# The Milky Way's Most Metal-Poor Globular Clusters and Their Tidal Streams

or: How I tried to learn about
Multiple Populations in GCs and
ended up studying tidal disruption


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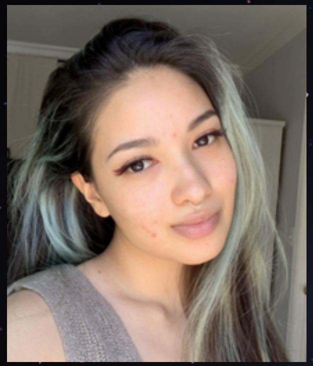


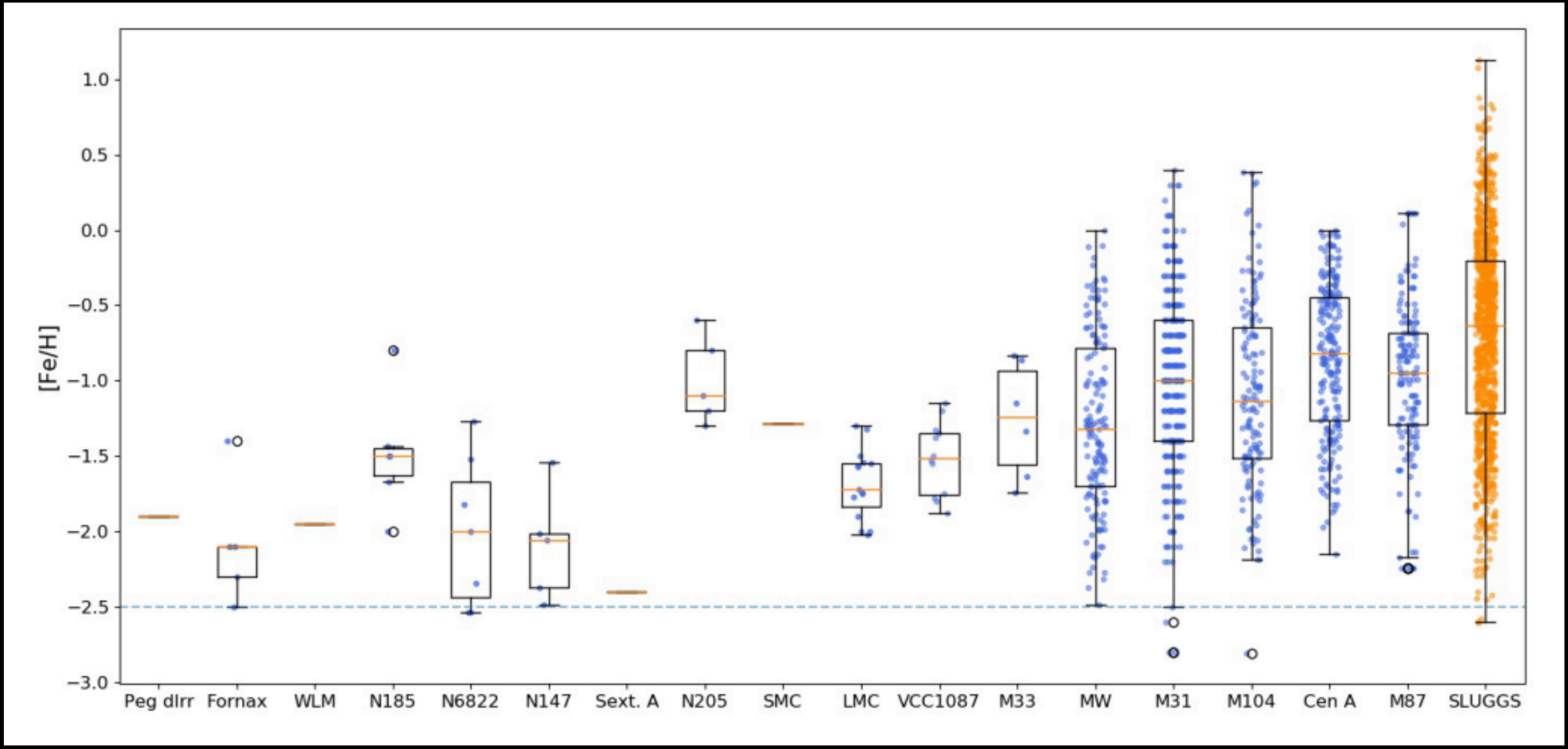
<u>Jandrie Rodriguez</u> (East LA College), Ji, Simpson, Li, Martell, Bonaca in prep

Wan, Lewis, Li, Simpson, S5 Collaboration 2020, Nature, 583, 768

# Summary

- There is no globular cluster metallicity floor
- The most metal-poor GCs are tidally disrupting
- Multiple Populations can potentially be used to recover the initial stellar mass of a GC

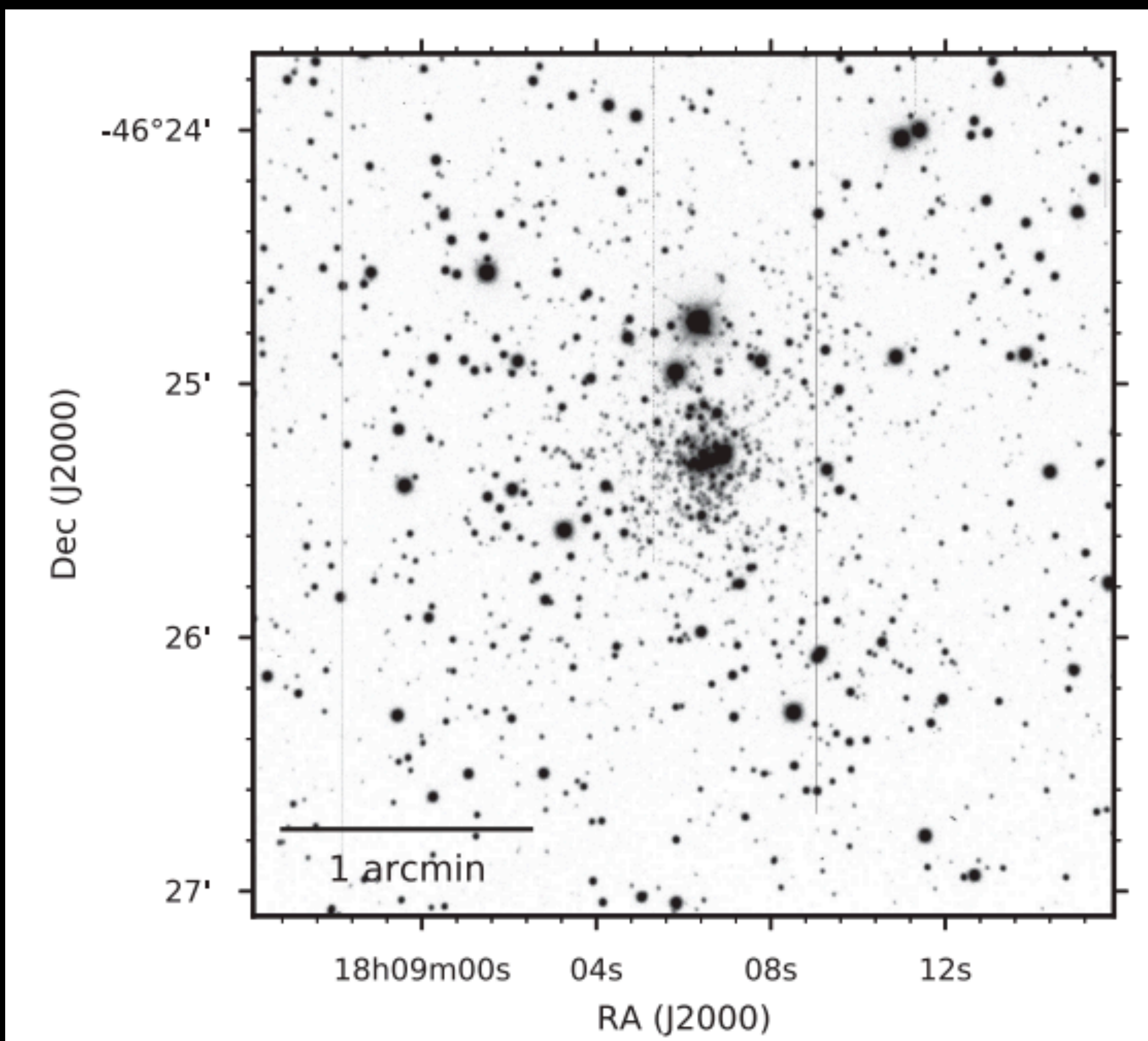
# The Globular Cluster "Metallicity Floor"

