Understanding Dwarf Galaxies in order to Understand Dark Matter

Hot gas explodes out of young dwarf galaxies

Simulation by **Andrew Pontzen**, **Fabio Governato** and **Alyson Brooks** on the **Darwin Supercomputer**, Cambridge UK.

Simulation code **Gasoline** by **James Wadsley** and **Tom Quinn** with metal cooling by **Sijing Sheng**.

Visualization by **Andrew Pontzen**.

Alyson Brooks

Rutgers, the State University of New Jersey

In collaboration with the University of Washington's N-body Shop™
makers of quality galaxies

Starting Assumption:
There is No Small Scale "Crisis"

STARTING ASSUMPTION:
THERE IS NO SMALL SCALE "CRISIS"

	CDM+Baryons	WDM	SIDM
Bulge-less disk galaxies	✓		
The Cusp/ Core Problem	✓		
Missing Dwarfs	✓		
Too Big To Fail	✓		

Starting Assumption:
There is No Small Scale "Crisis"

|	CDM+Baryons	WDM+Baryons	SIDM+Baryons
Bulge-less disk galaxies	✓	✓	✓
The Cusp/Core Problem	✓	✓	✓
Missing Dwarfs	✓	✓	✓
Too Big To Fail	✓	✓	✓

Key Problems

We need baryons in alternative DM models. Is there a smoking gun that points to a given DM model?

Can we understand the formation and evolution of dwarf galaxies in a Vanilla CDM Model?
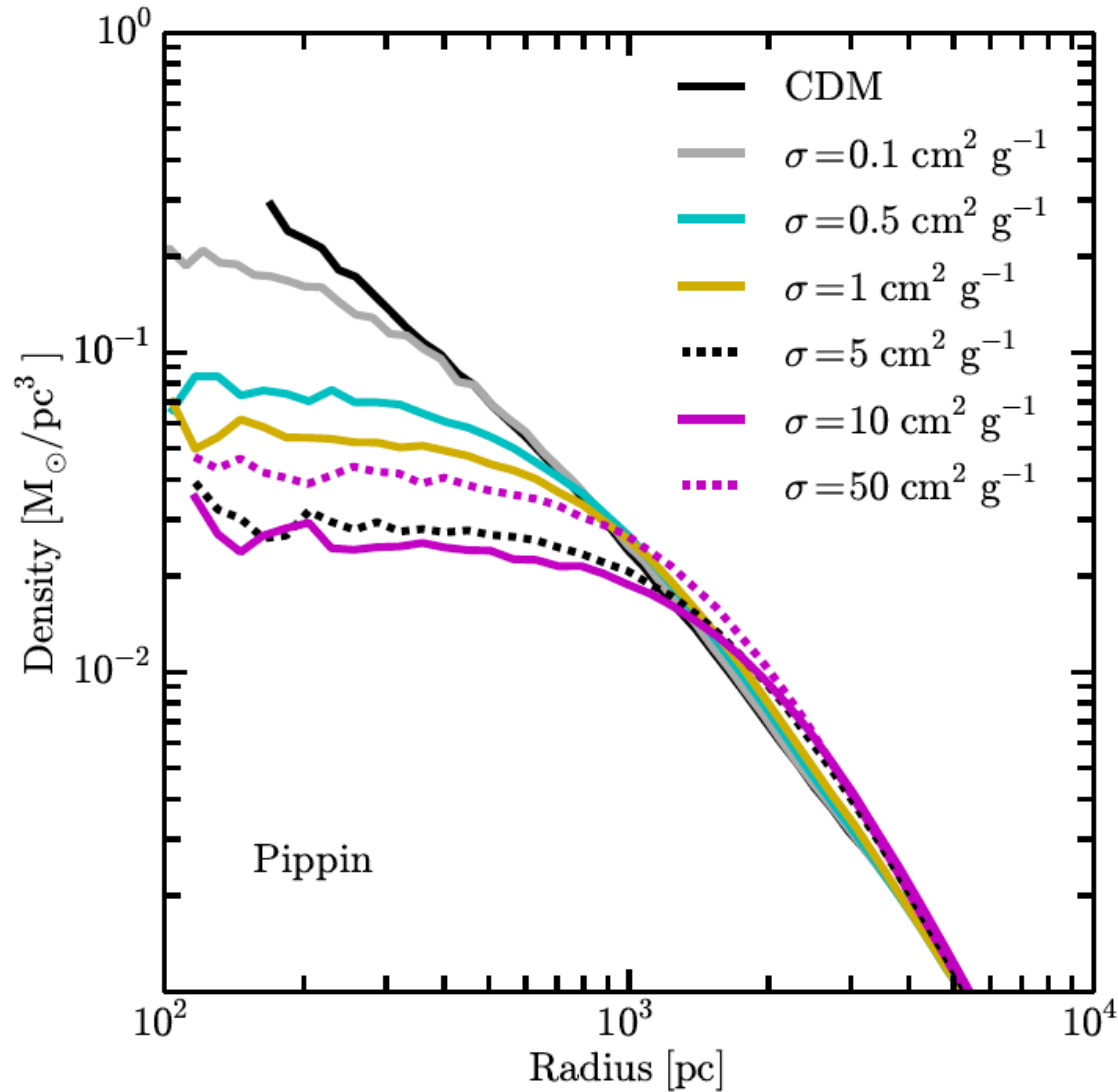
Key Problems

We need baryons in alternative DM models. Is there a smoking gun that points to a given DM model?

Can we understand the formation and evolution of dwarf galaxies in a Vanilla CDM Model?

LEARNING ABOUT DM FROM ULTRA-FAINT DWARFS

Lovell et al. (2017)
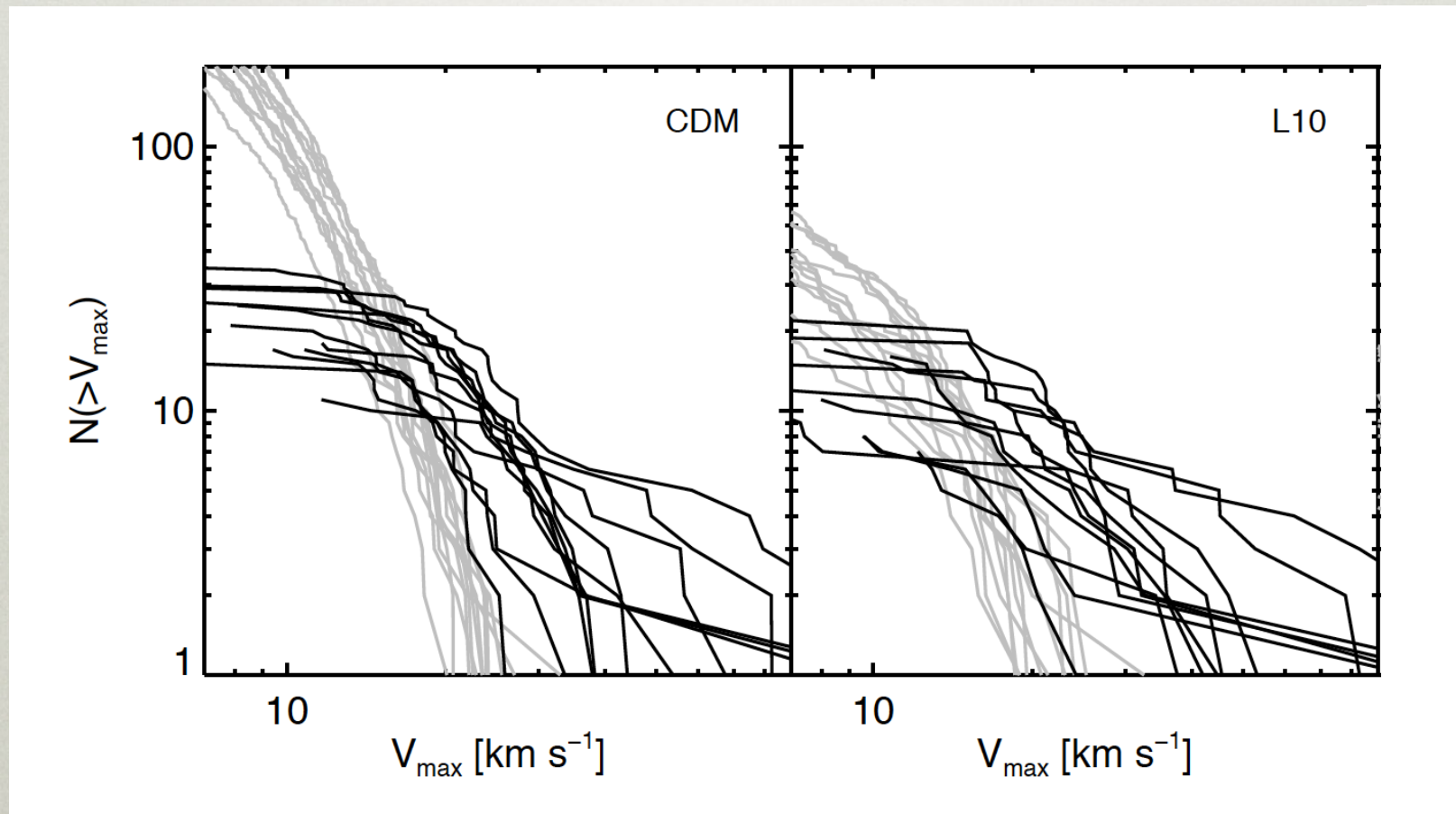
A Testable Prediction of delayed structure formation

