Rotational velocities of Blue Straggler stars in Galactic Globular Clusters

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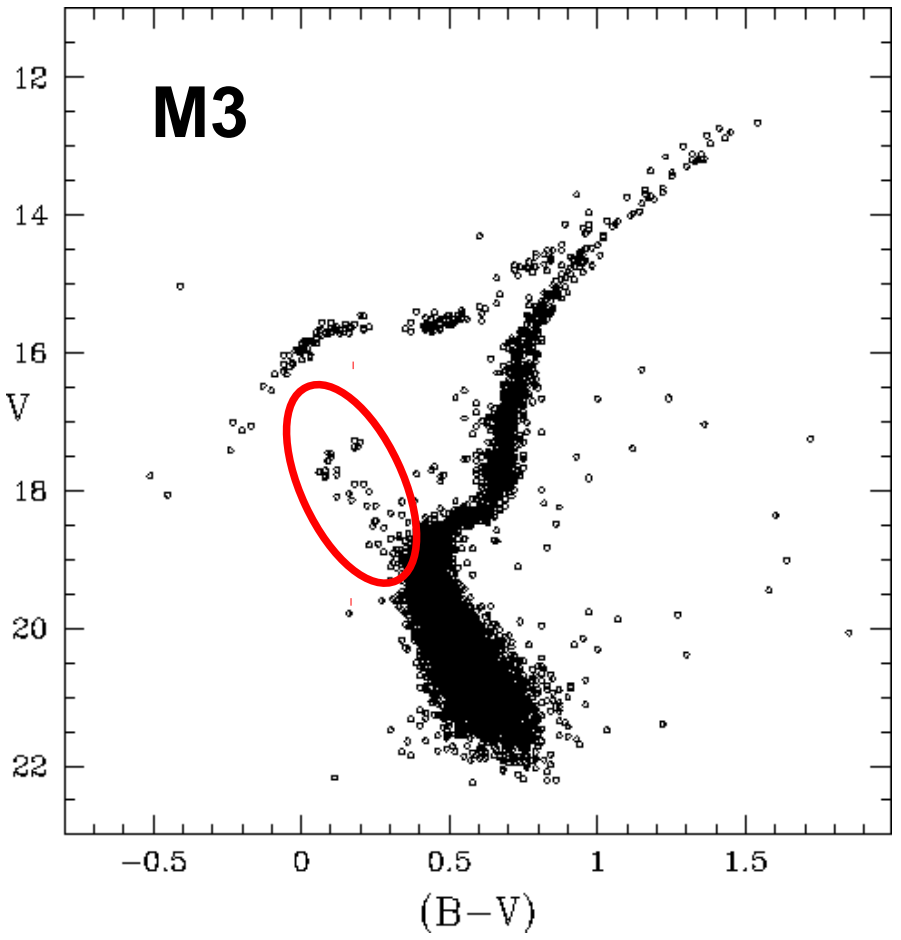
Cosmic-Lab

- 5-year project
- funded by the European Research Council (ERC)
- PI: Francesco R. Ferraro (Dip. of Physics & 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

Blue Straggler stars (BSS)



Discovered by Sandage (1953)

Brighter and bluer (hotter) than Main Sequence stars

More massive than TO
(Shara et al, 1997)

↓

BSS mimic a
rejuvenated stellar population

Blue Straggler stars (BSS)

a bunch of young vigorous folks in a meeting of old tired people..

BSS formation mechanisms

Two main scenarios for BSS formation

Mass Transfer BSS

Collisional BSS

BSS ➤ **crucial link between**

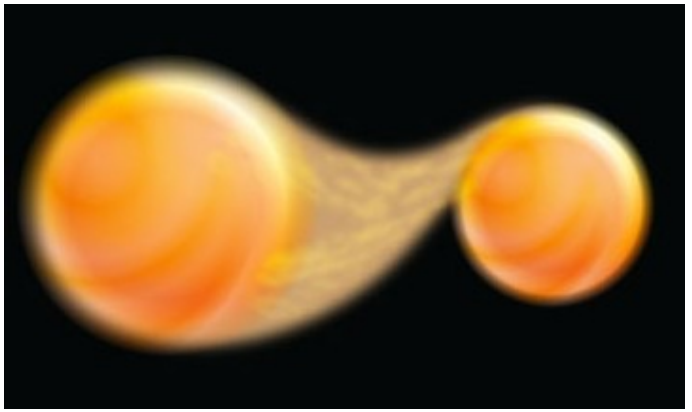
stellar evolution & stellar dynamics

The chemical composition of BSS

Searching for chemical signatures
of the BSS formation mechanisms

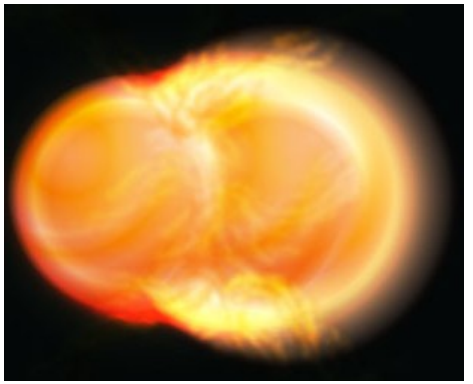
Mass Transfer BSS

C & O depletion expected in the BSS surface
(Sarna & de Greve, 1996)



Collisional BSS

No chemical signatures
(Lombardi et al. 1995)



Rotational velocities of BSS

Investigating the nature of BSS

Mass Transfer BSS
(Sarna & de Greve, 1996)

Collisional BSS
(Benz & Hills, 1987)

High rotational velocities

Rotational velocities of BSS

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High rotational velocities

BRAKING MECHANISMS MAY INTERVENE!!
(Leonard & Livio, 1995; Sills et al, 2005)

Observational evidence

1 BSS in 47 Tuc
(Shara et al, 1997)

FOS@HST
R ~ 1300

→ **v sin (i) ~ 150 km/s**

10 BSS in
M3, 47 Tuc,
NGC 6752
(De Marco et al, 2005)

FOS/STIS@HST
R ~ 1300-7000

→ **v sin (i) ~ 50-200 km/s**
(mainly upper limits)

Rotation in GC stars

As comparison...How fast do stars rotate in Globular Clusters?

MS/SGB stars → v sin(i) ~ 3-5 km/s

RGB stars → v sin(i) < 2 km/s

HB stars → v sin(i) ~ 2-40 km/s

The fastest rotating stars are in the HB (8000 K <Teff< 11000 K)

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High rotational velocities?

→ Low statistics

→ Low resolution

Systematic & extensive studies are lacking!!!

The spectroscopic dataset

High-res spectra with FLAMES@VLT (R ~ 20000)

First systematic survey

6 GCs

	[Fe/H]	
47 Tuc	-0.7	
M4	-1.1	
NGC 6752	-1.5	
NGC 6397	-2.0	
M30	-2.3	double BSS sequence
Omega Cen	-1.7	non-collisional BSS

Questions

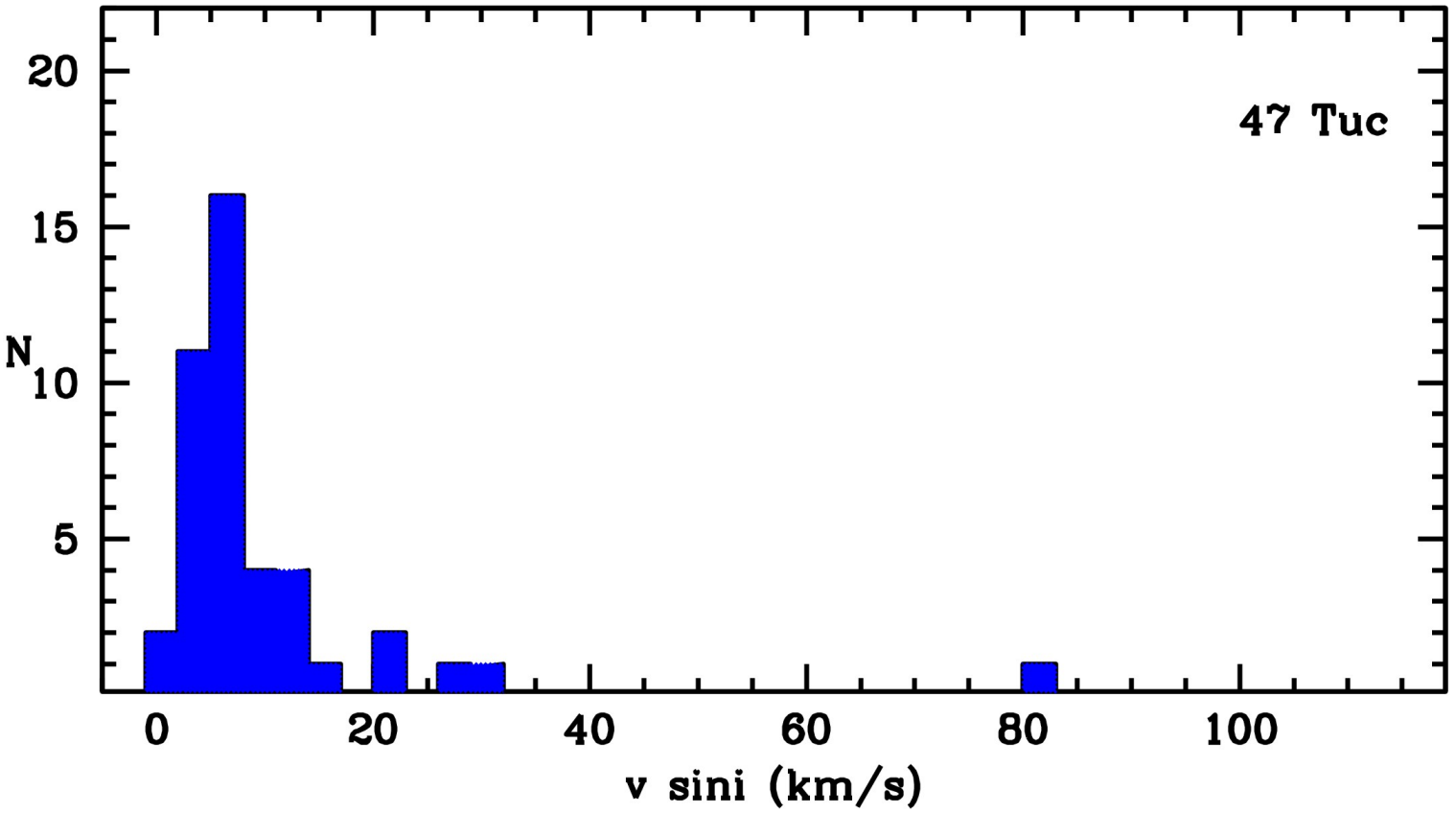
1) Are BSS slow or fast rotators?

