TeV gamma ray Observations of PSR J1420−6048 with the CANGAROO-II telescope

D.Nishida[1], H.Kubo[1], T.Tanimori[1], A.Asahara[1], G.V.Bicknell[2], R.W.Clay[3], Y.Doi[4], P.G.Edwards[5], R.Enomoto[6], S.Gunji[4], S.Hara[6], T.Hara[7], T.Hattori[8], Sei. Hayashi[9], C.Itoh[10], S.Kabuki[6], F.Kajino[9], H.Katagiri[6], A.Kawachi[6], T.Kifune[11], L.T.Ksenofontov[6], T.Kurihara[8], R.Kurosaka[6], J.Kushida[8], Y.Matsubara[12], Y.Miyashita[8], Y.Mizumoto[13], M.Mori[6], H.Moro[8], H.Muraishi[14] Y.Muraki[12] T.Naito[7] T.Nakase[8], K.Nishijima[8], M.Ohishi[6], K.Okumura[6], J.R.Patterson[3], R.J.Protheroe[3], N.Sakamoto[4], K.Sakurazawa[15], D.L.Swaby[3], H.Tanimura[1], G.Thornton[3], F.Tokanai[4], K.Tsuchiya[6], T.Uchida[6], S.Watanabe[1], T.Yamaoka[9], S.Yanagita[16], T.Yoshida[16], T.Yoshikoshi[17]

(1) Kyoto University, Sakyo-ku, Kyoto 606-8502, Japan
(2) Australian National University, ACT 2611, Australia
(3) University of Adelaide, SA 5005, Australia
(4) Yamagata University, Yamagata, Yamagata, 990-8560, Japan
(5) Inst. Space and Astronautical Sci., Sagamihara, Kanagawa 229-8510, Japan
(6) Inst. for Cosmic Ray Res., Univ. of Tokyo, Kashiwa, Chiba 277-8582, Japan
(7) Yamanashi Gakuin University, Kofu, Yamanashi 400-8575, Japan
(8) Tokai University, Hiratsuka, Kanagawa 259-1292, Japan
(9) Konan University, Kobe, Hyogo 658-8501, Japan
(10) Ibaraki Prefectural Univ. of Health Sciences, Ami, Ibaraki 300-0394, Japan
(11) Shinshu University, Nagano, Nagano 480-8553, Japan
(12) STE Laboratory, Nagoya University, Nagoya, Aichi 464-8602, Japan
(13) National Astronomical Observatoy of Japan, Mitaka, Tokyo 181-8588, Japan
(14) Kitasato University, Sagamihara, Kanagawa 228-8555, Japan
(15) Tokyo Institute of Technology, Meguro, Tokyo 152-8551, Japan
(16) Ibaraki University, Mito, Ibaraki 310-8512, Japan
(17) Osaka City University, Osaka, Osaka 558-8585, Japan

Abstract

PSR J1420−6048 is a young radio pulsar recently discovered within the error box of the EGRET source 3EG 1420−6038. The pulse period is 68 ms, and both the spin-down energy and flux are as large as those of the pulsars in the TeV gamma ray detected nebulae, Crab and PSR B1706−44. Thus PSR J1420−6048 is a good candidate TeV gamma ray source, and so we observed it with the CANGAROO-II telescope in March and June 2002. No significant excess of gamma ray events was detected, and we have placed an upper limit on

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the gamma ray flux. From the multi-wavelength spectrum we have calculated a lower limit for the magnetic field in the nebula.