Governato et al. (2014)
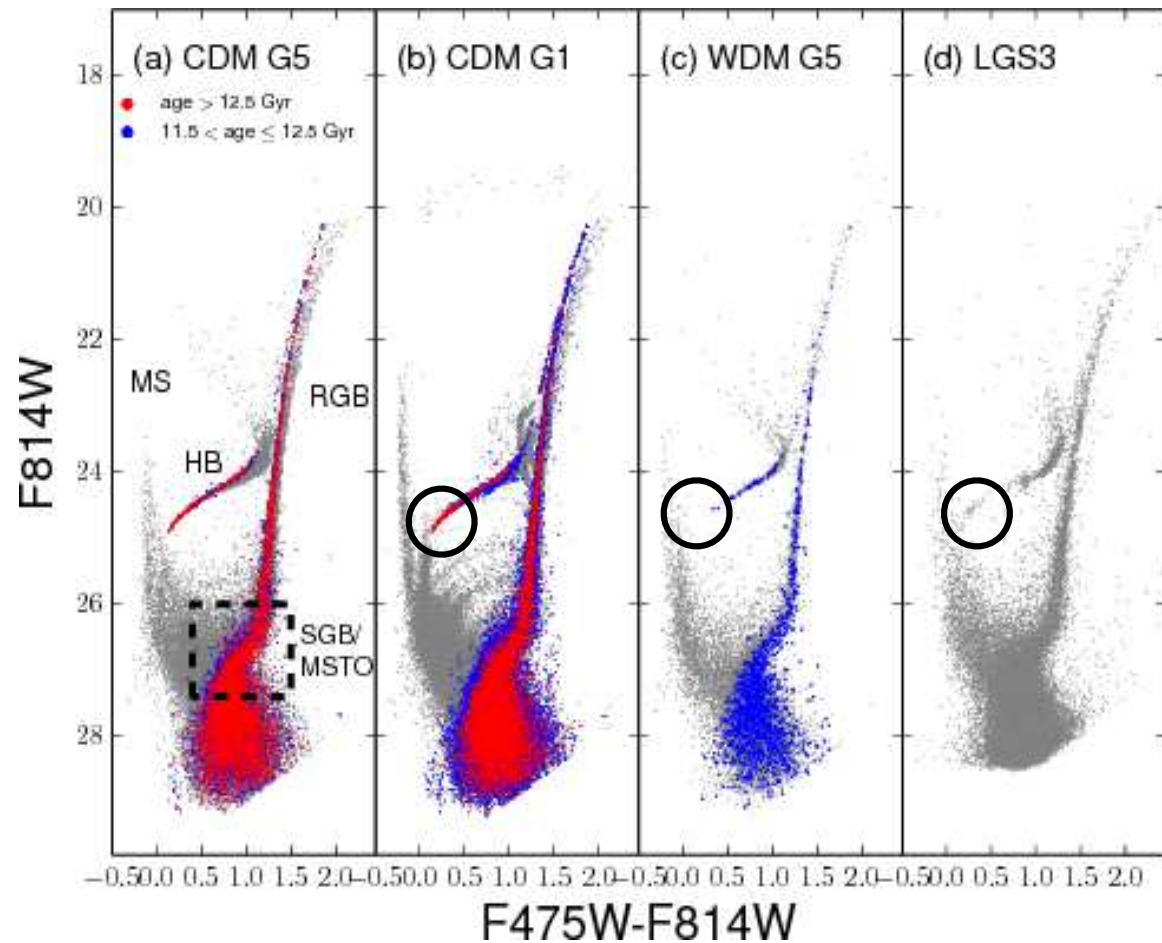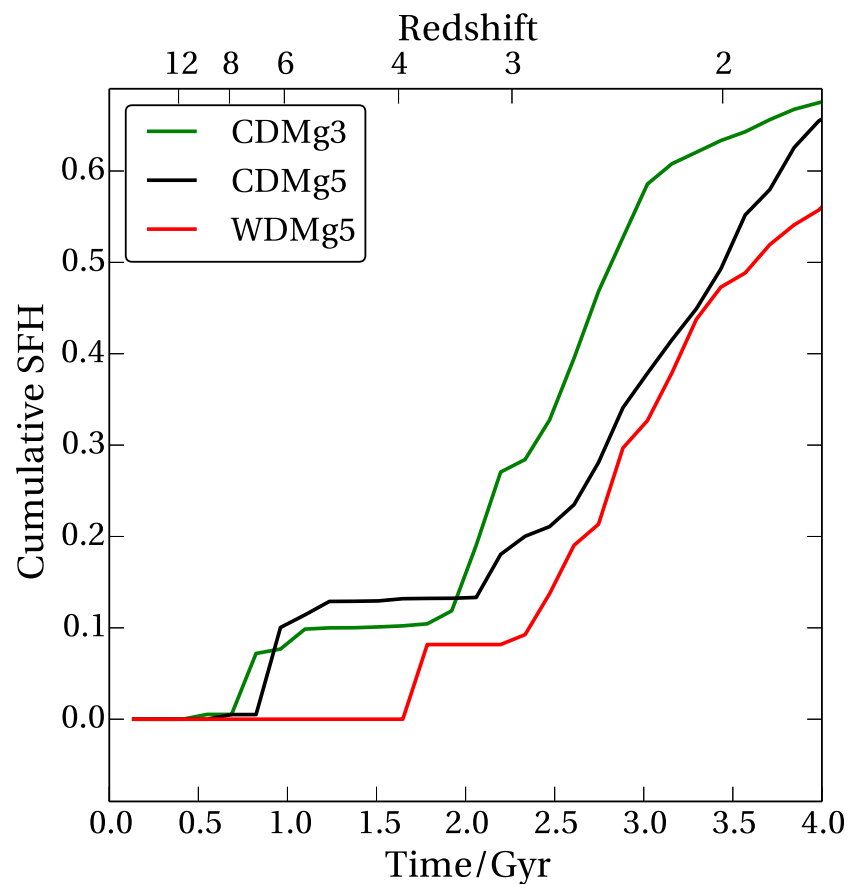
SIDM: the Constraints Are Weakening

