Young population

Emergence in old

Star clusters after

Smashing with dense

Interstellar clouds leading to the

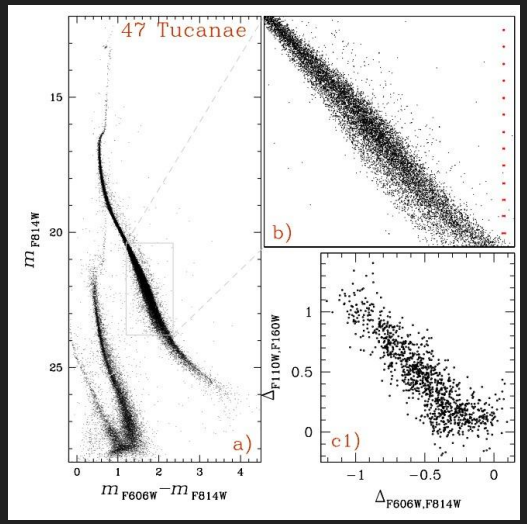
Regeneration of stars

YESSIR

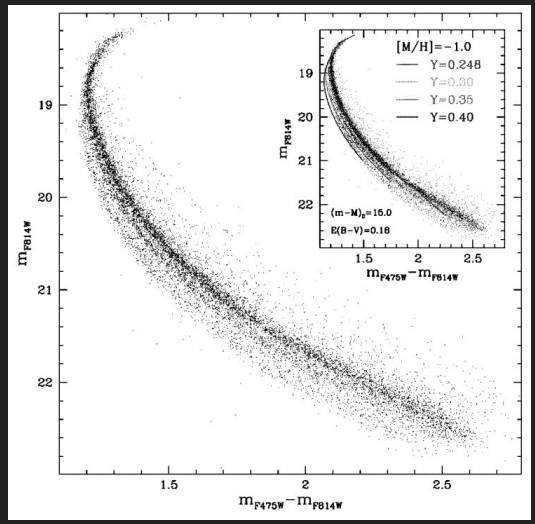
Kostas Tsalapatas
Erin Umuzigazuba
Yiqi Wu

Globular cluster with multiple populations

- Populations with different metallicities
  - metal-poor, evolved stars
  - metal-rich, main sequence stars
- Visible in color magnitude diagrams
  - Broadening of a branch
  - Distinct branches



Broadening of the main sequence branch in 47 Tucanae
Milone et al. (2023)

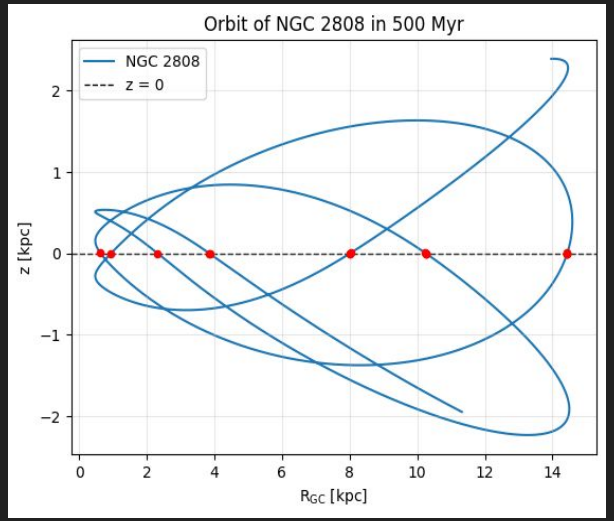


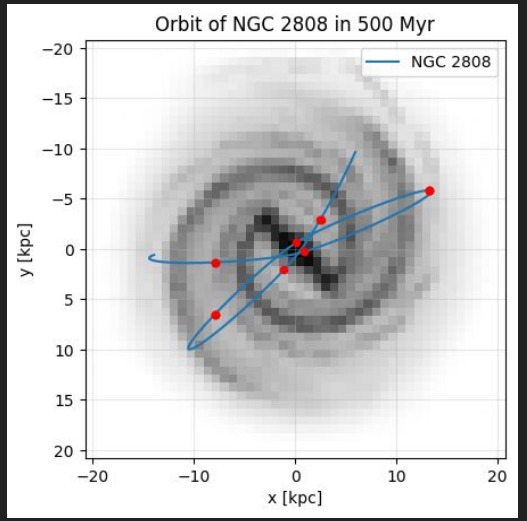
Three main sequence branches in NGC 2808
Piotto et al. (2007)

