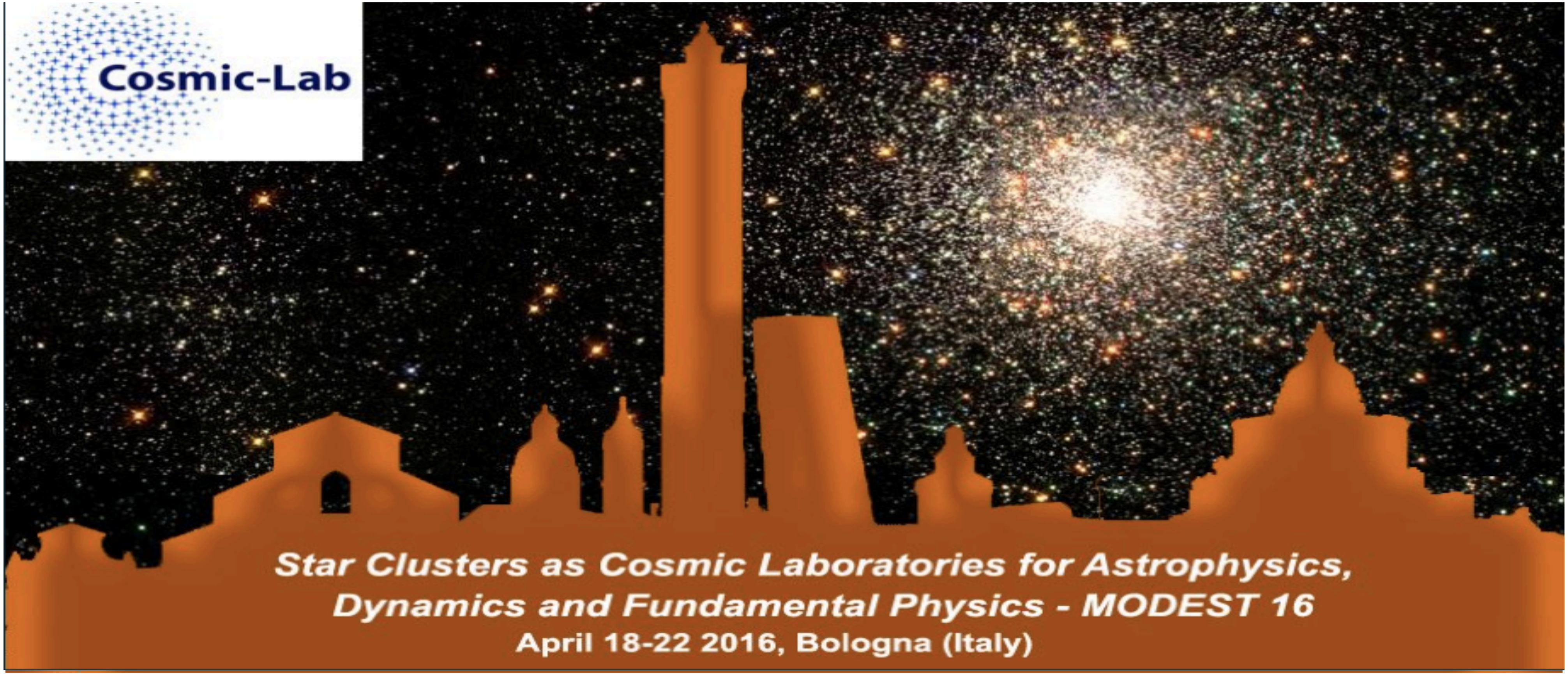

BSS in globular clusters: observational results

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Setting the dynamical clock

BSS
<u>more massive</u>
than normal stars

(Shara et al. 1997, Fiorentino et al 2014)

They are crucial gravitational probe-particles to test GC internal dynamical processes

BSS are heavy stars (M_{BSS} = 1.2-1.4 $M_{\odot}$) orbiting a "sea" of "normal" light stars (M_{mean} = 0.4 $M_{\odot}$): they are subject to **dynamical friction** that progressively makes them sink toward the cluster center

The **df** time-scale depends on:

(1) Star mass **(2) Local cluster density**

$$t_{df} \approx \frac{1}{M_{BSS}\,\rho(r)}$$

df is expected to affect, first, the most internal BSS and then BSS at progressively **larger distances from the center,** as function of time

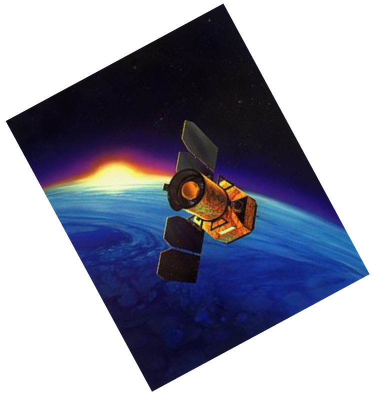
we need the radial distribution of these heavy objects along the entire cluster extension

The BSS RADIAL DISTRIBUTION: the general approach

✓ **central regions** (high-density): **high-resolution (UV + optical)**

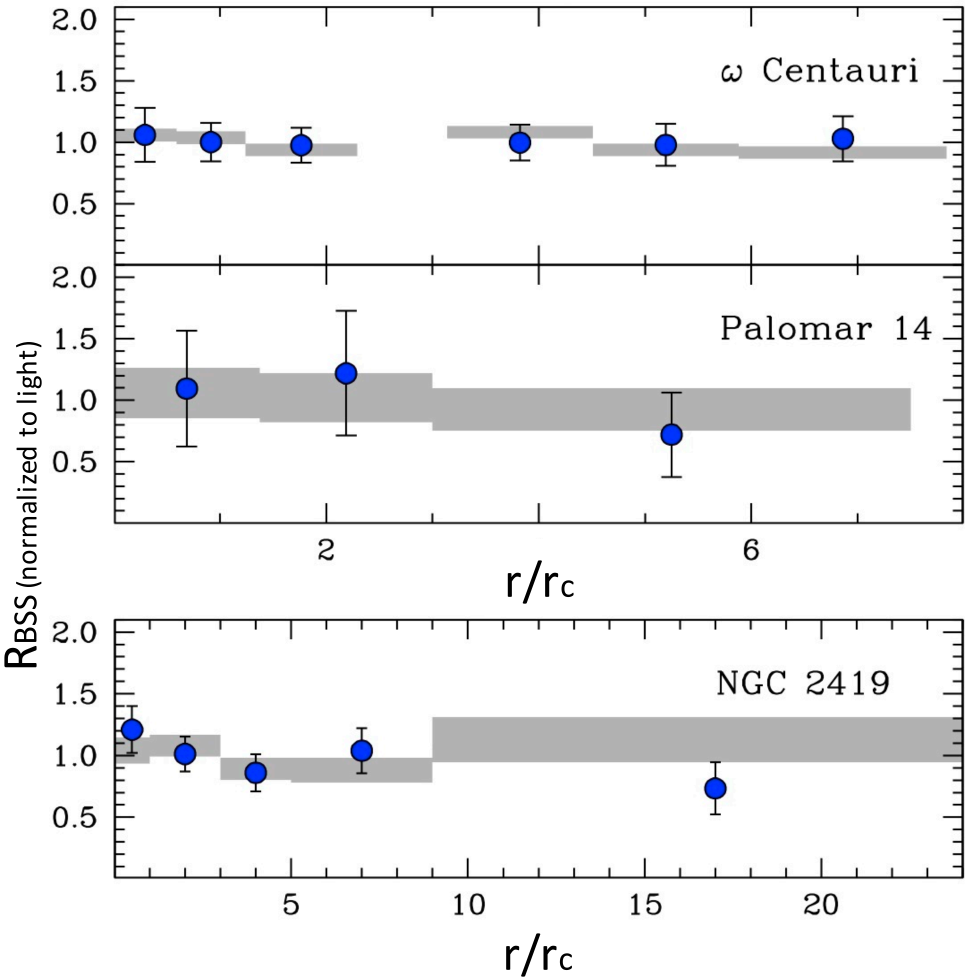
HST (WFPC2, ACS, WFC3)

