Detailed Views Into the Baryon Cycle of Dwarf Galaxies from HST Narrowband Imaging

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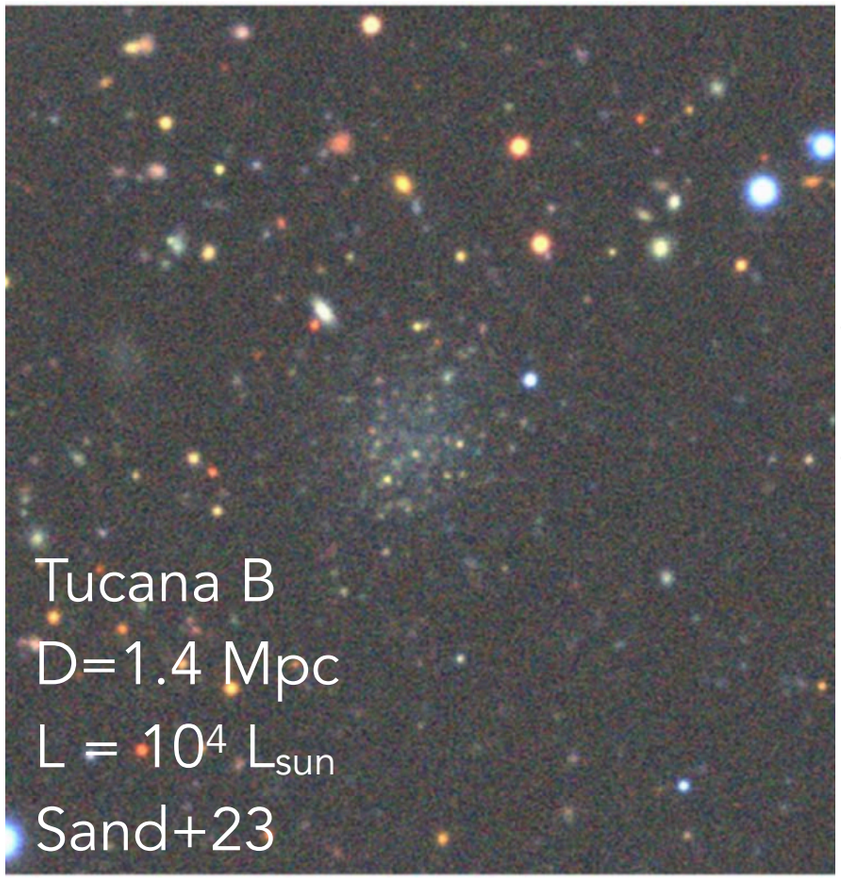
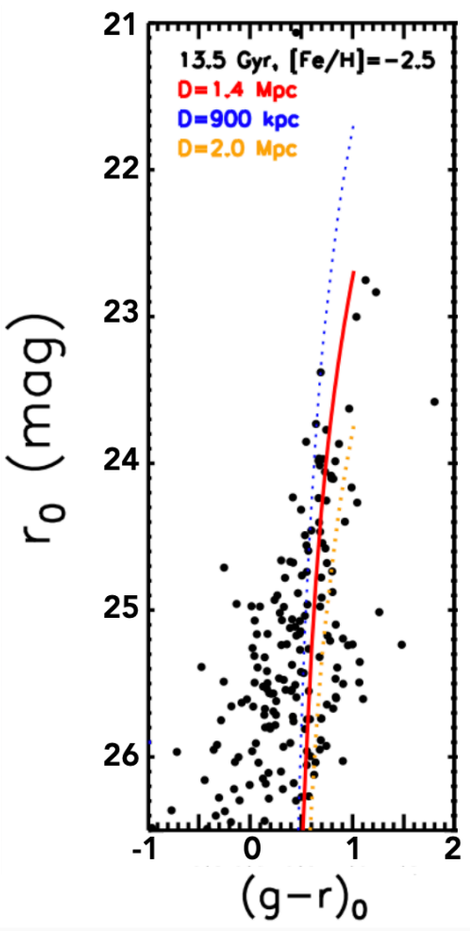
UC Berkeley

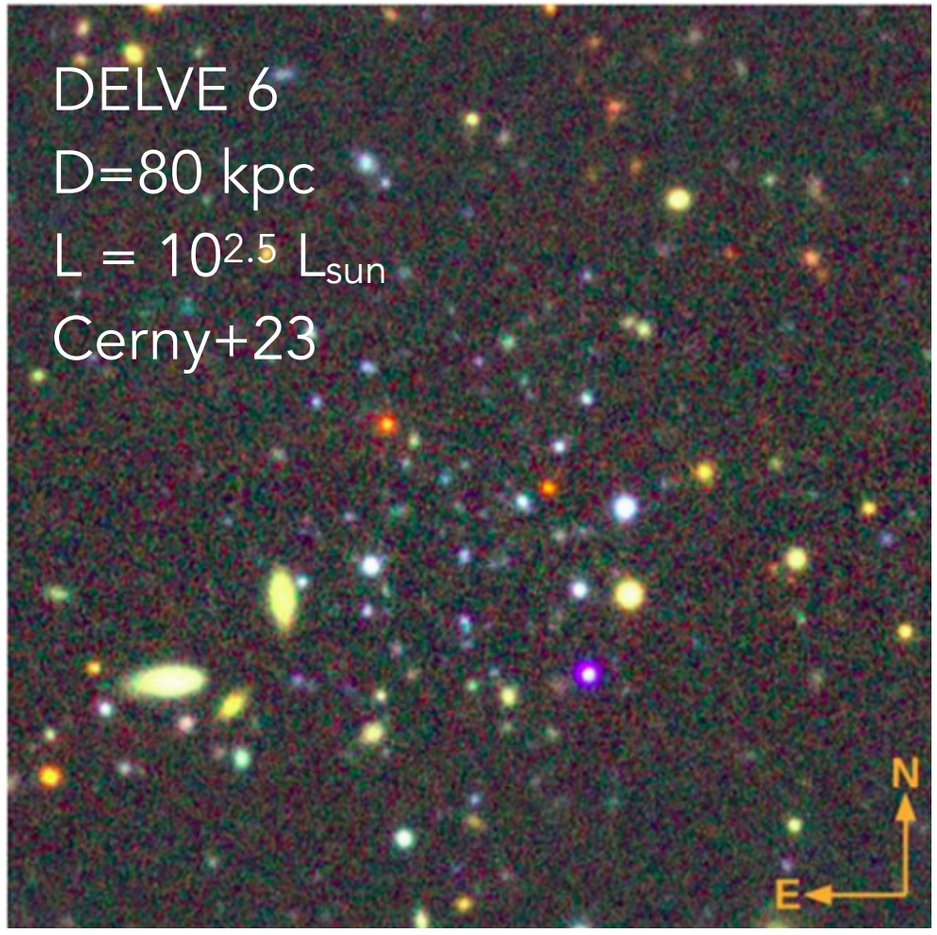
credit: NOIR Lab

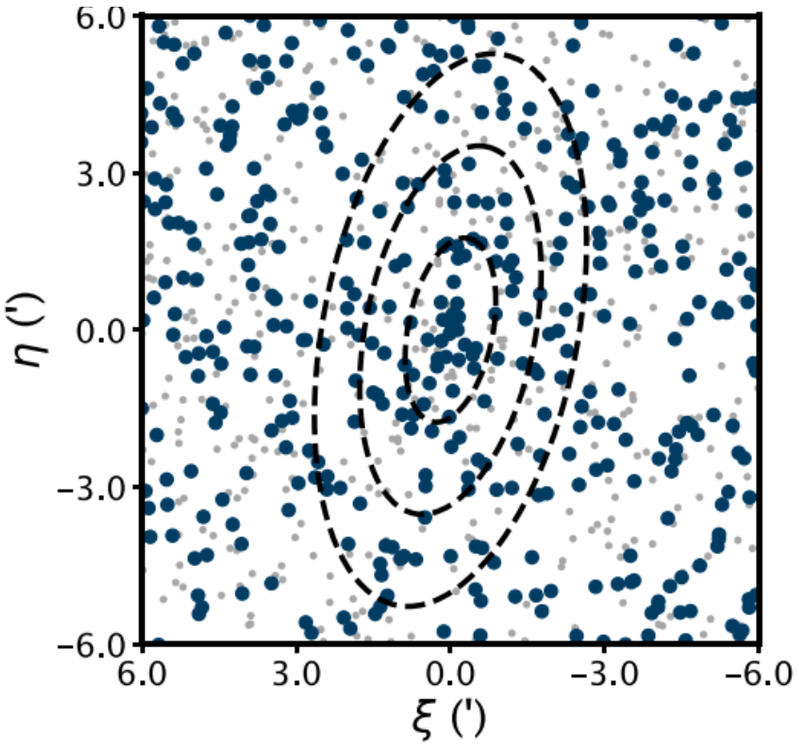
Dwarf Galaxies, Star Clusters, and Stellar Streams in the LSST Era, University of Chicago, July 9, 2024

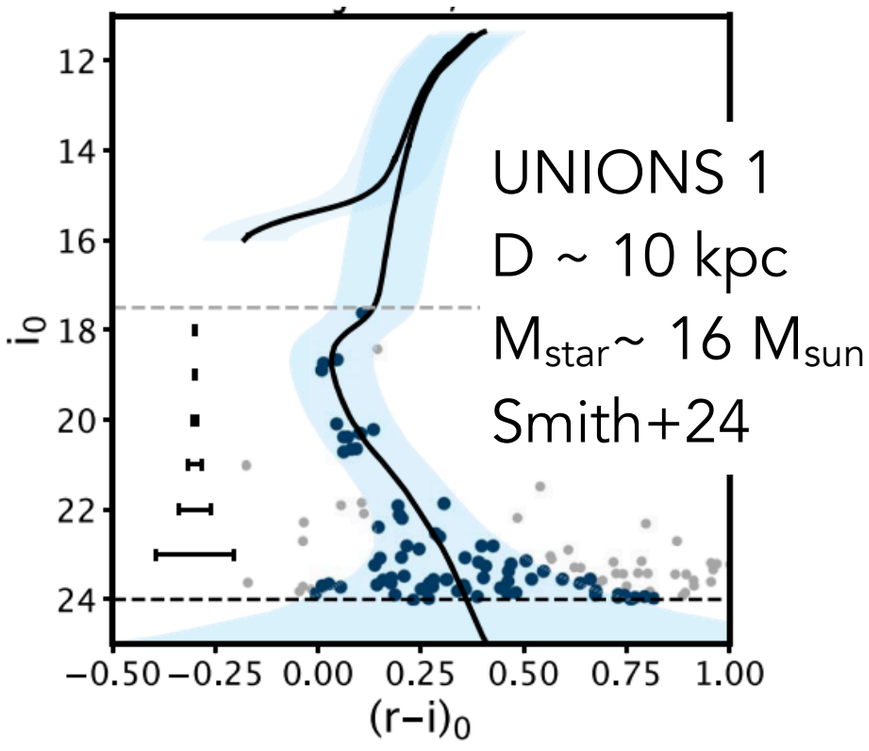
Dwarf Discoveries Enabled by Photometric Surveys





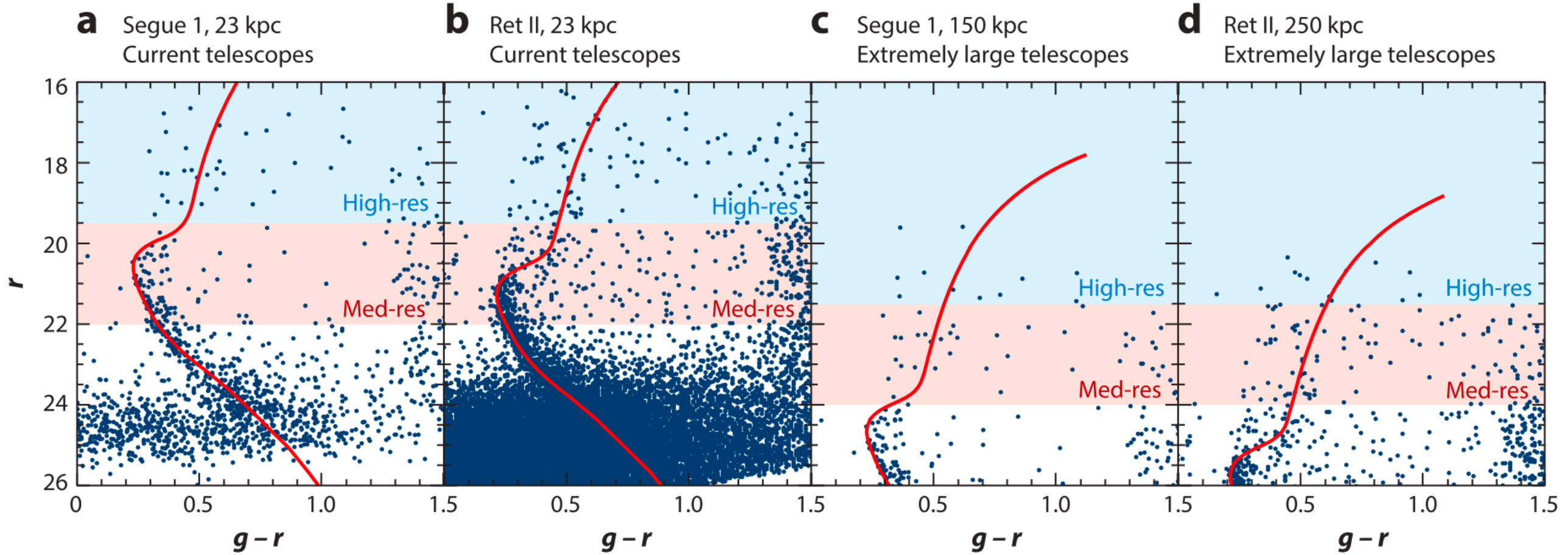






Difficulty of Measuring Stellar Metallicities in Distant and/or Faint Galaxies

- Only handful of spectroscopically accessible stars for radial velocity, metallicity, chemical abundance measurements
- Problem in era of accelerated dwarf galaxy discovery: Methods for efficiently sampling MDFs?

