Terzan 5: the remnant of a pristine fragment of the Galactic Bulge?

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European Southern Observatory (Santiago, Chile) – 29 November 2013

Cosmic-Lab

- 5-year project (web site at **www.cosmic-lab.eu**)
- *Advanced Research Grant* funded by the European Research Council (ERC)
- PI: Francesco R. Ferraro (Dip. of Physics & Astronomy – Bologna University)
- AIM: **to understand the complex interplay between dynamics & stellar evolution**
- HOW: using **globular clusters** as cosmic laboratories and

Blue Straggler Stars
Millisecond Pulsars
Intermediate-mass Black Holes
} as probe-particles

Globular Clusters …

GOLDEN RULE

Genuine GCs are homogeneous in their Fe content (and Fe-peak elements)

Fe produced by SN II + SN Ia

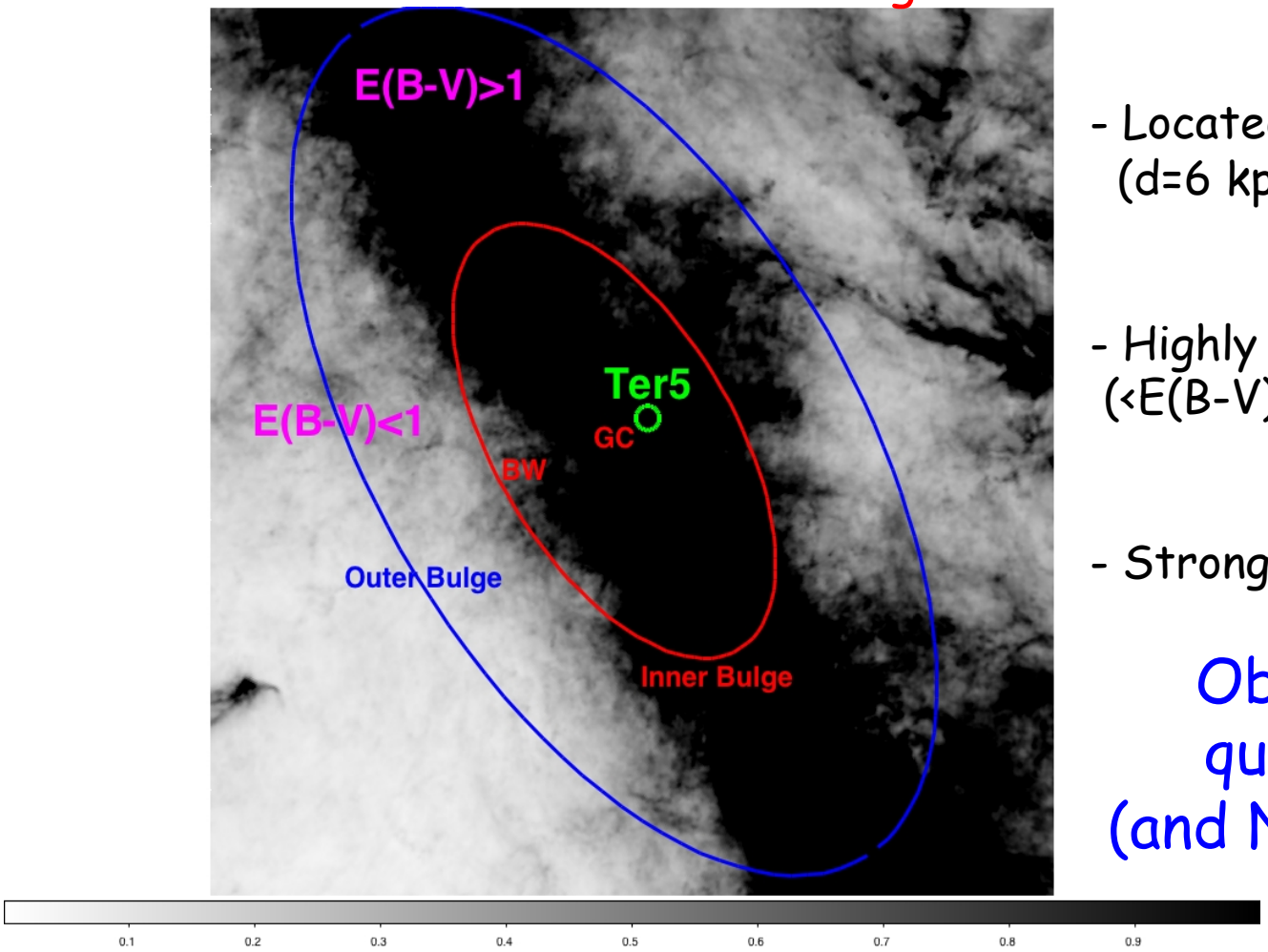
Genuine GCs

→ These systems did not retain the SNe ejecta (no Fe spread)

→ These systems did retain the AGB ejecta (Na,O,Al,Mg spread)

Terzan 5

Schlegel+98



- 34 MSPs (Ransom+04)

- Located in the inner bulge (d=6 kpc, d_{GC}=2.1 kpc)

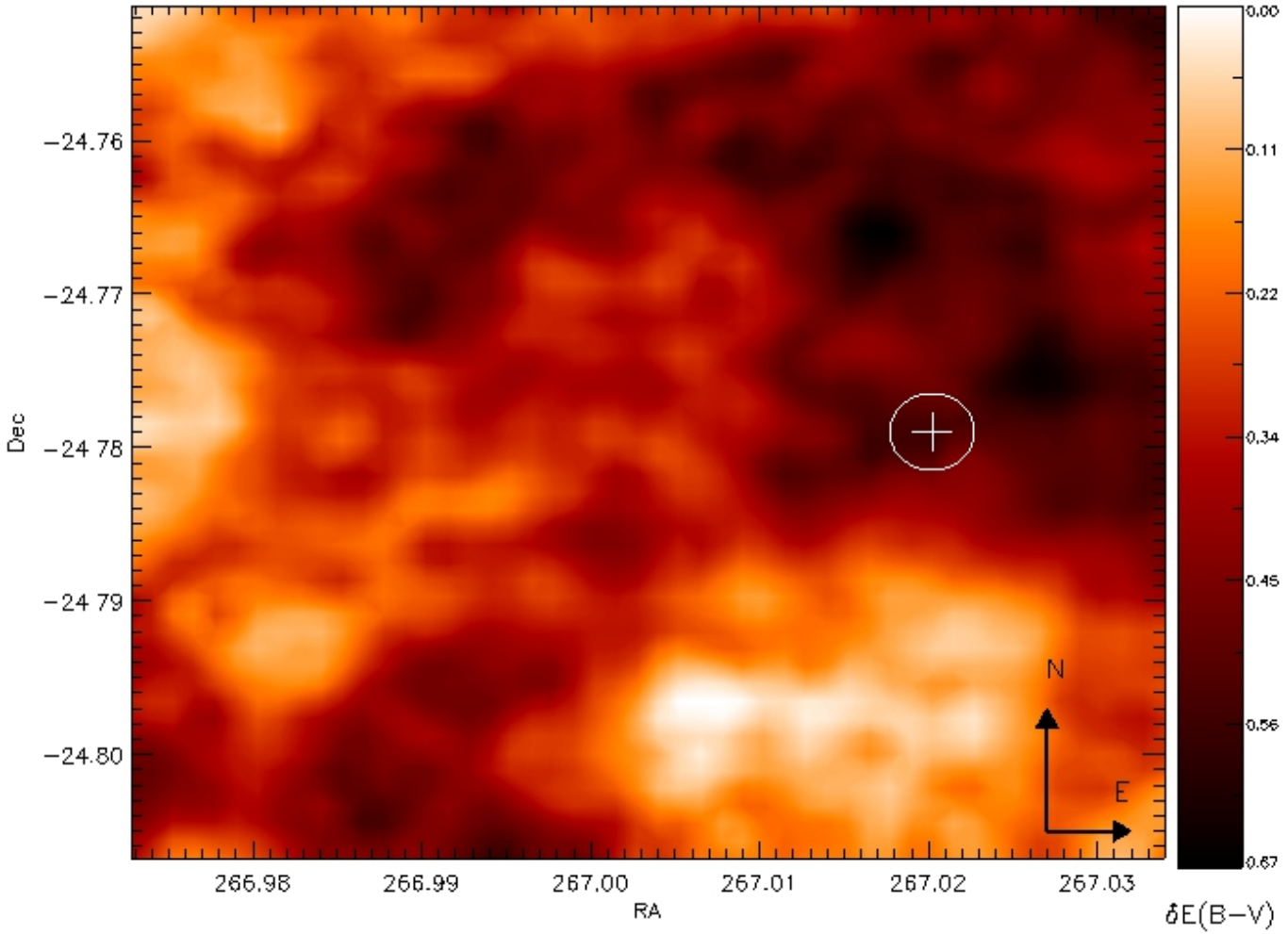
- Highly extincted region (<E(B-V)>=2.38 mag, Valenti+07)

- Strong differential reddening

Observations are quite challenging (and NIR is mandatory)

