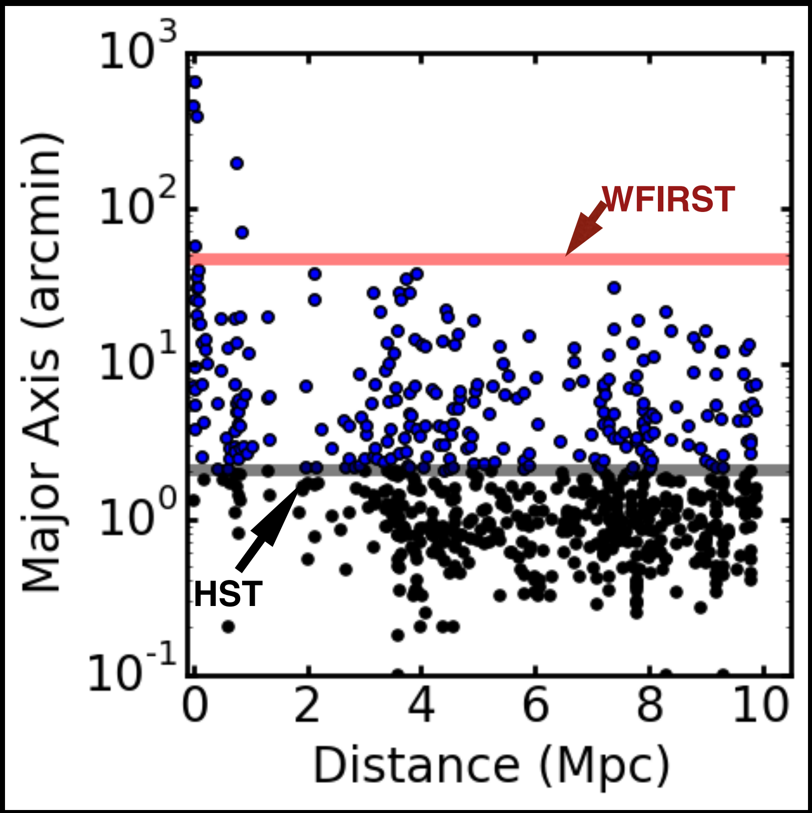
WFIRST Infrared Nearby Galaxy Survey

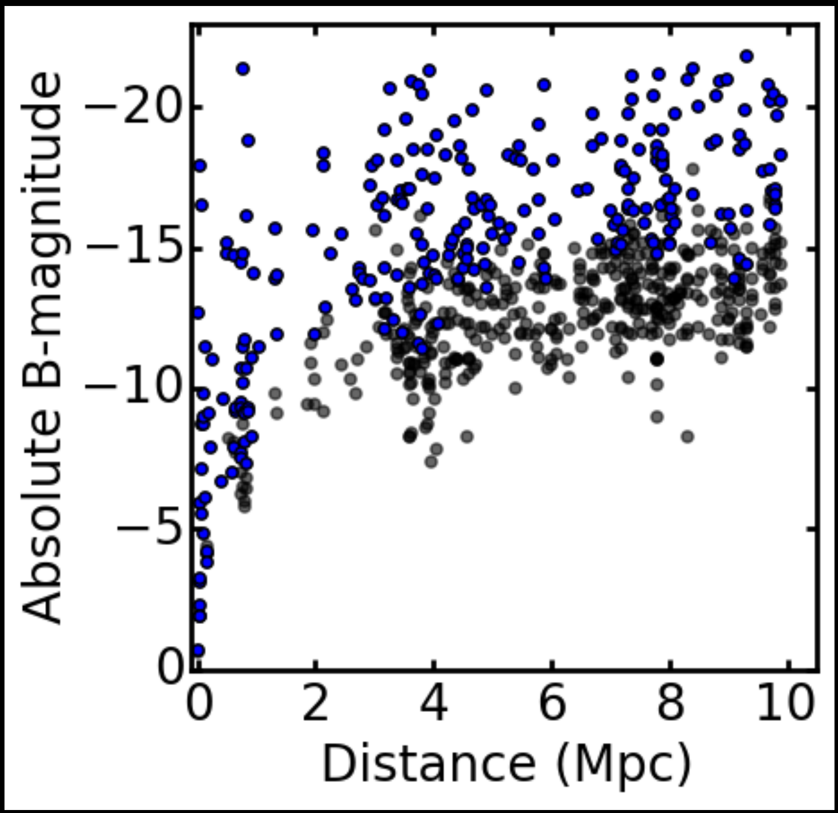
Ben Williams (University of Washington)

Nearby Galaxies Are Great for Astrophysics

- Detailed view and context simultaneously
- Sensitive to galaxy evolution and cosmology
- Anchor our knowledge for interpretation of more distant universe
- Large samples - Subdivide sample for specific goals
- Cover a wide range of galaxy properties

Huge Potential Data Set





Projects and Lead Co-Is

PI: Williams (U. Wash.) Deputy PI: *Dalcanton (U. Wash.)*

Postdoc: Open! (U.Wash.)

Photometry	Dolphin (Raytheon)
Stellar Halos	Bell (Mich.), Johnston (Columbia), Bullock (Irvine)
Dwarf Satellites	Sand (UA), Bullock (Irvine)
Small Scale Dark Matter	Walker (CMU), Johnston (Columbia)
Globular Clusters	Seth (Utah)
Star Formation Histories	Weisz (Berkeley)
Dust & ISM	Gordon (STScI), Dalcanton (UW)
Stellar Evolution	*Boyer (STScI)*

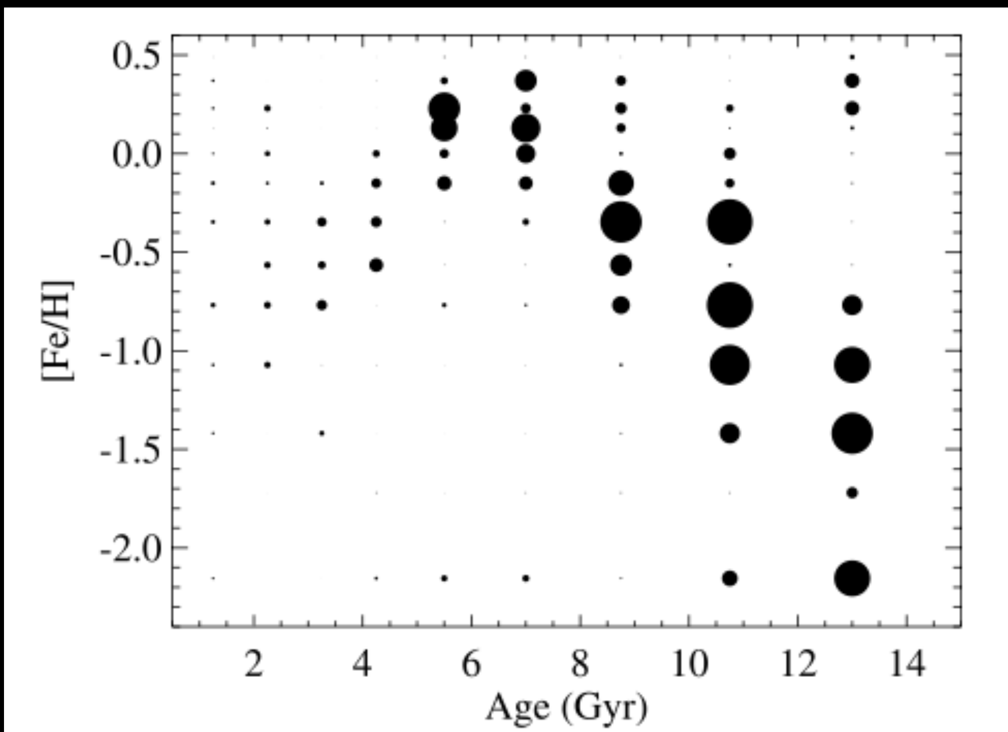
Collaborators

Raja Guhathakurta (UCSC)
Denija Crnojevic (TTU)
Marina Rejkuba (ESO)
Antonela Monachesi (MPA)
Alan McConnachie (HIA)
Laura Sales (UCR)
Karin Sandstrom (UCSD)
Julia Roman-Duval (STScI)
Alberto Bolatto (Maryland)
Josh Peek (STScI)
Jay Anderson (STScI)
David Hendel (Columbia)
Meredith Durbin (UW)
Andrew Graus (Irvine)
Tyler Kelley (Irvine)

Anna Yu (Irvine)
David Hendel (Toronto)
Amy Secunda (Columbia)
Beth Willman (LSST)
Margaret Meixner (STScI)
Leo Girardi (Padova)
Nicolas Martin (MPIA)
Kristy McQuinn (UT)
Cliff Johnson (UCSD)
Jay Strader (MSU)
Robyn Sanderson (Caltech)
Adrian Price-Whelan (Columbia)
Sergey Koposov (Cambridge)
Julio Chaname (Catolica)
Jorge Penarrubia (Edinburgh)
Coral Rose Wheeler (Caltech)

