TERZAN 5 : The remnant of a pristine fragment of the Galactic Bulge

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Cosmic-Lab

This research is part of the project COSMIC-LAB, a 5-year *Advanced Research Grant* funded by the European Research Council.

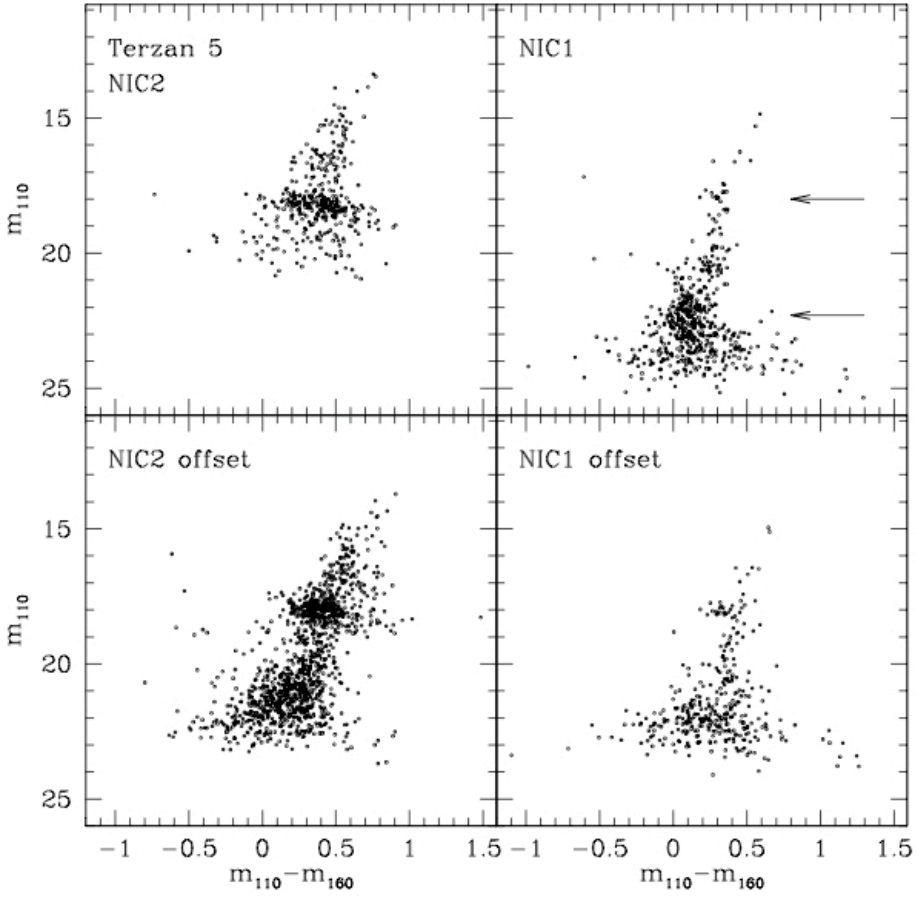
The aim of COSMIC-LAB is to explore the complex interplay between stellar evolution and the dynamical evolution of stellar systems by using exotic objects as BSS and MSP as probe particles.

COSMIC-LAB is led by Francesco Ferraro at the Physics and Astronomy Department of the Bologna University (Italy).

E(B-V)=2.3; d = 6Kpc; d_{GC}=2.1 kpc (Valenti et al 2007) i.e. in the outskirts of the inner Bulge. Suspected to have the largest collision rate of the entire GC system (Verbunt & Hut 1987, Lanzoni et al 2010)

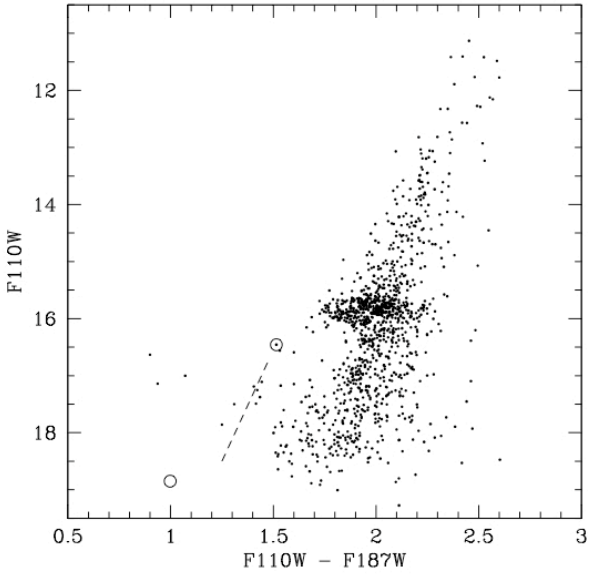
34 MSPs have been discovered in TERZAN 5 to date (see Ransom et al 2004) : this is the largest population of MSP ever detected in a GC

NICMOS@HST: First insight into the stellar population of Terzan 5

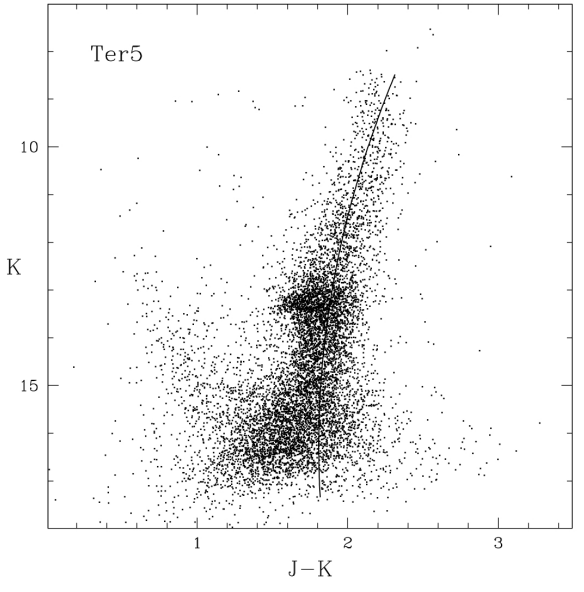


Ortolani et al (2001,A&A,376,878)

NIC2@HST- FoV:19''X19"



Cohn et al (2002, ApJ, 571, 818)



Valenti et al (2007, AJ, 133, 1287)

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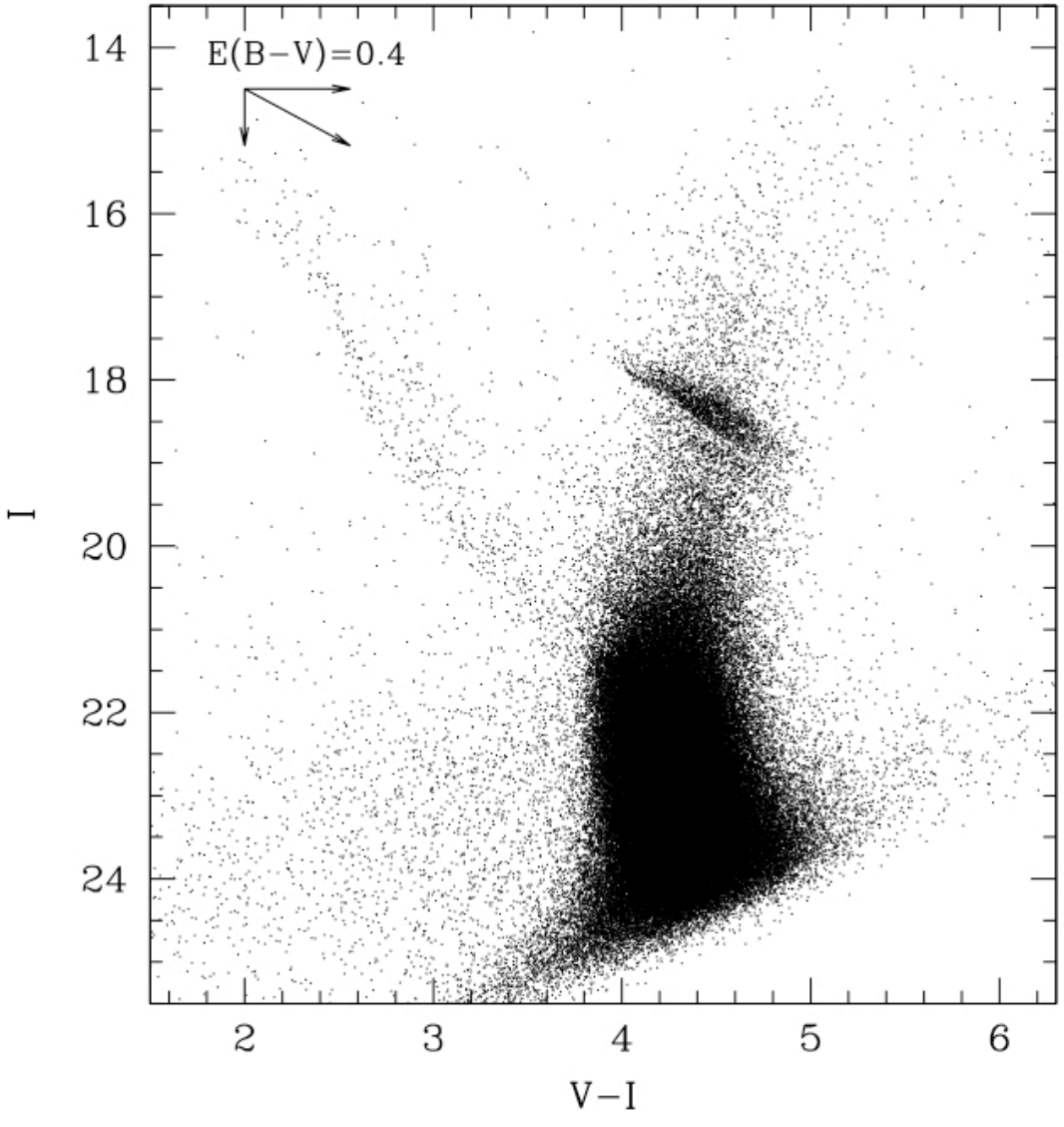
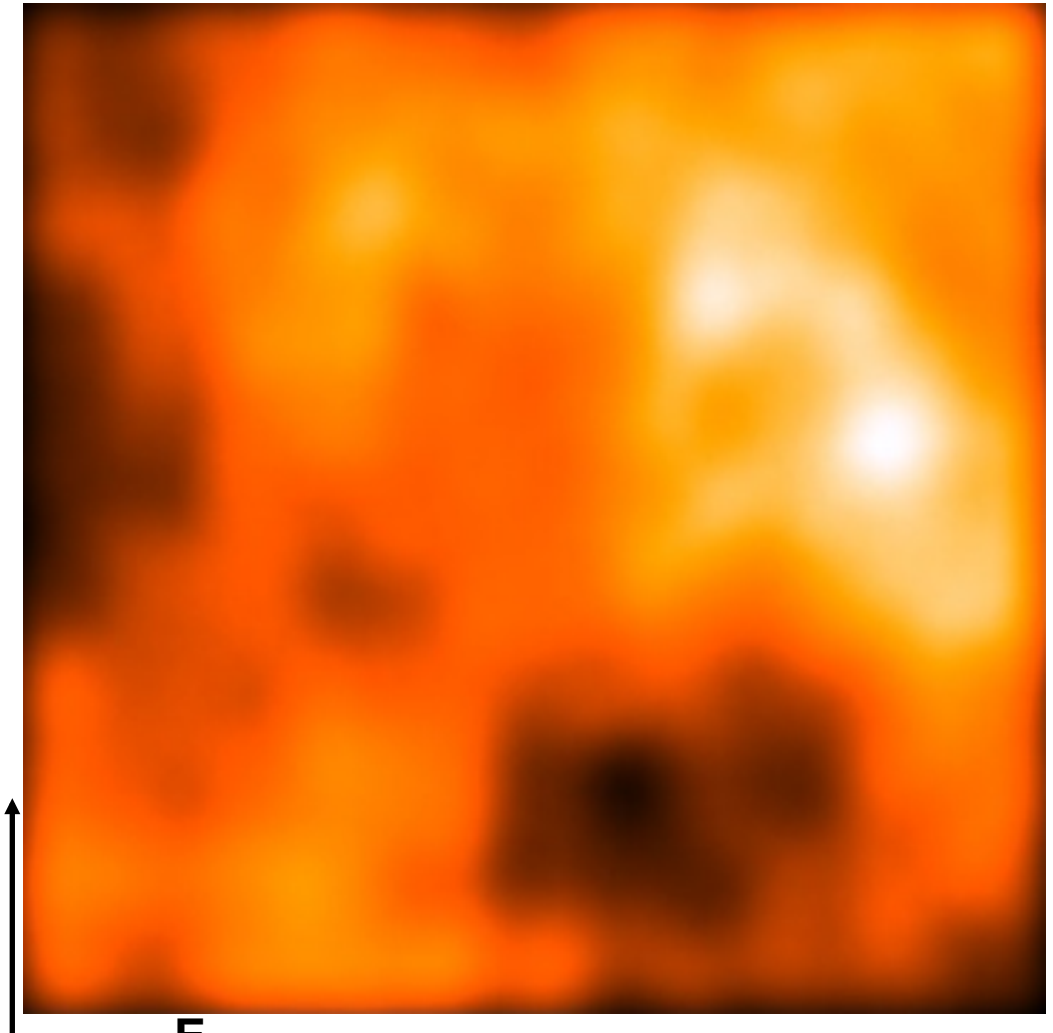
The deepest optical CMD of Terzan5 from ACS@HST



