

ASTR 511

Galactic Astronomy

Lecture 15

Galactic Astronomy in the Next Decade

Prof. James Davenport (UW)

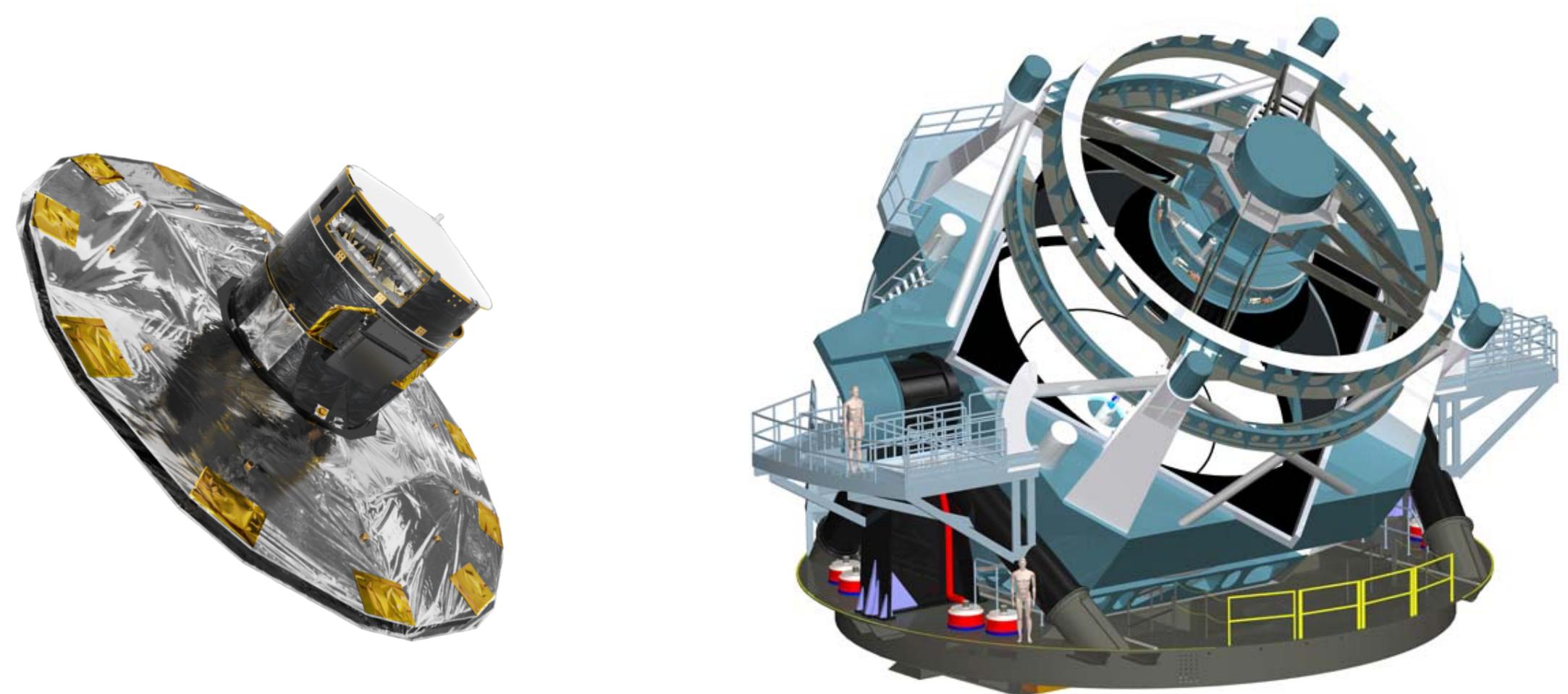
Winter 2023

Reminders

- HW 4 due: don't over-stress about how much your cluster disrupts!
- Next week: presentations. Schedule on the class Slack channel
 - LMK if you planning to be remote
- Finals Week: Term papers due!

Today...

- Galactic Astronomy in the next 10 years: predictions & hot takes
 - Esp. LSST, but also Gaia
- Review of cool things we've talked about

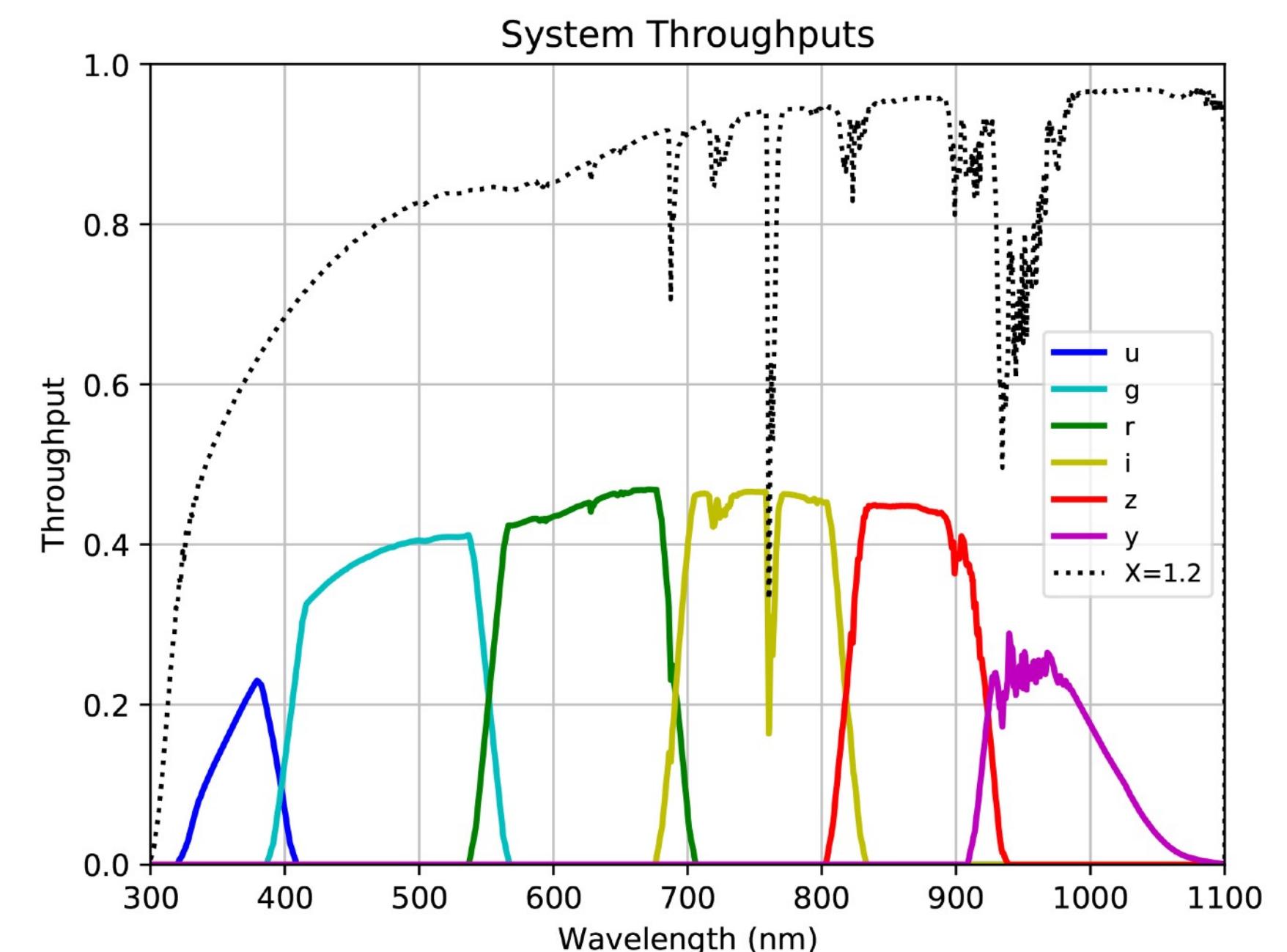
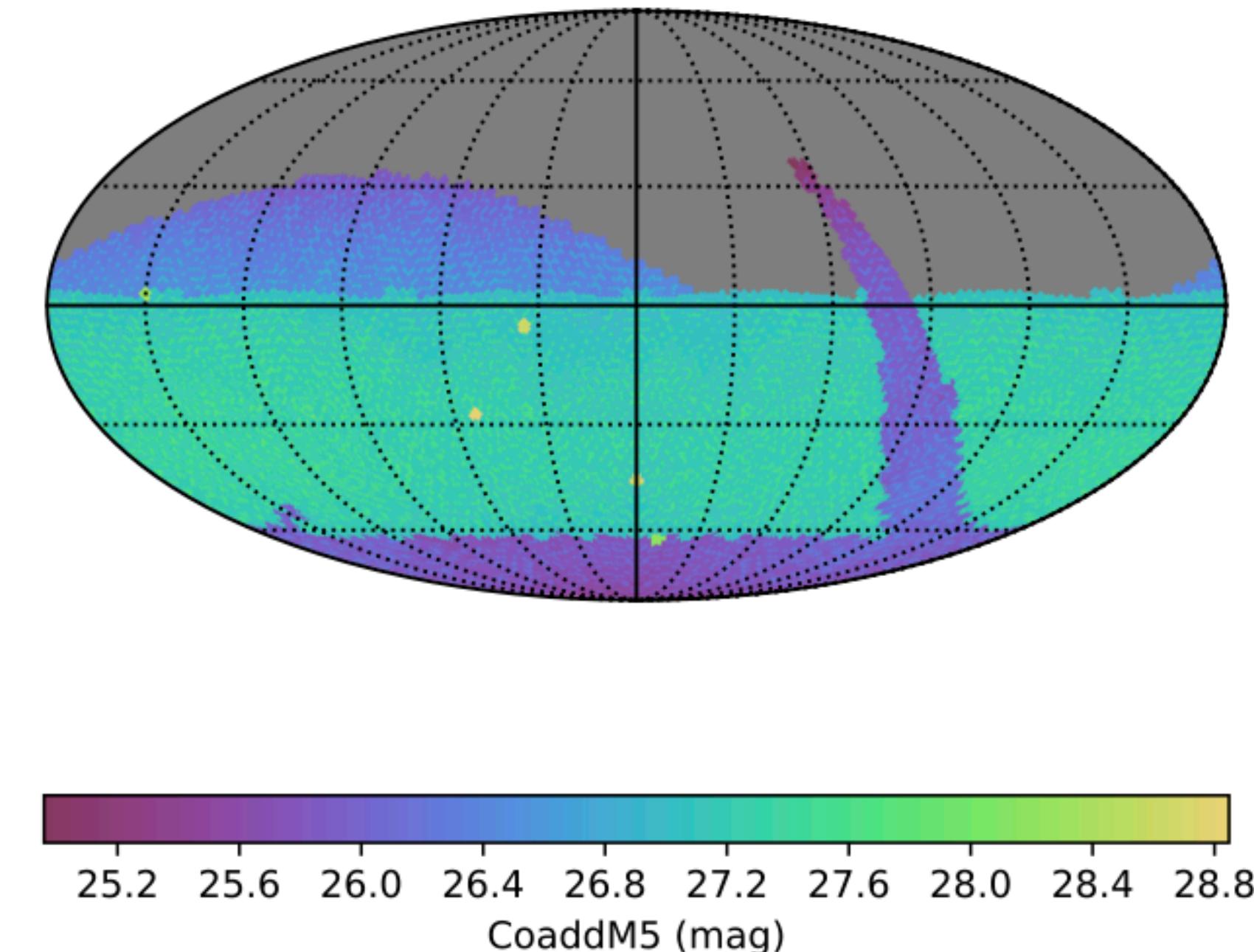


Rubin / LSST

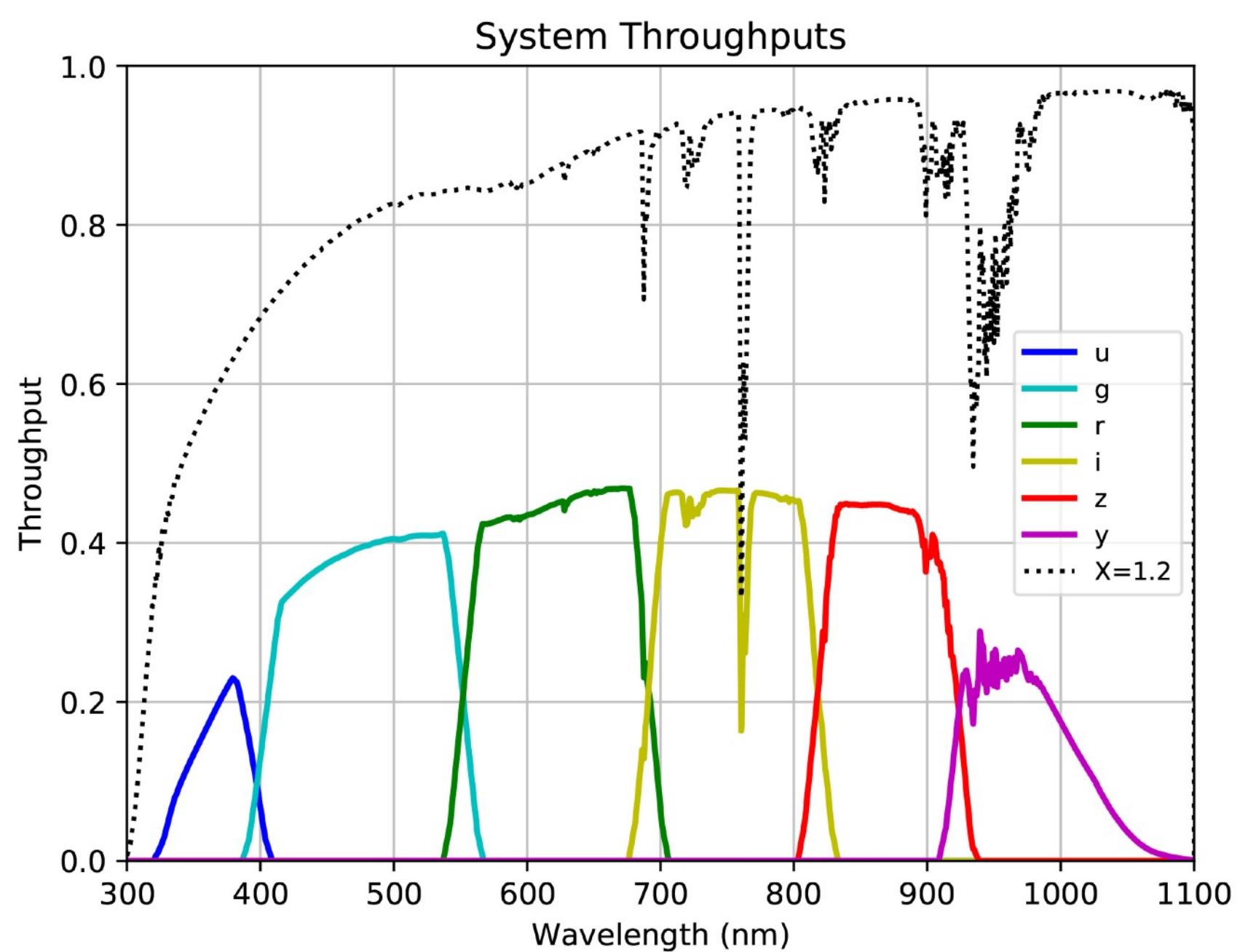
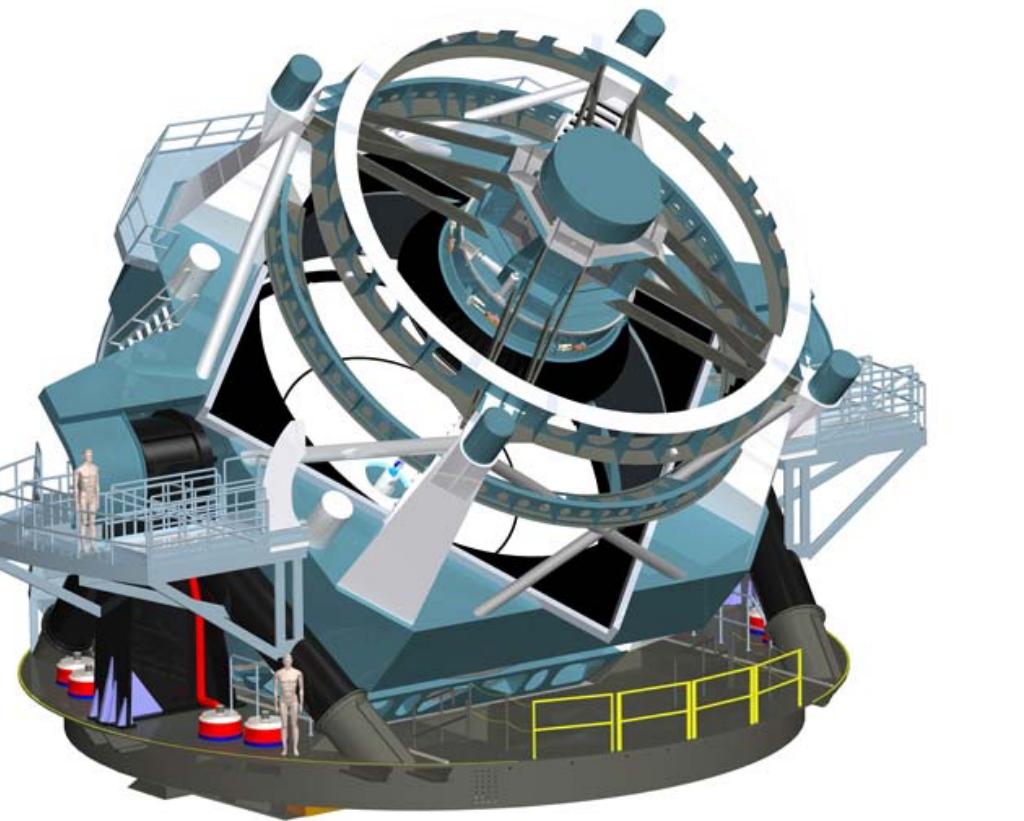
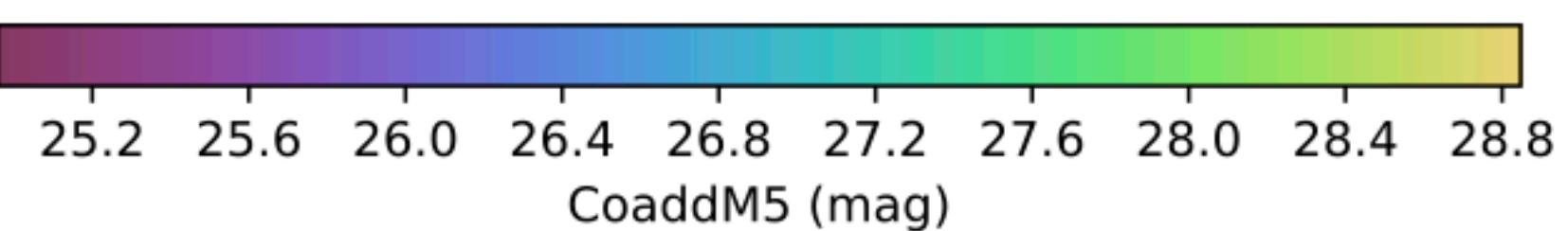
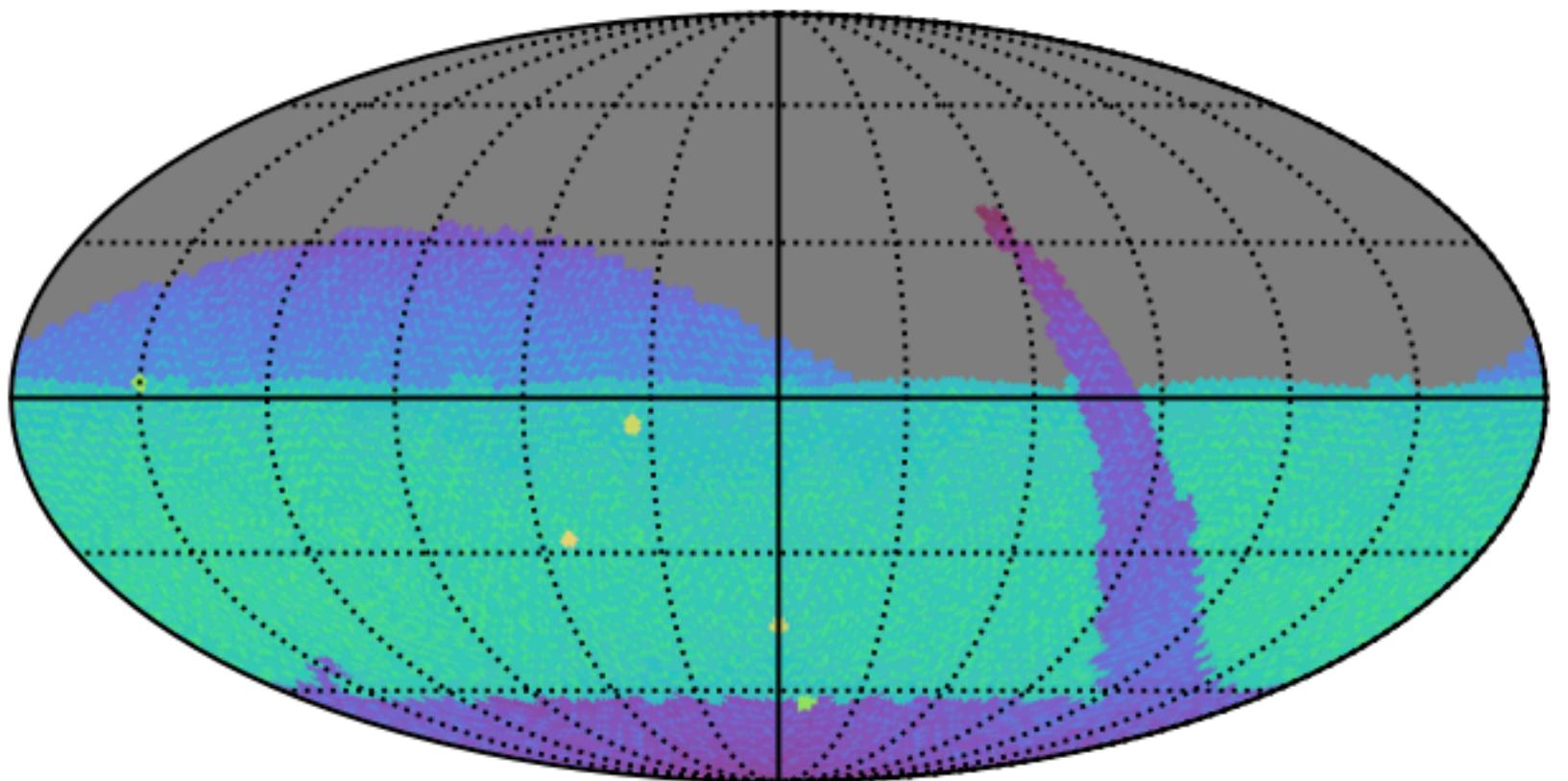


