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LETTER

Letter to the Editor

A Statistical Analysis of ΔPA for EGRET-Detected AGNs

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Abstract. A statistical analysis of position angle differences (ΔPA) between small- and large-scale structures of EGRET-detected AGNs has been made. The results show that γ-ray quasars have the alignment of radio jets, while γ-ray BL Lac objects have large ΔPA. This may contribute to a better understanding of different blazar types and of the AGN unification scheme.

Key words: radio continuum: EGRET-detected AGNs – galaxies: radio jets

1. Introduction

Since the launch of the *Compton Gamma Ray Observatory*, the Energetic Gamma Ray Experiment Telescope (EGRET) has so far detected 42 AGNs with high-confidence identifications (Thompson et al. 1995; 1996; Mattox et al. 1997). All these AGNs belong to the blazar category. At high energy γ-ray band ($\geq$ 300 MeV), the EGRET-detected blazars show a very high spectral luminosity and short time variability (Montigny et al. 1995). The γ-ray flare is often accompanied by a flare at low frequencies (e.g. Reich et al. 1993; Pohl et al. 1995; Lichti et al. 1995). All this evidence indicates that the γ-ray emission from the flaring blazars most probably is beaming nonthermal radiation supporting the relativistic beaming hypothesis and the unified scheme for AGNs (Schlickeiser 1996). The high energetic emission has been explained with the non-thermal Synchrotron Self Compton models or inverse Compton scattering of external soft photon (Melia & Konigl 1989; Dermer & Schlickeiser 1992; 1993; Bloom & Marscher 1993; Maraschi et al. 1993; Sikora et al. 1994, Ghisellini et al. 1996).

The fact that all EGRET-detected blazars are radio loud indicates that there is a strong relation between γ-ray and radio emission. Radio loud AGNs usually show core-jet structures (Pearson & Readhead 1988). It is generally believed that the energy of the large scale structure is supplied by the central object through the small scale jet (Blandford & Rees 1974; Scheuer 1974). The jet directions are not always aligned from pc- to kpc-scale. The distribution of the apparent misalignment between the position angles of pc- and kpc-scale jets in core dominated radio sources shows an unexpected bimodal form with one peak close to 0° and the other near 90° (Pearson & Readhead 1988; Wehrle et al. 1992; Conway & Murphy 1993; and Xu et al. 1994).

In this paper we investigate the ΔPA distribution of EGRET-detected sources, identified both with quasars and with BL Lac objects. In Sect. 2, we describe the collection of radio information in the EGRET-detected sample. In Sect. 3, we present statistical results of ΔPAs of available γ-ray AGNs and discussion of those results.

2. The sample

The 42 EGRET-detected AGNs with high-confidence are listed in Table 1. Available position angles of radio jets of the EGRET-detected sources both at large- and small-scales are collected from the literature by using the NASA/IPAC Extragalactic Database. Blazars often show curve jet structures with multi-components in their radio images. In order to minimize a possible bias, we selected the PAs at jet components with comparable projective distances for all objects. Because the view angle information is unavailable (angle to the line of sight), the projective separation is used as a criterion to discriminate pc- or kpc-scale jets. The position angles are obtained from VLBI results at average projective distance of 10 pc and VLA or MERLIN observations at average projective distance of 17 kpc for two different scales respectively.

The projective distance can be calculated using the angular distance $D_a = D_L/(1+z)^2$ to the object, where

$$D_L = \frac{c}{q_\circ^2 H_\circ}\left(zq_\circ + [q_\circ - 1]\left[\sqrt{1+2zq_\circ} - 1\right]\right), \quad (1)$$

where c is the speed of light, z is the redshift, $H_\circ$ is the Hubble constant, and $q_\circ$ is the deceleration parameter (Weinberg 1972). The values $H_\circ$=100 km s^{-1} Mpc^{-1} and $q_\circ$=0.5 are used in this paper.

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Table 1. The position angle information of 42 γ-ray AGN

