Can you constrain dark matter at the limits of galaxy formation?

Ferah Munshi
University of Oklahoma
Aspen Center for Physics 3/23/2021
In collaboration with: Alyson Brooks, Elaad Applebaum, Charlotte Christensen + UW N-body Shop

@fdmtweets

email: fdm@ou.edu

Starting Assumption:

There is No Small Scale “Crisis”

CDM= cold dark matter, WDM= warm dark matter, SIDM= self-interacting dark matter

“challenge”	CDM+Baryons	WDM+Baryons	SIDM+Baryons
Bulge-less disk galaxies	✓	✓	✓
The Cusp/Core Problem	✓	✓	✓
Too Big to Fail	✓	✓	✓
Missing Satellites	✓	✓	✓
Missing Dwarfs	✓	✓	✓
Diversity	✓?	?	✓
Planes of Satellites	Still to be explored		

Scorecard adapted from A. Brooks

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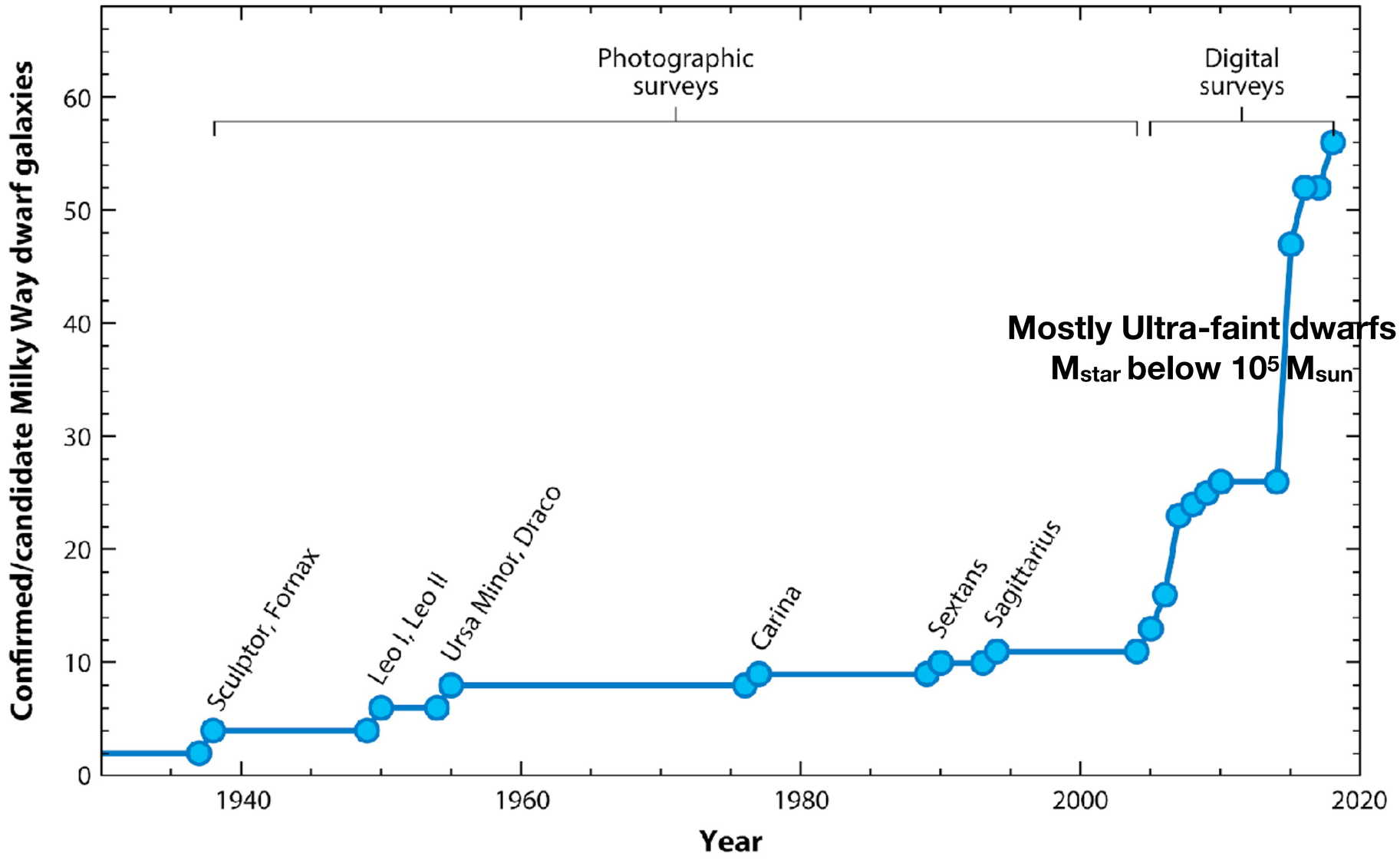
A.B.’s talk

Scorecard adapted from A. Brooks

There has been an explosion in finding fainter and fainter dwarfs



Simon JD. 2019.
Annu. Rev. Astron. Astrophys. 57:375–415

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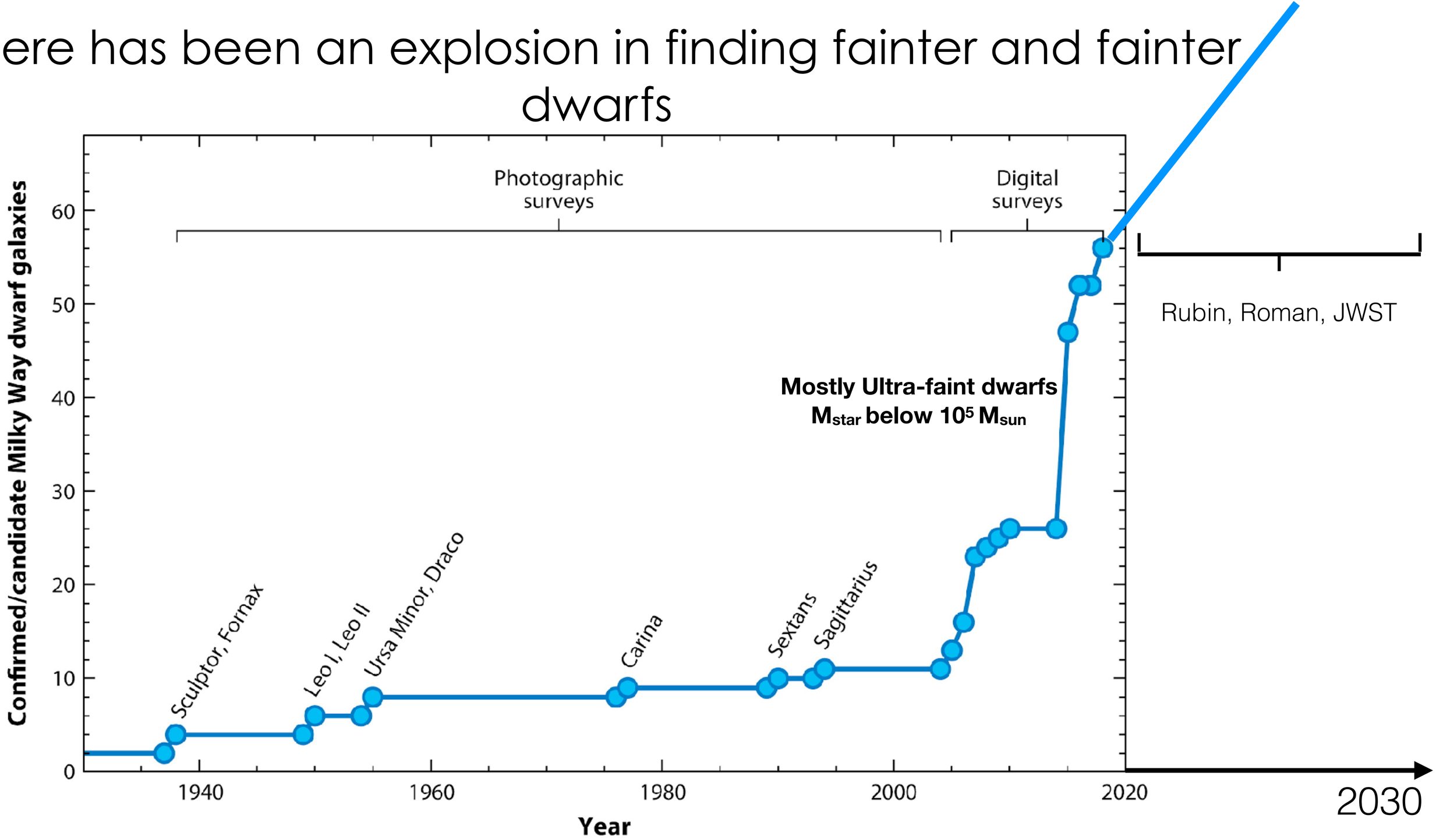


