Pre-Reionization Fossils, Ghost Halos and the “Bright” Satellite Problem

Mia S. Bovill

University of Maryland

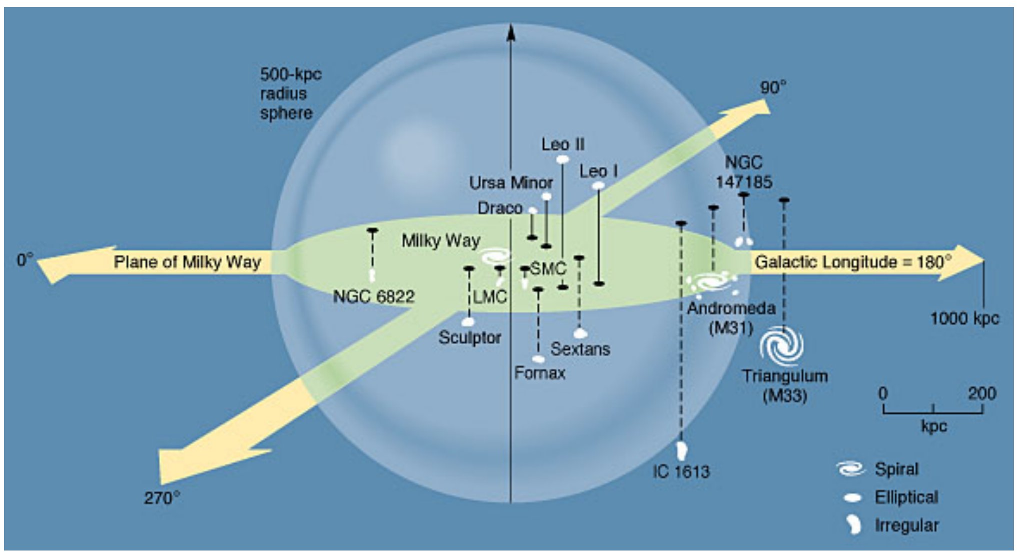
with **Massimo Ricotti**
and Stacy McGaugh

Bovill & Ricotti (2011a,b) (ApJ accepted)

Near Field Cosmology

First galaxies formed in minihalos before reionization, too dim for direct detection.

Instead we study them using “galactic paleontology.”



The smallest in the Local Group are likely the fossil remnants of these first galaxies.

What do these fossils look like?

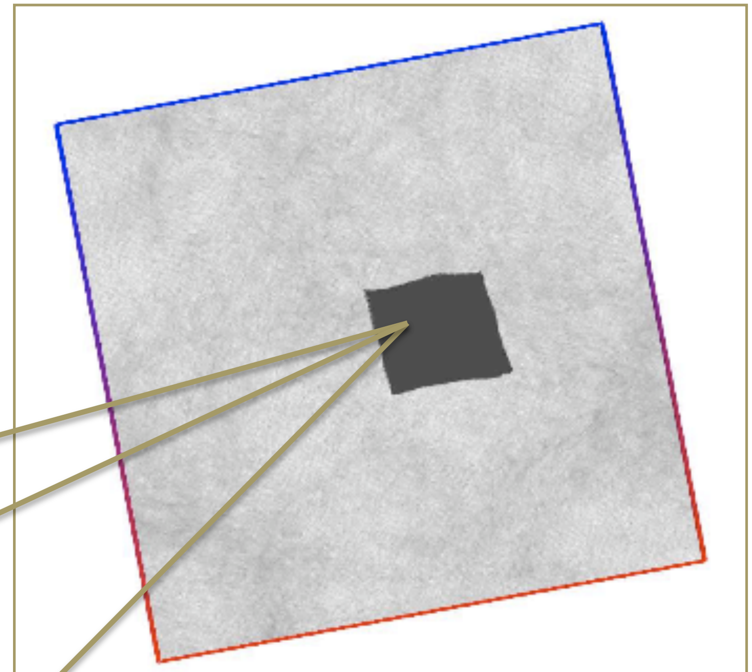
Where are they?

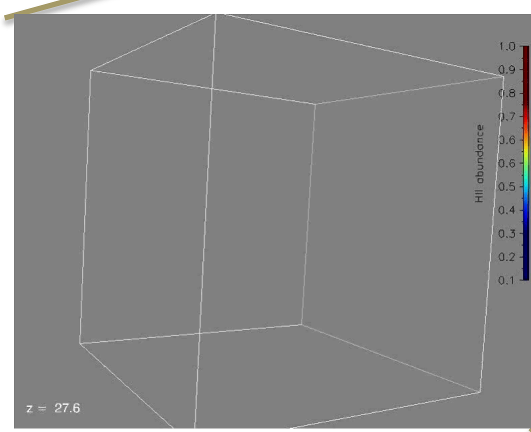
Simulations

The final pre-reionization outputs are transformed in a 1 Mpc^3 box of particles.

Each particle is a pre-reionization halo.

We build a 10 Mpc high resolution region with the box, adding larger scale density perturbations.





