A Field Theory Approach to Transport Processes in Tokamak Plasmas: the Nonlinear Classical and Pfirsch-Schlüter Regimes and Nonlinear Transport Equations in the Banana and Plateau Regimes

Giorgio SONNINO

EURATOM - Belgian State Fusion Association
Free University of Brussels (U.L.B.)
Blvd du Triomphe, Campus de la Plaine, C.P. 231, Building NO
Brussels, B-1050, Belgium
E-mail: gsonnino@ulb.ac.be

Abstract

A field theory approach to transport phenomena in magnetically confined plasmas is presented. The thermodynamic field theory (TFT), previously developed for treating generic thermodynamic system out of equilibrium, is applied to plasmas physics. The TFT is a covariant field theory extending the theory previously formulated by Prigogine in 1954, which was applied only to thermodynamic systems close to equilibrium.

Transport phenomena are treated as the *effect of the field* linking the thermodynamic forces with their conjugate flows combined with statistical mechanics. In particular, the Classical and the Pfirsch-Schlüter regimes are analyzed by solving the thermodynamic field equations of the TFT in the weak-field approximation. We found that, the TFT does not correct the expressions of the ionic heat fluxes evaluated by the neoclassical theory in these two regimes. On the other hand, the fluxes of matter and electronic energy (heat flow) is further enhanced in the nonlinear Classical and Pfirsch-Schlüter regimes. This phenomenon would even be more amplified if we would have used the strong (i.e., the non-approximated) thermodynamic field equations. These results seem to be in line with the experimental observations.

The complete set of the electronic and ionic transport equations in the nonlinear Banana and Plateau regimes, are also reported. The gauge-invariant solutions valid for the Classical and the Pfirsch-Schlüter

transport and for the Plateau and Banana regimes are shown to be substantially different. In the Classical and Pfirsch-Schlüter case, the expression of the thermodynamic forces is the product of a universal function times the Onsager matrix. In the Plateau and Banana regimes the thermodynamic fluxes are linked to the thermodynamic forces through functions which differ from one case to the other. A complete analysis of the nonlinear Plateau and Banana regimes, where the ITER parameters are taken into account, will be subject of a further publication.