ASCA Galactic Plane and Galactic Center Region Survey

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Abstract

This paper presents the results of Galactic plane and Galactic center region survey observations with the X-ray satellite ASCA, aimed at the systematic study of Galactic X-ray sources and diffuse emission. More than 200 sources were found and about 60% of the resolved sources were unidentified. A large number of the unidentified sources have hard X-ray spectra obscured by the interstellar medium. The diffuse emission extended along the Galactic plane was also studied.

1 Introduction

In order to investigate what kinds of objects emit X-rays, various survey observations in the X-ray band have been carried out since the beginning of X-ray astronomy. A large number of X-ray sources have been discovered and the emission mechanism and their nature have been investigated. However, our knowledge of the Galactic X-ray sources is quite incomplete. X-rays with energy below 3 keV are absorbed by the interstellar medium, and hence the coverage of soft X-ray observations is limited to near the solar system. Above the 3 keV energy range, the interstellar medium is essentially transparent even for lines of sight through the Galactic plane, but the spatial resolution and sensitivity of non imaging detectors are limited.

The ASCA imaging capability in the 0.5–10 keV energy band (Tanaka et al. 1994) is essential to search for X-ray sources in the Galactic plane. The spectral resolving power can also provide crucial information to classify the resolved X-ray sources. ASCA makes unbiased sample of the Galactic X-ray sources which provides us with the systematic study of Galactic X-ray sources and Galactic diffuse emission. The ASCA Galactic plane and Galactic center region survey, was planned to cover the Galactic inner disk ($-45^\circ < l < 45^\circ$, $-0.4^\circ < b < 0.4^\circ$) and the Galactic center region ($-2^\circ < b < 2^\circ$ for $-2^\circ < l < 2^\circ$) with successive pointing fields of about 50 arcmin diameter and about 10^4 s exposure for each. In addition to the survey data, we utilized data observed in the outer region of the Galactic inner disk (l=57°.5–62°.5) and high-latitude data up to $b \sim 5^\circ$ observed in the Scutum region ($l \sim 28^\circ$). We also analyzed data of follow-up observations and archival data.

2 Results and Discussion

2.1 Source Survey

An image fitting method taking account of the complicated point spread function of the ASCA XRT was employed. More than 200 sources with an X-ray flux down to $10^{-12.5}$ erg sec^{-1}cm^{-2} were found. About 60% of the resolved sources were unidentified. Spectral analysis of each source shows that a large number of the unidentified sources have hard X-ray spectra obscured by the interstellar medium.

We could derive the log N–log S relations of the resolved sources in the energy bands below and above 2 keV separately (Sugizaki et al. 2001; Sakano et al. 2002). Below 2 keV, the log N–log S relation has a complex profile, far from a single power-law function. In the 2–10 keV band, the log N–log S relation of Galactic X-ray sources was obtained for the first time (figure 1). The relation of X-ray sources in the Galactic plane is well approximated by a single power-law with a slope of ∼0.8 that is flatter than that of extragalactic sources (Ueda et al. 1999). The number density in the Galactic center region is larger than that on the Galactic plane (figure 1).

Sky positions and spectral information of each source are reported by Sugizaki et al. (2001) and Sakano et al. (2002).

2.2 Supernova Remnants and Supernova Remnant Candidates

Based on the survey observations in the radio band, 231 supernova remnants (SNRs) have been cataloged (Green 2001). In the X-ray band, however, the number of the X-ray detected SNRs is less than half of the radio SNRs.

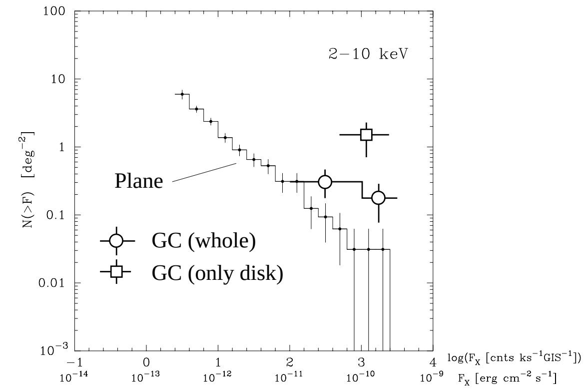

Figure 1: log N–log S relation of Galactic X-ray sources in the 2–10 keV energy band. The small closed circles show the data obtained in the Galactic plane (Sugizaki et al. 2001). The open circles show the data with the Galactic center bright sources in the surveyed region, while the open box shows the same data but only on-plane data with $|b| < 0^\circ.3$ (Sakano 2000).

ASCA detected X-rays from 30 cataloged radio supernova remnants in the surveyed region. X-ray emissions from 17 SNRs were discovered for the first time with this survey.

