INDIANA UNIVERSITY
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Painting by Alina Böcker

Using binaries in globular clusters to catch sight of intermediate-mass black holes

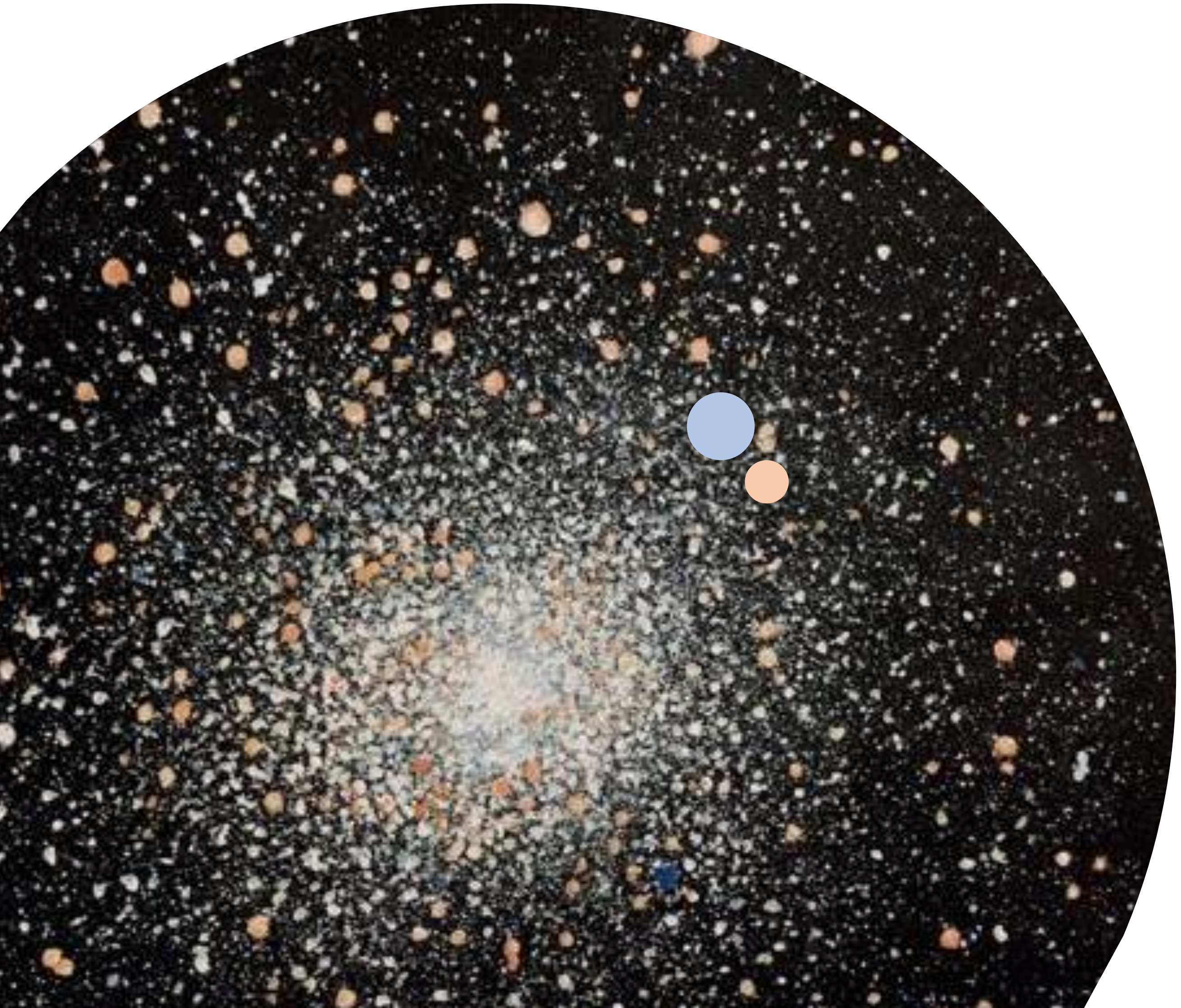
Francisco I. Aros

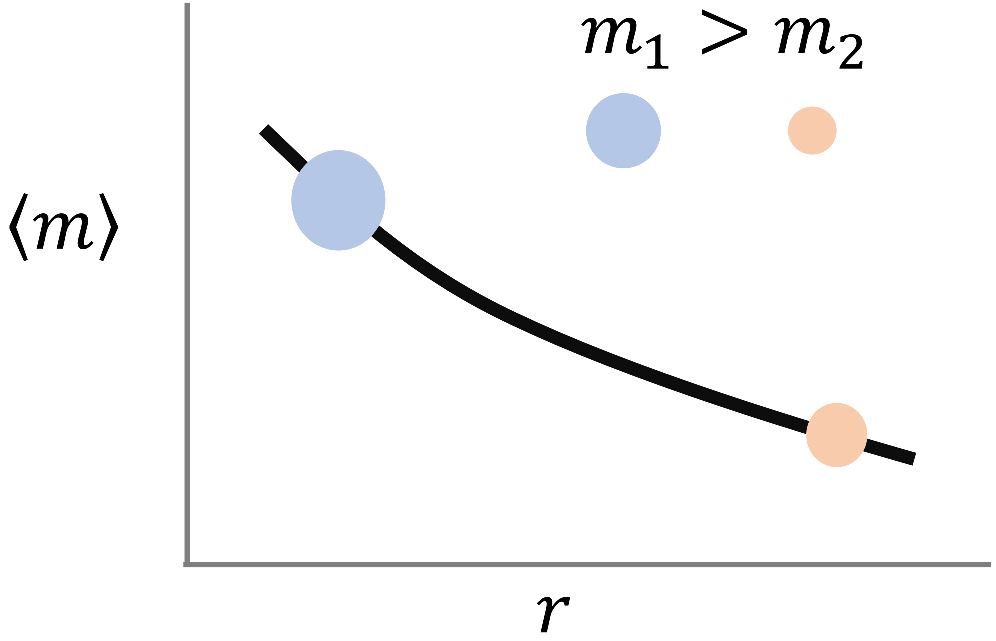
In collaboration with

Anna C. Sippel, Alessandra Mastrobuono-Battisti, Paolo Bianchini, Abbas Askar and Glenn van de Ven

Mass segregation in Globular Clusters

See e.g. Spitzer. (1969,1987); Heggie & Hut(2003)





Different studies have used mass segregation as tracer for the presence of an IMBH or BHS (see e.g Pasquato+ 2009,2016; Alessandrini+2016; Weatherford+2018,2020; Wu+2021)

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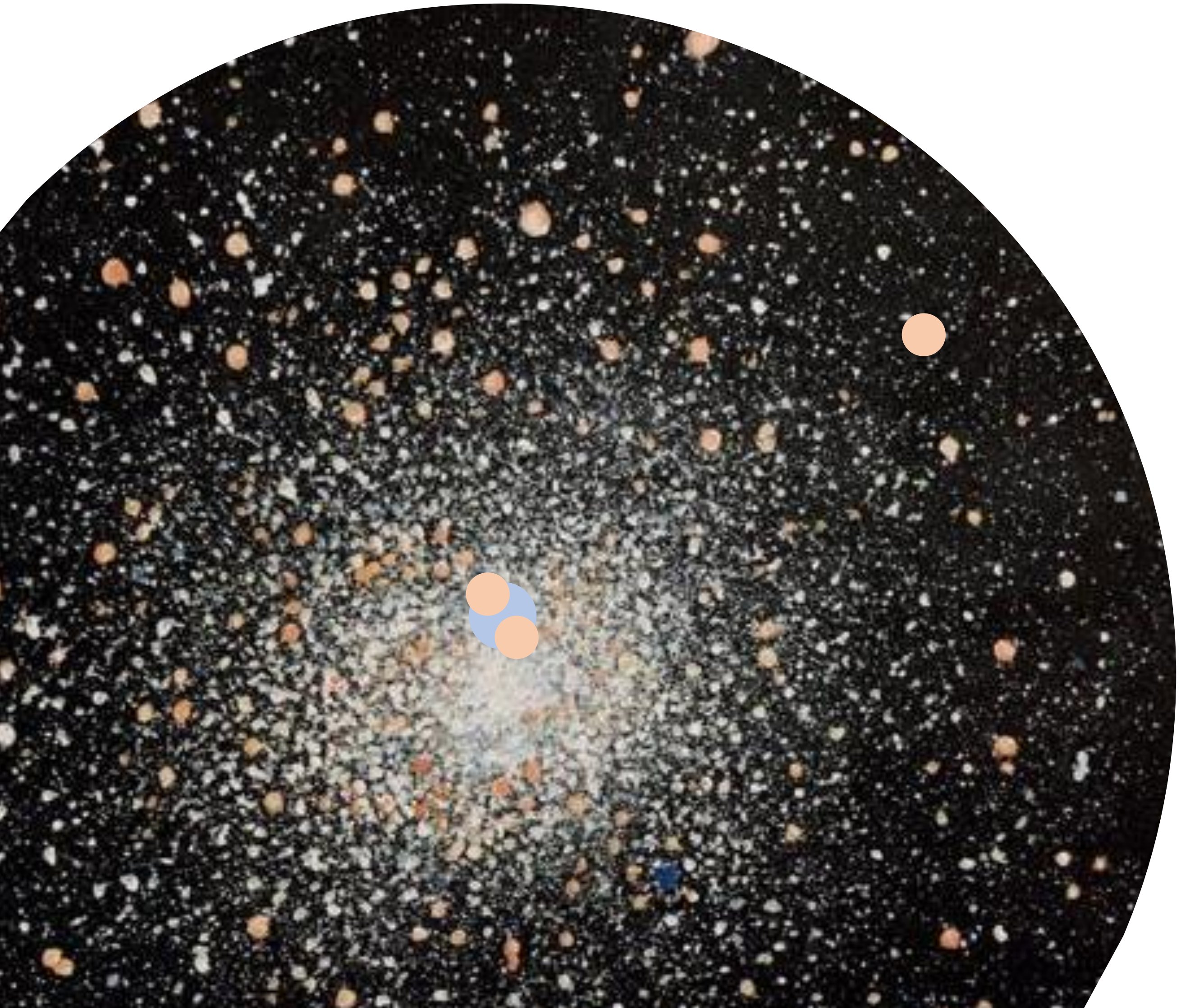

