Acta Polytechnica **53**(Supplement):631–634, 2013
doi:10.14311/AP.2013.53.0631

THE SEARCH FOR BLAZARS AMONG THE UNIDENTIFIED EGRET γ-RAY SOURCES

Pieter J. Meintjes[a,*], Pheneas Nkundabakura[a,b]

[a] *Department of Physics, University of the Free State, PO Box 339, Bloemfontein, 9300, South Africa*
[b] *Kigali Institute of Education, P.O. Box 5039, Kigali, Rwanda*
[*] corresponding author: MeintjPJ@ufs.ac.za

Abstract. In this paper we report the results of a multi-wavelength follow-up study of selected flat spectrum extragalactic radio-optical counterparts within the error boxes of 13 unidentified EGRET sources. Two of these previously unidentified counterparts have been selected for optical photometric and spectroscopic follow-up studies. Spectroscopic observations made with the 4.1 m *SOAR* telescope at Cerro Pachón, Chile, showed that the spectra of the optical counterparts of 3EG J0821−5814 (PKS J0820−5705) and 3EG J0706−3837 (PMN J0710−3835) correspond to a flat spectrum radio quasar (FSRQ) and LINER-Seyfert I galaxy respectively. Optical photometry of these sources, performed with the 1.0 m telescope at Sutherland (South Africa) shows noticeable intranight variability for PKS J0820−5705, as well as a 5 sigma variation of the mean brightness in the R-filter over a timescale of three nights. Significant variability has been detected in the B-band for PMN J0710−3835 as well. The gamma-ray spectral indices of all 13 candidates range between 2–3, correlating well with the BL Lacs and FSRQs detected with Fermi-LAT in the first 11 months of operation.

Keywords: radiation mechanisms: non-thermal, line: identification, techniques: spectroscopic, galaxies: jets, BL Lacertae objects.

1. Introduction

The Energetic Gamma Ray Telescope Experiment *EGRET* (20 MeV ÷ 30 GeV) provided the highest gamma-ray window on board the Compton Gamma-Ray Observatory (CGRO). The main scientific objective was to survey the gamma-ray sky to identify and study possible point sources of gamma-ray emission. *EGRET* detected 271 gamma-ray sources above 100 MeV, 92 % of which were blazars. Of the 271 sources detected, 131 remained unidentified, i.e. could not be associated with any specific point source of gamma-ray emission [5]. The aim of this study is to search for possible extra-galactic radio loud Active Galactic Nuclei (AGN), i.e. blazars and Flat Spectrum Radio Quasars (FSRQs) within some selected *EGRET* error boxes. To avoid confusion with possible galactic sources, especially molecular cloud distributions, the search was restricted to some unidentified sources at galactic latitudes $|b| > 10$ deg.

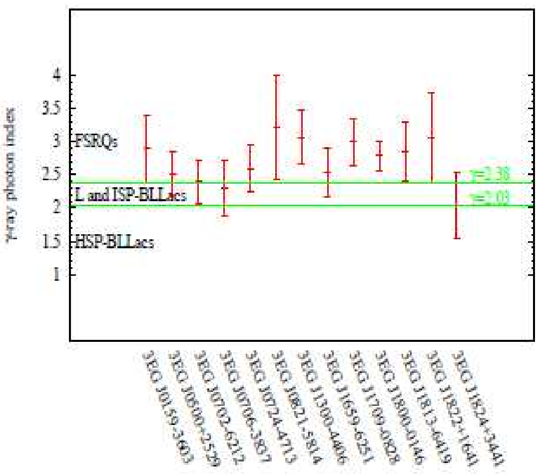


Figure 1. Gamma-ray spectral index distribution of selected unidentified sources.

Selection criteria The counterparts should be inside the error box associated with the detection [5], confirmed as extragalactic in the NASA Extragalactic Database (NED), have radio brightness above 100 mJy at 8.4 GHz [8], exhibiting hard spectra with spectral indices $|\alpha| < 0.7$ [8] and display variability (e.g. [4]) that may be associated with an inner accretion disc or jet. Based upon these criteria, 13 sources have been selected for further follow-up study.