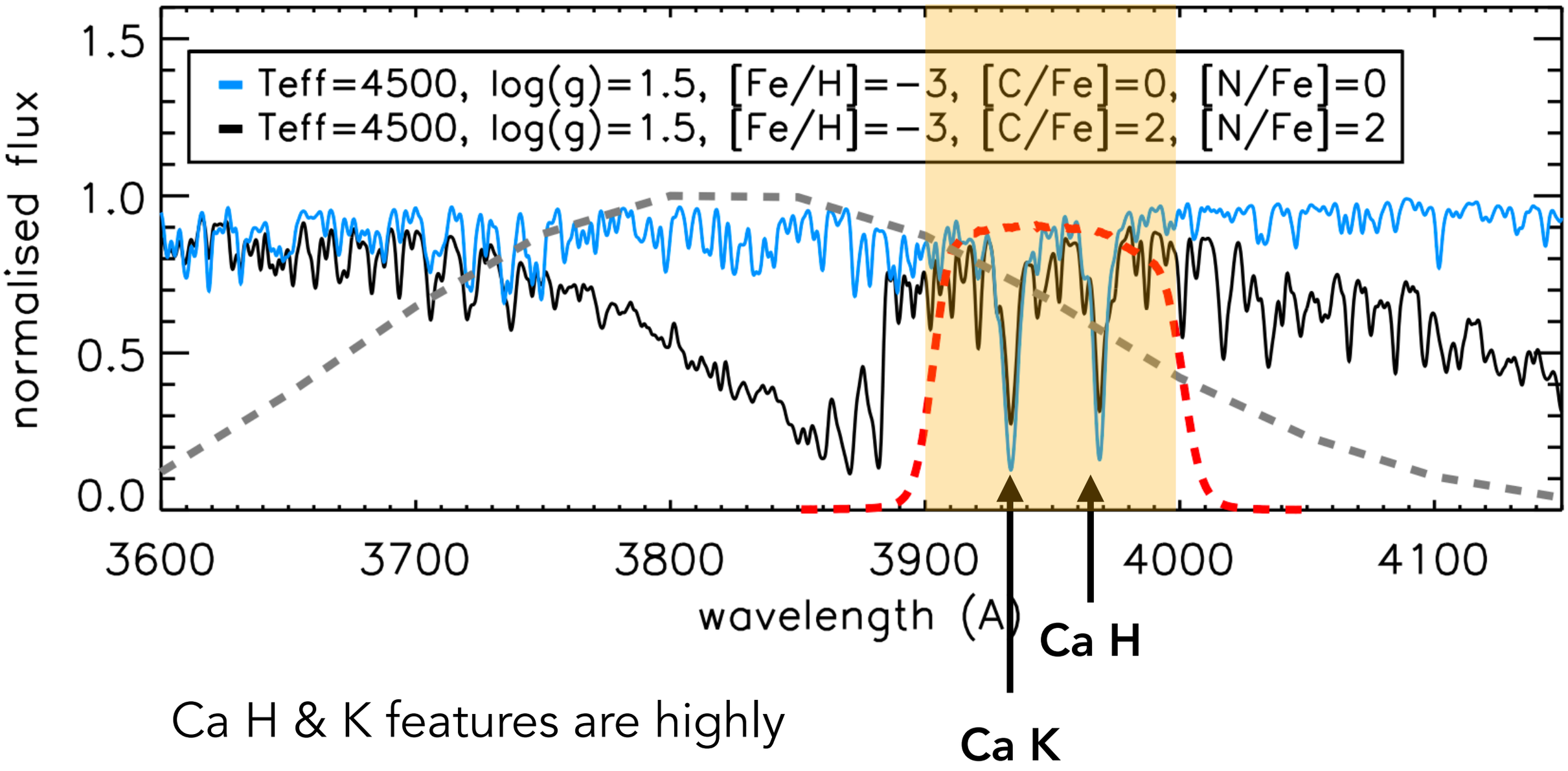


observing capacity for current spectrographs of currently-known UFDs

projected observing capacity for ELT spectrographs for anticipated UFD discoveries

Simon 2019

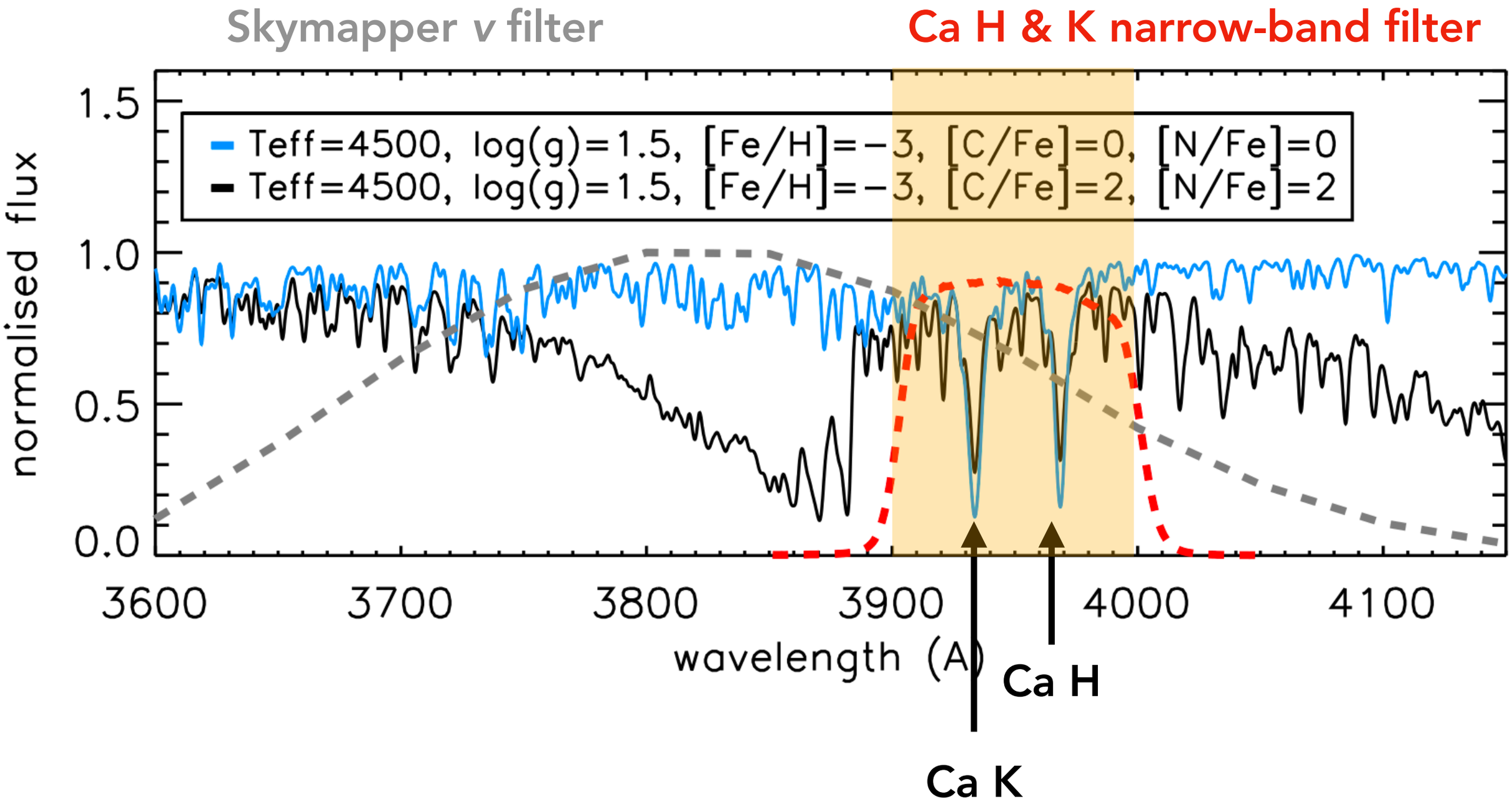
Photometric Metallicities Using Ca H & K



Ca H & K features are highly sensitive to [Fe/H] (e.g., Strömgren 1966)

Starkenburg+2017

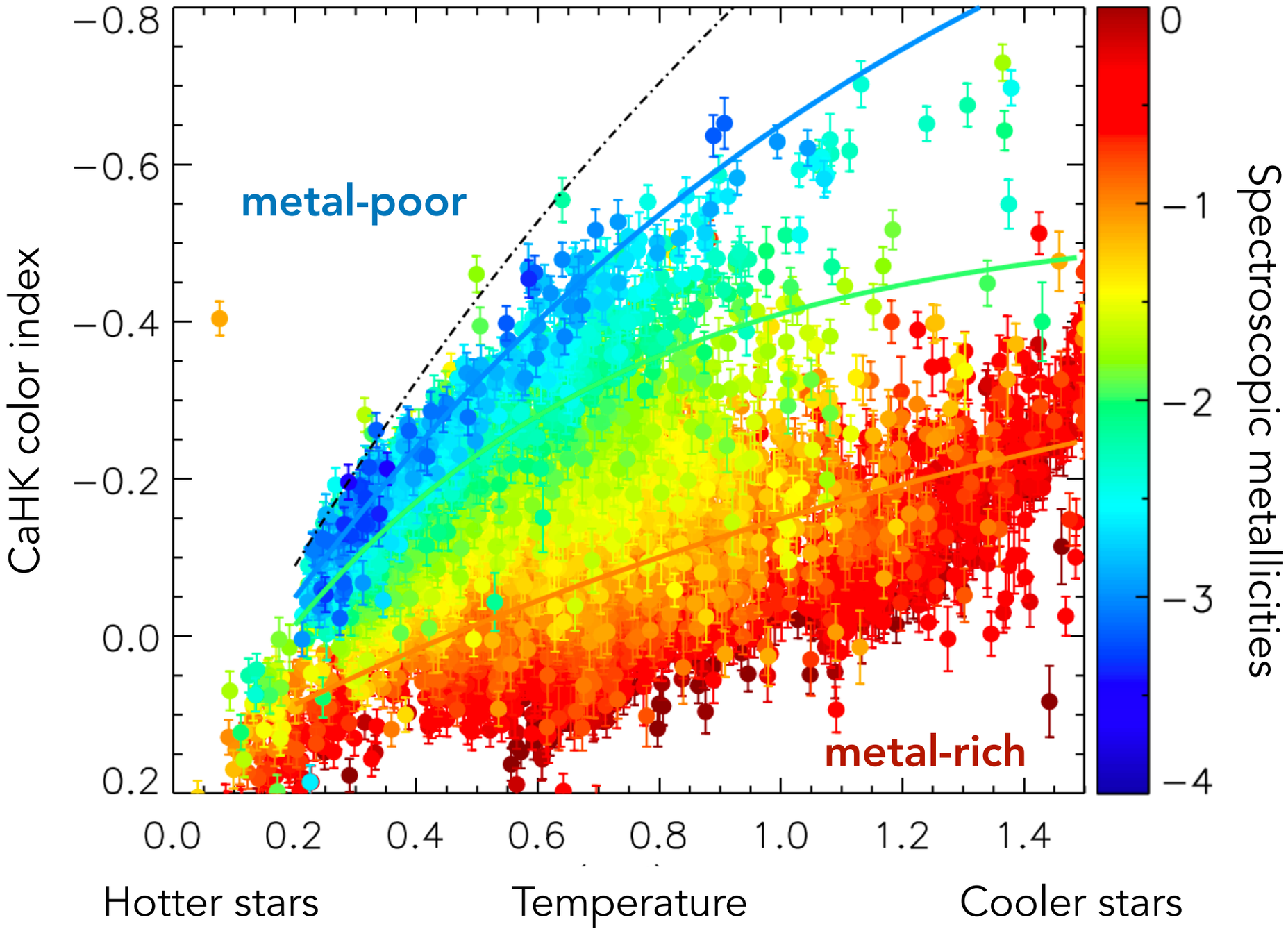
Photometric Metallicities Using Ca H & K