Main Problem:
Differential reddening

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

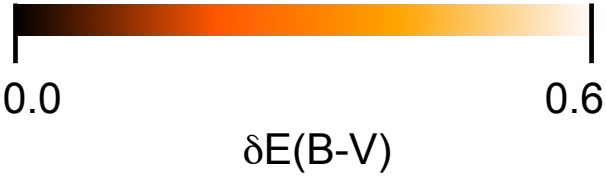
The differential reddening map in the direction of Terzan5



Massari et al (2012, ApJ, 755, L32)

Cardelli (1989)& Schegel et al (1998) Extinction law at the λ_{eff} of the filters has been used :

$A_v = 2.82/E(B-V)$
$A_I = 1.75/E(B-V)$



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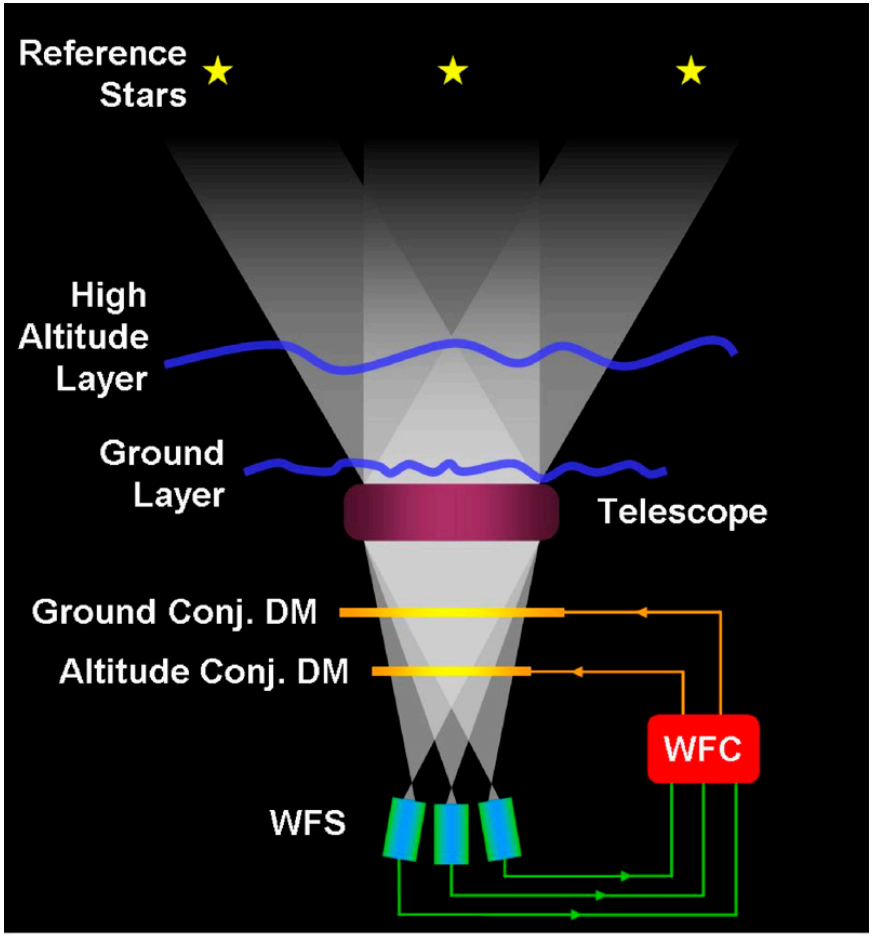
MAD = Multi-conjugate Adaptive Optics Demonstrator



The MCAO Concept

ESO Press Photo 19c/07 (30 March 2007)

MAD operated in the near-IR
By using up to three Reference stars MAD is able to perform good and uniform AO correction over a large FoV (1` x 1`)
MAD was temporally installed on VLT in summer 2008

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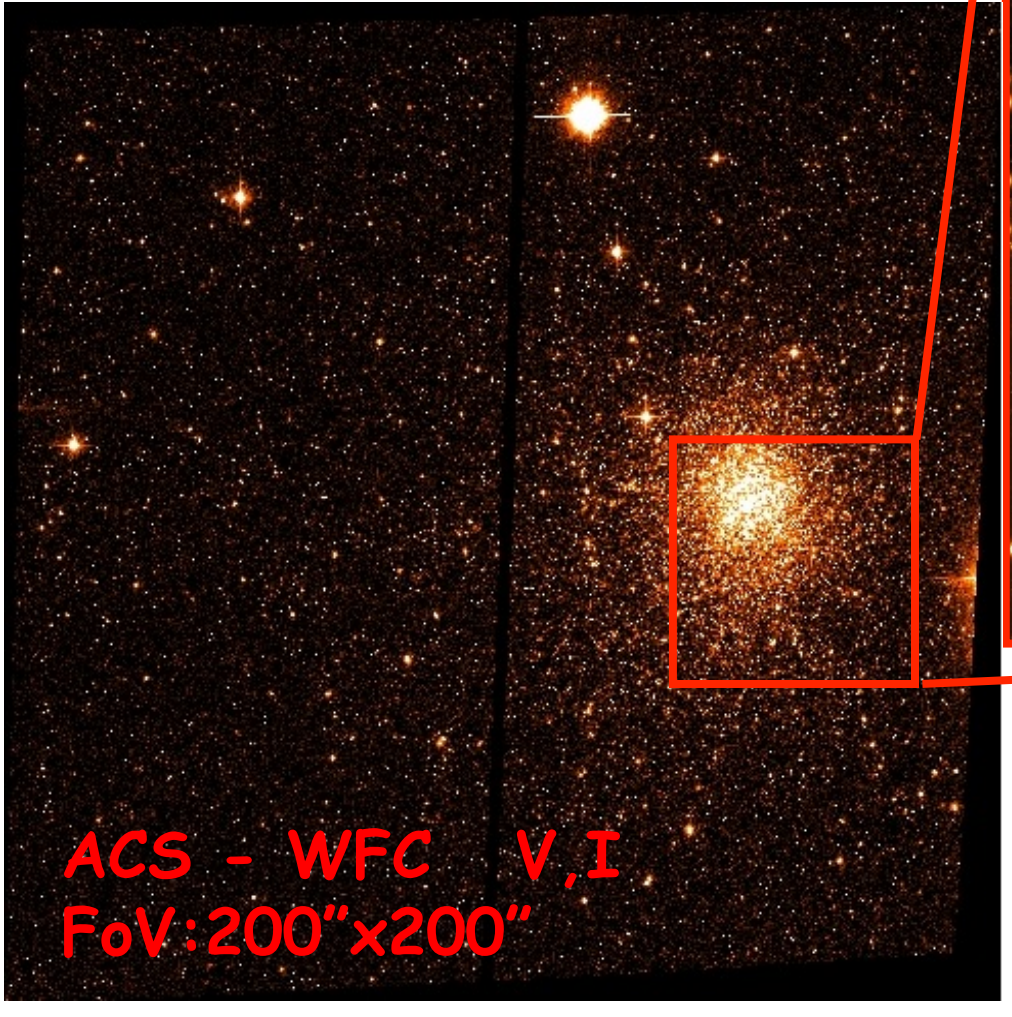
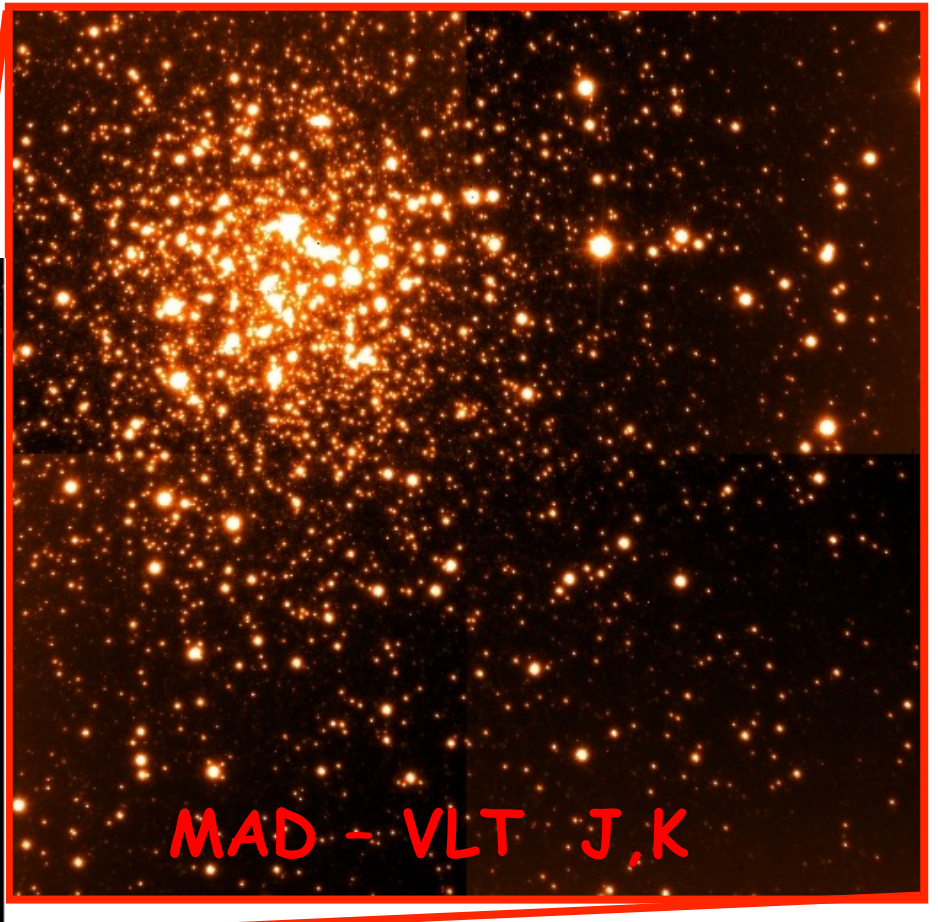
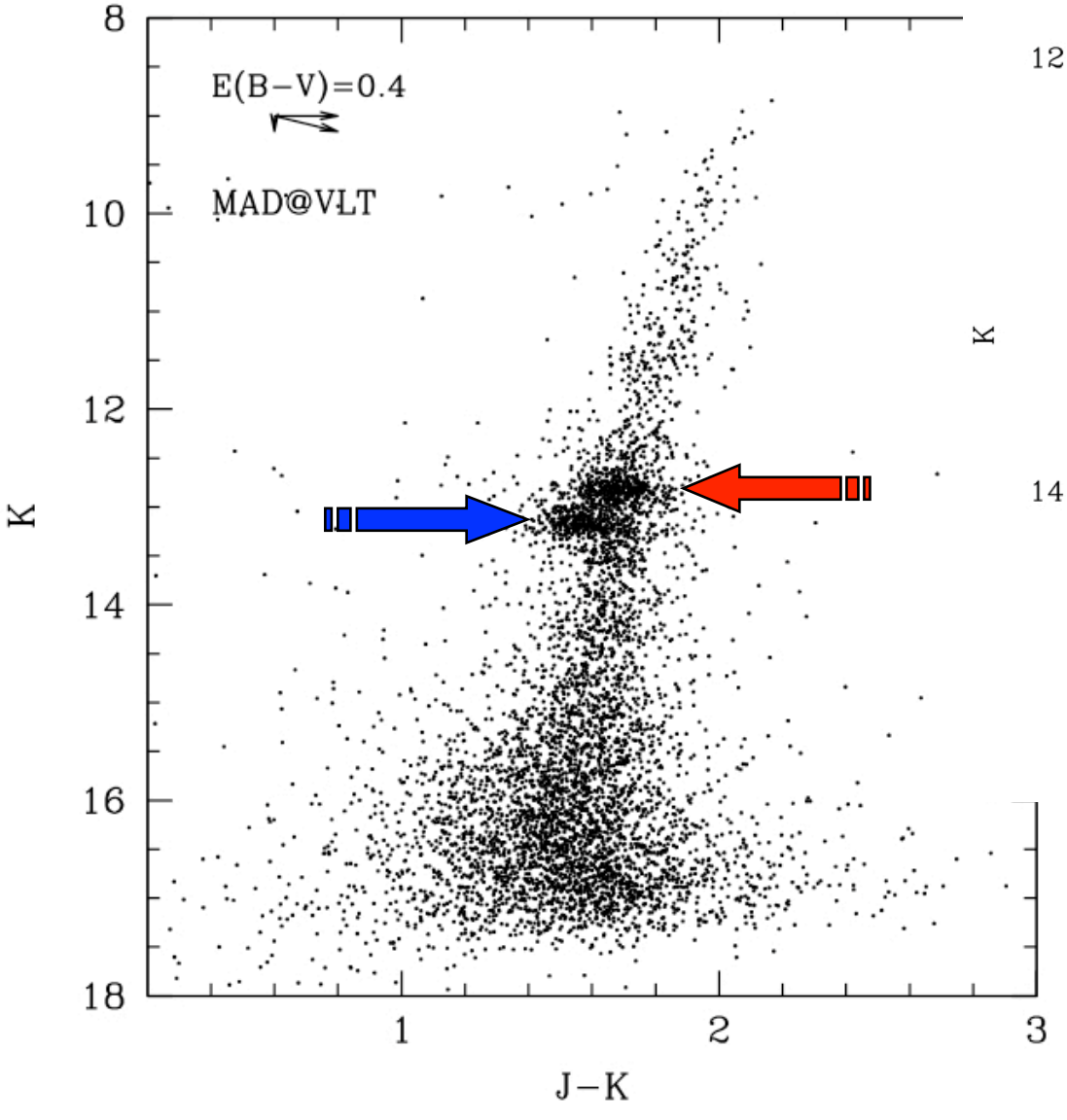
The incredibly sharp image in the K band obtained with MAD

