



FOSSILs in the Galactic Halo



Credit: Don Dixon

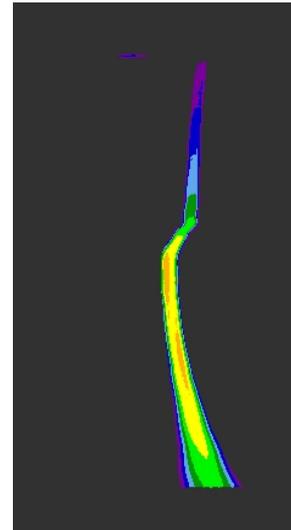
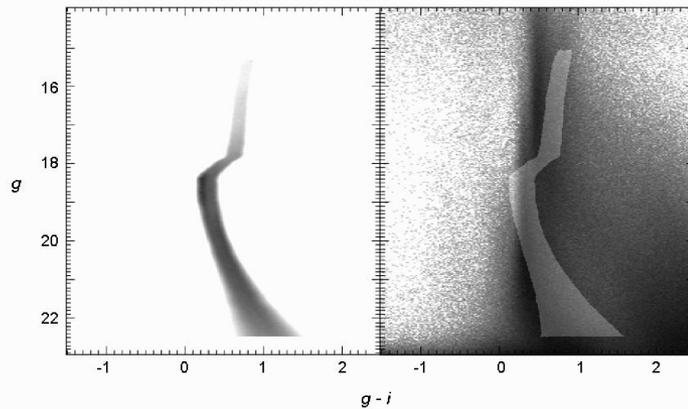
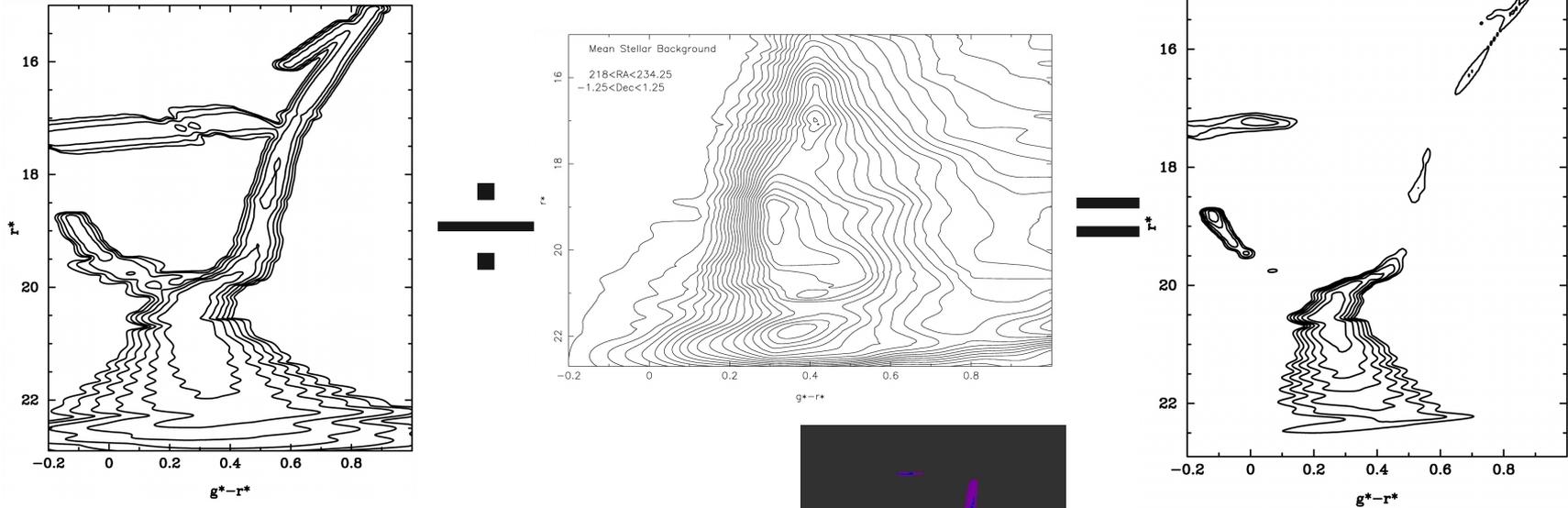
Carl Grillmair
27 June 2018

Galactic Substructures

- With $<2\%$ of the baryonic mass of the Galaxy, the halo appears to be little more than a junkyard of old relics.
- In addition to ~ 35 dwarf or ultrafaint galaxies and ~ 150 globular clusters, the last decade has seen the discovery of 50+ tidal debris streams out to ~ 50 kpc.
- $\sim 20\%$ of the halo (and ~ 20 globular clusters) are contributed by the Sagittarius Stream.
- Estimates of the fraction of halo stars in substructures have grown from $\sim 0\%$ (ELS) to 100% (Helmi et al. 2016).