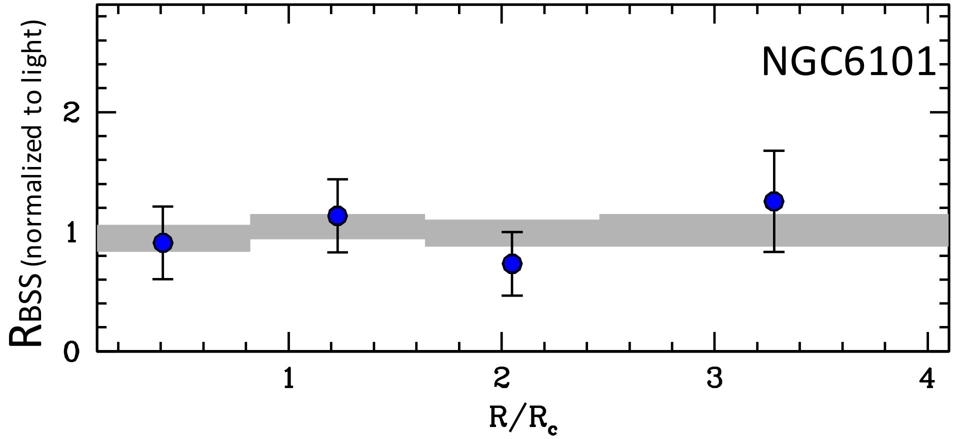
✓ **external regions** (large extension): **wide-field capabilities**



- **optical: ground-based** (ESO-WFI, Megacam)
- **UV: GALEX**

Family I: flat radial distribution



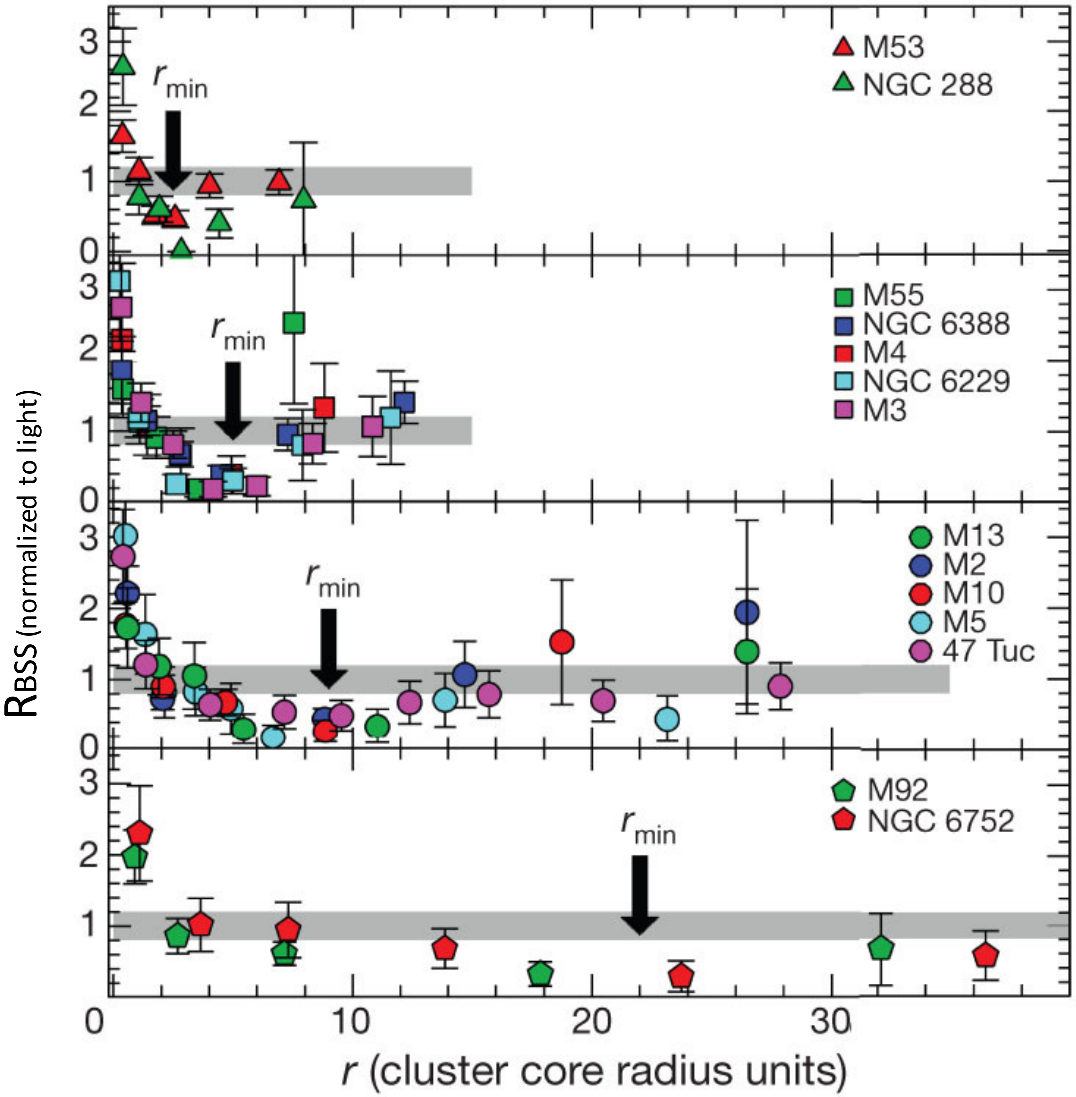


Ferraro et al. 2006; Beccari et al. 2011
Dalessandro et al. 2008, 2015

dynamical friction has not affected the BSS distribution yet, not EVEN in the cluster center

Family I: dynamically young GCs

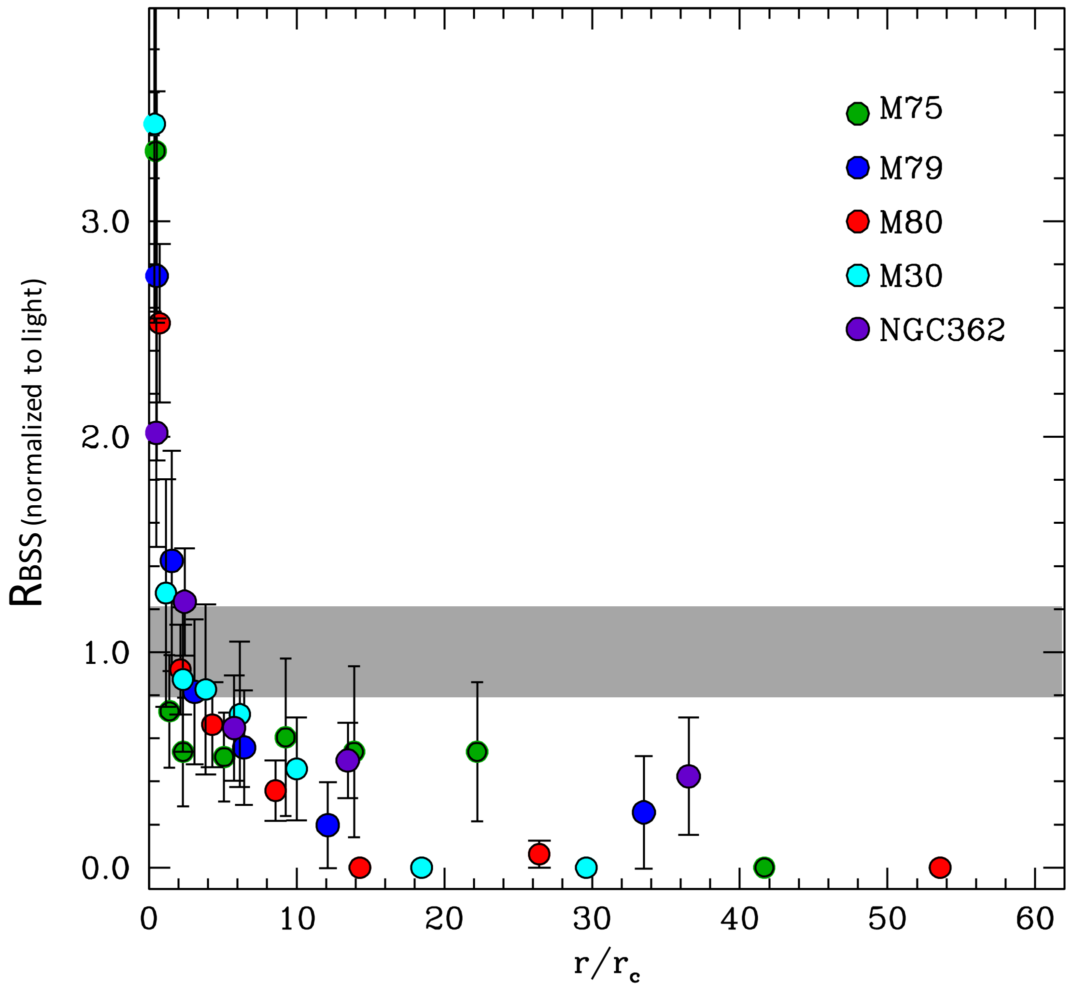
Family II: bimodal radial distribution



df is effective in segregating BSS, starting from those at shorter distances from the cluster center