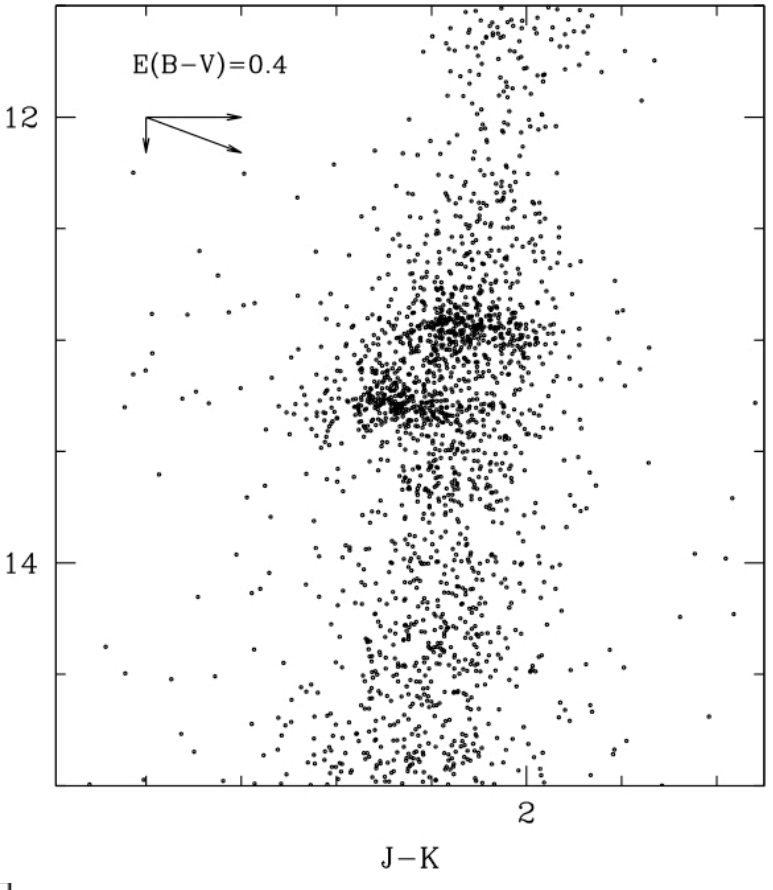




FWHM=100mas
By using
only 2 AOGS !!!!

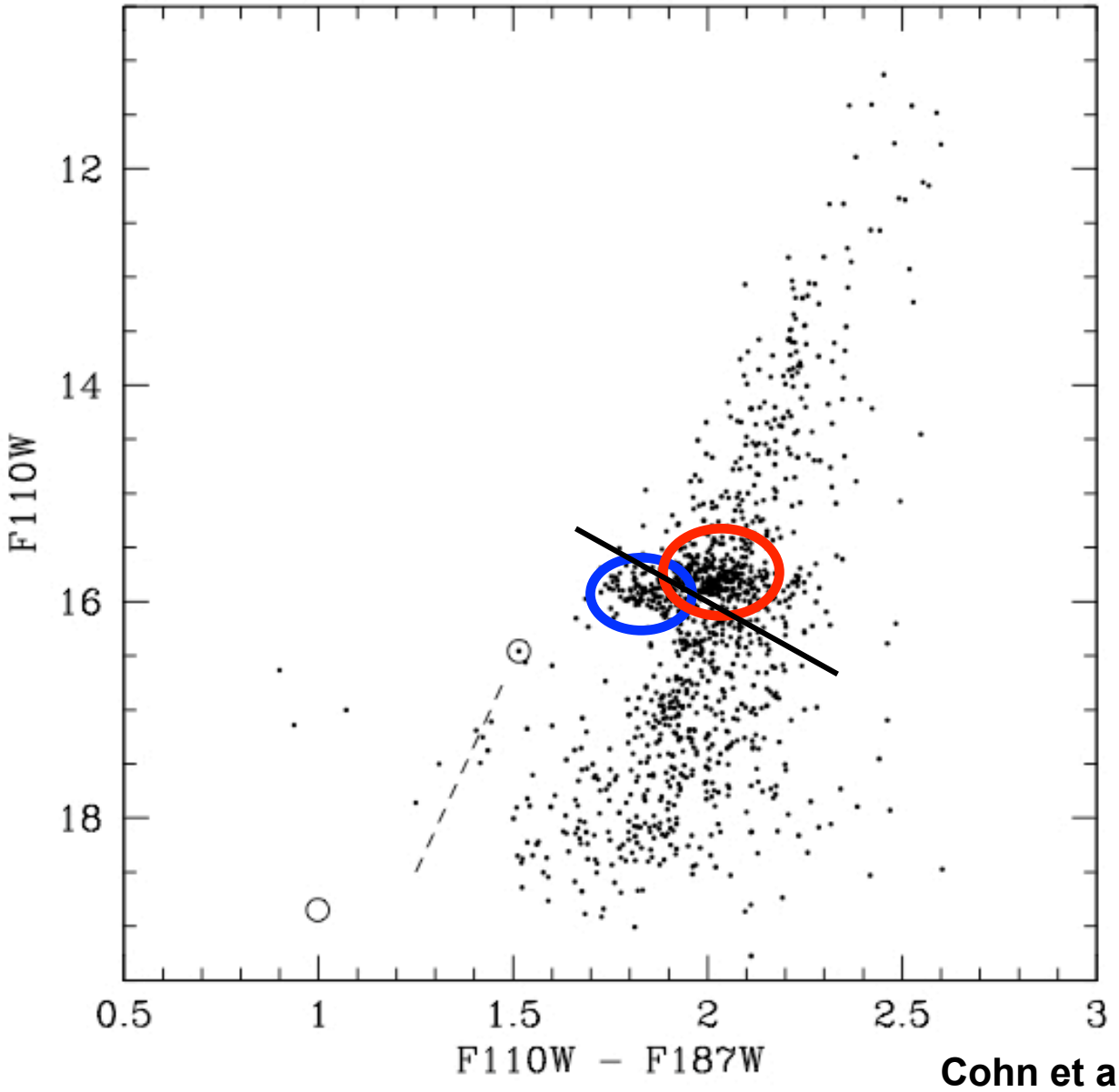
THE MAD CMD OF TERZAN 5



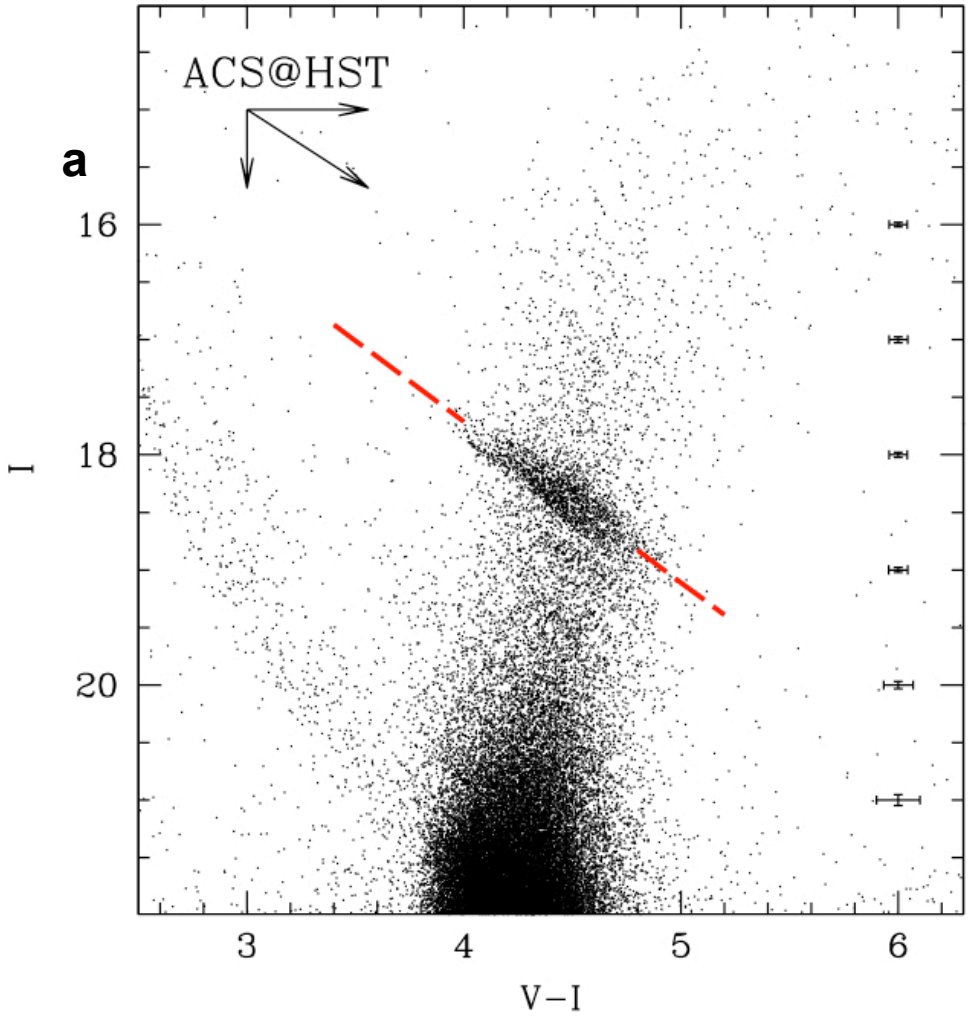


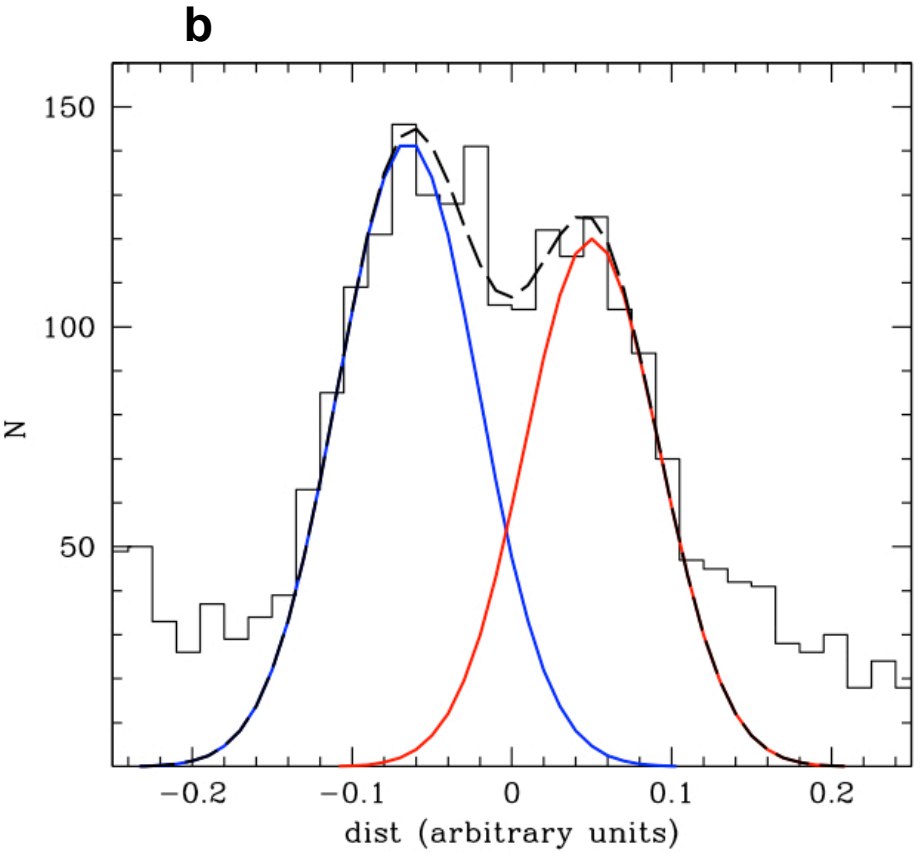
TWO HBs !!!

