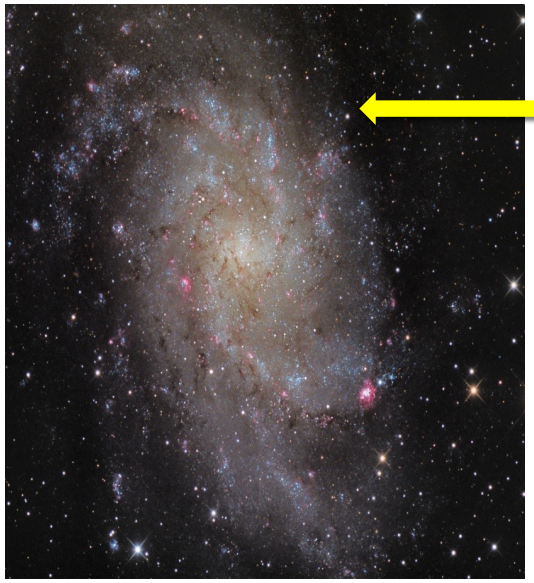
What is a Dwarf Galaxy?

MASS : $\sim 10^5 < M_* < 5 \times 10^9 M_\odot$; $M_V > -19$

ROTATION CURVE : $V_{rot} < 100$ km/s

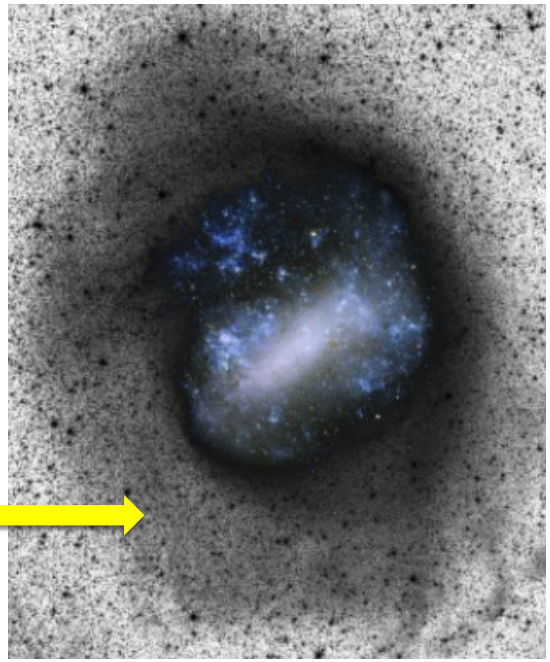
METALLICITY : [Fe/H] $< -0.4 \sim 1/3\ Z_\odot$

Evidence for a dark matter halo

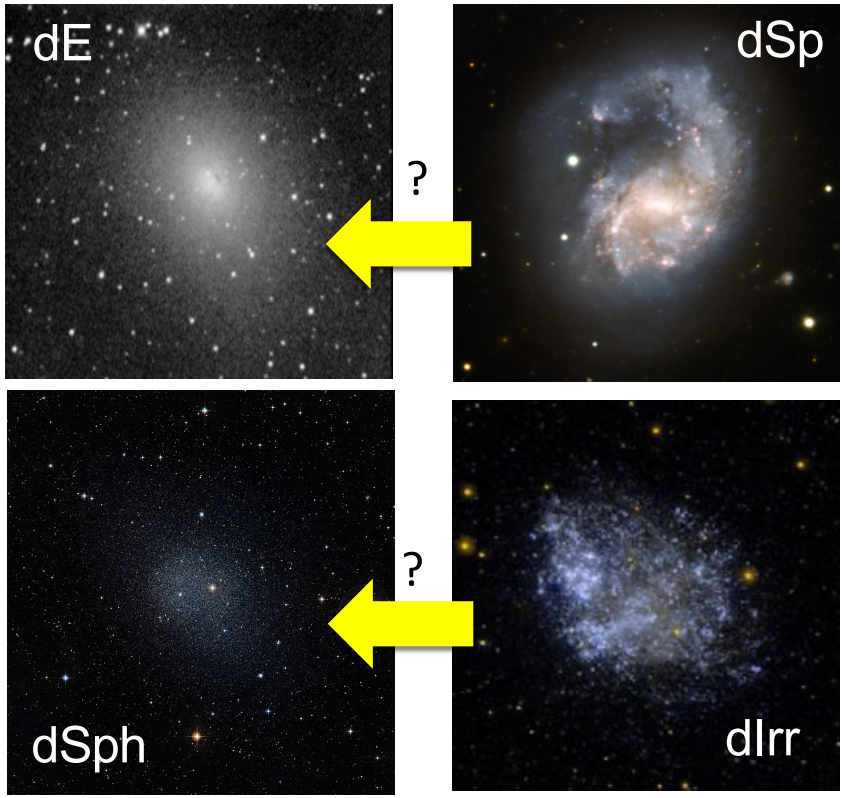


M33 is a satellite, but not a dwarf.

