GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN IN PUBLICA COMMODA SEIT 1737

INSTITUT FÜR ASTROPHYSIK & GEOPHYSIK

muse multi unit spectroscopic explorer

„Two in a million“ in Garching, September 2023

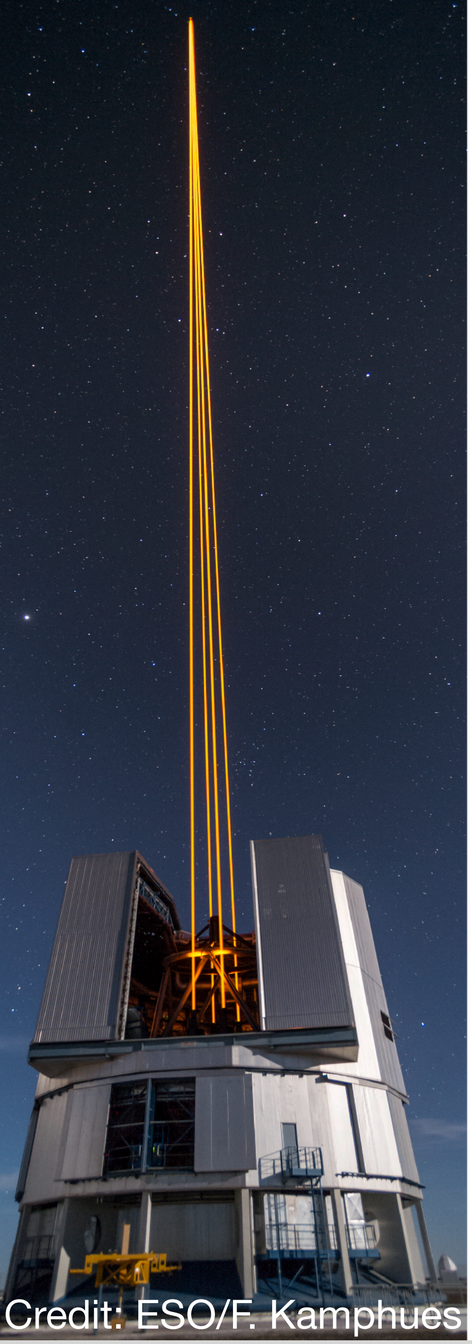
Binary Properties of 47 Tuc (NGC 104)

Searching for spectroscopic binaries in globular clusters with MUSE

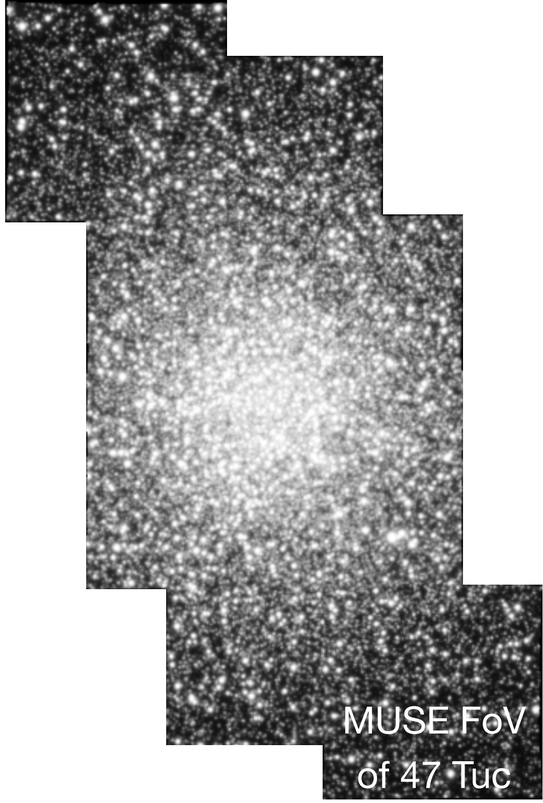
Johanna Müller-Horn

Fabian Göttgens, Stefan Dreizler, Sebastian Kamann, Sven Martens, Sara Saracino

47 Tuc, Credits: NASA, ESA


Credit: ESO/F. Kamphues

MUSE view of 47 Tuc


MUSE FoV of 47 Tuc

47 Tuc old, massive and nearby globular cluster

- age 10 to 12 Gyr *(1)*
- ~10^6 $M_\odot$ *(2)*
- distance 4.5 kpc *(3)*

MUSE IFS observing campaign of globular clusters

Sara Saracino, Sven Martens, Fabian Göttgens, Elena Balakina, Florence Wragg

(1) Broogard et al. (2017)
(2) Baumgardt & Hilker (2018)
(3) Harris (1996, 2010 edition)
(4) Kamann et al. 2013

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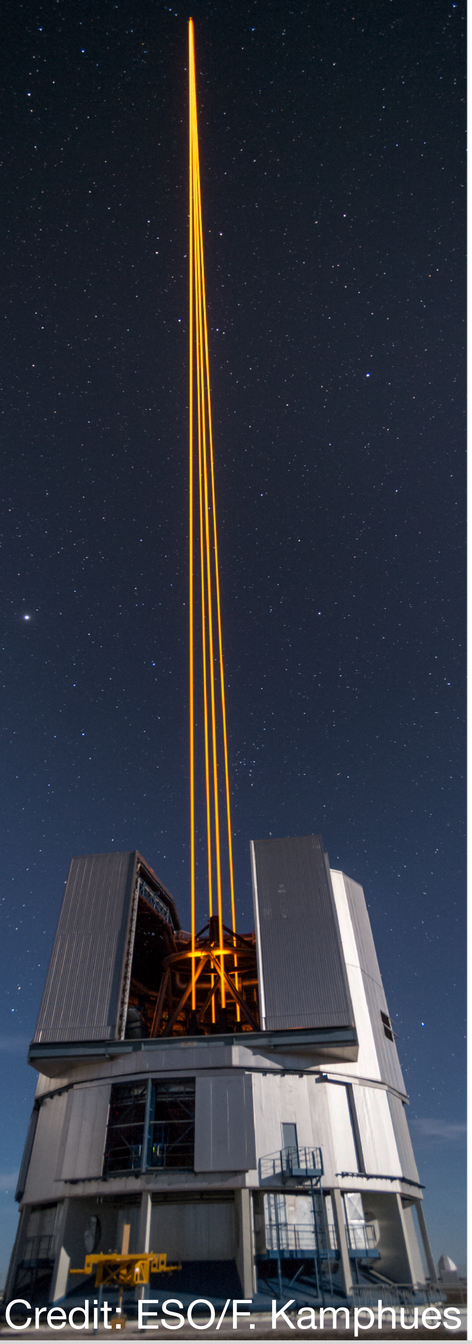
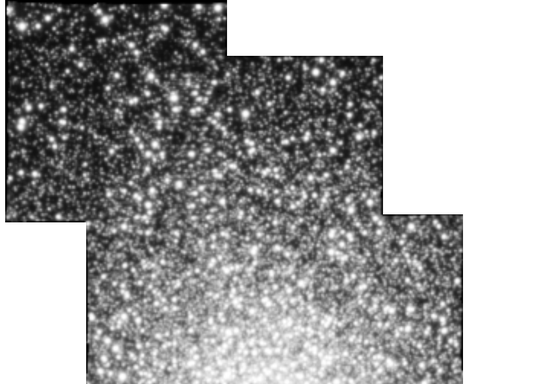

Credit: ESO/F. Kamphues

47 Tuc old, massive and nearby globular cluster

MUSE IFS observing campaign of globular clusters

- **8 years** of observations
- reliable spectra of **>20,000 stars** *(4)*
- on average **11 epochs** per star


MUSE FoV of 47 Tuc

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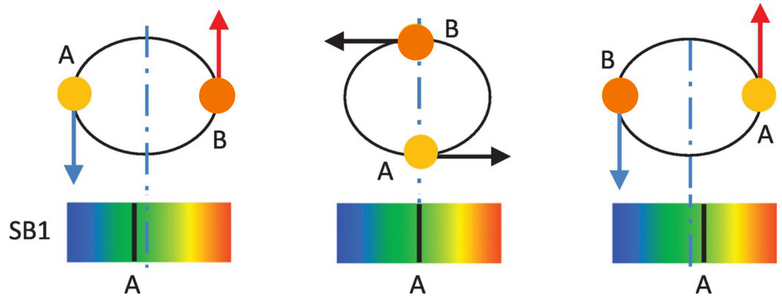
Search for SB1 binaries

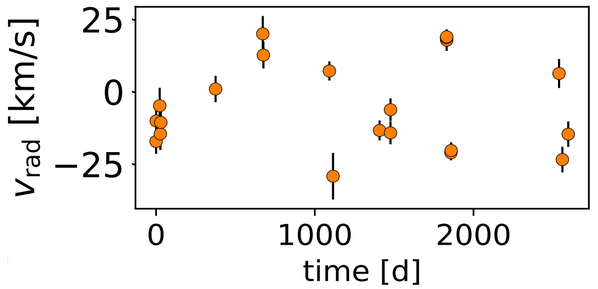
data $t, v_{\mathrm{rad}}, \sigma_{v_{\mathrm{rad}}}$

model $v_{\mathrm{rad}} = v_{\mathrm{z}} + K\left(\cos(\omega + f) + e\cos(\omega)\right)$



