Project Details

ROSES ID: NNH22ZDA001N-LWS
Selection Year: 2022
Program Element: Focused Science Topic

Topic: FST #2: Coupling of the Solar Wind Plasma and Energy to the Geospace System

Project Title:
Foreshock Transients Impact on Magnetospheric Perturbations and Plasma Population

PI Name: Jiang Liu
PI Email: atn@g.ucla.edu
Affiliation: University of California, Los Angeles
Project Member(s):
- Pinto Abarzua, Victor Alejandro;Collaborator;Universidad de Santiago
- Liu, Terry Zixu;Co-I;UNIVERSITY OF CALIFORNIA, LOS ANGELES
- Lin, Yu;Co-I;Auburn University
- Hartinger, Michael;Co-I;University of California, Los Angeles

Summary:
When the interplanetary magnetic field (IMF) is approximately parallel to the normal direction of Earth's bow shock, a foreshock forms with many dynamic structures in the upstream solar wind. Foreshock transients are ion kinetic structures commonly observed in the foreshock, characterized by dynamic pressure disturbances. Of these transients, hot flow anomalies (HFAs) and foreshock bubbles (FBs) have the most significant dynamic pressure perturbations. The perturbations can induce oscillations in the bow shock and magnetopause, driving ultra-low frequency (ULF) perturbations in the magnetosphere. During this process, the transients have transferred solar wind energy into the magnetosphere in the form of the perturbations. When foreshock transient disturbances propagate tailward along the magnetopause surface, they can continue inducing perturbations in the magnetosphere. Because ULF perturbations can modulate particle flux non-adiabatically and cause radial diffusion, foreshock transients are potentially important for redistributing the magnetospheric plasma population. This redistribution is key to deciphering magnetic storms and space weather phenomena. Knowledge about the transients' impact on the magnetosphere is crucial for understanding how solar wind energy control magnetospheric processes and increasing the predictive abilities of them. We thus propose to determine whether and how foreshock transients impact the magnetosphere and its plasma population, especially for electrons of the inner magnetosphere. We will investigate the whole chain of the solar wind-magnetosphere coupling related to fore-shock transients: from the significance of the transients' perturbations in the solar wind to how and how much of the perturbations enter the magnetosphere; from whether the perturbations interact with magnetospheric particles in the small scale to whether the particle population varies in the macroscale due to conditions favoring transients-related perturbations. Specifically, we will answer the following questions:_x000D_
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- How significant is the contribution of foreshock transients to those caused by magnetic storm-causing interplanetary shocks? The answer to this question will reveal the geo-effectiveness of the transients, such as a first-order modification to the existing storm models._x000D_
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- How do the perturbations triggered by HFAs and FBs cross the magnetopause into the magnetosphere? How much of the perturbation can be transmitted to the magnetosphere? The answer to these questions will inform us to what extent the transient-driven perturbations can effectively drive perturbations in the magnetosphere._x000D_
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- Can the perturbations triggered by HFAs and FBs modulate magnetospheric electron flux nonadiabatically? The answer to this question will tell us whether and how the energy from foreshock transients controls magnetospheric electron flux._x000D_
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- Does the IMF cone angle control the radial diffusion during magnetic storms? When the solar wind cone angle is smaller, the foreshock, and thus the transients, are closer to Earth. The perturbations caused by the transients are less damped when arriving at the magnetosphere, so they can cause stronger radial diffusion. The answers to this question determine whether the cone angle must be considered in next-gen prediction models of the storm-time particle population._x000D_
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To answer these questions, we will employ a global 3D hybrid simulation (note that this simulation will not be used to investigate any electron scale physics) and spacecraft data from NASA's THEMIS, MMS, and Van Alen Probes missions and OMNI datasets. The results of the proposed study will significantly advance the understanding of FST #2 of the LWS call by providing insight into non-reconnection coupling between solar wind fluctuations and the magnetosphere. The budget of the proposal will support young researchers and a graduate student.

Publication References:

no references