6th Asia-Pacific Conference on Plasma Physics, 9-14 Oct, 2022, Remote e-conference

Existence of finite and anisotropic heavy ion parallel compressibility pinch in gyrokinetic turbulence

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Turbulence-driven heavy ion transport in hot magnetized plasma is investigated by means of the gyrokinetic theory and simulations [1]. A finite heavy ion parallel compressibility pinch ($\Gamma_{s,\parallel}$) is found for the first time in the gyrokinetic framework (Fig.1), in contrast to the conventional understanding that $\Gamma_{s,\parallel}$ is negligible [2,3]. A perturbation theory clarifies the turbulence frequency dependence of $\Gamma_{s,\parallel}$, resolving the discrepancy with the experimental observations. It is also newly predicted by a non-local approach of the parallel advection term that $\Gamma_{s,\parallel}$ is strongly anisotropic on the magnetic surface (Fig.2). The parameter dependence shows that decreasing the heavy ion mass m_s strongly enhances $\Gamma_{s,\parallel}$ through kinetic effects, leading to deviation from the $1/m_s$ scaling (Fig.3). Moreover, the pinch direction can be reversed in nonlinear trapped electron mode turbulence through the inverse cascade (Fig.4).

References

[1] Shaokang. Xu, S. Maeyama, T.-H. Watanabe, "Existence of finite and anisotropic heavy ion parallel compressibility pinch in gyrokinetic turbulence" (Submitted)
[2] C. Angioni, Plasma Physics and Controlled Fusion 63, 073001 (2021)
[3] C. Bourdelle, X. Garbet, F. Imbeaux, A. Casati, N. Dubuit, R. Guirlet, and T. Parisot, Phys. Plasmas 14, 112501 (2007)

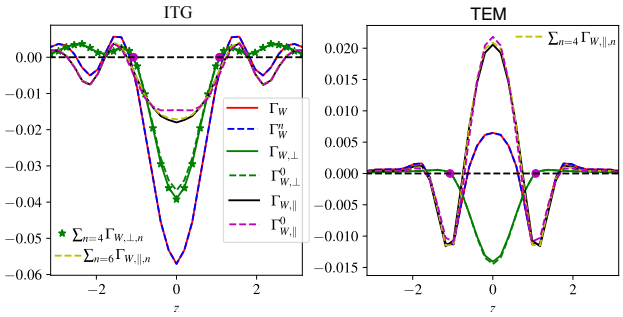

Figure 1. Profile of the normalized tungsten pinch along the magnetic field line z in the ITG (left) and the TEM (right) cases for the most unstable modes.

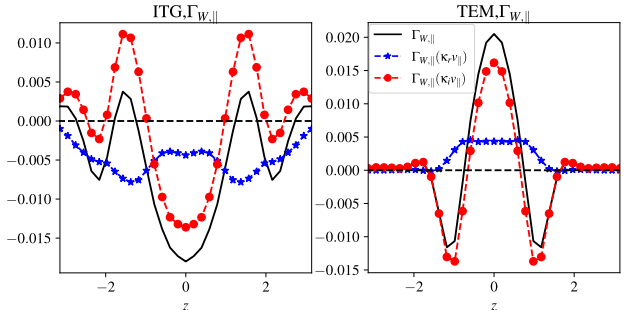

Figure 2. The parallel compressibility pinch $\Gamma_{w,\parallel}$ (black) and its components $\Gamma_{W,\parallel}(\kappa_r v_\parallel)$ (blue) and $\Gamma_{W,\parallel}(\kappa_i v_\parallel)$ (red) as a function of z in ITG and TEM cases.

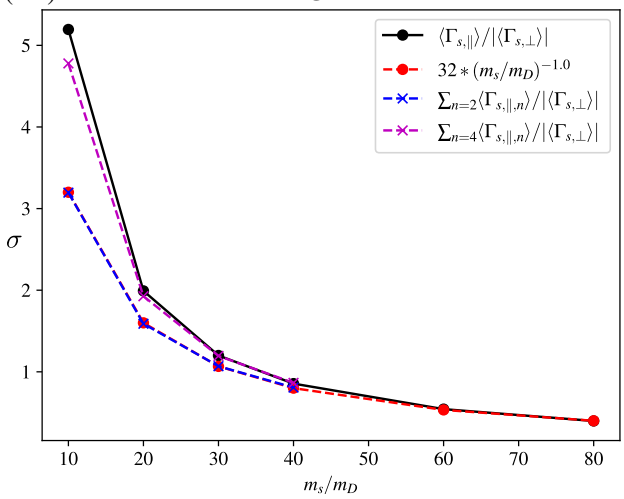

Figure 3. Plot of $\sigma =< \Gamma_{s,\parallel} >/| < \Gamma_{s,\perp} > |$(black) as a function of the mass m_s/m_D.

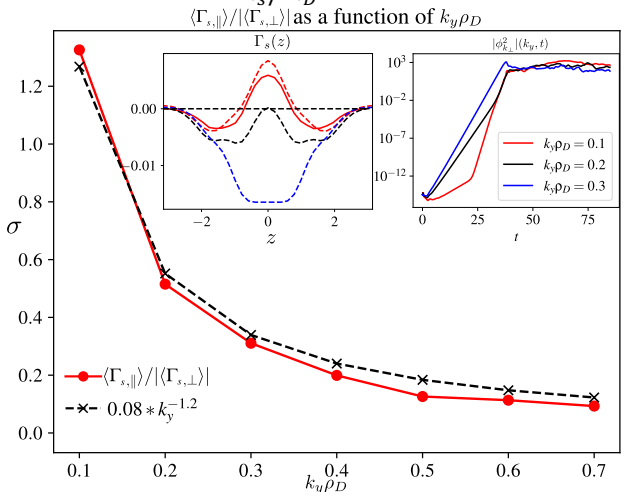

Figure 4. Plot of $\sigma =< \Gamma_{s,\parallel} >/| < \Gamma_{s,\perp} > |$(black) as a function of the wave number $k_y\rho_D$.