Ultraluminous X-ray Sources in Extragalactic Globular Clusters

Authors: Kristen Dage(1)*; Steve Zepf(1); Mark Peacock(1); Arash Bahramian(1, 2); Thomas Maccarone(3); Arunav Kundu(4)
*kcdage@msu.edu

1. Physics and Astronomy, Michigan State University, East Lansing, MI, United States. 2. International Centre for Radio Astronomy Research – Curtin University, Perth, WA, Australia. 3. Texas Tech University, Lubbock, TX, United States. 4. Eureka Scientific, Oakland, CA, United States.

Abstract

The question whether globular clusters host black holes has been of longstanding interest. This interest has grown dramatically with the LIGO detection of merging black holes, as black hole mergers formed in globular clusters is one of the leading explanations for these LIGO sources. Determining whether black holes are common in globular clusters (GCs) has been an observational challenge. One of the most successful ways to identify candidate black holes in globular clusters is to identify globular cluster X-ray sources with very high luminosities that are much greater than the Eddington limit for neutron stars (known as ULXs). A number of ULXs have been found within extragalactic globular clusters, and are candidate accreting black holes. We study spectral properties of GC ULXs over a large span of *Chandra* observations. **We find that the globular cluster ULXs seem to follow one of two distinct trends: one group show a strong correlation between the accretion disk temperature and X-ray luminosity, while another group show no change in disk temperature with significant variations in X-ray luminosity.** We discuss how these observational results impact our understanding of the nature of these sources.

Globular Cluster ULXs

A number of ULXs have been found within extragalactic globular clusters.

- Optical spectroscopy of RZ2109 (NGC 4472) reveals a broad, bright [OIII] emission line. This, and the absence of hydrogen emission implies a **white dwarf donor.**
- GC ULXs studied in optical also note an absence of hydrogen emission.

Many ULX studies focus on objects in star forming galaxies. However, GC ULXs are different than ULXs in star forming galaxies in many ways:

- The donor star in GC ULX sources has to be a lower mass star; donors in star forming galaxies are typically hydrogen rich, massive stars.
- The binaries in GCs are likely to be formed dynamically, while massive stars in star forming ULXs probably formed and evolved together.
- Compact objects in GCs form a very long time ago, whereas in star forming galaxies, the compact object in the ULX was just recently formed.
- **GC ULXs appear to be more readily explained by having BH primaries.** Further observations will test this conclusion and perhaps answer the question whether merging BHs in GCs are a viable source for the LIGO events.

X-Ray Luminosity and Spectral Parameter

Our sample of GC ULXs comes from matching high L_x sources to optical globular clusters (see Figure 1), combined with previously studied sources.

To characterize X-ray variability, we plot the luminosity of these sources versus the most well constrained best-fit spectral parameter. Figure 2(a) (right) shows L_x versus Γ, Figure 3(a) (lower right) shows L_x versus T_{in}.

- Most of the sources indicate that the **luminosity is tied to the best fit spectral parameter** in some way.
- Two sources (lower right: orange, purple) show that the **changes in L_x are not linked to the best fit parameter**. Also note their inner temperature is well below 1keV.

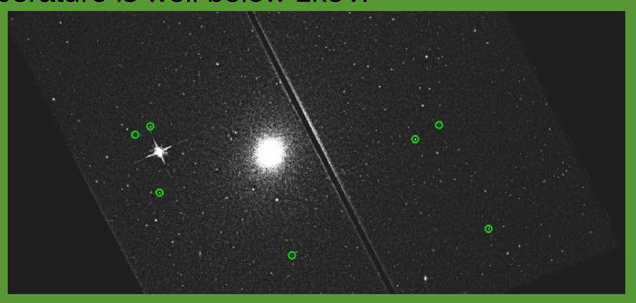

Figure 1: regions of log10(L_x)>38. 5 that matched with globular clusters overlaid on Hubble ACS image of NGC 4472

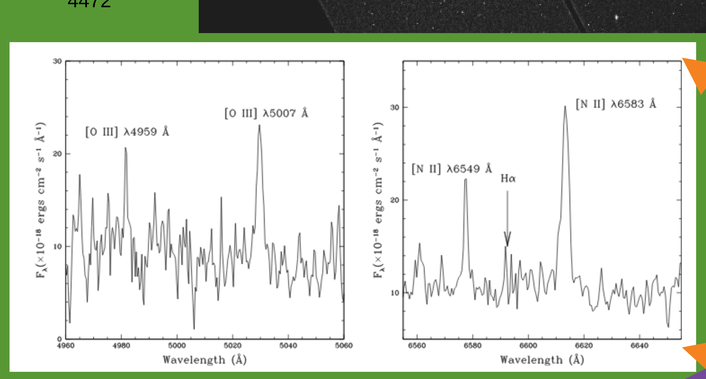

Figure 3 (b): Optical emission spectrum from GC ULX in 1399.

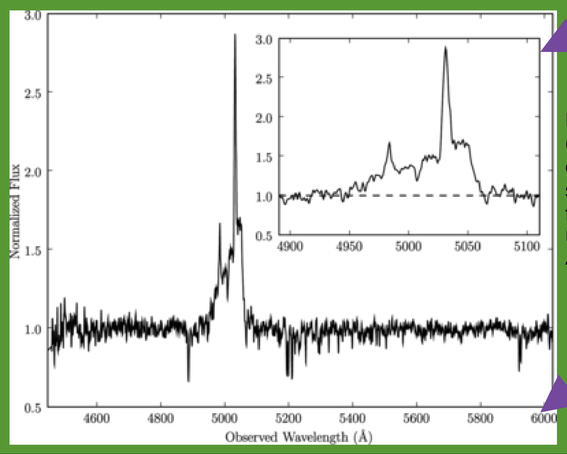

Figure 3 (c): Optical emission spectrum from GC ULX in 4472.