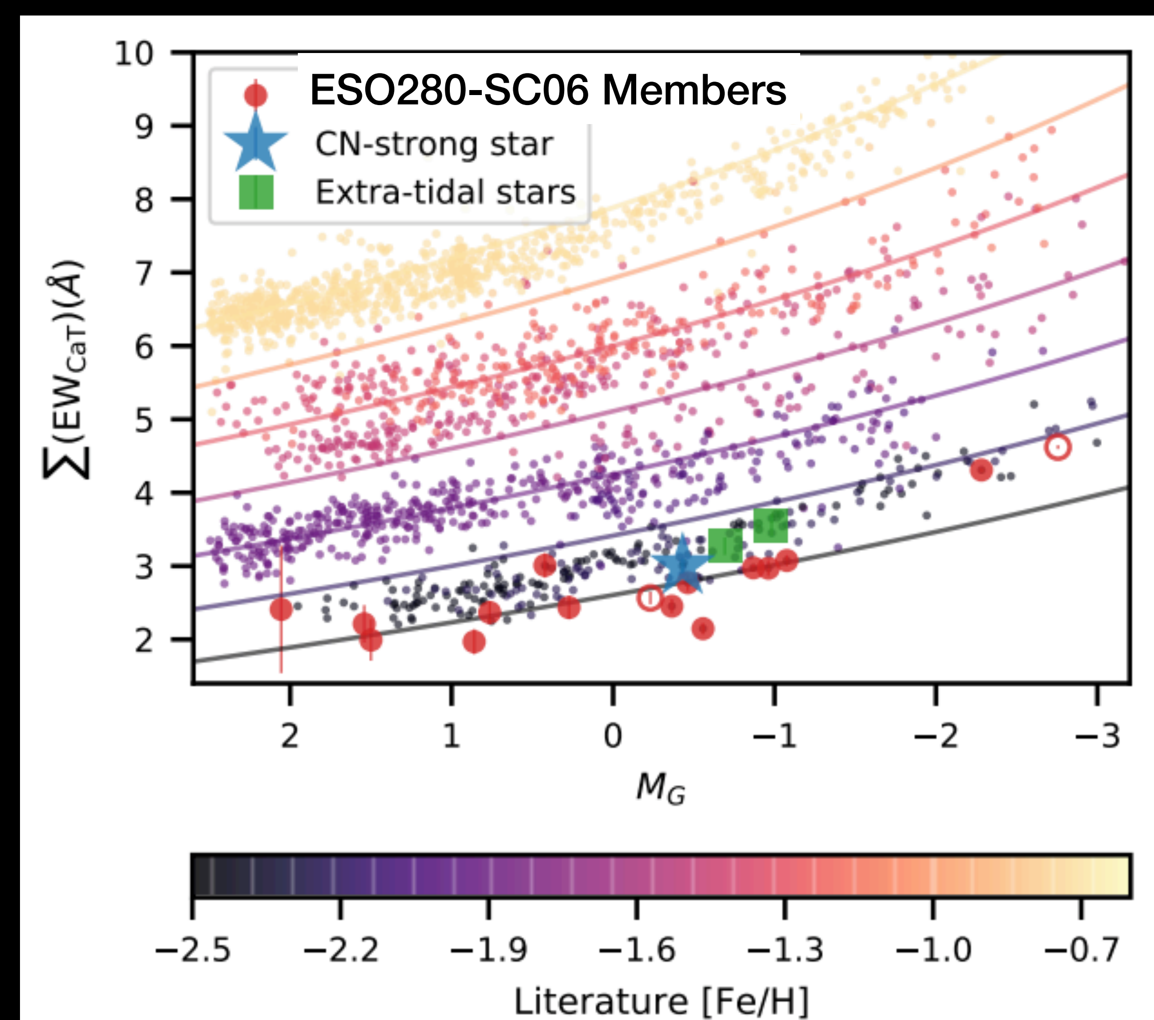



Beasley et al. 2019

# The Faint, Metal-Poor Globular Cluster ESO280-SC06

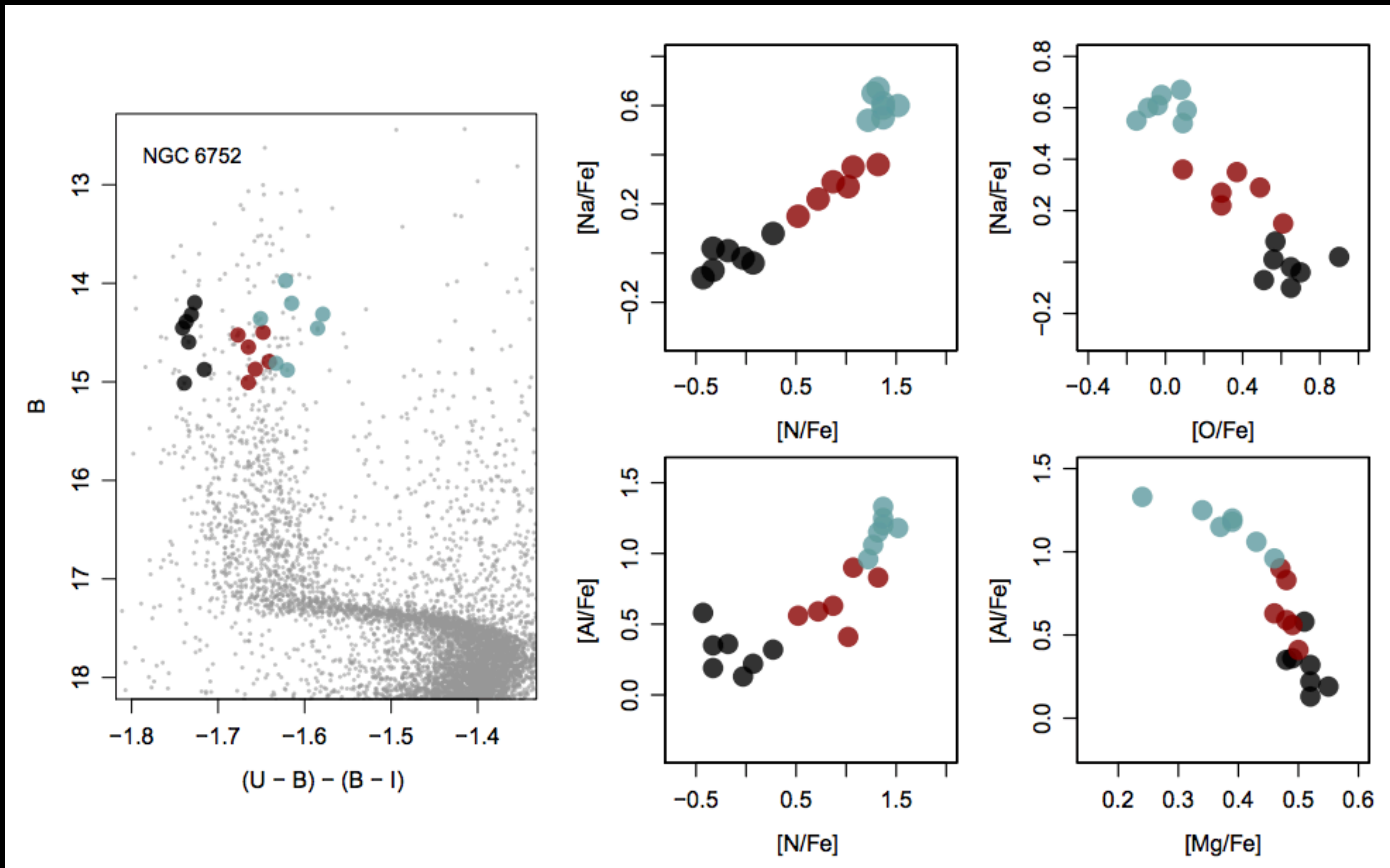
$M_V$ = -4.9, [Fe/H] = -2.5
$M_{star}$ ~ $10^4$ $M_{sun}$, d=22kpc
The most Fe-poor MW GC known (in 2018)




Simpson 2018, Simpson & Martell 2019

# Multiple Populations

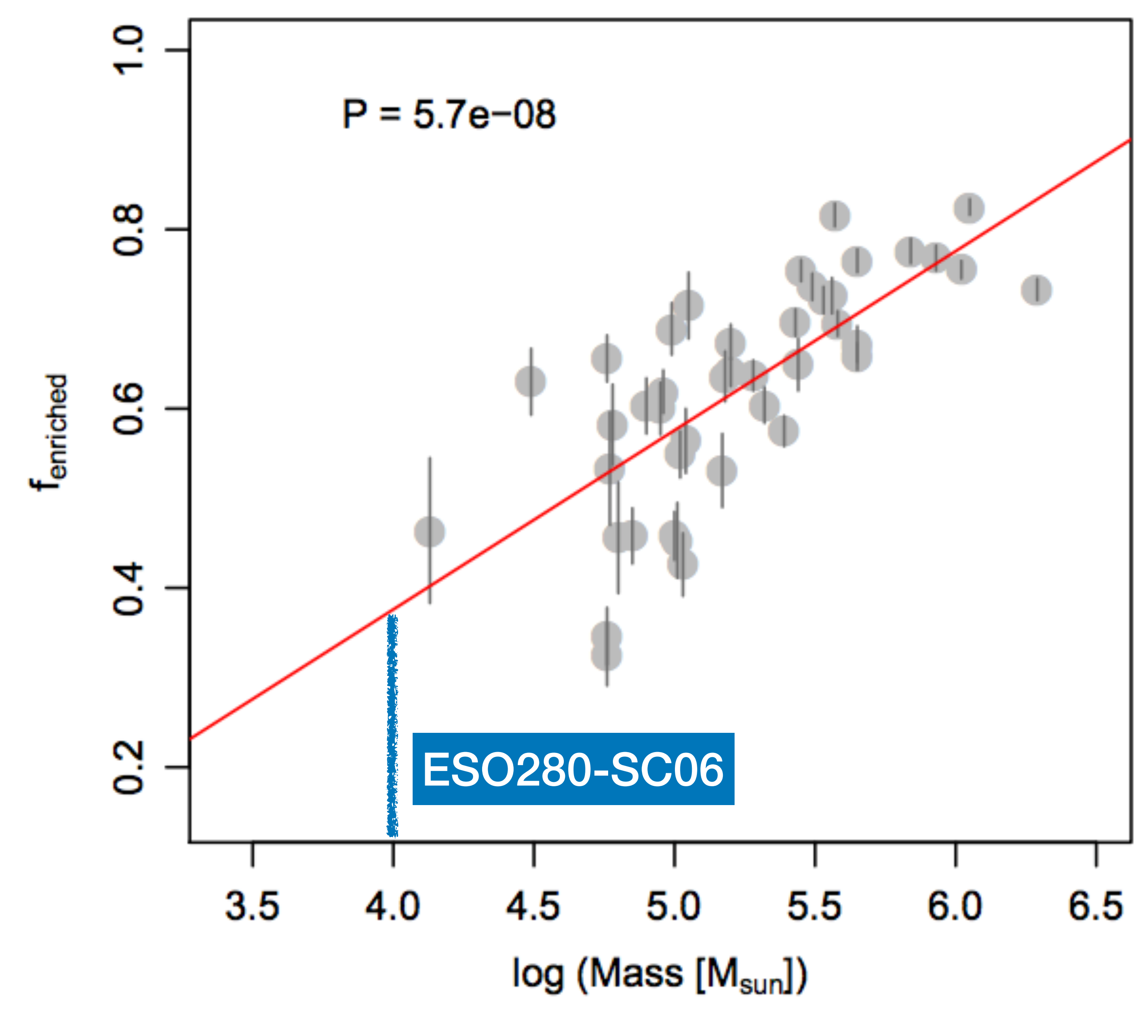



Bastian + Lardo 2018

Black points = “regular” halo star abundances (1P, 1G, primordial, normal, etc)
Red and green points = 2nd/3rd population (2P, 2G, enriched, anomalous, weird, etc)