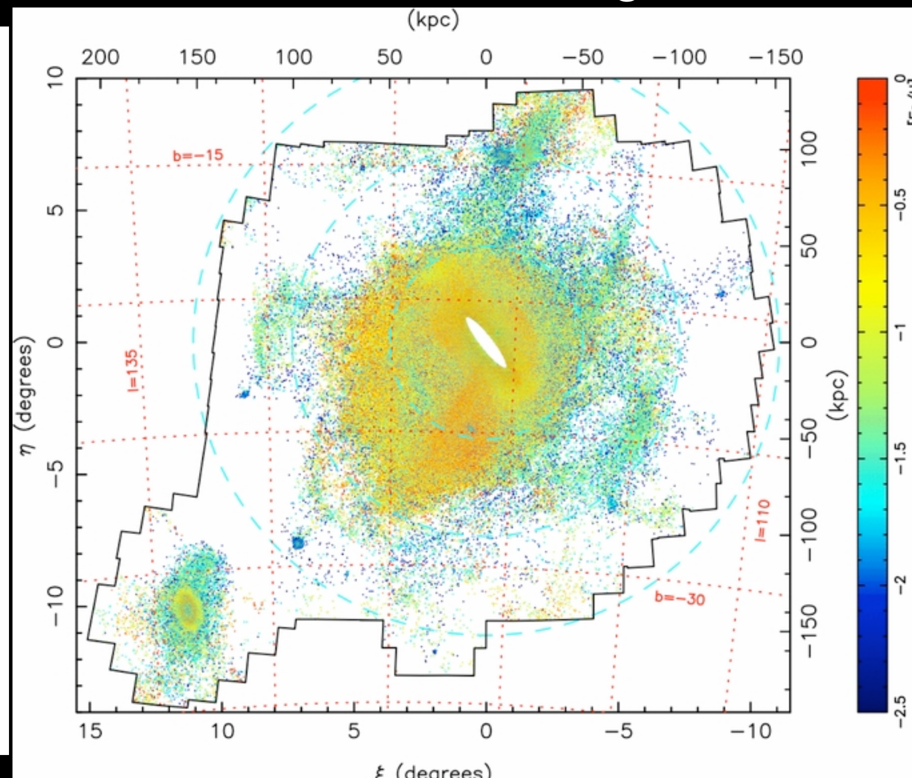
Stellar Halos

Details from HST



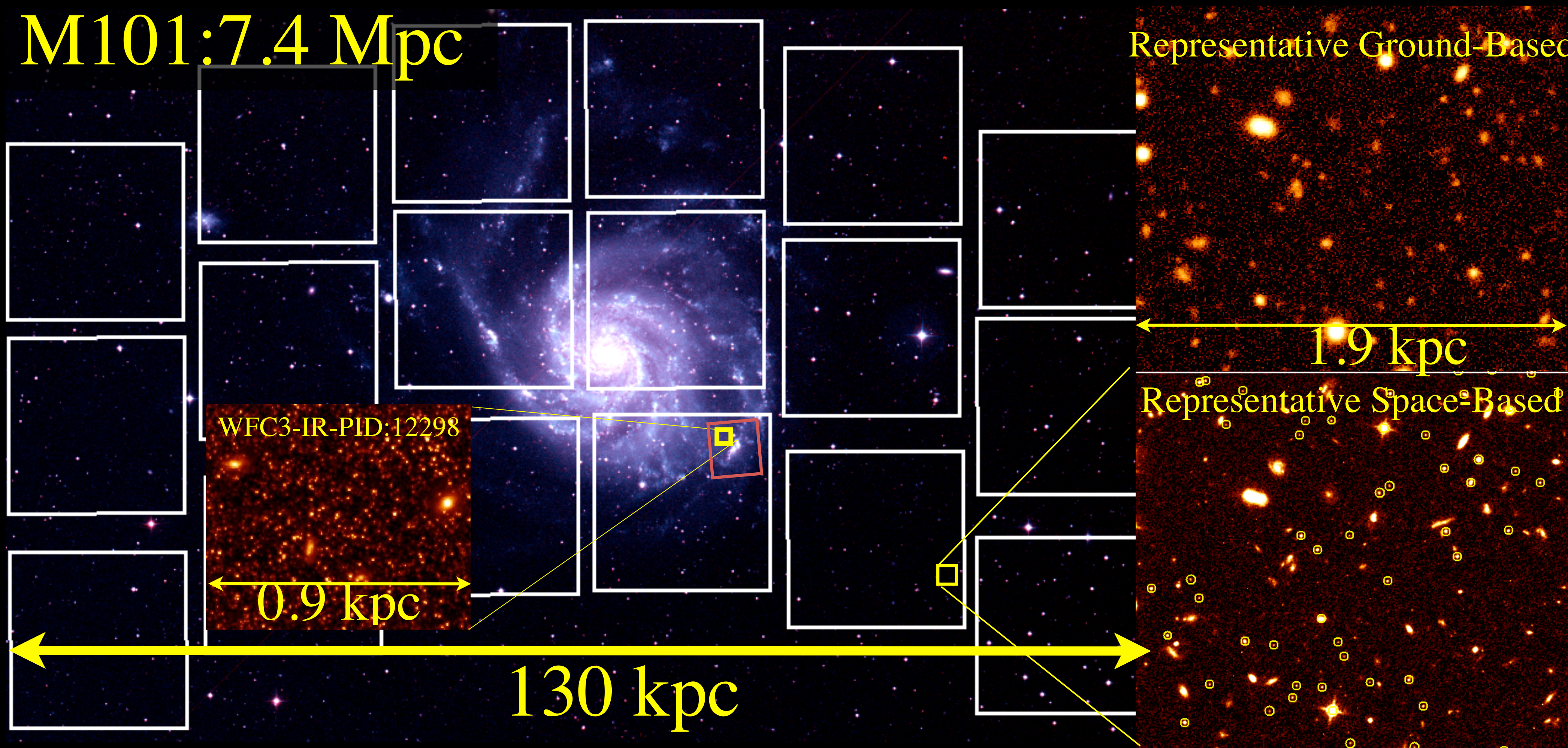
Brown et al. 2006

Context from ground

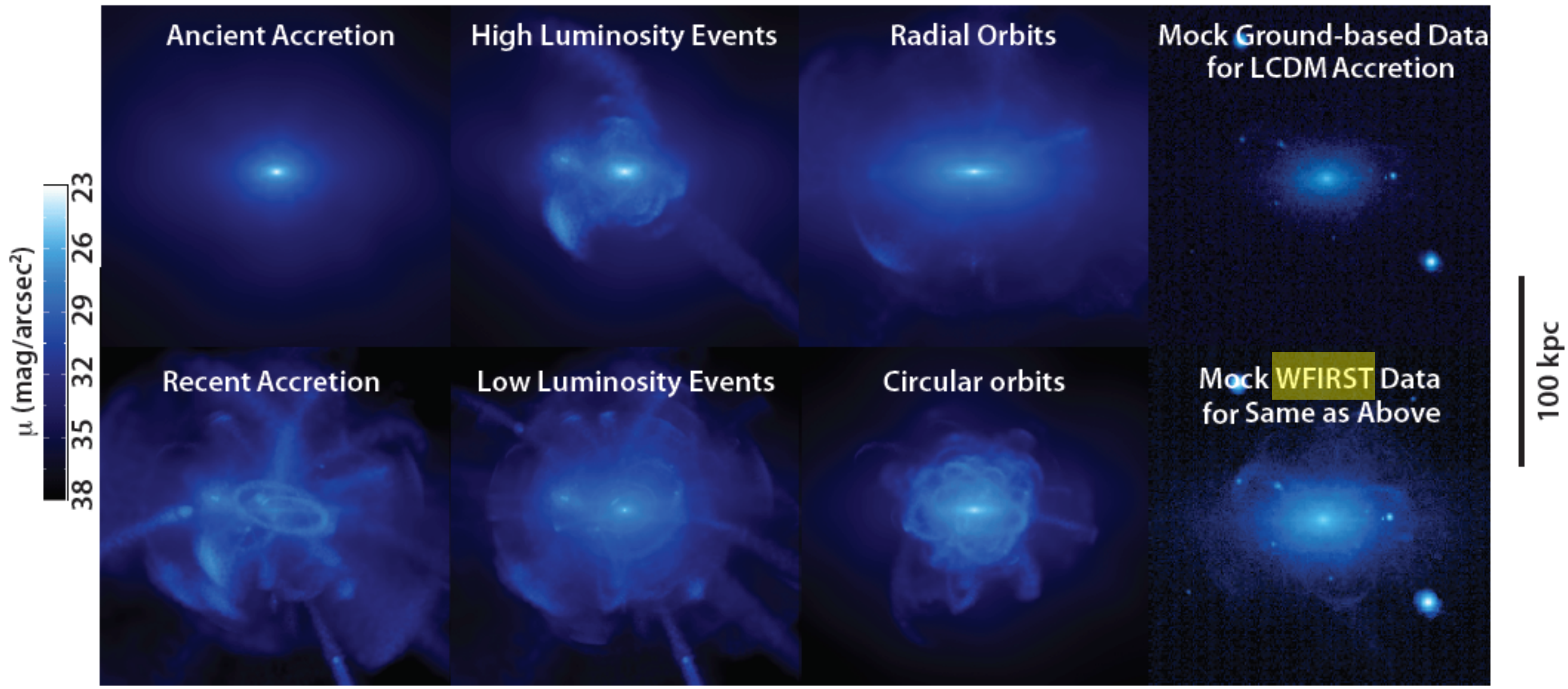


Ibata et al. 2014

Stellar Halos with WFIRST



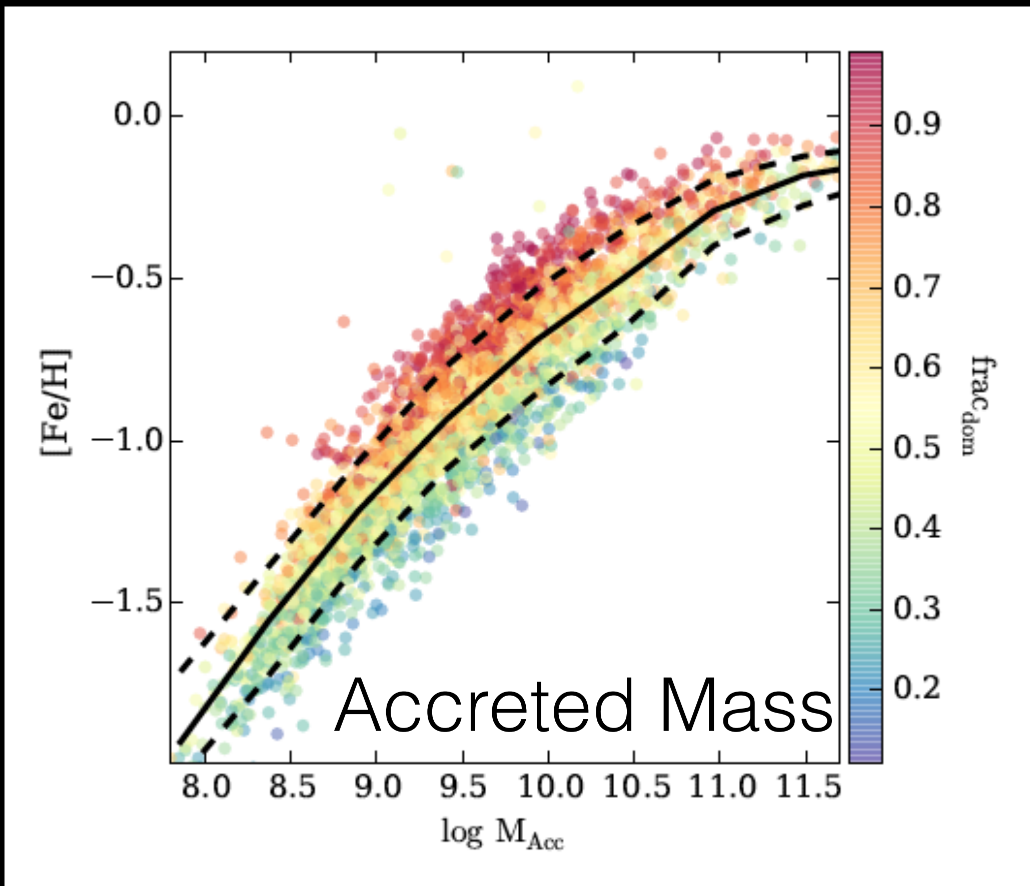
Stellar Halo Structures

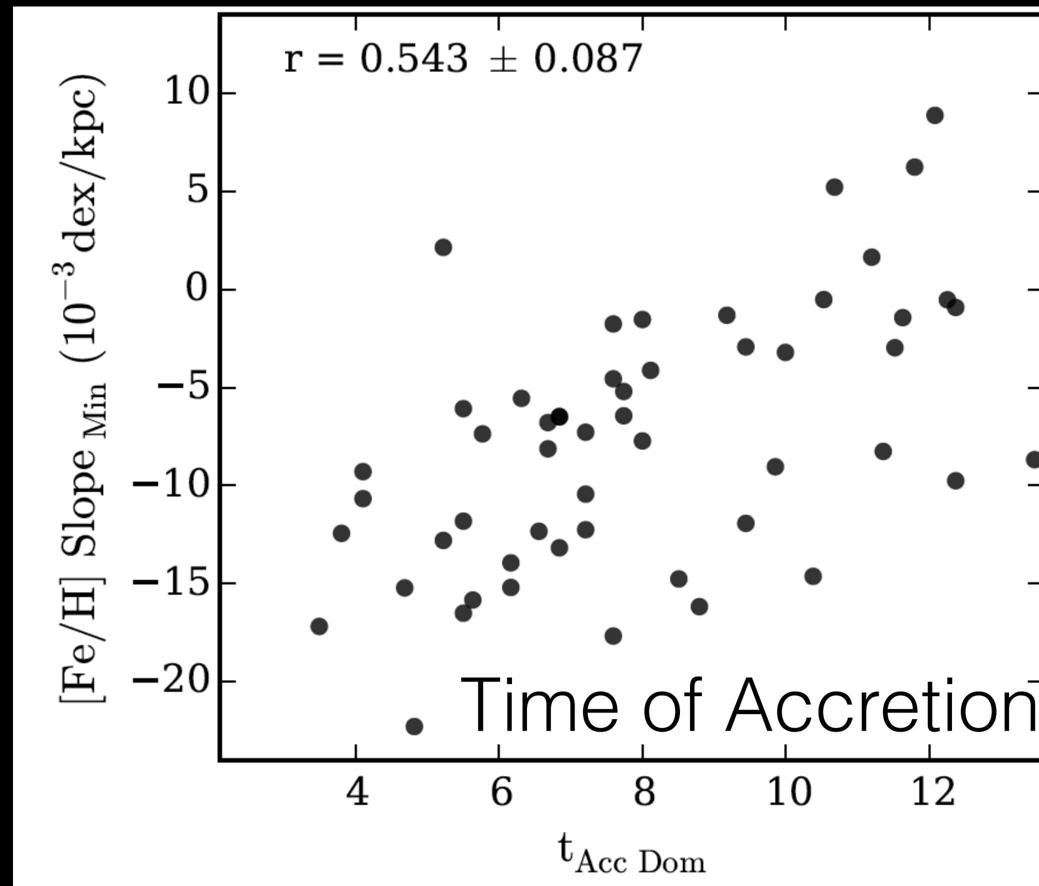


Number, luminosity, shape of streams → Types, timing and orbits of galaxies accreted.

Disrupted streams → Small-scale dark matter halos.

