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MHD Simulation of Three-dimensional Turbulent Magnetic Reconnection within the Solar Flare Current Sheet

Solar flares can release coronal magnetic energy explosively and may impact the safety of near-Earth space environments. Their structures and properties on the macroscale have been interpreted successfully by the generally accepted 2D standard model, invoking magnetic reconnection theory as the key energy conversion mechanism. Nevertheless, some momentous dynamical features discovered by recent high-resolution observations remain elusive.
Here, we report a self-consistent high-resolution 3D magnetohydrodynamical simulation of turbulent magnetic reconnection within a flare current sheet. It is found that fragmented current patches of different scales are spontaneously generated with a well-developed turbulence spectrum at the current sheet, as well as at the flare loop-top region. The close coupling of tearing mode and Kelvin–Helmholtz instabilities plays a critical role in developing turbulent reconnection and in forming dynamical structures with synthetic observables in good agreement with realistic observations.
We also develop an efficient method for identifying locations and configurations of 3D reconnection. It is shown that this method can precisely identify the local structures of discrete magnetic field. Through the information of nonideal electric field and the geometric attributes of magnetic field, the local structures of reconnection sites can be effectively and comprehensively determined. With the aid of this method, we precisely recognize and trace the 3D fine reconnection structures in our simulation and obtain their statistical rules, which intuitively exhibit the multi-scale physical pictures of 3D turbulent reconnection within the flare current sheet.

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