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On the existence of fast Petschek reconnection in two-dimensional magnetohydrodynamics

Hubert BATY (1), Eric R. PRIEST (2), and Terry G. FORBES (3)

(1) Observatoire Astronomique, 11 Rue de l'Université, 67000 Strasbourg, France (baty@astro.u-strasbg.fr), (2) Institute of Mathematics, University of St. Andrews, Fife KY169SS, Scotland, United Kingdom, (3) Institute for the Study of Earth, Ocean, and Space, University of New Hampshire, Durham, New Hampshire 03824, USA

We address the controversial topic of the existence of a Petschek solution in steady-state magnetic reconnection for a uniform resistivity, by using results obtained in two-dimensional time-dependent magnetohydrodynamic simulations. A classical localized nonuniform resistivity with a profile that is exponentially decreasing from the X-point is helpful to set up the Petschek solution as a first step, using a procedure with overspecified boundary conditions. The response to changing the spatial resistivity profile in three various ways is then studied in three different studies as a second step:
1) When a quasiuniform resistivity is adopted, a stationnary Petschek reconnection can be maintained. This is the case if the resistivity profile exhibits a weak negative gradient close to the X-point, which dominates an inherent numerical contribution; otherwise an instability develops which disrupts the configuration. However, the reconnection process is considered to be slow as the rate remains substantially smaller than the maximum rate allowed by the Petschek's original.
2) The impact of using a nonlocalized electrical resistivity having a spatially asymmetric profile is also considered. It is shown that a stationary Petschek-like reconnection is obtained in the half plane where a uniform resistivity is adopted. The latter configuration is maintained by a co-existing Petschek configuration that is formed in the second half plane where the resistivity exhibits a classical exponentially decreasing variation. The structure of the central diffusion region is asymmetric, with a stagnation point flow which does not coincide with the X-point.
3) Finally, we report for the first time the existence of fast stationary magnetic reconnection with a spatially uniform plasma resistivity. This is achieved through the use of a nonuniform well tailored explicit viscosity profile (note that the viscosity was negligibly small in the two previous studies), following requirements deduced from the asymmetric resistivity simulations. The quasisteady state exhibits the global features of a classical Petschek solution, with two pairs of standing slow-mode shocks attached to a central diffusion region and a fast-mode expansion of the inflowing plasma. The diffusion region is however influenced by the viscosity with a two-component structure, and the reconnection rate is observed to be slightly higher than nonviscous nonuniform resistive reconnection.

These results show that Petschek solutions can exist in different situations where the resistivity is almost uniform, or uniform with an extra added well chosen viscosity.We can also clarify the conditions under which a Petschek solution with the fastest rate can indeed exist in the presence of a small uniform resistivity in the whole domain.