results for
a 9x10⁹ M_sun halo

Elbert et al. (2015)
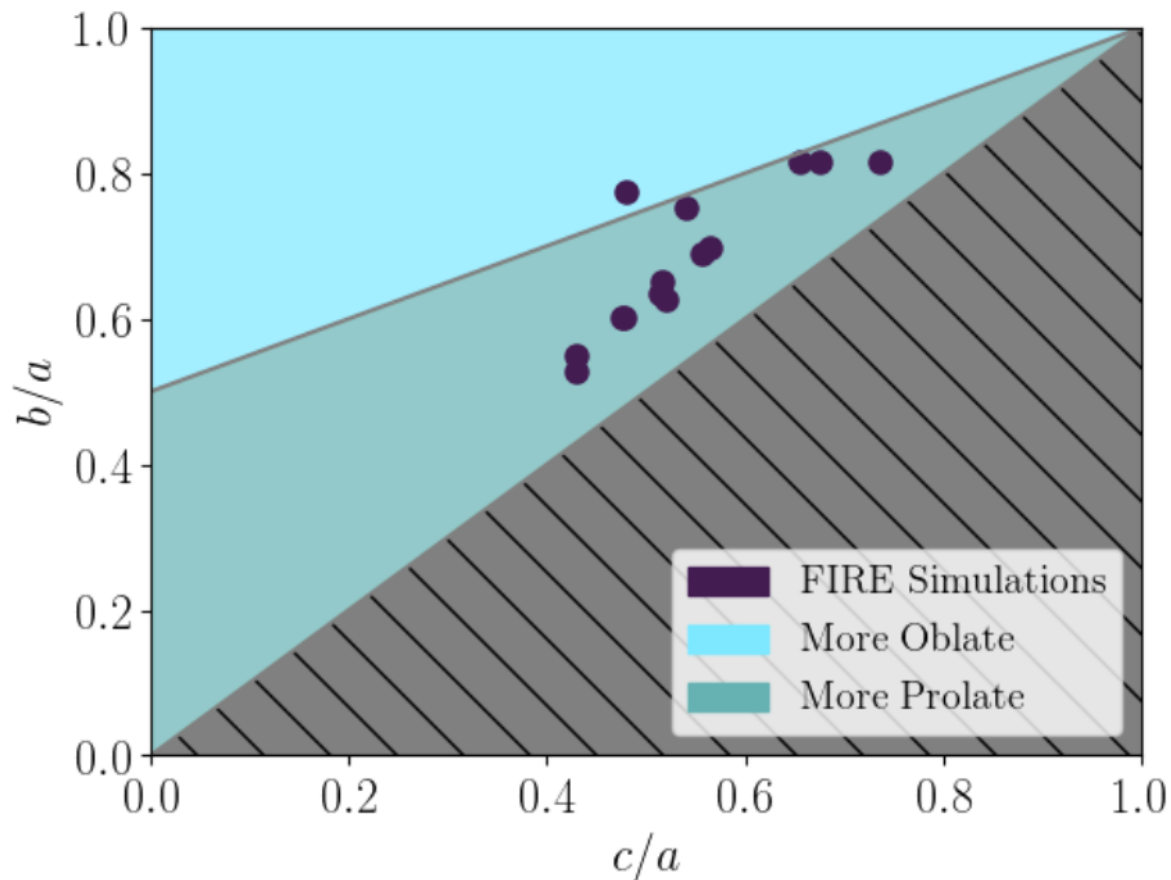
But... baryons win

Bastidas-Fry et al. (2015)
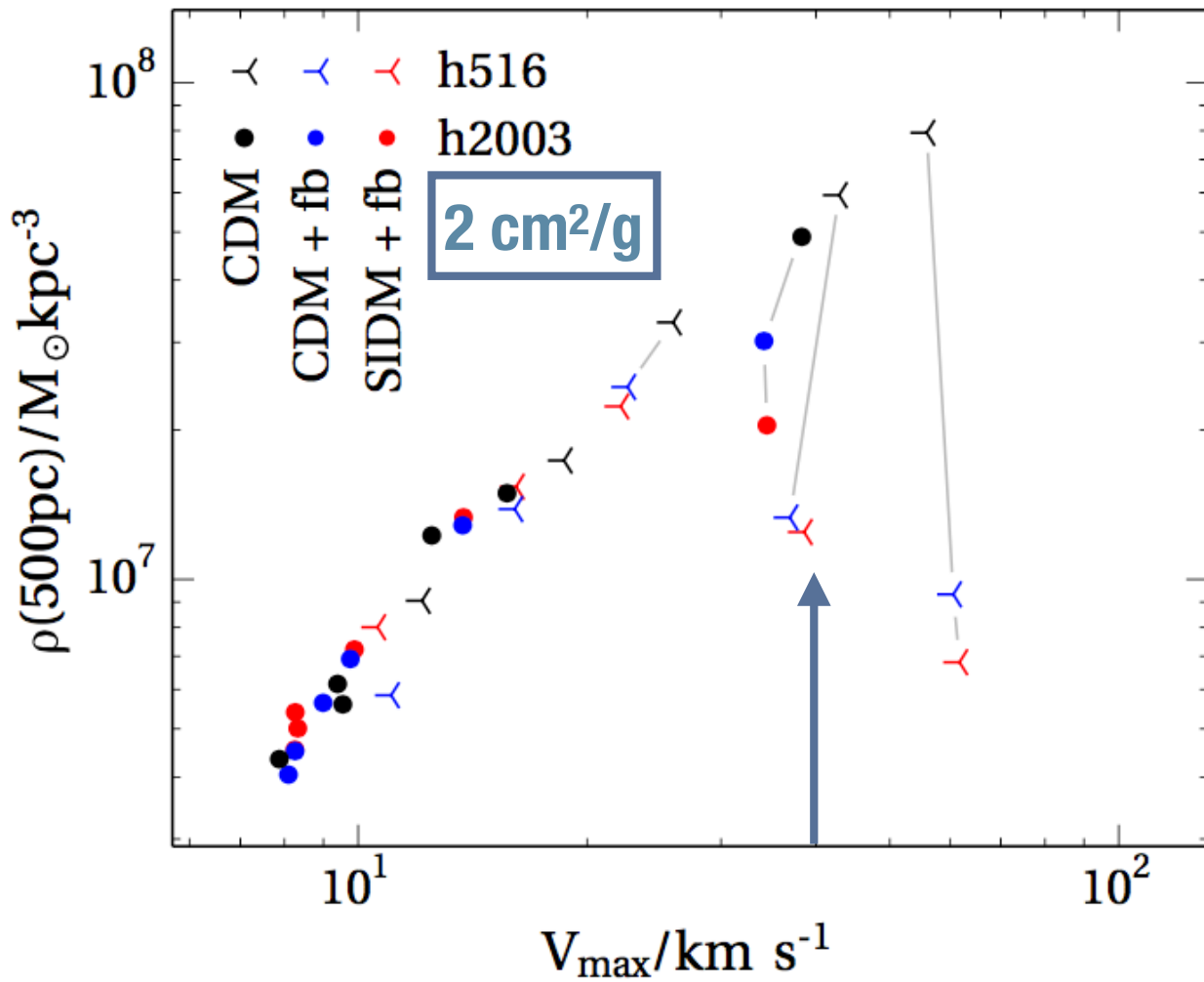
Learning about DM from Ultra-Faint Dwarfs

If galaxies in this mass range are observed to have large cores, then something beyond CDM is necessary

Pontzen & Governato (2014)

LEARNING ABOUT DM FROM ULTRA-FAINT DWARFS

(a) Distribution of stellar axis ratios b/a, c/a evaluated at half-light. As shown, the FIRE galaxies are largely prolate in stellar distribution
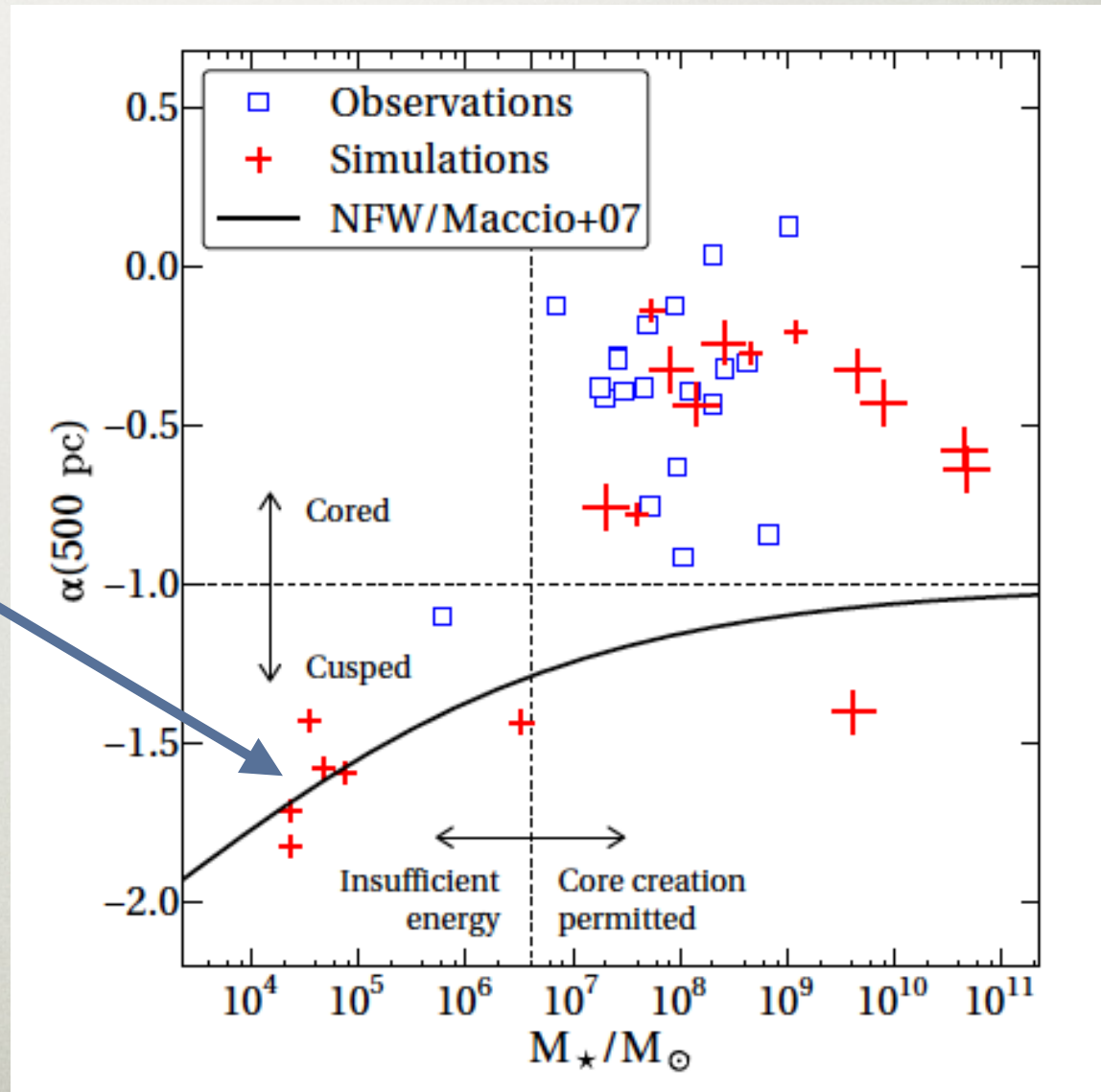
Large cores should affect the shapes of dwarf galaxies?

