

Challenges Posed by Ultra-faint Dwarf Galaxies

Nitya Kallivayalil

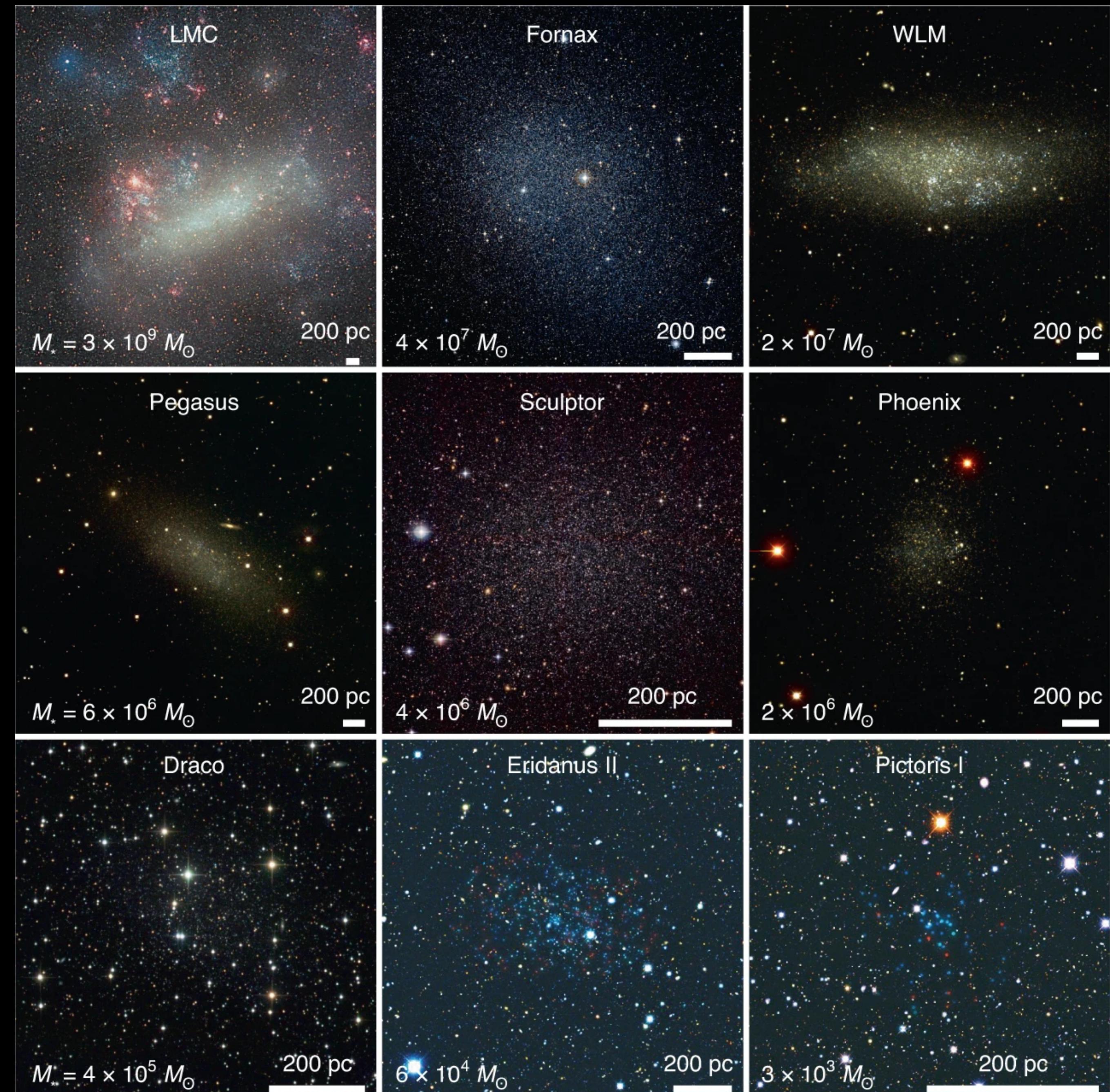
The University of Virginia





Understanding our Universe through low mass galaxies

- “Satellites of satellites”
- Star formation histories
- Structure of the smallest satellites and comparison to simulations
- Beyond the LG: is the Milky Way satellite system typical?



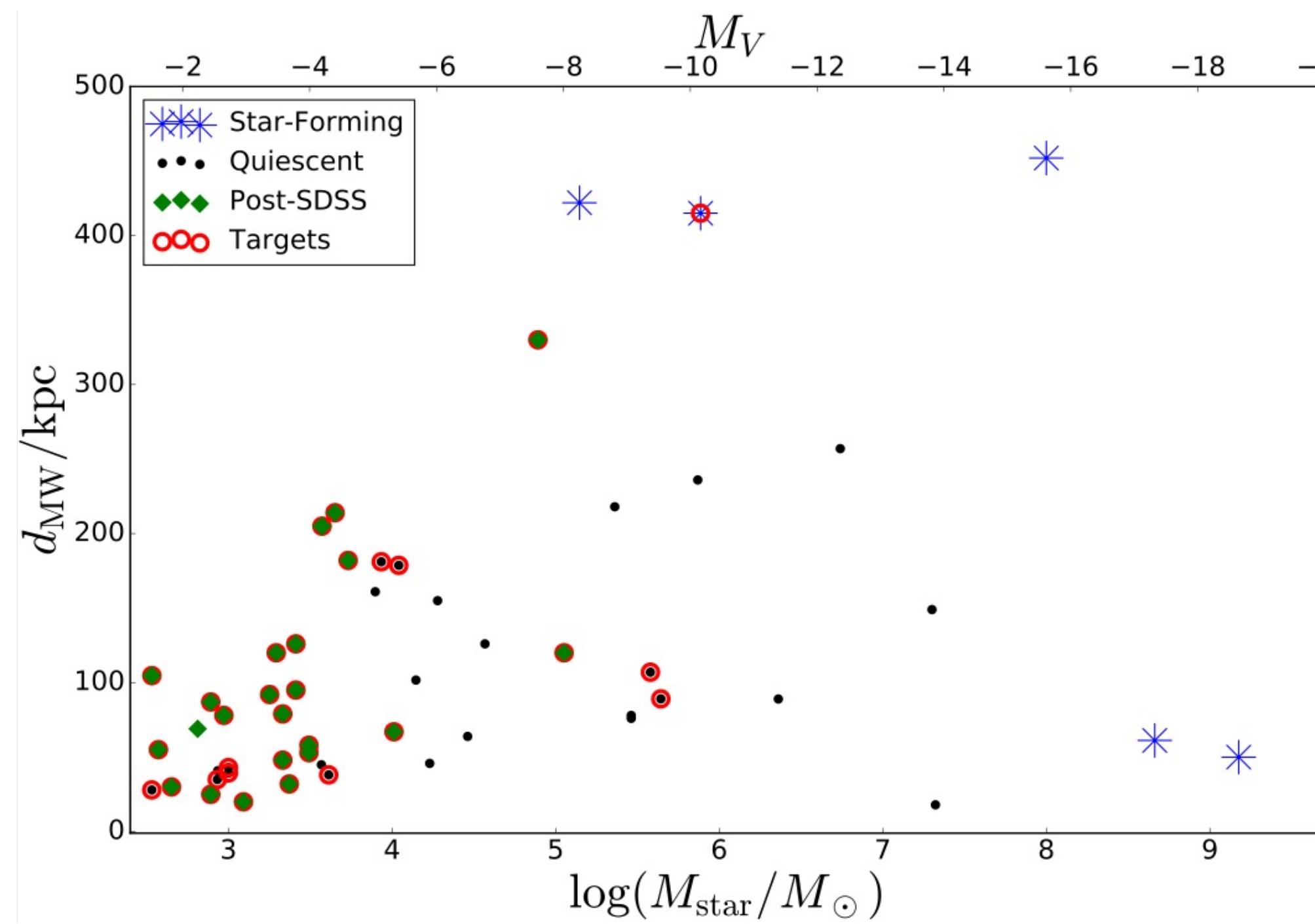
Two HST Treasury Programs



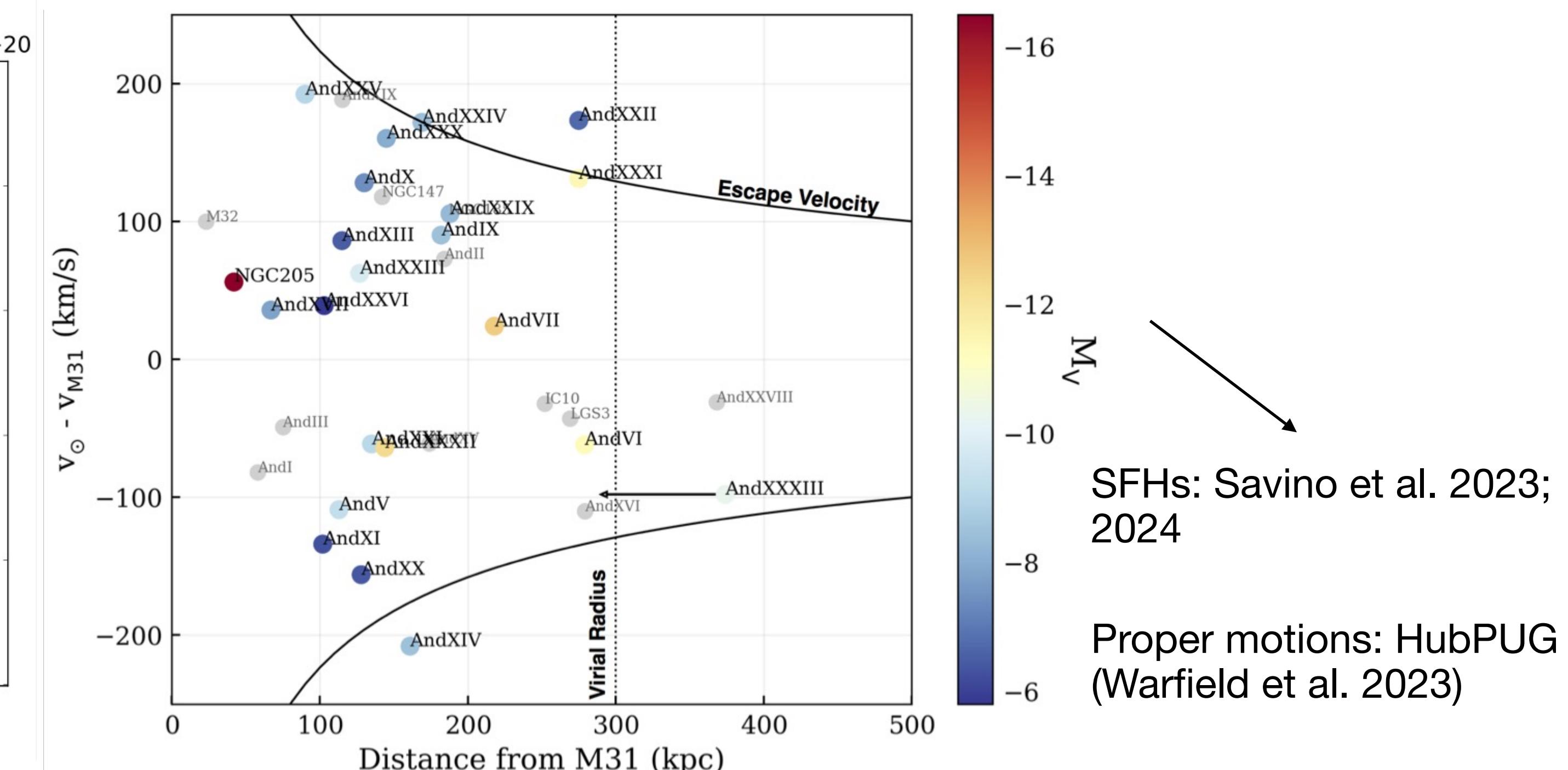
Milky Way: 30 dwarf galaxy targets
164 orbits

