Simulations Of Protostellar Collapse Using Multigroup Radiation Hydrodynamics

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Abstract

Radiative transfer plays a major role in the process of star formation. Many simulations of the gravitational collapse of a gas cloud use a **grey** treatment of radiative transfer. However, dust and gas opacities show **large variations as a function of frequency**. We used a **multigroup radiation hydrodynamics code** to simulate the collapse of a gas cloud and the formation of the first and second Larson cores. Using multigroup RHD yields **differences of ∼ 10%** in core masses and sizes. We also show that the resulting cores are largely **insensitive to the initial conditions**. The first cores **live for only 100 – 1000 years** before the onset of the second collapse, which makes them difficult to observe. Finally, we have begun **full 3D simulations** with the AMR code RAMSES.

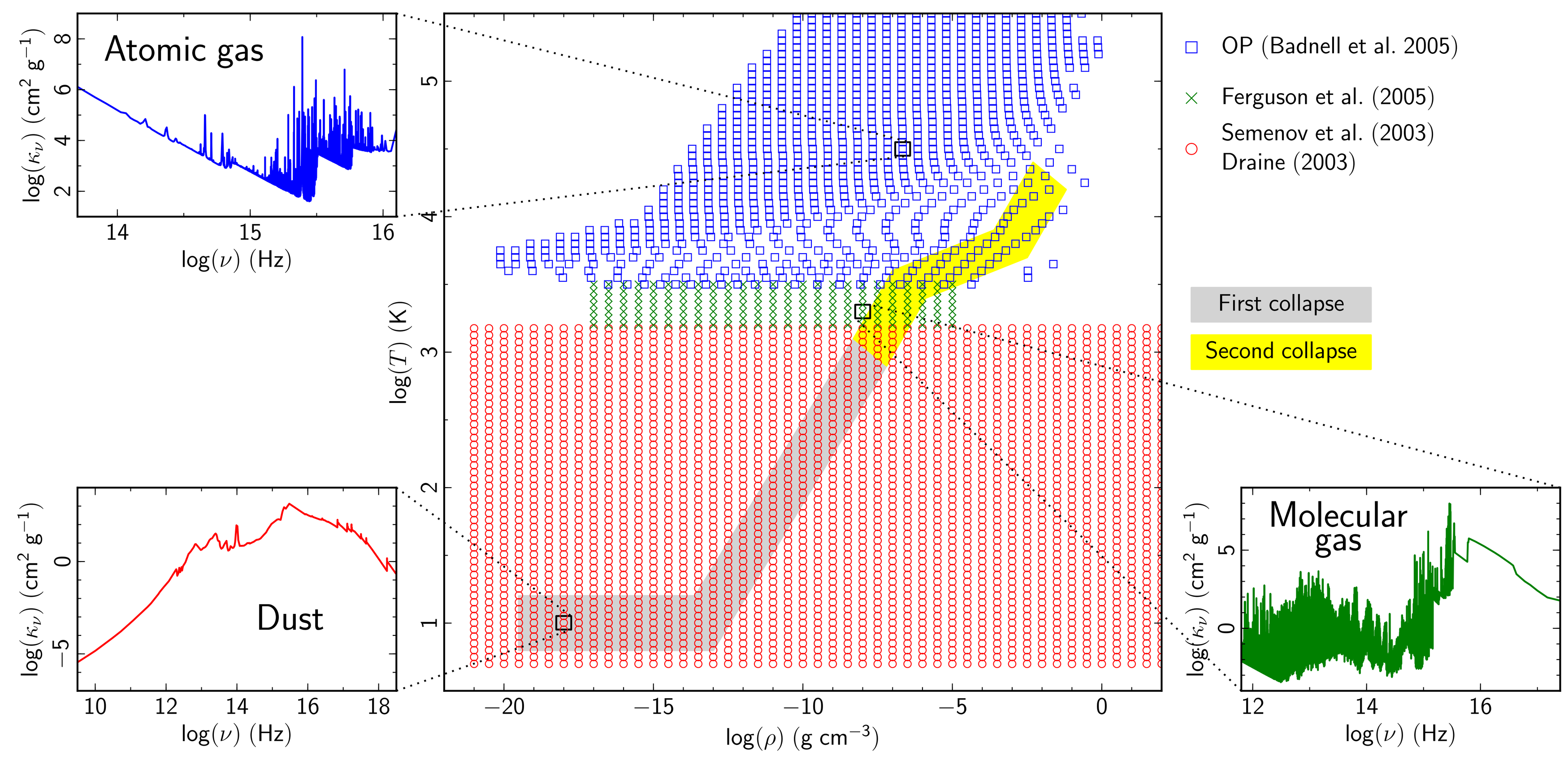
The multigroup RHD model

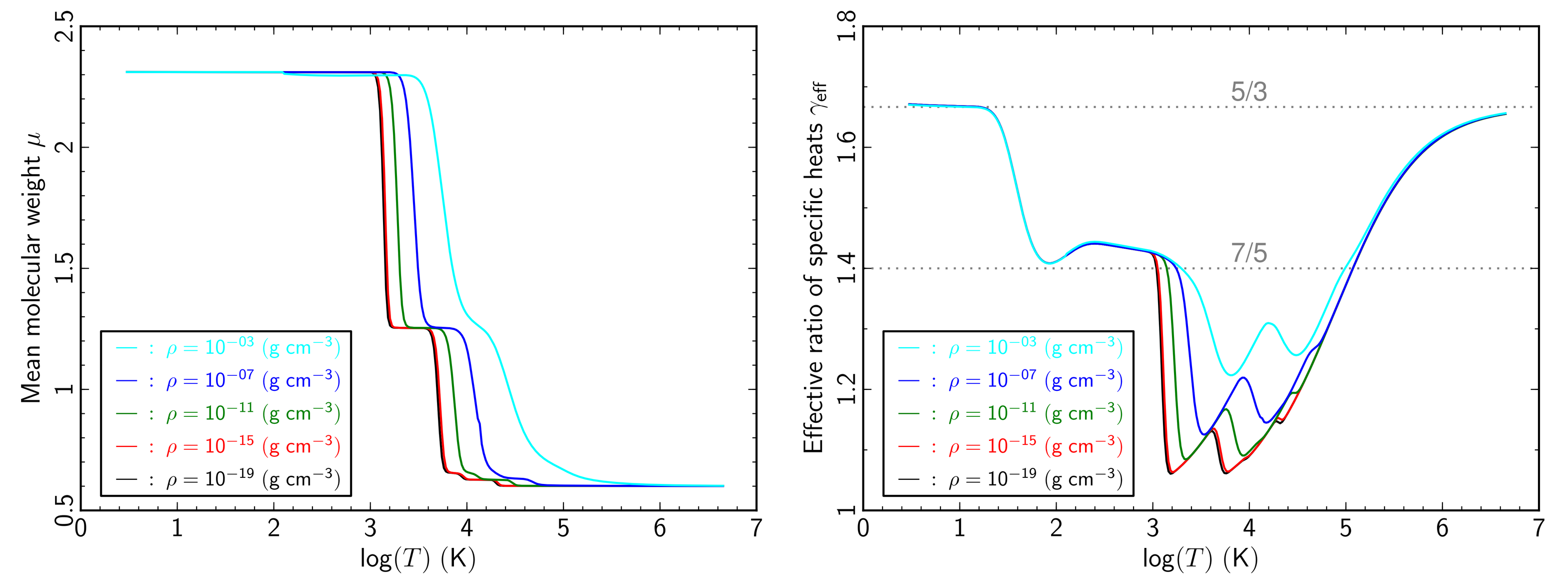
Physical model: We use the multigroup M_1 moment model for radiative transfer coupled to the gas hydrodynamics in the comoving frame (Vaytet et al. 2011) with a non-ideal equation of state (Saumon et al. 1995).

Numerical method: Fully implicit spherically symmetric Lagrangean second order Godunov code with adaptive mesh.

