The Nature of the Fornax 6 Globular Cluster with Magellan/M2FS Spectroscopy

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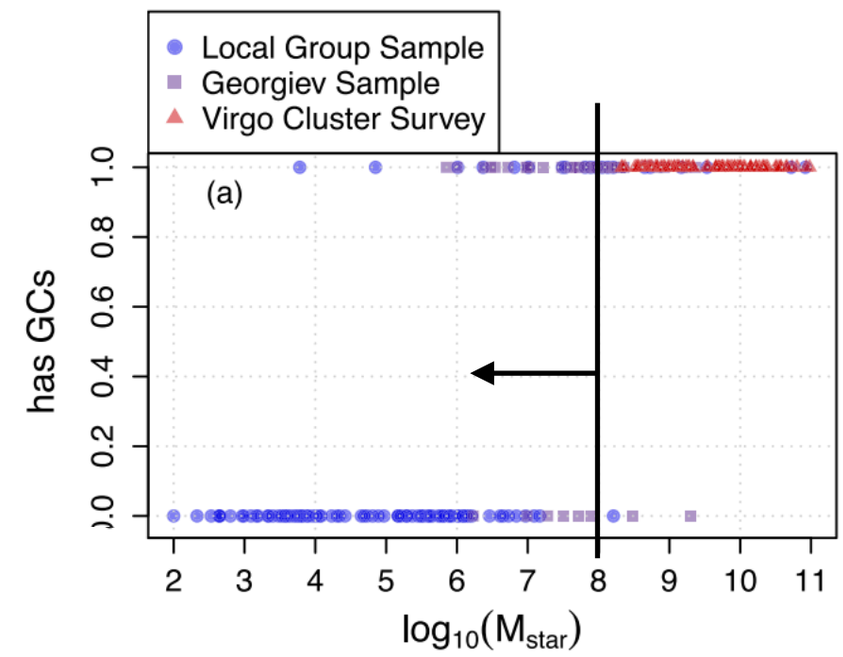
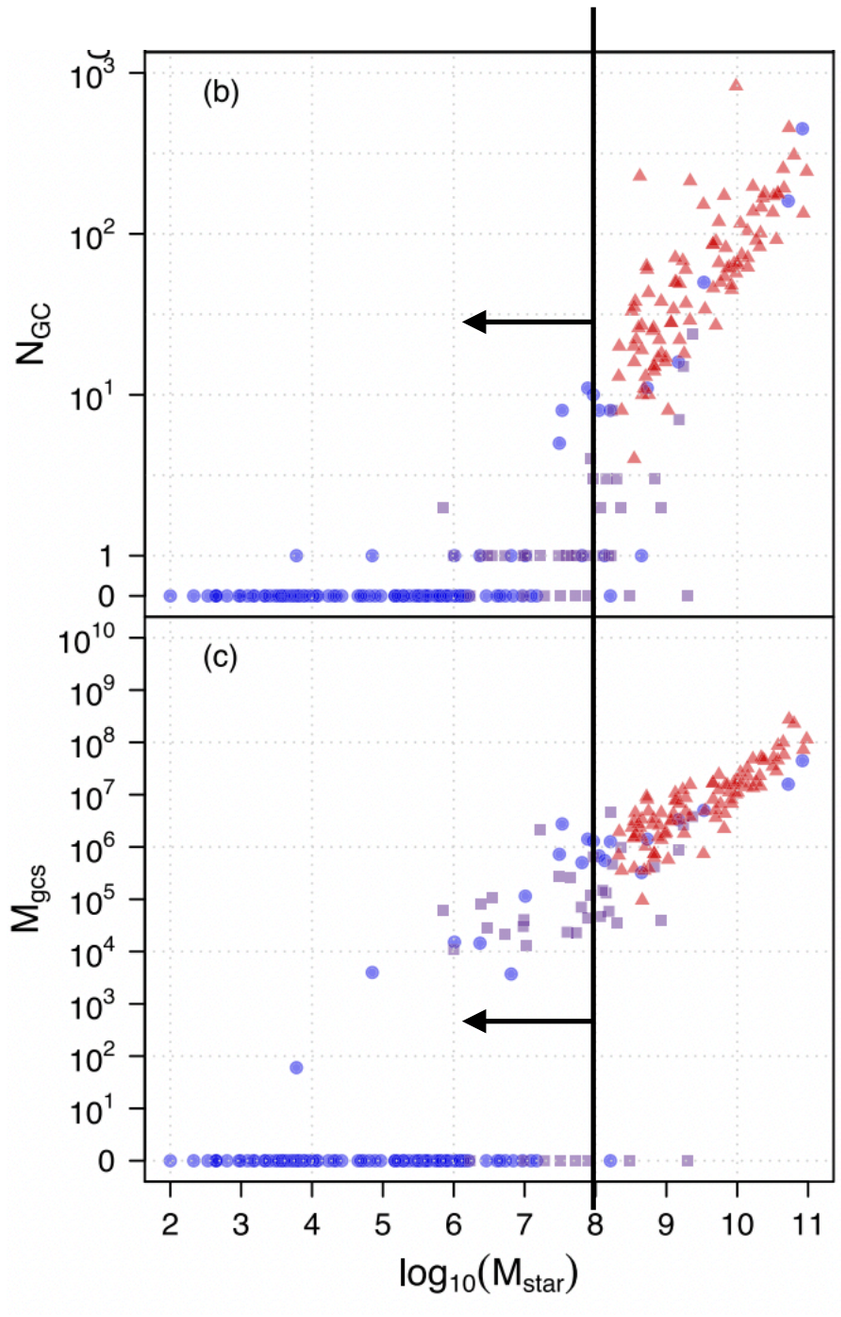
3/17/2022

Pace et al. 2021 (2105.00064)

Globular Cluster Population of Dwarf Galaxies



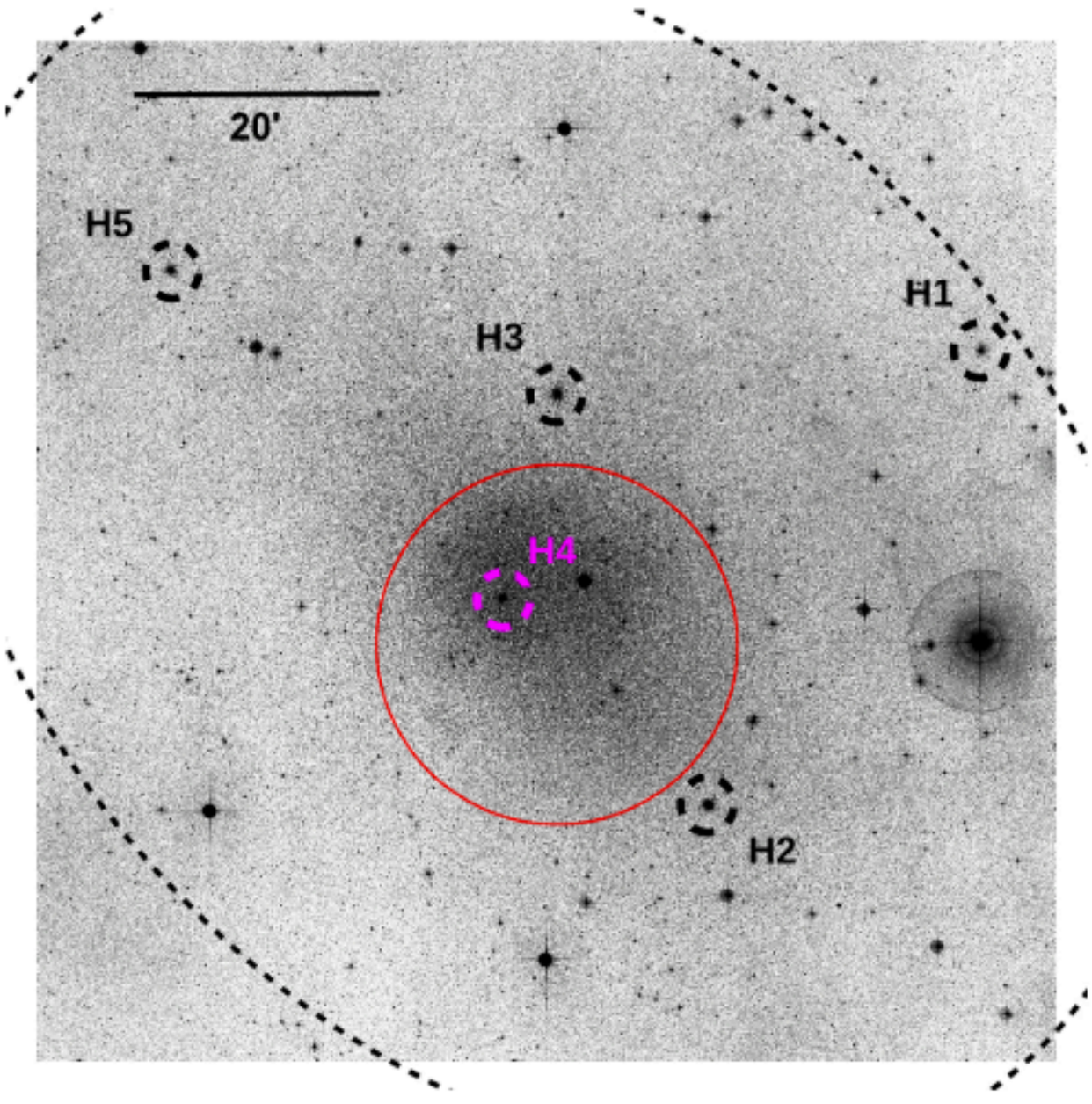


Eadie et al. 2022

Fornax dSph and Globular Cluster Population

Quick Facts:

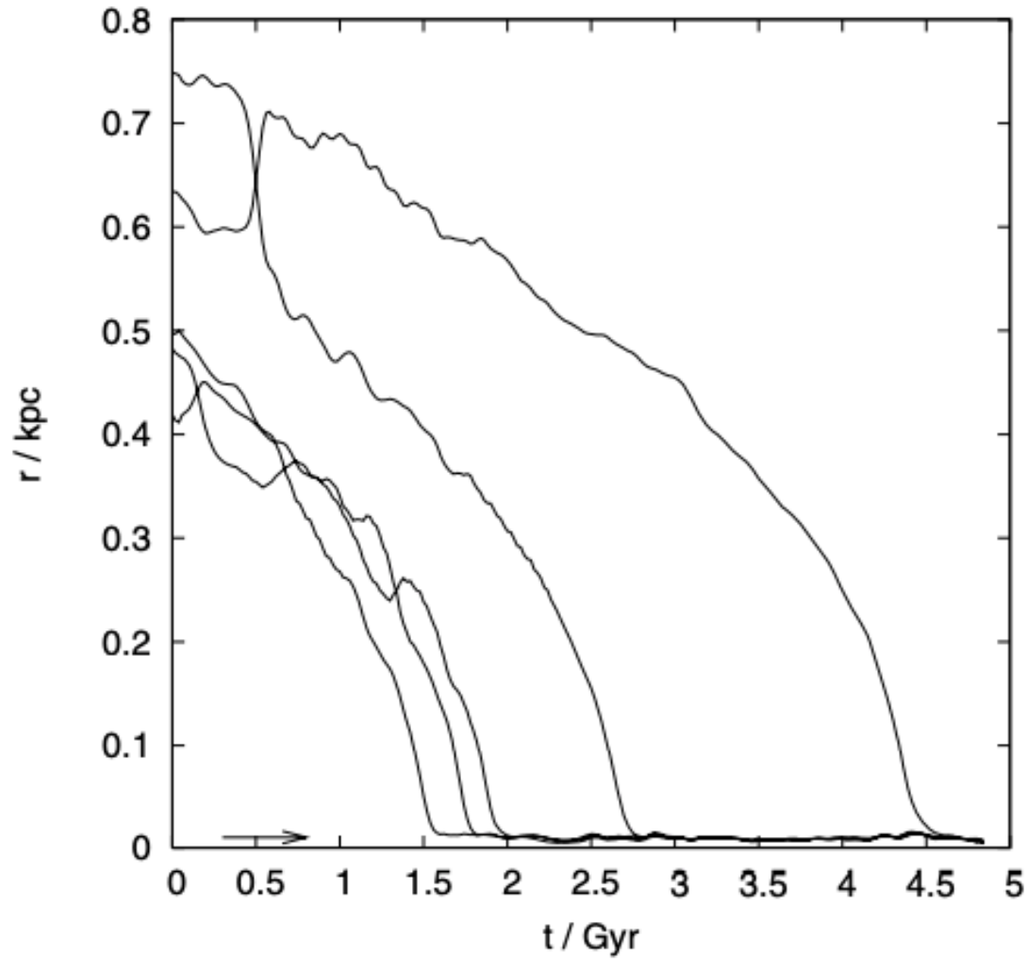
- **Dwarf Spheroidal Galaxy (dSph)**
- **L~5x10^7 Lsun**
- **sigma_los ~ 12 km/s**
- **Half-light radius ~ 700 pc**
- **[Fe/H]~ -1**
- **Dispersion dominated system**
- **Extended star formation history**
- **Recently quenched and no gas currently.**
- **5 Globular Clusters**
- **4th most luminous Milky Way satellite after LMC, SMC, and Sgr**



