Search for GeV gamma-ray emission from X-ray binaries

MASAKI MORI[1], YOSHIHIRO UMEDA[1], KENJI NAKAGAWA[1] AND TAKU OHMORI[1]
[1]*Department of Physical Sciences, Ritsumeikan University, Kusatsu, 525-8577 Shiga, japan*
morim@fc.ritsumei.ac.jp
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Abstract: Six X-ray binary systems have been reported to emit gamma-rays to date, and a new category of "gamma-ray binaries" is emerging. In this study, gamma-ray emissions from some other well-known X-ray binaries (Sco X-1, Cen X-3, Vela X-1 and Her X-1) have been searched for using the *Fermi-LAT* data in the GeV energy range. We could not observe positive gamma-ray signal from any of these sources and upper limits on gamma-ray fluxes have been set.

Keywords: Gamma-rays; X-ray binaries; observations

1 Introduction

X-ray binaries are rather common Galactic X-ray objects and about 300 sources are catalogued [1]. At gamma-ray energies, LS5039 [2], LSI+61° 303 [3], PSR 1259-63/SS2883 [4], Cyg X-1 [6], Cyg X-3 [5], and recently 1FGL J1018.6-5856 [7] have been reported to emit gamma-rays of GeV and/or TeV energies which are modulated in their orbital periods. Thus a new category of "gamma-ray binaries" is emerging, but their emission mechanism, which should accelerate particles to multi-TeV energies very efficiently, is not understood well. Compact binary systems have distinct features compared with other GeV emitters: the presence of intense photon field and magnetic field, the changing geometry in interactions due to the orbital motion of the system, and the varying particle injection in the eccentric orbits. These components add complexities in analyzing emission mechanisms in binaries, but, in turn, information can be extracted from observations in various wavelength. Thus, it is claer that we need more samples observed in multiwavelengths for the detaild study of these systems [8].

In this study, gamma-ray emissions from some other well-known X-ray binaries have been searched for using the *Fermi-LAT* data in the GeV energy range.

2 Analysis

In Table 1 are listed four objects analyzed in this study with some parameters. *Fermi-LAT* archival data were extracted from Fermi Science Support Center [9] and analyzed using tools provided by FSSC (Fermi Science Tools v9r17p0). Energy ranges used in the present analysis are from 200 MeV to 100 GeV. Only 'diffuse' class events detected at zenith angles smaller than 105° were used for analysis, assuming 'P6_V3_DIFFUSE' instrument response function along with the standard analysis pipeline suggested by FSSC. Significance of gamma-ray signal has been estimated by maximum likelihood method with a help of the 'gtlike' program (we used it in the 'binned' mode) included in the tools. The data periods are more than two years as shown in Table 1.

3 Results

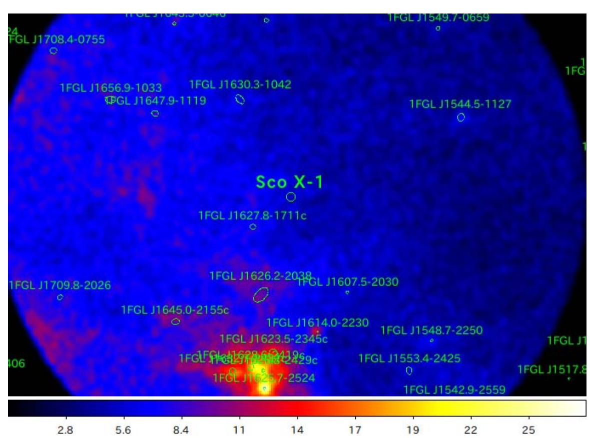

Figure 1: GeV gamma-ray countmap around Sco X-1.

Gamma-ray countmaps for each source are shown in Figs.1–4. Positions of each source and catalogued sources (1FGL) [10] are marked. Apparently we could not find significant gamma-ray signal from any of four sources, and

Object	Other name	α (deg)	δ (deg)	Orbital period	Distance	Observation period
Sco X-1	V818 Sco	244.979	-15.640	18.9hr	2.8 kpc	Aug. 04, 2008 – Oct. 28, 2010
Cen X-3	V779 Cen	170.316	-60.623	2.09d	8–10 kpc	Aug. 04, 2008 – Nov 18, 2010
Vela X-1	GP Vel	135.529	-40.555	8.96d	1.9 kpc	Aug. 04, 2008 – Nov 18, 2010
Her X-1	HZ Her	245.548	35.342	1.70d	6.6 kpc	Aug. 04, 2008 – Nov 18, 2010

Table 1: X-ray binaries analyzed in this study.

detailed analysis with 'gtlike' also revealed no positive detections, showing *TS* (test statistics) values of less than 25 which is the standard threshold (corresponding to about 4σ) for positive detection. Upper limits on gamma-ray flux have been calculated with the maximum likelihood method provided with the Fermi Science Tosols and results are summarized in Table 2. Note that the upper limit for Vela X-1, which lies near the Galactic plane, is significantly higher than other three sources maily because of the presence of the intense Galactic diffuse gamma-ray background.