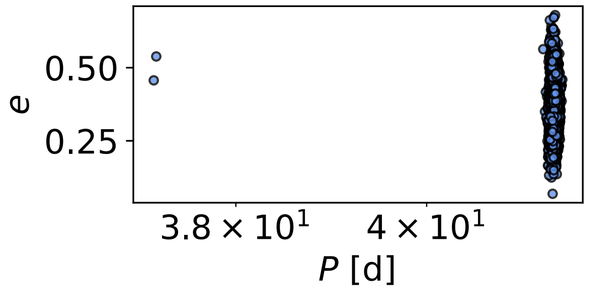
Walker (2017)

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

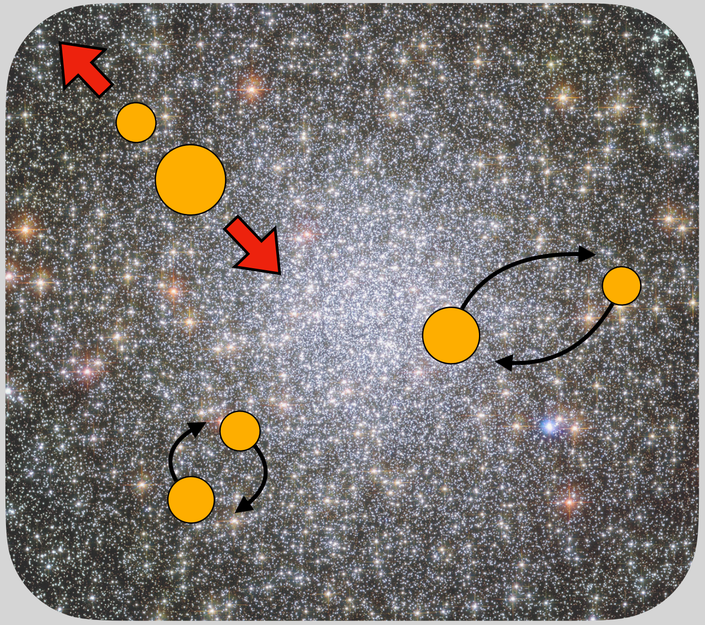


larger RV scatter ⇔ higher binary probability

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



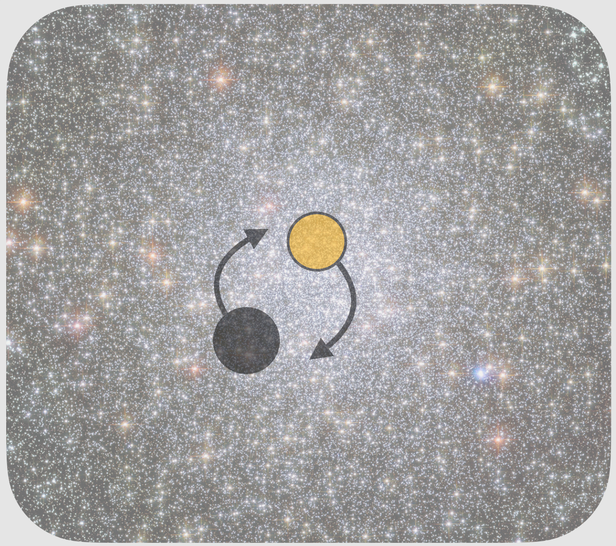
nested sampling works well for multi-modal solutions



47 Tuc, Credits: NASA, ESA

study binary fraction and demographics

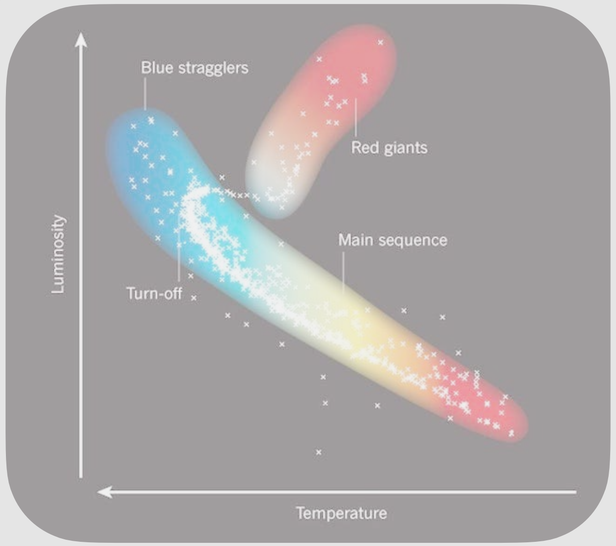
(Goodman & Hut 1989)



47 Tuc, Credits: NASA, ESA

probe the dormant **BH population**

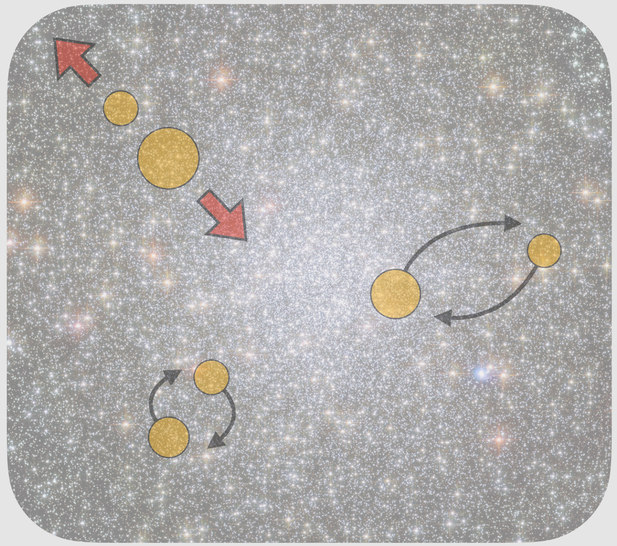
(Giesers et al. 2018)



C. Tout (2011)

study binarity among **blue straggler stars**

(Sandage 1953)



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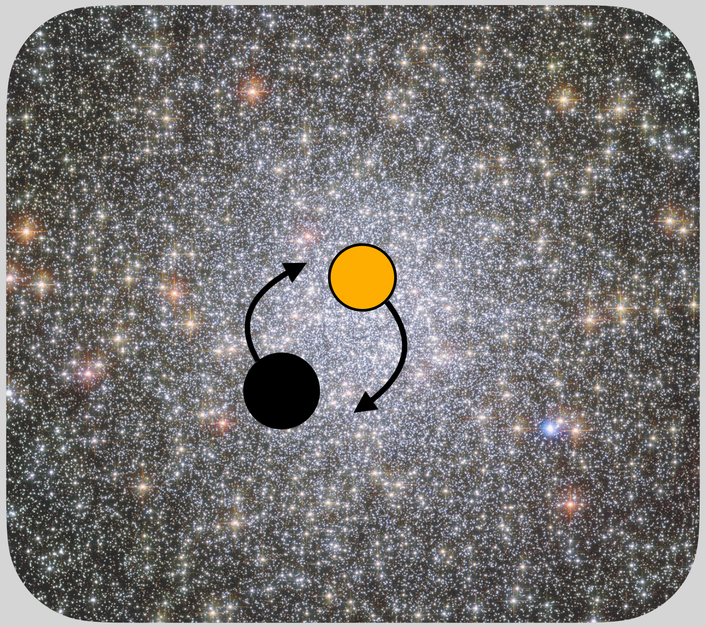

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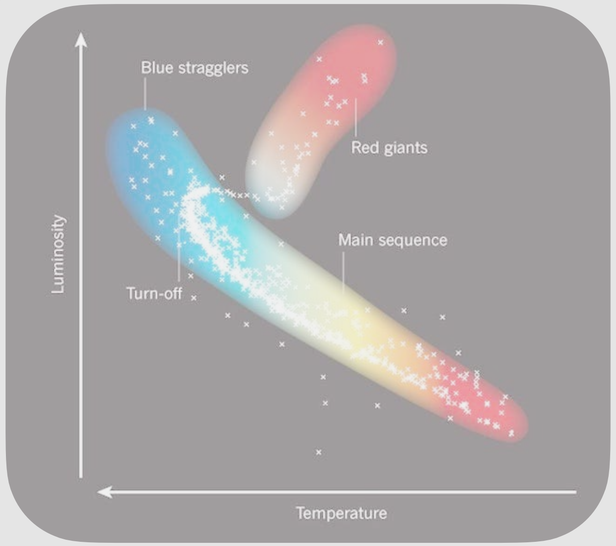

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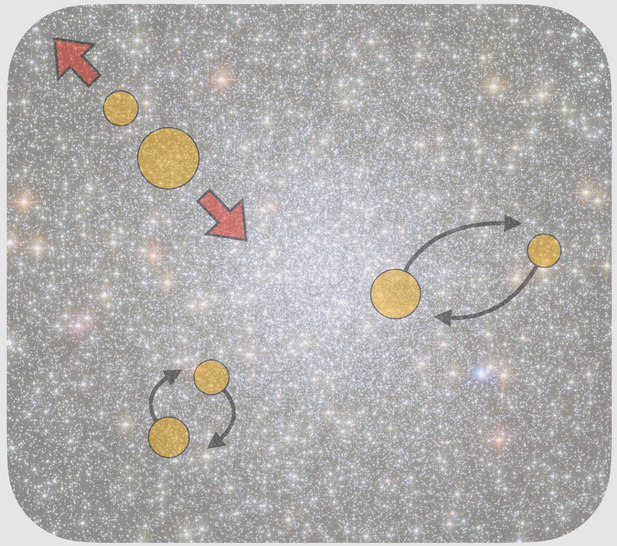