1. Introduction

The EGRET detector onboard the *CGRO* satellite discovered 3EG J1420 −6038 in the GeV band, but the source had not previously been identified at other wavelengths [1]. In 1998 the X-ray source AX J1420.1−6049 was discovered with *ASCA* in the error box of 3EG 1420−6038, as shown in Fig. 1. (K3 in left panel). The X-ray source has a hard spectrum with photon index 1.6 ± 0.4. A pulsed component is marginally detected and size of the nebula was not measured [6,8]. In 2001, PSR J1420−6048 was discovered by the Parkes multibeam pulsar survey at a position $(\alpha, \delta) = (14^h20^m08^s, -60°48'16'')$ (J2000), consistent with AX J1420.9-6049. The pulse period of PSR J1420−6048 is 68 ms in Fig. 1. A distance of $d = 7.7 \pm 1.1$ kpc was estimated from the dispersion measure ($DM = 360\,\mathrm{pc\,cm^{-3}}$), however a distance of 2 kpc was inferred from the X-ray observation [5]. The characteristic age of the pulsar is $\tau_c = 13$ kyr, confirming the pulsar is relatively young. The inferred spin-down energy is $1.0 \times 10^{37}\,\mathrm{erg\,s^{-1}}$ and the spin-down flux $\dot{E}d^{-2}$ is $2.5 \times 10^{36}\,\mathrm{erg\,s^{-1}\,kpc^{-2}}$ for $d = 2$ kpc, and 3rd-ranked pulsar among GeV gamma ray pulsars. Comparing the spin-down flux with those of the Crab pulsar and the PSR B1706−44 [3], the nebulae of which have been detected in TeV gamma rays, the value of PSR J1420−6048 is the second highest (as the $\dot{E}/d^2$ is $1.3 \times 10^{38}\,\mathrm{erg\,s^{-1}\,kpc^{-2}}$ and $9.6 \times 10^{35}\,\mathrm{erg\,s^{-1}\,kpc^{-2}}$ for the Crab and PSR B1706−44, respectively) Pulsar systems detected at TeV gamma ray energies generally have large spin-down fluxes. Thus PSR J1420−6048 is a strong candidate TeV gamma ray source, and so we observed the pulsar in May and June 2002 with the CANGAROO-II telescope [4].

2. Observation & Analysis

We observed PSR J1420−6048 for 12.8 hours in May and for 13.2 hours in June, with background (OFF source) observations of 13.2 hours in May and 5.1 hours in June. The total observation times are 26 hours (ON source) and 18.3 hours (OFF source). We selected the observation data taken under good sky conditions and at elevation angles of more than 50 degrees. The observation times after these cuts are 12.6 hours in May and 9.5 hours in June (ON source), and 10.9 hours and 4.5 hours (OFF source). We eliminated events dominated by the night sky background from the data. To discriminate cosmic-ray–like events from gamma-ray–like events, we adopted the standard Imaging analysis techniques [2,9]. We carried out Monte Carlo simulations of gamma ray events assuming a differential flux spectral index of −2.5 and for an elevation angle of 60 degrees. The energy threshold was estimated to be 600 GeV from these simulations.

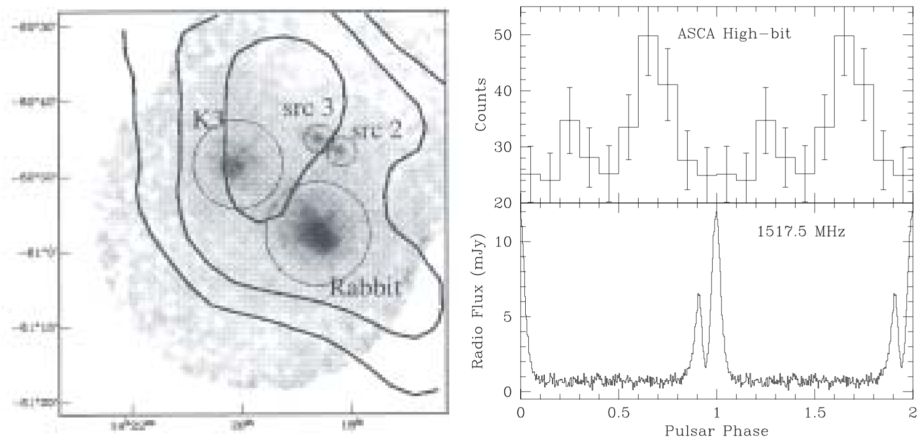

Fig. 1. *ASCA* GIS image (left panel). The contours are the 68%, 95%, 99% levels of the 3EG1420−6038 [8]. The pulse profiles of AX J1420.1−6049 and PSR J1420−6048 are shown in the right panel [7], the *ASCA* GIS data in the top panel and the 20 cm Parkes radio data in the bottom panel.

