

Small-Scale Structure in the SDSS and LCDM

Erik Tollerud
UC Irvine

KITP 2012: First Light/Faintest Dwarfs



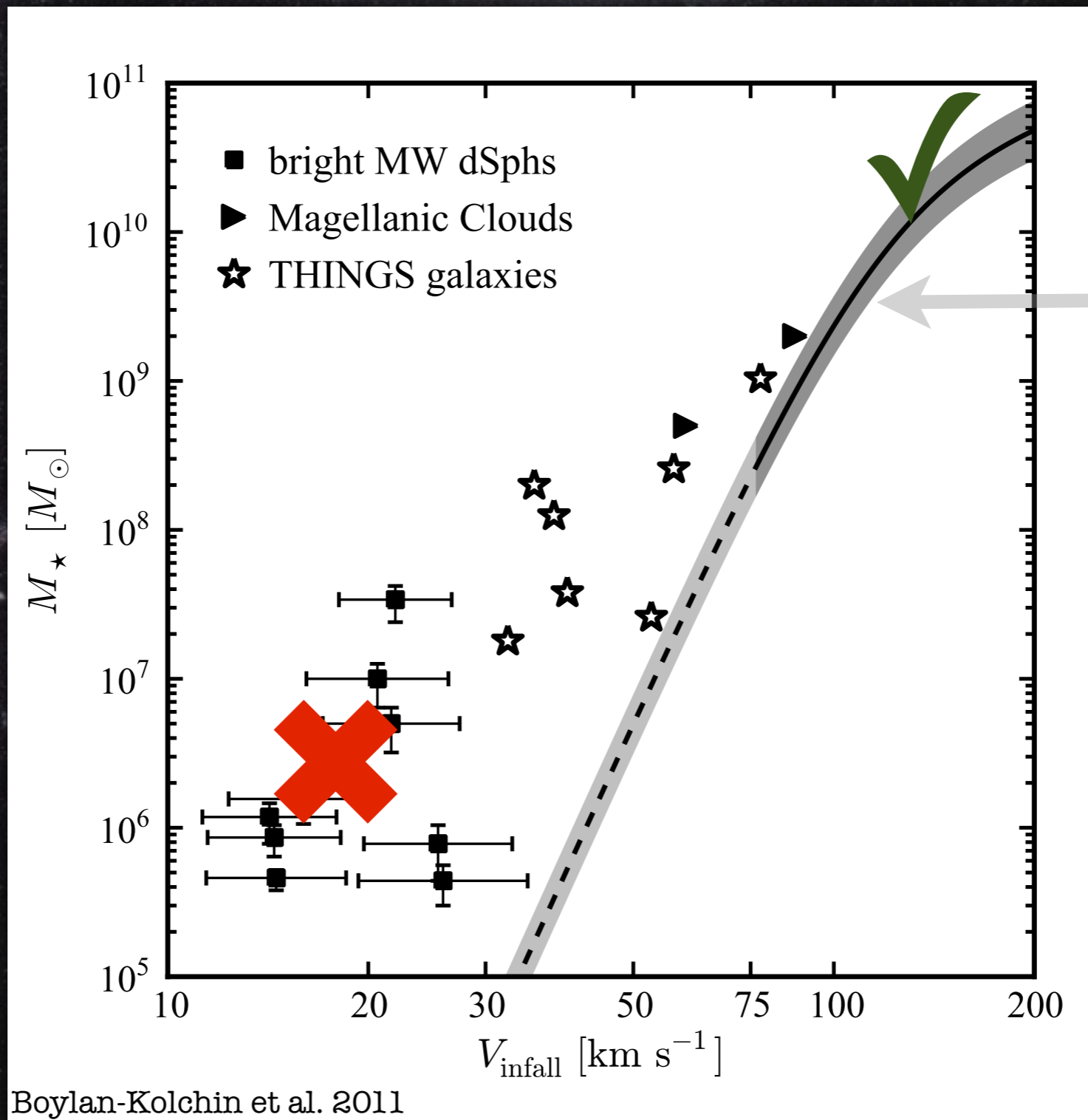
In Collaboration with:
Michael Boylan-Kolchin¹, Betsy
Barton¹, James Bullock¹, John
Phillips¹, Coral Wheeler¹, Chris Trinh²
¹UCI, ²U of Sydney

ApJ, 738, 102 (2011)

Image Credit: Robert Gendler

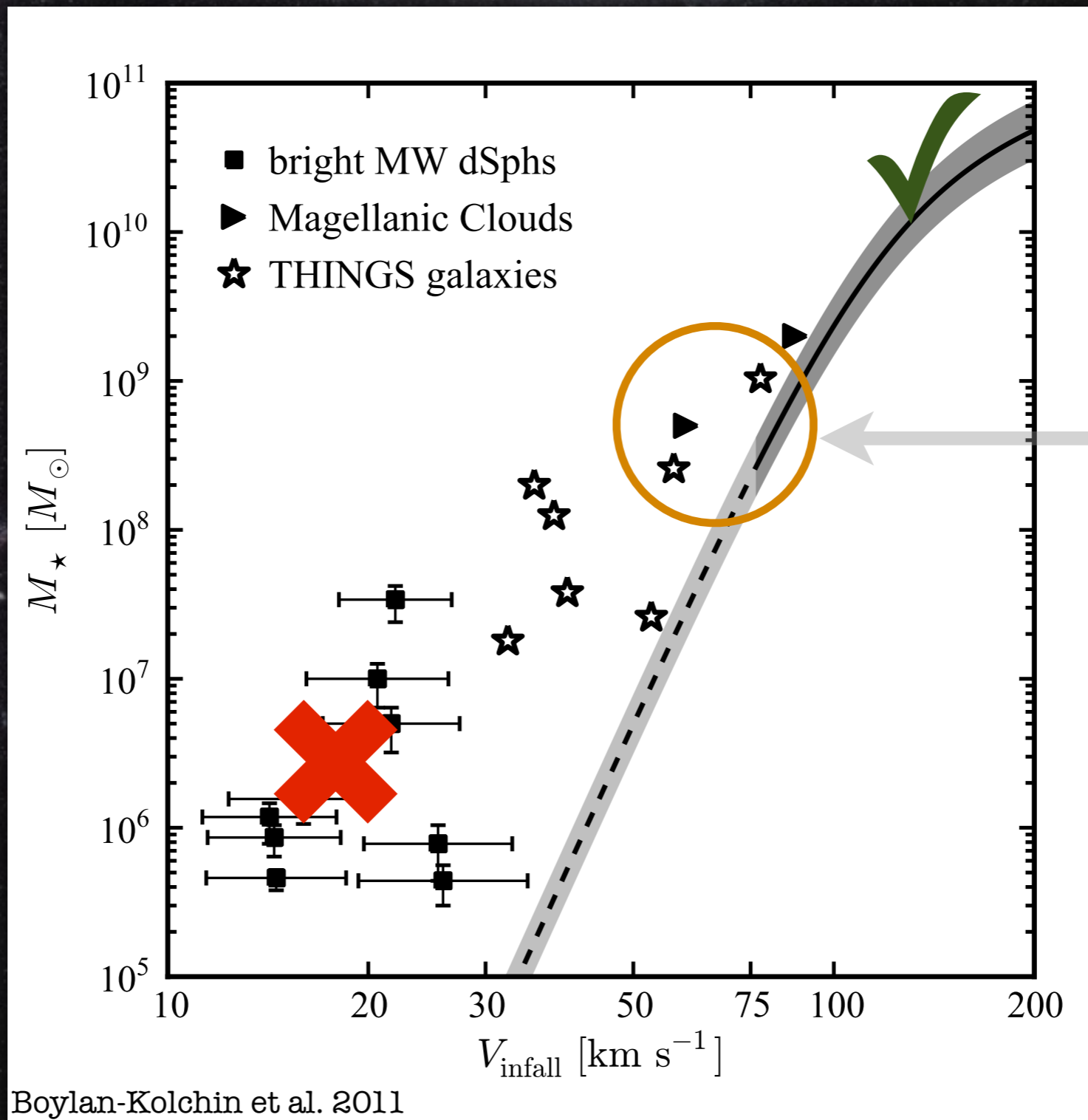
E. Tollerud

Why LMC Scales?



Abundance
Matching

Why LMC Scales?

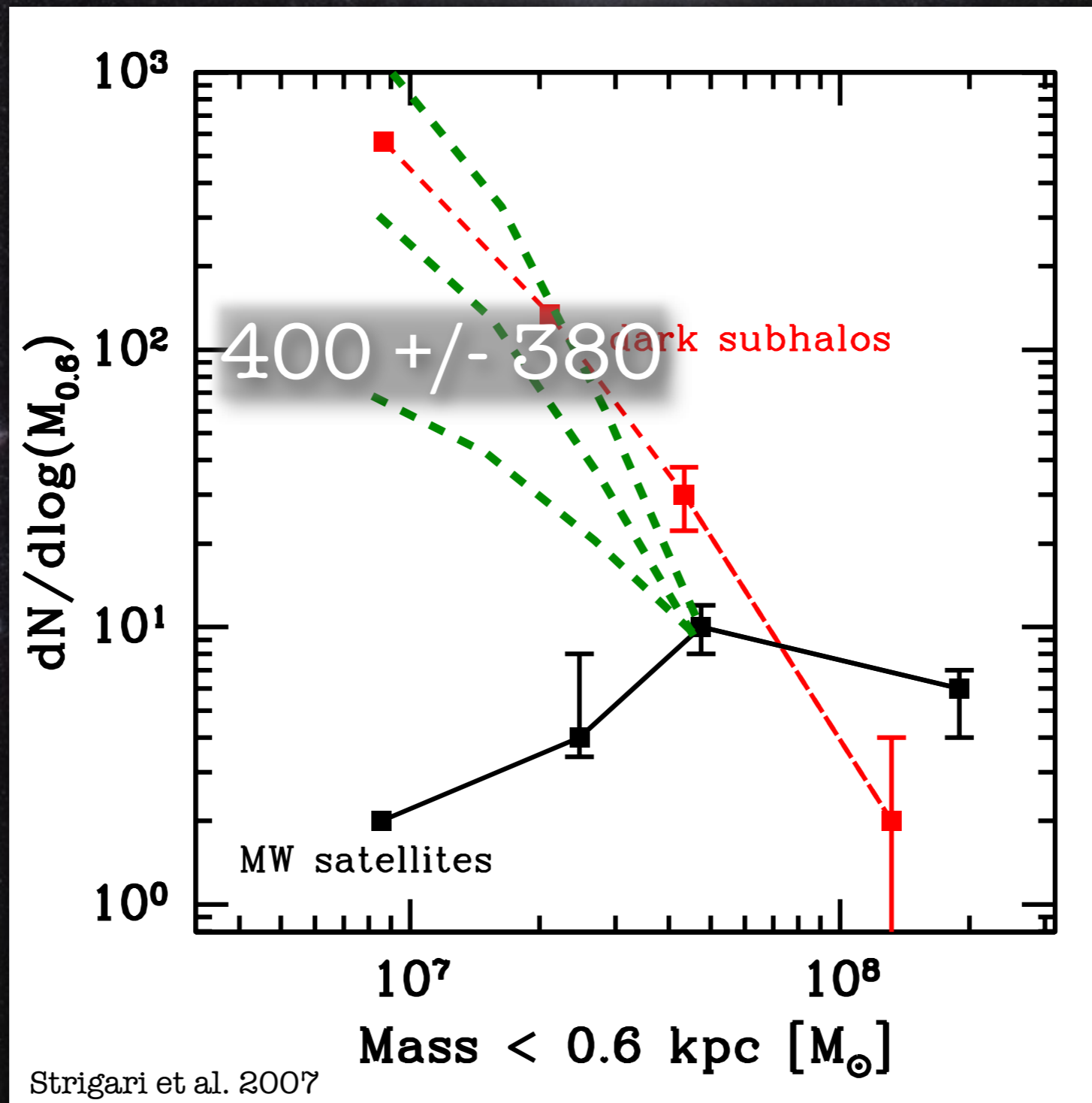


Does it
work
here?