2) Any link between v sin(i) and BSS formation mechanisms?

3) Any link with the cluster environment?

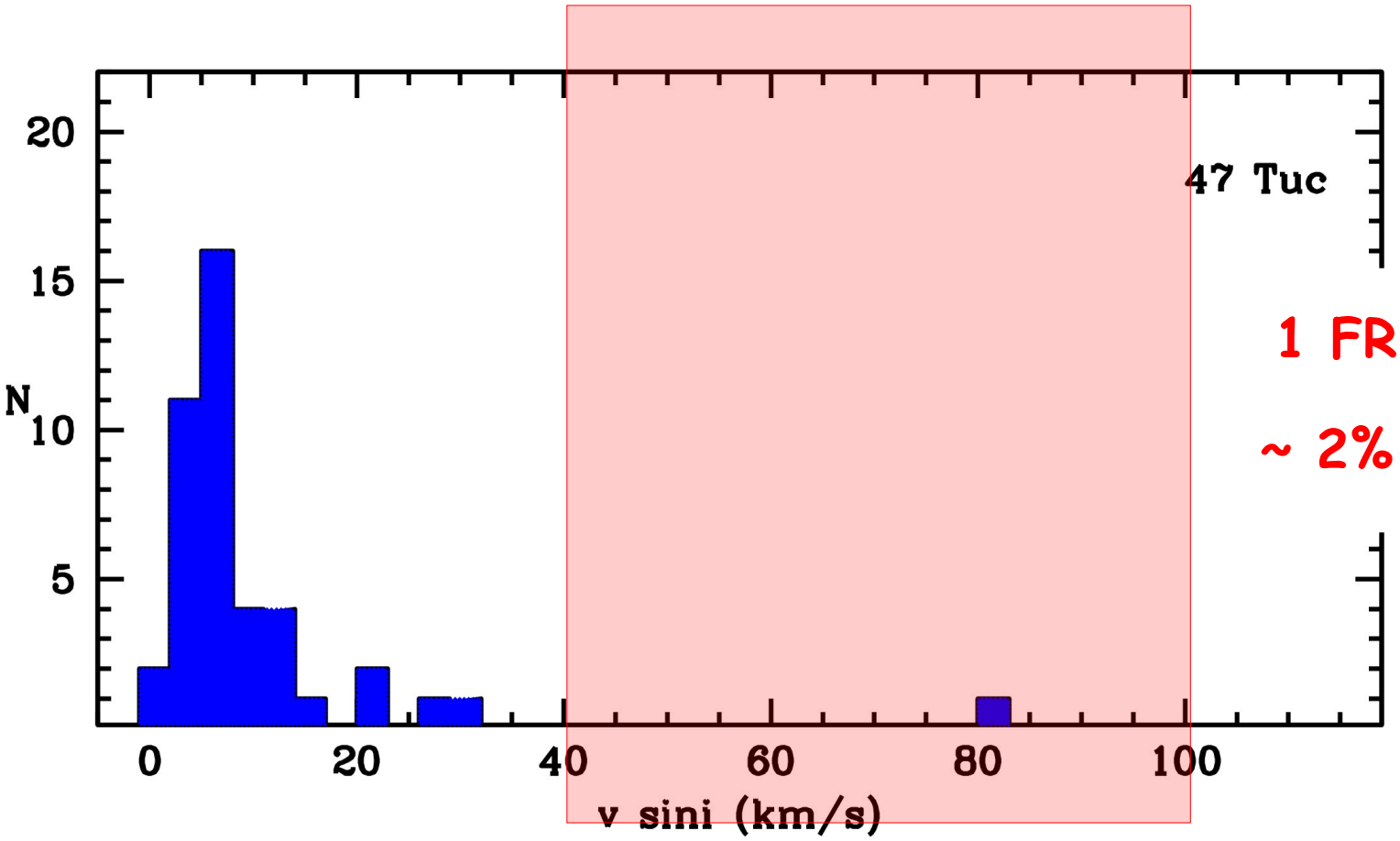
47 Tuc

Rotational velocities of 43 BSS
(Ferraro et al, 2006)



47 Tuc

FR ⟶ v sin (i) > 40 km/s

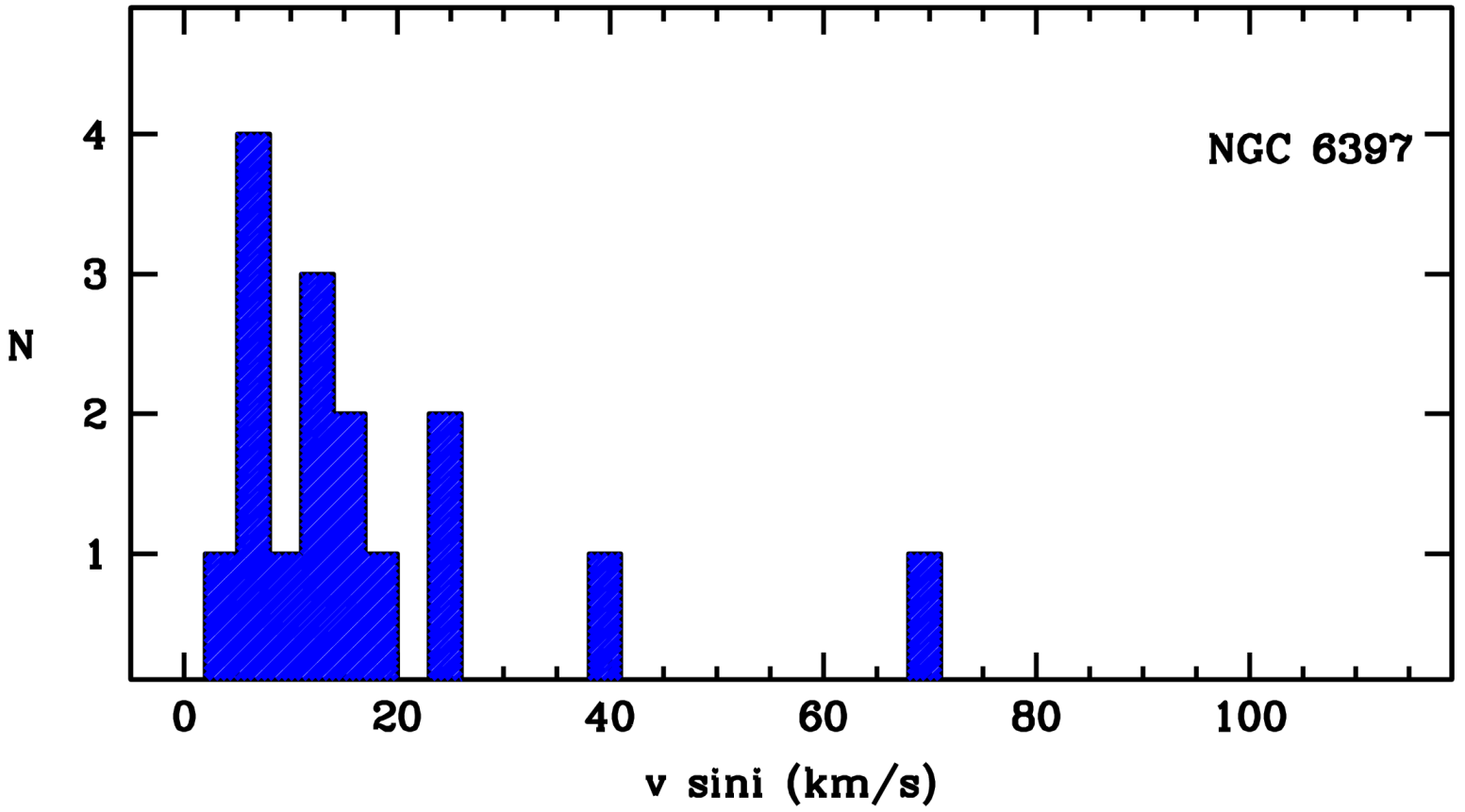


1 FR BSS

~ 2% are FR

NGC 6397

Rotational velocities of 16 BSS
(Lovisi et al, 2012)