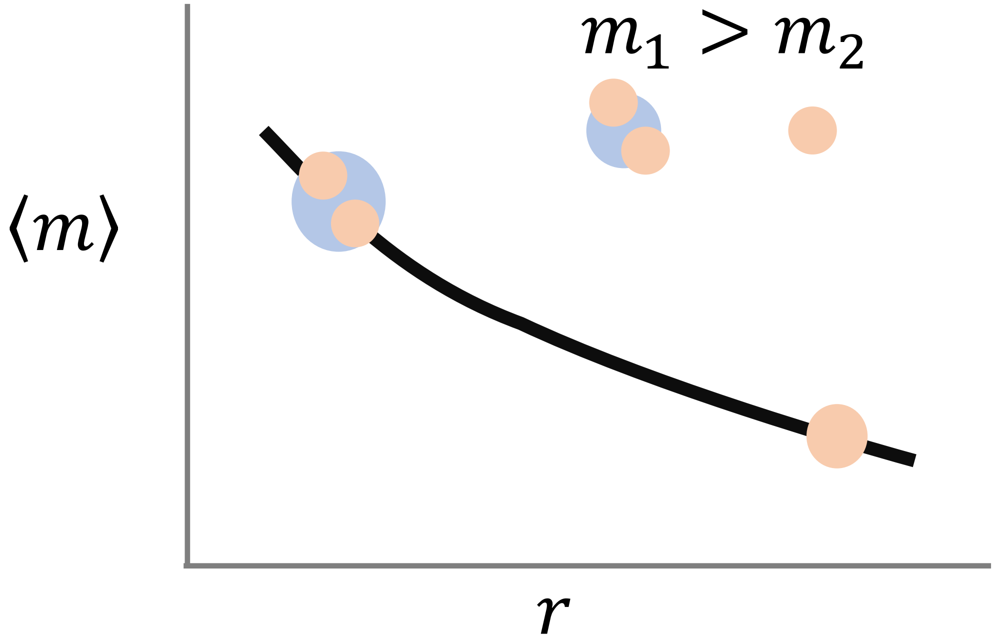

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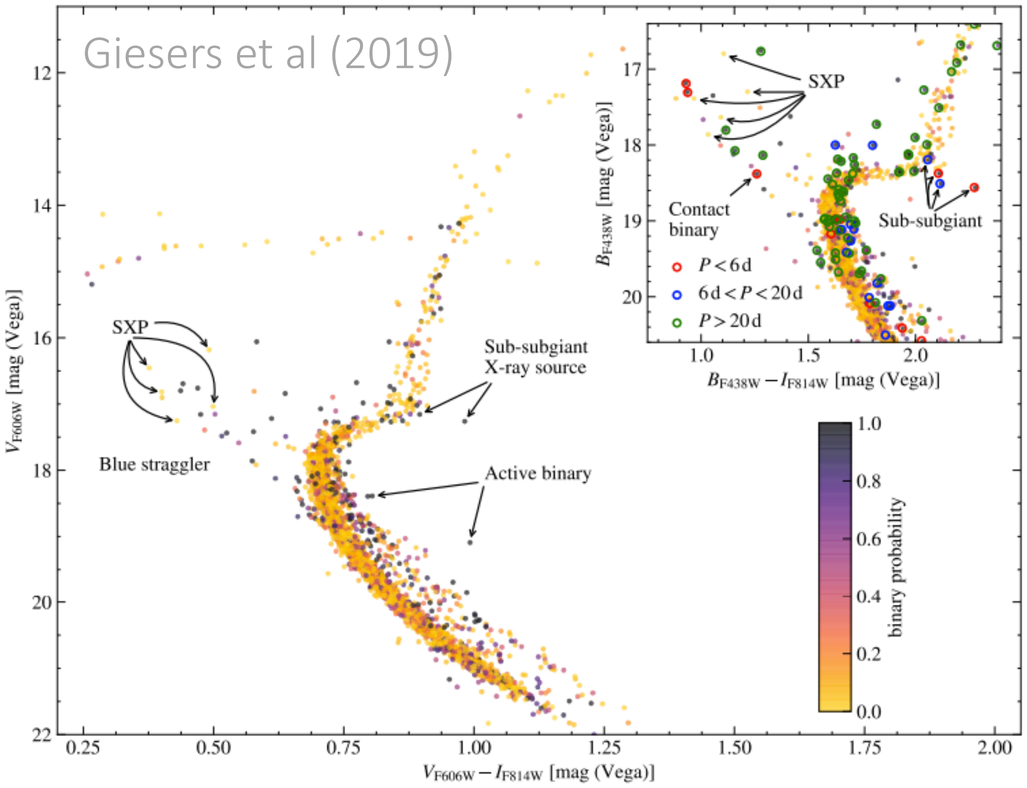
Mass segregation in Globular Clusters + Binaries

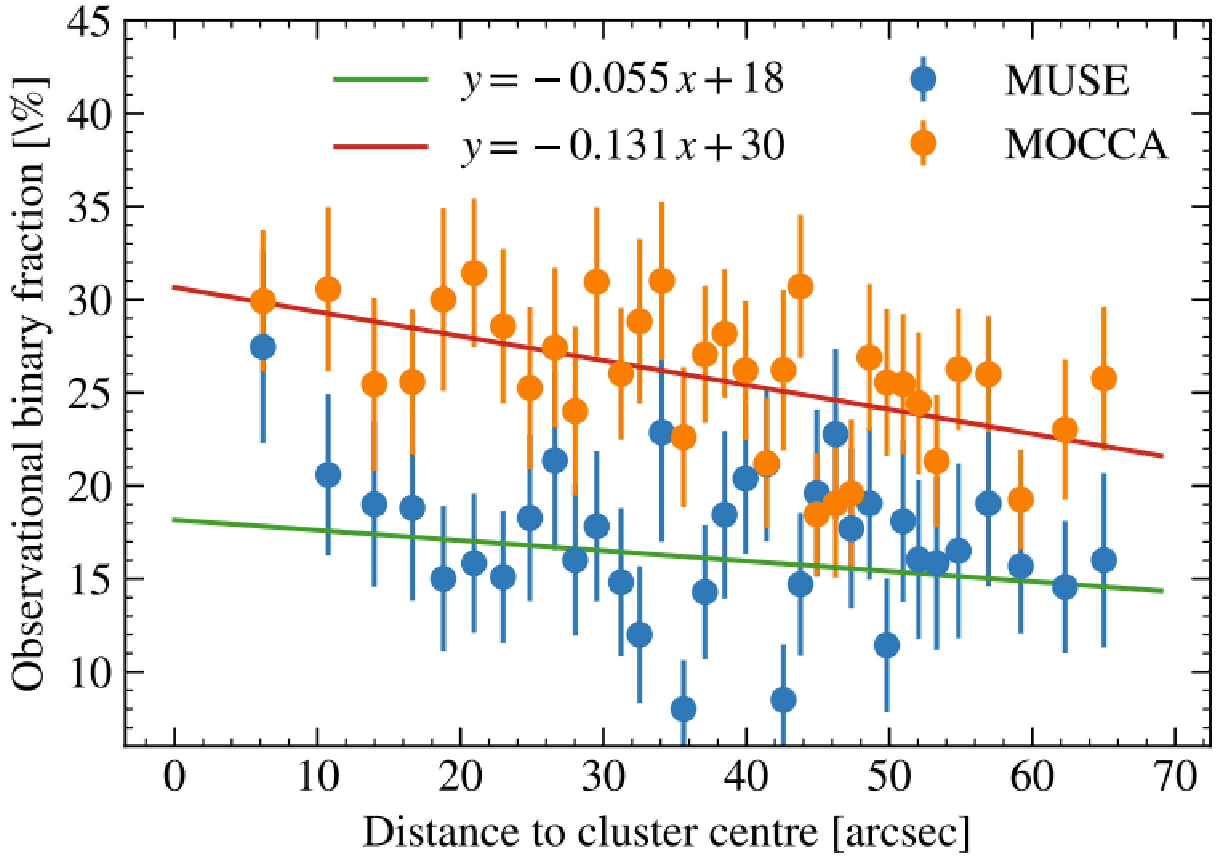
A stellar census in globular clusters with MUSE: Binaries in NGC 3201★

