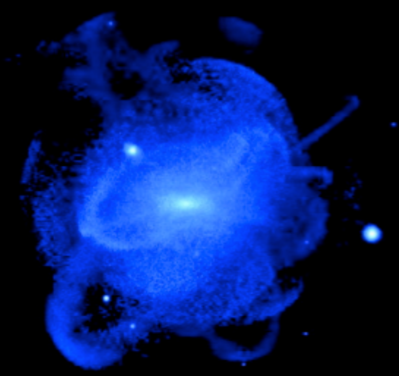
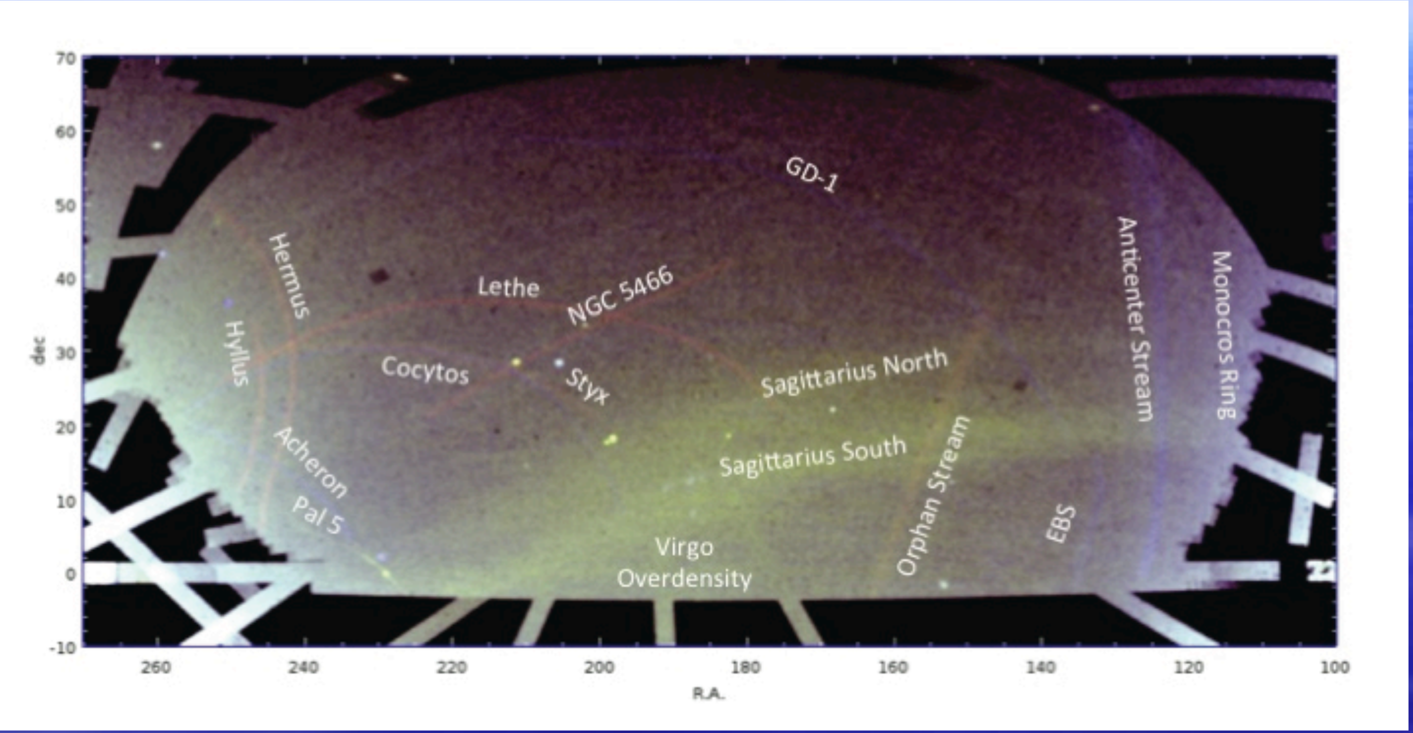