Rubin / LSST

- 6 bands, over 10 years
- 17 Billion Stars, 20 Billion Galaxies
- +20TB/night
- 30 second exposures, ~800-1000 over 10yrs
- 5sigma limit: r=24 per visit, r=27 10-yr stack
g=25, 27.5
- ~10M “alerts” each night, within 60 seconds (!)

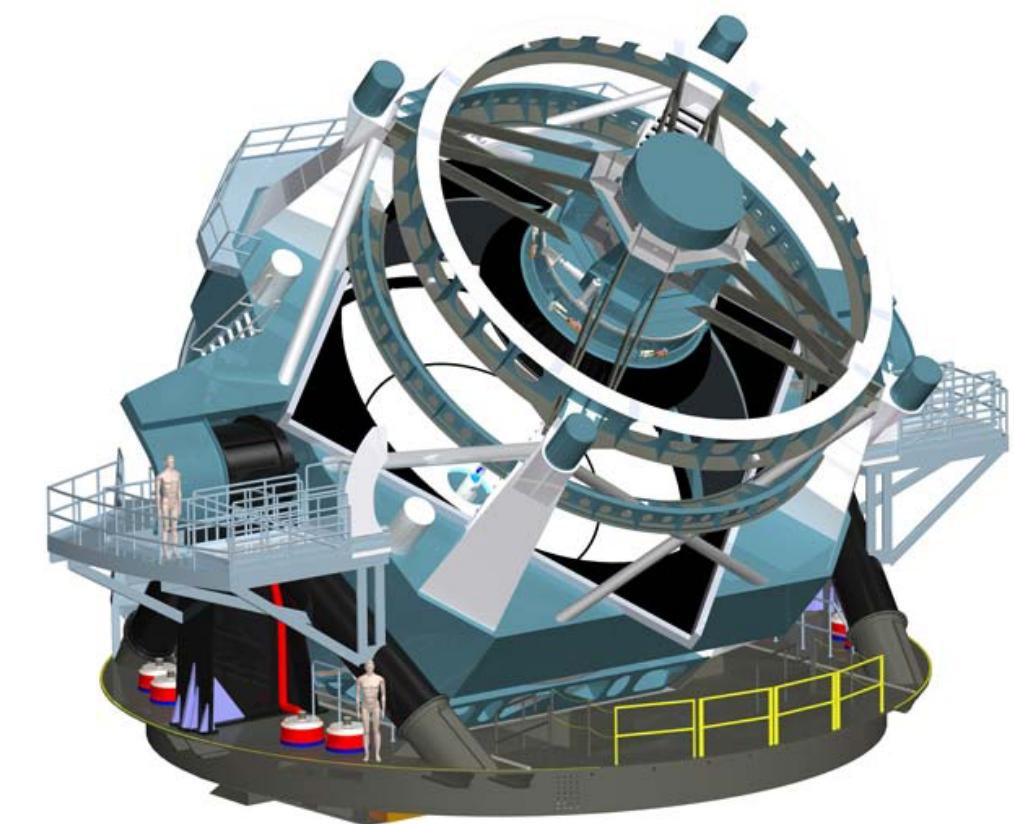


Rubin / LSST



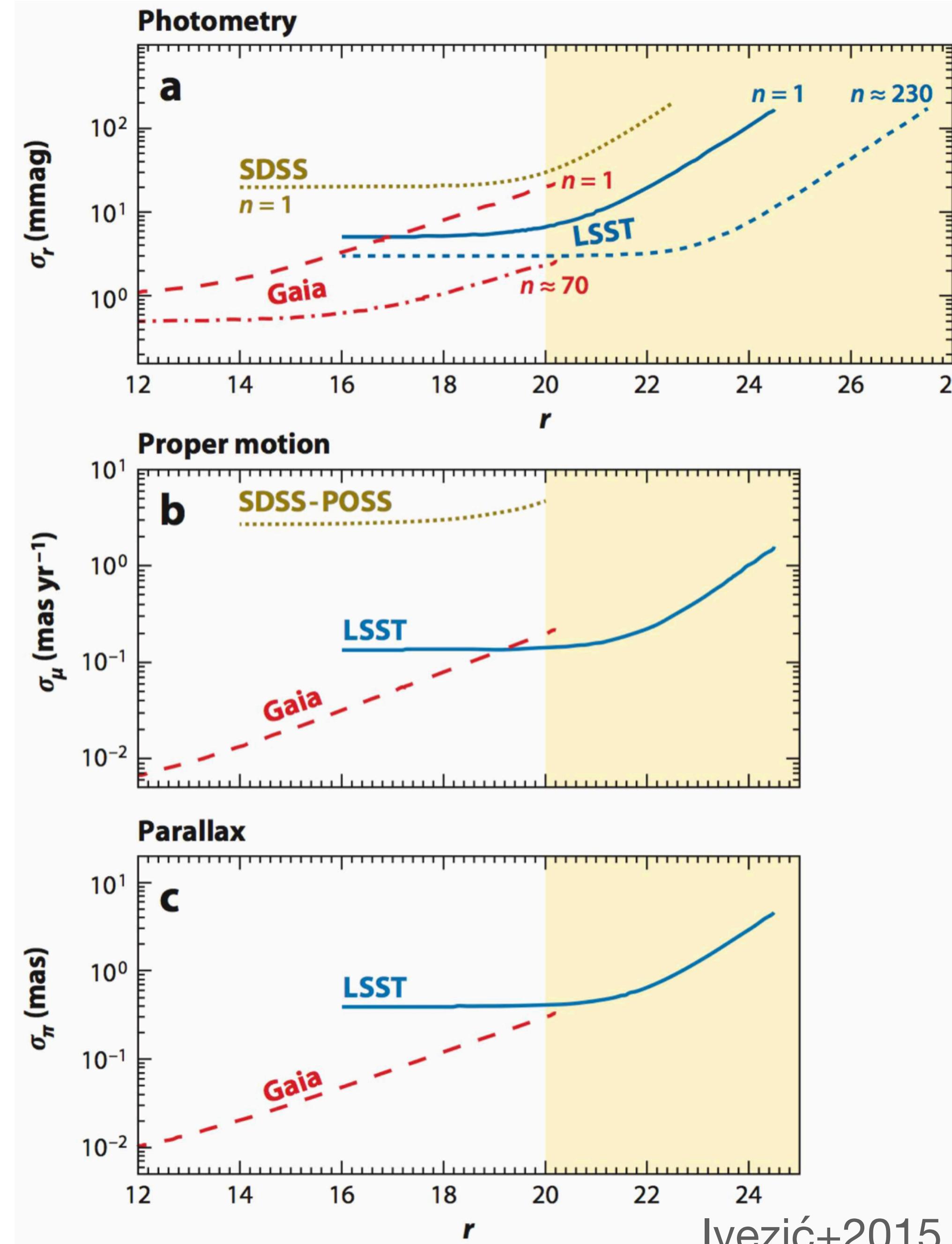
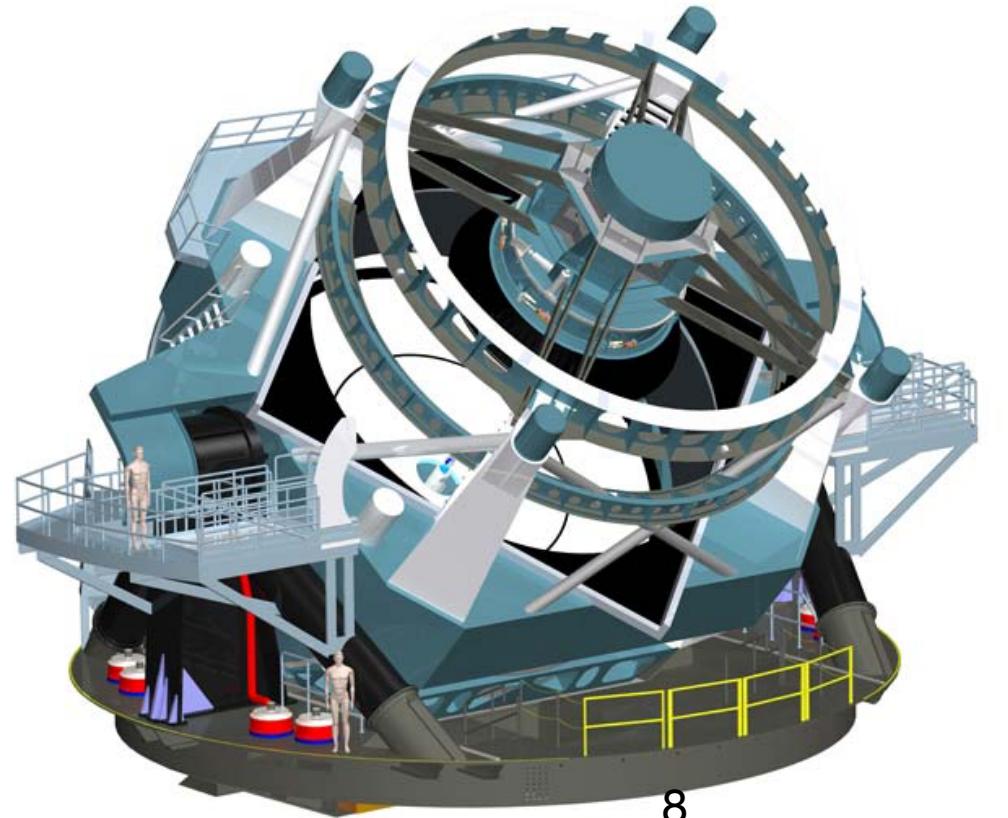
Gaia versus Rubin

- For galactic astronomy, Gaia has a +7yr head start
- Gaia photometry *very* precise (noise floor ~10x lower), but limited to 20th mag
- Gaia has distances + spectra (will have largest stellar spectra dataset to date)
- By LSST DR1, Gaia should release ~10yr light curves (with “low res spectra”) for ~2 Billion stars



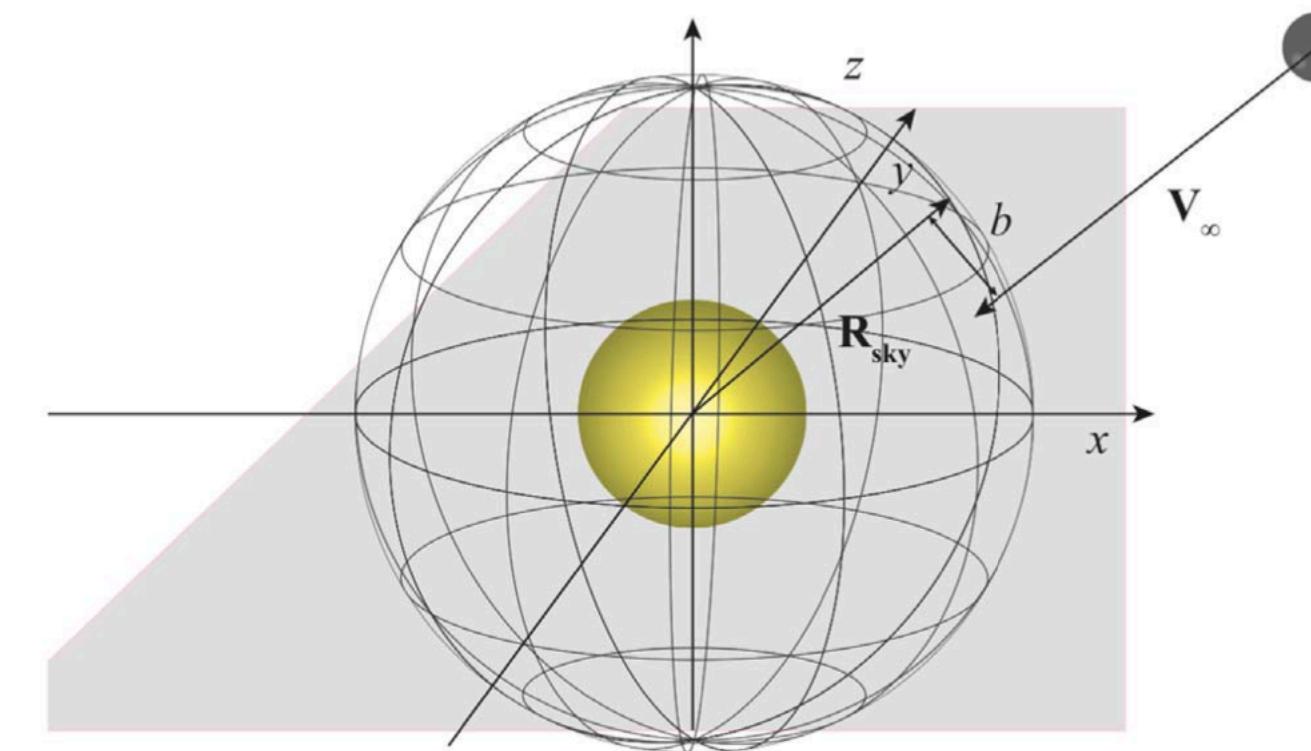
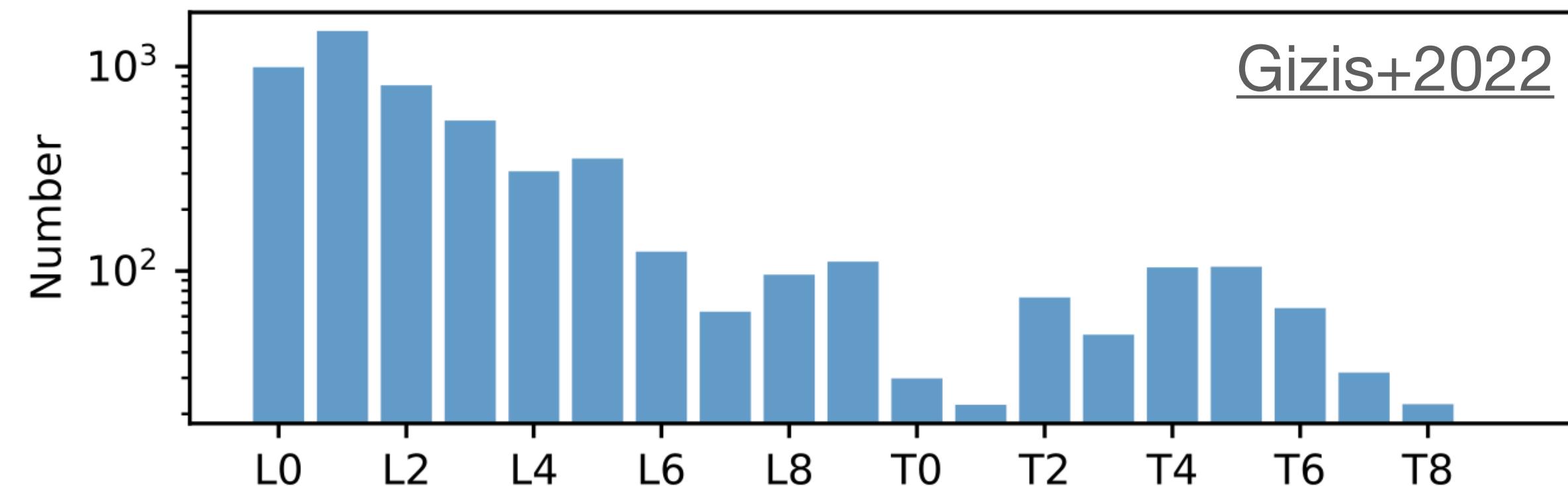
Gaia versus Rubin

- Rubin is complimentary to Gaia!
- LSST will have 10X more stars, further distances, better cadence
- LSST will go on for ~10yrs *after* Gaia, ~20yr baseline
- LSST releases data very quickly & openly!



