A Radio Continuum Search for Black Holes in the Milky Way Globular Cluster M10

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Abstract

Globular clusters are expected to have large populations of stellar mass black holes at early stages in their lifetimes. These stellar-mass black holes were long predicted to have been kicked out of globular clusters through gravitational interactions during the clusters' evolution, with some clusters retaining only one or two stellar-mass black holes and most clusters not retaining any. Using deep radio continuum observations from the Jansky Very Large Array, our group has identified and published non-central radio sources in two Milky Way globular clusters (two in M22; one in M62) that are best explained as stellar-mass black holes accreting from binary companions. We have now begun a systematic radio continuum survey of Milky Way globular clusters to establish statistics on the frequency of stellar-mass black holes and determine which cluster parameters influence the presence of black holes. Here we present the preliminary findings of our radio search for black holes in one of these sample clusters, M10.

Background

The presence of stellar-mass black holes in globular clusters (GCs) was long thought to be rare. However, in a recent survey of five Milky Way GCs our team discovered stellar-mass black hole candidates in M22 (Strader et al. 2012a) and M62 (Chomiuk et al. 2013), with strong candidates in additional clusters observed subsequently. Further, since many black holes are not actively accreting and thus undetectable at radio wavelengths, the true black hole population may be much larger. Are these findings a lucky accident, or is the fate of stellar-mass black holes in GCs misunderstood?

With our current small sample, it is impossible to generalize our initial results to the overall population of Milky Way globular clusters. We have begun a VLA survey of 28 Milky Way GCs to assess the frequency of stellar-mass black holes in GCs, and identify which cluster characteristics correlate with the presence of detectable black holes.