**Enriched star abundances: high N, Na, Al, only occur in GCs**

# Mass-Enriched Fraction Relation for GCs



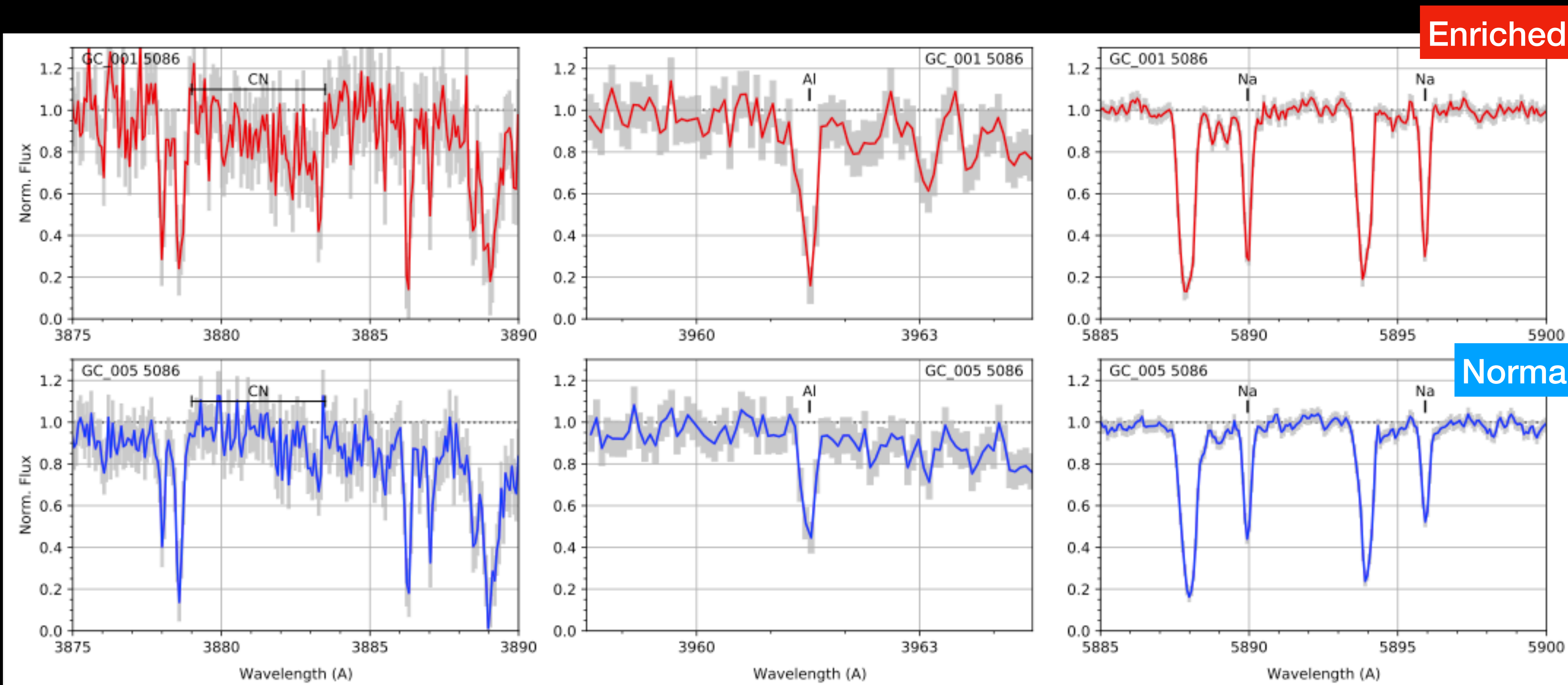

Q: could we detect multiple populations in a metal-poor and faint globular cluster?

(Can't use photometry for multiple populations in metal-poor stars)

Bastian + Lardo 2018

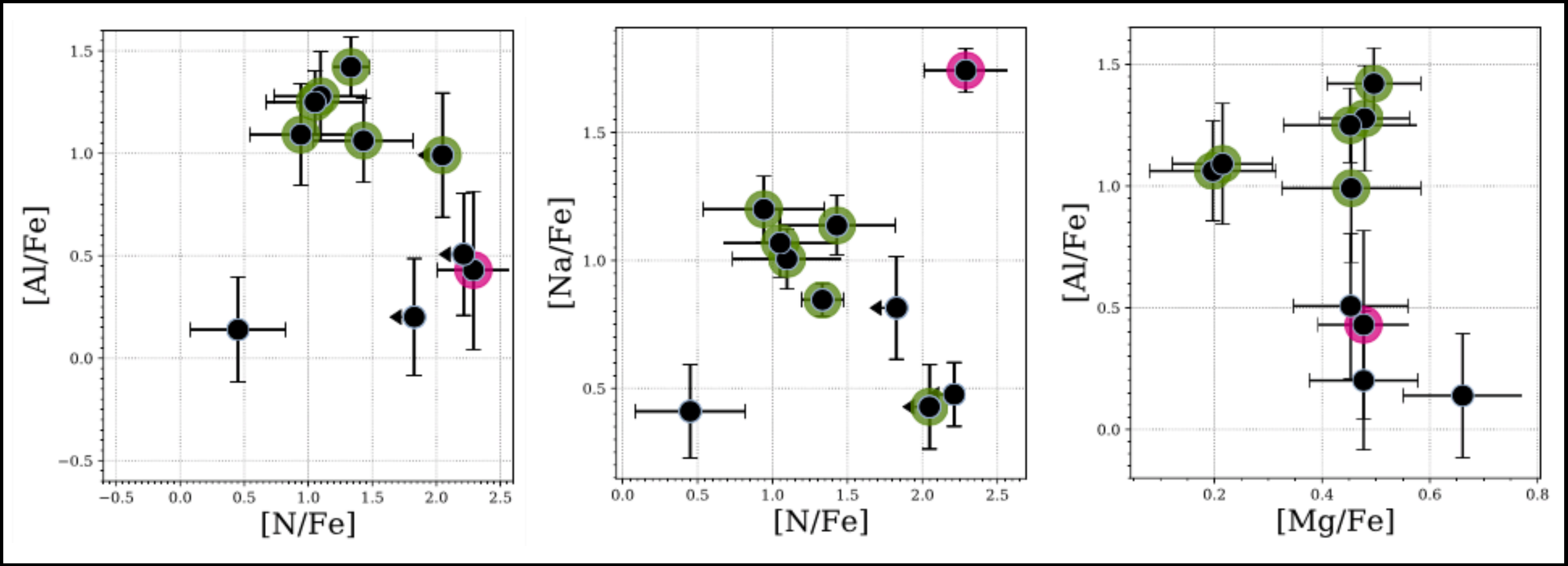
# Measure Abundances with MIKE Spectra

**CN** **Al** **Na**




J. Rodriguez, Ji et al. in prep

# 50-70% of ESO280-SC06 stars are enriched

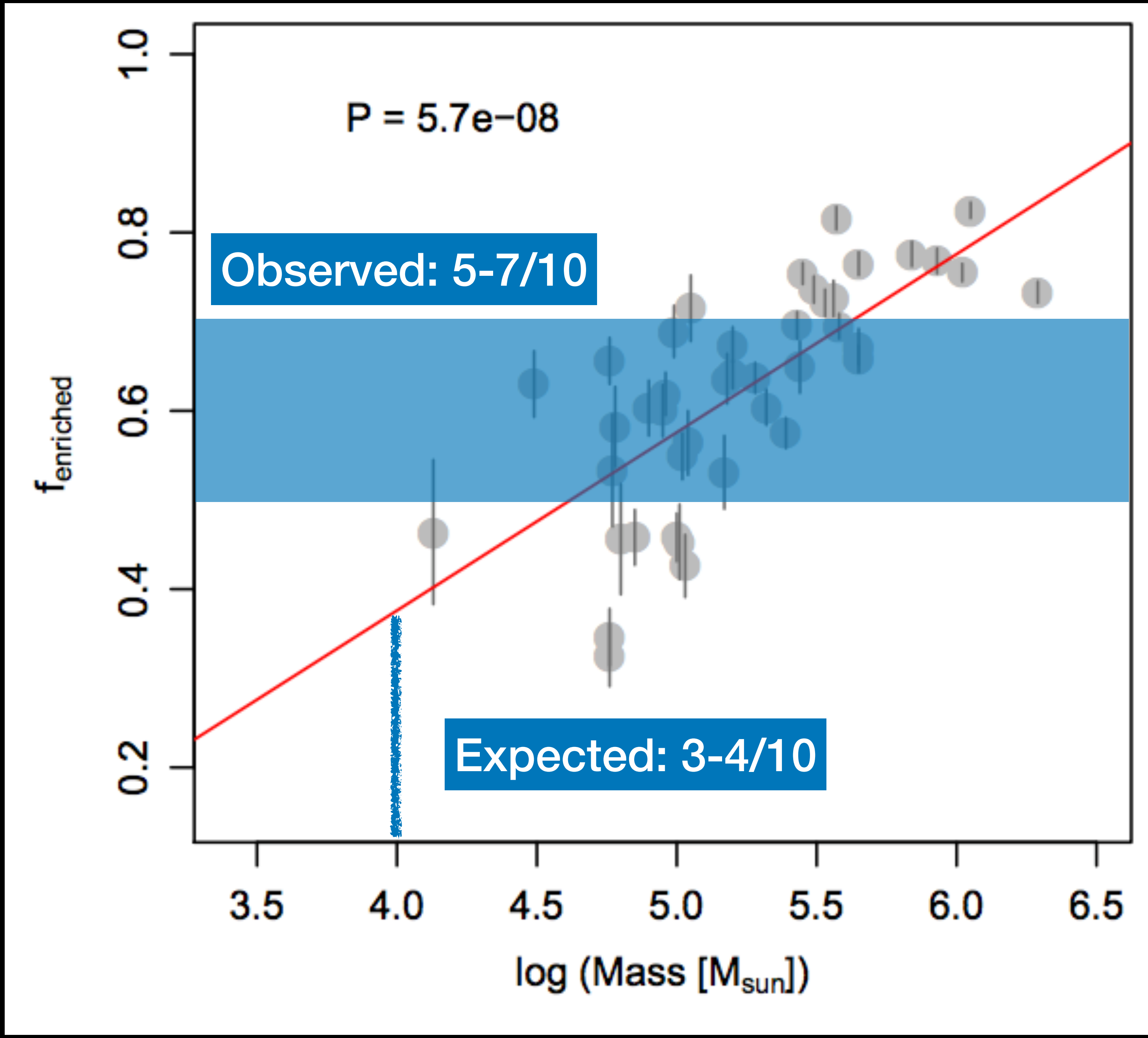



6 stars have high Al (+1 in LTE); 6 stars have high Na

(1 star has high C, N, and Ba, AGB binary mass transfer)

