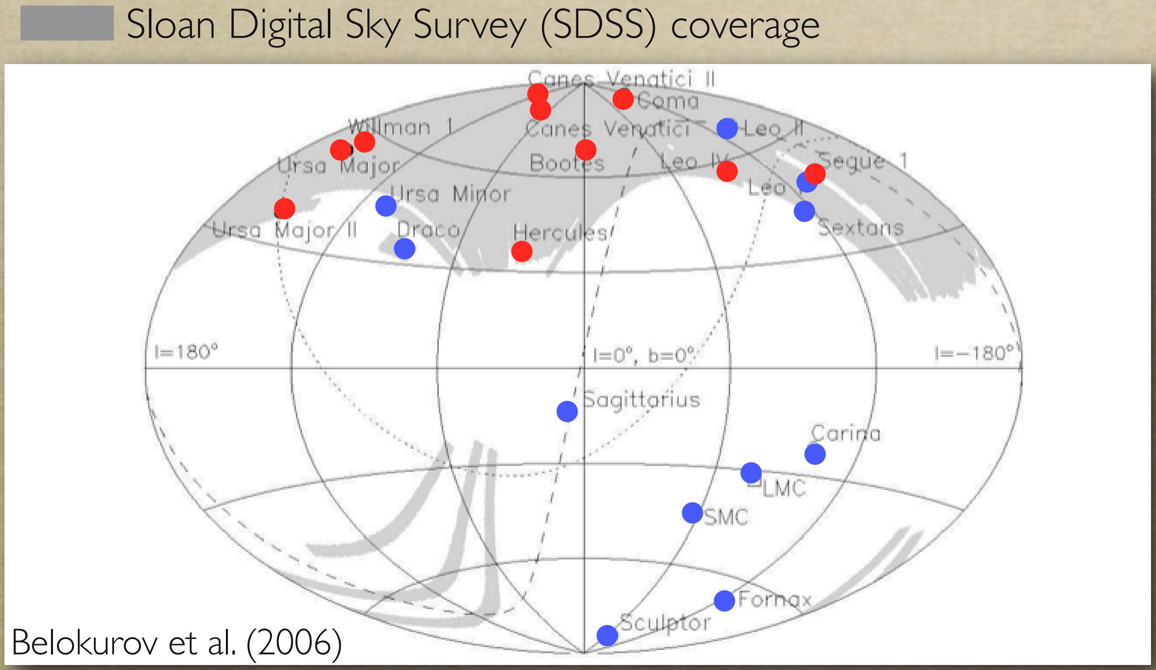
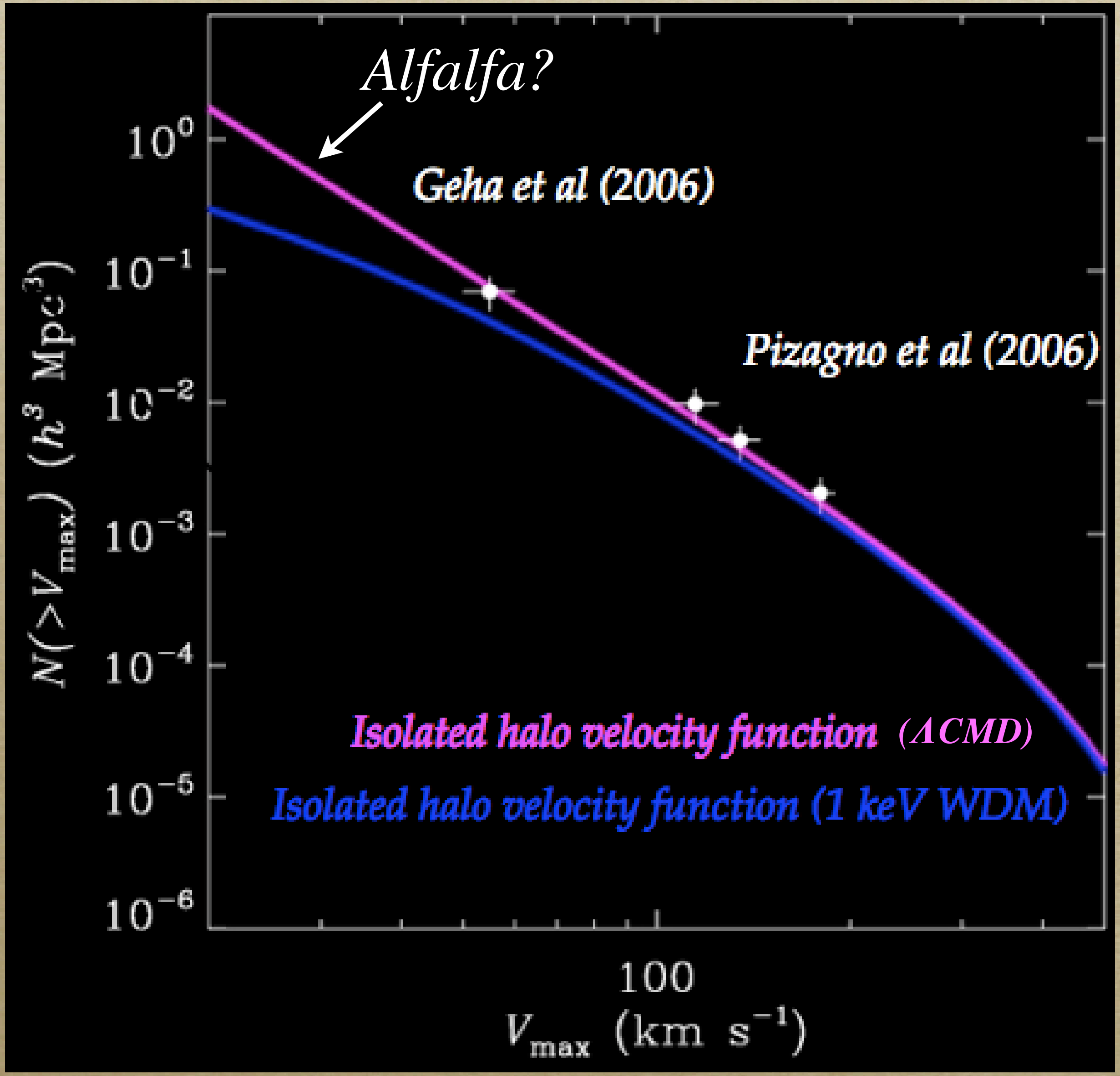
Observations of Ultra-Faint Galaxies

Marla Geha
Yale University



WDM Constraints from Isolated Dwarf Galaxies

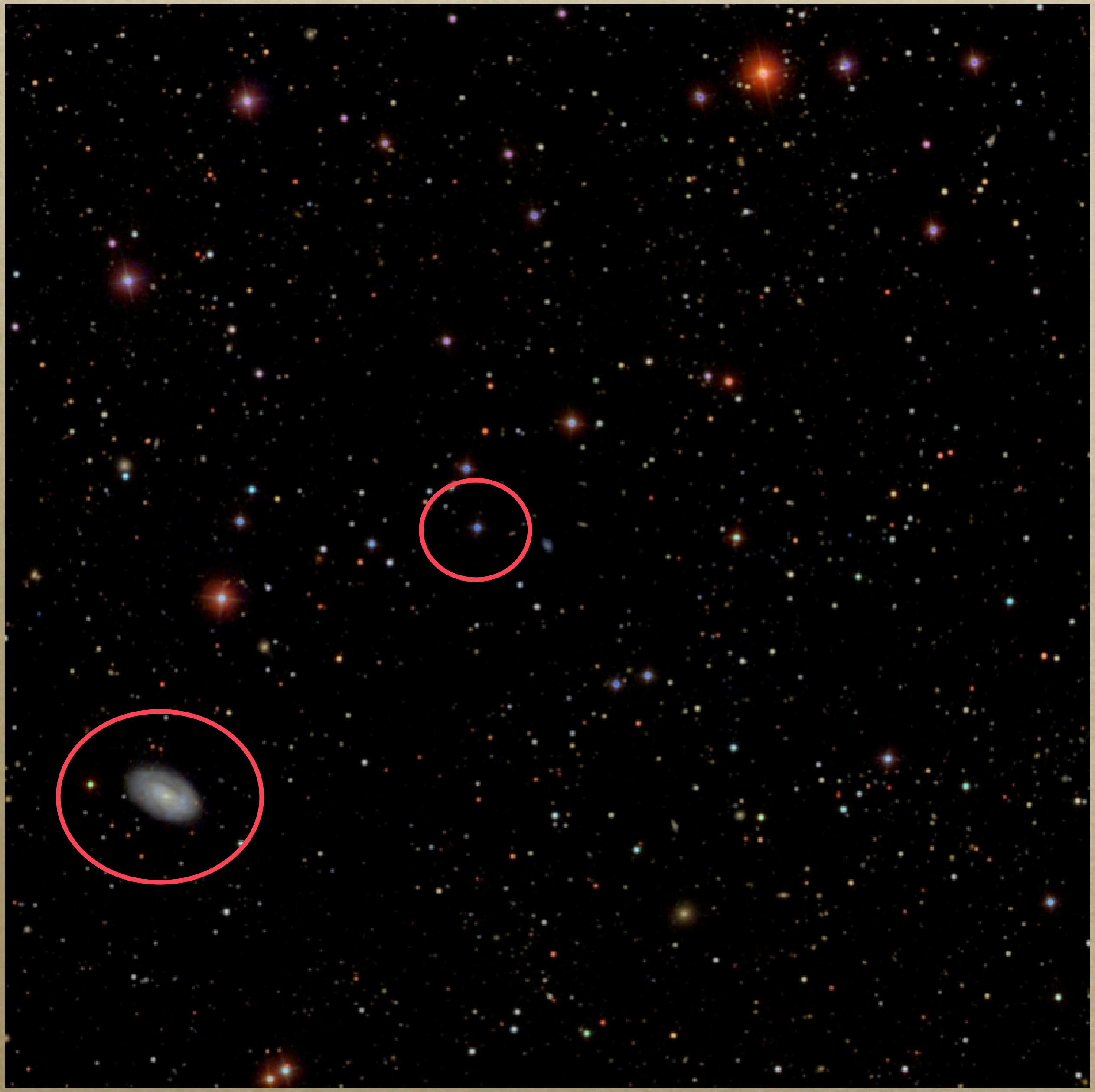


Predicted mass function of ΛCDM vs. WCD differ at low masses.

Isolated galaxies presumably suffer less astrophysics (gas/tidal stripping).

