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Cross-energy coupling process via wave-particle interactions in Geospace observed by the Arase satellite

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There are several plasma and particle populations in the Geospace. The plasmasphere consists of cold/dense plasma populations, and the ionosphere is the source of the plasmaspheric plasma. The ring current and plasma sheet energies range from a few keV to about 100 keV, and these populations contribute to the ambient plasma pressure. The energies of the radiation belt particles range from a few hundred keV to more than 10 MeV, which are the highest energy population in geospace. Thus, plasma and particle populations with a wide range of energies from a few eV to more than 10 MeV coexist in the inner magnetosphere.

Besides plasma/particle populations, there are different kinds of plasma waves at the wide frequency range from ULF to HF frequency range in geospace. Geospace is often referred as "zoo of plasma waves", i.e., there exist MHD waves in the low-frequency range, ion cyclotron waves, whistler mode waves, free space mode waves, and several kinds of electrostatic waves. These waves work essential roles for dynamical evolutions of plasma/particles in geospace via the cross-energy coupling [1].

The geospace exploration satellite Arase (ERG) has been launched in 2016 and started the prime mission from the end of March 2017[1]. The Arase satellite observes 3-dimenational distribution function and/or pitch angle distribution for wide energy electrons (~20 eV – a few MeV) and ions (10 eV/q – 180 keV/q with mass discriminations. The satellite also measures electric fields from DC to 10 MHz with three different receivers and magnetic fields from DC to 100 kHz with fluxgate and search coil magnetometer.

The Arase satellite has observed various wave-particle interactions at different frequency range, which have different roles for particle transportation, accelerations and loss.

(Transportation) Drift-resonance between relativistic electrons of the radiation belts and MHD fast mode waves, which cause radial transportation of radiation belt electrons [2].

(Accelerations) Cyclotron-resonance between energetic electrons and whistler mode waves cause rapid accelerations of tens keV electrons through the non-linear phase trapping[3][4]. Chorus waves cause accelerations of MeV electrons inside the radiation belts [5].

(Loss into the atmosphere) Cyclotron-resonance between electrons and chorus waves causes precipitations of tens keV electrons, which cause the pulsating aurora[6][7][8]. MeV electrons are also precipitated into the atmosphere[5][9][10][11]. Cyclotron resonance between MeV electrons and electro-magnetic ion cyclotron (EMIC) waves also causes precipitations of relativistic electrons of the outer belt[12][13].

The Arase satellite has also observed generation of plasma waves through plasma/particle instabilities. The satellite identified that the spatial gradient of ring current ions is the primary free energy source to generate the fast mode waves[14][15]. The satellite has also successfully identified the relative phase differences between EMIC waves and gyration of ring current ions and specified that the ion hill in the phase space contribute to generation of the falling tone of EMIC waves[16].

In this presentation, we present several highlights about wave-particle interactions and discuss how these wave-particle interactions are important for the cross-energy couplings in the inner magnetosphere.

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