Probing the dynamical state of stellar aggregates with BSS double sequences

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Cosmic-Lab

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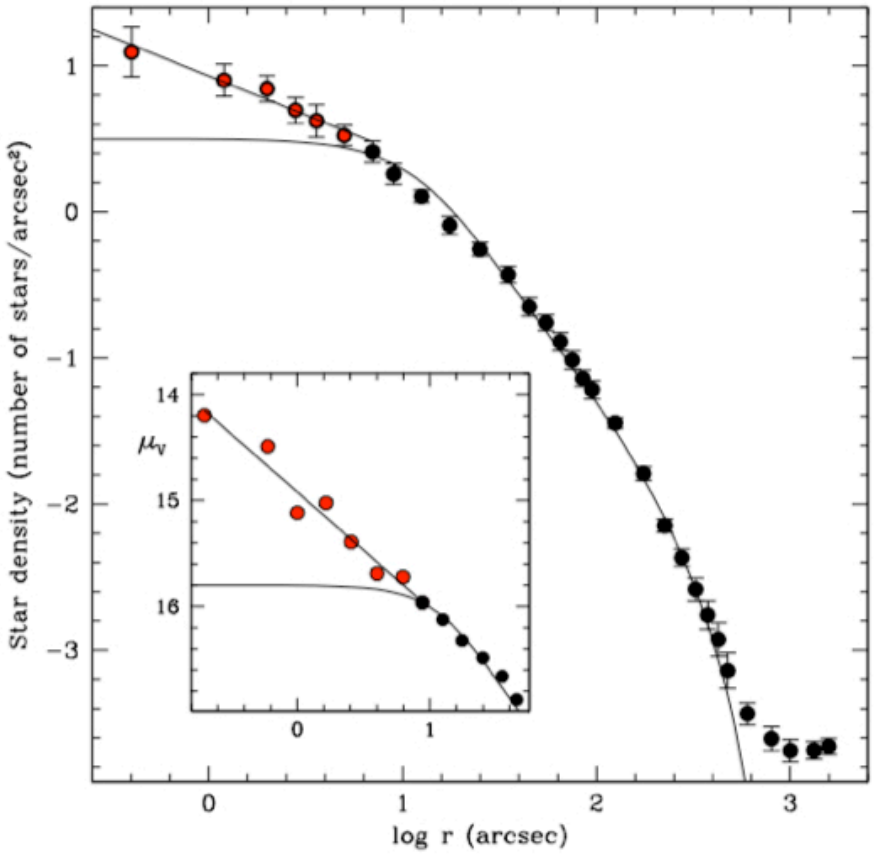
erc

Cosmic-Lab

- 5-year project
- *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

The case of M30



- Post-core collapse (PCC) cluster

  power-law central cusp:
  - scale: r_{cusp} = 5” = 0.2 pc
  - slope: α = -0.5

Dataset: HST/WFPC2 + HST/ACS + MegaCam@CFHT

A BSS double sequence

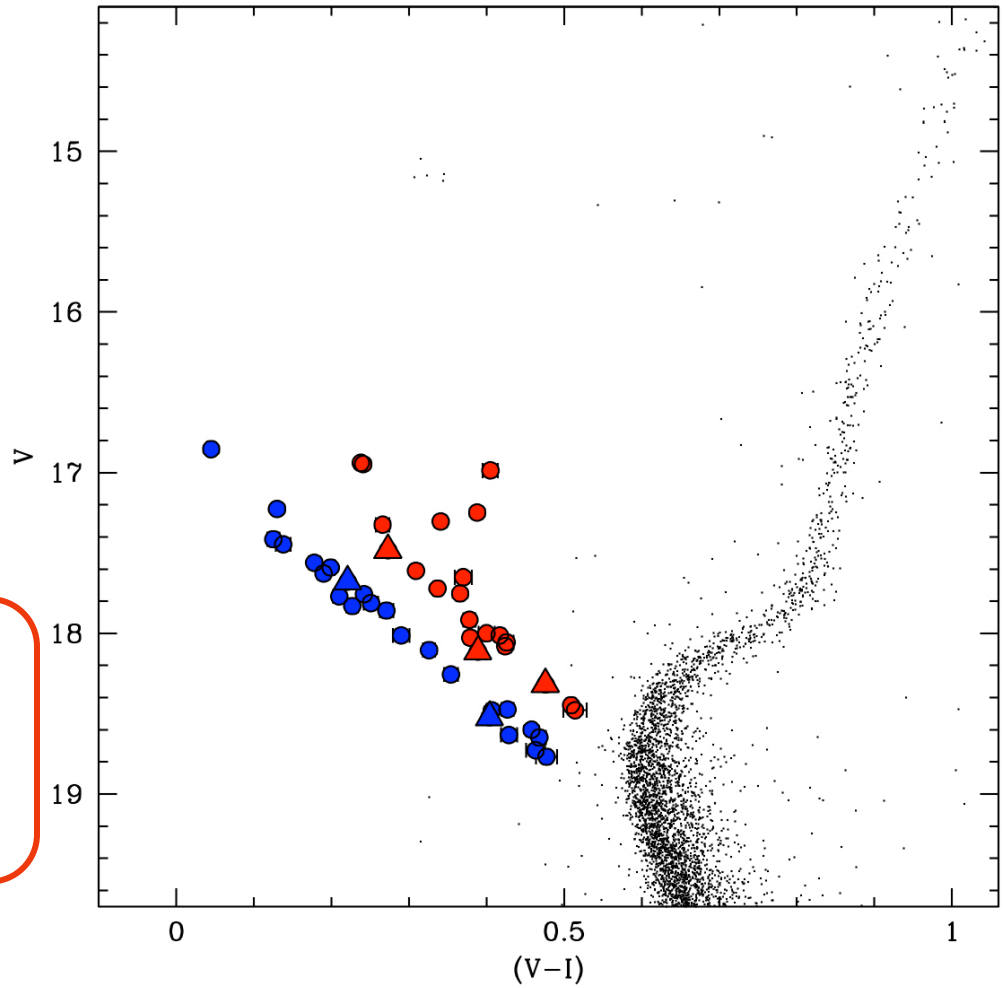
HST/WPC2 dataset (1999, GO7379)

- 22 images in filter F814W (I)
- 22 images in filter F555W (V)

photometric error ≤ 0.01 mag
both in color and magnitude
at the BSS level

2 distinct sequences of BSS !!

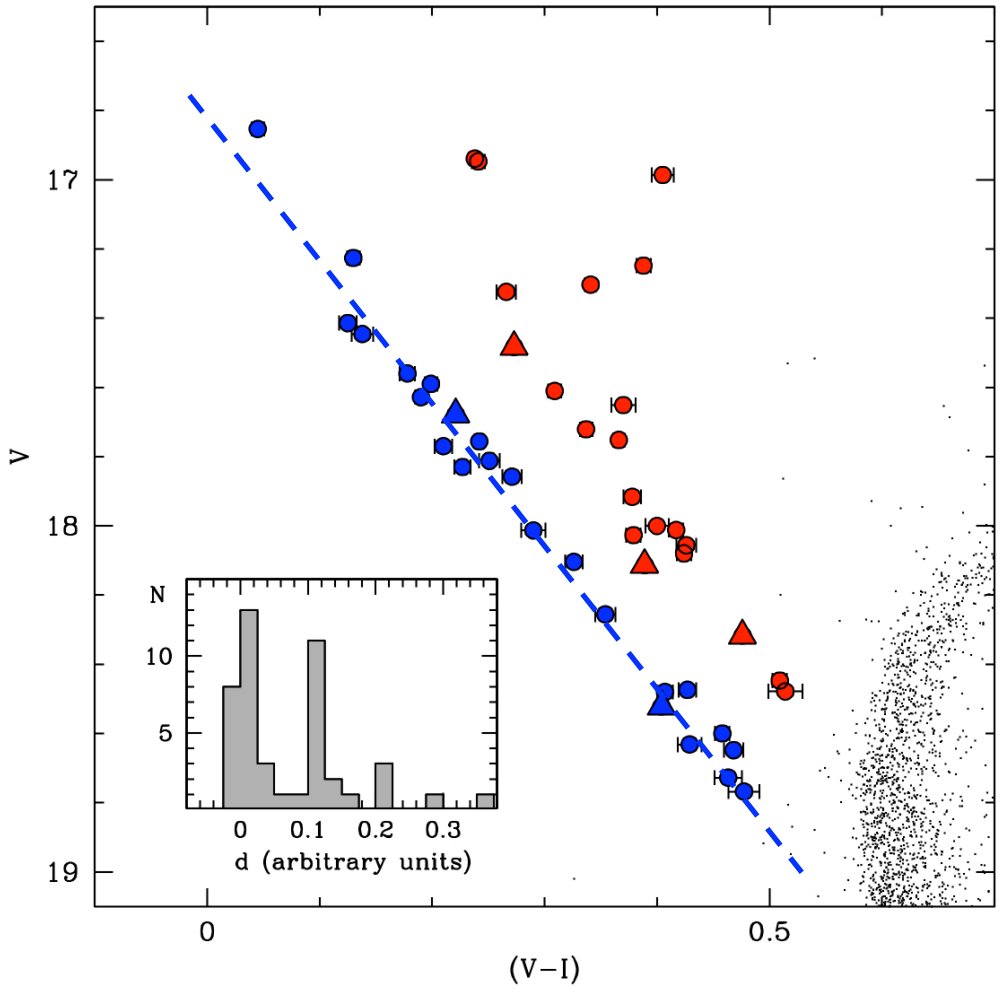
Ferraro et al. (2009, Nature 462, 1028)



