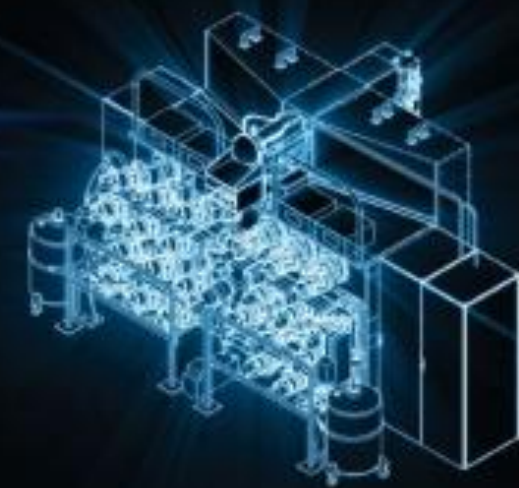


Binaries in Galactic Globular Clusters

**A decade of discoveries
with MUSE and beyond**

18–22 November 2024
Garching b. Muenchen



*Johanna Müller-Horn, Sara Saracino, Fabian
Göttgens, Flo Wragg, **Stefan Dreizler**, Sebastian
Kamann, Sven Martens, Tim-Oliver Husser,
Benjamin Giesers, MUSE-, oMEGACat-, CMC-,
MOCCA-team*



47 Tuc, Credits: NASA, ESA

Galactic Globular Clusters and MUSE

GCs

old, massive star clusters in the halo



$\sim 10^5$ to 10^6 M_{\odot} within a few pc

MUSE

GTO + GO



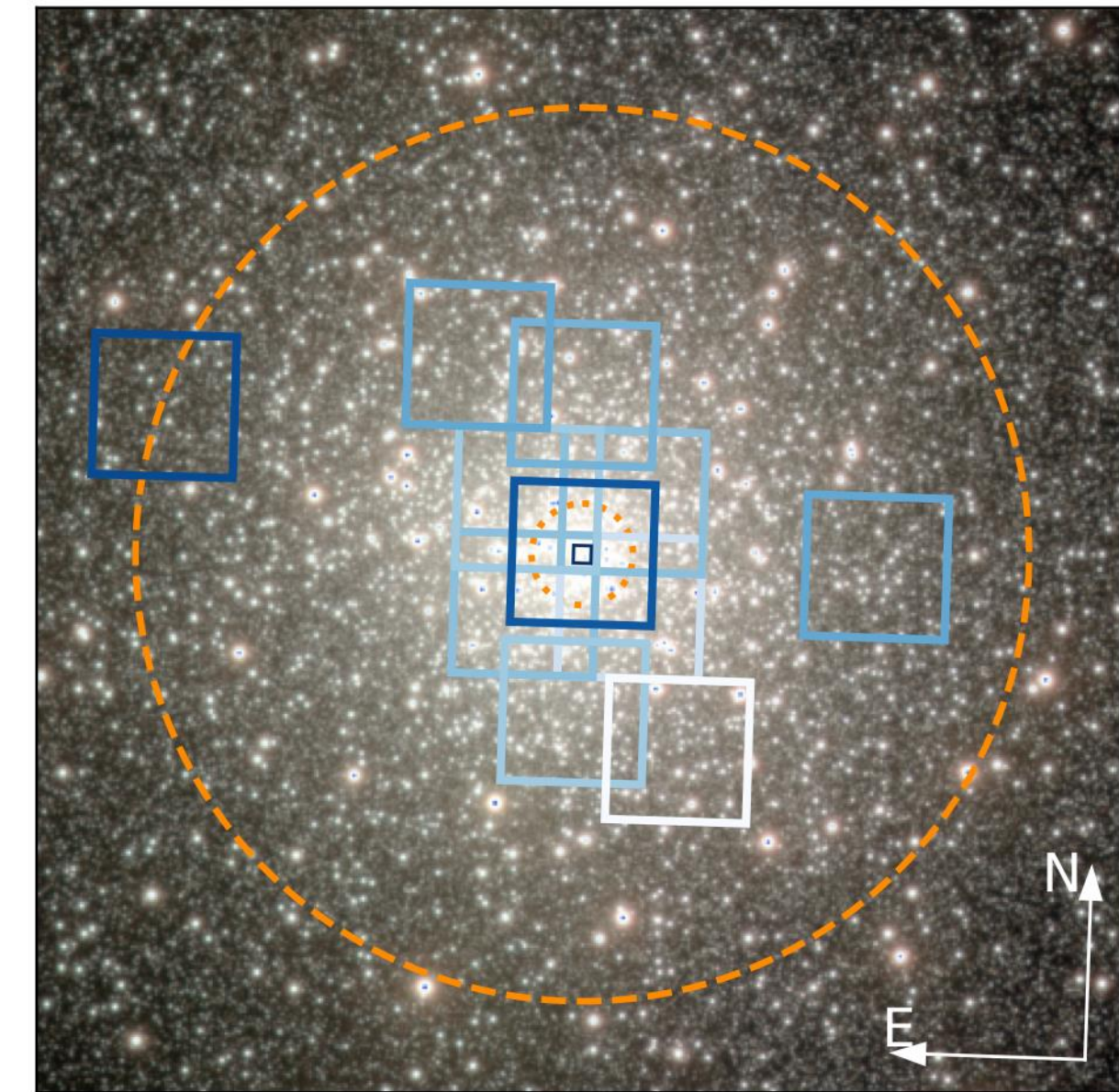
\sim a decade of MUSE observations



reliable spectra of $> 400,000$ stars ⁽¹⁾



Multiple epochs per star

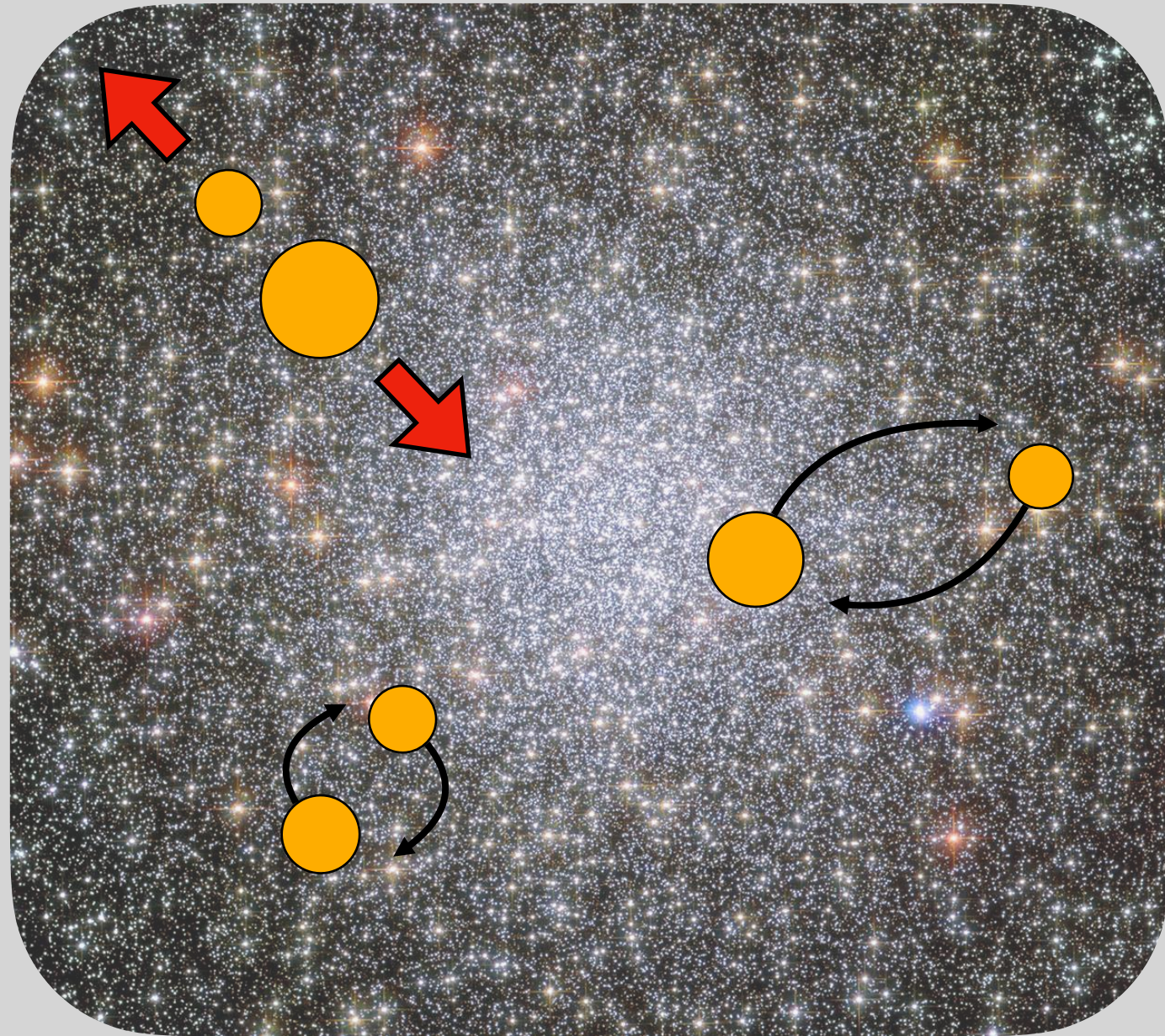


MUSE FoV of 47 Tuc,
image taken from VMC survey

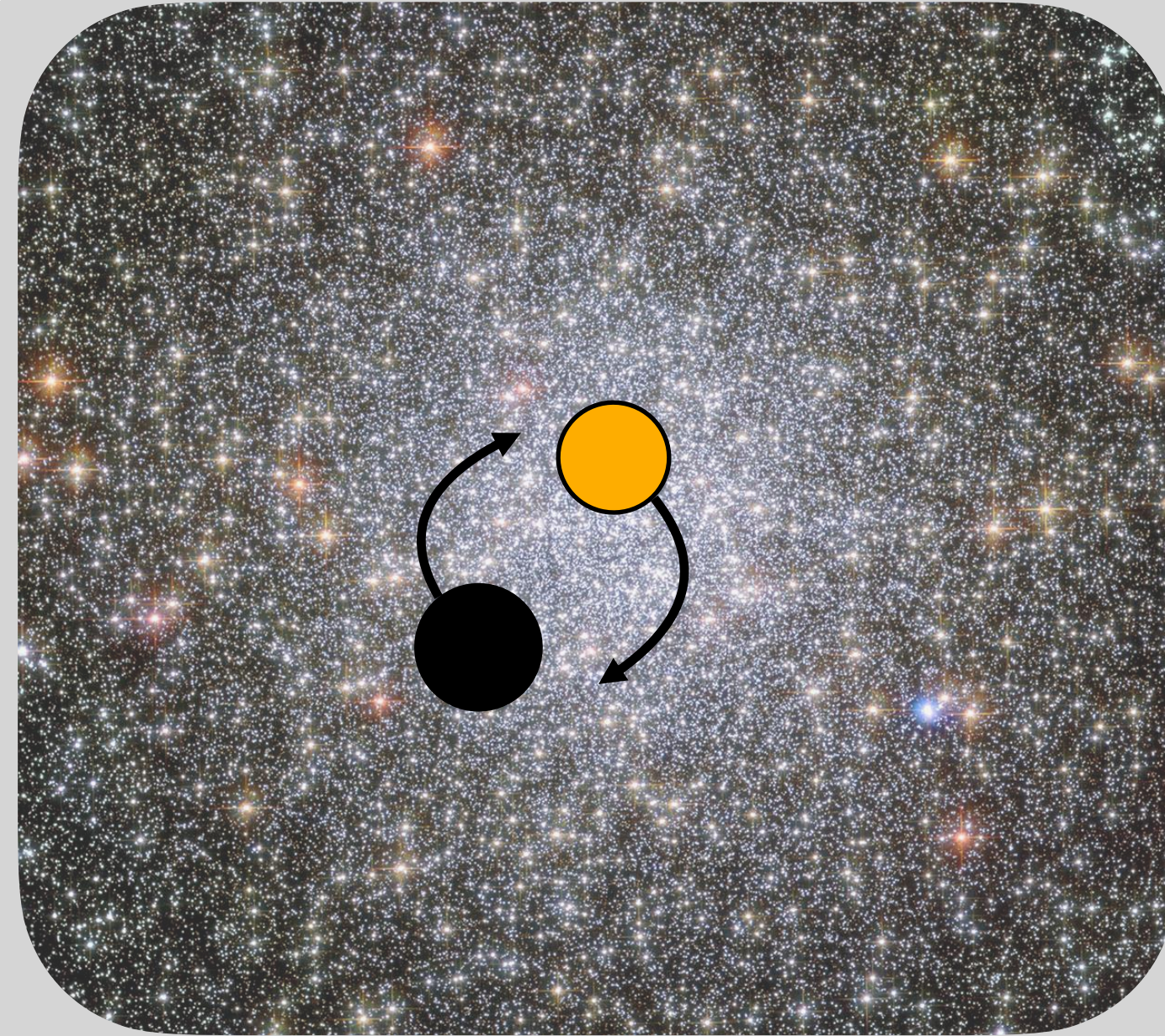
(1) Kamann et al. (2013)