Narrow-band photometry around Ca H & K can trace stellar metallicity

Starkenburg+2017

Applying photometric metallicities to Milky Way surveys



Stars in Ca H & K color space separate in metallicity, especially cooler stars

Starkenburg+2017

Narrow-band photometric metallicities of faint stars in distant galaxies using HST

GO 15901

Wed May 17 20:30:27 GMT 2023

Principal Investigator: Daniel Weisz
PI Institution: University of California - Berkeley
Investigators (xml)

Title: The Metallicity Distribution Functions of Ultra-Faint Dwarf Galaxies
Cycle: 27
Allocation: 43 orbits

GO 16226

Fri Jun 24 00:13:38 GMT 2022

Principal Investigator: Sal Fu
PI Institution: University of California - Berkeley
Investigators (xml)

Title: Metallicity Distribution Functions of Quenched Field Dwarf Galaxies
Cycle: 28
Allocation: 23 orbits

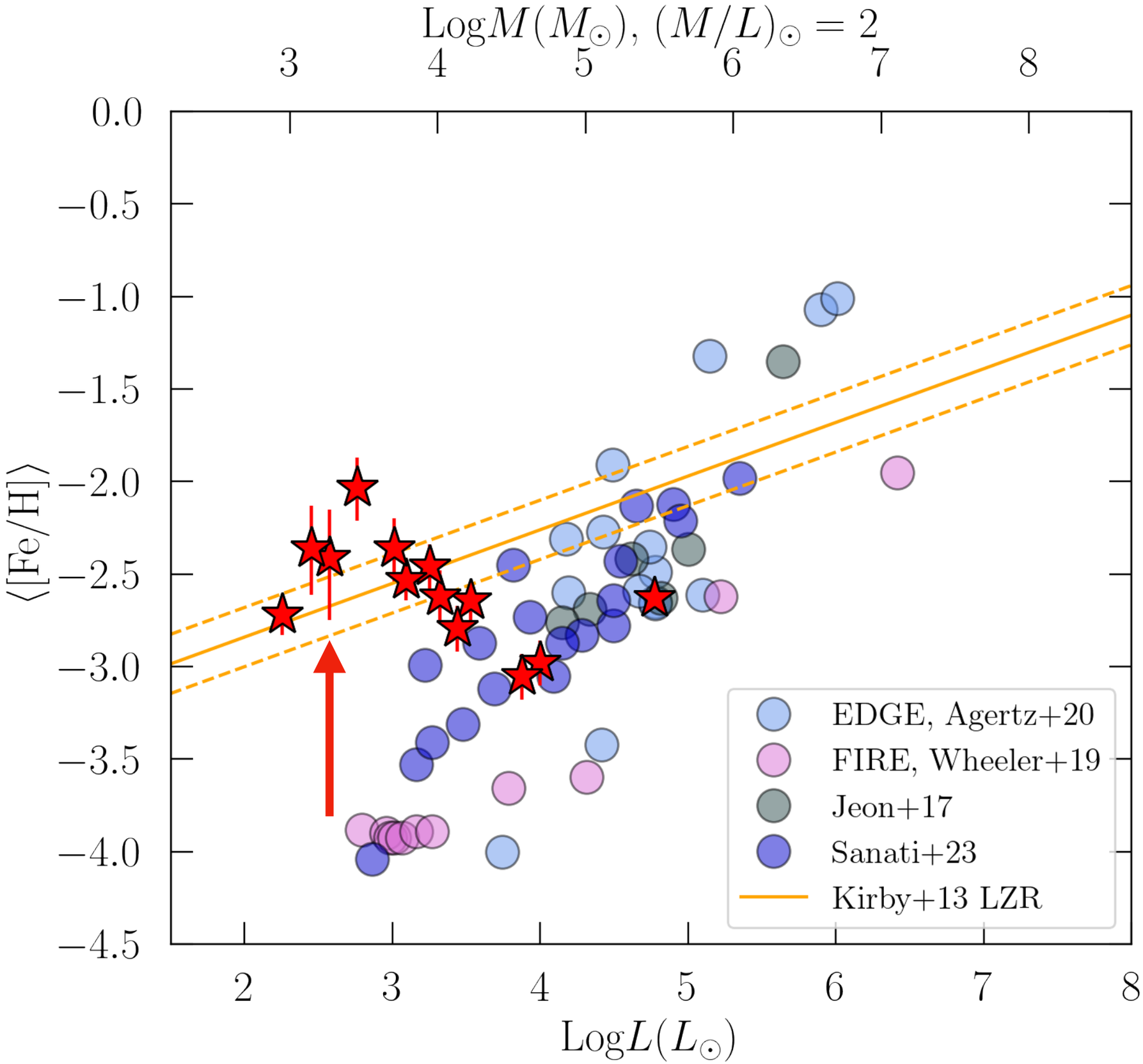
GO 16686

Fri Jun 24 00:14:40 GMT 2022

Principal Investigator: Daniel Weisz
PI Institution: University of California - Berkeley
Investigators (xml)

Title: The Metallicity Distribution Functions of Faint M31 Satellites
Cycle: 29
Allocation: 30 orbits

> 1 dex Discrepancy Between Observed and Simulated Metallicities for Galaxies Below 10^4 L_{sun}

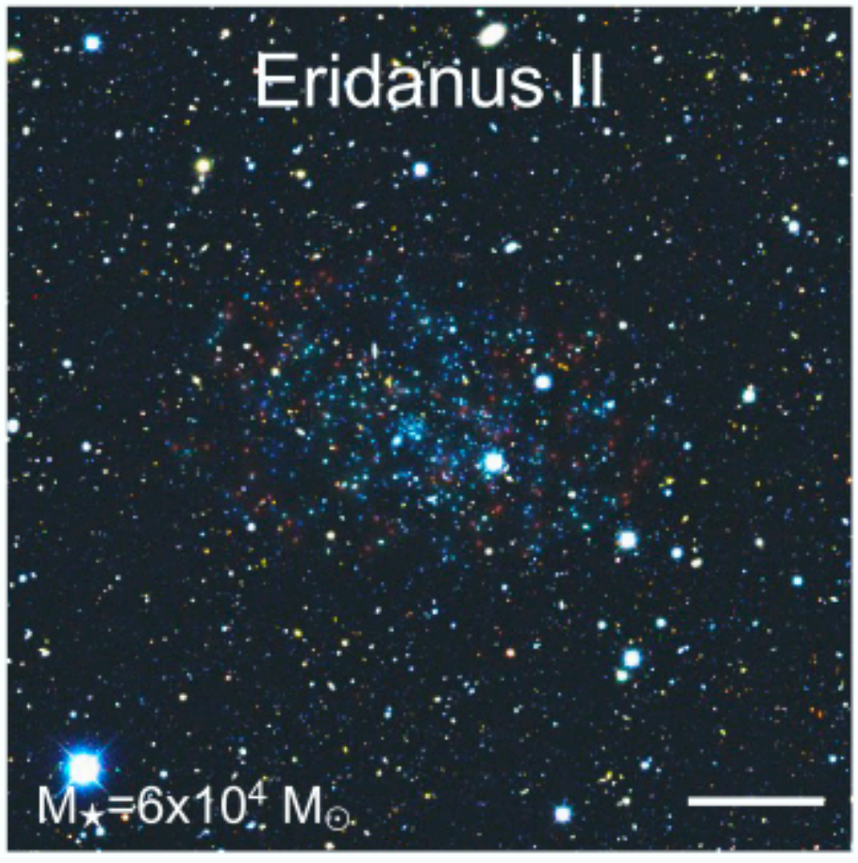


Implementation of simulation physics:

- SNe feedback energy (Agertz+2020)
- Metal diffusion (Escala+2018)
- IMF sampling (Prgomet+2022)
- [Fe/H]-dependent Type Ia SNe (Gandhi+2022)
- Pop III stars (Sanati+2023)
- SNe implementation (Azartash-Namin+2024, Zhang+2024)
- Simulation resolution, pre-enrichment of natal gas, …

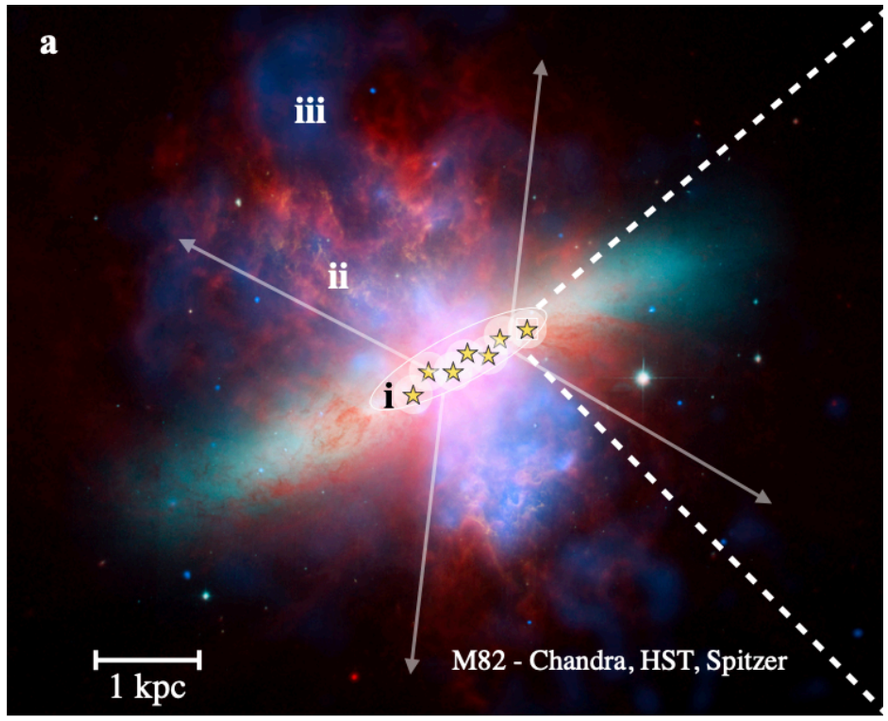
Fu+2023

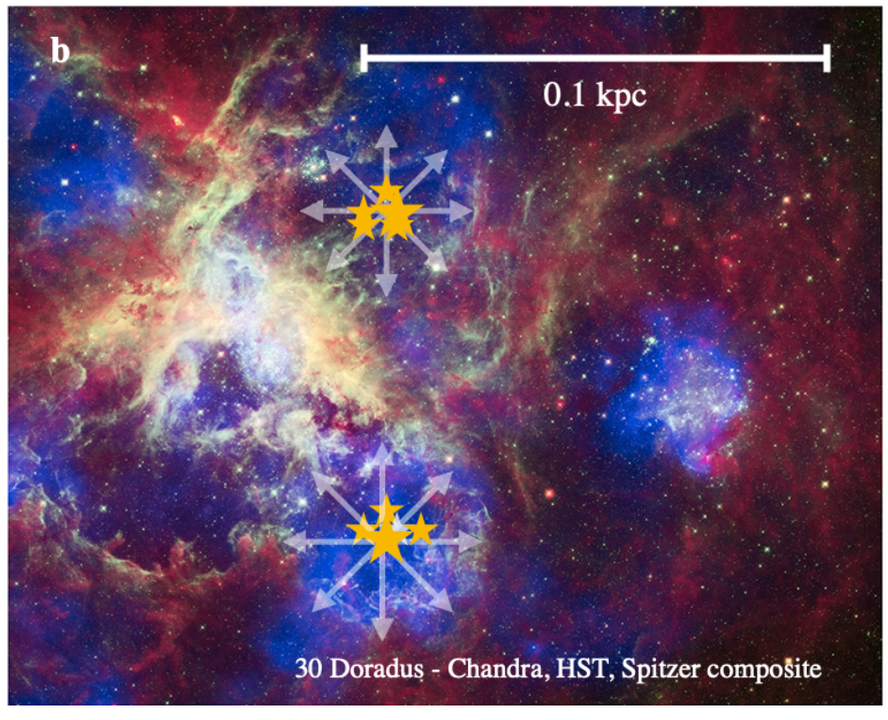
Chemical Evolution as an Archaeological Lens into Star-Forming Astrophysics