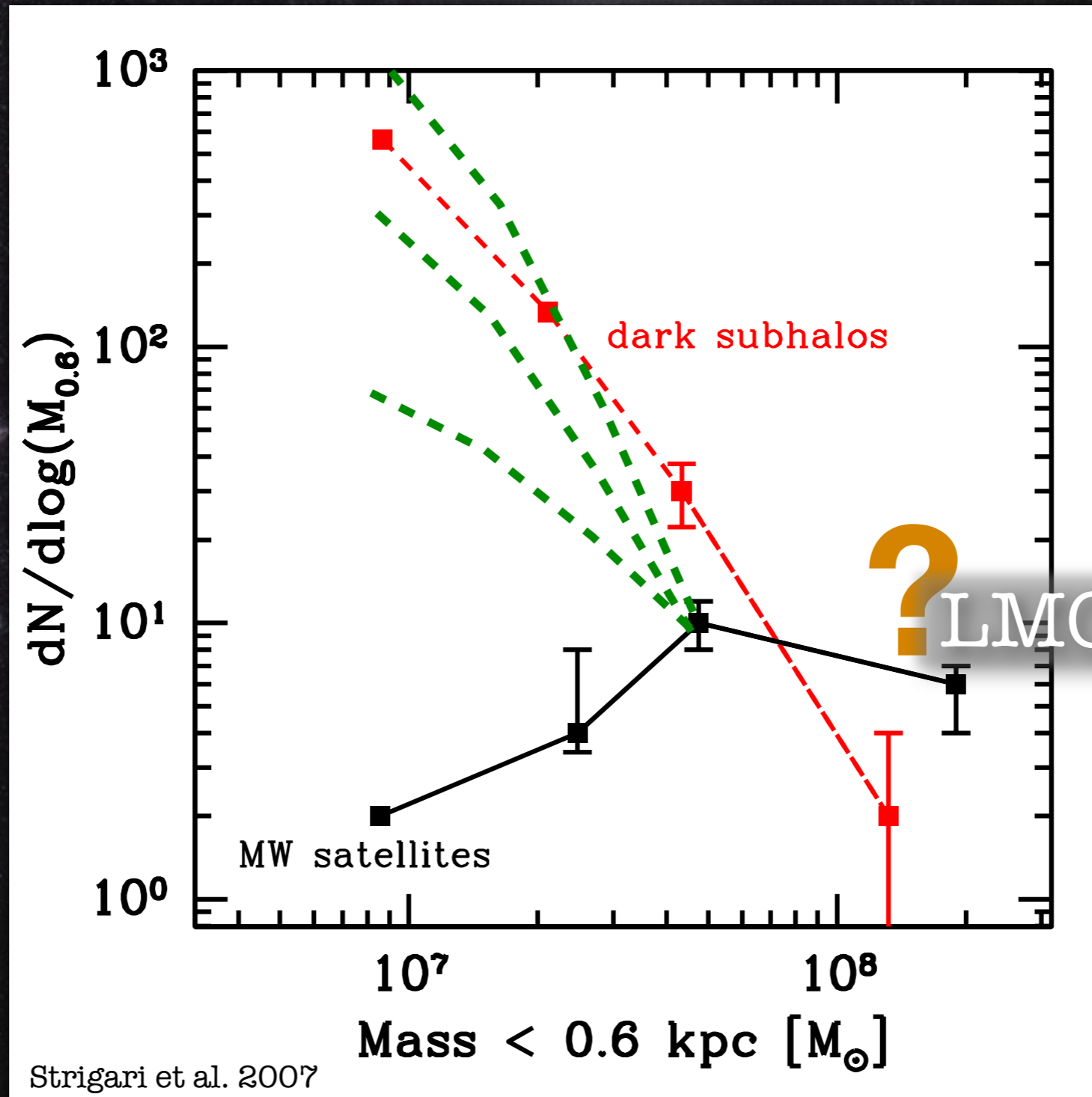
Missing Satellites

Absence of Smaller Galaxies

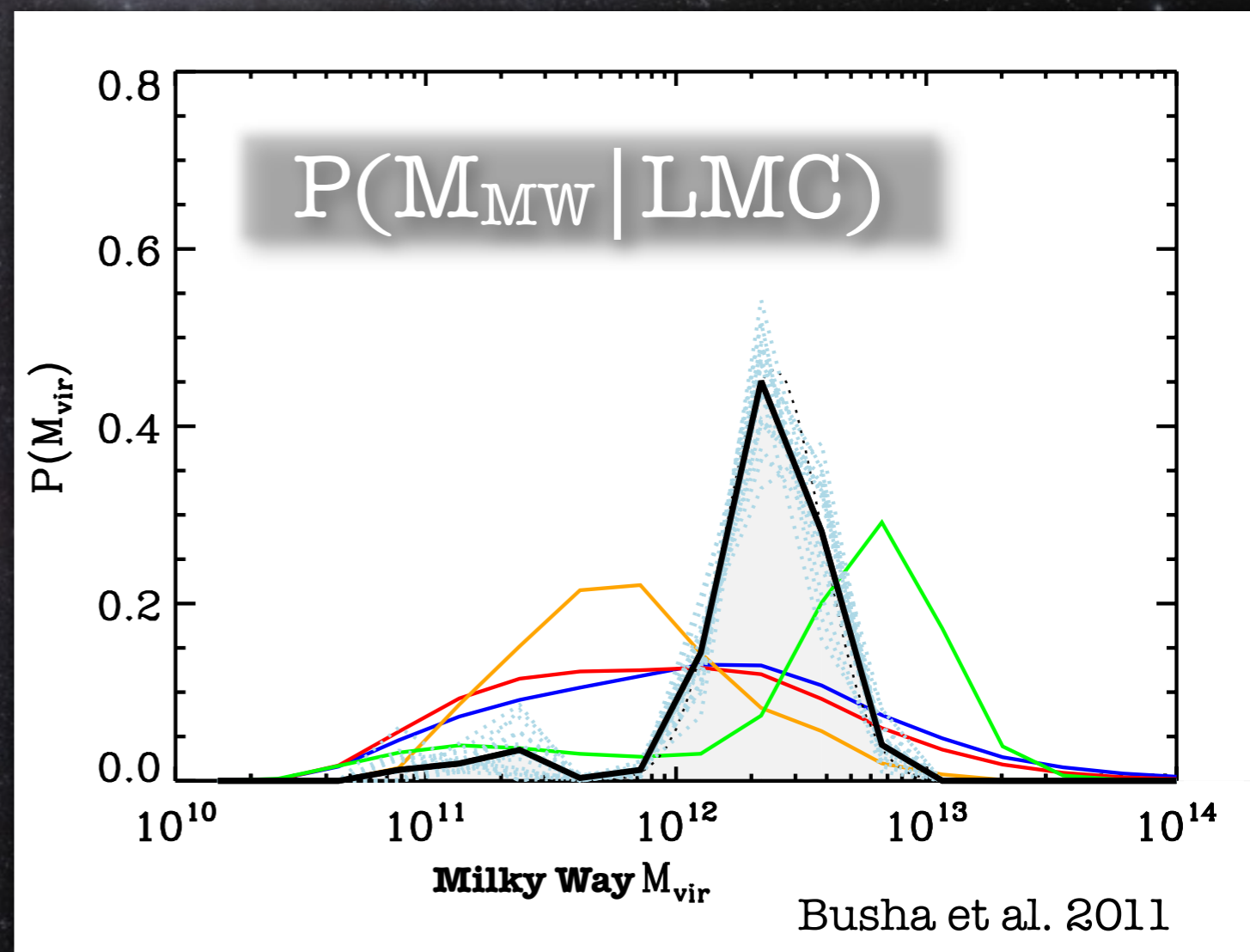
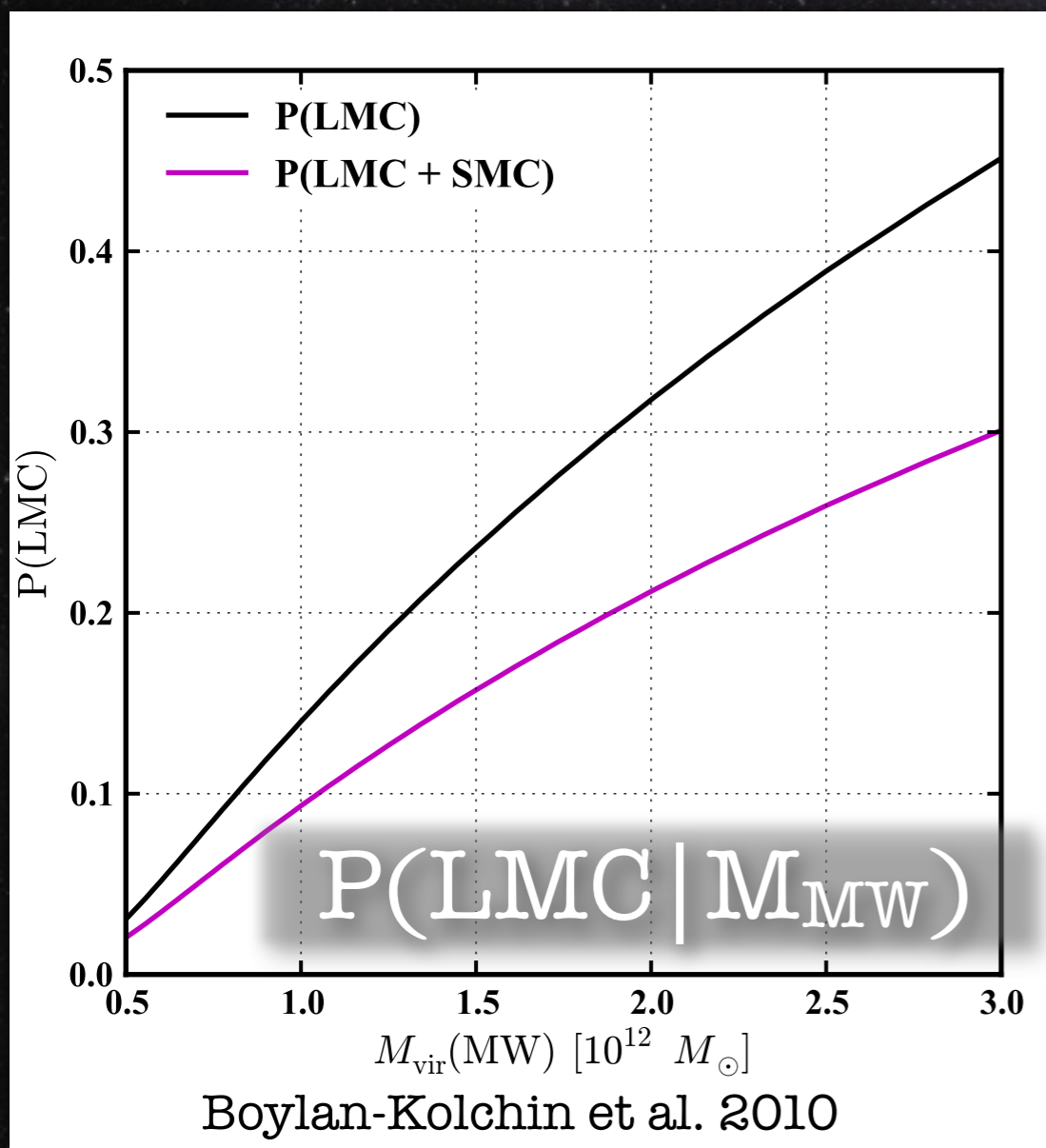
Nearby Bigger Ones Problem



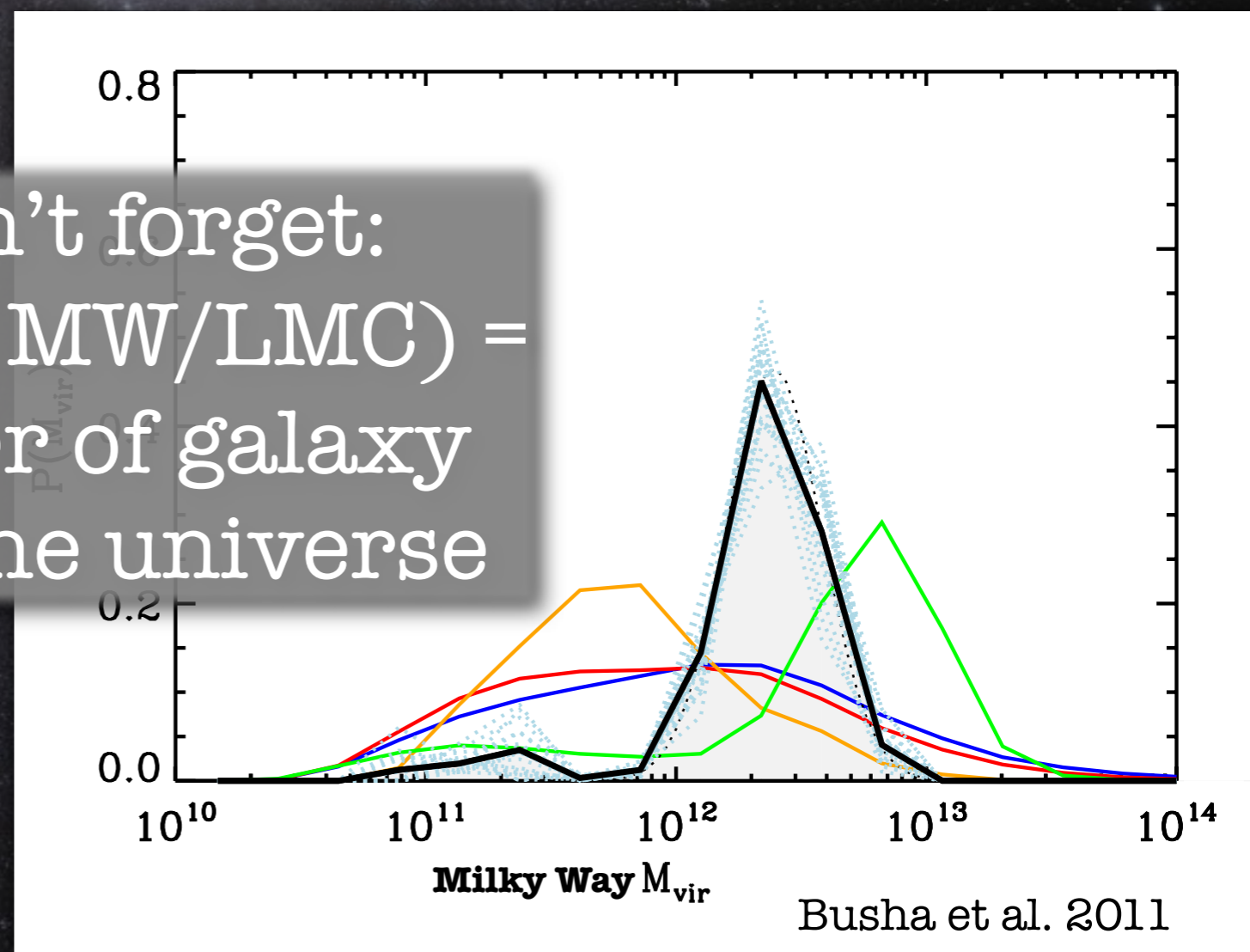
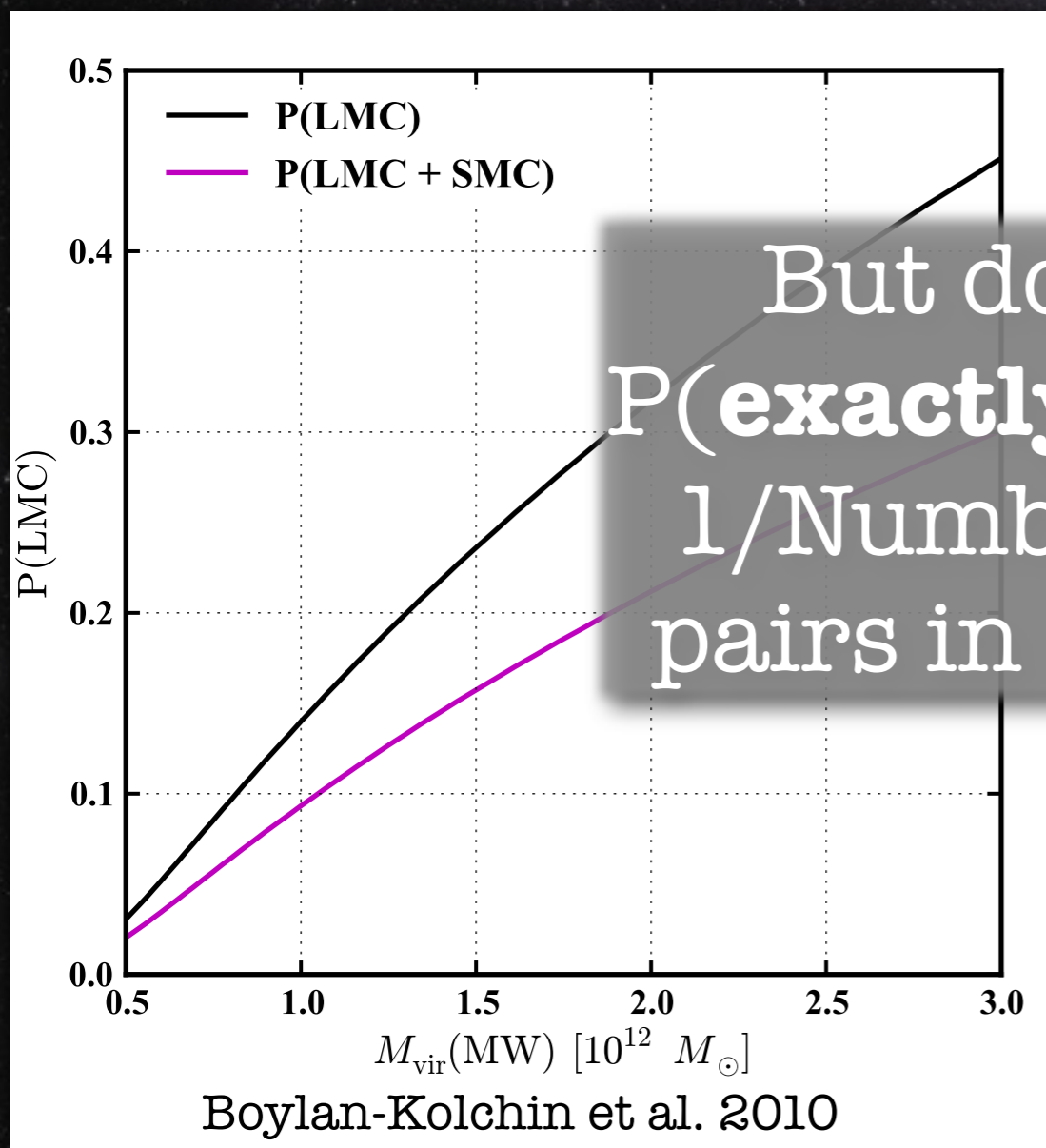
“Found” Satellites Problem?