Ricotti et al (2002a,b,2008)

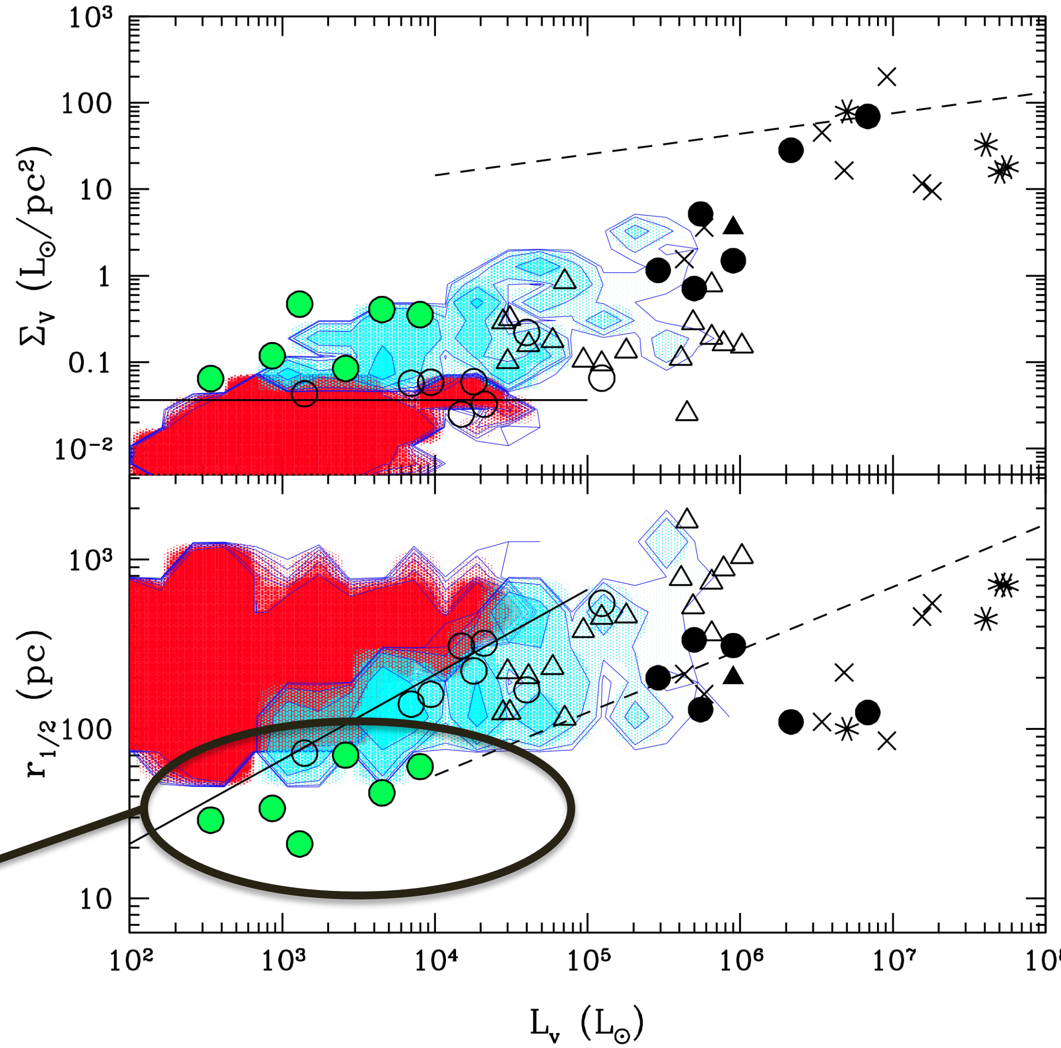
No need to re-resolve the pre-reionization halos.

Unique IDs retrieve z=0 stellar properties from $M \sim 5 \times 10^6\ M_\odot$ - $2 \times 10^{12}\ M_\odot$.

Run with Gadget (Springel, 2005) and analyzed with AHF (Knollmann & Knebe, 2009)

The Ultra-Faint Dwarfs as Fossils

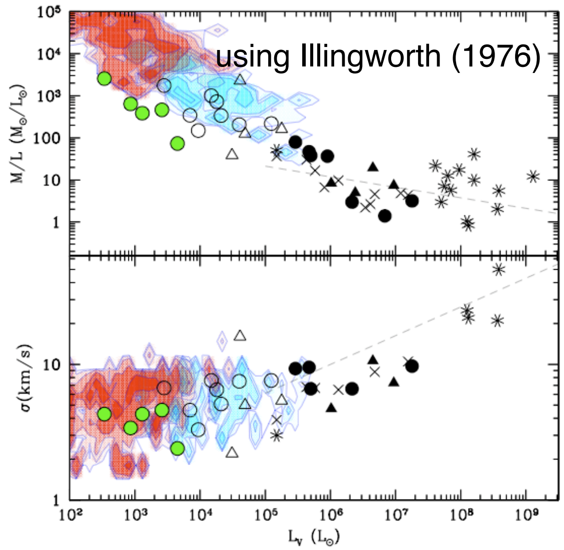
- dIrr
- dE
- classical MW dSph
- MW ultra-faints
- classical M31 dSph
- M31 ultra-faints
- fossils detected by SDSS
- undetected fossils