Looking Close

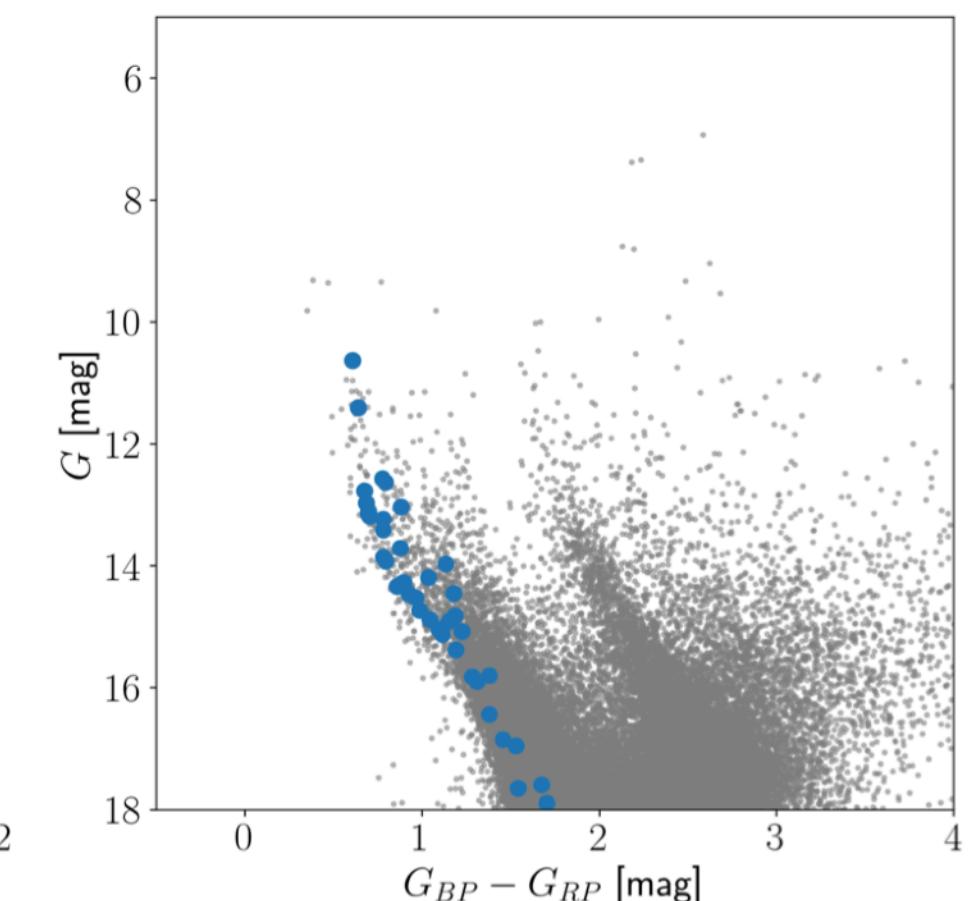
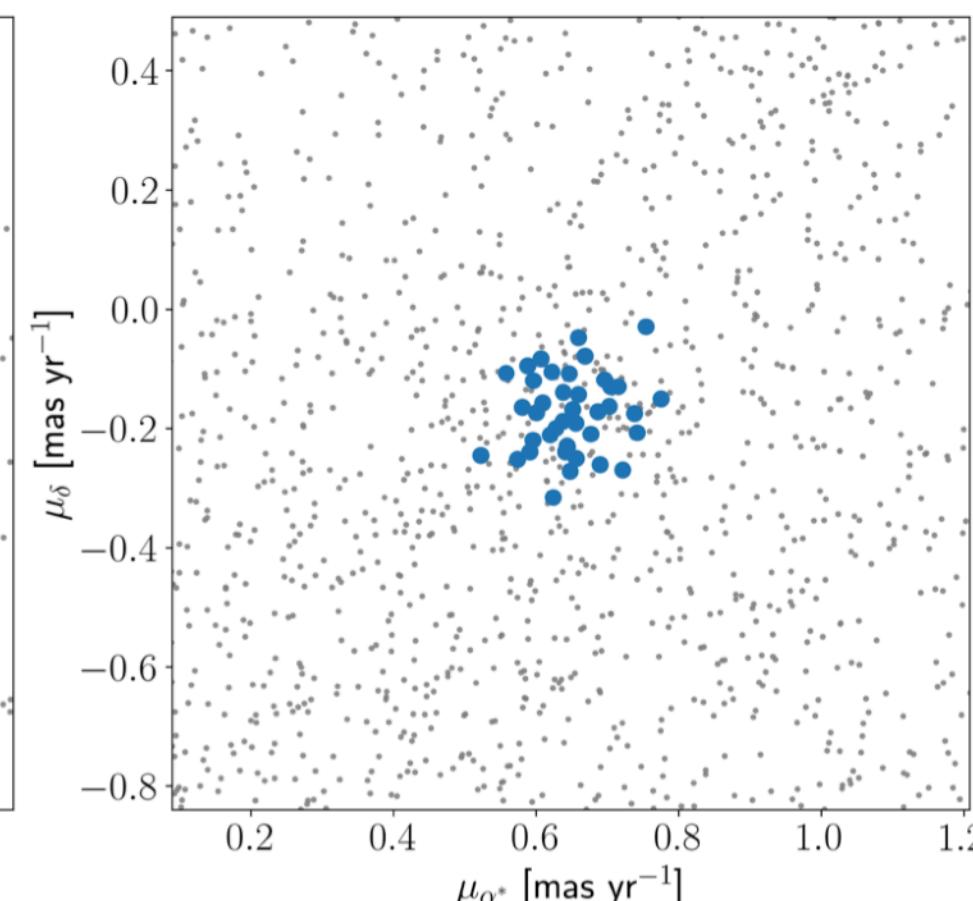
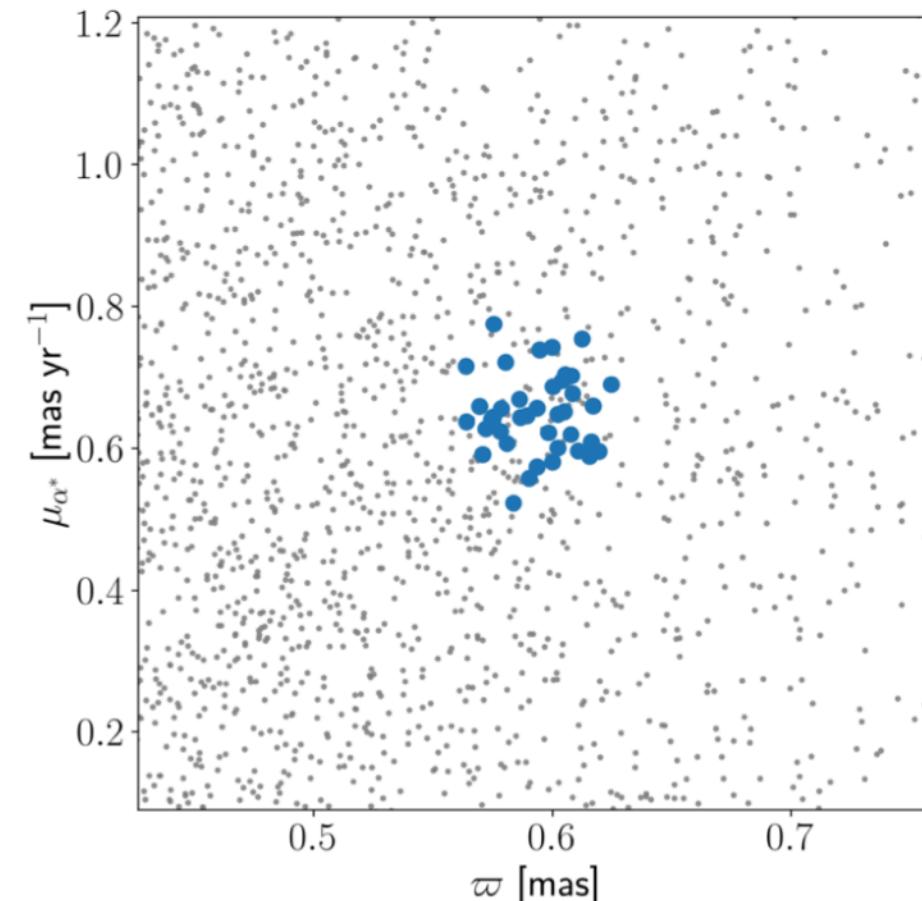
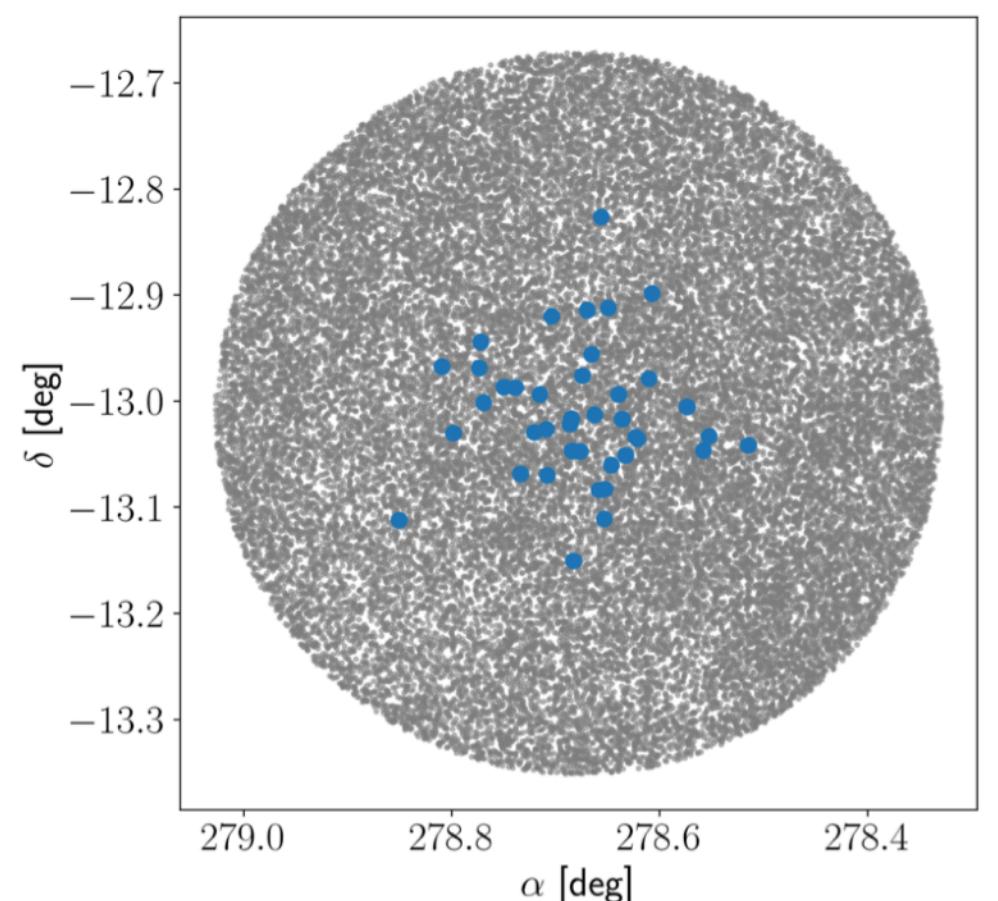
- Rubin is very good for looking at faint, nearby things... especially if they move quickly!
 - Planet 9
 - L/T dwarfs, free floating planets, etc
- +10x increase in L/T dwarfs (e.g. sample of late L's from ~20 to hundreds)
- Interstellar objects, improving understanding of what's in the empty spaces
 - +1 “ISO” per year ([Hoover+2022](#))