Our theory

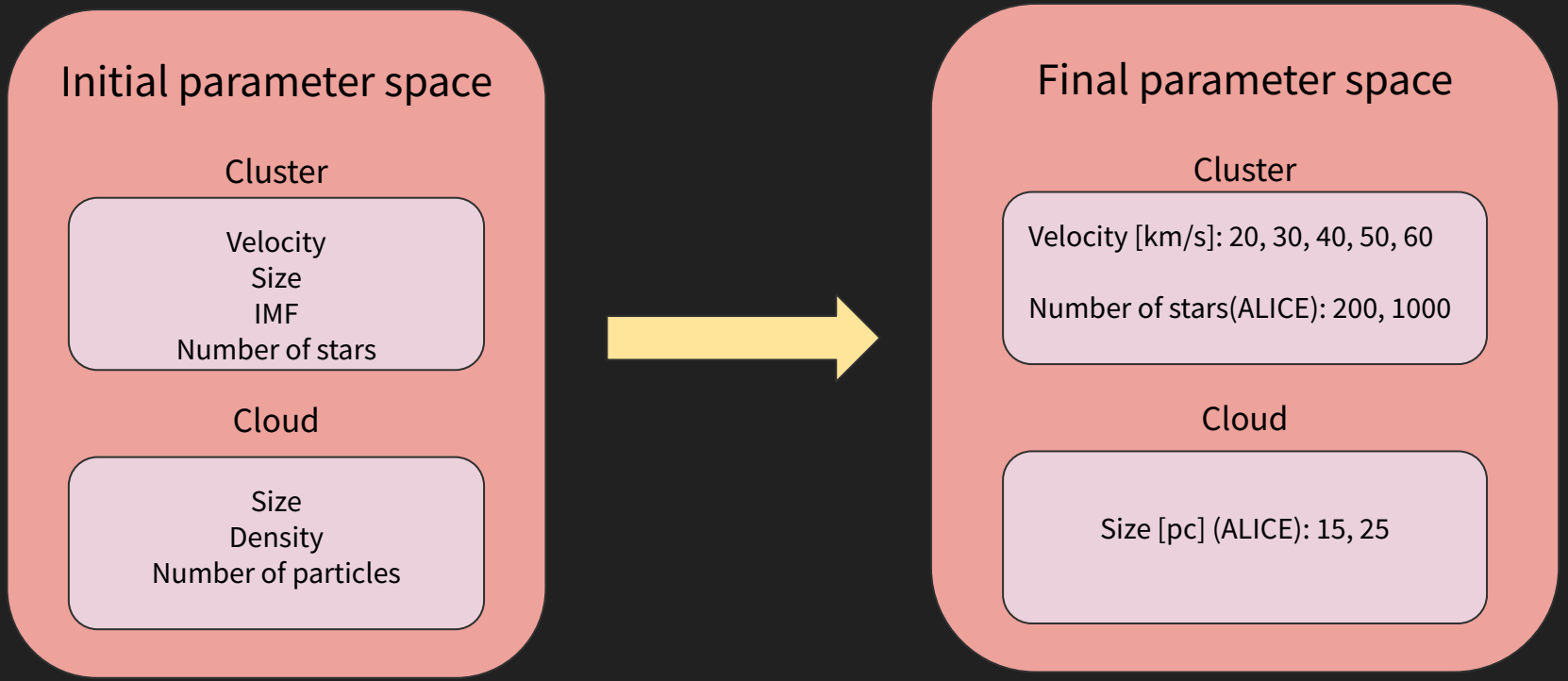
Caused by collisions between molecular clouds (MCs) and globular clusters (GCs)

- MCs are located around the spiral arms in the Galactic plane
- Rejuvenation of stars due to mass accretion





Parameter Reduction



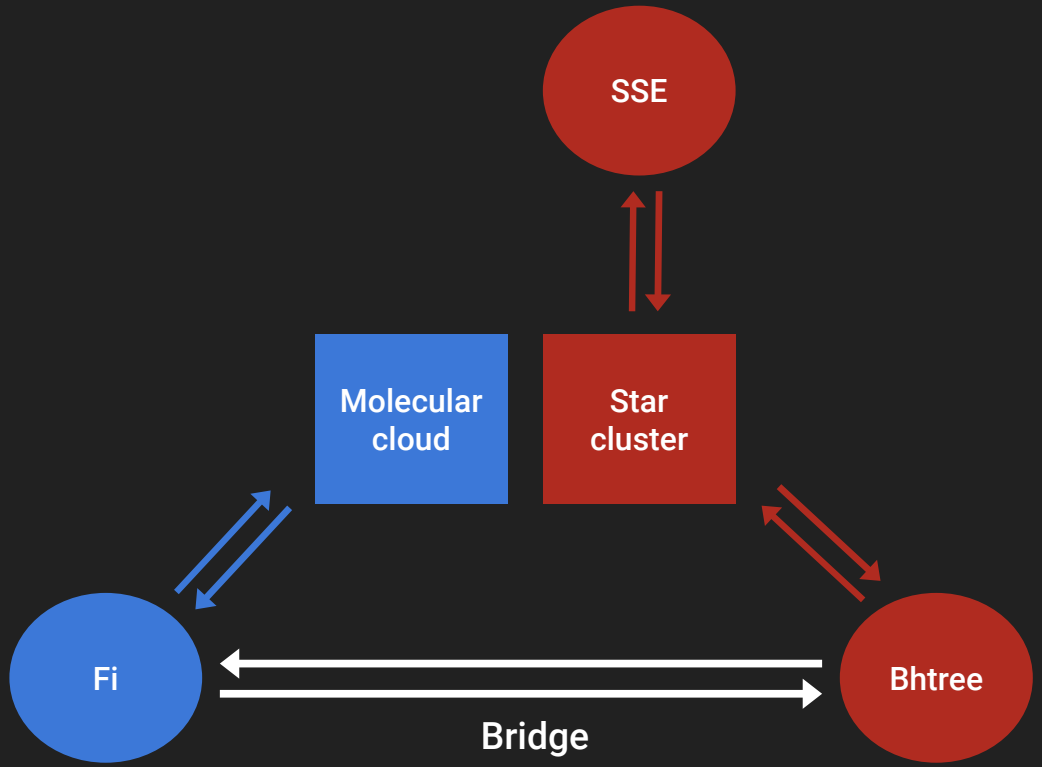
Setup & Initial conditions

- Hydrodynamic cloud
  - Fi
- Gravitational interaction
  - BHTree
- Stellar Evolution:
  - SSE
- Sink particles for accretion

