Effects of Early Forming Massive Stars

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- What about *when* massive stars form? Using our computational model we test the effects of early forming massive stars.

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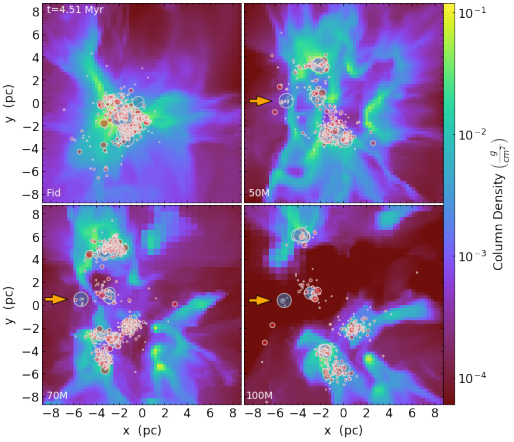
Torch

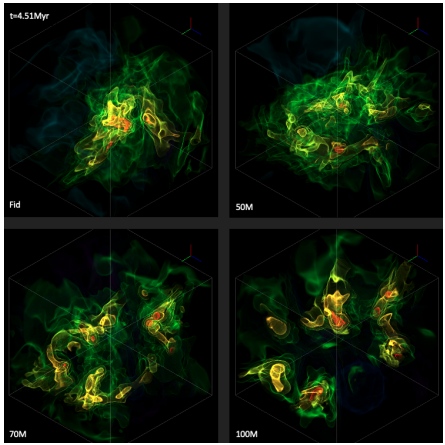
Stars from gas

- Couples N-body, stellar evolution, and feedback in `AMUSE` with self-gravitating magnetized gas in MHD code `FLASH`.
- Resolved dynamics of stars and gas; study star cluster formation within collapsing GMCs.
- Form stars from sink particles which each have a randomized star mass list sampled from the Kroupa (2001) IMF.

A Controlled Experiment



Lewis et al. in prep



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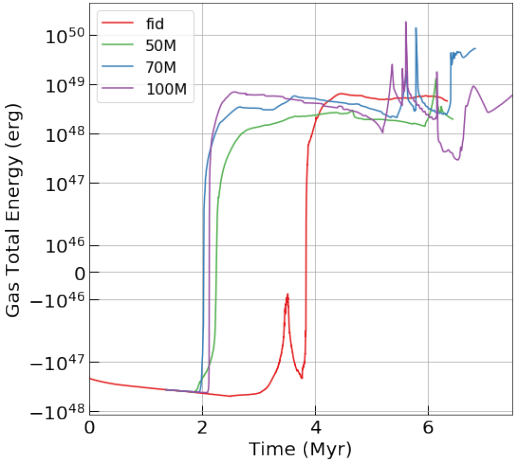
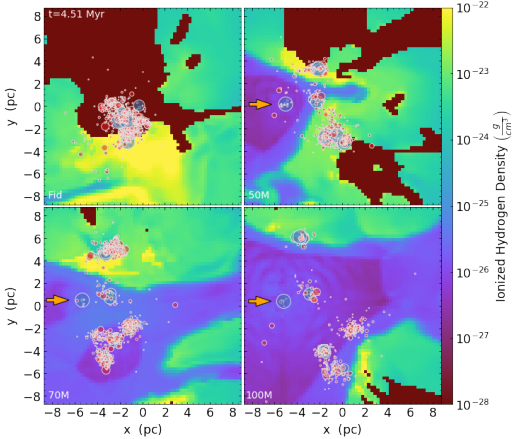
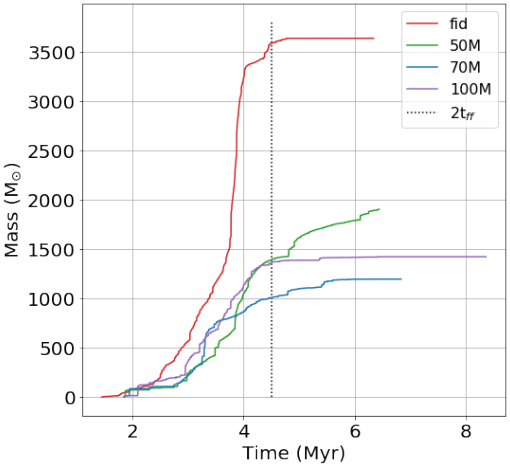
Effects on Gas





