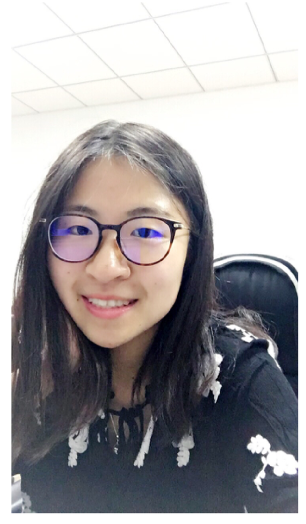
# A New Chandra Perspective of X-ray-Emitting, Close Binaries in the Nuclear Star Cluster



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## Introduction

The Galactic Center (GC) offers a unique laboratory for studying galactic nuclei due to its proximity ($d \approx 8$ kpc). The central super-massive black hole, known as SgrA*, greatly influence its immediate environment. X-ray observations of the GC, especially those afforded by the *Chandra X-ray Observatory*, can resolve close binary systems, young stars with strong winds and isolated BHs and NSs in the GC as well. A leading candidate for the faint X-ray sources in the GC is magnetic cataclysmic variables (mCVs), primarily intermediate polars (IPs). **In this work, we utilized 87 *Chandra* observations toward the GC allows, detecting fainter sources within innermost 500" region, making an updated source catalog and placing tighter constraints on the individual and global source properties.**

## Abstract

Based on decade-long, ultra-deep Chandra observations toward the Nuclear Star Cluster (NSC), we study the statistical (temporal, spectral, spatial) properties of ~3600 X-ray sources in our new catalog, presumably close binary systems that form and evolve in one of the most dynamic environments in our Galaxy. The vast majority of the X-ray sources, detected down to a luminosity of $10^{31}$ erg/s, exhibit little long-term variability; a dozen sources, on the other hand, have been identified as transients. The equivalent width and relative strength of the iron lines, measured from the cumulative source spectrum, suggest that these sources primarily comprise of magnetic and non-magnetic cataclysmic variables, in comparable numbers. These sources have a radial distribution closely following the near-infrared starlight, which places a strong constraint on the number of dynamically-formed close binaries within the NSC.