Key Problems

We need baryons in alternative DM models. Is there a smoking gun that points to a given DM model?

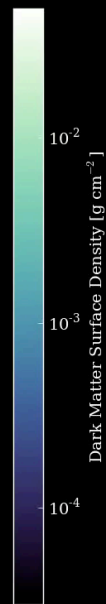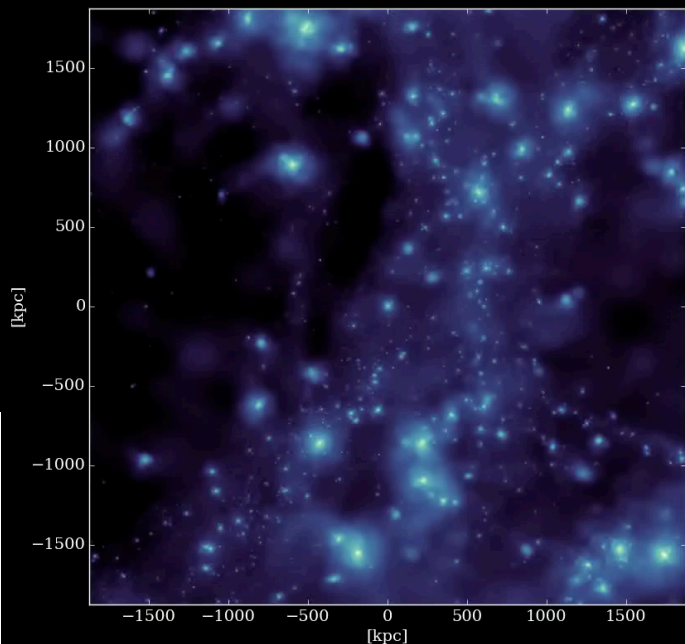Can we understand the formation and evolution of dwarf galaxies in a Vanilla CDM Model?

The Future is Dwarfy
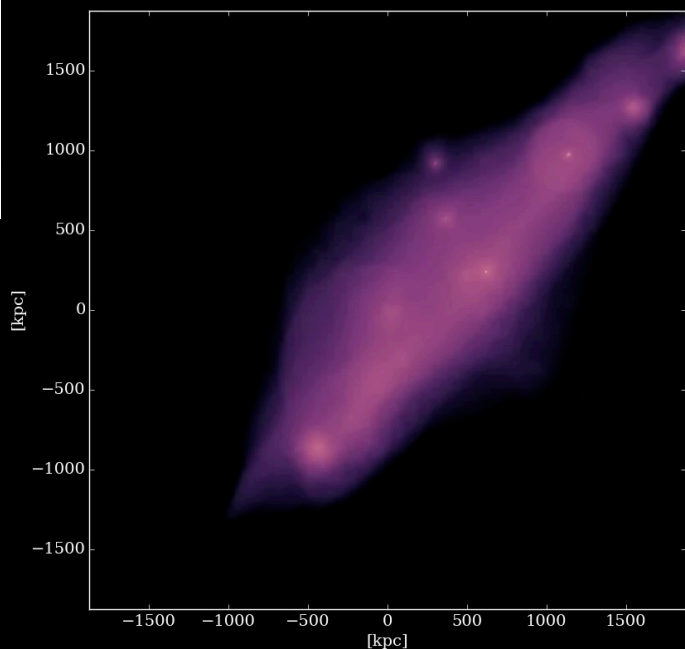

Fainter   Brighter

Tollerud et al. (2009)
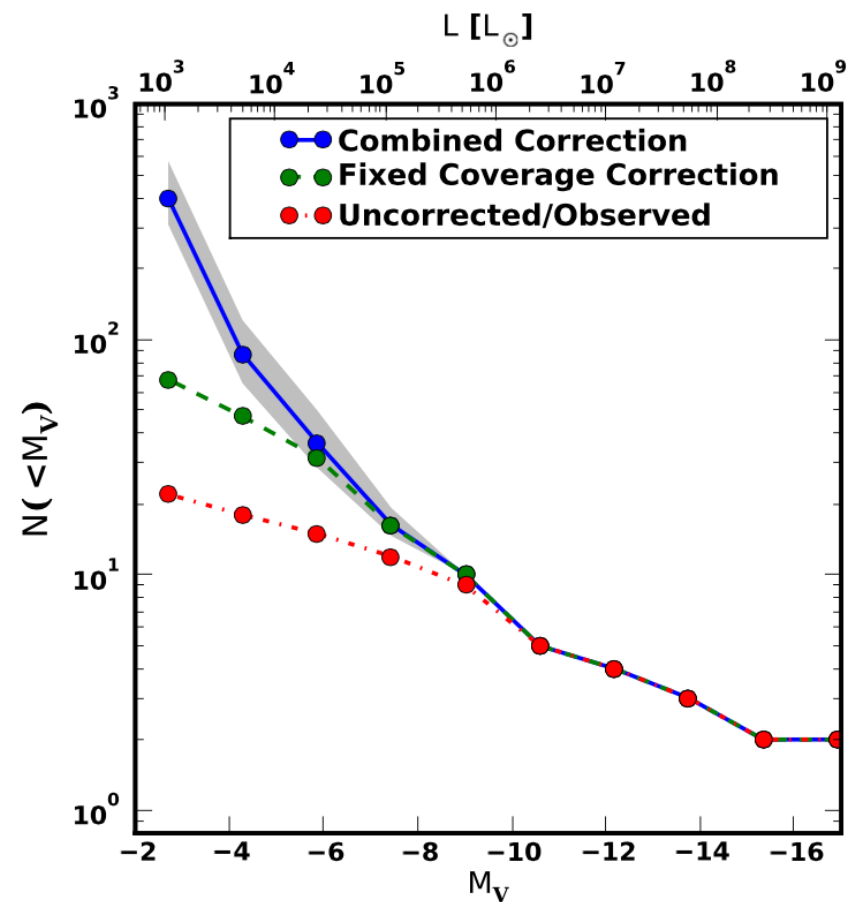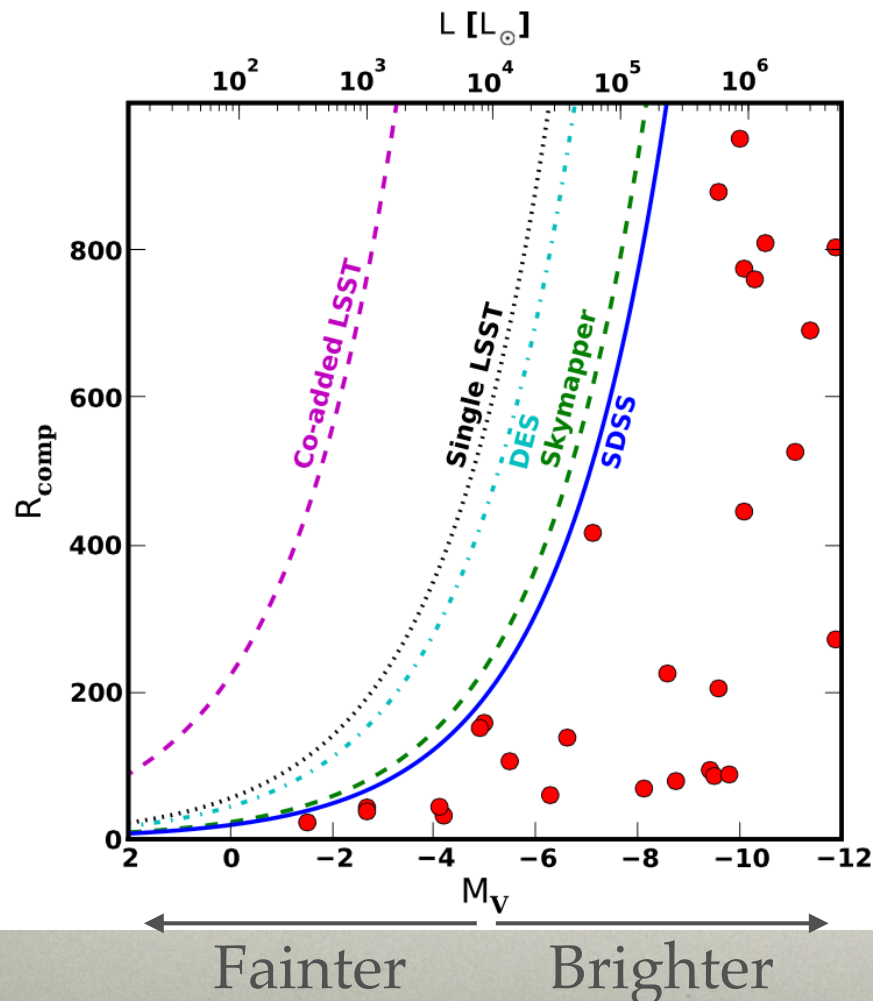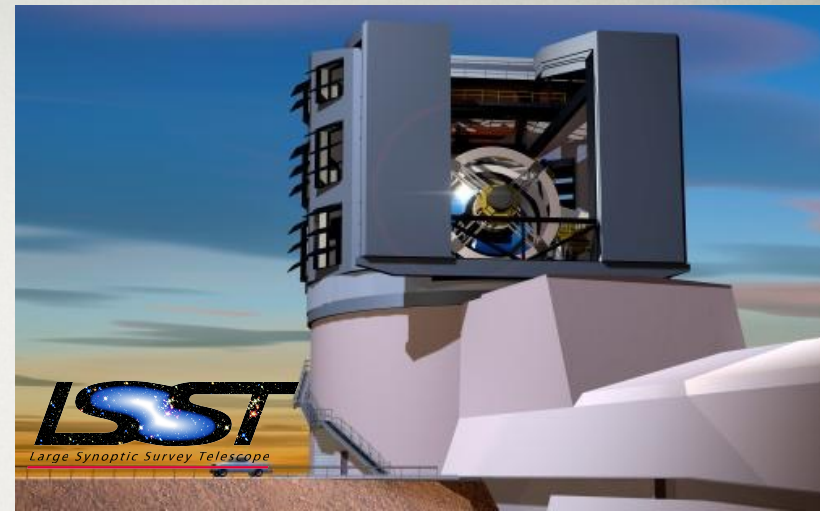
Will We Understand What We Find?