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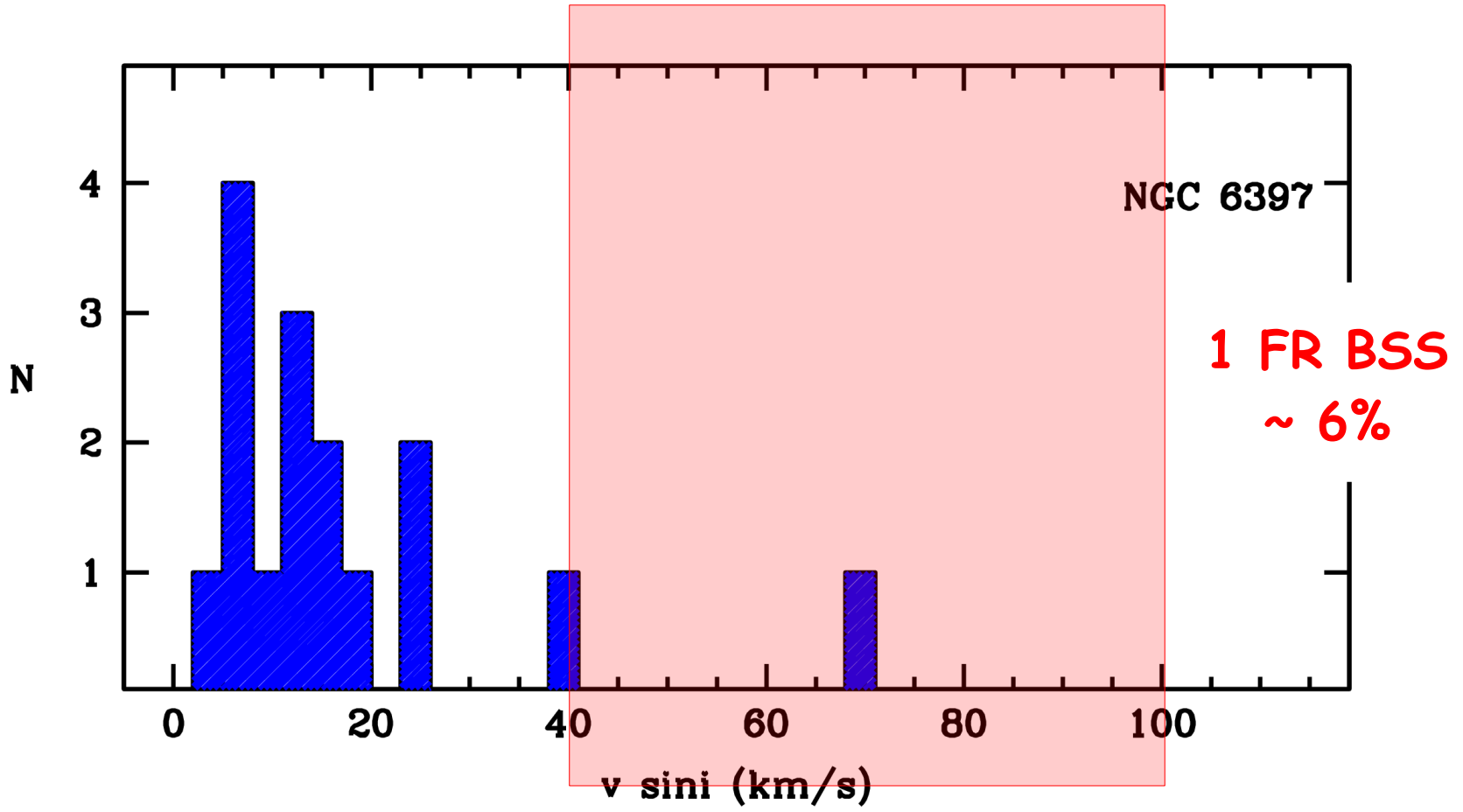
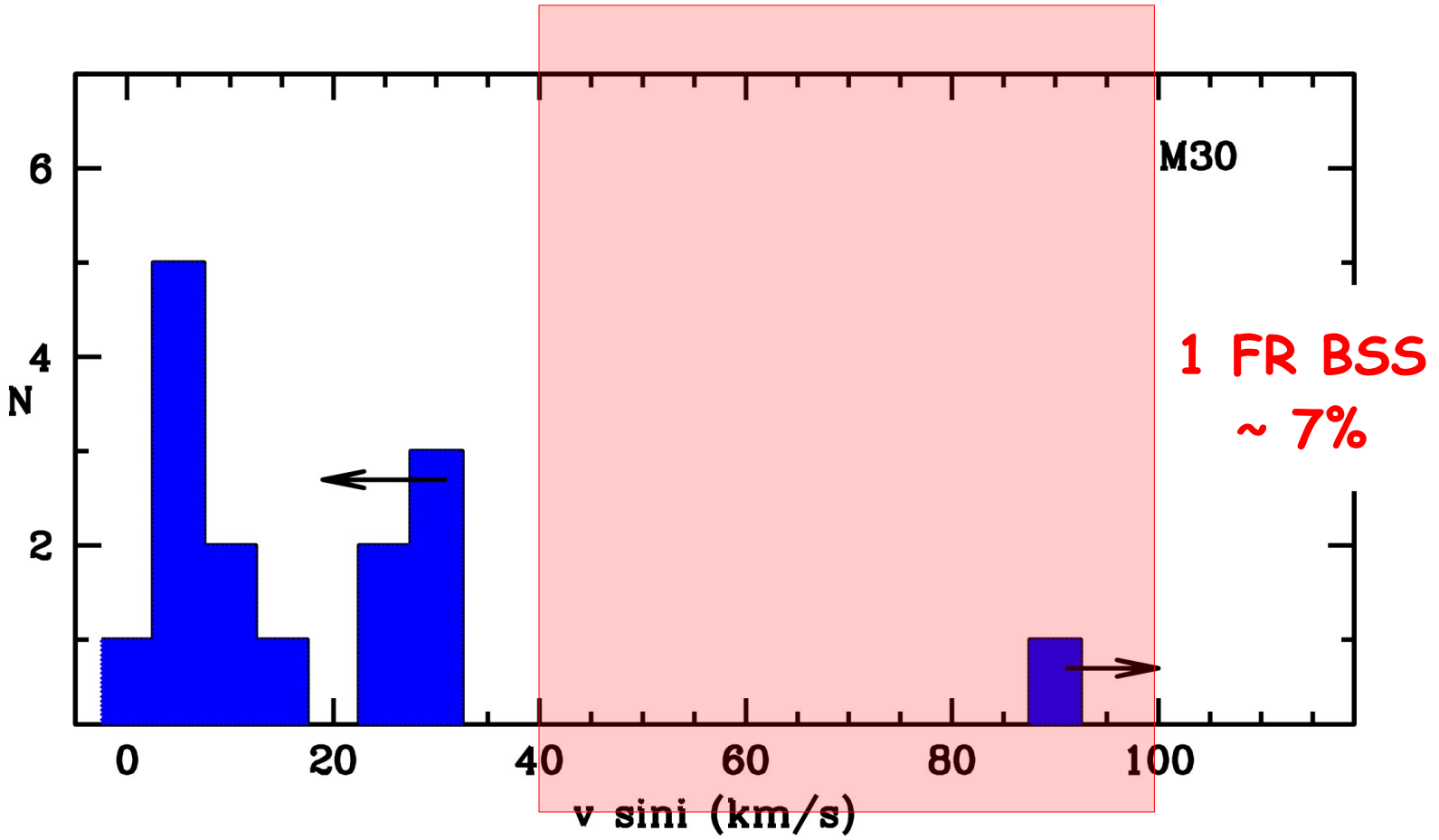


