Probing the dynamical evolution of stellar aggregates with Blue Straggler Stars

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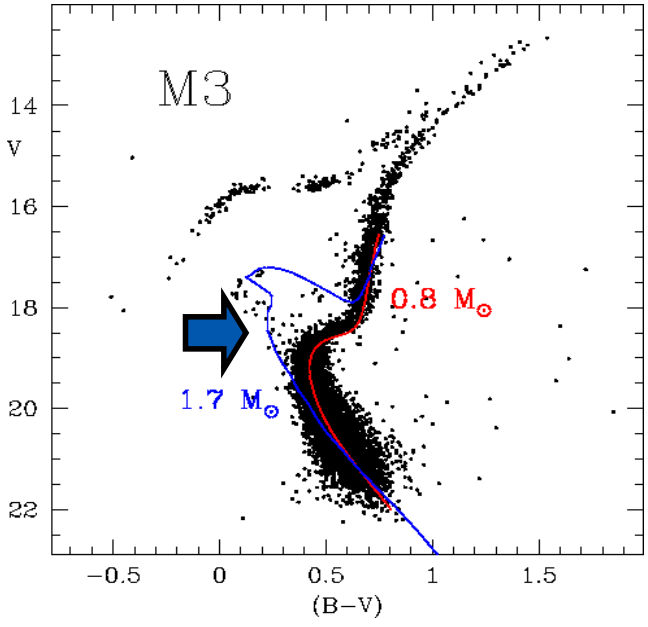
Cosmic-Lab

- 5-year project
- funded by the European Research Council (ERC)
- PI: Francesco R. Ferraro (Dip. of Astronomy – Bologna Univ.)
- AIM: **to understand the complex interplay between dynamics & stellar evolution**
- HOW: using **globular clusters** as cosmic laboratories and

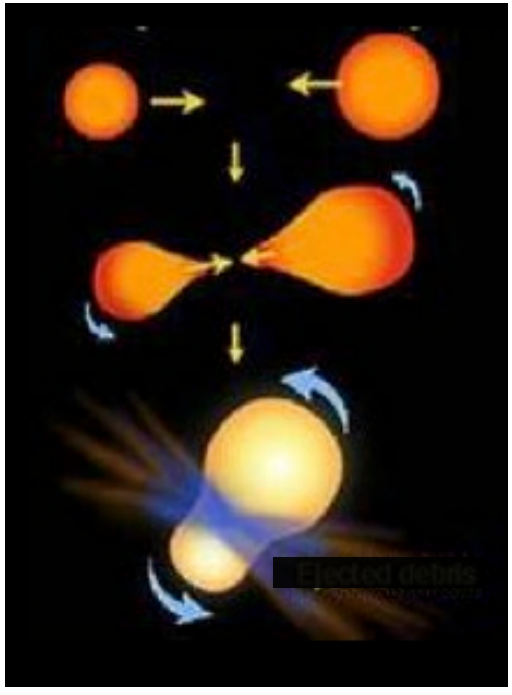
  Blue Straggler Stars
  Millisecond Pulsars
  Intermediate-mass Black Holes
  } as probe-particles

Why BSS?

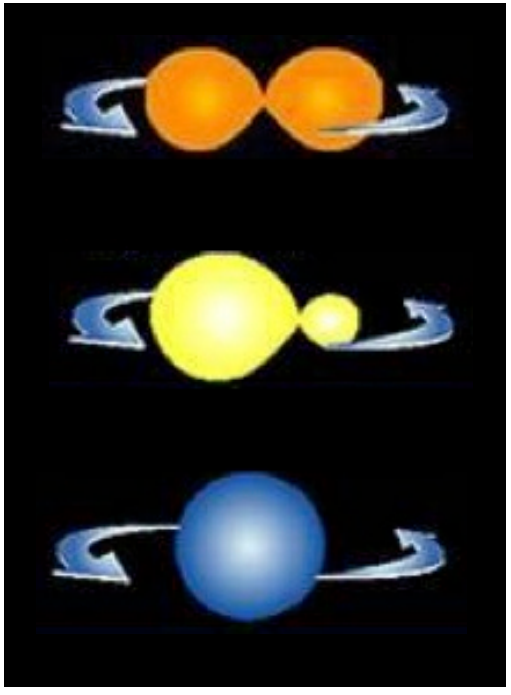
more massive than normal stars (=> dynamical friction)



