Resolving the Central Dynamics of GCs with MUSE

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& the MUSE consortium

muse
multi unit spectroscopic explorer

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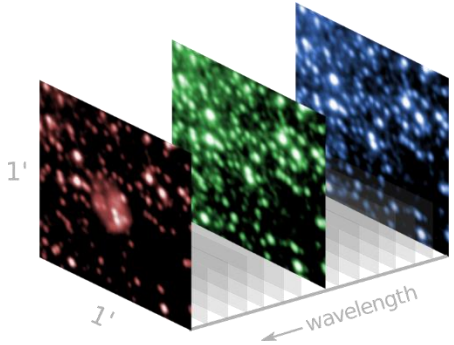
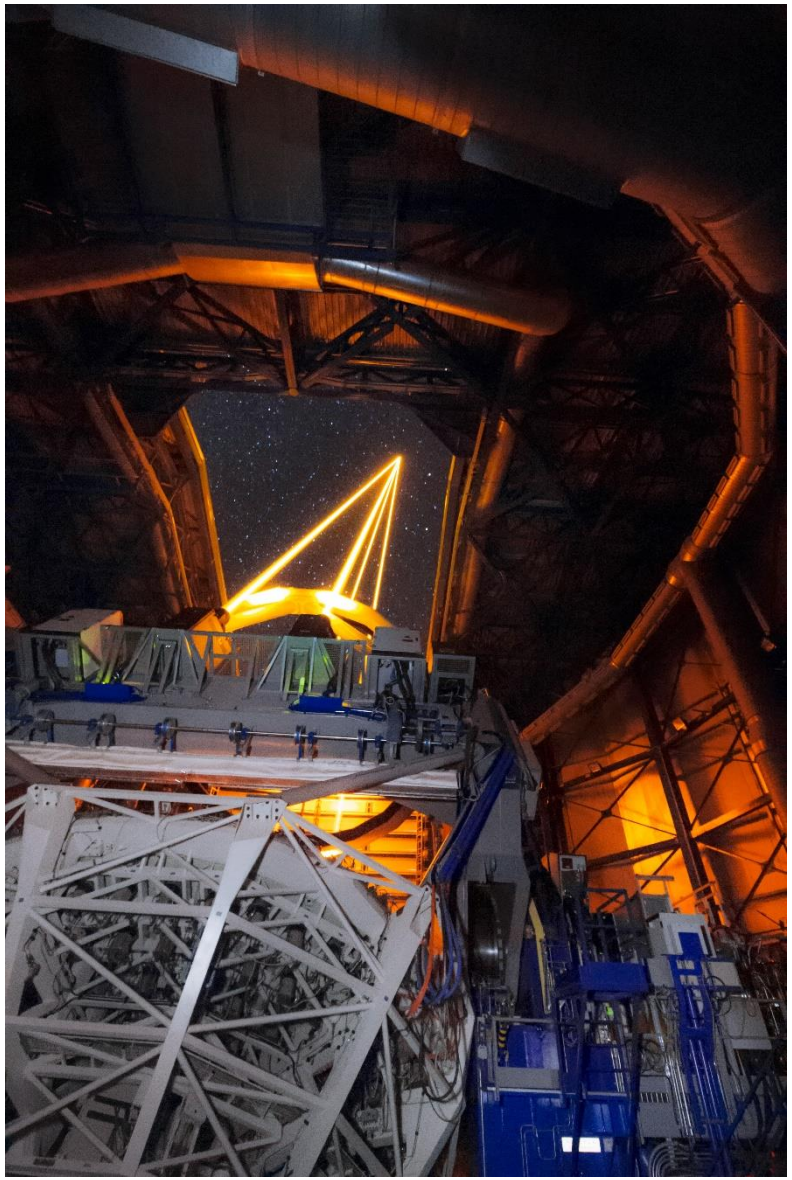
MUSE in a nutshell

- commissioned 2014 at the VLT UT4

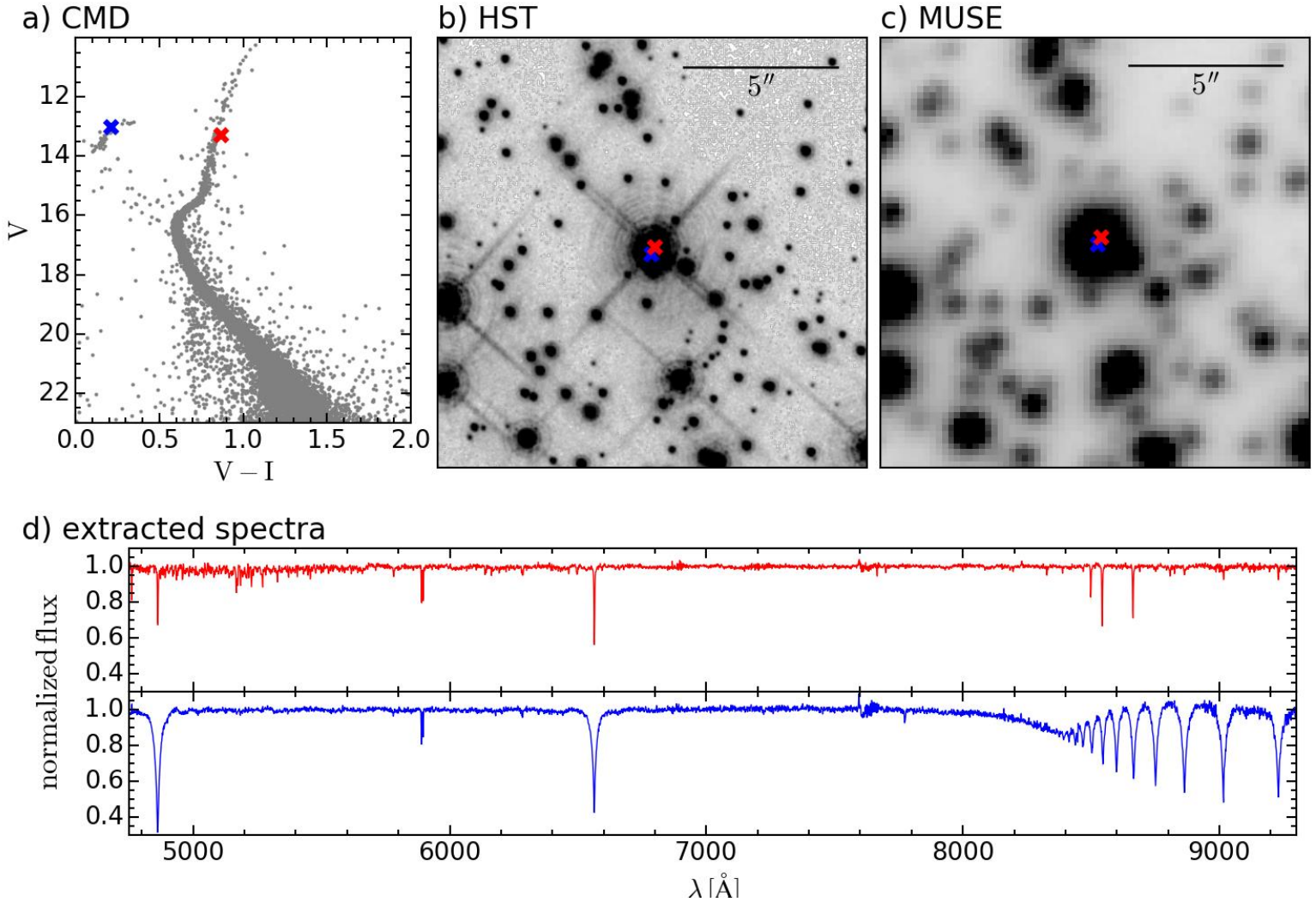
- panoramic IFS (24 IFUs)
- 1‘x1‘ FoV with 0.2“ sampling
- λ ~ 4800Å – 9300Å
- R ~ 1770 – 3590



