Local Group Cosmology: lessons from mapping the stellar populations of the nearby universe

Nitya Kallivayalil
University of Virginia

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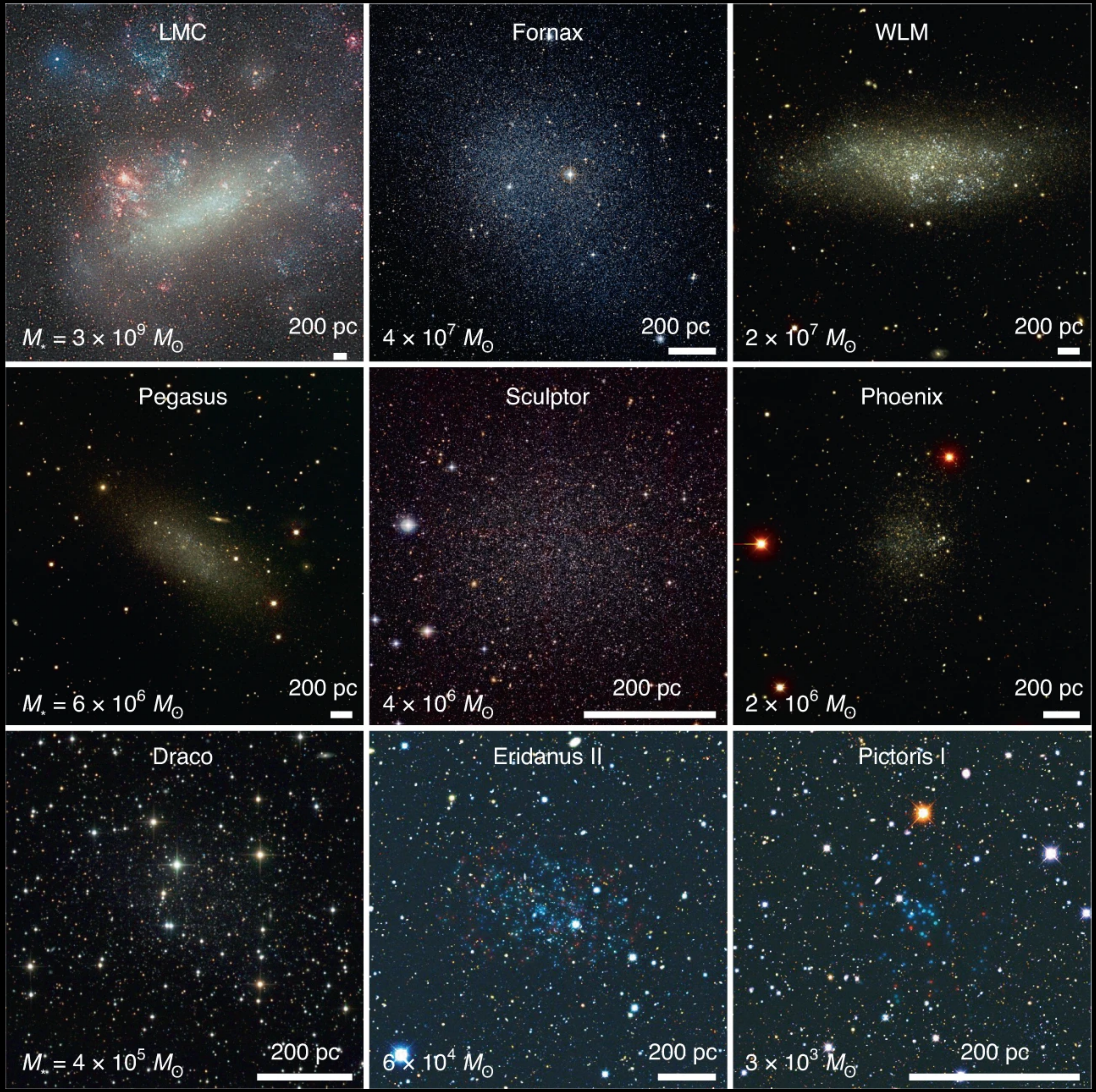
Understanding our Universe through low mass galaxies

- "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?

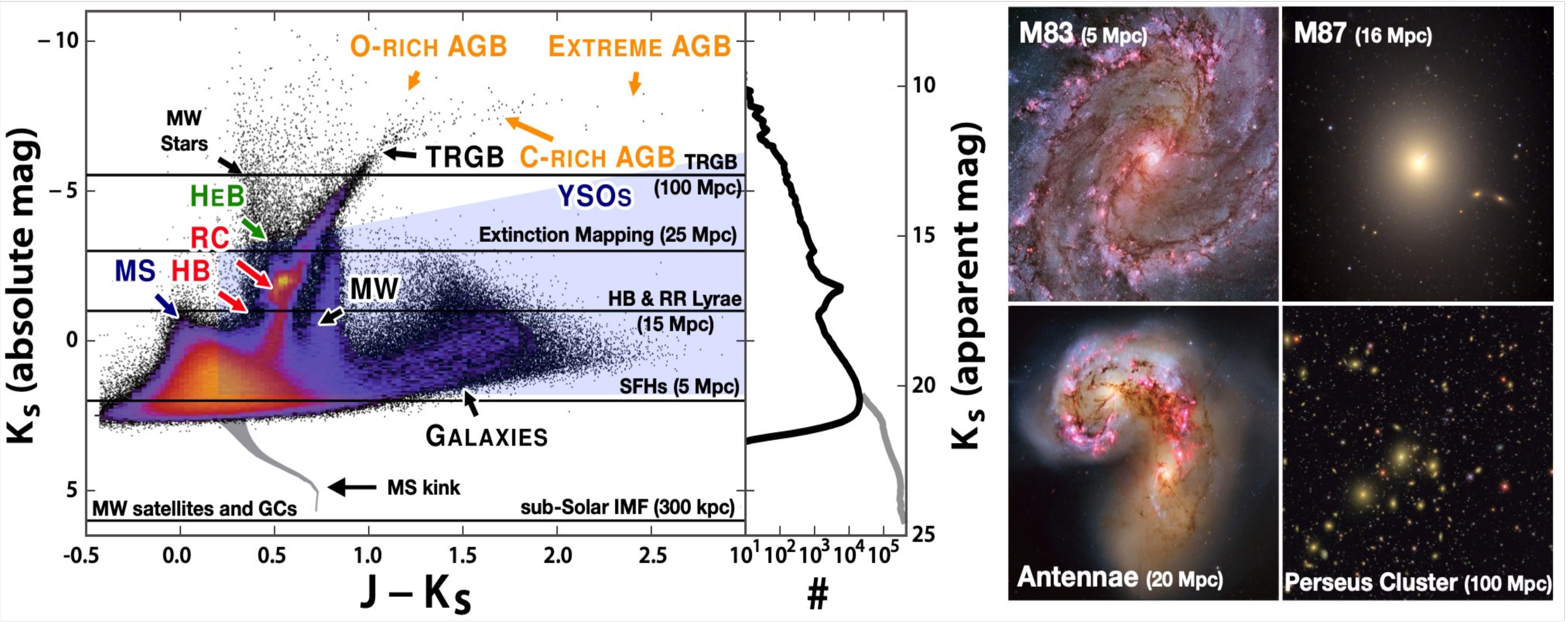


Crnojevic & Mutlu-Pakdil 2021

JWST Resolved Stellar Populations ERS Program

PI: Dan Weisz, co-leads: Boyer, Correnti, Geha, Kallivayalil, McQuinn, Sandstrom

JWST resolves individual stars at larger distances, to fainter luminosities, in more crowded areas, and in regions of higher extinction:



