X-ray Binaries in Terzan 5 and the Galactic Center

C. O. Heinke (Northwestern), R. Wijnands (U. Amsterdam), J. E. Grindlay (Harvard), H. N. Cohn, P. M. Lugger (Indiana),
P. D. Edmonds (SAO), D. Pooley (UC Berkeley), W. H. G. Lewin (MIT)
cheinke@northwestern.edu

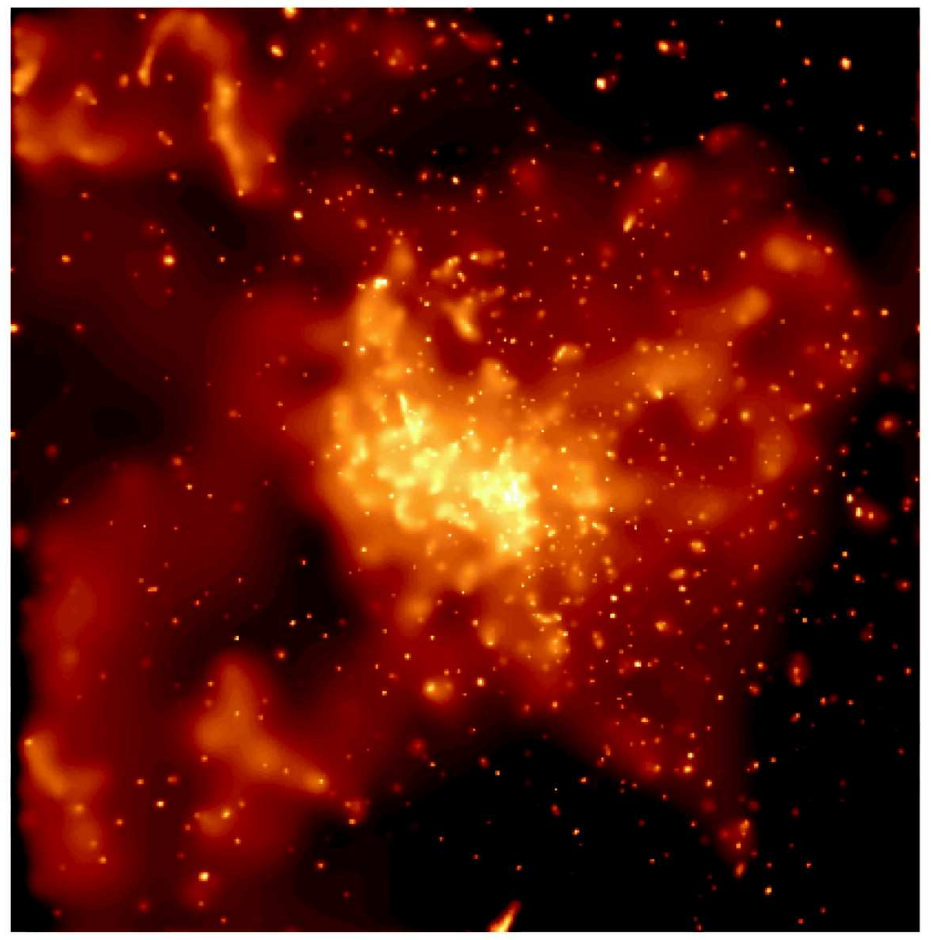
What is the nature of the low-luminosity, hard-spectra sources in globular clusters, and in the Galactic Center?

X-ray sources with relatively hard spectra and luminosities $L_X = 10^{31}$-10^{33} have been identified in globular clusters (e.g., 47 Tuc, Grindlay et al. 2001) and in the Galactic Center (Muno et al. 2003). Both groups of X-ray sources have been suggested (Grindlay et al. 1995, Muno et al. 2004a) to be members of the group of CVs known as intermediate polars (IPs), where the accretion flow is dominated by the magnetic field of the white dwarf. In this poster we test these assertions by comparing the spectral hardness ratios of each group to each other and to known bona fide intermediate polars.