Terzan 5

Massari+13

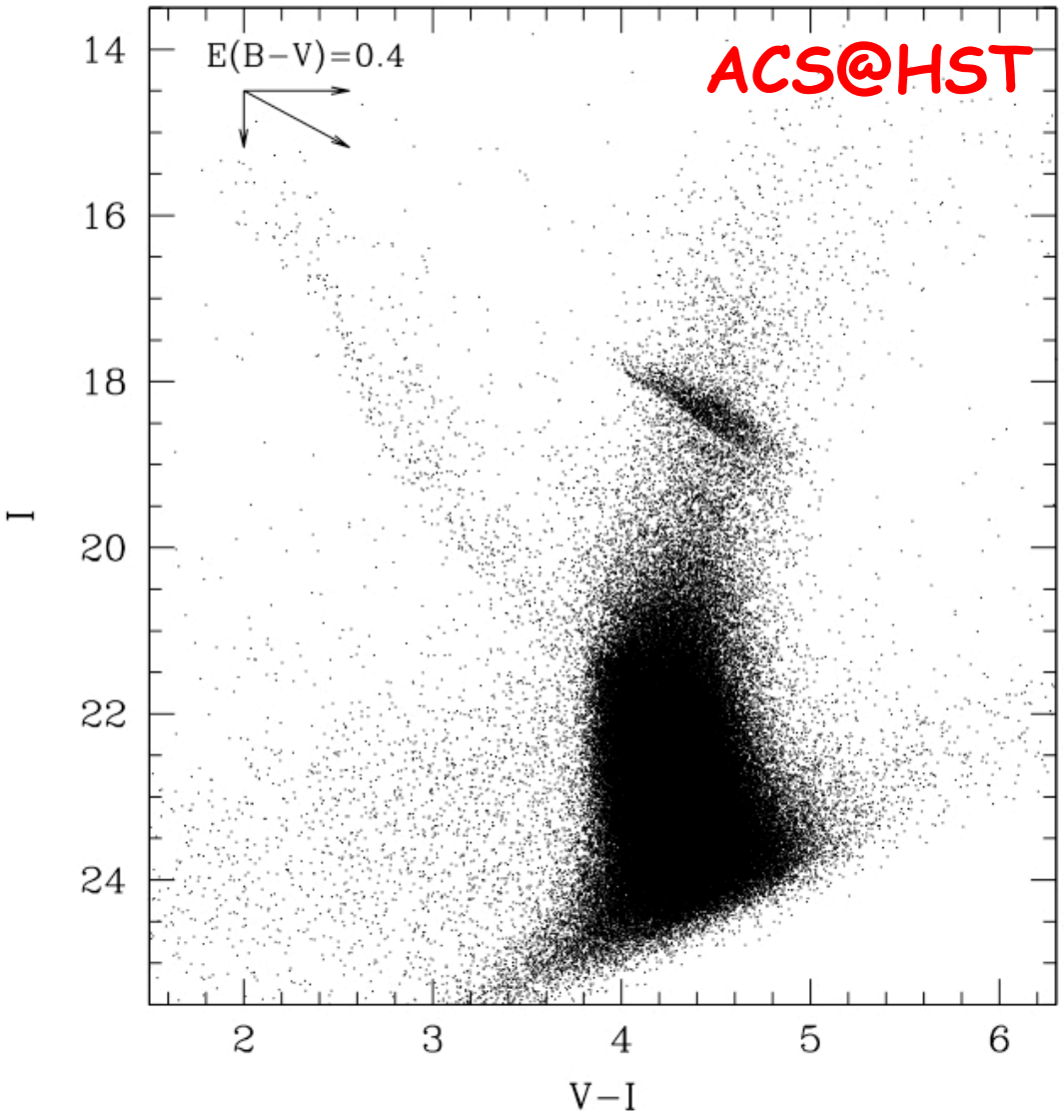


ACS FoV:
200″ x 200″

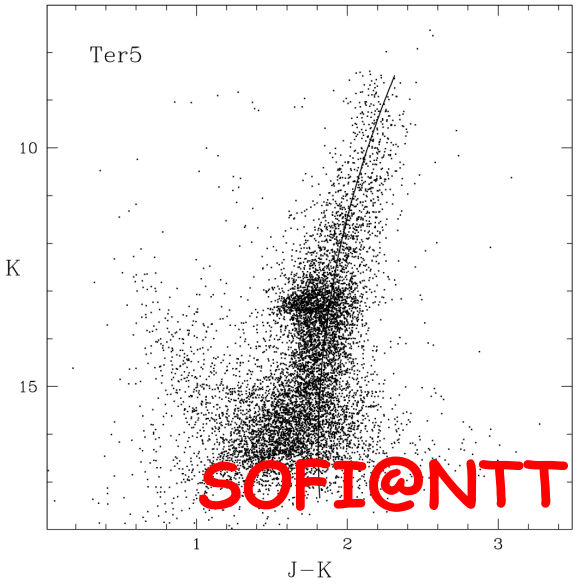
E(B-V)=2.15-2.82

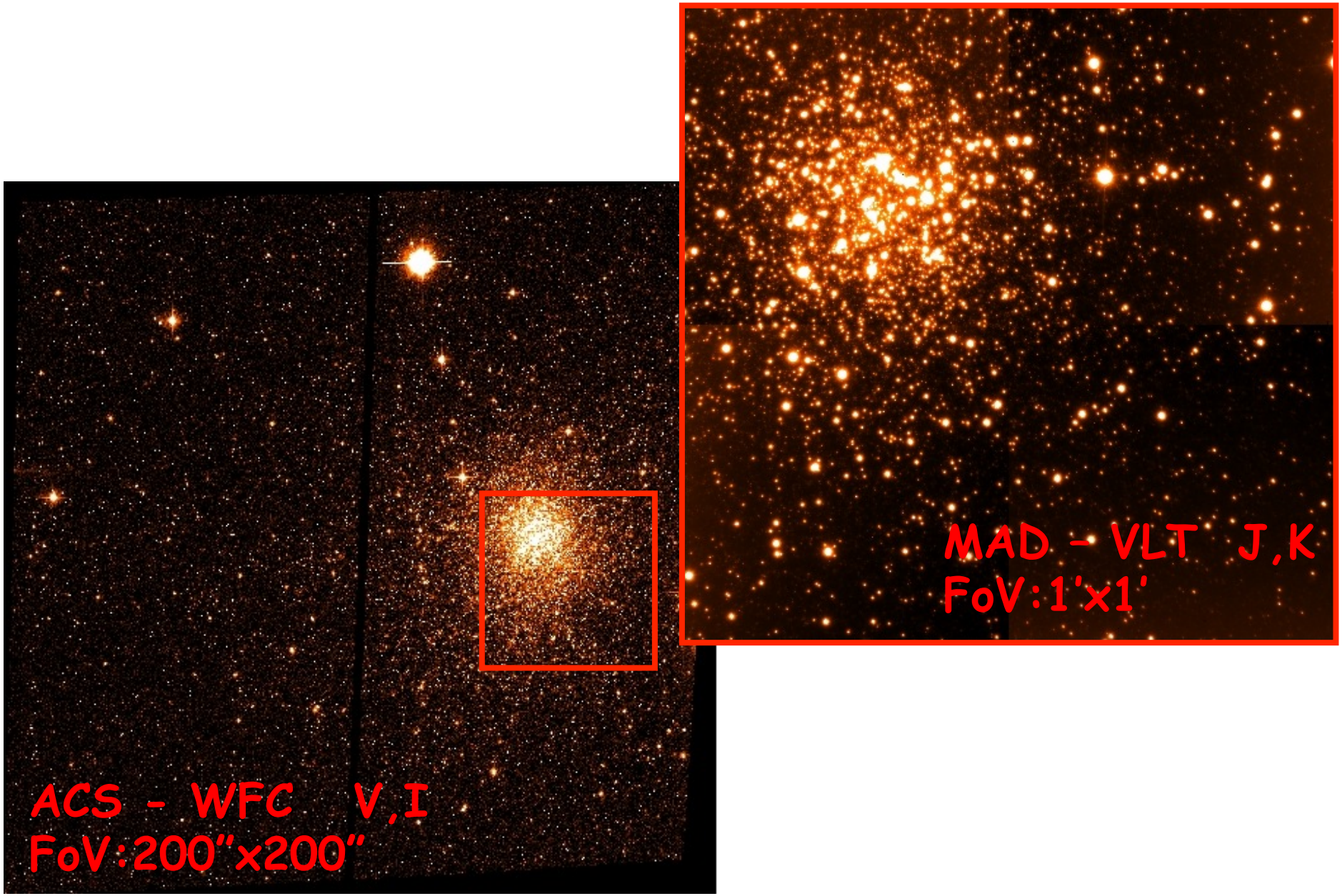
δ[E(B-V)]=0.7

Ferraro+09

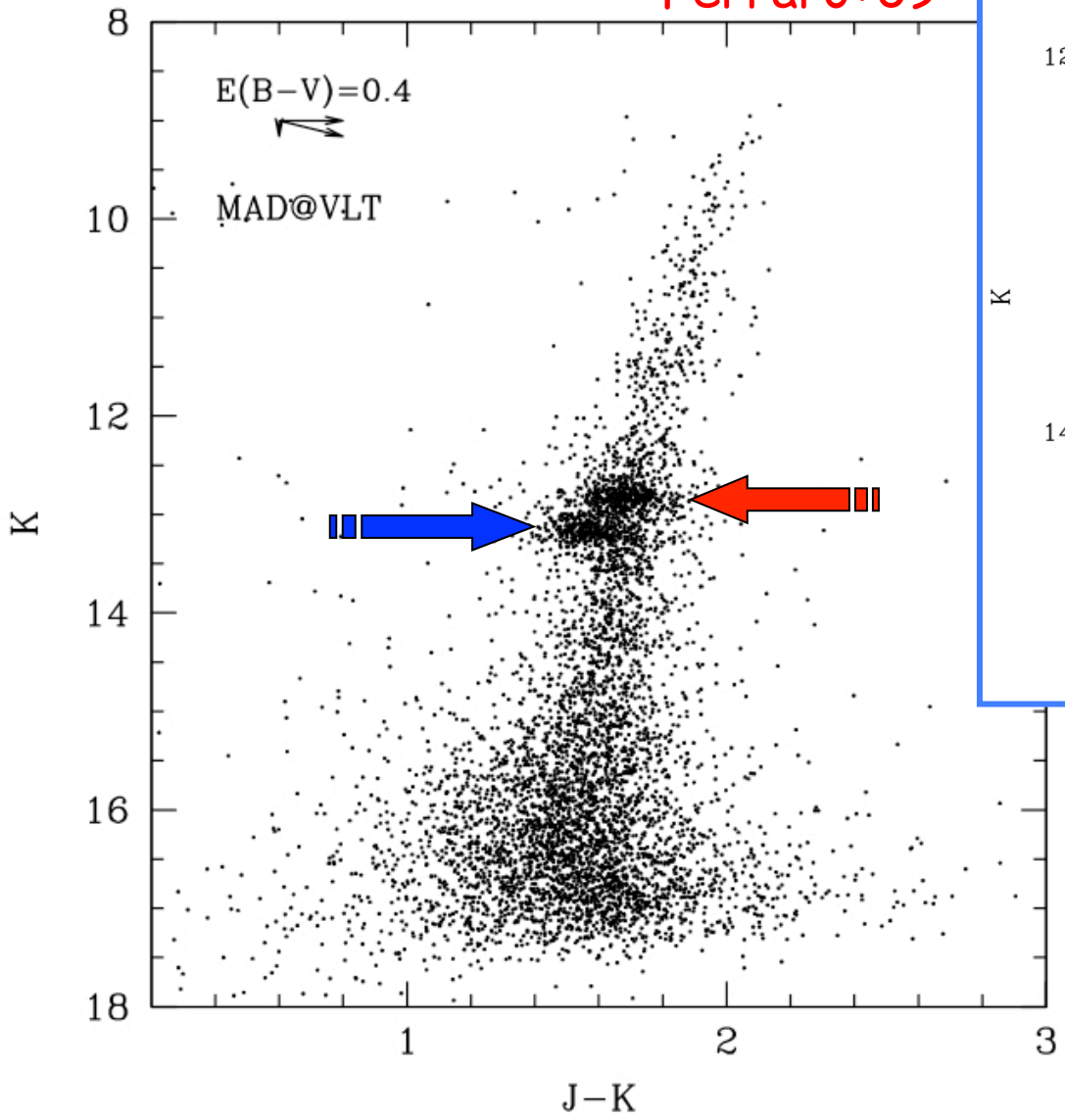


