

# 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”

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



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## **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?**

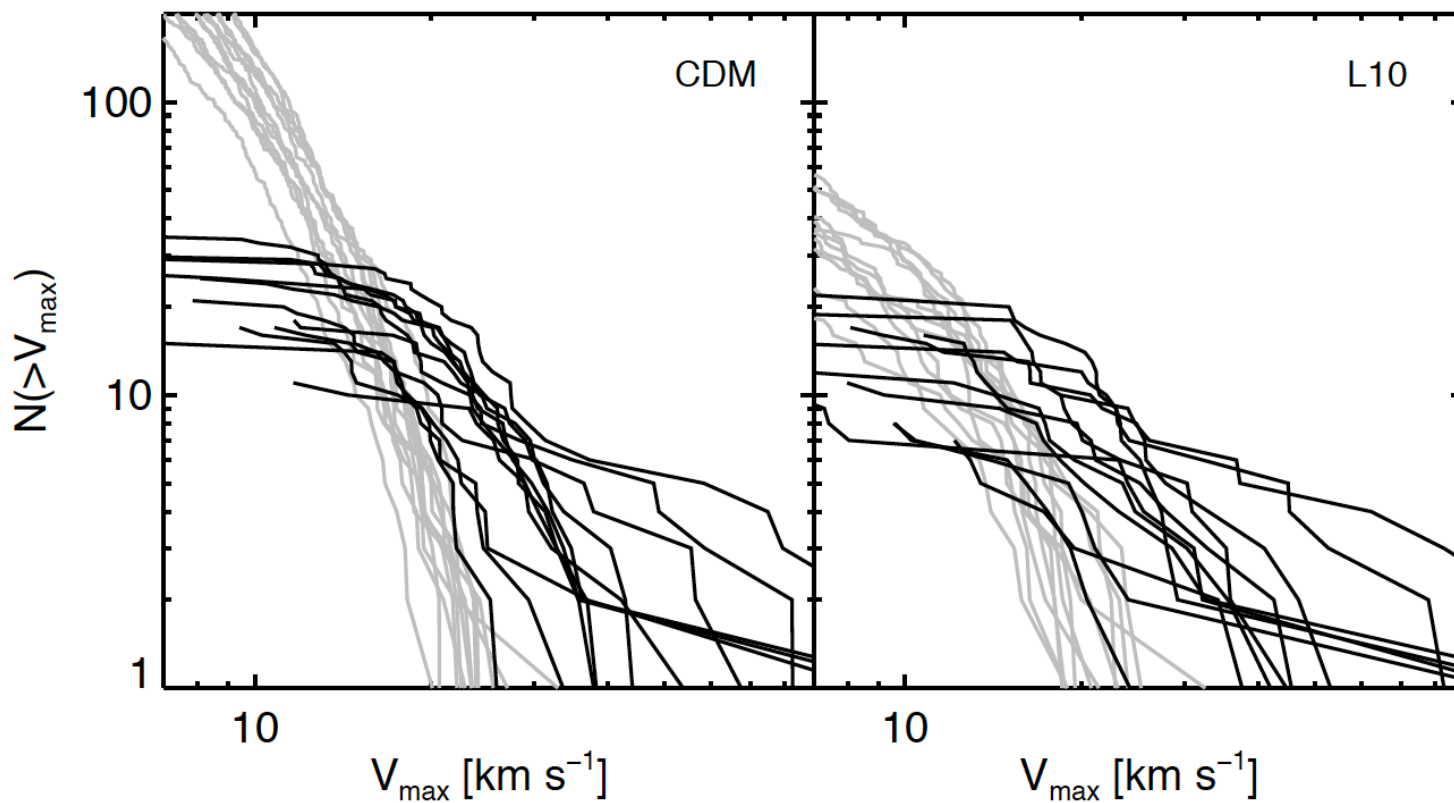


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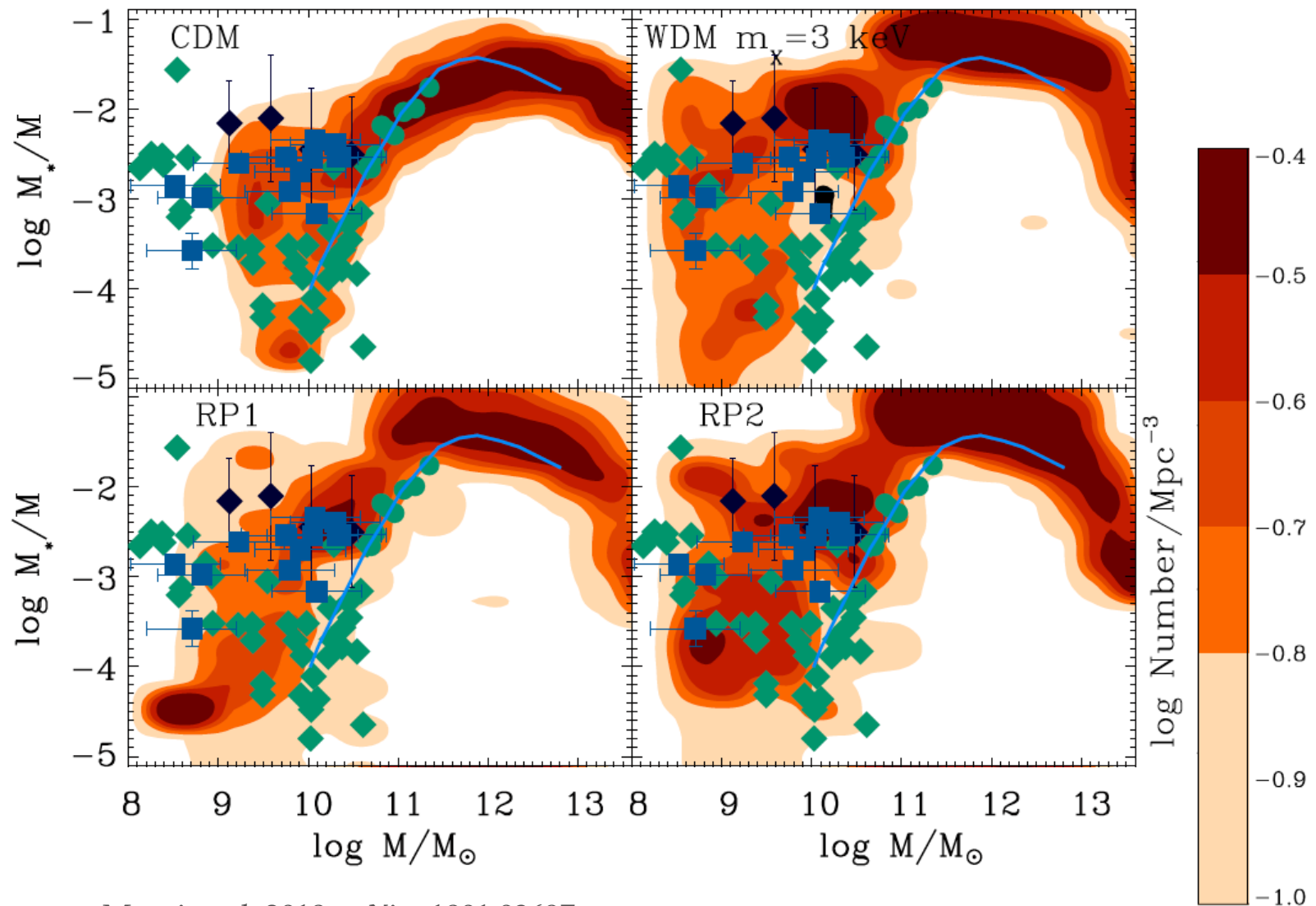
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# LEARNING ABOUT DM FROM ULTRA-FAINT DWARFS

