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Coronal rain: plasma circulation in the solar corona

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Coronal rain is a widely observed phenomenon where dense and cool condensations form in the hot corona, and then fall down along magnetic loops to the solar surface. It presents us with a clear multithermal coronal plasma, which displays the emission of different wavelengths co-spatially. Coronal rain takes an essential part in the mass cycle between the chromosphere and the corona.

Since moving magnetic features and turbulent convection are almost ubiquitous in the solar lower atmosphere, the formation of coronal rain is affected by the multiscale and continuous localized heating in the solar photosphere. Here we present 2.5-dimensional magnetohydrodynamic simulations using the MPI-AMRVAC code, which includes thermal conduction and radiative cooling, to investigate the formation and evolution of the coronal rain phenomenon [1]. We perform the simulation in initially linear force-free magnetic fields that host chromospheric, transition-region, and coronal plasma, with turbulent heating localized on their footpoints. Due to thermal instability, condensations start to occur at the loop top, and fragment into smaller blobs moving downwards, which are manifested as coronal rain shown in Figure 1. Following coronal rain dynamics for more than 10 hr, we carry out a statistical study of all coronal rain blobs to quantify their widths, lengths, areas, velocity distributions, and other properties. The coronal rain shows us continuous heating–condensation cycles, as well as cycles in EUV emissions. We also track the movement of individual blobs to study their dynamics and the forces driving their movements. The blobs have a prominence-corona transition-region-like structure surrounding them, and their movements are dominated by the pressure evolution in the very dynamic loop system.

Besides the small-scale heating events, large scale eruptions caused by the flux emergence could also influence the development of coronal rain. By adding emerging flux at one footpoint of the coronal arcades, we also investigate the eruptions caused by the emergence and the response of coronal rain in the emerging magnetic fields [2]. The emergence changes the pressure in the loops, and the internal coronal rain all moves to the other side. The emerging flux reconnects with the overlying magnetic field, forming a current sheet and magnetic islands. The plasma is ejected outwards and heated, forming a cool jet ~6000 K and a hot X-ray jet ~4 million Kelvin (MK) simultaneously. The jet dynamical properties agree very well between observation and simulation. In the simulation, the jet also displays transverse oscillations with a period of 8 minutes, in a so-called whiplike motion. The movement of the jet and dense plasmoids changes the configuration of the local magnetic field, facilitating the occurrence of the Kelvin-Helmholtz instability, and vortex-like structures form at the boundary of the jet. Our simulation clearly demonstrates the effect of emergence on coronal rain, the dynamical details of reconnecting plasmoid chains, the formation of multithermal jets, and the cycling of cool mass between the chromosphere and the corona.

References

[1] Li X., Keppens R., & Zhou Y., 2022, ApJ, 926, 216
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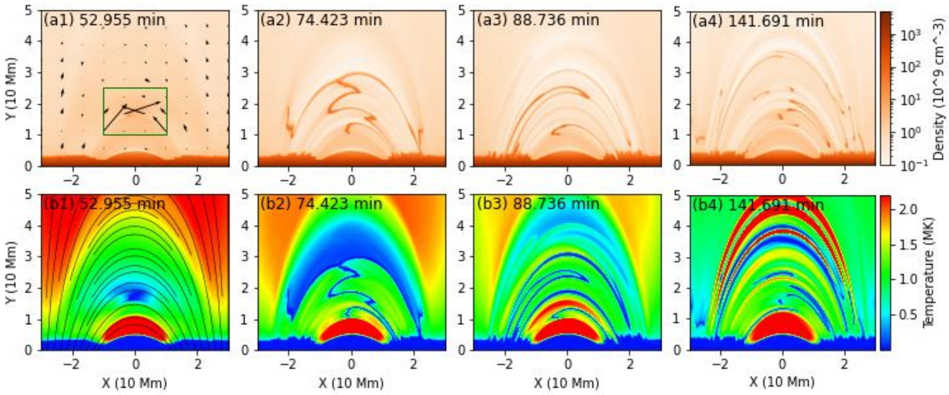

Figure 1. Snapshots at different times showing the evolution of coronal rain. The upper and lower panels display the number density and temperature respectively.