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“Found” Satellites Problem?

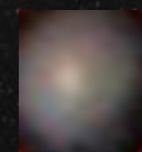
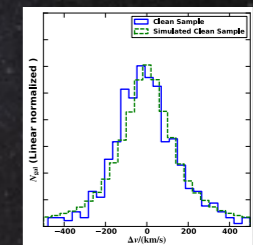
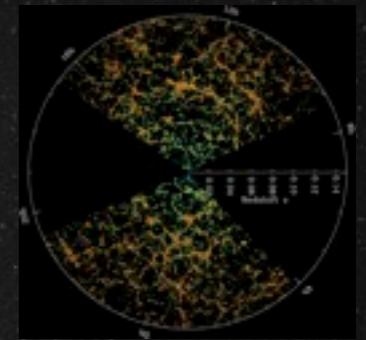


Two Key Questions

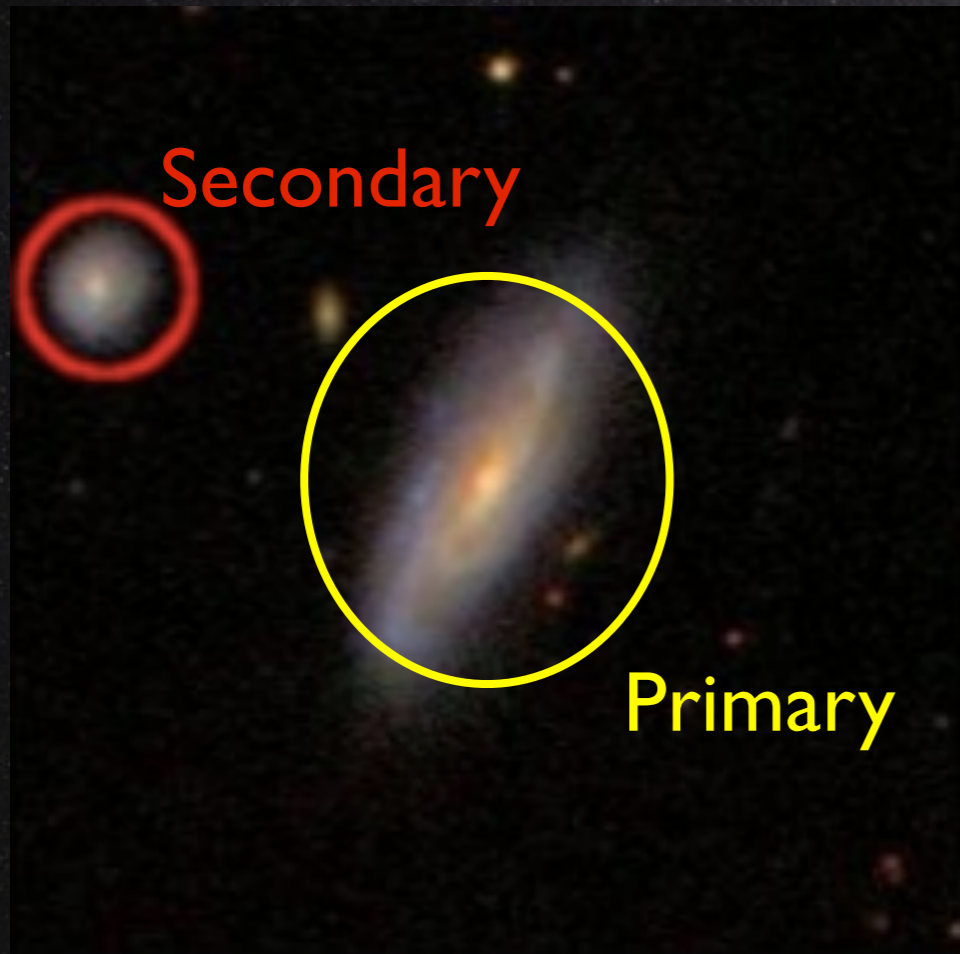
- ◆ Does LCDM reproduce simple observables of the brightest satellites of L^* galaxies?
- ◆ Is the LMC Weird? (empirically)
 - ◆ (Depends on how you ask the question!)

Approach

- ◆ SDSS (Spectroscopic) sample of $\sim 0.1 L^*$ companions of Isolated $\sim L^*$ galaxies
- ◆ Identical sample from cosmological simulation
- ◆ Compare easy observables: Δv_{pair} and radial distribution
- ◆ Compare the satellites to the LMC
- ◆ (Bonus: Study the satellites themselves)



Approach



SDSS
VAGC DR7

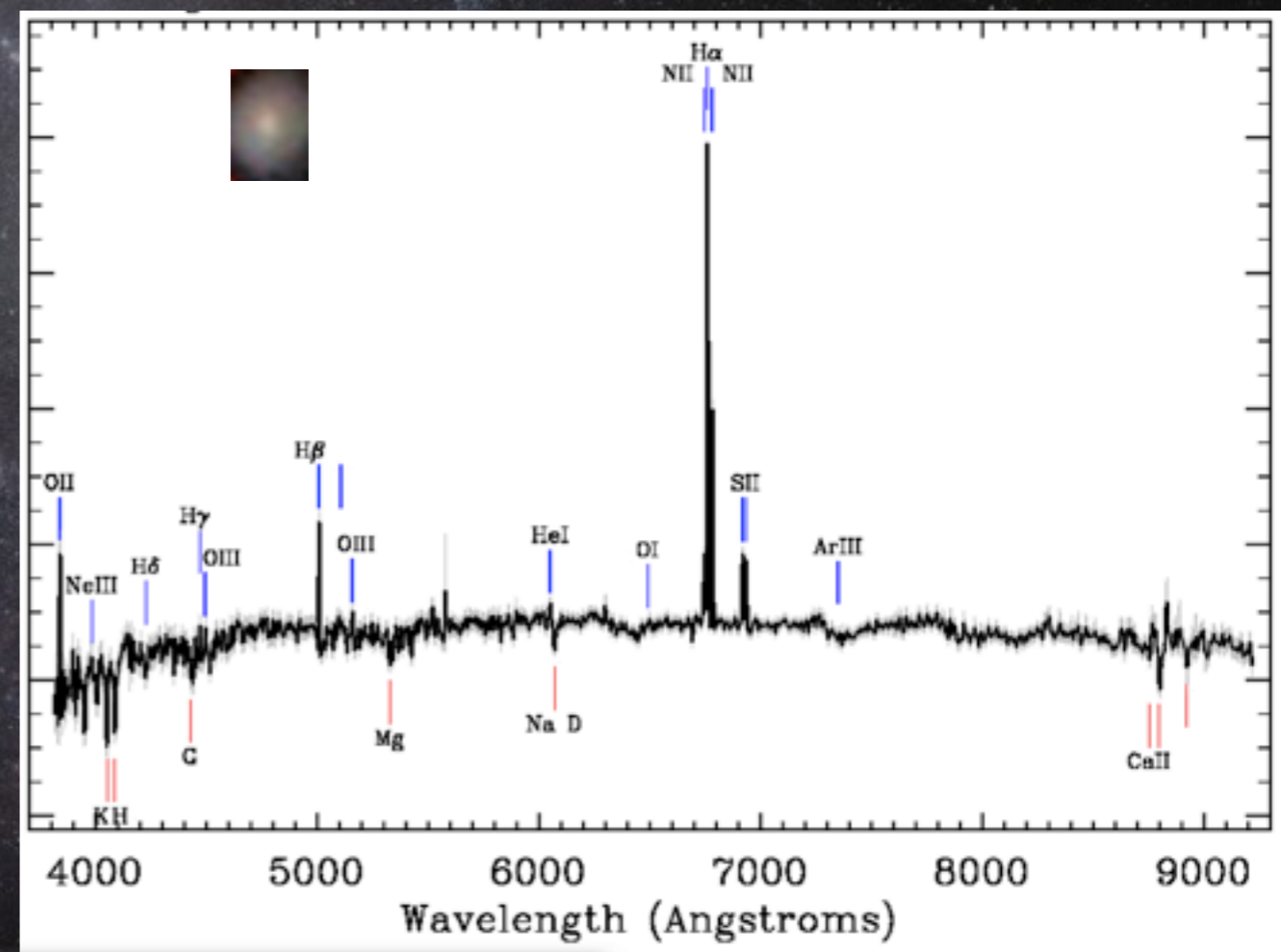
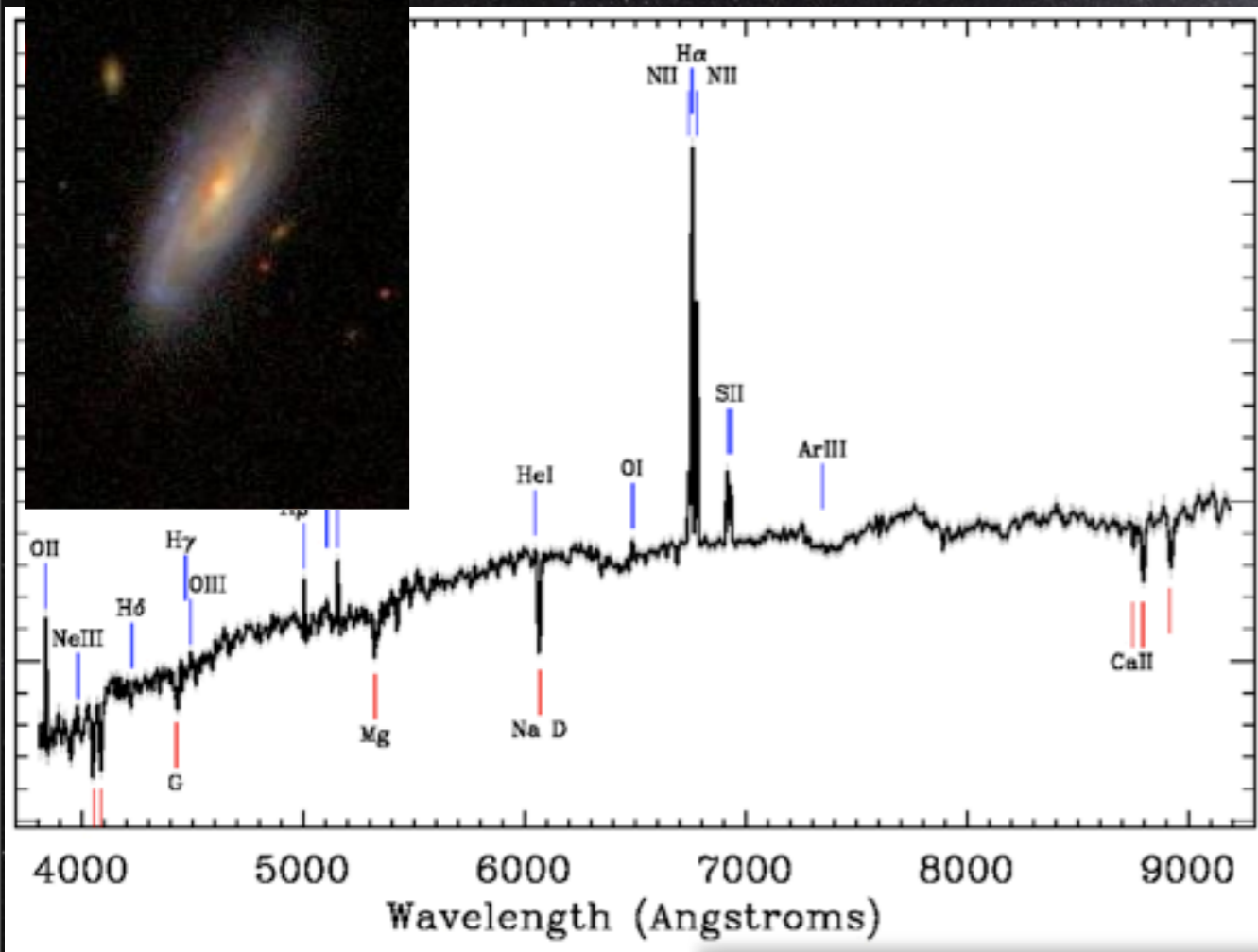
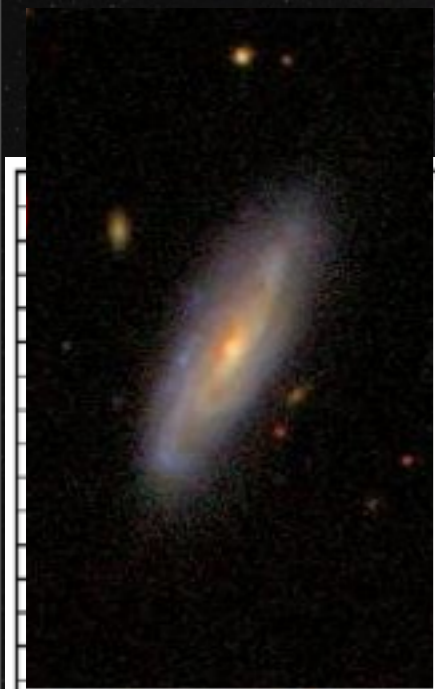
Blanton et al. 05