- „point and shoot“
- very stable
- high troughput
- adaptive optics
- narrow field mode (7.5"x7.5") New

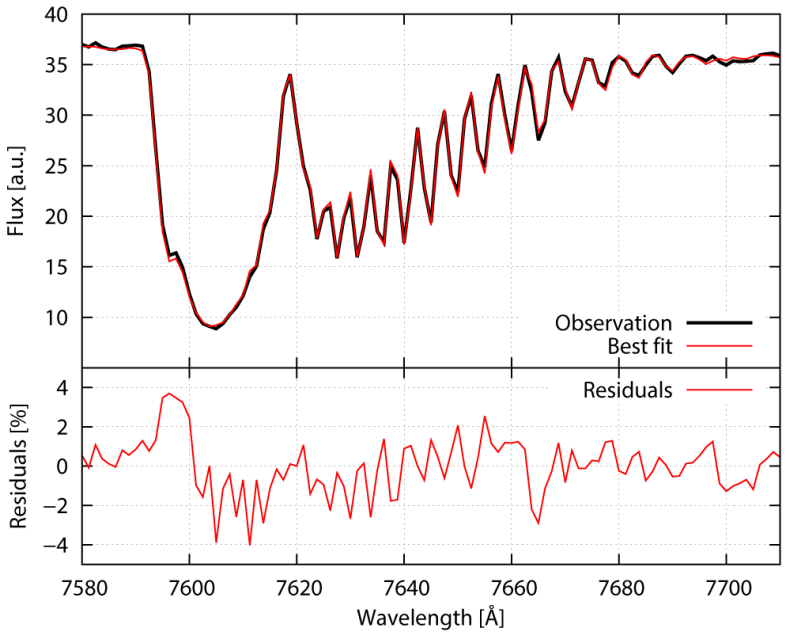


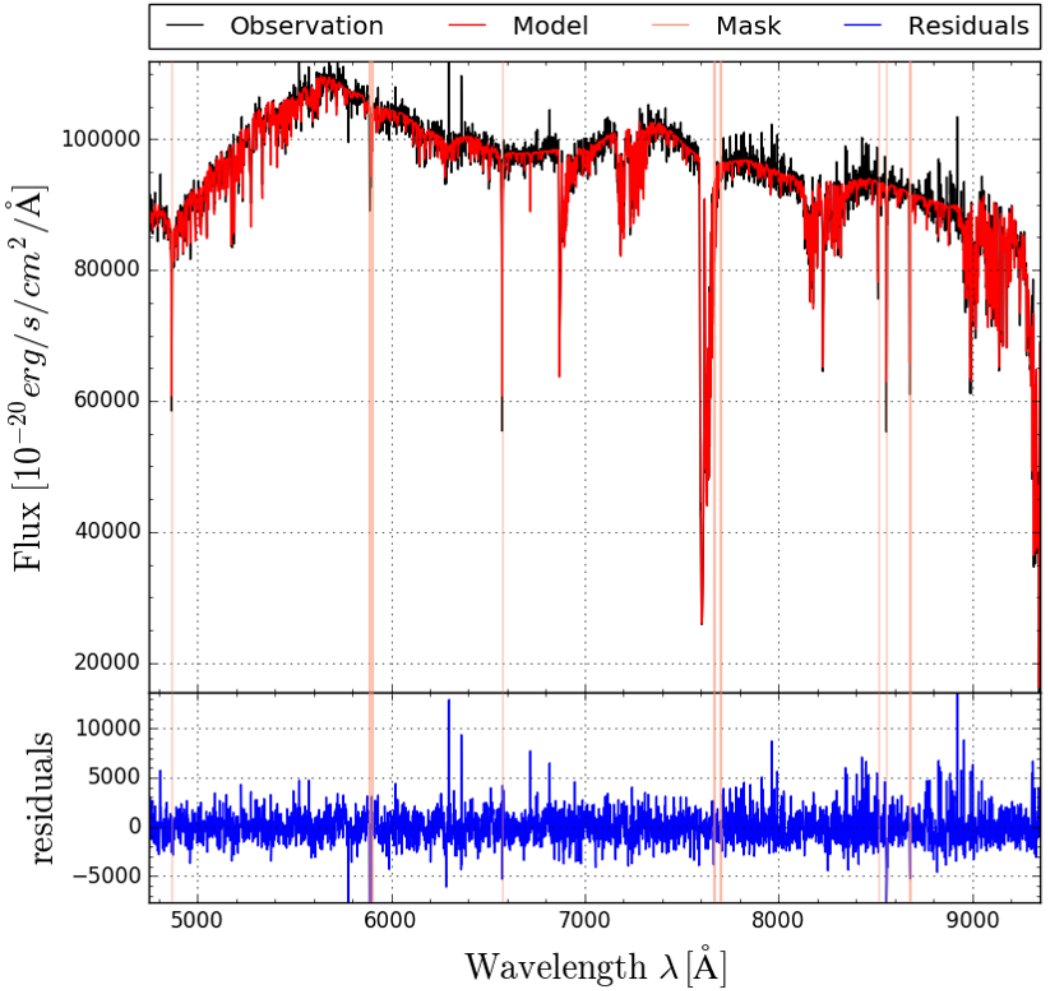
Source extraction with PSF fitting



Full spectrum fit

- Using extensive **library** of **PHOENIX** stellar atmospheres and synthetic spectra.