Family II: intermediate dynamical age

Family III: unimodal distribution

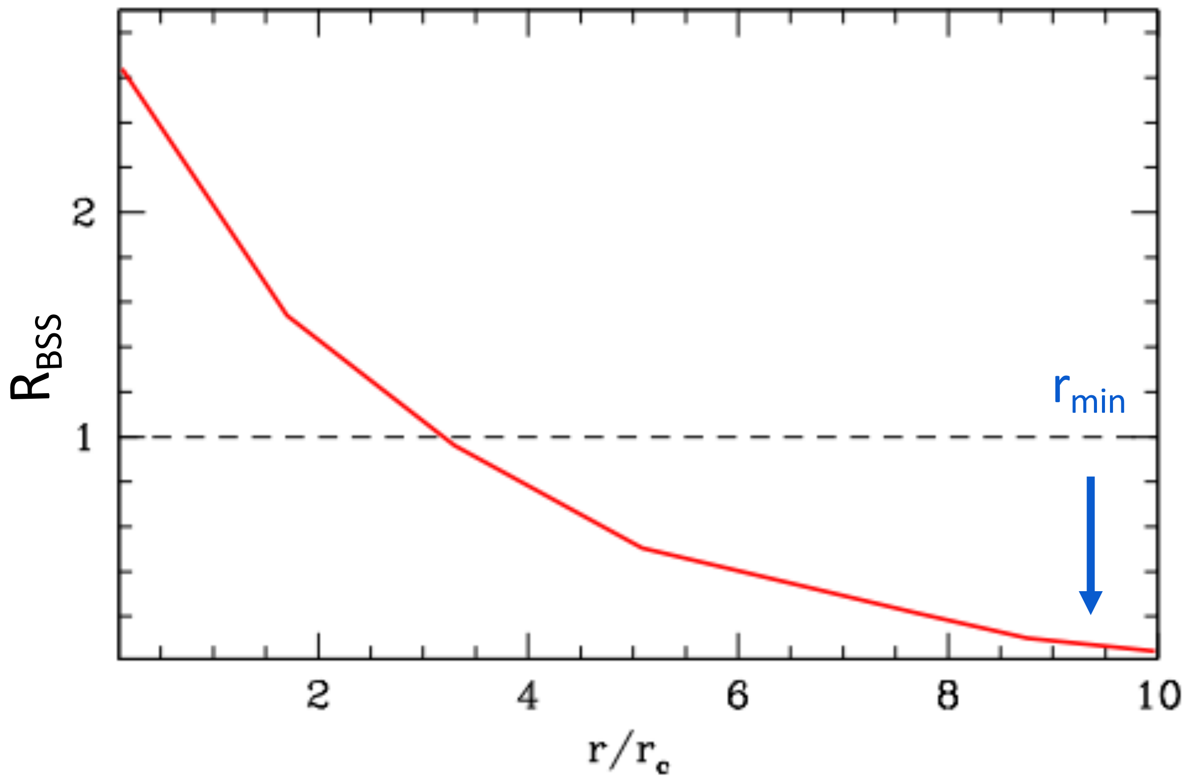


The BSS distribution is **unimodal** with a well defined peak at the cluster center but no rising branch

df has segregated ALL the BSS, even the most remote ones. The external rising branch disappears

Family III: dynamically old clusters

The dynamical clock

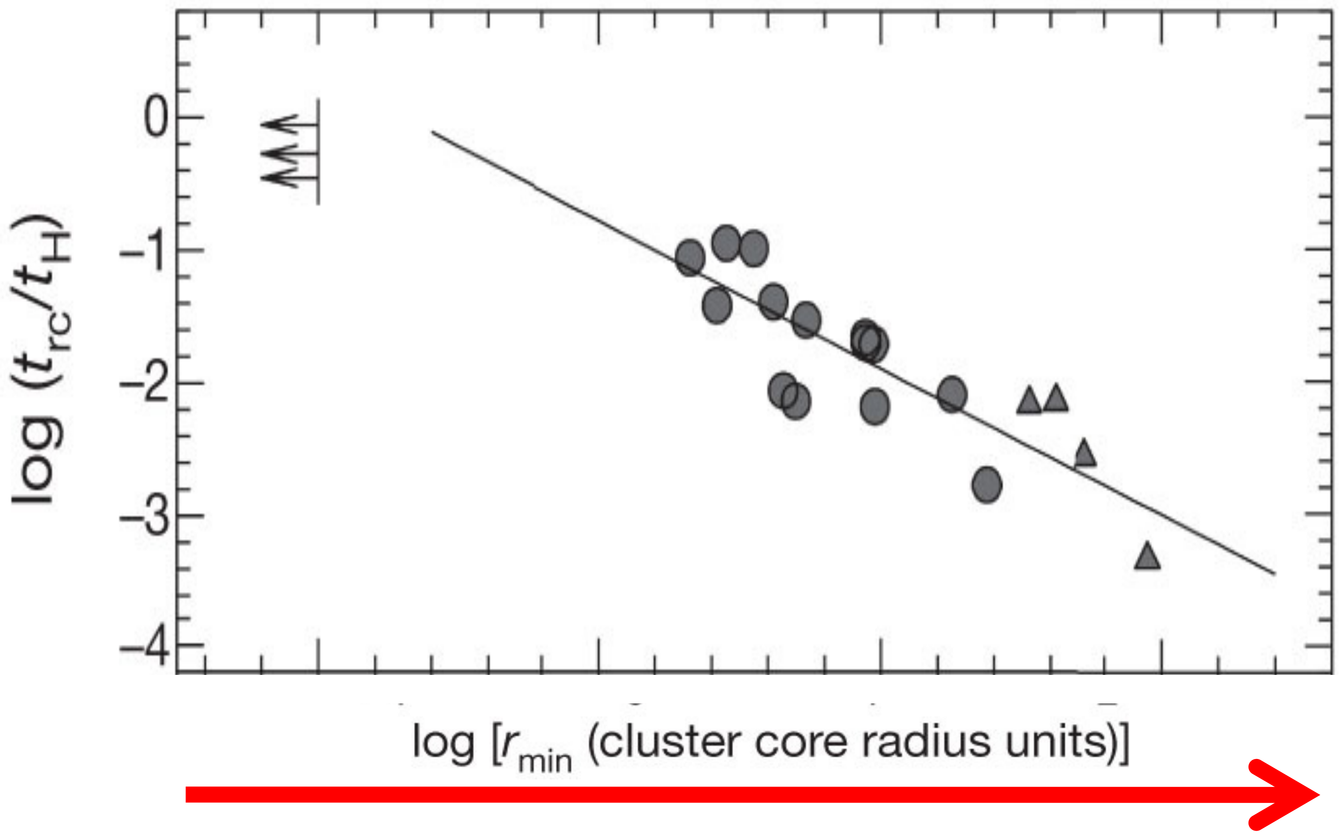


As the engine of a chronometer advances a clock-hand to measure the flow of time, in a similar way **dynamical friction** moves the minimum outward measuring the dynamical age of a stellar system

The dynamical clock

A fully empirical tool able to rank stellar systems in terms of their dynamical age

