Only the Special Survive: Star Cluster Disruption in Galaxy Simulations

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Introduction

- **Star clusters** are groups of stars (10^4) that are born together and are bound by gravity, many of which are found in the disk of our own galaxy, the **Milky Way**
- The majority of stars in disk galaxies are born in star clusters (including our sun ☀)
- Studying these star clusters reveals essential information about **the rich history of our Galaxy**, as we can measure their age and their chemical composition independently

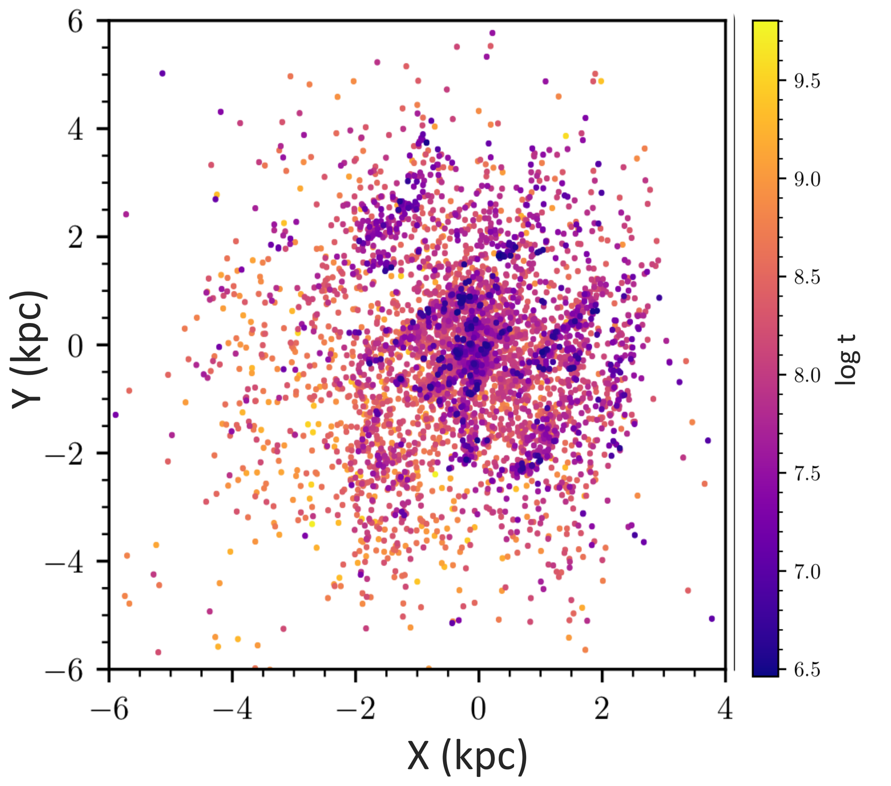


Figure 1: Top-down view showing the locations of star clusters that can be found in the disk of the Milky Way galaxy. Star clusters are often used as a tool to understand the history of our galaxy. Credit: (Hunt et. al 2018)

Simulations

What star clusters am I studying, and why?

- While some clusters interact with their environment, causing them to fall apart, other star clusters remain bound for billions of years
- To investigate why some star clusters get disrupted while others do not, I will track their trajectories through cosmic time in zoom-in Milky Way-like cosmological simulations
- These **simulations** maintain large scale environmental effects (e.g. galactic bars, spiral arms, gas inflow), while simultaneously resolving small scale star formation and dynamics like those seen in star clusters (Figure 2).

Figure 2: large-scale gas distribution (left), face-on (middle) and edge-on (right) real-color stellar image of a FIRE cosmological simulation of a Milky Way-mass galaxy. Credit: Andrew Wetzel

Specifically, we:

- **Track individual star clusters** over time & in different environments
- **Calculate properties of stars** within each cluster, such as age, chemistry & velocity
- **Compare to observations** to strengthen our understanding of the fundamentals of galaxy formation

