# Energetics of Intracluster Stars and Dark Matter

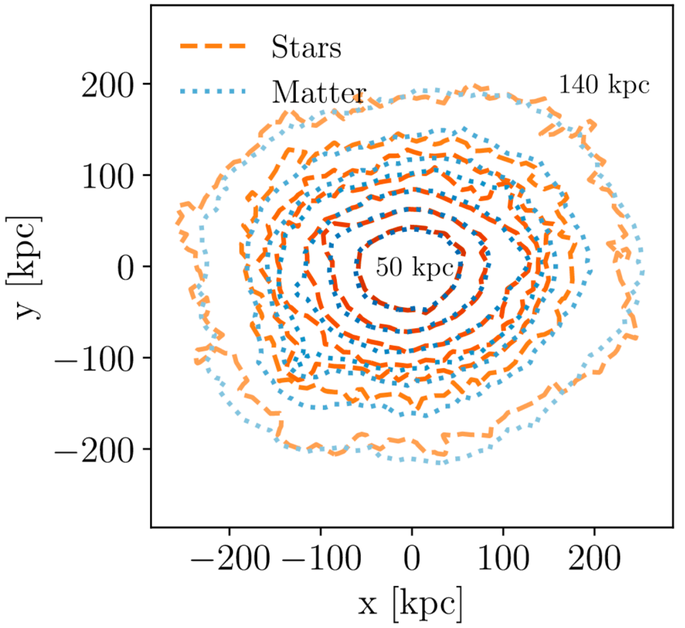
**J. Butler[1], G. Martin[1], N. Hatch[1], F. Pearce[1], S. Brough[2], Y. Dubois[3]**

1. University of Nottingham
2. University of New South Wales
3. Institut d'Astrophysique de Paris

Based on the paper "Intracluster light is a biased tracer of the dark matter distribution in clusters" (Butler+25).

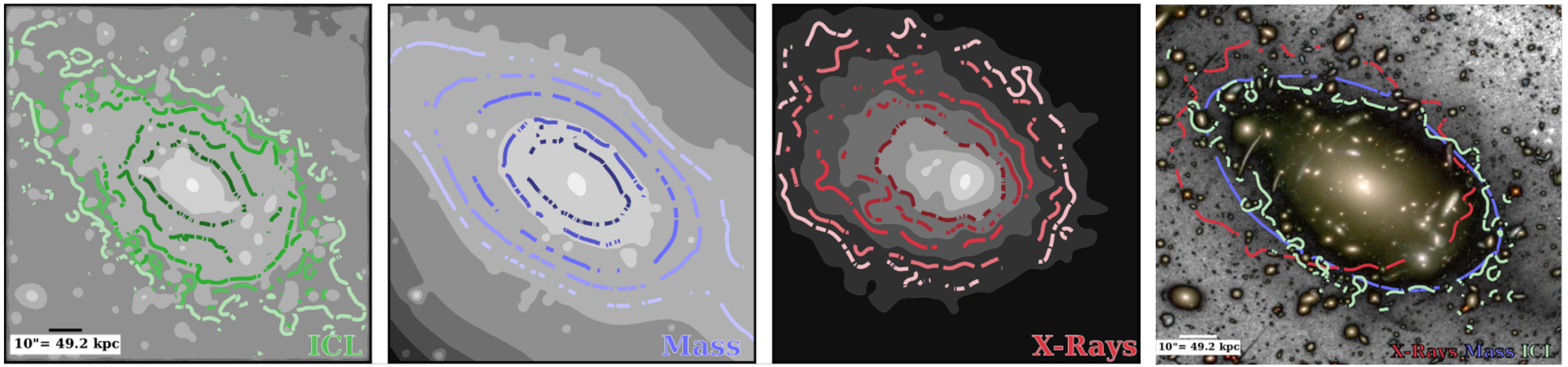
# Intracluster Light: A Dark Matter Tracer?

- Intracluster stars and dark matter (DM) are both collisionless, so dynamics governed by cluster potential.
- Orbital properties must be compared to understand how these components are related.




*Alonso Asensio+ 2020*

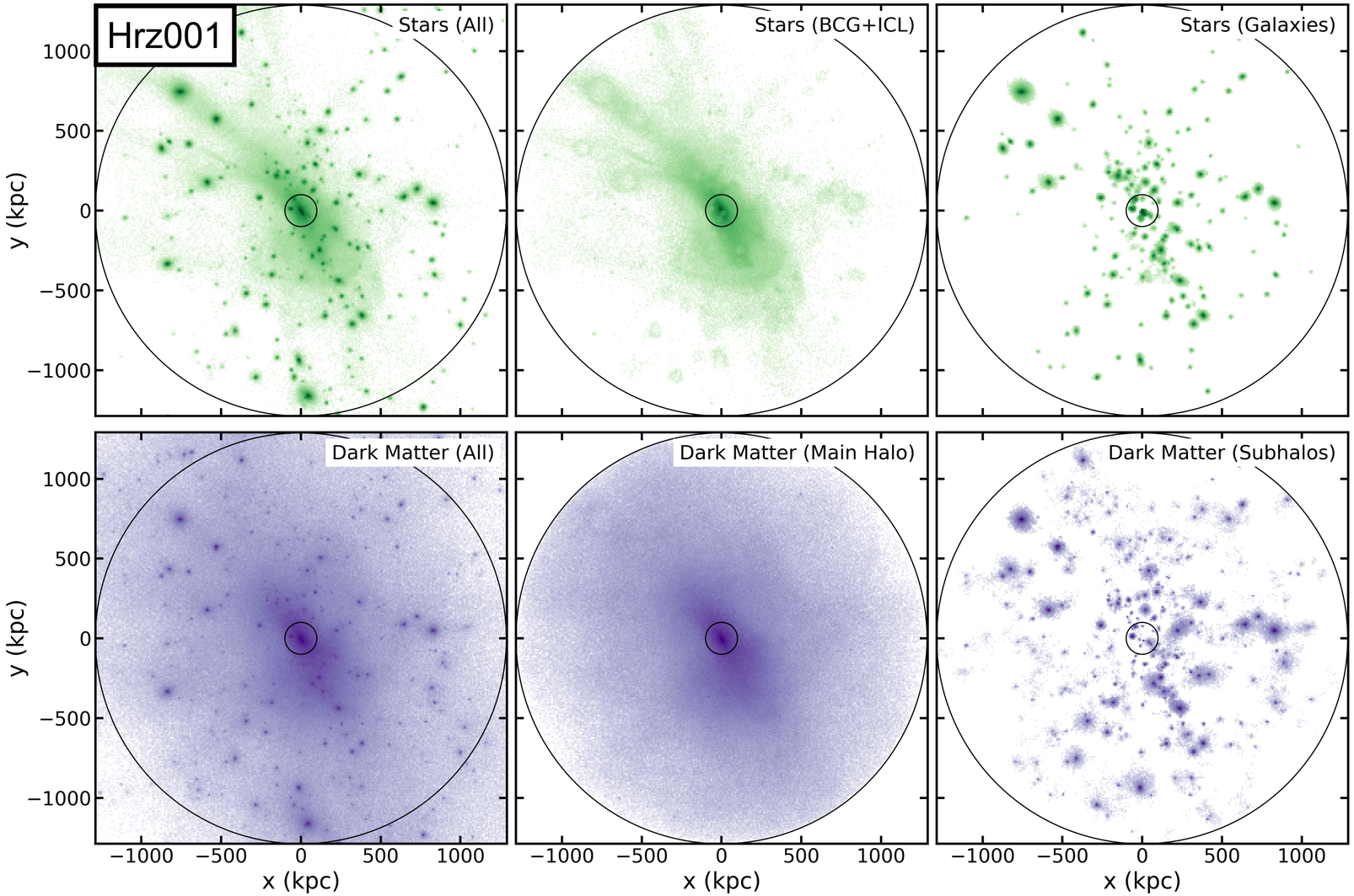
*Montes & Trujillo 2019*



# Simulation

- 12 clusters from Horizon-AGN, a cosmological hydrodynamic simulation.
- BCG & ICL separation at 100 kpc.

