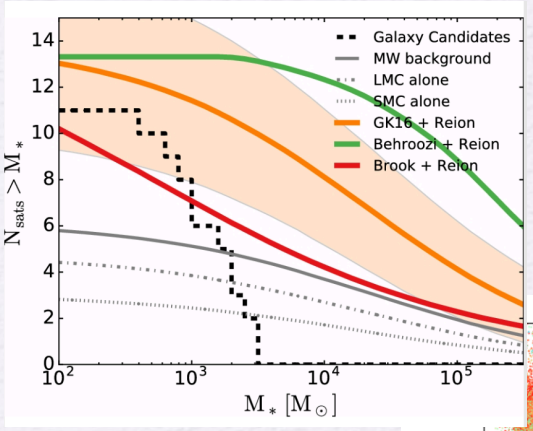
Dwarf Galaxy Groups: A Unique Test of ΛCDM

Sabrina Stierwalt
(Occidental College/Caltech)*

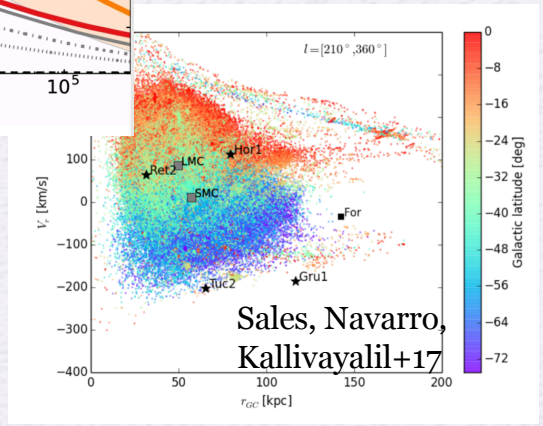
Gurtina Besla, Nitya Kallivayalil,
Kelsey Johnson, Dave Patton,
Mary Putman, George Privon,
Ekta Patel, Sarah Pearson

Under the CDM paradigm, the sub-halo mass function is predicted to be scale-free.

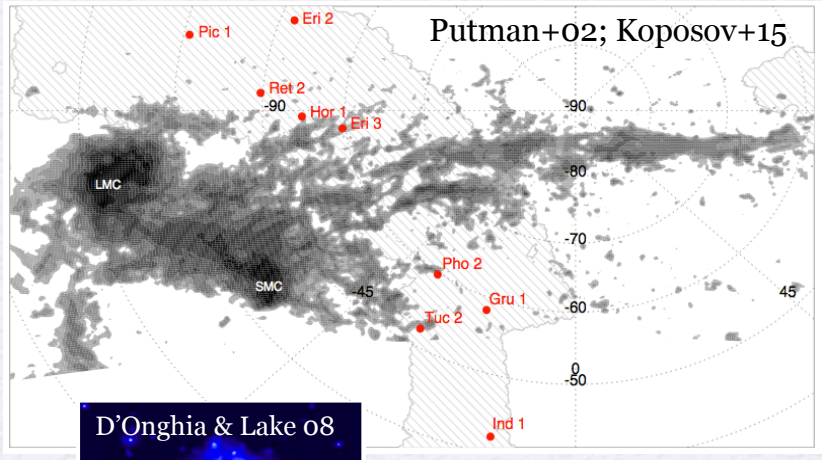
ΛCDM predicts that dwarf galaxies should have their own satellites.

