Galactic Structure with LSST

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What's the goal?

- My goal is to understand how one builds a galaxy out of its constituent parts, and understand how specific observed properties are created by a galaxy's particular history.
- The Milky Way is a tremendously detailed single case-study — the challenge is learning what can be generalized vs what is particular or peculiar.

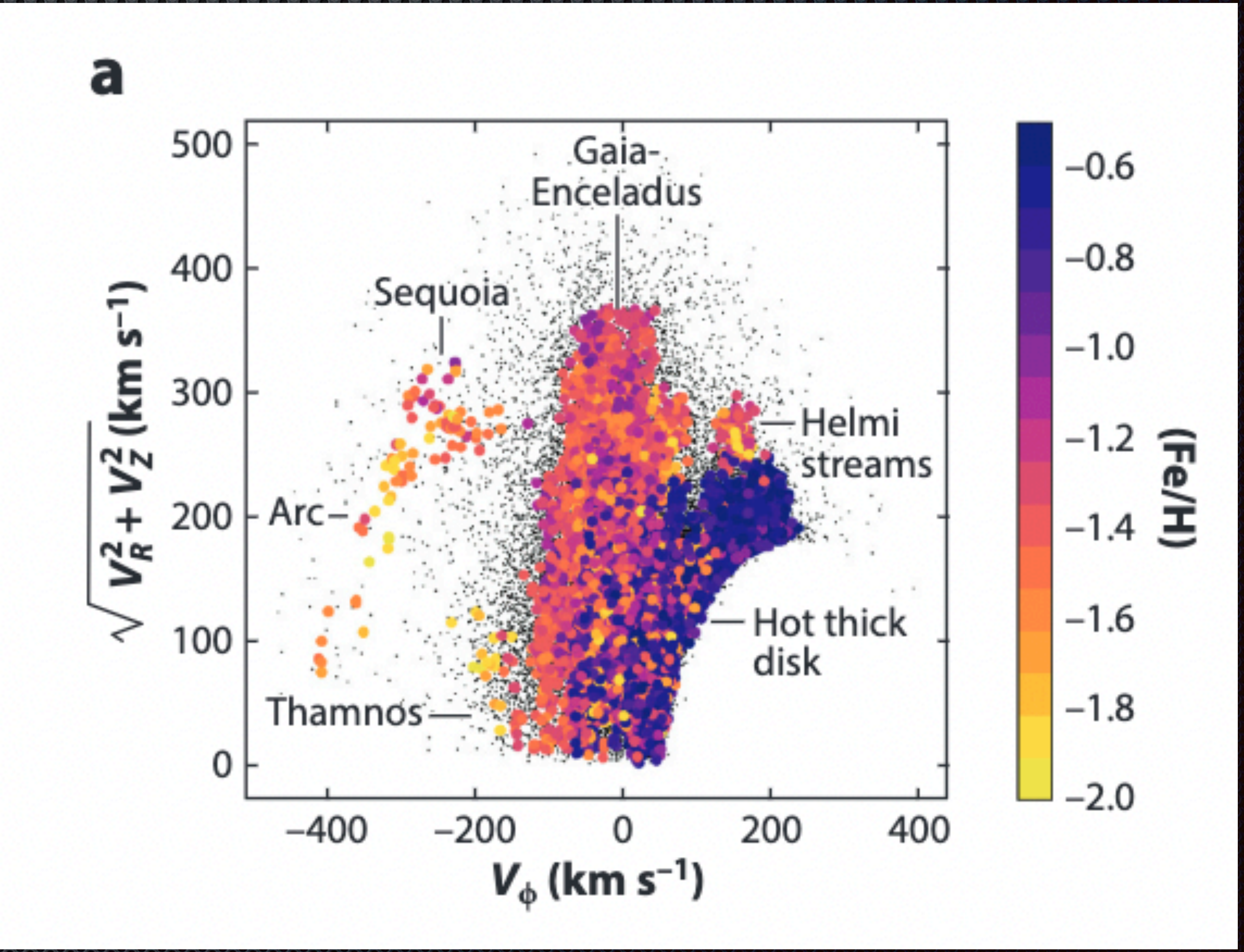
- Hierarchical accretion motivates us to think about the MW in a very “bottom-up” way — as a product of its ingredients
- Lots of MW science is an attempt to extract those constituent inputs from the Galaxy we see today, even after they’ve been amalgamated.

Where can we go looking for “history”?

- Disk — Mostly very young, not very “historical”
  - But! There are older disk stars mixed in (e.g. the “thick disk”). Also a useful dynamical tracer
- Bulge — “Old” but also very well-mixed
  - But! Gaia is very powerful in the inner galaxy, more structure than one might guess.
- Stellar Halo — Least well-mixed, oldest dynamically. But may reflect recent history.
- Dwarf galaxies (a.k.a satellites) — Surviving analogs of early-universe galaxies?

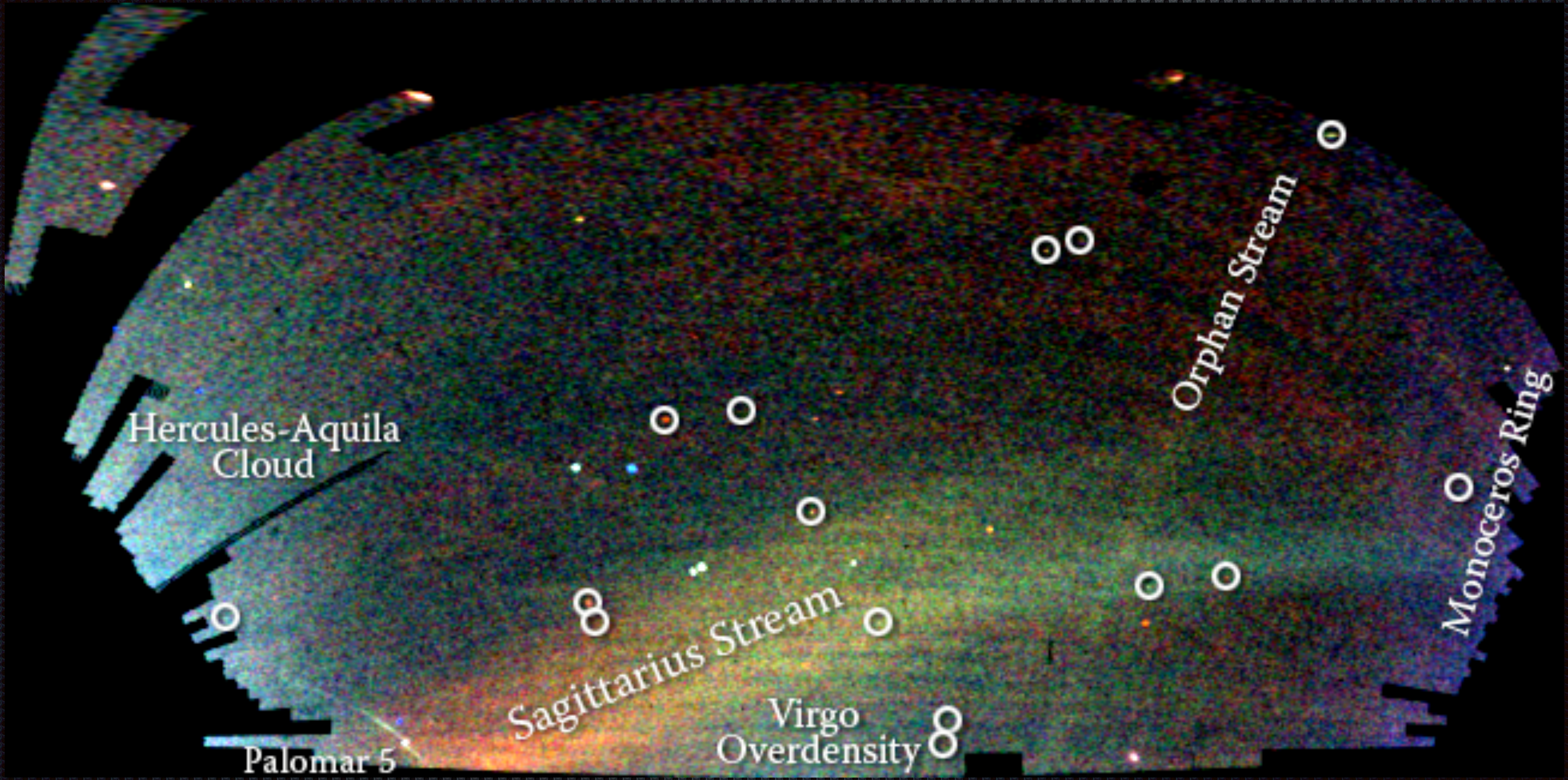
Nearby Substructure

- Disk+Bulge contain structures in velocity spaces — seen clearly with Gaia + APOGEE et al for RVs, within 3kpc
- Gaia-Enceladus merger estimated ~10 Gyr-ago
- More difficult to extract features with photometry, but they're still there!