collisional BSS

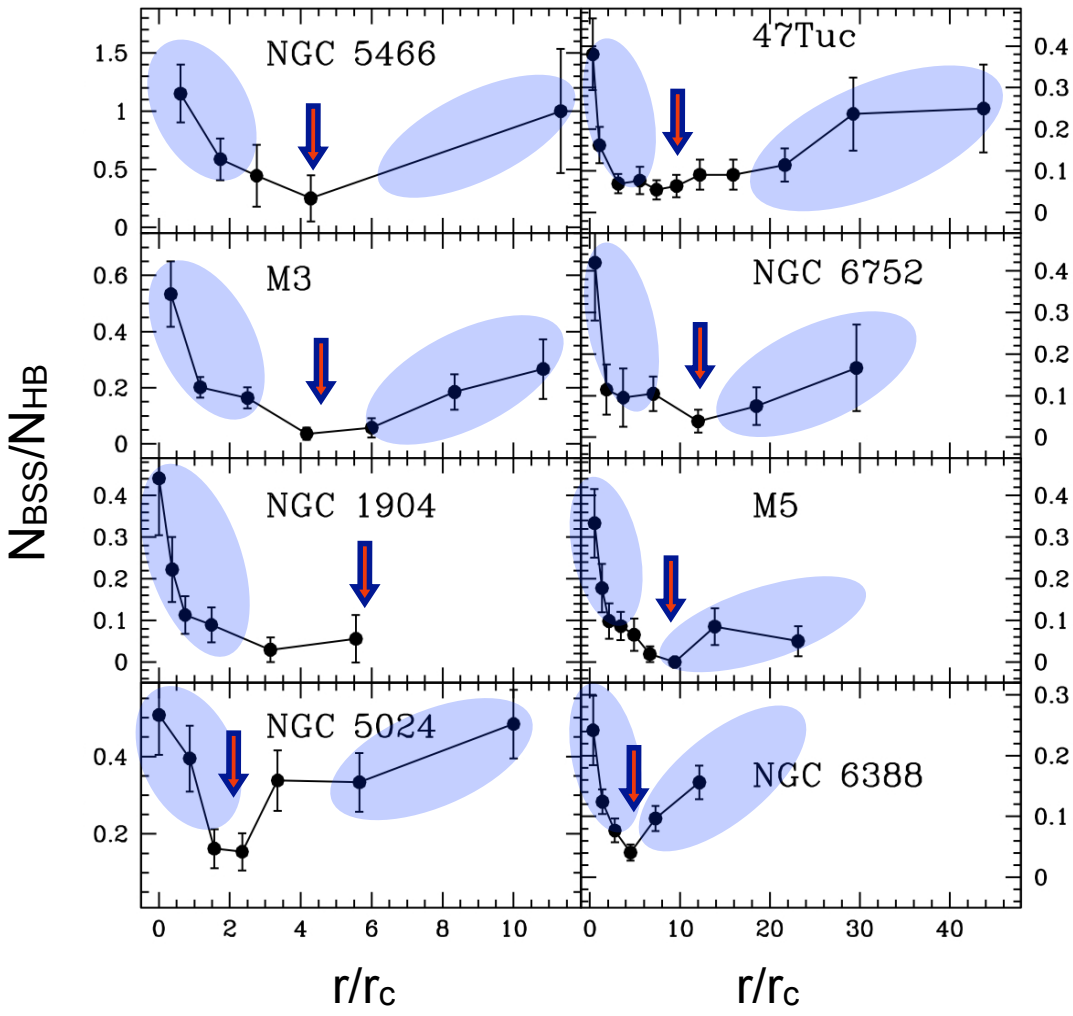


mass-transfer BSS



BSS: crucial probes of stellar evolution & stellar dynamics

BSS radial distribution



- **centrally peaked / bimodal in most (~18) GCs**

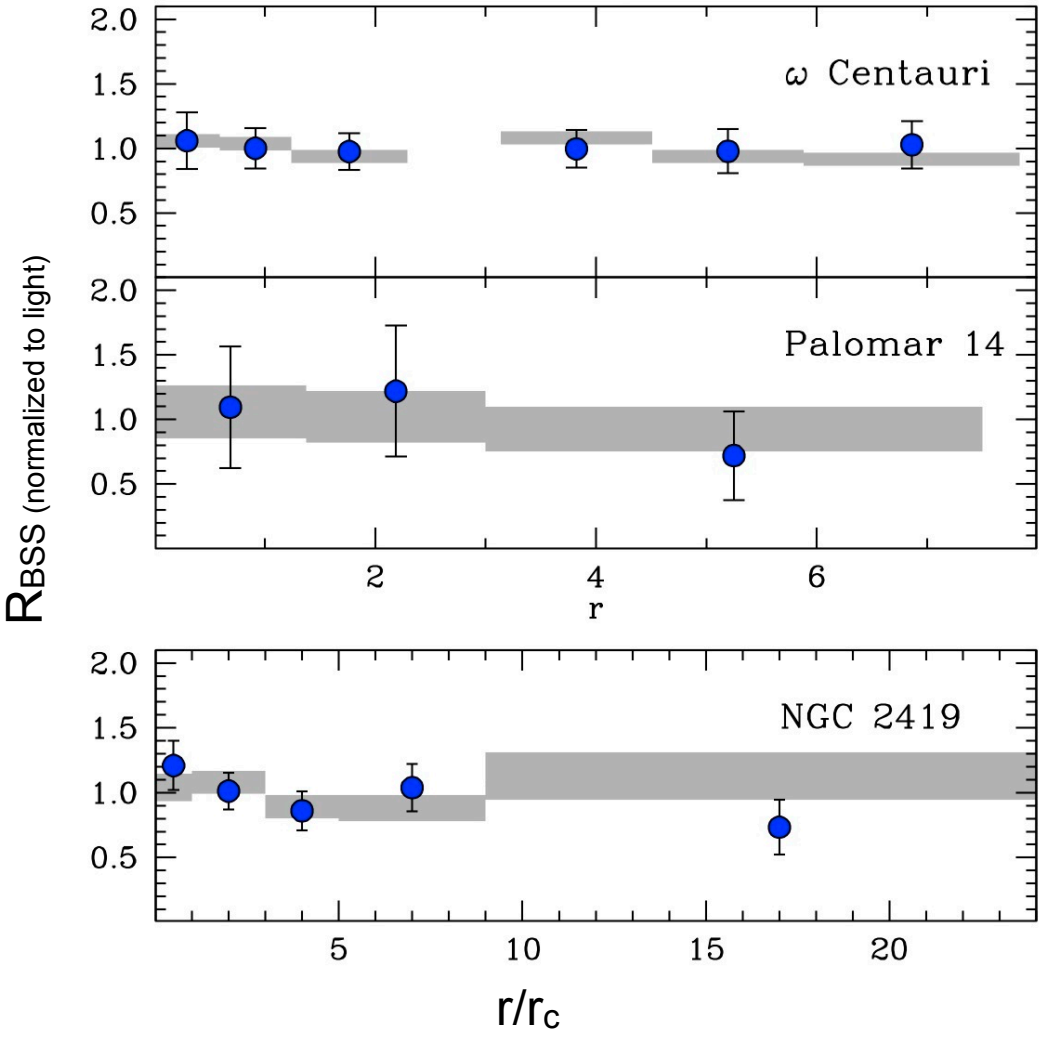
  Ferraro et al. (93, 94, 04);
  Sabbi et al. (04);
  Lanzoni et al. (07ab);
  Dalessandro et al. (08);
  Beccari et al. (08, 09);
  Contreras Ramos et al. (12);
  ...

- **position of the minimum**

radius of avoidance

all stars with BSS-mass sunk at $r < r_{avoid}$ because of <u>dynamical friction</u>

BSS radial distribution



- **flat in 3 GCs**

  Ferraro et al. (2004); Dalessandro et al. (2008); Beccari et al. (2011)

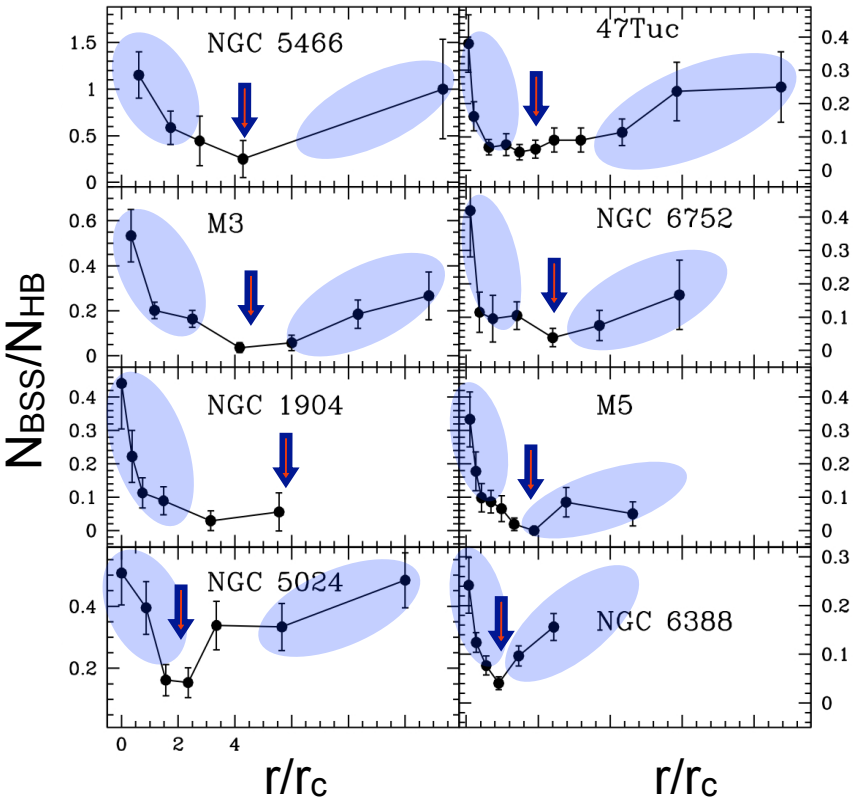
- same as in dwarf galaxies

  (e.g., Mapelli et al. 2009; Monelli et al. 2012)

