Multiple stellar populations in dwarf galaxies

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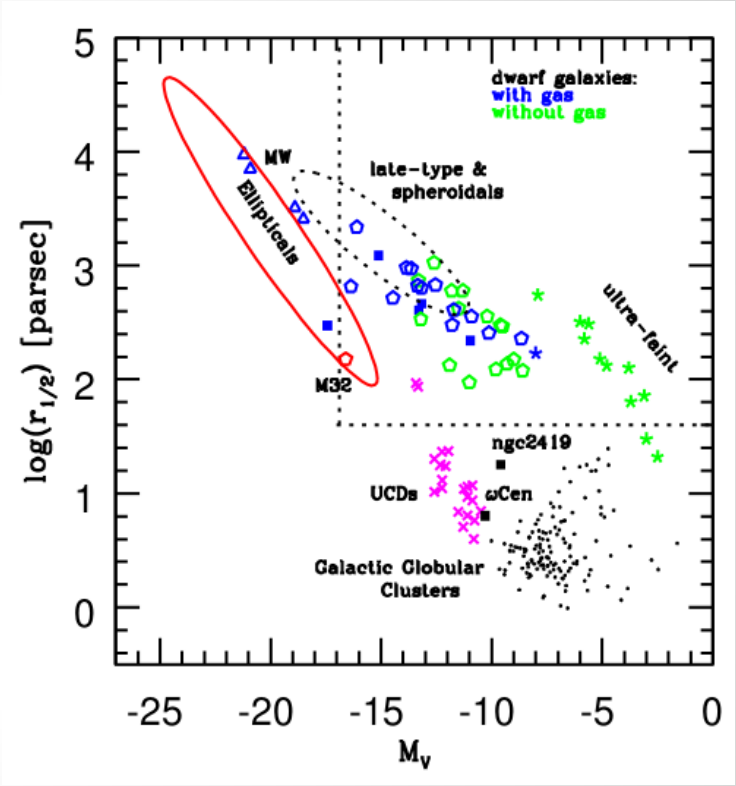
Dwarf galaxies

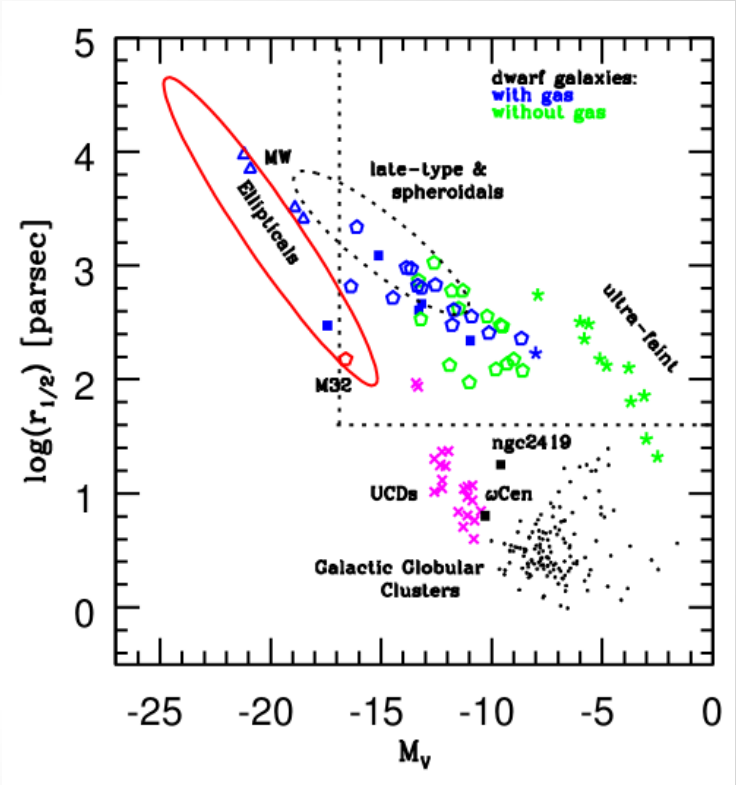
- Galaxies:
  - fainter than $M_B \sim -16$ ($M_V \sim -17$).
  - more spatially extended than globular clusters.
- Spreaded into different morphologies:
  - dSphs
  - dIs
  - uFd
  - BCDs
- In terms of stellar mass:
  - galaxies less massive than a few 10^9 M_{sun}
  - halos less massive than a few 10^{11} M_{sun}



Tolstoy et al. 2009

Dwarf galaxies

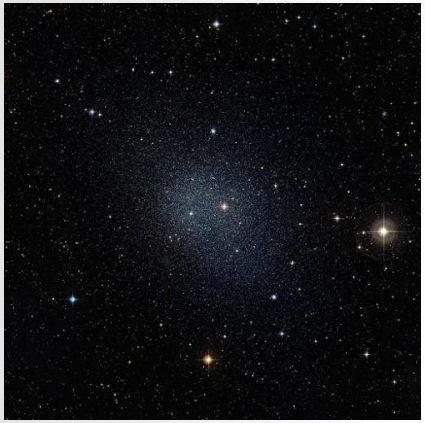
- Galaxies:
  - fainter than $M_B \sim -16$ ($M_V \sim -17$).
  - more spatially extended than globular clusters.
- Spreaded into different morphologies:
  - dSphs → No Gas
  - dIs
  - uFd → Gas
  - BCDs
- In terms of stellar mass:
  - galaxies less massive than a few 10^9 M_{sun}
  - halos less massive than a few 10^{11} M_{sun}



Tolstoy et al. 2009

Dwarf galaxies

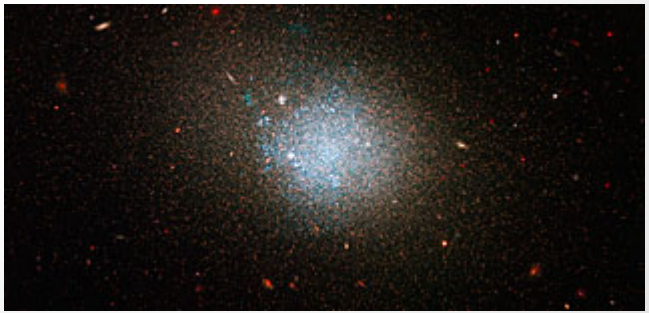
Fornax (dSph)



Pegasus Dwarf (dI)

I Zwicky 18 (BCD)

