examples of such explosive processes, with their impressive manifestation in auroral brightening, and they have long been associated with the onset of magnetic reconnection.

The mechanisms and driving forces behind magnetic reconnection, particularly in the magnetotail, have remained controversial for several decades.

Magnetic reconnection—ubiquitous throughout the universe—is the poorly understood process that breaks and reconnects oppositely directed magnetic field lines and converts magnetic field energy to plasma kinetic and thermal energy. The mechanisms and driving forces behind magnetic reconnection, particularly in the magnetotail, have remained controversial for several decades because of the fundamental physical complexity and limitations of observations.

Through various observations NASA established a close relationship between magnetic reconnection and other key signatures of the magnetotail activity, such as dipolarization fronts (DFs; thin sheets of electrical current associated with coherently structured disturbances) and bursty bulk flows (BBFs; brief high-speed flows in the plasma sheet). These observations were conducted by the Time History of Events and Macroscale Interactions during Substorms (THEMIS) (http://www.nasa.gov/mission_pages/themis/main/) and Geotail (http://science.nasa.gov/missions/geotail/) missions, as well as the European Space Agency's Cluster (http://sci.esa.int/cluster/) and other missions. However, major fundamental questions remain, including the preonset configuration and the stability of the magnetotail, the role of DFs in driven versus spontaneous reconnection onset scenarios, the role of ideal magnetohydrodynamic instabilities resulting in buoyancy and flapping plasma motions, and the general properties of DFs and BBFs throughout the tail.

These observational and theoretical challenges, together with the launch of NASA's dedicated reconnection Magnetospheric Multiscale (http://mms.gsfc.nasa.gov/) (MMS) mission, motivated us to convene a workshop on magnetotail reconnection onset and dipolarization fronts (https://sites.google.com/site/mrodfworkshop/home). The goal was to gather scientists with diverse views and approaches to these topics and to have an open forum with ample opportunity for discussions.

To provide a broader context for the primary topics of the workshop, we also invited presentations discussing similar processes at the magnetopause (http://www-spof.gsfc.nasa.gov/Education/wmpause.html), in the solar corona, and in laboratory experiments, leading to a balanced mix of theoretical, simulation, and observational presentations. Summaries of the presentations are available in the online supplement (https://sites.google.com/site/mrodfworkshop/downloads).

The lack of sufficient observations was a permeating theme throughout the workshop. Even with the five THEMIS spacecraft distributed throughout the magnetotail, we can barely capture the spatial and temporal complexity of these processes.

Even with more data, a complete understanding will also require major improvements in the physical realism and resolution of current global and regional models.
Thus, existing data are mostly insufficient to provide stringent constraints on models, which would require multiscale spatially distributed measurements. These could be provided, for example, by a constellation-class mission combining observations on different scales and involving more satellites than the present missions. However, even with more data, a complete understanding will also require major improvements in the physical realism and resolution of current global and regional models.

Forty-eight scientists attended the workshop (seven remotely), and international participants came from Sweden, Austria, Russia, the United Kingdom, Belgium, and China. We received an overwhelmingly positive response, and we plan to repeat the workshop in the fall of 2016. In the interim, we will be engaged in discussions with the workshop participants to refine the topics, scope, and science questions, as well as logistical items such as the workshop location and time.

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