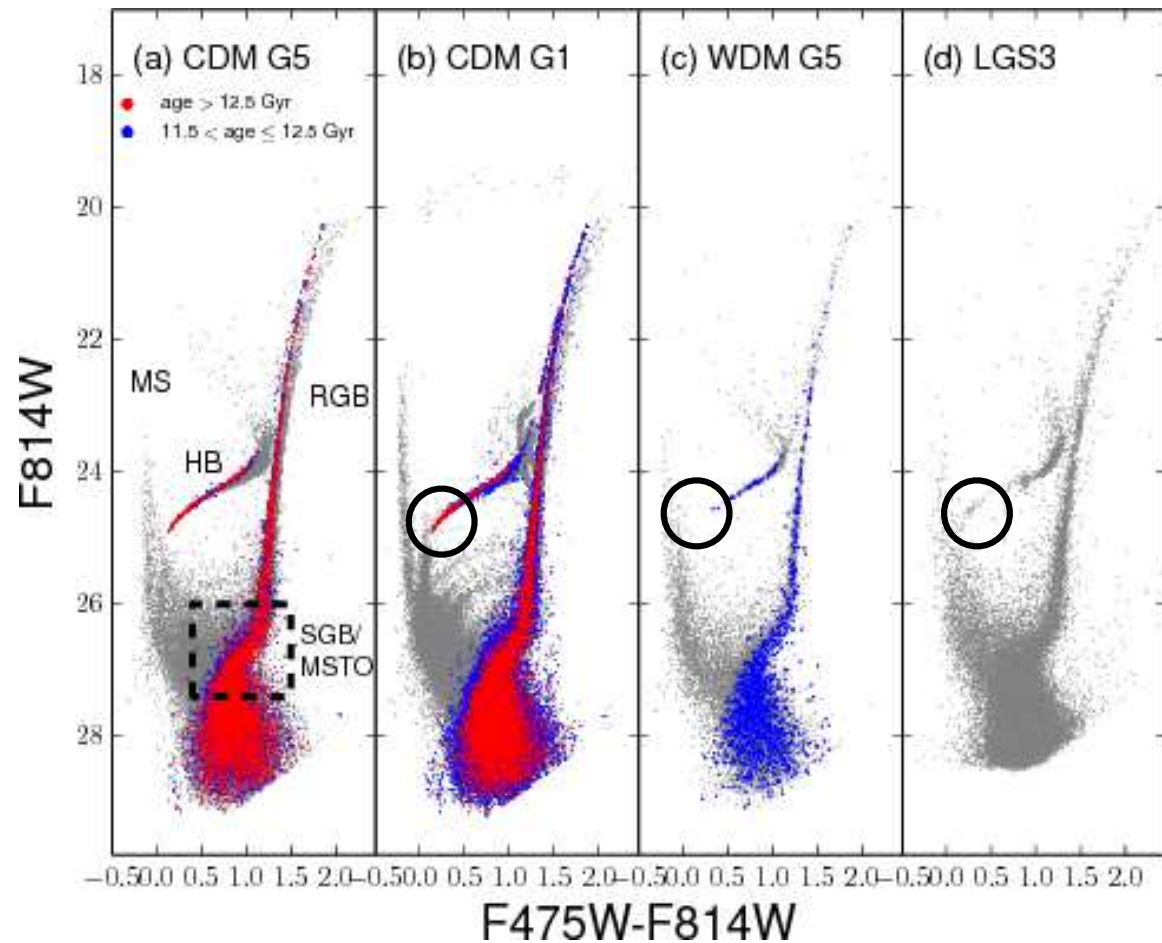
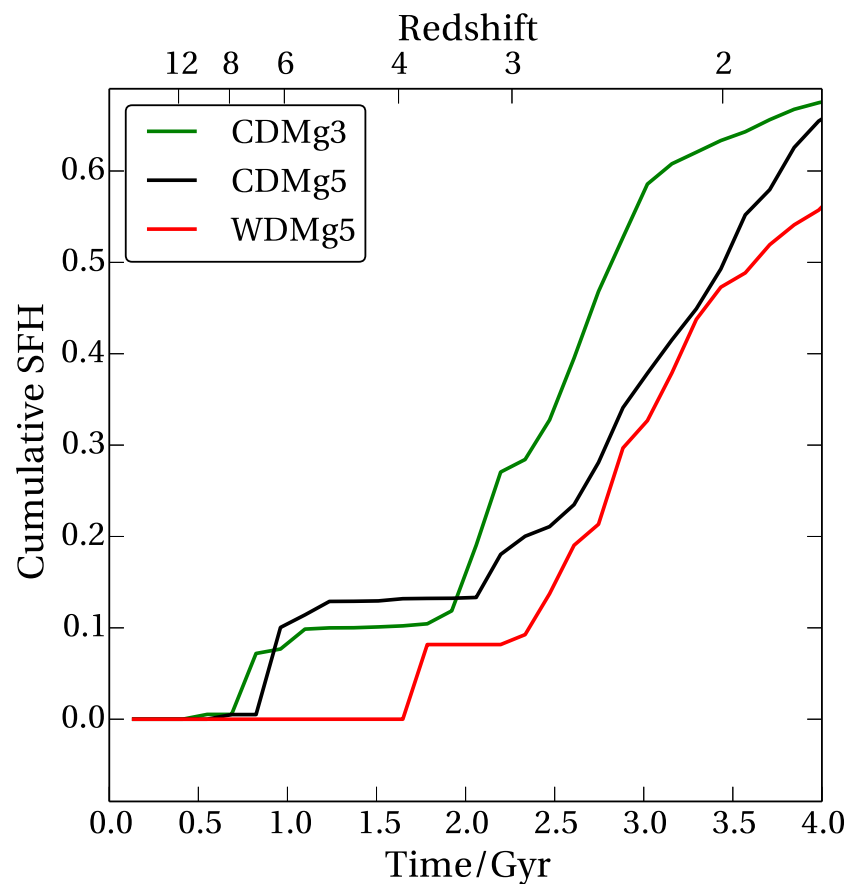




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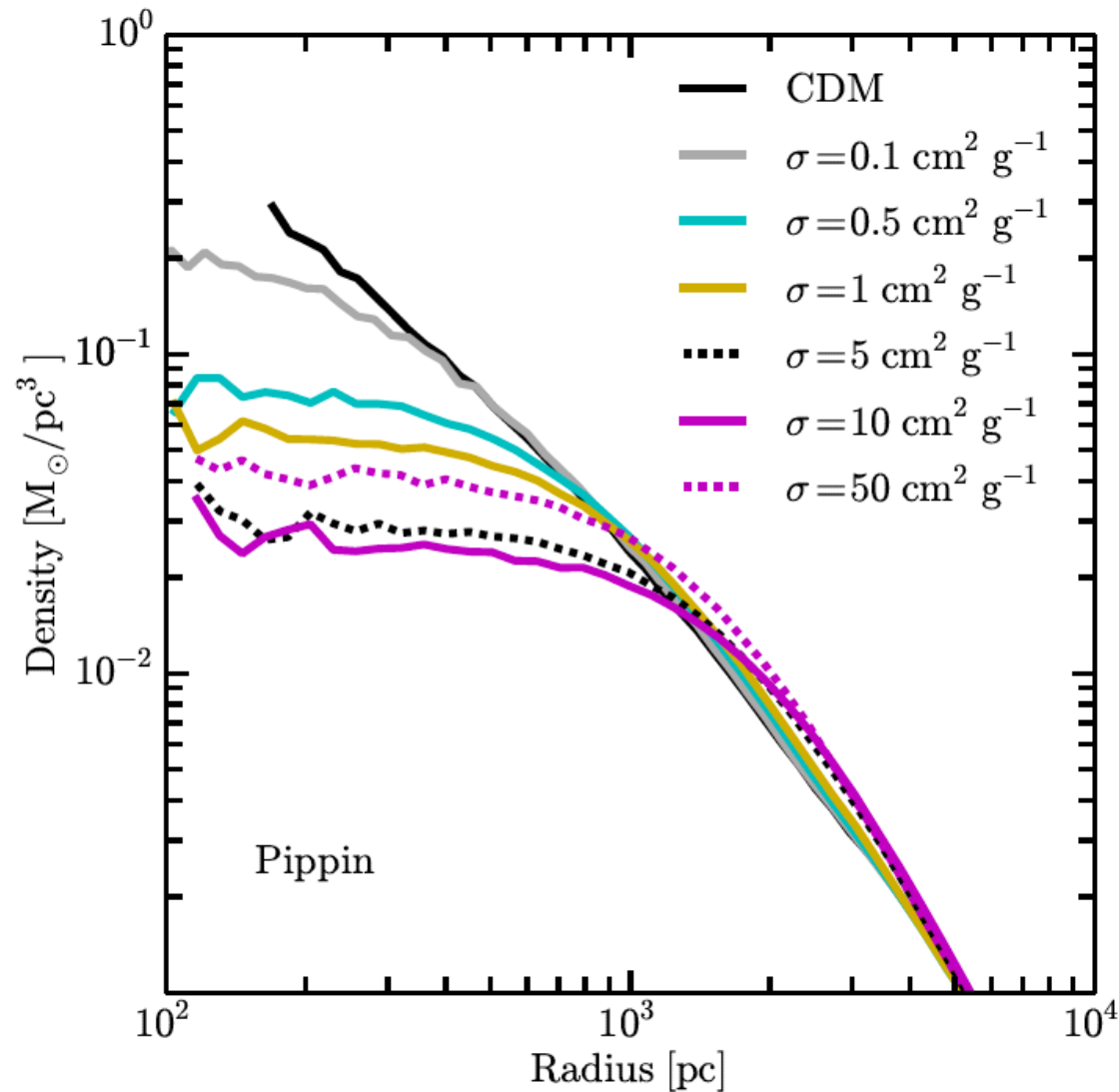


