# Challenges in reproducing Ultra-Faint Dwarf Galaxies :

# failure of galaxy formation models or questioning the ΛCDM ?



Yves Revaz

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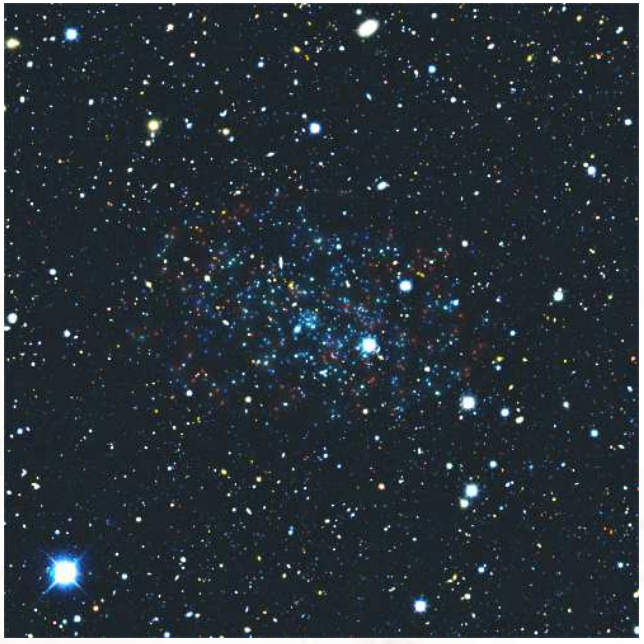
Pascale Jablonka (EPFL)

EPFL

# UFDs : The Faintest among the Faintest

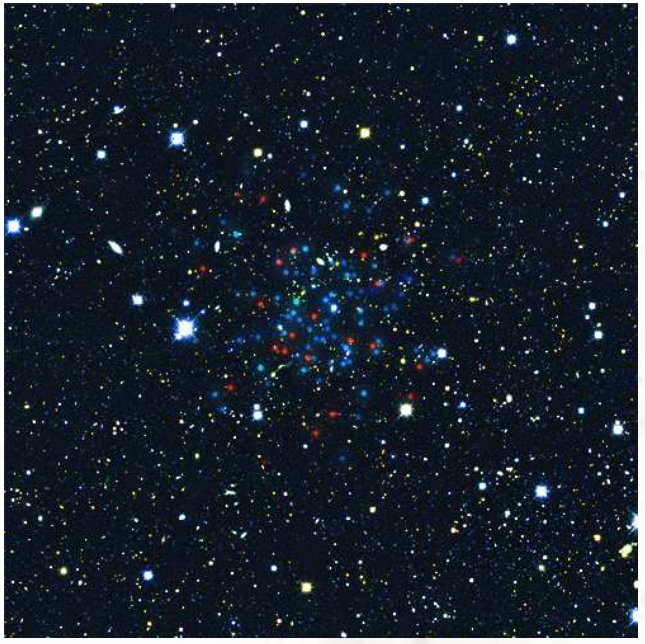
$L_V < 10^5\,\mathrm{L}_\odot$



Eridanus II

$L_V = 6 \cdot 10^4\,\mathrm{L}_\odot$

$r_h = 200\,\mathrm{pc}$



Horlogium I

$L_V = 2 \cdot 10^3\,\mathrm{L}_\odot$

$r_h = 35\,\mathrm{pc}$

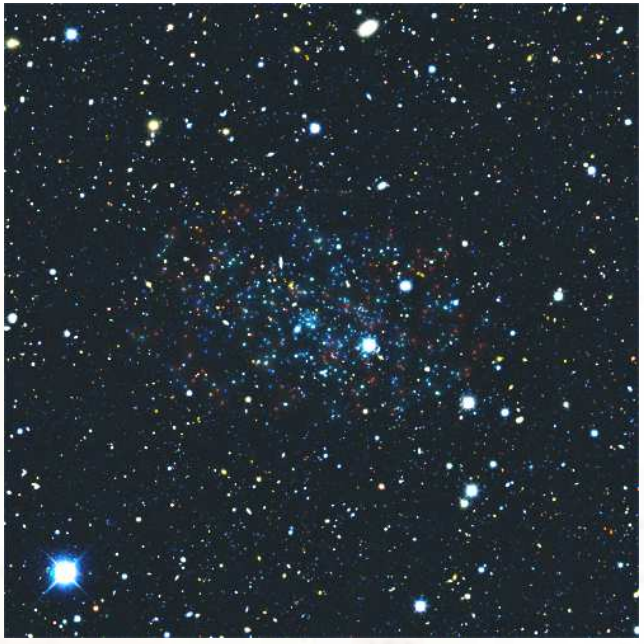
Pictoris I

$L_V = 2 \cdot 10^3\,\mathrm{L}_\odot$

$r_h = 50\,\mathrm{pc}$

Images credit : V. Belokurov & S. Koposov

# UFDs : The Faintest among the Faintest



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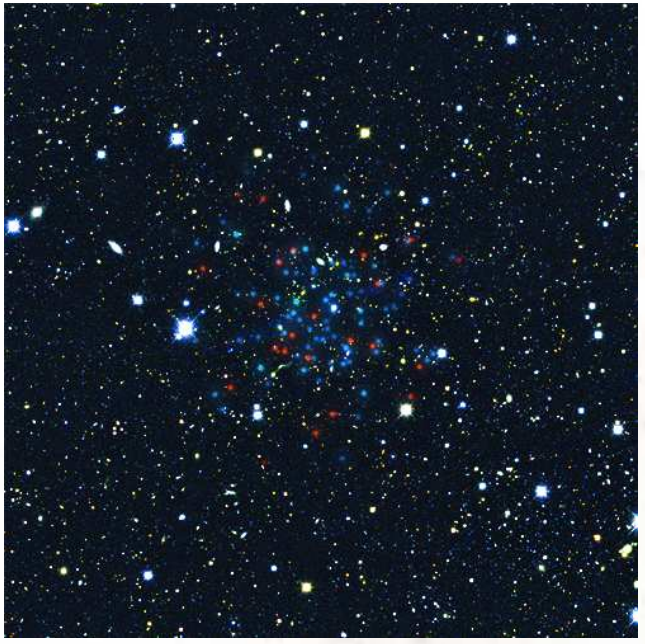

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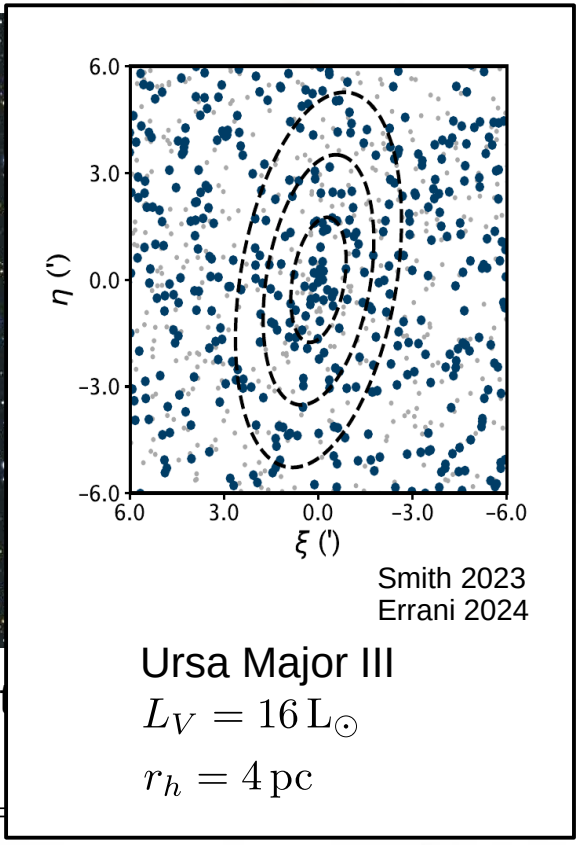
Pict

$L_V$

$r_h$




Smith 2023
Errani 2024

Ursa Major III

$L_V = 16\,\mathrm{L}_\odot$

$r_h = 4\,\mathrm{pc}$

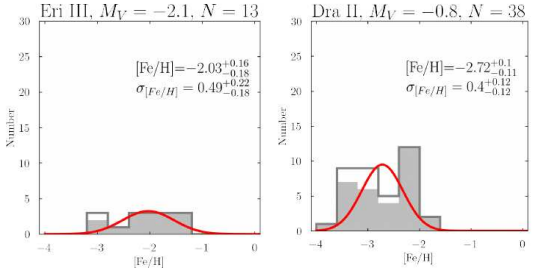
Images credit : V. Belokurov & S. Koposov

# UFDs : The Faintest among the Faintest

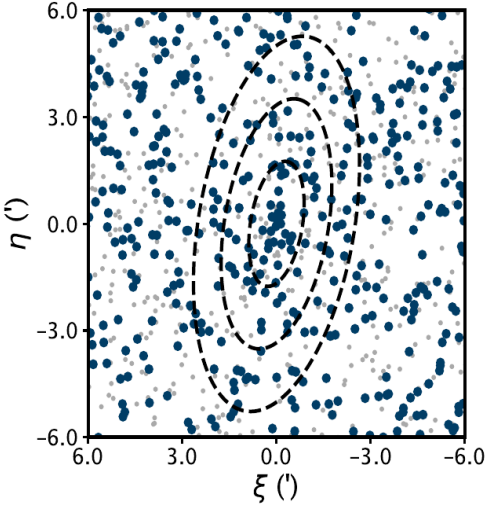
- Faint
- Compact
- Metal poor
  *(e.g. Munoz+06, Martin+07)*
- Dominated by old stellar populations
  *(e.g. Okamoto+12, Brown+12)*
- Dark matter dominated
  *(e.g. Simon+19, Errani+23)*