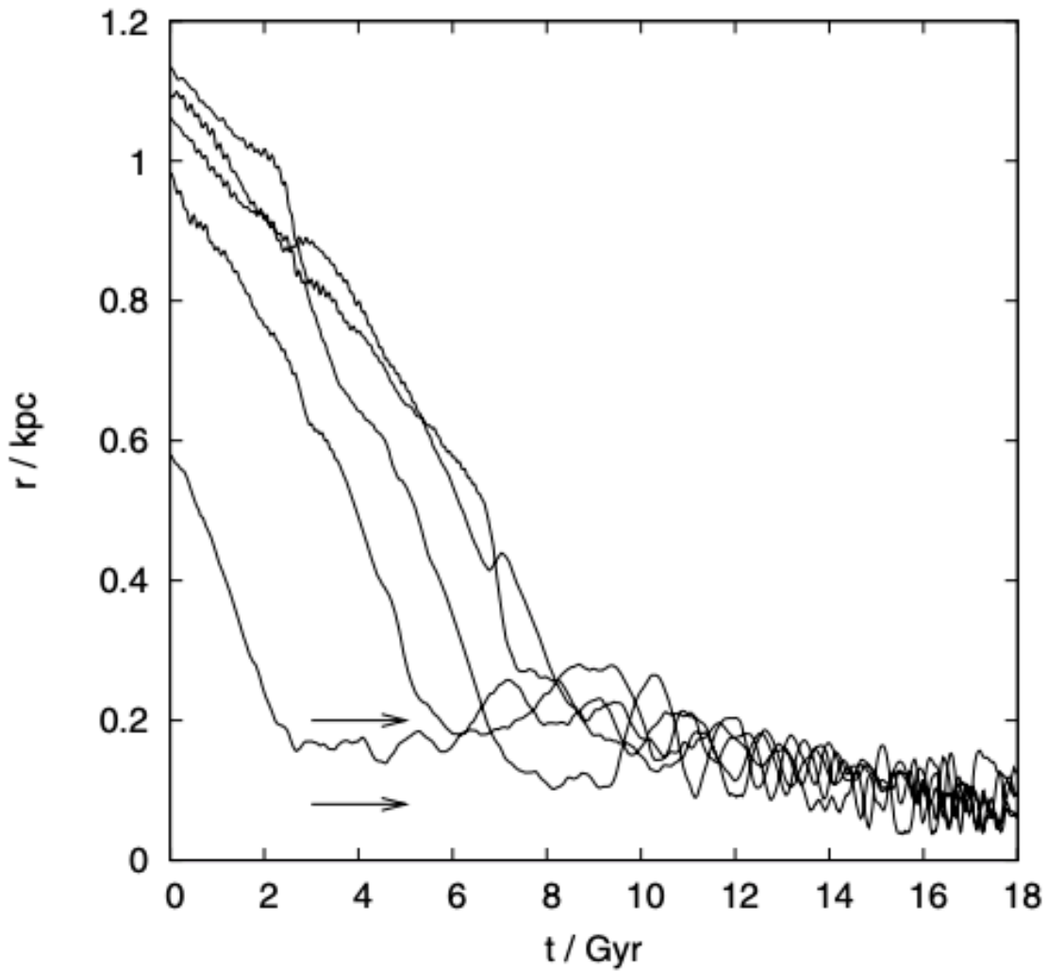
Hendricks et al. 2016

Fornax Timing Problem

Cuspy dark matter halo



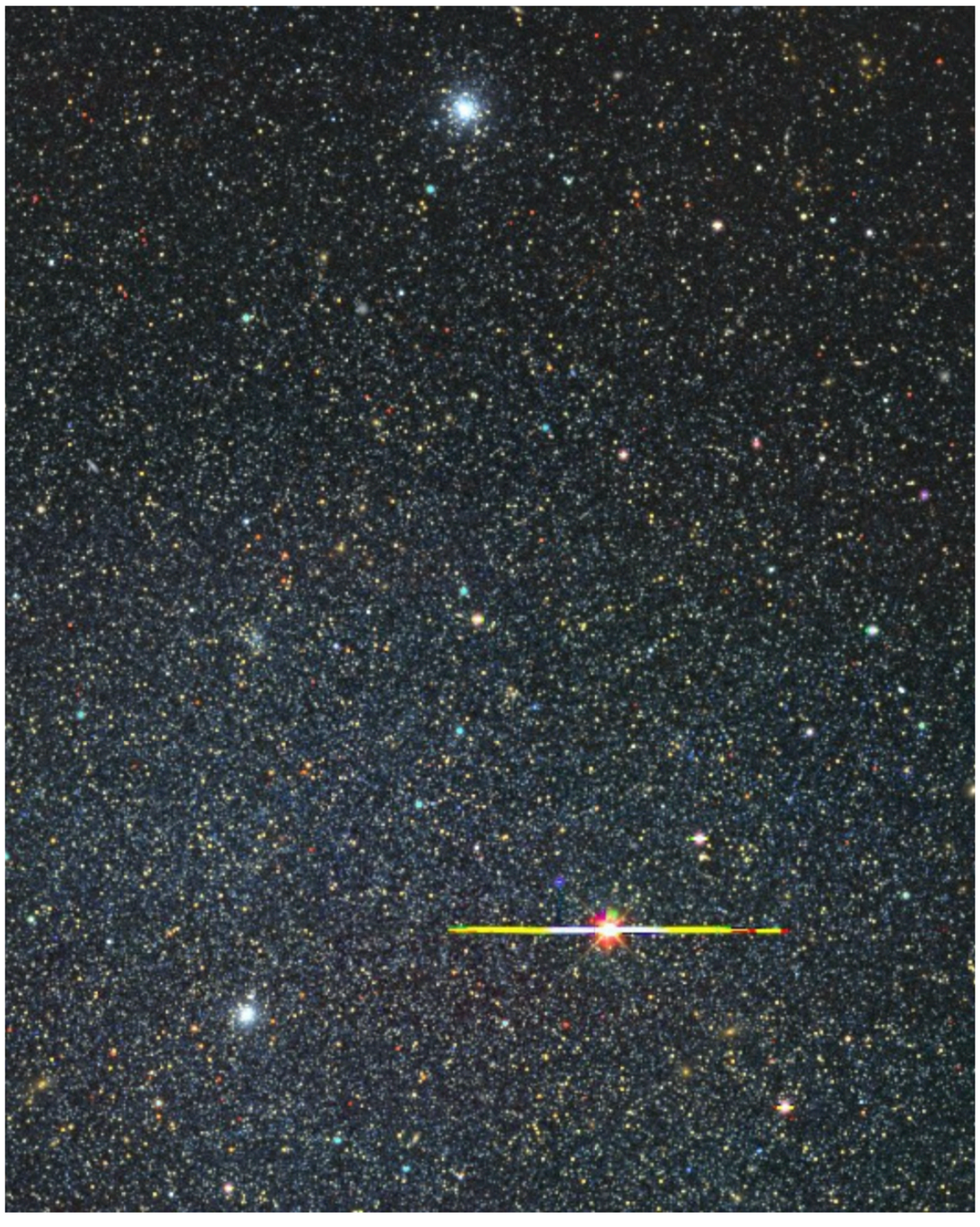
Cored dark matter halo



5 Fornax Globular Clusters can survive over ~10 Gyr in a cored DM halo but no Cuspy DM halo

Goerdt et al. 2006

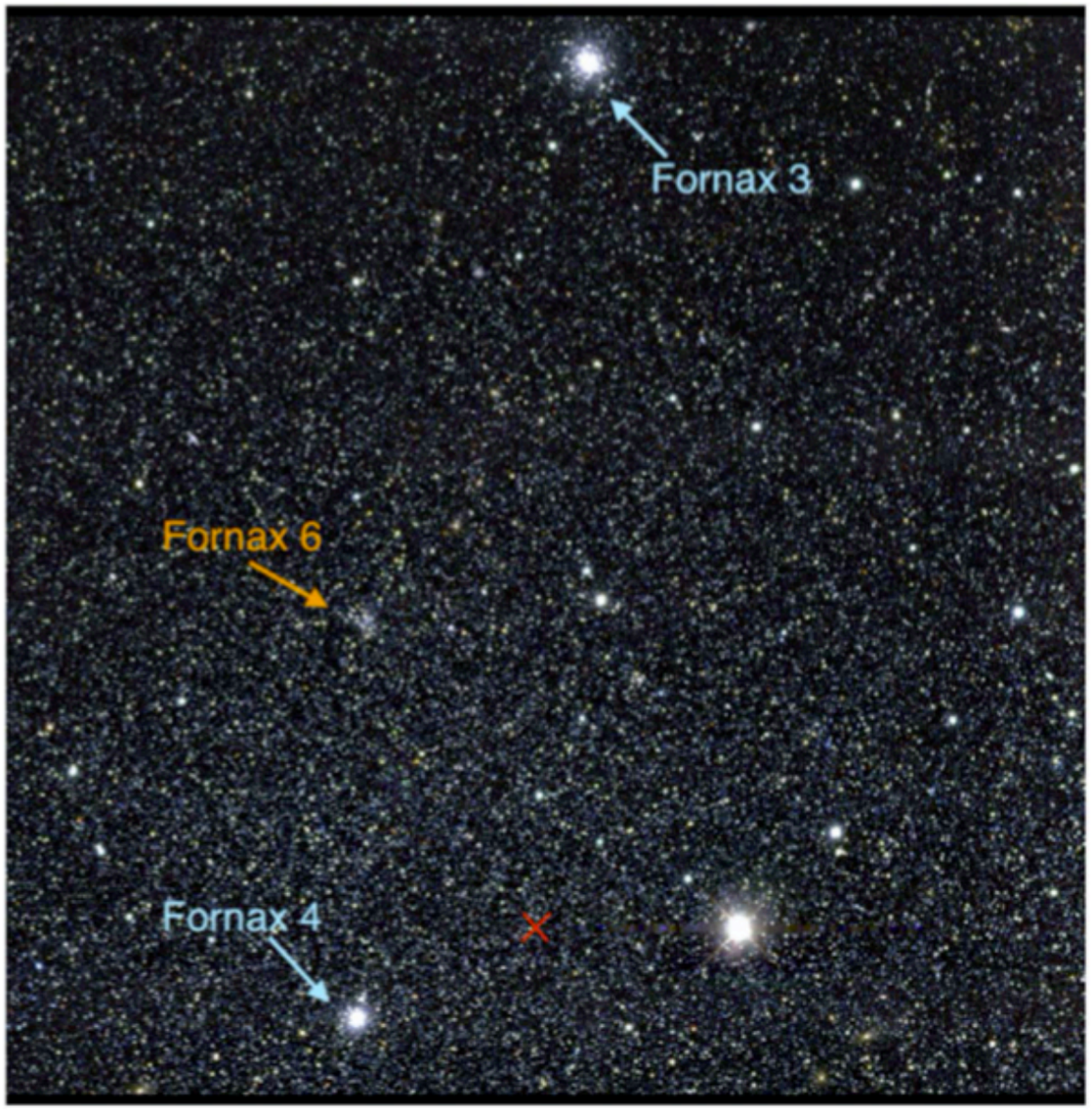
(Re)Discovery of Fornax 6



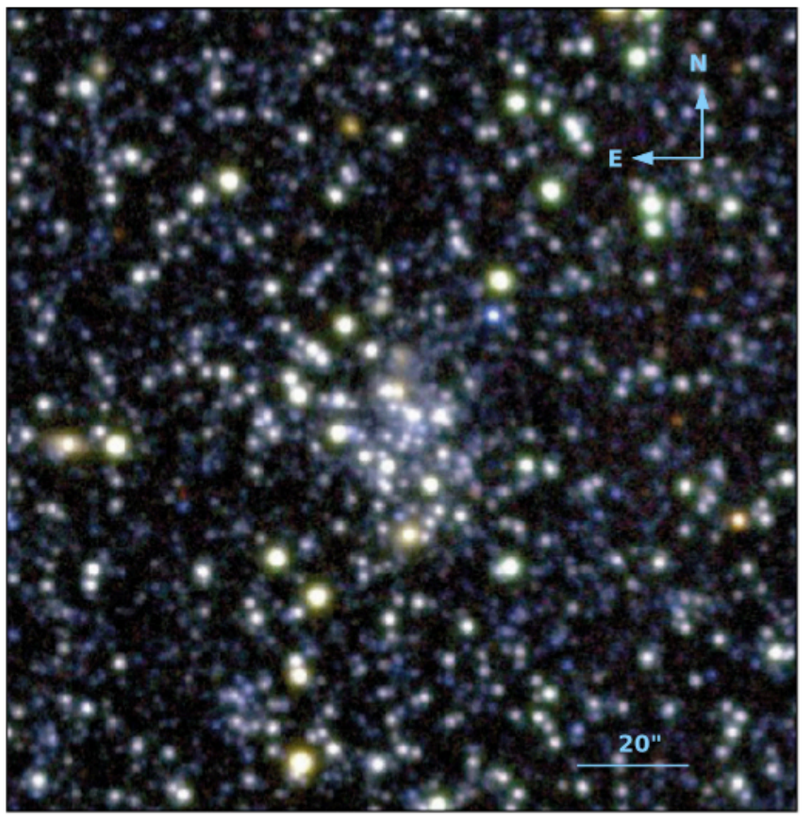
From DECaLs Legacy Viewer

https://www.legacysurvey.org/viewer/?ra=40.0227&dec=-34.4224

(Re)Discovery of Fornax 6



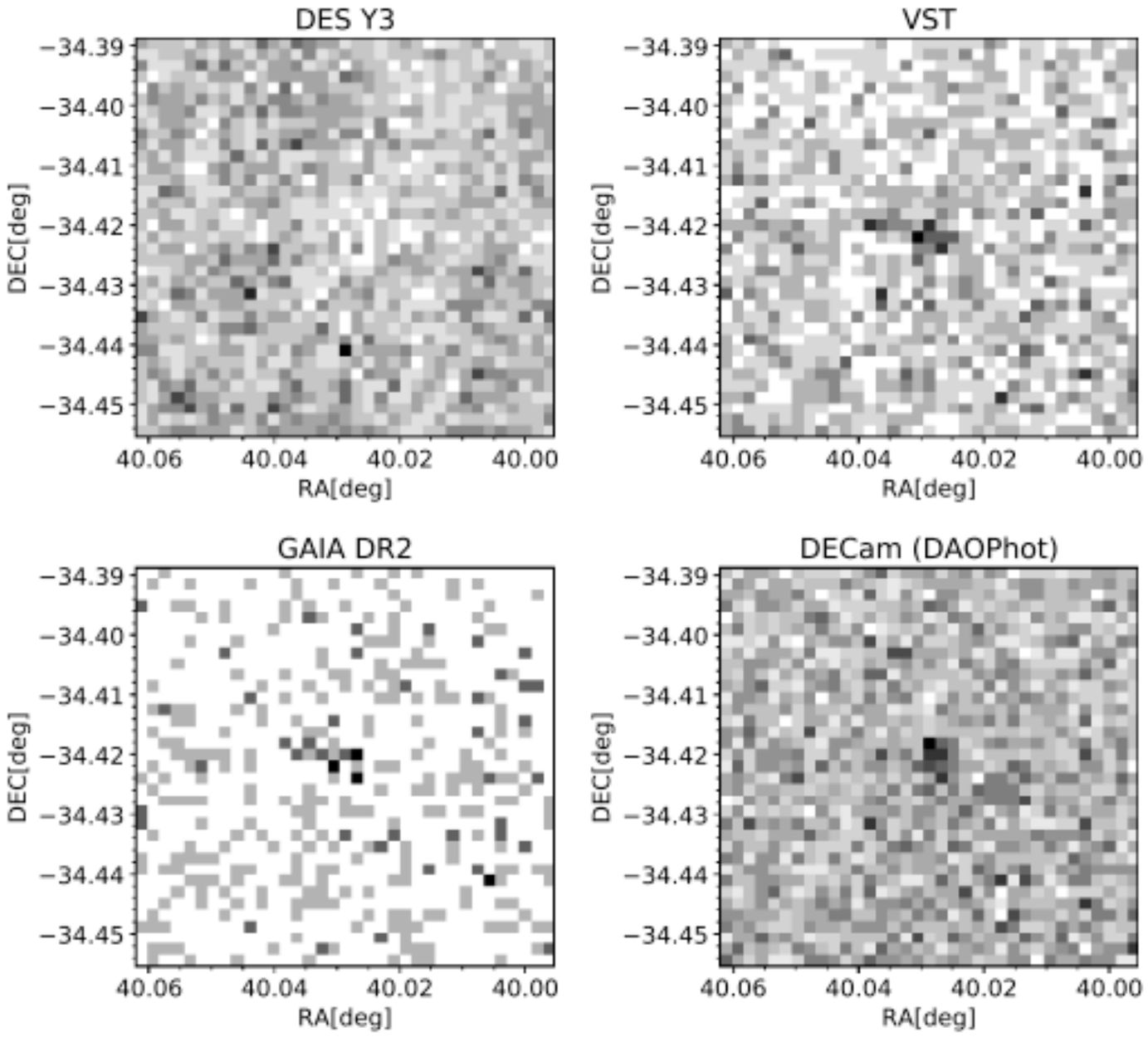
First mentioned in Shapley 1939,
Photometric plates (Verner et al. 1981; Demers et al. 1994), clump of stars or too few stars to be a cluster
CCD photometry (Stetson et al. 1998) as a mixture of stars or galaxies.
Not Discussed in literature for ~20 years