3. Results & Discussion

Fig. 2. shows the orientation angle *alpha* distribution after above selections. No significant excess of gamma ray events was detected. Two sigma upper limit for the gamma ray flux from PSR J1420−6048 is plotted in the multi-wavelength spectrum (Fig. 2.). Assuming that the TeV gamma rays are generated via the inverse Compton scattering of 2.7 K CMB process, the expected flux with several different values of the magnetic field strength is shown in the multi-wavelength spectrum (Fig. 2.). From the TeV gamma ray upper limit, the lower limit of the magnetic field in the nebula is derived (Fig. 2.). To obtain the maximum energy of accelerated electrons, we have to search the cutoff energy of synchrotron emission and strength of magnetic field in a nebula. Using *Chandra* whose angular resolution is higher than *ASCA*, we can discriminate between pulsed and unpulsed components, and obtain cutoff energy of synchrotron emission more precisely. Further analysis in higher energy band observed with the CANGAROO-II can place limit on the magnetic field in the nebula more strongly. It is important for study of the emission mechanism to obtain the size of X-ray nebula. But the size was not derived with *ASCA*. The higher angular resolution of *Chandra* can reveal the size of nebula surroundings PSR J1420−6048.

4. Conclusion

We observed PSR J1420−6048 in May and June 2002, with no significant excess being detected. From the multi-wavelength spectrum including the upper

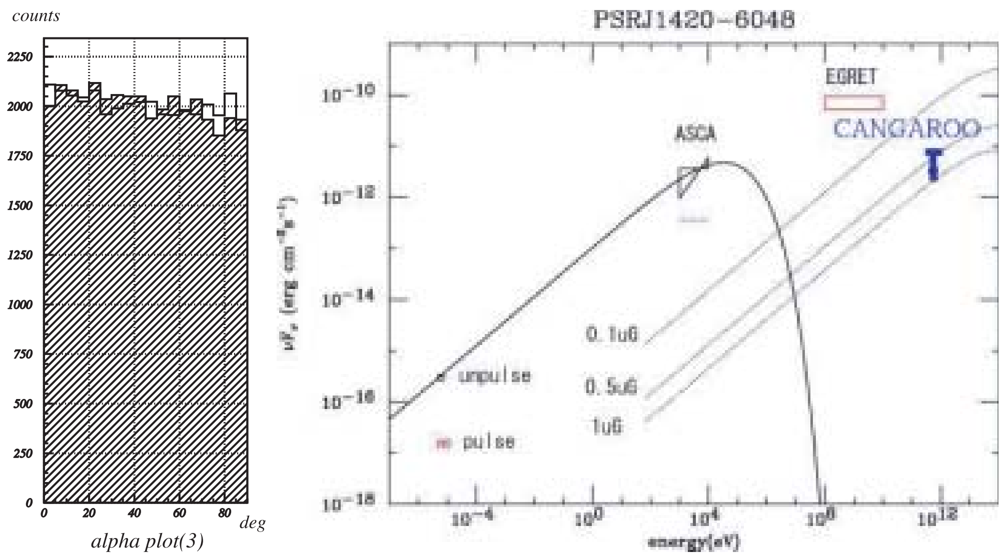

Fig. 2. (left)*Alpha* distribution. Solid and hatched histograms are for ON source and OFF source data, respectively. (right) The multi-wavelength spectrum of PSR J1420−6048 is shown in the right-hand panel. The solid line from radio to X-ray energies is fitted with synchrotron radiation model, with the dotted lines showing the resulting inverse Compton scattering of the 2.7 K CMB photons.

limit of the TeV gamma ray flux, we obtained a lower limit for the magnetic field. *Chandra* observed PSR J1420−6048 in September 2002, and we intend to obtain the size and the spectrum of the nebula with the archived data.

5. References

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