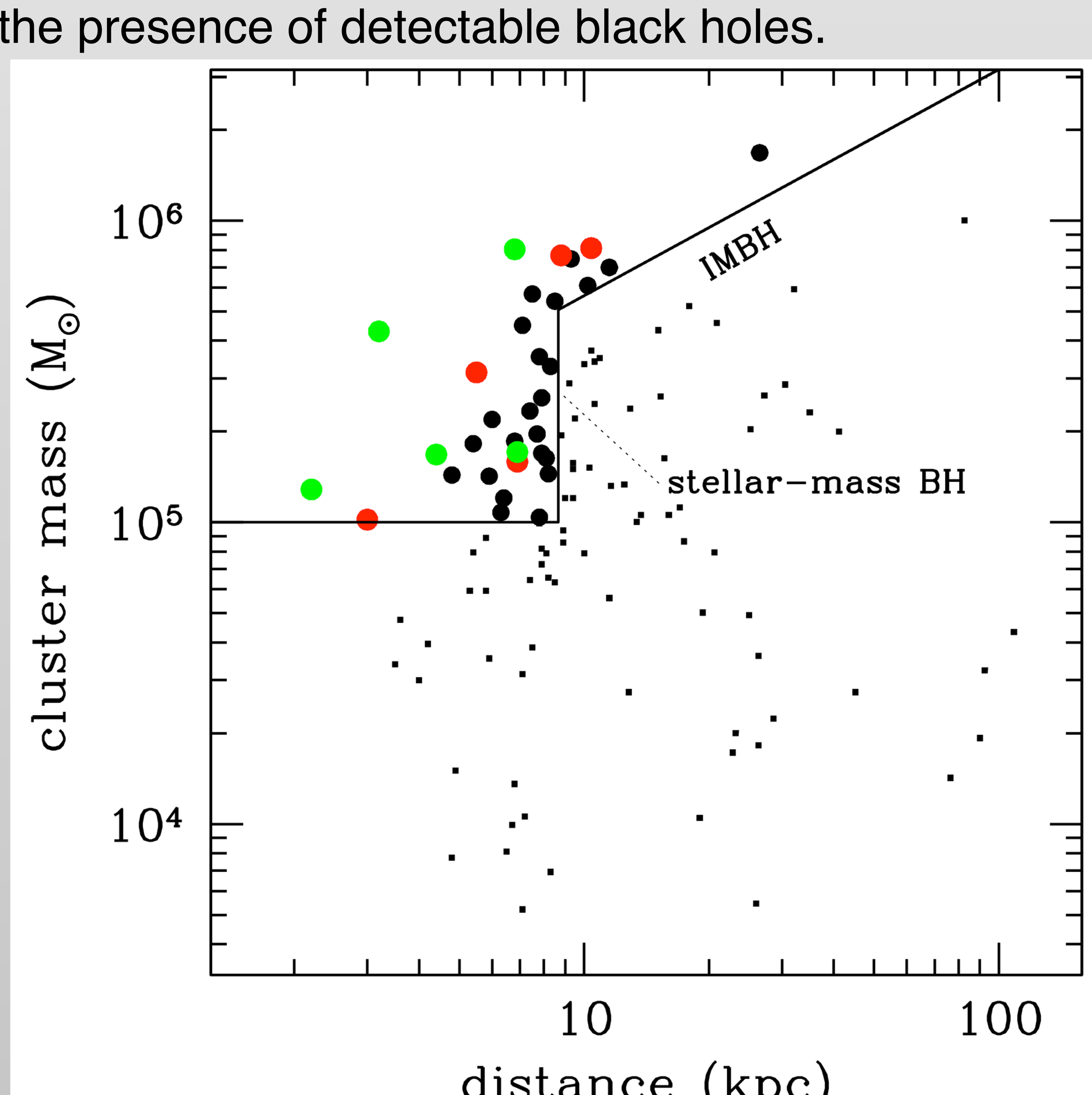

Figure 1: Plot of cluster mass vs. distance for all Milky Way globular clusters with δ > -35°, illustrating our selection criteria for the survey. Cluster targets are above and left of the solid line. Constraints are provided by cluster mass, sensitivity to stellar-mass black holes (distance), and potential for intermediate black hole discovery. Black circles are targets without complete data; red and green circles are VLA targets without and with candidate black holes, respectively.

Implications

If black holes are in fact common in globular clusters, it could have important scientific implications:

- Finding new stellar-mass black holes
- Measuring accurate physical parameters for black holes.
- Studying the physics of low-luminosity accretion.
- Discerning differences with field stellar-mass black hole formation and mass function.
- Increased likelihood of black hole-black hole/pulsar binaries — sources of gravitational waves!

Method

The cluster cores will be imaged to locate any sources of radio emission. Candidate black holes will be identified through their flat radio spectra, and followed up with optical and X-ray observations to rule out the presence of a neutron star or accreting white dwarf (Figure 2).