Credit: ESO/F. Kamphues

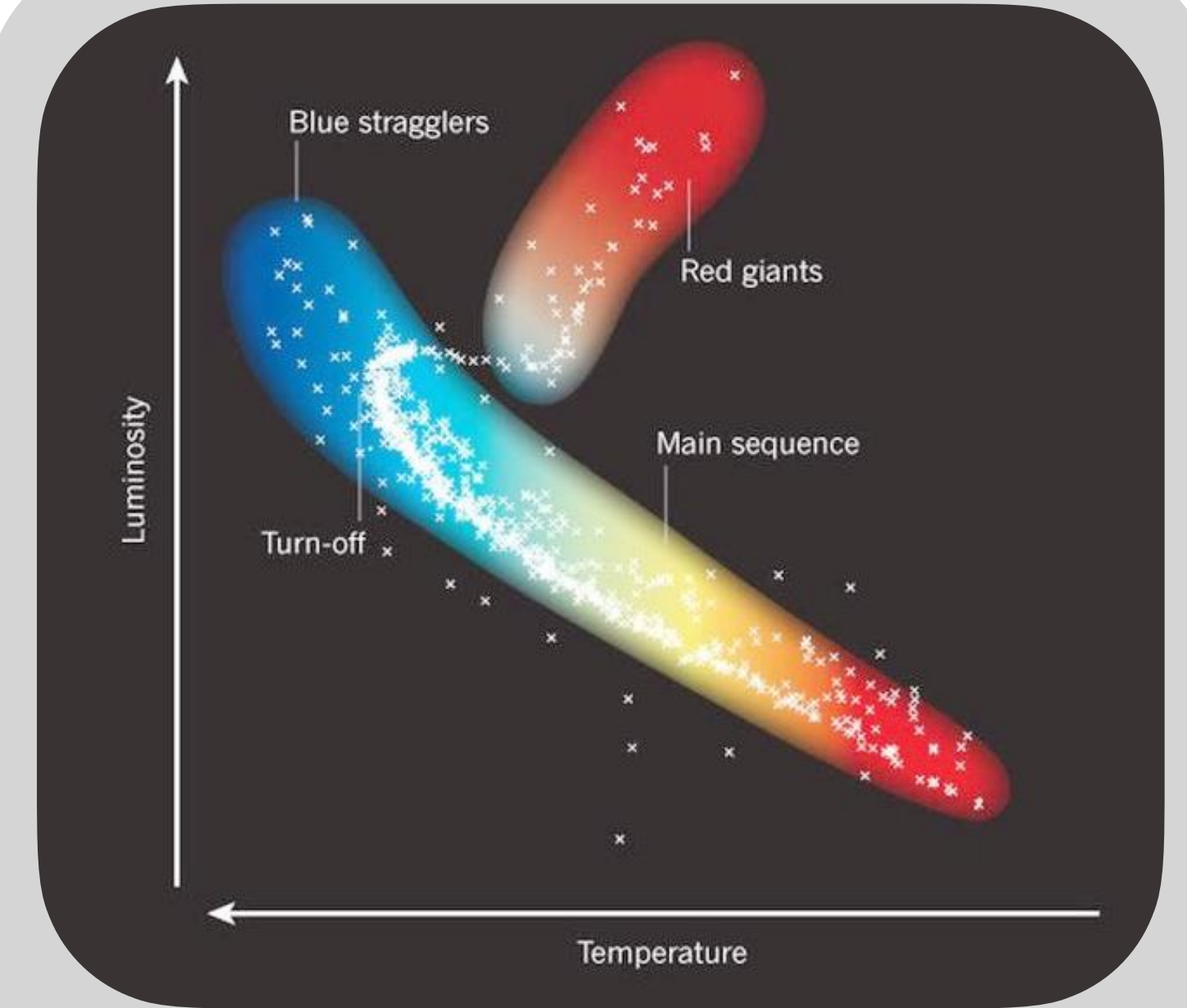
Binaries in Globular Clusters



Binary fraction, mass segregation and cluster dynamics



Stellar and intermediate mass **Black Holes, GW sources**



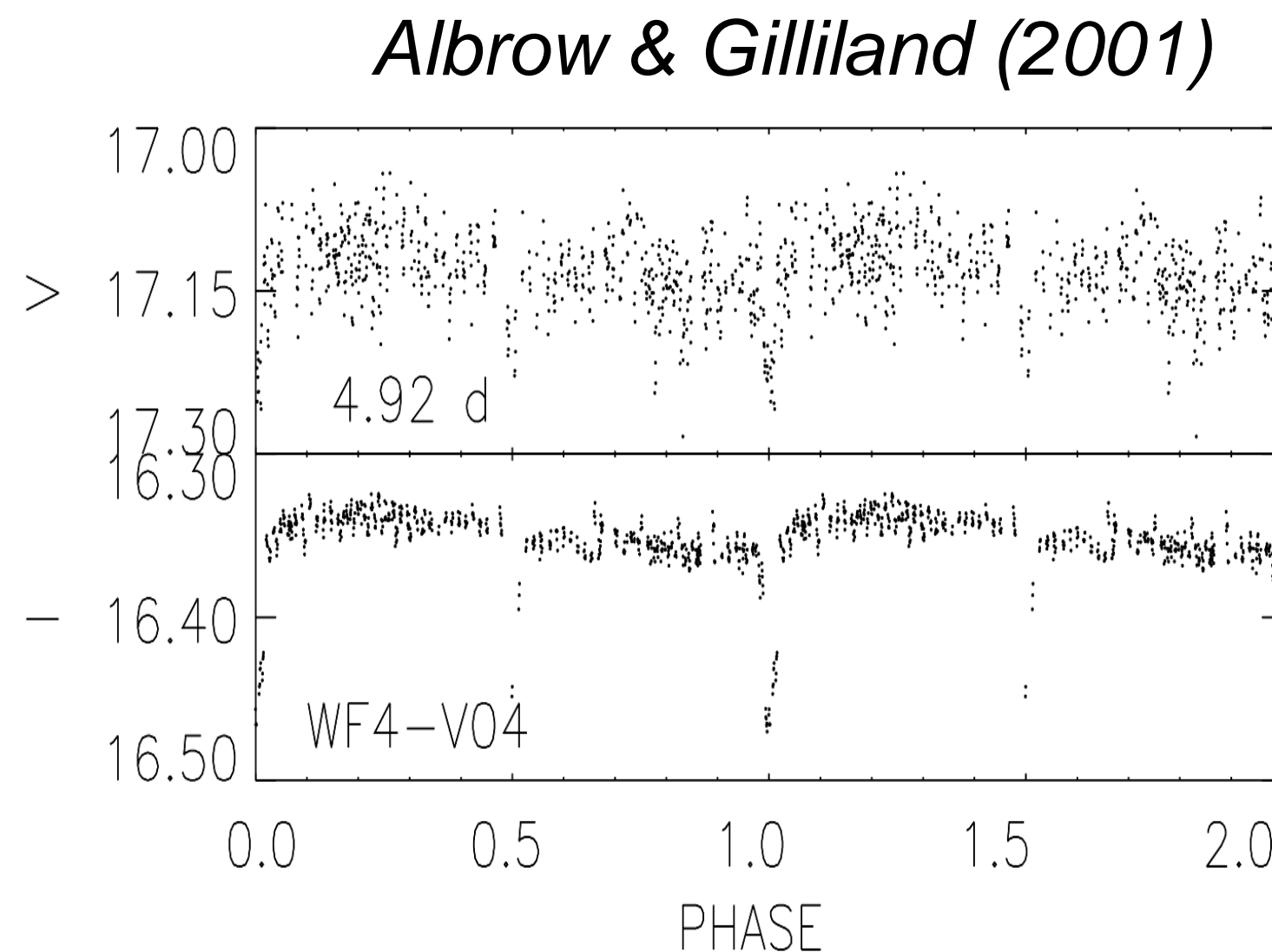
High stellar density favors formation of exotic binaries:
Blue stragglers, x-ray pulsars, ...

47 Tuc, Credits: NASA, ESA

Previous observations

eclipsing binaries

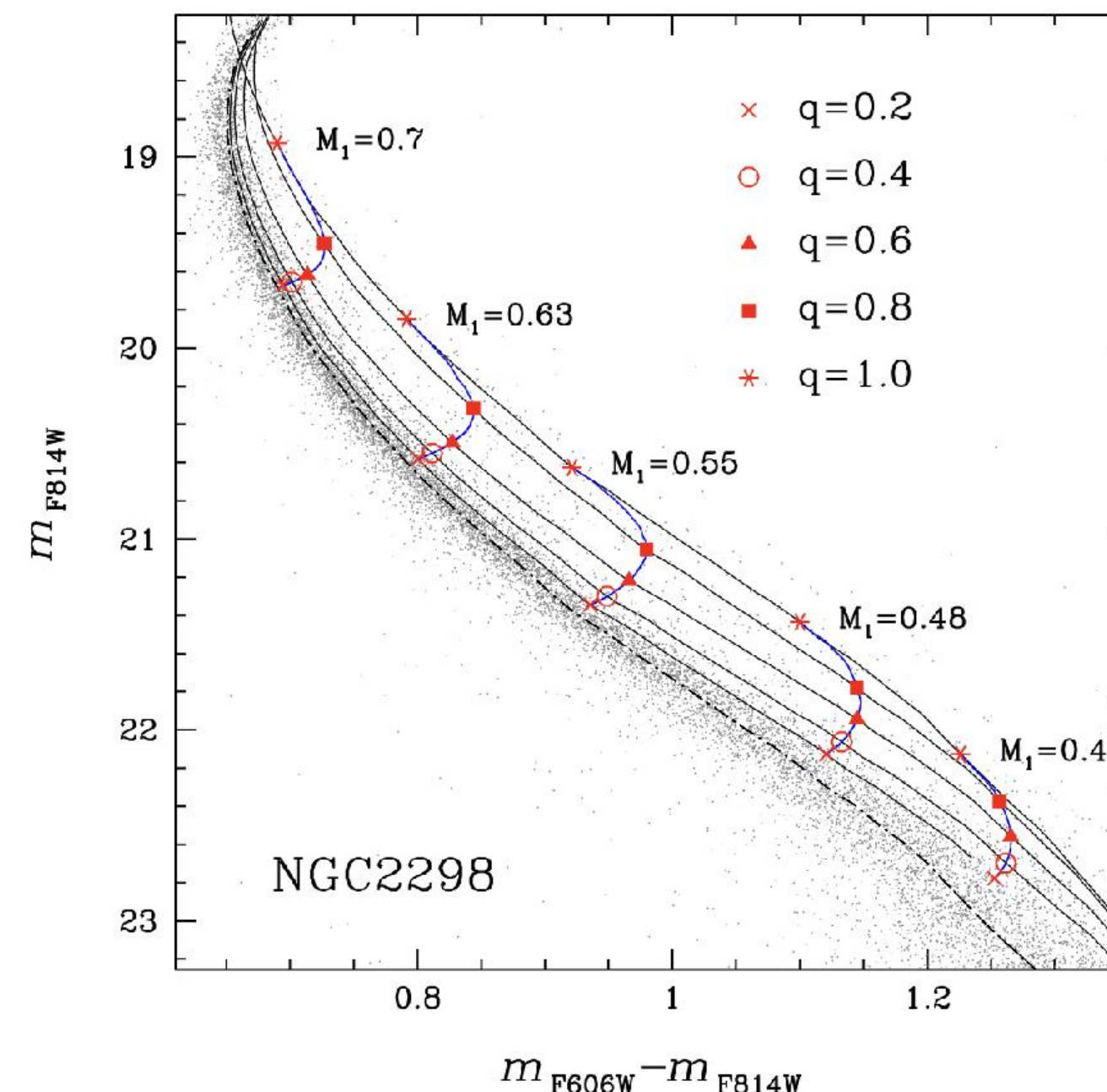
*Albrow & Gilliland (2001),
Weldrake & Sackett (2004),
Kaluzny et al. (2013),
Nardiello et al. (2019)*



