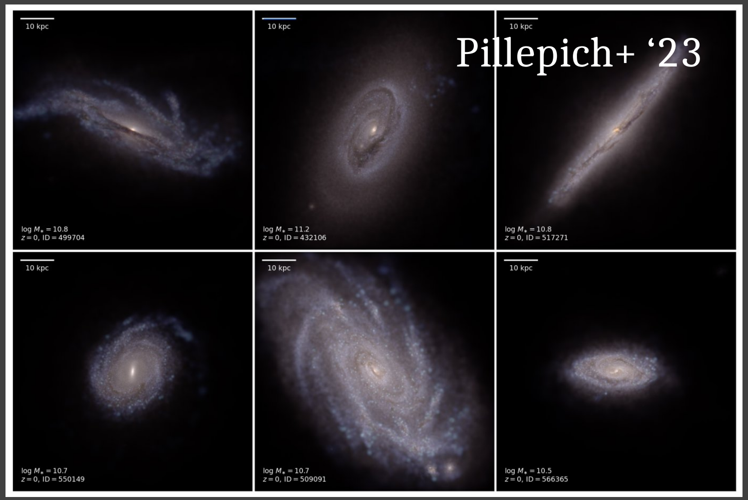
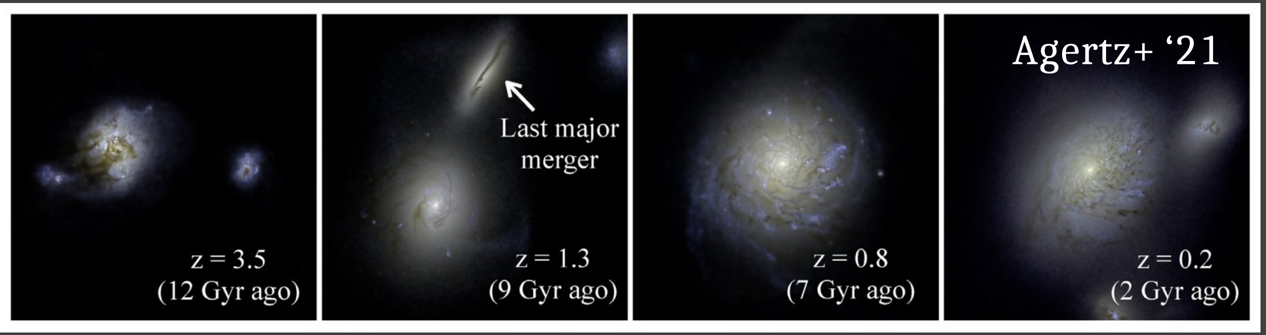
The fate of Milky Way satellites: The role of halo assembly history and the dependence on subgrid physics

Gandhali Joshi
ICC, Durham University

Collaborators: Andrew Pontzen, Oscar Agertz, Justin Read, Martin Rey

11/07/2025, NAM 2025, Durham University



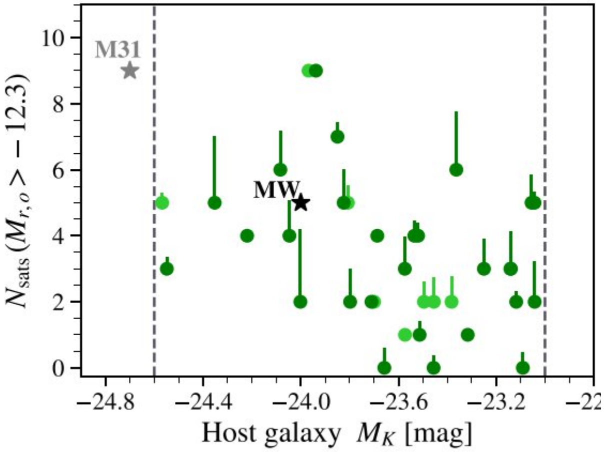


GMGalaxies

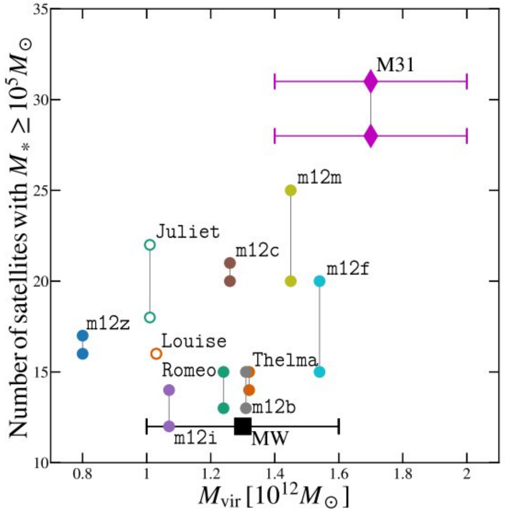
Durham University

Satellite abundance of MW/M31 mass systems

SAGA Survey
Mao+ 2021



LG simulations with FIRE
Garrison-Kimmel+ 2019



Satellite abundances likely to be correlated with host mass (or proxies) …

Satellite abundance of MW/M31 mass systems

SAGA Survey
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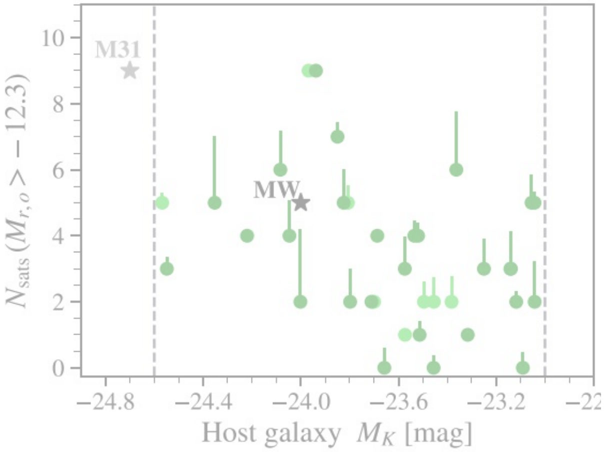