Exploring the Local Volume with WFIRST and LSST

Carl J. Grillmair

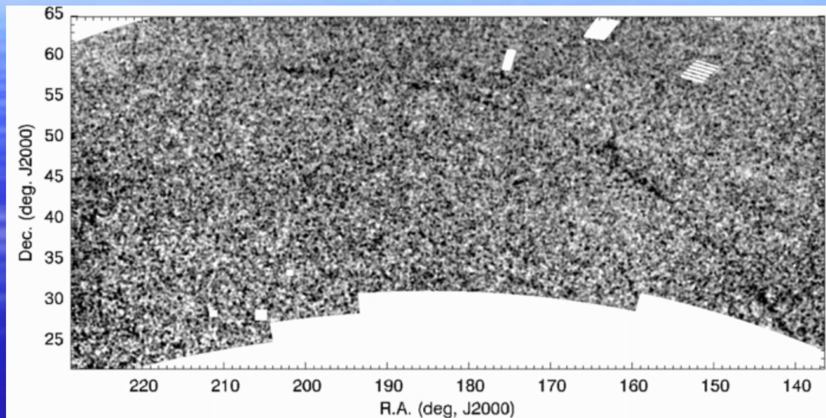
18 November, 2014

Streams everywhere…

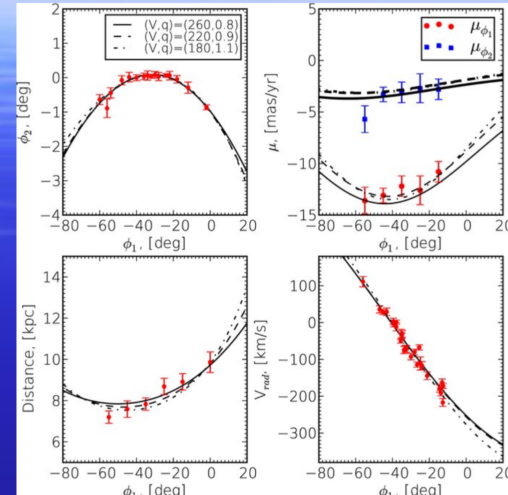


- ~20 halo streams are now known, with a similar number of "clouds", "overdensities", and ultrafaint dwarf galaxies.
- The sample is highly biased and severely incomplete.
- Virtually all stars not still in clusters or dwarf galaxies should be in streams of some form.
- Expect a power-law stream distribution function similar to IMF of stellar clusters.

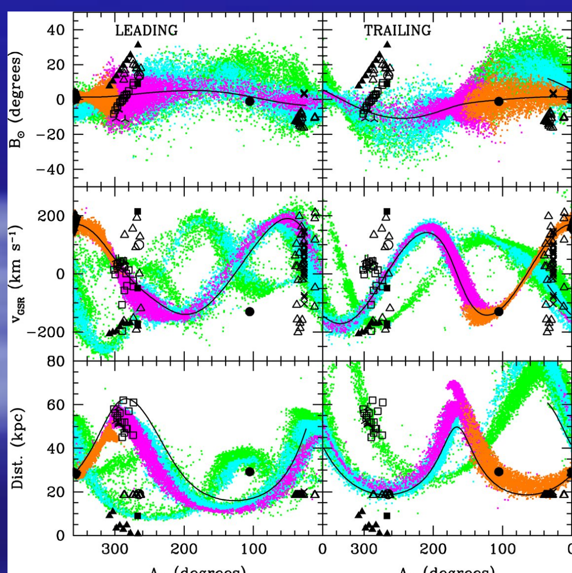
Probing the Galactic Halo with Streams



Grillmair & Dionatos 2006



Koposov, Rix, & Hogg (2009)



