The Ultra-Faint Galaxies as Targets for Indirect Dark Matter Studies

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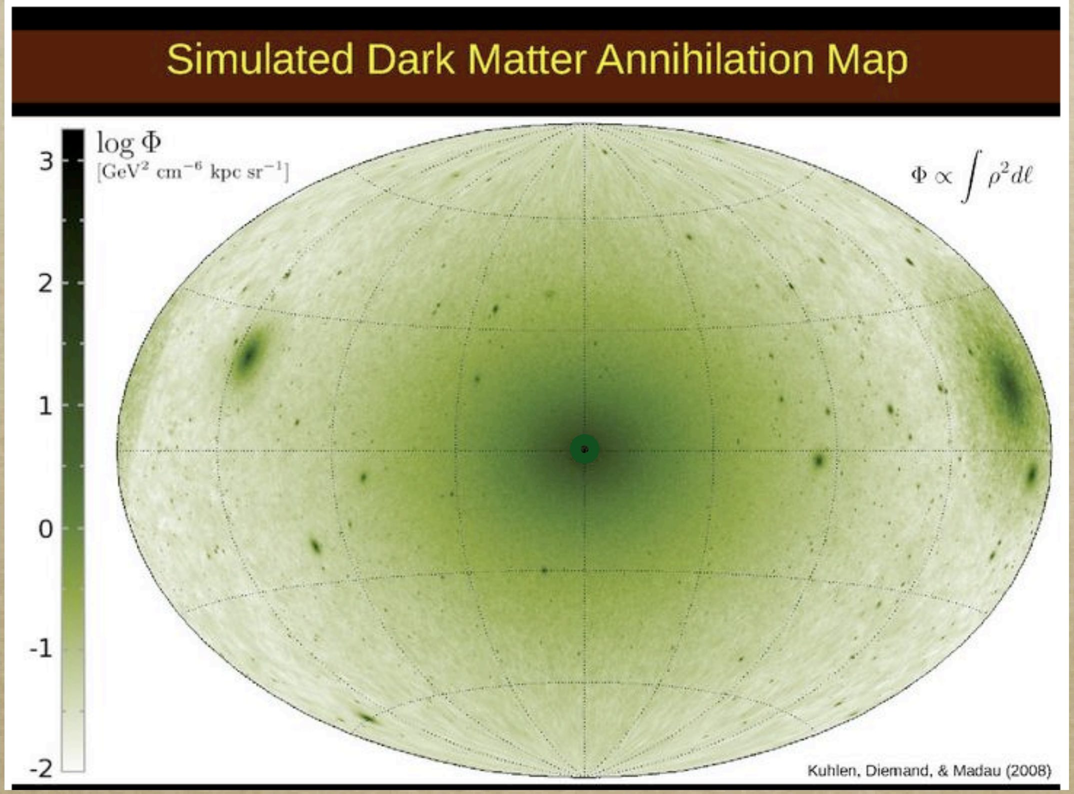

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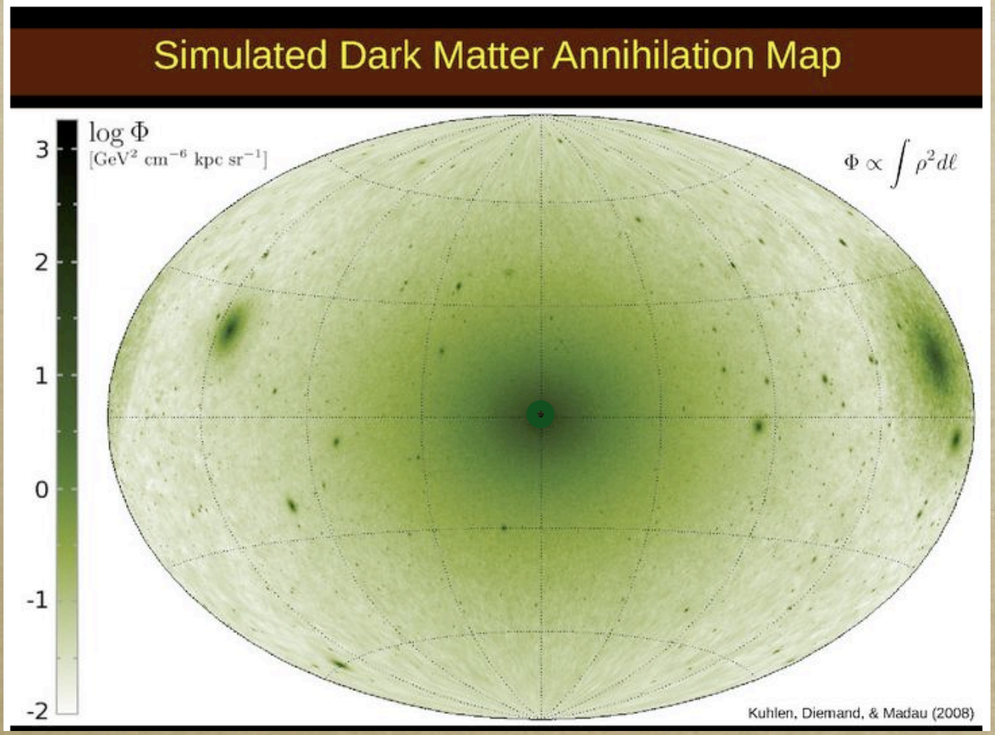
Louie Strigari (Stanford)
James Bullock (UCI)
Manoj Kaplinghat (UCI)
Joe Wolf (UCI)

Indirect Dark Matter Detection



Dark matter particles occasionally annihilate to produce observable γ-rays. Predicted flux depends on:

1. Particle Physics:
   Cross sections, particle masses

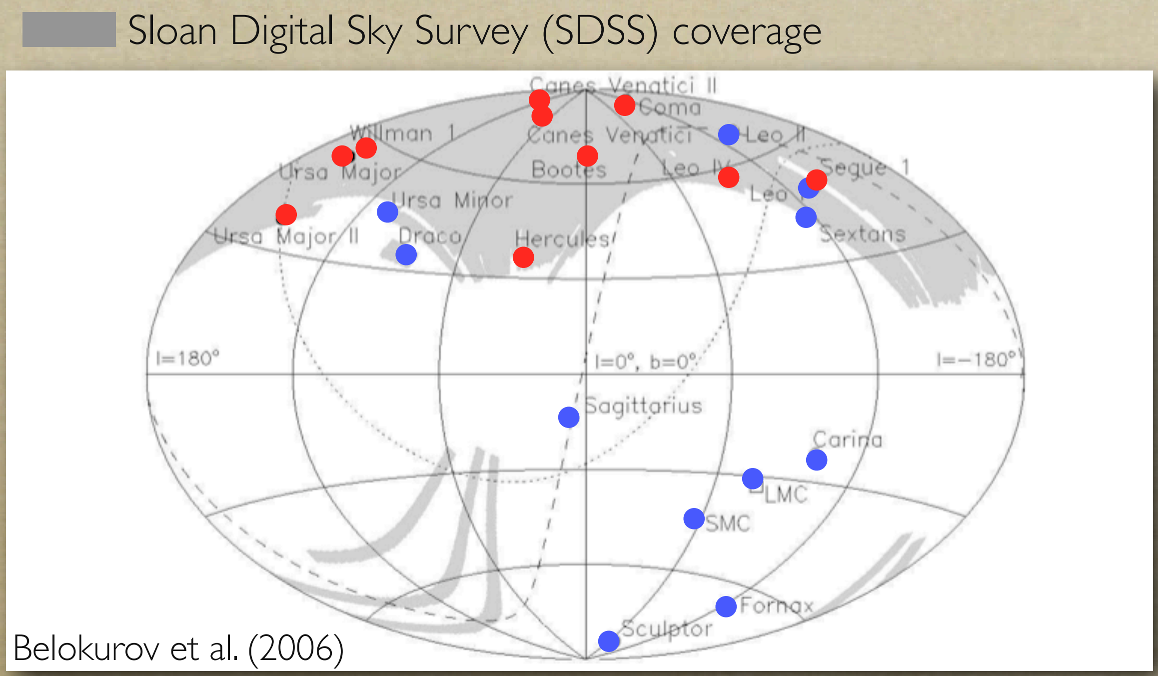
2. Astrophysics:
   Mass density^2, distance^2

Galactic Center is bright source of the annihilation signal: highest DM density, nearby (8 kpc).

However, many other sources of γ-rays in this region (central BH, recent star formation).

→ Dwarf galaxies satellites are next best place to look for this signal!

The Milky Way Satellite Census



2003 Census Data:

- Classical dSphs = 11

2009 Census Data:

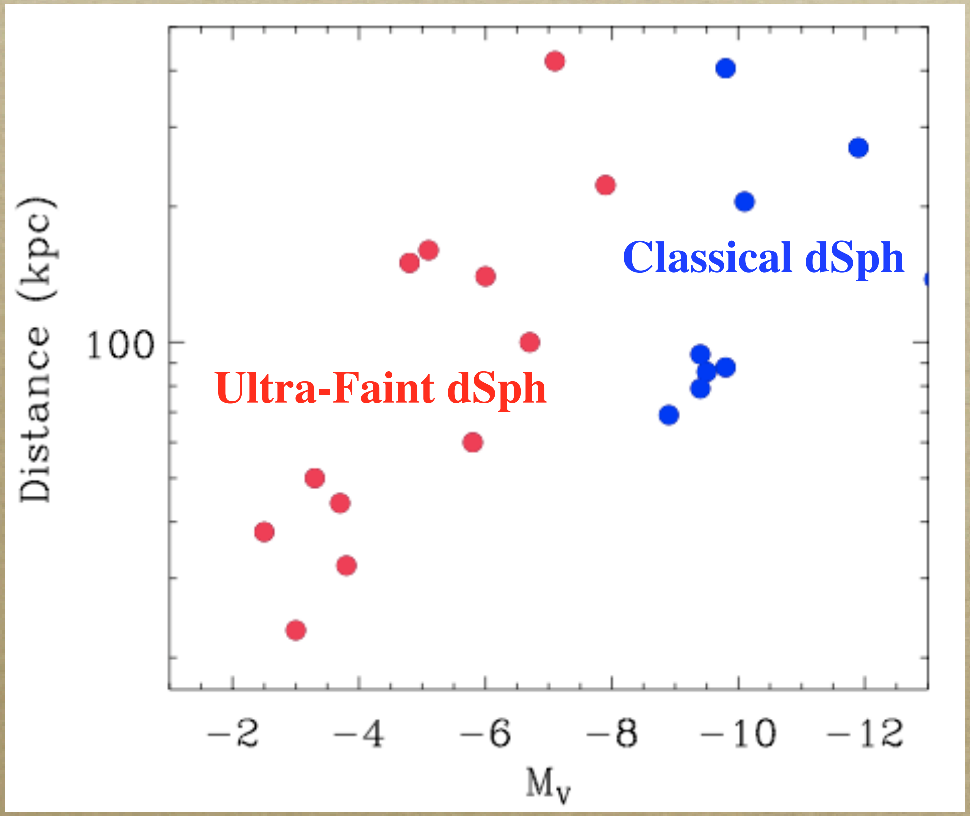
- Classical dSphs = 11
- Ultra-Faint dSphs = 14

Total number of MW satellites between 70 -- 500.

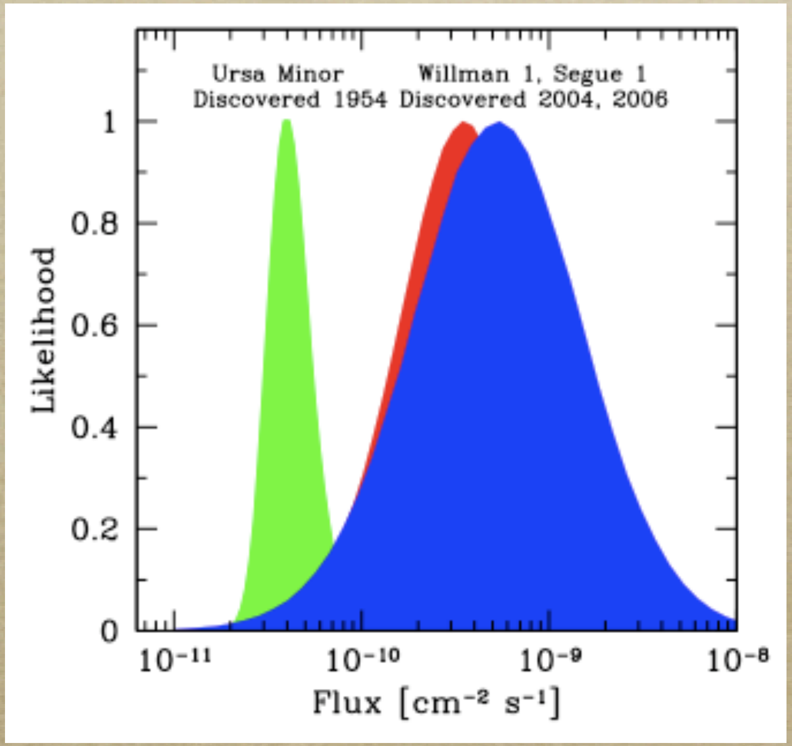
Many additional objects expected to be discovered in wide area surveys (Pan-Starrs, LSST, DES, etc.)

MW Satellites + Indirect Dark Matter Detection

The recently discovered ultra-faint dwarfs are on average closer than the ‘classical’ dwarfs.



