

Simulation Study of Three-Dimensional Flux Tube Dynamics in the Solar Corona

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The eruption of magnetic flux tube in the solar corona is a key process for the formation of Coronal Mass Ejections (CMEs). The trigger mechanism of that, however, is not yet clearly understood, and the different models based on the loss-of-stability theory and the loss-of-equilibrium theory have been proposed so far. For instance, Priest Forbes (1990) proposed the model that the flux tube embedded in magnetic arcade may erupt as a consequence of that the equilibrium condition of coronal magnetic field is broken due to the change in the photospheric boundary condition. Furthermore, they pointed out magnetic reconnection should occur in the lower part of flux tube, while it ascends. This model, however, was limited to the two-dimensional geometry, in which the translational symmetry along magnetic neutral line was adopted, and the three-dimensional (3D) instability was not taken into account. In this paper, in order to reveal the 3D effect in the flux rope eruption, we carried out the 3D linear stability analysis of the flux tube equilibrium proposed by Priest Forbes, and also performed the nonlinear 3D simulations.

As a result of that, we found that the flux tube in the Priest Forbes' model is certainly unstable to the kink modes, as the system approaches to the loss-of-equilibrium state. The 3D simulation shows that, when the flux tube is long enough, the kink instability sufficiently grows and the flux tube can ascend continuously, even if the equilibrium condition is still satisfied in the initial state. On the other hand, the ascending of relatively short flux tube stops at certain height, although the kink mode can grow in the beginning phase. The results suggest that the continuous ascending of flux tube could be realized through the multiple phase dynamics, which consists of the initial driving due to the instability and the extended ascending through the loss-of-equilibrium process.