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How Are Strong Flares Produced in the Sun? Flux Emergence and Formation of NOAA AR 11158

Shin Toriumi (1), Yusuke Iida (2), Kanya Kusano (3,4), Yumi Bamba (3), and Shinsuke Imada (3)

(1) Department of Earth and Planetary Science, University of Tokyo, Tokyo, Japan (toriumi@eps.s.u-tokyo.ac.jp), (2) Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Sagamihara, Japan, (3) Solar-Terrestrial Environment Laboratory, Nagoya University, Nagoya, Japan, (4) Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokohama, Japan

We present observational and numerical studies of NOAA active region (AR) 11158. It is well known that flares and CMEs occur around the ARs of the Sun, especially at sheared polarity inversion lines (PILs) between delta-shaped sunspots. However, it still remains unclear how these structures are formed through a large-scale magnetic flux emergence from the convection zone. In this study, aiming to investigate the formation process of the flare-productive AR 11158, we compared SDO observations of this AR and numerical simulations of flux tube emergence. As a result of the observation, we found that AR 11158 is composed of two main bipoles, P1-N1 and P2-N2, between which a highly-sheared PIL is created. The series of intense flares including X2.2-class event occurred along this PIL. Based on the observations, we then proposed two possible models for the creation of AR 11158 and conducted flux emergence simulations of the two cases to reproduce this AR. Case 1 is the emergence of a single flux tube, which splits into two in the convection zone and emerges at two locations, while case 2 is the emergence of two independent tubes. We found that, in case 1, a sheared PIL is successfully created in the middle of the region, which agrees with the AR 11158 observation. However, case 2 never build a clear PIL, which deviates from the observation. Therefore, we concluded that the flare-productive AR 11158 is, between the two cases, more likely to be created from a single split emerging flux than two independent flux bundles.