For details, see Nishimichi et al., Astrophysical Journal 783, 94 (4pp) (2014)

Fifth Fermi Symposium, 20-24 Oct 2014, Nagoya

Fermi-LAT Detection of Two High Galactic Latitude Gamma-ray Sources, Fermi J1049.7+0435 and J1103.2+1145

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Introduction

• During a search for gamma-ray emission from NGC 3628 (Arp 317), two new unidentified gamma-ray sources were discovered, Fermi J1049.7+0435 and J1103.2+1145. The detections were made using data from the Large Area Telescope (LAT), on board the Fermi Gamma-Ray Space Telescope, in the 100 MeV to 300 GeV band during the period between 2008 August 5 and 2012 October 27. Neither detection is coincident with any source listed in the second Fermi-LAT (2FGL) catalog. Fermi J1049.7+0435 is at Galactic coordinates (l, b) = (245.°34, 53.°27), (α_{J2000}, δ_{J2000}) = (162.°43, 4.°60). Fermi J1103.2+1145 is at Galactic coordinates (l, b) = (238.°85, 60.°33), (α_{J2000}, δ_{J2000}) = (165.°81, 11.°75). Possible radio counterparts are found for both sources, which show flat radio spectra similar to other Fermi-LAT detected active galactic nuclei, and their identifications are discussed.

Analysis

Our original goal was to search for gamma-ray emission from NGC 3628 (Arp 317), for which possible starburst activity has been reported. Five years of archival data from Fermi-LAT have been analyzed using the Fermi Science Tools supplied by Fermi Science Support Center (FSSC 2013, Fermi Science Tools v9r23p1). The energy range used in the present analysis was from 100 MeV to 300 GeV. "Source" class events detected at zenith angles smaller than 100° were used for analysis, assuming the "P7SOURCE_V6" instrument response function along with the standard analysis pipeline suggested by FSSC. The significance of the gamma-ray signal has been estimated using a maximum likelihood method with the help of the `gtlike` program (which we used in the binned mode) included in the tools. The data periods for this studies span from 2008 August 4 to 2012 October 27.

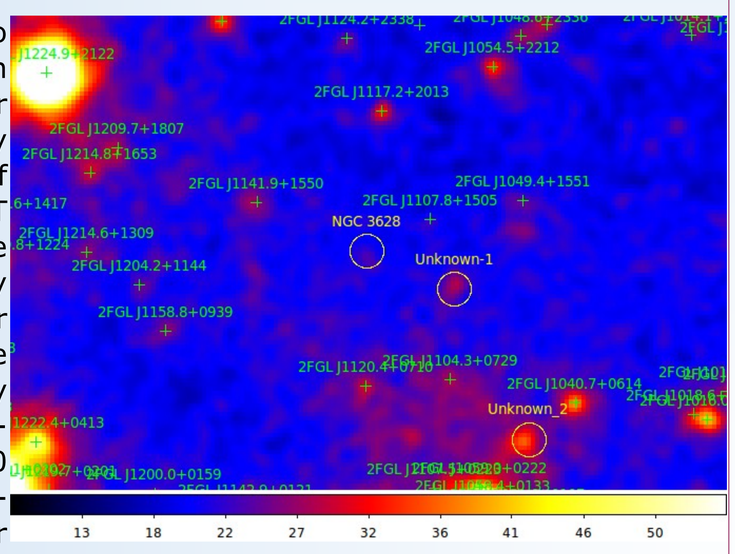

Fig.1 Gamma-ray skymap around the NGC 3628 region. Two new gamma-ray sources are marked as "Unknown_1" (J1103.2+1145) and "Unknown_2" (J1049.7+0435).

During the study of NGC 3628, we noticed two rather bright gamma-ray sources in the field of view centered on NGC 3628 and within a radius of 15° (Nishimichi & Mori 2013). These detections are not coincident with any source listed in the 2FGL catalog (Nolan et al. 2012) or in the third EGRET catalog (3EG, Hartman et al. 1999). Figure 1 shows a gamma-ray countmap of this area. The positions for these sources were estimated using the `gttsmap` program which calculates the TS value assuming an unknown source at various positions in the field of view of interest, and the maximum TS values were obtained for the positions shown in Table 1. The errors of the positions are conservatively estimated as the radius at which the TS value drops to the half value.