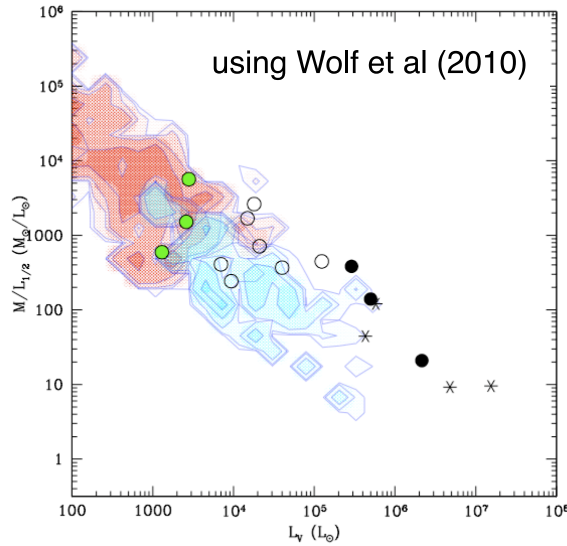


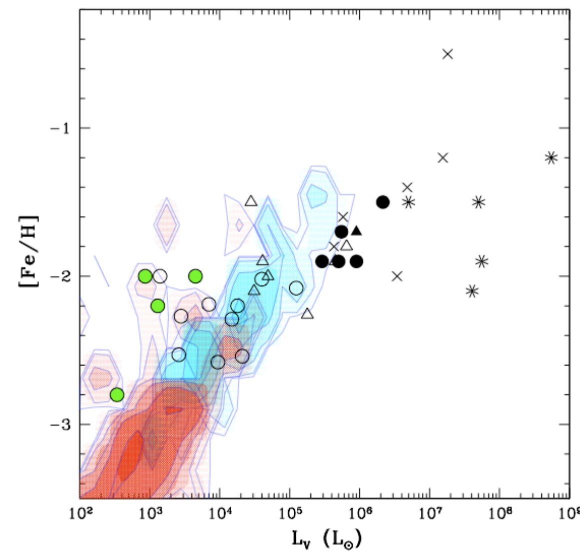
Σ_V and r_{hl} are not in agreement with predictions for true fossils.

Bovill & Ricotti (2009, 2011a)

Undetected Dwarfs







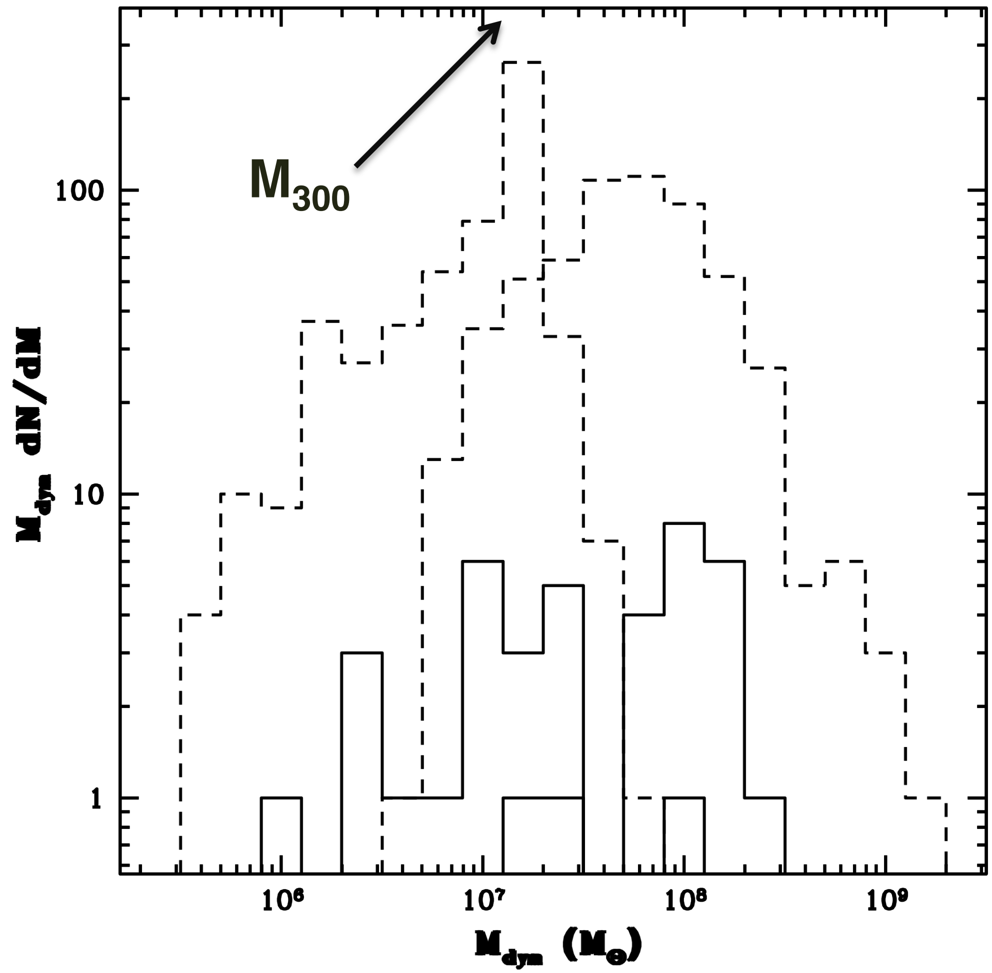
Undetected dwarfs have higher M/L but the *same* velocity dispersion!