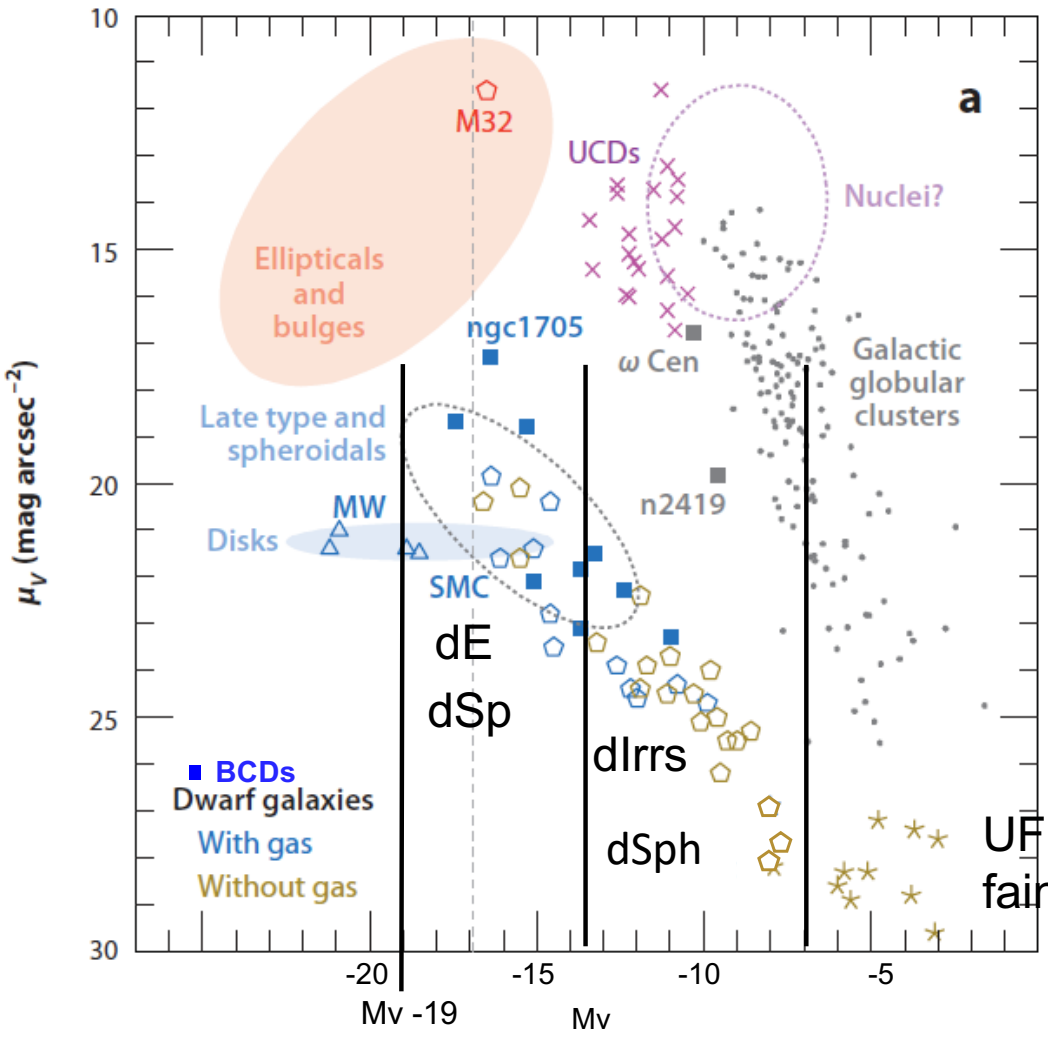
The LMC is both a satellite and a dwarf



The Dwarf Galaxy Zoo: 2 Main Flavors at all mass scales

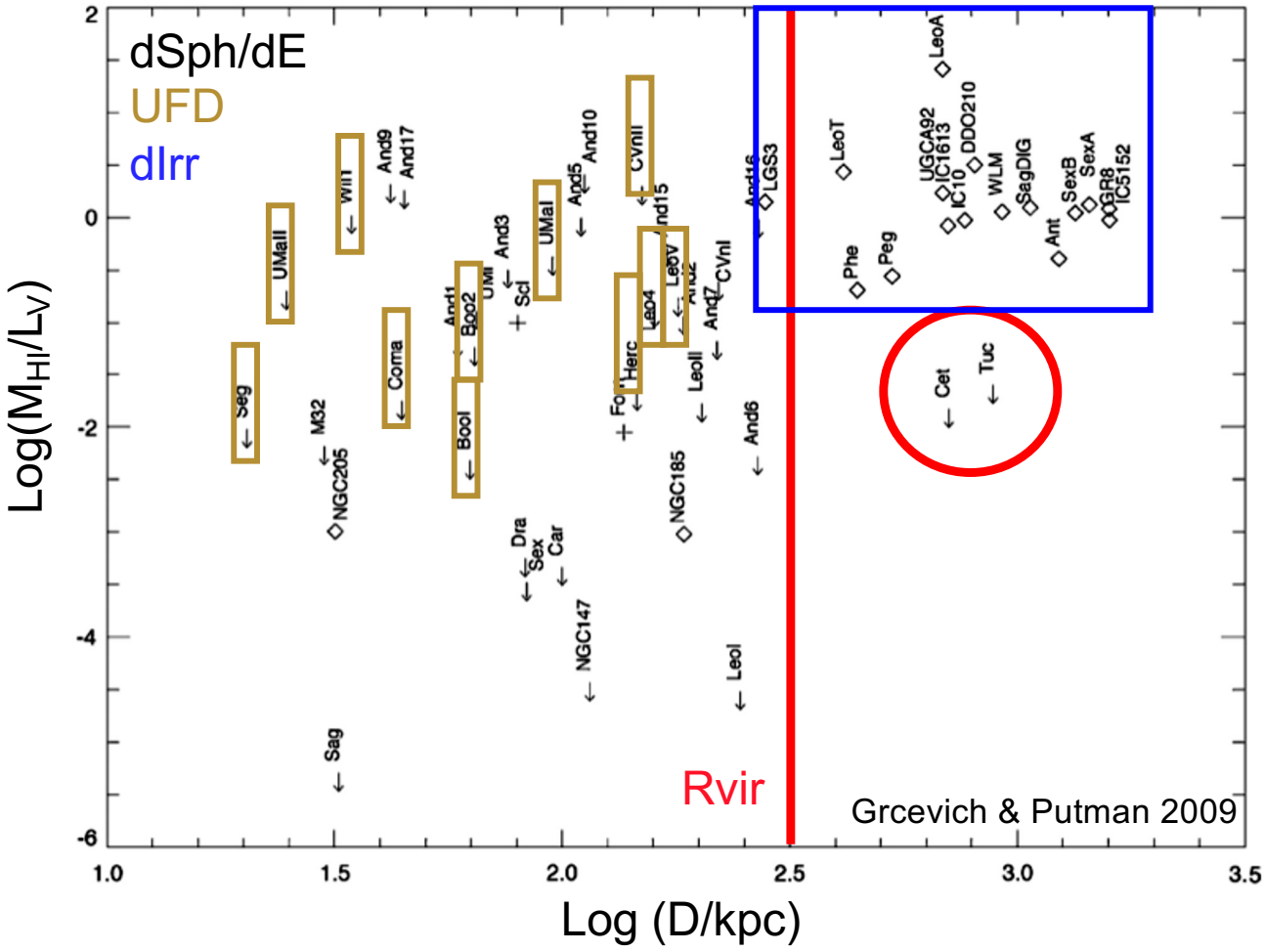


Tolstoy+ 2009

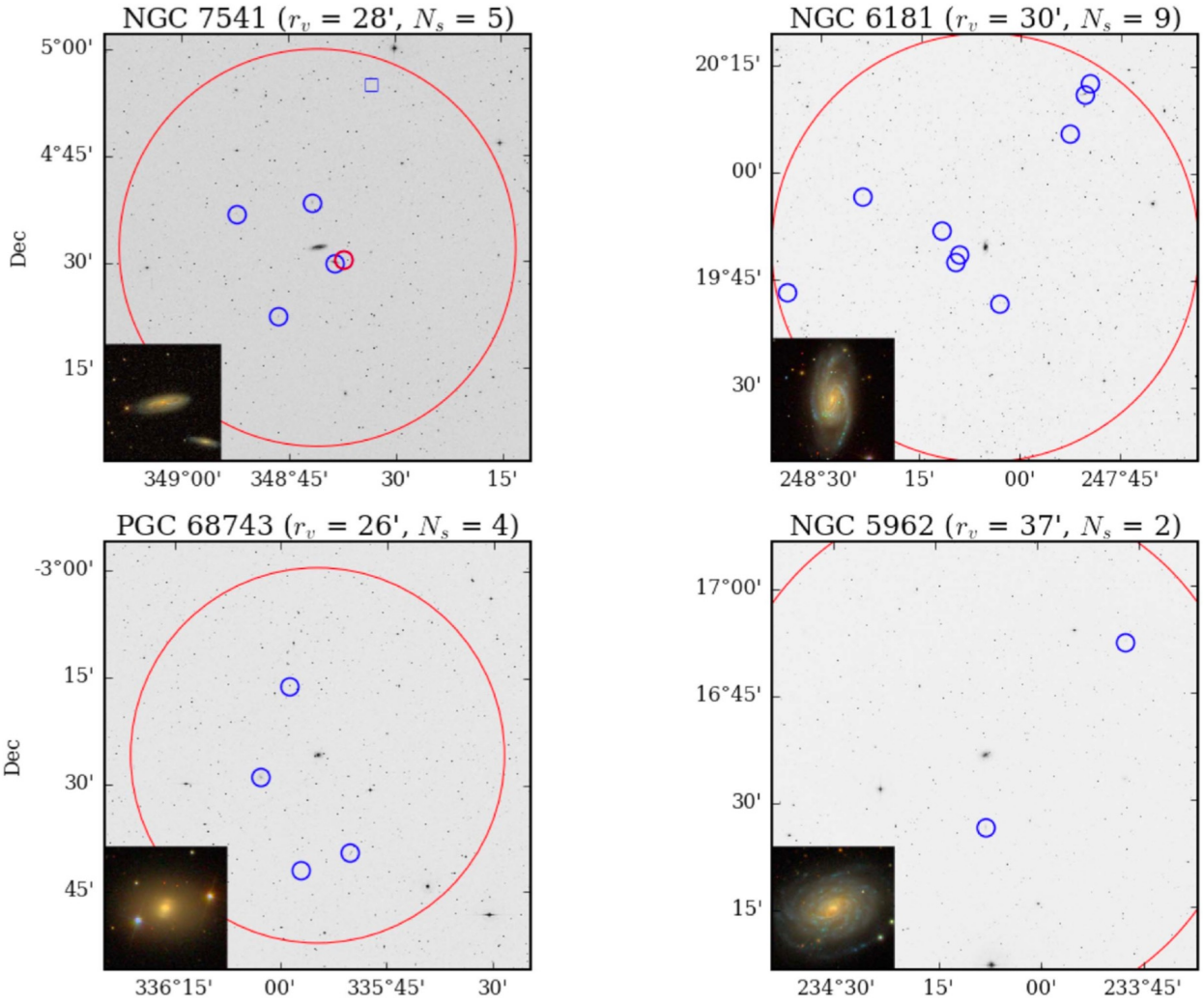


UFD ultra faint dwarf

Distance Morphology Relationship

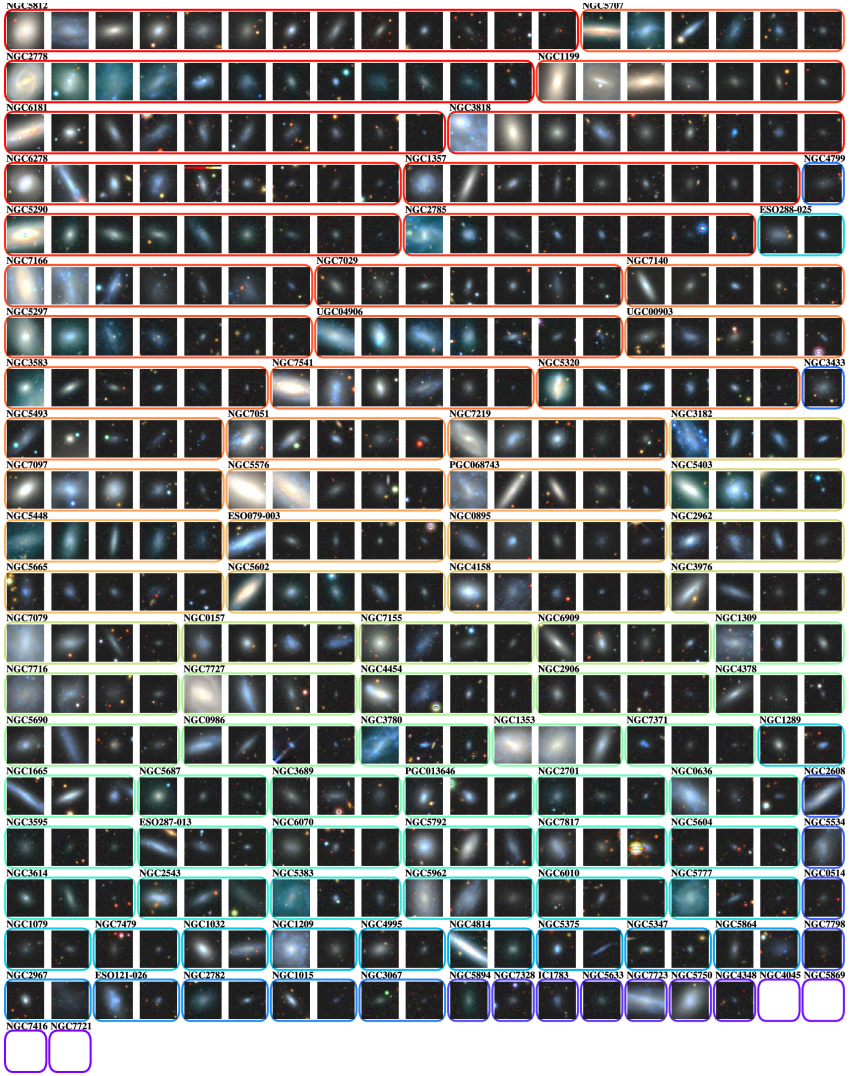


SAGA Survey: Placing the MW and M31 in context



Geha+2017, ApJ , 847
SAGA Survey I

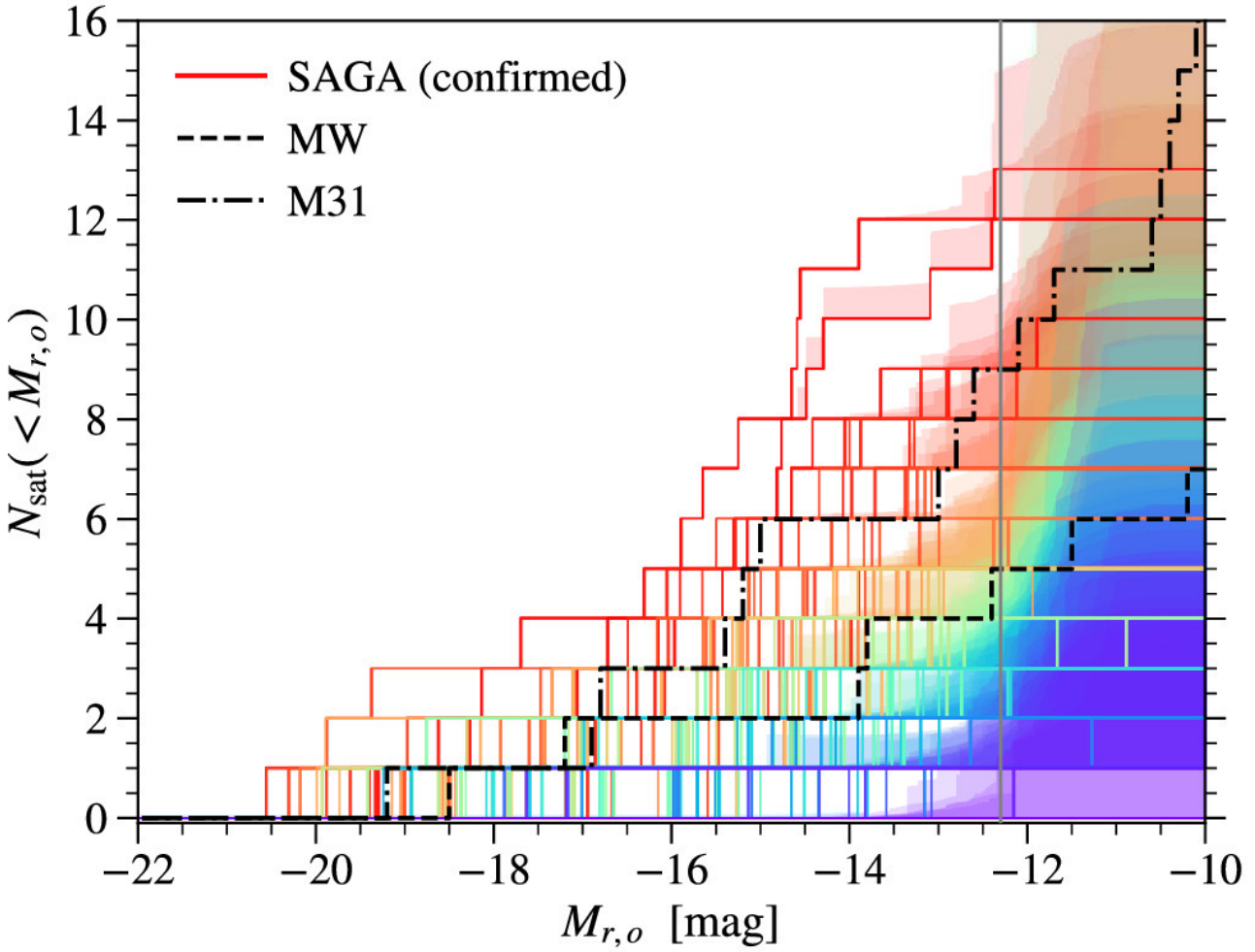
The SAGA Survey DR3 includes **378 satellites** identified across **101** MW-mass systems in the distance range of **25–40.75 Mpc**



