Tracing mass segregation in globular clusters with three different indicators

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Cosmic-Lab

www.cosmic-lab.eu

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

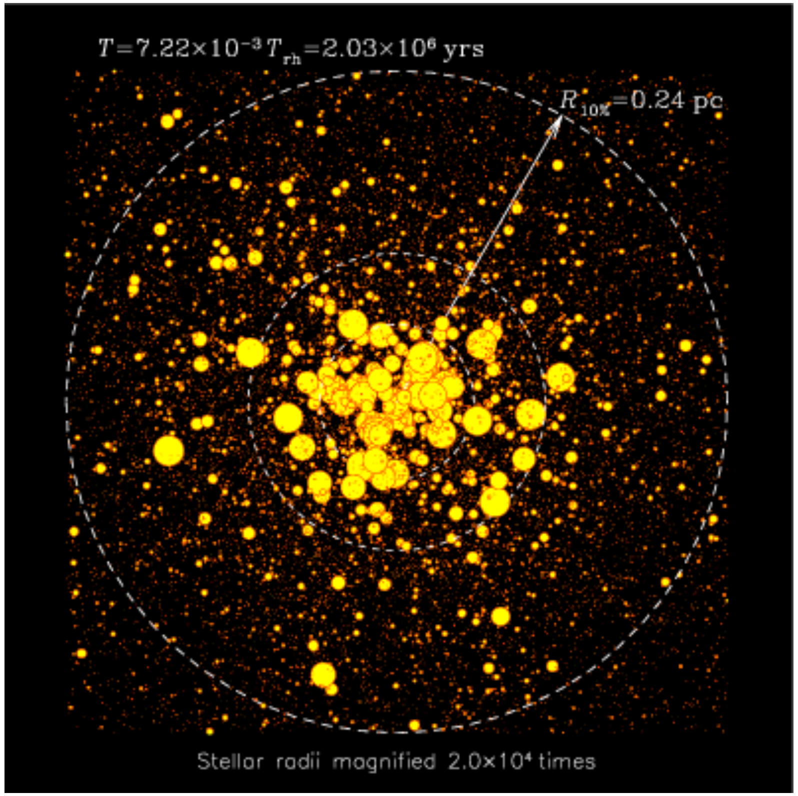
  Blue Straggler Stars
  Millisecond Pulsars
  Intermediate-mass Black Holes

  } as probe-particles

The dynamical evolution of GCs

STELLAR EVOLUTION drives the evolution of the first 1-2Gyr of star clusters

TWO-BODY RELAXATION drives in the long term dynamical evolution

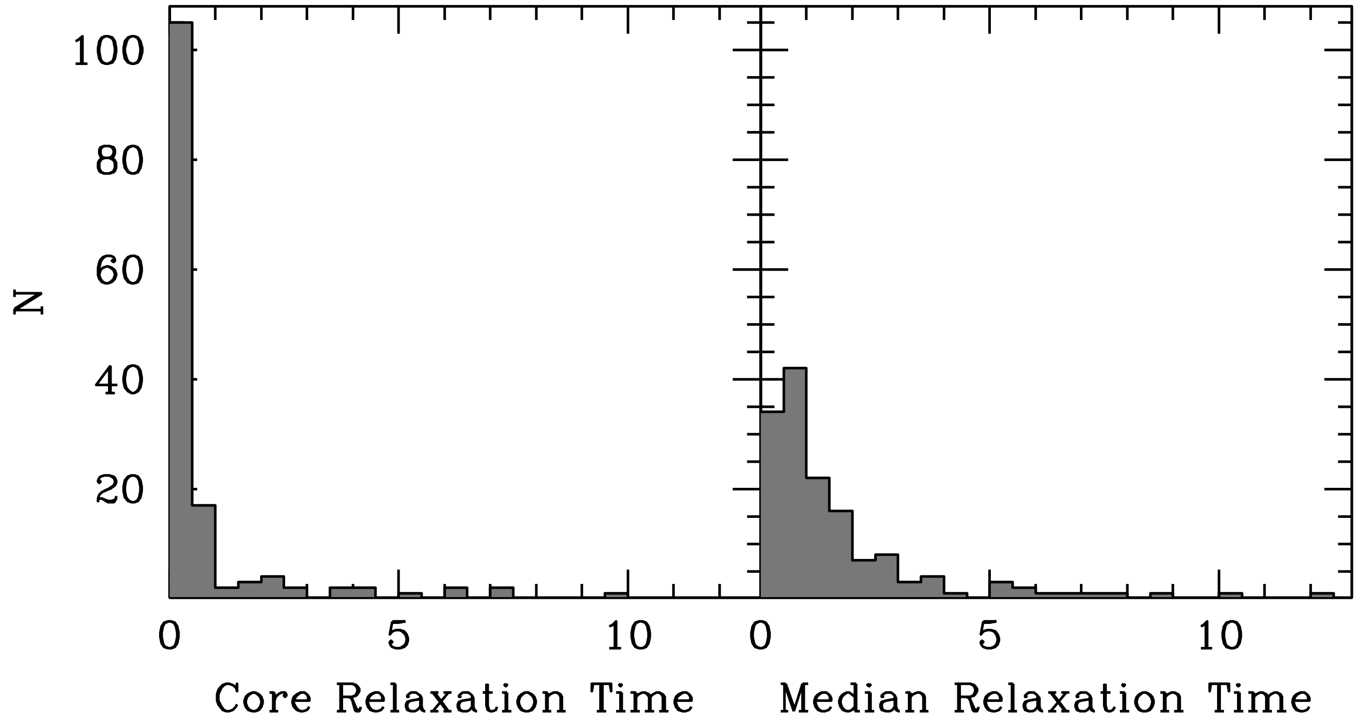


MASS SEGREGATION

Heavier stars tend to sink toward the cluster centers while less massive objects are forced on more external orbits

The dynamical evolution of GCs

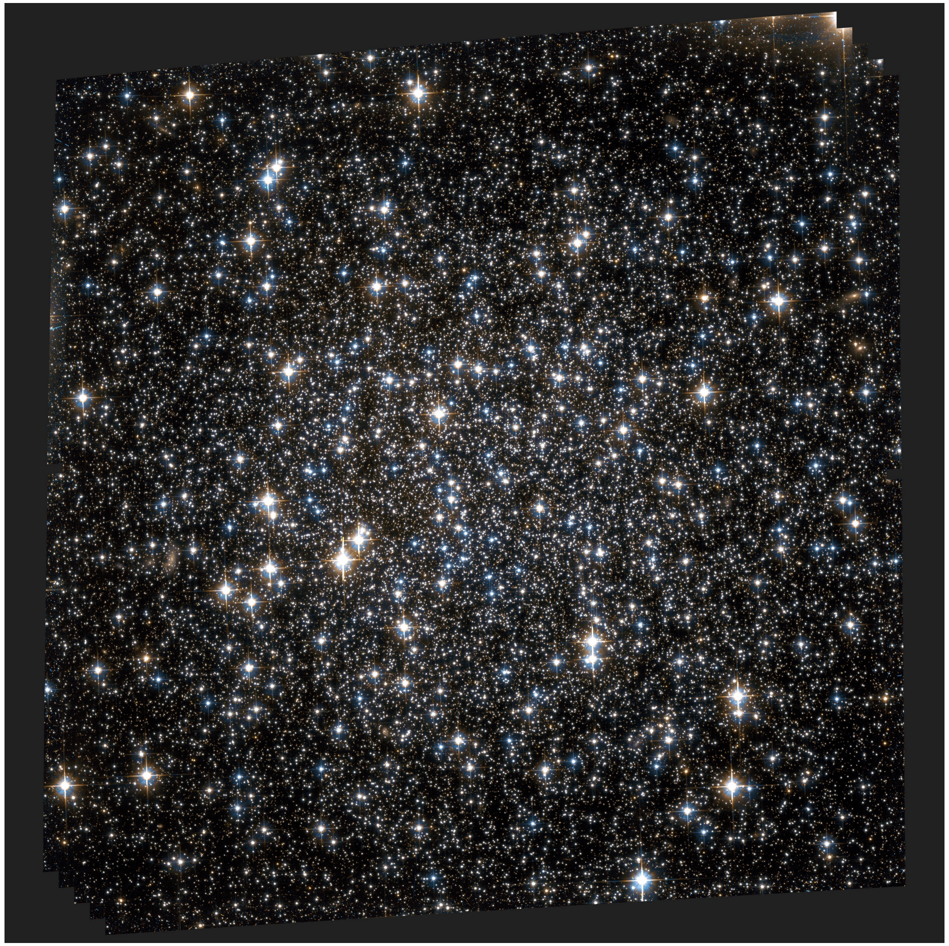
The typical time-scale in which relaxation is reached depends on the number of stars (Spitzer 1987)



