Enhancement of whistler-mode chorus in association with Pc 4-5 ULF waves and related variation of high energy electrons

*Atsuhiro Ono[1], Yuto Katoh[1], Atsushi Kumamoto[1], Fuminori Tsuchiya[1], Mariko Teramoto[2], Yoshiya Kasahara[3], Shoya Matsuda[4], Ayako Matsuoka[4], Takefumi Mitani[4], Tomoaki Hori[2], Satoshi Kasahara[5], Shoichiro Yokota[6], Kunihiro Keika[5], Yoshizumi Miyoshi[2], Iku Shinohara[4]

1. Tohoku University, 2. Nagoya University, 3. Kanazawa University, 4. ISAS/JAXA, 5. The University of Tokyo, 6. Osaka University

Whistler-mode chorus emissions play significant roles in the acceleration and loss of energetic electrons in the magnetosphere. One of the important factors which control periodic enhancement of chorus emissions is ULF (Ultra Low Frequency) waves. Previous studies reported that the compressional component of Pc4-5 ULF waves modulates the intensity of chorus waves [Li et al., 2011] and that the toroidal and poloidal components of Pc4-5 ULF waves as well [Jaynes et al., 2015]. Previous studies also suggested that enhancement of the temperature anisotropy of energetic electrons in the wave generation region should be required for the chorus generation. In order to understand the reported correspondence, in addition to the wave observation, we should examine simultaneously observed variations of the flux and the pitch angle distribution of energetic electrons.

In the present study, we investigate the relationship between chorus emissions and ULF waves using particle and electromagnetic field observations made by the Arase satellite. First, we analyze data observed by the Onboard Frequency Analyzer (OFA) of the Plasma Wave Experiment (PWE) and the Magnetic Field Experiment (MGF) during the campaign observation period of the Arase satellite with ground stations from March to April in 2017. As a result, we identified the simultaneous enhancement of chorus emissions and Pc4-5 ULF waves, which was dominated by the toroidal component, from 2130 to 2200 UT on March 27, 2017. The Arase satellite was located at the magnetic local time about 04:00, the magnetic latitude about -10 degrees, and the L-value about 6 during the event. We find that there is one-to-one correspondence between chorus emissions and the toroidal component of ULF waves; chorus emissions enhanced at the timings when the toroidal magnetic field component of ULF waves had a peak in the westward direction. The identified phase relationship is different from that reported by Jaynes et al. (2015), which isn't one-to-one correspondence. Next, we evaluate the resonance energy of the observed chorus emissions, using the ratio of the plasma frequency to the electron cyclotron frequency (f_p/f_{ce}) based on the upper-hybrid resonance frequency derived from the spectra observed by the High Frequency Analyzer (HFA) of PWE and the ambient magnetic field intensity observed by MGF. We find that f_p/f_{ce} is 3.3-3.4 during the event and that the resonance energy for whistler-mode waves in the frequency range of 0.1-0.2 f_{ce} is estimated to be about 100-400keV, which is larger than typical energies of resonating electrons observed in the inner magnetosphere. The estimated large resonant energy can be explained by the frequency range of the observed chorus emissions, approximately 0.1 - 0.2 f_{ce}, is relatively lower than that observed in typical cases.

We also analyze variations of the flux and the pitch angle distribution of energetic electrons during the event using data observed by the High-energy electron experiments (HEP) instrument onboard Arase. The result shows that both the flux and the pitch angle distribution of electrons in the kinetic energy range from 100 to 400 keV, which corresponds to the estimated resonance energy, did not fluctuate with the intensity variation of the chorus emissions and the ULF waves. In addition, we analyze the data observed by the Medium-energy particle experiments - electron analyzer (MEP-e) for energetic electrons in the energy range of 10-80 keV, lower than the estimated resonance energy. Then we identify the

corresponding variation of both the flux and the pitch angle distribution in the 40-60 keV energy range. One of the possible reasons why no significant variations were observed in the hundred keV range would be that the Arase satellite was located in the off-equatorial region during the event, and that the satellite was away from the wave generation region.

Keywords: ULF waves, chorus emissions