Millennium II
Simulation

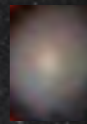
Boylan-Kolchin et al. 09

Primary and Secondary Must Have Similar Redshifts



Need for Spectroscopic
Completeness sets the
volume limit

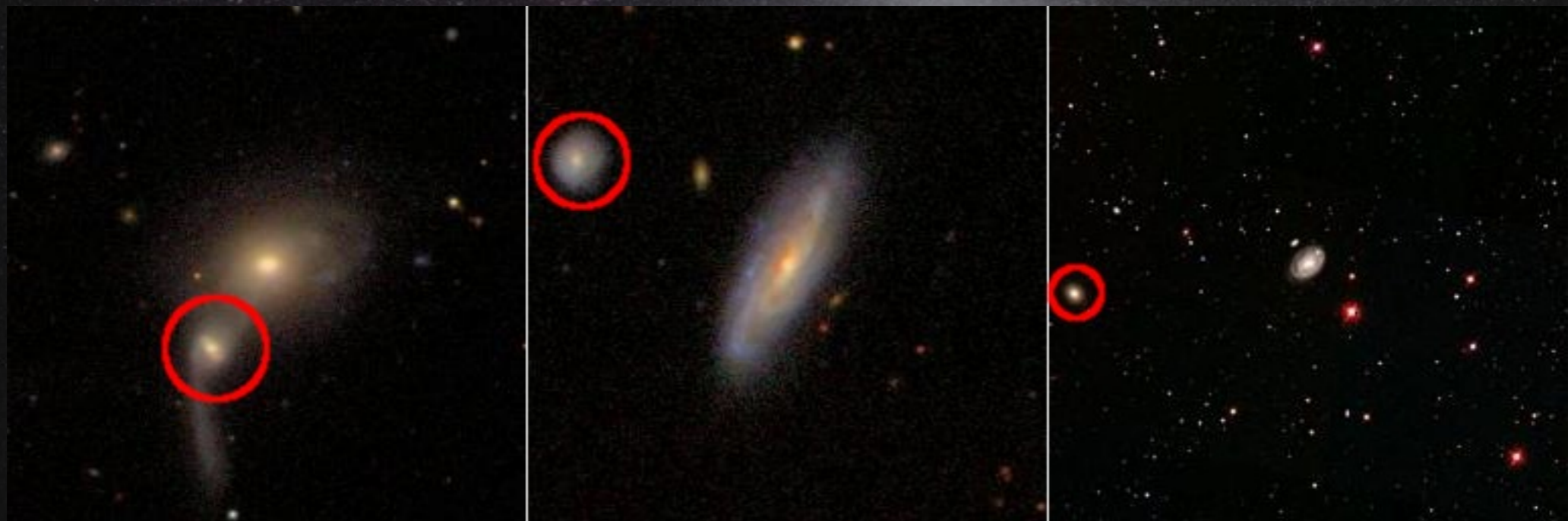
Primaries must be Isolated



$250 < d_{\text{proj}} < 700 \text{ kpc}/h$

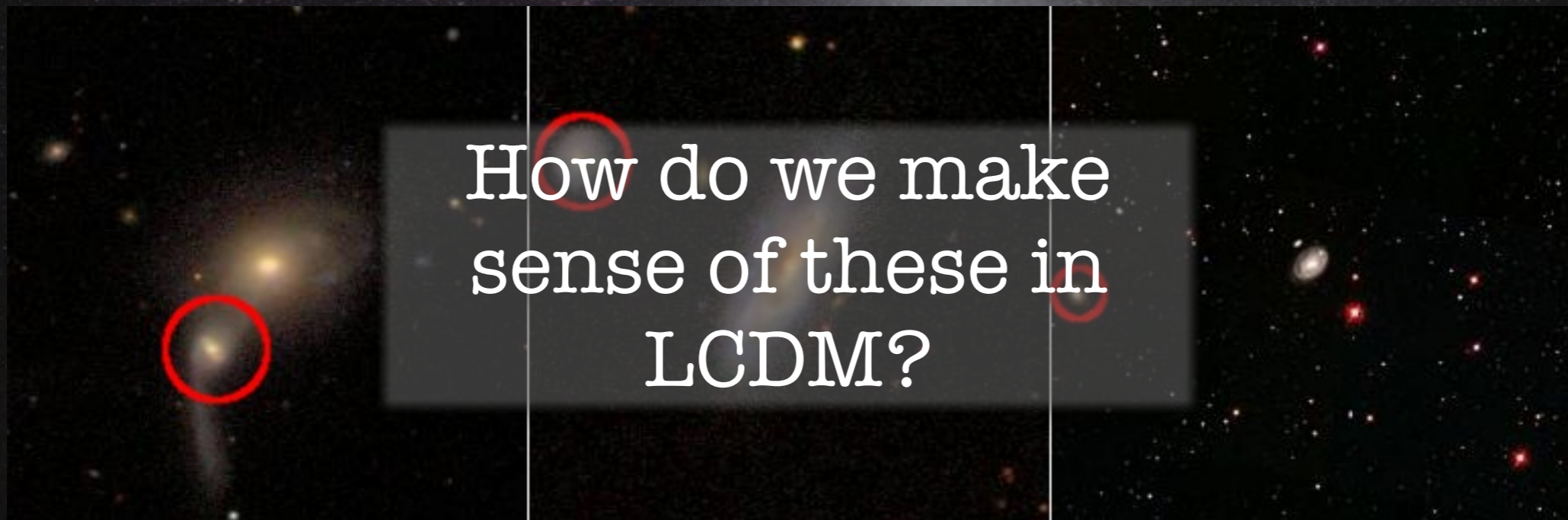
Primary/Secondary Pairs

- ◆ 1075 Primaries, 467 Secondaries
- ◆ Local ($z_{\text{median}}=.028$) due to spectroscopic limit

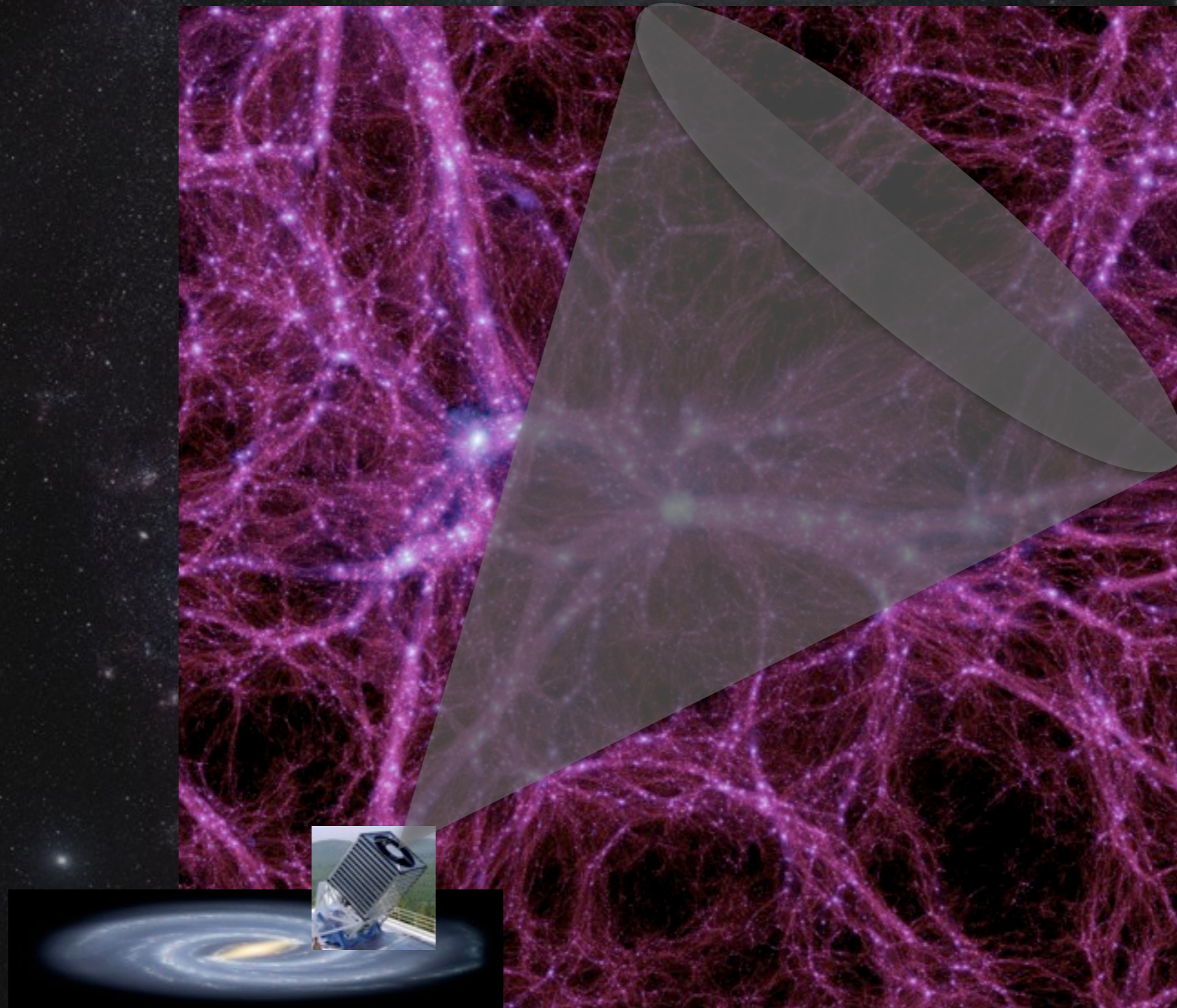


Primary/Secondary Pairs

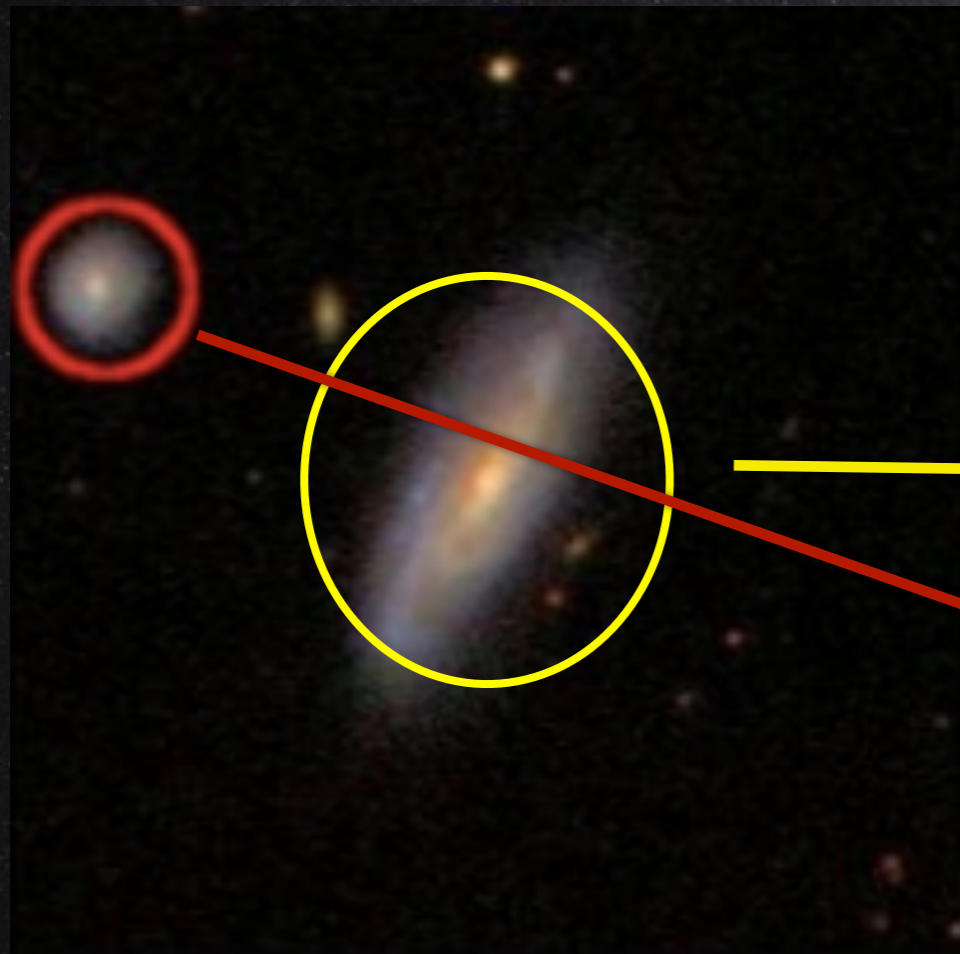
- ◆ 1075 Primaries, 467 Secondaries
- ◆ Local ($z_{\text{median}}=.028$) due to spectroscopic limit



