collisional formation of massive stars in accreting clusters

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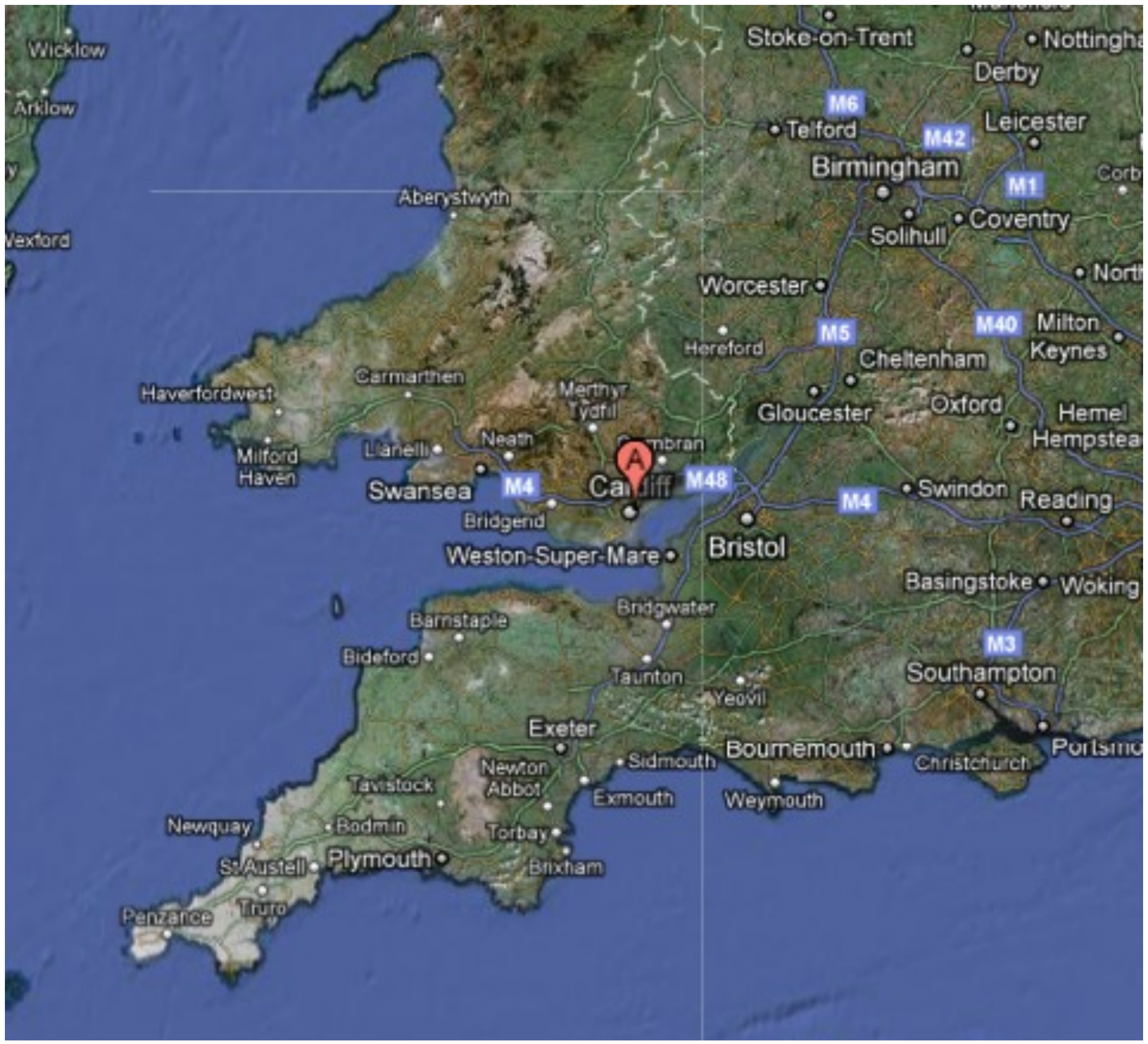
The Origin of Stellar Masses, Tenerife 19 October 2010

CONSTELLATION school on numerical astrophysics and its role in star formation



"*N*-body codes can't tell us anything more about star formation"

Matthew Bate
(paraphrased, but only slightly)
January 23, 2009

n-body techniques for star formation

We've reached the end of the usefulness of standard n-body studies applied to very young clusters.

spherical initial conditions

gas treated, if at all, as a spherical potential

otherwise, no gas–star interaction

sub-structured ICs

(Aarseth & Hills 1972;
McMillan+2007; Allison+2009; Moeckel & Bonnell 2009)

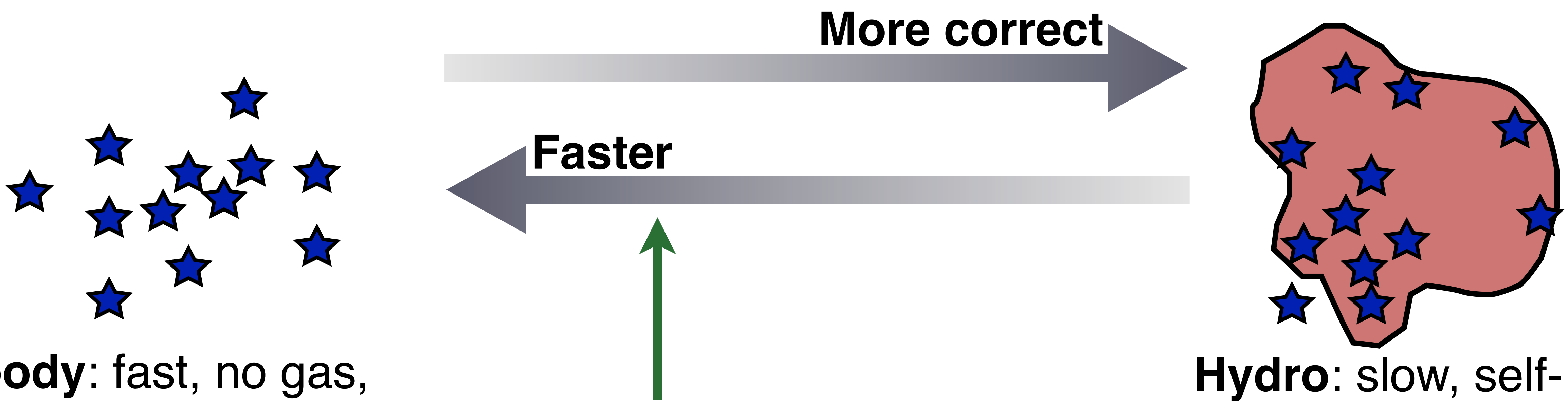
spheroidal gas potential, introduce stars over time

