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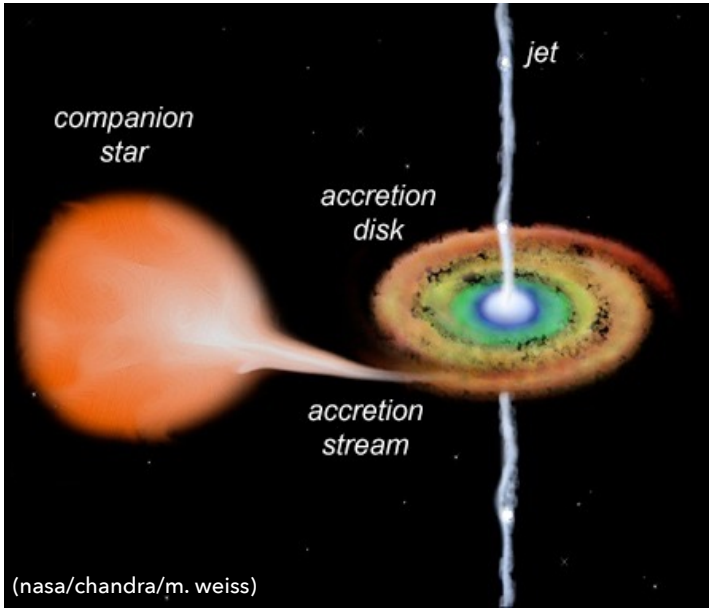
THE MAVERIC SURVEY: BLACK HOLES IN GLOBULAR CLUSTERS

COMPACT OBJECTS & GLOBULAR CLUSTERS



BH, NS, or WD with mass transferring companion

Accretion rate controls the energetics of the binary, more accretion means more X-rays

Dense clusters of ~10^4–10^6 old stars

~20 bright NS LMXBs in GCs — Much more common than field LMXBs (per mass)

BLACK HOLES IN GLOBULAR CLUSTERS?

No GC black holes? Explained by mass segregation, and violent 3-body + 4-body interactions ejecting BHs from the clusters

More recent candidate discoveries and theoretical predictions dispute this!

LIGO discoveries of BH-BH merger events have renewed interest in the frequency of BHs in GCs — In particular, how massive BH-BH binaries are formed

WHO CARES?

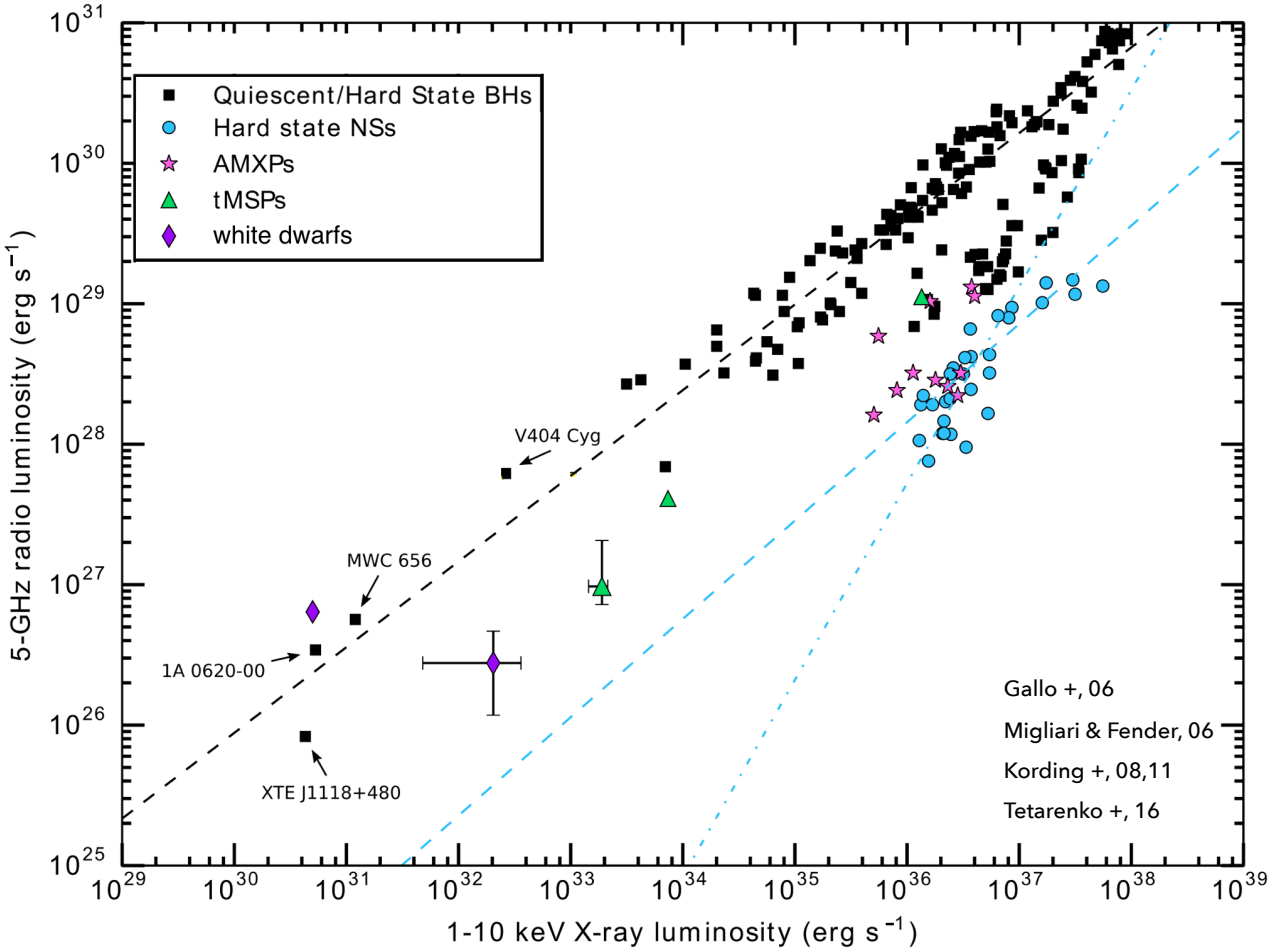
Most massive stellar-mass BH known previously only about 20 solar masses