- About 60 in the Local Group

The smallest galaxies, «fossils» of the EoR
*(Ricotti+05, Salvadori+09, Sanati+23)*




Fu+2023

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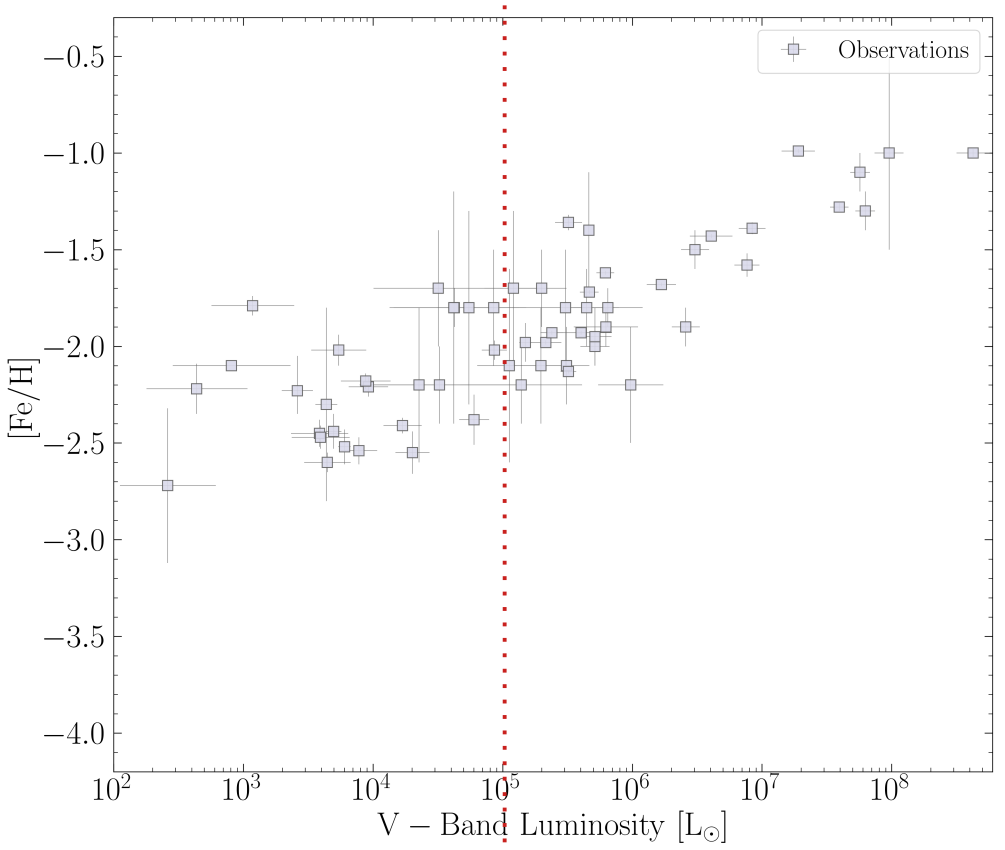
# The Metallicity-Luminosity relation of faint dwarfs




*McConnachie 2012, updated catalog (2021)*

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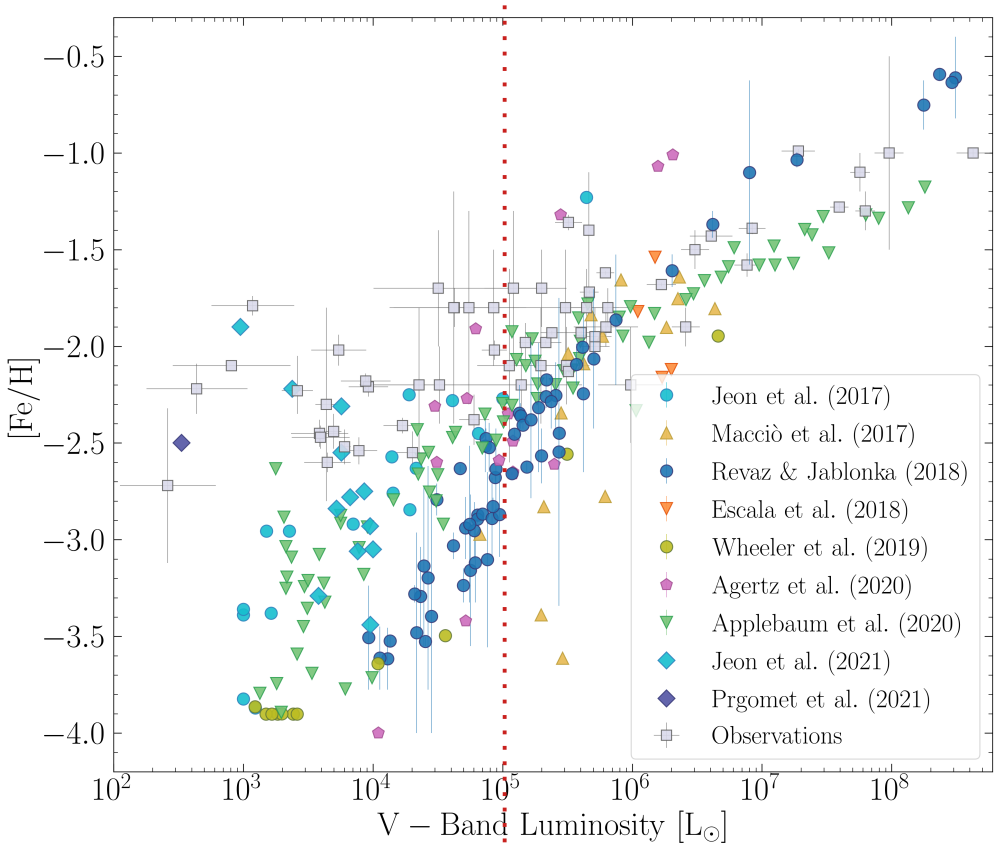


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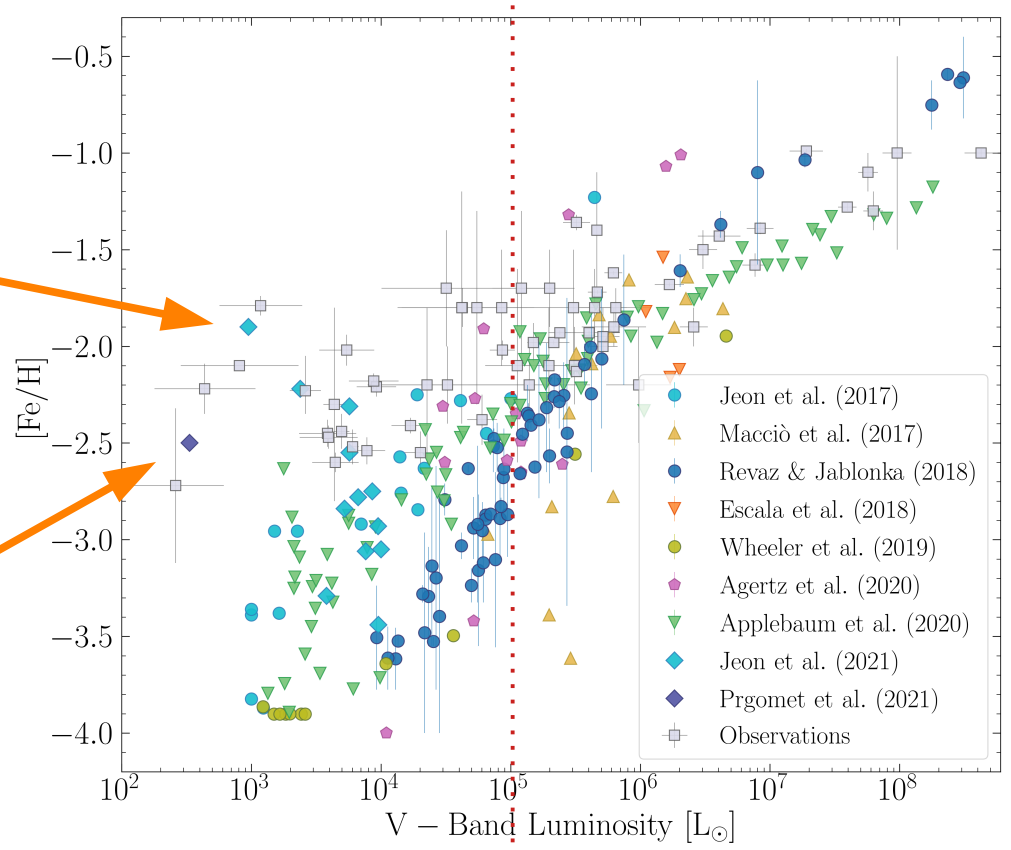
# The Metallicity-Luminosity relation of faint dwarfs