(Adams+2006; Proszkow+2009)

early dynamical evolution occurs with gas present.

can't ignore this.

numerical context

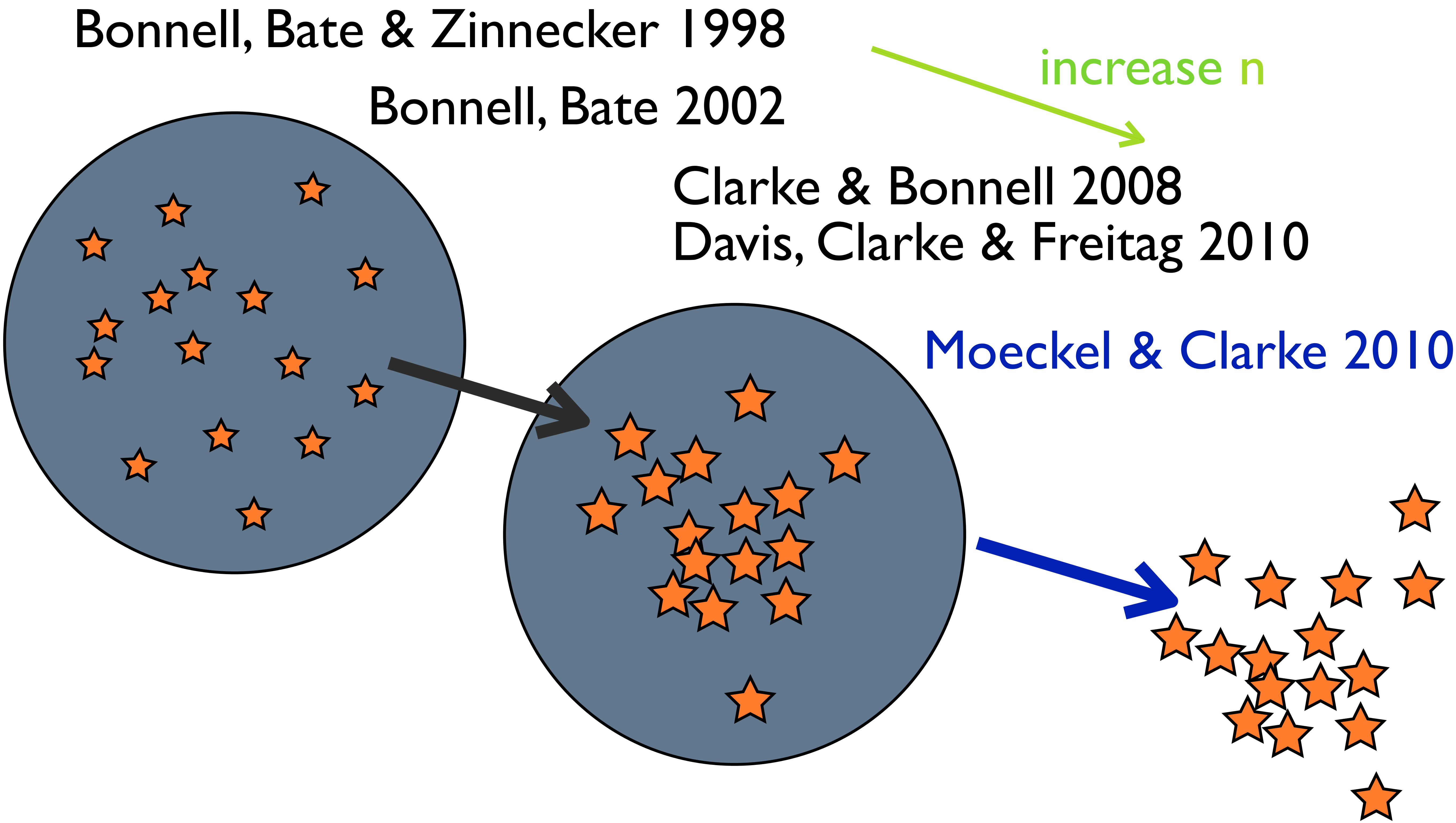


N-body: fast, no gas, large-N.
Initial conditions?

Now, and the near future: still fast, but take steps toward a more consistent hydro treatment.

Hydro: slow, self-consistent gas-star interactions.

the basic picture



initial conditions for simulations

start with low mass seeds 0.03 - 3.0 $M_{\odot}$, Salpeter slope

grow in mass linearly with time, proportional to mass
(so the IMF shape is preserved)

