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Energy dissipation and distribution among particle species for Alfvenic turbulence at kinetic scales in wavenumber space

Jiansen HE[1], Die DUAN[1], Daniel Verscharen[2], Honghong WU[1,2], Linghua WANG[1], Hui TIAN[1], Chuanyi TU[1]

[1]School of Earth and Space Sciences, Peking University [2] Mullard Space Science Laboratory, University College London

e-mail (speaker): jshept@pku.edu.cn

Alfvenic turbulence is prevalent in solar and astrophysical plasmas, and plays a crucial role in transporting and converting energy. How to correctly describe and estimate the energy dissipation of Alfven waves at kinetic scales is becoming an important and realistic issue to be addressed, as the measurement quality of current density and electric field is getting better. For the conversion of magnetic energy to other forms, J·E' usually represents the conversion to plasma thermal kinetic energy, and J·E for the conversion to both plasma bulk kinetic and thermal kinetic energies. Therefore, people prefer to call J·E' as the real energy dissipation. However, when concerning the dissipation of waves/turbulence, we find that $\langle \delta J \cdot \delta E' \rangle$ is not consistent with $\gamma \delta E_B$ according to the linear Vlasov theory, where γ is the theoretical predicted damping rate. On the contrary, $\langle \delta J \cdot \delta E \rangle$ is exactly the same as $\gamma \delta E_B$ in the wavenumber space ($k_{\parallel}$, $k_{\perp}$). This is a seemingly "counterintuitive" but theoretically correct result. So we would like to call for attention to the choice of dissipation formula when studying the turbulence/waves dissipation. The underlying physical reason needs to be further explored. We speculate the term of $\langle \delta V \cdot \nabla \delta \mathbf{P} \rangle$, which appears as the energy conversion between bulk and thermal kinetic energies, may behave like a kind of catalyst in some sense helping to facilitate the ultimate conversion from magnetic energy to plasma thermal kinetic energy. Such speculation will be testified in the next step of work. Furthermore, we study the distribution of dissipated magnetic energy between protons and electrons. We find that the energy is mainly converted the thermal energy of protons leaving only a tiny portion for the electrons. The relation and difference between $J_{\parallel} \cdot E_{\parallel}$, parallel heating, and Landau damping, as well as the relation and difference between $J_{\perp} \cdot E_{\perp}$, perpendicular heating, and cyclotron damping are also discussed. We find that the non-diagonal terms of the plasma fluctuating kinetic energy tensor, if existent, would cause the thermal kinetic energy transfer between parallel and perpendicular directions, in addition to the original $J_{\parallel} \cdot E_{\parallel}$ for parallel heating and $J_{\perp} \cdot E_{\perp}$ for perpendicular heating.

References

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