All GCs are expected to show evidence of mass segregation

BUT SEE CASES LIKE ωCentauri, NGC2419, Pal14, Sgr clusters

The dynamical state of NGC 6101



NGC 6101 is an old, low concentrated Galactic Halo GC

… with some peculiarities

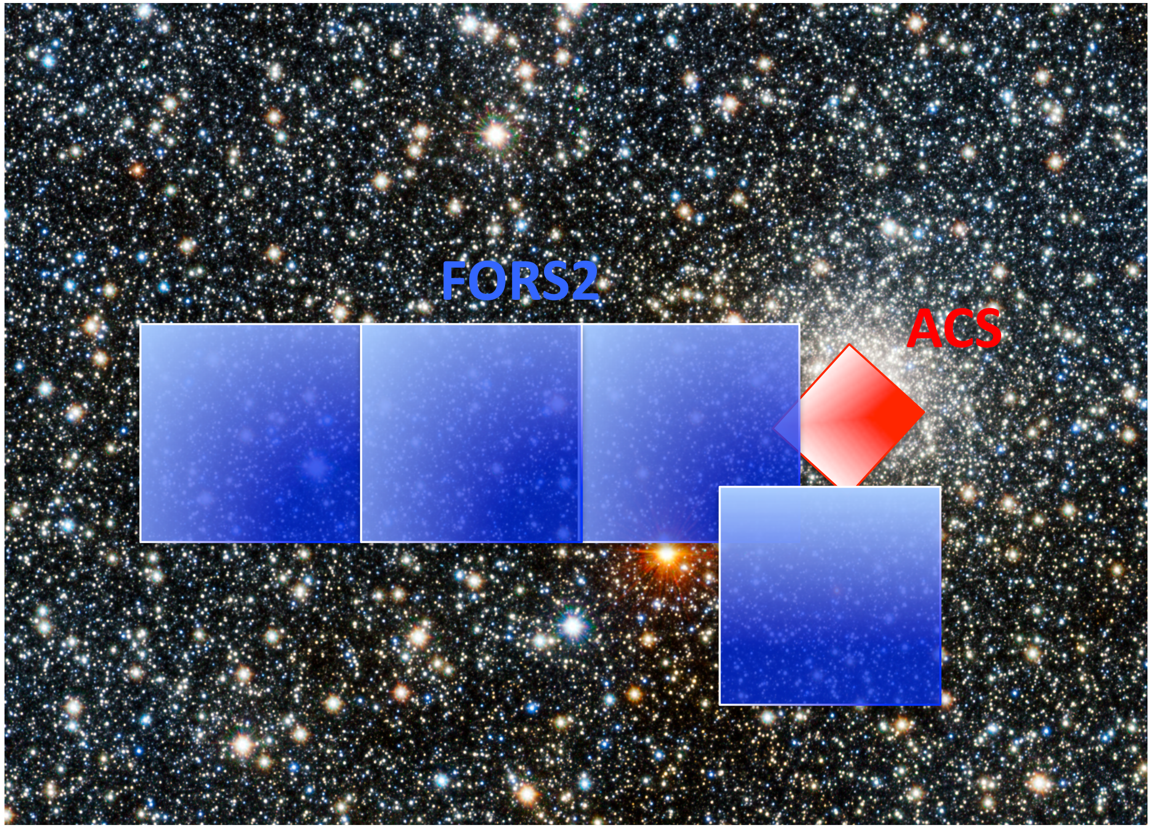
1. It's an Oosterhoff II cluster
   (Cohen et al. 2010)

2. It has a retrograde motion
   (Geisler et al. 1995)

3. It's potentially connected to the Canis Major (Martin et al. 2004)

“The binary fraction in the outer regions of GGCs”

Binary stars are a crucial ingredient for the formation and dynamical evolution of GCs

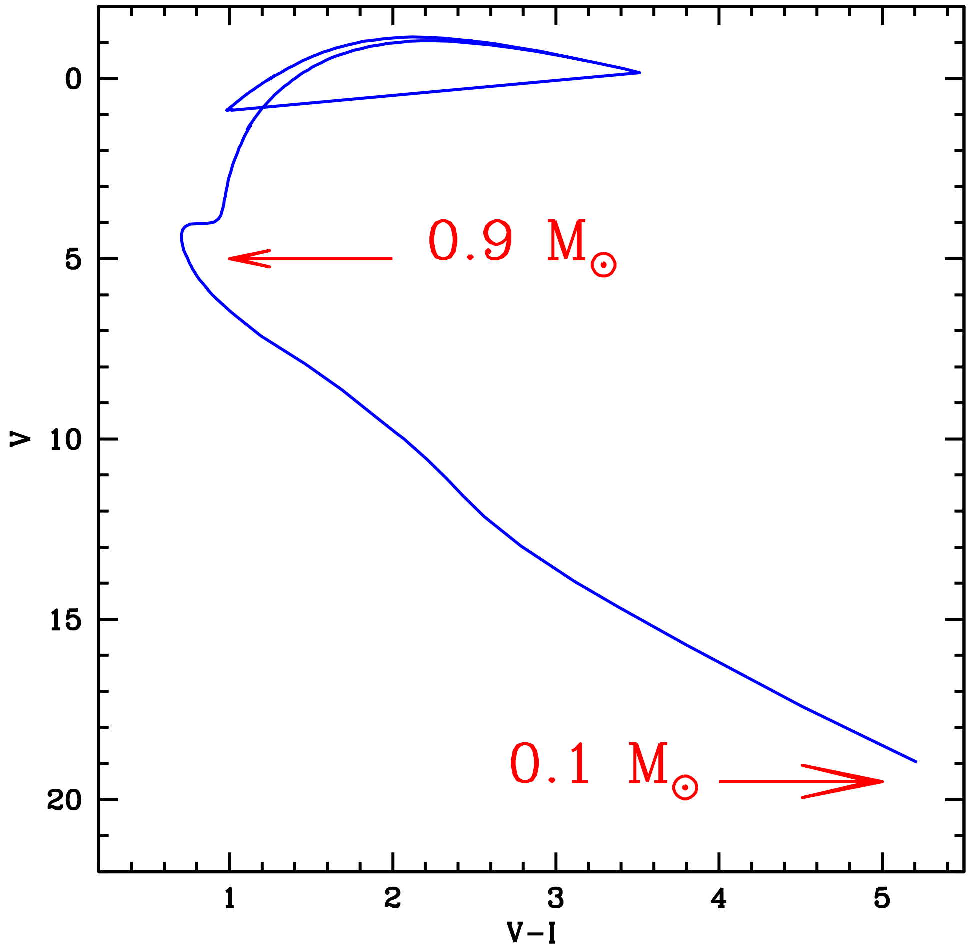


We targeted 6 low density GCs by using FORS2@VLT to sample the MS down to 5-6 magnitude below the TO

Additional clusters in the Northern emisphere have been observed with LBC@LBT

The MS LUMINOSITY and MASS FUNCTIONS

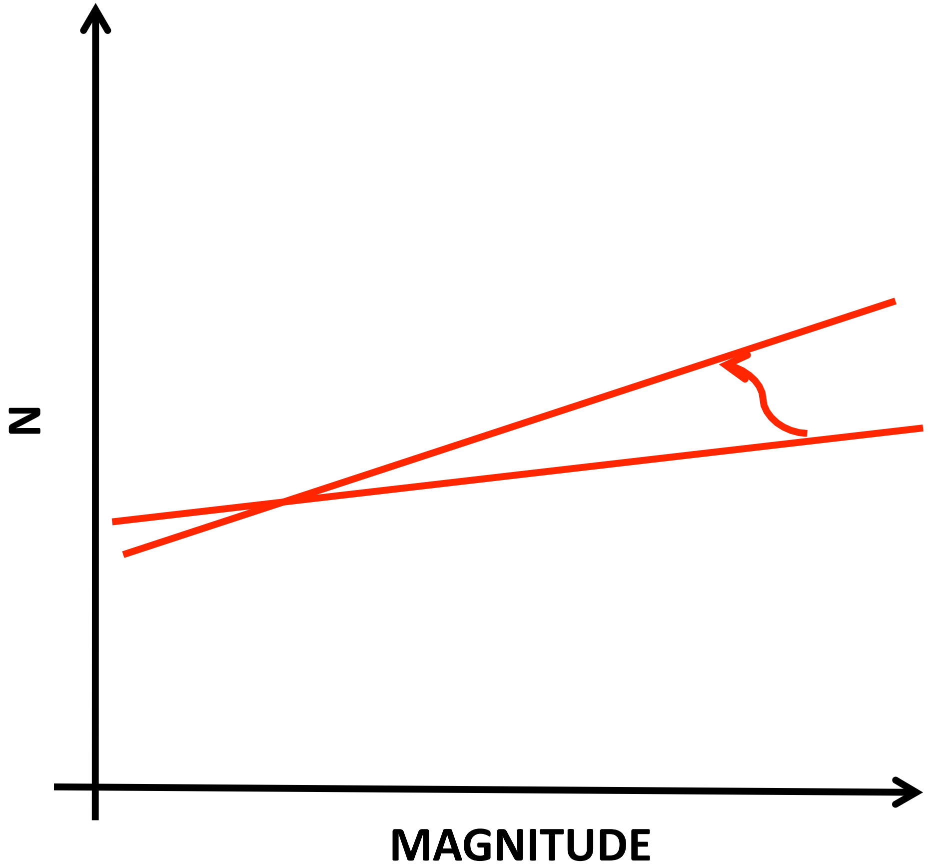
THE LUMINOSITY FUNCTION



- In GCs the MS spans a wide range of masses

- Because of the effect of mass segregation the relative ratios between stars of different masses is expected to vary with the distance