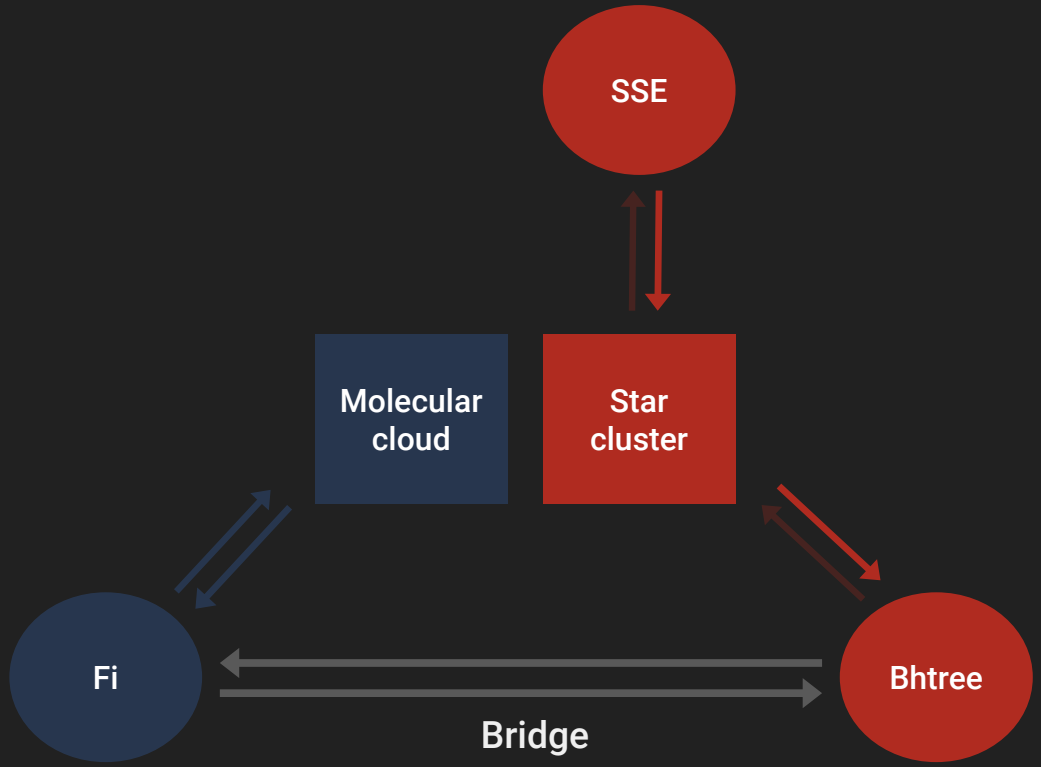
- Molecular cloud
  - Age = 2 Myr
  - Density = 10 amu/cm^3
  - SPH particle < 0.06 MSun
- Globular cluster
  - Kroupa IMF
  - Core radius = 4 pc
  - Metallicity = 0.002
  - Age = 10 Gyr

Implementation - Bridge and channels

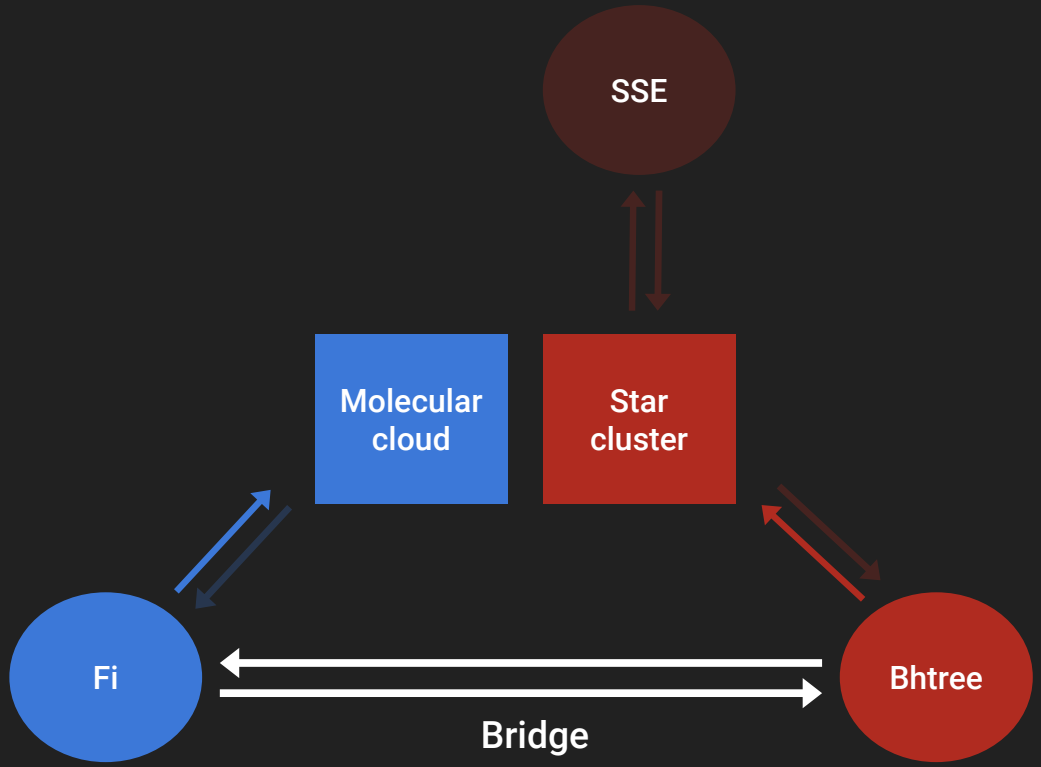
- Hydrodynamics
  - Timestep = 0.1 Myr
- Bridge
  - Timestep = 0.10.2 Myr
- Evolution
  - Timestep = 0.1 Myr