Jeon+21

Prgomet+21
(EDGE group)
metallicity-dependent IMF
slope

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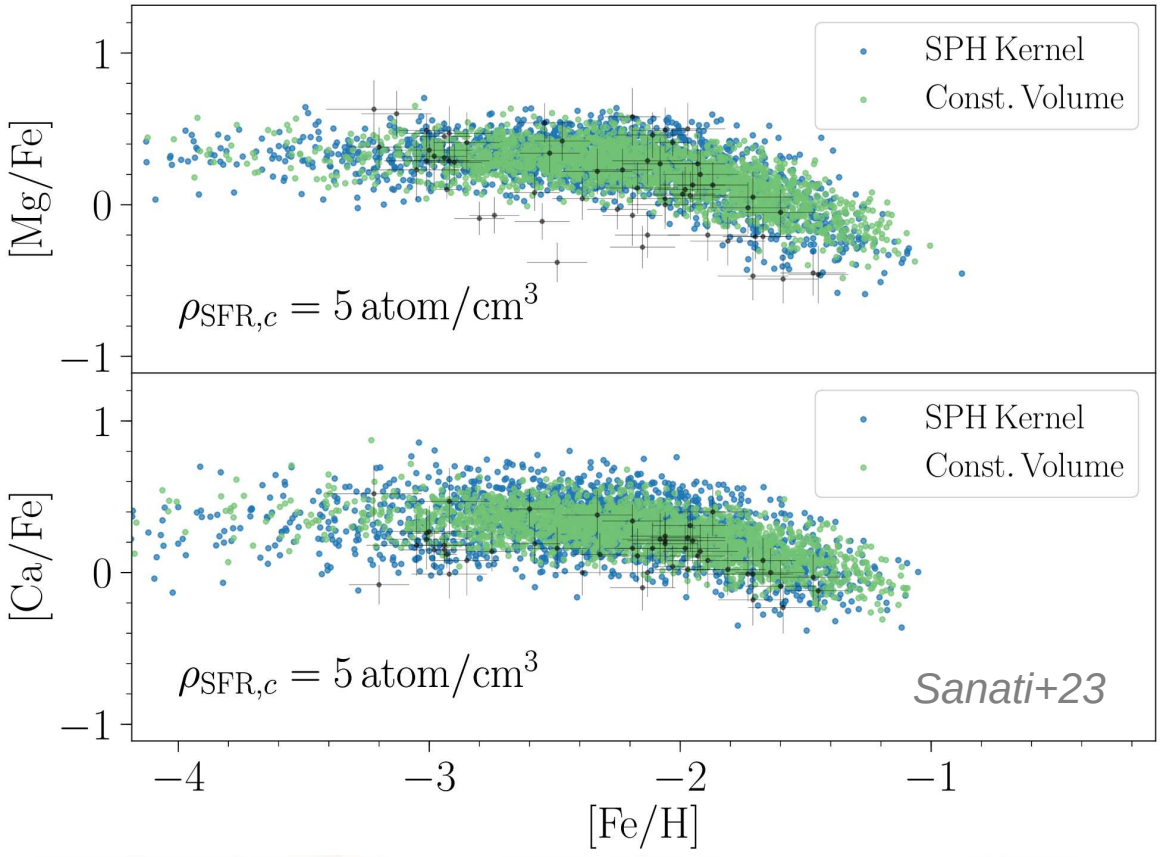
# What is the impact of Pop III stars on UFDs ?

GEAR model
Revaz+12,16,18

Pop III stars (PISNE)
Sanati+23

Calibration on Sextans

18 UFDs (zoom-in)
resolution of 380 $M_\odot$



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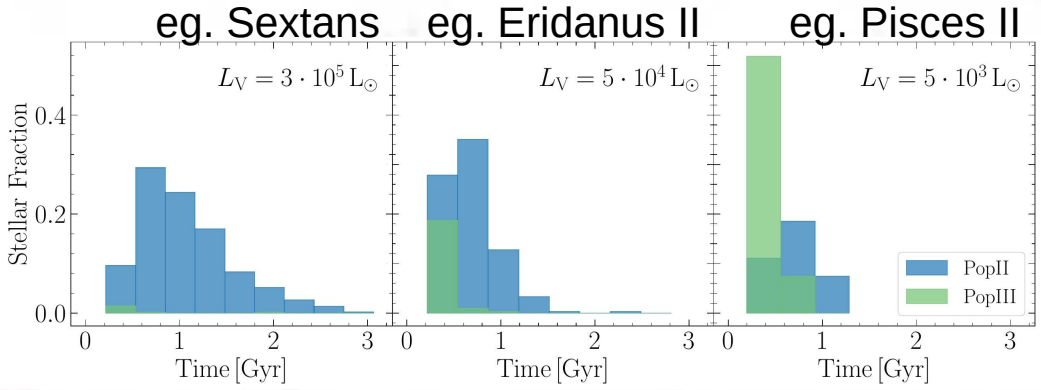


Faint systems are :

- quenched after about 1 Gyr
- strongly dominated by Pop III stars (> 80 %)

*Sanati et al. 2020*

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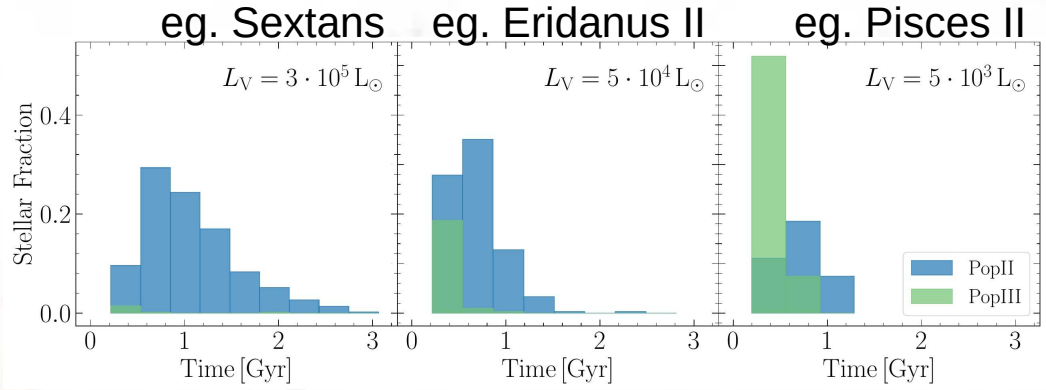


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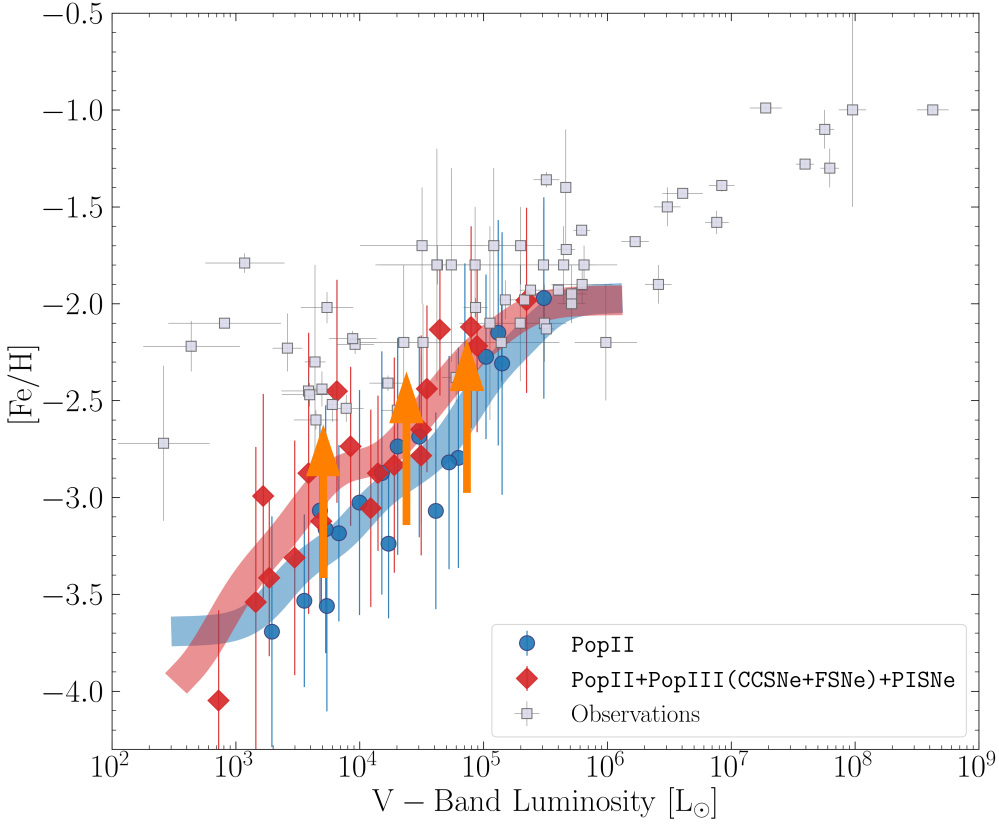


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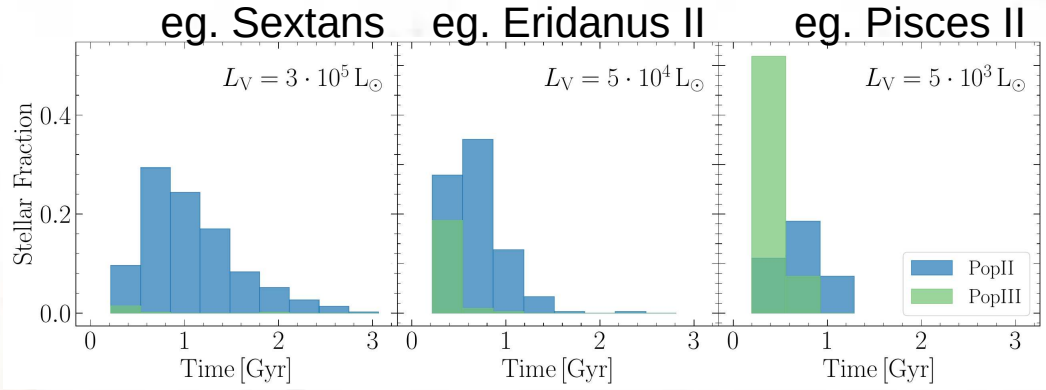


