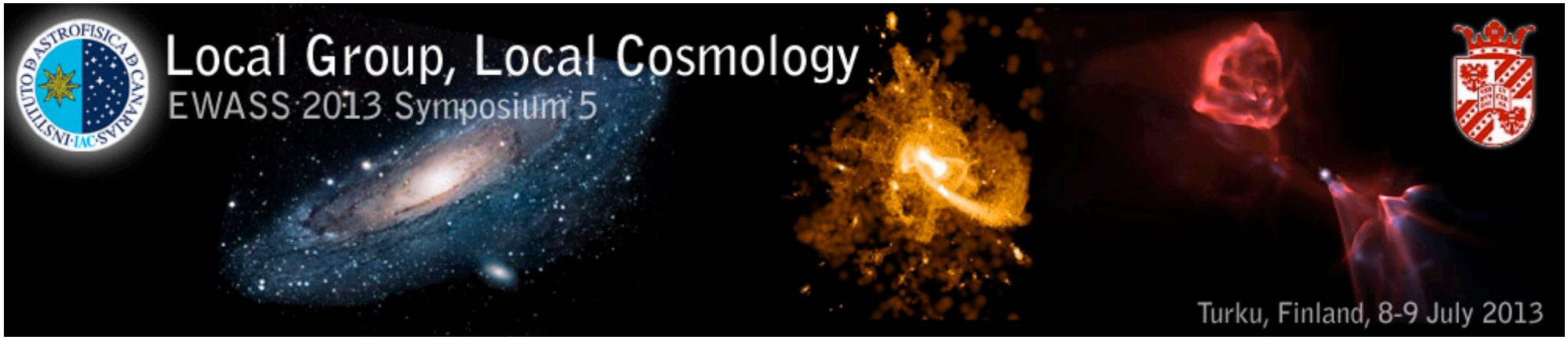

Terzan 5: the remnant of a pristine fragment of the Galactic Bulge?

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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

Context: formation of galaxy bulges

Still debated, several models:

- monolithic collapse (e.g., Eggen+62)
- mergers (e.g., Toomre & Toomre 1972; Aguerri+01)
- evolution of bars (e.g., Combes & Sanders 1981; Pfenninger & Norman 1990)
- disk instability (e.g., Noguchi 1999; Immeli+03, 04; Elmegreen+08)

Instability of a GAS disk (Immeli+04; Elmegreen+08):

- disk fragments in **massive clumps** of stars & gas
- clumps spiral to the centre & merge => massive bulge forms
- **high SFR** in the clumps & in the bulge => fast iron & α-elements enrichment

Clearly, **finding massive clumps with the predicted properties** is crucial to validate the model...

***Chain and clumpy galaxies* observed out to z ~6**

in UDF, GEMS,GOODS (e.g., Cowie+95, Elmegreen+05, 09, ...)

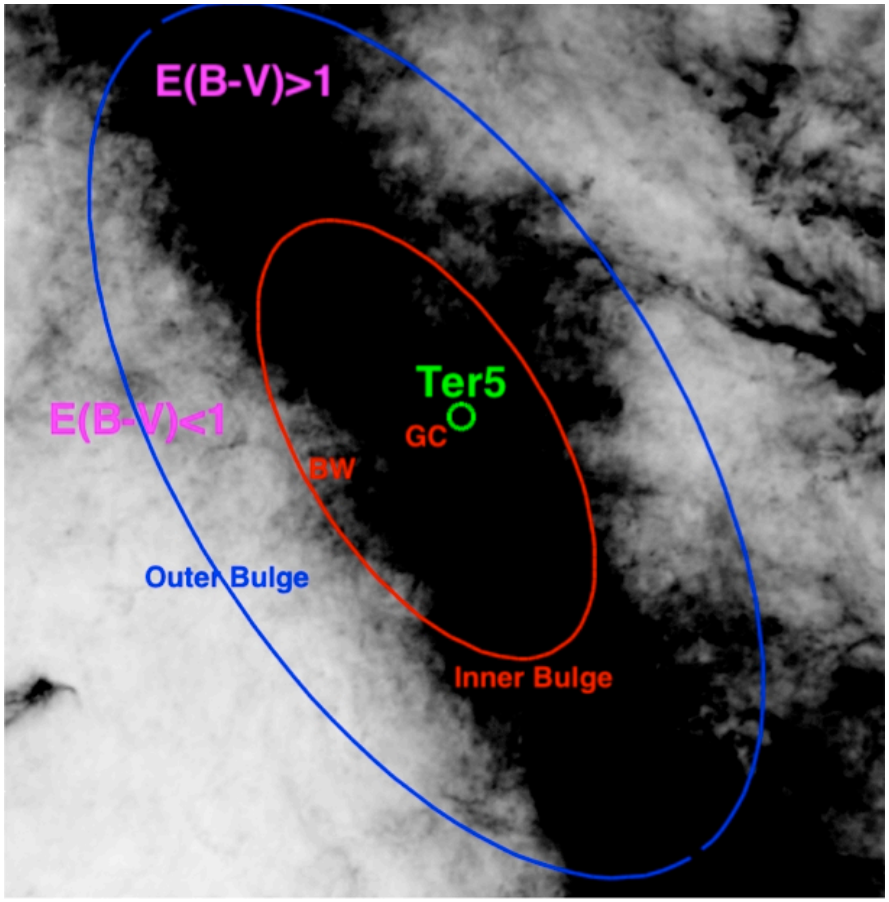
seem to be consistent with the model predictions

However our **closest** bulge (the **Galactic Bulge**)

could provide much more stringent constraints...

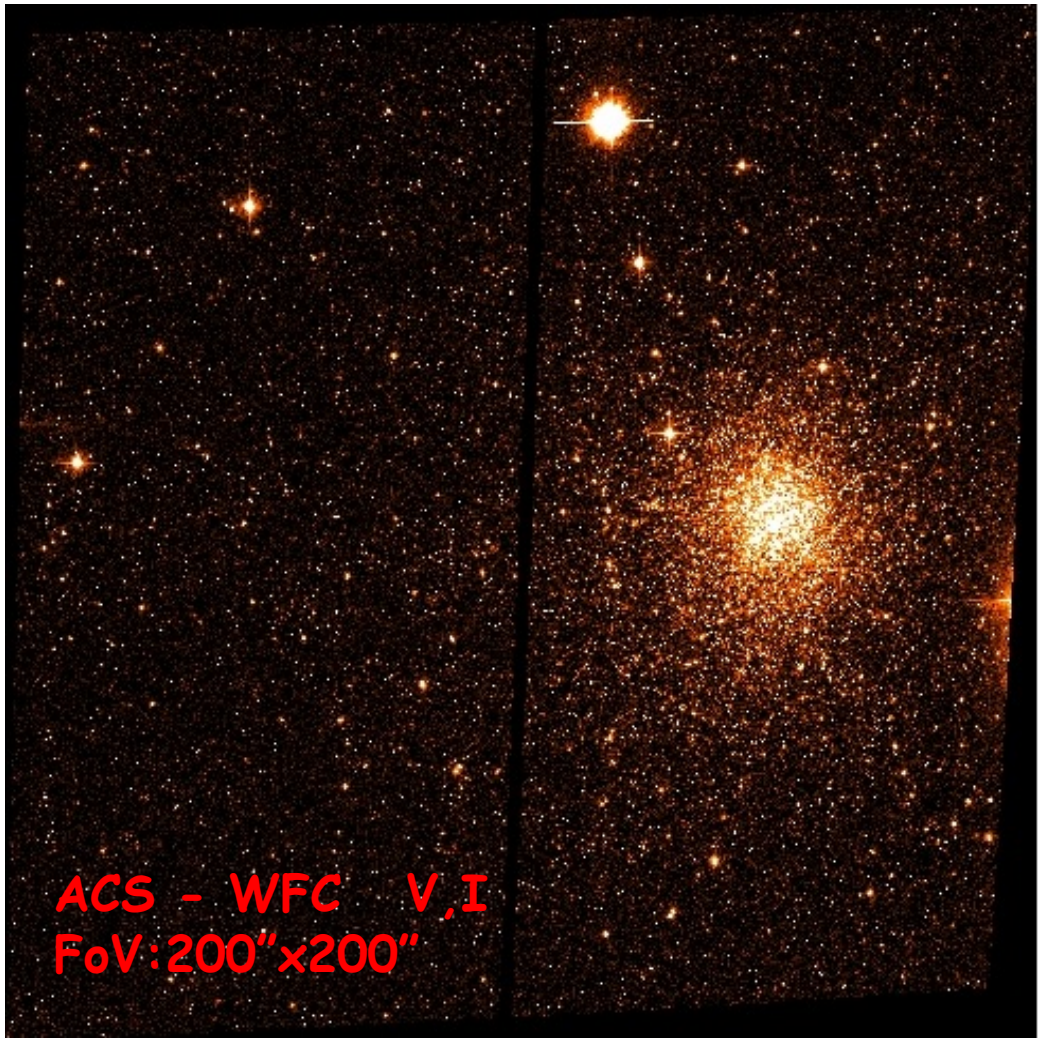
Terzan 5

- catalogued as a **globular cluster** (Terzan 1968)
- located in the outskirts of the **inner Galactic Bulge**:
  d = 6 kpc; d_{GC}=2.1 kpc
- **E(B-V)=2.3** (Valenti et al 2007)
- severe **differential reddening**
- **largest population of millisecond pulsars** ever detected in a GC (Ransom+04)

