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Magnetohydrodynamic Modeling of Solar Erupting Flux Ropes

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Determining the initiation and evolution of magnetic flux ropes (MFR) is essential to understanding the mechanisms driving solar eruptions. In order to understand the dynamics of the MFR leading the eruptions, we conducted data constrained magnetohydrodynamic (MHD) simulations of the flare productive active region (AR) 11158. We first performed a nonlinear force-free field (NLFFF) extrapolation based on the photospheric magnetic field, which corresponds to 90 minutes before the M6.6 flare observed in 2011 February 13, to obtain the three-dimensional coronal magnetic field. Next we inserted the NLFFF in the MHD simulation as the initial condition. The NLFFF showed that small flux ropes (which are clusters of twisted magnetic field lines) where the twist is less than one-turn, lie along the polarity inversion line where M6.6 flare and also X2.2 were observed. Once one of small MFRs starts to erupt via. loss of equilibrium (LOS)/torus instability (TI), we found that a large and highly twisted MFR can be formed through reconnection occurring between each small MFR. This reconnection can increase the magnetic twist and also total current flowing in the MFR, resulting in the further acceleration of the MRF even in areas stable to the TI. This process can also enhance the writhing motion of the MFR. The LOS/TI is important for the initiation of MFR but we suggest that the nonlinear interaction of the MFR evolution and the reconnection is also greatly important in the production of further dramatic eruptions. We further show our latest results of MFR dynamics in AR12673 and AR12017.