source (1)	ID (2)	z (3)	PA_{kpc} (4)	r_{kpc} (5)	ref_{kpc} (6)	PA_{pc} (7)	r_{pc} (8)	ref_{pc} (9)	Δ PA (10)	ref (11)	Note (12)
0202 + 149	Q	0.833	unr.		MU93	292		BO96			1
0208 − 512	Q	1.003				233	8.3	TI96			
0234 + 285	Q	1.213	-25	30.1	MU93	-10	4.3	FE96	15		
0235 + 164	B	0.940	-37	16.9	MU93	45		MU90	82		2
0336 − 019	Q	0.852	-15	21.6	PE82	9	12.0	WE92	24	AP96	3
0420 − 014	Q	0.915	180	33.7	AN85	-147	4.6	FE96	33		
0440 − 003	Q	0.850	e-w	10.4	PE82	102	11.3	FE97	12		4
0446 + 112	Q	1.207	270	10.8	PE82						
0458 − 020	Q	2.286	-126	7.9	BR89	-55	15.8	WE92	71	AP96	
0521 − 365	Q	0.054	305	4.3	KE86	310	5.6	TI96	5		
0528 + 134	Q	2.060	0	8.1	PE82	24	4.4	PO95	24		
0537 − 441	B	0.896	305	30.2	PE82	5	16.8	TI96	60		
0716 + 714	B	0.30	-60	20.6	PE82	16	5.5	WI86	76		
0735 + 178	B	0.424	170	6.0	PE82	60	13.9	GA89	110	MU90	
0827 + 243	Q	0.939	200	33.4	PE82						
0829 + 046	B	0.180	180	29.4	AN85						
0836 + 710	Q	2.172	200	5.2	PE82	214	7.2	PE88	14	PE88	
0954 + 556	Q	0.909	300	13.4	MU93						
0954 + 658	B	0.368	205	11.7	PE82	-65	9.2	MU90	90		
1101 + 384	B	0.031	83	17.1	AN85	-52	18.0	XU95	135	MU90	5
1127 − 145	Q	1.187	41	129	RU88	65	12.9	WE92	24	WE92	6
1156 + 295	Q	0.729	340	7.7	PE82	-5	10.0	FE96	15		
1219 + 285	B	0.102	250	16.3	AP96	110	7.5	AP96	140	AP96	
1222 + 216	Q	0.435				-15	11.5	HO92b	23	HO92a	7
1226 + 023	Q	0.158	222	37.3	PE82	-130	9.2	WA90	8		
1253 − 055	Q	0.538	202	17.2	PE82	-137	11.0	UN86	21	MU90	
1406 − 076	Q	1.494									
1424 − 418	Q	1.552	-10		PR89						8
1510 − 089	Q	0.361	160	24.4	PE82	173	12.2	RO84	13		
1606 + 106	Q	1.226	-90	25.8	MU93						
1611 + 343	Q	1.401	-170	21.5	MU93	-178	6.4	FE96	8		
1622 − 253	Q	0.786	303	8.2	PE82	6	7.4	FE96	63		
1633 + 382	Q	1.814	-60	0.8	XU95	-64	4.6	PE88	4		9
1730 − 130	Q	0.902	unr.			0	21.0	BO96			1, 10
1739 + 522	Q	1.375	260	15.0	PE82	319	8.6	AP96	59	AP96	
1830 − 210	Q	1.0									
1908 − 201											
2052 − 474	Q	1.489									
2200 + 420	B	0.086	unr.		UL83	183	3.2	PE88			1
2209 + 236	Q										
2230 + 114	Q	1.037	140	6.8	PE82	137	42.2	BA86	3	MU90	
2251 + 158	Q	0.859	-49	21.7	BR82	-65	41.7	PA84	16	BR86	

Notes: 1. The source was unresolved by VLA. 2. The position angle of VLBI jet component varied within 10° to 45°(MU90), the largest ΔPA was chosen. 3. The ΔPA=76° or 24°, 24° was selected here. 4. VLA result showed 3 components in east-west direction. 5. The PA of VLBI jet at 0.6 pc is -24°. 6. A VLA image made at 1375 MHz (RU88) shows a weak, thin jet extending 30 arcseconds at PA=41°. 7. The VLBI jet closely aligned with the MERLIN jet (HO92b). 8. Because of the low declination of the source 1424-418, no enough observed results to be deduced a ΔPA at a comparable scale. 9. MERLIN image was used for PA_{kpc}. A jet at separation of 4 mas in PA -65° curved to west. MERLIN image shows the elongation at PA=-40°. VLA show a jet component at 3 arcseconds in PA=176° curved to east. 10. VLA result of 1730-130 showed an unresolved core and a secondary component at $PA.$ = 273° separated 11 arcsecond from the core. It is believed that the secondary has no connection to 1730-130 (RO84). This may indicate that the secondary component is not a jet component of 1730-130.

The sample is shown in Table 1. Column 1 lists the source name. Column 2 is the class (Q: quasar, B: radio selected BL Lac Object). Column 3 is redshift. Columns 4, 5, and 6 list the information of kpc jet, they are position angle, projective distance to the core in kpc, and the reference respectively. Columns 7, 8, and 9 list the position angle, projective distance to the core in pc, and reference of pc (VLBI) jet respectively. Column 10 is the ΔPA. Column 11 is the reference of column 10. Some notes are listed in column 12.