- Lowest mass halo that contains a galaxy?

- Stellar Mass to Halo Mass? Scatter?

- Occupation fraction?

- Sizes/surface brightness?

- How does the earliest star formation proceed?

z=0 DM density

The Goal:
Hundreds of Simulated
Dwarf Galaxies to Interpret
Local Volume Studies

z=0 Gas density

The Marvel-ous Volumes

Captain Marvel

Elektra

Rogue

Storm

Force resolution: 60pc
SPH resolution: 6pc
M_{star}: 400 Msun
M_{dm}: 6000 Msun
z~129 to 0

Many flavors:
- DM only
- With H2 + Black Holes
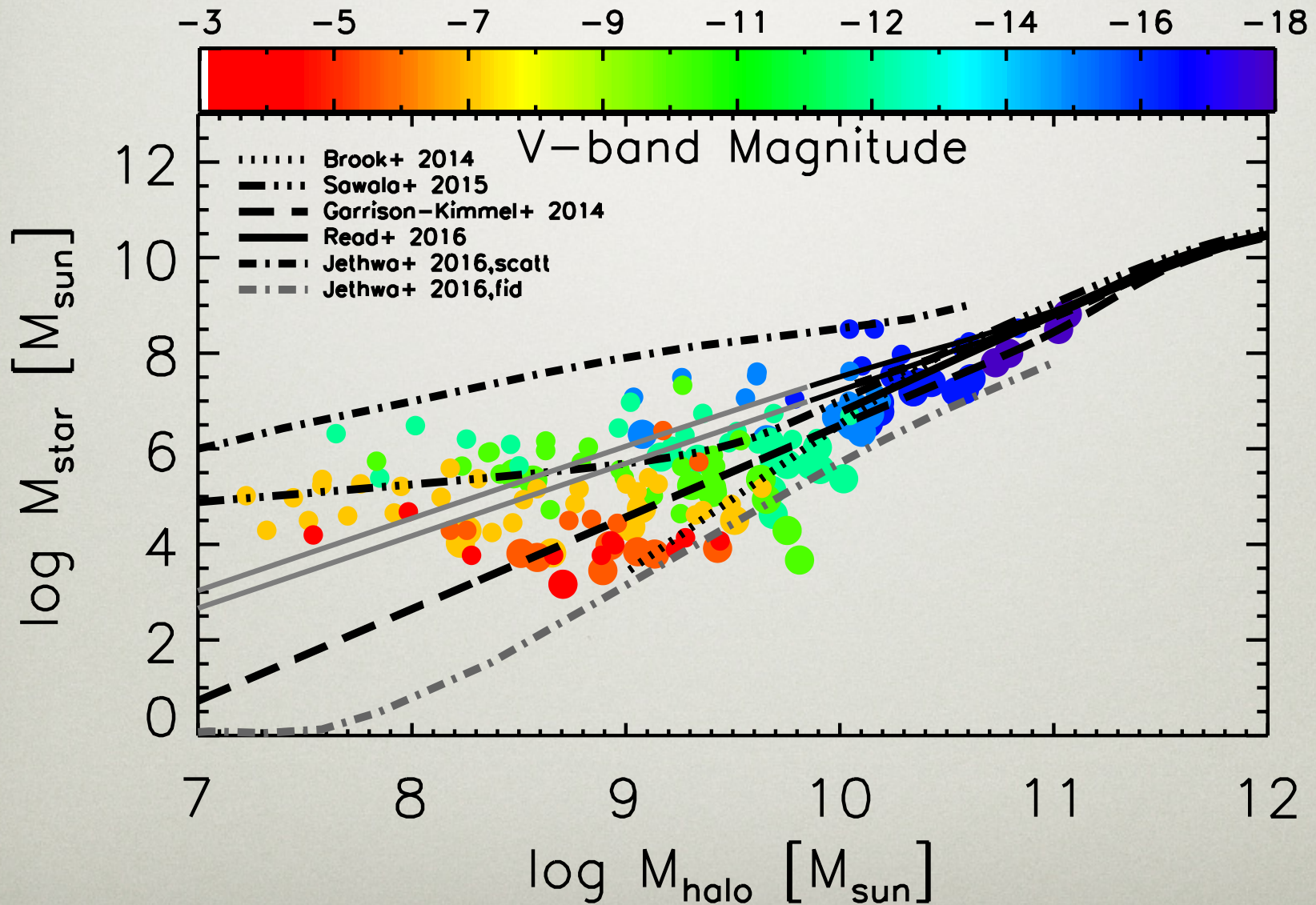- Metal cooling + self shielding
- SIDM