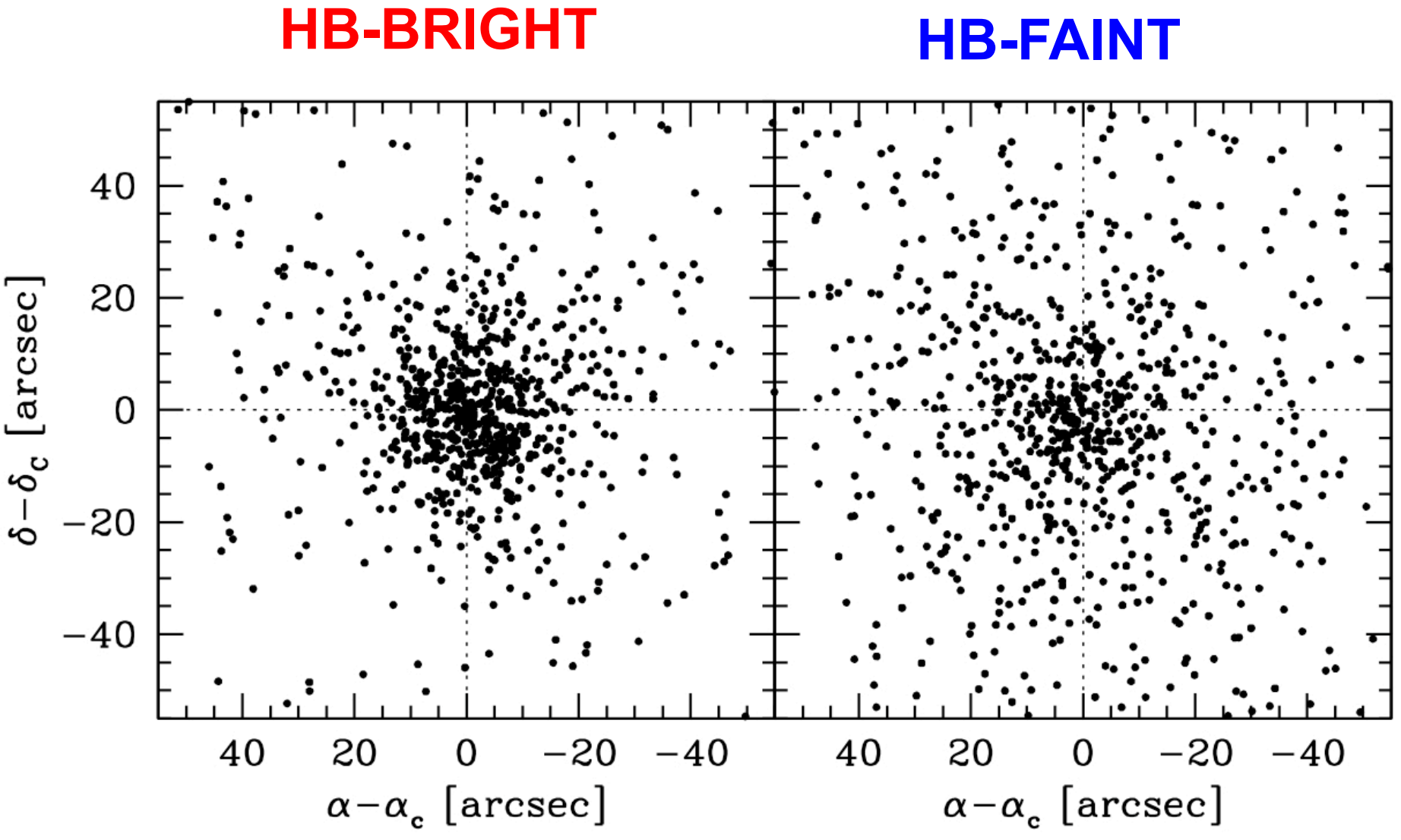
Ferraro et al (2009, Nature, 462, 483)



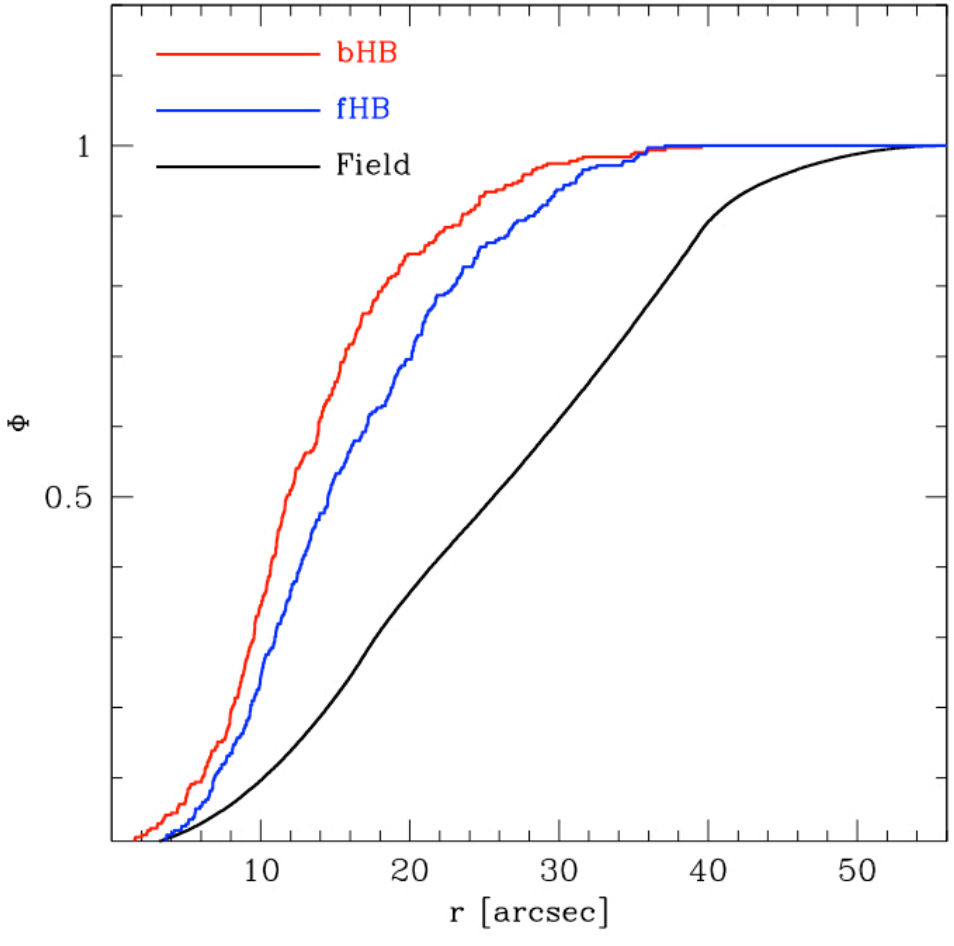
Cohn et al (2002, ApJ, 571, 818)

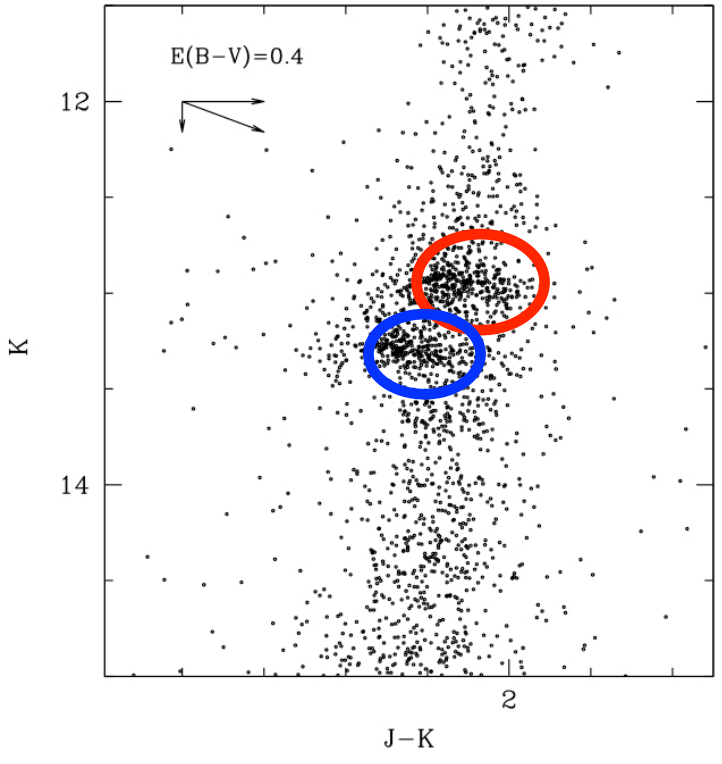

a
ACS@HST
16
18
20
I
3
4
5
6
V−I


b
150
100
50
N
−0.2
−0.1
0
0.1
0.2
dist (arbitrary units)



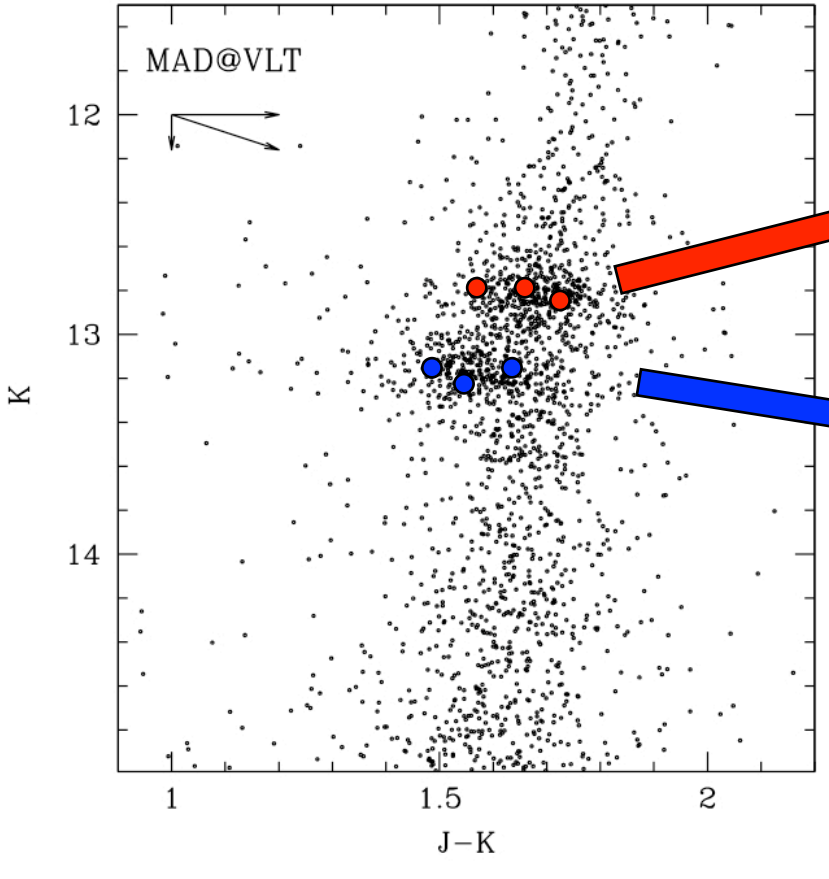
Lanzoni et al. (2010)





THE BRIGHT-HB POPULATION IS MORE CENTRALLY SEGREGATED THAN THE FAINT-HB ONE

NIRSPEC @ Keck II observations of HB stars (in the **bHB** and **fHB**)

