Terzan 5: a pristine fragment of the Galactic bulge?

DAVIDE MASSARI

Dipartimento di Fisica e Astronomia – Università di Bologna

Supervisors and collaborators:

Francesco R. Ferraro, Barbara Lanzoni, Emanuele Dalessandro,
Alessio Mucciarelli, Livia Origlia

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

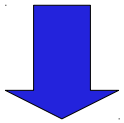
Blue Straggler Stars
Millisecond Pulsars
Intermediate-mass Black Holes

} as probe-particles

General context: formation of galaxy bulges

Still disputed topic, several models:

- monolithic collapse (e.g. Eggen+62)
- evolution of bars (e.g. Combes & Sanders 1981)
- mergers (e.g. Toomre & Toomre 1972)
- disk instability (e.g. Immeli+04, Elmegreen+08)

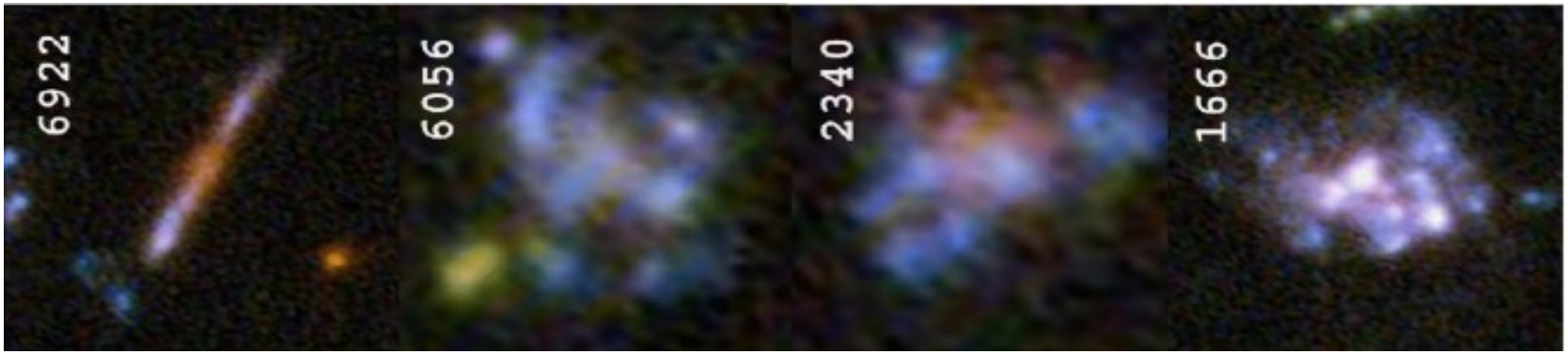


Instability of a GAS disk:

- the disk could fragment in **massive clumps** of gas and stars
- they spiral to the center and merge forming a bulge
- mergers (e.g. Toomre & Toomre 1972)
- high **SFR** in the clumps and the bulge ---> fast iron and α-elements enrichment

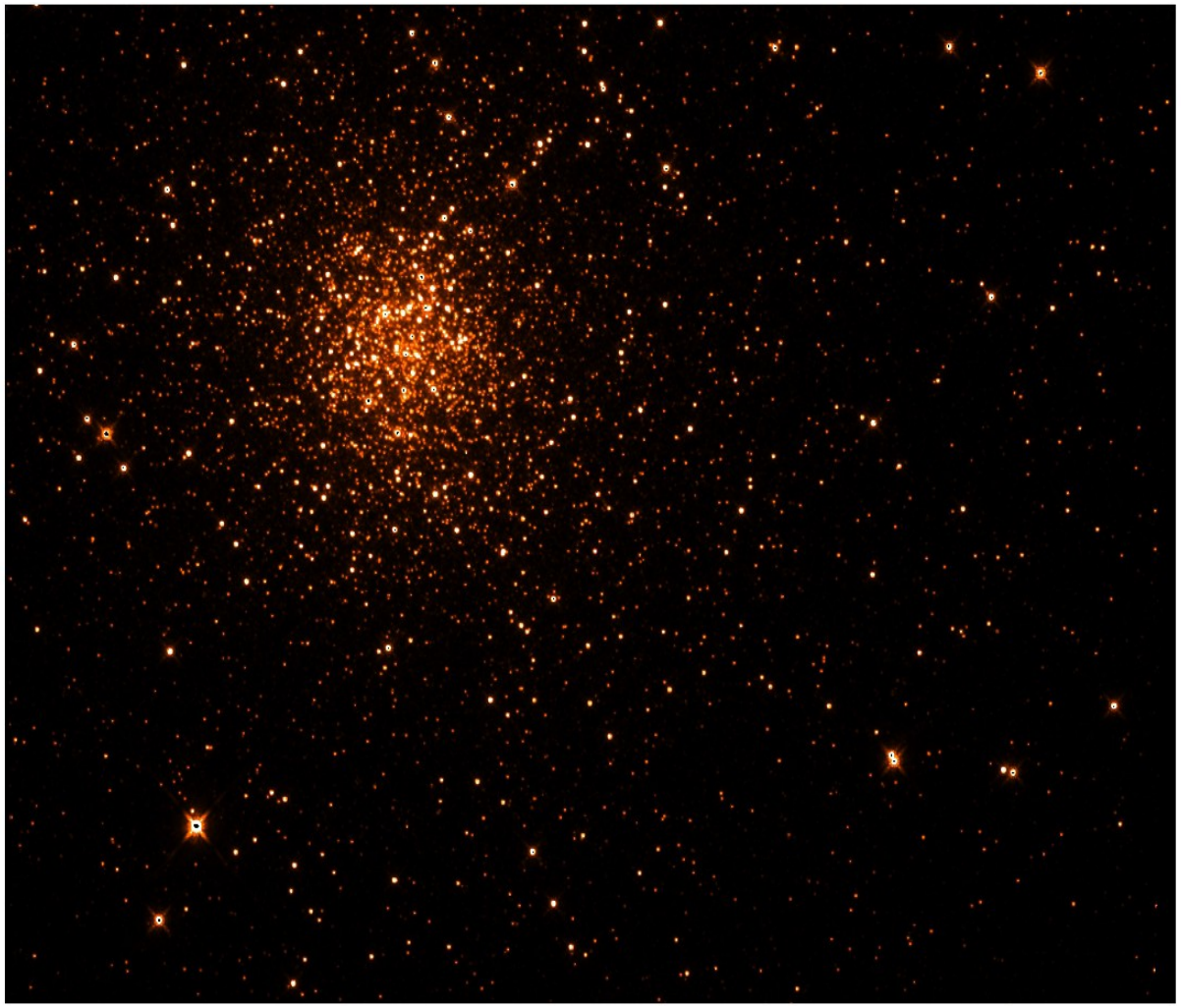
General context: formation of galaxy bulges

Possible observational evidence: chain and clumpy galaxies
(Cowie+95, Elmegreen+05,09)

