Letter to the Editor

EGRET gamma-ray source 2EG J0809+5117, a quasar with redshift of 1.14?

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Abstract. The low dispersion (400Å/mm) spectrum of the optical counterpart of a flat-spectrum radio source 87GB 080315.5+512613, which is one of two possible radio counterparts of 2EG J0809+5117, was obtained recently. The optical counterpart, which is $2.02''$ away from 87GB 080315.5+512613 and $19.3'$ away from 2EG J0809+5117, was identified as a quasar with redshift of 1.14. We noted that Mattox et al. (1997) suggested the other radio counterpart 87GB 080459.4+495915 (OJ 508), which is $87.1'$ away from 2EG J0809+5117, is the more potential identification, though it was previously suggested to be the identification (with low confidence) of another nearby EGRET source 2EG J0807+4849. Our observation suggests that it is quite possible that 87GB 080315.5+512613 is the identification of 2EG J0809+5117 rather than 87GB 080459.4+495915. But we still can not exclude the possibility of 87GB 080459.4+495915 at present. Moreover, in order to determine whether or not 87GB 080315.5+512613 is a blazar type quasar, the optical polarization and variability measures of its optical counterpart are strongly encouraged.

Key words: galaxies: active – galaxies: nuclei – gamma rays: observations – quasars: general

1. Introduction

The Energetic Gamma Ray Experiment Telescope (EGRET) is the high-energy γ-ray telescope on the *Compton Gamma-Ray Observatory (CGRO)*. The telescope covers the energy range from about 30 MeV to over 20 GeV. From April 1991 to October 1994, the all-sky survey program of EGRET has completed three phases observations. Up to now, the published EGRET catalogs include 157 γ-ray sources (Fichtel et al. 1994; Thompson et al. 1995; Thompson et al. 1996). Among them, 61 sources

have been identified, including 43 AGN with high confidence, 11 AGN with lower confidence, 5 pulsars, one solar flare and Large Magellanic Cloud (LMC). Other 96 sources still remain unidentified.

Except LMC, all previously identified EGRET sources with higher galactic latitude (e.g., $|b| > 10^o$) are blazar type AGN. These AGN usually have strong, compact, flat-spectrum ($\alpha \geq -0.5$, where $S(\nu) \propto \nu^{\alpha}$) radio emission, strong optical polarization and significant optical variations on short time scales. The blazar class includes objects classified as BL Lacertae type objects, high polarization quasars (HPQ), and optically violently variable (OVV) quasars. Although the γ-ray radiation of blazars has not been well understood, some observational properties of blazars are believed to result from a relativistic jet which is directed within $\sim 10^o$ of the line of sight.

By introducing Bayes' theorem to assess the reliability of the identification of EGRET sources with extragalactic radio sources, Mattox et al. (1997) recently demonstrated conclusively that EGRET is detecting the blazar class of AGN. They also indicated possible radio identifications of sources with $|b| > 3^o$ in the second EGRET catalog and its supplement. Most of these radio sources have 5GHz radio flux larger than 50 mJy and spectra index larger than -0.5. In order to assure some of these radio sources are more probably the identifications of EGRET sources, optical identifications of these radio sources are necessary. Based on this idea, we are planning a program at Beijing Astronomical Observatory to do the optical spectroscopic studies of the possible optical counterparts of these flat-spectrum radio sources.

2. 2EG J0809+5117 and its radio counterparts

The main properties of γ-ray source 2EG J0809+5117 were summarized in the second EGRET catalog (Thompson et al. 1995). The source position is R.A.=122.27^o, Decl.= 51.29^o (J2000) and the Galactic coordinates is $l = 167.46^o, b = 32.74^o$. Its semiminor axes of an eclipse fited to the 95% confidence

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Table 1. Two possible radio counterparts of 2EG J0809+5117

$Name$	$R.A.$	$Decl.$	S_{5G}	α	r	$Contour$(%)	LR
$87GB\,080315.5+512613$	$08h07m01.01457s$	$51^o17'38.6721''$	237	0.3	$19.3'$	32.8	26.8
$87GB\,080459.4+495915$	$08h08m39.66670s$	$49^o50'36.5280''$	1229	0.3	$87.1'$	98.0	4.0

