A new paradigm for plasma transport and zonal flows

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Abstract

Most tokamak experimental results indicate dependence of the ion thermal conductivity on the isotopic mass close to $\chi_\perp \sim m_i^{-0.5}$, i.e., inverse gyro-Bohm. This is in stark contradiction to most present theoretical models predicting Bohm (m_i^0) or gyro-Bohm ($m_i^{0.5}$) scaling. A basic physics isotopic scaling experiment (ISE) [V.Sokolov and A.K.Sen, Phys. Rev. Lett. **8 9**, 095001 (2002)] on the anomalous ion thermal conduction due to ion temperature gradient instabilities in two different gases (hydrogen and deuterium) closely confirms the tokamak results. Another series of experiments designed to explore the physics basis of this scaling appears to lead to a new model for this scaling based on 3-wave coupling of two ion temperature gradient radial harmonics and an ion acoustic wave. The resulting isotopic scaling of transport is $\sim m_i^{-0.5}$ dictated primarily by the ion acoustic damping. This basic physics may be extrapolatable to tokamaks resolving the paradox [V.Sokolov and A.K.Sen, Phys. Rev. Lett. **92**, 165002 (2004)]. Lastly, the much discussed theoretical role of zonal flows in transport regulation is critically examined by another set of experiments. A novel diagnostic has been developed on the observation that the effect of zonal flow can be seen in the FM modulation (at zonal flow frequency) of the carrier frequency of the large equilibrium Doppler shift frequency of Ion Temperature Gradient (ITG) modes both in tokamaks and Columbia Linear Machine (CLM) [V.Sokolov, X.Wei and A.K.Sen, APS DPP meeting, Savannah, '04]. The present results indicate zonal flow levels close to the theoretical prediction, but its shear is much lower than that predicted by theory for transport regulation.