

The formation of ultra-compact dwarf galaxies and their black holes

Rebecca Mayes¹

Michael Drinkwater¹, Holger Baumgardt¹, Joel Pfeffer²

1. University of Queensland

2. Liverpool John Moores University

Background

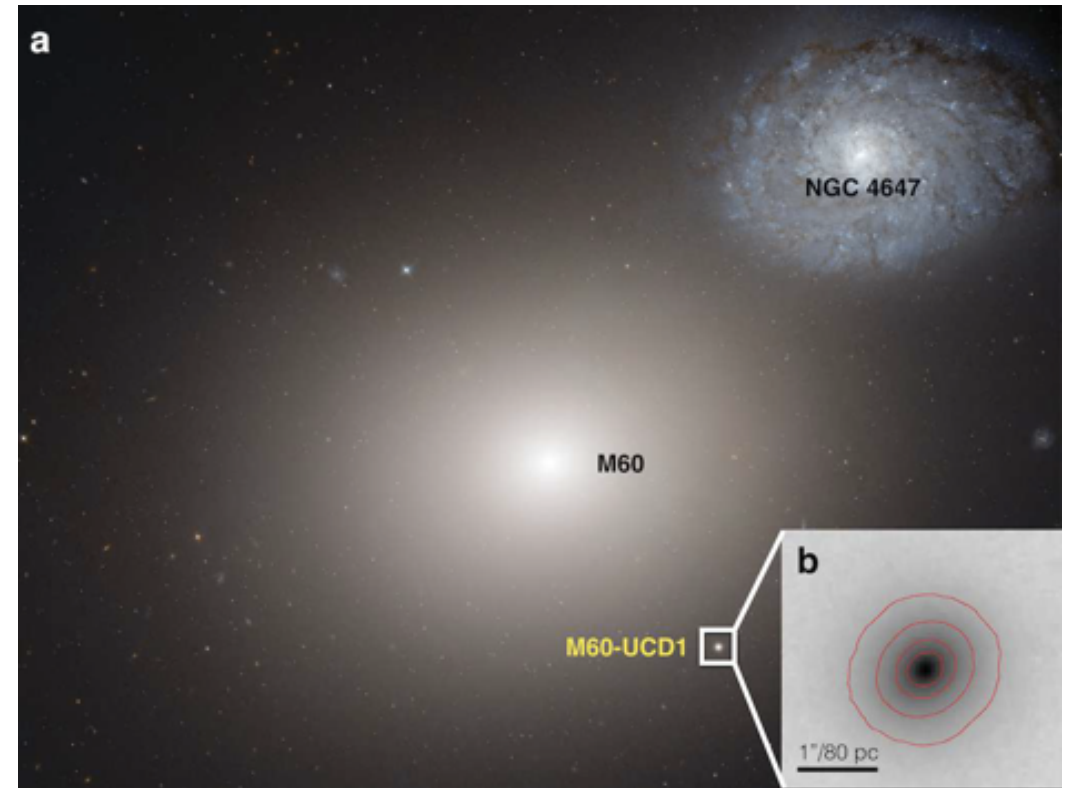
- Ultra-compact dwarf galaxies (UCDs)
- Do UCDs contain black holes?
- Research aims
- The EAGLE Simulation

Results

- Added UCD formation process to EAGLE
- Radial and mass distributions match observations
- Predict black hole masses of UCDs

Ultra-Compact Dwarf Galaxies

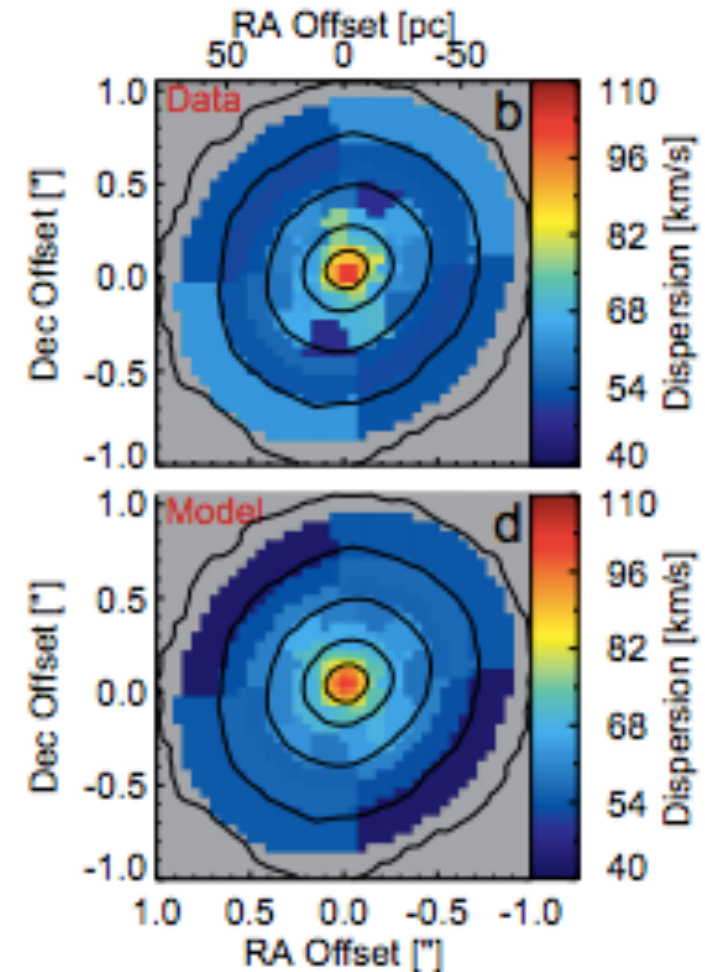
- Discovered in the Fornax cluster
- Larger and brighter than **globular clusters**, smaller and more compact than **dwarf galaxies**
- Formation method is under debate
- One theory: stripped nuclei of disrupted dwarf galaxies