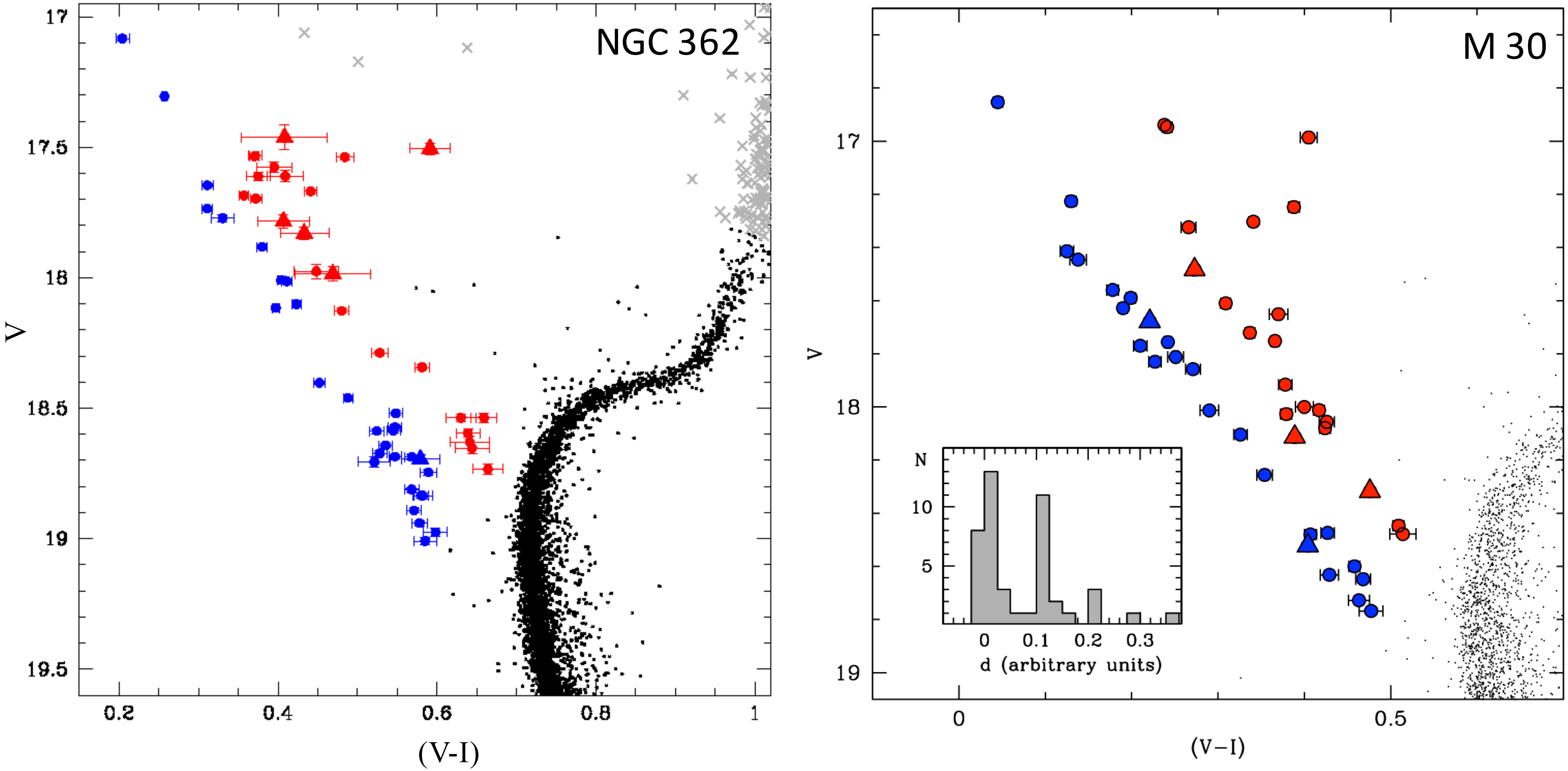
Ferraro et al (2012)



Increasing dynamical age

BSS double sequences

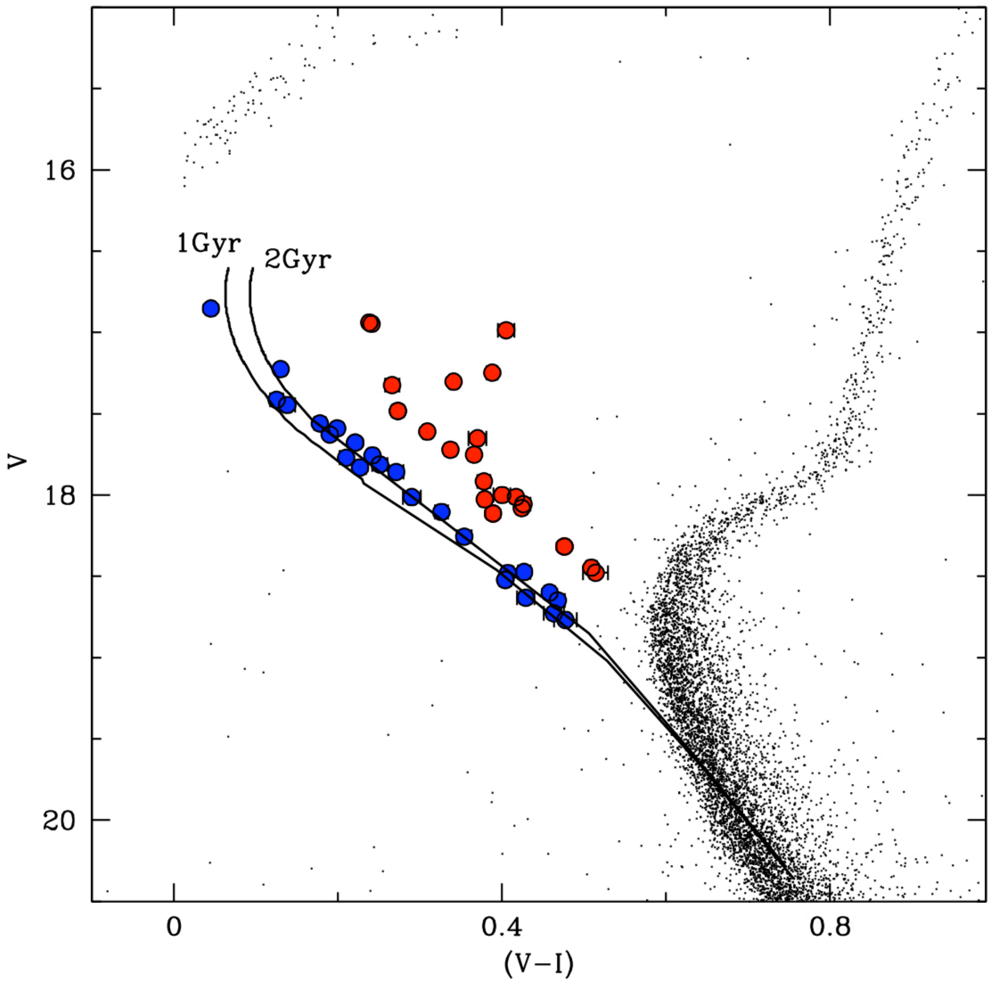
Dalessandro et al. 2013; Ferraro et al. 2009



BSS double sequences

Blue-BSS sequence well reproduced by collisional isochrones of 1-2 Gyr

- red-BSS sequence **too red** to be reproduced by collisional isochrones of **any** age