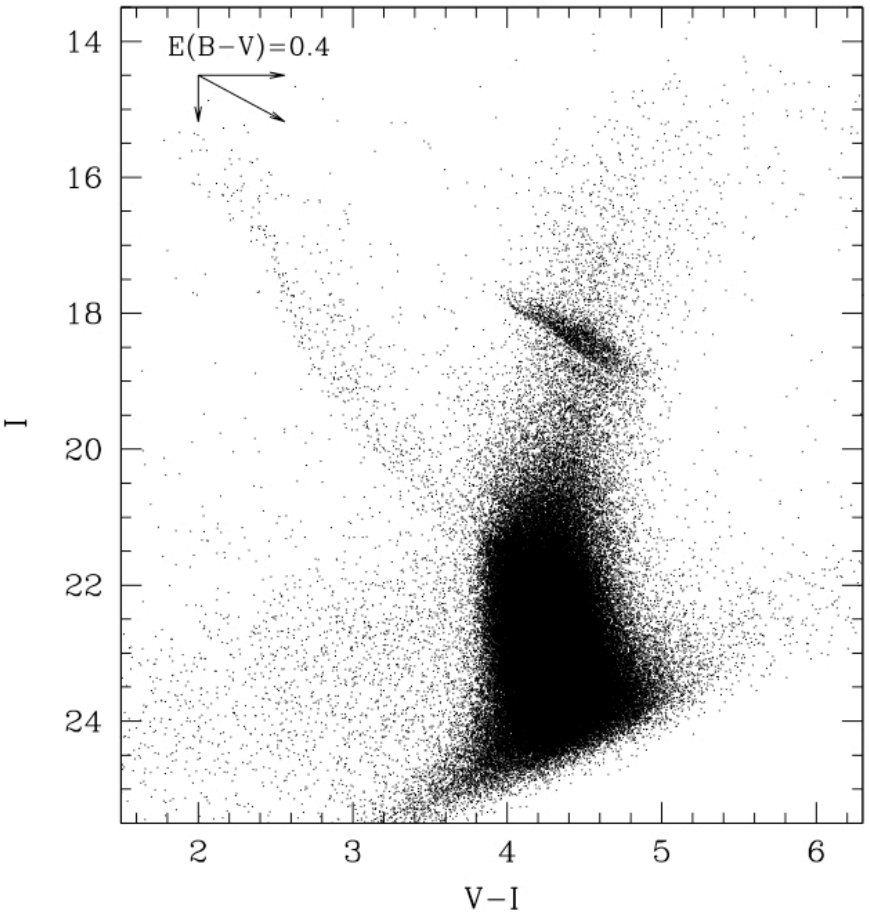


Main Problem: differential reddening

deepest **optical** image (ACS@HST)