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FIT
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Red. χ²:    0.94
S/N:        64.82

T_eff:    (5401.08±18.39)K
log g:    (3.15)dex
[Fe/H]:   (-1.31±0.03)dex
v_rad:    (489.52±0.96)km/s
v_tell:   (-5.22±0.38)km/s
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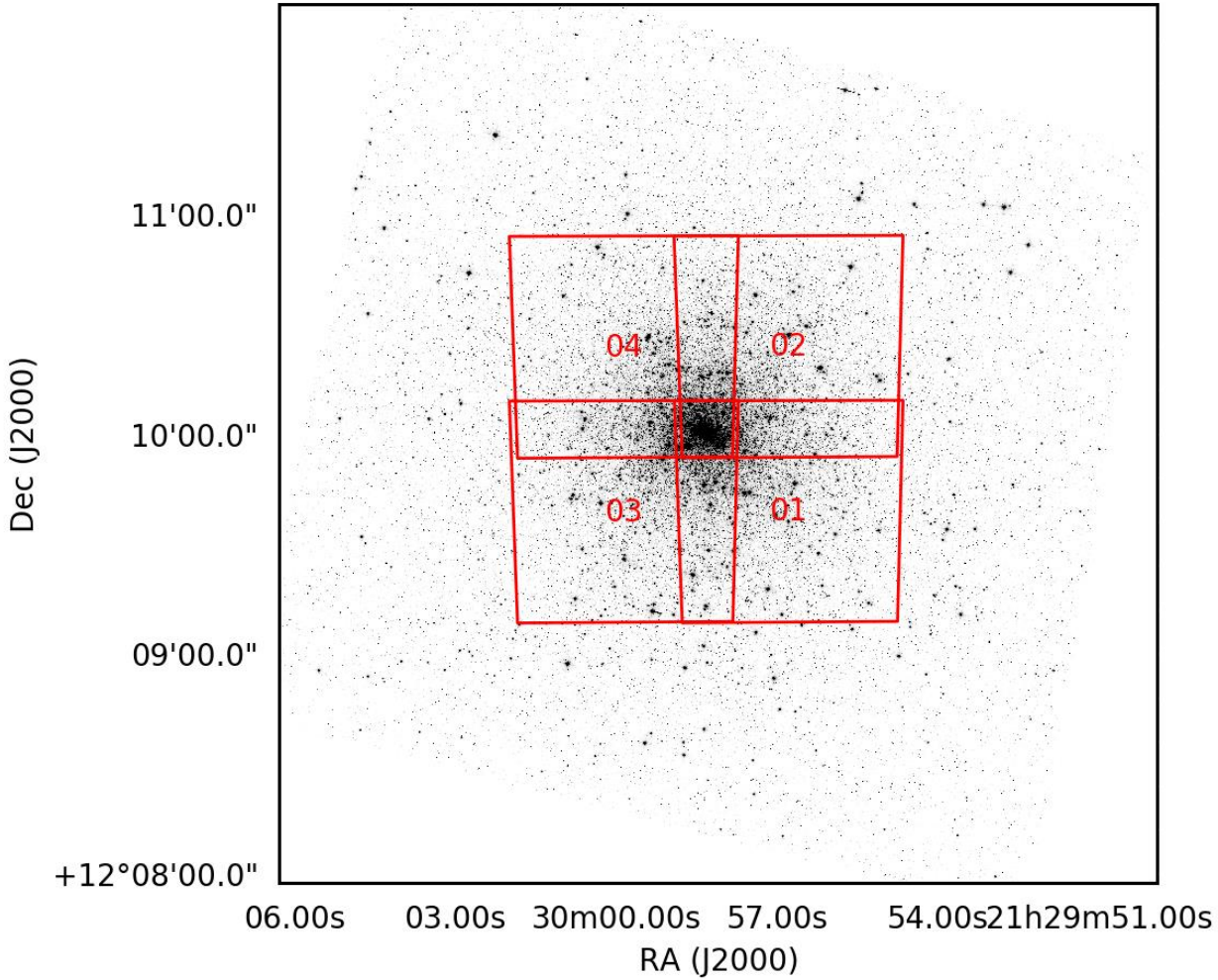
The MUSE survey of globular clusters

- 25 clusters (so far)
- massive ($\sigma > 5$ km/s)
- nearby ($d < 15$ kpc)
- focus on central regions (within 1 r_{HL})

- Analysis completed for 1 000 000 spectra of 200 000 stars (SNR > 10)
  (see Kamann+18)