FIRE: Feedback In Realistic Environments

- I work with galaxies generated using the Feedback In Realistic Environment code (FIRE) (Hopkins 2016, 2018)
- **FIRE is a Lagrangian code**: it tracks the location of particles as they flow through a volume over time
- These simulations are seeded from **initial conditions soon after the Big Bang**, and are evolved using hydrodynamics and the force of gravity
- Each simulation contains dark matter and gas particles, then stars form when gas reaches appropriate temperature and density
- I use the ***Latte* suite of FIRE-2 galaxies** (Wetzel, 2016), all of which are Milky Way-like galaxy simulations

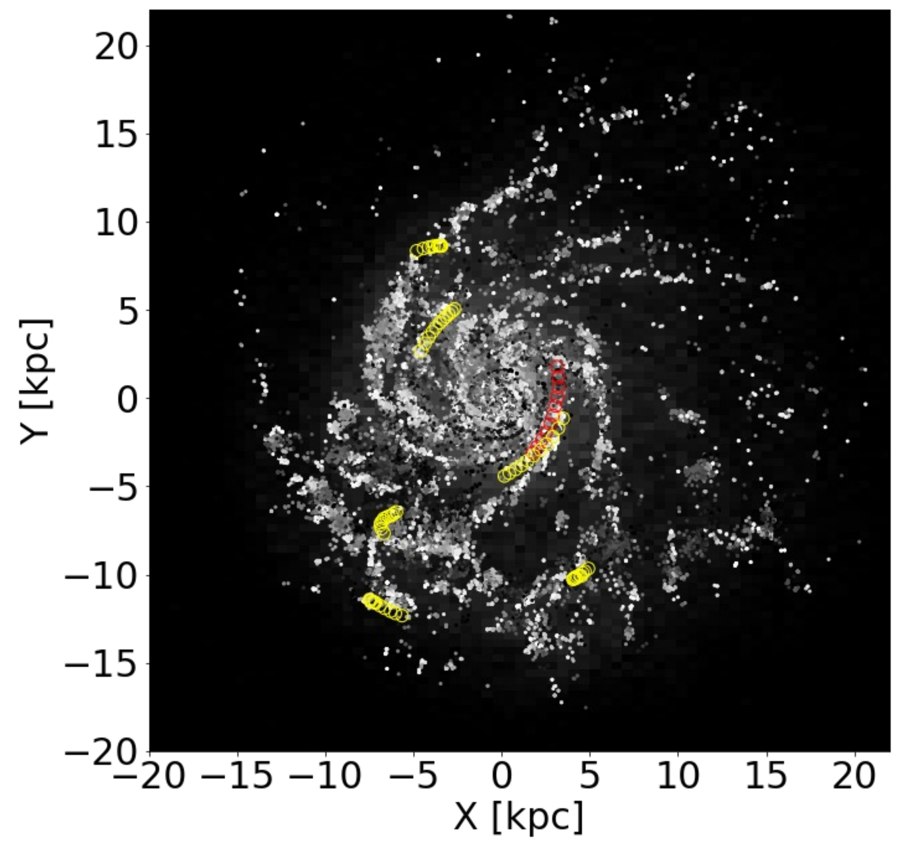
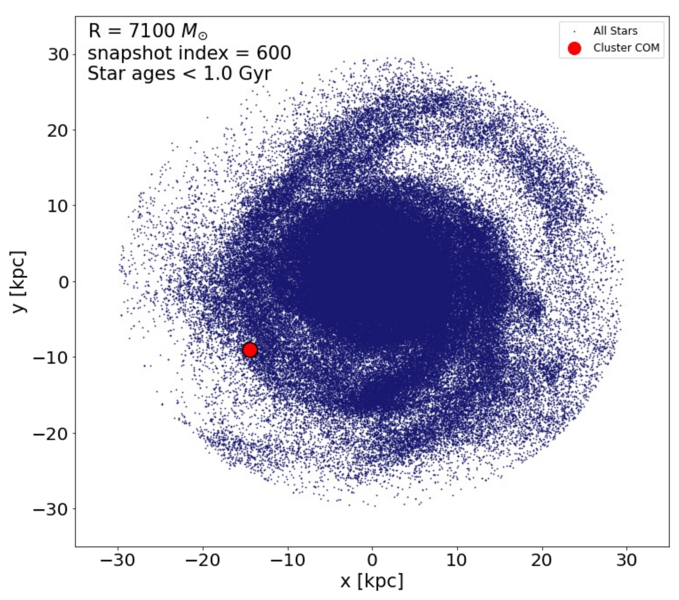


