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Numerical Testing of Magnetic Reconnection in the Presence of Turbulence

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We study the effects of turbulence on magnetic reconnection using three-dimensional direct numerical simulations. This is the first attempt to test a model of fast magnetic reconnection in the presence of weak turbulence proposed by Lazarian & Vishniac. This model predicts that weak turbulence, which is generically present in most astrophysical systems, enhances the rate of reconnection by reducing the transverse scale for reconnection events and by allowing many independent flux reconnection events to occur simultaneously. As a result, the reconnection speed becomes independent of Ohmic resistivity and is determined by the magnetic field wandering induced by turbulence. We test the dependence of the reconnection speed on turbulent power, the energy injection scale, and resistivity. We apply the open and experiment with the outflow boundary conditions in our numerical model and discuss the advantages and drawbacks of various setups. To test our results, we also perform simulations of turbulence with the same outflow boundaries but without a large-scale field reversal, thus without large-scale reconnection. To quantify the reconnection speed we use both an intuitive definition, i.e., the speed of the reconnected flux inflow, and a more sophisticated definition based on a formally derived analytical expression. Our results confirm the predictions of the Lazarian & Vishniac model. In particular, we find that the reconnection speed is proportional to the square root of the injected power, as predicted by the model. The dependence on the injection scale for some of our models is a bit weaker than expected, i.e., $l_{inj}^{3/4}$, compared to the predicted linear dependence on the injection scale, which may require some refinement of the model or may be due to effects such as the finite size of the excitation region, which are not a part of the model. The reconnection speed was found to depend on the expected rate of magnetic field wandering and not on the magnitude of the guide field. In our models, we see no dependence on the guide field when its strength is comparable to the reconnected component. More importantly, while in the absence of turbulence we successfully reproduce the Sweet-Parker scaling of reconnection, in the presence of turbulence we do not observe any dependence on Ohmic resistivity, confirming that the reconnection of the weakly stochastic field is fast. We also do not observe a dependence on anomalous resistivity, which suggests that the presence of anomalous effects, e.g., Hall MHD effects, may be irrelevant for astrophysical systems with weakly stochastic magnetic fields.