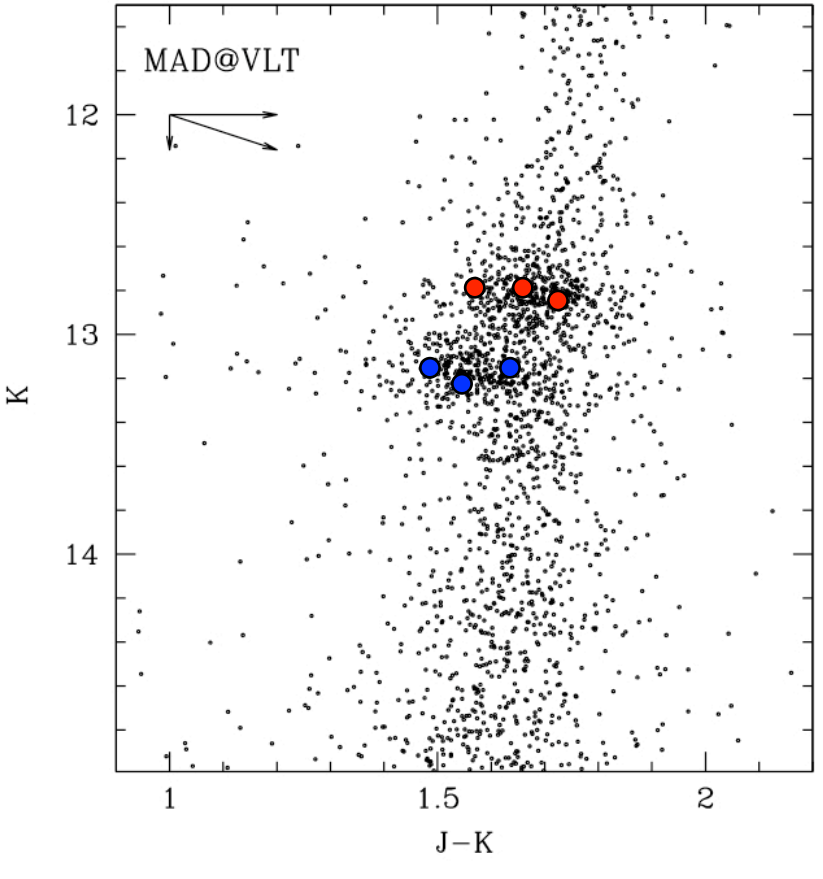


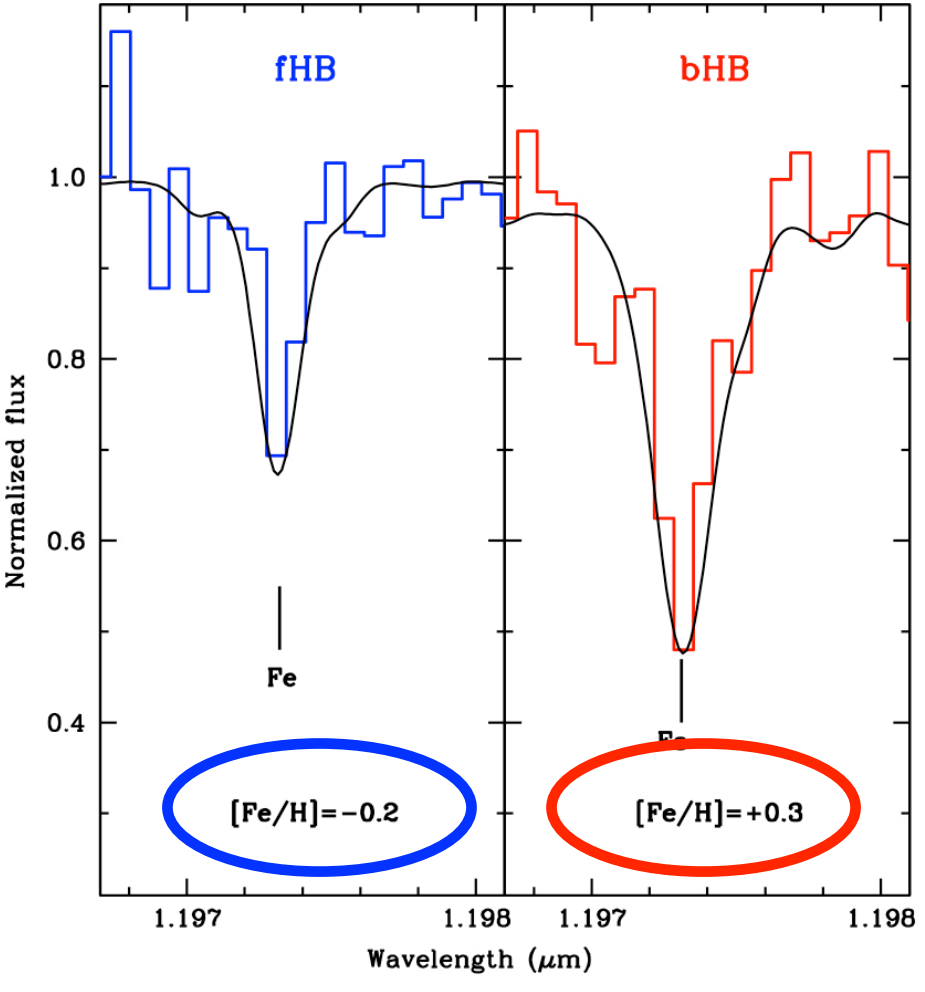
V_{rad} = -85 Km/s (σ=10 Km/s)

V_{rad} = -85 Km/s (σ=9 Km/s)

The two populations belong to the same stellar system

NIRSPEC @ Keck II observations of HB stars (in the **bHB** and **fHB**)



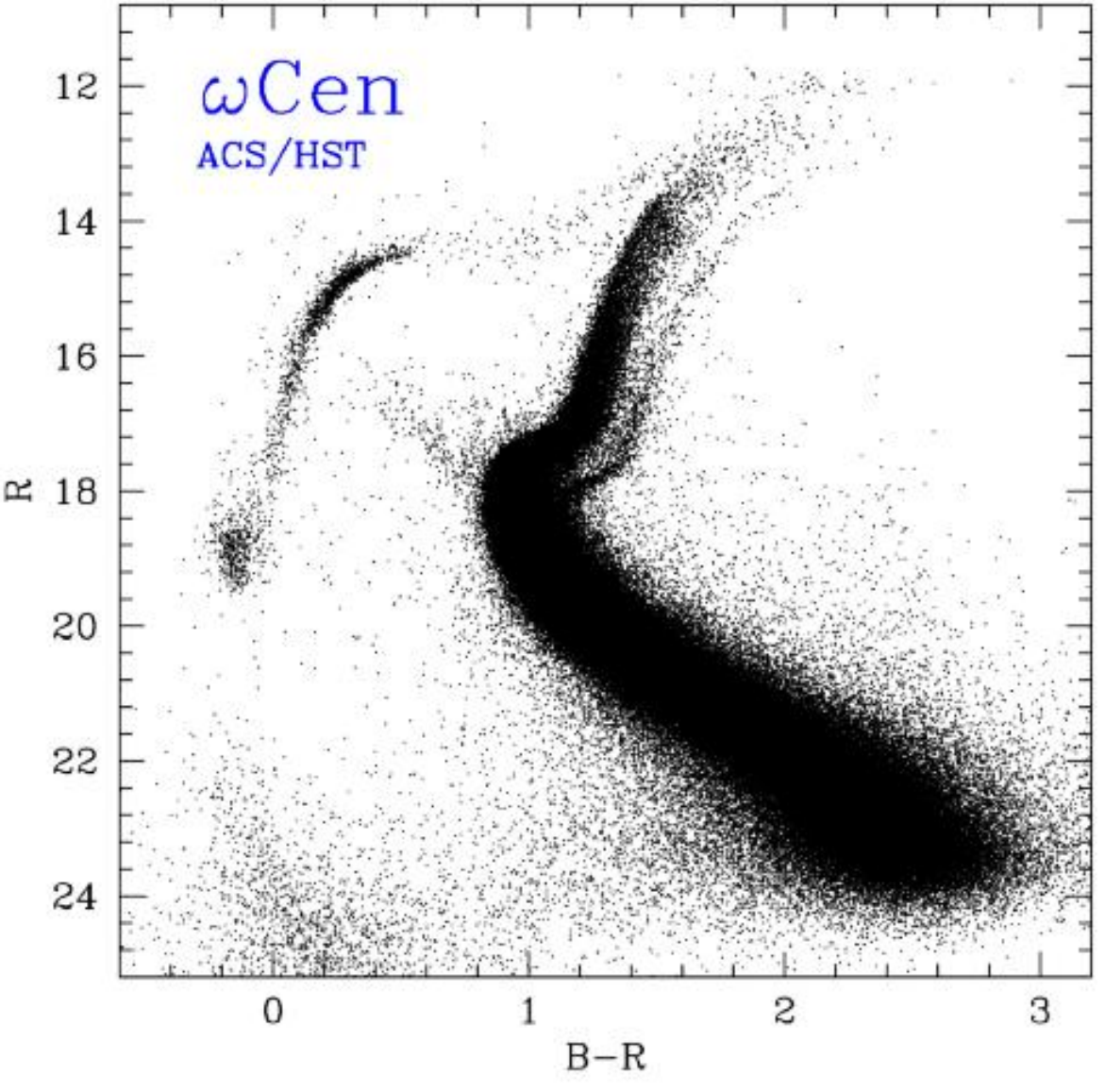


The two populations have different Iron abundance !!!

This is quite exceptional since NO GENUINE cluster has been found to harbor stars with such a large difference (Δ[Fe/H]>0.5 dex) in Iron abundance

The only known example is OMEGA CENTAURI in the galactic Halo which is considered to be the remnant of a larger structure

TERZAN 5 IS NOT A GENUINE GC



Spectroscopic screening of Ter5

NIRSPEC @ Keck II near-IR spectroscopy at R @ 25,000

Chemical abundances for 33 Red Giant Stars

Table 2

Average Abundance Ratios of the Two RGB Populations in Terzan 5

Abundance Ratio	Metal-poor Population	Metal-rich Population
[Fe/H]	-0.25 ± 0.07	$+0.27 \pm 0.04$
[O/Fe]	$+0.34 \pm 0.06$	-0.04 ± 0.04
[Ca/Fe]	$+0.32 \pm 0.05$	$+0.02 \pm 0.03$
[Si/Fe]	$+0.36 \pm 0.08$	$+0.02 \pm 0.10$
[Mg/Fe]	$+0.33 \pm 0.10$	$+0.08 \pm 0.06$
[Ti/Fe]	$+0.34 \pm 0.10$	$+0.06 \pm 0.06$
[Al/Fe]	$+0.52 \pm 0.13$	$+0.13 \pm 0.13$
[C/Fe]	-0.35 ± 0.12	-0.38 ± 0.08

Origlia et al (2010, ApJ, 726, L20)

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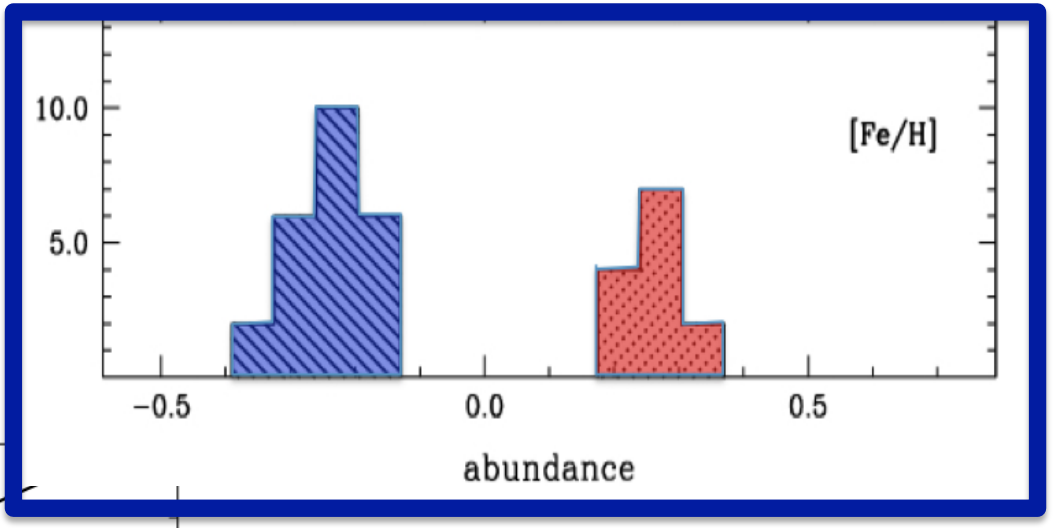
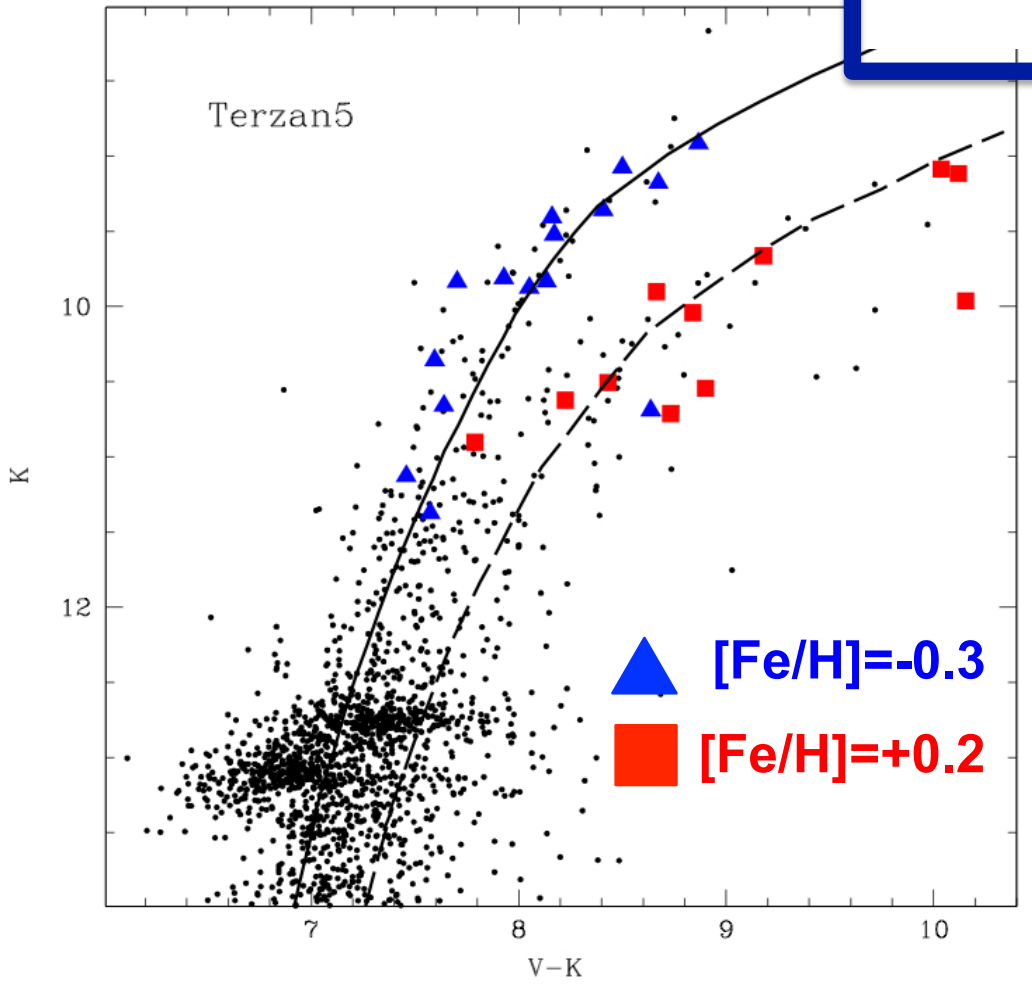
Spectroscopic screening of Ter5