Cioni et al. 2011

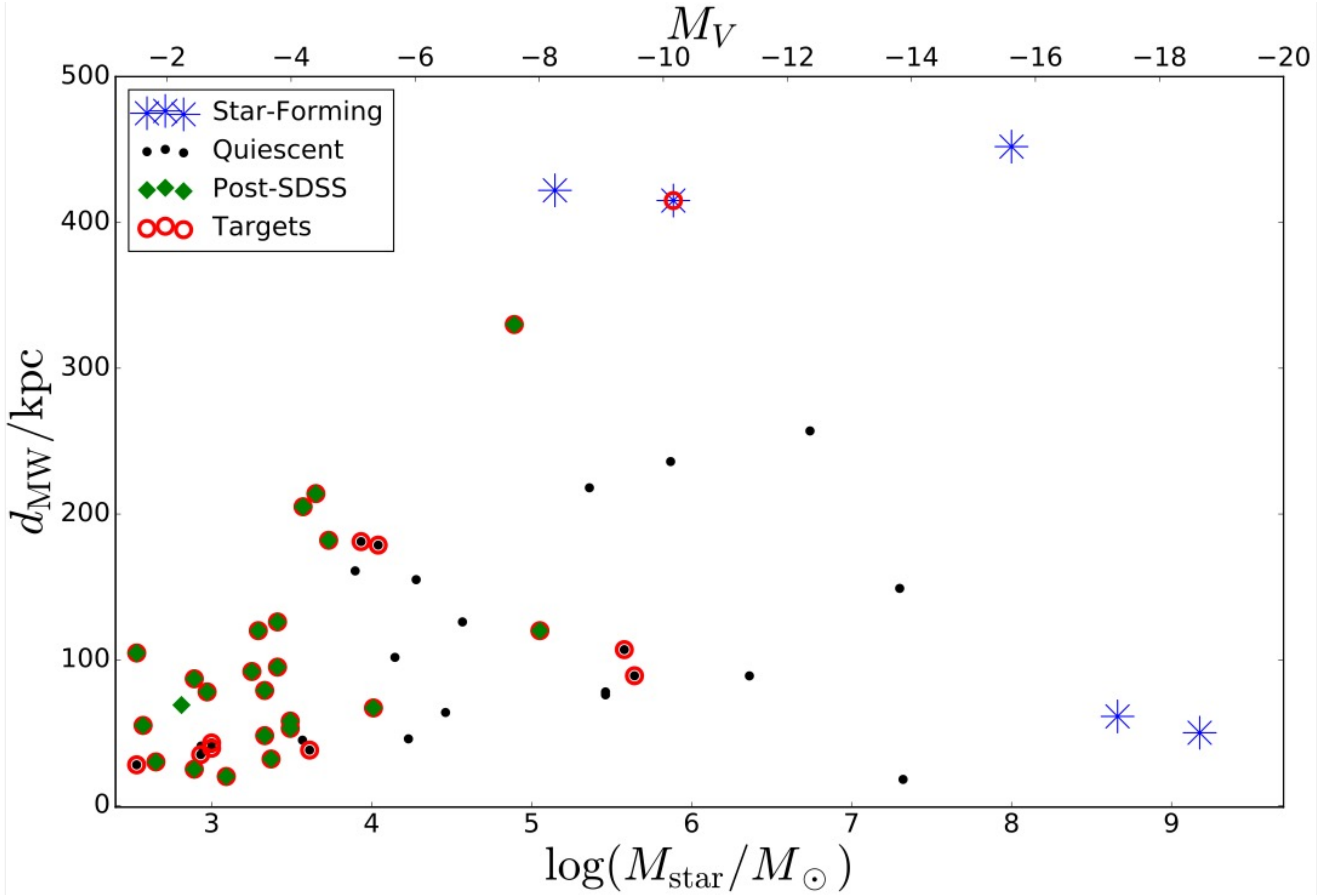
Two HST Treasury Programs

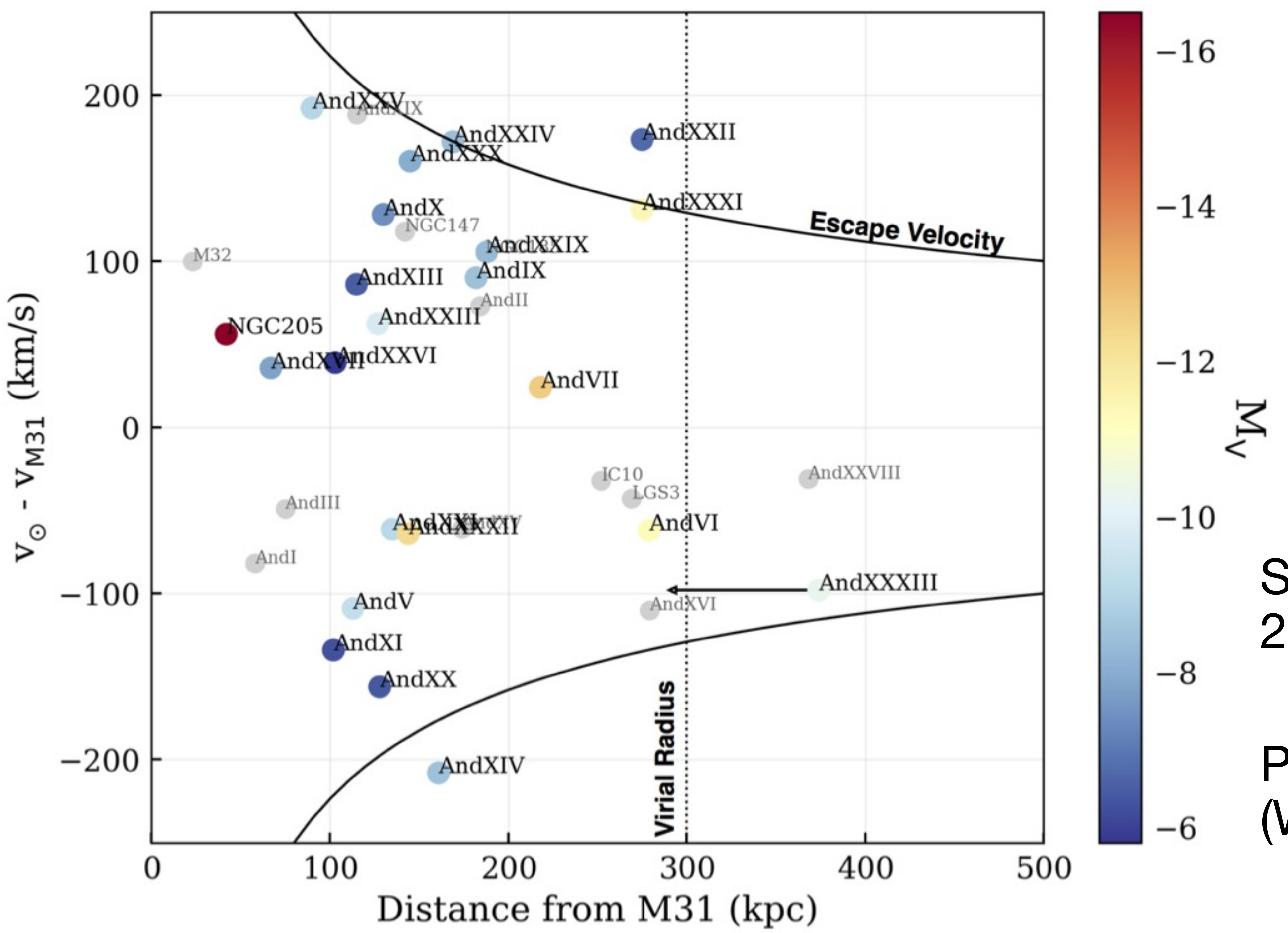
Milky Way: 30 dwarf galaxy targets
164 orbits

M31: 23 dwarf galaxy targets
244 orbits

Co-PIs: Nitya Kallivayalil & Andrew Wetzel

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





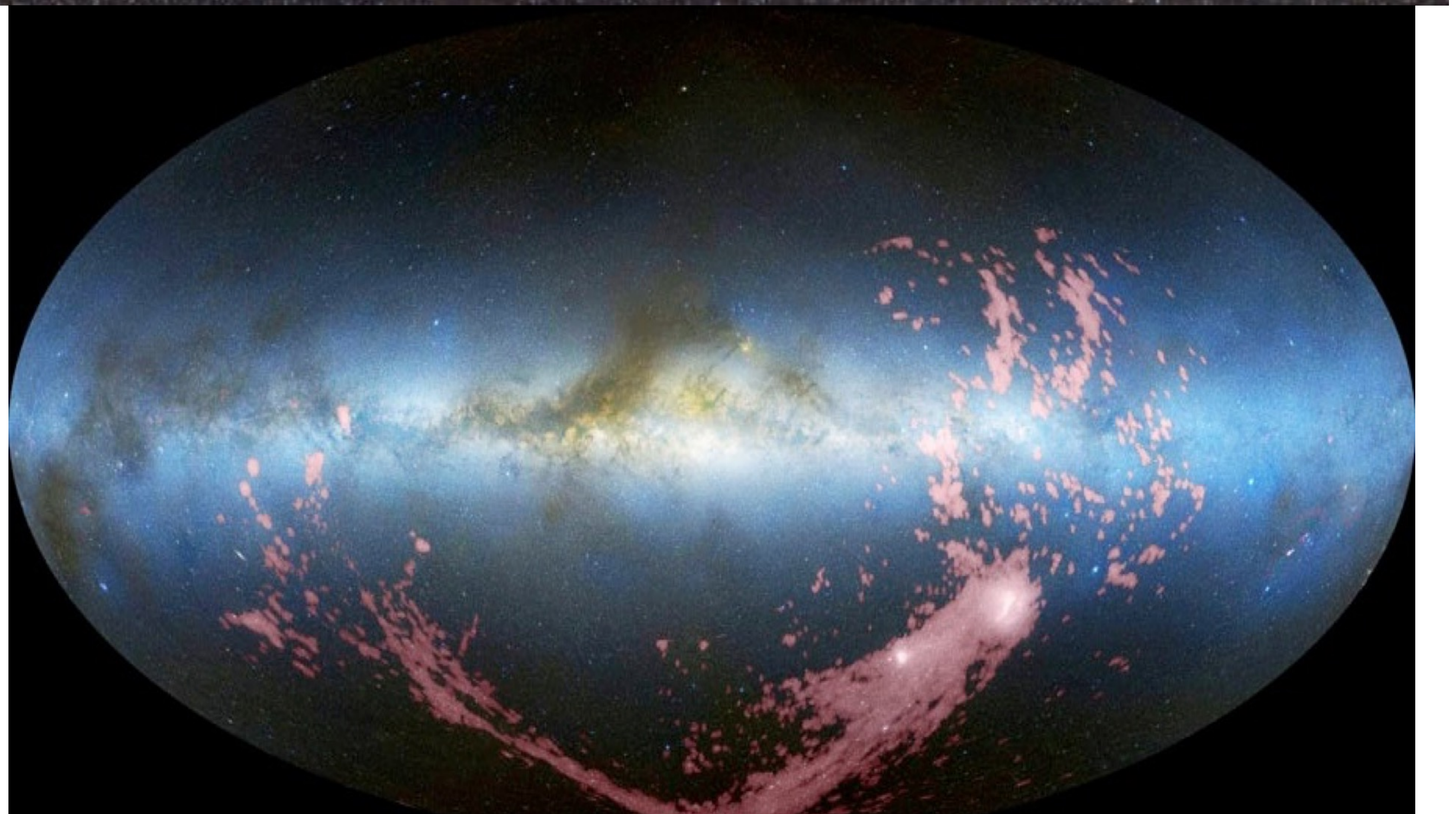
SFHs: Savino et al. 2023; 2024

Proper motions: HubPUG (Warfield et al. 2023)

A bit of history…

- NK et al. (2006) measured PMs of LMC/SMC from HST measurements with a 2-year baseline.
- Besla, NK et al. (2007) suggested that LMC is on first infall.
- This picture seems to be holding up (NK et al. 2013) and with Gaia: Helmi et al. 2018, Luri et al. 2021, Jimenez-Arranz et al. 2023, Vasiliev 2024