A BSS double sequence

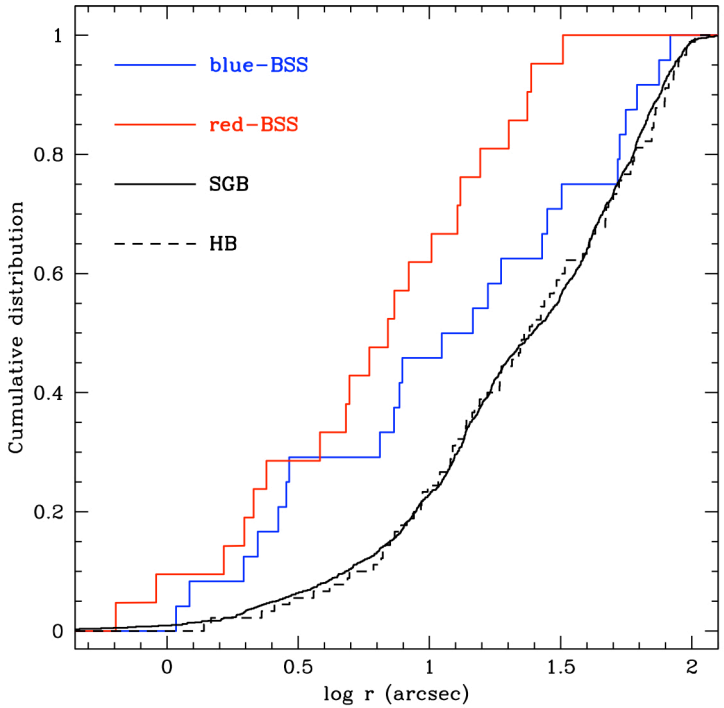
- **similarly populated:**
  24 blue-BSS
  21 red-BSS

- **almost parallel:**
  separated in mag by $\Delta V \approx 0.4$
  in col by $\Delta(V\text{-}I) \approx 0.12$

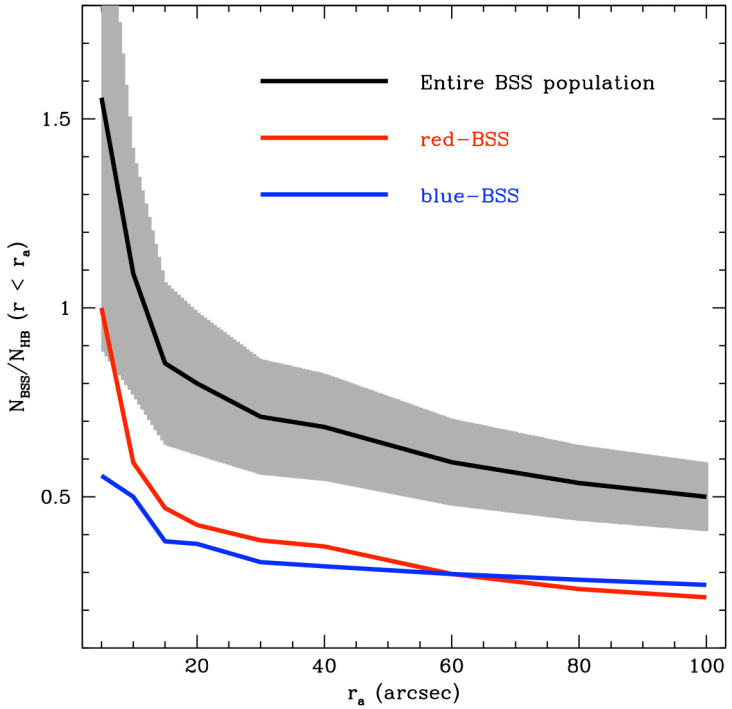


- **centrally segregated:**

cumulative radial distribution



specific frequency N_{BSS}/N_{HB}



- BSS more centrally concentrated than SGB & HB stars (> 4 σ significance level)
- red-BSS more concentrated than blue-BSS (~ 1.5 σ significance level)

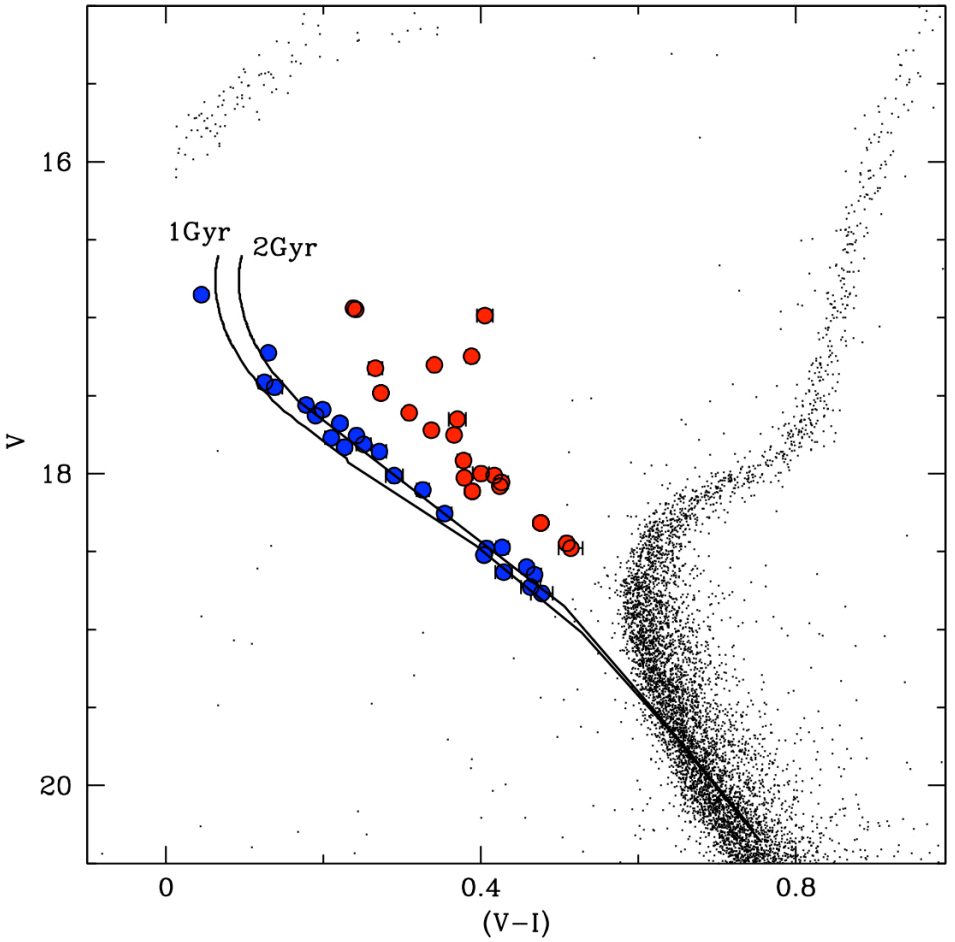
different formation mechanism for red- and blue-BSS?

Evolutionary models of COL-BSS (Sills et al. 1997, 2009)

- collisions between two MS stars (0.4 - 0.8 $M_{\odot}$)
- $Z = 10^{-4}$ ($Z_{M30} = 2.5\ 10^{-4}$)

- **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



Binary evolution models (Tian et al. 2006)

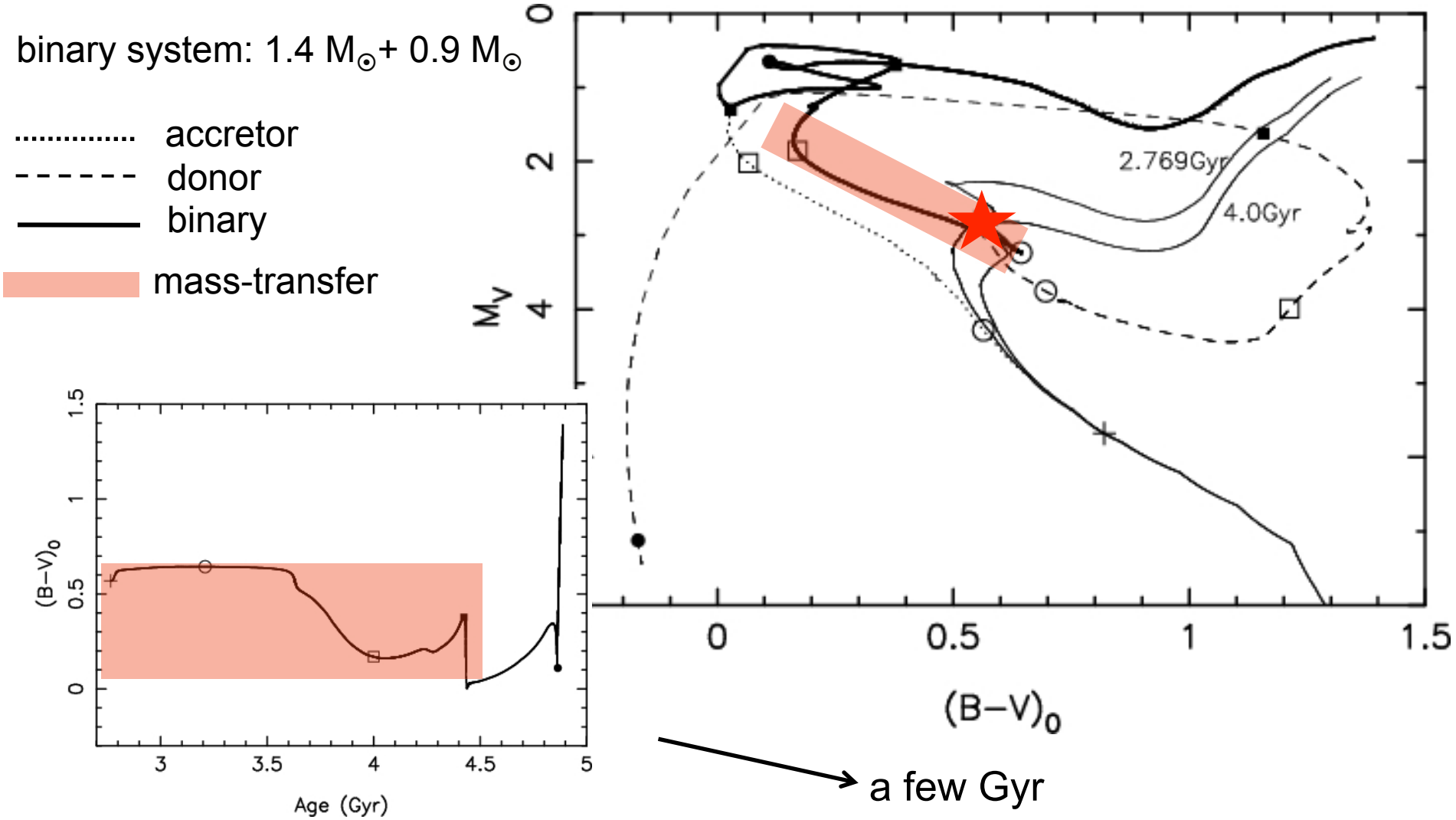
binary system: 1.4 $M_\odot$ + 0.9 $M_\odot$