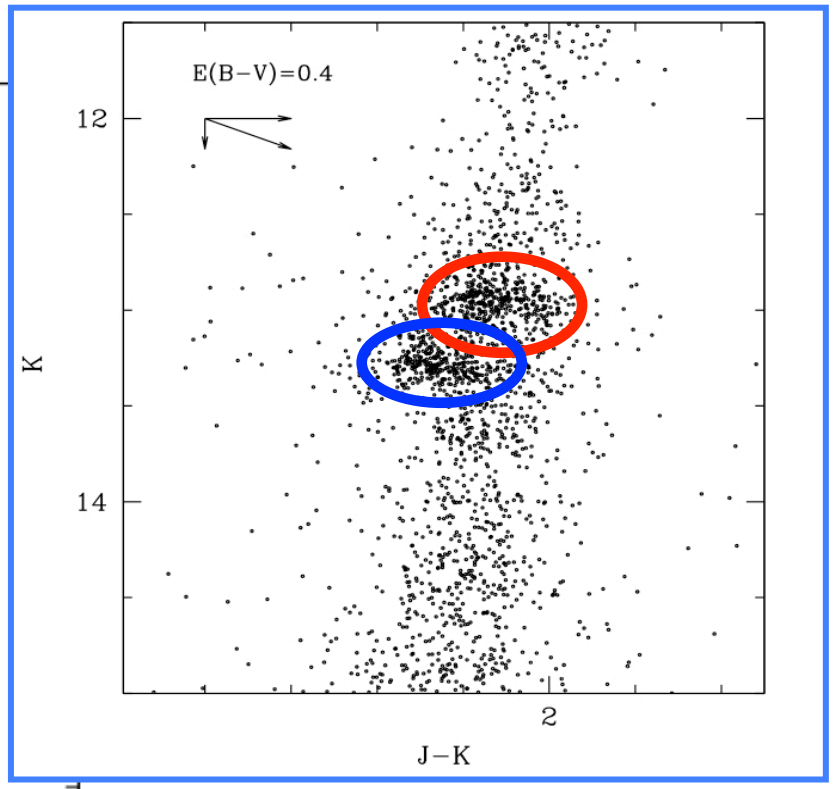
Valenti+07




MAD - VLT J,K
FoV:1'x1'
ACS - WFC V,I
FoV:200"x200"

Ferraro+09

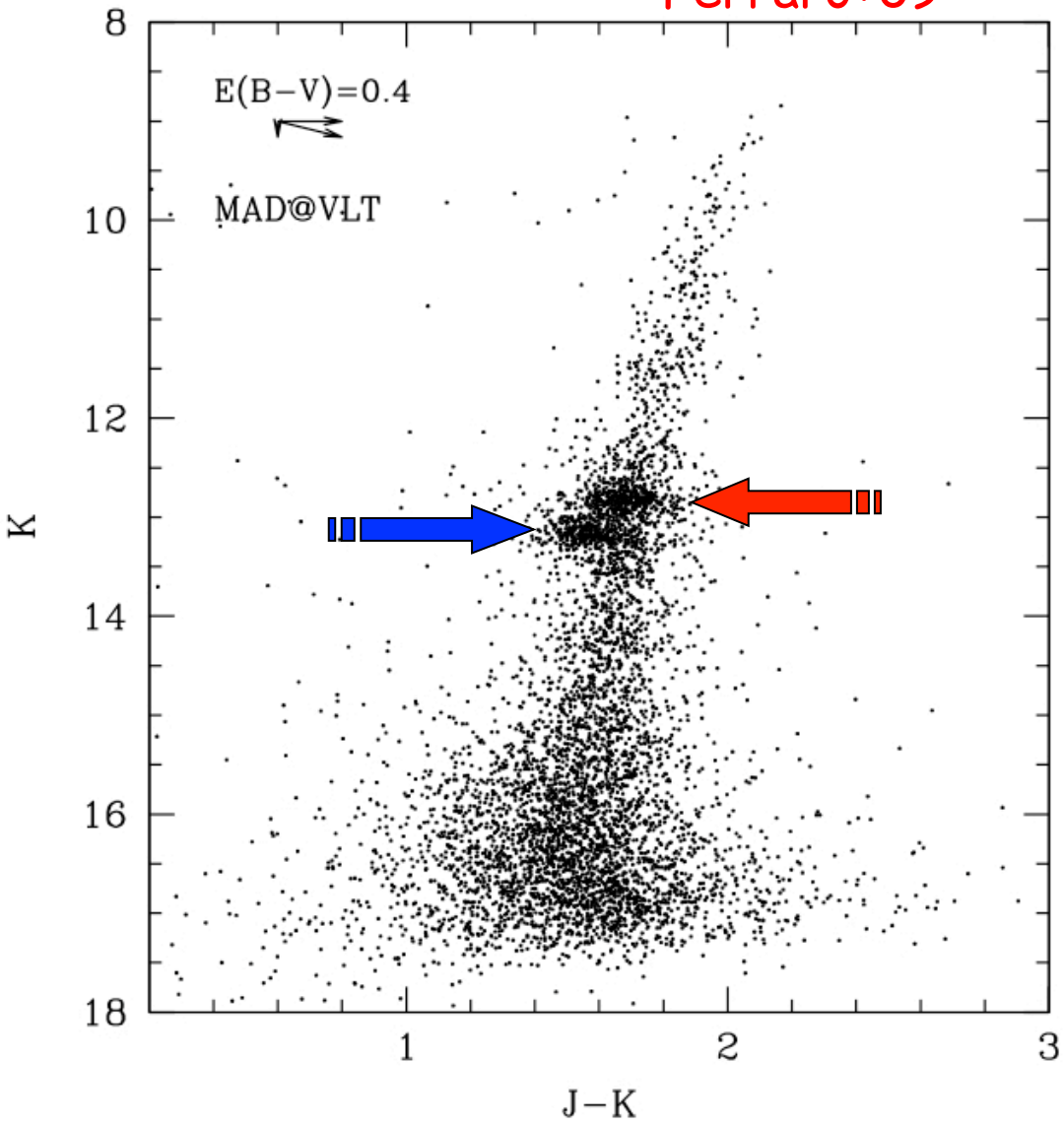




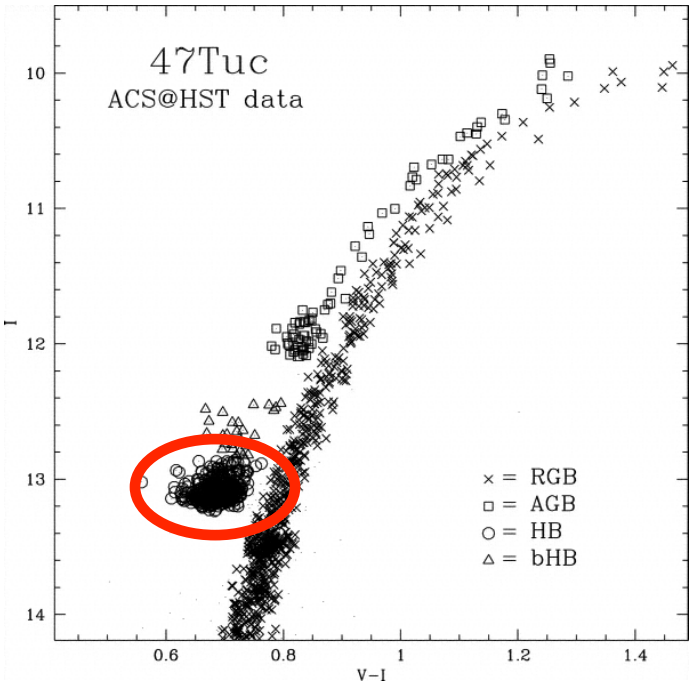
TWO HBs !!!