Match of ultra-faints in M/L is independent of mass estimator.

Undetected dwarfs would have [Fe/H] < -2.5

[Fe/H] of the tidal ultra-faint dwarfs suggests a primordial fossil origin.

Fossil Mass Function

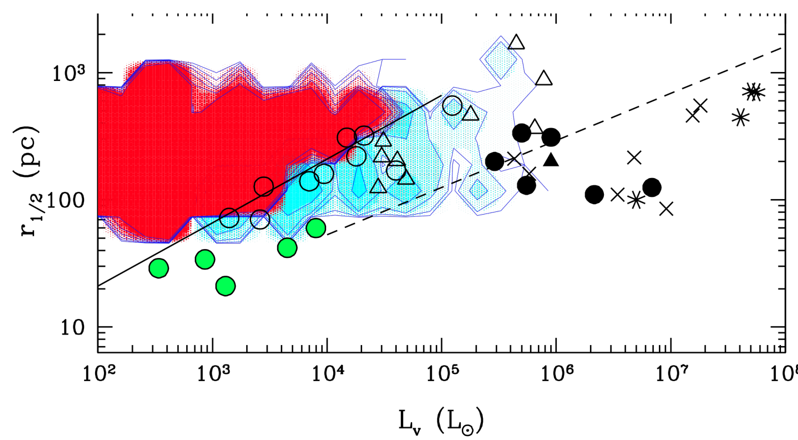


Bovill & Ricotti (2011a)

M$_{dm}$ – from halo finder

M$_{dyn}$ – $M_{1/2}$ from Wolf et al (2010)