Wang et al. 2019

(Re)Discovery of Fornax 6

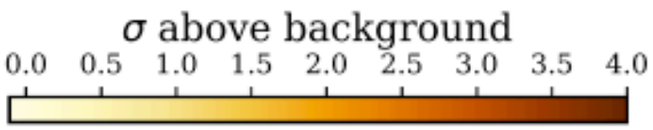
Number density in several different surveys

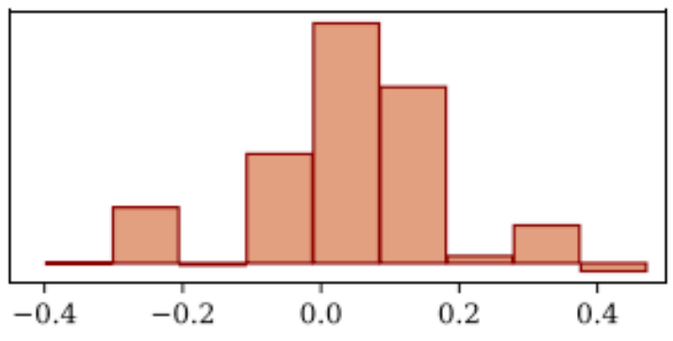


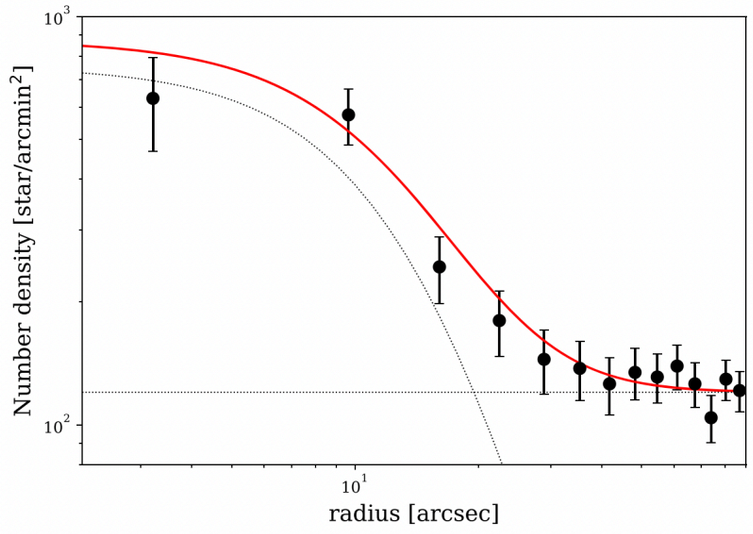
Detected as an over density in several surveys.
~6 sigma detection in DECam and Gaia catalogs compared to random Fornax positions

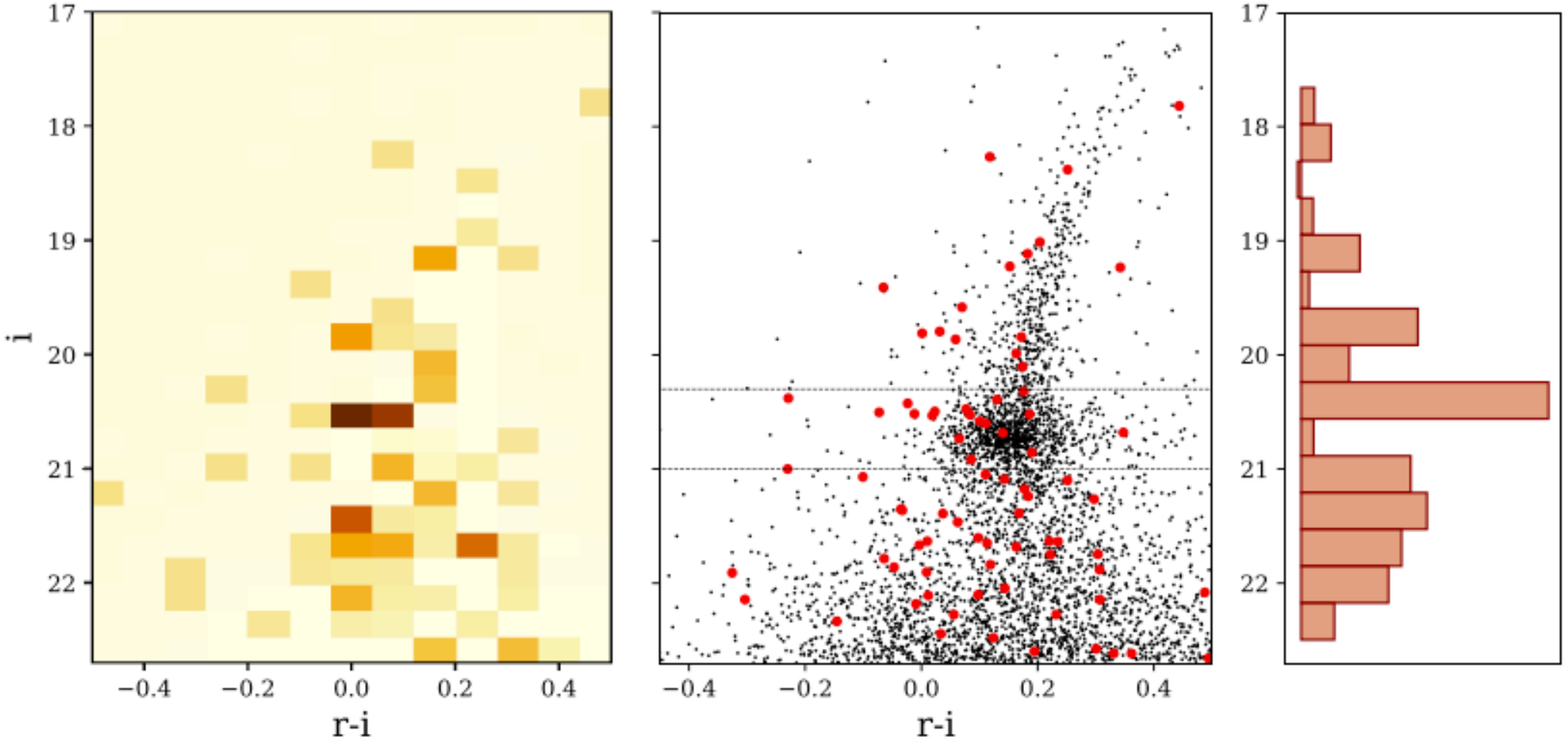
Wang et al. 2019

(Re)Discovery of Fornax 6





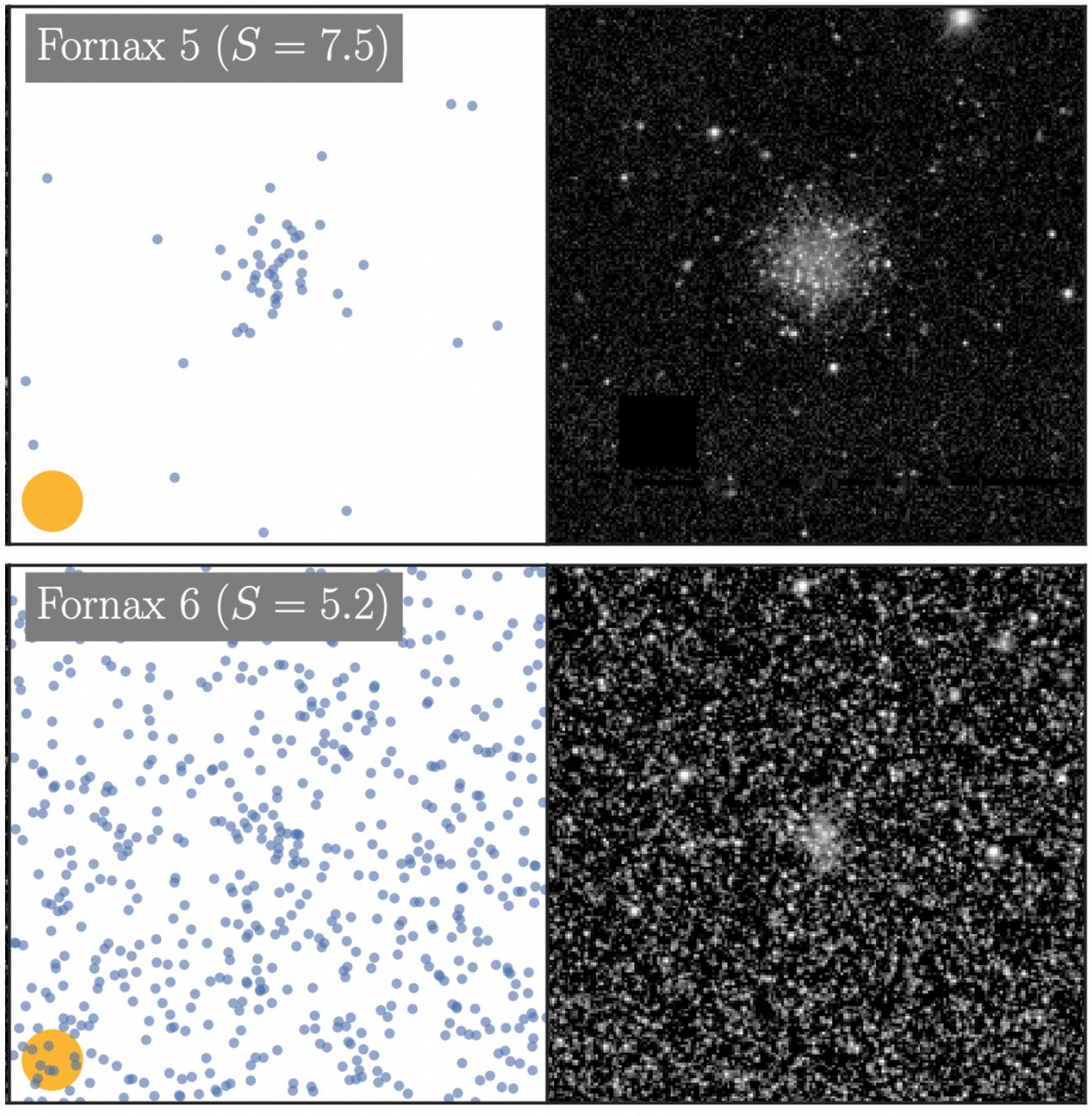




Parameter	
R.A.(J2000)	$2^h40^m6^s.9$
Decl.(J2000)	$-34°25'19''.2$
ϵ	0.41 ± 0.10
P.A. (deg)	$13.1^{+10.4}_{-7.3}$
r_h (arcsec)	16.8 ± 2.0
r_h (pc)	11.3 ± 1.4
M_V (mag)	-4.8 ± 0.4