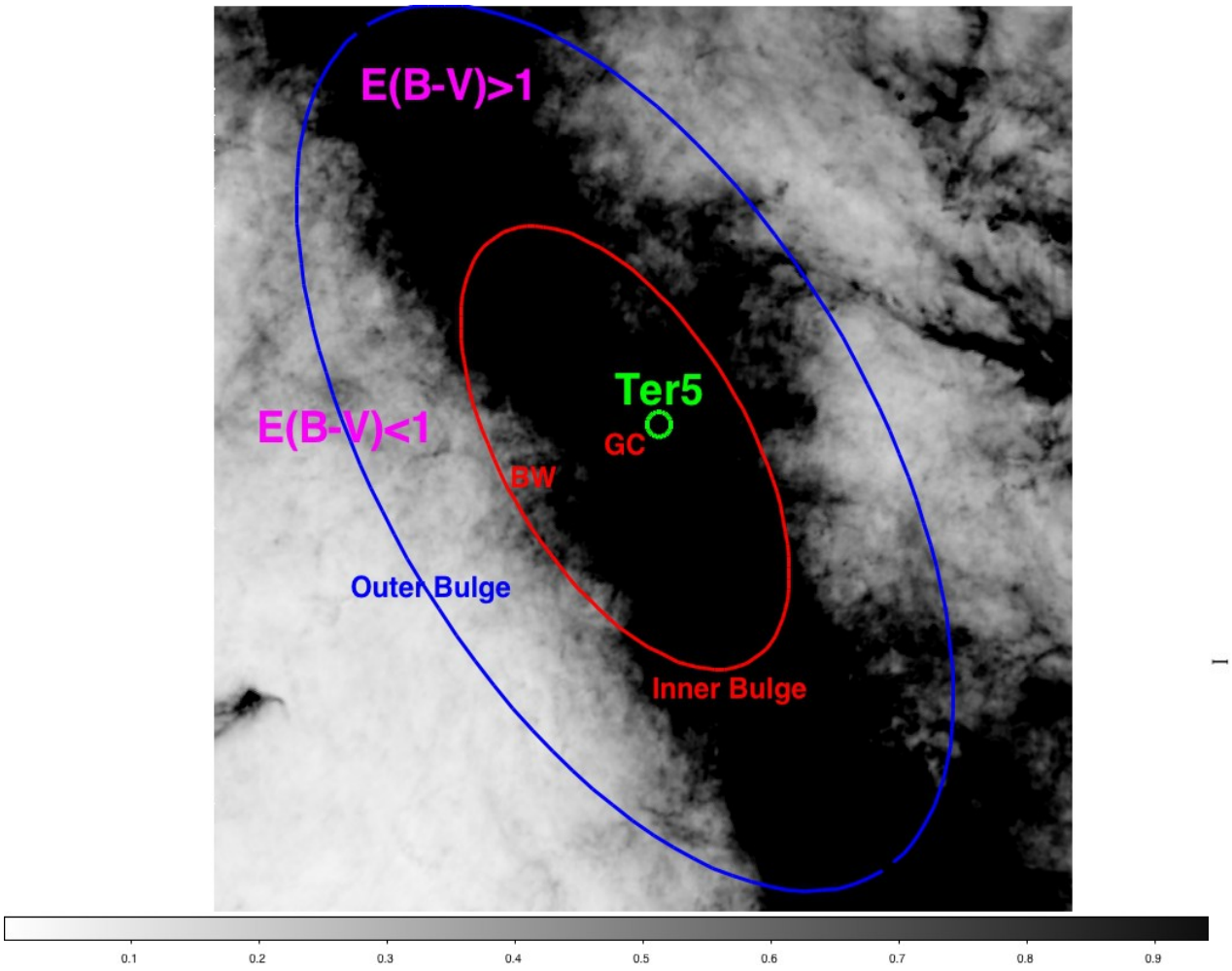


The best constraints from the Galactic bulge

Terzan 5



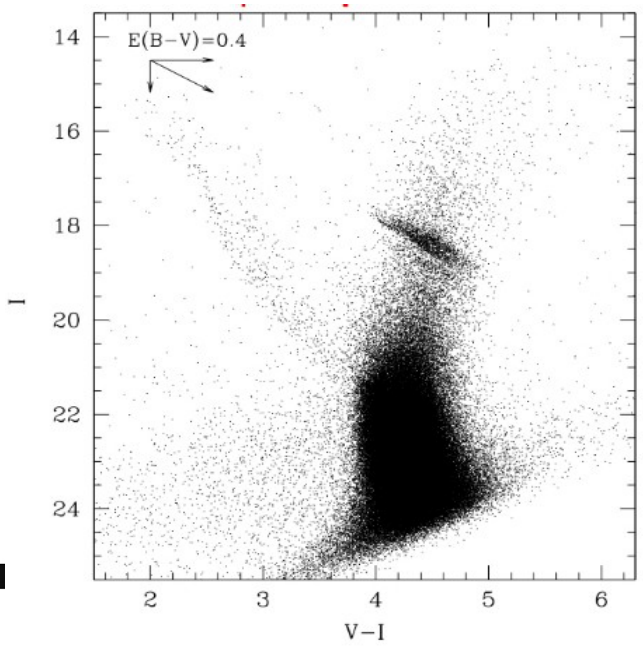
Terzan 5



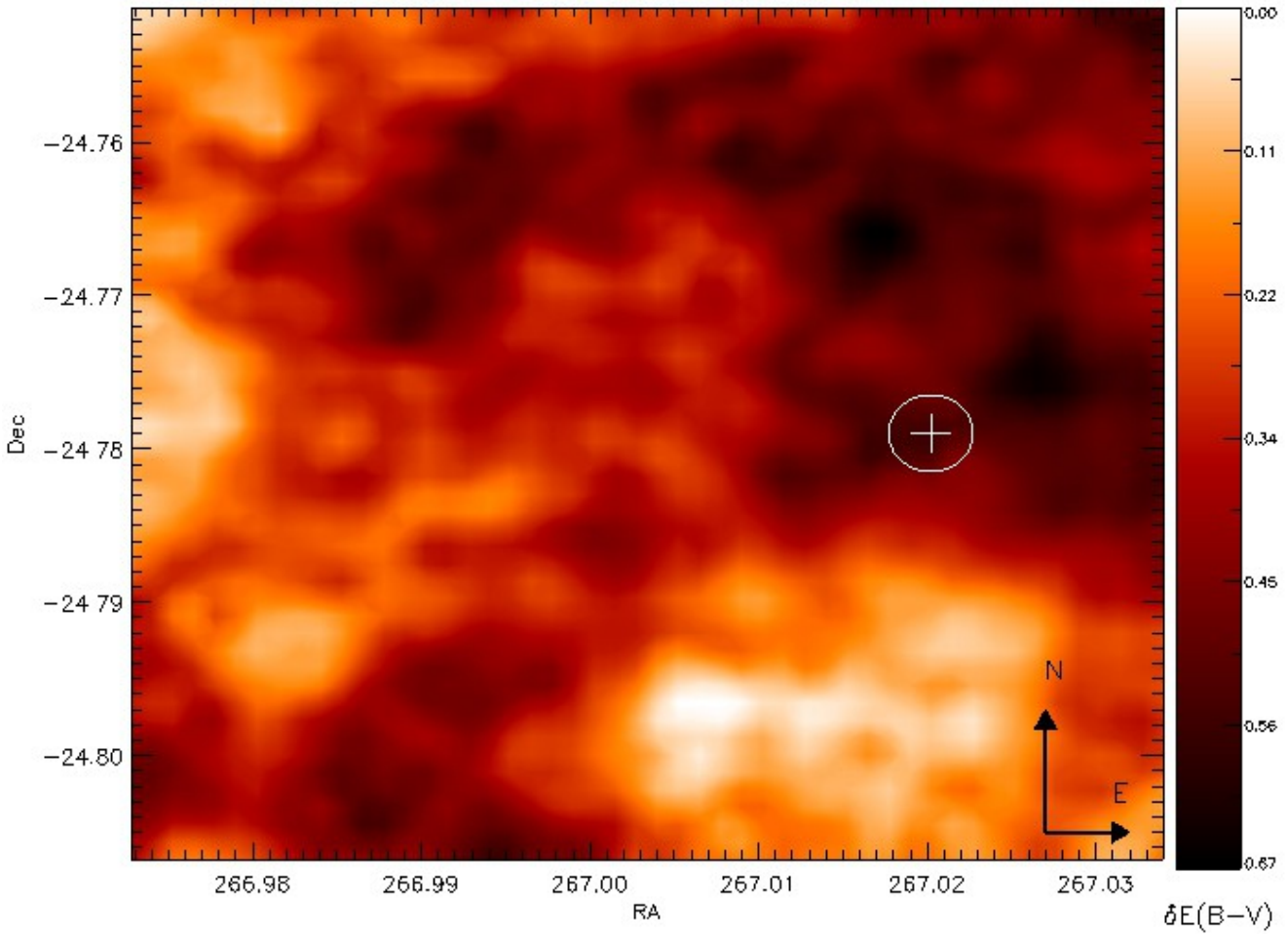
- Located in the inner bulge (d=6 kpc, d_{GC}=2.1 kpc)