[Fe/H]:

-0.25 +/- 0.07

+0.27 +/- 0.04

Δ[Fe/H] ≅ 0.5

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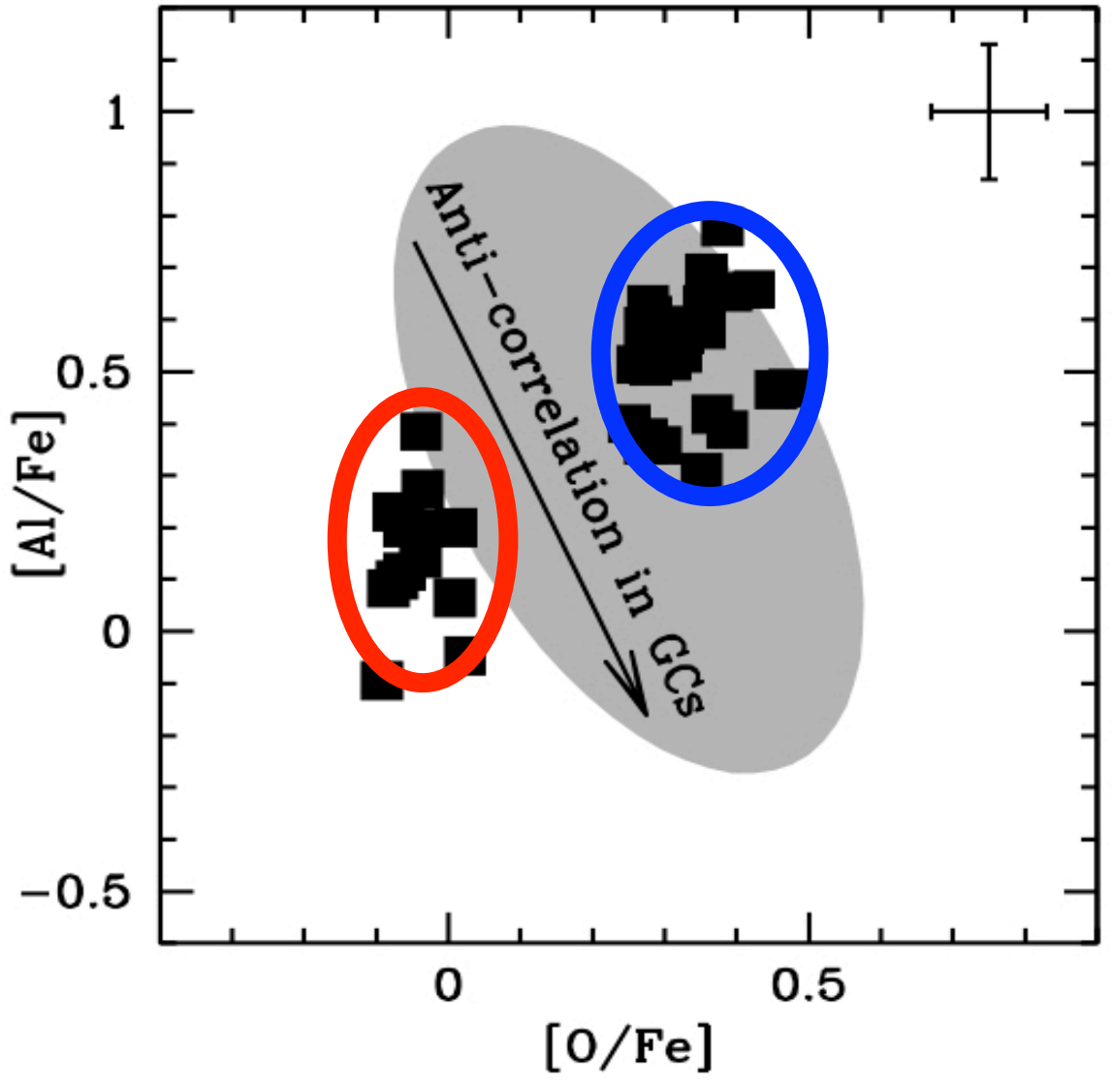
The two populations do **NOT** show any evidence of the Al-O anti-correlation that is typically observed in GCs



TERZAN 5 IS NOT A GENUINE GC

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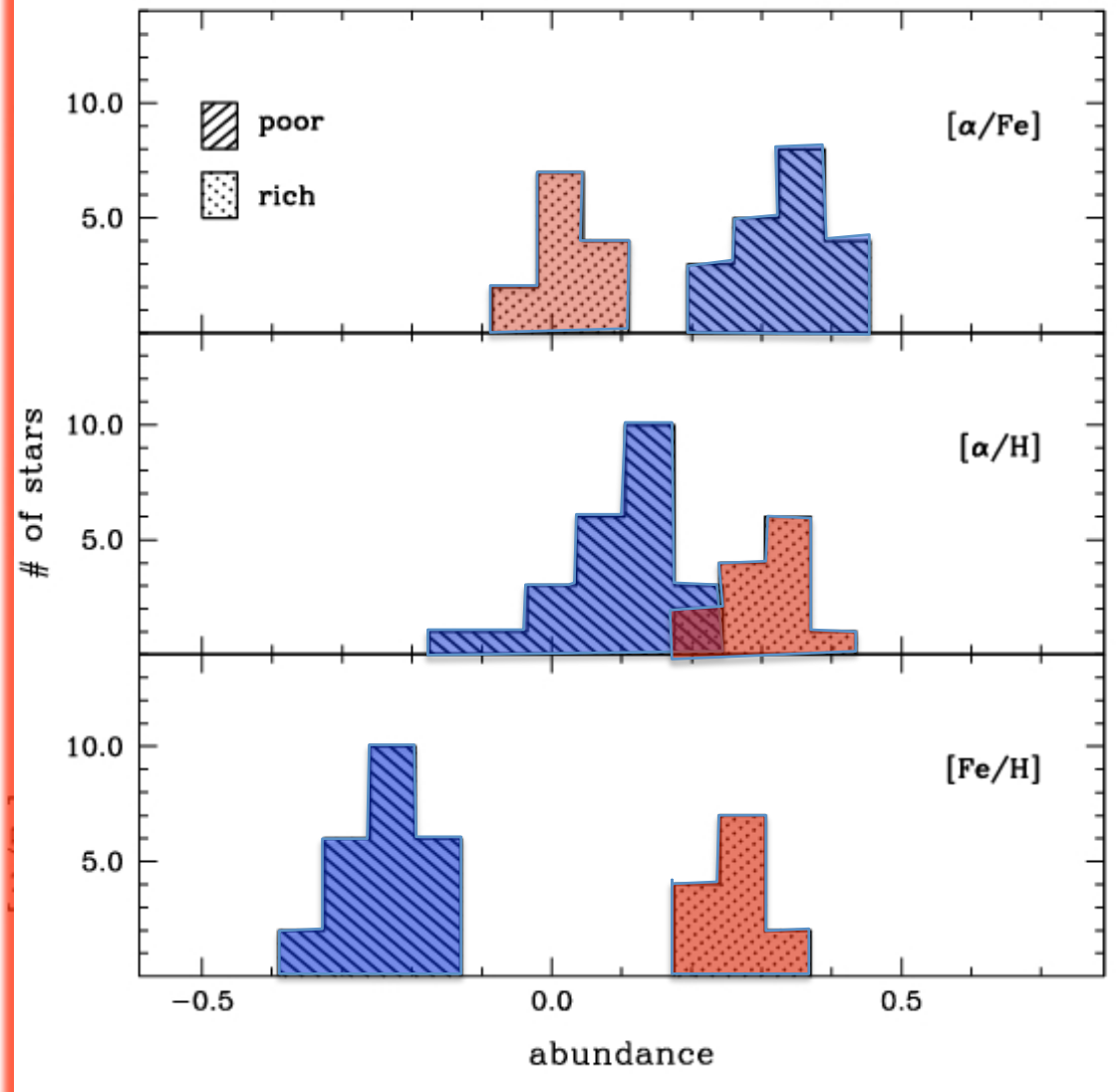
Spectroscopic screening of Ter5: chemistry



[α/Fe]:

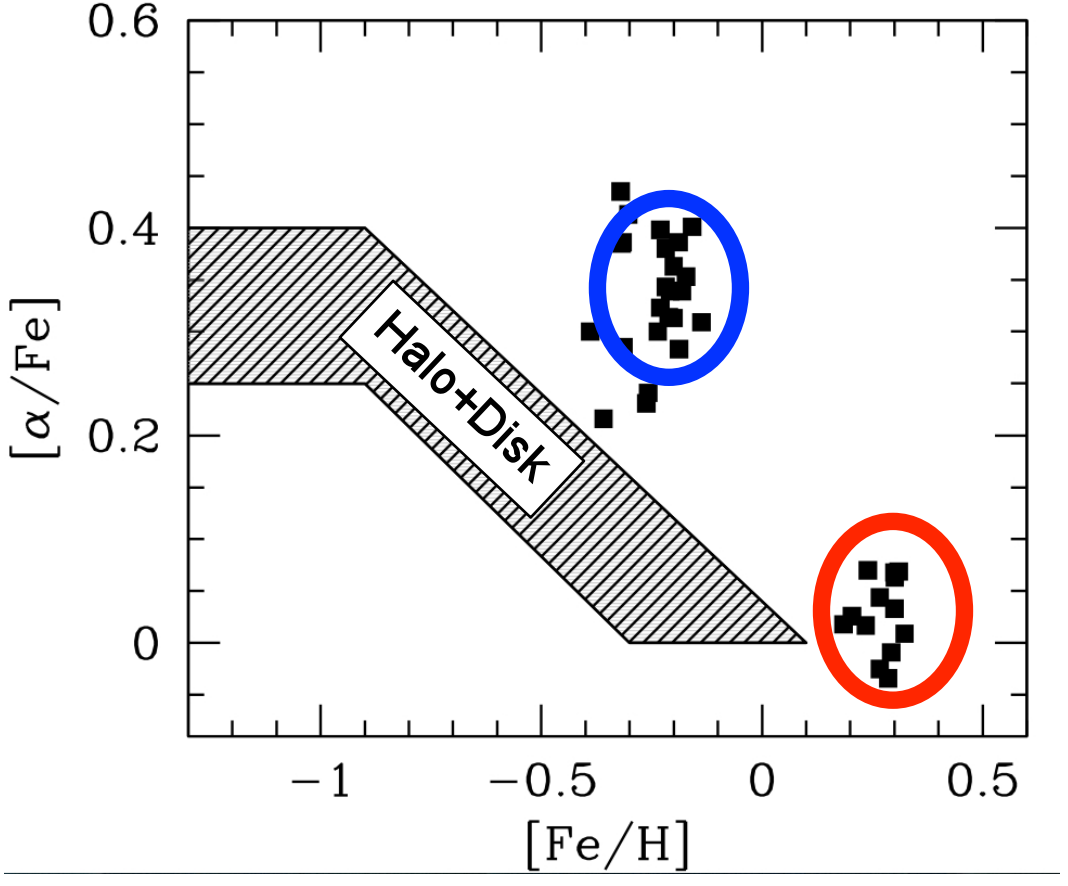
+0.34 +/- 0.06

+0.03 +/- 0.04

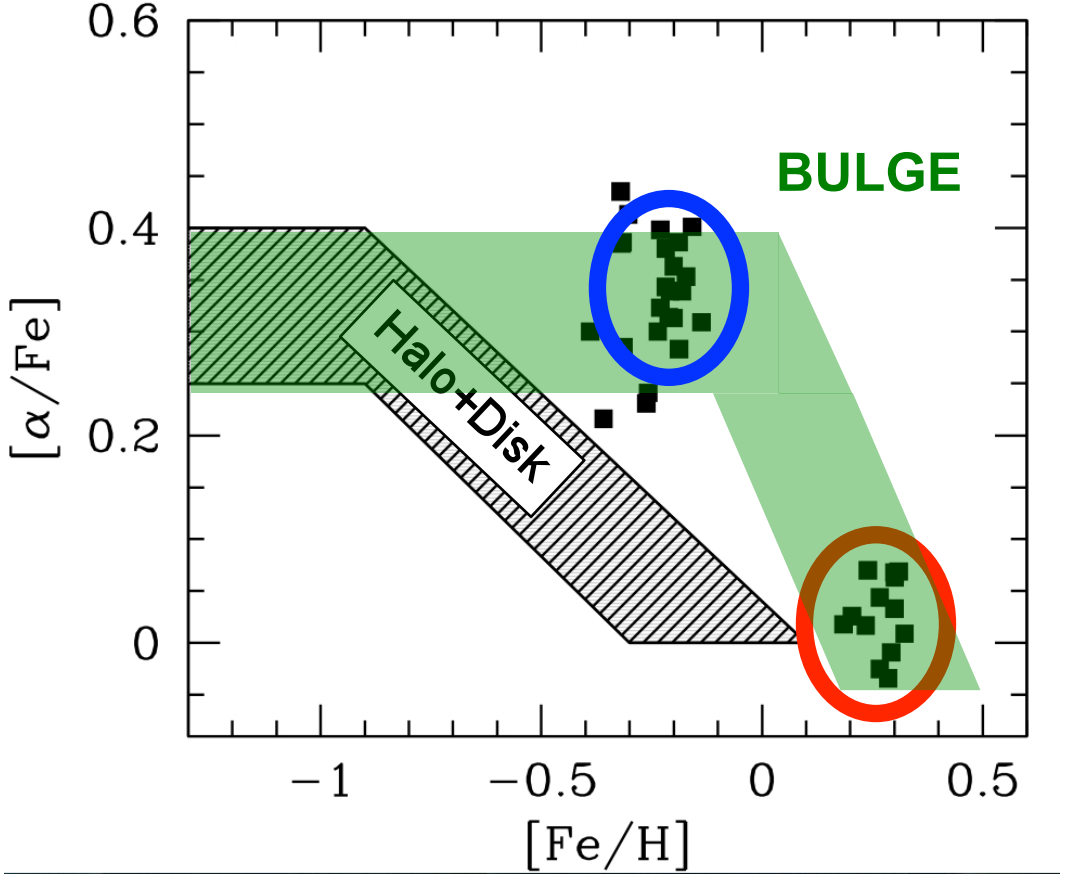
Δ[α/Fe] ≅-0.3

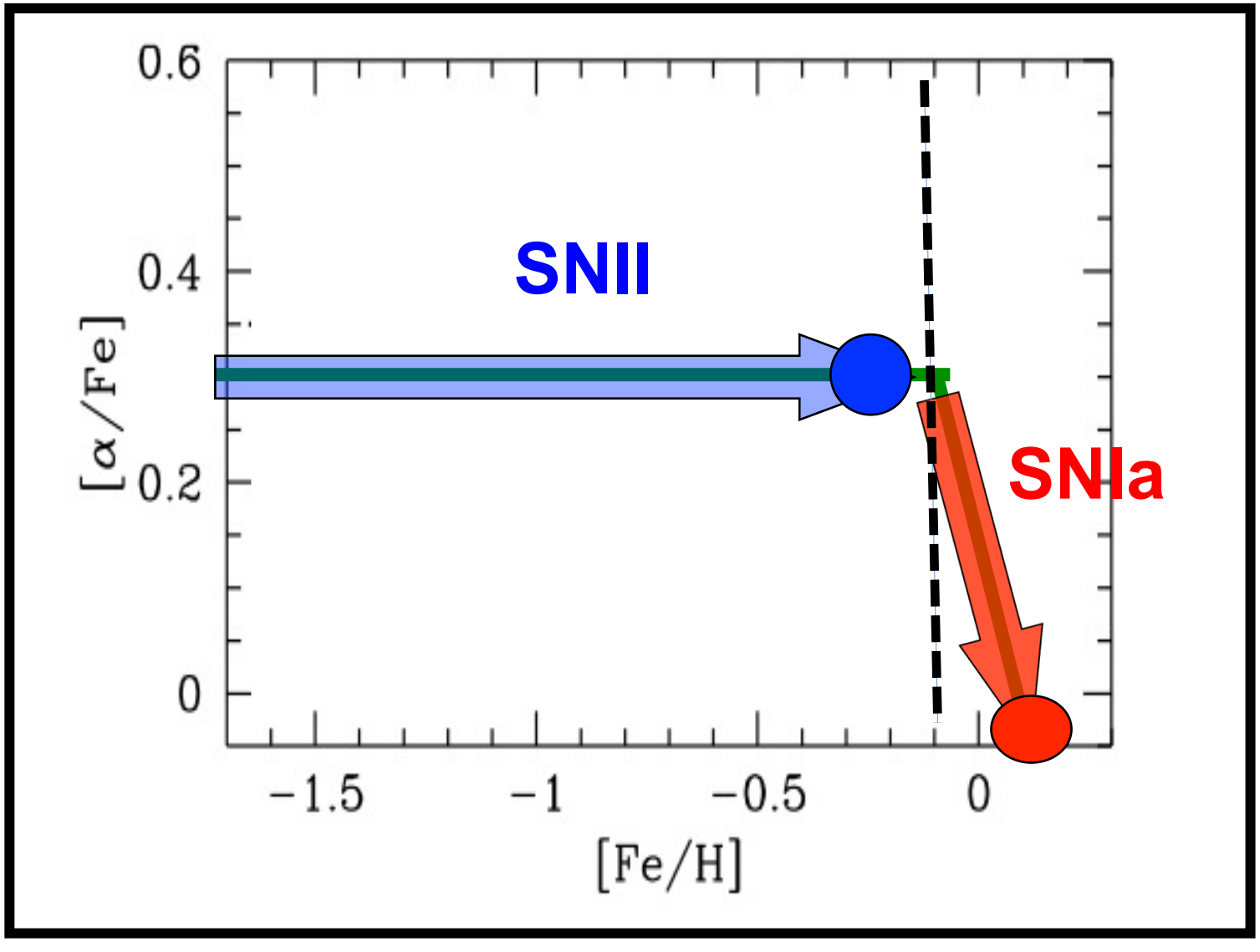
Δ[α/H] ≅0.2

The chemistry of the two stellar populations in Ter5 is completly different from that observed in the Halo and Disk of the Galaxy

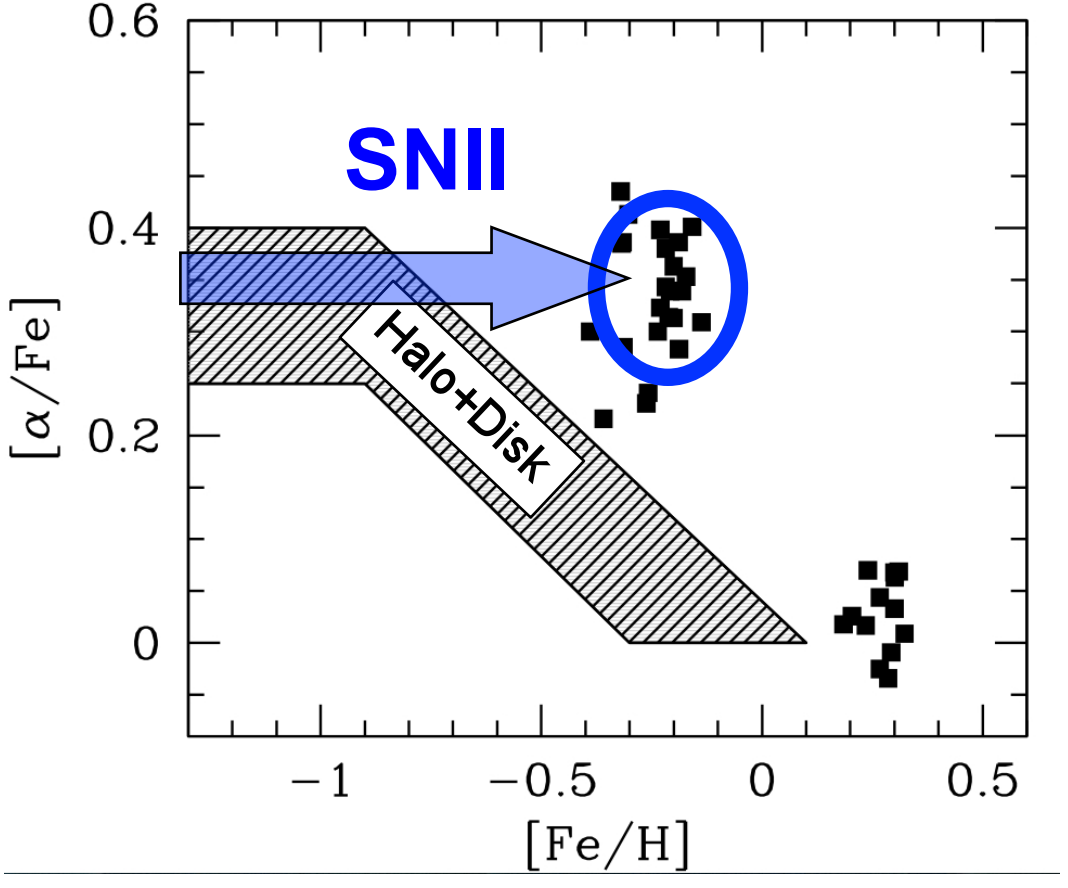


Iron and alpha –elements abundance are similar to those measured in the **Bulge**, thus suggesting **quite similar star formation and chemical enrichment processes**

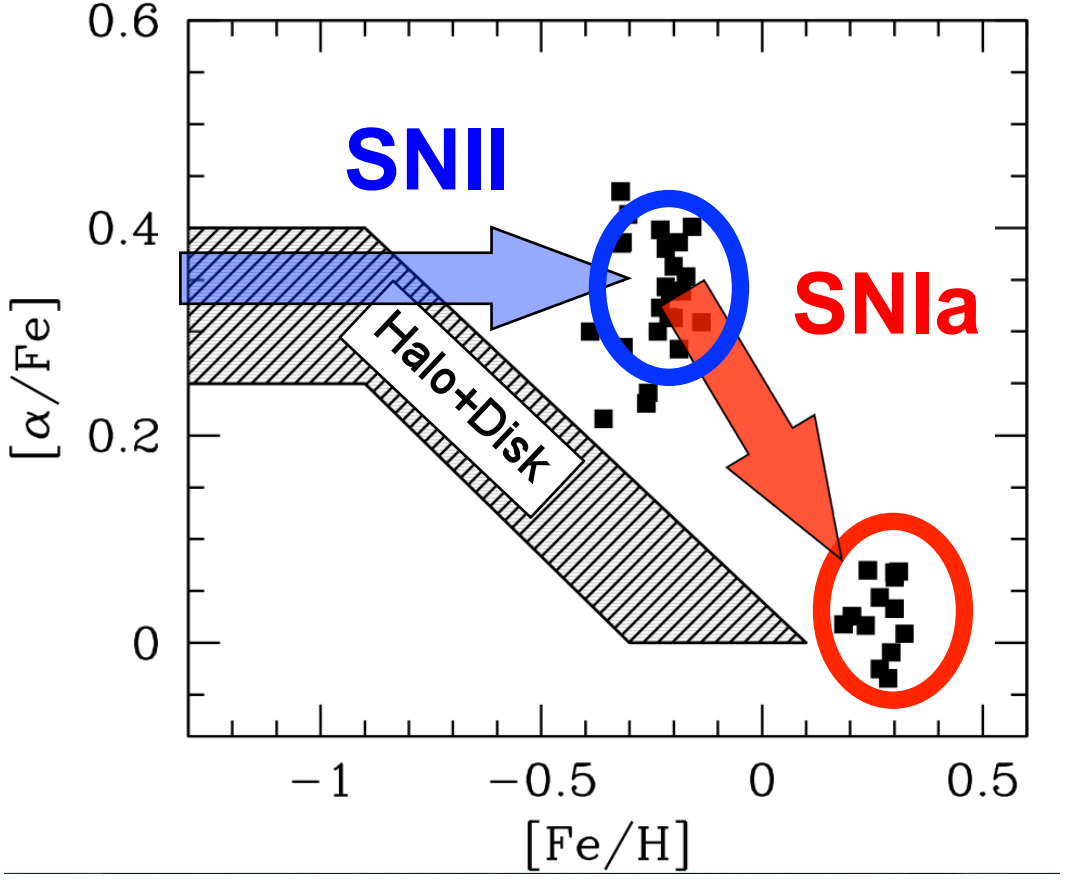



SNII
SNIa
0.6
0.4
0.2
0
[α/Fe]
−1.5
−1
−0.5
0
[Fe/H]