Figure 2 shows an example of an X-ray mosaic image. In this region, G344.7−0.1, G349.7+0.2, and G352.7−0.1 which are unseen with ROSAT were detected as bright X-ray sources. From the spectral analysis for the 3 bright SNRs, we found that they have thin thermal X-ray spectra with temperatures of 1–2 keV (Kinugasa et al. 1998b; Yamauchi et al. 1998, 1999).

The ASCA survey observed the northwest shell of RX J1713.7−3946 (the crescent shape around $l \sim 347^\circ$ in figure 2), a SNR originally found with ROSAT. The spectrum surprisingly shows non-thermal with no emission lines (Koyama et al. 1997). This is the second clear example of non thermal X-rays from the SNR shell after SN 1006, which strongly suggests the existence of high-energy electrons accelerated by the Fermi mechanism in the SNR shell (Koyama et al. 1995). This result indicates that the non-thermal X-ray emission is universal.

We discovered several unidentified extended sources. Some of them exhibited thin-thermal X-ray spectra (Sakano et al. 2002), while at least 4 are extended hard X-ray sources without no clear emission lines in their spectra (Bamba et al. 2001a, 2002). These are X-ray SNR candidates. The surveyed area is a small part of the Galaxy, hence many SNRs are hidden in the Galaxy.

2.3 X-Ray Pulsars

We discovered 4 X-ray pulsars with fluxes of ∼(2–3)×10^{-11} erg s^{-1} cm^{-2}; 1RXS J170849.0−400910 (P = 11 s, Sugizaki et al. 1997), AX J1820.5−1434 (P = 152 s, Kinugasa et al. 1998a), AX J1740.1−2847 (P = 729 s, Sakano et al. 2000), and AX J183220−0840 (P = 1549 s, Sugizaki et al. 2000). The properties of the spectra and the pulse period suggest that 1RXS J170849.0−400910 is a new example of anomalous X-ray pulsars, AX J1820.5−1434 and AX J1740.1−2847 are likely to be neutron star binaries, and AX J183220−0840 is a magnetized white dwarf binary.

As well as the spectral properties and pulse periods, long-term variability and pulse period change of X-ray pulsars are important information to discuss their nature. Significant variability on timescales of a few years were found from

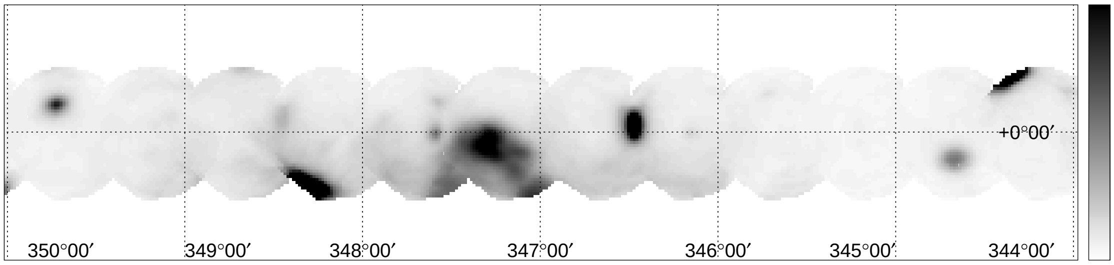

Figure 2: A part of the X-ray image of the ASCA Galactic Plane Survey with the Galactic coordinates.

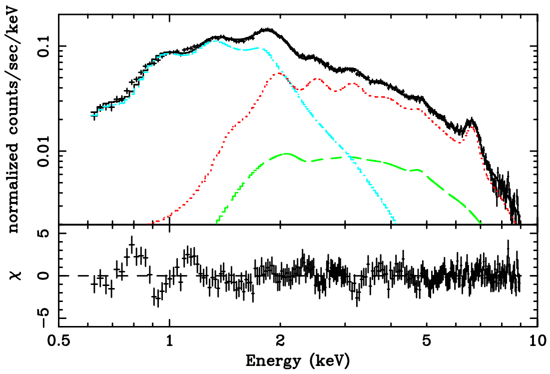

Figure 3: Upper panel: X-ray spectrum of the Galactic Ridge X-ray emission. The crosses show the data, while the dash-dotted, dotted, and dashed lines show the cool component, hot component, and the contribution of the cosmic X-ray background, respectively. Lower panel: the data residuals from the best-fit model.

AX J1841.0−0536 (P = 4.7 s, Bamba et al. 2001b), AX J1845.0−0300 (P = 7 s, Torii et al. 1998a), AX J1749.2−2725 (P = 220 s, Torii et al. 1998b), discovered by other observations with ASCA.