binary main sequence

*Milone et al. (2012),
Ji & Bregmann (2015)*

Milone et al. (2012)



radio & X-ray sources

*Heinke et al. (2005)
Bahramian et al. (2017),
Miller-Jones et al. (2015)
Rivera Sandoval et al. (2018)*

„tip of the iceberg“

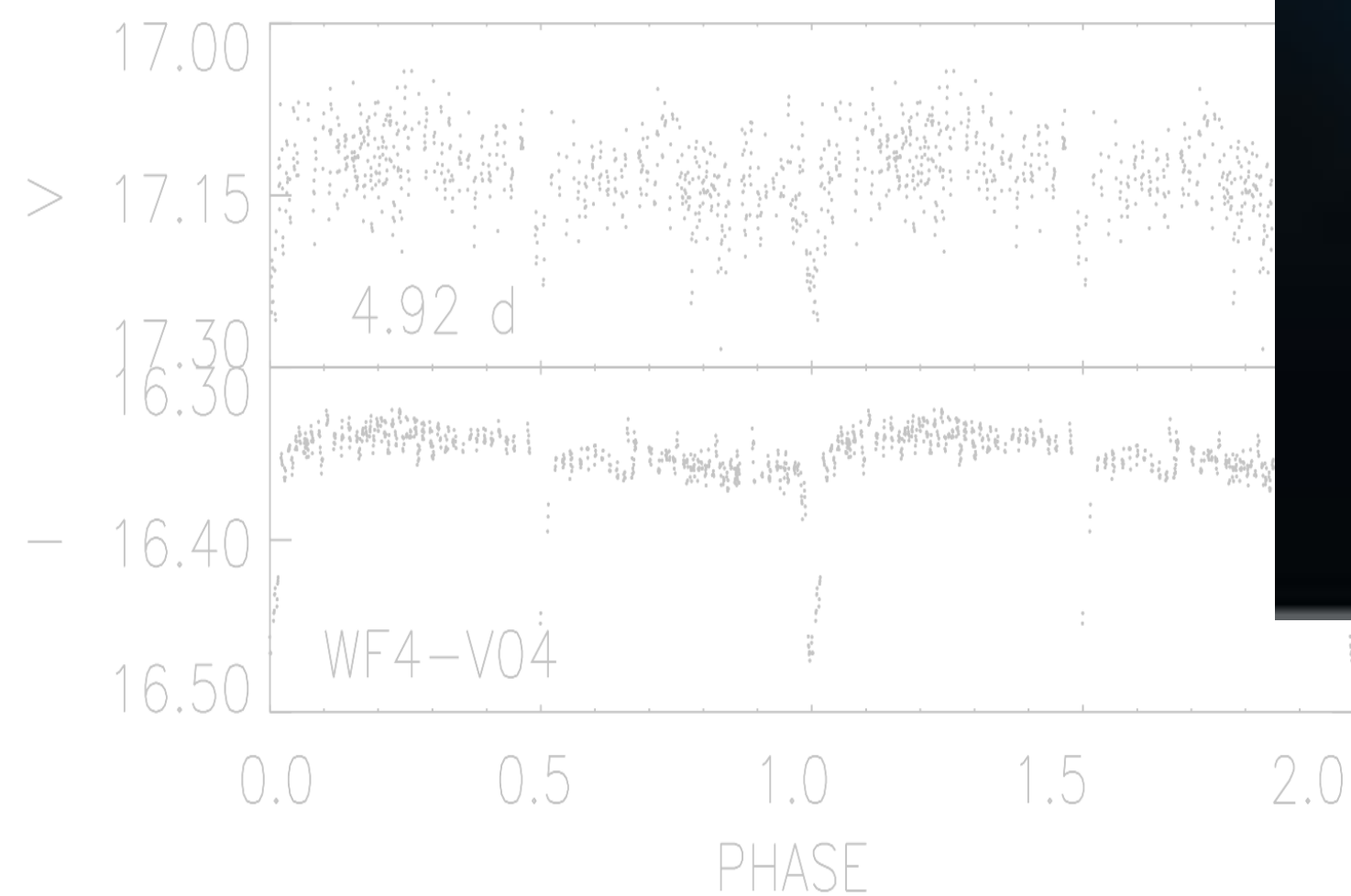
- limited information on companion masses and period distribution
- low overall binary fraction

P

eclipsing binaries

*Albrow & Gilliland (2001),
Weldrake & Sackett (2004),
Kaluzny et al. (2013),
Nardiello et al. (2019)*

Albrow & Gilliland (2001)



& X-ray sources

*Wolk et al. (2005),
Kraus et al. (2017),
Gonzalez et al. (2015),
Gonzalez et al. (2018)*

„tip of the iceberg“

Additional information on
companion masses and
distribution

Overall binary
fraction

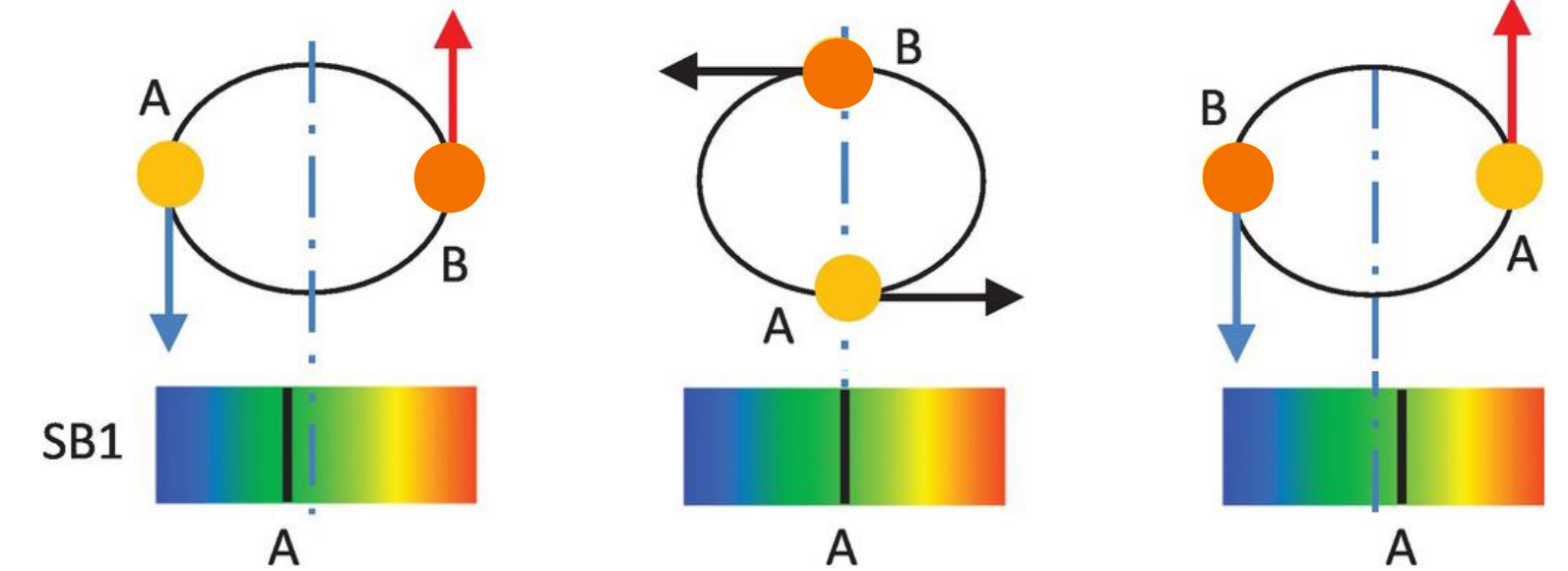
Search for SB1 binaries

data

$$t, v_{\text{rad}}, \sigma_{v_{\text{rad}}}$$

model

$$v_{\text{rad}} = v_z + K(\cos(\omega + f) + e\cos(\omega))$$



Walker (2017)