error contour are A=84′ and B=51′ respectively. The flux (E>100MeV) is F=9.4 and the 1 σ statistical uncertainty in the flux is $\triangle$F=2.6 (both in unit of $10^{-8}photonscm^{-2}s^{-1}$). Thompson et al. (1995) listed 2EG J0809+5117 as an unidentified source in the second EGRET catalog. Mattox et al. (1997) found two flat-spectrum radio sources from 5GHz radio catalog (Becker, White & Edwards 1991) as possible counterparts of 2EG J0809+5117. One is 87GB 080315.5+512613 and the other is 87GB 080459.4+495915. Some properties of these two sources are summarized in Table 1. The positions of these two sources have been measured with VLA and their position errors are about 12 milliarcseconds in both right ascension and declination (Patnaik et al. 1992). The source coordinates (R.A. and Decl.) in Table 1 are given in epoch J2000.0. S_{5G} and α are the 5GHz flux (in mJy) and spectra index. r is the angle between the radio source and the EGRET source. The contour(%) shows the position confidence contour at the radio position. LR is the likelihood ratio indicating the strength of the indication for the identification.
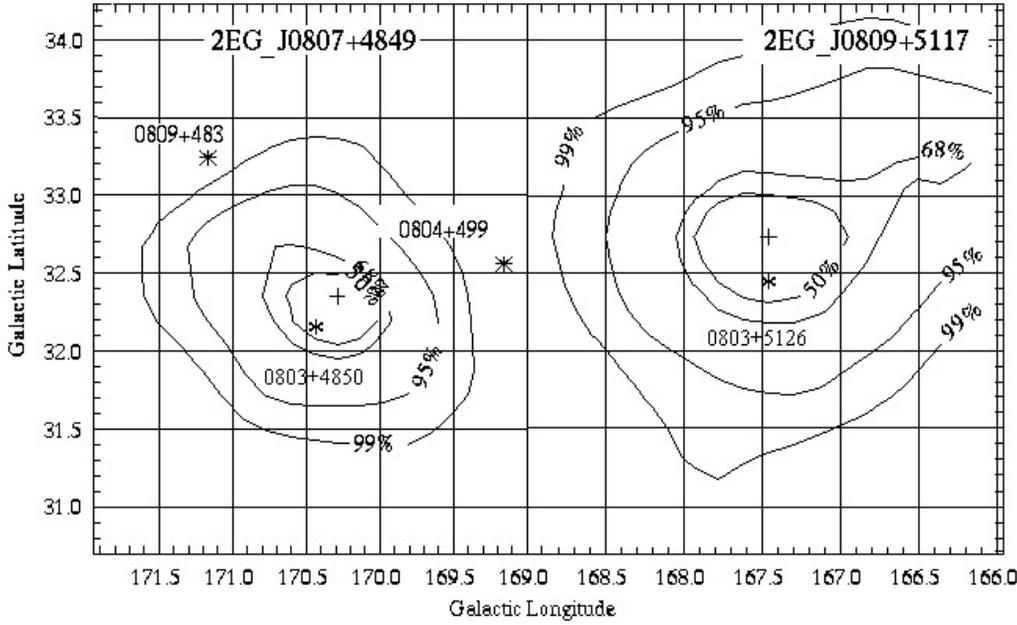
The location of these two sources and the error contour map of 2EG J0809+517 are shown in Figure 1. 87GB 080459.4+495915 has been identified as a HPQ with z=1.43, namely OJ508. But 87GB 080315.5+512613 has not been optically identified previously. Although 87GB 080315.5+512613 is within the 50% error contour of 2EG J0809+5117 and has larger likelihood ratio, Mattox et al. (1997) still listed 87GB 080459.4+495915 as the more potential identification of 2EG J0809+5117 based on the probability analyses which gave the posteriori probability for 87GB 080459.4+495915 and 87GB 080315.5+512613 as 0.079 and 0.014 respectively. This is because that the posteriori probability strongly depends on the priori probability which, for 87GB 080459.4+495915 and 87GB 080315.5+512613, were estimated as 0.0213 and 0.0005. This large difference of the priori probability reflects the fact that strong flat-spectrum radio sources are much more likely to be detected by EGRET. However, we also noted that 87GB 080459.4+495915 has been suggested as the identification (with lower confidence) of another nearby EGRET source 2EG J0807+4849 (Thompson et al. 1993; Nolan et al. 1996). Fig. 1 also shows the locations of there possible radio counterparts and the contour of 2EG J0807+4849. Mattox et al. (1997) also listed 87GB 080459.4+495915 as one of these three possible radio counterparts. But they thought another OVV quasar 3C 196, namely 87GB 080959.9+482202 (z=0.87), is the more possible identification of 2EG J0807+4849 than 87GB 080459.4+495915. The other radio source, 87GB

