3D massive star formation models with detailled sink particles description

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Context

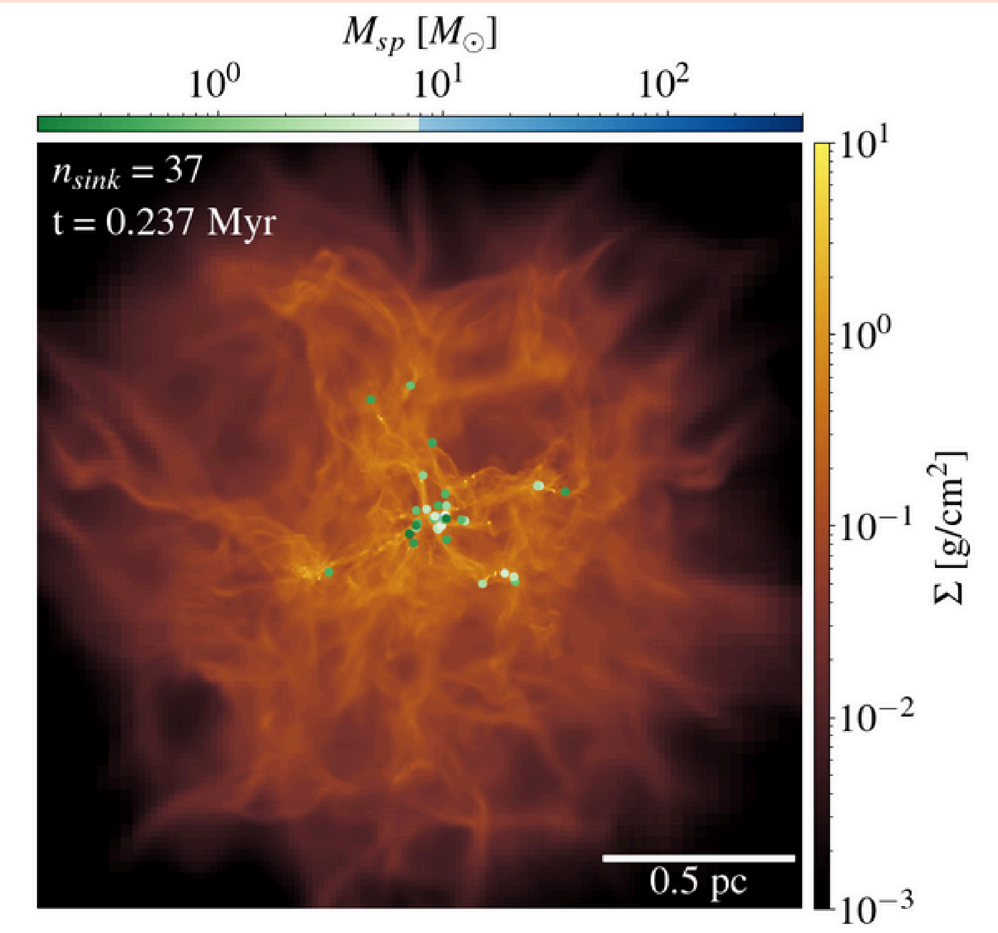
The study of stars with masses > 8 $M_\odot$ is still an active research topic despise century of stars observation.

- They produce powerful **feedback**: wind, ionizing radiation...
- Their death produce the most energetic event in the universe, the **Supernovae explosions** (SNe).
- **They shape the galaxy** and its evolution, by **modulating the efficiency at which other stars form.**

Their formation mechanism is poorly constrained and hard to observe

- Due to their **rare nature** compare to low mass stars.
- They **evolve faster** than lower mass stars.
- The accreting protostar is completely **embeded** in gas and dust which makes it impossible to observe at the earliest stage.

Hence, we generally use models to study their formation mechanisms.



3D MHD simulation

- **Dense core,** 10^3 $M_\odot$ for **1 pc radius**, collapsing and forming massive stars.
- **FLASH code** (Fryxell et al. 2000): 3D magnetohydrodynamics (MHD), Adaptive Mesh Refinement (AMR) grid.
- Feedback mechanisms from the stars: **radiative feedback of non ionizing and ionizing radiation** and **radiation pressure**.
- Stars are modeled as **sink particles** and can only represent one single star.

We know that the majority of **massive star are in binary or higher order of systems**. Thus, only considering single stars could lead to **overestimating the feedback** and **faster cloud disruption than anticipated** (Zimmermann et al. in prep). A **model enabling the formation of binary systems** in the simulations becomes necessary.