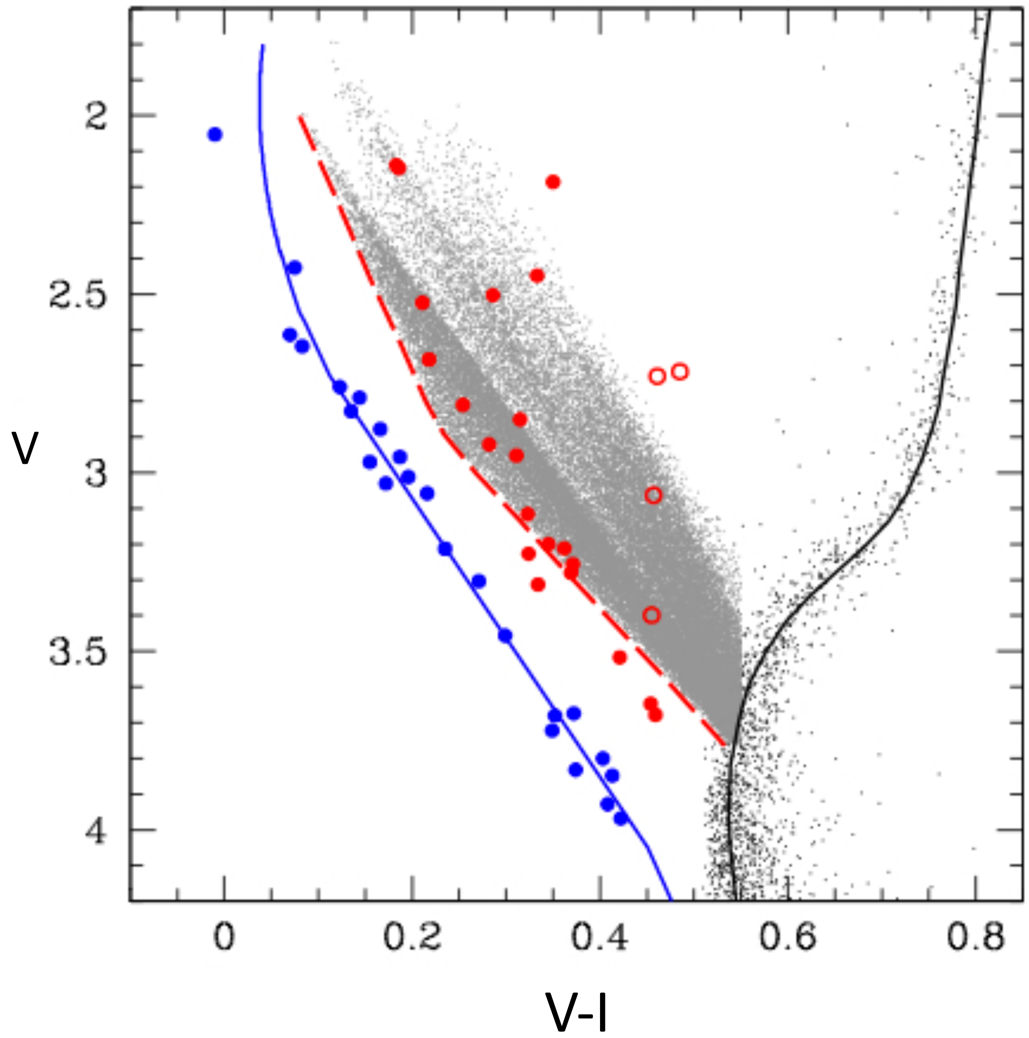


BSS double sequences

Xin et al. (2015)

Blue-BSS sequence well reproduced by collisional isochrones of 1-2 Gyr

Red-BSS sequence is located in the region where MT binaries are expected



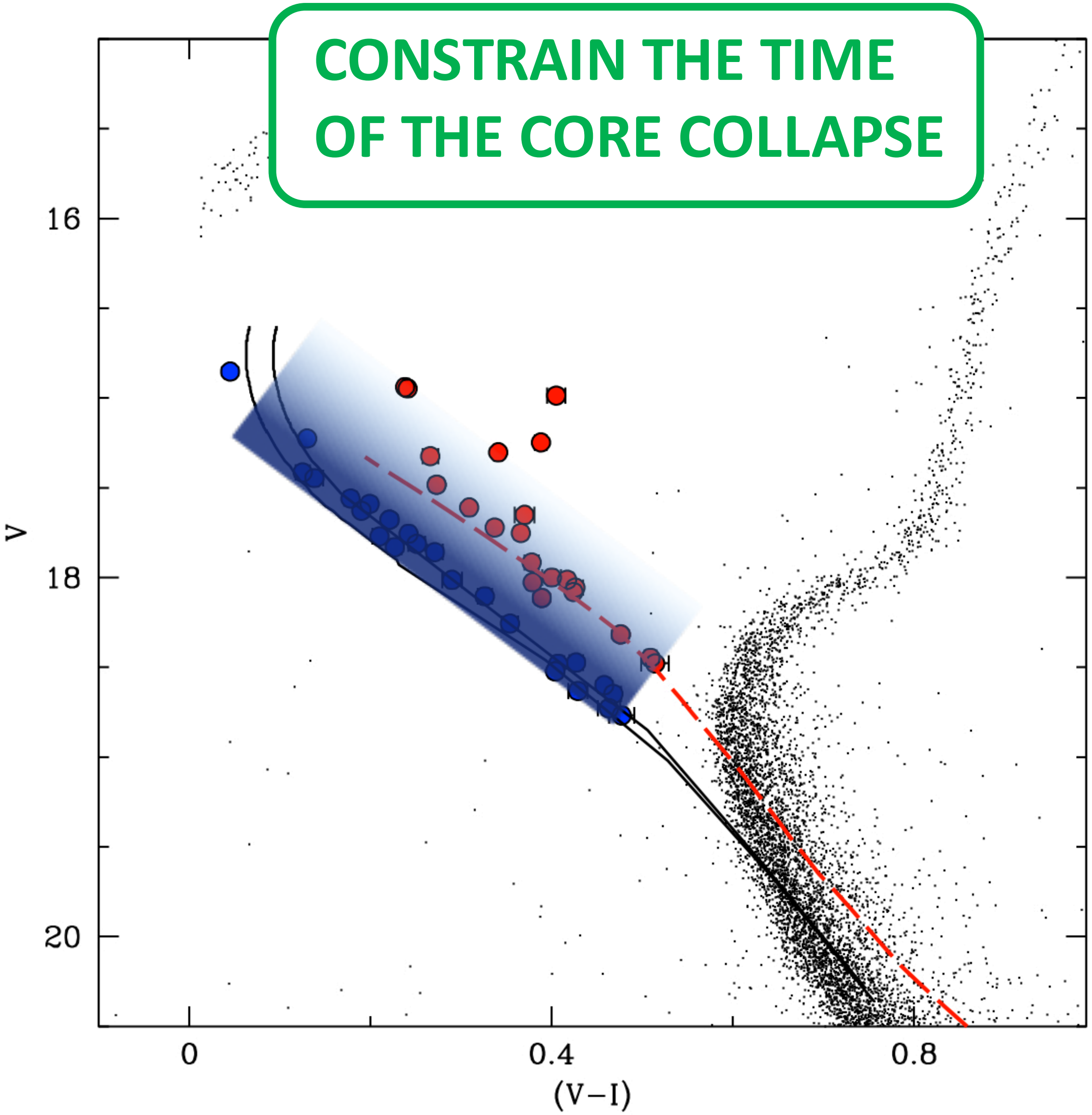
blue-BSS → collisional red-BSS → MT binaries

The blue-BSS population must have formed recently 1-2 Gyr ago

double BSS seq. is NOT a permanent feature

The evolution of the **BLUE** Seq. will fill the gap in a few Gyr

This feature can be generated by an event which increases the core collisional activity (core collapse?)



SCALES

to search for Evolved-BSS in GCs

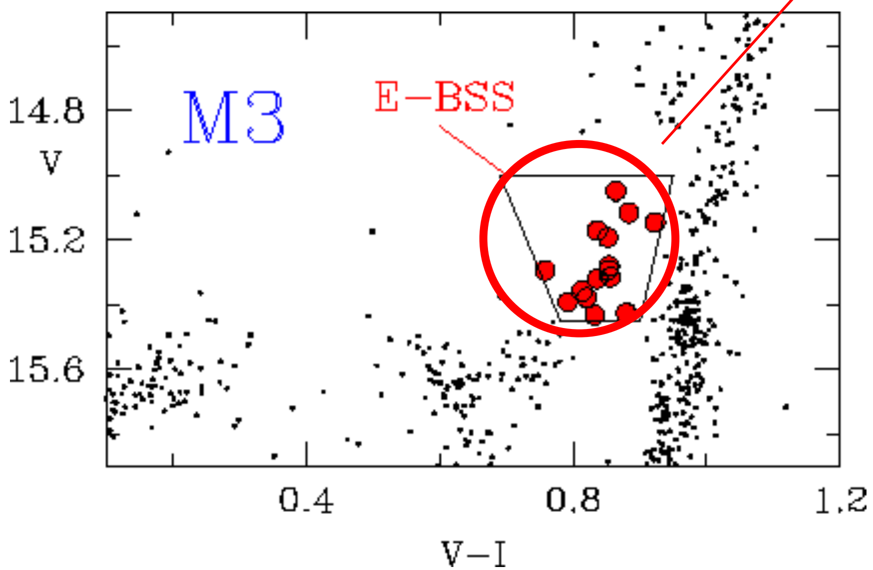
Indistingushible from normal stars photometrically

