High-Resolution Three-Dimensional MHD Simulations of Plasmoid Formation in Solar Flares

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In highly conducting plasmas, reconnecting current sheets are often unstable to the generation of plasmoids, small-scale magnetic structures that play an important role in facilitating the rapid release of magnetic energy and channeling that energy into accelerated particles. There is ample evidence for plasmoids throughout the heliosphere, from in situ observations of flux ropes in the solar wind and planetary magnetospheres to remote-sensing imaging of plasma ‘blobs’ associated with explosive solar activity such as eruptive flares and coronal jets. Accurate models for plasmoid formation and dynamics must capture the large-scale self-organization responsible for forming the reconnecting current sheet. However, due to the computational difficulty inherent in the vast separation between the global and current sheet scales, previous numerical studies have typically explored configurations with either reduced dimensionality or pre-formed current sheets. We present new three-dimensional MHD studies of an eruptive flare in which the formation of the current sheet and subsequent reconnection and plasmoid formation are captured within a single simulation. We employ Adaptive Mesh Refinement (AMR) to selectively resolve fine-scale current sheet dynamics. Reconnection in the flare current sheet generates many plasmoids that exhibit highly complex, three-dimensional structure. We show how plasmoid formation and dynamics evolve through the course of the flare, especially in response to the weakening of the reconnection “guide field” linked to the global reduction of magnetic shear. We discuss implications of our results for particle acceleration and transport in eruptive flares as well as for observations by Parker Solar Probe and the forthcoming Solar Orbiter.