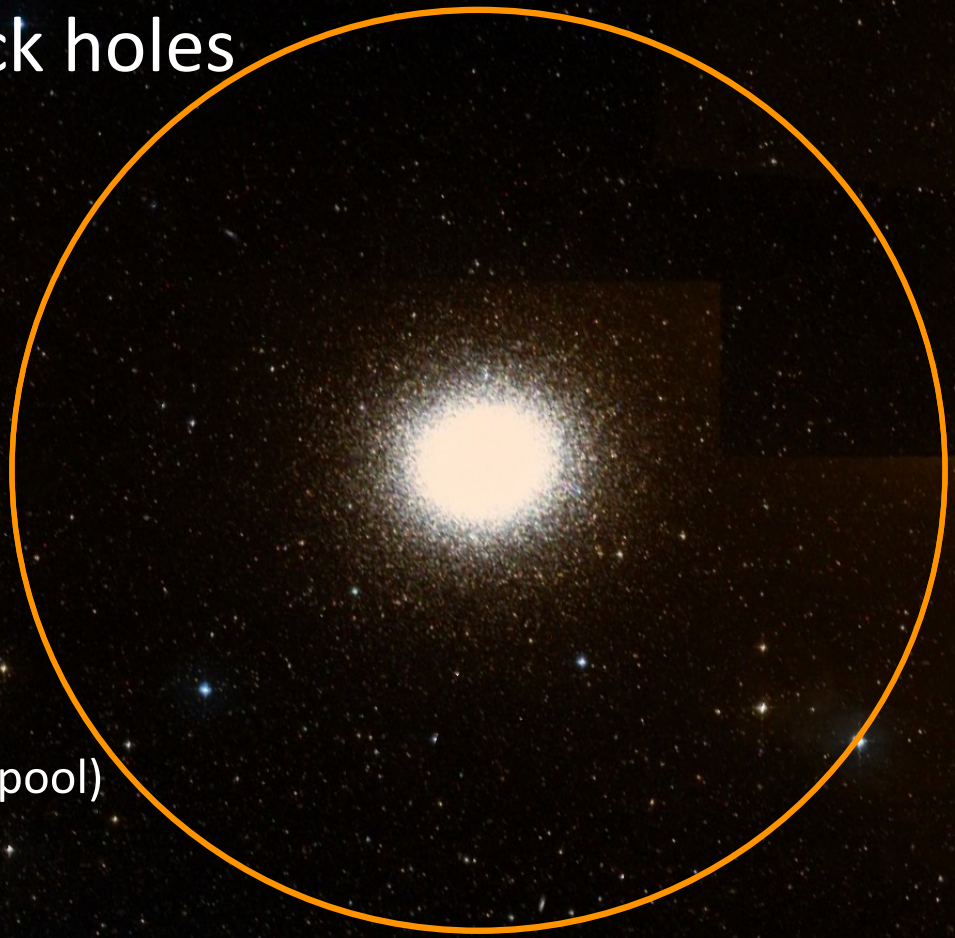
Are there stellar-mass black holes in the globular cluster ω Centauri ?