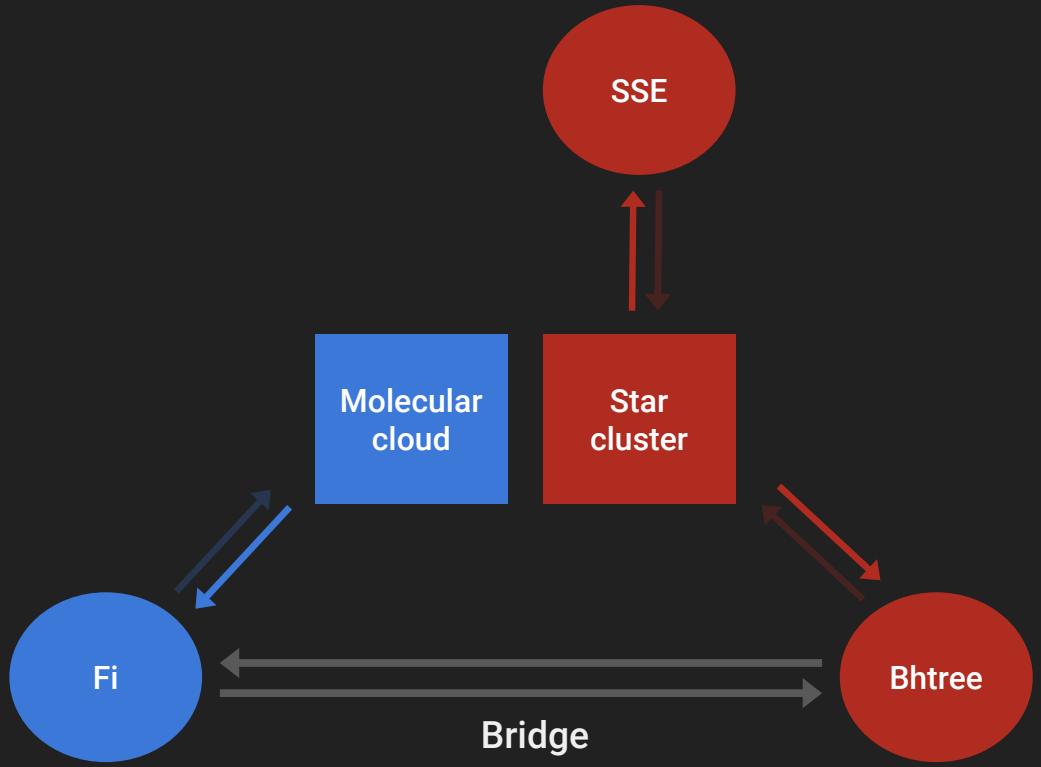
Bridge and channels - Stellar evolution



Bridge and channels - Bridge



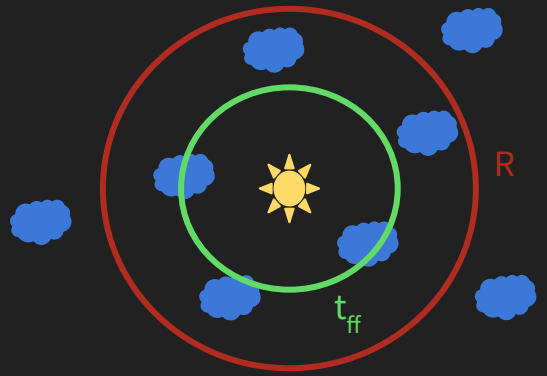
Bridge and channels - Accretion



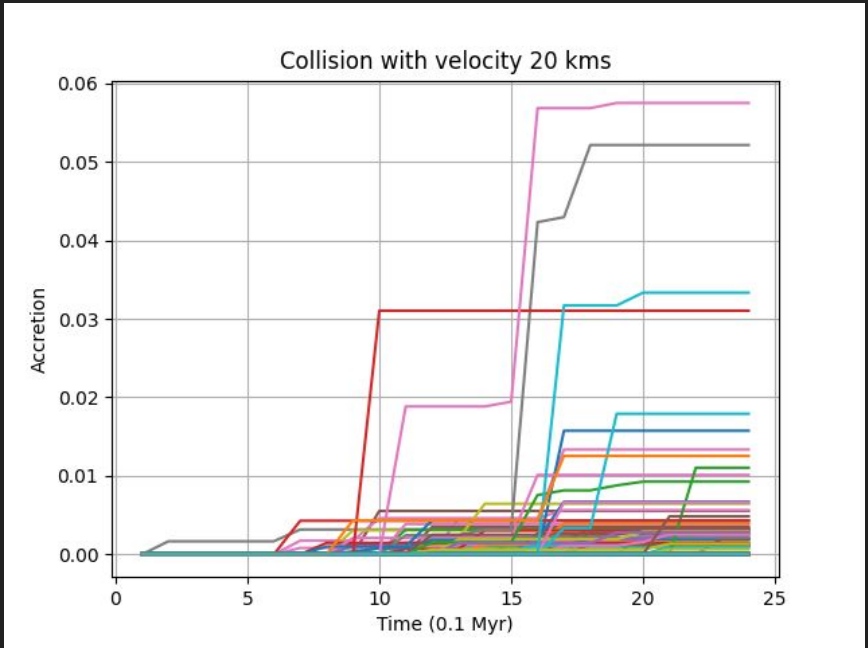
Accretion implementation

Sink particles accretion criteria:

- Bondi radius $R = \frac{2GM}{c_s^2}$
- Gravitationally bound gas particles (hard binaries)
- Free-fall time t_{ff}