Massive BH-BH binary co-evolution? Tricksy theorists think maybe, but it's complicated

Massive BH-BH binaries formed dynamically? If GCs retain BHs, likely that some BH-BH systems form dynamically

Also more confirmed stellar mass BHs would be nice!

FINDING BLACK HOLES



Ultimately want dynamical confirmation of BHs – but use Radio and X-ray to select inital candidates

This helps rule out neutron star or accreting white dwarf systems (but there are some imposters)

At low accretion rates BHs relatively more detectable in radio vs. X-ray

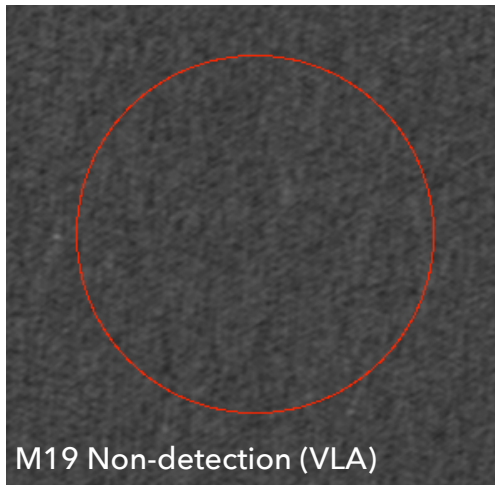
FINDING BLACK HOLES

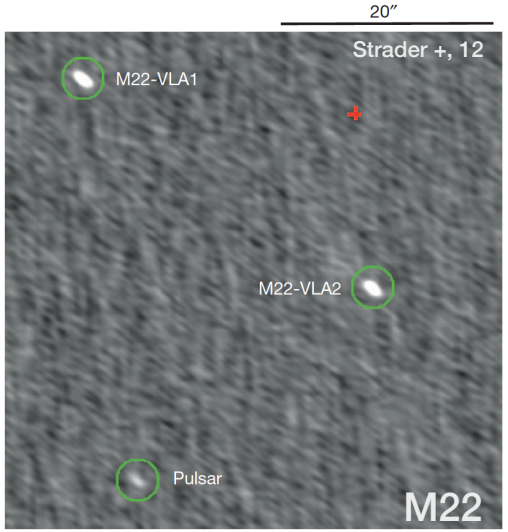
Image cluster cores looking for unresolved significant radio sources — BHs expected here

Changes in flux density (S) are related to changes in frequency (ν) by the spectral index (α),