SAGA Survey III
Yao-Yuan Mao et al 2024 *ApJ* **976**

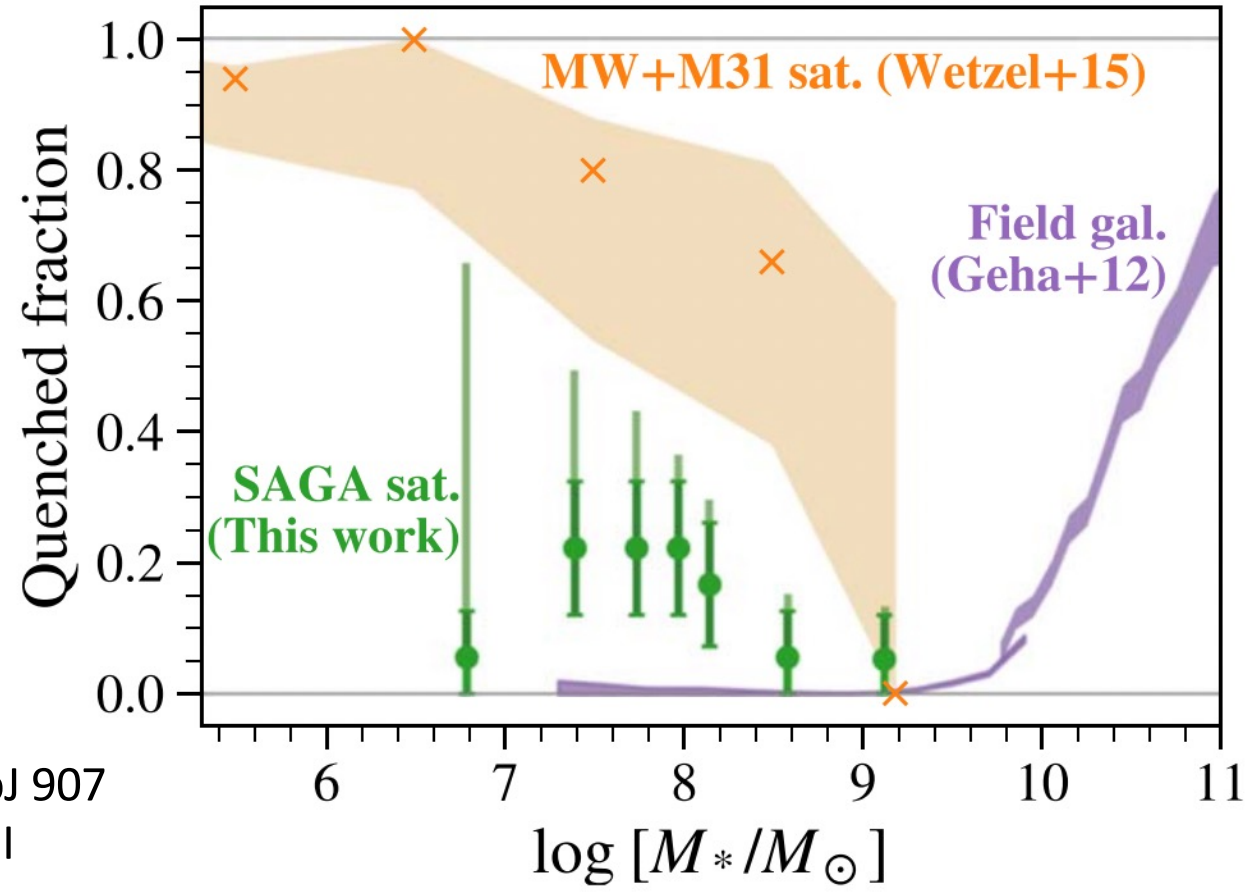
"Perhaps the most remarkable aspect of the SAGA results is how this exhibit satellite systems around MW analogs solidifies the idea that our very own satellite system of the MW is just one "realization" from a diverse distribution."

Mao+2021
ApJ 907
SAGA Survey II



SAGA Survey III Yao-Yuan Mao et al 2024 *ApJ* **976**

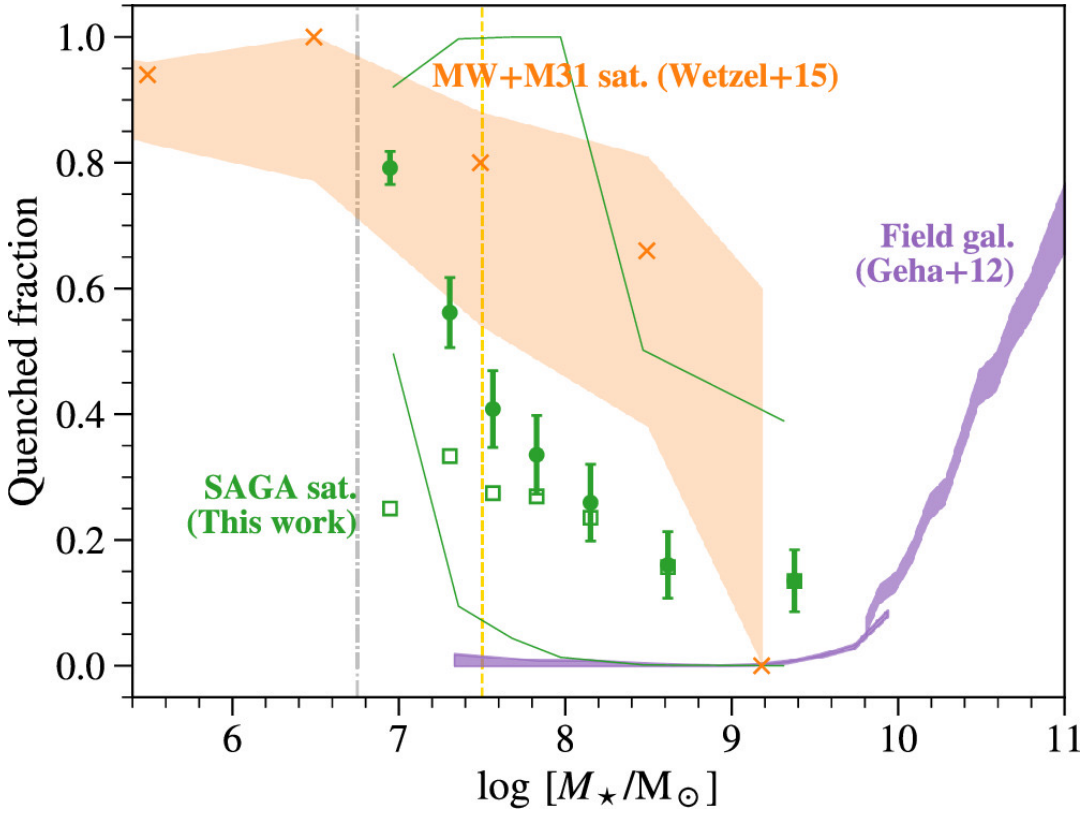
SAGA Quenched Fraction
(satellites galaxies of MW analogs)



