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Prominence Formation and Destruction

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Abstract. In earlier work, we demonstrated the in-situ formation of a quiescent prominence in a sheared magnetic arcade by chromospheric evaporation and thermal instability in a multi-dimensional MHD model. Here, we improve our setup and reproduce the formation of a curtain-like prominence from first principles, while showing the coexistence of the growing, large-scale prominence with short-lived dynamic coronal rain in overlying loops. When the localized heating is gradually switched off, the central prominence expands laterally beyond the range of its self-created magnetic dips and falls down along the arched loops. The dipped loops recover their initially arched shape and the prominence plasma drains to the chromosphere completely.

Keywords. Sun: prominences, filaments — MHD

The present work brings great improvements to our earlier work (Xia *et al.* 2012), such as a larger domain, higher resolution, more accurate numerical scheme, and more realistic localized heating restricted in finite chromospheric regions. Our computational box is in a vertical plane perpendicular to the polarity inversion line (PIL, taken in the z-direction) and reduced to only the right half of the simulated area using the symmetry of the model. Our model starts from a force-free sheared magnetic arcade permeated by stratified solar atmosphere in overall force-balance. We numerically solve the MHD equations with optically thin radiative cooling, thermal conduction, coronal heating, and gravity terms using the Adaptive Mesh Refinement Versatile Advection Code (MPI-AMRVAC, Keppens *et al.* 2012). An equivalent resolution of 1024×1280 is achieved by a 5-level AMR grid with the smallest spacing of 39 km. To get an equilibrium state, we start the simulation with a background heating $\propto |B|$ until the system relaxes to a quasi-equilibrium (see Fig. 1(a)). Starting from this state, a relatively strong localized heating H_1 is added in selected regions (see the contours in Fig. 1(b)).

As H_1 is introduced, chromospheric plasma of the heated region gets evaporated into the coronal loops increasing the density and the temperature. At $t = 6$ mins, the temperature near the top of the heated coronal loops reaches a maximum value of 2.2 MK and starts to decrease slowly. At $t = 79$ mins, the temperature decreases significantly in an extensive region in the loops with height around 20 Mm where the increase of density is less prominent. At $t = 86$ mins, first condensations appear off center as a pair of horizontally extended thin sheets at 20 Mm height. Soon the condensation sheets extend and connect at the center below where a verical condensation appears along central axis sheets after the collision of strong counter flows driven by the loss of pressure from thermal instability (see Fig. 1(b)). At the same time, a smaller condensation forms at the center of lower loops. Then successive condensations happen on the top of neighbouring loops, and cool dense plasma assembles along the y-axis forming a curtain-like prominence.

Along with the growing prominence, an assembly of condensations resembling a zigzag belt appears at the shoulders of large loops. At this moment, the inner part of the belt connects with the top of the prominence and the zigzag condensation has three sharp cusps. The one closer to the top of the arcade is drawn uphill and merges with its symmetric twin at the top of their loop. The other two fall down along their loops. The belt of condensed plasma is stretched to a very long extension before fragmentation. The

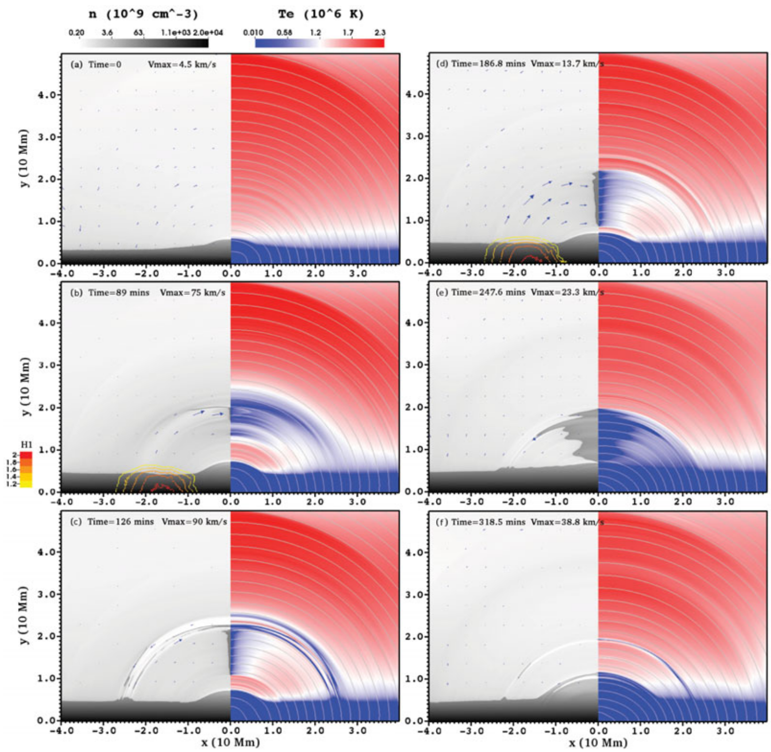

Figure 1. Snapshots of the prominence lifecycle. In each panel, the left halves show the density distribution with the projected velocity in blue arrows and the localized heating H_1 in contours (not in panel (c)). The right halves show the projected magnetic field lines on top of the temperature distribution.

falling blobs of condensations resemble coronal rain (see Fig. 1(c)). In those loops with coronal rain, the localized heating lengthscale over the loop length is small enough so that condensations occur off-center (Xia *et al.* 2011). Due to the arched shape of the loops, the off-center condensations have to fall down due to gravity unless an upward pressure gradient force dominates.

The coronal rain stops and the prominence sits stably in self-created bended dips at the top of the loops (see Fig. 1(d)). All processes mentioned above are under steady localized heating H_1. We then decrease H_1 linearly to zero over 29 minutes. In the prominence-hosting loops, the temperature in the hot corona decreases but remains the same inside the prominence, which leads to a gas pressure gradient causing the prominence to swell. As the prominence expands laterally, the plasma density in the dips decreases and the Lorentz force overcomes the gravity restoring the field line from dipped to flat and finally to arched shape. Without magnetic dips, the prominence plasma falls down along the loops into the chromosphere (see Fig. 1(e)-(f)). 150 minutes after H_1 stopped, the prominence drains completely and the system recovers to its initial state.

References

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