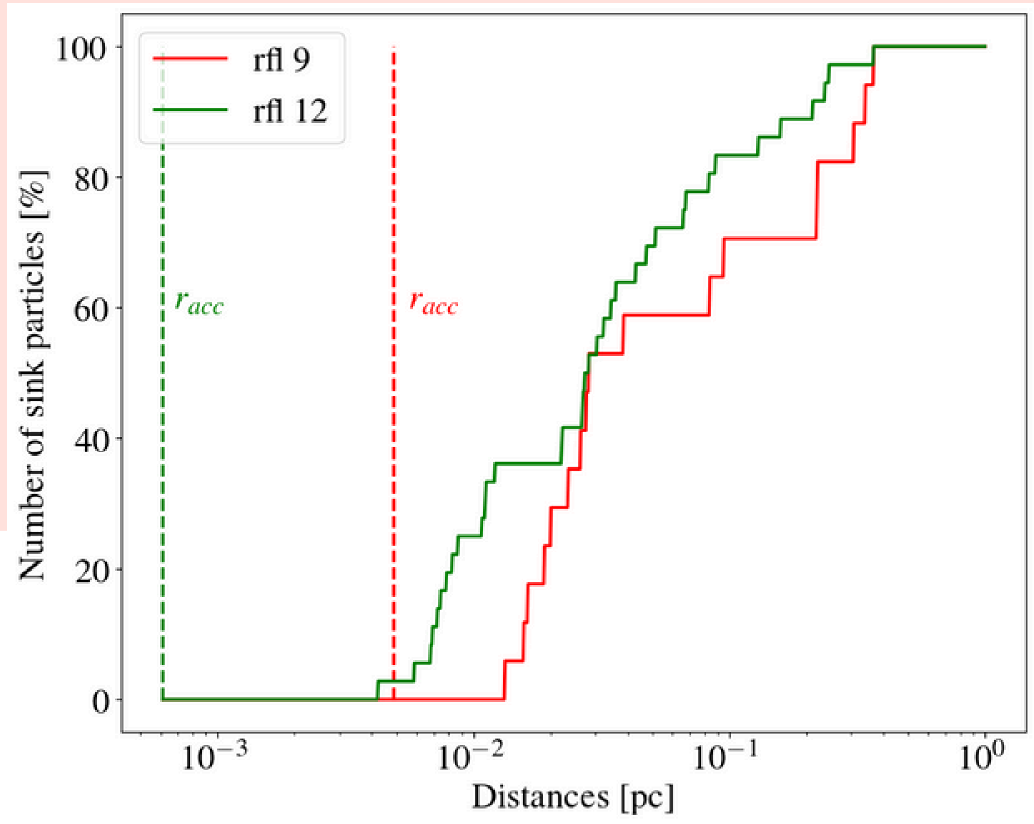
Slice of the 3D simulation: Column density 0.237 Myr after the collapse of the dense core, of 50 au resolution, from Zimmermann et al. in prep. The dots represent the sink particles.

Fragmentation of the core

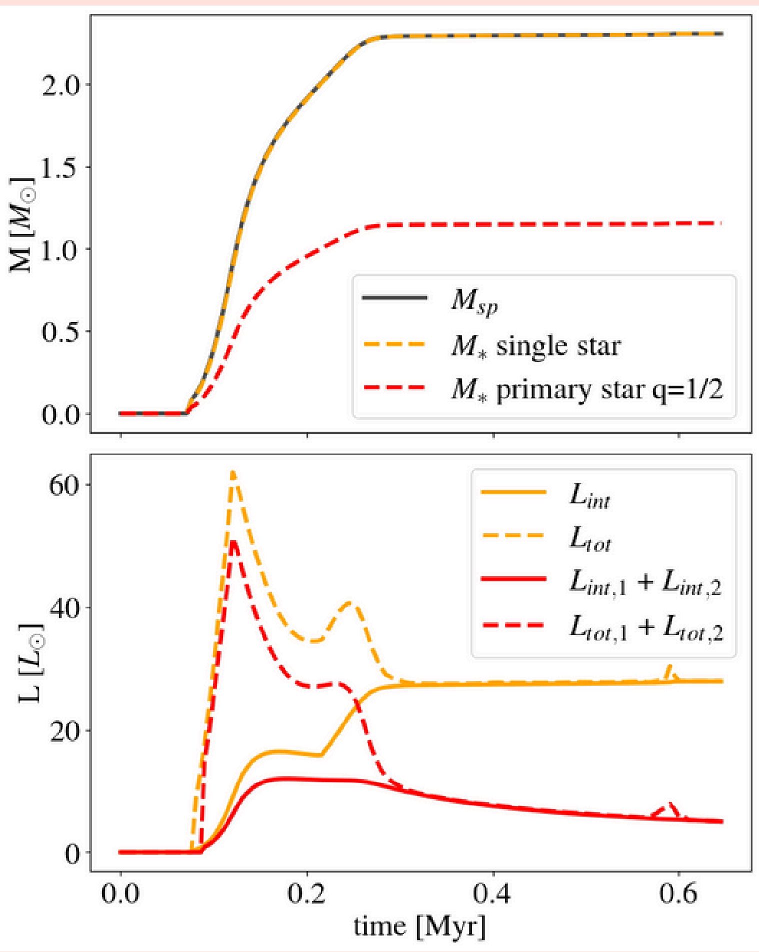
By studying the simulations, we want to understand the **fragmentation history** of the core also depending on **the refinement level (rfl)**.