Why do we care?

At ultra-faint masses, the number of halos that host a galaxy (may) drop low (low occupation fraction). How low and at what mass this drop occurs shapes the **low mass end of the stellar mass function** (*& can distinguish dark matter models*!)

This is important to constrain for upcoming telescopes/missions like JWST, Roman Space Telescope (WFIRST), Vera Rubin Observatory (LSST)

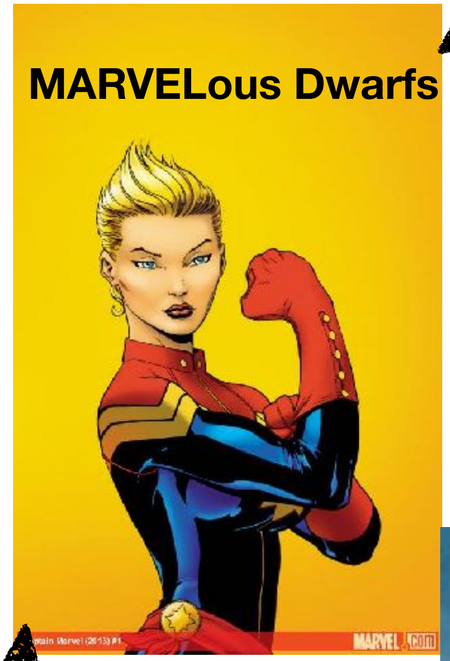
It is commonly assumed that ultra-faint dwarfs are “simple” systems

- They’re old- reionization truncated their star formation
- The least massive/faintest live in the least massive dark matter halos, but they are extremely dark matter dominated.

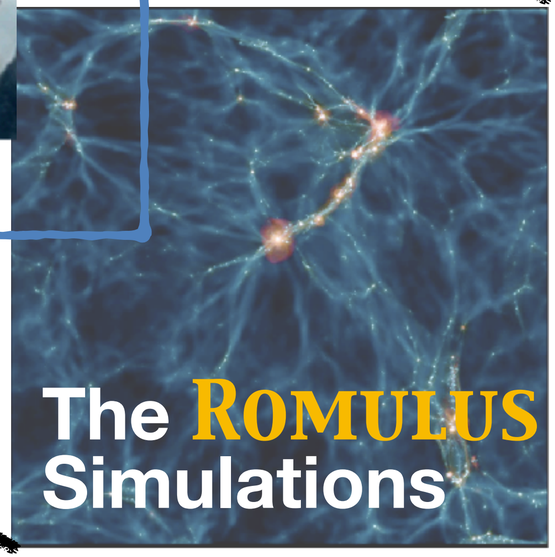
But are they really this simple?

In the N-body Shop, there's been an explosion of dwarf galaxy simulations

Ultra-faints in isolation

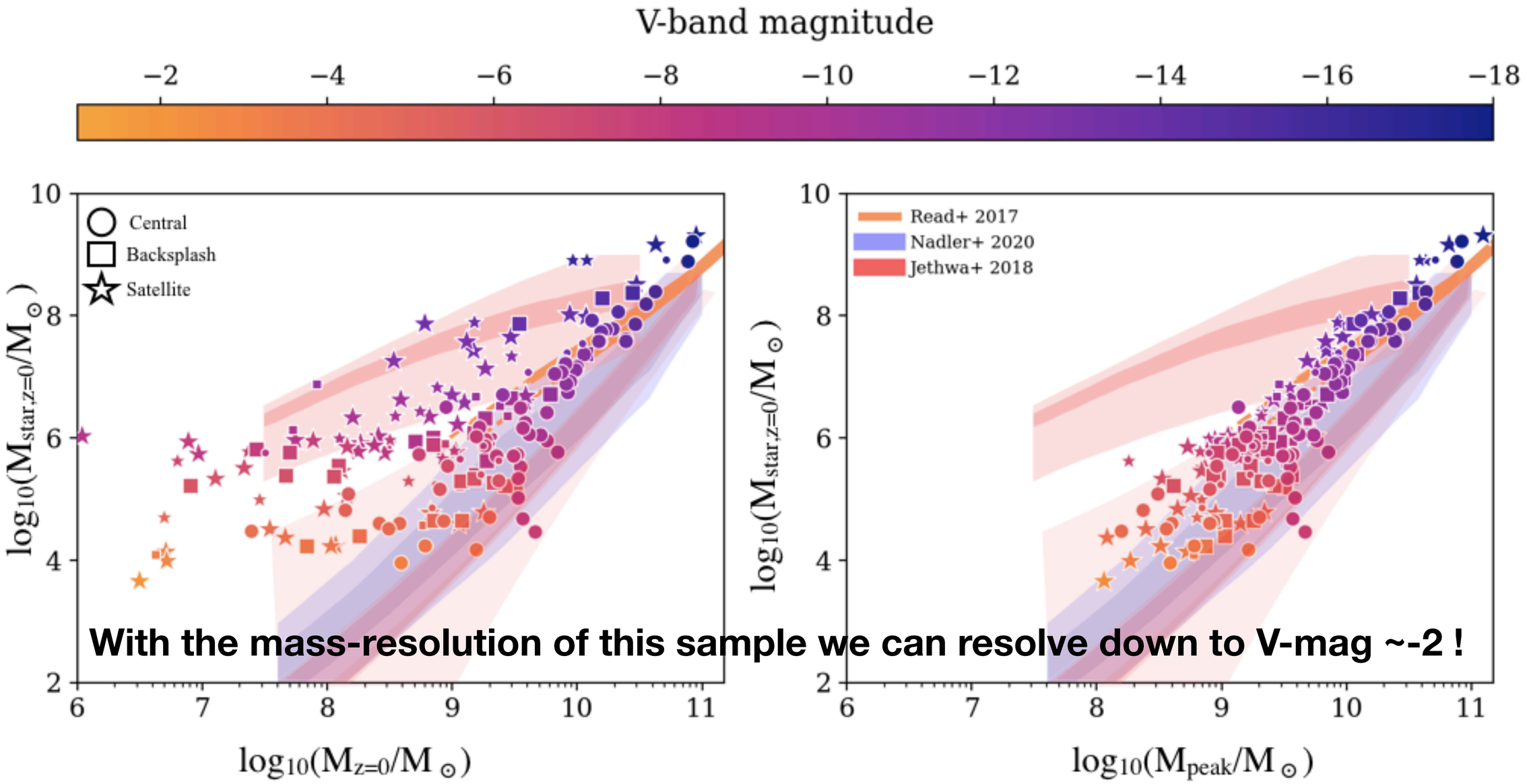


Ultra-faints in the vicinity of a MW



Dwarfs (and UDGs) across environments

MARVELous Dwarf Volumes + Justice League Dwarfs = **211 High-resolution simulated dwarfs**