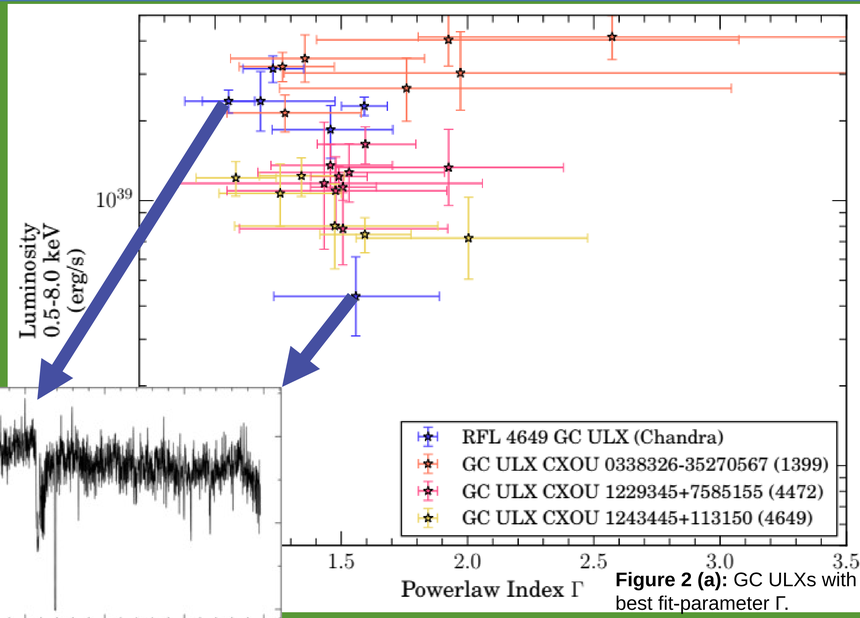

Figure 2 (a): GC ULXs with best fit-parameter Γ.

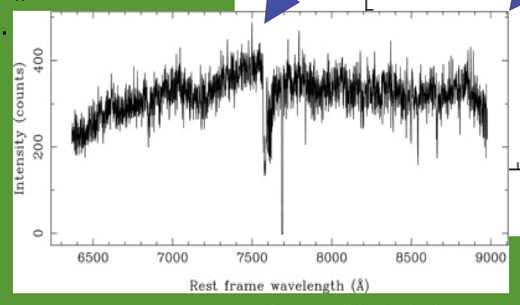

Figure 2 (b): Optical emission spectrum from GC ULX in 4649.

An X-Ray-Optical Emission Correlation?

Three of these sources have published optical spectra:

- Two of these sources have **emission lines and show very similar behavior in X-ray** (Figure 3 (b,c), below-left)
- The third has **no emission** beyond the cluster continuum and behaves differently from the first two. (Figure 2 (b), above-left)
- This indicates that **there may be a link between the behavior in X-ray and the presence of optical emission** in the system.

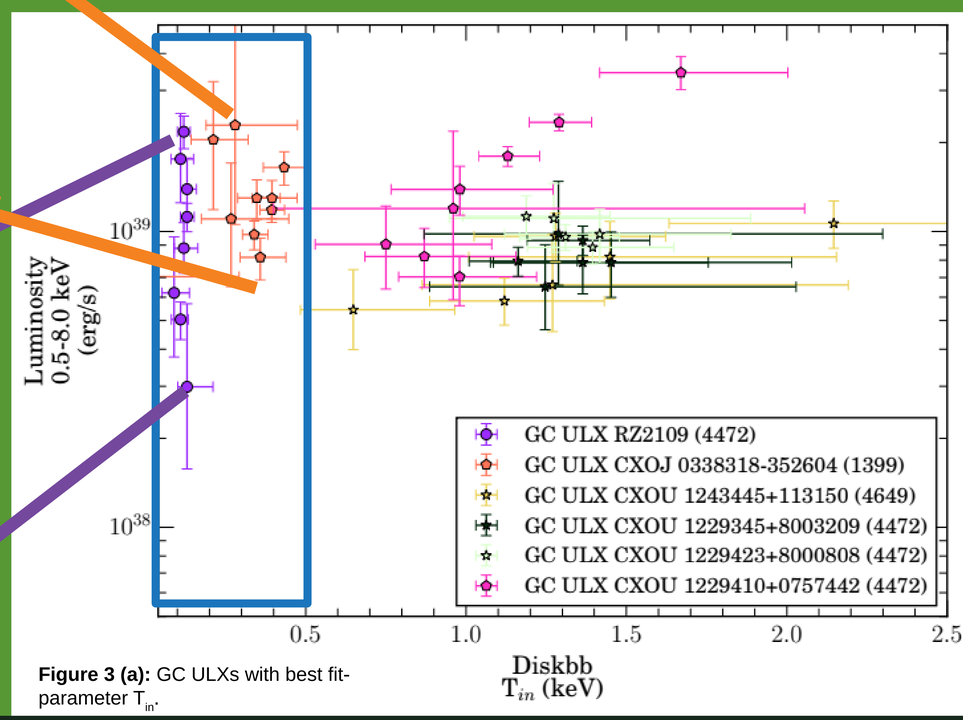

Figure 3 (a): GC ULXs with best fit-parameter T_{in}.

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