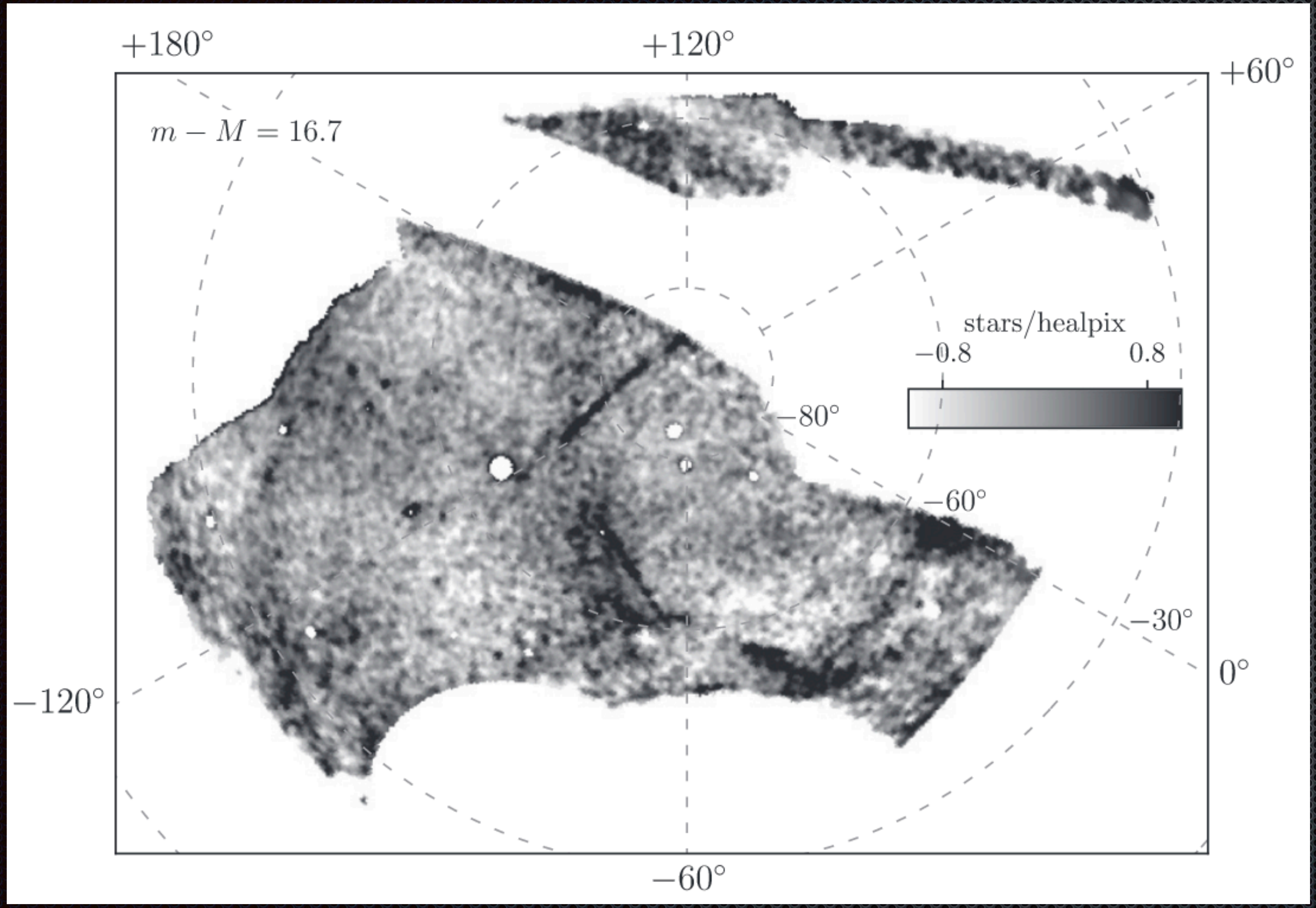
Helmi 2020 ARA&A

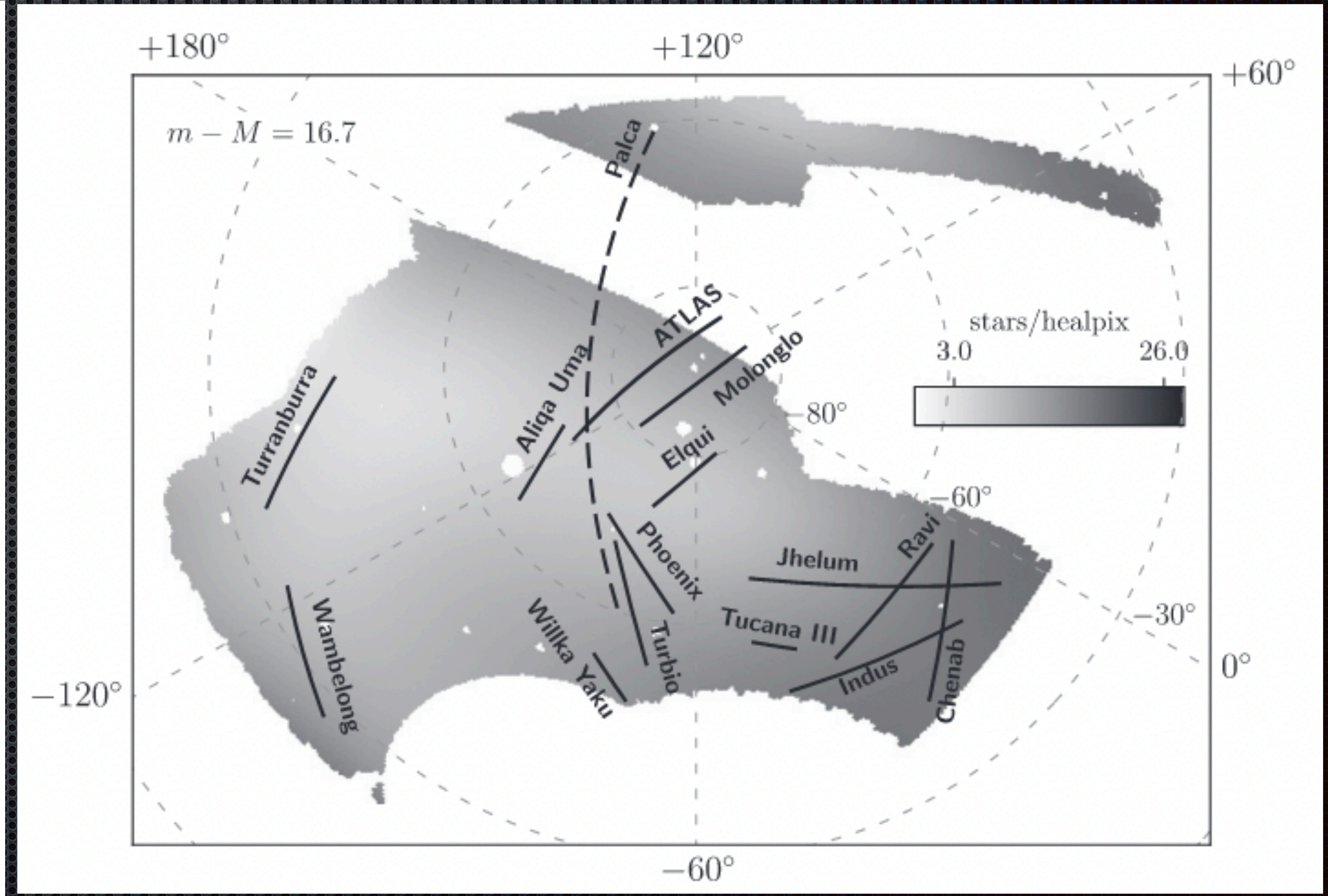
Field of streams - SDSS



Belokurov et al. 2006

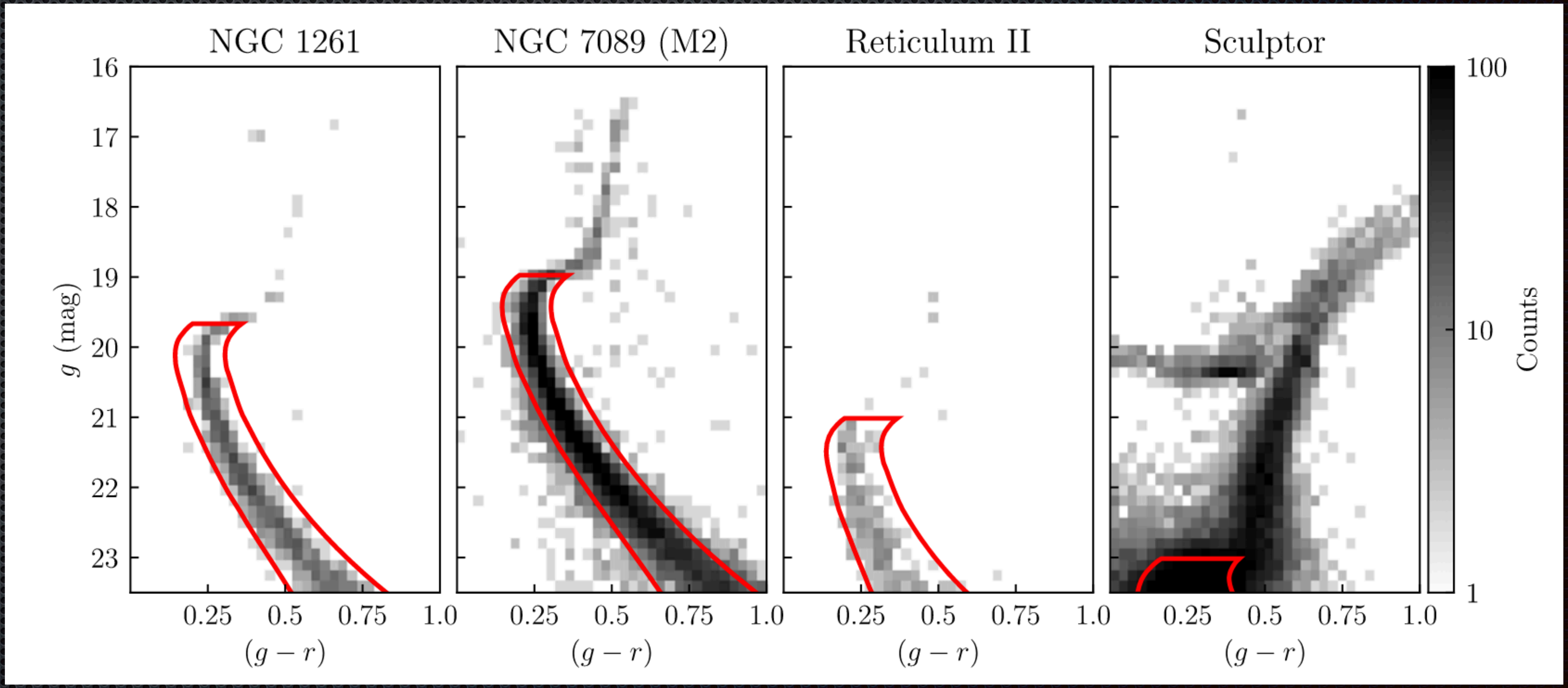
More recent field of streams - DES





Shipp et al. 2018