ΔK~0.3 mag
Δ(J-K)~0.2 mag

Ferraro+09



Beccari+06



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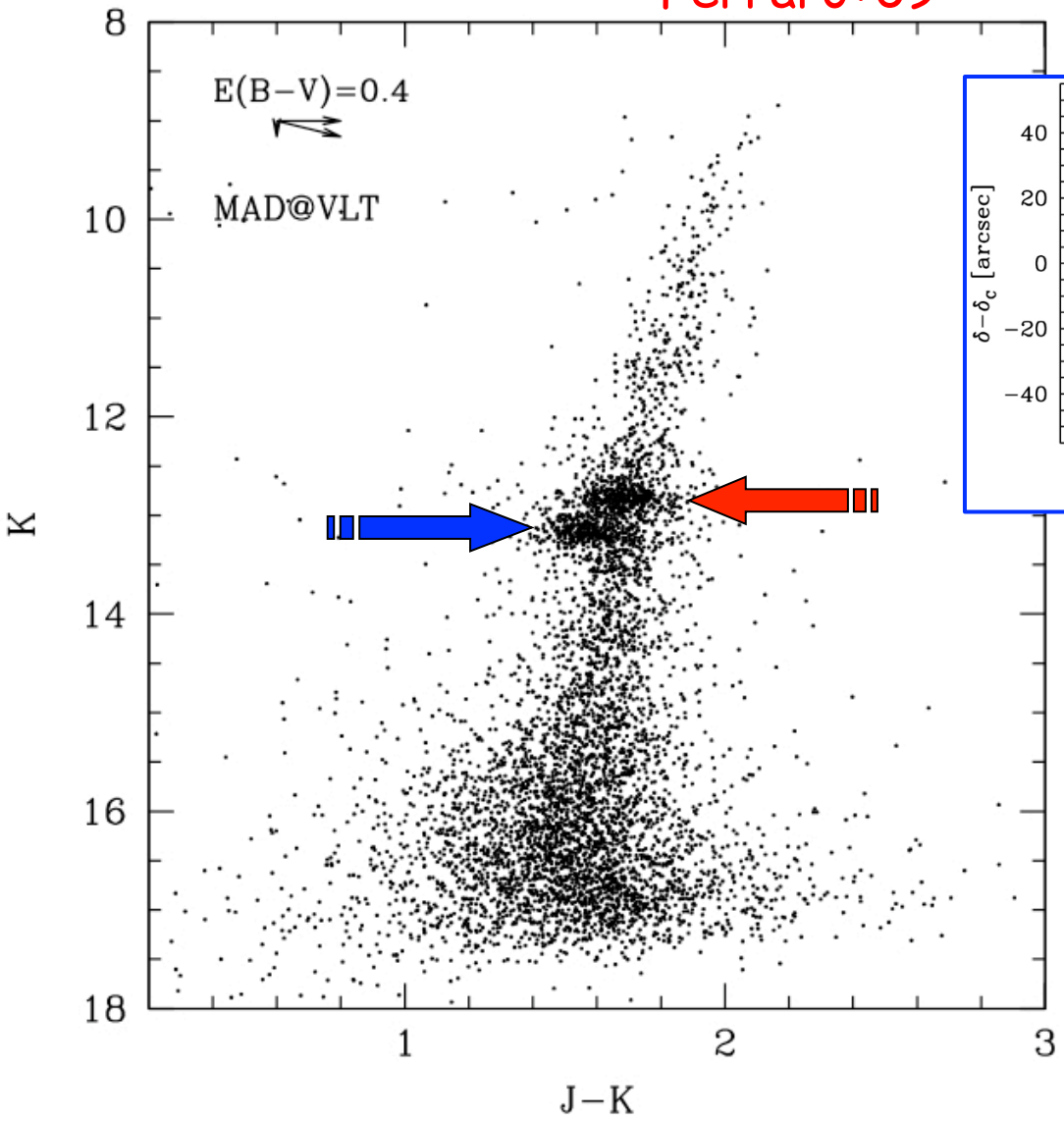
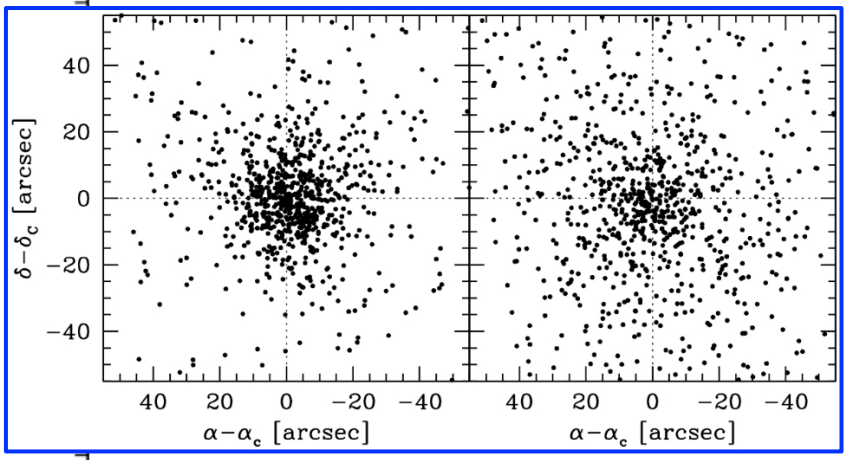
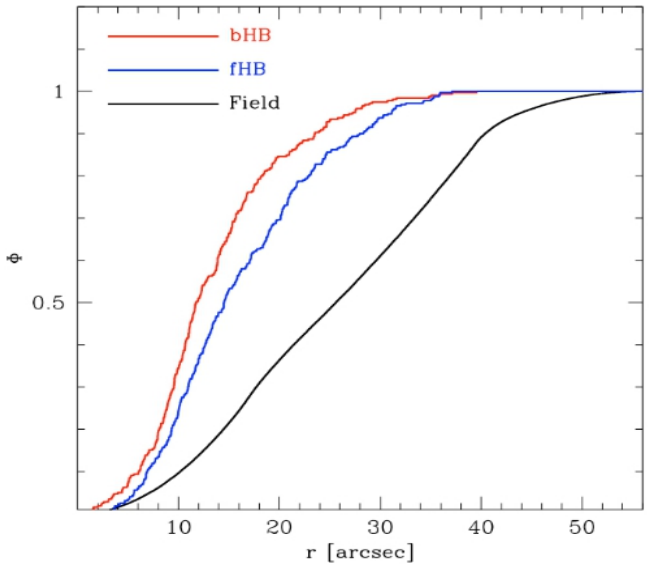


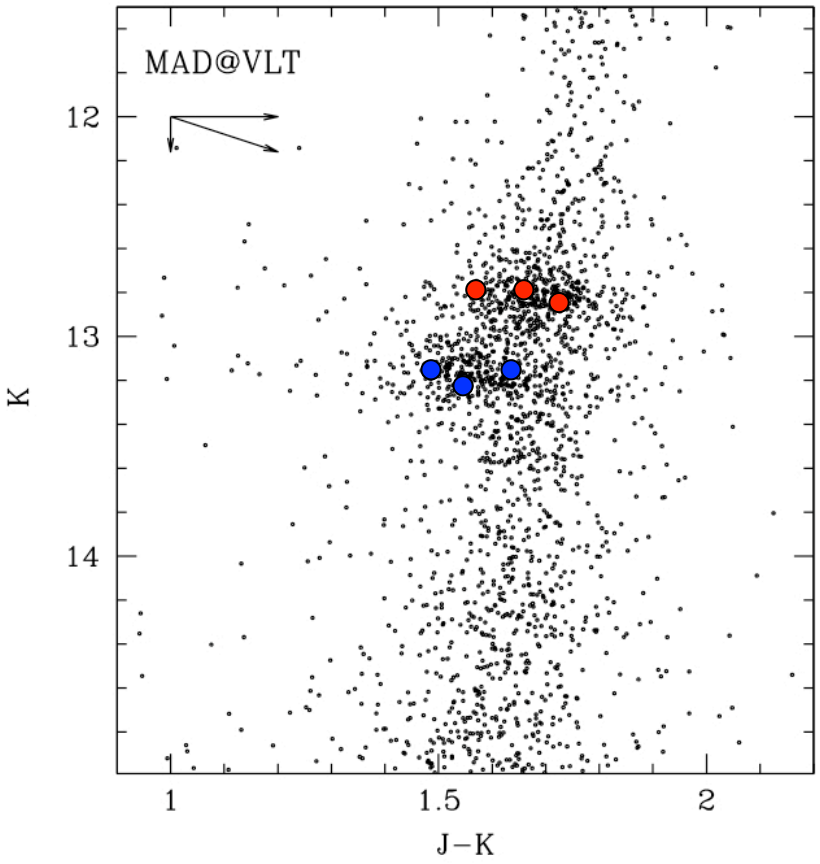
Red HB Blue HB





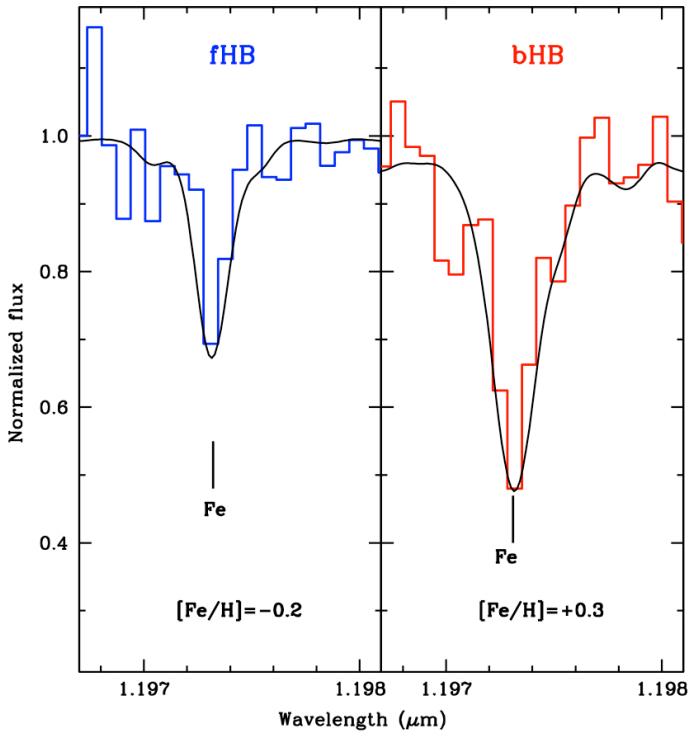
Spectroscopic survey: NIRSPEC – I (6 HB stars)