Mock Galaxy Catalogs



Abundance Matching for Luminosities



SDSS
VAGC DR7

Blanton et al. 05



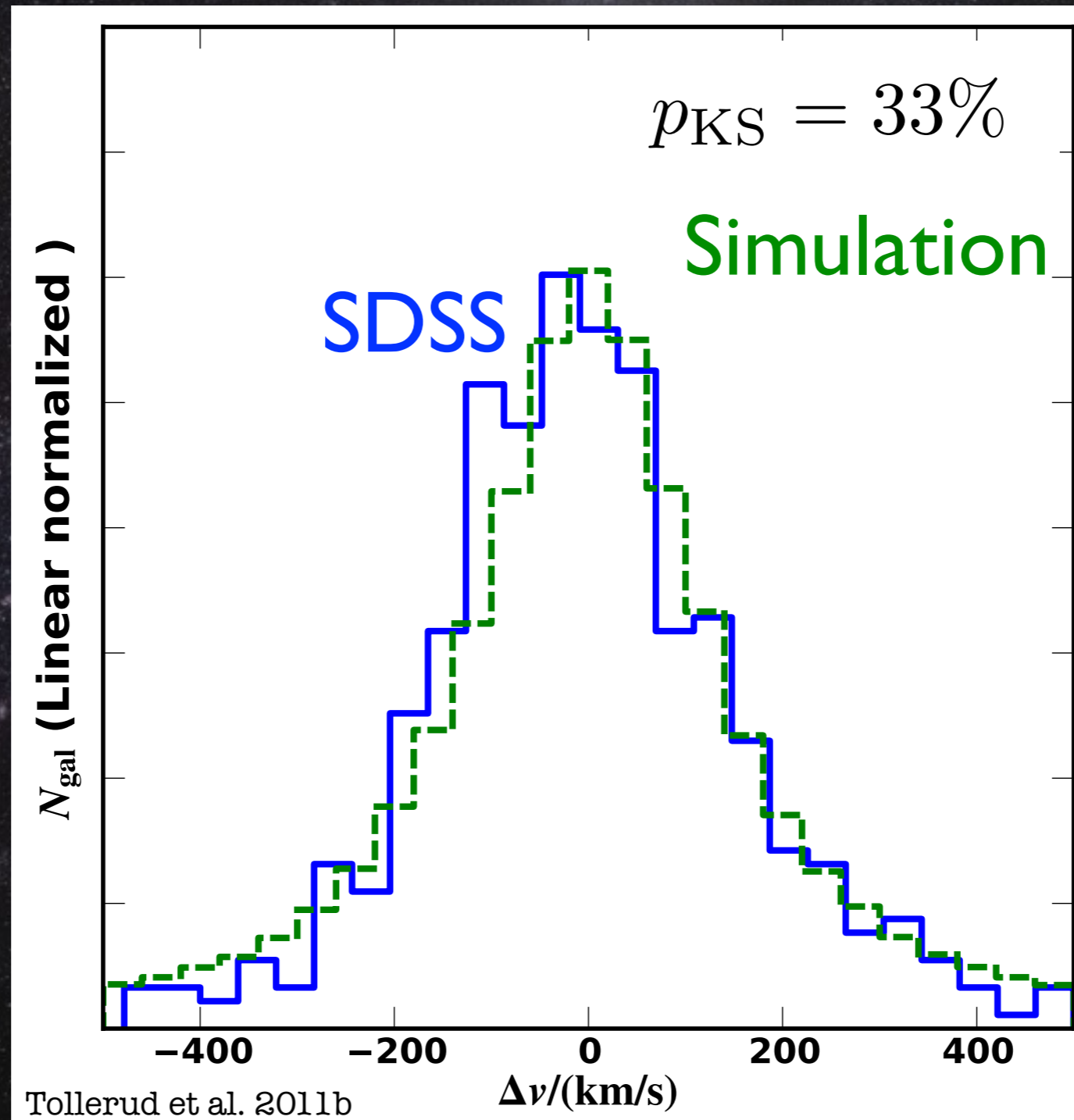
Millennium II
Simulation

Boylan-Kolchin et al. 09

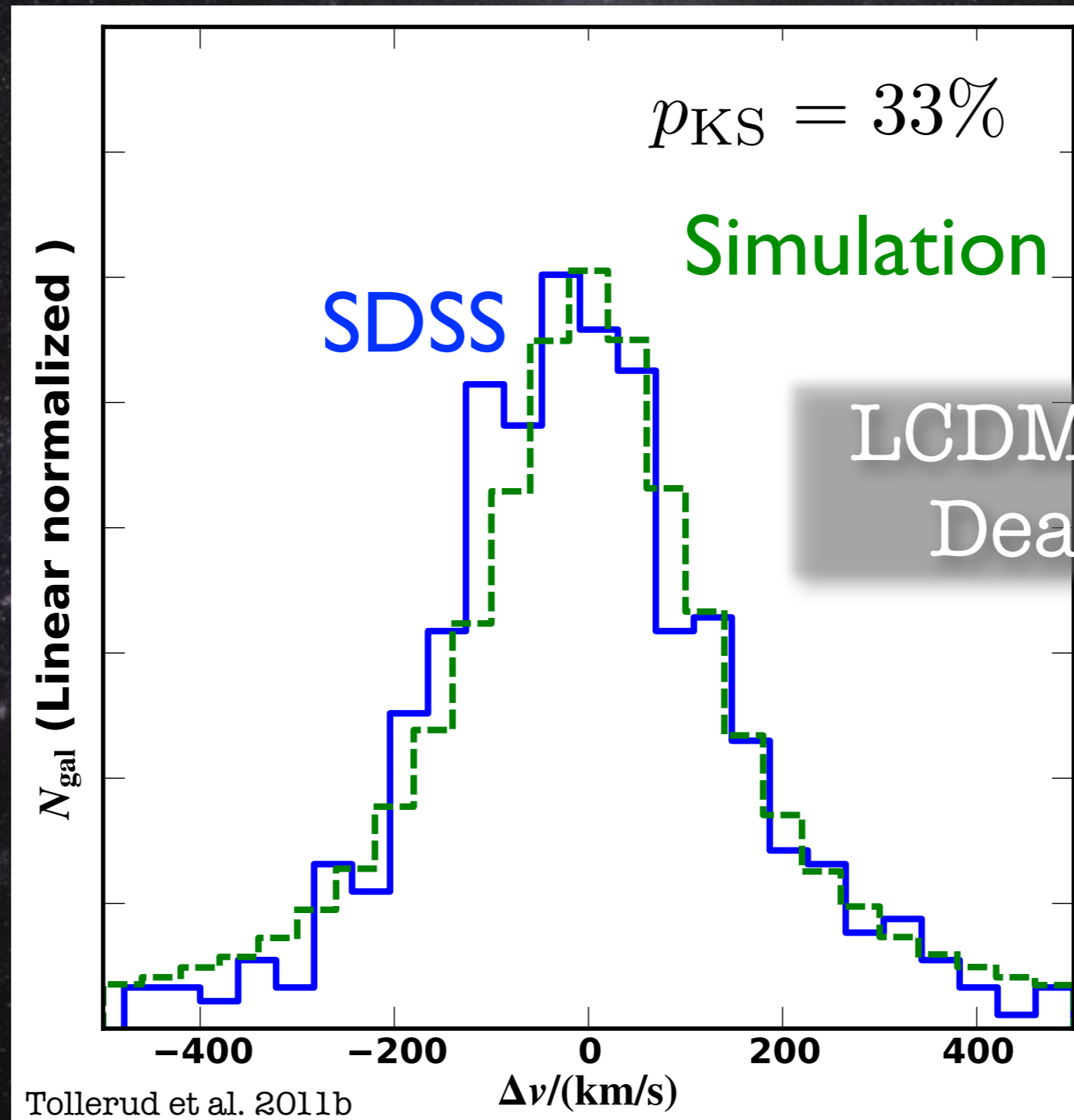
Only Three Assumptions for MS-II \leftrightarrow SDSS

- ◆ Gravity
- ◆ LCDM Initial Conditions/Cosmology
- ◆ Monotonic $L_{\text{gal}} \leftrightarrow M_{\text{halo}}$

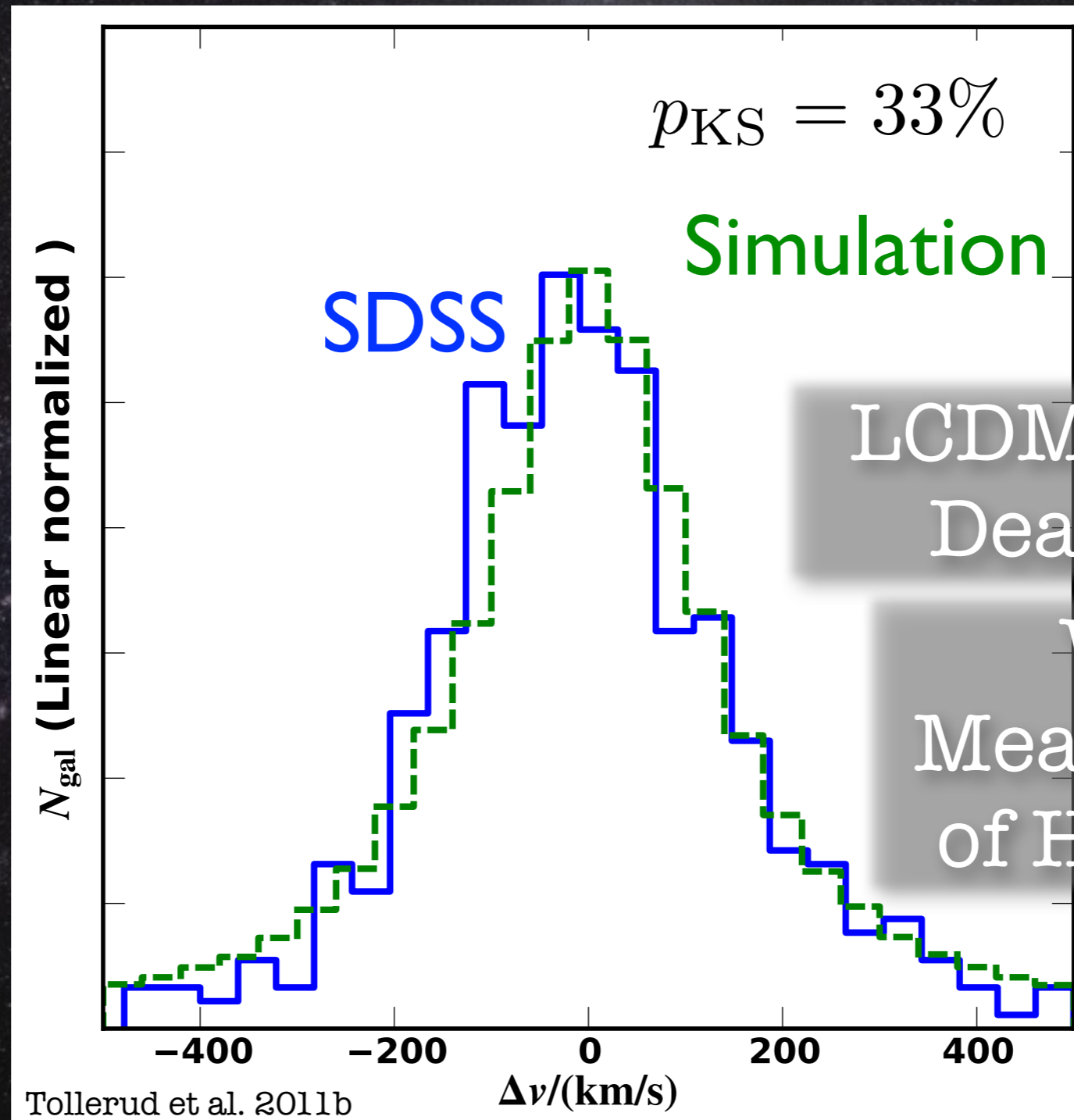
Pairwise Velocity Distribution



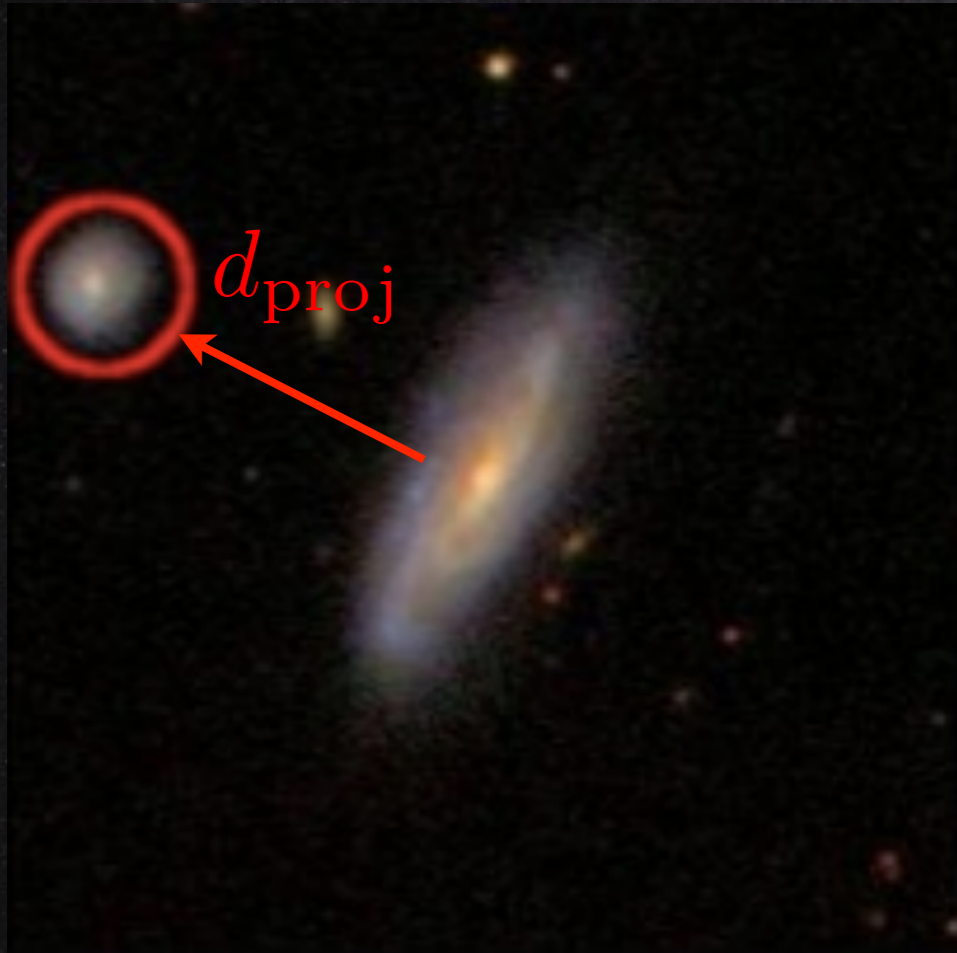
Pairwise Velocity Distribution



Pairwise Velocity Distribution



Radial Distribution

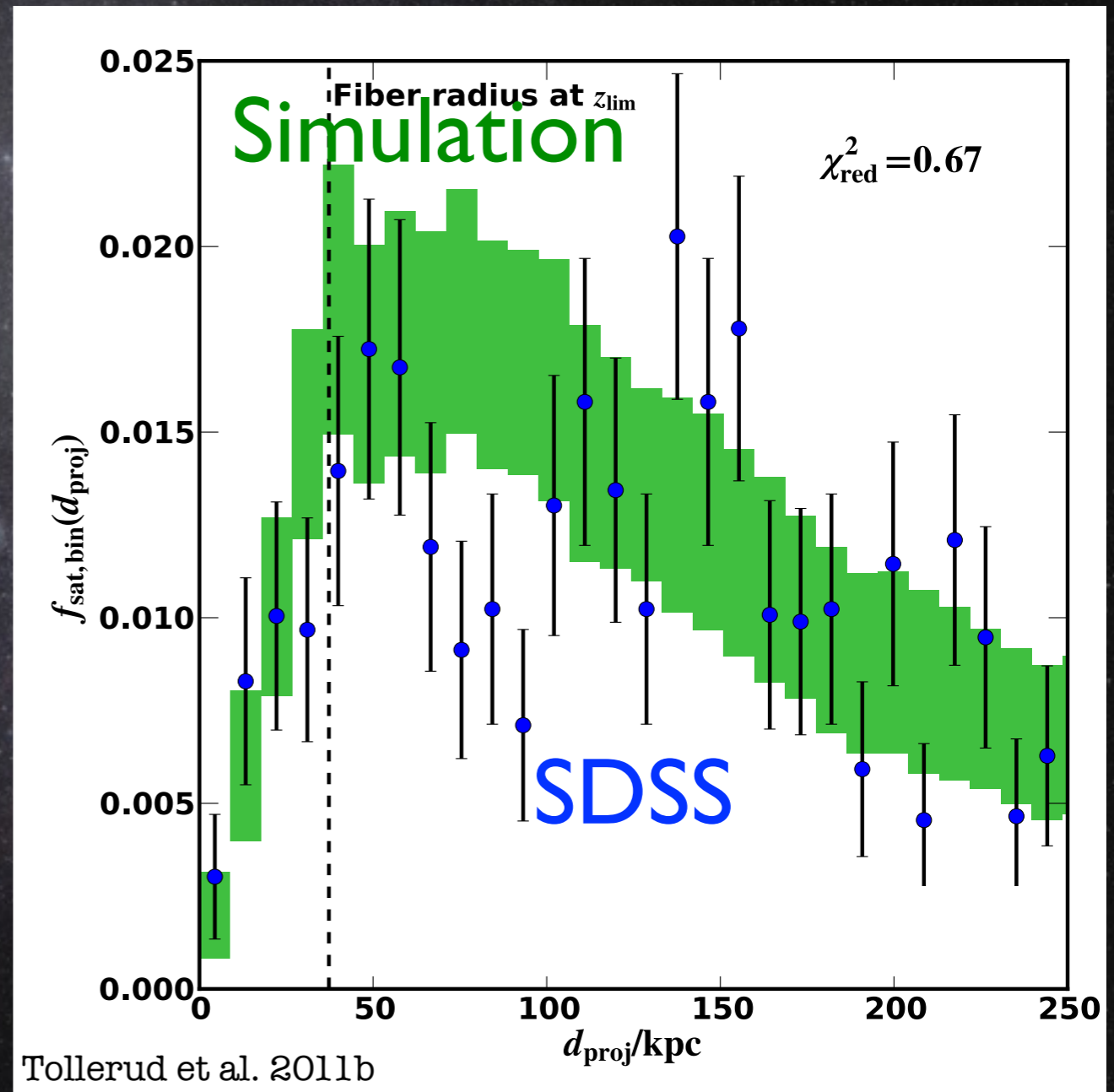
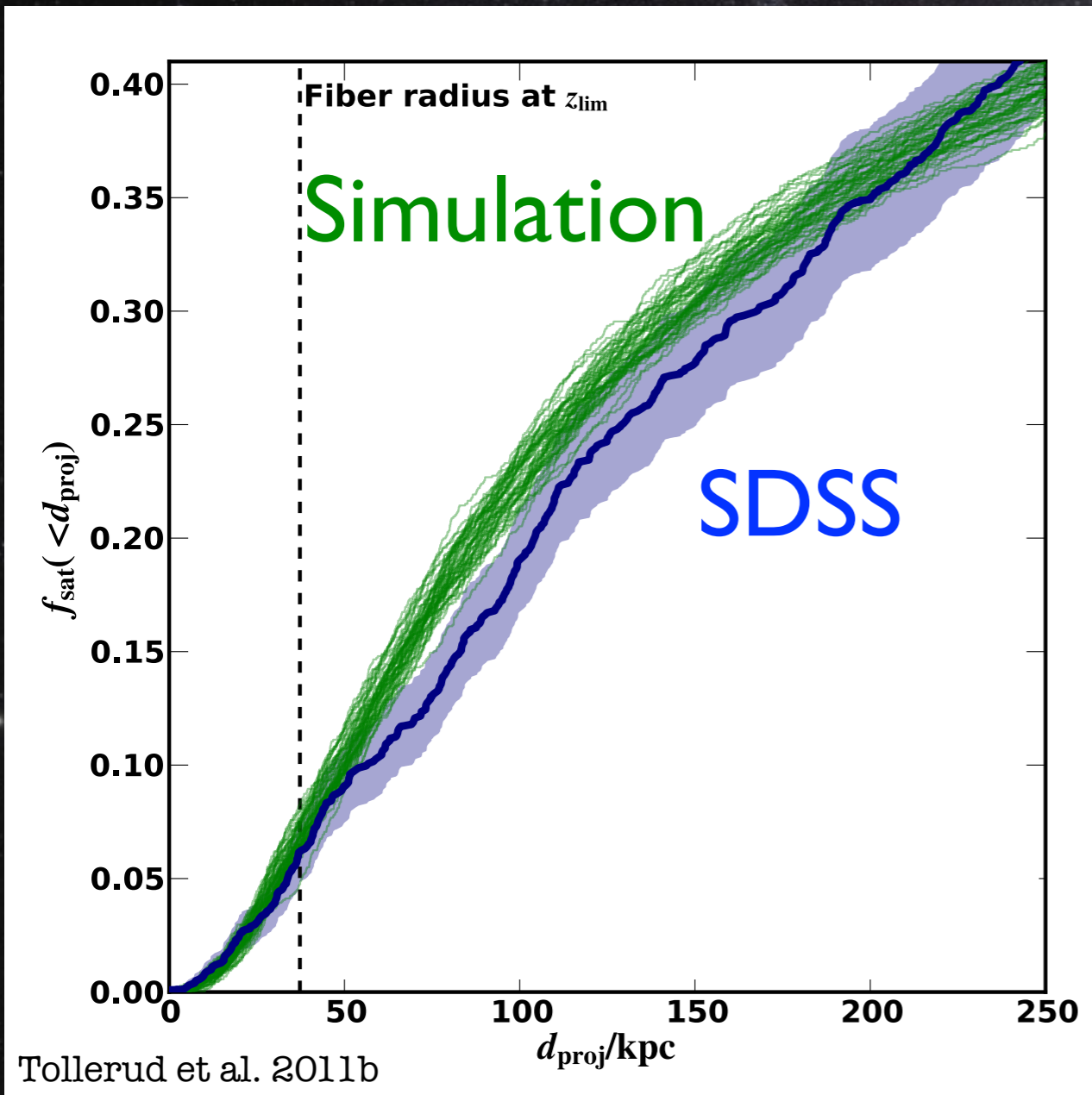