Ultra-faints are largely free of intrinsic γ-ray sources and are promising sites to detecting annihilation signal.

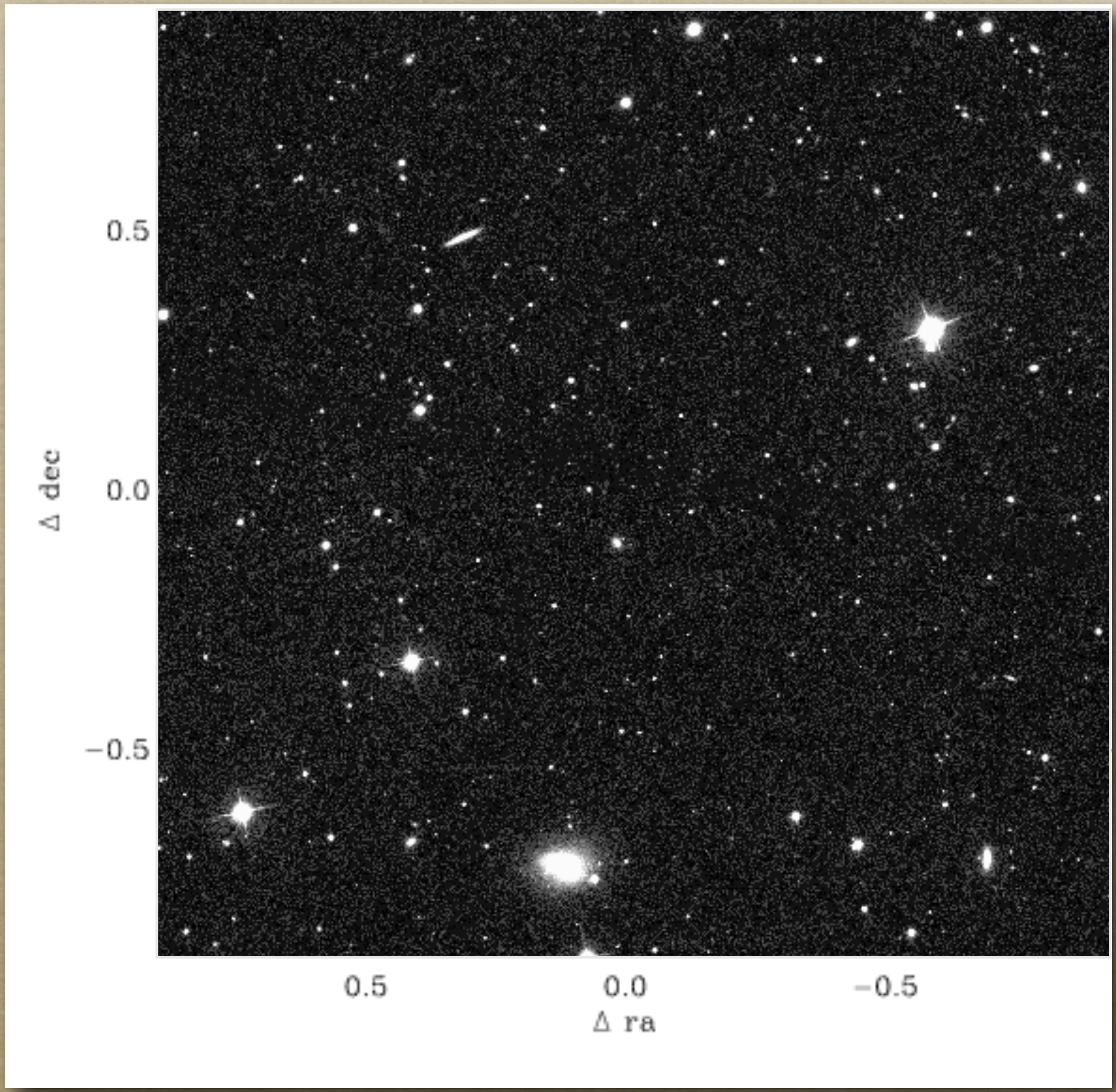


Strigari et al. (2008)

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.



Willman et al (2005a,b), Zucker et al (2006a,b)
Belokurov et al (2006a,b,2008,2009), Walsh et al. (2007)

Finding the Milky Way Ultra-Faint Galaxies

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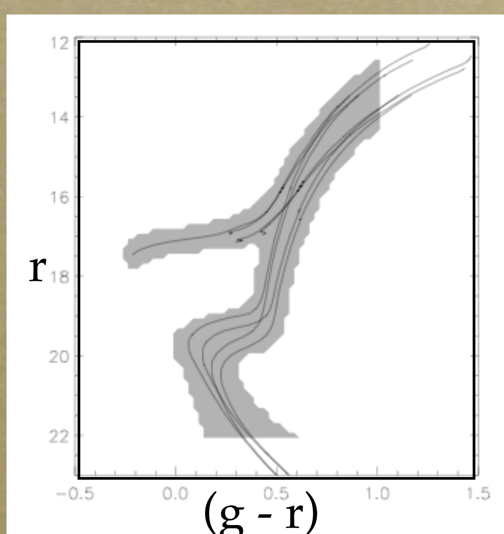
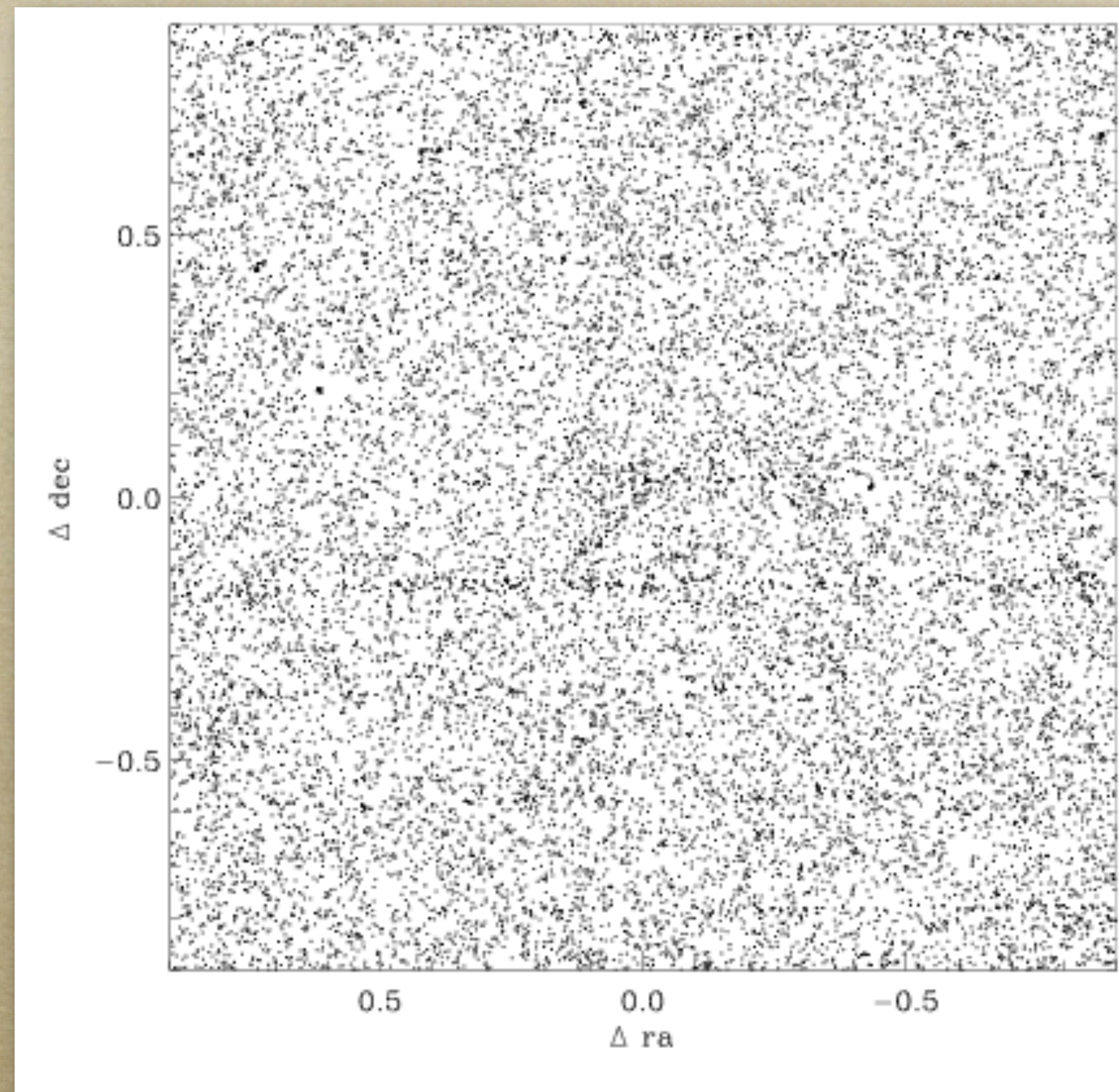
Apply CMD filter to star count maps, search for over-densities.