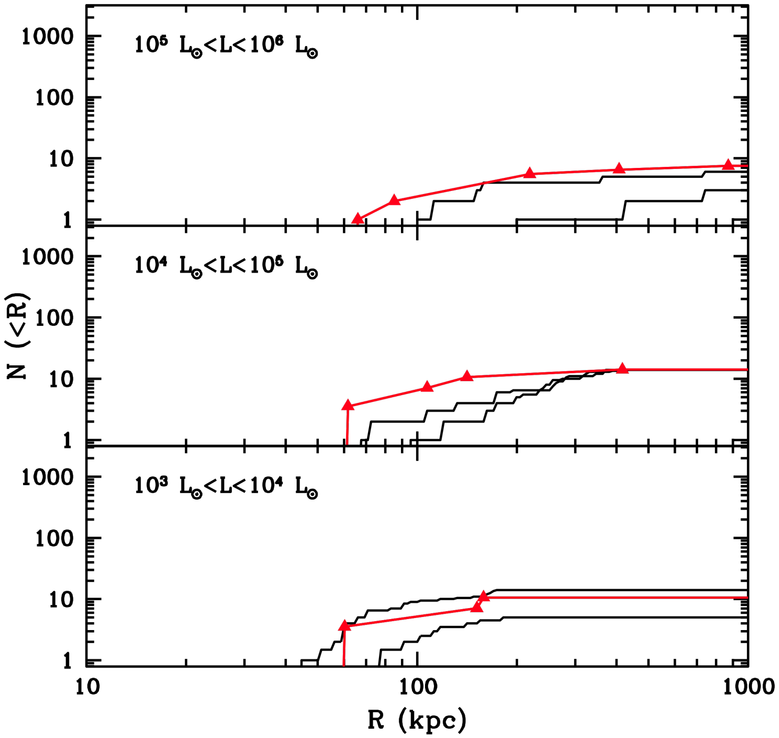
Our r_{hl} ~ 80-1000 pc



Beyond the Fossils

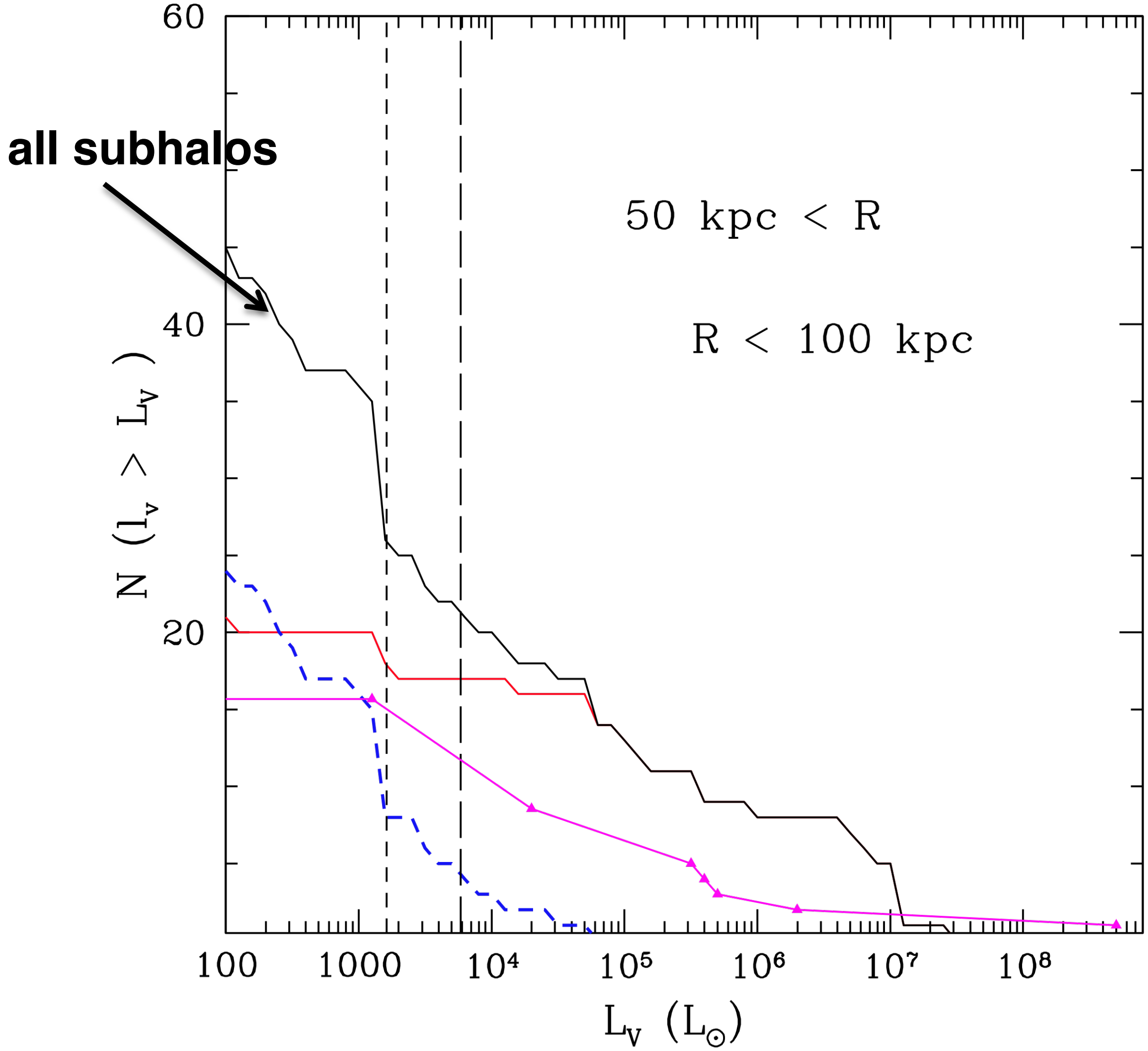
The properties and distribution of the ultra-faint dwarfs are consistent with the fossils of the first galaxies.

We have found the tip of the fossil iceberg!