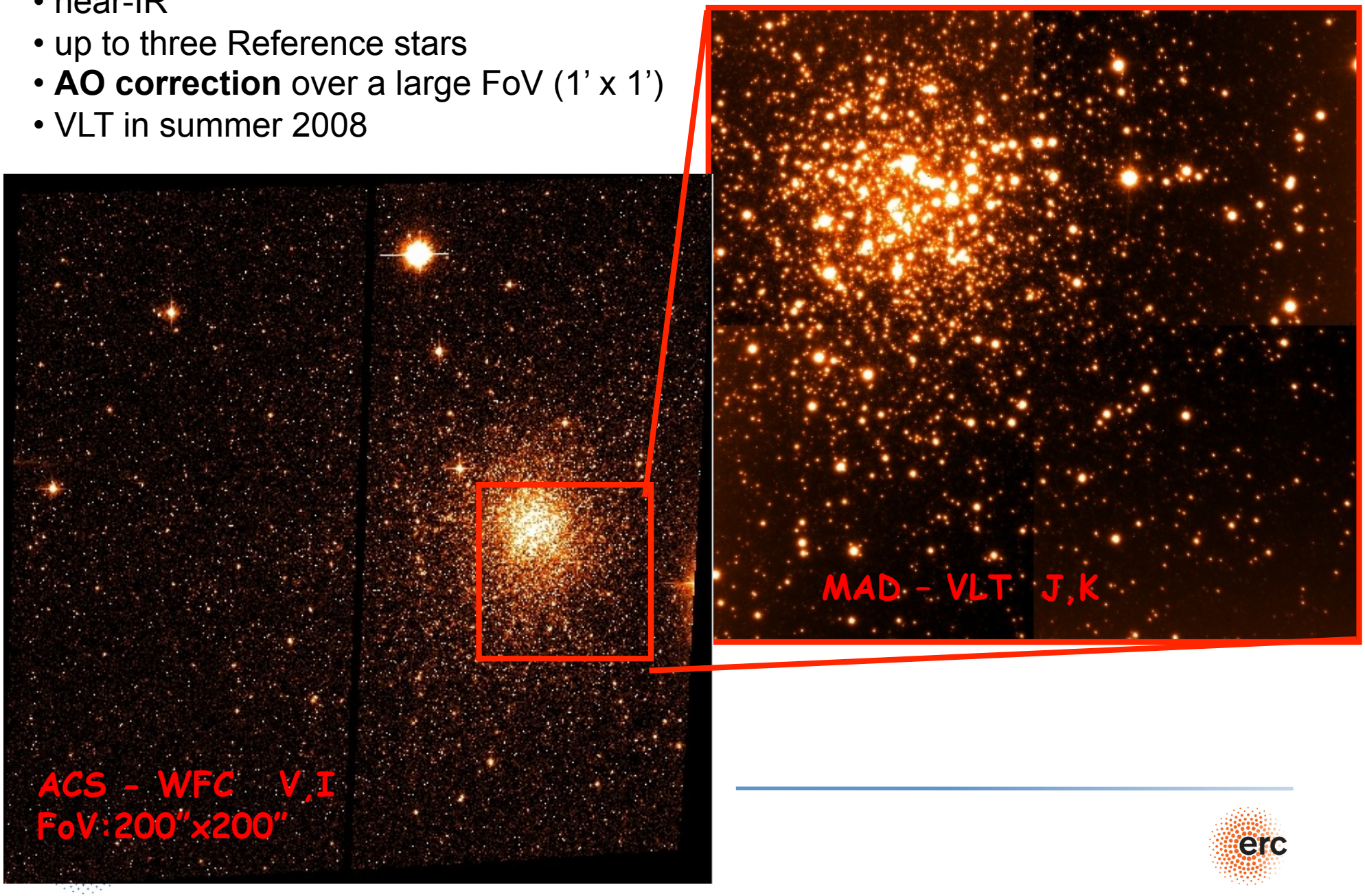
deepest **optical** CMD



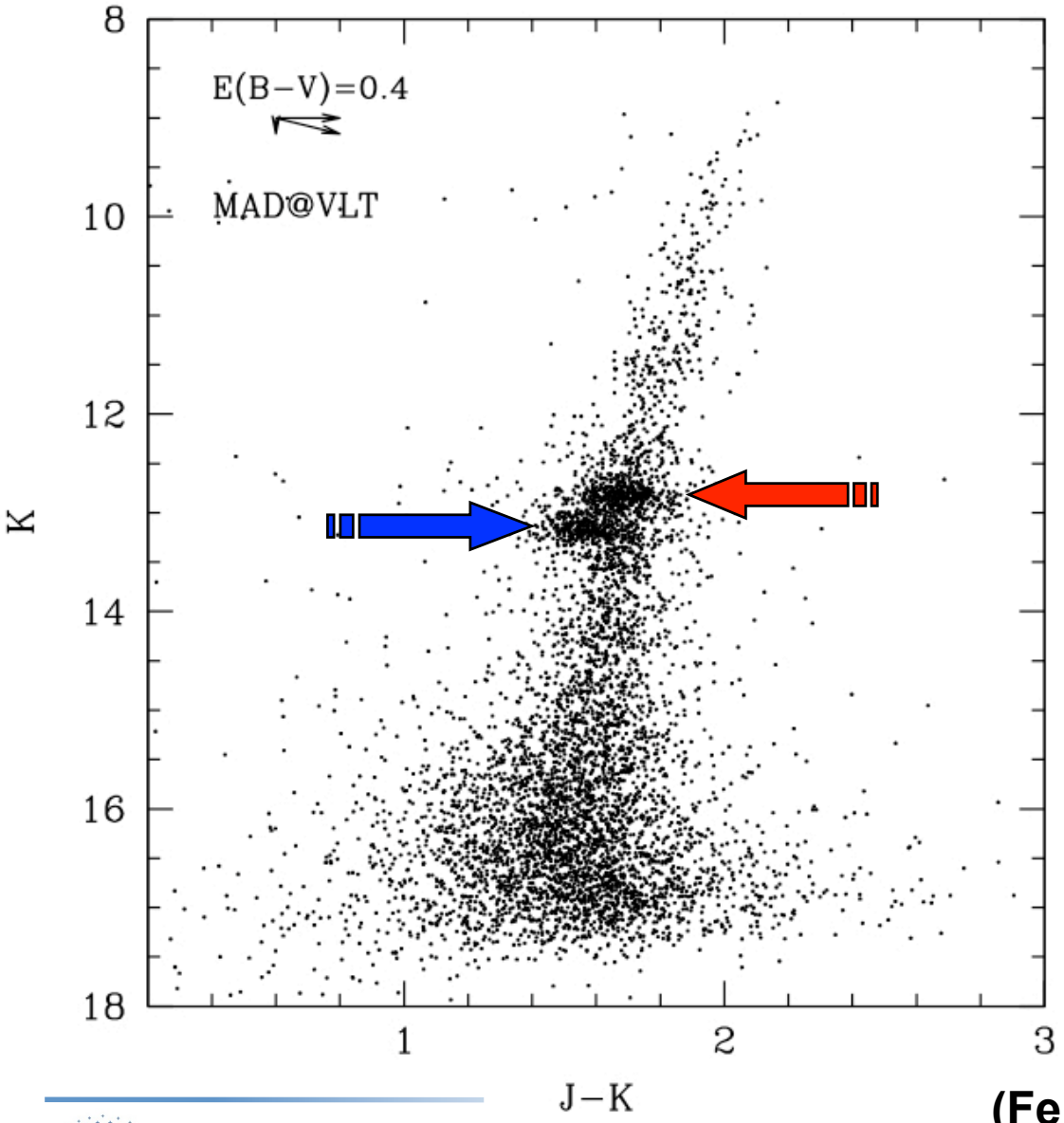
evolutionary sequences **highly stretched** along reddening vector direction

MAD = Multi-conjugate Adaptive Optics Demonstrator

- near-IR
- up to three Reference stars
- **AO correction** over a large FoV (1' x 1')
- VLT in summer 2008



The MAD CMD of TERZAN 5



TWO distinct Horizontal Branches (HB)!

ΔK~0.3

Δ(J-K)~0.2

(Ferraro et al. 2009, Nature, 462, 483)

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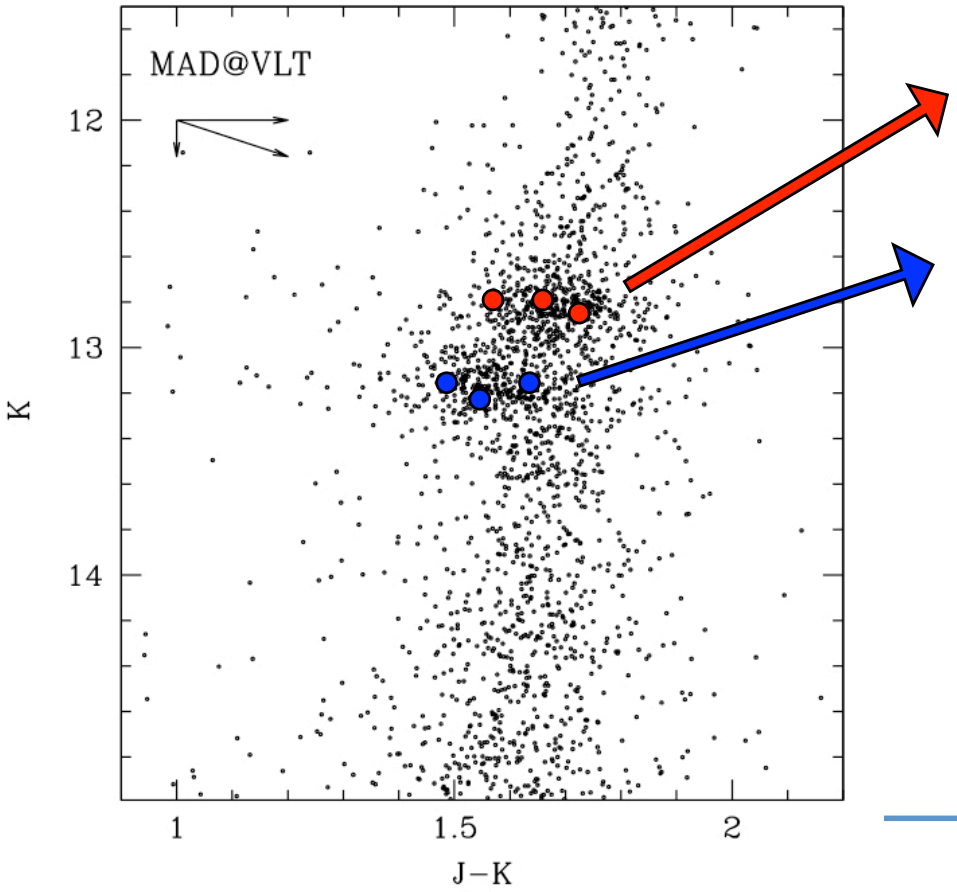
NIRSPEC @ Keck II observations of HB stars

The two populations belong to the same stellar system



V_{rad} = -85 km/s

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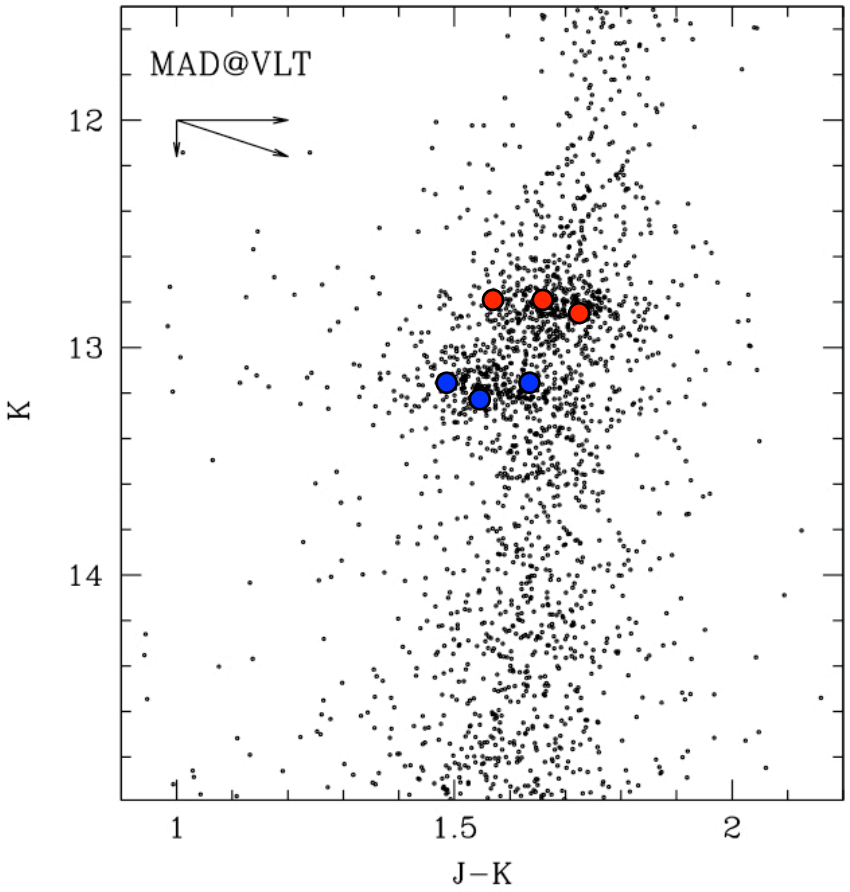
(Ferraro+09, Nat. 462, 483)