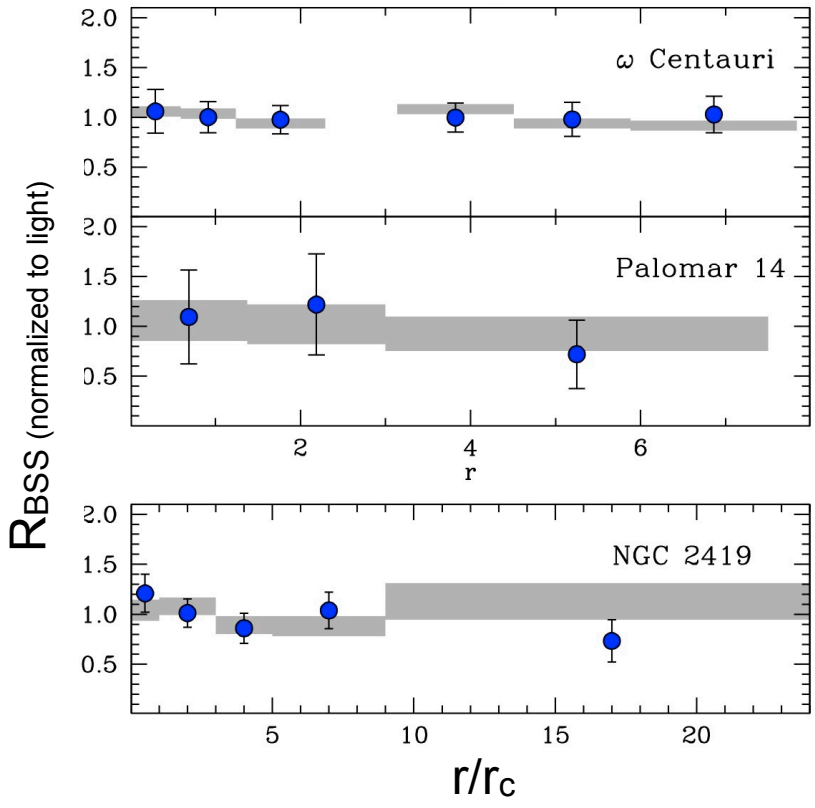
- **not mass-segregated yet**

the BSS radial distribution

peaked/bimodal

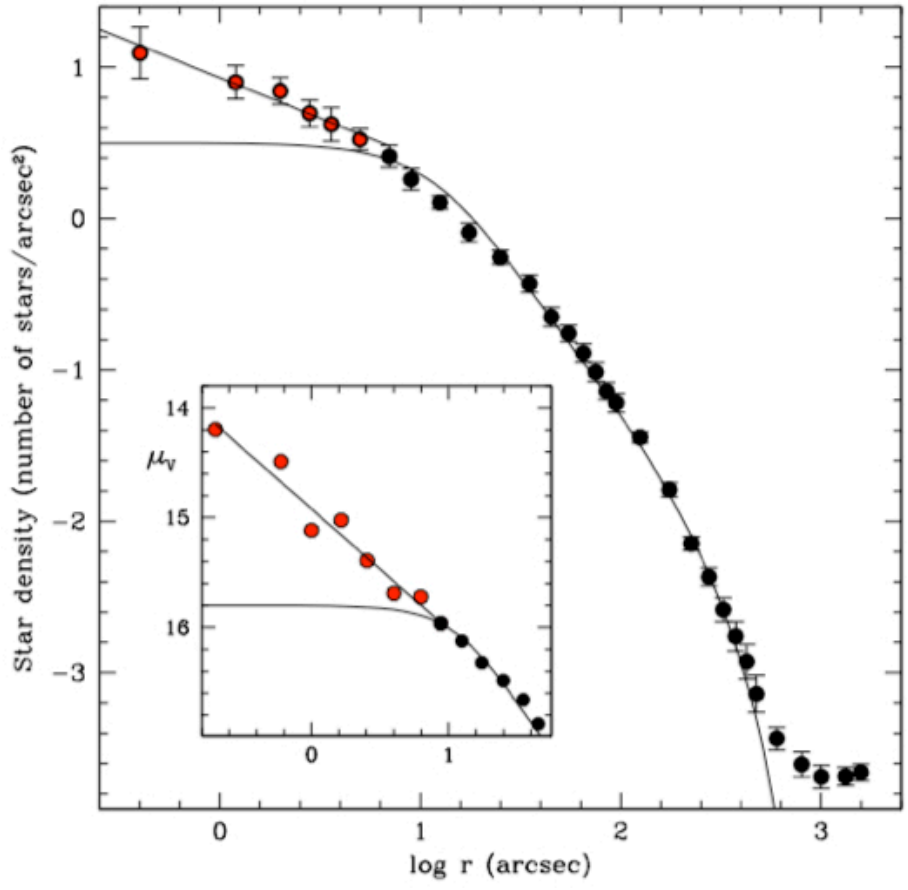


flat



probes the degree of mass-segregation and the efficiency of dynamical friction

M30 (NGC 7099)



- Post-core collapse (PCC) cluster

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

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

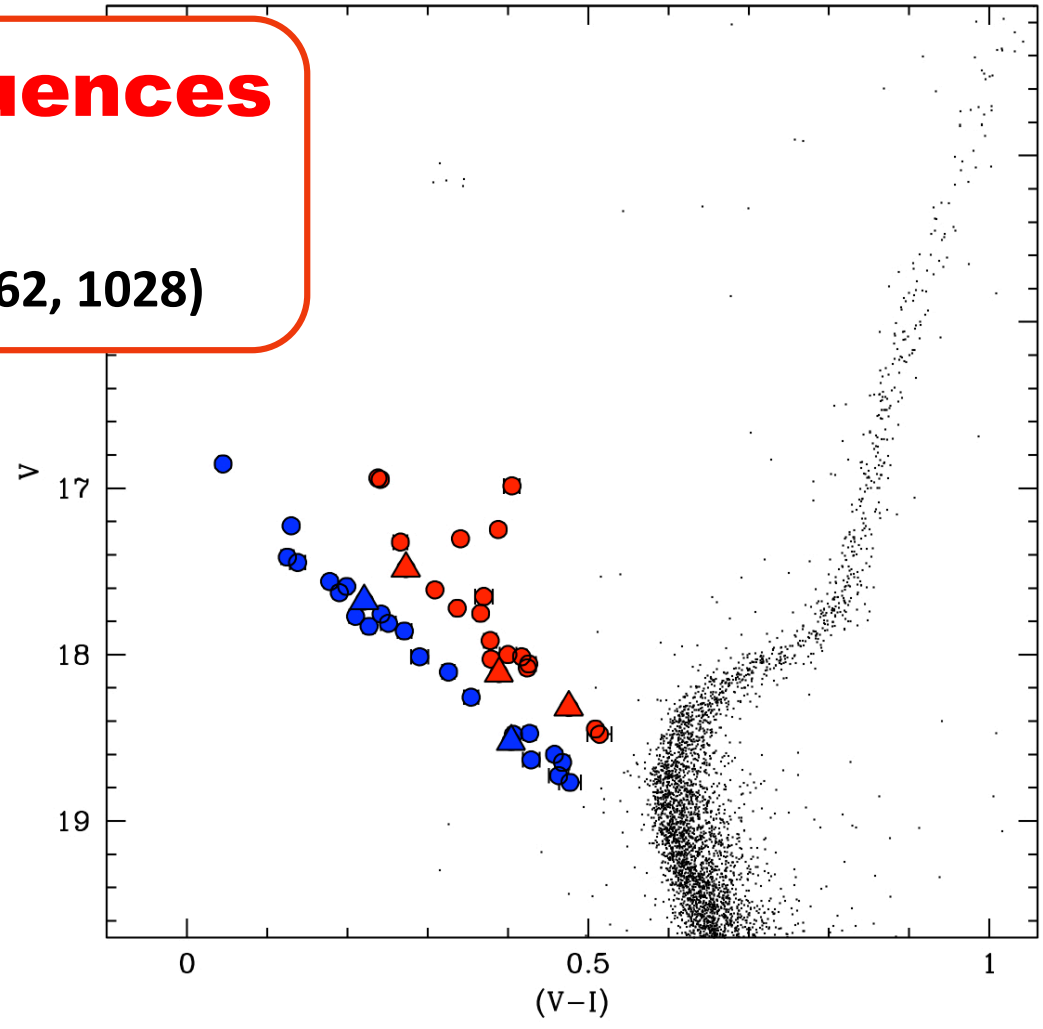
HST/WPC2 dataset (1999, GO7379)

- 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

Two distinct sequences of BSS !!