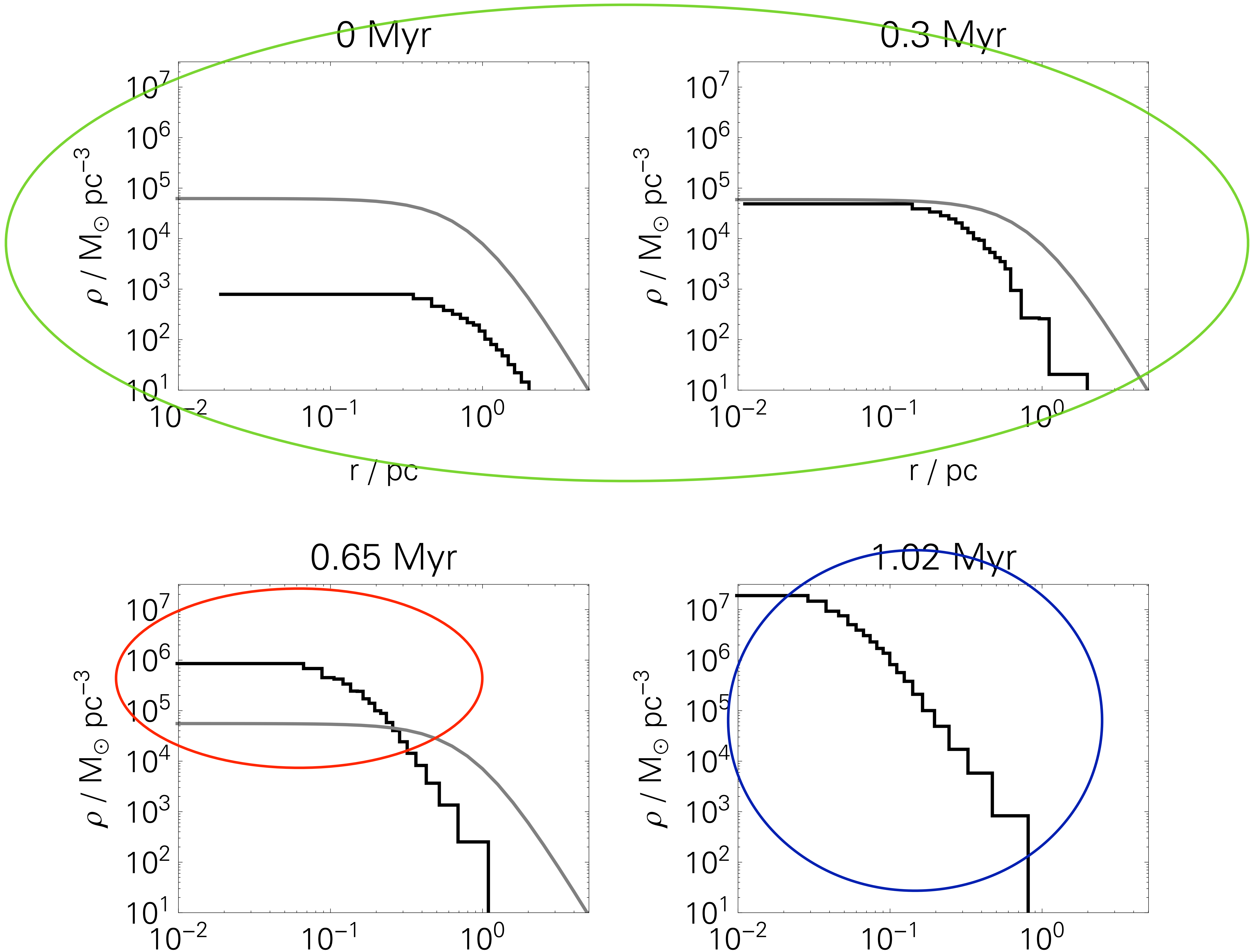
Plummer spheres, 32k stars

gas potential that lowers with increasing stellar mass

after stars have grown to max of 30 $M_{\odot}$, gas removed

global sfe = 30%

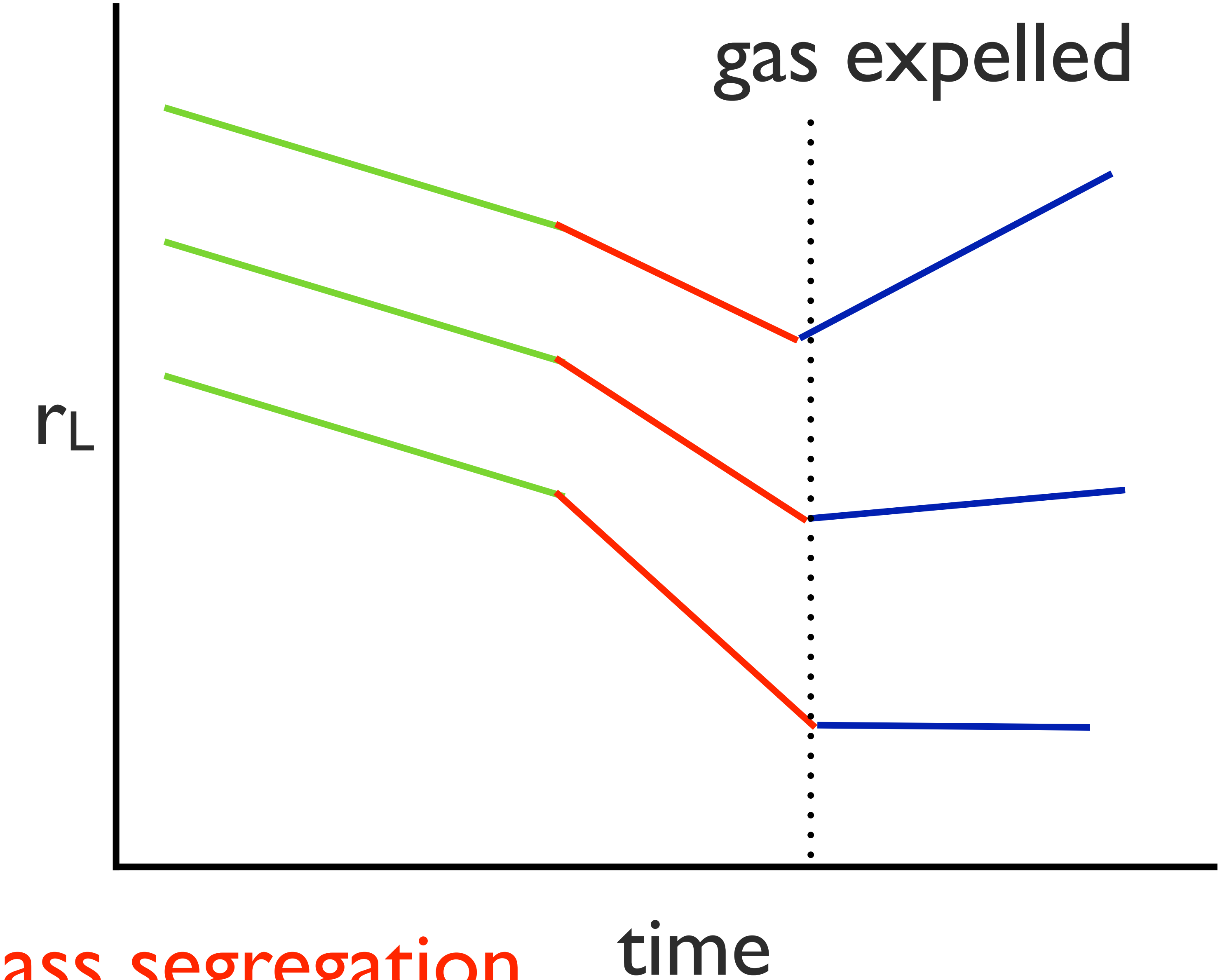
collisions with perfect efficiency



0 Myr
0.3 Myr
0.65 Myr
1.02 Myr
ρ / M⊙ pc⁻³
r / pc

(gas/stars) evolves, determines behavior

gas potential dominates the dynamics, accretion drives contraction of stellar component

