Full particle simulations of quasi-parallel and quasi-perpendicular Bow shocks and comparison with GEOTAIL space observations

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The GEOTAIL wave observation provided a strong motivation for a study of micro-scale plasma dynamics in and in the vicinity of the Earth's Bow shock. In the course of multiple traversal of the transition layer of the Bow shock, GEOTIAL discovered that a variety of plasma waves are generated with a shorter and faster time scale than ever expected. In this paper, we will discuss our recent particle simulations for both cases of quasi-parallel (QPL) and quasi-perpendicular (QPD) shocks. The simulation models are both one-dimensional and two-dimensional.

In the QPL simulations, it was found that the electron heating in the transition and down-streaming regions is caused by a strong ion acoustic waves which are generated by a current driven instability. The current is produced by a differential acceleration of electrons and ions in the transition layer. Reflected ions form a beam streaming back towards the upstream. It excites a slow mode X-mode wave in the transition layer and an ion beam mode wave with a frequency near the electron plasma frequency in the upstream region. The latter wave interacts with electrons and thereby traps resonant electrons. The nonlinear trapping of electrons by the ion beam mode wave produces ESW (Electrostatic Solitary Waves or BGK solitary waves). The EWS's exhibit an intermittent nature when the angle of the shock deviates from zero angles. The observed intermittent nature of the ESW is thus reproduced by the simulations and understood. Large amplitude whistler trains are launched in the upstream region. The electrostatic electric component of the whistlers sometimes accelerates electrons along the magnetic field in the upstream region.

In the QPD simulations, we have studied wave generation mechanism of two types of waves which are generated in the upstream region of the quasi-perpendicular bow shock. One is electrostatic wave with a frequency near the upper hybrid frequency at a place where reflected ion beam exists. We have examined the generation mechanism of this upstream wave and found that the waves are generated by upper hybrid two stream (UTS) instability due to the reflected ion beam. The theoretical linear analysis and backup simulations without the presence of the shock confirmed the generation mechanism. The other is whistler waves found in the downstream surface of the shock front. The whistler waves propagate along the magnetic field parallel to the shock front. We examined the generation mechanism of the waves and found that the Whistler waves are generated by anisotropy-driven instability due to electron temperature anisotropy which in turn is the result of the interaction of electrons with the shock. The detailed results will be presented in the talk.