M31: 23 dwarf galaxy targets
244 orbits

Co-PIs: Nitya Kallivayalil
& Andrew Wetzel



Co-PIs: Dan Weisz,
Nitya Kallivayalil &
Andrew Wetzel





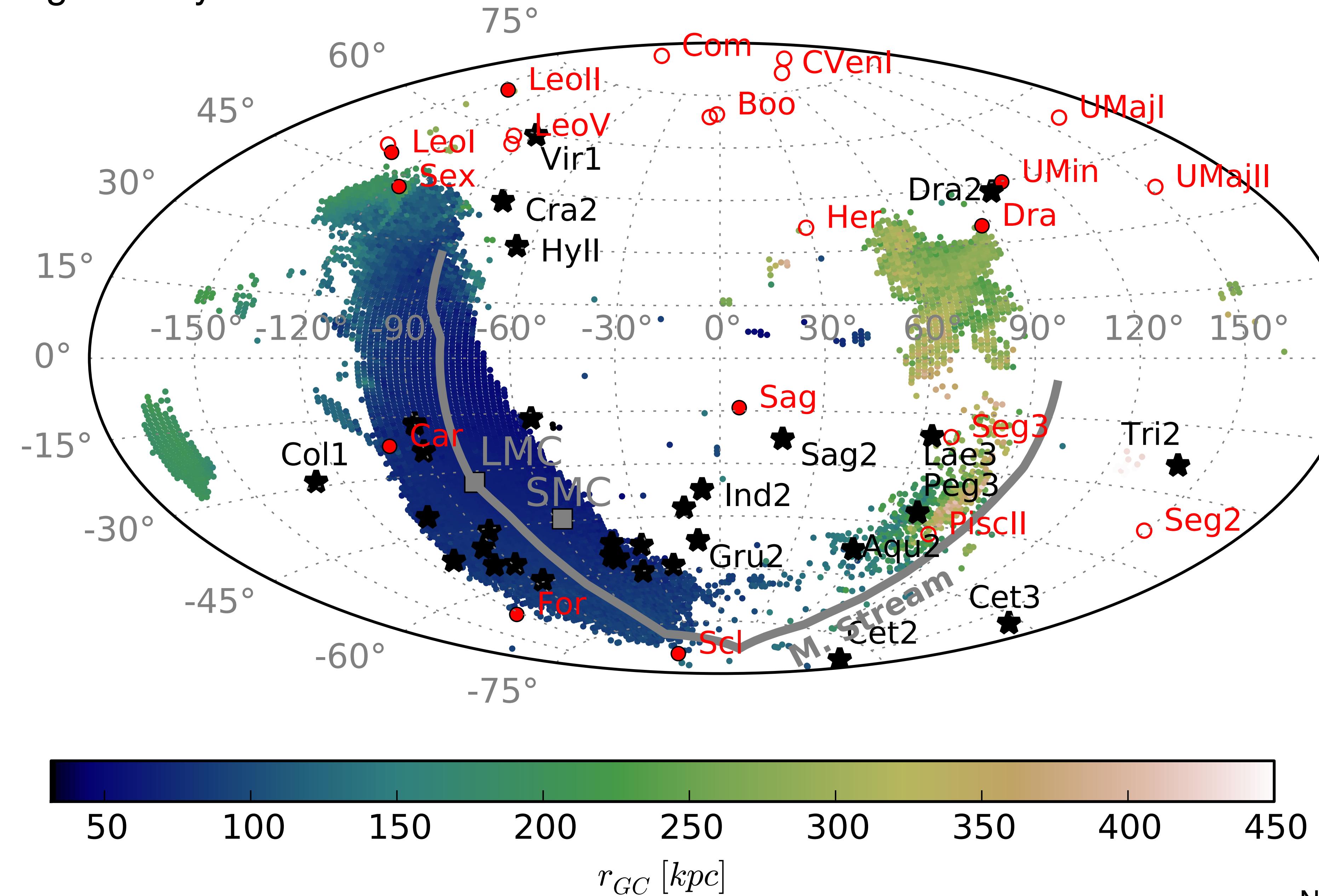
Satellites of satellites

Patel, NK et al. 2020, NK et al. 2018

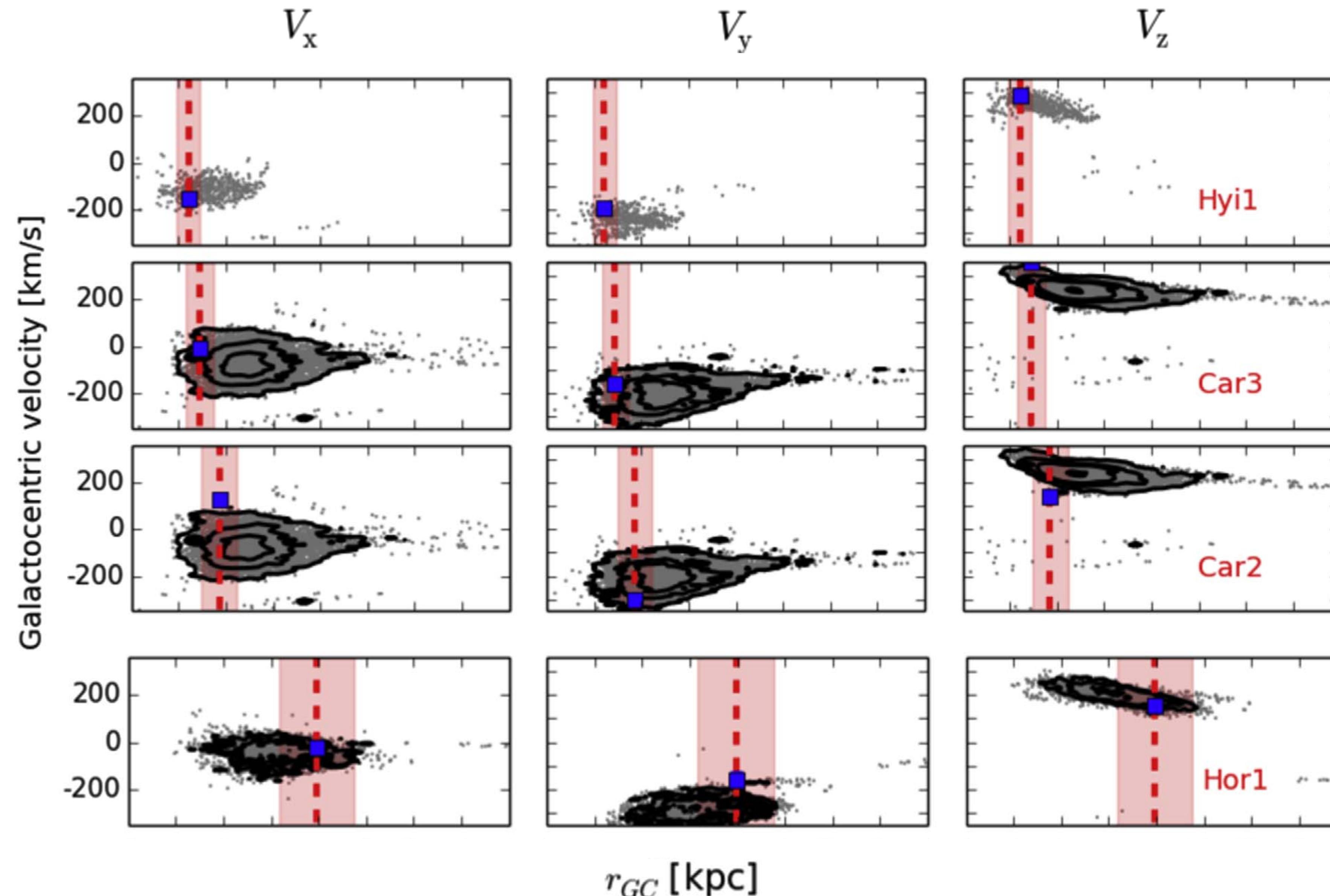
see also Jethwa et al. 2016, Sales et al. 2017, Erkal & Belokurov 2019, Pace et al. 2022

Battaglia et al. 2022, Correa Magnus & Vasiliev 2022; Vasiliev 2024

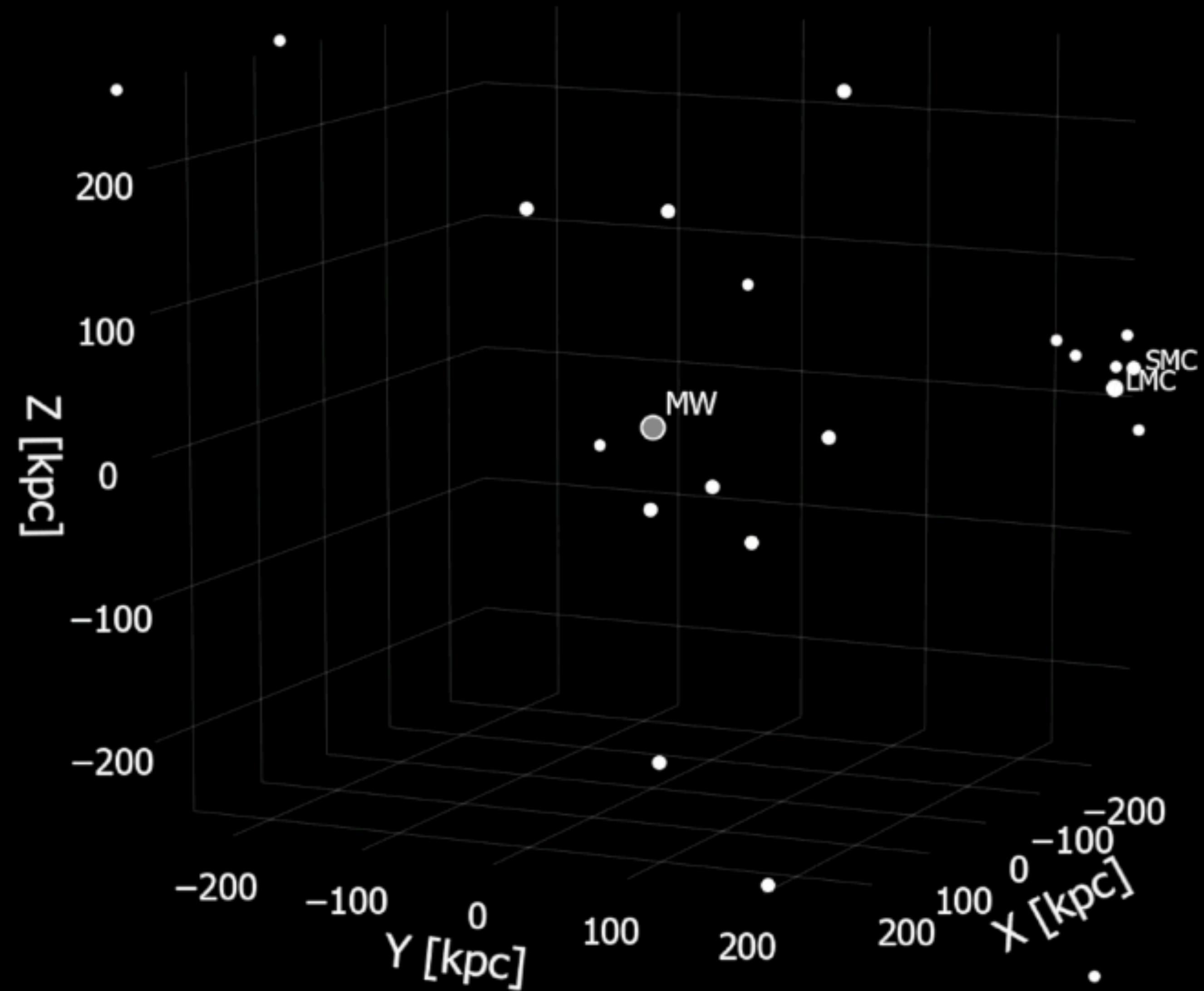
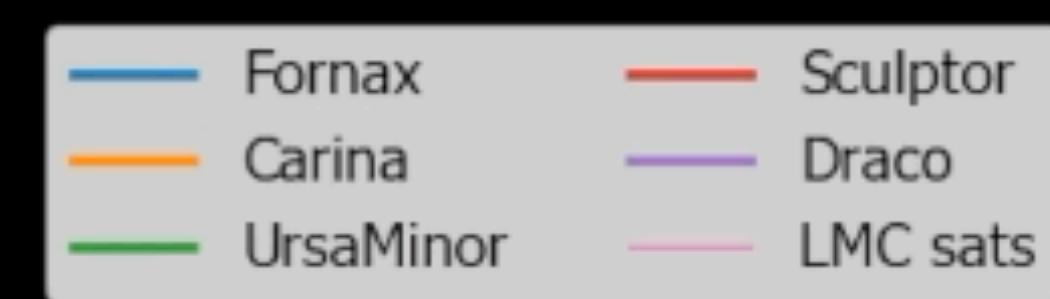
The Infalling LMC system

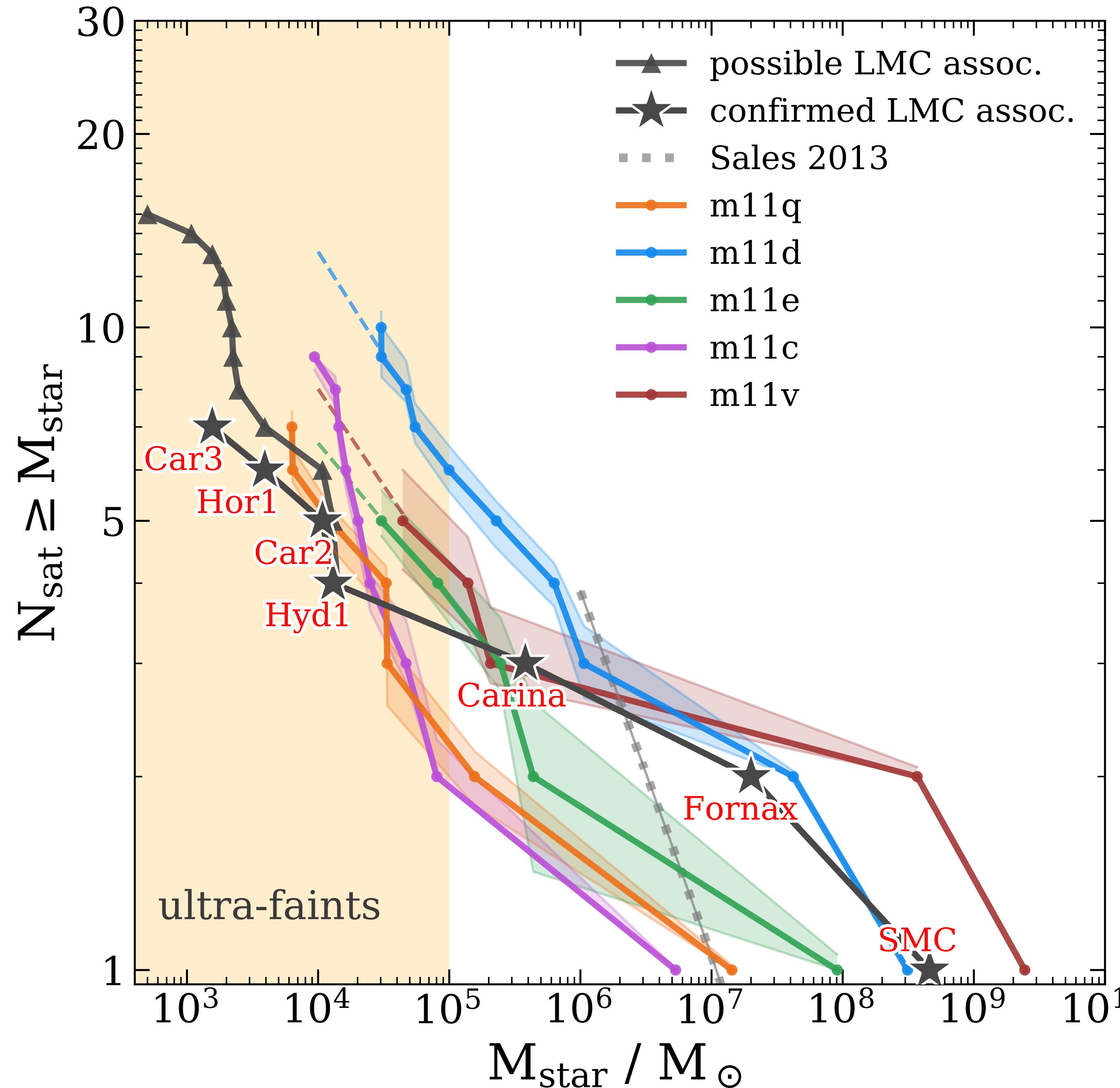


Velocities and Distances



$t=3.5$ Gyr ago





Consistent with LCDM?

Where are the classical dSphs associated with LMC infall?