Photo Credit: Andrew Lockwood



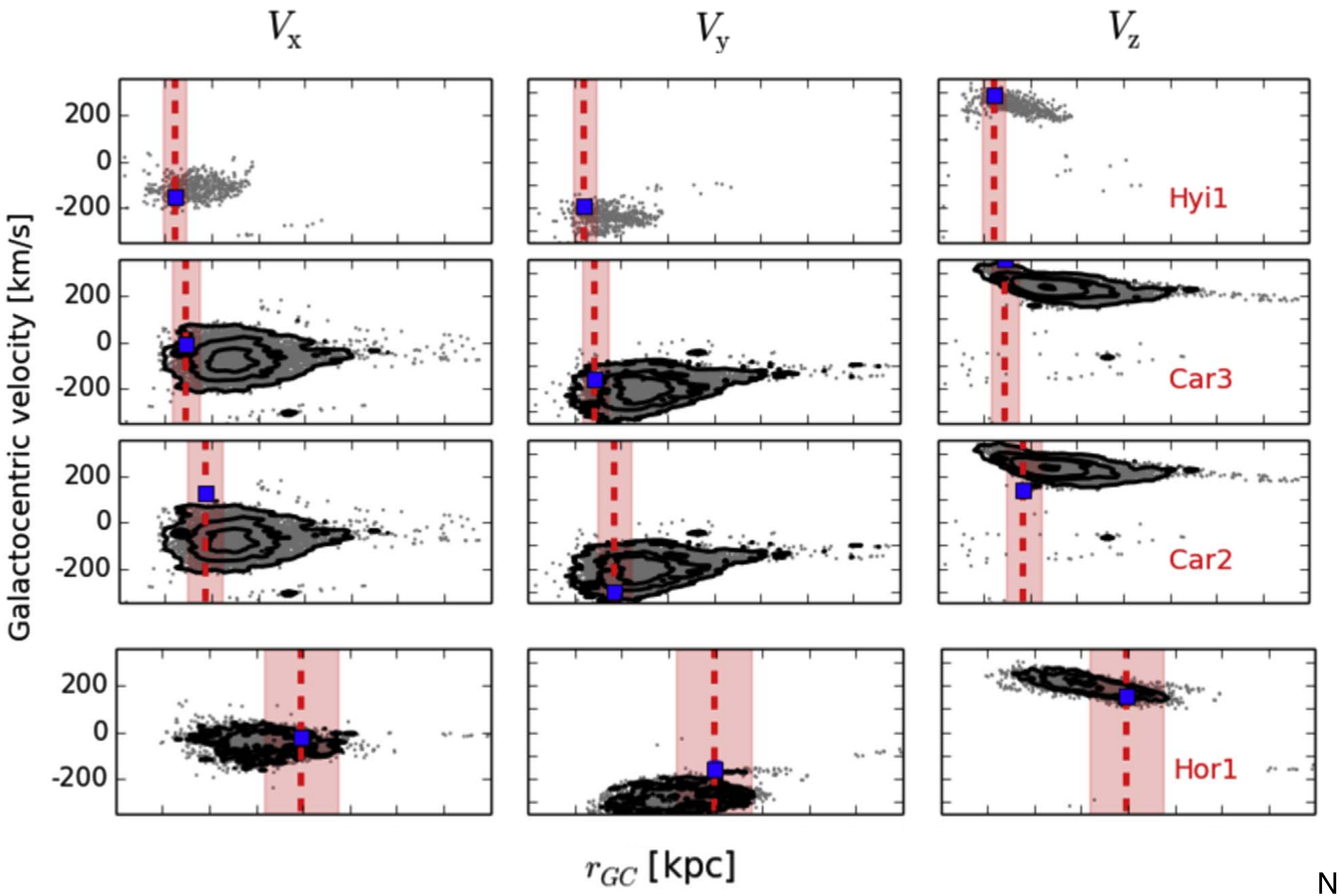
Satellites of satellites

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

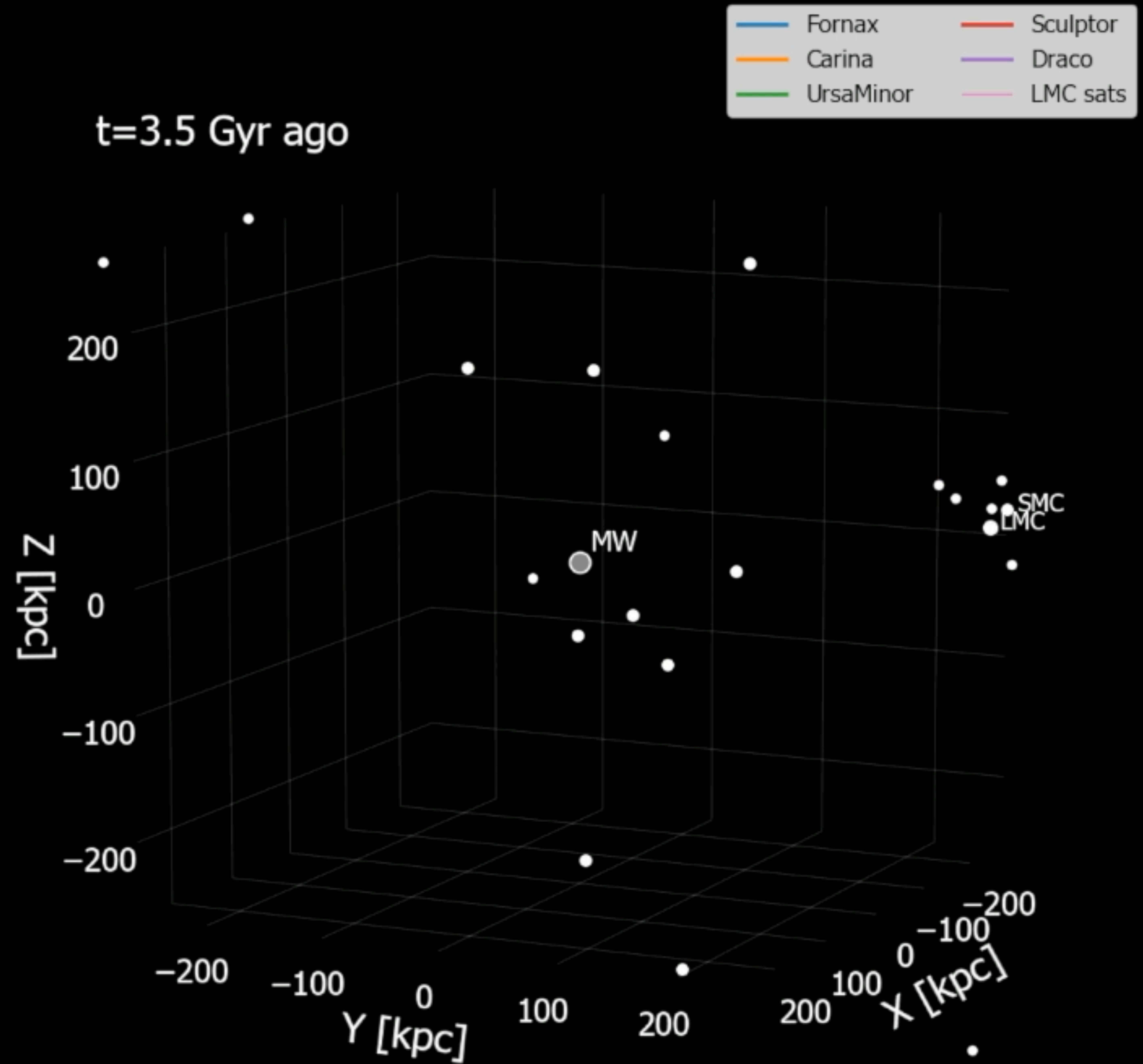
see also Jethwa et al. 2016, Sales et al. 2017, Erkal & Belokurov 2019, Battaglia et al. 2022, Correa Magnus & Vasiliev 2022; Vasiliev 2024

The Infalling LMC system
Com
CVenI
LeoII
Boo
UMajI
LeoV
LeoI
Vir1
UMin
UMajII
Sex
Dra2
Cra2
Dra
Her
HyII
Sag
Seg3
Tri2
Car
LMC
Lae3
Col1
Peg3
SMC
Ind2
Sag2
PiscII
Seg2
Gru2
Aqu2
For
Cet3
Cet2
Scl
M. Stream
50
100
150
200
250
300
350
400
450
r_{GC} $[kpc]$
NK, Sales et al. 2018

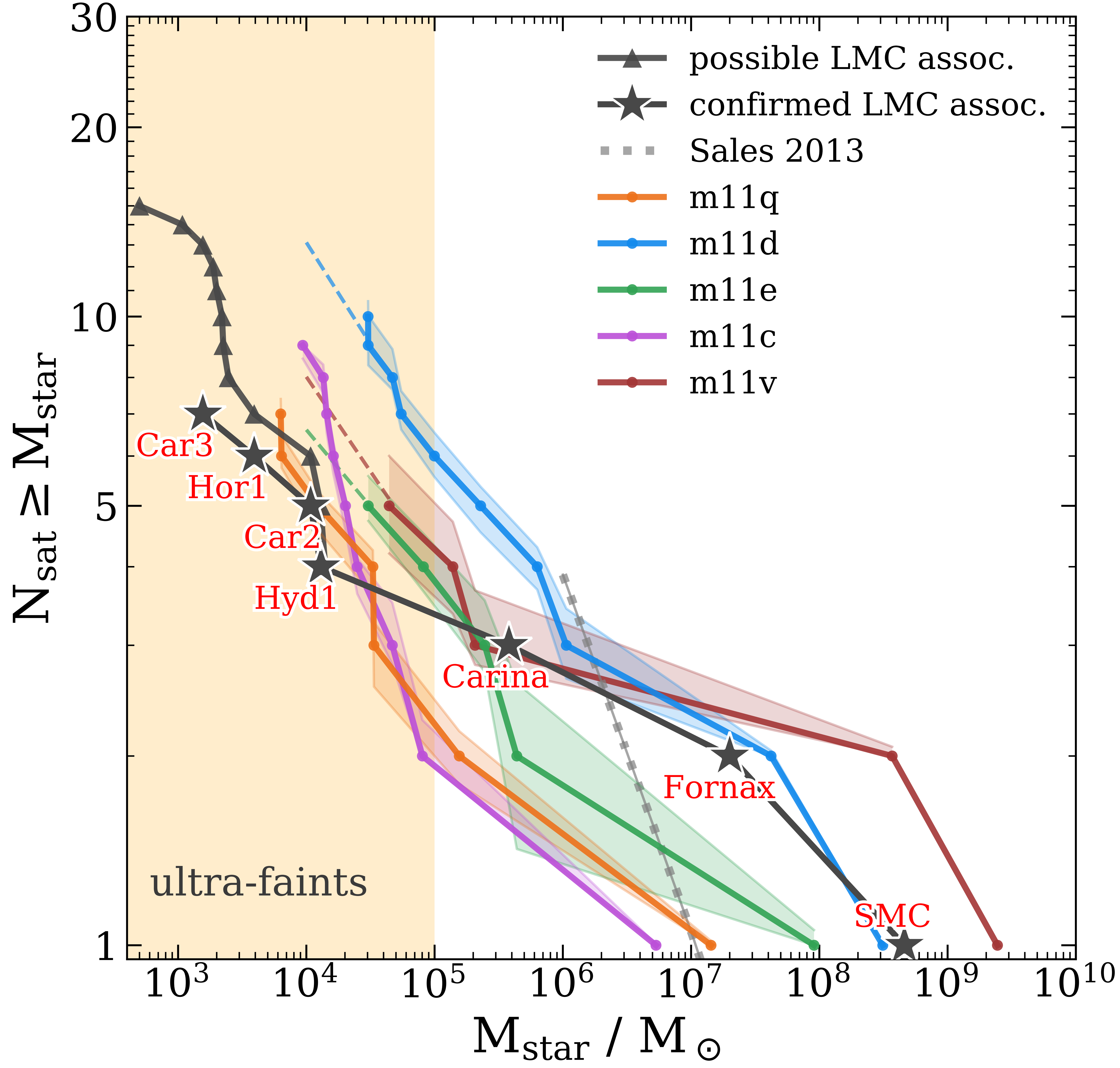
Velocities and Distances



NK, Sales et al. 2018



Patel et al. 2020



Consistent with LCDM?