Effects on Gas Accretion and Star Formation



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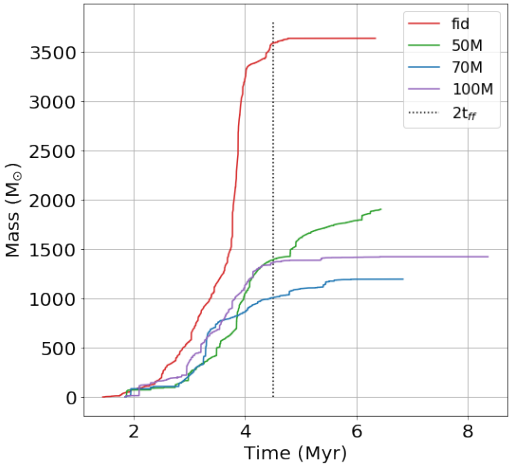
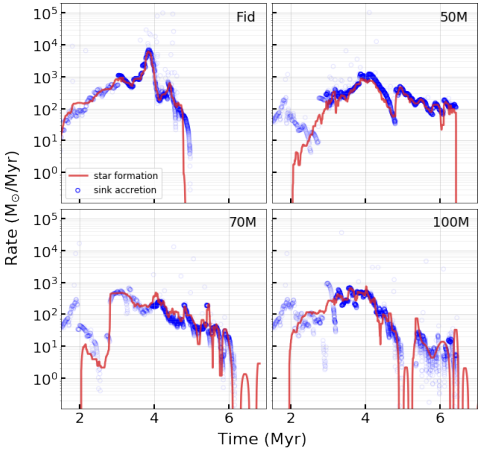


Without early forming massive stars,

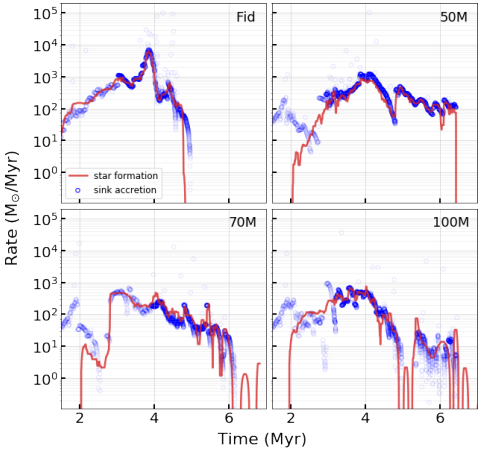
- More gas is converted to stars.
- More stars form more quickly.

Effects on Gas Accretion and Star Formation



Early forming massive stars reduces sink accretion and star formation rates.

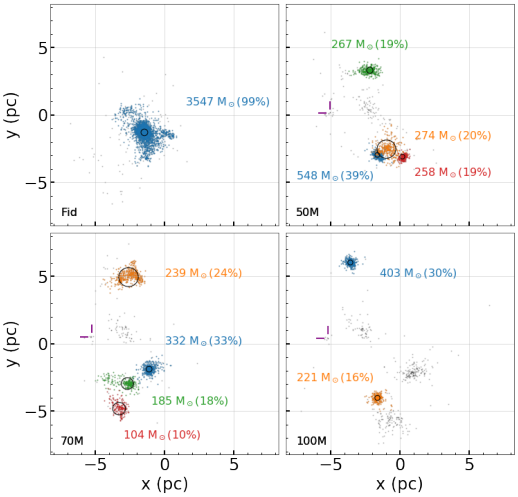
Effects on Gas Accretion and Star Formation



Early forming massive stars reduces sink accretion and star formation rates.

