The X-Ray Population in the Magellanic Clouds

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Abstract. We have systematically analyzed all the ASCA archival data of the LMC and the SMC to clarify the difference of their X-ray source population. We revealed extraordinary higher density of high mass X-ray binaries in the SMC. This indicates the SMC experienced an active star formation epoch some 10^7 years ago.

1. Introduction

The population of stars of various classes in a galaxy can give us clues to investigate its past activity. The X-ray binary pulsar is one such class, and great effort has been paid to discover both in and out of Our Galaxy. Contemporary X-ray satellites such as ASCA (Advanced Satellite for Cosmology and Astrophysics), ROSAT, XTE (X-ray Timing Explorer) and Beppo-SAX enhanced the chances of discovery with higher sensitivity, bringing about "pulsar rush" in the Small Magellanic Cloud (SMC).

The successive discoveries of X-ray pulsars since the end of 1997 made us to pay attention to this small galaxy along with its companion, the Large Magellanic Cloud (LMC). The enormous number of new pulsars in the SMC and only two in the LMC during this period strongly infers the difference of X-ray source population between these two galaxies. Our prior interest is to clarify the difference and to obtain any arguments to discuss their past activities.

Fortunately enough, the LMC and the SMC are suitable targets to classify its X-ray sources and to compare their population for several reasons. First, they are proximate to us so that X-ray sources can be separated from each other. Second, their distance from us are well-measured (50 kpc to the LMC and 65 kpc to the SMC), enabling us to convert observational values into physical values with fewer uncertainty. Third, they are both located at high galactic latitude where there is less absorption, and we do not have to worry about detection bias in favor of hard sources. In addition to these advantages, we have bulk of observations performed so far in these regions by ASCA.

Table 1. Number of Detected X-ray Sources by ASCA : We first separated detected sources into already cataloged sources and faint unknown sources for classification.

	LMC	SMC
observations we used	40	8
detected sources	34	37
cataloged sources	23	21
unknown sources	11	16

In section 2, we present the ASCA data we used for this study. Using all these data, in section 3, we classified X-ray sources into four classes, making use of catalogs for bright sources and spectral hardness ratio for faint sources. In section 4, we compare the X-ray population of each galaxy and present the peculiar population of the SMC. In the last section, we discuss this in association with their past activities.

2. ASCA Data

ASCA has performed 42 pointing observations in its career in the LMC , and 40 of them are in the archive. We used these archival data to detect X-ray sources. In the SMC on the other hand, ASCA has performed 10 pointing observations so far, and we used 8 of them which are at hand now. Figure.1 and 2 show the ASCA's past observations of the LMC and the SMC respectively. The optical main body of both the galaxies are almost covered.

We set the criterion of S/N $>$ 5 to extract X-ray sources from these observations, and detected 34 sources in the LMC and 37 sources in the SMC, including already classified sources in the published catalogs and faint unknown sources.

3. X-ray Population

To classify all sources listed in Table 1, we set four classes — SNRs (Crab-like SNRs, or SNRs with a rotation-powered pulsar inside are excluded.), high mass X-ray binary pulsars (HMXBPs), black hole candidates (BHCs), and Crab-like SNRs.