HST image of the M60-NGC4647 system with M60-UCD1 visible in the bottom right. (Seth et al., 2014)

Black holes in UCDs

- Elevated M/L ratios in UCDs – evidence of black holes? (Mieske et al., 2013)
- SMBHs detected in several UCDs (Seth et al., 2014; Ahn et al., 2018)
- UCDs could double the number of known black holes in galaxy clusters (Seth et al., 2014)
 - Revise modelling of black holes in simulations? (Naab & Ostriker 2017)



High central velocity dispersion of M60-UCD1 indicates the presence of a black hole (Seth et al., 2014)

My Research

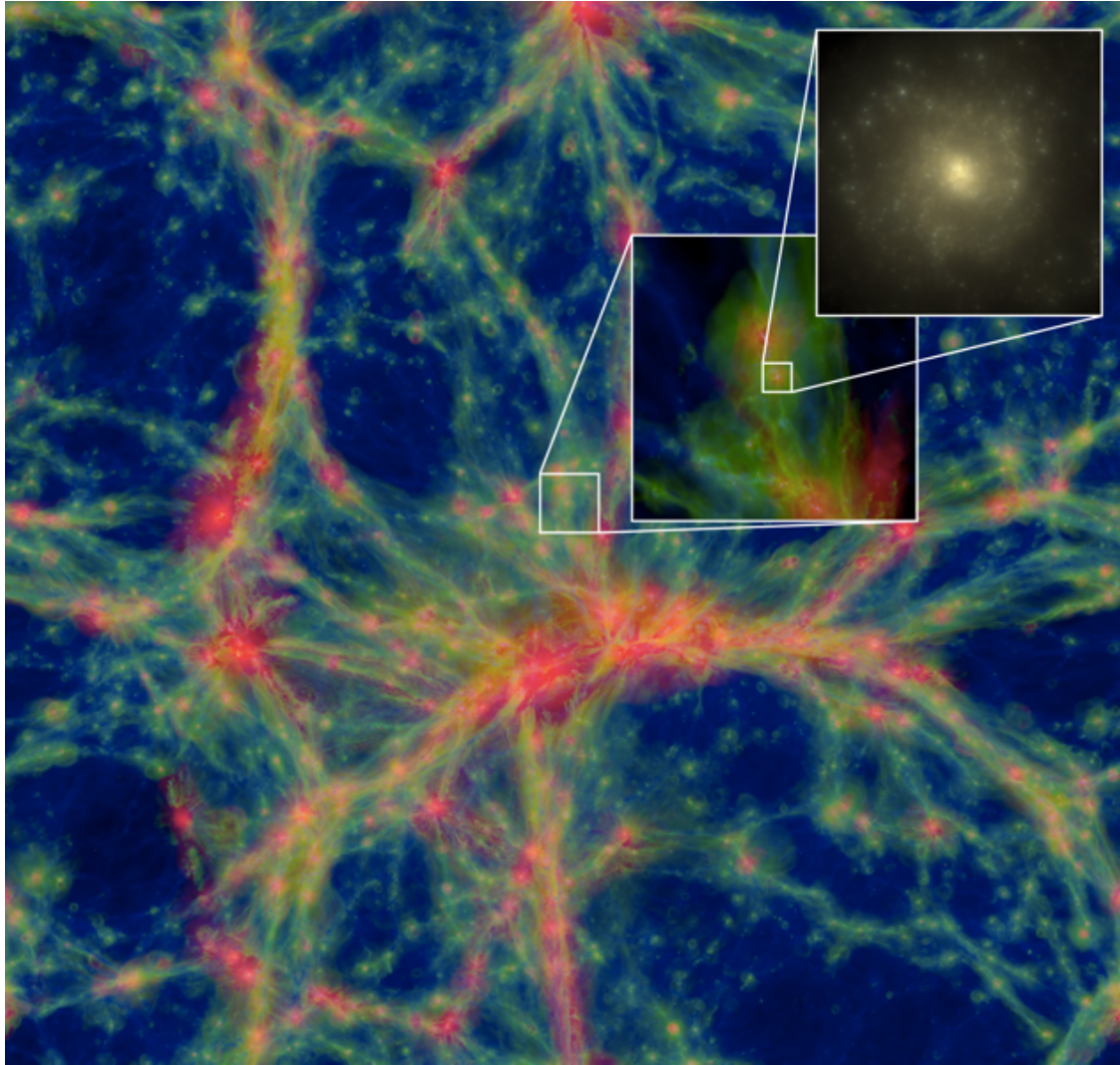
Research Questions:

- Can UCDs form by galaxy stripping?
- Can black holes explain the high M/L ratios of UCDs?
- Are the UCD black hole populations predicted by the simulation consistent with observations?

Method:

- Find disrupted galaxies in a galaxy cluster in EAGLE database
- Track stripped nuclei (UCDs) using EAGLE particle data
- Predict black hole masses in UCDs with EAGLE

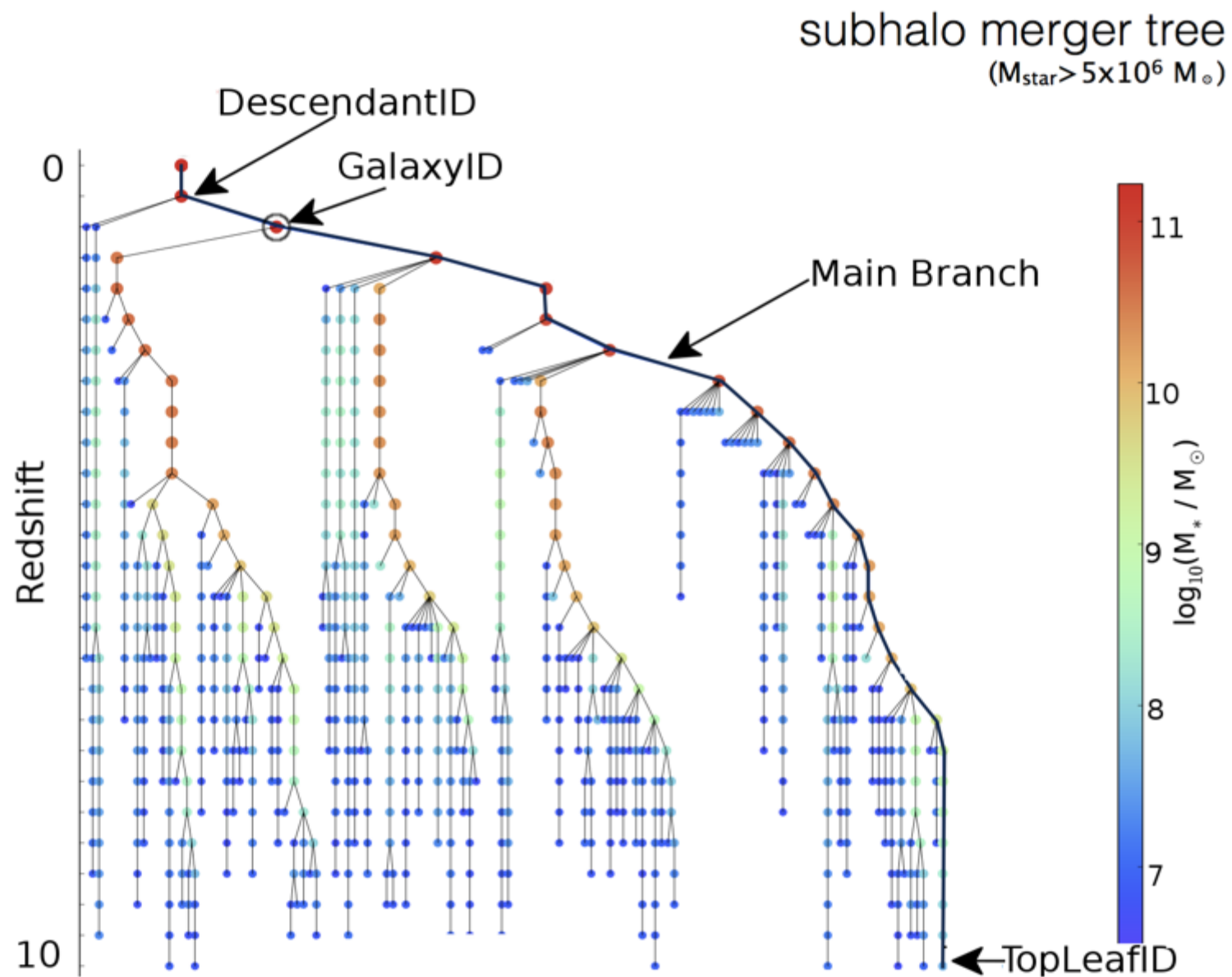
The EAGLE Simulations



- Massive enough to contain 10,000 large galaxies and modelled with nearly 7 billion particles
- Particle size: $1.81 \times 10^6 M_{\odot}$ (baryonic), $9.70 \times 10^6 M_{\odot}$ (dark matter)
- Hydrodynamic, containing baryonic particles in addition to dark matter particles
 - Can calculate properties of stripped nuclei from particle data