To find a sufficiently large sample of isolated dwarf galaxies, need to survey large volume

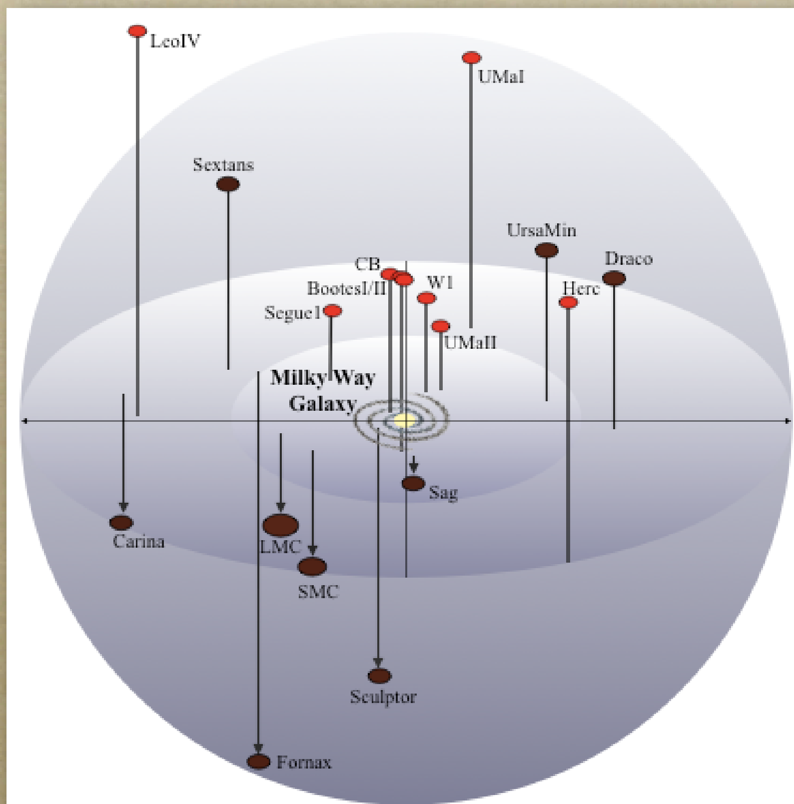
Blanton, Geha & West (2008)

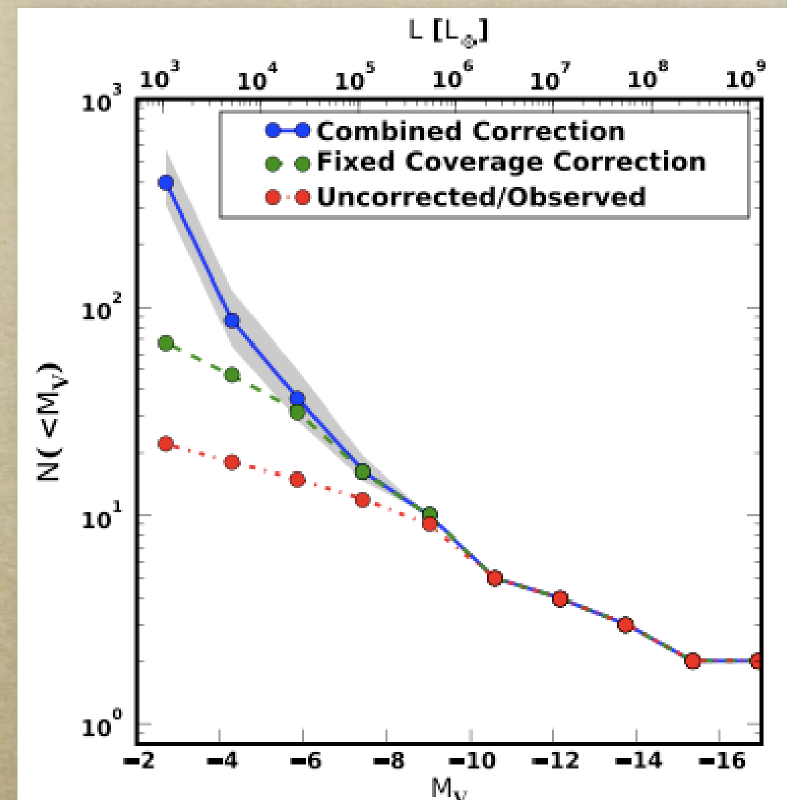


Why don’t larger samples of isolated dwarf galaxies exist?

Nearby (>100Mpc) dwarfs have similar sizes / colors as more numerous higher redshift objects.

The Milky Way Ultra-Faint Galaxies





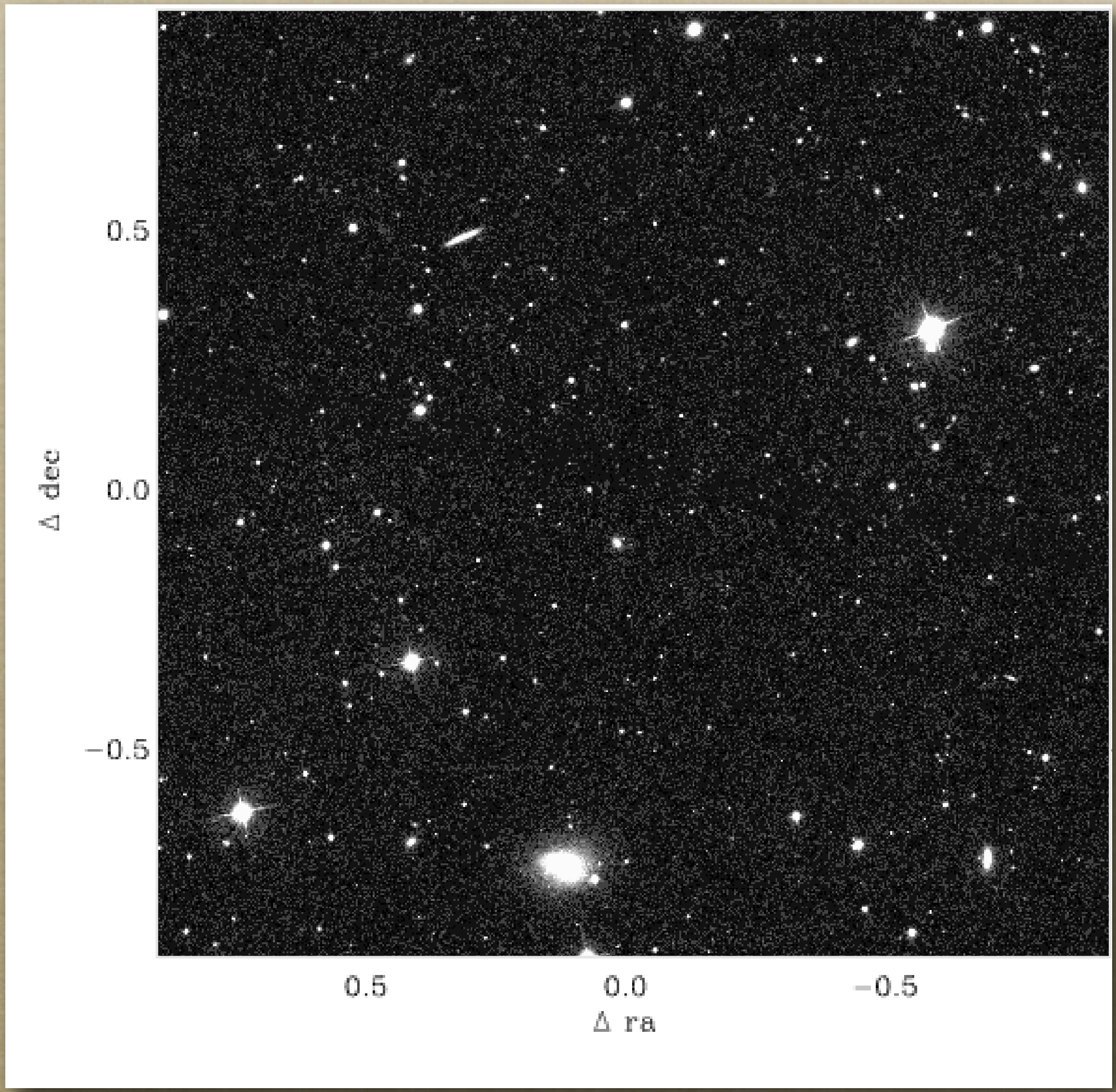
Dark matter uses for ultra-faint galaxies:

a) Luminosity/mass function of satellites as test of CMD

b) Indirect detection experiments

Finding the Milky Way Ultra-Faint Galaxies

The ultra-faint galaxies are found via over-densities of resolved stars.



Milky Way stellar foreground overwhelms the dwarf galaxy.

Finding the Milky Way Ultra-Faint Galaxies

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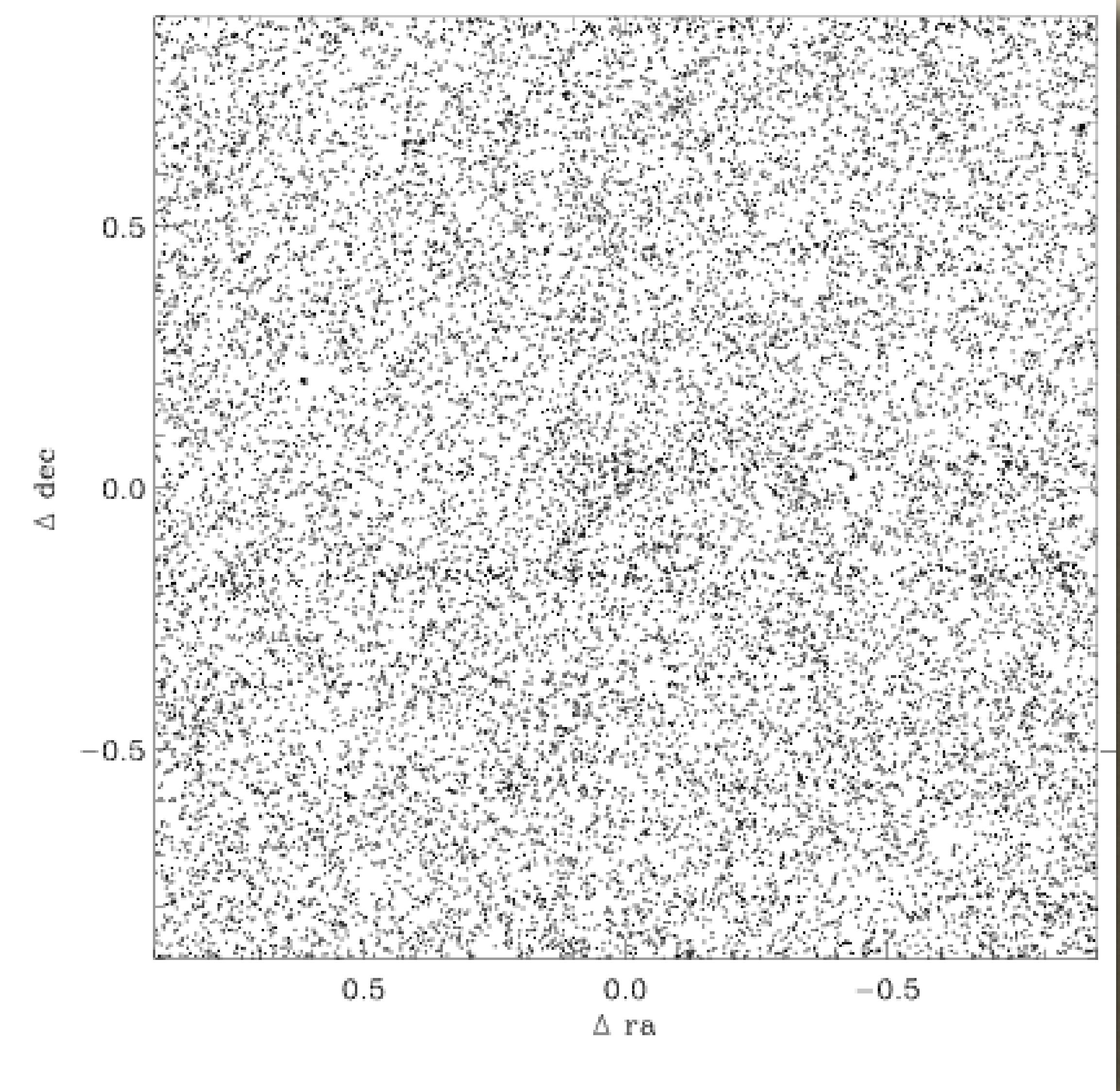
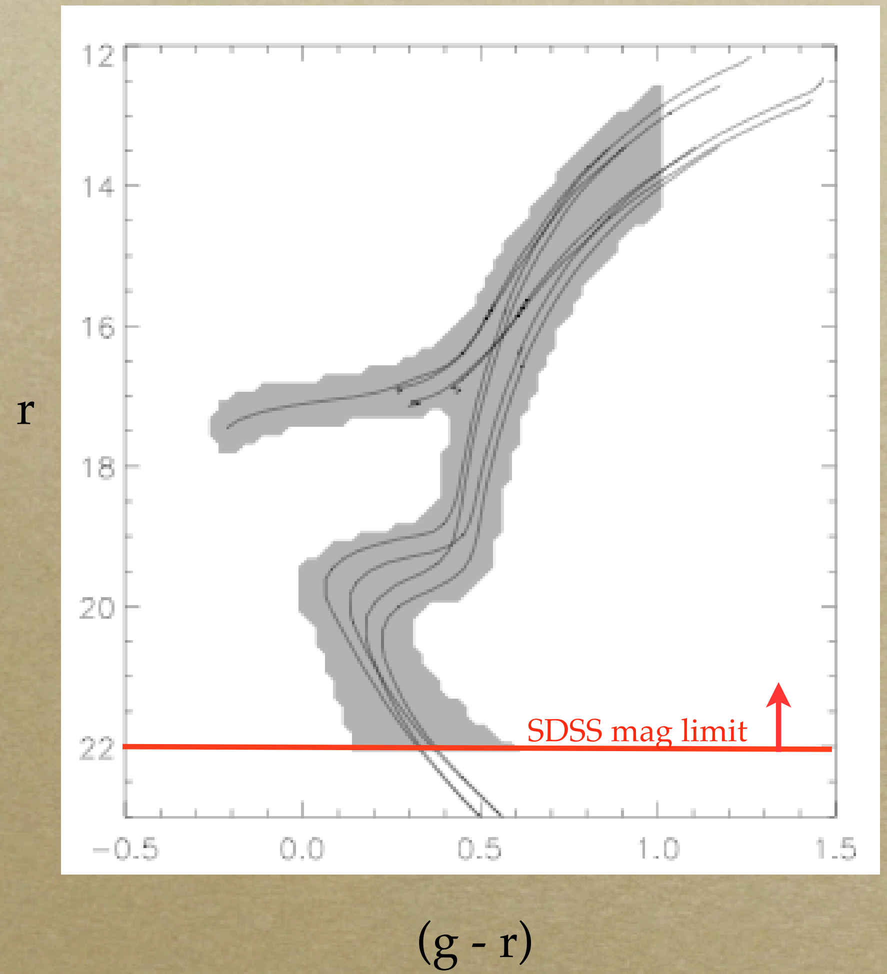