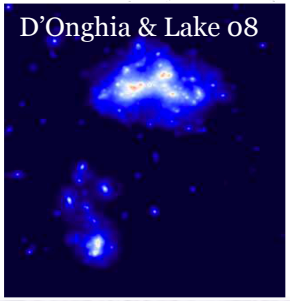


Dooley+17b



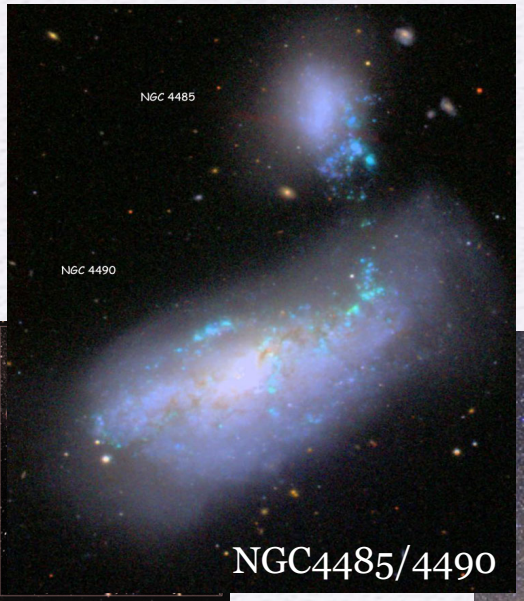
Sales, Navarro, Kallivayalil+17





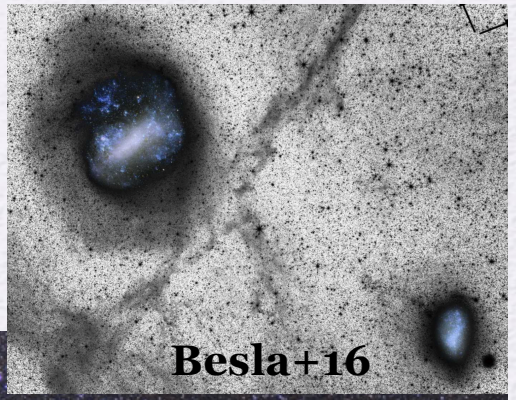
But what if we could instead determine the satellite mass function in isolation …

A few examples of likely dwarf-dwarf interactions exist.

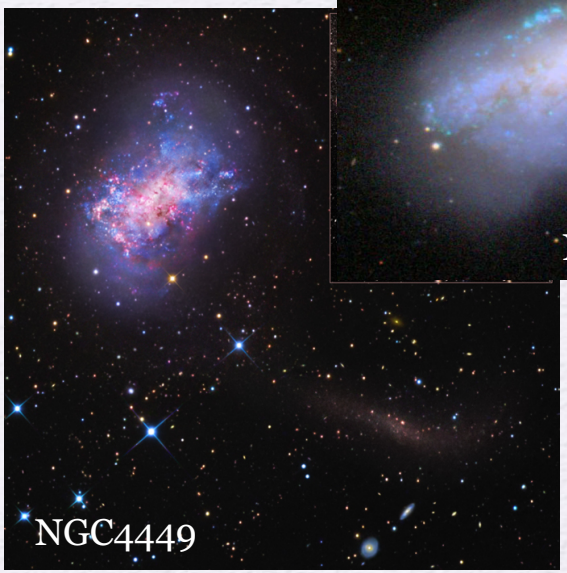


NGC4485/4490

BUT how representative are these examples?



Besla+16

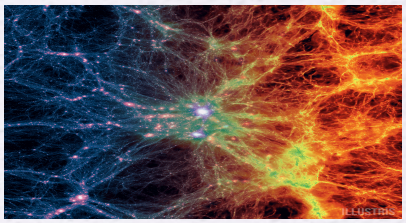


NGC4449

Magellanic Clouds

TiNy Titans (TNT) is a systematic study of interacting dwarf galaxies.

Theoretical Program:
(lead: Gurtina Besla)



Local Volume Sample:
(lead: Mary Putman)

Low-z (z<0.07) Pair Sample:
(Stierwalt et al. 2015)