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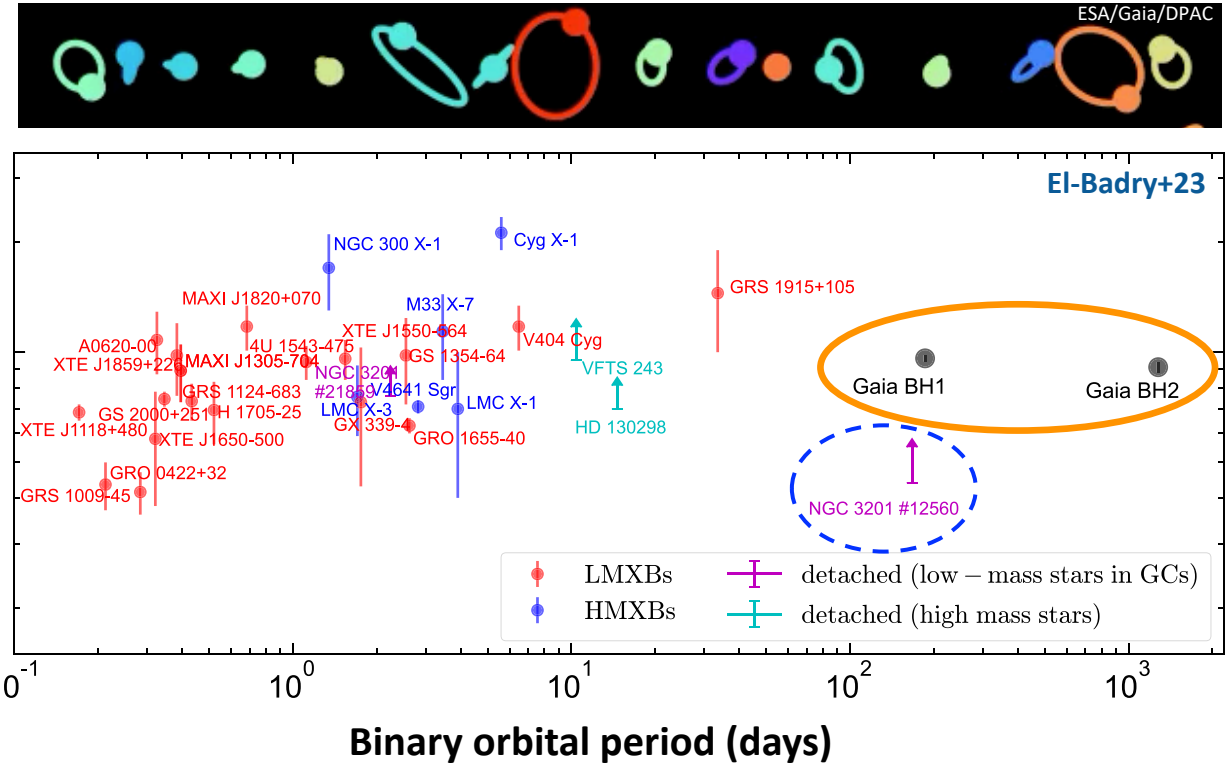
Background DSS2

Gaia DR3 astrometric orbits uncovered a new family of black holes
Star clusters may be their birthplace

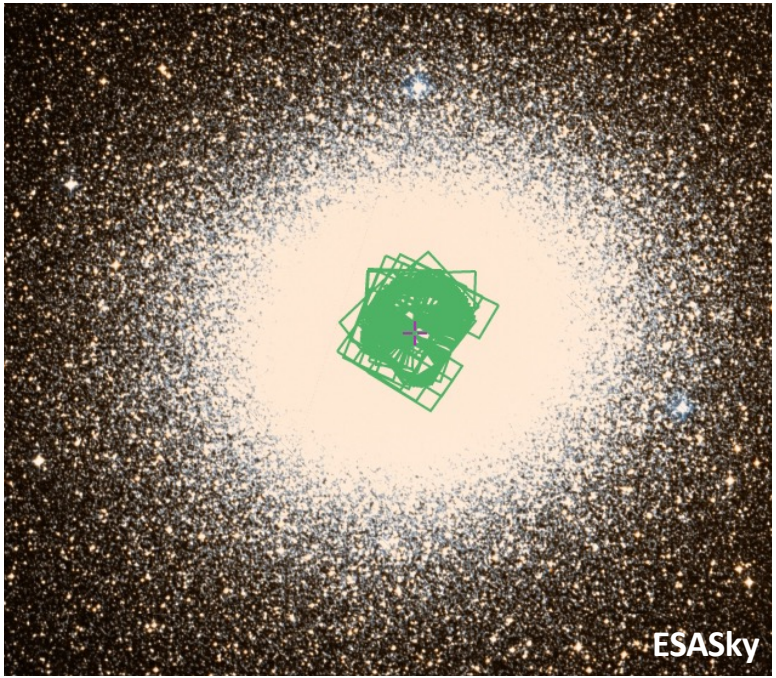
- In the field (<1.2 kpc)
- “Dormant”: no X-rays
- In “wide” binaries

- How and where do these form?
- Dynamical capture and exchange in Star clusters?