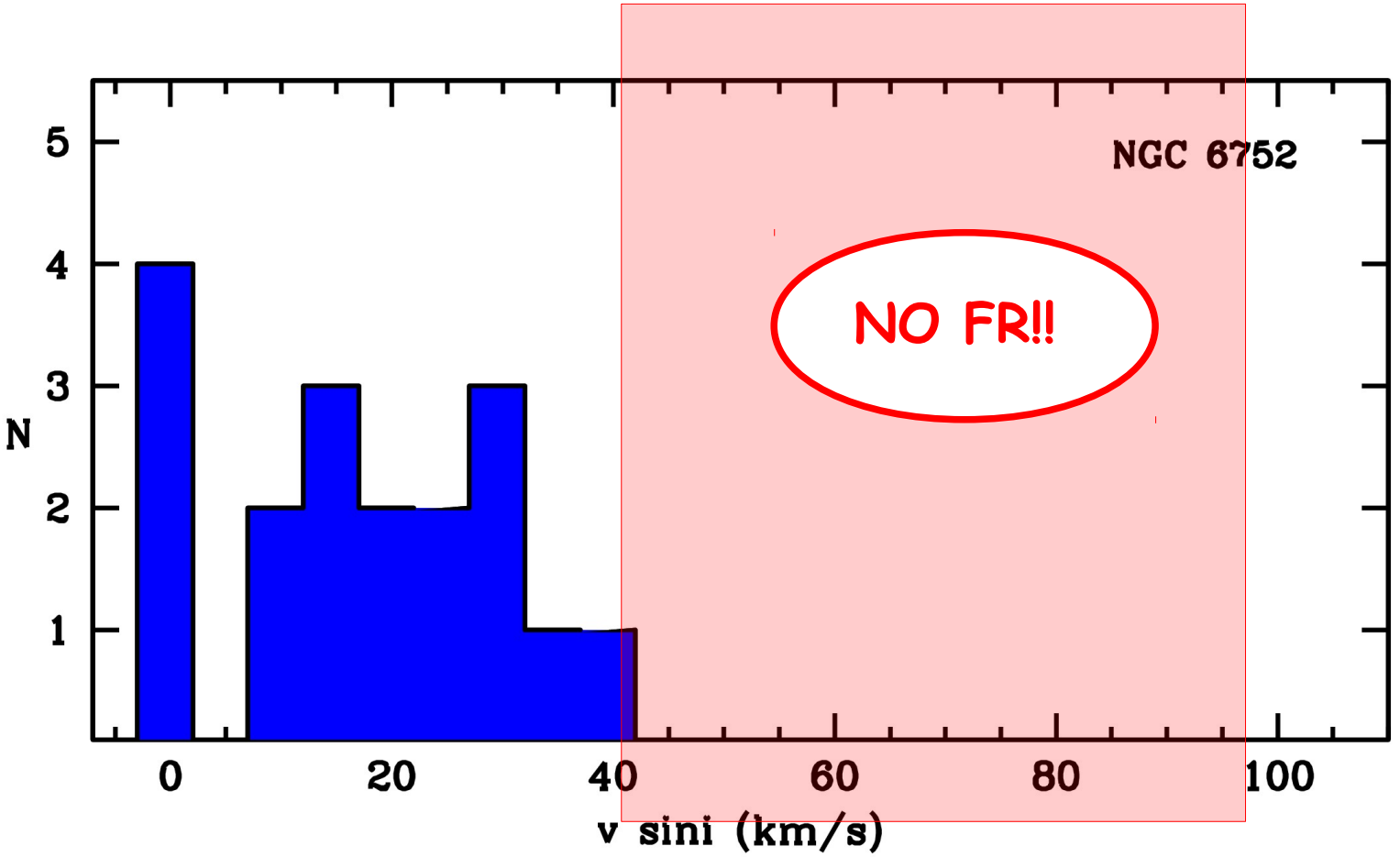
M30

Rotational velocities of 15 BSS
(Lovisi et al, 2013a)



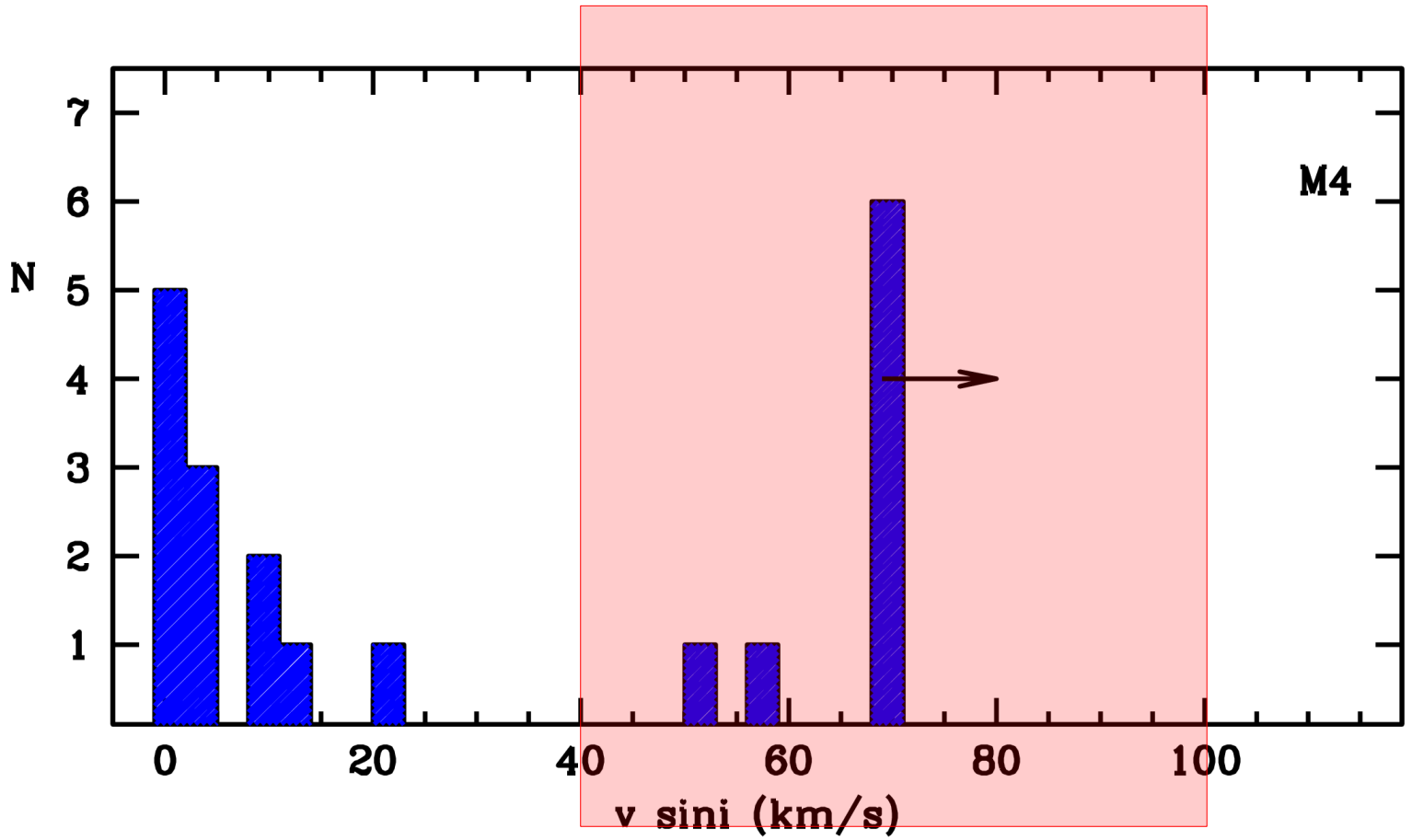
NGC 6752

Rotational velocities of 18 BSS
(Lovisi et al, 2013b)



M4

Rotational velocities of 20 BSS
(Lovisi et al,2010)



M4

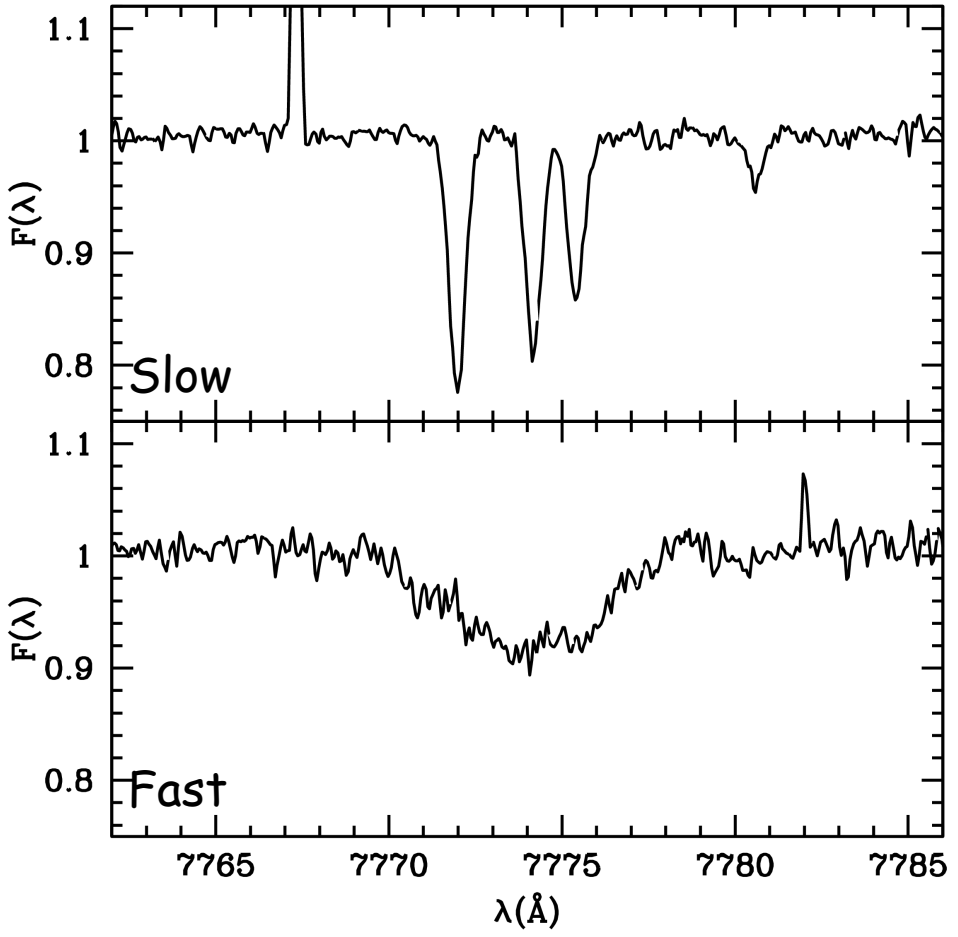
Rotational velocities of 20 BSS
(Lovisi et al,2010)

OI triplet

8 fast rotators !!