z = 0

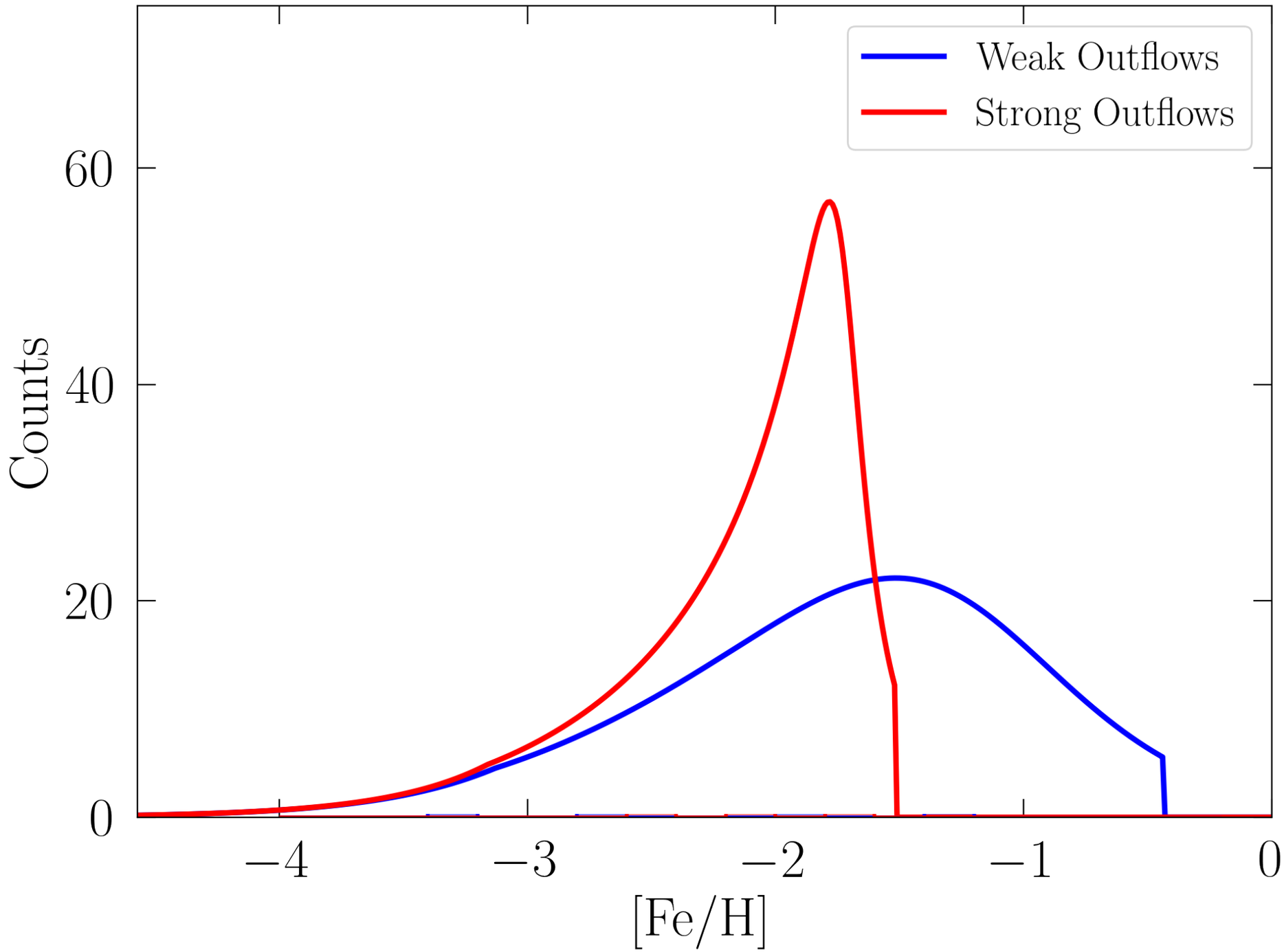
HST CaHK MDF + chemical evolution models (Sandford+2024)





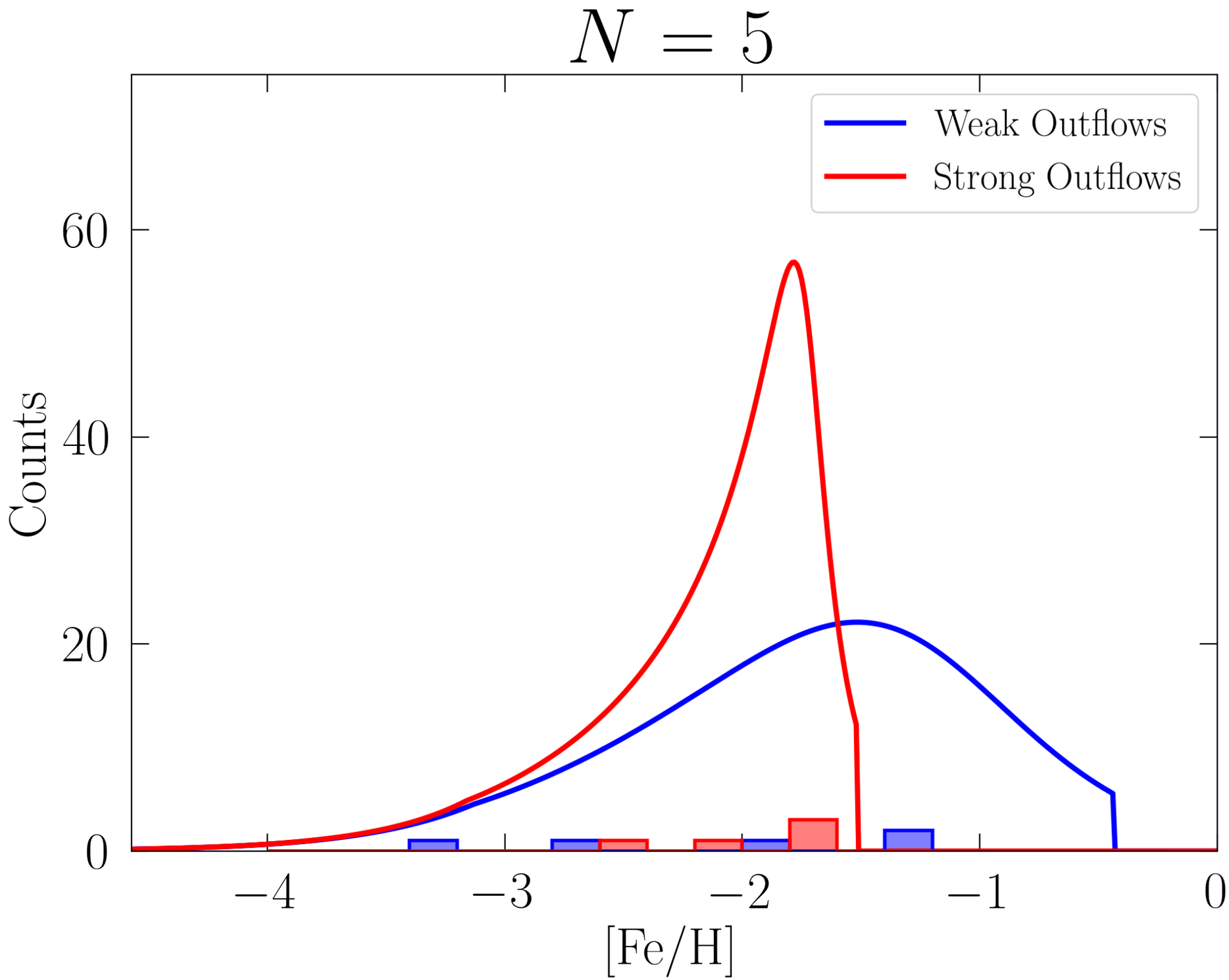
Eri II, *z* ~ 7?