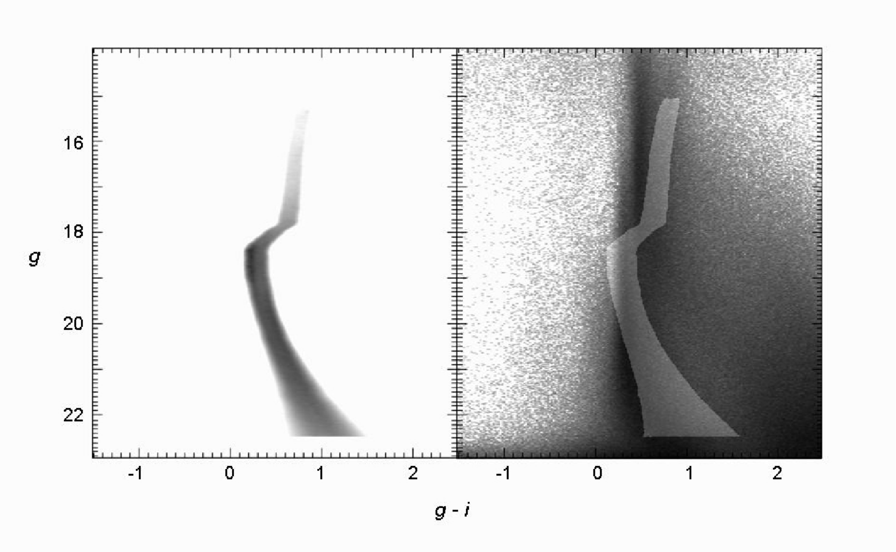
Law & Majewski 2010

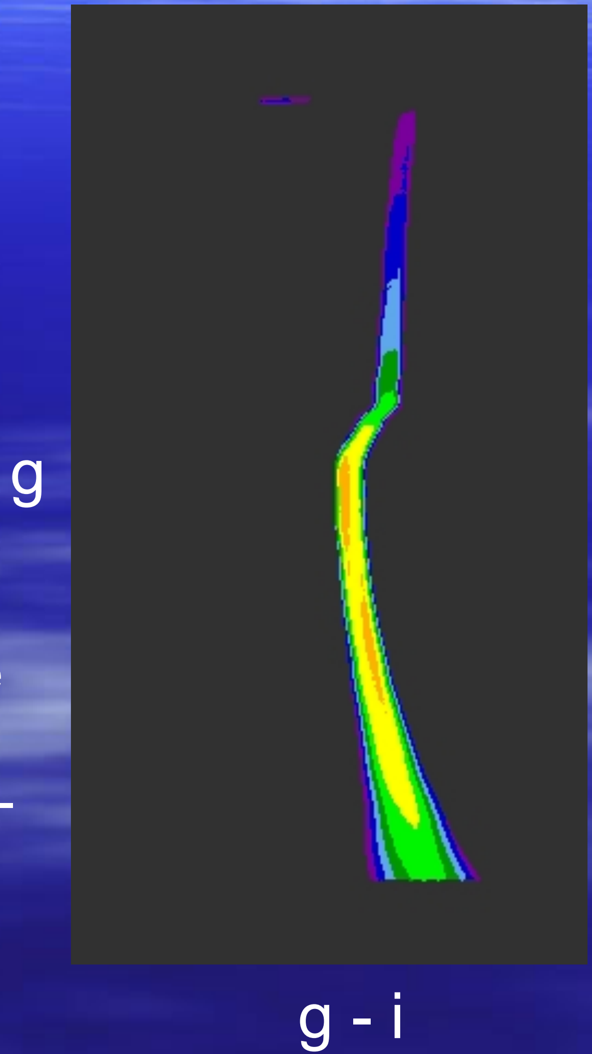
- Full 6-d phase space analysis of GD-1 has yielded the tightest constraint yet on V_c (224 +/- 13 km/s) and the interior mass of the Galaxy.
- Sagittarius Stream may be forcing us to consider an (unstable) triaxial halo mass distribution.
- Gaps in cold streams may help us constrain the number and masses of putative dark matter subhalos.

Photometric Detection of Halo Substructures

- Due to their proximity, MW halo substructures are generally too extended and tenuous to be detected in integrated light.
  – surface densities of streams detected to date are of order 10-100 stars per square degree to g ~ 22.
- Instead we must use color-selected star counts, where signal-to-noise ratio goes roughly as $N_{substructure}/\sqrt{N_{foreground+background.}}$ This requires that we:
  -- select on particular stellar populations
  – push as far down the stellar luminosity function as possible
  – keep the photometric errors small, the color selection envelope narrow
  – Reduce foreground/background contamination as much as possible
- The advantage is that, once detected, we can measure positions and velocities within or along a substructure ***much*** more accurately than in any other galaxy.