Ferraro+09



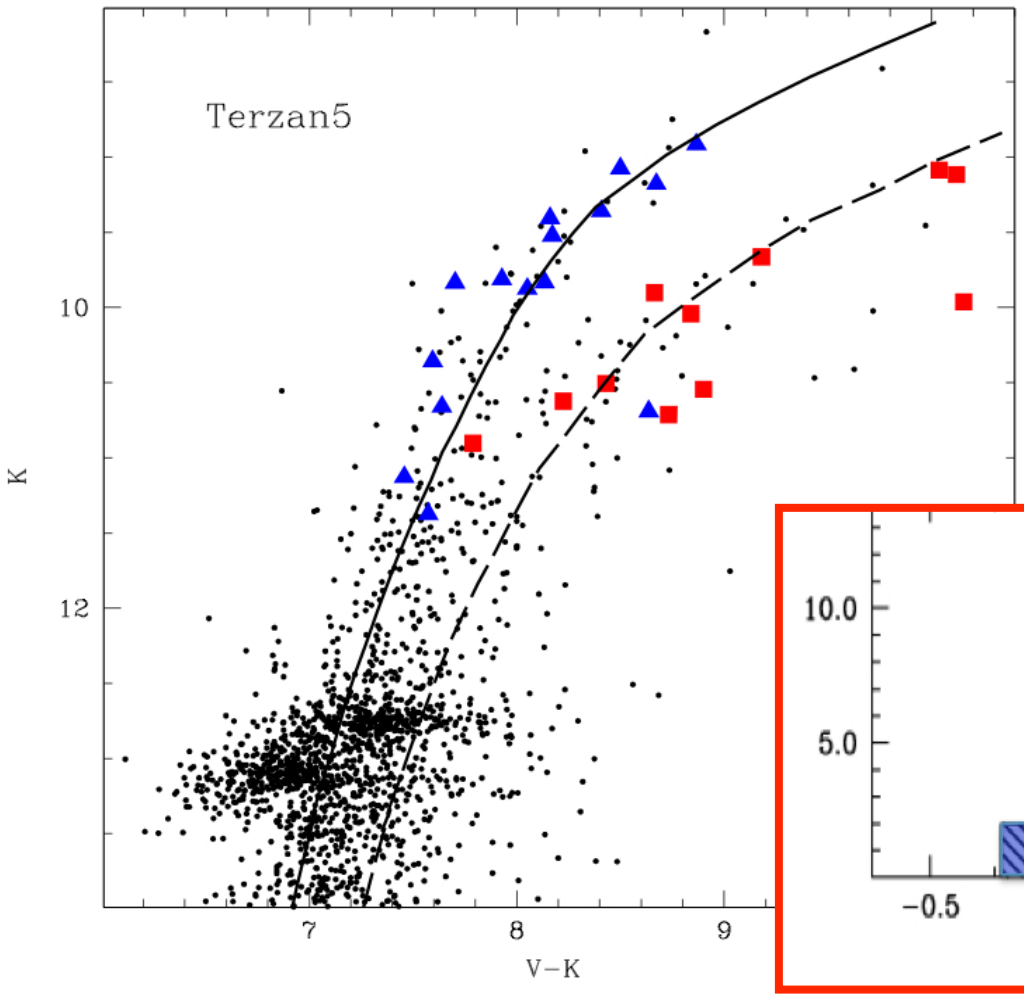
Blue HB: <RV> = -85 km/s
[Fe/H] = -0.2

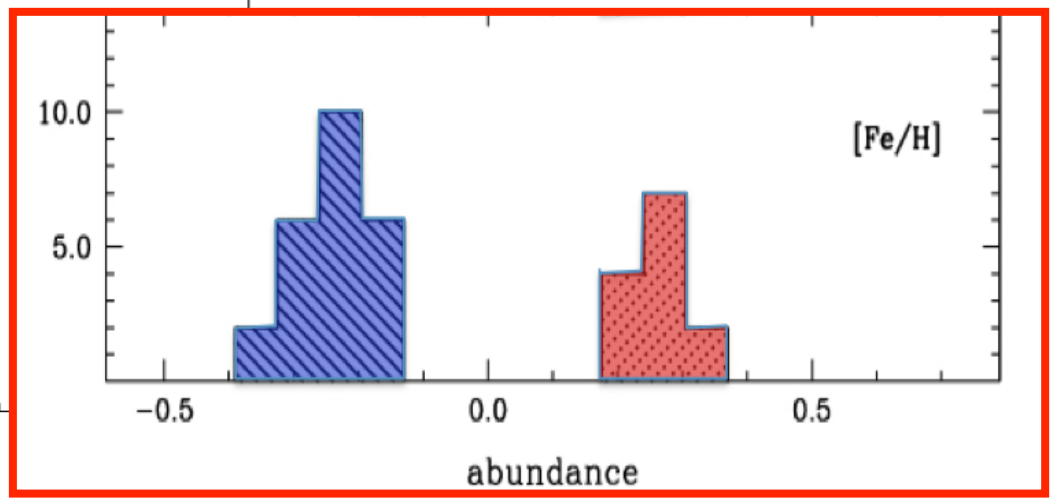
Red HB: <RV> = -85 km/s
[Fe/H] = +0.3



Spectroscopic survey: NIRSPEC – II (33 RGB stars)

Origlia+11



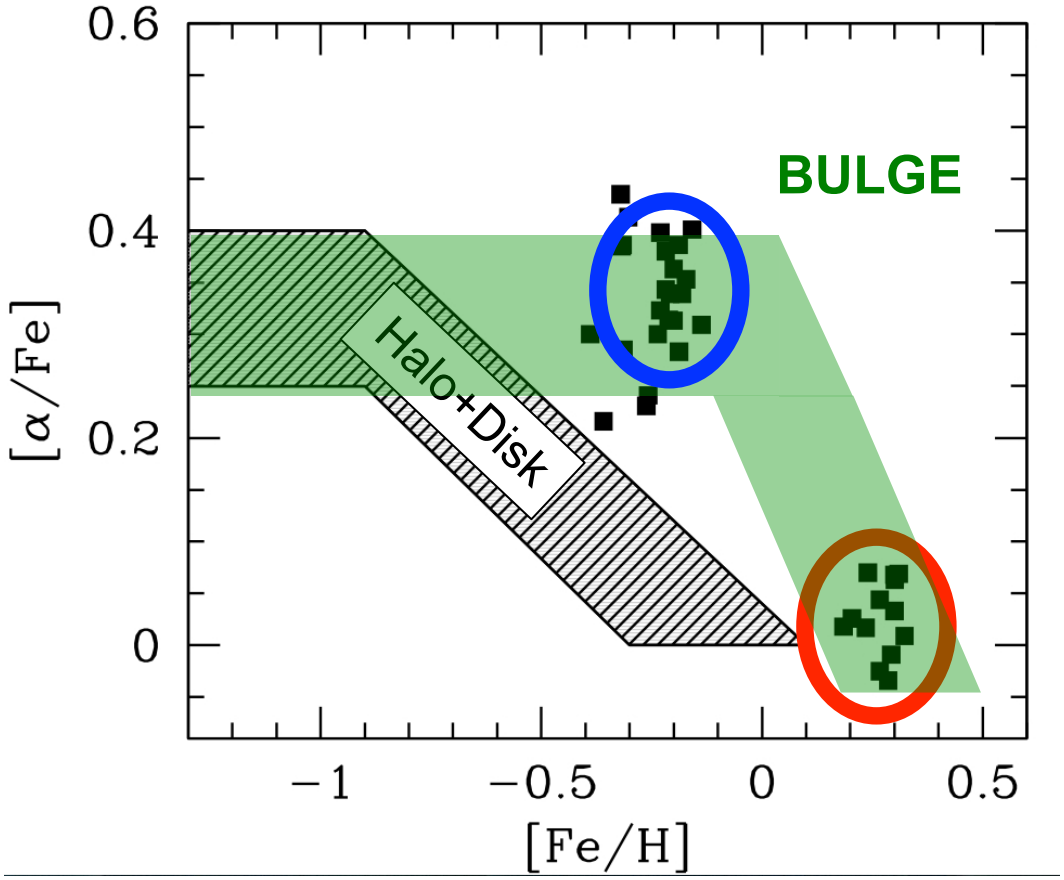


<[Fe/H]>=-0.25±0.07

<[Fe/H]>=+0.27±0.04

Spectroscopic survey: NIRSPEC – II (33 RGB stars)

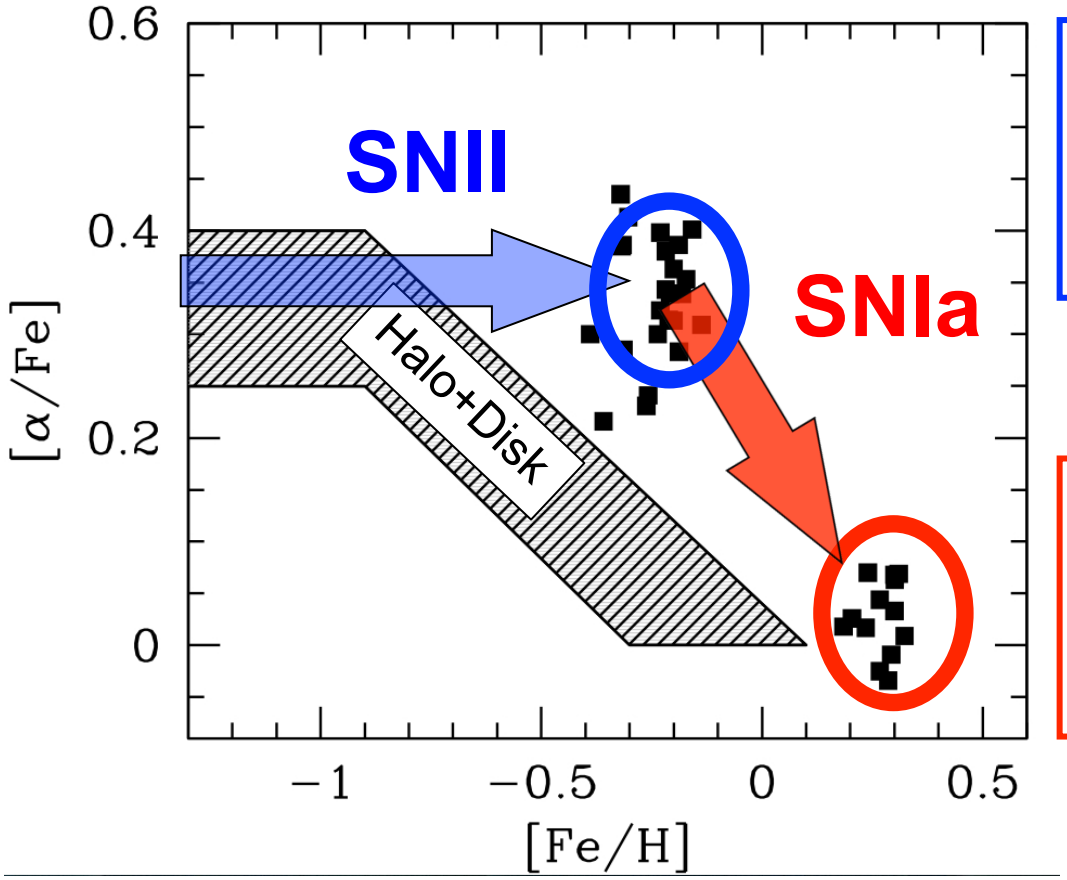
(1) metal-poor + α–enh
(2) metal-rich + α–solar



Halo + disk ?