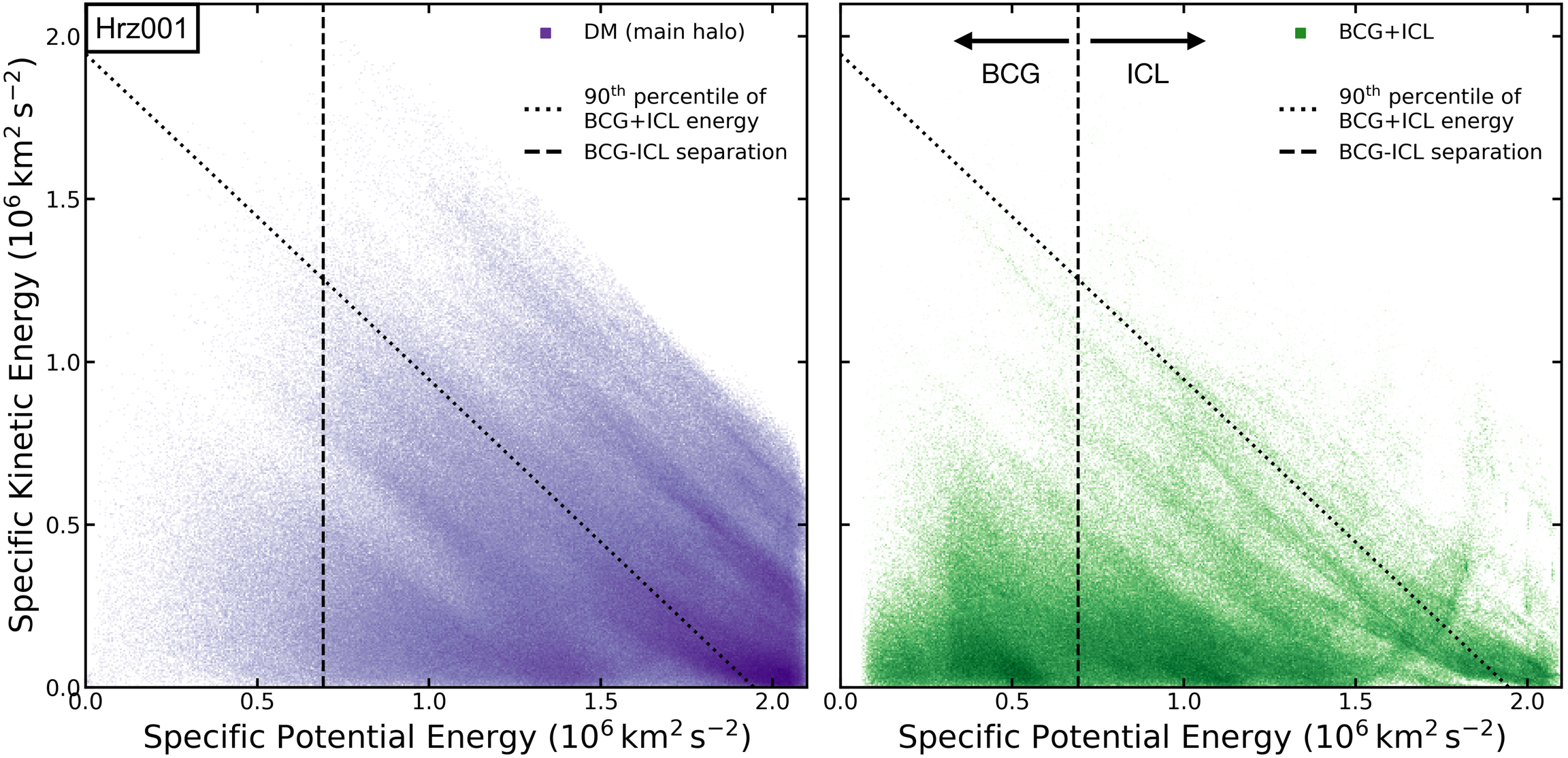
| | |
|---|---|
| $L_{\mathrm{box}}$ | $100\,h^{-1}\,\mathrm{Mpc}$ |
| $M_{\mathrm{DM,res}}$ | $8 \times 10^7\,\mathrm{M}_\odot$ |
| $M_{\mathrm{gas,res}}$ | $1 \times 10^7\,\mathrm{M}_\odot$ |
| $M_{\mathrm{star,res}}$ | $2 \times 10^6\,\mathrm{M}_\odot$ |
| $M_{\mathrm{cluster}}$ | $1 - 4 \times 10^{14}\,\mathrm{M}_\odot$ [1] |




[1] The two most massive clusters in Horizon-AGN are excluded from this study, and thus are not included in this range.

