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Optically thin cooling curves and thermal instability

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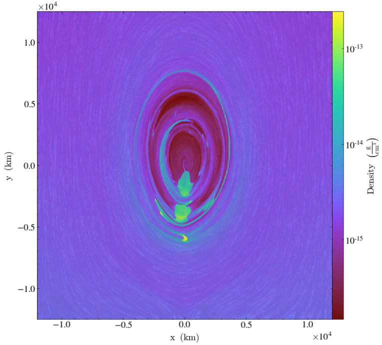
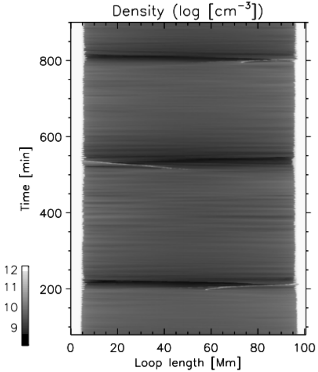
VLAAMS SUPERCOMPUTER CENTRUM Vlaanderen is supercomputing

Instead of solving the full radiative transport equations, precomputed optically thin cooling curves are commonly used in multidimensional, magnetohydrodynamic (MHD) simulations.



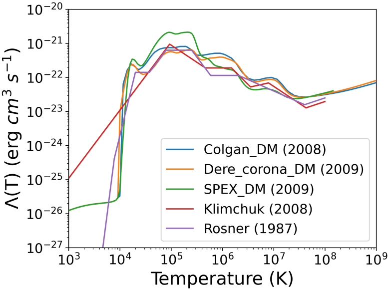
Solar prominences, figure provided by J. Jenkins (Jenkins and Keppens, 2021)



Coronal rain (Antolin, 2020)

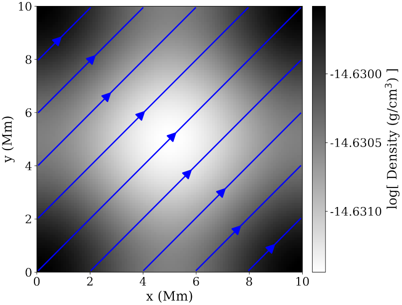
Optically thin cooling curves

- In the literature, there exists a wide variety:
  - Cox and Tucker (1969)
  - Hildner (1974)
  - Rosner et al. (1978)
  - Colgan et al. (2008)
  - Schure et al. (2009)
  - ...
- Differences not only in strength, but also in numerical implementation (interpolated curve vs piece-wise power law)
- They are often used as unquestionable ingredients

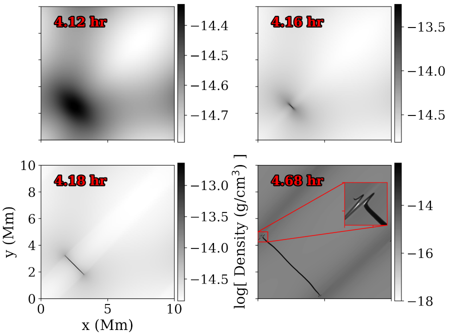


Do optically thin cooling curves affect condensation formation (by thermal instability)?

- Open-source software MPI-AMRVAC (see QR code)
- Thermal equilibrium in a 2D local coronal volume: 10^6 K, 10 G
- Perturbed by interacting adiabatic slow MHD waves as trigger for the thermal instability
- Finest resolution of 3 km, but also at lower resolutions
- For technical details: Hermans and Keppens (2021a)



- Using SPEX_DM cooling curve (Schure et al., 2009)
- The slow MHD are damped, the thermal mode is excited.
- Rapid accretion of matter along the magnetic field lines leads to condensation formation.
- In the nonlinear phase, the filament fragments in locations of thin geometry due to ram pressure differences.

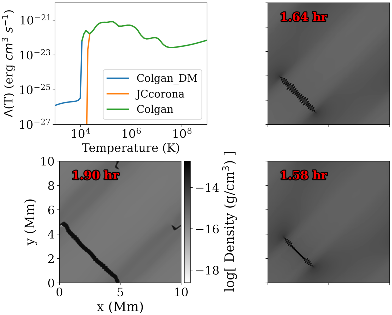


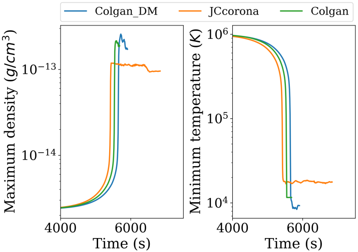
Want to watch the full simulation?

Low-temperature (< 10 000 K) treatment

- Keeping temperature fixed (Colgan)
- Vanishing cooling rate (JCcorona)
- Extending by non-vanishing cooling rate (Colgan_DM)

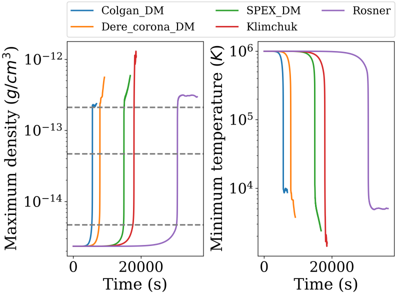
–> Strong effect on density and temperature evolution of condensations, indirectly on fragmentation process.

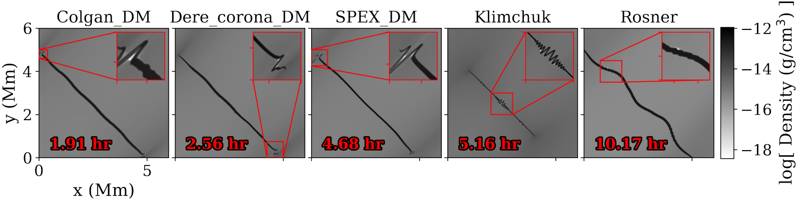




Top right to bottom left and bottom right: Density views at the end of the evolution at a resolution of 12.5 km. They correspond to the Colgan_DM, JCcorona, and Colgan cooling tables, respectively.

- Condensation forms for all cooling curves
- Differences in timescales because of different growth rates of the thermal instability
- Differences in morphology of fragmented condensations





Conclusions

- Condensations are formed by thermal instability for all cooling curves
- Differences in timescales and morphology arise between simulations with different cooling curves
- The low-temperature treatment has a large influence on the fragmentation. This emphasises the need of non-optically thin treatment of cool plasma.

* The implementation of the cooling curve (interpolated table or piece-wise power law) does not have a significant influence –> see Hermans and Keppens (2021b)

We advocate the use of modern cooling curves, based on accurate computations and up-to-date atomic parameters and solar abundances.

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