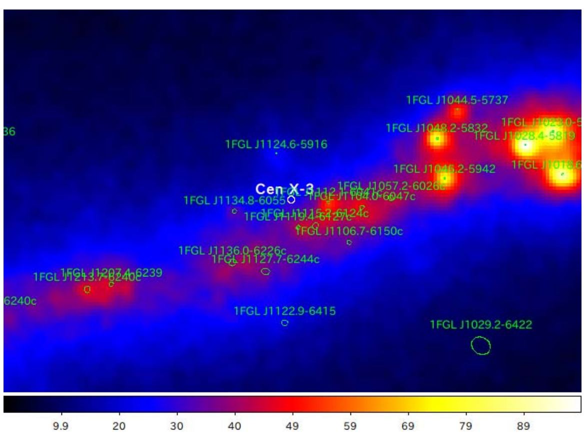

Figure 2: GeV gamma-ray countmap around Cen X-3.

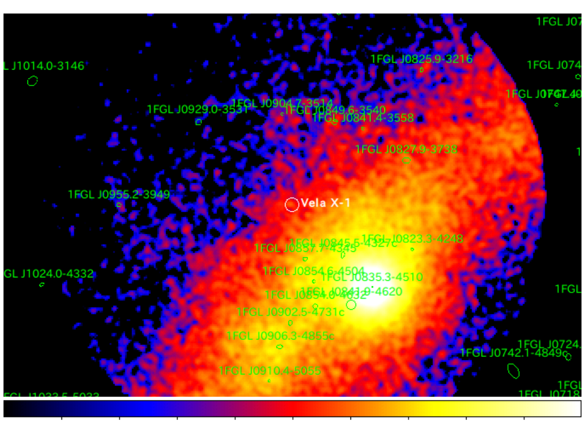

Figure 3: GeV gamma-ray countmap around Vela X-1.

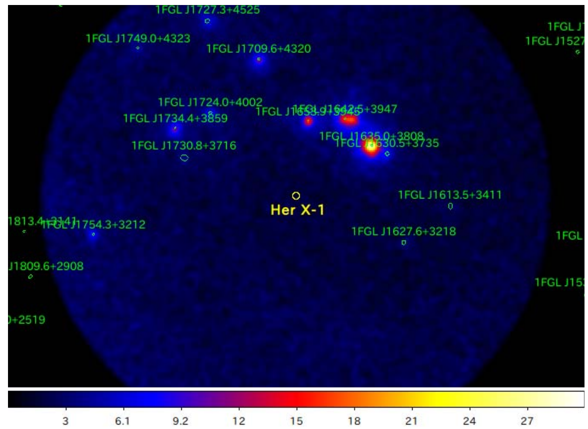

Figure 4: GeV gammma-ray countmap around Her X-1.

Object	Upper limit ($\mathrm{cm^{-2}s^{-1}}$)
Sco X-1	1.03×10^{-9}
Cen X-3	4.28×10^{-9}
Vela X-1	2.41×10^{-7}
Her X-1	1.51×10^{-9}

Table 2: Upper limits on gamma-ray fluxes from each source (200 MeV–10 GeV, 95%C.L.,).

4 Discussion

Figure 5 shows a relation between X-ray luminosities and gamma-ray luminosity upper limits of each source assuming distances shown in Table 1. Also plotted are the similar points for LS5039 [2], LSI+61° 303 [3], PSR 1259-63/SS2883 [4], and the flare activity of Cyg X-3 [5]. While the upper limits on gamma-ray luminosities obtained in this study are less than 10^{-3} of X-ray luminosities, gamma-ray luminosities of detected sources are the same order of or larger than X-ray luminosities. This may mean the X-ray binaries studied here and "gamma-ray binaries" could be classified into different categories. It is interesting to study what properties of binaries produce this difference by collecting further samples and taking various correlation of parameters.

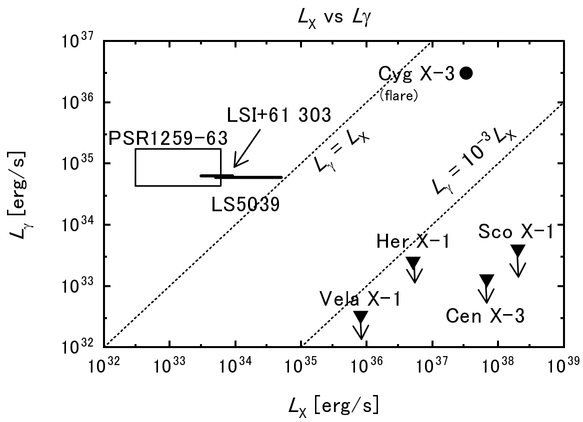

Figure 5: X-ray luminosities versus gamma-ray luminosity upper limits.

5 Summary

We have searched for GeV gamma-ray emission from some of selected X-ray binaries using the *Fermi-LAT* data. No significant signal was found from any of four sources analyzed here (Sco X-1, Cen X-3, Vela X-1 and Her X-1) and upper limits on gamma-ray fluxes were given. Their gamma-ray luminosities relative to X-ray luminosities are weaker by 1/1,000 compared to 'gamma-ray binaries' which are detected in GeV and/or TeV gamma-rays.

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