Planets, UFD and LRD + Galacticus

CENTER
FOR ASTROPHYSICS
AND SPACE SCIENCE

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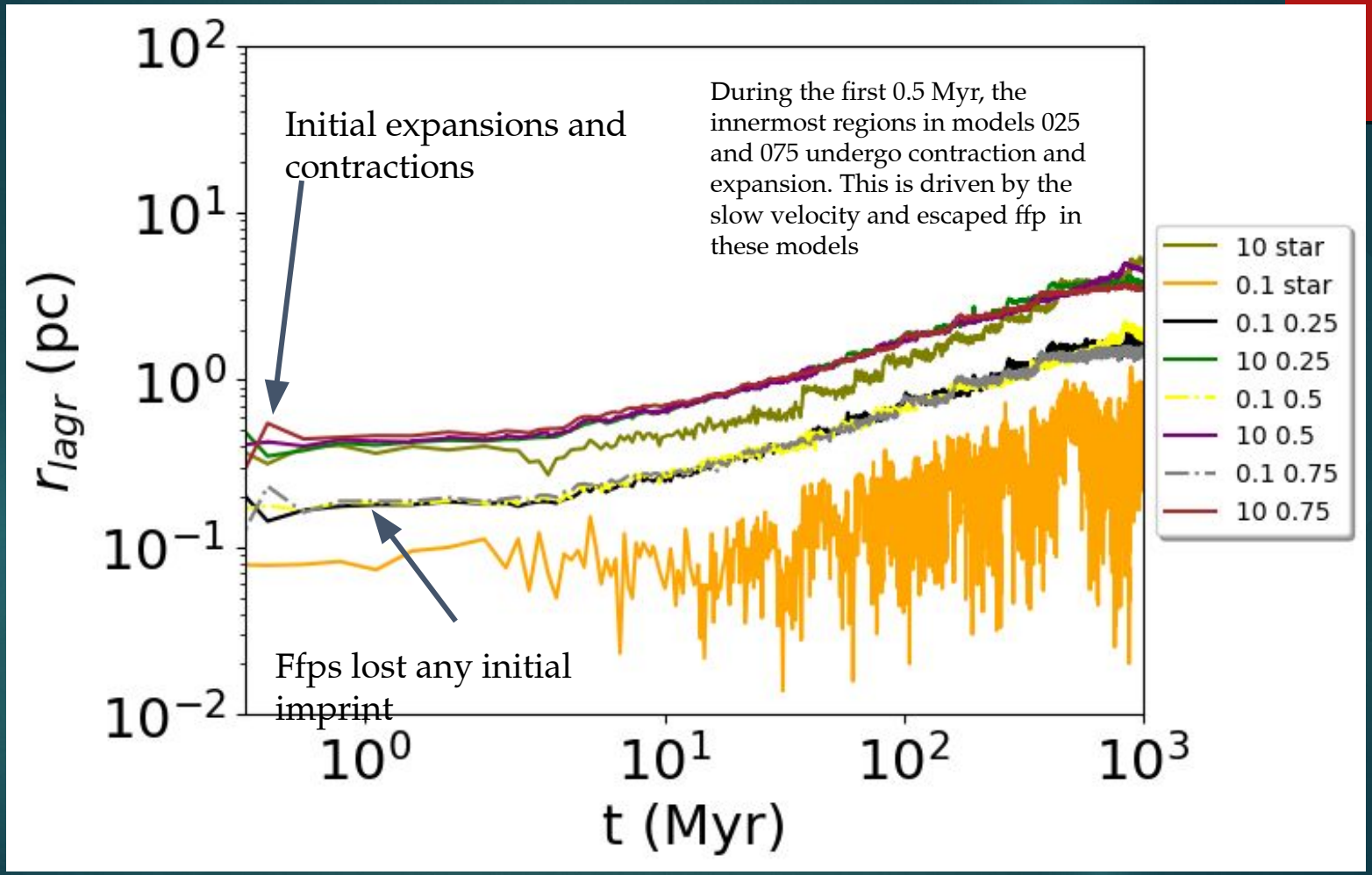
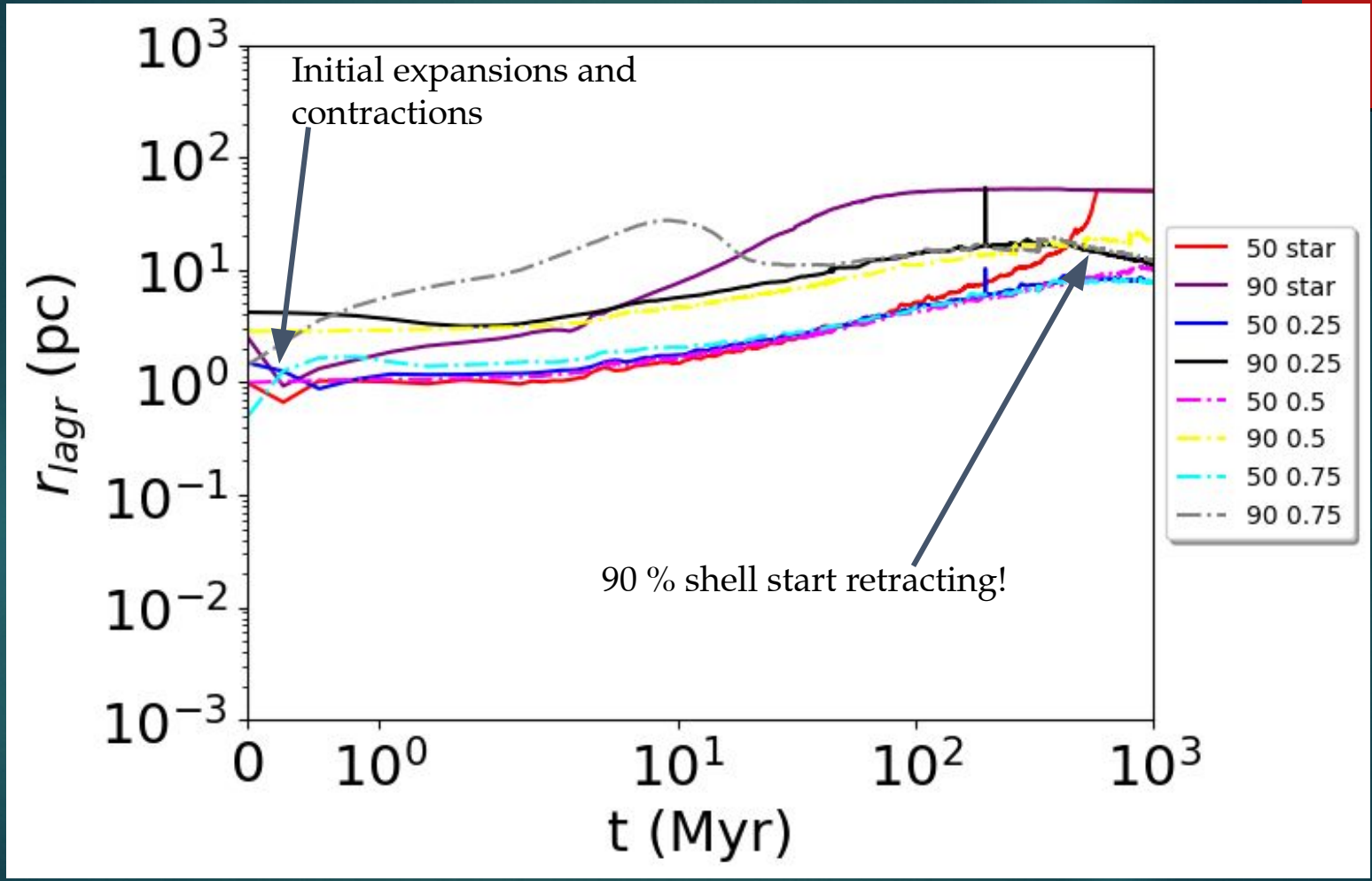
Nbody6++GPU
massless