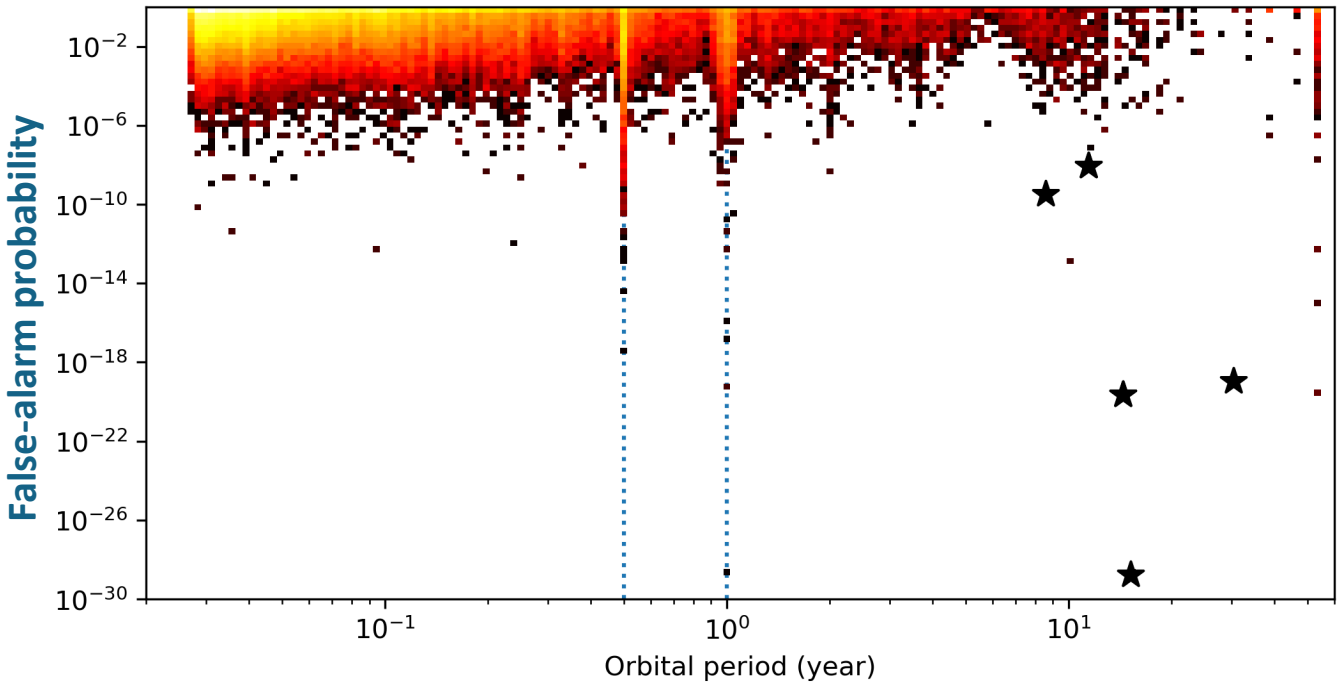
We search for stellar-mass black holes in the globular cluster ω Cen using Hubble Space Telescope (HST) astrometry

- Most massive known globular cluster in our galaxy (~10^6 stars)
- Idea: extract astrometric timeseries from HST WFC3/UVIS calibration observations and look for binary motion
- Project started in Q1 2021, partly funded through HST archival research program 16629
- Data: 13 years of repeated visits of ω Cen (~170 frames, a few arcminutes^2)
- Extracted ~160,000 astrometric timeseries