# A TESTABLE PREDICTION OF DELAYED STRUCTURE FORMATION



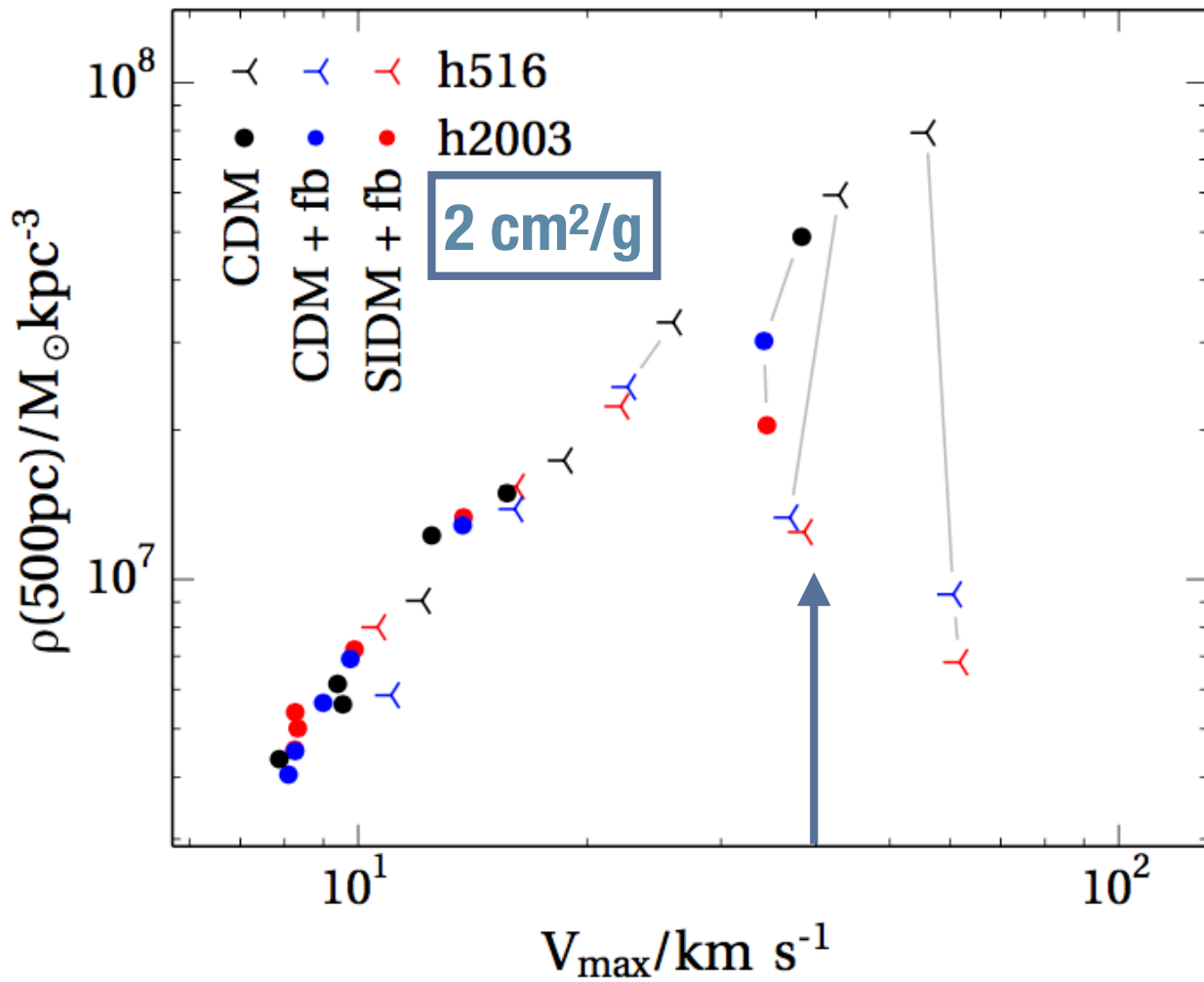


# SIDM: THE CONSTRAINTS ARE WEAKENING



results for  
a  $9 \times 10^9 M_{\text{sun}}$  halo

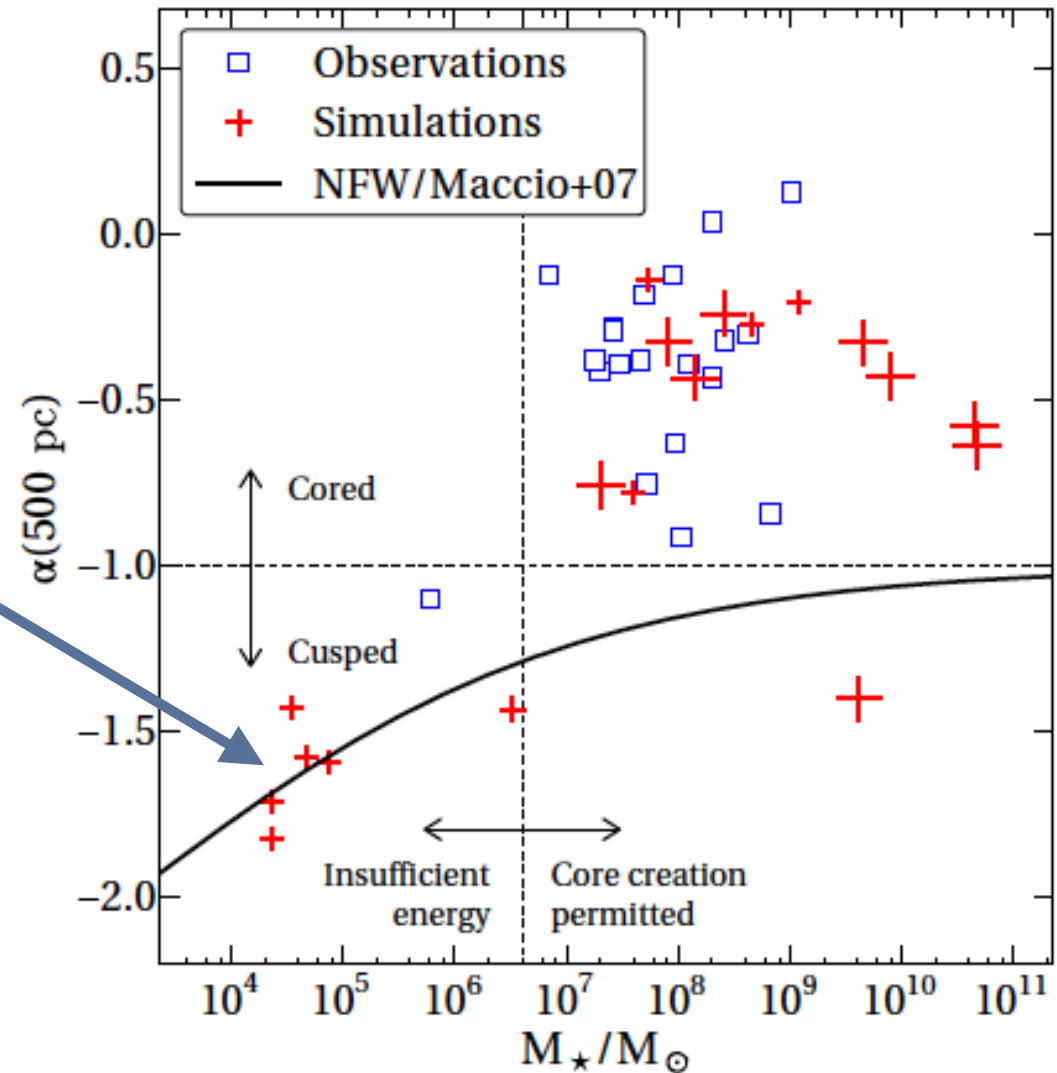
