Baryons Matter:
Interpreting our Cosmological Model

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

But...

The Small Scale "Crisis" of CDM

- The cusp/core problem
- Bulge-less disk galaxies
- The "Missing Satellites" problem
- The dense satellites problem (too big to fail)

So...
CDM is Wrong?

Maybe it needs to be modified?

Maybe WDM?

Maybe SIDM?

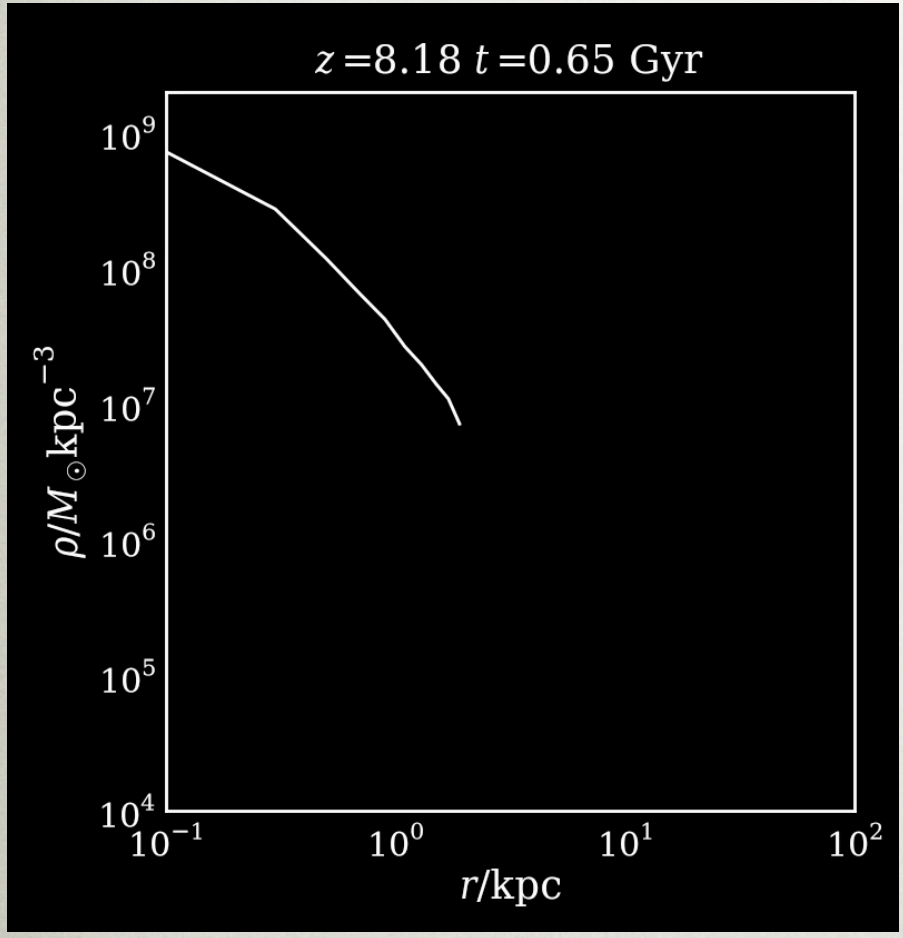
So...
CDM is Wrong?

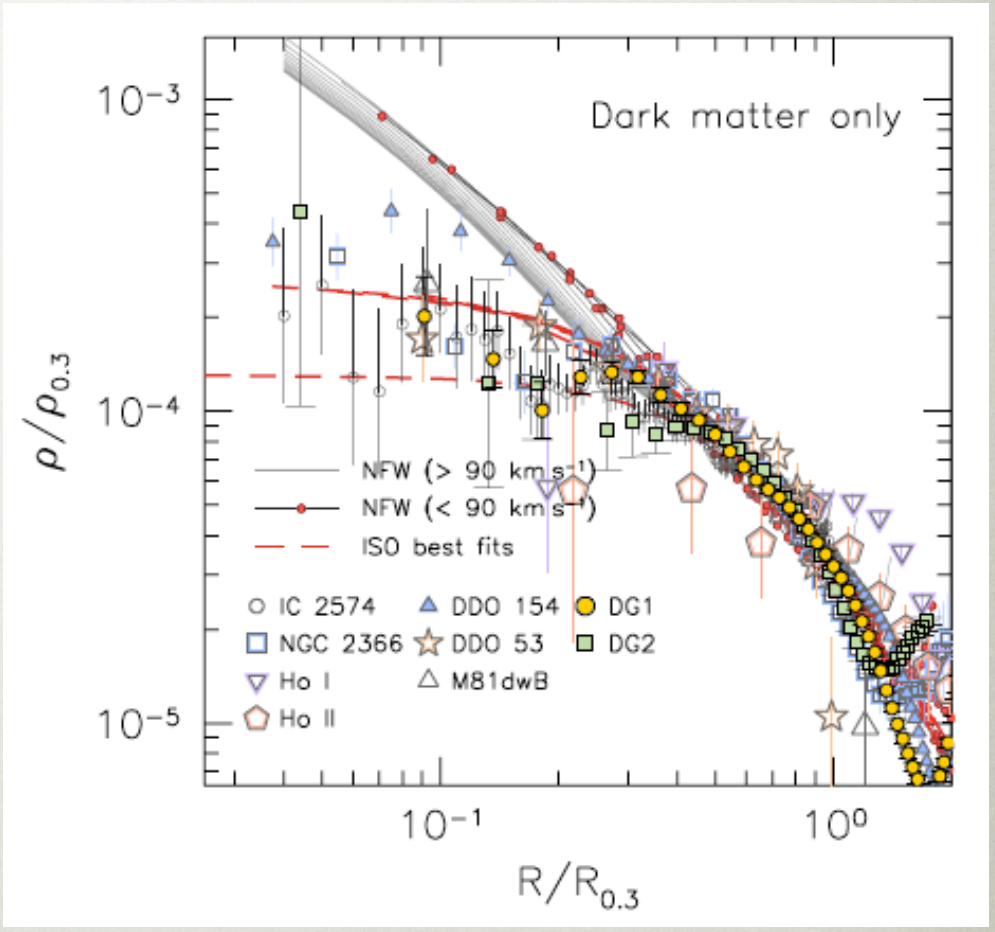
But what about the 4%?

The small scales where there are problems
are also the places dominated by baryons!

All of the predictions that lead to the small scale crises
are based on Dark Matter-only simulations.