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



Two distinct sequences of BSS !

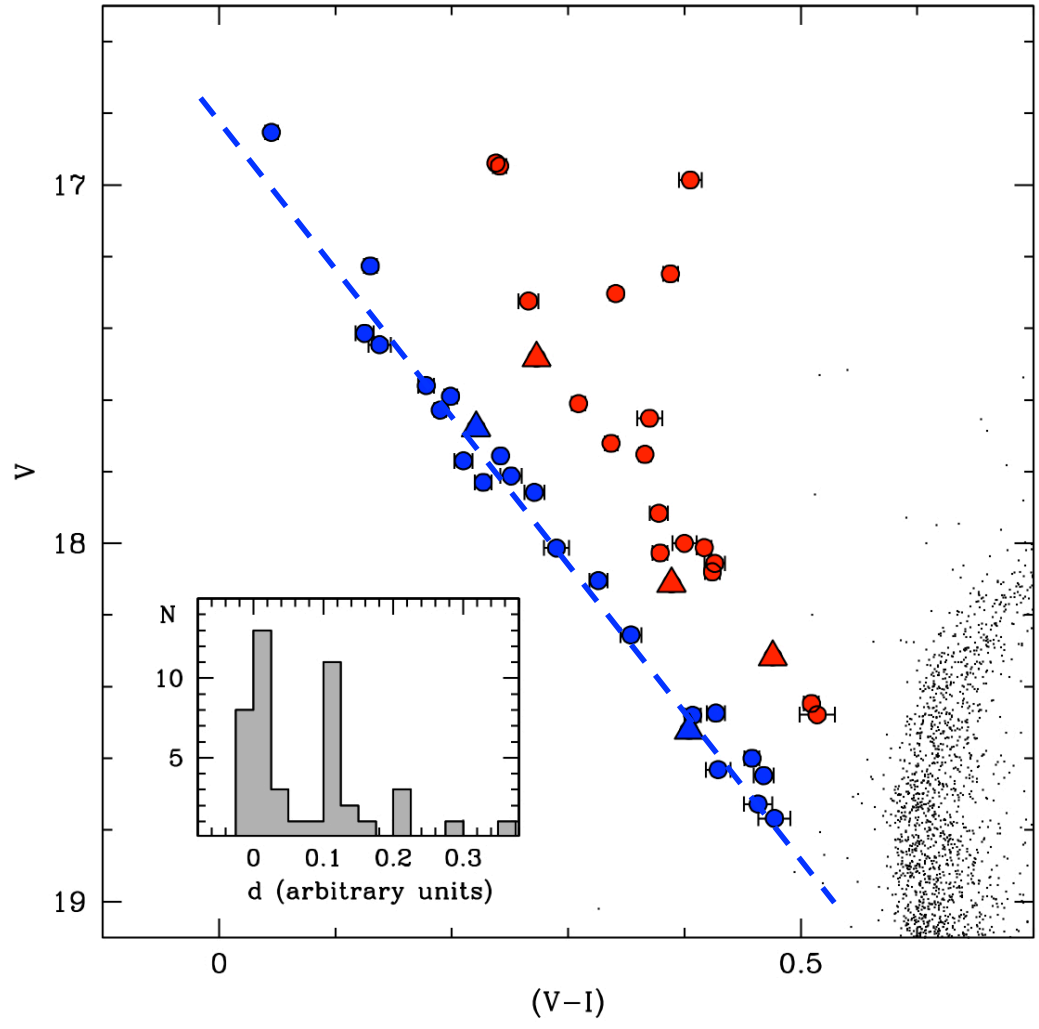
Ferraro et al. (2009, Nature 462, 1028)