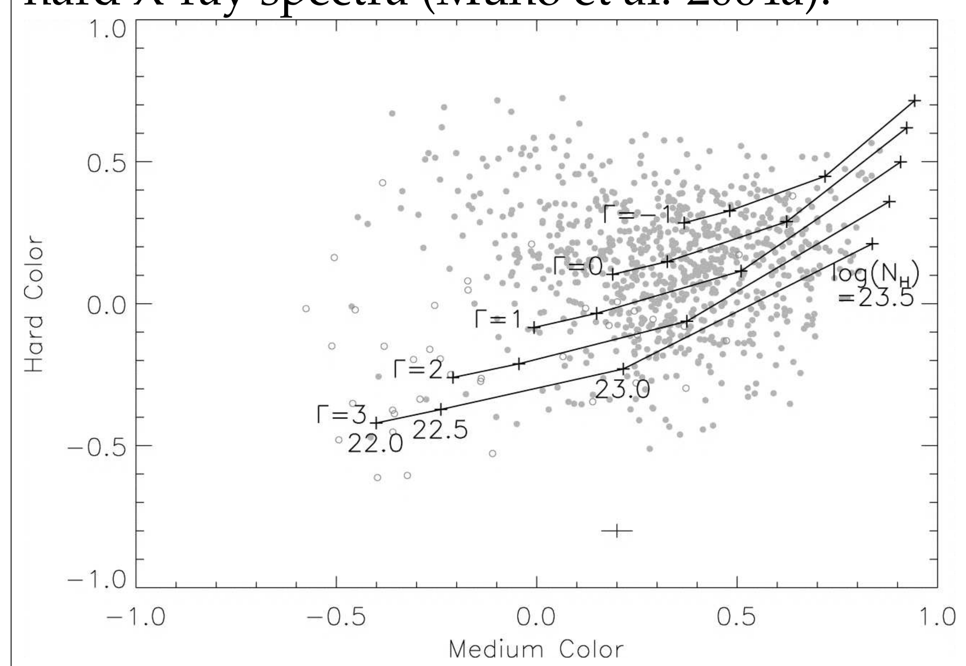
Are globular cluster X-ray sources intermediate polars? Bright X-ray binaries (consisting of accreting neutron stars) have long been known to be overproduced in globular clusters compared to the rest of the Galaxy (Katz 1975). Predictions have also been made for overproduction of cataclysmic variables (CVs) in globular clusters (e.g. di Stefano & Rappaport 1994), which were supported by the discovery of faint X-ray sources coincident with H-α bright, blue variable objects (Cool et al. 1995). Yet few dwarf novae outbursts have been seen from globular clusters, nor are bright novalike CVs seen (Shara et al. 1996). This motivated Grindlay et al. (1995) to suggest that most CVs in globular clusters are magnetic in nature, with the magnetic field of the white dwarf truncating the inner accretion disk of the CV and thus dramatically reducing the incidence of dwarf novae. This suggestion was supported by spectroscopy of some globular CVs (Grindlay et al. 1995, Edmonds et al. 1999), although the optical magnitudes of these CVs suggest lower mass transfer rates than in typical IPs (Edmonds et al. 2003).

Are Galactic Center X-ray sources intermediate polars?

Deep Chandra observations of the Galactic Center revealed a population of 2000 centrally concentrated X-ray sources with luminosities L_X (2-8 keV)= 10^{31-33} ergs s^{-1} (Muno et al. 2003).