The highest percentage of fast rotating BSS ever found in any GC !!

~ 40%

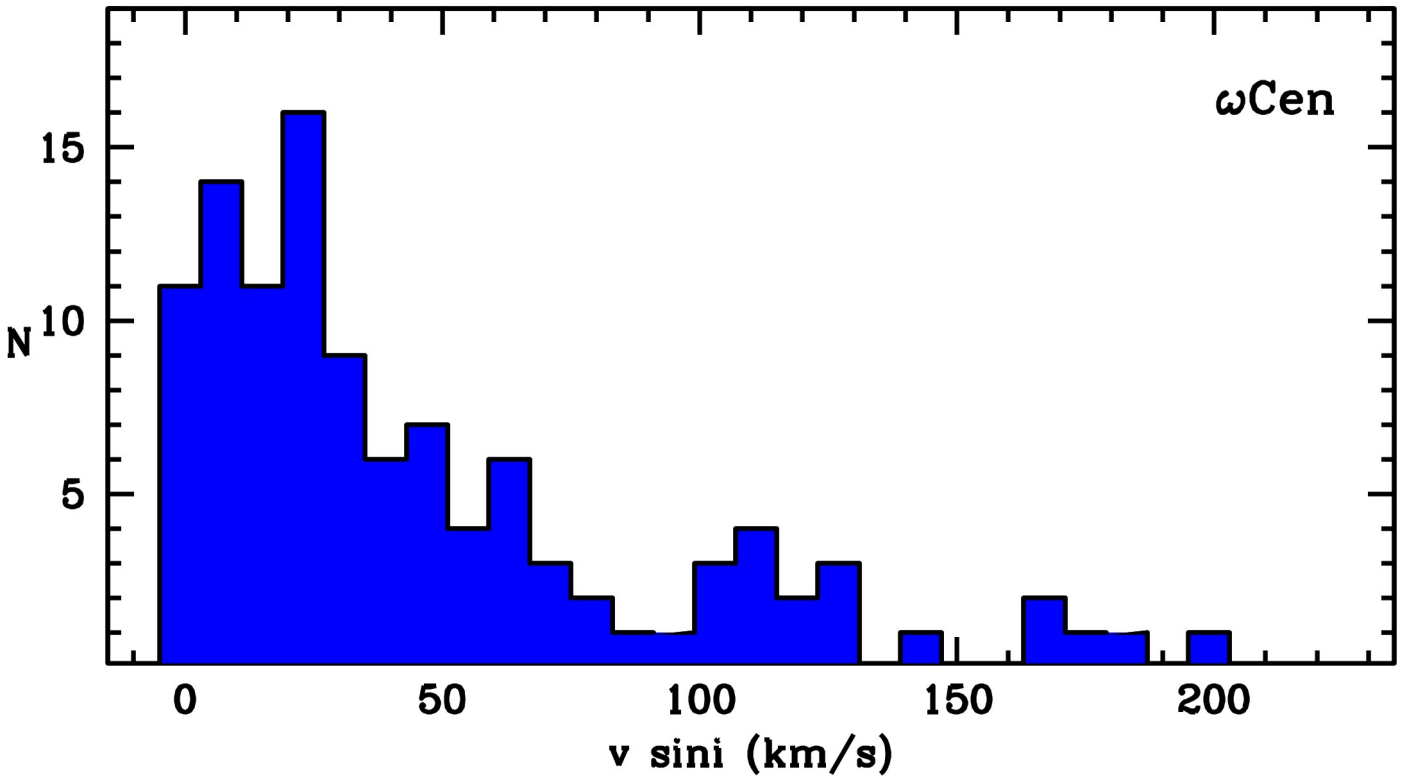


Omega Cen

Rotational velocities of 109 BSS
(Mucciarelli et al. 2014, in preparation)

See Mucciarelli's poster

The largest sample in our GC dataset



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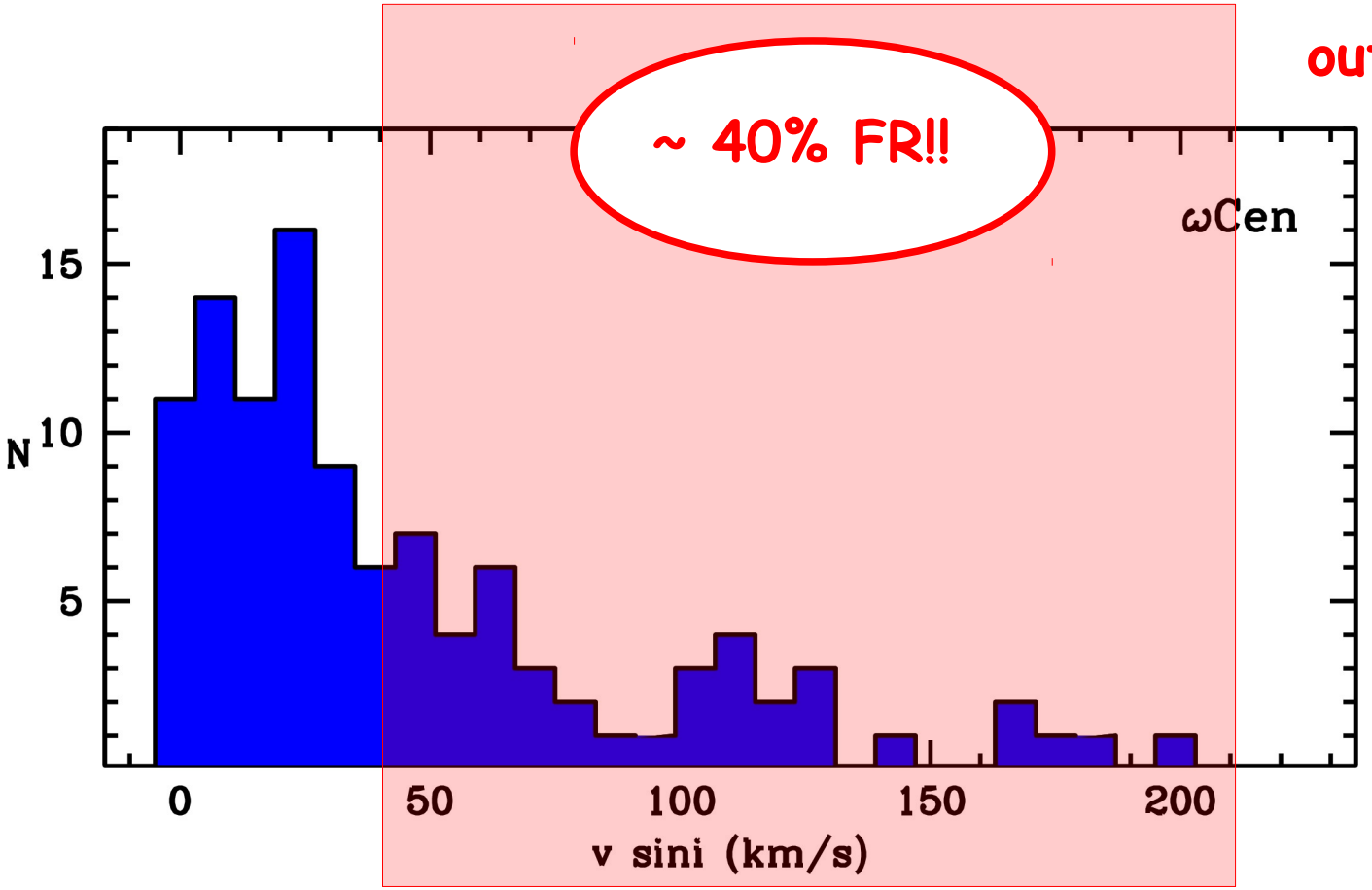
44 FR out of 109