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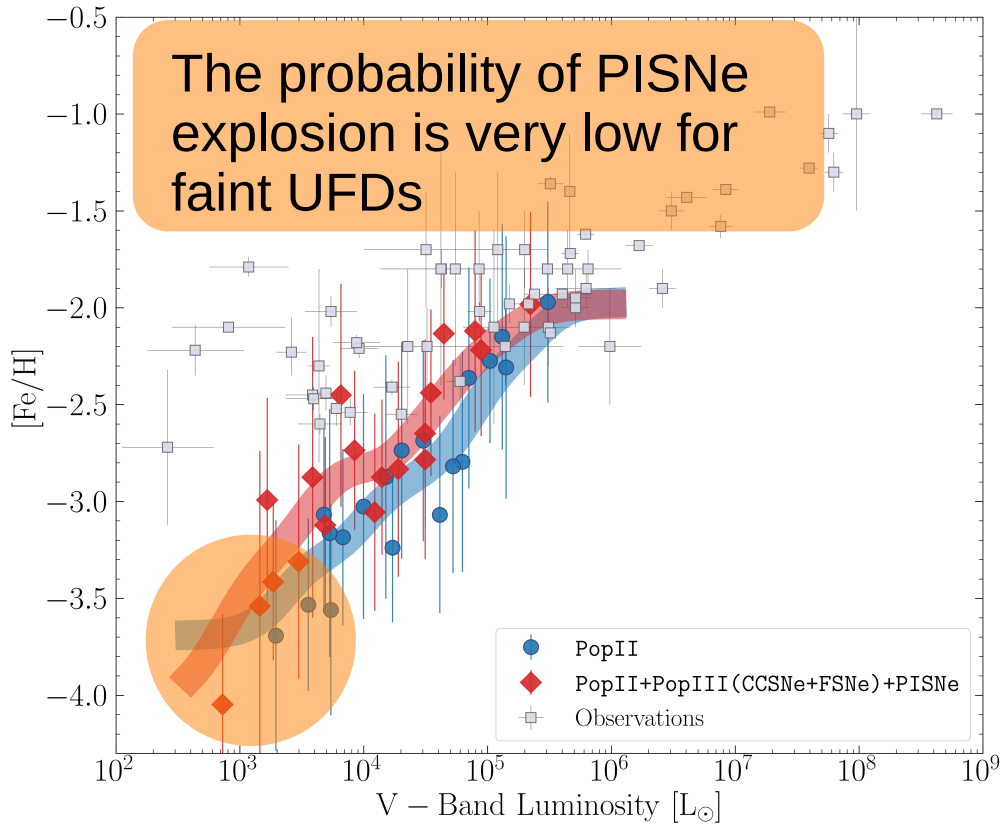
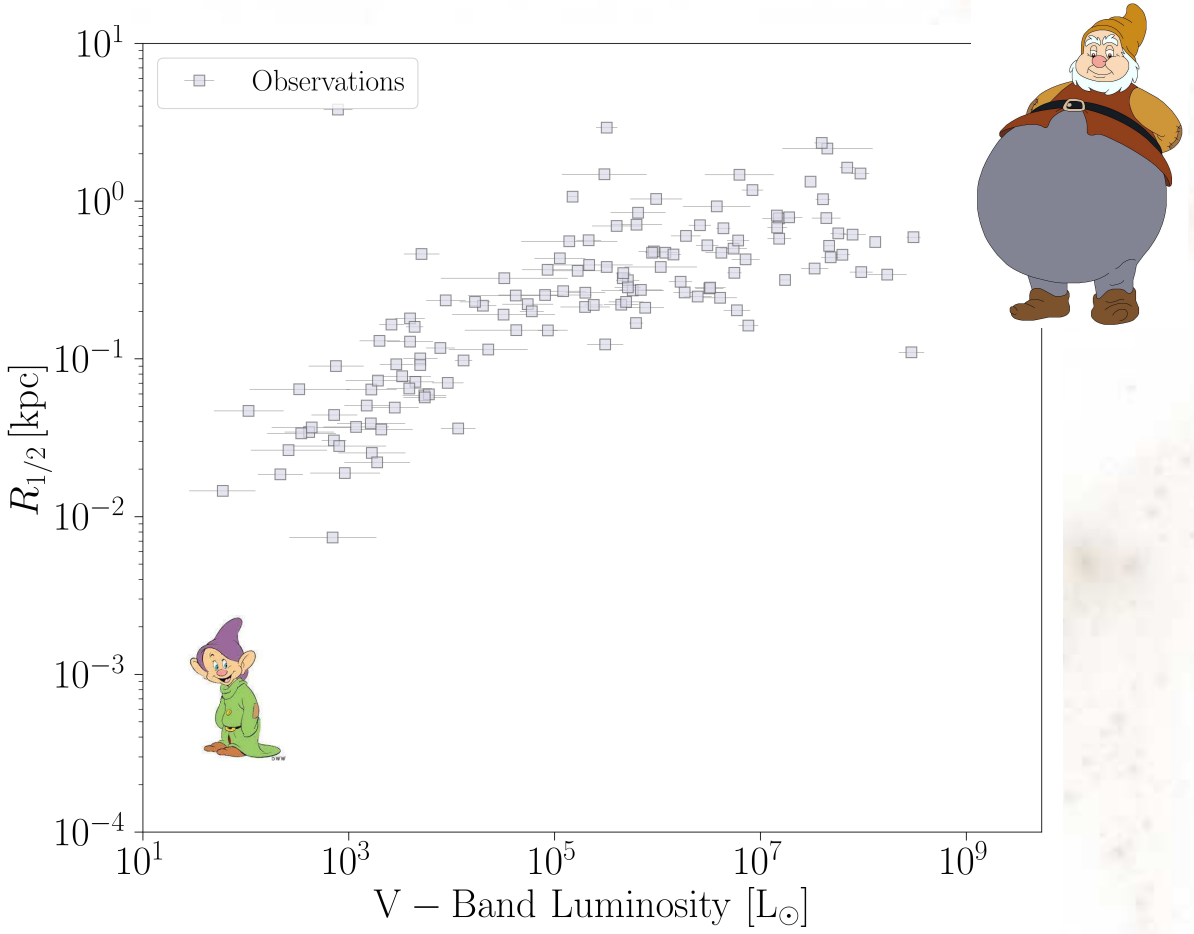



*Sanati et al. 2023*

# The size-luminosity relation of UFDs



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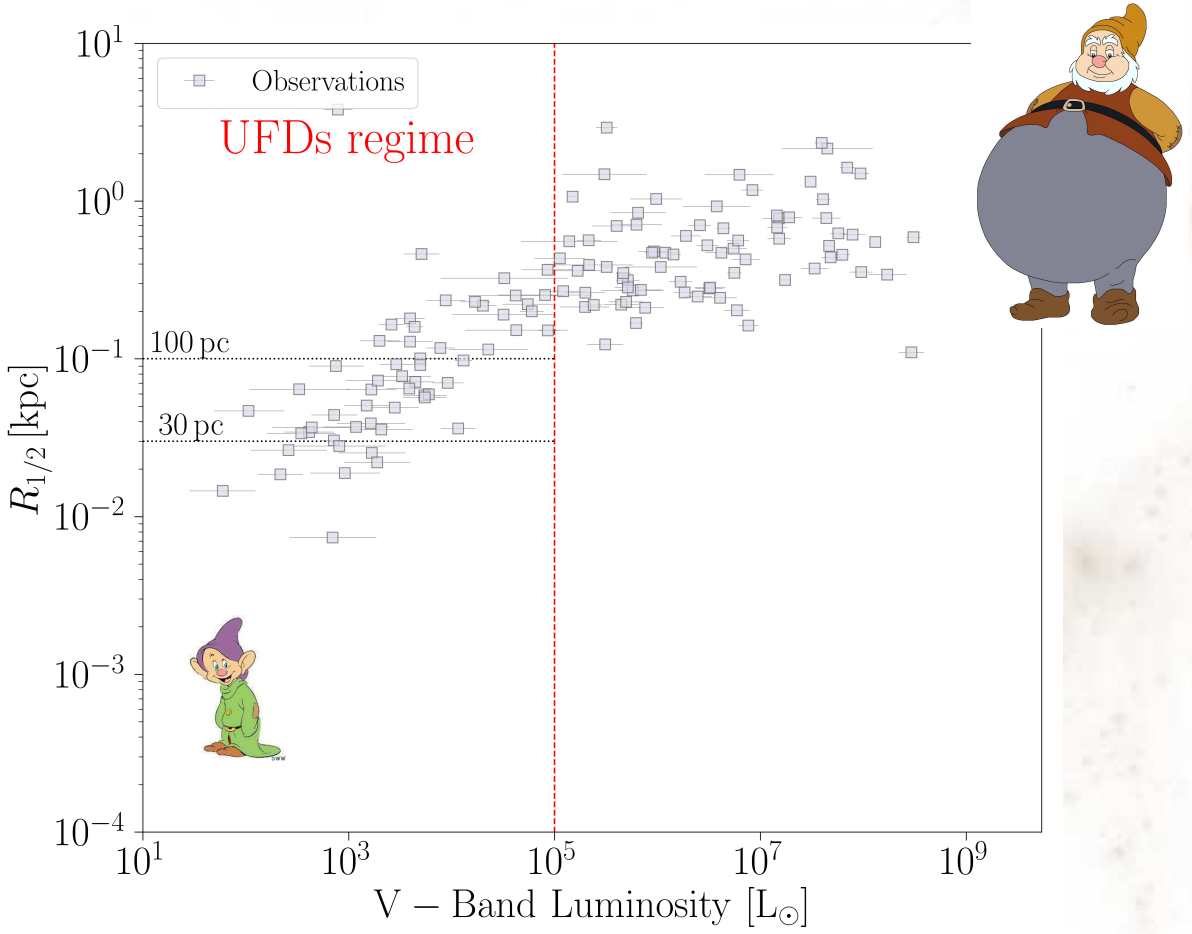