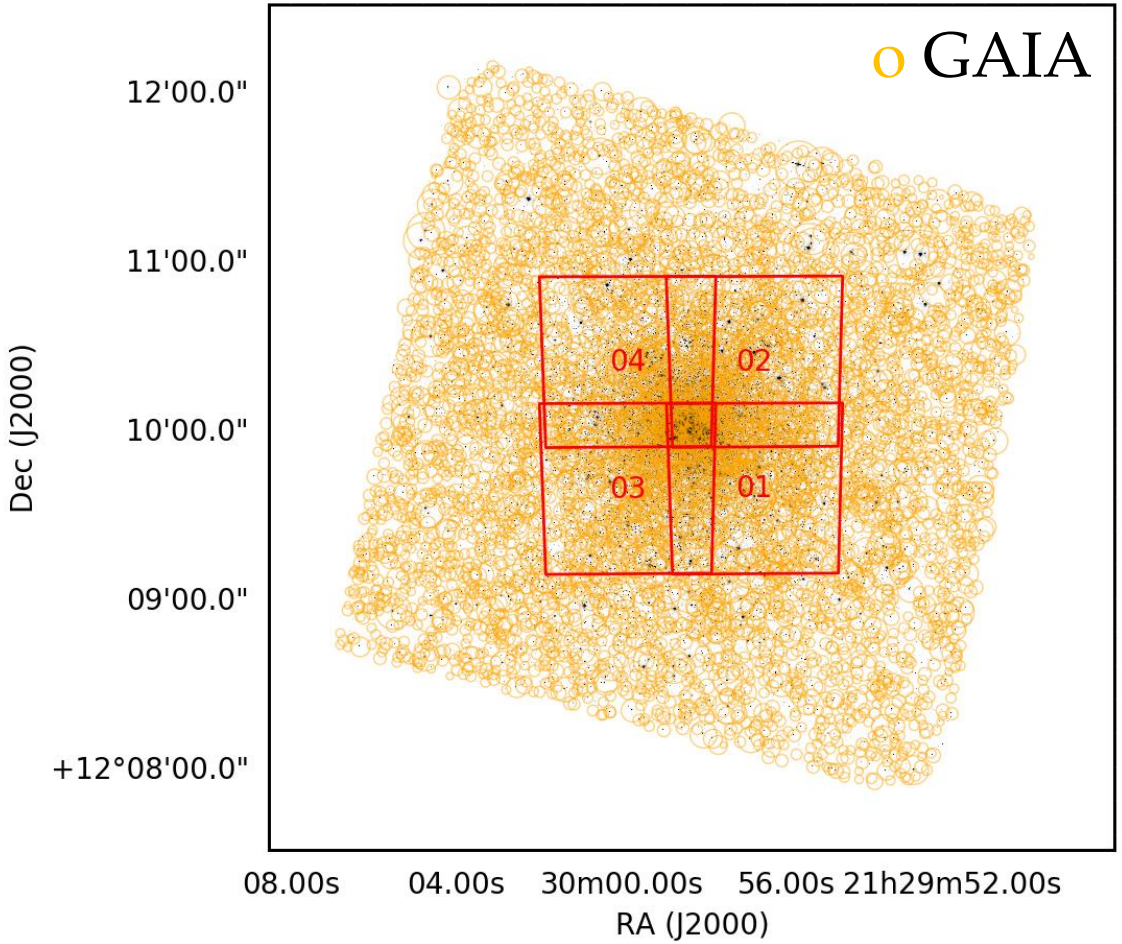
Complementary to GAIA

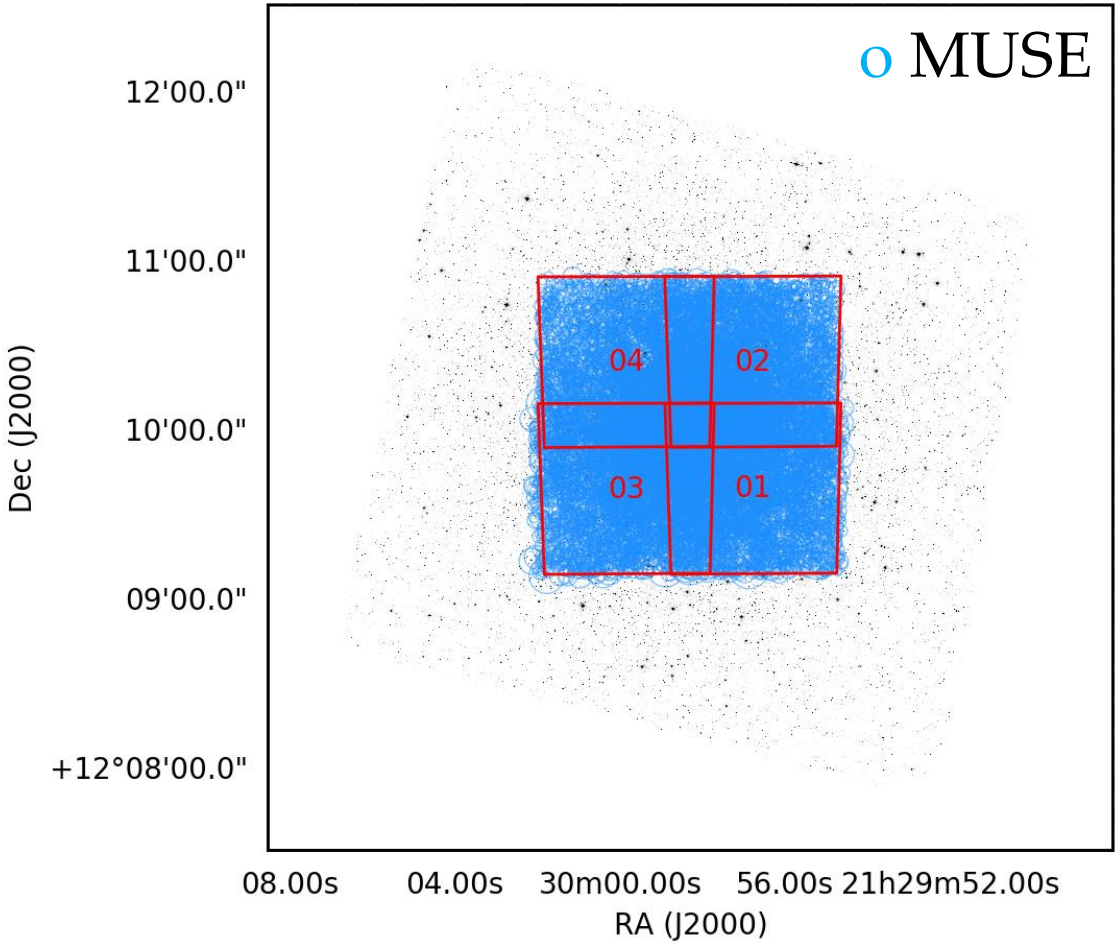
- NGC 7078
  M15



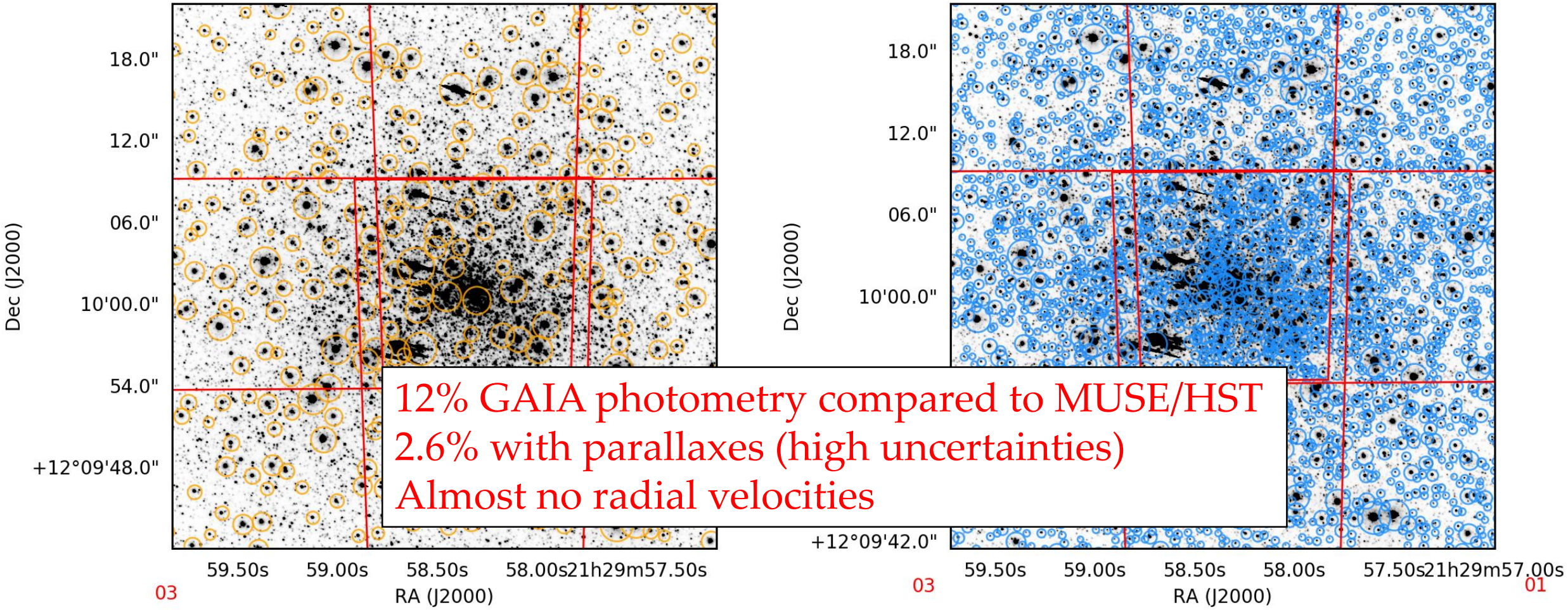
- HST ACS
- MUSE pointings

Complementary to GAIA