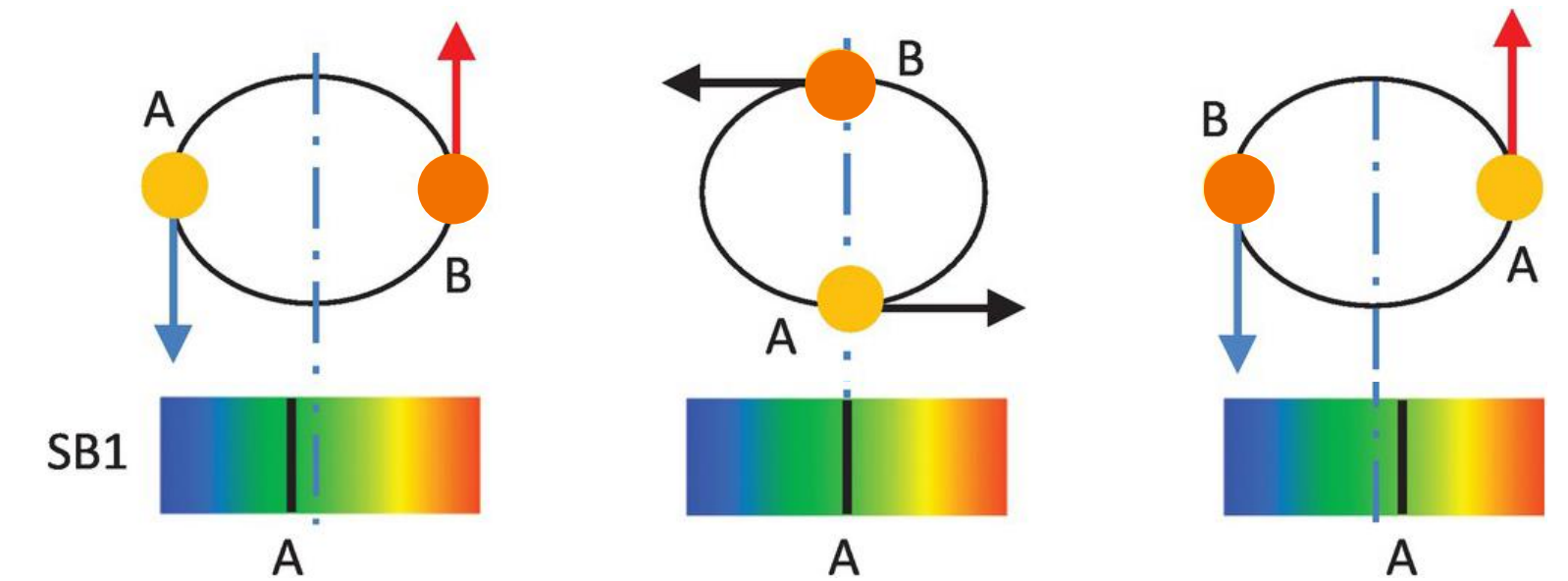
Search for SB1 binaries

data

$$t, v_{\text{rad}}, \sigma_{v_{\text{rad}}}$$

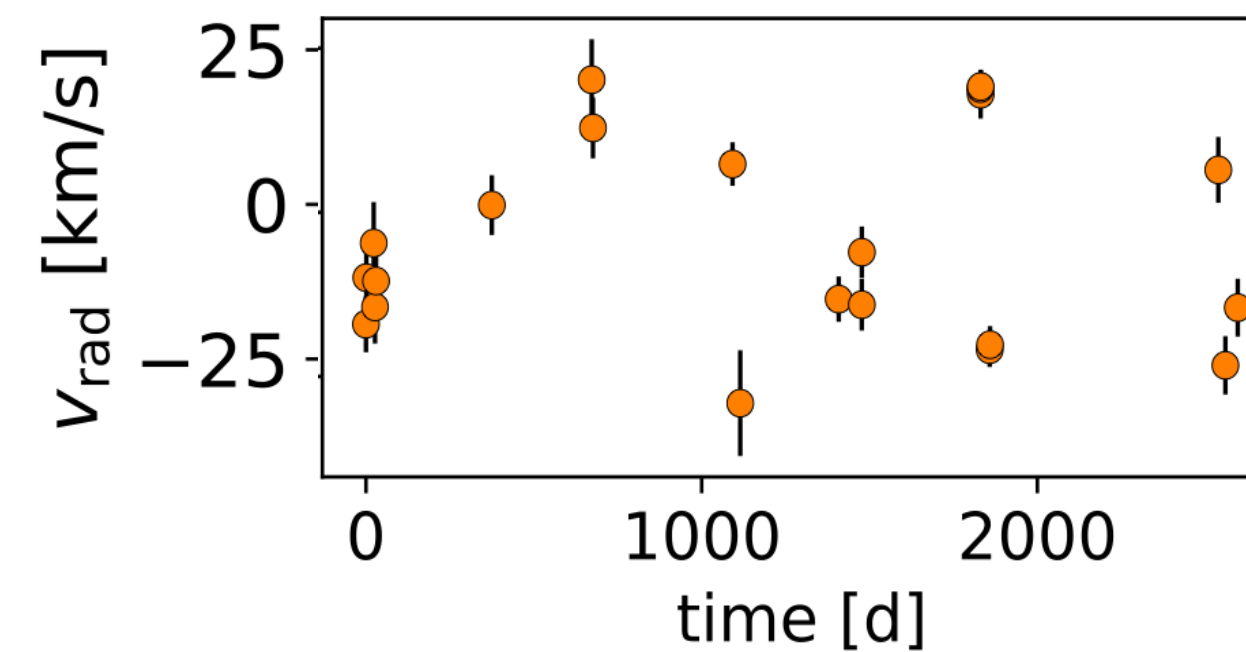
model

$$v_{\text{rad}} = v_z + K(\cos(\omega + f) + e\cos(\omega))$$



Walker (2017)

A. identify binaries in a statistical approach (*Giesers et al. 2019*)



larger RV scatter \Leftrightarrow
higher binary probability

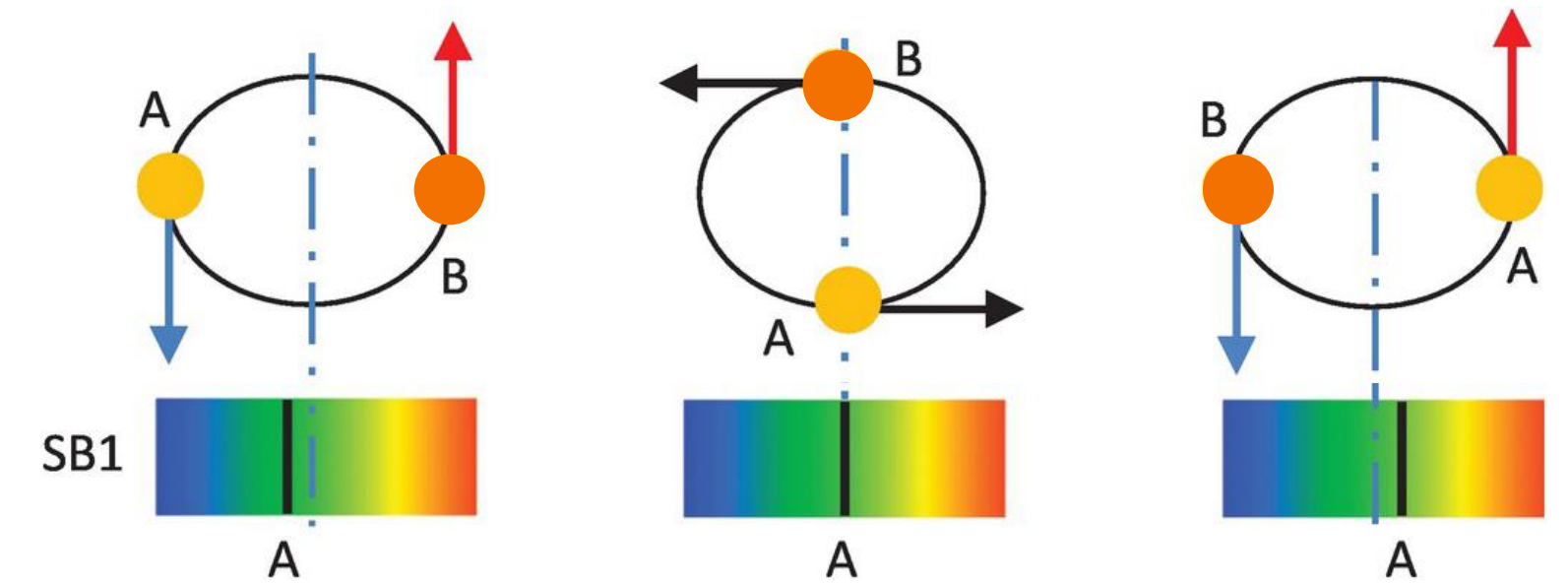
Search for SB1 binaries

data

$$t, v_{\text{rad}}, \sigma_{v_{\text{rad}}}$$

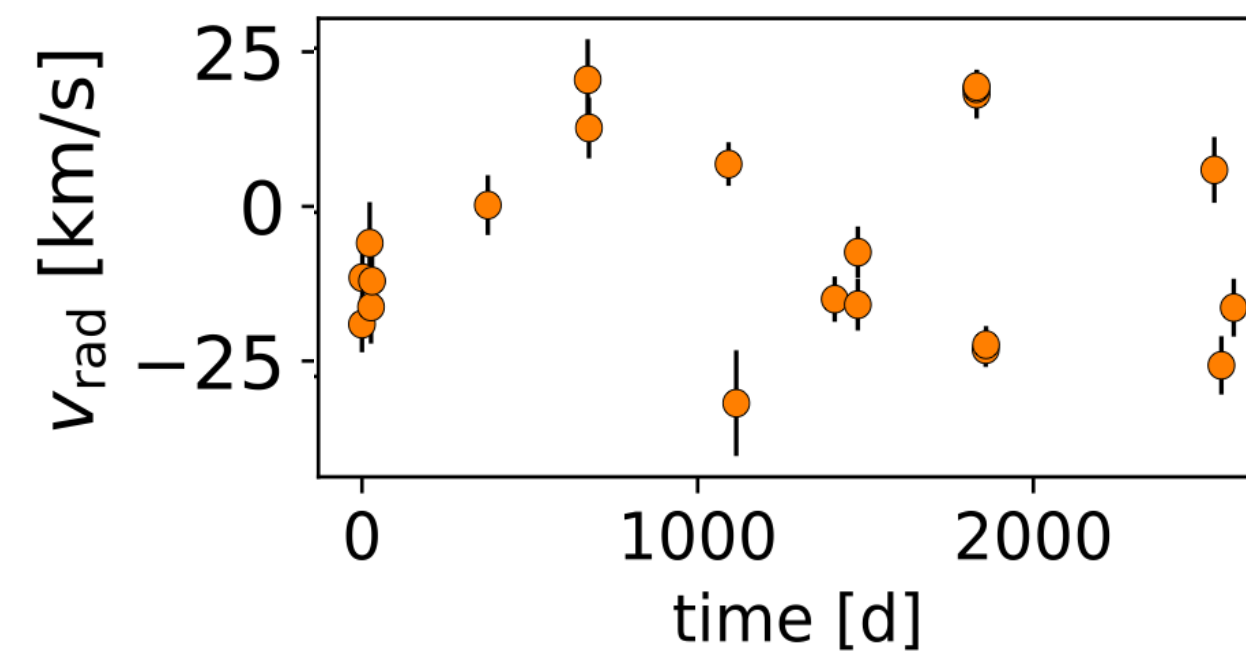
model

$$v_{\text{rad}} = v_z + K(\cos(\omega + f) + e\cos(\omega))$$



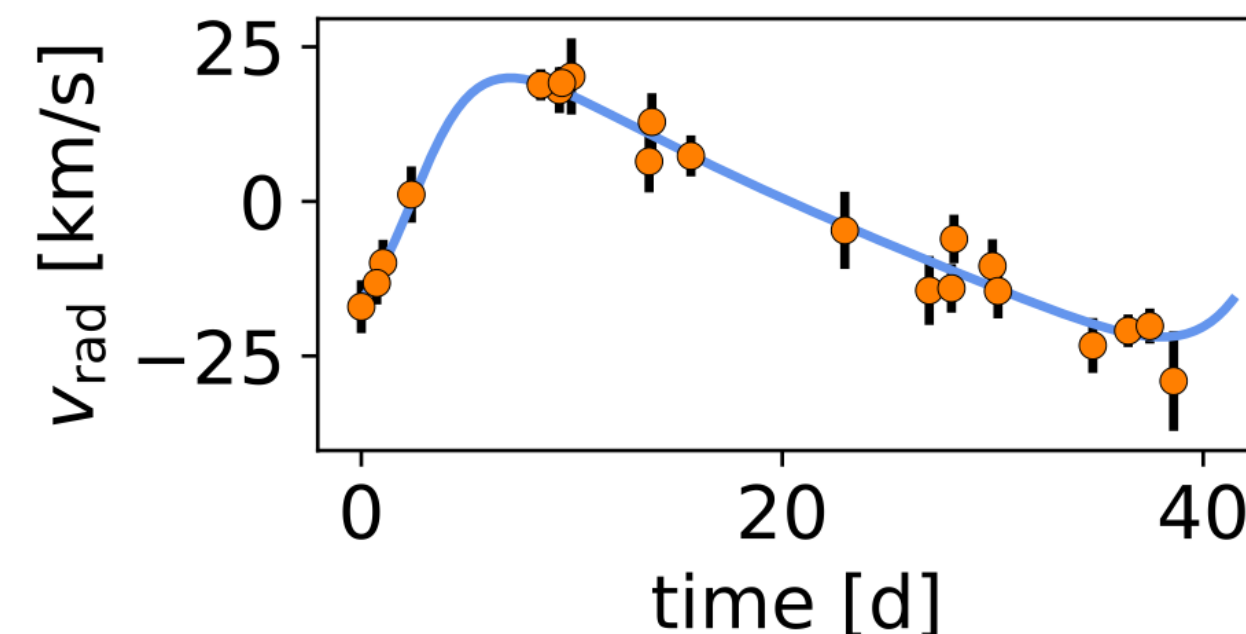
Walker (2017)