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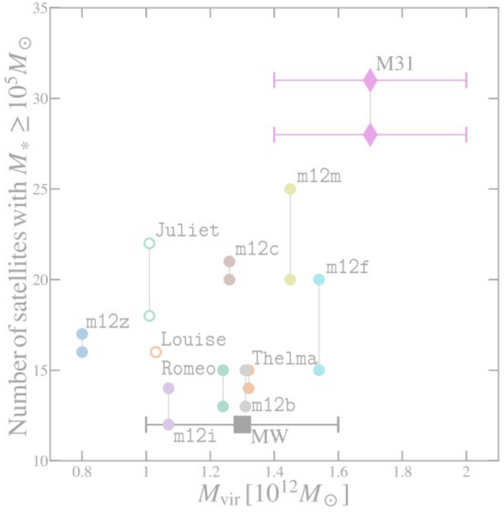
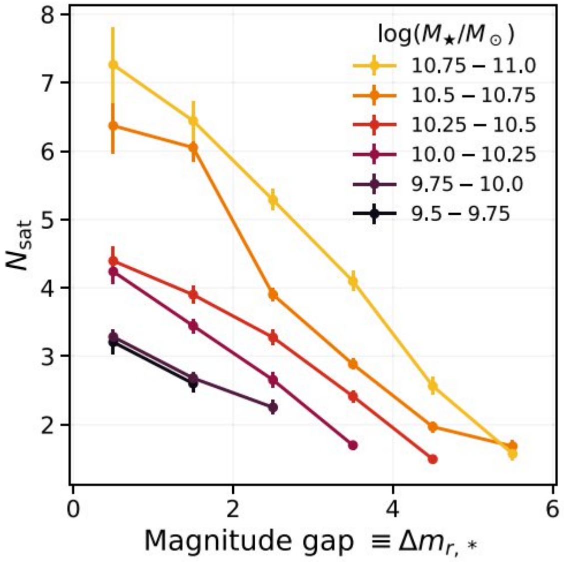
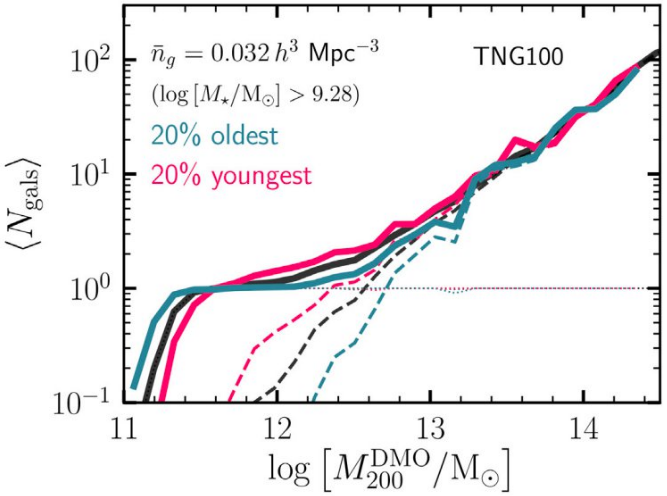


... and host assembly history.

xSAGA survey
Wu+ 2022



IllustrisTNG (HOD model)
Bose+ 2019



Satellite abundances likely to be correlated with host mass (or proxies) ...

The PARADIGM project

*(**P**robing the **A**ltered **R**esponse of **A**lgorithms to **D**iverse **I**Cs with **G**enetic **M**odifications)*

Two suites of zoom-in simulations of MW-mass haloes with RAMSES+VINTERGATAN (Agertz+ '21) and AREPO+IllustrisTNG50 (Pillepich+ '19, Nelson+ '19)

- $M_{200c} \sim 10^{12} M_{\odot}$
- $m_{DM} = 2 \times 10^{5} M_{\odot}$
- $m_{bary} = 3.6 \times 10^{4} M_{\odot}$
- minimum gas resolution: ≈ 11 pc (VINTERGATAN), ≈ 46 pc (IllustrisTNG)