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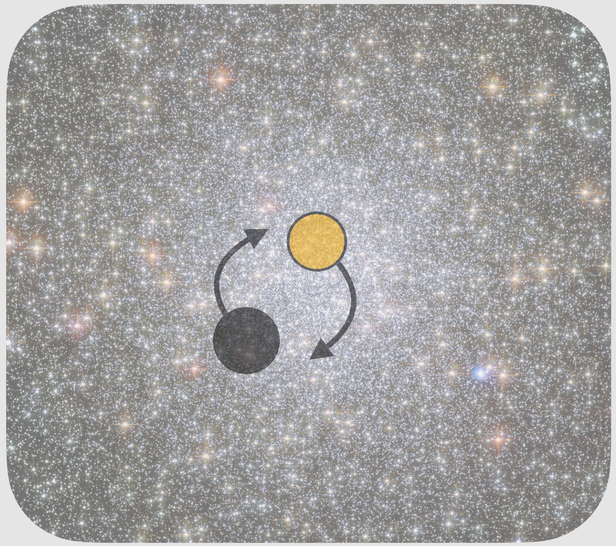

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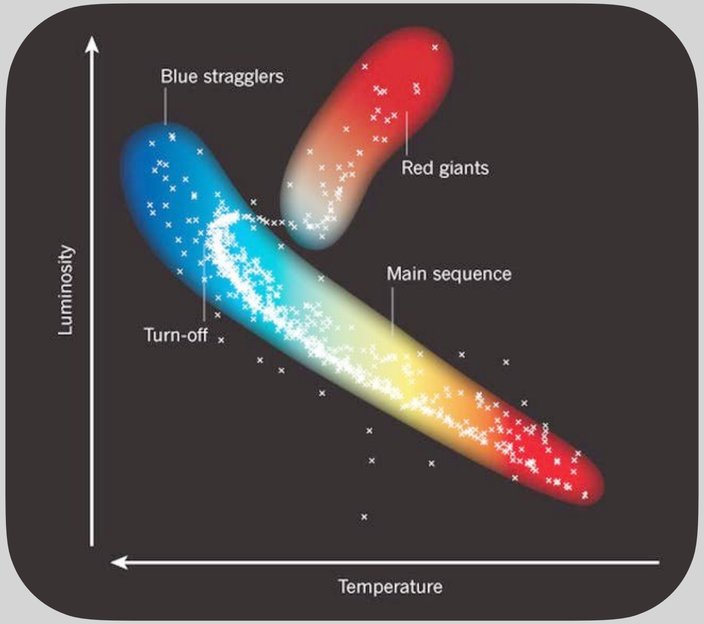

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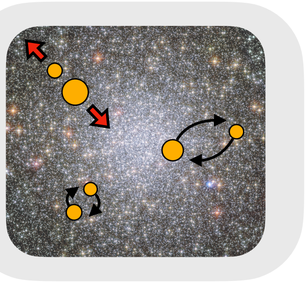


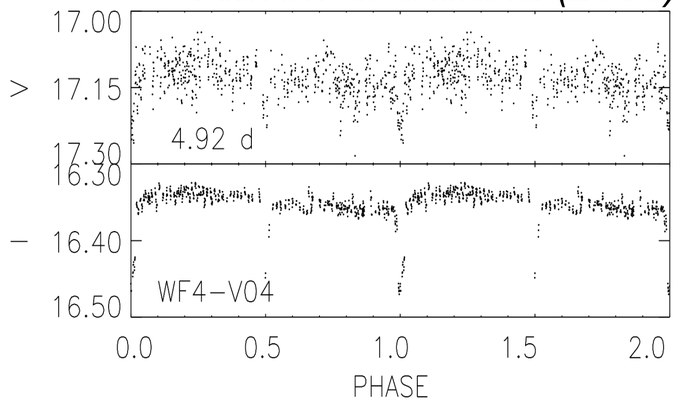
Binary demographics

Prior observations

eclipsing binaries

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

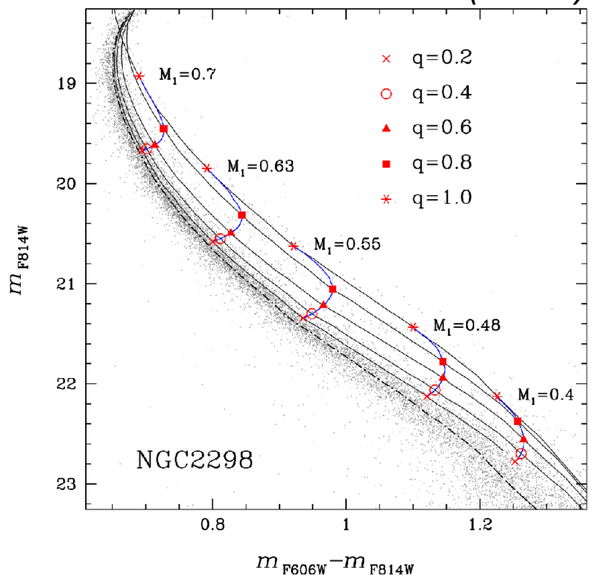
Albrow & Gilliland (2001)



binary main sequence

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

Milone et al. (2012)

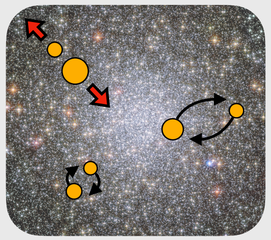


radio & X-ray sources

Heinke et al. (2005)
Bahramian et al. (201
Miller-Jones et a
Rivera Sandoval et a

need spectroscopy!

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



Binary demographics

Binary fraction

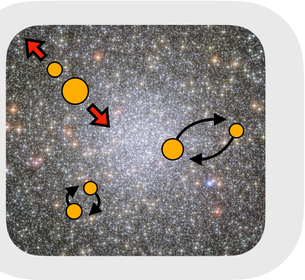
Discovery binary fraction — **(3.1 ± 1.1)%**

↓ account for limited discovery probability

↓ correct for limited sensitivity and FoV

↓

Total binary fraction



Binary demographics

Binary fraction

Discovery binary fraction

↓

account for limited discovery probability ← depends on CMC binary parameters

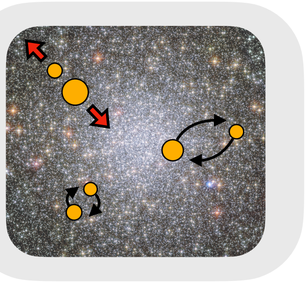
↓

correct for limited sensitivity and FoV ← depends on CMC radial and q profiles

↓

Total binary fraction **(2.6 ± 0.9)%**

low total binary fraction, consistent with photometric estimates ✓



Binary demographics

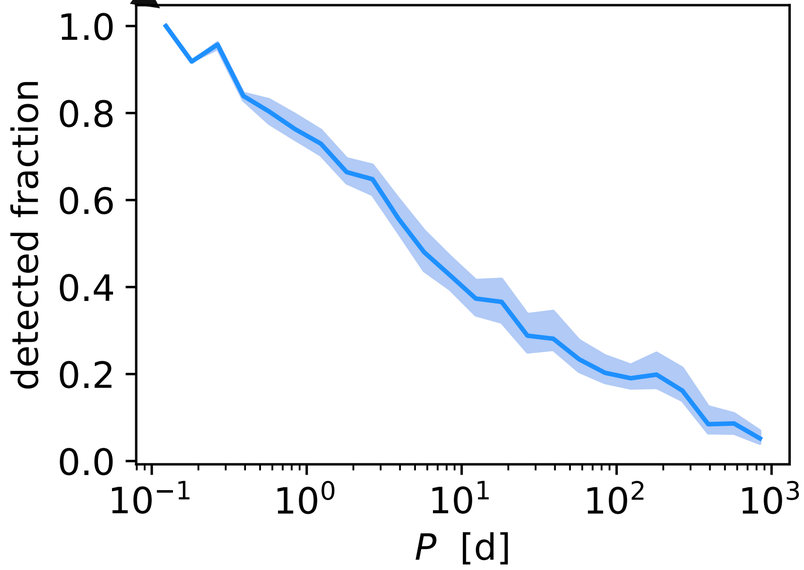
Predictions from simulations

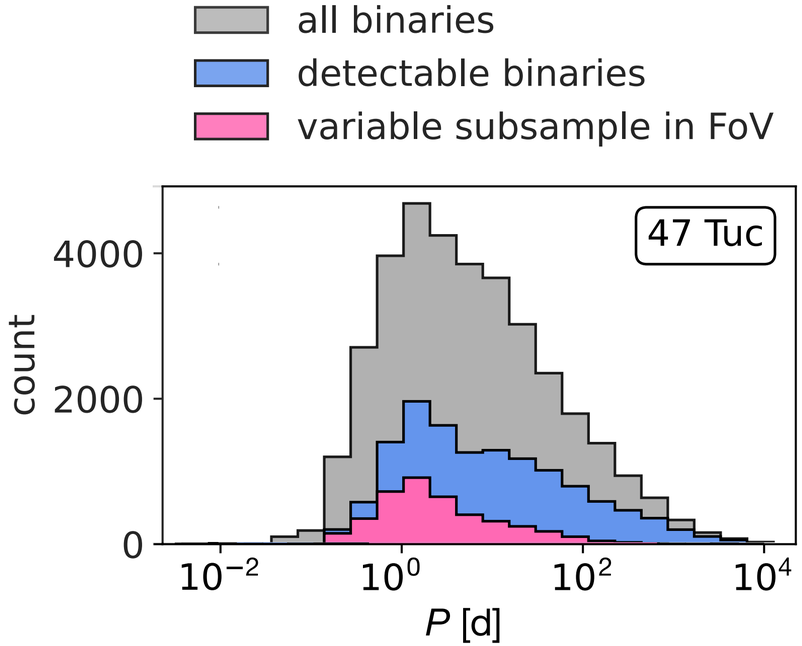
CMC simulations of 47 Tuc (*Ye et al. 2022*)

