7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Towards Understanding the Mechanism of Heat and Particle Transport Decoupling in I-mode Edge Plasmas

Hongwei Yang[1], Tianchun Zhou[2] and Yong Xiao[1]
[1] Institute for Fusion Theory and Simulation, Zhejiang University, Hangzhou, China
[2] School of Physics & Laboratory for Space Environment and Physical Science, Harbin Institute of Technology, Harbin, China
e-mail (speaker): hwyang@zju.edu.cn

I-mode [1,2] is an important alternative operational scenario for burning plasmas. A possible theoretical understanding is presented for a unique turbulent transport phenomenon in the I-mode regime, i.e., the so-called transport decoupling between heat and particle in tokamak edge plasmas. Based on our particle simulations by running gyrokinetic toroidal code (GTC) [3], we found that a particular instability [4] can account for such experimental phenomenon, which makes it the major candidate for experimentally observed weakly coherent modes (WCMs) in the I-mode regime. This instability is driven by steep electron temperature gradient up to a certain value, with characteristic time scale around transit time of passing electrons while the spatial scale falling in the range of ion's poloidal gyro-radius. A crucial feature about this instability is that neither ion nor passing electron can be treated adiabatically, which distinguishes it from the conventional drift-like instabilities such as ion temperature gradient (ITG) modes, trapped electron modes (TEM) and normal electron temperature gradient (ETG) modes. Those non-adiabatic responses for both ions and electrons excited this unique instability and would be reduced by typical flow shearing suppression mechanism including low frequency zonal flow and geodesic acoustic modes (GAMs) instead of radial electric field well (Er-well) induced poloidal mean flow to give rise to the considerable particle and heat transport compared with experimentally observed values. A detailed discussion about this individual instability and its nonlinear saturation mechanism which may account for experimentally observed WCMs turbulence and associated turbulent transport will also be presented in this talk.[a]

Keywords: I-mode, WCMs, Transport decoupling

Table 1. Characteristics from the C-Mod experiment and GTC simulations

		C-Mod #1120907032	GTC simulation results
WCM	Wavelength	$k_\theta \rho_s \simeq 0.01 \sim 0.3$	$k_\theta \rho_s \simeq 0.13$
	Frequency	$f \simeq 150 - 400\ kHz$	$f \simeq 290\ kHz$
	Propagating direction	EDD	EDD
GAM/LFZF		Regulates WCM Sucks energy from WCM	Self-generated by turbulence Regulating turbulence during nonlinear phase
Transport properties	χ_{eff}	$0.2 - 0.3\ m^2 s^{-1}$	$0.15 - 0.35\ m^2 s^{-1}$
	D_{eff}	Typically, in the order of magnitude of $0.1\ m^2 s^{-1}$ [b]	About $0.05\ m^2 s^{-1}$

[b] This is estimated according to the experimental particle flux Γ in [5]

References
[1] F. Ryter et al. Plasma Phys. & Controlled Fusion 40, 725 (1998)
[2] D. Whyte et al. Nucl. Fusion 50, 105005 (2010)
[3] https://sun.ps.uci.edu/gtc
[4] H. Yang et al. Nucl. Fusion 61, 056006 (2021)
[5] A. Dominguez 2012 PhD Dissertation

[a] This work has been published in Nuclear Fusion [4].