Finding the Milky Way Ultra-Faint Galaxies

Assume: Dwarf galaxies are old, metal-poor stellar populations, with typical size ~ 50-100pc. This defines a narrow region in color-magnitude space.



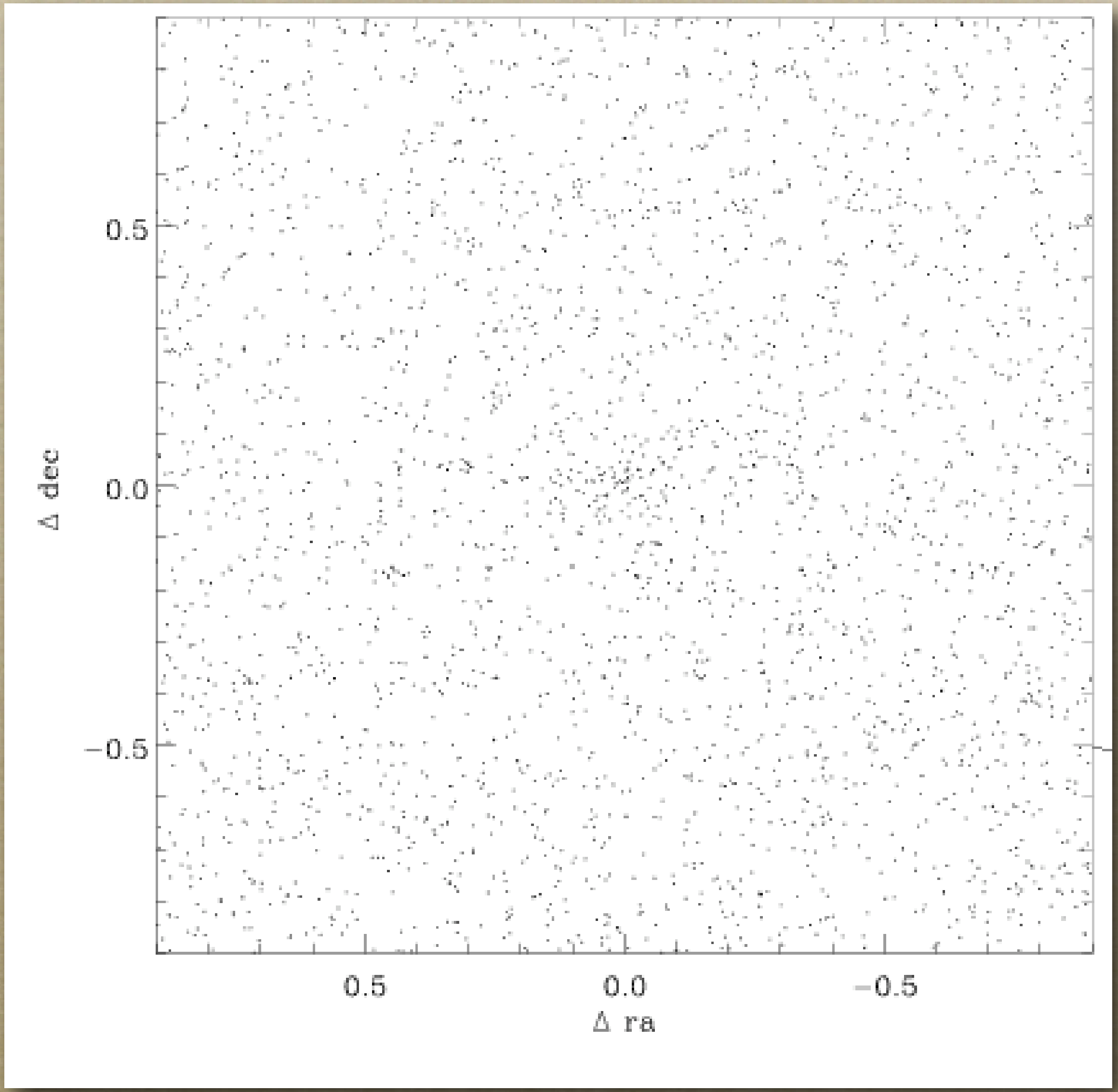
Walsh, Willman & Jerjen (2008)

A generous definition of old and metal-poor:
age = 8 to 14 Gyr
[Fe/H] = -1.5 to -2.3