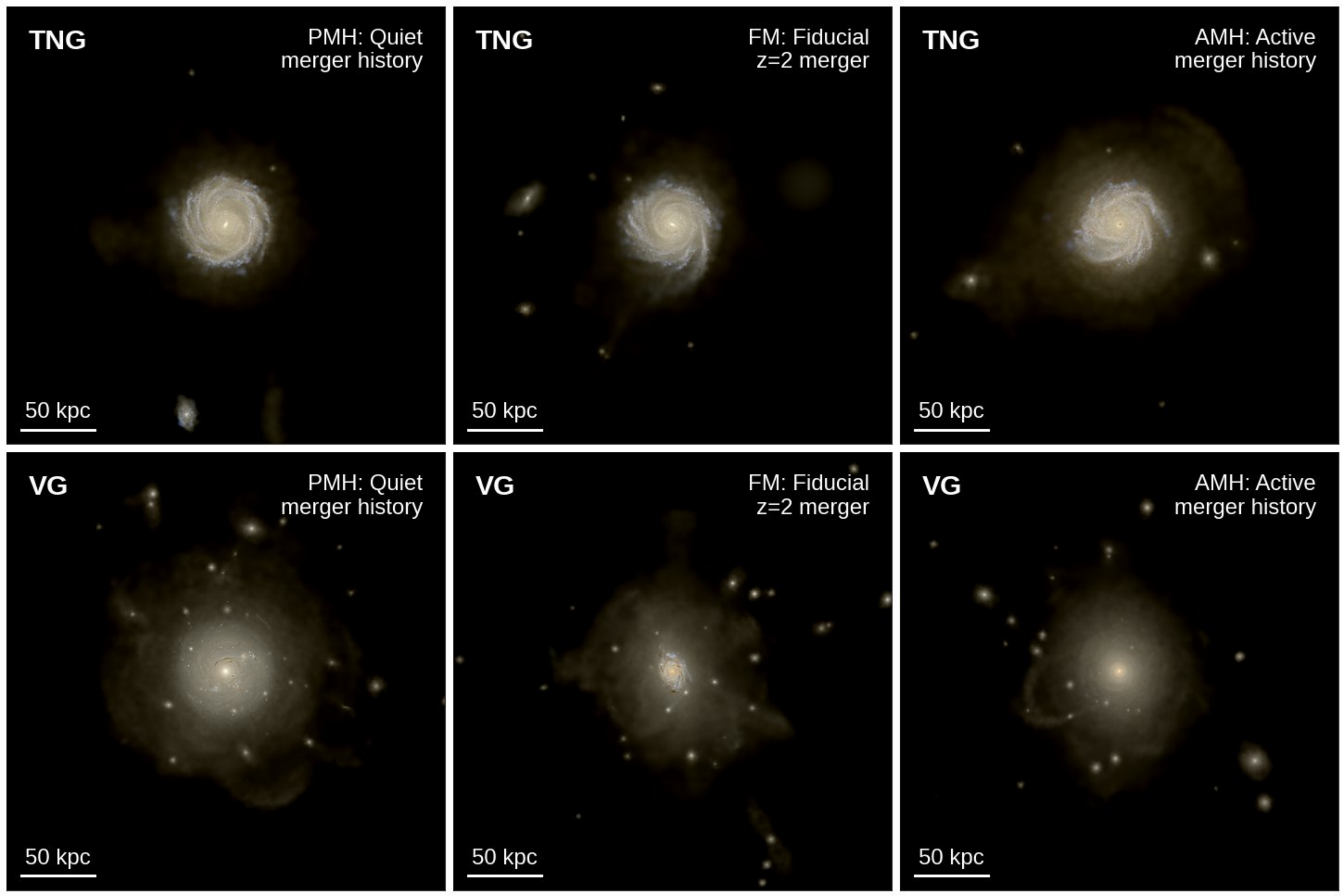
Three MW-mass haloes:

- Fiducial (**FM**): similar to MW merger history
  - + 4 GMs altering z=2 merger using **GenetIC** (Roth+ '16, Rey & Pontzen '18, Stopyra+ '21) (1:10, 1:9.8, <u>1:6</u>, 1:2.9, 1:2.1 in halo mass)
  - + Fiducial IC with early collapse
- Early former (**EF**)
- Late former (**LF**)

Key differences between the TNG and VG models

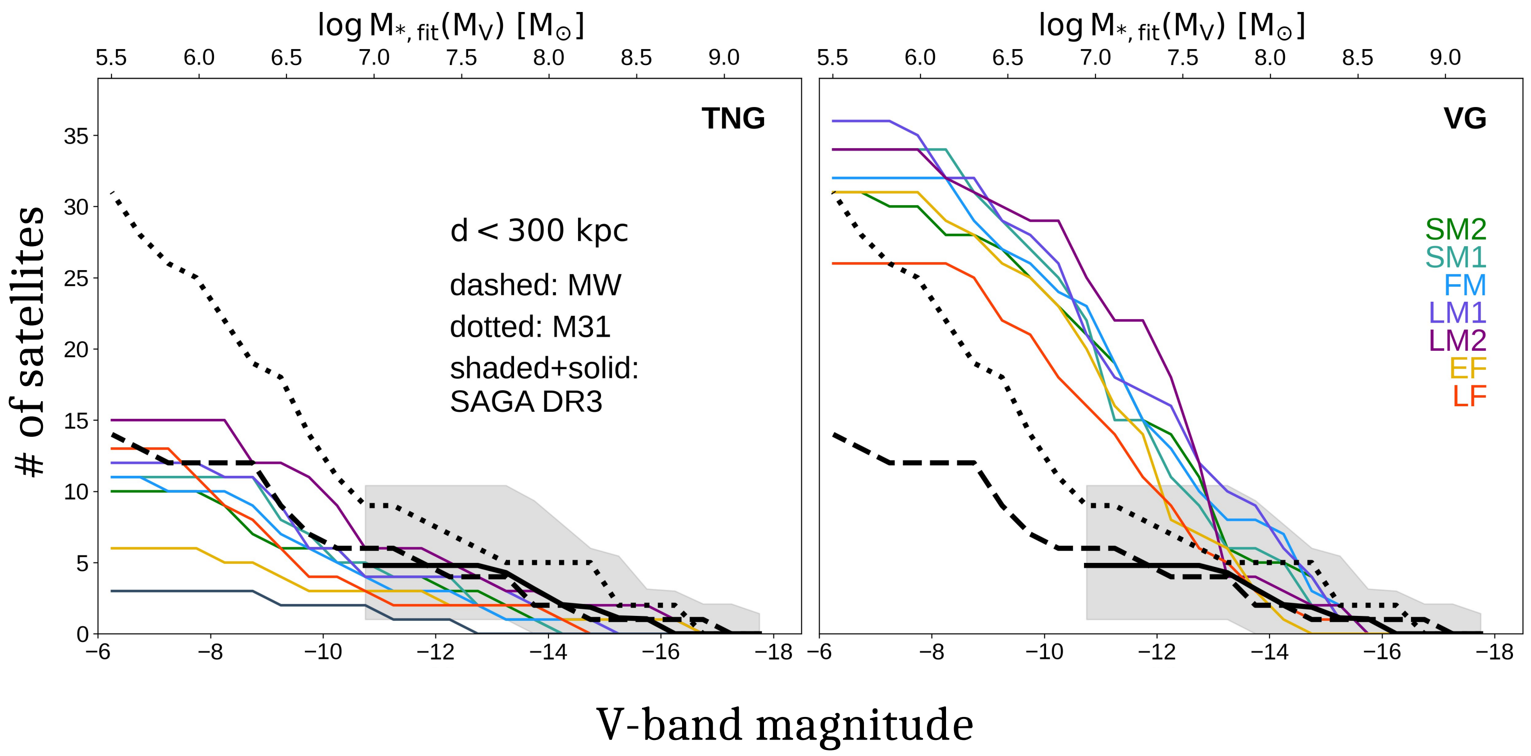
TNG	VG
Effective prescription for two-phase ISM, temperature floor at 10^4 K	Resolved ISM, gas can cool to 10 K
Includes prescription for AGN feedback	No AGN feedback
Lower resolution in gas cells with minimum effective radius of ~46 pc Lower density threshold for star-formation: 0.1 $m_p\ cm^{-3}$	Higher resolution in gas cells with minimum effective radius of ~11 pc Higher density threshold for star-formation: 100 $m_p\ cm^{-3}$