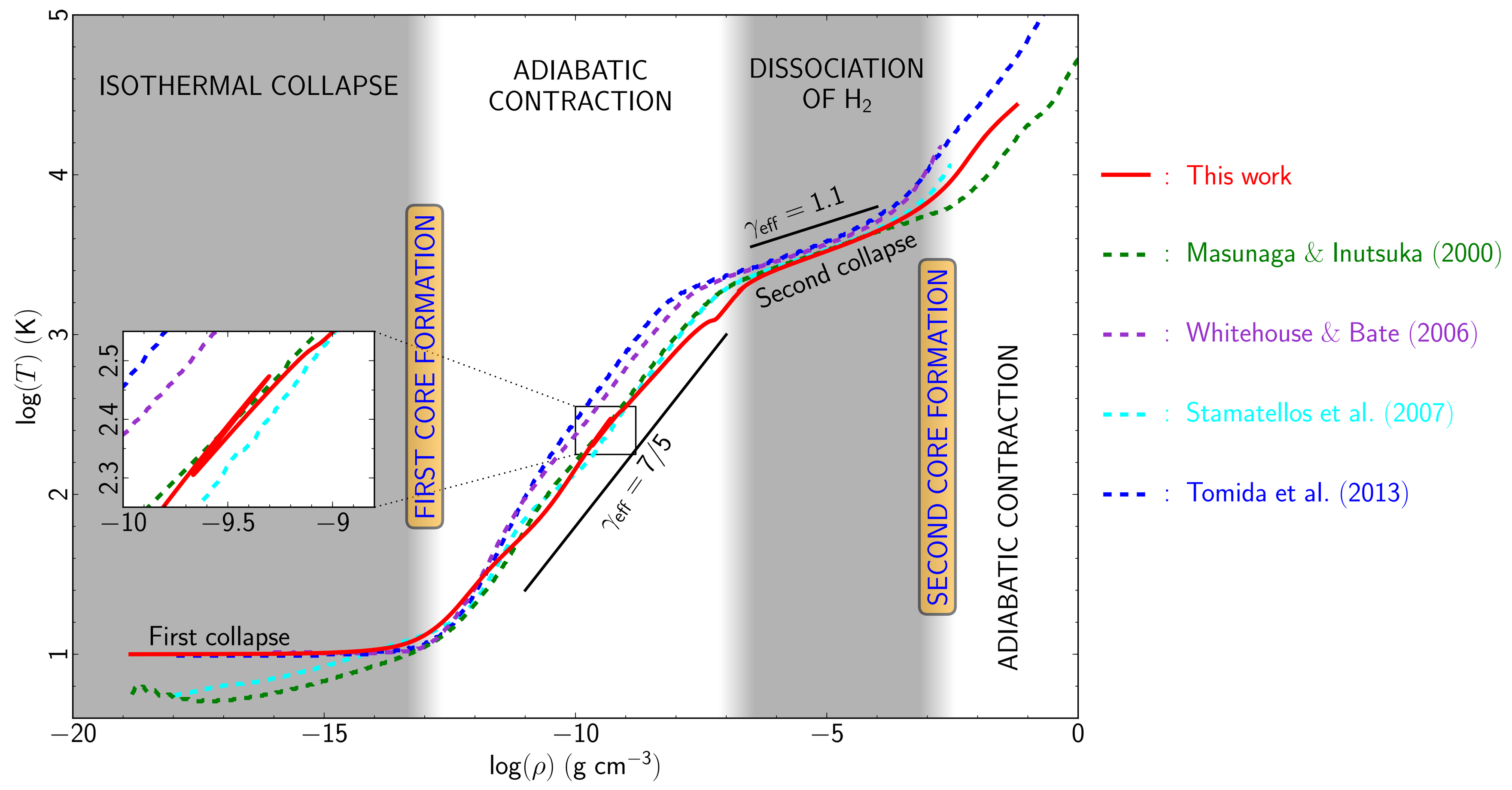
Initial conditions: A uniform density sphere of mass 1 $M_\odot$, radius 10^4 AU and temperature 10 K collapses under its own gravity.