THE LUMINOSITY FUNCTION



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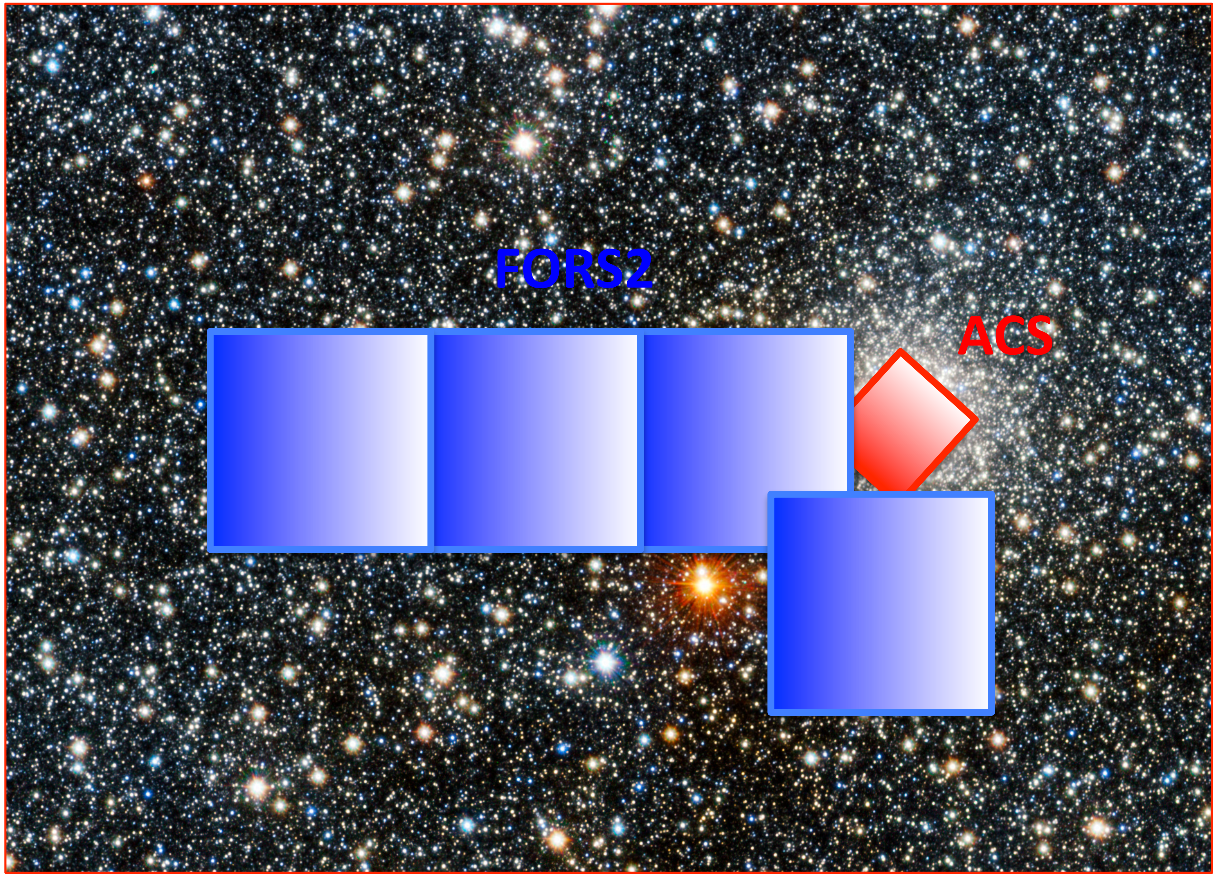
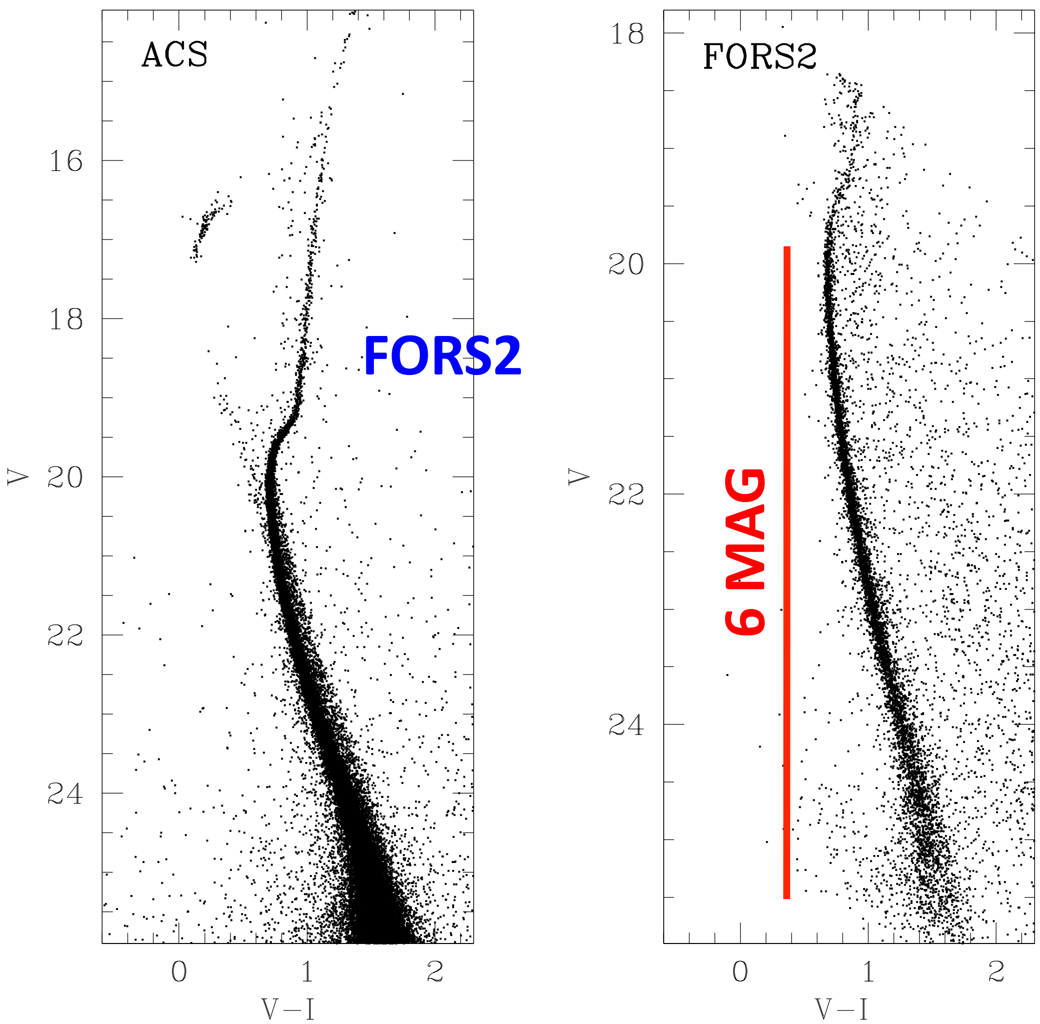


1. Deep and accurate photometry – wide spatial coverage
2. Control of completeness and blends (artificial stars experiments)

THE LUMINOSITY FUNCTION



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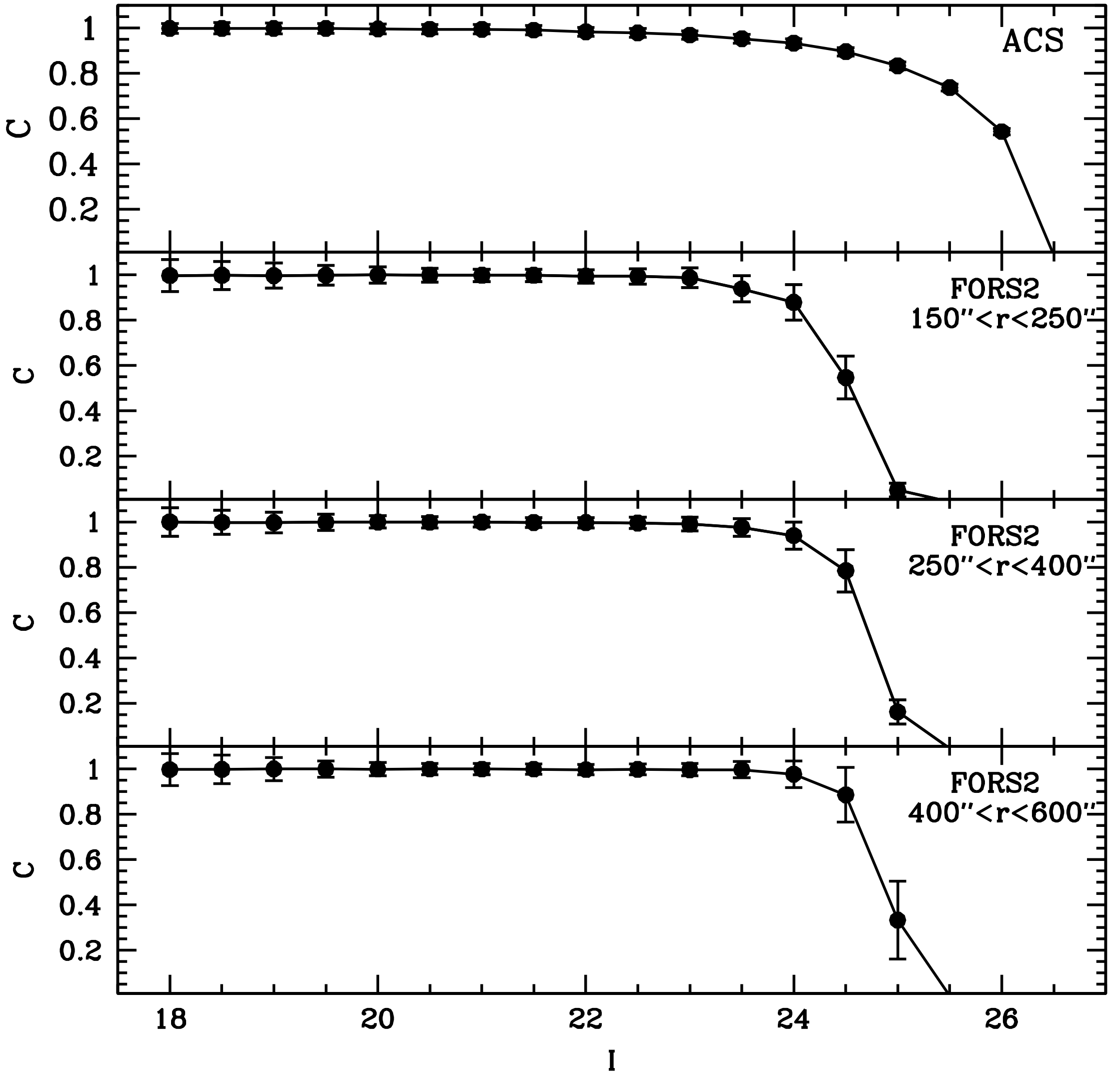

