Galactic Centre X-ray Sources

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Abstract.

We report on a campaign to identify the counterparts to the population of X-ray sources discovered at the centre of our Galaxy by Wang et al. [7] using Chandra. We have used deep, near infrared images obtained on VLT/ISAAC to identify candidate counterparts as astrometric matches to the X-ray positions. Follow up Ks-band spectroscopic observations of the candidate counterparts are used to search for accretions signatures in the spectrum, namely the Brackett-γ emission line [1]. From our small initial sample, it appears that only a small percentage, \(\sim 2\%\) to \(3\%\) of the \(\sim 1000\) X-ray sources are high mass X-ray binaries or wind accreting neutron stars, and that the vast majority will be shown to be canonical low mass X-ray binaries and cataclysmic variables.

Keywords: X-ray binaries, stars: infrared

SEARCH FOR COUNTERPARTS

Imaging 26 fields towards the Galactic Centre in the near infrared with VLT/ISAAC, we were able to astrometrically identify possible counterparts to 79 of the \(\sim 1000\) weak, hard X-ray sources discovered in the Chandra survey of Wang et al. [7].

Follow-up spectroscopic observations using VLT/ISAAC of 28 of these targets, some with multiple candidate counterparts, yielded 36 spectra. The spectra of almost all the candidate counterparts were late type red giant stars, identified by their strong CO absorption bands beyond 2 \(\mu\)m, and metal absorption lines. None of these spectra contained evidence that the star was in an accreting system; Brackett-γ emission lines were absent from all (see Fig. 1). We discuss a few of the possible reasons why the accretion signatures were not seen in these spectroscopic targets.

The accretion signatures could be too weak to be measurable in the spectra if the rate of accretion was low, or it could be self-absorbed by a corresponding absorption feature of the companion star. Another possibility is that the physical composition of the systems means that there is no accretion at the time of observation; an example is the propeller phase which inhibits accretion onto neutron stars with strong magnetic fields.

More likely is that the candidate counterparts, for which we obtained spectroscopy, were not the counterparts to the X-ray sources, but merely coincidental astrometric matches due to the high stellar density at the Galactic centre [3, 2]. Our imaging survey obtained a limiting Ks magnitude of 20. Assuming an average extinction across the survey region (an assumption that is not valid, but used in this case for an example, see Section: Extinction), the survey will have been able to detect all stars on the giant branch as well as all stars of A V main sequence or earlier. If the matches are incidental, then the counterparts will be part of the later type main sequence stars beyond the limits of this survey.
FIGURE 1. Examples of 2 of the $K_S$-band spectra obtained of possible counterparts to the Galactic centre X-ray sources. From the sample of 36 targets for which spectra were obtained, none had obvious signatures of accretion i.e: Brackett-$\gamma$ emission [1]. The spectra of almost all of the stars observed appeared to be K and M type giants with strong CO absorption features as well as other metal absorption lines.

**X-RAY SOURCE COUNTERPART PROPERTIES**

Combining our results with those of a second group [Mikles et al., U. Florida; 4] who have spectroscopically confirmed one counterpart to a *Chandra* Galactic centre X-ray source (see Fig. [2]), we are able to draw some early conclusions as to the probable population of X-ray sources at the Galactic centre.

A small proportion, $\sim$ 2-3% may be high-mass X-ray binaries or wind accreting neutron stars detectable in similar surveys. These will most likely be the brighter sources in the population with $L_X \sim 10^{35}$ ergs$^{-1}$.

The vast majority of the population, those with lower luminosities, $L_X \sim 10^{33}$ ergs$^{-1}$ will have main sequence counterparts with lower masses are likely to be canonical low-mass X-ray binaries with a main sequence counterpart or cataclysmic variables. These counterparts will not be observable without very deep, high resolution imaging.

**EXTINCTION**

As part of our attempts to provide accurate photometry for the candidate counterparts to the X-ray sources, we discovered that infrared extinction towards the Galactic centre varies on scales much smaller than previously observed, and that the absolute value of extinction is also much greater than previously thought in some regions. The extinction can rise to levels of as much as $A_K \sim 6$, and varies on angular scales of $5'' - 15''$, corresponding to a physical scale of $0.2$ pc $- 0.6$ pc at a Galactic centre distance of $8.5$ kpc [3].

These results are in agreement with other papers such as Schultheis et al. [6] who suggested that smaller-scale structures in the extinction distribution, not measurable in their survey, were responsible for the observed double-peaks in histograms of stellar number versus $A_V$ in the Galactic centre. A recent paper by Nishiyama et al. [5] found that the infrared extinction varies from sight-line to sight-line in the regions around the Galactic centre, and that the previously stated universality of the infrared extinction law for the Galactic centre is not valid.
FIGURE 2. The $K_S$-band spectra of the first of the Galactic centre x-ray sources to have a spectroscopically identified counterpart. The emission line that identifies this target as an accreting system is the prominent Brackett-$\gamma$ (H1 7-4) line at 2.16 $\mu$m \cite{1}. The system may also contain a wind or outflow as some of the lines show a P-Cygni profile. Image courtesy of Valerie Mikles, U. Florida \cite{4}.

We will produce a full and comprehensive map of the extinction for all the fields observed as part of this survey (Gosling et al. in prep.), and will work as part of the UKIDSS and VISTA survey team to completely map the extinction towards the Bulge.

CONCLUSIONS

We have presented results from the search for the counterparts to the X-ray sources of the Galactic centre. We found astrometric matches to the positions of $\sim$ 70% of the X-ray sources. The photometry of these sources and follow up spectroscopy revealed that almost all of these candidate counterparts were late type K and M giants. The spectroscopy of this team, combined with that of the team of Mikles et al. in Florida discovered evidence that only one of these candidates could be positively identified as the counterpart to an X-ray sources. From this we can estimate that $\sim$ 2-3% may be high-mass X-ray binaries or wind accreting neutron stars and that the rest are low-mass X-ray binaries and cataclysmic variables.

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FIGURE 3.  (a) $K_S$ image of a field with no apparent structure in the stellar distribution. (b) C-C diagram of the stars in the field shown in (a). There are two main loci of stars: the local population to the bottom-left and the Galactic centre population in the centre. (c) The measure of granularity for the field shown in (a). In all three bands it does not deviate from zero, as expected for a random distribution. (d) $K_S$ image of a field with obvious regions of low stellar density compared to the field average. (e) C-C diagram for the field shown in (d). Note, compared to the C-C diagram in (b), the locus for the Galactic centre stars is extended to high reddening. (f) The measure of granularity for the field shown in (d) shows that there is measurable structure in all three bands. Reproduced by permission of the AAS

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