080305.0+485033, given by Mattox et al. (1997) as also a possible counterpart of 2EG J0807+4849, is shown within the 50% contour of 2EG J0807+4849. It was previously identified as a galaxy with visual magnitude of 18.5 (Becker, White & Edwards 1991). However, 3C 196 and 87GB 080305.0+485033 have much steep radio spectra, with spectra index of -0.9 and -0.6 respectively. Because we believe that EGRET is detecting only flat spectrum radio sources, we can not state conclusively that they are the more possible identifications of 2EG J0807+4849 than 87GB 080459.4+495915. Although Mattox et al. (1997) obtained much larger posteriori probability for 3C 196 and 87GB 080305.0+485033 than that for 87GB 080459.4+495915, we must note that this is due to the large difference in the priori probability. They assumed that the priori probability is only dependent on the 5GHz radio flux. This may bring some errors in estimating the priori probability because the flat-spectrum radio sources are more likely to be detected by EGRET. In this letter, we will not make more discussions about the identification of 2EG J0807+4849 but only focus on the identification of 2EG J0809+5117. For latter case, the optical identification of the other possible flat-spectrum radio counterpart of 2EG J0809+5117, namely 87GB 080315.5+512613, is helpful to see whether or not it could be the true identification.

3. Probability analysis and spectroscopic observation of the optical counterpart of 87GB 080315.5+512613

It is very easy to find the nearest optical source of 87GB 080315.5+512613 in DSS (Palomar Digitized Sky Survey) image. We think this source, which is only 2.02″ away from the radio position, is probably the optical counterpart of 87GB 080315.5+512613. Its position is R.A.=08h07m01.1s, Decl.=51°17′40.5″ (J2000), which is also about 19.3′ away from the estimated position of 2EG J0809+5117. Fig. 2 show its DSS image with size of 10′ × 10′ and also the location of radio position.

In order to exclude the possibility that this optical source is a confusion source of 87GB 080315.5+512613, we performed a simple quantitative probability analysis. We adopted the method used by de Ruiter, Arp & Willis (1977) to identify optical counterparts of 1.4GHz radio sources. The posteriori probability of an optical counterpart can be expressed as $p(id|r) = \frac{\theta}{1-\theta}LR(r)/(\frac{\theta}{1-\theta}LR(r) + 1)$ where θ is the priori probability and $LR(r)$ is the likelihood ratio given by $LR(r) = \frac{1}{2\lambda}exp(\frac{r^2}{2}(2\lambda - 1))$. The dimensionless variables r and λ are defined as $r = (\frac{\Delta\alpha^2}{\sigma_\alpha^2} + \frac{\Delta\delta^2}{\sigma_\delta^2})^{1/2}$ and $\lambda = \pi\sigma_\alpha\sigma_\delta\rho(b)$,

Fig. 1. The error contours of 2EG J0809+5117 and 2EG J0807+4849 and the locations of their possible radio counterparts. The crosses represent the estimated position of EGRET sources and the stars represent the position of their possible radio counterparts. 0803+5126, 0804+499, 0803+4850 and 0809+483 are short for 87GB 080315.5+512613, 87GB 080459.4+495915 (OJ508), 87GB 080305.0+485033 and 87GB 080959.9+482202 (3C 196) respectively.
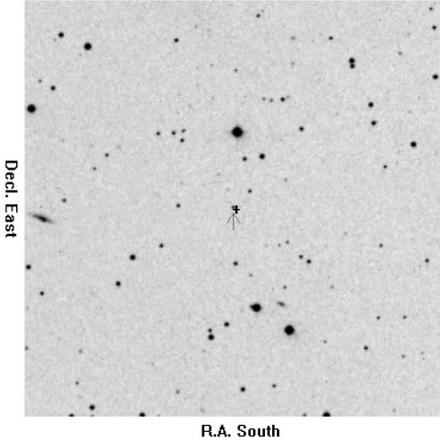

Fig. 2. The DSS image ($10' \times 10'$) centered at the location of 87GB 080315.5+512613. The arrow points to its optical counterpart and the cross indicates the radio position.

where $\rho(b)$ is the number density of optical sources, $\Delta\alpha$ and $\Delta\delta$ are the measured position difference between the radio source and an optical object, and σ_α, σ_δ are given by $\sigma_\alpha^2 = \sigma_{\alpha_{rad}}^2 + \sigma_o^2$ and $\sigma_\delta^2 = \sigma_{\delta_{rad}}^2 + \sigma_o^2$. $\sigma_{\alpha_{rad}}$ and $\sigma_{\delta_{rad}}$ are the standard deviations of the right ascension and declination positions of the radio source and σ_o is the measurement error of the optical position. Patnaik et al. (1992) estimated that $\sigma_{\alpha_{rad}}$ and $\sigma_{\delta_{rad}}$ for their VLA measurements are both about 12 milliarcseconds. For optical sources in Palomar Sky Survey, we take a conservative value of σ_o as 1 arcsecond. The number density $\rho(b)$ of optical

sources in POSS Plate at galactic latitute of 32.5^o is estimated about $6 \times 10^{-4} arcsec^{-2}$ (de Ruiter et al. 1977). The position differences $\Delta\alpha$ and $\Delta\delta$, in the sense radio-oprical, are -0.0854 arcsec and -1.8279 arcsec for our optical counterpart of 87GB 080315.5+512613. Therefore, we obtain that $LR(r) = 50.04$. If we assume the priori probability θ of finding an optical counterpart to a radio source is about 25%, the posteriori probability for our optical counterpart will be 0.943. Even when we assume θ is 10%, the probability is still as high as 0.917. Therefore, we think that the nearest optical source to 87GB 080315.5+512613, is most probably its optical counterpart. The probability that it is a confusion source is very low.