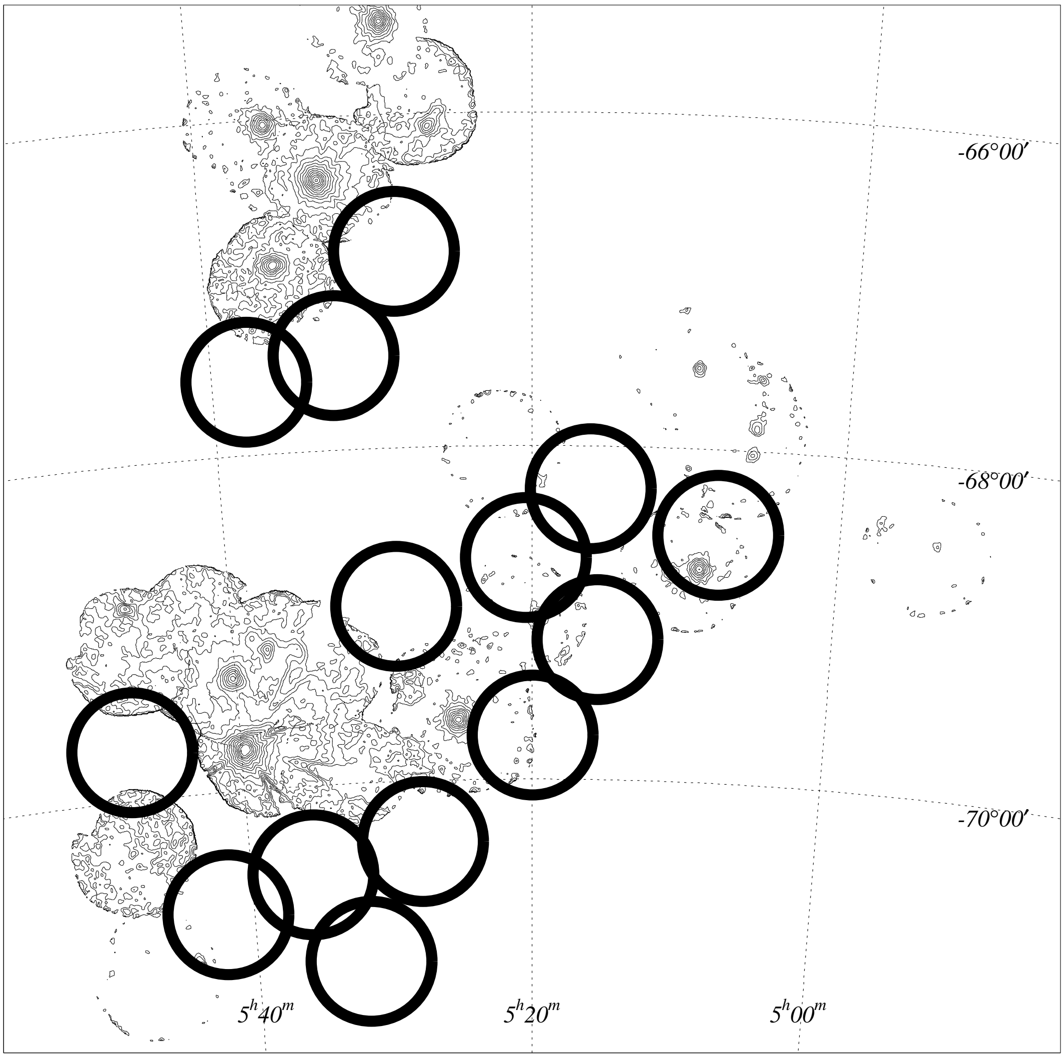

Fig. 1. The Mosaic Image of LMC in the ASCA hard band (*j2000*): Circled fields will be coverd in the next term of the observation.

We dealt already cataloged sources and faint unknown sources separately for classification.

- Already Cataloged Sources
  Bright sources are already well-studied case by case. To classify these sources, we basically followed the classification listed in the Einstein and ROSAT catalog [1]–[7] of their LMC and SMC survey.
- Faint Unknown Sources
  Spectrum plays key role to classify X-ray sources. For instance, SNRs are represented by thermal plasma model, and HMXBPs by simple power-law with photon index of ~ 1. For faint sources, however, it is difficult to follow this process due to poor statistics. As is already shown in Yokogawa *et al.* in this proceeding, the spectral hardness ratio is another key to estimate the class of these faint sources. Hardness ratio is defined as

$$hardness\ ratio = \frac{H-S}{H+S} \quad (1)$$

where S and H are the background subtracted photon counts of ASCA GIS soft band (0.7[keV]−2.0[keV]) and hard band (2.0[keV]−7.0[keV]) respectively, and this parameter can be calculated model-independently. For the LMC and SMC X-ray sources, SNRs and HMXBPs falls on the SNR region and HMXBP region in the luminosity − hardness ratio diagram(Figure. 3). We estimated faint sources on the SNR region to be candidates for SNRs, and faint sources on the HMXBP region to be the candidates for HMXBPs.