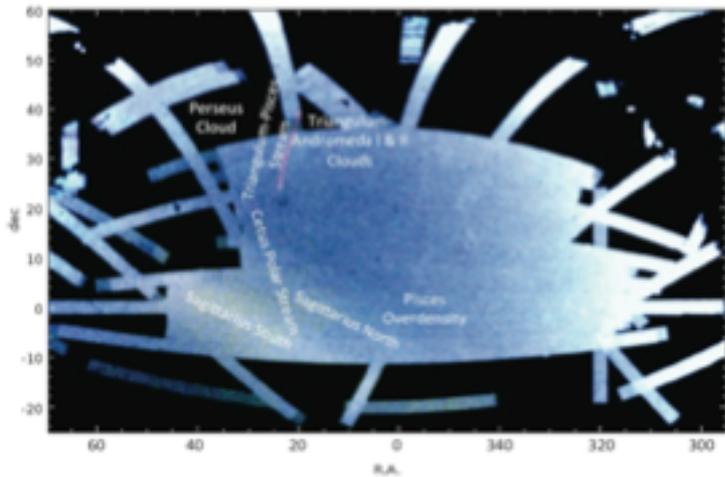
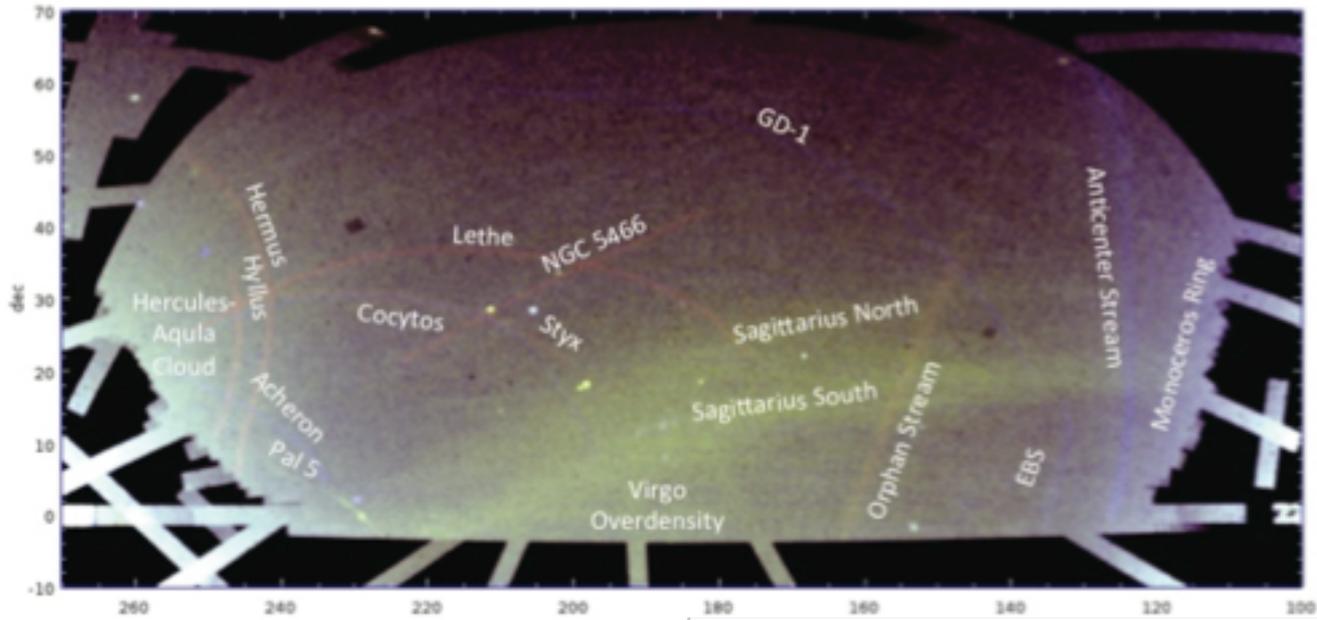
Optimal Matched Filtering of Wide Area Photometric Catalogs

- from Rockosi et al. 2003

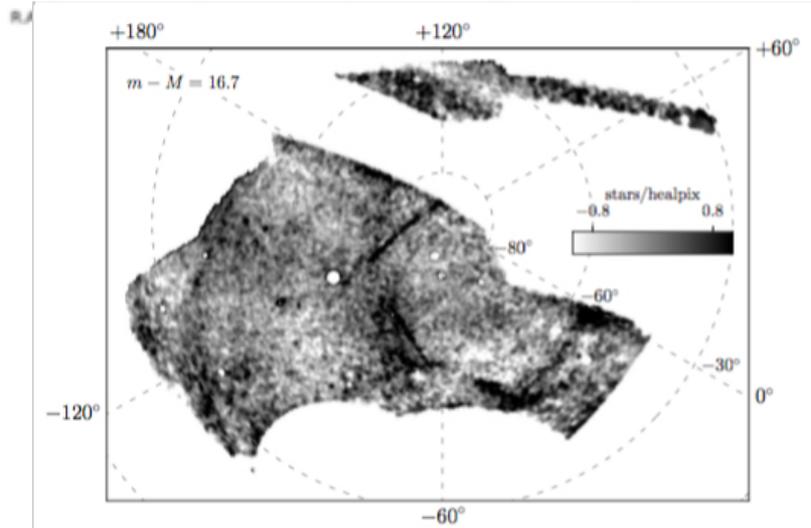


- majority of power comes from main sequence turn-off and below.