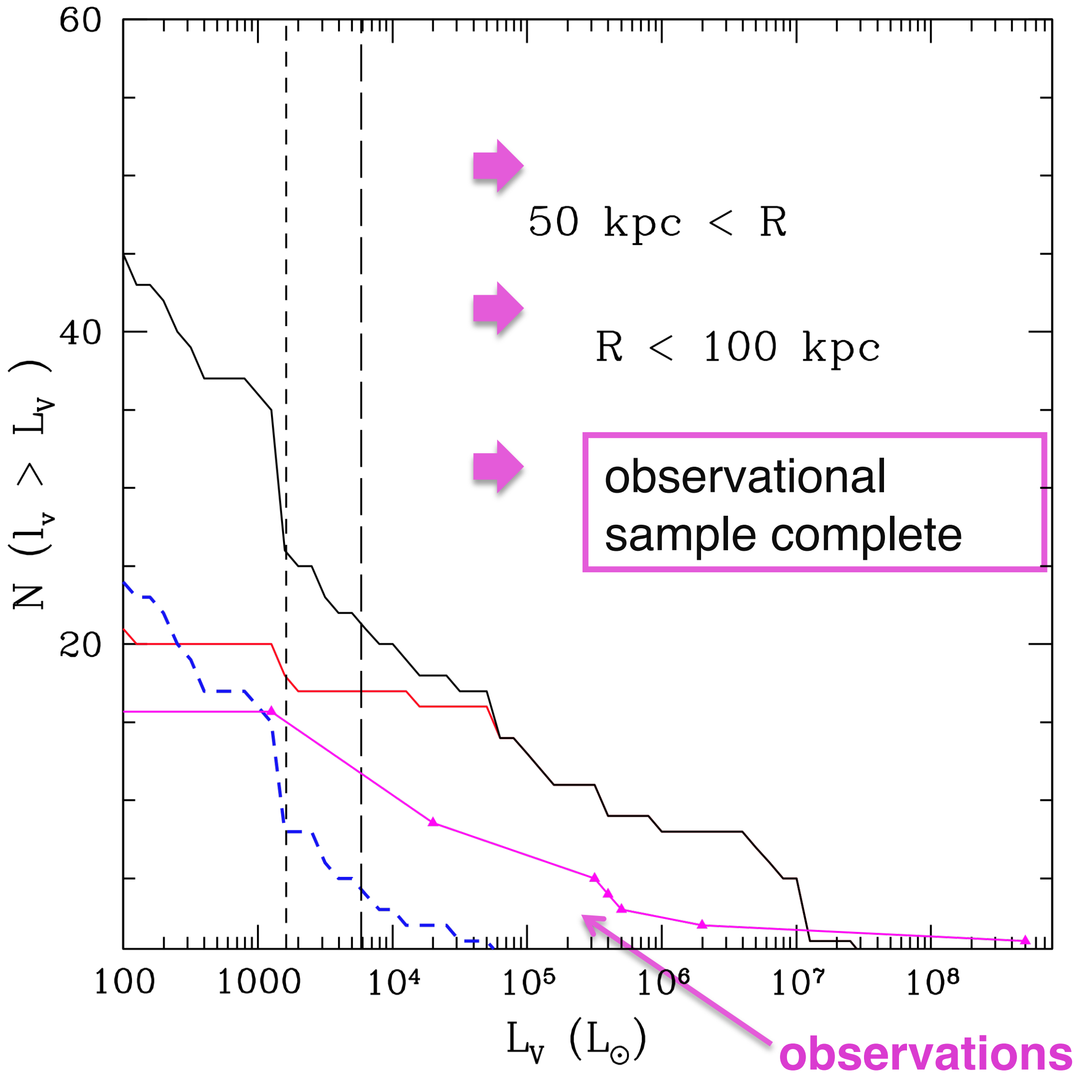
However, for the bright non-fossils the agreement between theory and observation does not hold.

"Primordial" Luminosity Function



Dominated by **fossils** for $\mathbf{L_V <\sim 10^4\ L_\odot}$, and by **non-fossils** for $\mathbf{L_V >\sim 10^4\ L_\odot}$.