Mao+2021 ApJ 907
SAGA Survey II

SAGA Quenched Fraction - Update

SAGA quenched fraction below $10^{8.5}$ $M_\odot$ is lower than the MW's, but in both cases, the MW is within 1σ of SAGA system-to-system scatter



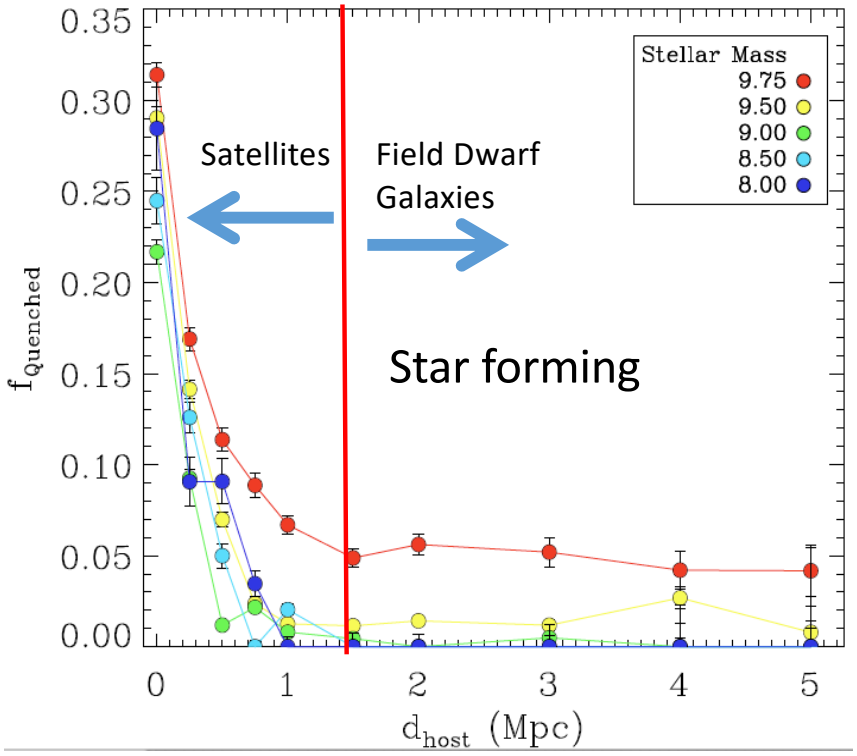
SAGA Survey III
Yao-Yuan Mao et al 2024 *ApJ* **976**

Dwarf galaxies are gas rich & forming stars

UNLESS they are close to a massive galaxy

Dwarfs (10^8-10^9 $M_\odot$) DON'T quench via secular processes

Geha+2012

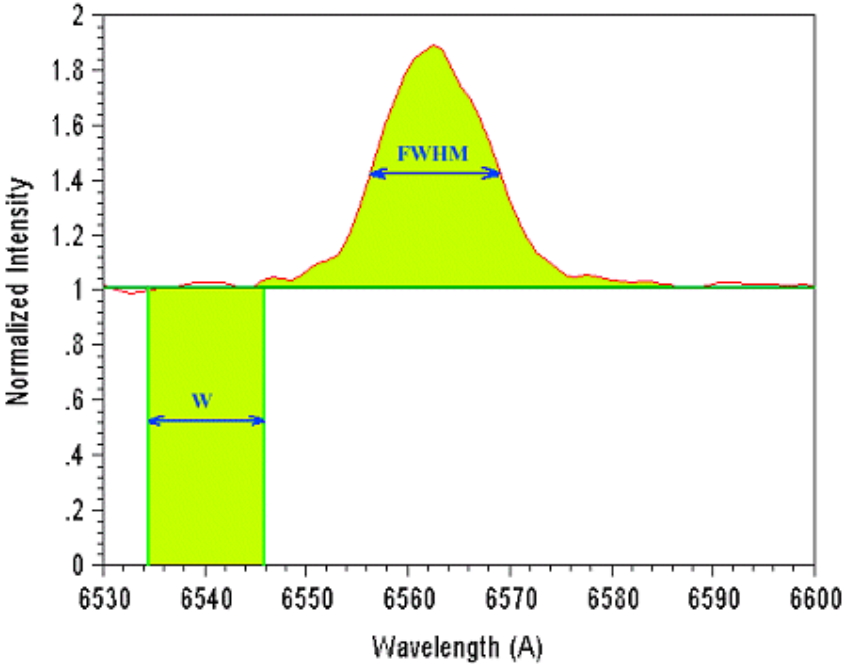


How do we know that a galaxy is no longer forming stars? i.e. that they are “quenched”

Why dwarfs quench → next class!

Quenched Definition

1) No strong Hα emission (EW < 2 Angstrom) [no star forming regions]



2) a strong 4000 Angstrom-break [spectrum dominated by old stars]

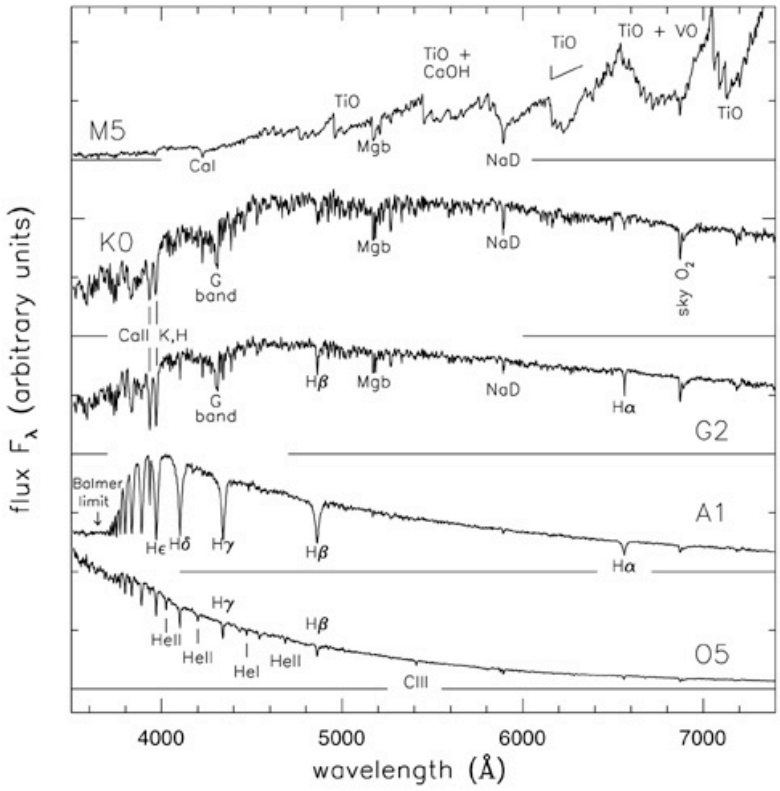
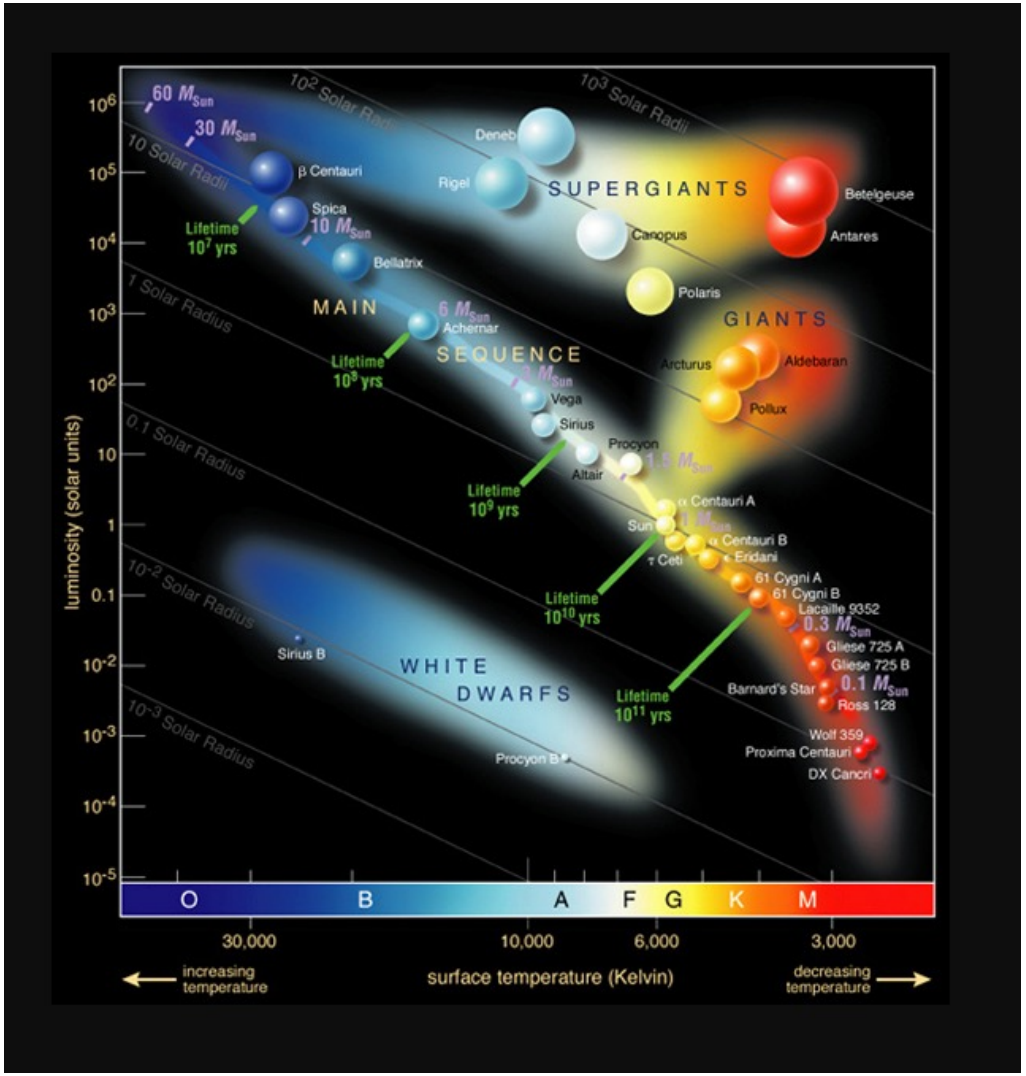