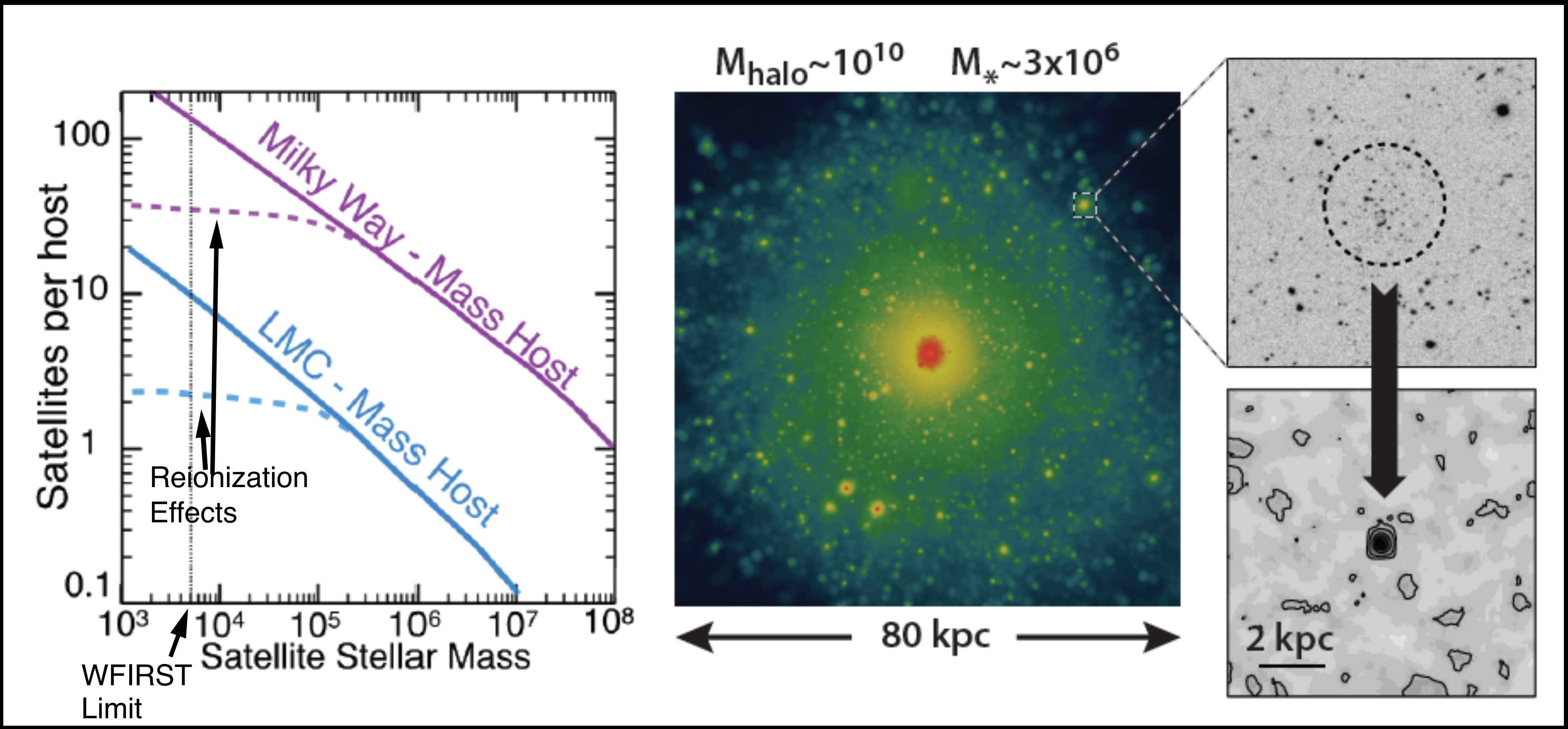
Accreted Halo Metallicity and Accretion History





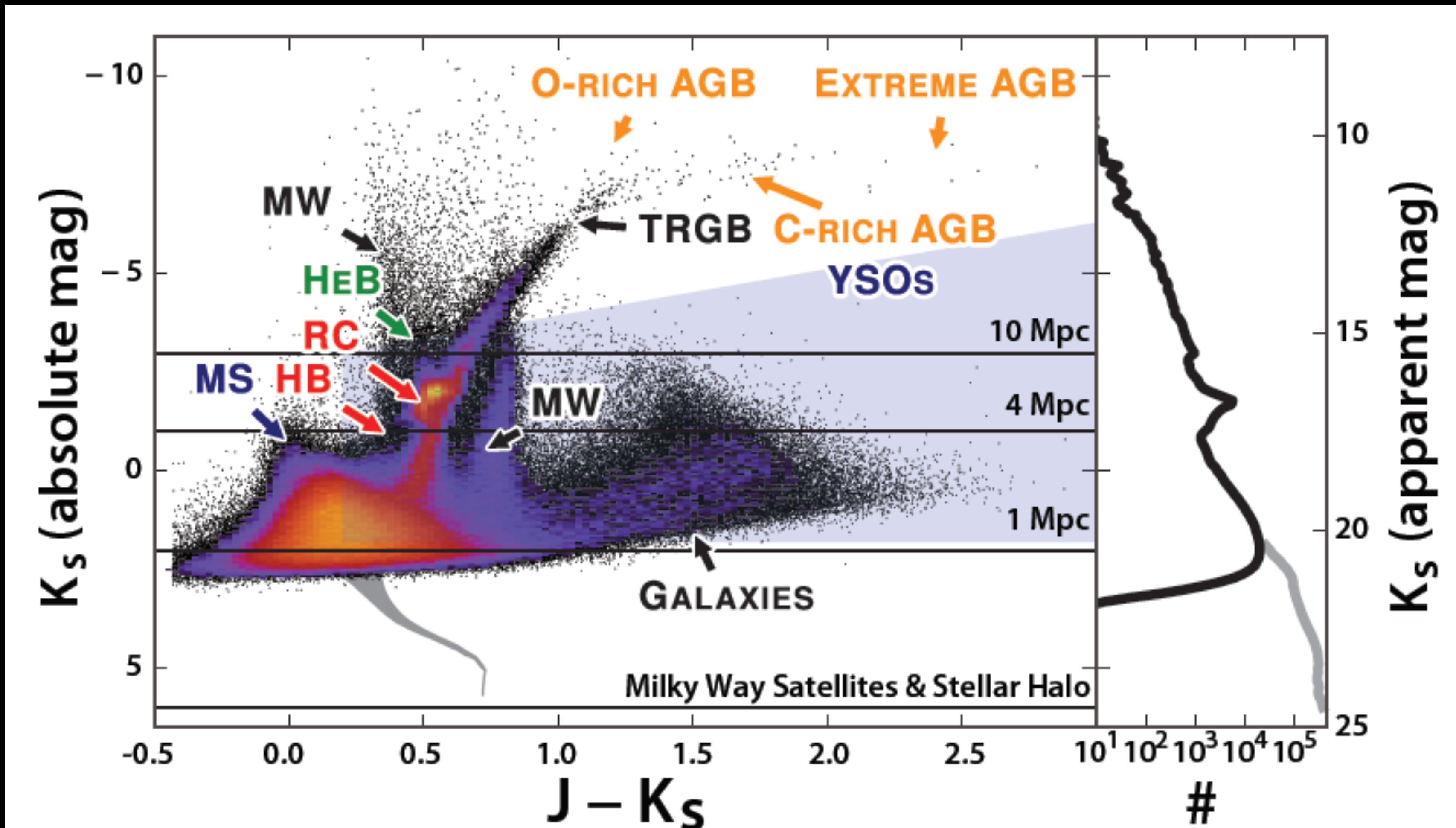
D'Souza & Bell, 2017; from Illustris simulations

Dwarf Satellites



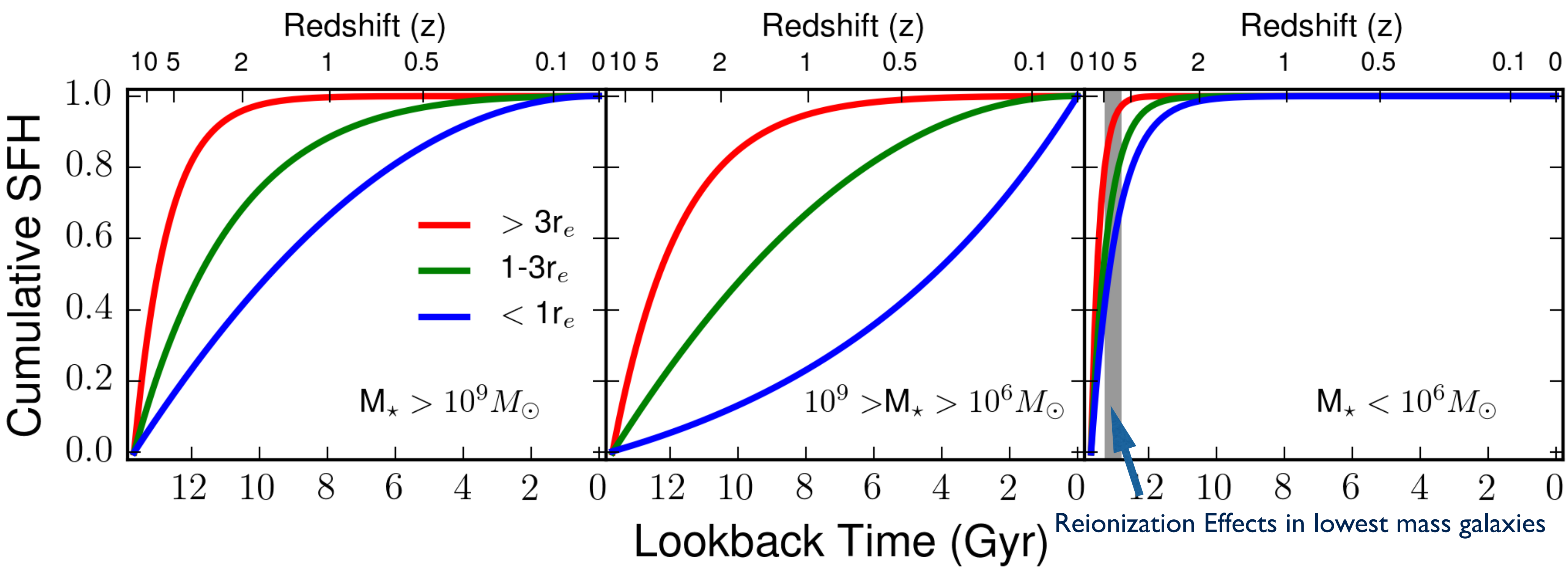
Lots of dark, sub-galactic halo satellites predicted

Stellar Populations with WFIRST



Huge increase in sampling of short-lived, high-luminosity phases

Star Formation Histories

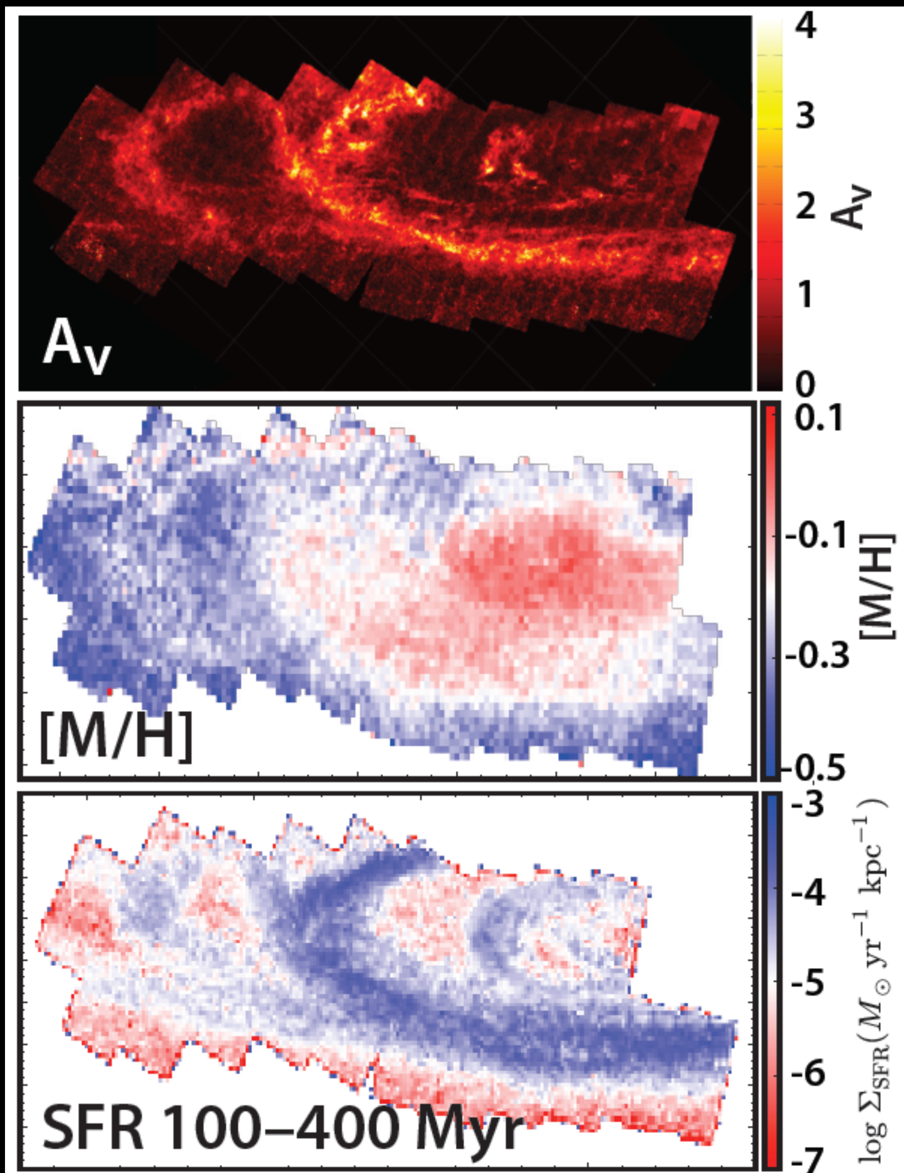


Wide Field Coverage Probes Trends with Radius

Large Sample Probes Trends with Galaxy Mass.

