Studies on X-ray Sources from *Chandra* Observations of the Galactic Globular Cluster M92 (NGC 6341)

Ting-Ni Lu[1] and Albert K. H. Kong[1, 2]

[1] Institute of Astronomy & Department of Physics, National Tsing Hua University, Taiwan
[2] Kenda Foundation Golden Jade Fellow
E-mail(TL): s9825802@m98.nthu.edu.tw

Abstract

We analyzed two observations of M92 from the *Chandra* X-ray Observatory. We combined the two datasets with a total exposure of ∼52 ks. With the combined observation, we detected 10 X-ray sources inside the half-mass radius (1.09′), while 5 of them inside the core radius (0.23′) of M92. The luminosities of the 10 sources are roughly within the range of 10^{30}–10^{32} ergs s^{-1} assuming cluster memberships. We fitted the spectrum of the brightest source with photon counts > 150 within the half-mass radius and the color-color diagram showed that most of the X-ray sources have relatively soft spectral features. Furthermore, the short term light curves of the brightest sources do not show obvious variation. In order to study the possible formation mechanisms of the X-ray sources in M92, we need to identify these X-ray sources. Therefore, further information from optical observations is necessary for the identification and we will outline our ongoing works using data taken with the *Hubble Space Telescope* (*HST*) and *CFHT*.

Key words: binaries: close—globular clusters: individual (M92)—novae, cataclysmic variables—X-rays: binaries

1. Introduction

X-ray sources are much more easier to be found in globular clusters than that in the galactic disk. Most of the X-ray sources in globular clusters are close binary systems which are not well studied and investigated. Studying on X-ray sources in globular clusters can help us know more about not only the populations but also the properties of the X-ray binary systems. With these information, we could further constrain the formation mechanisms and dynamical evolution scenarios for both the X-ray binary systems and the globular clusters.

Previous studies of X-ray sources in globular clusters mainly focus on high-density core globular clusters because background contamination is not a major problem. These X-ray sources can be formed by primordial binaries or dynamical interactions. Pooley & Hut (2006) and Bassa et al. (2008) report that the number of X-ray sources with luminosity $L_X < 10^{34.5}$ ergs s^{-1} in the 0.5 to 6.0 keV range will scale with the encounter rate (for the case of dynamical origin) and the total mass (for the case of primordial origin) of globular clusters. M92 has a relatively high encounter rate and an intermediate mass when compared with other previously studied globular clusters. The physical properties of M92 make it suitable to investigate the correlation between the number of X-ray sources and the encounter rate as well as the

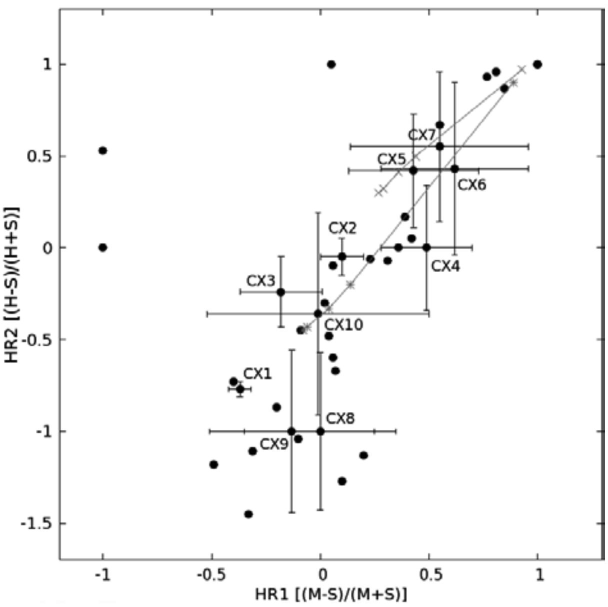

Fig. 1. Color-color diagram of the X-ray sources in M92. The points with error bars are the X-ray sources within the half-mass radius; source numbers are labelled. The blue lines are the hardness ratios predicted from power law models with different column densities (star and cross points) with a photon index of 1 (upper line) and 2 (lower line). The column density from left to right is 1×10^{19}, 1.06×10^{20}, 5×10^{20}, 1×10^{21}, and 1×10^{22} cm^{-2}, respectively.