We used periodograms to identify binary candidates

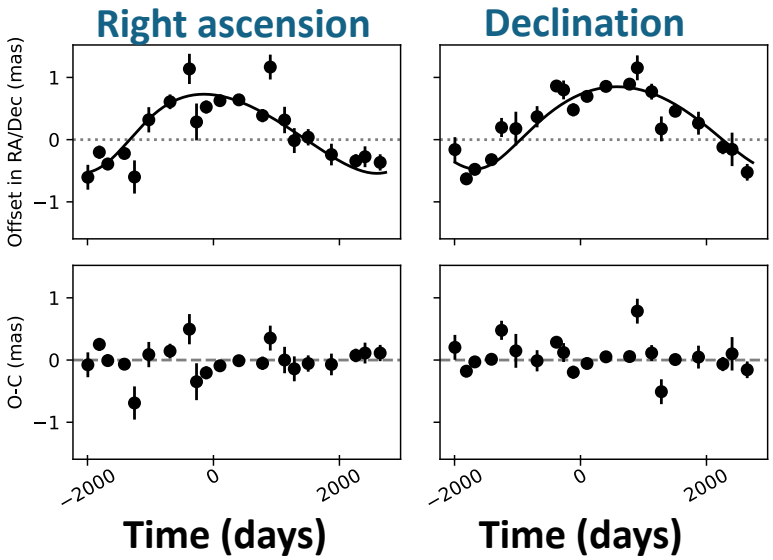
- Keplerian motion → periodic position offsets
- Analyse residuals of a 4-parameter-model fit (no parallax)
- *kepmodel* software (Delisle & Ségransan 2022)
- Discovery of 5 genuine binaries



We discovered 4 binaries in the cluster and 1 foreground binary

- Example: HSToC-4
- Period ~13 years
- Amplitude ~0.9 mas
- Primary mass ~0.8 Msun

- Companion mass (if dark) ~1.4 Msun
- If the companion were not dark, it must be even heavier



We determined preliminary Keplerian parameters and (dark) companion masses

Designation / ID	Period (yrs)	e	$a_{\rm photo}$ (mas)	M_1 ($M_\odot$)	M_2 ($M_\odot$)	$K_{\rm RV}$ km/s	
HSToC-1 / 143023	19 ± 8	< 0.3	0.9 ± 0.3	0.68 ± 0.03	$0.15^{+0.06}_{-0.05}$	~ 0.9	foreground
HSToC-2 / 212028	15 ± 3	0	0.91 ± 0.27	0.80 ± 0.01	$1.25^{+0.87}_{-0.70}$	~ 9	NS candidate?
HSToC-3 / 233697	8.8 ± 0.5	0.2 ± 0.2	0.47 ± 0.05	0.784 ± 0.005	0.77 ± 0.14	~ 6	
HSToC-4 / 290133	13 ± 2	0.3 ± 0.2	0.86 ± 0.08	0.78 ± 0.01	$1.36^{+0.36}_{-0.26}$	~ 10	NS candidate
HSToC-5 / 317591	11.5 ± 2.0	< 0.3	0.53 ± 0.07	0.75 ± 0.02	$0.71^{+0.23}_{-0.16}$	~ 7	

2 companions are likely white dwarfs

2 companions are either massive WDs, pairs of WDs, or neutron stars

Conclusions and Outlook

- We discovered the first astrometric binaries in ω Cen
- The Gaia Focused Product Release (FPR, Oct'23) on ω Cen indirectly confirmed 2 binaries
- At least one companion is a neutron-star candidate
- Our survey is sensitive to systems akin to Gaia-BH2 in ω Cen (0.9 mas at 3.5y)
- We demonstrated that astrometry is powerful for identifying massive, dark companions in star clusters
- Gaia DR4 will enable these searches on a much larger scale

Paper accepted in ApJ: https://arxiv.org/abs/2312.16186

Discovery of astrometric accelerations by dark companions in the globular cluster ω Centauri

