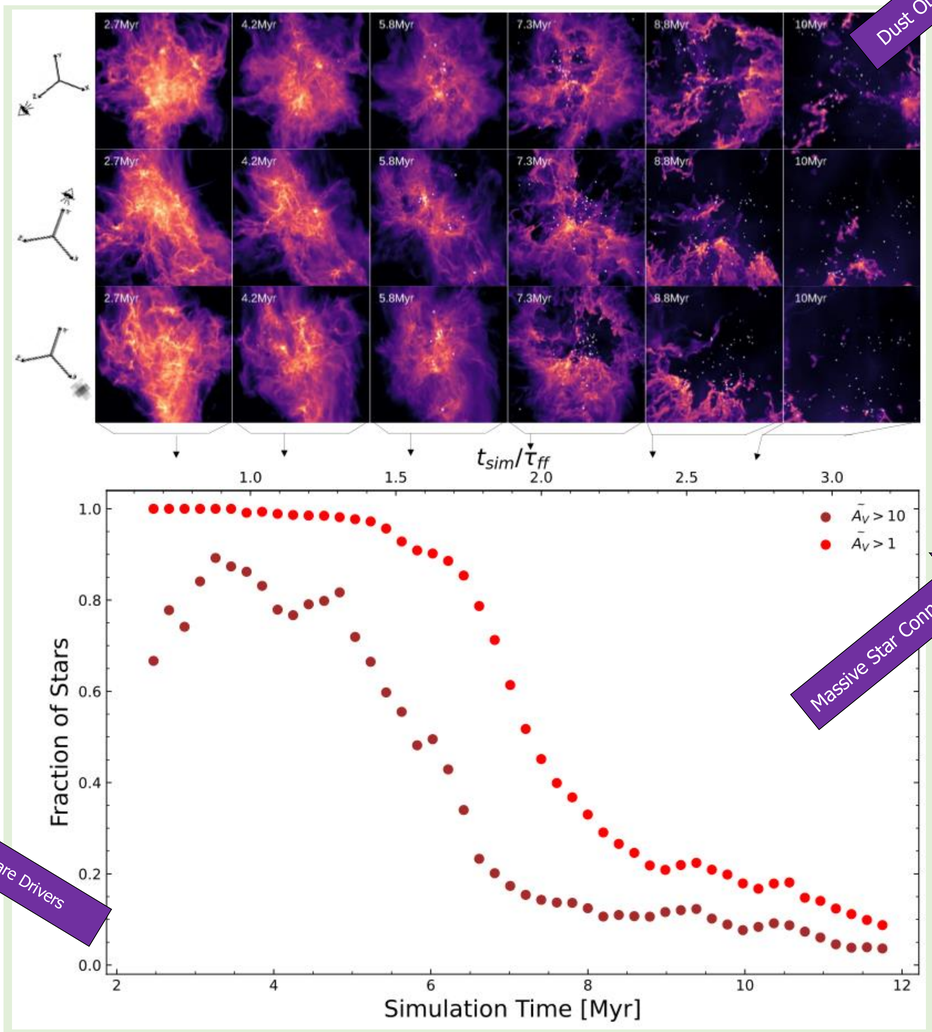
# Timescales of Embdedded Star formation in STARFORGE


## Tobin Wainer[1], Mike Grudić[2], Julianne Dalcanton[1,2]

1: University of Washington;
2: Center for Computational Astrophysics


## 1) The embedded stage of formation is brief, lasting only a few Myrs.



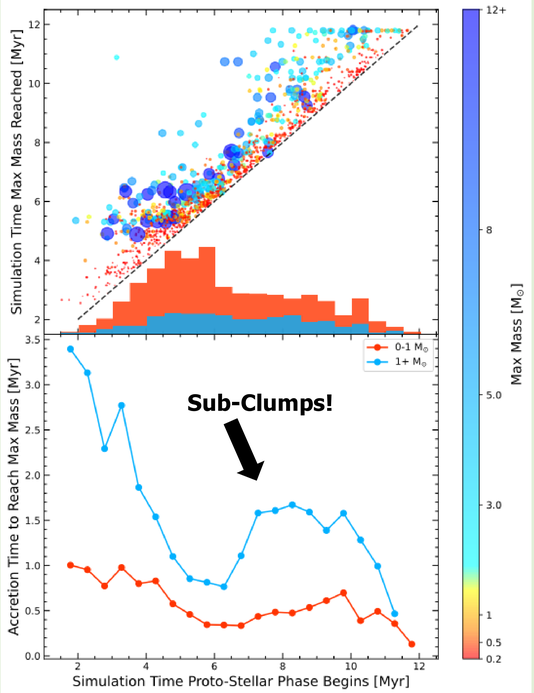

**The transition from embedded to non-embdedded also happens quickly, driven by the most massive stars.**
Top: Snapshots from six simulation times: different rows correspond to three different viewing angles. Gas surface density is shown in the color map, and stars rendered with a standard HST PSF. Stellar magnitudes are determined by considering the line-of-sight gas column density. Below is a scatter plot showing the fraction of stars with a median $A_v$ greater than 10 (brown), and 1 (red) as a function of simulation time, where the median is defined by 60 different viewing angles.

