High accuracy Landau collision operator and transport coefficients for gyrokinetic and fluid turbulence simulations

K. Hallatschek

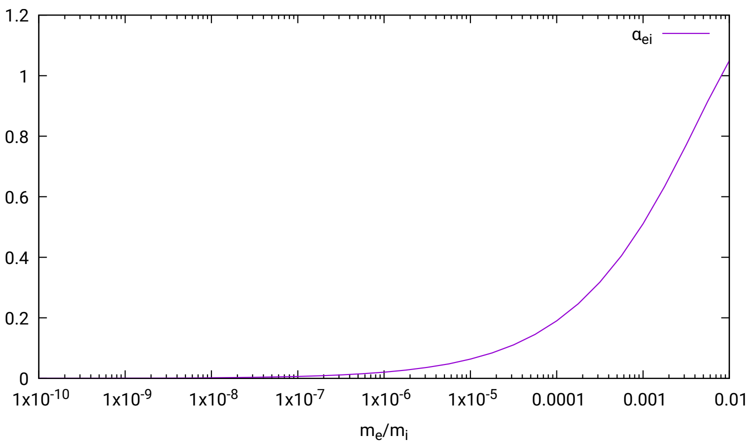
Max-Planck-Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany

A code for the gyro-transformed (pulled-back) matrix elements of the linearized but otherwise complete Landau operator required by gyrokinetic (GK) [1] edge turbulence simulations was developed, inspired by the advantageous use of half-sided Hermite (or related) polynomials P_i as velocity space basis functions in [1, 2].

This approach turned out to be amazingly successful. It takes only seconds to calculate the Landau matrix elements for hundreds of polynomials for all normally required perpendicular wavenumbers of a turbulence simulation up to machine precision, automatically fulfilling all applicable conservation laws and the H-theorem. In the case that extremely high wavenumbers are to be computed $k\rho_i \gtrsim 100$ (e.g. for ETG turbulence) nevertheless a cut-off was required. For these a novel fast asymptotic approximation procedure is presented.

With the code it is also possible to calculate Braginskii-style transport coefficients, much more precise than so far published [3, 4] and study alternative *definitions* of fluid transport coefficients – those are usually based on the particular ordering scheme used, and cannot provide more than the first order in the expansion parameters.

This way, certain analytically overlooked, transport coefficients can be computed, such as the mass-ratio dependent ion electron cross heat flux $q_{i,e} = \alpha_{ei} n T_i \tau_{ii} / m_i \partial_\| T_e$, the coefficient of which (α_{ei}) is shown on the side.



Clearly these effects are significant and should be taken into account in any fluid turbulence simulation of realistic collisional Deuterium plasmas, not the least to arrive at a meaningful comparison between fluid and kinetic simulations.

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[2] M. Landreman, D.R. Ernst, J. Comput. Phys. **243**, 130 (2013)

[3] P.J. Catto, A. N. Simakov, Phys. Plasmas **11**, 90 (2004)

[4] A.S. Richardson, NRL plasma formulary, (2019)