Pitch angle scattering by electrostatic electron cyclotron harmonic waves based on Arase observations

Mizuki Fukizawa[1]; Takeshi Sakanoi[2]; Yoshizumi Miyoshi[3]; Yoichi Kazama[4]; Yoshiya Kasahara[5]; Shoya Matsuda[6]; Ayako Matsuoka[7]; Shiang-Yu Wang[8]; Sunny W. Y. Tam[9]
[1] PPARC, Tohoku Univ.; [2] Grad. School of Science, Tohoku Univ.; [3] ISEE, Nagoya Univ.; [4] Institute of Astronomy and Astrophysics, Academia Sinica, Taiwan; [5] Kanazawa Univ.; [6] ISAS/JAXA; [7] ISAS/JAXA; [8] Institute of Astronomy and Astrophysics, Academia Sinica, Taiwan; [9] ISAPS, NCKU, Taiwan

Pulsating auroras (PsAs) are thought to be generated by precipitating electrons scattered by lower-band chorus (LBC) waves near the magnetic equator through cyclotron resonance. One-to-one correlations between LBC wave intensity observed by satellites near the magnetic equator and PsA intensity obtained by ground-based all-sky imager have been reported by previous studies [e.g., Nishimura et al., Science, 2010, Nishimura et al., JGR, 2011]. In addition, electrostatic electron cyclotron harmonic (ECH) waves can also interact with magnetospheric electrons and scatter their pitch angle theoretically [e.g., Lyons, JGR, 1974]. In our previous study [Fukizawa et al., GRL, 2018], we reported that not only LBC but also ECH wave intensity has correlation with the PsA intensity using coordinated Exploration of Energization and Radiation in Geospace (ERG, also called Arase) satellite and ground-based imager observations. Recently, Kasahara et al. [Nature, 2018] reported that LBC wave intensity had correlation with electron flux inside a loss cone and pulsating auroral intensity based on coordinated Arase satellite and ground-based optical observations. Their study confirmed that wave-particle interactions indeed occur between LBC waves and electrons with the energy of 24.5 keV and cause pulsating auroral emissions. On the other hand, correlations between ECH wave intensity and loss cone electron flux have not been reported yet. Therefore, this study aims to reveal whether wave-particle interactions between ECH waves and electrons occur or not at the magnetic equator.

To verify whether ECH waves indeed scatter electrons into a loss cone, we compared ECH wave intensity with electron flux inside the loss cone obtained with low-energy particle experiments-electron analyzer (LEP-e) onboard Arase. Cross-correlation coefficients between ECH intensity and loss cone electron flux in the energy range of 4-6 keV were statistically significant while those between LBC intensity and loss cone electron flux in the same energy range were not statistically significant. To estimate the cyclotron resonance energy of ECH waves, we fitted the observed distribution function by a sum of four subtracted Maxwellian components [e.g., Ashour-Abdalla and Kennel, JGR, 1978]. The dispersion relation was calculated with Kyoto University Plasma Dispersion Analysis Package (KUPDAP), which is a dispersion solver developed by the Space Group at Kyoto University, with changing the wave normal angle of ECH waves from 84.00 degrees to 89.99 degrees. In the case that the wave normal angle is 85.50 degrees, the growth rate has a peak at a frequency of 1.6 fce, where fce is the electron cyclotron frequency. In the case that the wave normal angle is 89.00 degrees, the growth rate has two peaks at 1.3 and 1.6 fce. We suggest that wave normal angle was close to 89.00 degrees since ECH waves observed by OFA had two peaks at 1.1 and 1.6 fce. Using the dispersion relation calculated by KUPDAP, we estimated the cyclotron resonance energy of ECH waves as a function of wave normal angle. The result indicates that the resonance energy reaches the energies of 4-6 keV which cross-correlation coefficients were statistically significant if the wave normal angle is larger than 89.98 degrees. However, the calculated growth rate has single peak at 1.1 fce when the wave normal angle is 89.98 degrees, which is inconsistent with the wave power spectrum observed by OFA. It would be necessary to take effects of wave propagation into account because the observed wave spectrum possibly contains ECH waves not only locally enhanced but also propagated from different source region [e.g., Horne et al., JGR, 2003].

Unfortunately, we could not compare ECH wave intensity and loss cone flux with pulsating auroral intensity at the Arase's footprint due to contamination of sunlight. However, this study suggests that ECH waves scatter a few keV electrons which contribute to cause auroral emission.