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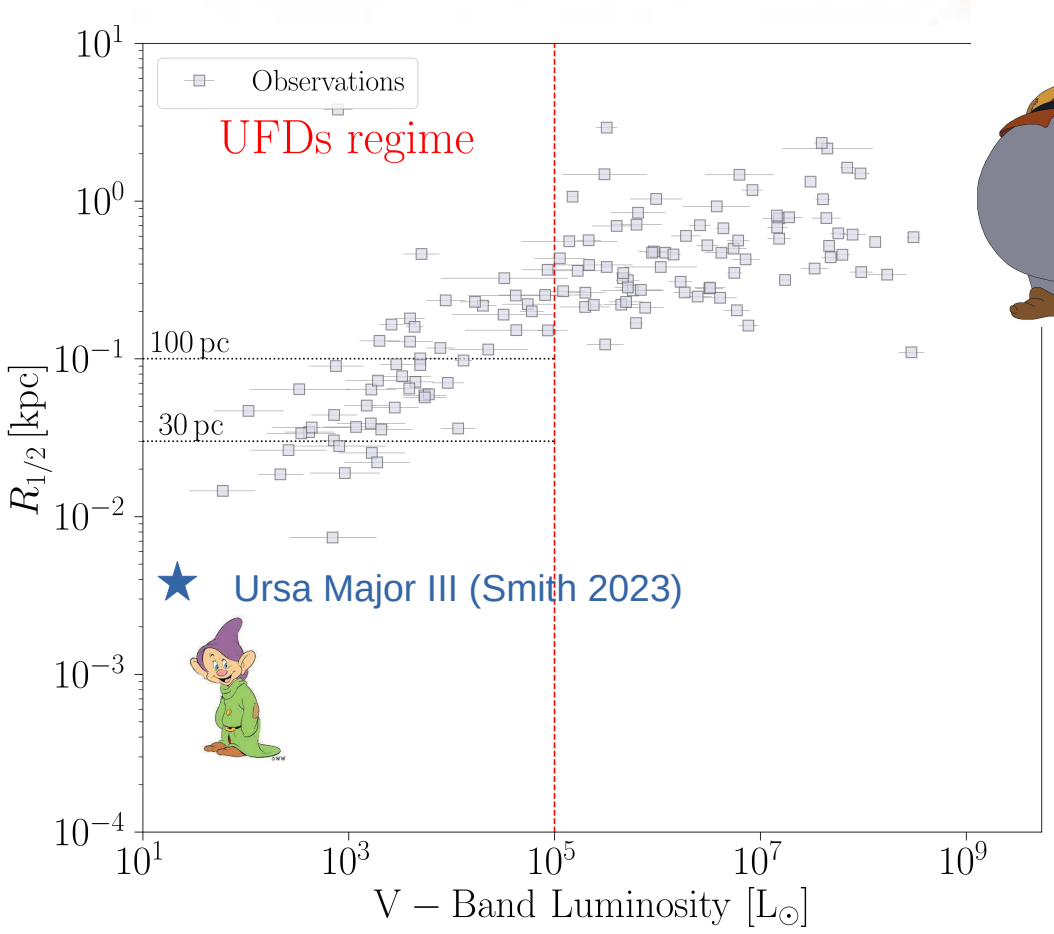