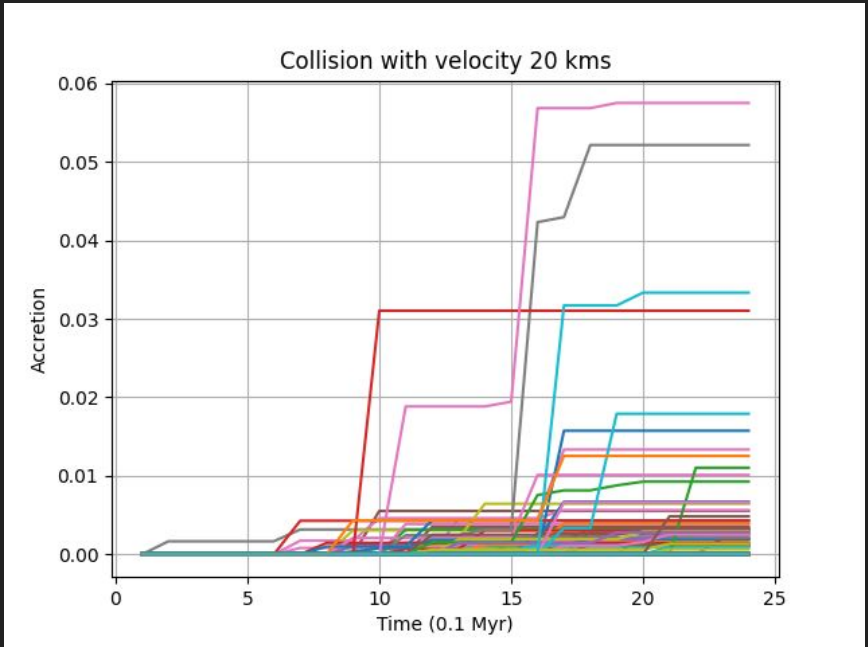


Results

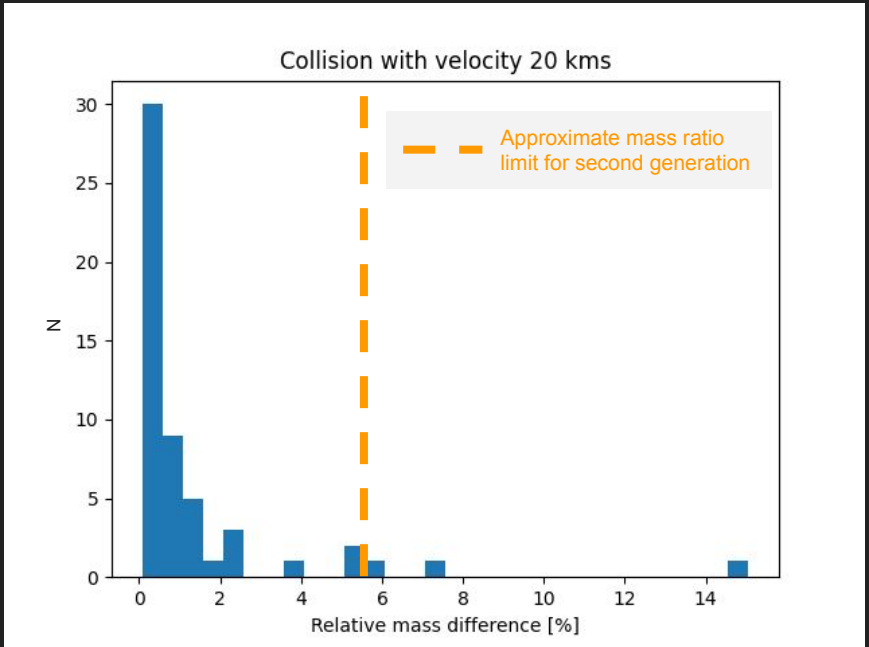


Accreted mass [Msun] for each star, with respect to time.
Only stars that accreted mass are shown.

Results

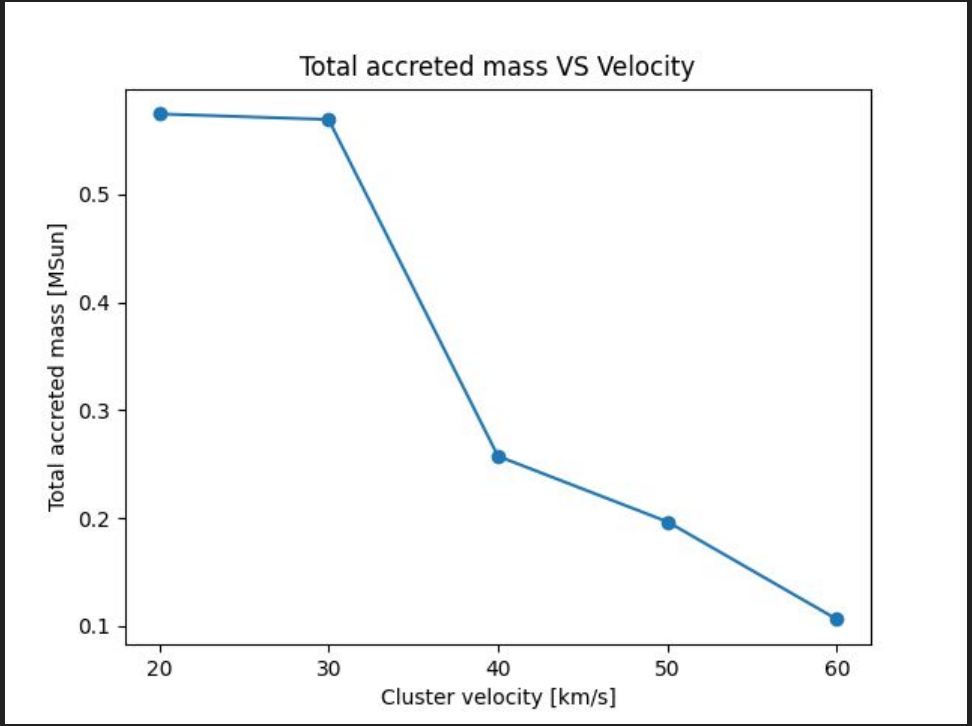


Accreted mass [Msun] for each star, with respect to time. Only stars that accreted mass are shown.