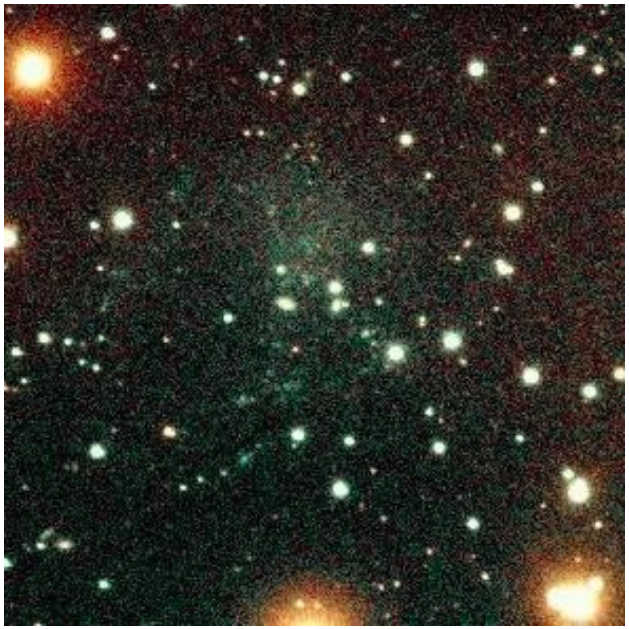
Fig 1.1 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Hertzsprung Russell Diagram

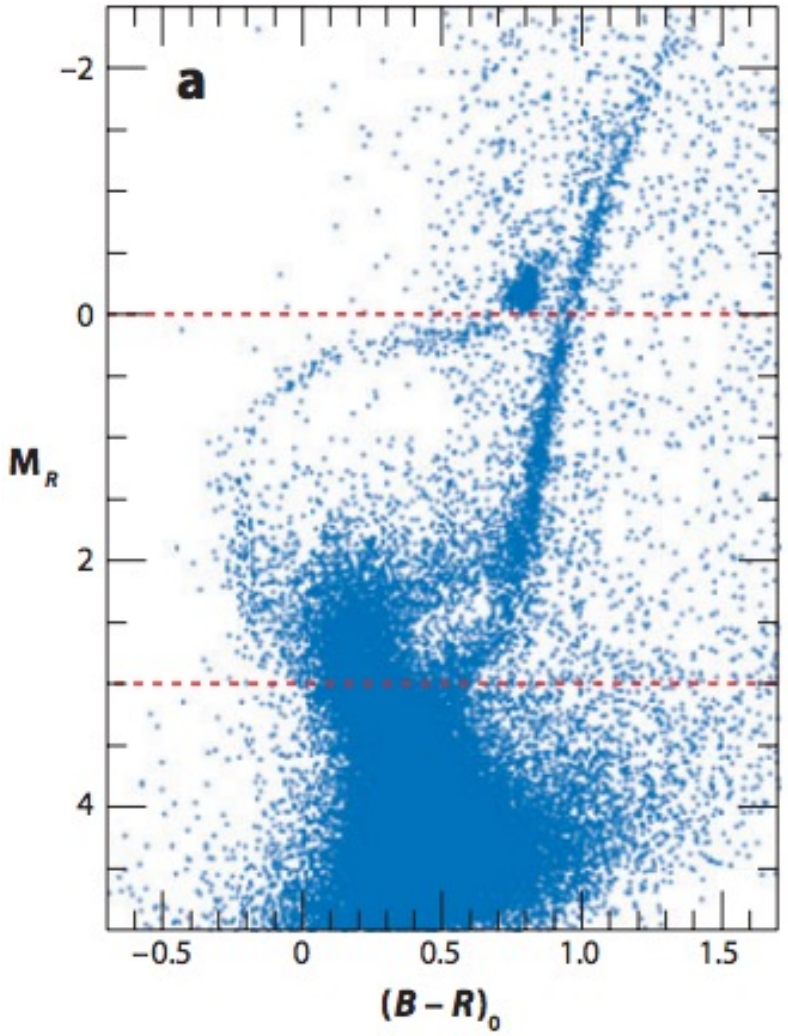
the simple version..



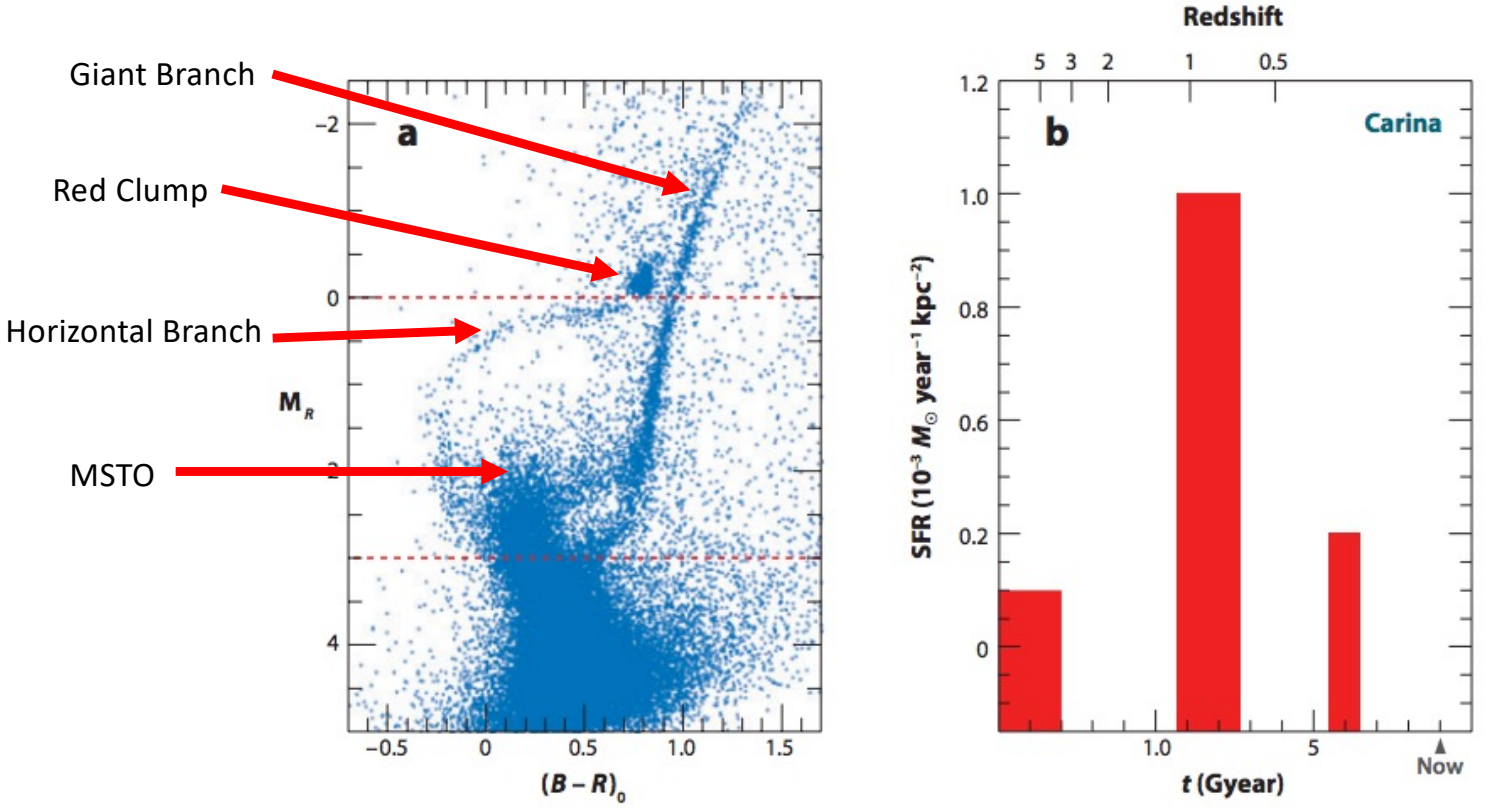
So what is this?