Benjamin Giesers[1], Sebastian Kamann[2], Stefan Dreizler[1], Tim-Oliver Husser[1], Abbas Askar[3], Fabian Göttgens[1], Jarle Brinchmann[4,5], Marilyn Latour[1], Peter M. Weilbacher[6], Martin Wendt[7], and Martin M. Roth[6]



Binary probability based on radial velocities curves (variations)

Fig. 8 - Giesers et al (2019)



An observational binary fraction of ~**17%** within NGC 3201's core radius

Brief parenthesis: MOCCA-SURVEY Database I (Askar et al.2017)

MOCCA-Survey, a collection of ~2000 simulated GCs with different initial conditions that include the **formation of IMBHs** and **the retention of stellar mass BHs** (see Askar et al., 2017 ; Giersz et al. 2015)

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY
MNRAS **454**, 3150–3165 (2015) doi:10.1093/mnras/stv2162

MOCCA code for star cluster simulations – IV. A new scenario for intermediate mass black hole formation in globular clusters

Mirek Giersz,[1★] Nathan Leigh,[2,3★] Arkadiusz Hypki,[1,4] Nora Lützgendorf[5] and Abbas Askar[1]

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY
MNRAS **464**, 3090–3100 (2017) doi:10.1093/mnras/stw2573
Advance Access publication 2016 October 10

MOCCA-SURVEY Database I: Is NGC 6535 a dark star cluster harbouring an IMBH?

Abbas Askar,[1★] Paolo Bianchini,[2★] Ruggero de Vita,[3] Mirek Giersz,[1] Arkadiusz Hypki[4] and Sebastian Kamann[5]

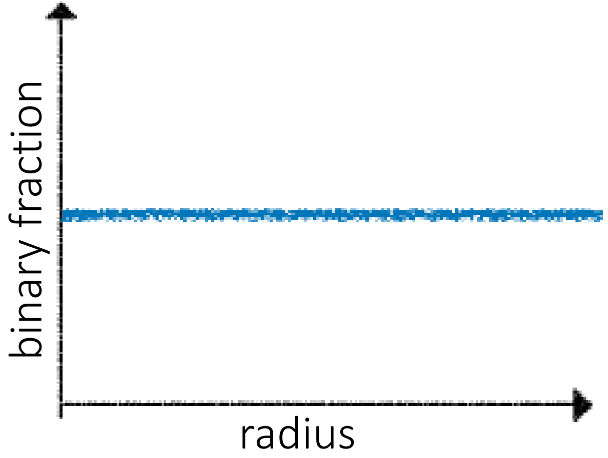
Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY
MNRAS **464**, L36–L40 (2017) doi:10.1093/mnrasl/slw177
Advance Access publication 2016 September 4

MOCCA-SURVEY Database – I. Coalescing binary black holes originating from globular clusters

Abbas Askar,[1★] Magdalena Szkudlarek,[2] Dorota Gondek-Rosińska,[2] Mirek Giersz[1] and Tomasz Bulik[3]

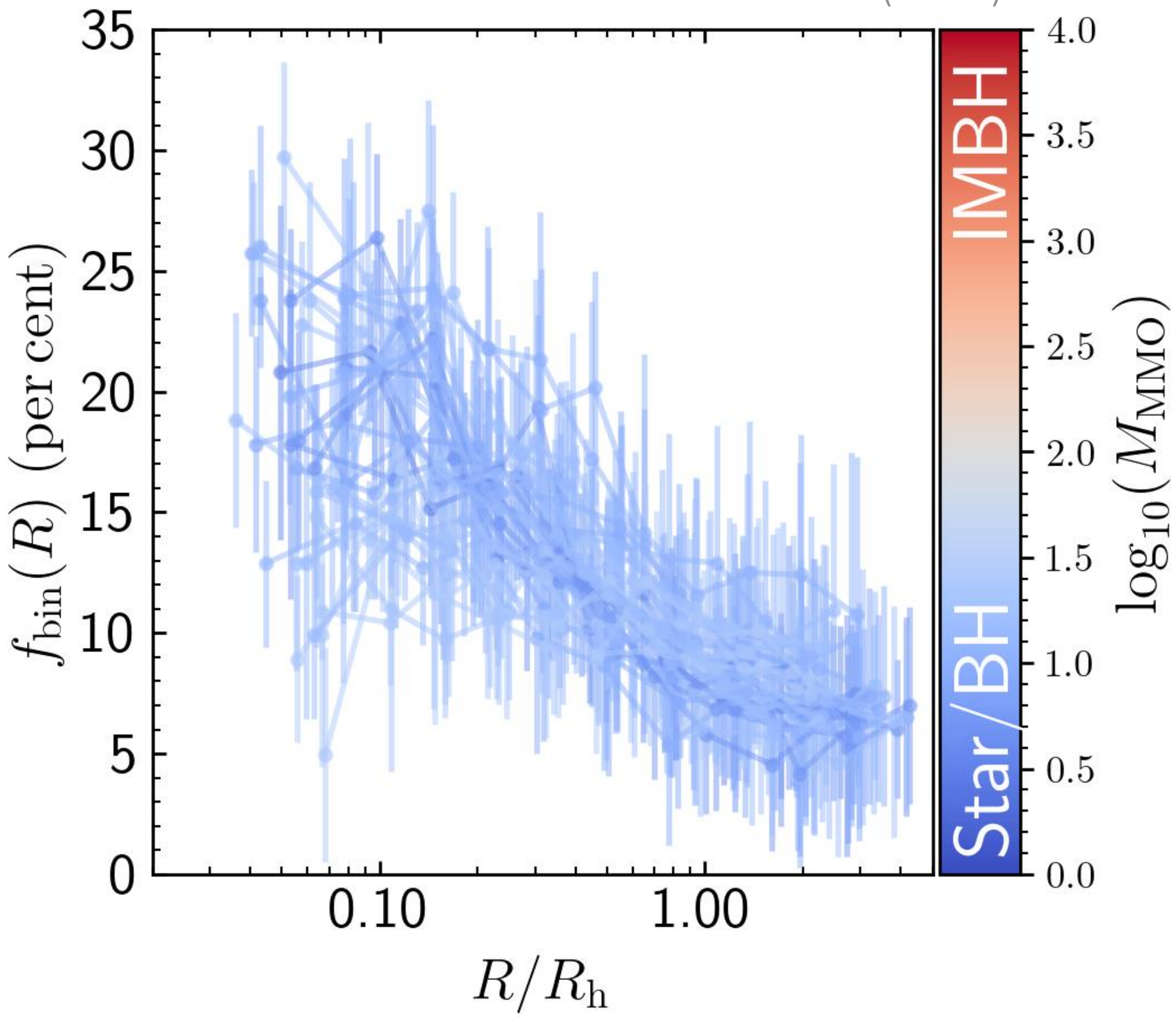
- 95 simulated clusters
- Initial binary fraction of 10%
- Can have an IMBH, multiple stellar-mass BHs or neither of them at 12Gyr