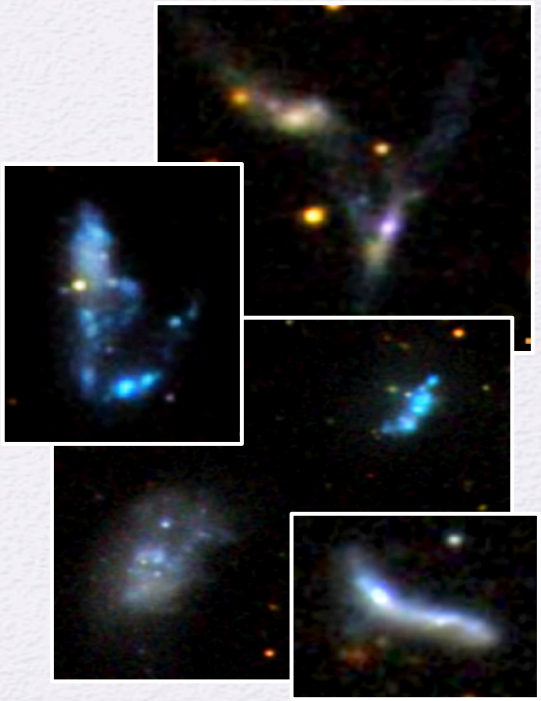
60 SDSS-selected Dwarf Pairs

$10^7\ M_{sun} < M_* < 5 \times 10^9\ M_{sun}$

Projected Separation < 50 kpc

Velocity Separation < 300 km/s

D > 1.5 Mpc from a massive neighbor

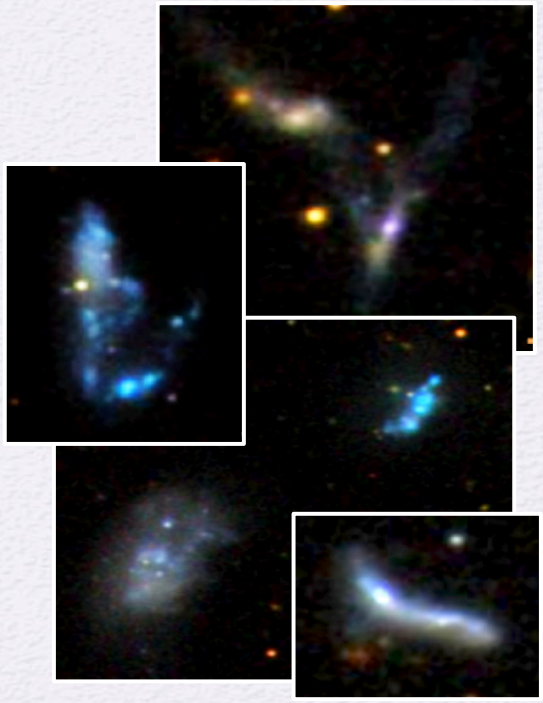


TiNy Titans (TNT) is a systematic study of interacting dwarf galaxies.

1) How do galaxy mergers proceed at low mass and what does that mean for their role in the build up of more massive galaxies?

2) How do mergers affect the evolution of dwarf galaxies themselves (for example, can they explain the burstiness of dwarfs?)

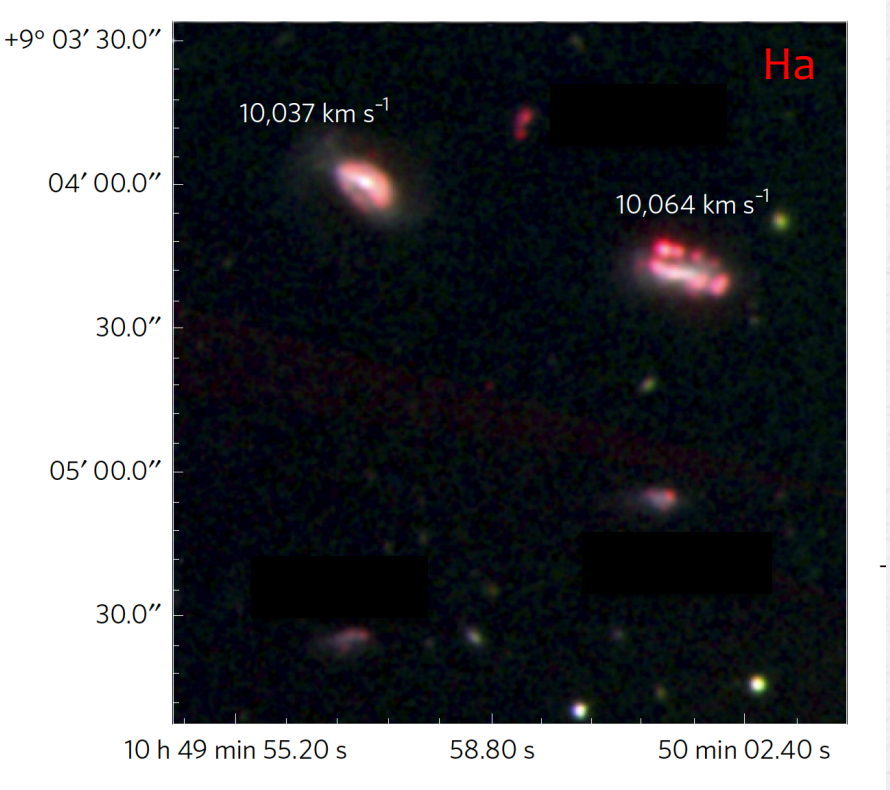
3) Can we characterize the physics of star formation and feedback triggered by interactions at low metallicity, as windows to high z?