Streams Everywhere



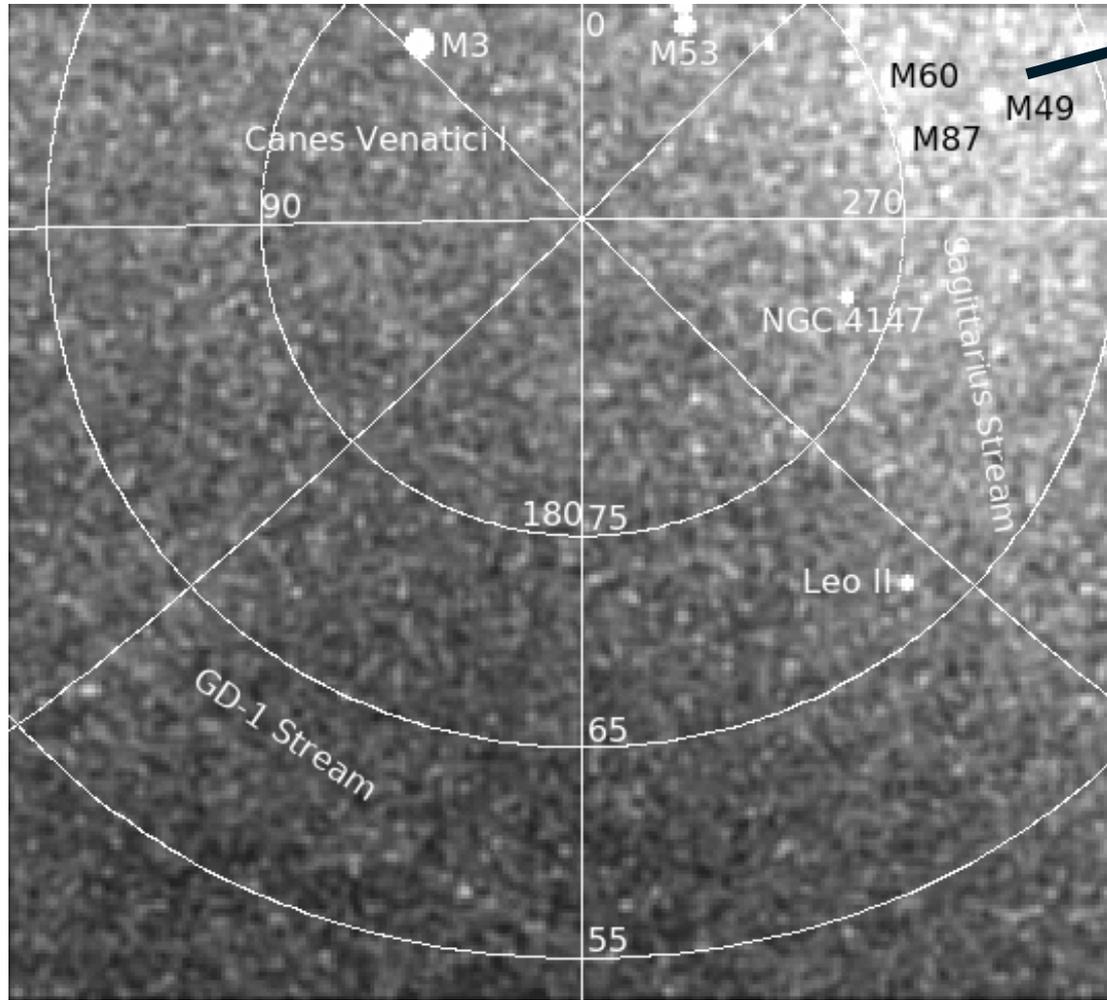
Grillmair & Carlin 2016



Shipp et al. 2018

Compact Groups

Virgo Cluster

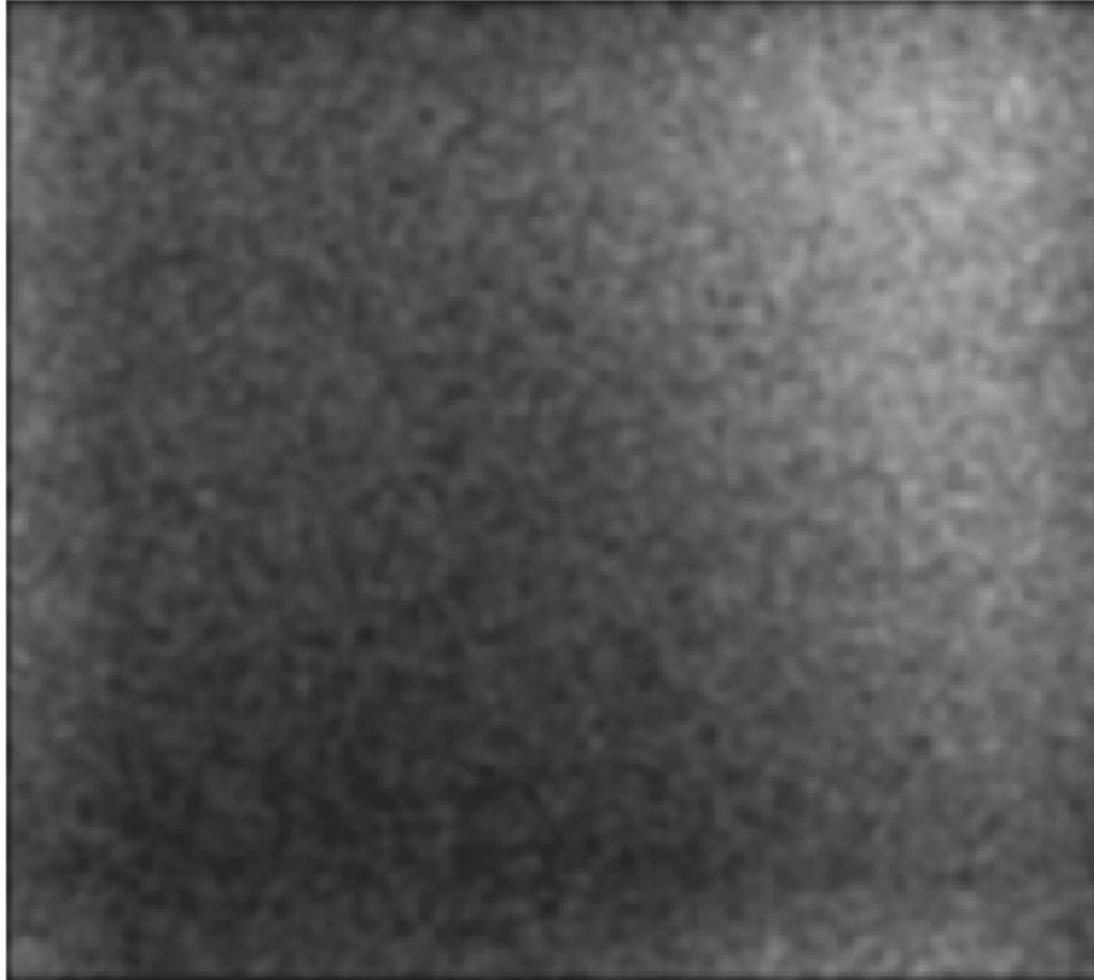


Filtered for populations with:
 $[Fe/H] = -2.2$