Only four candidate EBSS (3 with asteroseismology, 1 Cepheid)

Crucial to constrain evolution models

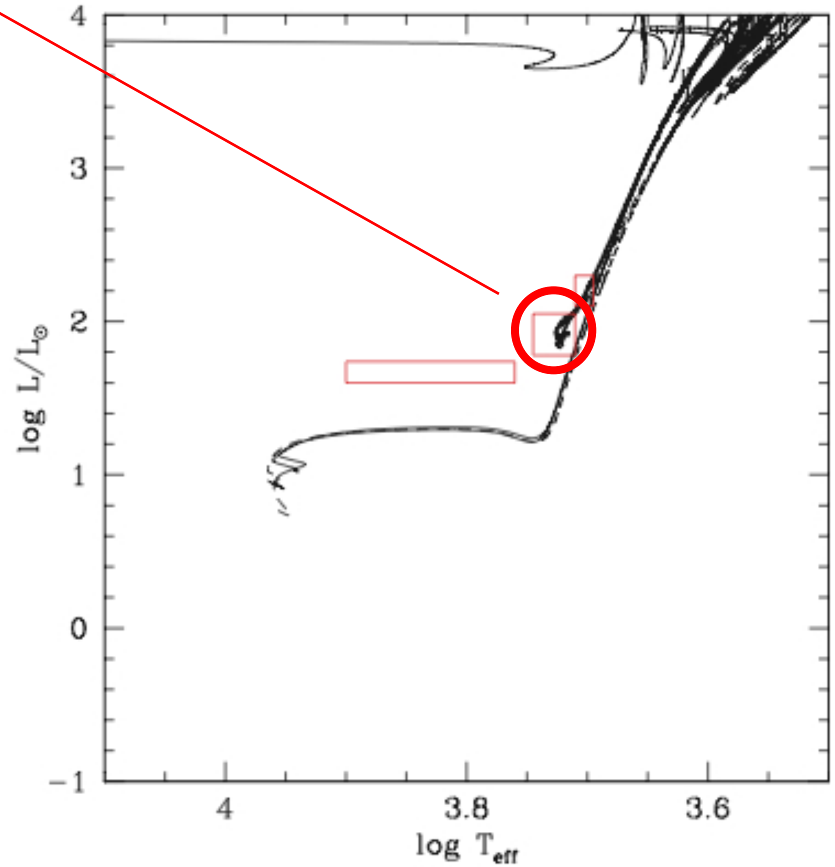
The E-BSS search in GCs

Both observational and theoretical arguments suggest that a **region** located in the CMD between the HB level and the AGB clump is the best place where E-BSS can be identified



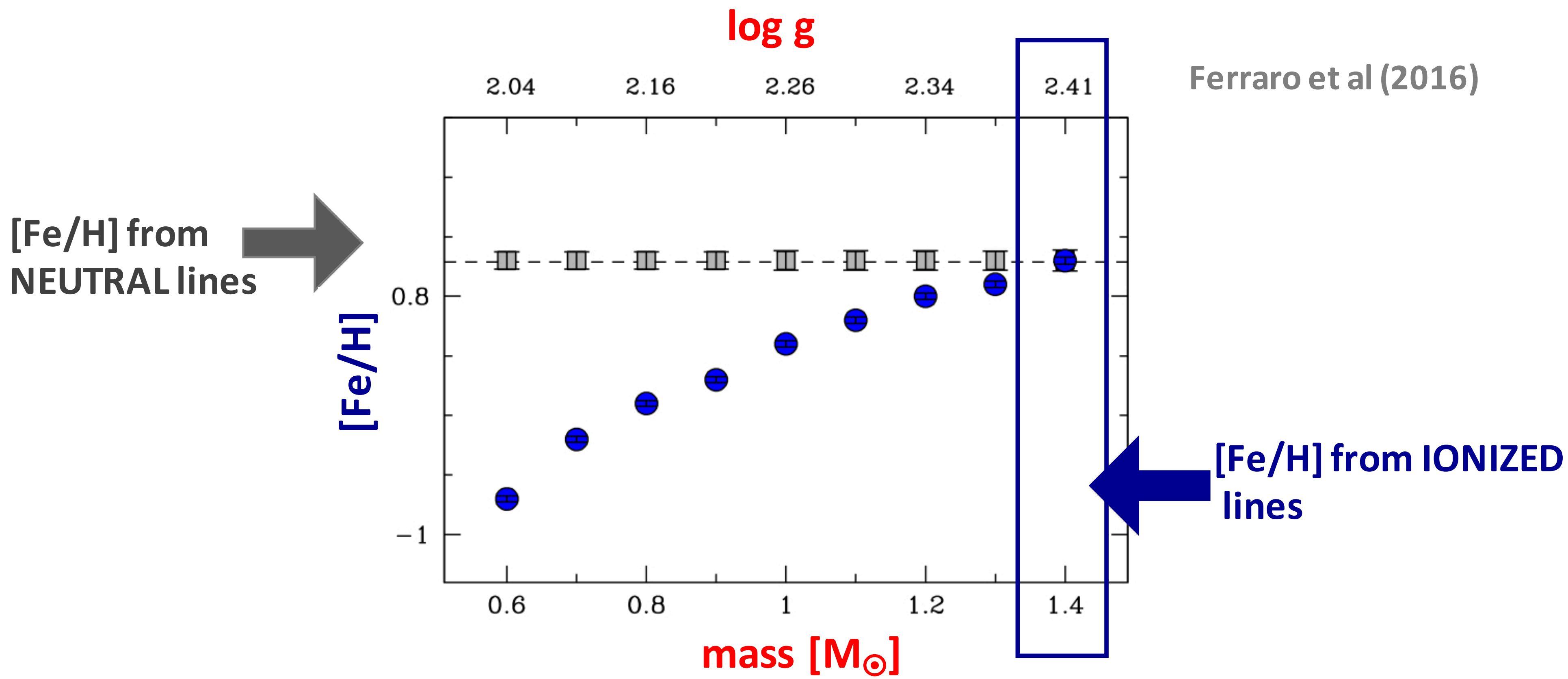
Indirect evidence found in M3, M80, 47Tuc and M2

Ferraro et al. 1997,1999; Beccari et al. 2006; Dalessandro et al. 2009



A “stellar scale” to search for E-BSS

The abundances obtained **from neutral lines are independent of the adopted gravity,** the **abundances from ionized absorption lines are quite sensitive to gravity**