Lowest masses sensitive to reionization.

Dust and Population Maps

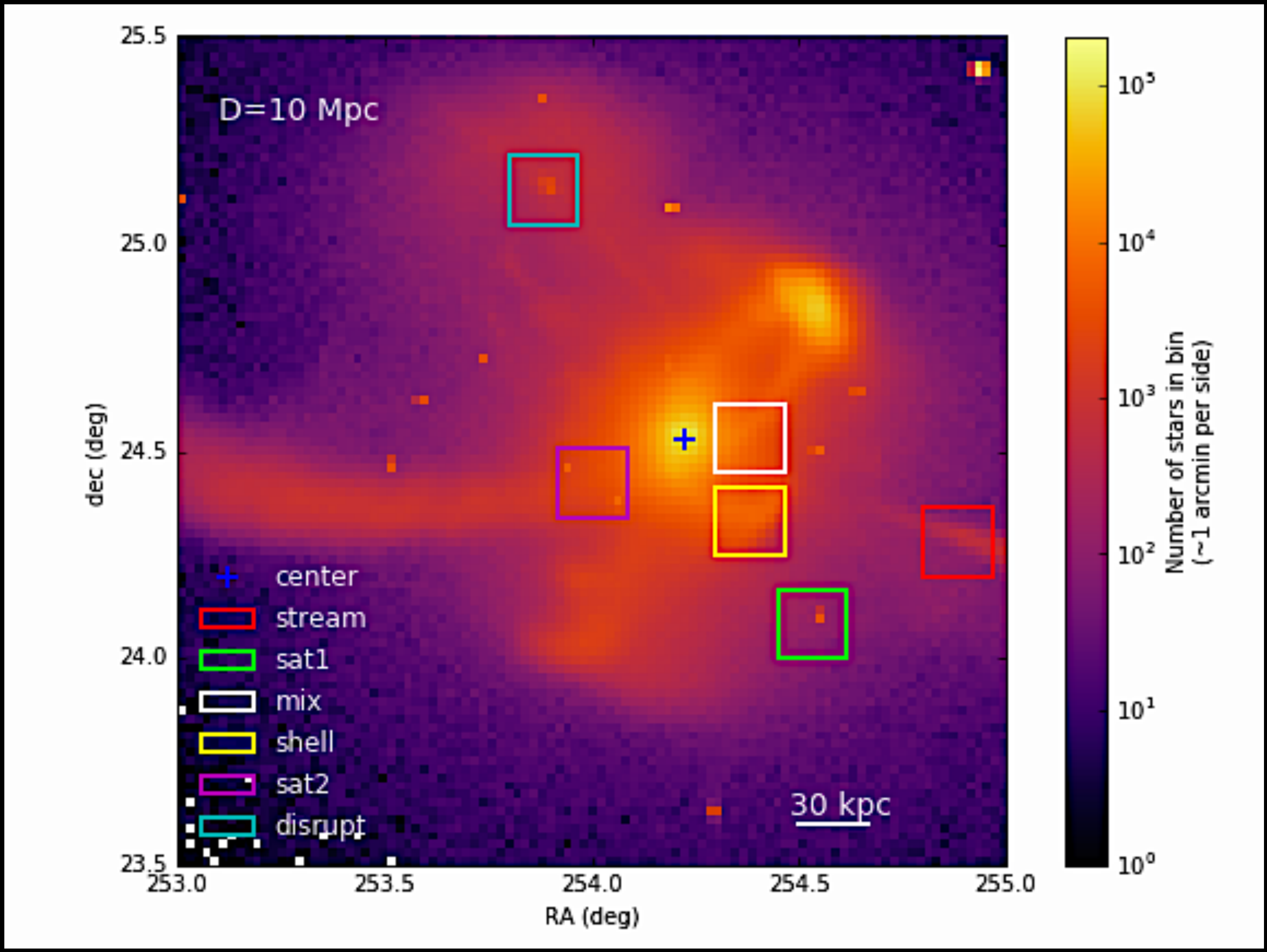


- RGB Width → Dust Absorption
- RC/RGB Color → Metallicity
- Main Sequence → Star Formation Rate

GO-program synergy: Resolved Population Needs

- Field of View (context and more stars)
- Wavelength coverage (colors)
- Resolution (depth and background removal)

WFIRST Imaging of Bullock & Johnston Simulations



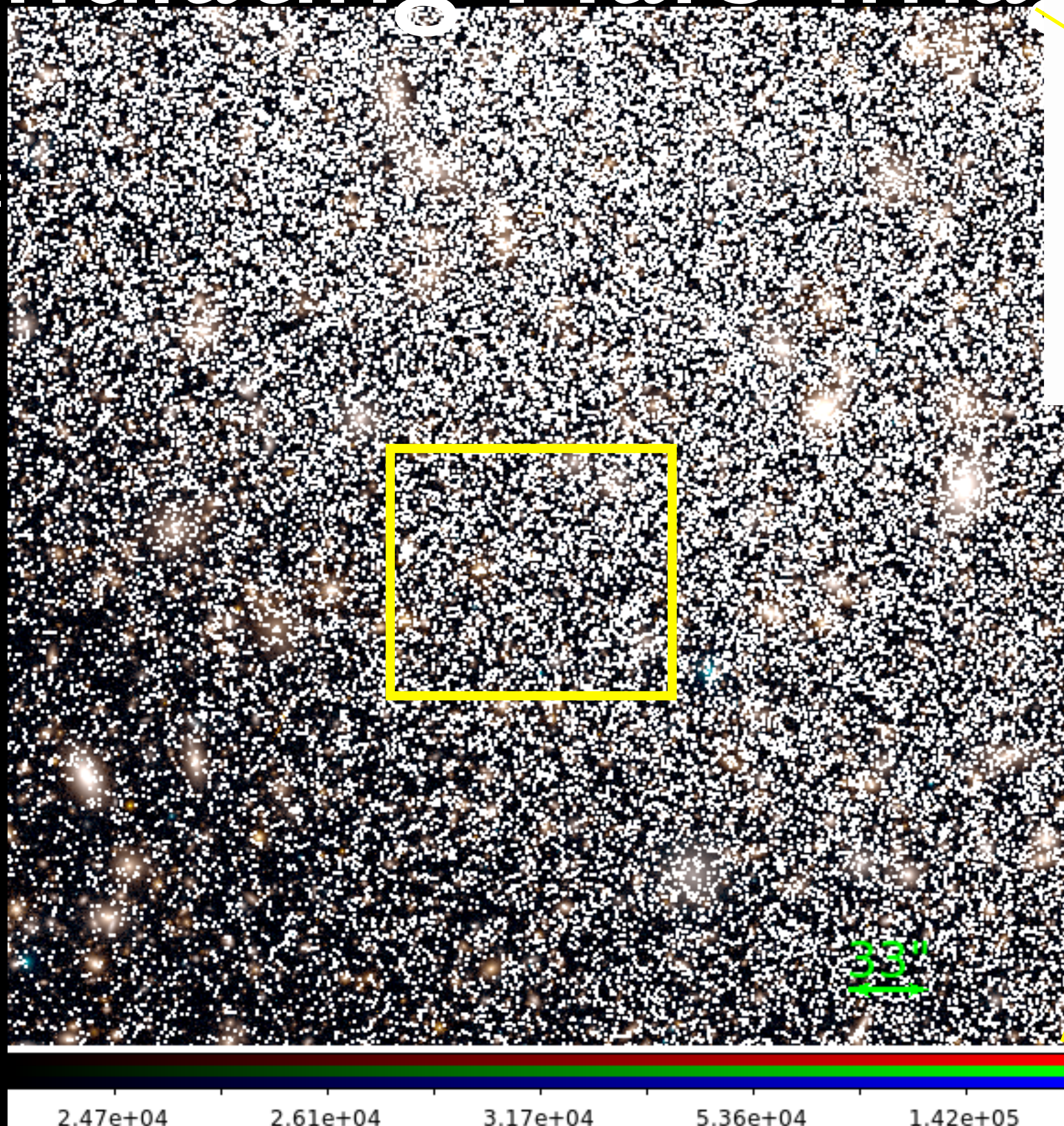
Halo populations by Robyn Sanderson

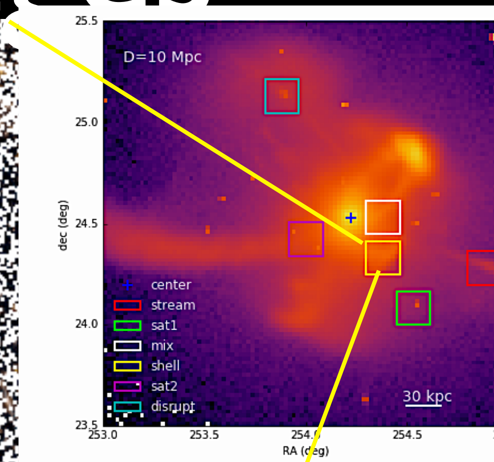
Simulating Halo images

Backgrouind: CANDELS-based catalogs

Stars: Galaxia catalogs of simulations

Blue = Z087
Red = H158





Stars in a Halo at 5 Mpc

Simulating Halo Images

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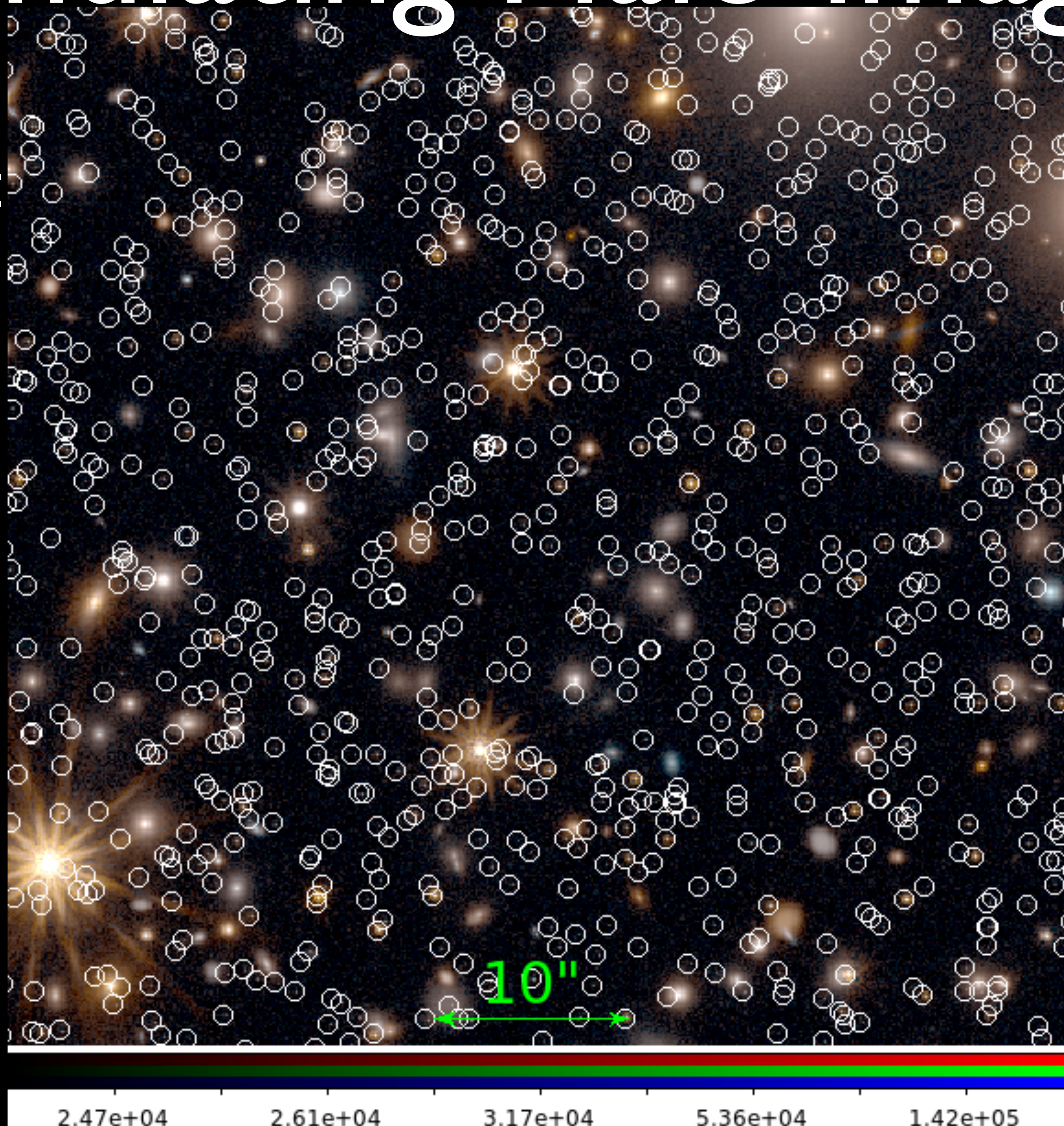
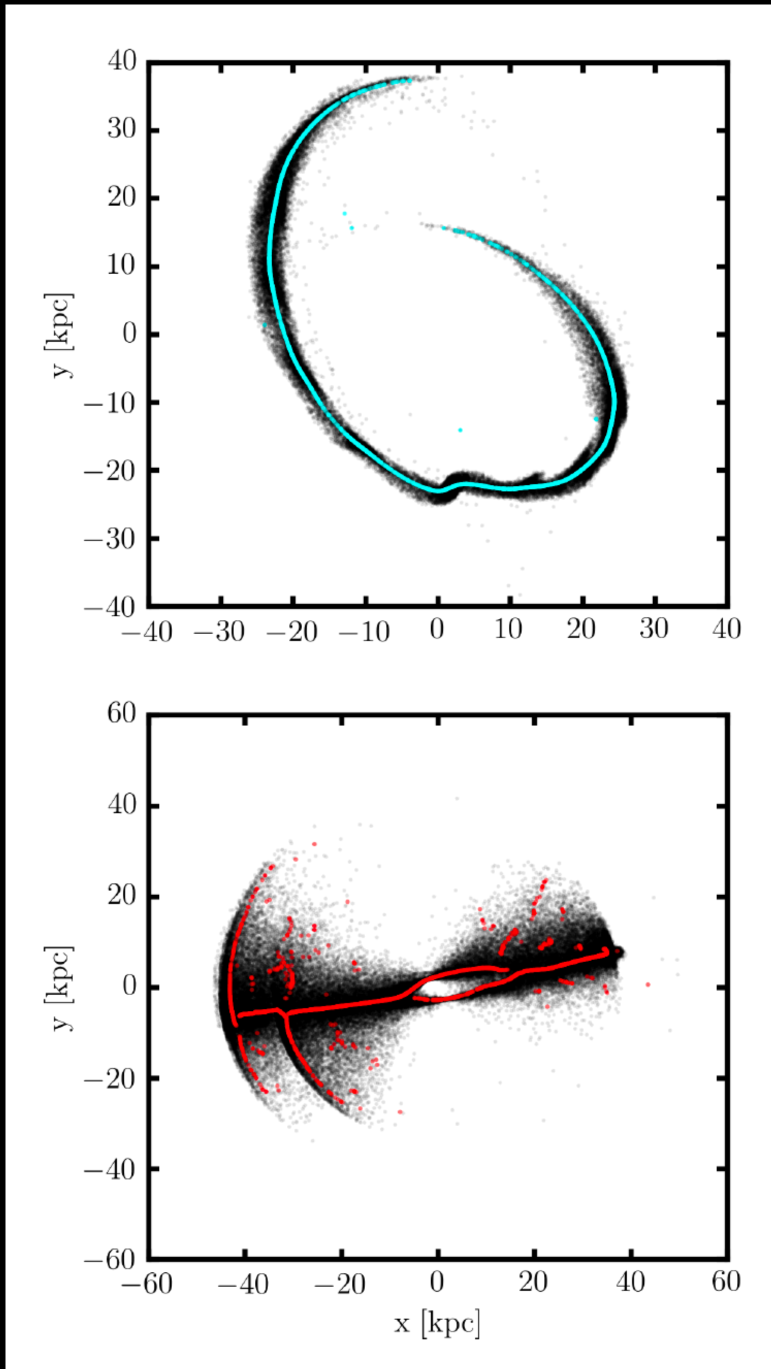