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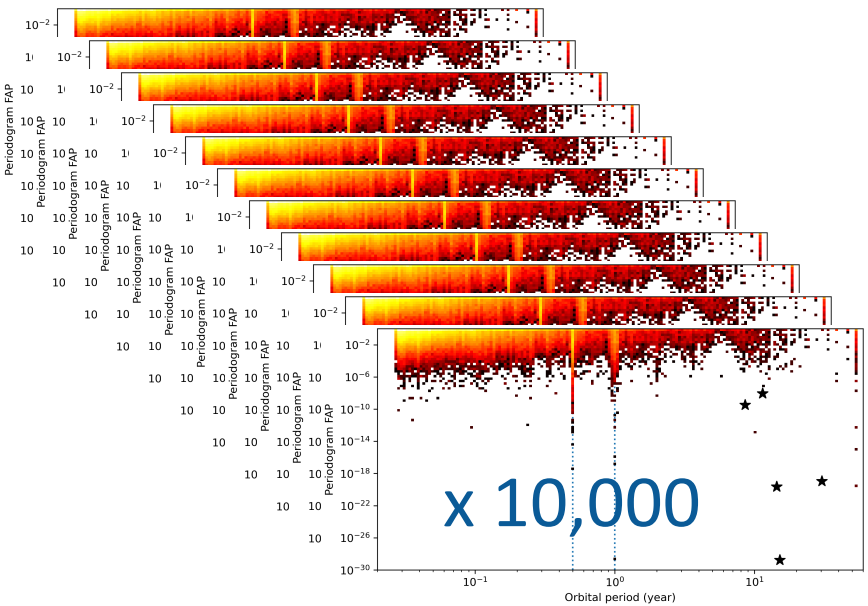
Outlook: We will prepare for computing the periodograms of the 2 billion astrometric timeseries to be released in Gaia DR4.



This has broad scientific and technical applications.

A dedicated traineeship is starting in March 2024 at ESAC in collaboration with the Gaia team and the SCI-S Data Science section.

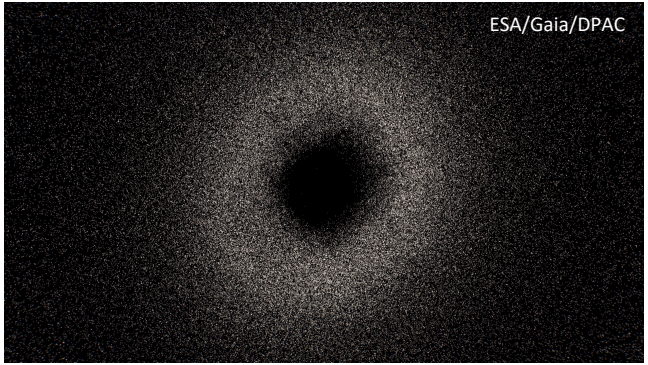
Gaia DPAC
Data Processing & Analysis Consortium

