On Relativistic Braginskii Transport Equations: Mixed Approach

I. Marushchenko[1], N. A. Azarenkov[1]

[1] *V. N. Karazin Kharkiv National University, Krarkiv, 61022, Ukraine*

It is well known that the relativistic and ultra-relativistic effects are important in astrophysics for description of transport processes in space plasmas. In last decades it was also recognized that the relativistic effects can play the significant role for transport processes in the laboratory fusion plasmas, where typical temperature are about tens of keV (see, for example, [1, 2, 3]). In particular, the physics of electron transport processes in hot plasmas requires a special attention in calculation of plasma fluxes [2, 3]. Nevertheless, practically all transport codes which are in use for simulation of the fusion reactor scenarios are based on the non-relativistic limit of transport theory; see, for example [4].

The present work is focused on transport processes in hot plasmas with relativistic electrons with $v_{te} < c$ and relatively slow macroscopic fluxes $V \ll c$. Formally, the required equations can be obtained from the general co-variant formulations (see, for example, [5]). However, it was found that it's more physically transparent to derive the Braginskii equations from the first principles. A presence of the hydrodynamic flow is accounted in weakly relativistic approach, neglecting the terms of the order higher than V^2/c^2 and Vv_{te}/c^2, while the bulk electrons are considered rigorously, i.e. in fully relativistic approach. The ions are taken as classical. This mixed approach makes possible to omit the requirements of Lorentz invariance, while including the relativistic effects related to the kinetics of hot electrons.

For the closure of the relativistic transport equations, the linearized kinetic equation has to be solved. It is proposed to apply for this procedure the generalized Laguerre polynomials $L_n^{(\alpha)}(\mu(\gamma-1))$ of order $\alpha = 3/2+\mathscr{R}(\mu)$ with $\mathscr{R}(\mu) = 15/8\mu + \mathscr{O}(\mu^{-2})$ and $\mu = m_e c^2/T_e \gg 1$. In contrast to earlier attempts to apply Sonine polynomials for relativistic transport (see [6]), generalised Lagguerre polynomials allows to use a finite number of terms for the right-hand-side of the relativistic linearized kinetic equation.

References

[1] T. Mettens, and R. Balescu, Phys. Fluids **2**, 2076 (1990)

[2] I. Marushchenko *et al.*, Plasma Phys. Control. Fusion 55, 085005 (2013)

[3] G. Kapper *et al.*, Phys. Plasmas **25**, 122509 (2018)

[4] P. Helander and D.J. Sigmar, *Collisional Transport in Magnetized Plasmas*, Cambridge Univer. Press, 2005.

[5] S.R. de Groot *et al.*, *Relativistic Kinetic Theory*, North-Holland Publish. Comp., 1980.

[6] D.I. Dzhavakhishvili and N.L. Tsintsadze, Sov. Phys. JETP **37**, 666 (1973)