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Magnetic Reconnection in high-Lundquist-number plasmas

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Magnetic reconnection is the driver of explosive phenomena in both laboratory and astrophysical contexts. Sawtooth crashes in fusion experiments and solar flares are prominent examples of fascinating events where reconnection plays a key role. Over the past few years, the basic understanding of this fundamental process has undergone profound changes. The validity of the most basic, and widely accepted, reconnection paradigm – the famous Sweet-Parker (SP) model, which predicts that, in MHD, reconnection is extremely slow, its rate scaling as $S^{-1/2}$, where S is the Lundquist number of the system – has been called into question as it was analytically demonstrated that, for $S \gg 1$, SP-like current sheets are violently unstable to the formation of a large number of secondary islands, or plasmoids. Subsequent numerical work has confirmed the validity of the linear theory, and shown that plasmoids quickly grow to become wider than the thickness of the original SP current sheet, thus effectively changing the underlying reconnection geometry. Ensuing numerical work has revealed that the process of plasmoid formation, coalescence and ejection from the sheet drastically modifies the steady state picture assumed by Sweet and Parker, and leads to the unexpected result that MHD reconnection is actually fast (i.e., independent of S). In this talk, we review these recent developments and present a novel theoretical model of MHD reconnection in high Lundquist number plasmas. The results of a detailed numerical study are presented, validating the main predictions of this theory, which we thus suggest as valid replacement of the SP paradigm. In particular, we discuss the formation of so-called monster plasmoids (whose widths are 10% of the system size, and thus not only detectable but also potentially disruptive), predicted by the theory and observed in our simulations.