Table 1
Best Positions of New Sources

Name	α_{J2000} (deg)	δ_{J2000} (deg)	ℓ^{II} (deg)	b^{II} (deg)	Error Radius (arcmin)
J1049.7+0435	162.43	4.60	245.34	53.27	51
J1103.2+1145	165.81	11.75	238.85	60.33	66

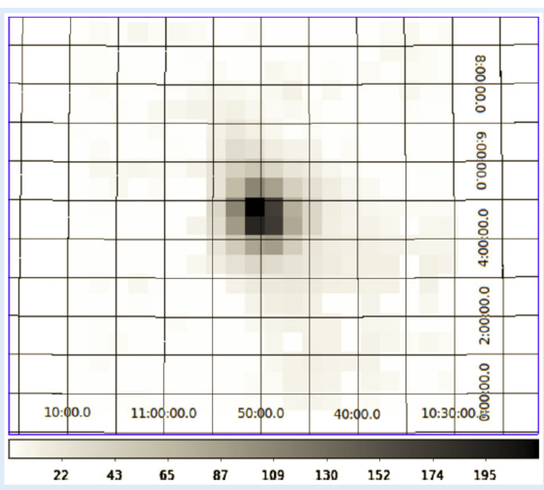

Fig.2 Test-statistics map around the J1049.7+0435 region for the period from 2011 October 27 to 2012 April 27, where the TS value is the highest (TS = 222).

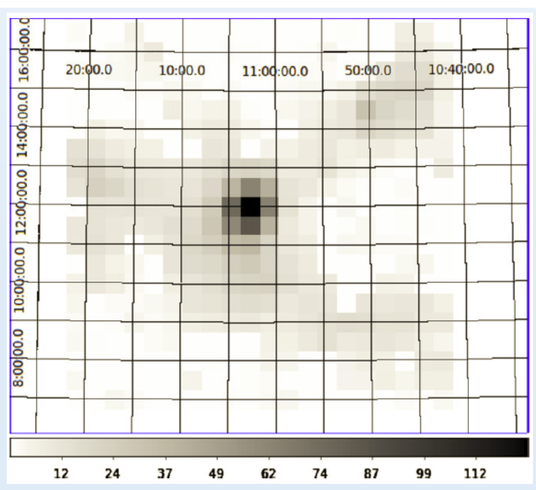

Fig.3 Test-statistics map around the J1103.2+1145 region for the period from 2013 April 27 to 2013 October 27, where the TS value is the highest (TS = 197).

Figures 2 and 3 show the TS maps around the new sources for the half-year period when the TS value takes the maximum, which is consistent with the assumed of point sources. The average fluxes, power-law indices, and TS value for the entire analyzed period (from 2008 August 27 to October 10, 2013) are $(3.68\pm0.36)\times10^{-8}$ cm^{-2} s^{-1} (>100 MeV), –2.60±0.07 and TS = 332 for J1049.7+0435; $(2.35 \pm 0.30) \times 10^{-8}$ cm^{-2} s^{-1} (>100 MeV), –2.55 ± 0.09 and TS = 196 for J1103.2+1145.

Figures 4 and 5 show the time variation of the gamma-ray fluxes of the newly detected sources in half-year bins. For these plots we added data until 2013 October 10. One can see in the first two years that their fluxes are below the detection threshold (TS < 25), which is why they are not listed in the 2FGL catalog based on data over a similar period (Nolan et al. 2012). The first of our two sources has subsequently been detected in the Fermi All-sky Variability Analysis Ackermann et al. 2013) and cataloged as 1FAV J1051+04.

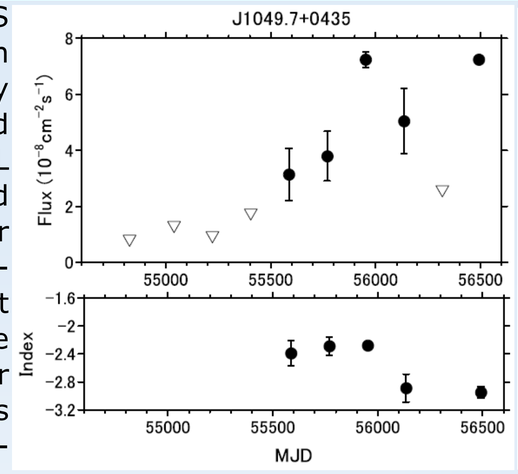

Fig.4 Time variation of gamma-ray flux of J1049.7+0435 in half-year bins for the period from 2008 August 5 to 2013 October 10. Triangles are upper limits (95% C.L.).