Distance = 20 kpc

Finding the Milky Way Ultra-Faint Galaxies

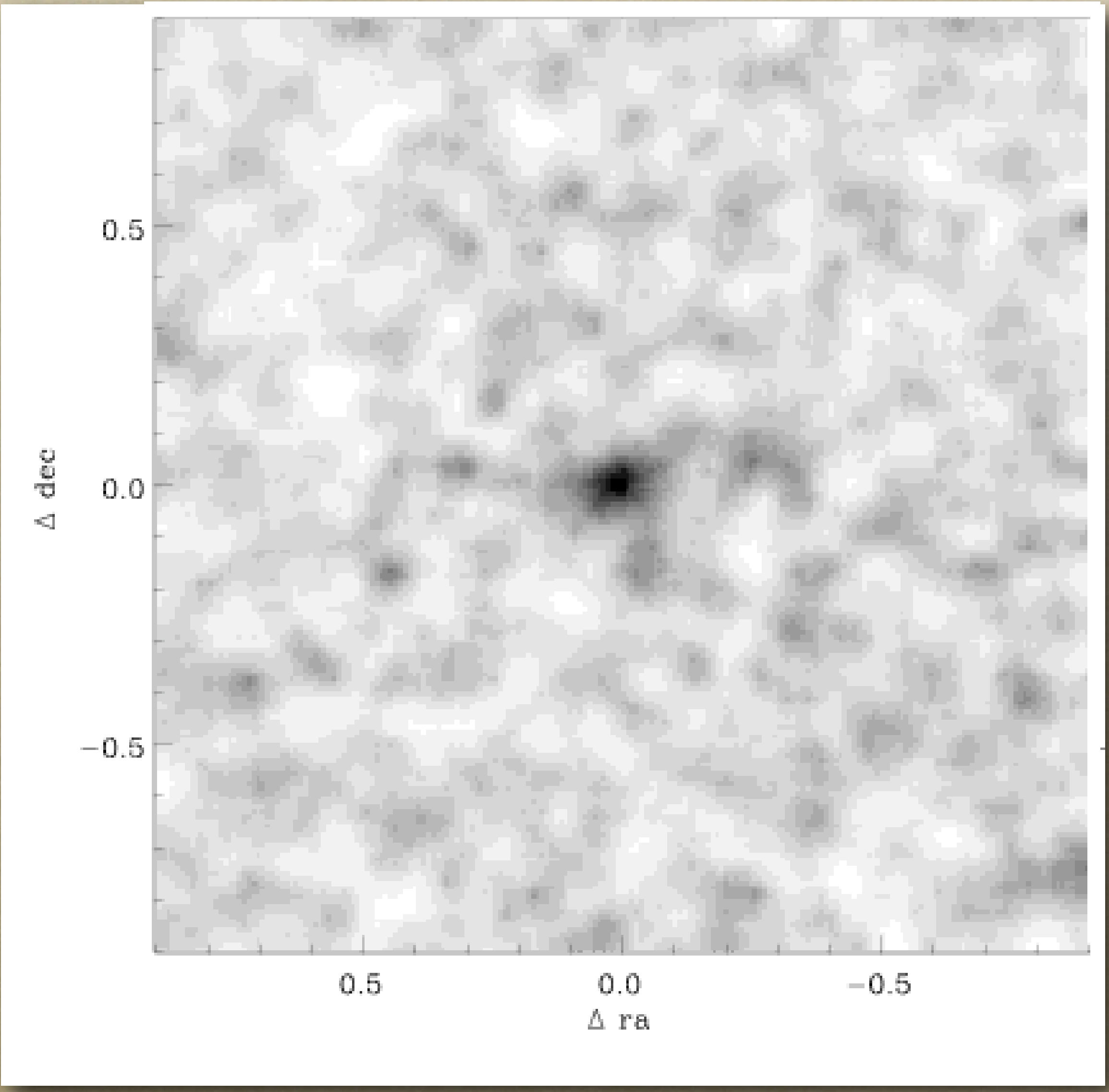
Filtered CMD Stars



Finding the Milky Way Ultra-Faint Galaxies

1. Assumed old/metal-poor stellar population
2. Assumed physical size

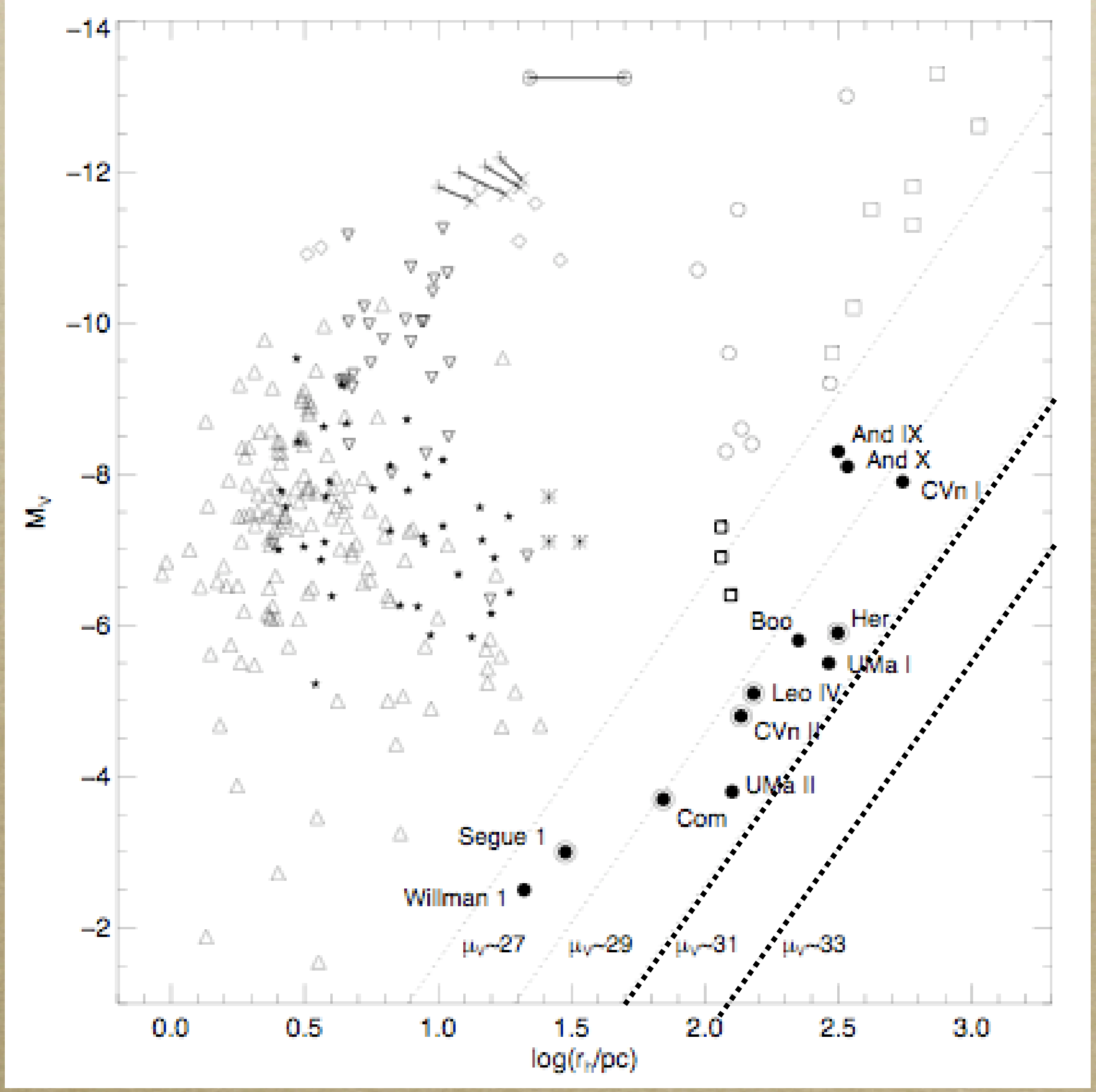
Filtered+Smoothed



Finding the Milky Way Ultra-Faint Galaxies

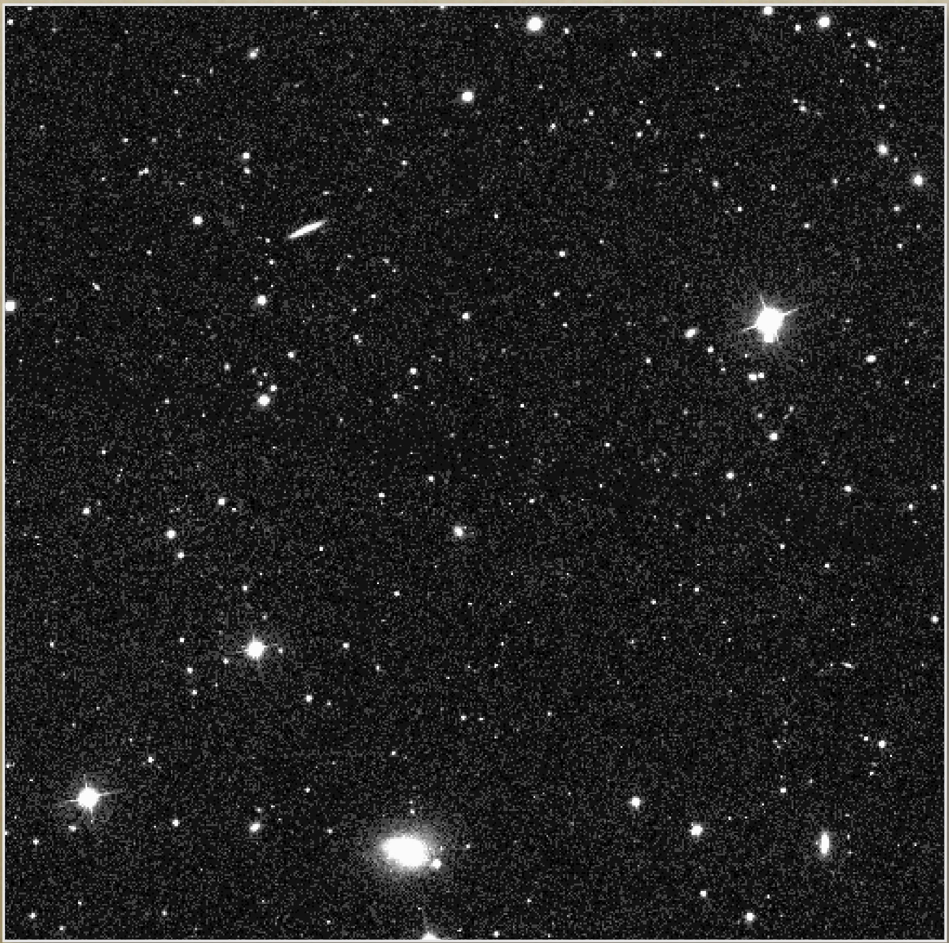
1. Assumed old/metal-poor stellar population
2. Assumed physical size

=> could still be missing even lower surface brightness galaxies.



Finding the Milky Way Ultra-Faint Galaxies

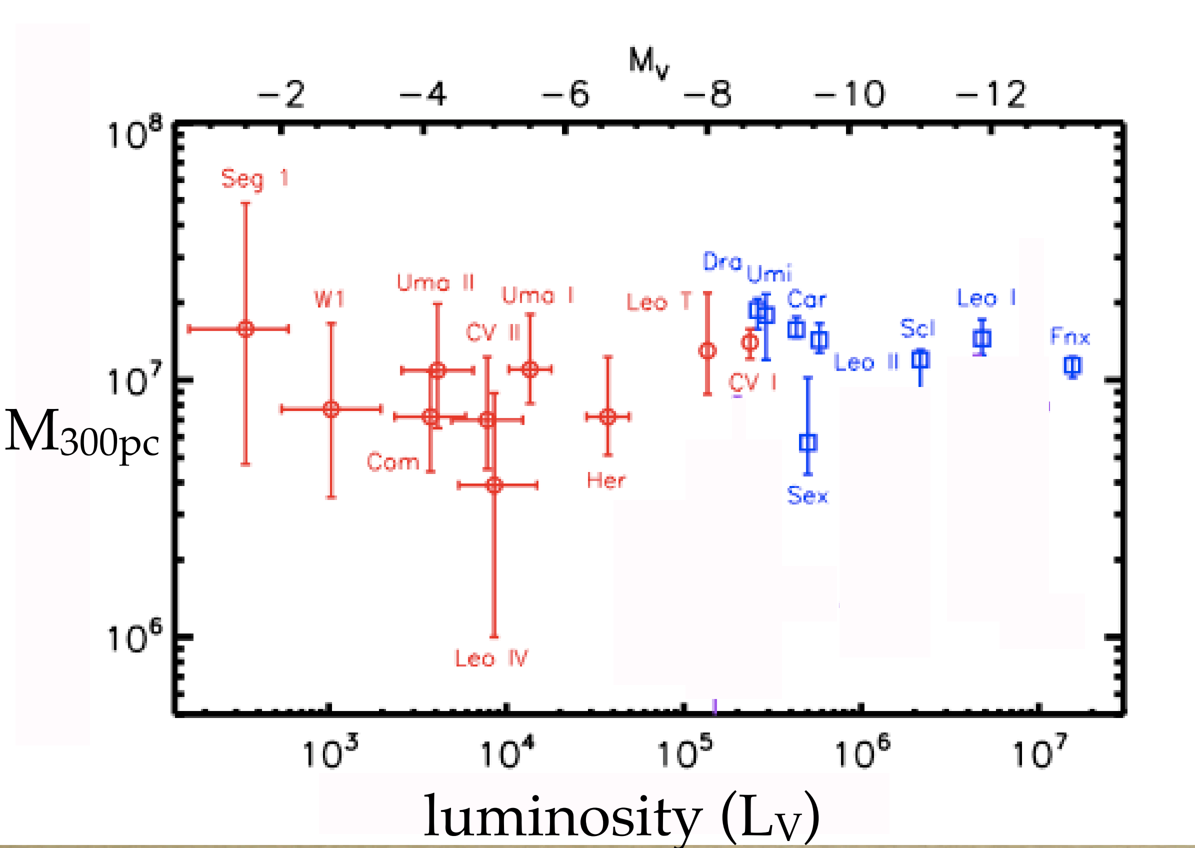
Raw Image



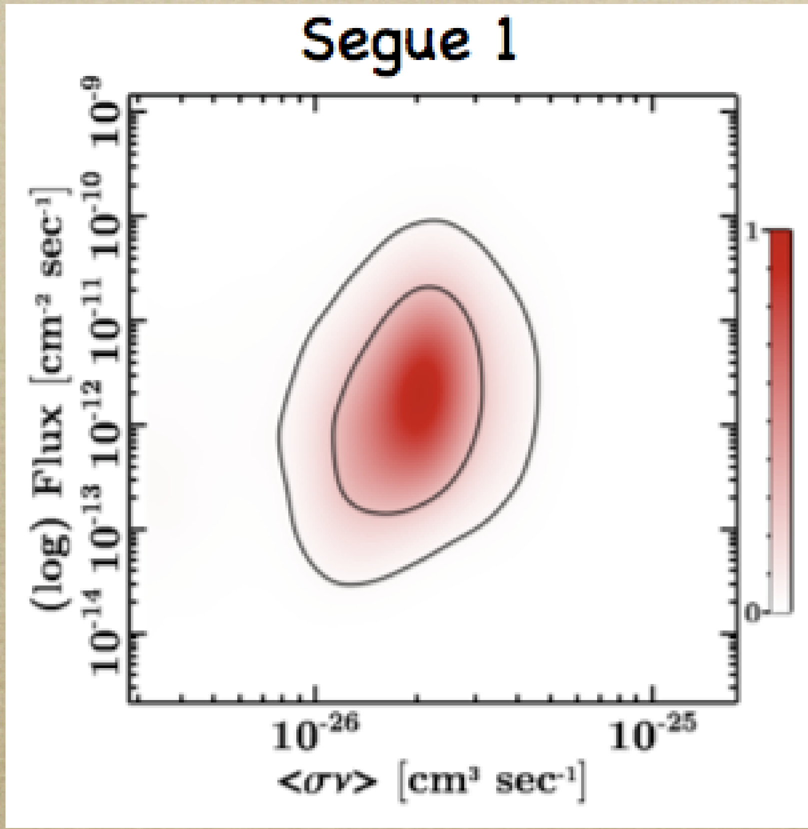
Ultra-faint Stars-only

Milky Way stellar foreground overwhelms the ultra-faint dwarf galaxy.