Where are the classical dSphs associated with LMC infall?

Pardy et al 2019 make a case for Carina and Fornax

Vasiliev 2024 makes a case if LMC is on second infall

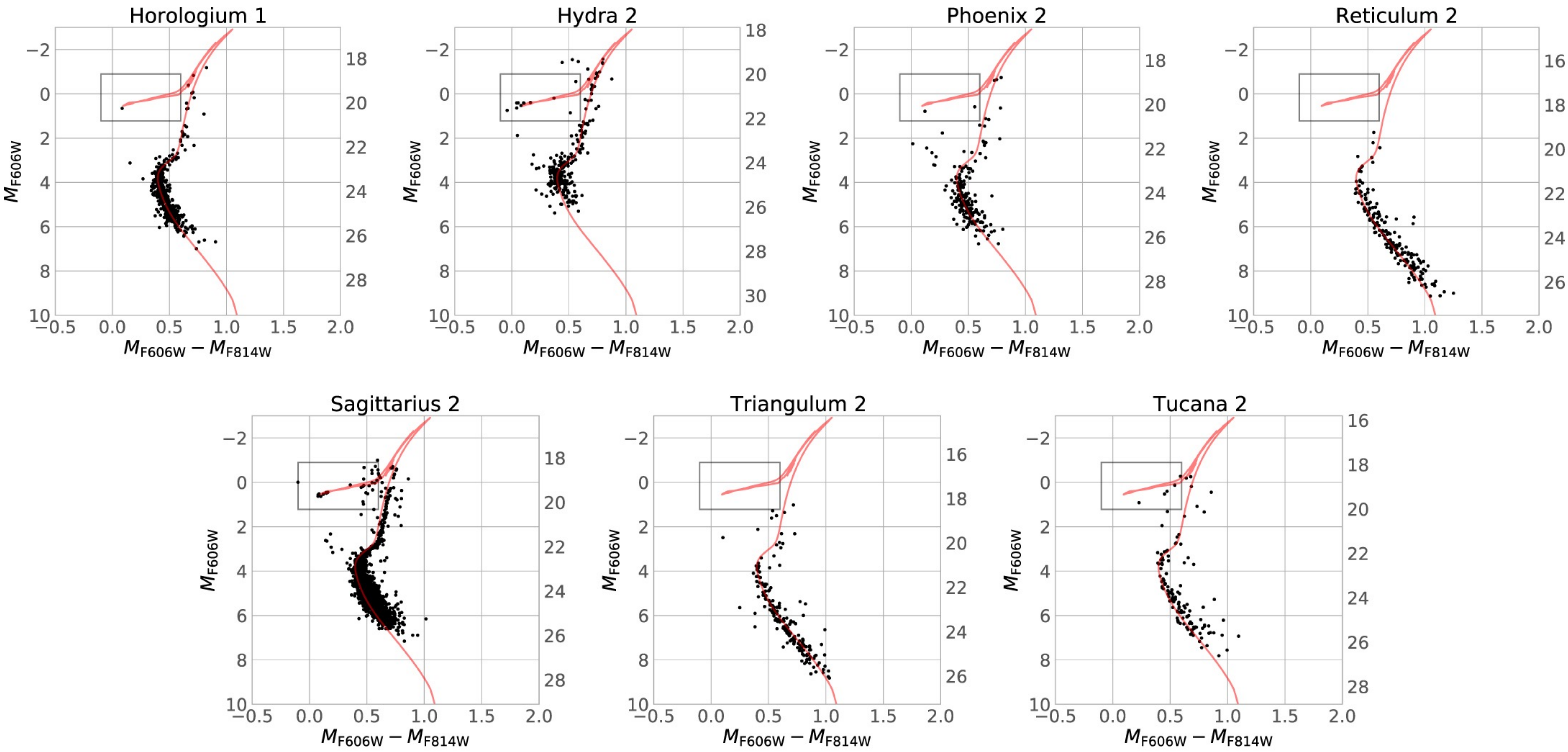
Jahn et al. 2019
See also Sales et al. 2013; Dooley et al. 2017; Munshi et al. 2019