J. Rodriguez, Ji et al. in prep

# Observed vs expected

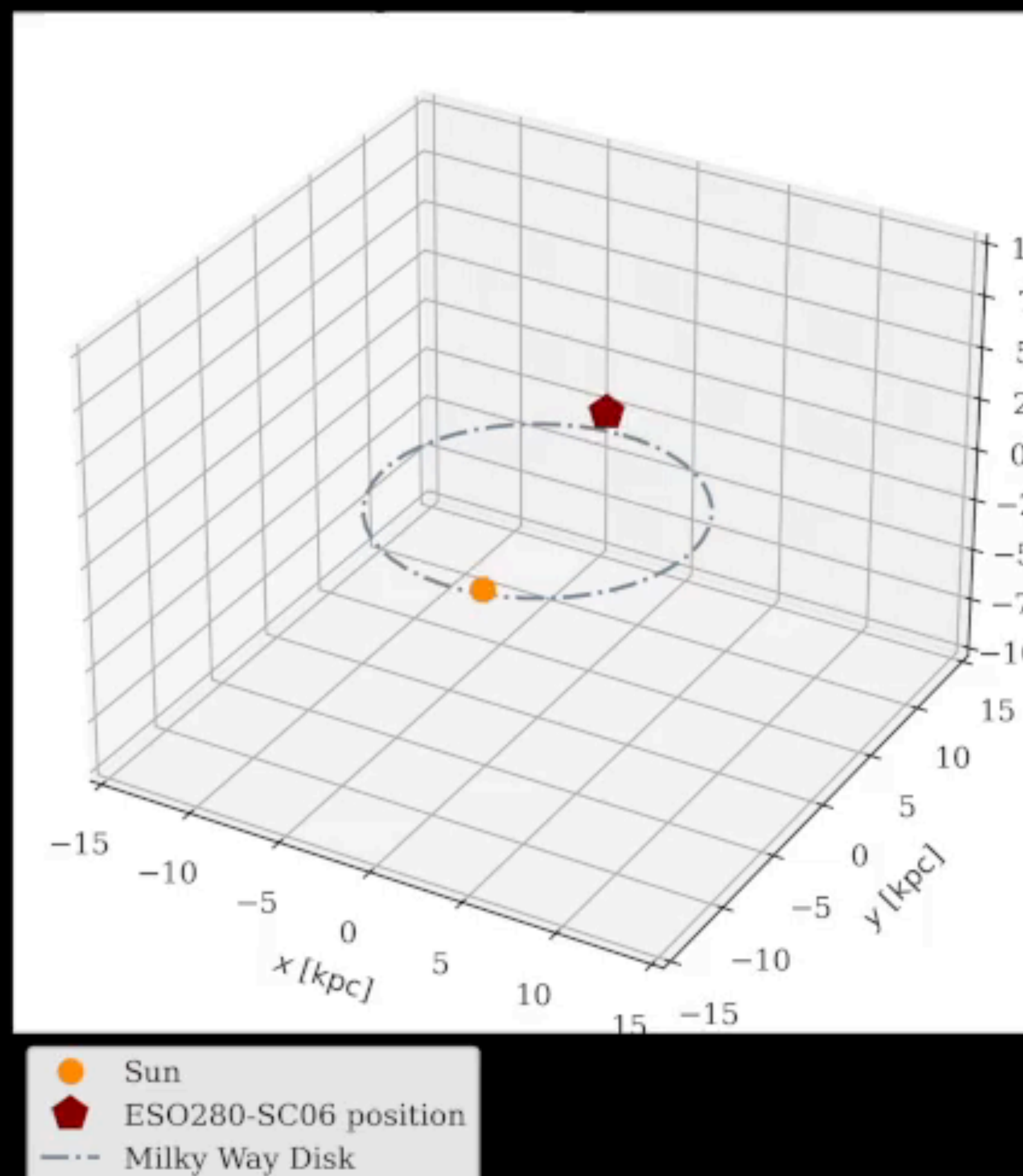



Bastian + Lardo 2018

J. Rodriguez, Ji et al. in prep

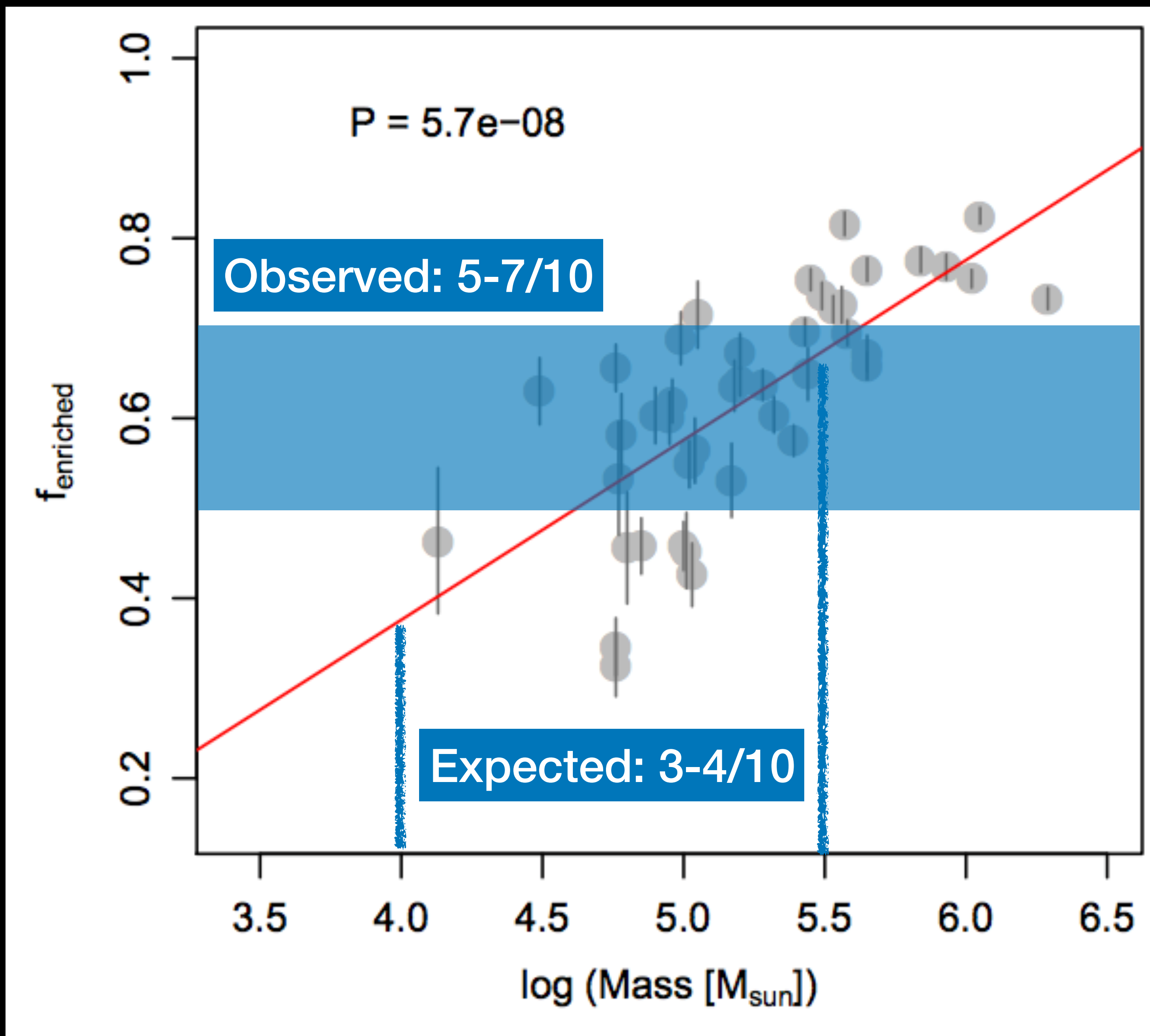
# ESO280-SC06 Orbit

**Low pericenter -> Likely Tidal Disruption**




J. Rodriguez, Ji et al. in prep

# Observed vs expected mass based on orbit



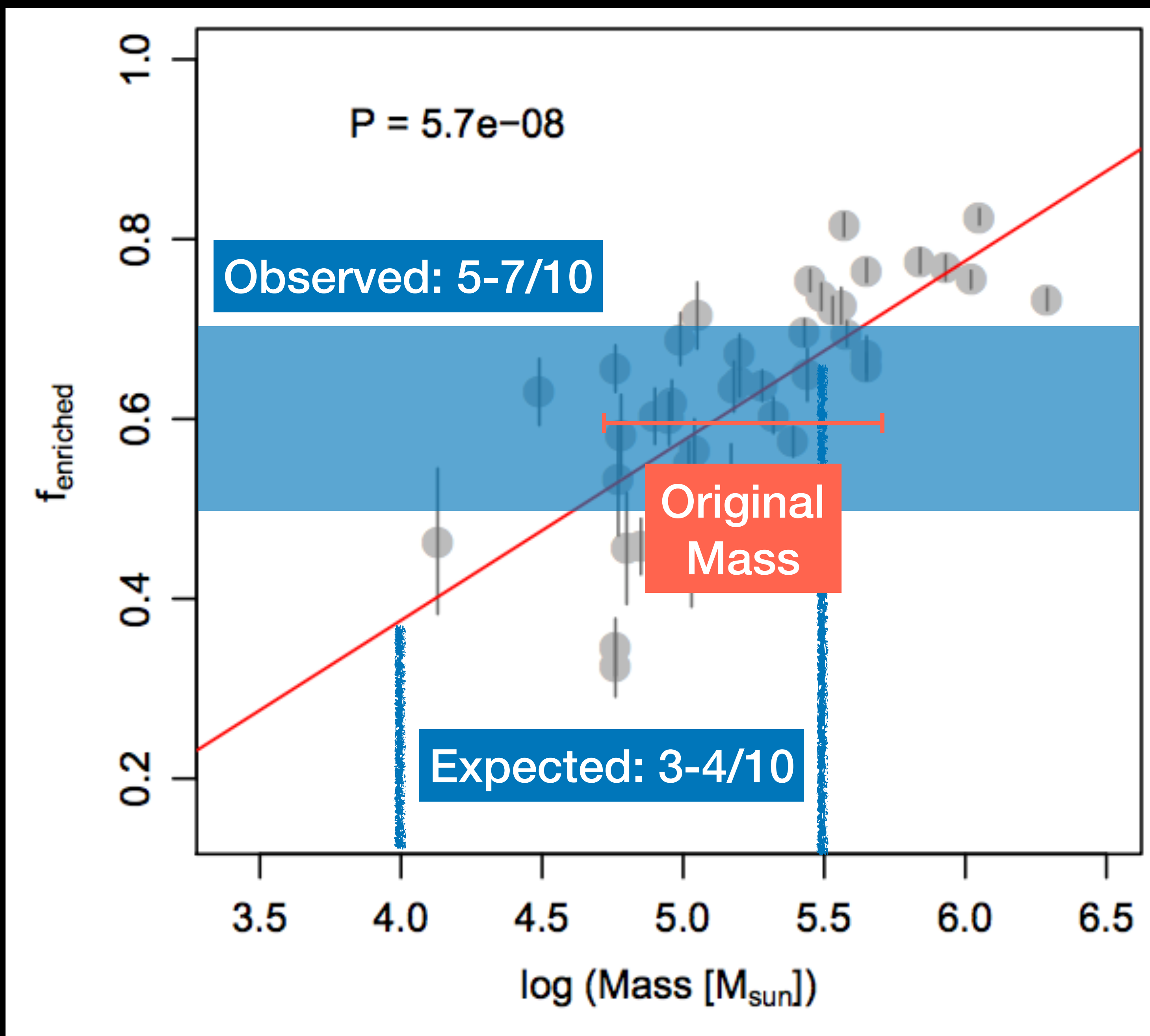

Orbital tidal stripping analysis predicts ~$10^{5.5}$ $M_{sun}$ original mass

Currently a few % of its original mass: Right before full disruption

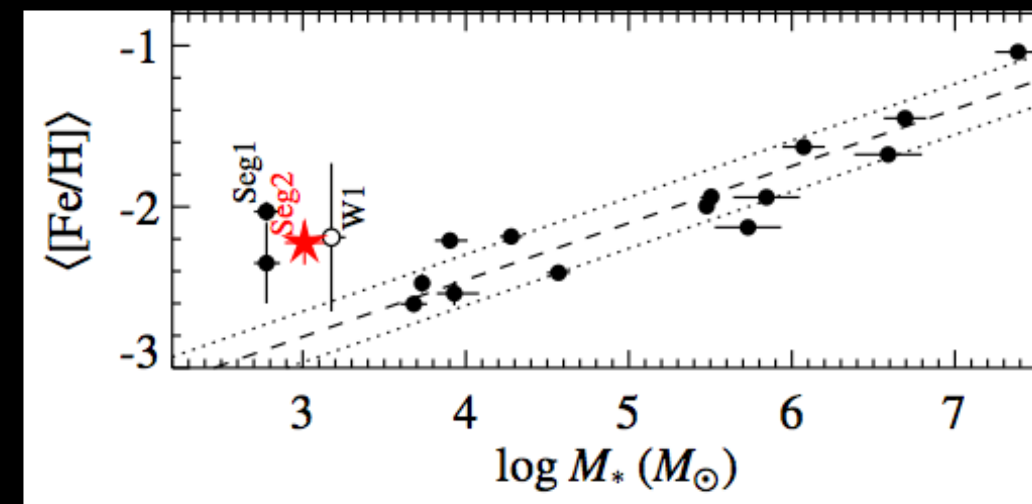