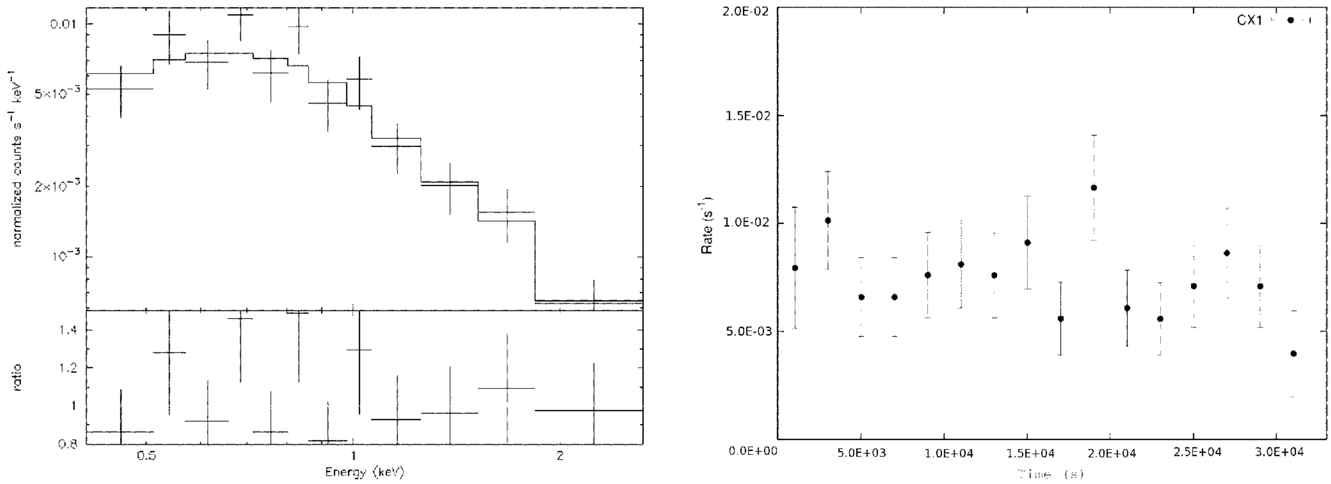

Fig. 2. **Left**: the spectrum of CX1 from the observation 3778. The cross represents the data points. The counts per spectral bin is 15 and we fitted the spectrum with an absorbed two-blackbody model (solid line). The lower panel is the ratio. **Right**: the light curve of CX1 in the energy range 0.3 to 7.0 keV from the observation 3778. For each bin time is 2000 seconds. Total exposure time is $\sim$ 29.6 ks. The probability of constancy tested by a Kolmogorov-Smirnov (K-S) test is 27.64%.

mass of globular clusters between the low and high core density end.

2. Data Analysis

M92 was observed by *Chandra* X-ray Observatory on Oct. 2003 (Obs. ID 3778 & 5241). The aim point is on the ACIS-S3 chip. We reprocessed the level 1 event files of both datasets by CALDB 3.4.2 and combined the two datasets with a total exposure of $\sim$52 ks by CIAO 3.4. We then performed source detections by WAVDETECT imposing a detection threshold of 10^{-6}, which corresponds to less than one false detection due to background fluctuations.

The source detections were performed on the soft (0.3–1 keV), medium (1–2 keV), hard (2–7 keV), and total (0.3–7 keV) energy bands. A total of 39 *Chandra* X-ray sources were detected on the ACIS-S3 chip and 10 sources are inside the half-mass radius of M92. We also estimated the number of background sources from the logN–logS relation derived from the *Chandra* Deep Field (Brandt et al. 2001). A total of 22 $\sim$ 34 sources within the ACIS-S3 chip and 1 $\sim$ 2 sources within the half-mass radius are expected to be backgrounds. We therefore can conclude that the majority of the sources within the half-mass radius are associated with M92.

We constructed the color-color diagram by calculating the color ratios of the X-ray sources (Figure 1). We further extracted the energy spectrum for the most luminous X-ray source inside the half-mass radius (CX1) and fitted it with an absorbed two-blackbody model. The fitted temperatures are 0.157 $\pm$ 0.019 and 0.807 $\pm$ 0.631 keV respectively. The estimated flux from the fitting of CX1 is 3.81×10^{-14} ergs s^{-1} cm^{-2}. The light curve of CX1 is also extracted with a time resolution of 2000 seconds (Figure 2).

3. Discussion & Outlook

Most of the *Chandra* X-ray sources are faint with luminosities $\sim 10^{30}$–10^{32} ergs s^{-1} and have relatively soft spectral feature (Figure 2). With current information from the *Chandra* X-ray observations, we can not classify these X-ray sources securely because of their low count rates. From the background estimation, at least 8 sources inside the half-mass radius are related to M92. Therefore, we will further investigate the *HST* and *CFHT* observations of M92 in order to find the possible optical counterparts with astrometric calibrations. We will then construct the color-magnitude diagram of M92 from the *HST* data to see whether the optical counterparts have special colors (e.g. excess in UV and/or Hα emission), which is one of the indicators of X-ray binary systems. Finally, we will be able to identify the nature of the X-ray sources (cataclysmic variables, active binaries, or quiescent low mass X-ray binaries). With the information of the X-ray sources classification, we can further investigate the correlation between the number of faint X-ray sources, and the encounter rate, and the mass of globular clusters, which can help us study and construct the possible formation mechanisms of these sources in M92.

References

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