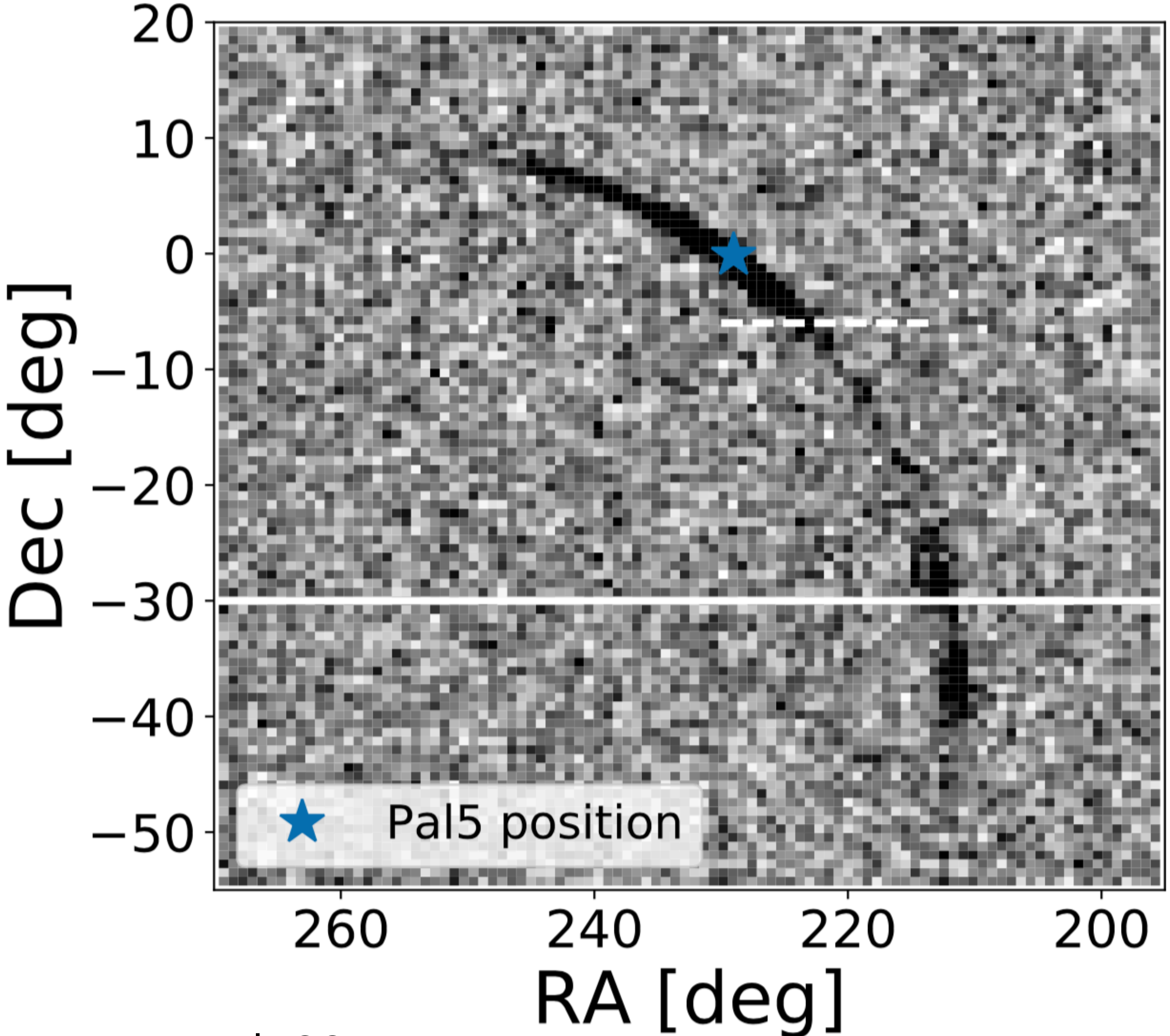


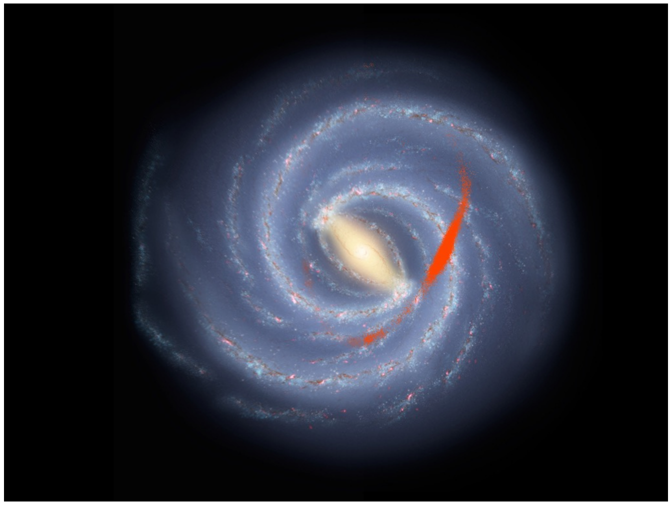
Automated Identification of Streams and Shells

Allows quantitative comparisons between stellar halo structure and formation history