Outflow Strength on MDF Shape



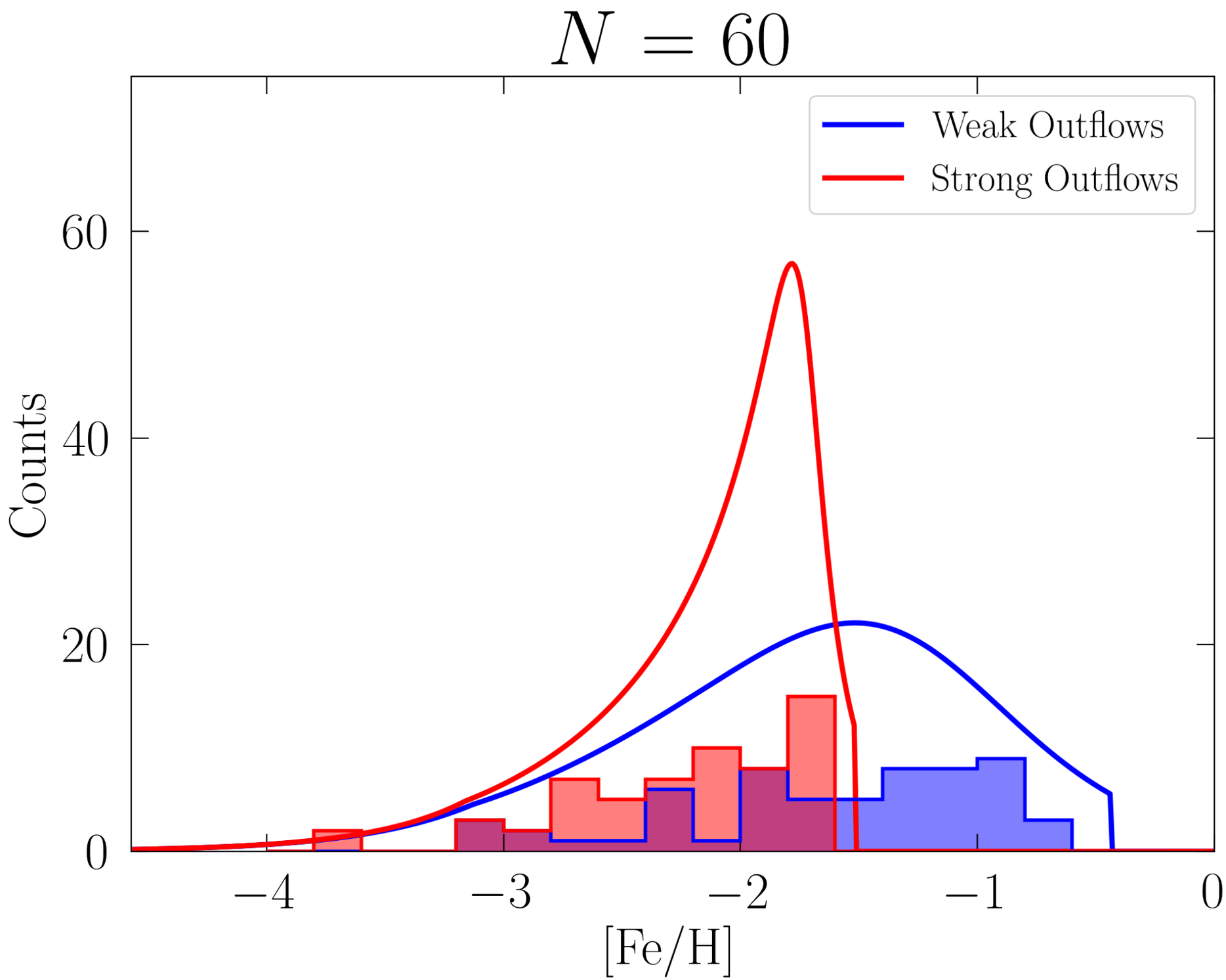
Weinberg+17

Outflow Strength on MDF Shape



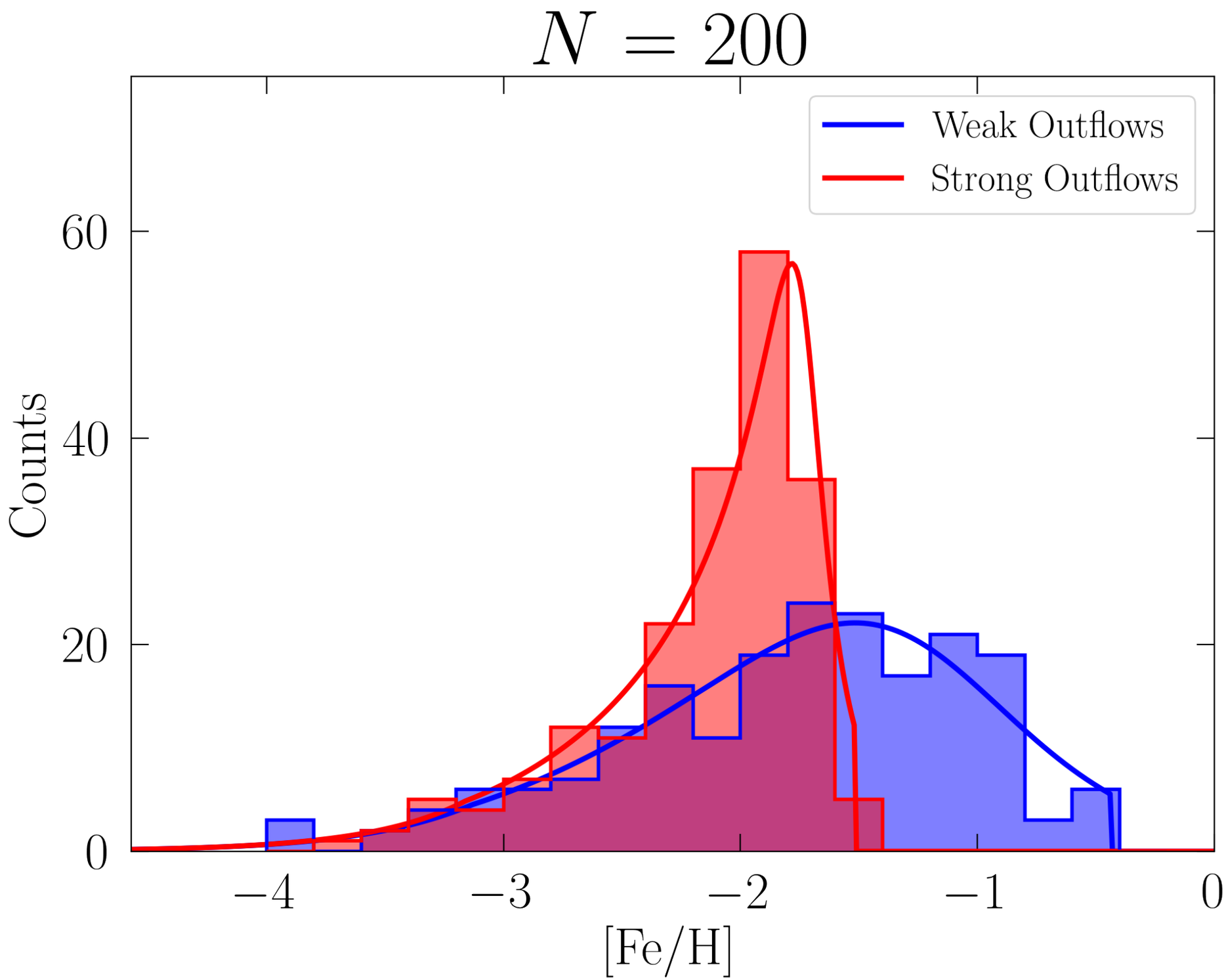
Weinberg+17

Outflow Strength on MDF Shape



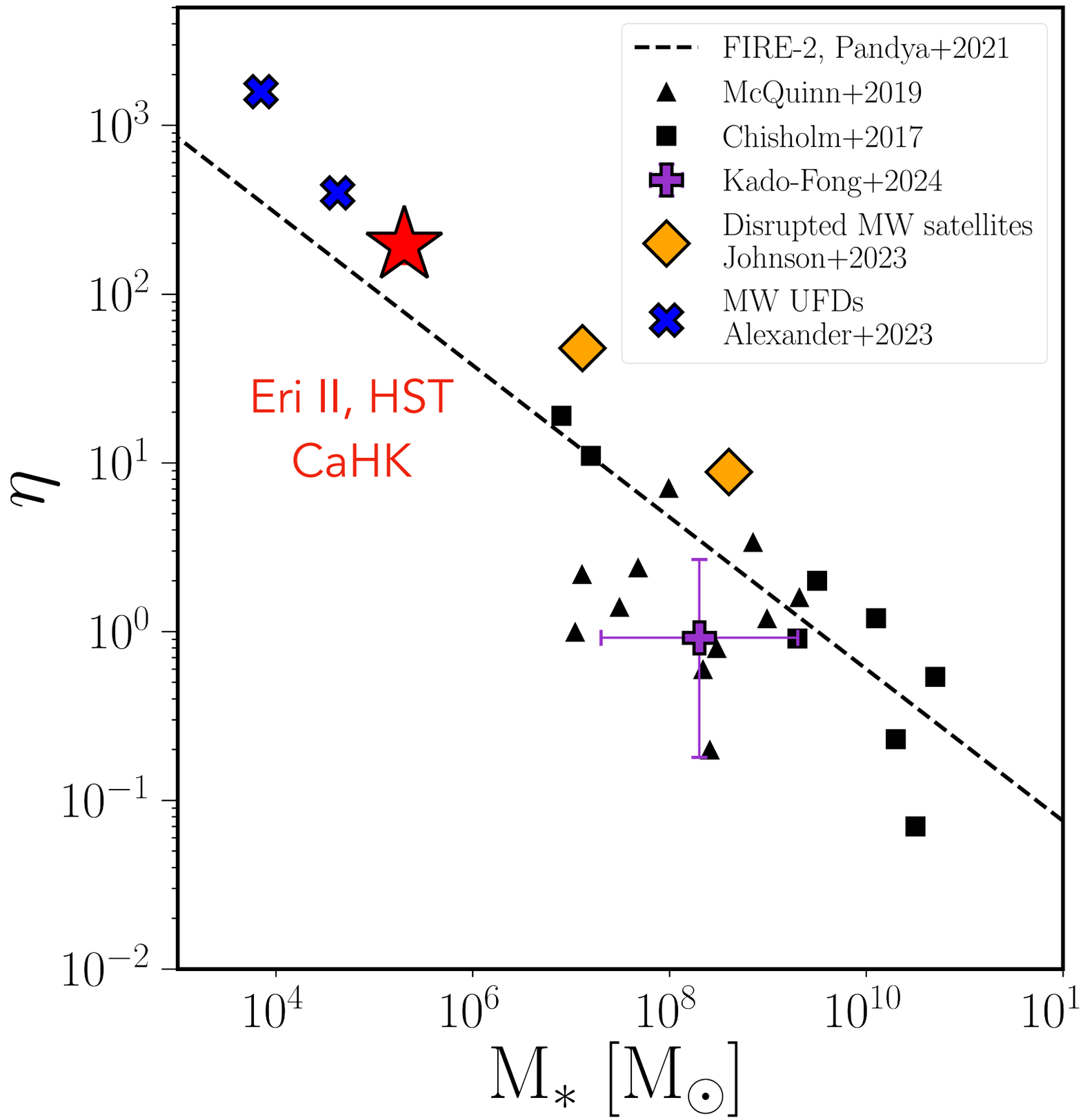
Weinberg+17

Outflow Strength on MDF Shape



Weinberg+17

Outflow Strength in Dwarf Galaxies



z_{sform} ~ 7

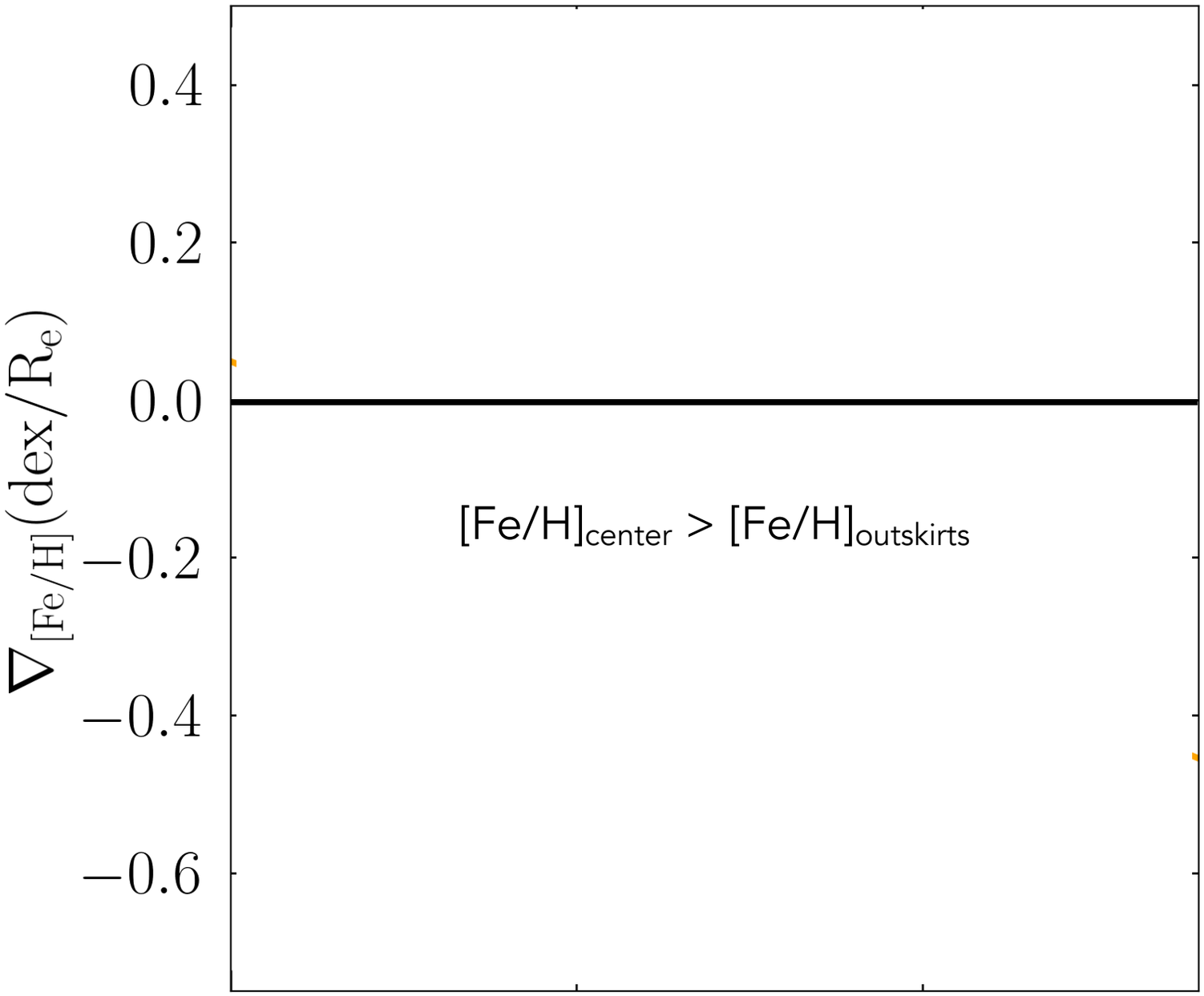
z_{sform} ~ 1-2

z_{sform} ~ 0.01-0.21

z_{sform} ~ 0

Adapted from Sandford+2024

Metallicity Gradients as Tracers of the Baryon Cycle

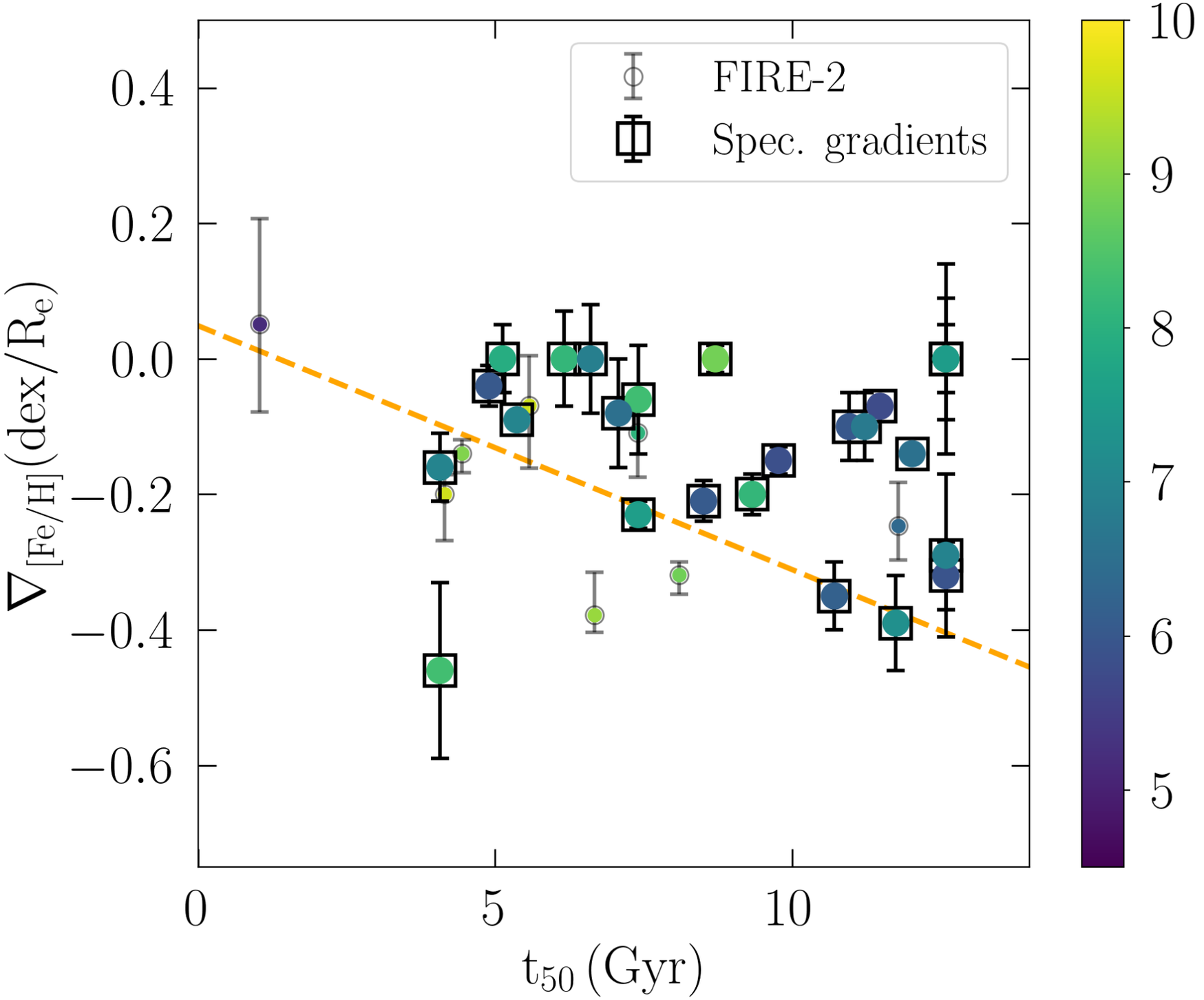


Gradient strength causes?