 $d = 10 \text{ kpc}$

All known ultrafaint dwarf galaxies are easily detected.

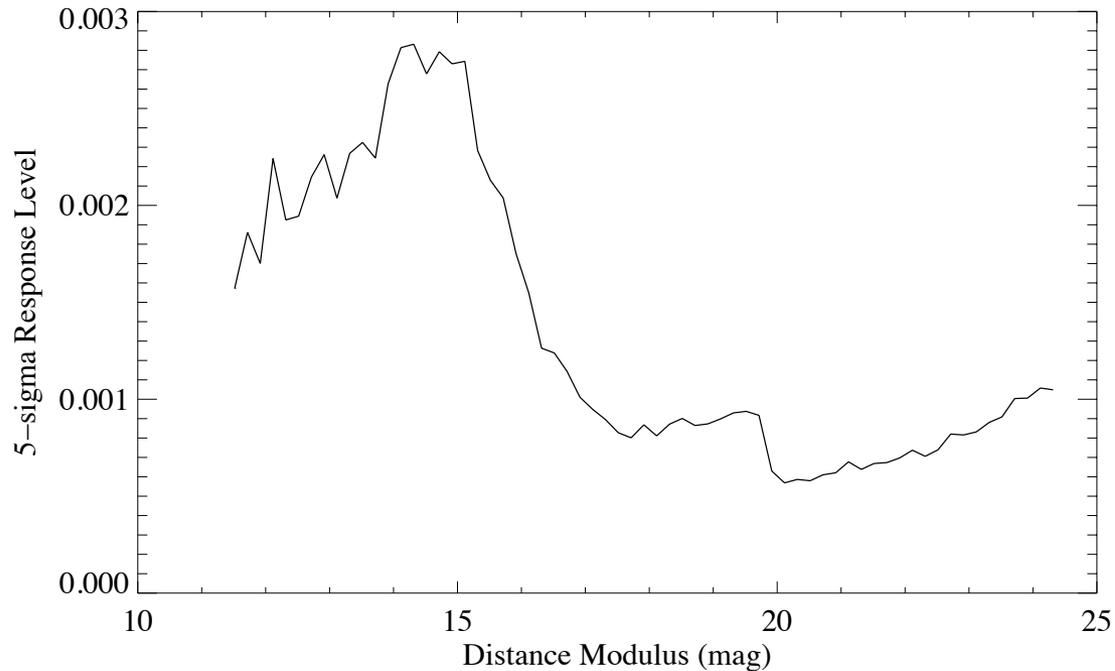
PanSTARRS I, North Galactic Pole, $g_{lim} = 21.7$
Field size: $52^\circ \times 47^\circ$, pixel size: $12' \times 12'$

