Master Thesis

Relationship between plasma waves at the magnetic equator and pulsating aurora based on coordinated Arase satellite and ground-based optical observations

Mizuki Fukizawa

Department of Geophysics, Graduate School of Science
Tohoku University

(Supervisor: Associate Professor Takeshi Sakanoi)

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Abstract

Pulsating auroras (PsAs), which have quasi-periodic fluctuations of their luminosity, are thought to be generated by precipitating electrons scattered by lower-band chorus (LBC) waves near the magnetic equator through the cyclotron resonance. One-to-one correlations between the LBC wave intensity observed by satellites near the magnetic equator and the PsA intensity obtained by ground-based all-sky imager have been reported in previous studies [e.g., Nishimura et al., 2010, 2011a]. In addition, electrostatic electron cyclotron harmonic (ECH) waves can also interact with magnetospheric electrons and scatter their pitch angle theoretically [e.g., Lyons, 1974]. Similar periodicity between the ECH intensity observed by satellites near the magnetic equator and the PsA intensity observed by ground-based all-sky imager was given by Liang et al. [2010]. However, one-to-one correspondence between them has not been reported yet. In this study, we report for the first time in the world that not only the LBC but also ECH wave intensity has correlation with the PsA intensity using coordinated ERG (Arase) satellite 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 transversed the field of view of all-sky imager at Sodankylä (SOD) 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 at SOD during 01:30–02:00 UT. We calculated the cross-correlation coefficients between auroral in-

tensity 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 the LBC intensity was shorter than 10 s and that correlated with the ECH intensity was 10–20 s. We estimated the precipitating electron energy by 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 $\sim$ 20–67 keV and that interacted with ECH waves was $\sim$ 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. The estimated cyclotron resonance energy of LBC waves was $\sim$ 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 estimated the cyclotron resonance energy of ECH waves to be a few keV with probable assumptions. The estimated energy of precipitating electrons scattered by LBC waves or ECH waves was reasonable compared with the estimated cyclotron resonance energy of each wave. 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. To verify this model, it is necessary to carry out ground-based spectroscopic observations, and space- or rocket-borne imaging measurement in the future studies.