

# **Electrostatic solitary waves in the earth's foreshock: GEOTAIL observations**

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Electrostatic Solitary waves (ESW) are frequently observed in several regions such as the earth's magnetotail, polar magnetosphere and bow shock transition. They are also observed in the foreshock region. The generation of ESW is understood as the result of nonlinear evolution in electron beam instabilities. The electrostatic potential of ESW correlated to the electron hole in the phase space, which means the positive potential. Solitary waves similar to ESW are also reported in the polar region. They correspond to the negative potential. They are believed to be formed as the nonlinear evolution of ion beam instabilities. In the foreshock region, we can observe electron beams in the electron foreshock and ion beams in the ion foreshock. Therefore we can expect that the nonlinear wave structures such as solitary waves excited by the electron beams or ion beams in the foreshock region.

In the present paper, we focus on the observations of ESW by the GEOTAIL spacecraft in the foreshock region. As we expect, GEOTAIL waveform observations showed the existence of ESW type waves in both electron and ion foreshock regions. In order to understand the wave features of ESW in the foreshock region, we conducted the statistical analyses based on the GEOTAIL waveform data. Since the GEOTAIL crosses the bow shock two times a week on its orbit since November 1994, there exist plenty of data sets, which are very suitable for the present analyses.

The significant difference of ESW observed in the electron and ion foreshock regions is their amplitudes. The typical wave amplitude of ESW in the electron foreshock region is several tens of microvolts per meter, whereas their amplitude in the ion foreshock region is several tens of millivolts per meter. Their difference suggests the difference of kinetics, which control the formation of hole in the phase space.

We find that observations of ESW are correlated with existence of electron beams. The plasma conditions are similar to those in the Plasma Sheet Boundary Layer, in which ESW are discovered first by the GEOTAIL spacecraft. We estimate the depth of ESW potentials using observed parameters as 0.15 eV.

We find several types of ESW in the ion foreshock region. Occurrences of ESW correlate with non-thermal ions reflected by the bow shock. We perform the analyses of the spatial distribution of ESW. The results show occurrences and amplitudes of ESW are decreases depending on the distance from the bow shock transition. We also found the angle between the magnetic field and the shock normal and Mach number dependence of the occurrence of ESW in the ion foreshock region.

In the present paper, we discuss the generation of ESW comparing the observation results in the electron and ion foreshock regions.