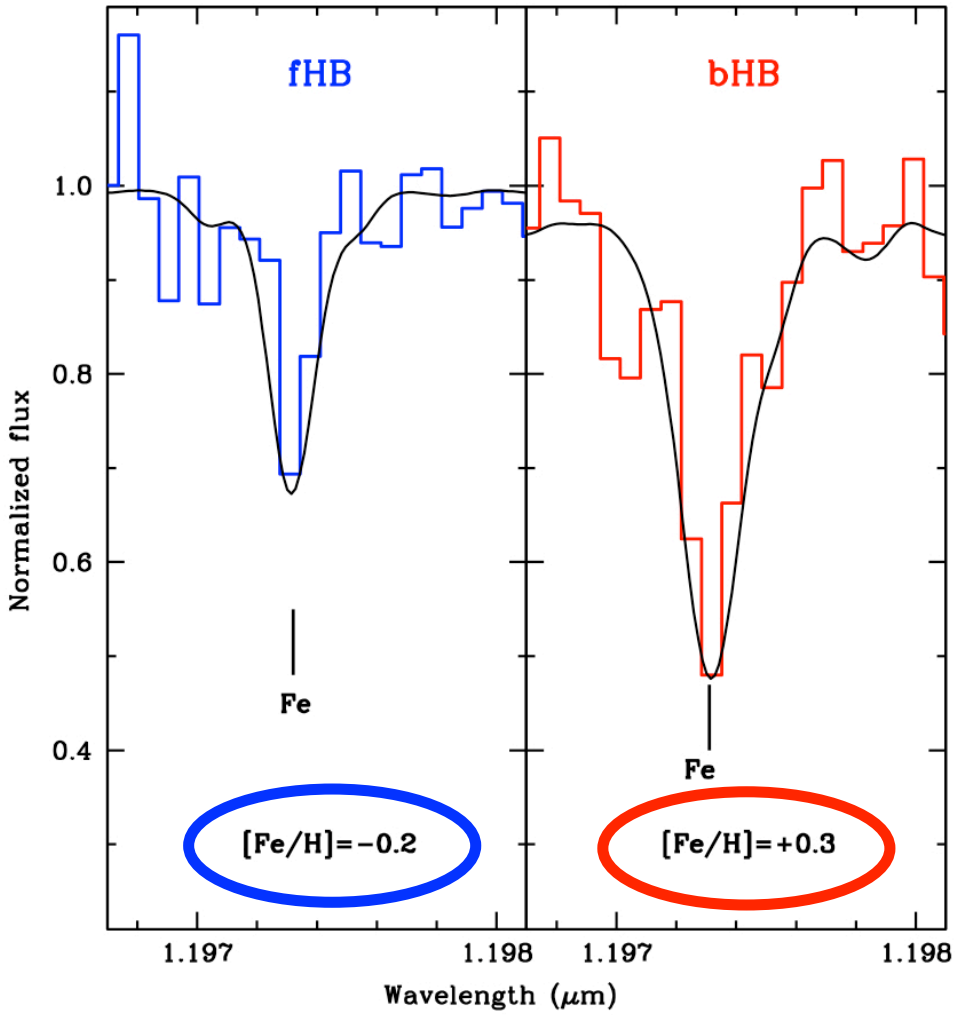
NIRSPEC @ Keck II observations of HB stars

The two populations have different IRON abundances!

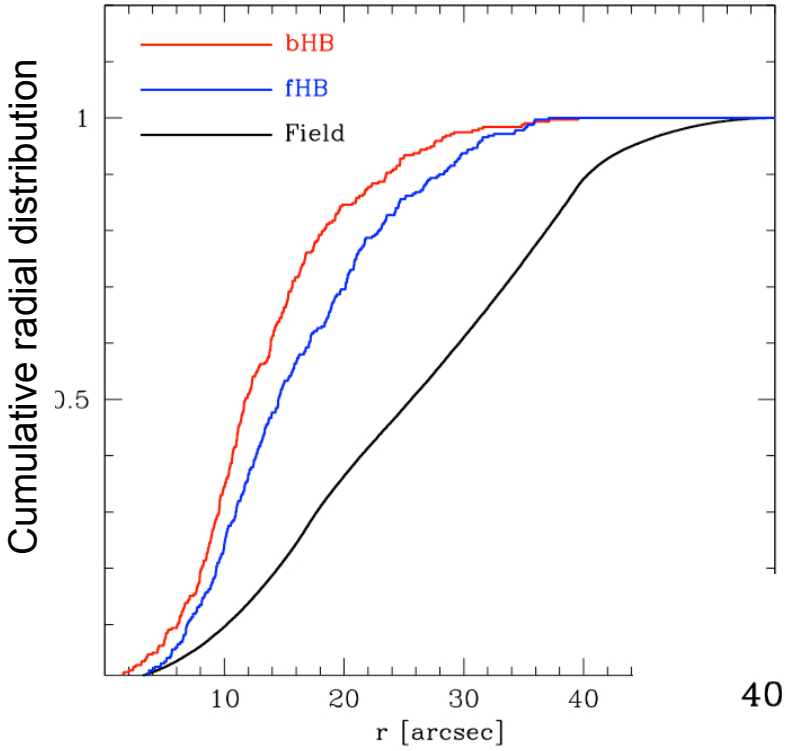
Δ[Fe/H] ≅ 0.5



(Ferraro+09, Nat. 462, 483)



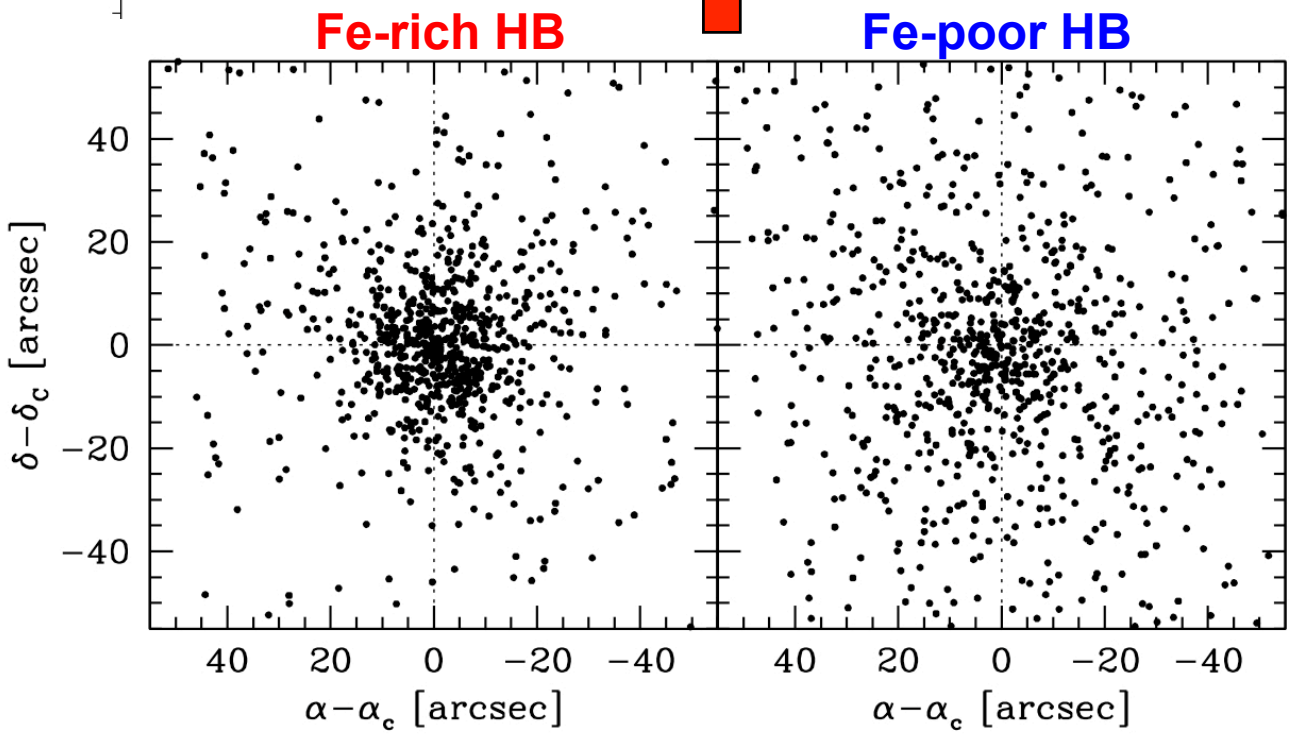
Radial distribution



With respect to the centre of Terzan 5:

- **both HBs more segregated than field stars**
- **Fe-rich HB more segregated than Fe-poor HB**

self-enrichment (in IRON)



