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Direct measurement of energy transfer from magnetosonic waves to electromagnetic ion cyclotron waves through heating of cold ions in space

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We applied a novel wave-particle interaction analysis method (WPIA: Wave-Particle Interaction Analyzer) to observed plasma particle and field data obtained by the Arase satellite in the terrestrial inner magnetosphere. WPIA method[1] has been applied to investigate the energy transfer between plasma waves and particles. The WPIA method calculates the inner product of the wave electric field vector and particle velocity vector, multiplies by the particle charge, and then, sums (W_{Eint}) in velocity space. A positive W_{Eint} corresponds to the Joule heating of particles by plasma waves, whereas a negative W_{Eint} indicates wave growth due to particles. Application of the WPIA method to in-situ observation data of plasma particles and waves provides direct evidence of energy transfer between them. However, there are only several examples[2-6] of analysis based on the WPIA method for space plasma and wave data so far, since the WPIA method is rather new method.

Flux enhancement of low-energy ions (~100eV) in a component perpendicular to the background magnetic field direction was observed by Arase on February 10, 2018. At the same time, Arase detected magnetic field fluctuations around 11 Hz and 2 Hz (Figure 1(a)). Investigation of polarization and wave normal angles identified these waves as magnetosonic waves (MSWs) and electromagnetic ion cyclotron (EMIC) waves, respectively.

Figure 1(d) shows the calculated W_{Eint} for the observed MSW activity. W_{Eint} was mostly positive although there were a few exceptions with a negative W_{Eint}. A positive W_{Eint} indicates that the MSWs gave their energies to low-energy protons. Figure 1(e) shows the results of the WPIA calculations for the EMIC waves. W_{Eint} is negative throughout the event period with a clear enhancement. Our results suggest that the plasma sheet and ring current ions transfer some energy to the low-energy ions through excitation and damping of MSWs in the inner magnetosphere. Furthermore, a portion of the transferred energy is then converted to excite EMIC waves. Such cross-energy coupling is important for the heating of plasmaspheric plasmas and may contribute to the generation of EMIC waves and the non-thermal population of the inner magnetosphere, such as ion cloaks.

References
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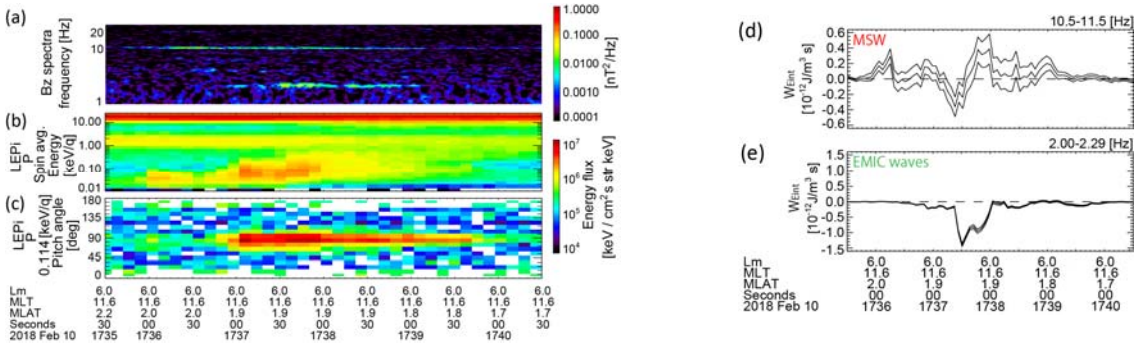

Figure 1. (a-c) Particle (proton) flux and magnetic field fluctuations observed by the Arase satellite. (a) Dynamic spectra of wave magnetic energy in the spin axis direction of Arase, (b) Energy spectra of omnidirectional proton energy fluxes, (c) Pitch angle distribution of proton energy fluxes at an energy of 114eV. (d-e) Results of WPIA calculations. W_{Eint} for (d) MSW activities and (e) EMIC waves. Three solid lines indicate calculated values and confidence intervals.