- Streams are usually narrow-ish in distance, ideally want to make maps in distance slices.
- A “matched filter” uses an isochrone to identify stars that could be at a candidate distance.



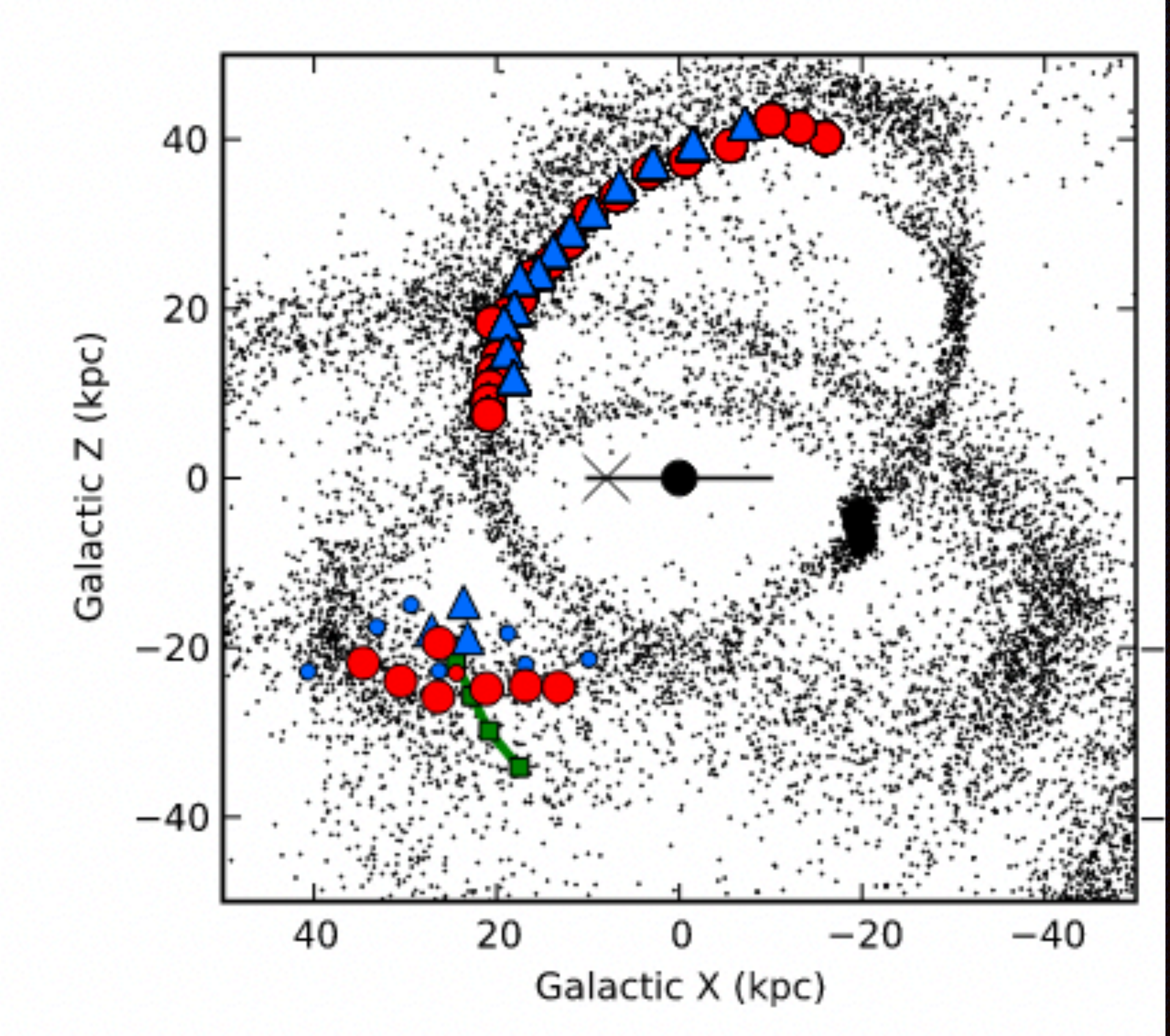
Shipp et al. 2018

What is this telling us?

