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MHD turbulence formation in solar flares: 3D simulation and synthetic observations

Wenzhi Ruan[1], Limei Yan[2] and Rony Keppens[1]

[1] Centre for Mathematical Plasma Astrophysics, Department of Mathematics, KU Leuven,

[2] Key Laboratory of Earth and Planetary Physics, Institute of Geology and Geophysics, Chinese Academy of Sciences

e-mail (speaker): wenzhi.ruan@kuleuven.be

Turbulent plasma motion is common in the universe, and invoked in solar flares to drive effective acceleration leading to high energy electrons. Unresolved mass motions are frequently detected in flares from extreme ultraviolet (EUV) observations, which are often regarded as turbulence. However, how this plasma turbulence forms during the flare is still largely a mystery.

Here we successfully reproduce observed turbulence in our 3D magnetohydrodynamic simulation where the magnetic reconnection process is included.[1] The turbulence forms as a result of an intricate non-linear interaction between the reconnection outflows and the magnetic arcades below the reconnection site, in which the shear-flow driven Kelvin-Helmholtz Instability (KHI) plays a key role for generating turbulent vortices.

The turbulence is produced above high density flare loops, and then propagates to chromospheric footpoints along the magnetic field as Alfvenic perturbations. High turbulent velocities above 200 km/s can be found around the termination shock, while the low atmosphere reaches turbulent velocities of 10 km/s. The turbulent region with maximum non-thermal velocity coincides with the region where the observed high-energy electrons are concentrated, demonstrating the potential role of turbulence in acceleration. Synthetic views in EUV and fitted Hinode-EIS spectra show excellent agreement with observational results.[2] A cartoon of the scenario and our simulation results are illustrated in Figure 1.

References

[1] W. Ruan, L. Yan, R. Keppens, ApJ, 947, 67 (2023)

[2] M. Stores, N. L. S. Jeffrey, E. P. Kontar, ApJ, 923, 40 (2021)

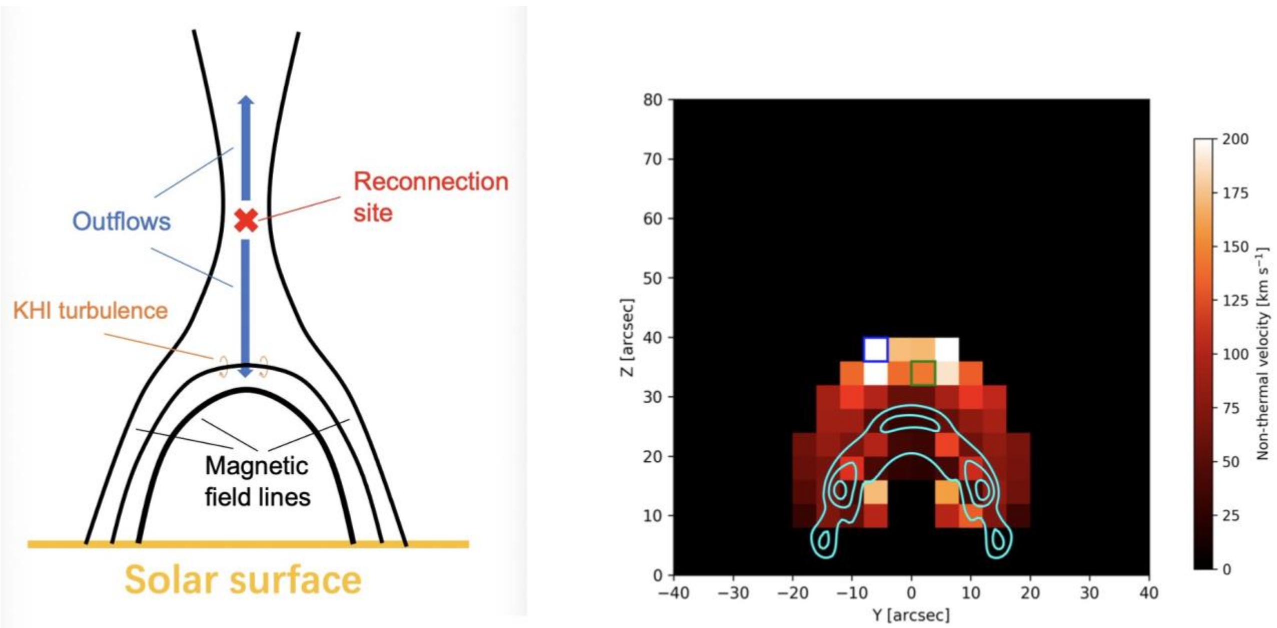

Figure 1. The left panel shows a cartoon of the scenario. Reconnection outflows collide with magnetic arcades and then produce Alfvénic turbulence through KHI. The right panel gives the nonthermal velocity distribution in our simulation, which is obtained from Gaussian fitting of synthesized EIS/255 spectra. The cyan contours give the locations of the bright loop in the AIA/131 image, where the contour lines show the intensity levels of 25%, 50%, and 80% of peak AIA/131 flux.