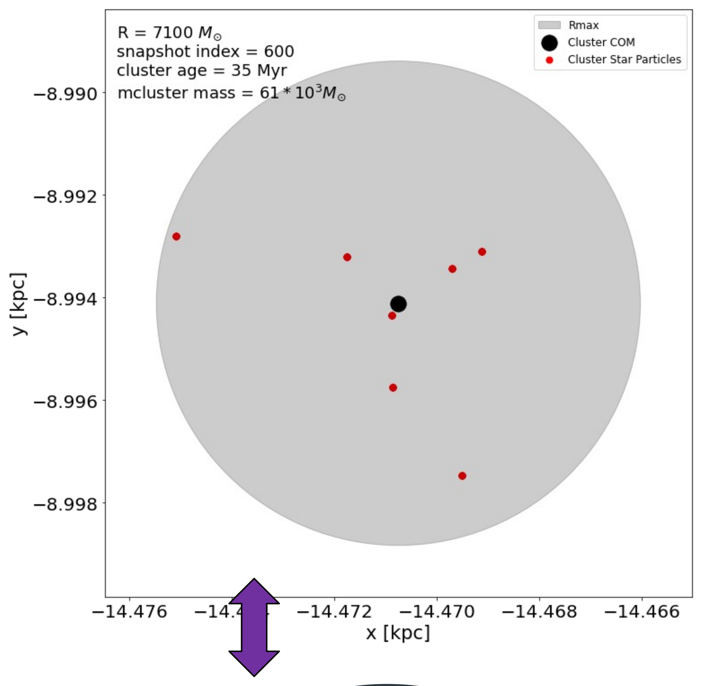
Figure 3: Mock image of a simulated galaxy in the FIRE simulations known as m12i. In the background, we show star densities, and young stars (<40 Myr) are plotted on top. The trajectories of seven illustrative star clusters are represented in yellow, their ages range between 0.5-35 Myr. (Wiggins, in prep).

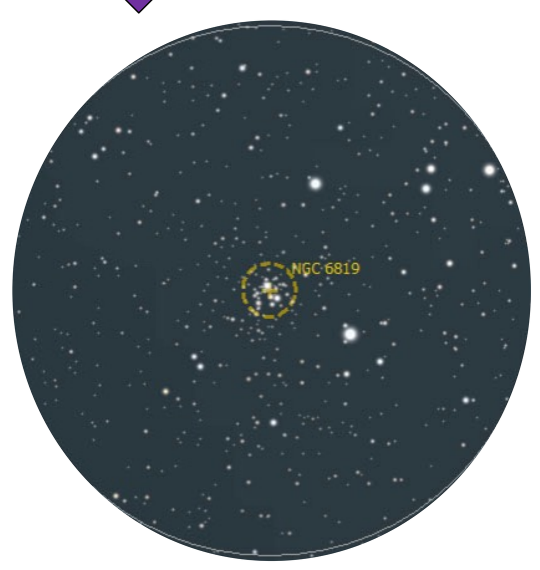
Exploring Cluster Identification in FIRE

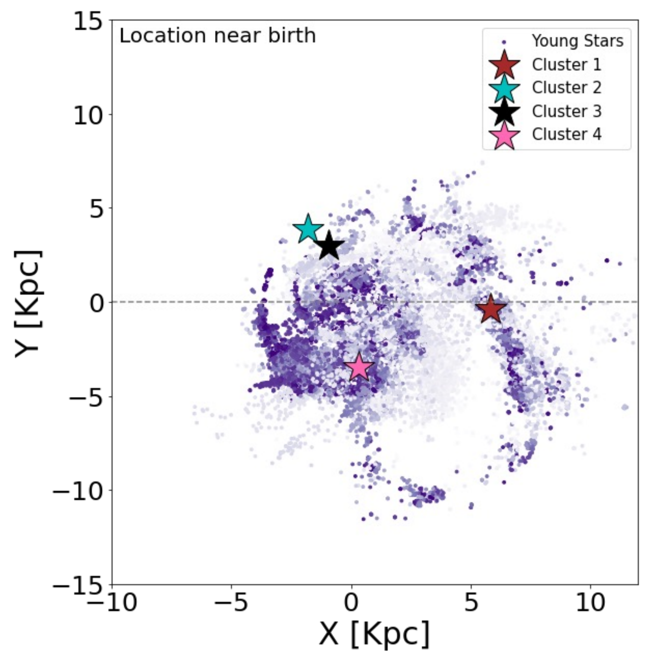
The Goal: to identify simulated star clusters that live a very long time, understand their dynamic history, and investigate how these unique clusters impact the Galactic chemical gradient that observers measure.