BVI mock images



Joshi+ 2025

Satellite abundances in MW-mass hosts



Magnitude measured within $R_{SB=30}$

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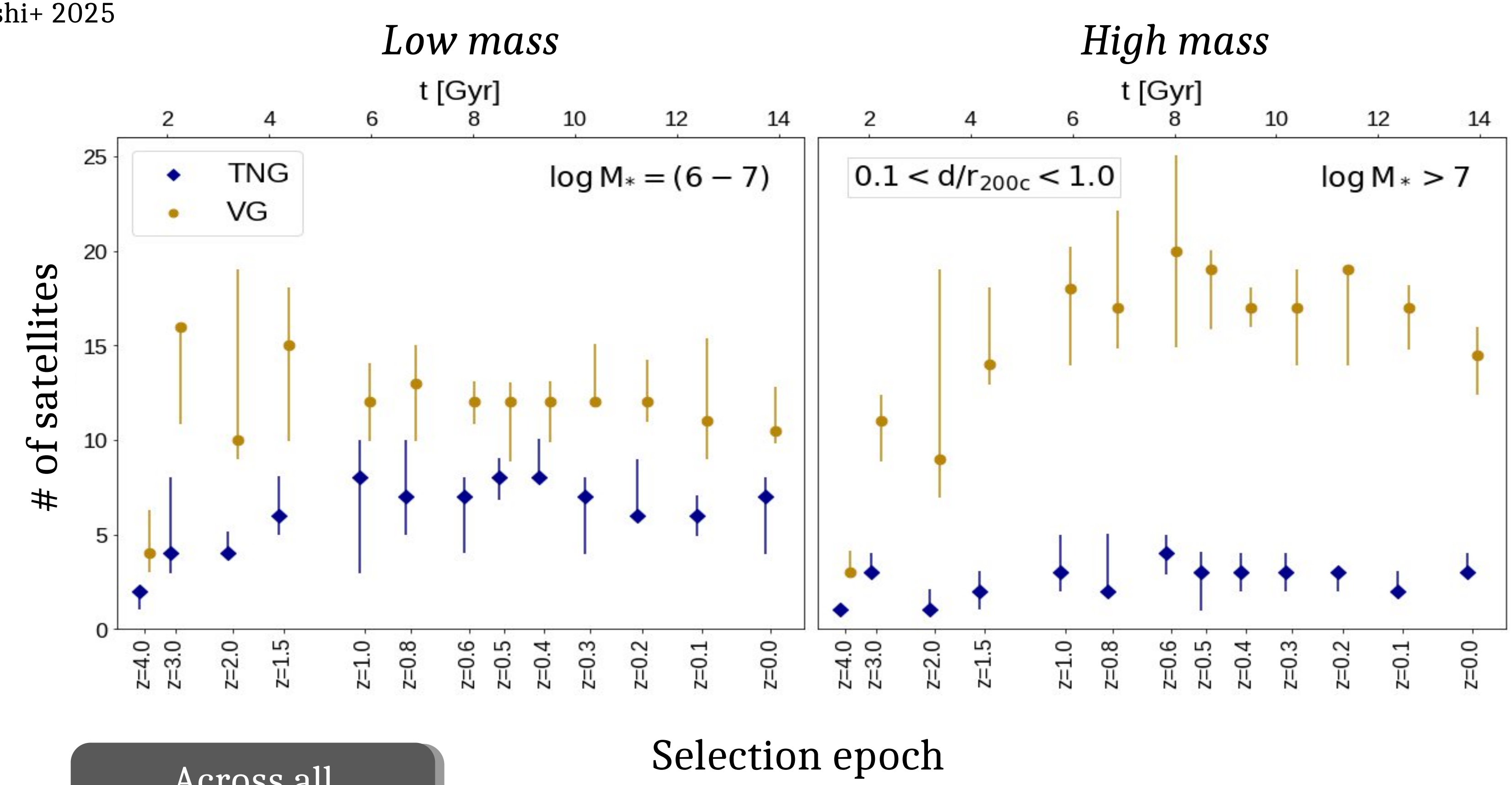
TNG shows good agreement with observations
VG produces too many satellites ...