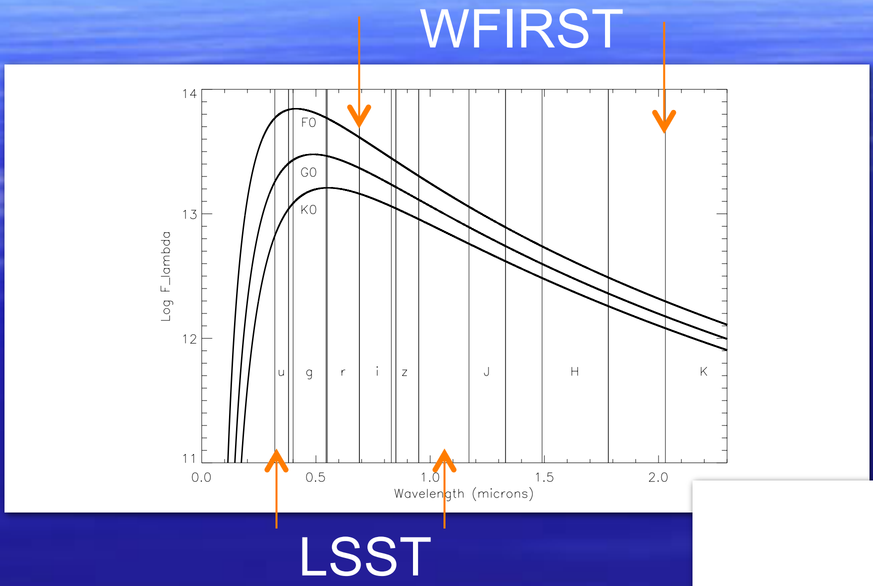
Optimal Matched Filtering





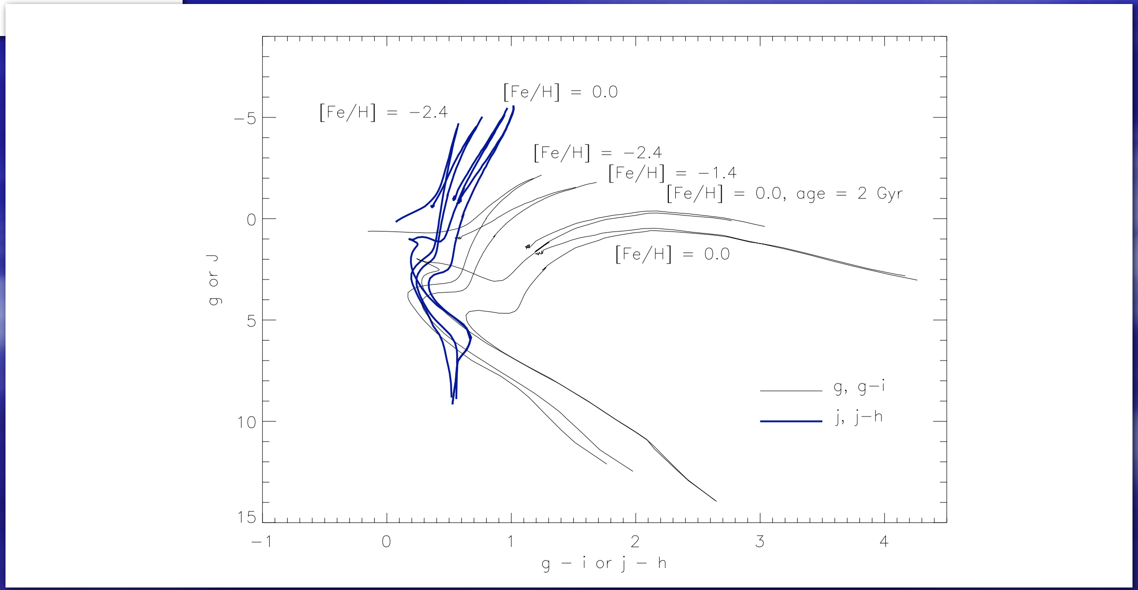
The power of the matched color-magnitude filter (Rockosi et al. 2002) for old, metal-poor populations comes primarily from turn-off stars (because they are blue) and the main sequence (because they are numerous).