- **similarly populated:**

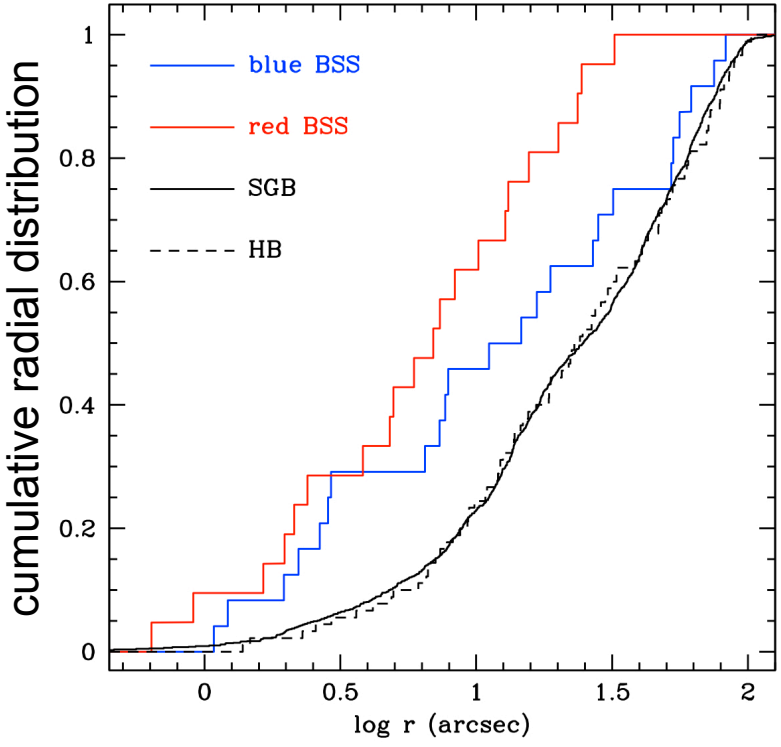
  24 blue-BSS
  21 red-BSS

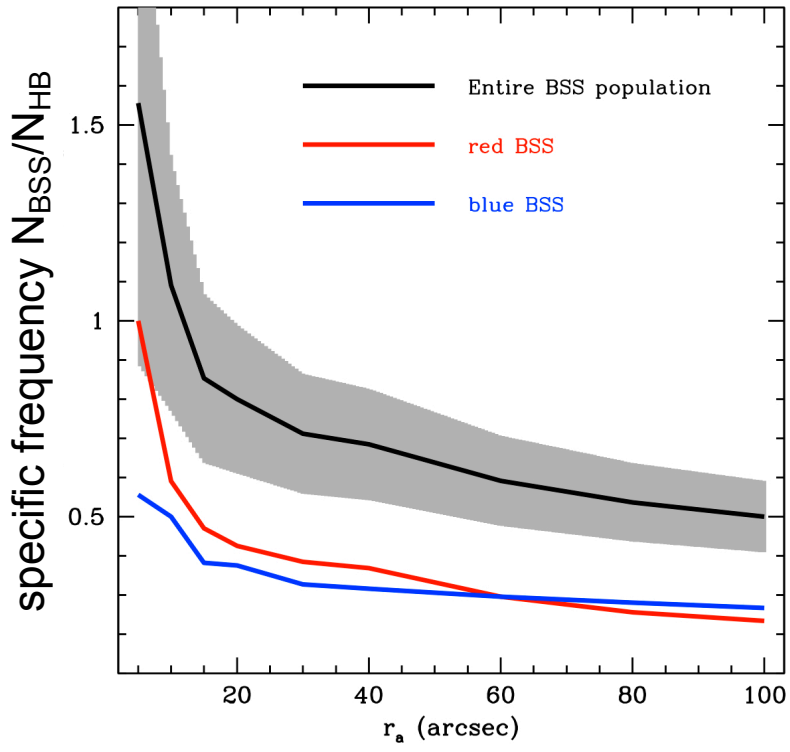
- **almost parallel:**

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



- **centrally segregated:**





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

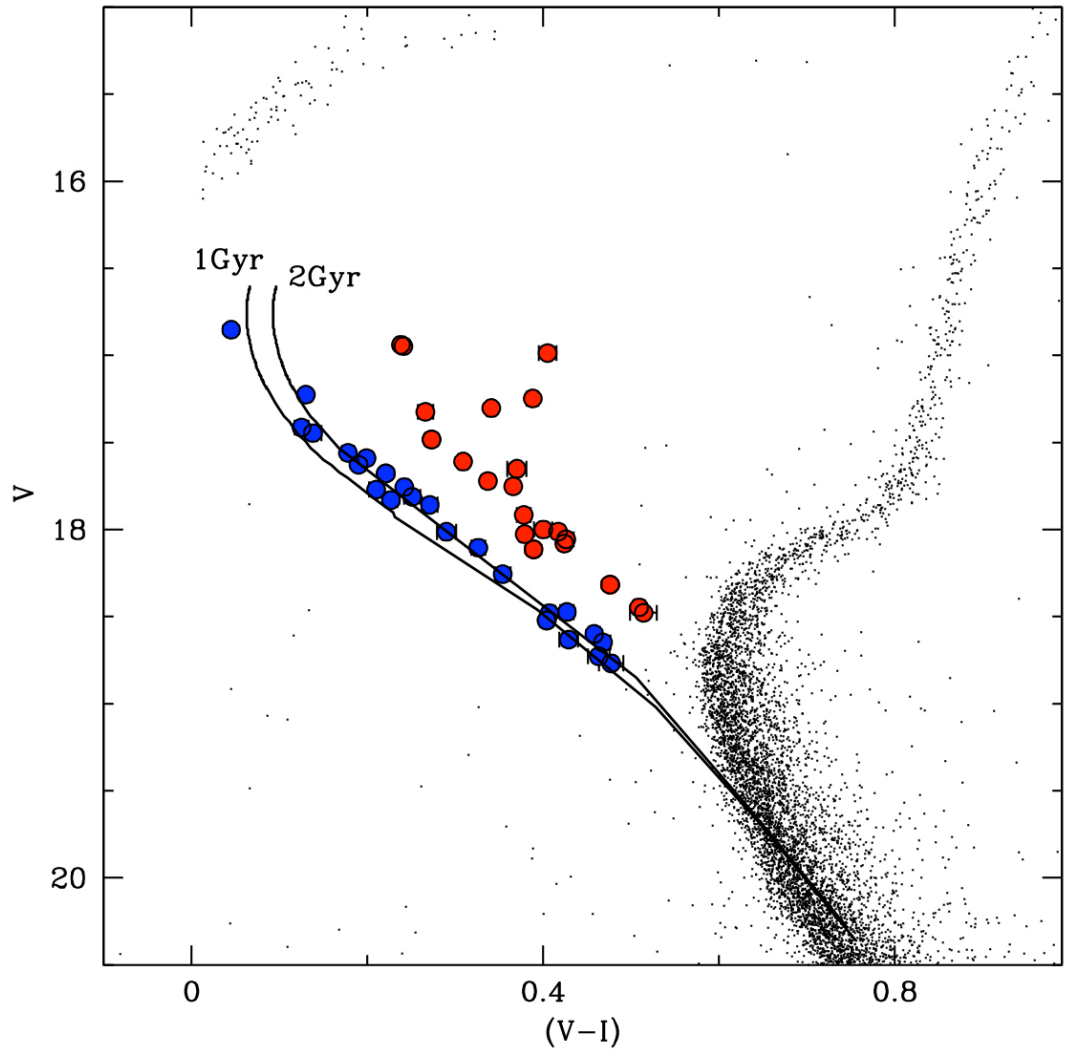
different formation mechanism for red- and blue-BSS?

Evolutionary models of COL-BSS (Sills et al. 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**

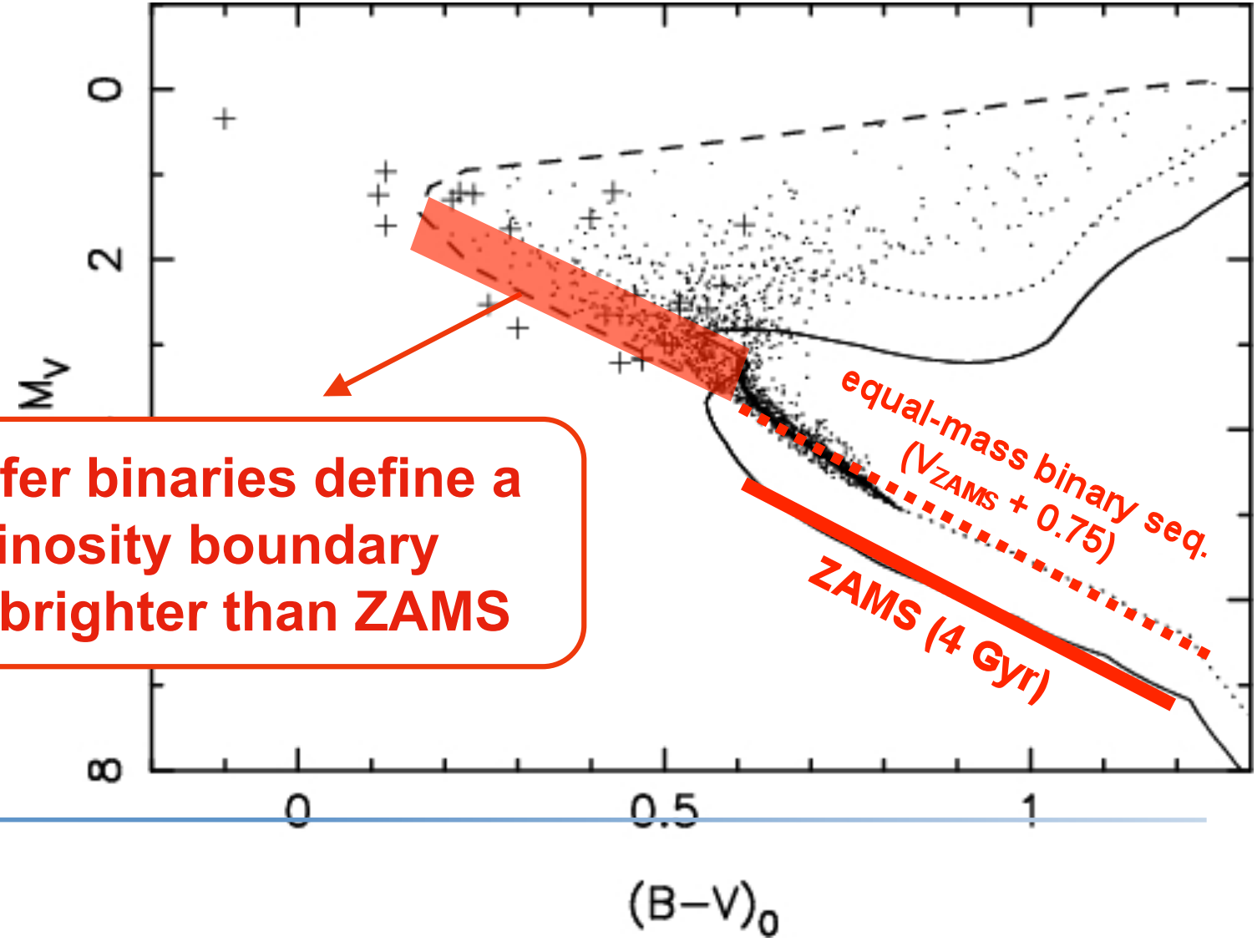
- red-BSS sequence **too red** to be reproduced by collisional isochrones of **any** age



Binary evolution models (Tian et al. 2006)

dots: simulated mass-transfer binaries (donor: 0.1-2.0 $M_\odot$, accretor: 0.1 $M_\odot$- M_{donor})