Mass segregation through binary fractions

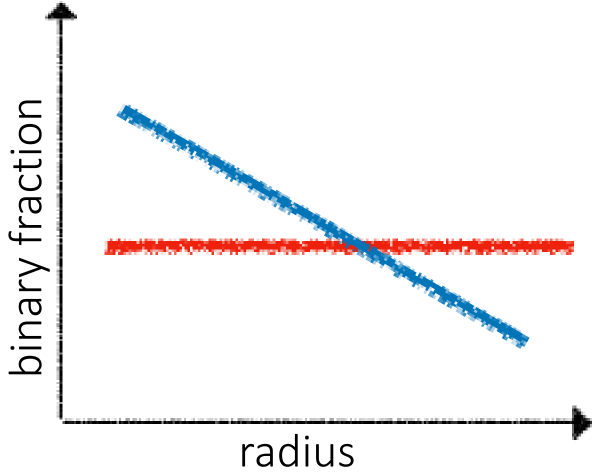


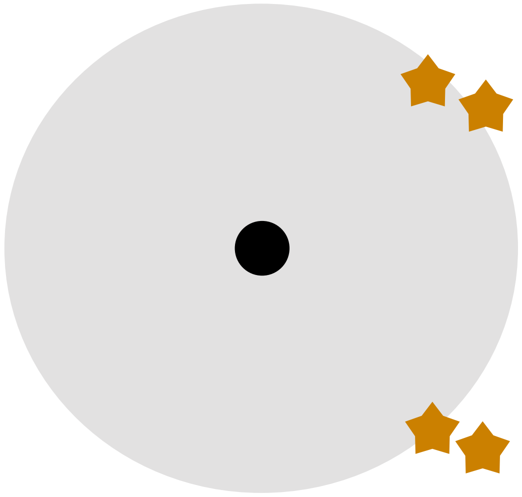
Binaries fall in towards
the centre of the GC

Aros et al. (2021)



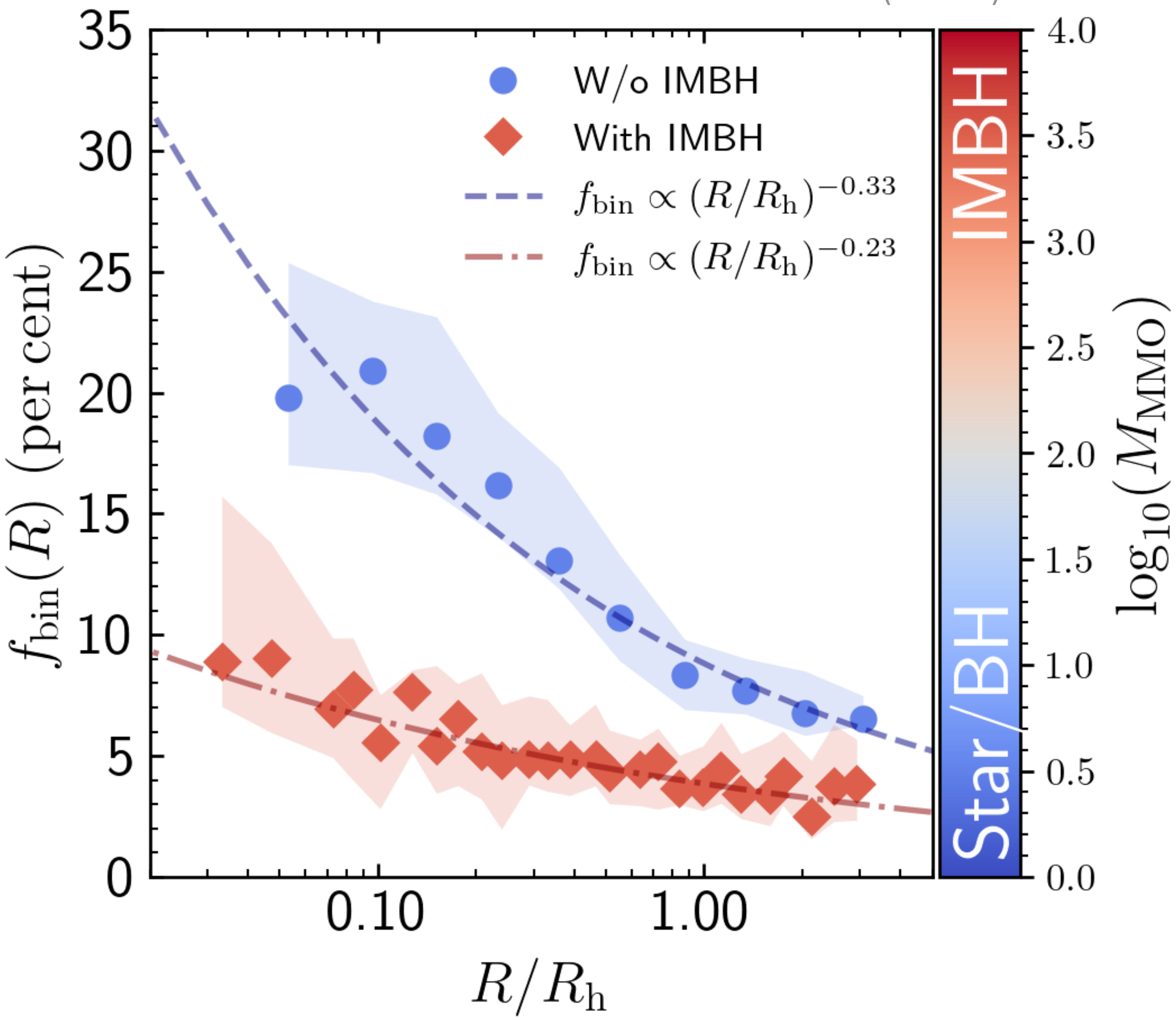
Mass segregation through binary fractions



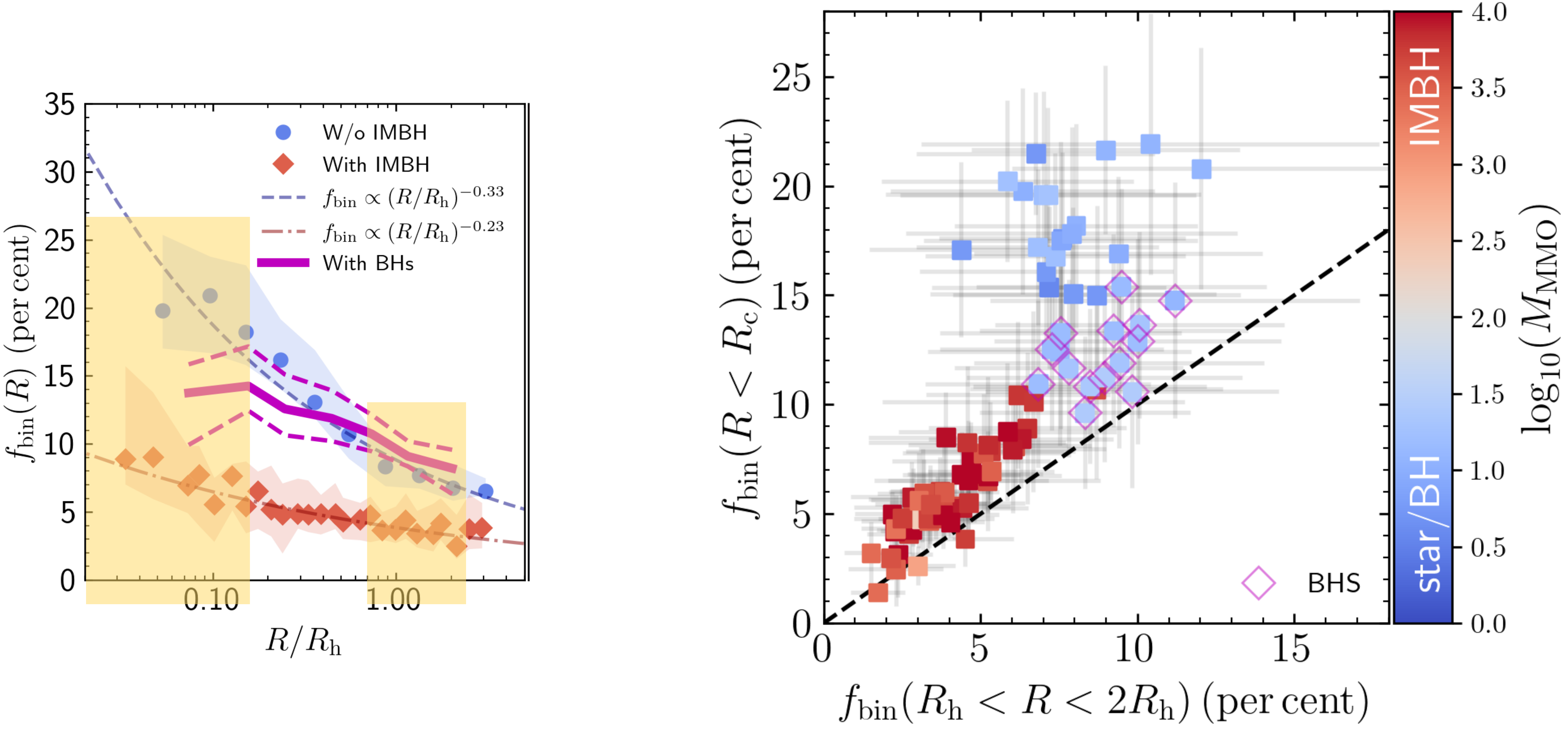


Less efficient segregation of binaries and disruption of the segregated ones.