Satellite abundances in MW-mass hosts

Joshi+ 2025

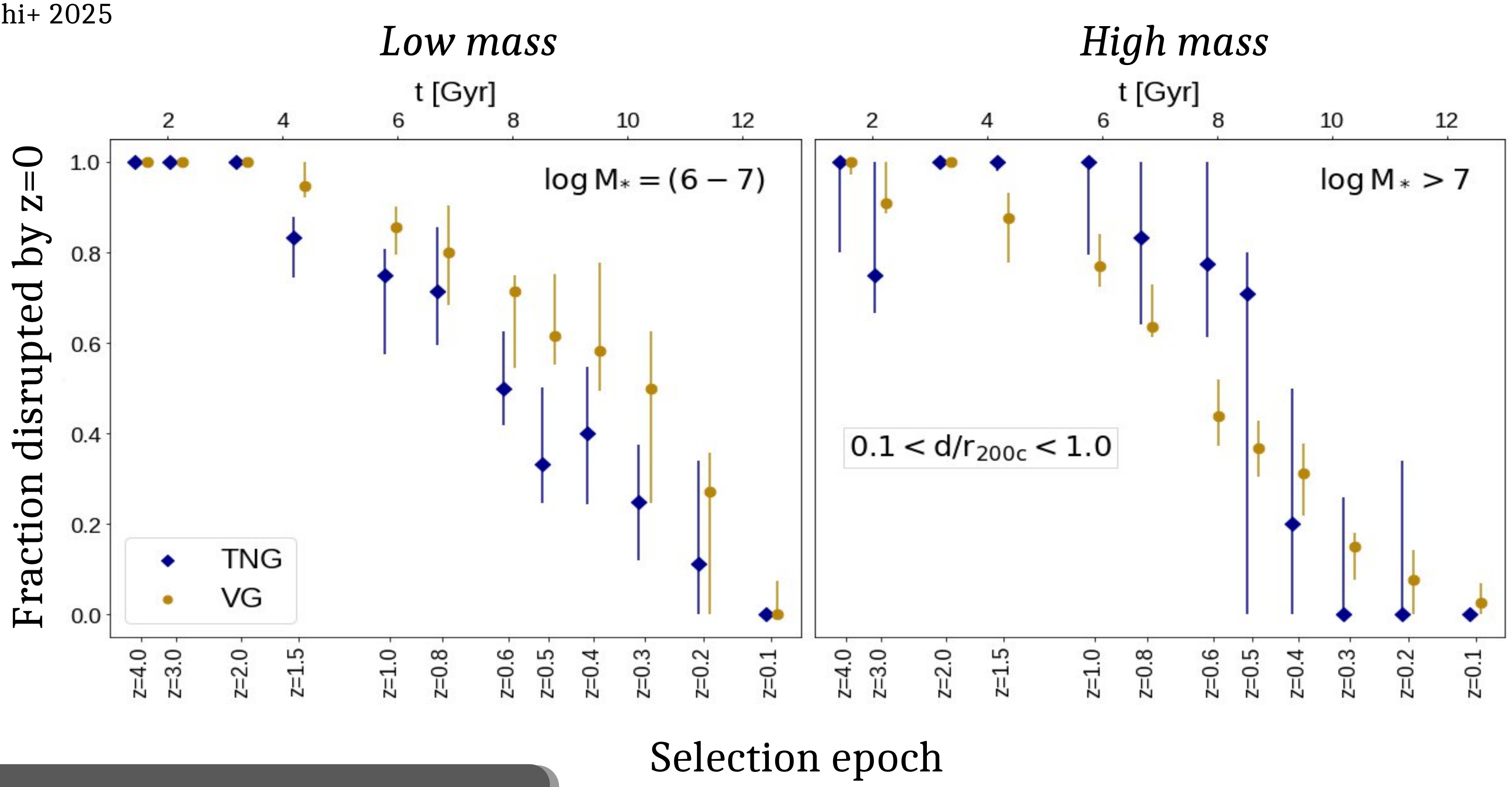


Across all assembly histories

Numbers of satellites increase rapidly at early times and then stay approximately constant

Satellite disruption fractions

Joshi+ 2025



But most satellites from early times have been disrupted

Present-day satellites are likely from z<0.6 (~5-6 Gyr ago)

Disruption occurs when R_{50} of satellite grows by a factor of >5

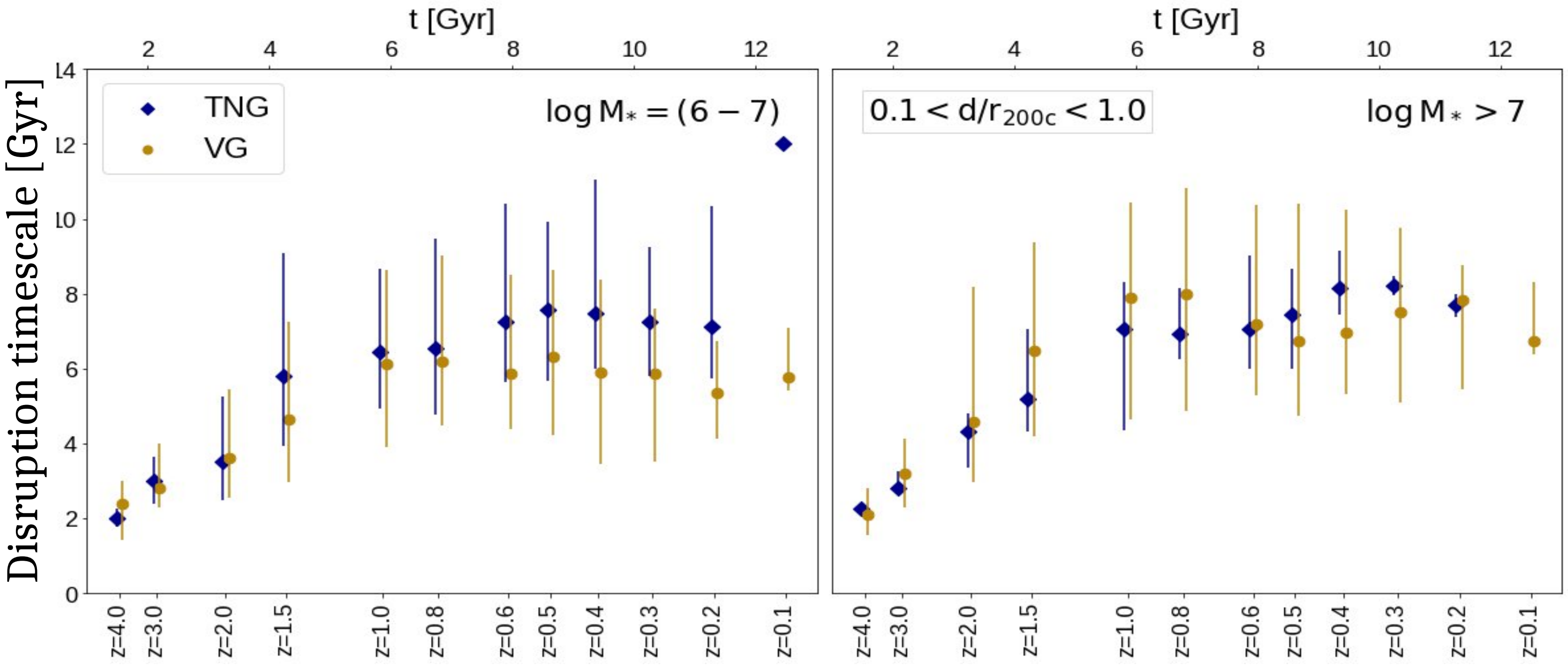
How long do satellites survive in MW-mass hosts

