Unravelling the effects of gas and dust dynamics during protostellar collapse

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Motivation & Aim

Stars and protostellar discs form due to the gravitational collapse of dense, gaseous and dusty cores in magnetised molecular clouds. Dust grains form an essential ingredient for planet formation, which is initiated during early stages of star and disc formation. Our aims are:

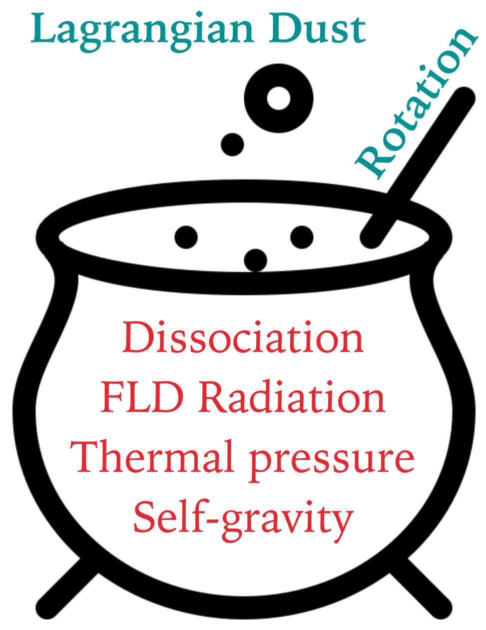
- Modelling gas *and* dust dynamics in collapsing molecular cloud cores, with a focus on self-consistently treating the microphysics.
- Investigating the role of gas and dust interaction during the formation and evolution of the protostellar core and disc.
- Obtaining a dependence of the hydrostatic core and disc properties on the initial cloud core properties.

Numerical Method

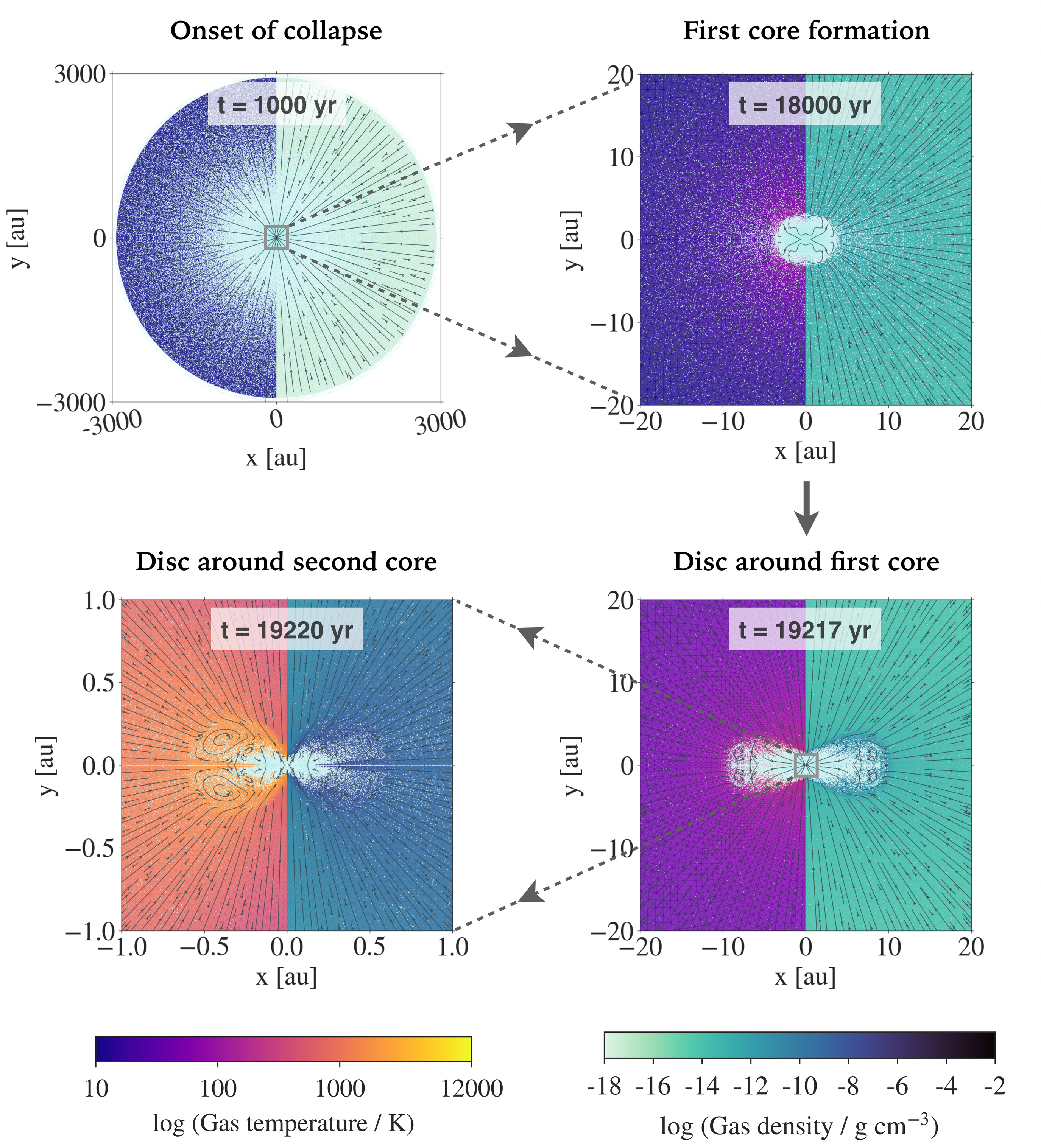
Two-dimensional radiation hydrodynamic simulations using the PLUTO code, which includes a hybrid (gas) fluid - (dust) particle treatment to account for the mutual drag forces.