Ferraro+09, Nat. 462, 483

Lanzoni+10, ApJ 717, 653

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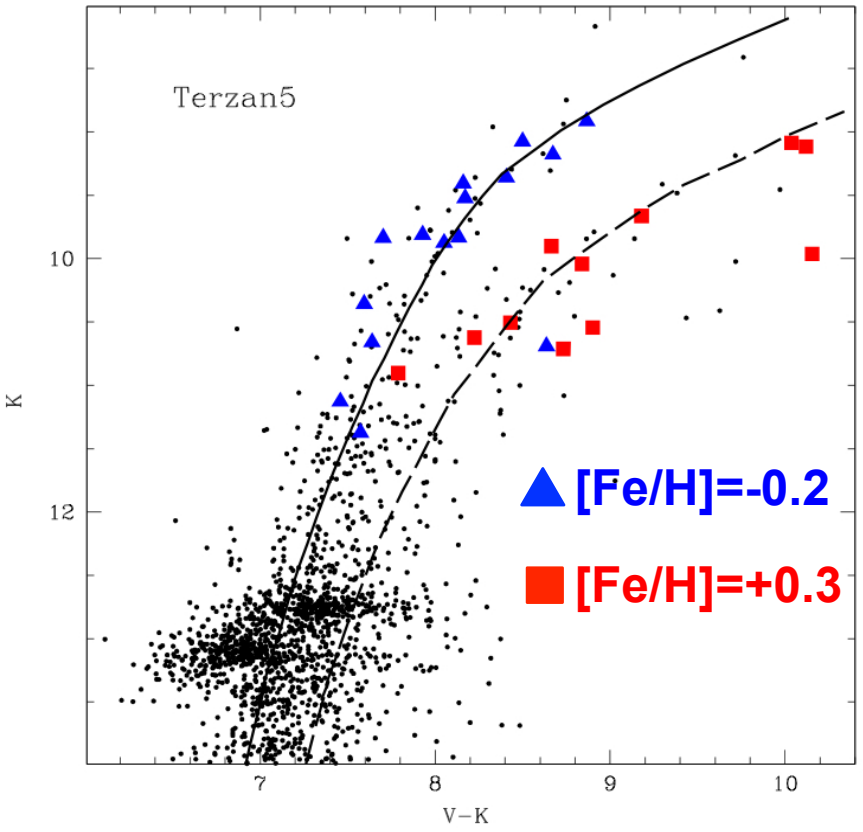
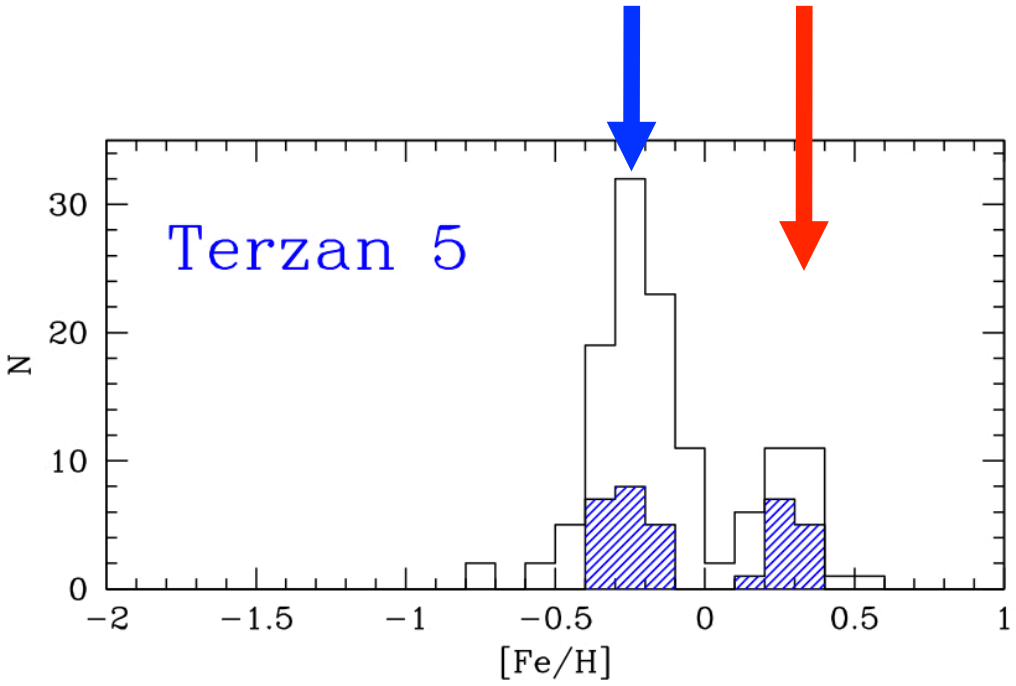
Spectroscopic screening of RGB stars: IRON

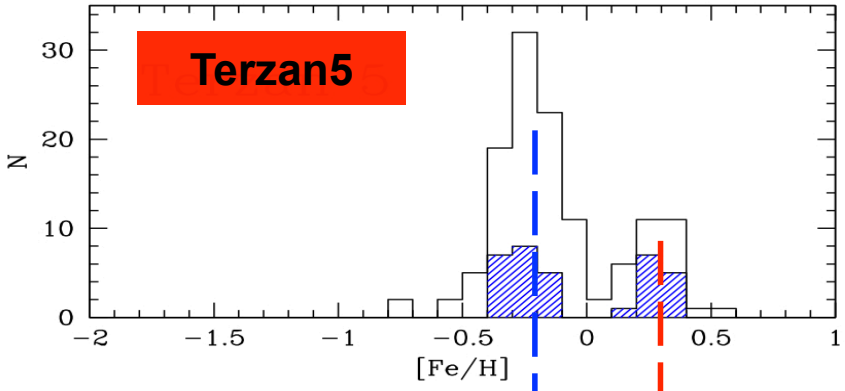
33 giants with NIRSPEC@Keck (Origlia et al. 2010, ApJ, 726, L20)
93 giants with FLAMES@ESO (Massari et al. 2013, in prep)

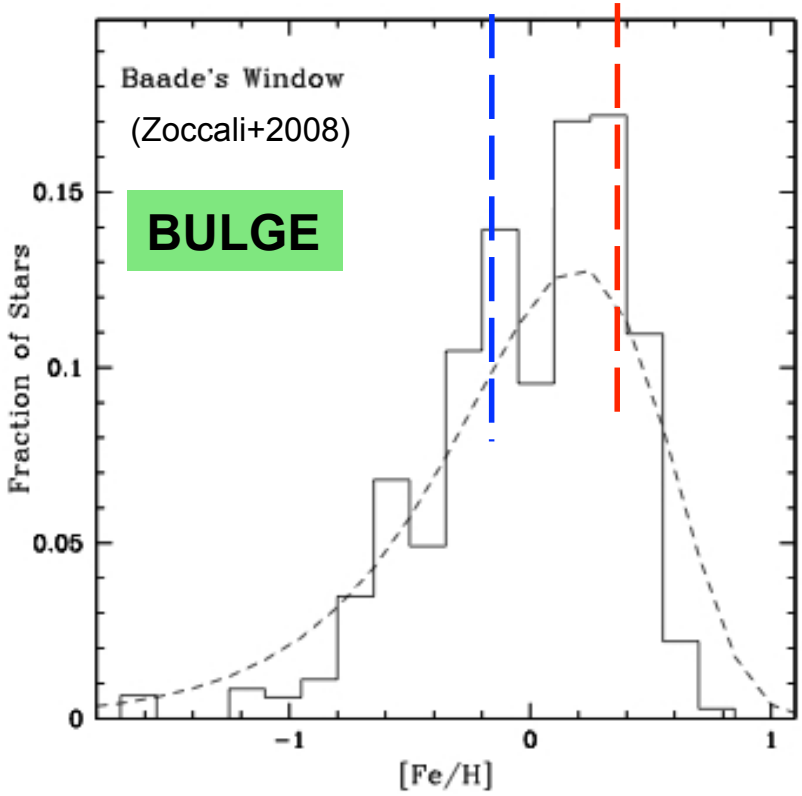


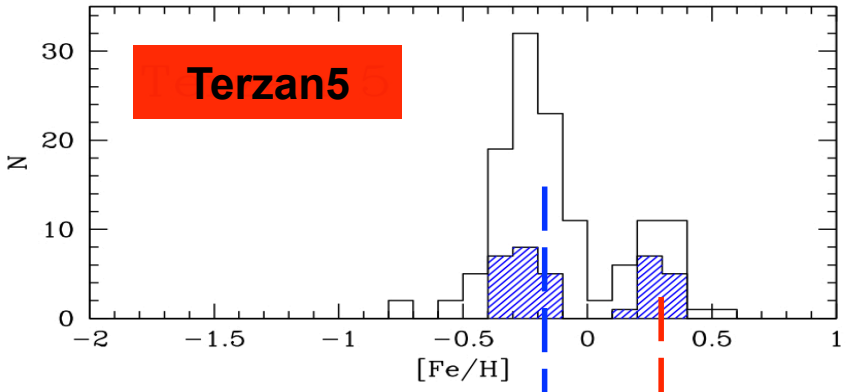
Two distinct peaks in the iron abundance