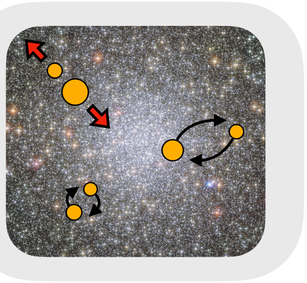
➡ account for **observational biases** using mock data

➡ make **predictions of binary properties**

binary **detection probability** is highest for short periods





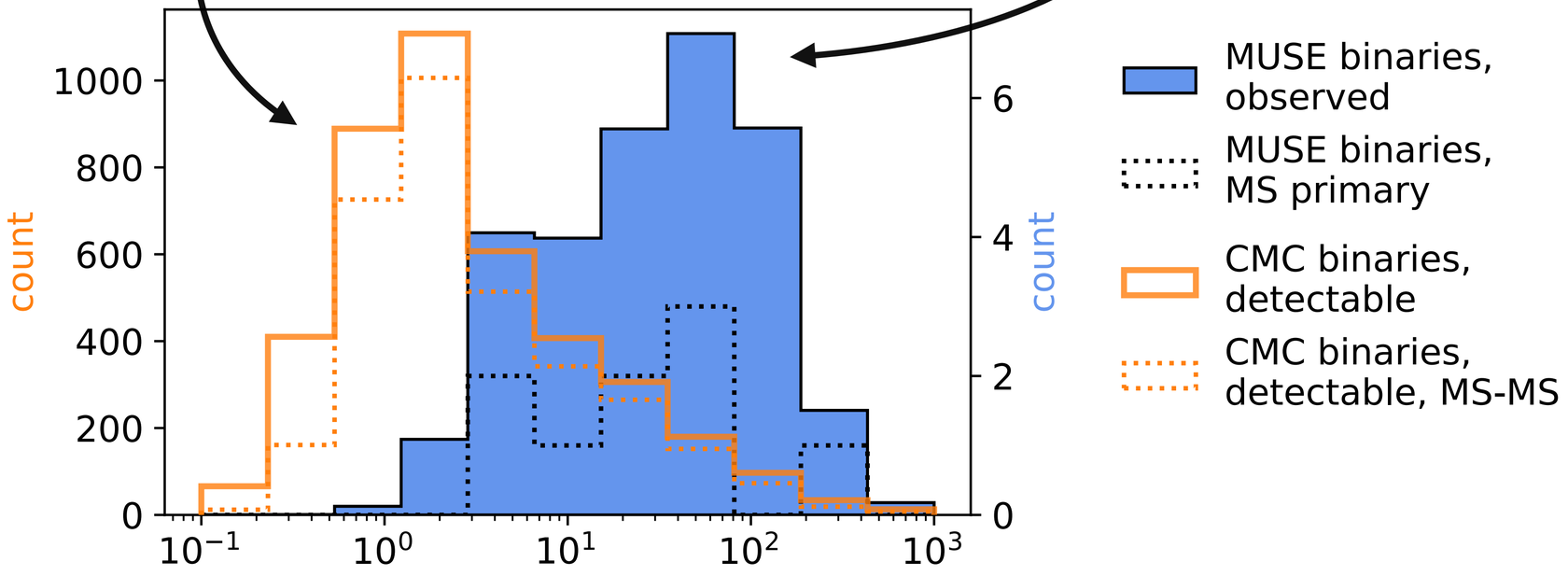


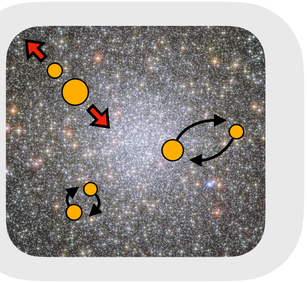
Binary demographics

Orbital parameters

We expect to find and are more sensitive to short-period binaries

but instead we find binaries with longer periods.





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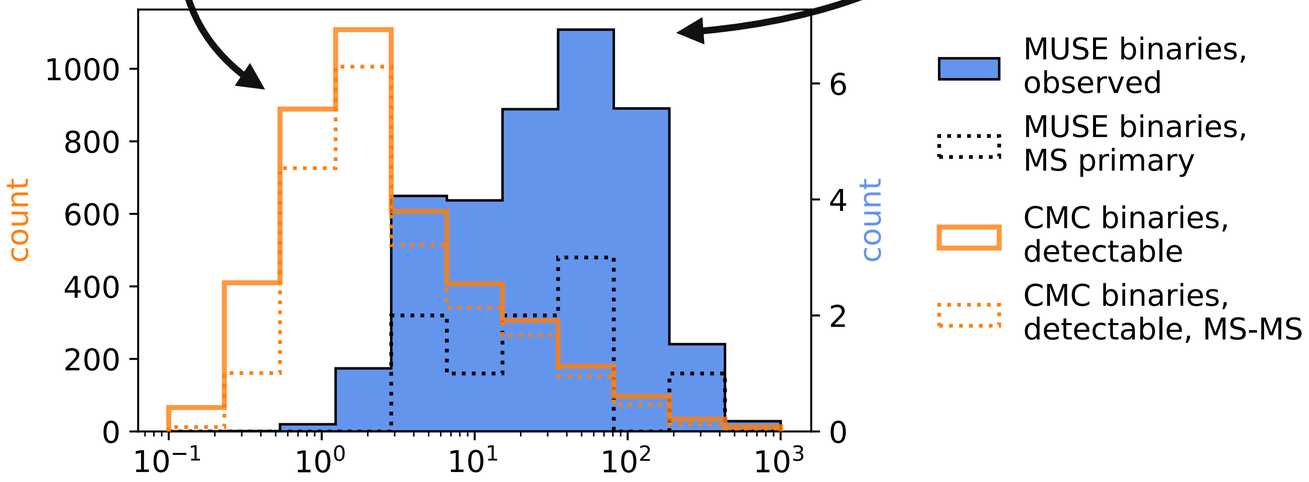