## Mosaic

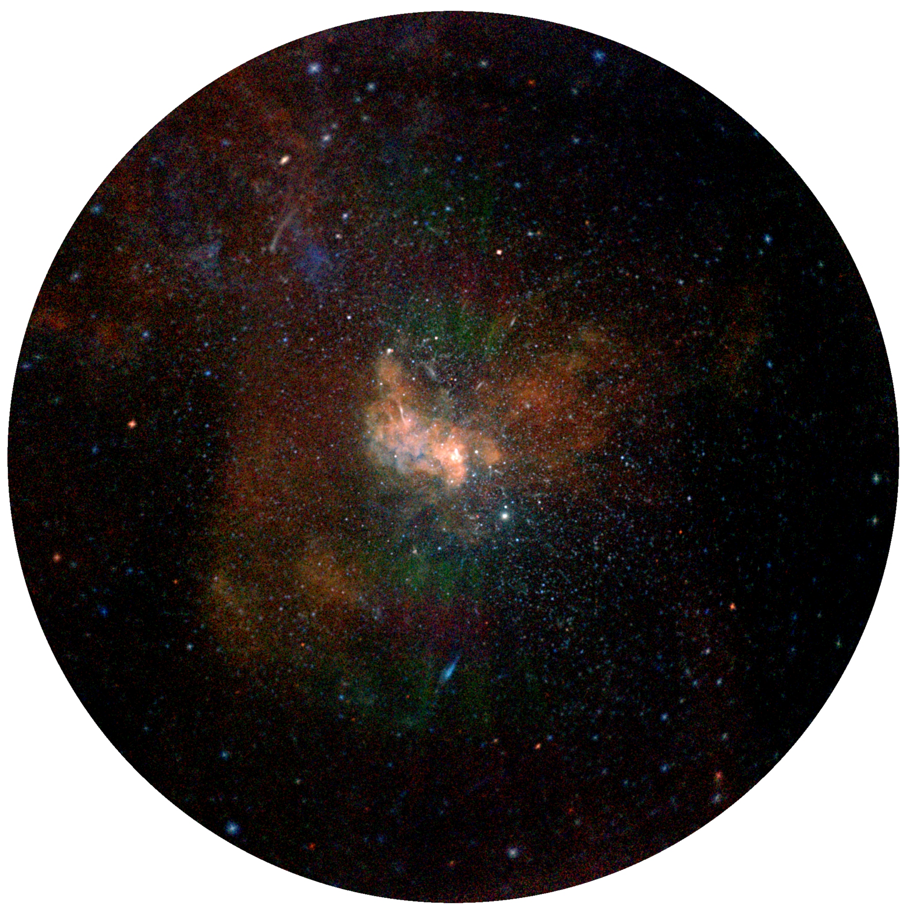

Fig1. Tri-color image of the inner 500″ region (~20 pc) of the Galactic center, as seen by the 4.44 Ms *Chandra*/ACIS observations. Red for 2–3.3 keV, green for 3.3–4.7 keV and blue for 4.7–8 keV.

## Variability

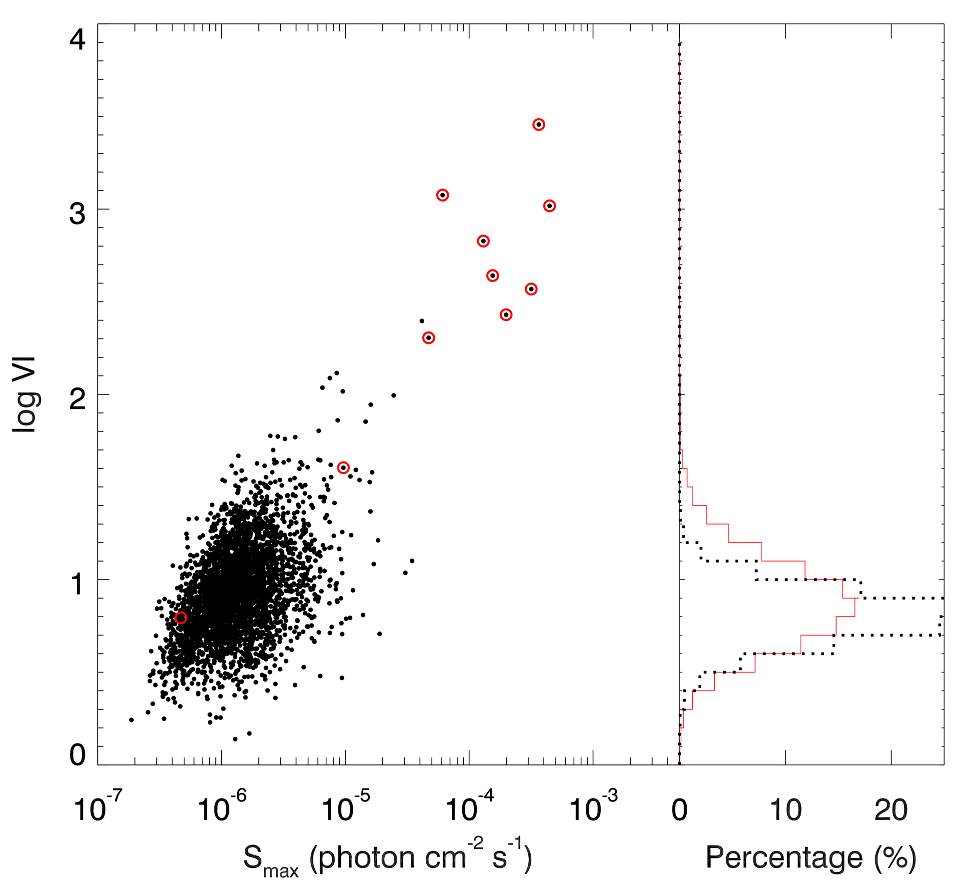


Fig2. The X-ray variability index (VI $=S_{max}/S_{min}$) versus the maximum 2–8 photon flux. The red circles highlight previously known transients (Degenaar et al. 2015). The right panel shows the histogram of VI (solid red), in comparison with the simulated VI distribution of constant sources following pure Poisson fluctuations and a power-law luminosity function (dashed black).