TNT First Results (Stierwalt+15,+17; Besla+18)

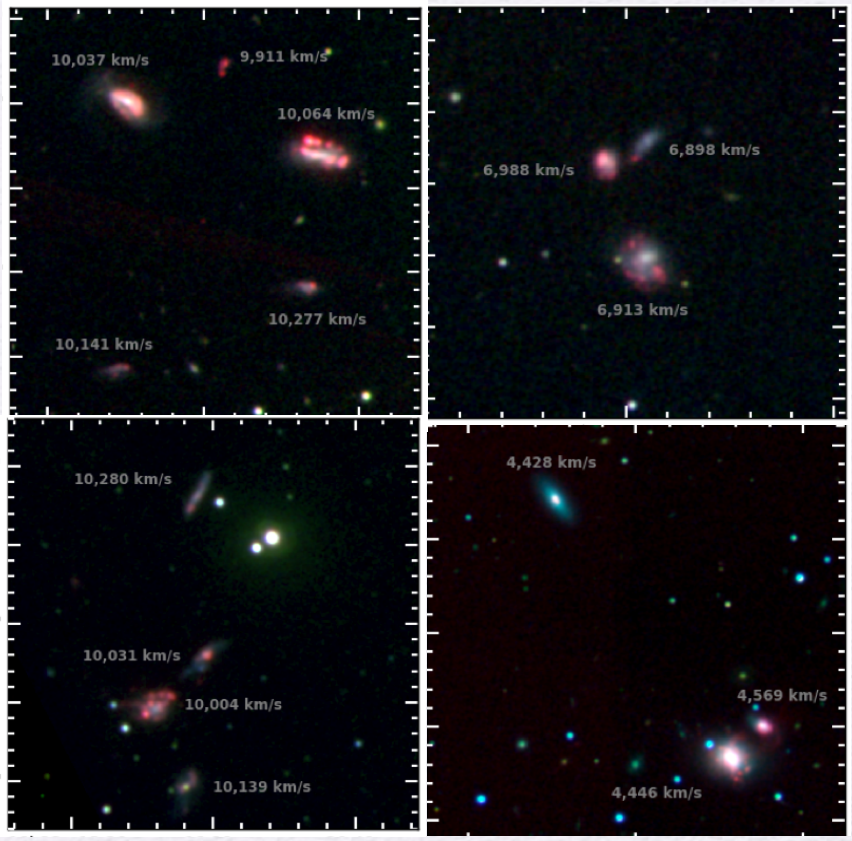
- Star formation is enhanced in paired dwarfs relative to unpaired dwarfs
- Paired dwarfs do not show signs of quenching outside the presence of a massive neighbor
- < 5% of dwarfs at z=0 are found in pairs
- Mean number of companions per dwarf (N=0.04) agrees between SDSS & Illustris (when applying SDSS sensitivity limits)

Starting with the TNT pair sample, we look for isolated dwarf galaxy groups.