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

- Strong differential reddening



Differential reddening map

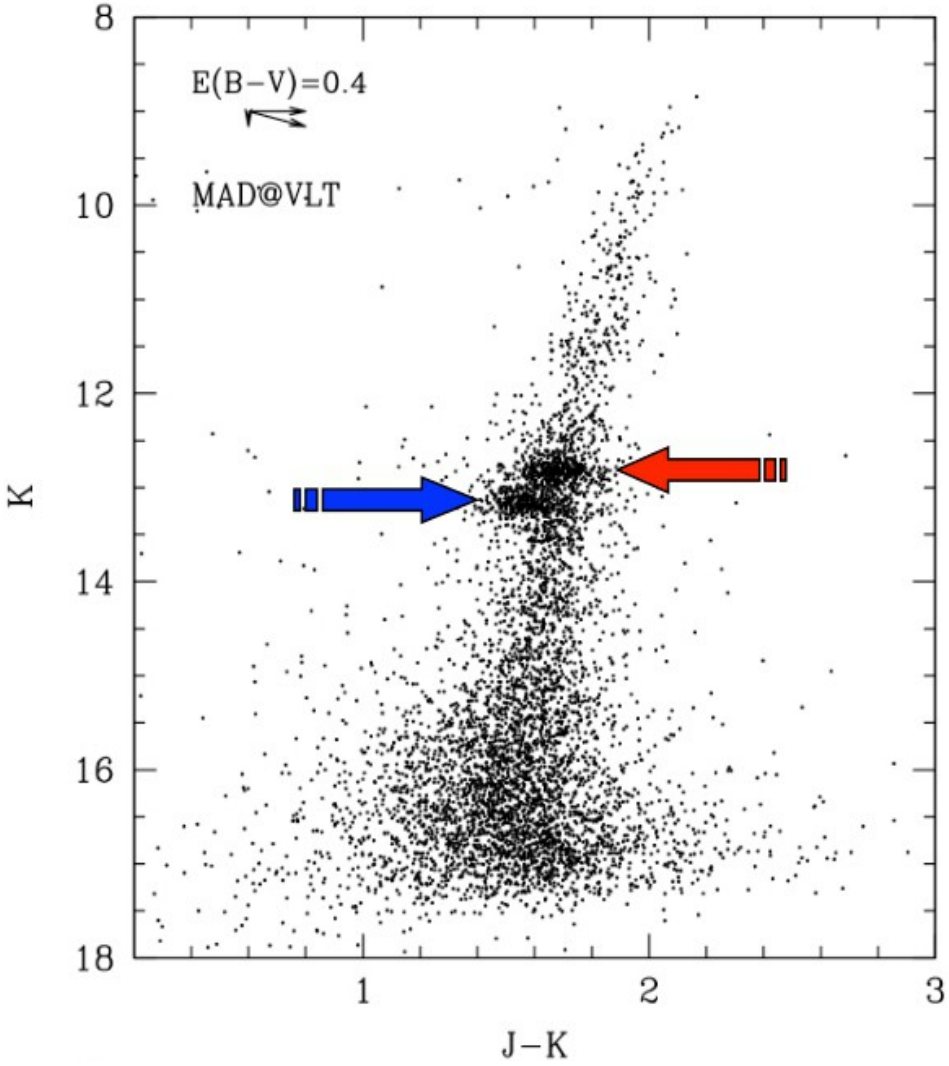


E(B-V)=2.15-2.82

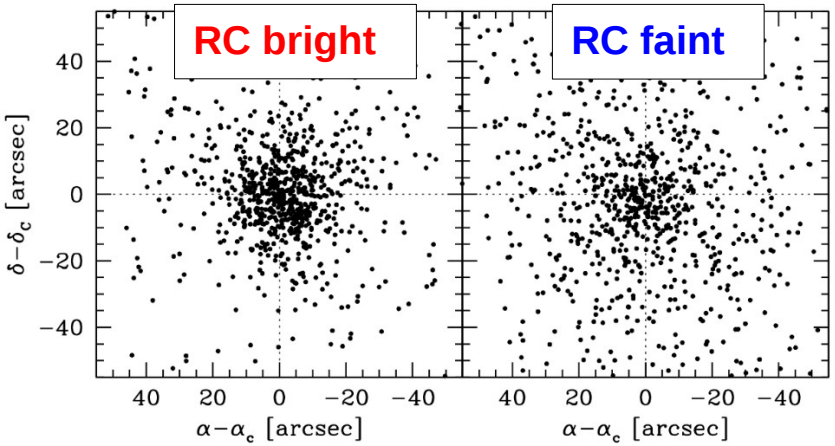
δ[E(B-V)]=0.7

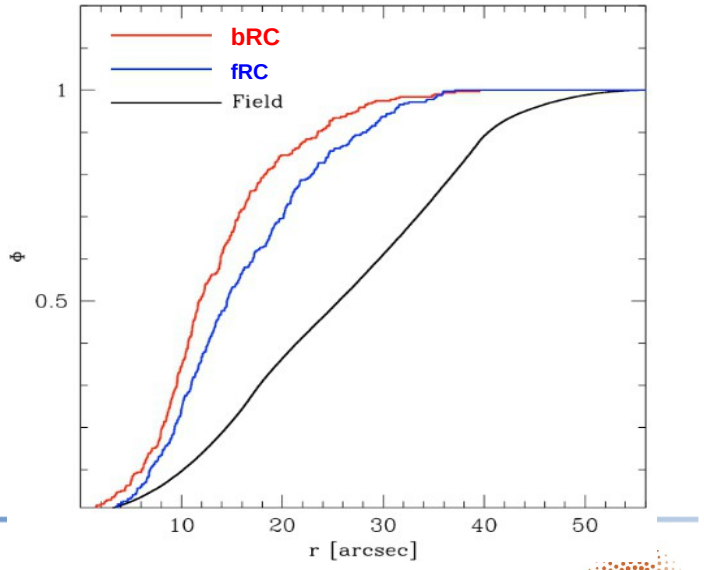
Massari et al. 2012, ApJL, 755, L32

IR observations with MAD@VLT



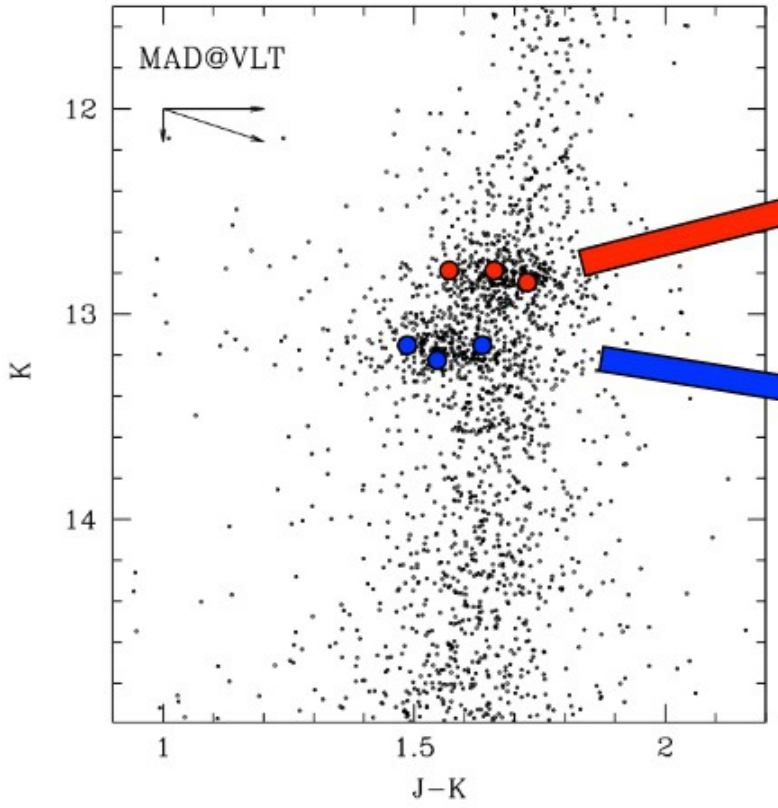
Two RCs in the IR CMD
(Ferraro et al. 2009, Nature, 462,483)





First spectroscopic follow-up

6 targets observed with NIRSPEC@Keck II



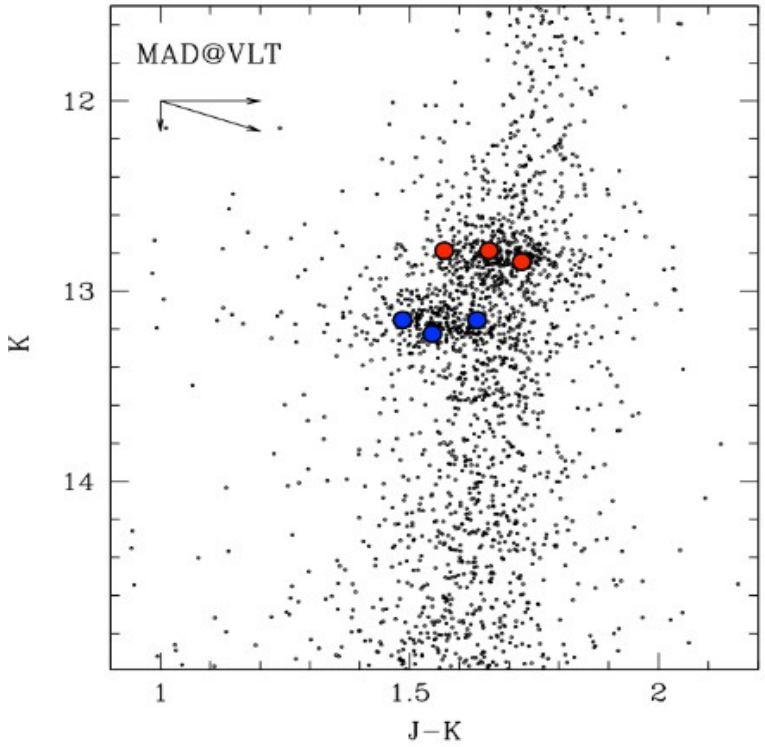
V_{rad} = -85 Km/s (σ=10 Km/s)

V_{rad} = -85 Km/s (σ=9 Km/s)