Hendel et al. 2019
https://arxiv.org/abs/1811.10613

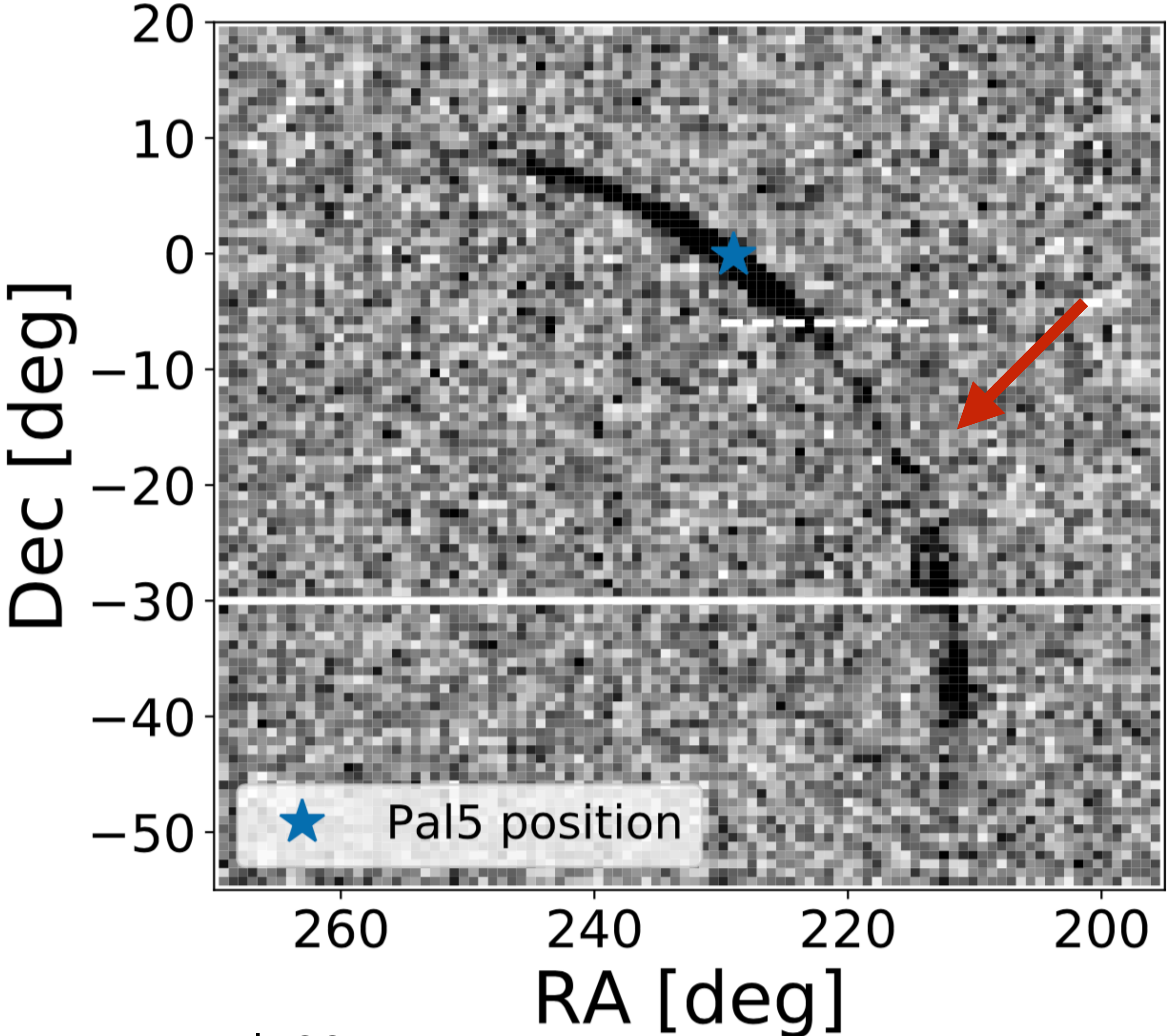
Gaps in streams





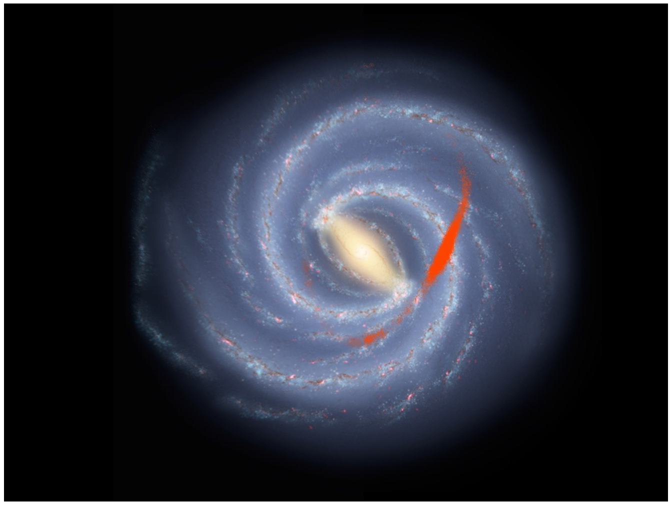
Pearson et al. 2017

Gaps in streams



Pearson et al. 2017

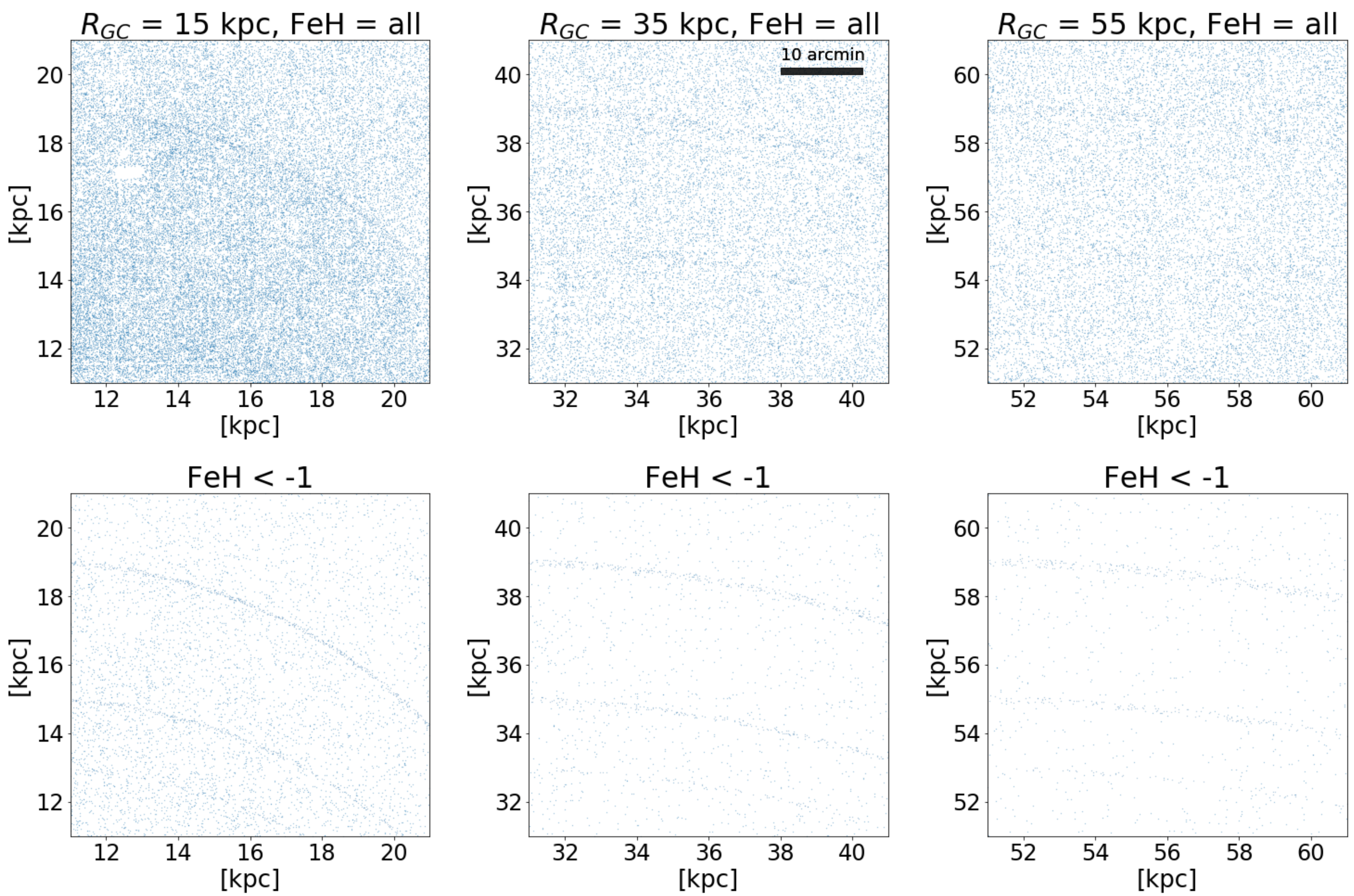
The bar can create gaps too!



And spiral arms, molecular clouds ....

e.g. Amorisco et al. 2016, Banik & Bovy 2019

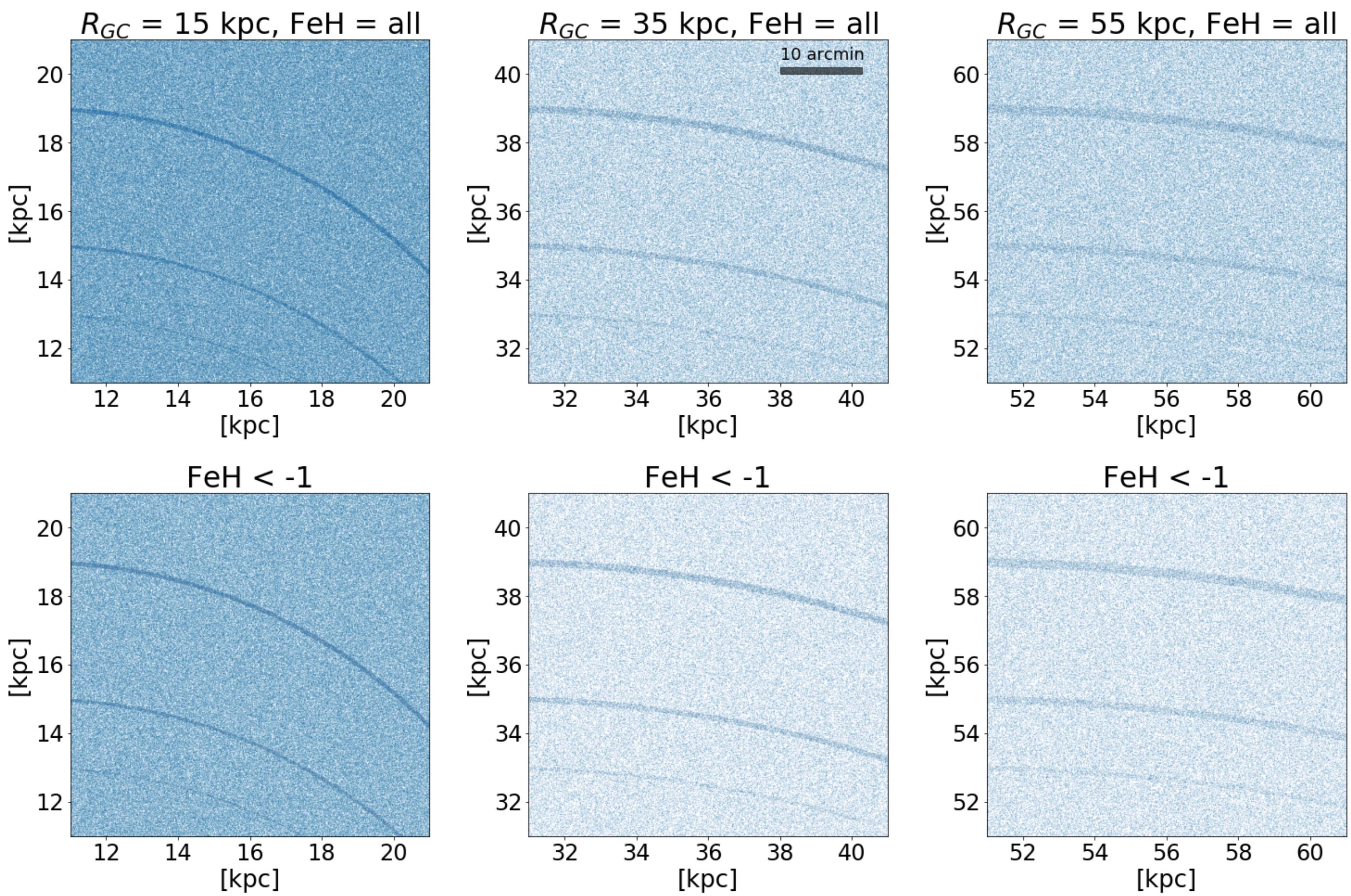
GC streams in external galaxies



Pearson et al. 2019
ArXiv/1906.03264

PAndAS ($g_0 < 25.5$)

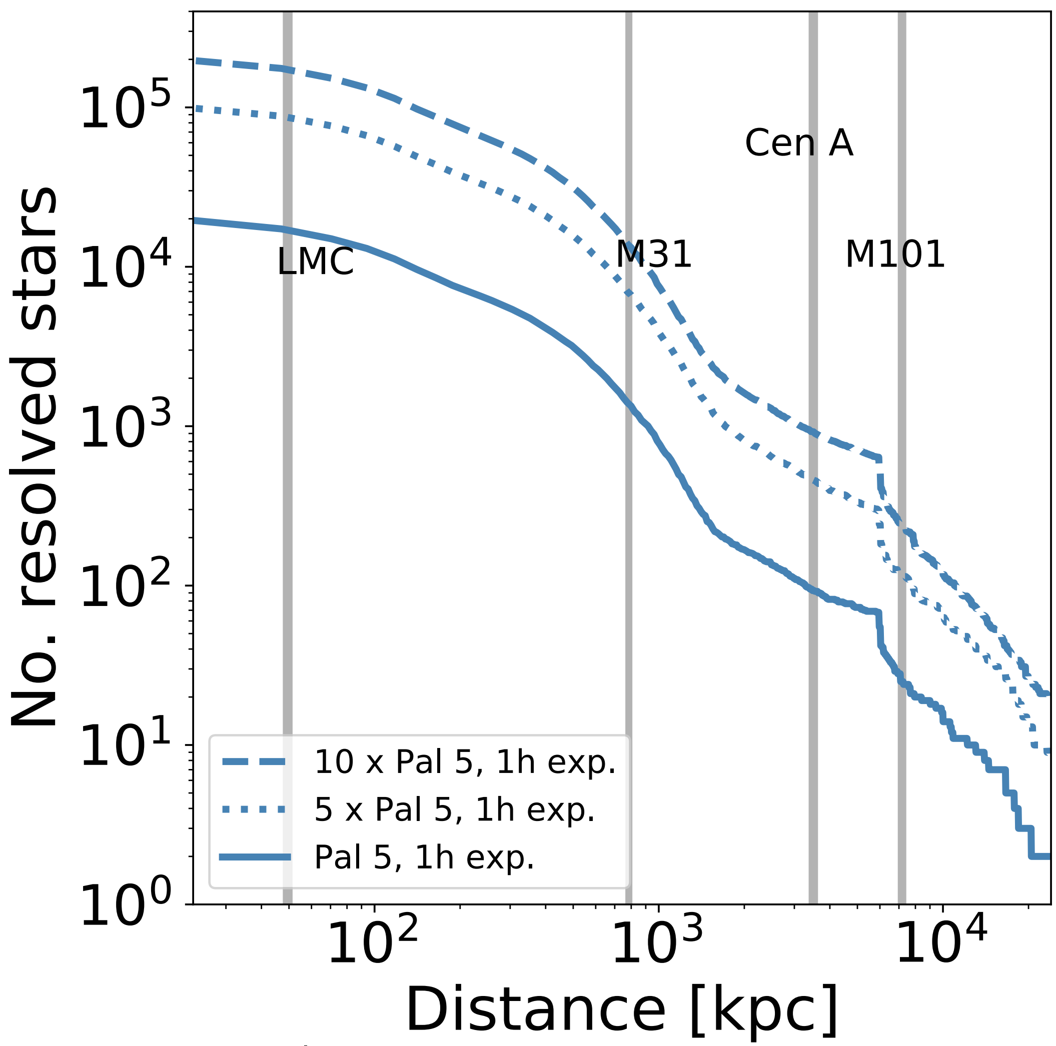
GC streams in external galaxies



Pearson et al. 2019
ArXiv/1906.03264

WFIRST (1h exposure)

How far out should we find thin streams?



