Cosmic Magnetic Fields:
From Planets, to Stars and Galaxies
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Effects of turbulence on magnetic reconnection: 3D numerical simulations

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Abstract. Turbulent reconnection is studied by means of three dimensional (3D) compressible magnetohydrodynamical numerical calculations. The process of homogeneous turbulence is set up by adding three-dimensional solenoidal random forcing implemented in the spectral space at small wave numbers with no correlation between velocity and forcing. We apply the initial Harris current sheet configuration together with a density profile calculated from the numerical equilibrium of magnetic and gas pressures. We assume that there is no external driving of the reconnection. The reconnection develops as a result of the initial vector potential perturbation. We use open boundary conditions. Our main goal is to find the dependencies of reconnection rate on different properties of turbulence. The results of our simulations show that turbulence significantly affects the topology of magnetic field near the diffusion region. We present that the reconnection speed does not depend on the Reynolds numbers as well the magnetic diffusion. In addition, a fragmentation of current sheet decreases the disparity in inflow/outflow ratios. When we apply the large scale and more powerful turbulence the reconnection is faster.

Keywords. MHD – numerical simulations – magnetic fields – turbulence

1. Introduction and numerical model of turbulent reconnection

Fast reconnection should have speeds close to the Alfvén speed V_A. Sweet-Parker (1958, 1957) found that their model of magnetic reconnection applied to the astrophysical bodies is very slow. The reconnection rate, according to this model, depends on the magnetic Reynolds number R_M (as $V_A R_M^{-1/2}$). Petschek (1964) introduced a fast mechanism of magnetic reconnection, which is proportional to $(\log R_M)^{-1}$. Later on, it was shown that the X-point region required in Petschek mechanism collapsed to Sweet-Parker geometry for large R_M (Biskamp, 1996). Lazarian & Vishniac (1999, 2000) suggested that the presence of a stochastic magnetic field component enhances the reconnection rate enabling fast reconnection.

Numerical Model of Turbulent Reconnection is calculated in a box with open boundary conditions. We use Harris current sheet setup as a initial configuration and we set V=0 initially. Reconnection develops as a result of initial vector potential perturbation. We do not drive reconnection! Input parameters: B_x=1.0 above the Y=0 plane and B_x=-1 below it, B_z varies from 0.0 to 1.0. We numerically solve 3D non-ideal normalized isothermal MHD equations varying the power of turbulence, its injection scales and magnetic resistivity. For details refer to Kowal *et al.* (2008).

2. Results

In the left panel of Figure 1 we demonstrate XY-cut across our computational box at time 12. The map shows current density (visible as color plot) with magnetic field vectors superimposed onto the figure. The stable in the beginning Sweet-Parker configuration

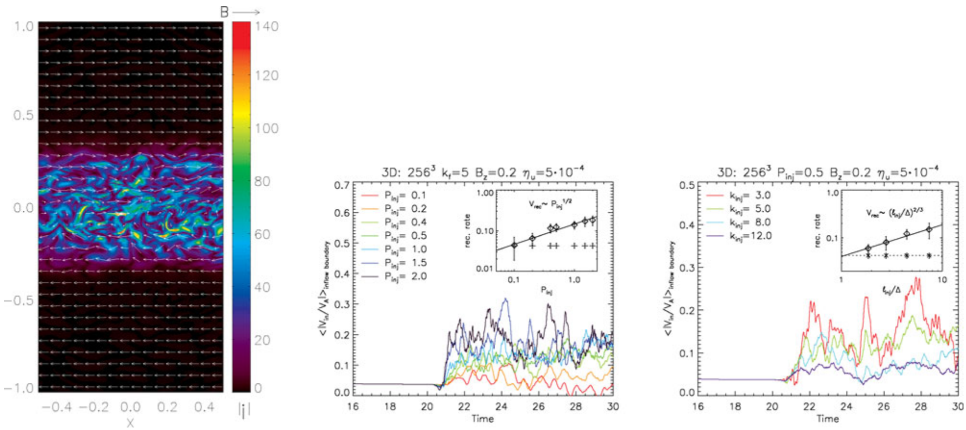

Figure 1. *Left*: XY-cut through the box showing the colors of absolute value of current density and vectors of magnetic field at time t=12 for model with P=1.0 and k=8. Resistivity is set to 10^{-3}. *Middle*: Dependence of the reconnection rate $\langle V_{in}/V_A\rangle$ on the power of turbulence P_{inj}. *Right*: Dependence of the reconnection rate $\langle V_{in}/V_A\rangle$ on the injection scale l_{inj}.

after introduction of turbulence quickly changes its character. We observe fragmentation of current sheets. The middle and right panels of Figure 1 show the time dependence of the reconnection rate defined as $< V_{in}/V_A >$ on the power of turbulent motions (middle) and the injection scale l_{inj} (right). We observe the growth of the reconnection rate with the increasing power strength P_{inj} and injection scale l_{inj}. We also report no dependence of the reconnection rate on the resistivity (not presented here, see Kowal, 2008).

3. Conclusions

(*a*) Numerical studies of stochastic reconnection are finally possible, even though the reconnection in numerical simulations is always fast.

(*b*) Turbulence significantly affects the topology of B near the diffusion region.

(*c*) Fragmentation of current sheet decreases the disparity in inflow/outflow ratios.

(*d*) For large scale turbulence, the reconnection rate V_{rec} scales as V_T^2 and $(l_{inj}/\Delta)^{2/3}$ with the strength and injection scale

(*e*) Reconnection rate is independent on resistivity

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Puerto Santiago

Meeting room

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Hotel lobby

Farewell Tenerife

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