Creation of a Dark Matter Core

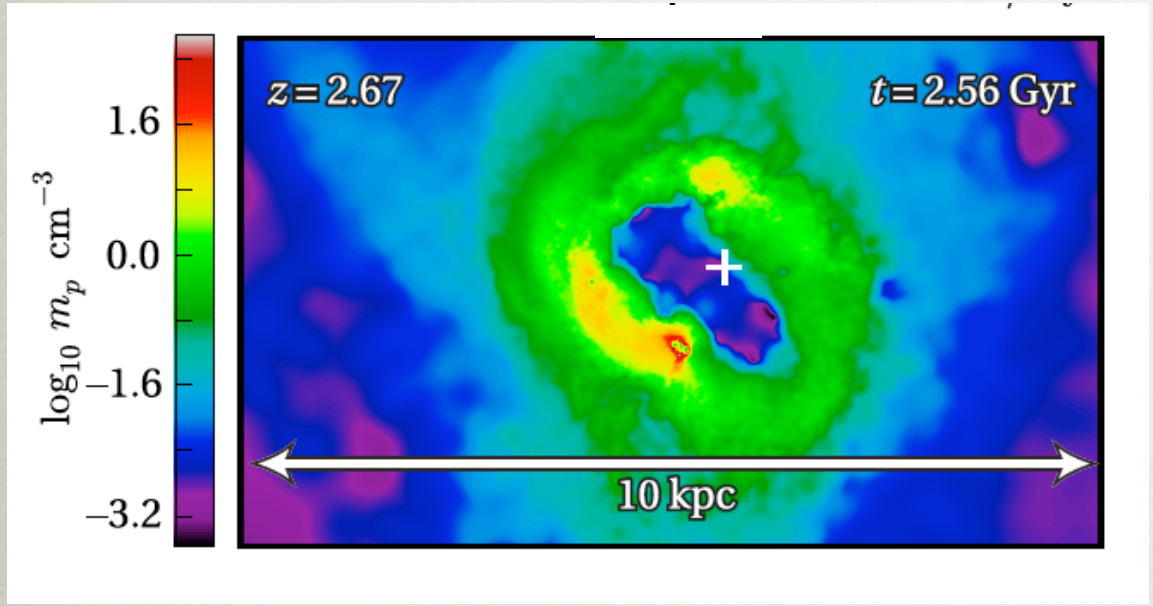


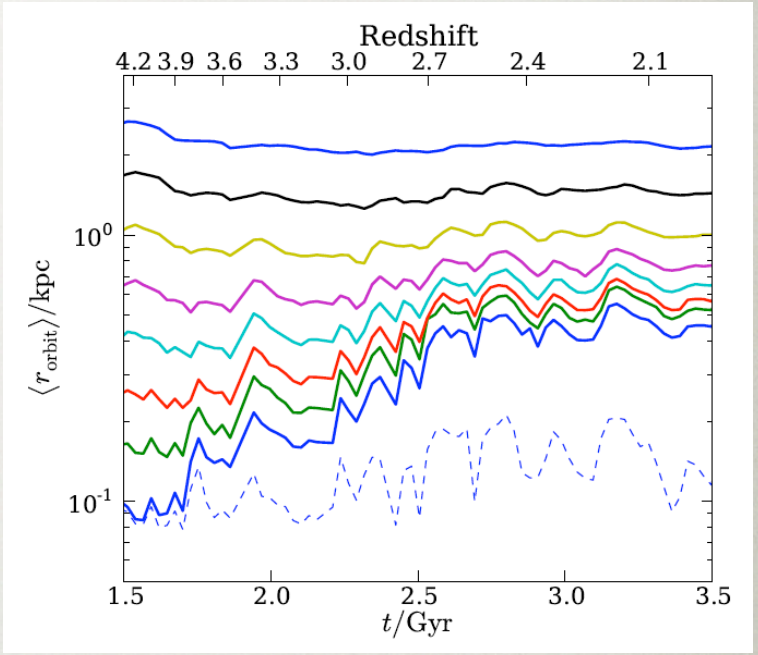


Oh et al., 2011, AJ, 142, 24

See also: Navarro et al. 1996; Read & Gilmore 2005; Mashchenko et al. 2006, 2008; Pasetto et al. 2010; de Souza et al. 2011; Cloet-Osselaer et al. 2012; Maccio et al. 2012; Teyssier et al. 2012; Ogiya & Mori 2012

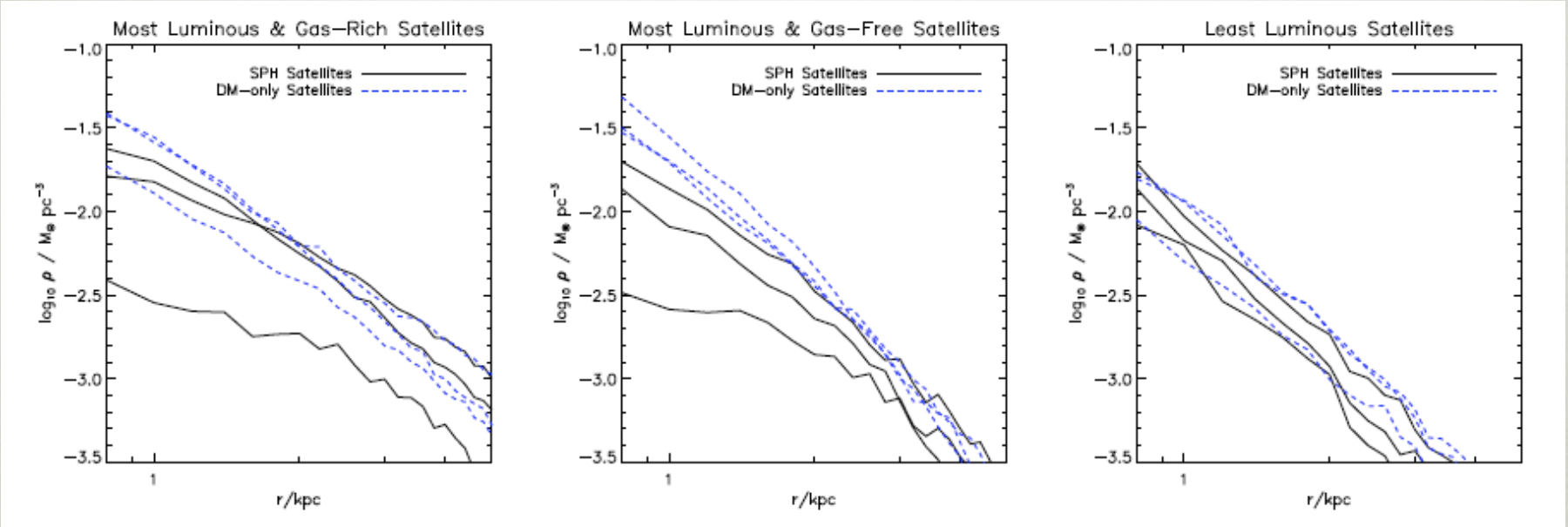
How are Cores Created?





Pontzen & Governato (2012), MNRAS, 421, 3464, arXiv:1106.0499

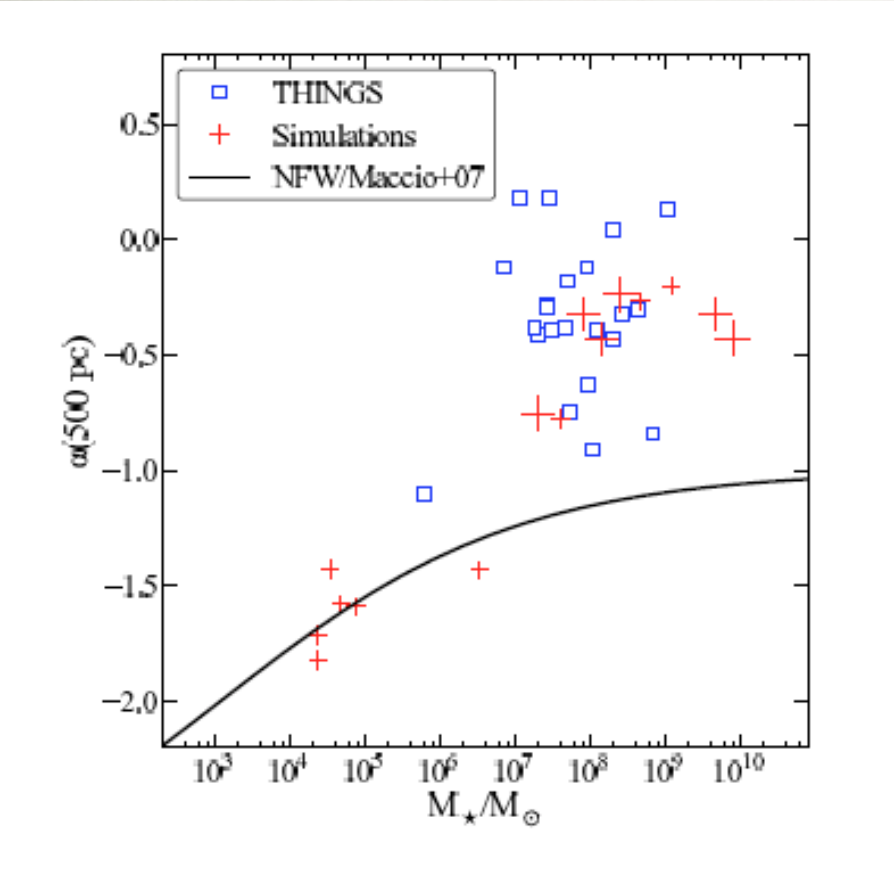
CDM predicts denser satellites than we observe (or does it?)

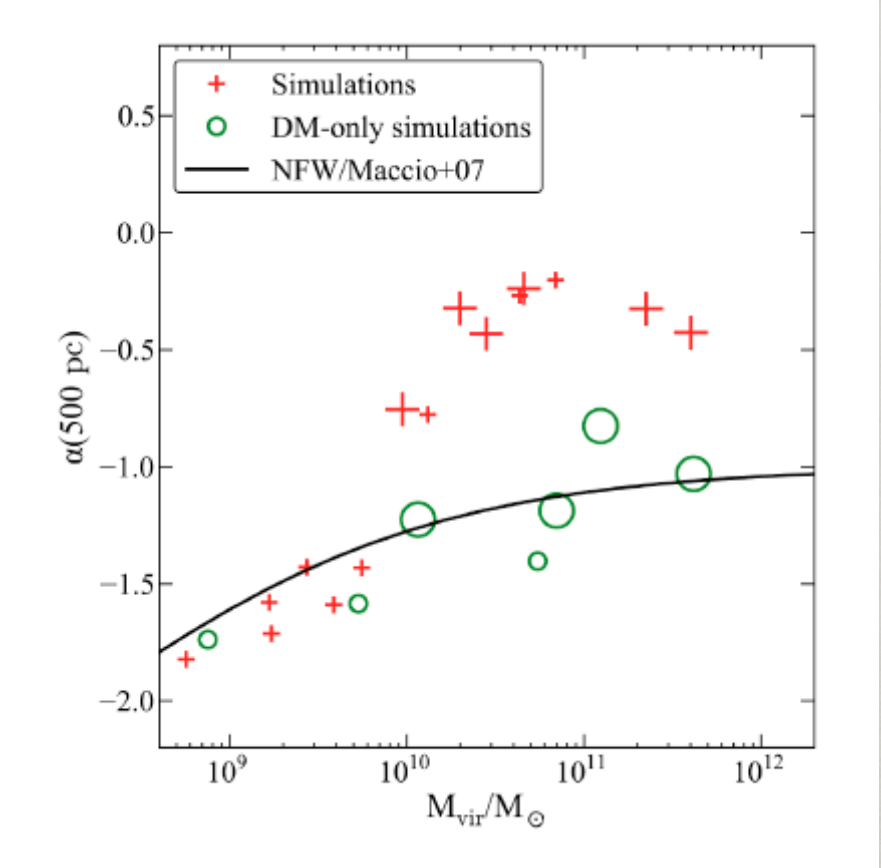


Zolotov, Brooks, et al., 2012, ApJ, 761, 71, arXiv:1207.0007

Core Creation varies with Mass!