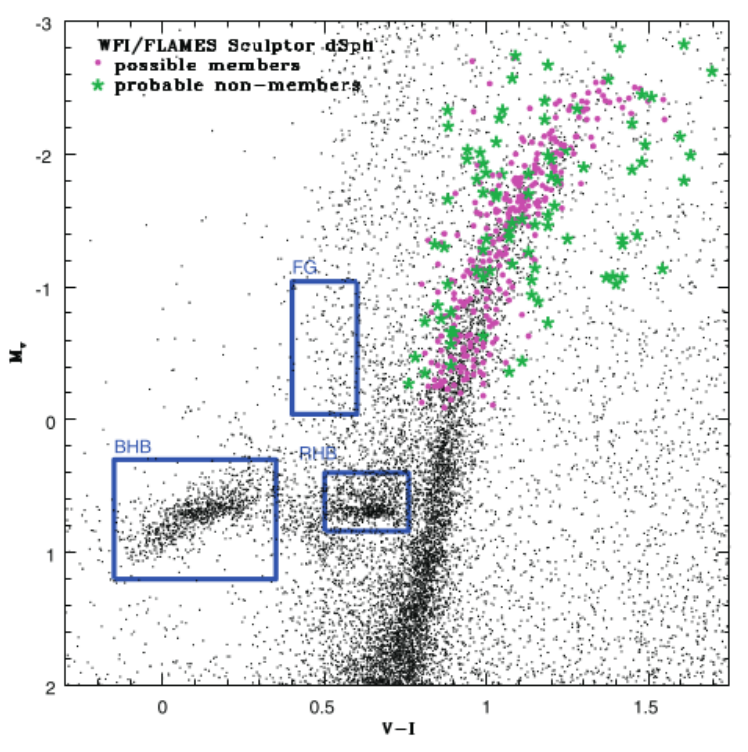
Sculptor
(dSph)

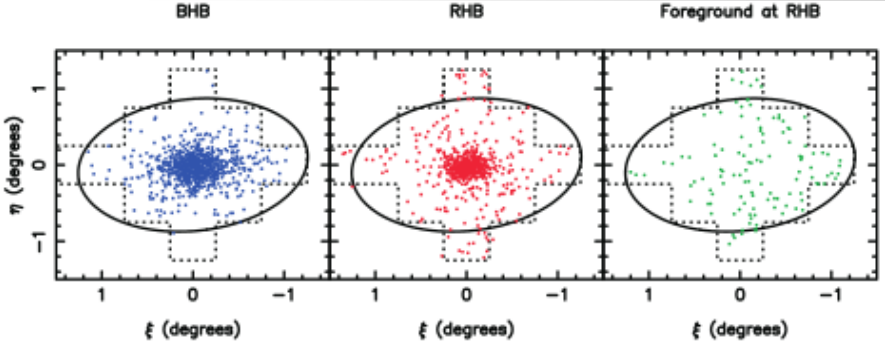


NGC 4163
(dI)

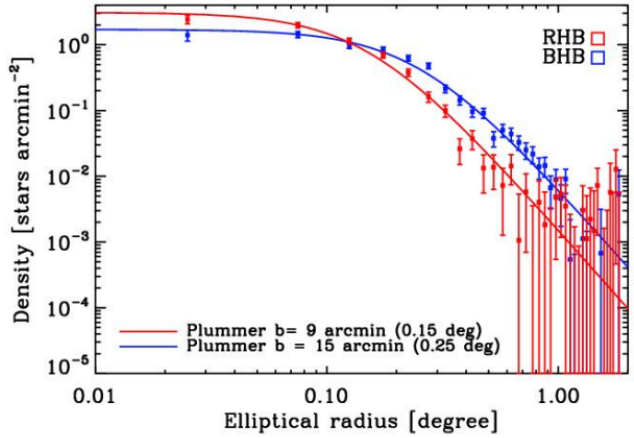
Tolstoy et al. 2004

Multiple populations



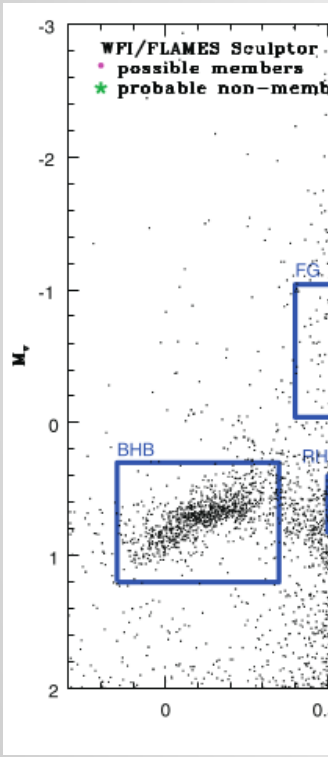


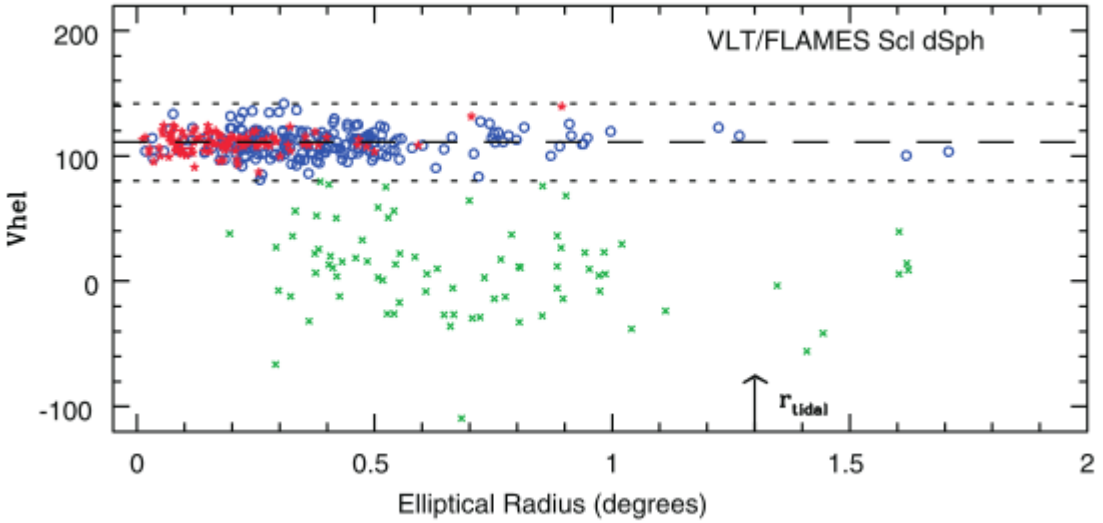
- Metal rich/younger population is more centrally concentrated than the older/metal poor counterpart.