A. identify binaries in a statistical approach (*Giesers et al. 2019*)

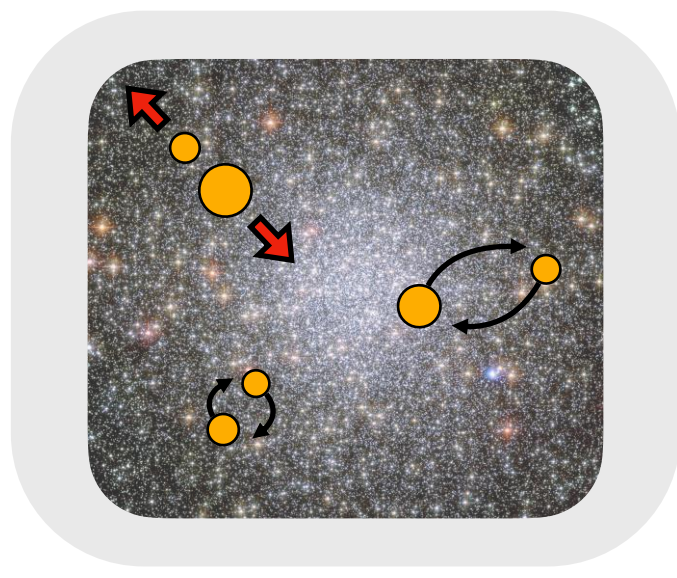


larger RV scatter \Leftrightarrow
higher binary probability

B. determine orbital parameters using nested sampling (*Buchner 2021*)

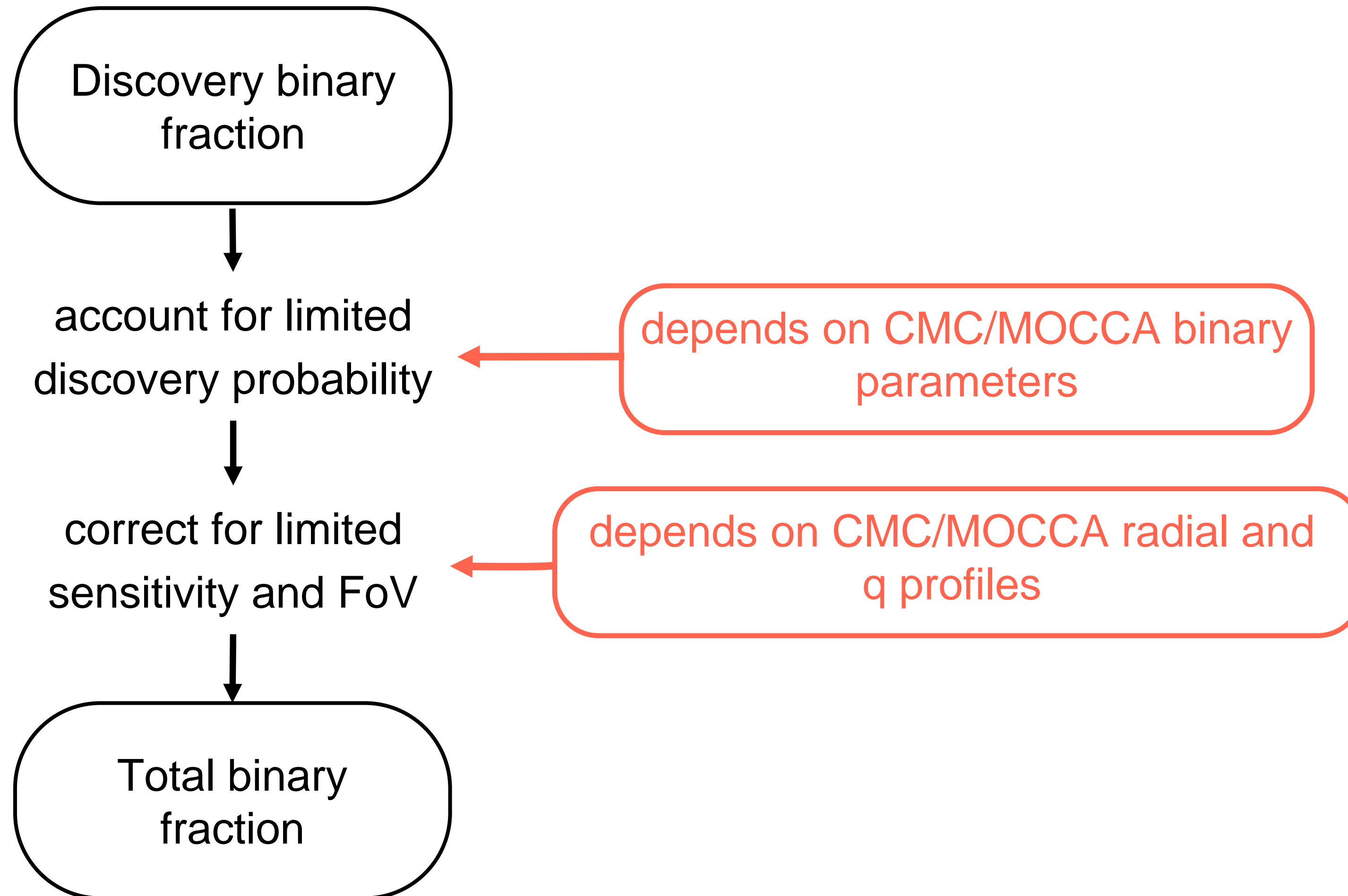


nested sampling works well
for multi-modal solutions



Binary demographics

Binary fraction



47 Tuc

2.4 ± 0.9

Müller-Horn et al. 2024, under review

ω Cen

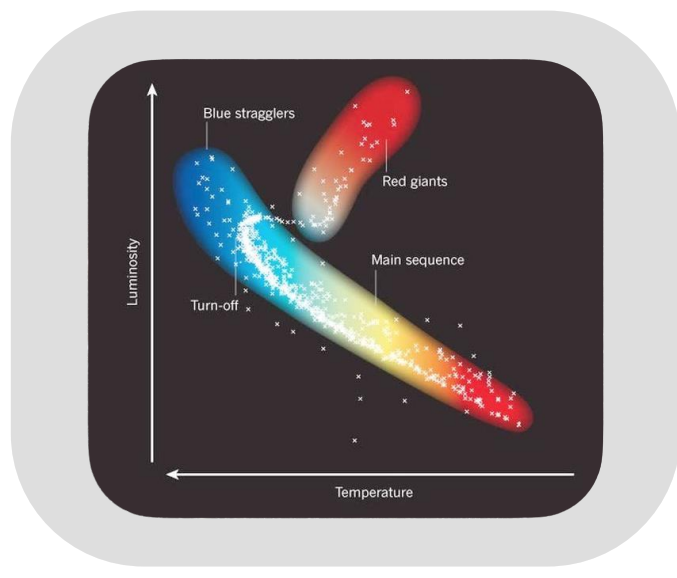
2.1 ± 0.4

Wragg et al. 2024, arXiv

NGC 3201

6.75 ± 0.72
 $P1 > P2$

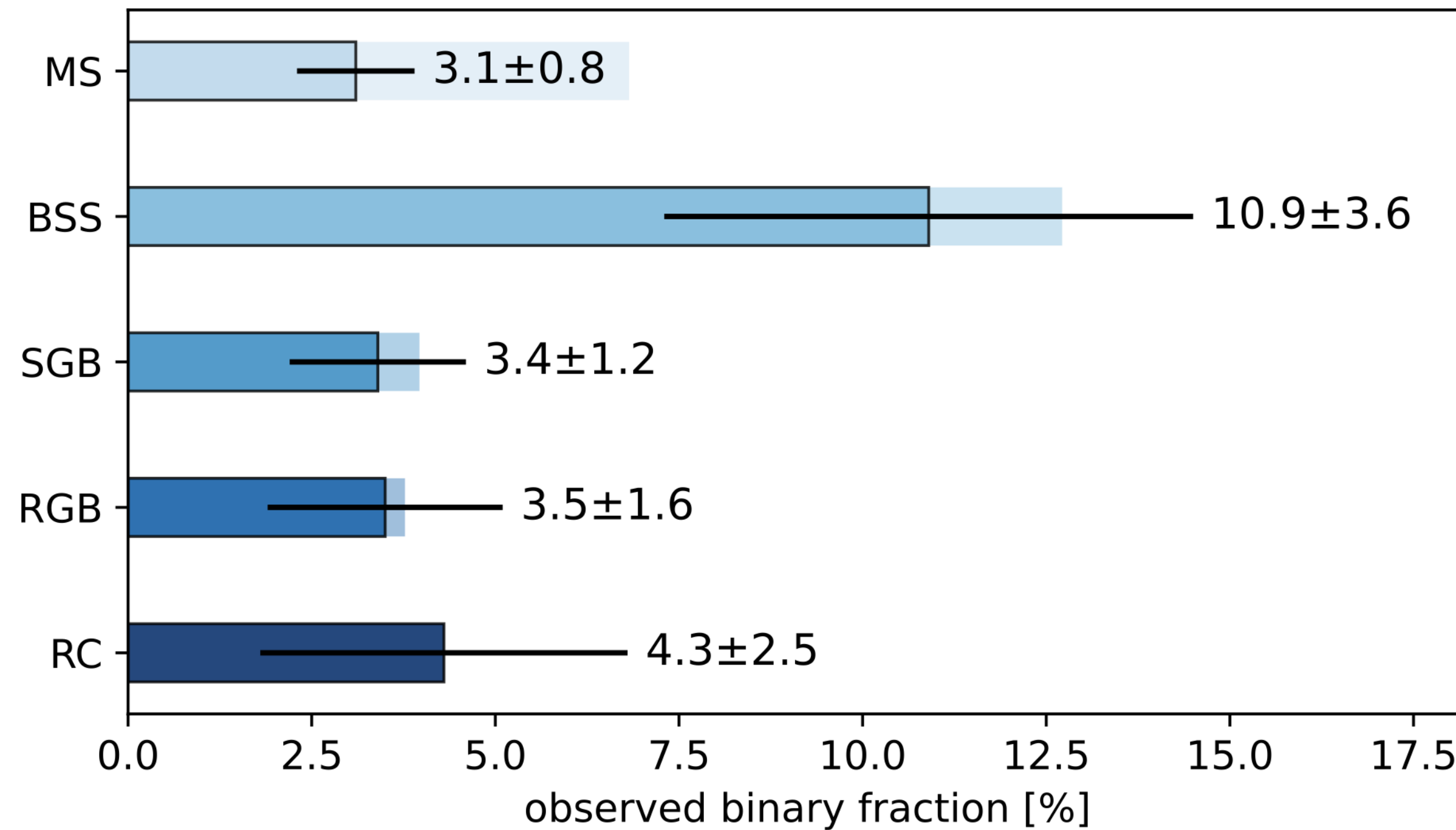
Giesers et al. 2019, A&A
Kamann et al. 2020, A&A