Bastian + Lardo 2018

J. Rodriguez, Ji et al. in prep

# Use $f_{enriched}$ to find initial mass before tidal disruption



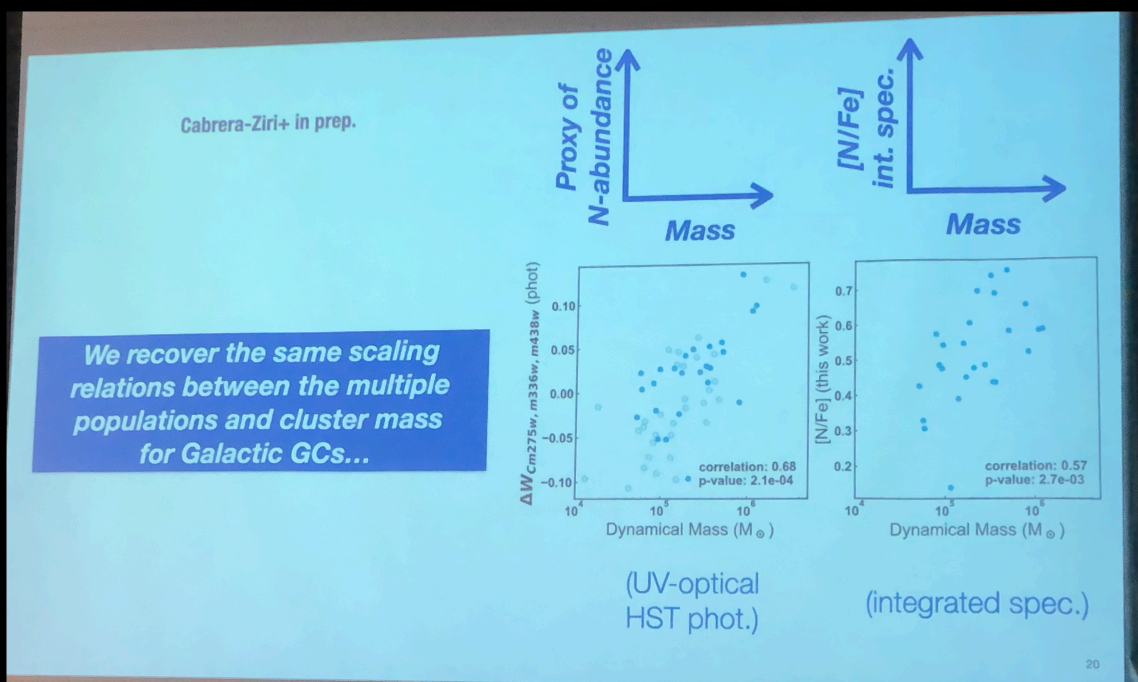

Bastian + Lardo 2018

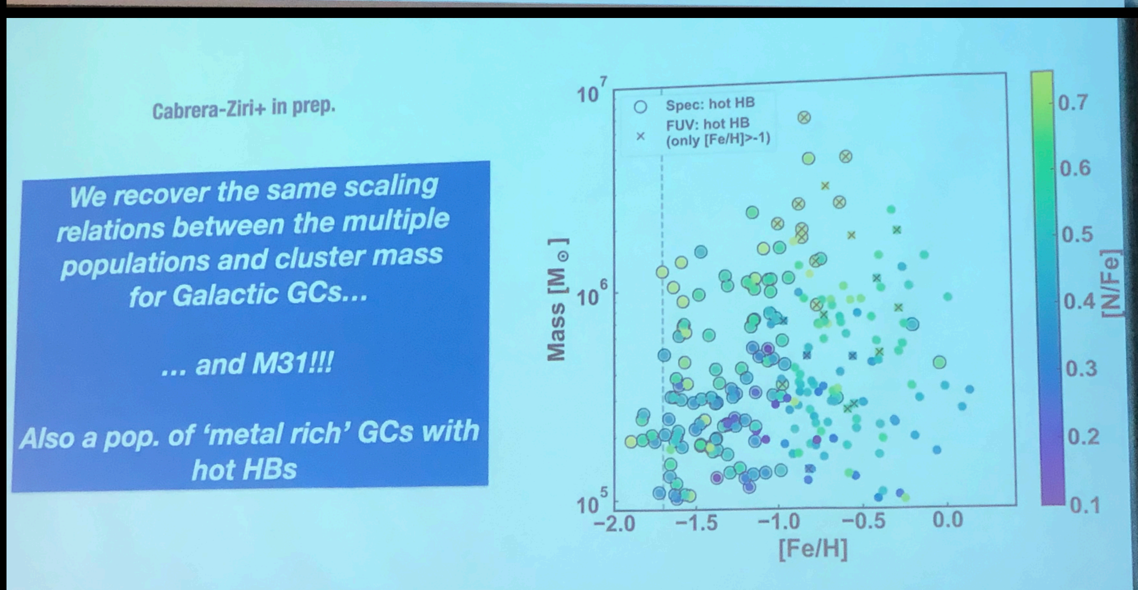



Kirby et al. 2013
Same mass loss argument for
dwarf galaxy mass-metallicity relation

J. Rodriguez, Ji et al. in prep

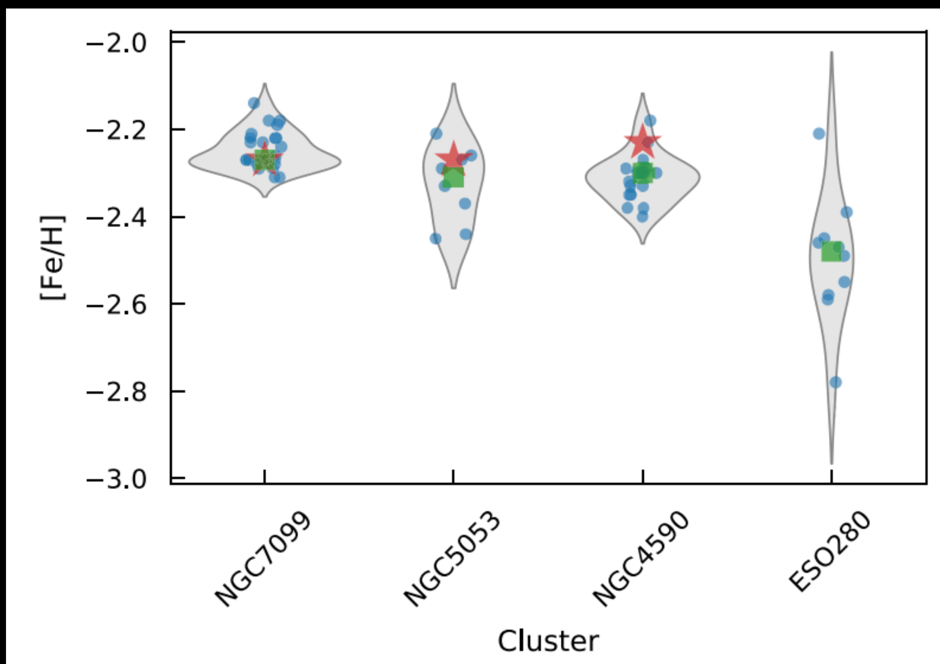
# Do this outside the Milky Way?!



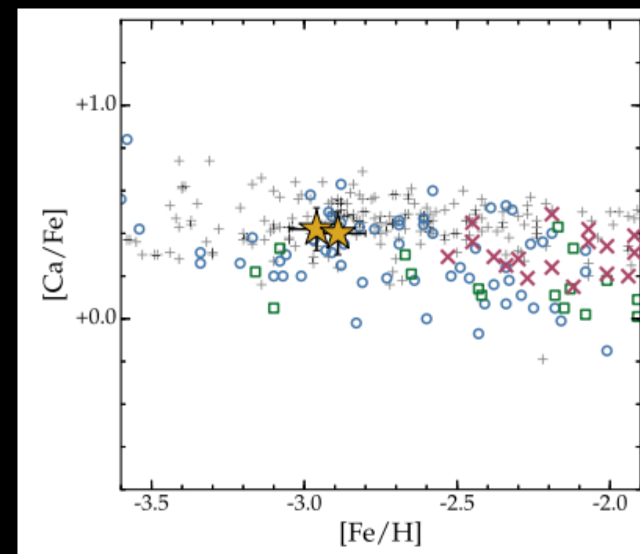




- Ivan Cabrerra-Ziri's talk this morning: $[N/Fe]_{IL}$ -> Dynamical Mass
- GC mass loss in external galaxies