Opacities and equation of state

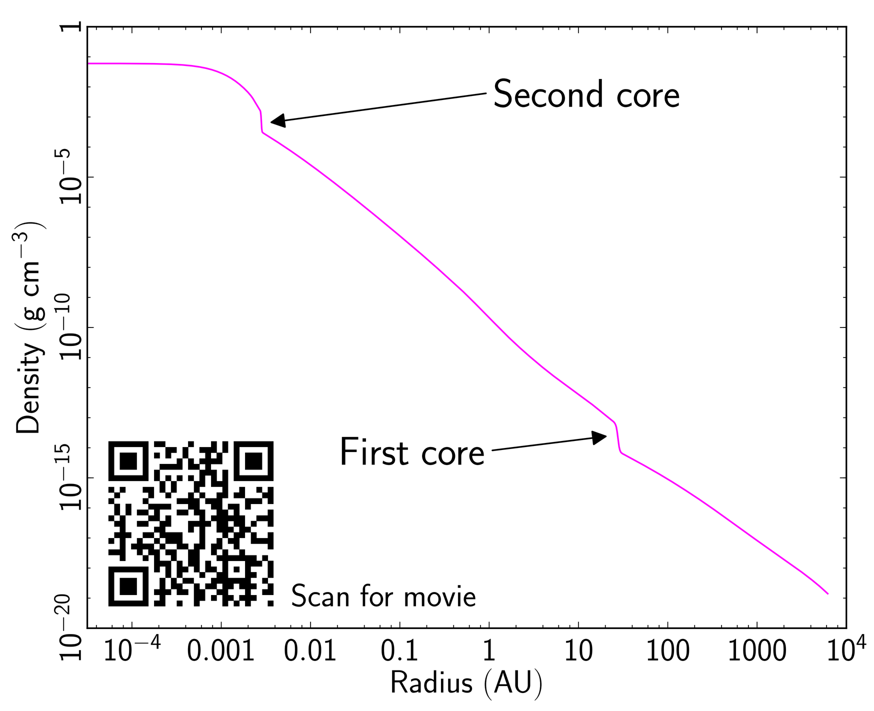


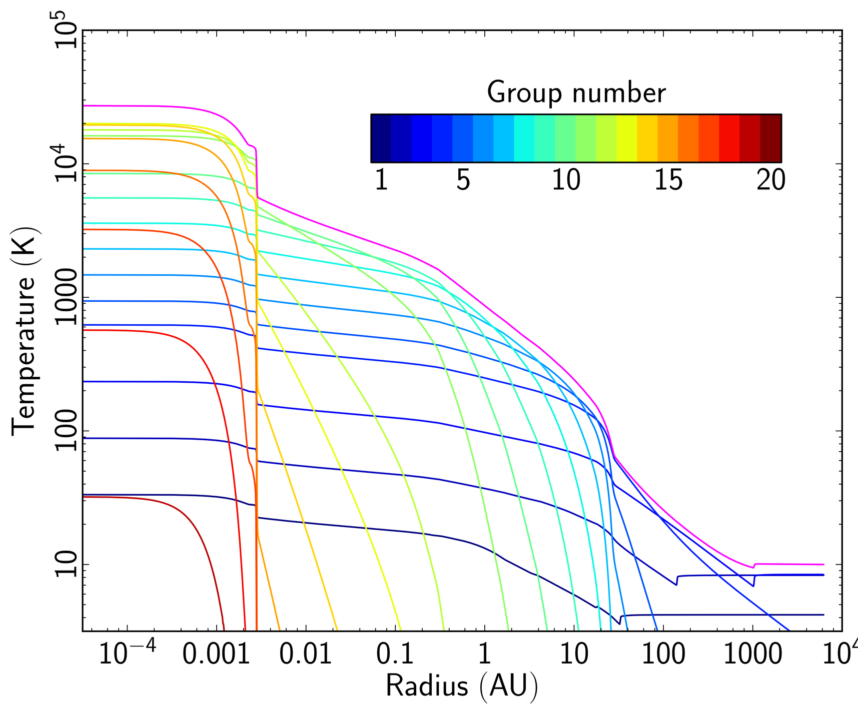


Thermal evolution



First and second core profiles

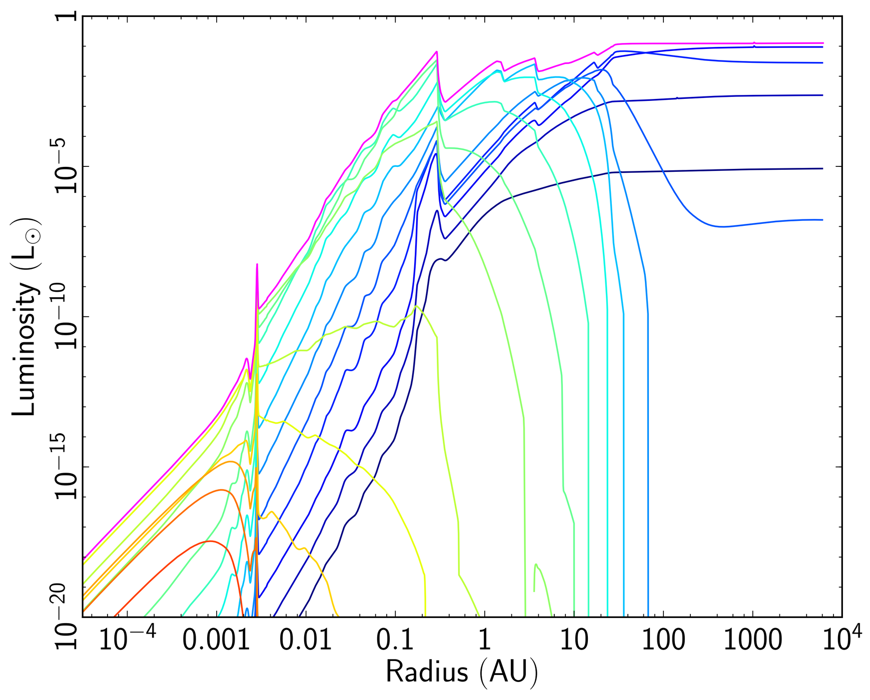




Simulation parameters

Run	N_g	M_0 ($M_\odot$)	R_0 (kAU)	T_0 (K)	R_1 (AU)	M_1 (m$M_\odot$)	R_2 (mAU)	M_2 (m$M_\odot$)	t_1 (yr)
1	1	1	10	10	24.1	43	3.1	1.3	886
2	20				28.2	47	2.8	1.2	982
3	1	0.1	1	10	33.3	50	3.1	1.3	2121
4	20				39.6	54	2.9	1.2	2424
5	1	10	100	10	20.5	40	3.1	1.3	614
6	20				23.0	43	2.9	1.3	644
7	1	1	5	10	5.99	24	3.3	1.5	148
8			20	5	35.0	51	3.2	1.4	2638
9			10	5	21.2	41	3.1	1.4	763
10			5	20	6.26	24	3.3	1.6	131

N_g = number of groups; M_0 = initial cloud mass; R_0 = initial cloud radius
T_0 = initial temperature; R_1 = first core radius; M_1 = first core mass
R_1 = first core radius; M_1 = first core mass; t_1 = first core lifetime