Time between accretion and disruption

Satellites can survive for ~6-8 Gyr after accretion, regardless of:

- stellar mass
- accretion epoch
- galaxy formation model

Low mass *High mass*



Selection epoch

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What is the impact of merger history?

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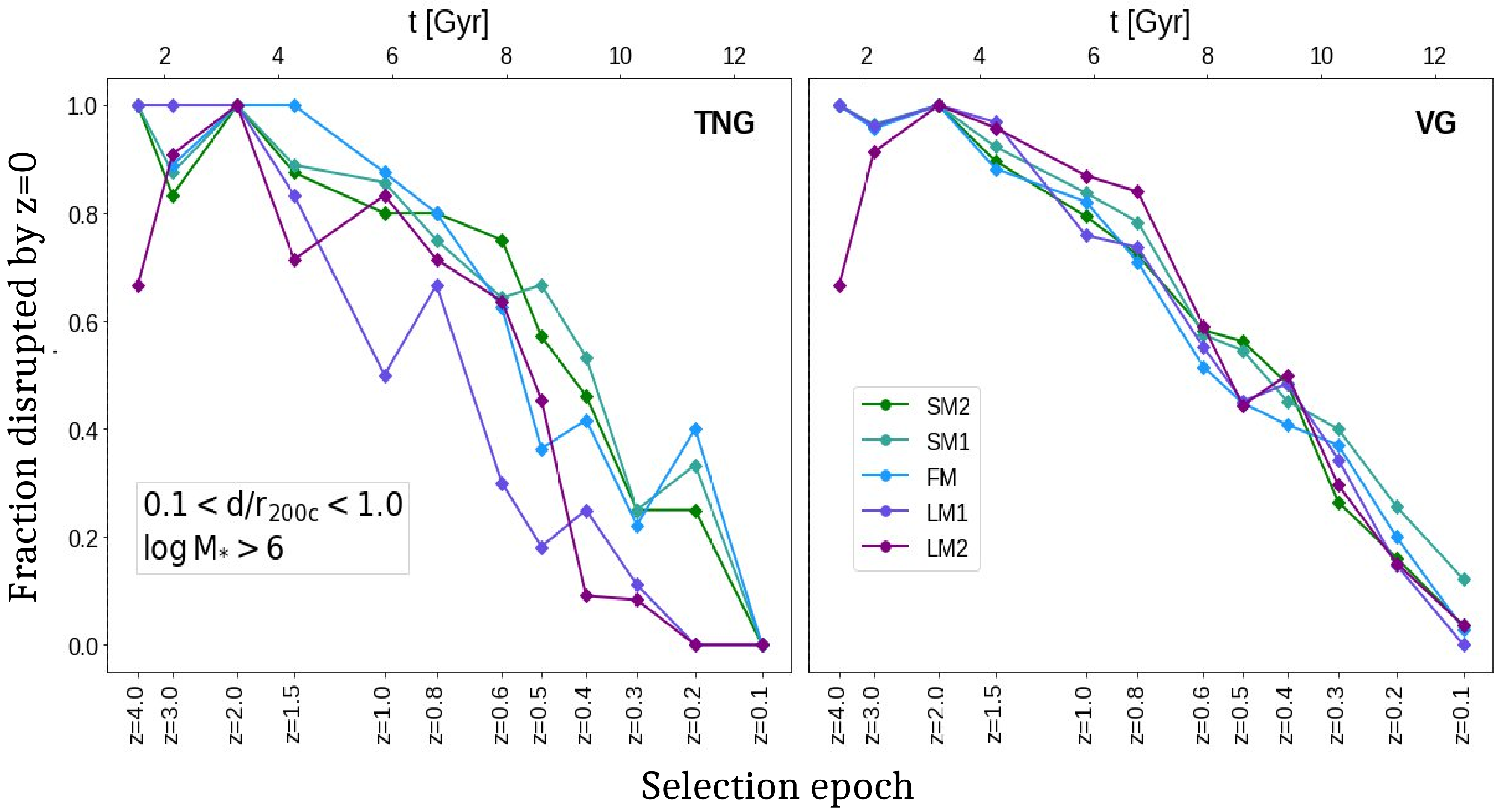
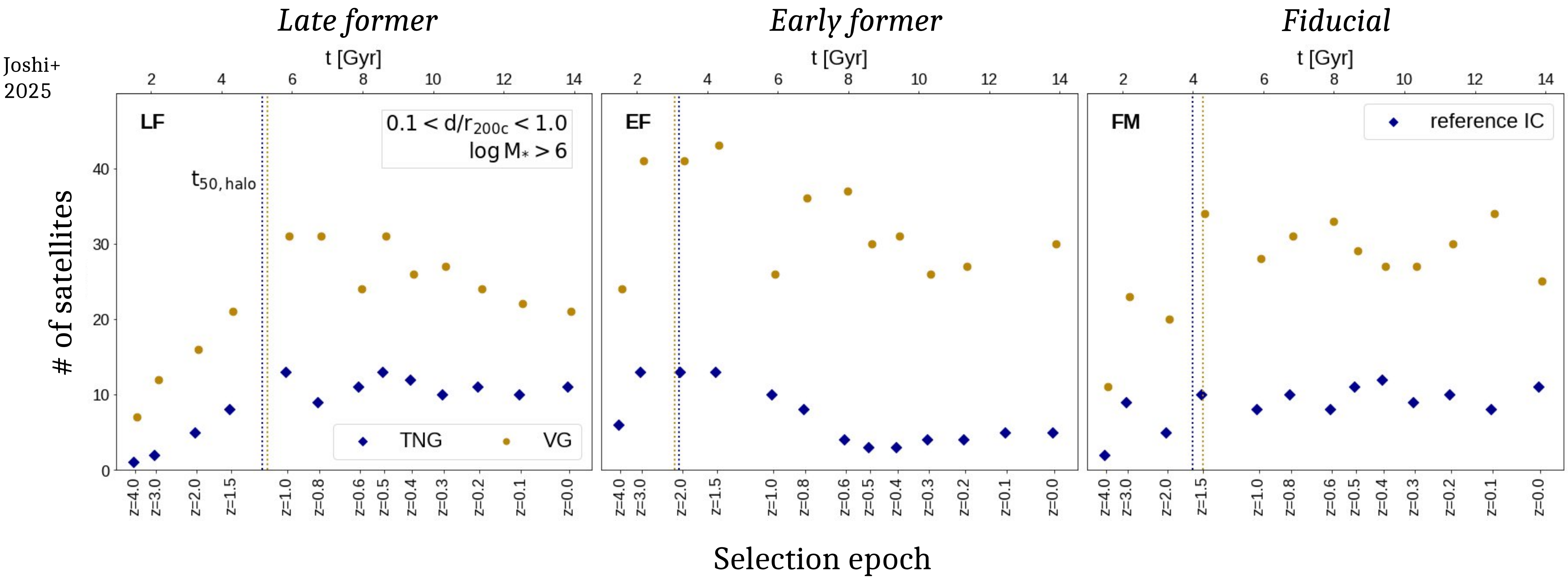


