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論文審査の結果の要旨および担当者

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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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別紙１－２

論 文 審 査 の 結 果 の 要 旨

Solar flares and coronal mass ejections (CME) are the biggest explosion in the solar system and release the magnetic energy stored in active regions (ARs) of the Sun through magnetic reconnections and MHD instabilities. Although the two phenomena are the different manifestations of the identical energy release process, 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 thesis, the applicant performed statistical analysis based on the 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 the data obtained by the Solar Dynamics Observatory/ Helioseismic and Magnetic Imager, the coronal magnetic field of the 29 ARs that produced 51 flares larger than M5.0 class was reconstructed using the nonlinear force-free field extrapolation model. The applicant proposed and analyzed a new parameter “r_m” as a key parameter to determine the CME-eruptivity of the assumed flare-associated magnetic flux rope (MFR). The parameter r_m is defined by the ratio of the magnetic flux of twist higher than a threshold T_c to the magnetic flux surrounding and overlying the high twisted magnetic flux.

In the first part of the thesis, the applicant analyzed the parameter r_m to measure the possibility that a flare can be eruptive and produce a CME. The applicant found that the footpoints of field lines with twist larger than 0.2 can well represent the subsequent flare ribbons detected by the SDO/Atmospheric Imaging Assembly by comparing the magnetic twist to the flare-ribbon-associated magnetic flux. The results revealed by linear DA suggest that r_m is moderately able to distinguish ARs that have the capability of producing eruptive events. Moreover, the applicant found that field lines overlying and “fencing in” the highly twisted region will work to confine the eruption, generating confined flares.

In the second part of the thesis, the applicant examined why r_m failed to correctly classify the CME production of three specific flares originating from one particular active region. Variants on the r_m parameter were extended to a fuller “r-scheme” and compared to another new “q-scheme”, both proposed to analyze the eruptive and confined nature of solar flares. The magnetic flux of high twist in r_m is updated to use the “magnetic twist flux” and the reconnected flux, which anchors in the flare ribbons, in the r- and q-schemes, respectively. 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. The applicant found that the highly twisted field lines and the flare-ribbon field lines have equal average force-free constant a, but the averaged length of the flare-ribbon-related field lines are shorter than highly twisted field lines. The findings lead us to conclude that it is challenging to distinguish the magnetic flux forming MFR.

This thesis demonstrates the importance of considering the field lines’ topology and identifying the core MFR when analyzing the eruptivity. The applicant concludes 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 these schemes are only moderately able to classify the eruptions. The results and discussion of this thesis can contribute to improving our understanding of the mechanism of CME formation and the predictability of CMEs.

For the above reasons, the applicant is considered to be fully qualified to receive a doctoral degree (science).