- Streams make nice dynamical tracers, so we can infer properties about the accretion event by comparing to N-body models

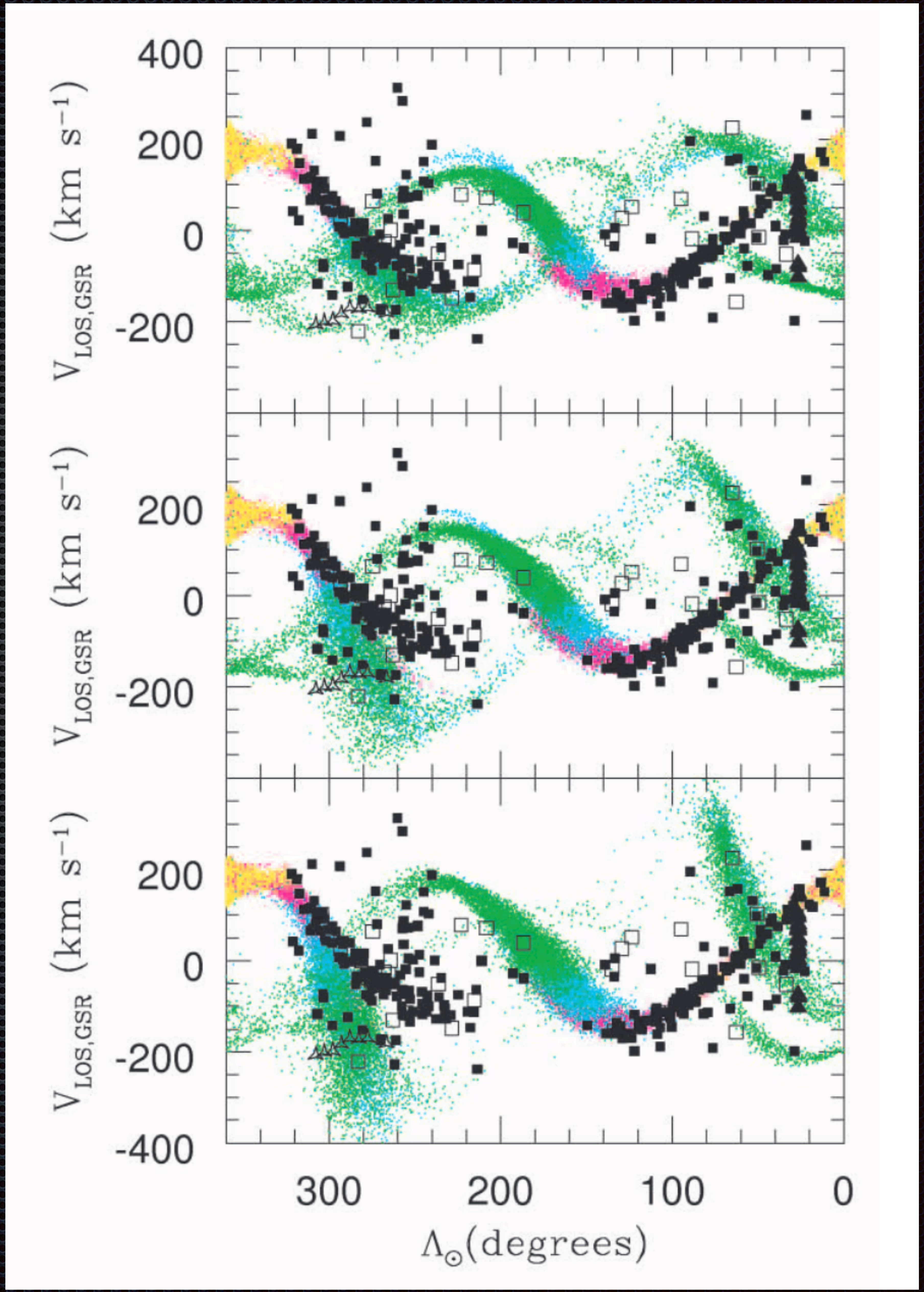
- This sounds really straightforward, but in practice the results have been extremely confusing.

- Broader “message” that streams and accretion are ubiquitous and significant; but hard to quantify



Slater et al. 2013

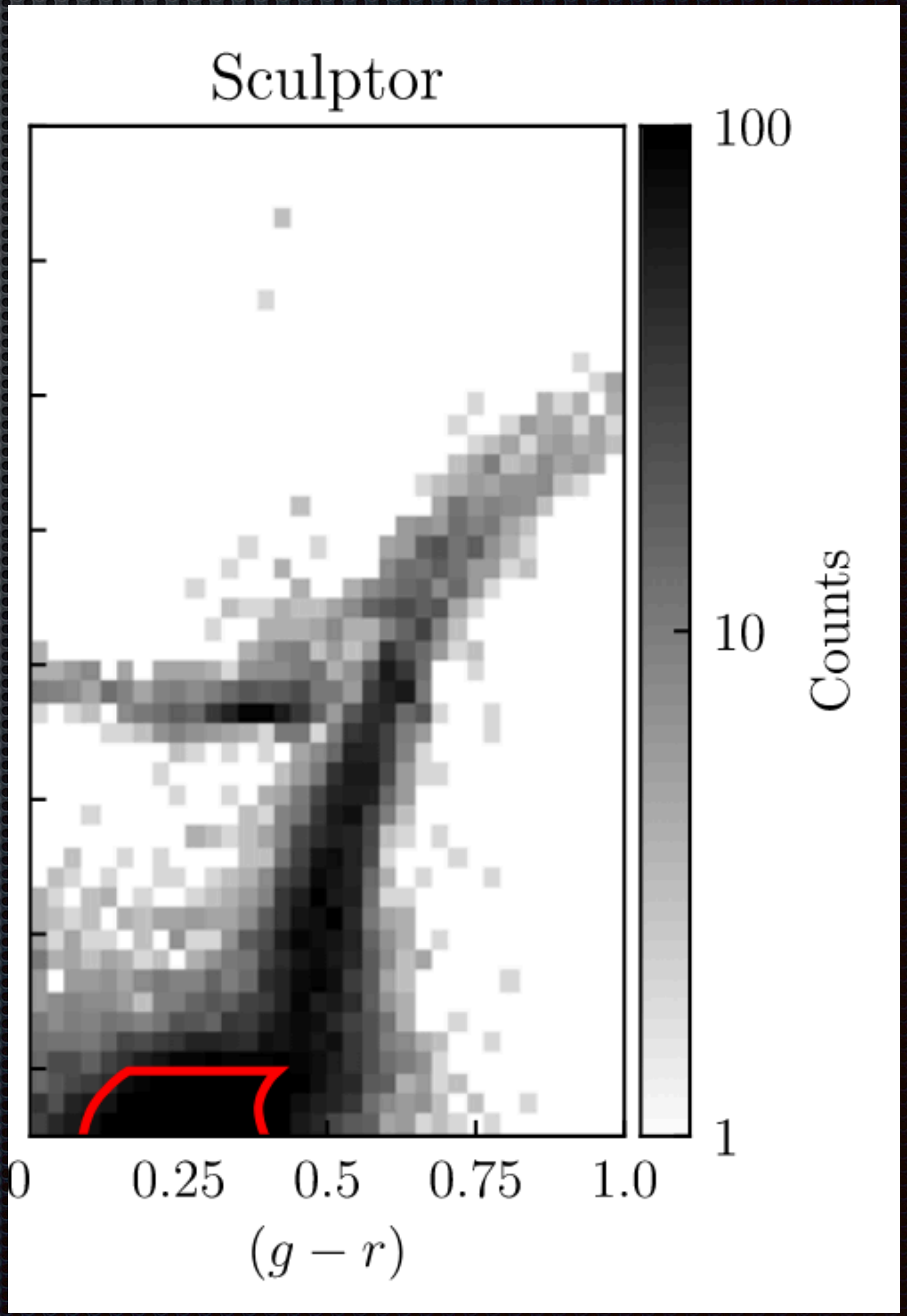
- Shape of the MW gravitational potential is a significant uncertainty
- Three different N-body simulations on the right, each with different degree of flattening of the MW potential. Big change in radial velocities of tidal debris.
- Different observables give conflicting best-fit parameters for the MW potential.