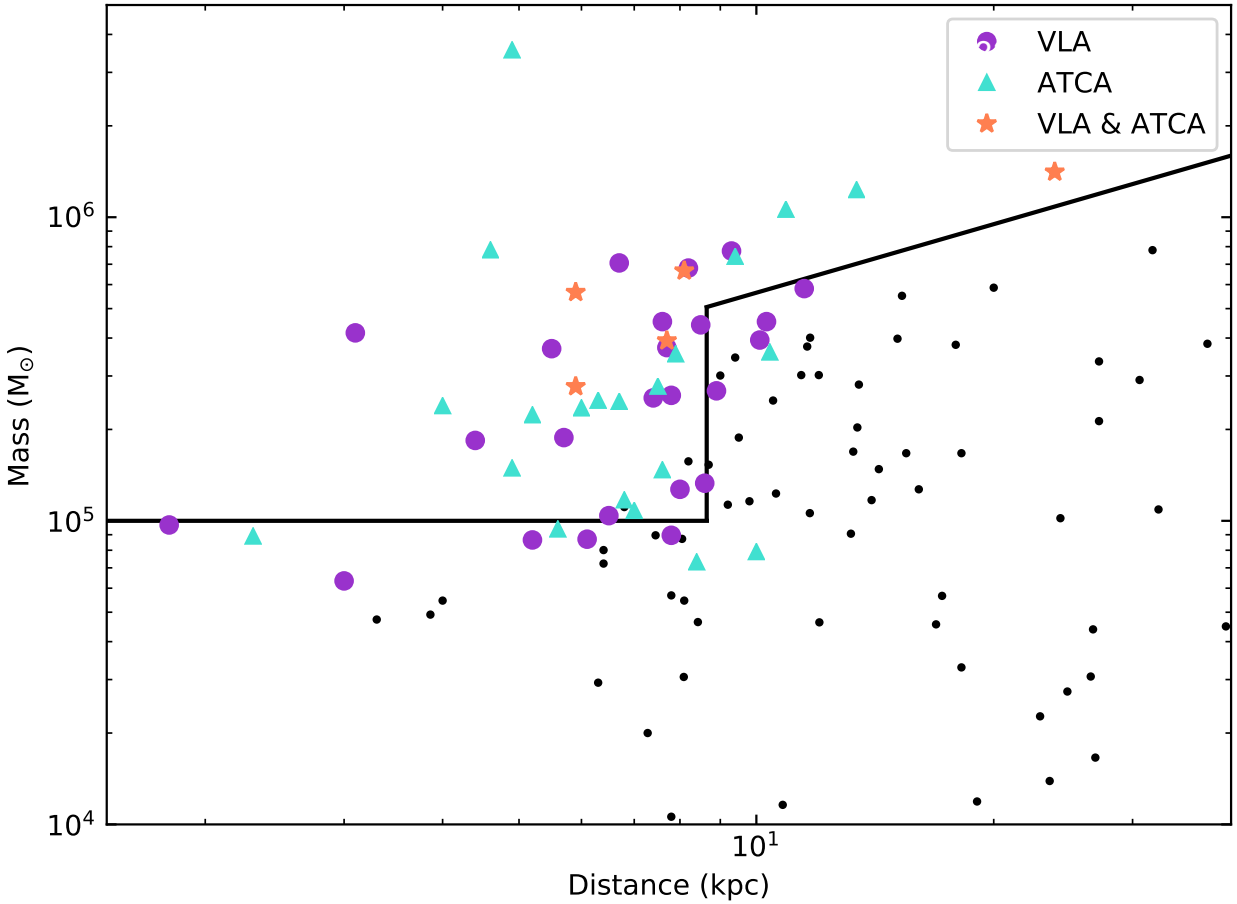
$$S \propto \nu^{\alpha}$$

Candidates should have $\alpha = 0$ (or close to it) due partially self-absorbed synchrotron — Helps rule out pulsars