Massless particle evolution with different energy distributions

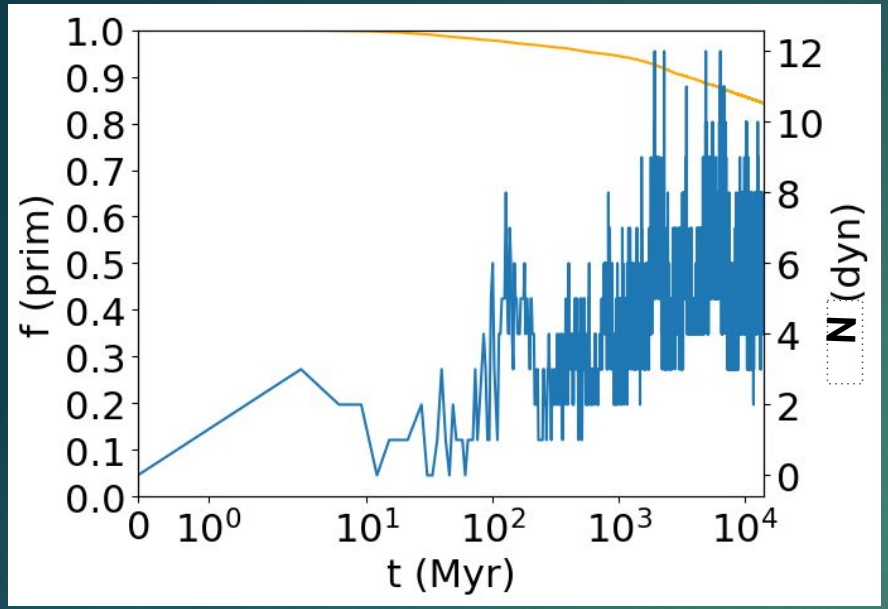
(Flammini Dotti, Kouwenhoven, Berczik, Askar, Giersz, Spurzem 2026)

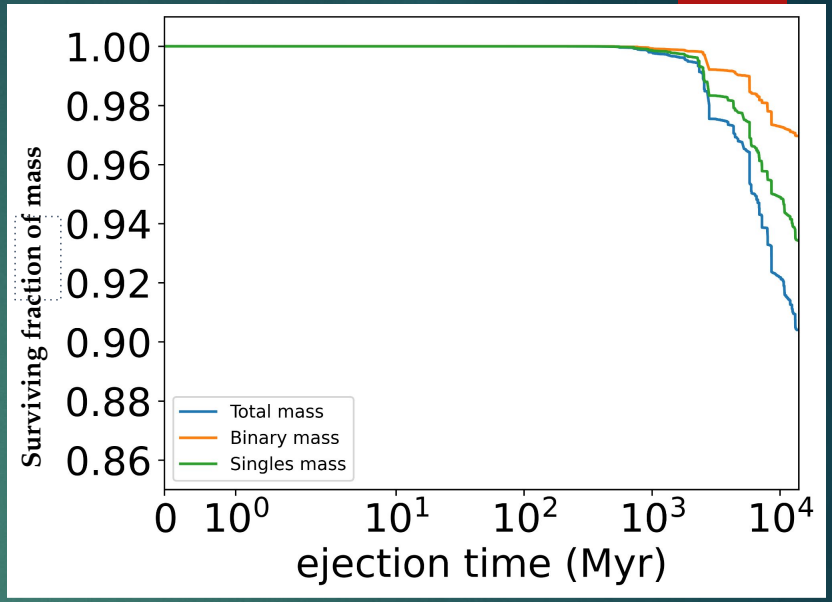

Initial expansions and contractions
During the first 0.5 Myr, the innermost regions in models 025 and 075 undergo contraction and expansion. This is driven by the slow velocity and escaped ffp in these models
Ffps lost any initial imprint
r_{lagr} (pc)
t (Myr)
10^2
10^1
10^0
10^{-1}
10^{-2}
10^0
10^1
10^2
10^3
10 star
0.1 star
0.1 0.25
10 0.25
0.1 0.5
10 0.5
0.1 0.75
10 0.75