Scrambled Sky



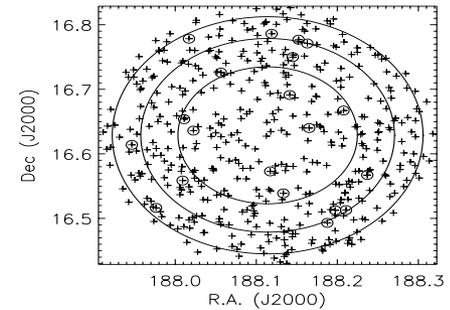
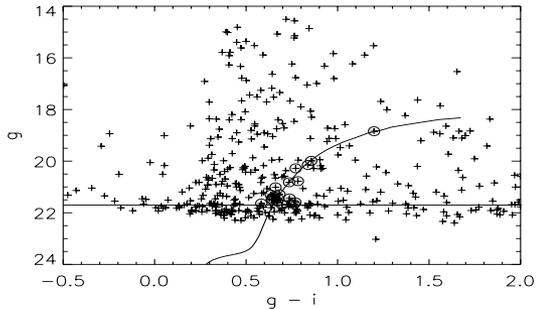
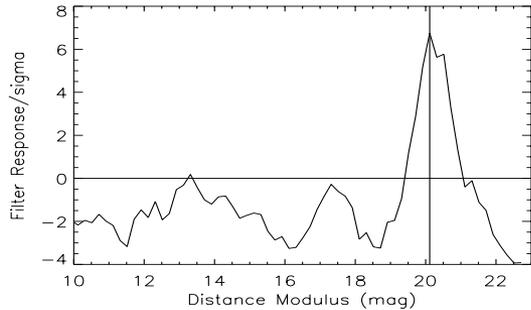
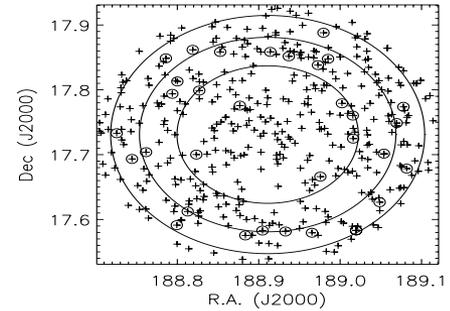
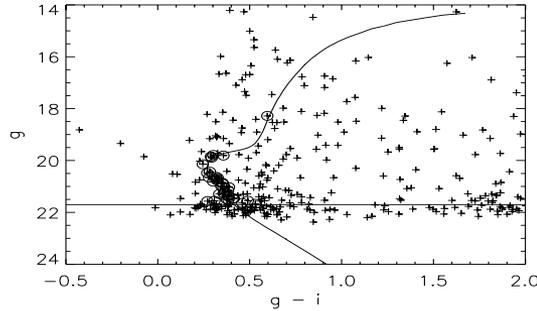
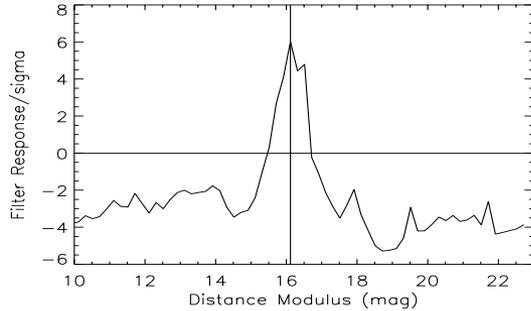
PS-1 magnitudes and colors are retained, while coordinates are uniformly scattered over $\pm 5^\circ$

Significance Tests



- Run matched filter on 100 realizations of scrambled sky.
- At a given signal level, detections at >25 kpc are ~3x less likely to be spurious.
- At a given distance, select a lower signal limit that yields $N_{\text{spurious}}/N_{\text{observed}} < 10\%$.