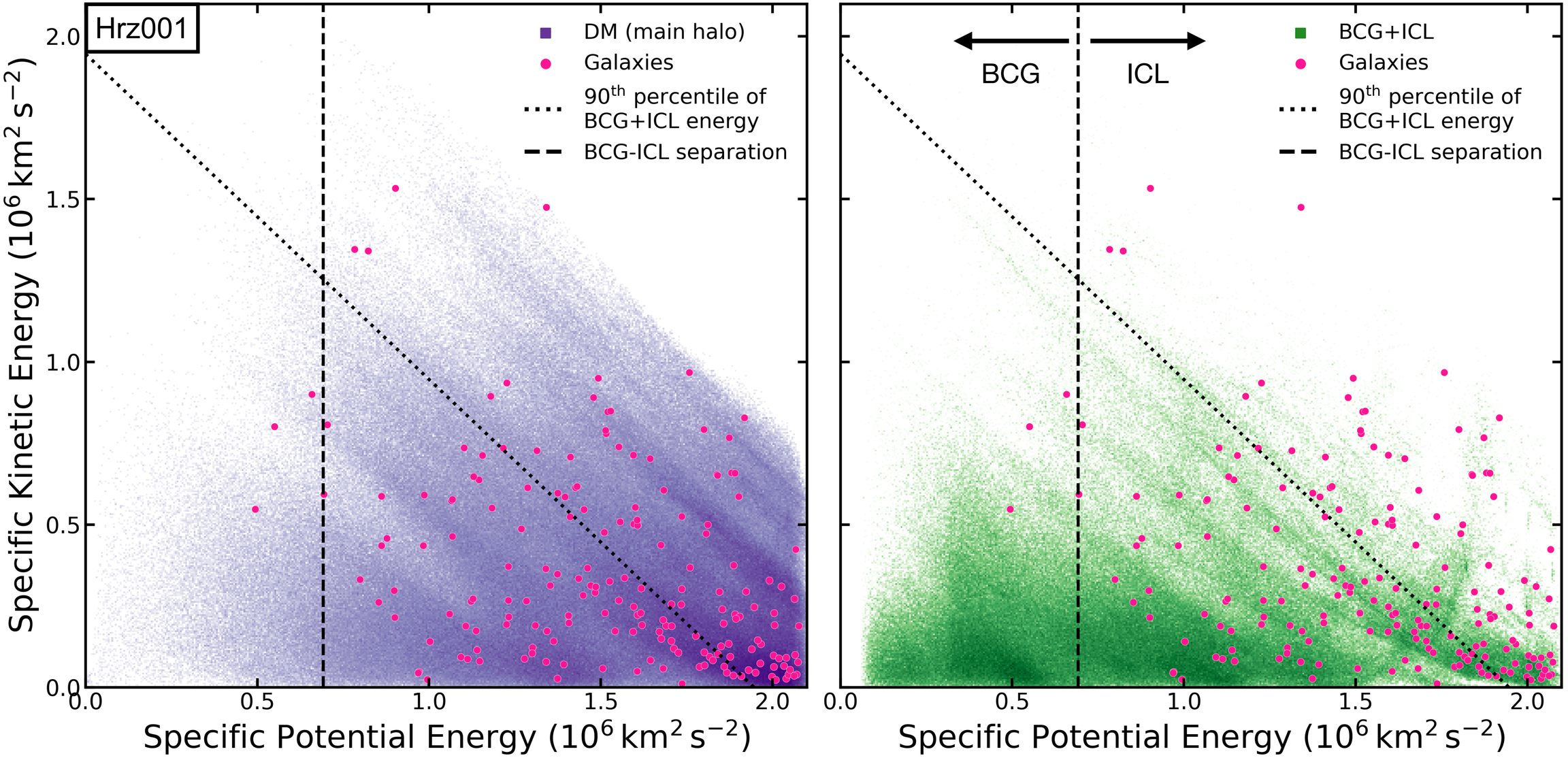
# Energetics

$$\text{Specific Energy} = \frac{v^2}{2} + (\phi - \phi_{\text{min}})$$



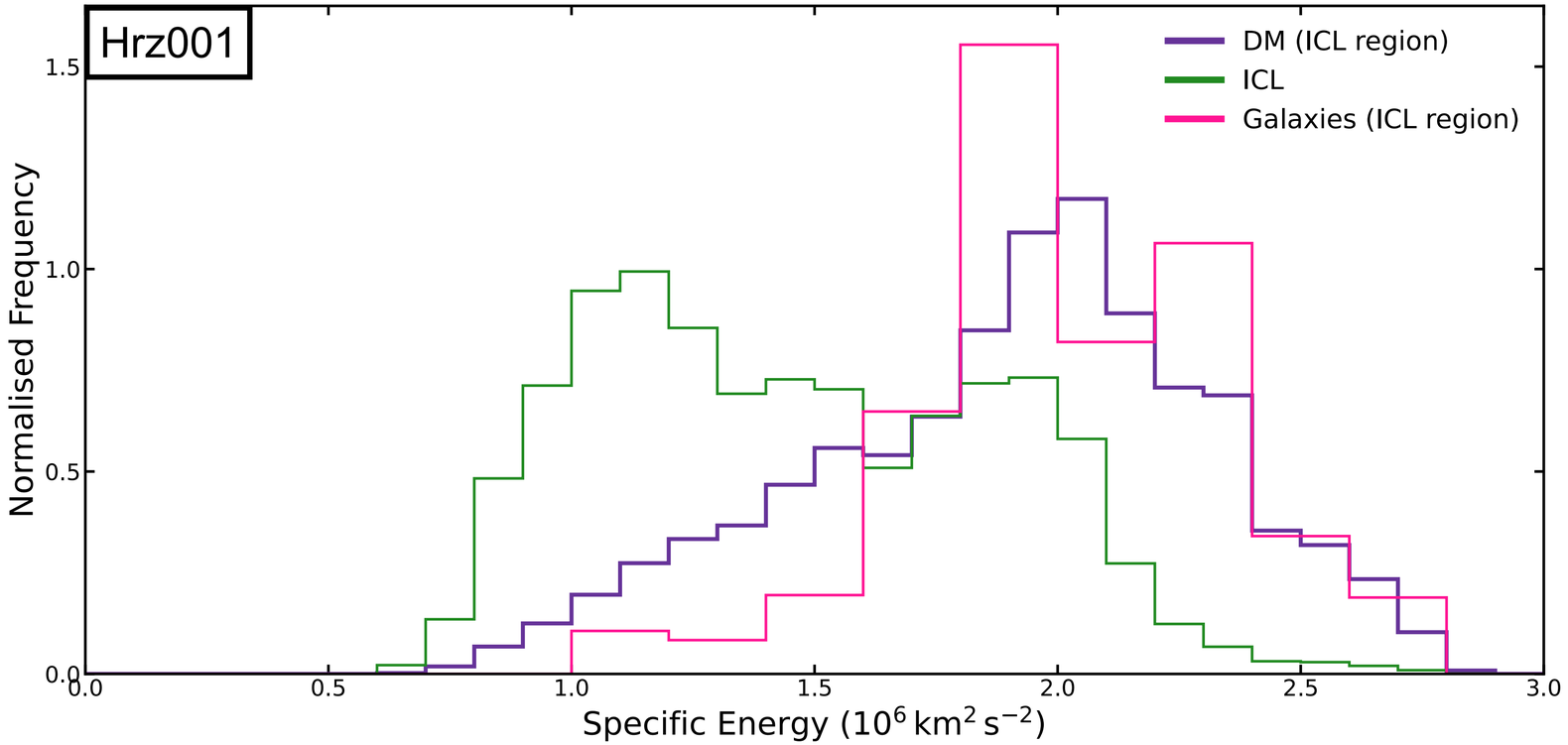
# Energetics

$$\text{Specific Energy} = \frac{v^2}{2} + (\phi - \phi_{\text{min}})$$



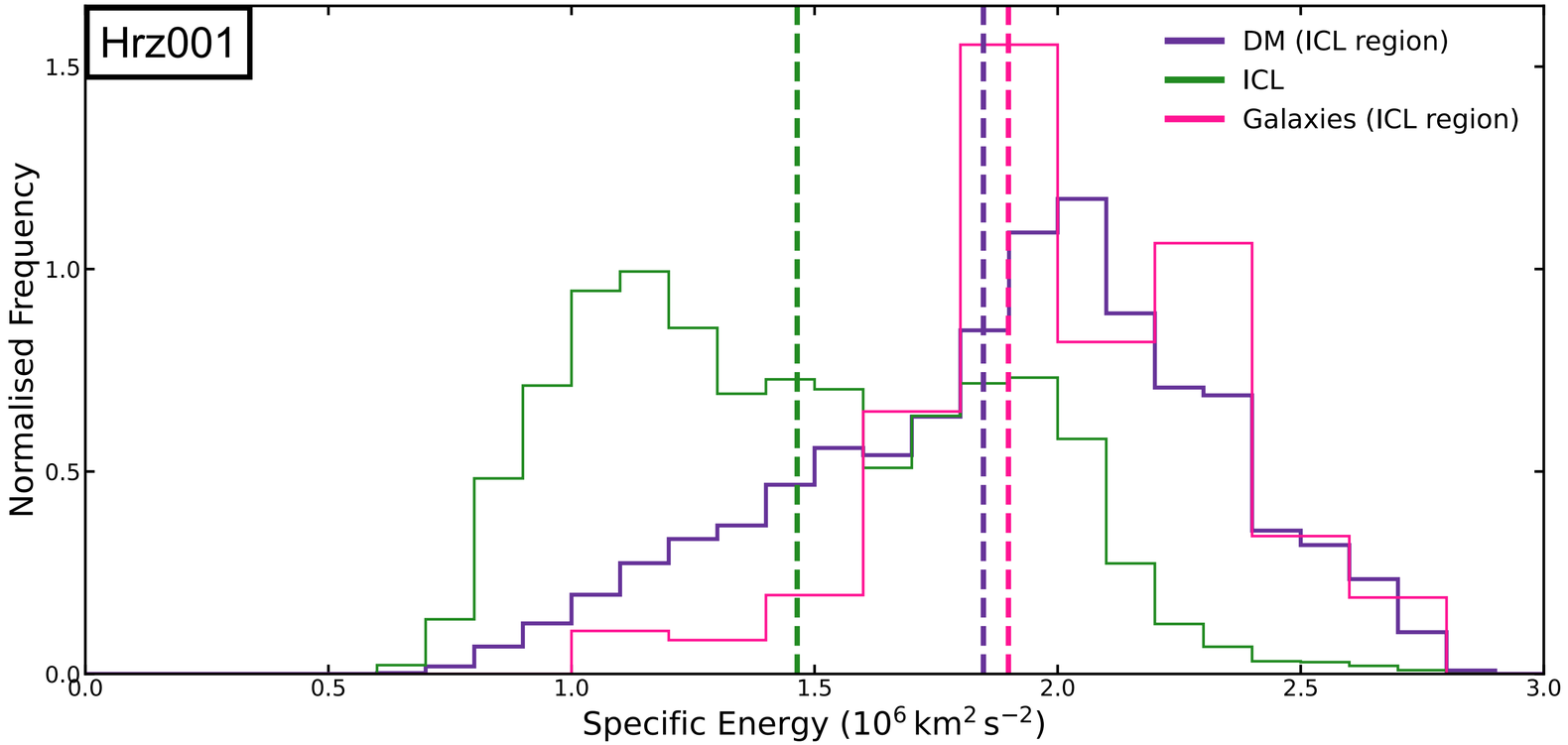
# Energetics

- Orbital energies of intracluster stars are ~25% lower than the DM and the shapes of the distributions are very different.