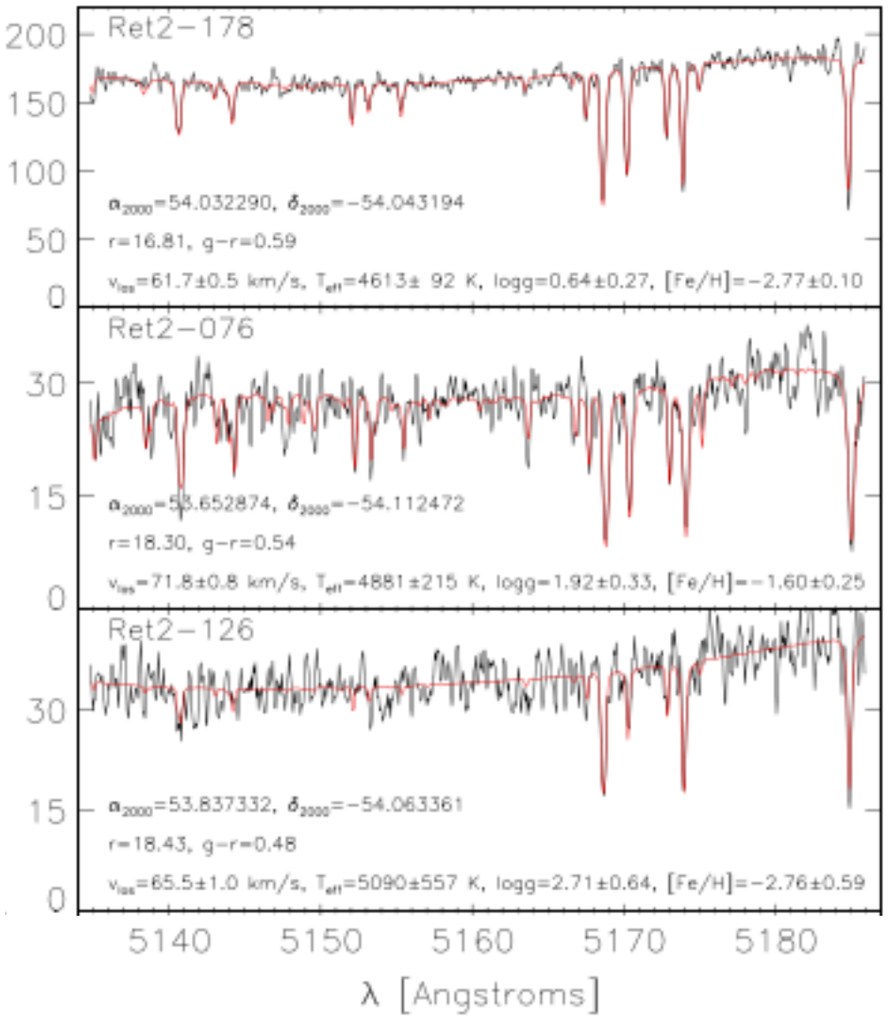
Wang et al. 2019

(Re)Discovery of Fornax 6



Huang & Koposov 2020

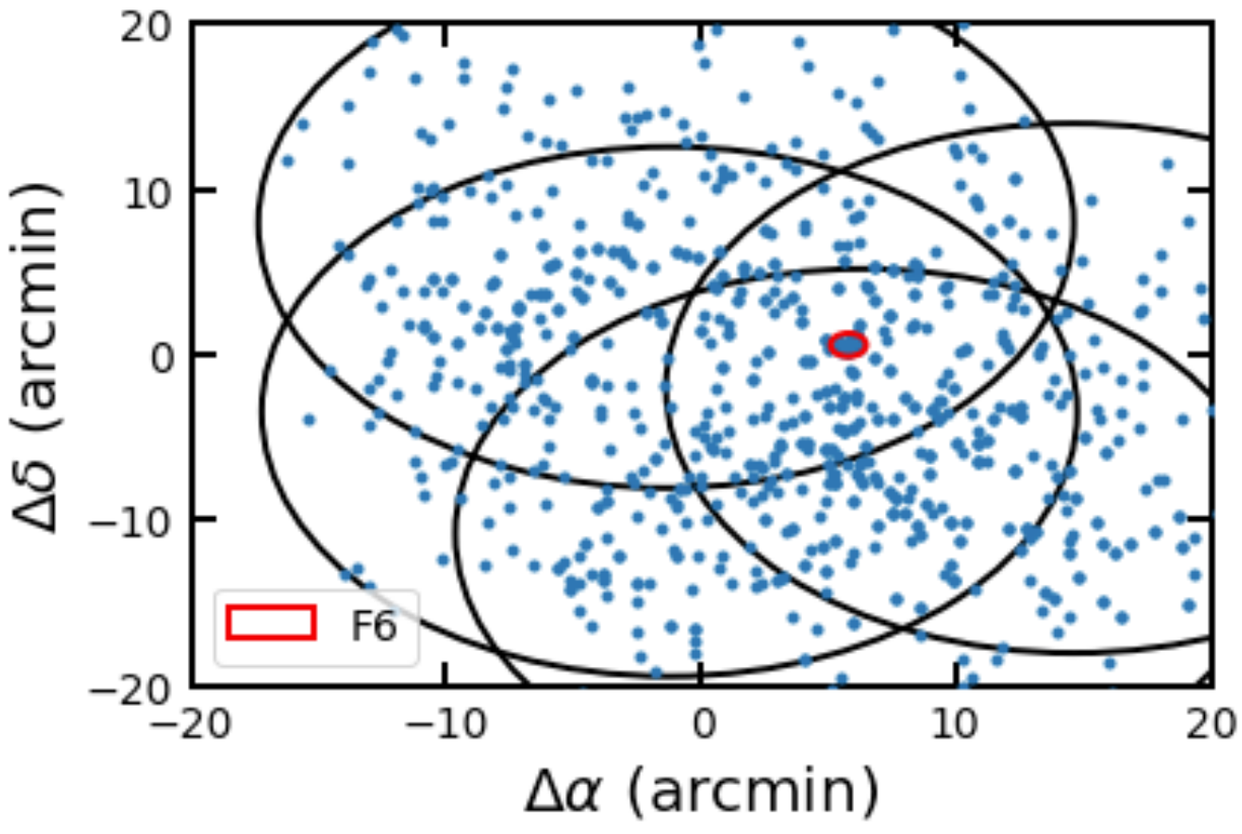
Magellan/M2FS Follow-up Spectroscopy



RGB spectra from Walker et al 2015

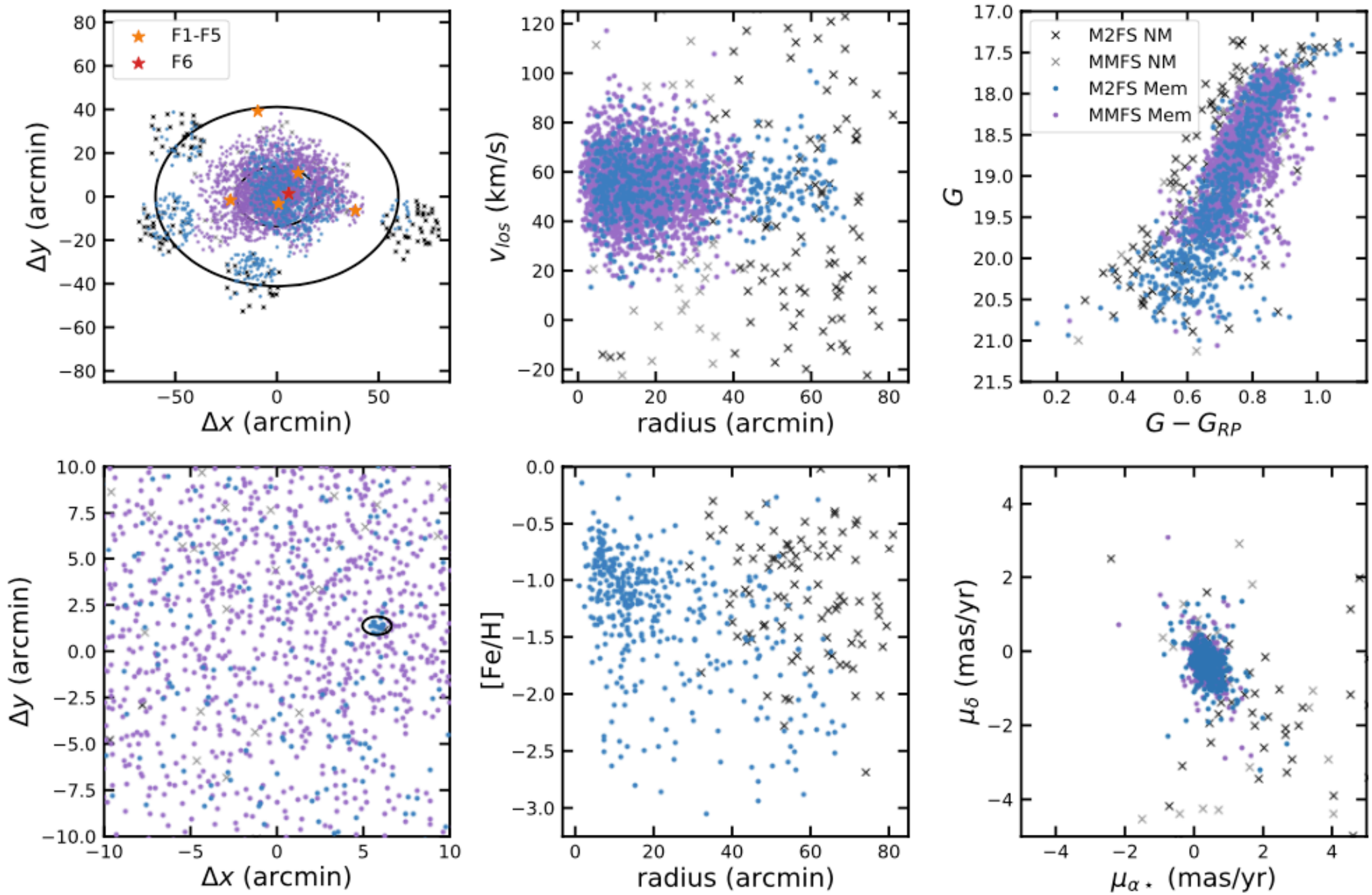
Michigan/Magellan Fiber System
Fiber-fed multi-object spectrograph
256 fibers. Wide field of view.
LoRes and HiRes modes
We target the Magnesium triplet with
R ~ 24, 000 for 1 km/s velocity precision

Fornax 6 Targeting



Pace et al. 2021

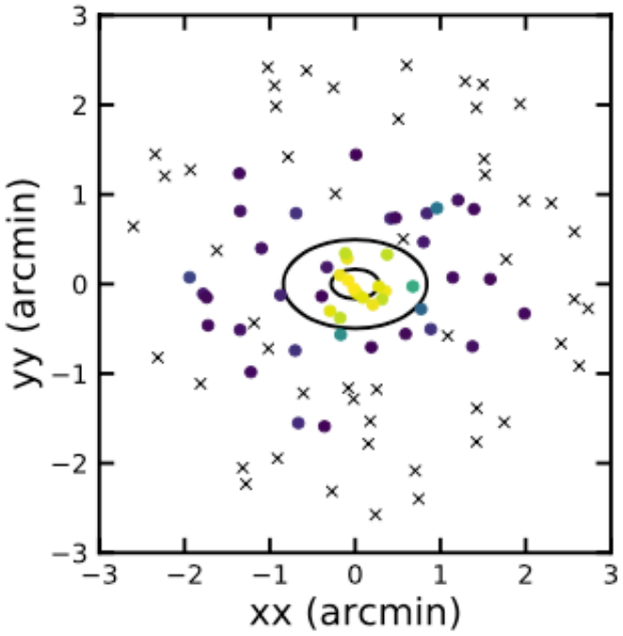
Magellan/M2FS Follow-up Spectroscopy

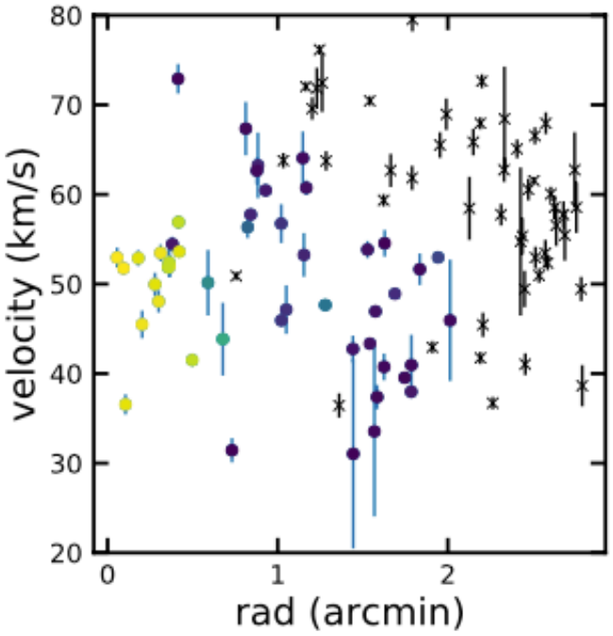


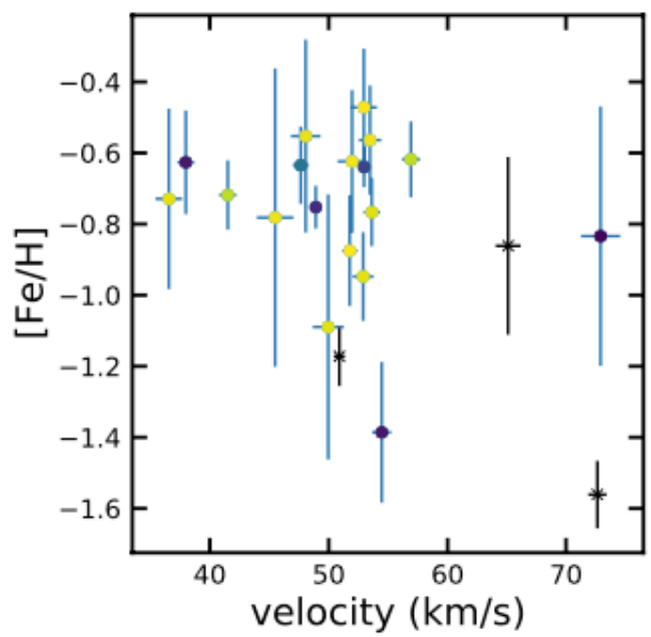
Combined with MMFS spectroscopy (Walker et al 2009) for ~3000 Fornax members

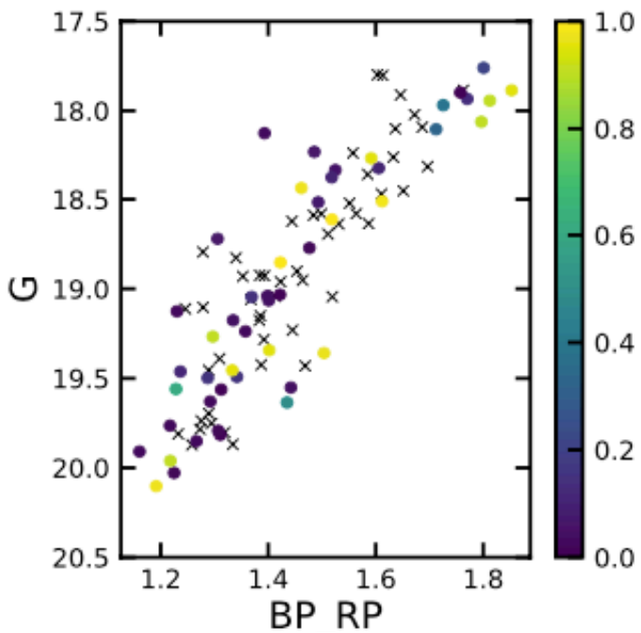
Pace et al. 2021

Identification of F6 members





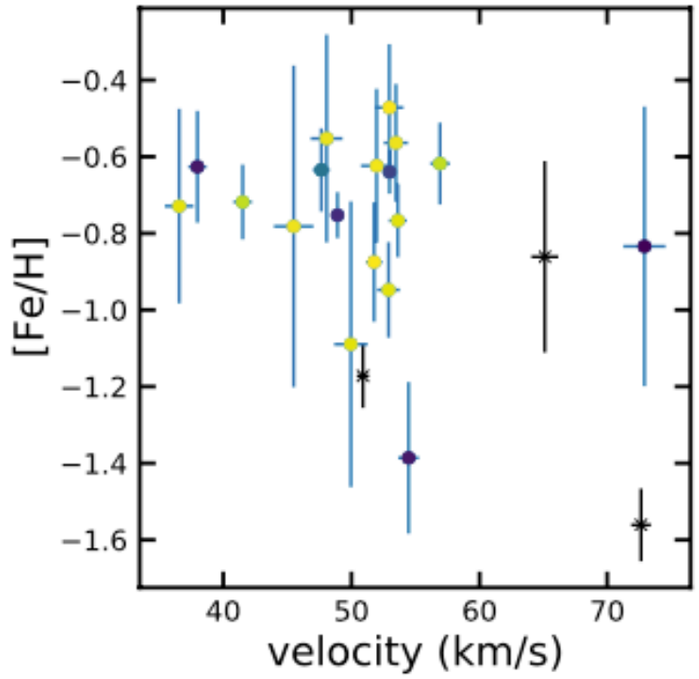


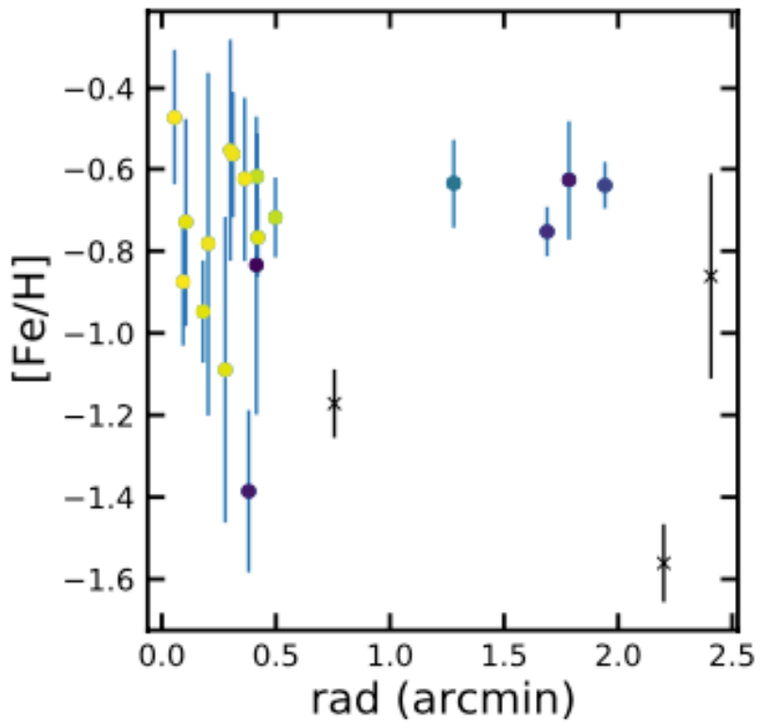


Construct mixture model of Fornax dSph and F6 stars to identify F6 members — Identify ~10-15 members. There are 2-3 stars with metallicity and position consistent with the cluster but offset by 8-12 km/s.
Sigma_los ~ 1 km/s for a stellar system similar to F6.