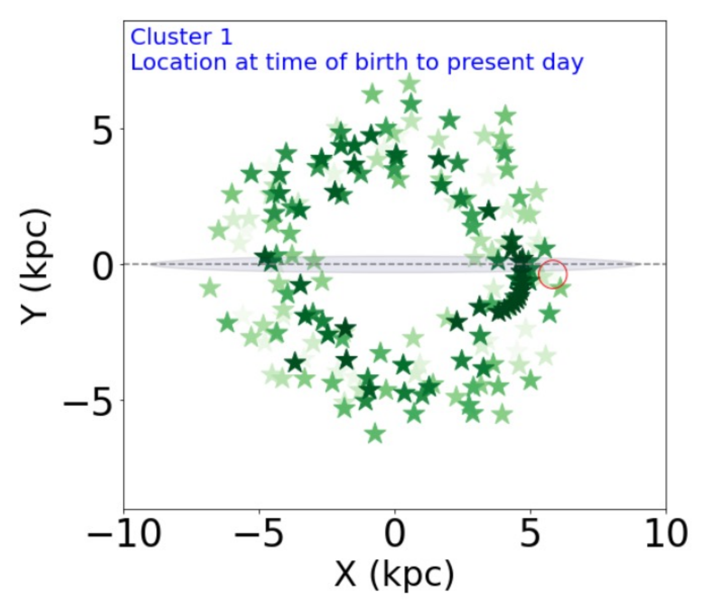


Minimum age [Gyr]	Maximum age [Gyr]	# Clusters found
0.0	0.1	24
0.1	0.2	5
0.2	0.3	6
0.3	0.4	4
0.4	0.5	4
0.5	0.6	3
0.6	0.7	3
0.7	0.8	4
0.8	0.9	6
0.9	1.0	3









- I use Friends-Of-Friends (FOF) code to identify clusters in the simulation. FOF is an algorithm that looks for stars that form close together
- FOF requires many parameters to be set (distance between stars, age threshold, location in the galaxy, etc.)
- After identifying star clusters within the simulated galaxy, I then track these clusters' locations over billions of years in the simulation and use this information to study the clusters interactions with the environment. I will then use this information to make comparisons to real, analogous, star clusters we can find in our own galaxy, to better understand their evolution, as well as their impact on the chemistry of our Galaxy.
- Initial results indicate that roughly a quarter of stars in the simulation form in star clusters, which is on par with expectations in the MW (Dobbs et. al, 2008)

Acknowledgments

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Current & Future Questions

Using the star clusters that I have identified, I first want to answer these questions:

1) *How much does the larger galactic environment affect how long a star cluster remains bound?*

2) *Why do clusters move from their original place of formation and how far they go?*

3) *Where are the actual clusters in the milky way and how much do their properties match with those we found in our simulation?*

- **How common is a cluster like this?**
- **What are the orbits of the clusters found in the simulation?**
- **What impact did the galactic environment have on it?**

SciCom

As we know, galaxies are made up of clumps of stars and gas. However, one of the best tools astronomers use to study the evolution of these galaxies is groups of stars known as star clusters. While some of these structures are strongly held together by gravity, many environmental factors can play a role in dissolving them, causing some to fall apart. Zoom-in cosmological simulations, such as FIRE, allow us to investigate the reasons behind these disruption events, which will provide us with a better understanding on how galaxies, like our own, evolve with time.