Initial setup:

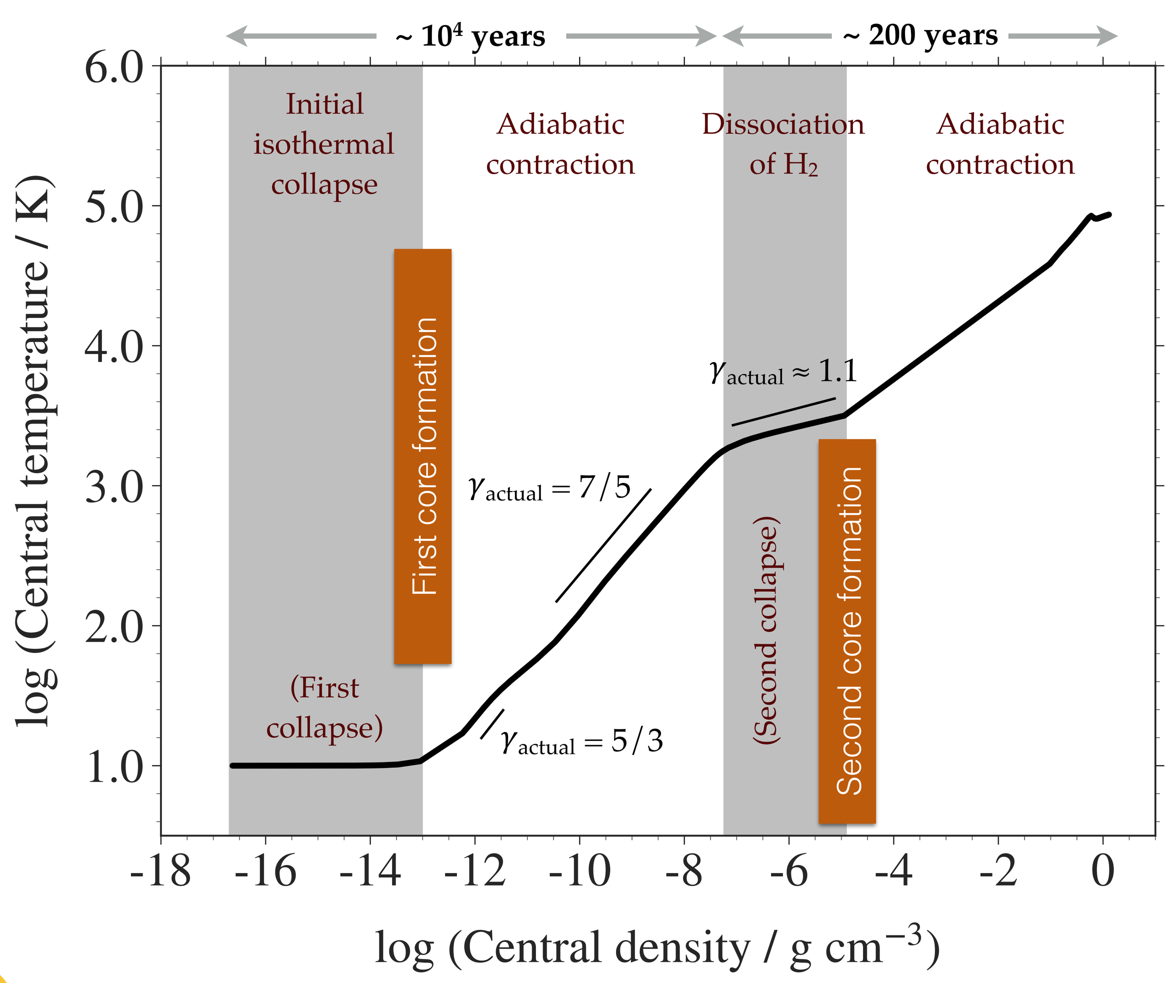
- Bonnor - Ebert sphere-like density profile
- Uniform temperature (10 K)
- Cloud mass → 0.5 $M_\odot$ to 100 $M_\odot$
- Grid size → 10^{-2} au - 3000 au
- Solid-body rotation + shear viscosity
- 1, 10 and 100 μm neutral dust