The DC Justice League

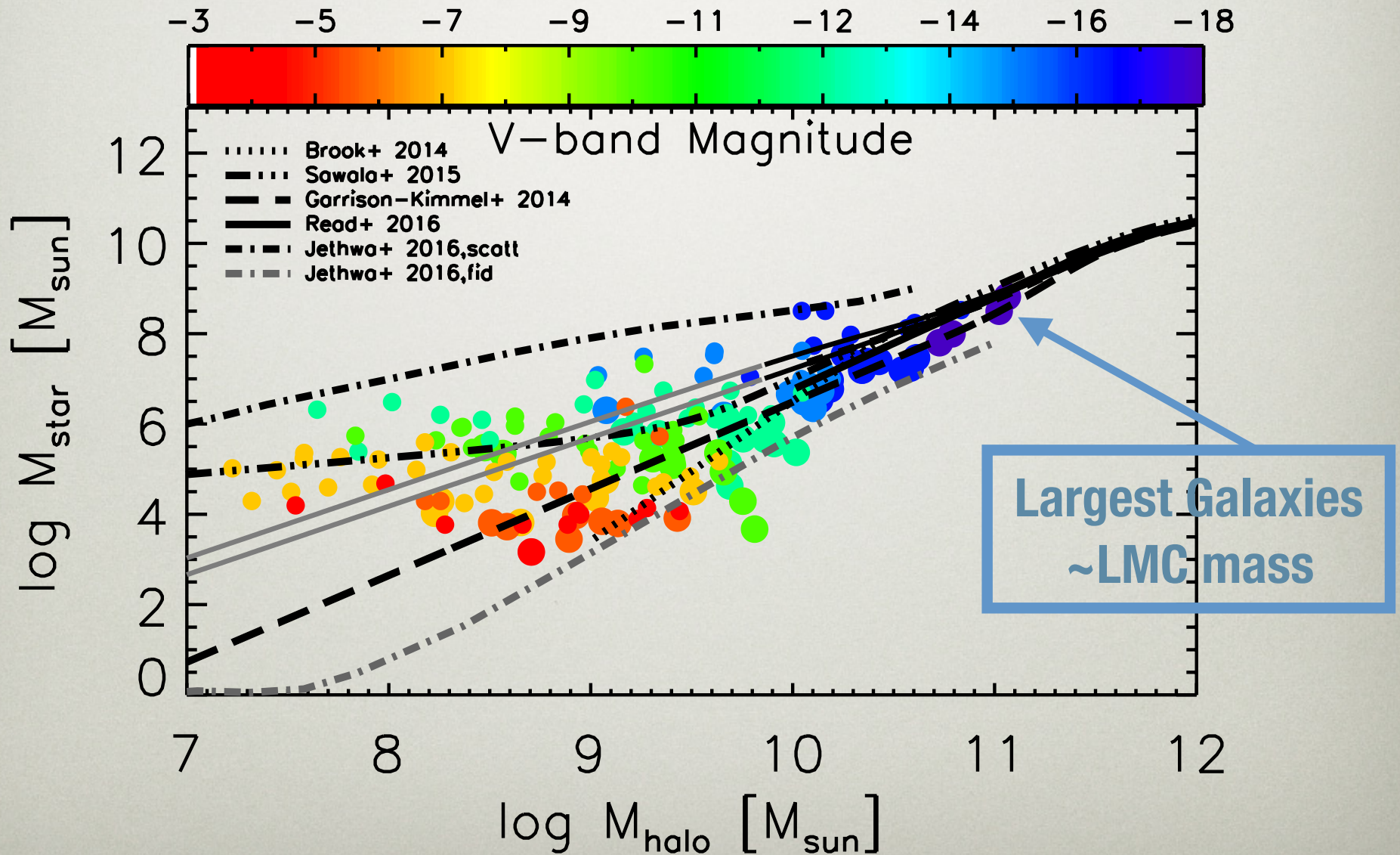## 4 volumes centered on MW-mass halos

Force resolution: 170 & 85pc

SPH resolution: 17 & 9pc

M_{star}: 8000/1000 Msun

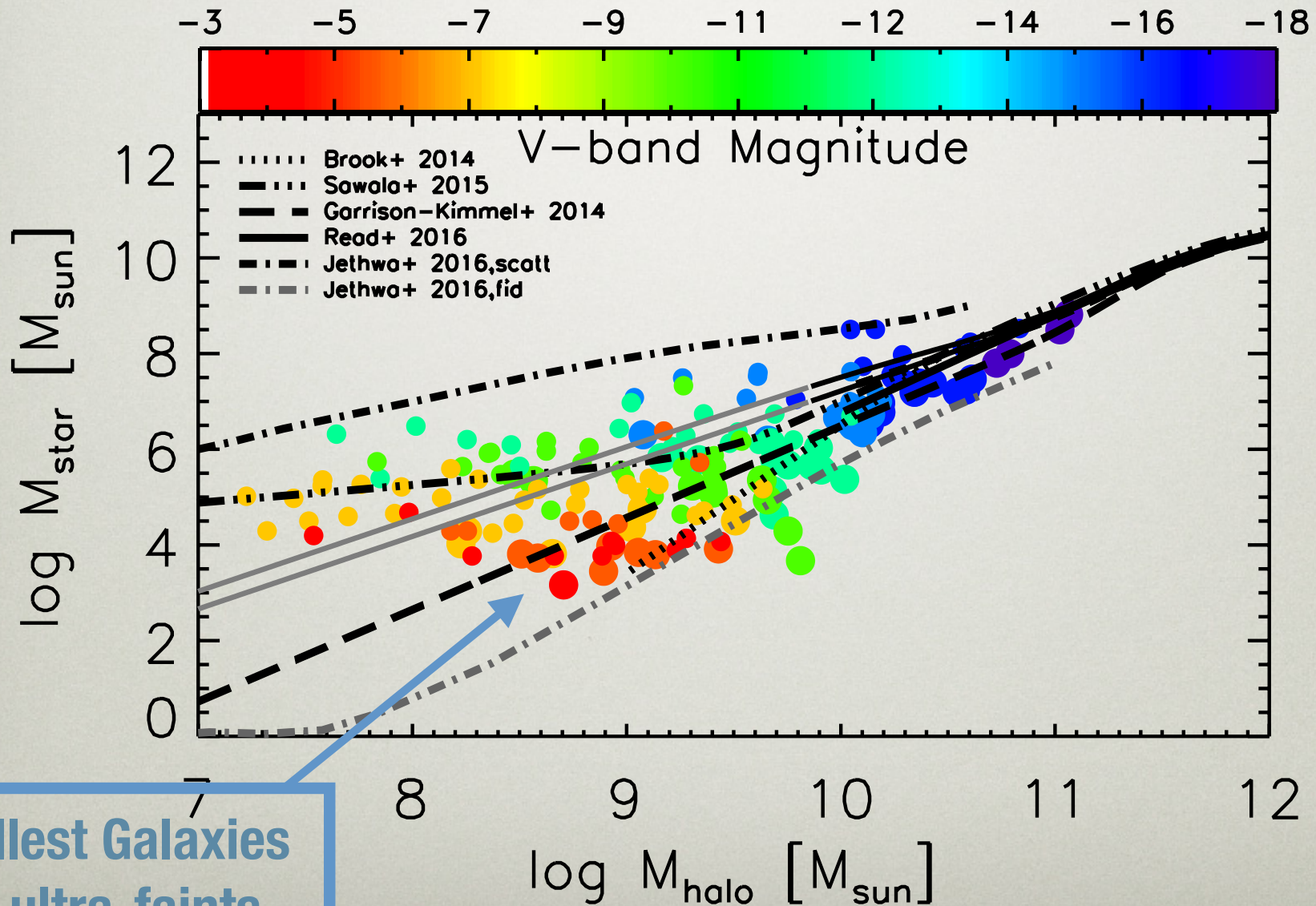M_{dm}: $1.3 \times 10^5 / 1.6 \times 10^4$ Msun

z~to 0

THE STELLAR MASS — HALO MASS RELATION
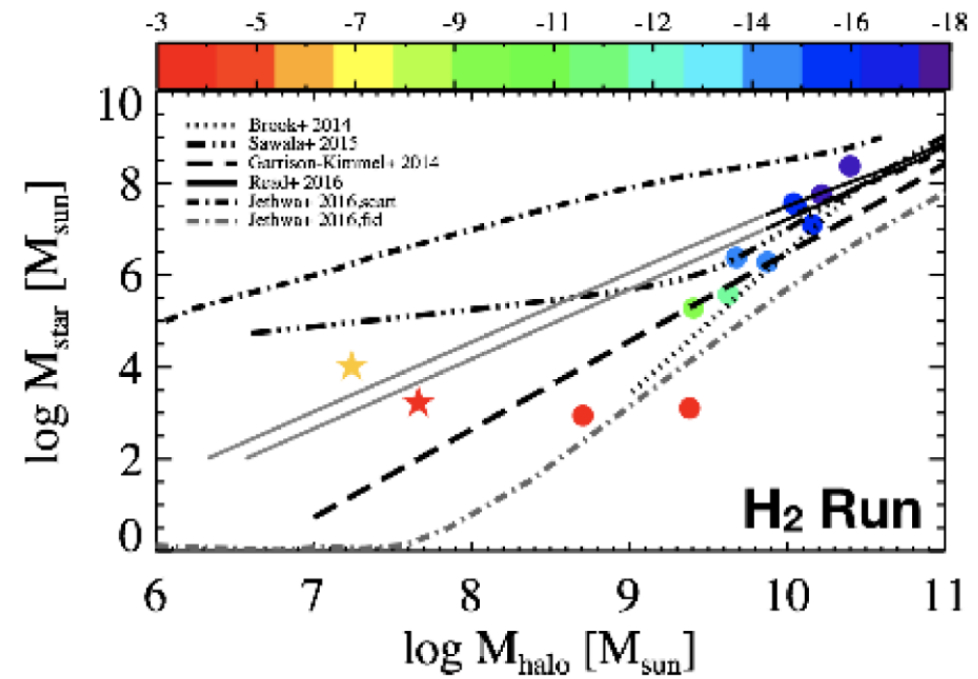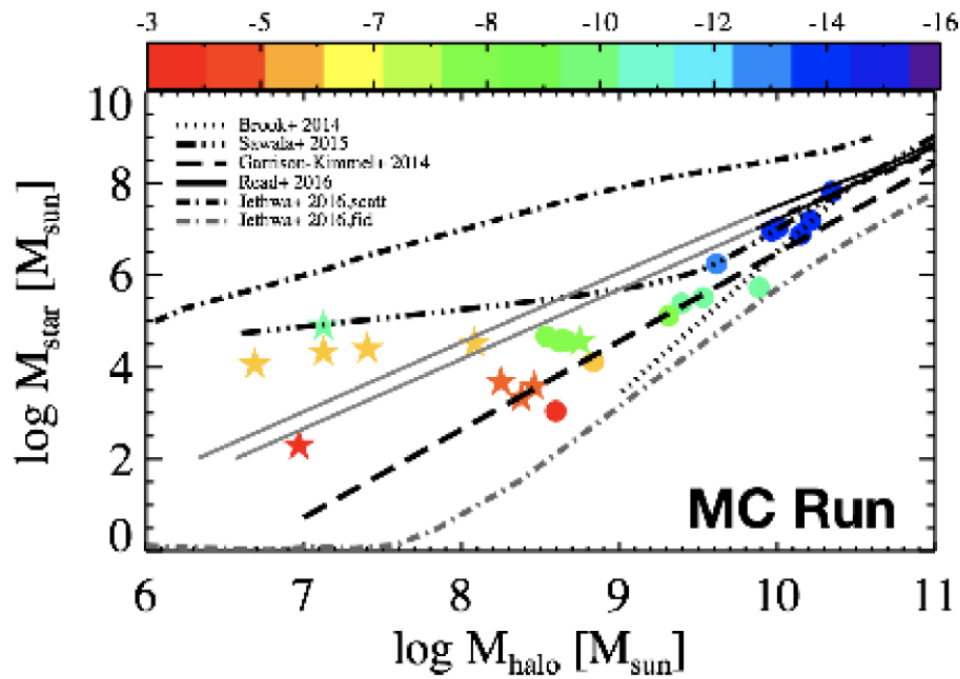
THE STELLAR MASS — HALO MASS RELATION