Pardy et al 2020 make a case for Carina and Fornax

Vasiliev 2024 makes a case if LMC is on second infall

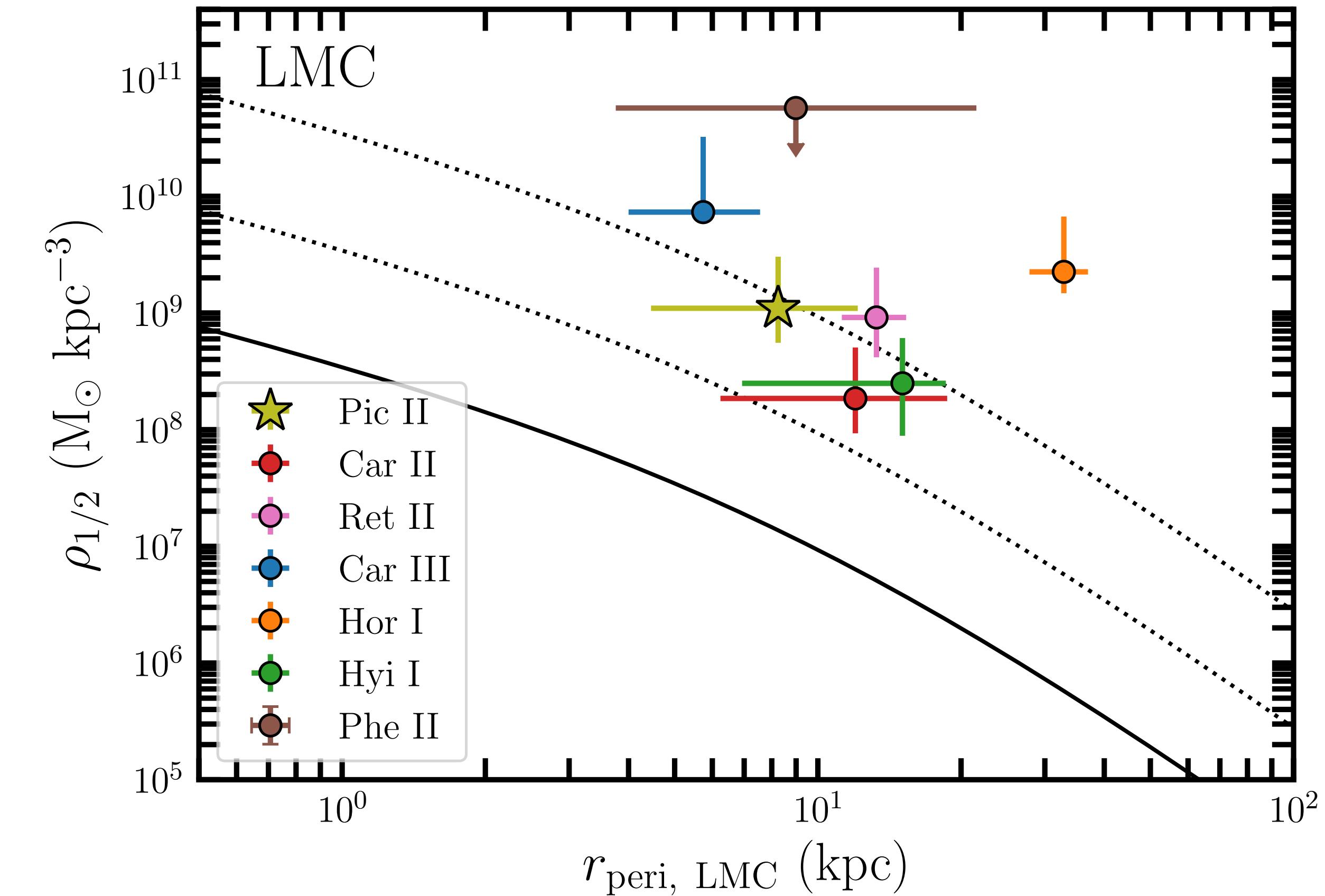
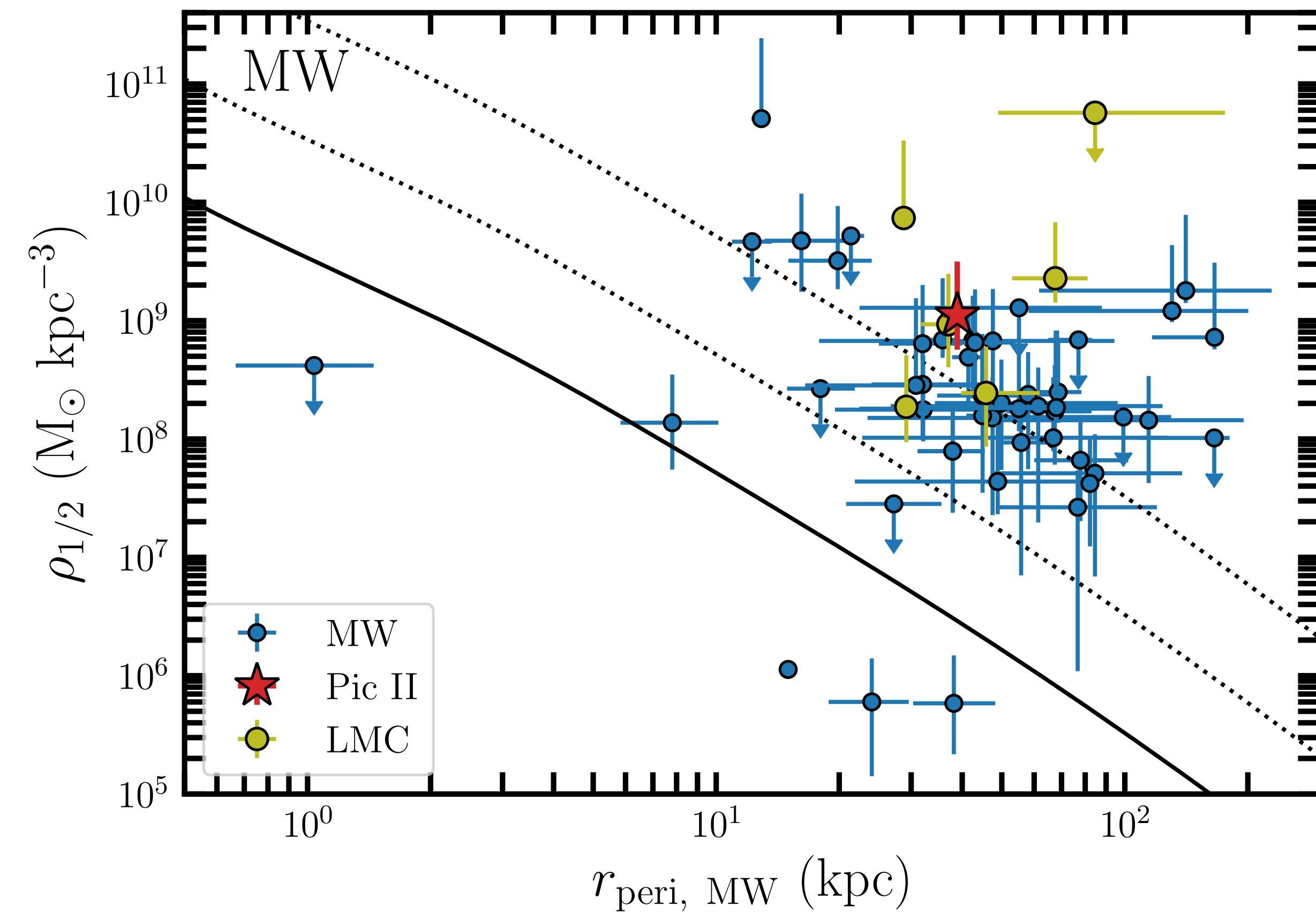
Jahn et al. 2019

See also Sales et al. 2013; Dooley et al. 2017; Munshi et al. 2019; Pardy et al. 2020; Santos-Santos et al. 2021

LMC streams: Shipp et al. 2025; Riley et al. 2025

Group infall: Li & Helmi 2008, D'Onghia & Lake 2008; Guo et al. 2011; Wetzel et al. 2015

Tidal disruption in LMC satellites?



Solid black line is twice the MW/LMC average density.