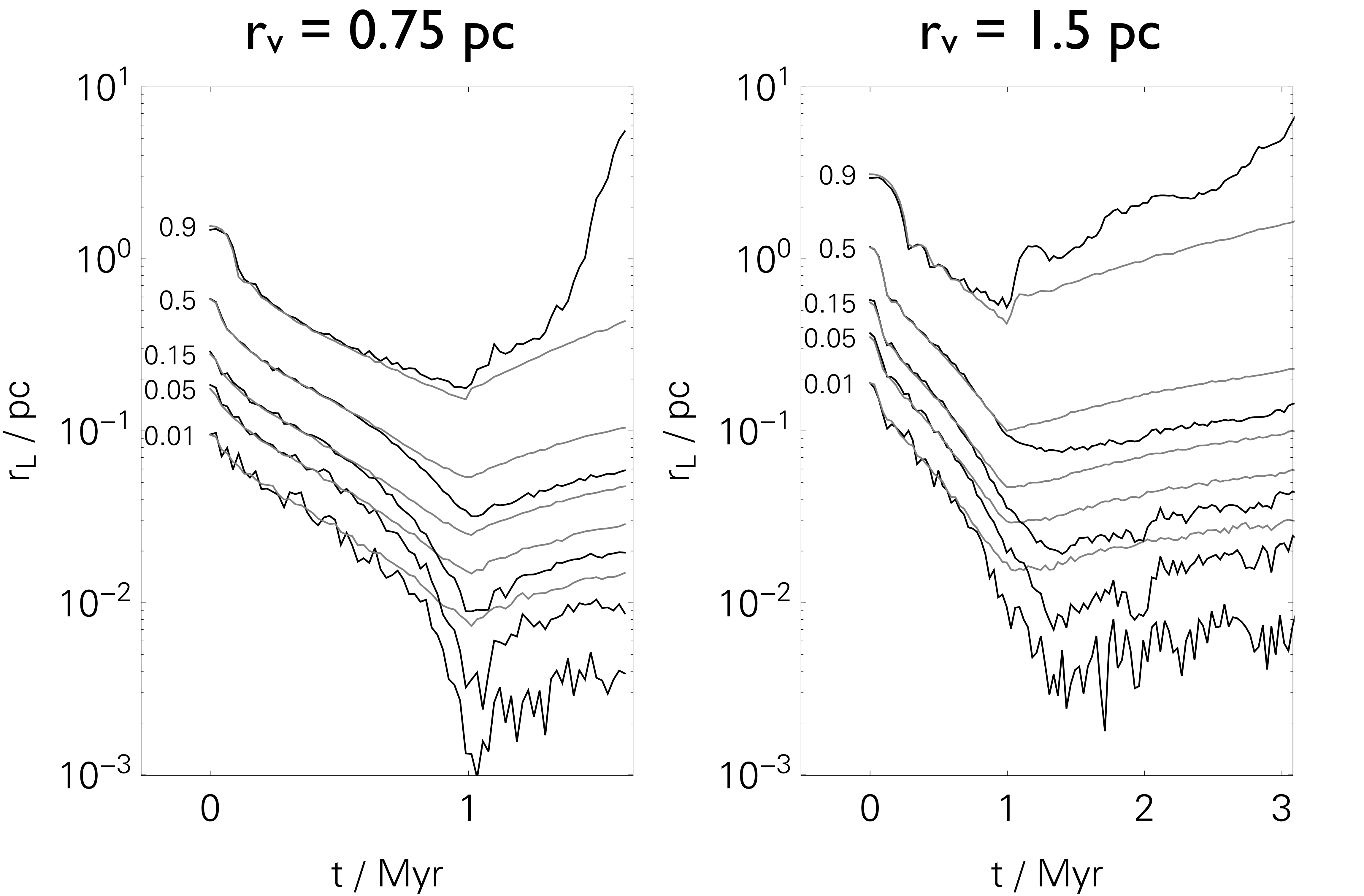


1) accretion behaves as if gas flowing from an external reservoir

2) mass segregation can begin to drive core collapse