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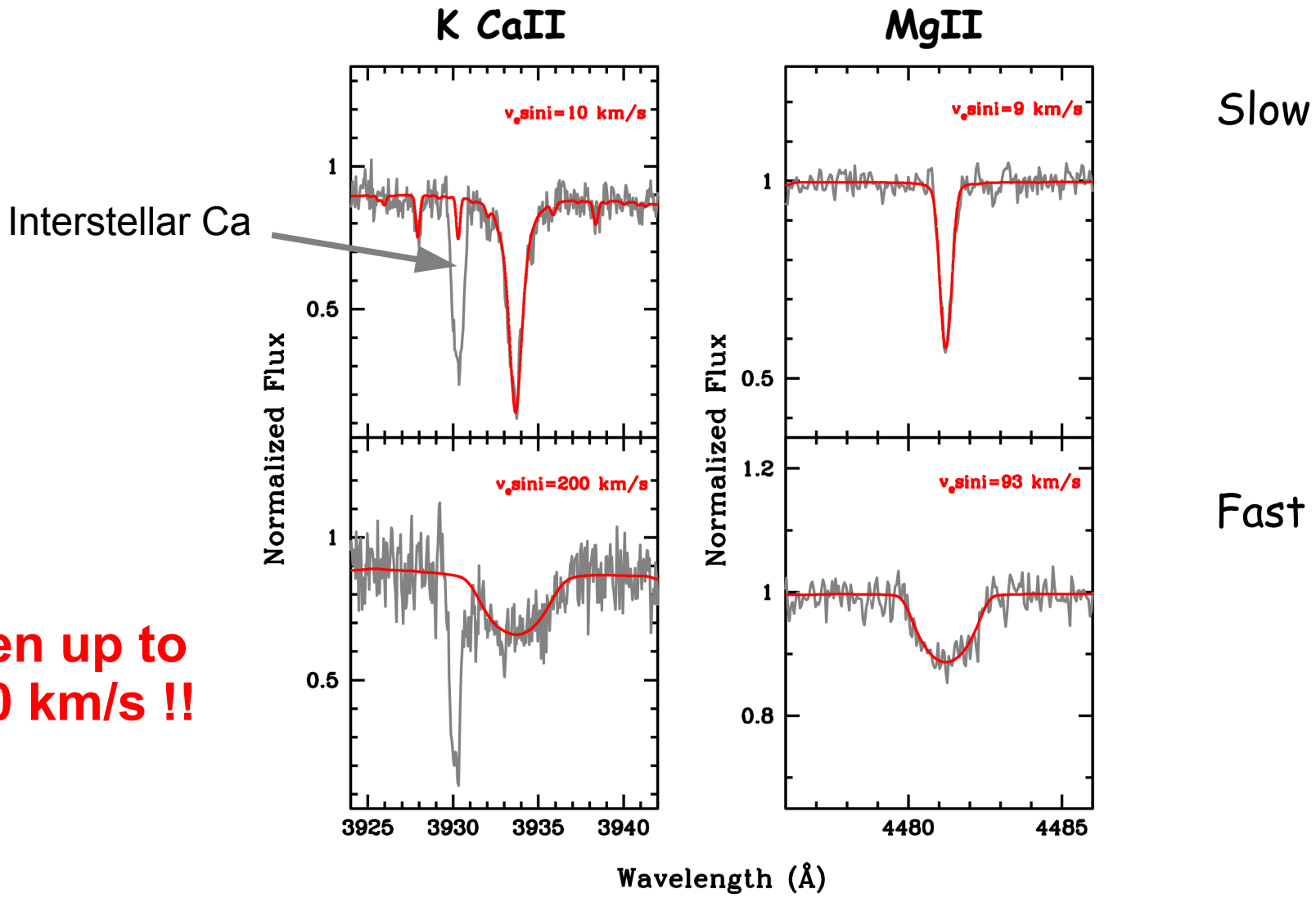


Even up to 200 km/s !!

Summary

47 Tuc → ~ 2%

NGC 6397 → ~ 6%

M30 → ~ 8%

NGC 6752 → 0 %

Low percentage of FR BSS

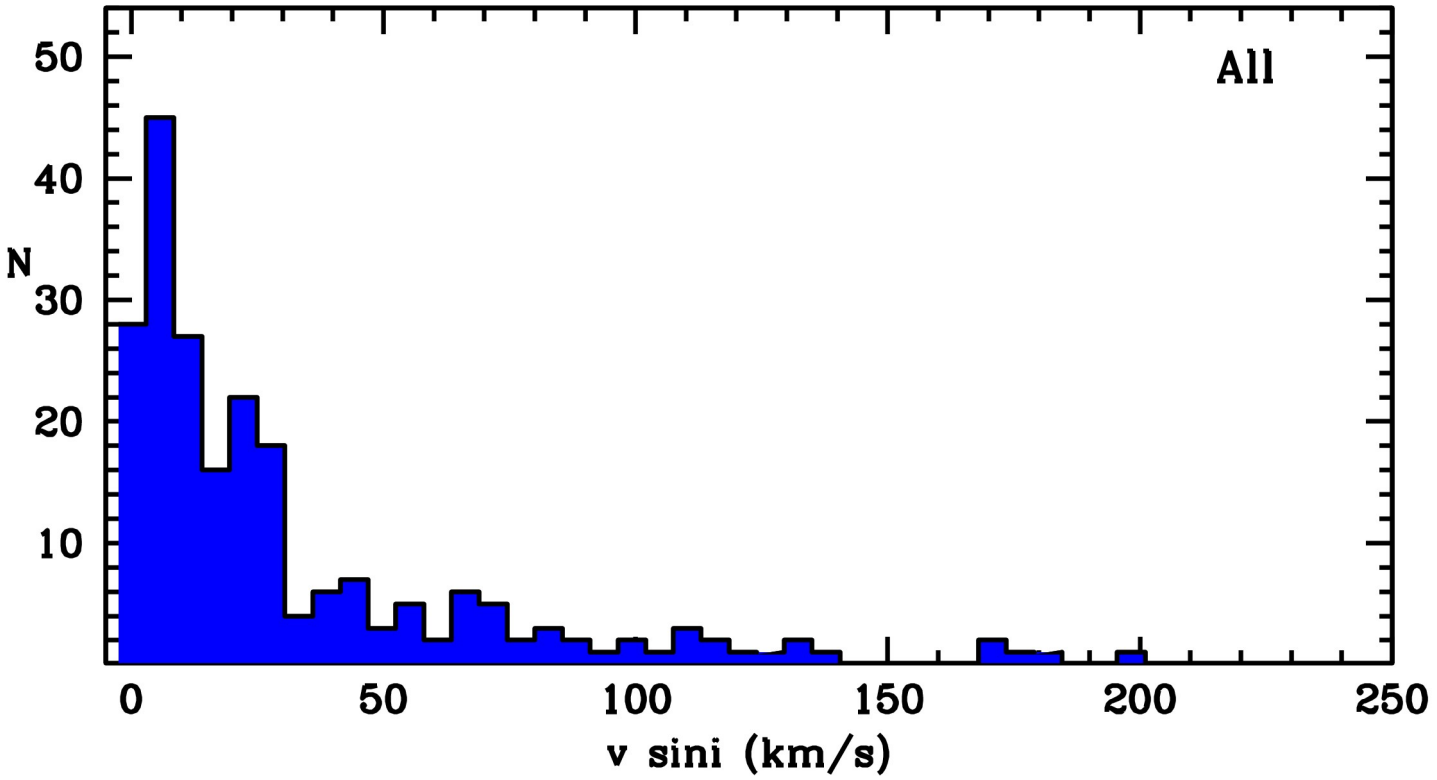
M4 → ~ 40%

ωCen → ~ 40%

The highest fraction ever found in GCs!!

Cumulative histogram

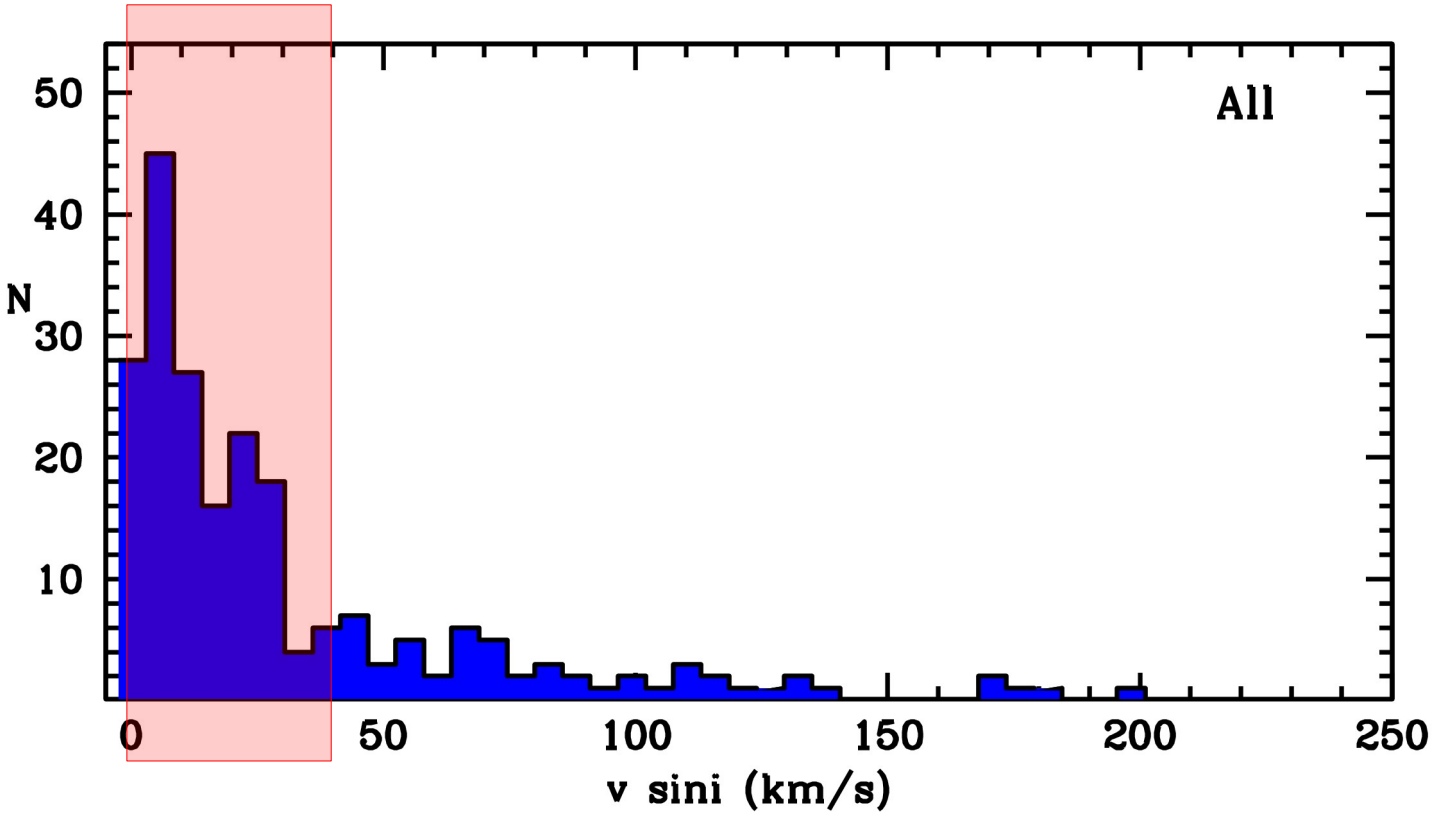
Are BSS slow or fast rotators?