The chemistry of the **“metal-poor”** component of Terzan 5 shows that it formed from a gas which was polluted by **Type II SNe** ejecta



The chemistry of the **metal-rich** component of Terzan 5 shows that it formed from a gas which was polluted by **Type Ia SNe** ejecta (over a large time-scale)



The observational facts demonstrate that Terzan 5 has experienced a quite complex formation history:

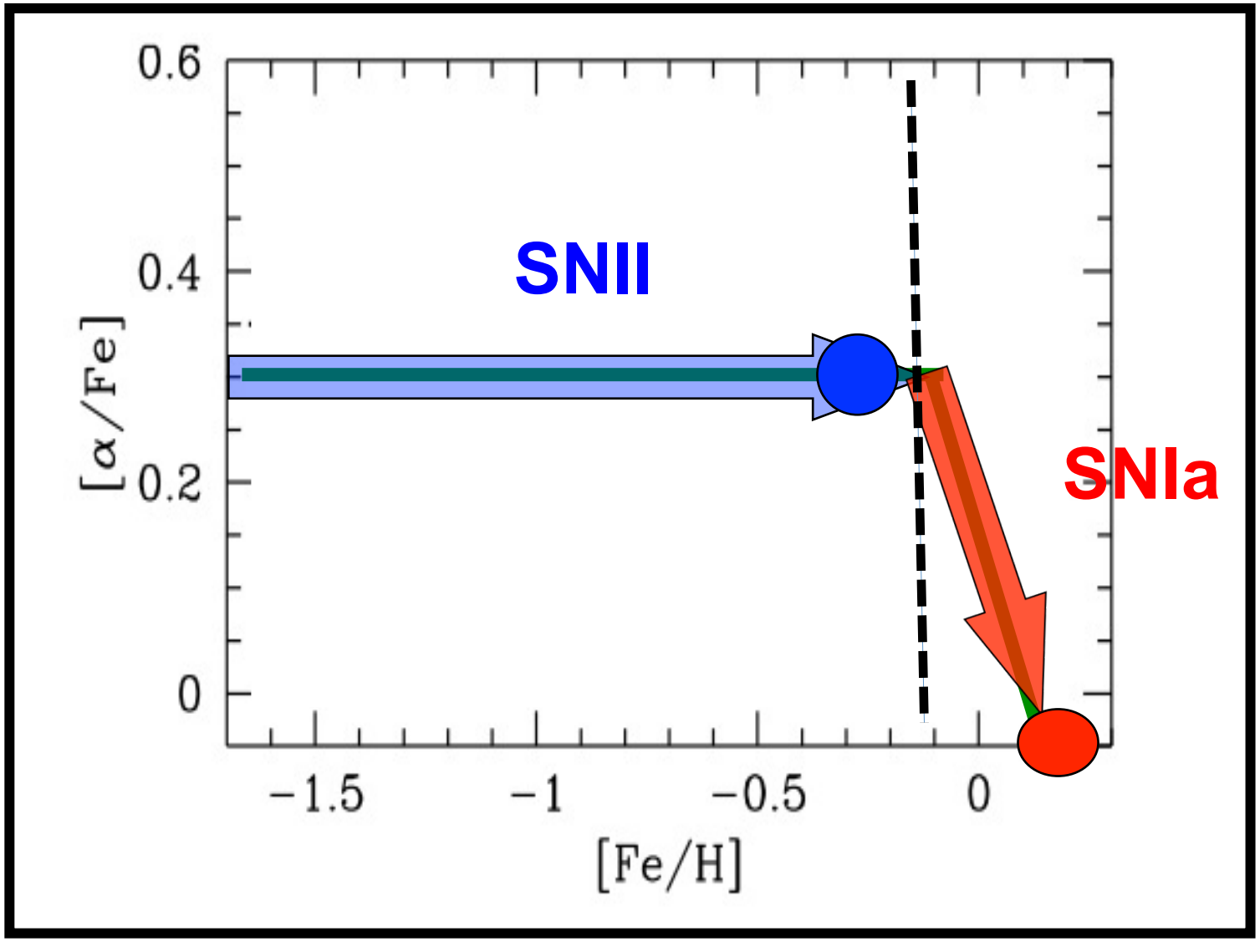
1. IT IS NOT A GENUINE GC

The significant iron abundance (Δ[Fe/H] =0.5 dex) measured in the two populations and the light elements abundance patterns (the Al-O CORRELATION!) demonstrate that it is **NOT** a genuine globular

2. IT IS A STELLAR SYSTEM SELF-ENRICHED IN IRON.

Hence it should have been much more massive in the past than what observed now (in order to retain the SN ejecta). We estimate that the current mass of Terzan 5 is a few 10^6 Mo.
It is the relic of a large stellar system (like Omega Cen).

3. However it is unlikely that Terzan 5 is a system "accreted" from outside the Galaxy, since the chemical composition of the two Populations are similar to that measured in Bulge stars, thus suggesting a Terzan5-Bulge "common" evolution
(**Is Terzan 5 a pristine fragment of the bulge?**)



Chemical evolution models for the Galactic Bulge (i.e.Ballero et al 2007) suggest that this trend can be reproduced by a high SFR and a flat IMF .. i.e. with a large number of SNII !!!

4. The assumption of a similar scenario for TERZAN5 would naturally explain the large number of MSP

Many SNII == Many NS
+ high collision rate == many recycled NS ==
Many MSP

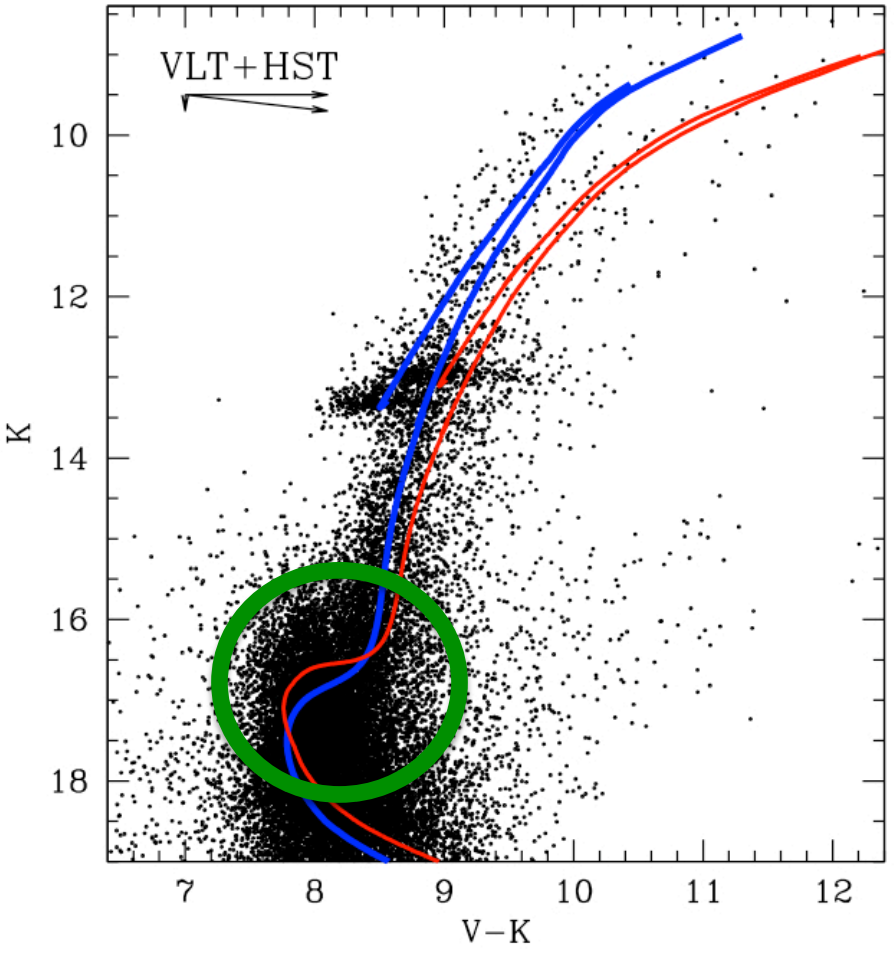
working hypothesis

AGE & METALLICITY

Ter5 is the remnant of a pristine fragment that contributed to build the Galactic Bulge and that survived the total disruption

The old, metal poor component could trace the early stages of the Bulge formation

The younger (?) metal-rich one could contain crucial information on the Bulge most recent chemical & dynamical evolution

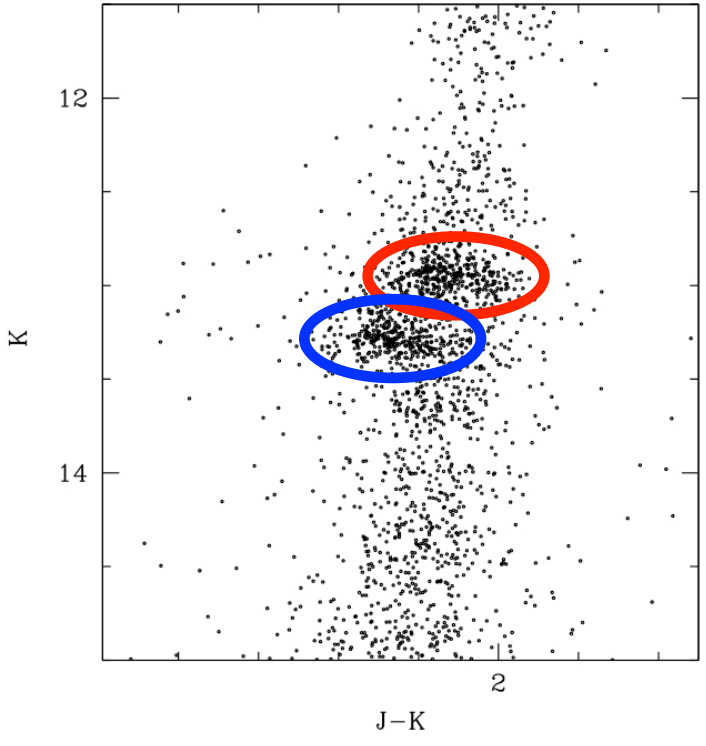


Z=0.01 t=12 Gyr

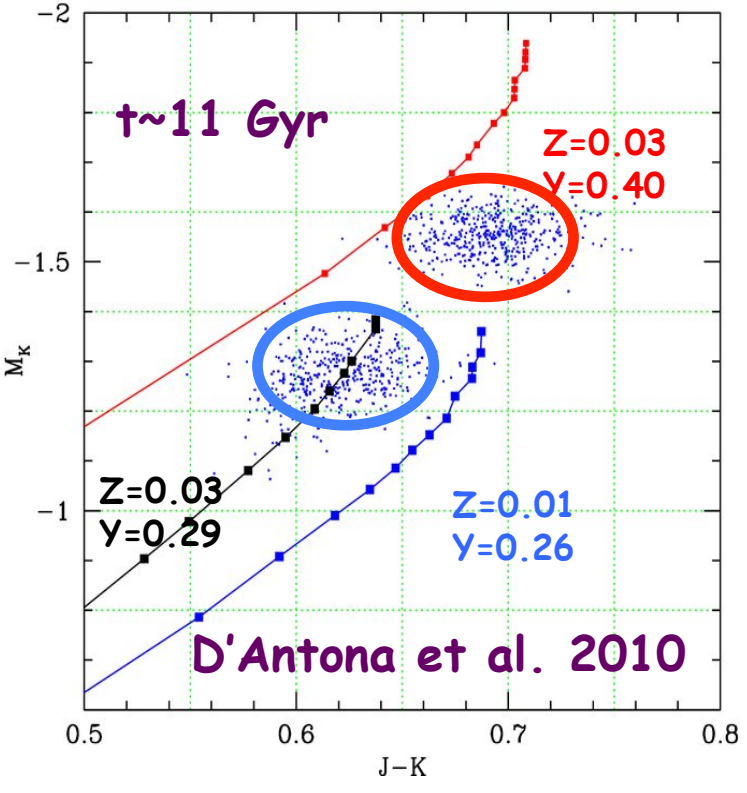
Z=0.03 t=6 Gyr

Z=0.01

Z=0.03



He effect …



In the attempt of interpreting the iron anomalies discovered in Terzan 5 into the framework of the scenario adopted for GCs, D'Antona et al (2010) suggested a possible difference in Helium abundance

However, the models do not reproduce the correct observed colors of the two clumps; higher Y for the bright HB implies lower mass making difficult to explain its central segregation compared to the faint HB

We are now leading a number of projects aimed at:

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 signatures (second epoch ACS planned in HST-Cycle 20)**

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

POTENTIAL WELL OF THE ORIGINAL STELLAR SYSTEM

THEY DID NOT RETAIN THE SNe EJECTA

GLOBULAR CLUSTERS

Anticorrelations +
Δ [He,C,…/H] ≠ 0

Δ [Fe/H] = 0

THEY RETAINED THE SNe EJECTA

M 22
M54

ω Cen

Terzan 5

Δ [Fe/H] ≠ 0

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

The End