The spectroscopic observations of this source were performed twice on Januray 5 and March 8, 1997 using the CCD detector TEK1024 mounted on the 2.16m reflector at Xinglong station of Beijing Astronomical Observatory. The spectra dispersion is about $400\text{Å}/mm$ and the exposures are 40 and 70 minutes respectively. The spectrum, after the standard light sky subtraction and the absolute flux calibration using MIDAS (Munich Image Data Analysis System developed by ESO), is shown in Fig. 3.

It is clear that the MgII line (2798Å at rest frame) has shifted to 6008Å and the CIII] line (1905Å at rest frame) shifted to 4080Å. The average redshift is 1.14. The V-band magnitude, measured at 5500Å, is about 18.5. The luminosity distance D_L is about $10738 Mpc$ and the V-band absolute magnitude M_v is about -26.7 (we adopted $H_0 = 50 kms^{-1} Mpc^{-1}$ and $q_0 = 0$). This quasar has not been listed in any published catalogs of
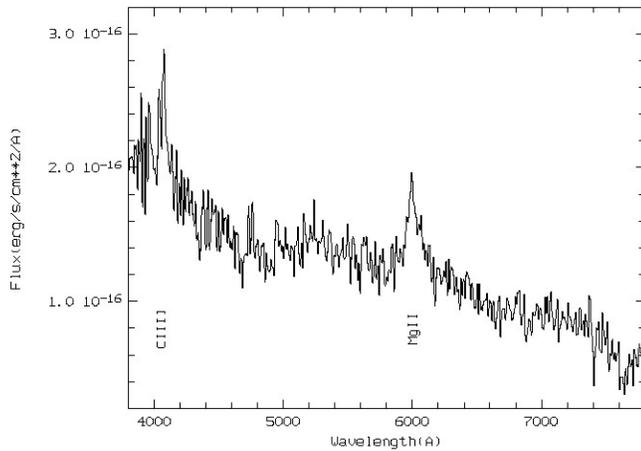
Fig. 3. The low dispersion spectrum of the optical counterpart of 87GB 080315.5+512613.

AGN including a well-known one edited by Véron-Cetty & Véron (1996).

Because all previously identified EGRET sources with higher galactic latitude are blazars, we expect that the optical source we observed is also a blazar-type quasar if it is really the counterpart of 2EG J0809+5117. However, it needs to be confirmed by more observations such as measuring its optical variability and polarization. Unfortunately, we are unable to do these measurements at Beijing Observatory at present. We strongly encourage other interested astronomers to do these observations.

4. Discussions

We have identified an optical source, which is most probably the counterpart of a flat-spectrum radio source 87GB 080315.5+512613, as a quasar with redshift of 1.14. Although more optical observations are still needed to be done to see whether or not it is a blazar-type quasar, we think it is quite possible that 87GB 080315.5+512613 is the identification of 2EG J0809+5117 rather than another nearby flat-spectrum source 87GB 080459.4+495915 (OJ508). The latter one has been previously suggested to be the lower confidence identification of another EGRET source 2EG J0807+4849 (Thompson et al.

1993; Nolan et al. 1996). But Mattox et al. (1997) recently indicated that another steep spectrum OVV quasar 3C 196 is the more potential identification of 2EG J0807+4849 than 87GB 080459.4+495915 based on the probability analyses. However, in their analyses the priori probability is assumed independent on the EGRET exposure and radio spectra index, which might bring some errors to the estimated posteriori probability.

Our observation still can not exclude the possibility that 87GB 080459.4+495915 is the counterpart of 2EG J0809+5117. If the future observations on the optical variability and polarization of the optical counterpart of 87GB 080315.5+512613 confirm it is a blazar-type quasar, we think it will enhance the possibility that 87GB 080315.5+512613 is the identification of 2EG J0809+5117. However, even at this stage we can not state conclusively that it is the true identification because there are still a lot of blazars not detected by EGRET. Therefore, in order to improve the present status of the EGRET source identifications, much more observations and analyses are still expected to be done.

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