Low-Temperature Plasma Transport Across Magnetic Fields: From Electric Propulsion And Negative Ion Sources To Tokomak Edge Plasmas

G. J. M. Hagelaar[1,2]

[1]*LAPLACE (Laboratoire Plasma et Conversion d'Energie), Université de Toulouse, UPS, INPT, 118 route de Narbonne, F-31062 Toulouse Cedex 9, France*

[2]*CNRS, LAPLACE, F-31062 Toulouse, France*

Magnetic plasma confinement is used not only in thermonuclear fusion but in also in various low-temperature plasma (LTP) sources for applications like materials processing, space propulsion or neutral beam generation. The operating conditions of these LTP sources are different from those of fusion plasma devices in several respects. The magnetic field is weaker, typically on the order of 0.01 T, and it can be complex, with strong variations across the same source. Collisions with neutral gas particles, electron-impact ionization, and plasma chemistry can play an important role. Often the ions are not or only weakly magnetized. These conditions lead to a variety of complex transport phenomena which are still not fully understood.

This presentation reports on recent advances in the numerical modeling and fundamental understanding of magnetized LTP transport. We present a fluid model designed to address the magnetized LTP source conditions, based on continuity equations and full momentum equations for electrons and ions and an electron energy equation, without a priori assumptions on the ordering of physical length scales (Larmor radii, mean free paths, geometrical dimensions). Results of this model (backed up by experimental results and PIC simulations) are then used to illustrate and analyze the magnetized LTP transport in several basic configurations, highlighting the fundamental differences between these configurations. We demonstrate the difference between transport in cylindrical devices with closed magnetic drift, such as Hall thrusters [1], and non-cylindrical configurations where the drift is bounded by the chamber walls, such as the ITER negative ion source developed at IPP Garching [2]. We also discuss instabilities occurring in the plane perpendicular the magnetic field, in particular in closed-drift devices. A comparison is made with transport in tokamak edge plasmas, governed by interchange instabilities.

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