The EGRET (30 MeV ÷ 10 GeV) gamma-ray spectra of these sources observed between April 1991 and October 1995 (cycles 1, 2, 3 and 4 of the mission) have been determined. The spectral index distribution is displayed in Fig. 1.

The spectral distribution of these unidentified sources corresponds remarkably well with the gamma-ray blazar spectral index distribution observed by Fermi-LAT in the first 11 months of operation [1].

In the first phase of this study, two of these previously unidentified counterparts, i.e. PKS J0820−5705 and PMN J0710−3850, were selected for further optical spectroscopic and photometric follow-up studies.

EGRET	Counterpart	Dec(J2000)	RA(J2000)
3EG J0159−3603	J0156−3616	−36 16 14	01 56 47
3EG J0500+2502	J0502+2516	+25 16 24	05 02 59
3EG J0702−6212	J0657−6139	−61 39 26	06 57 02
3EG J0706−3837	J0710−3850	−38 50 36	07 10 43
3EG J0724−4713	J0728−4745	−47 45 14	07 28 22
3EG J0821−5814	J0820−5705	−57 05 35	08 20 58
3EG J1300−4406	J1302−4446	−44 46 52	13 02 31
3EG J1659−6251	J1703−6212	−62 12 38	17 03 37
3EG J1709−0828	J1713−0817	−08 17 01	17 13 06
3EG J1800−0146	J1802−0207	−02 07 44	18 02 50
3EG J1813−6419	J1807−6413	−64 13 50	18 07 54
3EG J1822+1641	J1822+1600	+16 00 12	18 22 11
3EG J1824+3441	J1827+3431	+34 31 05	18 27 00

Table 1. Some unidentified high galactic latitude unidentified sources and counterparts.

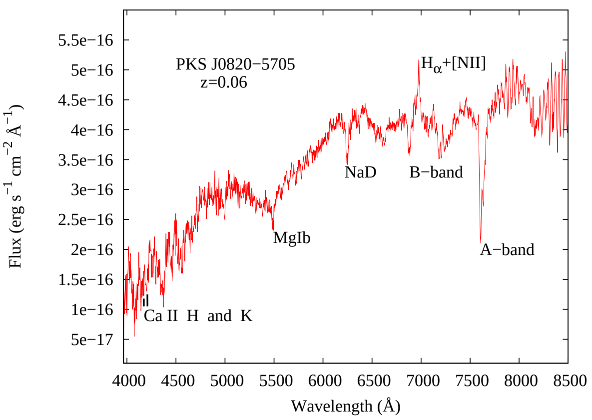


Figure 2. Spectrum of PKS J0820−5705 (FSRQ).

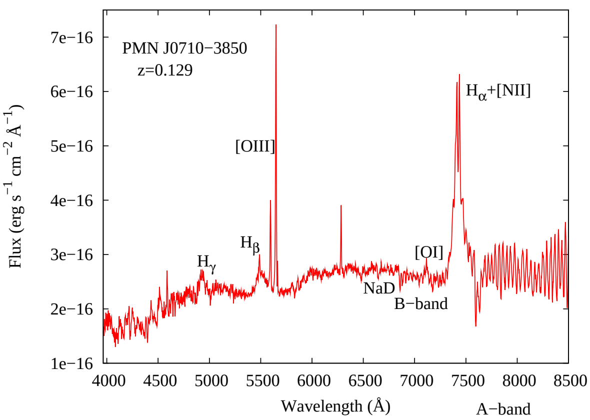


Figure 3. Spectrum of PMN J0710−3850 (LINER-Seyfert I).