SDSS Galaxies

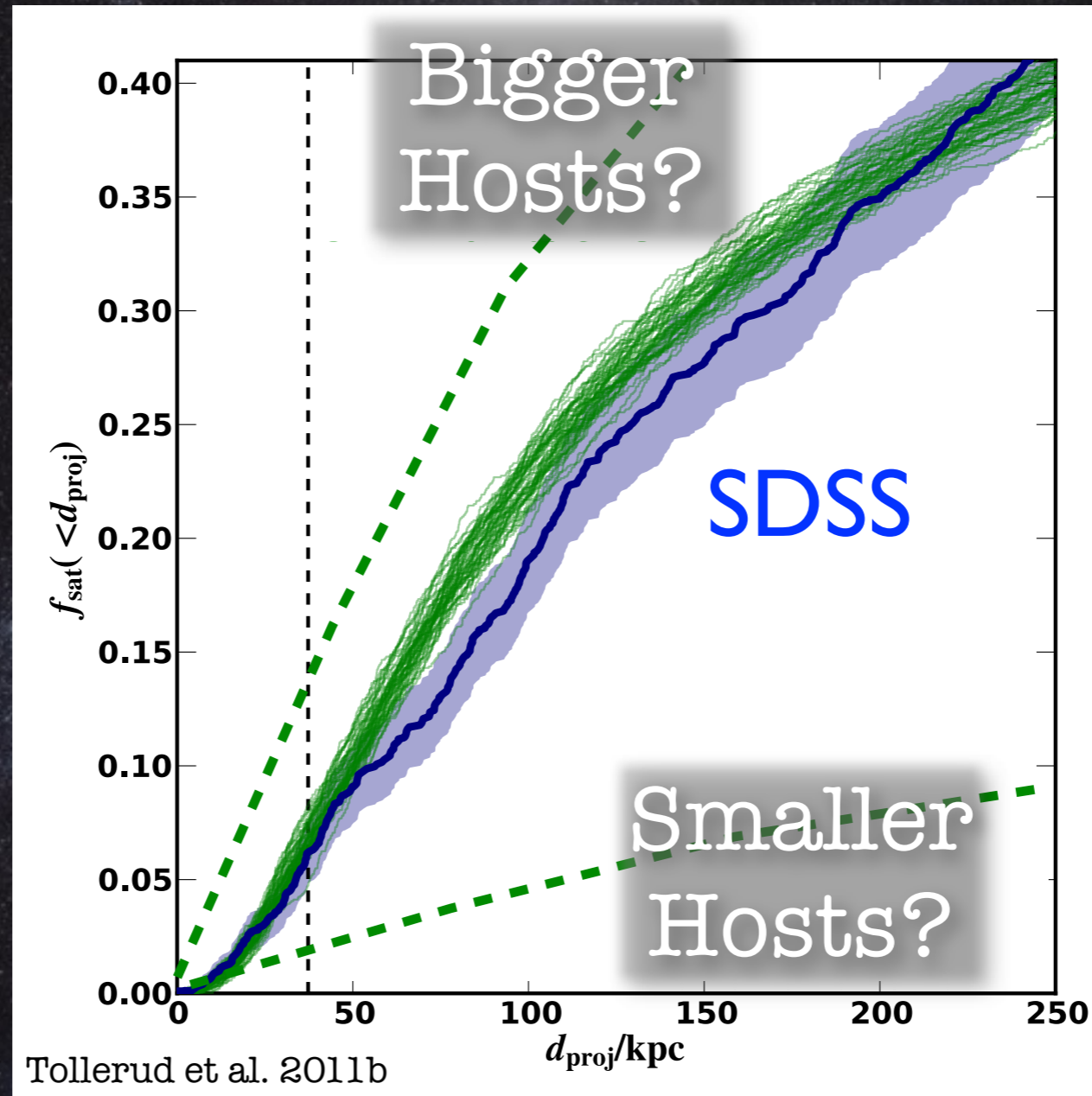


MS-II Halos

LCDM Gets The Right Radial Distribution!



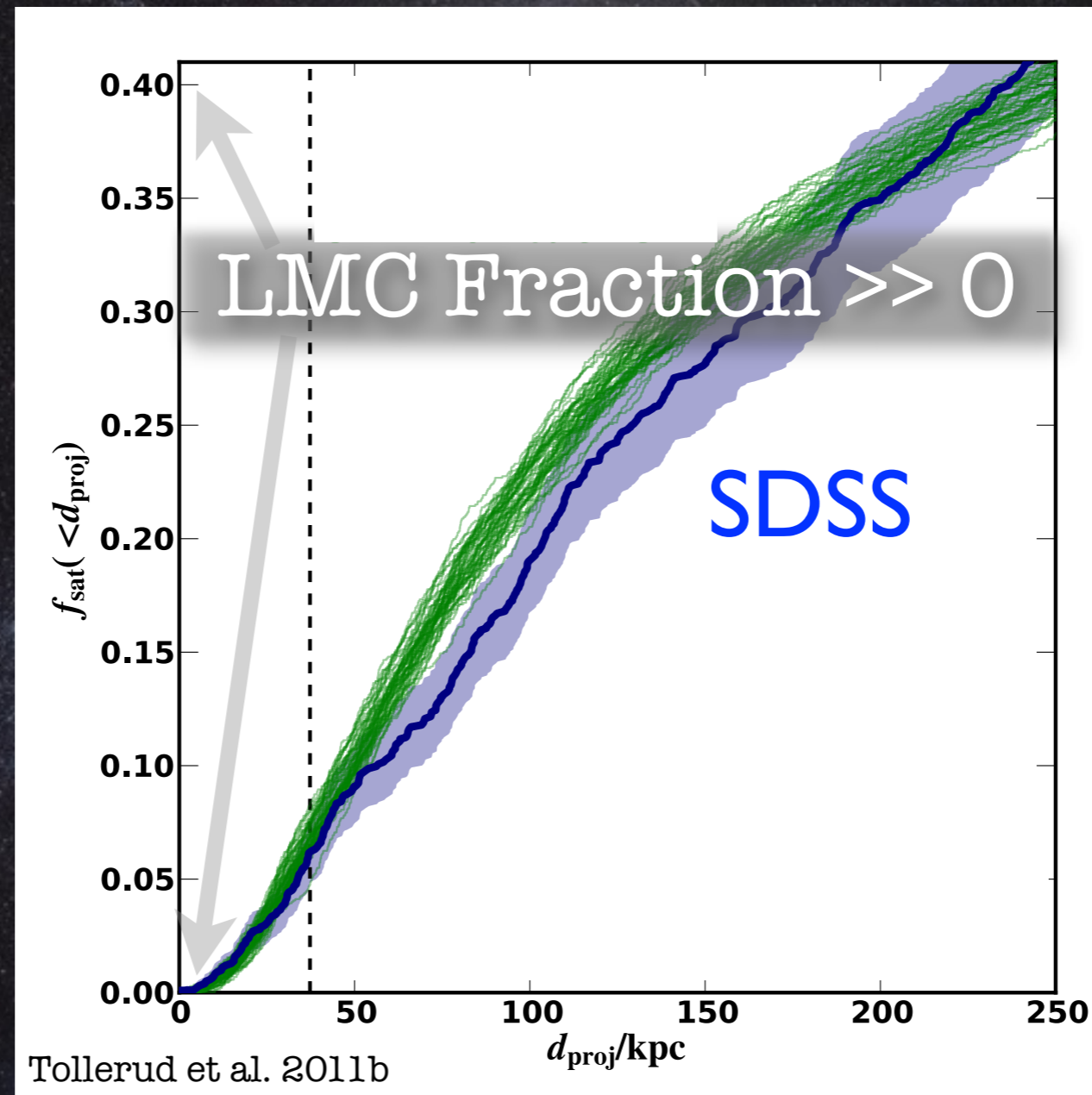
LCDM Gets The Right Radial Distribution!