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

Star Formation Histories

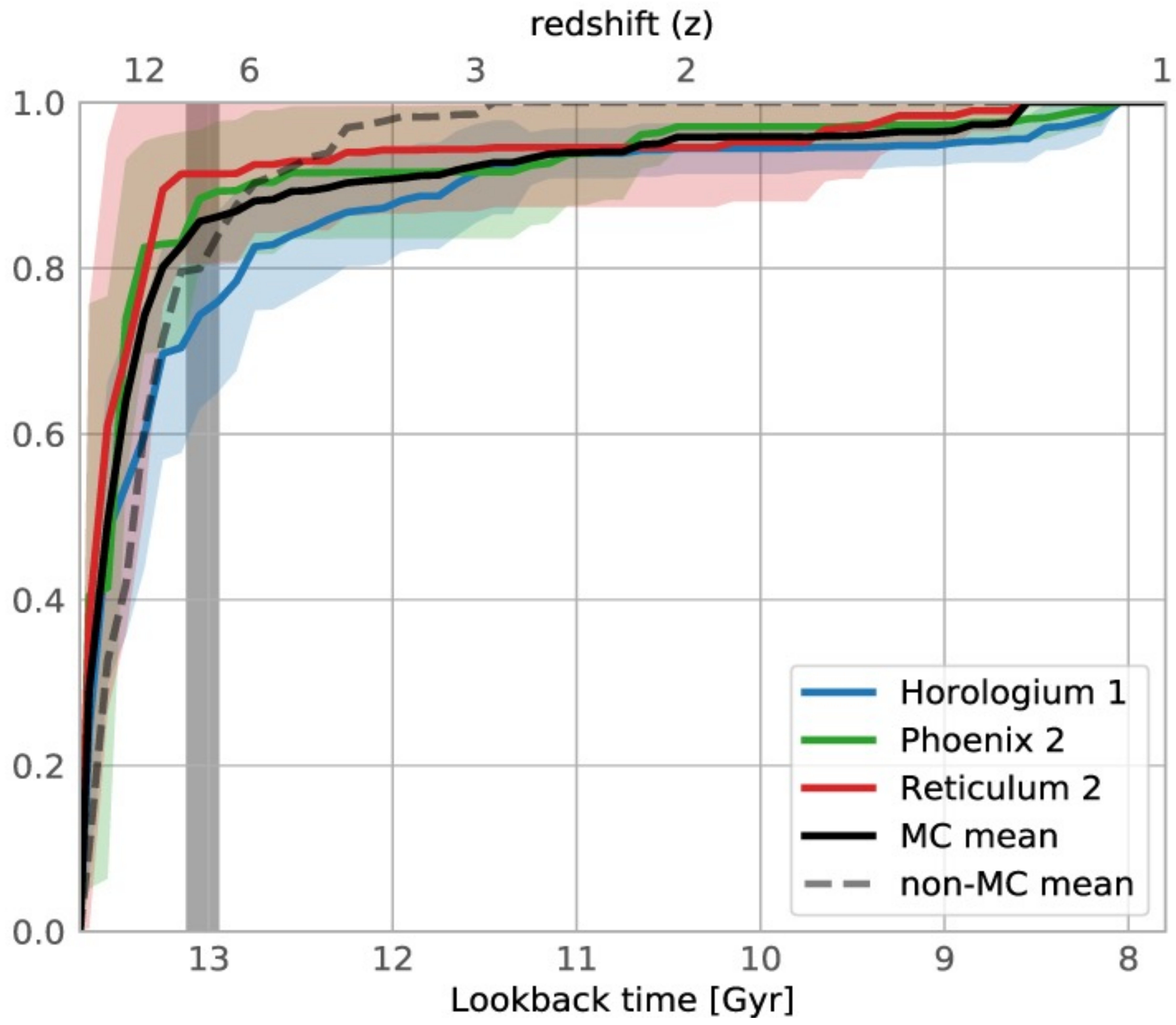
Satellites in groups versus not

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

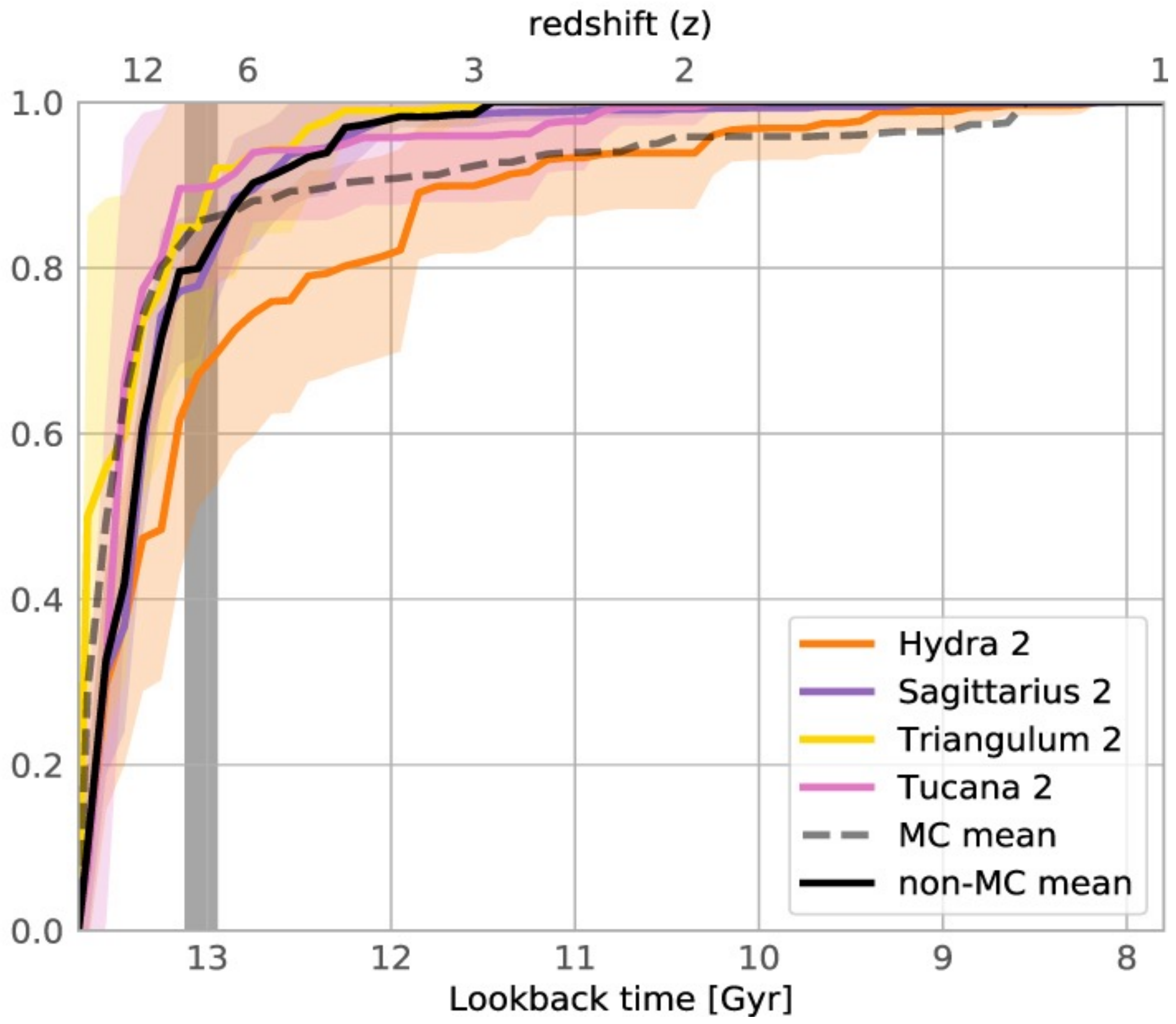


Sacchi, Richstein, Kallivayalil et al. 2021, ApJL

MC Satellites

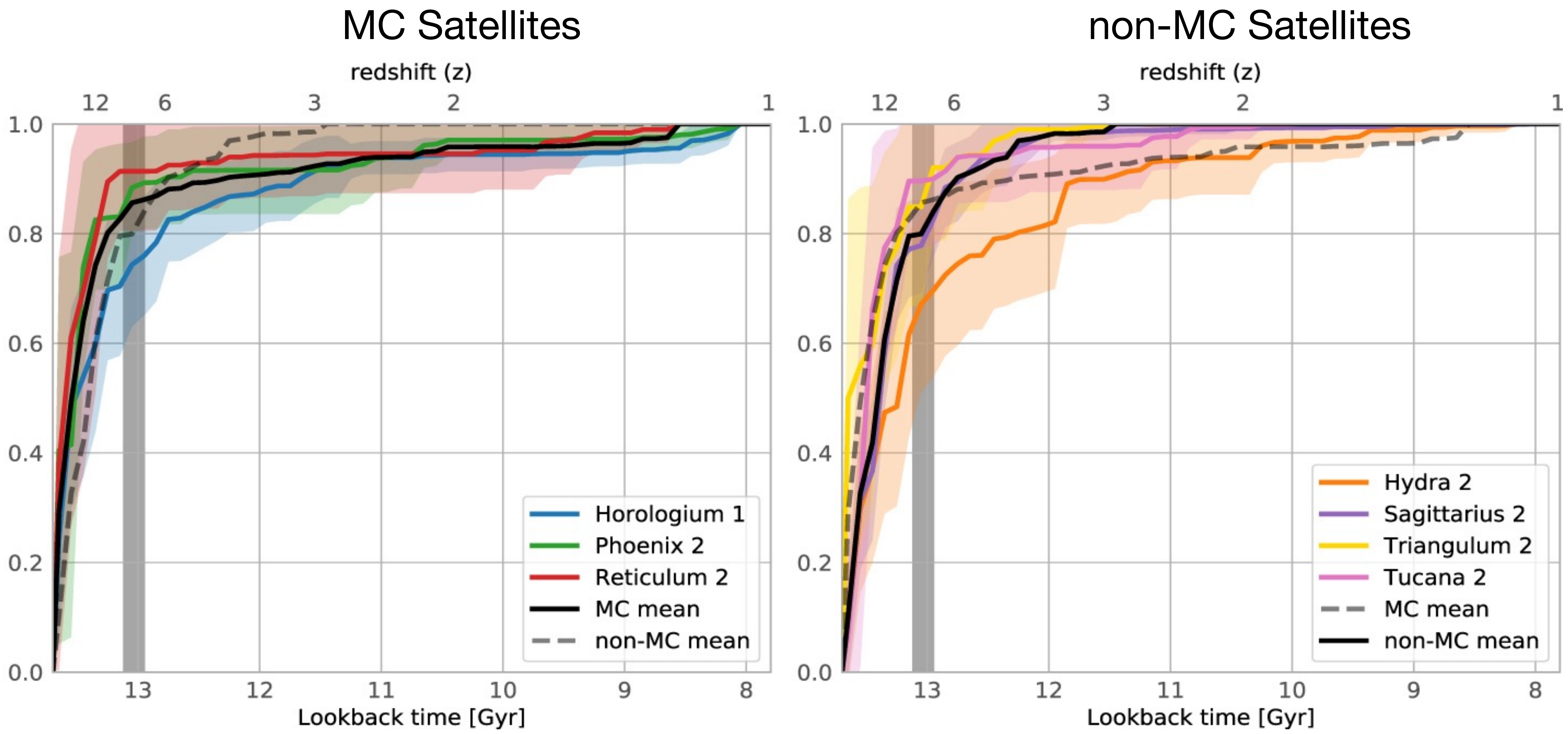


non-MC Satellites



Sacchi, Richstein, Kallivayalil et al. 2021, ApJL

Brown et al. 2014; Weisz et al. 2014



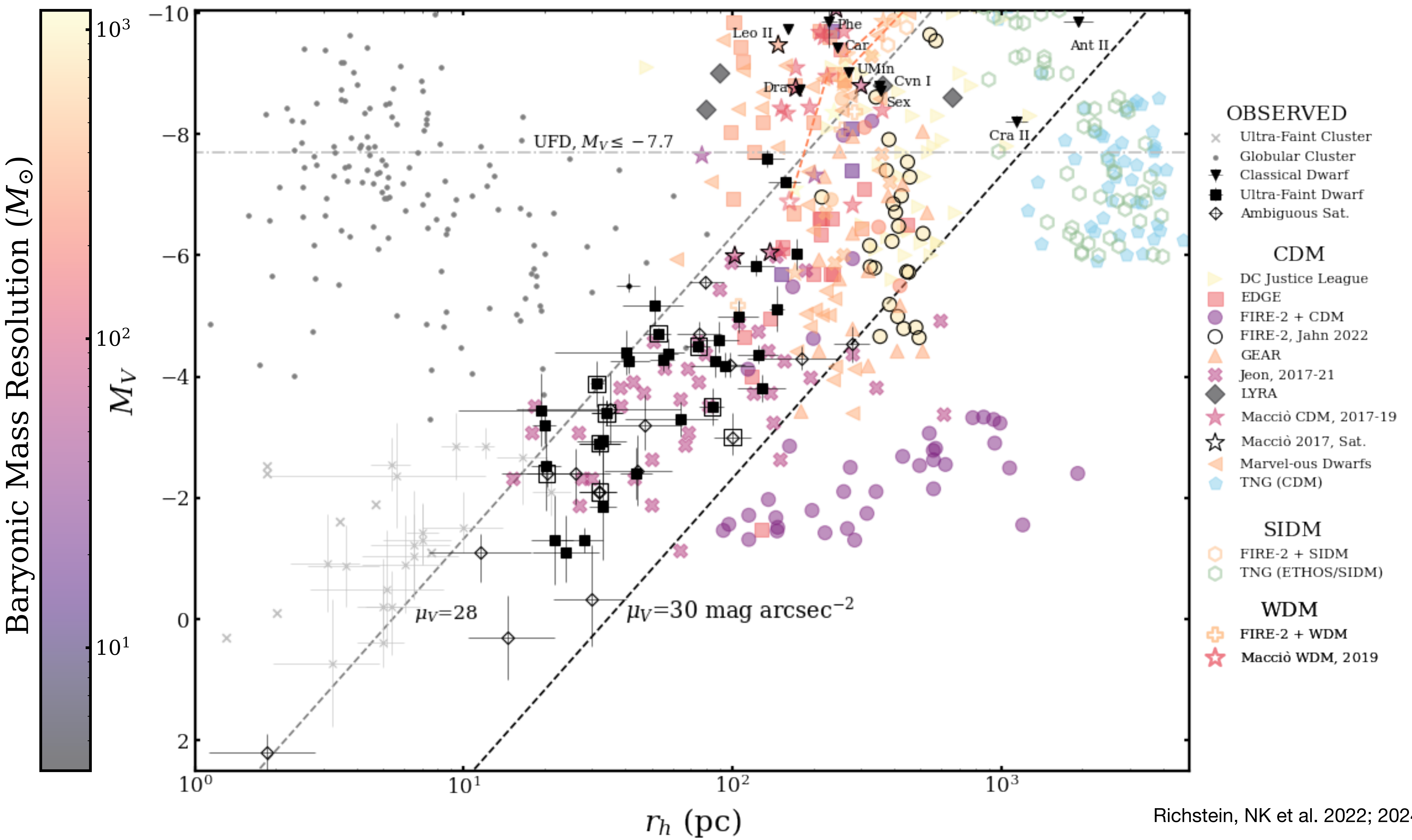
This may arise from "patchy" reionization that varied with individual environments of ultra-faints at the time, such as their proximity to their host galaxy and its intensity of UV photon emission (Kim et al. 2023; see also Aubert et al. 2018; Sorce et al. 2022)