because SF varies with mass





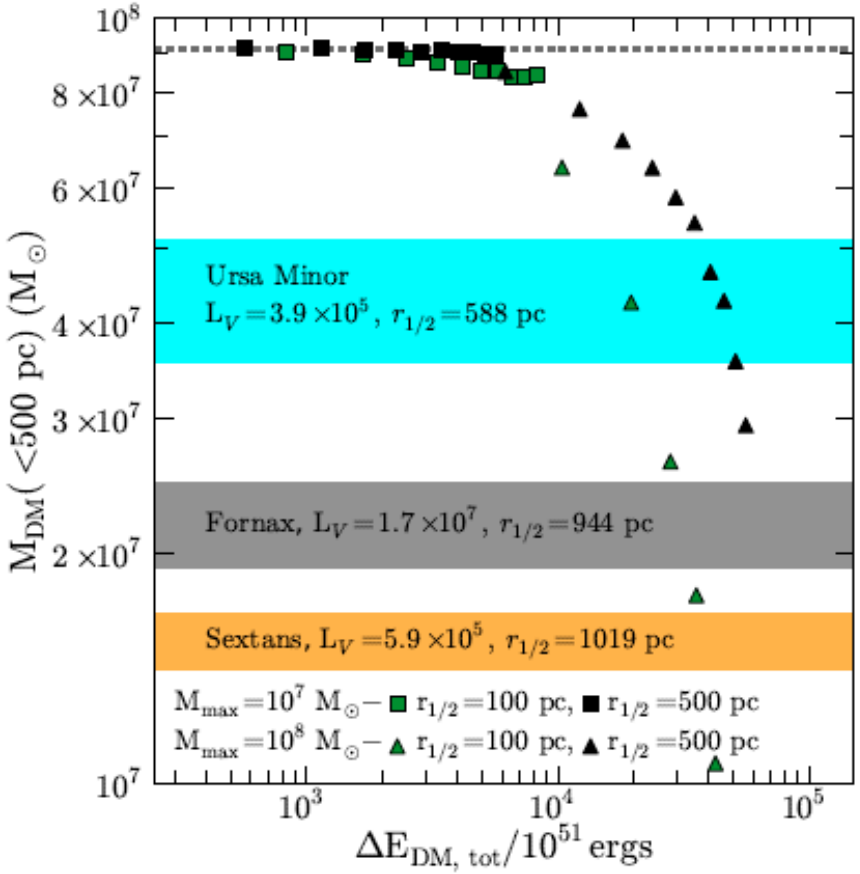
Galaxies in the THINGS survey have average α~-0.3

Lower mass galaxies do not undergo repeated bursts of SF; retain cusps

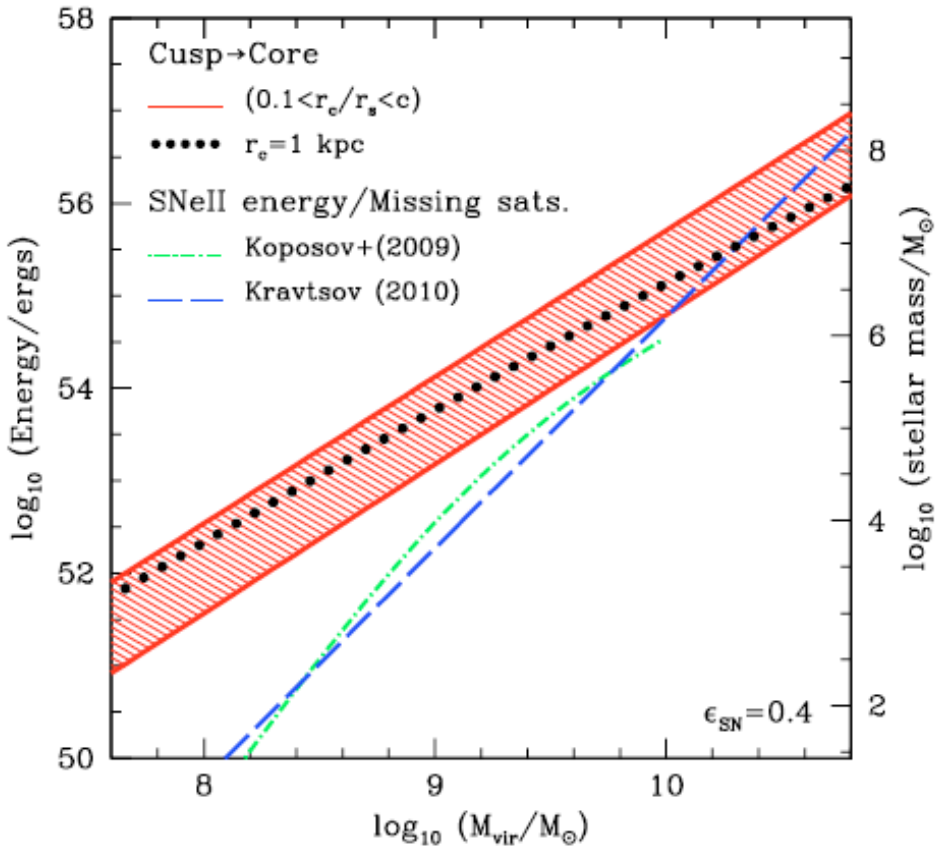
Governato et al., 2012, MNRAS, 422, 1231

Energetics

Garrison-Kimmel et al. (2013)



Penarrubia et al. (2012)



Energetics

Can Feedback Solve the Too Big to Fail Problem?

Shea Garrison-Kimmel*, Miguel Rocha, Michael Boylan-Kolchin†,
James S. Bullock, Jaspreet Lally
Center for Cosmology, Department of Physics and Astronomy, University of California, Irvine, CA 92697, USA

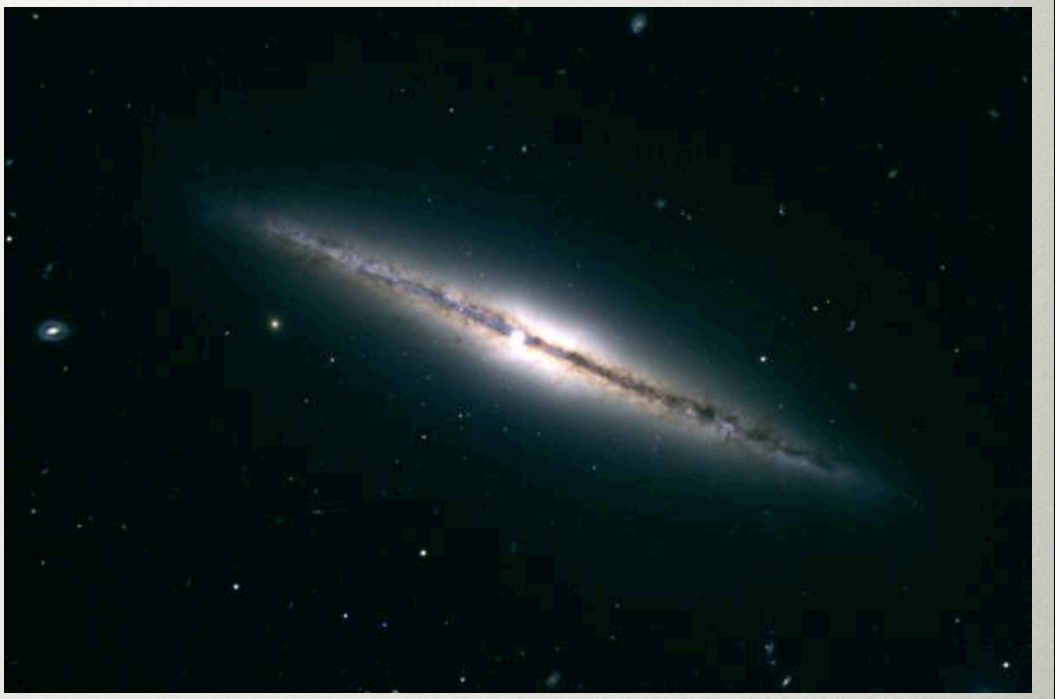
14 January 2013

NO!