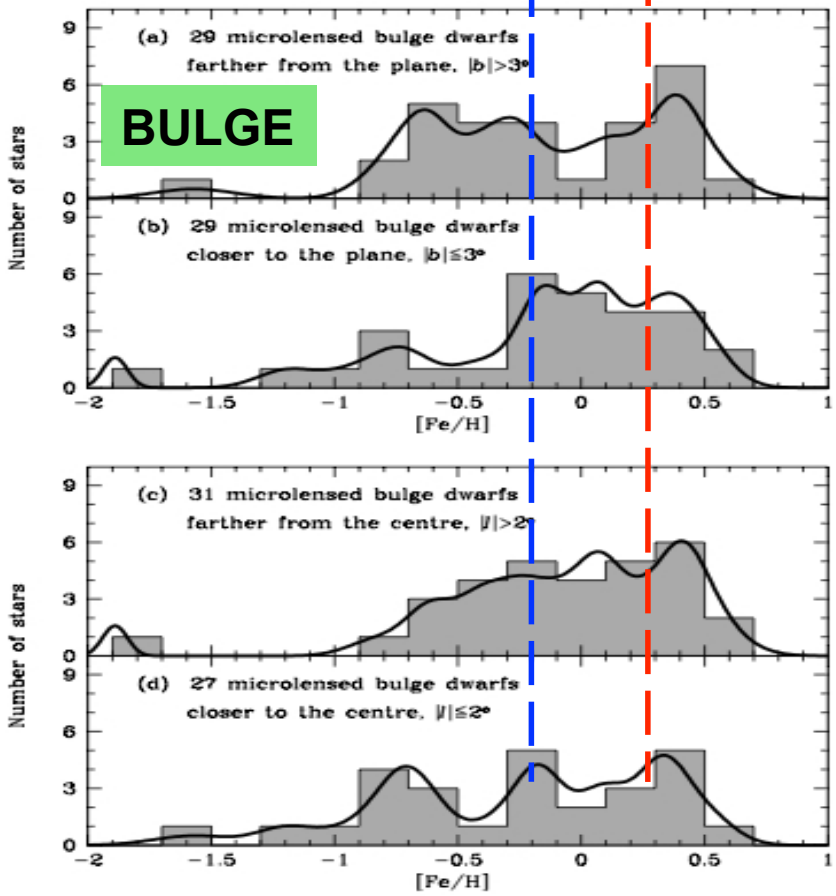


IRON distribution quite similar to that of the Bulge









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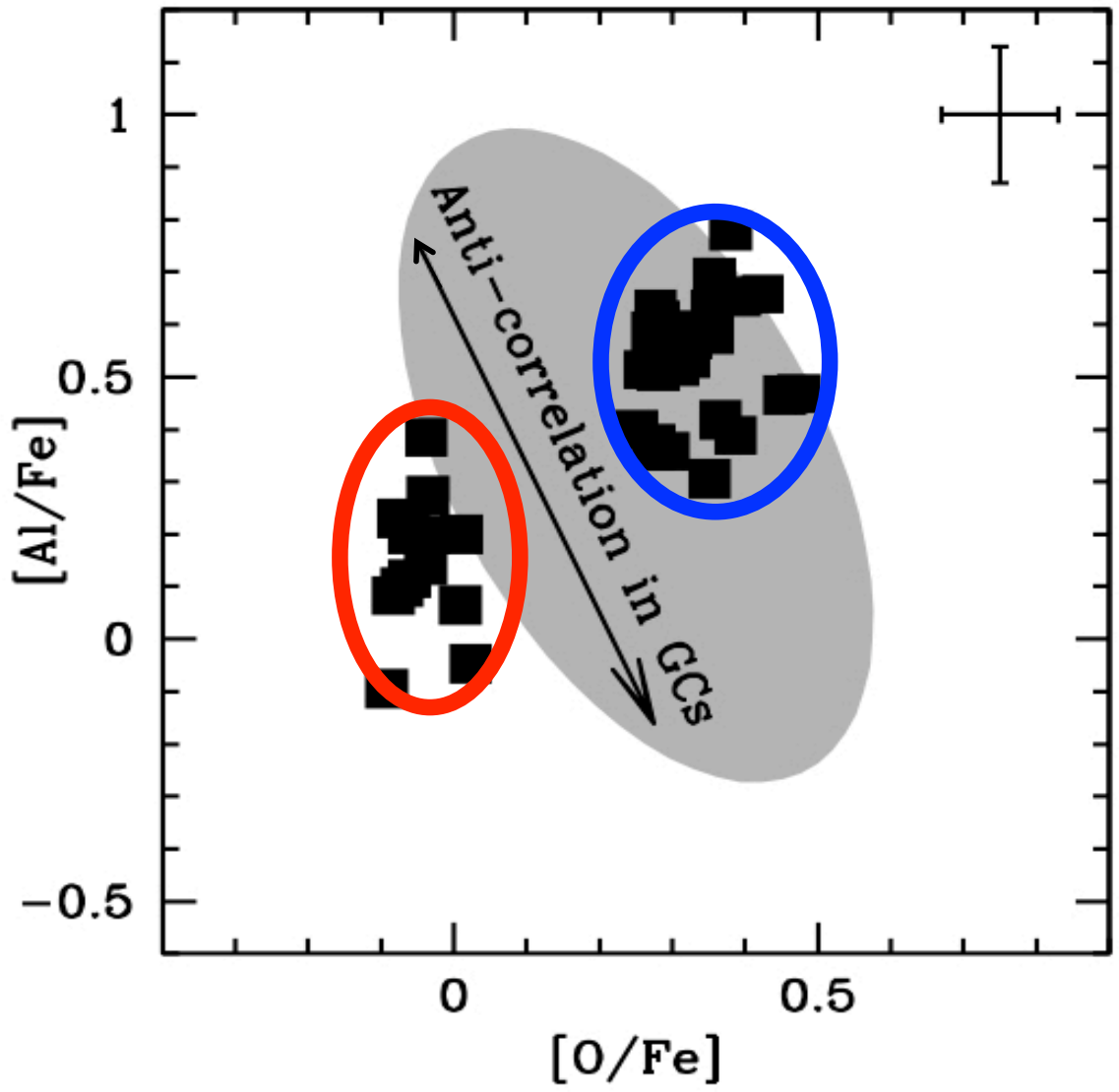
Bensby et al 2013, A&A,549,147

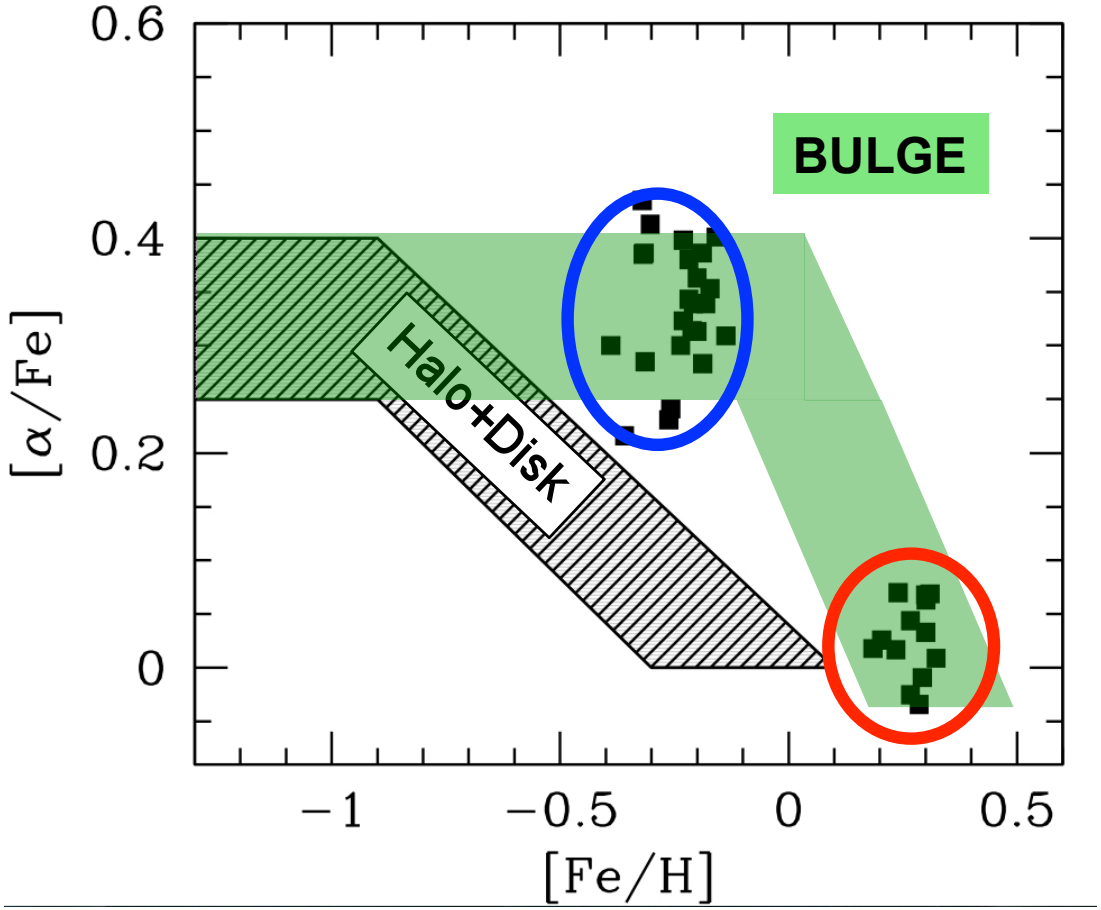
light elements anti-correlations?



