DPP17-2017-002008
Abstract for an Invited Paper
for the DPP17 Meeting of
the American Physical Society

First Satellite Measurement of the ULF Wave Growth Rate in the Ion Foreshock[1]

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Waves generated by accelerated particles are important throughout our heliosphere. These particles often gain their energy at shocks via Fermi acceleration. At the Earth's bow shock, this mechanism accelerates ion beams back into the solar wind; the beams can then generate ultra low frequency (ULF) waves via an ion-ion right hand resonant instability. These waves influence the shock structure and particle acceleration, lead to coherent structures in the magnetosheath, and are ideal for non-linear interaction studies relevant to turbulence.

We report the first satellite measurement of the ultralow frequency (ULF) wave growth rate in the upstream region of the Earth's bow shock [1]. This is made possible by employing the two ARTEMIS spacecraft orbiting the moon at ~ 60 Earth radii from Earth to characterize crescent-shaped reflected ion beams and relatively monochromatic ULF waves. The event to be presented features spacecraft separation of ~ 2.5 Earth radii (0.9 ± 0.1 wavelengths) in the solar wind flow direction along a nearly radial interplanetary magnetic field. By contrast, most prior ULF wave observations use spacecraft with insufficient separation to see wave growth and are so close to Earth (within ~ 30 Earth radii) that waves convected from different events interfere.

Using ARTEMIS data, the ULF wave growth rate is estimated and found to fall within dispersion solver predictions during the initial growth time. Observed frequencies and wave numbers are within the predicted range. Other ULF wave properties such as the phase speed, obliquity, and polarization are consistent with expectations from resonant beam instability theory and prior satellite measurements. These results not only advance our understanding of the foreshock, but will also inform future nonlinear studies related to turbulence and dissipation in the heliosphere.

[1] S. Dorfman, H. Hietala, P. Astfalk, and V. Angelopoulos, Geophys. Res. Let. 44 (2017).

[1]Supported by NASA, NASA Eddy Postdoctoral Fellowship