- M_{star}
- Environment (Sales+2010)
- Angular momentum (Schroyen+2013)
- Merger events (Cardona-Berrero+2021)
- Median stellar age (El-Badry+2016, Mercado+2021)

Mercado+2021

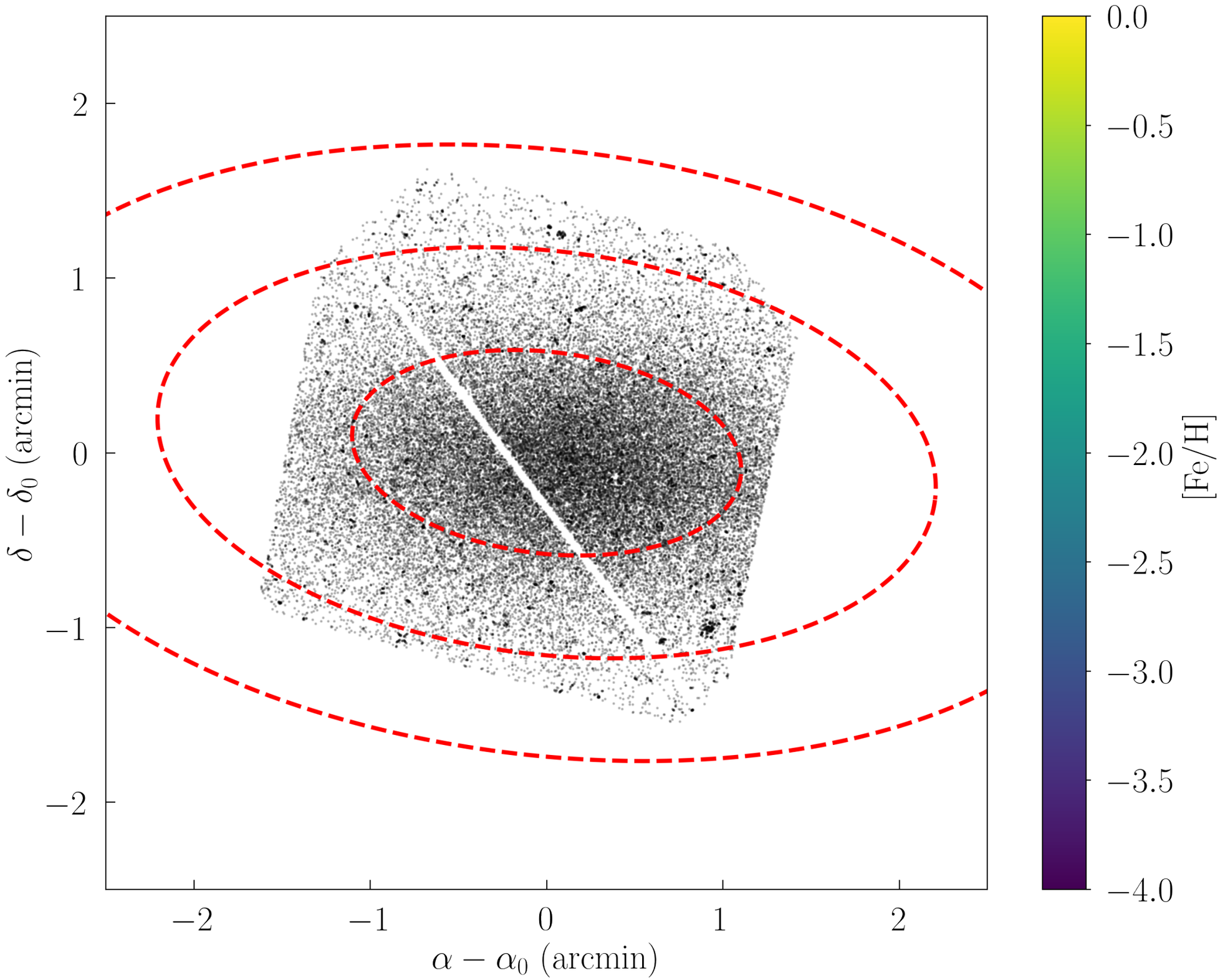
Metallicity Gradients as Tracers of the Baryon Cycle



predicted age-gradient strength relation from stellar feedback-driven gradients and DM core formation

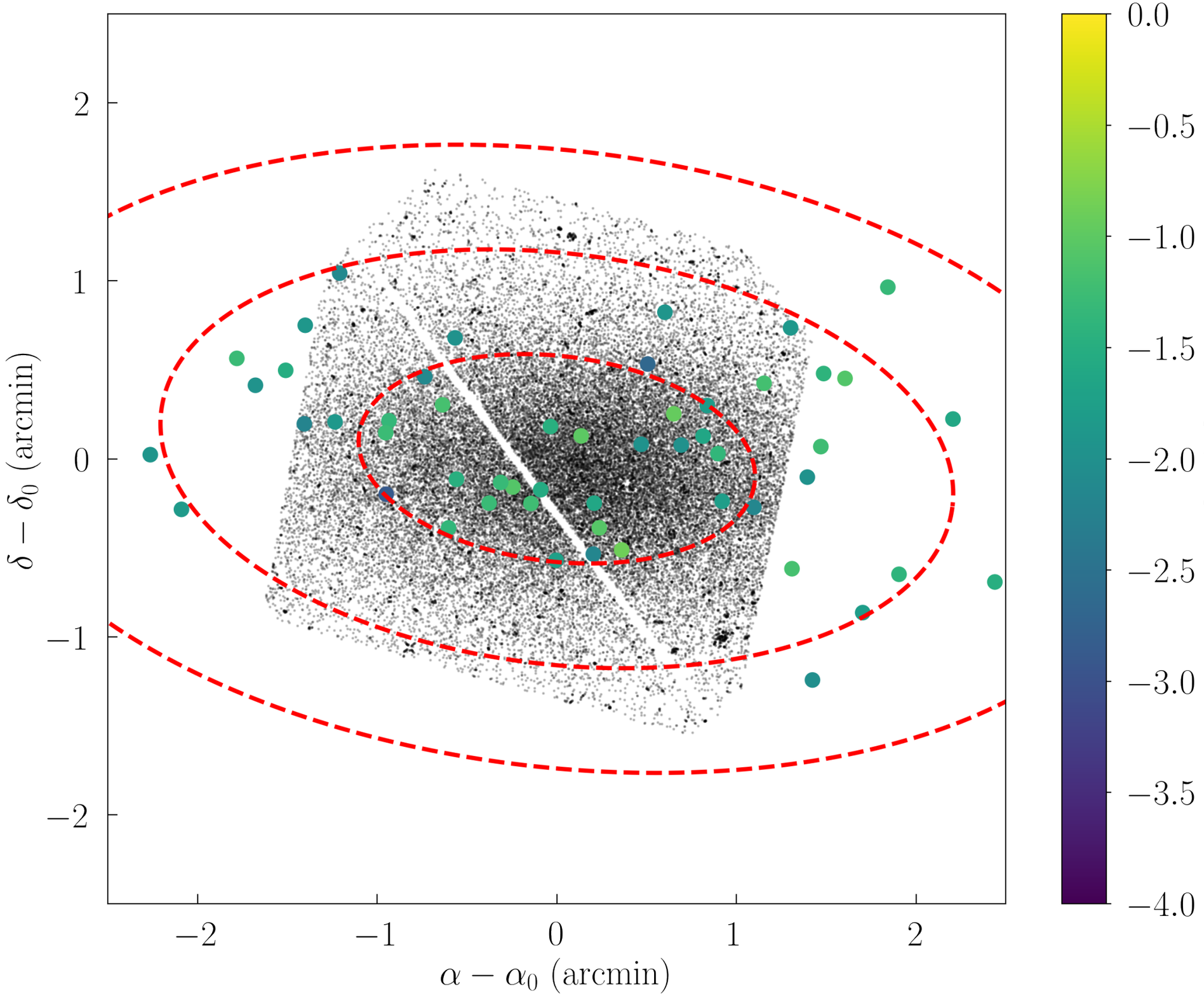
Mercado+2021, Taibi+2022

Spatially Resolved Stellar Metallicity Maps of Distant Galaxies: Tucana dSph (~1 Mpc)



Fu+2024a

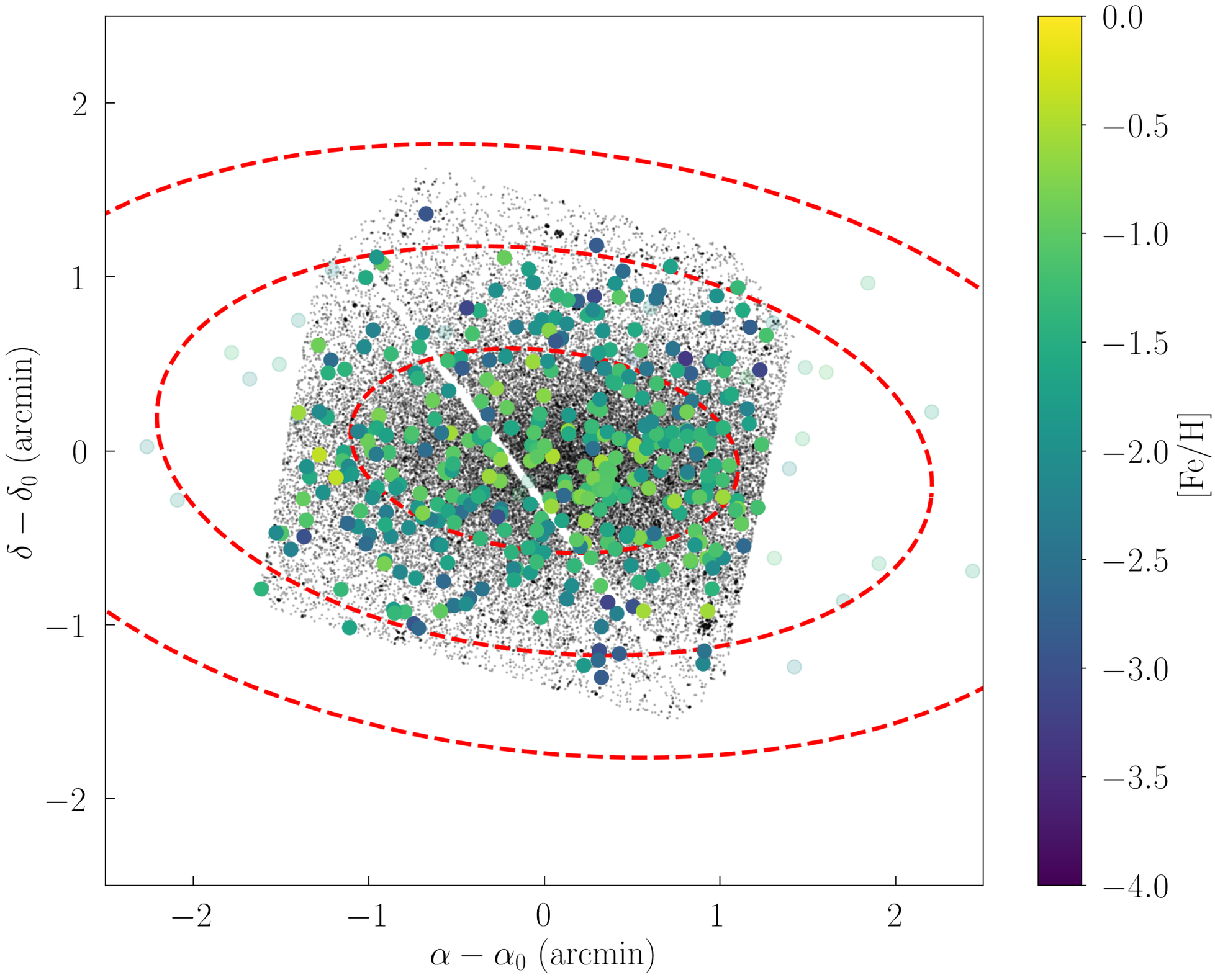
Spatially Resolved Stellar Metallicity Maps of Distant Galaxies: Tucana dSph (~1 Mpc)



