Ionisation and the formation of low-mass protostars

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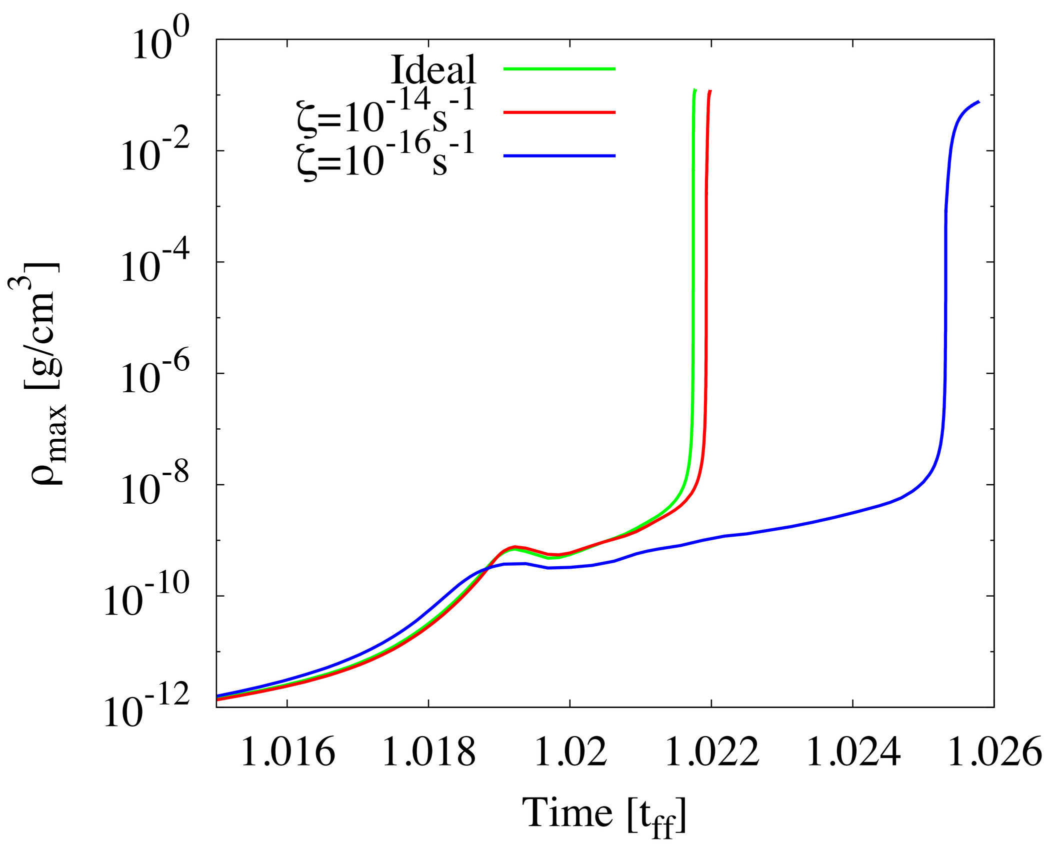
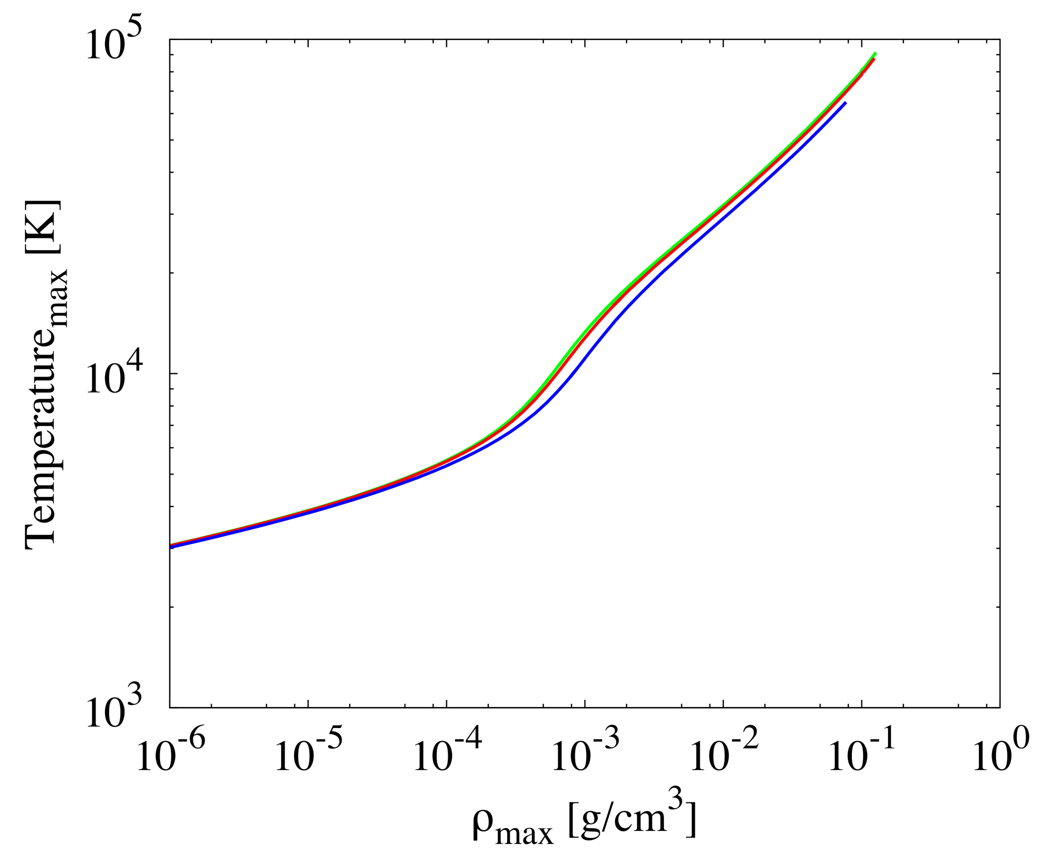
We numerically model the early stages of the formation of a low-mass protostar using the radiative, non-ideal, smooth particle magnetohydrodynamic code SPHNG. We self-consistently calculate Ohmic resistivity, the Hall effect and ambipolar diffusion using the NICIL library.