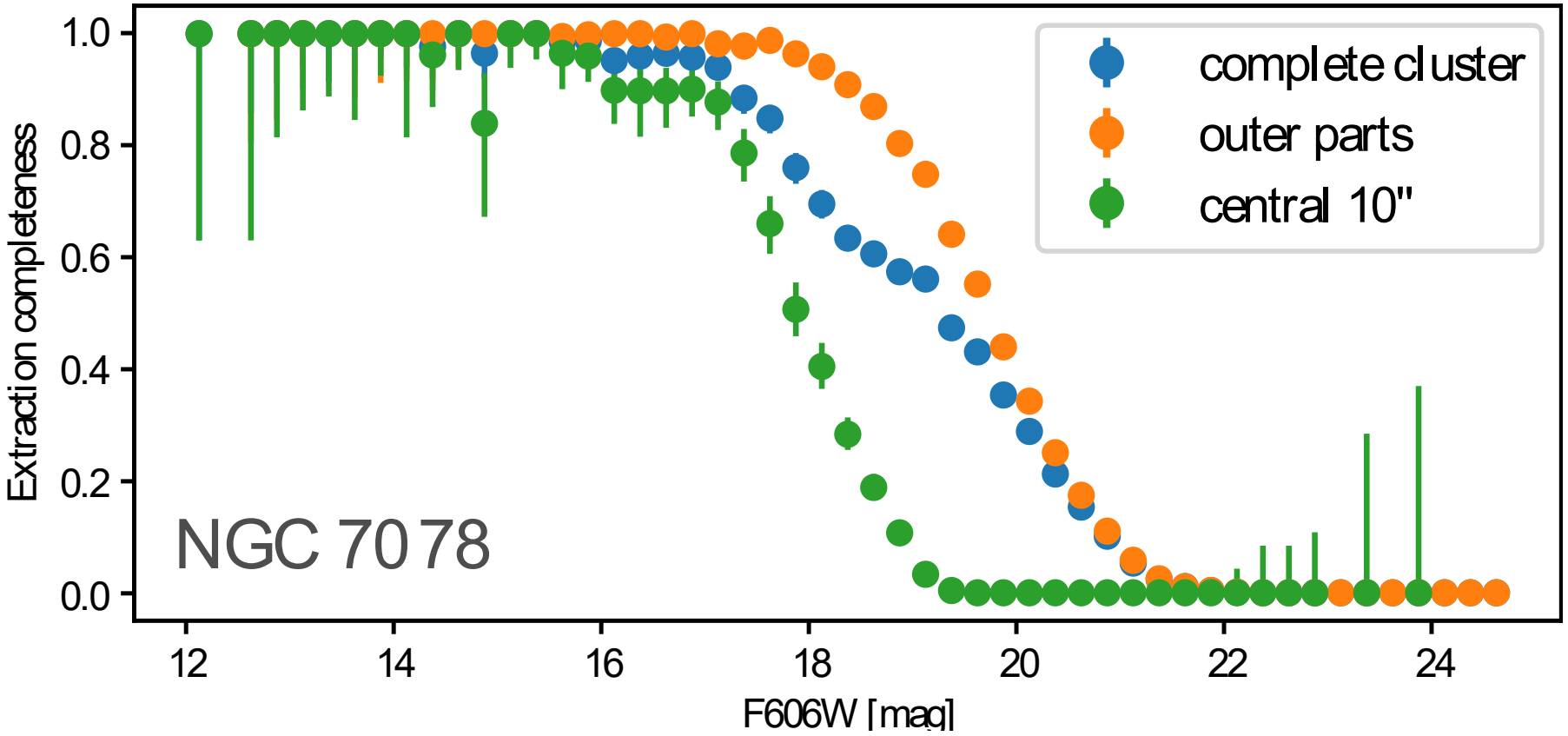


Complementary to GAIA

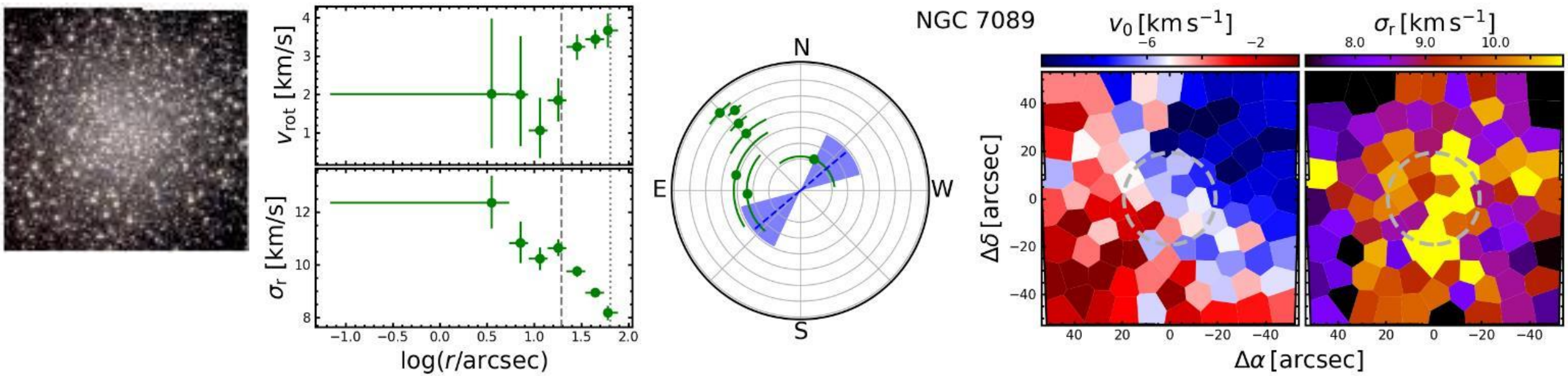


12% GAIA photometry compared to MUSE/HST
2.6% with parallaxes (high uncertainties)
Almost no radial velocities