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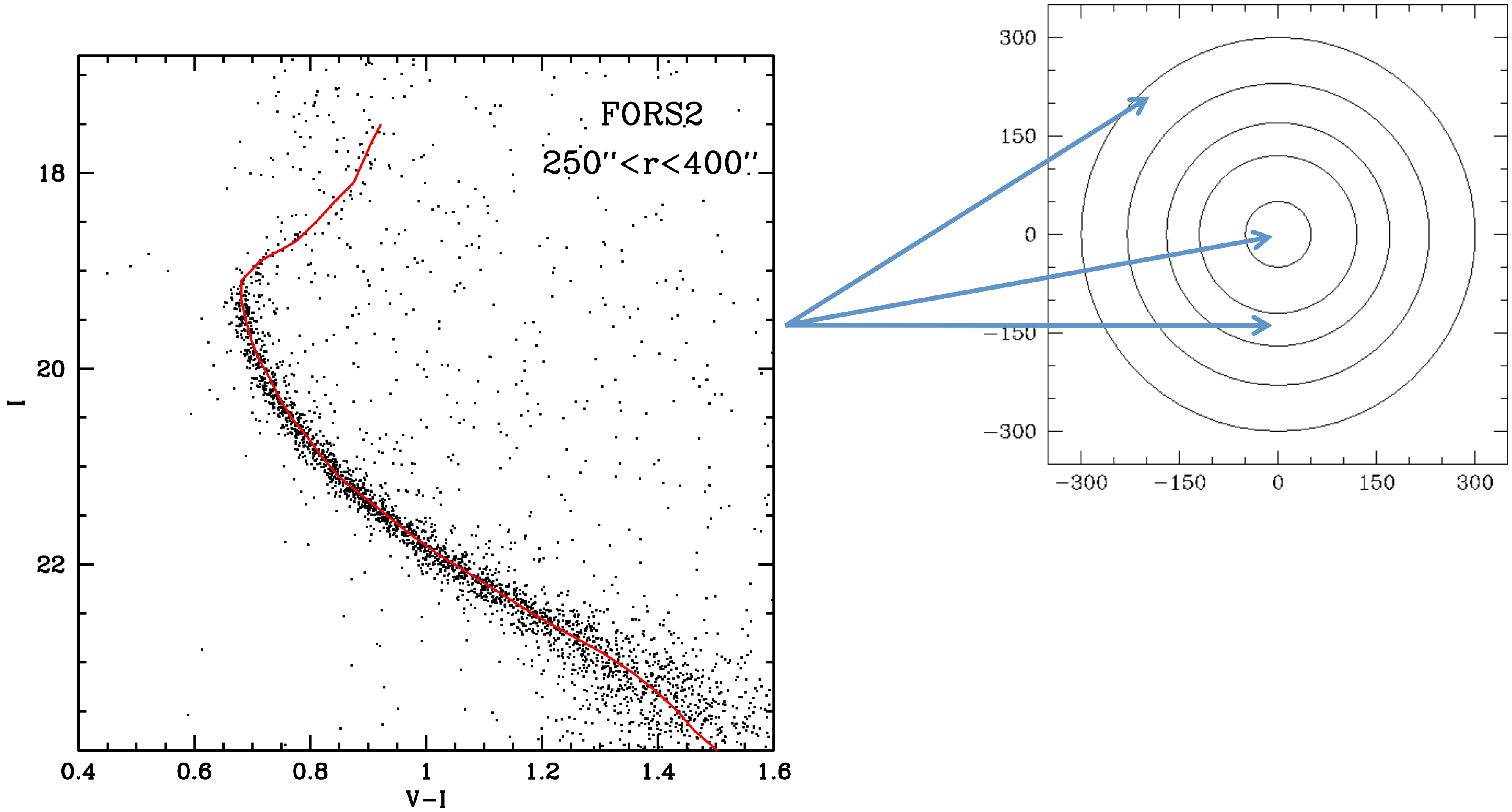

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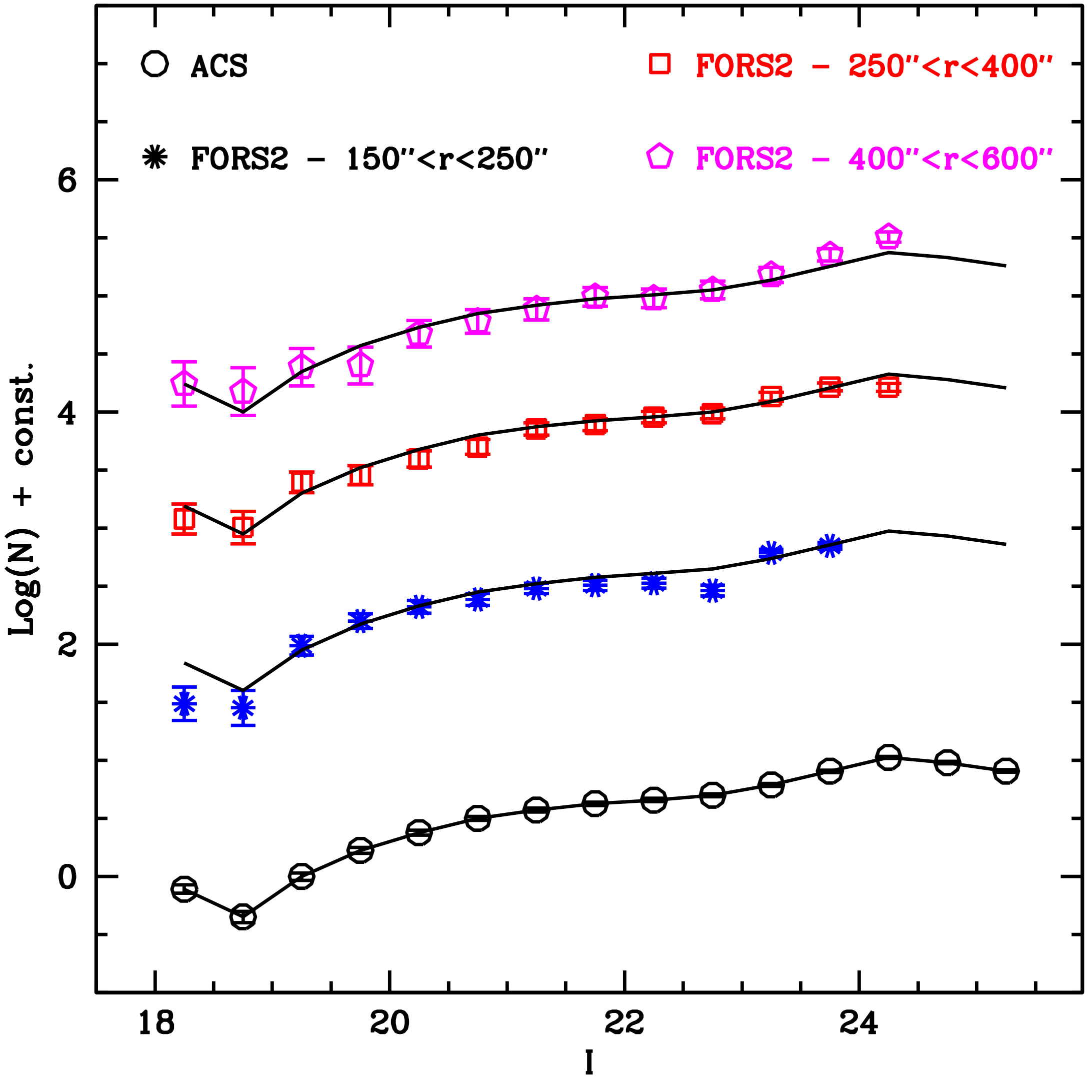
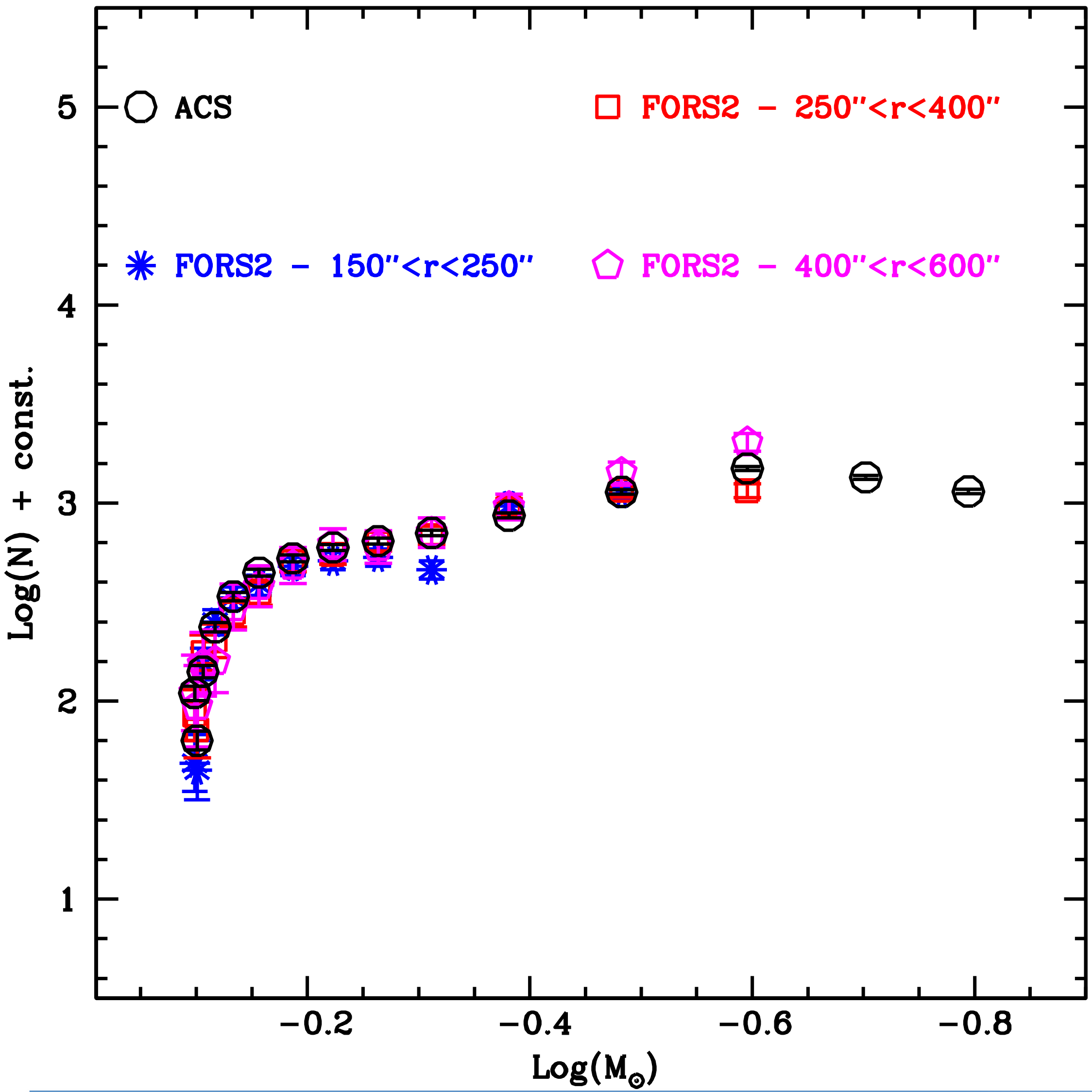


