2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

Ion versus electron heating in astrophysical gyrokinetic turbulence

Yohei Kawazura[1], Michael Barnes[1,2], and Alexander A. Schekochihin[1,3]

[1] Rudolf Peierls Centre for Theoretical Physics, University of Oxford, [2] Culham Centre for Fusion Energy, Culham Science Centre, and [3] Merton College

e-mail (speaker): yohei.kawazura@physics.ox.ac.uk

Many astrophysical systems, such as accretion disks and the solar wind are weakly collisional. Therefore, ions and electrons in these systems can have different temperatures. Understanding what sets the temperature ratio between ions and electrons is crucial for identifying the various properties of far-distant astronomical objects. The key is the distribution of collisionless heating between ions and electrons. While there are a number of mechanisms that heat ions and electrons differently, in this study, we focus on the dissipation of turbulence — when turbulence is dissipated, how is its energy partitioned between ions and electrons?

We simulated collisionless turbulent heating using the hybrid gyrokinetic (GK) approach [1,2]. Unlike the previous full GK simulations [3], which were limited to a single parameter case, we revealed the parameter dependence of the ion-to-electron heating ratio $Q_\mathrm{i}/Q_\mathrm{e}$ via examining the wide-range of parameter space which covers most space and astrophysical plasmas [4]. The parameter dependence of $Q_\mathrm{i}/Q_\mathrm{e}$ is especially crucial in the context of low-luminosity accretion flows [5]. The simulation results show that $Q_\mathrm{i}/Q_\mathrm{e}$ is an increasing function of ion beta β_i when $\beta_\mathrm{i} \lesssim 10$, while $Q_\mathrm{i}/Q_\mathrm{e}$ is constant, ~ 30, when $\beta_\mathrm{i} \gtrsim 10$ [Fig.1 (left)]. We also found that $Q_\mathrm{i}/Q_\mathrm{e}$ is insensitive to the background ion-to-electron temperature ratio $T_\mathrm{i}/T_\mathrm{e}$ [Fig.1 (right)]. This tendency indicates that a collisionless plasma heated by turbulence prefers a two-temperature state where ions are hotter than electrons.

We also analyzed the phase space structure of the ion distribution function using Hermite-Laguerre spectral decomposition and revealed that ion heating is mediated by nonlinear phase mixing [6] when β_i is low and by linear phase mixing when β_i is high.

References

[1] A. Schekochihin, et al., The Astrophysical Journal Supplement Series **182**, 310 (2009).

[2] Y. Kawazura and M. Barnes, Journal of Computational Physics **360**, 57 (2018).

[3] G. G. Howes, et al., Physical review letters **107**, 035004 (2011); D. Told, et al., Physical review letters **115**, 025003 (2015); A. B. Navarro, et al., Physical Review Letters **117**, 245101 (2016).

[4] Y. Kawazura, M. Barnes, and A. Schekochihin, in preparation.

[5] E. Quataert and A. Gruzinov, The Astrophysical Journal **520**, 248 (1999).

; F. Yuan, and R. Narayan, Annual Review of Astronomy and Astrophysics **52**, 529 (2014).

[6] W. Dorland and G. Hammett, Physics of Fluids B: Plasma Physics **5**, 812 (1993); T. Tatsuno, et al., Physical review letters **103**, 015003 (2009); G. Plunk, et al., Journal of Fluid Mechanics **664**, 407 (2010).

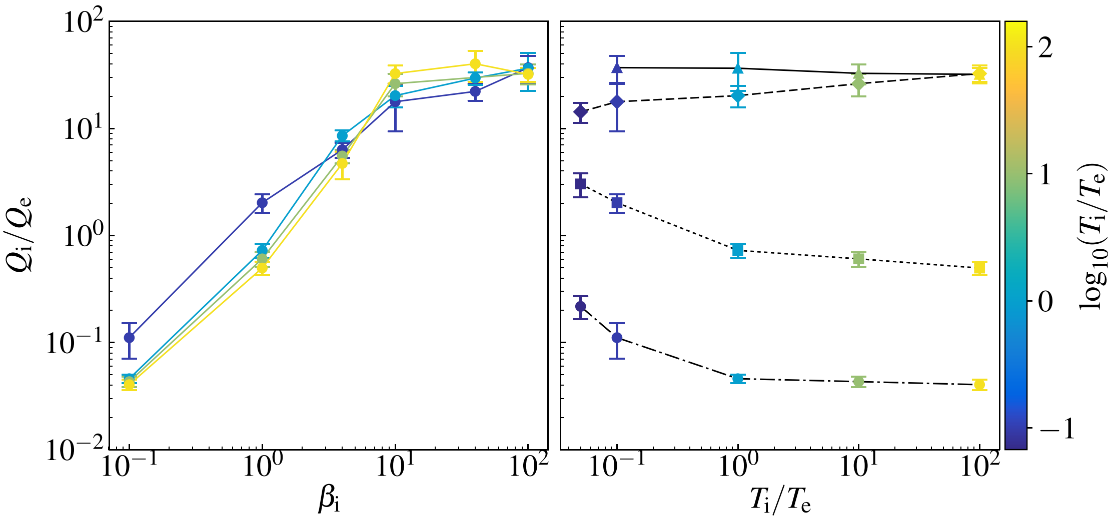

Fig. 1: $Q_\mathrm{i}/Q_\mathrm{e}$ vs β_i (left) and $T_\mathrm{i}/T_\mathrm{e}$ (right)