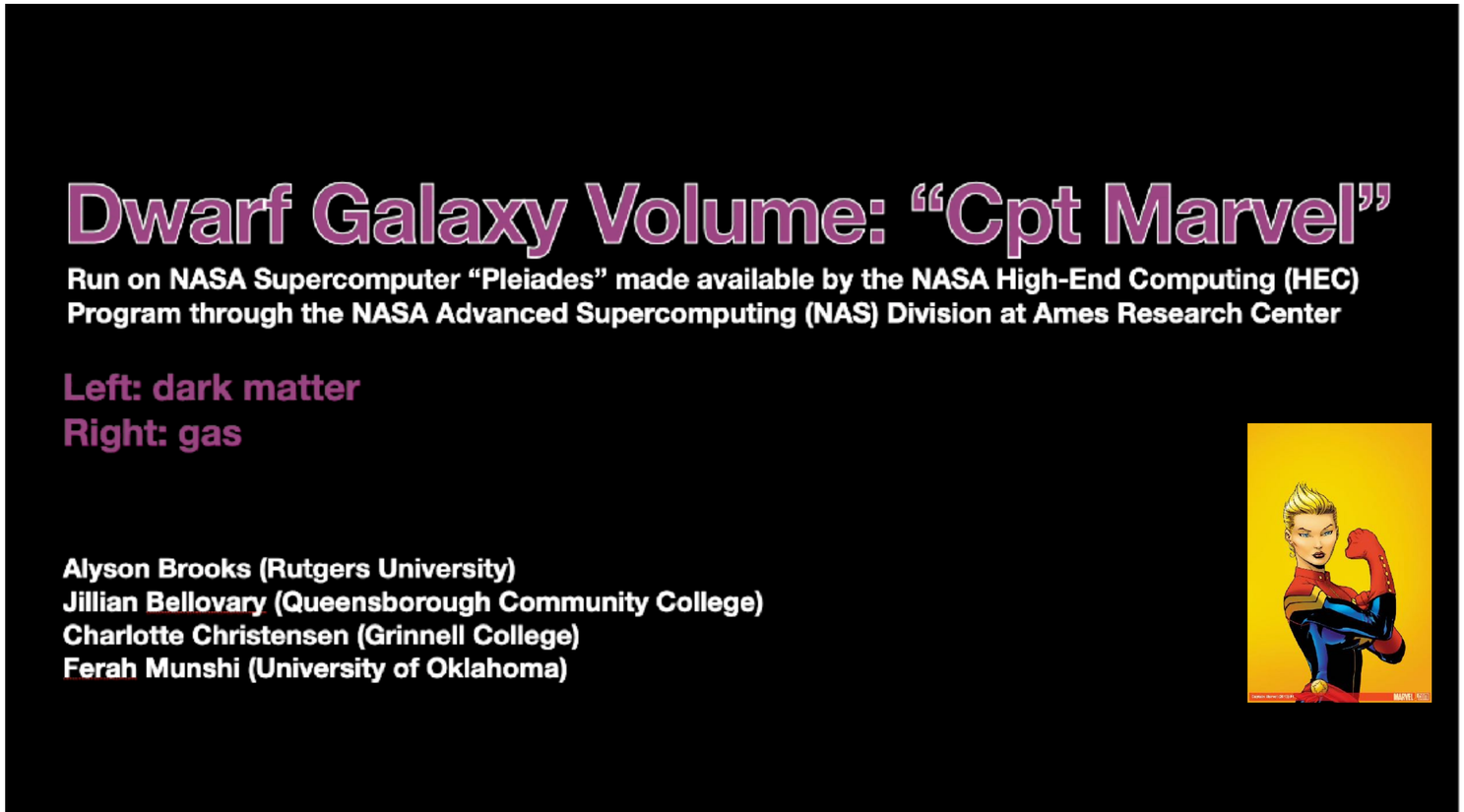


With the mass-resolution of this sample we can resolve down to V-mag ~-2 !

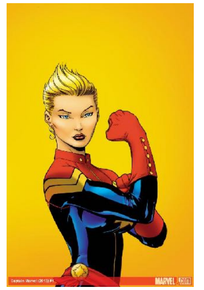
Munshi, Brooks, Applebaum+, under review arXiv:2101.05822

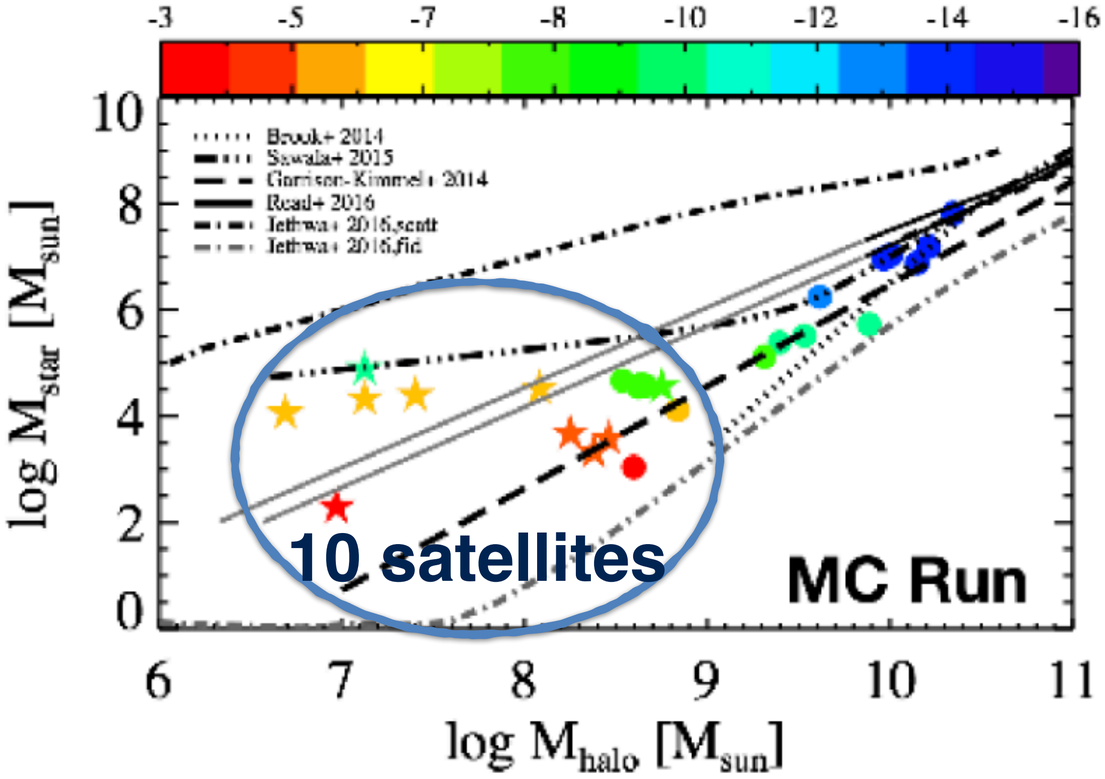
With a simulation sample like this, we can begin to constrain:

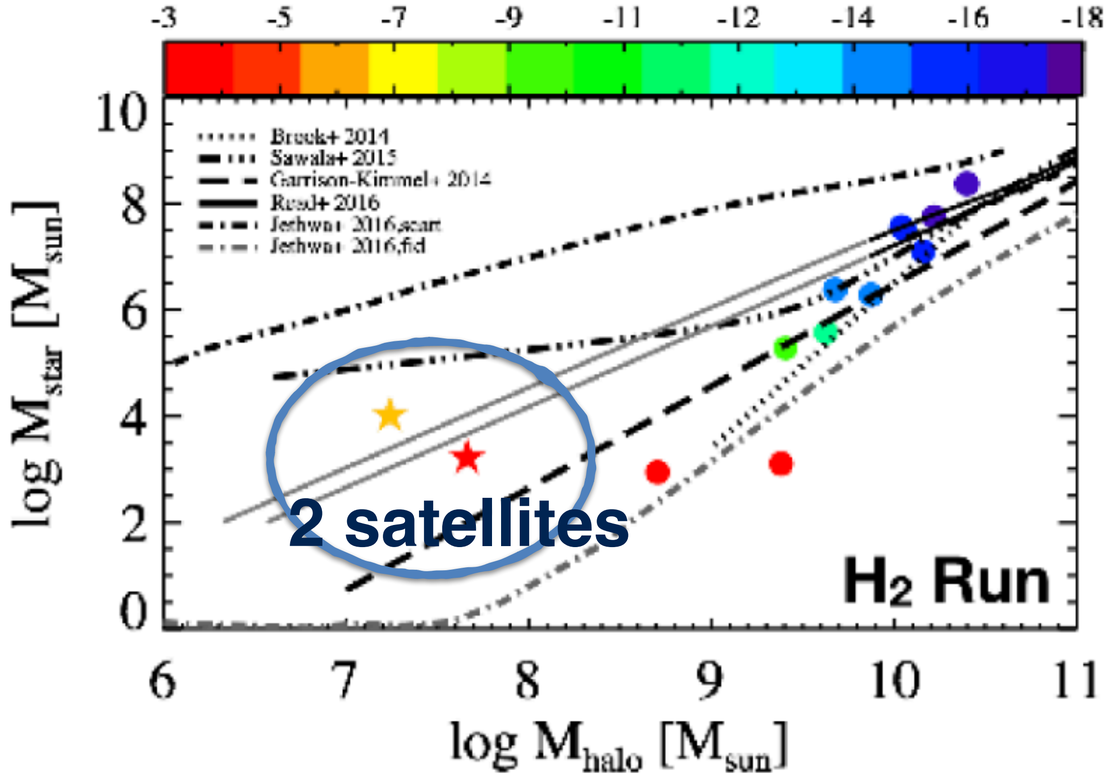
1. The abundance of ultra-faint dwarfs
2. How they populate dark matter halos