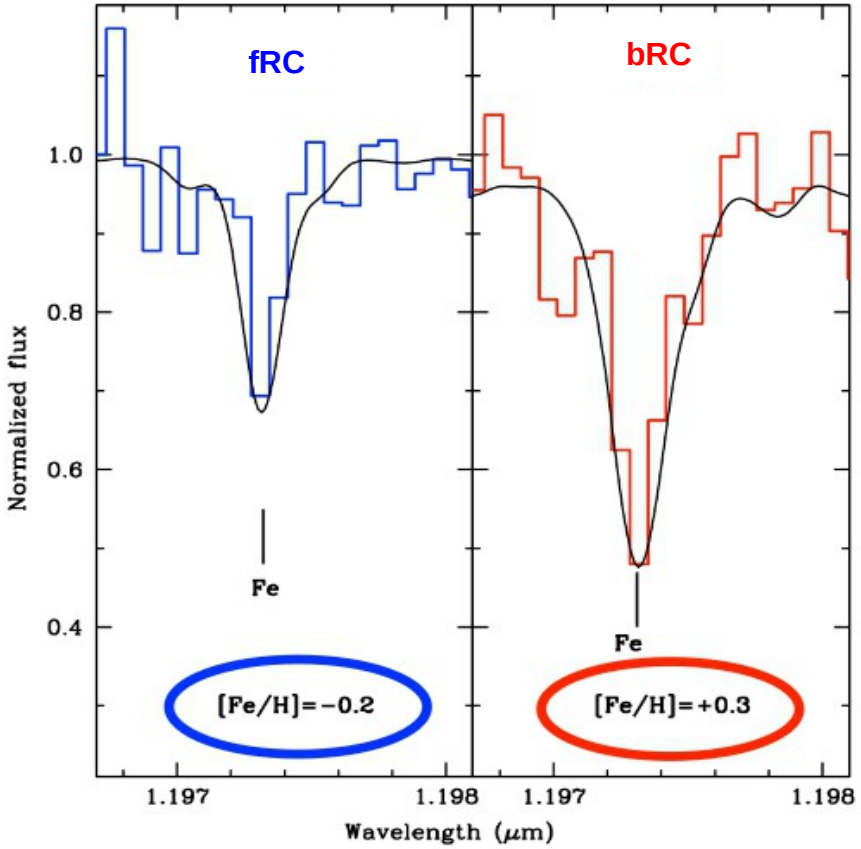
The two populations belong to the same stellar system

First spectroscopic follow-up

6 targets observed with NIRSPEC@Keck II



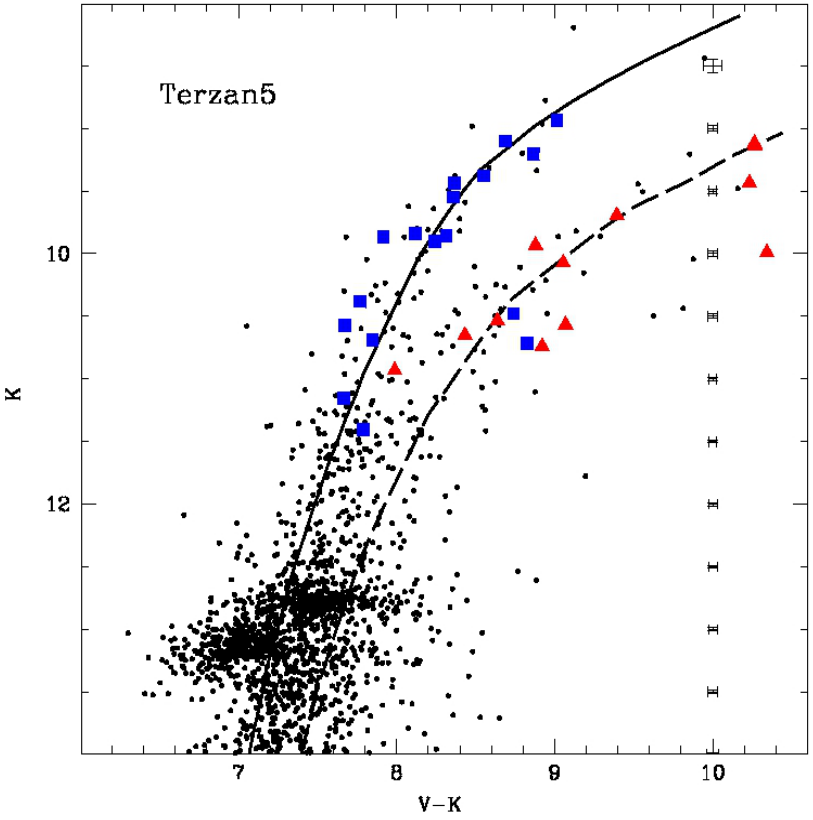
(Ferraro+09, Nat. 462, 483)



Δ[Fe/H]=0.5 dex

Spectroscopic screening

33 targets observed with NIRSPEC@Keck II (Origlia et al.2011)



- Metal-rich component more centrally concentrated than the metal-poor one: strong hint of SELF-ENRICHMENT

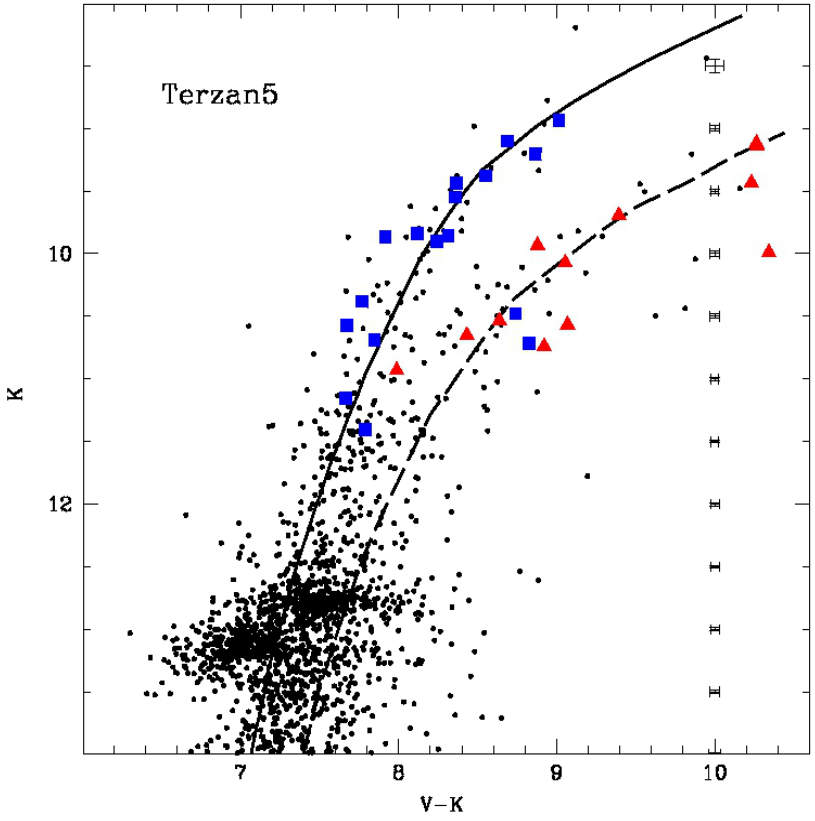
- Initial mass of Terzan 5 much larger than the current one!

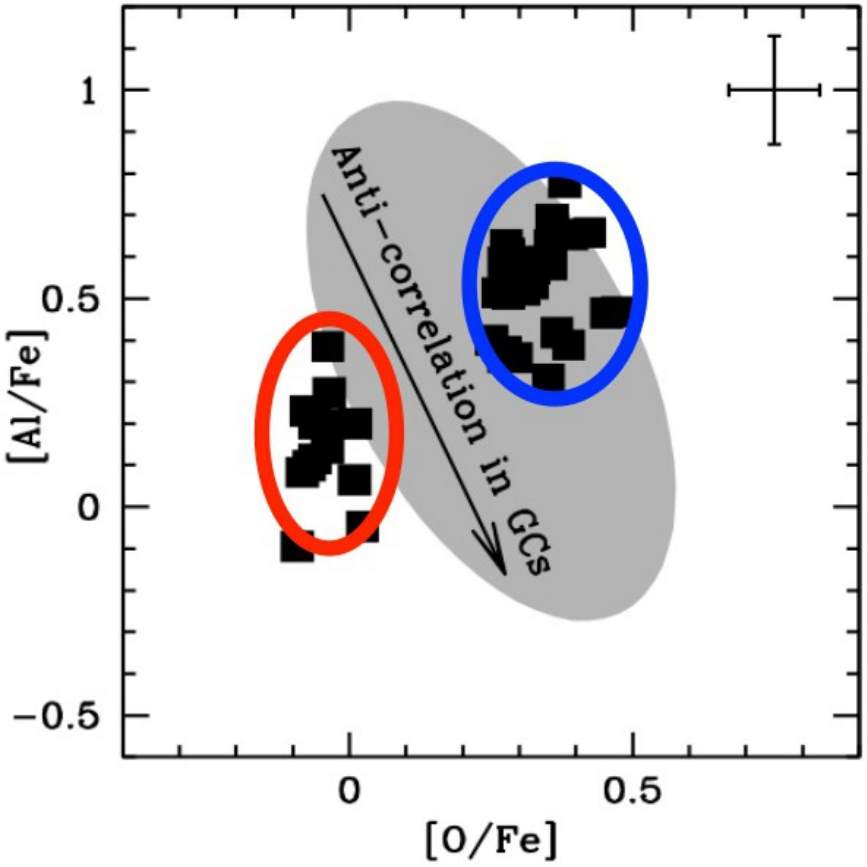
[Fe/H]=-0.25±0.07

[Fe/H]=+0.27±0.04

Spectroscopic screening

33 targets observed with NIRSPEC@Keck II (Origlia et al.2011)