CLUSTER SURVEY



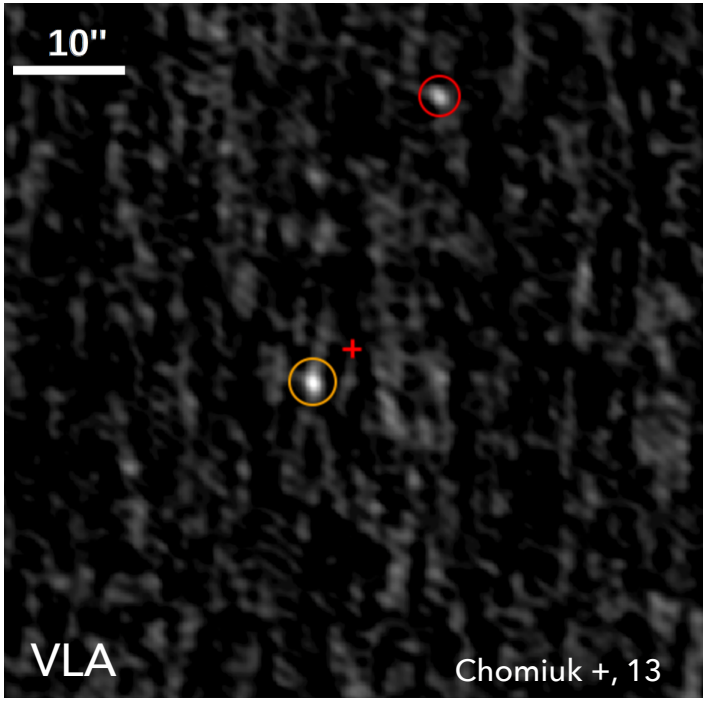
VLA survey of ~31 Milky Way GCs (including pilot study)

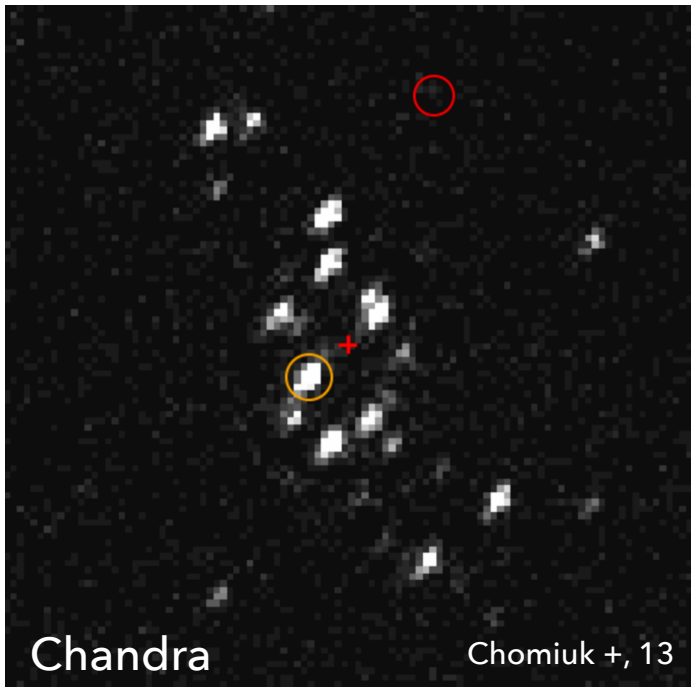
ATCA survey of ~26 southern Milky Way GCs

50 total (some VLA/ATCA overlap)

Want massive (enough)and close (enough) clusters!

M62 IN RADIO & X-RAY





M62-VLA1

Chomiuk +, 13

19.9 +/- 3.2 μJy (5 GHz)

18.1 +/- 2.3 μJy (7.4 GHz)