accretor

donor

binary

mass-transfer

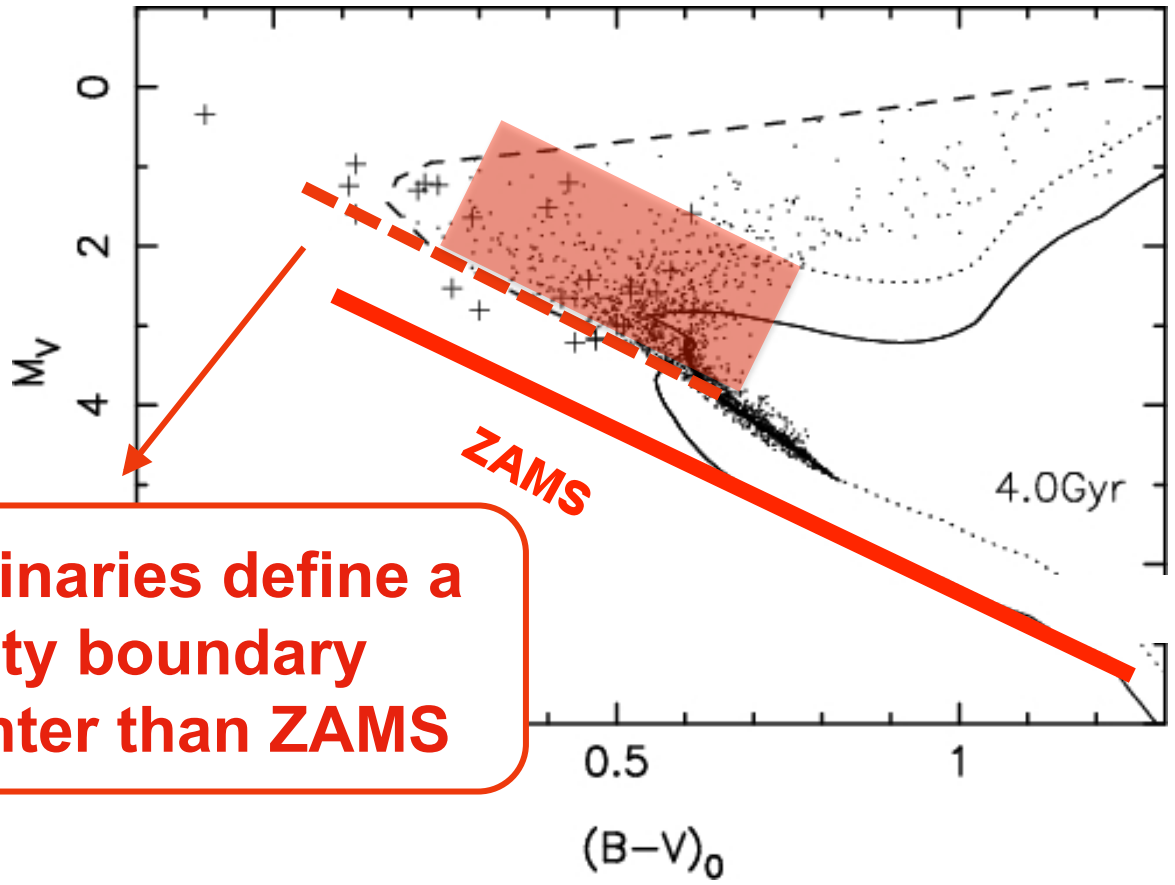


a few Gyr

Binary evolution models (Tian et al. 2006)

+ : observed BSS in M67 (Deng et al. 1999)

dots: simulated mass-transfer binaries **(2000 PB, donor: 1.2-1.4 $M_{\odot}$,q: 0.35-0.95)**

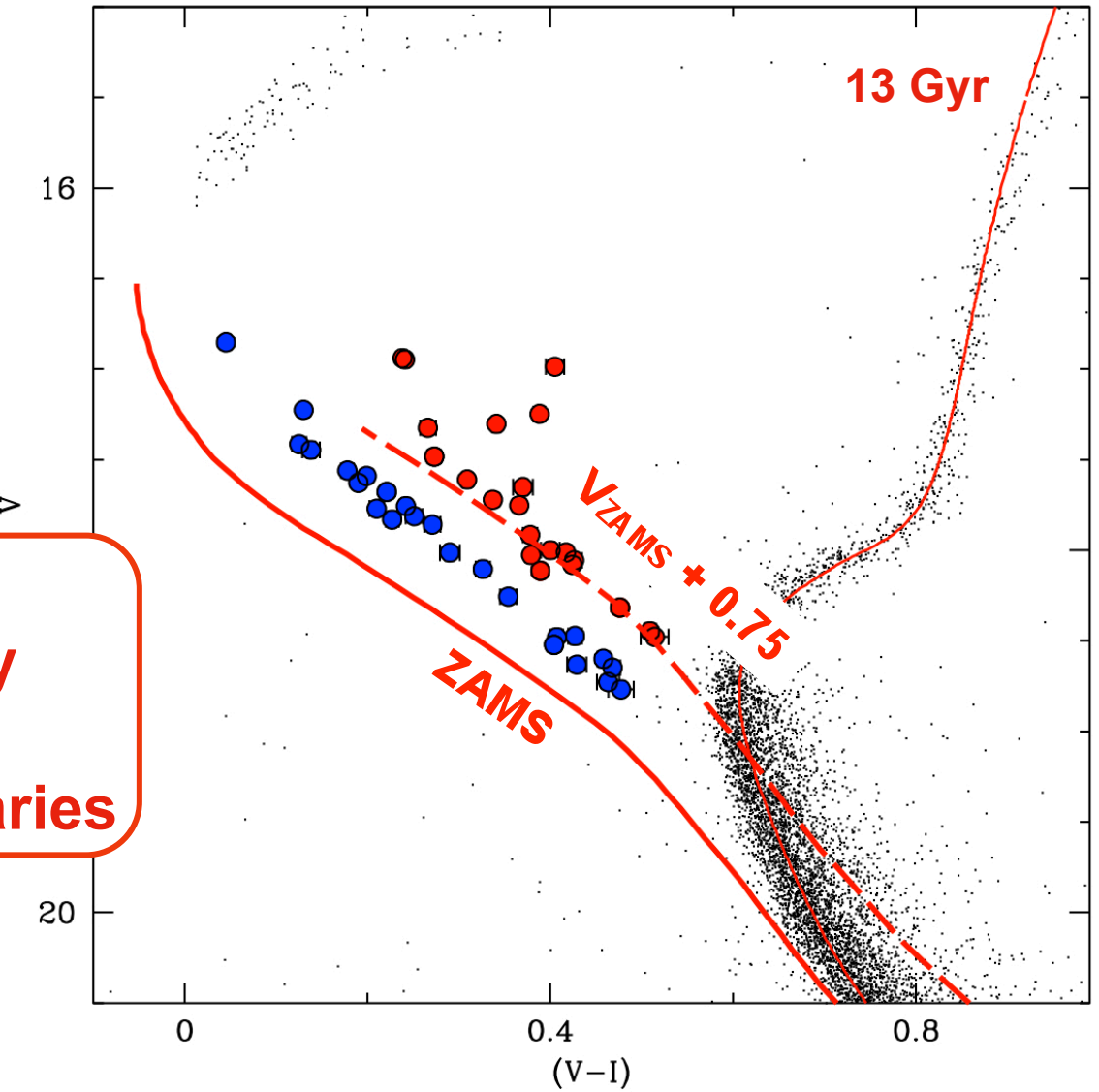


mass-transfer binaries define a low-luminosity boundary ~0.75 mag brighter than ZAMS

Single star isochrones of Z = 2 10^{-4} (Cariulo et al. 2004)