Full Star Counts



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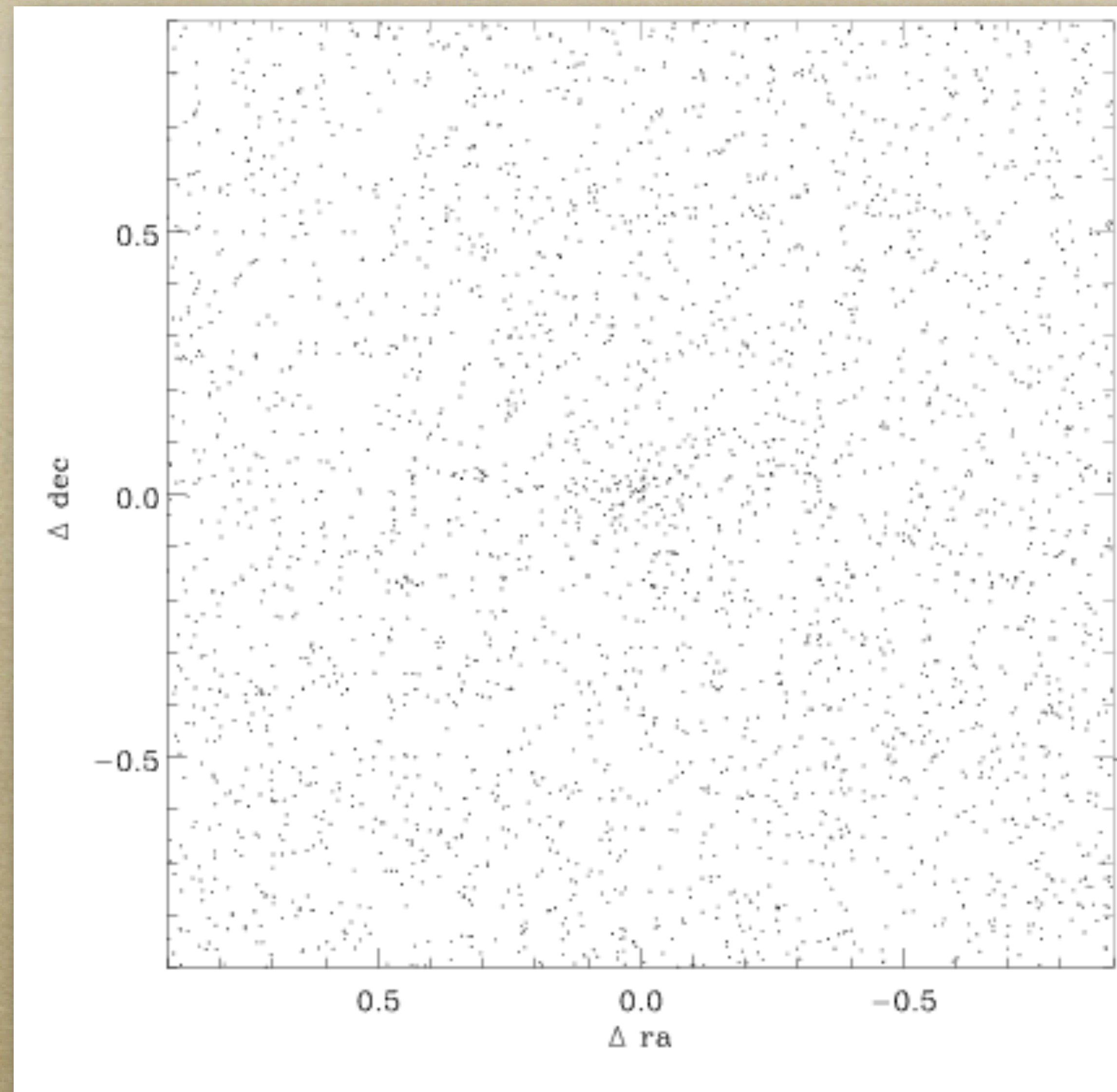
Filtered CMD Stars