We all agree!

Also: Baryons Make a Disk (Dark Matter Doesn't)

Dark Matter

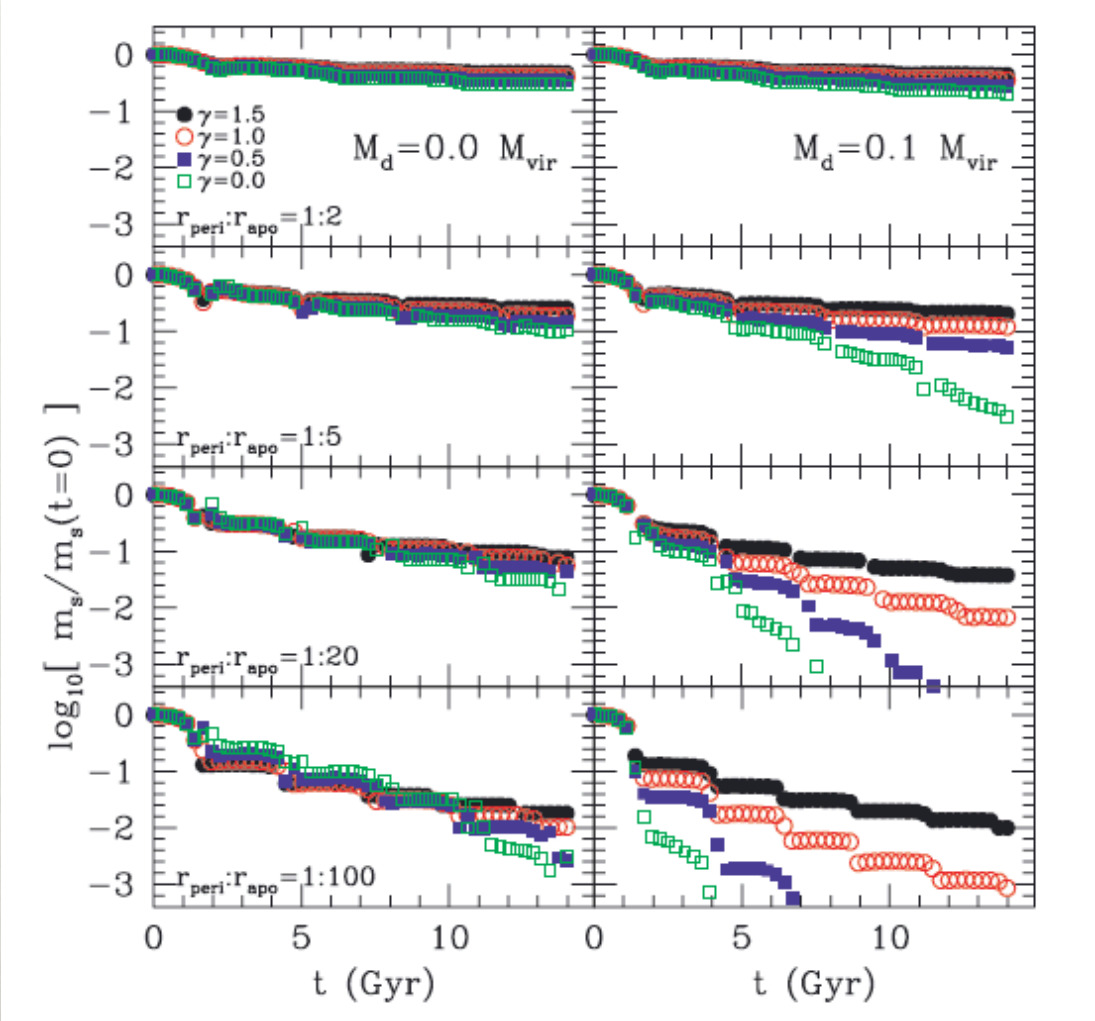


Baryons

(or any central baryonic concentration)

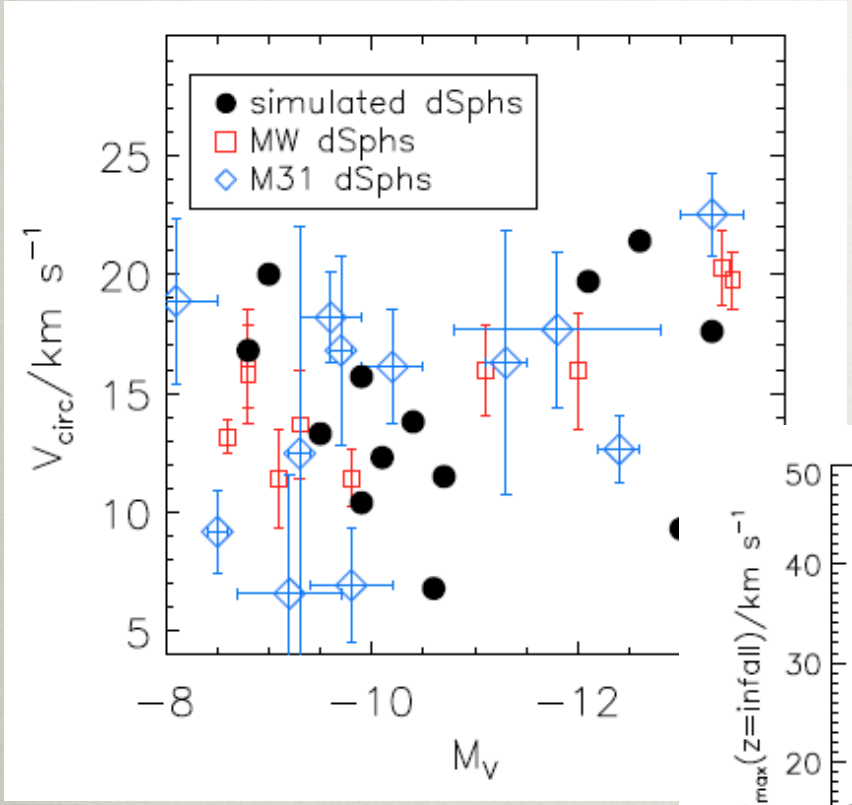
Chang et al. (2012)

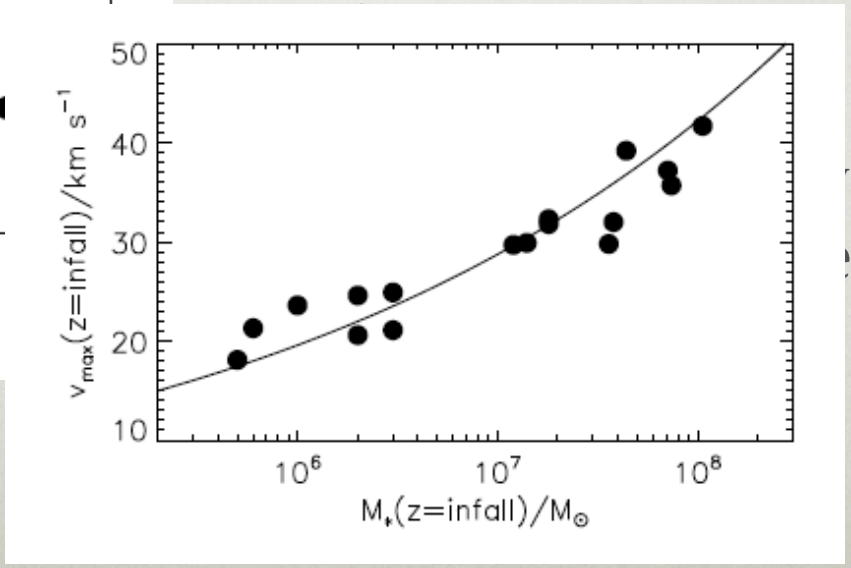
Not Just Core Creation: The Tidal Effect of the Disk



Penarrubia et al. (2010), see also Arraki et al. (2012)

The First Simulated Dwarf Spheroidals to Match Observed Kinematics





- satellites show no trend across luminosity
- scatter fainter than M_V=-12 after infall
- =-12 have stripping

