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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 velocity, 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. There are several studies which report plasma waves around the wakes of a satellite and of the moon. Although there are not so many studies which report plasma waves generated in association with the rocket wake, observational results from two rocket experiments performed in 1998 and 2012 have shown generation of plasma waves around the wake of a rocket. It is very important to reveal the generation process of plasma waves near the rocket wake for understanding the universal physics related to the interaction between streaming plasma and a non-magnetized body as well as for interpreting wave data obtained in rocket experiments more accurately.

Our analysis has revealed three kinds of plasma waves observed in the S-520-26 rocket experiment in 2012. They are likely to be electrostatic electron cyclotron harmonic (ESCH) waves, upper hybrid resonance (UHR) mode waves, and whistler mode waves. They have spin-phase dependence in characteristic manners. These results indicate that the plasma waves should be generated inhomogeneously around the rocket. We have 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) has performed a one-dimensional simulation of plasma entering a void region from the two sides using a Vlasov-Poisson code. They have 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 is 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 rocket experiment data. We also discuss the velocity distribution of the electrons which can generate the plasma waves as observed. In addition, we report initial results of our simulation for investigating the velocity distribution of electrons around the wake.

Keywords: ionosphere, sounding rocket, wake, plasma wave, Vlasov simulation