Finding the Milky Way Ultra-Faint Galaxies

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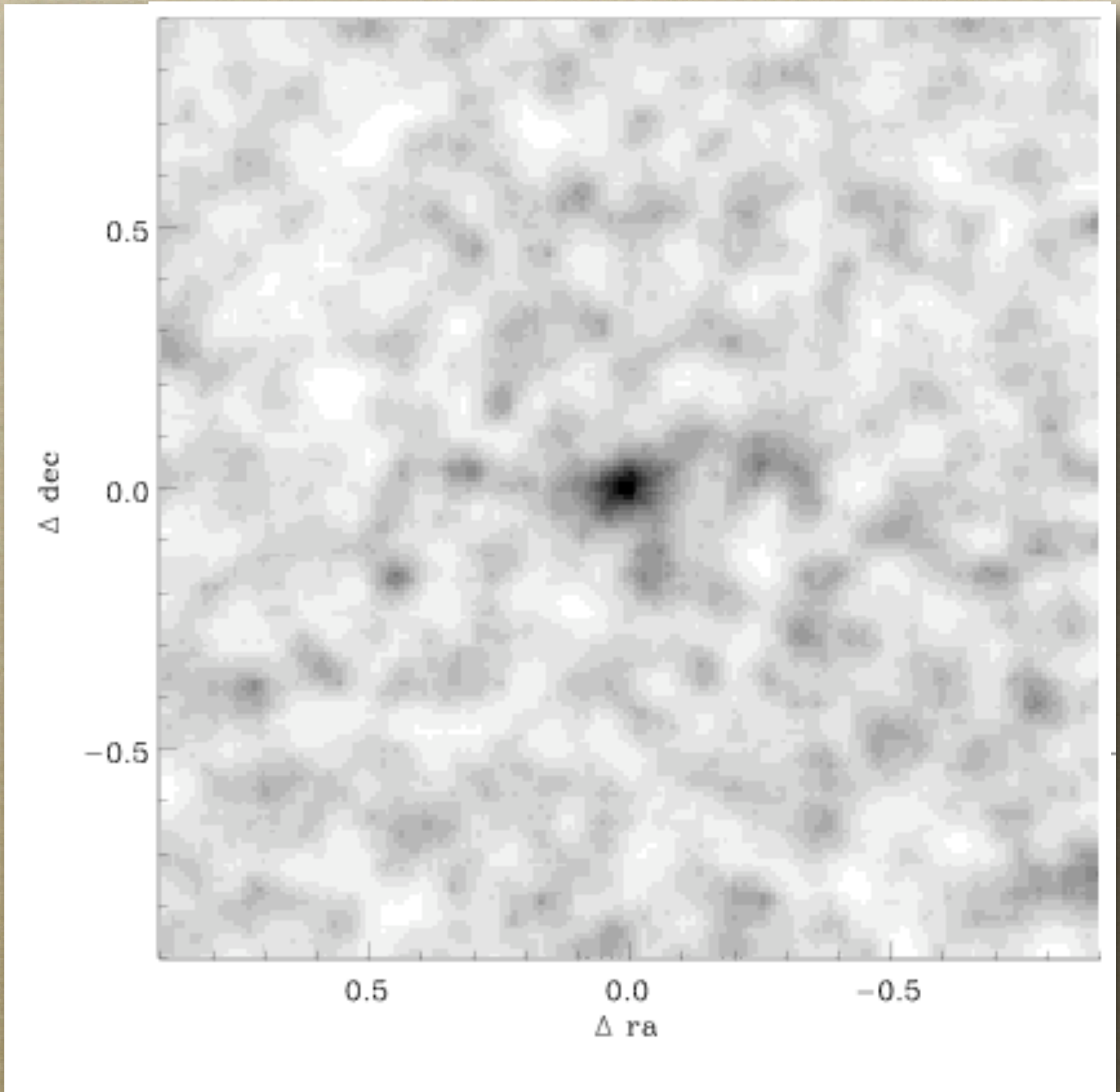
Milky Way stellar foreground overwhelms the dwarf galaxy.

Filtered+Smoothed



Finding the Milky Way Ultra-Faint Galaxies

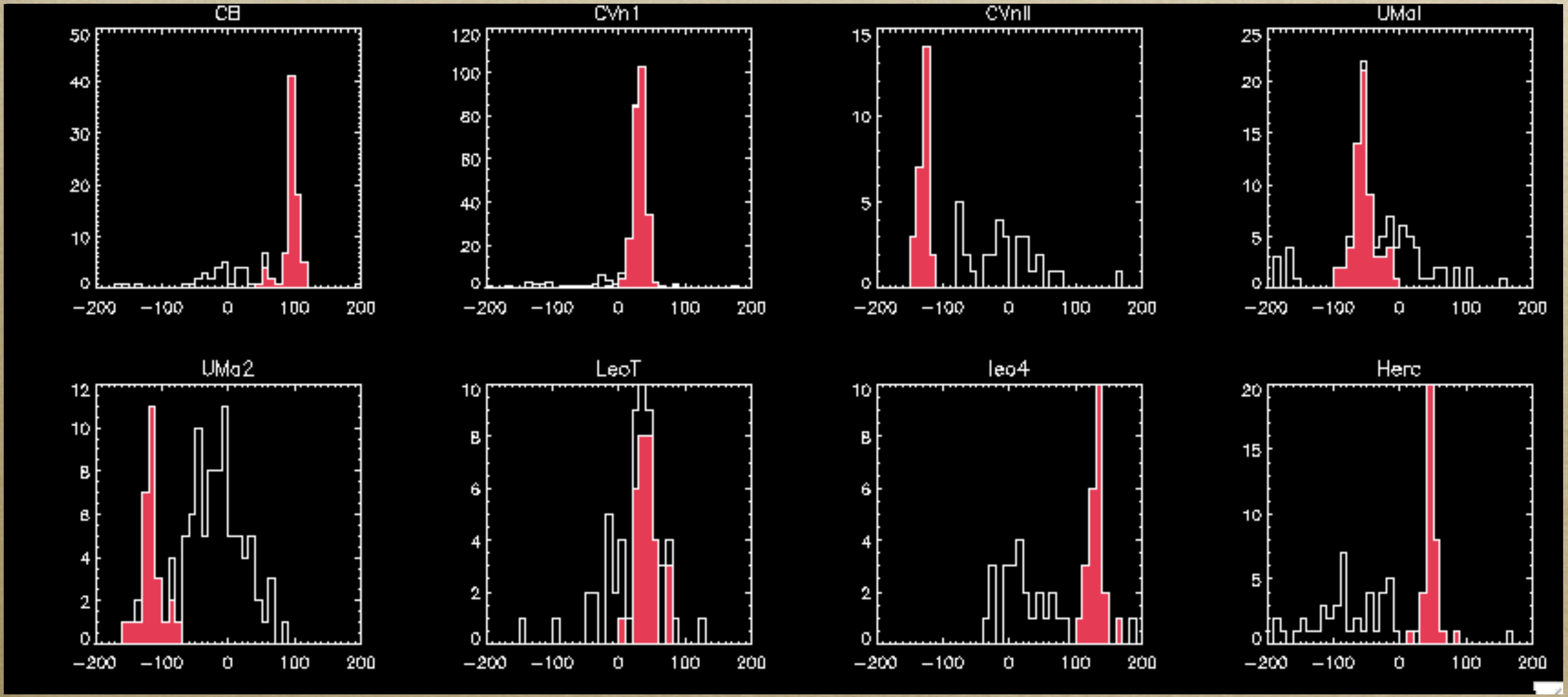
Raw Image

Member Stars only

=> need spectroscopy to answer question "are these galaxies".