VLT spectroscopy, N=52 (Taibi+20)

Fu+2024a

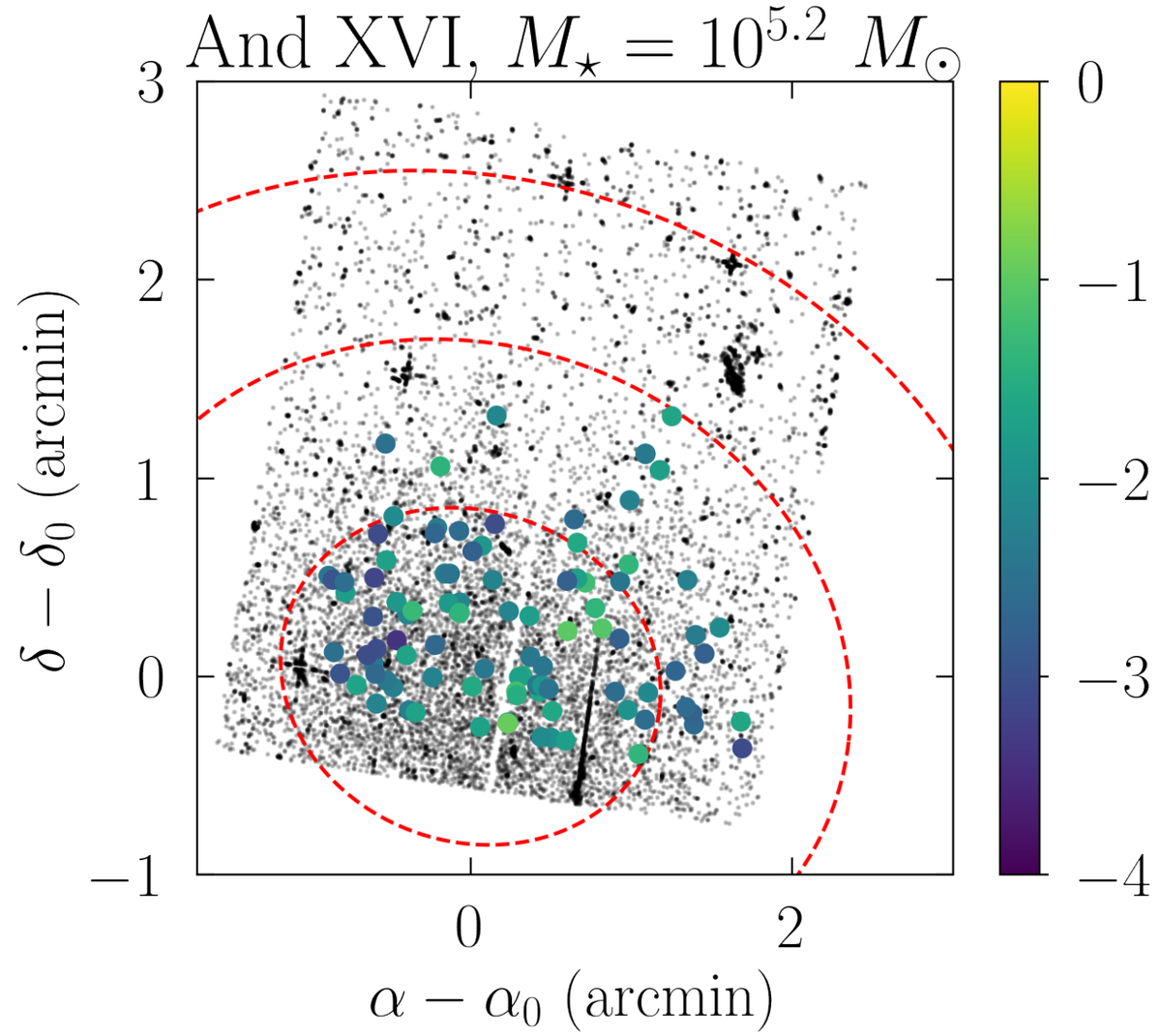
Spatially Resolved Stellar Metallicity Maps of Distant Galaxies: Tucana dSph (~1 Mpc)



HST CaHK, N=374 (Fu+2024a)

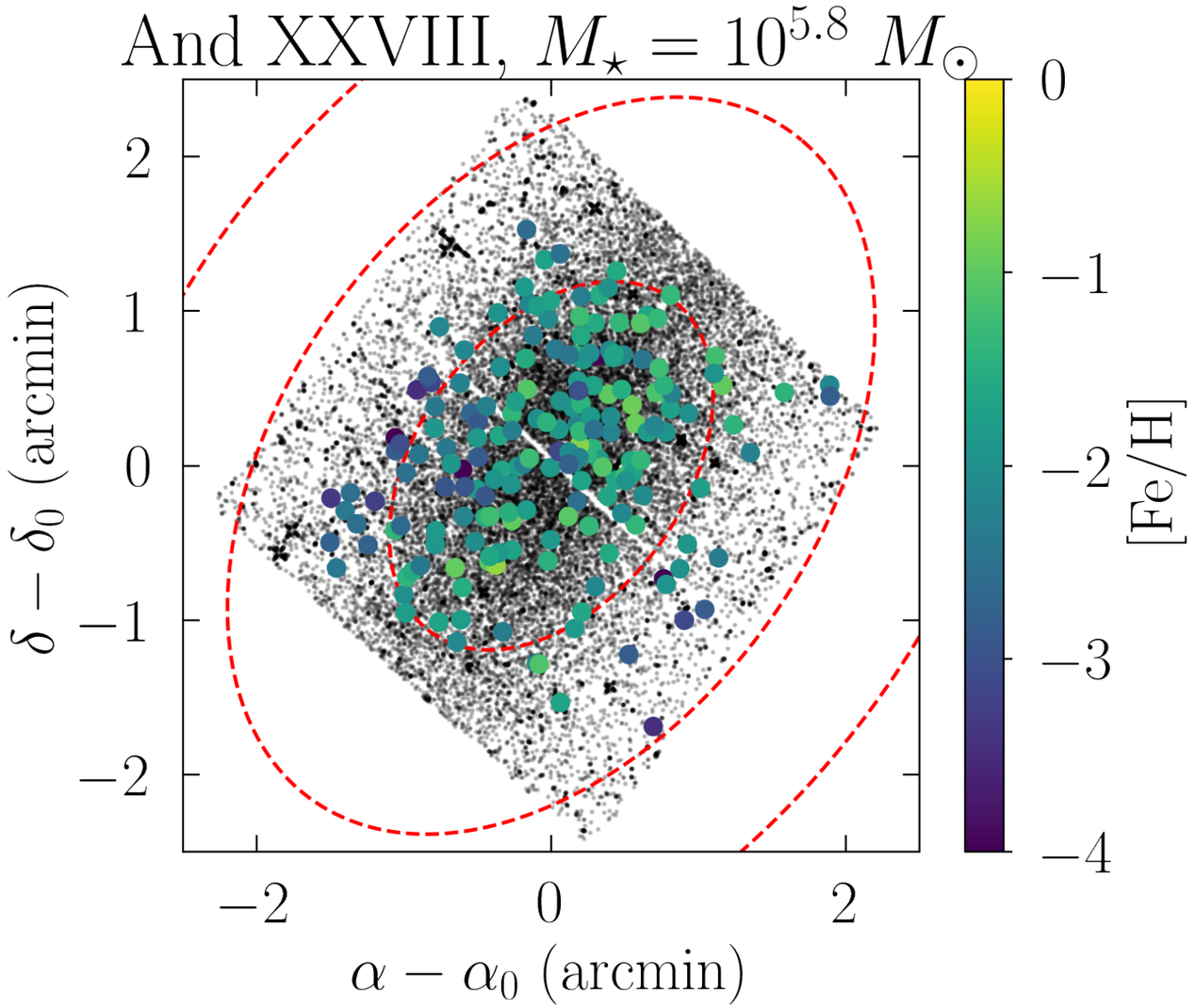
Fu+2024a

New on arXiv: Spatially Resolved Stellar Metallicity Maps of M31 Dwarf Galaxies



95 stars

(N_{lit} = 0)

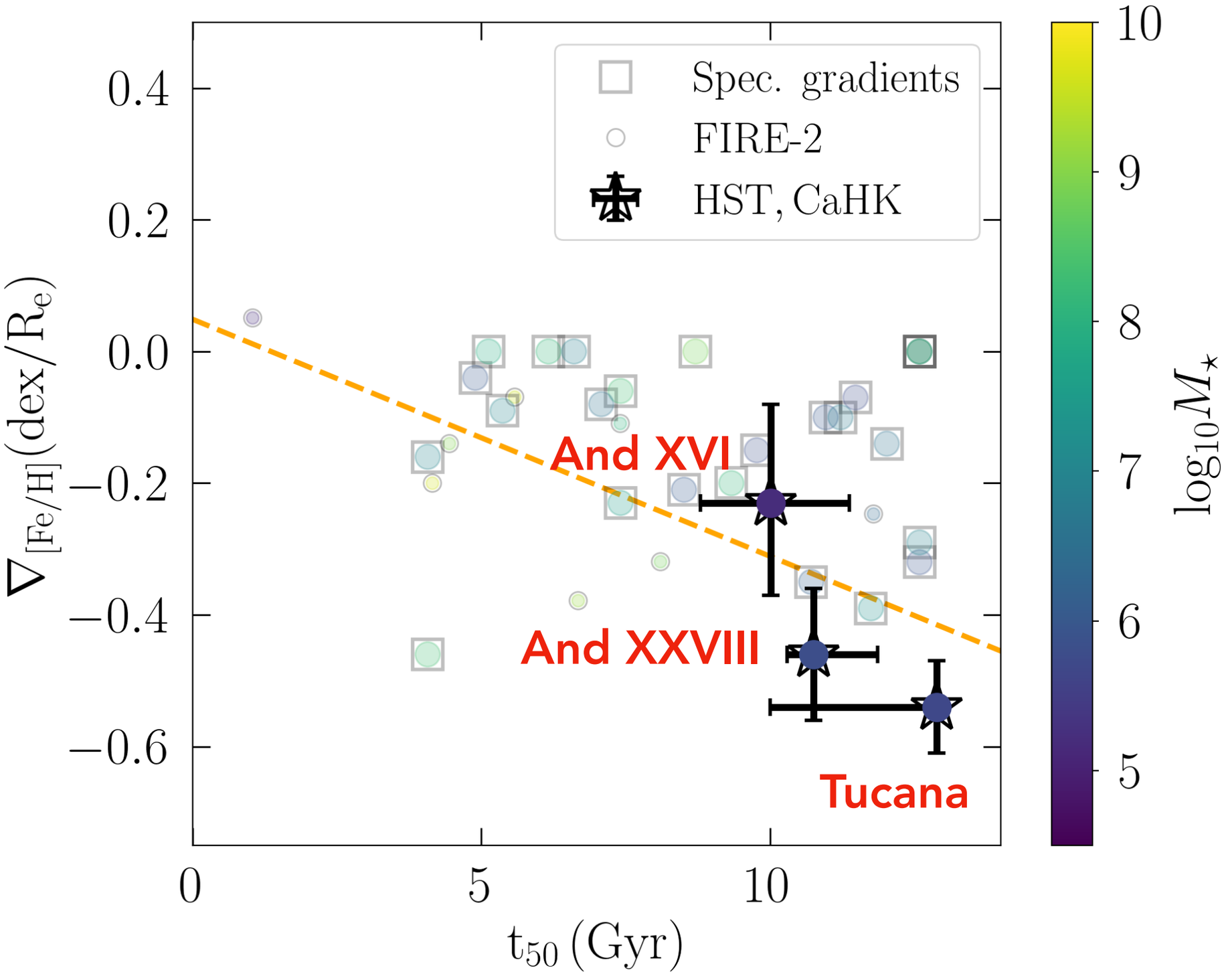


191 stars

(N_{lit} = 13)