Kinematics of Ultra-Faint Galaxies



Strigari et al 2008

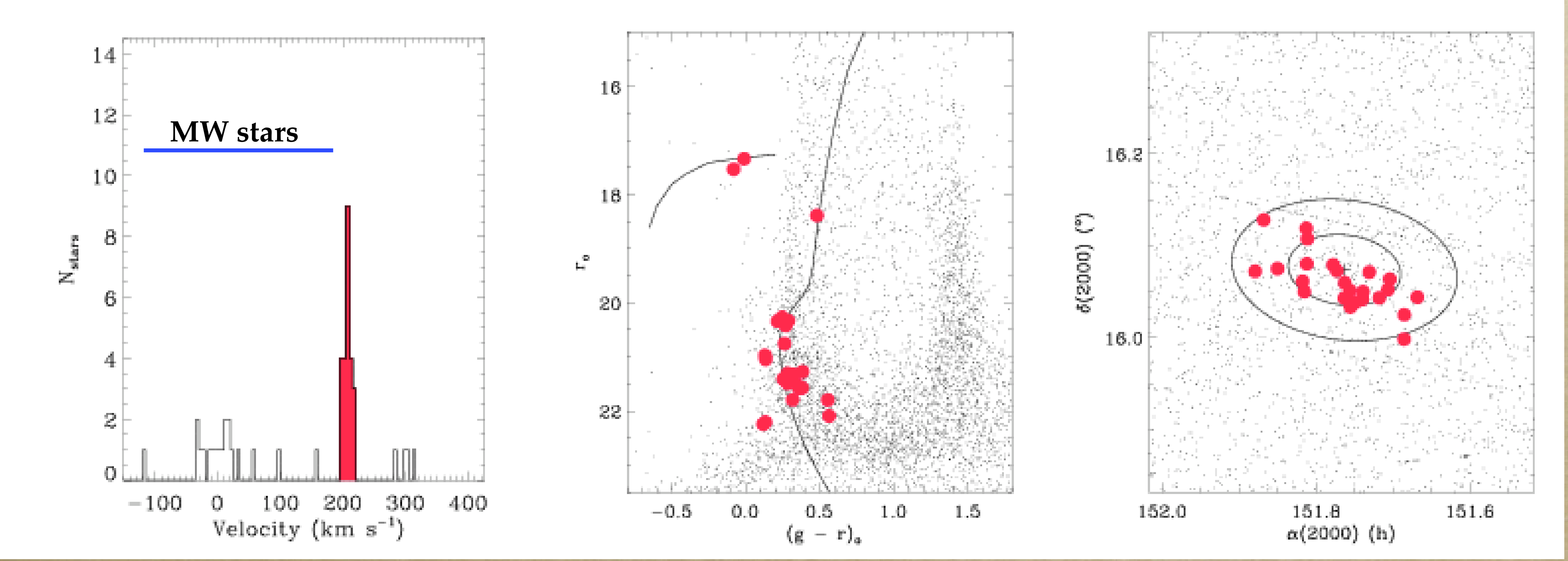


Martinez et al 2009

Mass/density profiles depend on assumption that measured velocities probe gravitational potential

Kinematics of Segue 1

$M_V \sim -1.5$
$L_V \sim 340\ L_{sun}$



Geha et al (2009)

Kinematics of Segue 1

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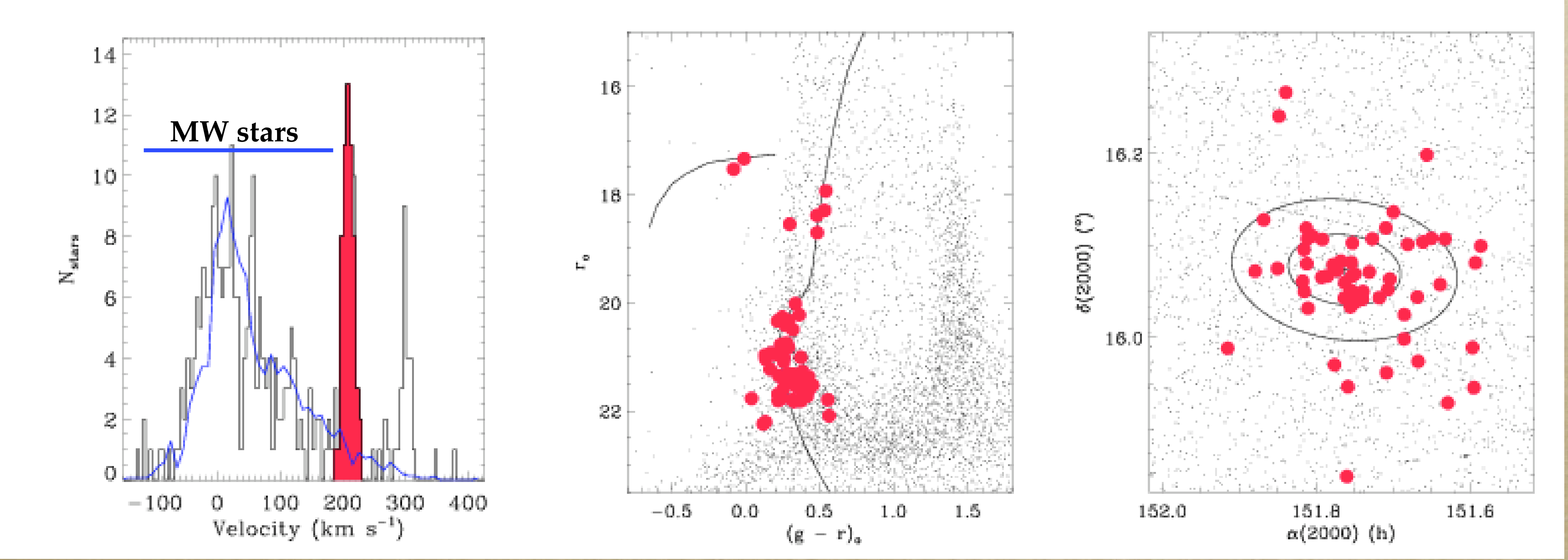
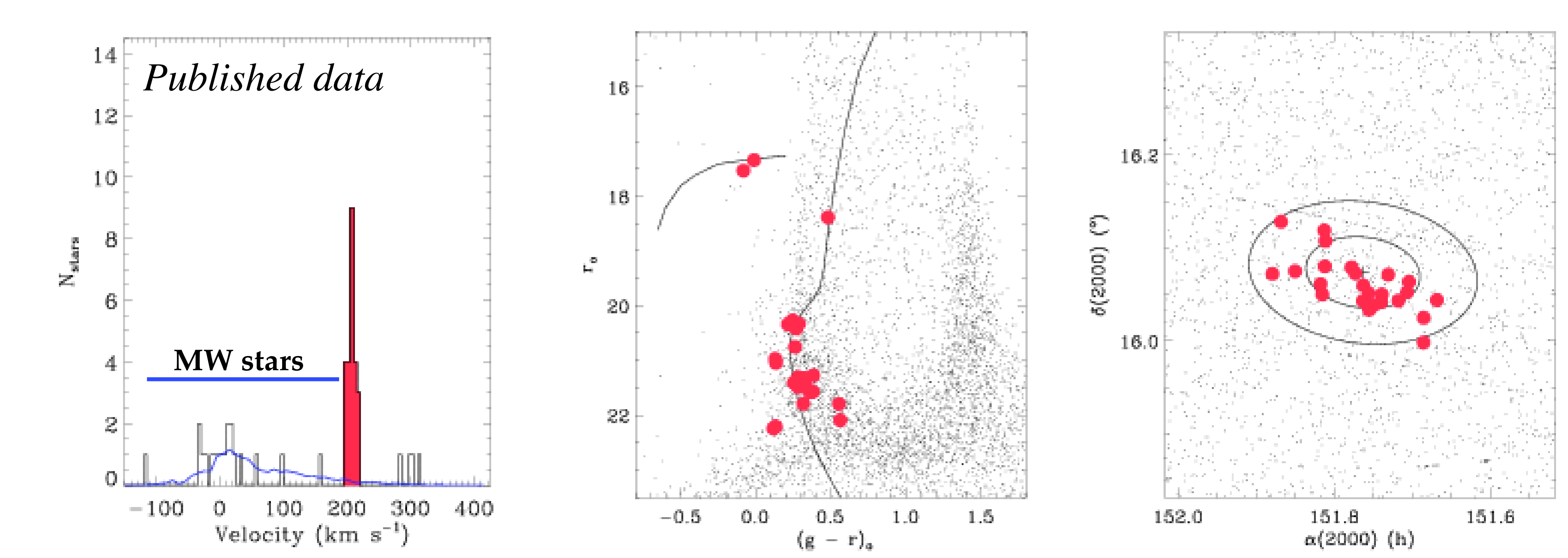
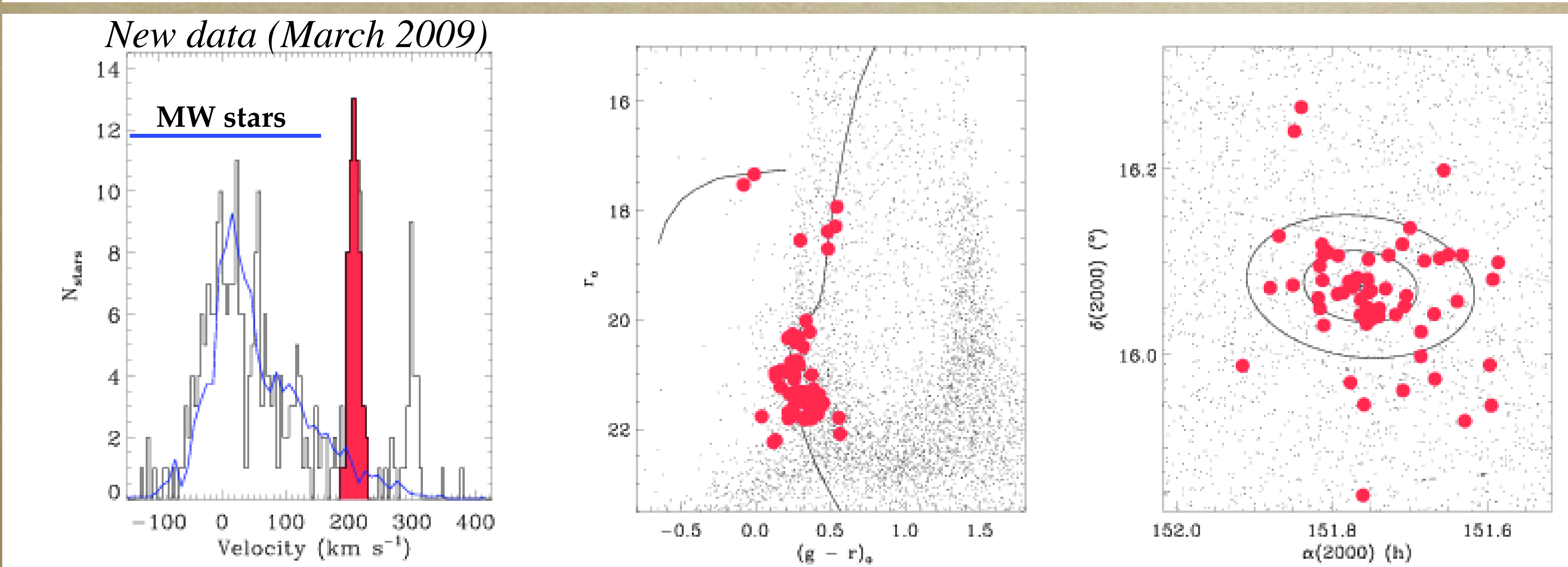