The Ultra-Faint Galaxies

Keck + DEIMOS data

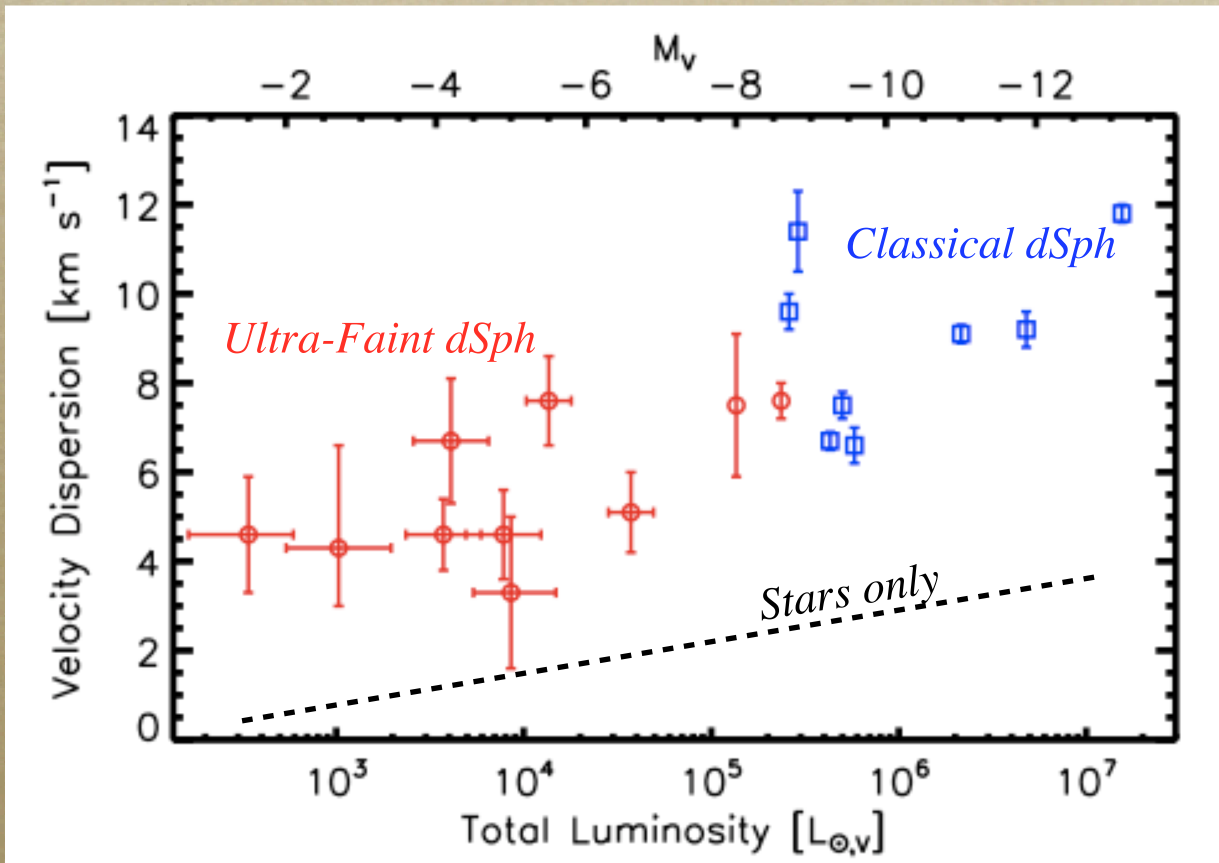


Velocity (km s^{-1})

All have clear velocity peak with width 3-8 km/s.

Simon & Geha 2007
Martin et al 2007
Munoz et al. 2006

Kinematics of the Ultra-Faint Galaxies



Plot courtesy J. Wolf (UCI)

10^5 decrease in luminosity

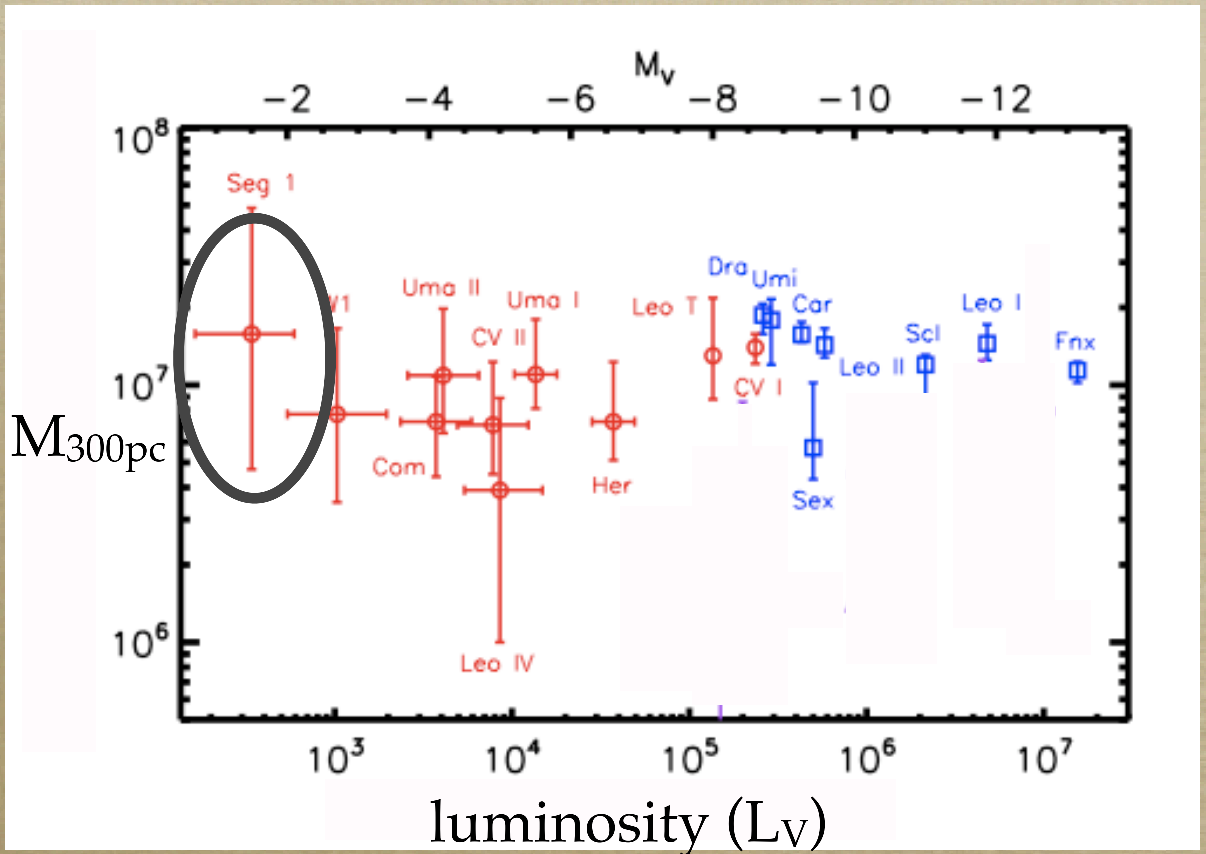
vs.