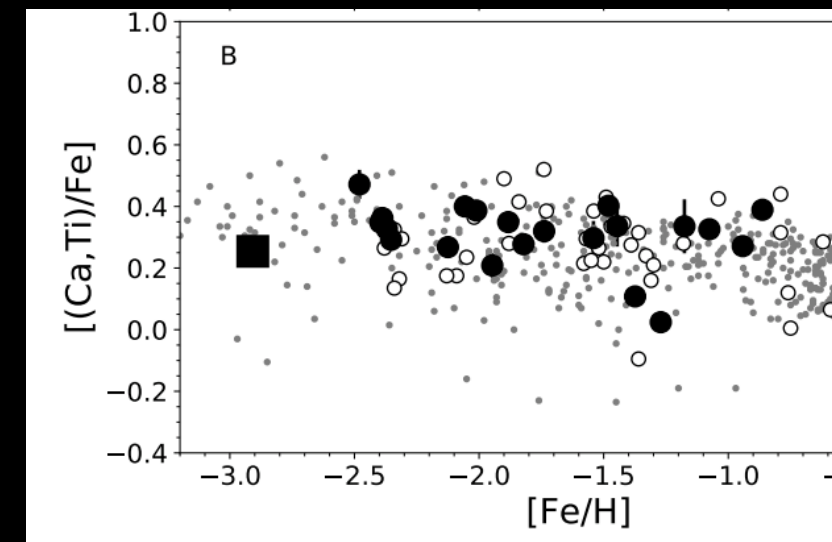
# No GC metallicity floor



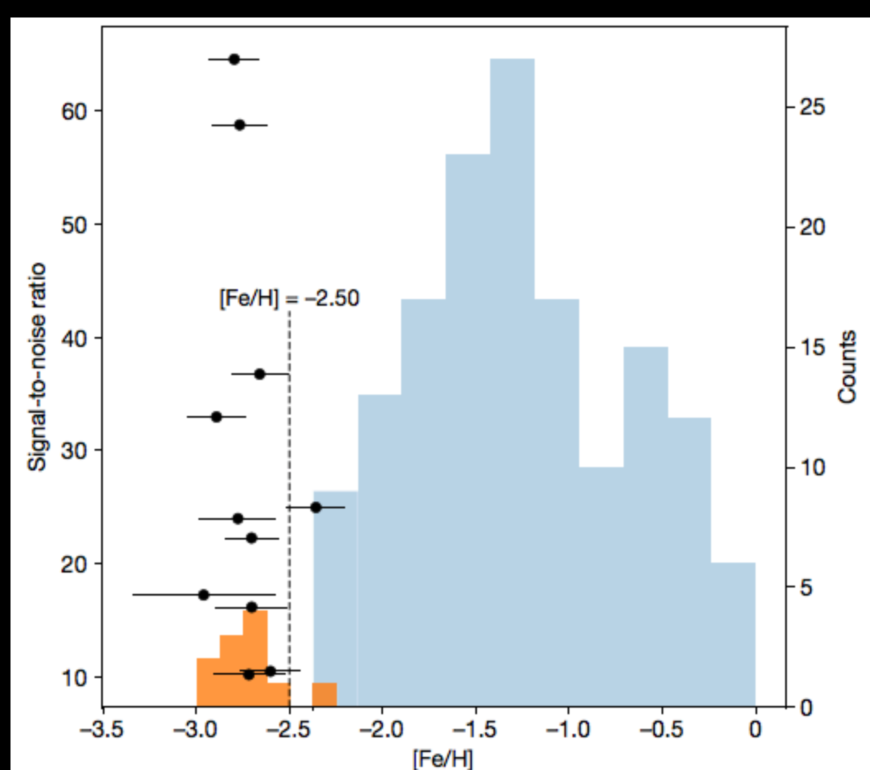

ESO280-SC06, [Fe/H]=-2.5; Simpson 2018



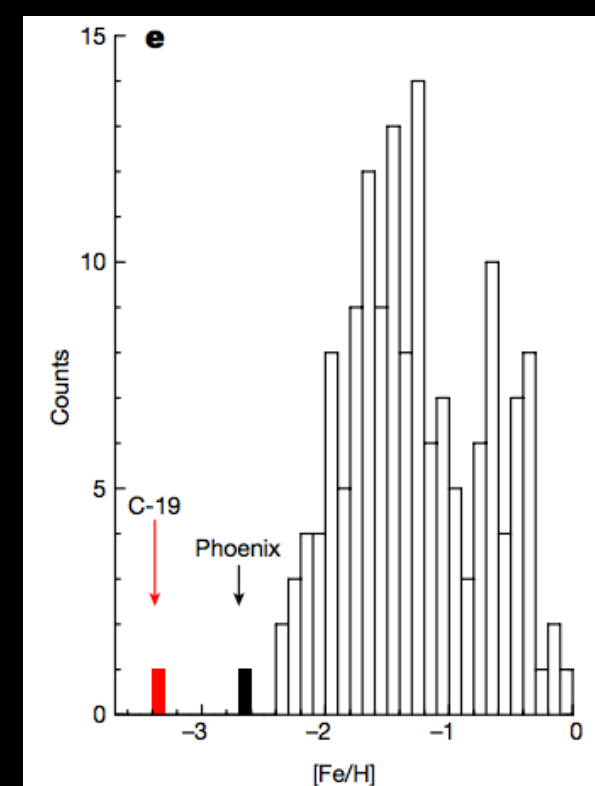

Sylgr Stream, [Fe/H]=-2.9
Roederer & Gnedin 2020




EXT8 in M31, [Fe/H]=-2.9
Larsen et al. 2020

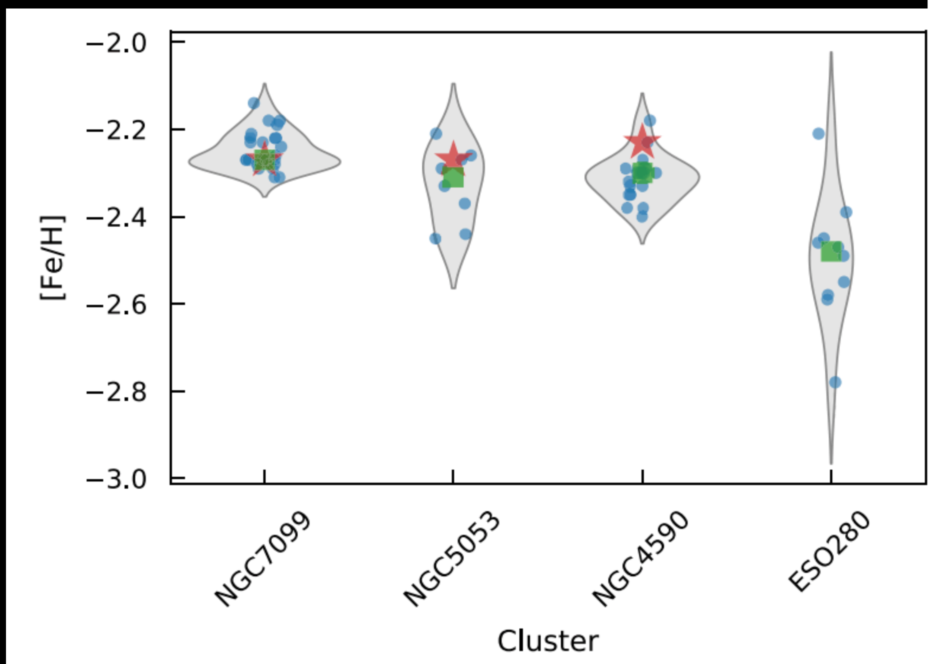



Phoenix Stream, [Fe/H]=-2.7
Wan et al. 2020

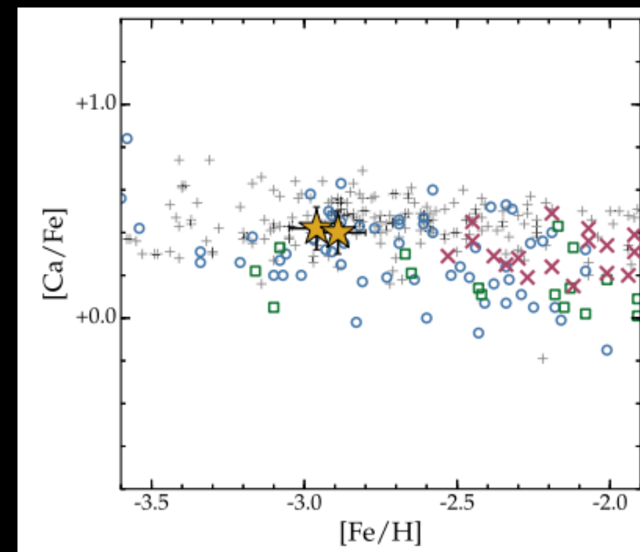



C-19 Stream, [Fe/H]=-3.3
Martin et al. 2022

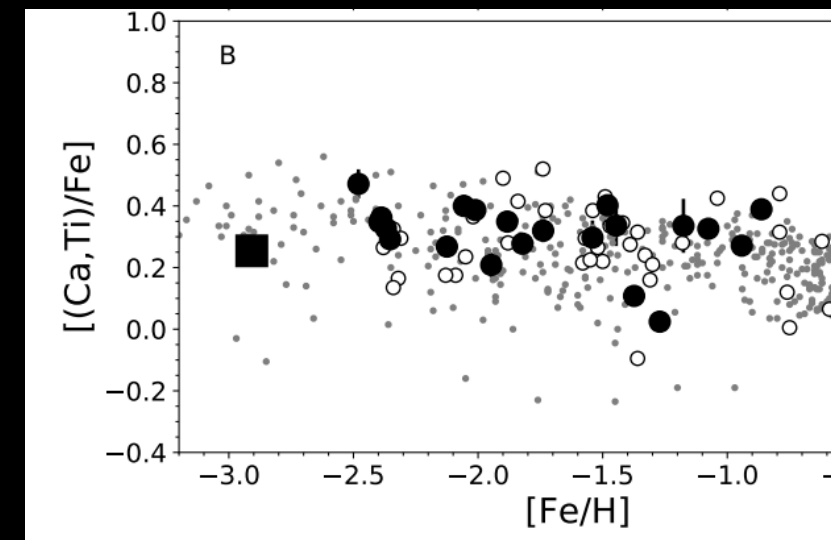
# The most metal-poor MW GCs are tidally disrupting/disrupted




ESO280-SC06, [Fe/H]=-2.5; Simpson 2018




Sylgr Stream, [Fe/H]=-2.9
Roederer & Gnedin 2020




EXT8 in M31, [Fe/H]=-2.9
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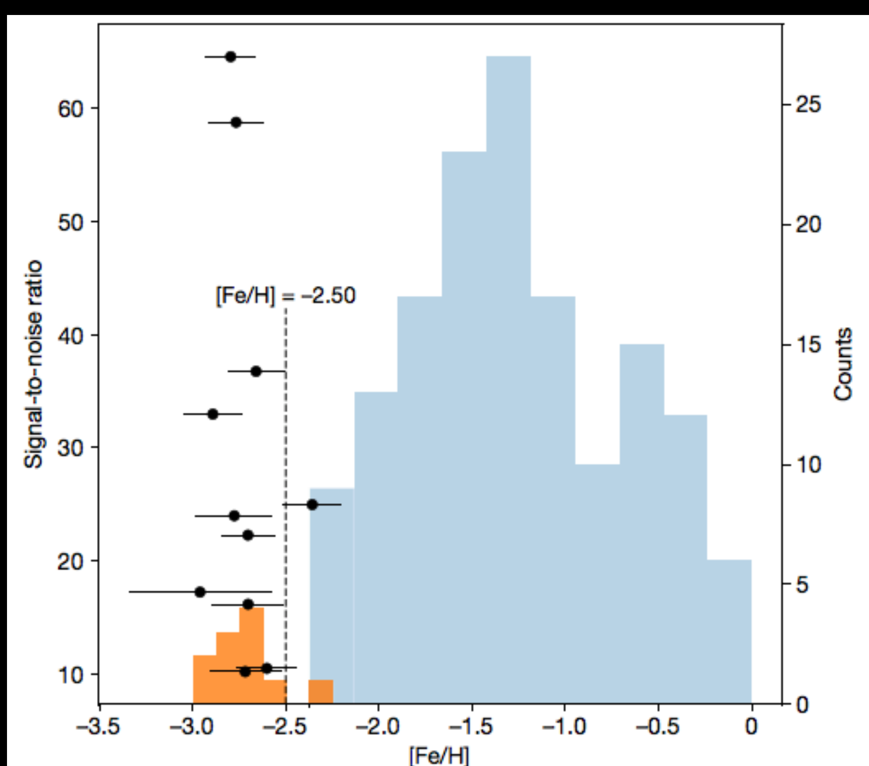
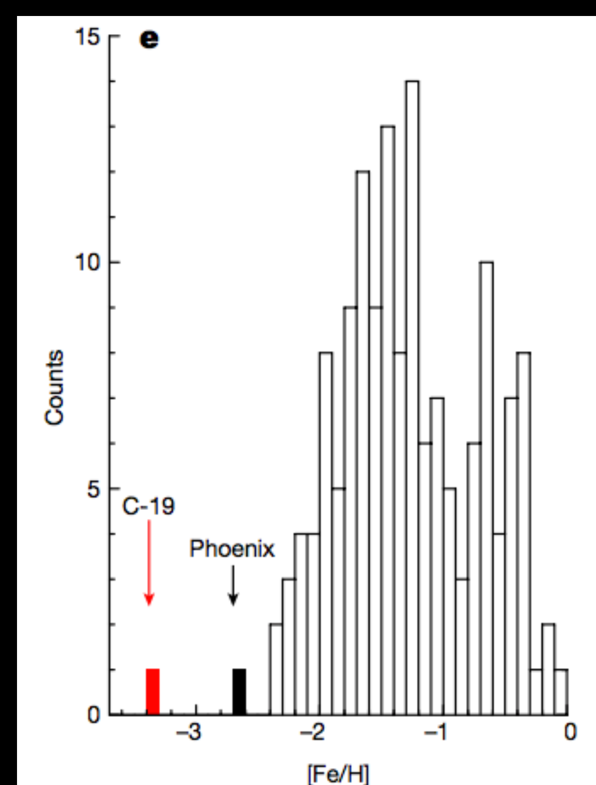
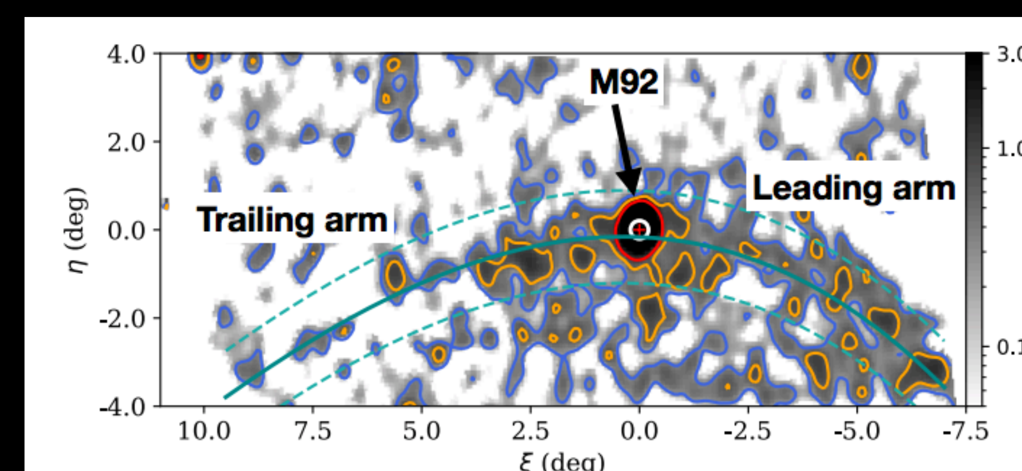