- **Mass distribution** in the core.
- **Distances between the stars trhough a Maximum Spanning Tree (MST) analysis.**

This already give us an idea on how the **fragmentation** and the **formation of binary systems** would accure with an infinity resolution.



Cumulative MST: the cumulative distribution of the edge lengths derived from a MST analysis of the sinks at the end of the 12 rfl simulation. The green curve is above the red curve meaning that sinks from the rfl 12 simulation are closer to each other, the core is a bit more clustered than for rfl 9 simulation.



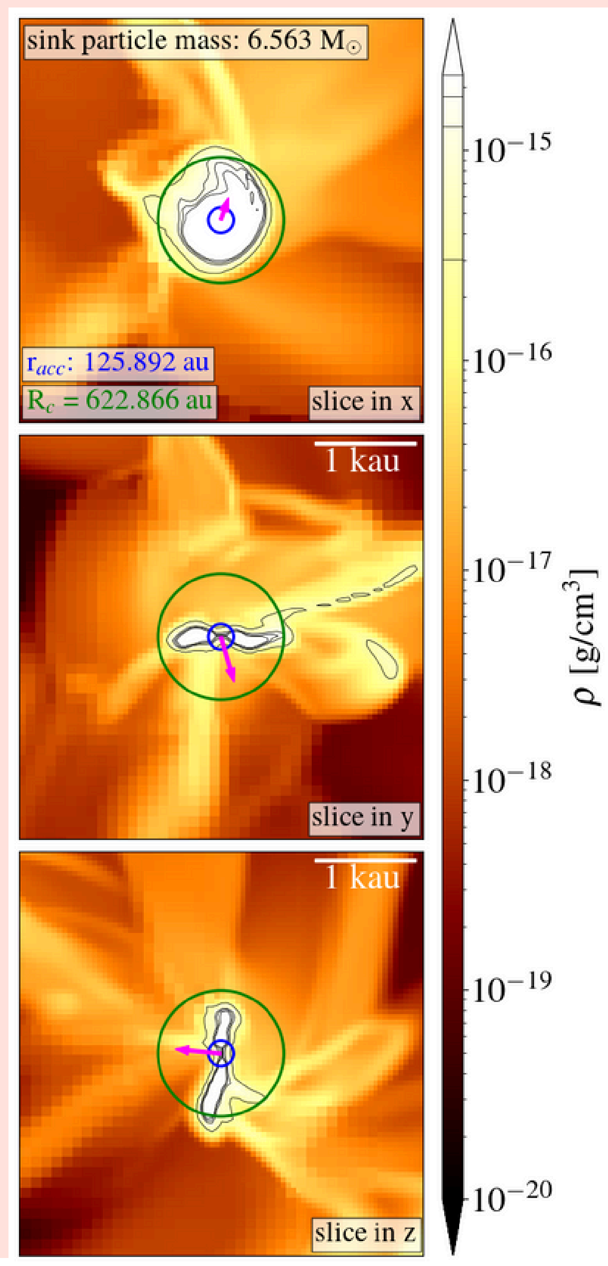
Simple binary model for the sink particles

As a first test to study the **evolution of the core with the presence of binaries** I implemented a **simple binary model in FLASH**

- **The sink particle describe a binary from the time its created.**
- **Same mass binary** i.e. q = 1/2.
- The **luminosity and the feedback are recomputed** to fit a binary.

The **luminosity is divided by 8** compared to the single star. On the bigger simulation we expect to see a huge difference.

Binary stars Luminosity: *Top*, mass of, the sink particle, the single star, and the primary star of the binary system. *Bottom*, luminosity coming from the two systems.



Conclusion and Prospect

Our goal, in the A5 project of the SFB1601, is to improve our understanding of massive star formation by **detailing the close surroundings of massive protostars**, in larger scale simulations. The next step will be to describe the star and its disk thanks to a **subgrid model**.

Zoom onto one sink particle: Density around a sink particle in the same simulation as the first figure. The resolution is high enough to resolve the outer disc. The blue circle is the size of the sink particle and the green one is the supposed size of the disk.

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