anti-correlation TYPICAL of genuine GCs

NO anti-correlation in Terzan 5 (both populations)

α−elements



metal-poor component:
α-enhanced

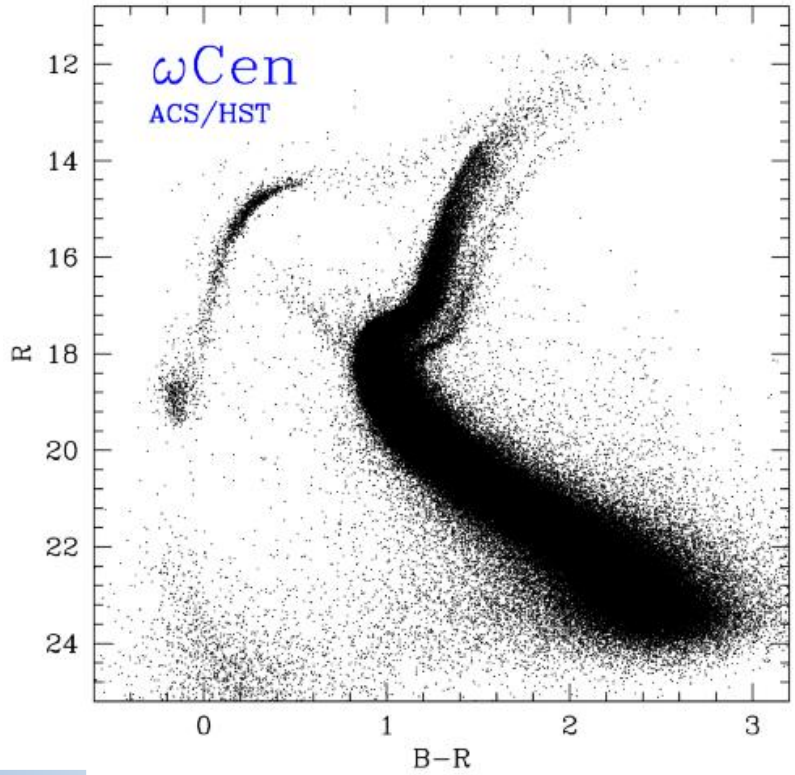
metal-rich component:
solar

Abundance patterns (iron & α-elements) very similar to those of the Bulge

Striking chemical similarity between Terzan 5 & the Bulge

Terzan5 unlike to be the remnant of a dwarf galaxy accreted by the MW

as it is thought to be ωCentauri (e.g., Norris+95, Sollima+05)

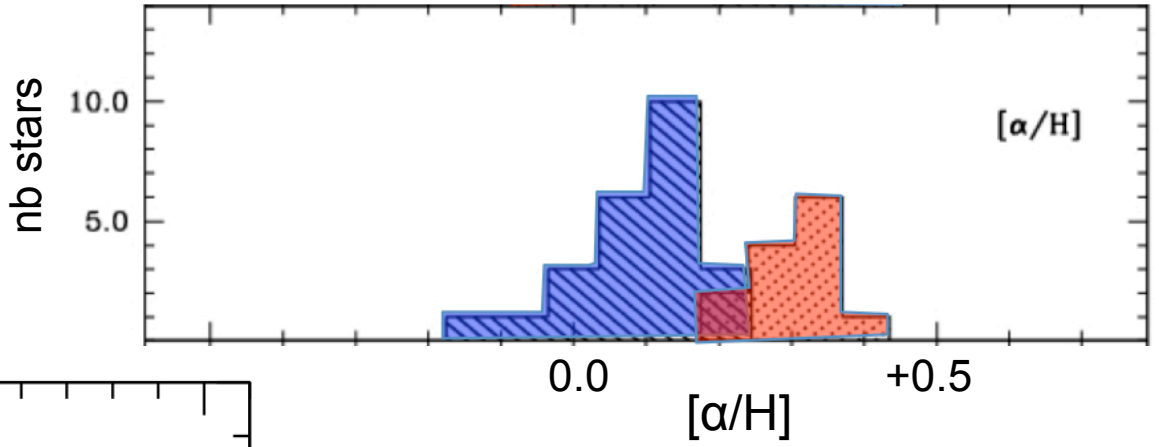


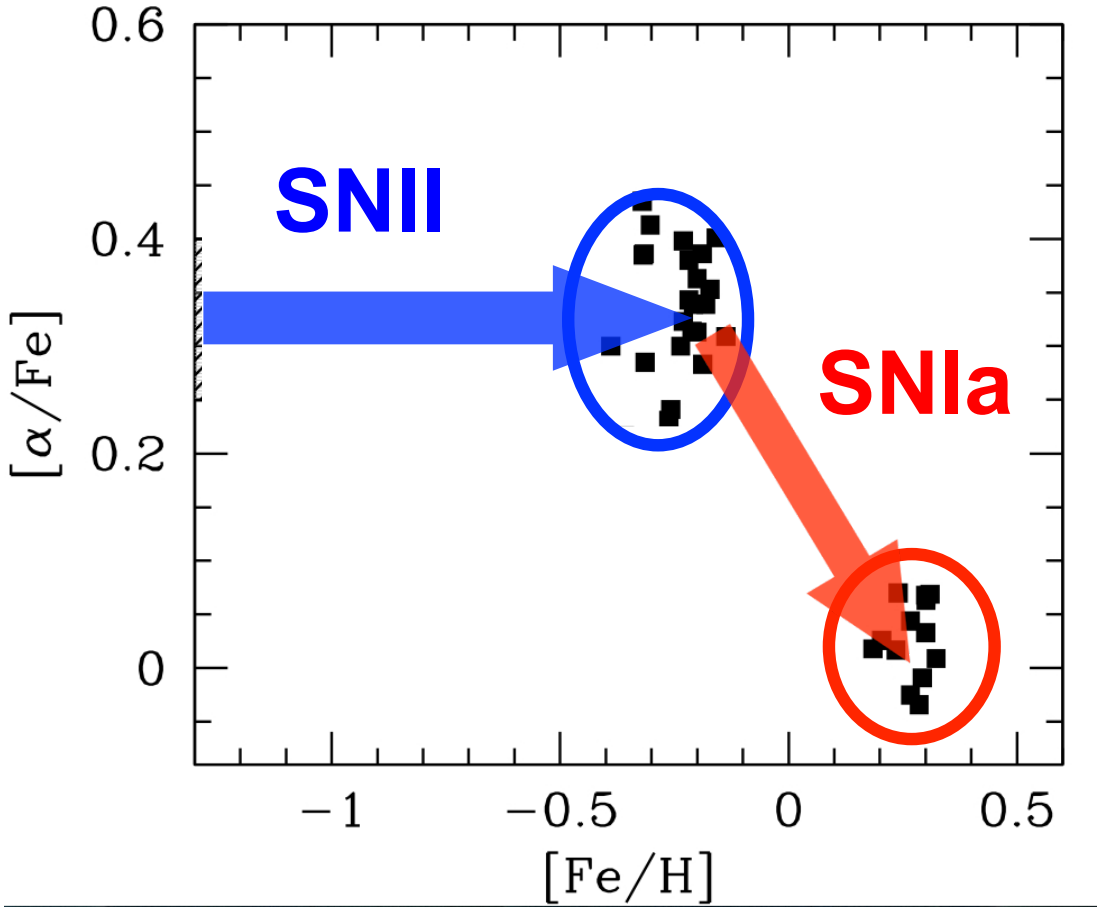
Striking chemical similarity between Terzan 5 & the Bulge

Terzan5 unlike to be the remnant of a dwarf galaxy accreted by the MW

Terzan 5 & the Bulge shared quite similar star formation and chemical enrichment histories!