Variability in most of the faint sources can be explained by statistical fluctuations, while sources with VI $\gtrsim$ 15, which account for 14.6% of all sources, probably exhibit some intrinsic variability.

## Cumulative Spectra

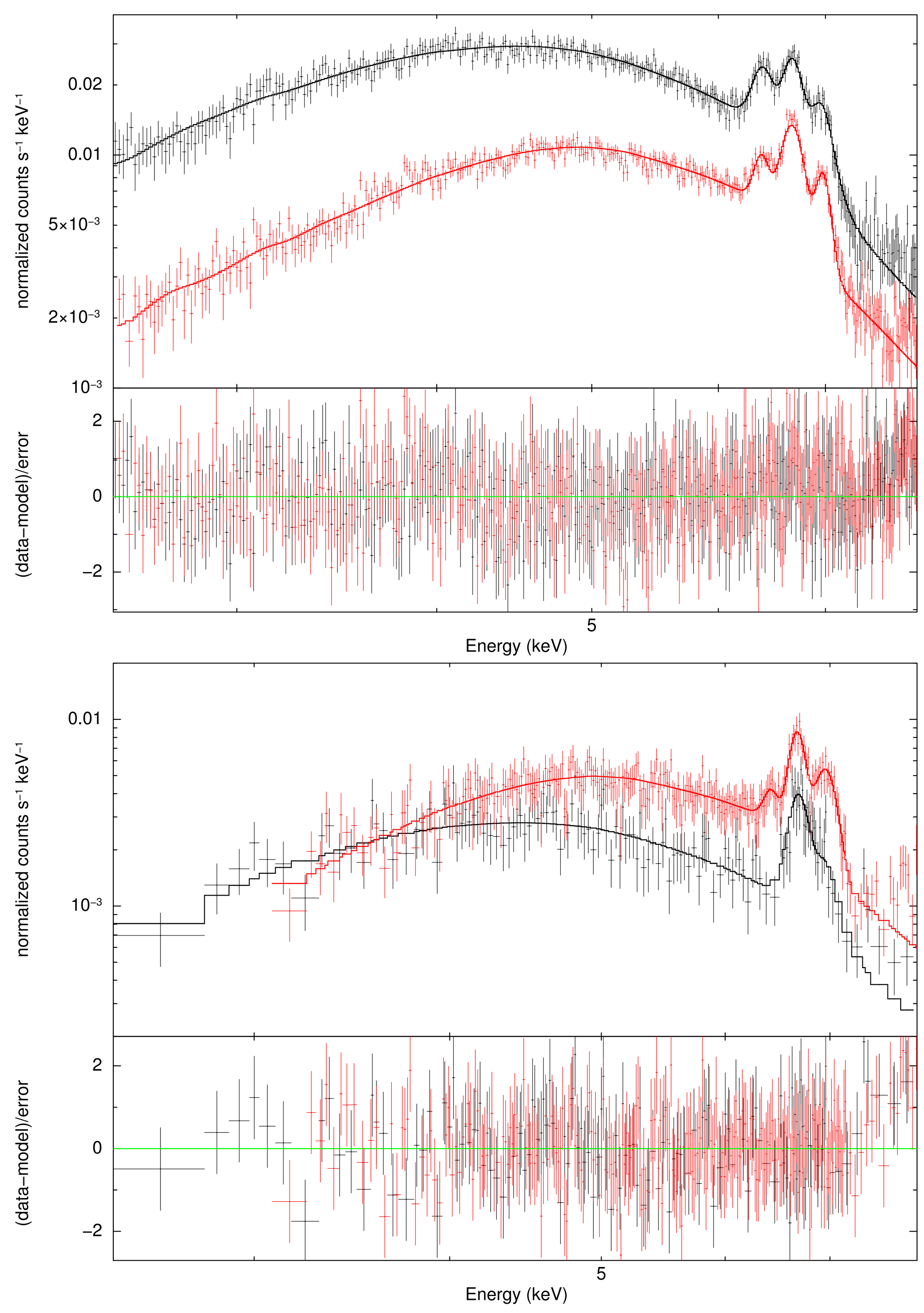


Fig3. Cumulative source spectra with the best-fit model, an absorbed bremsstrahlung plus three Gaussians for the 6.4, 6.7 and 7.0 keV Fe lines. The ACIS-I and ACIS-S spectra are shown in black and red, respectively. The *upper panel* displays bright sources ($L_X \gtrsim 6\times10^{31}$ erg s$^{-1}$), while the *lower panel* is for faint sources ($L_X \lesssim 6\times10^{31}$ erg s$^{-1}$).

