§11. Multi-scale Simulation Study of Solar and Heliospheric Plasmas

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The sun and the heliosphere are complex plasma systems, in which processes at vastly different scales interact to each other. The objective of this study is to develop a numerical framework, which is capable to simulate multi-scale processes occurring in the sun and the heliosphere, aiming at improving our understanding and advancing the predictability of space weather and space climate. In FY 2010, we focus on the trigger mechanism of solar flare. Although flare is the biggest explosion in our solar system and sometimes impacts the satellite system and the power grid, the trigger mechanism of flare is not well understood yet and the predictability of the onset of flare is still very poor.

In this study, we have proposed the hypothetical scenario that solar flares can be triggered by the emerging of small magnetic flux into the solar active region which is largely sheared. A series of three-dimensional magnetohydrodynamic simulations was performed in order to verify it. Various runs have been carried out for different azimuth of the emerging magnetic flux, ϕ_e in Fig.1. As results of it, we found that there are two preferential azimuth for which the emerging flux can trigger explosive magnetic reconnection corresponding to the onset of solar flare.

Figure 2 is the result of simulation, in which the emerging flux is oriented to the opposite to the preexisting sheared magnetic field. In this case, magnetic reconnection between the preexisting field and the emerging flux causes the collapse of magnetic arcade into the centre, and explosive reconnection is driven. On the other hand, the emerging flux is directed to the opposite to potential component of magnetic field, the reconnection between the emerging flux and the preexisting field forms a long flux tube, which is ejected upward due to the hoop force. As the result of elevation of flux tube, the arcade is collapsed and magnetic reconnection driving flare starts, as shown in Fig.3.

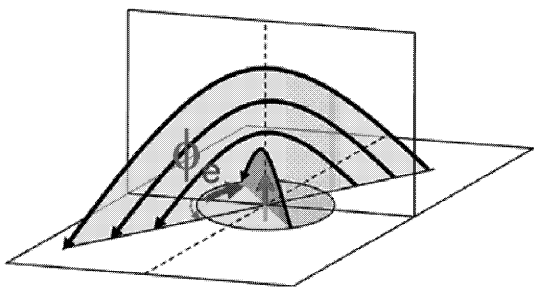

Fig. 1: Schematic diagram of the initial setup of simulation.

All the results indicate that the onset of solar flare is susceptible to the flux emerging activity. The physical condition for the onset of flare is given by the mutual interaction of large-scale magnetic shear and small-scale flux emerging. There are two different processes for which the small reconnection evolves to solar flare; so called "collapse-to-erupt" and "erupt-to-collapse," respectively. The interpretation of simulation results is consistent with the recent analysis of magnetic twist in flare productive active region[1].

1) Inoue, Kusano, and Magara, "Twist and Connectivity of Magnetic Field Lines in the Solar Active Region NOAA 10930", ApJ (2011) in press.

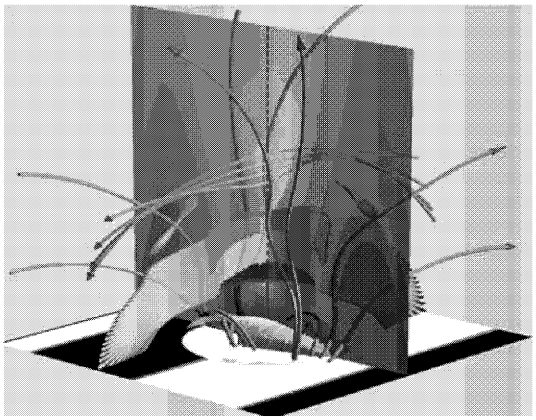

Fig. 2: The result of flare simulation, in the case of collapse-to-erupt process.

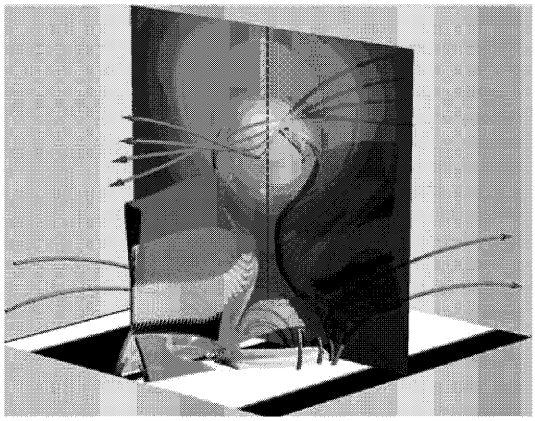

Fig. 3: The result of flare simulation, in the case of erupt-to-collapse process.