Stellar Populations

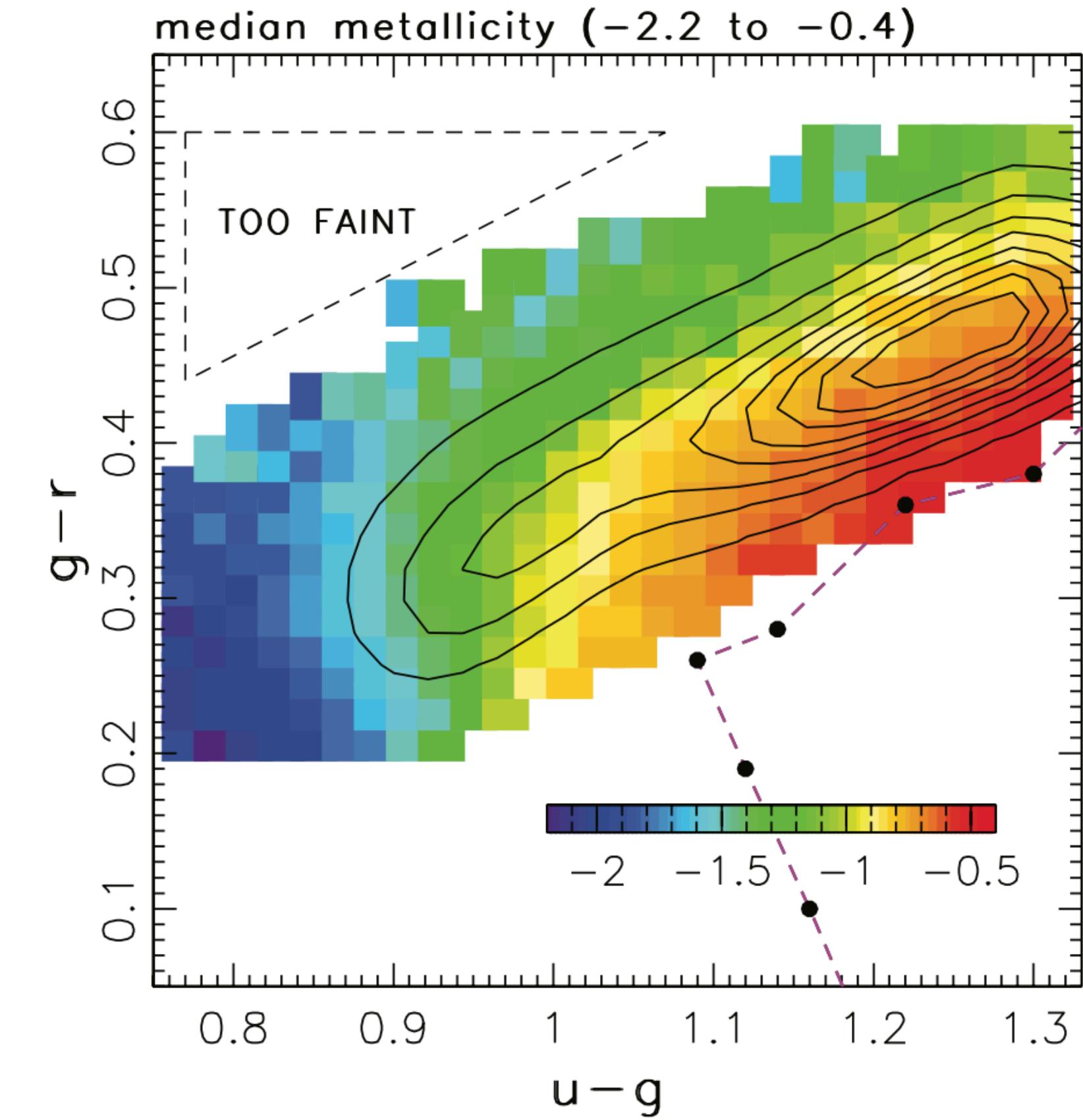
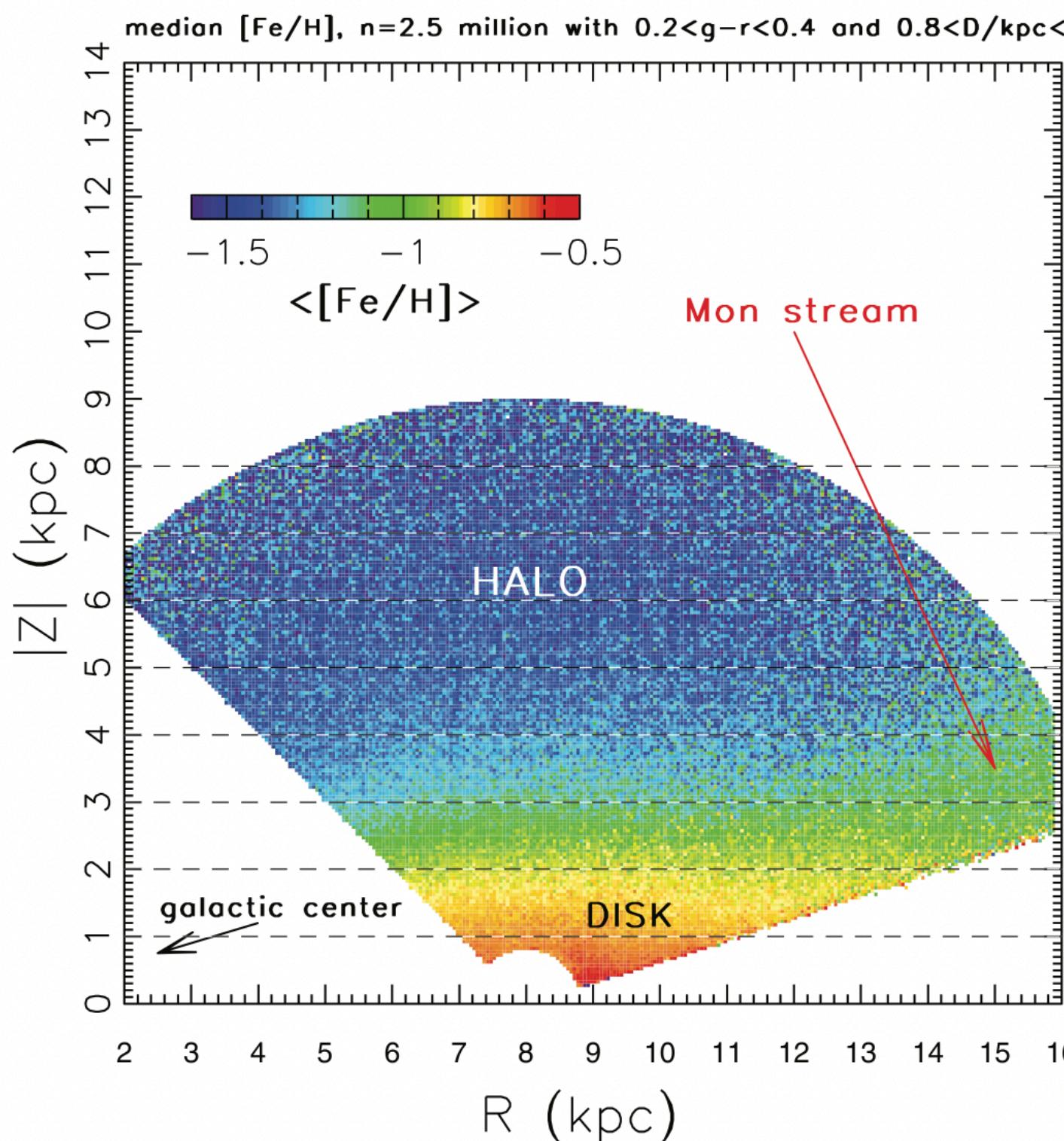
M 67

- Clusters
 - Pushing membership to lower mass (e.g. probing low-mass IMF)
 - Faint structures around clusters (i.e. tidal tails)
 - Identify more, especially distant clusters!



Stellar Populations

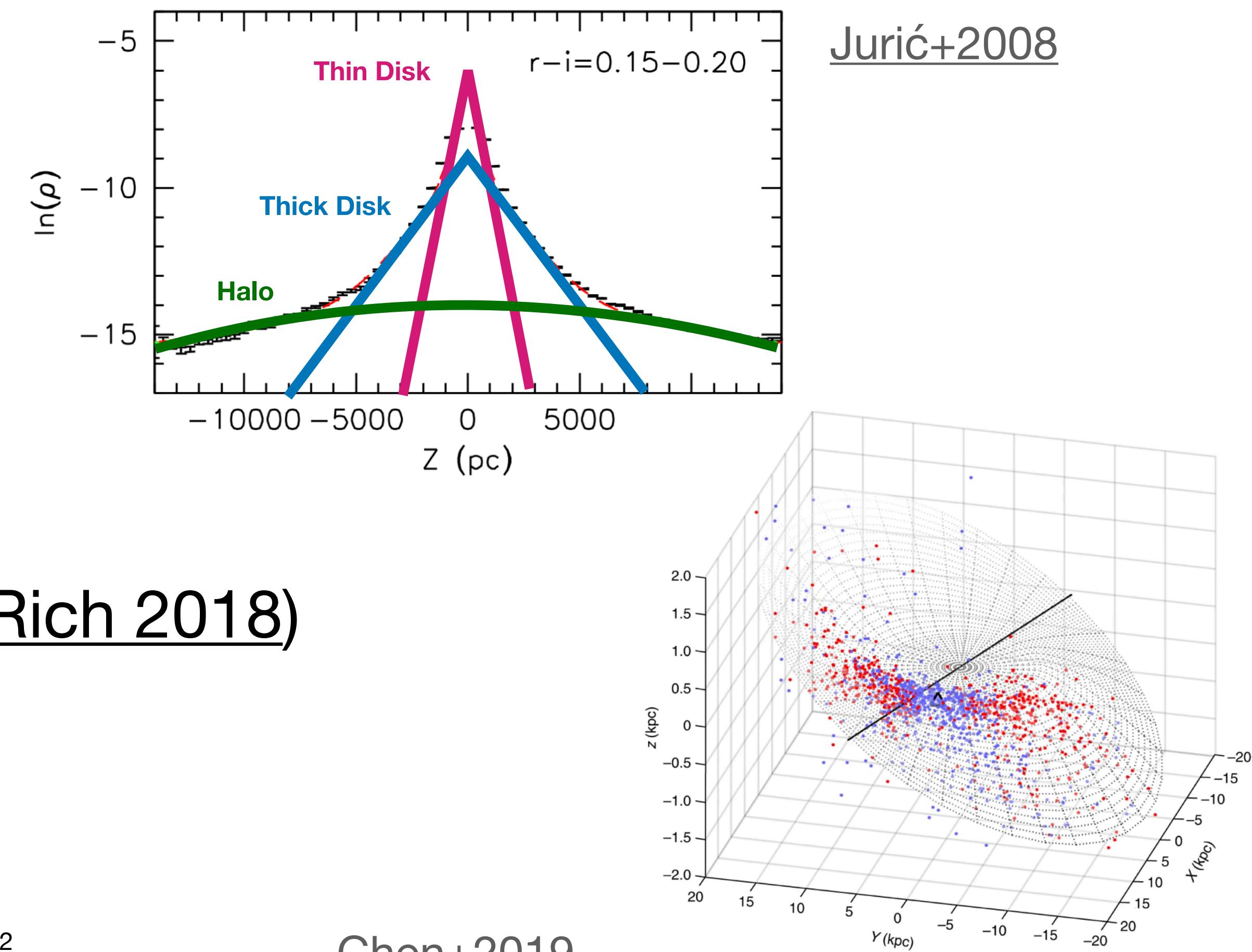
- Photometric metallicity will be very good with LSST
 - New y -band will help anchor temperatures especially for cool stars



- Can map metallicity across galaxy!

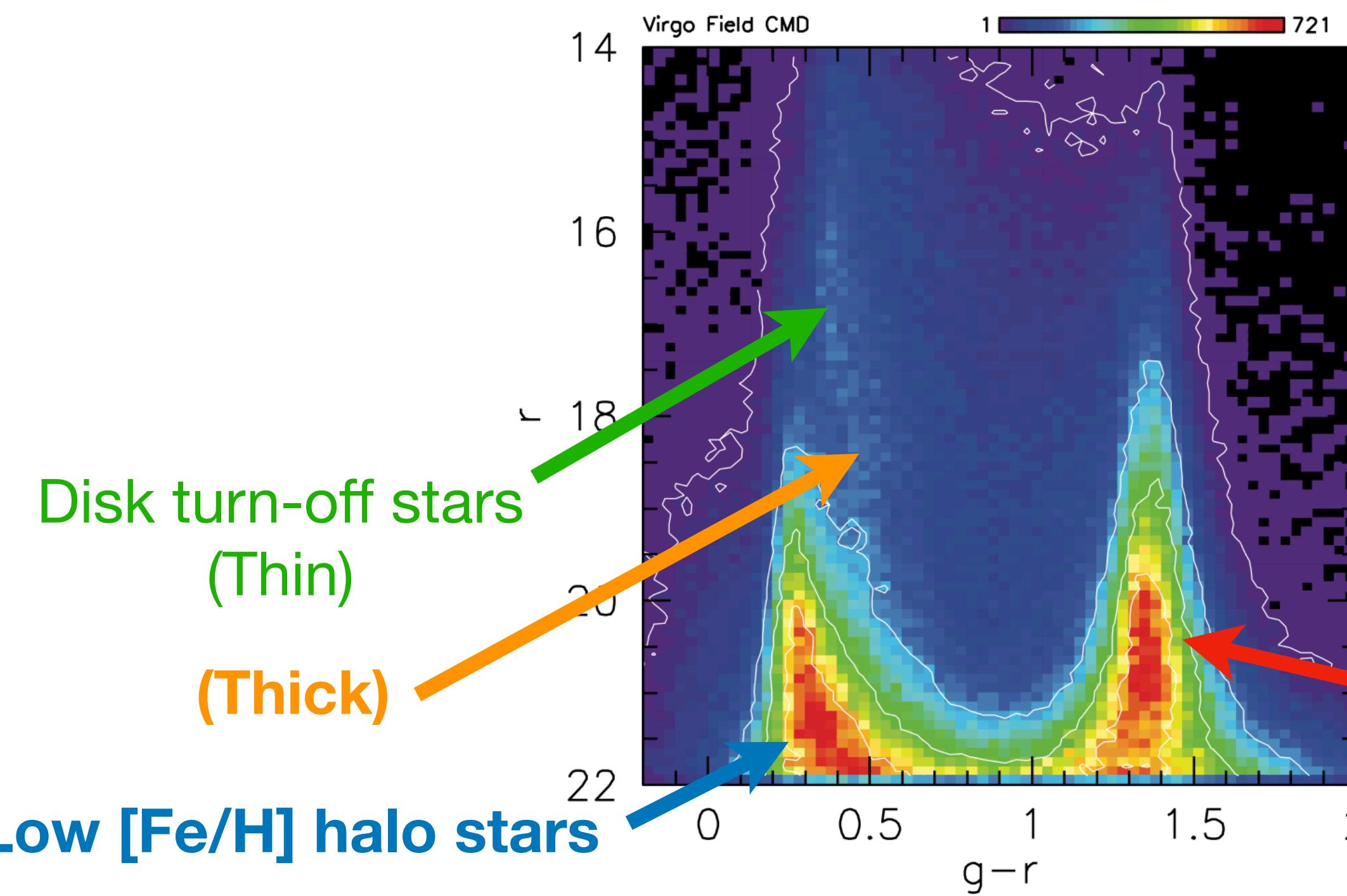
Milky Way Structure

- LSST will create a huge map of the MWY out to many kpc (for giant stars: visible out to several Mpc)
 - Arm structure(s)
 - Warped disk shape & extent
 - Star counts & thin versus thick disk
 - Bulge/bar structure
 - Mapping halo out to +400kpc (e.g. [Rich 2018](#))

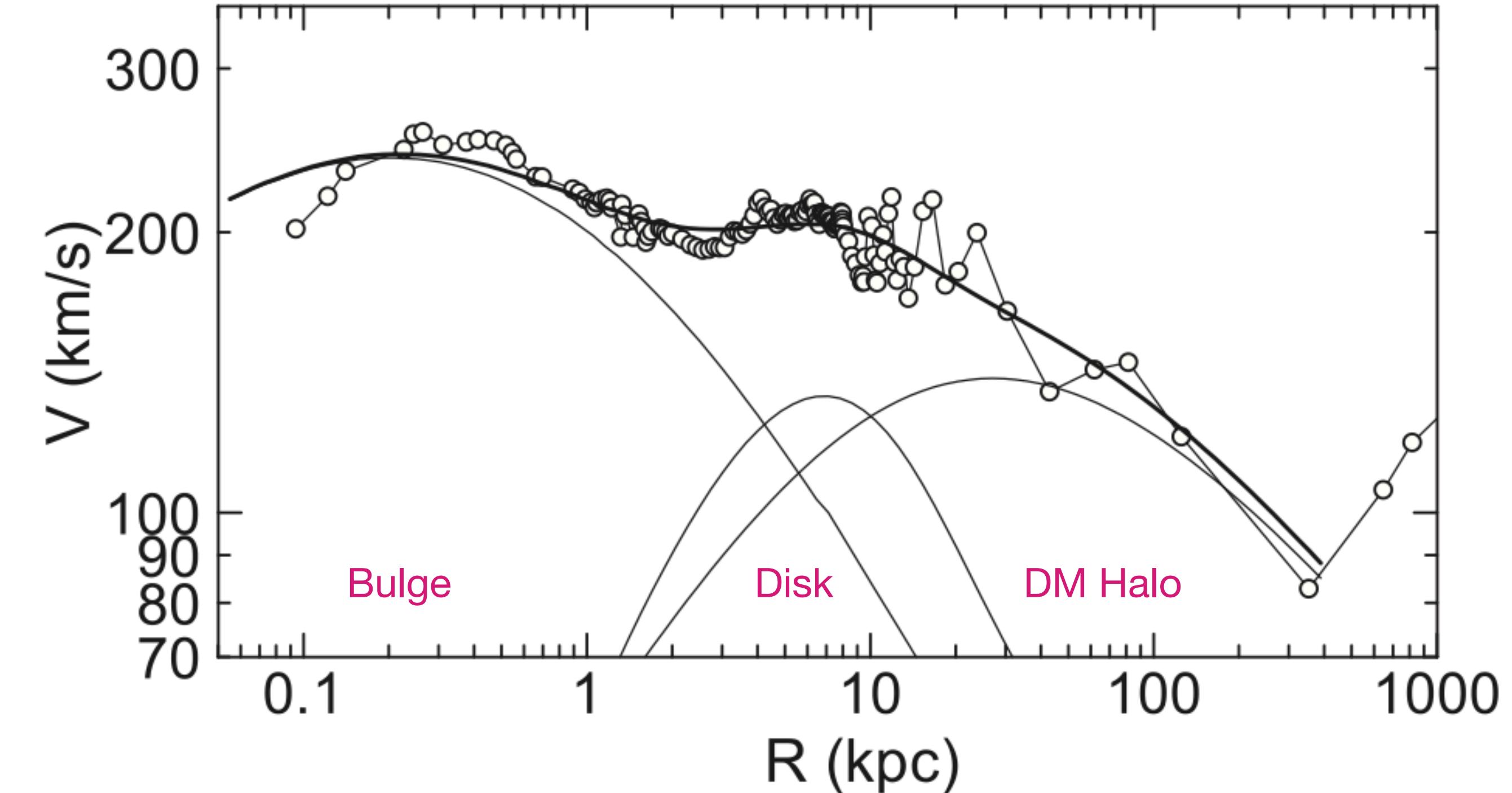


The Halo

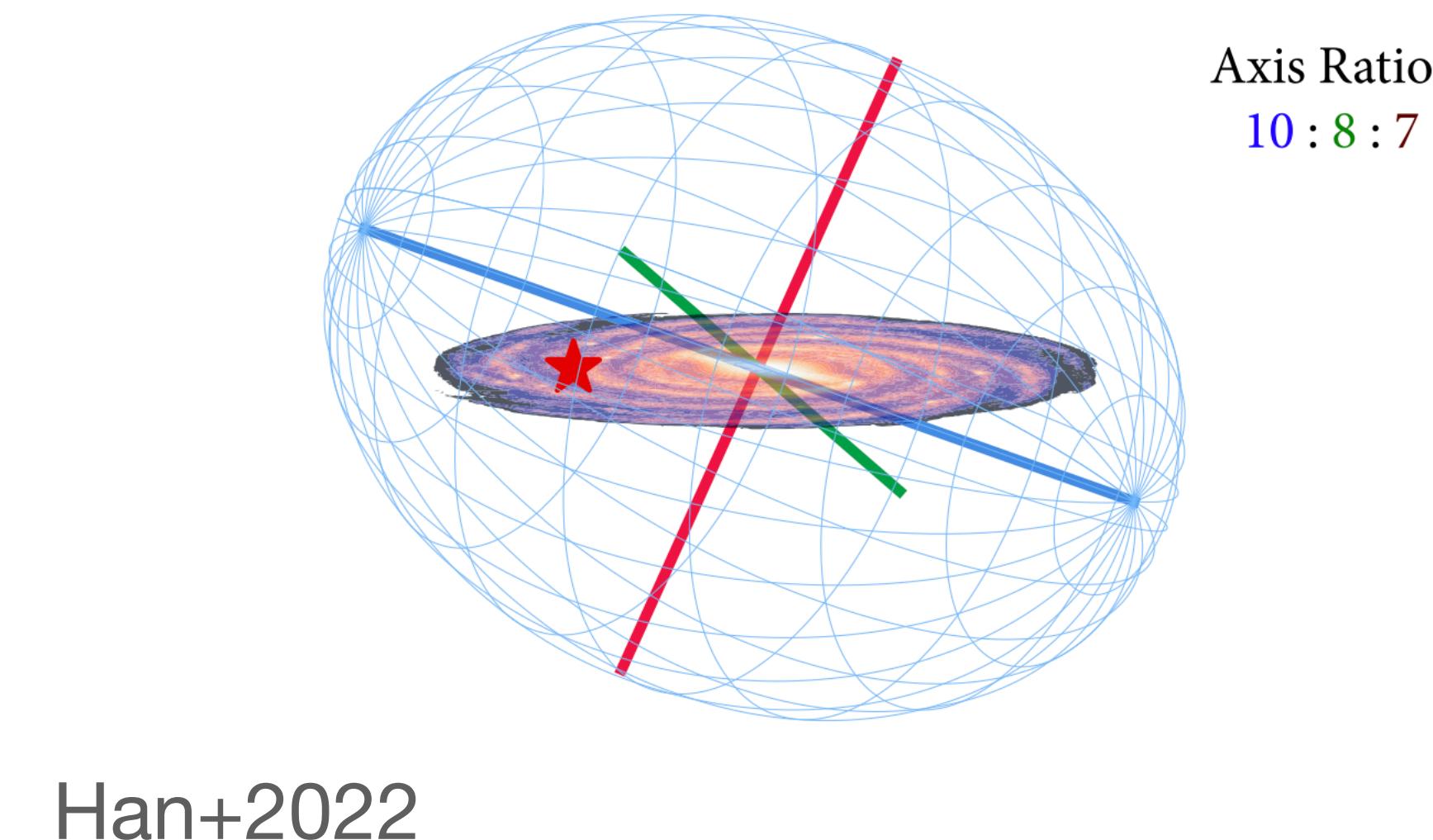
- As has been true for the last ~20 years, MWY halo is going to be a hot topic during LSST
- Measure stellar halo shape, constrain DM halo (potential)