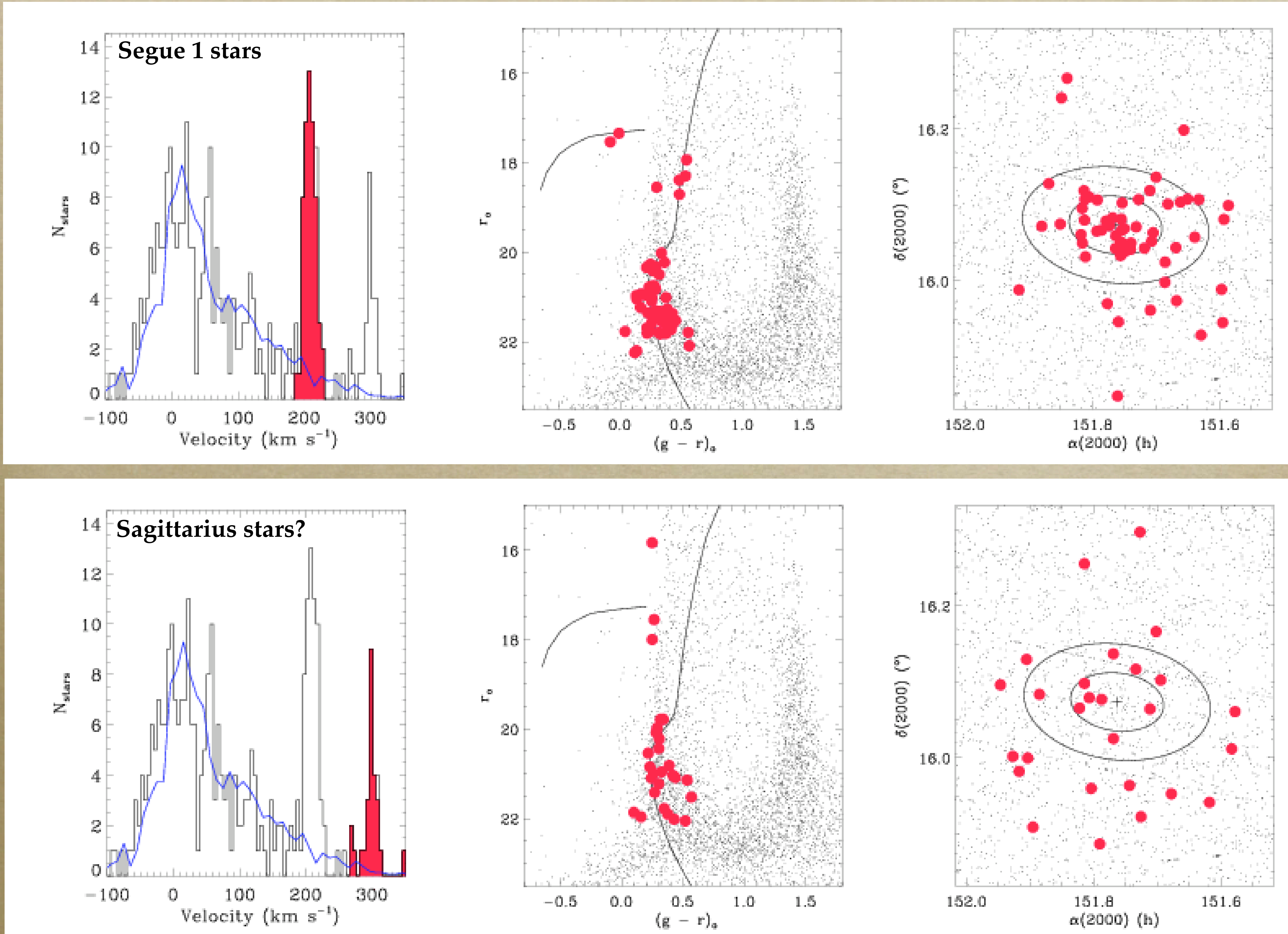
If mass from stars only = 0.4 km/s

Measured = 4.5 km/s

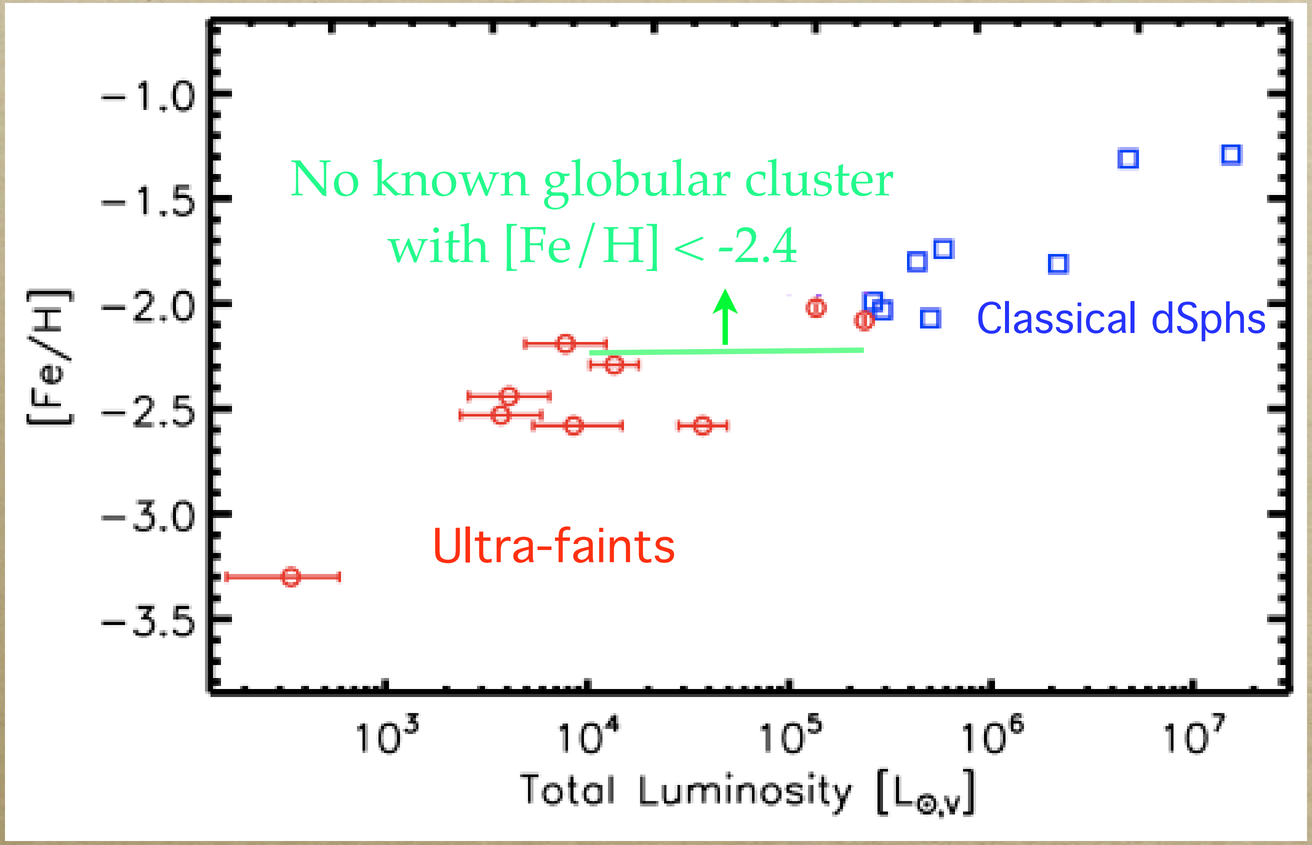
Geha et al (2009)


Published data
MW stars
N_{stars}
Velocity (km s^{-1})
r_o
$(g-r)_o$
$\delta(2000)$ (°)
$\alpha(2000)$ (h)


New data (March 2009)
MW stars
N_{stars}
Velocity (km s^{-1})
r_o
$(g-r)_o$
$\delta(2000)$ (°)
$\alpha(2000)$ (h)


Segue 1 stars
N_{stars}
Velocity (km s^{-1})
r_o
$(g - r)_o$
δ(2000) (°)
α(2000) (h)
Sagittarius stars?
N_{stars}
Velocity (km s^{-1})
r_o
$(g - r)_o$
δ(2000) (°)
α(2000) (h)