Run	$\langle \epsilon_{ff} \rangle$
Fid	0.23
50M	0.08
70M	0.03
100M	0.04

Effects on Star Clustering, Cluster Assembly



- blah
- blah

Run	Mass in Clusters $10^3\ M_\odot$	Frac Mass M_c / M_{tot}	r_h MMC pc	E_{bind} MMC 10^{46} erg
Fid	3.6	0.99	0.25	-140
50M	1.4	0.97	0.17	-12
70M	0.86	0.85	0.21	-4.2
100M	0.62	0.46	0.18	-3.8

Effects of Early Forming Massive Stars

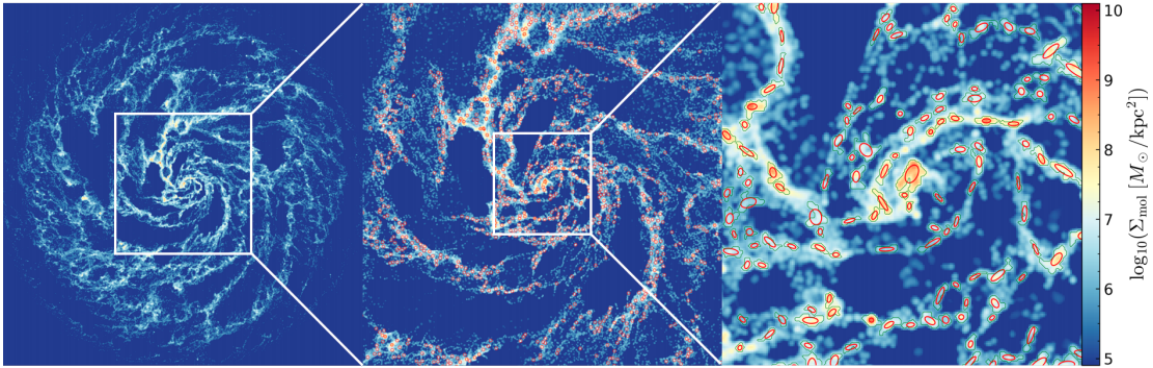
- Significantly disrupt the natal gas structure, resulting in fast evacuation from the star forming region.
- The star formation rate is suppressed, reducing the total mass of stars formed.
- Early forming massive stars stifle the hierarchical assembly process of massive star clusters, instead promoting the formation of spatially separate and energetically unbound subclusters.

The Problem with Initial Conditions

- Self consistent galactic scale simulations with resolution down to sub-tenth parsec scales and include Nbody individual stellar dynamics and individual stellar feedback all at once? A little tough.

- Creating our own isolated clouds from scratch? "Creative liberties..."

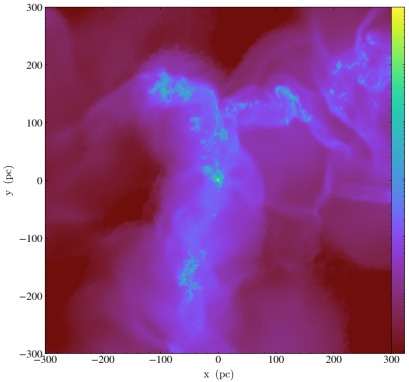
Clouds from Galactic Simulations



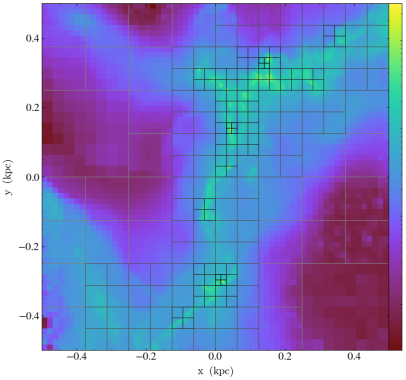
GMC identification [Li, H. et al. 2020]

From AREPO to FLASH

Try CIC Mapping?