- I bet the “Hess” diagram comes back in style...
- Nearby M dwarfs (disk)



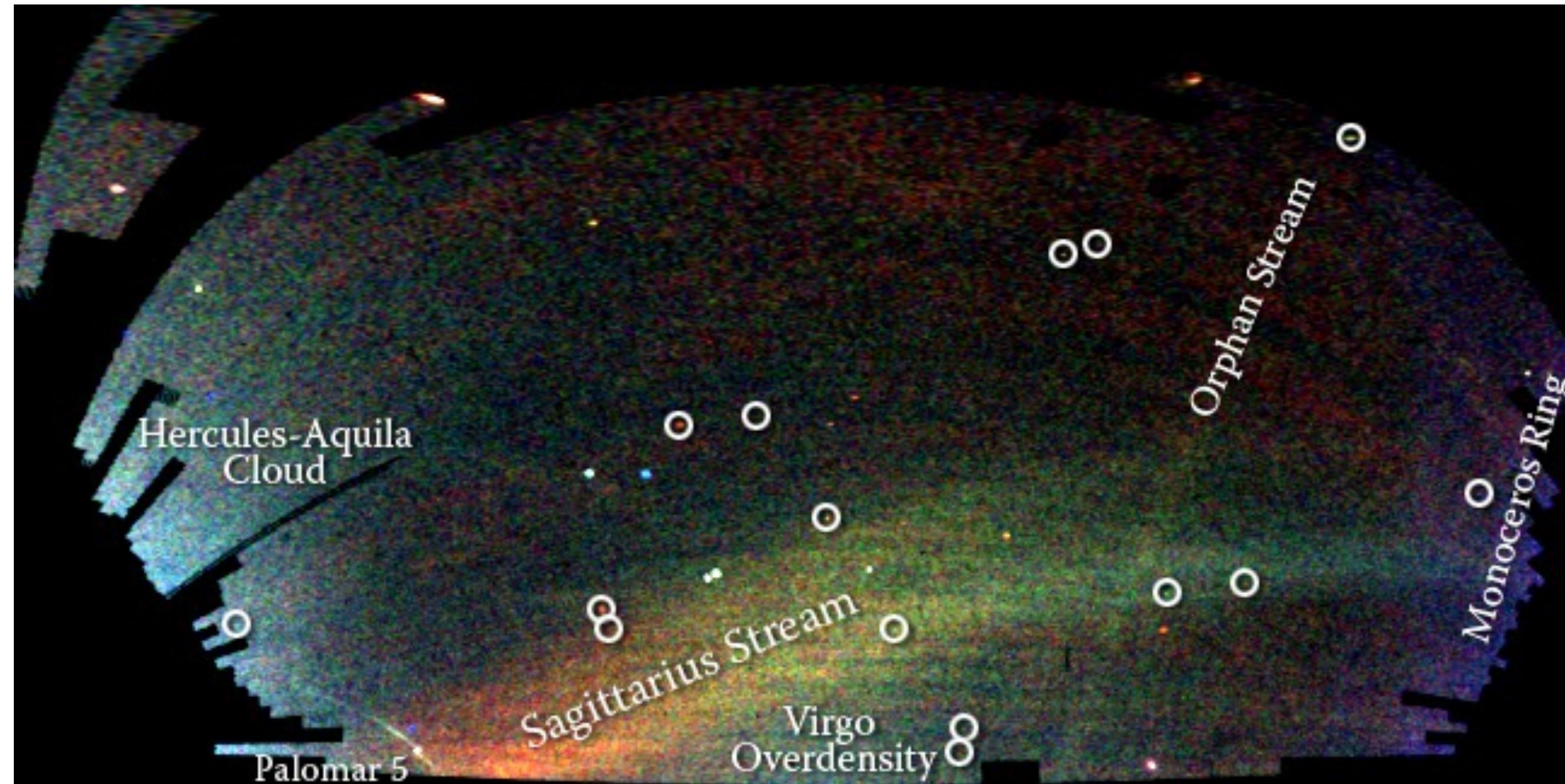
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The Halo

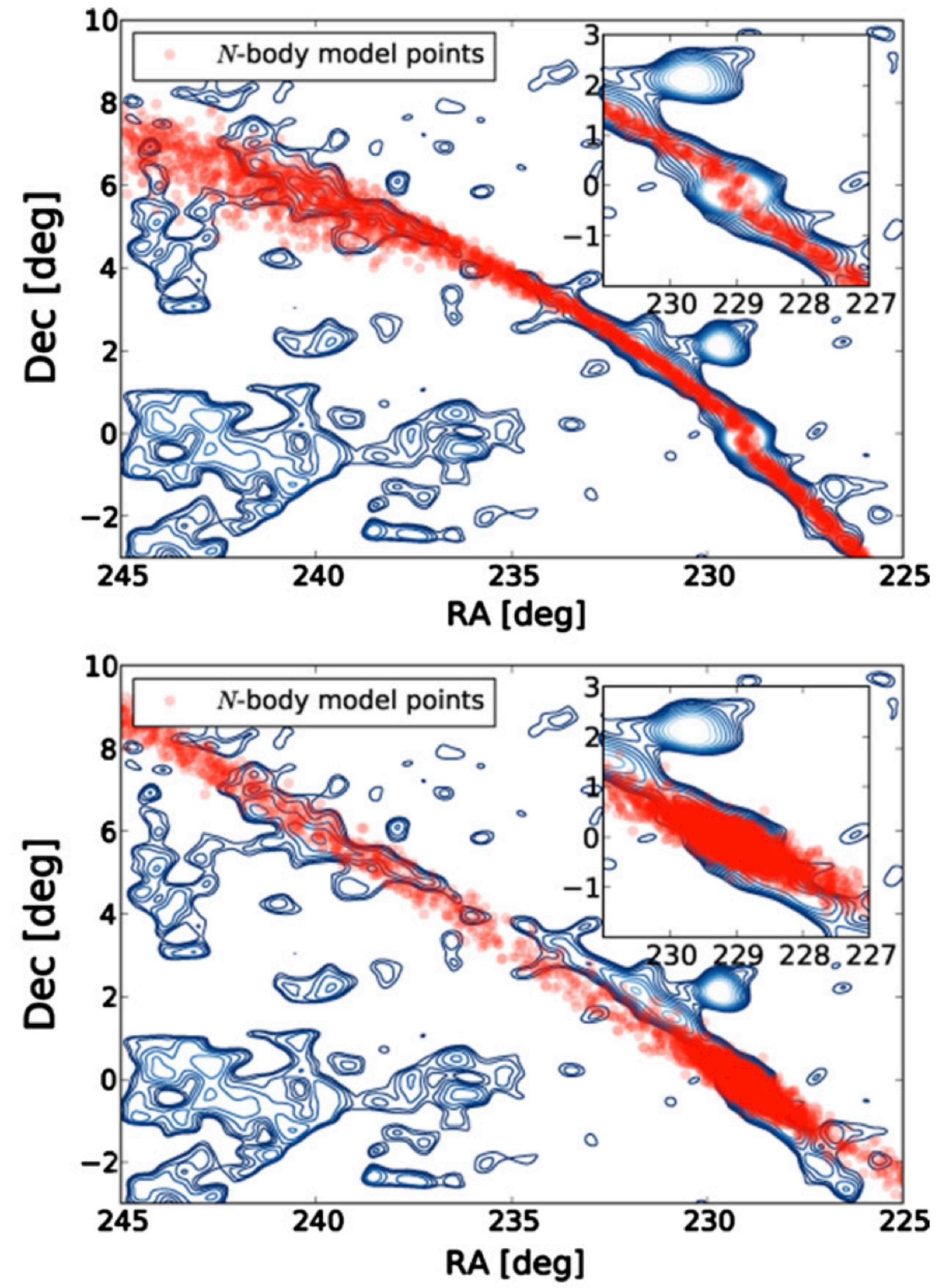
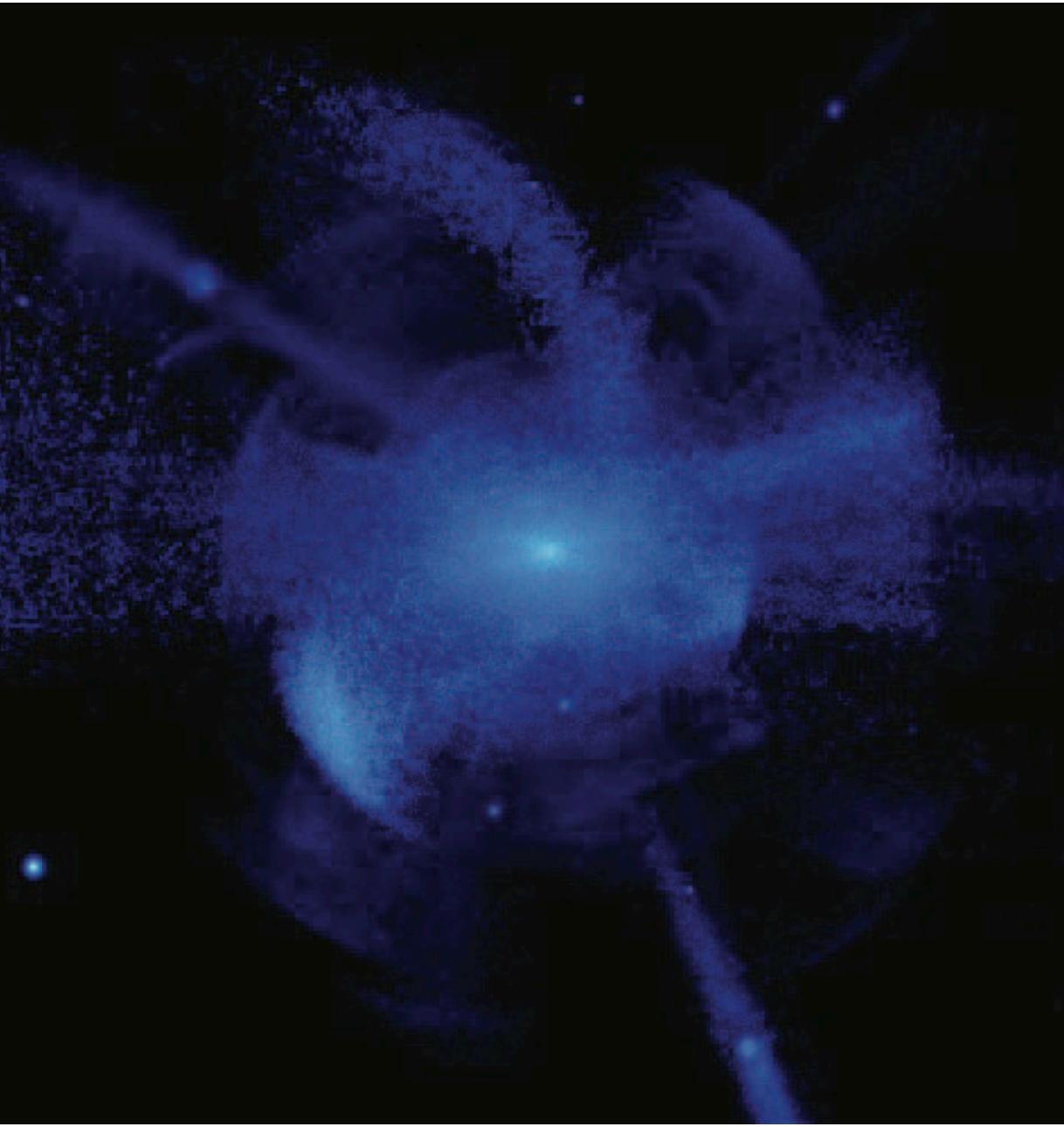
- Halo substructure & tidal streams! (Chasing Φ)