The number of ultra-faints predicted depends on SF model

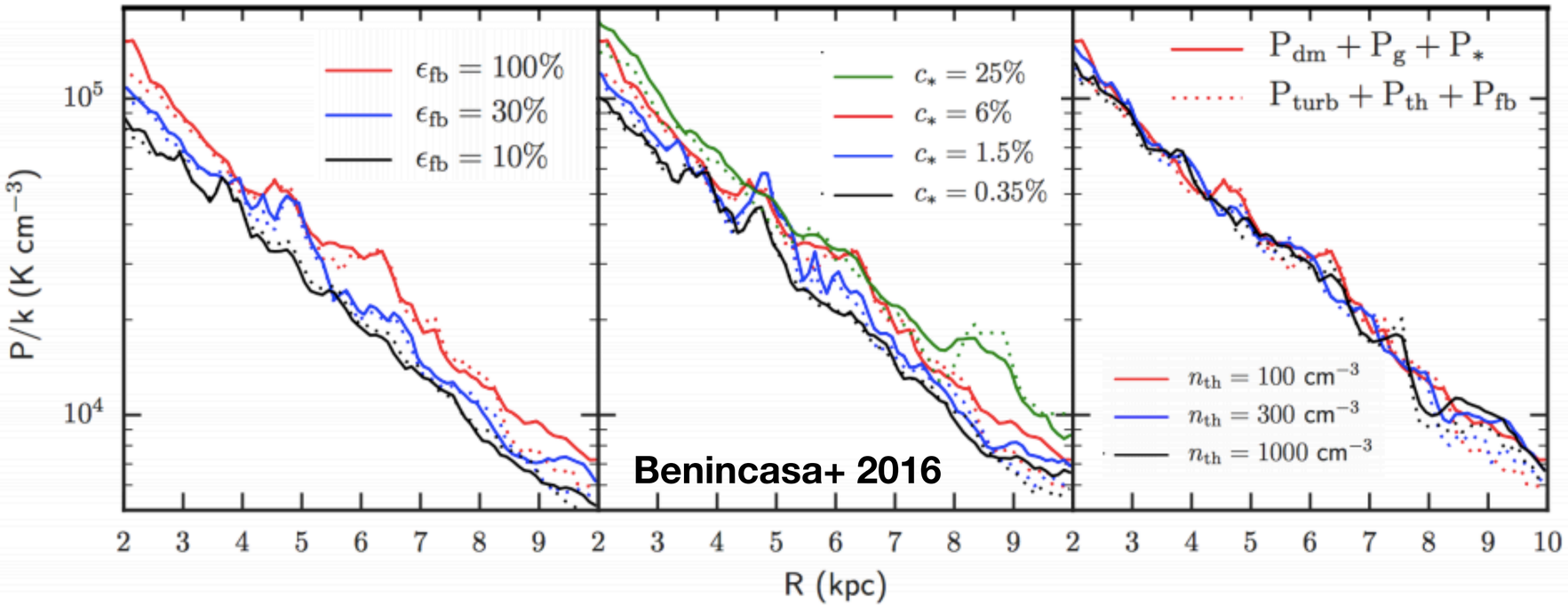






Munshi+ 2019

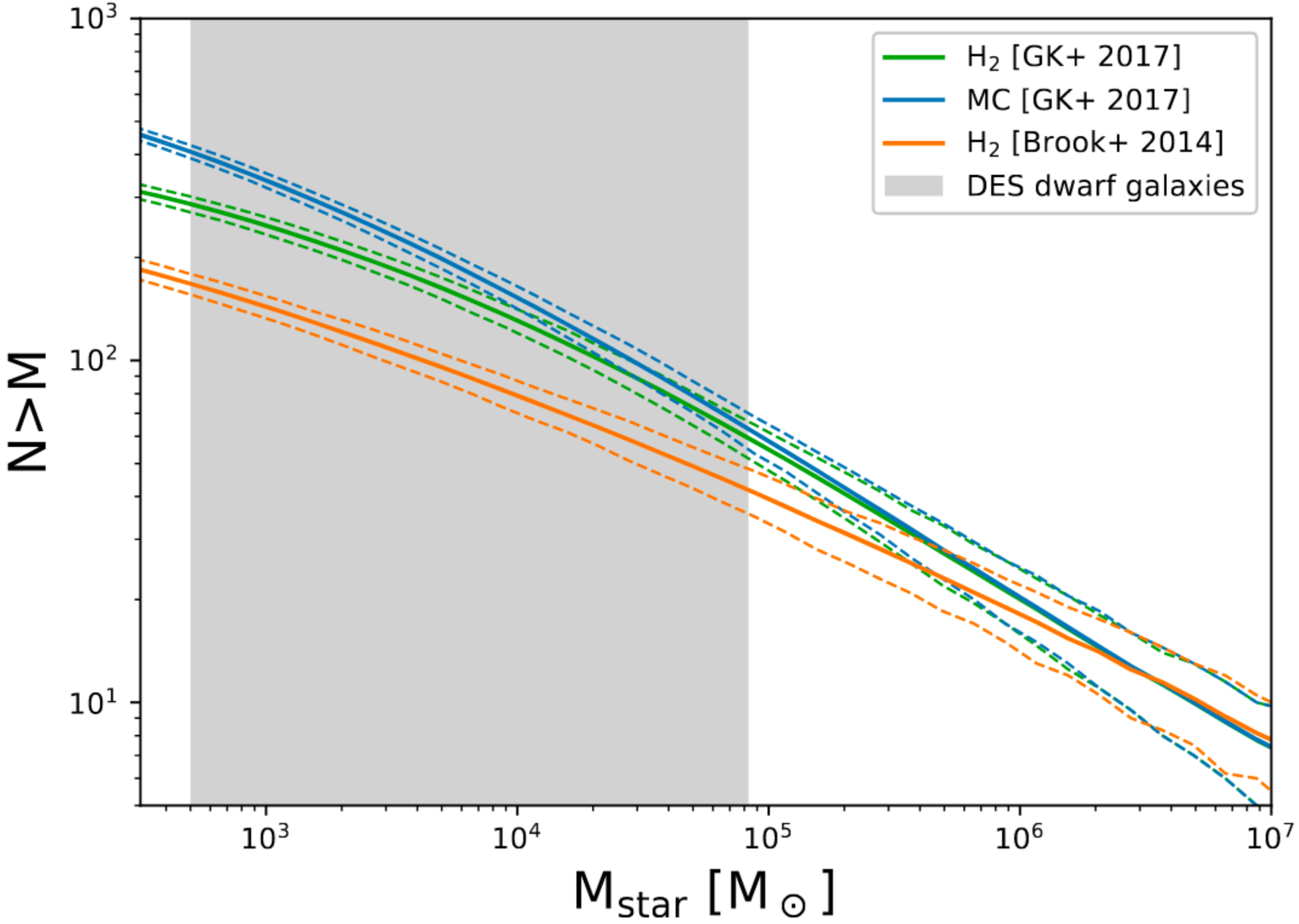
Why haven't we worried before?



Classical dwarfs can self-regulate, so prescription doesn't matter.

Ultra-faints are unable to self-regulate

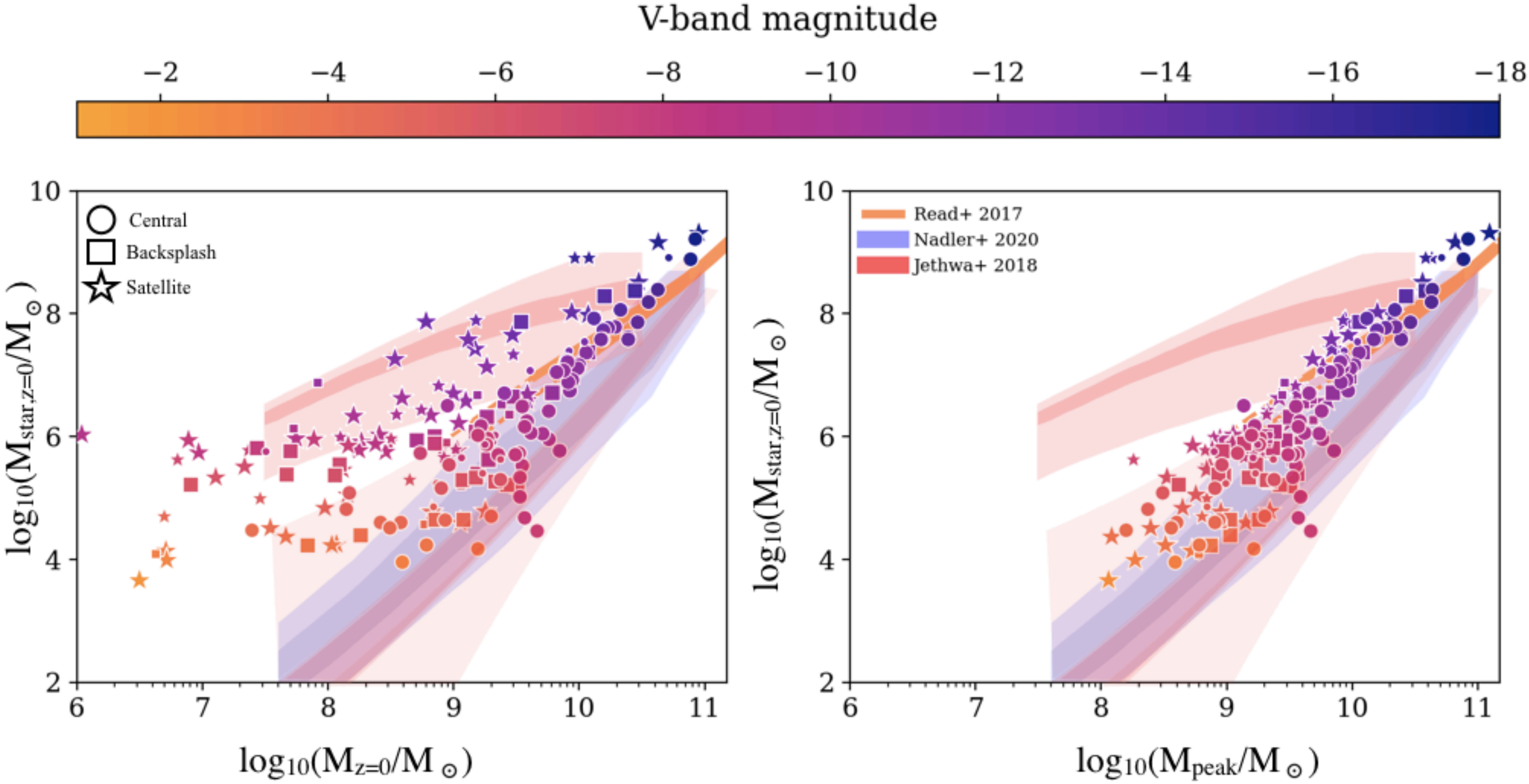
Any predictions you make depend on your star formation and feedback model



Munshi+ 2019

With a simulation sample like this, we can begin to constrain:

1. The abundance of ultra-faint dwarfs: *abundance and occupation fraction depend on SF model (in isolation)*
2. **How they populate dark matter halos**