Isolating Stellar Populations

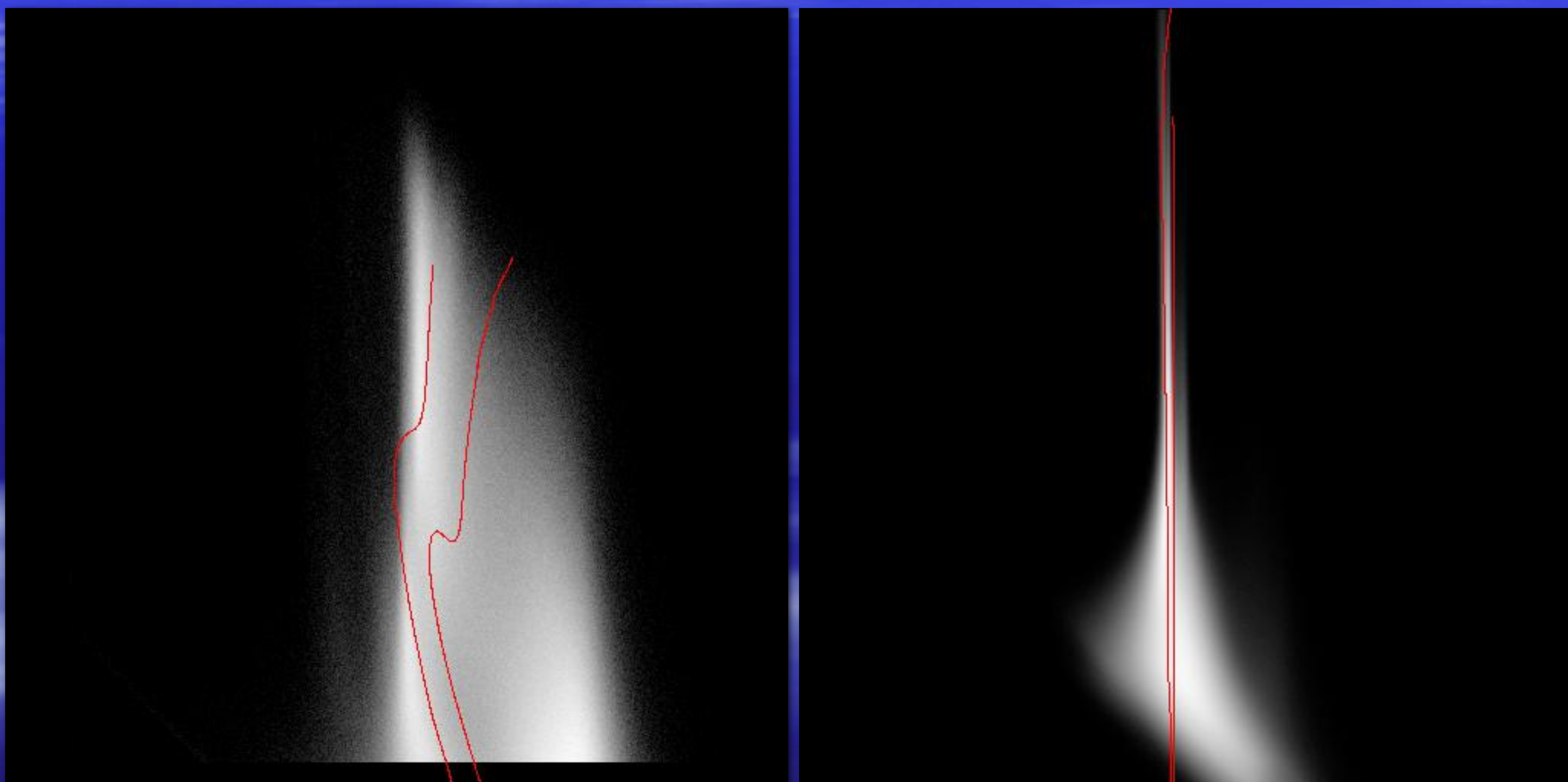


The infrared is not ideal for distinguishing between stellar populations…