Answer: none
Impact is seen on satellite abundances, but not on disruption

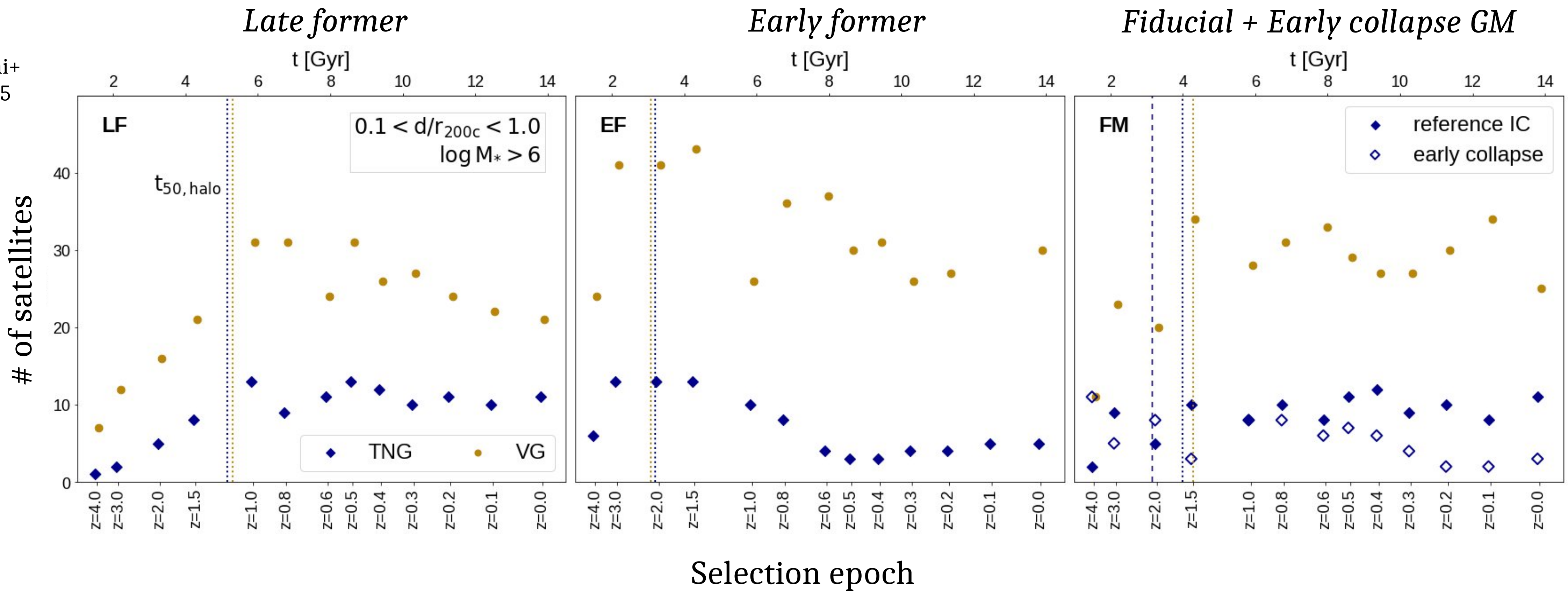
What is the impact of halo formation history?



Late-forming haloes build up satellites slowly, have more satellites at z=0.
Early-forming haloes build up satellites quickly, then gradually lose them.

What is the impact of halo formation history?