$\overline{v_{\rm los}}\,(\rm km\,s^{-1})$	$50.5^{+1.8}_{-1.7}$
$\sigma_v\,(\rm km\,s^{-1})$	$5.6^{+1.9}_{-1.5}$
$\overline{\rm [Fe/H]}$ (dex)	$-0.71^{+0.05}_{-0.05}$
$\sigma_{\rm [Fe/H]}$ (dex)	$0.03^{+0.06}_{-0.02} < 0.16$
N	17.5 ± 5.6

Properties of F6 Cluster - Metallicity





F6 cluster is quite metal-rich ([Fe/H] = -0.7).
More metal-rich than any of the other clusters
(-2.5 < [Fe/H] < -1.5) and the bulk of the Fornax dSph

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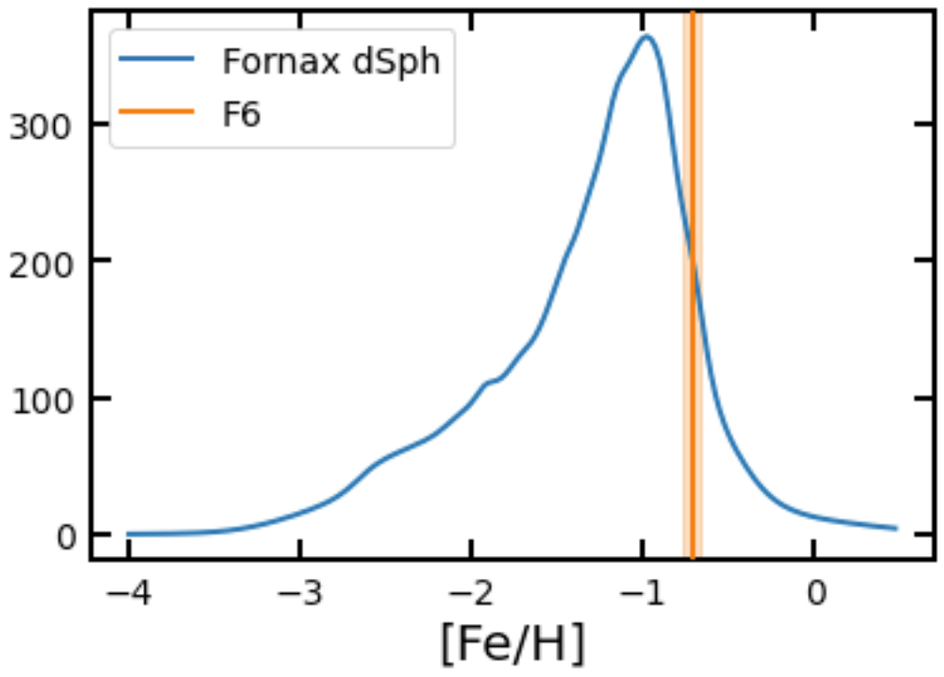
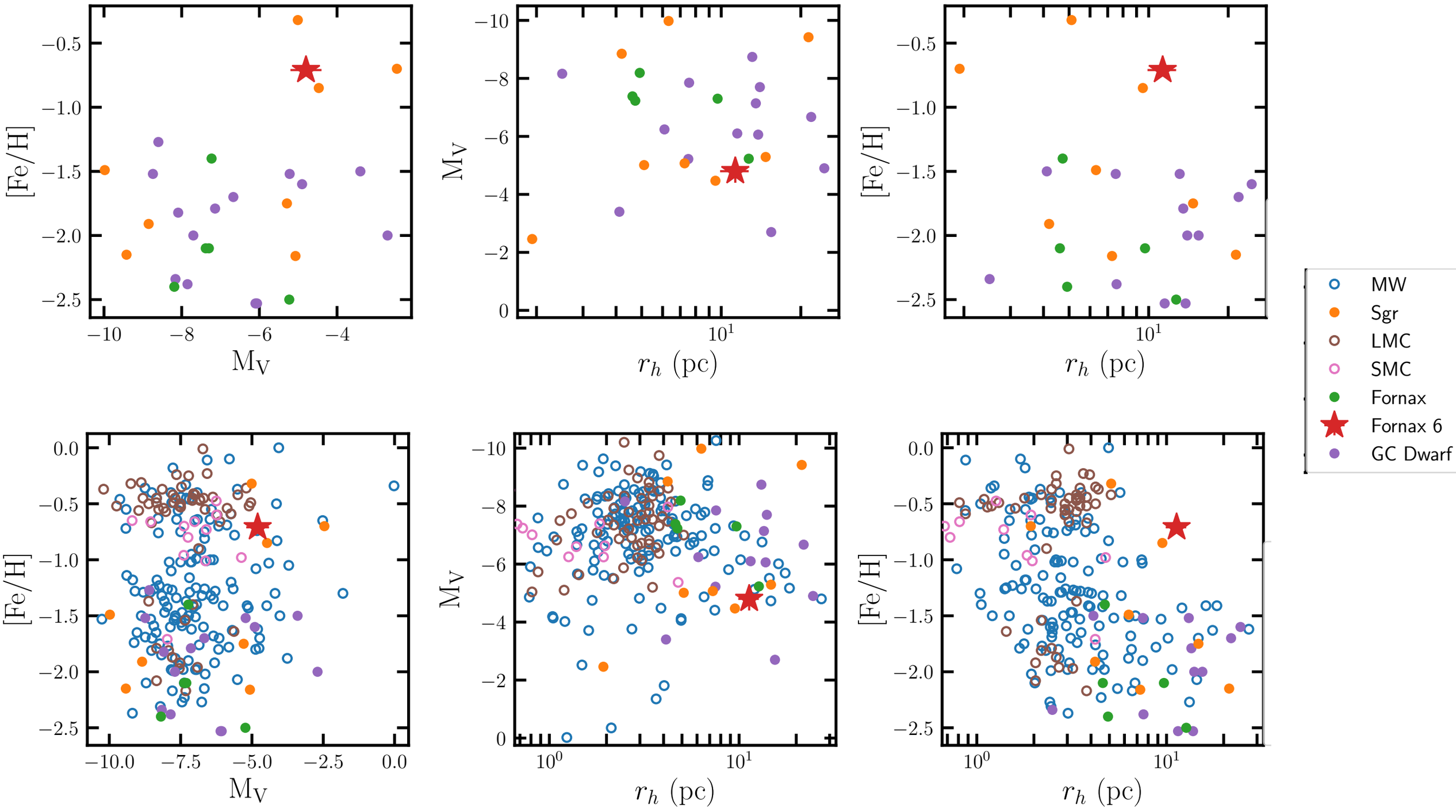
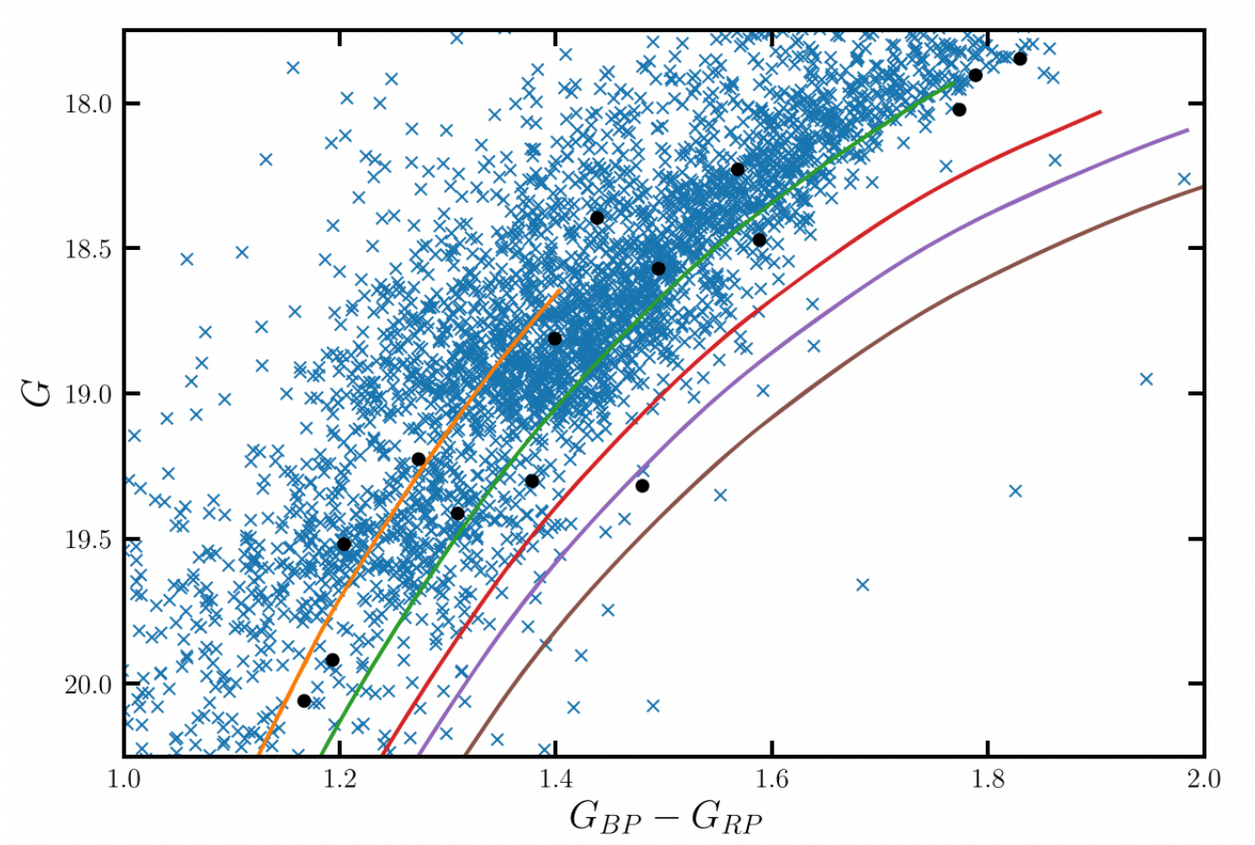


