Magnetic Reconnection:
from the Sweet-Parker model to stochastic plasmoid chains

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Magnetic reconnection is the topological reconfiguration of the magnetic field in a plasma, accompanied by the violent release of energy and particle acceleration. Reconnection is as ubiquitous as plasmas themselves, with solar flares perhaps the most popular example. Other fascinating processes where reconnection plays a key role include the magnetic dynamo, geomagnetic storms and the sawtooth crash in tokamaks.

Over the last few years, the theoretical understanding of magnetic reconnection in large-scale fluid systems has undergone a major paradigm shift. The steady-state model of reconnection described by the famous Sweet-Parker (SP) theory, which dominated the field for ~ 50 years, has been replaced with an essentially time-dependent, bursty picture of the reconnection layer, dominated by the continuous formation and ejection of multiple secondary islands (plasmoids). Whereas in the SP model reconnection was predicted to be slow, a major implication of this new paradigm is that reconnection in fluid systems is fast (i.e., independent of the Lundquist number), provided that the system is large enough.

This conceptual shift hinges on the realisation that SP-like current layers are violently unstable to the plasmoid (tearing) instability — implying, therefore, that such current sheets are super-critically unstable and thus can never form in the first place. This suggests that the formation of a current sheet and the subsequent reconnection process cannot be decoupled, as is commonly assumed.

This talk aims to review the recent developments in reconnection that led to this essentially new framework, and discuss the outstanding challenges that remain at the frontier of this subject.