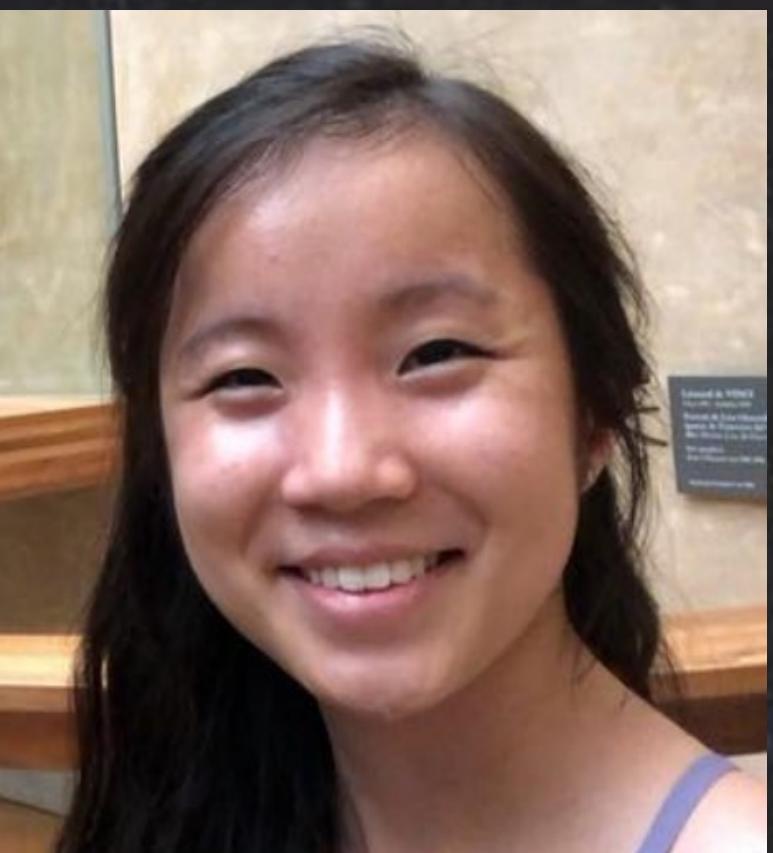
Pace et al. *in prep.*

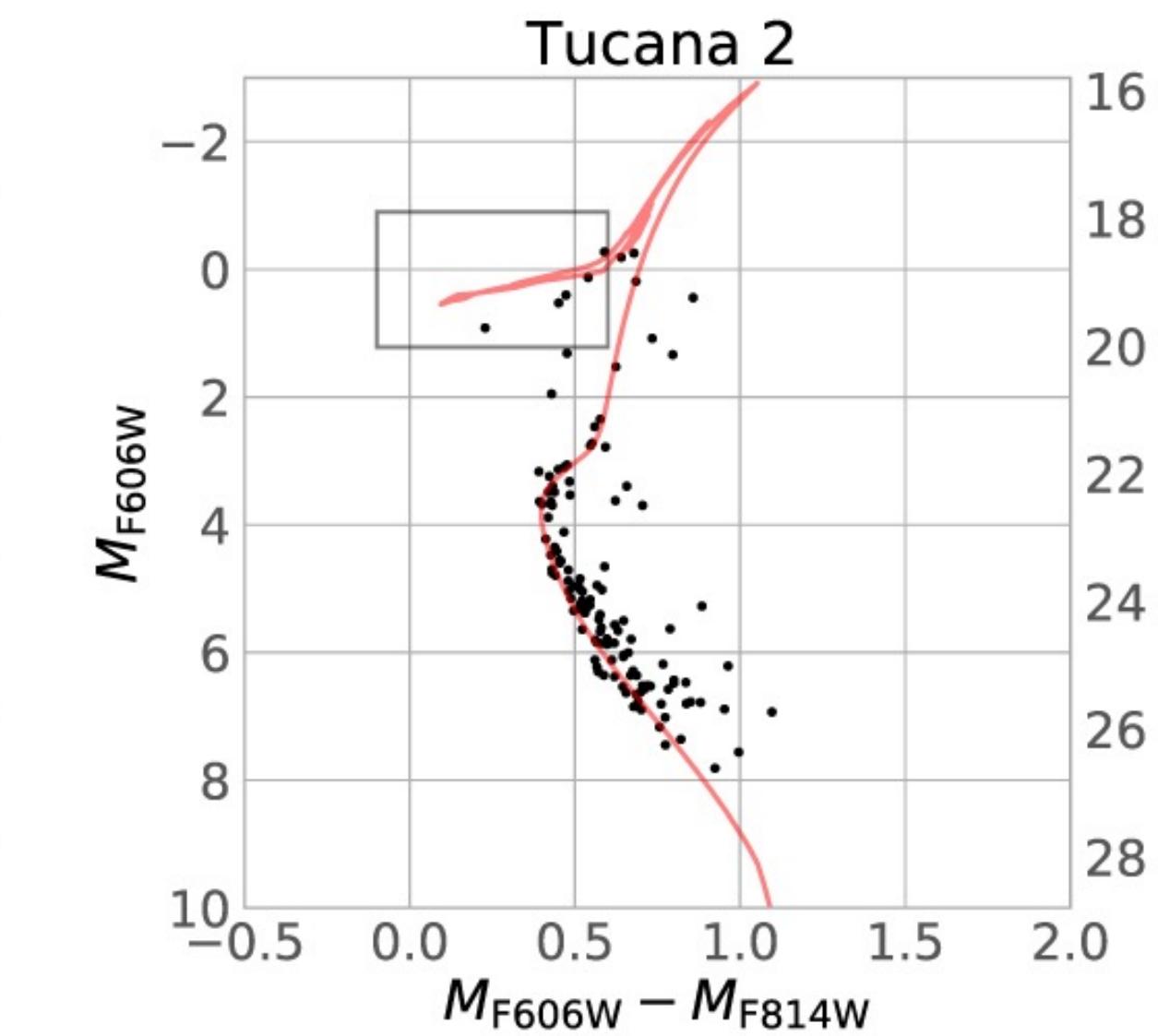
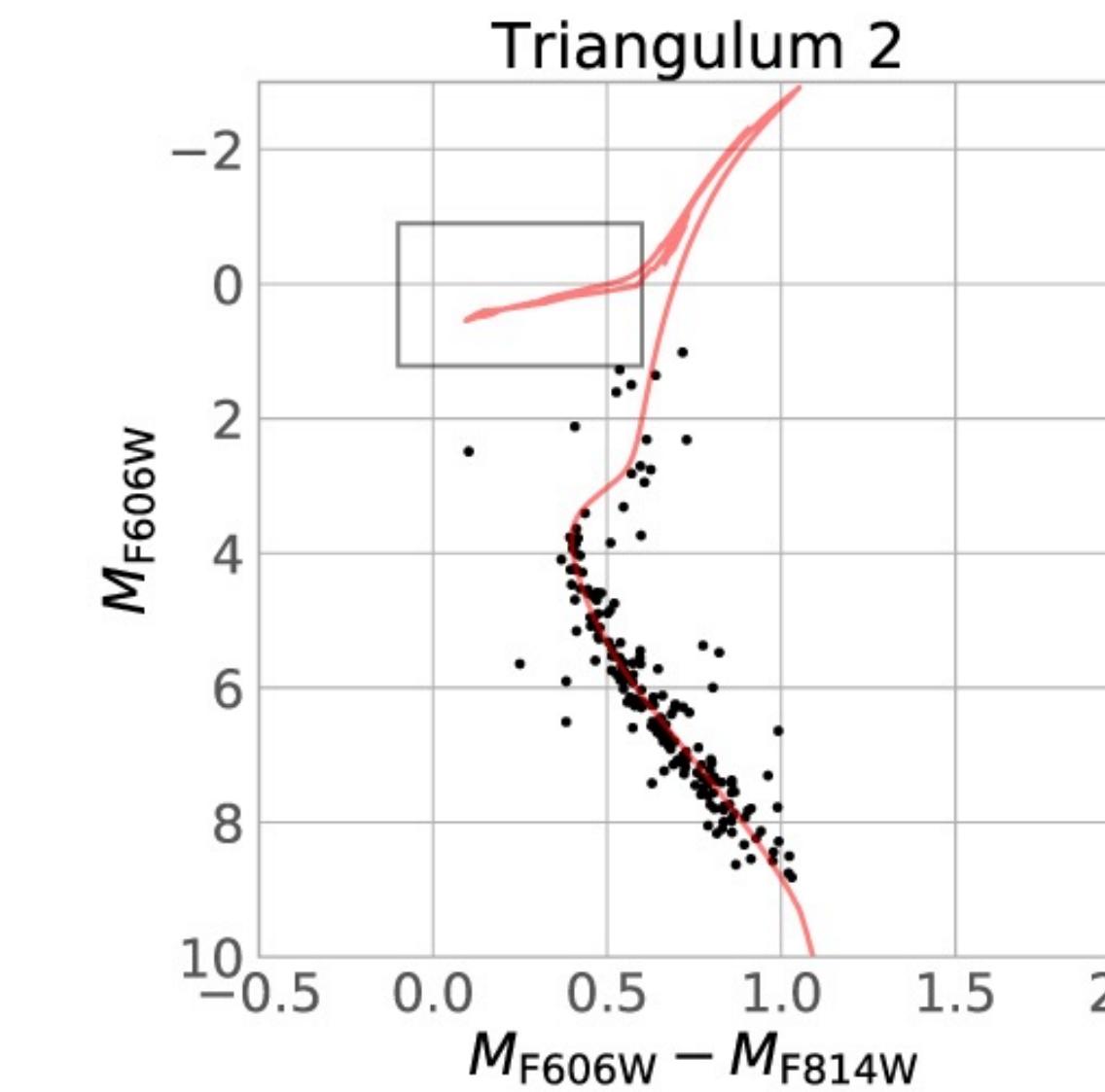
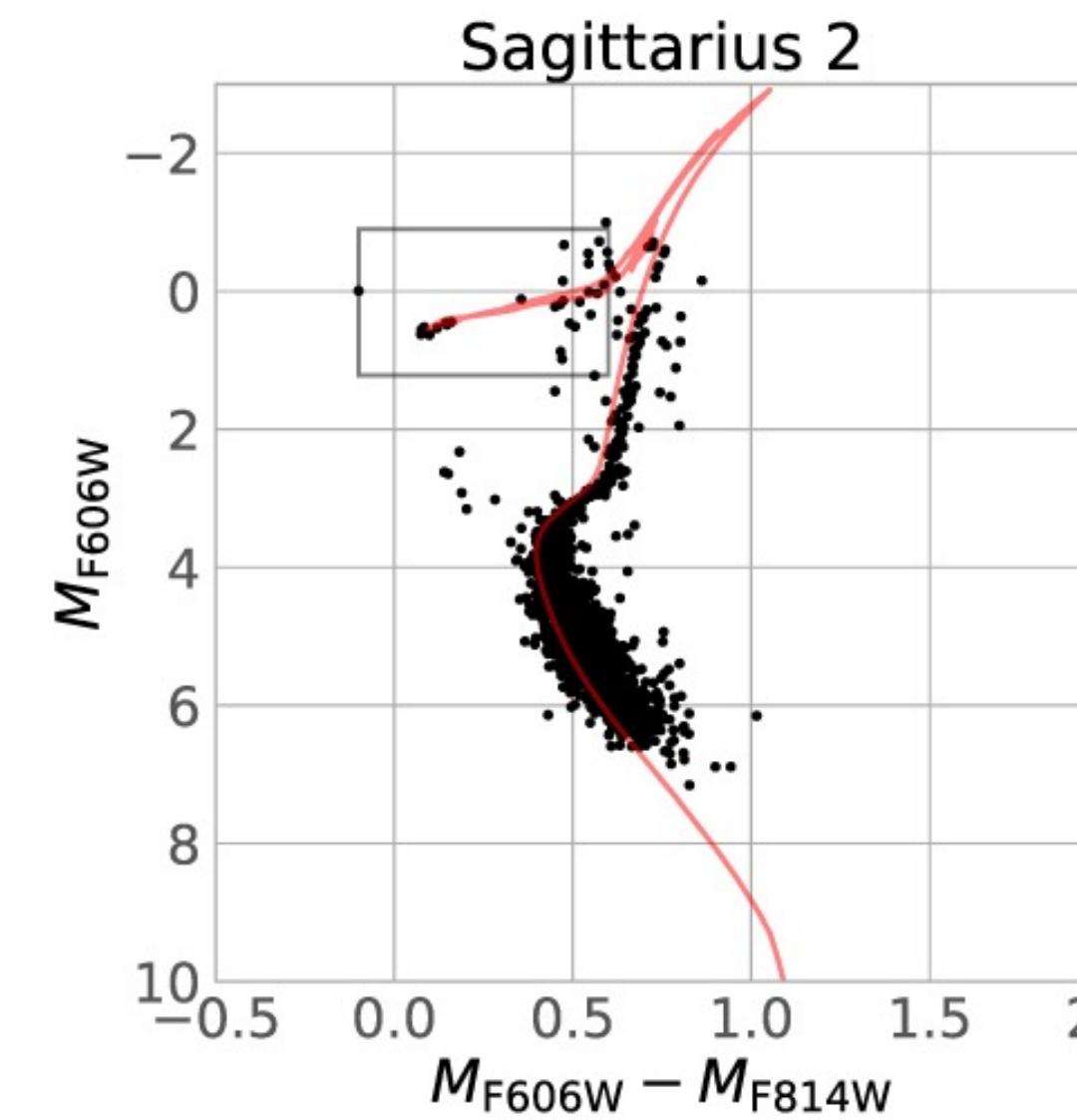
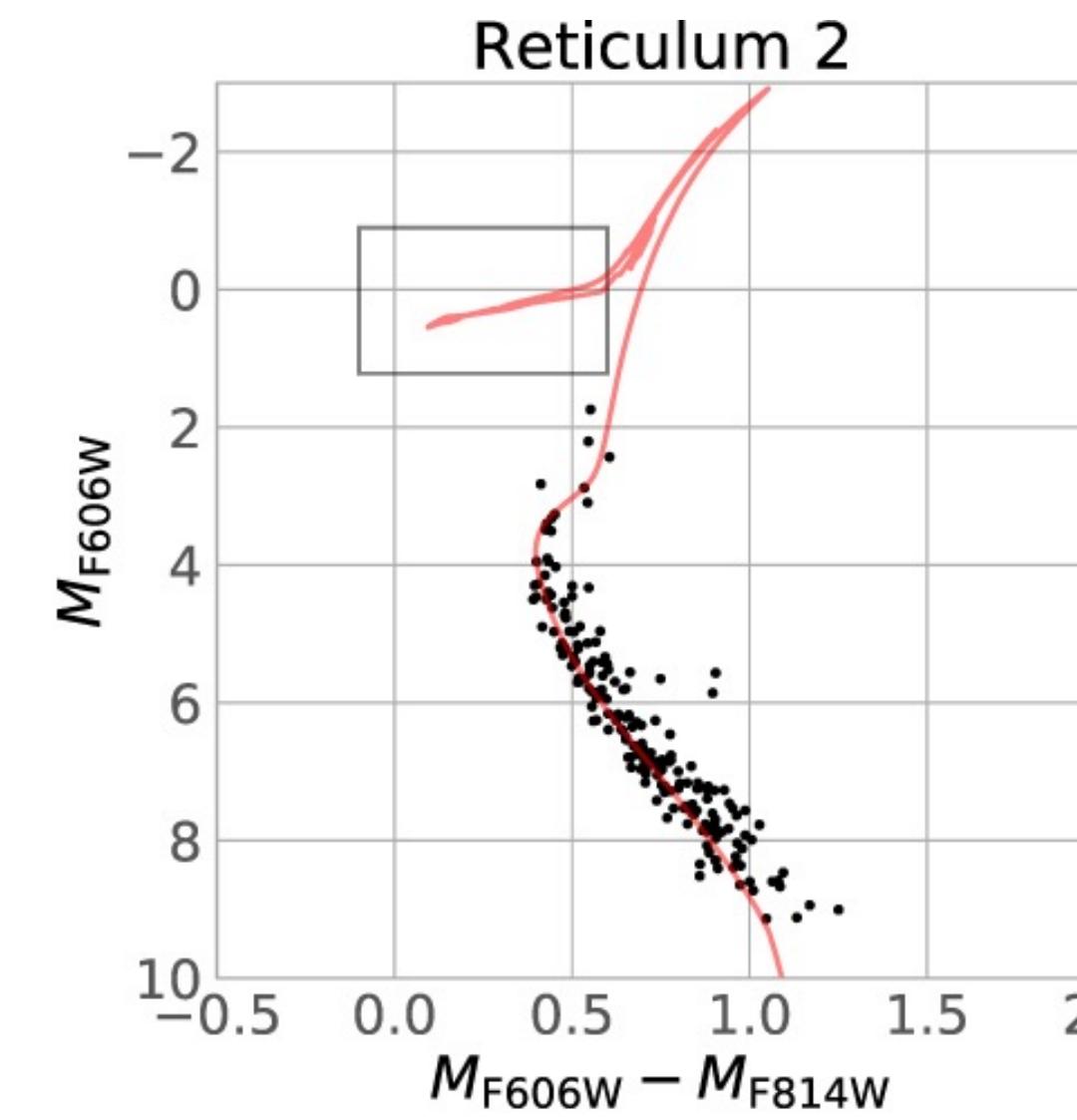
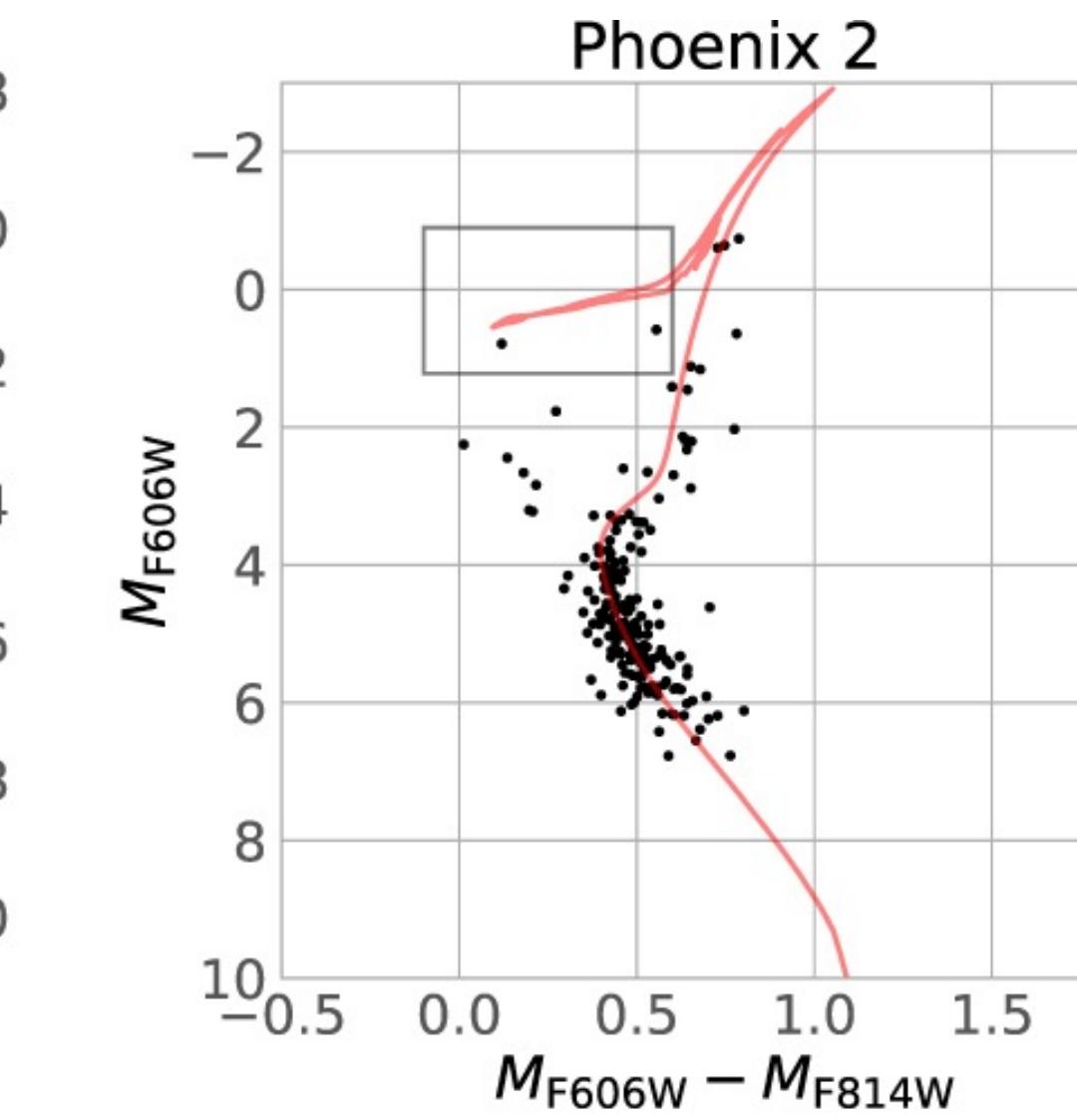
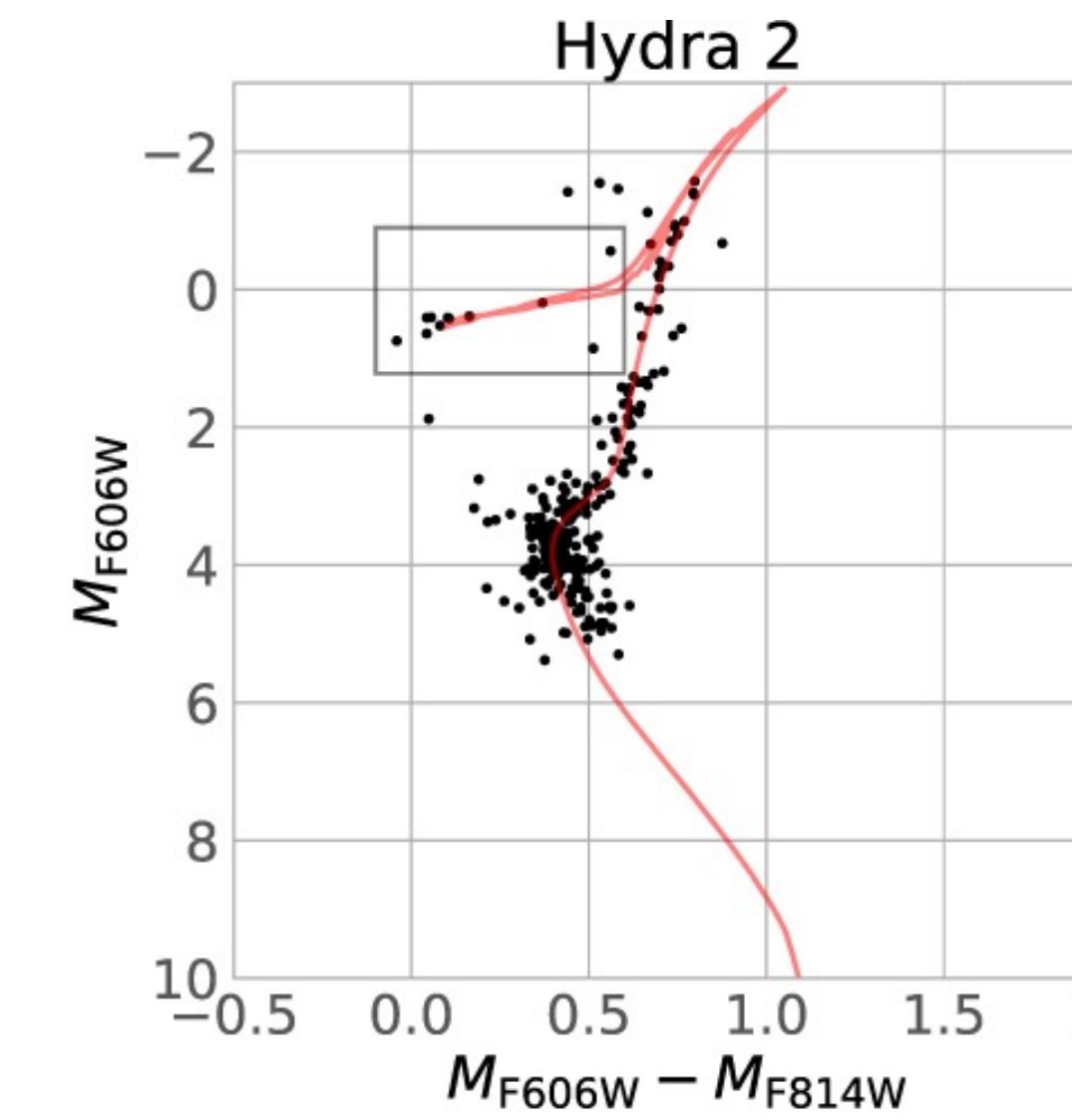
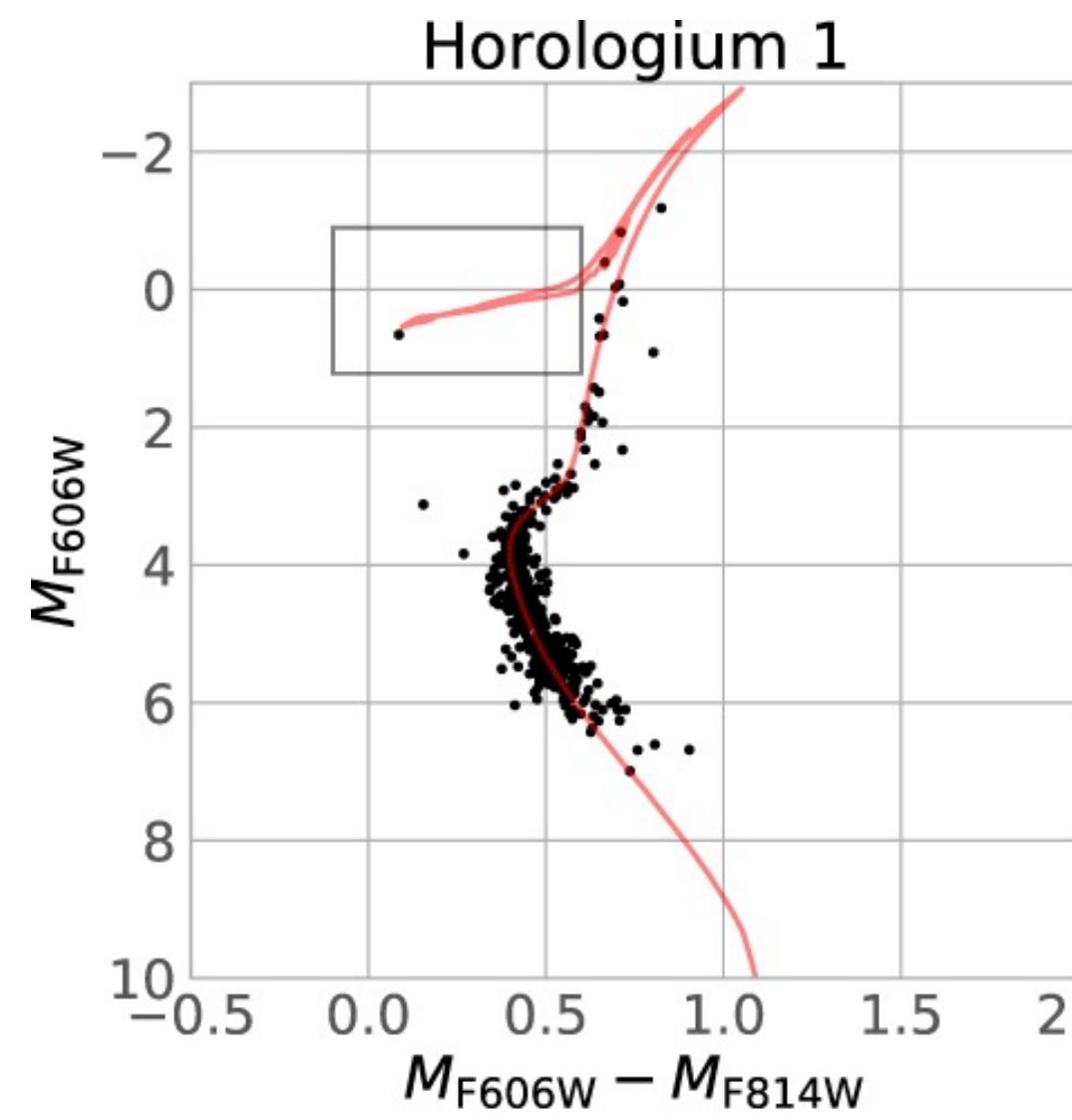
c.f. Shipp et al. 2025; Riley et al. 2025