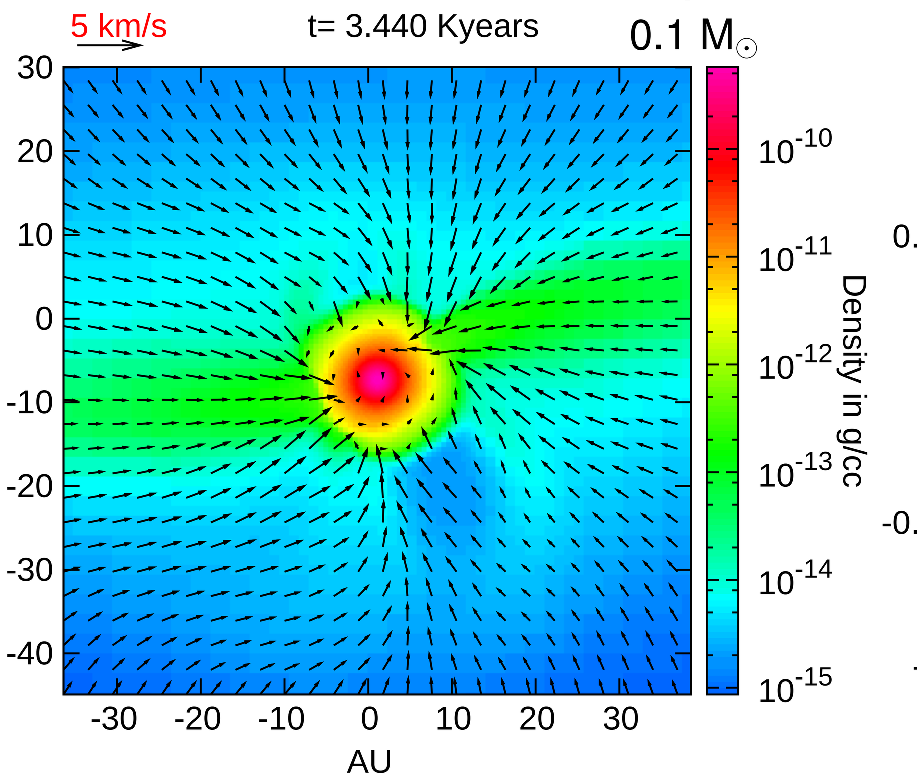


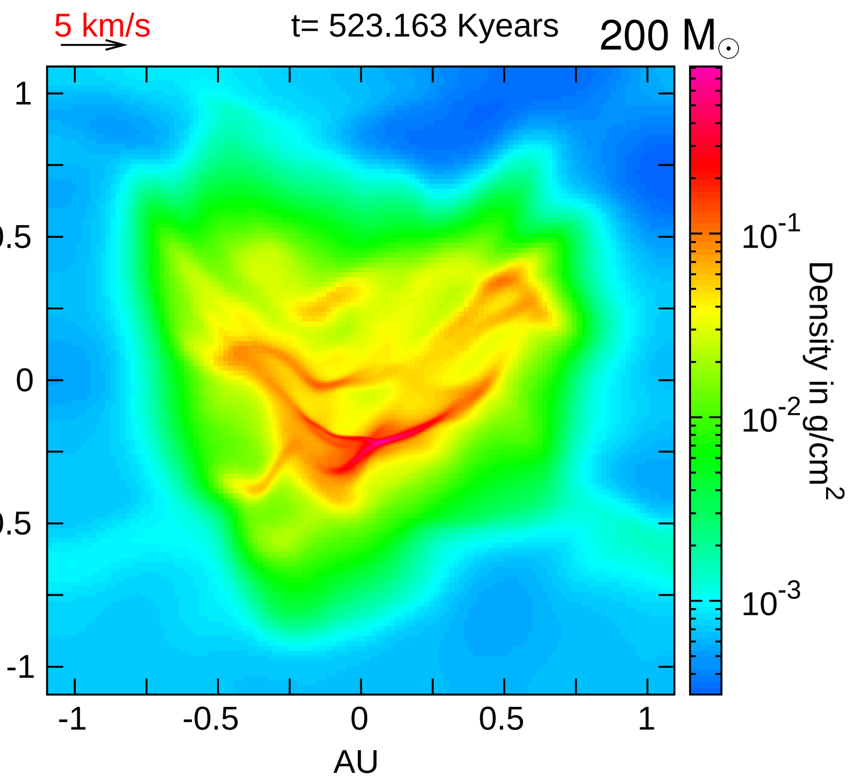
Early 3D RAMSES results

RAMSES simulations include:

- AMR grid
- Multigroup FLD 5 groups (+ M_1 soon)
- Non-ideal MHD (ambipolar diffusion + ohmic dissipation)

0.1 $M_\odot$ 200 $M_\odot$





Conclusions and future work

- Using multigroup RHD yields differences of ∼ 10%
- First cores have very short lifetimes (∼ 100 – 1000 years)
- The main properties of the first and second cores are quasi-independent of initial conditions
- 3D simulations using RAMSES are under way

Vaytet et al. 2013 (arXiv:1307.1010) – neil.vaytet@ens-lyon.fr