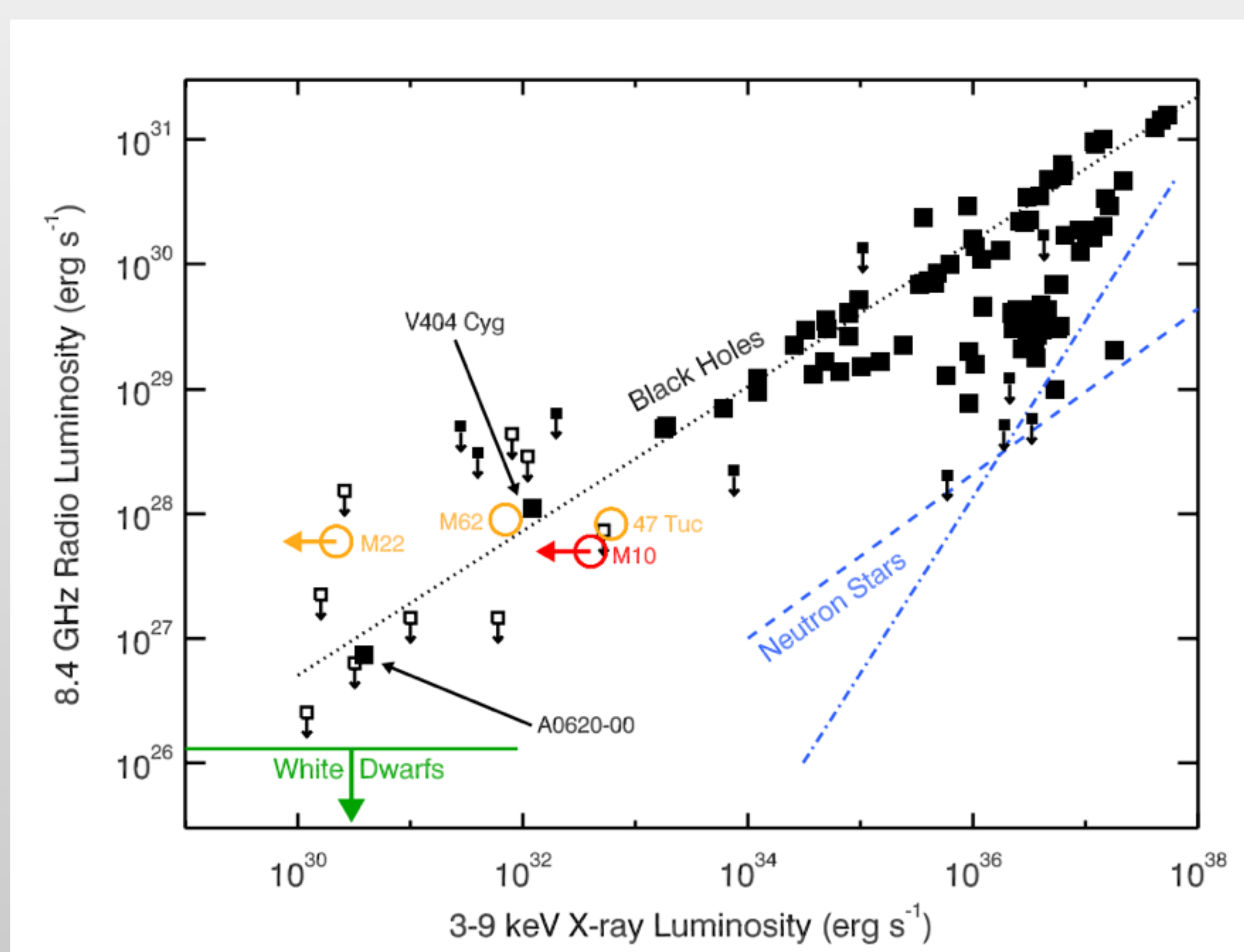

Figure 2: Radio—X-ray correlation for stellar-mass black holes. Black hole L_R expected to be over an order of magnitude higher than white dwarf and neutron star radio L_R for a given L_X. The orange circles represent our black hole candidates in M22, M62, and 47 Tuc. Filled objects have simultaneous data; unfilled points are non-simultaneous. Black points are from the literature (Gallo et al. 2012). The dotted black line is the black hole correlation (Gallo et al. 2006); blue lines are two possible neutron star correlations (Migliari & Fender 2006); solid green line is the upper limit for white dwarfs (Körding et al. 2008). Figure adapted from Chomiuk et al. (2013).

Results: M10

A significant flat spectrum radio source, M10-VLA1, was found near the cluster core. It is 0.2 pc from the cluster photometric center, with a mean flux density of 26μJy, observed at an average frequency of 6 GHz.

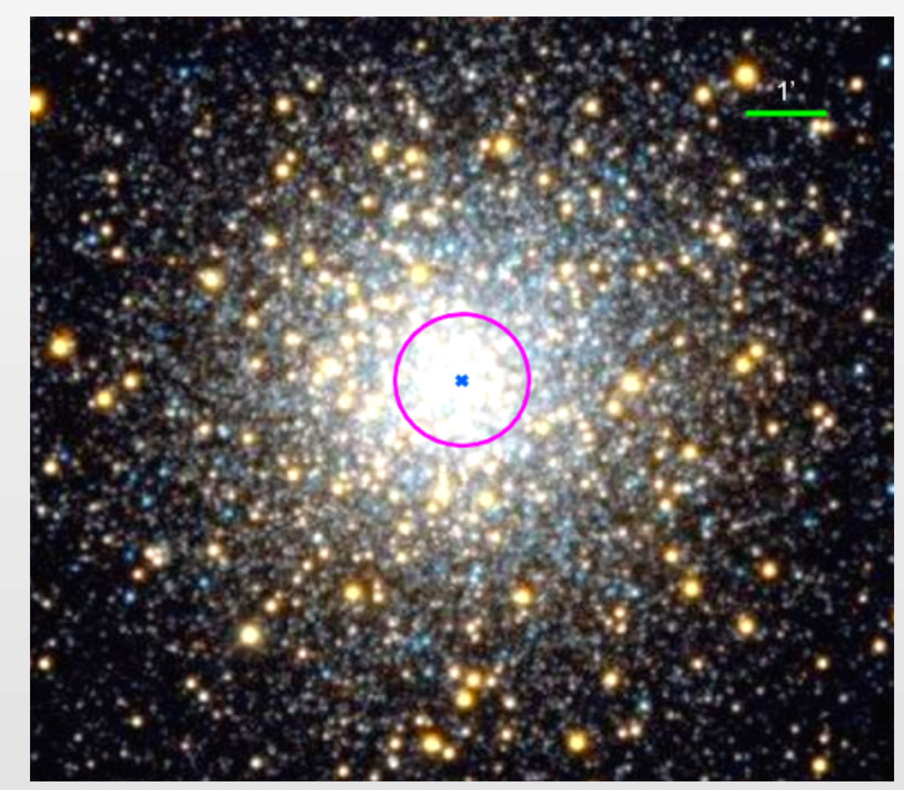

Figure 3: Optical image of M10, showing the photometric center (blue cross) and cluster core (magenta circle). Candidate M10-VLA1 is 10'' from the photometric center. The 1' scale bar is 1.3 pc. M10 is a metal-poor cluster ([Fe/H] = -1.6) of typical mass (2 x 10^5 $M_\odot$) with a moderately large core radius of 1 pc (46''), and 4.4 kpc from the Sun. Image credit: Till Credner, Sven Kohle (Bonn University), Hoher List Observatory.