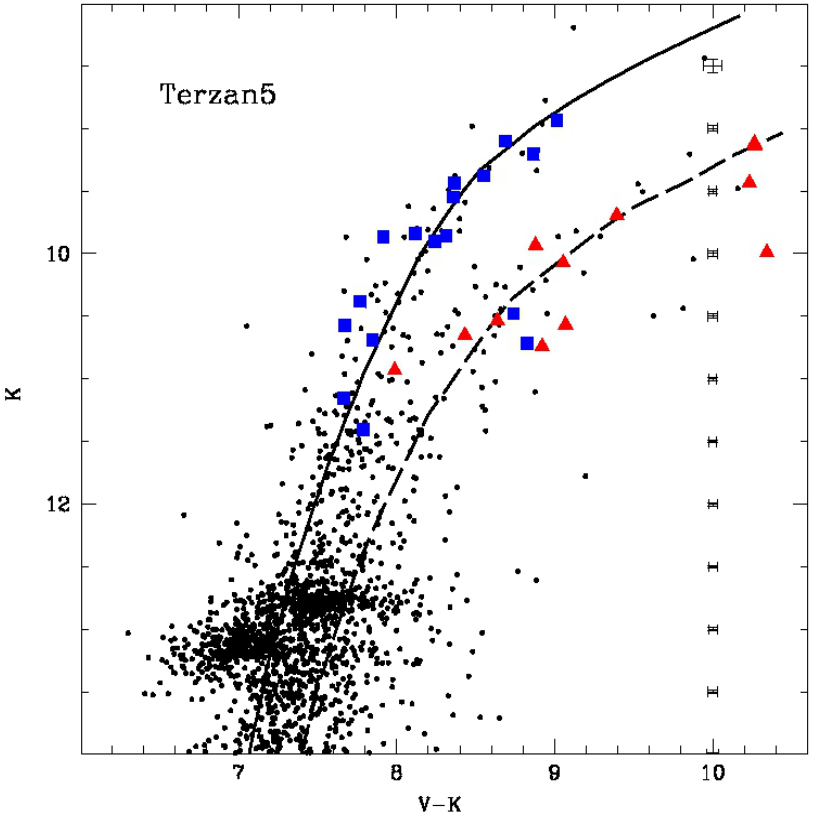
[Fe/H]=-0.25±0.07
[Fe/H]=+0.27±0.04

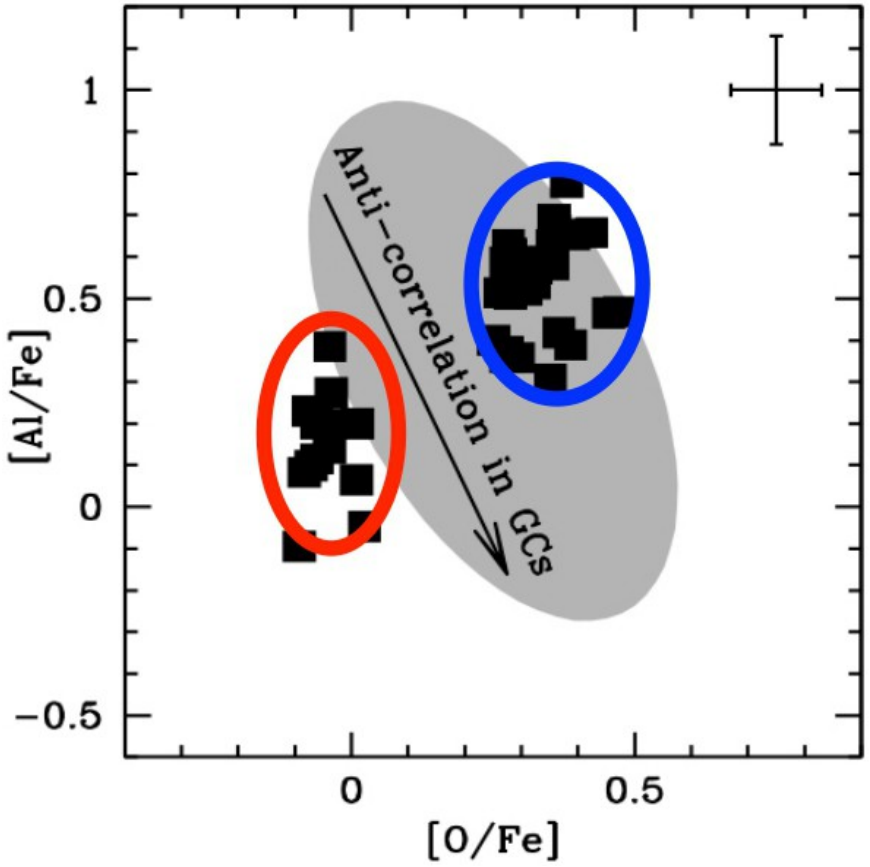
+

No evidence of the anticorrelations typically observed in genuine GCs

Spectroscopic screening

33 targets observed with NIRSPEC@Keck II (Origlia et al.2011)

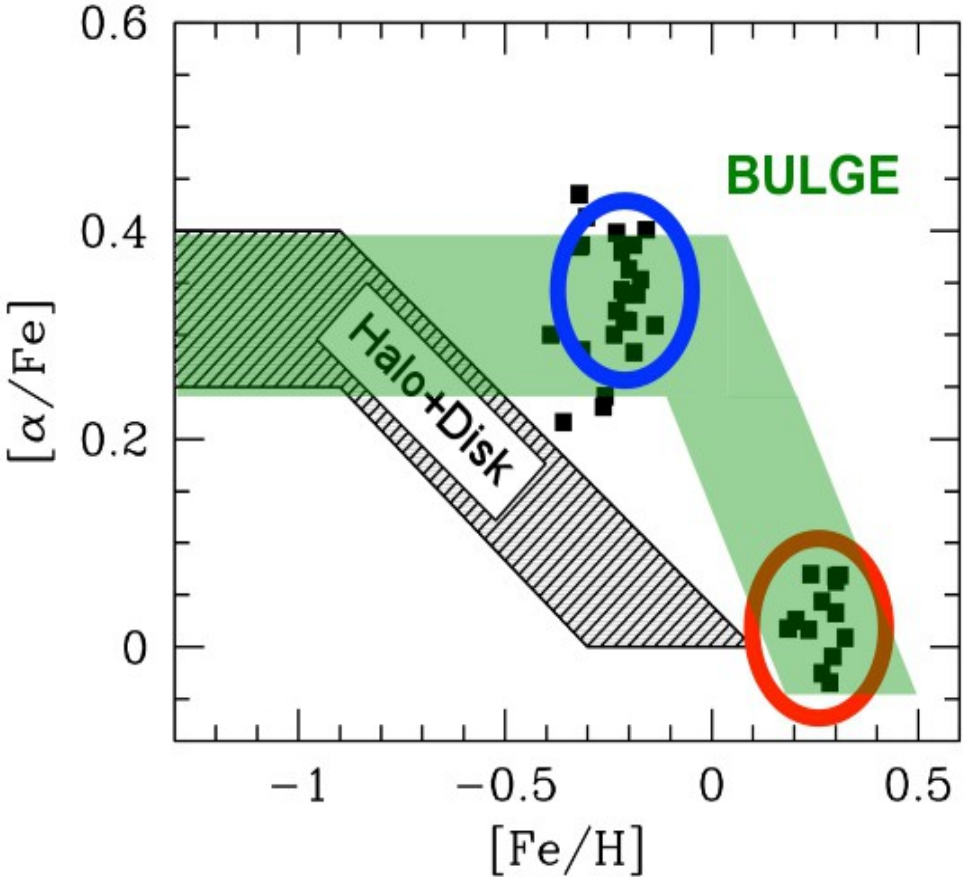




NO GENUINE GC!

Spectroscopic screening

α-elements



[Fe/H]=-0.25±0.07 [α/Fe]=0.34±0.06
[Fe/H]=+0.27±0.04 [α/Fe]=0.03±0.04

- Chemistry completely different from that observed in the Halo and in the Disk

- Striking similarity with the chemistry observed for Bulge stars!