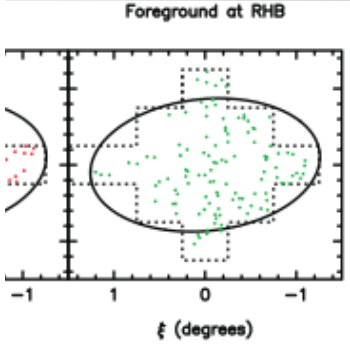


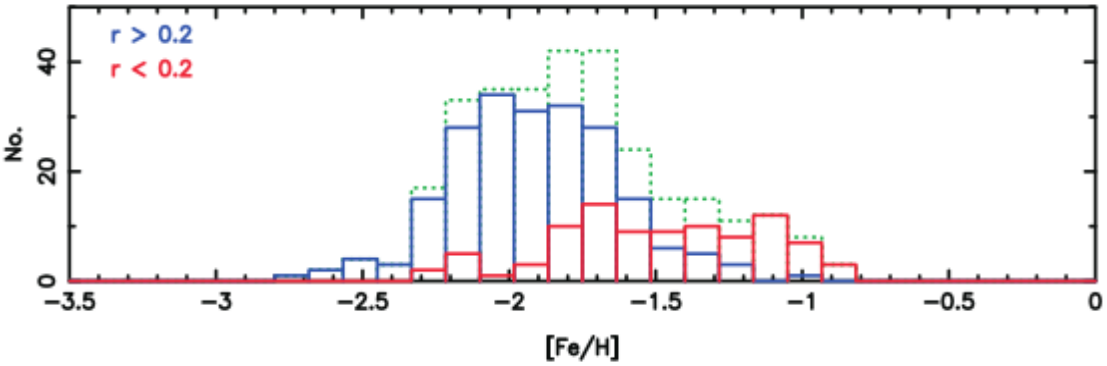
Multi

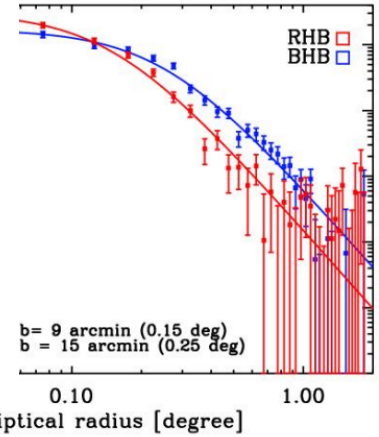
Tolstoy et al. 2004







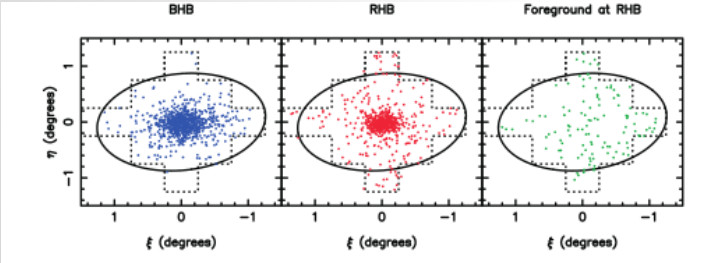




Multiple populations

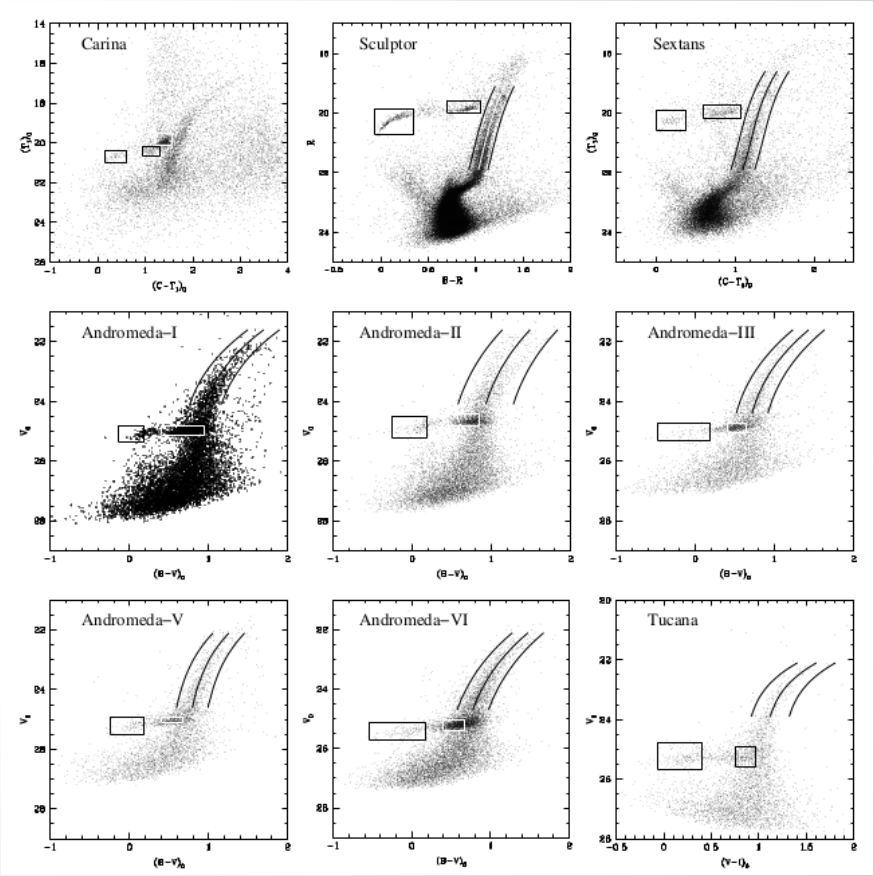
Harbeck et al. 2001:

-Existence of a morphological gradient of the HB is a common feature on dSph's.
- If there is a population gradient, the RHB stars are always more concentrated than the BHB stars



Tolstoy et al. 2004

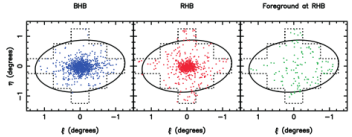
Harbeck et al. 2001:



What about LCDM?

- Does LCDM predict the existence of dwarf galaxies hosting multiple stellar populations?

- Is it an evolutionary consequence? or different populations were already in place at the formation time?



- Why some dwarfs have an ongoing star formation and others do not?

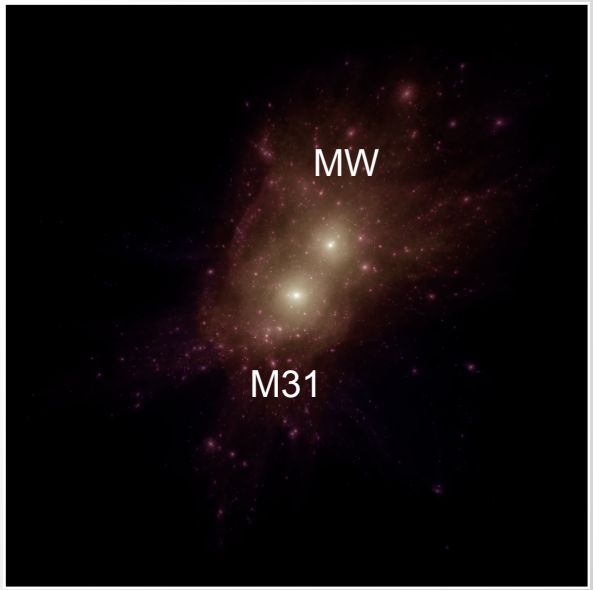
- What can we learn from cosmological simulations?