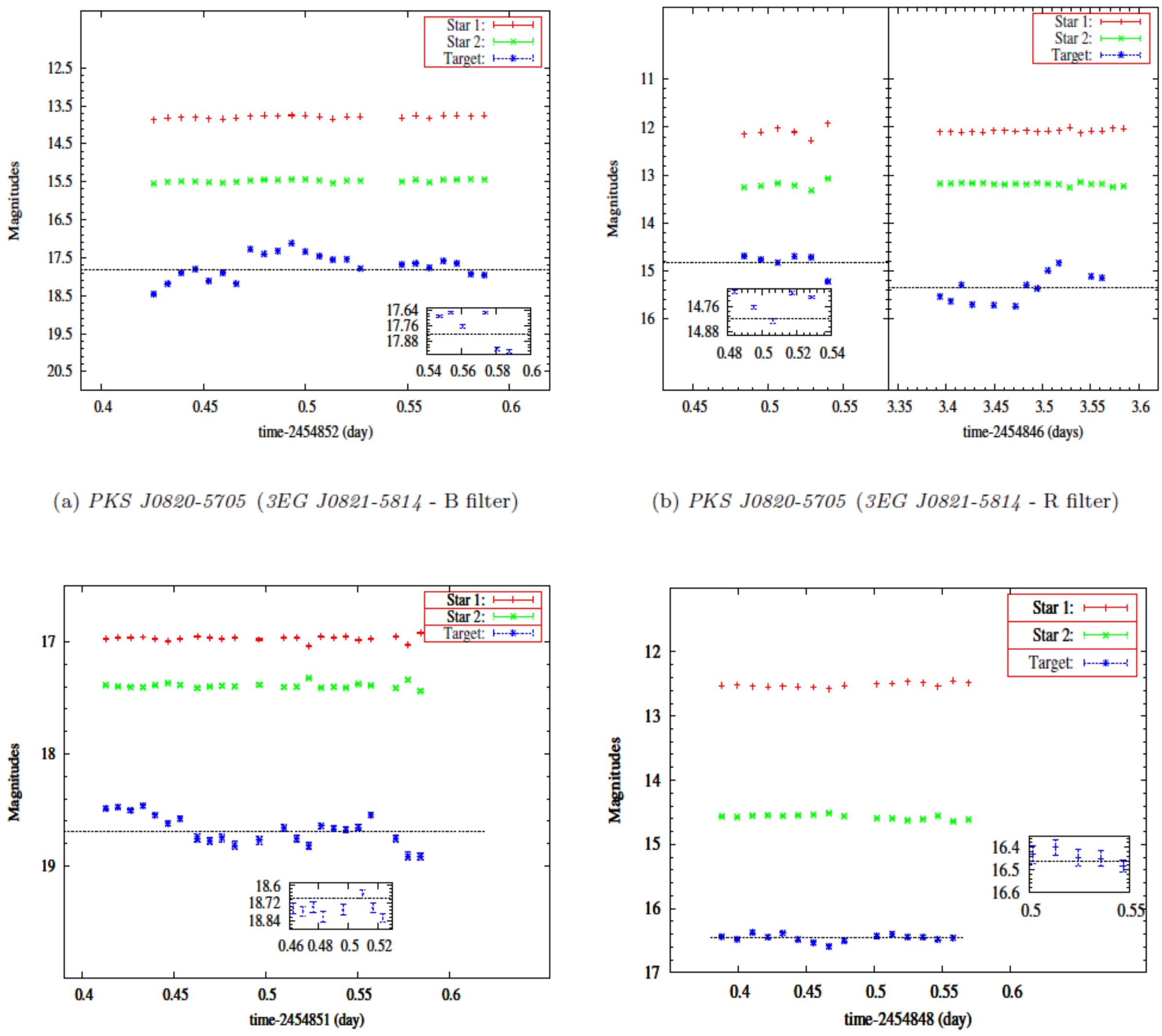
2. Optical follow-up studies

Optical spectroscopy of the two selected counterparts was performed using the 4.1 m *SOAR* telescope in Chile on the night of January 16–17 2009, utilizing the *Goodman* spectrograph. The spectra of both these sources are shown in Fig. 2 (PKS J0820−5705) and Fig. 3 (PMN J0710−3850), respectively. The spectrum for PKS J0820−5705 resembles that of an FSRQ at redshift $z = 0.06$, while the spectrum of PMN J0710−3850 shows broad and narrow lines resembling the spectrum of a LINER or Seyfert I galaxy at redshift $z = 0.129$. What distinguishes the spectrum of PKS J0820−5705 from that of a normal radio galaxy is the shallow K4000 depression of only $8.8\,\% \pm 2.5\,\%$, indicating substantial non-thermal activity, while the corresponding value for PMN J0710−3850 is $80\,\% \pm 1\,\%$, in agreement with the value expected for a LINER-Seyfert I galaxy (e.g. [2]).

