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Polarization properties of BBELF waves contributing to ion acceleration in the cusp region observed by the Akebono satellite

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The Earth's polar ionosphere supplies plasma containing multi-species ions such as H^+, He^+, O^+, and molecular ions to the magnetosphere. Hydrodynamic theories can explain outflows of light ions (H^+ and He^+) but are not enough to explain outflows of heavy ions. Outflowing O^+ ions ions are often observed as ion conics resulting from transverse acceleration followed by the adiabatic motion due to the mirror force. The non-Maxwellian distribution indicates wave-particle interactions play an essential role in the heavy ion outflow process. One of the most important plasma waves in the acceleration mechanism is BBELF waves. BBELF waves are characterized by their spectra showing (1) amplitude decreases following the power law from DC to several kilohertz, (2) electromagnetic in the frequency range below f_{cO}, where f_{cO} represents the cyclotron frequency of oxygen ion, and (3) electrostatic in the frequency range higher than f_{cO}. Ishigaya (2017) analyzed six ion heating events observed by the Akebono satellite. They found that the ratio of the electric field amplitude to the magnetic field amplitude (E_w/B_w) exceeded 10^8 m/s, larger than the Alfven speed (~2 x 10^6 m/s), in the frequency range between fcH and fLH in intense heating events, where fcH and fLH indicate the cyclotron frequency of proton and the lower hybrid resonance frequency, respectively. Their results suggested the importance of the enhancement of electrostatic waves in the frequency range from f_{cH} to f_{LH} in addition to the enhancement of waves below f_{cO} in intense ion acceleration events. However, the properties of wave mode have not been clarified yet.

In this study, we study the properties of plasma waves observed by the Akebono satellite during the intense ion acceleration events reported by Ishigay(2017). Firstly, we have constructed a new, 0.5-sec resolution dataset from wave spectrum data measured by VLF/MCA and the DC magnetic field data observed by MGF onboard the Akebono satellite, which enables us to analyze the oscillation direction of the wave electromagnetic field with respect to the ambient magnetic field and its frequency dependence. Secondly, we reanalyze the intense heating event observed on 11 February 1990, 18:00-18:15 UT in the northern cusp region reported by Ishigaya(2017) to investigate how the intensities of the wave electromagnetic field depend on the oscillation direction with respect to the ambient magnetic field in the frequency range up to 1 kHz. Finally, we compare the observed oscillation direction and frequency dependence with the polarization characteristics derived from the dispersion relation in cold plasma.

Results of the analysis show that the intensities of the electromagnetic field variations in the frequency range from f_{cH} to f_{LH} enhanced at a certain direction with respect to the ambient magnetic field. Based on the cold plasma dispersion relation, R-mode waves exist in the frequency range from f_{cH} to f_{LH}. The observed properties rule out R-mode waves propagating neither parallel nor perpendicular to the ambient magnetic field and suggest the presence of obliquely propagating R-mode waves during the event. We discuss the resonance condition between obliquely propagating R-mode waves and ions based on the observed properties.