CLUES Simulations

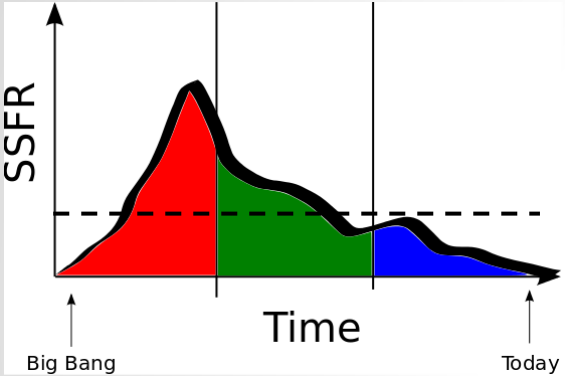
CLUES evolve a region that resembles the Local Group of Galaxies in the WMAP3-WMAP5 cosmology.

- SPH-Gadget 2-3 + reionization + star formation + feedback-driven winds -

- Halos are identified by a FoF algorithm.
- SUBFIND to identify substructures.
- We retain isolated galaxies (only those centrals to each FoF).
- Focus on dwarfs hosting two different stellar populations with different age only.

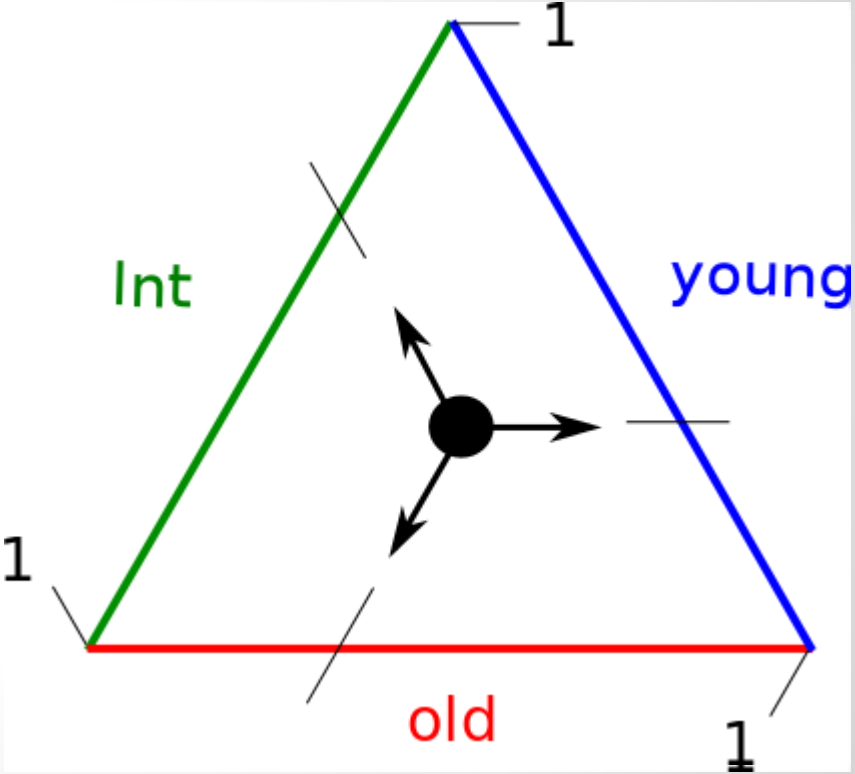


Summarizing SFHs



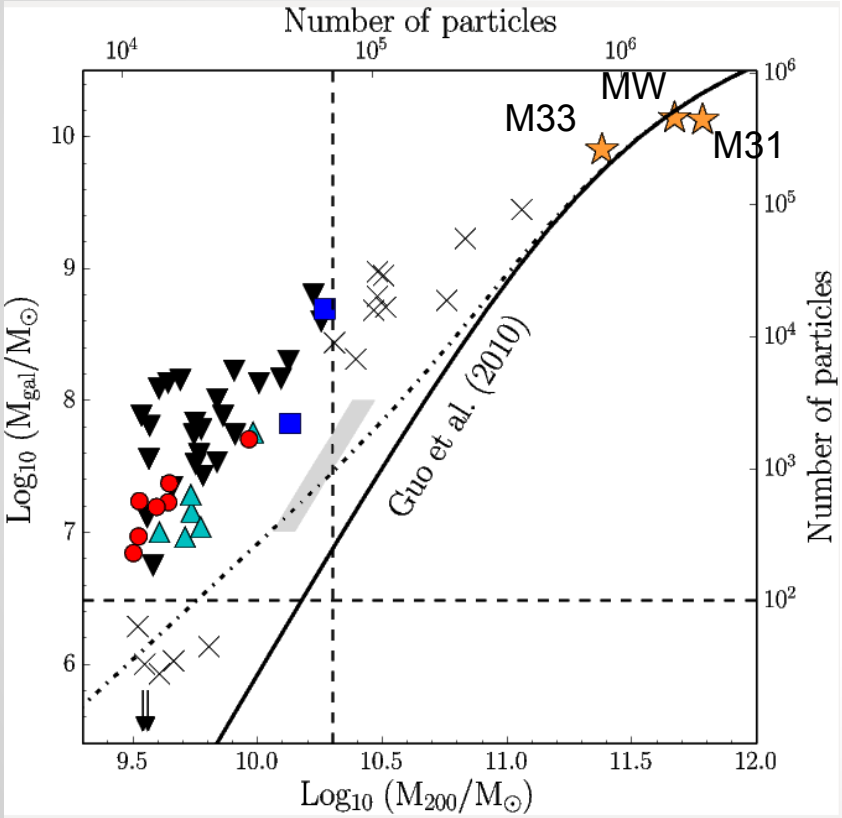
constant
SFR

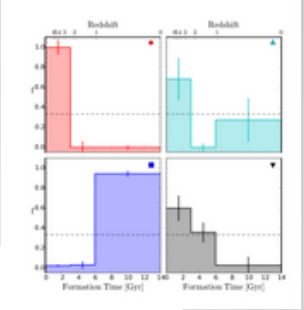
f1+f2+f3 = 1

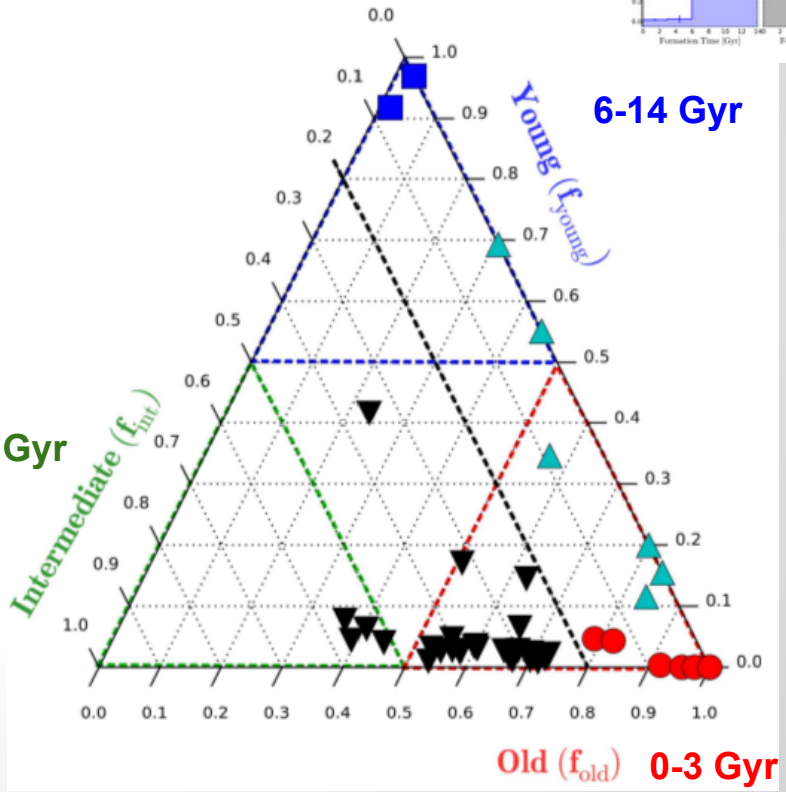


Benitez-Llambay et al. 2014

Summarizing SFHs







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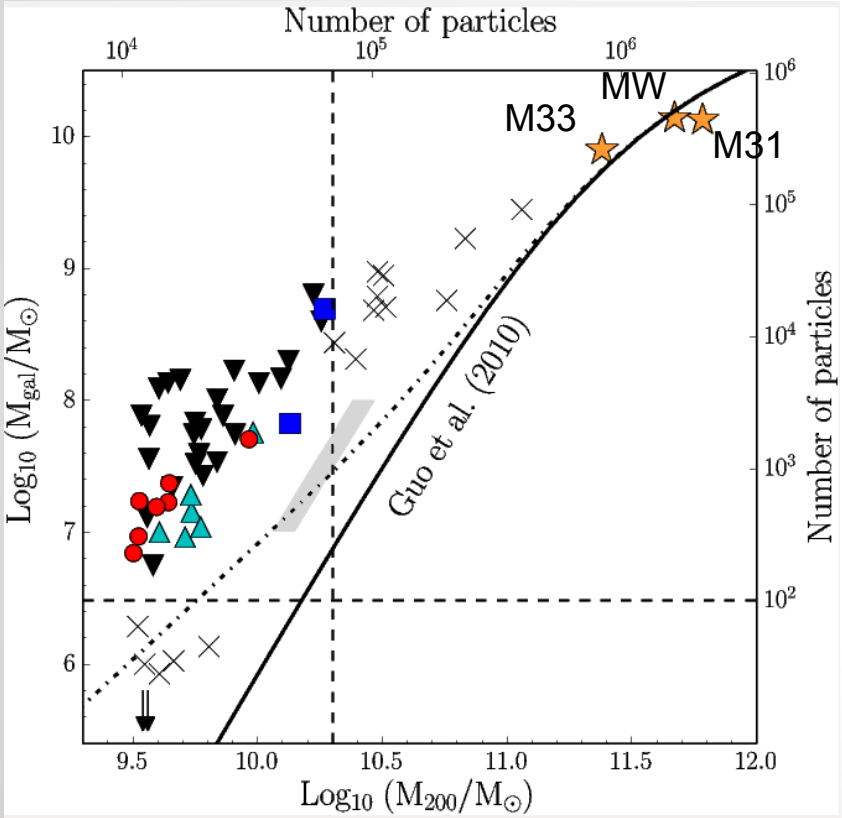
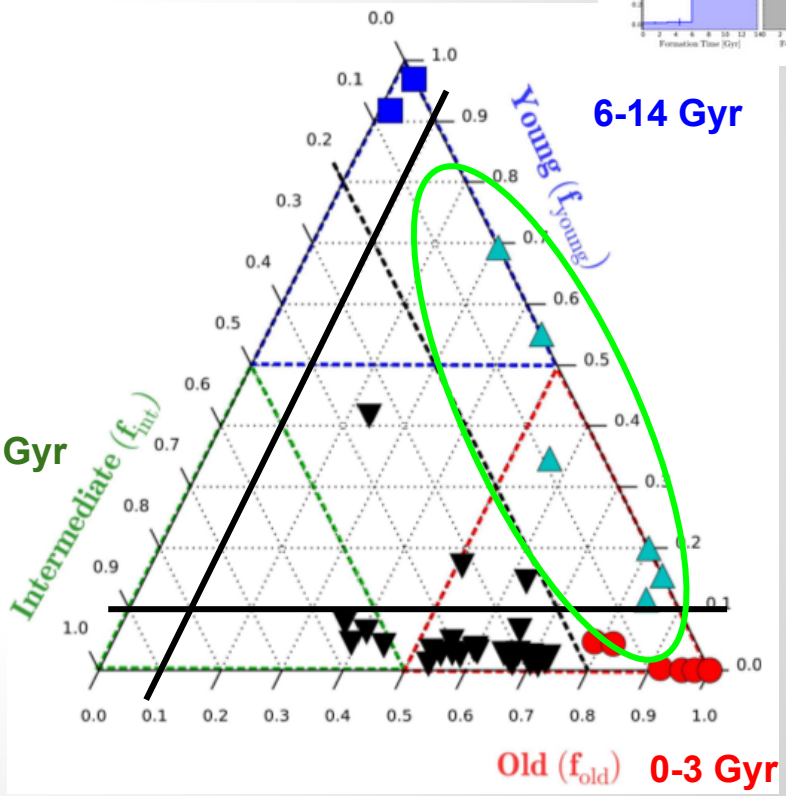
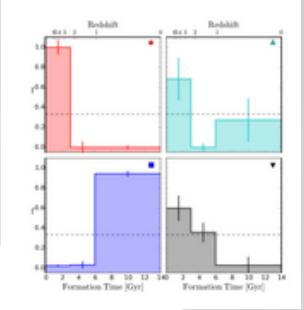
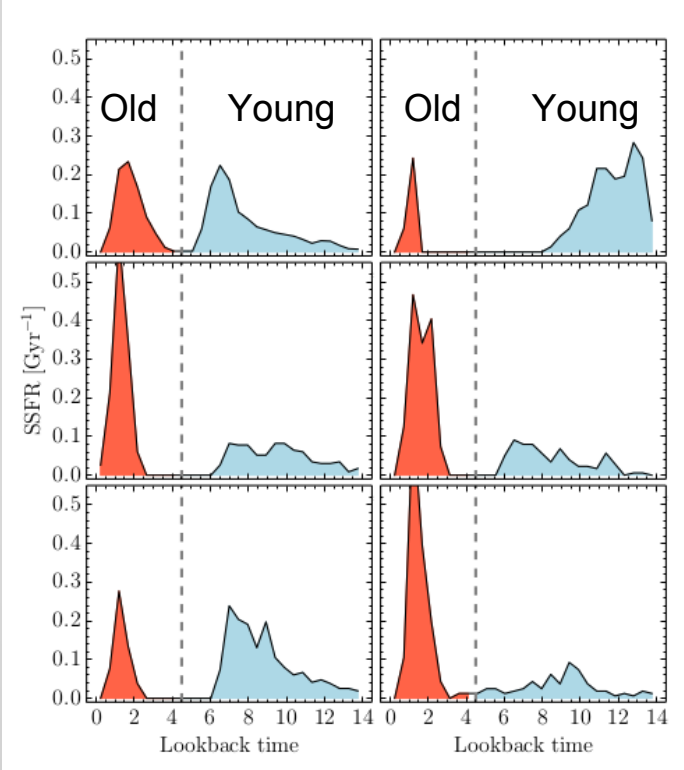