NO VARIATIONS OF THE SLOPE OF THE LF IS OBSERVED

NO EVIDENCE OF MASS SEGREGATION

THE MASS FUNCTION



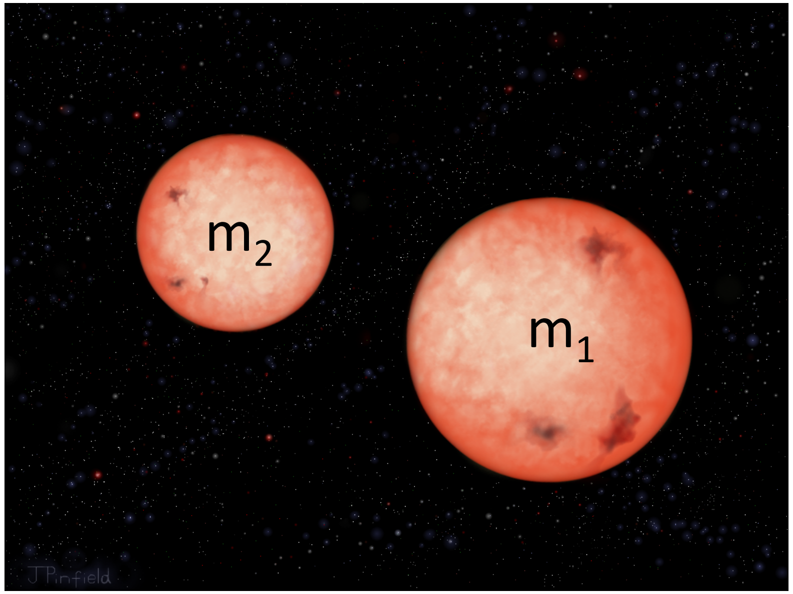
MFs at different radial distance are INDISTINGUSHABLE

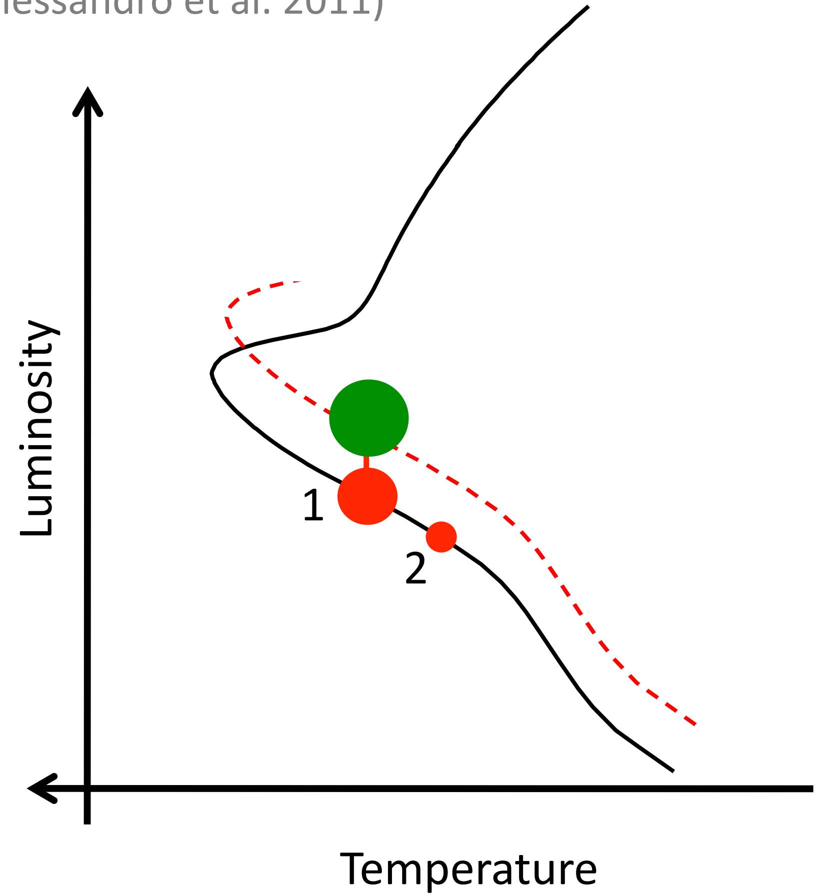
The BINARY STARS RADIAL DISTRIBUTION

Binary stars in NGC 6101

Studies of the distribution of stars along the cluster MS in the CMDs

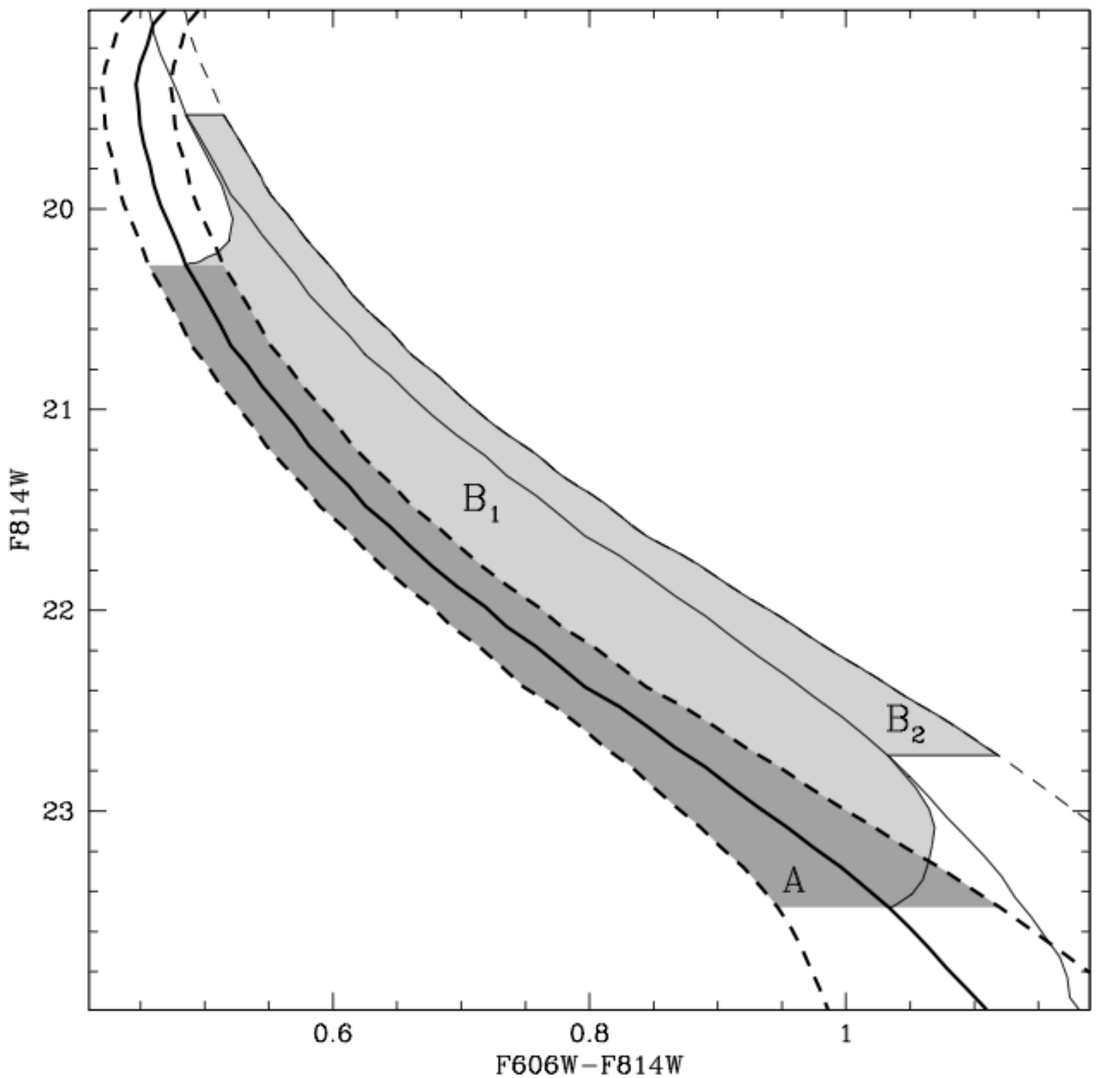
(Romani & Weinberg 1991; Bellazzini et al. 2002; Dalessandro et al. 2011)





$$q = \frac{m_2}{m_1}$$

The minimum binary fraction



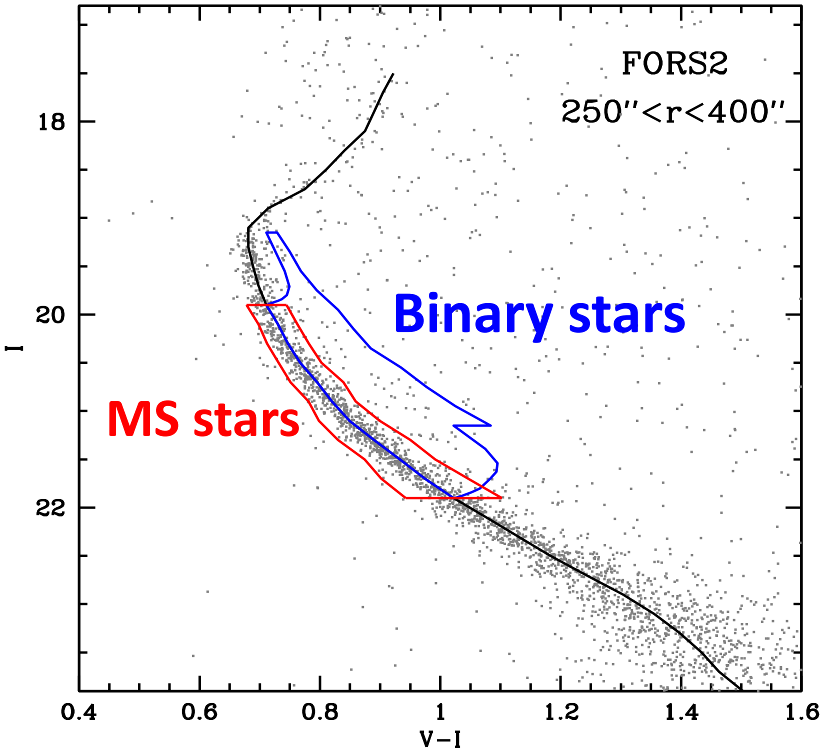
$$\xi_{min} = \frac{N_B}{N_A + N_B}$$

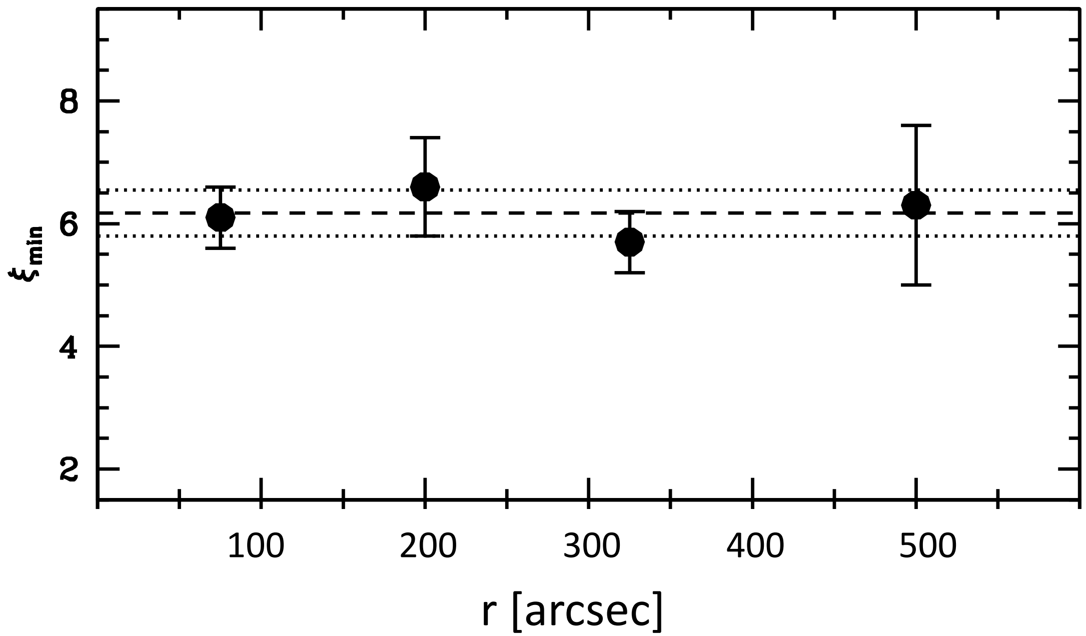
✓ NO dependence on the distribution of the mass ratio (q)