Collapse overview



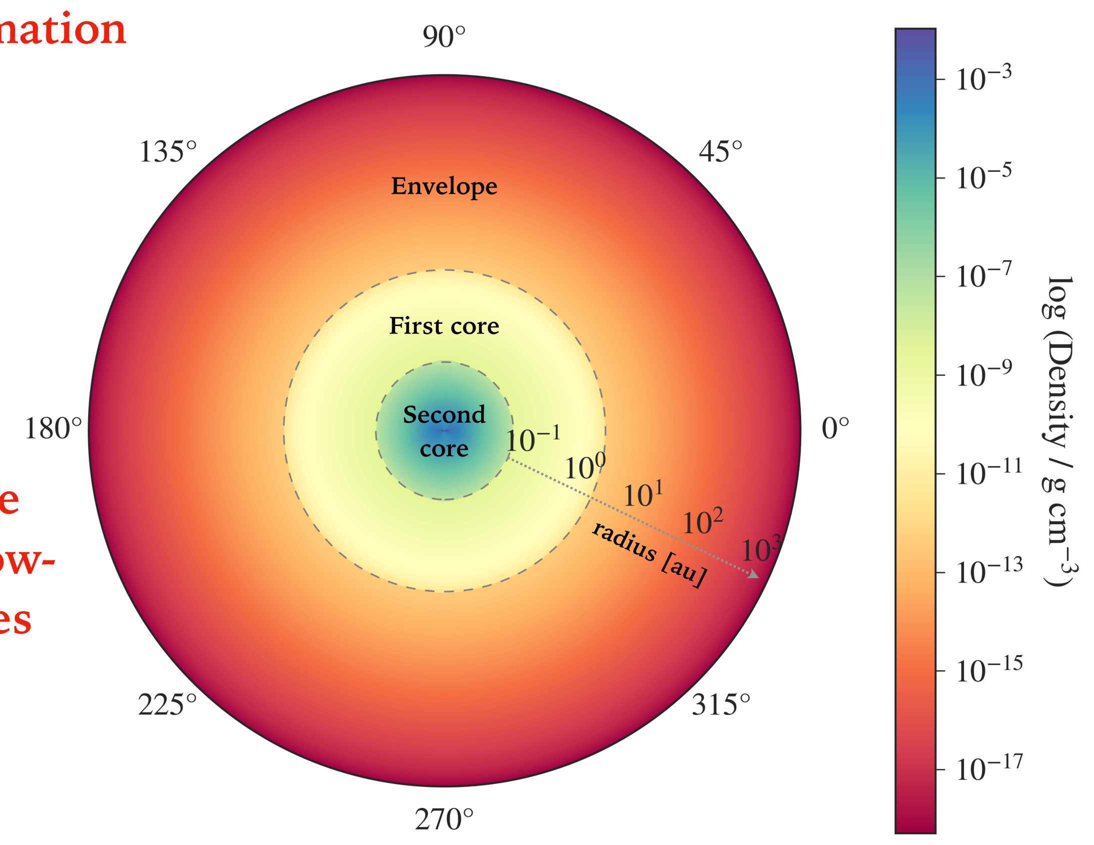
Temperature and density evolution showing the hydrostatic cores and disc formation phases for a 1 $M_\odot$ molecular cloud core collapse.