"Primordial" Luminosity Function

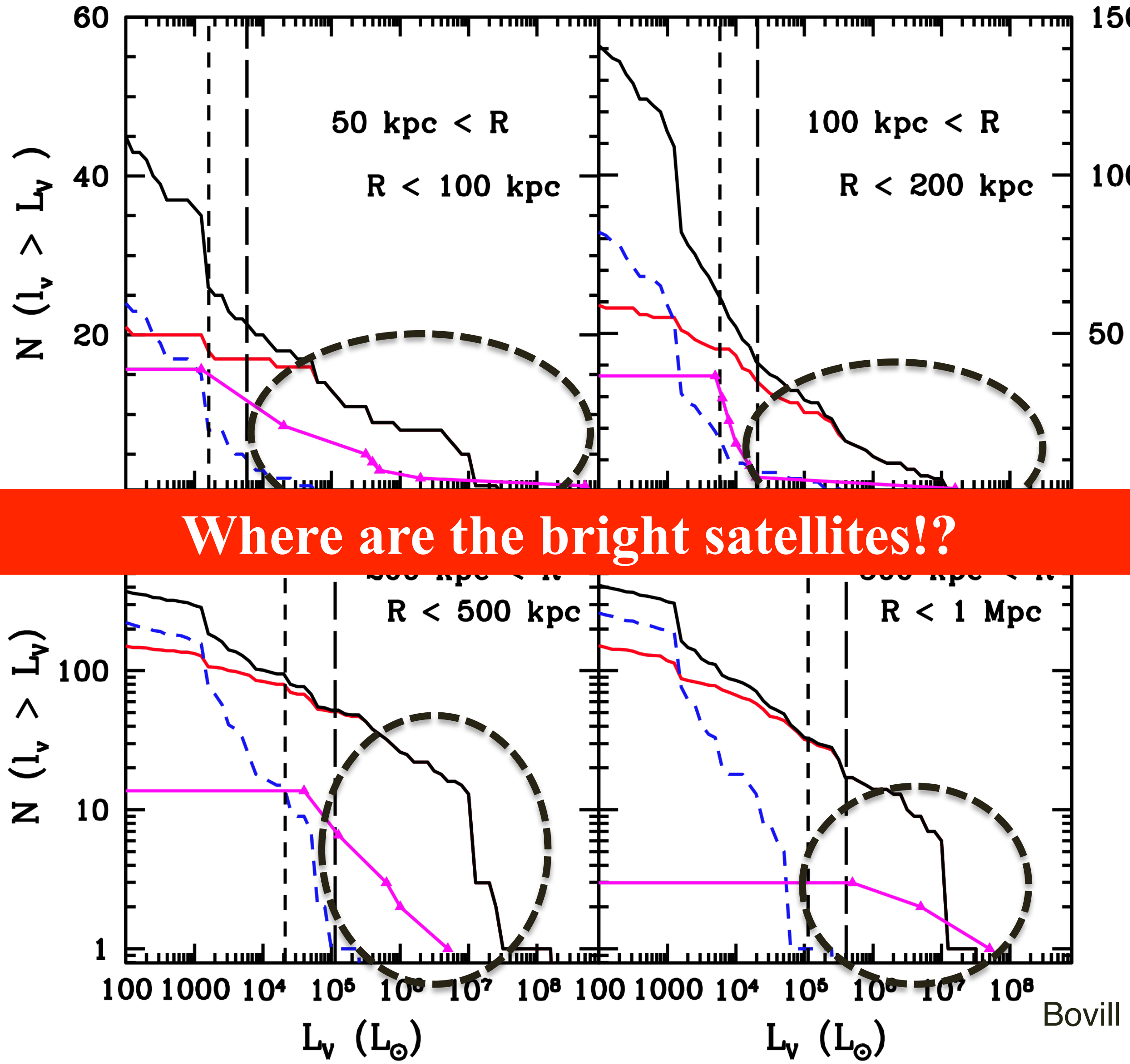


Includes all known dwarfs with R > 50 kpc.

Ultra-faint sample is corrected for SDSS sky coverage and completeness (Walsh et al, 2009)

Sample is complete to the right of the dashed lines.

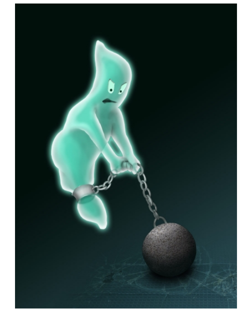
The “Bright” Satellite Problem



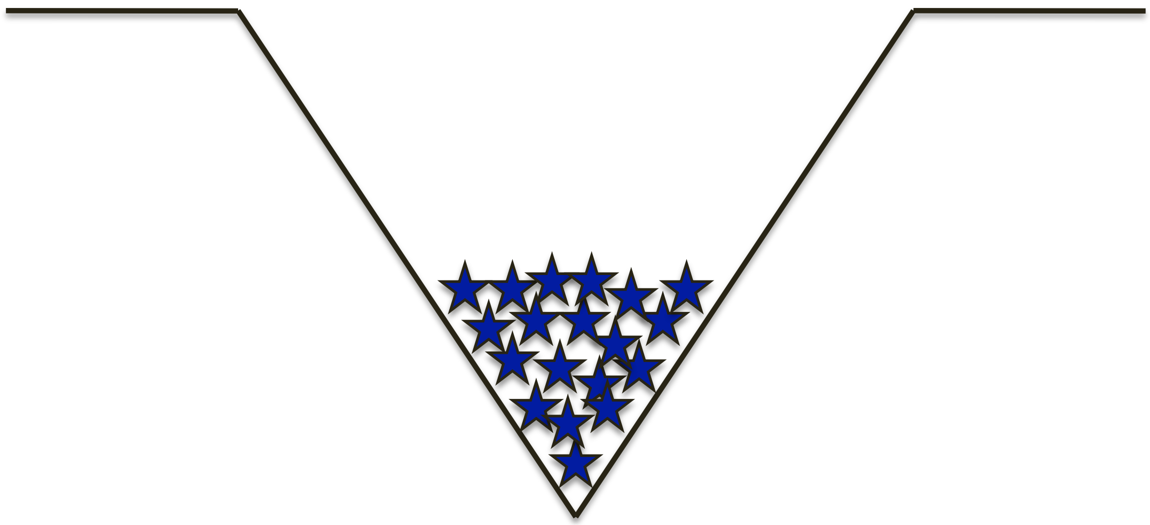
Where are the bright satellites!?

