# Precise Localizations of LMXBs with Chandra: The "Big Dipper" X1624-490

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## Introduction

X1624-490 belongs to the group of so-called X-ray dippers among the low mass X-ray binaries (LMXBs). These sources are high inclination systems that exhibit pronounced dips in their X-ray light curves due to occultations of the central X-ray source by a thickened region of the accretion disk rim where the gas stream from the companion impacts upon the outer disk. X1624-490 is one of the most unusual members of this class; its persistent X-ray emission is the brightest (~6 x $10^{37}$ erg $sec^{-1}$), its dip profiles the most erratic, and its 20.878 hour orbital period is the longest, ~5-25 times longer than the other dipping sources. Dipping is deep, ~75% in the 1-10 keV band. The source also exhibits strong flaring in which the X-ray flux can increase by ~30% over timescales of a few thousand seconds (Smale et al. 2001). Despite the wealth of X-ray observations, the optical counterpart of X1624-490 has proven elusive, largely due to the uncertainty in the X-ray positions and the corresponding large number of candidates in the crowded regions of the Galactic Bulge. We present here a precise localization of X1624-490 with *Chandra* and the search for the optical/IR counterpart.

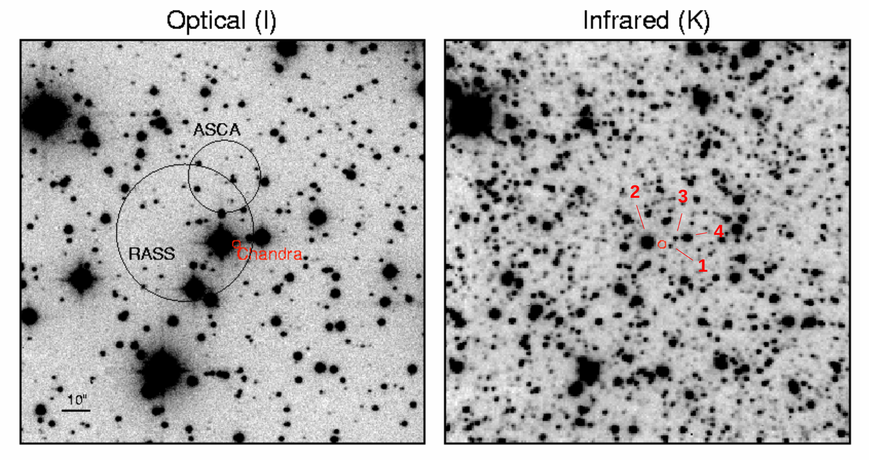
## Observations

**X-ray:** We observed X1624-490 with the *Chandra* HRC-I on 2002 May 30 for 1 ksec. A single bright source is visible in the 30'x30' field of view. The best position of the source was determined with the wavdetect tool within CIAO 2.2. There are no known aspect offsets for this data set. We therefore assume the nominal error of 0.6" ($1\sigma$, Aldcroft et al. 2000) on the position. Unfortunately, no other X-ray sources are detected that could aid in the transfer of the X-ray astrometric frame to our optical and IR observations.

**Optical:** We obtained CCD I band time series observations on UT 1997 April 30 – May 6 with the CTIO 1.5m telescope and on UT 1999 July 5 – 13 with the CTIO 0.9m telescope in an effort to identify the counterpart through photometric variability on the 20.878 hour orbital period. No variable sources are detected in the vicinity of the *Chandra* position.

**IR:** Near-infrared J and Ks band observations were obtained on UT 1997 April 26 – 28 with the CTIO 1.5m telescope and CIRIM.

| $A_V$ | J | Ks |
|---|---|---|
| 50 | 29.3 | 20.7 |
| 30 | 23.7 | 18.4 |
| 10 | 18.0 | 16.1 |




## Results

The figure shows our best *Chandra* position (1.2" radius error circle) overlaid on one of our I band optical (left panel) and Ks band IR frames (right panel). The previously best known X-ray positions from the *ROSAT* All Sky Survey and *ASCA* are also shown for comparison. No source is visible at the *Chandra* X-ray position.

We performed PSF photometry with DAOPHOT for all sources in our J and Ks IR frames. The magnitudes of detected sources were standardized by comparison to the 2MASS archival data. Our observations reach limiting magnitudes of J=19 and Ks=18. We can use these limits to derive constraints on the expected counterpart of X1624-490. The properties of X1624-490, such as its X-ray flaring, X-ray luminosity, absence of type I X-ray bursts and orbital period, suggest that it is to a certain extent similar to Sco X-1 (orbital period = 18.9 hours). The comparable orbital periods of the two systems at the very least imply a similar physical size and nature of the mass donor. If we assume that both have comparable IR magnitudes (with the caveat that the orbital inclination of the two systems might be quite different), we arrive at apparent magnitudes of J = 15.2, Ks = 15.0 for Sco X-1 at the distance of X1624-490 (~15 kpc, Christian & Swank 1997) in the absence of any reddening. The interstellar absorption towards X1624-490 appears to be very high. Spectral fitting of various X-ray data suggests an interstellar column density of 6 – 9 x $10^{22}$ $cm^{-2}$ implying $A_V$ = 30 – 50 according to the relationship by Predehl & Schmitt (1995). However, it is not clear how much of this absorption is intrinsic to the system. The table lists the expected magnitudes for various values of $A_V$. Our IR data already exclude $A_V$ = 10, and $A_V$ = 30 is only marginally consistent with our upper detection limits. Even for $A_V$ = 50, the counterpart should be easily detectable with a large aperture telescope in Ks unless it is substantially fainter than Sco X-1.

We also considered whether any of the sources close to the *Chandra* position are possible counterparts in the case of an overall offset between the X-ray and IR astrometric frames. Stars 2, 3, and 4 are clearly foreground objects, they are not only detected in J and Ks, but also in our V and I band optical data. Source 1 is a more plausible choice since it is undetected at V, I, and J, implying a large reddening value. However, with Ks = 15.7 it appears too bright in comparison to Sco X-1. We could consider a reduced value for the distance, however this would then still conflict with the non-detection in J. The source appears to be much redder (larger J - Ks) than a source with a spectrum similar to Sco X-1.

## References

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### Acknowledgments

This work was supported by Chandra General Observer Project award G02—3044X. The research was carried out, in part, at the Jet Propulsion Laboratory, California Institute of Technology, and was sponsored by the National Aeronautics and Space Administration. This publication makes use of data products from the 2 Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. It also utilized NASA's Astrophysics Data System Abstract Service and the SIMBAD database operated by CDS, Strasbourg, France.