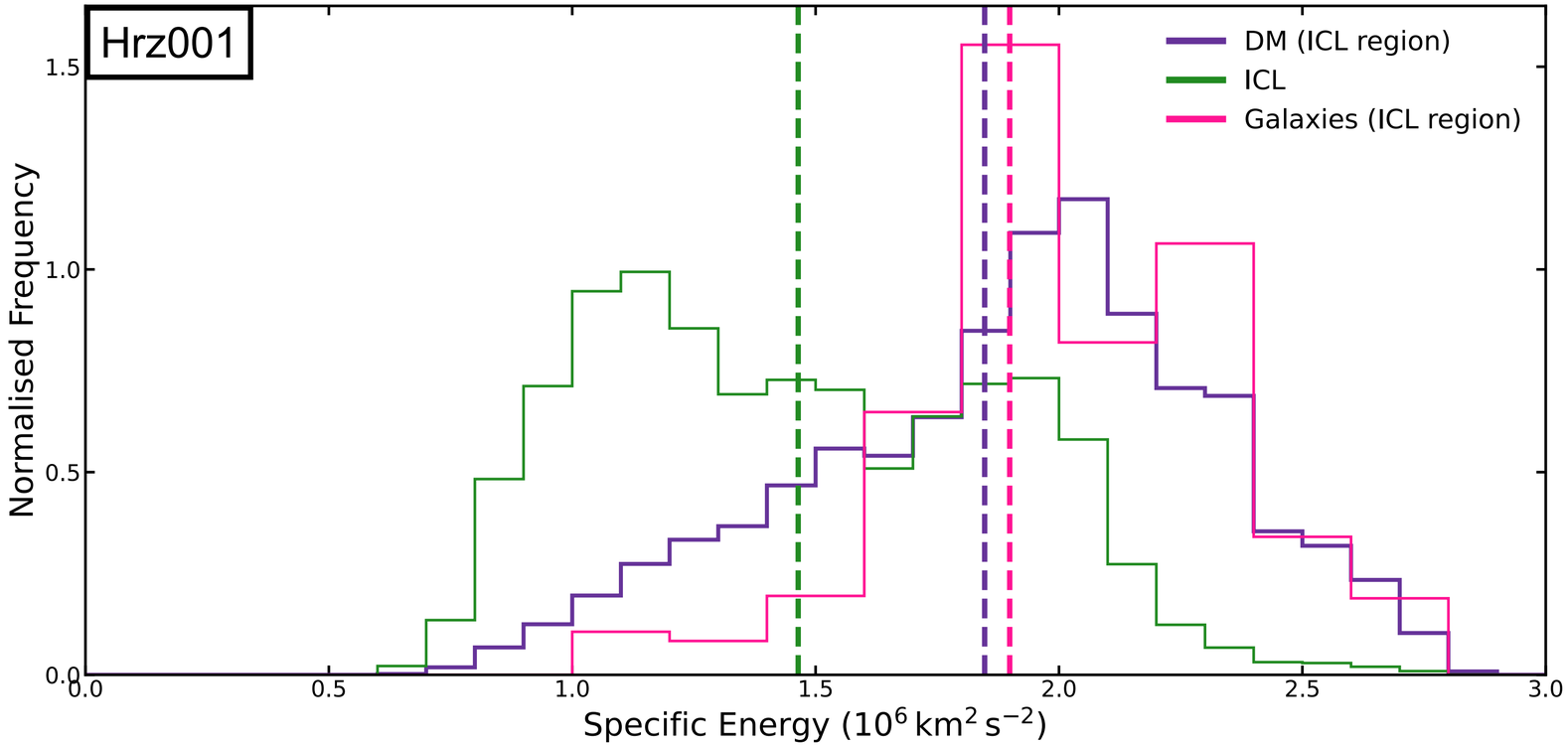
# Energetics

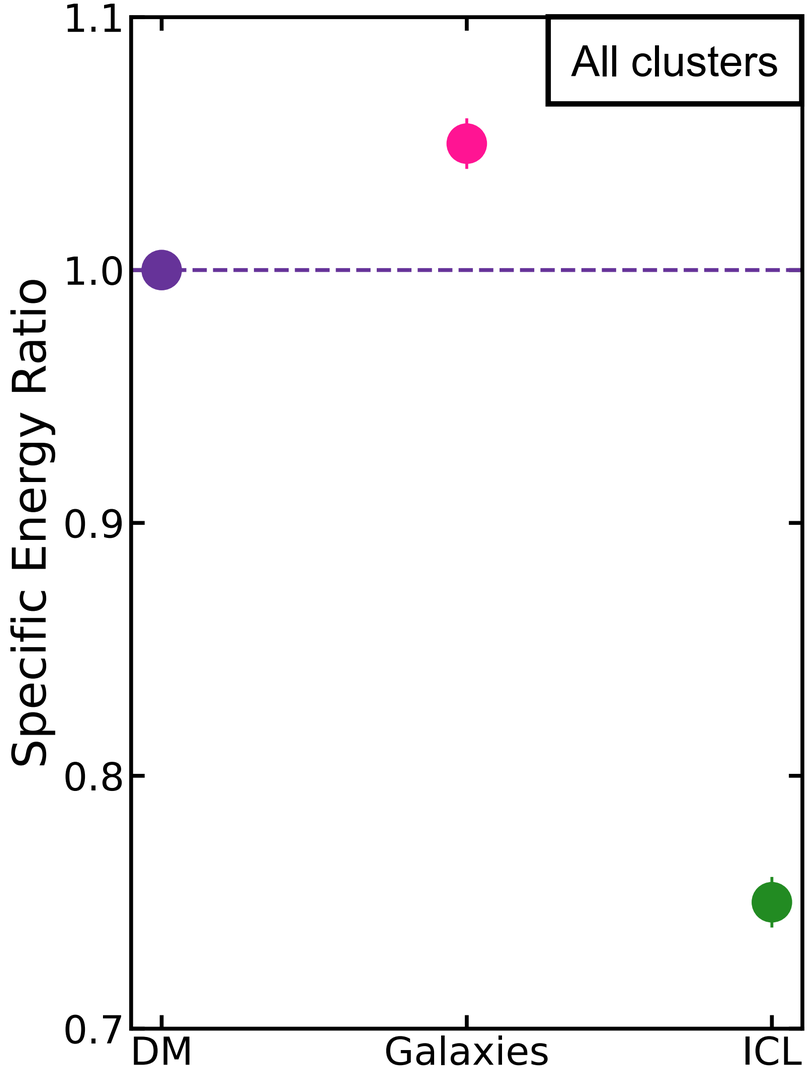
- Orbital energies of intracluster stars are ~25% lower than the DM and the shapes of the distributions are very different.



# Energetics

- Orbital energies of intracluster stars are ~25% lower than the DM and the shapes of the distributions are very different.