Comparison to Other Globular Clusters

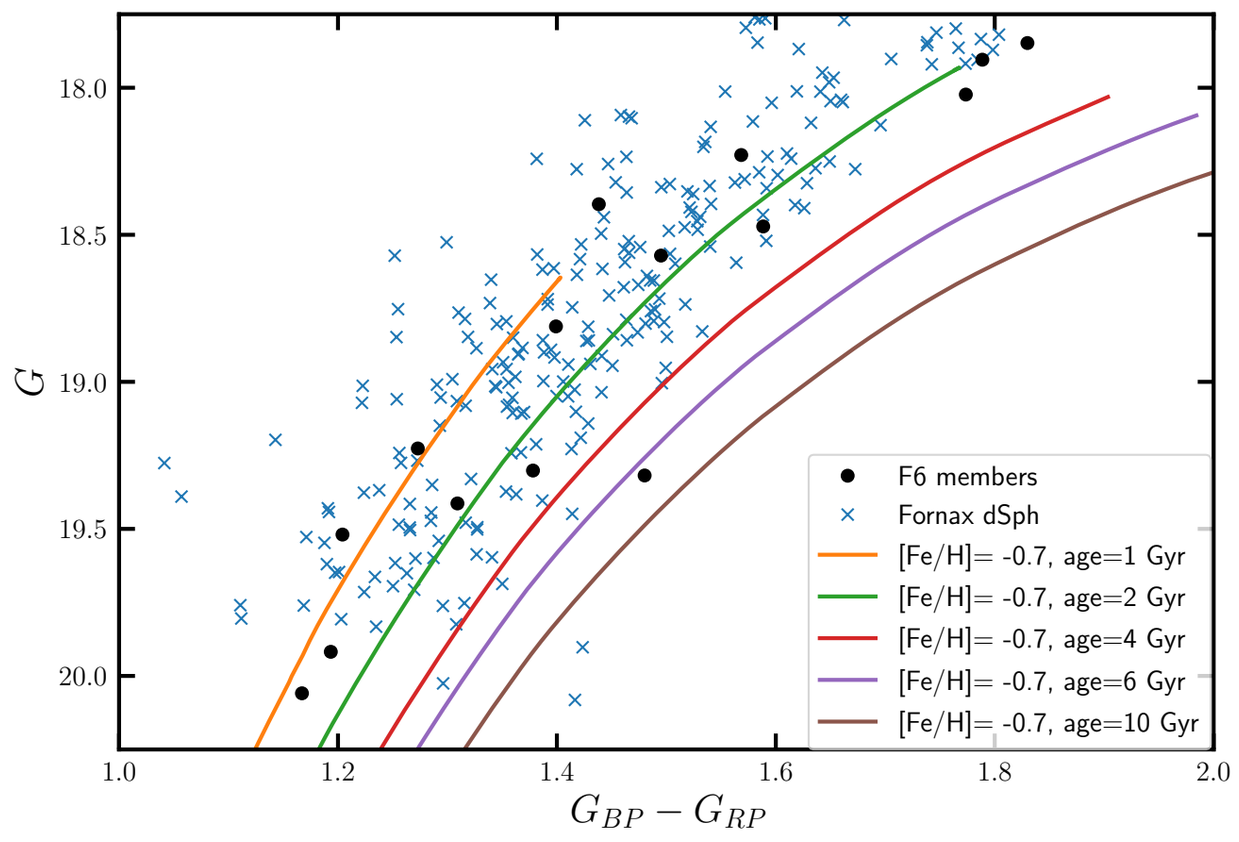


Age Estimation

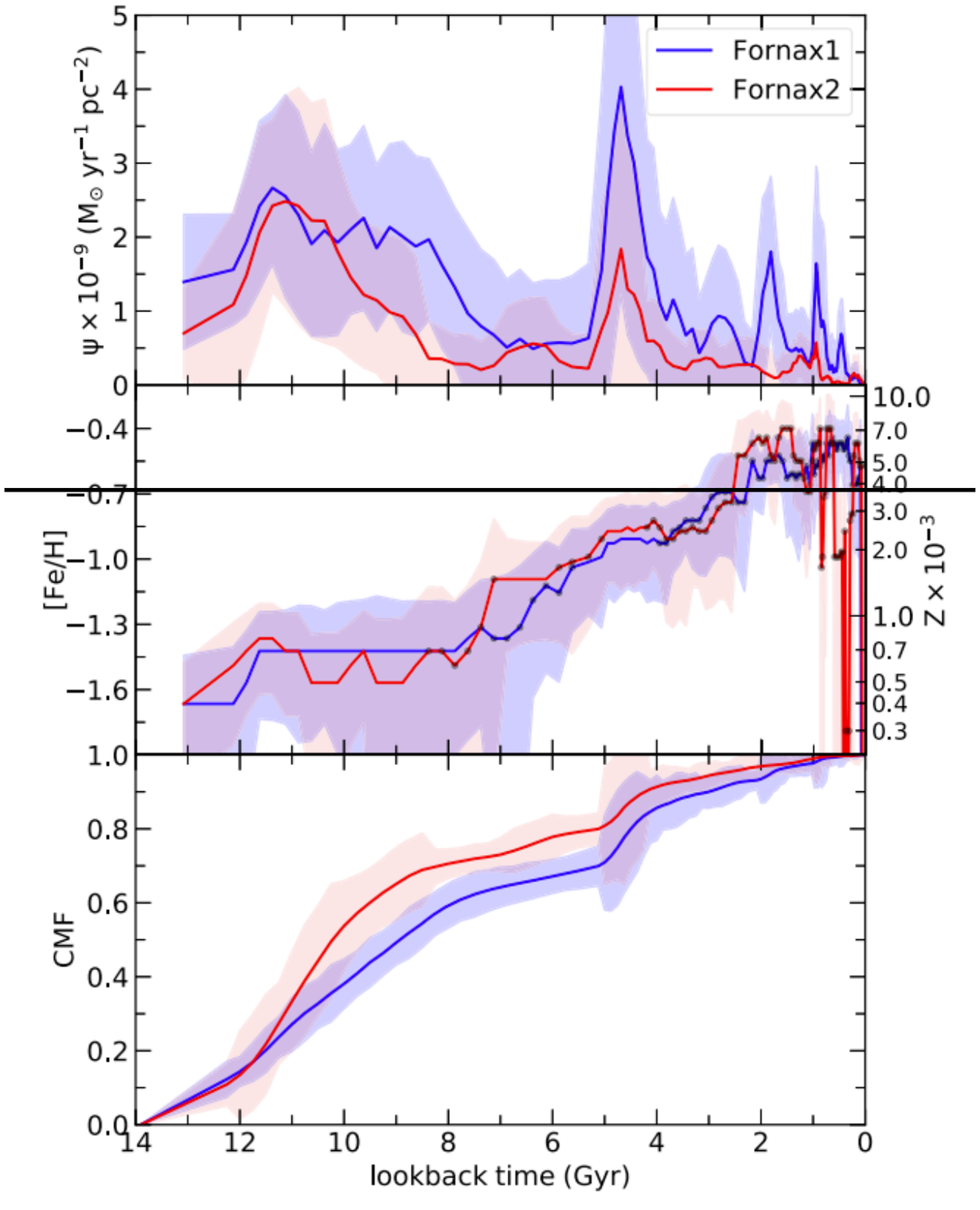


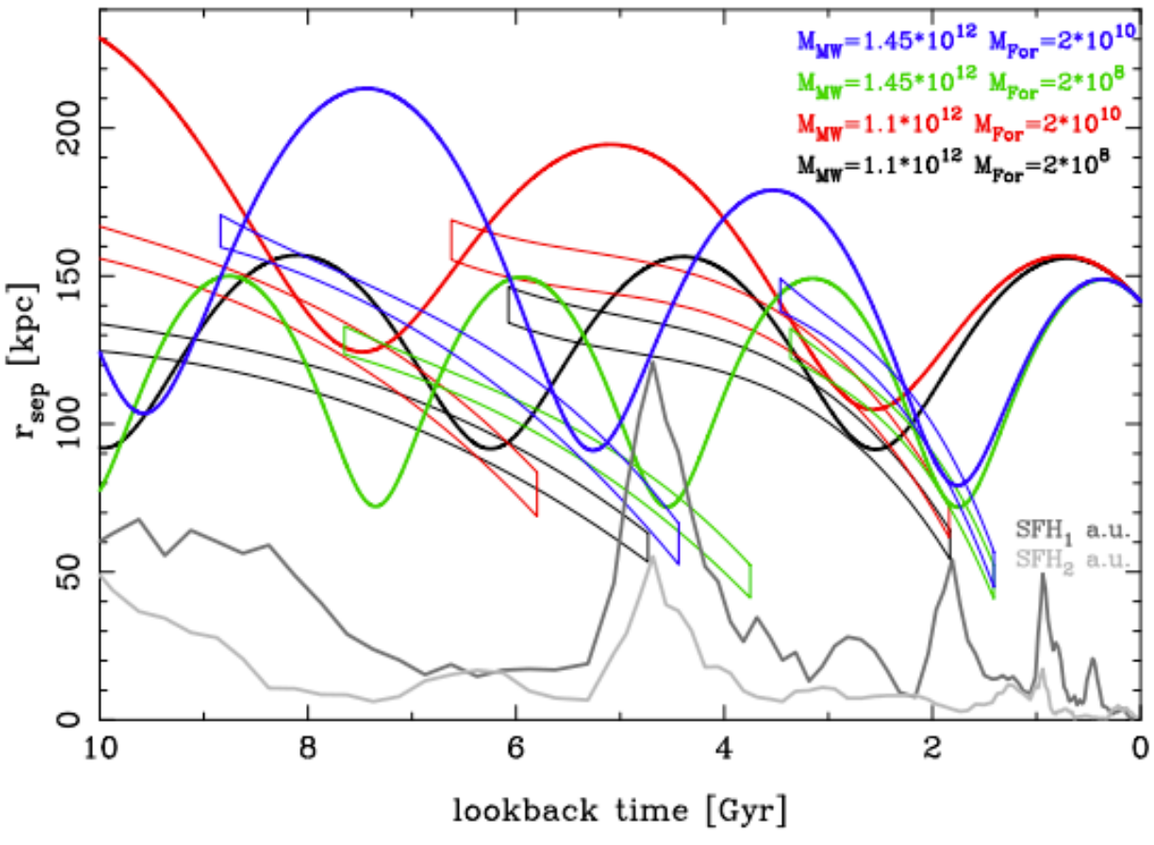
Fornax 6 stars are redder than Fornax dSph stars

A young, metal-rich isochrone matches the Fornax 6 stars (Age ~ 2 Gyr, [Fe/H]~ -0.7)



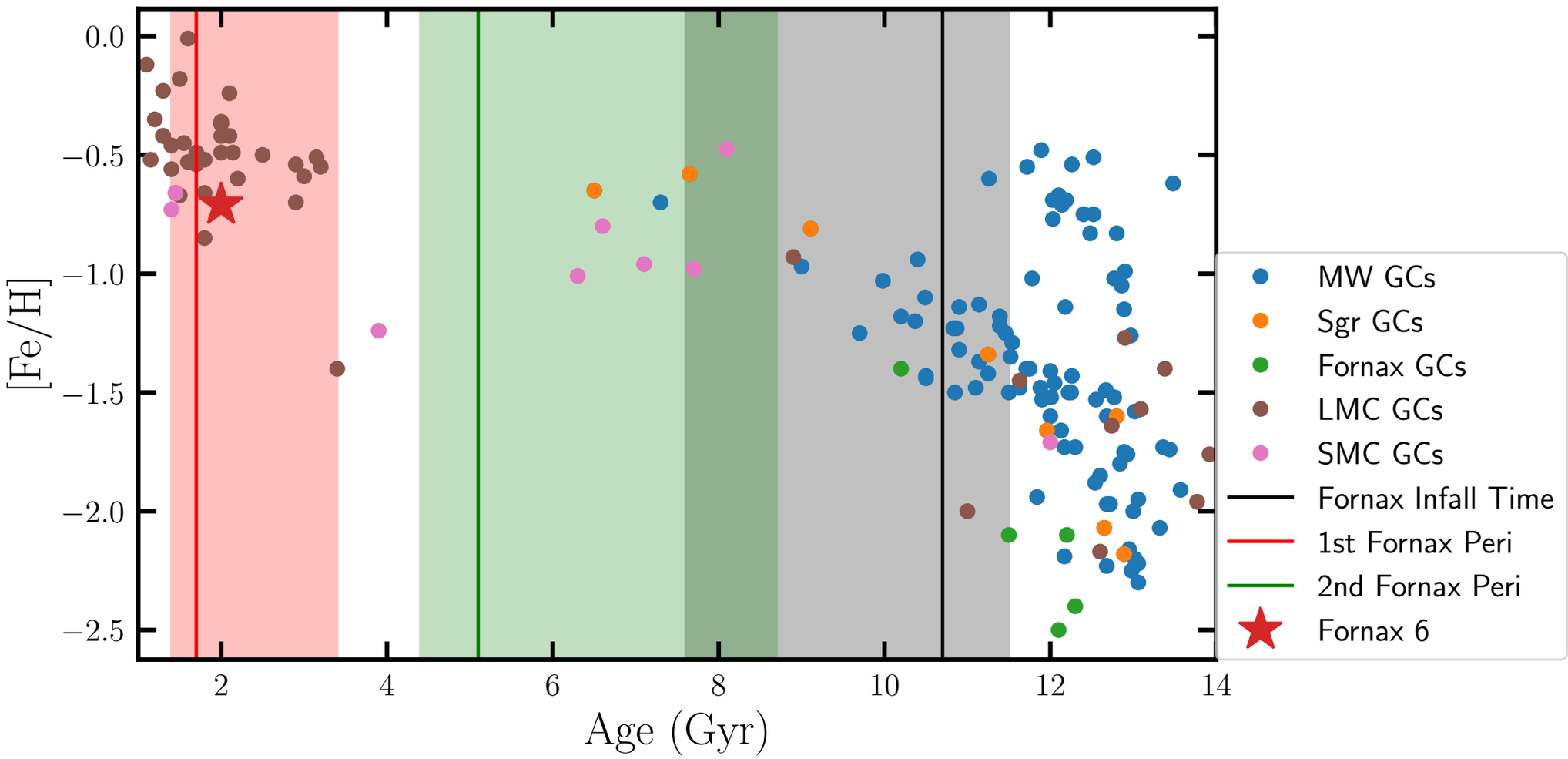
Star Formation History of Fornax





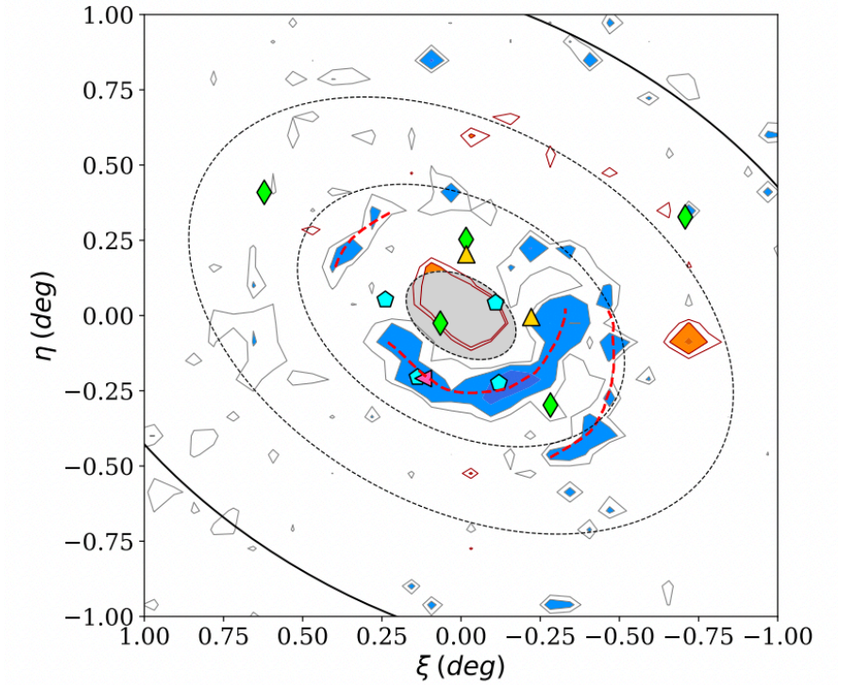
Rusakov et al. 2021

Age-Metallicity Relation



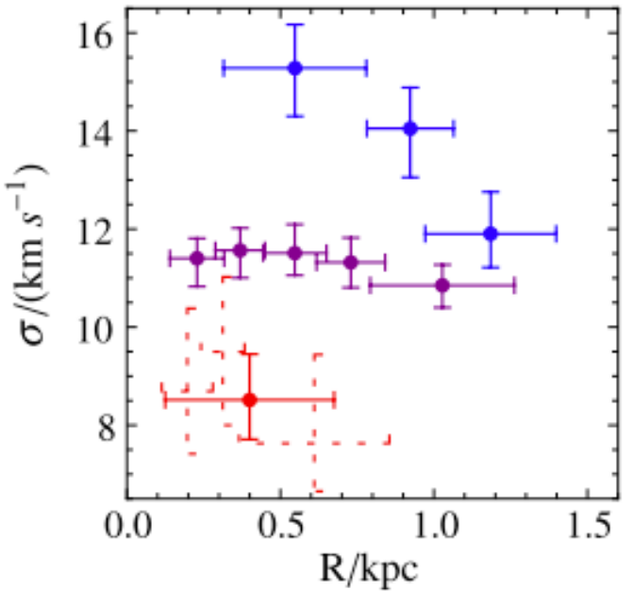
A Late Merger in Fornax?

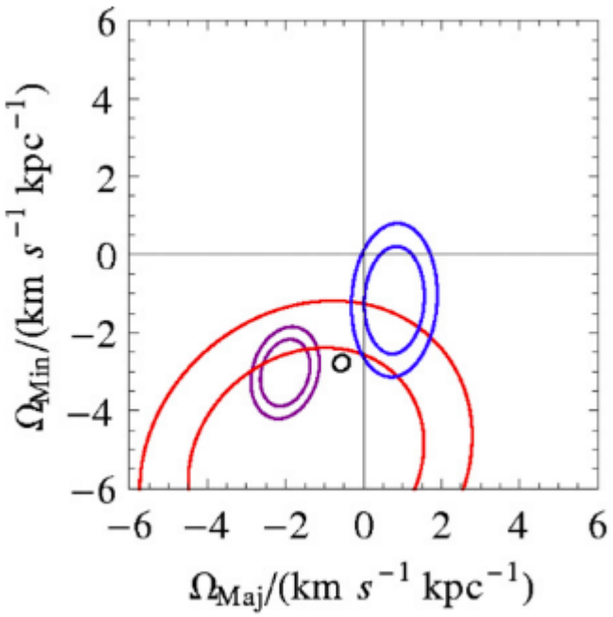
Evidence from stellar overdensities



Wang et al 2019

See also Coleman et al 2004
del Pino et al 2015





Late merger of bound pair from chemo-dynamics of Fornax.
The angular momentum vectors of the metal-poor and intermediate metallicity populations are misaligned