Star Formation Histories

Satellites in groups versus not

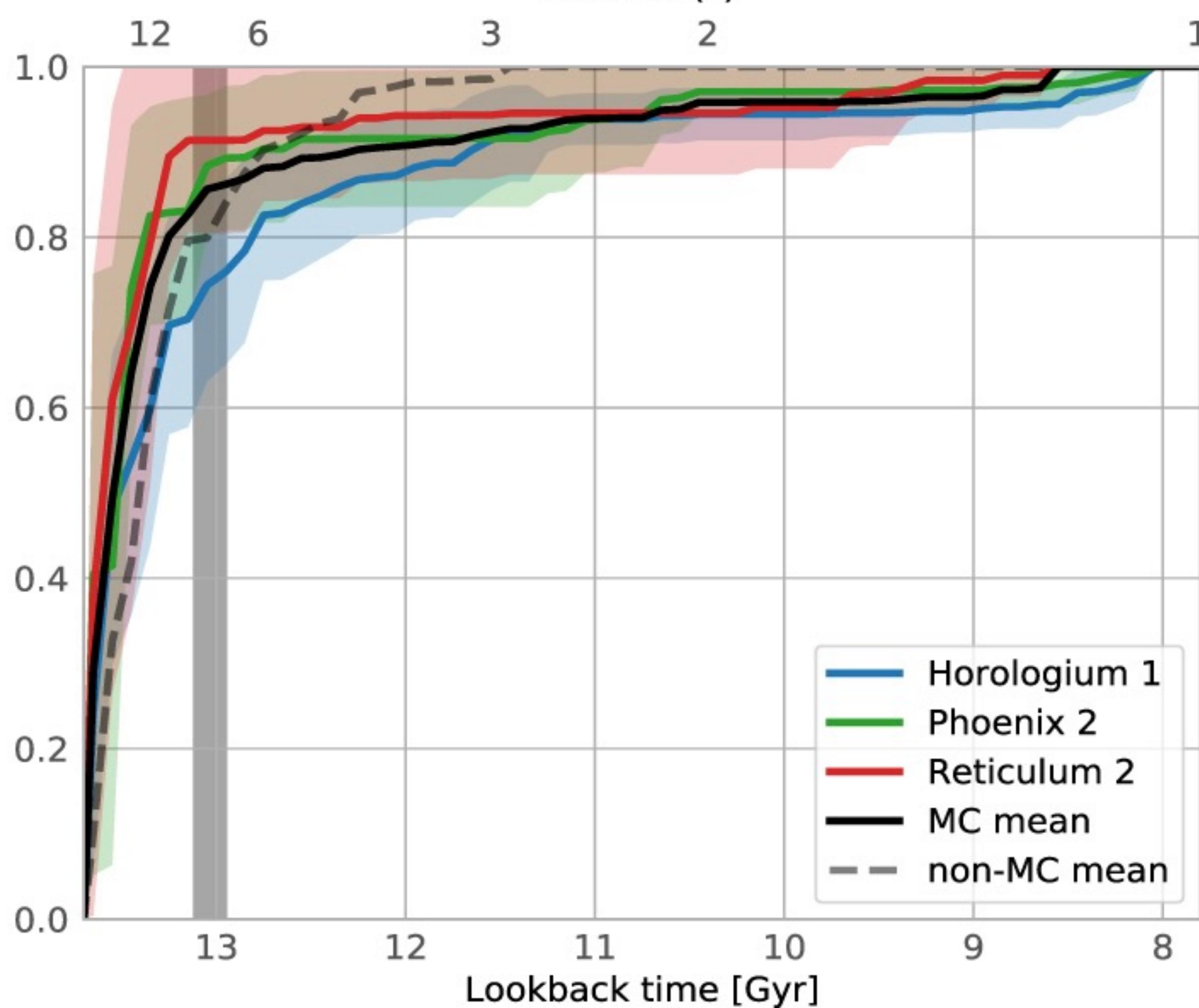
Sacchi, E, Richstein, H et al. 2021, ApJL, 920, L19 (arXiv:2108.04271)





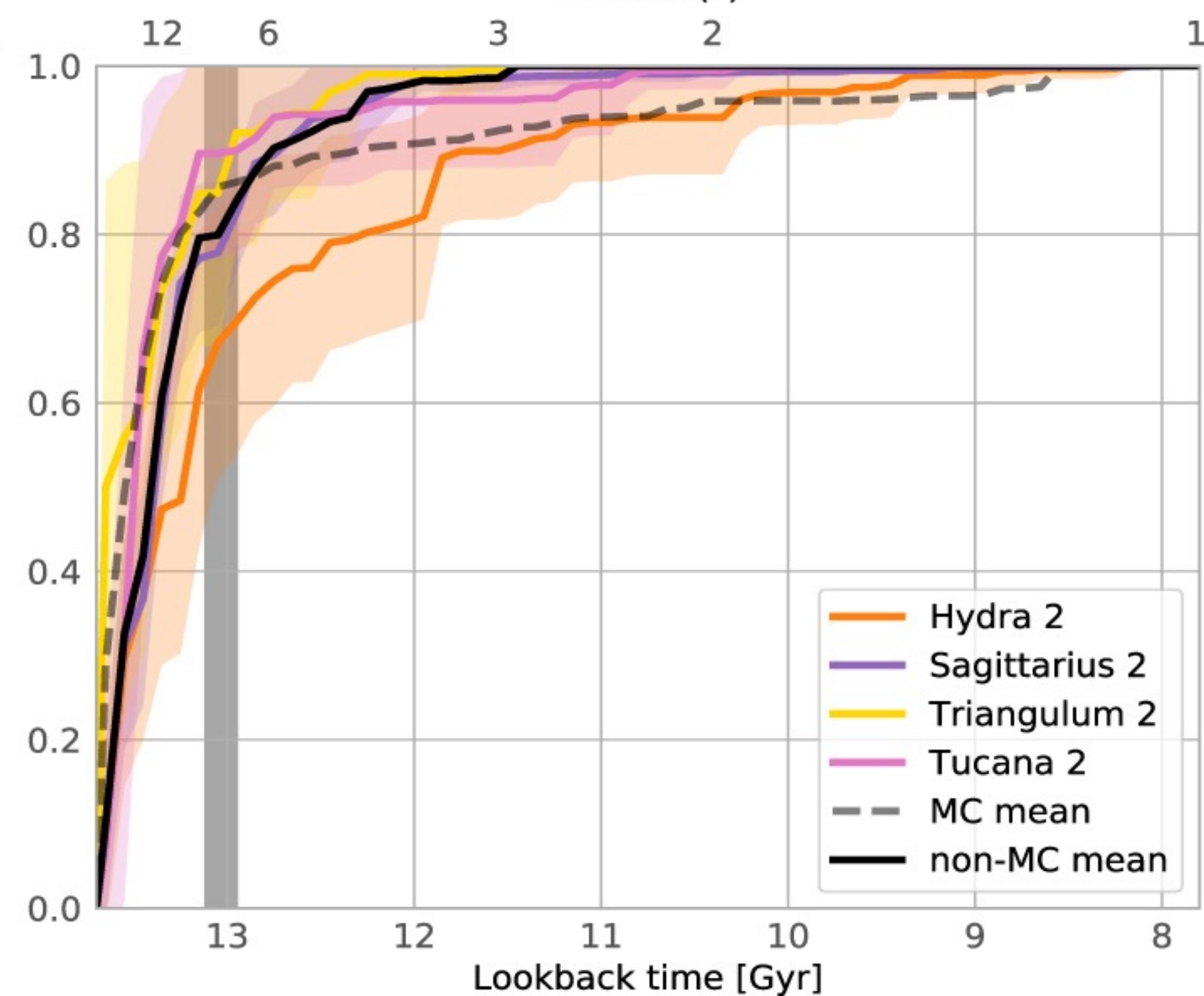
MC Satellites

redshift (z)

