Numerical approach to collisional plasmas: collisional effects on electrostatic plasma waves

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The problem of collisions in a plasma is a wide subject with a huge historical literature. The description of realistic plasmas is a tough problem to attach, both from the theoretical and the numerical point of view. In fact the Landau operator [1], that describes Coulomb interactions, is nonlinear in nature and multi-dimensional. In order to overcome these difficulties, some analytical results have been obtained by approximating the original Landau integral by simplified differential operators in reduced dimensionality.

We present here a Eulerian time-splitting algorithm [2] for the study of the propagation of electrostatic waves in collisional plasmas. At first we focus on one-dimensional operators of the Fokker-Planck type in $1D-1V$ phase space (1D in physical space, 1D in velocity space). The accuracy of the numerical code is discussed by comparing the numerical results to the analytical predictions obtained in some limit cases when trying to evaluate the effects of collisions in the phenomenon of wave plasma echo and collisional dissipation of Bernstein-Greene-Kruskal waves. Particular attention is devoted to the study of the nonlinear Dougherty collisional operator, recently used to describe the collisional dissipation of electron plasma waves in a pure electron plasma column [3]. A receipt to prevent the filamentation problem in Eulerian algorithms is provided by exploiting the property of velocity diffusion operators to smooth out small velocity scales.

Finally we show the effects of the whole Landau operator on the propagation of plasma waves by implementing an algorithm in $1D-3V$ phase space. In order to evaluate the Landau collisional integral Pareschi et al. [2] proposed a spectral method in velocity space based on the use of Fast Fourier Transform (FFT) routines. Despite the usual reduction of the computation cost that one obtains using FFT routines, these authors needed to periodize the distribution function in the velocity domain as well as the Landau operator, thus introducing unphysical effects of fake binary collisions. Instead here we model collisions through the direct evaluation of the Landau collisional integral in velocity space.

References

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