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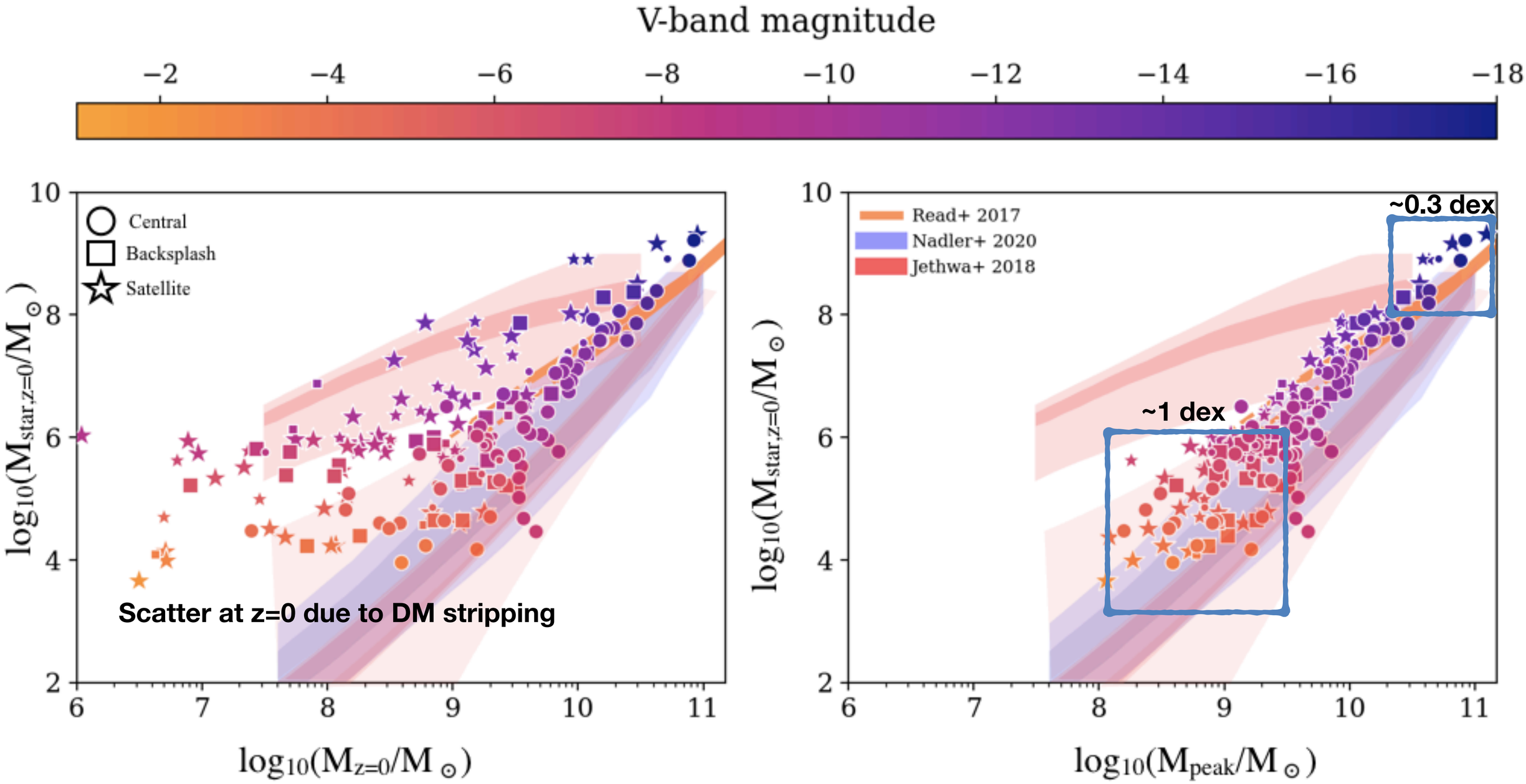

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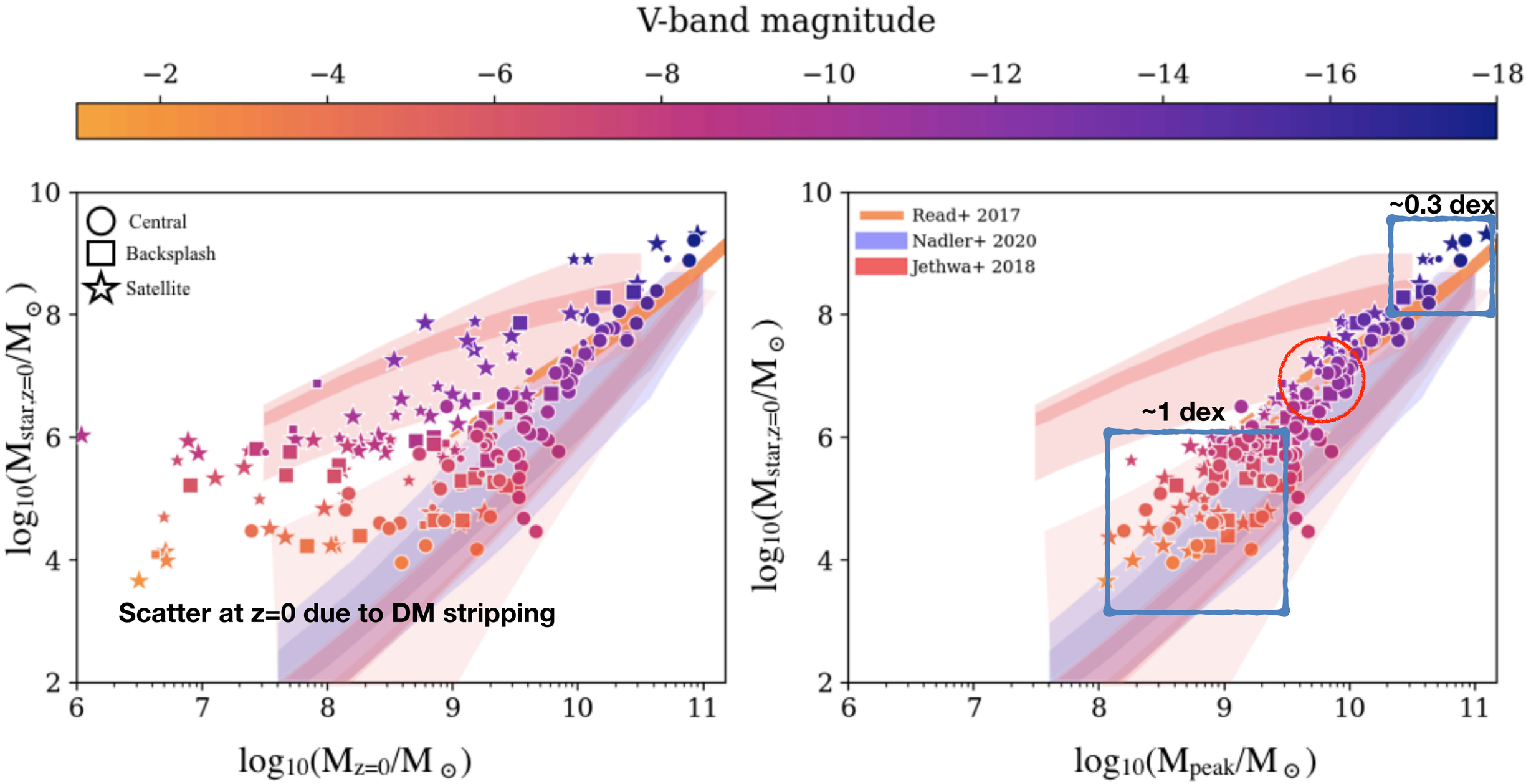