Spectra extraction completeness



Globular cluster kinematics

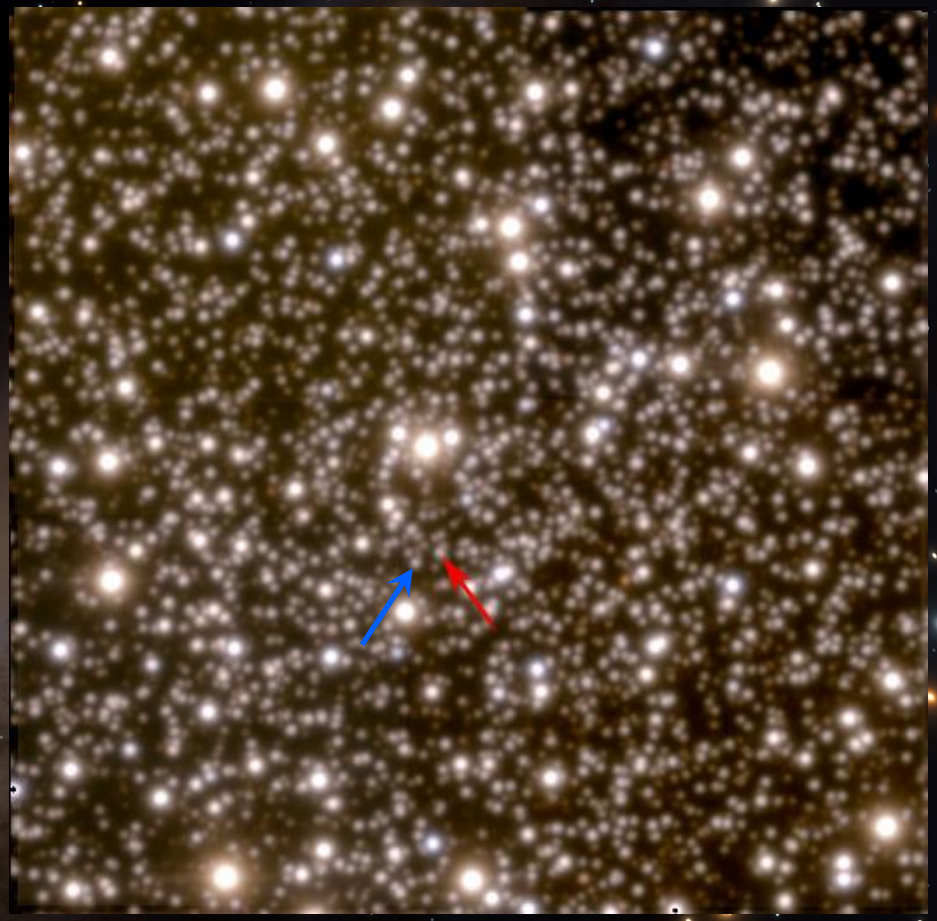


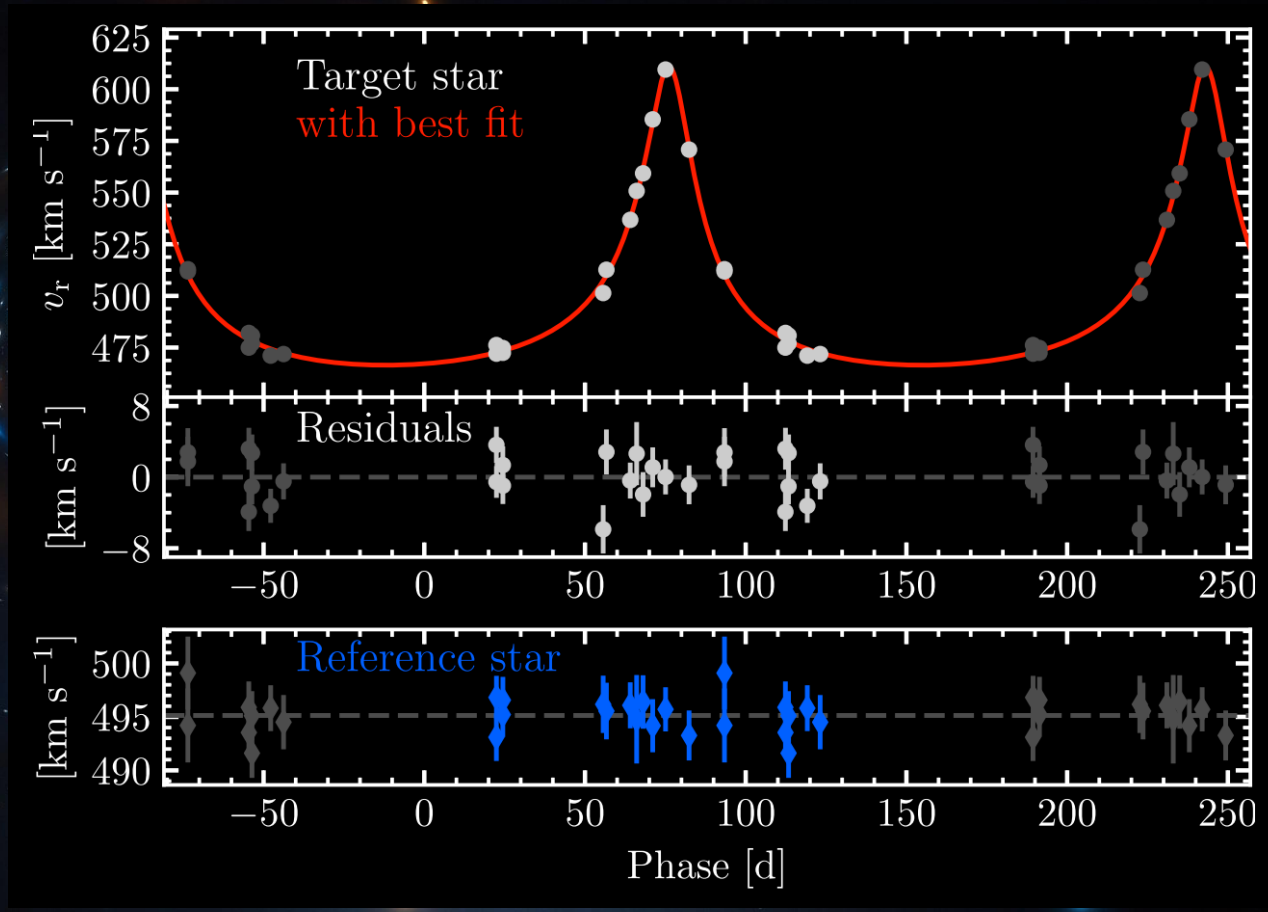
- Significant (central) rotation detection in 13/22 clusters
- Link to relaxation time suggests clusters were born rotating
- see Kamann+18

eso1802 — Science Release

A detached stellar-mass black hole candidate in the globular cluster NGC 3201

Giesers et al. 2018, MNRAS





Stellar-mass black hole in NGC 3201

- Target star

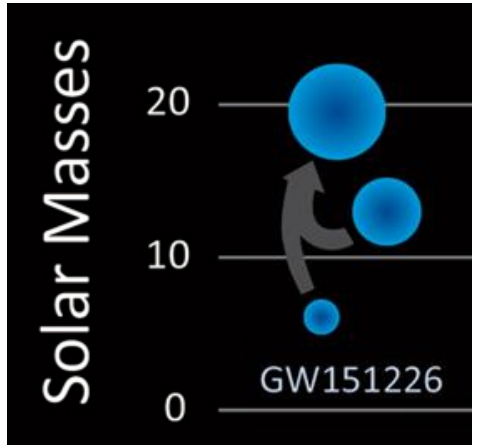
RA	$10^h\ 17^m\ 37\overset{s}{.}090$	Decl	$-46°\ 24'\ 55\overset{''}{.}31$
I_{F814W}	16.87 ± 0.02 mag (Vega)		
M	$(0.81 \pm 0.05)\ M_\odot$	$\log g$	(3.99 ± 0.05) dex
T_{eff}	(6126 ± 20) K	[M/H]	(-1.50 ± 0.02) dex