Aros et al. (2021)



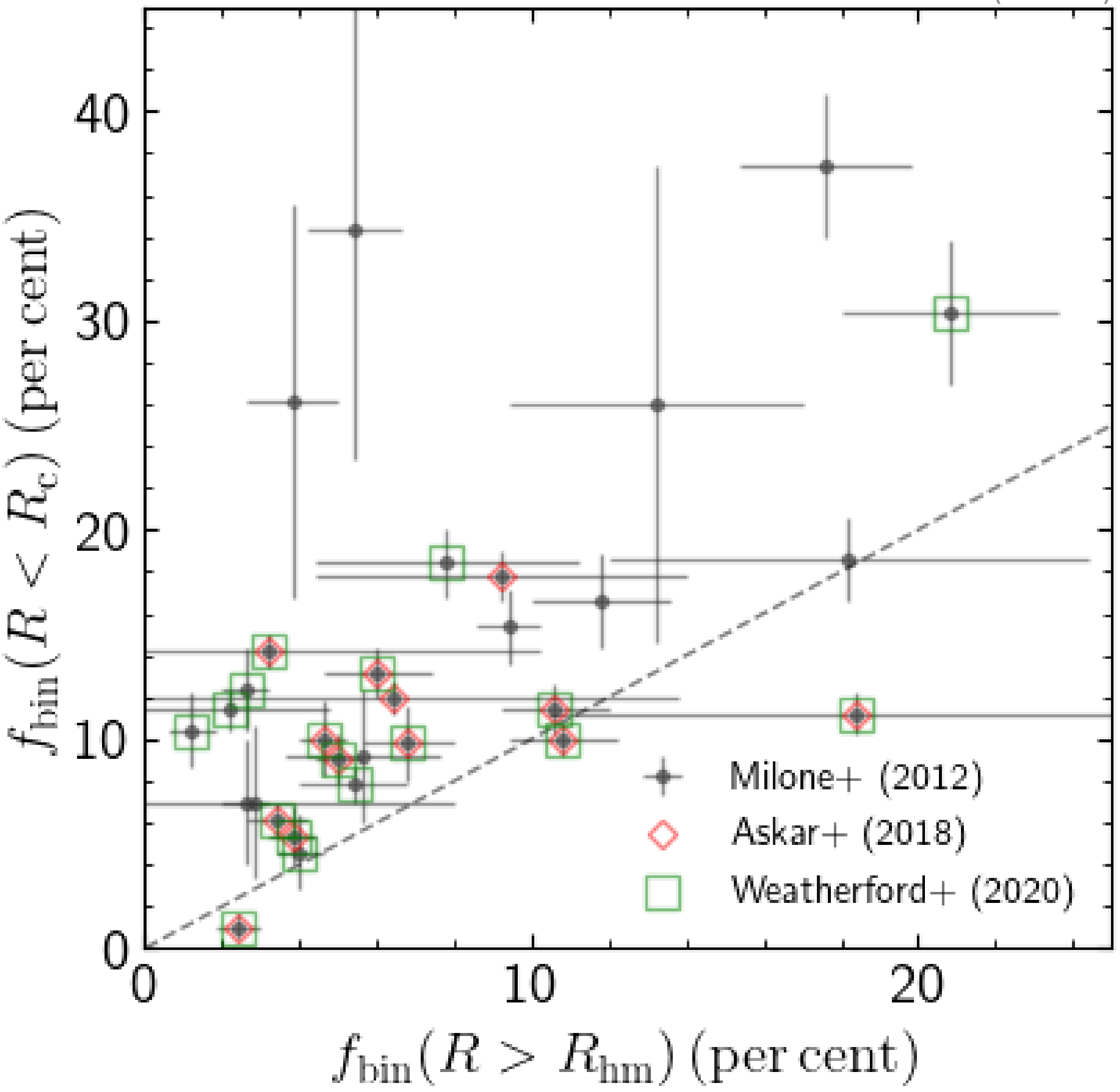
GCs that host an IMBH have fewer binaries and flatter binary fraction distributions



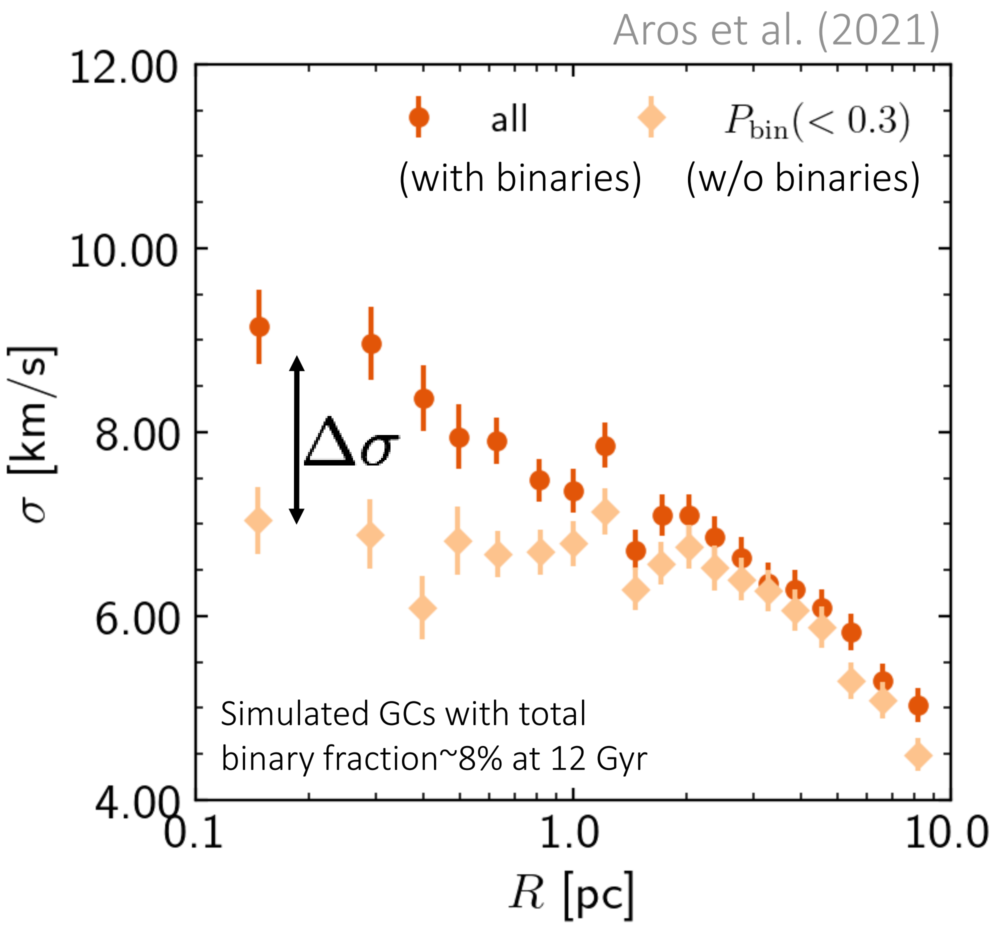
Figures from Aros et al. (2021)