FOSSILs – Fragments of Stellar Systems in Limbo

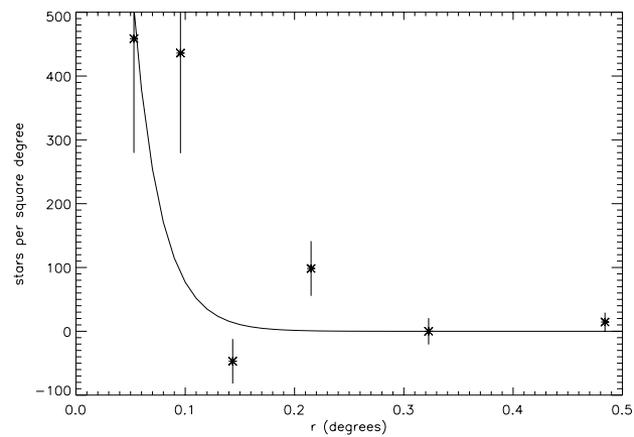
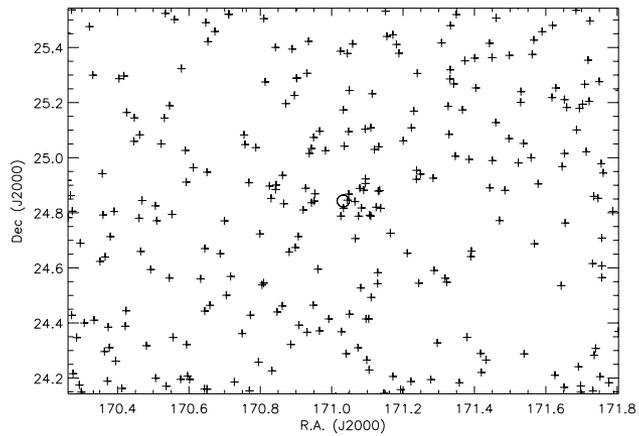
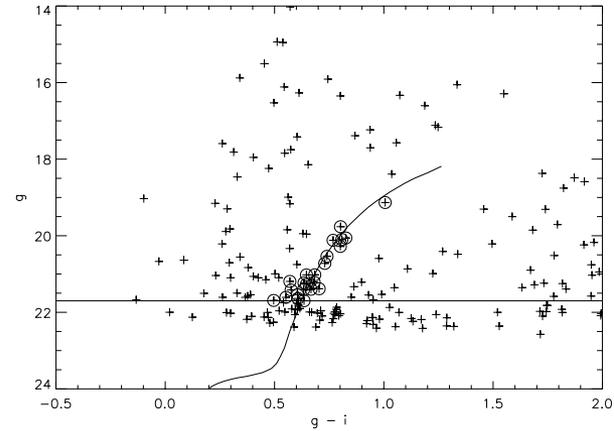
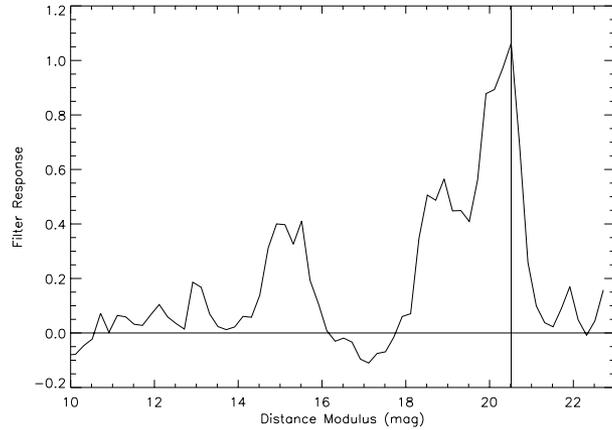


Filter Response

All Stars within 0.2°

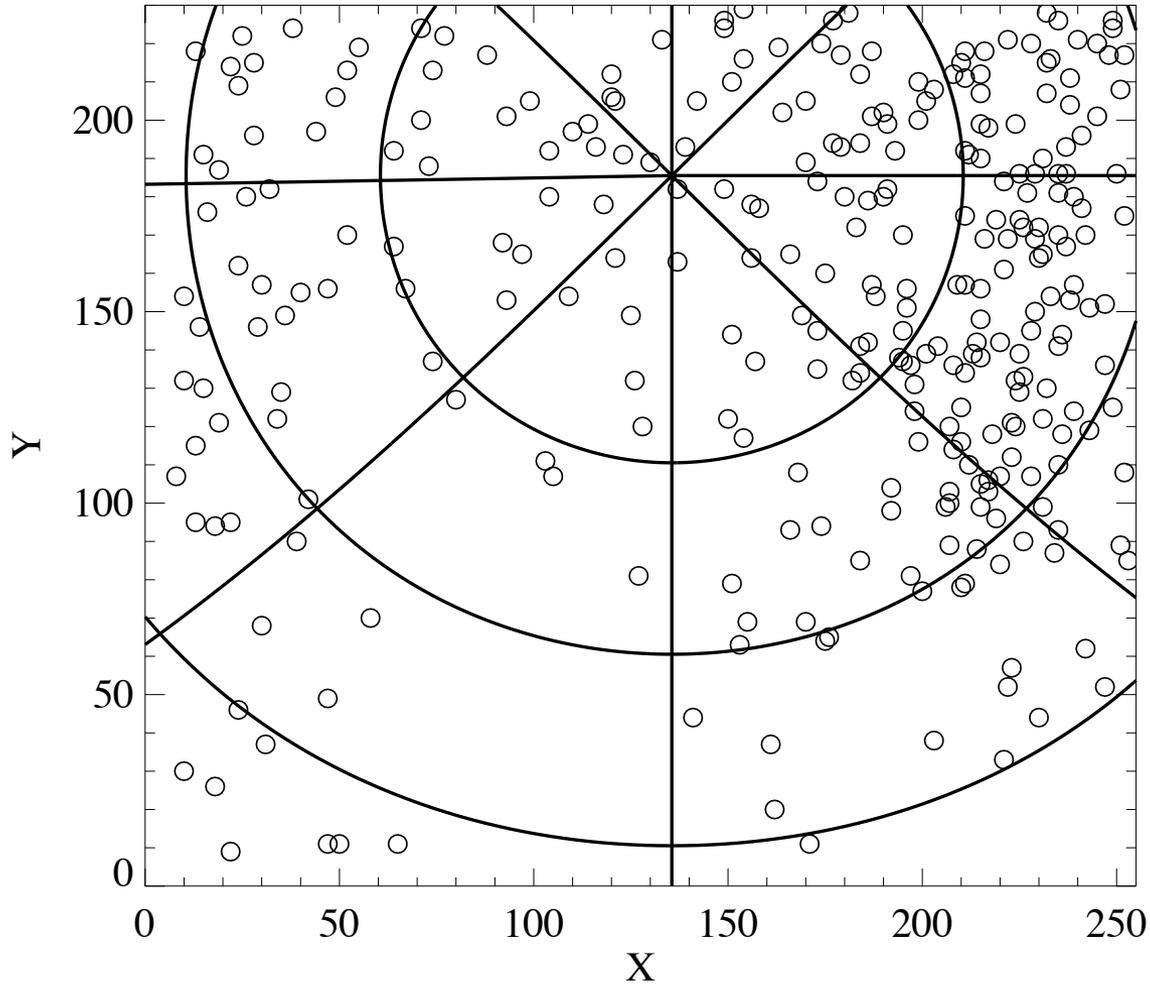
Distribution of Matching Stars on the sky

