Phase velocities of electron cyclotron harmonic waves and their relation to energies of cold electrons: Arase observations

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Phase velocities of electron cyclotron harmonic (ECH) waves are discussed based on the observations by the Arase satellite in the inner magnetosphere. There have been a lot of studies on generations of ECH waves and their roles in precipitating low energy electrons. What baffles us in interpreting the phenomena theoretically is that information about low energy electrons is missing in data, deriving from the difficulty to observe low energy electrons without effects of satellite potentials. The present paper shows estimating phase velocities of ECH waves provides thermal energies of cold electrons that low energy particle sensors do not cover in their lower limit of observed energy ranges. Kazama et al. (2018) shows the coincidence of local density depletion with enhancements of the ECH waves in a specific event using the Arase observation data [1]. They also find the existence of a cold electron population by showing plasma densities obtained from the UHR frequencies are much larger than the density of hot electrons calculated from the data observed by the low energy electron detector (LEP-e). This means that there exists the cold electron population with energies that the LEP-e does not cover. The Arase data show this relation between cold electrons and hot electrons is not special in the events of ECH waves. Linear dispersion analyses are conducted using the realistic parameters. The results show solutions of the dispersion equation for the ECH waves strongly depend on temperatures of core cold electrons but not temperatures of hot electrons. This implies that knowing phase velocities of ECH waves leads to estimating thermal energies of cold electrons by referring to the dispersion relations of the ECH waves. Plasma wave experiment (PWE) on board the Arase satellite has a special observation mode called "monopole mode," which is equivalent to the so-called "interferometry mode" [2]. This mode has the capability to identify phase differences between two waveforms observed by two monopole electric field sensors. The PWE succeeded in identifying phase velocities of the ECH waves using the monopole mode. Since the Arase does not have an electric field sensor along its spin axis, identified phase velocities are the projected components on the sensor plane. However, by assuming the orientation of ECH electric field oscillations is perpendicular to the ambient magnetic field, absolute values of phase velocities can be obtained. By comparing obtained phase velocities with the dispersion relations, thermal velocities of cold electrons can be estimated. In the present paper, we show our results about phase velocities of the ECH waves using the Arase data and discuss thermal velocities of cold electrons.

References

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