Slice through the EAGLE simulation volume showing hot gas, dark matter structures and a modelled galaxy (Schaye et al. 2015)

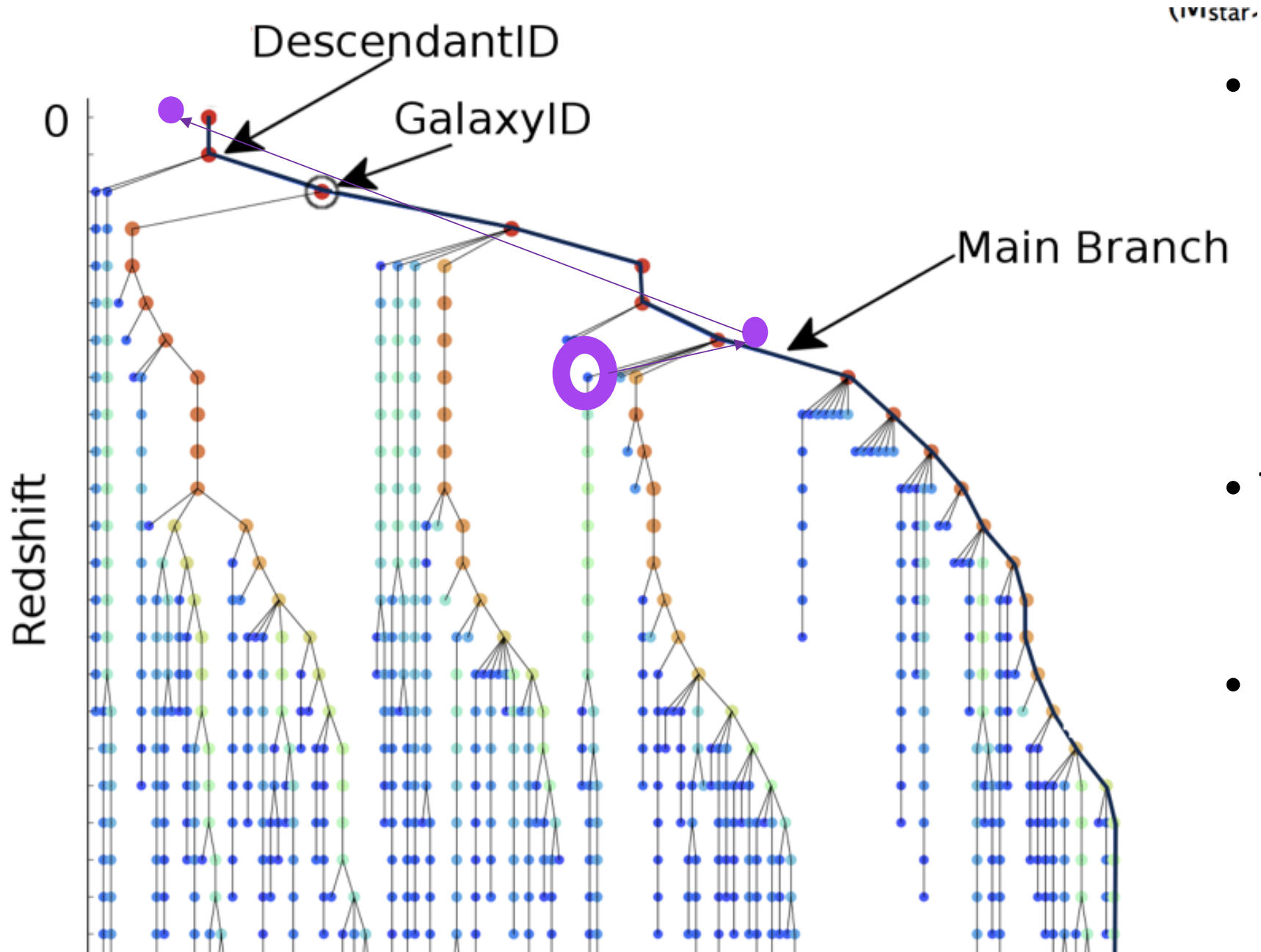
UCD Host Galaxies and merger trees



- EAGLE database:
- For each large “host” galaxy
- Find UCD “progenitor” galaxies
- Where does the stripped nucleus go?