# BUT... BARYONS WIN



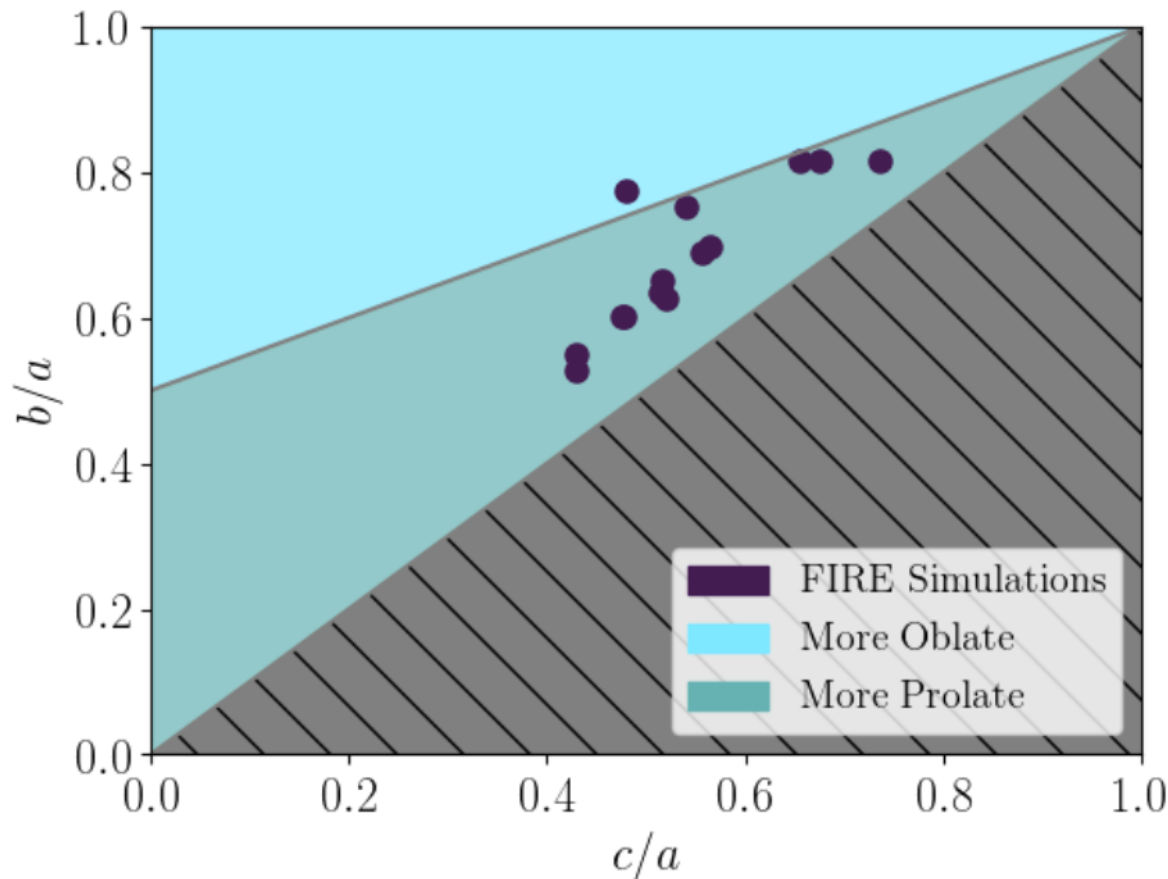


# LEARNING ABOUT DM FROM ULTRA-FAINT DWARFS

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



# LEARNING ABOUT DM FROM ULTRA-FAINT DWARFS

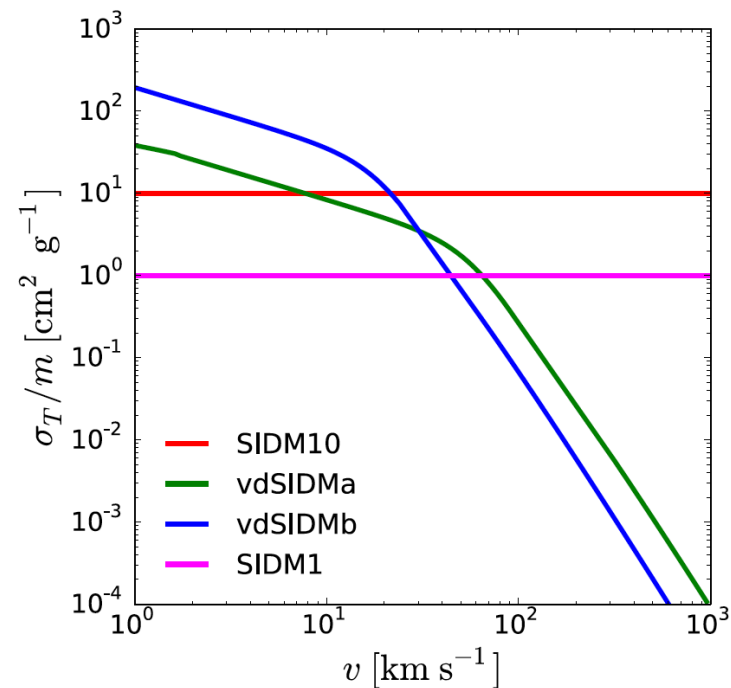
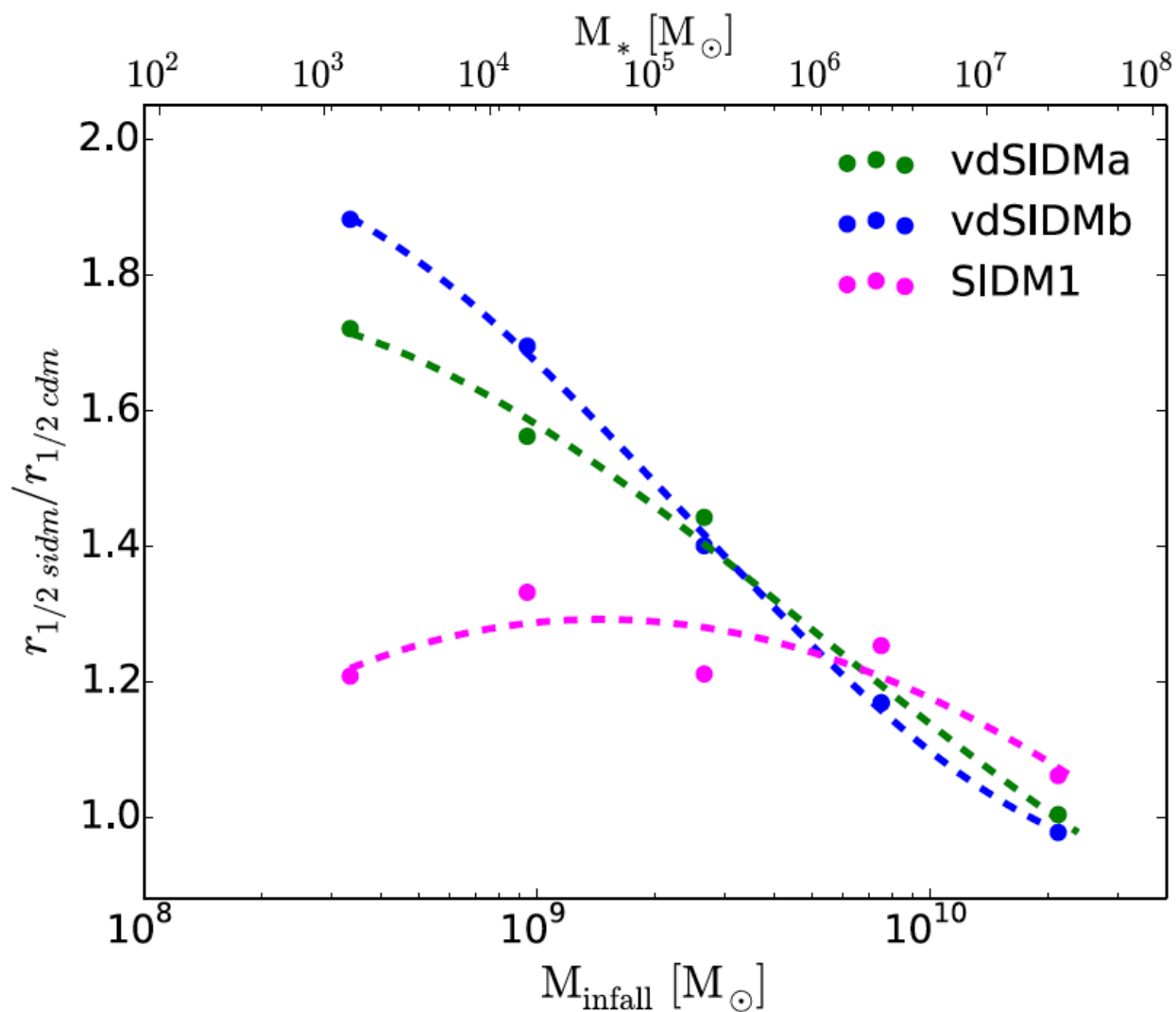