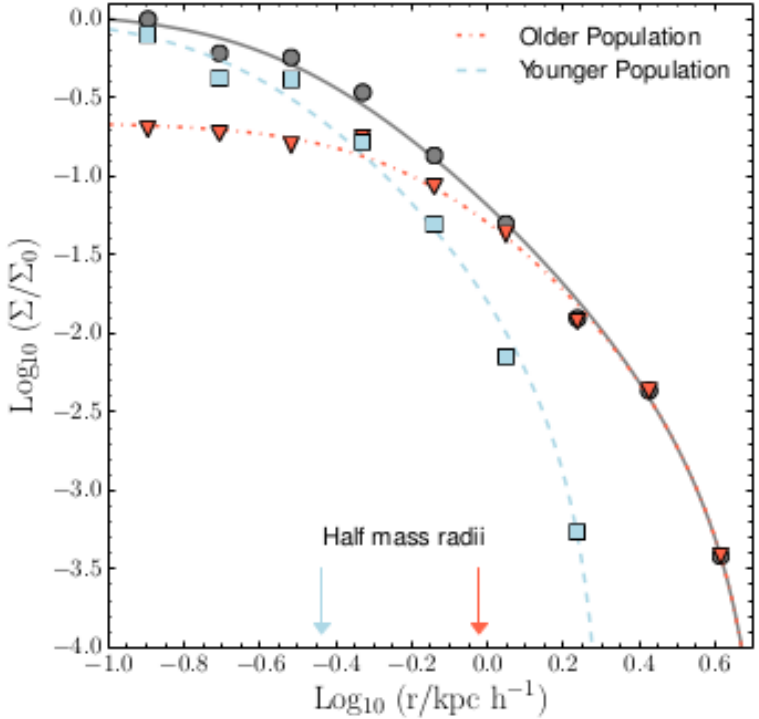




Different populations



After splitting the stellar populations

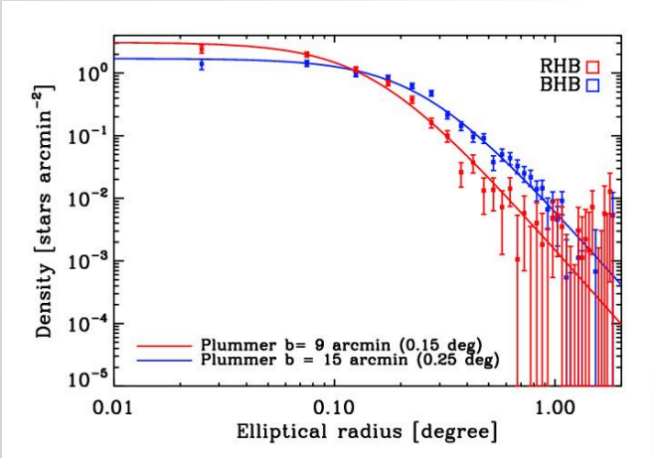


King Profile (King 1963)

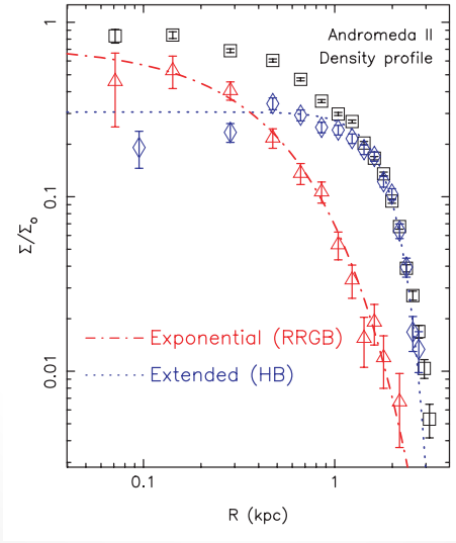
$$I_K(R) = I_{0,K}\left(\frac{1}{\sqrt{1+\left(\frac{R}{r_c}\right)^2}} - \frac{1}{\sqrt{1+\left(\frac{r_t}{r_c}\right)^2}}\right)^2$$

Different populations

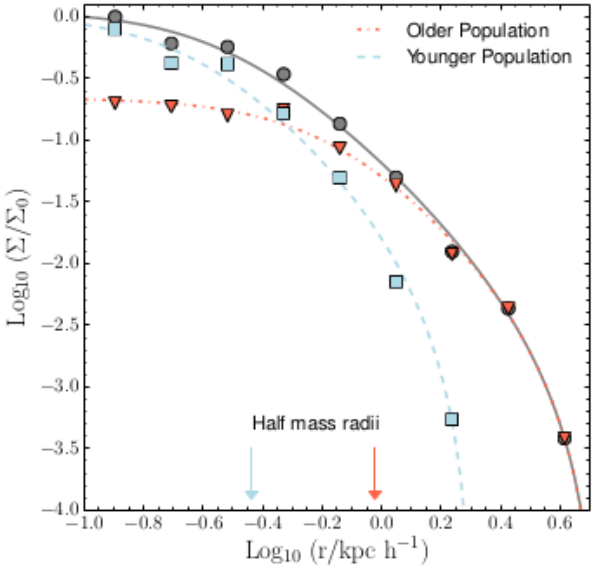
Sculptor (Tolstoy et al. 2004)



Andromeda II
(Mcconnachie et al. 2007)



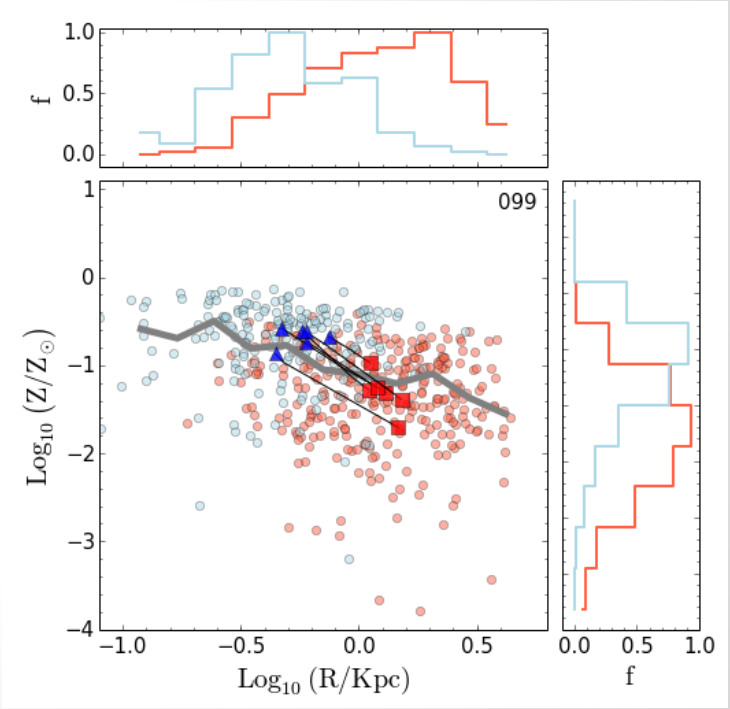
CLUES



Different populations

After splitting stellar content according to the age:

- Younger stars are always more centrally concentrated than the older stars.
- Metal-rich stars are systematically more concentrated than the metal-poor stars.
- Simulated dwarfs consistent with the presence of negative age/metallicity gradients.