Example of a particular galaxy's merger tree (The EAGLE team, 2017)

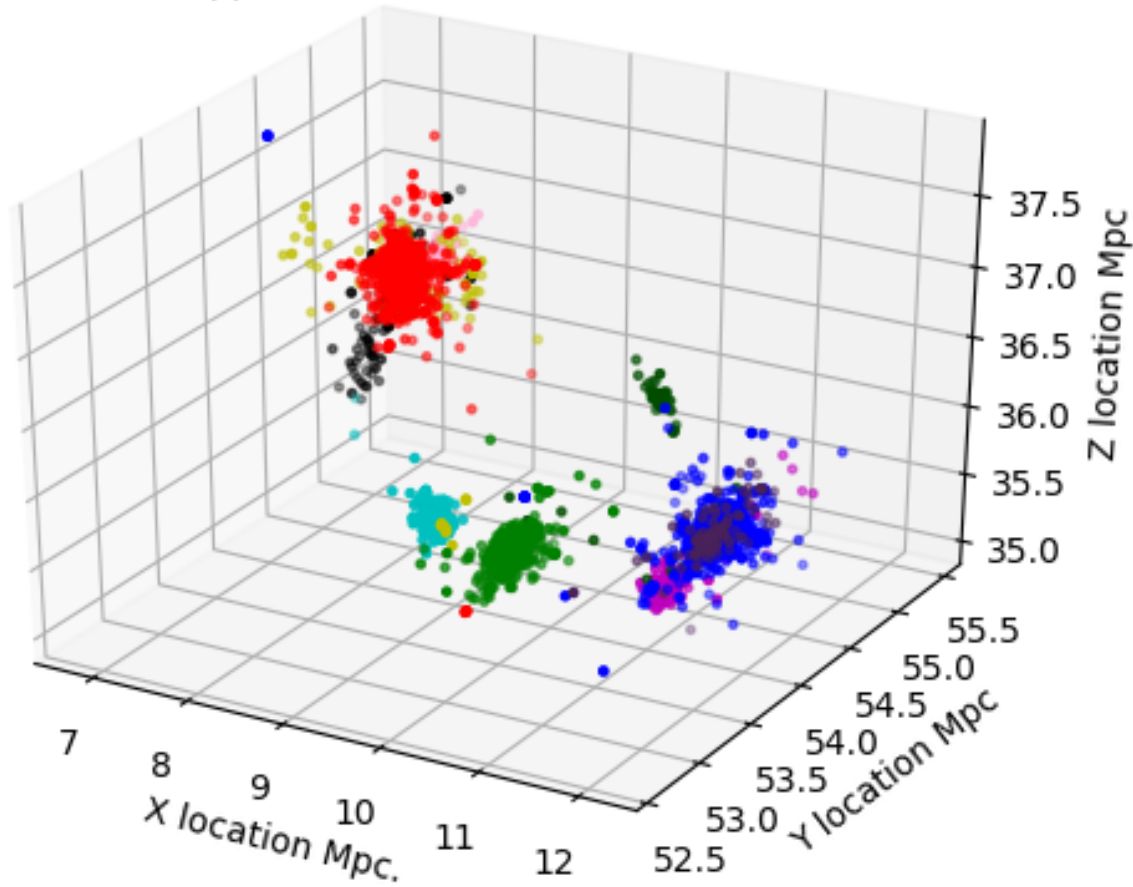
Tracking a UCD



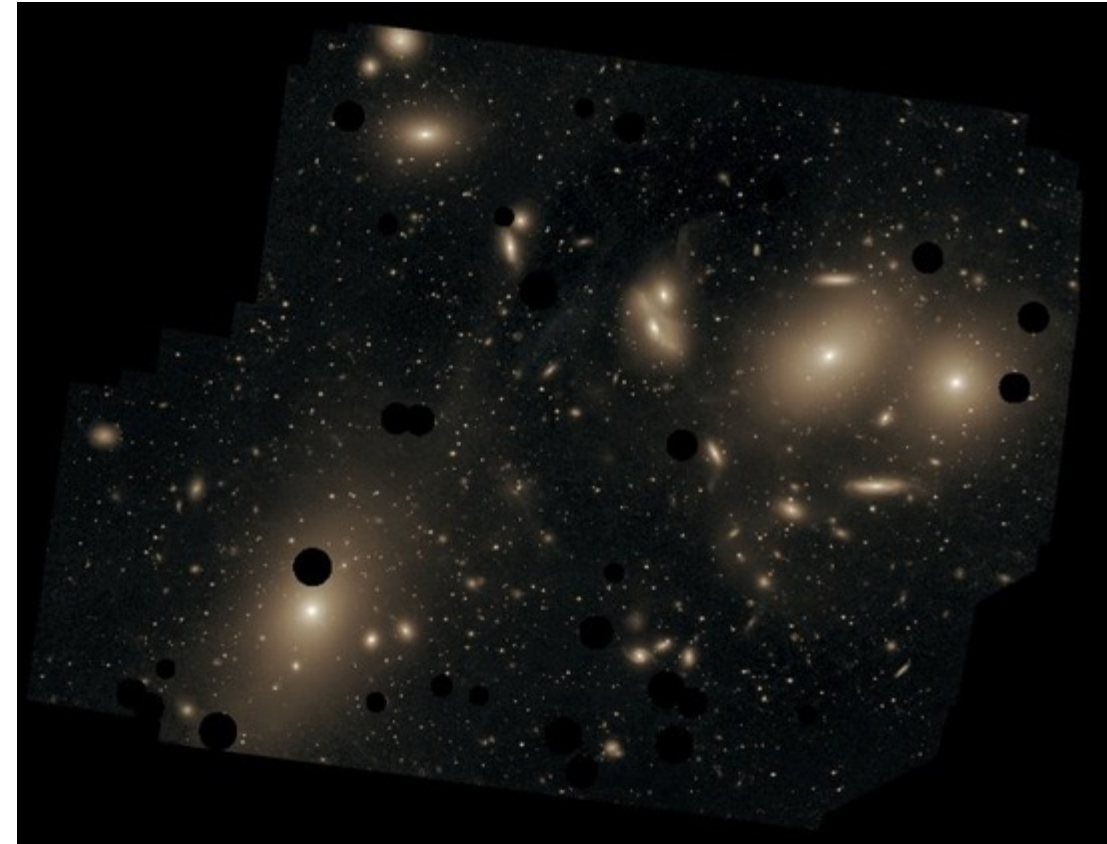
- Eagle particle data:
 - Particle mass: $1.81 \times 10^6 M_{\odot}$ (baryonic), $9.70 \times 10^6 M_{\odot}$ (dark matter)
 - Similar to UCD mass range: 2×10^6 to $10^8 M_{\odot}$
- Track stripped nucleus using Most Bound Particle
- Identify particles at redshift 0 as UCDs