Brooks & Zolotov (2012), arXiv:1207.2468

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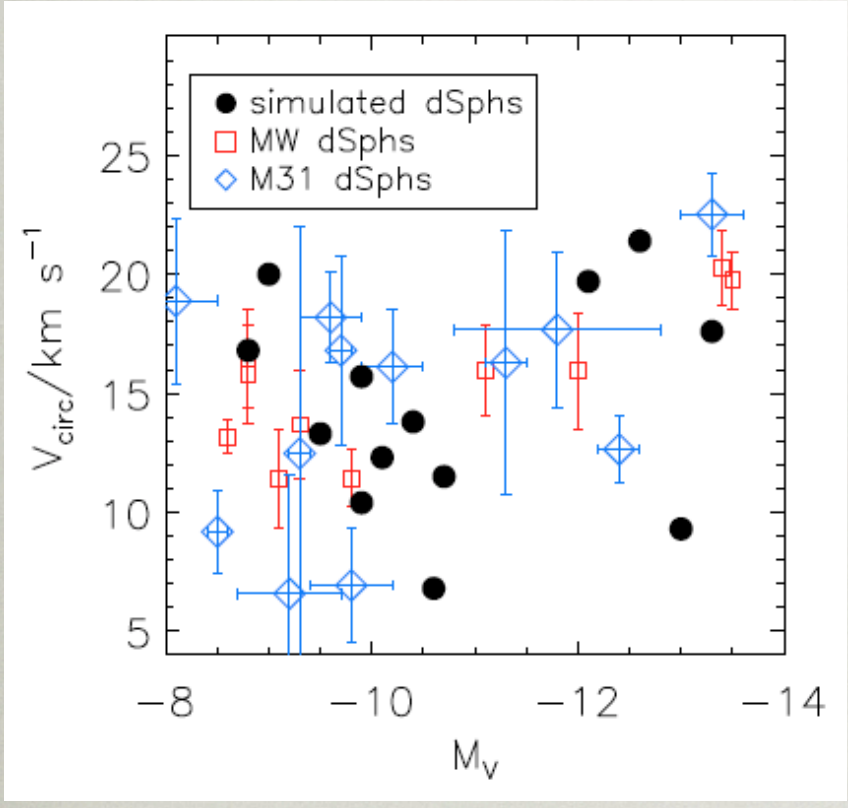

- satellites show no trend across luminosity
- scatter fainter than M_V=-12 due to stripping after infall
- brighter than M_V=-12 have cores, even more stripping

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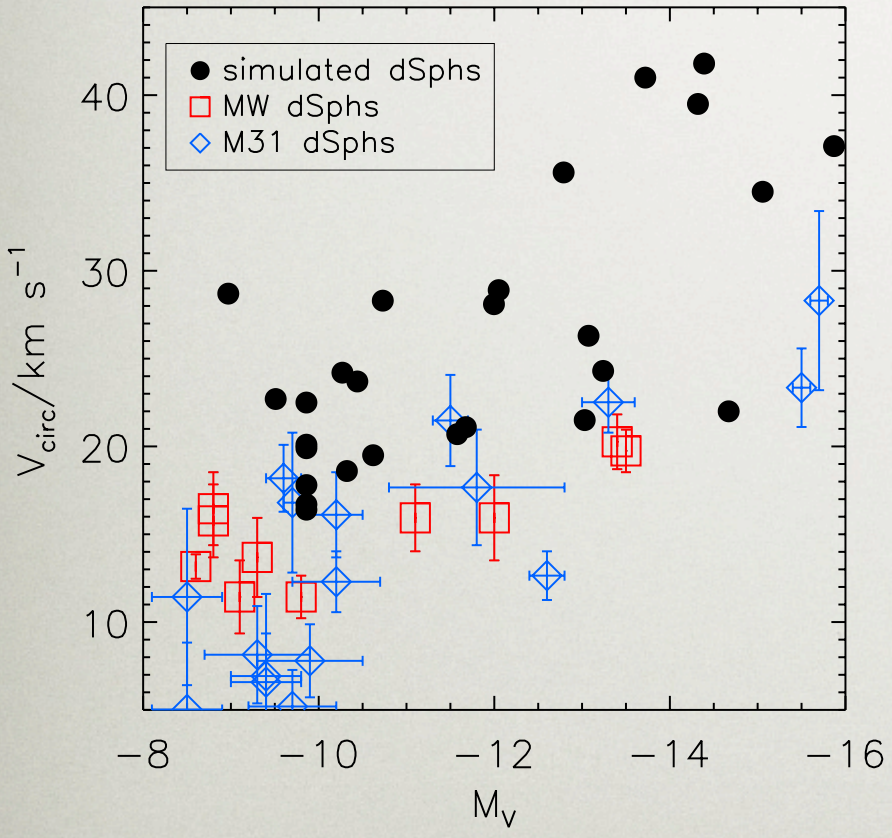
DM-Only Results fail to Match Observed Kinematics



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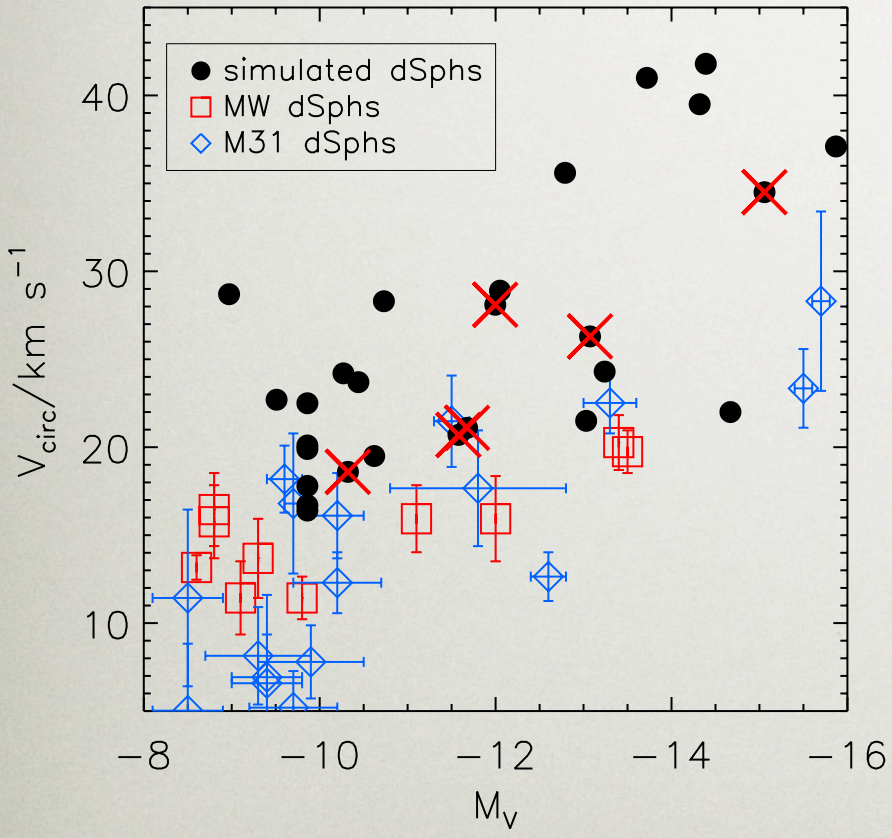
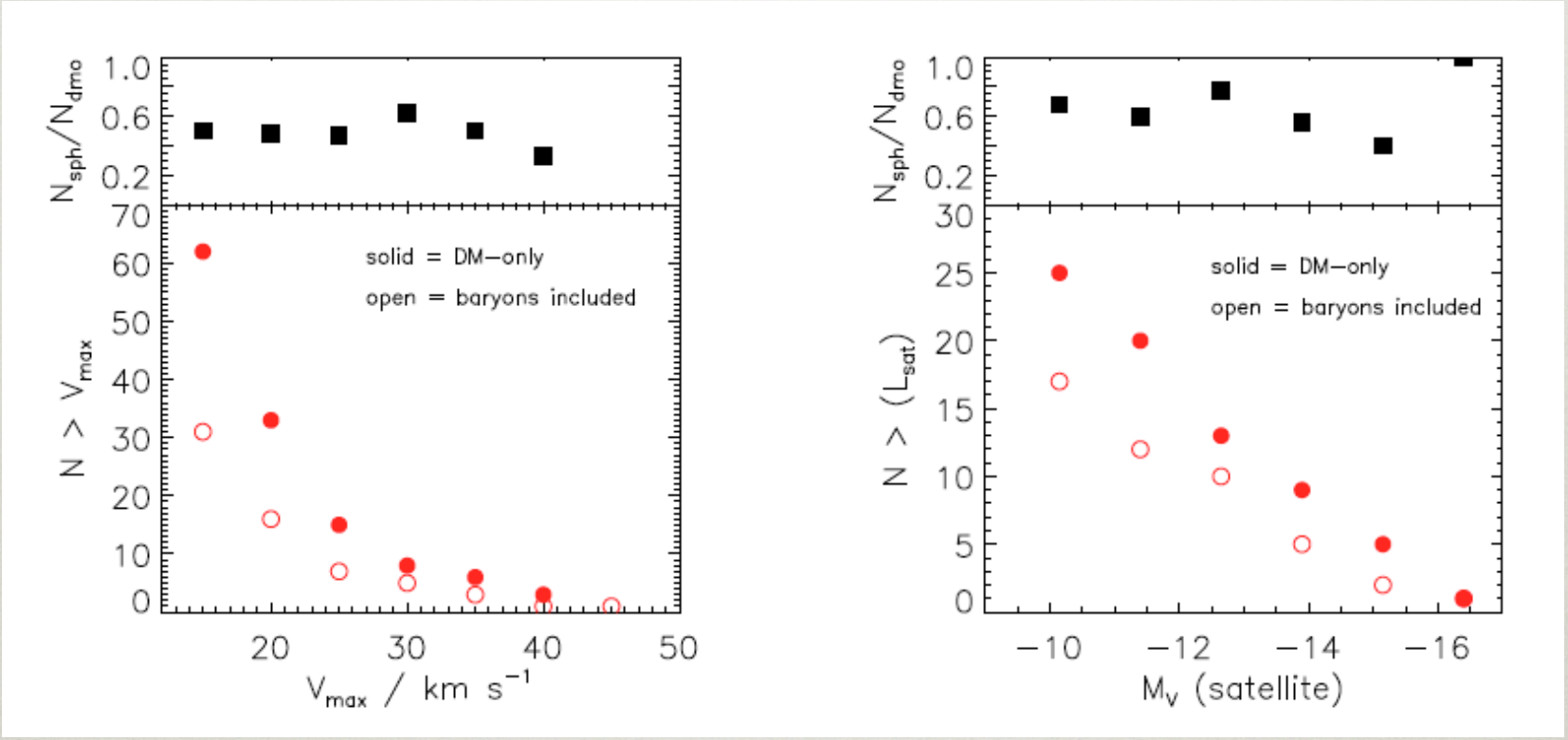


