RECENT RESEARCH ACTIVITIES

Simulations and Modeling of Geospace Environment

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We gave a brief account of the nonlinear theory of the generation mechanism of chorus emissions, which has been revealed by the simulations and observations. We described the nonlinear dynamics of resonant electrons, and the formation of the electromagnetic electron “hole” that results in resonant currents generating rising-tone emissions. In contrast, falling-tone emissions are generated through the formation of electron “hills.” We also described the mechanism of nonlinear wave damping due to quasi-oblique propagation, which results in the formation of a gap at half the electron cyclotron frequency. The nonlinear wave-growth theory of chorus emissions can also be applied to the generation mechanism of electromagnetic ion-cyclotron (EMIC) triggered emissions, recently found in spacecraft observations. Hybrid code simulations confirmed that coherent rising-tone emissions are generated by energetic protons at frequencies below the proton cyclotron frequency. Electromagnetic ion-cyclotron waves can also interact with relativistic electrons. Both chorus emissions and electromagnetic ion-cyclotron-triggered emissions play important roles in controlling radiation-belt particle dynamics [Omura, Radio Sci. Bull., 2014].

We performed parametric analyses of electromagnetic ion cyclotron (EMIC) triggered emissions with a gradient of the nonuniform ambient magnetic field using a hybrid simulation. According to nonlinear wave growth theory, as the gradient of the ambient magnetic field becomes larger, the theoretical threshold of the wave amplitude becomes larger, although the optimum wave amplitude for nonlinear wave growth does not change. With a larger magnetic field gradient, we obtain coherent rising-tone spectra because the triggering process of the EMIC triggered emission takes place only under a limited condition on the wave amplitude. On the other hand, with a smaller magnetic field gradient, triggering of the emissions can be caused with various wave amplitudes, and then the subpackets are generated at various locations at the same time. The concurrent triggering of emissions results in incoherent waves, observed as “broadband” EMIC bursts [Shoji and Omura, J. Geophys. Res., 2014].

We surveyed the THEMIS probe data and found various types of emissions mainly on the dayside at radial distances of 6–10 RE. We studied three distinctive events in detail. The first is a typical event with an obvious rising tone emission in the afternoon sector. The emissions in the second event are simultaneously excited in different frequency bands separated by the cyclotron frequency of helium ions. In the third event, which occurred near local noon, rising tone emissions were excited in an extended region near the equator where the field-aligned B gradient was much reduced because of compression of the magnetosphere by the solar wind. We compared these events with the nonlinear wave growth theory developed by Omura et al. (2010). In all events, the observed relationship between the amplitudes and frequencies of the emissions are in good agreement with the theory [Nakamura, Omura et al., J. Geophys. Res., 2014].

A substorm is known to be one of the most drastic phenomena in the near-Earth space environment. The substorm redistributes the particles trapped by Earth's magnetic field. Utilizing a global magnetohydrodynamics (MHD) simulation, we demonstrated for the first time that the direction of the convection electric field is reversed just after a substorm. Calculated magnetic disturbances on the ground from pole to equator are consistent with those observed [Ebihara, Tanaka and Kikuchi, J. Geophys. Res., 2014]. We identified that the high-pressure region retreats tailward in the plasma sheet just after the substorm onset. The variations of the pressure, the magnetic field, and the velocity are consistent with the MHD simulation [Yao, Ebihara and Tanaka, J. Geophys. Res., 2015]. Utilizing a test particle simulation, we investigated an entry process of the oxygen ions originating from the ionosphere to the inner magnetosphere. The ions are accelerated non-adiabatically from ~eV to ~10^5 eV in the plasma sheet just after the onset. A “void” structure appears in the energy-time spectrogram of the phase space density of the ions, which results from quasi-electrostatic acceleration taking place in the stretched plasma sheet [Nakayama, Ebihara and Tanaka, J. Geophys. Res., 2015].