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Can turbulent reconnection be fast in 2D?

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Abstract. Turbulent reconnection is studied by means of two-dimensional (2D) compressible magnetohydrodynamical numerical calculations. The process of homogeneous turbulence is set up by adding two-dimensional 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 the uniform resistivity. We present that the reconnection speed depends on the Lindquist number in 2D in the case of low as well as high resolution. When we apply more powerful turbulence the reconnection is faster, however the speed of reconnection is smaller than in the case of our three-dimensional numerical simulations.

Keywords. magnetic fields, turbulence, methods: numerical

1. Introduction

Magnetic reconnection plays a major role in various astrophysical phenomena such as star formation, solar explosions or galactic dynamo. For instance, in order for astrophysical dynamos to function smoothly the reconnection should have speeds close to Alfvén speed V_A. This is called fast reconnection, meaning that it does not depend on resistivity or depends on the resistivity logarithmically. The generally accepted Sweet-Parker (Parker 1957, Sweet 1958) model of magnetic reconnection applied to astrophysical bodies gives very slow reconnection rate which depends on the Lundquist number S as $V_A \sim S^{-1/2}$. Lazarian & Vishniac (1999) (LV99) proposed that in 3D a stochastic magnetic field component can dramatically enhance reconnection rates. This model has been recently confirmed numerically (including the insensitivity to the Lundquist number) by Kowal *et al.* (2009). Because the claim in LV99 model is that 3D effects are essential for fast reconnection, we are interested to test the effects of dimensionality on the reconnection rate. What is more, in a number of earlier studies of 2D reconnection it was conjectured that magnetic reconnection could become fast in the presence of turbulence.

2. Dependence on the uniform resistivity

In our work we studied the dependence of the reconnection rate on the uniform resistivity η_u in low (1024×2048) and high (4096×8192) resolution numerical simulations. We run several simulations with different values of the uniform resistivity η_u and with

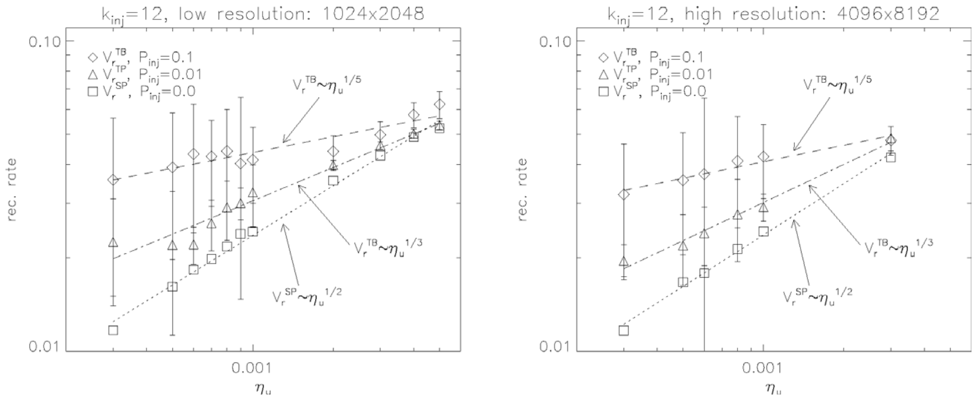

Figure 1. Dependence of the reconnection rate on the uniform resistivity η_u for models with and without turbulence, V_r^{TB} (diamonds and triangles) and V_r^{SP} (squares), respectively. Turbulence is injected at the scale $k = 12$ with $P_{inj} = 0.1$ and $P_{inj} = 0.01$. Simulations are performed with low (left panel) and high (right panel) resolution. For the Sweet-Parker reconnection (squares) the variance is negligible and not shown.

two values of the power of turbulence $P_{inj} = 0.1$ and $P_{inj} = 0.1$. For the Sweet-Parker model (Fig. 1, left panel) the obtained dependence of reconnection pace on the uniform resistivity coincide in 2D and 3D and agrees with the theoretical prediction, i.e., $V_r^{SP} \sim \eta_u^{1/2}$. Kowal *et al.* (2009) showed that in 3D the turbulent reconnection process is not constrained by Ohmic resistivity. In contrast to their work, we find that adding turbulence to the system leads to a weaker dependence between the reconnection rate and the uniform resistivity. Moreover, the dependence between reconnection rate and uniform resistivity is stronger for lower values of P_{inj}. Namely, for $P_{inj} = 0.1$ and $P_{inj} = 0.01$ we see that the reconnection rate scales as $\sim \eta_u^{1/5}$ and $\sim \eta_u^{1/3}$, respectively. For a more detailed description of these results we refer the reader to Kulpa-Dybeł *et al.* (2010).

To verify the influence of the numerical resolution on the recconection rate we made several simulations with different values of the resolution. The rest of the input parameters have the same value in all these models. In Fig. 1 we show the comparison of reconnection rates obtained for low and high resolution simulations. We can see that in both cases the reconnection rate depends on the uniform resistivity. This indicates that increasing the numerical resolution does not lead to a stable state of reconnection and does not change our results.

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