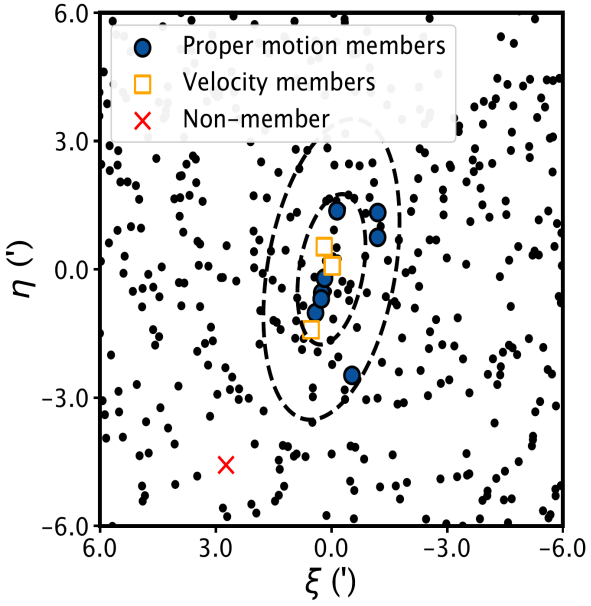

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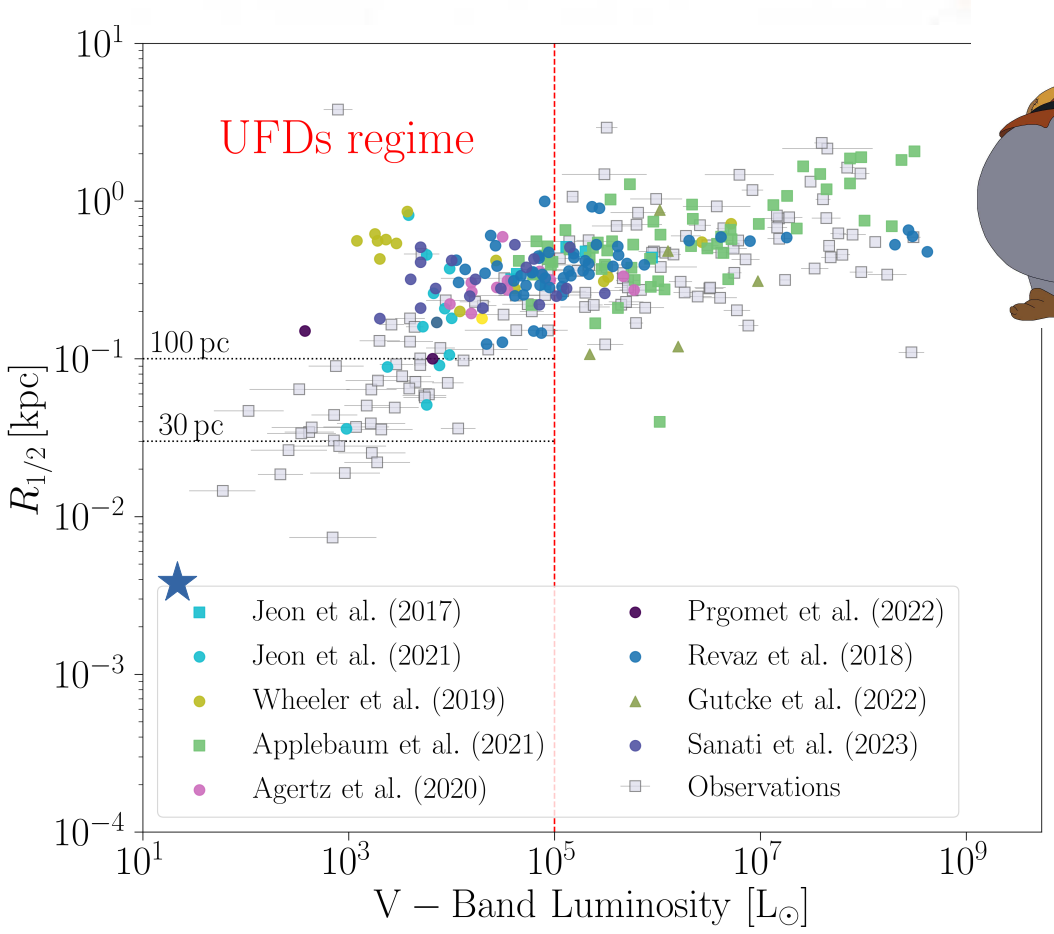
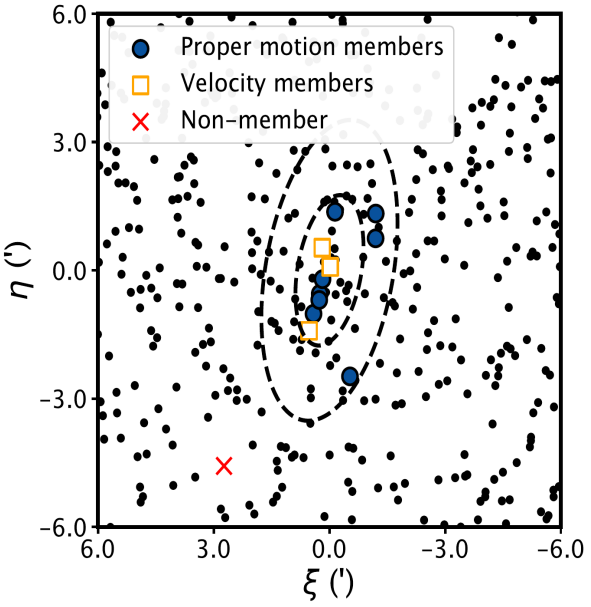
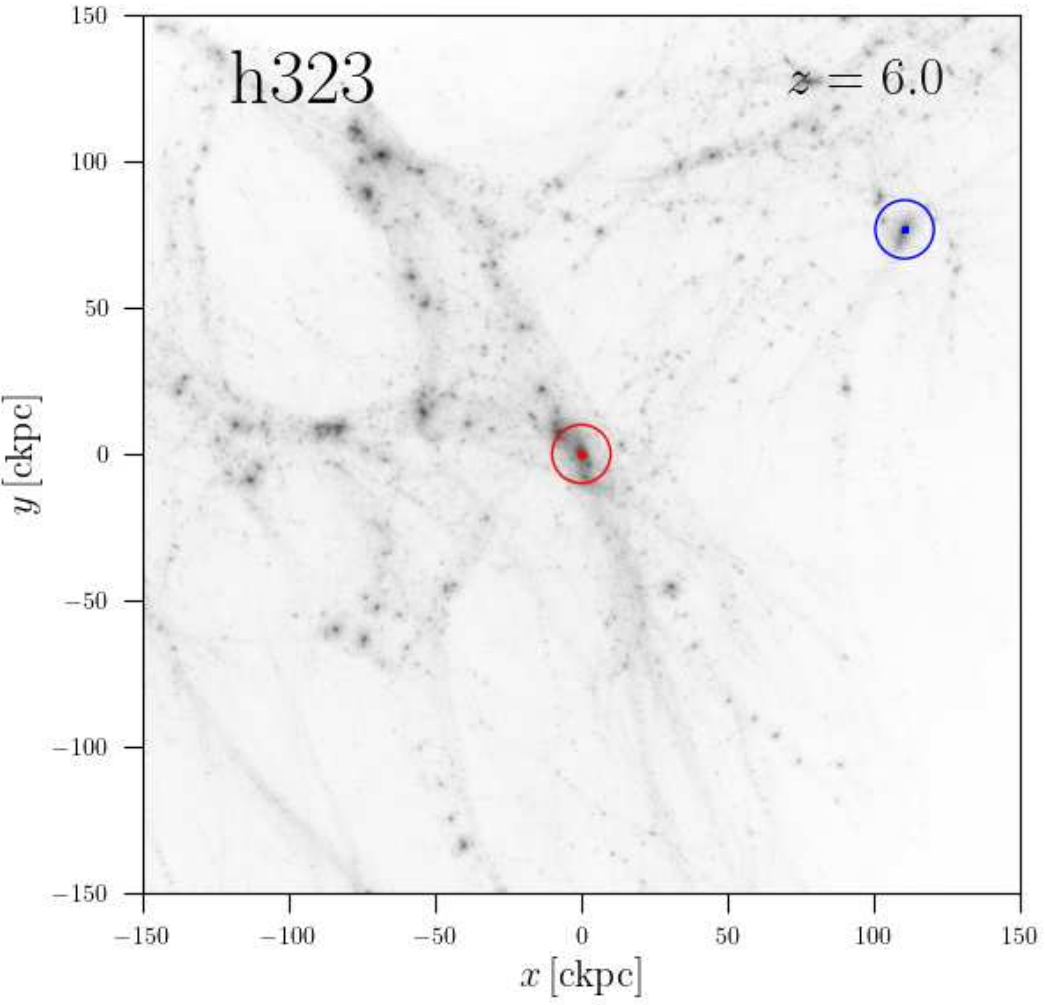
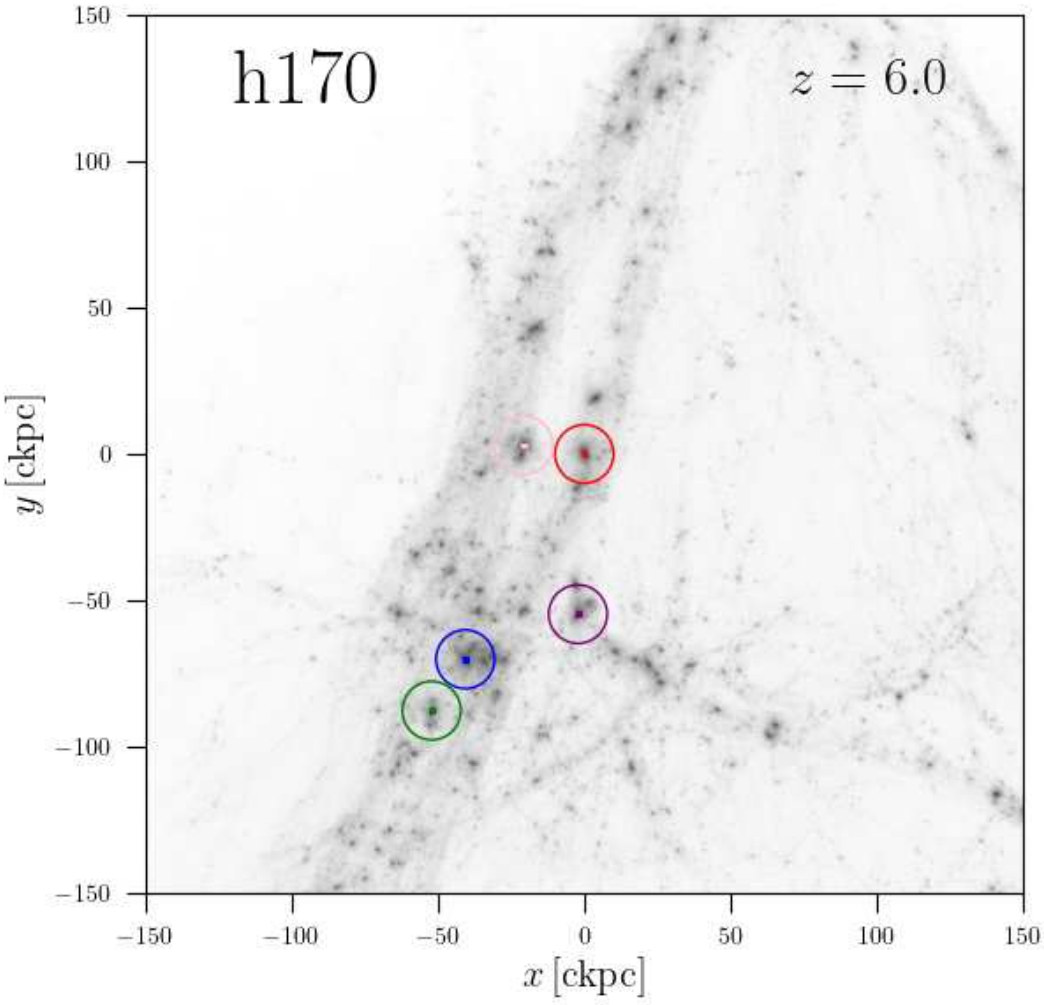


# Hierachical formation : stellar building blocks at z=6

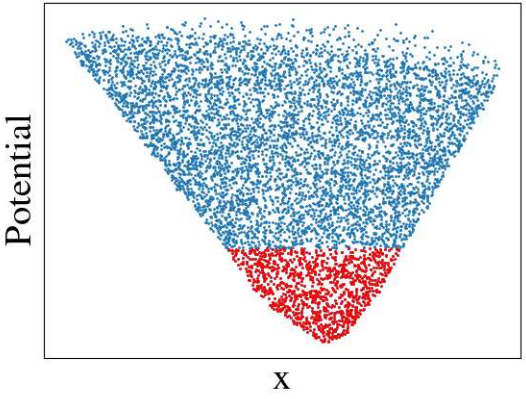


# Our approach

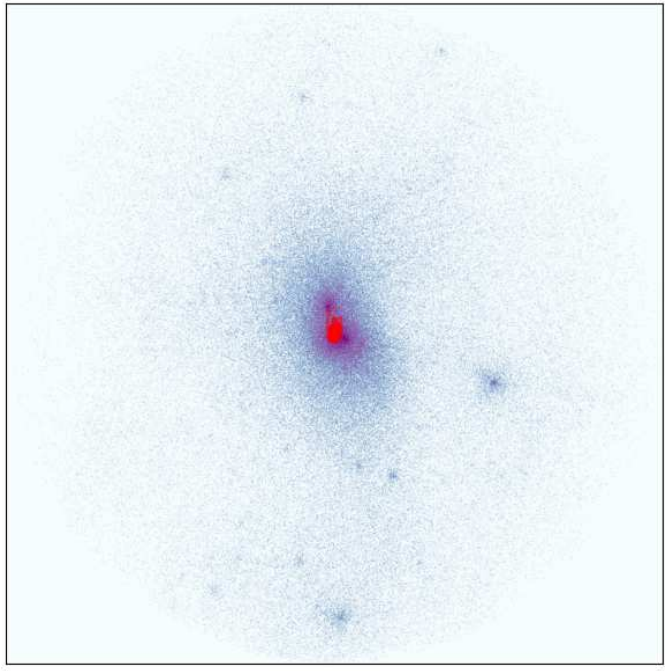


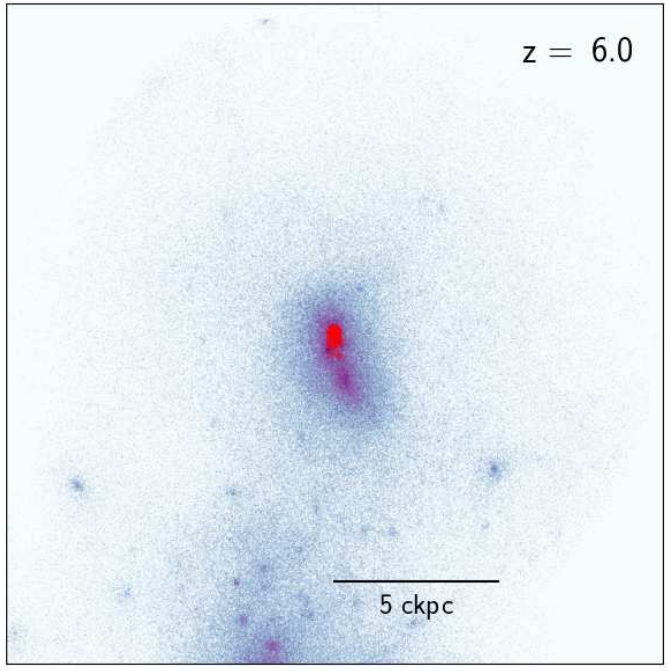
From a very high resolution DMO cosmological simulations, follow the evolution of compact bounded “clusters” extracted at z=6, that form an UFDs at z=0.