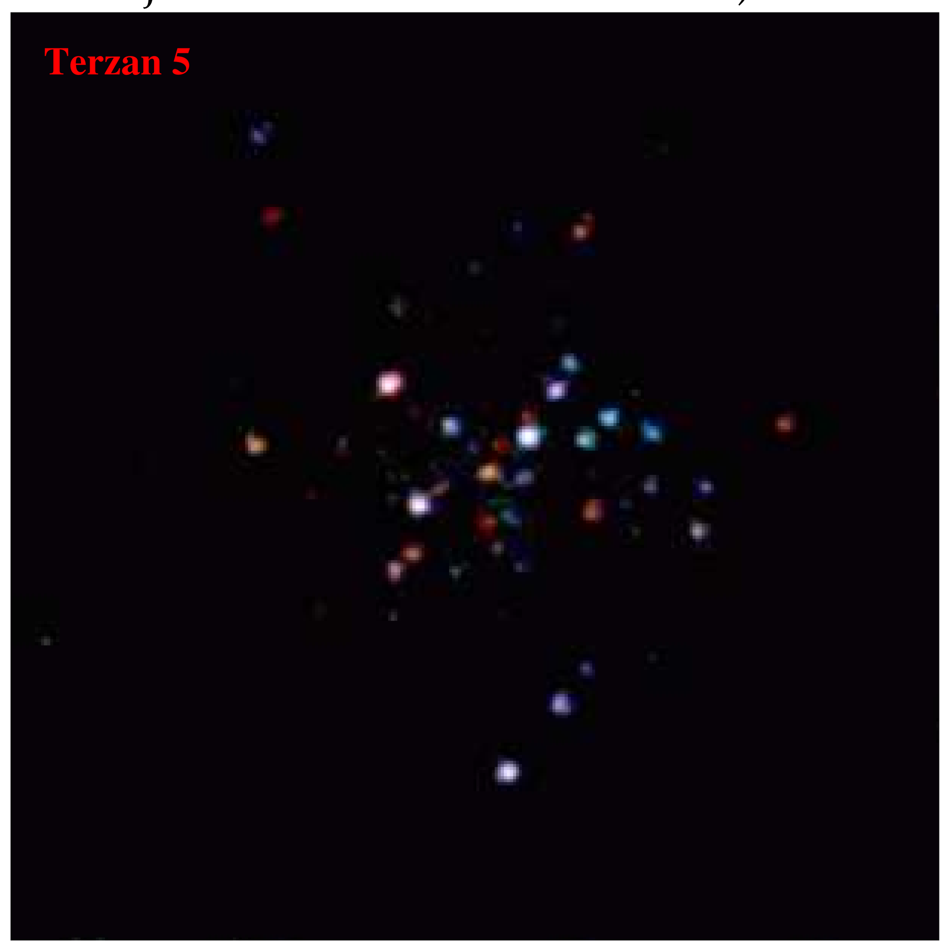
The hard X-ray spectra of these sources (consistent with absorbed powerlaws of photon index 0-1) suggested that they might be magnetic CVs or high-mass X-ray binaries (in quiescence), two classes with relatively hard X-ray spectra (Muno et al. 2004a).



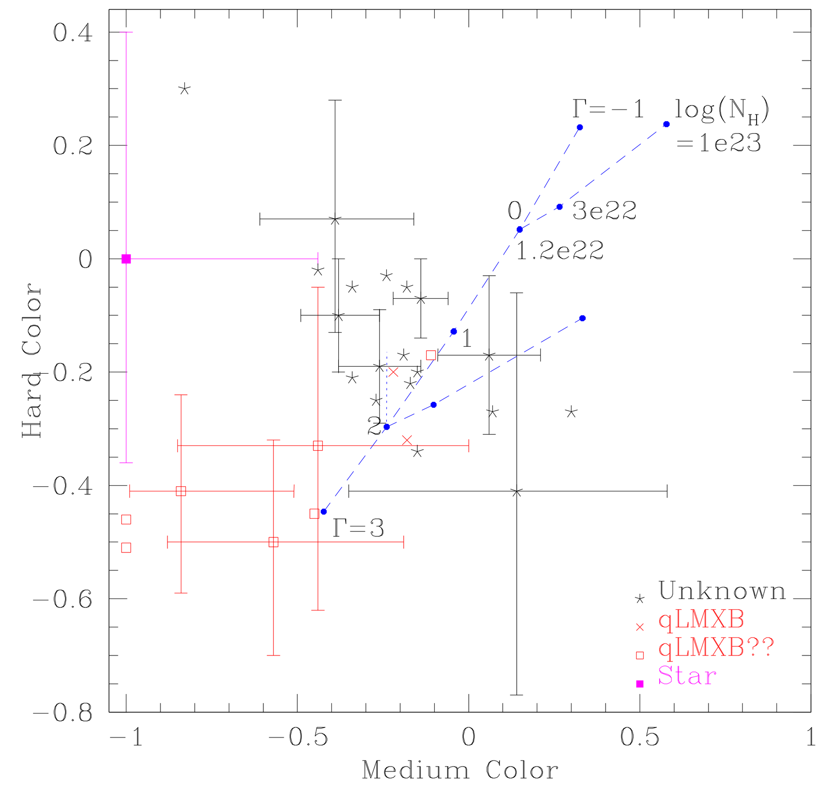
A few of the Galactic Center objects were found to have regular periods, from 300 s to 4.5 hrs, supporting these interpretations (Muno et al. 2004b). Recently, Laycock et al. (2005) have shown that a sample of these sources are fainter than K=15, and thus must have spectral types later than B0, supporting an IP nature.