Binary demographics

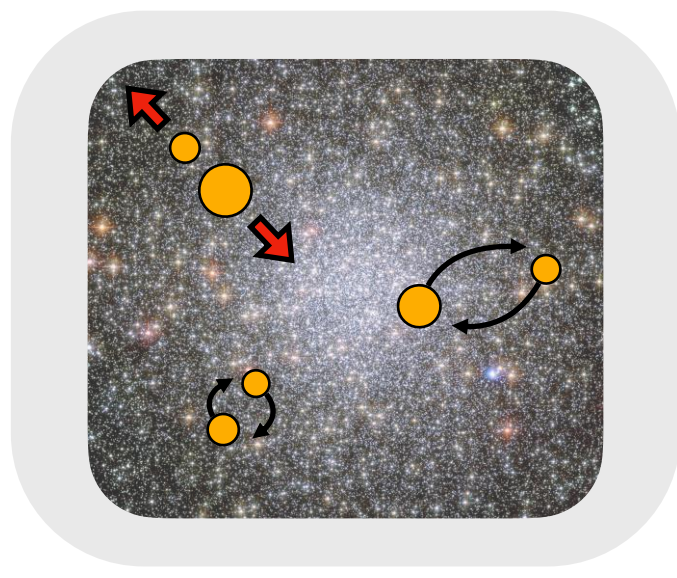
Binary fraction

Dependence on stellar type



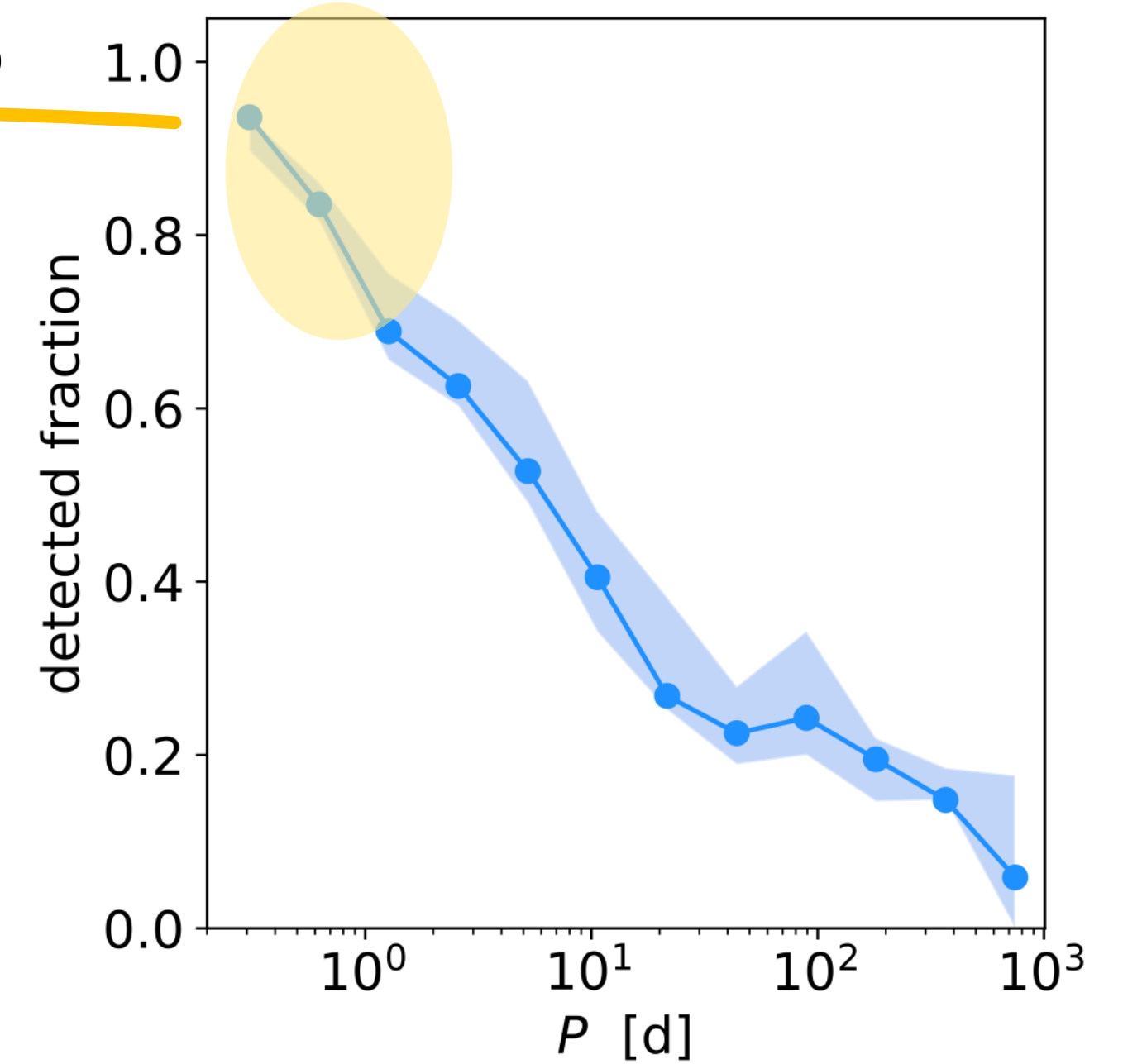
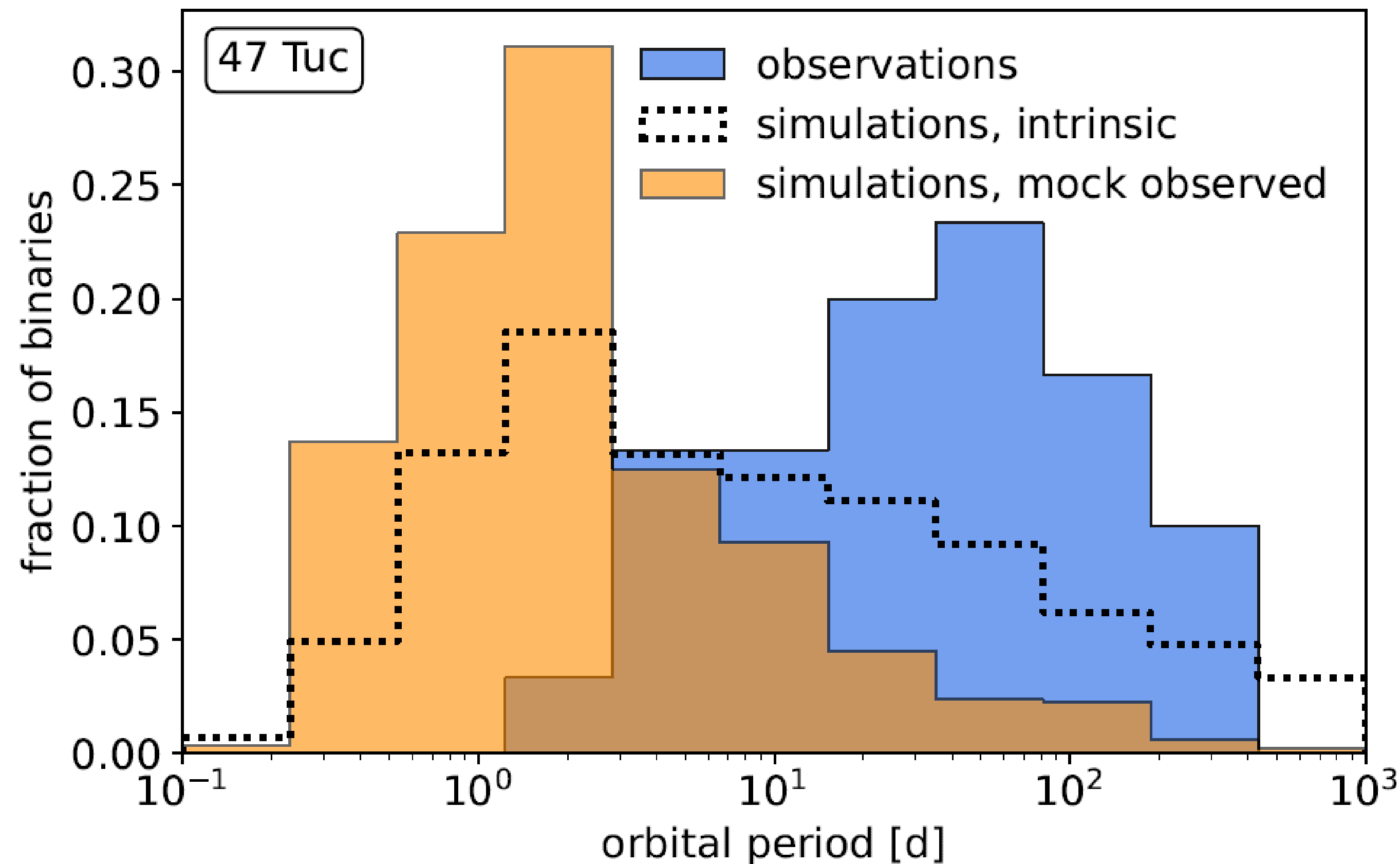
higher binary fraction among blue stragglers