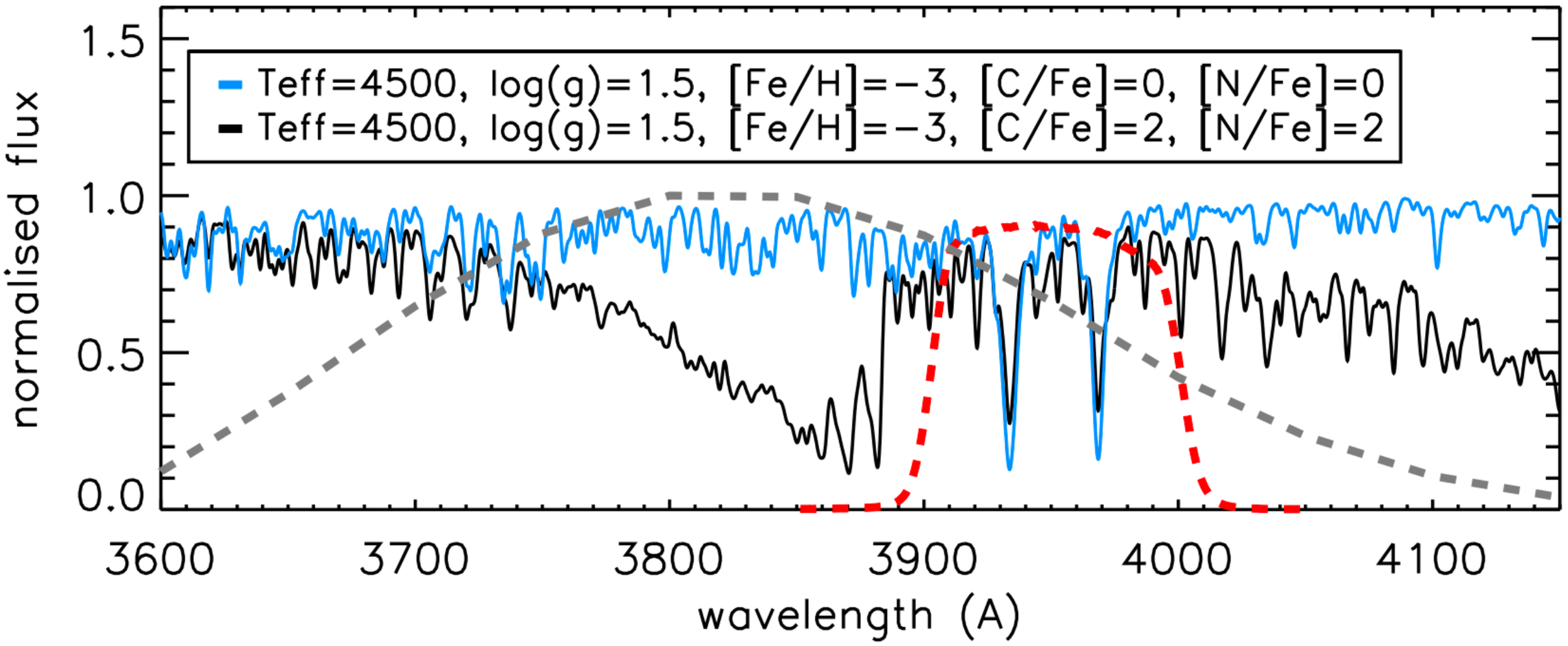
Fu+2024b

Metallicity Gradients as Tracers of the Baryon Cycle



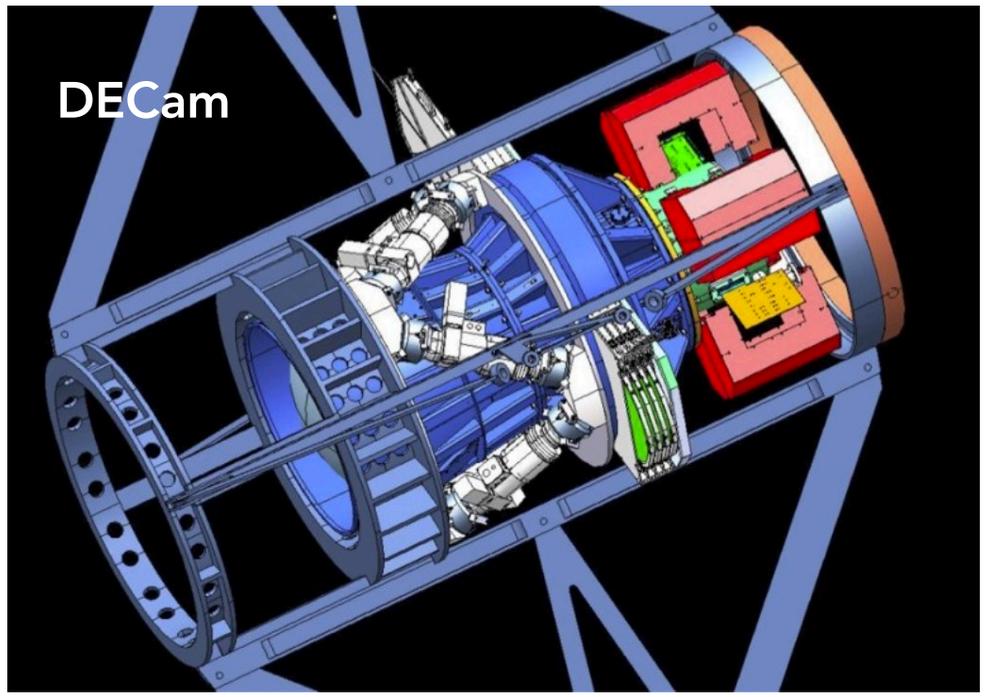
Fu+2024a,b

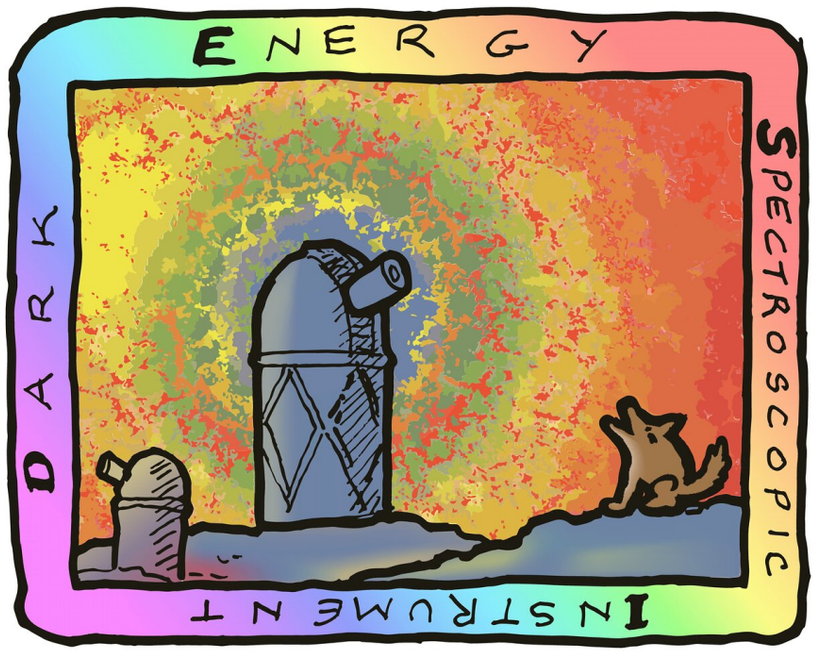
Photometric metallicities with Rubin Observatory?

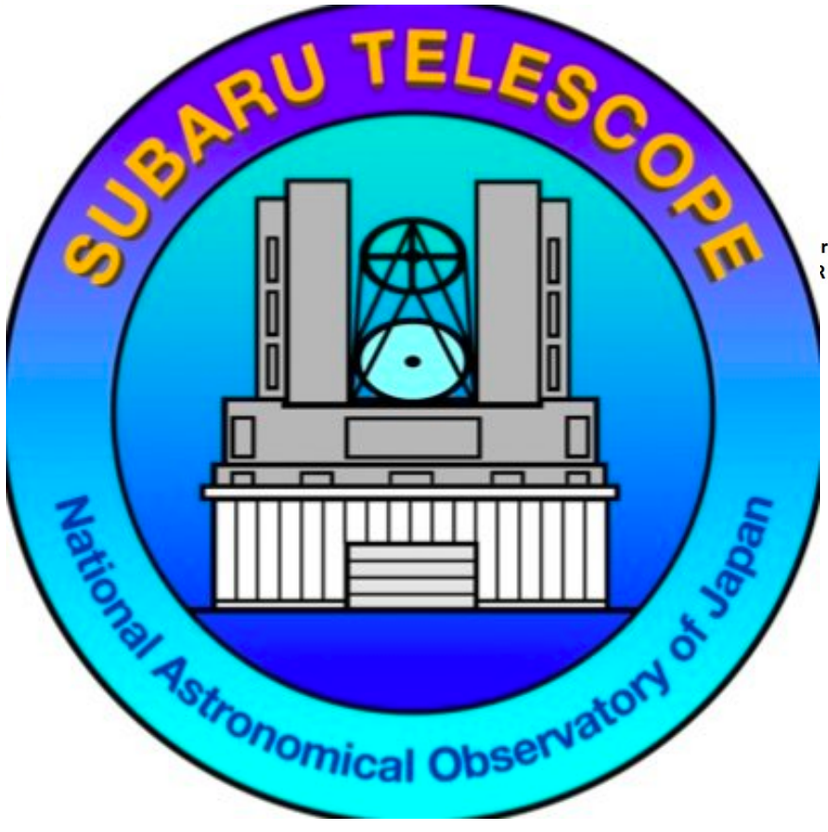


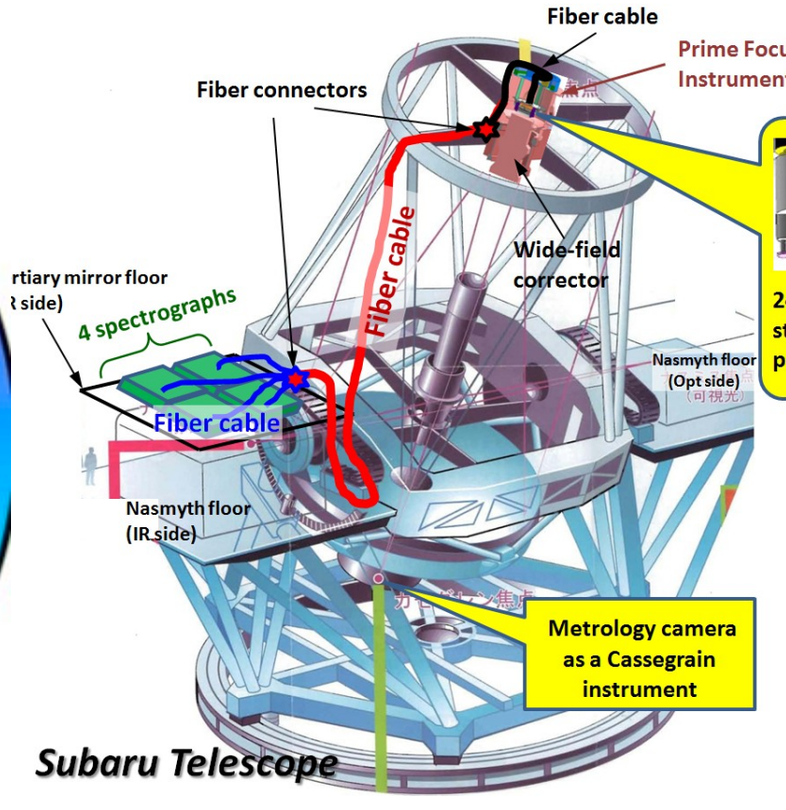
- *u*-band metallicity sensitivity?
- Kahn+19 on narrowband filter legacy surveys: minimum filter width of ~100 angstroms

Contemporary Photometric Metallicity Surveys & Synergies









Conclusions

- Photometric metallicities using HST CaHK narrow-band imaging enables stellar MDF measurements in distant and/or faint galaxies
- Data enable following perspectives into the baryon cycle of dwarf galaxies:
  - Measuring the mass-metallicity relation in ultra-faint dwarf galaxies for benchmarking against simulations
  - Quantifying outflows faint dwarf galaxies through chemical evolution modeling
  - Novel metallicity gradient measurements in faint dwarf galaxies to constrain metallicity gradient formation physics
- Abundant potential for photometric metallicities with upcoming surveys, including LSST