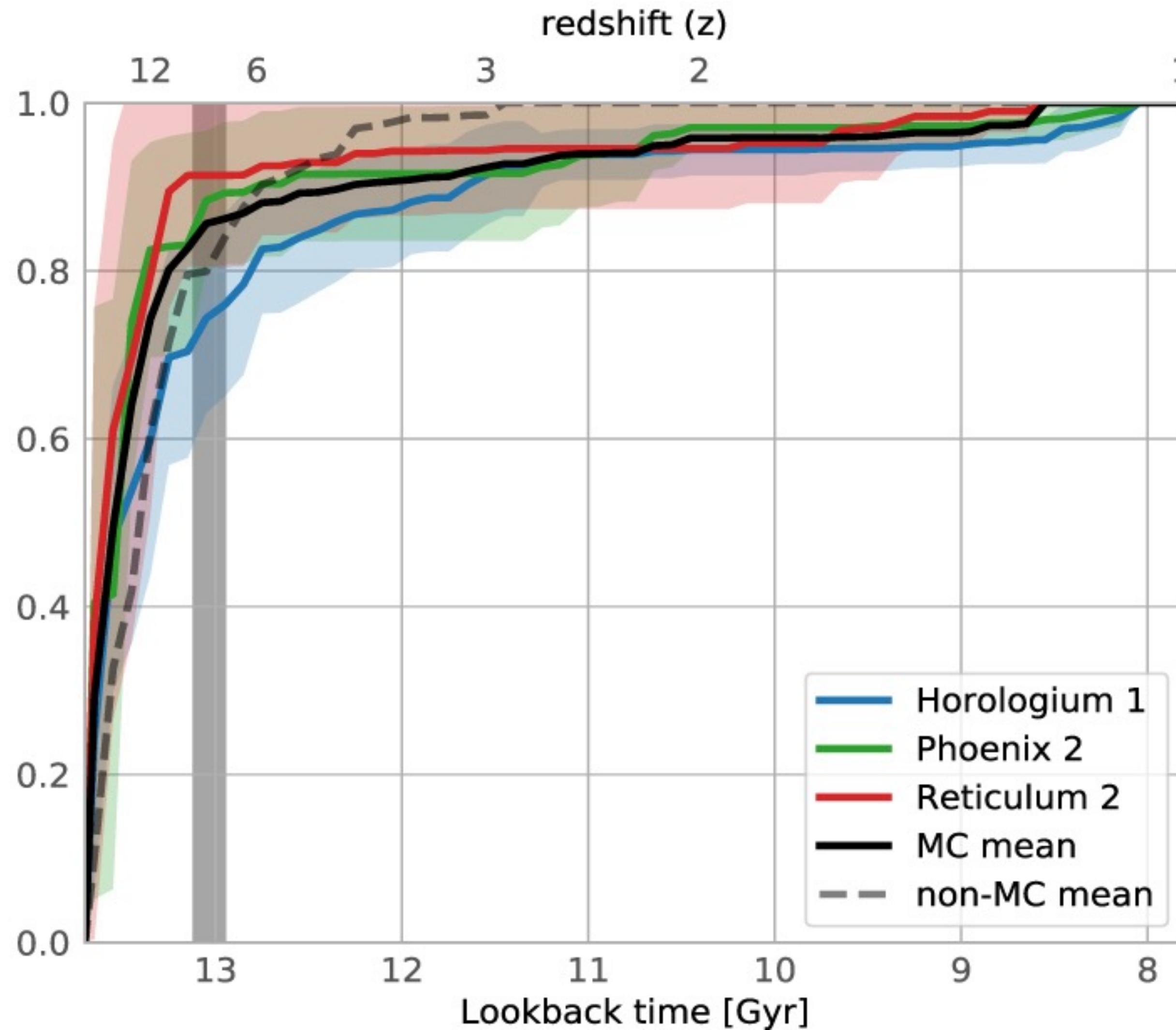


non-MC Satellites

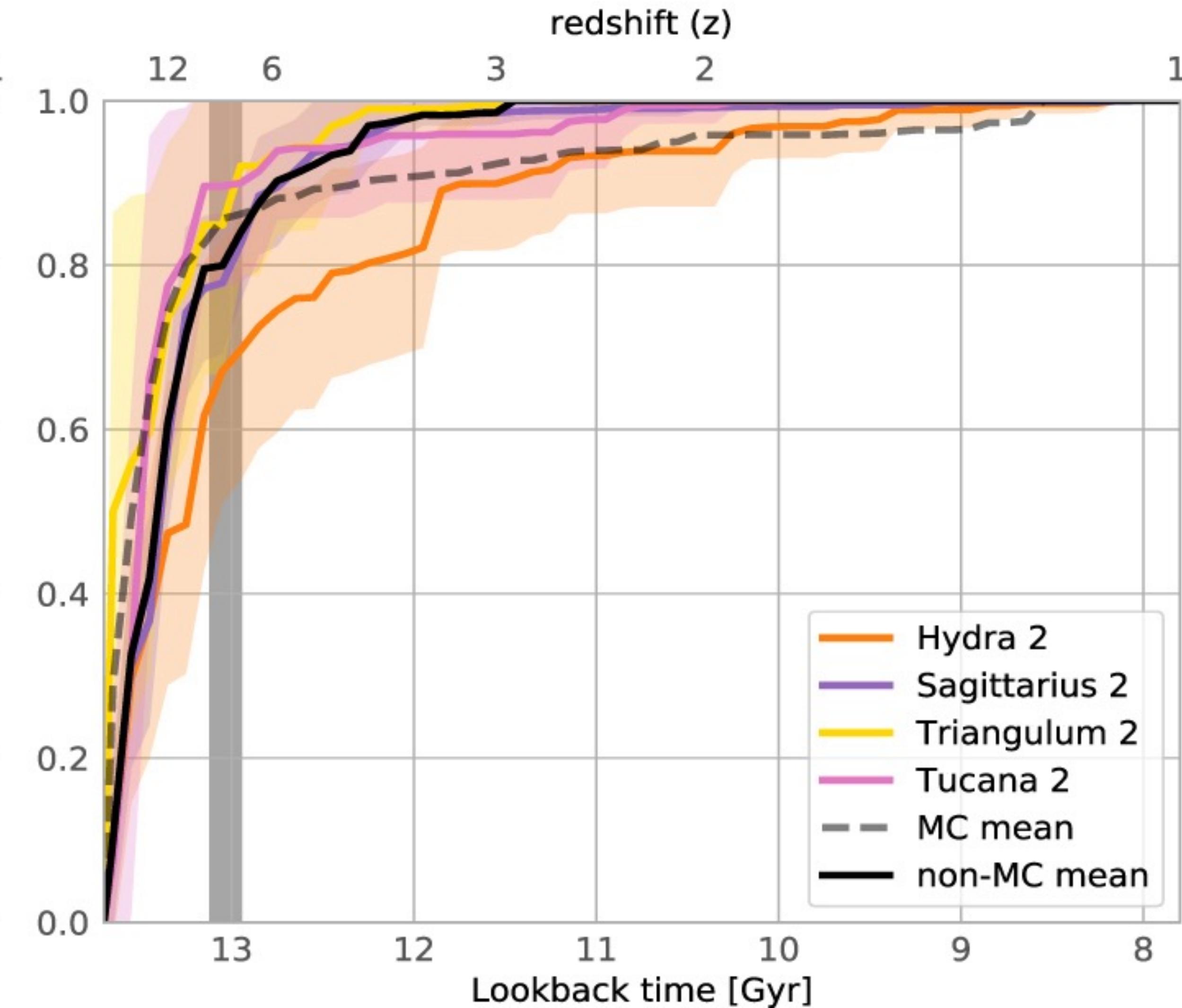
redshift (z)



MC Satellites



non-MC Satellites



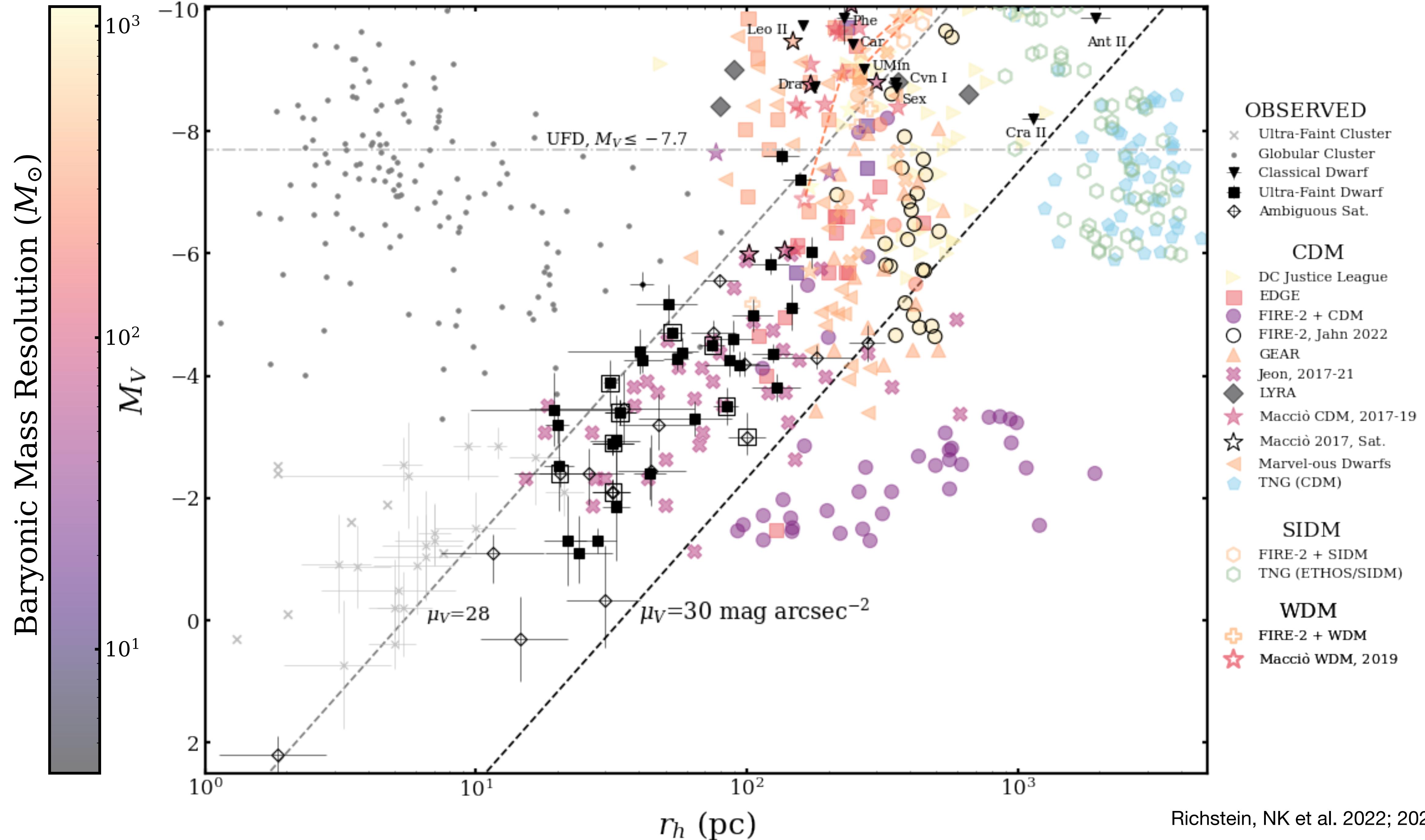
This may arise from “patchy” reionization that varied with individual environments of ultra-faints at the time, such as their proximity to their host galaxy and its intensity of UV photon emission (Kim et al. 2023; see also Aubert et al. 2018; Sorce et al. 2022)

Structural analysis and comparison to simulations

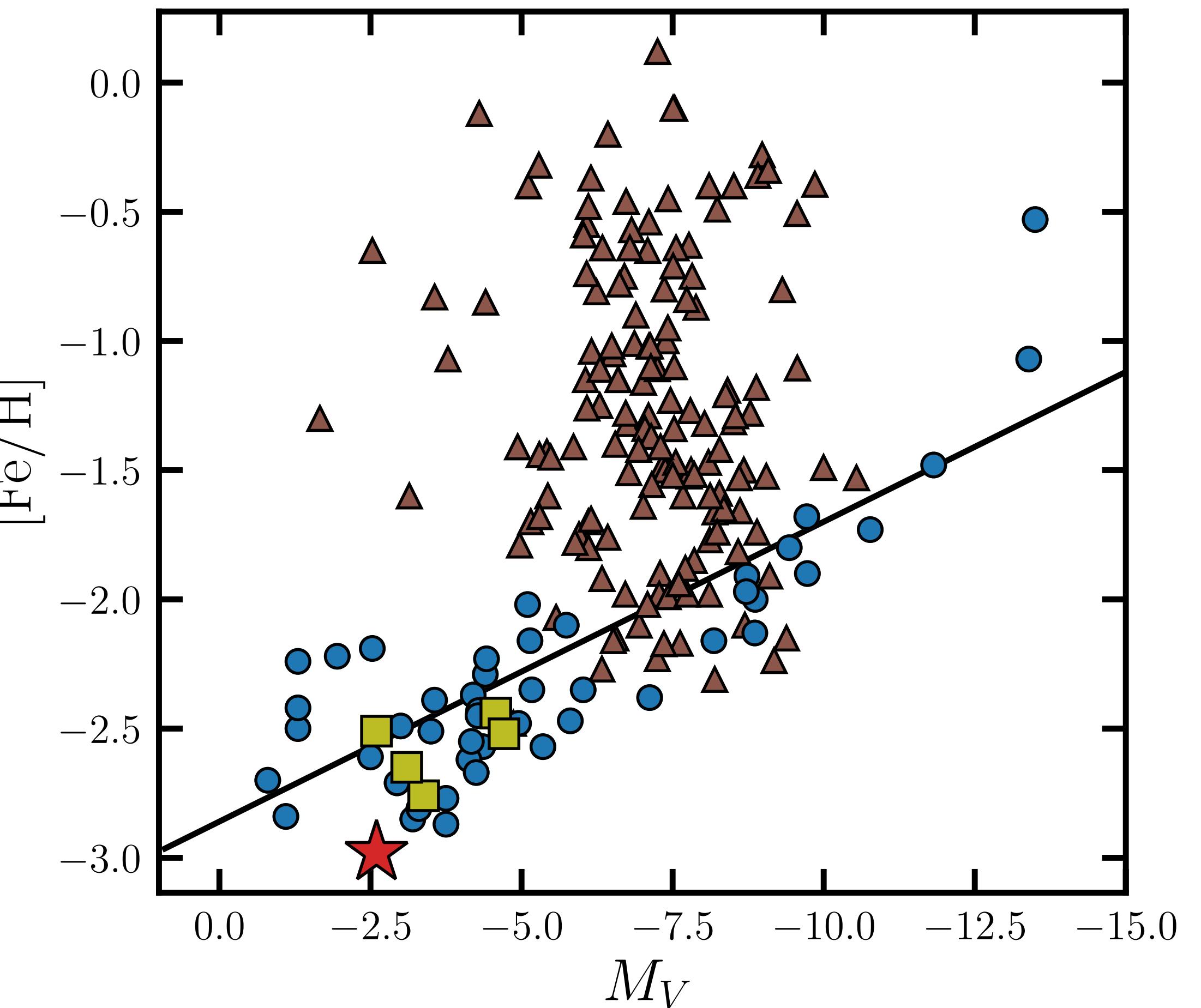
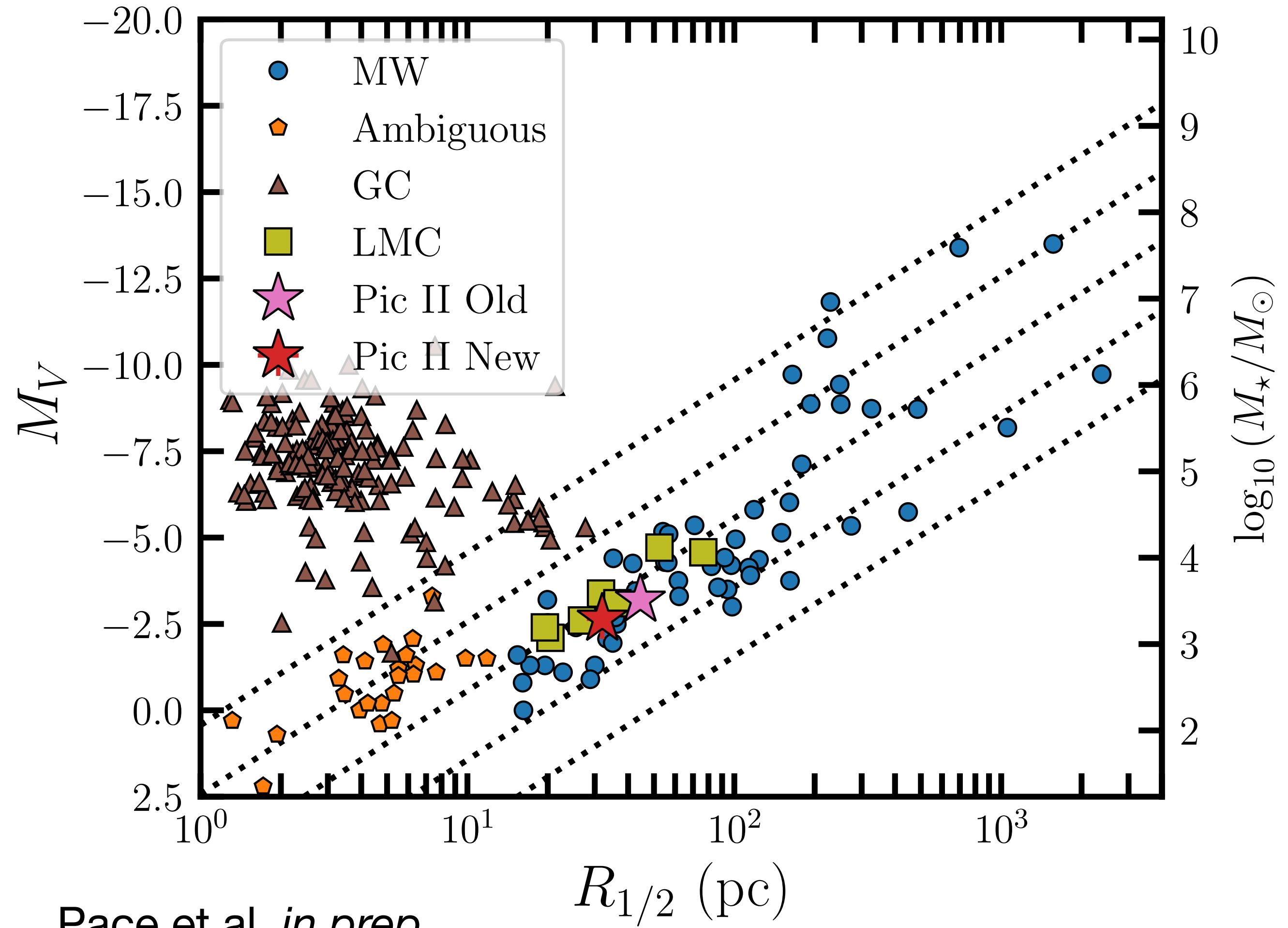
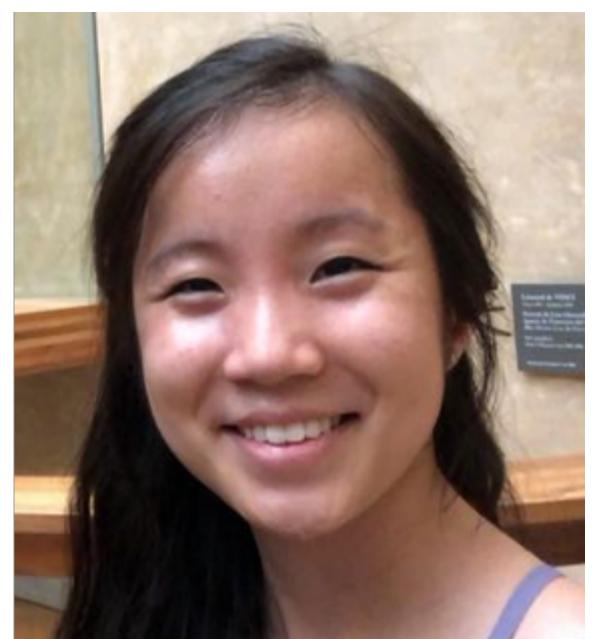
Satellite size

