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主　論　文　の　要　旨

論文題目 Study of the Conditions that Determine the Formation of Coronal Mass Ejections Using Models of the Coronal Magnetic Field (太陽コロナ磁場モデルに基づくコロナ質量放出の形成条件に関する研究)

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論　文　内　容　の　要　旨

Solar flares and Coronal Mass Ejections (CME) are two important solar eruptions that release the magnetic energy stored in the Active Regions (ARs) of the Sun through the magnetic reconnections and MHD instabilities. Notwithstanding these two phenomena are two different manifestations for an identical energy release, observations have shown that solar flares and CMEs do not have a one-to-one relationship. To date, it is still unclear what determines the capability of an AR to specifically produce eruptive flares and CMEs, and this hinders our knowledge of the initiation mechanism for the eruptive phenomena. In this paper, we performed the statistical analysis based on linear Discriminant function Analysis (DA) to answer the question of what determines the capability of an AR to specifically produce eruptive flares and CMEs. Based on data obtained by the Solar Dynamics Observatory/ Helioseismic and Magnetic Imager, the coronal magnetic field for 51 flares larger than M5.0 class, from 29 distinct ARs, is constructed using a nonlinear force-free field extrapolation model. We analyzed the relative strength of Magnetic Flux Ropes (MFRs) to the magnetic field in the immediate vicinity, which is key to determining the CME-eruptivity.

In the first part of this paper, we propose a new parameter r_m to measure the possibility that a flare can be eruptive and produce a CME. The parameter r_m is defined by the ratio of the magnetic flux of twist higher than a threshold T_c to the surrounding and specifically the overlying magnetic flux. We find that the footpoints of field lines with twist larger than 0.2 can well represent the subsequent flare ribbons by comparing the flare-ribbon-associated magnetic flux. The results revealed by linear DA suggest that r_m is moderately well able to distinguish ARs that have the capability of producing eruptive events. Moreover, field lines overlying and “fencing in” the highly twisted region will work to confine the eruption, generating confined flares.

Second, to understand why r_m failed to correctly determine the CME-eruptivities of three flares originating from AR 12192, two new schemes, the r-scheme, and q-scheme, are proposed to analyze the eruptive and confined nature of solar flares. The magnetic flux of high twist in r_m is updated by the magnetic twist flux and the reconnected flux, which anchors in the flare ribbons respectively in the r- and q-schemes. The linear DA results show that despite both schemes providing moderately successful classifications, the CME-eruptivity classification for the three target events can only be improved with the q-scheme. We find that the highly twisted field lines and the flare-ribbon field lines have equal average force-free constant α, but the averaged length of the flare-ribbon-related fieldlines are shorter than highly twisted field lines. The findings lead us to conclude that it is challenging to distinguish the magnetic flux forming MFR.

Our results demonstrate the importance of considering the field lines' topology and identifying core MFRs when analyzing the eruptivity. We conclude that even though both the r- and q-schemes can be applied to most of the solar eruptions, more than one mechanism may govern CME production such that they are only moderately able to classify the eruptions.