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Simulation Study on Trigger Mechanism of Solar Flare and Plasmoid Ejection
シミュレーションで探る太陽フレアとプラズモイド放出のトリガー機構

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What triggers solar flares is not yet well understood, and the predictability of flare onset is still very much limited, although the forecasting of flare and coronal mass ejection is highly demanded to protect the health of astronauts and satellite systems from severe space weather impacts. We have carried out a systematic simulation study to clarify the physical condition for the onset of solar flare, based on the hypothesis that the emerging of magnetic flux onto the solar surface may trigger solar flares. As a result, it is found that only two types of emerging flux can trigger solar flares. The simulations indicate that the causal relationship between magnetic reconnection and plasmoid ejection is different between the cases that the different types of emerging flux trigger flare, although the both cases result in a morphologically similar dynamics. The simulatino results are well consistent with the data of two major flares observed by Solar Optical Telescope aboard Hinode satellite.

1. Introduction

Solar flare may eject a large-scale plasmoid, and it sometimes forms coronal mass ejection in the inter-planetary space. Although the energy release process of flares is now believed to be driven by magnetic reconnection, the fundamental question “what triggers solar flares” is still open to be answered. The understanding of trigger mechanism of flares is important also for the space weather forecast, because it is demanded to predict the flare onset in order to protect the health of astronauts on the orbit and the advanced infrastructure from the impact of severe space weather disturbance. However, the predictability of flare onset is still very much limited. In this study, we have carried out a systematic simulations to clarify the physical condition for the onset of solar flares, based on the hypothesis that the emerging of magnetic flux onto the solar surface may trigger solar flares.

2. Simulation Model

The initial condition of simulation is given by the linear force-free field, which is characterized by the shear angle θ with reference to the potential field. After the simulation starts, a bi-pole field, which is oriented to the azimuth φ, is injected onto the center of magnetic arcade. We have surveyed the parameter space $0 \le \theta < 90°$ and $0 \le \varphi < 360°$ in terms of 3D MHD simulation.

3. Results

As a result of systematic survey, it is found that the occurrence of flare is very sensitive to φ, and that there are two different parametric windows in which the emerging flux can trigger flare eruption. They are the cases for opposite polarity (OP) for $\varphi=180°$ and reversed shear (RS) for $\varphi=270°$, respectively. In the case of OP, the emerging flux forms elongated twisted rope by reconnecting two sheared loops, and cause the eruption of plasmoid, which is followed by flare reconnection. On the other hand, in the case of RS, the emerging flux reconnects with the originally sheared field, and cause the internal collapse of magnetic arcade. As a consequence, flare reconnection is triggered. Once flare reconnection proceeds, the both cases result in similar dynamics, which is consistent with the standard flare model.

4. Discussion and Conclusion

The simulation study reveals that there are two different preferential magnetic configurations for triggering flares. We have analyzed the magnetic data observed by Solar Optical Telescope aboard Hinode satellite. As a result, at least two flares occurring on 2006 Dec. 13 and 2011 Feb. 13 are found to be well consistent with this prediction. The results strongly suggest us that small reconnection caused by flux emerging may trigger large-scale flare reconnection and plasmoid ejection [1].

References

[1] K. Kusano, Y. Bamba, T. T. Yamamoto, to be submitted.