Sacchi, Richstein, Kallivayalil et al. 2021, ApJL

Structural analysis and comparison to simulations

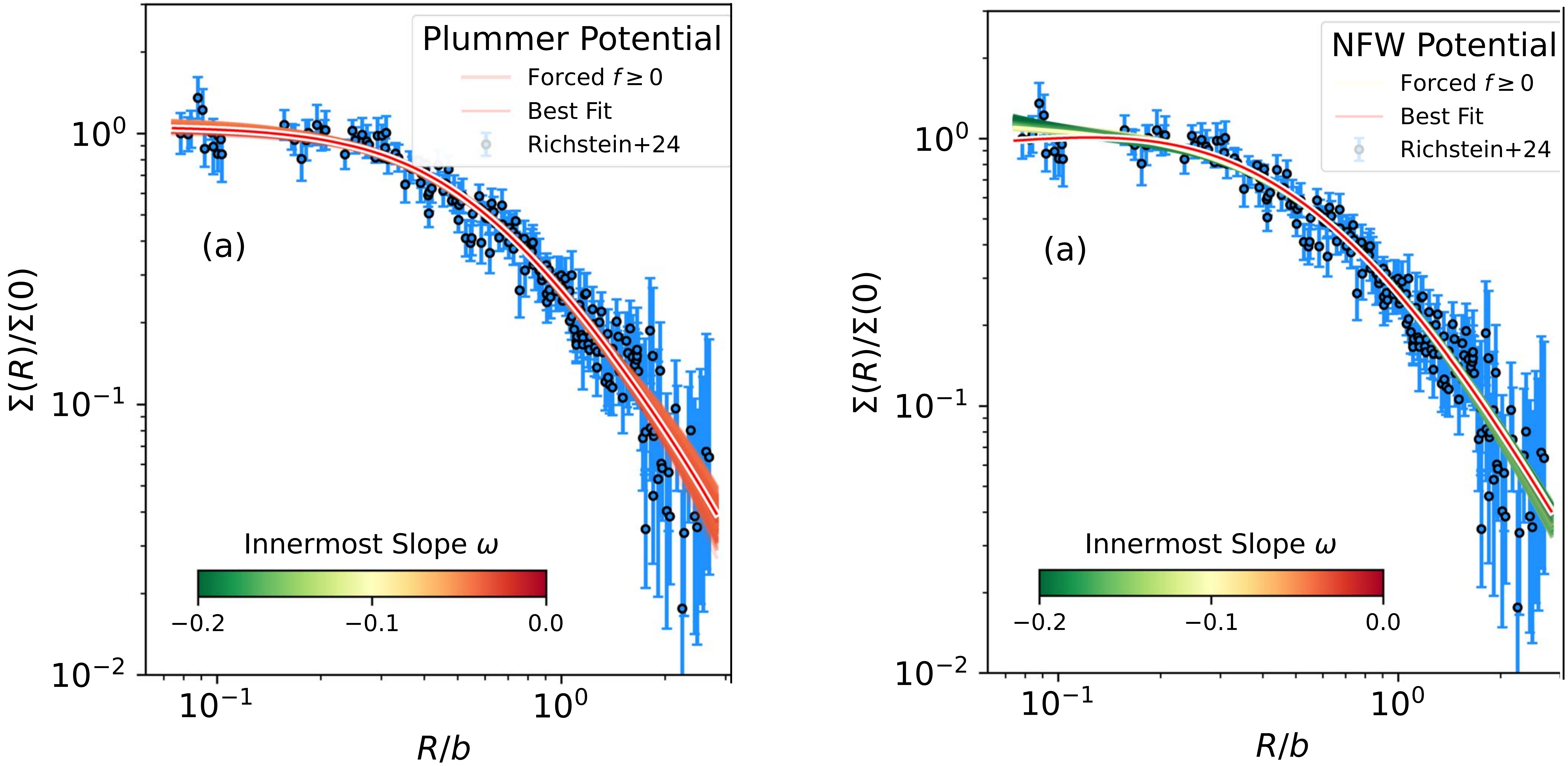
Satellite size

Richstein, H; Kallivayalil, N et al. 2024



Richstein, NK et al. 2022; 2024

Stellar distributions of UFDs favor cores



Sánchez Almeida et al. 2024

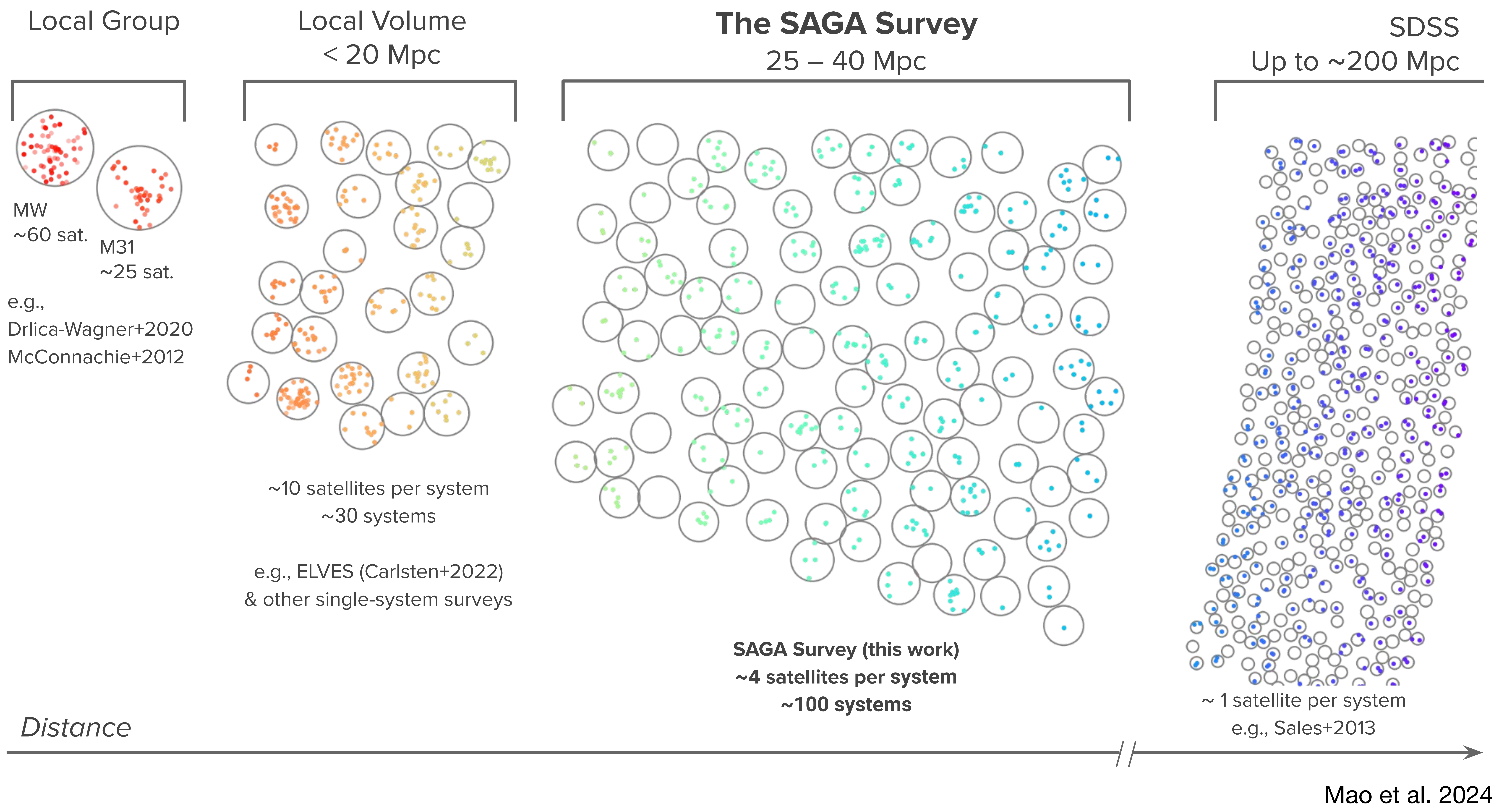
The Milky Way in Context

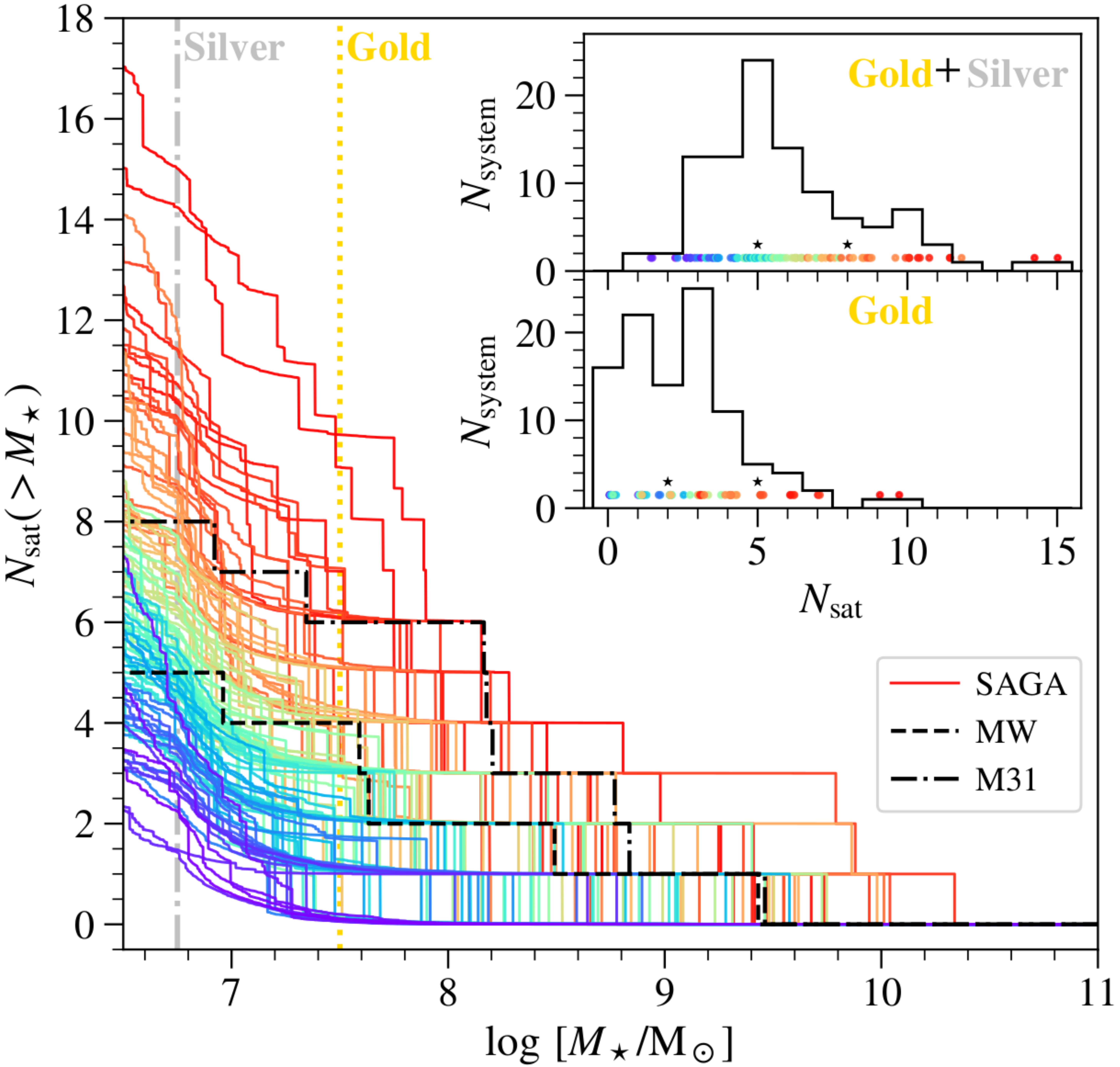
THE SAGA SURVEY

EXPLORING SATELLITES AROUND GALACTIC ANALOGS

DATA RELEASE 3

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


Local Group
Local Volume
< 20 Mpc
The SAGA Survey
25 – 40 Mpc
SDSS
Up to ~200 Mpc
MW
~60 sat.
M31
~25 sat.
e.g.,
Drlica-Wagner+2020
McConnachie+2012
~10 satellites per system
~30 systems
e.g., ELVES (Carlsten+2022)
& other single-system surveys