- 13 Gyr → good fit to CMD
- 0.5 Gyr → ZAMS

red-BSS sequence well reproduced by models of mass-transfer binaries

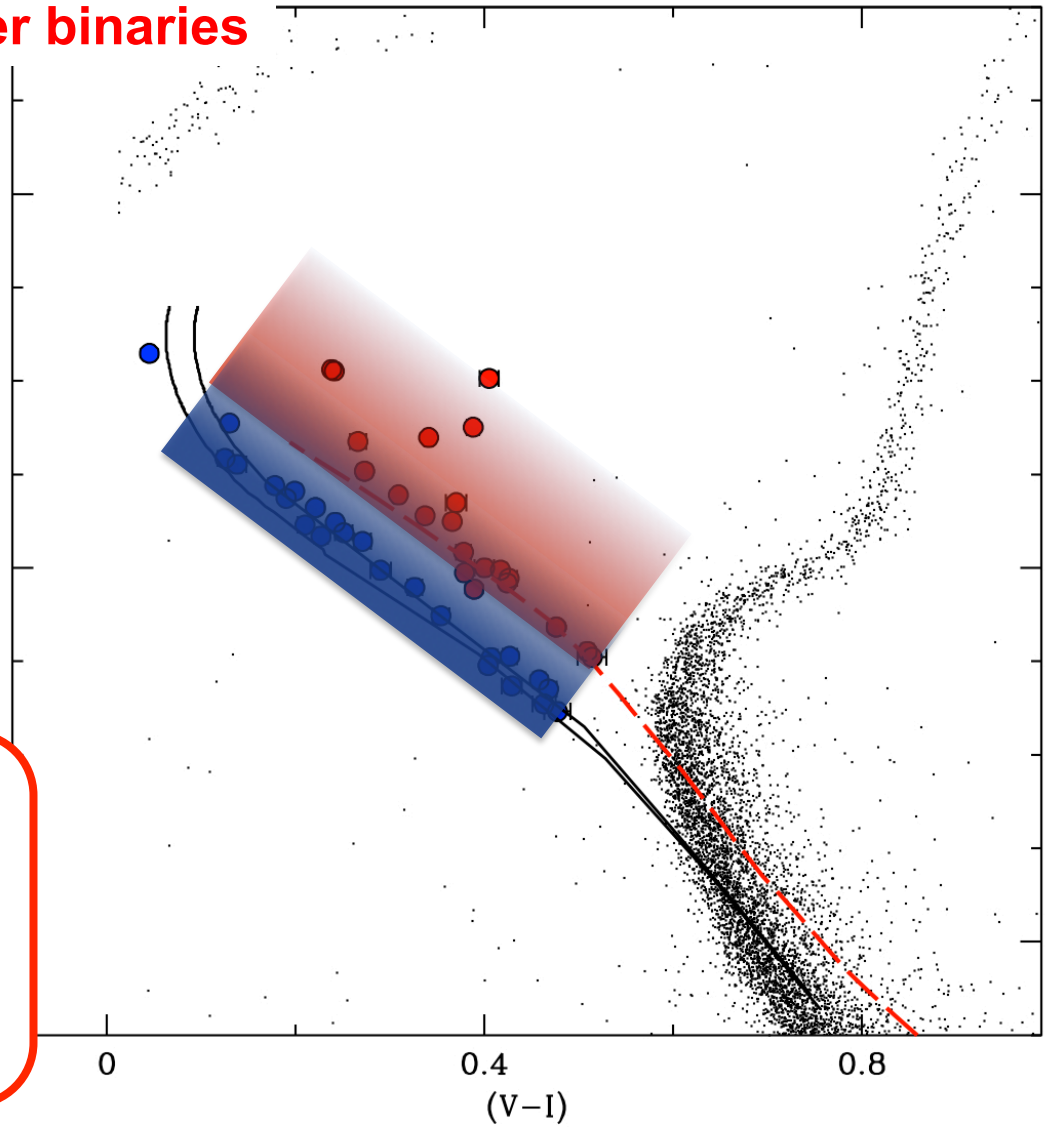


- **blue-BSS ⟶ collisional**
- **red-BSS ⟶ mass-transfer binaries**

- both will quickly evolve

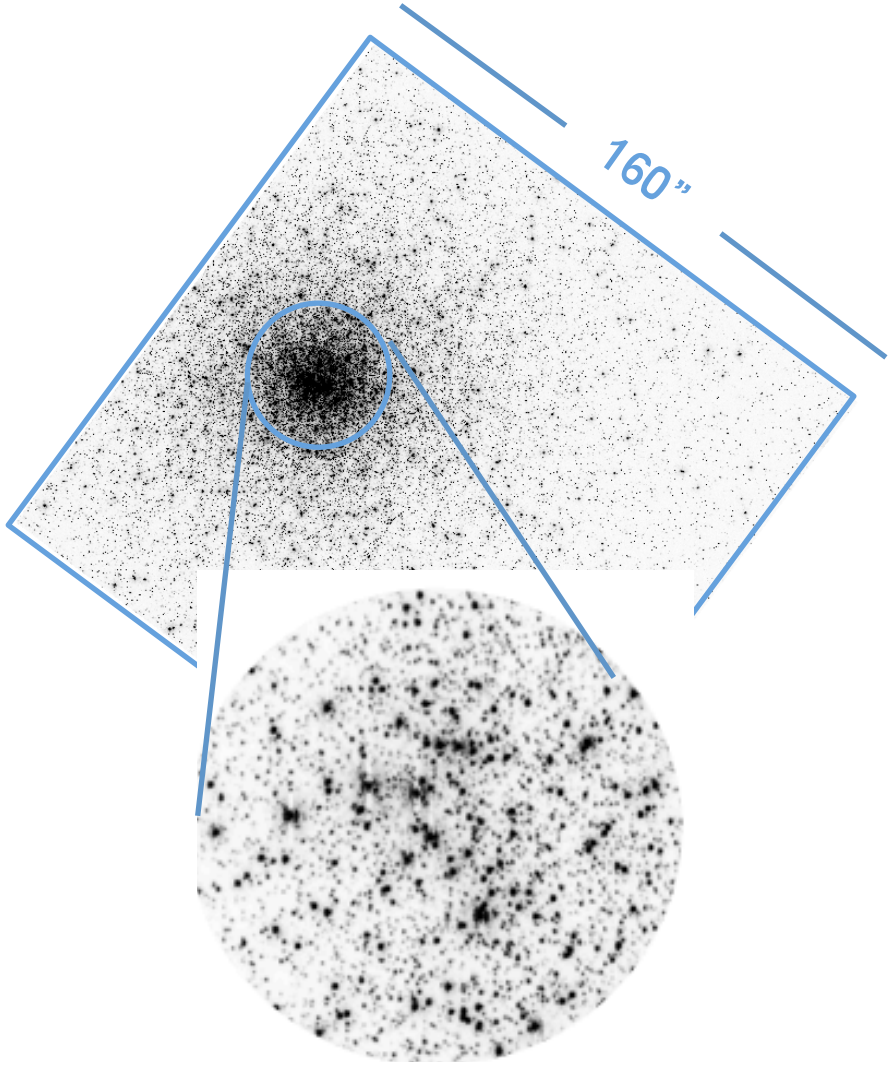
  → gap filled in a few Gyr

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



cluster core-collapse occurred 1-2 Gyr ago and boosted the formation of (at least) the COL-BSS

Double BSS sequences: an HST proposal



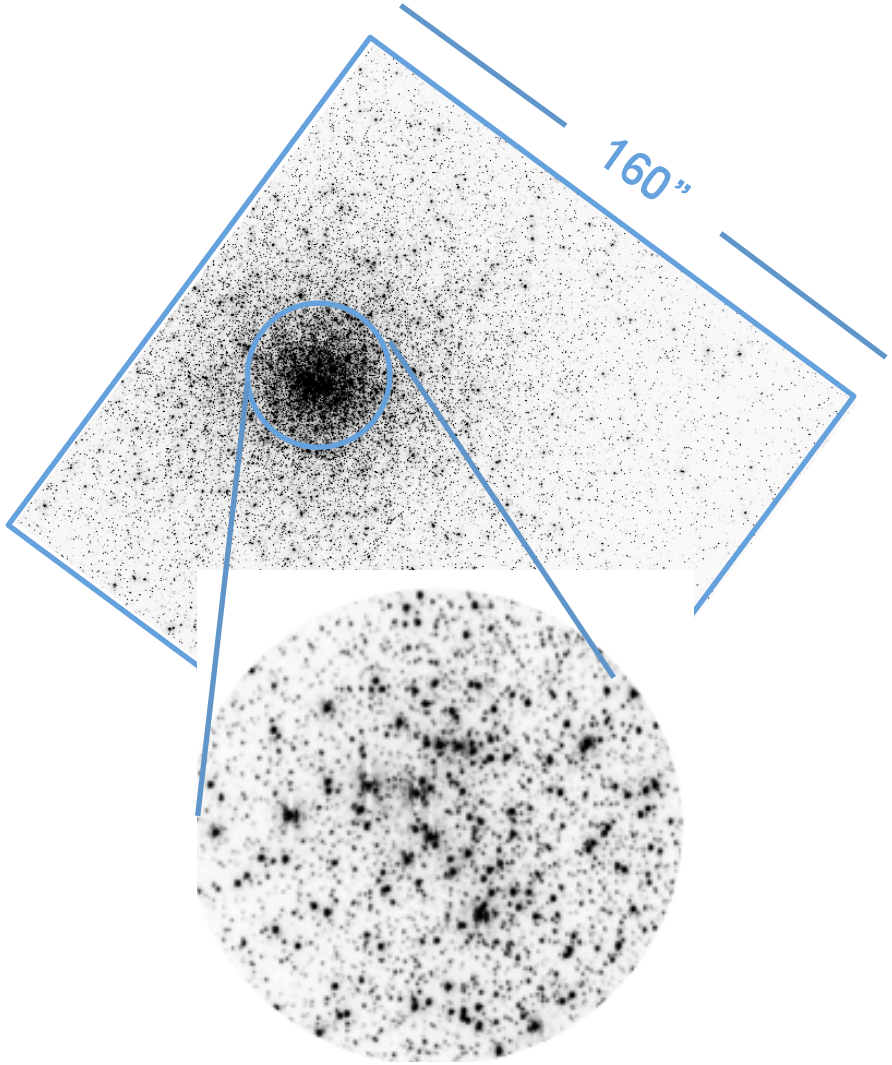
21 HST orbits allocated
with WFC3@HST – Prop 12516
(PI: F. Ferraro)