Large cores should affect  
the shapes of dwarf  
galaxies?

(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



# SATELLITES AS AN OBSERVATIONAL PROBE



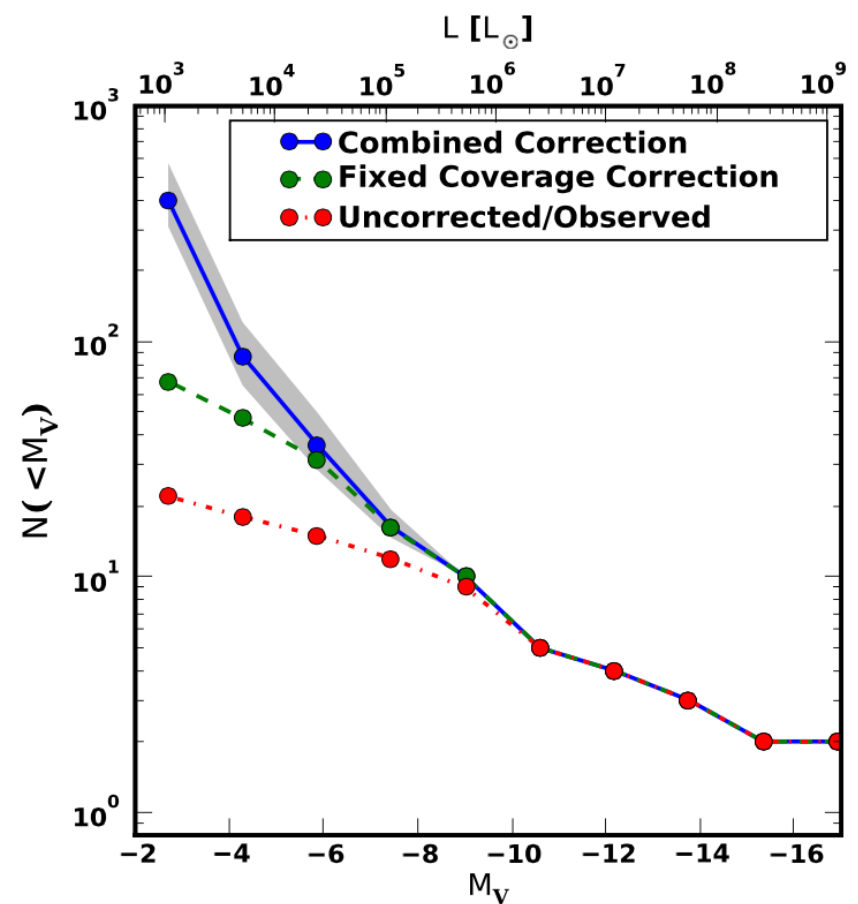
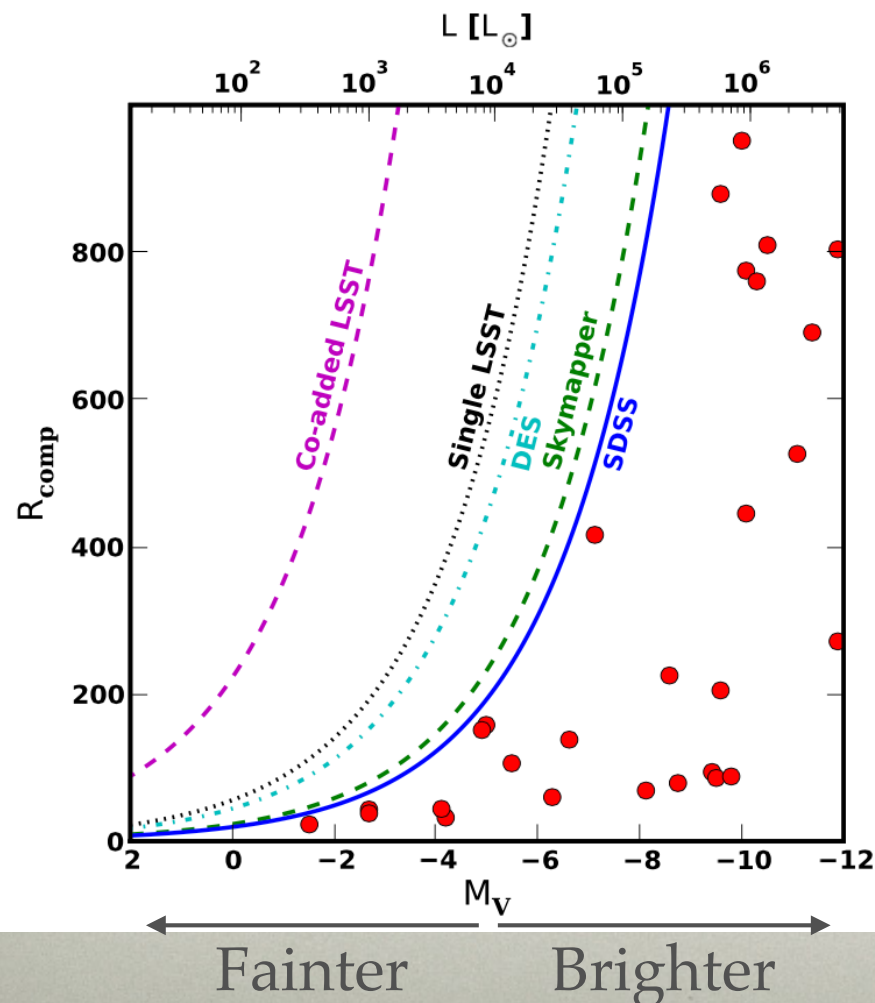
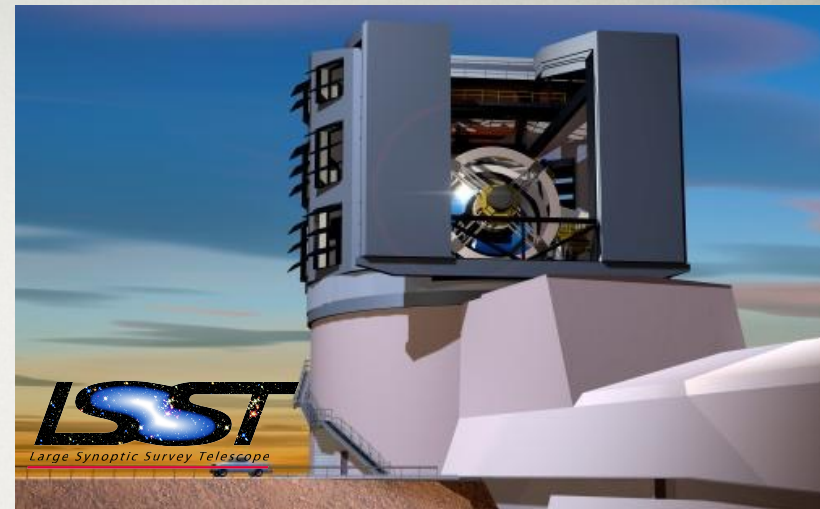
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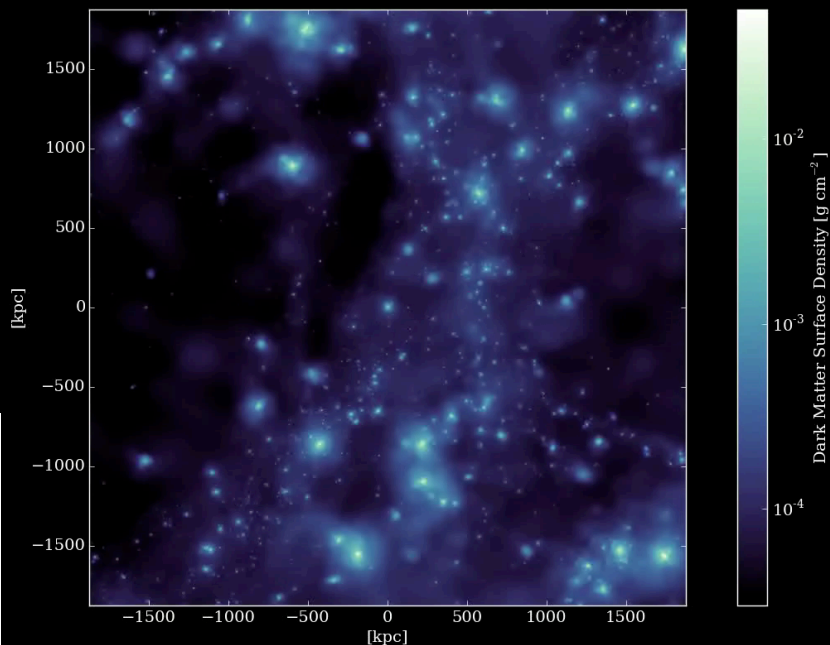
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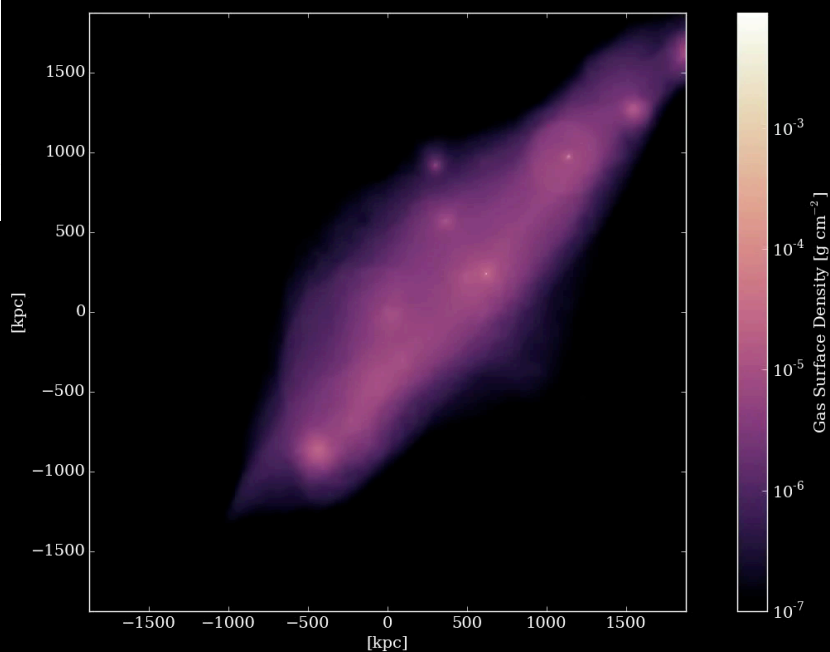