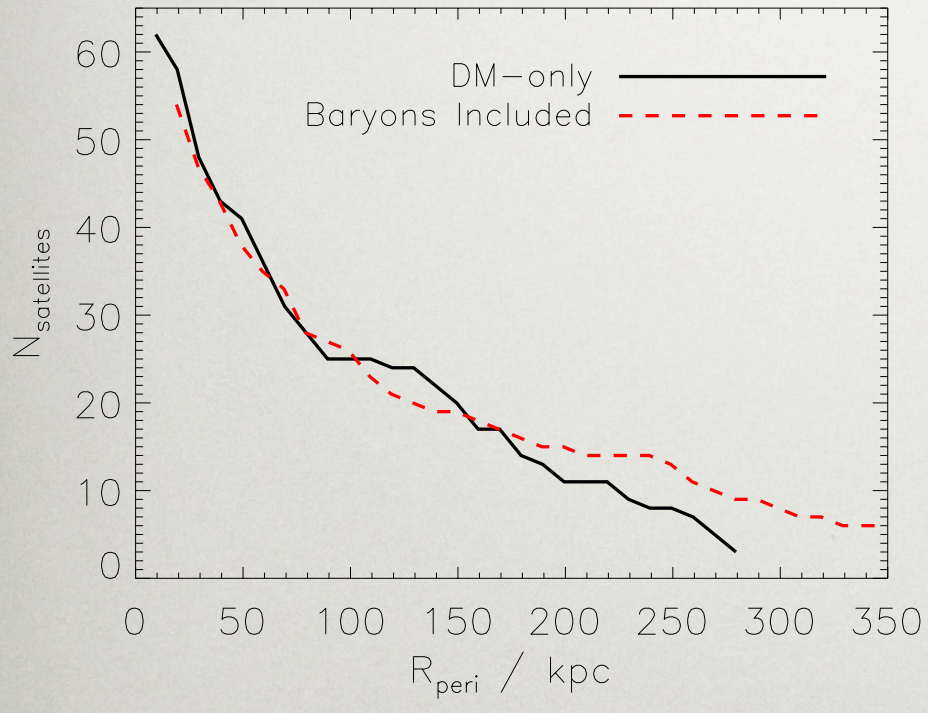
- 1/3 of DM-only subhalos are destroyed in baryonic runs (disk shocking)

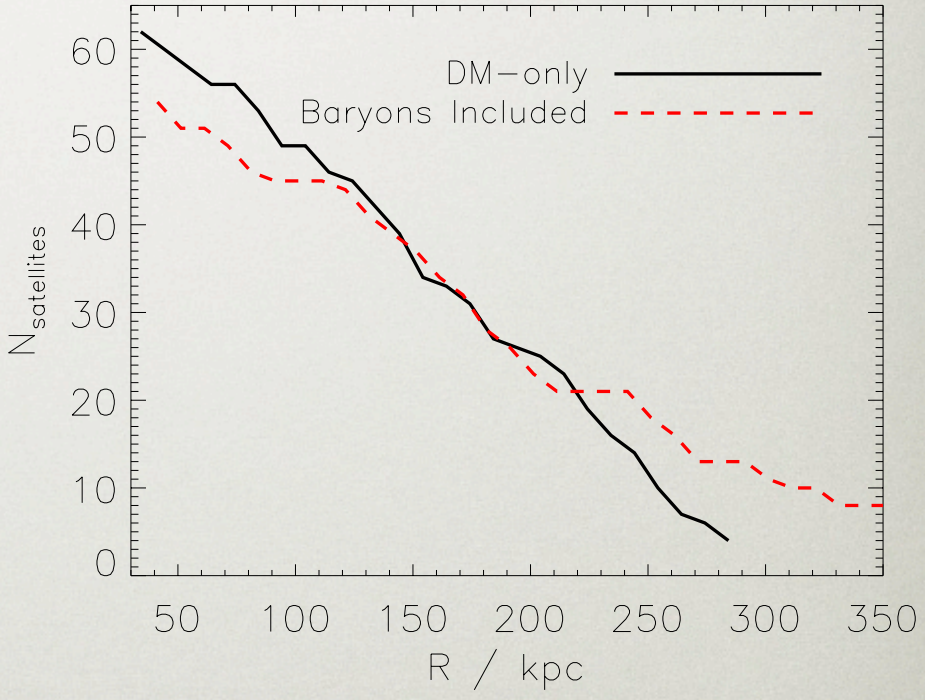
Brooks & Zolotov (2012), arXiv:1207.2468