Carina Dwarf Spheroidal



Tolstoy+2009



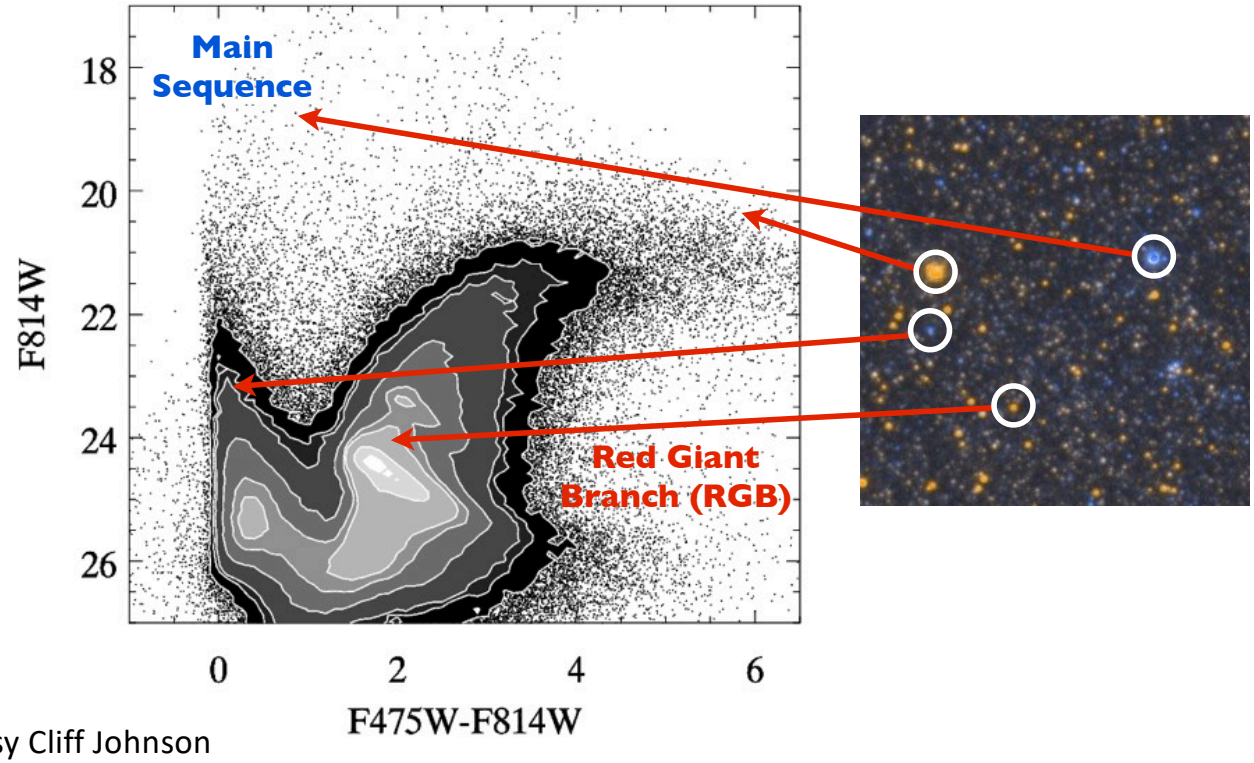
Tolstoy+2009

Figure 4

(*a*) A color-magnitude diagram of the Carina dwarf spheroidal (obtained by M. Mateo with the CTIO 4-m and MOSAIC camera, private communication) in the central 30′ of the galaxy. This clearly shows the presence of at least three distinct MSTOs. (*b*) The star-formation history of the central region of Carina determined by Hurley-Keller, Mateo & Nemec (1998), showing the relative strength of the different bursts. The ages are also shown in terms of redshift.

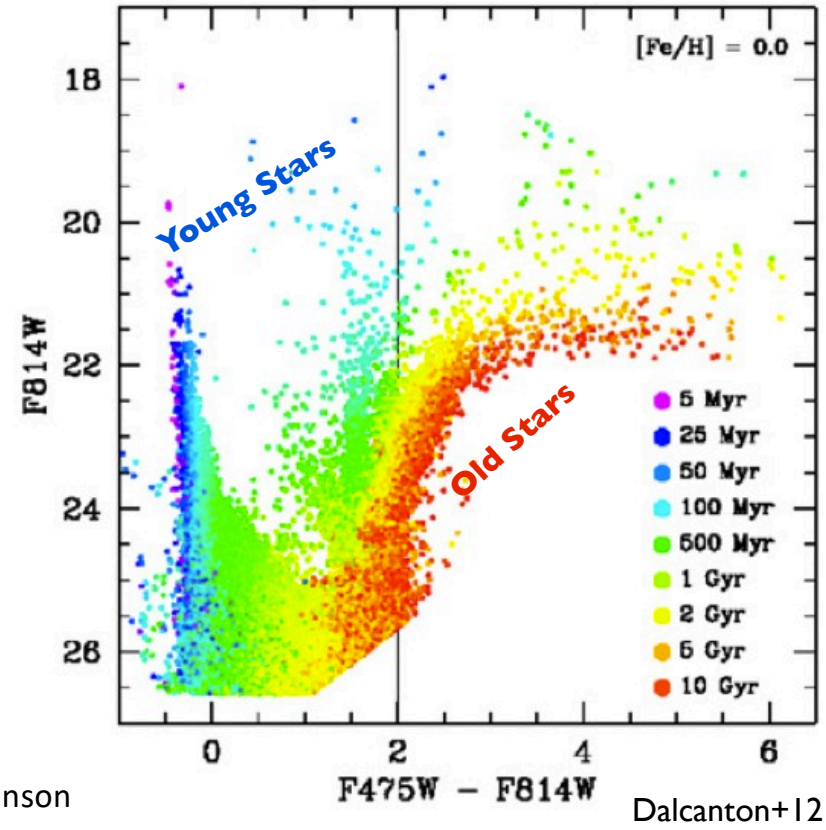
The Color-Magnitude Diagram (CMD)

Real galaxies ....



Courtesy Cliff Johnson

Age Dating with CMDs



Courtesy Cliff Johnson

Dalcanton+12

Isochrones

Isochrones show the theoretical evolution of a single population of stars of the same metallicity but varying initial mass, frozen at a certain instant in time.

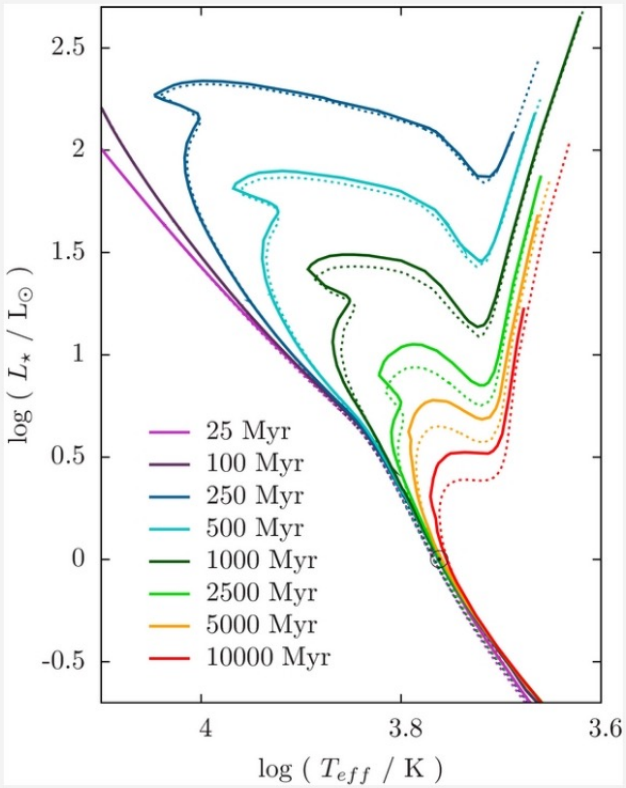
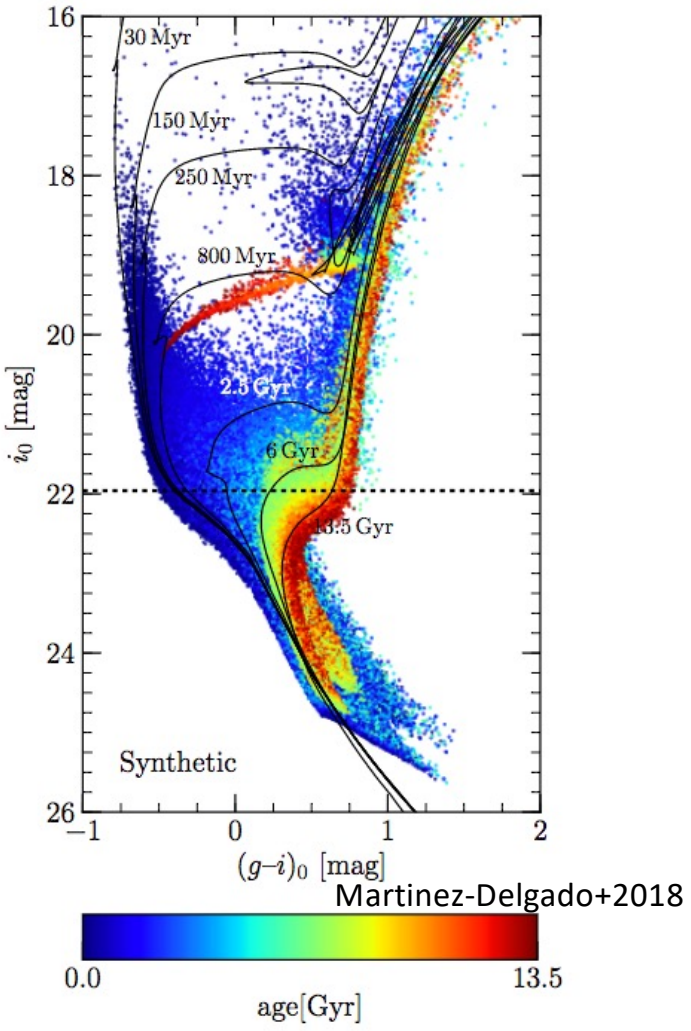


Figure 2. These lines illustrate how a population of stars evolves with time. The y-axis is brightness and the x-axis is temperature which directly corresponds to color.