- Unseen Companion

Period P	$166.88^{+0.71}_{-0.63}$ d
Doppler semi-amplitude K	$(69.4 \pm 2.5)\ \mathrm{km\,s^{-1}}$
Eccentricity e	0.595 ± 0.022
Argument of periastron ω	$(2.6 \pm 3.2)°$
Periastron passage T_0	$(57\,140.2 \pm 0.5)$ d
Barycentric radial velocity γ_0	$(494.5 \pm 2.4)\ \mathrm{km\,s^{-1}}$
Linear trend $\dot{\gamma}$	$(-0.27 \pm 2.70)\ \mathrm{km\,s^{-1}}$
Jitter s	$0.68^{+0.40}_{-0.25}\ \mathrm{km\,s^{-1}}$
Minimum companion mass $M \sin(i)$	$(4.36 \pm 0.41)\ M_\odot$
Minimum semi-major axis $a(M)$	(1.03 ± 0.03) au

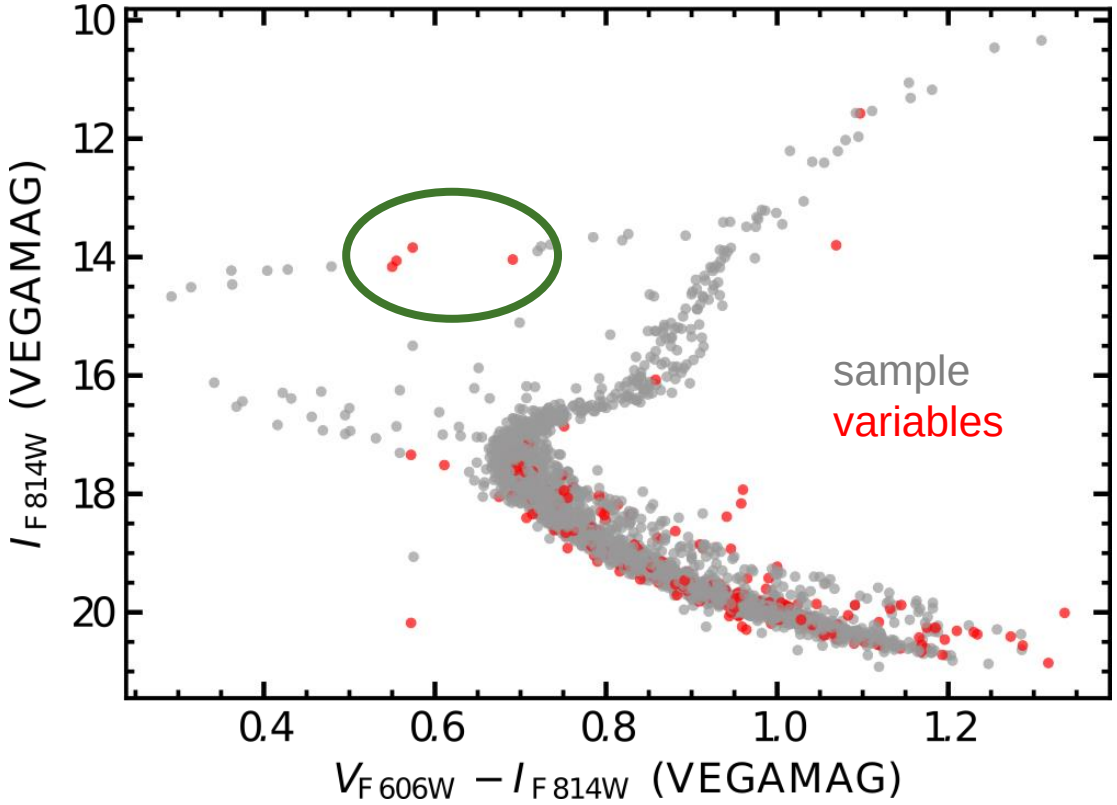
Stellar-mass black hole in NGC 3201

- Globular clusters could be catalysers for black-hole (BH) evolution (from stellar-mass to intermediate-mass).
- Maybe we will see some gravitational waves from BH binaries in globular clusters.
- Compared to other clusters NGC 3201 has a large core radius (1.3 armin).
- Probably the core is expanded by an extensive BH system.
- We should find more BHs with MUSE!