possible interpretation

A. uncertainty in binary evolution models

B. different fractions of RGB stars

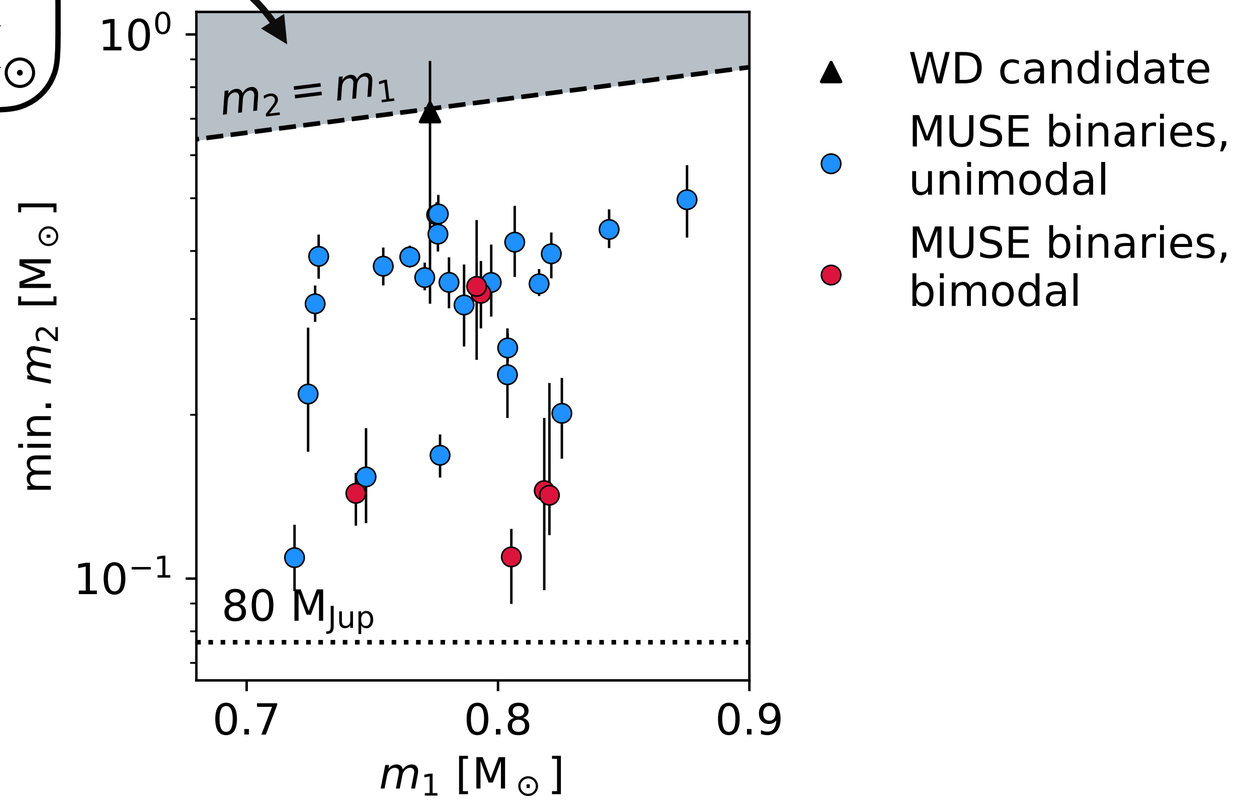
C. (excessive) dynamic hardening in CMC

Black holes in 47 Tuc

Dark remnant companions

no evidence for BH/NS companions; all min. $m_2 \ll 1.4\,\mathrm{M}_\odot$

~7 MS-BH binaries expected from CMC simulation

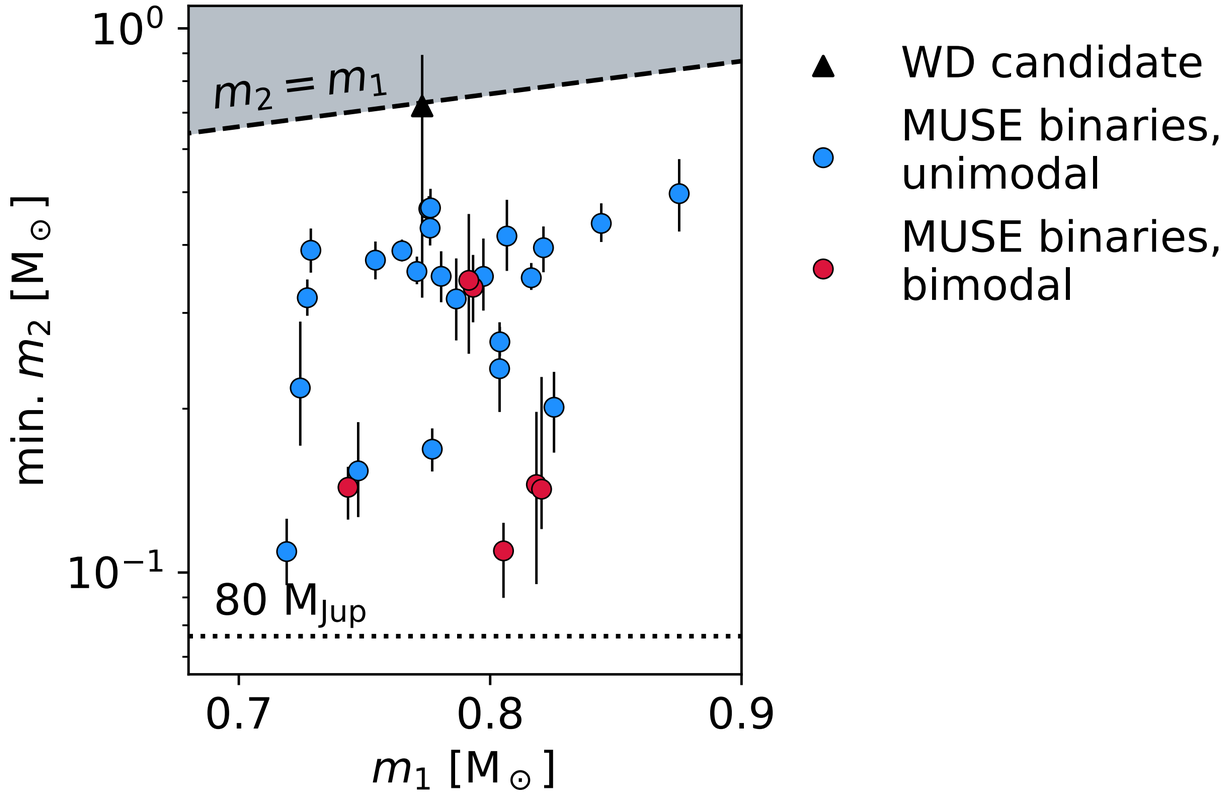


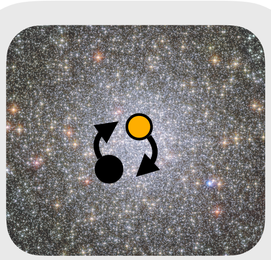
Black holes in 47 Tuc

Dark remnant companions

possible interpretation

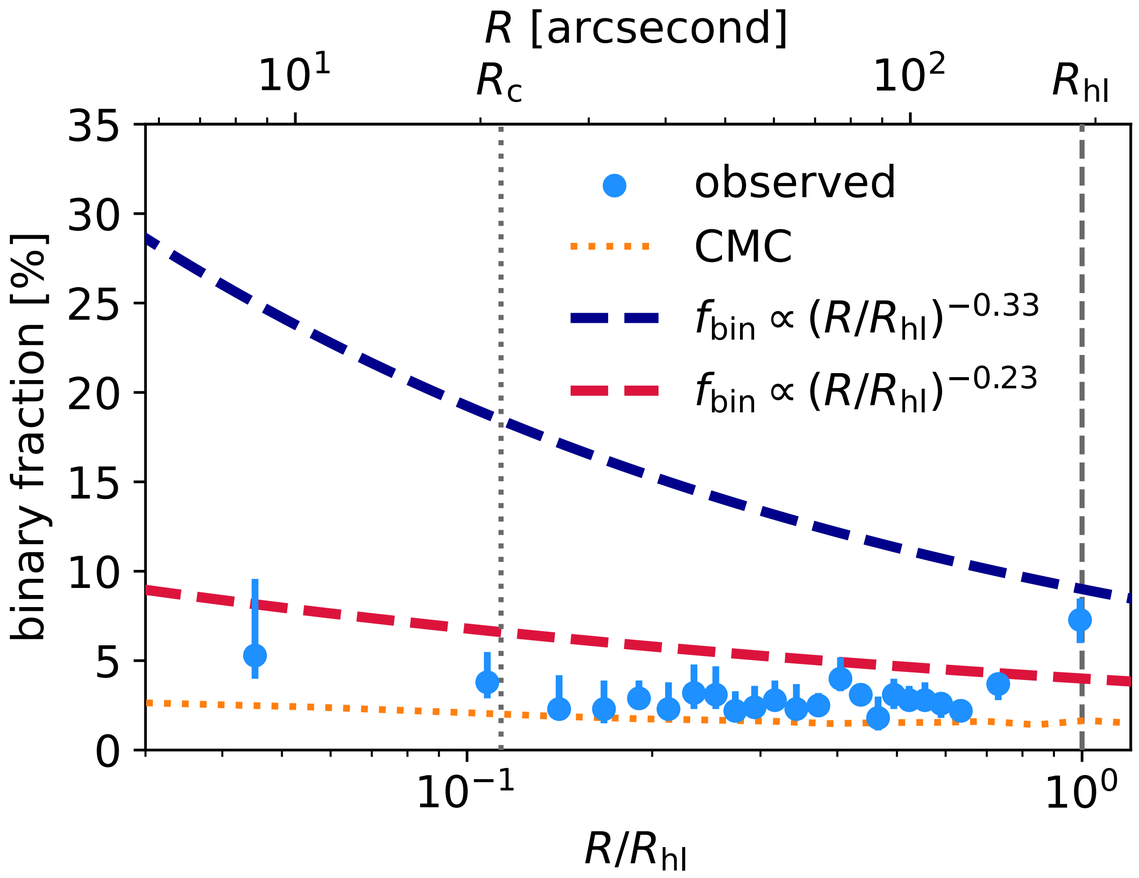
- low inclinations, unfortunate time sampling
- magnitude limit, restricted FoV
- low number of binary BHs / unobservable configurations





