Early stages of star and disk formation

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Motivation & Aim

Stars form by the gravitational collapse of dense, gaseous and dusty cores in magnetized molecular clouds. Our aims are:

- Modeling molecular cloud core collapse to investigate the properties of Larson's [1] first and second hydrostatic cores.
- Obtaining a dependence of the core properties on the initial cloud properties.
- Investigating the formation of early disks around these objects.
- Understanding early stages of star formation via detailed thermodynamical modeling in terms of radiation transport [2] and phase transitions [3,4].

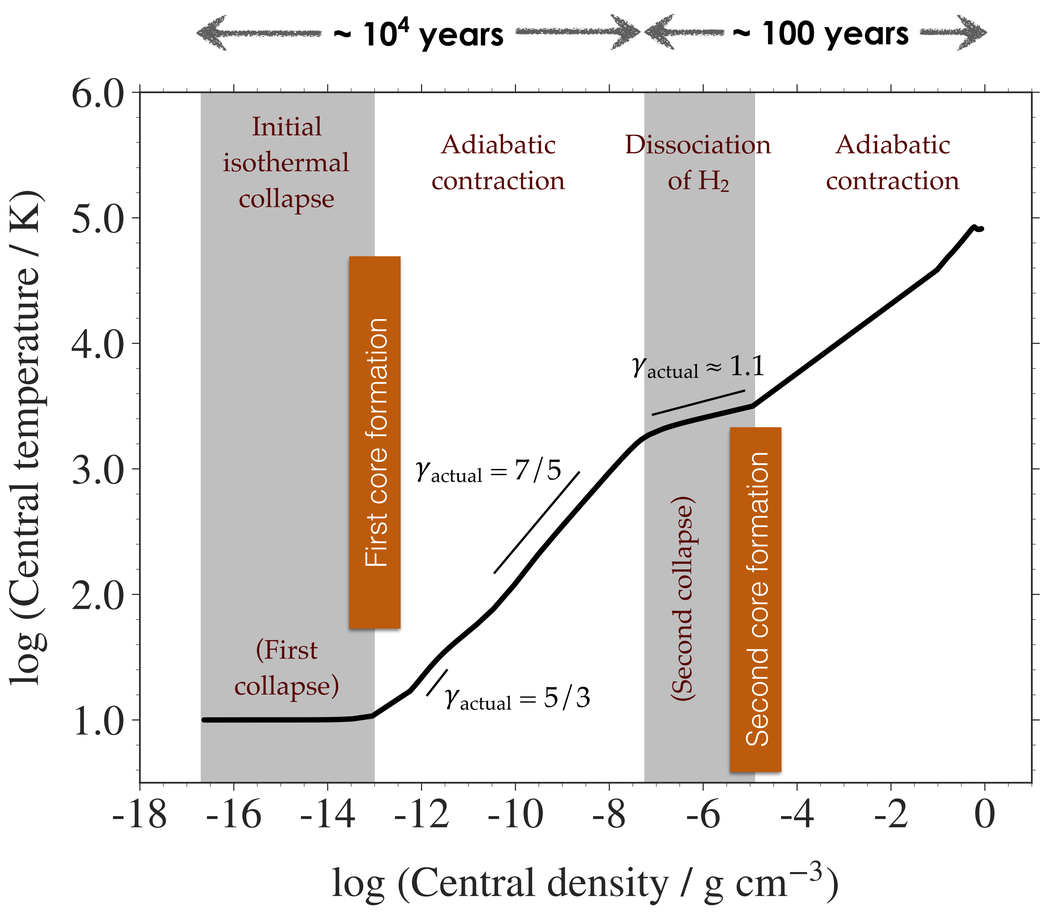
Numerical Method

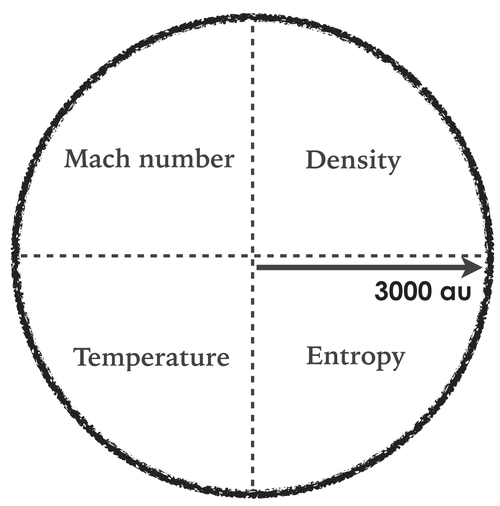
- 1D & 2D radiation hydrodynamic simulations using PLUTO [5].
- Gray (frequency independent) flux limited diffusion approximation.

Initial setup:

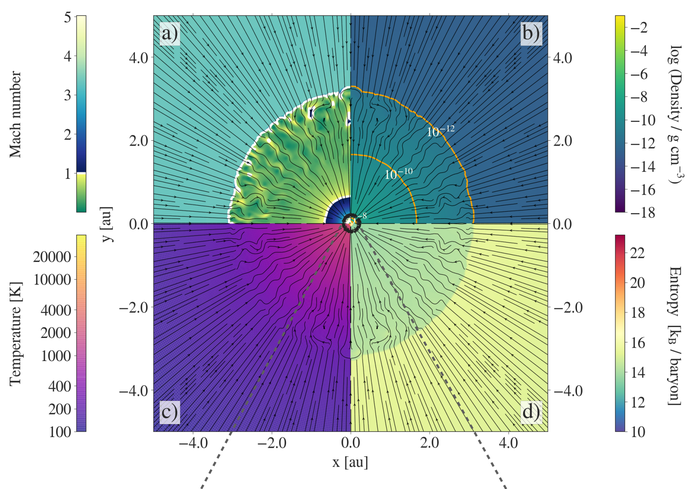
- Bonnor - Ebert [6,7] sphere like density profile
- Uniform temperature (10 K)
- Cloud mass → 0.5 $M_\odot$ to 100 $M_\odot$
- Grid size → 10^{-4} au - 3000 au
- $E_{rot} / E_{grav} = 0.007$ (solid body rotation), $E_{thermal} / E_{grav} = 0.30$
- Shear viscosity

Thermal evolution showing the collapse phases for a 1 $M_\odot$ cloud.

