# Correlation between pulsating aurora and electrostatic electron cyclotron harmonic waves obtained from coordinated Arase and ground data

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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. Previous studies showed one-to-one correlation between LBC wave intensity observed by satellites near the magnetic equator and PsA intensity obtained by ground-based all-sky imager [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]. However, characteristics of aurora caused by ECH are not understood. In our study, we report for the first time in the world that not only LBC but also ECH wave intensity has correlation with the PsA intensity using coordinated Arase and ground-based imager observations. The first campaign observations between the Arase satellite and ground-based optical imager were conducted in March 2017. A typical substorm occurred on 27 March 2017 and the ionospheric footprint of Arase traversed the field of view of all-sky imager at Sodankylä during 00:00–03:15 UT on 29 March 2017. Quasi-periodic LBC and ECH waves were observed by Arase near the magnetic equator and PsA was detected by the all-sky imager during 01:30–02:00 UT. We calculated the cross-correlation coefficients between auroral intensity and LBC or ECH wave intensity from 01:30 UT to 02:00 UT with a time window of every 2 minutes. The highest cross-correlation coefficient between auroral intensity and LBC wave intensity was 0.73 and that between auroral intensity and ECH wave intensity was 0.62 from 01:46 UT to 01:48 UT, and they were statistically significant. The period of auroral intensity which correlated with LBC intensity was shorter than 10 s and that correlated with ECH intensity was 10–20 s. We estimated the precipitating electron energy assuming that the time lag when the cross-correlation coefficient became the highest equals to the travel time of electrons from the modulated source region to the auroral emission height. We shifted the variation of auroral intensity against that of ECH or LBC wave intensity with a time step of 0.01 s using 100 Hz sampling image data taken by the all-sky imager. The estimated energy of precipitating electron interacted with LBC waves was ~20–67 keV and that interacted with ECH waves was ~3–4 keV. On the other hand, we independently estimated the cyclotron resonance energy of LBC and ECH waves from the Arase's observation data and geomagnetic field model by TS04 Model [Tsyganenko and Sitnov, JGR, 2005]. The estimated cyclotron resonance energy of LBC waves was ~30 keV. Although the cyclotron resonance energy of ECH waves could not be estimated because it was difficult to obtain the electron temperature and wave normal angle of ECH waves from Arase data, we suggest the cyclotron resonance energy of ECH waves to be a few keV with probable assumptions. From these results, we suggest that LBC waves interact with high energy electrons which cause auroral emission at lower altitudes, while ECH waves interact with

 

relatively low energy electrons which cause auroral emission at higher altitudes. These results were published in Fukizawa et al. [GRL, 2018].
To verify whether ECH waves indeed scatter the pitch angle of electrons, we compared ECH wave intensity with electron flux in the loss cone obtained with low-energy particle experiments-electron analyzer onboard Arase. We also give results of other coordinated observation events.

Keywords: pulsating aurora, ECH waves, wave-particle interaction