Müller-Horn et al. 2024, under review

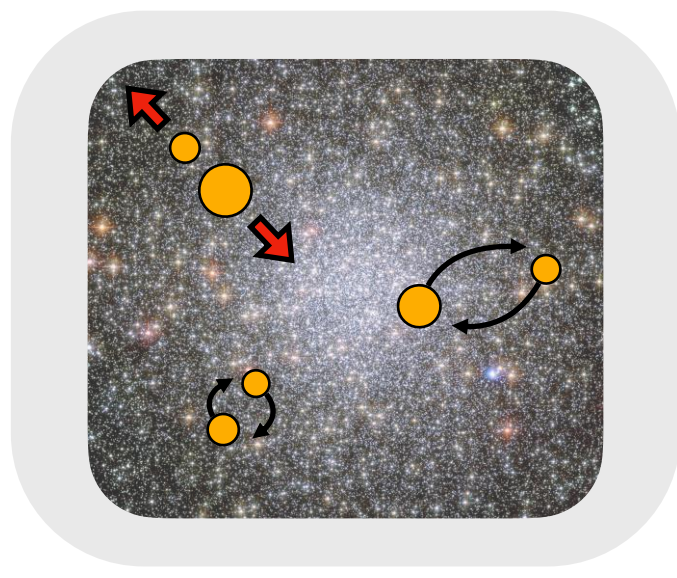


Binary demographics

Orbital parameters

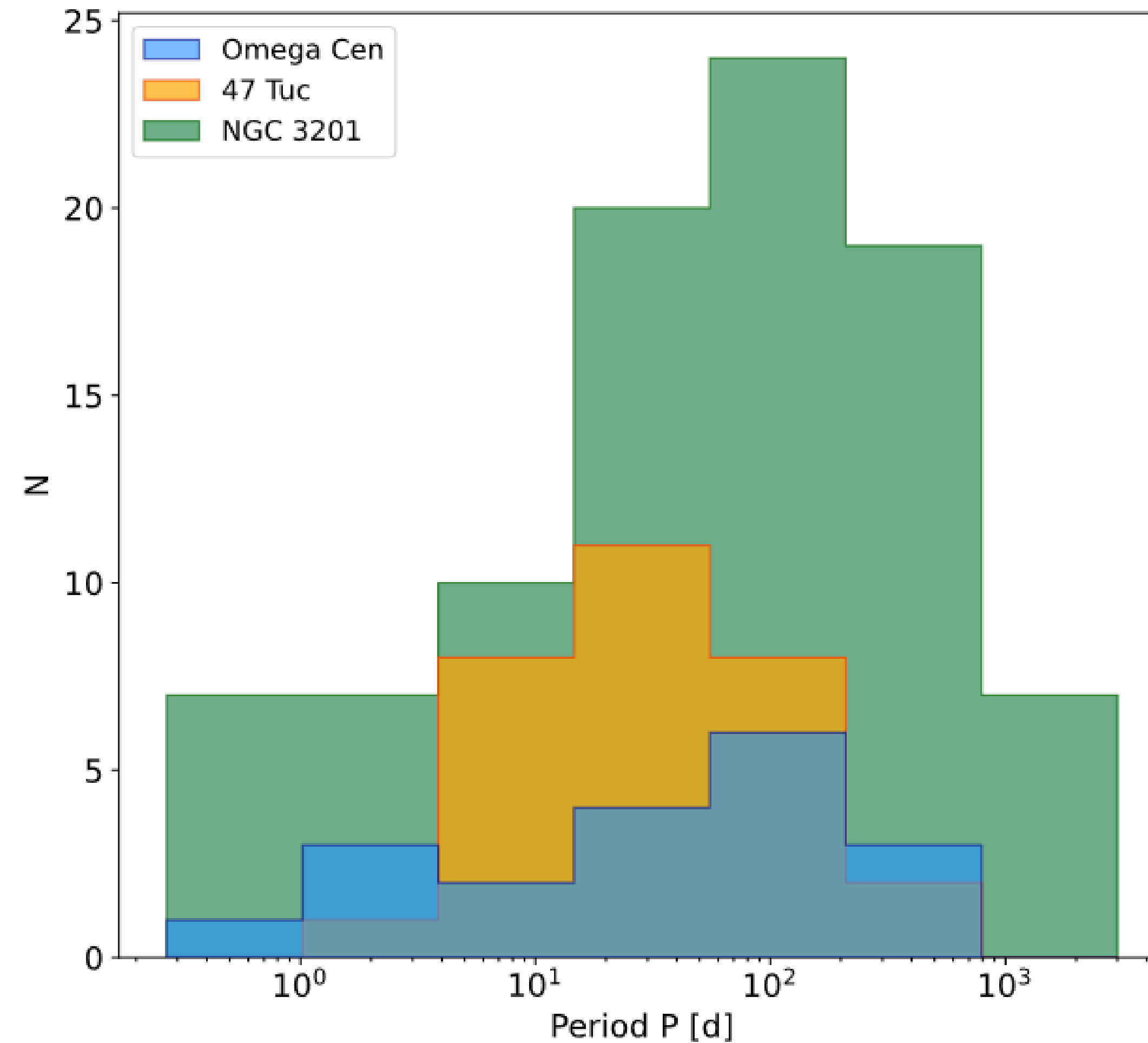


Müller-Horn et al. 2024, under review

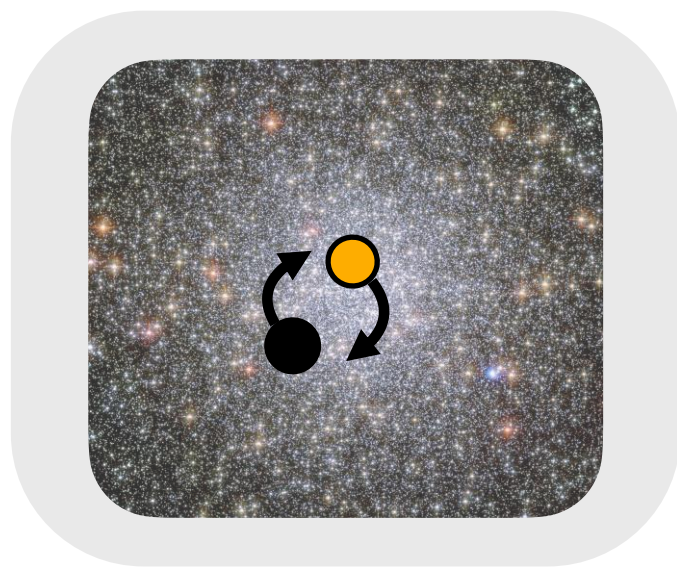


Binary demographics

Orbital parameters

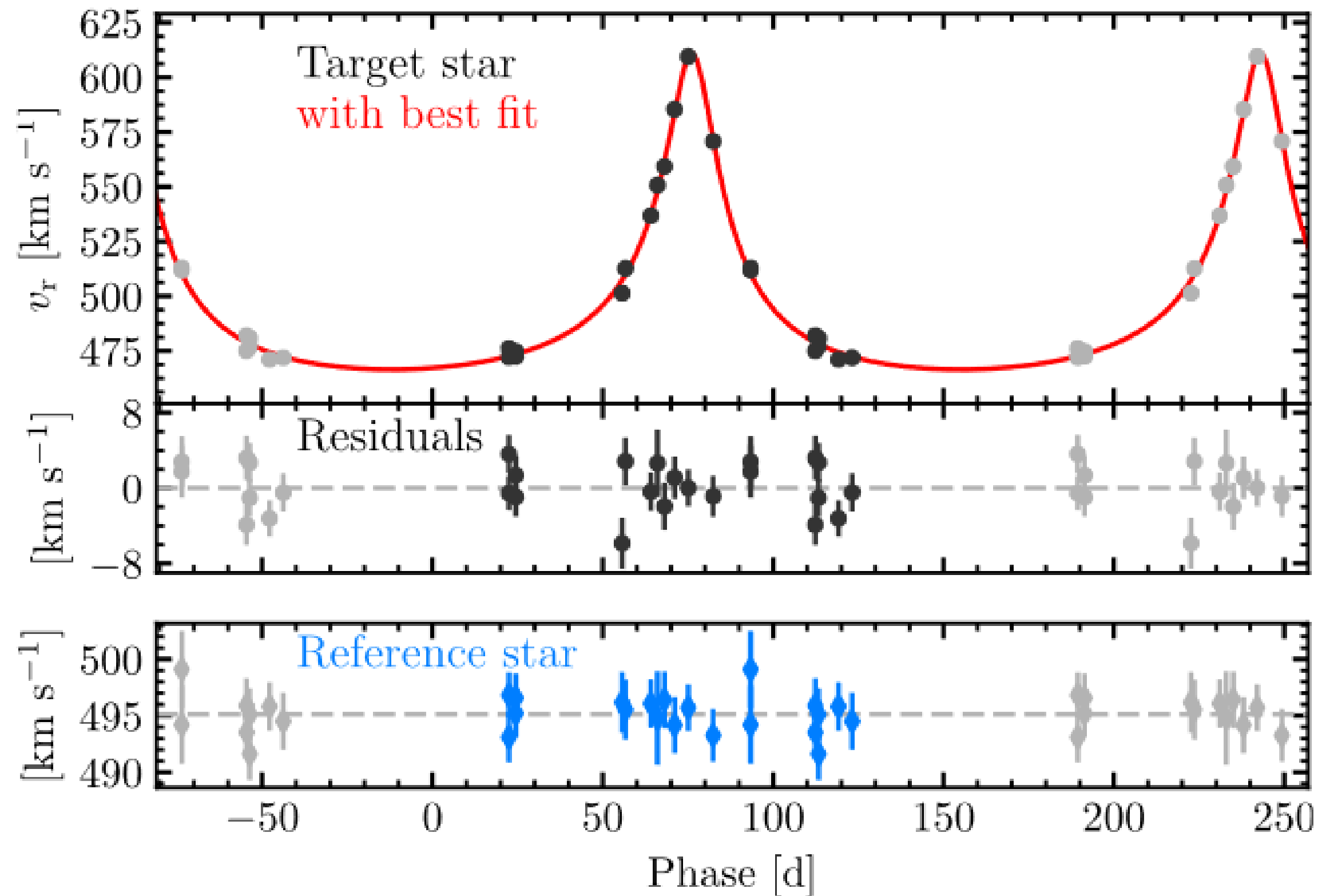


Saracino et al. 2024, submitted



Black hole(s) in NGC 3201

Dark remnant companions



BH + MS

3

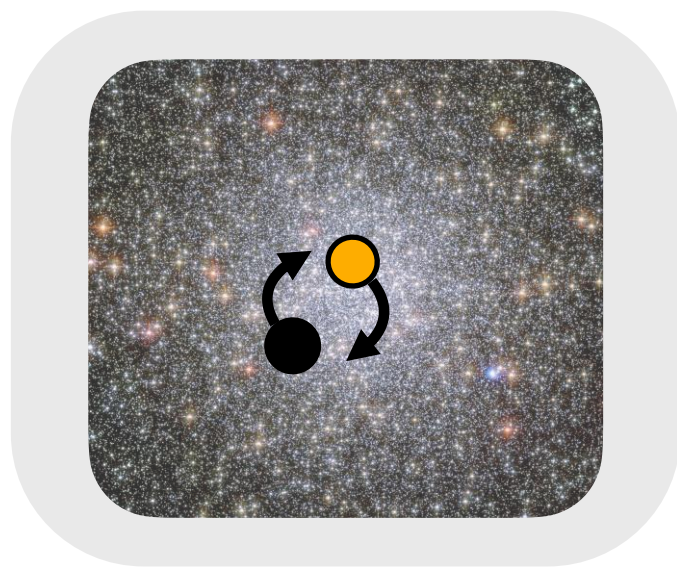
NS + MS

1

WD + MS

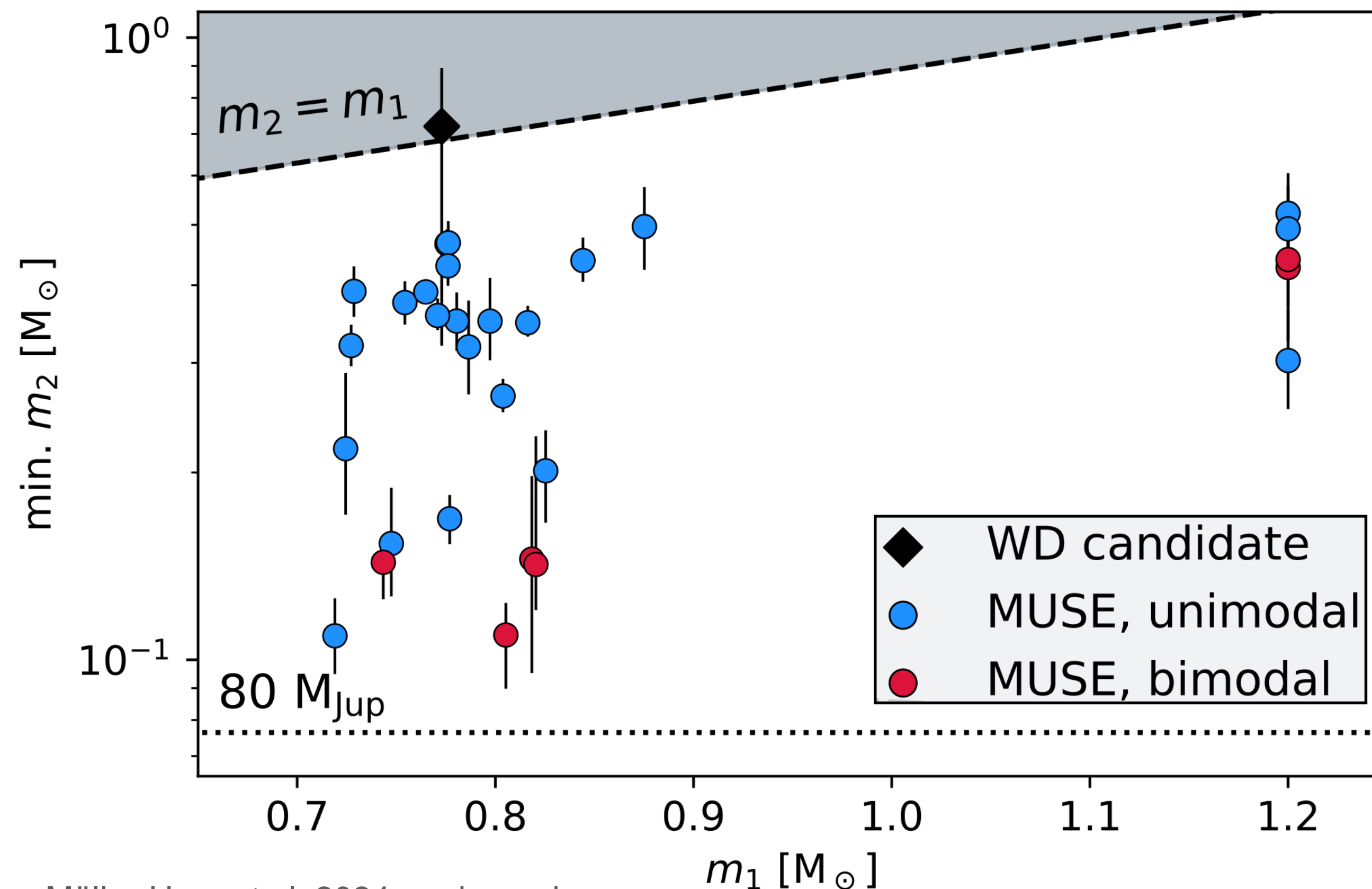
25

Giesers et al. 2018, A&A, Giesers et al. 2019, A&A

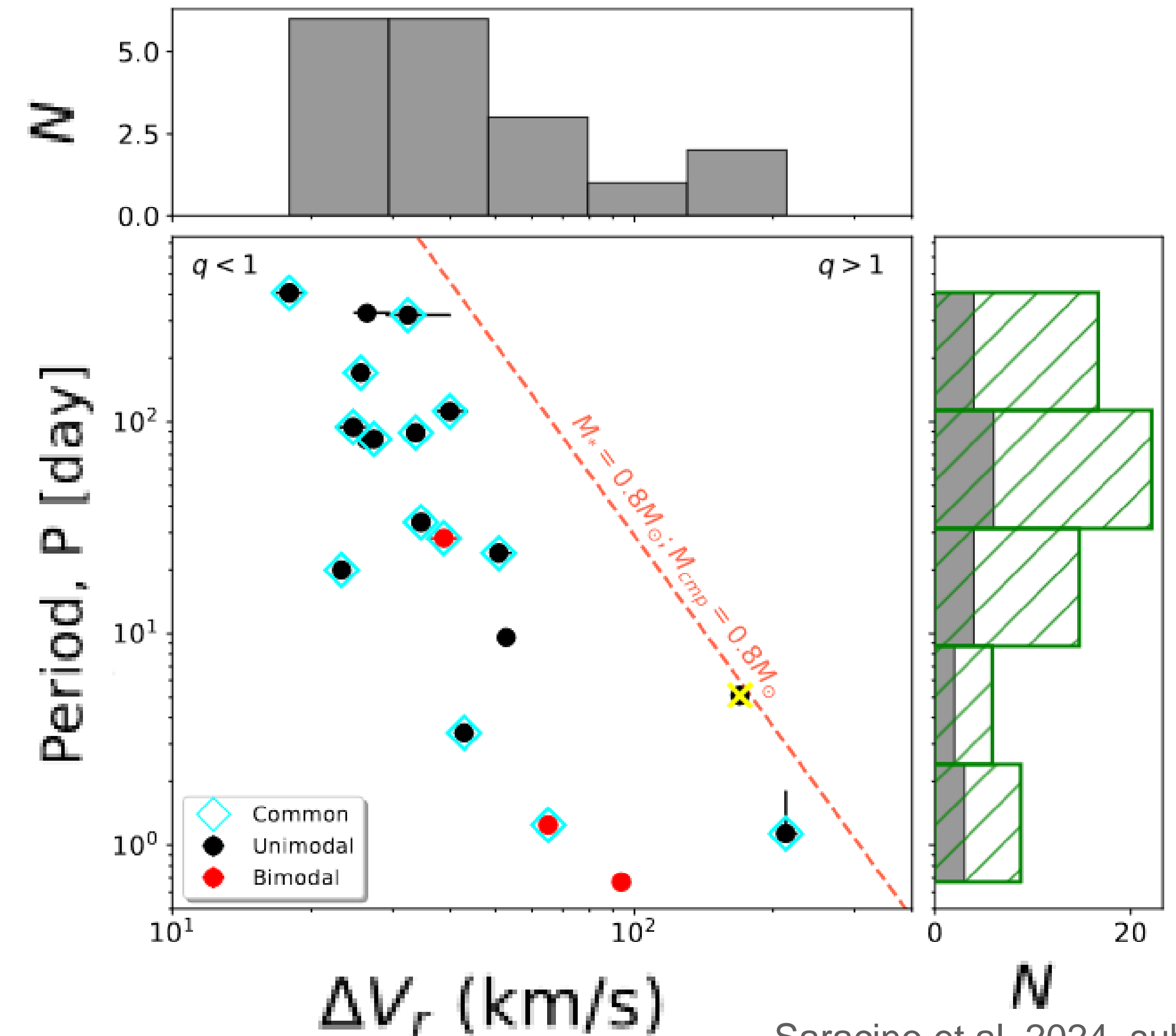


Black holes in 47 Tuc and ω Cen ?