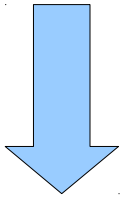
The true nature of Terzan 5

- Not a genuine GC

- Large initial mass to retain the gas enriched by Sne

- Located in the inner Bulge

- Ter5 and the Bulge share similar chemical evolutionary histories

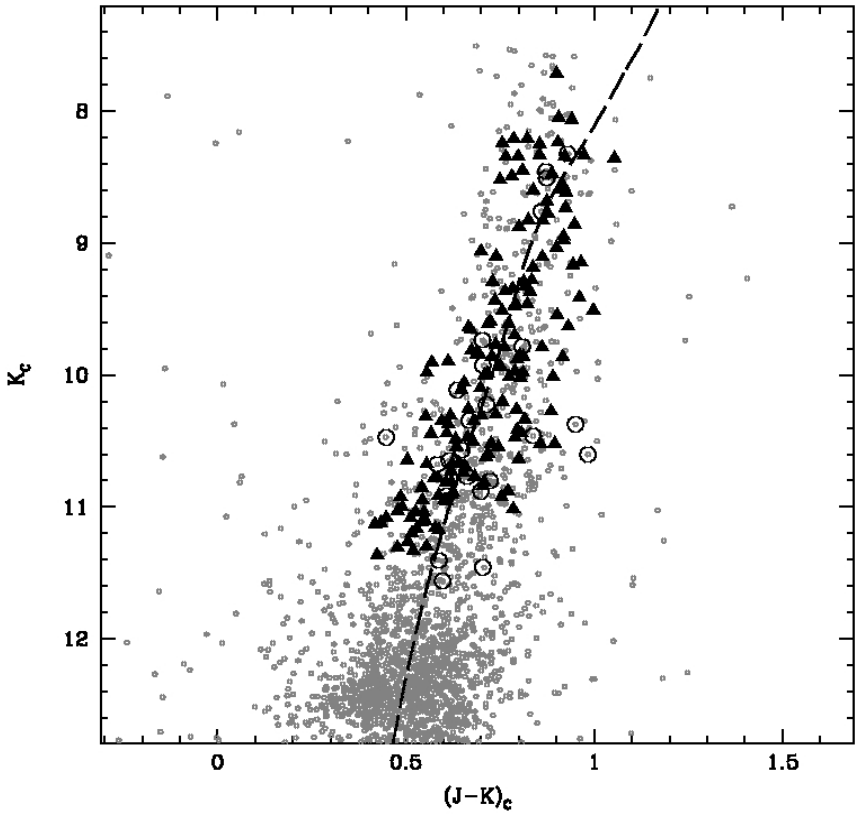


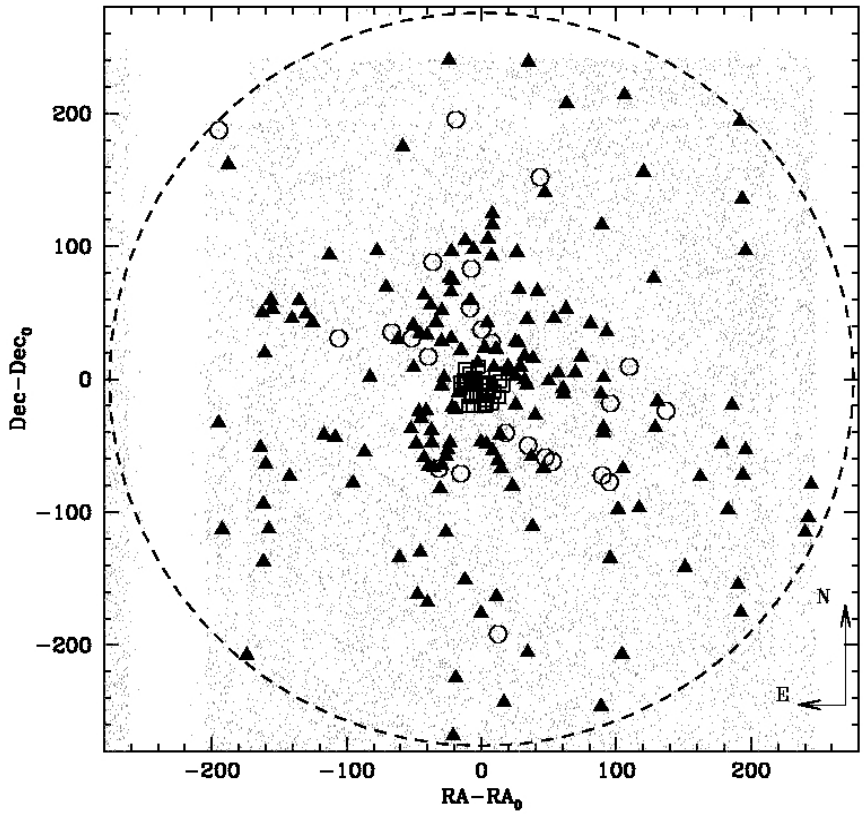
Could it be the relic of one of the Bulge pristine fragments?

First task: enlarging the sample

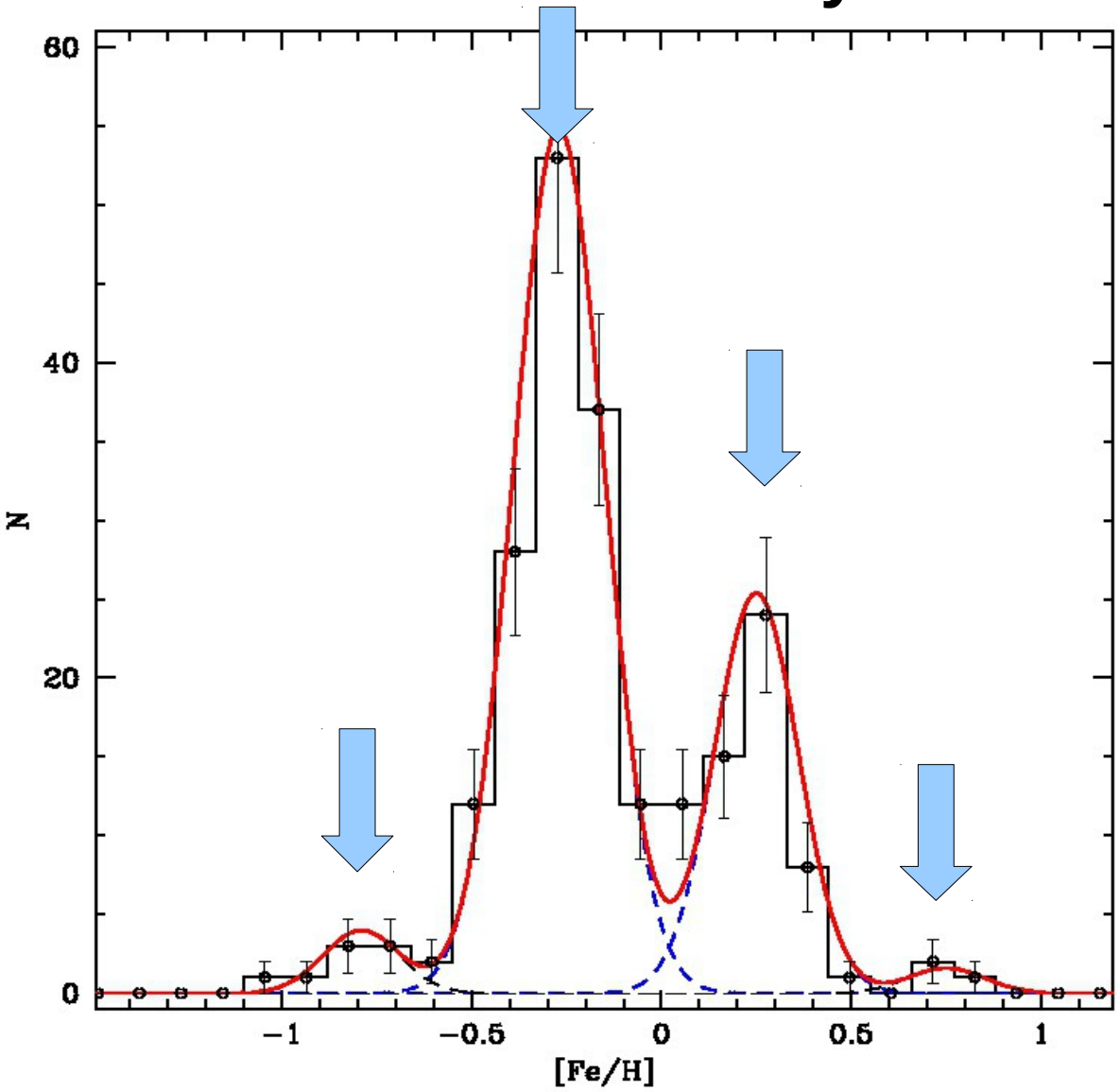
33 NIRSPEC + 158 FLAMES + 24 DEIMOS = 215 stars

Cluster members according to radial velocities





Metallicity distribution



Δ[Fe/H] > 1.5 dex

Multi-modal distribution (possibly 4 peaks)