HST images of the candidate location reveal an optical counterpart, a *V* = 17.2 star at the base of the red giant branch.

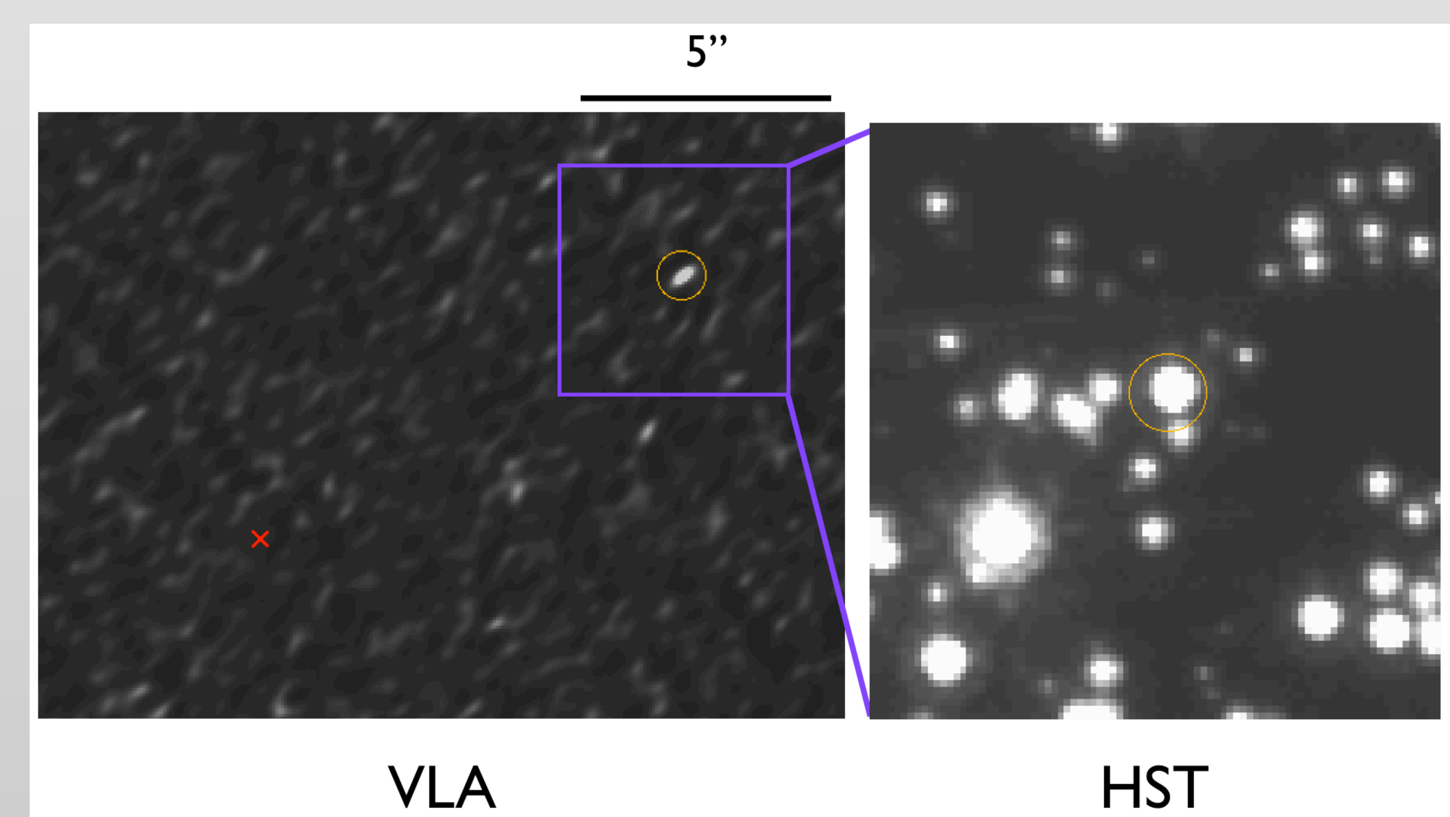

Figure 4: VLA radio (left) and *HST* (right) images of the center of M10, showing the candidate black hole M10-VLA1 (orange circle). A red cross marks the cluster photometric center. The candidate optical counterpart in the *HST* F814W (*I* - band). The 5'' scale bar is 0.1 pc.

There is no archival *Chandra* data available for M10, but we have obtained simultaneous *Swift* observations which provide a 3σ upper limit of 6.1 x 10^{32} erg/s, assuming a photon index of 2 (Figure 2). We have approved *Chandra* time to observe the candidate in order to completely rule out a white dwarf or neutron star as the compact companion.