Initial expansions and contractions
90 % shell start retracting!
r_{lagr} (pc)
t (Myr)
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
0
10^0
10^1
10^2
10^3
50 star
90 star
50 0.25
90 0.25
50 0.5
90 0.5
50 0.75
90 0.75

Long term evolution of Ultra-Faint Dwarf Galaxies

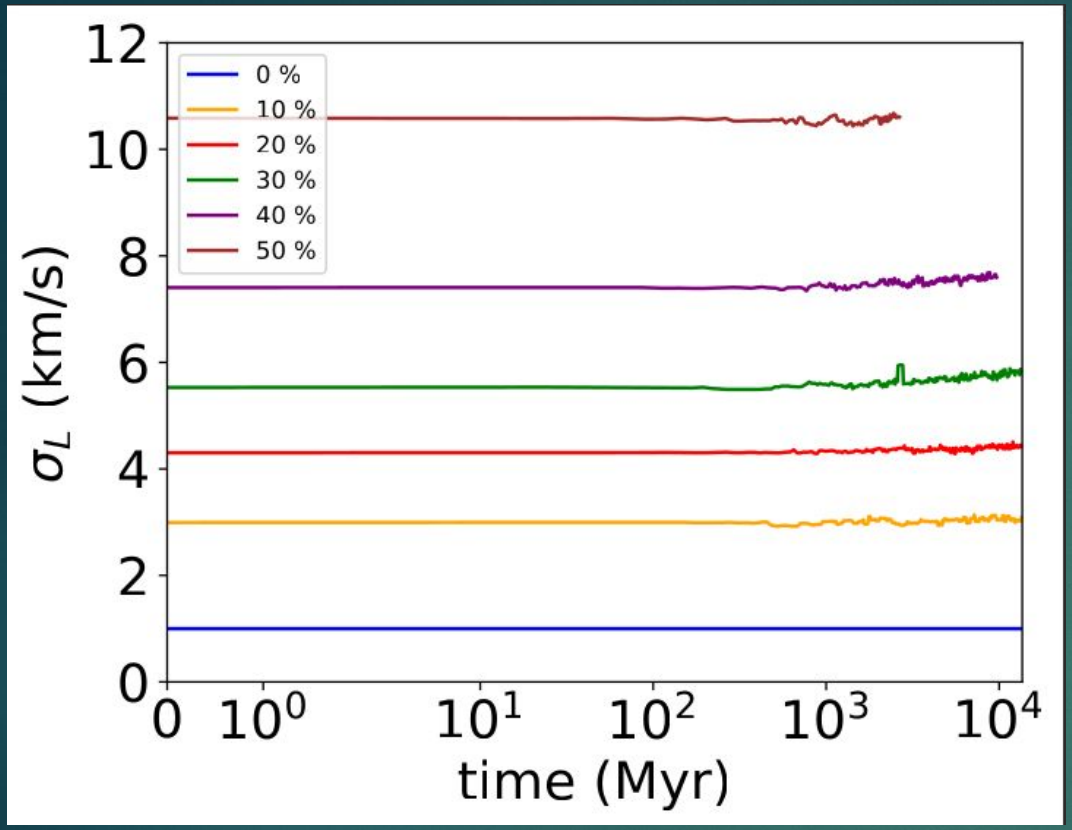
(Flammini Dotti, Capuzzo Dolcetta, Carraro, Trani, Spurzem 2026)





Dynamical binaries are too little and are destroyed quite quickly. All these binaries, in all models, are wide (> 10^3 AU).