Bulge ?

Spectroscopic survey: NIRSPEC – II (33 RGB stars)

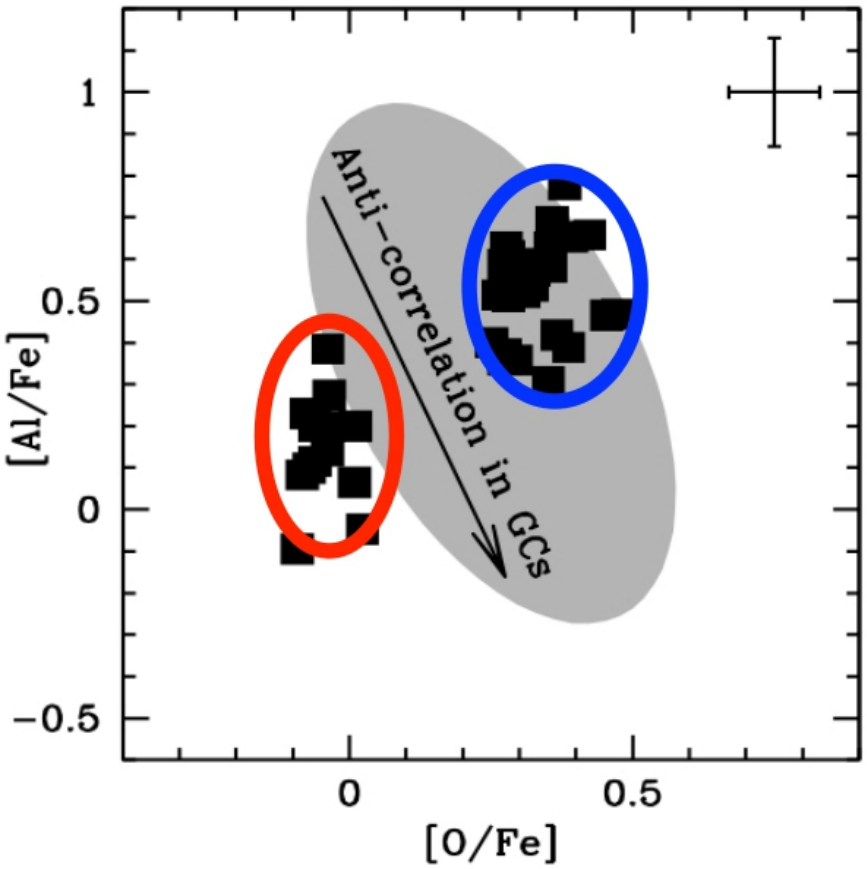


"metal-poor" component : it formed from a gas which was polluted by Type II SNe ejecta

"metal-rich" component : it formed from a gas which was (mainly) polluted by Type Ia SNe ejecta

Spectroscopic survey: NIRSPEC – II (33 RGB stars)

Origlia+11



No evidence for the anticorrelations typically observed in genuine GCs (O-Al but also Mg-Al)

Spectroscopic survey: FLAMES+DEIMOS

Main goal: the radial velocity dispersion profile (work in progress)
FLAMES@VLT spectra (HR21, R~16000)
DEIMOS@Keck spectra (R~6000)

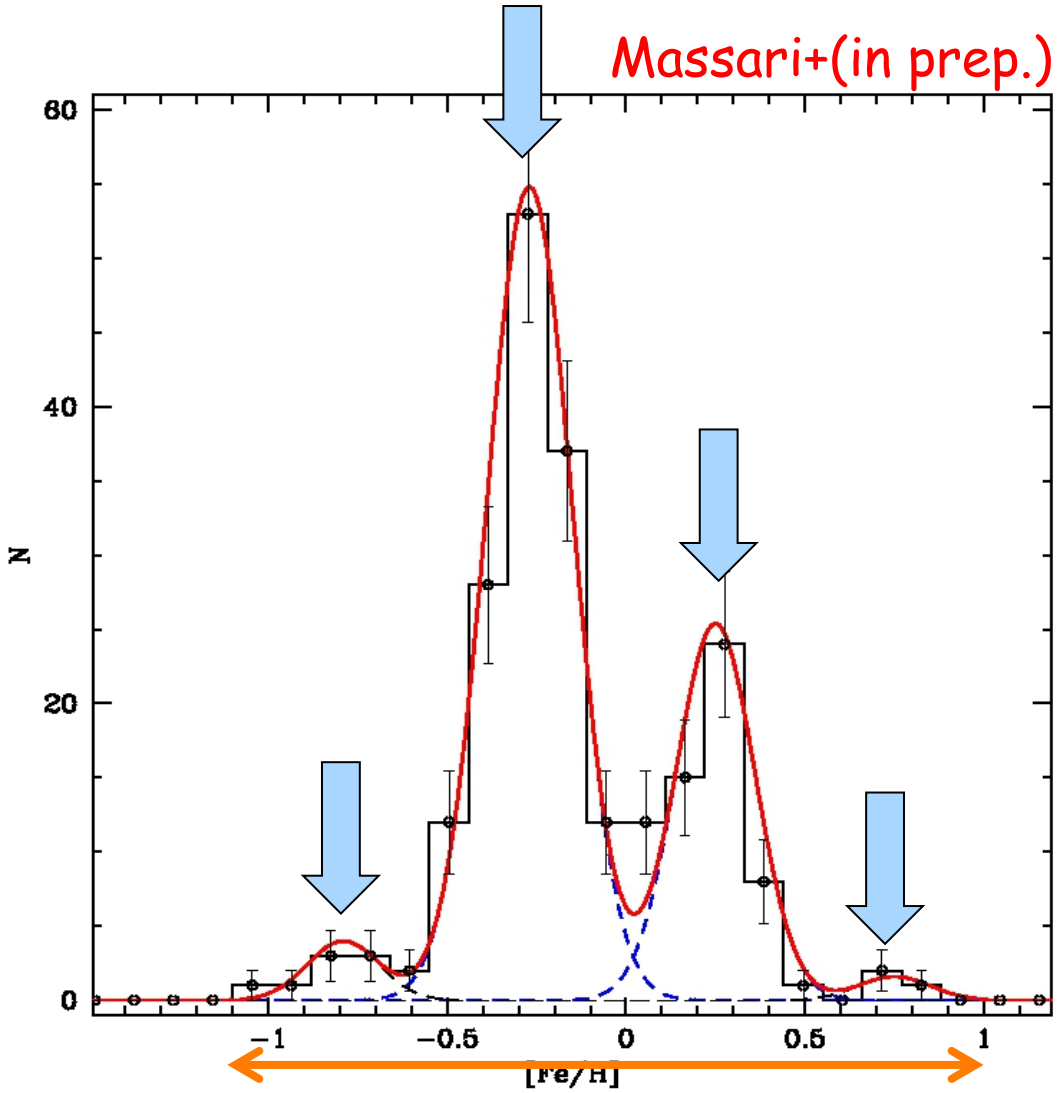
Fe determination for a sub-sample of stars

- Within the tidal radius (R=4.6')
- Radial velocities
- No TiO molecular bands

182 RGB stars

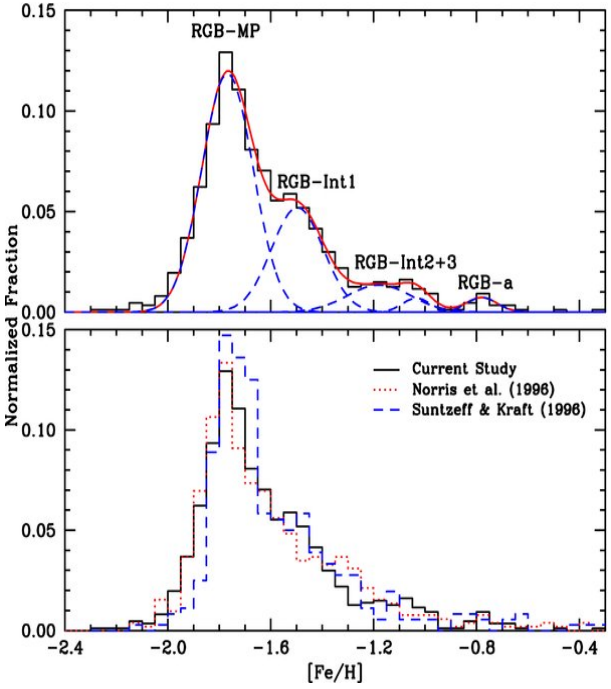
Metallicity distribution (215 stars)

Massari+(in prep.)