Bovill & Ricotti (2011b)

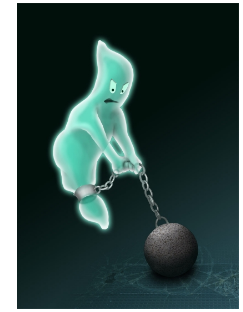
Ghost Halos



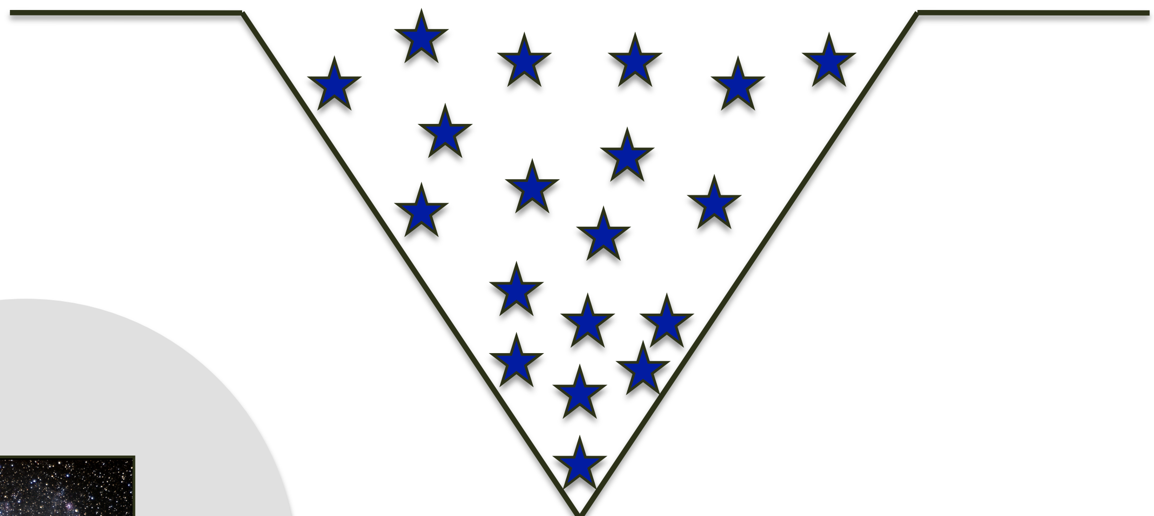
Stars initially form at the center of a dark matter halo.



Ghost Halos



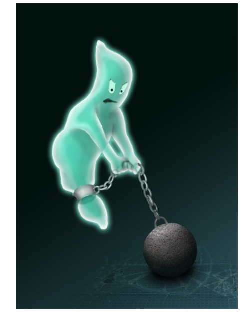
Kinetic energy from the repeated collisions heats the primordial stellar population.

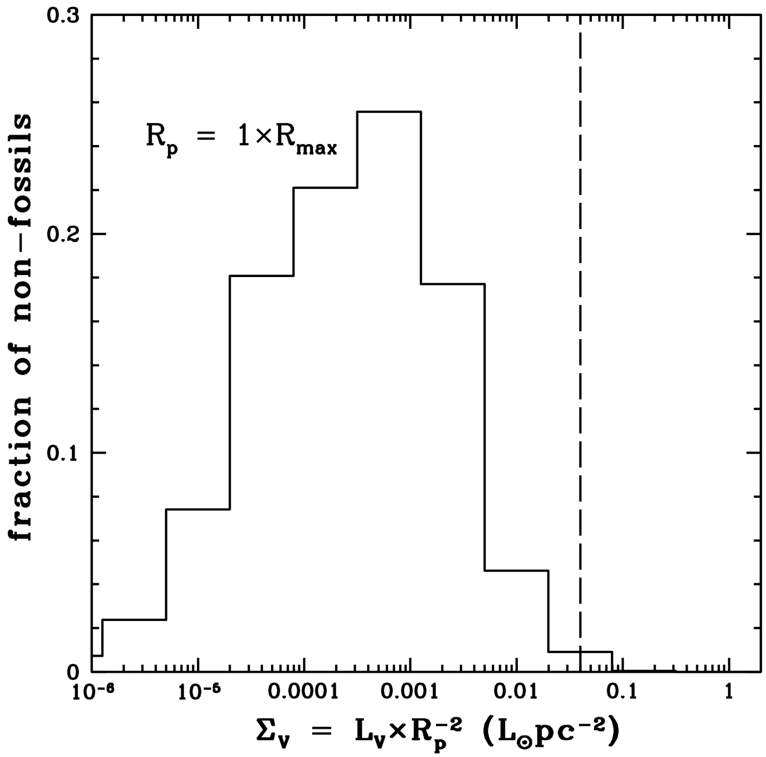


Primordial stars become a diffuse “ghost halo” around a dIrr.

But, is it still detectable by SDSS??

Detection of Ghost Halos





Bovill & Ricotti (2011b)

Nearly all ghost halos would be below SDSS limits. However …

if non-fossils form stars after reionization the bright satellite problem remains!

Take Home Points

A subset of the ultra-faint dwarfs are likely the tip of the fossil iceberg.

- There should be > 100 undetected fossils around the Milky Way.
- The "inner" ultra-faints have r_{hl} inconsistent with fossils

The "bright satellite problem" from 50 – 1000 kpc from the Milky Way.

- Possible Solution: The primordial populations of these dwarfs may be extremely diffuse, below current survey limits.

We have developed observational tests for high z star formation.

- **The number and properties of the undetected ultra-faint dwarfs.**
- **The detection of the ghost halos.**

Bovill & Ricotti (2009), Bovill & Ricotti (2011a,b) (ApJ accepted)


Thank you!