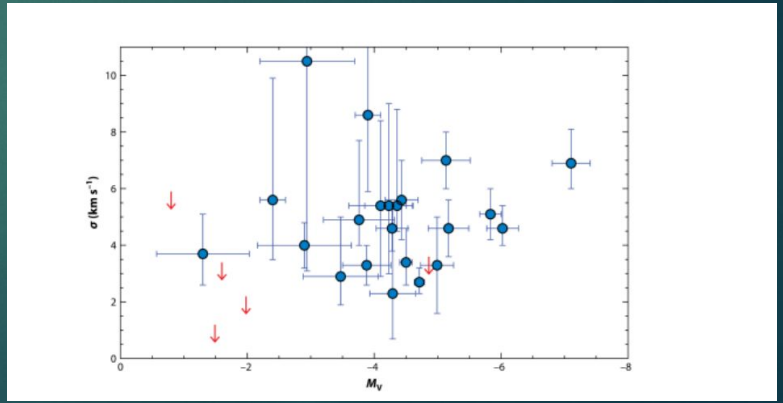
Primordial binaries, are ejected up to 16 % compared to the initial number of binaries, resulting in the mass loss on the right.



More binaries larger dispersion velocity.

We can estimate roughly, the binary percentage.

20-30 % seems a good estimation… ***but we didn't account for DM!!!!!***

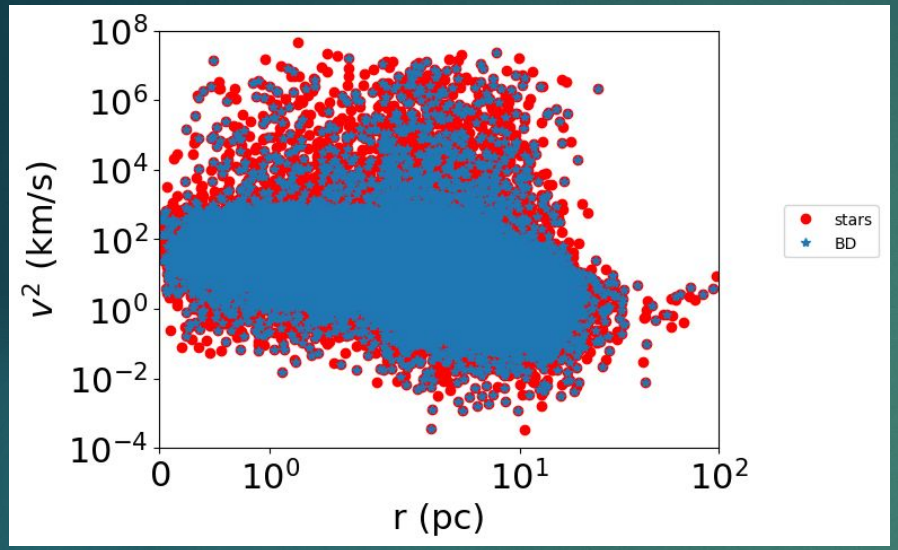


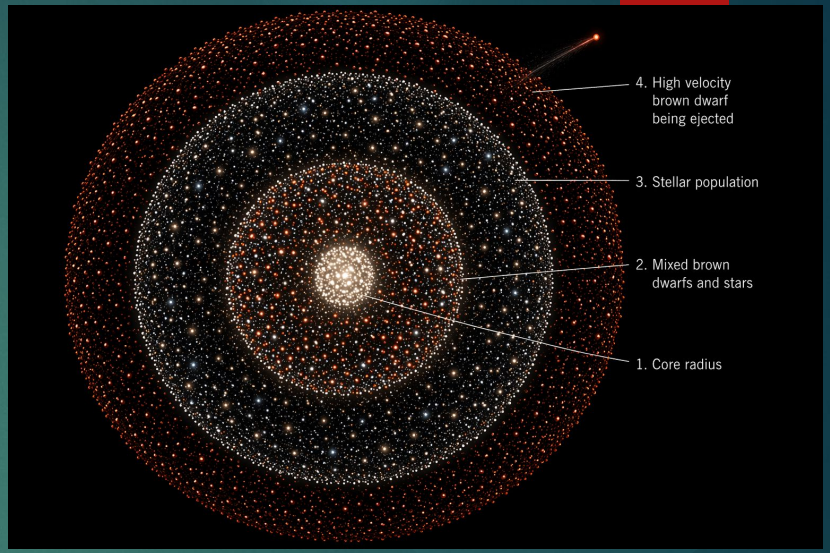
And how about the estimation on DM dominated UFD?
These results tell us that there is an overestimation of DM, as our system have comparable dispersion velocity to observational ones!