# THE FUTURE IS DWARFY





$z=0$  DM density

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



$z=0$  Gas density



# THE MARVEL-IOUS VOLUMES

**Captain  
Marvel**



**Elektra**



**Rogue**



**Storm**



Force resolution: 60pc

SPH resolution: 6pc

$M_{\text{star}}$ : 400  $M_{\text{sun}}$

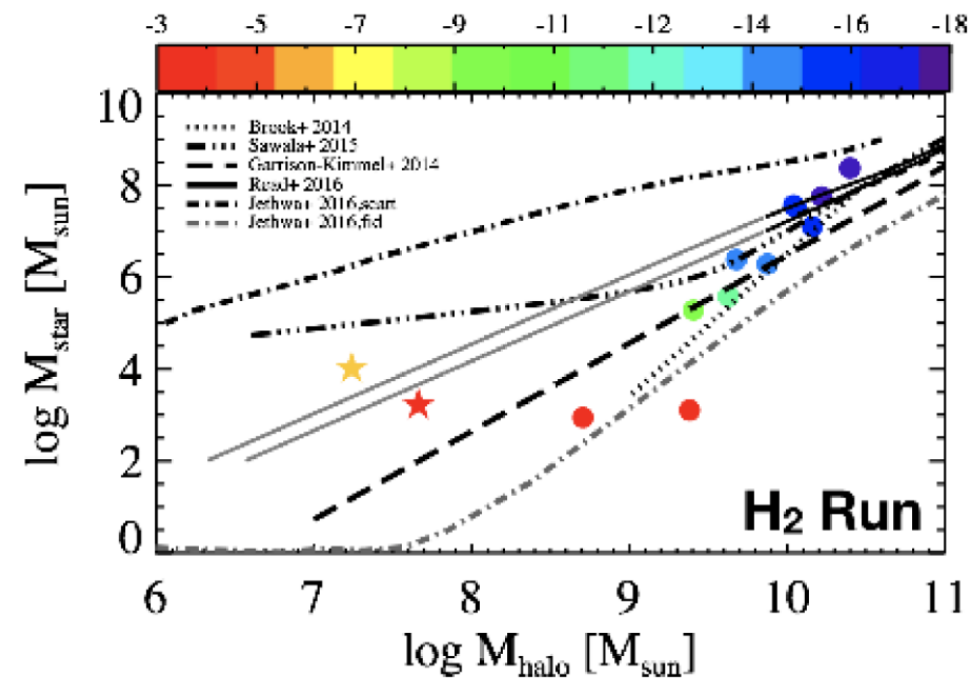
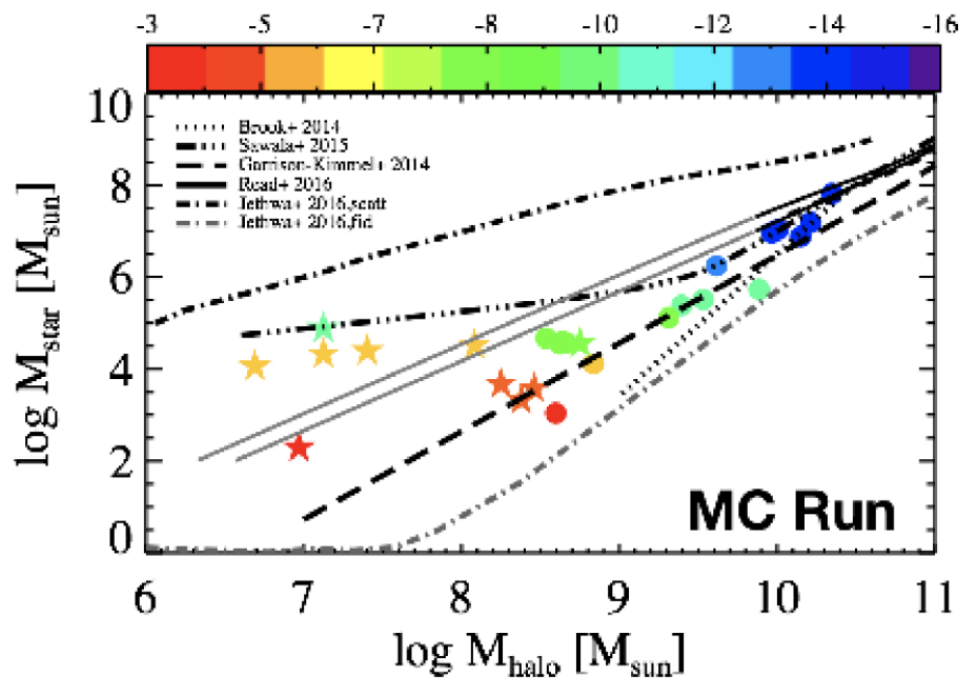
$M_{\text{dm}}$ : 6000  $M_{\text{sun}}$