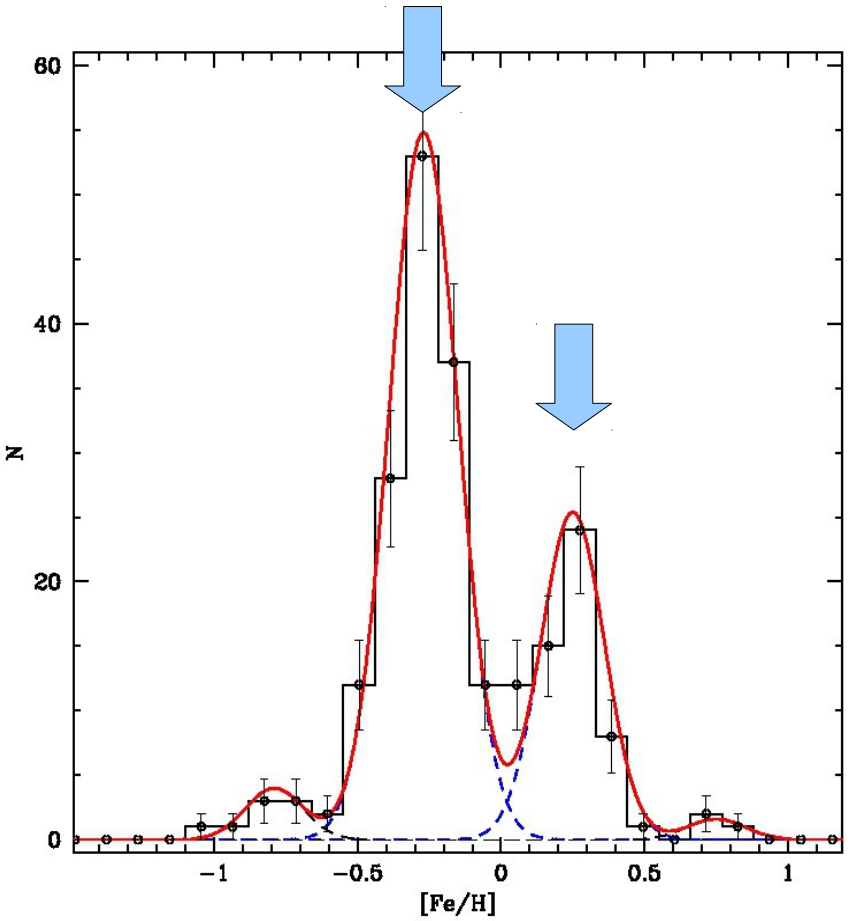
The two main peaks

- Dominant one at [Fe/H]∼-0.3
  Secondary at [Fe/H]∼+0.3

Confirm previous findings by Origlia+11

- Bimodality

Two main bursts of star formation,
possibly separated in age (few Gyr)

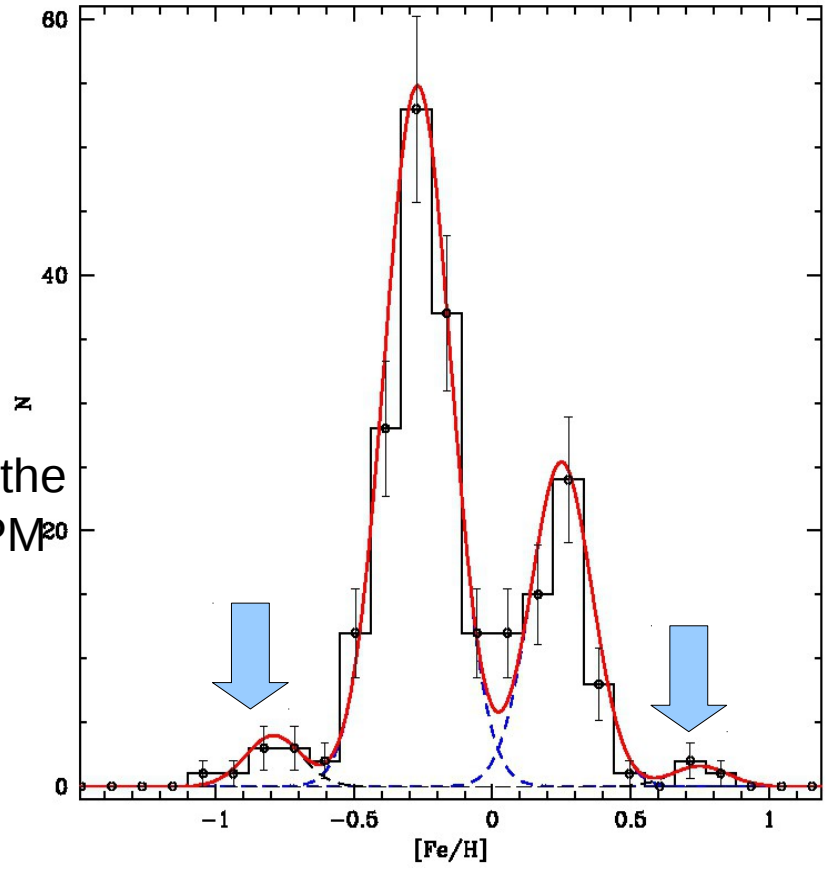


The two secondary peaks

- Metal-poor one at [Fe/H]∼-0.8
  Metal-rich at [Fe/H]∼+0.75

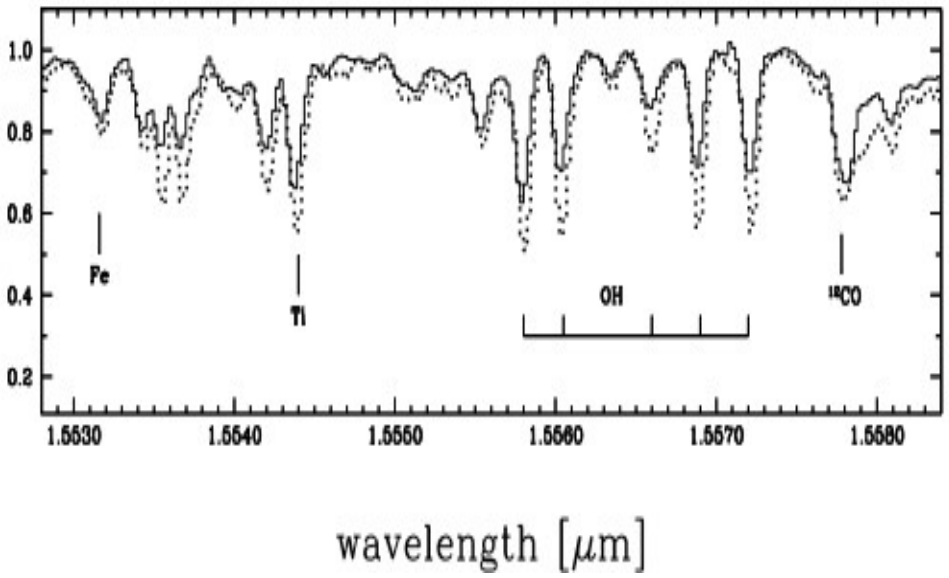
- Metal-rich peak composed by only 3 stars
  → a detailed follow-up is needed to better determine its nature

- Metal-poor peak composed by 6 stars i.e. 3% of the sample (5 members according to PMs, 1 out of PM catalog)
- Besancon model predicts 0.5% of contamination at these vrad and [Fe/H]--> good significance

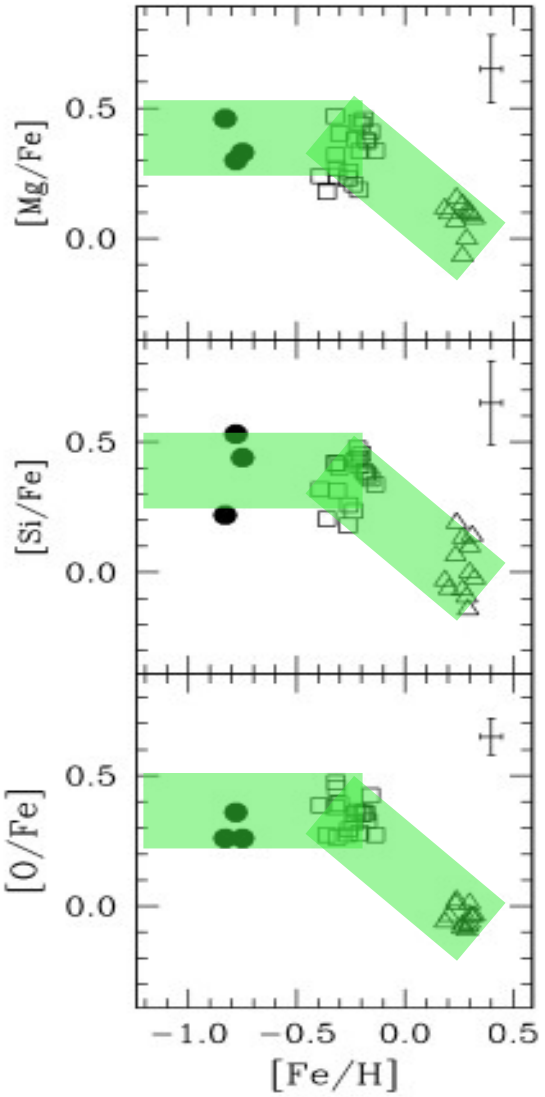


- Follow-up with NIRSPEC for 3 of these stars (Origlia et al., submitted)

Very metal poor (VMP) peak
(Origlia et al. submitted)



[Fe/H]=-0.79±0.04



[α/Fe]=0.36±0.04

Interestingly, a small (5%) VMP component has also been found in ω-Cen! (Pancino et al. 2010)

Terzan 5 vs. ω-Cen

Similarities

- Δ[Fe/H]>1.5 dex

- Multi-modal metallicity distributions

- Small (few %) VMP components: first born populations of the two systems?

