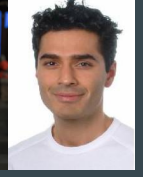
TMOCS Theoretical Modeling of Cosmic Structures

THE UNIVERSITY OF EDINBURGH



Hunting for Globular Clusters in the Early Universe

Motivation

Globular clusters (GCs) are among the most ancient gravitationally bound star clusters and can be found around any type of galaxy from dwarf to elliptical. Understanding GC formation and evolution can aid in constraining galaxy formation models.

Outline

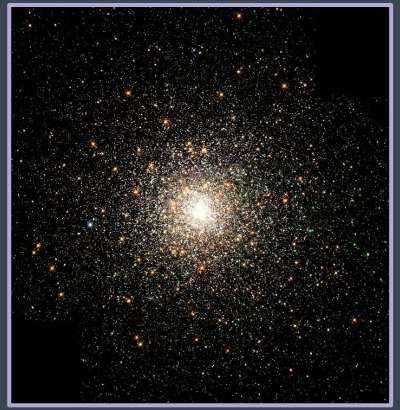
We explore a suite of high-resolution cosmological simulations at high redshift to investigate theoretical scenarios concerning the formation of old, low-mass stellar systems with a particular focus on GCs

FiBY Simulations

The First Billion Years (FiBY) project is a set of high-resolution, physics rich, cosmological SPH simulations. The simulations track metal pollution for 9 elements and include prescriptions for supernova feedback and formation of both Population II and III stars.

Our Numerical Set-up

In this work, a simulated box of volume $(4\ \mathrm{cMpc})^3$ with 684^3 particles per type was used. The mass resolution for particles is: 1250 and 6160 $M_\odot$ for SPH and dark matter particles respectively.



Images: Messiers 28 and 80 (credit: ESA/Hubble & NASA)

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Identifying infant GC candidates

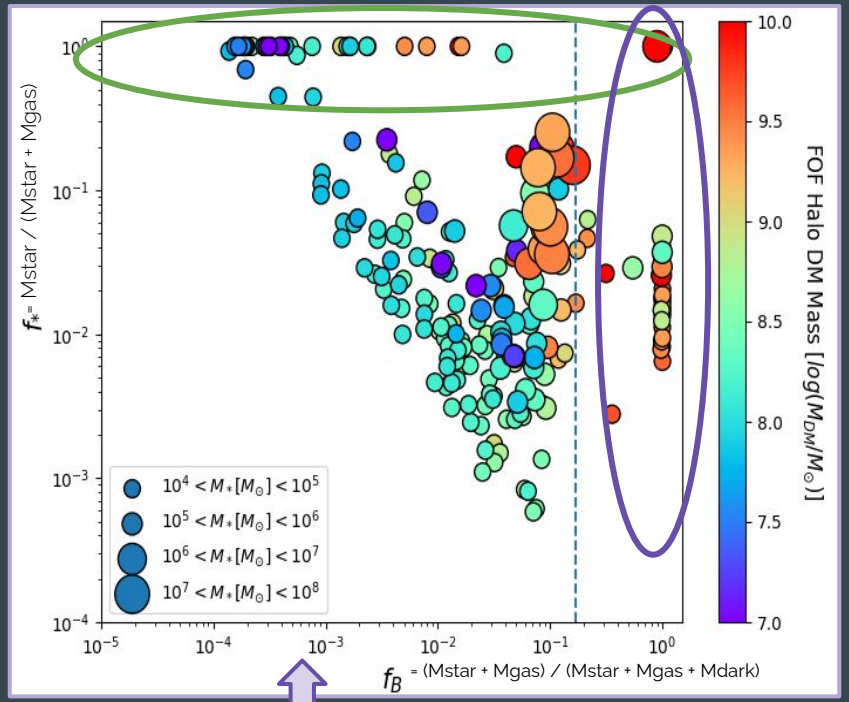
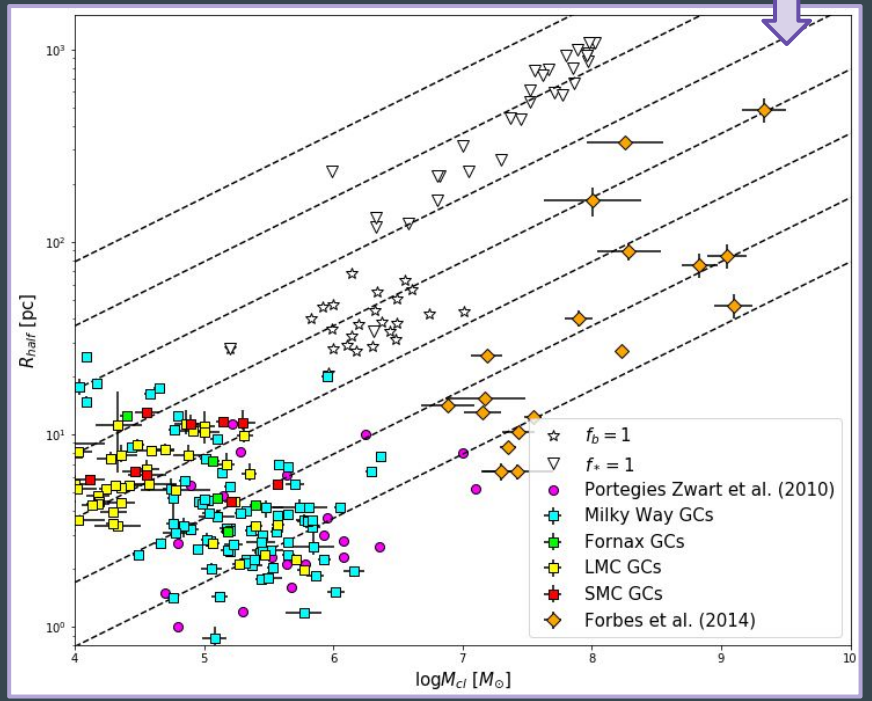