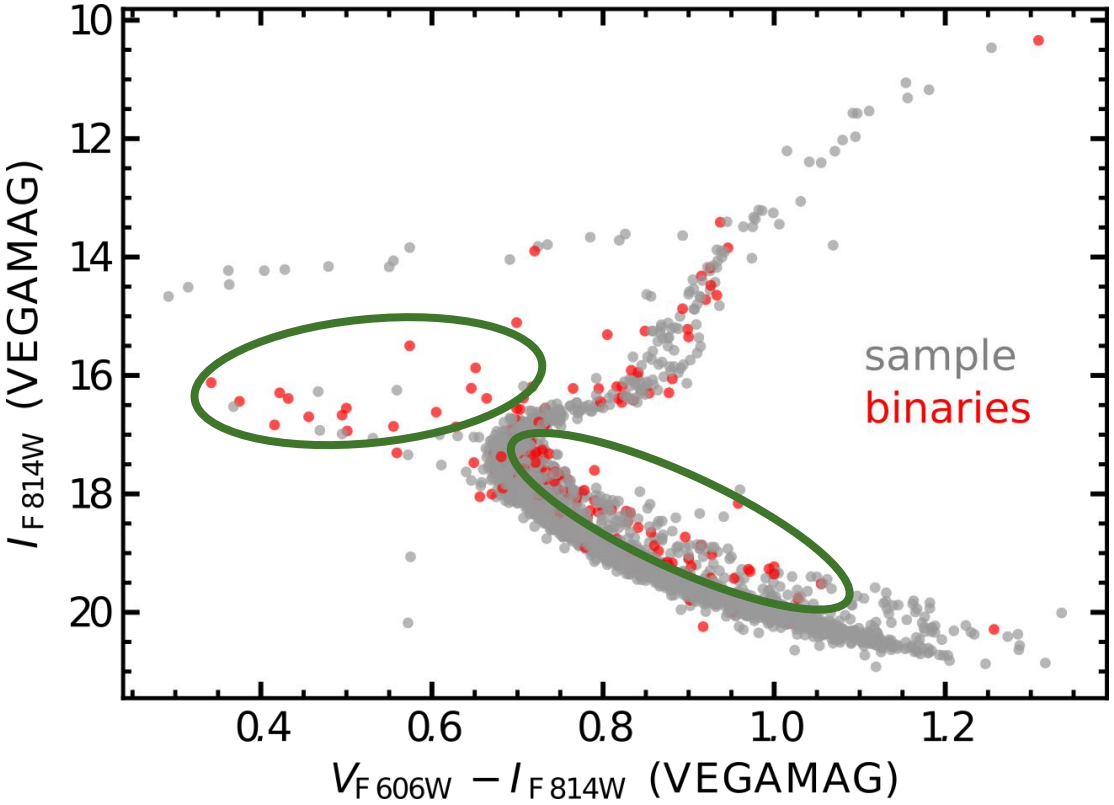


Binaries and variables in NGC 3201

- Photometric variables

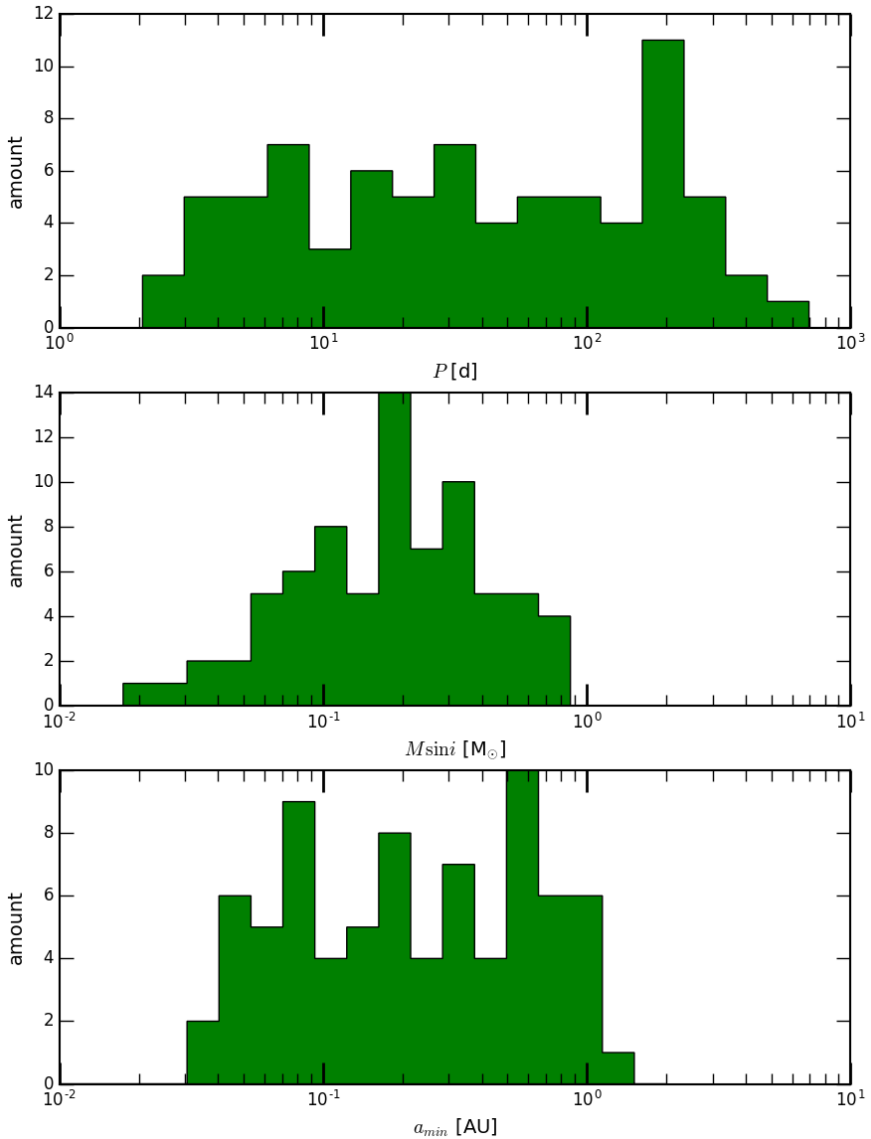


- Binaries



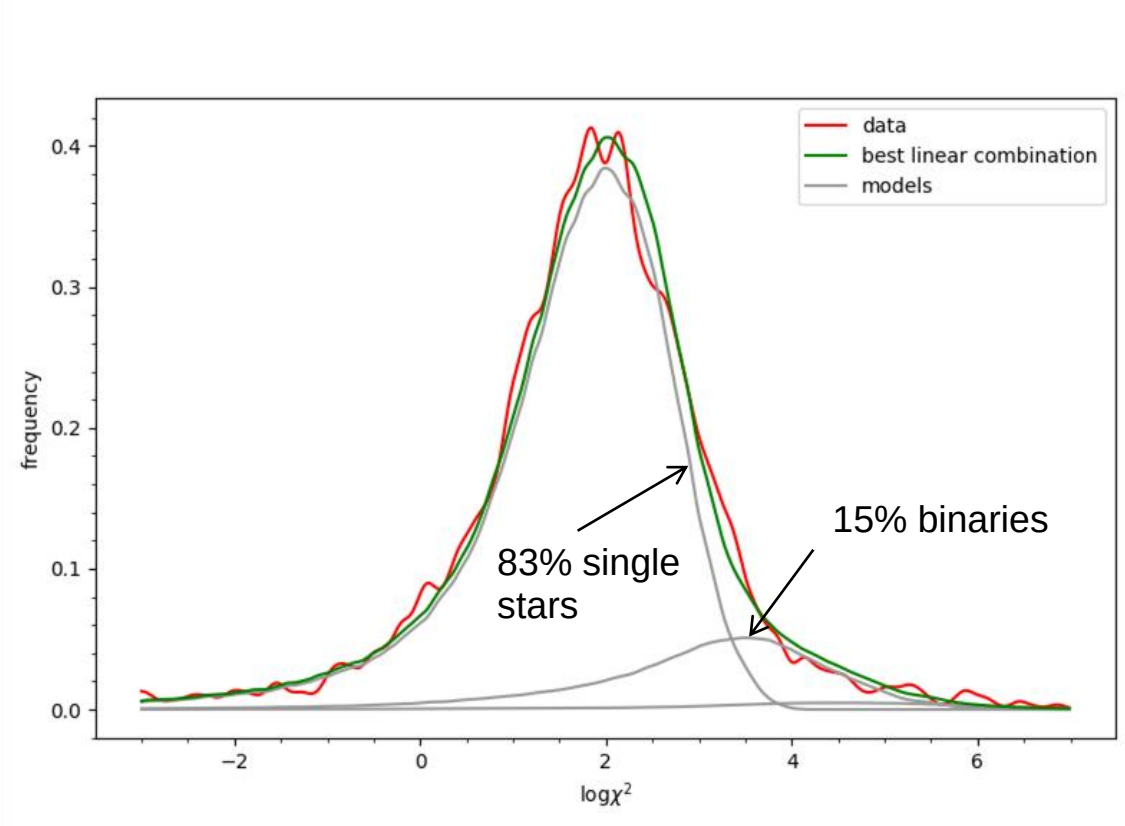
Binary star fraction

- Clusters for which we aim to do binary system orbit fits:
  - 47 Tucanae
  - NGC 3201
  - ω Cen
  - (NGC 1851)
- For all other clusters we aim to have 3 epochs each.



Binary star fraction

- Observed binary fraction is biased by
  - selection effects and
  - detection limits.
- To get real binary fraction we need input from globular cluster simulations which take detailed binary evolution into account.
- Distribution of binary properties are highly correlated:
  $f(M_1, P, q, e) \neq f(M_1) \times f(P) \times f(q) \times f(e)$
  (see Moe & Di Stefano, 2017)



Questions?