Although we could not find coherent pulsations due to limited photon statistics, we found X-ray sources with flat power-law spectra with large absorption (typical for binary X-ray pulsars) and transient behaviors. These are candidates of binary X-ray pulsars.

2.4 Galactic Ridge X-Ray Emission

The Galactic ridge X-ray emission (GRXE) is unresolved X-ray emission along the Galactic plane whose origin has been debatable.

The on-plane spectra of GRXE obtained with ASCA are well represented by a two-component model, a cool component and a hot component (figure 3), and are quite similar from field to field with almost no significant variations in the spectral parameters.

The cool component is thin thermal emission. The observed properties such as ∼0.8 keV temperature, low ionization degree, and surface brightness are well consistent with the scenario of the SNR origin (Kaneda et al. 1997).

The hot component is well-known thermal plasma emission from the past observations with a temperature of ∼7 keV out of ionization equilibrium (Kaneda et al. 1997) or ∼3 keV in full equilibrium (Valinia & Marshall 1998). The distribution of the hot component was globally symmetric with respect to the Galactic center with a scale height of ∼100 pc (Yamauchi & Koyama, 1993; Sugizaki et al. 2001). The ASCA survey gave new information to discuss the origin of the hot component. If we extrapolate the log N–log S relation in the flux range lower than the detection limit from the power-law relation of the resolved sources, the integrated flux of point-sources contribute to the surface brightness of the hot component only by ∼10 % (Sugizaki et al. 2001). Therefore, the hot component possibly originates from a truly diffuse interstellar plasma, not a sum of discrete sources, which was confirmed by the Chandra observation (Ebisawa et al. 2001). Such a hot plasma, however, cannot be confined within the Galaxy gravitationally or by interstellar pressure.

Above 10 keV, a non-thermal component explained by a power-law model with an photon index of ∼2 was detected with Ginga (Yamasaki et al. 1997) and RXTE (Valinia & Marshall 1998). The emission extends up to γ-ray regime. ASCA suggests the presence of the non-thermal component at higher latitude ($b > 2°$) and in outer region of the Galactic inner disk ($l \sim 60°$) (Kaneda et al. 1997, 1999).

The origin of GRXE still remains unresolved. Models to explain GRXE in terms of interstellar-magnetic reconnection (Tanuma et al. 1999), or interaction of energetic cosmic-ray electrons (Valinia et al. 2000) or heavy ions (Tanaka et al. 1999; Tanaka 2002) with interstellar medium have been proposed.

Acknowledgements

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References

Bamba, A., et al. 2001a, PASJ, 53, L21
Bamba, A., et al. 2001b, PASJ, 53, 1179
Bamba, A., et al. 2002, ApJ, submitted
Ebisawa, K., et al. 2001, Science, 293, 1633
Green, D.A. 2001, A Catalogue of Galactic Supernova Remnants (2001 December version), (Cambridge UK: Mullard Radio Astronomy Observatory) available on the WWW at http://www.mrao.cam.ac.uk/surveys/snrs/
Kaneda, H., et al. 1997, ApJ, 491, 638
Kaneda, H. et al. 1999, AN, 320, 322
Kinugasa, K., et al. 1998a, ApJ, 496, 435
Kinugasa, K., et al. 1998b, PASJ, 50, 249
Koyama, K., et al. 1995, Nature, 378, 255
Koyama, K., et al. 1997, PASJ, 49, L7
Sakano, M. 2000, Ph. D. thesis, Kyoto University
Sakano, M. et al. 2000, PASJ, 52, 1141
Sakano, M., et al. 2002, ApJS, 138, 19
Sugizaki, M., et al. 1997, PASJ, 49, L25
Sugizaki, M., et al. 2000, ApJ, 534, L181
Sugizaki, M., et al. 2001, ApJS, 134, 77
Tanaka, Y., et al. 1994, PASJ, 46, L37
Tanaka, Y., et al. 1999, AN, 320, 181
Tanaka, Y. 2002, A&A, 382, 1052
Tanuma, S., et al. 1999, PASJ, 51, 161
Torii, K., et al. 1998a, ApJ, 503, 843
Torii, K., et al. 1998b, ApJ, 508, 854
Ueda, Y., et al. 1999, ApJ, 518, 656
Valinia, A., & Marshall, F.E. 1998, ApJ, 505, 134
Valinia, A., et al. 2000, ApJ, 543, 733
Yamasaki, N.Y., et al. 1997, ApJ, 481, 821
Yamauchi, S., & Koyama, K. 1993, ApJ, 404, 620
Yamauchi, S., et al. 1998, AN, 319, 111
Yamauchi, S., et al. 1999, Japan-German Workshop on High Energy Astrophysics, MPE report 270, p110