Cumulative histogram

Are BSS slow or fast rotators?

The majority are slow rotators



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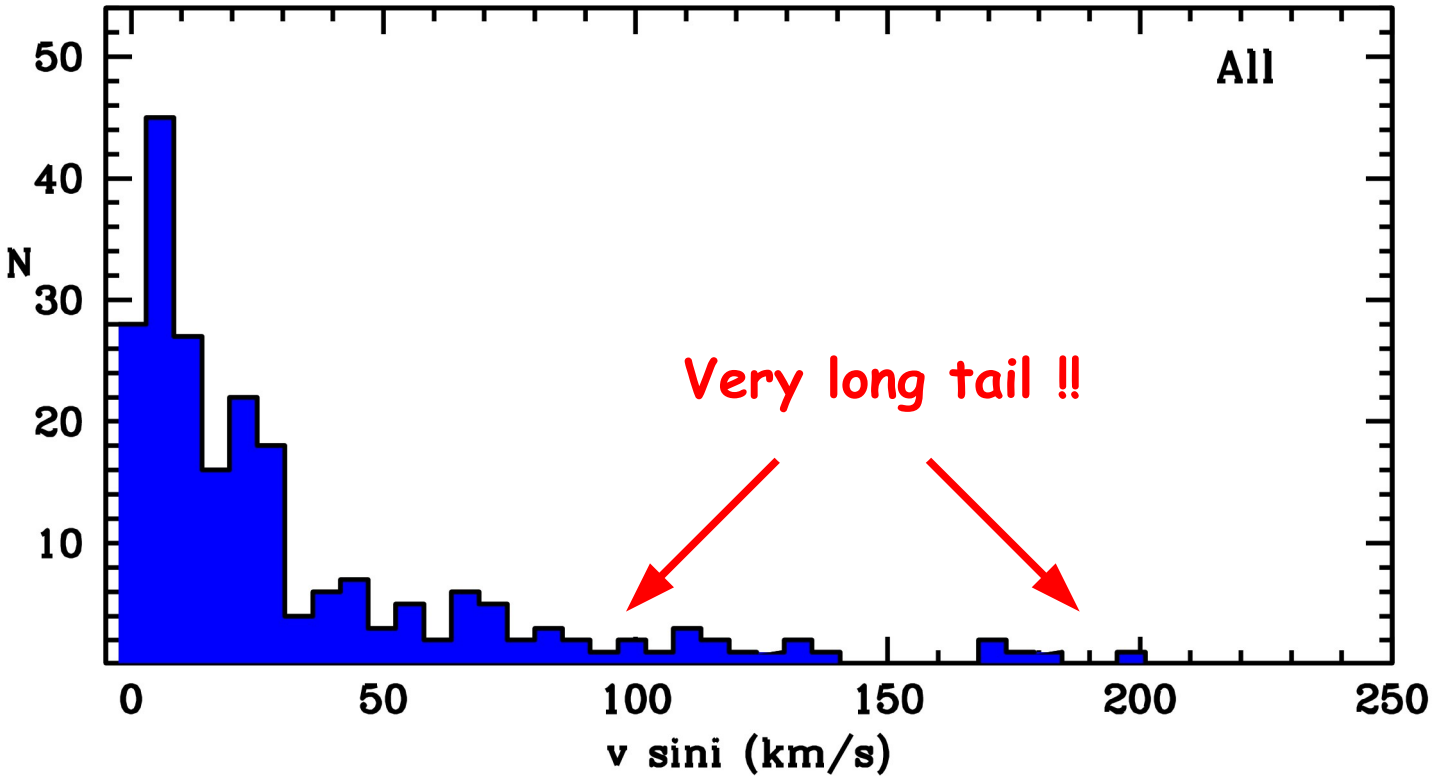


Searching for a link between v sin(i) and BSS formation mechanisms...

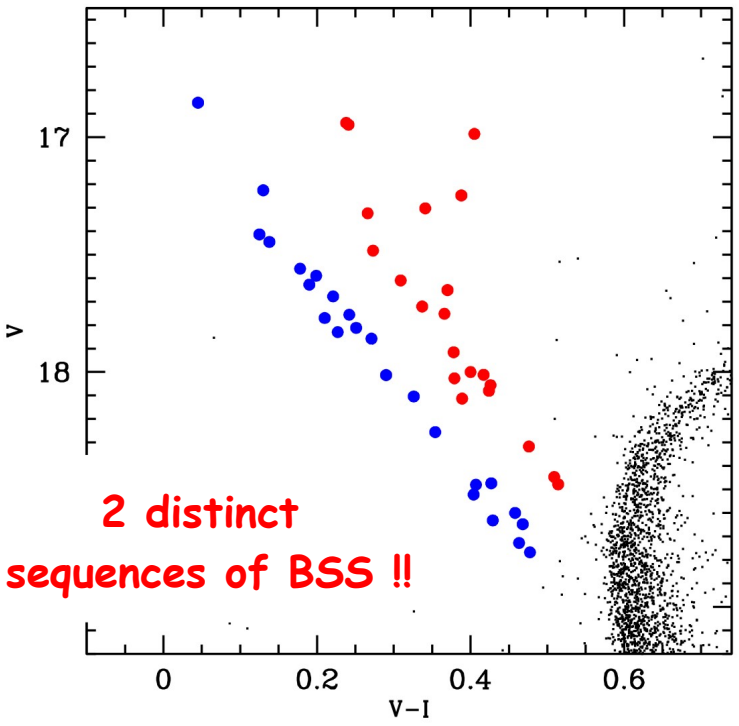
More than 10% of FR BSS are also WUMa contact binaries

Initally detached systems evolve to semi-detached and contact stages during MT and finally merge into a single star

Possible link between high v sin(i) and MT

Searching for a link between v sin(i) and BSS formation mechanisms in... M30

Ferraro et al.(2009)

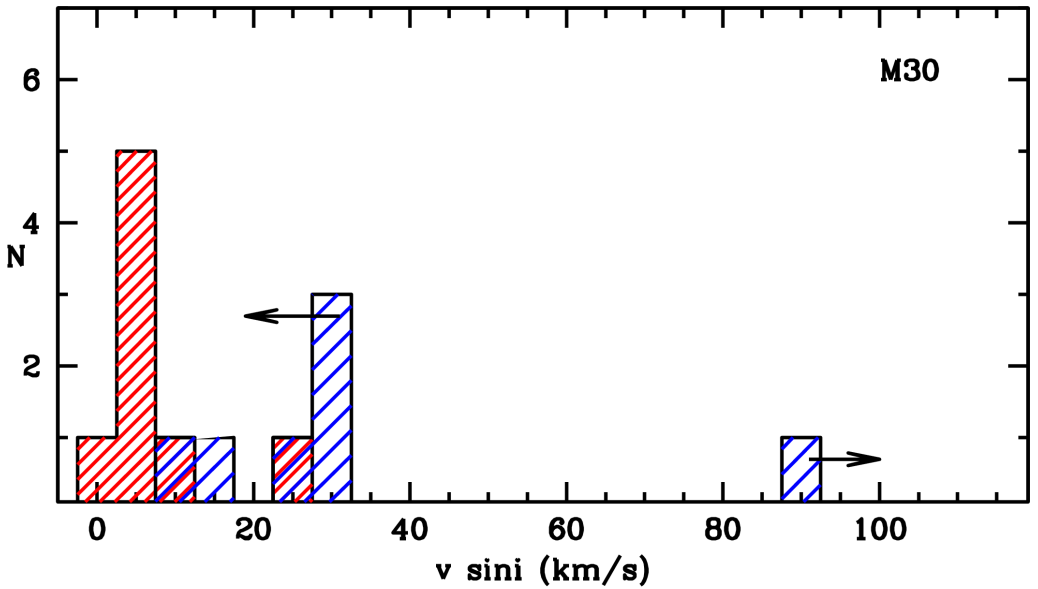


2 distinct sequences of BSS !!