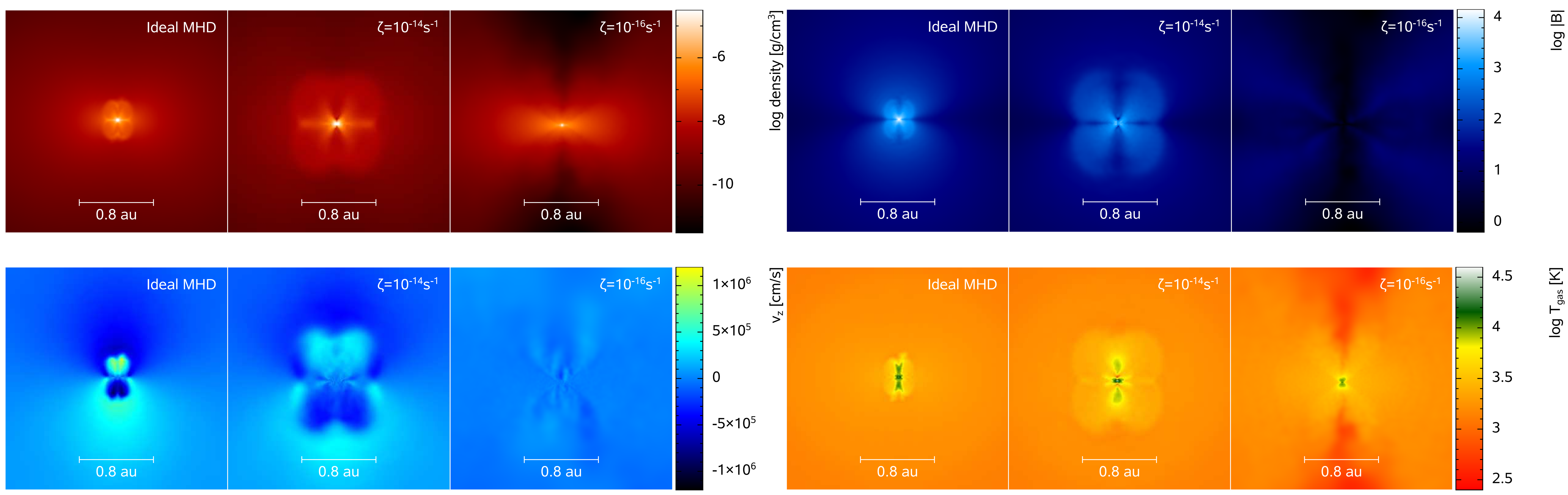
We model the collapse of a rotating $1M_{sun}$ gas cloud with an initial density of $\rho_0 \sim 7.4 \times 10^{-18}$ g cm^{-3}. This is done in the presence of a vertical magnetic field anti-aligned with the initial rotation axis. We use an initial mass-to-flux ratio of 5 times critical and compare two high ionisation rate models ($\zeta = 10^{-14}$ and 10^{-16} s^{-1}) to an ideal MHD model (i.e. fully ionised). Thermal ionisation becomes important after T~ 1000K, independent of ζ. The models are evolved until $\rho_{max} \sim 0.077$ g cm^{-3} (after the formation of the first hydrostatic core).

The evolution of the models diverges at $t \sim t_{ff}$, after which the collapse occurs faster for more ionised models. The more ionised models are hotter and have stronger outflow velocities and magnetic fields when comparing at similar maximum densities. The ionisation fractions in the core of the non-ideal MHD models are similar, but, as expected, fall off at different rates in the disc yielding a more neutral disc in the $\zeta = 10^{-16}$ s^{-1} model.





The following cross sections are cut though the first hydrostatic core, and show the inner (2.4 au)^2. The snapshots are taken at $\rho_{max} \sim 0.077$ g cm^{-3}.



References:
Wurster, Price & Bate (2016): Can non-ideal magnetohydrodynamics prevent the magnetic braking catastrophe?
Wurster (2016): NICIL
Wurster, Bate & Price (in prep)