“Field of Streams”
Belokurov+2006



The Halo: Tidal Streams

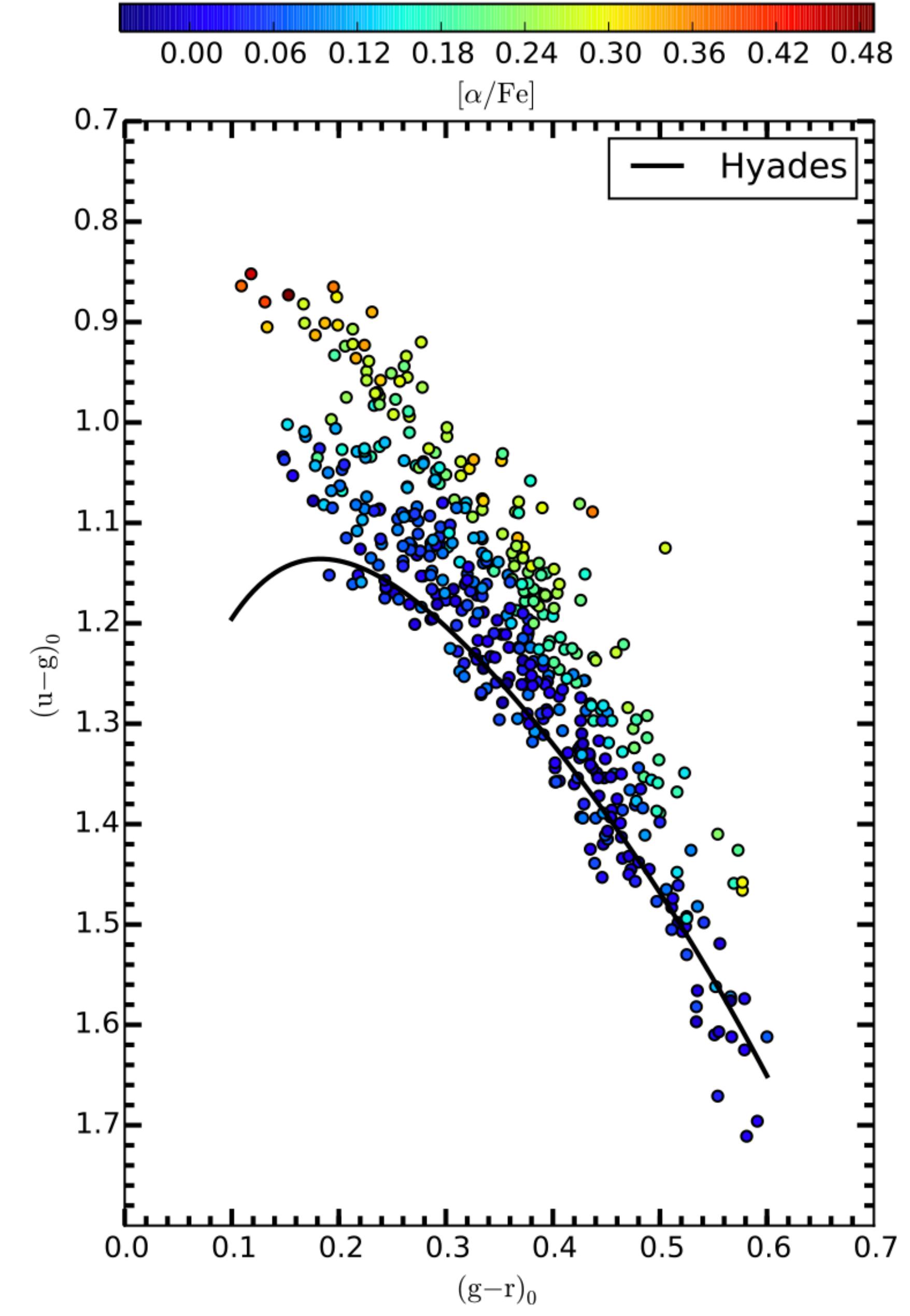
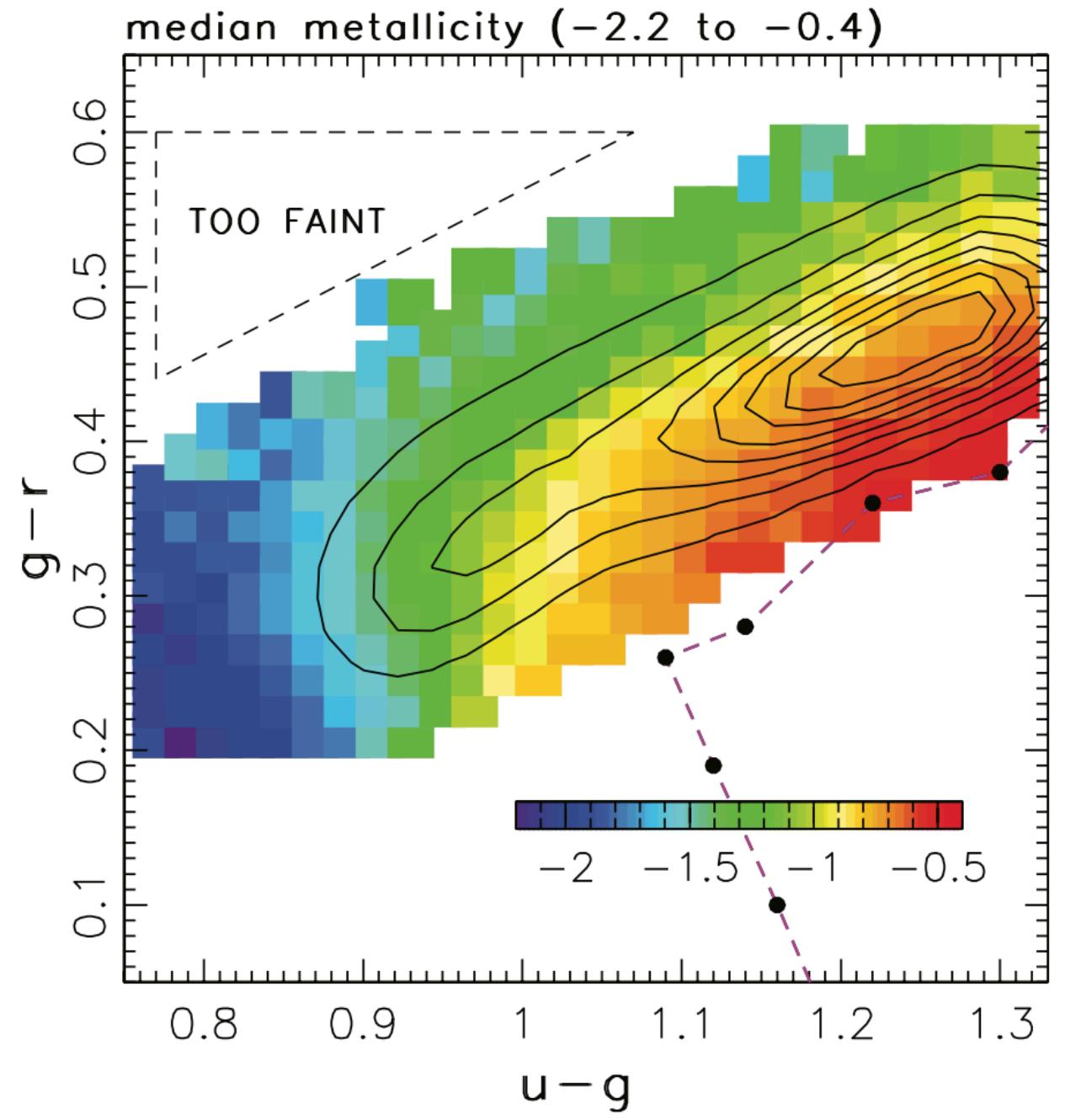
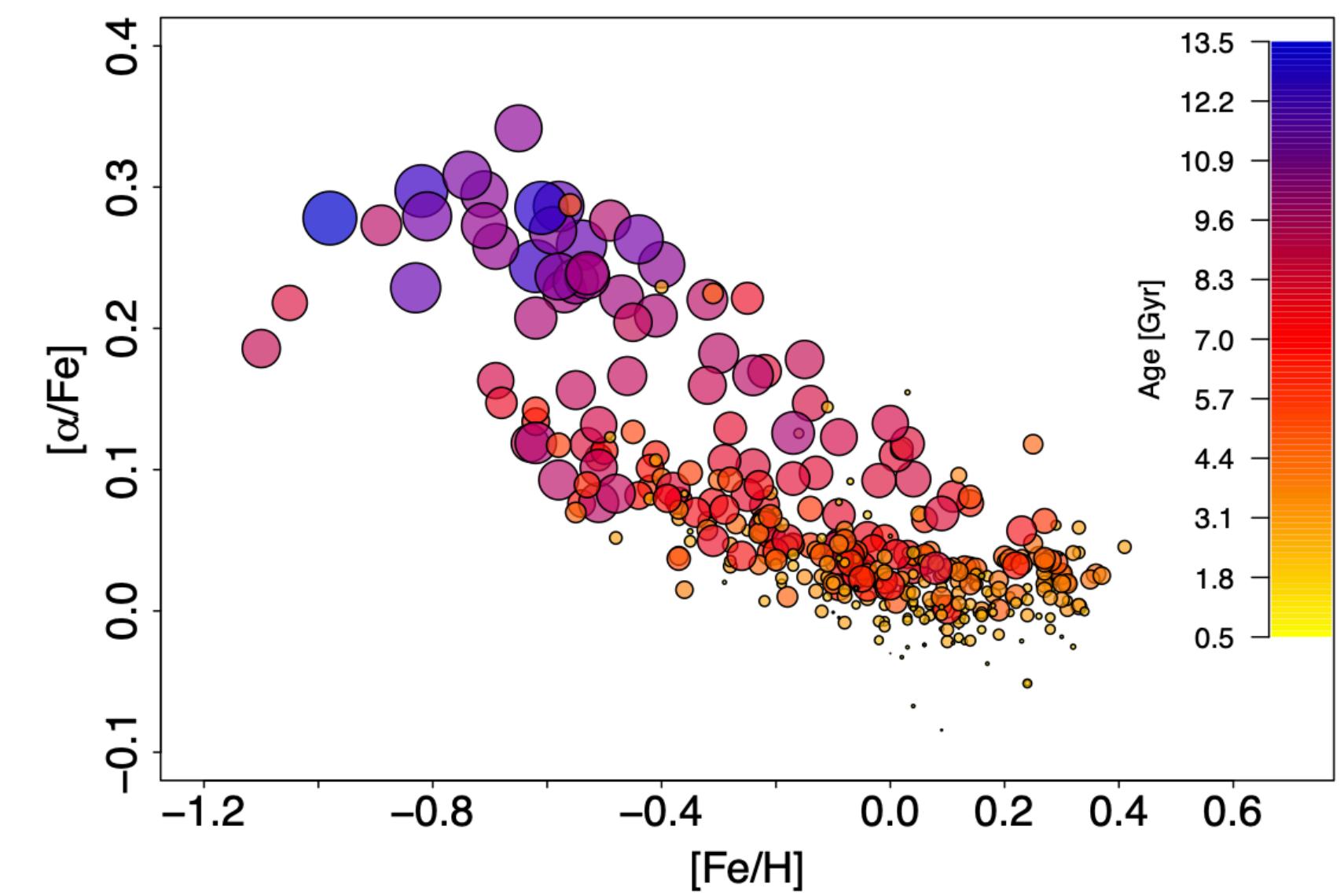
- Streams can measure shape of DM potential
- Stream populations/substructure trace the minor merger history for MWY



Pearson+2015

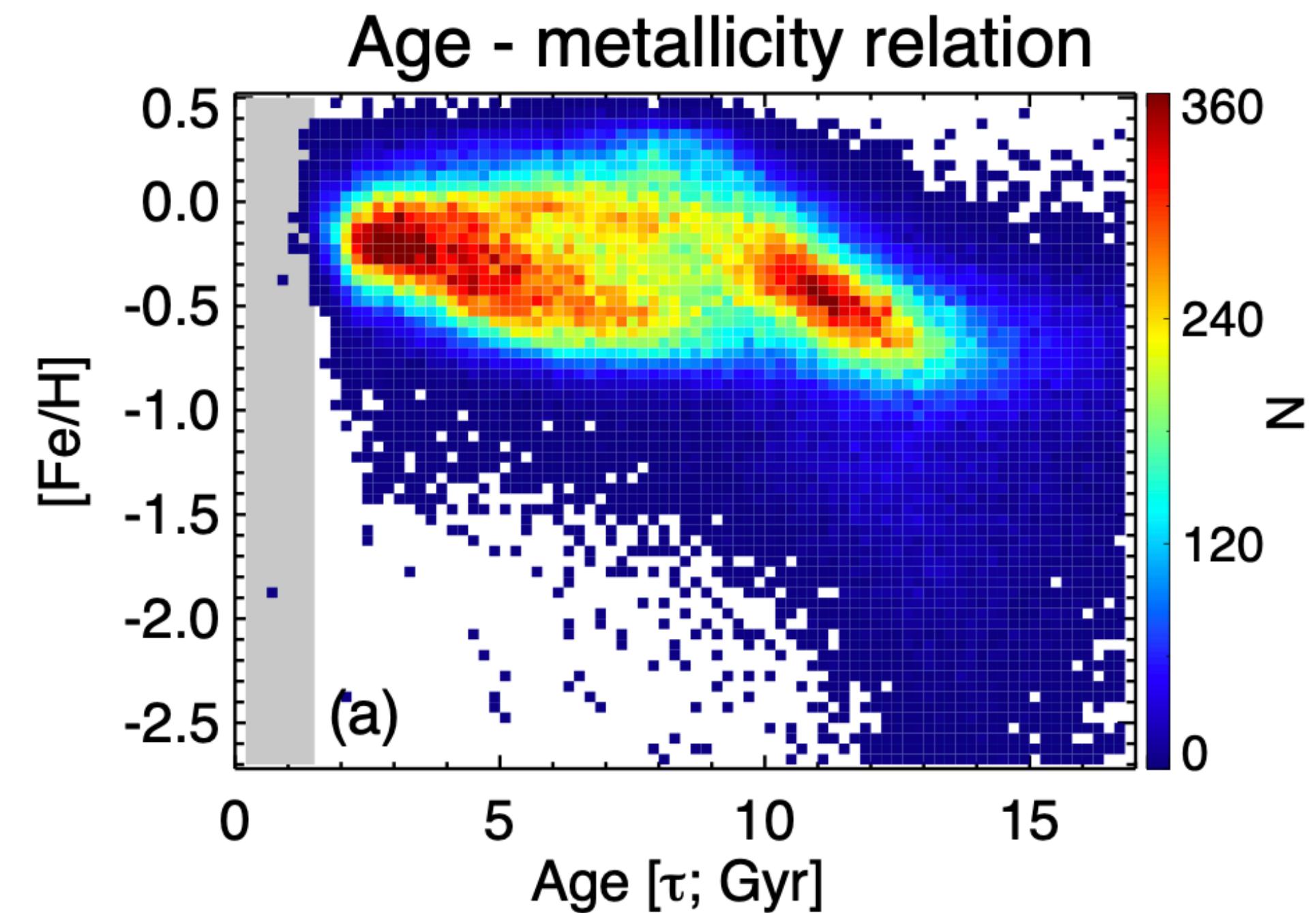
The Halo: Tidal Streams

- Might be able to tease out α -element indicators from photometry alone!
- Super useful for tracing halo structures (e.g. finding remnants)



Phase Space

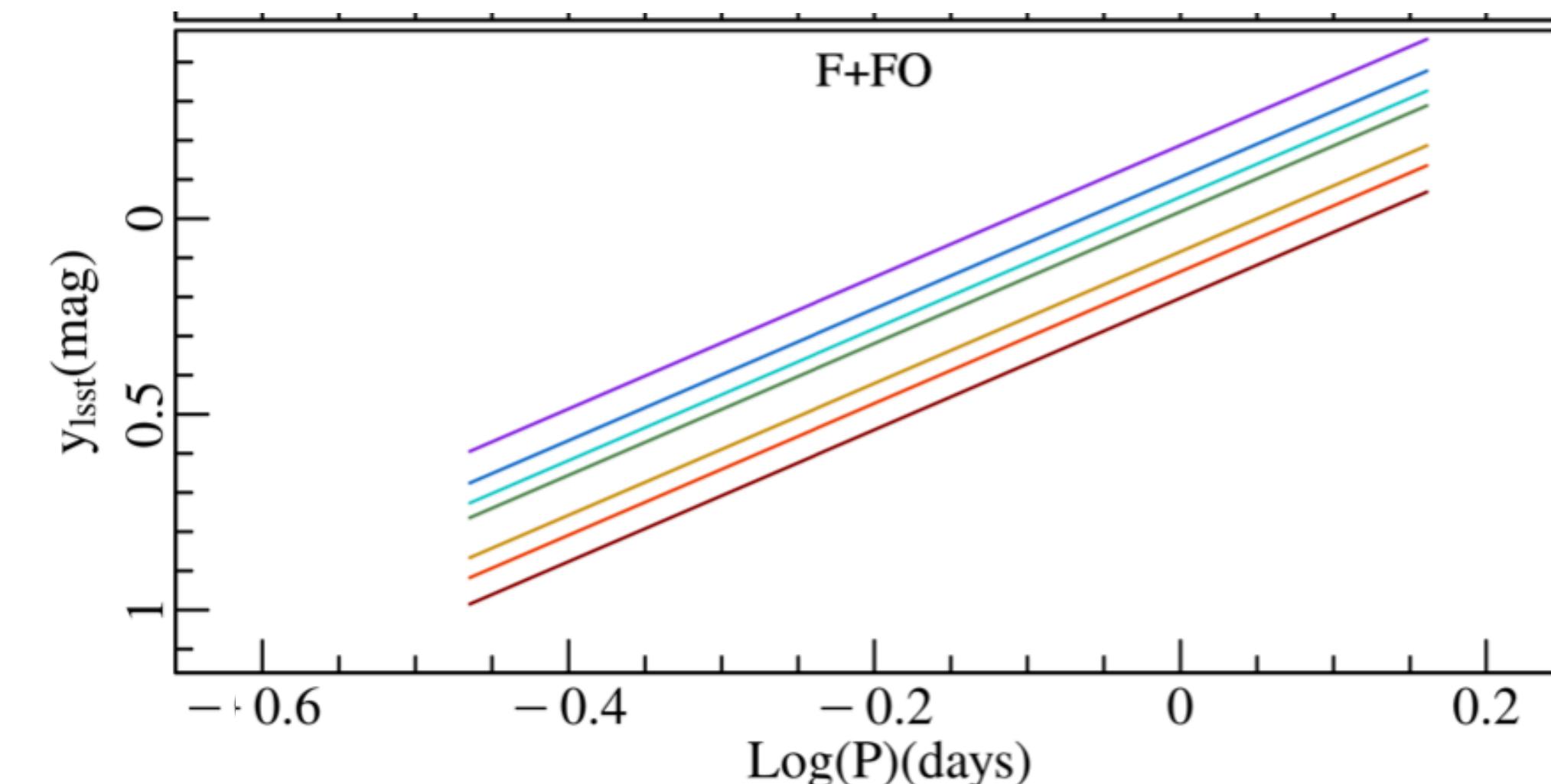
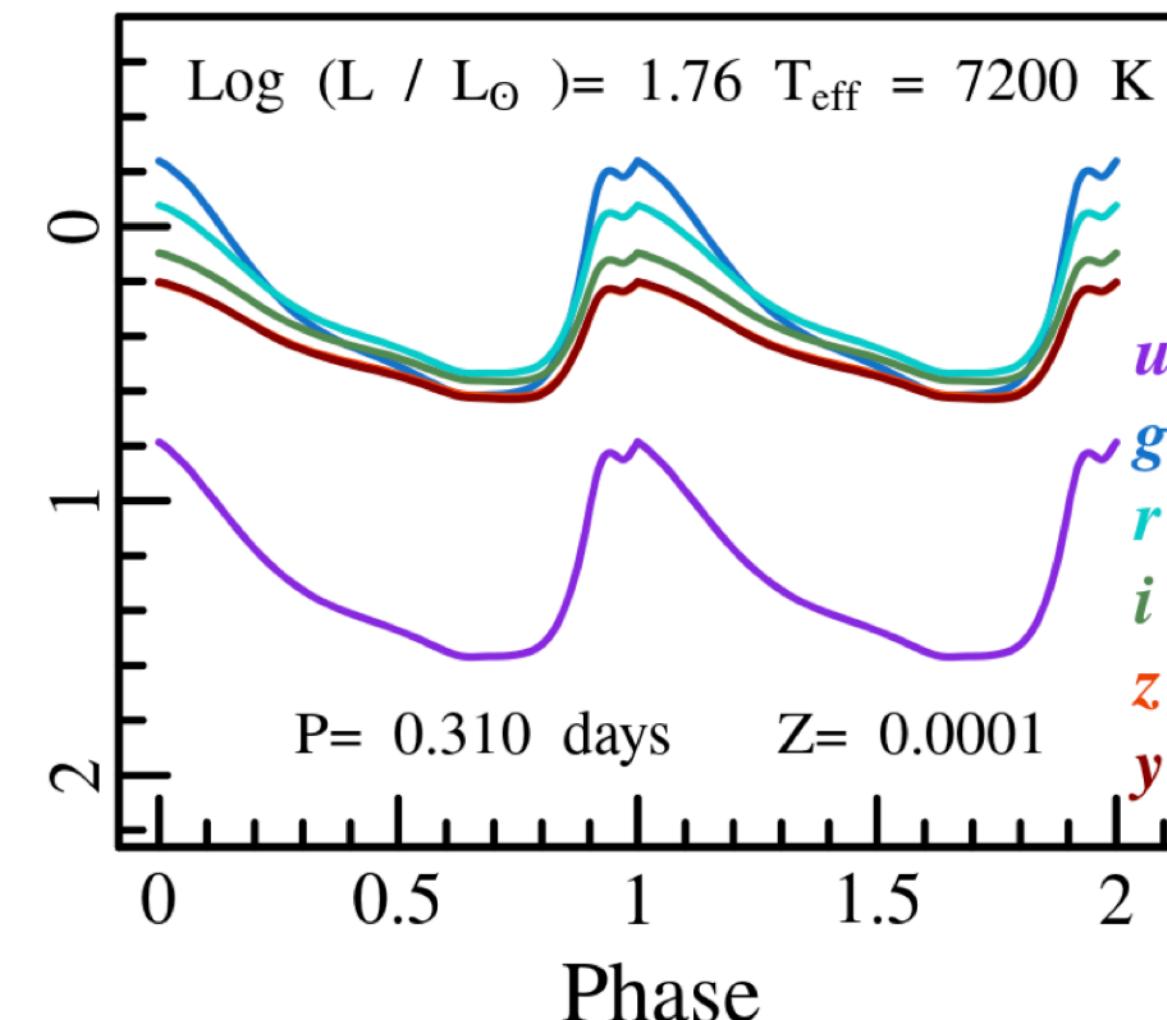
- This is ~all you can know about an objects instantaneous dynamics:
 - 3-D positions (u, v, w)
 - 3-D velocities (U, V, W)
 - 7-D if you include chemistry or age into the mix
- LSST will have excellent Photometric Metallicity
- LSST will have OK photometric distance
- But no radial velocities... **Only 6-D Phase Space**



