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Study of the turbulent reconnection by MHD simulations

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Many pieces of evidence have been found that support the magnetic reconnection model of solar flares. On the other hand, the theory of the reconnection is not yet completed. A self-consistent solution for the fast magnetic reconnection is not yet obtained that matches from the global to the microscopic scale under extremely large magnetic Reynolds number like the solar corona (approximately Rm = 1e13).

The model solution of the fast reconnection was proposed by Petschek (1964). Extensive numerical simulations have been done and a consensus is achieved that a spatially-localized magnetic diffusivity is necessary to realize the Petschek-type solution. For the application to the solar flares, this was not sufficient. In the Petschek's model, the spatial size of the diffusion region should be Rm^(-1) times the size of a flare. Since the typical size of a flare is approximately 10000 km, then the diffusion region should be around 1 micro-meter (!) by a straightforward estimation. In an actual case, the size of the diffusion region is limited by the micro-scale of the coronal plasma, i.e., the ion Larmor radius that is 10 meter. Even though this number is adopted, it is still physically unbelievable to consider that a tiny 10-meter diffusion region controls a huge 10000-km flare.

The turbulent magnetic reconnection model is proposed to solve this question by Tajima & Shibata (1997). Their suggestion was as follows: There is a global current sheet in the neutral point of the flare region. The size of the global current sheet may be larger than 1 km. The global current sheet contains many small magnetic islands, between which there are many small thin current sheets. They suggest that the size spectrum of the size of each magnetic island is power law, i.e. the current sheet has a fractal nature. In the smallest scale, the thickness of the current sheet is comparable to the ion Larmor radius, so that the reconnection can start from such smallest scale. As the reconnection goes on, the size of magnetic islands grows and grows, and finally the reconnection between the largest magnetic islands becomes possible. Since the time scale of each small scale reconnection is of order of the Alfven time, the final time scale for the reconnection of the largest scale islands is also the Alfven time.

The purpose of this study is to investigate the possibility of realization of the turbulent magnetic reconnection model. It is studied how the magnetic reconnection rate is affected by the presence of a turbulence by means of MHD simulations. The magnetic reconnection starts in an isolated current sheet between a set of anti-parallel magnetic fields by imposing a mildly localized diffusivity. In addition to this, random perturbations are imposed on the velocity fields all over the simulation box, which simulates the turbulence in the plasma. The reconnection rates are compared among the cases with and without the perturbations. Preliminary results show: A temporal oscillation appears in the reconnection rate when the perturbations are imposed. However, the energy release as a total does not change much from the case without perturbations.