✓ NO dependence on MF

X It's a LOWER LIMIT

The minimum binary fraction

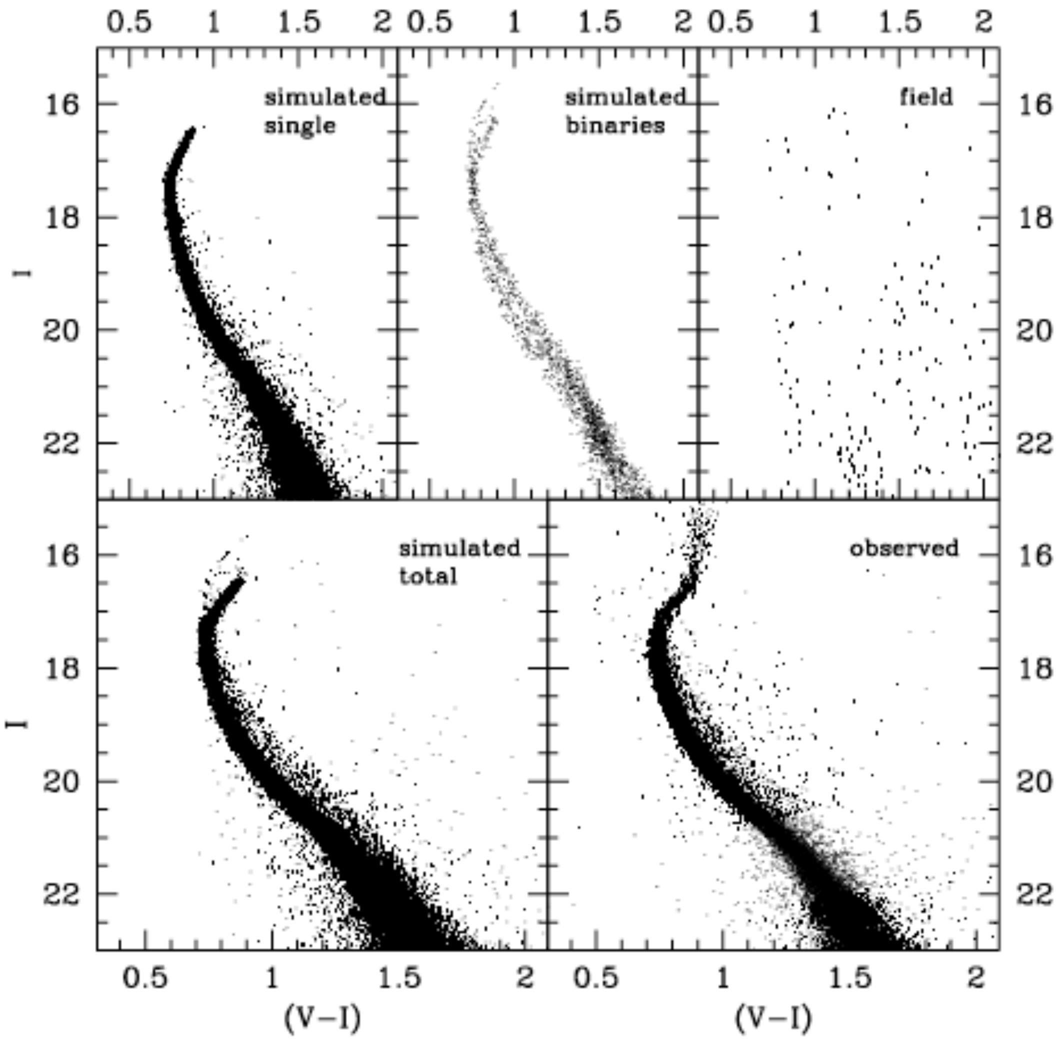




WE OBSERVE A FLAT RADIAL DISTRIBUTION

The average minimum binary fraction of NGC6101 is ~ 6%

The global binary fraction



Single MS stars are extracted from the observed MASS FUNCTION

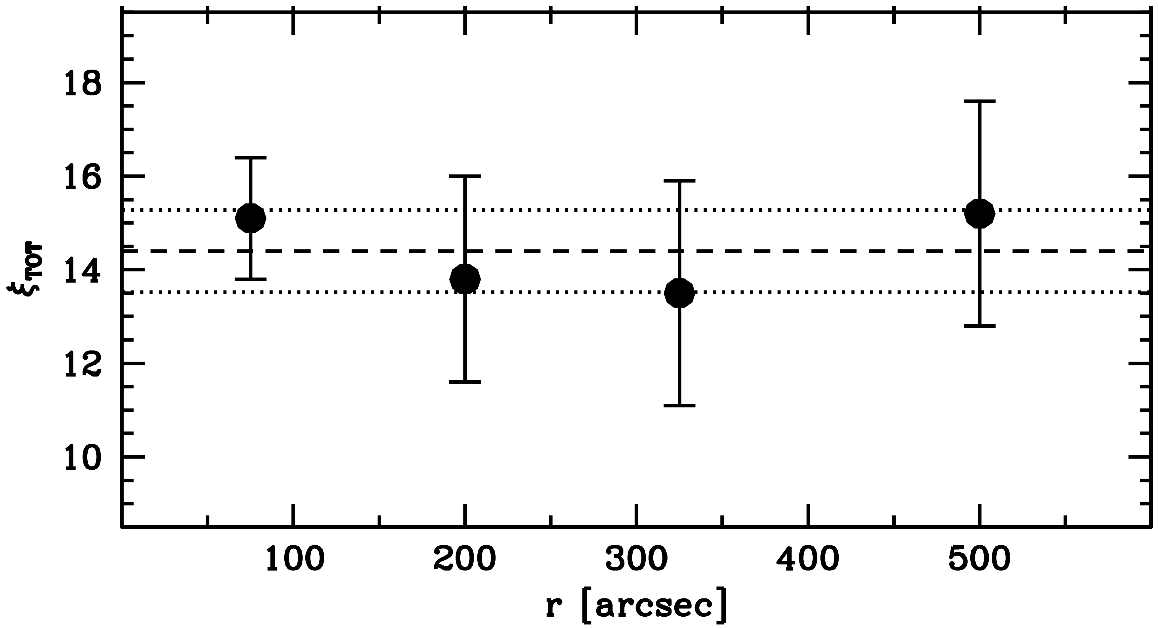
Binaries are generated from a Kruopa IMF

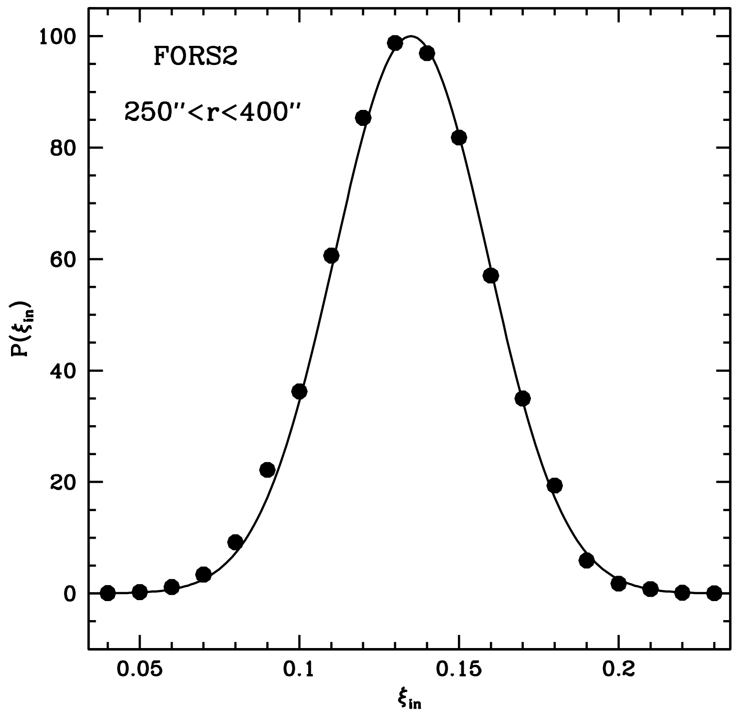
Field stars are extracted from a Galaxy population model (e.g. Robin et al. 2003)