Group status confirmed with APO spectroscopy and the Maryland Magellan Tunable Filter

From the TNT pair sample, we identified 7 isolated galaxy groups with only low mass members.



* Each group has at least 3 members (some have 4-5) with $7 < \log(M_*/M_{sun}) < 9.4$ each

* 2D projected sizes are:
  16 – 80 kpc

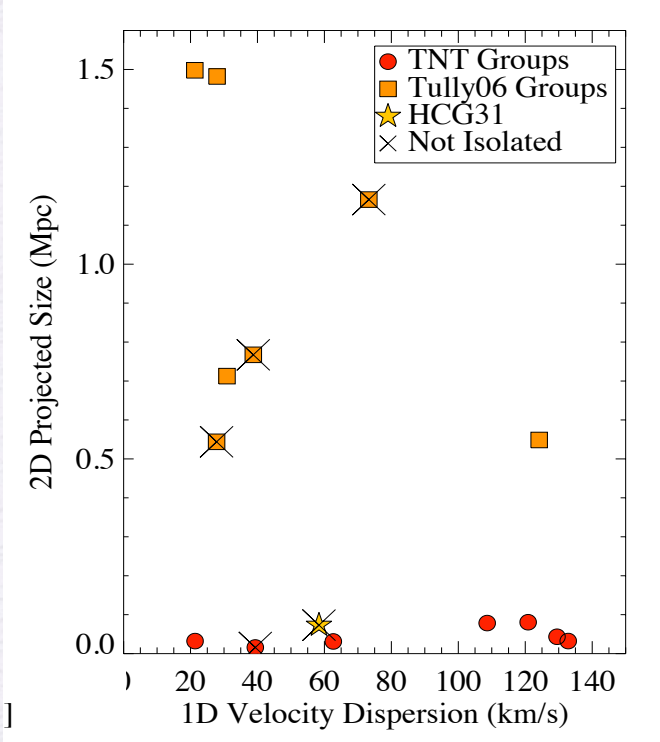
* 3D velocity dispersions are:
  $37 \text{ km/s} < \sigma_{3D} < 209 \text{ km/s}$

* Mass-to-light ratios predicted for groups to be bound groups:
  $12 < M_{tot}/L_B\ [M_{sun}/L_{sun}] < 80$

* Three groups have a $\log(M_*) \sim 9.2\text{-}9.4$ dwarf and a $\log(M_*) \sim 8.2\text{-}8.4$ dwarf

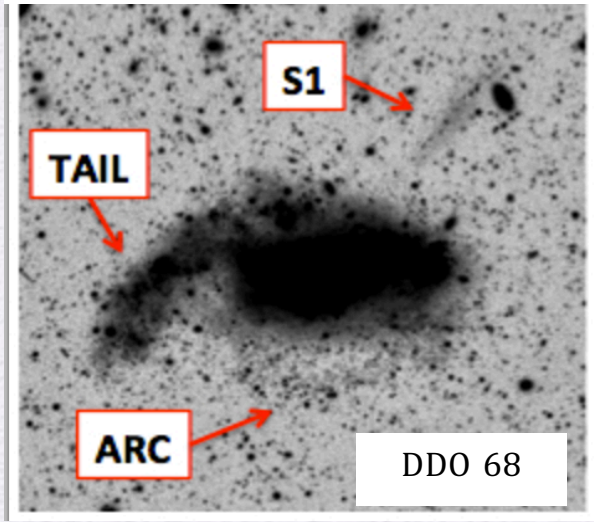
Stierwalt et al. 2017, *Nature Astronomy*

From the TNT pair sample, we identified 7 isolated galaxy groups with only low mass members.