$z \sim 129$  to 0

Many flavors:

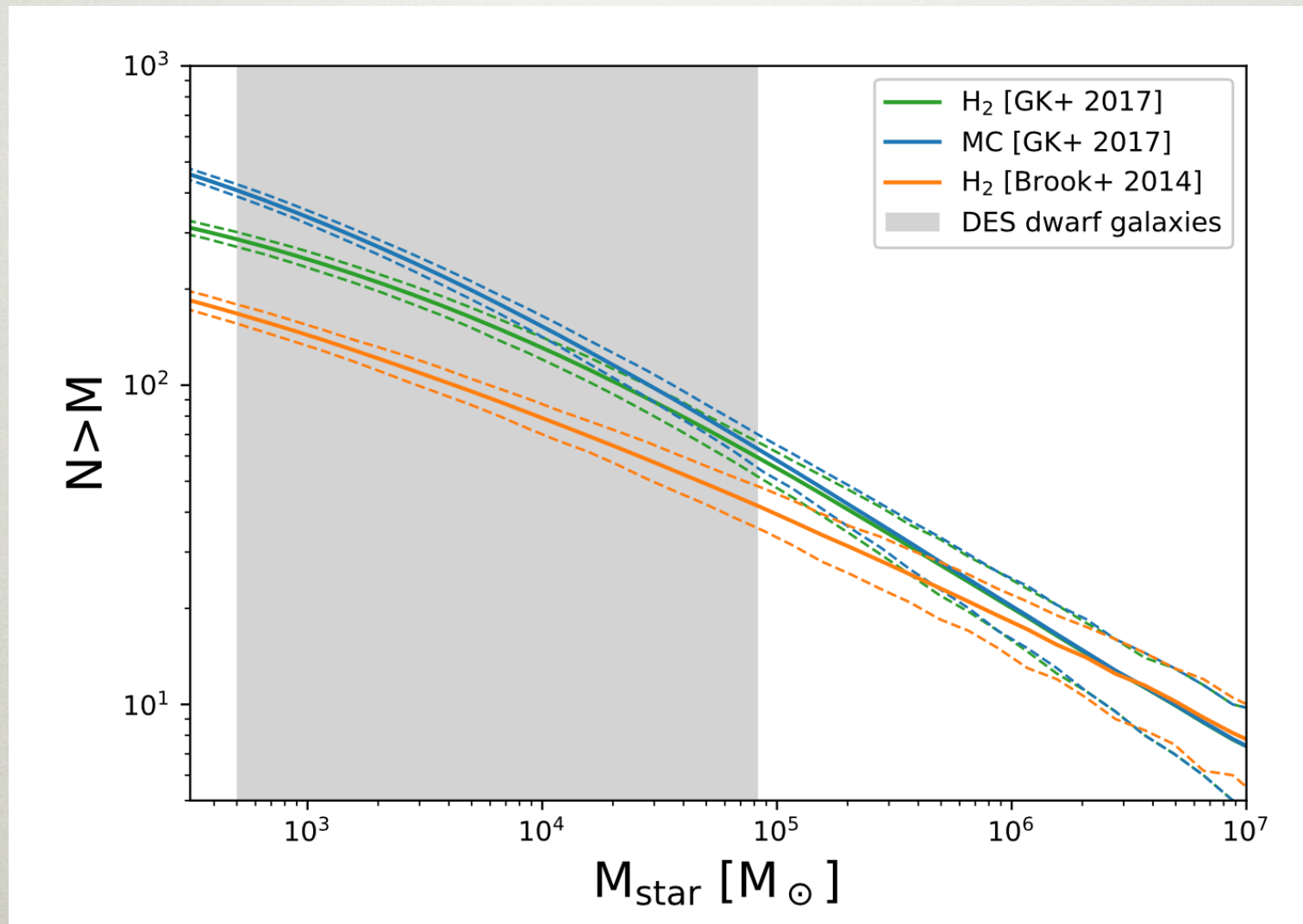
- DM only
- With H2 + Black Holes
- Metal cooling + self shielding
- SIDM