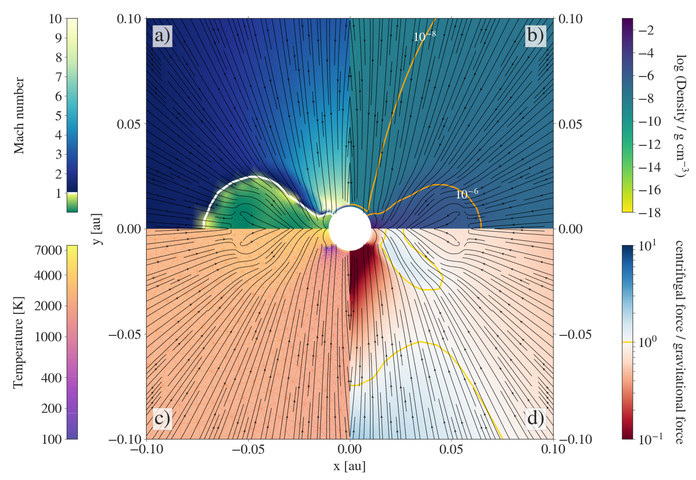




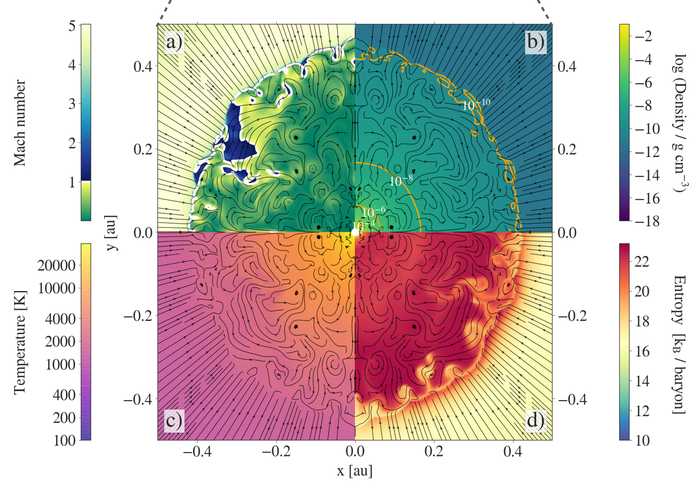
First core



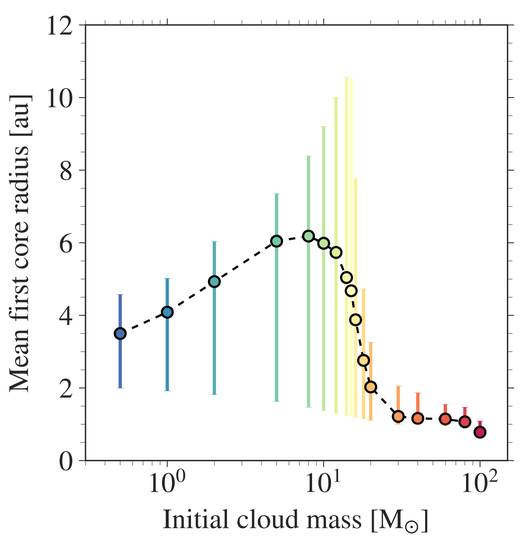
Protostellar disk

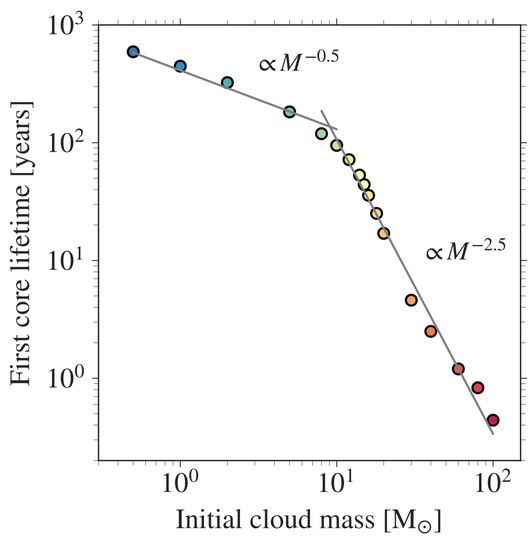


Convective second core



Dependence on initial cloud mass





First cores are practically non-existent in the high-mass regime.

Results & Summary

- First core properties show a strong dependence on the initial cloud mass.
- In a nutshell, low-mass protostars tend to evolve through two distinct stages of formation of the first and second hydrostatic cores. In contrast, in the high-mass star formation regime, the collapsing cloud rapidly evolves through the first core phase and essentially immediately forms Larson's second core [8].
- Zooming in on the second core using 2D RHD simulations and following the evolution for 100 years after its formation shows signs of convection.
- Owing to the conservation of angular momentum, we trace the formation and evolution of early disks around these objects.

References: [1] R. Larson, 1969, MNRAS, 145, 271. [2] R. Kuiper et al., 2010, A&A, 511, A81. [3] G. D'Angelo and P. Bodenheimer, 2013, ApJ, 778, 77. [4] B. Vaidya et al., 2015, A&A, 580, A110. [5] A. Mignone et al., 2007, ApJS, 170, 228. [6] W. B. Bonnor, 1956, MNRAS, 116, 351. [7] R. Ebert, 1955, ZAp, 37, 217. [8] A. Bhandare et al., 2018, A&A, 618, A95.