Dust Observability

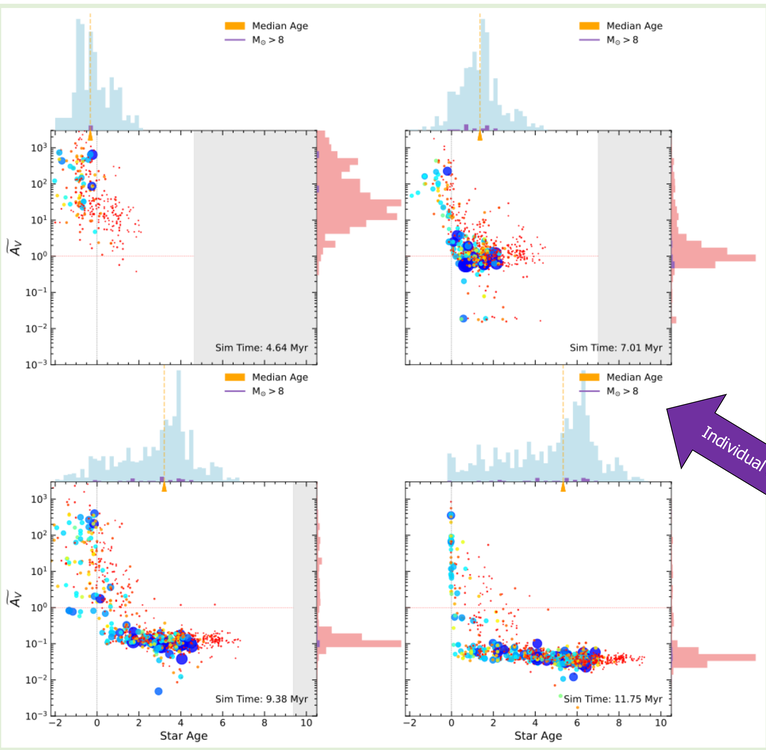
Individual Stars are Drivers

Massive Star Connection

## 2) The drop in extinction is driven by transitions experienced by individual stars.

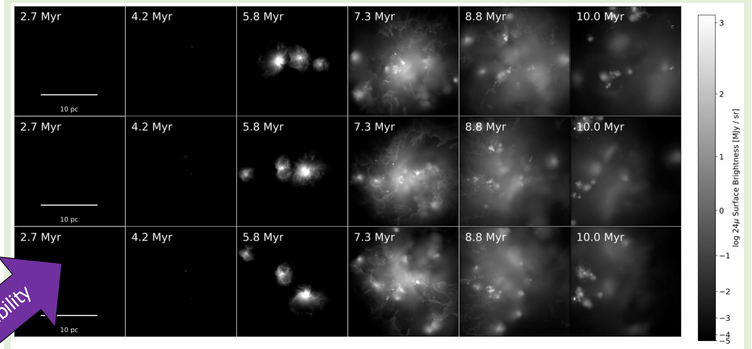



**Stellar Accretion times vary as a function of stellar mass, and formation time, and stars form across 10 Myrs.** The top panels shows each individual star, colored by its final mass, and the simulation time where that mass occurs. The bottom panel splits the sample into two bins, one for stars below 1 $M_\odot$, and one for stars larger than 1 $M_\odot$ and shows the average time it takes for the stars in the bin to achieve their maximum mass. In both bins, but specifically for the larger stars, the accretion time is dependent on simulation time, which encodes the gas density.



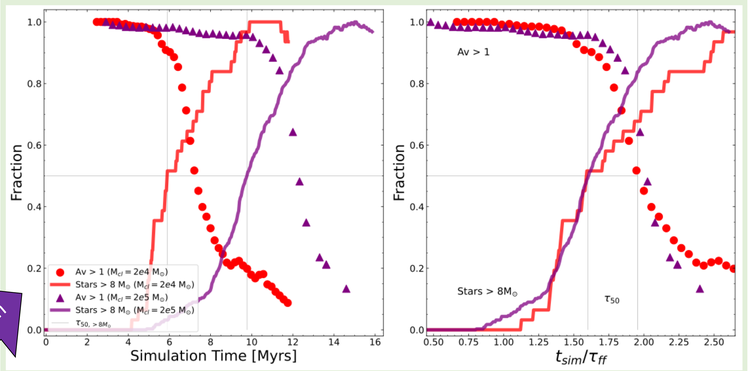

Stars all begin their lives with a high level of extinction, due to being embedded within their surrounding molecular cloud. The stars then experience a sharp, rapid decline in their typical extinction when they reach their maximum mass and stop accreting. As a result, the overall evolution of cluster embedding is a reflection of this individual evolution, convolved with the history of star formation within the cluster. **Individual stellar extinction tracks do *not* depend on when the star formed.**

## 3) Mid-IR View of Formation




**Intrinsic 24μ surface brightness: The IR luminosity from dust emission peaks before 20% of the stellar luminosity escapes and is visible.**

## 4) Timescales of Embdeddness Evolution Scale with Cloud Free Fall Time




**The fraction of highly embedded stars begins to drop precipitously at the point where 50% of the massive stars form, which equates to 1.6 free fall times, independent of cloud mass.** Shown is the comparison between two STARFORGE simulations, differing in molecular cloud mass. The fiducial 2e4$M_\odot$ cloud is shown in red, while the 2e5$M_\odot$ cloud is shown in purple. The solid lines show the fraction of stars greater than 8 $M_\odot$ which have begun their proto-stellar stage. The middle panel shows the same as the left, but is normalized by the respective cloud free-fall times, demonstrating that the start of emergence is related to initial cloud mass and density.


### Acknowledgements:
This work was completed as a part of the pre-doctoral fellowship at the Center for Computational Astrophysics. TW thanks the Flatiron Institute and the Simons Foundation. The Flatiron Institute is funded by the Simons Foundation.



### References:
- Grudić et al. 2021, MRNAS, 506, 2199G



tobinw@uw.edu
University of Washington