SAGA Survey (this work)
~4 satellites per system
~100 systems
~ 1 satellite per system
e.g., Sales+2013
Distance
Mao et al. 2024

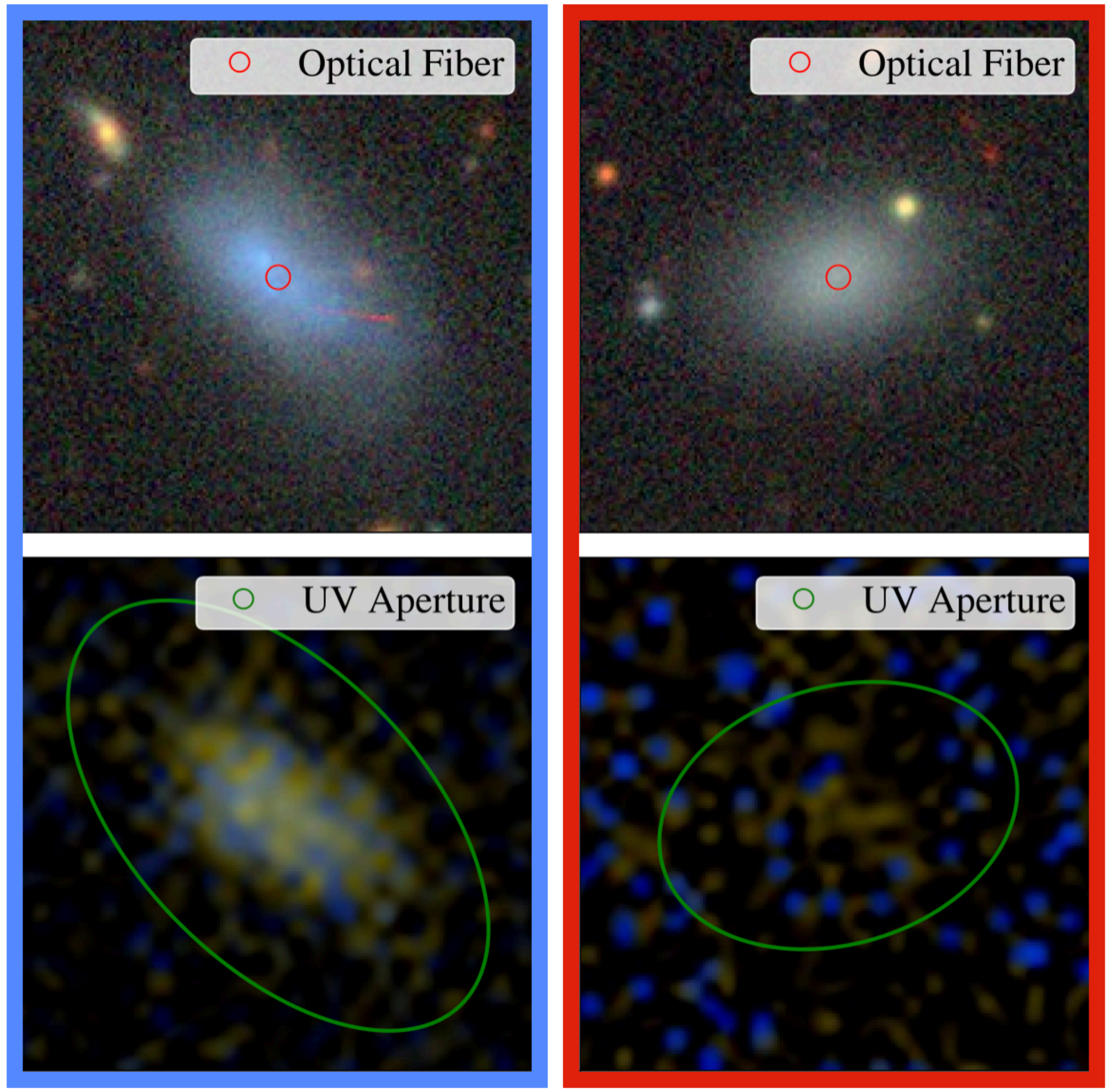


Satellite numbers

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

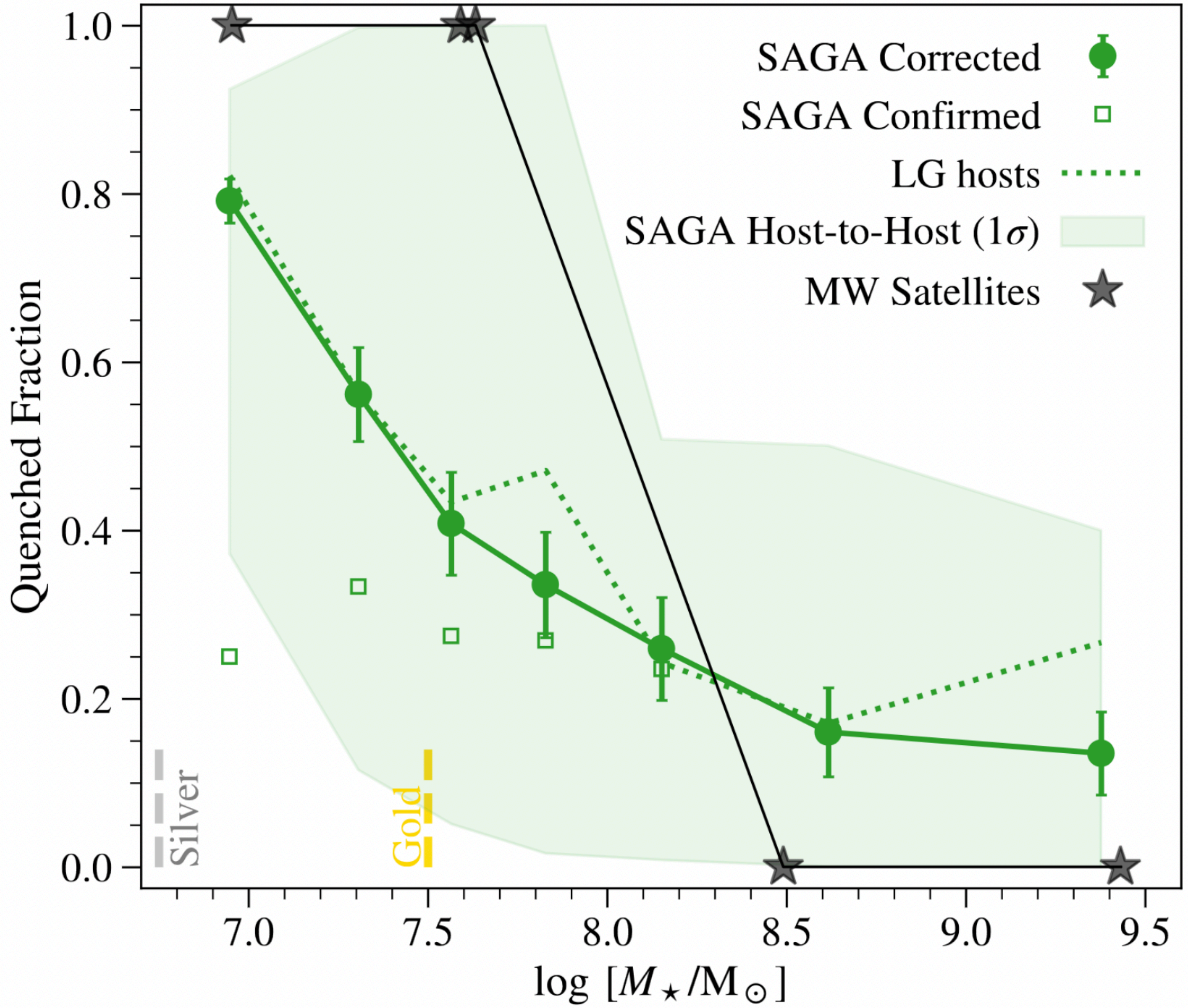
Mao et al. 2024

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

Geha et al. 2024

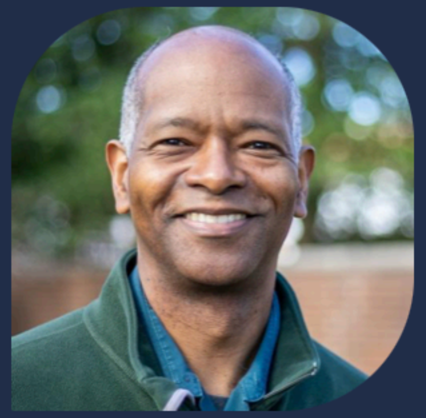
Takeaways

- The universe is in fact self-similar.
- Ultra-faint galaxies: promising to test dark matter models, but we need to understand the baryonic physics.
- UFDs promising probes of epoch of reionization and stellar feedback.
- The Milky Way and its satellite system are both typical and atypical in intriguing ways. The details of the MW’s merger history may hold clues to the explanation.