Optical photometry in the B and R filters (Fig. 4) of these systems during January 2009 shows peculiar intranight variability, as well as variability at the $5\,\sigma$ level over timescales of a few nights for PKS J0820−5705. This level of intranight variability from PKS J0820−5705 has also been observed in a few other sources e.g. blazars AO 0235+164 and PKS J0736+17 (e.g. [4]) respectively. The variability observed in PMN J0710−3850 corresponds to that observed from another Seyfert I galaxy, i.e. NGC 4395 (e.g. [3]).

3. SED modelling

The multi-wavelength data from the two counterparts from radio to gamma-rays have been combined to create the Spectral Energy Distribution (SED) over more than 15 decades in energy (Fig. 5). The data is fitted with a single zone Synchrotron self-Compton (SSC) model (e.g. [6]) and External Compton (EC) model (e.g. [7]), i.e. where relativistic jet electrons up-scatter



(a) *PKS J0820-5705* (*3EG J0821-5814* - B filter)

(b) *PKS J0820-5705* (*3EG J0821-5814* - R filter)

(c) *PMN J0710-3850* (*3EG J0706-3837*) - B filter

(d) *PMN J0710-3850* (*3EG J0706-3837*) - R filter

FIGURE 4. Optical photometry (B-band and R-band) of PKS J0820−5705 and PMN J0710−3850. Also shown are the lightcurves of constant brightness comparison stars in the same field.

infrared (IR) photons from the disc torus and possibly optical photons from the emission line regions to high energies. The model parameters are explained in the footnote of Table 2. The gamma-ray emission for 3EG J0706−3837 can readily be explained by an EC process, where jet electrons upscatter photons from both the disc torus and emission line regions to high energies, while for 3EG J0821−5814 the gamma-ray component is mostly compatible with an SSC process. For 3EG J0821−5814, a higher energy component of the *EGRET* spectrum below the indicated upper limits, could possibly be associated with an EC process.

4. Conclusions

We report the discovery of 13 flat spectrum extragalactic sources within the error boxes of some high galactic latitude unidentified *EGRET* sources. Four of these *EGRET* sources have been detected with Fermi-LAT within the first 11 months of operation. Optical spectroscopy of PKS J0820−5705 shows a featureless spectrum, shallow K4000 depression with broad absorption lines at $z = 0.06$ resembling an FSRQ, while the spectrum of PMN J0710−3850 shows broad and narrow emission lines at $z = 0.129$, resembling a LINER-Seyfert I galaxy. The optical spectrum of PKS J0820−5705 shows a very shallow K4000 depression of $8.8\,\% \pm 2.5\,\%$, implying the non-thermal emission associated with an FSRQ, while the K4000 depression for PMN J0710−3850 is significantly deeper at $80\,\% \pm 1\,\%$, in accordance with that expected of a LINER-Seyfert I galaxy. Photometry of both these sources shows ~ 1 magnitude intranight variability in the B-band, with an additional $5\,\sigma$ variability seen over a 3-day period in the R-band from PKS J0820−5705. The SED of these sources have been fitted with a combination of SSC and EC models.