Histogram of the relative accreted mass. Only stars that accreted mass are shown.

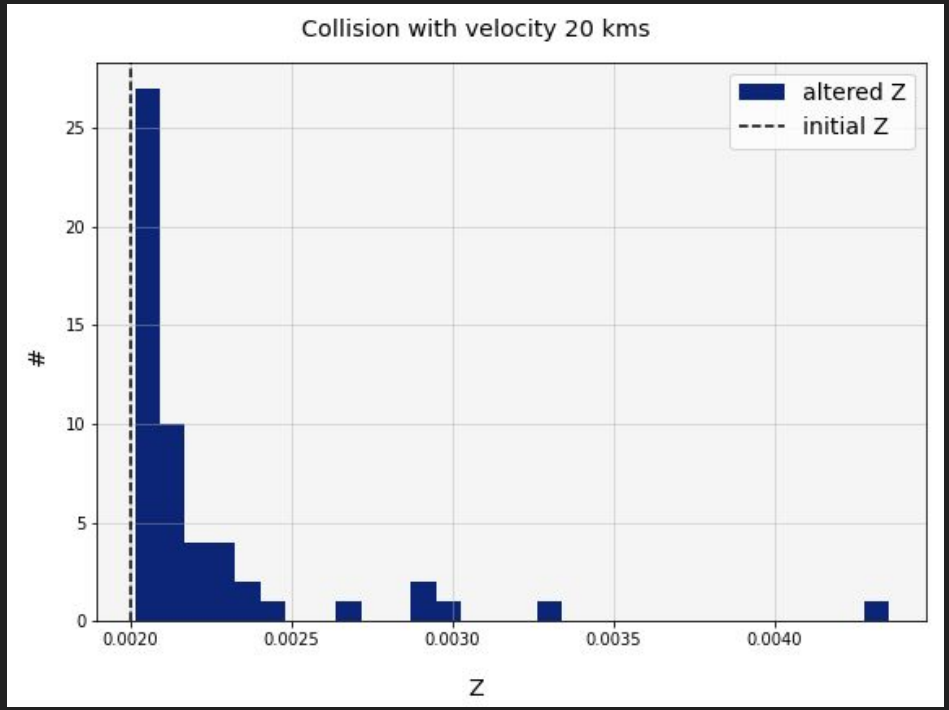
Results



Total accreted mass in the GC after one passage, with respect to the impact velocity.

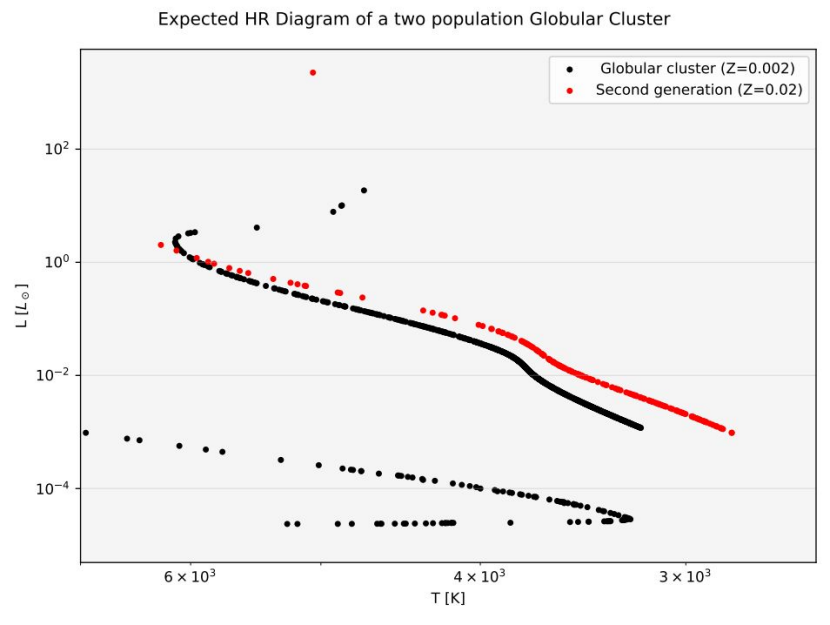
Discussion

- Molecular Cloud: Z = 0.02
- Globular Cluster : Z = 0.002
- Known accreted mass ⇒ known metallicity



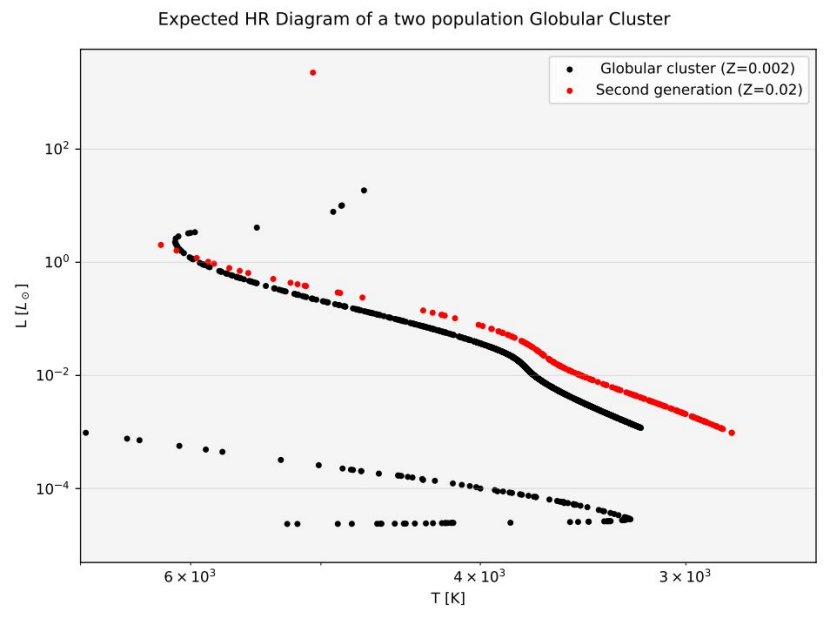
Simulation run with 100 stars and collision velocity of 20 km/s

