EMICライジングトーンとの相互作用によるプロトンのピッチ角散乱の直接検出

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Direct measurement of pitch angle scattering of protons by EMIC rising tones observed by THEMIS satellites

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Electromagnetic Ion Cyclotron (EMIC) waves with rising tone have been observed by various satellites in the Earth's inner magnetosphere (Pickett et al., 2010; Sakaguchi et al., 2013; Nakamura et al., 2014; Engebretson et al., 2015). EMIC waves are generated by anisotropic ions and scatter the pitch angle of energetic ions through the cyclotron resonant interactions. Previous simulation studies have reproduced EMIC rising tones using the one dimensional hybrid code. In the simulation, the pitch angle of energetic protons is effectively scattered by EMIC rising tones and velocity distribution function is strongly modulated (Shoji and Omura, 2011; 2013). Furthermore, observation study indicates protons scattered by EMIC rising tones precipitate into the atmosphere and cause proton aurora (Nomura et al., 2016).

Fukuhara et al. (2009) proposed a new type instrument called Wave-Particle Interaction Analyzer (WPIA) as a new means of the study of wave-particle interactions. One of methods of the WPIA is to calculate the energy exchange between waves and particles and the method enables us to evaluate wave-particle interactions directly and quantitatively (Katoh et al., 2013). The method is applied to EMIC rising tones observed by the THEMIS satellite and the feasibility of the method and the adequacy of the nonlinear theory is evaluated (Shoji et al., submitted). In addition to the method to detect the energy exchange, we have proposed a method to directly detect the pitch angle scattering of resonant particles by calculating G (Kitahara and Katoh, 2016), which is defined as the accumulation value of a pitch angular component of the Lorentz force acting on each particle and indicates the lost momentum of waves.

In this study, we apply the proposed WPIA method (Kitahara and Katoh, 2016) to the EMIC rising tone event observed by THEMIS satellite on September 9, 2010. During this event, THEMIS A, D, and E were close to each other (within 0.4 R_E) in the dayside inner magnetosphere (R_{GSM} ~8.5 R_E, LT ~13 h, LAT ~5 deg) and all of those satellites observed the same EMIC rising tone packets almost simultaneously. We calculate the G value from burst-mode data of the Electrostatic Analyzer (ESA), the Electric Field Instrument (EFI), and the Fluxgate Magnetometer (FGM) installed on each THEMIS satellite. In results of analysis, we detect the pitch angle scattering of protons in the energy range from 4 keV to 10 keV in the data of each satellite. We observed multiple enhancements of the amplitude of EMIC waves in the event, and we obtained significant G values at the timing of the enhancements. Using the WPIA analysis, we successfully identify the G values whose sign indicates the direction of the pitch angle scattering as a function of kinetic energy and pitch angle of protons. The results of analysis indicate that energetic protons are scattered toward the loss cone through the interaction at a timing of the wave enhancement. This characteristic depends on the proton energy range, and sometimes we obtained the opposite sign of G. In this presentation, we also discuss details of the calculation method and the statistical significance of G value.