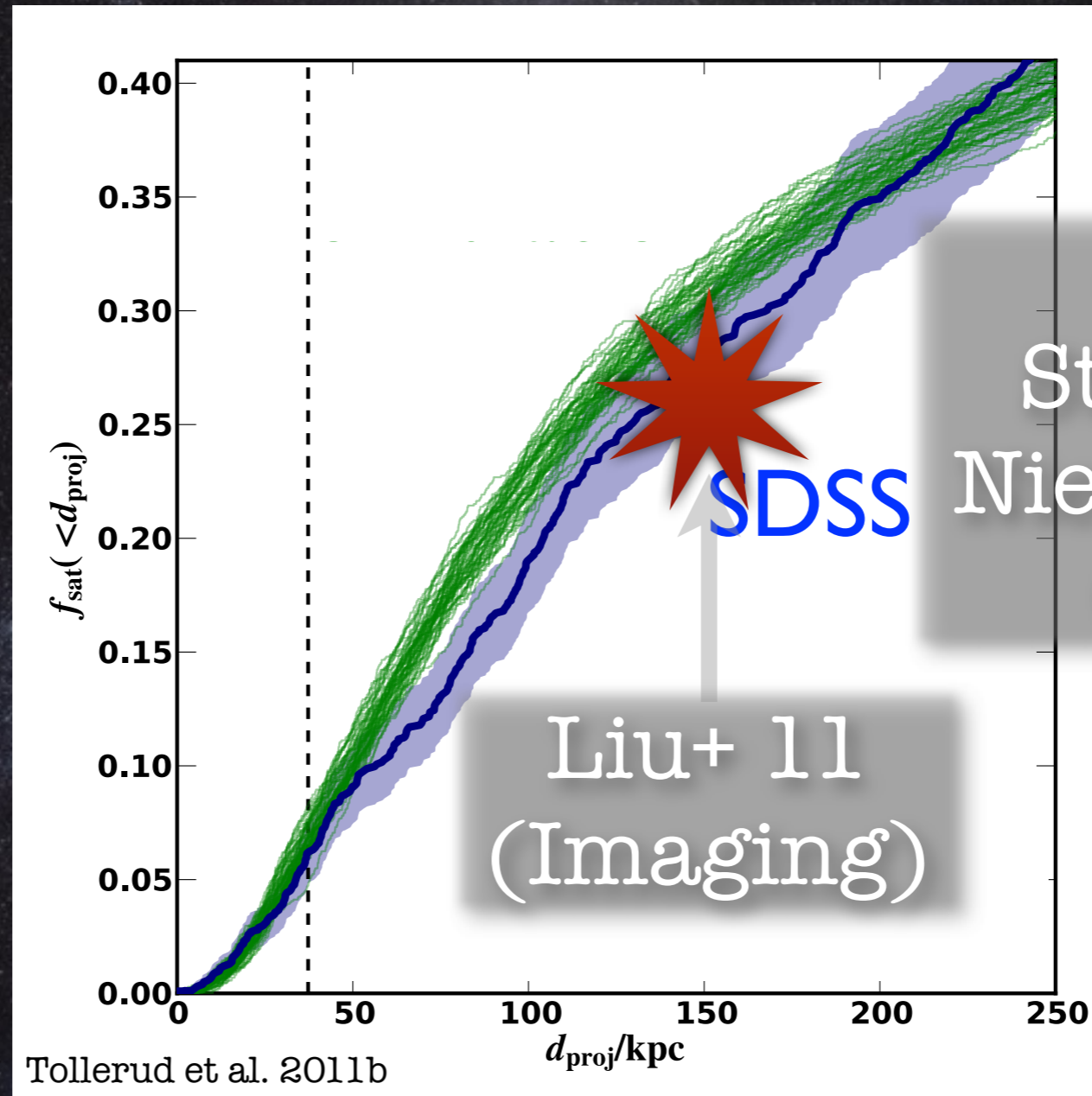
Tollerud et al. 2011b

Tollerud et al. 2011b

Empirically, MW/LMC Isn't Too Rare

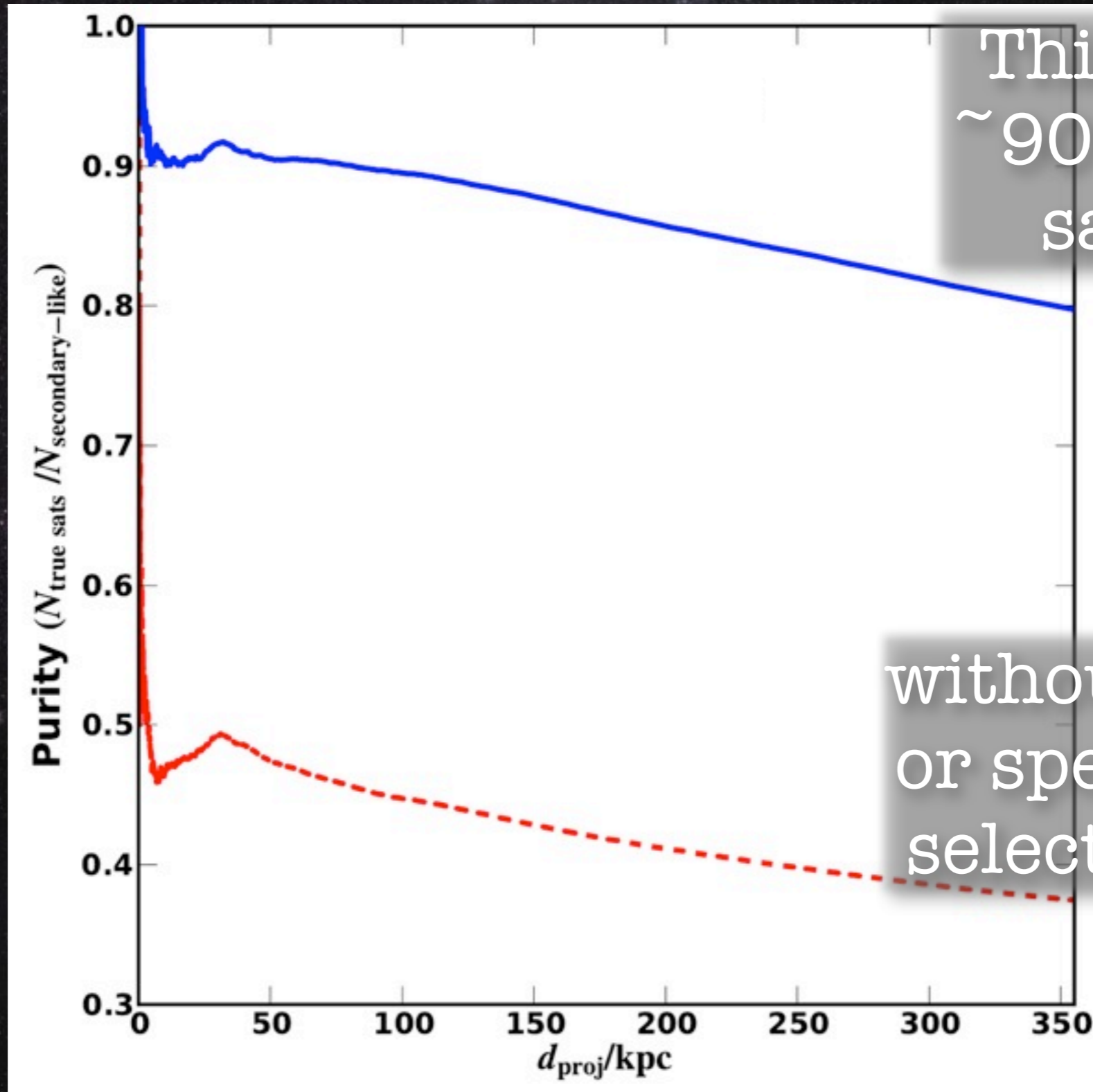


Imaging Can Do This Statistically



(See also
Strigari+ 12,
Nierenberg+ 12,
Guo+ 12)