4 PCC candidate clusters:
NGC362 –NGC6293 – NGC6541 – NGC6681

Relatively large field of view +
high spatial resolution (0.04”/px)

About 45 deep images in
F390W (U) – F555W (V)– F814W (I)
for each target

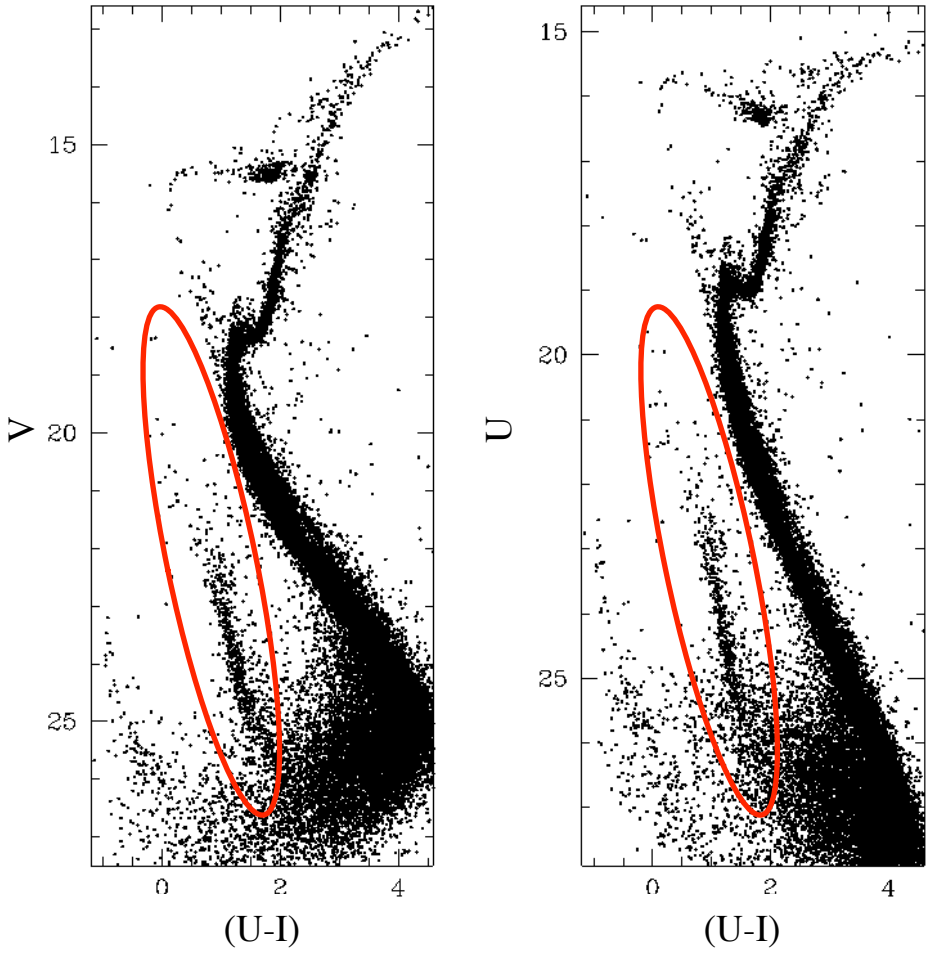
Double BSS sequences: an HST proposal



HIGH SPATIAL RESOLUTION + HIGH PHOTOMETRIC ACCURACY

The first target: NGC 362

(Dalessandro et al., in prep.)



MS down to M~0.2M_{sun}

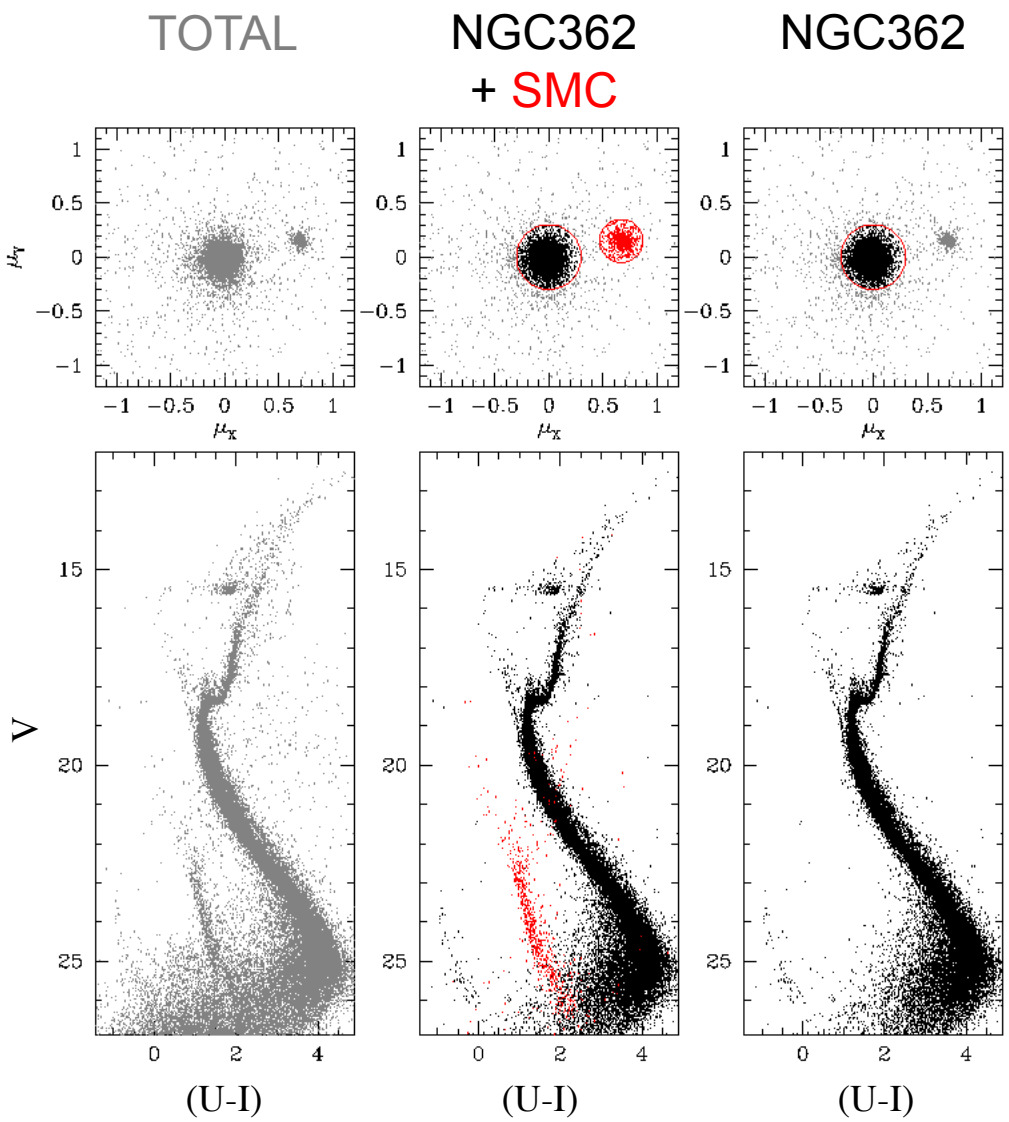
High-accurate photometric measures at the BSS mag level

