Project Details

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Program Element: Focused Science Topic

Topic: Origins, Acceleration and Evolution of the Solar Wind

Project Title:
Investigating the Interaction between Solar Wind Ions and Electromagnetic Waves Using New Observations and Hybrid Simulations

PI Name: Lan Jian
PI Email: lan.jian@nasa.gov
Affiliation: NASA Goddard Space Flight Center
Project Member(s):
- Wei, Hanying;Co-I;University of California Los Angeles
- Gershman, Daniel J;Co-I;NASA Goddard Space Flight Center
- Ofman, Leon;Co-I;The Catholic University of America
- Stevens, Michael Louis;Co-I;Smithsonian Astrophysical Observatory

Summary:
Electromagnetic cyclotron waves (ECWs) are extensively observed in the solar wind from 0.3 to 1 AU. They appear to be left-hand or right-hand polarized in the spacecraft frame, and propagate in directions close to the background magnetic field. On the other hand, the solar wind is often not in equilibrium, featured with the temperature anisotropy of particles with respect to the background magnetic field and relative drifts among ion components (proton core, proton beam, and alpha particles). The ECWs near the proton cyclotron frequency are most likely to have Landau and/or cyclotron resonances with solar wind ions. Using well-calibrated magnetic field and plasma data from Wind (continuous solar wind monitoring) and MMS mission (providing about 3 hours of high-cadence solar wind data per 3-day orbit), we will investigate the interaction between ECWs and solar wind ions.

Since the ion kinetic scale marks the transition from the inertial range to the dissipation range, our investigation directly addresses the acceleration and evolution of solar wind, which is the second Focused Science Topic of this LWS solicitation. In particular, we aim to answer the following three science questions. (1) How often are non-equilibrium ion velocity distributions and ECWs observed together in the solar wind? (2) In the case of multiple unstable modes of ion kinetic instabilities, how do the different modes interact? (3) Do all the instabilities propagate along with the solar wind?

In the solar wind, three types of ion-driven instabilities can generate such parallel-propagating ECWs: ion cyclotron, parallel firehose, and ion beam instabilities. There is often multiple sources of free energy for waves to grow. To fully investigate the nonlinear interaction between the different instabilities, we will conduct the hybrid simulation guided by solar wind observations. Our methodology includes the following three aspects. (1) We identify ECWs using Wind data and compare their existence with the growth rates of multiple ion kinetic instabilities to explain the discrepancies of their occurrence rates. (2) We search 20 long-lasting ECW events of multiple coexistent unstable instabilities using 2005-2007 Wind data, and examine how the different modes interact using hybrid simulation. (3) We search ECWs (especially the cases of close appearance of opposite polarizations) in the solar wind using MMS data and determine the wavevector and intrinsic polarization. By conducting hybrid simulations for selected events, we determine whether the unstable instabilities propagate along or against the solar wind.

The coherent electromagnetic waveforms and detailed particle velocity distributions provide unique opportunities to study the wave-particle interaction at ion kinetic scales. The improved understanding of ion kinetic physics through this coordinated project will be applicable to plasma in planetary magnetospheres and ionospheres, astrophysical systems, and laboratory plasma experiments. As more solar wind models and CME models start to incorporate the kinetic effects, the better understanding of wave-particle interaction gained from this project will ultimately help improving the prediction of solar wind and CME properties.

Publication References:

no references