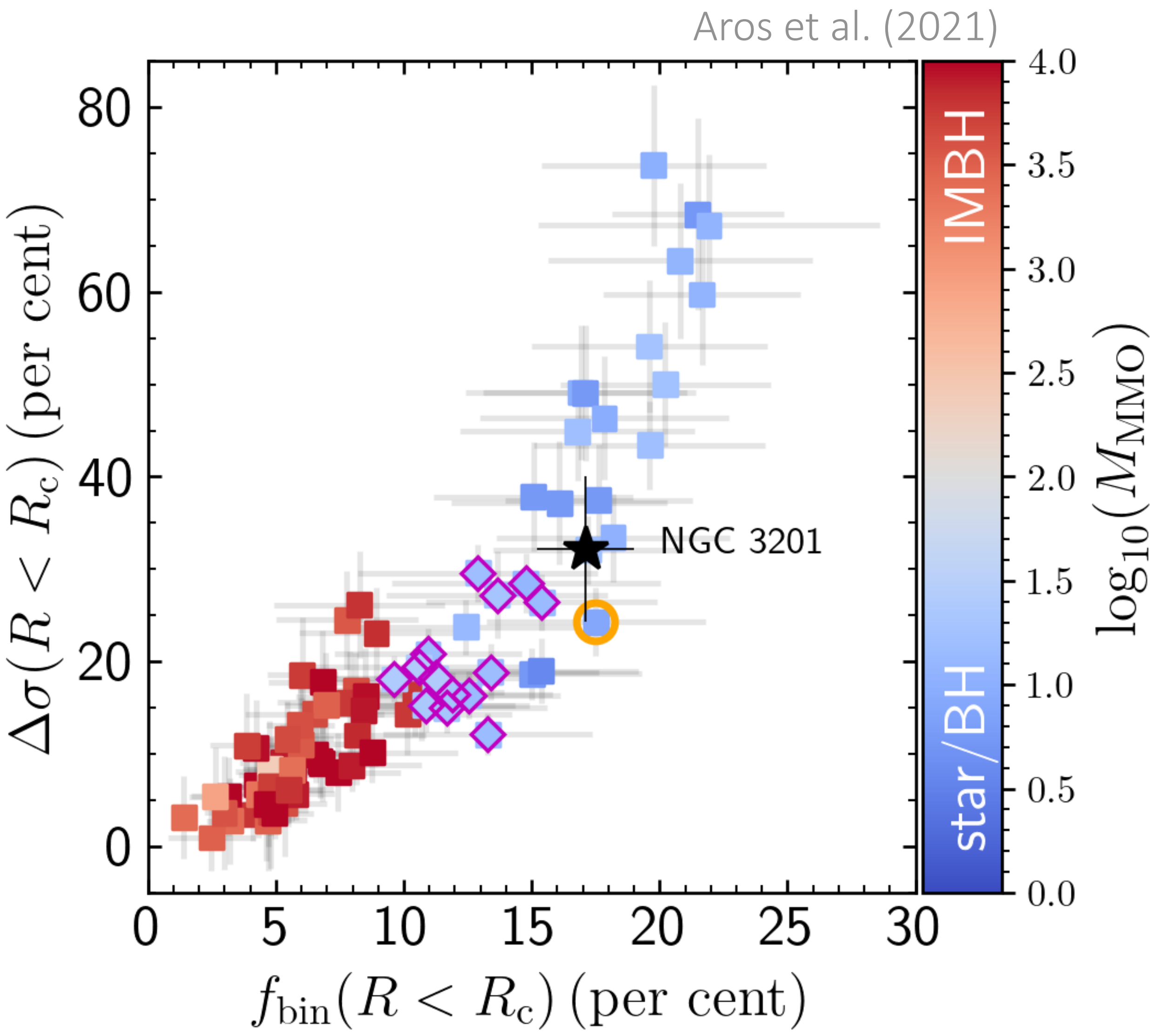
Binary fractions of candidate Galactic GCs to host a stellar mass black hole subsystem.

Aros et al. (2021)



We can quantify the velocity dispersion excess due to binary stars as an indication of the presence of an IMBH





Summary

- The binary fraction profile traces the effects of a GC's dynamical evolution (mass-segregation) and is susceptible to any additional source of energy: an IMBH or stellar-mass black holes.
- GCs that host an IMBH have fewer binaries and flatter binary fraction distributions.
- We can quantify the velocity dispersion excess due to binary stars as another indication of the presence of an IMBH

For more details see the full article:

Using binaries in globular clusters to catch sight of intermediate-mass black holes

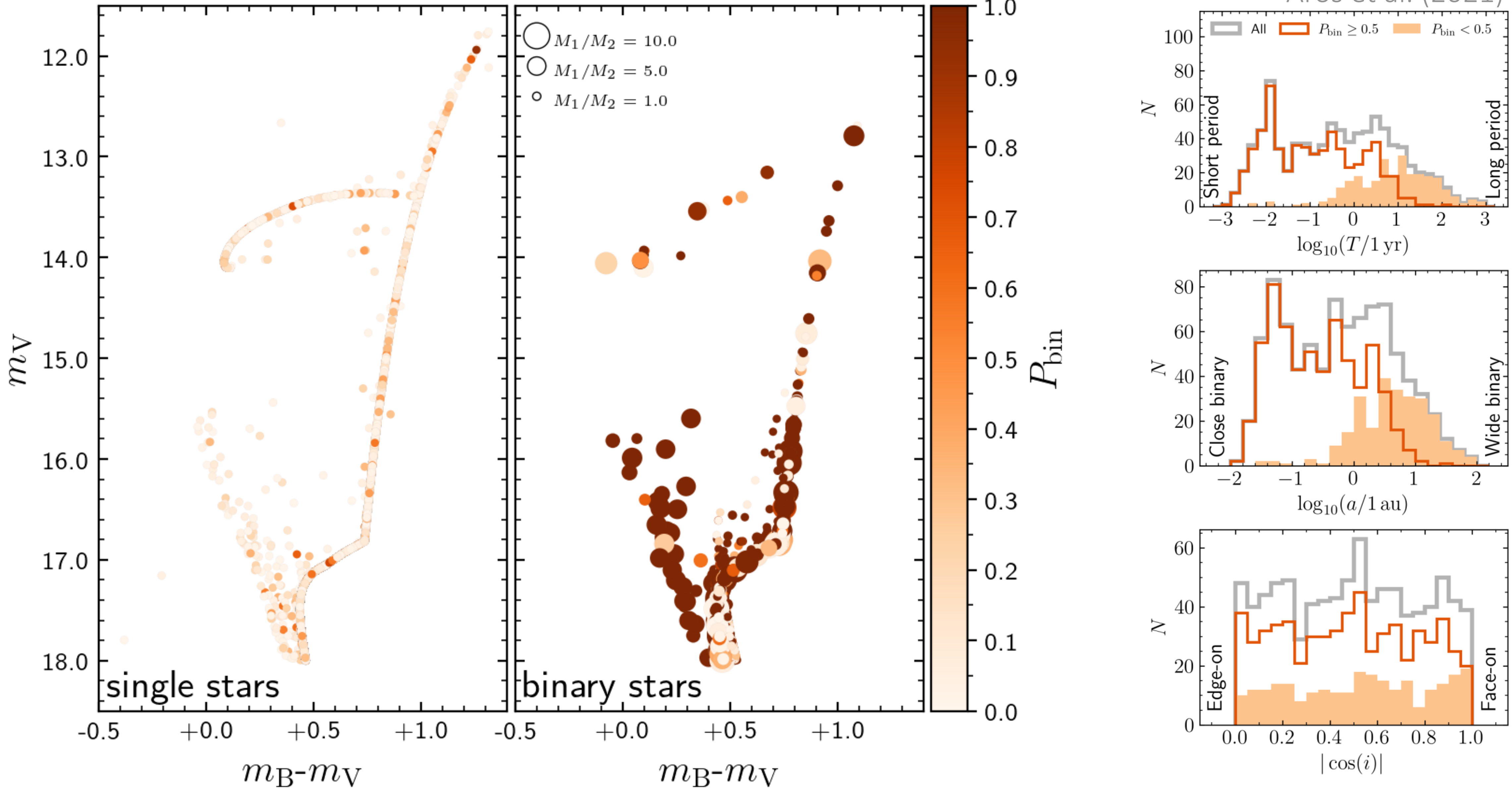
Francisco I Aros ✉, Anna C Sippel, Alessandra Mastrobuono-Battisti, Paolo Bianchini, Abbas Askar, Glenn van de Ven

Monthly Notices of the Royal Astronomical Society, Volume 508, Issue 3, December 2021,