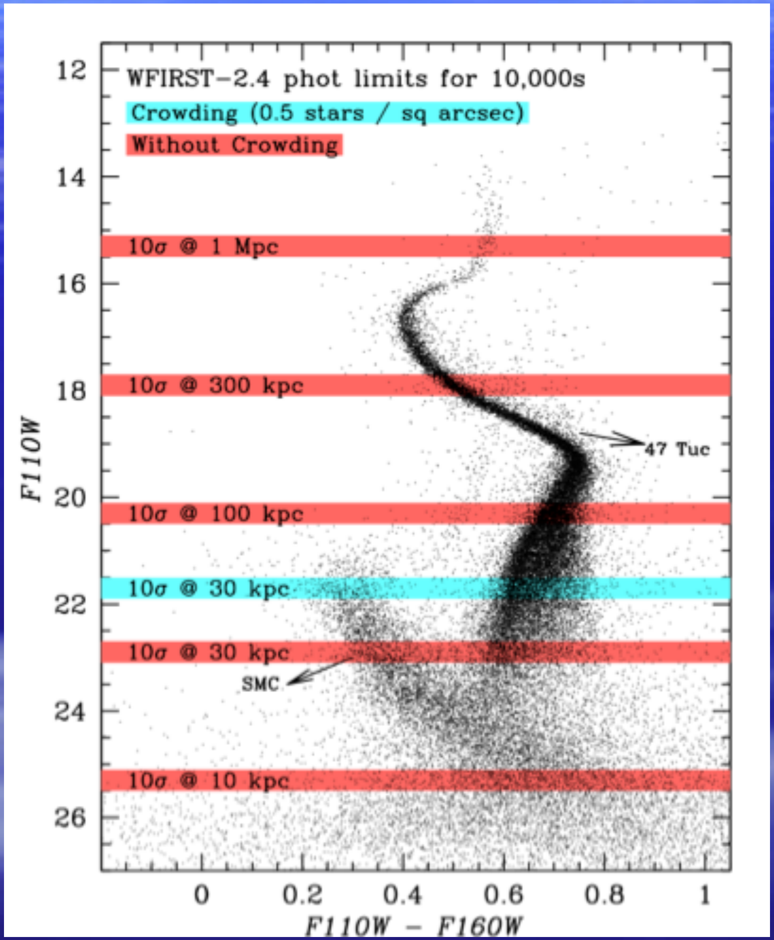
Color distributions become more and more degenerate as you go redward.