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$$C_{err} = \frac{N_{stream}}{\sqrt{N_{background}}}$$

$$C_{err} > 15$$

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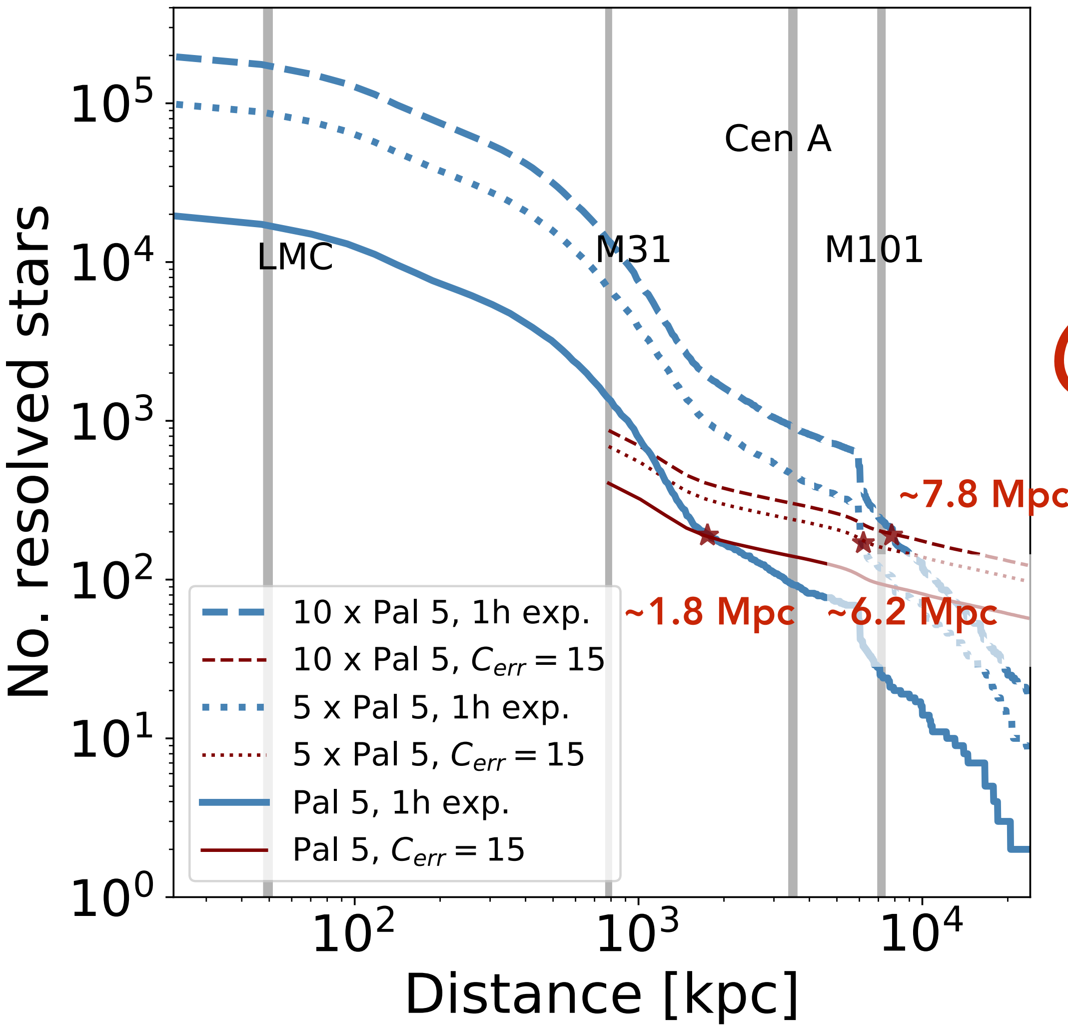

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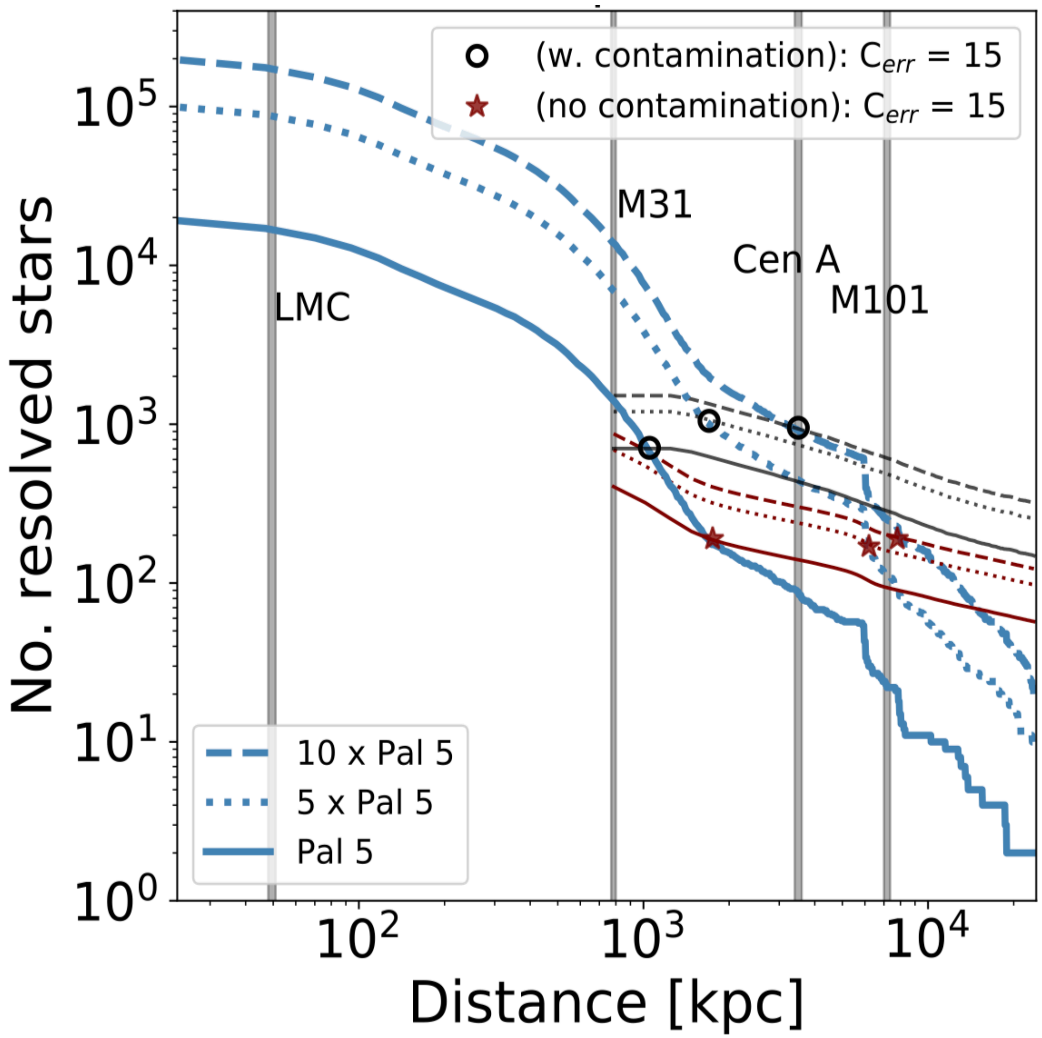

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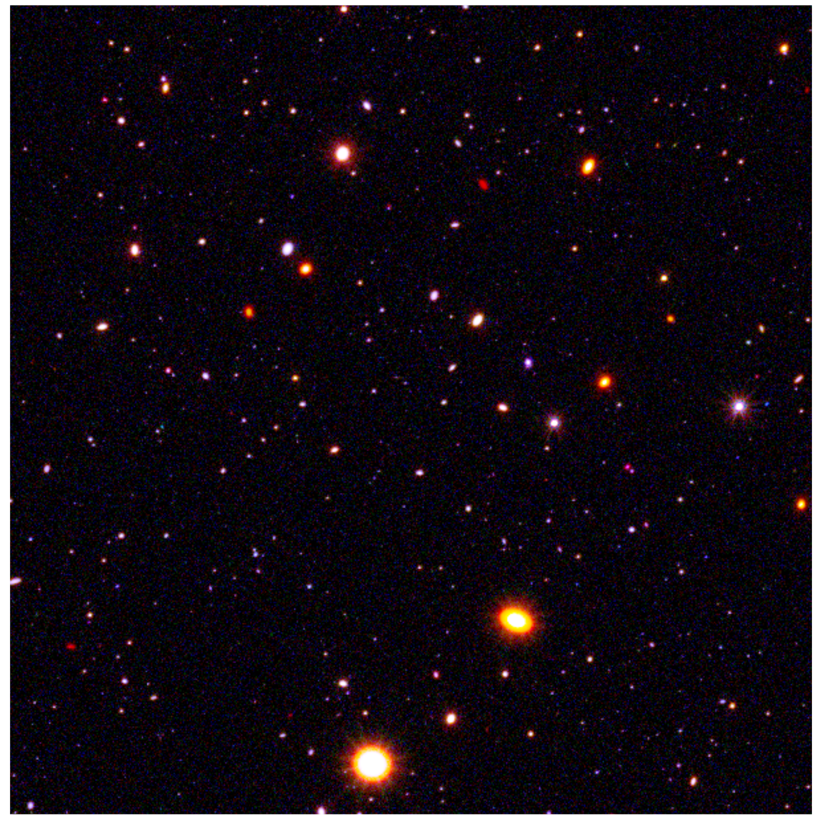
Potential Background Galaxy Contaminants



Maximizing the value of a WFIRST survey of nearby galaxies

Sample Selection: Number/properties we need for variety of projects

Distance Distribution: More tiling vs. longer exposures

Depth: What is optimal for various sub-projects?

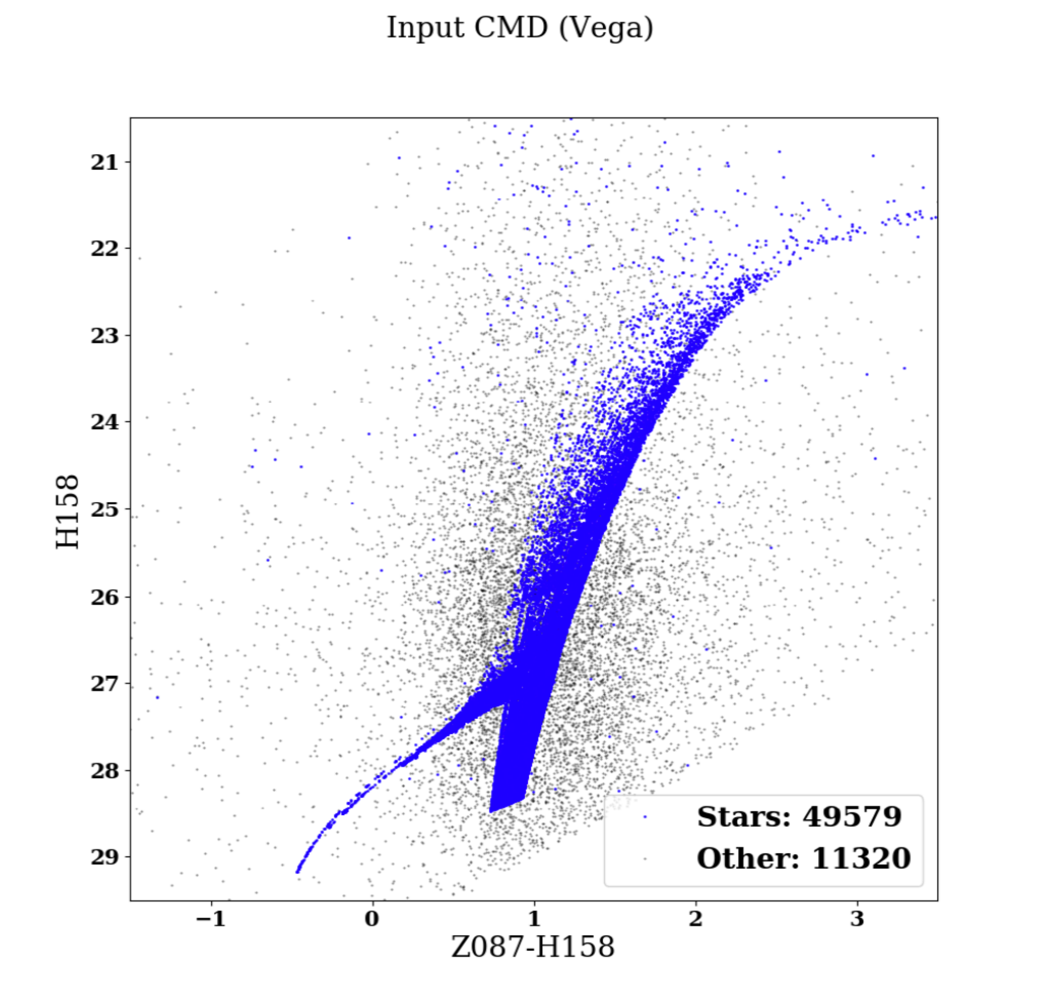
Area: How far out in the halo does the science return decrease?