The syntethic and observed CMDs are compared

$$\chi^2 = \sum_{i=1}^{100} (r_{sim} - r_{CMD})^2$$

The global binary fraction



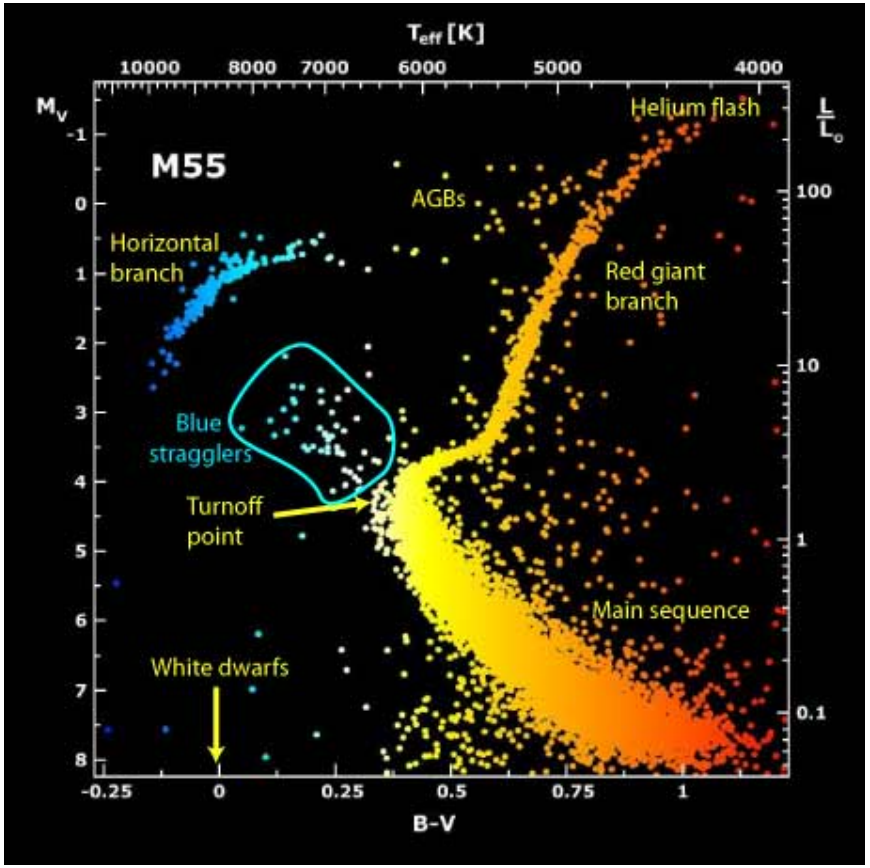


THE GLOBAL BINARY FRACTION IS ~14%

THIS BEHAVIOR IS FULLY COMPATIBLE WITH THE ONE OBSERVED FOR THE MINIMUM BINARY FRACTION

The BSS RADIAL DISTRIBUTION

The BSS population of NGC 6101



• They are a common population of all stellar systems (Mathieu & Geller 2009; Monelli et al. 2011)

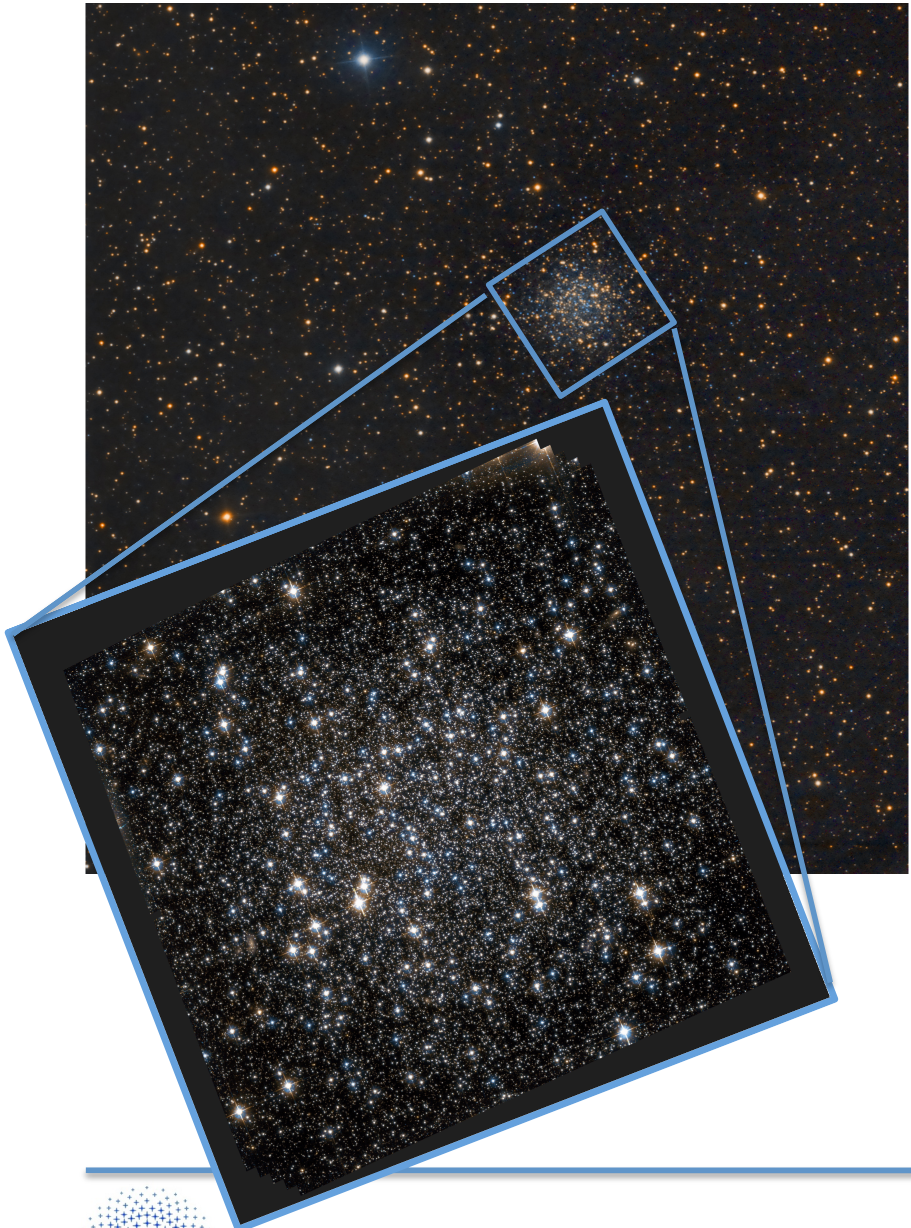
• They are brighter and bluer (hotter) than TO stars thus mimicking a younger stellar population

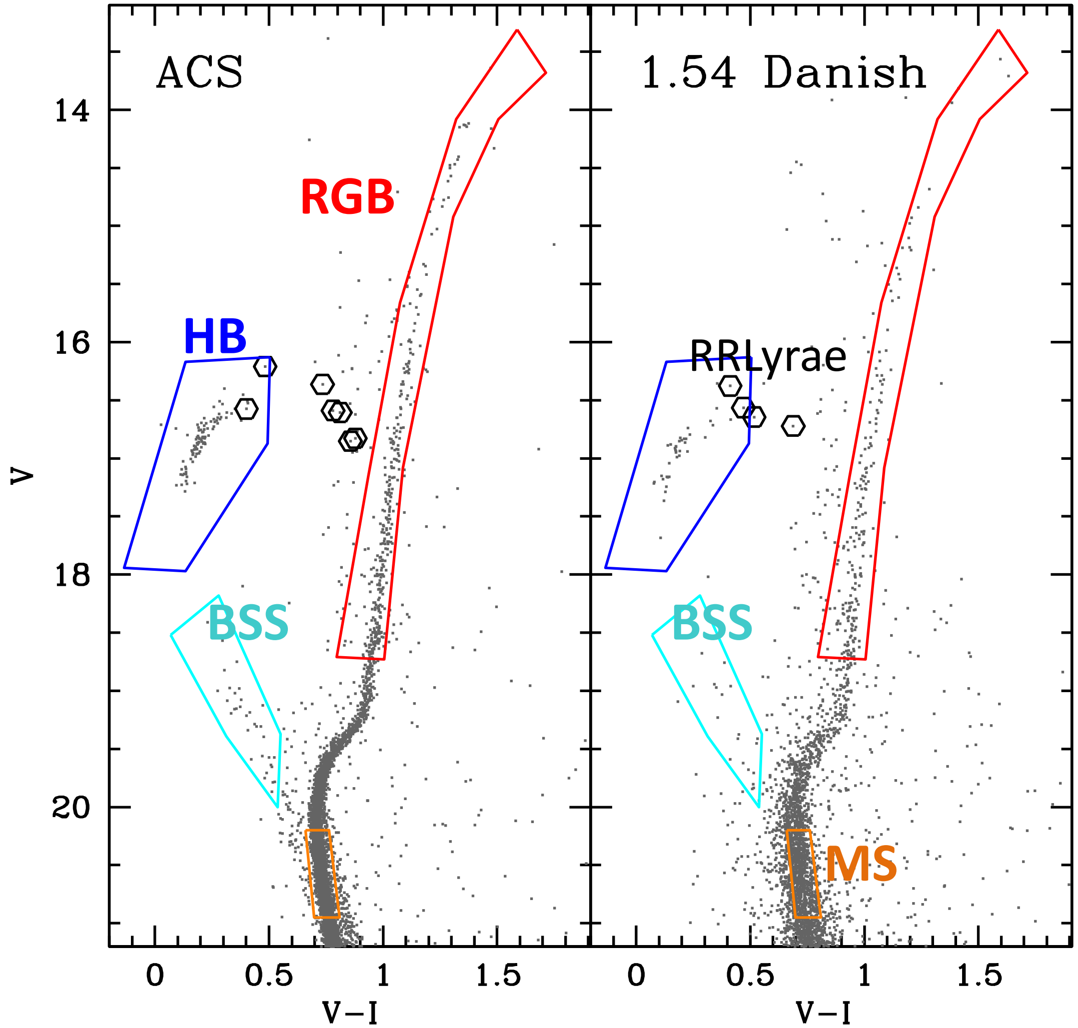
• Direct measure have shown that BSS are up to 2 times more massive than TO stars (Shara et al. 1996; Gilliland et al. 1998; Fiorentino et al. 2014)