S/N~200 roughly corresponding to photometric error ~ 0.01

Strong contamination from the Small Magellanic Clouds

Need of relative proper motion analysis

Relative proper motions: building a clean sample

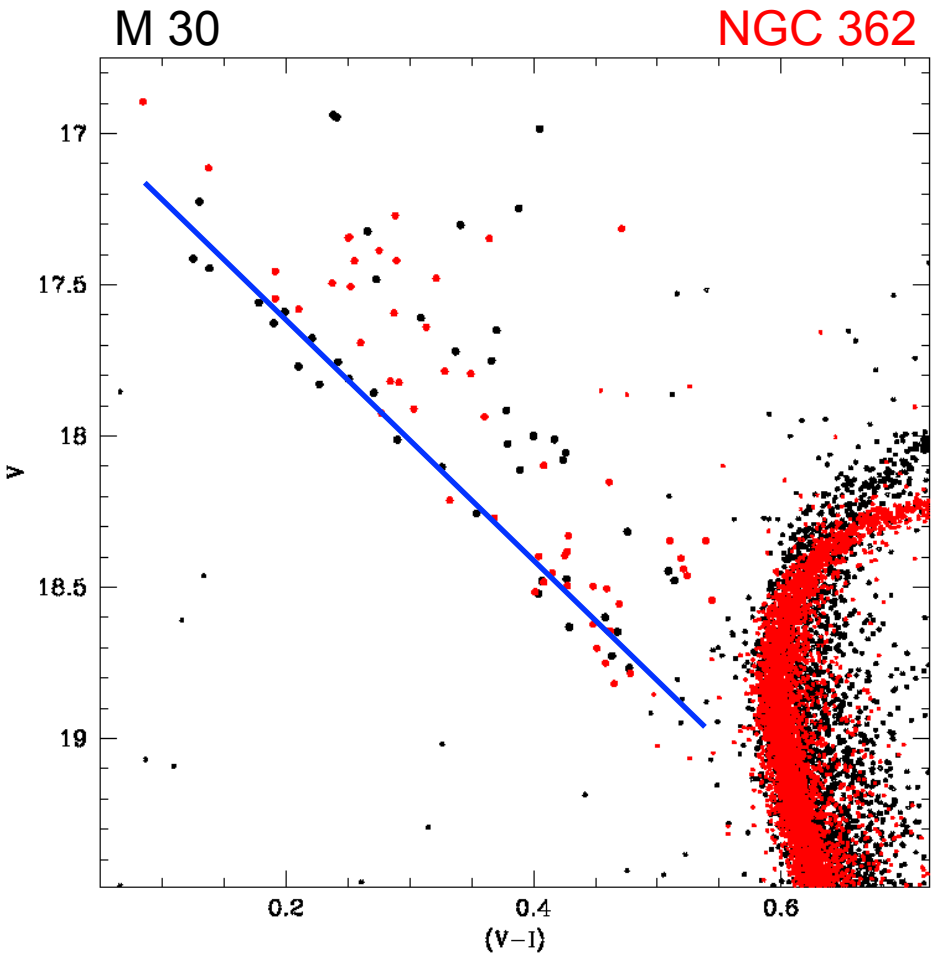


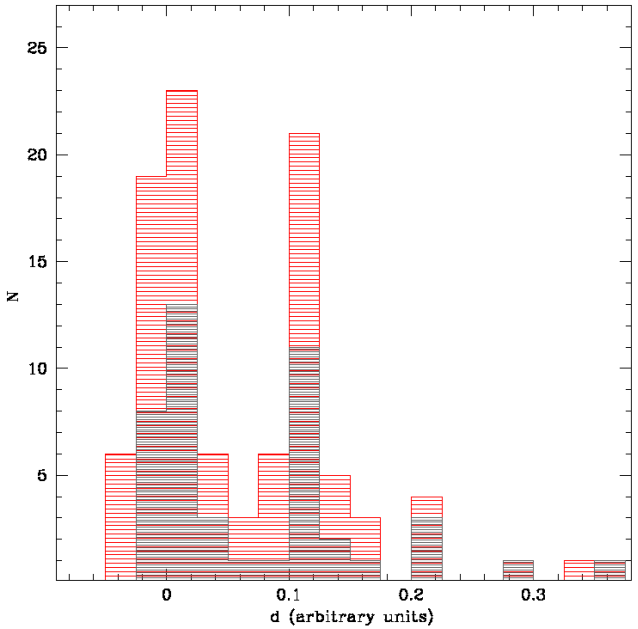
Time baseline of ~5years
GO11975 (I epoch) – GO12516 (II epoch)

Only stars with μ<0.3 pixels have been used for our analysis

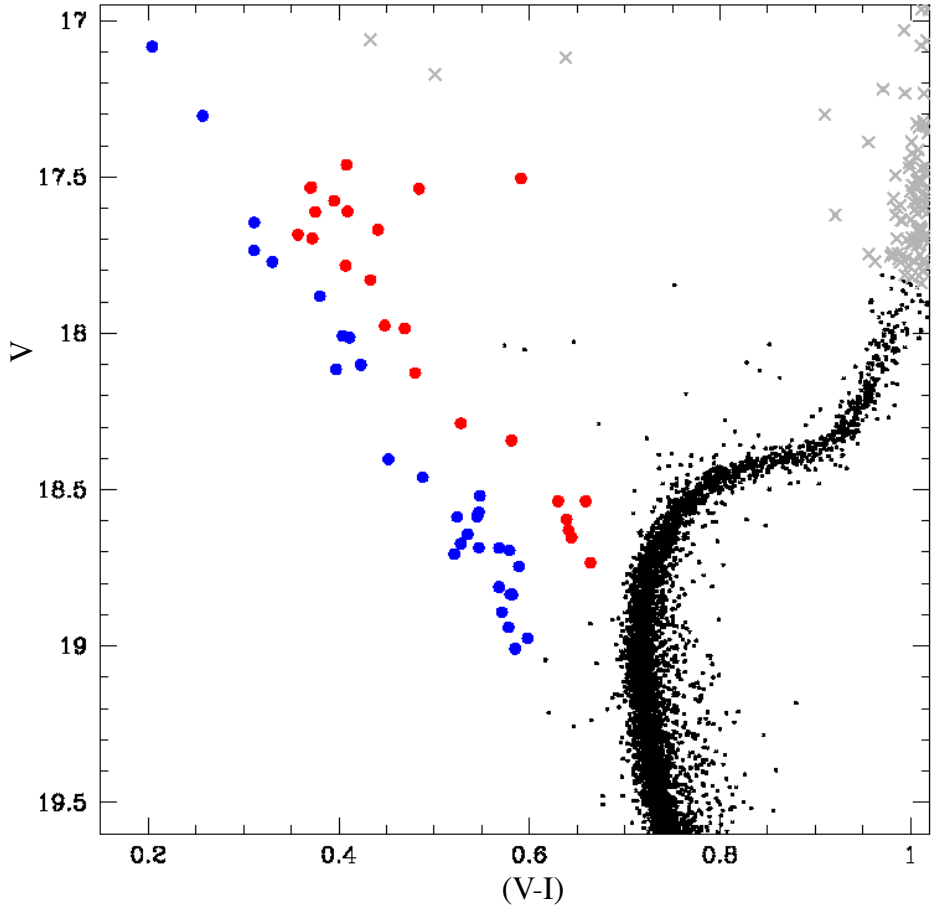
- stars with high membership probability
- stars with high-quality photometric accuracy

Another BSS double-sequence





Another BSS double-sequence

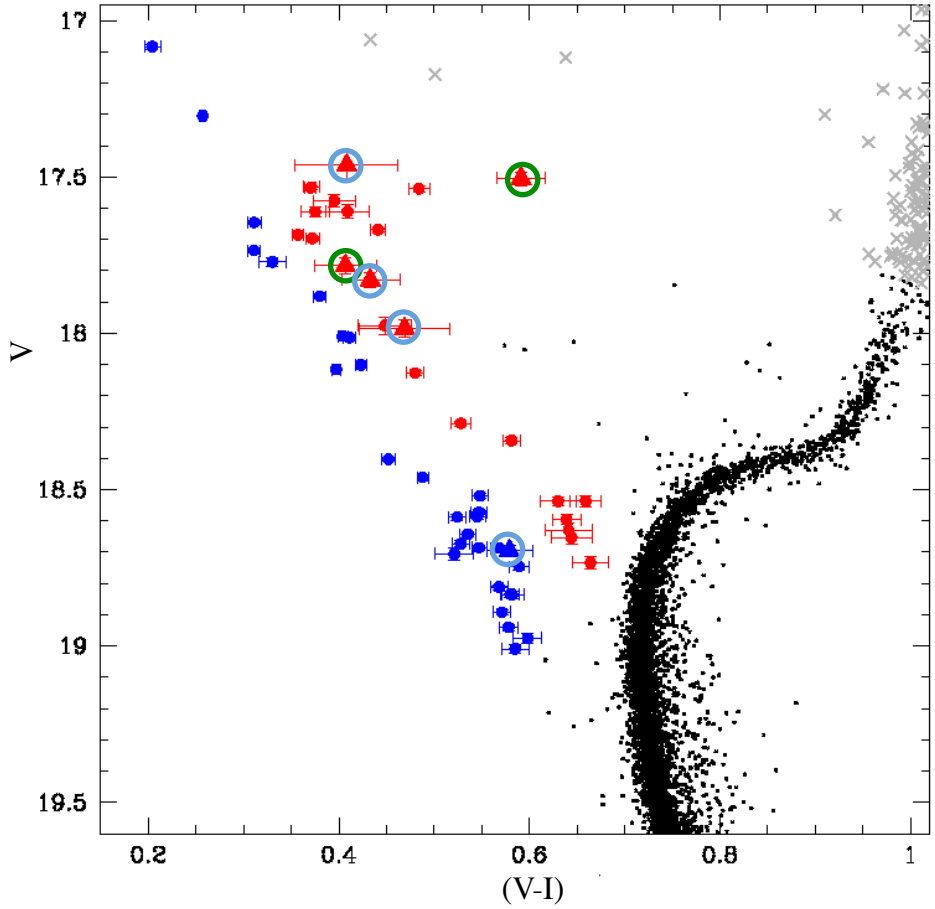


54 BSS:
30 blue-BSS + 24 red-BSS

The number of blue-BSS is compatible with what expected (Davies et al. 2004) on the basis of its mass (M_V=-8.6)