Different populations

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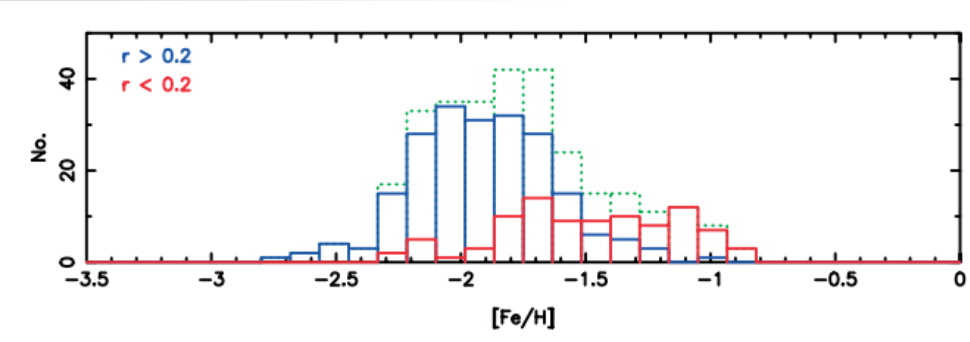
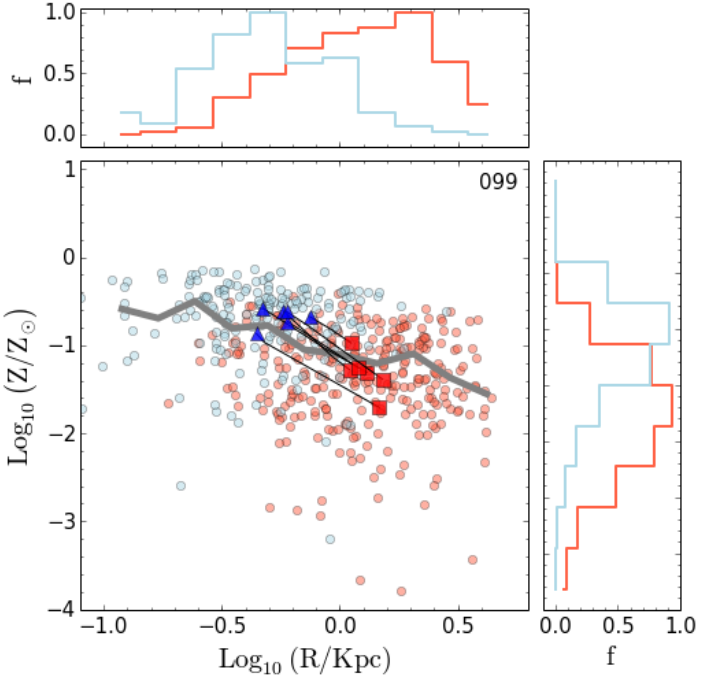
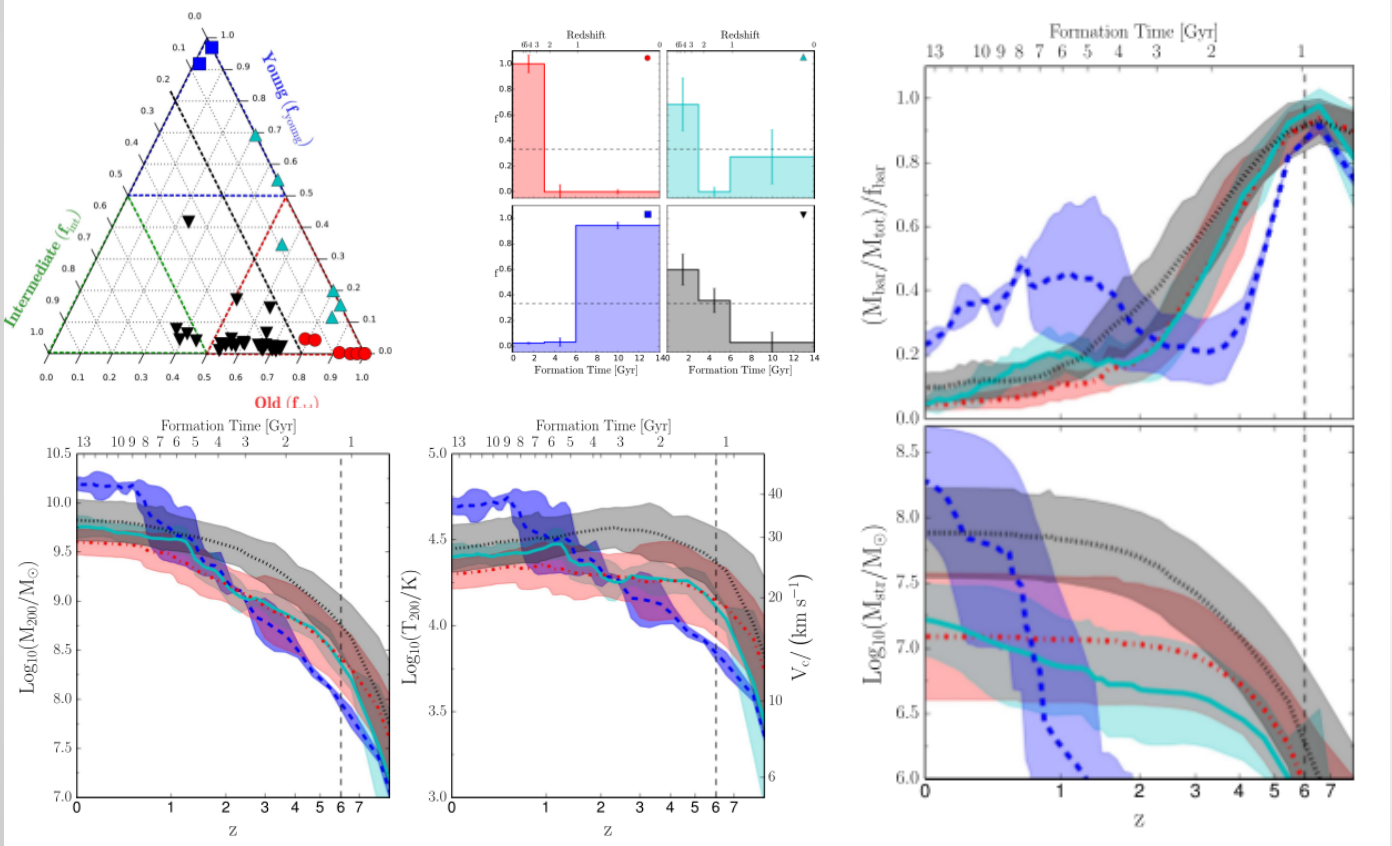