Figure 1

The first group of objects, $f_b = 1$ (purple circle), have stellar masses similar to local Universe GCs, have large gas reservoirs and appear to lie in an extended DM halo - these we identify as infant GC candidates. The second group (green circle) have $f_* = 1$ and could be akin to proto ultra-faint dwarfs (UFDs).

Figure 2

The infant GC candidates (star symbols) have been plotted on the size-mass plane along with local Universe data for GCs, young massive clusters and ultra-compact dwarfs. The infant GCs have slightly higher total masses than local GCs due to the former's copious amounts of gas. This indicates the potential for further star formation



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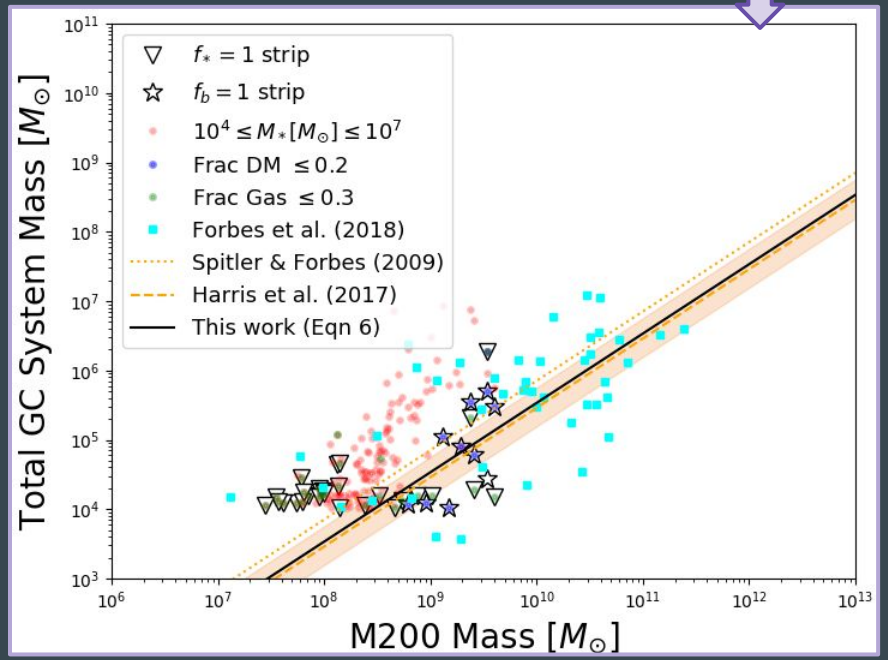
High and low redshift relations

Figure 3

Below we show the GC system mass vs halo mass for our infant GC candidates. Overlaid are two redshift-zero fits to local Universe data. The good agreement between the simulated and observed data implies that this relation could be set at formation.