Example: A Probable New Ultrafaint Dwarf Galaxy



$d = 127 \text{ kpc}, r_{\text{eff}} = 39 \text{ pc}$

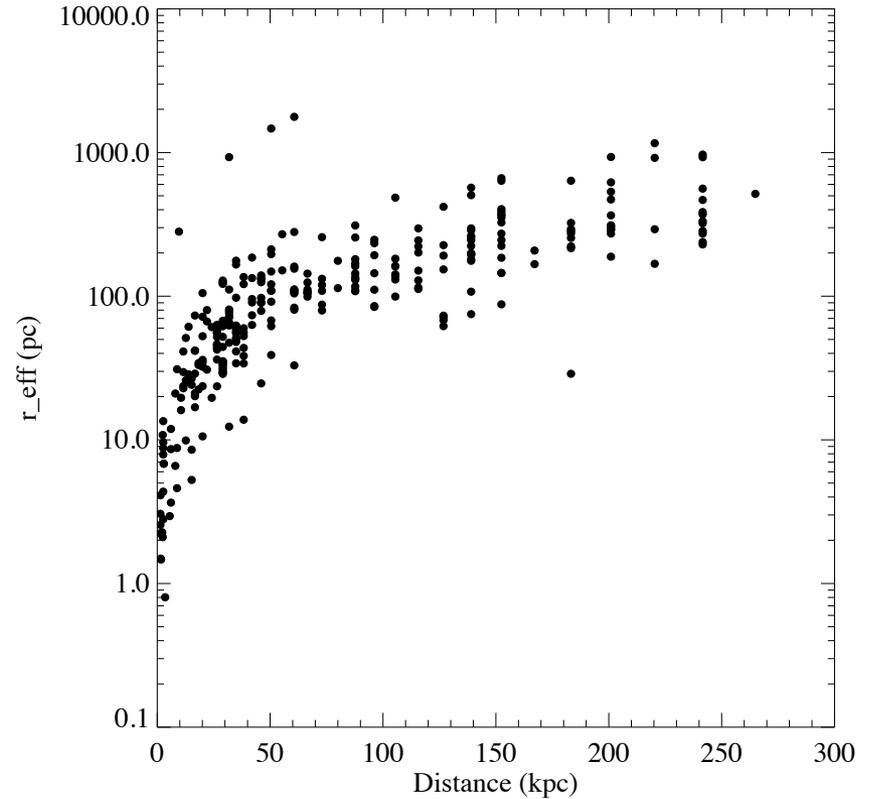
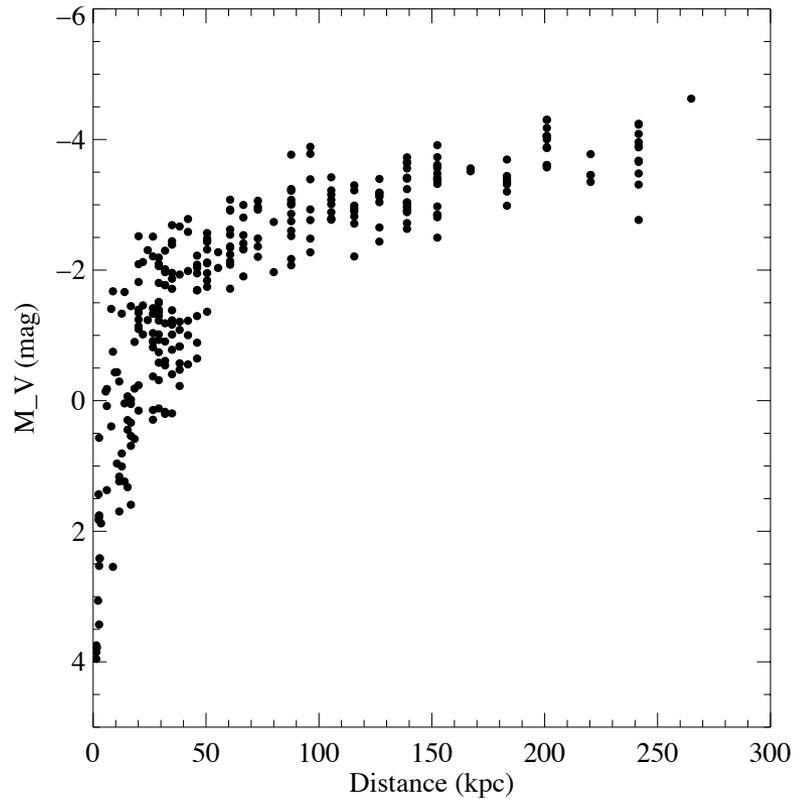
Where are They?