The cumulative source spectrum exhibits an intrinsically hard continuum and multiple emission lines, especially the neutral Fe K$\alpha$ (6.4 keV), Fe XXV K$\alpha$ (6.7 keV) and Fe XXVI Ly$\alpha$ (7.0 keV).

## Radial Distribution

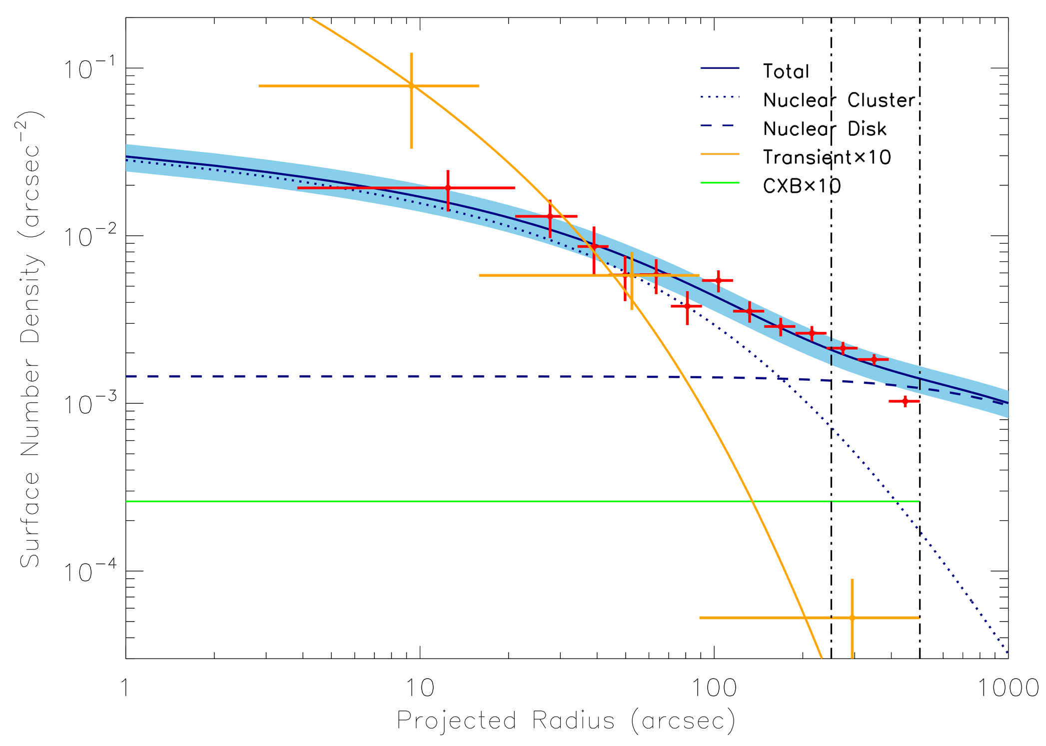


Fig4. Surface density profile of X-ray sources with $S_{2-8} > 3.5\times10^{-7}$ photon cm$^{-2}$ s$^{-1}$ (red points).

The surface density profile can be well characterized by the radial density distribution of resolved giant stars in the nuclear bulge (blue curve). The observed radial distribution of the transients (orange data point) consists with a projected $\rho_s^2(r)$ distribution, shown as an orange curve, motivated by the expectation that most LMXBs in the NSC were dynamically-formed.

## Reference&Acknowledgements

[1] N. Degenaar, R. Wijnands, J. M. Miller, M. T. Reynolds, J. Kennea, and N. Gehrels. *Journal of High Energy Astrophysics*, 7:137–147, 2015.