THE STELLAR MASS — HALO MASS RELATION
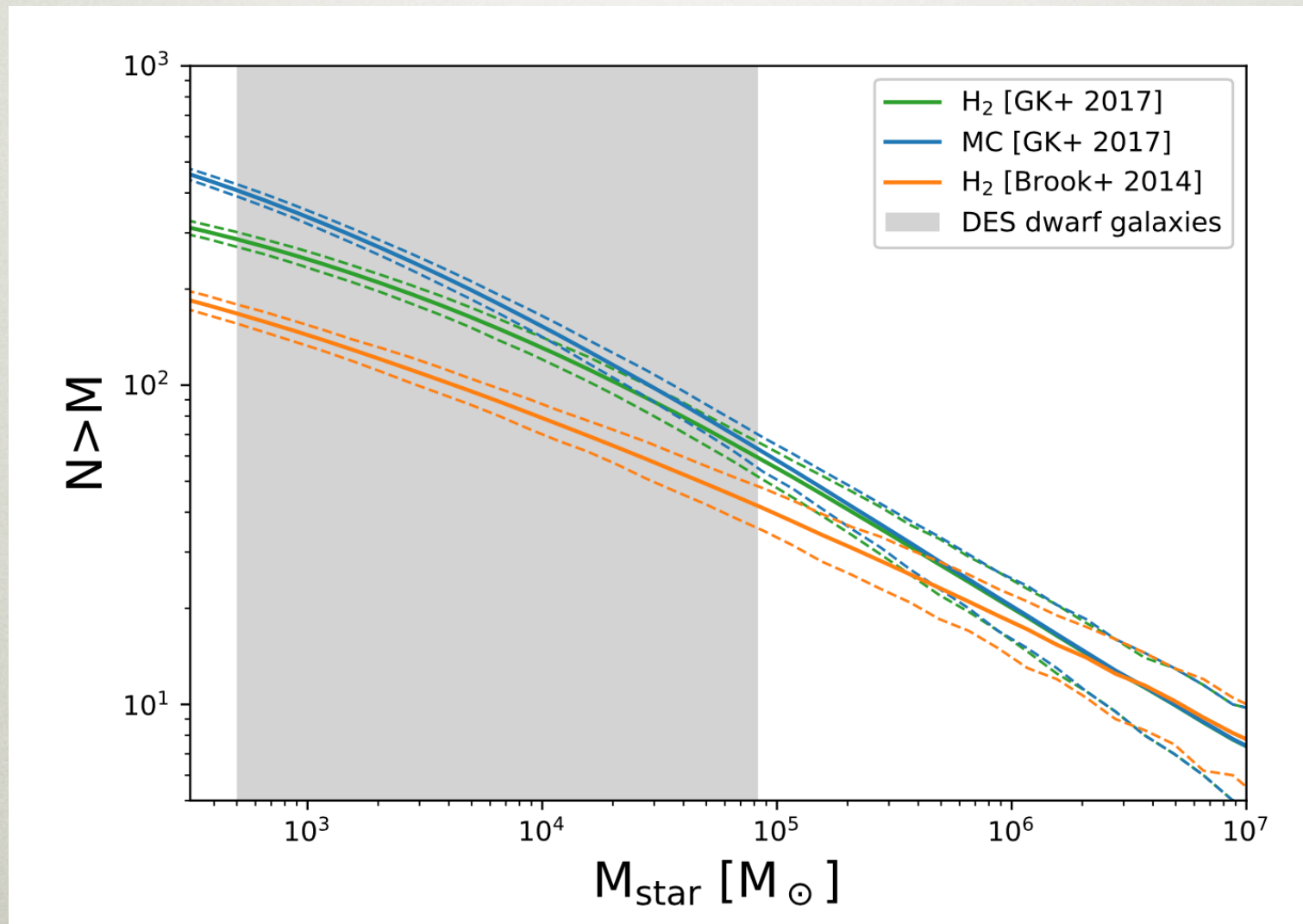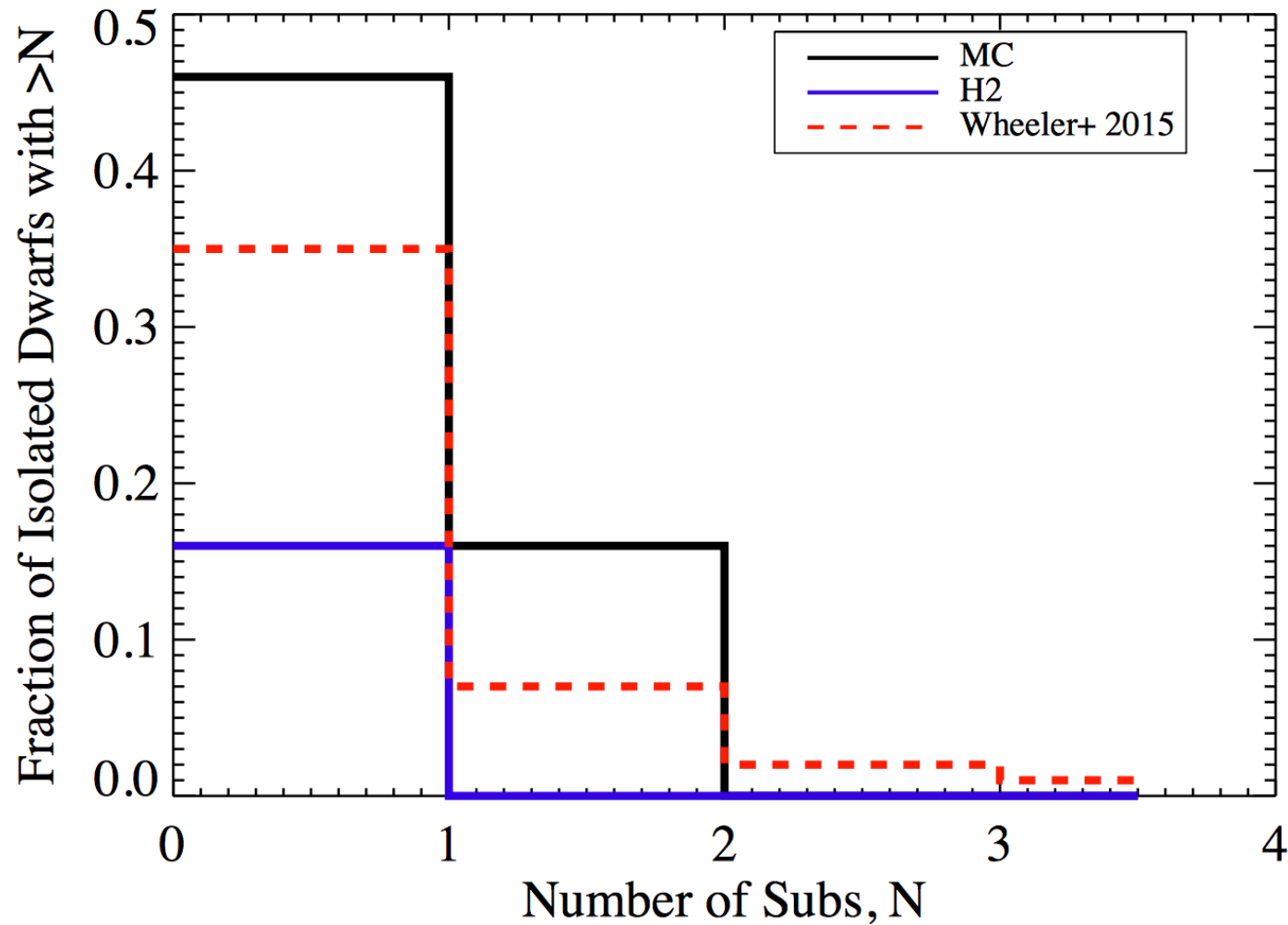
THE ROLE OF STAR FORMATION PRESCRIPTION