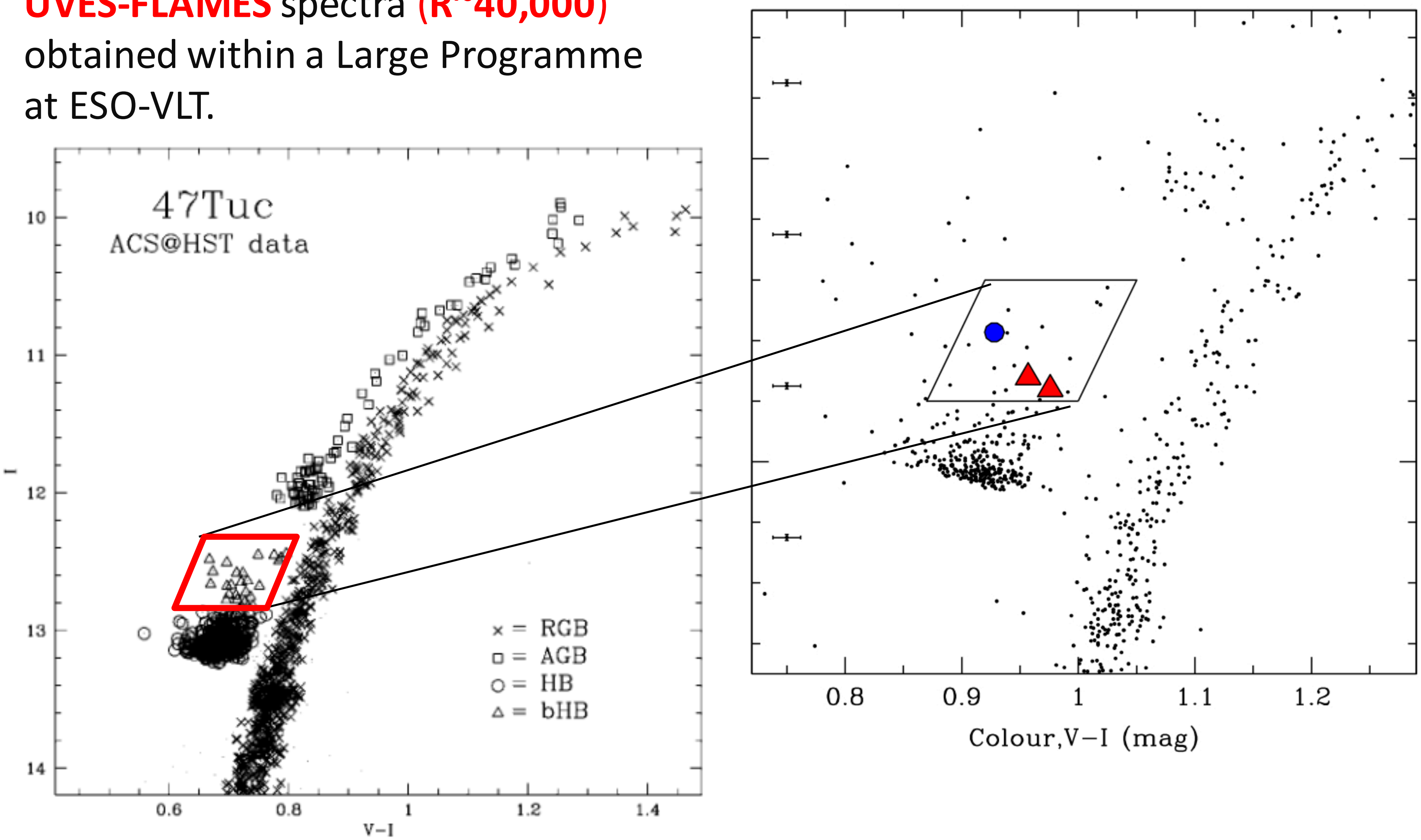


A "stellar scale" to search for E-BSS

Hence the BALANCE between the chemical abundances derived from neutral and ionized absorption lines can be used to determine the correct gravity of the star (hence its MASS !!)

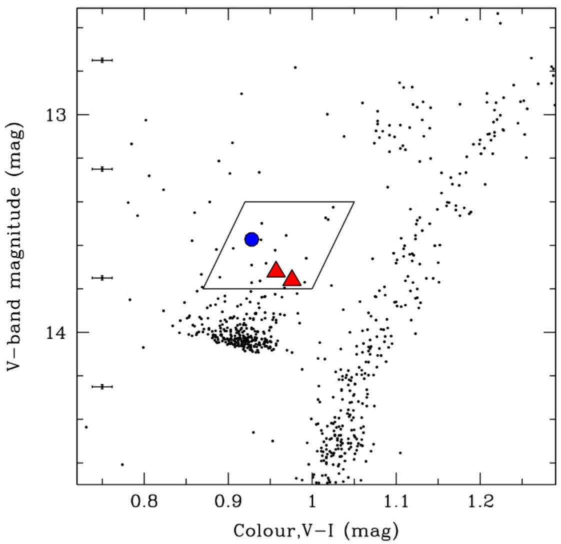
The E-BSS search in GCs

UVES-FLAMES spectra **(R~40,000)** obtained within a Large Programme at ESO-VLT.



Cosmic-Lab

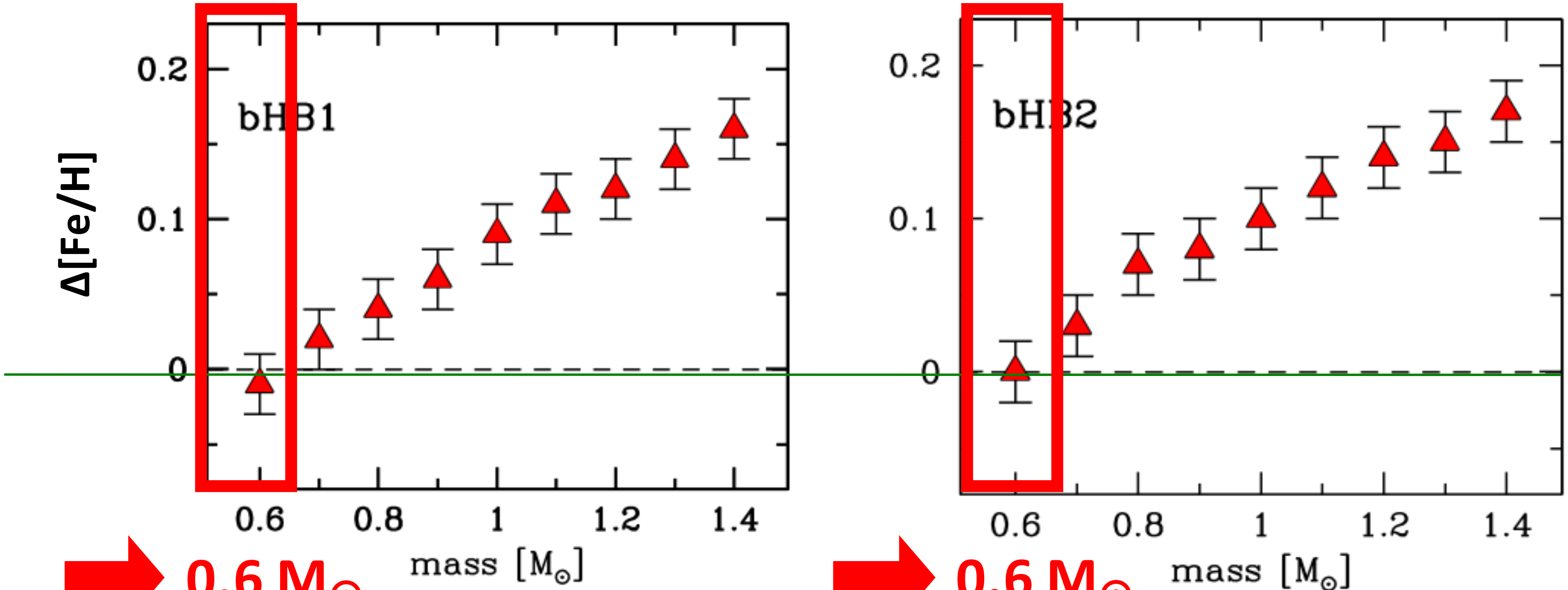
erc



A “stellar scale” to search for E-BSS

For two stars (bHB1 and bHB2) the “stellar scale” yields mass values which are in full agreement with “genuine” HB mass expectations

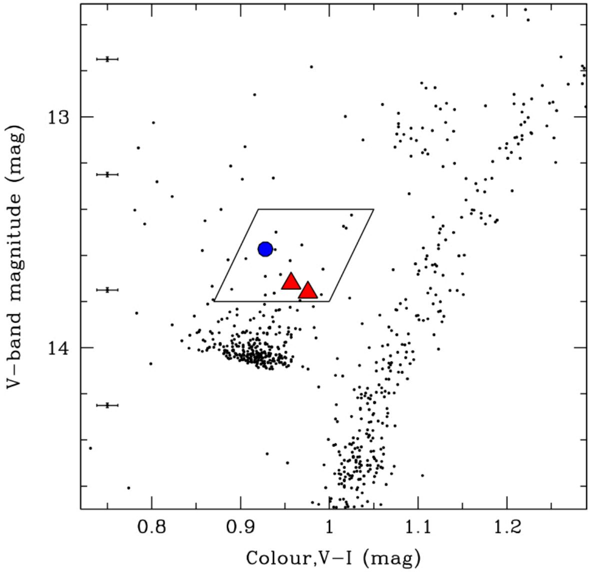
Ferraro et al (2016)