Joshi+ 2025



Late-forming haloes build up satellites slowly, have more satellites at z=0.
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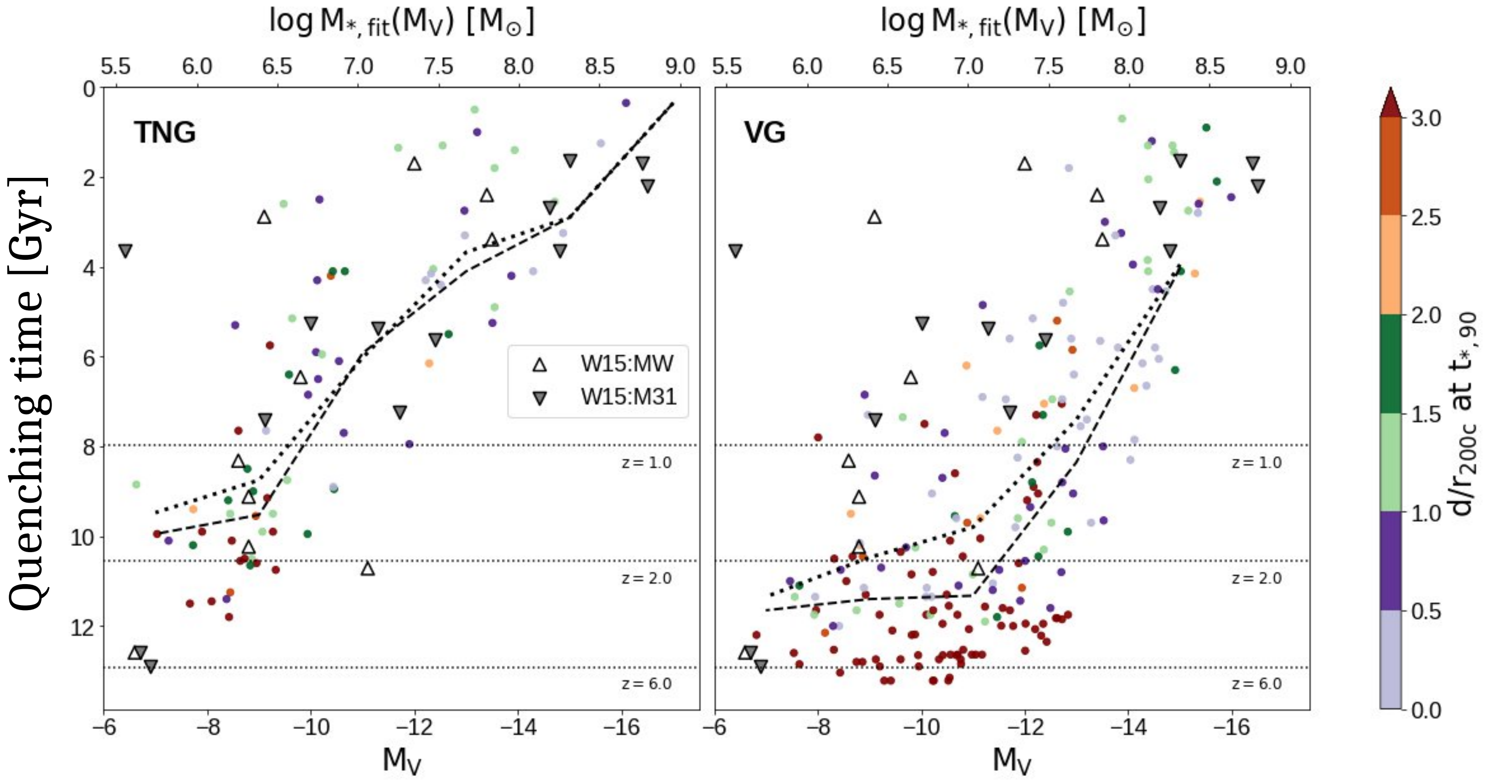
When and where did satellites quench?

Lookback time to $t_{*,90}$



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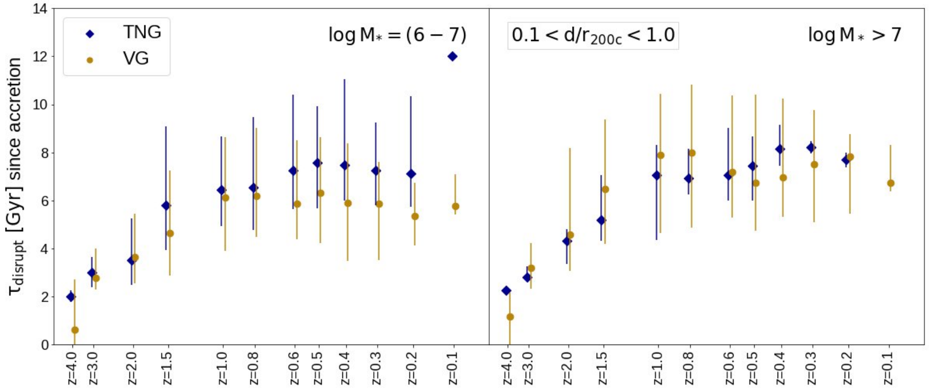
V-band magnitude

Massive satellites quenched later, within the halo, smaller satellites quenched early and outside the halo

- TNG agrees with observations
- VG has too many satellites that quench very early

Summary

- VG predicts too many satellites compared to observations — TNG satellite MFs are consistent with observations
- Despite the difference in normalization, there are robust trends in the two models:
  - Number of satellites, disruption fraction and disruption timescale as a function of cosmic time
  - No dependence on merger history, but satellite abundance does depend on halo formation time
  - At present-day, massive satellites were quenched more recently by the MW host, less massive satellites quenched early and outside the host



Joshi+ 2025a, MNRAS, 537, 3792

Joshi+ 2025b, arXiv: 2507.05401