The Change to Mass and Luminosity Functions



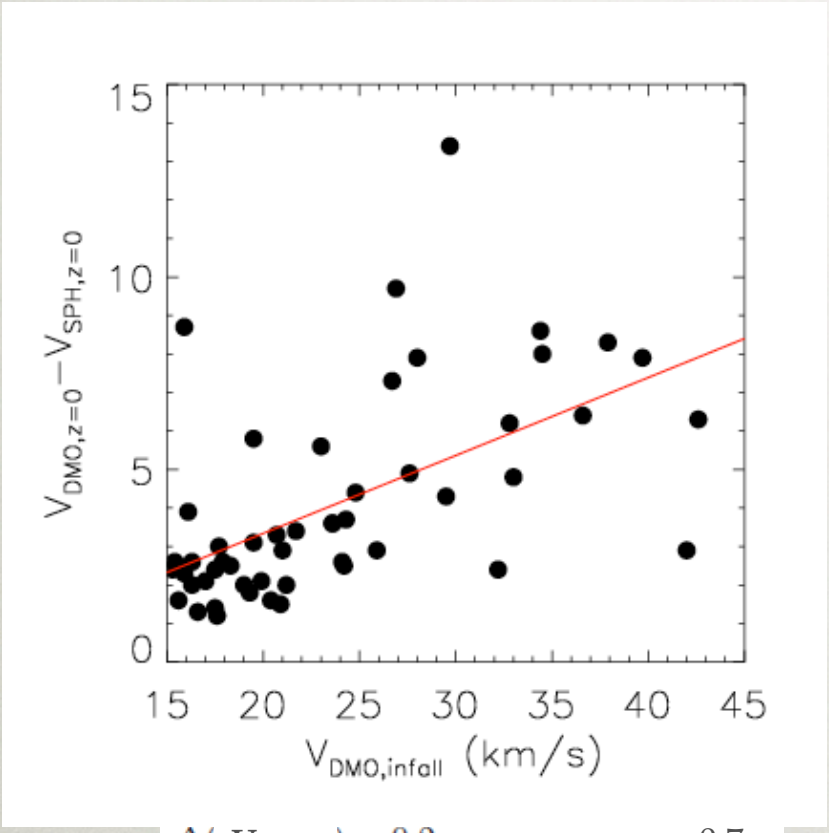
The Depletion Radius





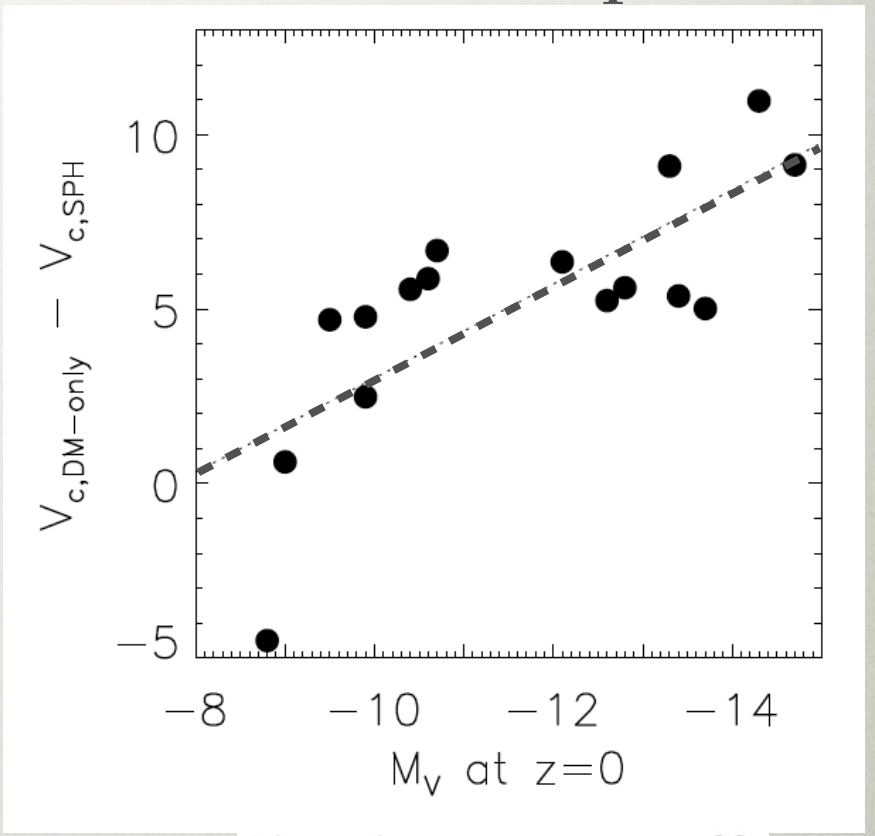
Corrections to DM-only DATA

Theory space:



$\Delta(\ V_{max}\ ) = 0.2 v_{peak,DM-only} - 0.7$

Observer space:

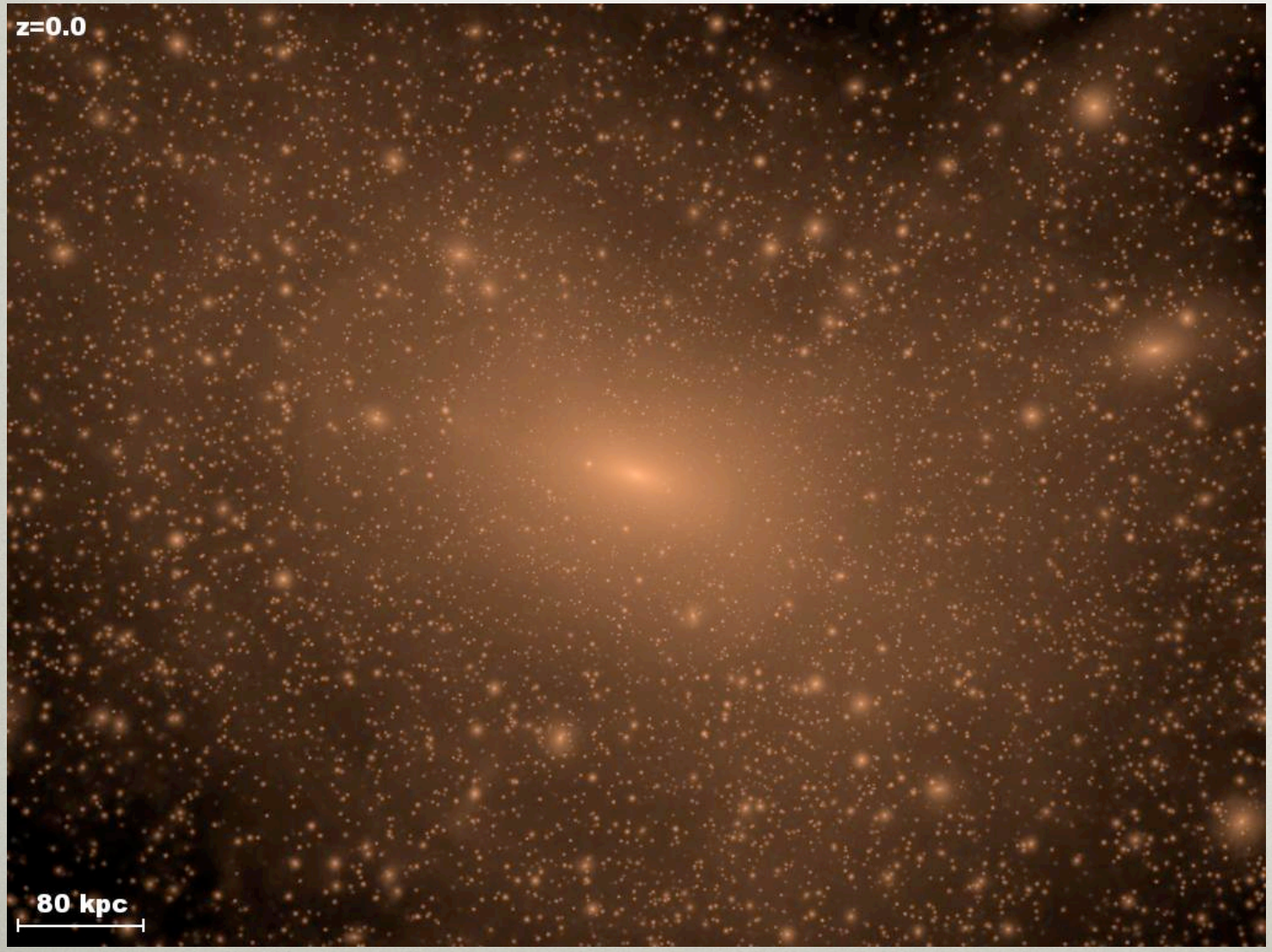


$\Delta(v_{c,1kpc}) = -10.47 - 1.35 \times M_V$

Zolotov et al. (2012); Brooks & Zolotov (2012)

But...

What About the Number of Luminous Satellites?



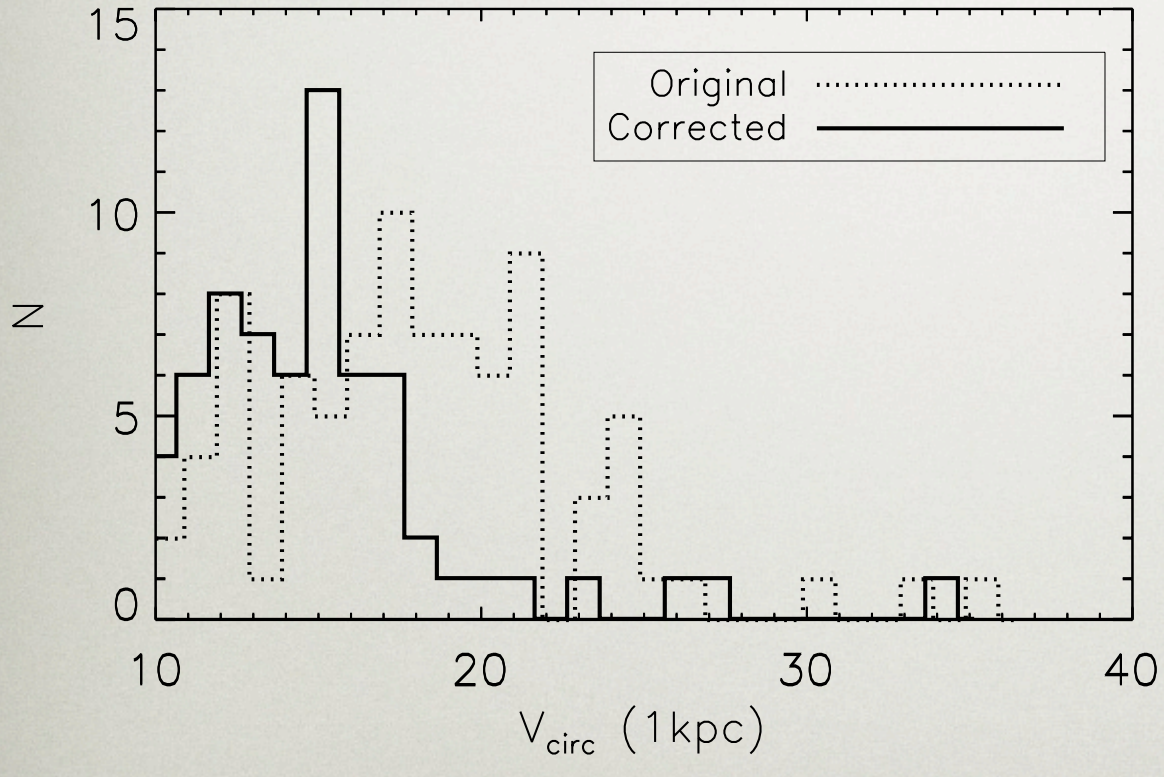
1000's of satellites predicted

dozens seen

"Via Lactea"

But...