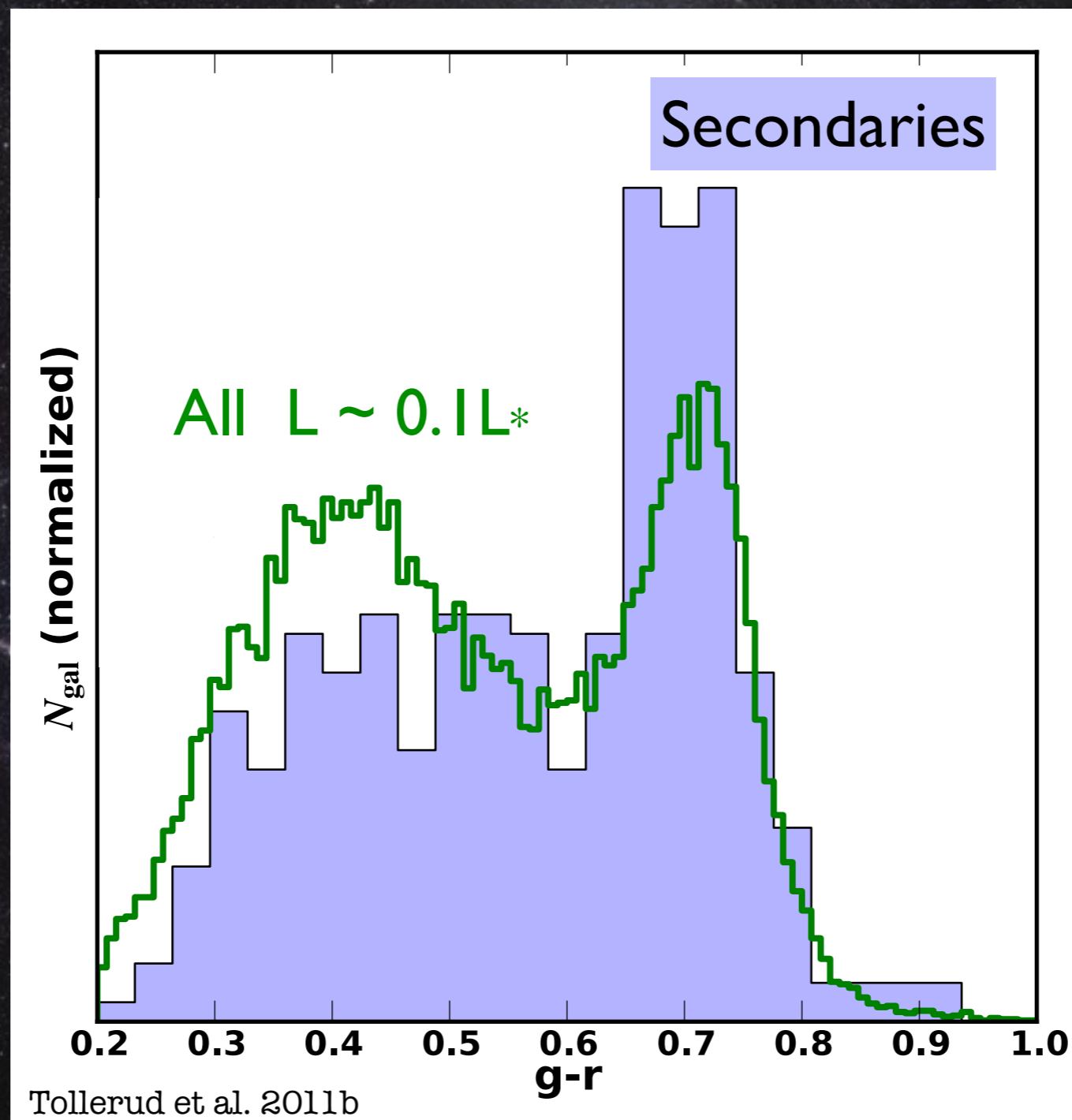
LCDM \rightarrow SDSS



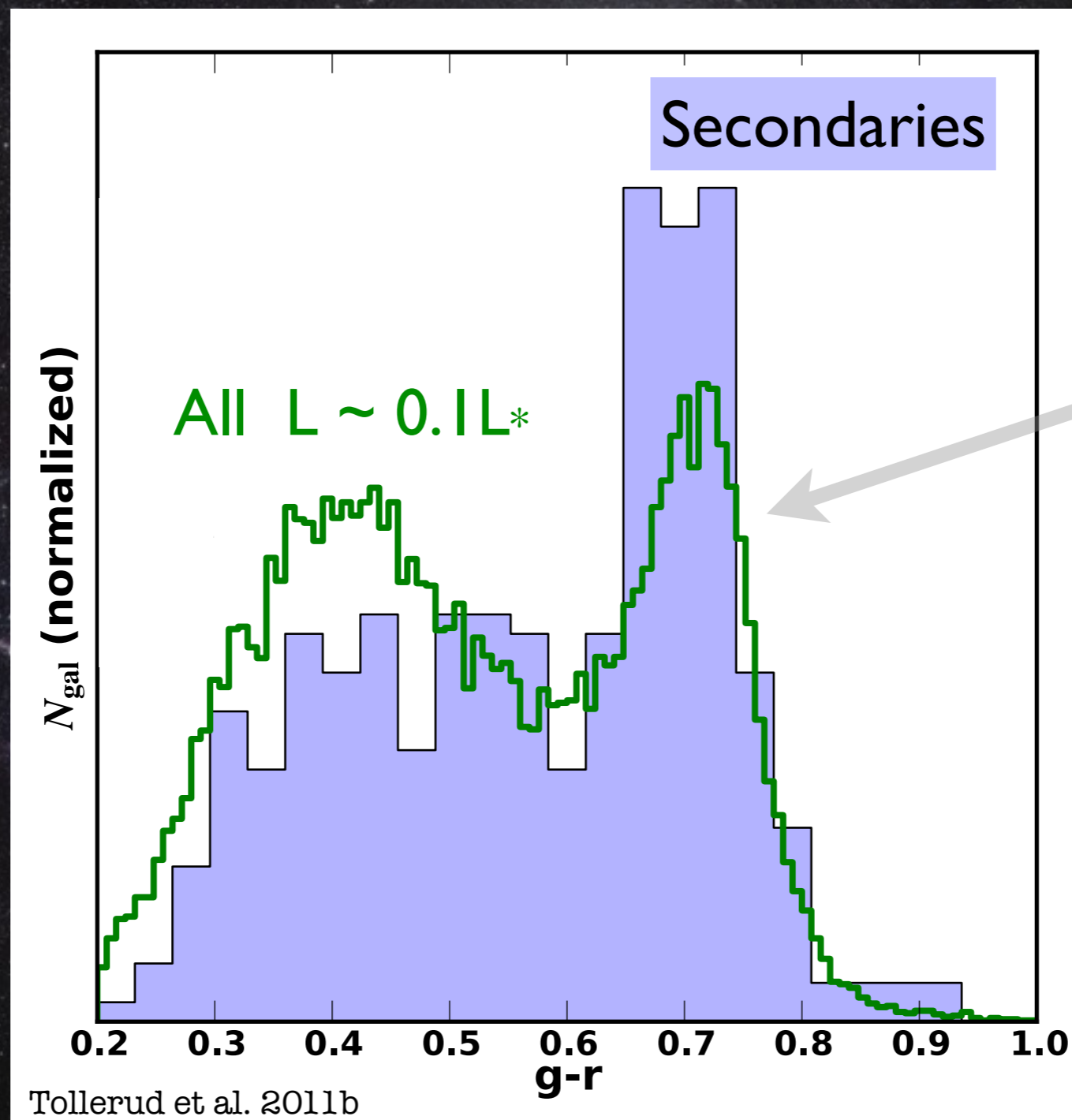
This sample:
~90% genuine
satellites

without isolation
or spectroscopic
selection, ~40%

Satellite Colors

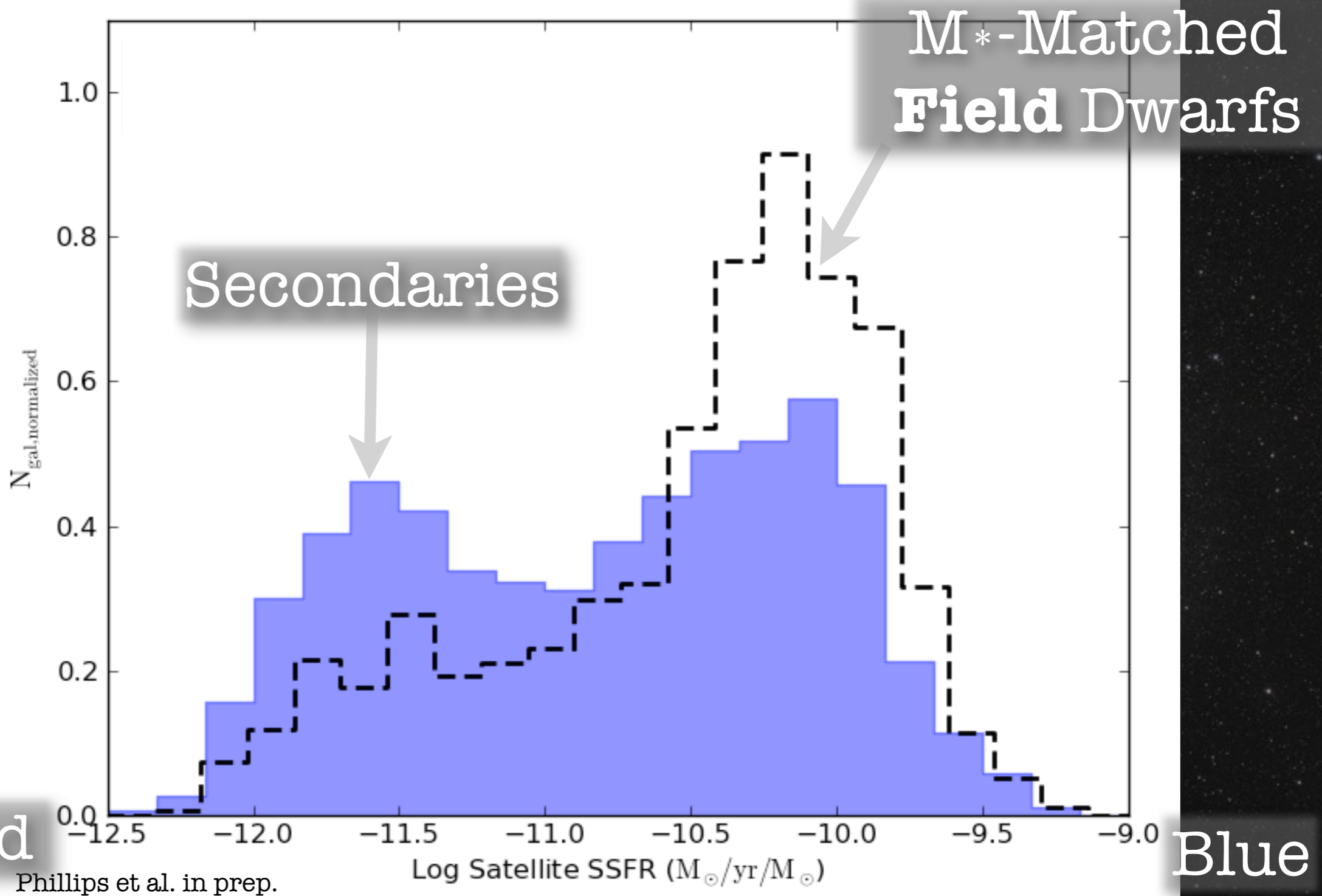


Satellite Colors



Satellites of
Isolated L^*
Galaxies
Are Red

Satellite SFRs

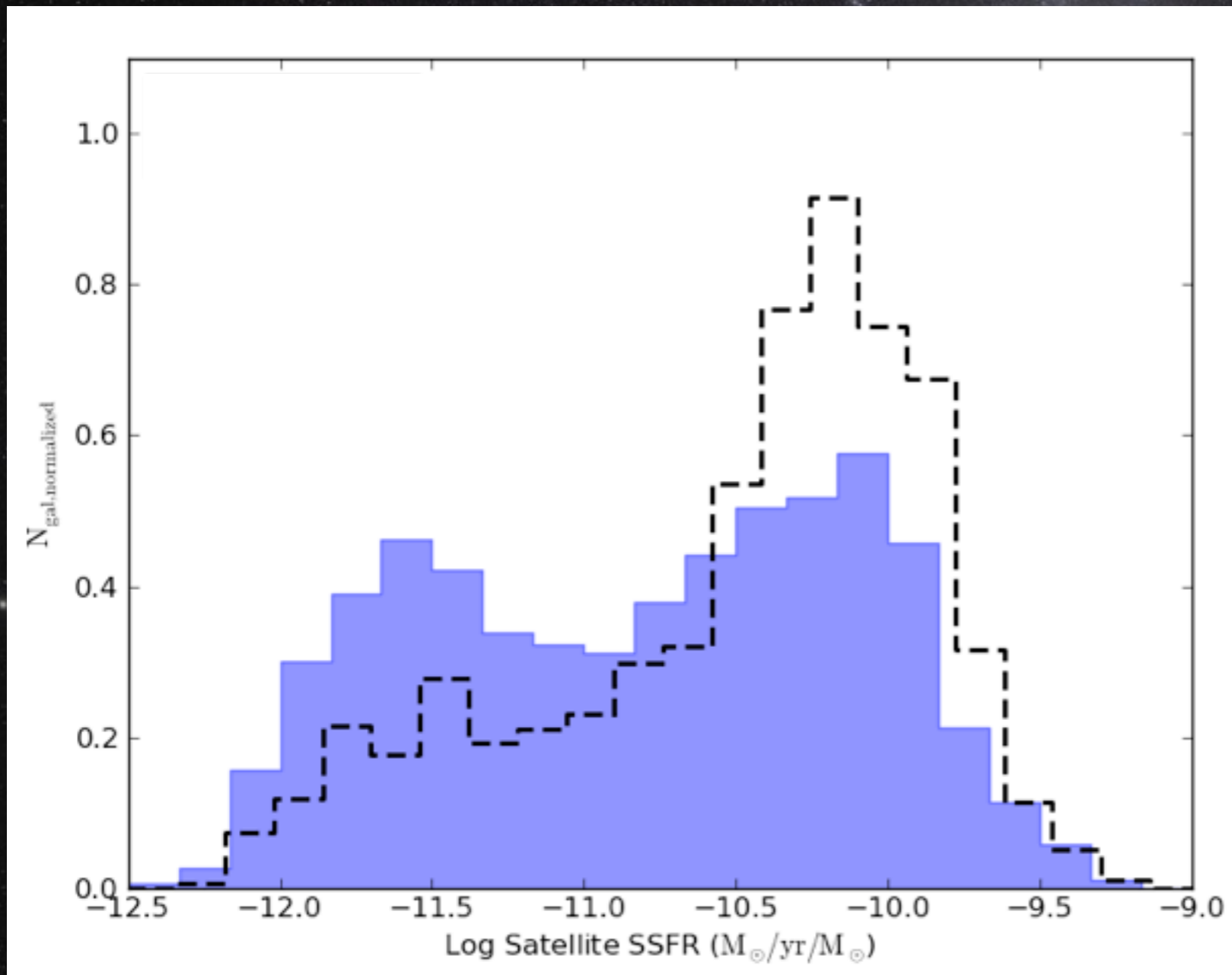


Red

Blue

Phillips et al. in prep.

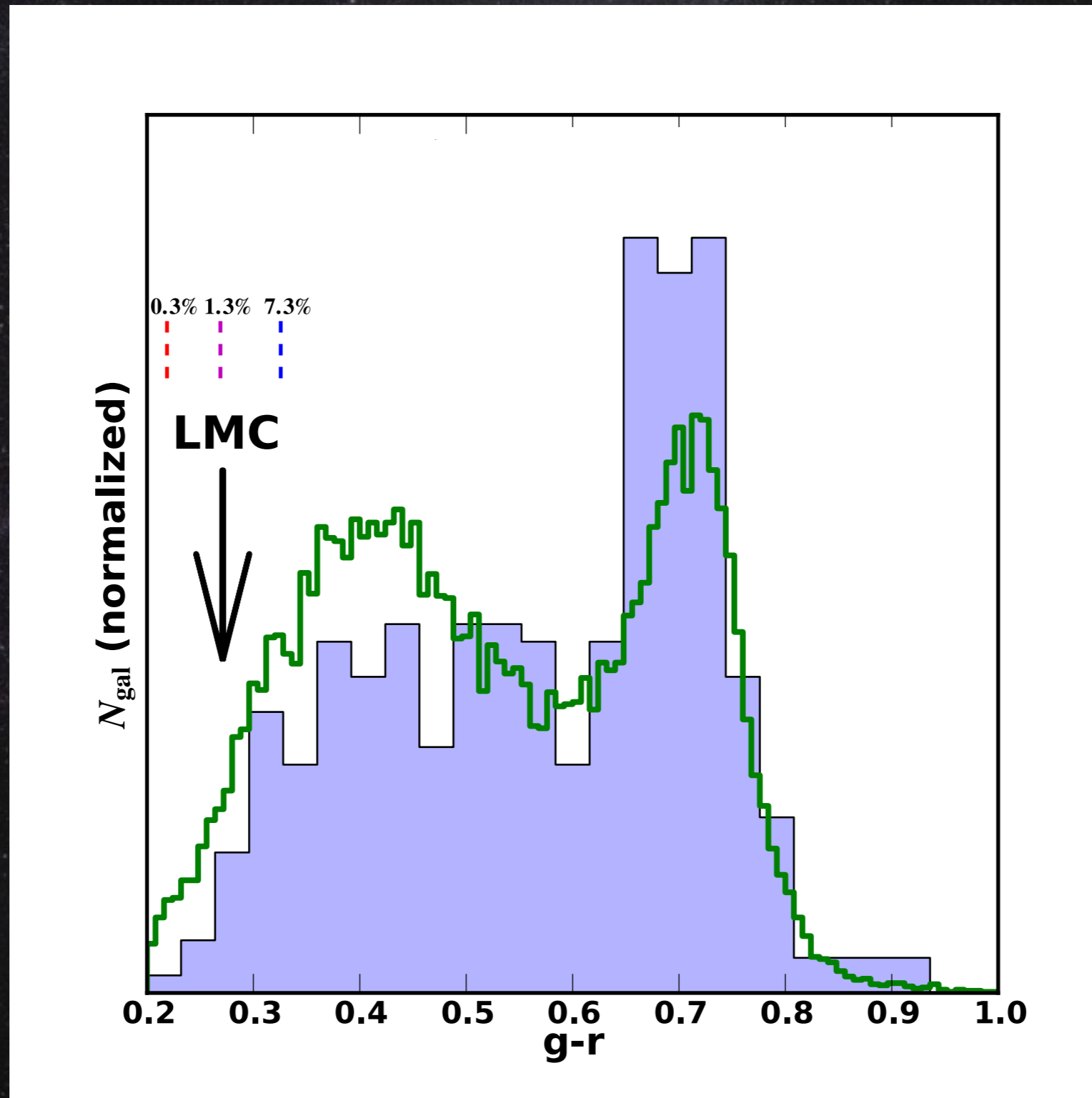
Why Are Secondaries Quenched?



- ◆ **Not** Harassment
- ◆ Ram Pressure Stripping?
- ◆ Strangulation?

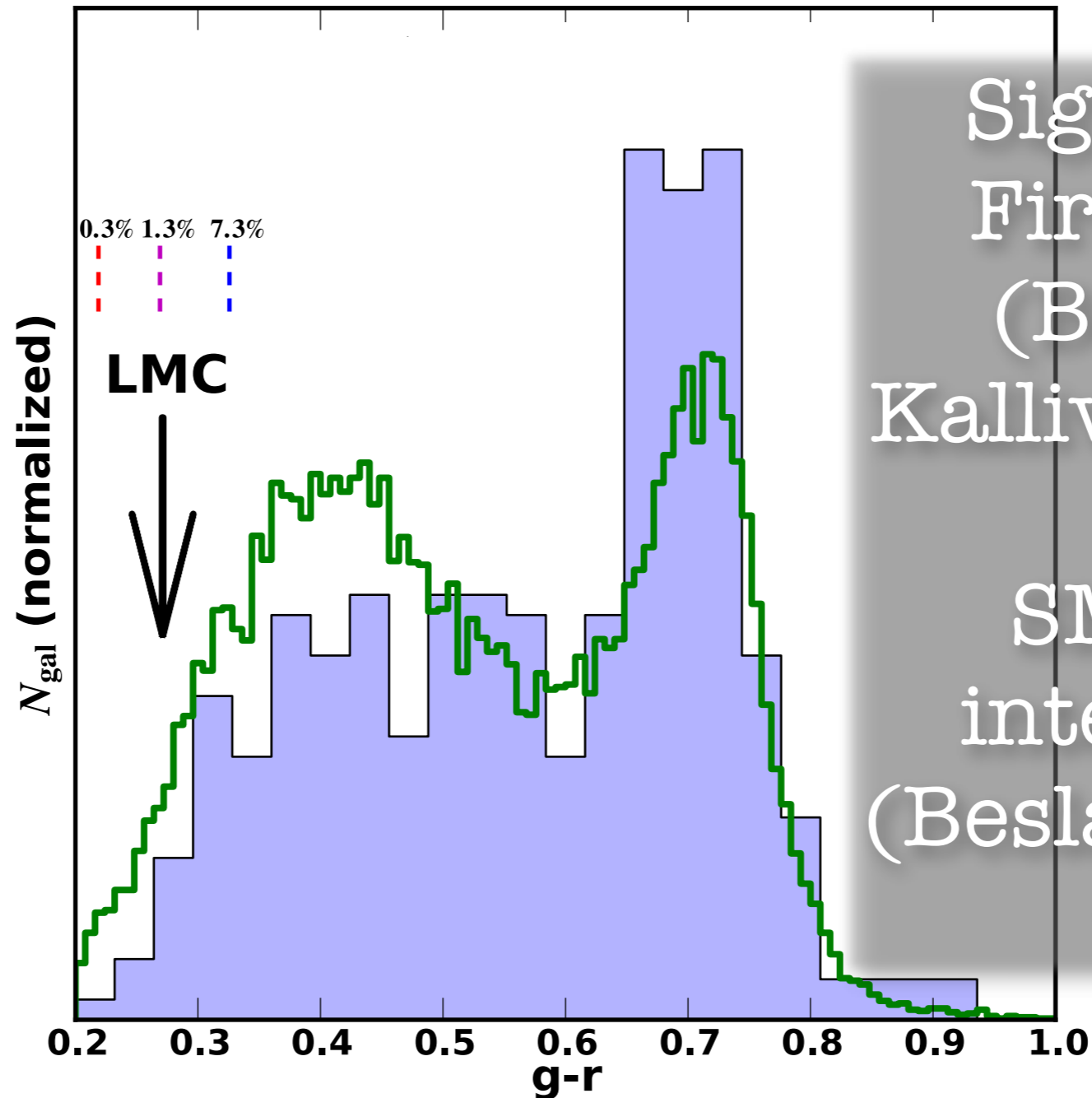
LMC is Very Blue

- RC3
- Eskew & Zaritsky 11
- Bothun & Thompson 88



LMC is Very Blue

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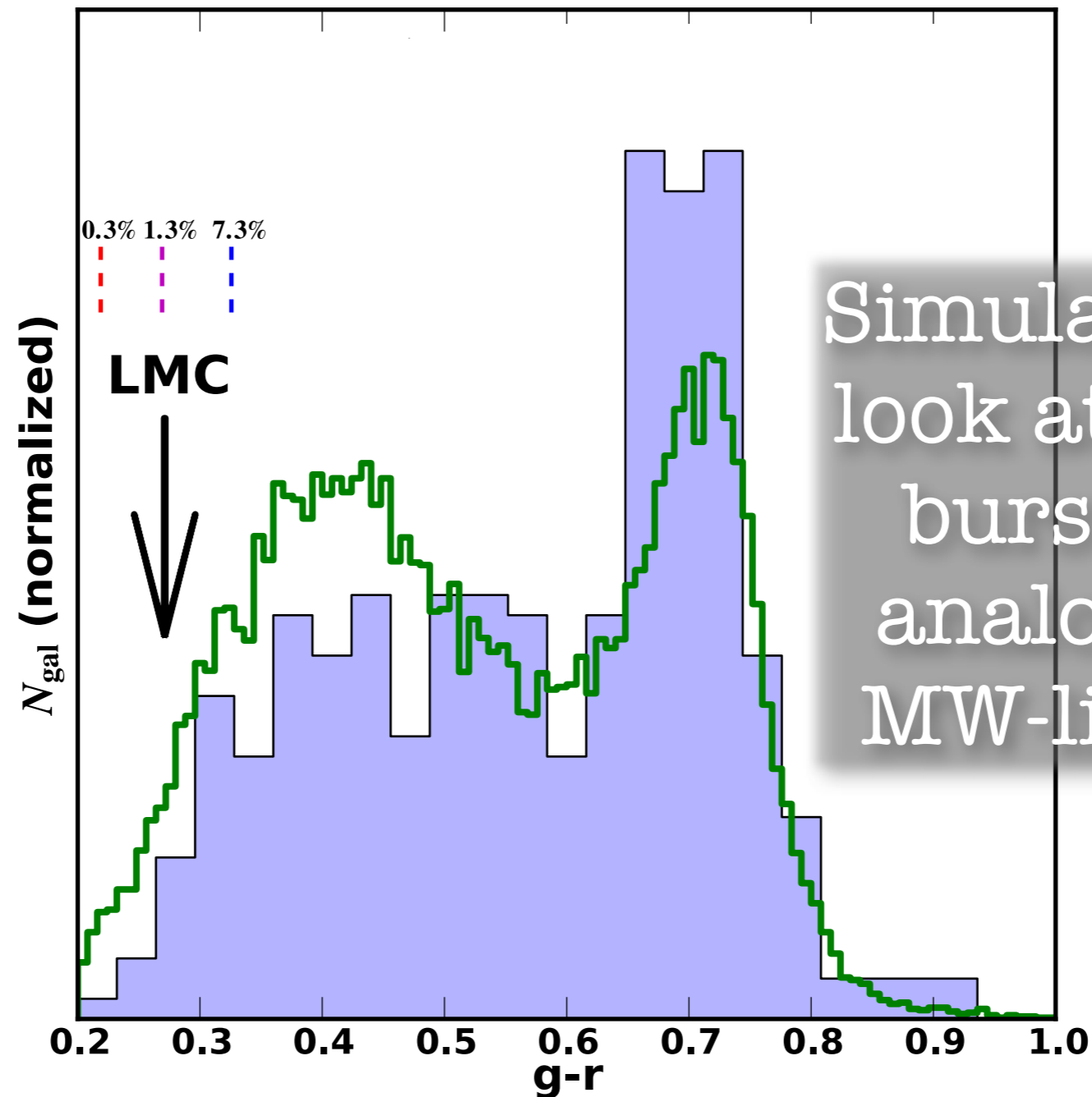


Signature of
First Infall?
(Besla+ 07,
Kallivayalil+ 06)

SMC/LMC
interaction?
(Besla+ 12, other
talks)

LMC is Very Blue

- RC3
- Eskew & Zaritsky II
- Bothun & Thompson 88



Simulators should look at halos with bursting LMC-analogs in their MW-like zooms?

Summary

- ◆ LCDM+Abundance matching successfully **predicts basic observables** for bright satellite ($\sim 0.1 L^*$) of L^* hosts.
- ◆ Δv_{pair} matches between SDSS and simulation, implying host masses are correct
- ◆ Radial distribution of satellite galaxies match subhalos
- ◆ Empirical fraction of L^* galaxies w/ bright satellites is not tiny (**LMC is not that weird**)
- ◆ Empirical bright satellite properties:
 - ◆ Satellites of **isolated** L^* galaxies are **quenched**
 - ◆ LMC is is very blue/starforming relative to similar objects (**LMC is weird**)