[2] X.-j. Xu, Q. D. Wang, and X.-D. Li. *ApJ*, 818:136, 2016.

*This work is supported by National Science Foundation of China under grants 11473010 and 11133001. M.M. acknowledges support from SAO/NASA grant 16151X for research with Chandra.*

**The paper of this work is available in ArXiv: https://arxiv.org/abs/1802.05073**

## Discussion

(1) The variability of most detected sources, on timescales from days up to 13.5 yrs, can be understood if these sources are primarily CVs. It is unlikely that significantly more LMXBs in their outbursting phase, which typically lasts for weeks, had been missed.

(2) The fact that the radial distribution of faint X-ray sources closely follows the NIR starlight thus suggests that dynamical effects leading to the formation and disruption of CVs in the NSC are either inefficient or canceling each other.

(3) Black symbols in Fig5 shows a general trend that IPs tend to have higher $I_{7.0}/I_{6.7}$, higher $I_{6.4}/I_{6.7}$ and smaller $EW_{6.7}$, when compared to the DNe. Thus, bright sources in GC (I1 and S1) should be dominated by IPs, and predominant fraction of the weak sources (S2 and I2 ) should be DNe.

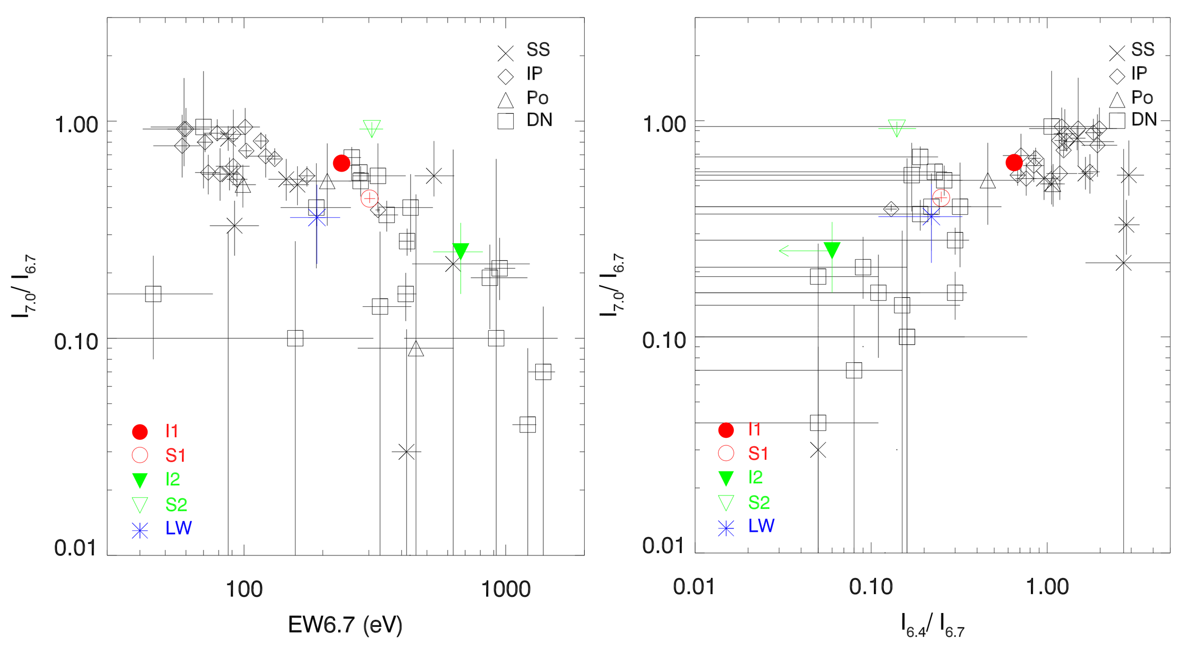


Fig5. Flux ratio between the 7.0 and 6.7 keV lines versus (a) equivalent width of the 6.7 keV line, and (b) flux ratio between the 6.4 and 6.7 keV lines. The color-coded symbols are for the GC and LW spectra. Black symbols are measurements in individual CVs in the Solar neighborhood (Xu et al. 2016). SS: symbiotic stars; IP: intermediate polars; Po: polars; DN: dwarf novae.