Benítez-Llambay et al. 2014

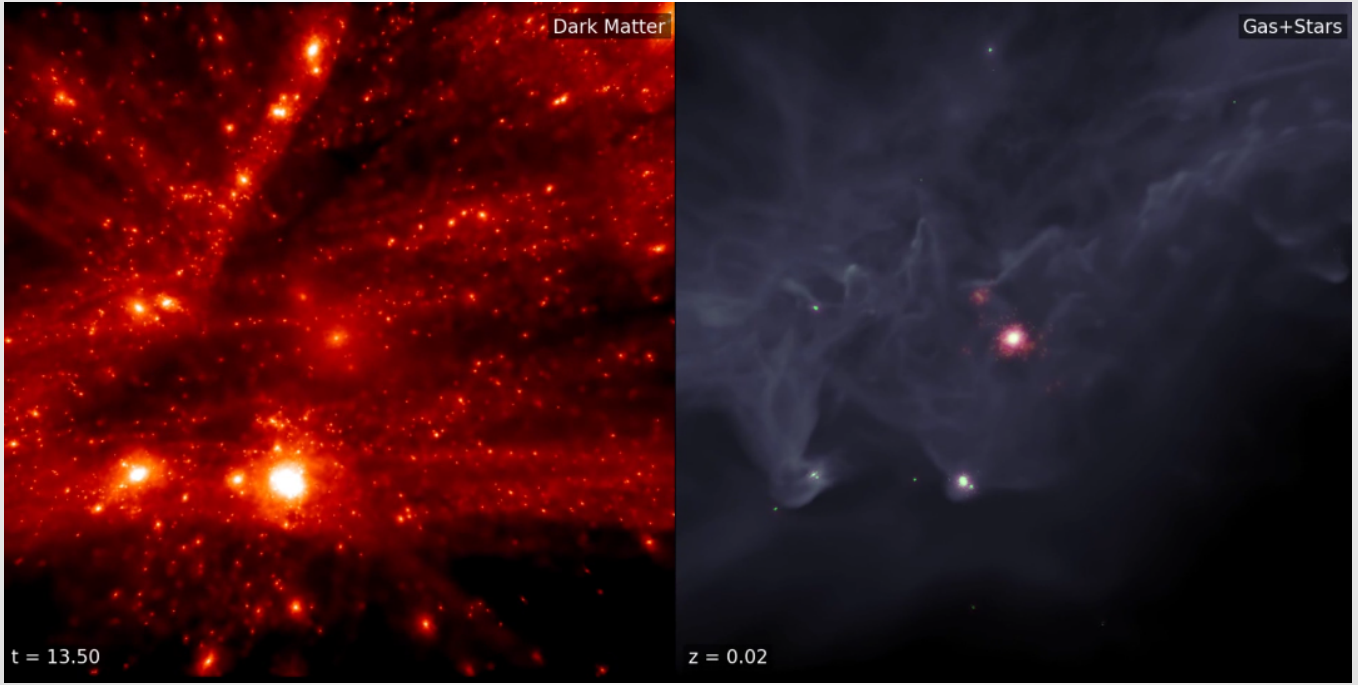
Where the segregation comes from?



- SFH correlates with mass of the progenitor at the time of reionization.
- Most massive progenitors define the group of dwarfs with protracted star formation (no gap is present).

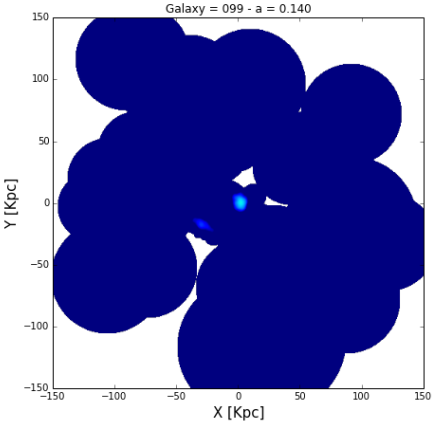
- Early collapse ensures that a substantial amount of gas in these halos is able to cool and start forming stars before z_{reion}

Movies

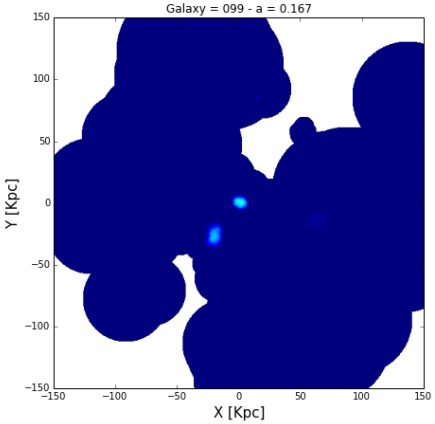


What about metallicity?

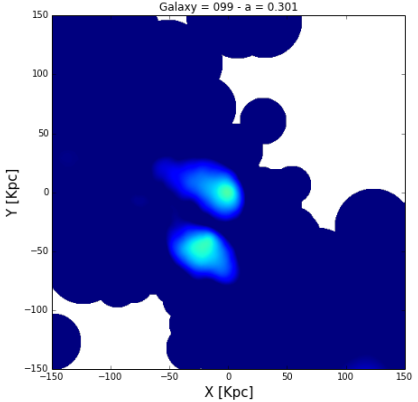
z ~ 6.14



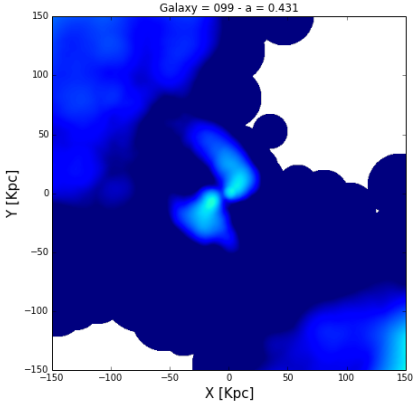
z ~ 5



z ~ 2.5



z ~ 1.3



- All dwarfs form a few stars before reionization is switched on.
- Metallicity of the gas available for the second SF episode has been polluted by the early star formation activity.
- It results in a younger stellar population with systematically higher metallicity.

Conclusions

- Presence of different stellar populations is a common feature on dwarfs galaxies: Fornax, Sculptor, Sextans...

- More metal-rich/younger stars are always more centrally concentrated than the older counterpart.

- The formation of such a gradients is compatible with a LCDM cosmology.

- According to CLUES simulation, two different components could be a signature of cosmic reionization.