~2 decrease in velocity dispersion.

Assuming simplest model where mass follows light:

$100 < M/L_V < 1000$

Kinematics of the Ultra-Faint Galaxies



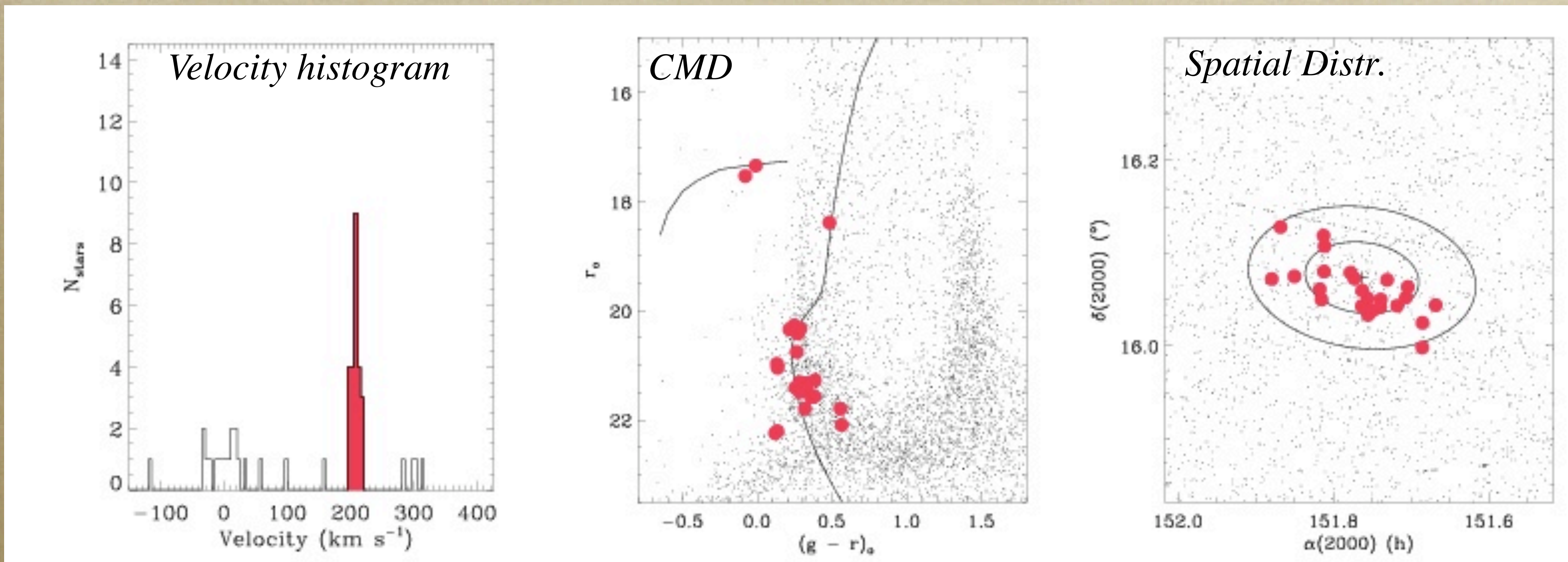
Strigari et al (2008): Assume mass follows a relaxed NFW profile.

M/L ratios increasing with decreasing luminosity.

Within a fixed radius (300pc), masses are similar across all Milky Way dSphs.

Kinematics of Segue 1

April 2009: A complete sample of stars $r < 22$ within 60pc = 2 r_{eff}



If mass from stars only = 0.4 km/s

Measured = 4.5± 1 km/s

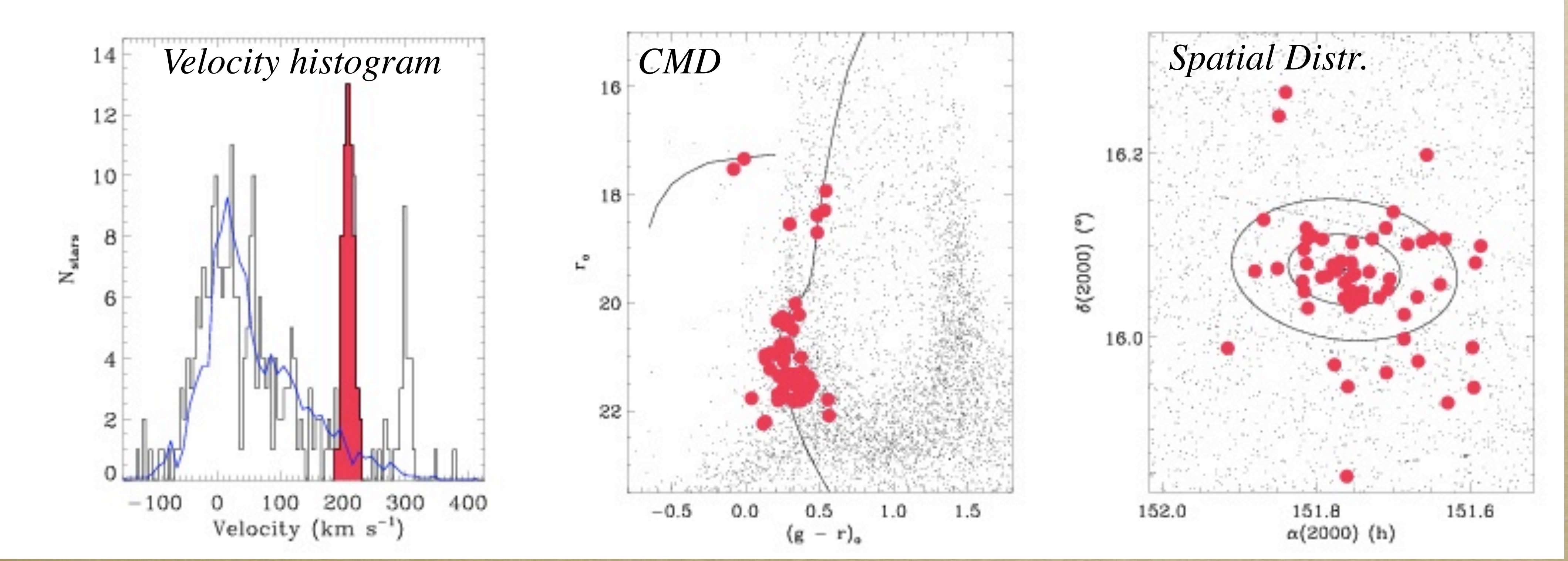
$M \sim 10^5 M_{sun}$

$M_{300pc} \sim 10^7 M_{sun}$

Geha et al (2009)

