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How differences in optically thin cooling curves affect condensations formed by thermal instability

J. Hermans[1] and R. Keppens[1],
[1] Centre for mathematical Plasma-Astrophysics, KU Leuven
e-mail (speaker): joris.hermans@kuleuven.be

Condensations are observed in many astrophysical environments. In solar physics, common phenomena are coronal rain and prominences. The first are transient dense blobs that form in magnetic loops and rain down along the magnetic field lines [1]. The second are cold, dense structures suspended in the hot, tenuous corona by the magnetic field [2].

Those structures are formed due to energy loss via optically thin radiative emission. Instead of solving the full radiative transfer equations, precomputed cooling curves are typically used in magnetohydrodynamic (MHD) simulations assuming an optically thin and fully ionised plasma. Precomputed cooling curves in the literature differ greatly, depending on the incorporated plasma emission processes, atomic physics data, and solar abundances. Three of them are shown in Figure 1, indicating the variety.

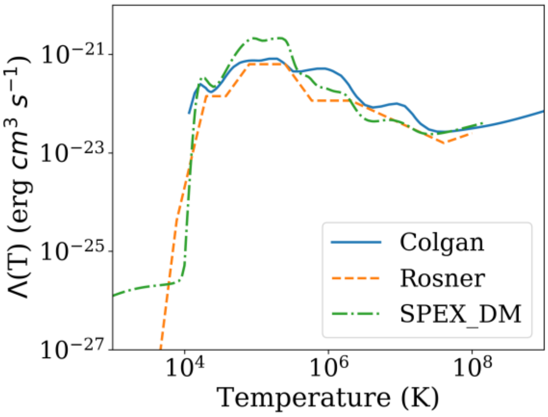

Figure 1: Three commonly used cooling curves which vary greatly [3, 4, 5]

In our work we study the effect of the optically thin cooling curves on the formation and evolution of condensations formed by thermal instability [6]. We use the open-source software MPI-AMRVAC [7] to setup idealised simulations following Claes et al. [8, 9], i.e. a thermal equilibrium in a local coronal volume perturbed by interacting slow MHD waves. For all cooling curves condensations are formed. However the differences are twofold. First, the growth rates of the thermal instability are different, leading to condensations being formed at different times. Second, the morphology of the condensations is widely varying. This is influenced by the low temperature treatment of the cooling curves. Condensations formed using cooling curves that vanish for temperatures lower than 20 000 K seem to be more stable against dynamical instabilities. Furthermore we discuss a bootstrap measure to investigate the far nonlinear regime of the thermal instability for which the time step might become unfeasible due to the Courant–Friedrichs–Lewy condition. For our benchmark setup, the condensation fragments dynamically to align with the background magnetic field and is redistributed over the domain.

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