4. Comparison of the LMC and the SMC

Ou results listed in Table.2 clearly shows there exists a certain difference in X-ray source population between these the LMC and the SMC. The most peculiar characteristic is that HMXBPs are quite populous in the SMC, particulary when the mass ratio of these two (LMC : SMC = 10 : 1) is taken into consideration. This characteristic is

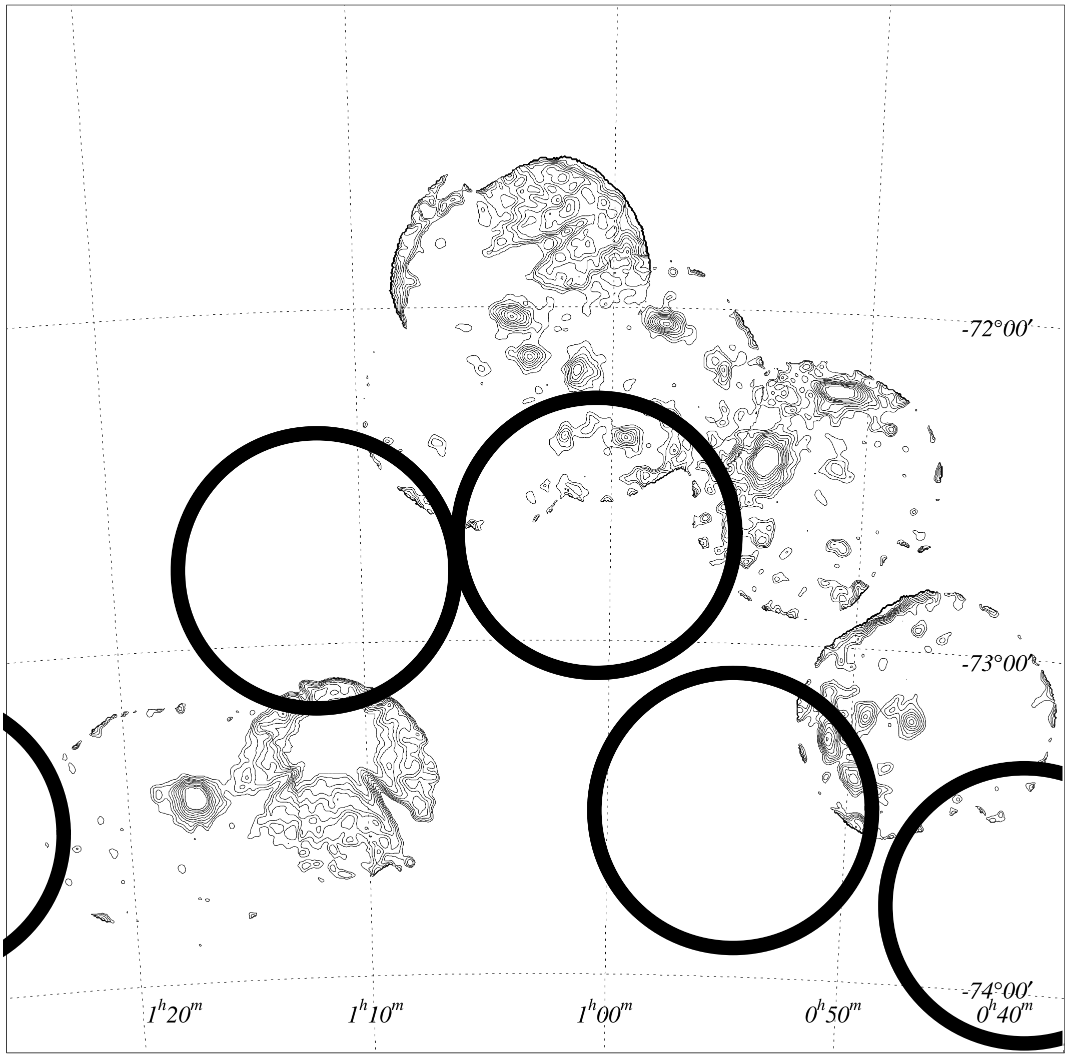

Fig. 2. The Mosaic Image of SMC in the ASCA hard band (*j2000*) : Circled fields will be coverd in the next term of the observation.

