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Velocity distribution of electrons generating plasma waves around the wake of an ionospheric sounding rocket

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When a body moves in plasma at supersonic velocities, a rarefied plasma region called 'plasma wake' is formed behind the body. Wakes can develop behind a solar system body immersed in solar-wind plasma as well as behind spacecraft such as satellites and ionospheric sounding rockets.

Plasma waves around the rocket wake have been suggested by the observational results from previous rocket experiments, while there are also several studies which reported plasma waves around the wakes of a satellite and of the moon. In the S-520-26 rocket experiment (apex: 298 km), carried out in Japan at dawn of January 12, 2012, three kinds of plasma waves were identified (hereafter denoted Group-A,B, and C). We concluded that they are electrostatic electron cyclotron harmonic (ESCH) waves or upper hybrid resonance (UHR) mode waves (Group-A waves), and whistler mode waves (Group-B and Group-C waves). They have spin-phase dependence in characteristic manners.

Meanwhile, it was found that Group-A waves were also observed in the S-520-23 rocket experiment (apex: 279 km), which was performed in Japan at dusk of September 2, 2007, and that their spin-phase dependence is nearly the same with that of the Group-A waves observed in the S-520-26 rocket experiment.

We performed numerical calculations of plasma dispersion relations by assuming anisotropic velocity distribution functions such as electron beam and temperature anisotropy. As a result, positive linear growth rates have been obtained in the wave number and frequency ranges of UHR mode waves and ESCH waves in addition to electrostatic whistler mode waves. Accordingly, there have to be electrons with some anisotropic velocity distribution functions which are equivalent to those we assumed in the calculations. However, we have to clarify what kind of velocity distribution can be generated around the actual wake through the interaction between a sounding rocket and ionopsheric plasma.

Singh et al. (1987) performed a one-dimensional simulation of plasma entering a void region from the two sides using a Vlasov-Poisson code. They found counterstreaming electron beams in the very near wake. However, their study concentrates on electrons on the wake axis and does not indicate distribution functions in other areas. Besides, temperature anisotropy could not be treated in their simulation because it was performed in one dimension in velocity space.

In order to investigate inhomogeneity of electron distribution functions around the rocket wake, we are developing a Vlasov-Poisson code with one-dimensional space and two-dimensional velocity space, which is redesigned from the simulation code used in Singh et al. (1987). In this simulation, we deal with cases that electrons and ions are filling in a void space. The time evolution can be understood as spatial distribution along the wake axis. The direction of one-dimensional space is along the geomagnetic fields, along which electrons and ions can move easily. The size of space is 10 m, which is divided into 1024 grids in the calculation.

In this presentation, we clarify the frequency range and spatial distribution of the plasma waves around the wake based on the analyses of S-520-26 and S-520-23 rocket experiment data. We also discuss the velocity distribution of the electrons which can generate the plasma waves as observed. In addition, we report the results of our simulation for investigating the velocity distribution of electrons around the wake.

Keywords: wake, plasma wave, sounding rocket, ionosphere