2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

Cometary and Interplanetary Plasma Turbulence: Inference on Their Development from In Situ Magnetic Field and Plasma Spacecraft Observations

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When cometary neutral atoms and molecules are ionized by either charge exchange with the solar wind plasma or photoionization from solar UV, the newly formed ions become subjected to interaction with the supersonically flowing solar wind and thus form well-known plasma instabilities. The wave amplitudes generated are as large as the solar wind guide fields, thus the waves are highly nonlinear. The various wave modes are associated with the direction of the interplanetary magnetic field relative to the solar wind plasma flow. What is particularly interesting about these nonlinear waves is that the magnetosonic waves (driven by a beam instability) phase-steepen, forming a right-hand circularly polarized foreshortened front and an elongated, compressive trailing edge. The former is a form of "wave breaking" and the latter that of "period doubling". Understanding the individual wave cycle evolution is thus critical for visualizing the overall development of cometary plasma turbulence.

The solar wind is composed of highly nonlinear Alfvén waves. This same technique of examining single nonlinear (Alfvénic) waves is applied to the interplanetary medium. Alfvén waves are found to be "arc-polarized", have a ~180° foreshortened phase front with an elongated trailing edge. This is also a form of "wave breaking" and "period doubling" but in a different form from that of cometary magnetosonic waves. Nonlinear Alfvén waves kinetically dissipate, forming depressions in the magnetic field magnitude, thus making the solar wind "compressive". This view of examining single interplanetary wave cycles can explain all of the features of solar wind compressive turbulence.

The local decreases in the interplanetary magnetic field are called "magnetic decreases" or MDs. A new, nonresonant mechanism is envisioned for the interaction of energetic solar flare particles with MDs. From Monte Carlo simulations, it is shown that ~2 MeV protons will cross-field diffuse at ~5.5% of the Bohm rate. If there are MDs existing between the Earth and the Sun, this could be the mechanism that causes solar flare particles to be detected with wide longitudinal ranges. The upcoming Parker Solar Probe and Solar Orbiter missions should be able to address this issue.

The solar wind interplanetary Alfvén wave magnetic field southward components cause reconnection with the Earth's magnetic field leading to continuous geomagnetic substorms and convection events. The injection of ~10 to 100 keV anisotropic electrons into the nightside magnetosphere lead to the generation of whistler mode waves called "chorus" and their interaction with the ~100 keV electrons leads to their acceleration to relativistic energies. This is the mechanism for the formation of "killer" electrons in the magnetosphere.

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