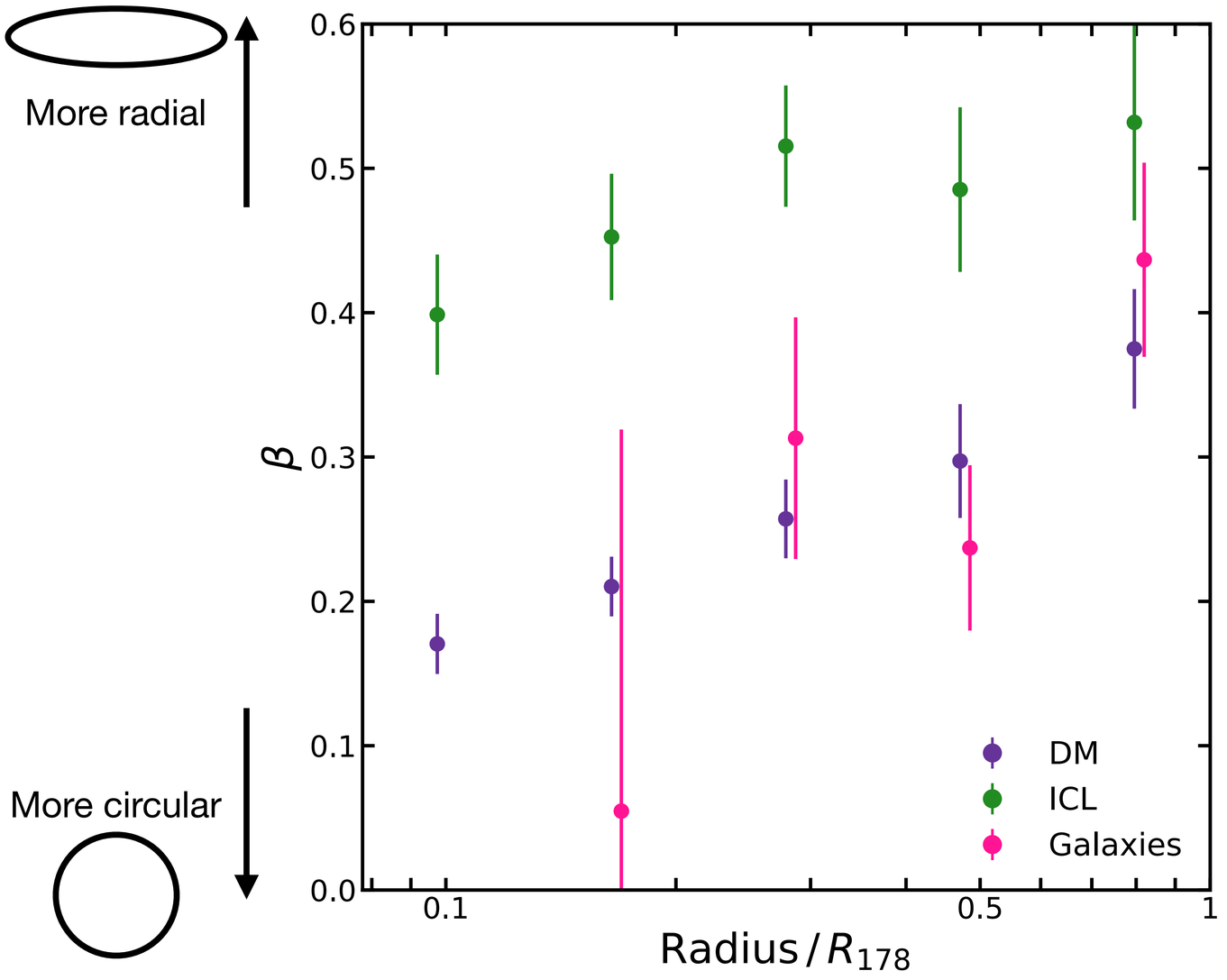


# Anisotropy

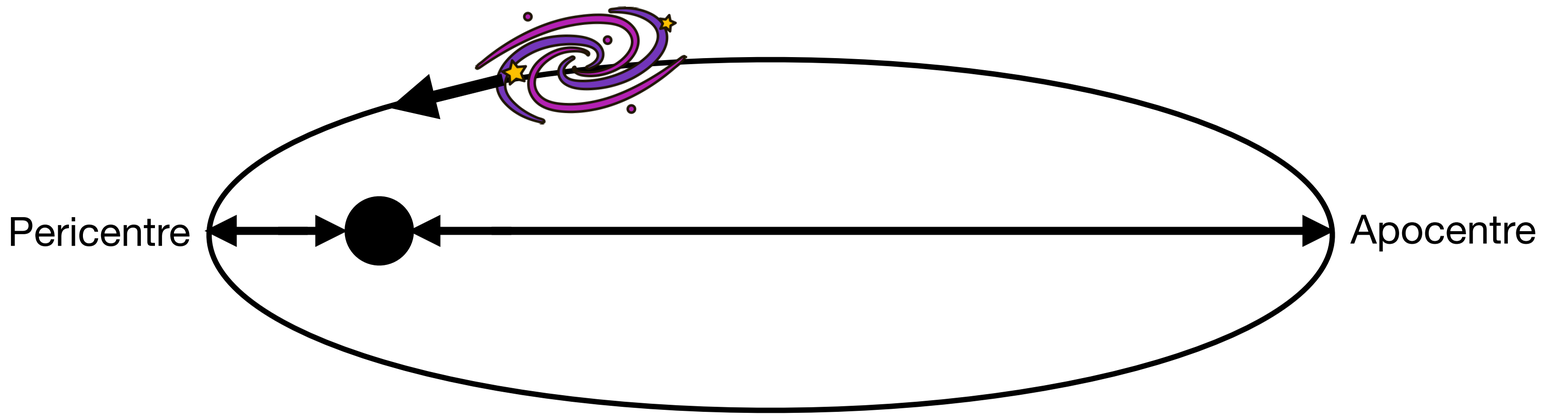
$$\beta(r) = 1 - \frac{\sigma_\theta(r)^2 + \sigma_\phi(r)^2}{2\,\sigma_r(r)^2}$$

- $\beta$ = 1: Radial orbits
- $\beta$ = 0: Isotropic orbits
- $\beta$ -> -∞: Circular orbits
- Galaxy and DM profiles similar.
- ICL more radially biased.



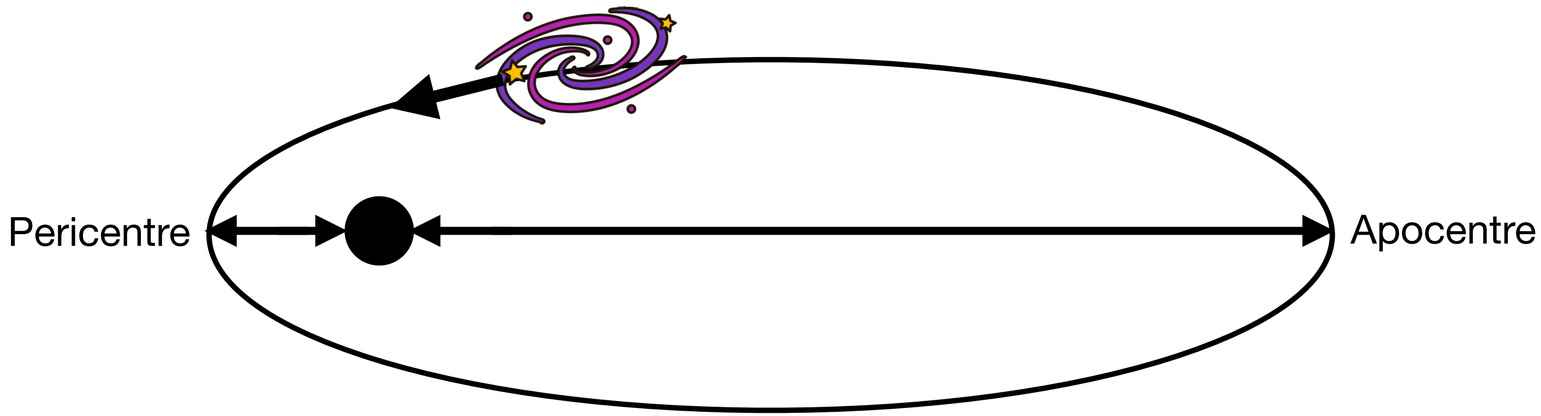
# A possible mechanism

- Most tidal stripping occurs at pericentre.



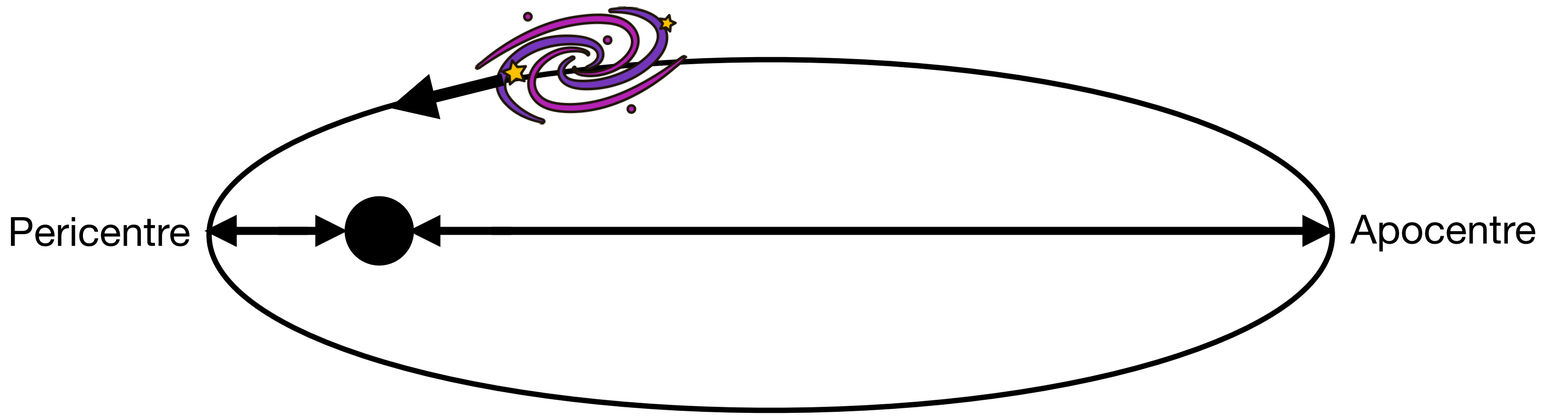
# A possible mechanism

- Most tidal stripping occurs at pericentre.
- Tidal stripping more efficient at smaller pericentric distances.