What About the Number of Luminous Satellites?



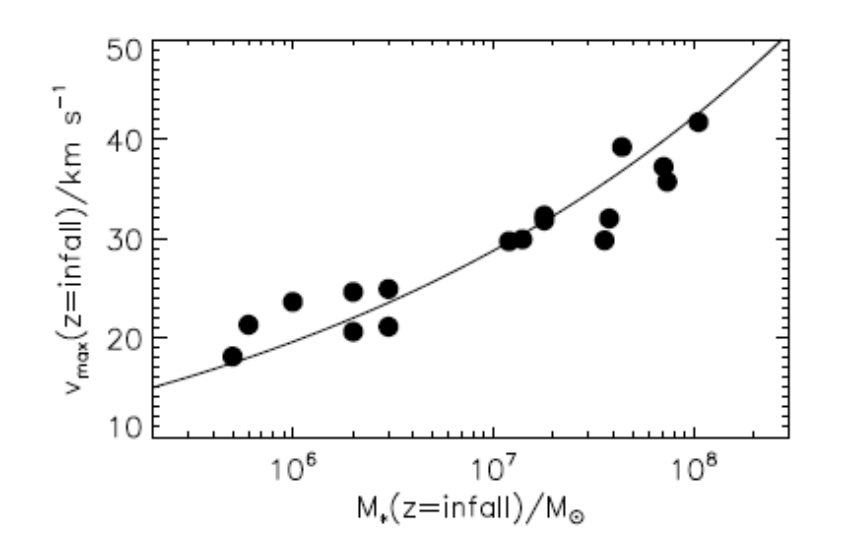
Apply the model to VL2:

VL2 has 28 subhalos with $v_{1kpc} > 20$ km/s

After correction: 5 subhalos with $v_{1kpc} > 20$ km/s

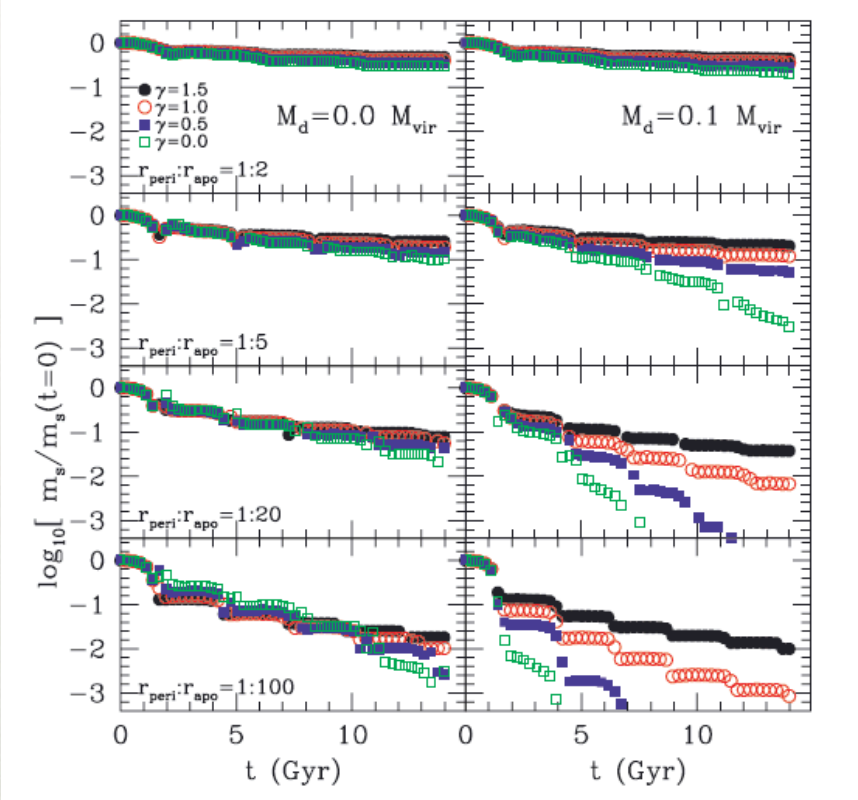
So the Number of Massive Satellites is Reduced...

but what about Luminous Satellites?



Assume

v_{peak} -- M_{star} relation



and destruction

Zolotov et al. (2012); Penarrubia et al. (2010)

So the Number of Massive Satellites is Reduced...

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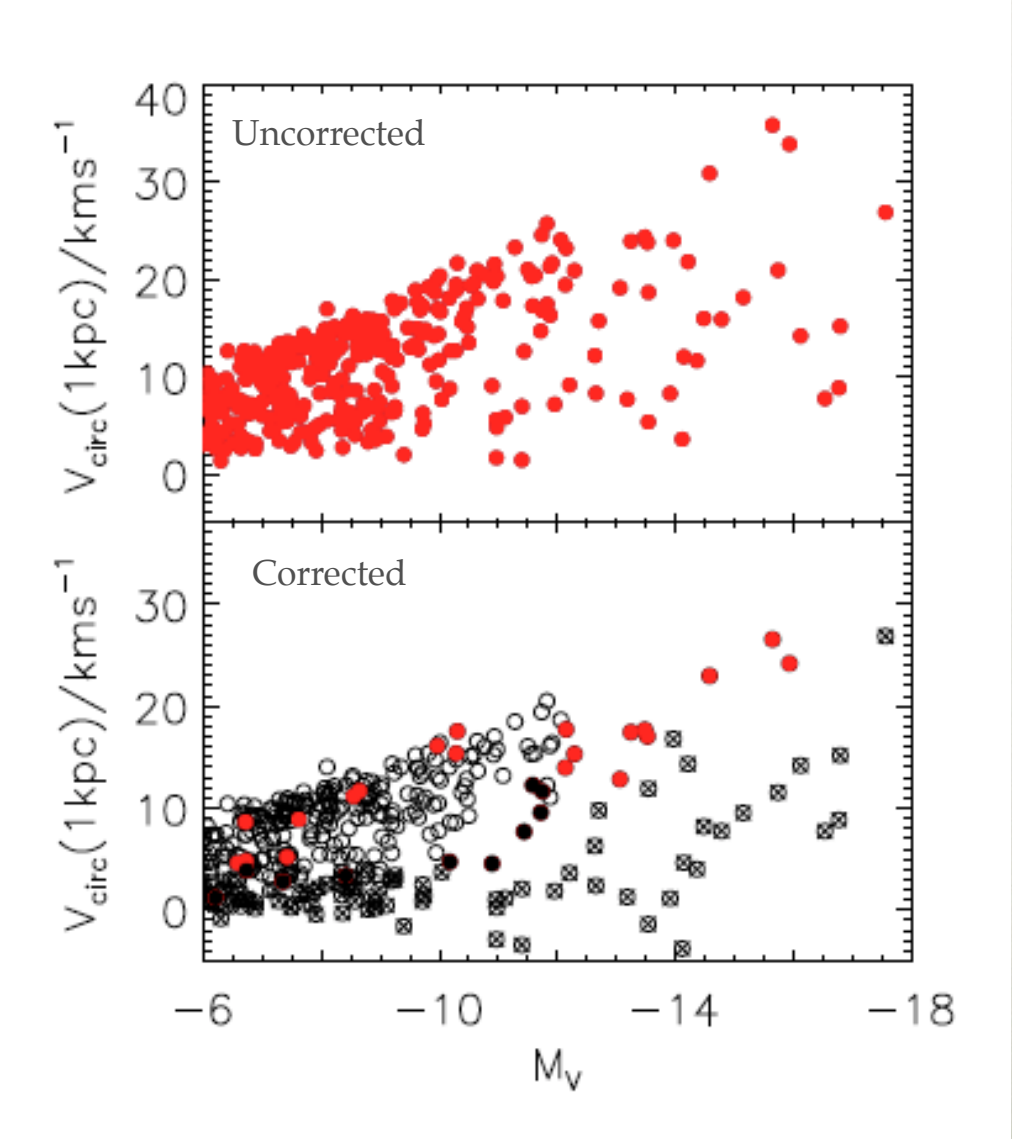

Brooks, Kuhlen, Zolotov, & Hooper (2012), ApJ, 765, 22, arXiv:1209.5394

We must understand the impact of baryonic physics on galaxy formation (in any model)!

A better treatment of baryonic physics may alleviate the small scale crisis of CDM

WDM: no cores without baryons

SIDM: cores below the scale that baryons can contribute (field dwarfs)?