Results: Locations of stripped nuclei

Locations of stripped nuclei

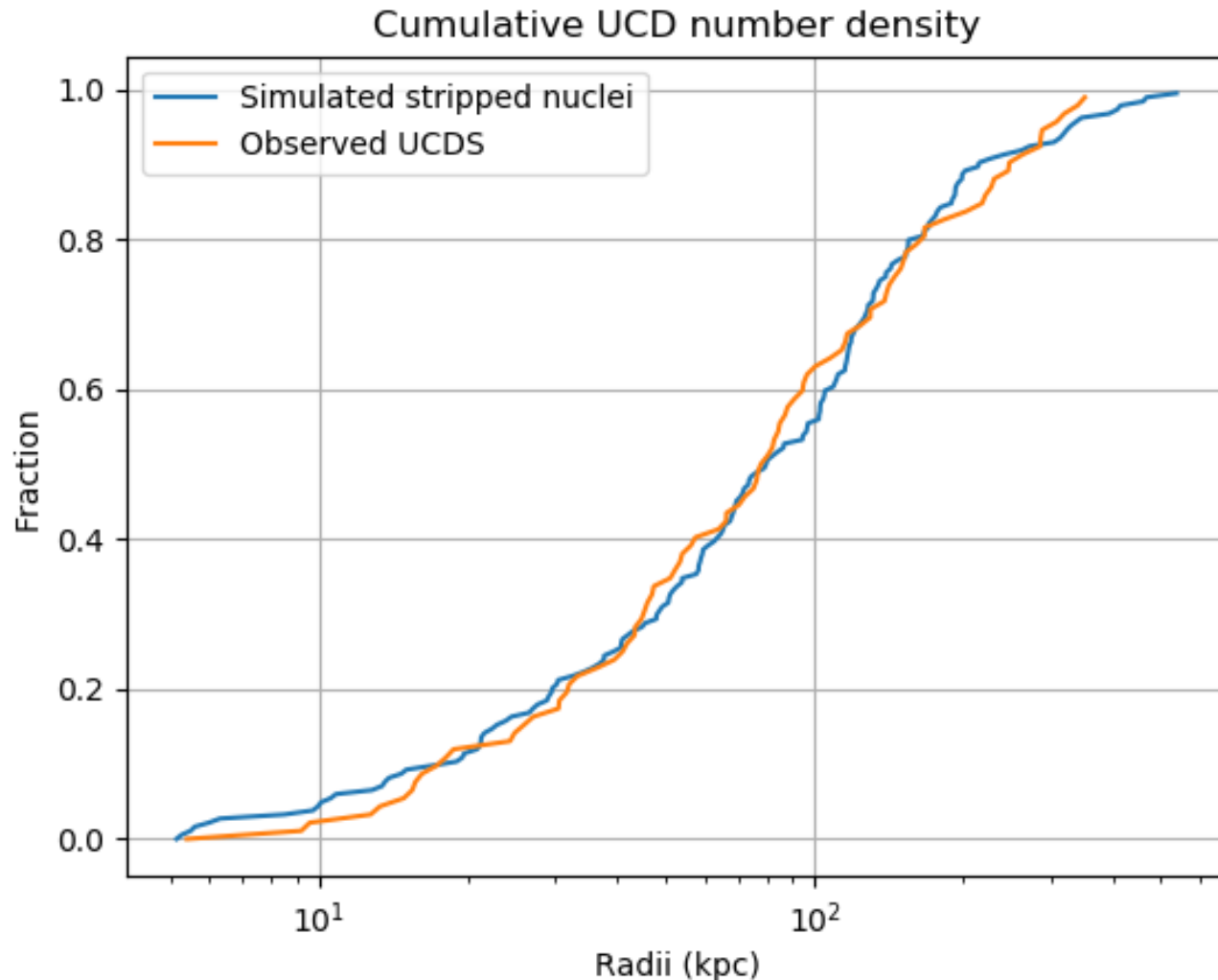


Stripped nuclei locations for the 10 most massive galaxies of the simulated cluster



