Magnetic dissipation: spatial and temporal structure

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Abstract A magnetically dominated plasma driven by motions on boundaries at which magnetic field lines are anchored is forced to dissipate the work being done upon it, no matter how small the electrical resistivity. Numerical experiments have clarified the mechanisms through which balance between the boundary work and the dissipation in the interior is obtained. Dissipation is achieved through the formation of a hierarchy of electrical current sheets, which appear as a result of the topological interlocking of individual strands of magnetic field. The probability distribution function of the local winding of magnetic field lines is nearly Gaussian, with a width of the order unity. The dissipation is highly irregular in space as well as in time, but the average level of dissipation is well described by a scaling law that is independent of the electrical resistivity.

If the boundary driving is suspended for a period of time the magnetic dissipation rapidly drops to insignificant levels, leaving the magnetic field in a nearly force-free, yet spatially complex state, with significant amounts of free magnetic energy but no dissipating current sheets. Renewed boundary driving leads to a quick return to dissipation levels compatible with the rate of boundary work, with dissipation starting much more rapidly than when starting from idealised initial conditions with a uniform magnetic field.

Application of these concepts to modelling of the solar corona leads to scaling predictions in agreement with scaling laws obtained empirically; the dissipation scales with the inverse square of the loop length, and is proportional to the surface magnetic flux. The ultimate source of the coronal heating is the photospheric velocity field, which causes braiding and reconnection of magnetic field lines in the corona. Realistic, three-dimensional numerical models predict emission measures, coronal structures, and heating rates compatible with observations.

When driv'n by extreme agitation,
I am subject to fierce dissipation;
In each current sheet
There's created much heat,
And my field thus achieves saturation.