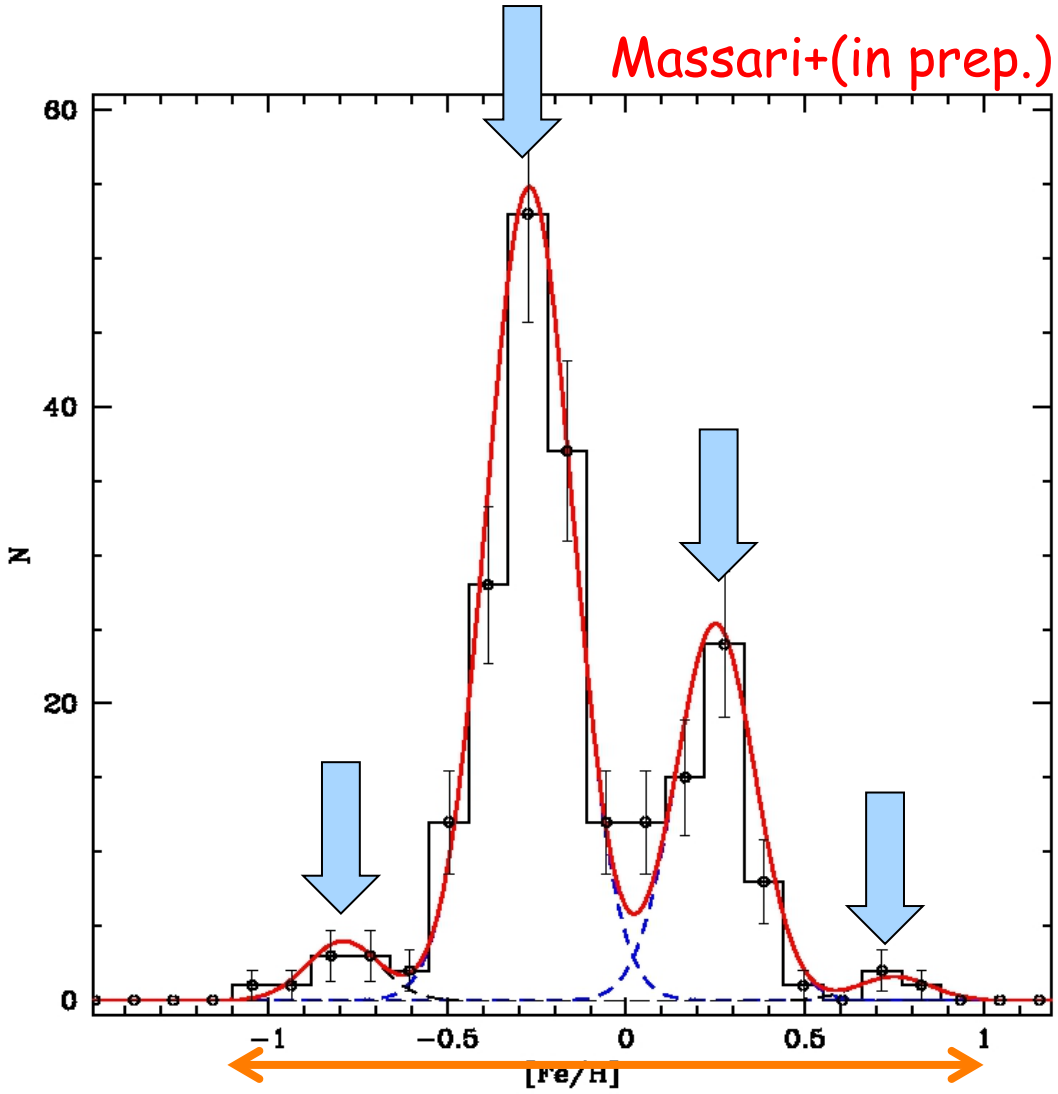


OMEGA CENTAURI

Johnson & Pilachowski (2009)



Metallicity distribution (215 stars)



Terzan 5 has been able to retain the SN ejecta
(at variance with the *genuine GCs*)

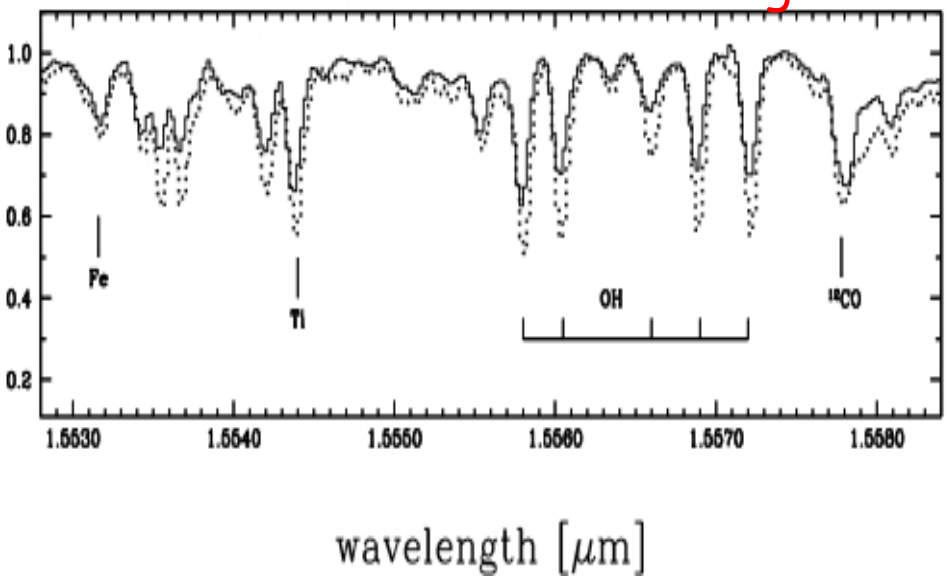
Terzan 5 was more massive in the past than today ($M \sim 10^6\ M_{SUN}$)

Spectroscopic survey: NIRSPEC – III (3 RGB stars)