Richstein, H; Kallivayalil, N et al. 2024





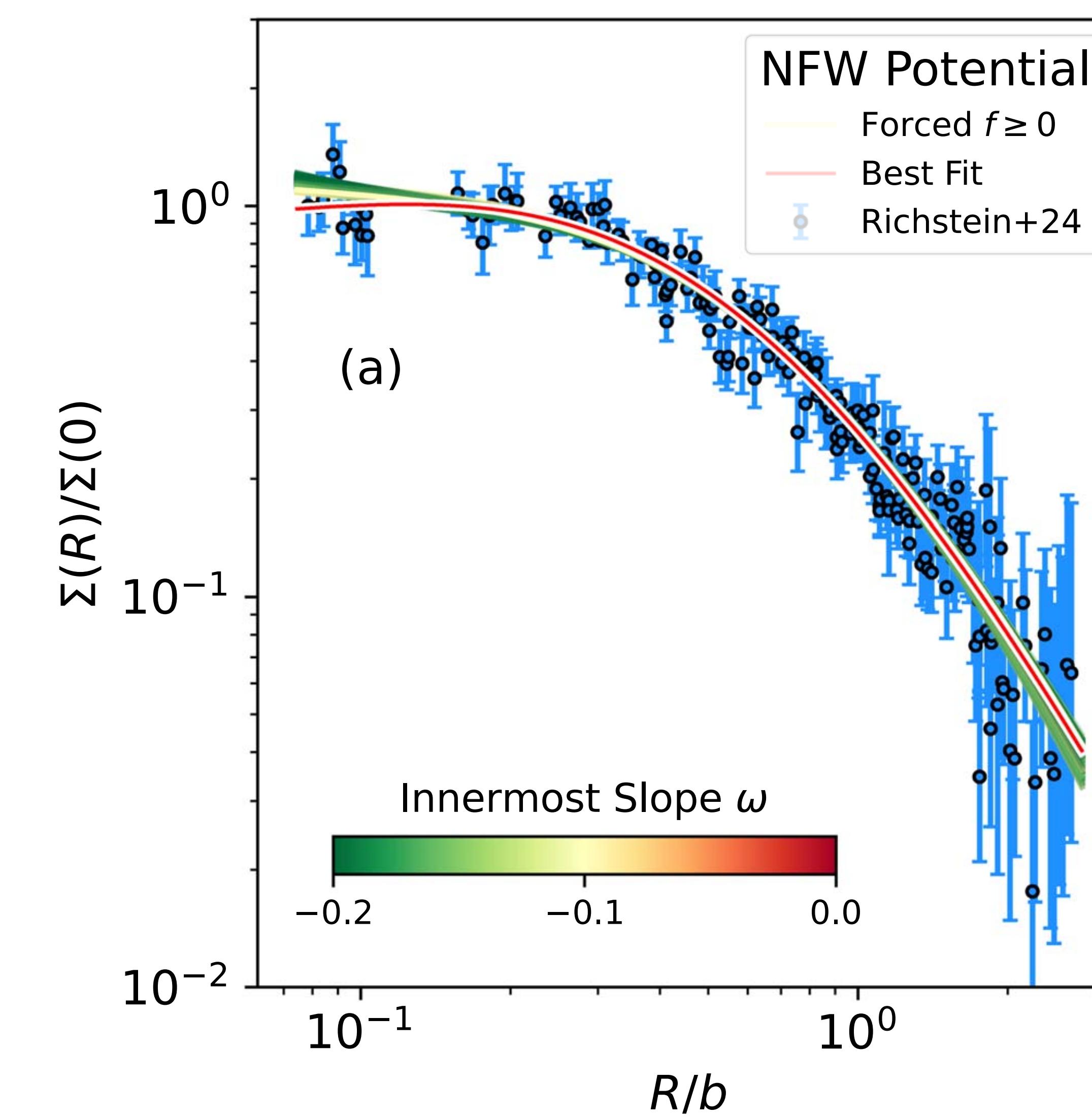
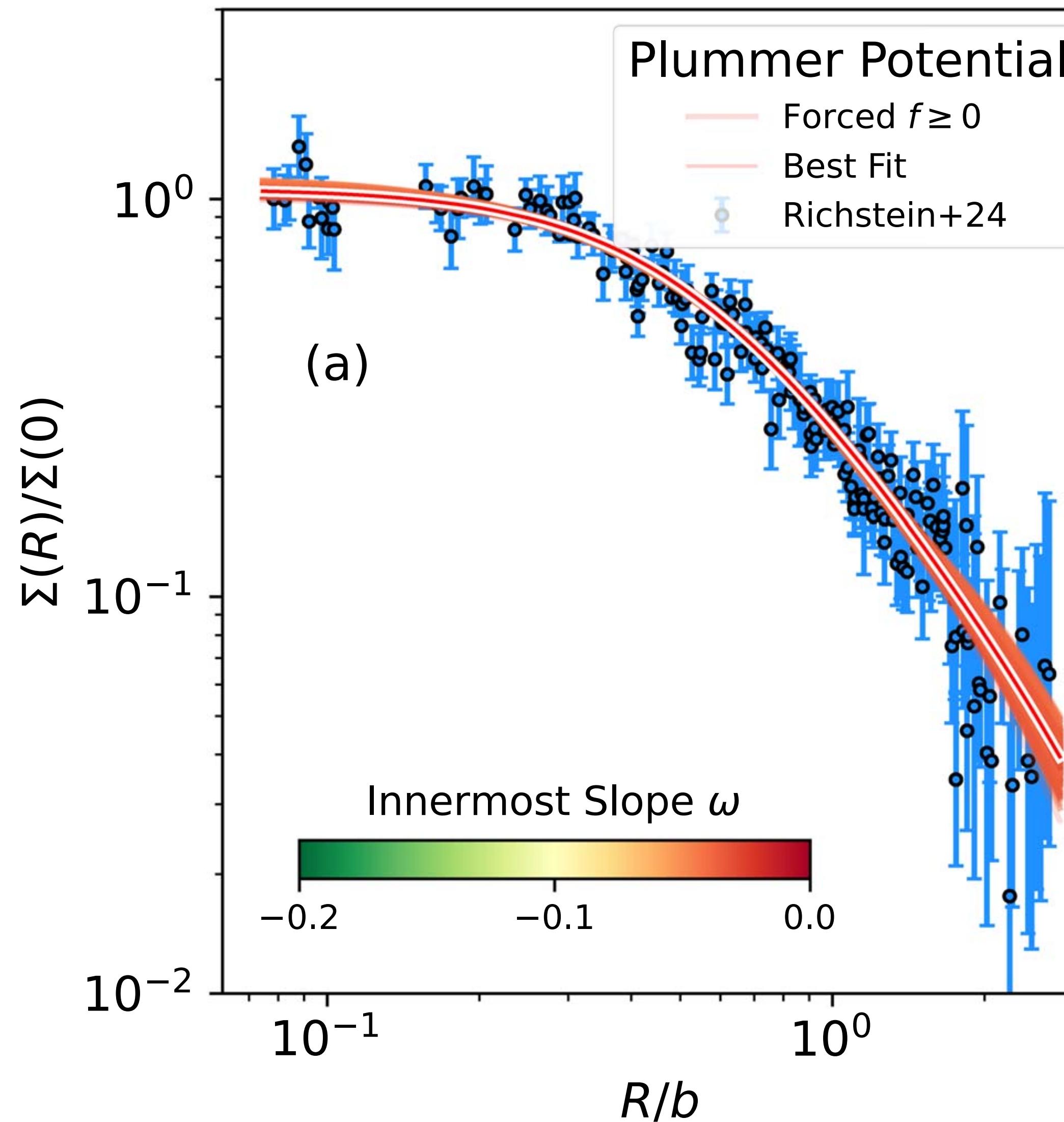
Sizes and Metallicities:



Pace et al. *in prep.*

Richstein et al. 2024

Stellar distributions of UFDs favor cores



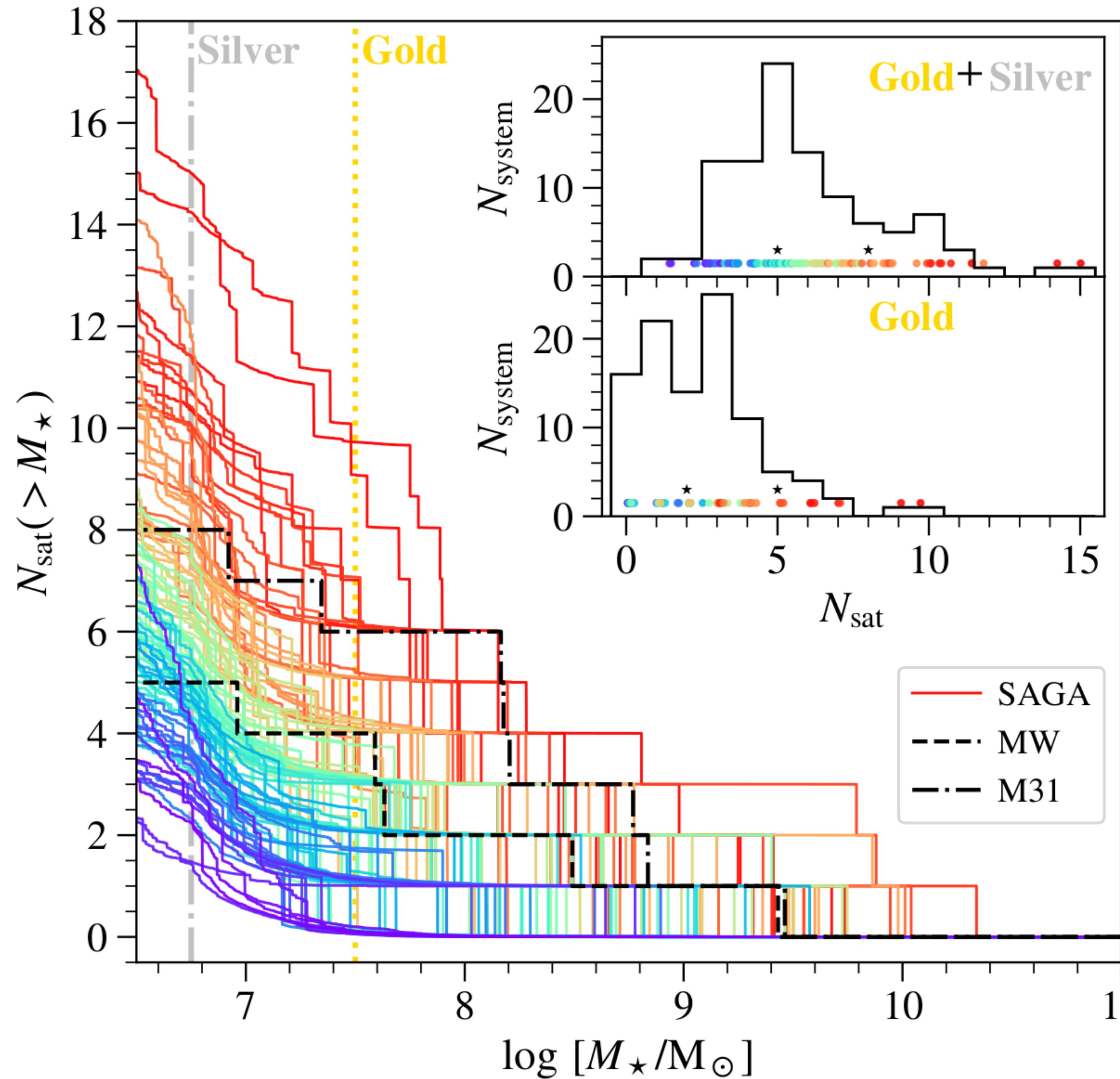
The Milky Way in Context

THE SAGA SURVEY

EXPLORING SATELLITES AROUND GALACTIC ANALOGS

DATA RELEASE 3

25 - 40.75 Mpc DR3: Yao et al. 2024; Geha et al. 2024; Wang et al. 2024

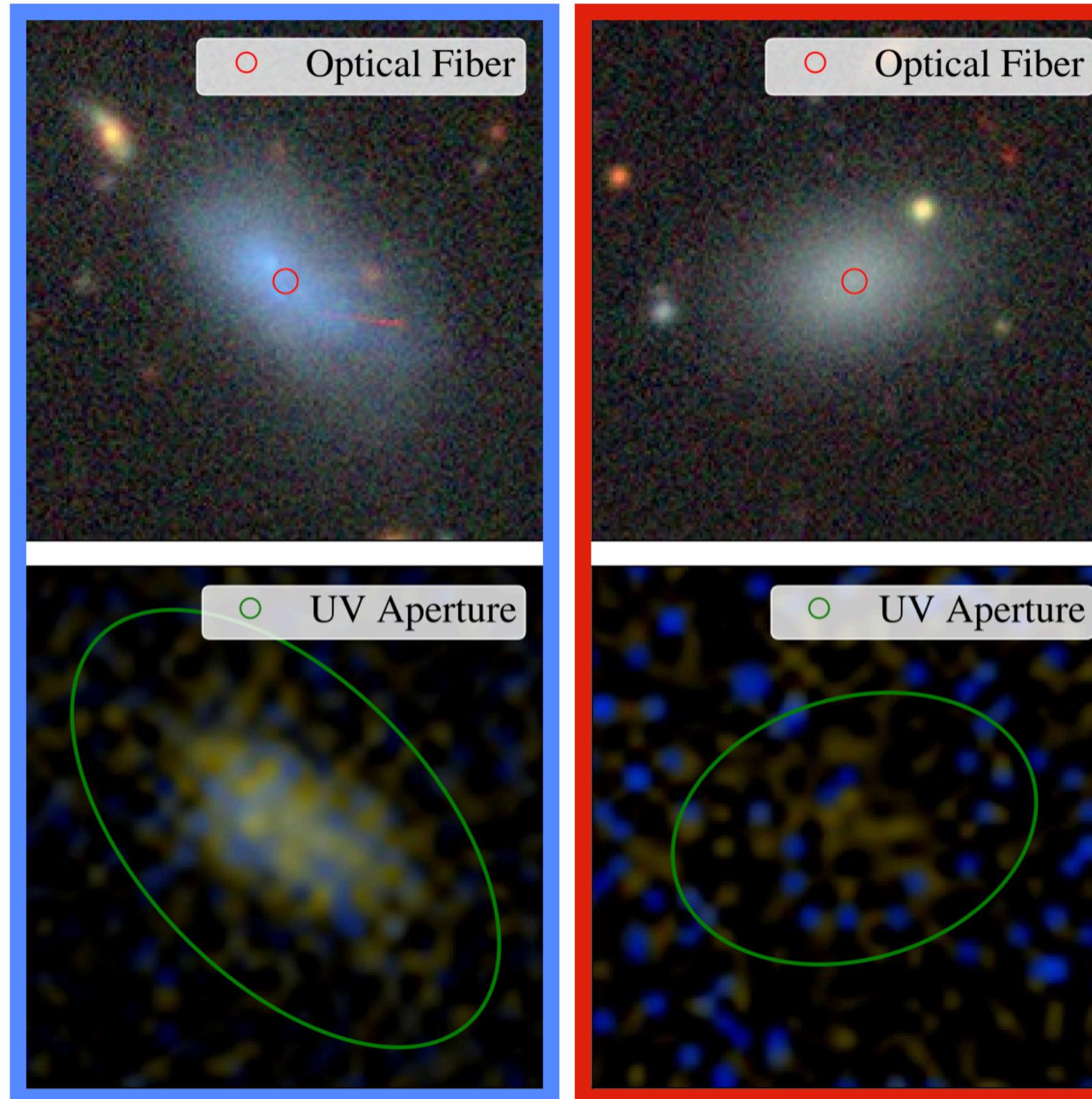


Satellite numbers

SAGA DR3 includes 378 satellites identified across 101 MW-mass systems. The number of confirmed satellites per system ranges from 0 to 13.

Star forming

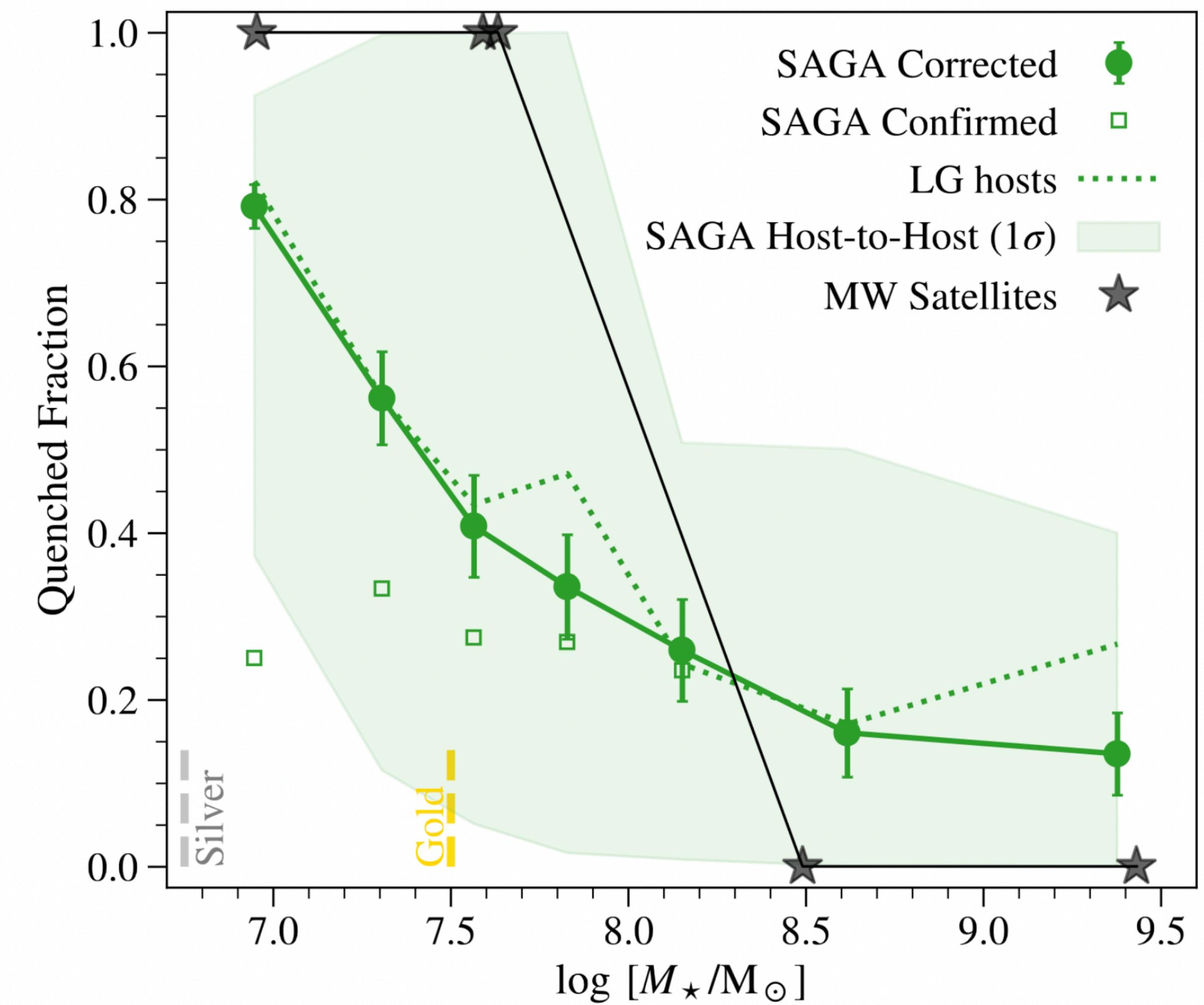
Quenched



Is it Quenched?

We define whether a given SAGA satellite is 'star-forming' or 'quenched' based on combined criteria in H-alpha and NUV-based star-formation rates.

Star forming properties of the satellites



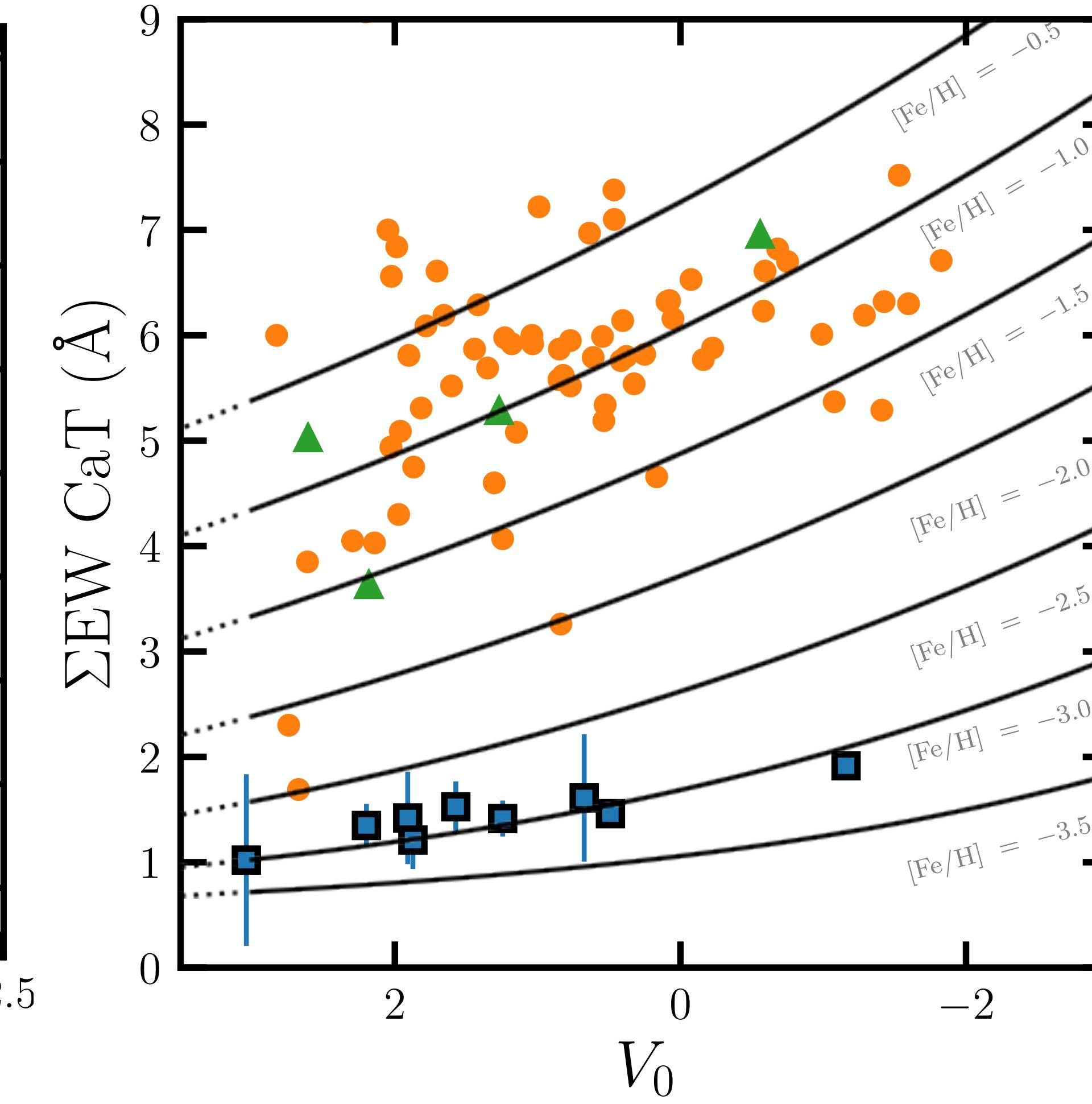
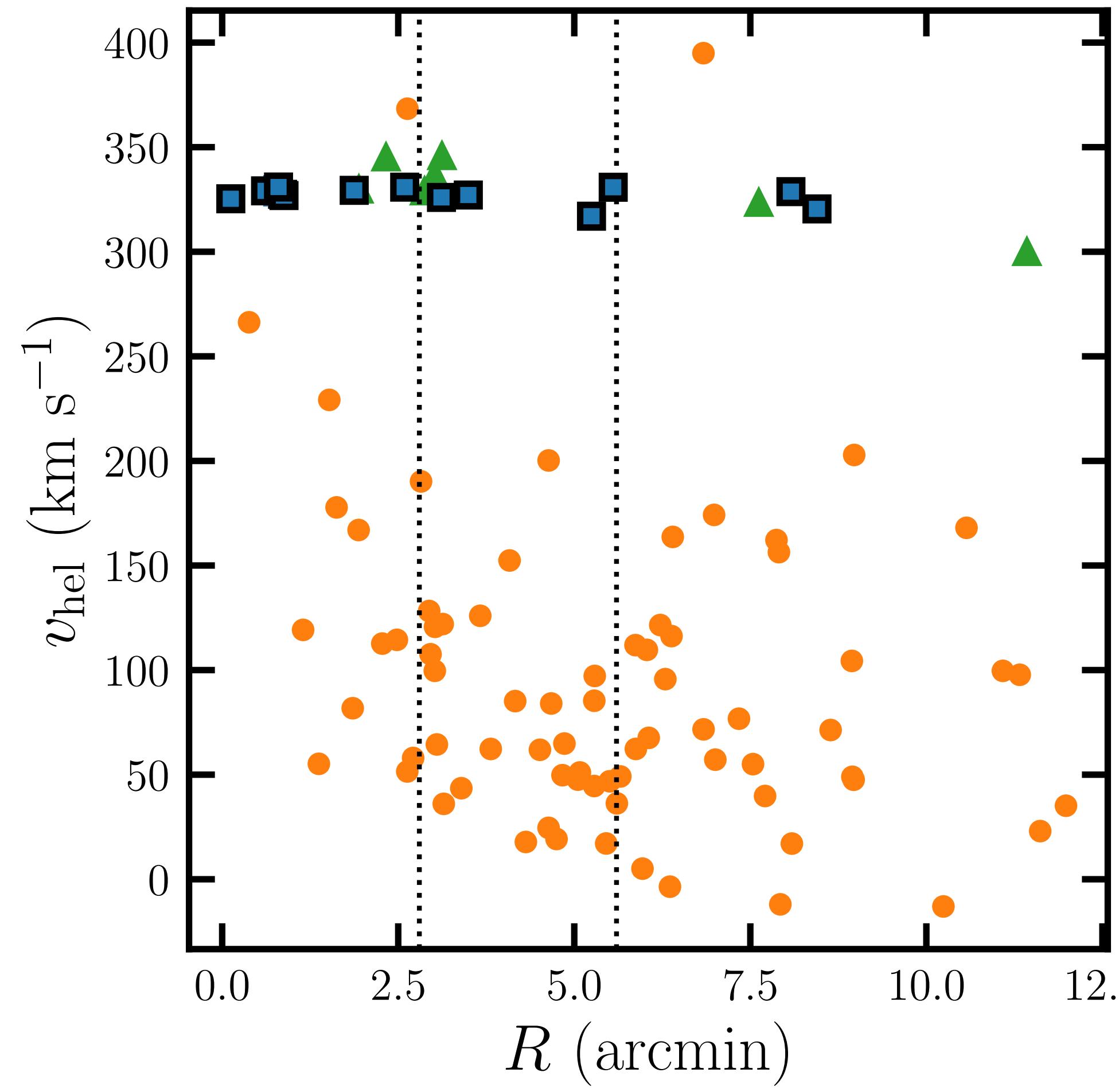
The Milky Way's quenched fraction is more extreme than SAGA

Take Aways

- The Universe is in fact self-similar.
- UFDs are promising probes of the epoch of reionization.
- UFDs are simple systems, with their baryonic processes basically complete by high redshift. Their sizes and metallicities are hard to replicate in simulations, but may hold the key to constraining dark matter.
- Further perhaps it's interesting for this community to think about modeling their stellar distributions.
- The MW and its satellite system are both typical and atypical in intriguing ways. The details of the MW's accretion history may hold clues to the explanation.

A new confirmed LMC satellite: Pictoris II

Discovered in the MagLiteS survey (PI: Bechtol) at only ~ 11 kpc from LMC (Drlica-Wagner et al. 2016).



A new confirmed LMC satellite: Pictoris II