Isolating Stellar Populations

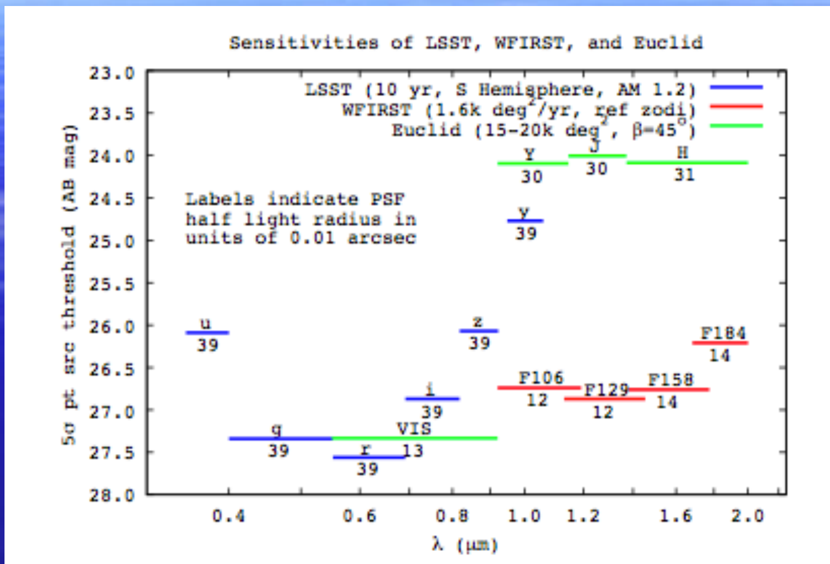


Isolating Stellar Populations

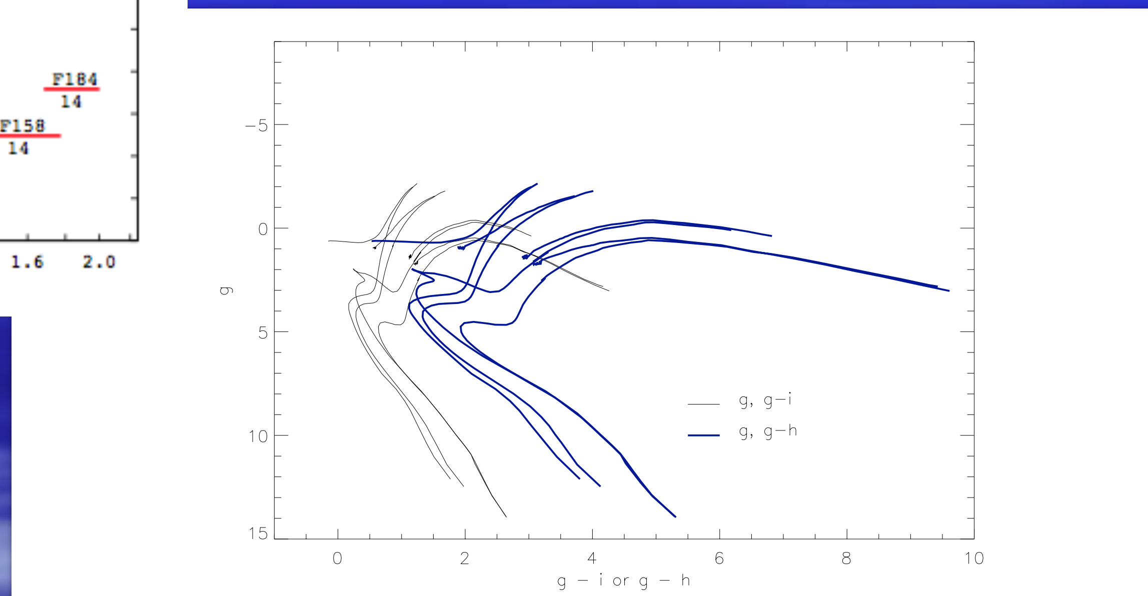


By virtue of depth and accurate photometry, WFIRST will be quite capable of substructure detection on its own.

WFIRST+LSST Photometry

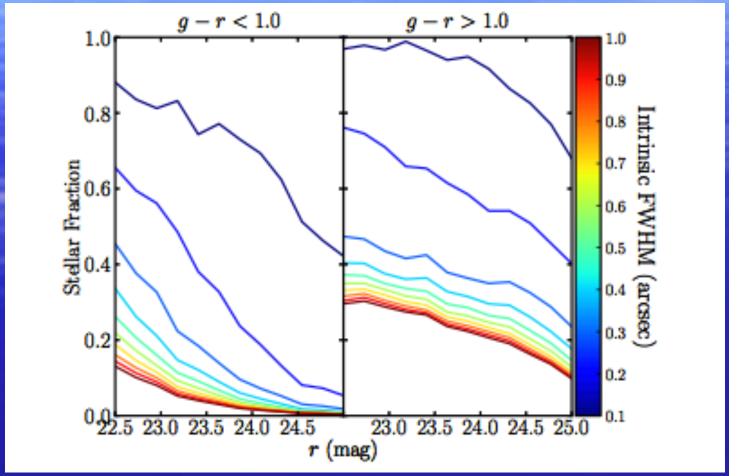


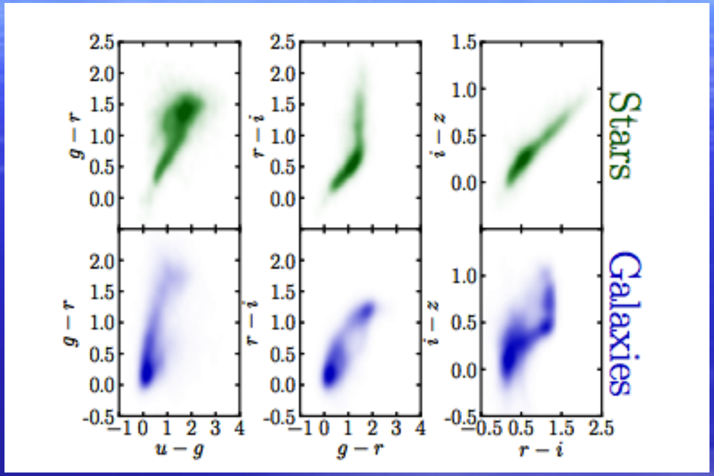
WFIRST HLS and LSST surveys are reasonably well matched.