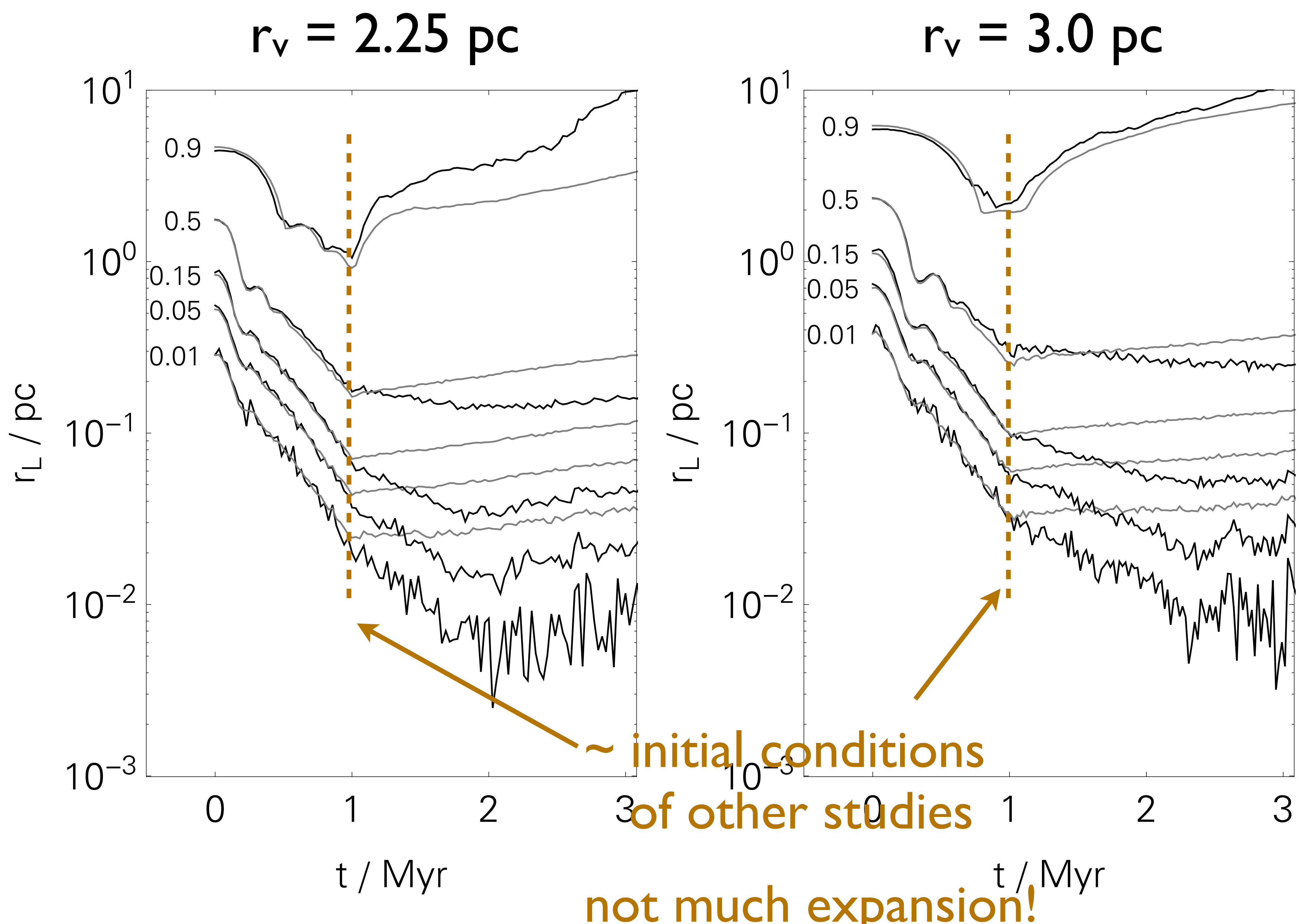
move into pure n-body dynamics

regime 1: smaller initial radii



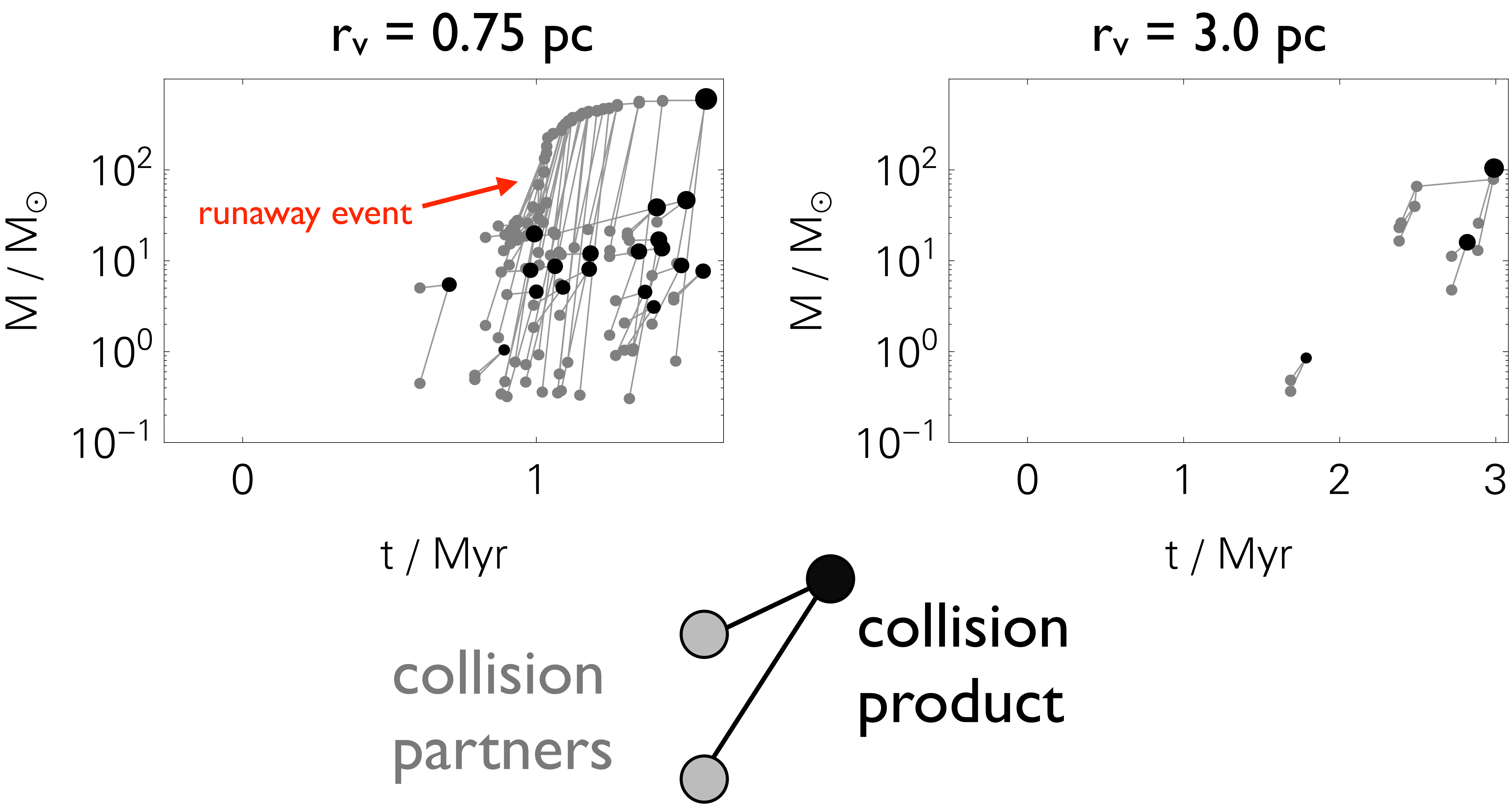
mass segregation and collapse begin during accretion