THE ROLE OF STAR FORMATION PRESCRIPTION

THE ROLE OF STAR FORMATION PRESCRIPTION

THE DC JUSTICE LEAGUE
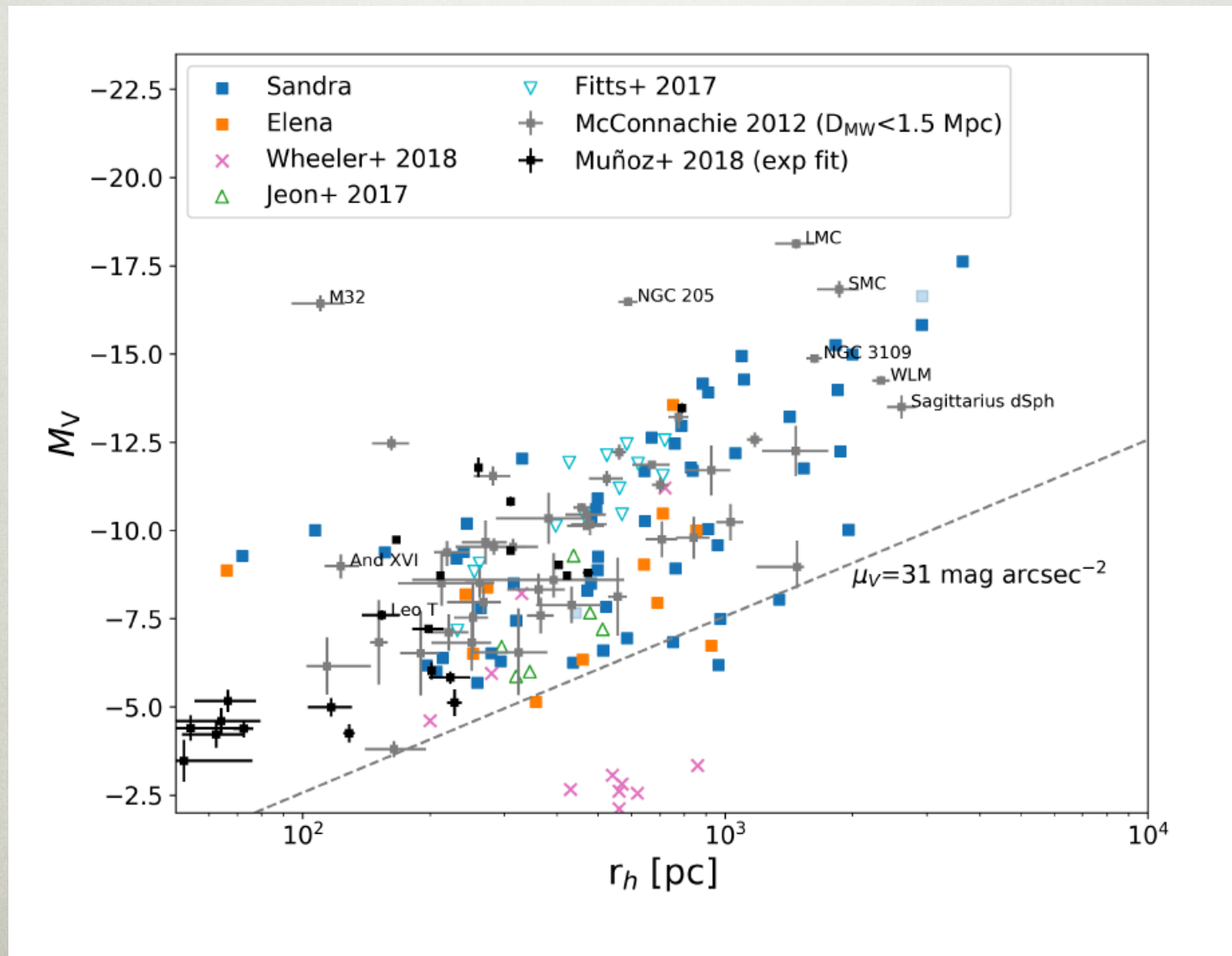
4 volumes centered on MW-mass halos

Force resolution: 170 & 85pc
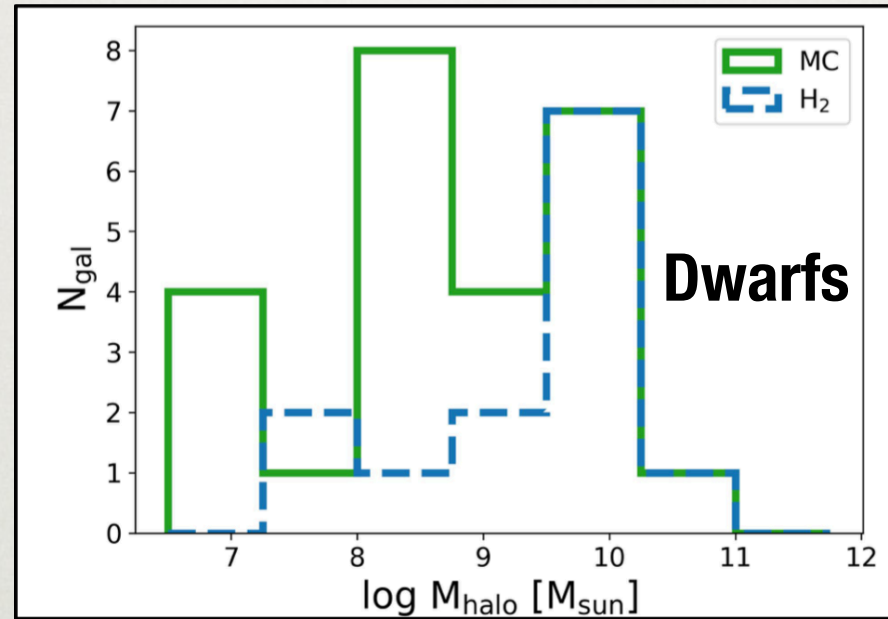
SPH resolution: 17 & 9pc

M_{star}: 8000/1000 Msun

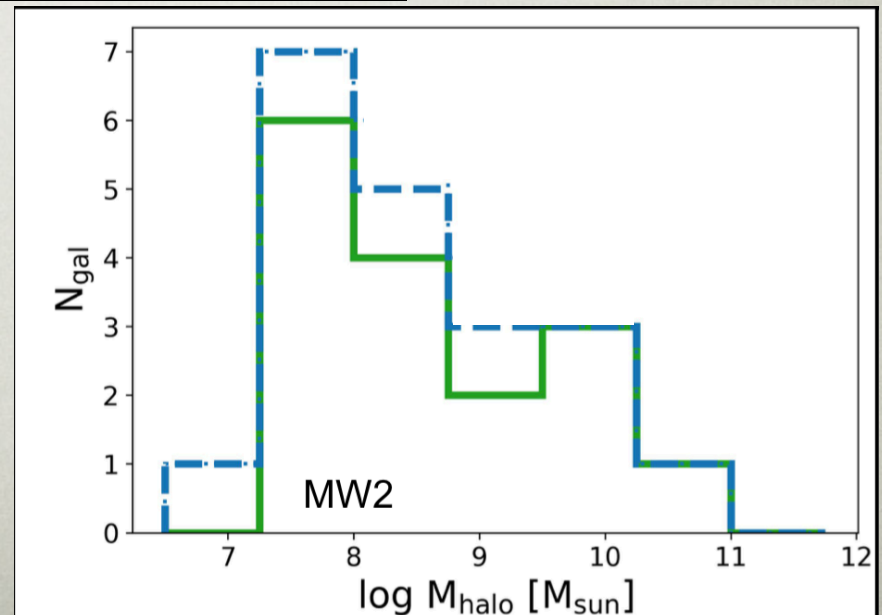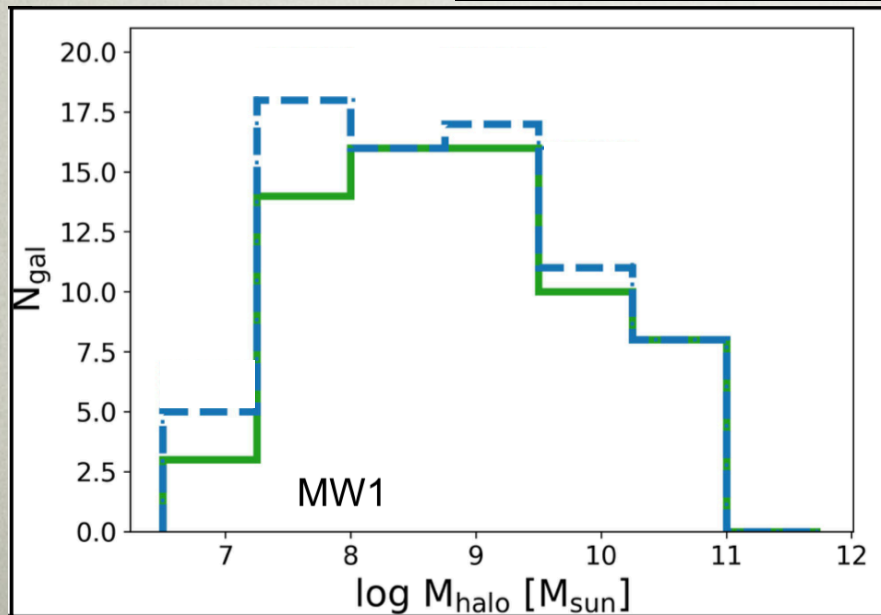M_{dm}: $1.3 \times 10^5 / 1.6 \times 10^4$ Msun

z~to 0

Size-Mass Relations

Unlike Dwarf Environment, no dependence on Star Formation

Dwarfs

i.e., need Milky Way sims to avoid these issues!

Conclusions

To constrain the Dark Matter model, we must understand dwarf galaxy formation!

There is a lot we don't yet understand about modeling the faintest dwarfs! Likely, LSST will guide the modelers

Caveat emptor: simulation prescriptions lead to differing results based on the *environment* the ultra-faint resides in. To understand UFDs around the Milky Way, need Milky Way-mass simulations (challenging!)