Metallicity of Ultra-Faint Dwarfs

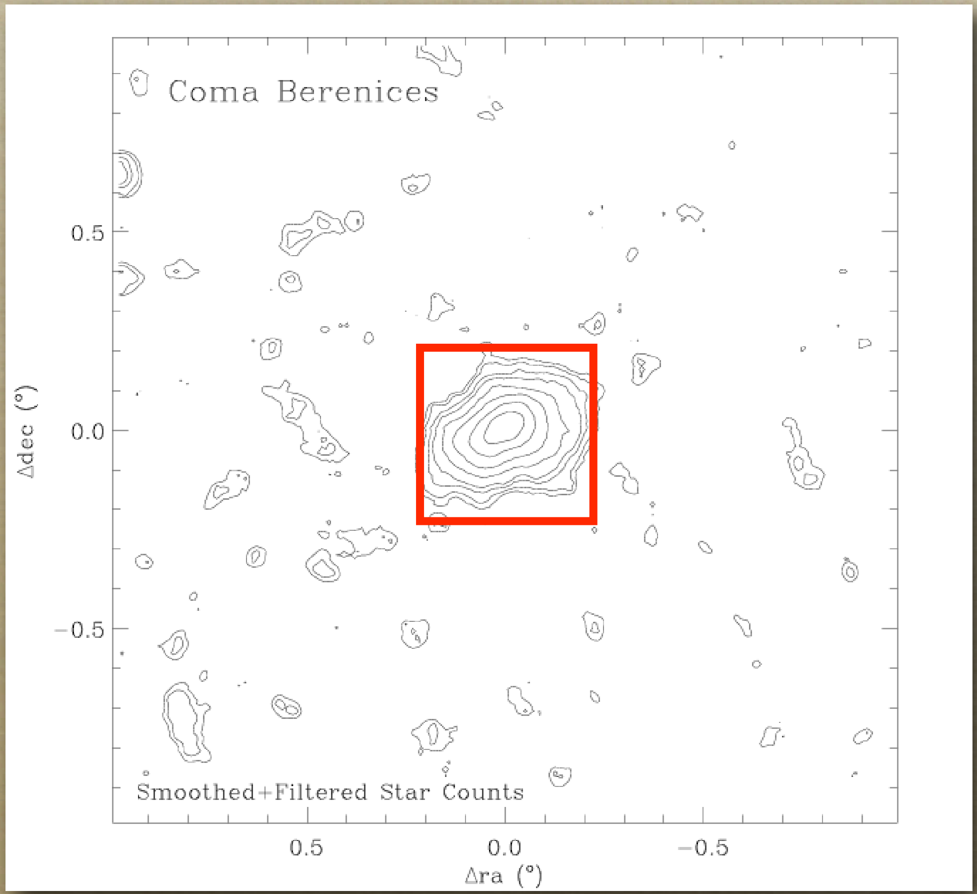


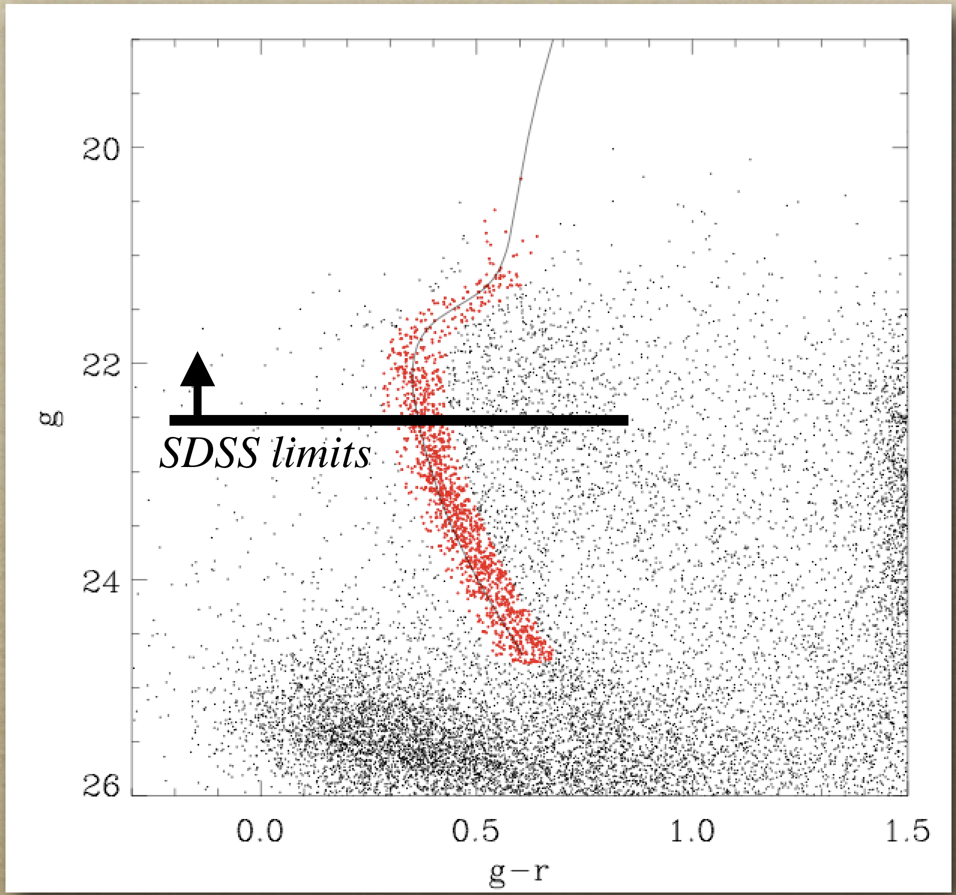
Kinematics data also provides estimate of stellar metallicity.

Luminosity-metallicity relationship suggests ultra-faints formed as galaxies.

Testing Tidal Stripping Another Way

R. Munoz et al (2009)





<u>Prelim Result:</u> Coma does not show evidence for tidal stripping at large radius / low surface brightness.

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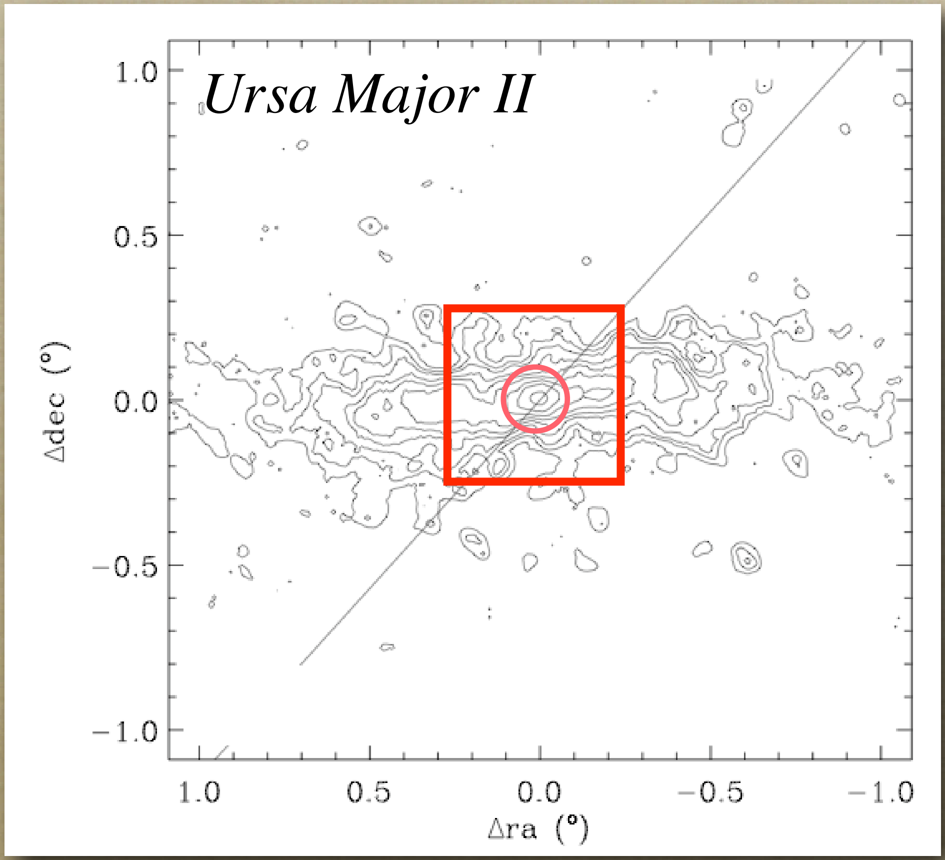
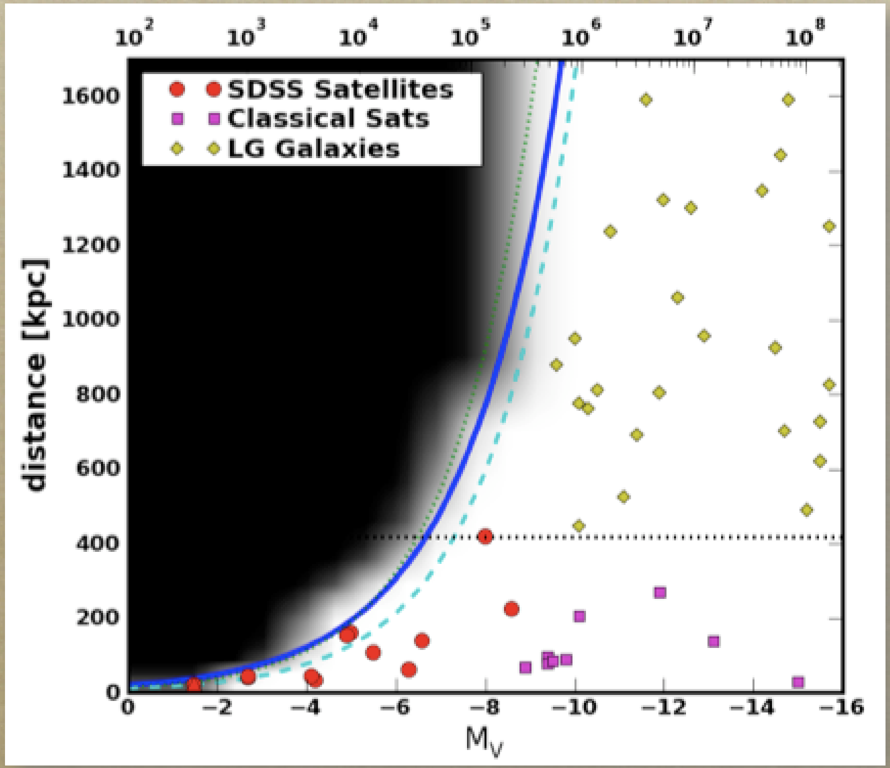
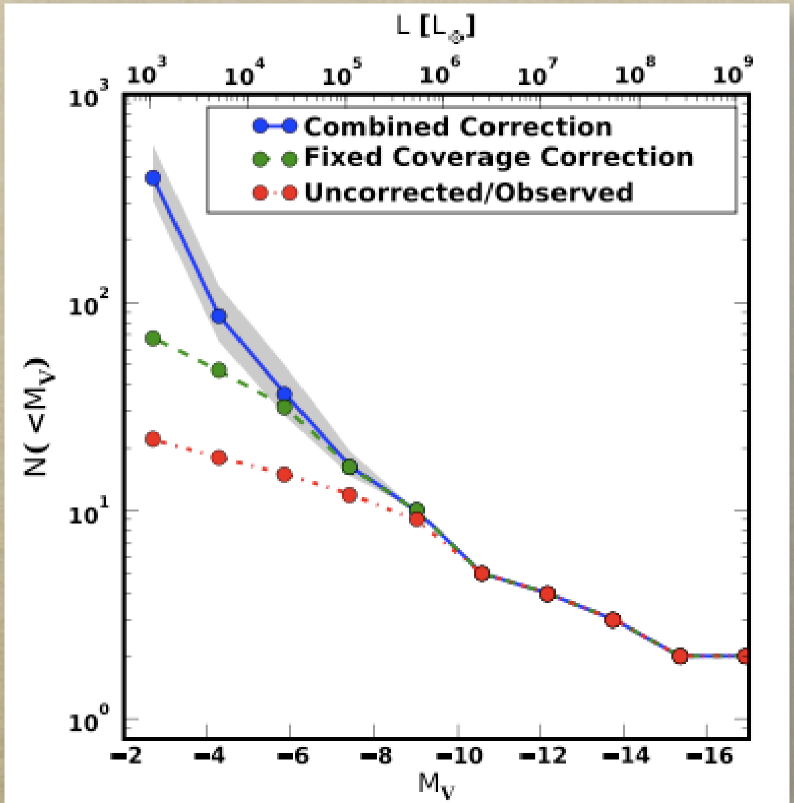


<u>Prelim Result:</u> UMaII shows evidence for elongation well beyond the expected tidal radius.