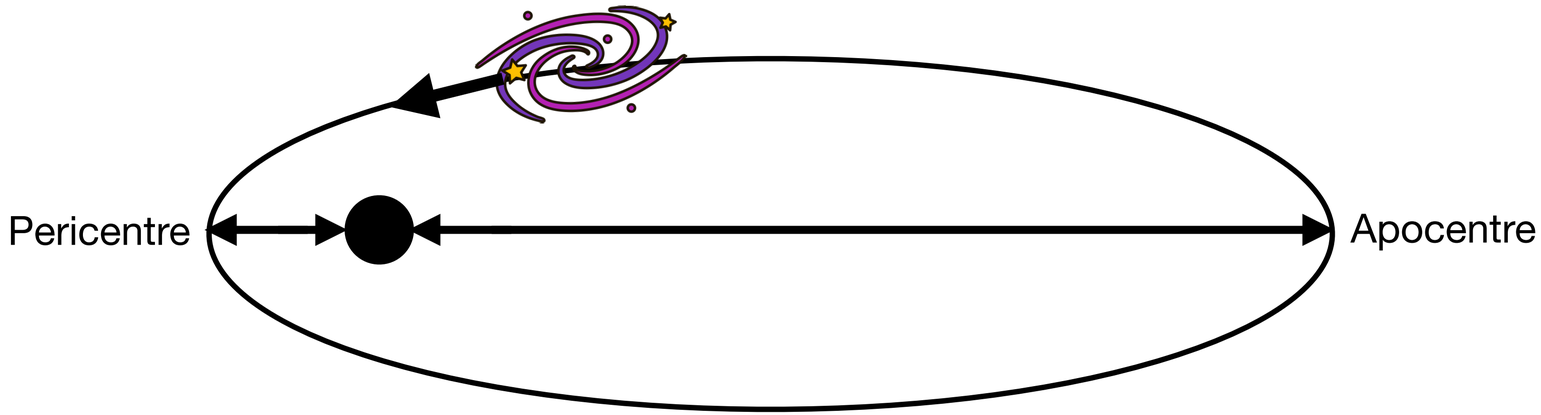
# A possible mechanism

- Most tidal stripping occurs at pericentre.
- Tidal stripping more efficient at smaller pericentric distances.
- Pericentric distance minimised for low energy and radial orbits.



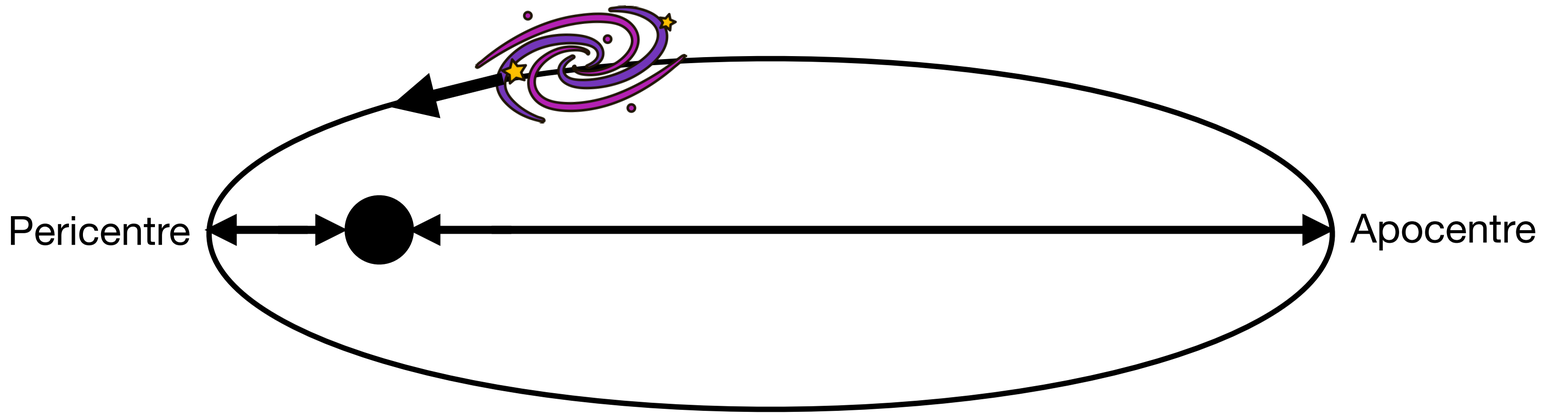
# A possible mechanism

- Most tidal stripping occurs at pericentre.
- Tidal stripping more efficient at smaller pericentric distances.
- Pericentric distance minimised for low energy and radial orbits.
- Could lead to biases in orbital properties of stripped material.