No need for large DM abundance if there are undetected binaries!

Brown dwarfs in a star cluster
(Flammini Dotti et al, in preparation)

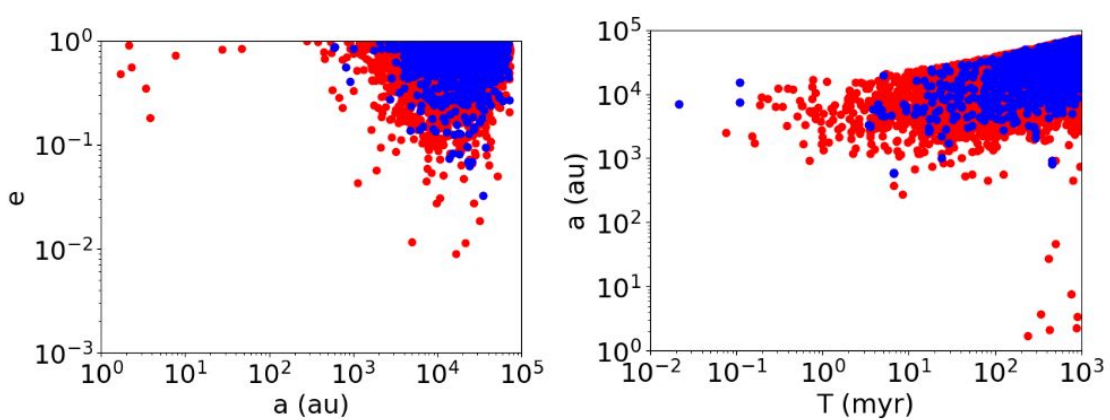
In this scenario, the mass of the brown dwarf is 12.6 % of the star cluster, making it comparable to the core mass of the stellar population.





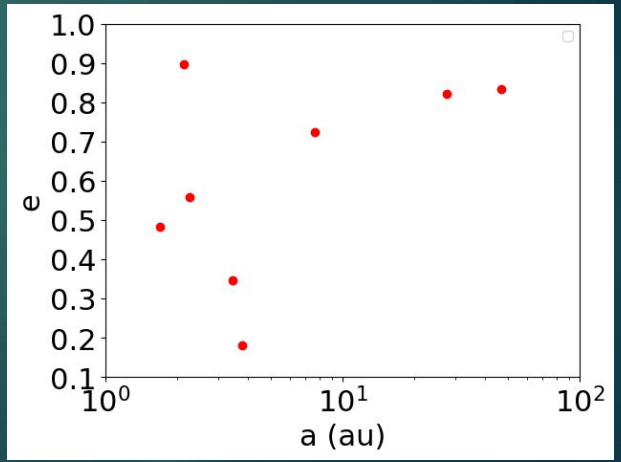
We find a distribution of high velocity brown dwarfs. These objects starts to become this accelerated around 500 Myr, when the dispersion velocity of the two population become similar, and become ejected after few Myr.

On the right an "idealised" distribution of BD and stars.