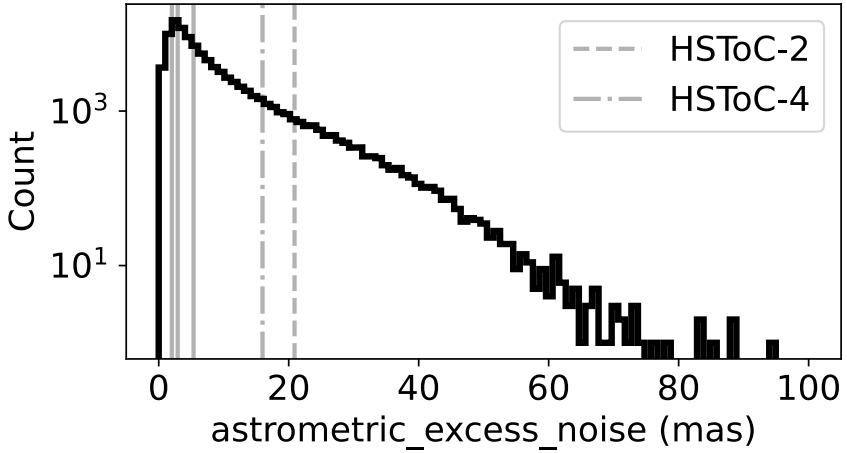
esa
ESA DATALABS

Backup slides

The Gaia Focused Product Release (FPR) on ω Cen confirms 2 binaries

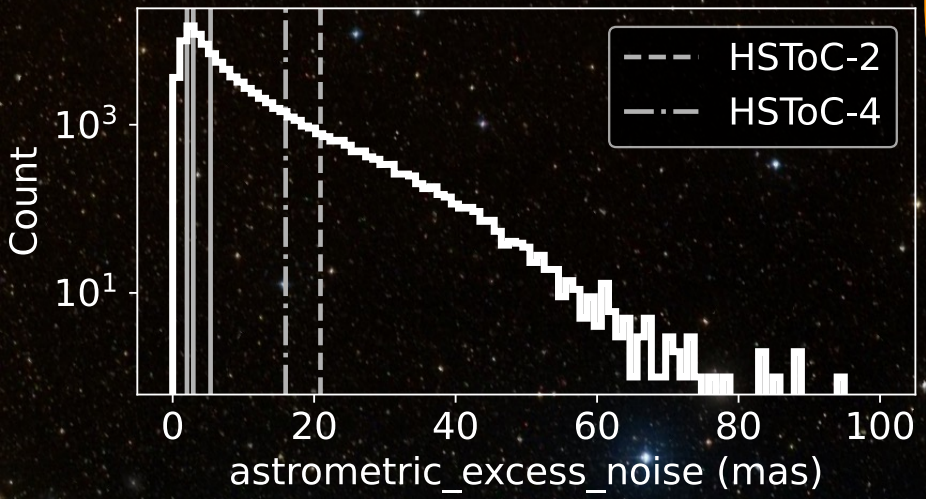
- Because of ω Cen's high density, none of the binaries was in Gaia DR3.
- But all of them are in the FPR! (Gaia collaboration, Weingrill+23)
- The 2 binaries with largest amplitude show elevated excess noise in Gaia FPR.





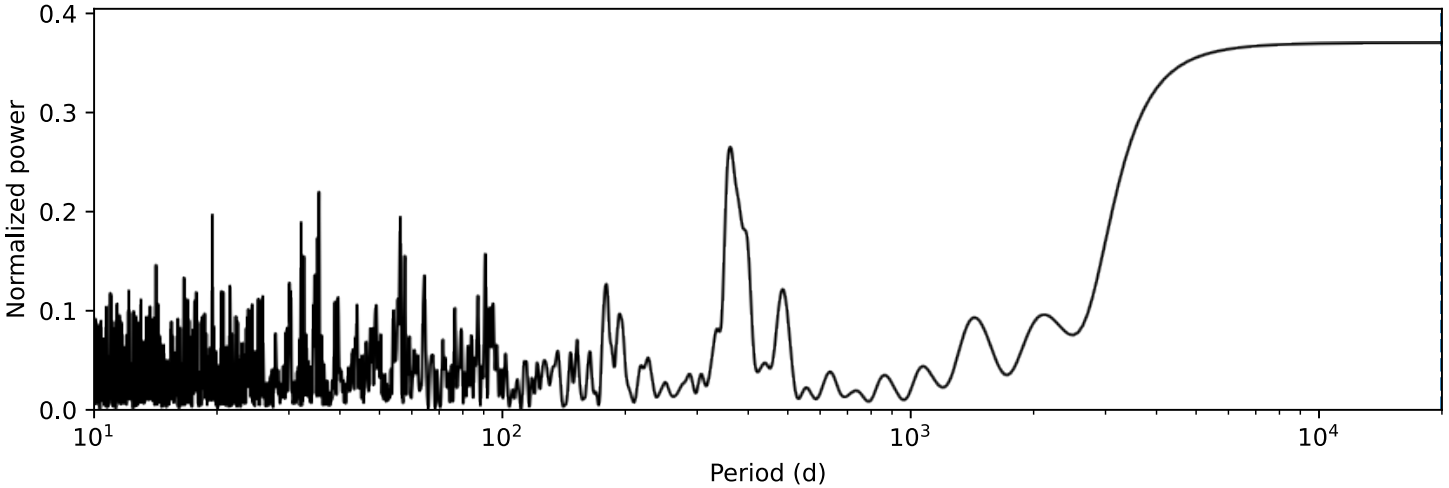
Outlook:

We will use the Gaia data in ω Cen to search for new binaries, e.g. by leveraging on the elevated excess noise.