regime 2: larger initial radii

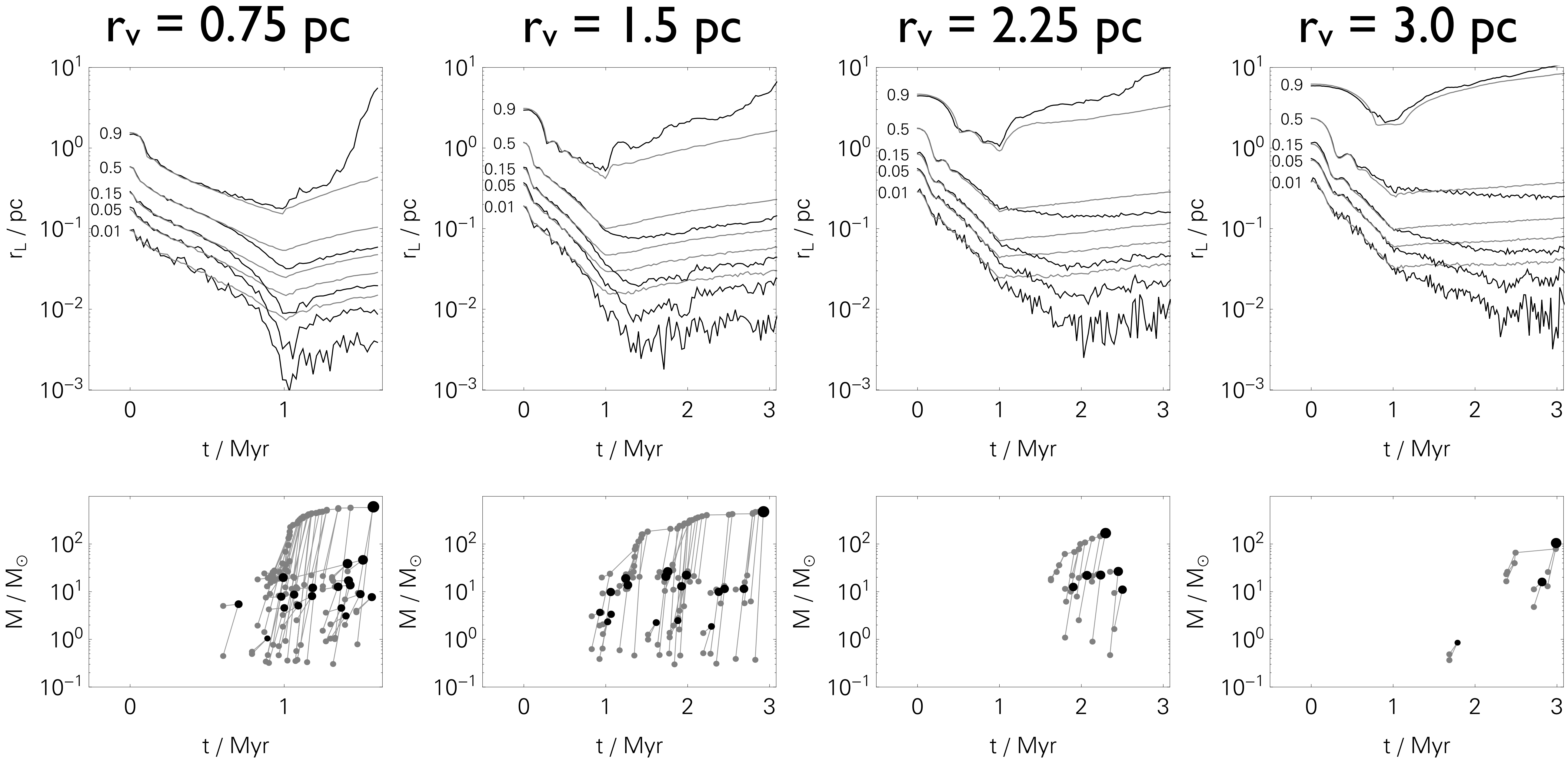


mass segregation and collapse begin after accretion

earlier core collapse = more collisions



earlier core collapse = more collisions

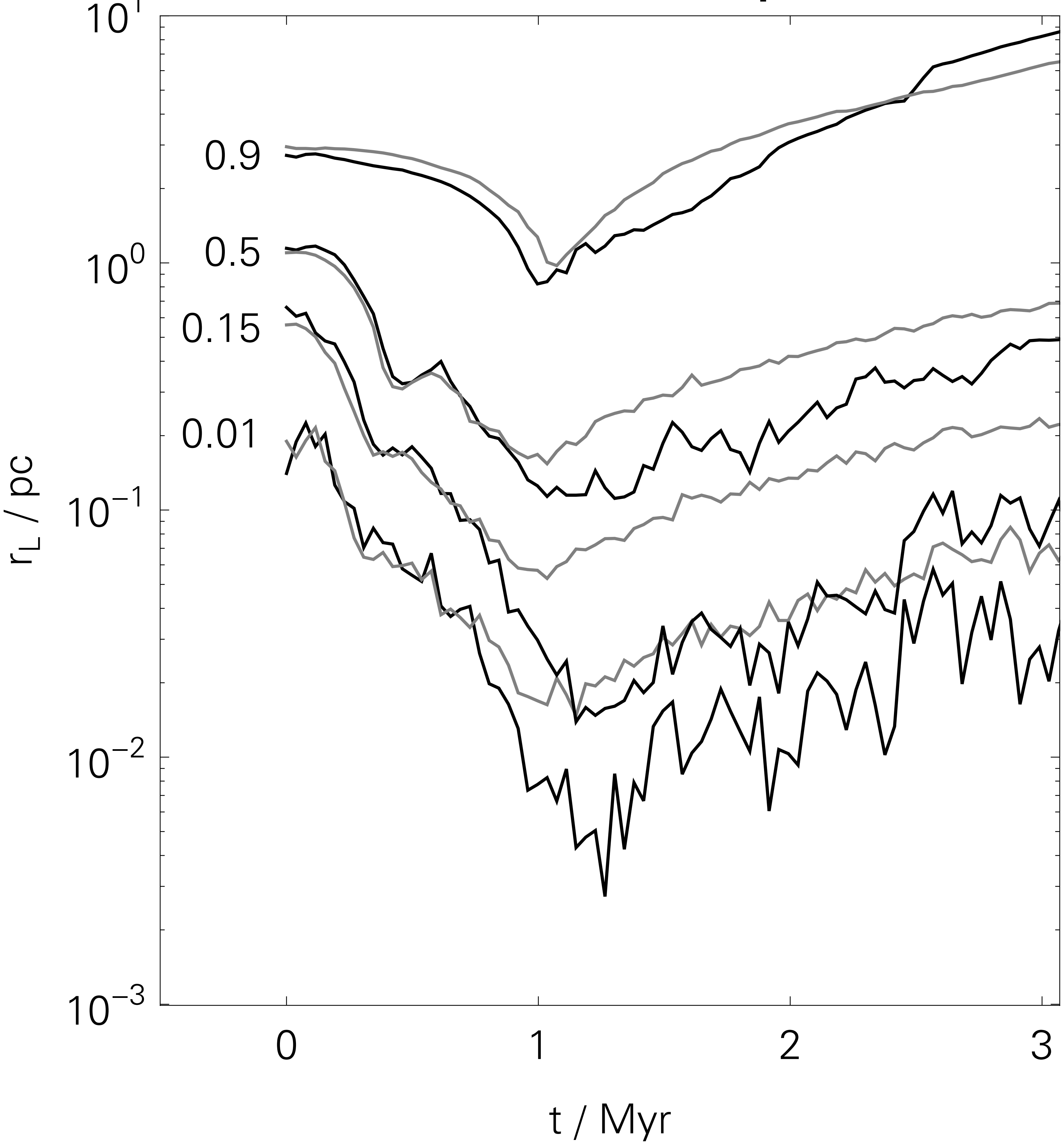


602, 46, 39	276, 37	100	---
	344	143	
	356, 31	145	
	368	65, 45	
	321	57, 39	

masses > 30 $M_\odot$
at 2 Myr

ONC-like system

2k stars, r_v = 1.5 pc

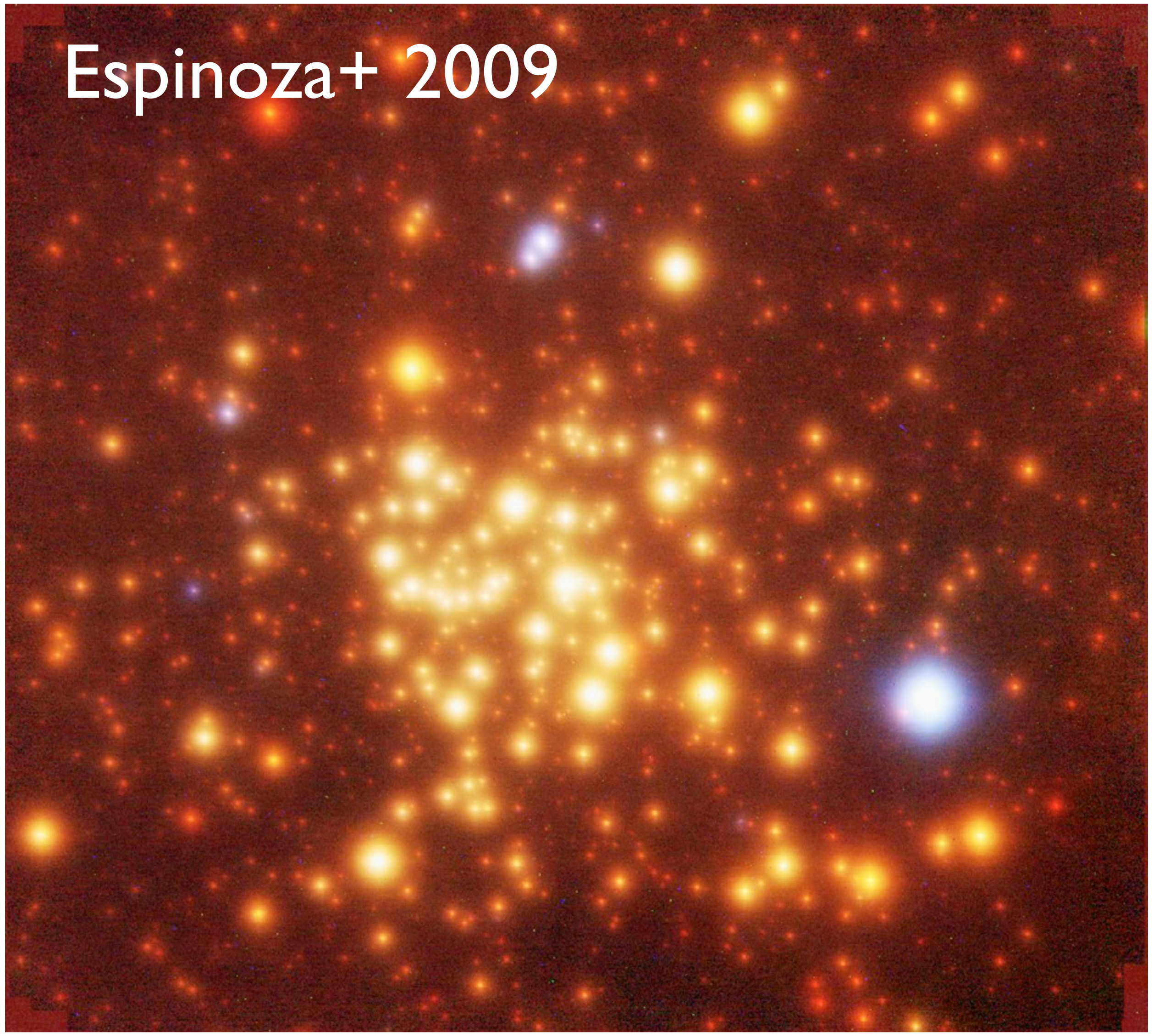


2 collisions in 5 simulations