Find ~300 FOSSILs that exceed minimum signal threshold.

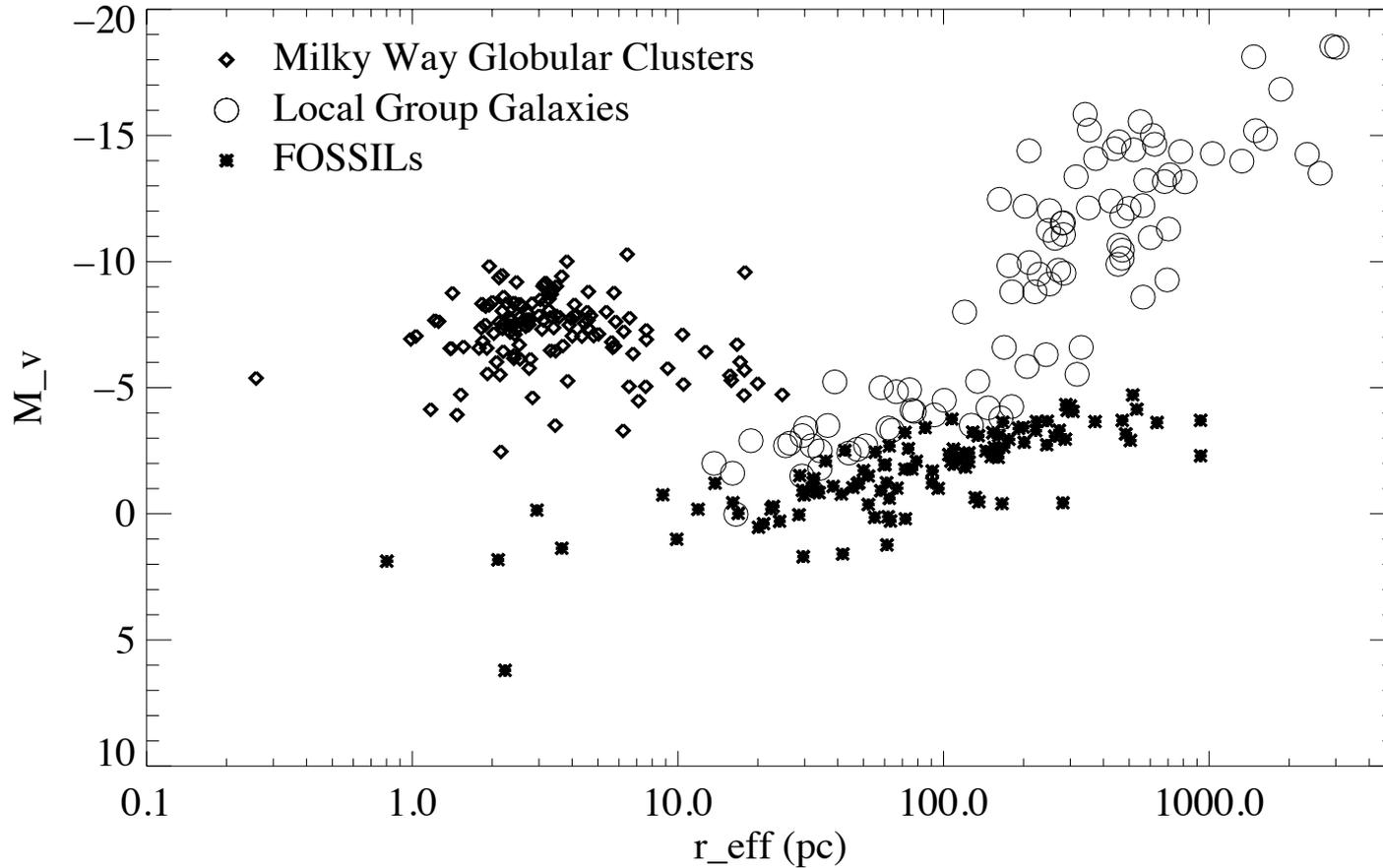
FOSSILs appear to be more concentrated both towards the Galactic center and along the Sagittarius Stream.

What are They?



Distributions are strongly modulated by completeness and areal effects.

What Are They?



FOSSILs preferentially lie along (and overlapping with) the ultrafaint dwarf galaxy sequence.

What Are They?

- Some FOSSILs are almost certainly ultrafaint dwarf galaxies.
- Their numbers imply at least another 100-200 UDGs over the whole sky.
- Could others be the last remnants of star clusters or dwarf galaxies?
 - If so, where are the tidal tails?
 - Unbound stars would disperse on a timescale of $\sim 10^7$ yrs.
- Are we detecting nearly “starless cores” made up almost entirely of dark matter?
- Deeper imaging, spectroscopy, and astrometry will be needed to confirm the nature of FOSSILs.
 - Metallicity spread?
 - Comoving?
 - What else?