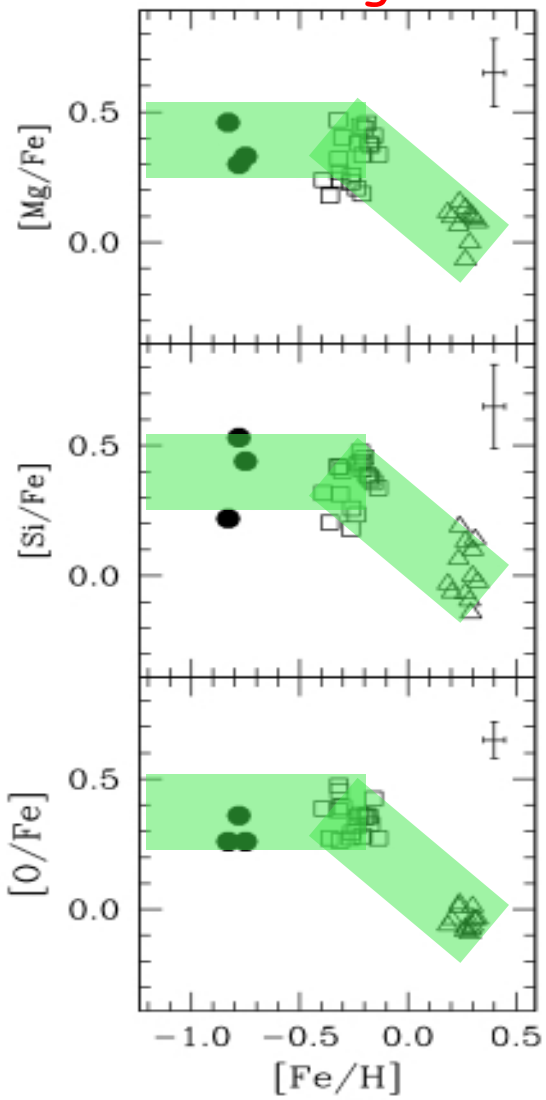
[Fe/H]=-0.79±0.04

[α/Fe]=0.36±0.04

Origlia+13

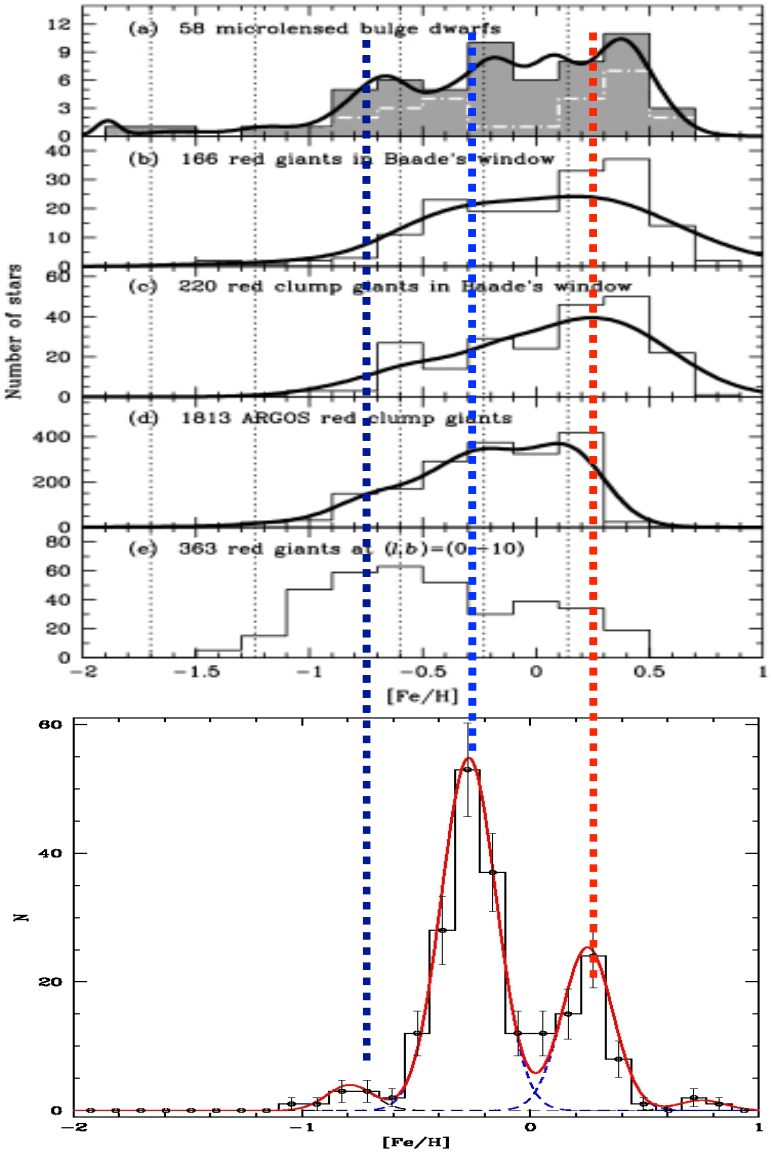


Origlia+13



A third, "very" metal-poor component

Terzan 5 vs. Bulge



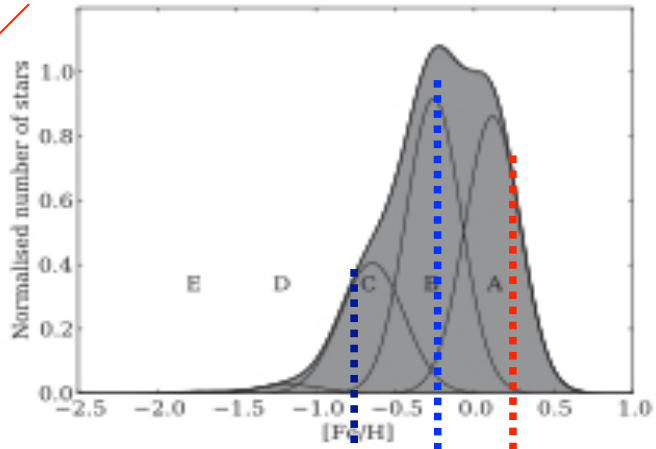
Bensby+2013

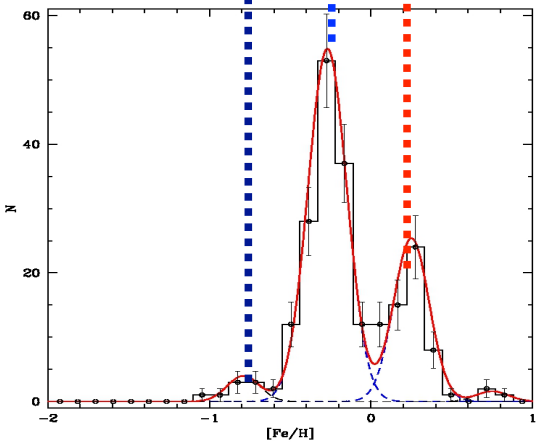
Hill+2011 - Giants

Hill+2011 - RC

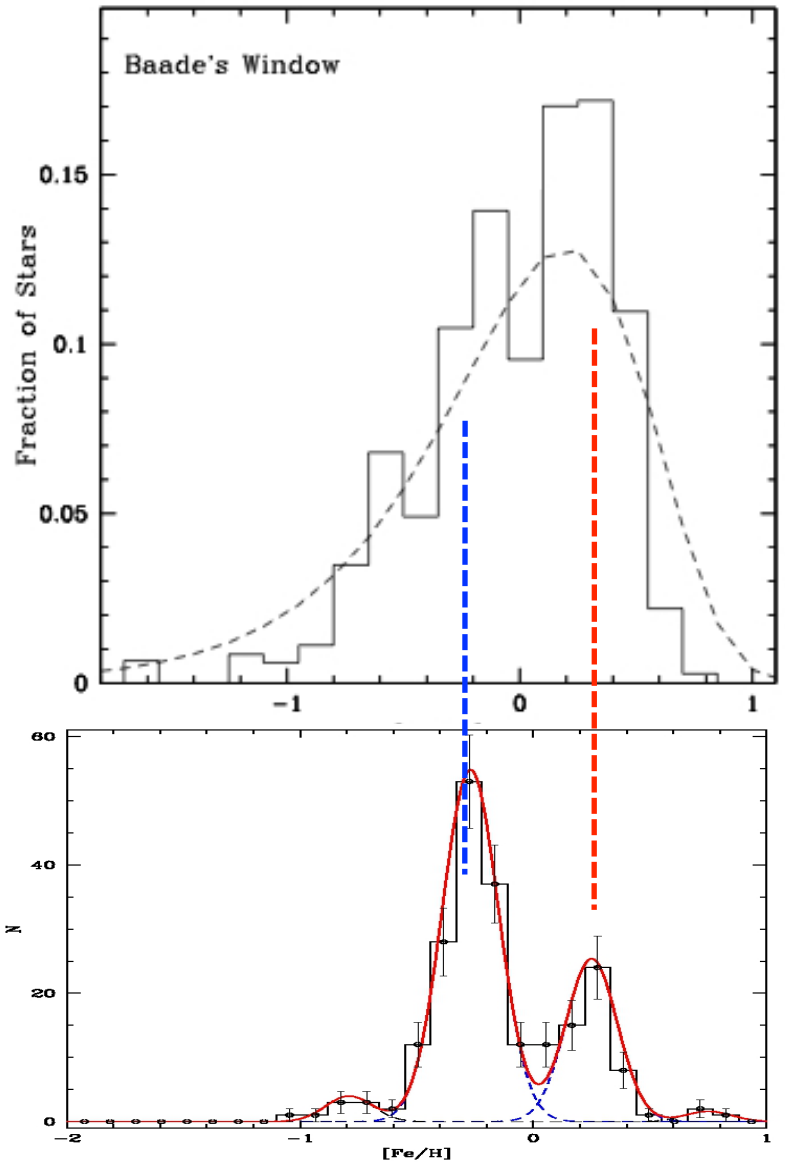
Ness+2013

Uttenthaler+2012





Zoccali+08



800 Bulge K giants
(Baade's Window)

Tight link between Terzan 5 and the Bulge

Summary …

- Two HBs
- Large [Fe/H] distribution
- Multi-modal [Fe/H] distribution
- Differences in the [α/Fe] ratio
- No hints of O-Al anticorrelations

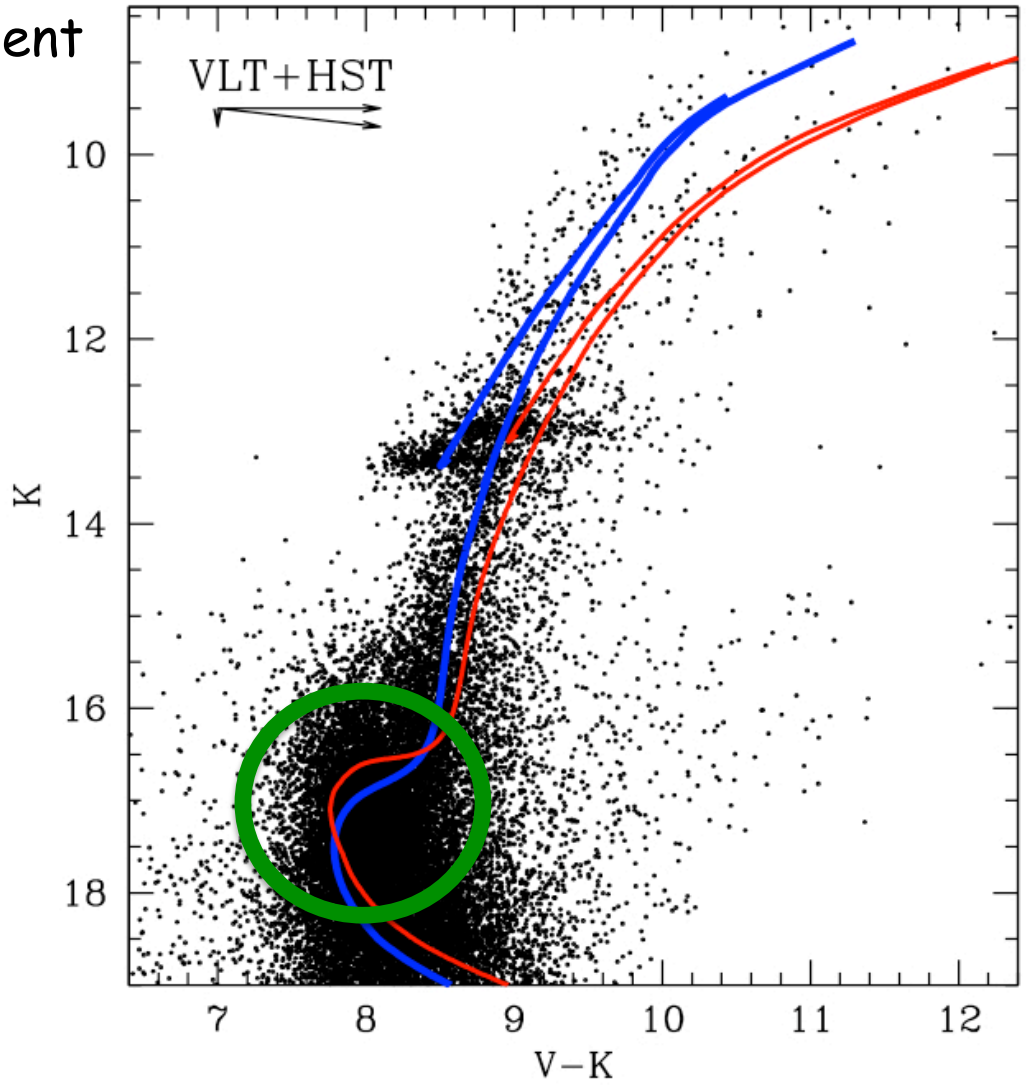
Terzan 5 is **NOT** a genuine GC

- Chemical similarities with the Bulge

The second (metal-rich) component could be younger than the metal-poor one

Z=0.01 t=12 Gyr

Z=0.03 t=6 Gyr (?)



Interpreting Terzan 5 …

(1) Terzan 5 was possibly **much more massive** in the past than today ($M \sim 10^6 M_{SUN}$) in order to retain the SN ejecta

(2) Terzan 5 could be the remnant of one giant primordial clumps that contributed to form the Galactic Bulge (Immeli+04, Elmegreen+08)

(3) The **metal-poor**, old component could trace the early stages of the Bulge formation

(4) The **metal-rich** (younger ?) component could contain crucial information on the most recent Bulge chemical evolution

Ongoing projects

1. **Measuring the ages of the two populations from the MS-TO.**
   Ultra-deep IR observations with WFC3-IR channel

2. **Investigating the radial velocity dispersion profile**
   ~1000 FLAMES/DEIMOS/NIRSPEC/XSHOOTER spectra

3. **Performing proper motion measures to search for kinematical signatures (second epoch with ACS)**

4. **Searching for other Terzan5-like systems in the Galactic Bulge**

Visit our web-site: **www.cosmic-lab.eu**

The End