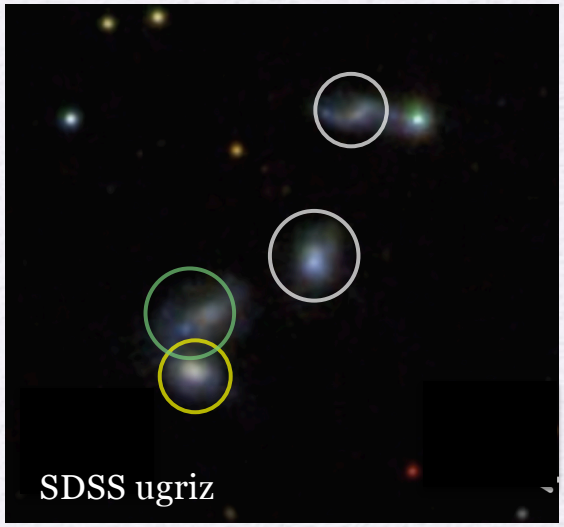
The TNT groups were different from known groups in the literature in three key ways: isolation, extent, and mass.

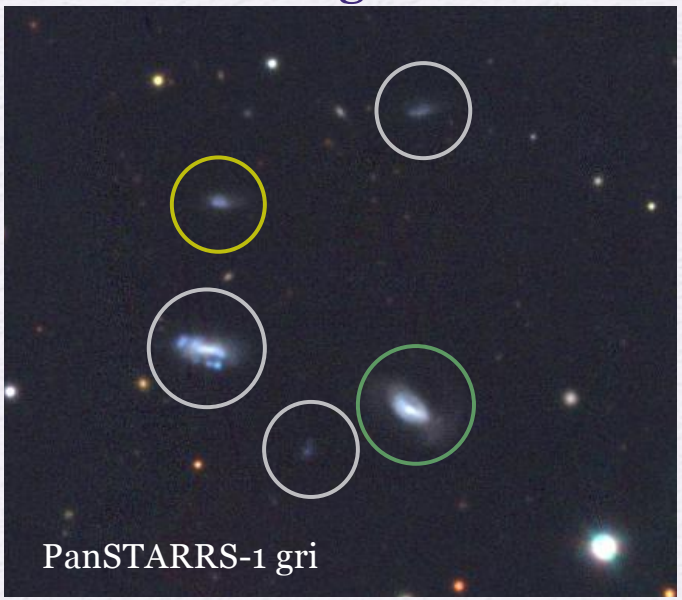
Annibali et al. 2016

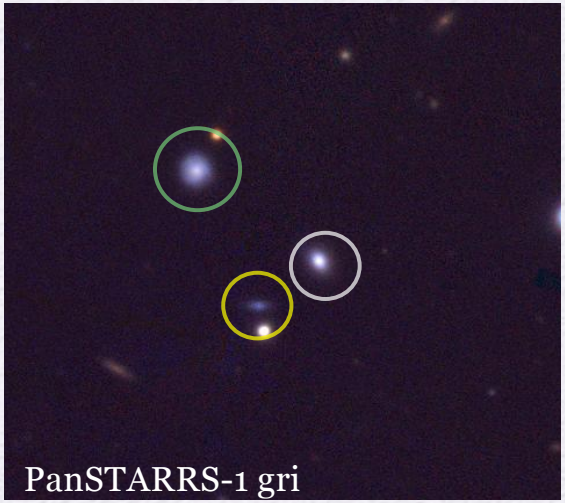


At least 3 TNT isolated dwarf groups contain approximate LMC/SMC analogs with one large caveat....

$M_* \sim$ LMC
$M_* \sim$ SMC
Additional Companions







The systematic selection of TiNy Titans allows for direct tests of ΛCDM.