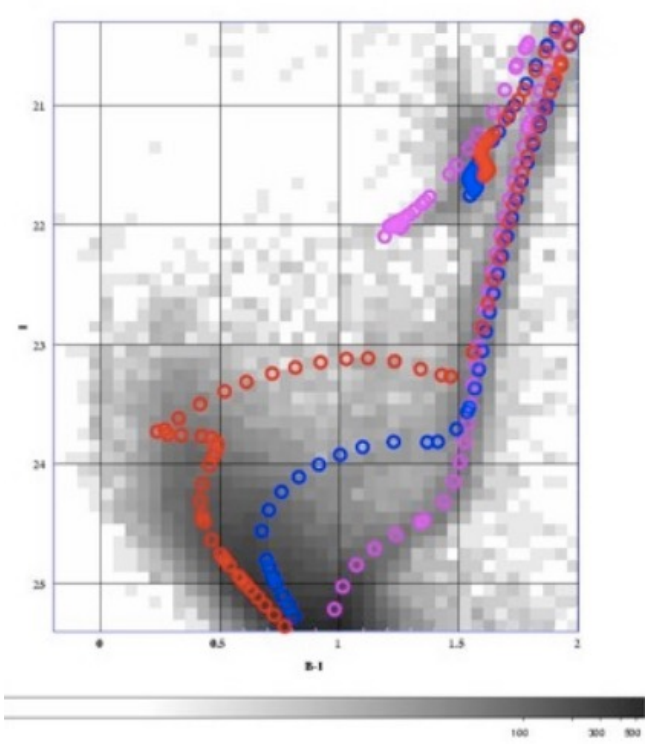
Source: Casanellas et al. 2011



Martinez-Delgado+2018

3) Deriving SFH from CMDs to define a “quenched” galaxy

Leo I dSph. $M_* \sim 5 \times 10^6 M_\odot$



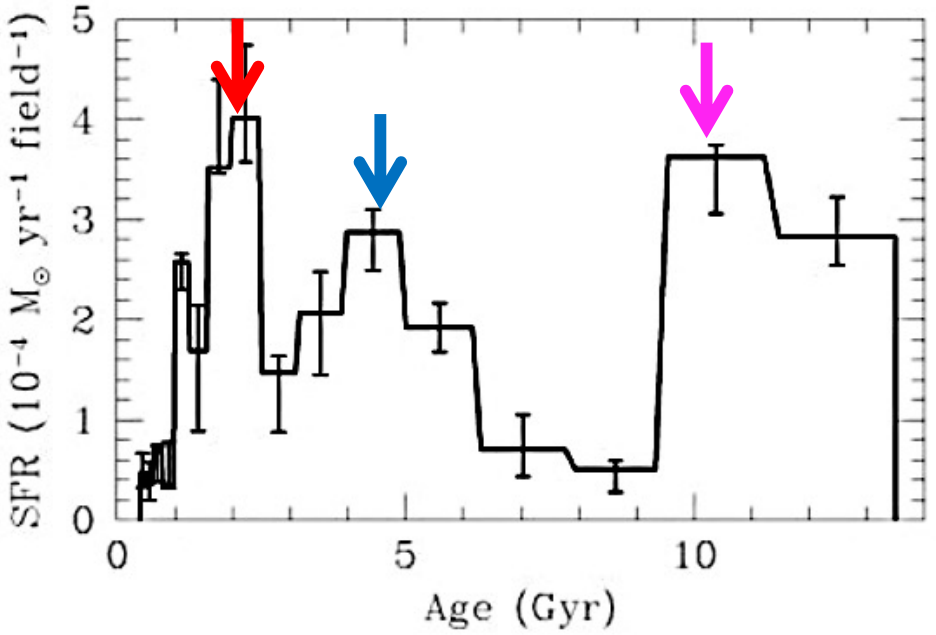
Gallart+1998

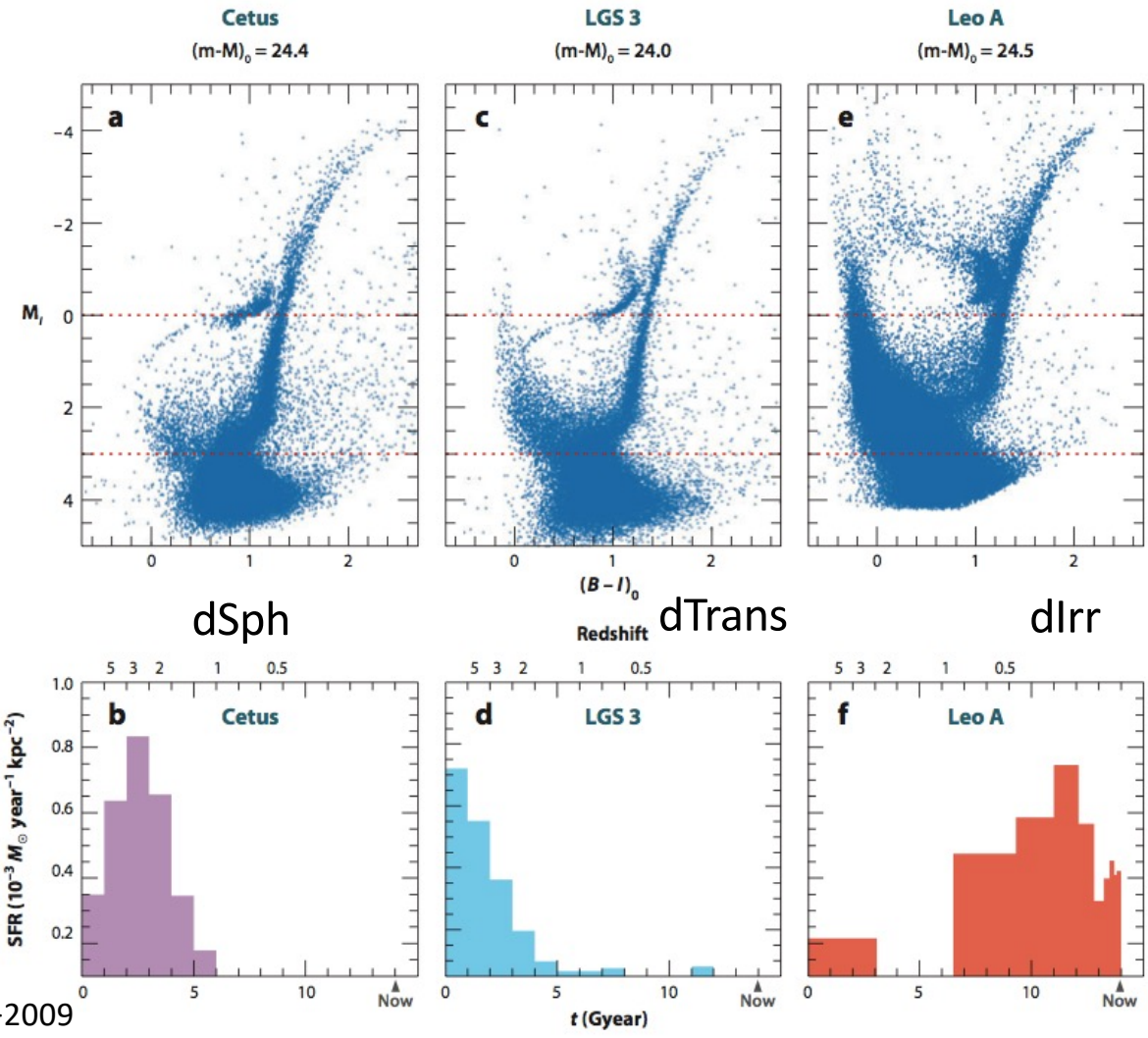
Orbits: HST Proper motions

Accretion by Milky Way

2 Gyr ago (Sohn, GB+2013)

Rapid quenching (Wetzel+2015)