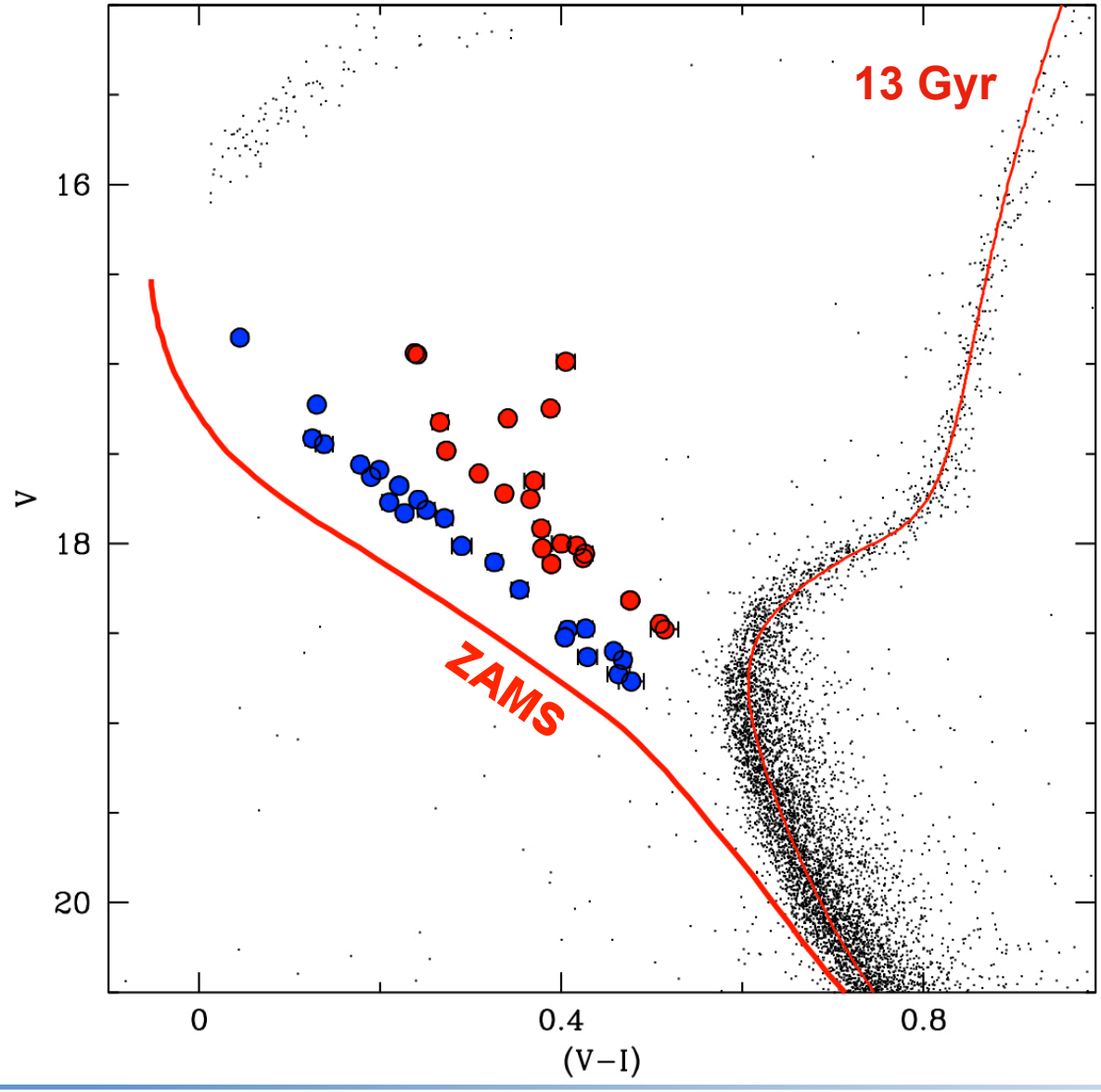
crosses : observed BSS in M67 (Deng et al. 1999)



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



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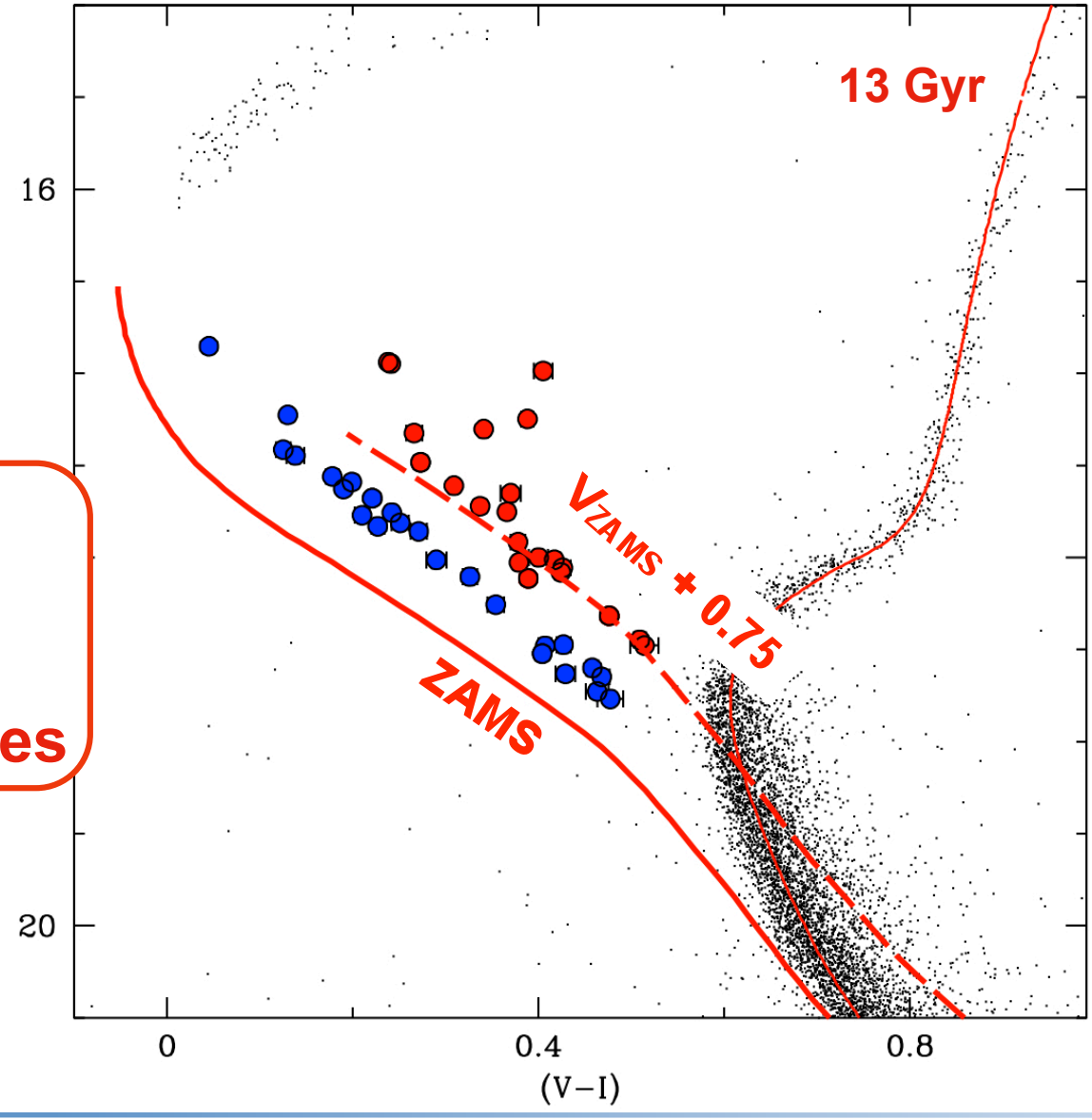
red-BSS sequence well reproduced by models of mass-transfer binaries



