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Searching for X-ray counterparts of Fermi Gamma-ray pulsars in Suzaku observations

Yu Aoki[1], Takahiro Enomoto[1], Yoichi Yatsu[1], Nobuyuki Kawai[1], Takeshi Nakamori[2], Jun Kataoka[2] and P. Saz Parkinson[3]

[1]Dept. of Physics, Tokyo Institute of Technology,
B2-12-1 Oookayama Meguro Tokyo, 152-8551, Japan
email: aoki@hp.phys.titech.ac.jp

[2]Research Institute for Science and Engineering, Waseda University, Japan

[3]Santa Cruz Institute for Particle Physics, Dept. of Physics and Dept. of Astronomy and Astrophysics, University of California at Santa Cruz, Santa Cruz, CA 95064, USA

Abstract. We report the Suzaku follow-up observations of the Gamma-ray pulsars, 1FGL J0614,13328, J1044.55737, J1741.82101, and J1813.31246, which were discovered by the Fermi Gamma-ray observatory. Analysing Suzaku/XIS data, we detected X-ray counterparts of these pulsars in the Fermi error circle and interpreted their spectra with absorbed power-law functions. These results indicate that the origin of these X-ray sources is non-thermal emission from the pulsars or from Pulsar Wind Nebulae (PWNe) surrounding them. Moreover we found that J1741.82101 exhibits a peculiar profile: spin-down luminosity vs flux ratio between X- and gamma-rays is unusually large compared to usual radio pulsars.

Keywords. Pulsar, Pulsar wind nebulae, Gamma-ray pulsars. Fermi.

1. Introduction

The Fermi gamma-ray observatory has discovered more than three thousands of gamma-ray sources. About 10 percent of the newly found objects were categorized into pulsars and pulsar wind nebulae. We focused on the newly found gamma-ray pulsars to study their nature. For this purpose we observed four bright gamma-ray pulsars with the Suzaku X-ray observatory. Here we present a summary of the observations.

2. Observation and analysis

Suzaku is the fifth Japanese X-ray observatory with 4 X-ray telescopes. Thanks to the low-earth orbit the particle background is low compared with the other large X-ray observatories. So it is suited for searching diffuse emissions in the universe. We conducted observations on 2010. Each exposure time was 20 ks.

First we performed astrometry. From the obtained X-ray images we discovered point sources clearly. These locations are consistent with the Fermi's error circles. The position of these point sources are also consistent with the timing position determined by radio follow-up observations. These positional coincidences strongly support that the discovered X-ray sources are the X-ray counterparts of gamma-ray pulsars.

Next we studied the spectroscopy. In order to accumulate source photons we chose circle regions with a radius of 1 arcmin centered on the pulsars. The obtained X-ray spectra were well modelled by absorbed power-law functions. The results of spectral fitting are summarized in Table. 1. 1FGL J1813,3-1246 shows a very flat spectrum with a photon index of 0.8 that cannot be explained by the standard acceleration model. While the other pulsars show relatively flat spectra.

Table 1. Fit results with power-law model or interstellar absorbed power-law model for the spectra of four pulsars

name	n_H $[\times 10^{22}\mathrm{cm}^2]$	Index	Flux(0.5-10.0keV) $[\mathrm{erg/s/cm}^2]$	χ^2/D.O.F
J0614.1-3328	–	$2.63^{+0.30}_{-0.27}$	$5.73 \pm 0.67 \times 10^{-14}$	11.95/14
J1044.5-5737	–	$2.00^{+0.36}_{-0.34}$	$7.50^{+1.22}_{-1.12} \times 10^{-14}$	5.56/8
J1741.8-2101	$0.28^{+0.11}_{-0.09}$	$2.81^{+0.23}_{-0.20}$	$6.56^{+1.35}_{-0.97} \times 10^{-13}$	7.44/24
J1813.3-1246	$1.36^{+0.31}_{-0.27}$	0.79 ± 0.16	$1.27 \pm 0.06 \times 10^{-12}$	9.25/20

3. Discussion

We estimate the X-ray luminosity from the X-ray flux for each pulsar using equation (1) which is the empirical formula between X-ray luminosity and spindown luminosity (Kanai D-thesis).

$$\frac{L_X}{10^{32}\mathrm{erg/s}} = (2.99 \pm 1.08) \times \left(\frac{L_{sd}}{10^{36}\mathrm{erg/s}}\right)^{1.10\pm0.14} \tag{3.1}$$

Then we calculated the distance and Gamma-ray luminosity of the four pulsars assuming $L_{X,\Gamma} = 4\pi d^2 f F_{X,\Gamma}$ from obtained X-ray flux, X-ray luminosity, and Gamma-ray flux.

Next, we compared the four pulsars to other Fermi pulsars used in Kanai D-thesis. Fig. 1 and 2 show the spin-down luminosity vs. Gamma-ray luminosity and spin-down luminosity vs. the X/Gamma flux ratio, respectively.

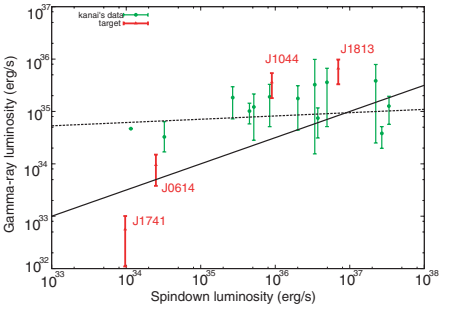

Figure 1. Relation between spindown luminosity and Gamma-ray luminosity for four pulsars and other Fermi pulsars

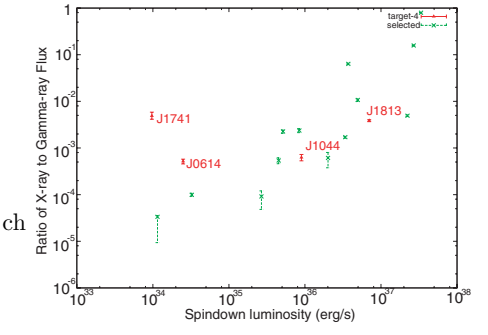

Figure 2. Relation between spindown luminosity and the ratio of X-ray and Gamma-ray flux for four pulsars and other Fermi pulsars

References

Amari, S., Hoppe, P., Zinner, E., & Lewis R. S. 1995, *Meteoritics*, 30, 490
Anders, E. & Zinner, E. 1993, *Meteoritics*, 28, 490
Bernatowicz, T. J., Messenger, S., Pravdivtseva, O., Swan, P., & Walker, R. M. 2003, *Geochim. Cosmochim. Acta*, 67, 4679
Busso, M., Gallino, R., & Wasserburg, G. J. 1999, *ARAA*, 37, 239
Croat, T. K., Stadermann, F. J., & Bernatowicz, T. J. 2005, *ApJ*, 631, 976
Draine, B. T. 2003, *ARAA*, 41, 241
Hoppe, P. & Zinner, E. 2000, *J. Geophys. Res.*, A105, 10371
Hoppe, P., Ott, U., & Lugmair, G. W. 2004, *New Astron. Revs*, 48, 171
Kanai.Y., 2010, Ph.D. thesis, Tokyo Institute of Technology
Lodders, K. & Fegley, B. 1998, *Meteorit. Planet. Sci.*, 33, 871
Meyer, B. S., Clayton, D. D., & The, L.-S. 2000, *ApJ* (Letters), 540, L49

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