A Data-based Magnetohydrodynamic Simulation of the X1.0 Solar Flare of 2021 October 28

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The solar active region NOAA 12887 produced an X1.0 flare on 2021 October 28. During the event, an X-shaped flare ribbon and a circular-shaped filament eruption were observed. In this study, we aim to understand the formation and the erupting process of the magnetic flux rope (MFR), which is associated with the circular-shaped filament. We performed a data-constrained magnetohydrodynamic simulation using a nonlinear force-free field as an initial condition. In our simulation, we successfully reproduced the MFR eruption in good agreement with the filament eruption observed in Halpha and SDO/AIA 304A images. From the simulation results, we found two possibilities as the driving mechanism of the MFR eruption; one is the torus instability, and the other is a push-up motion driven by newly created large magnetic loops below the pre-existing MFR via continuous magnetic reconnection between two sheared magnetic arcades. In order to quantitatively understand the scenario, we performed a hypothetical experiment in which the velocity is halted at the strong current density region. Therefore, the reconnection is halted forcibly there, which inhibits the formation of the large loops that push out the MFR. Consequently, we found that in the early phase of the eruption in our simulations the upward velocity of the pre-existing MFR associated with reconnection below is twice larger than that without reconnection, i.e., reconnection could help to accelerate the erupting MFR further. Since four footpoints of the MFR and the newly formed loops well anchored to each part of X-shaped flare ribbons observed in SDO/AIA 1600A images, we concluded that reconnection below the MFR played a key role in accelerating the erupting filament leading to the X1.0 flare.

Keywords: Sun: flares, Sun: magnetic fields, Magnetohydrodynamics (MHD)