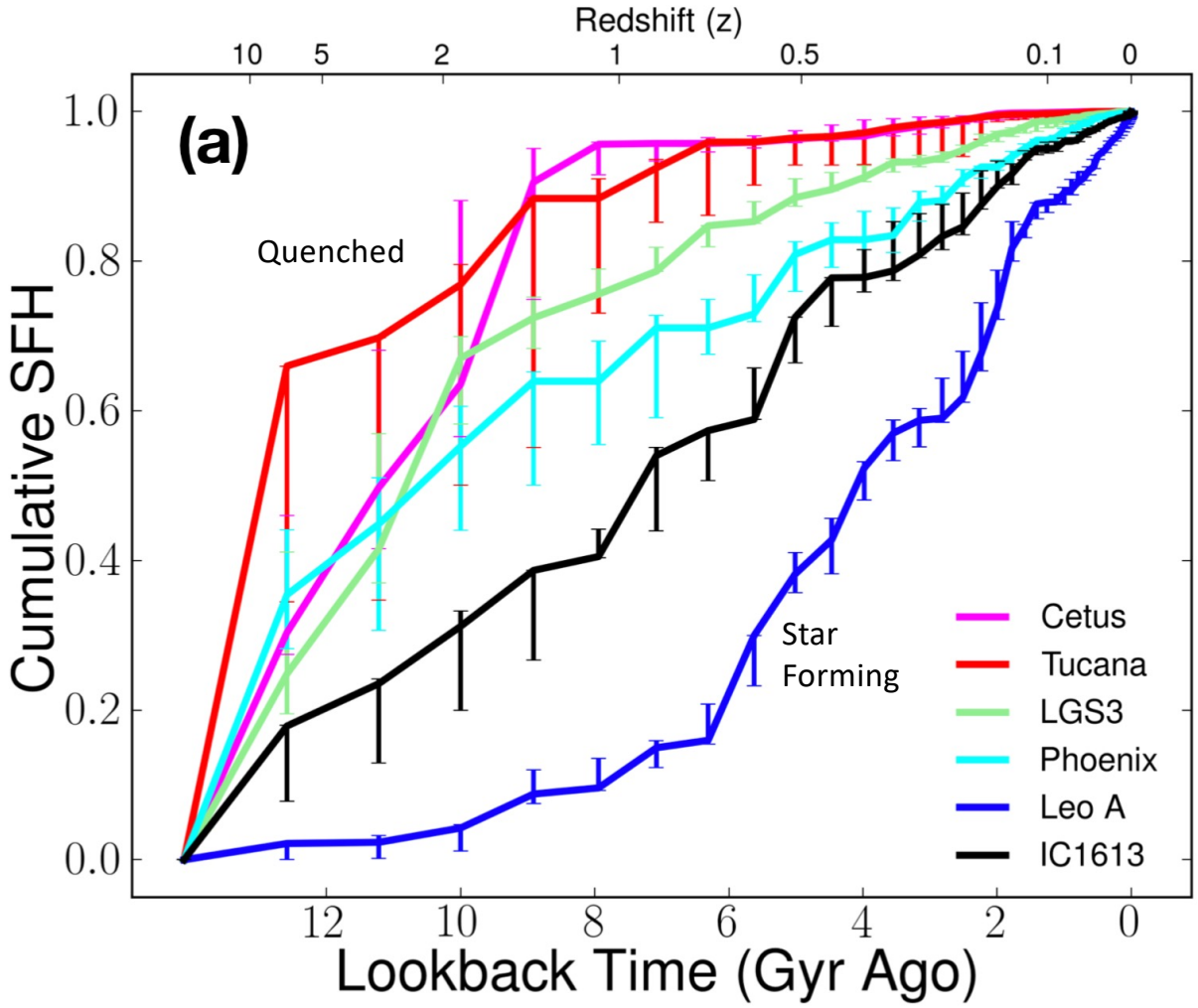


Tolstoy+2009

Cumulative SFHs

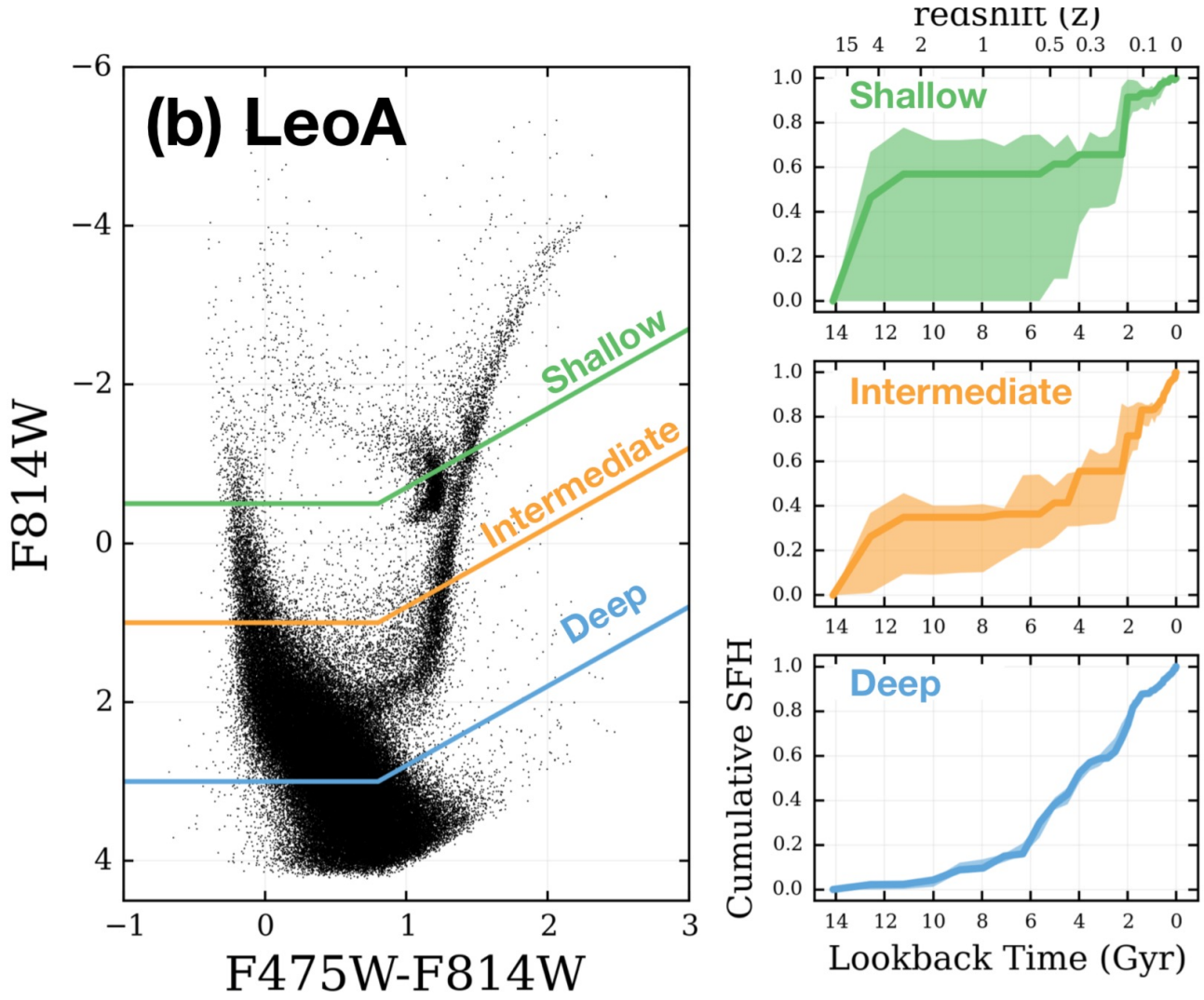
The SFHs of isolated (>300 kpc from the MW/M31) dwarf galaxies measured from deep CMDs (Skillman et al. 2014). The varied SFHs trace their diverse assembly history. *HST* can only provide deep CMDs for 9 isolated galaxies, while *JWST* can access hundreds.

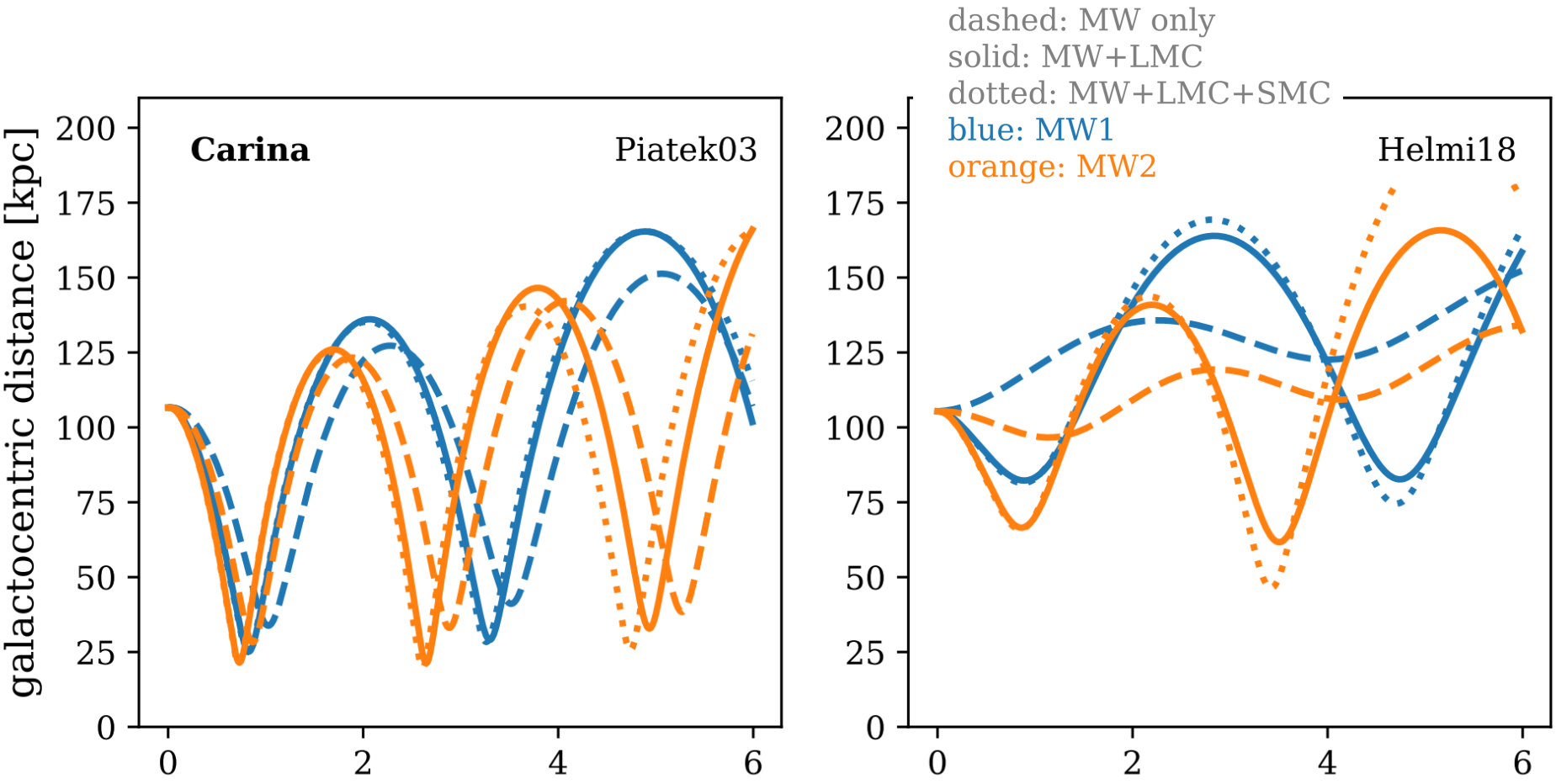
JWST ERS Proposal
PI Weisz



The Need for JWST

JWST ERS Proposal
PI Weisz




Carina
Piatek03
Helmi18
dashed: MW only
solid: MW+LMC
dotted: MW+LMC+SMC
blue: MW1
orange: MW2
galactocentric distance [kpc]
0
25
50
75
100
125
150
175
200
0
2
4
6

Patel + 2020