Xiang & Rix (2022)

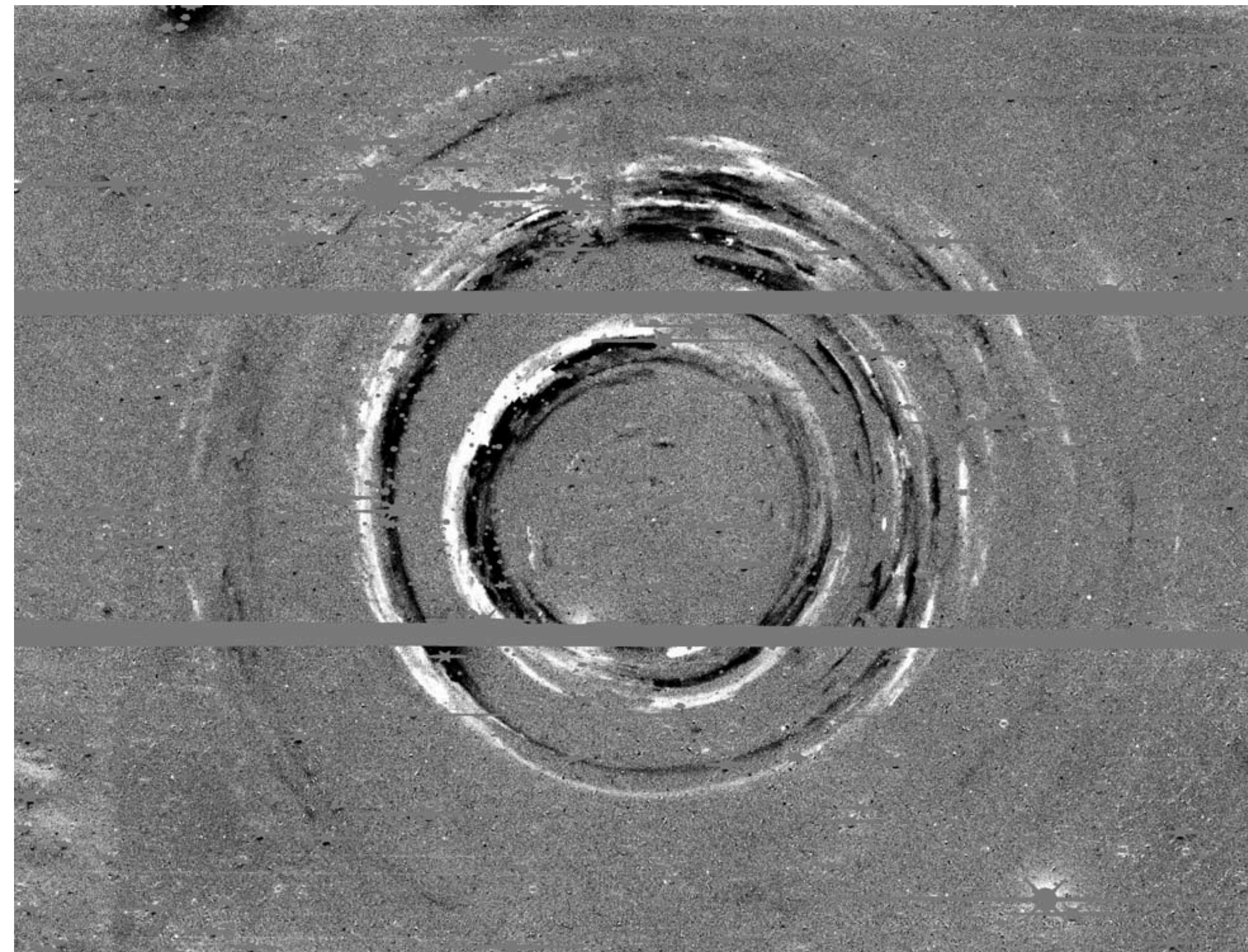
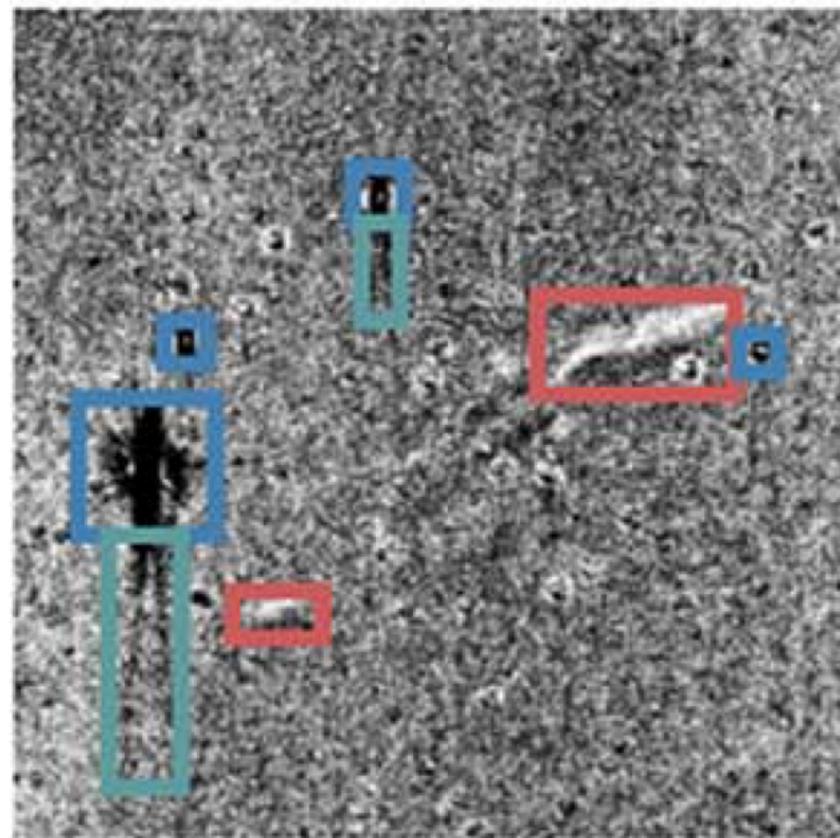
Phase Space & Rubin

- **Time series:** we haven't touched on time series in this class much, but e.g. RR Lyr, EBs, a few other critical variable types for studying the galaxy (esp. estimating distances)
- Also start to play statistical games: **can variability act as the new 7th-D for stars?** We'll have +10B of them.... Great compliment to Gaia here w/ ~2B
- Finding unique systems that challenge understanding of stellar formation and evolution, might be indicative of dynamical or chemical evolution



Many other cool things...

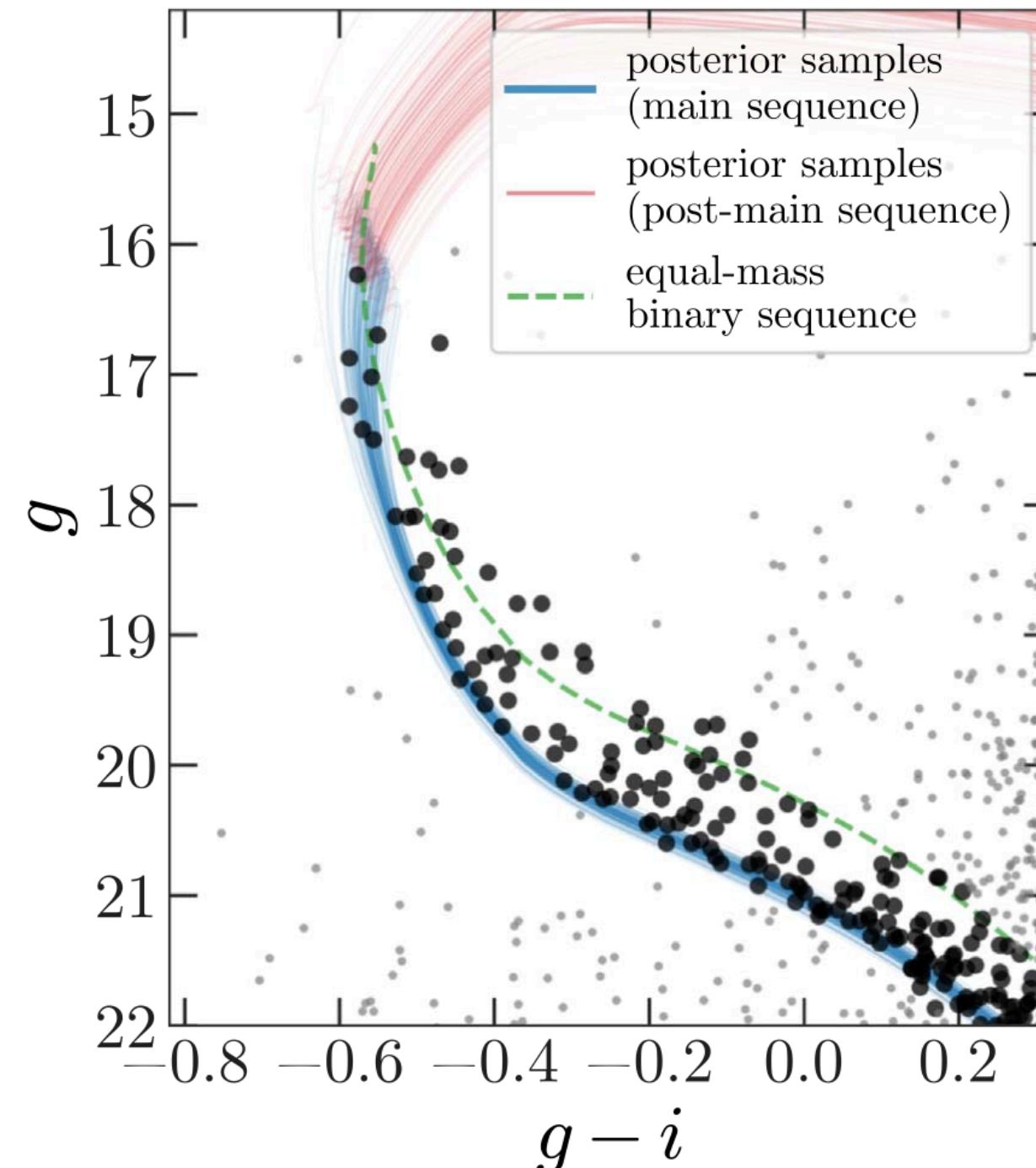
- *Historic* SNe light echos, a personal favorite (e.g. [Rest+2005](#))
 - Here an example from 4yrs of data in LMC: SN 1987A
 - Others seen, can find in MWY too
- Automate for Rubin! ([Li+2022](#))



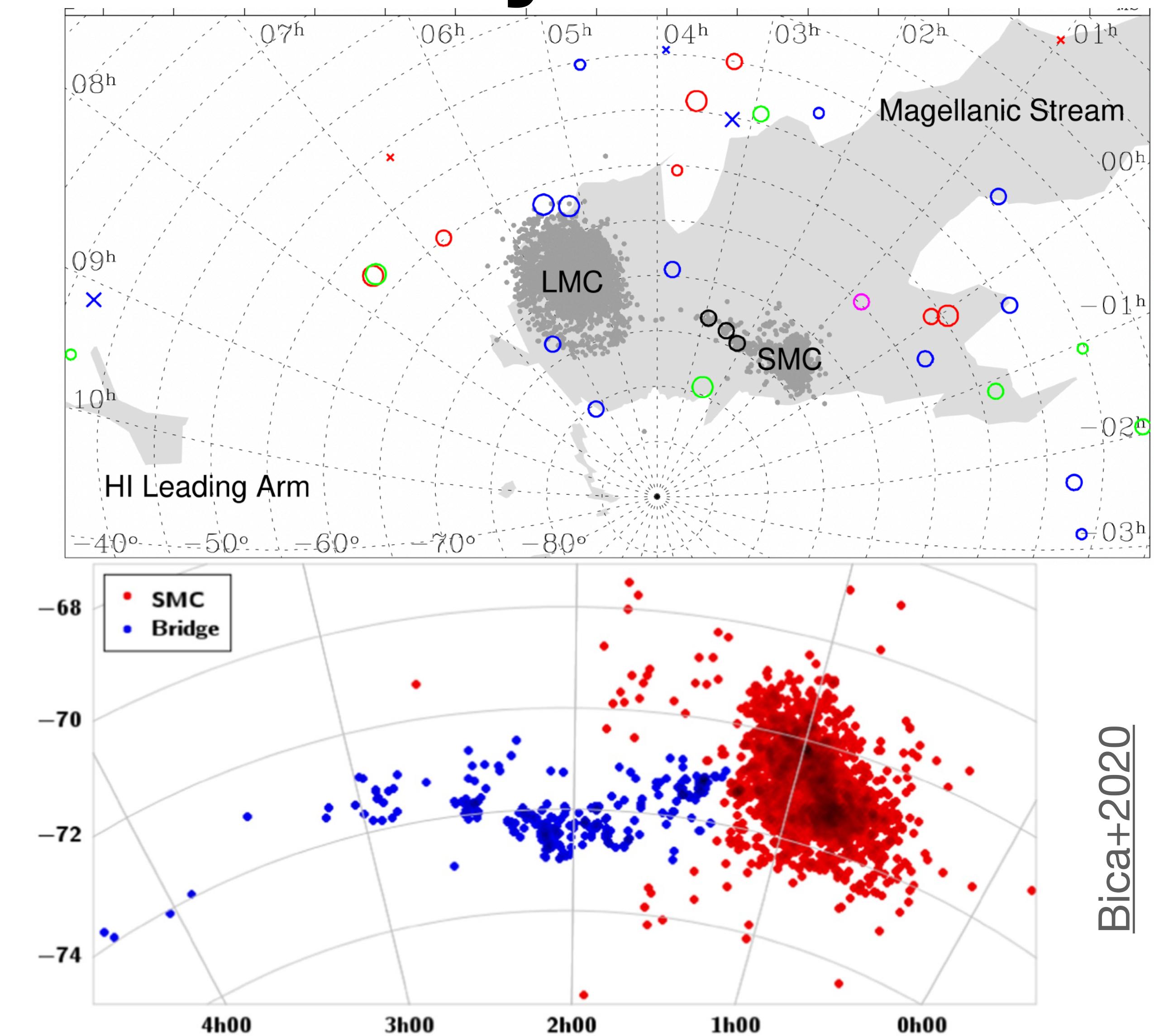
Rubin will observe LMC / SMC System!

- Study faint stars, structure across Bridge, Wing, Stream, Arms...
 - Look for new weird clusters in leading structure?