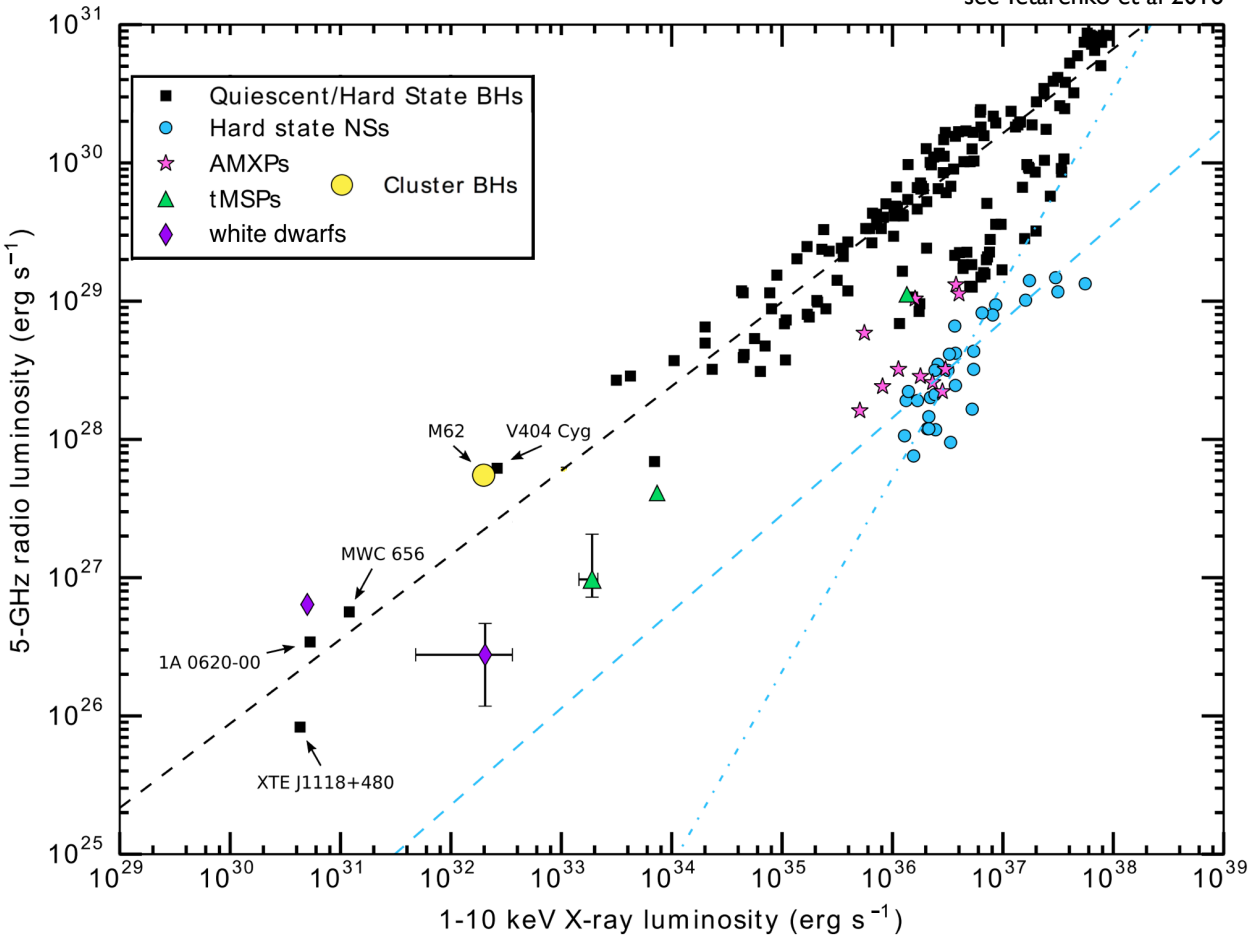
$\alpha = -0.24 +/- 0.42$

Unabsorbed $L_X = 5 \times 10^{32}$ erg/s

0.5 - 10keV

M62 RADIO/X-RAY CORRELATION

see Tetarenko et al 2016

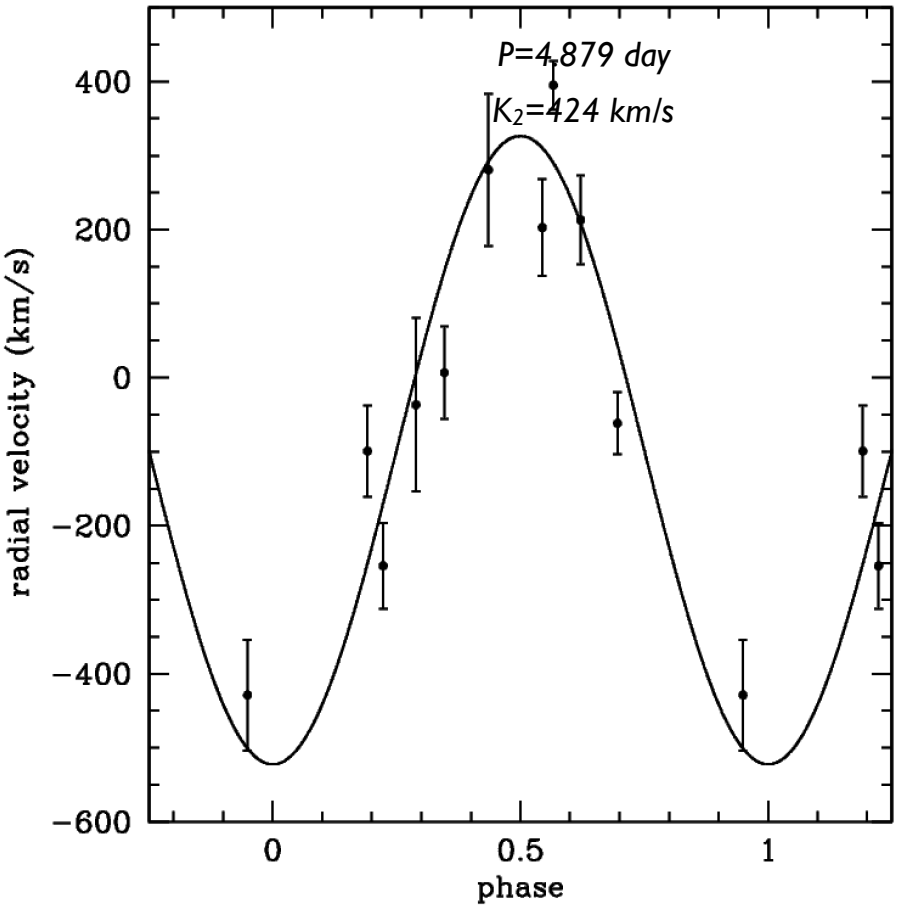


Simultaneous VLA & Chandra !