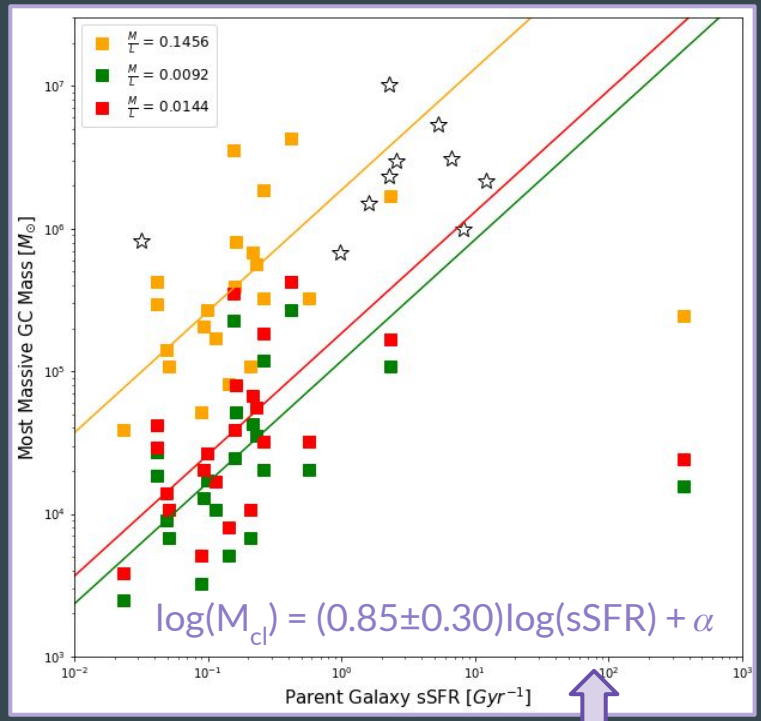
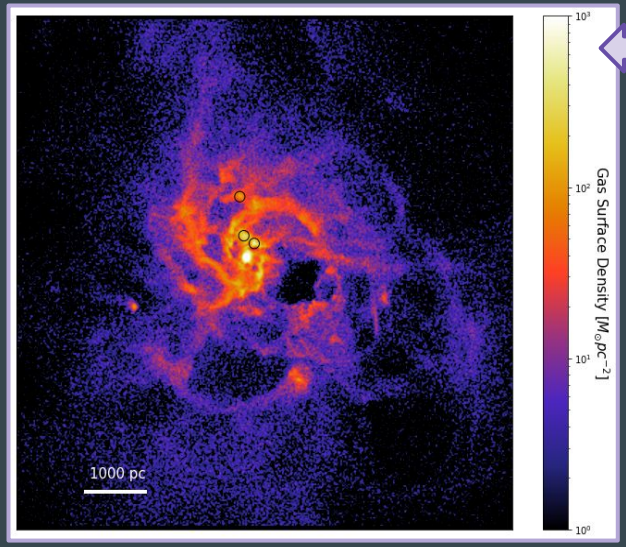


Figure 4

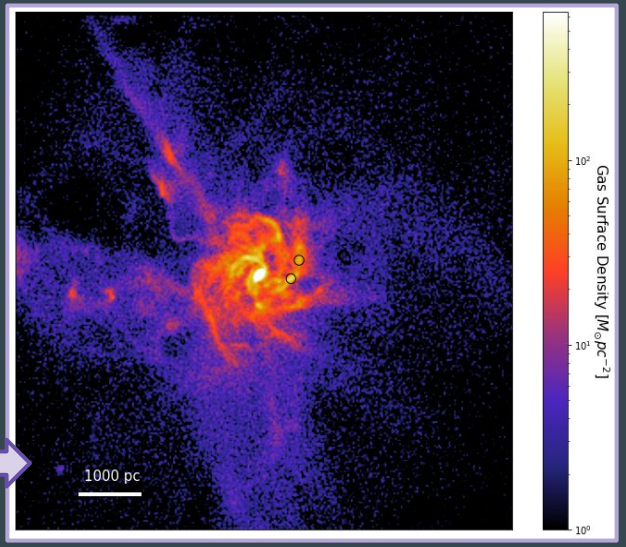
We investigate the relation between the most massive GC and the specific star formation rate (sSFR) of the host galaxy. A simple power law (where α = normalisation factor) simultaneously matches the observed low redshift GCs and predicted infant GCs at z =6.

Galactic environments of infant GC candidates



Figures 5 and 6

By examining the galactic environments of the infant GC candidates we can begin to establish a formation channel for these systems. We plot the gas surface density distribution for two representative galaxies hosting some of our infant GC candidates (black circles). The GC candidates are preferentially located in the spiral arms of the host galaxy, which are rich in high-density gas and ongoing clustered star formation events.



Conclusions and Open Questions

- We identified a group of objects in the FiBY simulations that are likely infant GC candidates.
- Their properties are similar to those of local Universe GCs although the simulated GCs have much more gas. What happens to this gas over the next 12 billion years?
- Their redshift-zero GC system mass - halo mass relation fits well to the z=6 simulated data. What is the formation channel of GCs and how is it linked to the formation of the host galaxy?
- We present a novel relation between the sSFR of galaxies and their most massive GC that holds across redshift. What is the physical origin of this relation?

Things to look forward to

We are now studying the detailed formation processes of our infant GC candidates at earlier redshifts. Thanks to the high resolution and large volume of the FiBY simulations, we are exploring the detailed physical properties of stellar systems on small scale, whilst still preserving a realistic cosmological context. Expect to see our paper on this analysis soon!

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