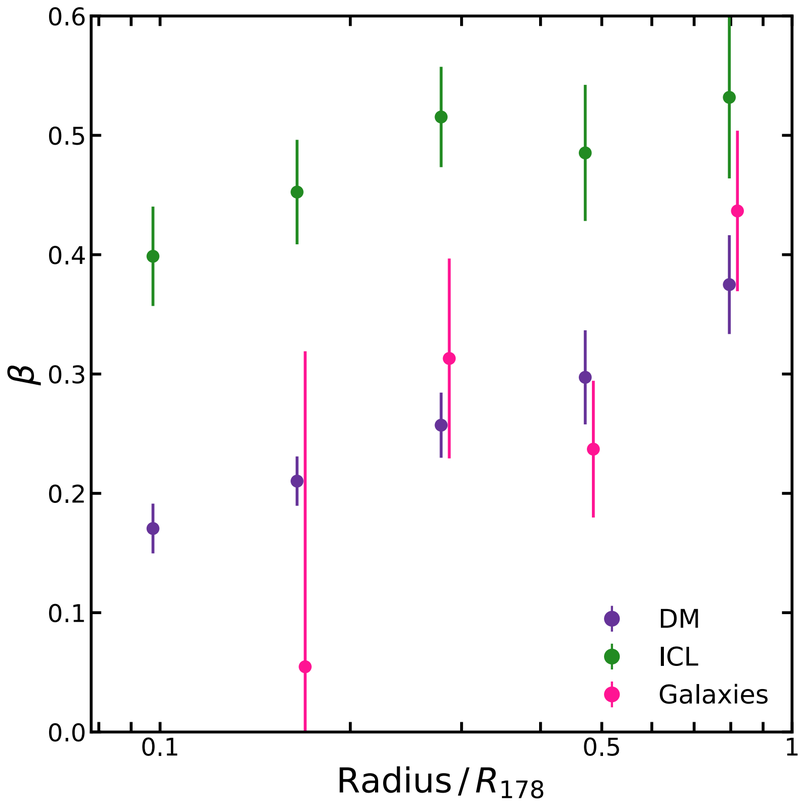


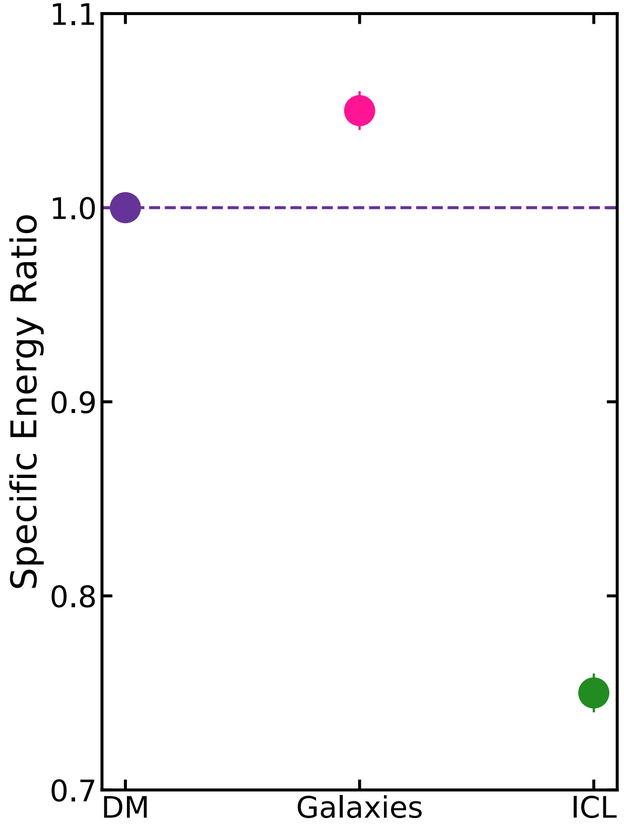
# A possible mechanism

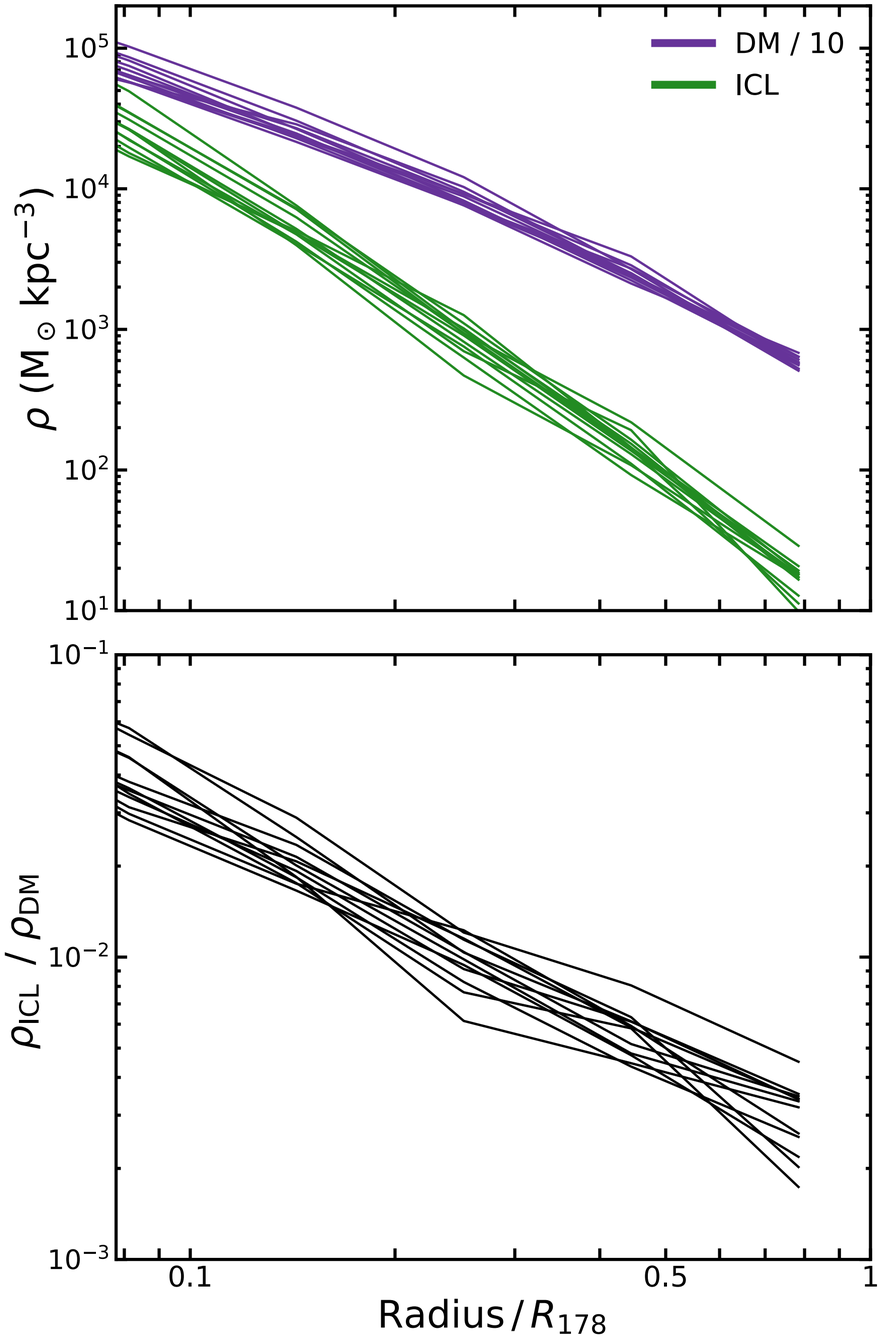
- Most tidal stripping occurs at pericentre.
- Tidal stripping more efficient at smaller pericentric distances.
- Pericentric distance minimised for low energy and radial orbits.
- Could lead to biases in orbital properties of stripped material.
- Stars are more tightly bound than dark matter in subhaloes -> biases less prominent for dark matter.



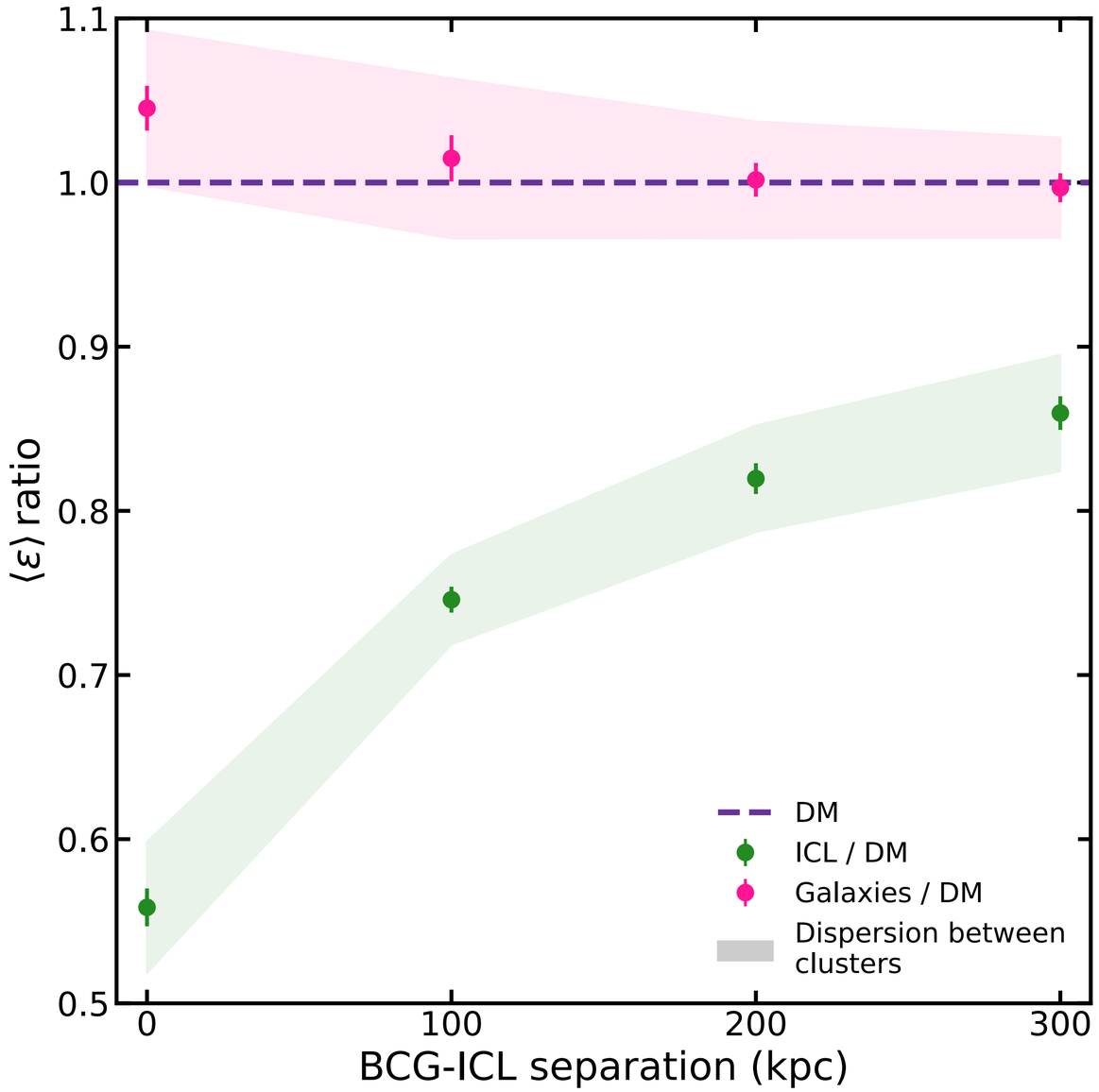
# Why is this important?