The Virgo Cluster Credit: Chris Mihos (ESO)

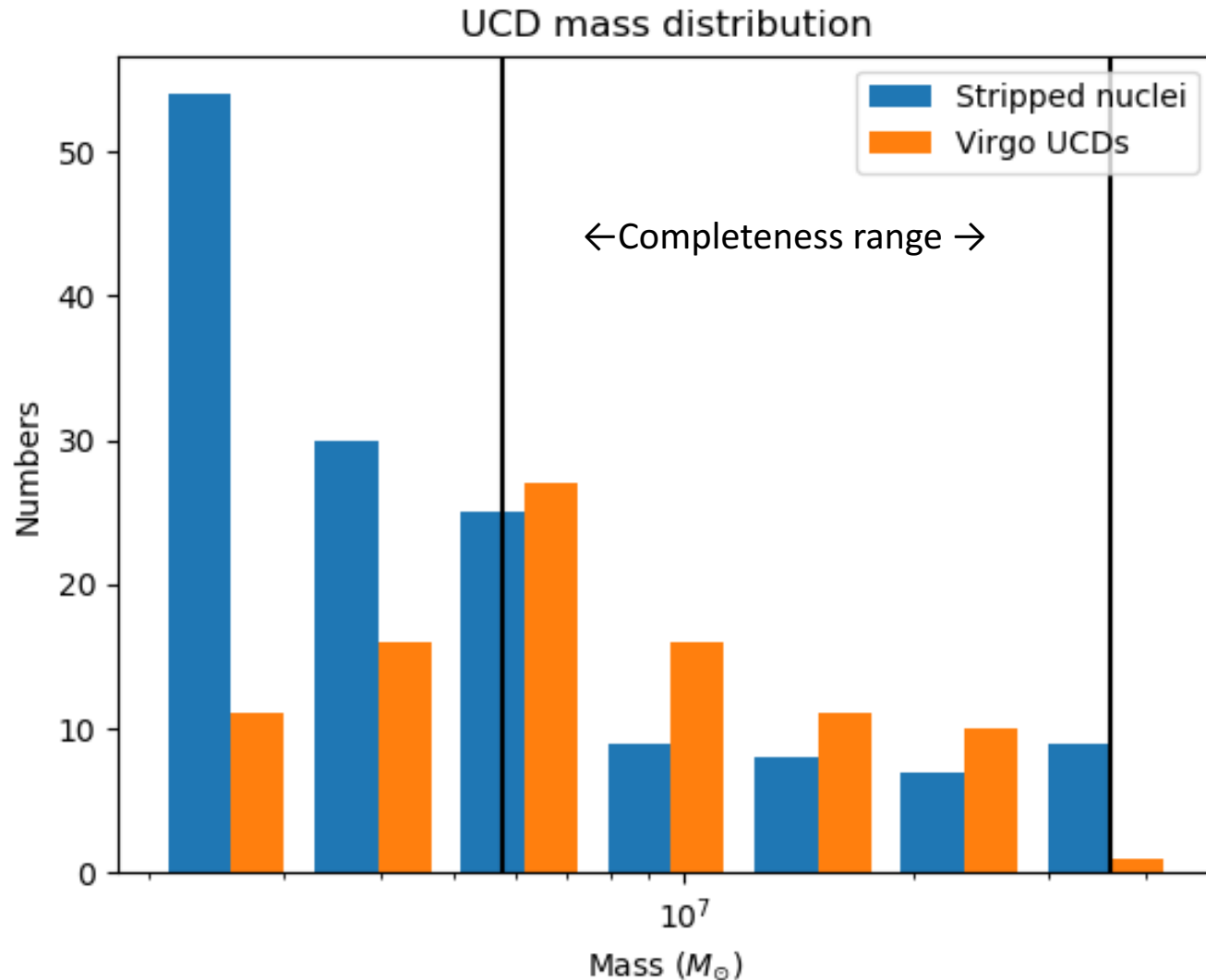
Results: Radial distribution comparison



Observations from: The Next Generation Virgo Cluster Survey (Liu et al. [2015]).