M62 candidate is very close to BH Lx-Lr relation!

Can we get mass limit?

M62 OPTICAL SPECTROSCOPY



Optical source at radio/X-ray position

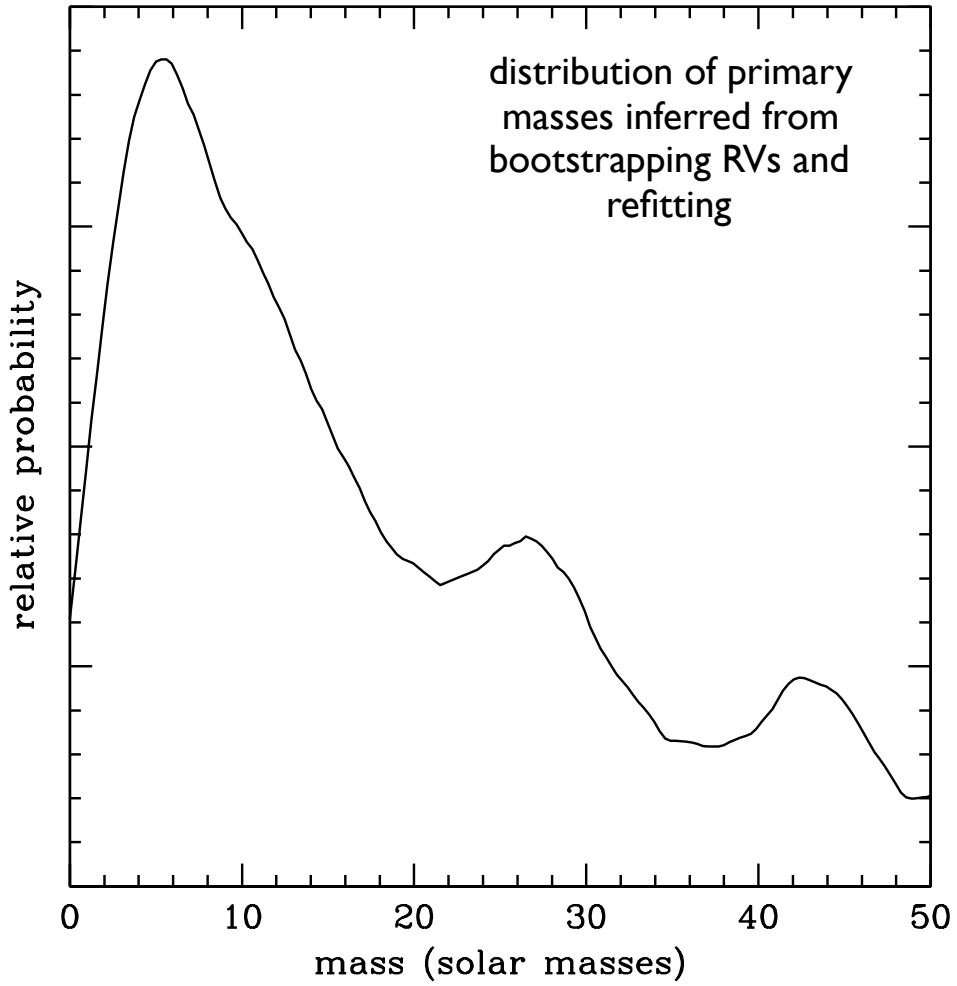
Giant with blue and H-alpha excess, double peaked

HST spectral observations of counterpart recently completed!