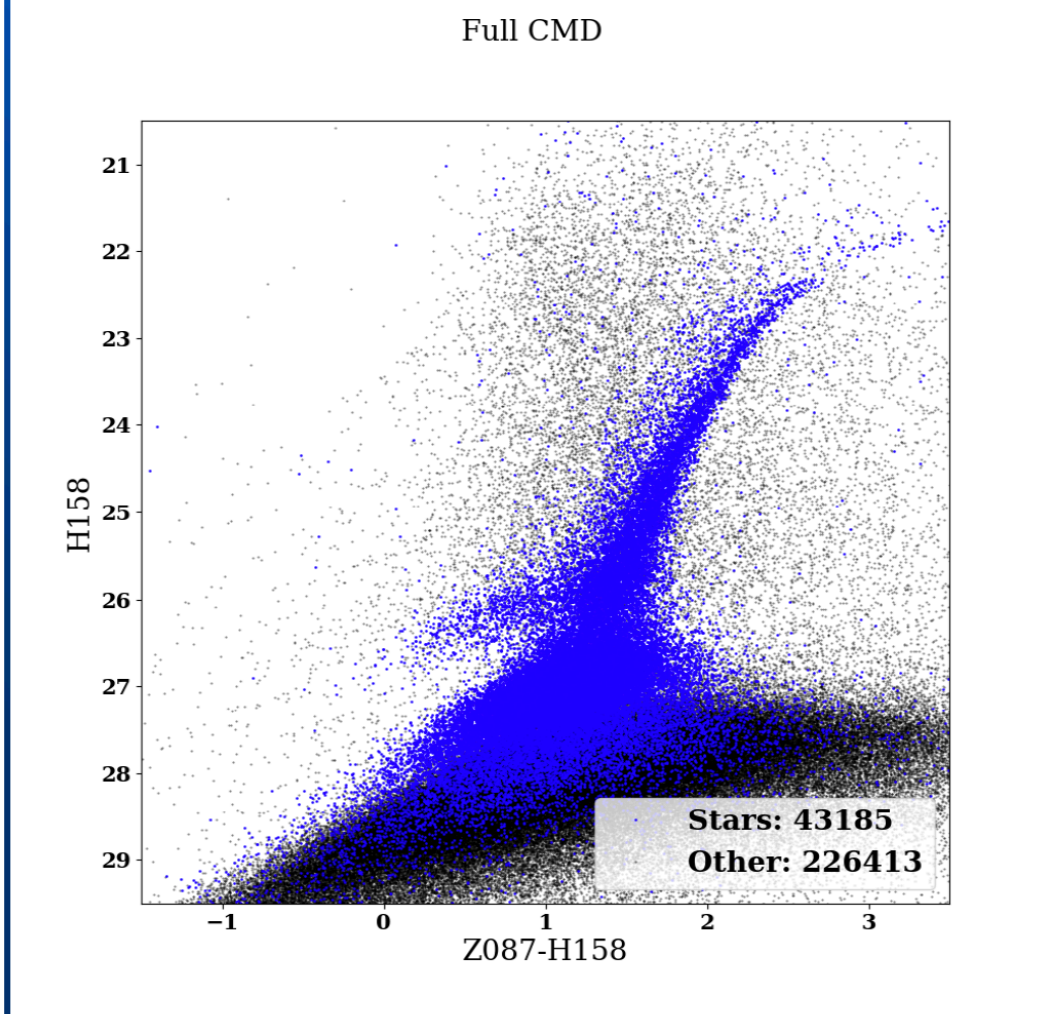
Filters: How many bands? Which bands?

Scheduling: Proper motion possibilities

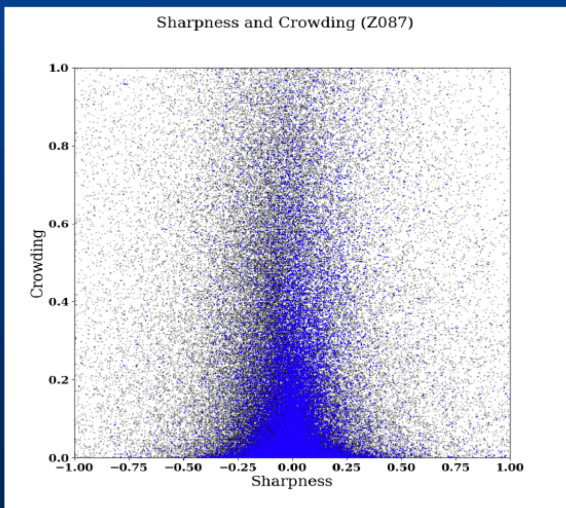
Data Products: Crowded field photometry (including quality metrics)

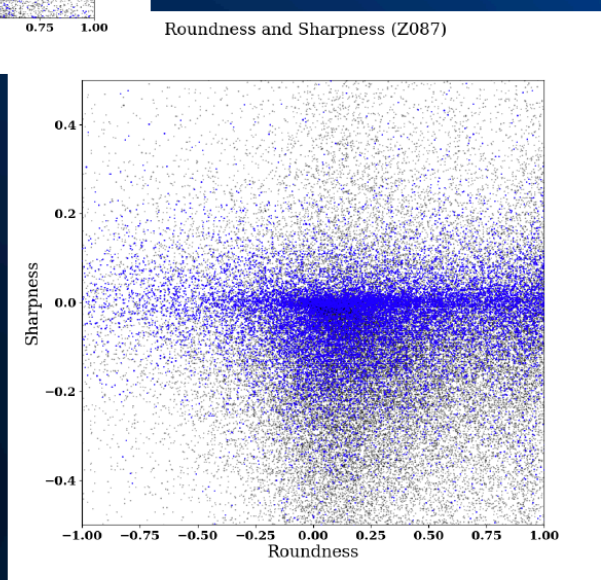
Input: Stars in Galaxies + galaxies

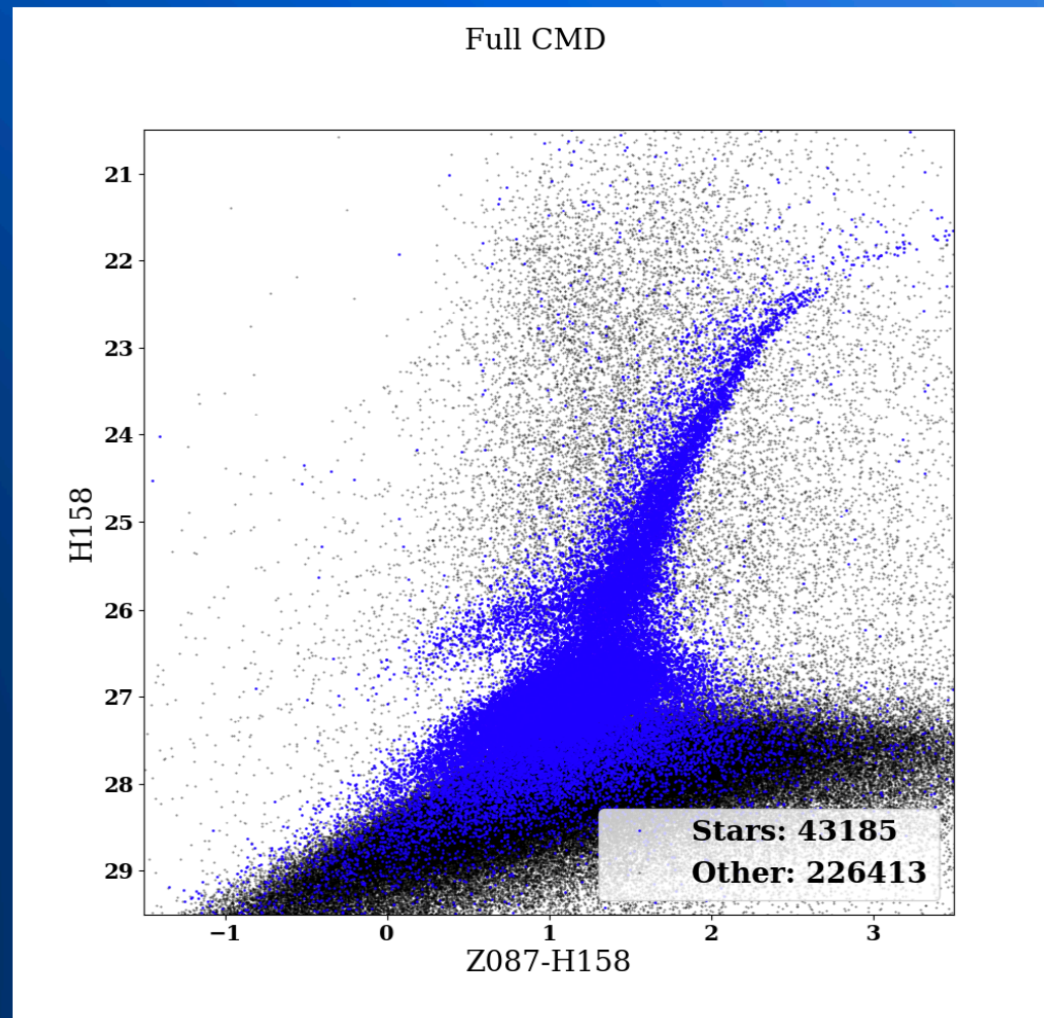




Quality Measures of A "Star"



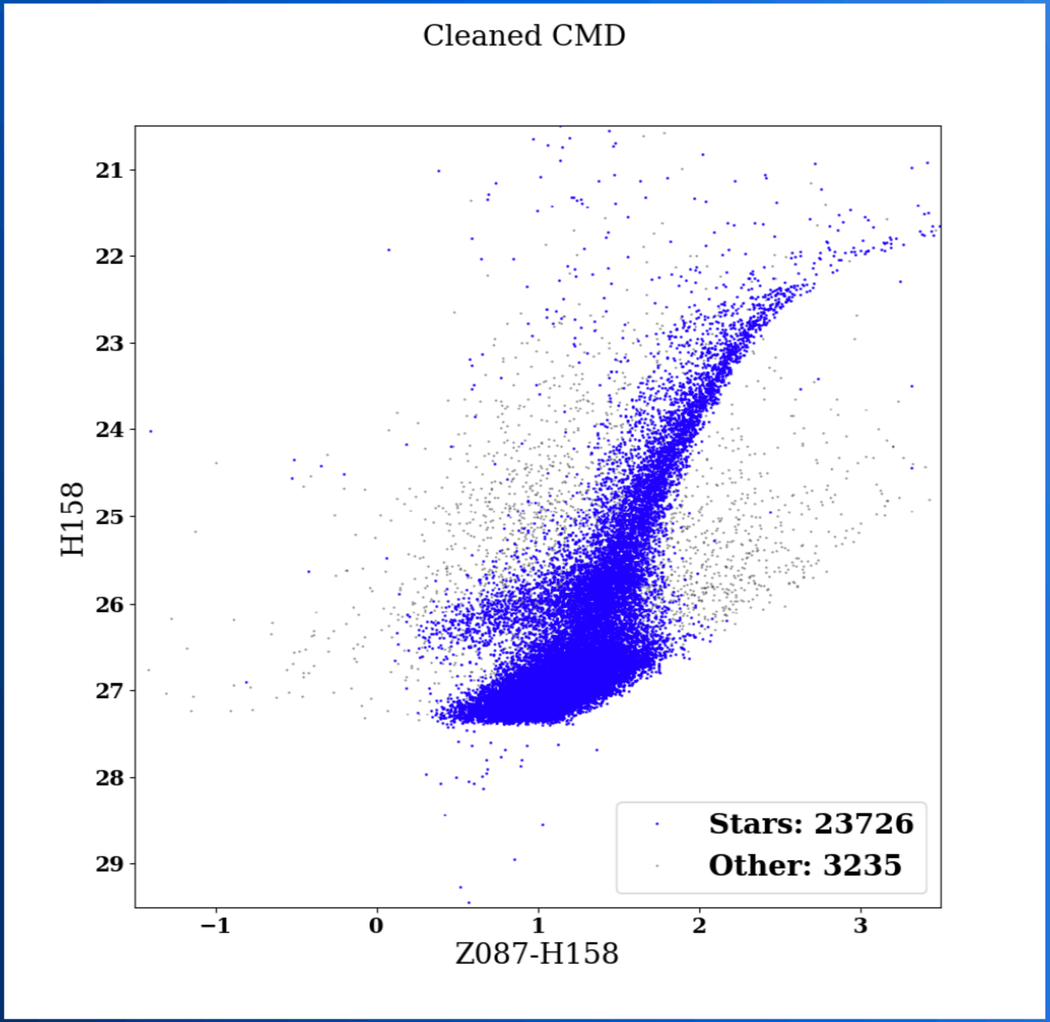




Roundness, Sharpness, Crowding, SNR …

Labelled Classification

- Label by location
- DecisionTree by single filters
- Re-label by location
- Do not repeat



Optimizing a WFIRST Nearby Galaxies Survey

- Generate input catalogs from simulated sample mimicking local volume
- Try different samples and coverage fractions
- Try different filter, dither precision, and PSF possibilities
  - Optimize science (density feature recovery, population recovery, tests of galaxy evolution model predictions) given the trades