X-ray Sources in Terzan 5

Terzan 5 is a dense globular cluster, of nearly solar metallicity, with the richest population of X-ray sources so far studied with Chandra (28 have L_X(0.5-2.5 keV) $> 10^{32}$ ergs s^{-1}). Its detected X-ray sources are probably dominated by quiescent LMXBs with soft spectra (dominated by blackbody-like radiation from the cooling neutron star), and CVs with hard spectra, as seen in other globular clusters (e.g. Heinke et al. 2003; but see Wijnands et al. 2005 for caveats).



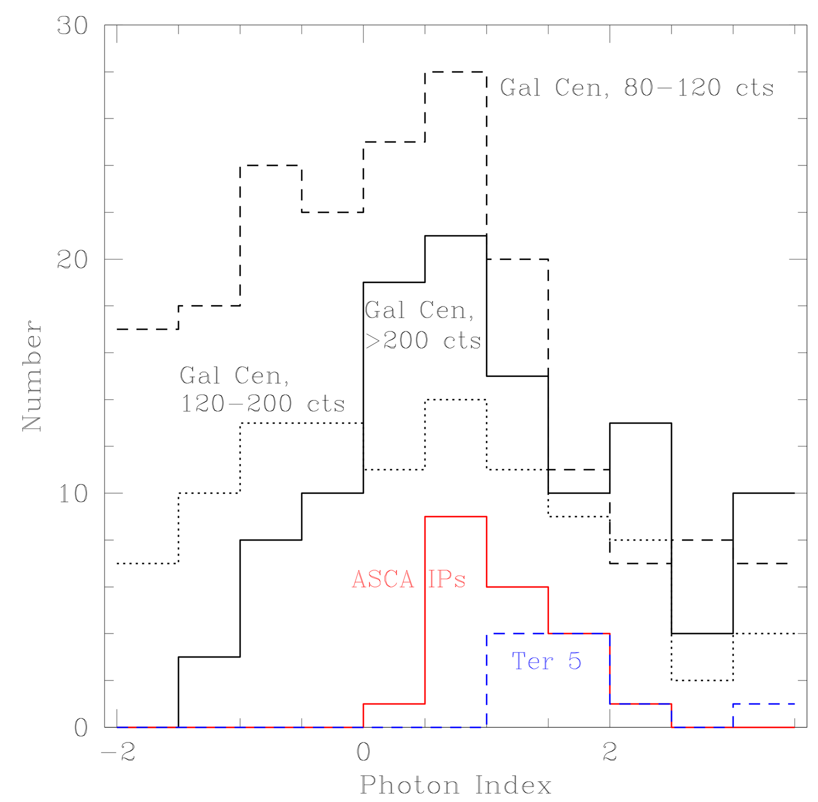
A color-color diagram for Terzan 5 (below, compare for Gal Cen left) shows the observed source colors, and predicted colors for powerlaw spectra of different photon indices, increasing N_H, and increasing Fe line equiv. width (dotted, up to 1.6 keV).



ASCA Observations of IPs

Surprisingly, the hardness ratios of the Terzan 5 hard X-ray sources are substantially softer than those for the Galactic Center X-ray sources (typical inferred photon indices ~1 vs. 0). This suggests that only one group may be spectrally consistent with being IPs. Which group?