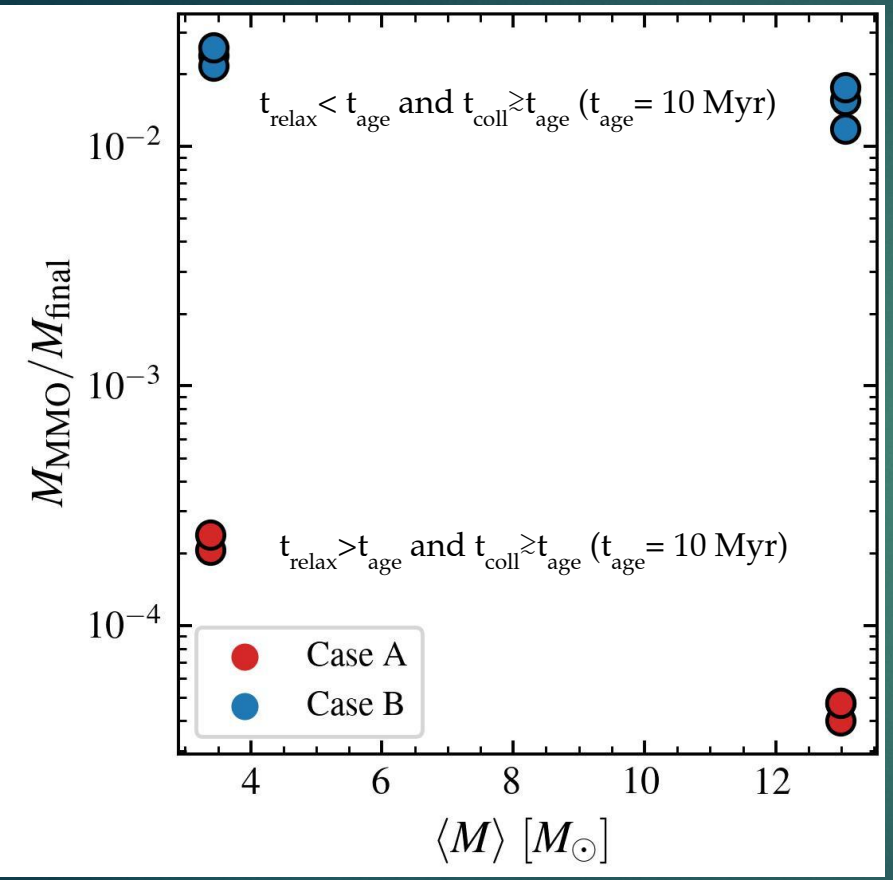


In blue BD-BD binaries, in red MS-BD binaries. All binaries there are dynamical.

Below BD desert binaries. Theseare binaries which have not yet been discovered in field systems. We found 8. Very rare and of great interest.