Phoenix Stream, [Fe/H]=-2.7
Wan et al. 2020

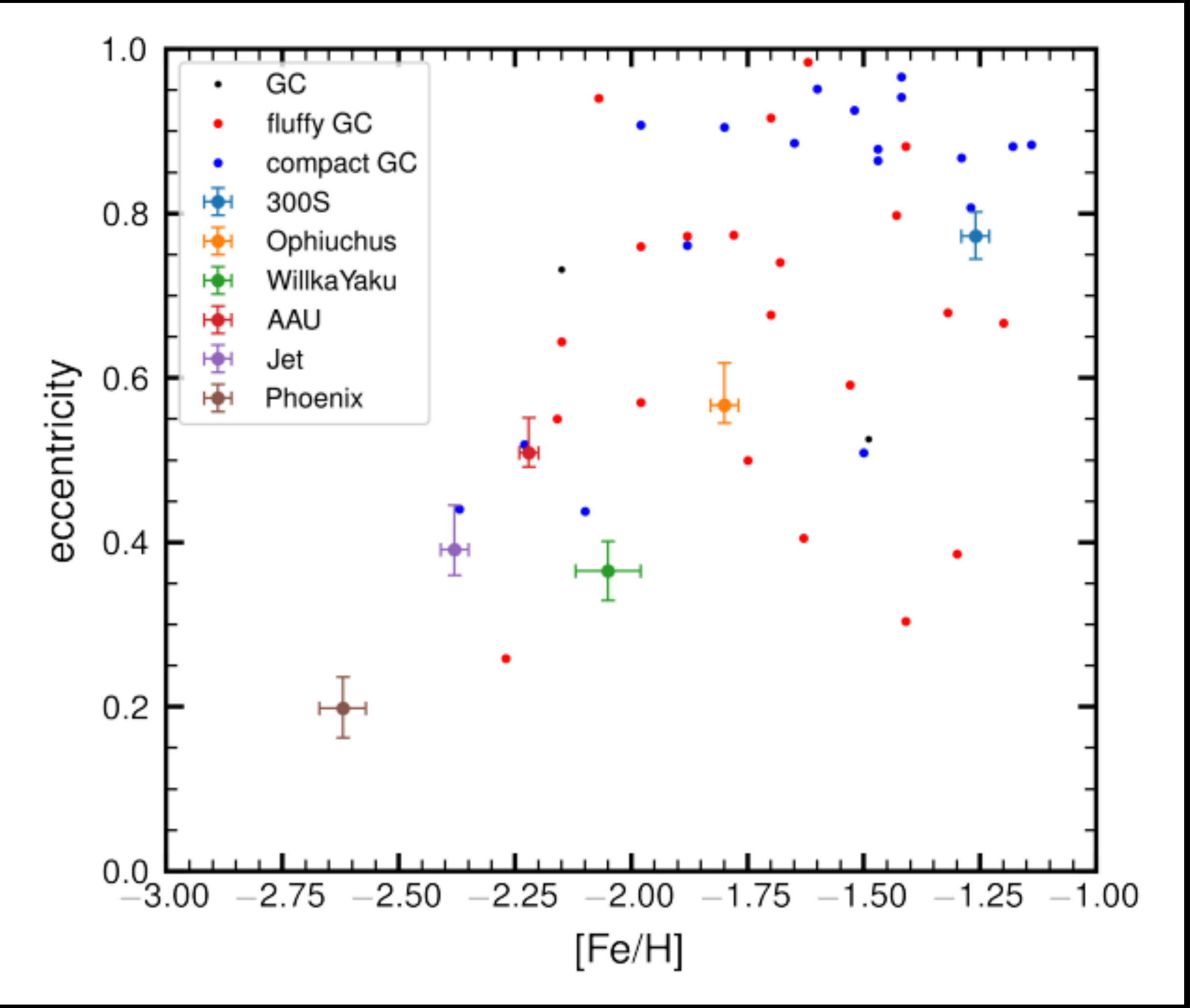



C-19 Stream, [Fe/H]=-3.3
Martin et al. 2022

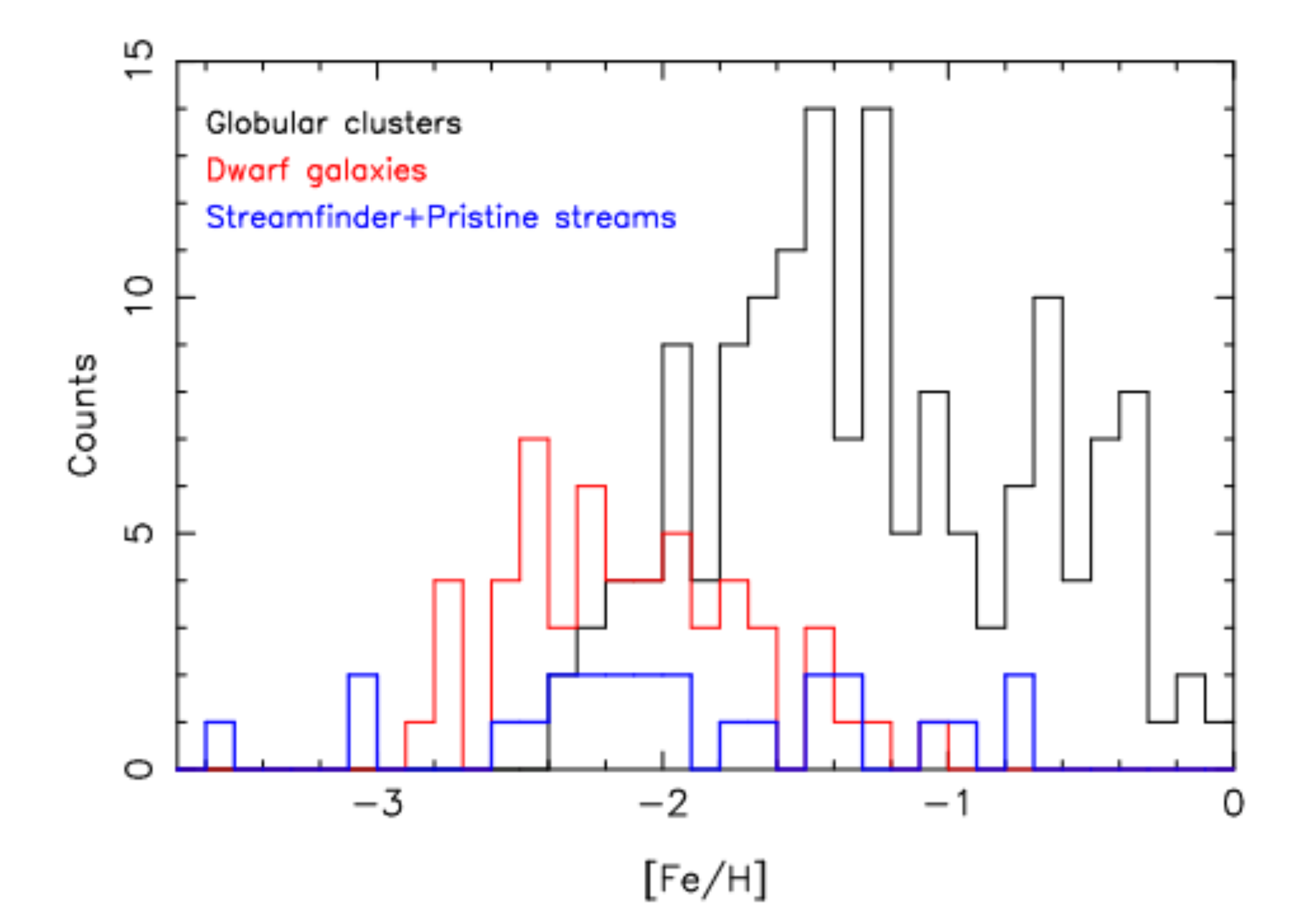



M92 Stream
Thomas et al. 2020

# MW GC Streams are Preferentially Metal-Poor



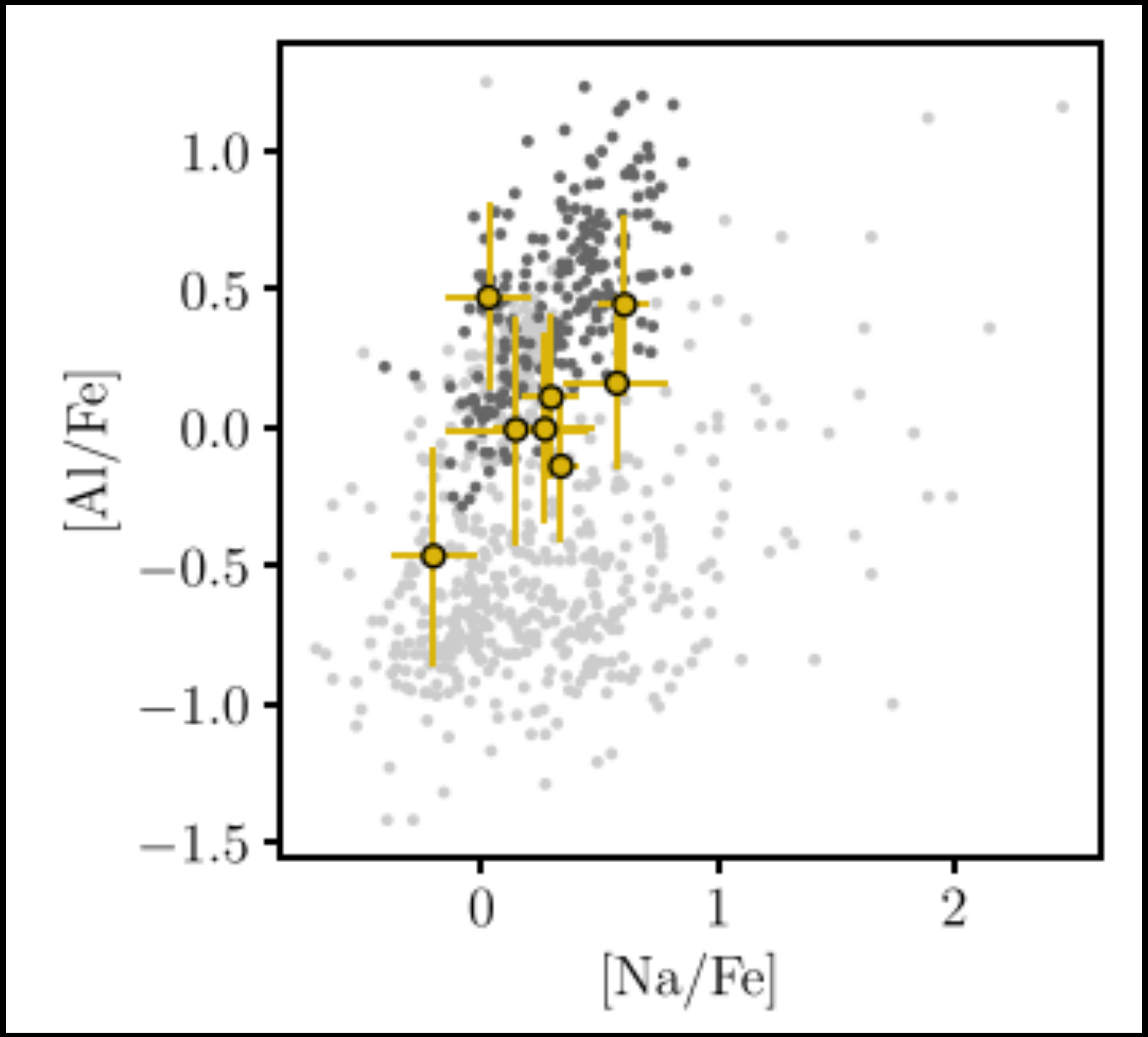

Li, Ji, S5 Collaboration 2022




Martin et al. 2022b

(Could be a selection effect?)

# Multiple Populations in Phoenix GC Stream [Fe/H]=-2.7




- Na-Al correlation but large uncertainties
- Best guess $f_{enriched}$ is ~2/8 = 25%
- To get ~10% $f_{enriched}$ statistical uncertainty, need to classify ~20 stars

Casey, Ji et al. 2021

Also see Balbinot et al. 2021 for GD-1

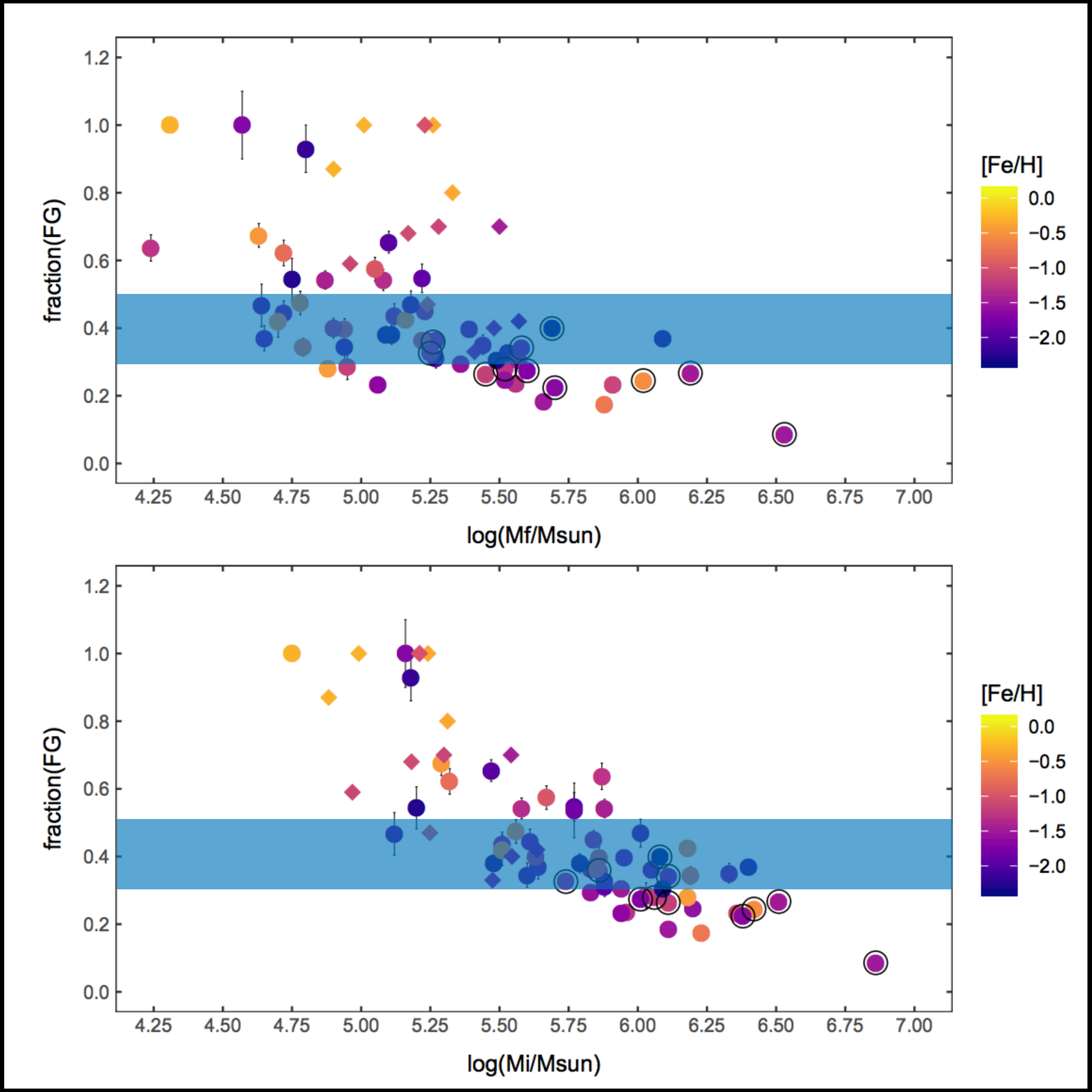
