4th Asia-Pacific Conference on Plasma Physics, 26-31Oct, 2020, Remote e-conference

Collisionless Magnetic Reconnection: Explaining its Progression via the Canonical Vorticity Framework and Identifying Stochastic Heating as the Anomalous Ion Heating Mechanism

Young Dae Yoon[1,2]
[1] California Institute of Technology, [2] Pohang Accelerator Laboratory
e-mail (speaker): yyoon11@postech.ac.kr

Magnetic reconnection is a process in which magnetic field lines come together, annihilate, reconnect, and convert its stored magnetic energy into particle energy. While reconnection is forbidden in ideal magneto-hydrodynamics (MHD), it is widely recognized that collisionless effects such as the Hall effect are responsible for the core process [1]. Despite being the subject of research for decades, numerous aspects of reconnection remain unfathomed; the present study aims to answer two of the most exigent questions.

First, due to its extremely complex nature, an intuitive understanding of magnetic reconnection is necessary. A relatively simple, intuitive explanation of the reconnection process is presented through the construction of the “canonical vorticity framework.” In this framework, a quantity called “canonical vorticity” is examined instead of the magnetic field, and this enables an intuitive explanation of the reconnection process [2, 3]. By including the “canonical battery” term which encompasses all kinetic effects via the pressure tensor, the framework may be extended down to first principles [4]. The framework is comprised of simply two terms that determine the temporal progression of canonical vorticity but contains all the information in the commonly used generalized Ohm’s law. The core explanations were verified by fluid and particle-in-cell simulations.

Second, the observed anomalous ion heating during magnetic reconnection has been a long-standing mystery. By using the previously established canonical vorticity framework, it is shown that the Hall electric fields that intrinsically develop during collisionless reconnection satisfy the criterion for stochastic ion heating [5]. The prediction of stochastic ion heating is verified by exact kinetic analyses, particle-in-cell simulations, and single-particle simulations [6]. Stochastic heating is thus established as the fundamental ion heating mechanism in collisionless reconnection.

This material is based upon work supported by the NSF Solar Terrestrial Research Program via award grant 1914599 and by the Air Force Office of Scientific Research Space Science Program via award grant FA9550-17-1-0023. The computations presented here were conducted on the Caltech High Performance Cluster partially supported by a grant from the Gordon and Betty Moore Foundation.

References

[1] J. Birn *et al.*, J. Geophys. Res.-Space **106**, 3715 (2001).
[2] Y. D. Yoon and P. M. Bellan, Phys. Plasmas **24**, 052114 (2017).
[3] Y. D. Yoon and P. M. Bellan, Phys. Plasmas **25**, 055704 (2018).
[4] Y. D. Yoon and P. M. Bellan, Phys. Plasmas **26**, 100702 (2019).
[5] Y. D. Yoon and P. M. Bellan, Astrophys. J. Lett. **868**, L31 (2018).
[6] Y. D. Yoon and P. M. Bellan, Astrophys. J. Lett. **887**, L29 (2019).