Amorisco & Evans 2012

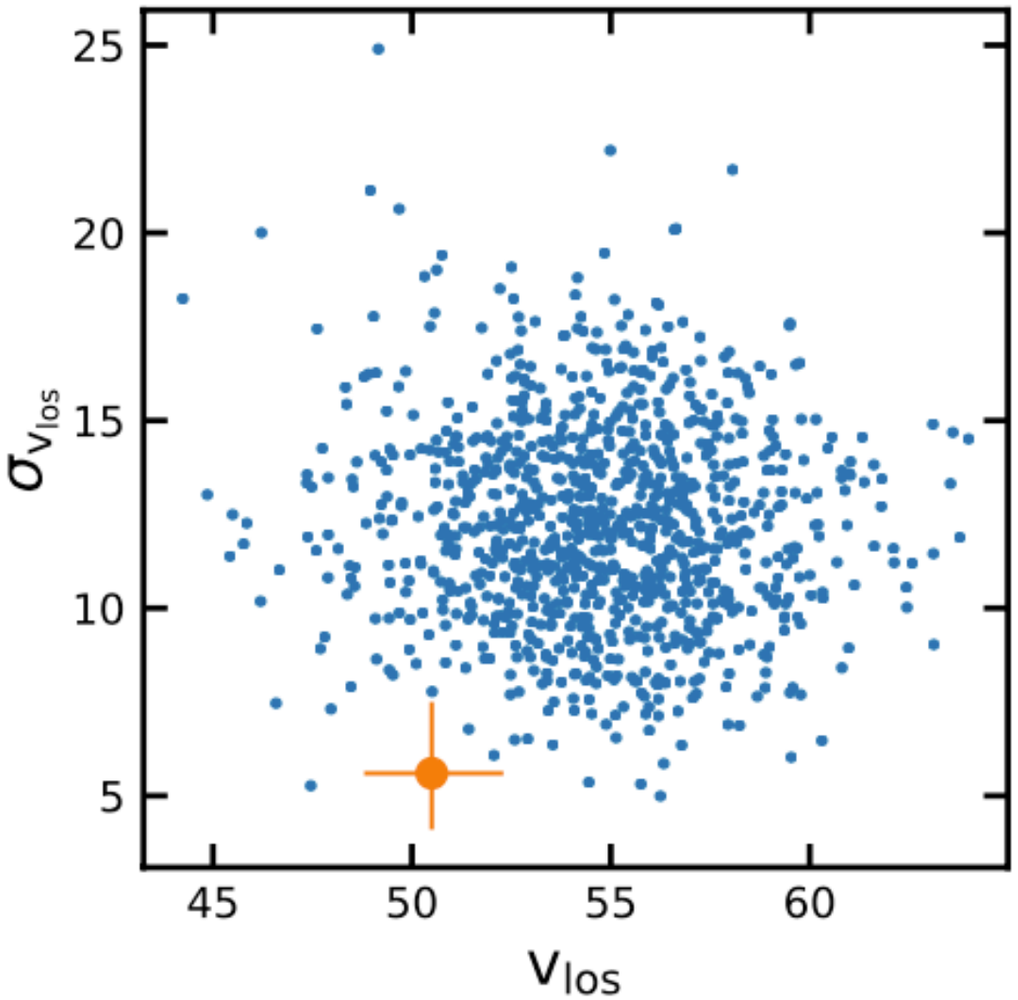
See also Yozin & Bekki 2012
del Pino et al 2017

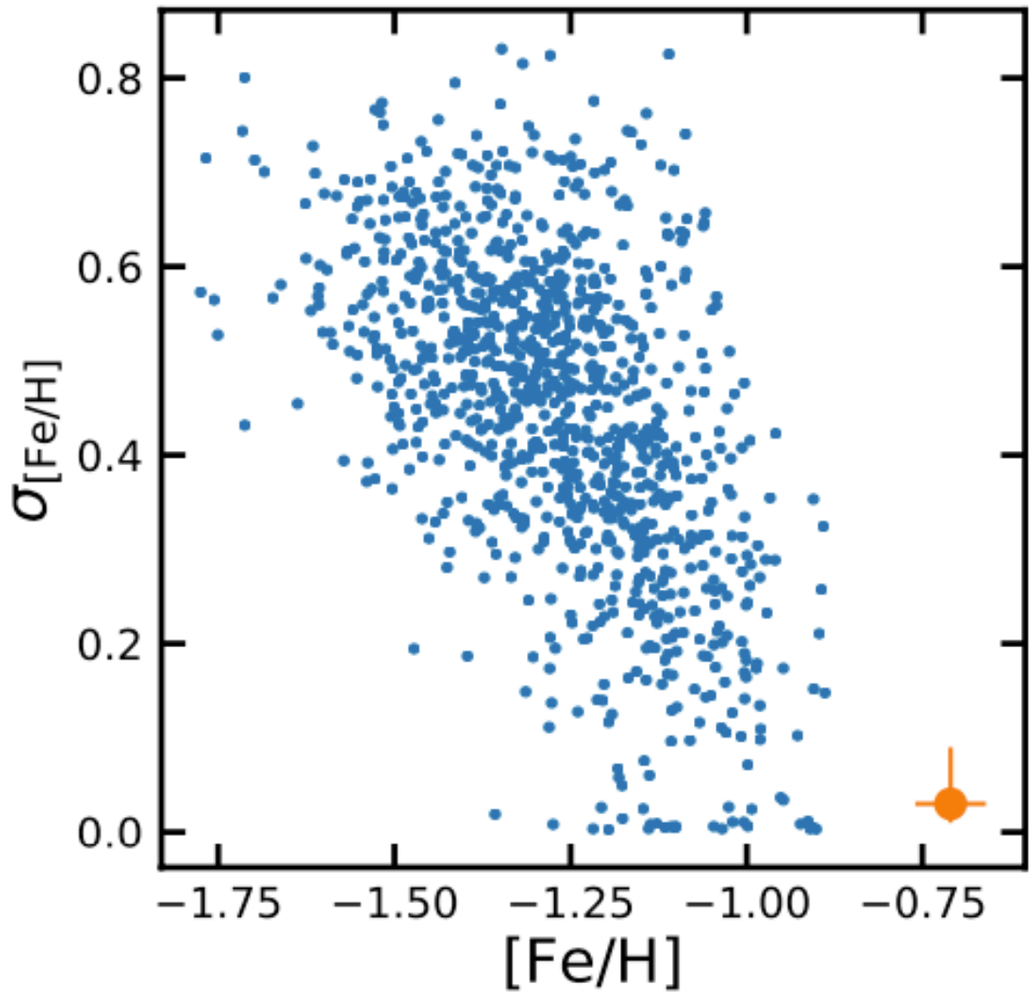
Conclusions

- **The Fornax 6 Globular Cluster has recently been (re)Discovered**
- **I presented follow-up Magellan/M2FS spectroscopy of the F6 GC.**
  - **This confirms the F6 GC is real.**
  - **F6 is metal-rich ([Fe/H]=-0.7)**
  - **No resolved metallicity dispersion. Consistent with a single stellar population.**
  - **The line-of-sight velocity is within 5 km/s of the Fornax dSph**
  - **The velocity dispersion is unresolved to ~5 km/s depending on the membership of two outliers.**
- **The F6 cluster has similar properties to the three metal-rich Sgr GCs**
- **The F6 cluster is likely the youngest Fornax GC (age ~ 2 Gyr).**
- **Formation**
  - **Previous star bursts possibly during a pericentric passage (~2, ~6 Gyr).**
  - **Driven by merger in Fornax**

Thanks

An Overdensity of Fornax dSph Stars is Unlikely





Randomly draw a similar number of Fornax 6 stars from the Fornax dSph sample
The velocity and metallicity distributions of the permutations tests do not match the Fornax 6 properties.

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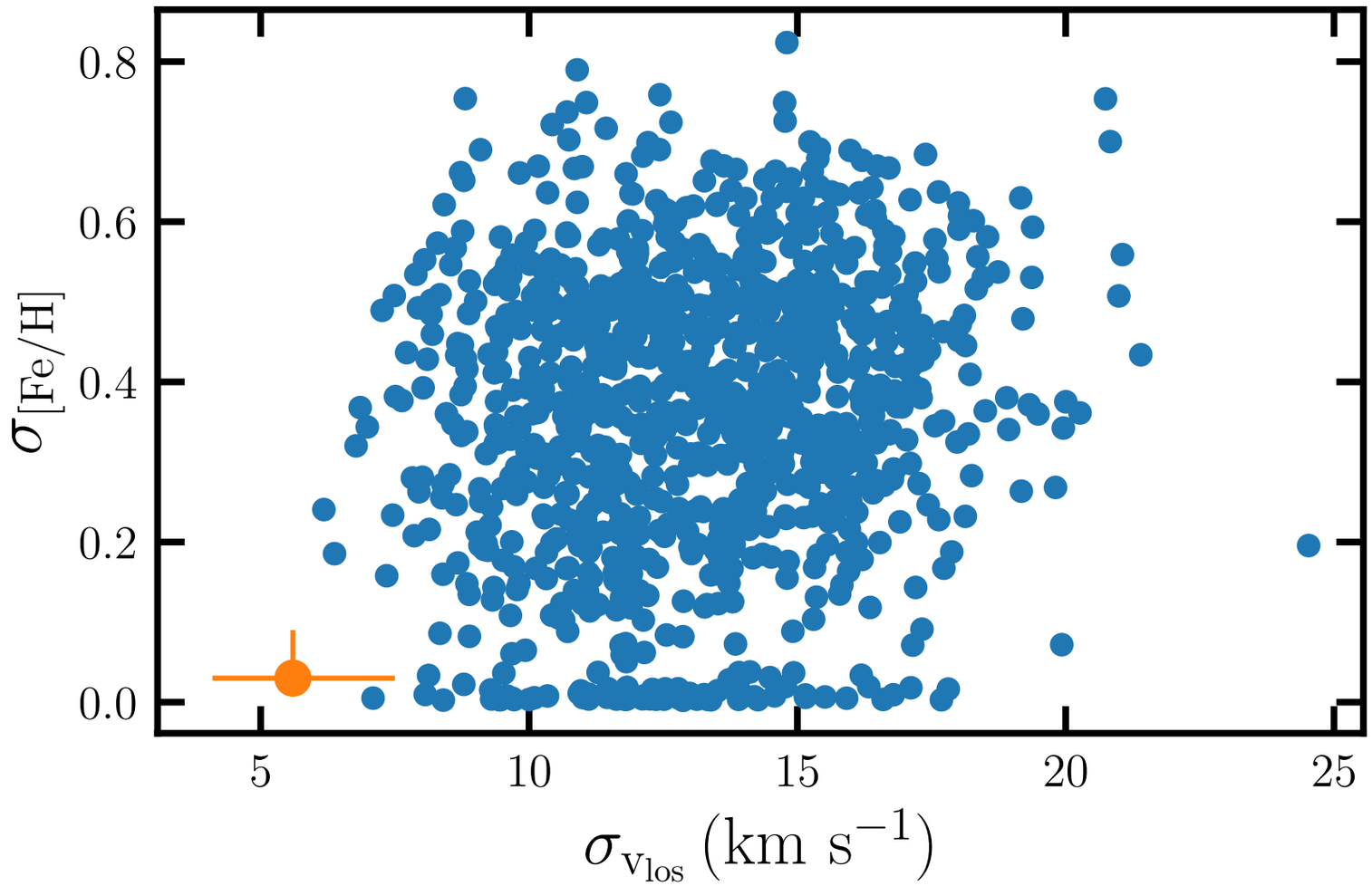

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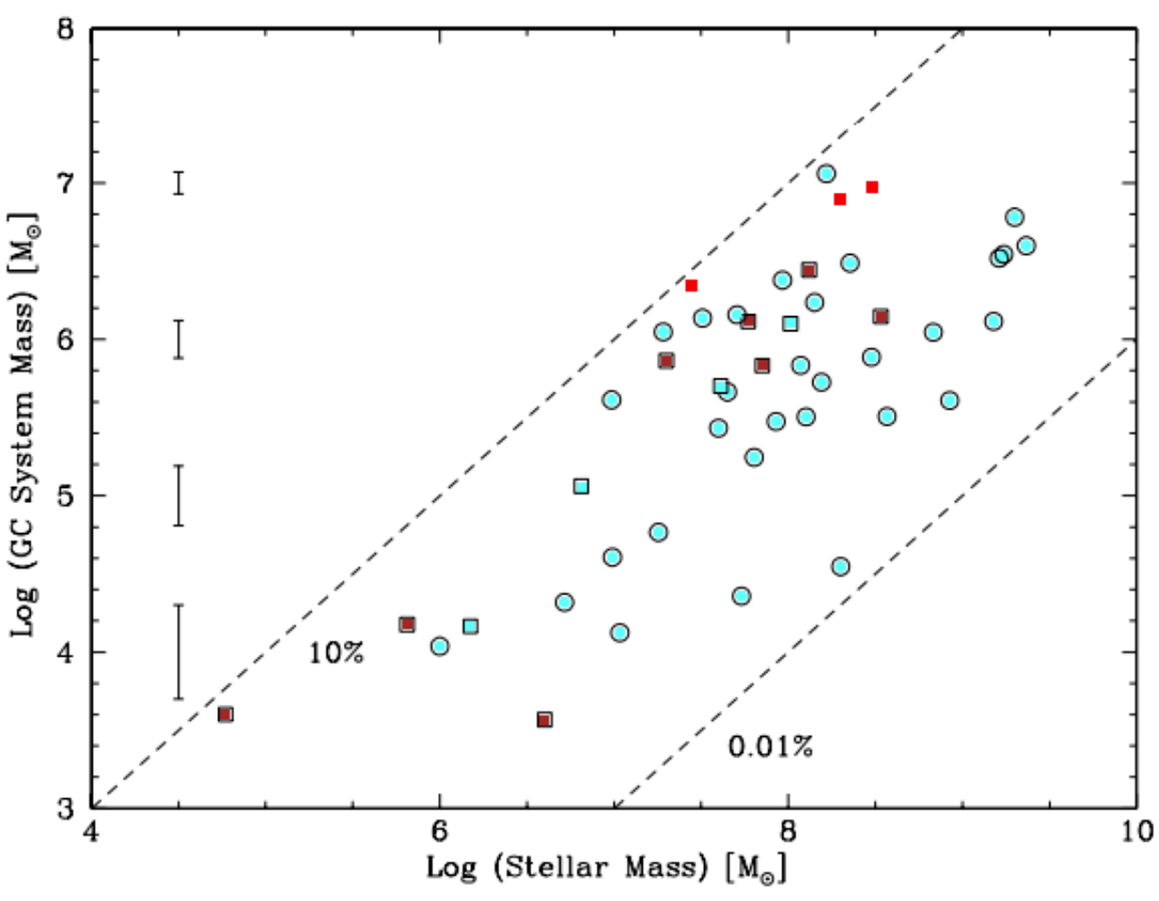
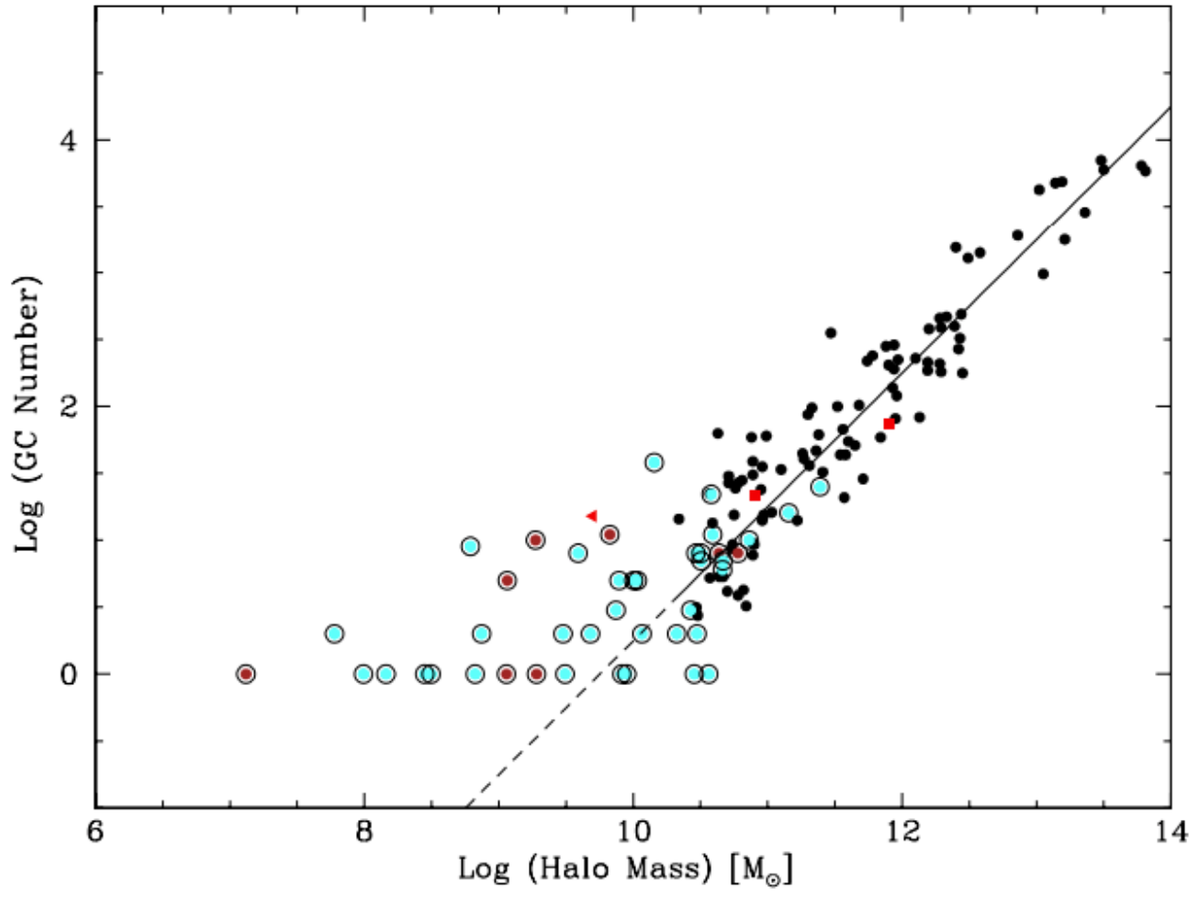
Halo Mass Globular Cluster Mass Relations