Kinematics of Segue 1

April 2009: A complete sample of stars r < 22 within 60pc = 2 r_{eff}



If mass from stars only = 0.4 km/s

Measured = 4.5± 1 km/s

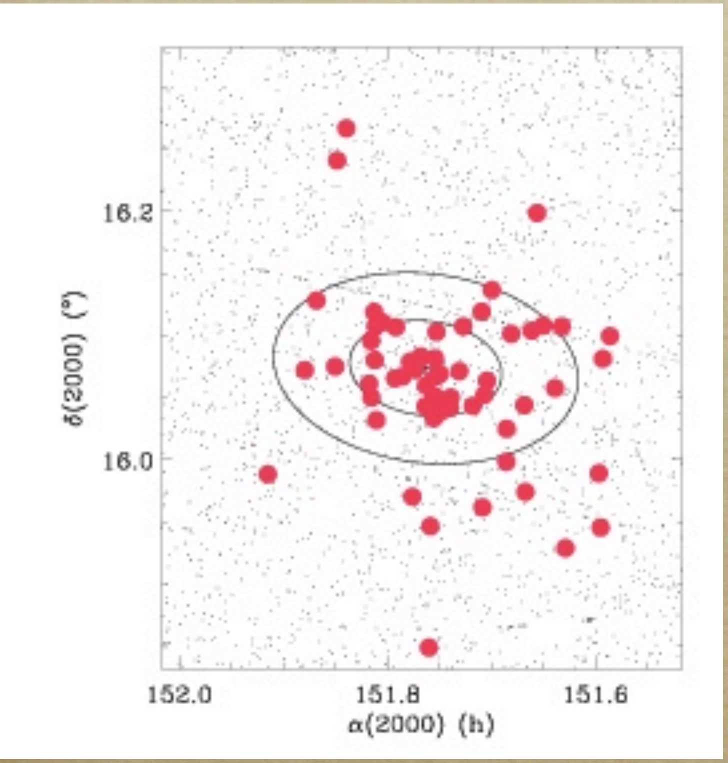
M ~ 10^5 M_{sun}

M_{300pc} ~ 10^7 M_{sun}

Simon et al (2009, in prep)

Kinematics of Segue 1

A complete sample of stars to 60pc: 65 member stars



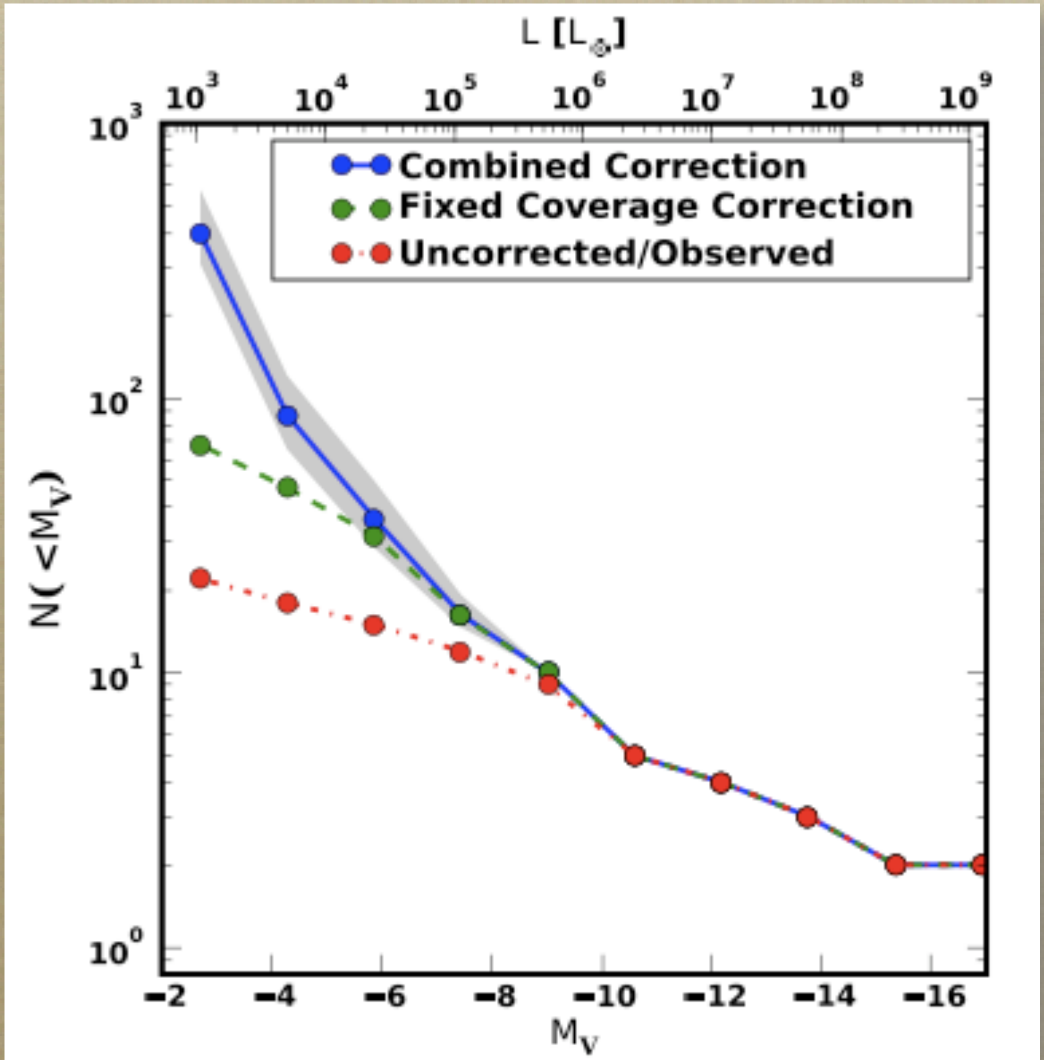
Indirect detection experiments require knowledge of the density profile:

First, prove that stars are tracing gravitational potential.

Given dataset (65 stars, radial velocities only), a prior is required to determine density profile.

Proper motions can significantly improve mass accuracy of mass profiles.

Finding New Milky Way Satellites



Tollerud et al (2008)

There are currently 25 known Milky Way satellites.

We expect between 70-500 satellites.

Use annihilation signal as discovery method?

Summary

The ultra-faint dwarfs are good targets for indirect DM experiments:

- High dark matter densities (M/L > 100)
- Old stellar populations (free of intrinsic sources).
- Nearby systems (20-50 kpc)