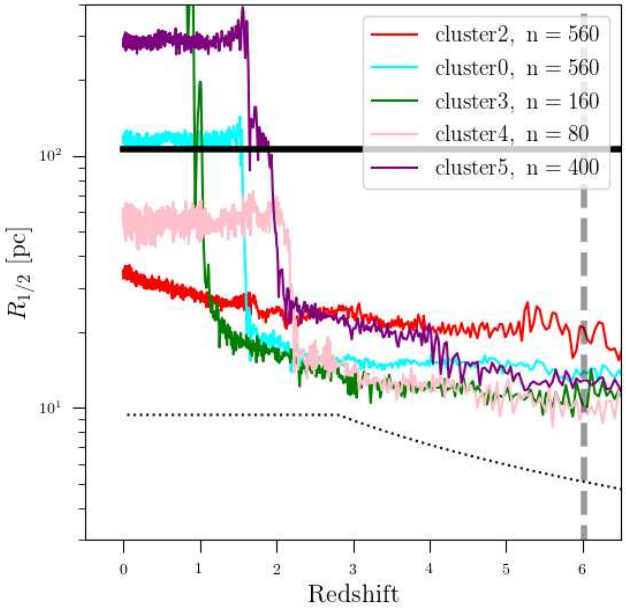



- Identify star forming halos from hydro runs at lower resolution (Sanati 2023)
- 7 UFDs DMO simulations $M_{200} \cong 2 \cdot 10^8 - 8 \cdot 10^8\,\mathrm{M}_\odot$
  - resolution: $m_{\mathrm{DM}} = 77\,\mathrm{M}_\odot$

h170 $L_V = 5 \cdot 10^3\, L_\odot$ $M_{200} = 6.2 \cdot 10^8\, M_\odot$ $R_{1/2} = 106\,\mathrm{pc}$





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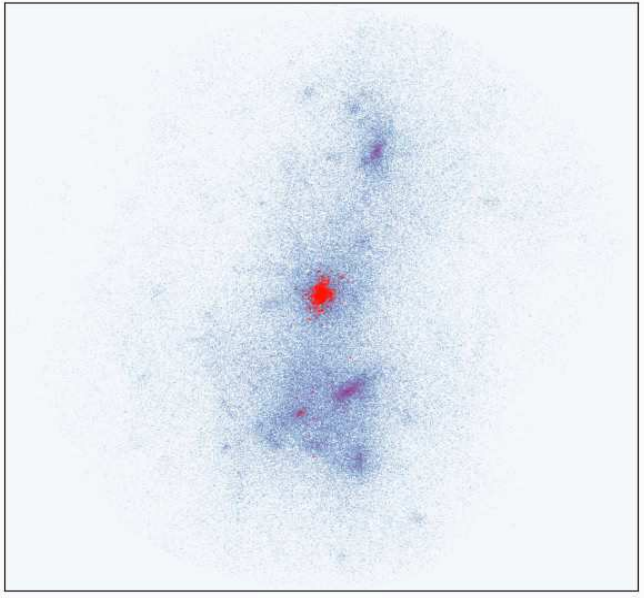
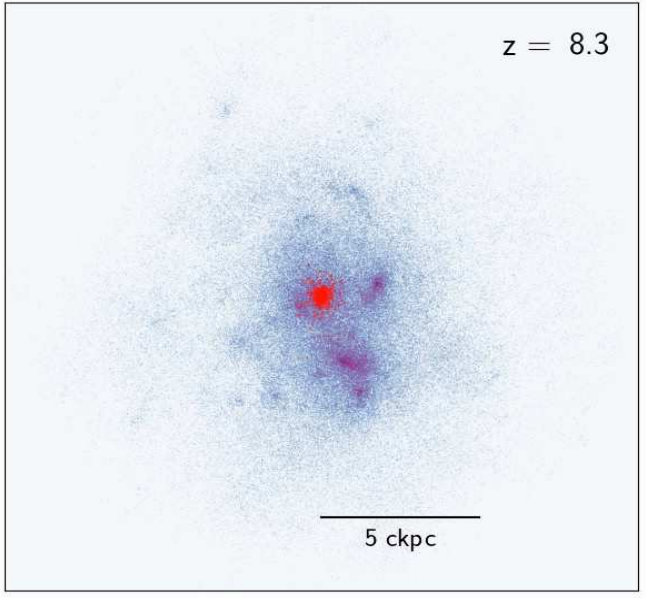
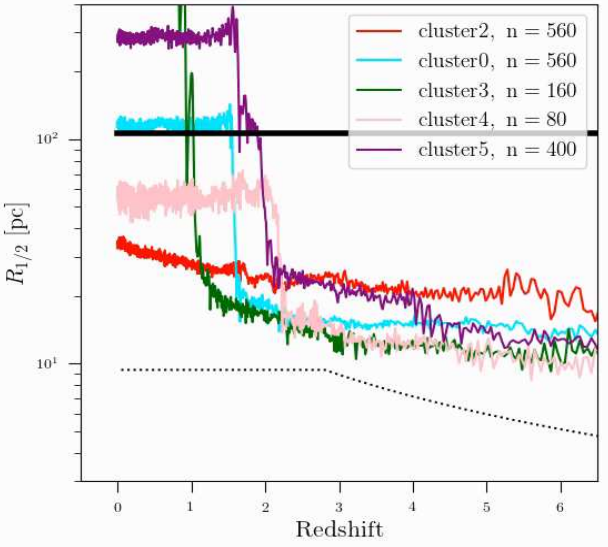


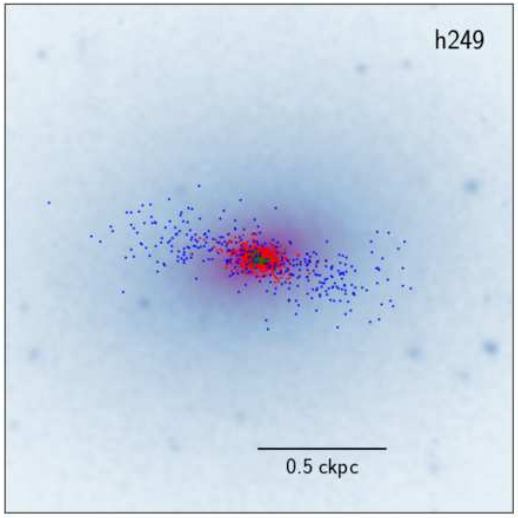


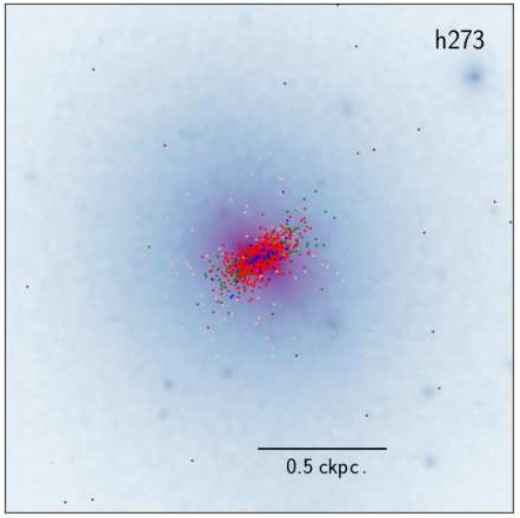



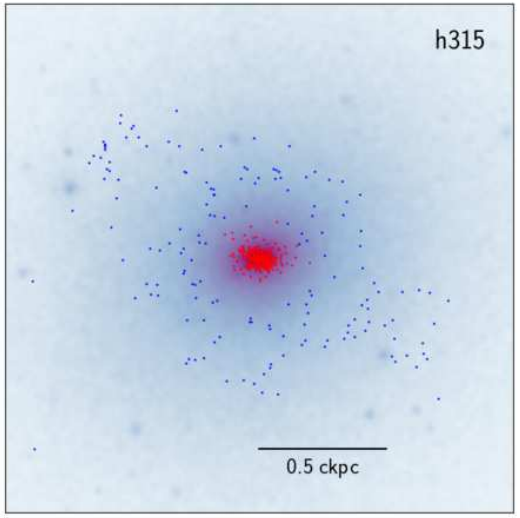
# First lesson learned:

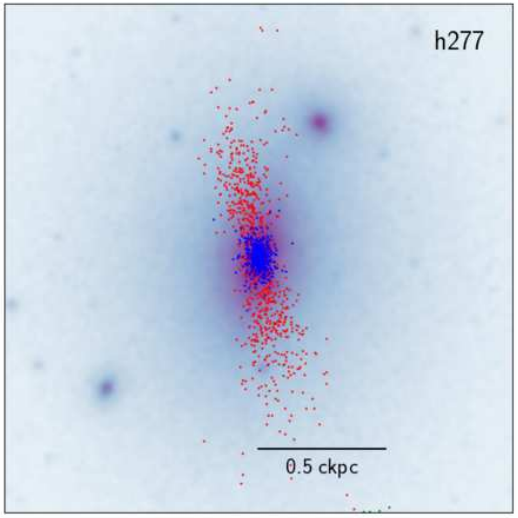
UFDs formed from a hierarchical scenario are complex object