Finding New Milky Way Satellites





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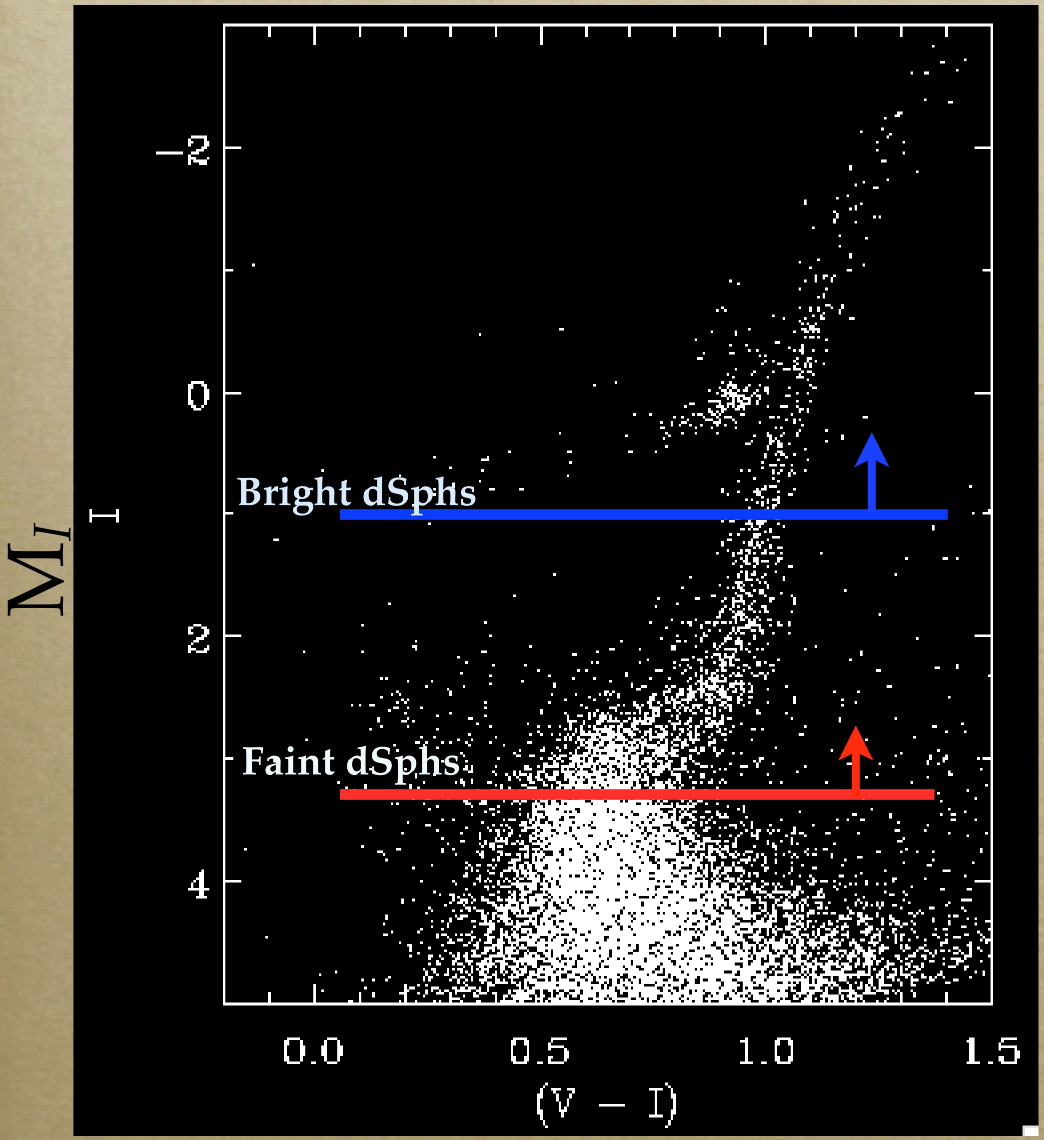
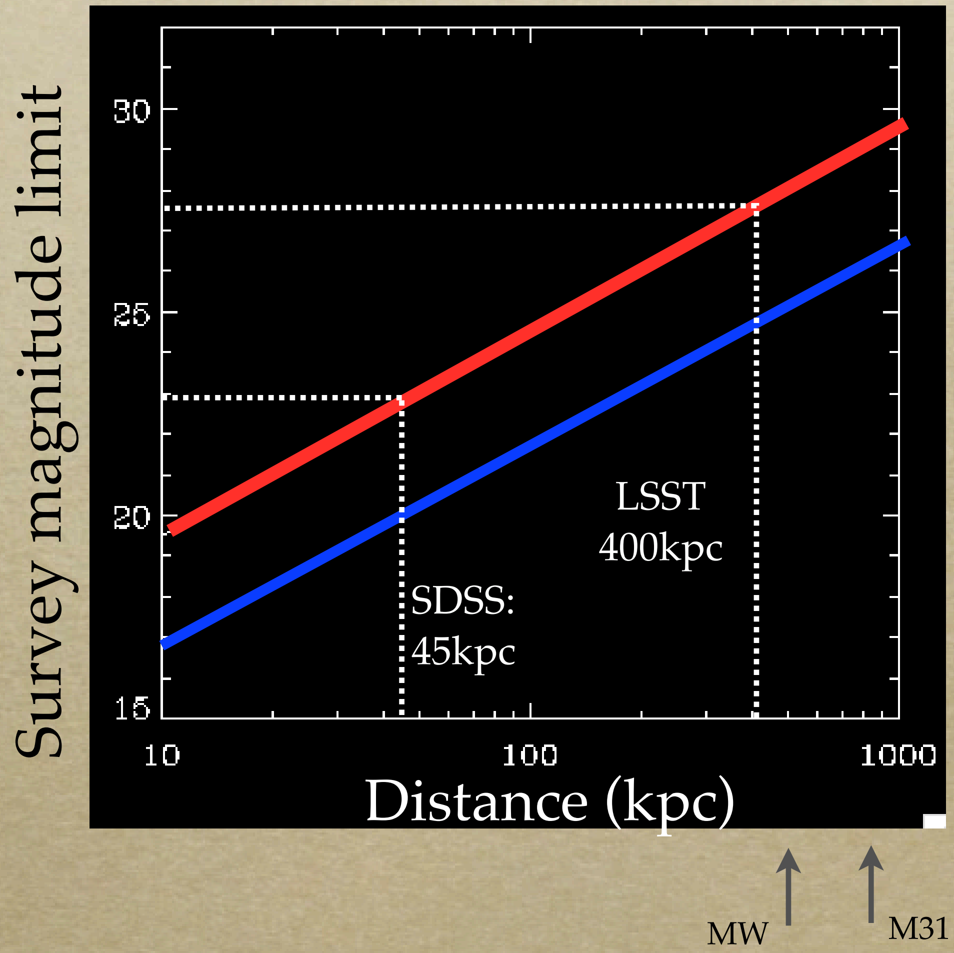
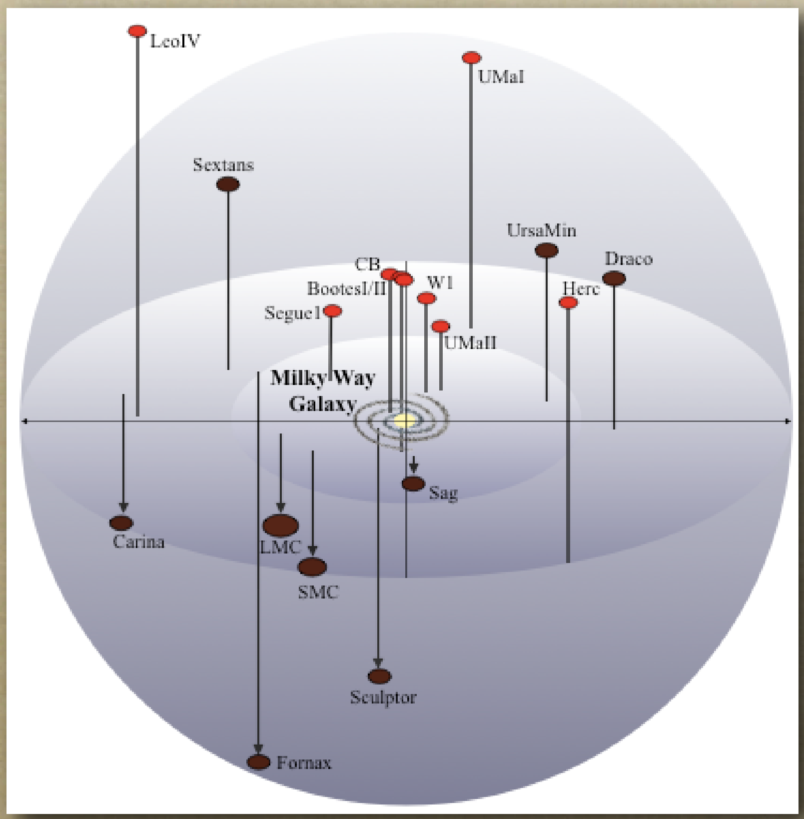
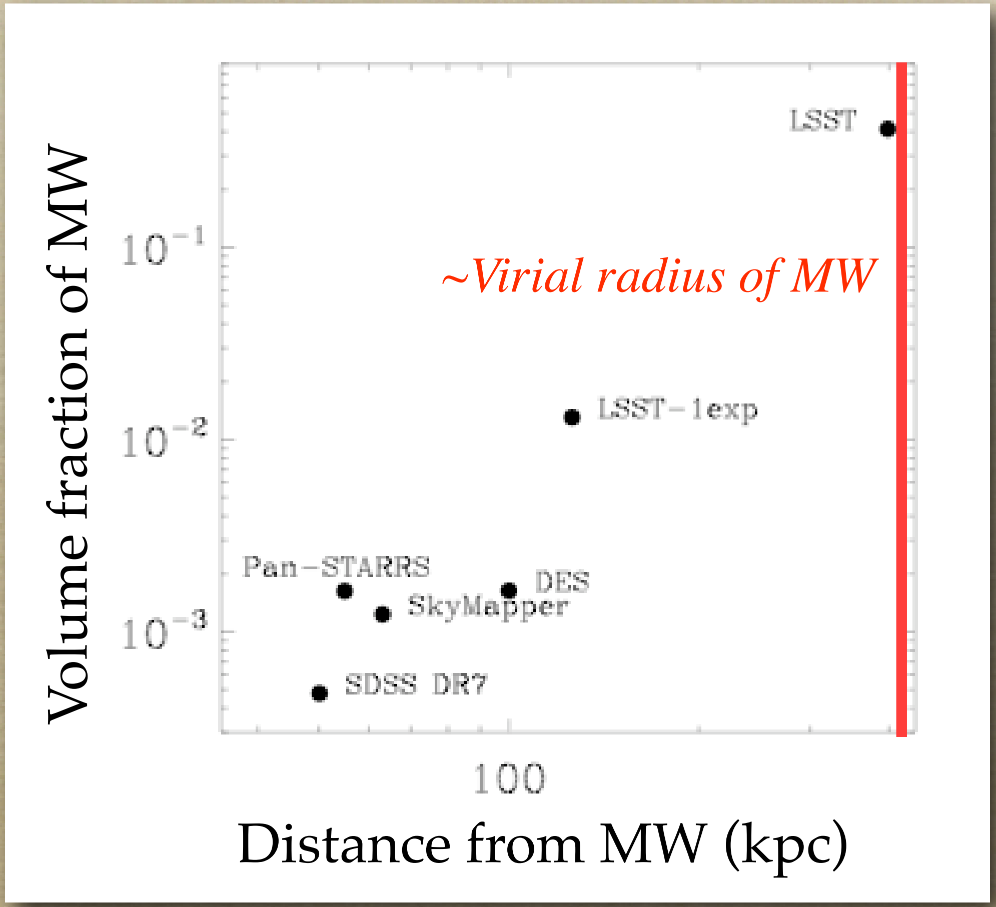




Finding New Milky Way Satellites





Summary

The ultra-faint dwarfs are extreme in every sense:

- Less luminous galaxies ($300 < L_\odot < 100{,}000$).
- Highest mass-to-light ratios ($M/L > 100$).
- Most metal-poor stellar systems ([Fe/H] ~ -2.5)

The ultra-faint dwarfs are good probes of dark matter:

- Minimum galactic halo mass reached?
- New dwarfs alleviate ‘Missing Satellite’ problem.
- Good targets for upcoming γ-ray observatories.