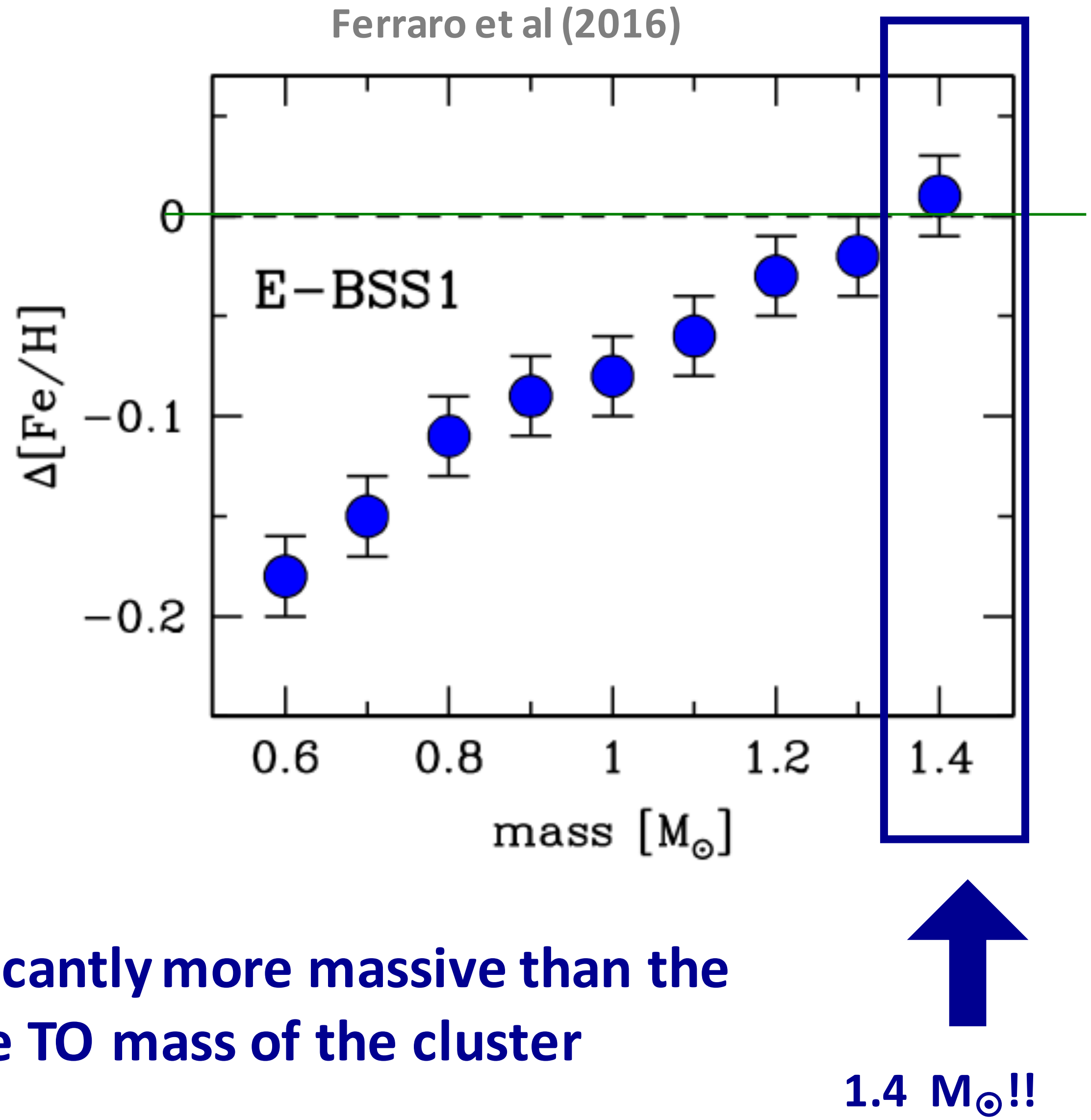


0.6 $M_\odot$ 0.6 $M_\odot$

Cosmic-Lab erc

A “stellar scale” to search for E-BSS





EBSS1 turns out to be significantly more massive than the other two stars and than the TO mass of the cluster

Cosmic-Lab

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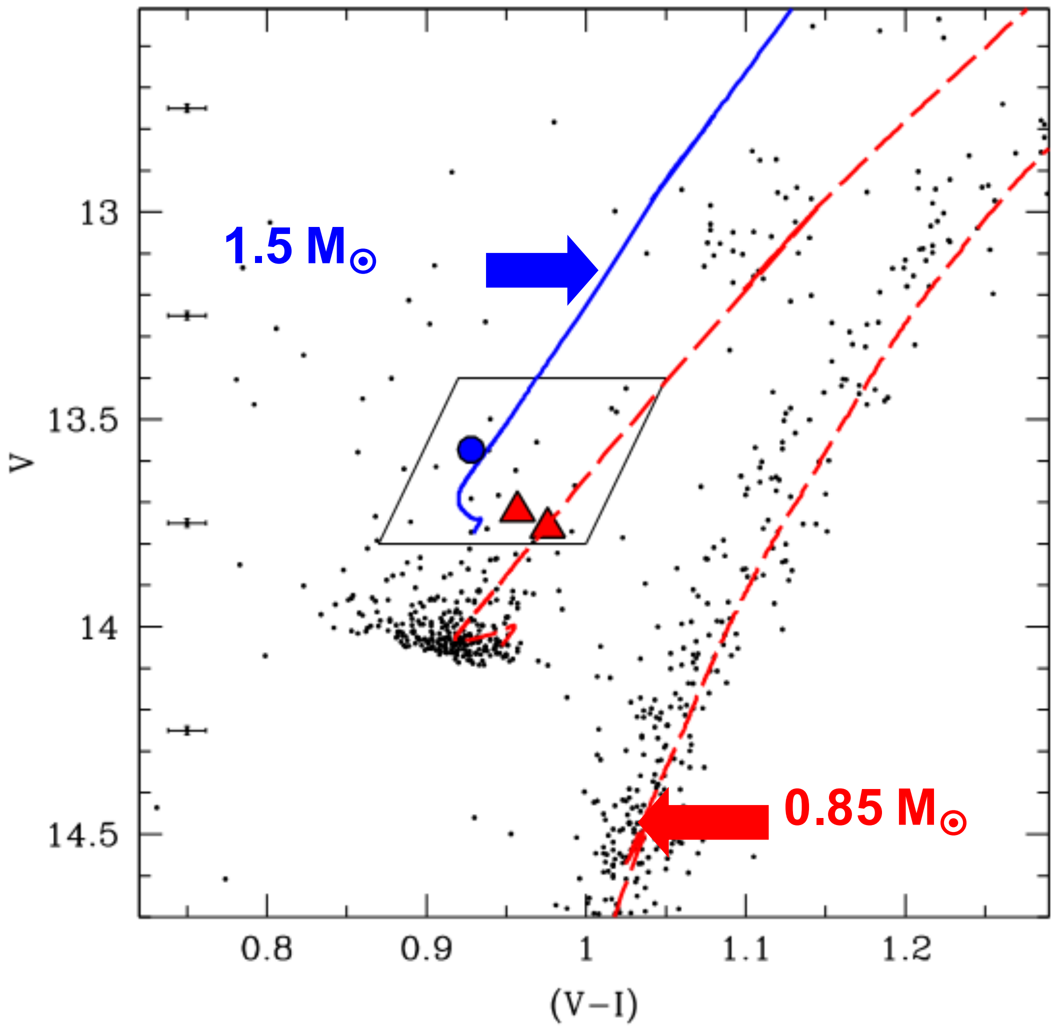
A "stellar scale" to search for E-BSS



EBSS1 is probably an **evolved Blue Straggler Star caught during its He-burning phase**

This identification opens the possibility to start a systematic search of E-BSS in GCs and to determine their chemical/kinematic properties

Note that in this evolutionary stage EBSS are 20 times more luminous of their BSS progenitors

SUMMARY

BSS are crucial and powerful gravitational test particles

- ✓ Their radial distribution traces the past dynamical history of the parent clusters
- ✓ They can possibly bring insights on the most catastrophic events

EBSS are now distinguishable from low-mass sisters

- ✓ They can keep memory of their formation mechanism offering alternative route to understand the BSS origin
- ✓ They allow to constrain theoretical models

Thank you!