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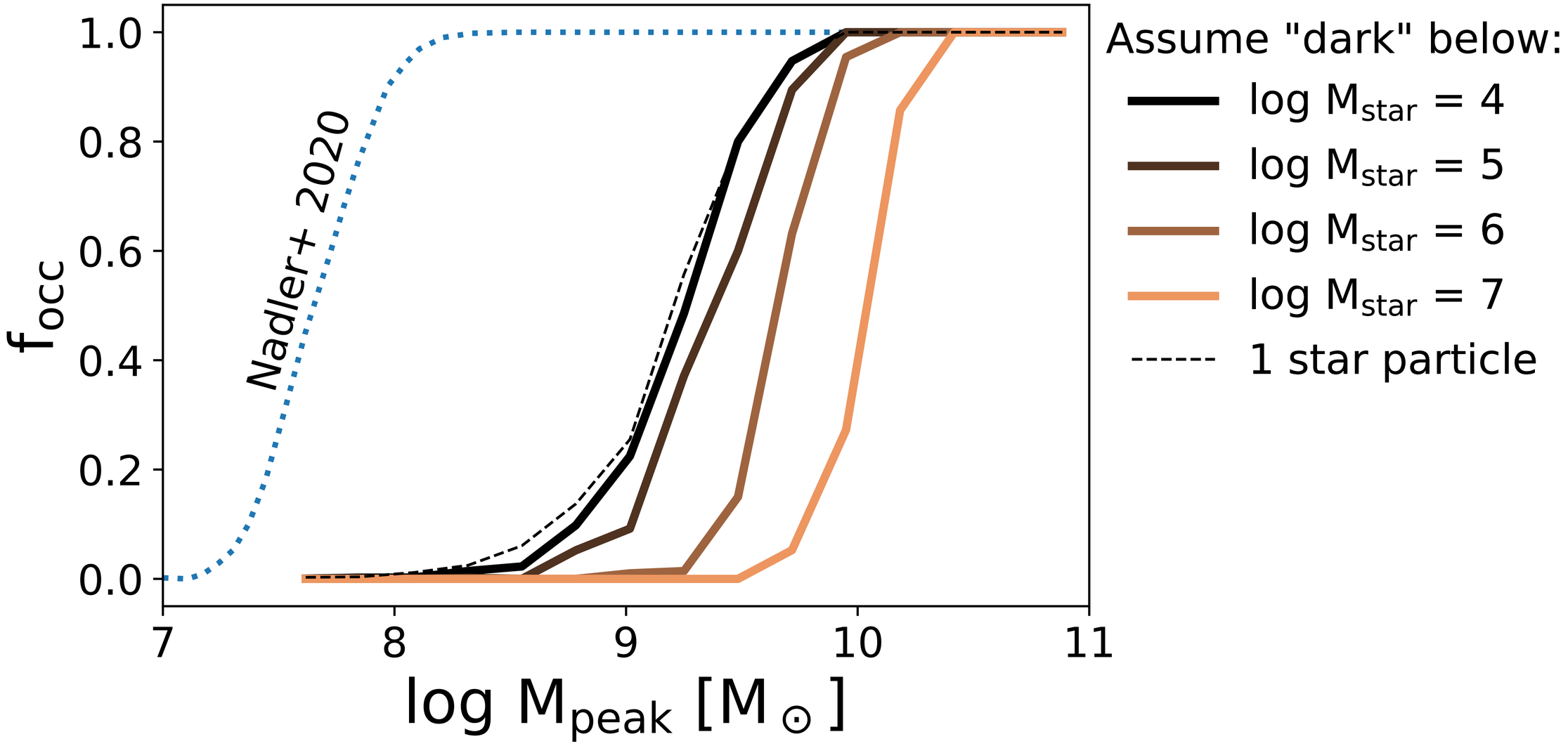
In simulations, occupation fraction is inherently resolution dependent.



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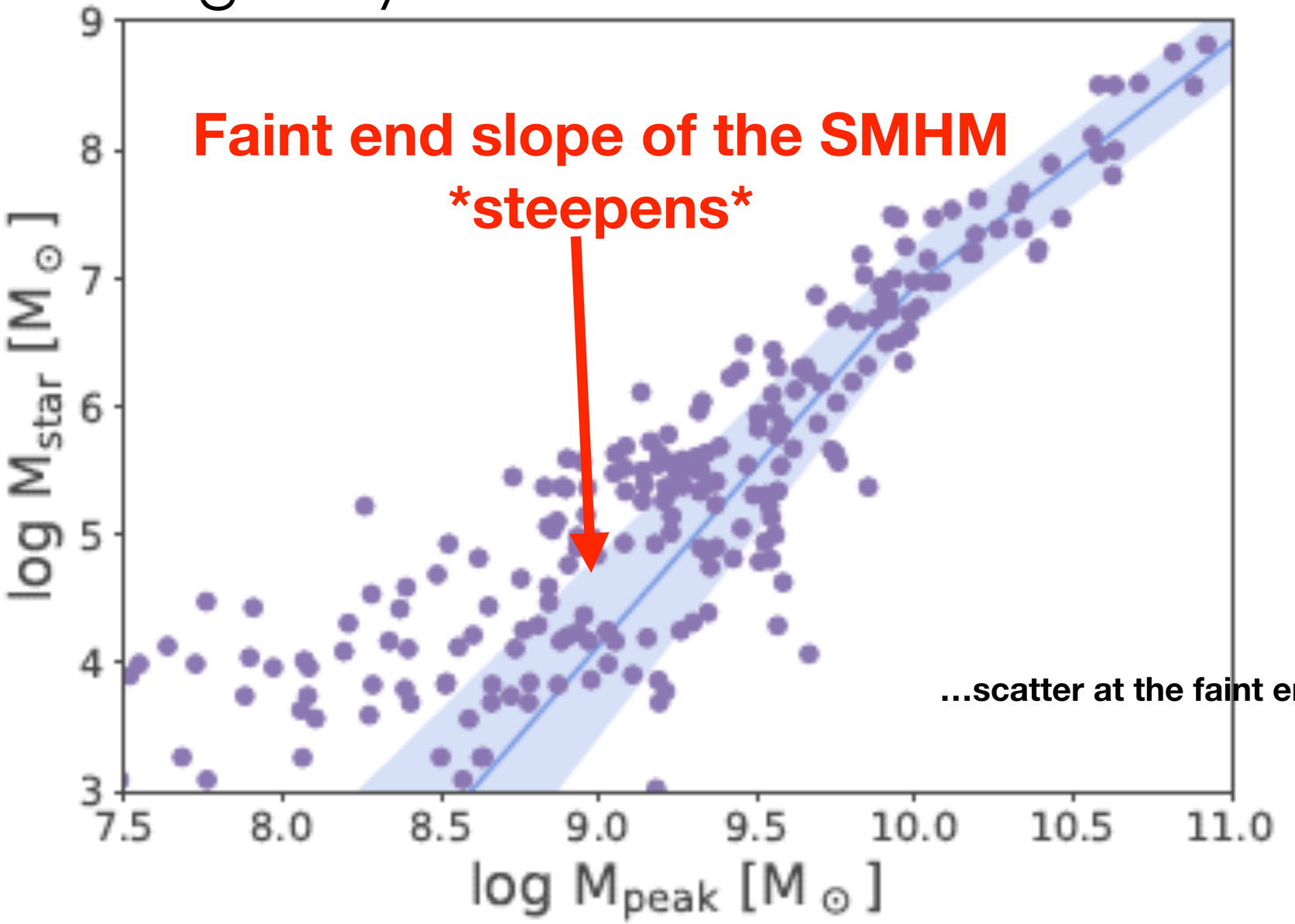
If we assume that halos that are "dark" are actually host a galaxy below our resolution limit..