Another BSS double-sequence

P~0.40days



P~0.32days

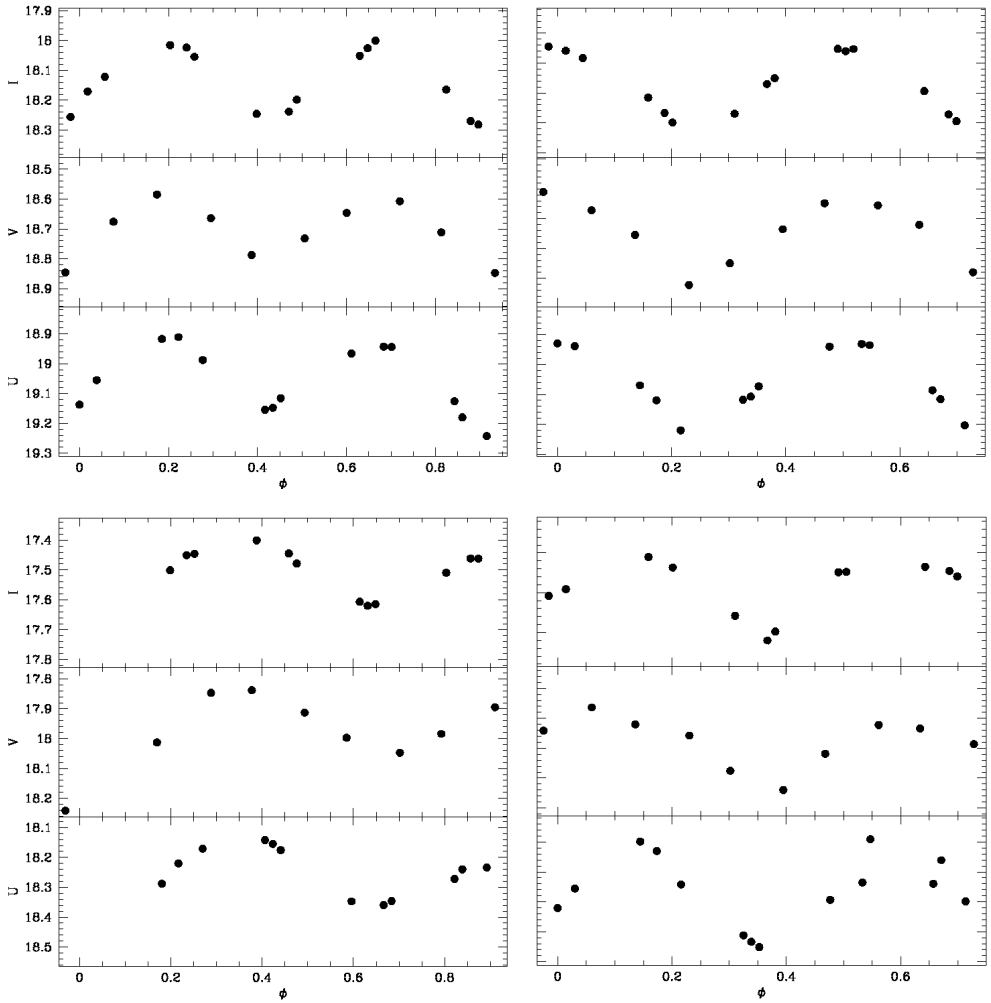
- 2 Sx Phoenicis (Szekely et al. 2007)
- 4 newly discovered W Uma candidate

Of 6 variables 5 are red-BSS

3 out of 4 WUMa are red-BSS

Another BSS double-sequence

P~0.40days



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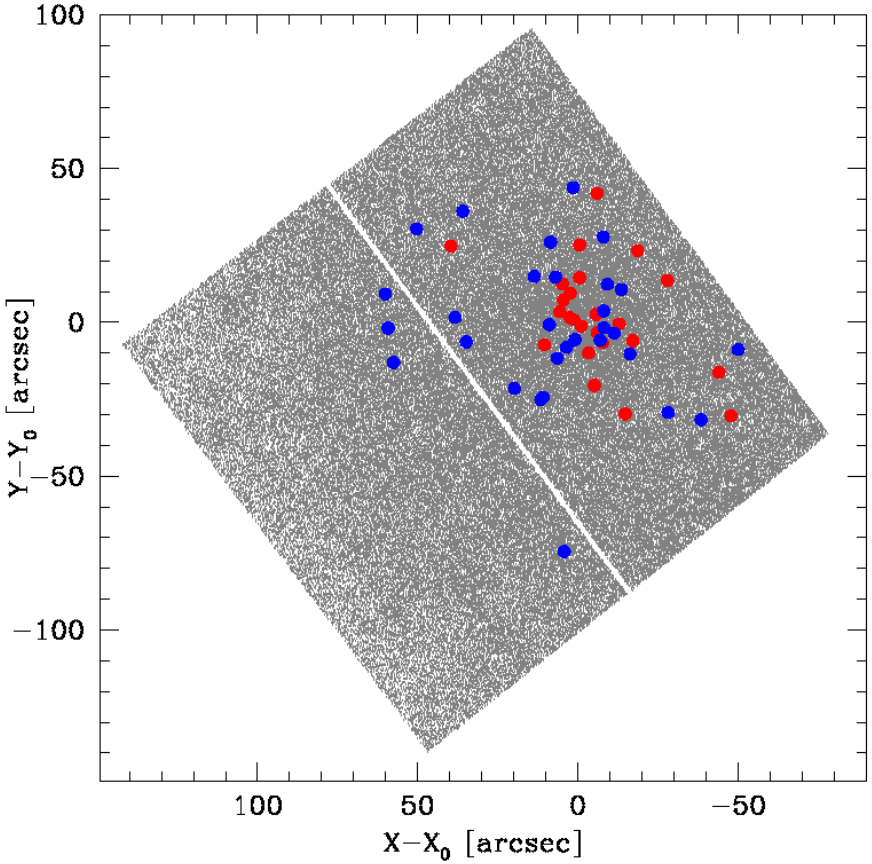
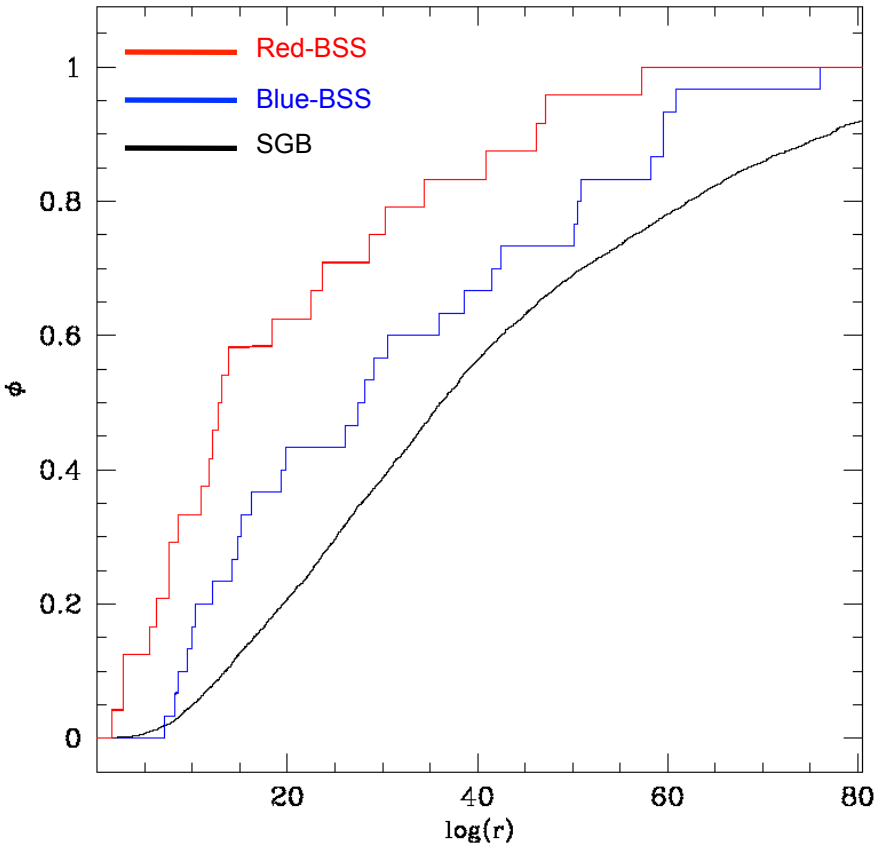
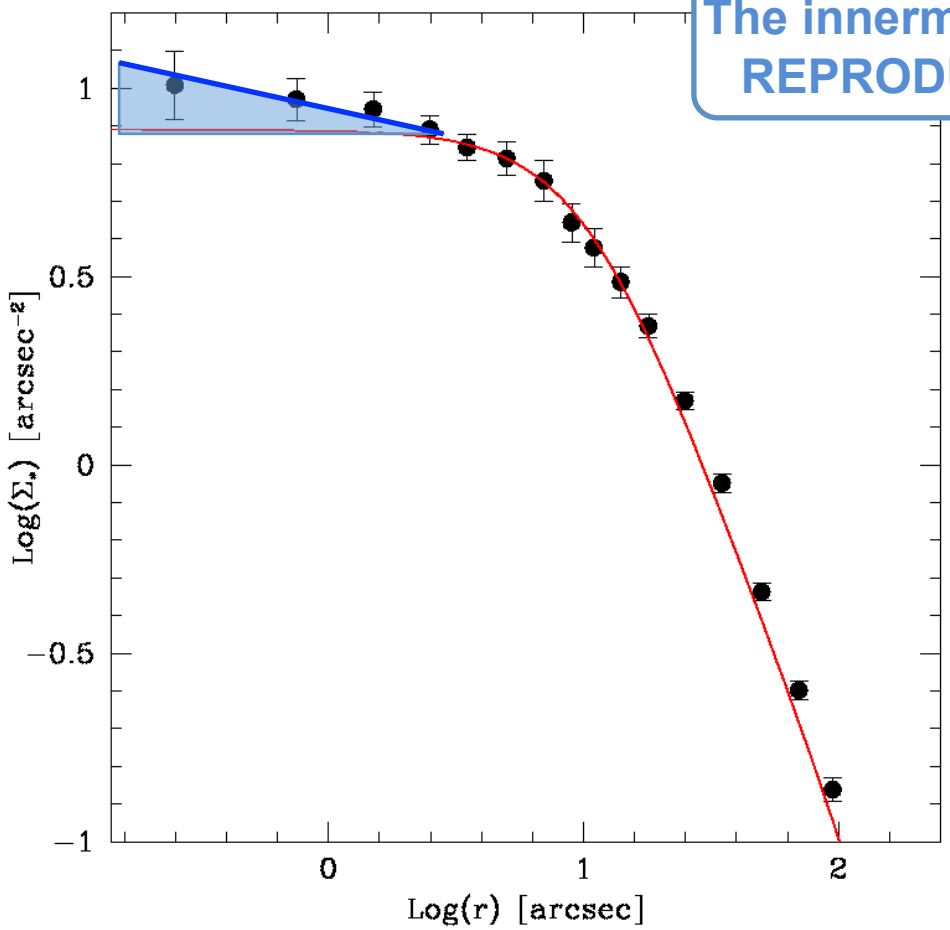
Their radial distribution