Law, Johnson & Majewski 2005

Tracer populations

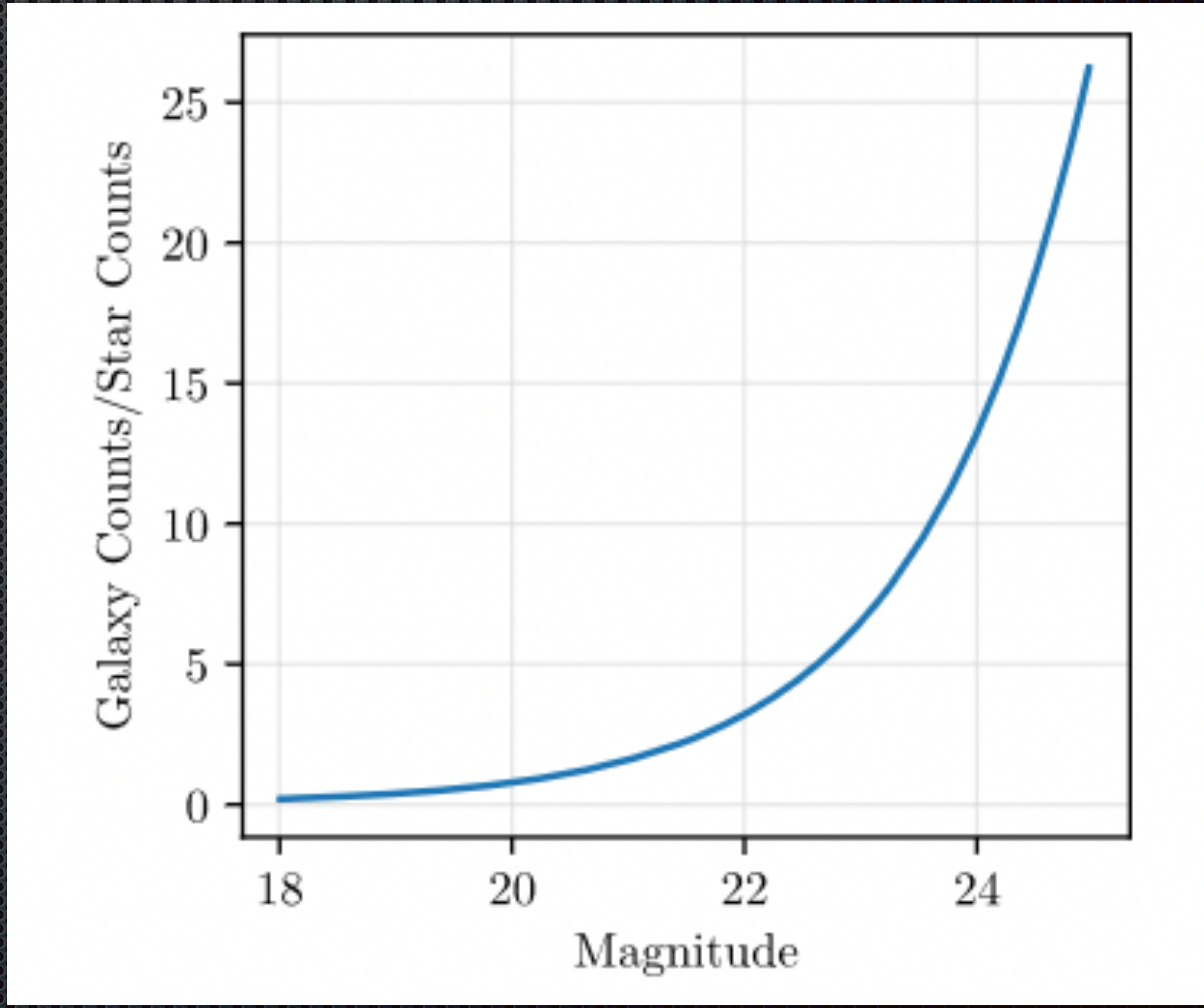
- These maps are very pretty because they show main sequence turn-off stars (MSTO).
- There are tons of MSTO stars, and they have a narrow-ish range of magnitudes -> high signal-to-noise maps.
- Other tracer populations are possible, but are less numerous, or are harder to select, or wider range of intrinsic mags, or are fainter.



LSST?

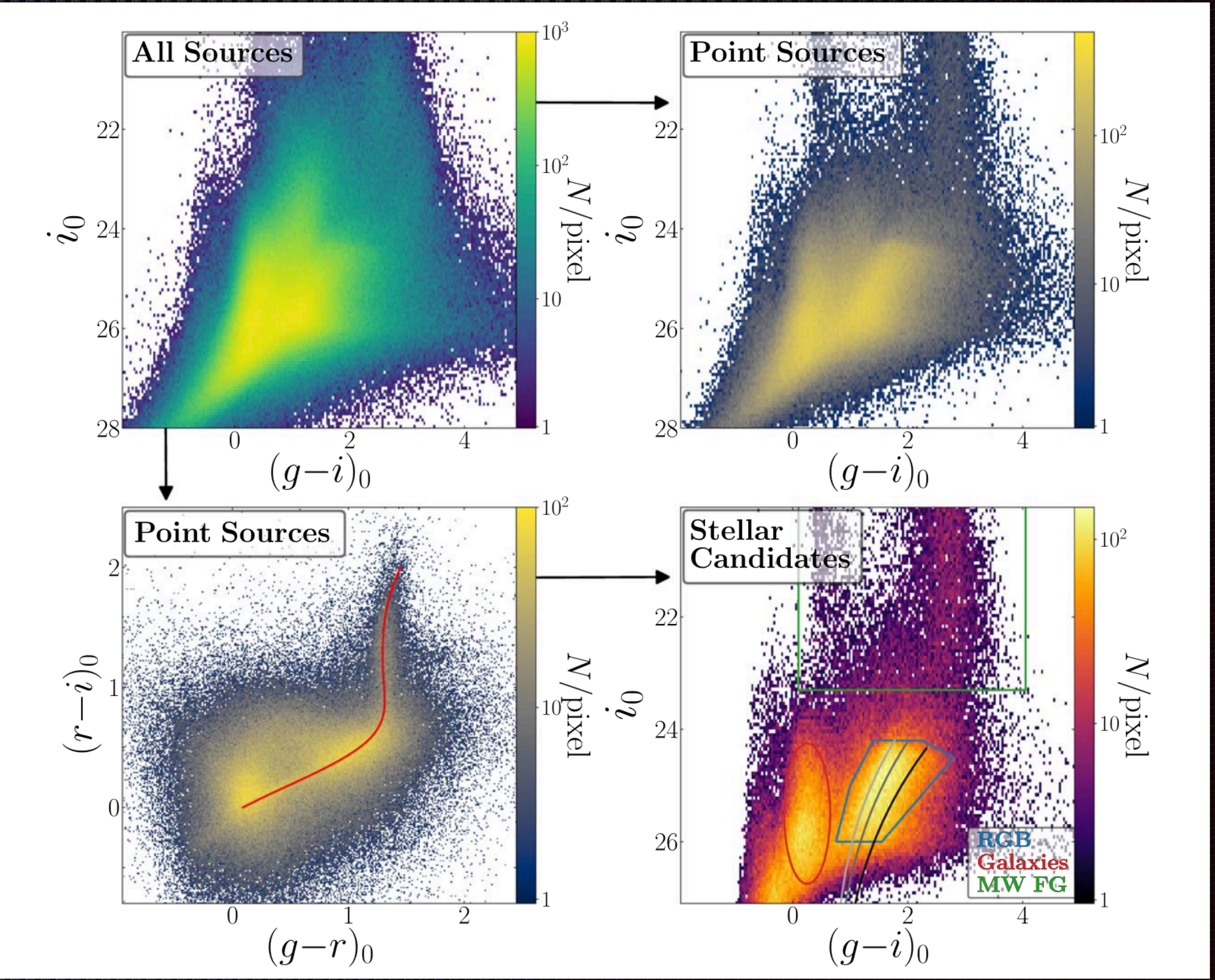
- Bigger mirror -> deeper images -> expand the volume available for mapping.
- Time domain -> variable stars become candidate tracers. Potentially high SNR at low counts.
- Mapping further out in the galaxy -> longer dynamical times, less disrupted streams?
- Wider area: cover large fraction of each stream, find more progenitors

- Fainter mags -> more galaxies, star-galaxy separation gets harder. But a big mirror helps!
- Time to get clever with different tracers?



