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Forward and backward test-kinetic simulations of non-Maxwellian velocity distribution functions in space plasmas

Gabriel Voitcu (1,2), Marius Echim (1,3), and Richard Marchand (4)

(1) Institute of Space Science, Magurele, Romania (gabi@spacescience.ro), (2) University of Bucharest, Bucharest, Romania (gabi@spacescience.ro), (3) Belgian Institute for Space Aeronomy, Brussels, Belgium (marius.echim@oma.be), (4) University of Alberta, Edmonton, Canada (rmarchan@ualberta.ca)

Test-kinetic simulations provide a useful tool to investigate plasma dynamics for various configurations of the electromagnetic field. This method gives useful information about the plasma kinetic structure in complex situations when self-consistent techniques are not practical. In this paper we make a review of forward and backward test-kinetic method applied to compute the velocity distribution function (VDF) of protons of a plasma stream in the vicinity of a magnetic discontinuity. We consider two different profiles of the electric field. The forward method is used first to investigate the formation of an energy-dispersed structure with typical ring-shaped and crescent-shaped velocity distribution functions formed at the edges of the cloud by the gradient-B drift. The backward method is applied to test the VDFs in the same spatial regions investigated with the forward approach. We compare in detail the results obtained with the forward and backward approaches. In the forward approach the velocity distribution function is computed for a two-dimensional spatial bin. In order to obtain results consistent with the forward approach, the distribution function computed with the backward approach is averaged over a spatial bin with the same size as for the forward method and using a two-dimensional trapezoidal integration scheme. It is shown that the forward and backward test-kinetic simulations lead to similar results, except for the situations when the VDFs are computed for spatial bins in which the velocity distribution function varies sharply. The kinetic features revealed by the numerical solutions have similarities with in-situ distribution functions observed by Cluster satellites in the magnetotail, close to the neutral sheet.