Relative to SDSS, the combination of WFIRST and LSST photometry will super-resolve the color-magnitude distribution, greatly increasing sensitivity at large distances, and improving signal-to-noise ratios for nearby substructures.

Star-Galaxy Separation



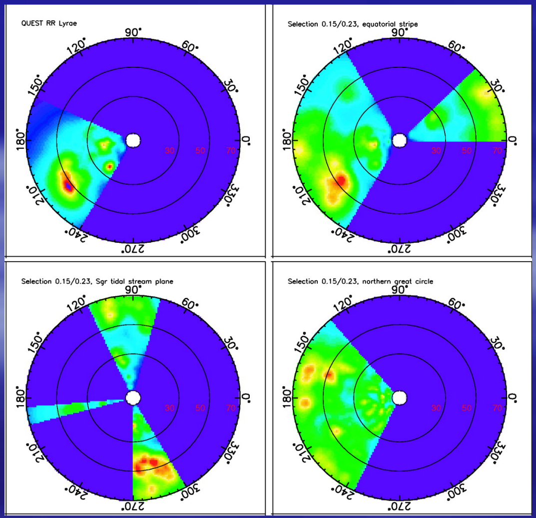


Fadely, Hogg, & Willman 2012

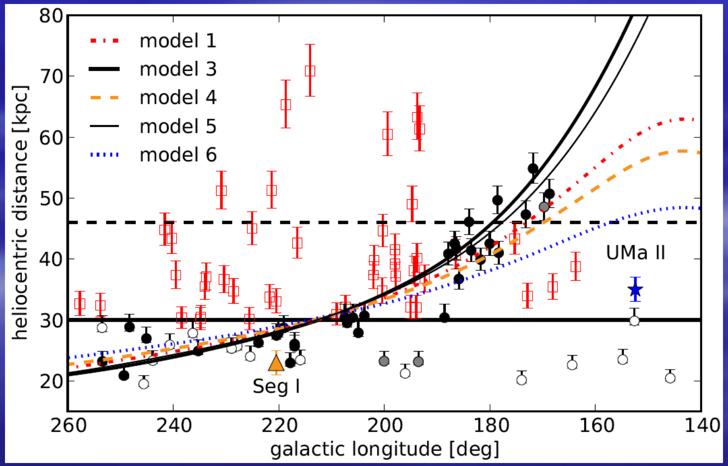
- Even if we can morphologically classify galaxies with FWHM > 0.2”, unresolved galaxies will dominate over stars at r ~ 23.5 (g – r < 1.0) or r ~ 24.5 (g – r > 1.0).
- Color overlaps of stars and galaxies are substantial, and simple color cuts will not help significantly.
- With FWHM ~ 0.11”, WFIRST can provide an enormous truth table for photometric star-galaxy separation in the LSST catalog (e.g. using data-driven Support Vector Machine or template-fitting Hierarchical Bayesian techniques).

RR Lyrae & Distances to Streams

- Accurate distances to subtructures are crucial for modeling the Galactic potential.
- Various transient surveys (LINEAR, PTF, Catalina) have now detected many thousands of RR Lyrae.
- Some of these are in known streams and are now being used to get ~2% distances with Spitzer.
- LSST will easily detect RR Lyrae to > 1 Mpc.
- WFIRST will not be very useful for detecting/identifying RR Lyrae, but may be useful for measuring accurate distances (via the IR Period-Luminosity relation).



Ivezic et al. 2005



Orphan Stream in RR Lyrae - Sesar et al. 2013

WFIRST-LSST Synergies for Local Volume Exploration

WFIRST HLS		LSST
2000 square degrees		>18,000 square degrees
FWHM ~ 0.11”	→	FWHM ~ 0.7”
0.9 – 2.0 μm	←	ugrizy
~10 km/s (?) RVs to AB ~ 20.5	→	none
0.1 mas/yr PMs to V ~ 20	→	0.3 mas/yr PMs to r ~ 20
RR Lyrae distances to 2%	←	RR Lyrae detection to > 1Mpc