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Can Gyrokinetics Really Describe Transport in L-Mode Core Plasmas?

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The common view in fusion theory is that nonlinear gyrokinetics constitutes a reliable first-principles approach to describe turbulent transport in MCF devices. Surprisingly, however, two recent findings challenged this notion. First, the experimental ion heat fluxes in the outer core of certain DIII-D L-mode discharges were underpredicted by GK simulations by almost an order of magnitude. This finding has been dubbed the „shortfall problem"and has triggered extensive theoretical efforts on an international level. Second, a careful analysis of some L-mode discharges in the JET tokamak revealed a significant reduction of ion temperature profile stiffness in the presence of strong NBI [1]. This was first attributed to a combination of high toroidal flow shear and low magnetic shear. However, nonlinear GK simulations failed to confirm this suspicion, overpredicting the observed fluxes by up to an order of magnitude. This finding could be called the „excess problem"and is as severe as the shortfall problem described above. The main goal of the present contribution is to revisit both of these problems and substantiate or refute them. At stake is the plasma theory community's confidence to devise a predictive transport capability for devices like ITER or DEMO on the basis of nonlinear GK. Via careful studies with the GENE code (using about 30 million CPUh), both of these challenges could be met successfully. While the transport levels in outer-core L-mode discharges of DIII-D, C-Mod, and ASDEX Upgrade [2] can be reproduced within the experimental error bars, the observed ion temperature stiffness reduction in JET can be explained in terms of nonlinear electromagnetic effects in the presence of fast ions [3]. Thus, a number of ideas about possible elements missing in the present theoretical description or even a possible breakdown of GK are identified as premature. Meanwhile, these studies highlight the fact that the search for adequate minimal models of turbulent plasma transport under various experimental circumstances is highly non-trivial.

[1] Mantica, PRL 107, 135004 (2011)
[2] Told, PoP 20, 122312 (2013)
[3] Citrin, PRL 111, 155001 (2013)

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