1 次元静電ブラソフシミュレーションを用いた電離圏飛翔体ウェイク近傍のプラズマ不安定に関する研究

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Study of plasma instabilities around the wake of an ionospheric sounding rocket by a 1D Vlasov-Poisson simulation

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Artificial satellites and sounding rockets travel in the ionosphere at supersonic velocities, which makes rarefied regions called ‘plasma wakes’. Through some recent rocket experiments, it has been suggested that plasma waves are excited around the rocket wake as reported by Yamamoto [PhD. thesis, Tohoku University, 2001]. From the results of the S-520-26 rocket experiment, Endo et al. (JGR, 2015) have concluded that the waves observed in the wake were electrostatic waves such as electrostatic electron cyclotron harmonic (ESCH) waves and UHR mode waves. The intensities of these waves, as well as of whistler mode waves observed in the same experiment, had spin-phase dependence, which was different depending on kinds of plasma waves. These results indicate that there was inhomogeneous spatial distribution of hot electrons with some anisotropic velocity distribution functions around the rocket wake. Singh et al. (JGR, 1987) have shown that two-stream type electron distribution functions are obtained on the wake axis of spacecraft by using a 1D numerical simulation. However, they have not discussed near the wake edges and the tail of the near-wake, and thus the wave data from the S-520-26 rocket experiment cannot be understood clearly.

In order to investigate inhomogeneity of hot electrons around the rocket wake, we are now developing a Vlasov-Poisson code. In the simulation with this code, we can calculate wake filling process of ambient ions and electrons in one-dimensional space along the X-axis, which is parallel to the ambient magnetic field. If we assume that the plasma is also flown in the y direction, the plasma distribution along the x-axis as a function of time can be understood as that as a function of distance in the y direction. Although this simplified model is also used in Singh et al. (JGR, 1987), plasma parameters are changed in our simulation to discuss an environment around the rocket wake. In addition, we adopt the rational CIP method [Xiao et al., CPC, 1996] in order to suppress the effect of numerical diffusion.

In our current code, electric oscillations whose amplitudes increase with time are observed outside the wake near the wake boundaries, which makes the CFL condition be unsatisfied at up to t=469dt (corresponding to 3.4 mm downstream; 0.8 % of the near-wake). Those electric oscillations are considered to be not physical, and their origin is now under study. For the purpose of suppressing the growing electric oscillation, we perform four test simulations, which are the cases of (1)using absorbing boundaries, (2)damping the longest-wavelength electric fields, (3)reducing the ion-electron mass ratio ($m_i/m_e=2.9*10^4$ is change to 40), and (4)increasing the initial densities in the wake ($n_{wake}/n_0 = 0$ is change to 0.3). As a result, it is found that the growth rate of the oscillation becomes smaller in the cases (3) and (4) although the growth rates are still positive in all of the four cases. In the case (3), for instance, we can proceed the simulation until t=612dt (corresponding to 4.4 mm downstream; 27.6 % of the near-wake), getting closer to the tail of the near-wake.

Even in the calculation described above, several hot electrons can be seen such as multi-stream electrons on the wake axis, and a single beam component outside the wake. The multi-stream electrons are considered to be composed of electrons periodically coming into the wake from the outside, and the single electron beam may be owing to the reflection of electrons by the polarized electric field at the wake boundaries. We need to introduce test particles to investigate the origin of the energetic electrons responsible for non-Maxwellian components.

In this presentation, we will describe the configuration, schemes, and our simulation results first. Then, we will discuss the generation process of anisotropic electrons and will compare the simulation results with the wave data obtained in the S-520-26 rocket experiment.