Black holes in 47 Tuc

Central IMBH



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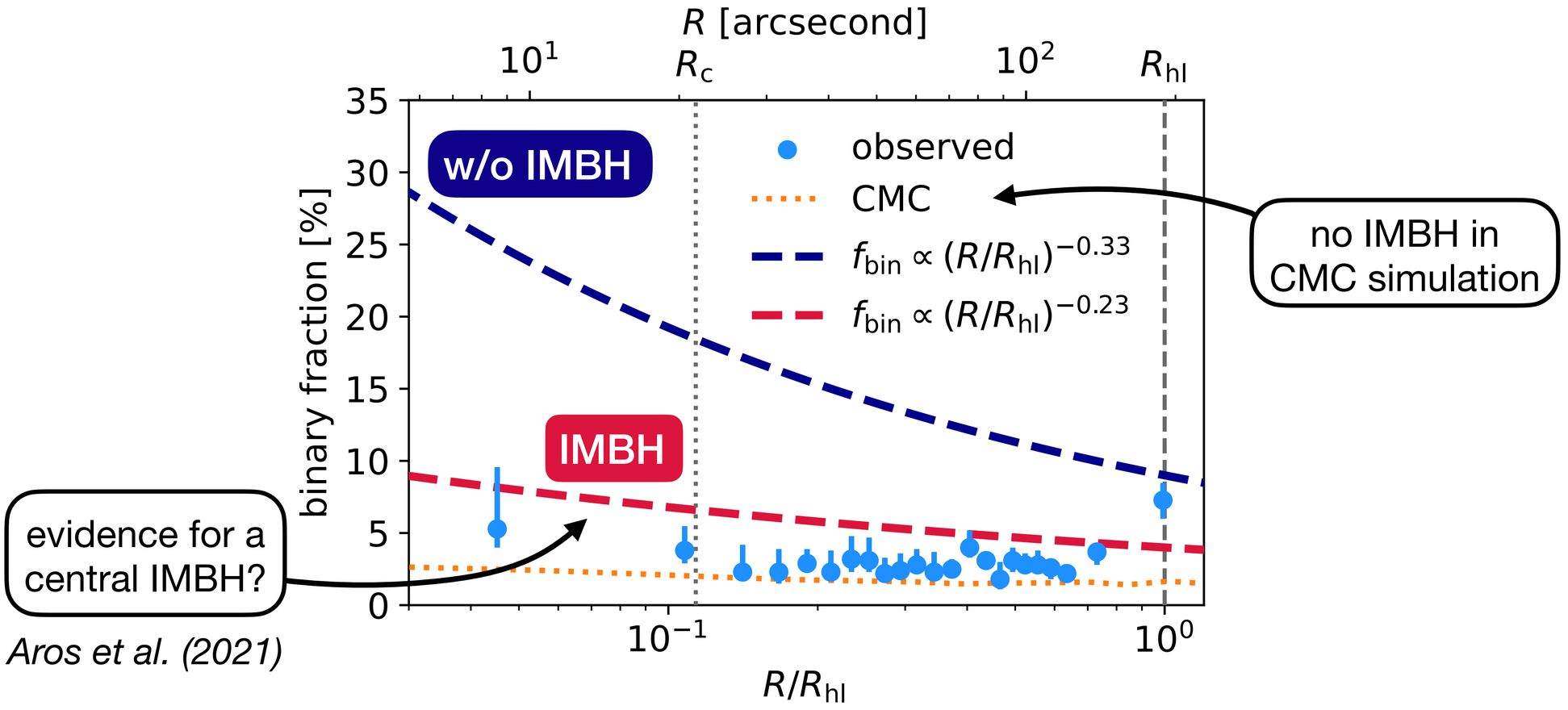
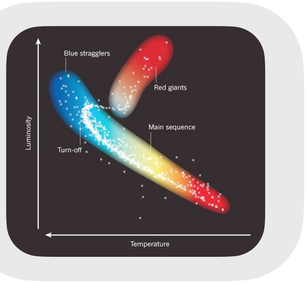
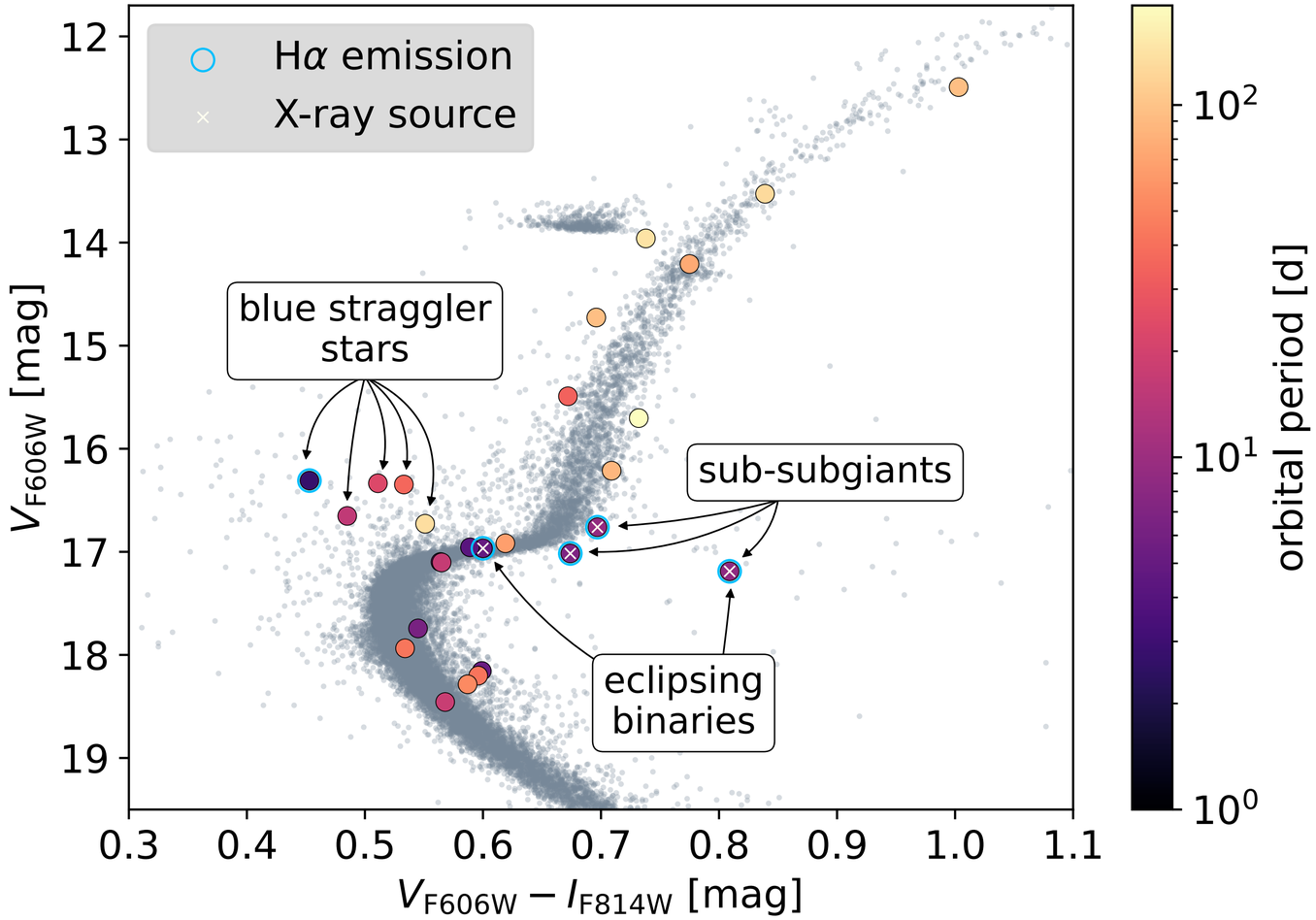
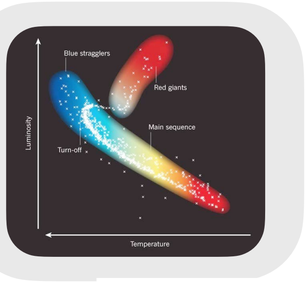


Aros et al. (2021)



Blue straggler stars (BSS)





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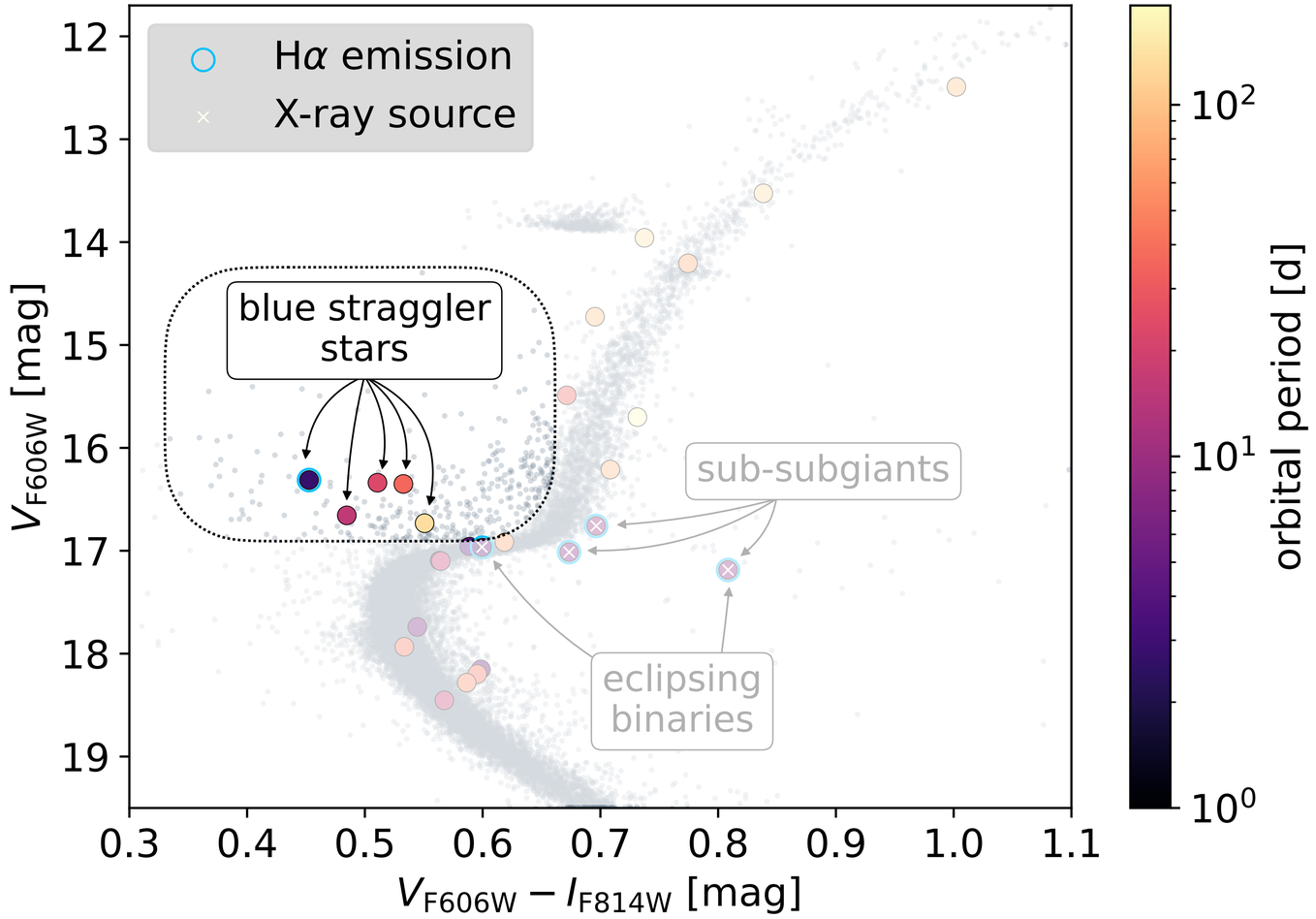
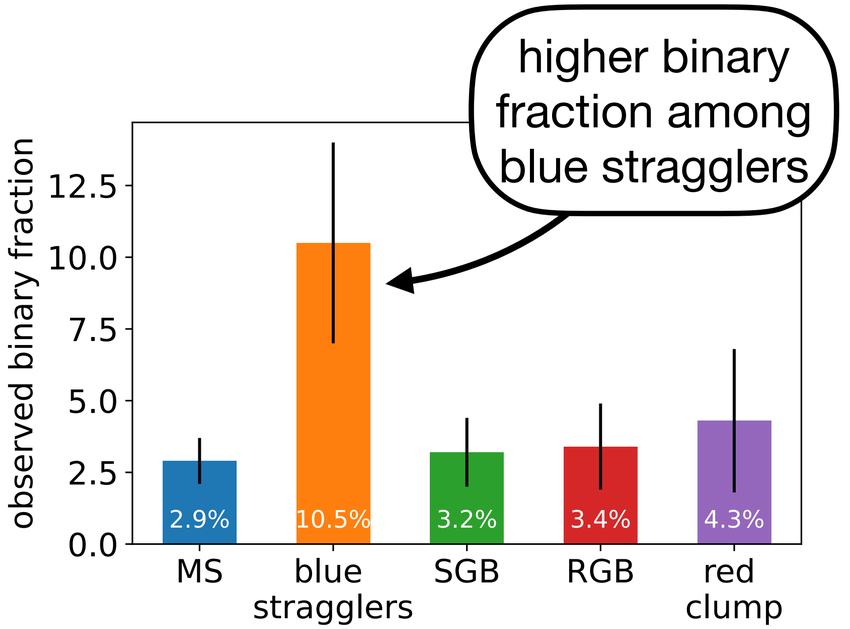
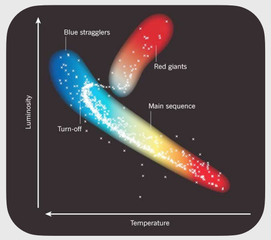