Expectation

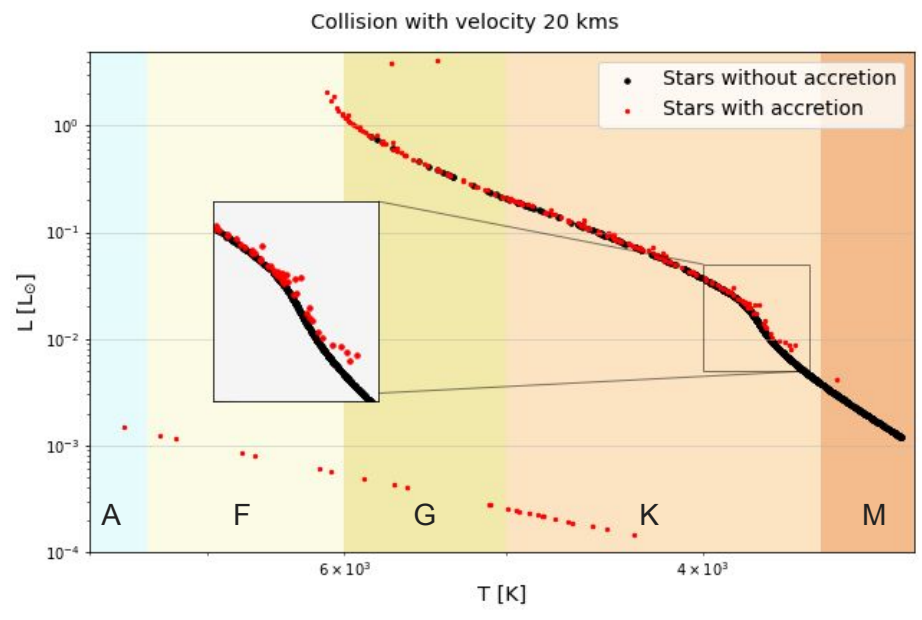


Project proposal

Expectation vs Result

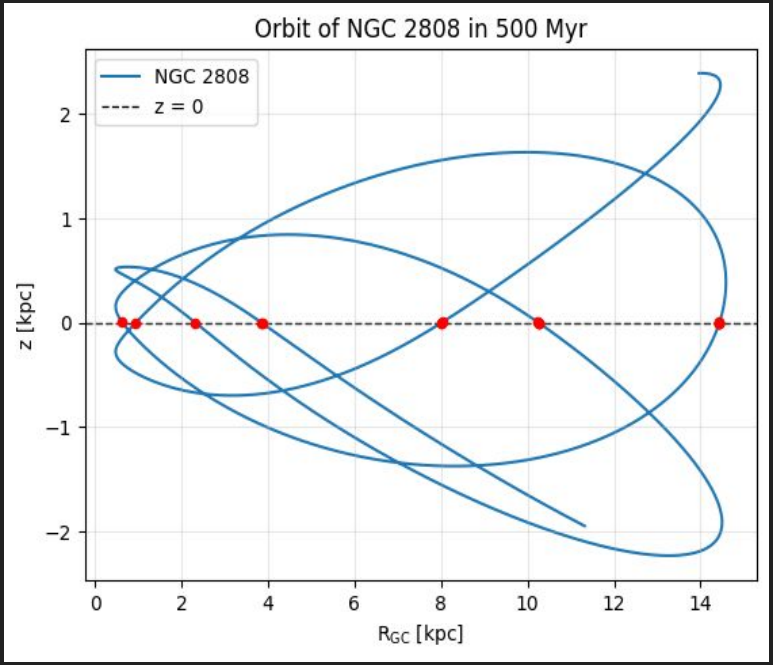


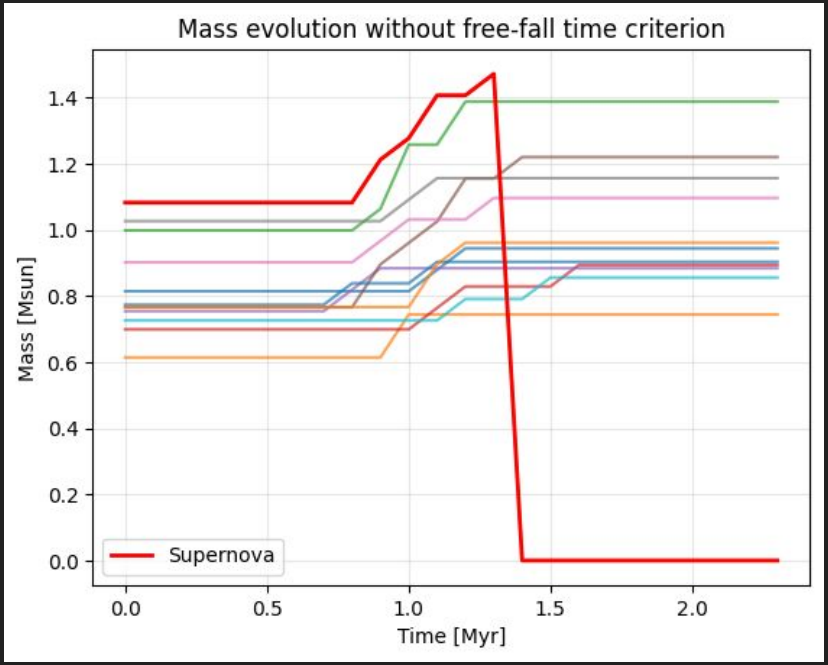
Project proposal



Simulation run with 1000 stars and cluster velocity of 20 km/s

Discussion


Orbit of NGC 2808 in 500 Myr
NGC 2808
z = 0
z [kpc]
R_{GC} [kpc]