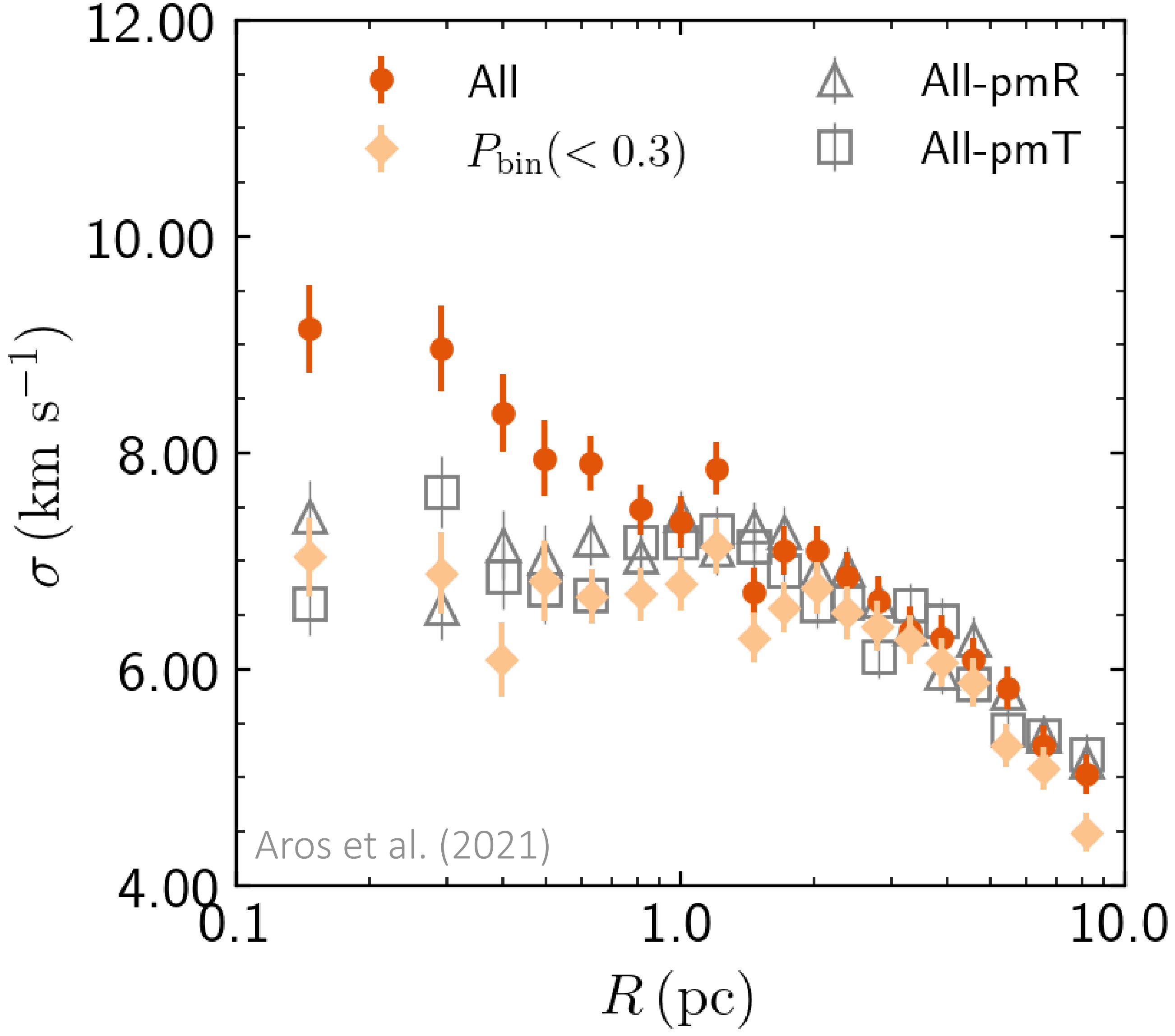
Additional slides

Binary detection and properties

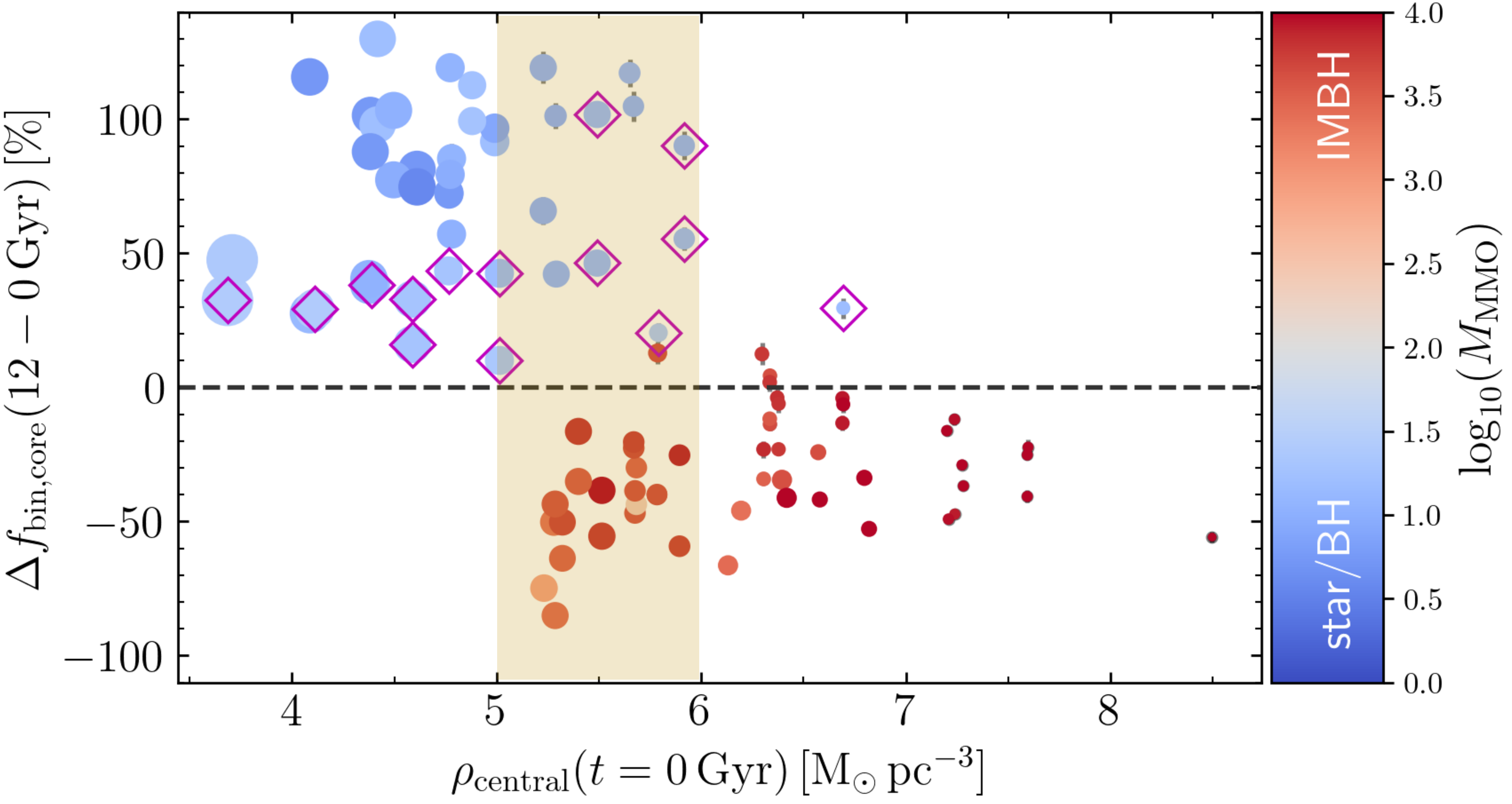
Aros et al. (2021)