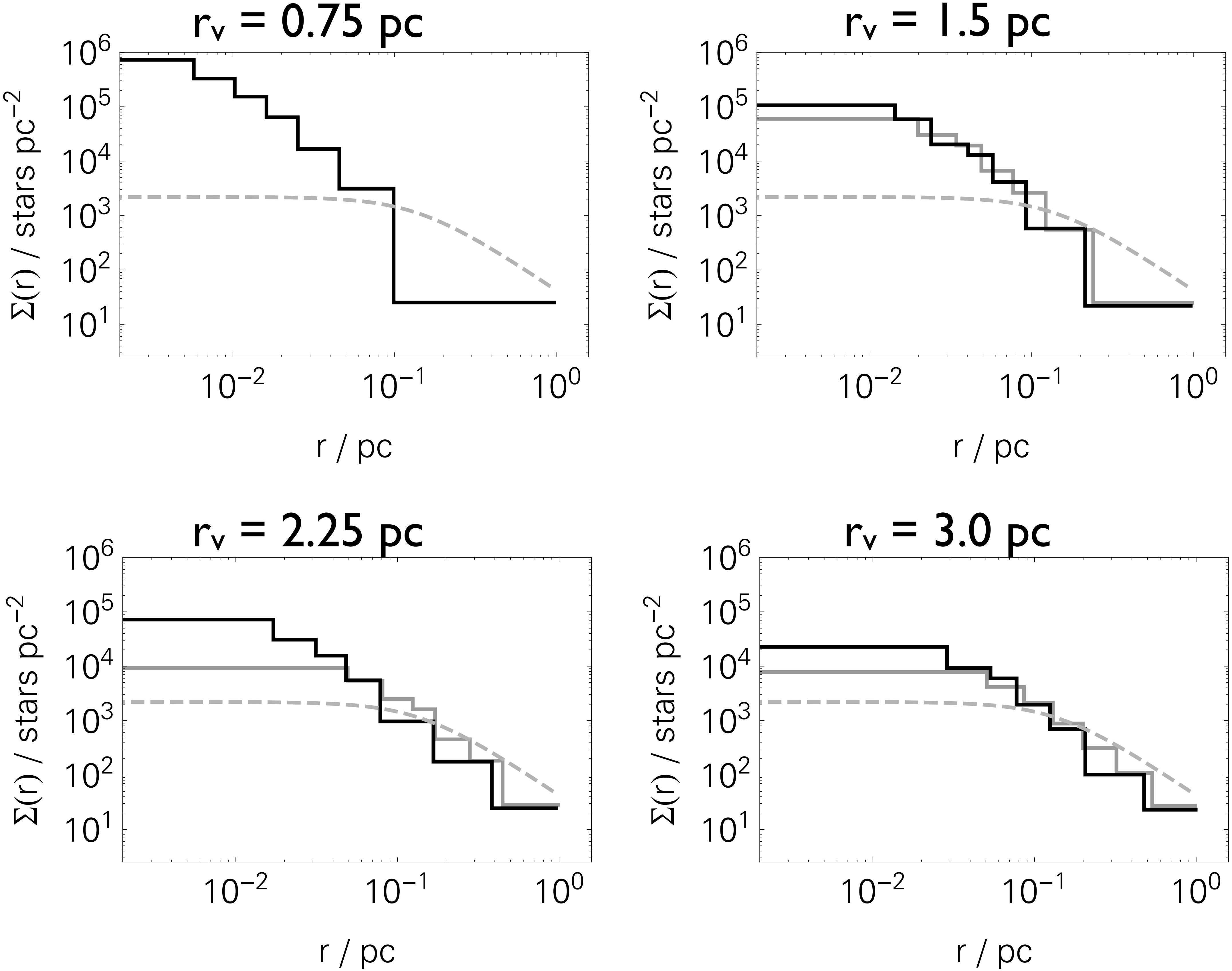
binaries formed at core collapse efficiently inflate the core with low-n cluster

compare to the Arches: mass density

Arches probably the most likely local place to look for something like this. These experiments aren't specifically tailored to the Arches, but can check bulk cluster properties.



compare to the Arches: surface density



conclusions

accretion during cluster formation can easily lead to high very densities

with populous compact clusters, collisions occur–generally have a runaway character

not going to smoothly fill up the upper IMF like this, but can get exotic objects

offers a way to form stars at comfortable separations, shrink the cluster, leave it compact after gas expulsion

binaries

replace most massive 1% of stars with equal-mass, circular binaries set to be hard at the end of accretion.

'depth' of core collapse is shallower, so binaries are affecting the relaxation dynamics. collisions rate enhanced.