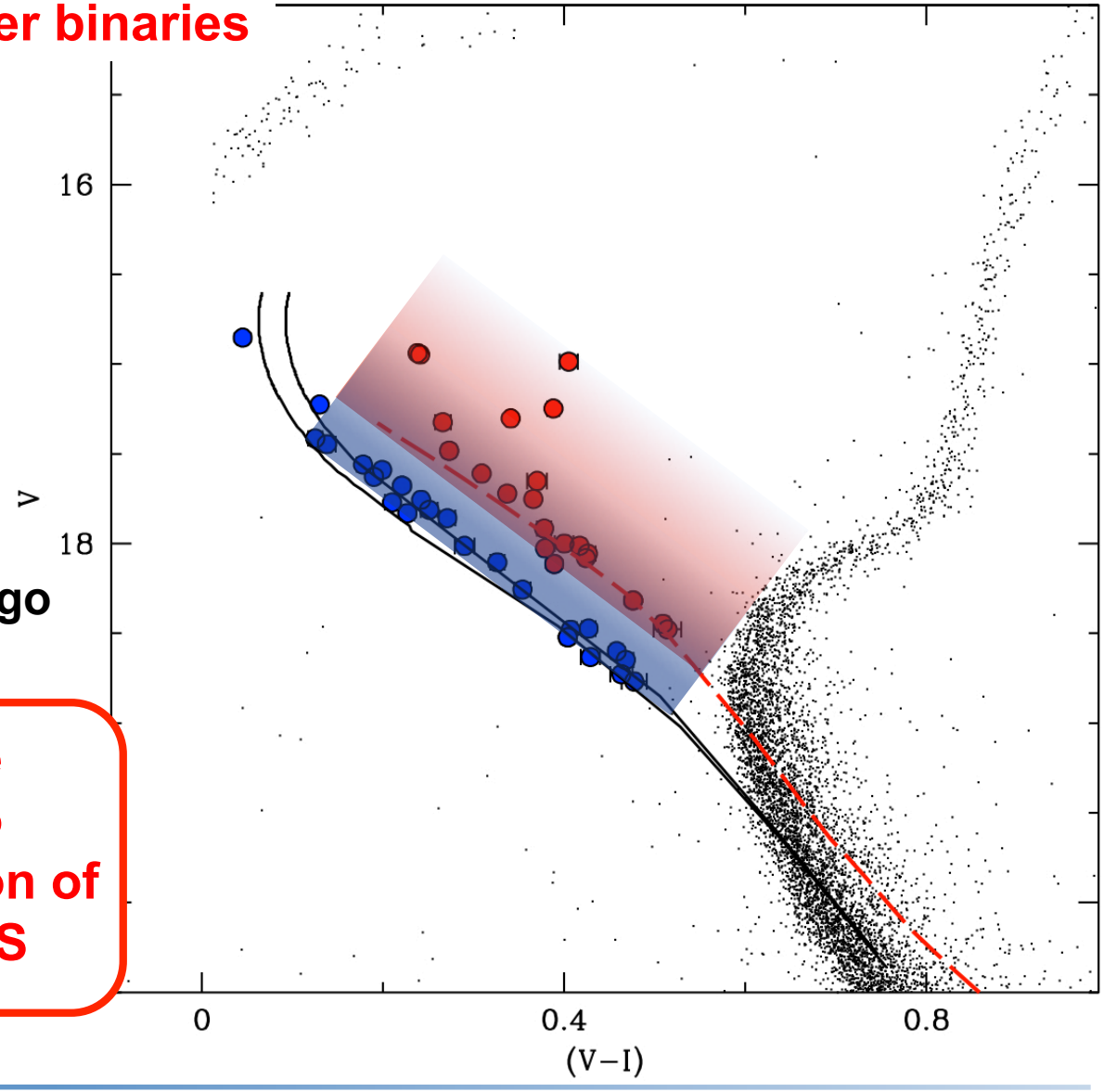
- blue-BSS → collisional
- red-BSS → mass-transfer binaries

- both will quickly evolve

  → gap filled in a few Gyr

⇩

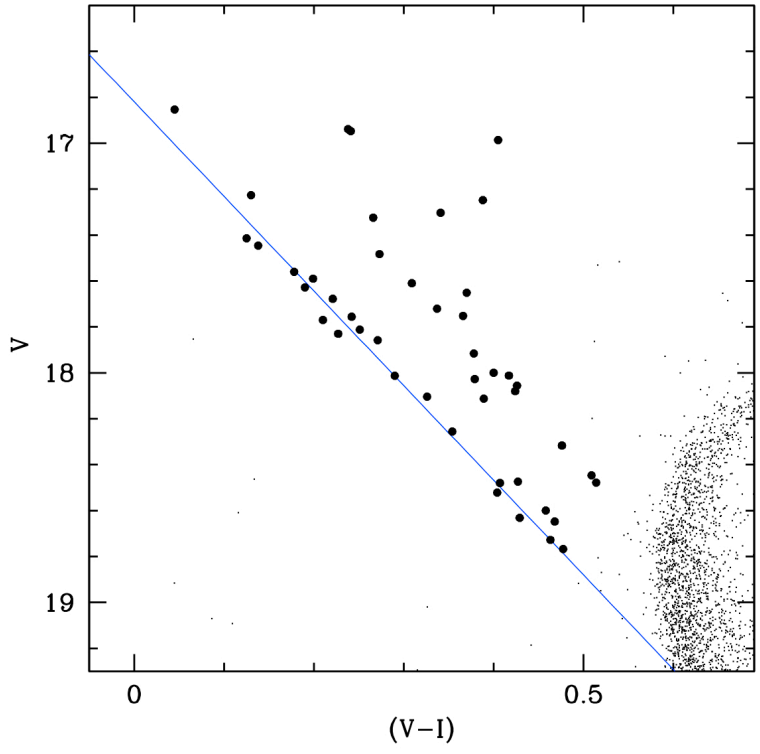
the two BSS populations must have formed 1-2 Gyr ago

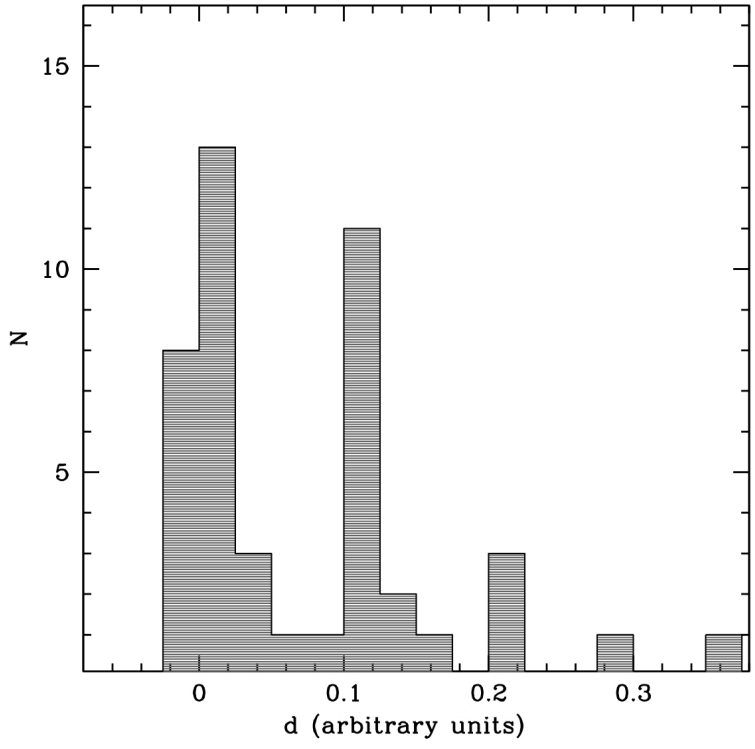


cluster core-collapse occurred 1-2 Gyr ago and boosted the formation of both COL- and MT-BSS