Table 2. Classification of X-ray Sources Detected by ASCA : The number of cataloged sources are listed separately in each class. For thermal SNR and HMXBPs, the number of candidates are also shown in the parentheses

class	LMC	SMC
SNRs	14(+4)	6 (+0)
HMXBPs	4(+1)	10 (+8)
BHCs	2	0
Crab-like SNRs	2	0

reinforced further by our discovery of candidate sources belonging to this class.

Since not all the galaxy is covered by ASCA yet, we should have also corrected for this. Our project to cover most of these two galaxies by ASCA in the next AO7 cycle will help resolve this problem.

5. Discussion

Our systematic analysis of the LMC and SMC sources revealed there exists difference in X-ray source population between these two galaxies. The most apparent characteristic is that HMXBPs are quite populous in the SMC.

The typical lifetime of a HMXBP is about 10^7 year. The fact that the SMC has larger population of this class implies this galaxy experienced an active star formation epoch which selectively produced bulk of high mass star binaries some 10^7 years ago.

The LMC and the SMC are considered to have experienced close encounter some 10^8 years ago[8] which triggered star formation lasting up to now, and the lighter component, the SMC, might have suffered severer gravitational instability through this interaction. Our result might be a snapshot of this SMC evolution.

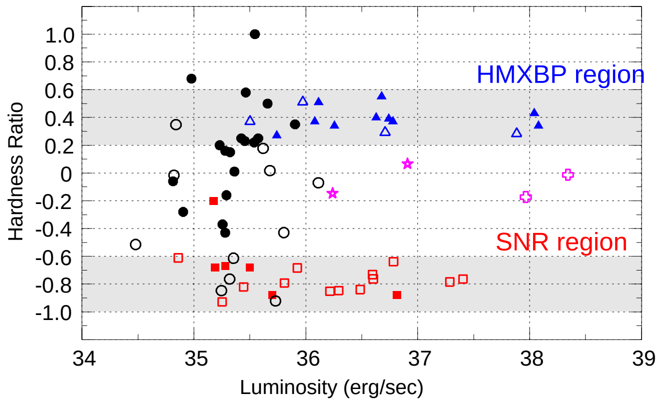

Fig. 3. Luminosity − Hardness Ratio Diagram : Luminosity (absorption not corrected) of LMC and SMC X-ray sources are plotted against their spectral hardness ratio. Squares are for SNRs, triangles are for HMXBPs, crosses are for BHCs, stars are for Crab-like SNRs, and circles are for unknown sources. Filled marks are LMC sources while open marks are SMC sources. All the HMXBPs fall on the region of $0.2 < hardness\ ratio < 0.6$ (HMXBP region), and most of SNRs fall on the region of $-1 < hardness\ ratio < -0.6$ (SNR region). The typical error of the hardness ratio is $\sim \pm$ 0.15 for sources with luminosity of $\sim 10^{35} erg/sec$ and $\sim \pm$ 0.05 for sources of $\sim 10^{36} erg/sec$

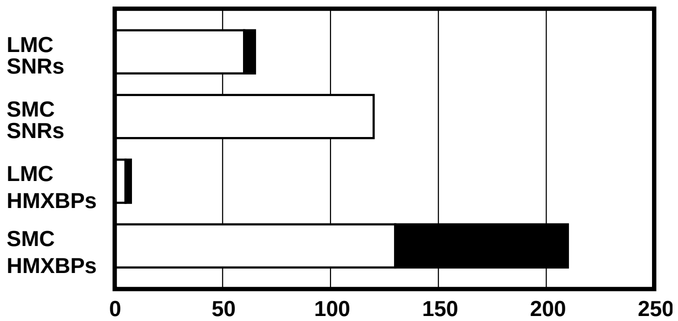

Fig. 4. The Normaliezed Number of LMC and SMC SNRs and HMXBPs : The number (normalize by mass) of all the SNRs (including radio SBRs) and HMXBPs idntified so far in the LMC and the SMC are shown by white bars. Our candidate sources are added to each them by black bars. Since not all the galaxy is covered by ASCA yet, the numbers of candidate sources only give the lower limit.

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