Cloud from raw AREPO data represented using SPH kernels



Cloud-in-cell mapping onto AMR FLASH grid

Voronoi Mesh to AMR Grid

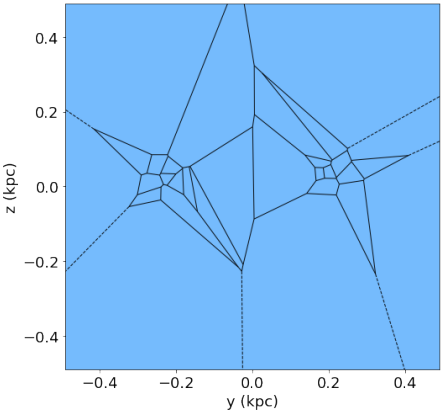


Figure: Voronoi mesh from 20 points

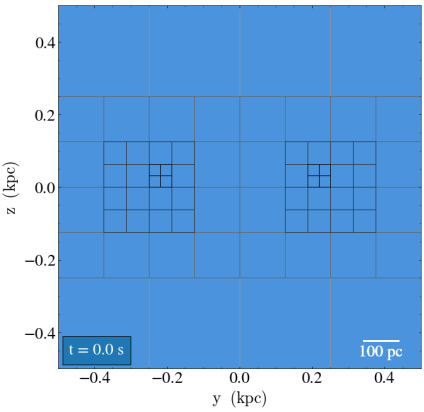
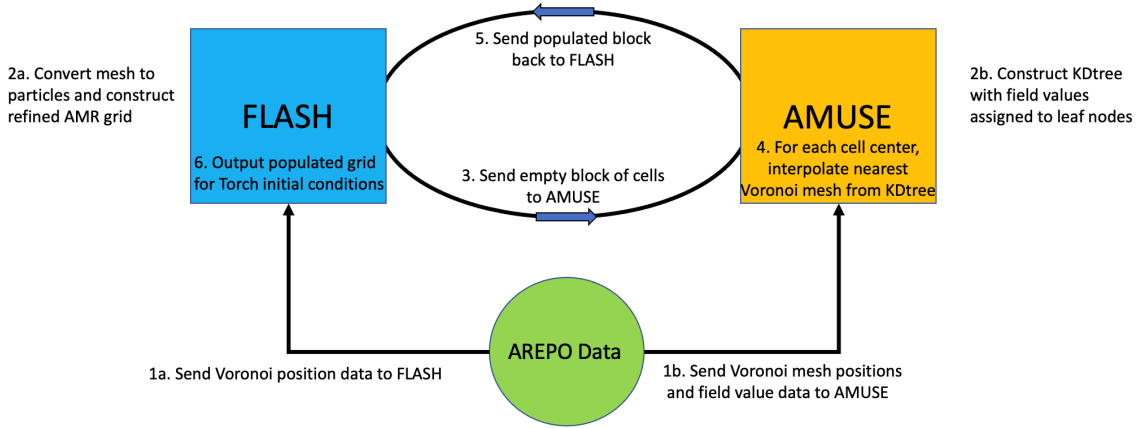


Figure: AMR grid from 20 points

VorAMR: Logic path



VorAMR: The Big Wins

- Significantly expands Torch's horizon and moves Torch to "completion".
- Opens wide avenue of collaboration; code bases do not have to be exclusive!
- More accurate visualizations (no more estimating Voronoi meshes as SPH kernels in `yt`).

Thank You!

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Questions?

Appendix

$$\epsilon_{\mathrm{ff}} = \dot{M}_* \frac{t_{\mathrm{ff}}}{M_{\mathrm{g}}} \tag{1}$$