Blue BSS → collisional

Red BSS → mass transfer binaries

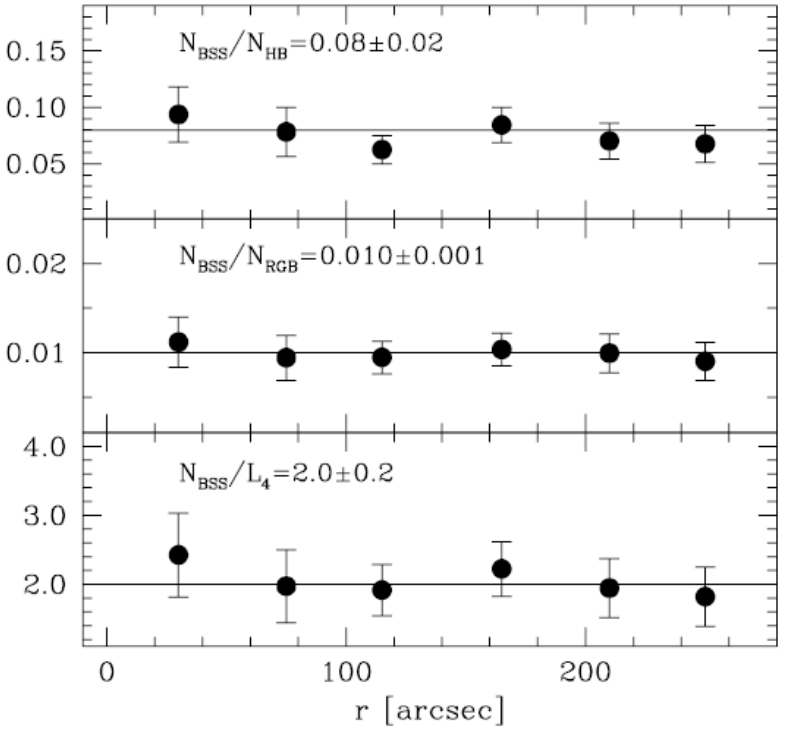
Cluster core-collapse occurred 1-2 Gyr ago and boosted BSS formation



MT- and COL-BSS share the same v sin(i) distribution

Searching for a link between v sin(i) and BSS formation mechanisms in... Omega Cen

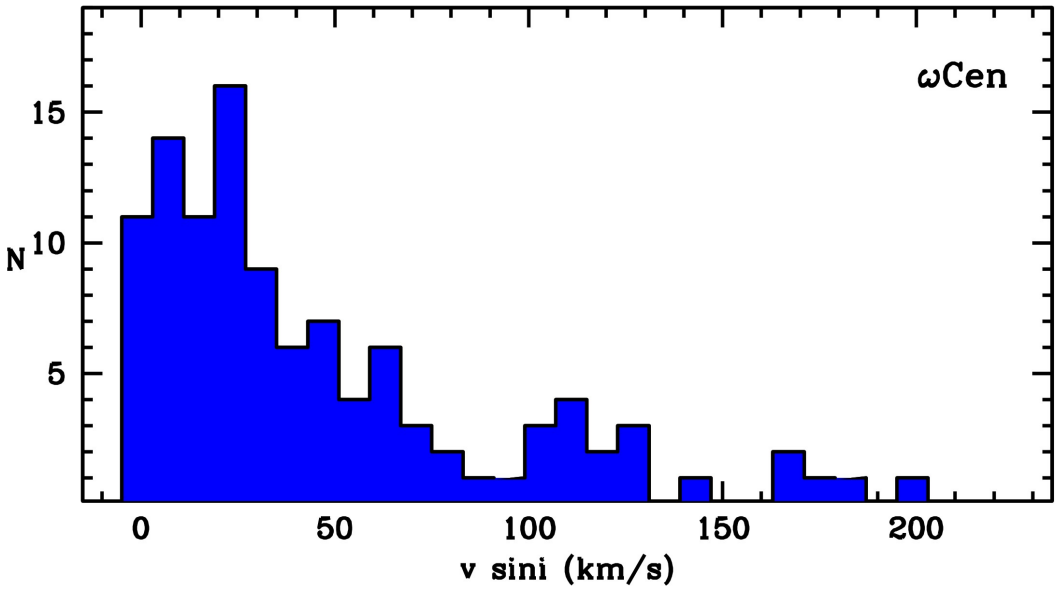
(Ferraro et al, 2006)



BSS radial distribution is a dynamical clock for the cluster evolution (Ferraro et al, 2012)

Flat distribution → **No mass-segregation**

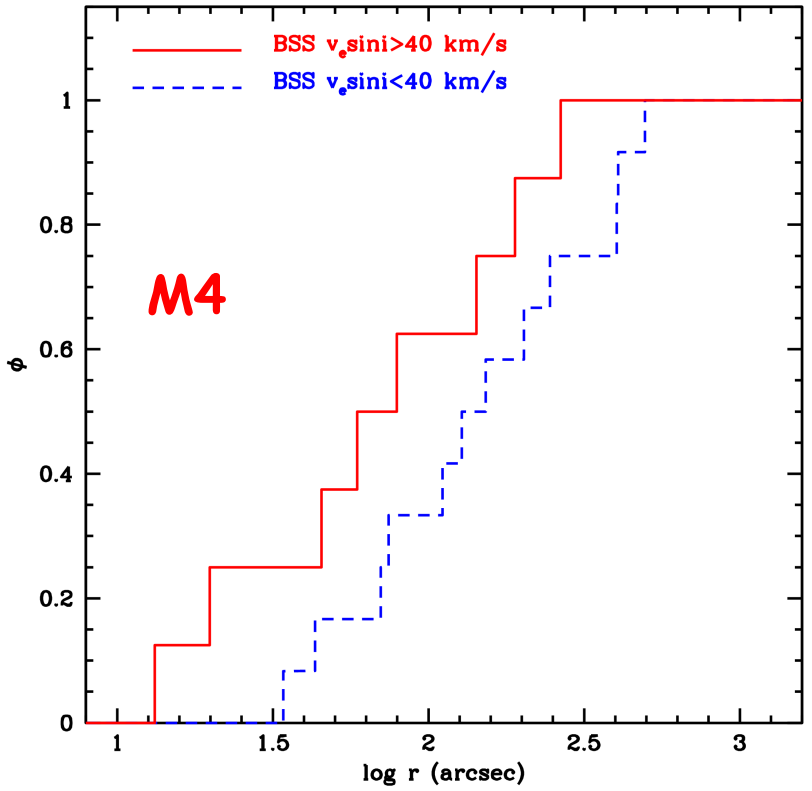
Non-collisional BSS population



MT-BSS can have both high and low v sin(i)

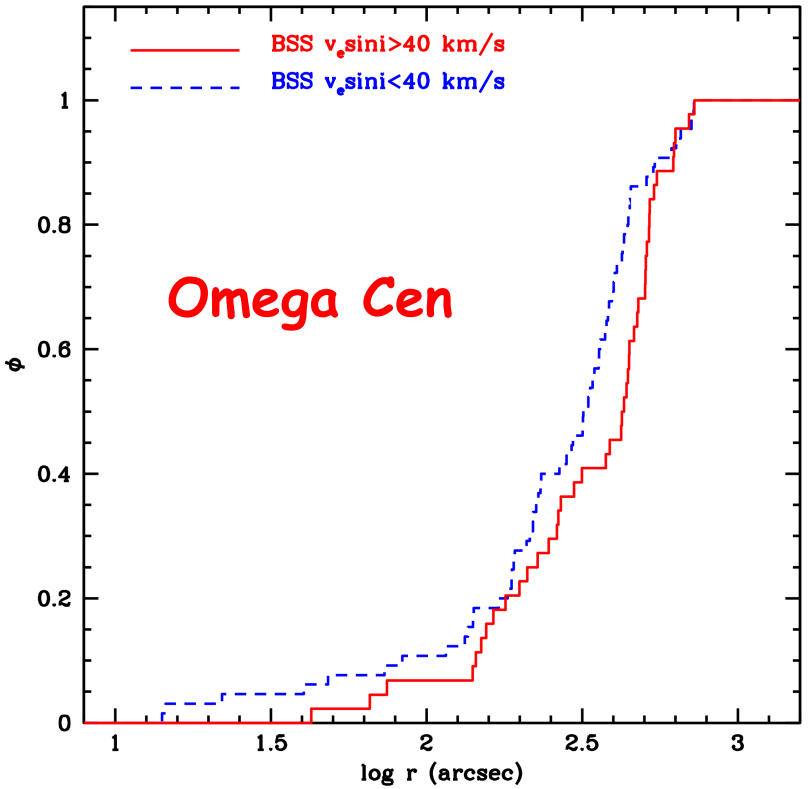
FR radial distribution

Any link with the cluster environment?



FR **more** centrally concentrated

KS test → 56% same population



FR **less** centrally concentrated

KS test → **2%** same population

Conclusions

First systematic survey performed on 220 BSS

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1) BSS are essentially slow rotators **BUT** they can have also v sin(i)~200 km/s

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2) No link with formation mechanisms **BUT** WUMa are FR

Conclusions

First systematic survey performed on 220 BSS

1) BSS are essentially slow rotators **BUT** they can have also v sin(i)~200 km/s

2) No link with formation mechanisms **BUT** WUMa are FR

3) FR might be less centrally concentrated in the cluster **BUT** too low statistics (only Omega Cen)

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