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主　論　文　の　要　旨

論文題目
Study of the Characteristics of Magnetic Field in the Flaring Active Regions Based on the Nonlinear Force-Free Field Extrapolation and Magnetohydrodynamic Simulations
(非線形フォースフリー磁場外挿法と電磁流体力学シミュレーションに基づいた、太陽フレアを引き起こす活動領域磁場の研究)

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論　文　内　容　の　要　旨

Solar flares release magnetic energy stored in the active regions (ARs) of the Sun to the interplanetary space by means of the magnetohydrodynamic (MHD) instabilities and magnetic reconnection in the solar corona. Although the basic morphological structure of solar flares has been well explained by the standard flare model, what kind of ARs can produce large solar flare are still unclear. The characteristics of the flaring AR is one of the crucial problems to understand the mechanism of solar flares. This is strongly related to the flare triggering process and the instability of the magnetic field in the AR. Therefore, studying these two fundamental processes is very important to improve our understanding about the onset mechanism of solar flare. In this study, we focus on investigating the feasibilities of applying the triggering mechanism proposed in the numerical simulations by Kusano et al. (2012) and the double-arc instability analysis by Ishiguro & Kusano (2017) for the real observational data. Numerical simulations by Kusano et al. (2012) revealed that two small emerging magnetic structures, which are opposite polarity (OP) and reversed shear (RS) structure, are effective to trigger solar flares. Their simulations were conducted on the linear force-free magnetic fields (LFFFs) with various force-free alpha that represent diverse shear angles. Although this kind of simulation is very important and useful to understand the basic properties of flare trigger structures, the result of the simulations needs to be examined for

more realistic magnetic field. On the other hand, Ishiguro & Kusano (2017) recently investigated the instability of the double-arc magnetic structure, which can be formed by the tether cutting reconnection. This kind of instability is then known as the double-arc instability (DAI). They proposed κ parameter that can represent the critical condition for the DAI to occur. However, this κ parameter has never been investigated for the real flare event in the Sun. Since the trigger mechanism proposed by Kusano et al. (2012) can create double-arc structure through tether cutting reconnection, this theory can complement the DAI theory by Ishiguro & Kusano (2017) in providing the more comprehensive scenario for a solar flare to happen. In this study, we aim to clarify the mechanism of a flare trigger proposed by Kusano et al. (2012) for the more realistic magnetic field and to perform the DAI analysis using the observed data in order to understand the flare onset. We investigated the possible mechanism that can trigger a solar flare through the modeling of an AR and parametric ensemble simulations based on the data observed by Hinode satellite. Furthermore, we developed a method that synthesizes the trigger process of solar flare that can be used to assess the possibility of the upcoming solar flare by applying DAI analysis using data from Solar Dynamical Observatory (SDO) satellites. We employed magnetic relaxation method by Inoue et al. (2014) to extrapolate coronal magnetic field as a nonlinear force-free field (NLFFF). We extracted magnetic twist parameter from the NLFFF model of an AR and proposed a new parameter so called κ^*, which is the proxy for κ in the DAI, that contains the information of the highly twisted flux and the total flux in an AR.From our simulations, we found that the trigger scenarios proposed by Kusano et al. (2012) can also work on more realistic magnetic field derived from observational data to drive a flare. This is confirmed by the similarities of the synthetic flare ribbon created in the simulation and the observed one. Moreover, our DAI analysis that we applied on real ARs show thatκ^* may serve as an indicator of impending solar flare. We found that κ^* evolution of the flaring ARs are consistent with the critical instability condition derived in the DAI analysis. Our result suggests that solar flare can occur when the amount of reconnected flux that increases the number of highly twisted field lines is large enough compared to the total flux within the core of the AR. These results show that the NLFFF extrapolation constructed from the photospheric magnetic field data significantly works to help our understanding of the process that determine the onset of a flare. Proper parameters derived from NLFFF can be useful to evaluate the possibility of the upcoming flare. We suggest that the use of κ^* and additional information of trigger structure in the AR can be beneficial for the better solar flare forecasting.