As in the case of M30, red-BSS are more centrally concentrated than blue-BSS (with a significance > 3σ)

Is NGC362 a post-core collapse cluster?



The innermost region (r<4”) is NOT REPRODUCED by a King model

The dynamical state of NGC362 is quite uncertain

A mild power-law (α=-0.25) is observed

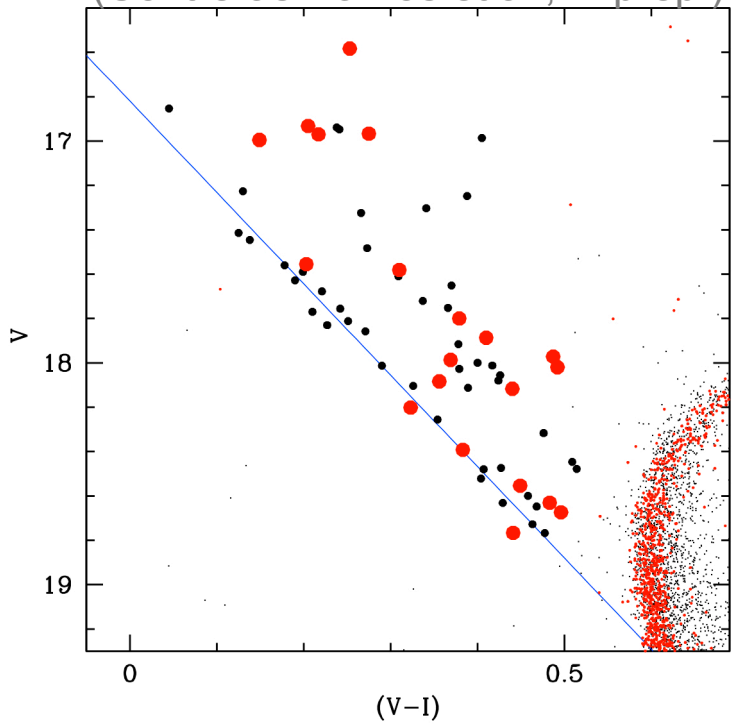
The observed density profile is compatible with that of a collapsed core

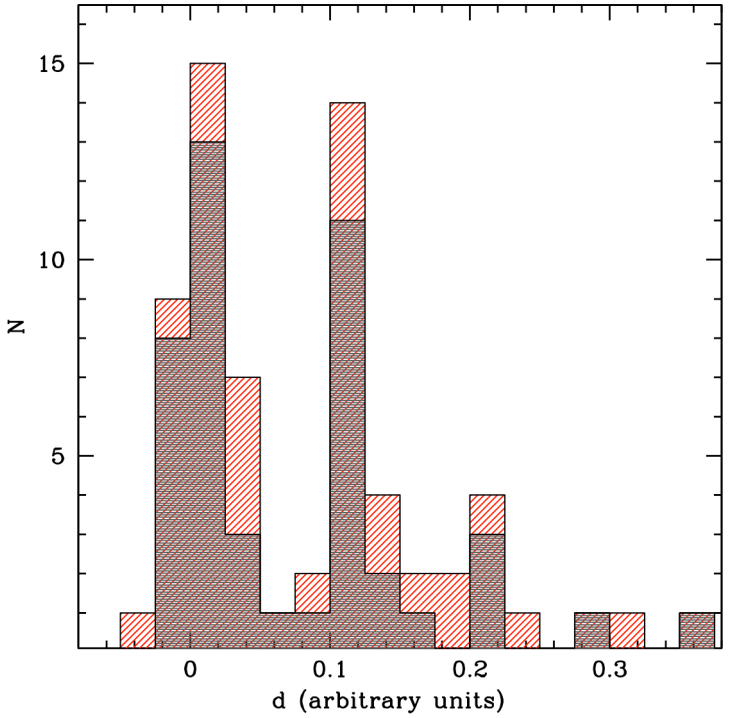
(Vesperini &Trenti 2010)

BSS double sequences probe & date the cluster core-collapse event

NGC 6397

(Contreras Ramos et al., in prep.)





BSS double sequences probe & date the cluster core-collapse event

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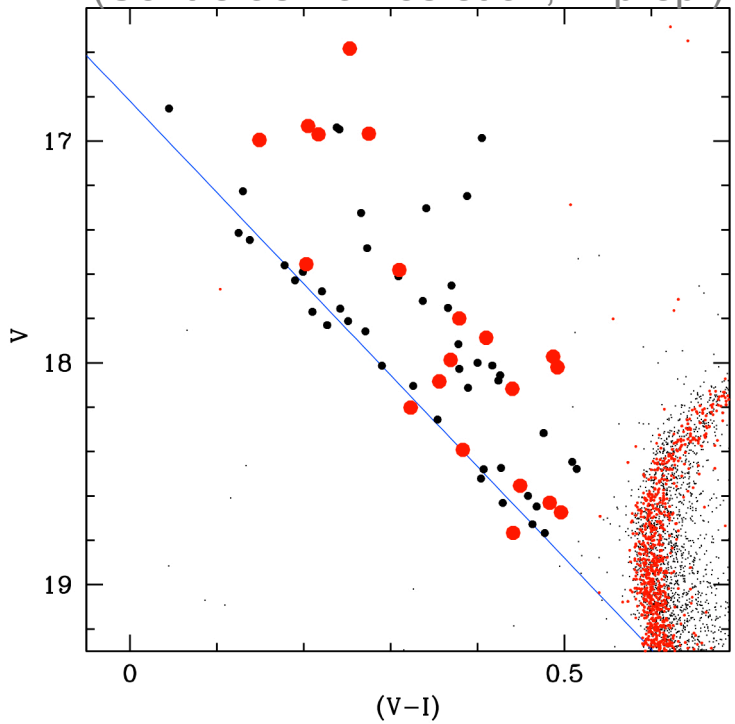
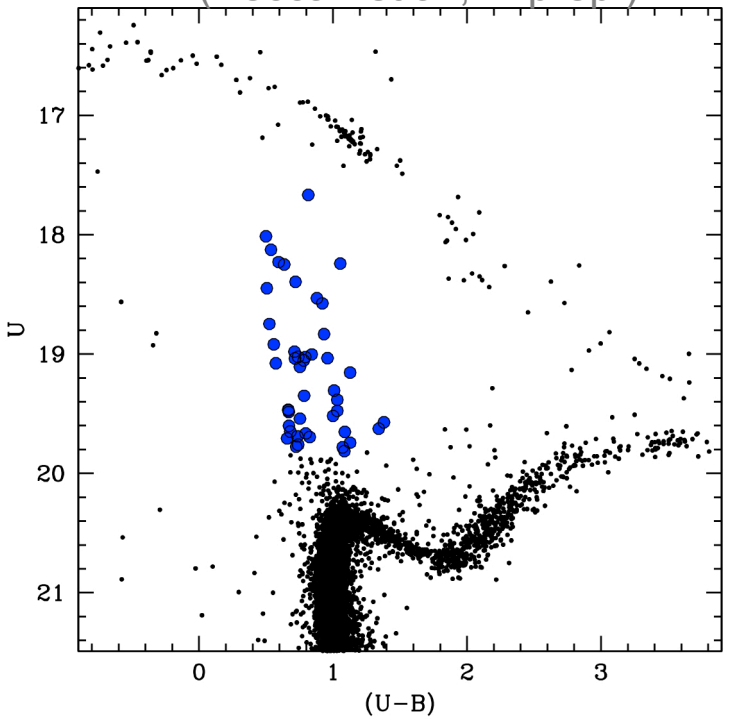


M15

(Beccari et al., in prep.)



Summary

- **We observed for the first time a BSS double sequence in M30**

- **A recent and short-lived event triggered the formation of the double sequence**

- **BSS can be useful for dating the collapse of the core**

- **NGC362 shows similar properties to M30**

- **Hints for a double sequence are observed also in NGC6397 and M15**

- **We are leading an observational campaign to understand how strong is the link between the double-sequence and the occurrence of the core collapse**

Thank you!

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