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

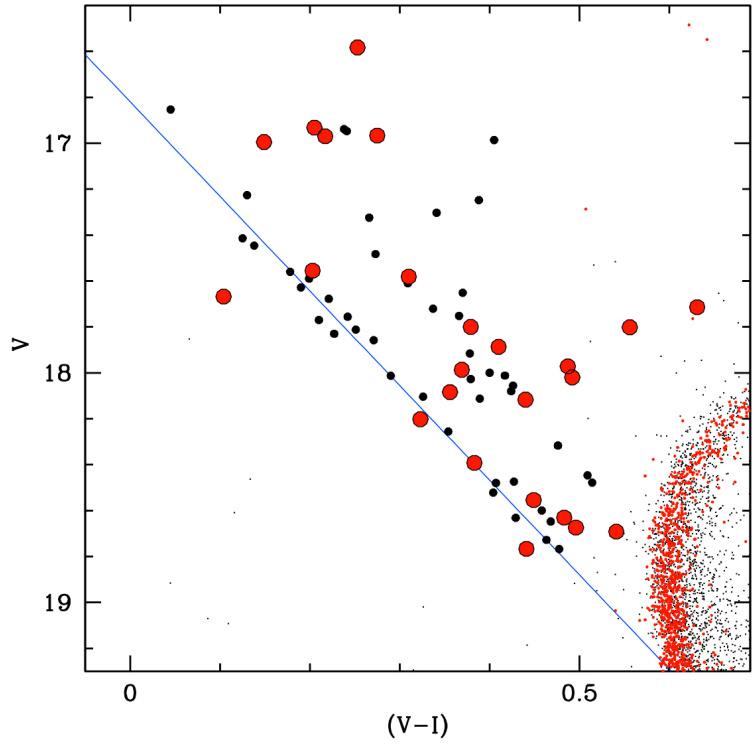
M30 (Ferraro et al. 2009)

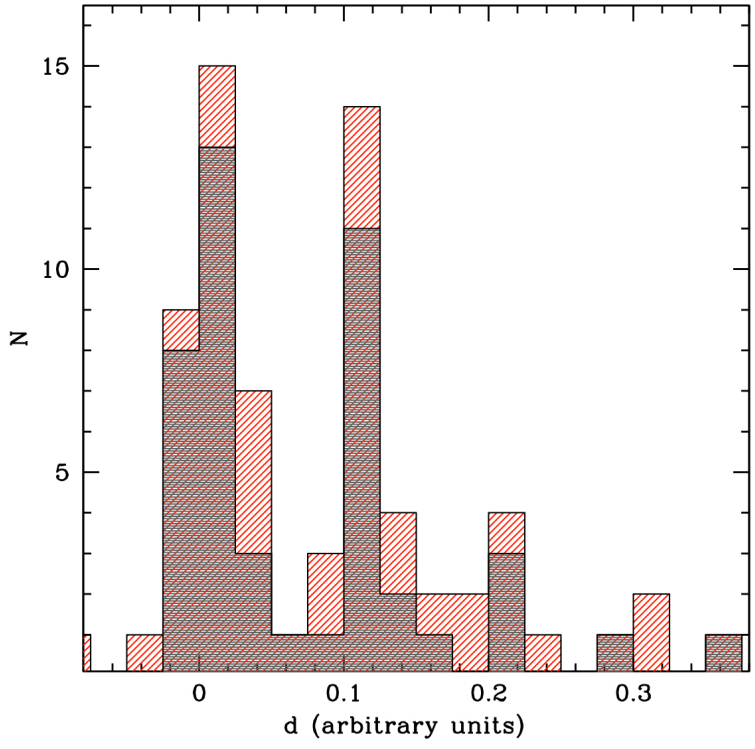




BSS double sequences probe & date the cluster core-collapse event

NGC 6397 (Contreras Ramos et al. 2012, in preparation)





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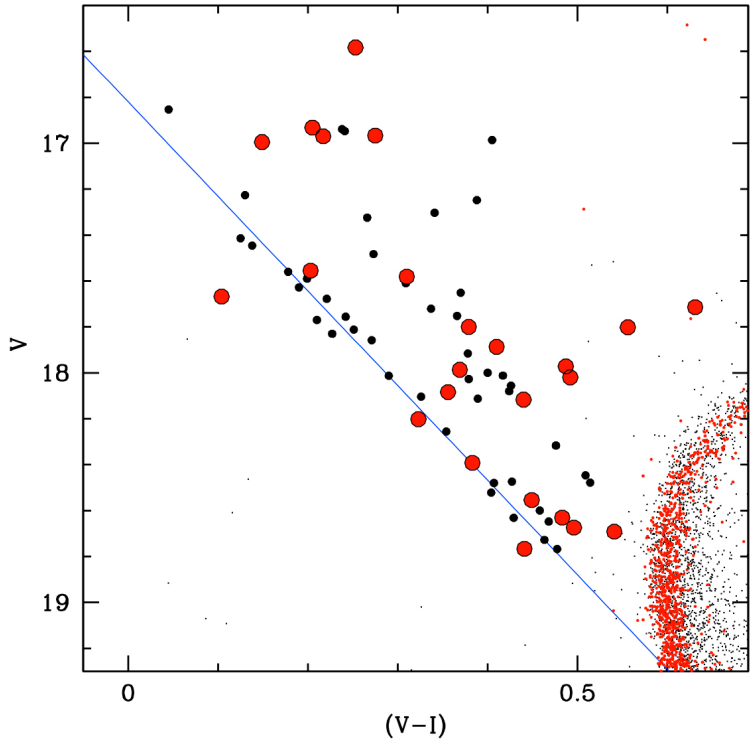
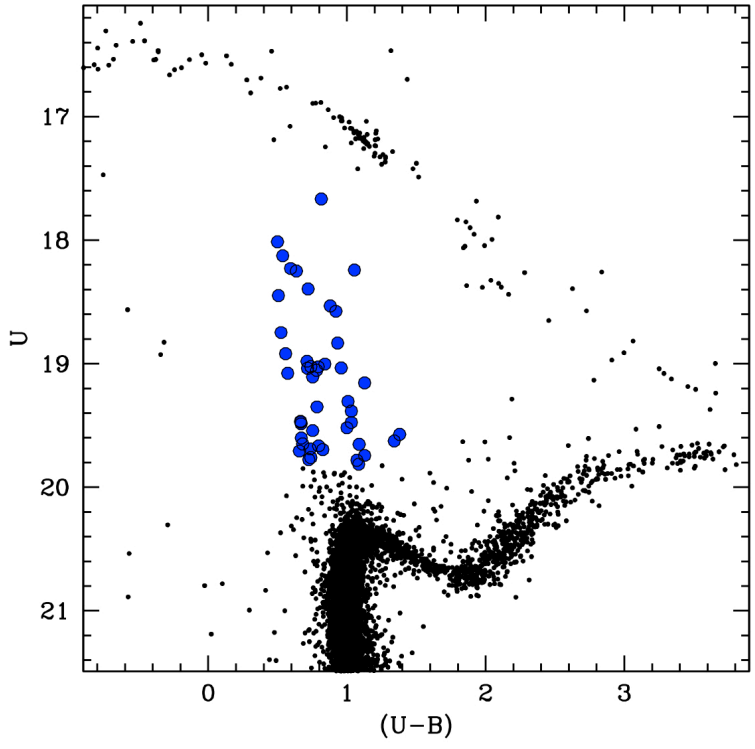


M15

(Beccari et al., in prep.)



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