# Some questions

- Do GC formation models make GCs with [Fe/H] ≤ -3? Are they mostly tidally disrupted today?
- Can we find disrupted metal-poor GC streams outside the Milky Way?
- Since we don't know its physical origin, is it reasonable to use the $f_{enriched}$ vs. mass trend to obtain GC initial masses?

# Summary

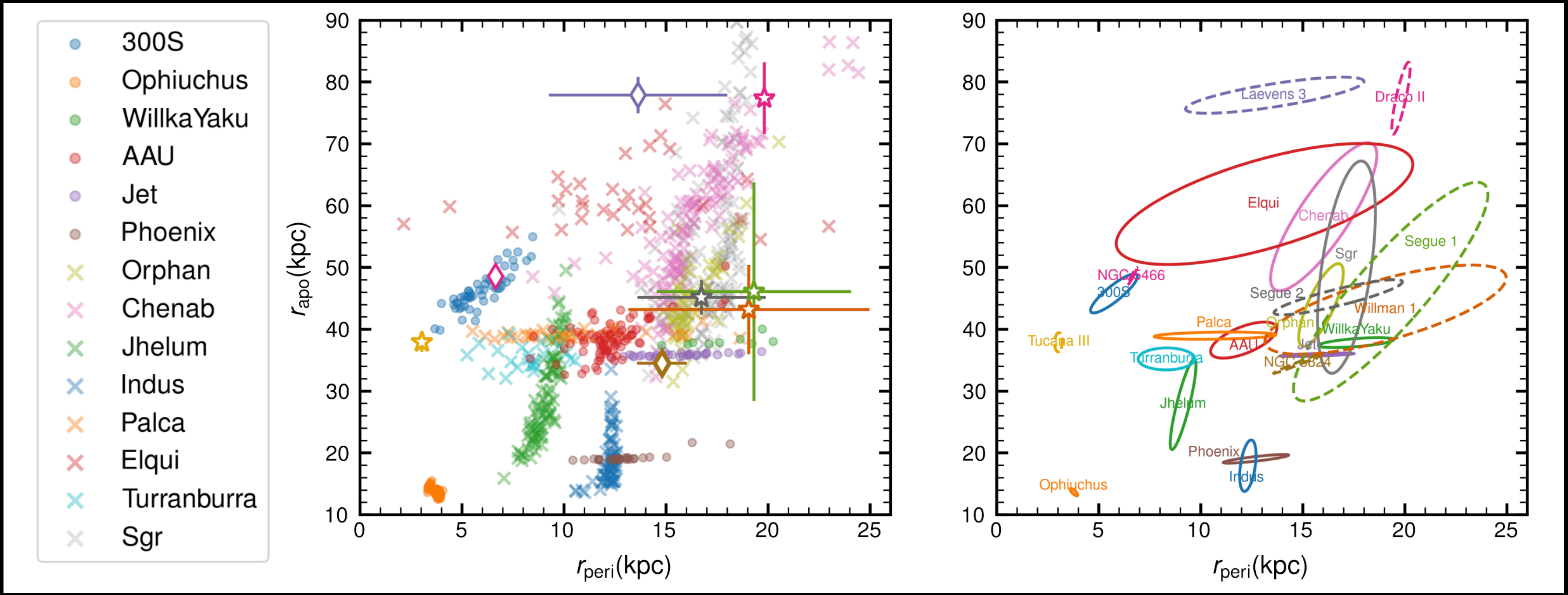
- There is no globular cluster metallicity floor
- The most metal-poor GCs are mostly tidally disrupted
- Multiple Populations can potentially be used to recover the initial stellar mass of a GC

# Correcting Initial Mass vs $f_{enriched}$ for tidal disruption




- Gratton+2019 using Baumgardt+2019 initial masses

# S5 Streams
# Apocenter + Pericenter




S5 GC strreams: pericenters 5-15kpc, apocenters 15-50 kpc

Li, Ji, S5 Collaboration 2022