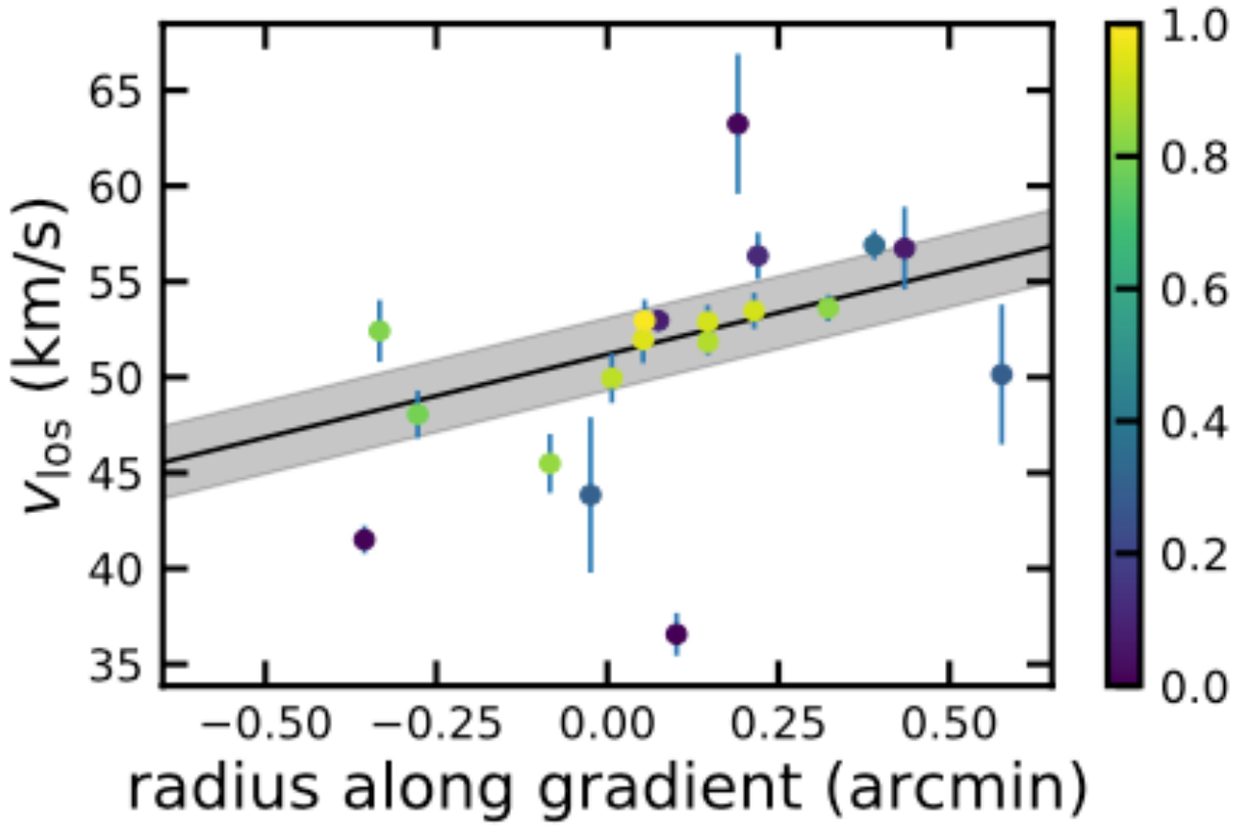




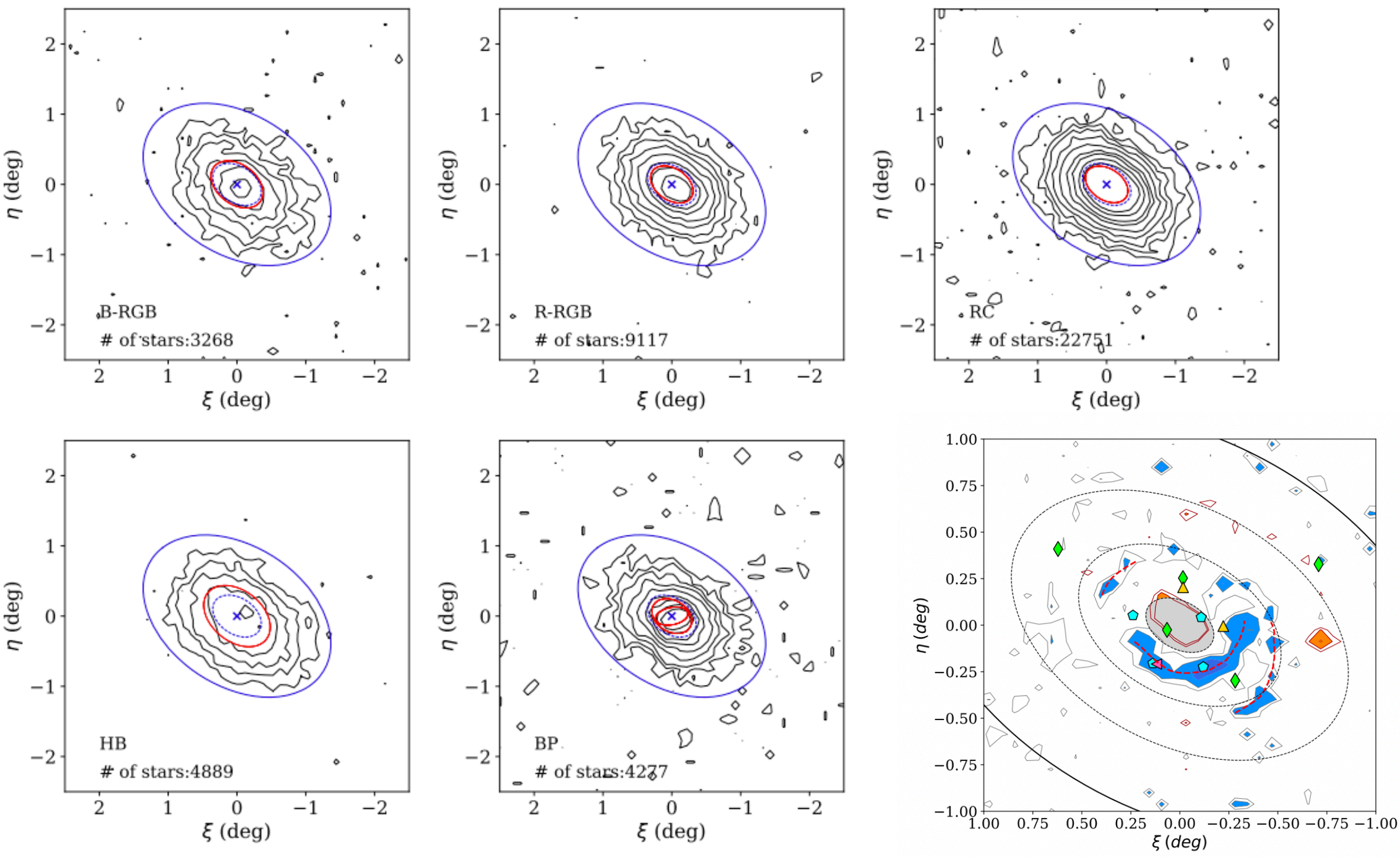
Forbes et al. 2018

Velocity Gradient/Tidal Disruption?

F6 cluster is quite elongated (e~0.41) for a globular cluster.
There is some (non-significant) evidence for a velocity gradient.



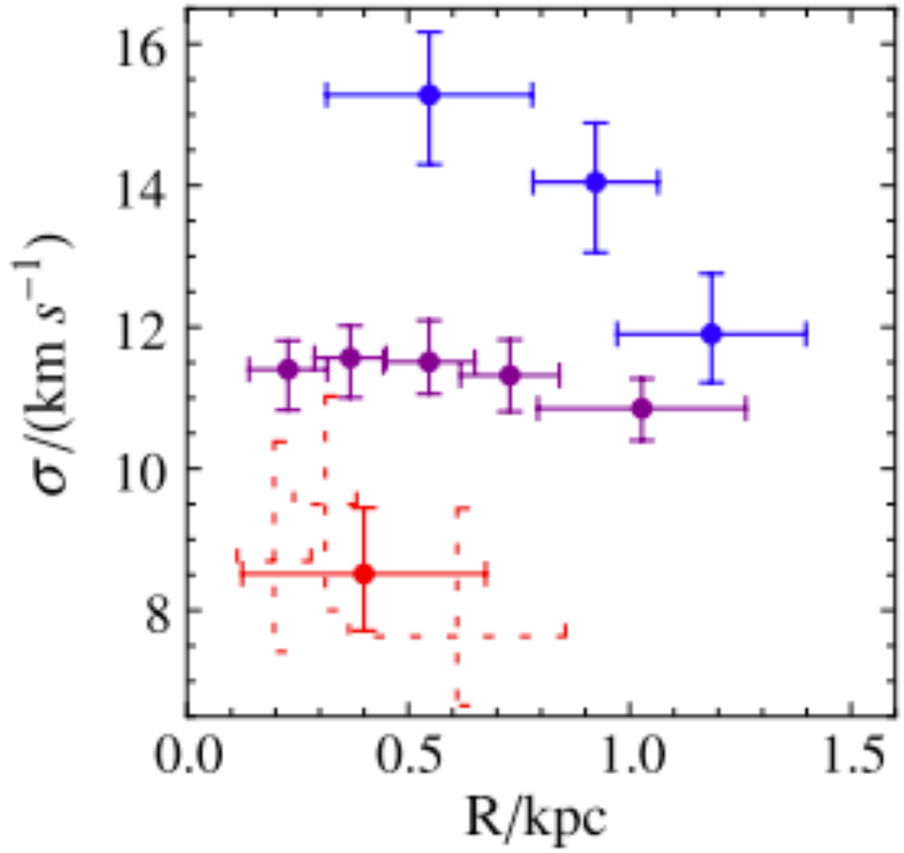
Photometric Evidence Late Merger in Fornax

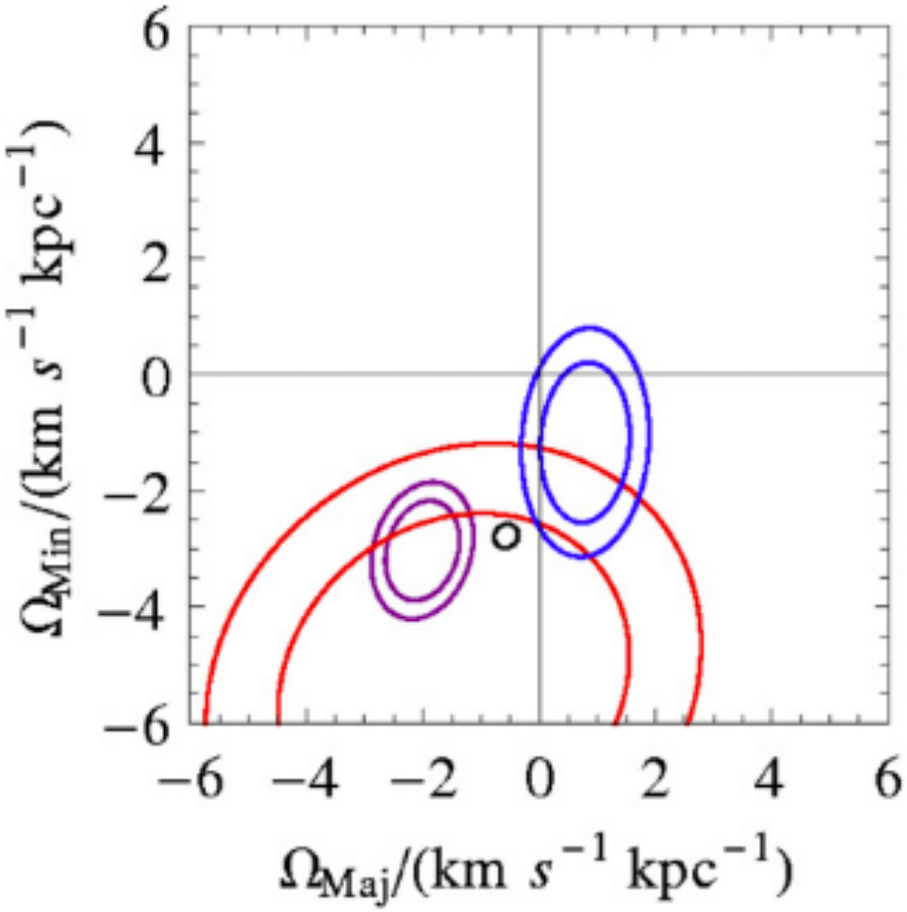


Wang et al 2019

See also Coleman et al 2004, del Pino et al 2015

Kinematic Evidence Late Merger in Fornax





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