Slater, Ivezić, Lupton 2020.

- Example: Looking for stars around M81 at ~3.6 Mpc, using Subaru
- Using multiple colors helps, but some galaxies still overlap stars in color-color space.

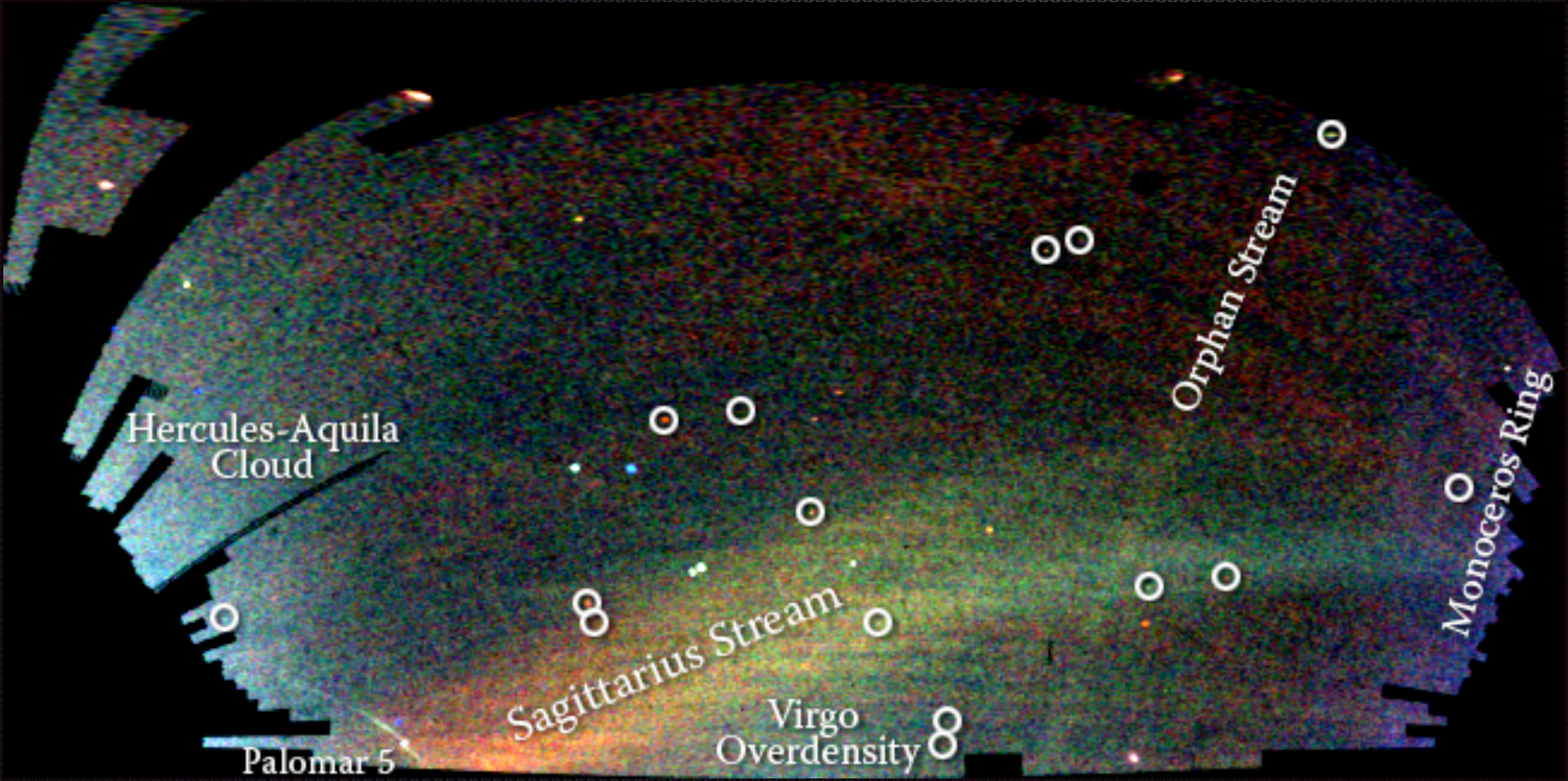


Smercina et al. 2020

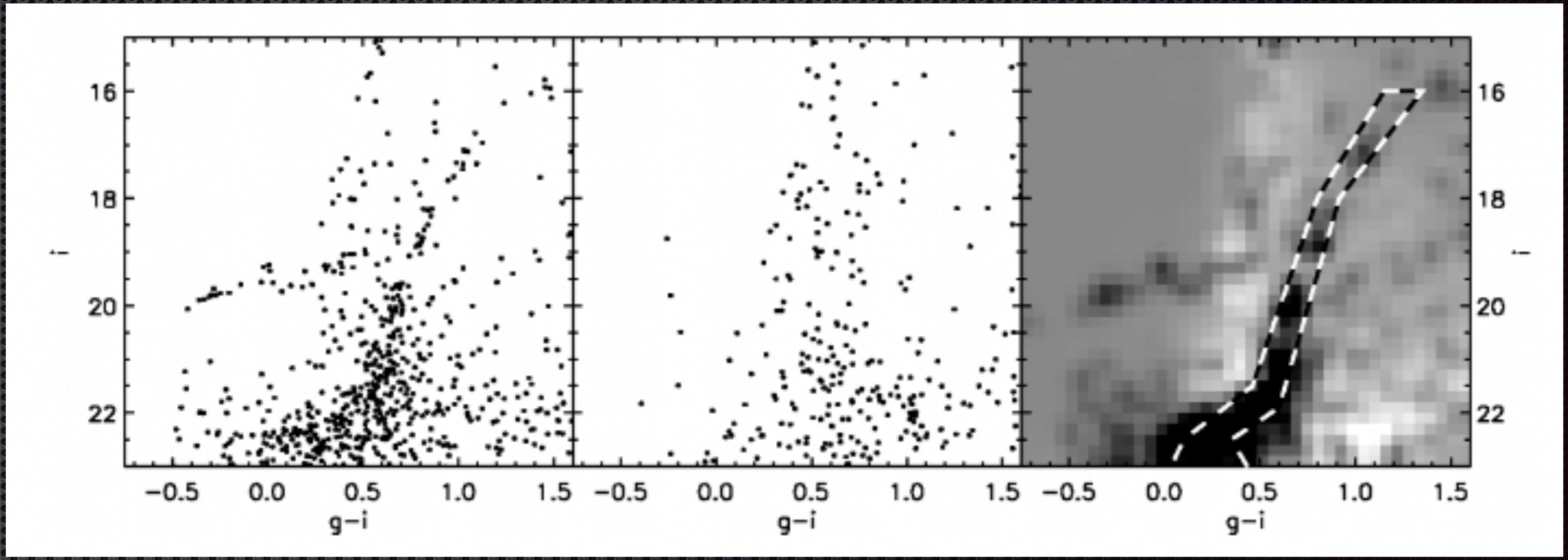
LSST?

- Bottom line: Signal to Noise ratio is what matters.
- Can I:
  - Find targets more accurately? Find a larger population of targets?
  - Find and eliminate “noise” sources? Model backgrounds/“noise” better? Move to a different target where the backgrounds are removable? Use other survey data to reduce backgrounds?

What are the little dots?