First and second hydrostatic core properties

First cores are non-existent during high-mass star formation

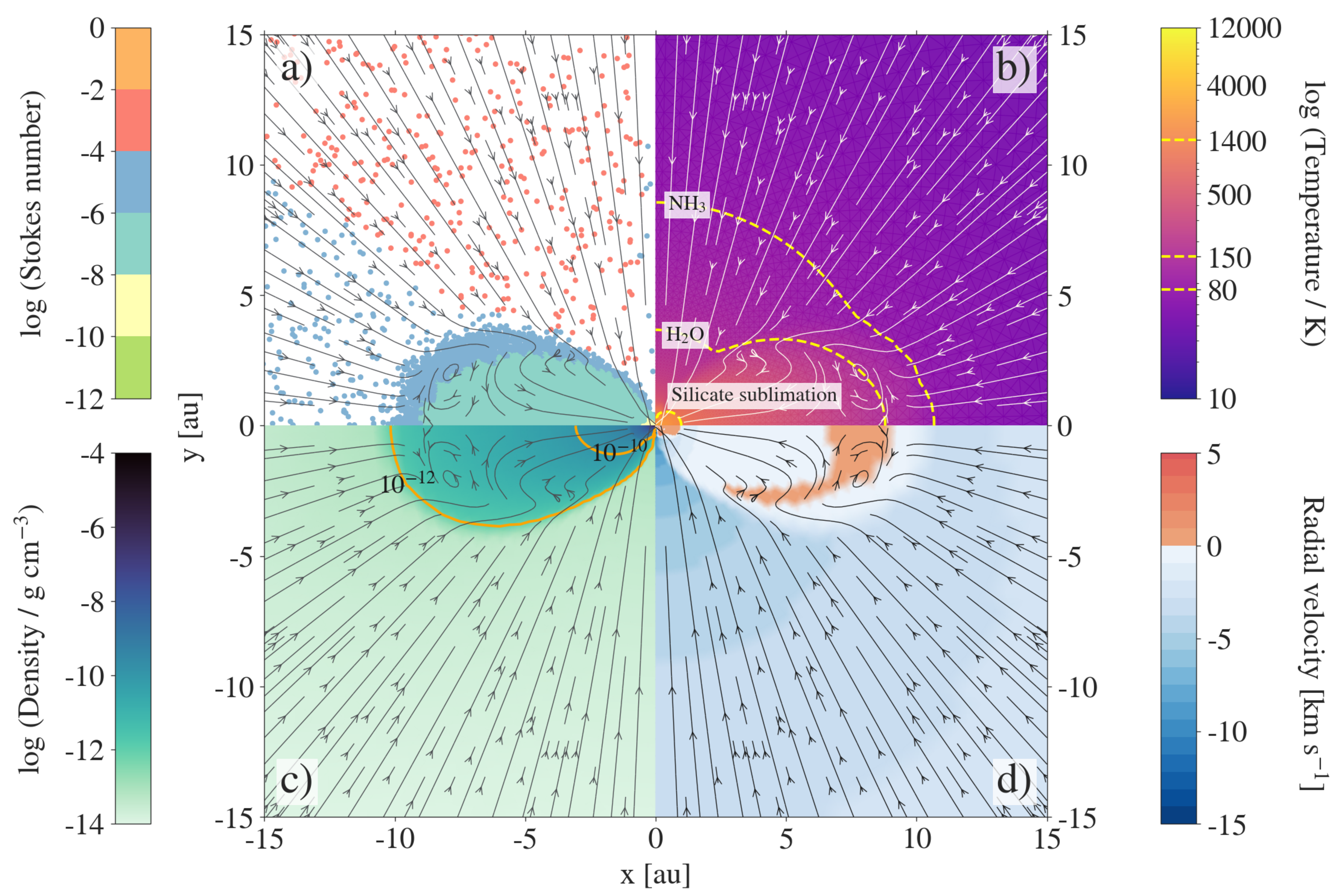
Onset of convection in the second core formed from low-mass collapsing cloud cores



Watch the birth of a protostellar disc

Access Tārā: A database for star & disc formation studies

Formation of dust pockets in a young protostellar disc (arXiv: 2404.09257)



A snapshot from a 2D radiation hydrodynamic simulation of a collapsing 1 $M_\odot$ cloud core with 1 μm neutral dust showing a) Stokes number, b) Gas temperature, c) Gas density, and d) Gas radial velocity.
Mixing and transport within the disc and infall from the envelope is highlighted by the velocity streamlines.
Dust concentrates in pockets formed due to gas flows within the young disc (~ 10 au).

References: PLUTO code: A. Mignone et al., 2007, ApJS, 170, 228, A. Mignone et al., 2012, ApJS, 198, 7, A. Mignone et al., 2019, ApJS, 244, 38.
Self gravity: R. Kuiper et al., 2010, ApJ, 722, 1556. **Radiative Transfer:** R. Kuiper et al., 2010, A&A, 511, A81. **Equation of state:** B. Vaidya et al., 2015, A&A, 580, A110.
Relevant author publications: A. Bhandare et al., 2018, A&A, 618, A95, A. Bhandare et al., 2020, A&A, 638, A86, A. Bhandare et al., 2024, arXiv: 2404.09257. **Database:** asmitabhandare.github.io/#tara