DECam data & isochrone models

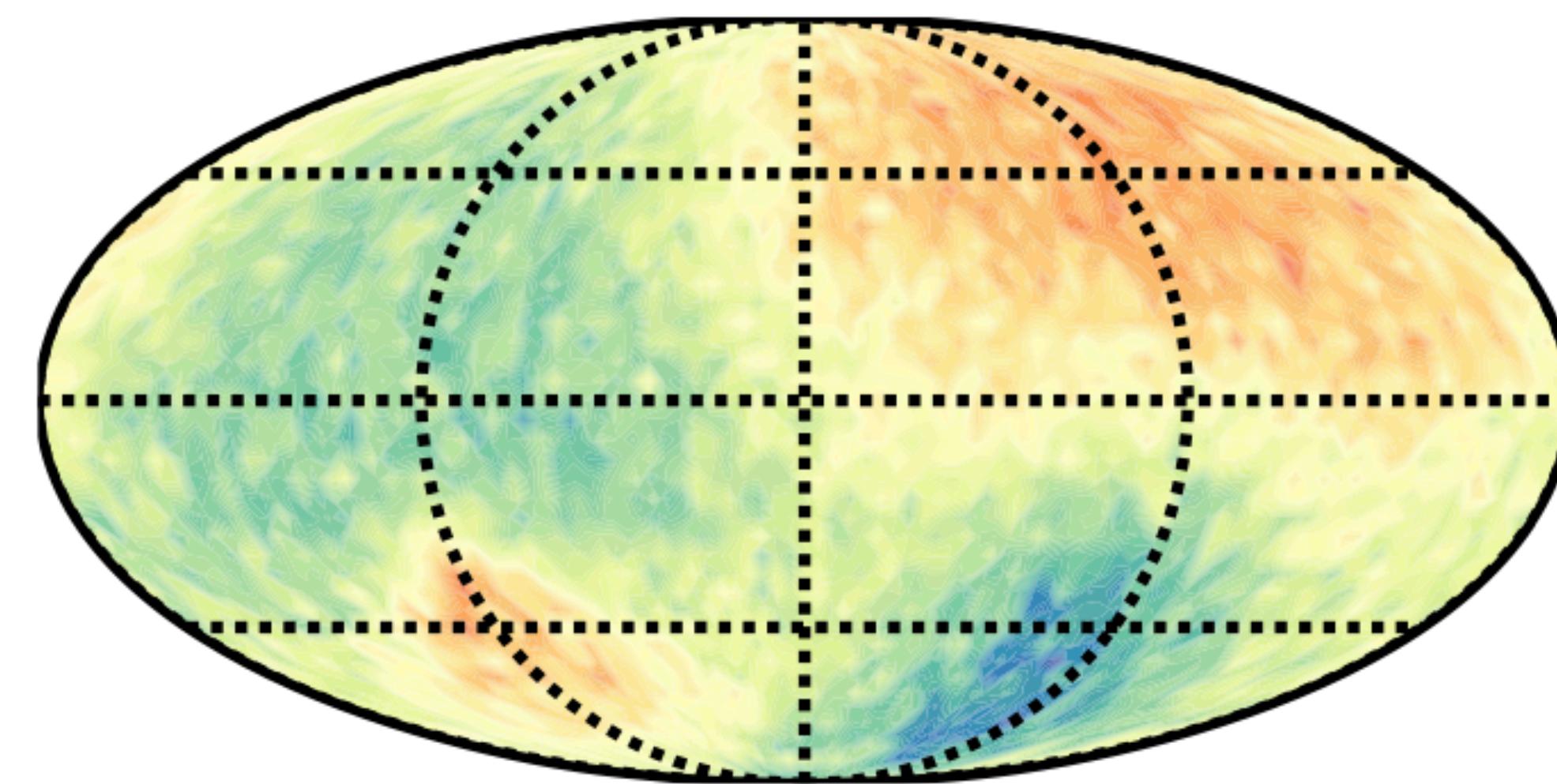
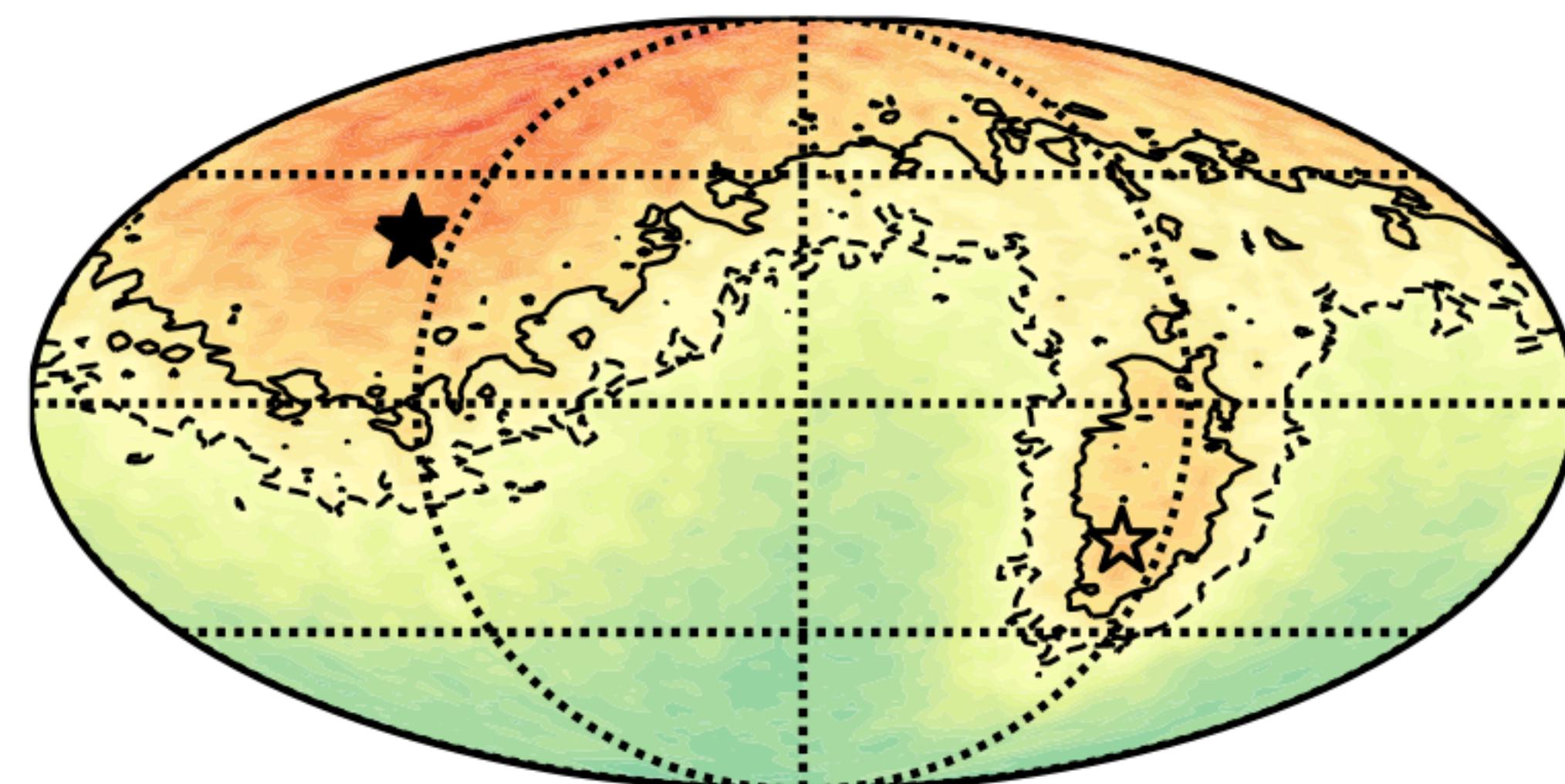


Price-Whelan+2019



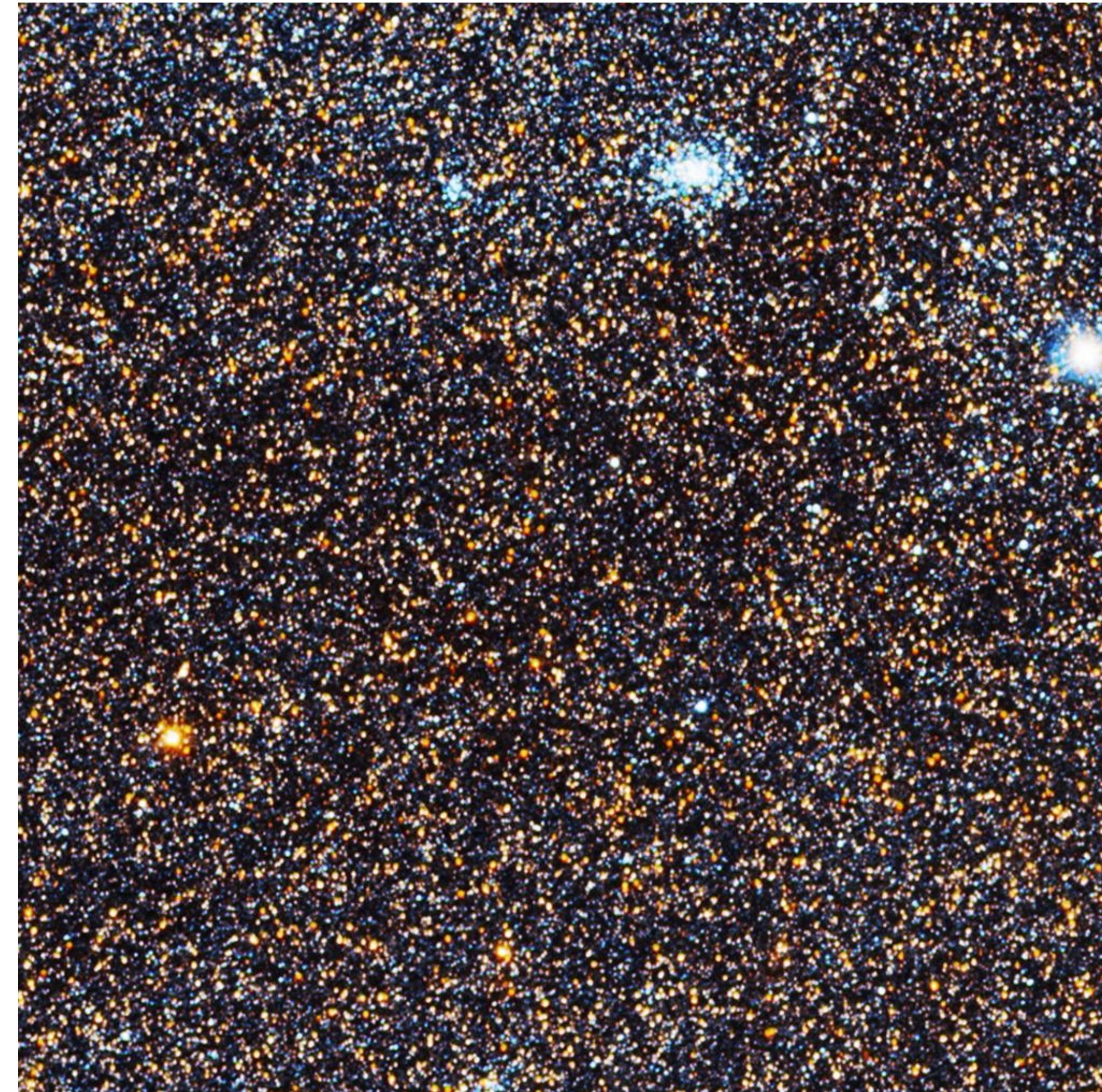
LMC Dark Matter Wake

- DM halo should already by interacting with MWY Halo
- *Should* be causing density (left) and RV (right) asymmetries in the MWY halo at large distances
- Help probe nature of DM particle?!



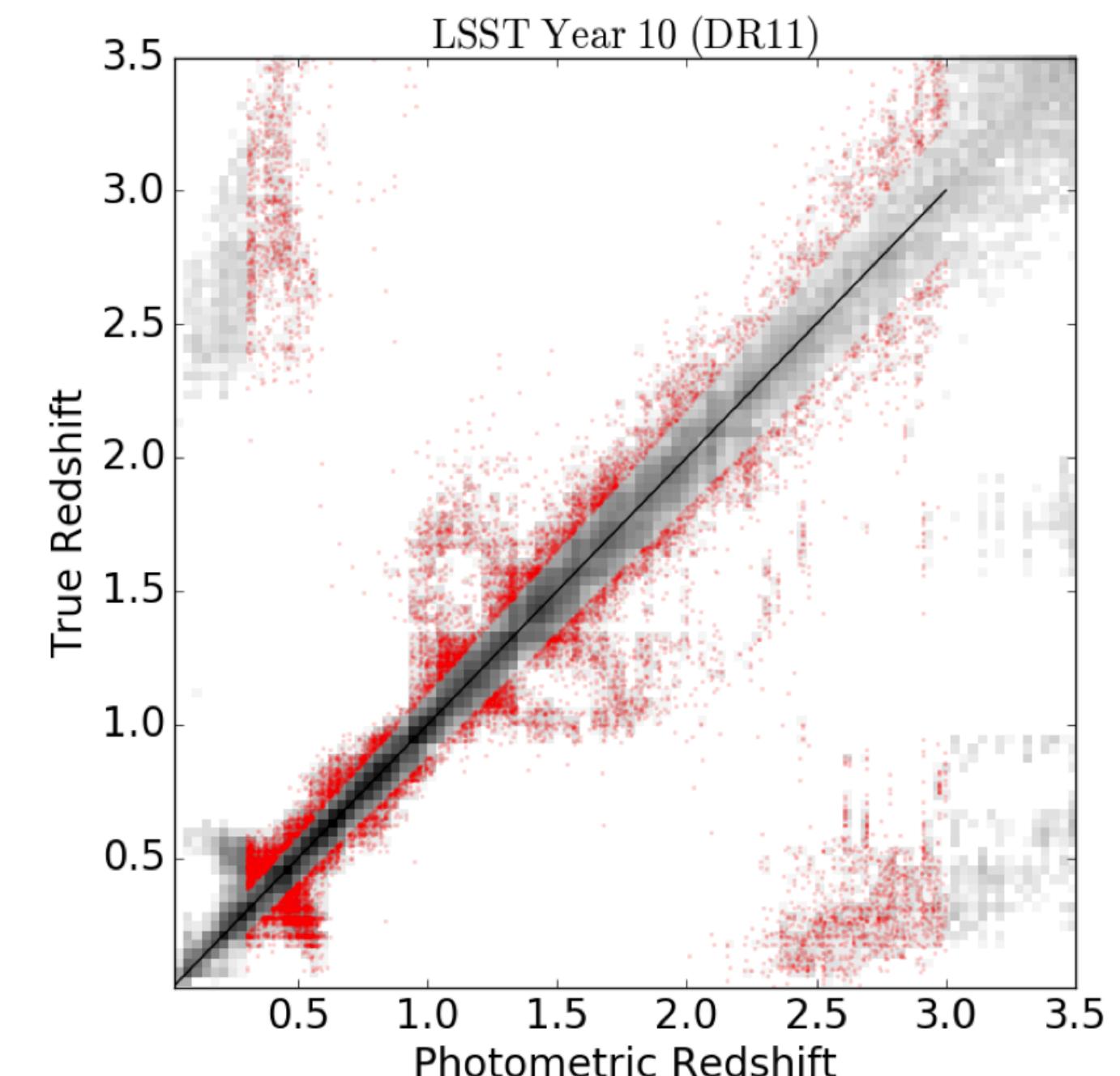
Nearby Galaxies

- Rubin can't quite resolve typical star separations ($\sim 1\text{pc}$) at 1Mpc
 - Only a factor of 2-3 off in spatial resolution for the Local Group
 - Brightest stars will be accessible
 - Search for variable sources (e.g. Novae, cepheids)



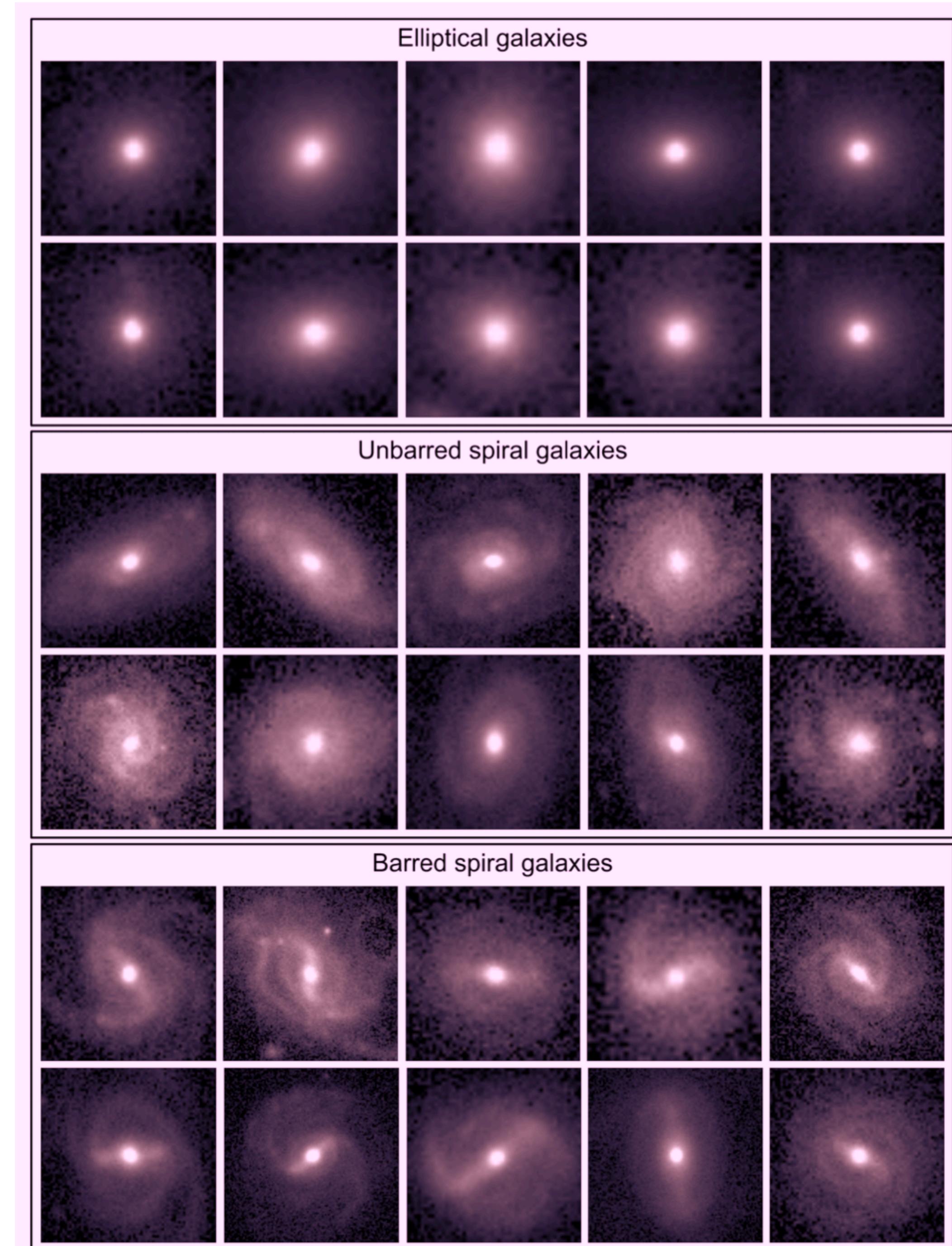
Distant Galaxies

- There will be ~20 Billion galaxies, possibly *most* numerous object type in 10-year LSST program!
- Galaxy morphology, low surface brightness streams/features
 - Best paper name I've seen this week: “A Stream Come True”
- Whole survey has design specifications around “photo-z” (redshift) estimates
 - That's why we have a y -filter, for super high redshift stuff (z-band drop-outs)



The Future

- We're already struggling to make efficient use of our data as a field... Rubin & LSST will make it worse/better
- Huge samples means asking questions via statistics & demographics (e.g. MWY structure)
- Also allows search for very unique/strange (e.g. sub-structure, tidal streams)
- Locally (UW) we likely to entire another “magic moment” where ~everyone is impacted by LSST for a few years!



The End

- Next week: your presentations! Schedule on the class Slack channel
- **THANK YOU for a fun quarter being your instructor**