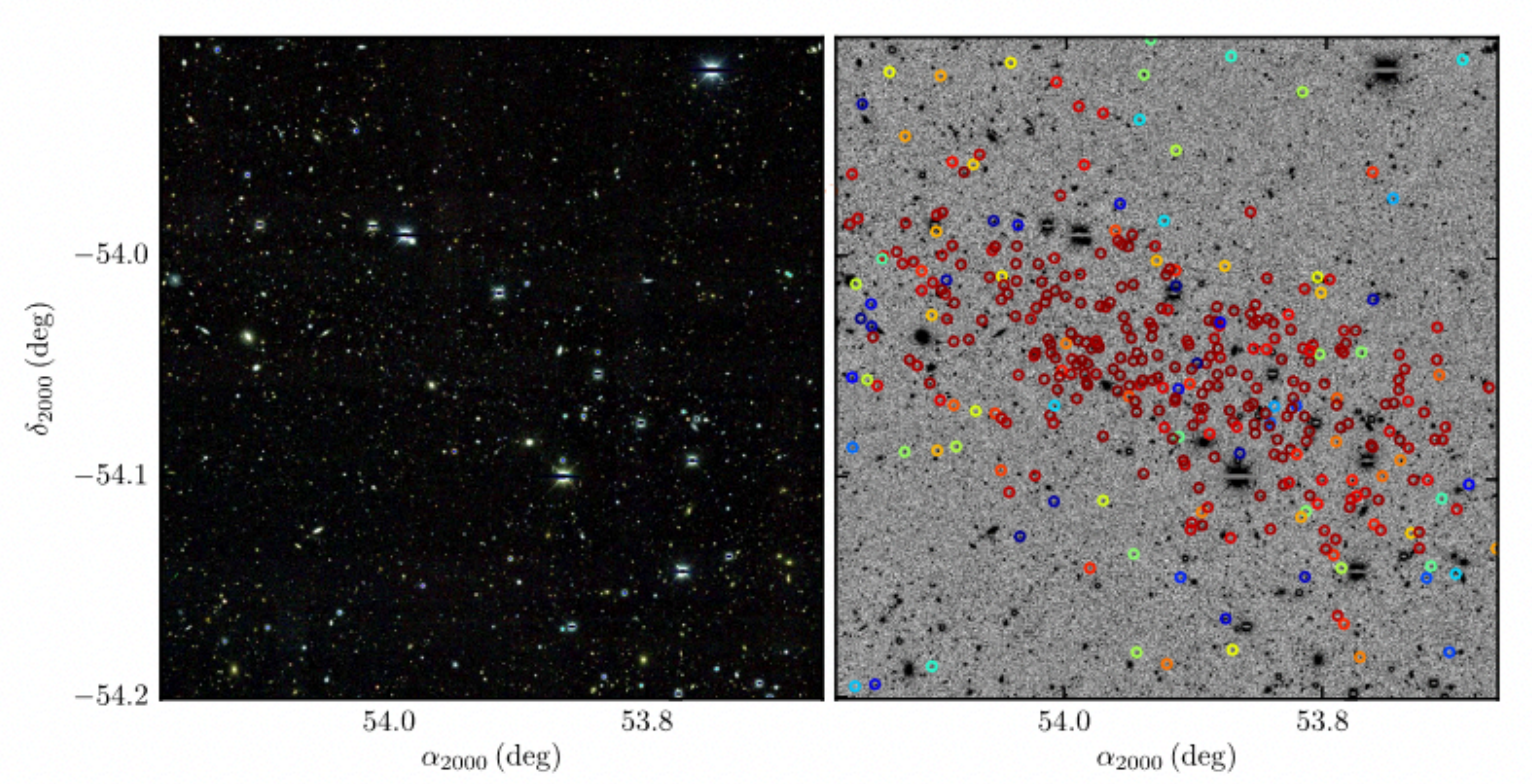


Boötes



Belokurov et al. 2006

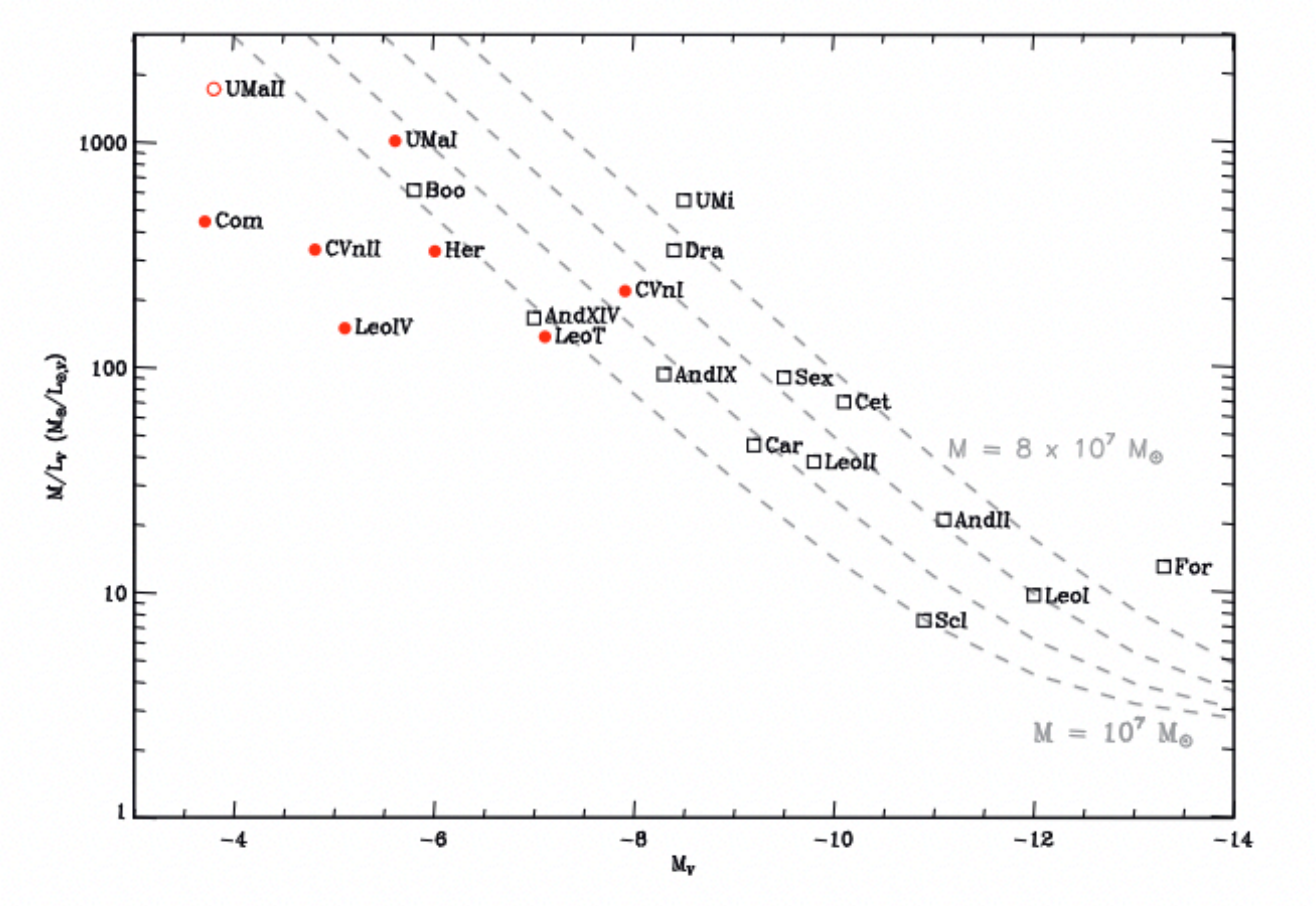
Reticulum II



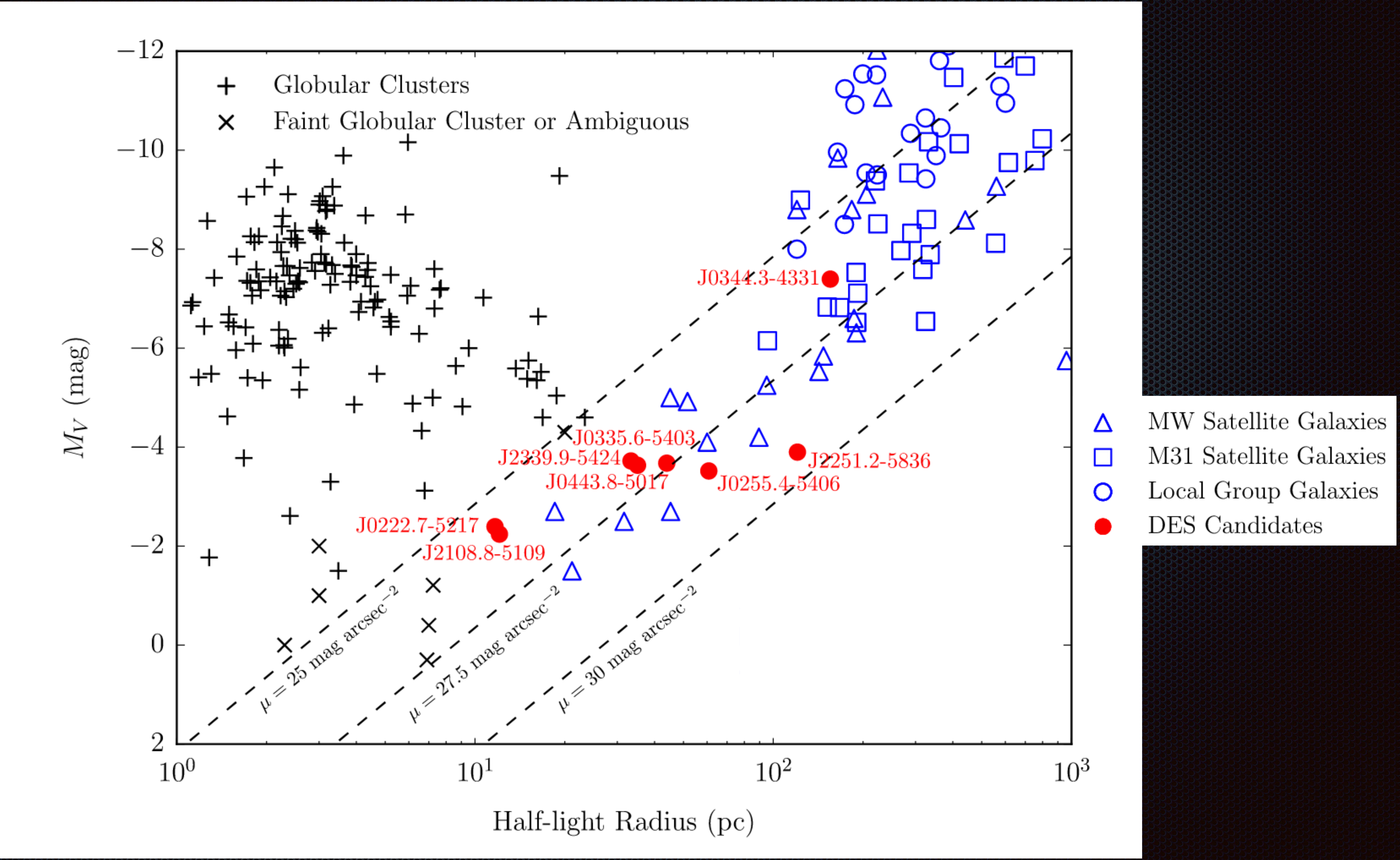
Bechtol et al. 2015

Are they galaxies?

- Definitionally:
  - Galaxies -> Have dark matter
  - Globular Clusters -> Do not have dark matter
- Want to spectroscopize every dwarf candidate, see if it had a high velocity dispersion.
- Even very faint things can have high velocity dispersions!

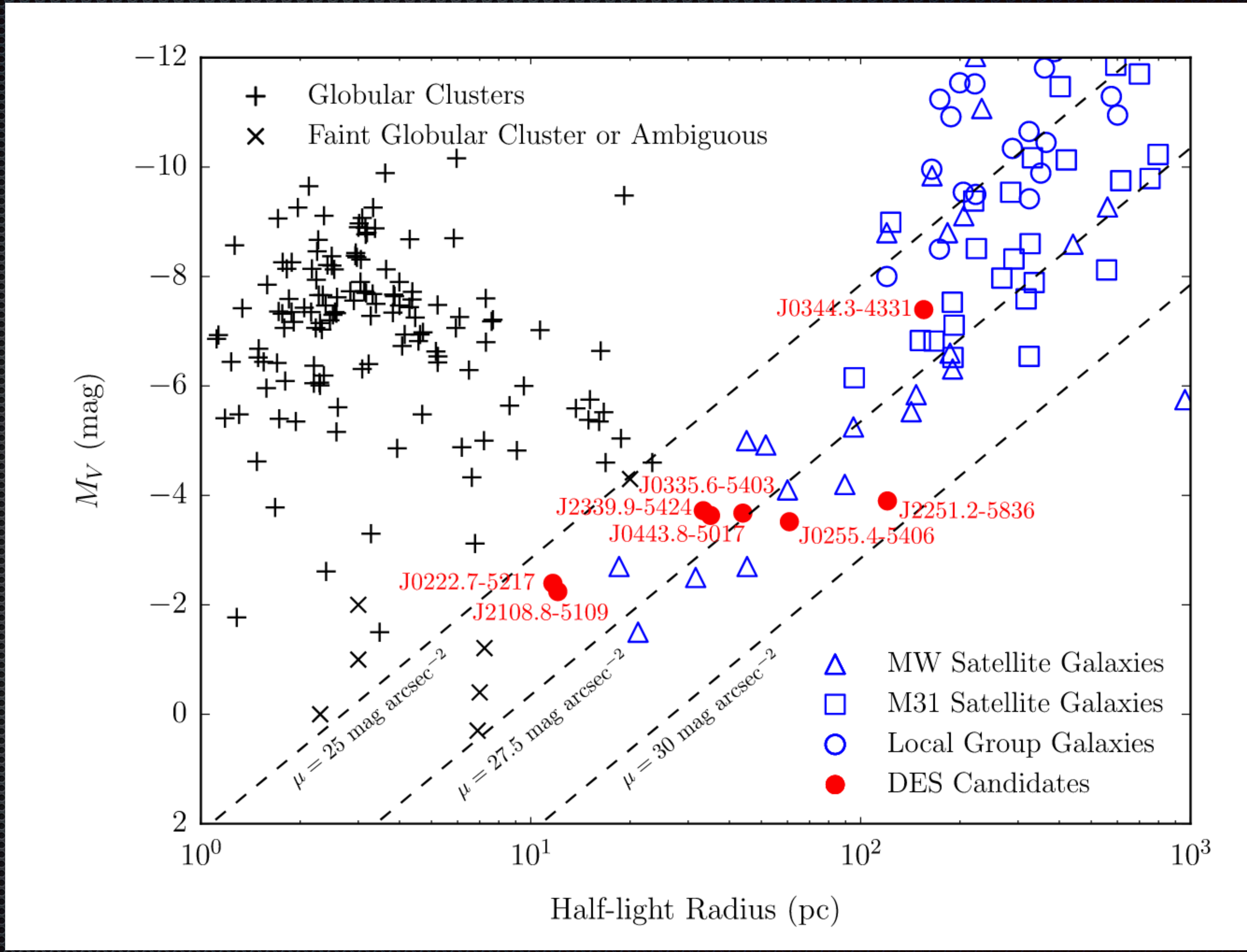


Simon & Geha 2007



Bechtol et al. 2015

- Why are these galaxies so faint!?
- What were they like before becoming MW satellites?
- What was their star formation history like?
- Are their dark matter properties less affected by baryons, more “prestine” tests of DM?



LSST?

- Push to lower surface brightness limits, expect to find galaxies that we couldn't find otherwise.
- Finding them might be the easy part — What do we do with them?
    - Spectroscopy is going to be harder. HST will get some extra depth, but intrinsically few stars.
    - What other data can we combine with LSST to tell us more about these?