5th Asia-Pacific Conference on Plasma Physics, 26 Sept-1Oct, 2021, Remote e-conference

Solar Prominence Formation by Reconnection and Condensation

Xiaozhou Zhao[1], Rony Keppens[1],
[1] Centre for mathematical Plasma-Astrophysics, KU Leuven
e-mail (speaker): xiaozhou.zhao@kuleuven.be

Solar prominences, the dense and cool materials embedded in the hot and tenuous solar corona, are one of the most intriguing structures in the solar atmosphere. There are various models for prominence formation, e.g., the levitation model, the evaporation-condensation model, the injection model, and the mixed model. To investigate the formation mechanisms of solar prominences, we previously reproduced the scenario of prominence formation by levitation [1, 2, 3]. In that model, the initial arcade-like linear force-free magnetic field is driven by an imposed slow motion converging towards the magnetic inversion line at the bottom boundary. A magnetic flux rope (FR) is formed by magnetic reconnection and eventually erupts as a coronal mass ejection (CME). An embedded prominence also gets formed directly by levitating material from the chromosphere.

In this abstract, we report a new potential scenario, namely the reconnection-condensation model, using grid-adaptive resistive two-and-a-half-dimensional magnetohydrodynamic (MHD) simulations in a chromosphere-transition-corona setup by MPI-AMRVAC code. In contrast with the levitation model, an FR pre-exists in the lower corona in the reconnection-condensation model. The pre-existing FR suddenly loses equilibrium and erupts due to catastrophe. Figure 1 illustrates the FR eruption and prominence formation in the reconnection-condensation model. The erupting FR eventually evolves to a CME and drives a bow shock beforehand, which may be identified as a bright leading front in observations. The fast-rising FR stretches the magnetic field lines, and a current sheet (CS) is formed underneath it. Some chromospheric matter is squeezed into the CS. The CS extends in length as the FR rises. The plasmoid instability occurs and multiple magnetic islands appear in the CS once the aspect ratio of the CS exceeds a critical value. The remnant chromospheric matter in the CS is pushed into the FR quasi-periodically by the newly formed magnetic islands. The magnetic islands thus play a role of mass carriers between the chromosphere and the FR. Besides CS fragmentation, magnetic islands contraction was also observed in our simulation. The dense and cool mass carried by the islands accumulated in the bottom of the FR, forming a prominence. The condensation starts as the FR rises. The coronal plasma continuously condenses into the prominence due to the thermal instability. The downward-moving magnetic islands reconnect with the magnetic field in the chromosphere, leading to the formation of flare loops. A termination shock is formed at the loop top due to the interaction between the reconnection outflow and the flare loops. The high resolution achieved in our simulation by grid-adaptive technique shows significant CS substructures. Turbulent and chaotic flow patterns are also observed in the CS. We also study the dynamics of magnetic islands.

References

[1] Zhao, X., Xia, C., Keppens, R., & Gan, W., ApJ, 841, 106 (2017).
[2] Zhao, X., Xia, C., Van Doorsselaere, T., Keppens, R., & Gan, W., ApJ, 872, 190 (2019).
[3] Zhao, X., & Keppens, R., ApJ, 898(1), 90 (2020).

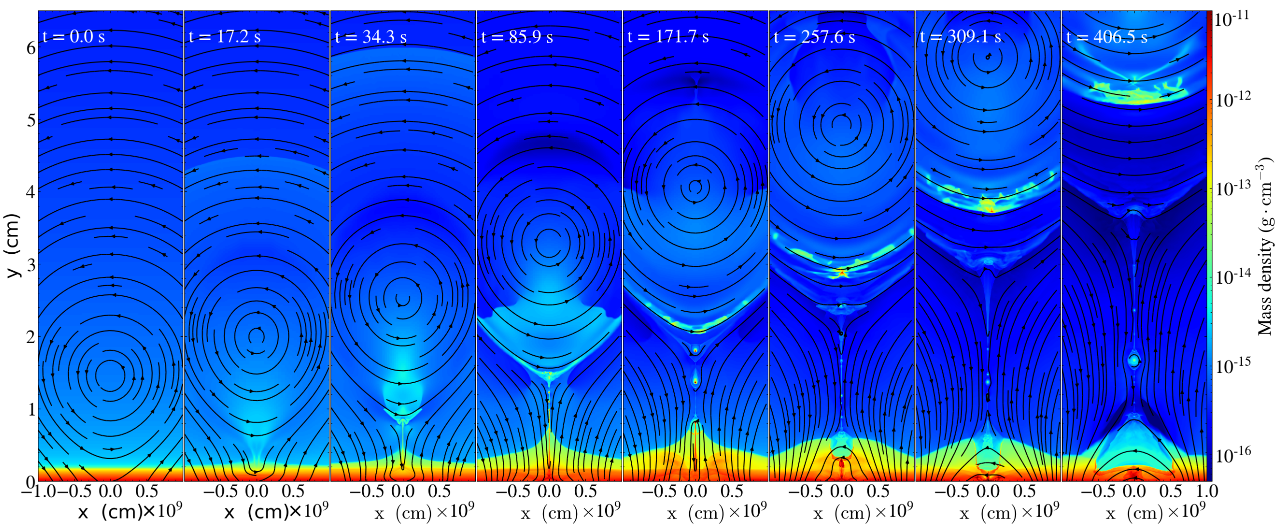

Figure 1. The density maps at different instants of time are plotted with magnetic field lines overlaid. The FR erupts due to catastrophe and a CS is formed. Multiple magnetic islands appear in the CS after the plasmoid instability starts. The islands carry the remnant chromospheric mass from the CS to the FR.