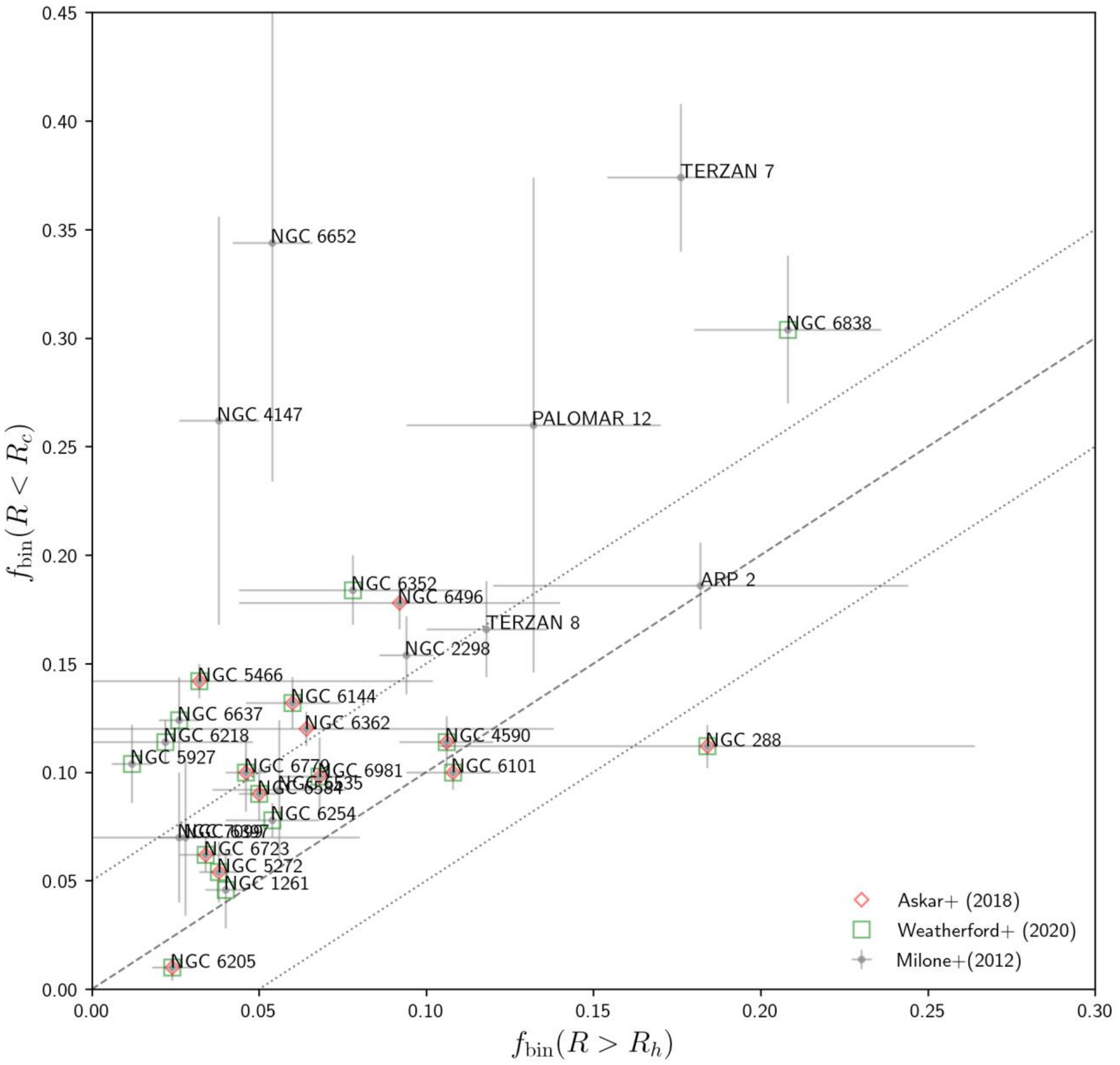
Kinematic effects of binaries and proper motions



Initial central densities and binary retention



Binary fractions of candidate Galactic GCs to host a stellar mass black hole subsystem.



GC	$f_c^{(a)}$ [%]	$f_{hm}^{(a)}$ [%]	Δ	$N_{\rm BHs}^{(b)}$	$M_{\rm BHs}^{(b)} [M_\odot]$	$N_{\rm BHs}^{(c)}$	$M_{\rm BHs}^{(c)} [M_\odot]$	$M_{\rm IMBH} [M_\odot]$
ARP 2	18.6 ± 2.0	18.2 ± 6.2	**0.3**					
E 3	72.0 ± 8.6	16.4 ± 21.4	39.3					
NGC 288	11.2 ± 1.0	18.4 ± 8.0	5.1	118^{+58}_{-35}	1473.0^{+566}_{-354}	26^{-14}_{+52}	594^{-305}_{+1216}	
NGC 1261	4.6 ± 1.8	4.0 ± 0.6	**0.4**			39^{-20}_{+81}	845^{-416}_{+1742}	
NGC 2298	15.4 ± 1.8	9.4 ± 0.8	**4.2**			1^{+0}_{+3}	21^{-4}_{+80}	
NGC 4147	26.2 ± 9.4	3.8 ± 1.2	15.8			2^{+0}_{+9}	55^{-9}_{+235}	
NGC 4590	11.4 ± 1.2	10.6 ± 1.4	**0.6**	71^{+29}_{-18}	847.8^{260}_{-166}	17^{-6}_{+38}	338^{-103}_{+888}	
NGC 5272	5.4 ± 1.4	3.8 ± 0.6	**1.1**	55^{+20}_{-13}	632.9^{+169}_{-109}	25^{-4}_{+112}	587^{-71}_{+2786}	$< 5.3 \times 10^3 (d)$
NGC 5466	14.2 ± 0.8	3.2 ± 7.0	7.8	191^{+110}_{-63}	2512.2^{+1165}_{-703}	19^{-10}_{+67}	423^{-197}_{+1740}	
NGC 5927	10.4 ± 1.8	1.2 ± 0.6	6.5			123^{-69}_{+273}	2499^{-1320}_{+6110}	
NGC 6101	10.0 ± 0.8	10.8 ± 1.4	**0.6**	89^{+40}_{-24}	1085.6^{+370}_{-234}	125^{-104}_{+236}	3051^{-2497}_{+5880}	
NGC 6144	13.2 ± 1.2	6.0 ± 1.4	5.1	84^{+40}_{-23}	1012.2^{+335}_{-213}	13^{-7}_{+36}	299^{-144}_{+855}	
NGC 6205	1.0 ± 0.6	2.4 ± 0.6	**1.0**	34^{+10}_{-6}	366.8^{+72}_{-46}	128^{-61}_{+345}	2786^{-1178}_{+8444}	$< 8.1 \times 10^3 (d)$
NGC 6218	11.4 ± 1.0	2.2 ± 2.6	6.5			22^{-11}_{+65}	509^{-233}_{+1507}	
NGC 6254	7.8 ± 0.8	5.4 ± 1.4	**1.7**			30^{-12}_{+69}	622^{-206}_{+1612}	
NGC 6352	18.4 ± 1.6	7.8 ± 3.4	7.5			14^{-5}_{+39}	298^{-98}_{+875}	
NGC 6362	12.0 ± 0.8	6.4 ± 7.4	**4.0**	86^{+38}_{-23}	1039.3^{+238}_{-221}			
NGC 6397	7.0 ± 3.6	2.8 ± 5.2	**3.0**			3^{+0}_{+16}	72^{+0}_{+421}	$600 \pm 200 (e)$
NGC 6496	17.8 ± 1.2	9.2 ± 4.8	6.1	58^{+22}_{-14}	672.2^{+185}_{-119}			
NGC 6535	9.2 ± 3.2	5.6 ± 2.0	**2.5**			1^{+0}_{+5}	24^{-2}_{+125}	
NGC 6584	9.0 ± 1.2	5.0 ± 0.6	**2.8**	40^{+13}_{-8}	451.5^{+101}_{-64}	11^{-3}_{+29}	231^{-61}_{+687}	
NGC 6637	12.4 ± 2.0	2.6 ± 0.6	6.9			58^{-25}_{+123}	1154^{-478}_{+2728}	
NGC 6652	34.4 ± 11.0	5.4 ± 1.2	20.5			5^{-1}_{+22}	107^{-13}_{+501}	
NGC 6723	6.2 ± 0.8	3.4 ± 0.8	**2.0**	51^{+18}_{-11}	577.7^{+147}_{-95}	60^{-24}_{+189}	1243^{-491}_{+4528}	
NGC 6779	10.0 ± 1.8	4.6 ± 0.6	**3.8**	48^{+17}_{-11}	543.1^{220}_{-141}	51^{-24}_{+103}	1068^{-430}_{+2329}	
NGC 6838	30.4 ± 3.4	20.8 ± 2.8	6.8			17^{-6}_{+60}	363^{-119}_{+1446}	
NGC 6981	9.8 ± 1.8	6.8 ± 1.2	**2.1**	84^{+37}_{-22}	1010.6^{+334}_{-212}	27^{-17}_{+61}	573^{-334}_{+1747}	
NGC 7099	7.0 ± 3.0	2.6 ± 0.6	**3.1**			5^{+0}_{+28}	130^{-1}_{+714}	
PALOMAR 1	66.6 ± 19.2	19.0 ± 6.2	33.7					
PALOMAR 12	26.0 ± 11.4	13.2 ± 3.8	9.1					
TERZAN 7	37.4 ± 3.4	17.6 ± 2.2	14.0					
TERZAN 8	16.6 ± 2.2	11.8 ± 1.8	**3.4**					