Geophysical Research Abstracts,
Vol. 10, EGU2008-A-05544, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-05544
EGU General Assembly 2008

Investigation of anisotropic velocity distribution functions using numerical solutions of the stationary Vlasov equation

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In this paper we investigate the anisotropy of velocity distribution functions (VDF) of protons and electrons convecting in non-uniform distributions of the electromagnetic field. The spatial variation of the VDF is determined by integrating numerically the characteristics of the stationary Vlasov equation. The method is applied to simulate the interaction between an electron and a proton cloud with a non-uniform, sheared distribution of the magnetic field. An electric field is also superimposed and computed such that it conserves the zero order drift. The fields are steady-state and one-dimensional (depend on x only). Their spatial variation is limited to a transition region whose scale length is an input parameter of the problem. Test-particles (protons and electrons) are injected from sources aligned along the x-axis with initial velocities distributed according to a displaced Maxwellian; their trajectories are integrated numerically. We use the Liouville theorem to "propagate" the initial VDF along the numerically integrated trajectories and to reconstruct it at the right side of the transition region. The numerical results illustrate how the charge-dependent gradient-B drift determines the overall dynamics of the cloud as well as the spatial variation of the VDF. The numerical solutions suggest that the velocity dispersion due to the gradient-B drift may perhaps contribute to the formation of nongyrotropic velocity distribution functions like those observed for instance by CLUSTER in the magnetotail. The solutions are compared with similar simulations and in-situ experimental data from CLUSTER.