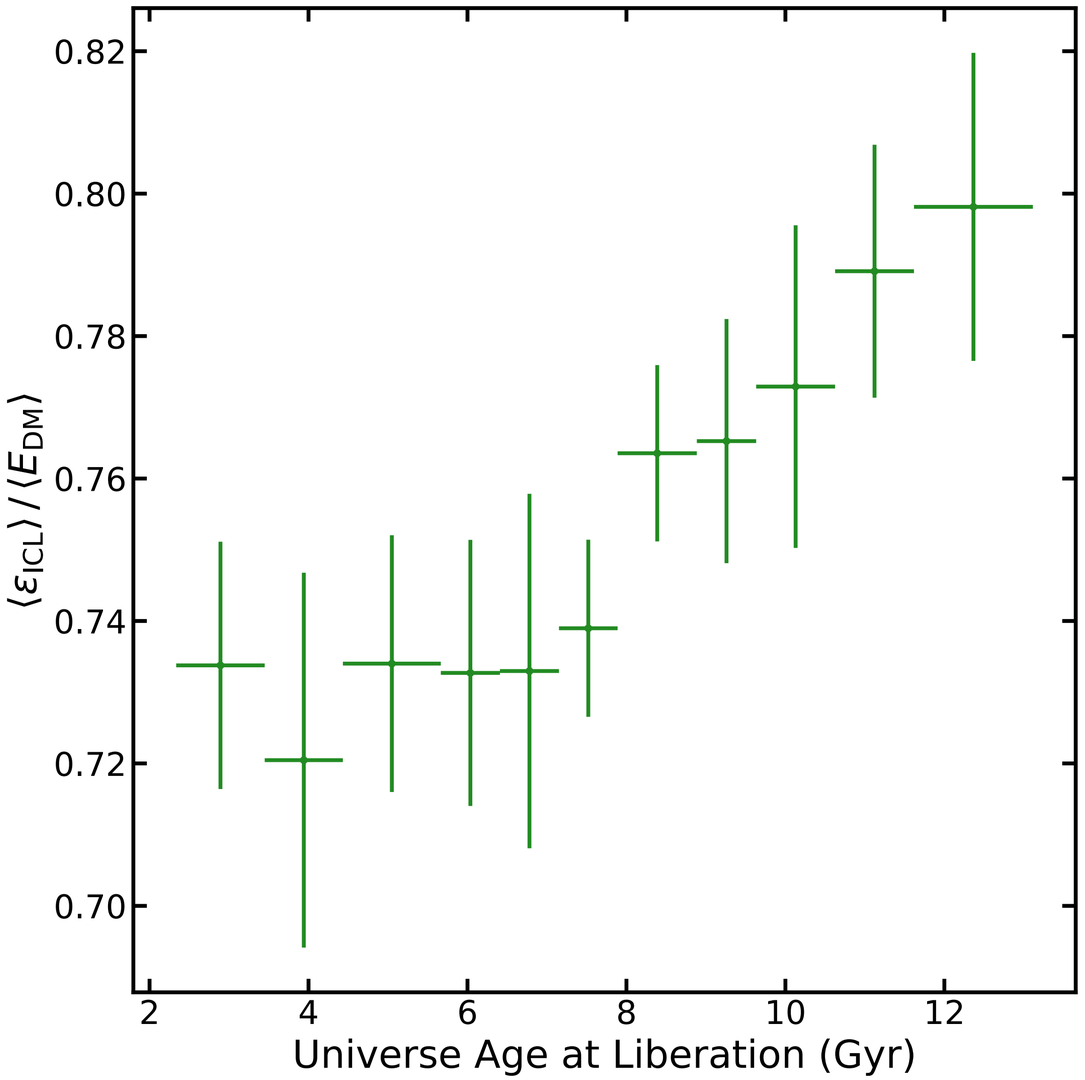


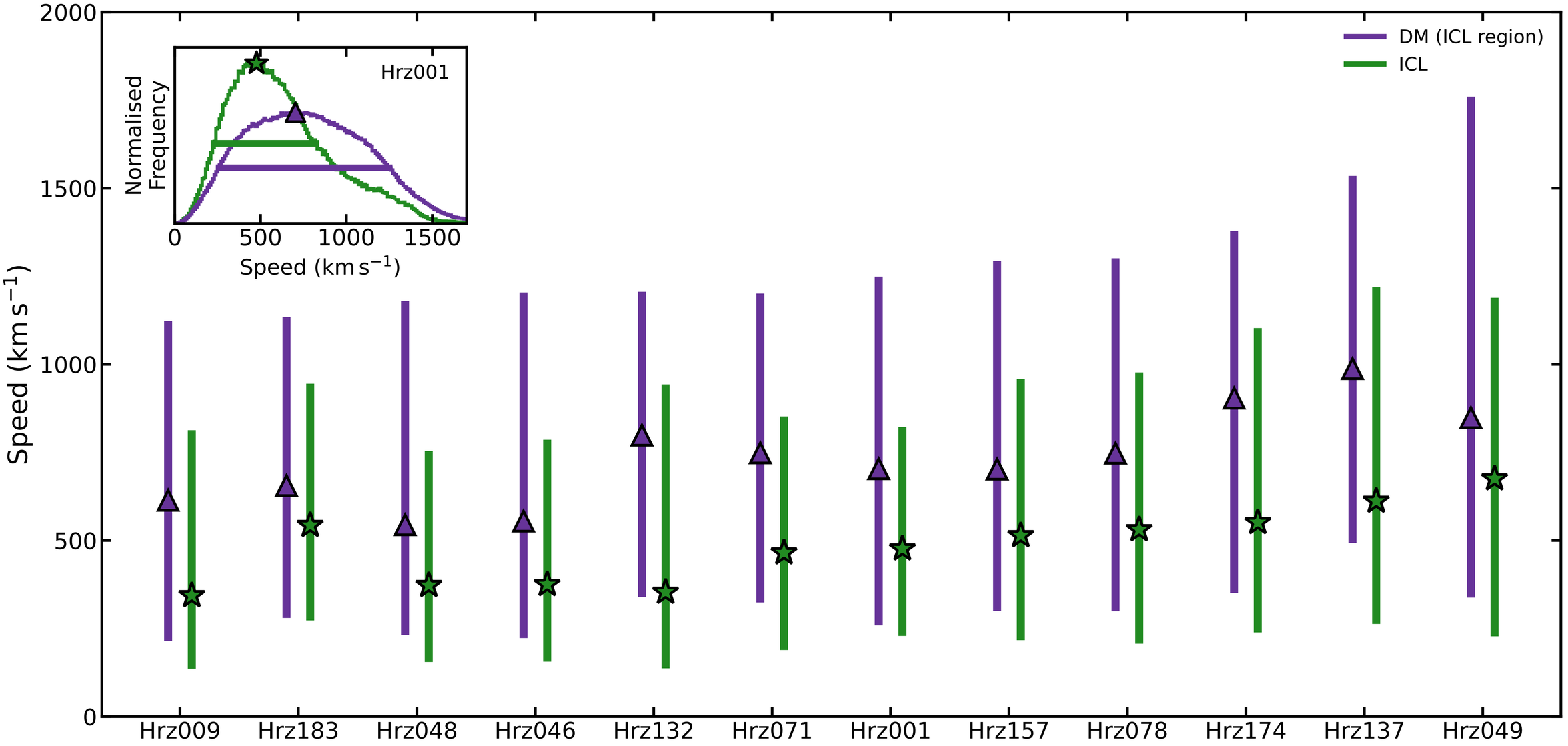




- ICL is not an unbiased proxy for the DM distribution.
- Need to understand the processes that produce the intracluster stars and the origin of these differences with the DM.


1.1
1.0
0.9
0.8
0.7
0.6
0.5
⟨ε⟩ ratio
0
100
200
300
BCG-ICL separation (kpc)
DM
ICL / DM
Galaxies / DM
Dispersion between clusters


0.82
0.80
0.78
0.76
0.74
0.72
0.70
$\langle \varepsilon_{ICL} \rangle / \langle E_{DM} \rangle$
2
4
6
8
10
12
Universe Age at Liberation (Gyr)


DM (ICL region)
ICL
Hrz001
Normalised Frequency
0
500
1000
1500
Speed (km s$^{-1}$)
2000
1500
1000
500
0
Speed (km s$^{-1}$)
Hrz009
Hrz183
Hrz048
Hrz046
Hrz132
Hrz071
Hrz001
Hrz157
Hrz078
Hrz174
Hrz137
Hrz049