

Strong and weak heating of H^+ and O^+ ions by BBELF in the dayside cusp region

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Most part of the Earth's ion outflow are found in the dayside cusp region. A lot of observations from the ground, rockets and satellites show the presence of ion heating and acceleration like transversely accelerated ions (TAI) and ion conics with simultaneous bipolar electric field and plasma waves. It is suggested that Broadband Extremely Low Frequency waves (BBELF) is one of the important plasma waves associated with ion heating. BBELF is observed as fluctuation of electric field with a power law in a frequency range from dc to proton gyrofrequency f_{cH} or lower hybrid frequency f_{LH} . In high frequency range, BBELF is electrostatic wave while electromagnetic components are also included in frequency range below oxygen gyrofrequency f_{cO} . The electromagnetic component of BBELF is suggested to be Alfvénic wave [Wahlund et al., 2003; Chaston et al., 2004] and relations among low frequency Alfvénic wave, BBELF and ion heating have been reported by observation [Kasahara et al., 2001] and simulation [Singh et al., 2004; 2007].

Kasahara et al., [2001] statistically reported correlation between electric field spectral density of BBELF below 10 Hz and energy density of ions below 340 eV based on Akebono observation. It was suggested that ions are heated when the wave spectral density is above $10^{-1} - 1 \text{ (mV/m)}^2$ and that there is a threshold level of the wave spectral density that ions are effectively heated by the waves. Singh et al., [2004; 2007] reported that relative polarization drift between light and heavy ions driven by low frequency Alfvénic waves could excite waves in lower hybrid mode and ion cyclotron mode and these electrostatic waves heated ions using 2.5-dimensional particle-in-cell simulations.

The correlation between low frequency Alfvénic waves and ion heating was reported by Kasahara et al., [2001] but studies of relations among low frequency Alfvénic waves, BBELF and ion heating like the heating process reported by Singh et al., [2004; 2007] based on observation was not enough. In order to understand ion heating processes by BBELF in the dayside cusp region especially focusing on contributions of electrostatic component as suggested by Singh et al., [2004; 2007], we performed statistical studies and some events studies using ELF/VLF wave data and thermal (0-25 eV) ion data observed by Akebono satellite. In our statistical studies, we investigated correlation between electric field spectral density of BBELF below f_{cO} and energy density of ions below 25 eV in ion heating events. From the analysis, it was suggested that ions were efficiently heated with BBELF waves above a threshold level of the wave spectral density of $10^{-1} - 1 \text{ (mV/m)}^2$ as reported by Kasahara et al., [2001]. However, ions in some events were not effectively heated even when electric field spectral density was above the threshold level. In order to find distinct differences between strong and weak ion heating events, we investigated six events in which electric field spectral density of BBELF below f_{cO} was above 1.0 (mV/m)^2 . As a result, we found that E field and E/B ratio of the wave in a frequency range from f_{cH} to f_{LH} in strong heating events was higher than that in weak heating events. The wave in frequency range from f_{cH} to f_{LH} seemed to be electrostatic because B field was not enhanced. Furthermore, O^+ relative polarization drift velocities in strong heating events were much higher than other events and exceed O^+ thermal velocity. These results suggest that electrostatic wave grows by lower hybrid instability and heated ions as suggested by Singh et al., [2004; 2007].

Further studies focusing on the difference of E field intensity and E/B ratio in frequency range from f_{cH} to f_{LH} will be needed in order to understand details of ion heating processes by ion cyclotron waves and lower

hybrid waves.

Keywords: BBELF, ion heating