5 BSS with well-constrained orbital solutions





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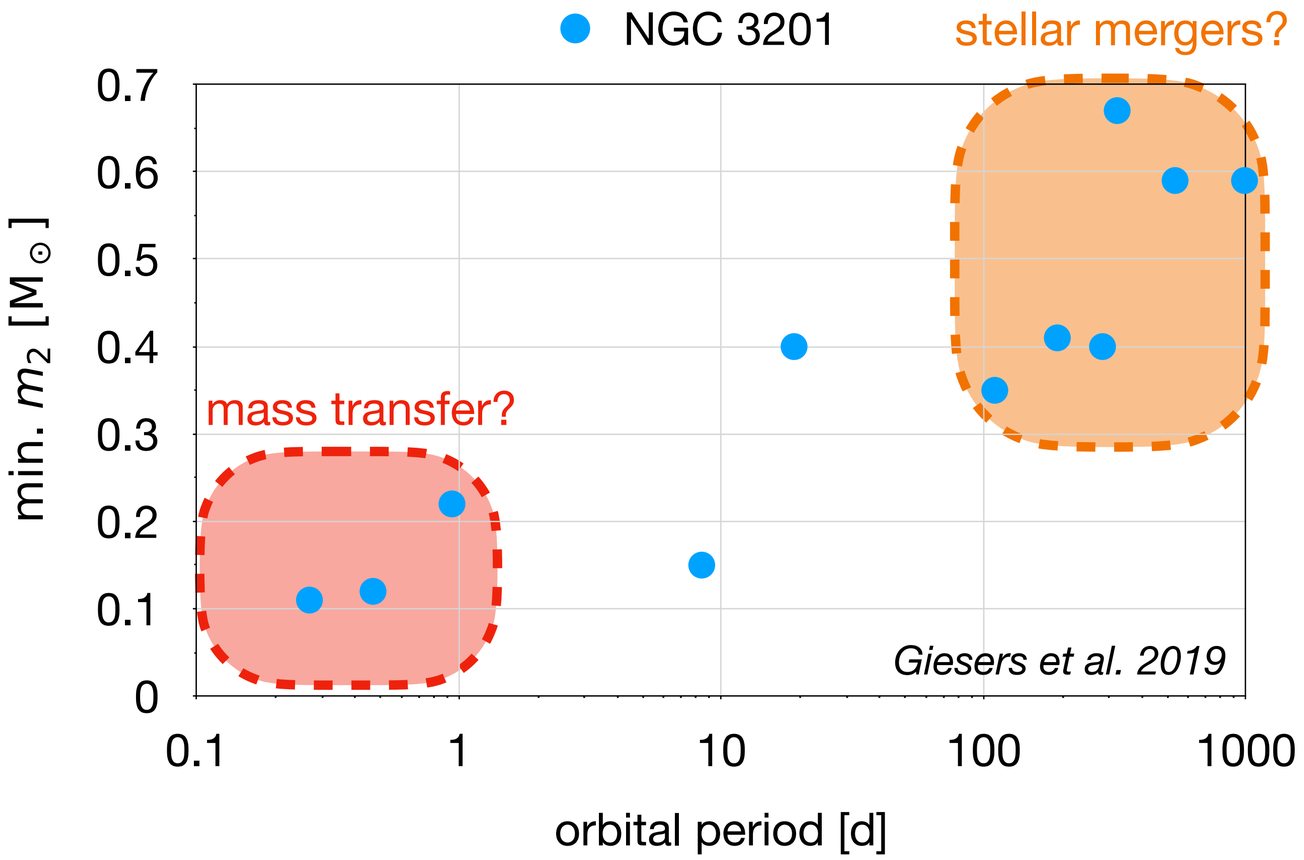

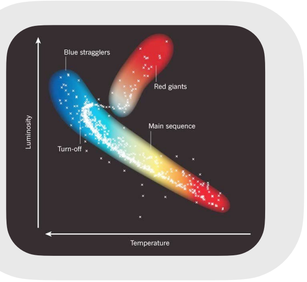

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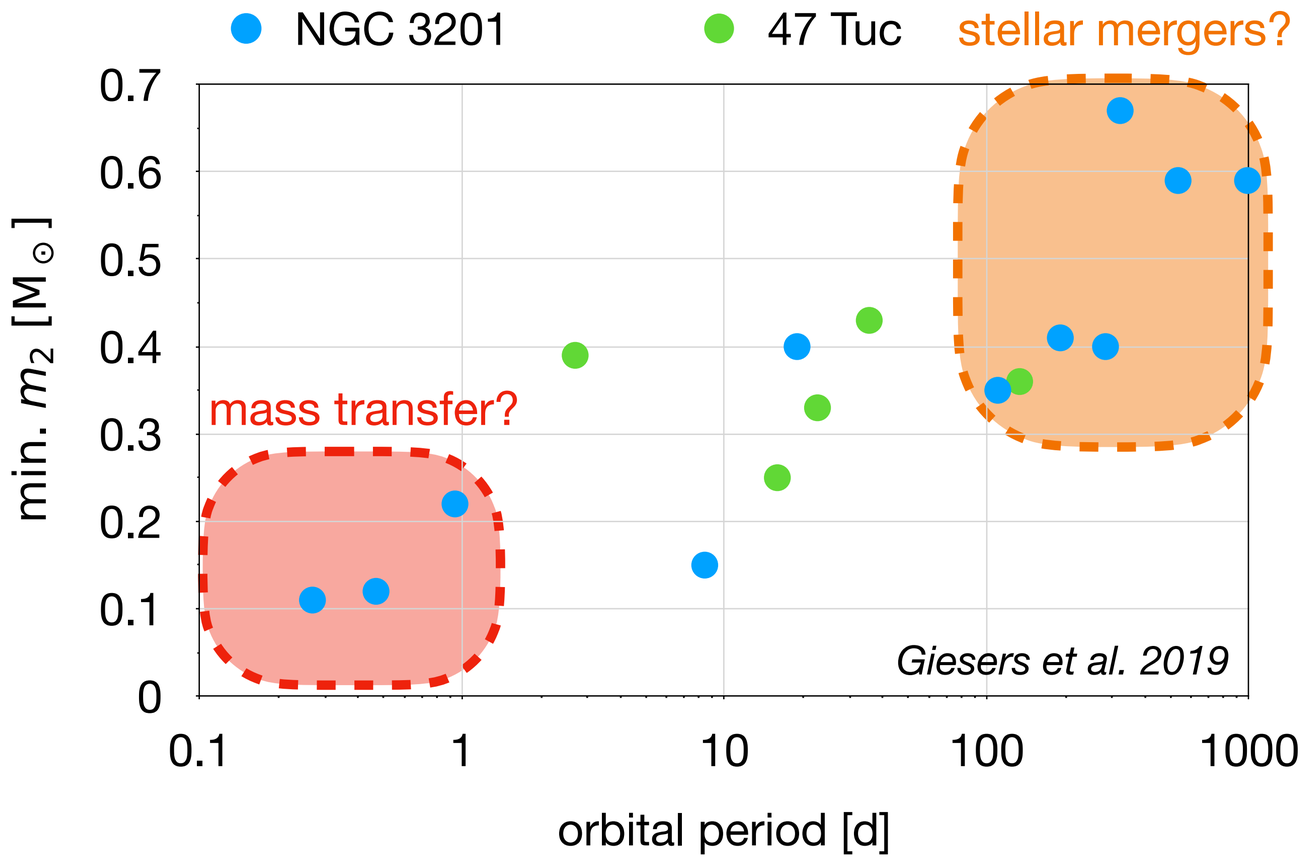