More epochs needed to determine orbit

$$f(M) = \frac{PK_2^3}{2\pi G} = \frac{M_1 (\sin i)^3}{(1+q)^2}$$

M62 OPTICAL SPECTROSCOPY



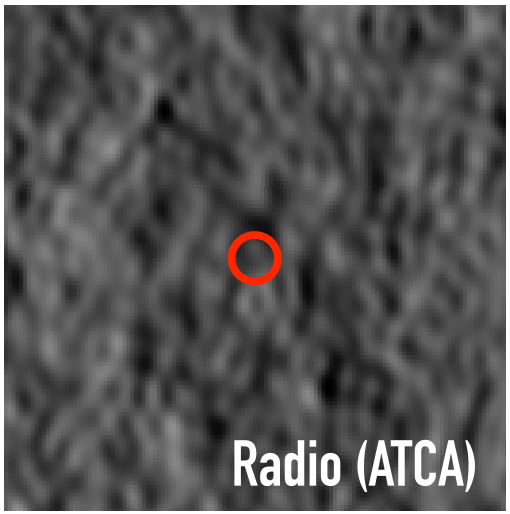
Mode ~ 5 M_{sun}

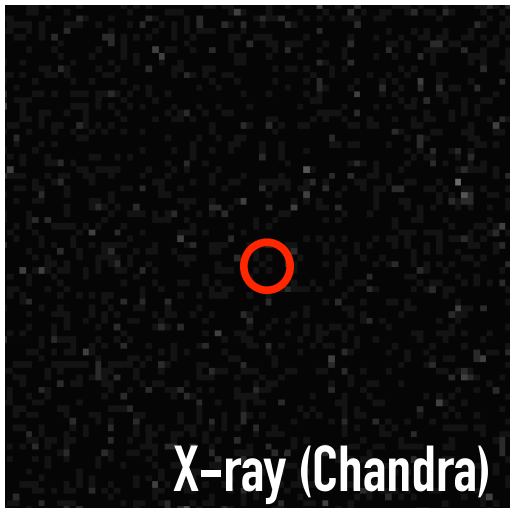
Median mass ~ 17 M_{sun}

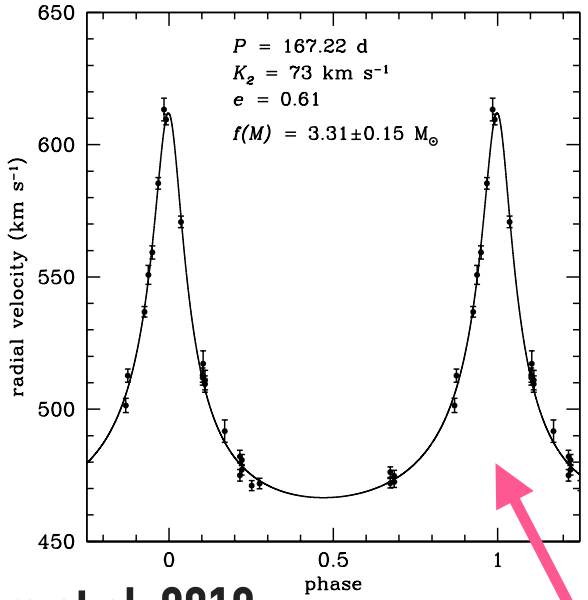
1/3 chance of Mass > 25 M_{sun}
Ligo-esque source

More RV measurments upcoming with MUSE — Approved for 15 1hr epochs in 2018A (4 completed already)

