Estimation of the frequency range of electromagnetic ion cyclotron waves contributing to the ion heating process in the Earth's polar magnetosphere.

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Previous studies revealed outflow of hydrogen and oxygen ions from the Earth's polar ionosphere (Dandouras, I. 2021). Plasma waves observed in the frequency range from a few Hz to several kHz are considered to be important in the acceleration mechanism of outflow ions. The perpendicular component of the wave electric field with respect to the background magnetic field contributes to the transversely accelerated ions (Chaston et al., 2004). Based on Freja satellite observations in the polar region on the Earth's night side, Erlandson (1994) suggested that oxygen ions are accelerated in the perpendicular direction with respect to the background magnetic field by electromagnetic waves in the frequency range from 5 Hz to 25 Hz, which is slightly lower than the cyclotron frequency of oxygen, and from 100 Hz to 256 Hz, which is around the cyclotron frequency of helium. Ishigaya (2017) conducted a statistical study of the correlation between the energy densities of both hydrogen and oxygen ions and the spectral densities of the wave electric field measured during ion heating events from Akebono satellite observations in the daytime cusp region. The results suggest an effective acceleration of ions by electrostatic waves in the frequency range from the hydrogen cyclotron frequency to lower hybrid resonance frequency, while the contribution of the electromagnetic component to the strong heating is also interpreted but requires further investigation.
In order to investigate the contribution of electromagnetic waves to ion heating, we evaluate the frequency range of the electromagnetic waves resonating with oxygen ions in the heating event studied by Ishigaya(2017). We use the dispersion relation of plasma waves in cold plasma and the first-order cyclotron resonance condition to determine the frequency range. The heating event was observed by the Akebono satellite from 18:03:00 UT to 18:13:00 UT on February 11, 1990, at an altitude of 5100 km to 6400 km, from 11 to 12 MLT, and ILAT from 71˚ to 80˚. During this event, the enhancement of electromagnetic waves was identified in the frequency range from 3.16 Hz to 20 Hz, electrostatic waves in the frequency range from around 20 Hz to around 1160 Hz, and the increase of ions in the energy range from 0 eV to 25 eV around the pitch angle of 90˚. The dispersion relation is calculated using the IGRF-12 magnetic field model with a magnetic field strength of 8.89*10^3 nT, an observed plasma density of 60 /cc, and a composition ratio of H+:O+:He+=0.46:0.11:0.43. We estimate that oxygen ions from 0 eV to 25 eV with velocity components along the background magnetic field resonate with electromagnetic waves in the frequency range from 8.40 Hz to 8.53 Hz near the cyclotron frequency of oxygen among the observed frequency band from 3.16 Hz to 20 Hz. This result reveals that the limited frequency range of the observed electromagnetic ion cyclotron waves contributed to the ion acceleration process during the analyzed event.

Keywords: cyclotron resonance, electromagnetic ion cyclotron wave, magnetosphere, ion outflow