GECO FACULTY

Nitya Kallivayalil
Professor, Dean's Research Fellow, GECO management committee
Near-field Cosmology, Resolved Stellar Populations, Local Group Dynamics

Paul Torrey
Assistant Professor, GECO Management Committee
Extragalactic Astrophysics; Computational Galaxy Formation



Aaron Evans
Hamilton Professor, GECO management committee
Hamilton Professor Extragalactic Astronomy, Starbursts and Active Galactic Nuclei

Shane Davis
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CMB studies, ISM studies, Dark Matter searches

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Visiting Professor
Large-Scale Structure, cosmological simulations, evolution of galaxies

Steve Majewski
Chair, Professor
Galaxy evolution, stellar populations and companions, observational astronomy, instrumentation
http://faculty.virginia.edu/srm4n/index.php

Maryam Modjaz
Professor
SNe and GRB host galaxy studies: metallicity, SFR, chemical evolution and SNe rates

Jonathan Tan
VITA, Research Professor
Pop III Star Formation, Supermassive Black Hole Formation; Galactic Interstellar Media; Star Formation Laws

Mark Whittle
Professor
AGN, starburst galaxies, galaxy evolution

Ilsang Yoon
NRAO Assistant Scientist
Astrophysics of the radio-millimeter observation of galaxies and AGNs; Vera C. Rubin LSST AGN science

David Nichols
Assistant Professor
Dark matter, black holes, gravitational waves

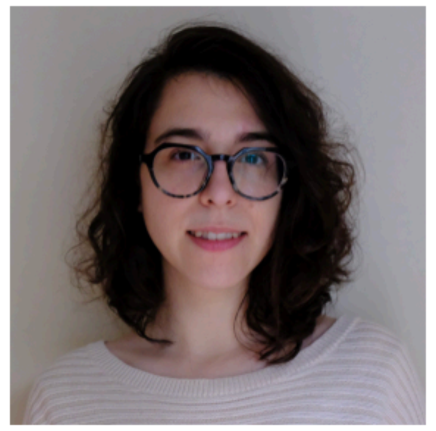
George C. Privon
Associate Scientist, NRAO
AGN, starburst galaxies, galaxy interactions and mergers

Galaxy Evolution and COsmology Initiative at UVa

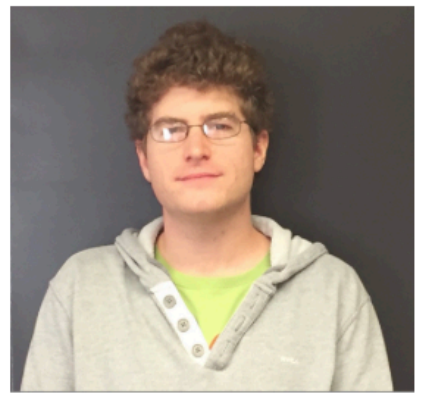
2024 GECO Fellows

Niusha Ahvazi is graduating from UC Riverside. She is a theorist interested in small galaxies as probes of alternative dark matter models. She has thought in detail about how to extend simulations and semi-analytic models to different resolution scales. She has worked with the CASSie internship program and formulated interesting undergrad and grad projects.

Aklant Bhowmick is joining us from a postdoc position at U Florida. He is a theorist interested in Black Hole seeds, of relevance to upcoming LISA and JWST observations. He is also interested in whether we can use low luminosity AGN populations to constrain alternative dark matter models. He is interested in postdoc community building and developed several outreach programs.



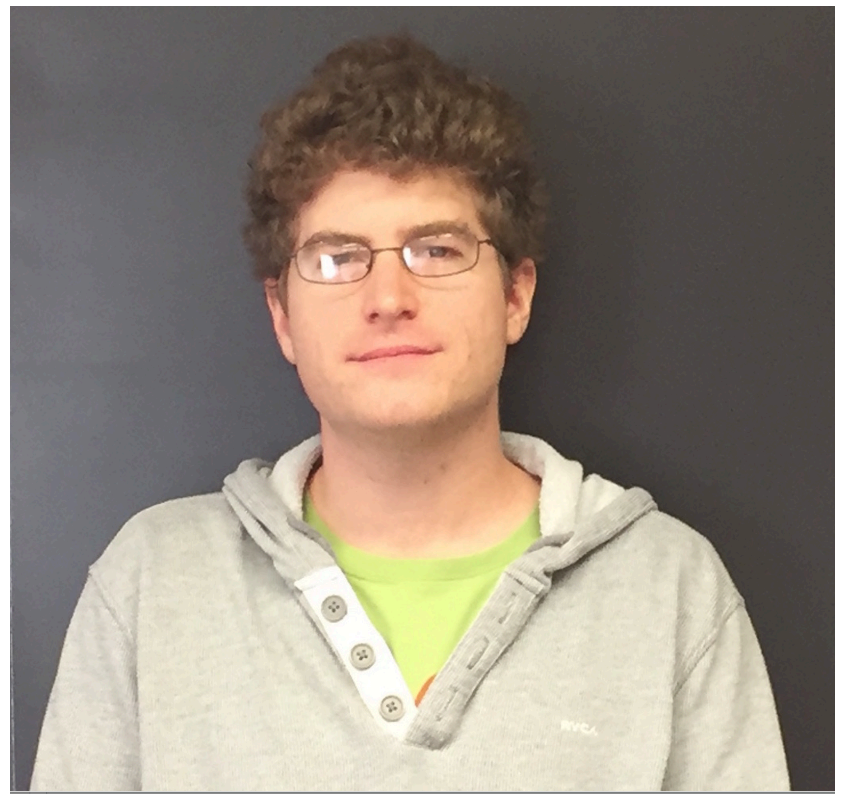
Núria Torres-Albà is joining us from a postdoc position at Clemson University, and broadly works on observations of Black Holes. Specifically she is interested in how and where material settles around a Black Hole, and how this impacts our understanding of feedback. She has already designed and supervised numerous PhD and undergraduate projects.

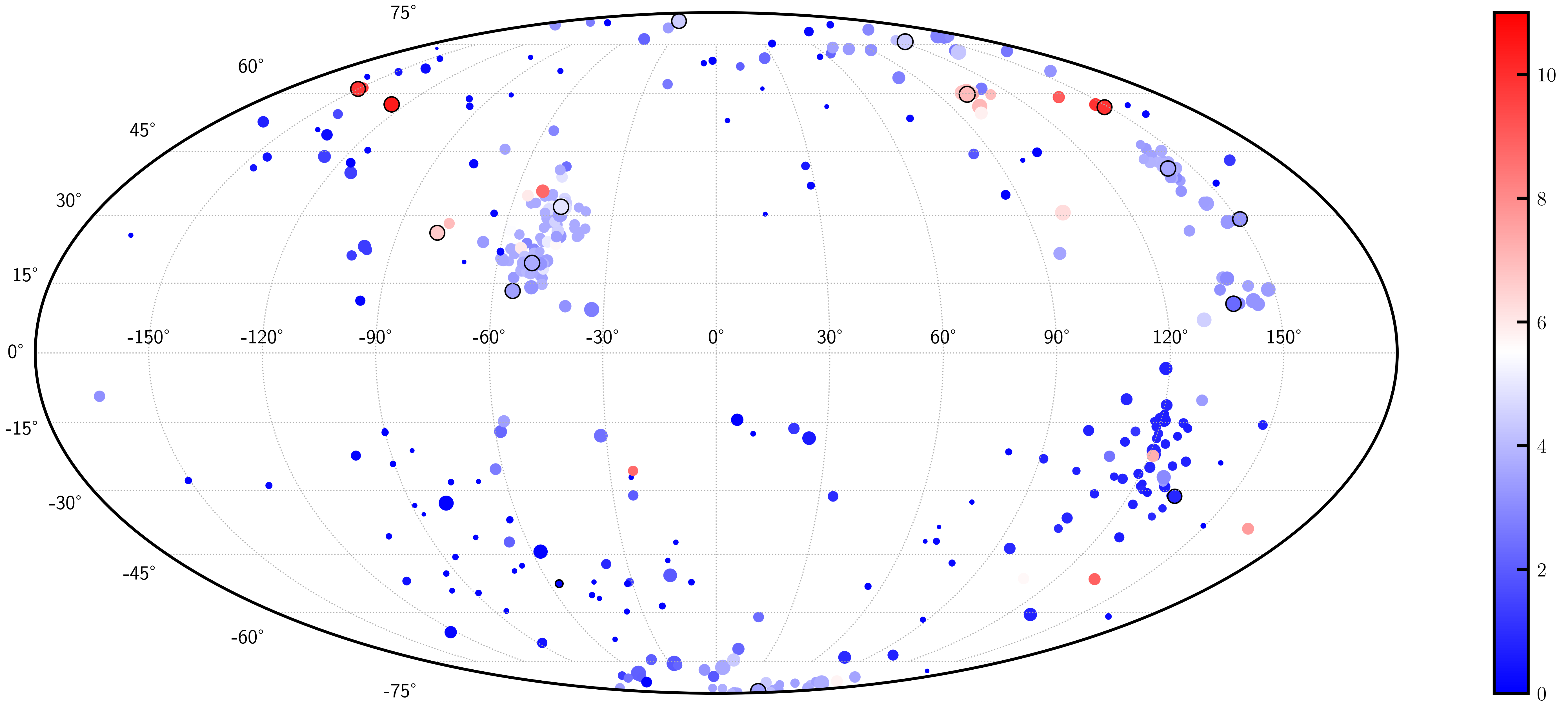


Andrew Pace is joining us from a postdoc position at CMU. He is an observer interested in the nature of dark matter, has experience in statistical analysis and mass modeling, and is an expert in spectroscopy. He is also an integral part of many survey teams. He is thoughtful about mentorship and interested in building a GECO undergraduate summer program.

Local Volume Database

Catalog/database of dwarf galaxies and star clusters in the Local Volume. Complete for dwarf galaxies with D < 3.5 Mpc (updated McConnachie 2012 catalog). Includes updated MW globular cluster catalogs, ambiguous faint and compact MW systems, and globular clusters in dwarf galaxies. Tables are available on the GitHub and community contributions/updates are welcome.





Galactic coordinates of all dwarf galaxies in the LVDB, with point size proportional to the stellar mass and color based on the heliocentric distance.

QR code to website/GitHub
https://github.com/apace7/local_volume_database

Pace 2024 (arxiv 2411.07424)


Roman's Immense Potential
Measure individual stars across entire galaxies
Revolutionize the study of dwarf galaxies
See to the cores of globular clusters
Capture a million distant galaxies in each image
Hubble
Wide Field Camera 3