α−elements





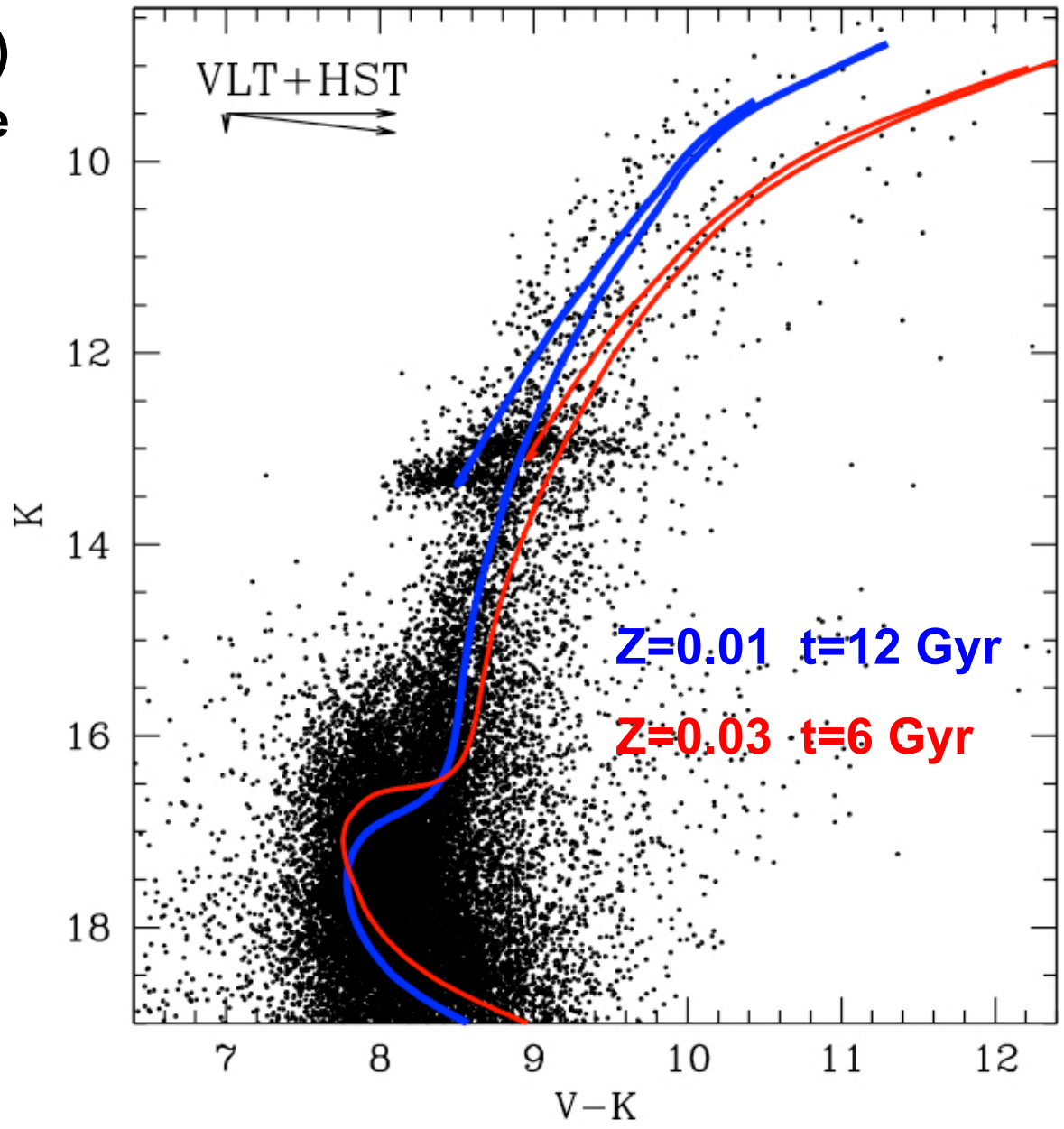
metal-poor component:

formed early & quickly from gas mainly polluted by SNII

metal-rich component:

formed from gas further polluted by SNII & SNIa on longer time-scales

The metal-rich component could be significantly YOUNGER (a few Gyr ?) than the metal-poor one

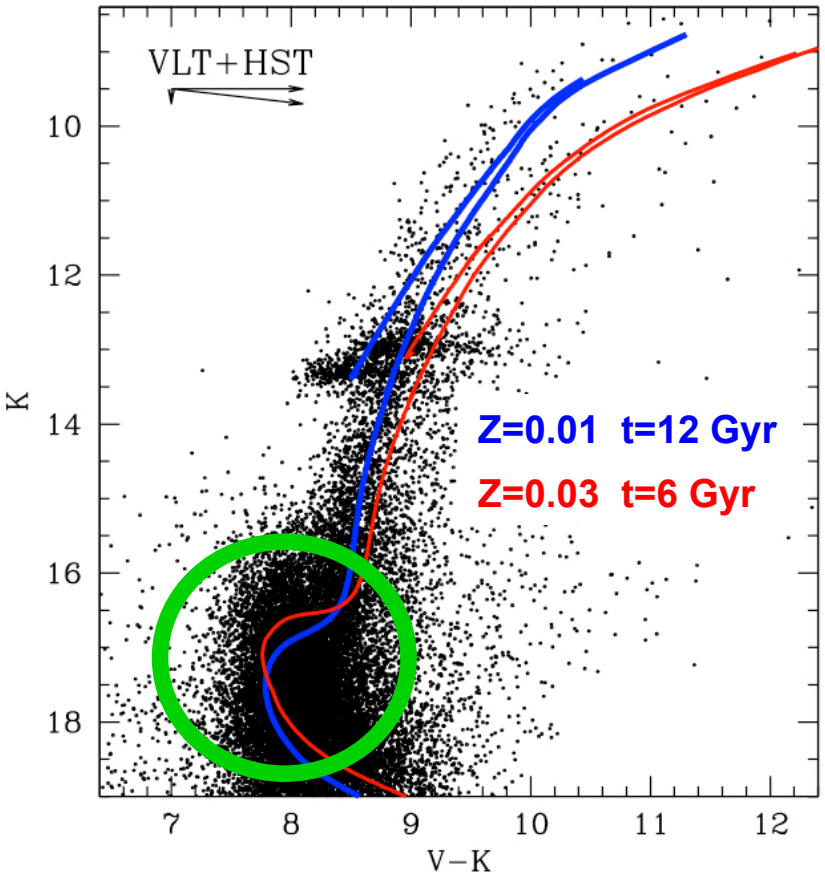


isochrones from Pietrinferni+04

Conclusions

Terzan 5 could be the remnant of one giant primordial clumps that contributed to form the Galactic Bulge (Immeli et al. 2004, Elmegreen et al. 2008) and, for some reasons, survived the total disruption.

The metal poorer (old) component could trace the early stages of the Bulge formation.
The metal-rich (younger) one could contain crucial information on the Bulge most recent chemical & dynamical evolution.



How to test this hypothesis?

1. **Measuring the ages of the two populations from the MS-TO.**

   Ultra-deep IR observations with WFC3-IR channel are planned in Cycle 20 (10 orbits allocated)

2. **Investigating the radial velocity dispersion profile.**

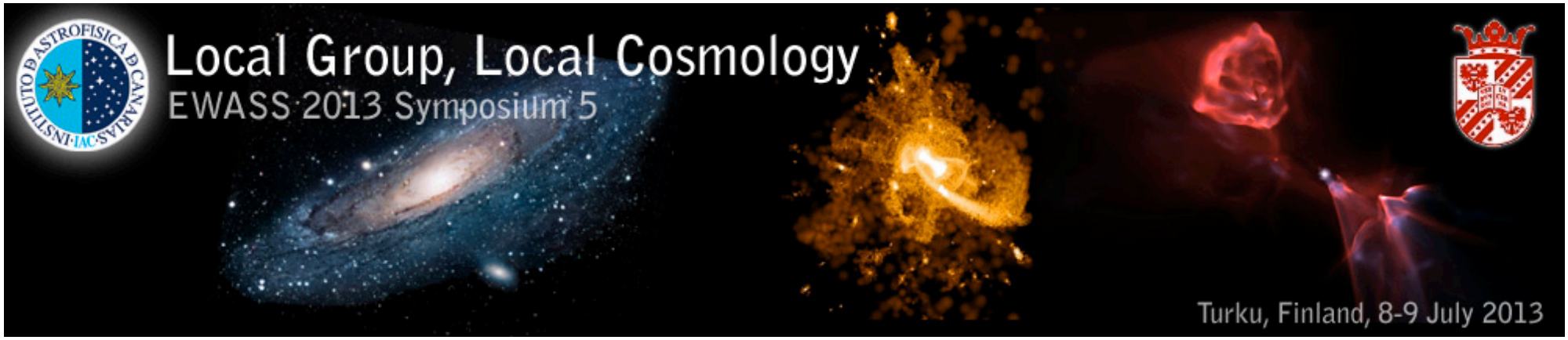
   We have collected 800 FLAMES spectra covering the entire cluster extension

3. **Performing proper motion measures**

   to search for kinematical differences between the two populations and clean the CMDs from field stars (second epoch ACS planned in HST-Cycle 20)

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

   ongoing photometric & spectroscopic campaigns at VLT, Keck, GEMINI



Thank you for your attention!

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