論文内容の要旨

Numerical Study of Solar Prominence Formation

（太陽プロミネンス形成の数値的研究）

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Solar prominences are cool dense plasma clouds in the hot tenuous corona. Since prominences suddenly erupt and evolve into coronal mass ejections, they have potential to give an impact on the plasma environment in the interplanetary space. The origin of cool dense plasma and mass maintenance mechanism of prominences are still unclear. In this thesis, we investigate the formation mechanism of a prominence by using magnetohydrodynamic simulations.

In Part II, we propose a new prominence formation model, reconnection-condensation model, and demonstrate it by using multi-dimensional magnetohydrodynamic simulations including optically thin radiative cooling and nonlinear anisotropic thermal conduction. In our model, magnetic reconnection changes a topology of coronal magnetic fields, leading to the formation of a flux rope. The flux rope traps dense plasmas inside it. Radiative cooling inside the flux rope is enhanced by the trapped dense plasmas, leading to a cooling- dominant thermal nonequilibrium state. Once the length of magnetic field exceeds the Field length, the thermal nonequilibrium can not be compensated by thermal conduction, leading to radiative condensation for prominence formation. From the parameter survey on footpoint motions, we find that anti-shearing motion, which reduces magnetic shear of an coronal

arcade field, causes radiative condensation, whereas the shearing motion, which increases magnetic shear, causes to eruption of a hot flux rope. The coronal heating model does not affect the triggering process of radiative condensation, whereas it can affect the properties of prominence. Multi-wavelength EUV emissions synthesized from our three-dimensional simulation results reproduced the observed temporal and spatial intensity shift from coronal temperatures to prominence temperatures.

In Part III, we reproduce a dynamic interior of a prominence in a framework of our proposed model. As mass of prominence increases by radiative condensation, magnetic tension force can not sustain prominence mass, leading to the Rayleigh-Taylor instability. Downward speed of spikes are much smaller than free-fall speed, because upward magnetic tension cancels gravity as spike extend. Spikes are reflected at the bottom boundary, and create upflows or vortex motions. By the interaction of downflows and reflected flows, the spikes are squeezed, resulting in the formation of thin vertical threads. We also found that the Rayleigh-Taylor instability enhances mass growth rate of radiative condensation. Our results suggest the presence of self mass maintenance mechanism of a prominence due to a coupling of radiative condensation and the Rayleigh-Taylor instability.

Through the studies in this thesis, we succeeded to propose a self-consistent model for a long-standing issue of solar prominence formation. Our model resolves several issues in the previous models: a previous theoretical model requires a strong steady footpoint heating and subsequent chromospheric evaporation to trigger radiative condensation, while such a footpoint heating and evaporated flows have not been detected in observations. In observations, it was found that magnetic reconnection at a polarity inversion lines (PIL) caused prominence formations, while the mechanism to trigger radiative condensation by reconnection was unclear. In addition to these, we revealed that a flux rope formation by reconnection drives radiative condensation when the length of reconnected loops exceeds the Field length. We found that anti-shearing motion is necessary to create cooling-dominant thermal imbalance in a flux rope. This suggests that relative position of supergranules along a PIL is an important factor for prominence formation. We also found that radiative condensation rate is enhanced by coupling with the Rayleigh-Taylor instability and becomes comparable to the mass drainage rate of downflows. This result indicates the presence of self mass maintenance mechanism of a prominence.