# 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

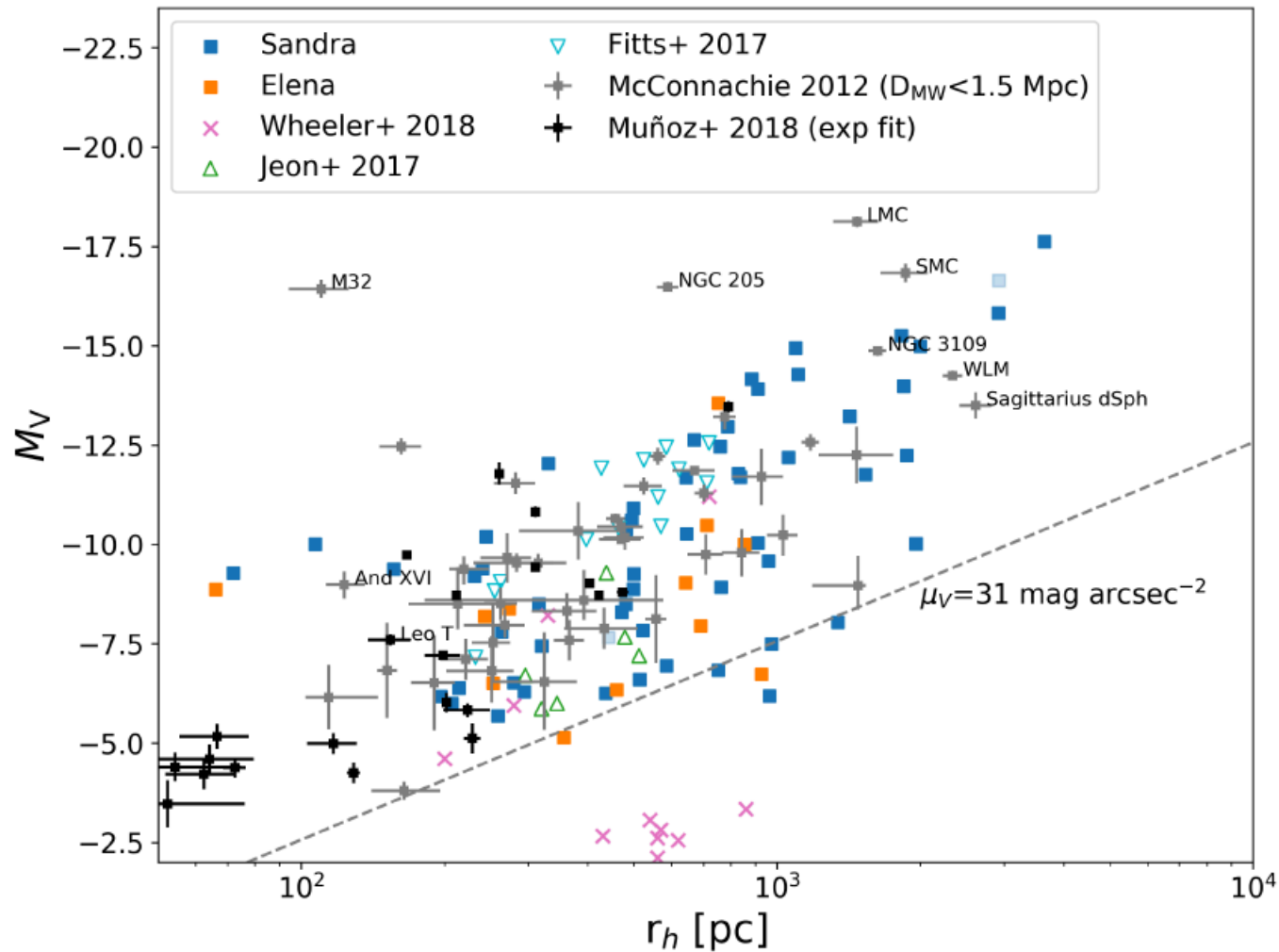
$M_{\text{star}}: 8000/1000 \text{ Msun}$

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

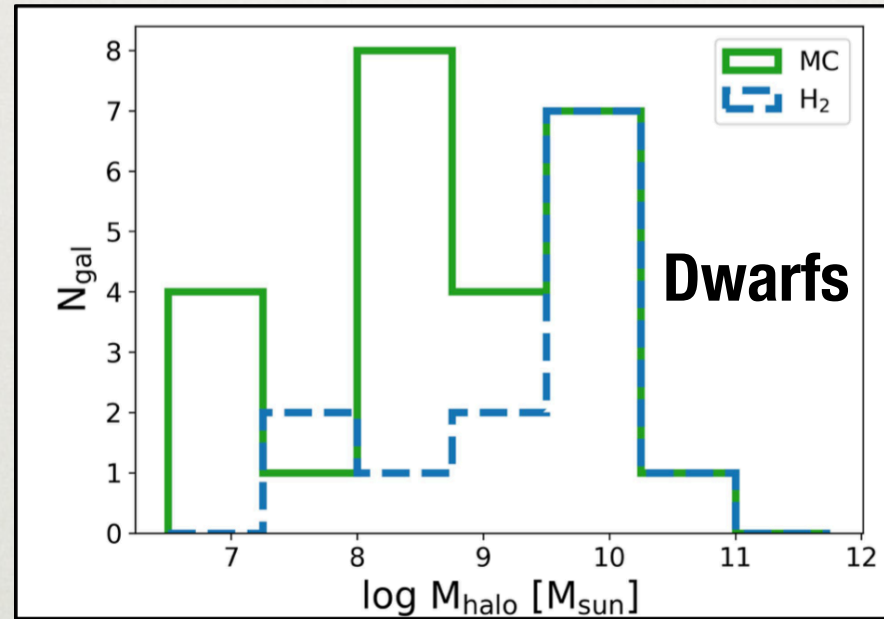
$z \sim 0$



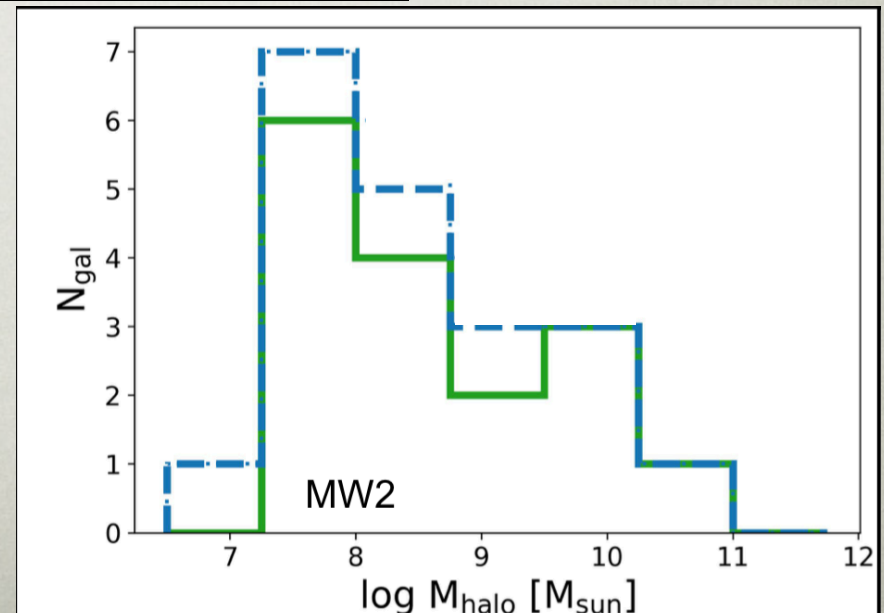
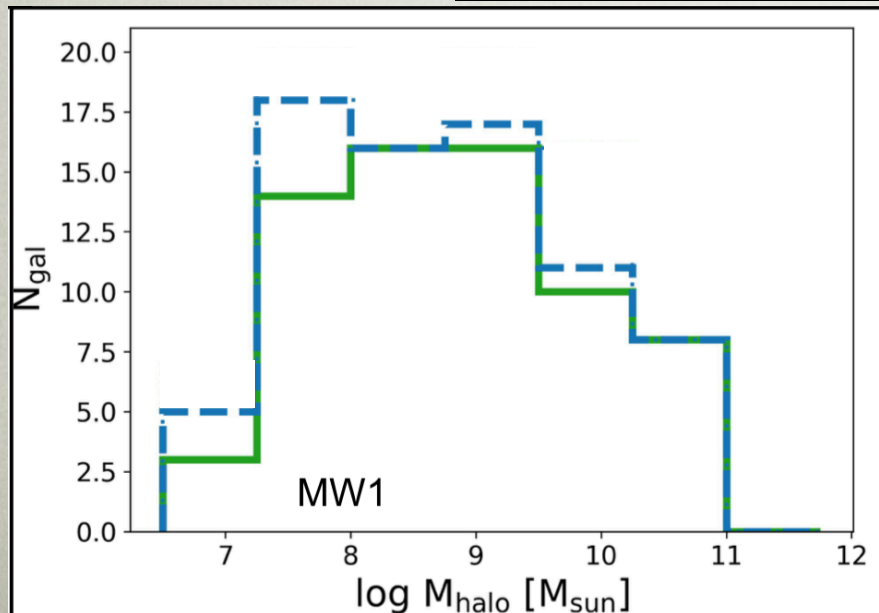
# SIZE-MASS RELATIONS



# UNLIKE DWARF ENVIRONMENT, NO DEPENDENCE ON STAR FORMATION



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





# Conclusions

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Baryons influence the structure of Dark Matter. To constrain the Dark Matter model, we must understand galaxy formation!

We do not currently understand how galaxy formation proceeds in the lowest mass halos that LSST will discover.

Very little work has been done to discover whether galaxy formation can be reproduced in models outside of CDM.