Differences

- Higher metallicity regime: $[Fe/H]_{Ter5} >> [Fe/H]_{\omega\text{-}Cen}$

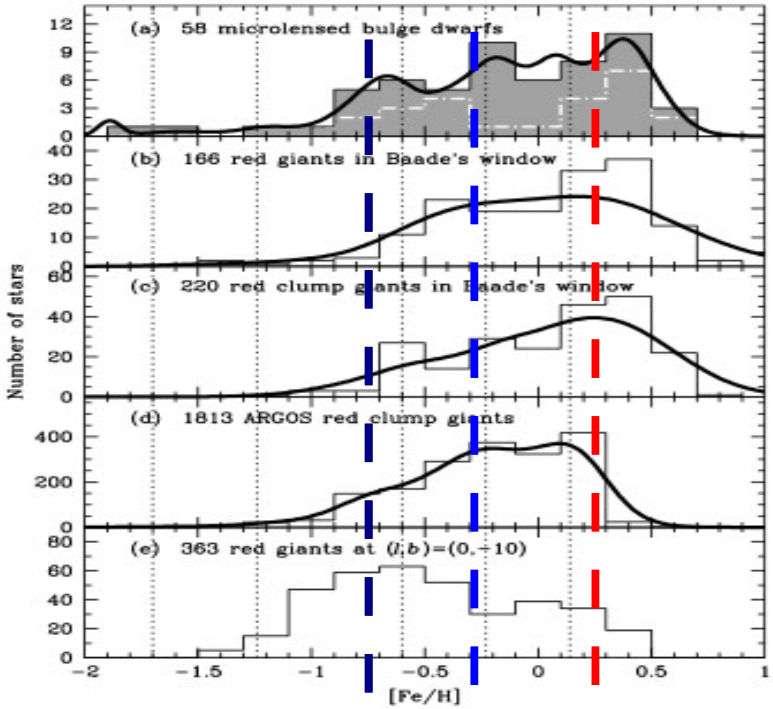
- Initial masses: $M_{i,Ter5} >> M_{i,\omega\text{-}Cen}$

- Locations: inner Bulge vs Halo

- Chemical link with the environment: Terzan 5 shares strikingly similar chemical properties with the Bulge

Terzan5 ≠ ω-Cen

Terzan 5 vs. Bulge



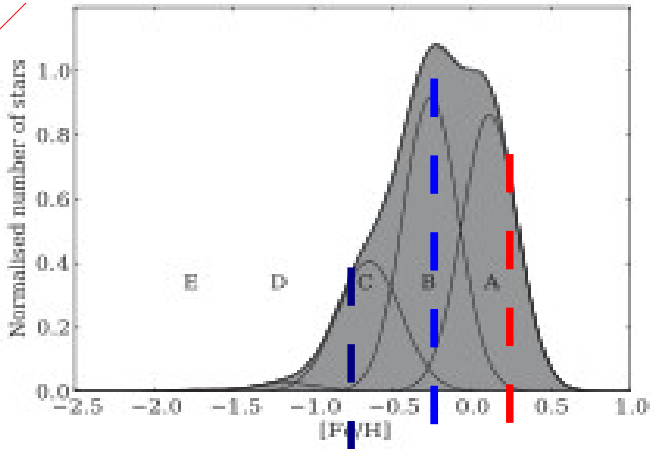
Bensby+2013

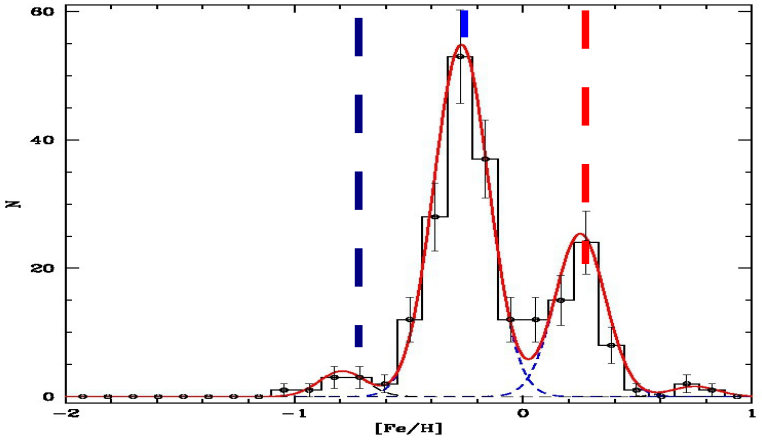
Hill+2011 - Giants

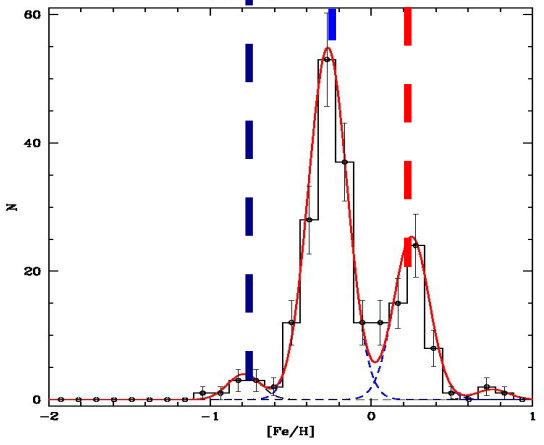
Hill+2011 - RC

Ness+2013

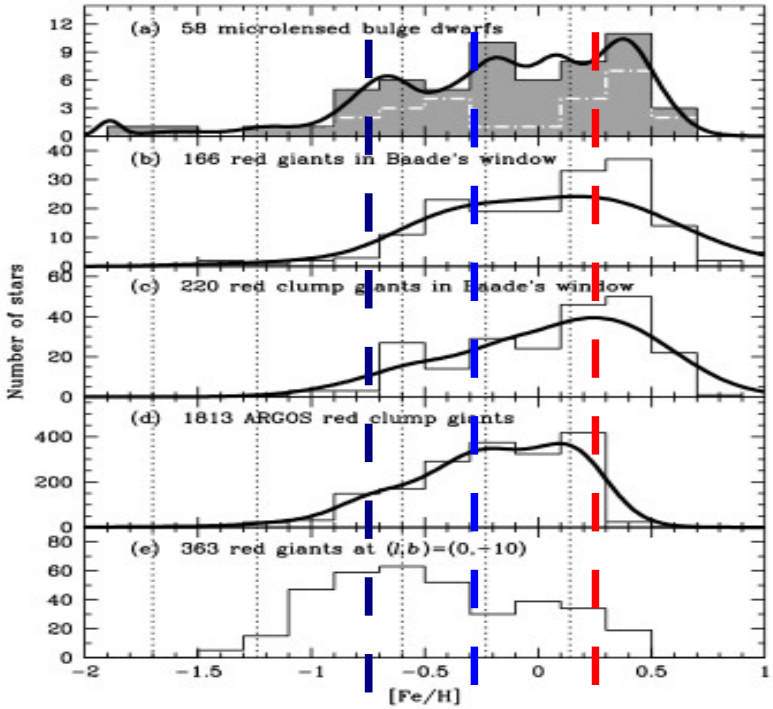
Uttenthaler+2012

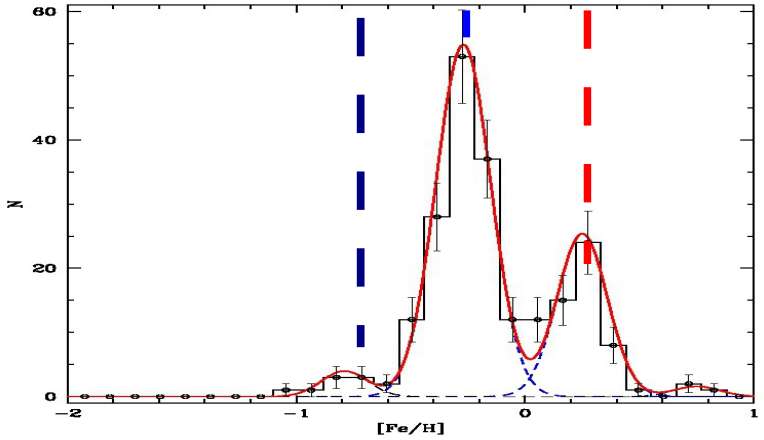






Terzan 5 vs. Bulge





Bensby+2013

Hill+2011 - Giants

Hill+2011 - RC

Ness+2013

Uttenthaler+2012

Tight link between the two systems!

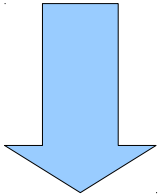
Conclusions

Chemical properties of Terzan 5:

- **No genuine GC** (Δ[Fe/H]>1.5 dex)

- **No remnant of a dwarf galaxy** (much higher metallicity regime)

- Striking similarity with the Bulge (α-elements, [Fe/H] multi-modality)



Remnant of a pristine fragment of the Bulge

Future perspective

- **Kinematics:** radial velocities and proper motions

- **Ages:** determine absolute ages of Terzan 5 populations

} Evolution of Terzan 5 and possibly of its environment

- **Search for Terzan 5-twins** among other bulge GCs

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

The End