LRD toy models

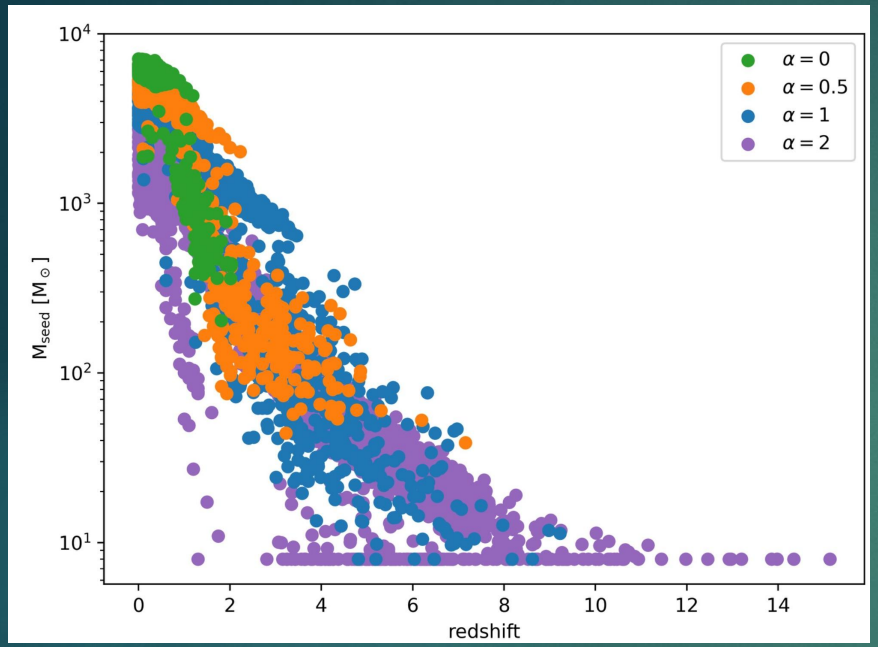


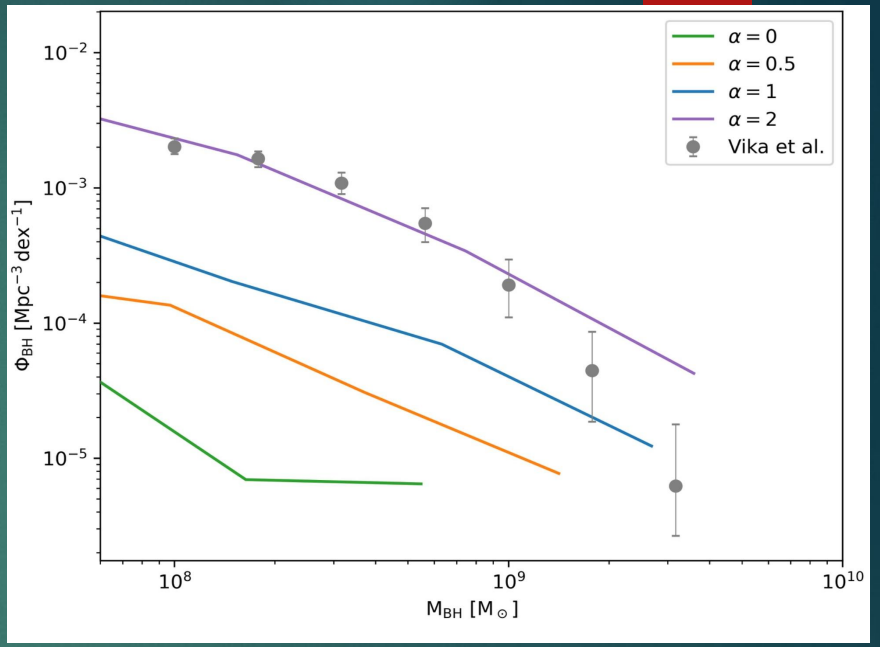
Determine if a stellar system can remain compact enough to match LRDs without collapsing prematurely.

Understanding if the relaxation time is greater than the system's age ($t_{relax} > t_{age}$) to know whether LRDs are "primordially" compact or if they evolved into that state through dynamical friction and mass segregation.

Formation of a central massive object due to collisions.

Built upon **Galacticus**, extending the formalism of **Liempi et al. (2025)** to model the evolution of NSCs.





BH seed formation in dense **dark cores** where velocity dispersion exceeds **500 km/s**. The seed mass is determined by an efficiency relative to the dark core mass $\epsilon_{seed} = 3.4 \times 10^{-3}$

$$\dot{m}_{gas} = 1.0 \times 10^{-2} \cdot \mathrm{SFR}_{bulge} \cdot (1+z)^{\alpha}$$

The α = 2 model is the only one in the set that 'successfully' reproduces the local Black Hole Mass Function.

What's next?

For planets:

1) Million body simulations: Dragonfly
2) Black hole-planetary systems interactions
3) Ffp abundance in the Galaxy

For UFD:

1) Role of DM and binaries (submitted large proposal for Leonardo)
2) Are some UFD actually GC?
3) UFD "true" long-term evolution

For LRD:

1) What are LRD? (LRD workshop on 22-24 June, you can apply for flash talks, scan QR code up on right)
2) Multi-code applications for LRD definition (combination of multiple codes)
3) How would an LRD would grow to become such?

Actual versions in development and out

1. **Standard version (post-newtonian version included)**
2. **Massless version (planet-size objects)**
3. Hip versions of 1. and 2. (Not official until further testings)
4. Star-Disk Version (SMBH and accretion disk) -> almost ready
5. Multiple Stellar populations -> almost ready
6. Neutron star binaries treatment -> in testing phase
7. VMS friendly version (unofficial version, with routines created to handle the VMS)
8. Population III (low metallicity treatment) -> in testing phase
9. Moving IMBH in the center -> implementation soon

We have a github. If interested, tell me and I send the link. The ones out are public and available to use