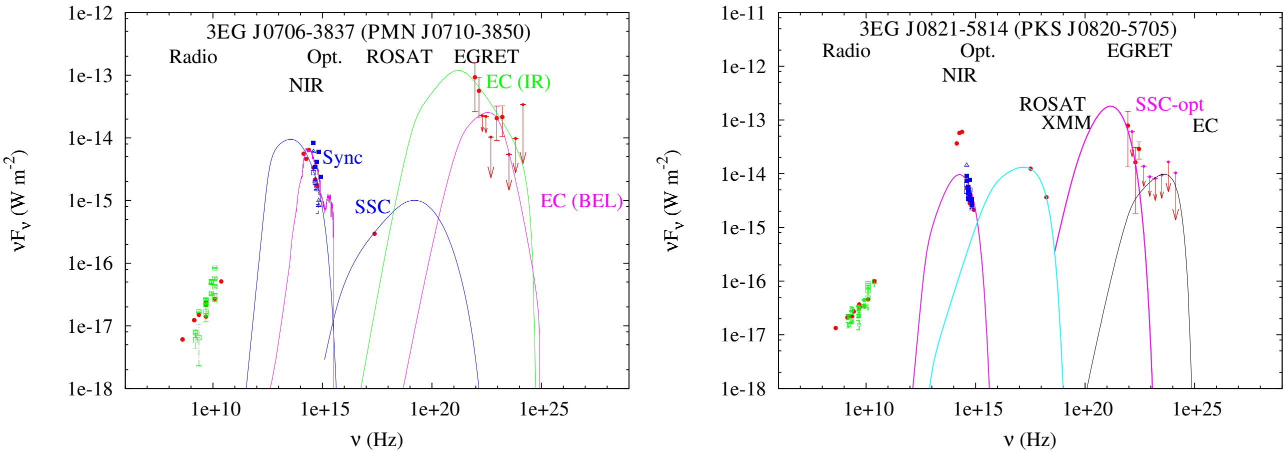


Figure 5. SED model fits for 3EG J0706−3837 (PMN J0710−3850) and 3EG J0821−5814 (PKS J0820−5705).

	SSC		
Parameter	*3EG J0821−5814* SSC (opt)	SSC (X-ray)	*3EG J0706−3837*
r (m)	1.00×10^{13}	1.00×10^{12}	3.50×10^{13}
B (T)	2.50×10^{-4}	2.50×10^{-4}	2.50×10^{-4}
δ	3.8	15	12
$\gamma_{\rm max}$	3.10×10^{3}	7.80×10^{4}	2.00×10^{3}
	EC		
Parameter	*3EG J0821−5814*		*3EG J0706−3837*
r (m)	1.0×10^{15}		1.0×10^{15}
B (T)	2.50×10^{-4}		2.50×10^{-4}
Γ	10		10
$\theta_{\rm obs}$ (rad)	0.2		0.52
$K_{\rm e}$	3.0×10^{50}		2.5×10^{53}
$u_{\rm IR}$ (in erg cm^{-3})	0.08		25
$\nu_{\rm IR}$ (in eV)	0.01		0.1

Table 2. SSC and EC model parameters for *3EG J0821−5814* and *3EG J0706−3837*. The SSC (opt) refers to the SSC model fit obtained using the optical data as part of the synchrotron emission while the SSC (X-ray) refers to the model fit obtained using the X-ray data as part of the synchrotron emission. Here r and B are the radius and the magnetic field intensity of the emitting region respectively; δ and $\gamma_{\rm max}$ are the Doppler factor and the maximum Lorentz factor of the electrons. The main parameters for the EC model are θ, $u_{\rm IR}$, $\nu_{\rm IR}$, Γ and $K_{\rm el}$ representing the viewing angle, the energy density of dust IR radiation, the IR radiation characteristic frequency, the bulk jet Lorentz factor and the normalization constant in the electron density distribution respectively.

References

[1] Abdo A.A. et al., 2010, ApJ, 710, 1271

[2] Caccianiga A., della Ceca R., Gioi I.M., Maccacaro T & Wolter T., 1999, ApJ, 513, 51

[3] Desroches L-B et al., 2006, ApJ, 650, 88

[4] Fan J-H., 2005, Chin. J. Astron. Astrophys. Suppl., 5, 213

[5] Hartman R., et al., 1999, APJS, 123, 79

[6] Katarzynski K., Sol H & Kus A., 2001, A&A, 367, 809

[7] Sikora M., Begelman M.C. & Rees M.J., 1994, ApJ, 421, 153

[8] Sowards-Emmerd D., Romani R.W. & Michelson P.F.: 2003, ApJ, 590

Discussion

James Beall — Does the variability you mentioned correlate with that observed in blazars? Thank you.

Pieter Meintjes — The level of intranight variability seen in in B and R-filter from PKS J0820−5705 has been seen a few other blazars, for example AO 0235+164 and PKS J0736+17. However, it must be stressed that in most cases the intranight (microvariability) is at a much lower level than has been observed from PKS J0820−5705. The intranight variability seen from PMN J0710−3850 resembles that of another Seyfert I galaxy NGC 4395. So the level of variability is not normally observed, especially in PKS J0820−5705, but it could represent an active phase from these sources. Regular optical monitoring will be performed to verify this.