DSS2

The 4-p periodogram of the foreground binary



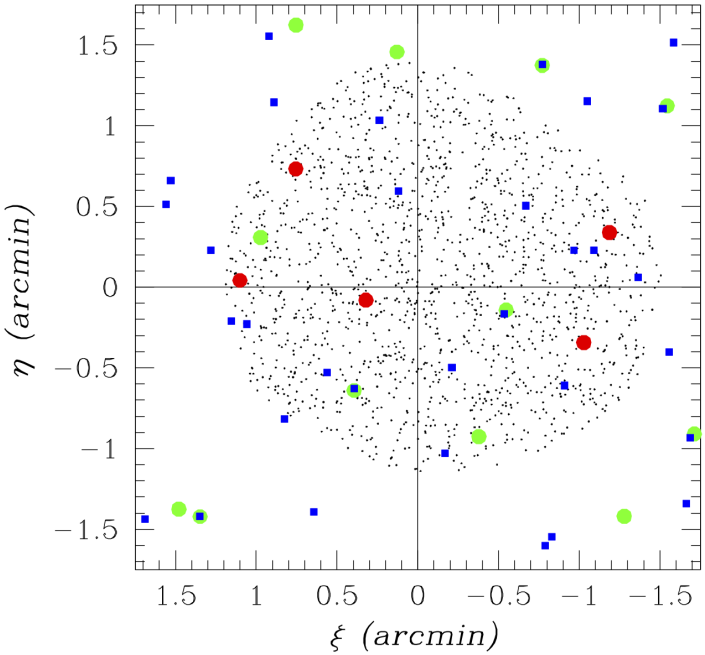
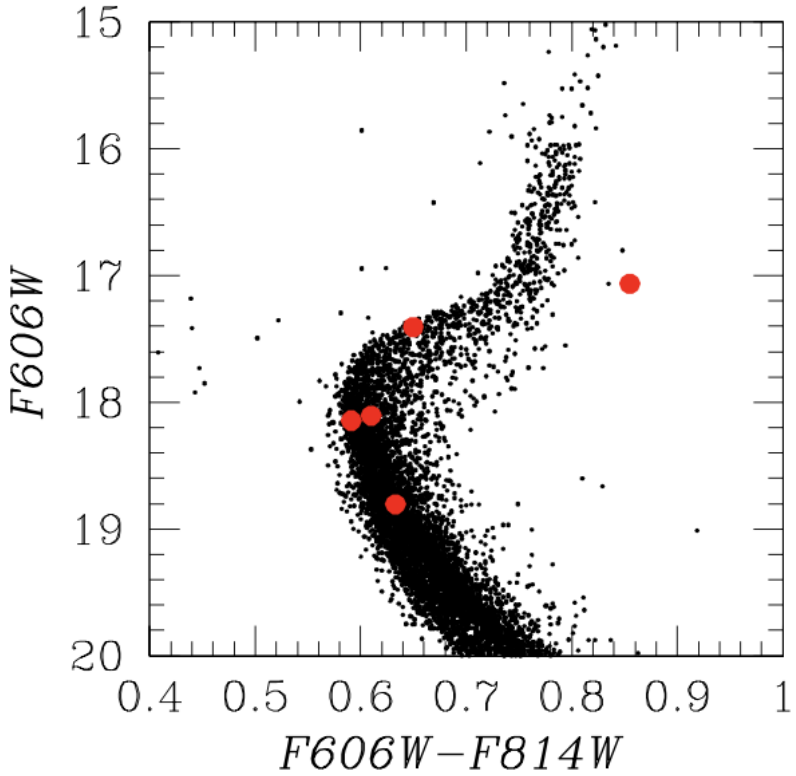
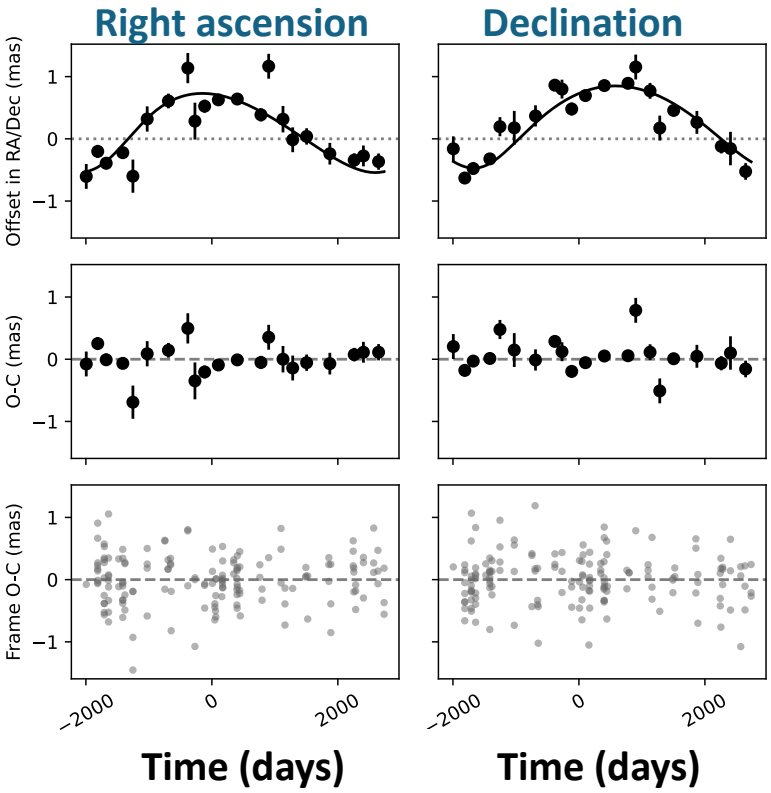
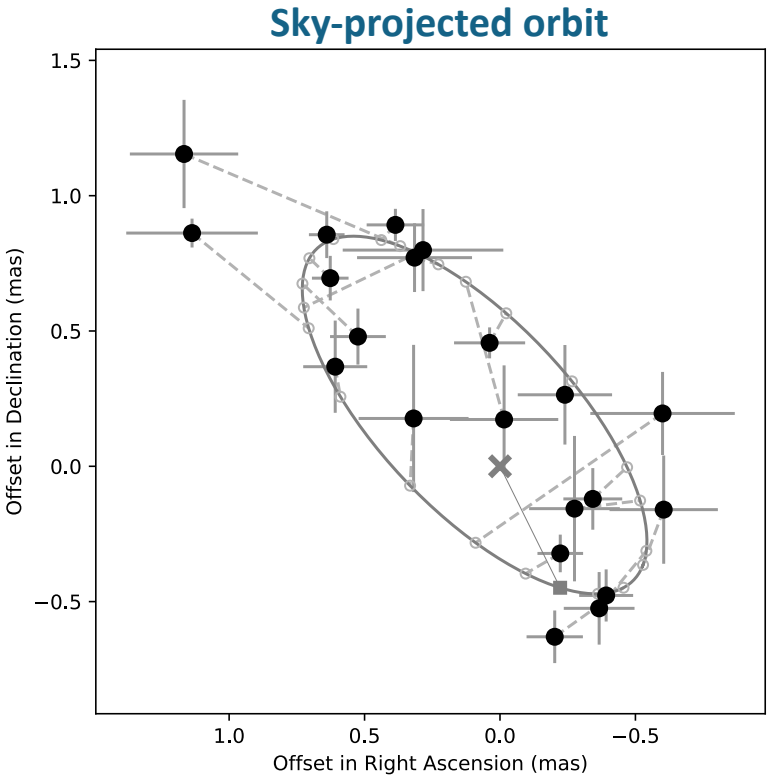


Figure 11. Distribution of rare objects in ω Cen. The center of the gnomonic projection is the best-known kinematic center of ω Cen. Black dots show randomly-chosen 7% of all program stars. Red points are oue newly-discovered binaries. The one in the upper-right quadrant is the foreground field binary. Green points indicate millisecond pulsars and blue ones X-ray sources.

Primary mass determination




Right ascension
Declination
Offset in RA/Dec (mas)
O-C (mas)
Frame O-C (mas)
Time (days)
Time (days)


Sky-projected orbit
Offset in Declination (mas)
Offset in Right Ascension (mas)