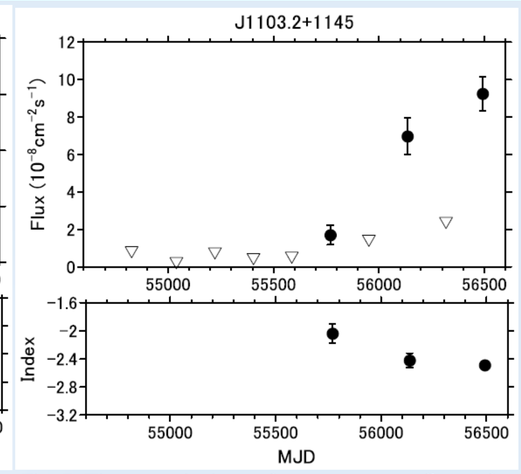

Fig.5 Time variation of gamma-ray flux of J1103.2+1145 in half-year bins for the period from 2008 August 5 to 2013 October 10. Triangles are upper limits (95% C.L.).

Discussion

We have searched for potential counterparts in the Green Bank 6 cm (GB6; Gregory et al. 1996) catalog and determined spectral indices between 20 cm and 6 cm using the NRAO VLA Sky Survey (NVSS; Condon et al. 1998) catalog. The closest GB6 radio source to J1049.7+0435 is GB6 J1050+0432, with an angular separation of 7′. The source has a flux density of 99 ± 10 mJy at 4.8 GHz, and the corresponding 20 cm source, NVSS J105010+043251, has a flux density of 101.2 mJy, yielding a spectral index α (where $S \propto \nu^{+\alpha}$) of 0.0. Two fractionally brighter GB6 sources have both larger angular offsets and significantly steeper spectra: GB6 J1049+0505, 113 mJy, 30′ separation, α = –0.8; GB6 J1051+0449, 101 mJy, 29′ separation, α = –0.9. We note that the GB6 and NVSS flux densities were made some years apart, and so these spectral indices should be taken as representative values rather than absolute measurements. For J1105.2+1145, the closest GB6 source is GB6 J1103+1158, with an angular separation of 14′. The source has a 4.8 GHz flux density of 306±27 mJy, with the corresponding 20 cm source, NVSS J110303+115816, having a flux density of 262.6 mJy, resulting in a spectral index of 0.1. Other relatively bright GB6 sources in the area are further away and with steeper spectral indices: GB6 J1103+1114, 116 mJy, 31′, α = –0.7; GB6 J1104+1103, 277 mJy, 46′, α = –0.8. A Seyfert 1 galaxy, Mrk 728, is 0.°89 from J1103.2+1145 and is not likely the counterpart. GB6 J1103+1158 corresponds to the quasar SDSS 110303.52+115816.5, which lies at a redshift of 0.912 (Schneider et al. 2007). Furthermore, the quasar has been detected in the Very Long Baseline Array Calibrator Survey VLBI observations (Petrov et al. 2005), confirming the presence of a compact core in this radio-loud AGN. Cataloged radio positions and flux densities for the two sources are tabulated in Table 2.

Table 2
Possible Radio Counterparts

Gamma-Ray Source	Catalog (Frequency)	R.A. (J2000)	Decl. (J2000)	Radio Flux Density (mJy)
J1049.7+0435	NVSS (1.4 GHz)	10 50 10.06	+04 32 51.3	101.2
	GB6 (4.8 GHz)	10 50 08.6	+04 32 37	99
J1103.2+1145	NVSS (1.4 GHz)	11 03 03.55	+11 58 16.6	262
	GB6 (4.8 GHz)	11 03 03.7	+11 58 20	306

We have additionally made snapshot observations of J1049.7+0435 and J1103.2+1145 with the Australia Telescope Compact Array at several epochs, as part of an ongoing program to monitor gamma-ray sources (Stevens et al. 2012) with the measured flux densities are listed in Table 3. We see significant time variation of radio fluxes which favors our identification of our gamma-ray sources with the radio sources.

Table 3. ATCA radio observations (unit: mJy)

Gamma-ray source	Epoch	5.5 GHz	9.0 GHz	17 GHz	38 GHz
GB6 J1050+0432	2013 Oct 20	276	311	371	
	2014 Apr 7			430	
	2014 Sep 14	274	341	275	265
GB6 J1103+1158	2013 May 10	254	238	216	230
	2013 Aug 20	254	245		
	2013 Sep 8	246	230		
	2014 Apr 7	237	205	173	147
	2014 Sep 14	210	210	209	225

Summary

Two new GeV sources, Fermi J1049.7+0435 and J1103.2+1145, have been found near the Leo Triplet region using Fermi-LAT archival data spanning 5 years. The fluxes for both sources increase over the 5 yr period: thus they are not included in 2FGL catalog. Their flux variability and spectral indices are compatible with those of gamma-ray detected AGN. Based on angular separation, radio flux density and spectral index, we associate J1049.7+0435 with GB6 J1050+0432, and J1103.2+1145 with the quasar GB6 J1103+1158. Further multiwavelength studies are required to confirm these identifications.

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