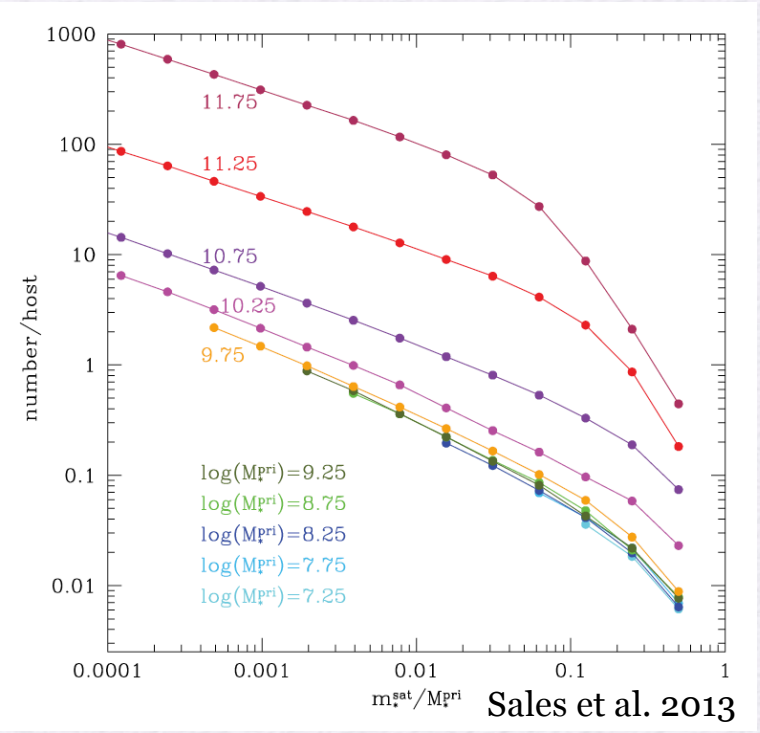
TNT observations match cosmological predictions to TNT M_* limits

For dwarfs hosts with $M_* \sim 10^9\ M_{sun}$ …

	Sales et al. Predicts	TNT Observes
% with companion of similar M_*	1-3%	< 5%
% with $0.02 < M_{sat}/M_{prim} < 0.4$	1-10%	11%

Besla+18: mean number of companions per dwarf (N=0.04) agrees between SDSS & Illustris

Predictions from Millennium-II



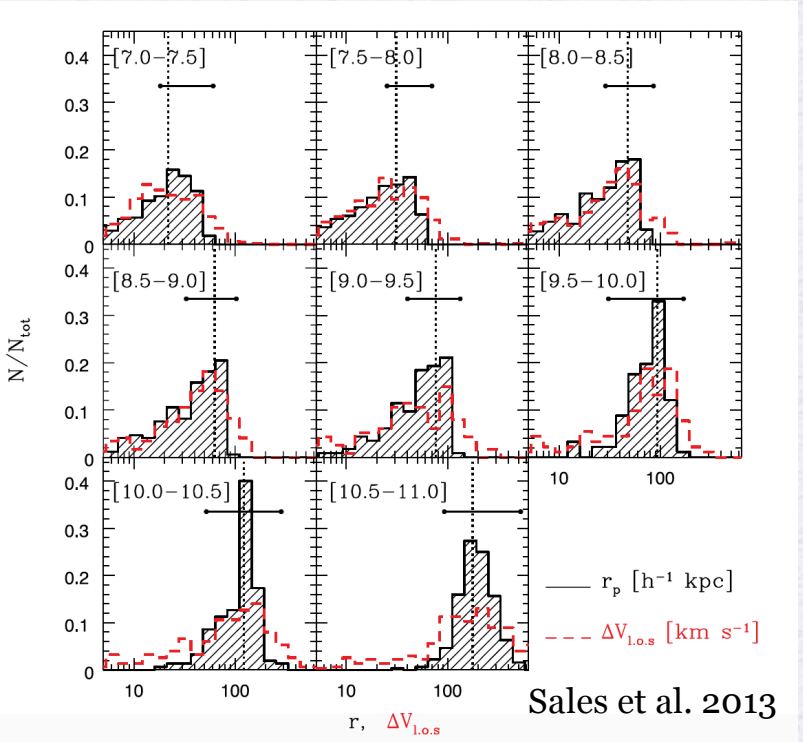
Sales et al. 2013

The systematic nature of TiNy Titans allows for direct tests of ΛCDM.