BSS at all radial distances

provide information on dynamical processes

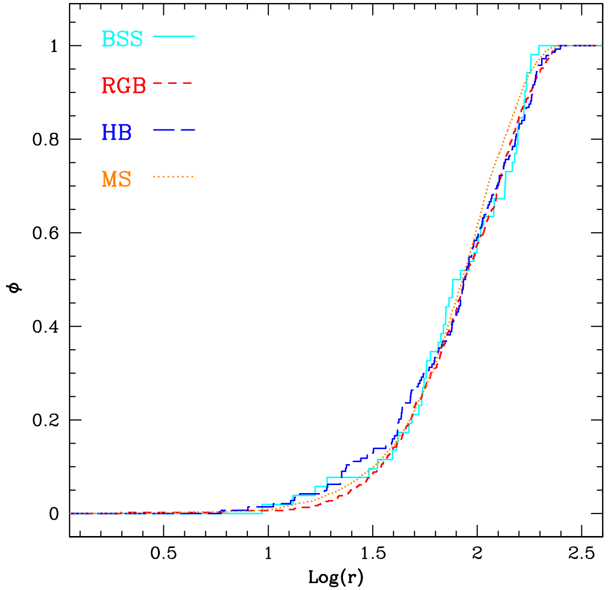
The BSS population of NGC 6101

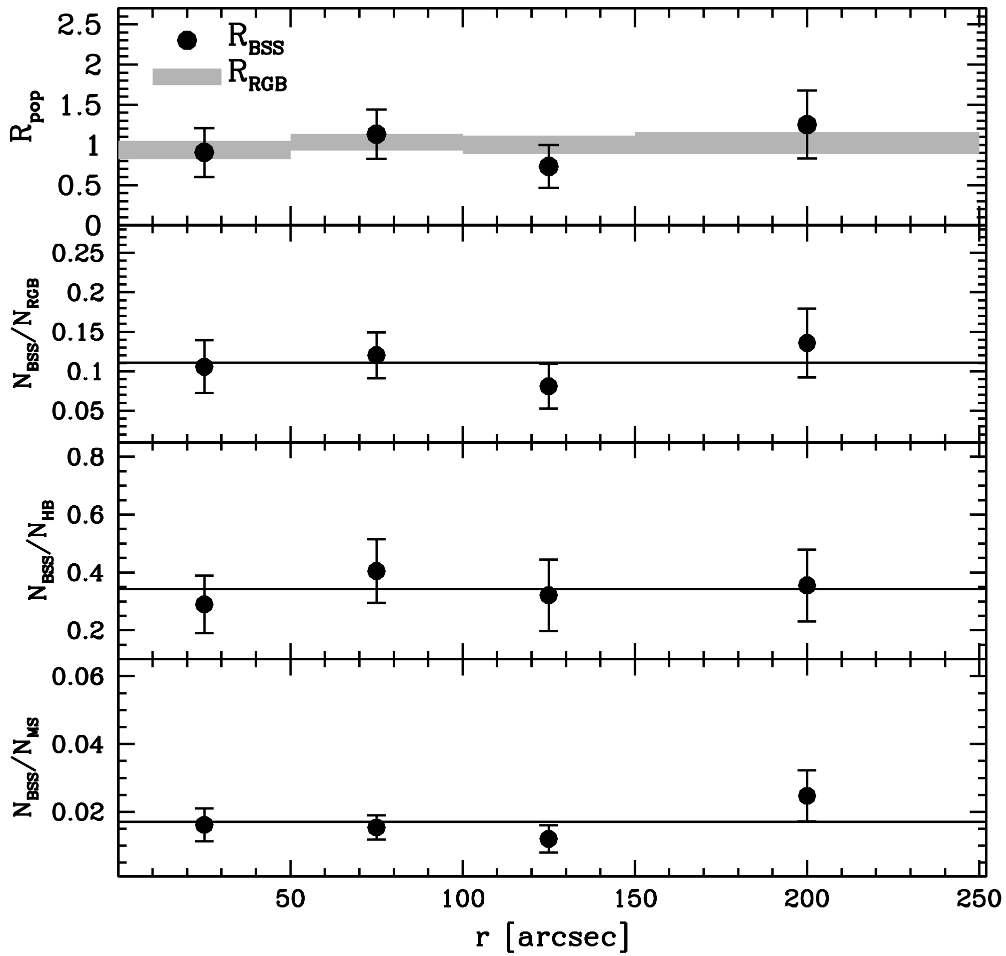




Marconi et al. 2001; Sarajedini et al. 2007

The BSS population of NGC 6101



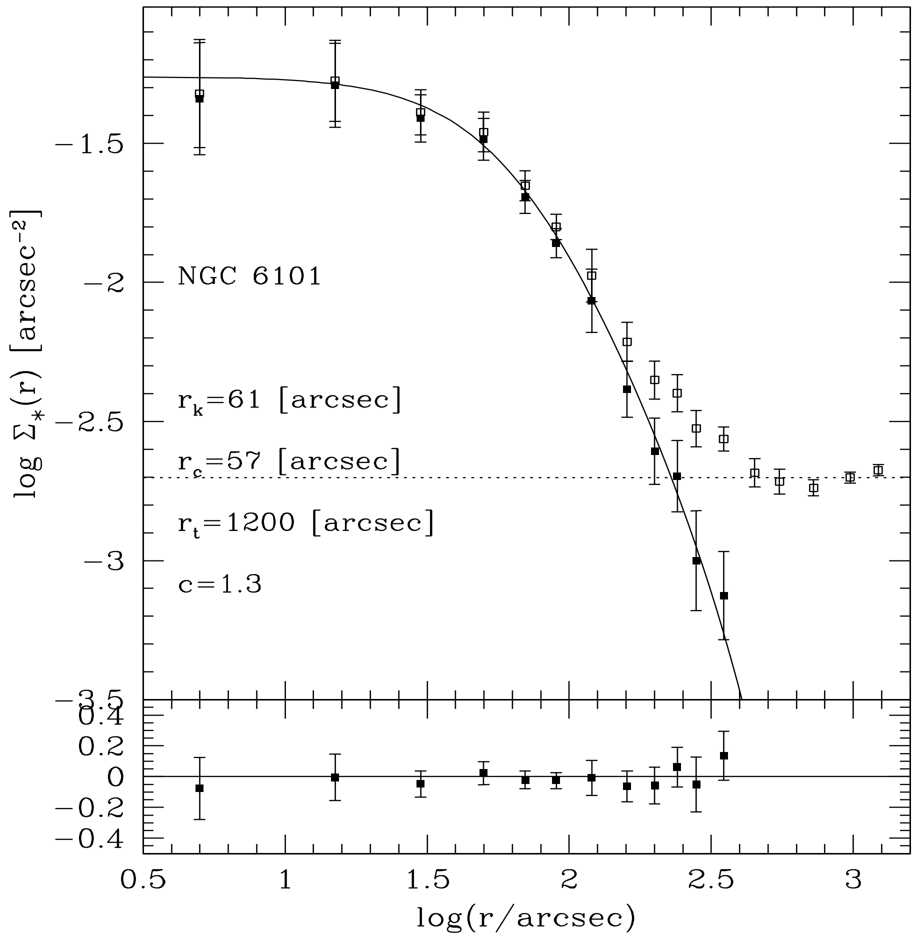


BOTH THE SPECIFIC FREQUENCIES and THE DOUBLE NORMALIZED RATIO SHOW A FLAT RADIAL DISTRIBUTION

like ωCentauri (Ferraro et al. 2006), NGC2419 (Dalessandro et al. 2008), Pal14 (Beccari et al. 2013)

CONCLUSION #1

NO MASS SEGREGATION IN NGC6101



t_{rc}~ 1.2 Gyr

t_{AGE}~13Gyr

t_{rh}~ 6 Gyr

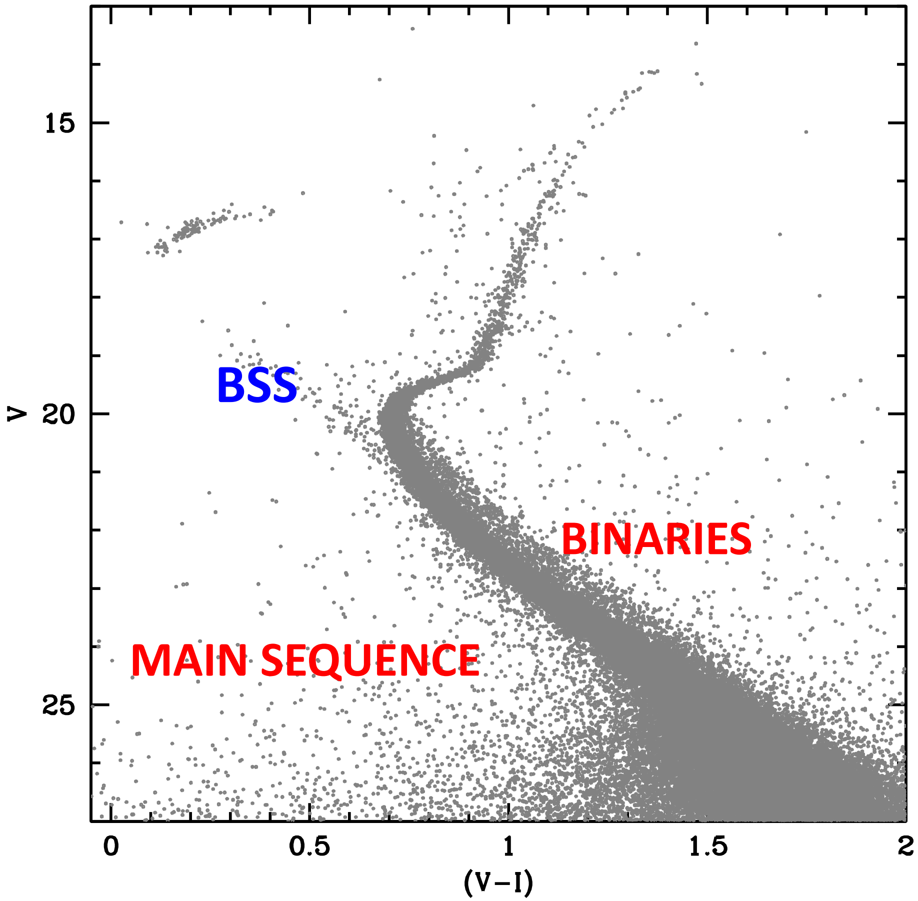
ROTATION?

DID NGC6101 LOOSE A SIGNIFICANT FRACTION OF ITS ORIGINAL MASS?

CURRENT THEORETICAL ESTIMATES ARE EXTREMELY ROUGH AND MUST BE USED WITH CAUTION

CONCLUSION #2

ALL INDICATORS NICELY AGREE, BUT ...



BSS ARE SIGNIFICANTLY BRIGHTER THAN BINARIES AND MS

BSS ARE LESS PRONE TO OBSERVATIONAL BIAS (like completeness)

THIS PROVIDES SUPPORT TO THE USE OF A TOOL BASED ON THE BSS RADIAL DISTRIBUTION AS INDICATOR OF DYNAMICAL EVOLUTION

Thank you!

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