- elliptical structure, stellar haloes



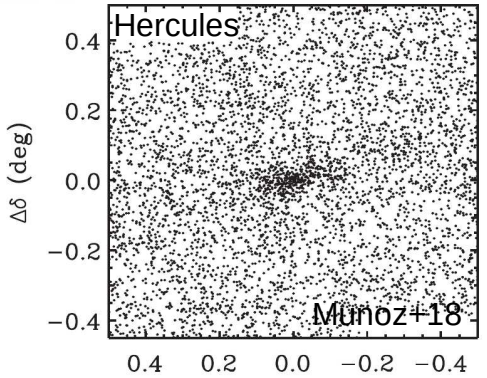




Similar observed features (Martin+08):

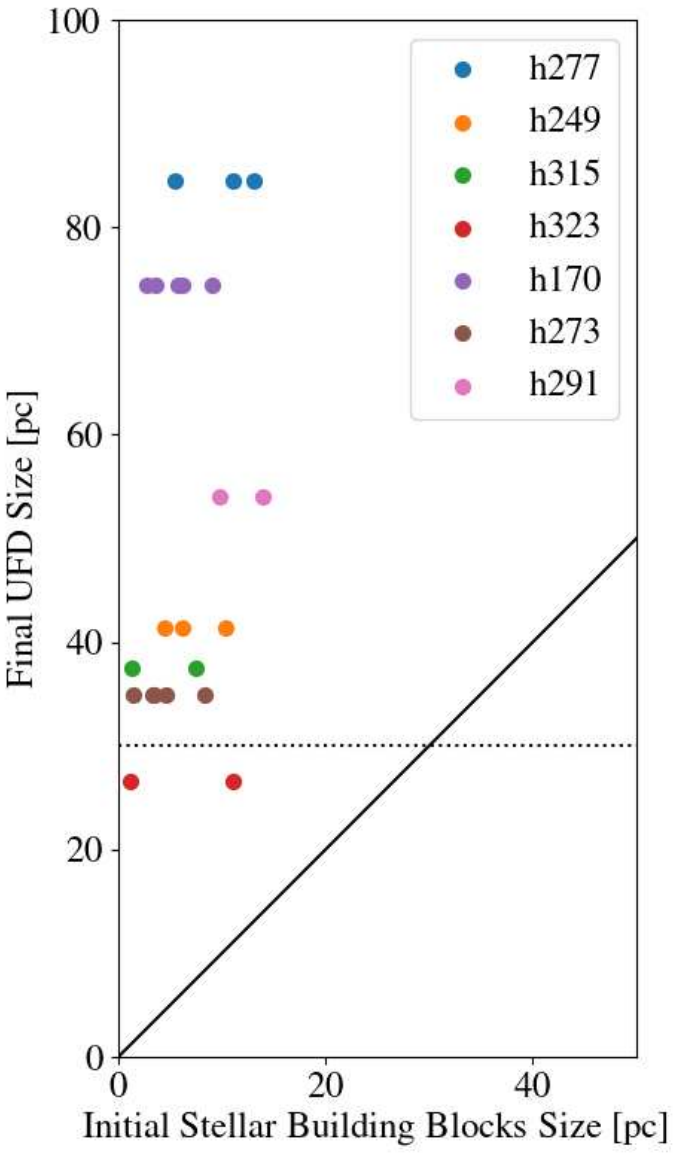
- Hercules and Boötes I (Roderick+15,Longeard+22)
- Tucana II (Chiti et al. 2021)

Their origin has nothing to do with tidal interactions with the Milky Way !



# Second lesson learned:

It is hard to obtain compact UFDs



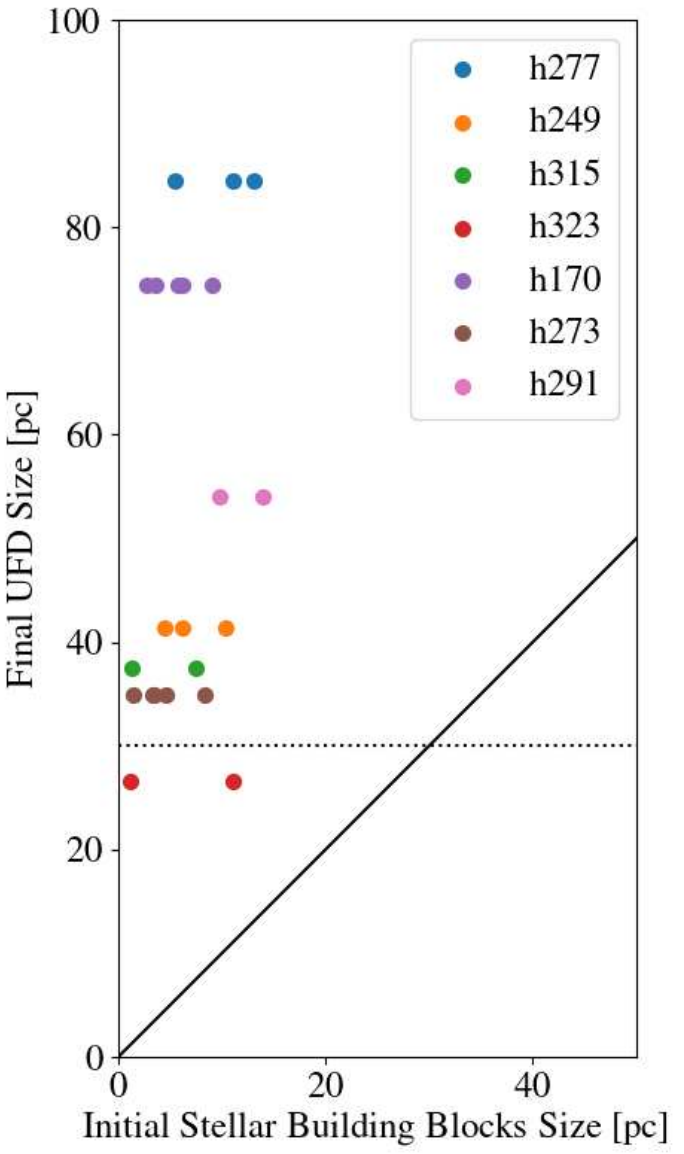
# Second lesson learned:

It is hard to obtain compact UFDs

$\sim 30\,\mathrm{pc}$

Possible, but requires

- isolated halo
- DM halo mass not larger $4 \cdot 10^8\ M_\odot$
- 10 - pc size cluster at z=6



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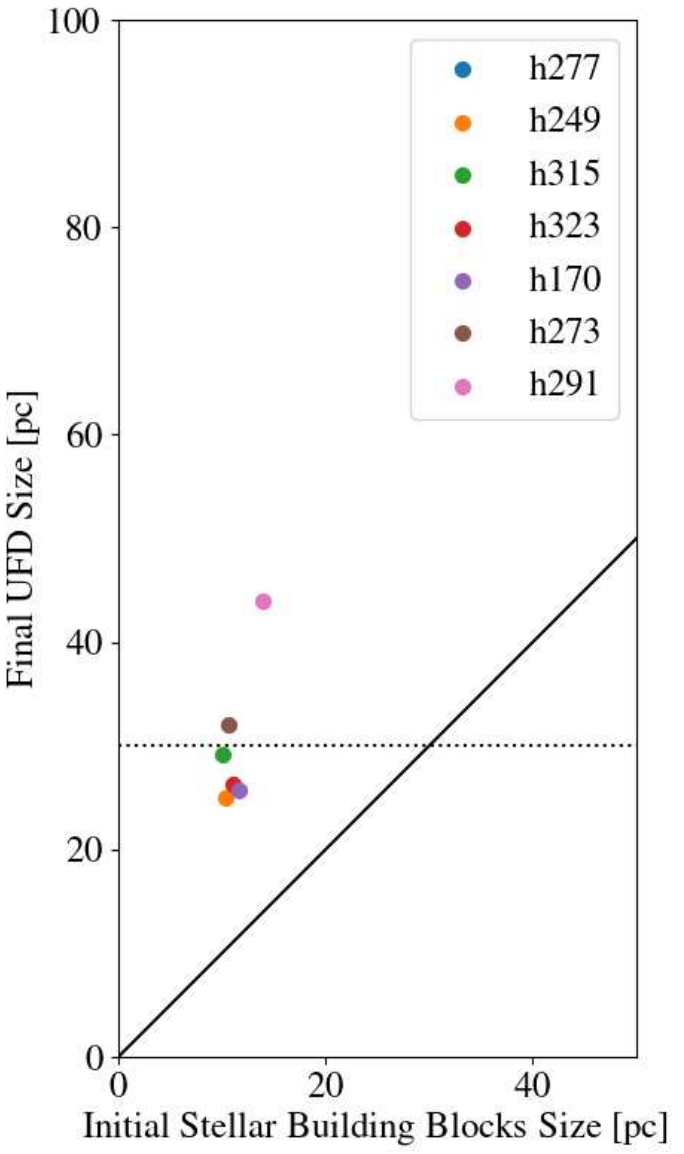
What if stars form in one single (more massive) halo ?

- Better, but still above 20 pc
- The final size depends on the merger with dark haloes



# Summary

Ultra-faint dwarf galaxies are fascinating objects that probe the smallest scales of the Universe.

Dominated by Pop III stars.

Current galaxy formation models in a ΛCDM paradigm fail to reproduce:

1. the metallicity – luminosity relation

2. the size – luminosity relation