Mass evolution without free-fall time criterion
Supernova
Mass [Msun]
Time [Myr]

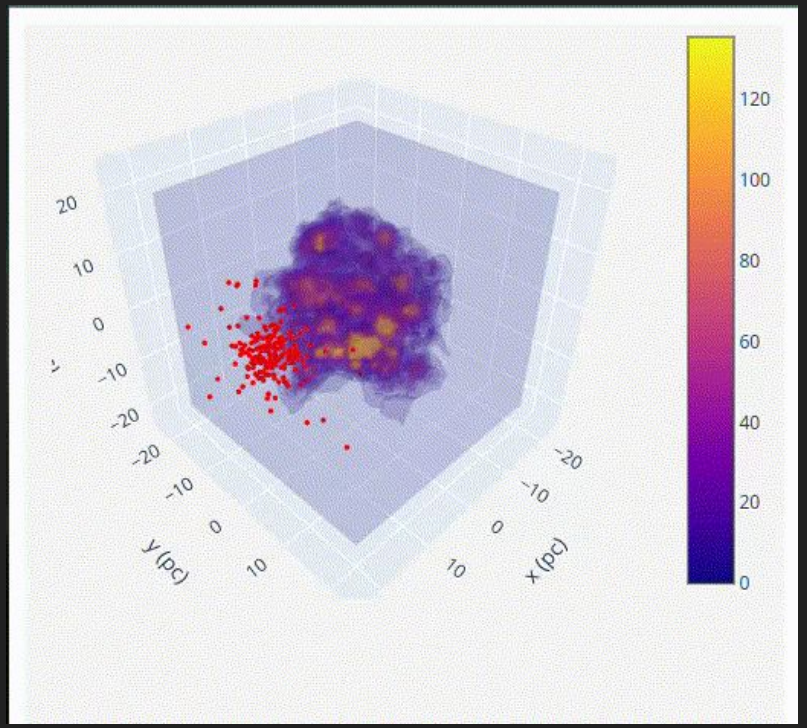
Future work

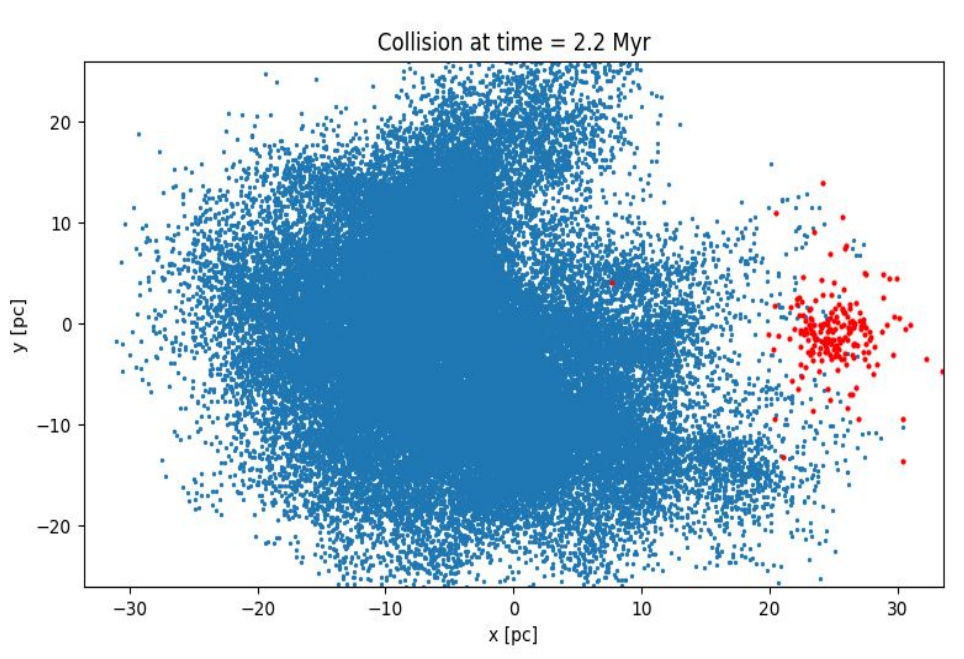
- Convergence test with temporal resolution
- Simulate for multiple collisions
- Other theories
  - Stripping stars from MC
  - Star formation triggering in MC

References

- Milone, A. P. and Marino, A. F., “Multiple Populations in Star Clusters”, Universe vol. 8, no. 7, p. 359, 2022.
- Bastian, N. and Lardo, C., “Multiple Stellar Populations in Globular Clusters”,Annual Review of Astronomy and Astrophysics, vol. 56, pp. 83–136, 2018.
- Piotto, Giampaolo, et al. "A triple main sequence in the globular cluster NGC 2808." The Astrophysical Journal 661.1 (2007): L53.
- Dame, Thomas M., Dap Hartmann, and P. Thaddeus. "The Milky Way in molecular clouds: a new complete CO survey." The Astrophysical Journal 547.2 (2001): 792.

Thank you for your attention




Collision at time = 2.2 Myr
y [pc]
x [pc]
20
10
0
−10
−20
−30
−20
−10
0
10
20
30