BLACK HOLE IN NGC 3201







Discovered in MUSE radial velocity survey, see Giesers et al. 2018

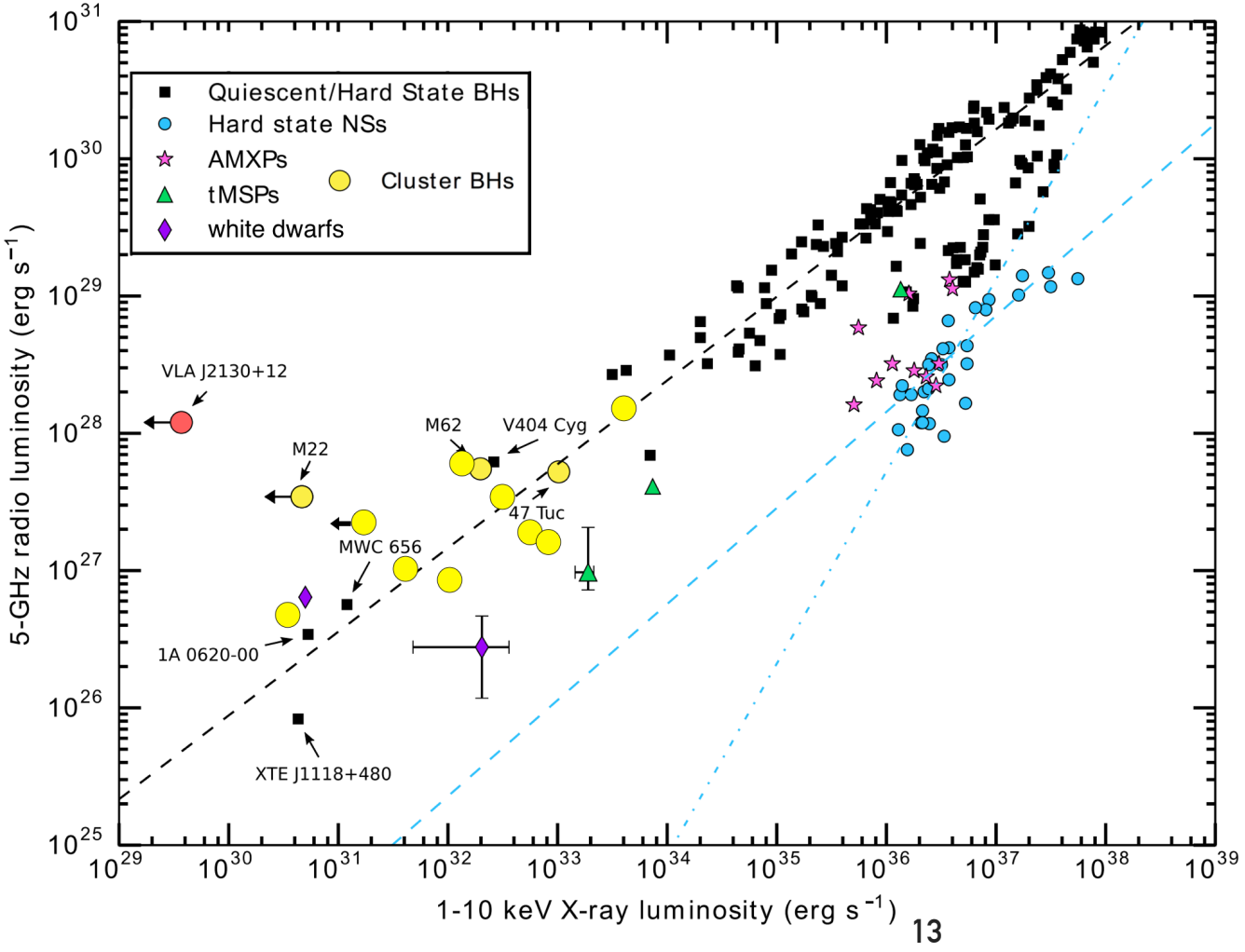
SOAR + MUSE

Minimum mass = $4.58 \pm 0.18 M_\odot$

Most likely = $6.1^{+10.2}_{-1.4} M_\odot$

First dynamical confirmation of BH in GC — we know they are out there!

OTHER CANDIDATES



12 candidates, hopefully more!

Other interesting objects found! Potential tMSPs, active binaries

Mass limits for presence of IMBHs (Tremou +, 2018 accepted)

Radio source counts, evidence of GC count excess?

OTHER CANDIDATES AND FUTURE!

12 new candidates found out of the 50 clusters surveyed — more expected

Continue with multi-wavelength follow up

With ngVLA we want to use our method to find other Milky Way black hole candidates — See Laura + Tom's poster!

Refine current sample with better proper motion measurements

Better sensitivity = potentially more GC candidates!