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Evolution of dynamic internal structure of solar prominence in reconnection-condensation scenario

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Solar prominences, or filaments, are cool dense plasma clouds sustained by coronal magnetic fields. They sometimes erupt and evolve into coronal mass ejections. Revealing the origin of cool dense plasmas has been a long-term issue in solar physics, and predictability of eruptions is of great interest in the studies of space weather as well as solar physics.

The high spatio-temporal observations by *Hinode*/SOT, *SDO/*AIA, *IRIS* etc. in the past decade successfully extended our knowledge of internal fine structures and turbulent flows of prominences [1]. By the observational data analyses and the associated magnetohydrodynamic (MHD) simulations, the interface instabilities such as the Rayleigh-Taylor instability and the Kelvin-Helmholtz instability have been discussed as drivers of the turbulent flows [2,3]. The recent development of high performance numerical scheme enables us to solve three-dimensional MHD equations including optically thin radiative cooling and nonlinear anisotropic thermal conduction, and reproduce more realistic prominence formation via radiative condensation [4]. In this talk, we introduce our numerical studies on the impact of the interface instability on the radiative condensation rate, and on the internal velocity field variation as a precursor of eruption.

In the observations, the evolution of upflow plumes and descending pillars has been clearly detected. Because the dense plasmas of prominences are located on the tenuous coronal plasmas, the Rayleigh–Taylor instability (RTI) is thought to be a driver of the flows. There is a hypothesis of dynamic equilibrium where the mass drainage via descending pillars and the mass supply via radiative condensation are balanced to maintain the prominence mass [5]; however, the background physics connecting the two different processes is poorly understood. We reproduced the dynamic interior of a prominence via radiative condensation and RTI using a MHD simulation including radiative cooling and thermal conduction. The process to prominence formation in the simulation was based on the reconnection–condensation model [6,7], where topological change in the magnetic field caused by reconnection led to radiative condensation. Reconnection was driven by converging motion at the footpoints of the coronal arcade fields. By randomly changing the speed of the footpoint motion along a polarity inversion line (PIL), the dynamic interior of prominence was successfully reproduced. We confirmed that the RTI-like mechanism corrugated the prominence-corona transition, leading to the dynamic state. We found that the mass condensation rate of dynamic prominence is higher than that of static prominence [8]. Our results support the observational hypothesis that the condensation rate is balanced with the mass drainage rate and suggest that a self-induced mass maintenance mechanism exists.

The evolution of the velocity field inside prominence is important for the prediction of eruptions as well. Recent observational studies using a newly developed Doppler Imager (SMART/SDDI, Hida Observatory [9]) found that the standard deviation of the Doppler velocity inside prominence started to increase even when the mean velocity was unchanged [10]. This phenomenon might be useful for the prediction of prominence eruptions; however, the physical relationship with the magnetically-driven eruptive mechanisms was unclear. We carried out numerical simulations and reproduced eruption of a turbulent prominence by combining reconnection-condensation model and flare-trigger model [11]. In the simulation, we introduce emerging flux along the PIL. The eruption happened due to torus instability. Before the eruption, the axis of the flux rope monotonically increased; however, the velocity field inside the prominence had complicated distribution containing both upflows and downflows. We confirmed that the increase in the standard of the vertical velocity is quantitatively consistent with the observational results. We found the clear link between acceleration of the flux rope (onset of the torus instability) and the increase of standard deviation. We discuss the detailed physical relationship between the MHD instability and the internal velocity field variation of prominence.

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