The two distributions are consistent (K-S test returns p-value = 0.79)

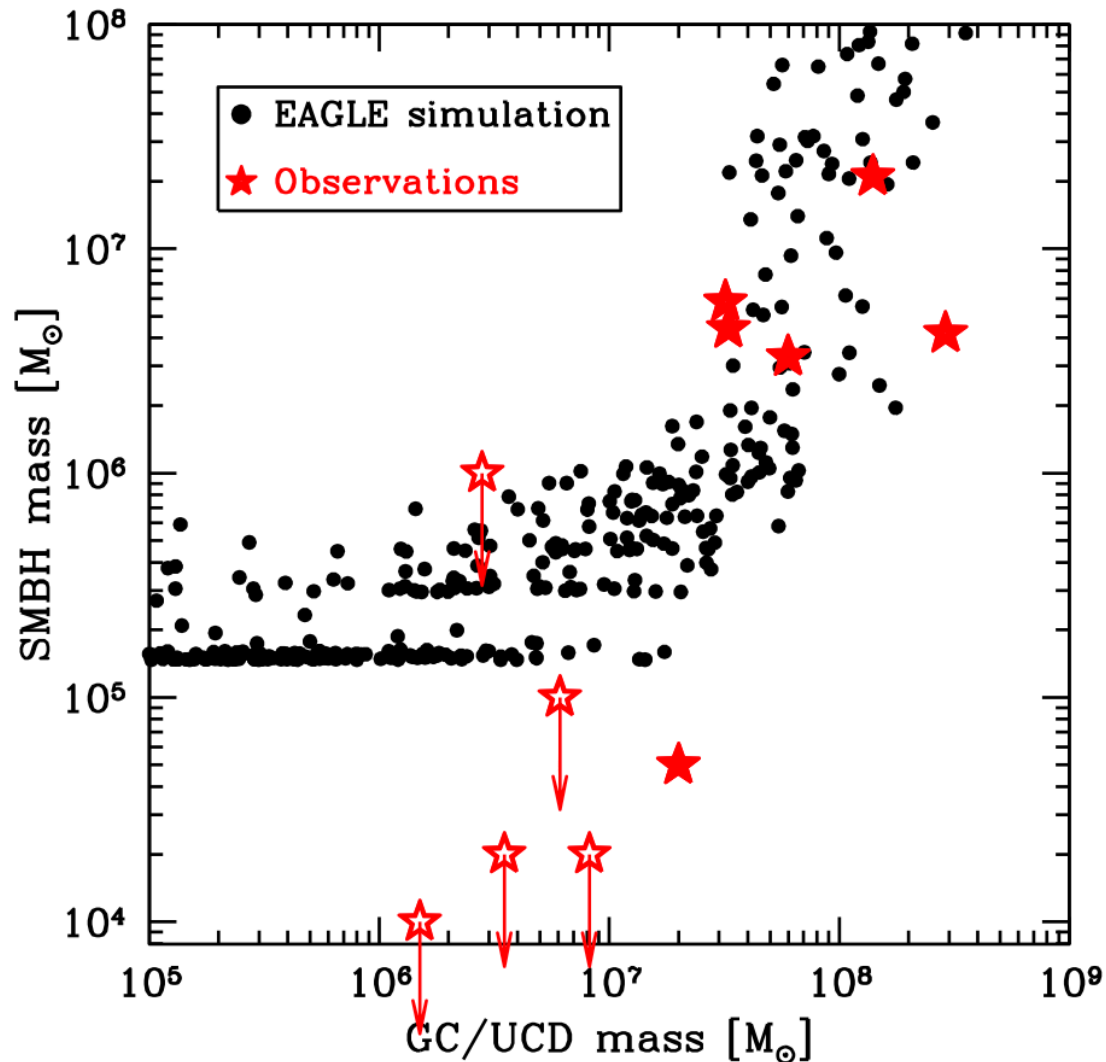
Results: Mass comparison



Observed UCD sample is complete in the mass range of 5.8×10^6 and 3.6×10^7 M_{\odot} and undersampled elsewhere

The two distributions are consistent in the complete mass range (K-S test p-value = 0.16)

Results: Preliminary black hole mass comparison



Black points represent nuclei of EAGLE galaxies

Red stars represent UCDs with detected black holes, open stars are upper limits on UCDs/GCs with possible black holes

Conclusion

- Made the first model of UCD formation based on a cosmological hydrodynamical simulation including baryons
- The model accurately predicts radial and mass distribution of UCDs around central galaxy
- Other work:
 - Determine internal properties of stripped nuclei such as colour and metallicity
 - Determine black hole masses of stripped nuclei and compare to observed UCD black holes

Locations of stripped nuclei