…scatter at the faint end remains similar

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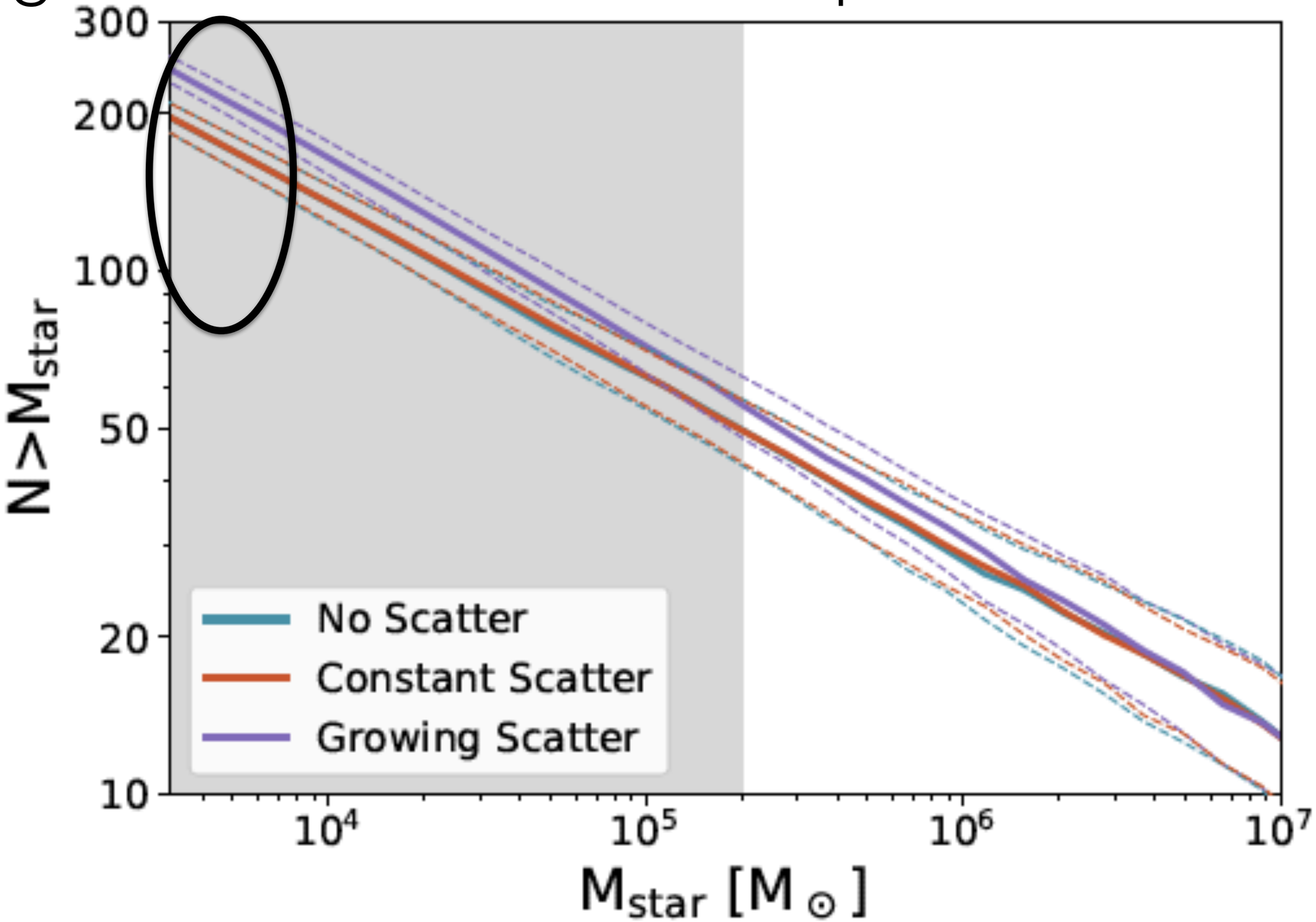
Growing Scatter in the SMHM steepens the faint-end SMF!



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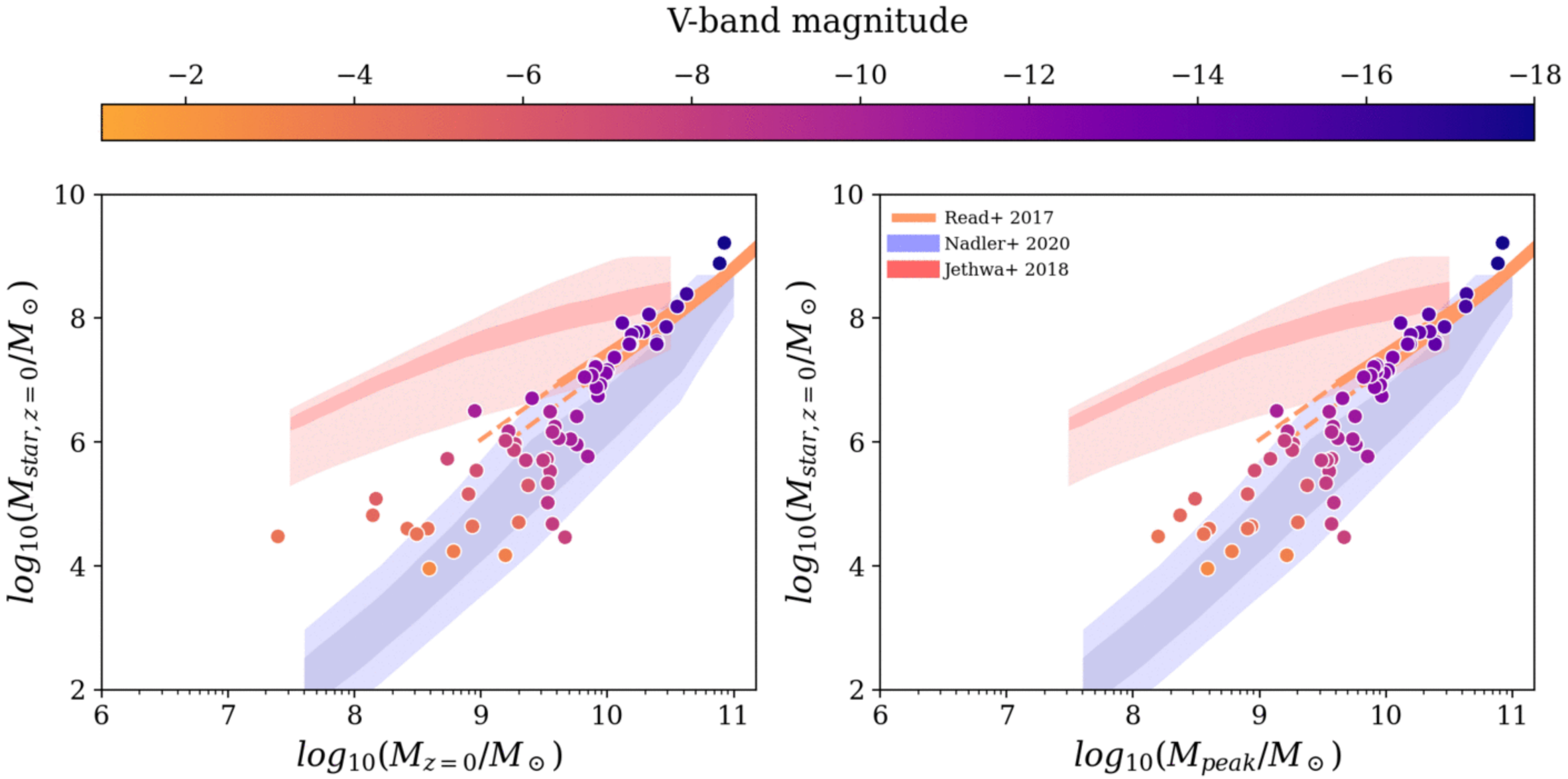
What have we learned so far?

1. There is uncertainty in estimating the abundance of ultra-faint dwarfs because of subgrid models
2. There is no one-to-one relationship between stellar and halo mass below 10^{10} M_{sun}- the scatter grows to ~1 dex at the faintest end we can probe.
3. Both scatter and uncertainty in subgrid models contribute to different predictions for the predicted SMF at low masses. Uncertainty in subgrid physics dominates.

A hint toward what is next…



All the small things!

- With *exquisite resolution* in MARVEL and DC Justice League: can constraint ultra-faint galaxy formation, scatter in stellar-to-halo mass relationship, dark matter** make predictions for Rubin Observatory, Roman Space Telescope and JWST

**more on this in Alyson's talk (probably Risa's & Annika's too!)

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