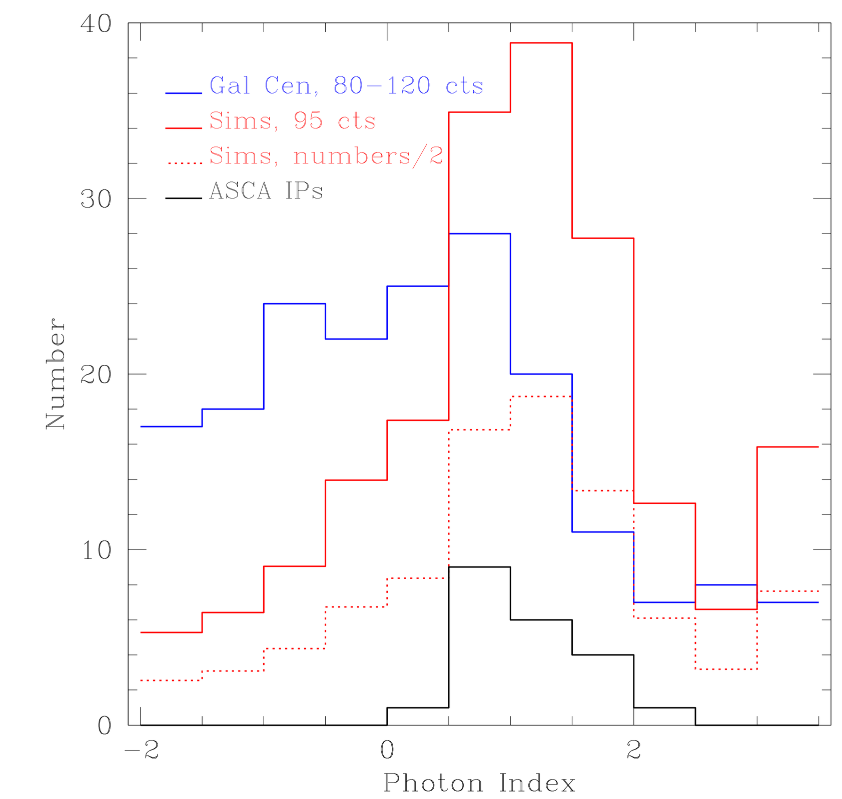
Spectral fits to observations of known IPs are usually performed with complicated multi-component models (e.g. Cropper et al. 1999). How would the known IPs appear when observed at low counts and behind significant obscuration?



We downloaded HEASARC ASCA GIS data for 20 targeted IPs and fit their spectra from 2-8 keV with an absorbed powerlaw. We show the histograms of power-law photon indices above, and use the Student's t-test to compare the mean values. The power-law photon indices are marginally consistent with those of the (>20-count) Terzan 5 X-ray sources (fit in the same energy range), and the brighter ($L_X > 2 \times 10^{32}$ ergs/s) Galactic Center X-ray sources. But the fainter Galactic Center sources (80-120 and 120-200 counts, $L_X \sim 8 \times 10^{31}$-$2 \times 10^{32}$ ergs/s) definitely require a component with harder X-ray spectra, comprising perhaps half these sources (~150). Their nature is unclear, as appropriate prototypes of such hard spectra are not known. There are a few theoretical suggestions, such as wind-accreting neutron stars (Pfahl et al. 2002).

XSPEC Simulations

Does the spectral fitting process cause a bias toward harder spectra? We addressed this question by making power-law plus gaussian fits to the 20 IPs, and using these fits, plus Galactic Center response and background files, as the basis of 1000 XSPEC simulations at each of three count rates. The simulations do not suggest a fitting bias.



Conclusions

The hard X-ray sources in the Galactic Center tend to be harder than those in globular clusters. Analysis of ASCA data on 20 IPs indicates that the globular cluster sources, the brighter Galactic Center sources, and half of the fainter Galactic Center sources may be IPs. The remaining fainter Galactic Center sources (~ 150) appear to be harder. This suggests that they are not similar to the known IPs, although their nature remains a mystery.

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