Sales et al. predicts: dwarf satellites of other dwarfs will have line of sight velocity differences of ~100 km/s

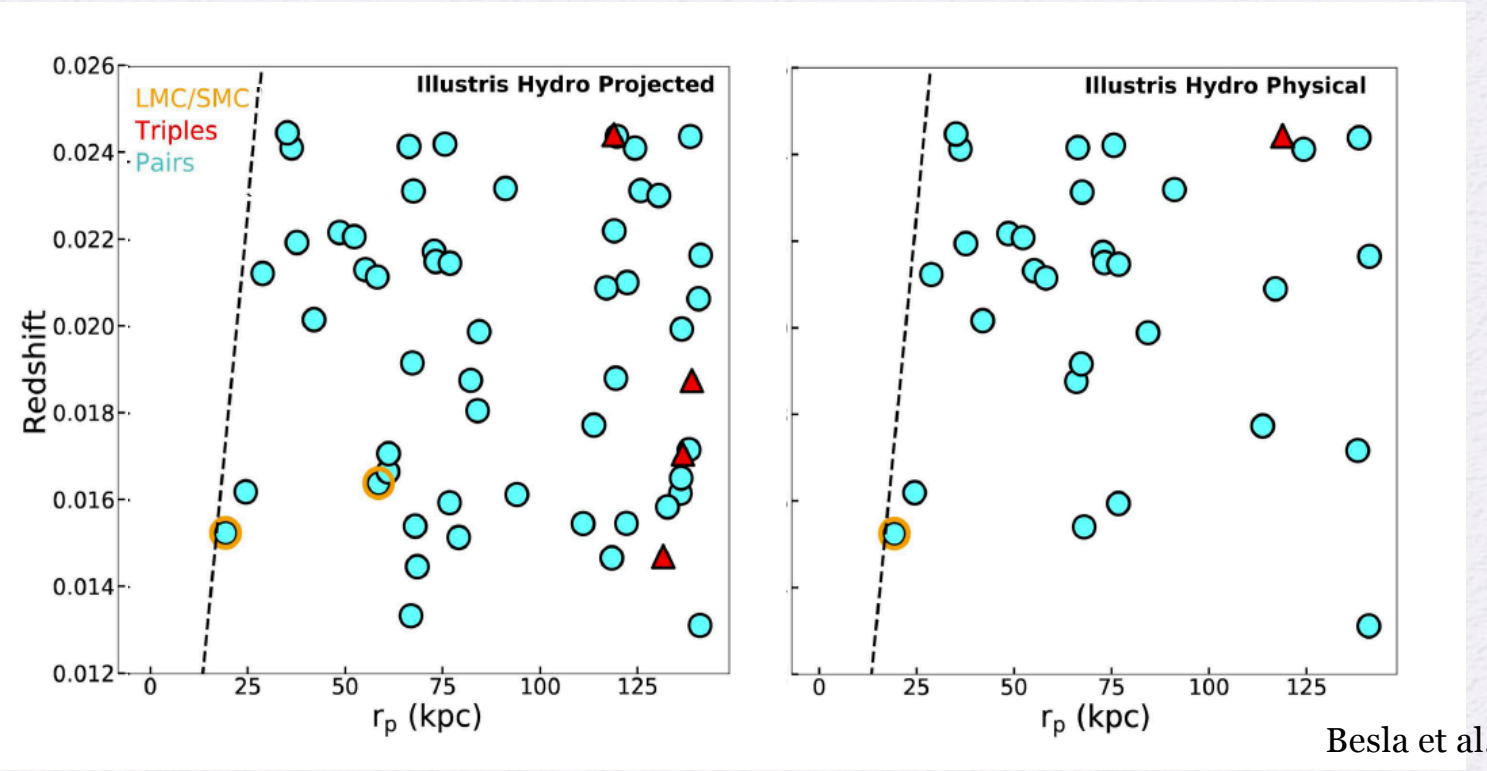
TNT observes: $\Delta V_{LOS} < 125$ km/s for 4 groups and $200 < \Delta V_{LOS} < 300$ km/s for 3 groups

Predictions from Millennium-II



Sales et al. 2013

But … Illustris suggests a contamination of 40% due to projection effects.



Besla et al. 2018