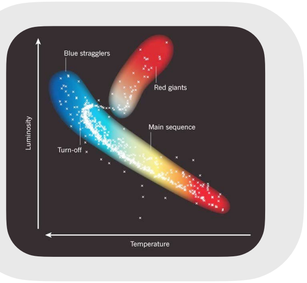

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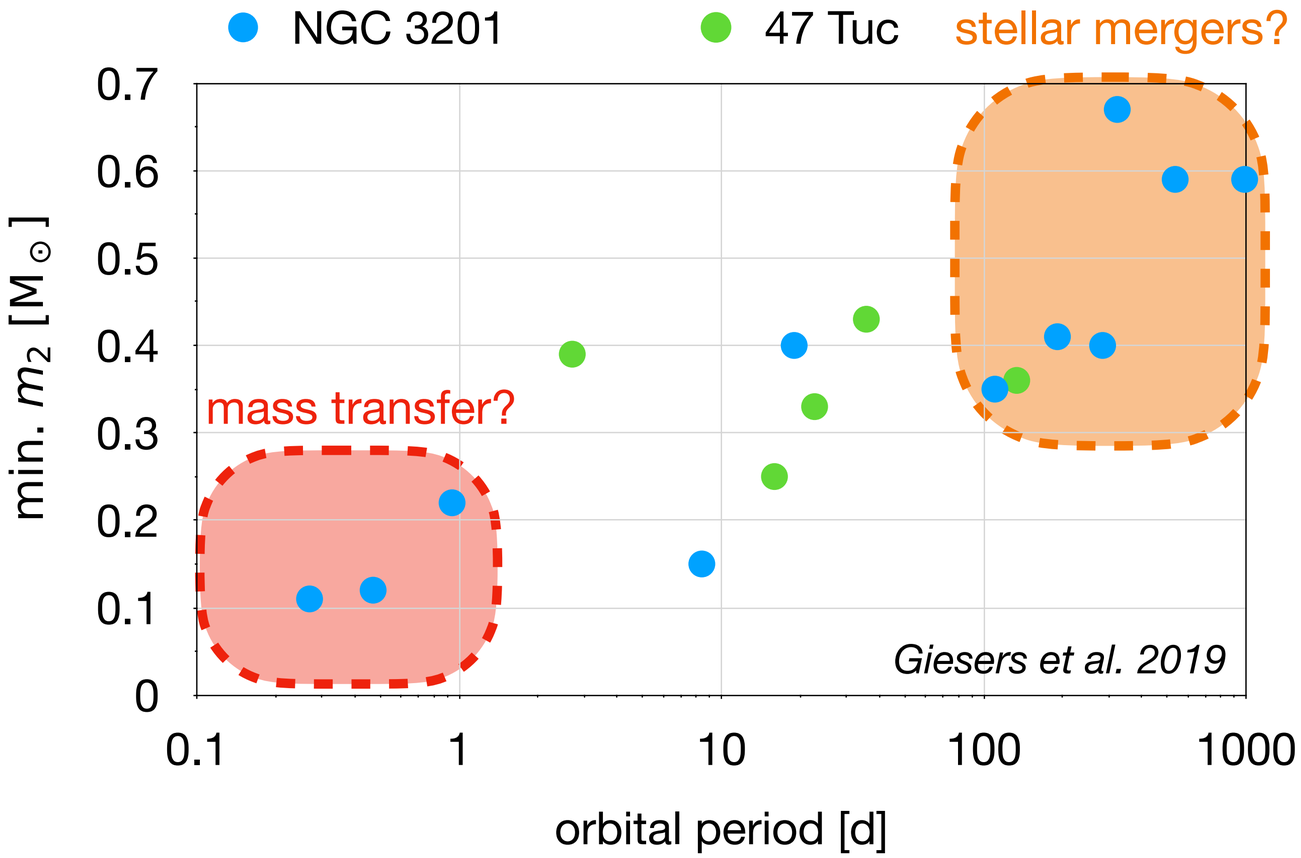


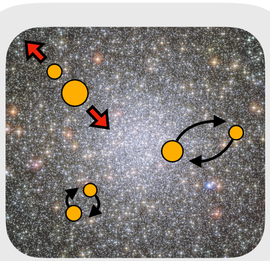
possible interpretation

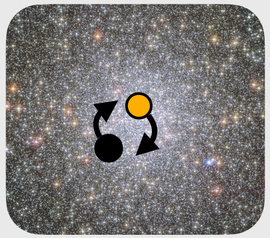
A. pattern in NGC 3201 is coincidental

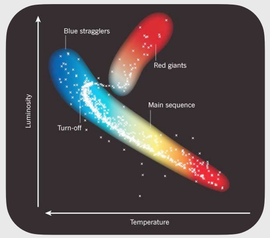
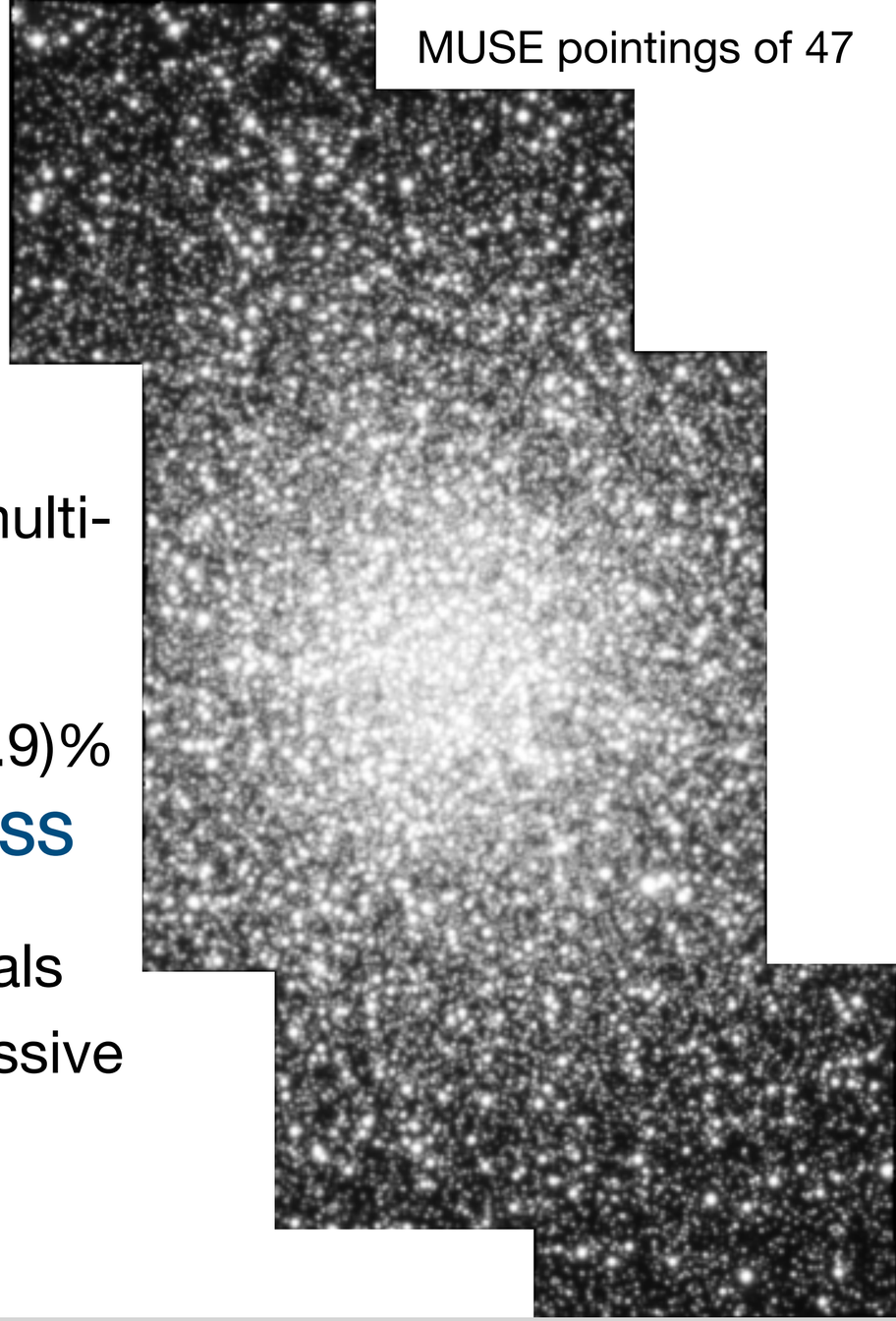
B. 47 Tuc sample of BSS is not representative

C. fewer BSS formed via binary mass transfer in 47 Tuc

Summary







- study binary population of 47 Tuc using multi-epoch spectroscopy from MUSE
- determine total binary fraction of (2.6 ± 0.9)% and **increased binary fraction among BSS**
- comparison with CMC simulations reveals **scarcity of short-period binaries** with massive companions