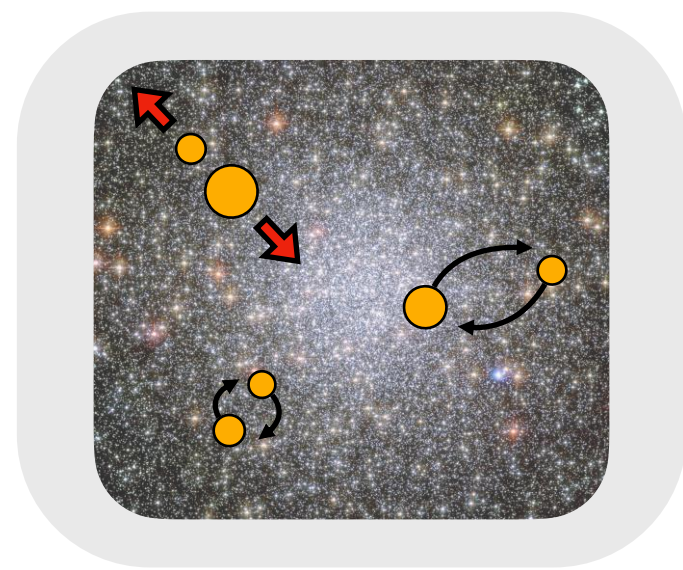
No BH or NS companions in 47 Tuc, ω Cen, NGC 6397, NGC 1851



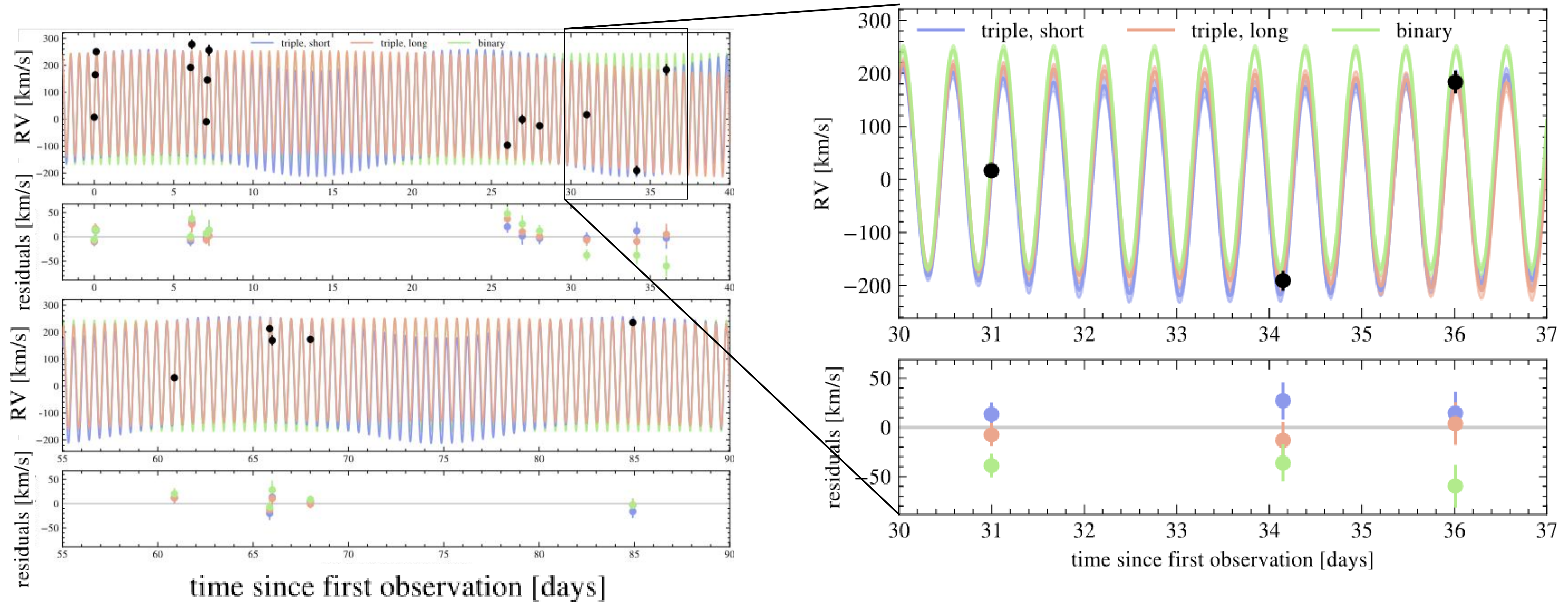
Müller-Horn et al. 2024, under review



Saracino et al. 2024, submitted

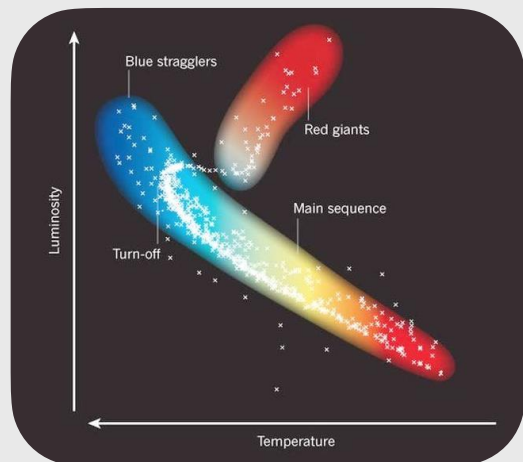
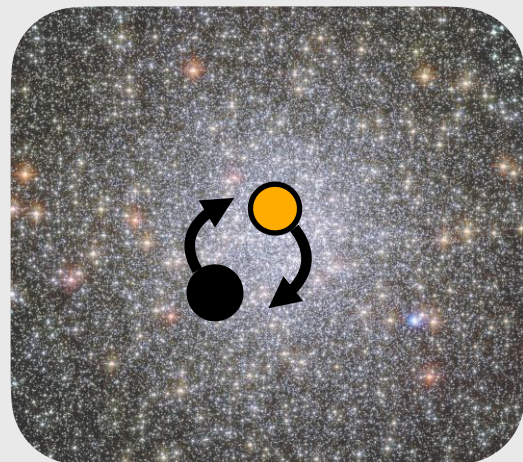
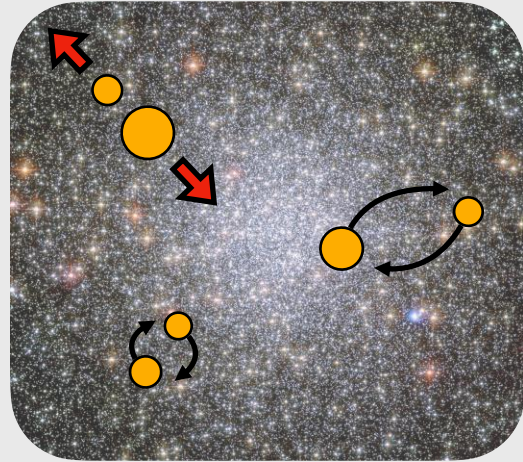


Possible Triple in NGC 6397 (WD+WD+NS?)



Göttgens et al. 2024, in preparation

Summary



- study binary population in GCs; not only the tip of the iceberg
- Constraints for cluster N-body simulations
- lack of binaries with massive/dark companions
- BlueMUSE with better RV resolution
- MICADO with complementing proper motions

