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Global structure and properties of ULF waves in the ion foreshock observed in a Hybrid-Vlasov simulation

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Energetic ions reflected and accelerated by the Earth's bow shock travel back into the solar wind, forming the ion foreshock, and generate ultralow frequency (ULF) waves. Such ULF waves have been extensively studied over the past few decades using satellite measurements. However, the spatial variations of the wave properties cannot be well resolved by satellite observations due to the limited number of available spacecraft simultaneously inside the ion foreshock. Therefore, we conduct a global survey of the ULF wave properties in the ion foreshock through analysis of a Vlasiator (a hybrid-Vlasov code) simulation and focus on the wave properties, including frequency, ellipticity, polarization, wave normal angle and growth rate, of the well-known 30-sec wave.

We report that oblique waves are observed near the edge of the foreshock while waves propagate parallel to the magnetic field in the center of the foreshock. We also report that linearly polarized waves are observed in a region deep in the foreshock, while left-hand circularly polarized waves are observed in the rest part of foreshock. In addition, we found that the second harmonics of the 30-sec waves are commonly observed throughout the foreshock region, however, the generation mechanisms of these multiple harmonic waves are still not well understood. Here we connect the observed ion distribution to the wave properties using LEOPARD, a dispersion solver, and discuss the potential connections between the ion beams and ULF waves, aiming at understanding the physical drivers of the observed wave properties in the ion foreshock region.

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