In the sample, 6 sources have no kpc scale images in literature; 3 sources are unresolved by VLA; 11 sources lack VLBI images. As a result, the position angle differences are available for 27 EGRET-detected blazars, which are listed in Table 1.

3. Results and discussion

The distributions of the ΔPA for 27 EGRET-detected blazars are shown in Fig. 1 (for quasars) and Fig. 2 (for BL Lac objects). The results reveal that γ-ray quasars have the alignment of radio jets (Fig. 1), while γ-ray BL Lac objects have large ΔPA (Fig. 2). The average ΔPA of quasars $\overline{\Delta PA_Q}$ is $21^\circ \pm 19^\circ$ and the average ΔPA of BL Lac objects $\overline{\Delta PA_B}$ is $99^\circ \pm 30^\circ$. The difference between the $\overline{\Delta PA_B}$ and the $\overline{\Delta PA_Q}$ is about 3σ. It seems that the difference of two ΔPA distributions is significant.

With some available core-dominated samples (e.g. Pearson & Readhead 1988, Wehrle et al. 1992), we can inspect the ΔPA of γ-ray quiet blazars. Some well know superluminal quasars show disalignment in the radio jets (e.g. 3C345, 0906+430, 1458+718), while some superluminal BL Lac objects show alignment(e.g. 1308+326, 2007+777). We also note some alignment superluminal sources are not detected by EGRET (e.g. 3C120).

A ΔPA which derived from radio observation may indicate a real bending of the radio jet or the result of projection of the jet trajectory onto the plane of the sky. In the later case, the projective ΔPA can be written as a function of the inclination angles θ and θ' of the pc- and kpc-scale jet axes with respect to the line of sight and the real bending angle $\Delta\phi$,

$$\cos(\Delta PA) = (\cos\Delta\phi - \cos\theta\cos\theta')/(\sin\theta\sin\theta'). \quad (2)$$

The Eq. (2) can be rewritten as,

$$\sin^2\frac{\Delta PA}{2} = \frac{2\sin^2(\Delta\phi/2) - 1 + \cos(\theta-\theta')}{2\sin\theta\sin\theta'}, \quad (3)$$

which indicates sin(ΔPA/2) is inversely proportional to θ (sin(ΔPA/2) $\sim$ $\Delta\phi/2\theta$) for small θ, θ', and $\Delta\phi$ ($\theta \approx \theta'$). It is clear that in the case of a closer alignment of the jet axis with the line of sight the observed misalignment between small- and large-scale jets is much more sensitive to a small deviation of the jet trajectory.

It is difficult to explain the observed jet misalignment of the jets in BL Lac objects with stronger external forces to the jets because of the absence or weakness of a broad line region in the BL Lac objects. The detection of BL Lac objects at TeV photon energies, together with the fact that the total energy output is dominated by radiation in the GeV to TeV regime, seems to indicate that the radiation emerging from the BL Lac objects is even more strongly Doppler boosted than in quasars. Obviously the large misalignment angles observed in BL Lac objects jets do not correspond to the real bending of the jets, but are the results of the projection of the jet trajectories onto the plane of the sky. Thus, the large misalignment angles in BL Lac objects indicate most probably a closer alignment of the jet structures with the line of sight in these objects. The radio jets of EGRET-detected BL Lac objects may be closer to the line of sight than that of γ-ray quiet sources, so the projective effect is much more obvious. The result is in agreement with the AGN unification schemes.

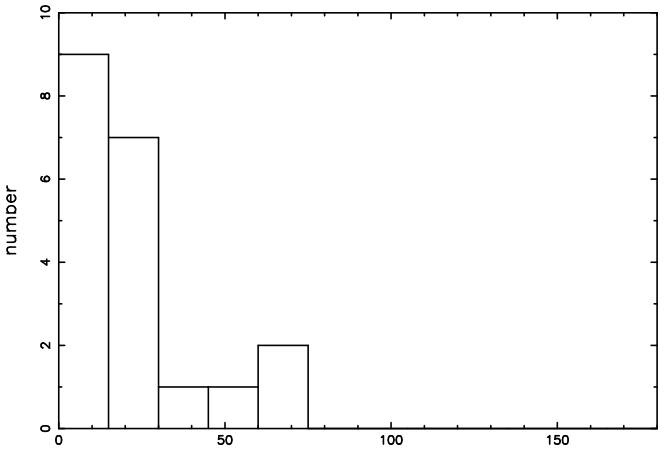

Fig. 1. The ΔPA (°) distribution of EGRET-detected quasars

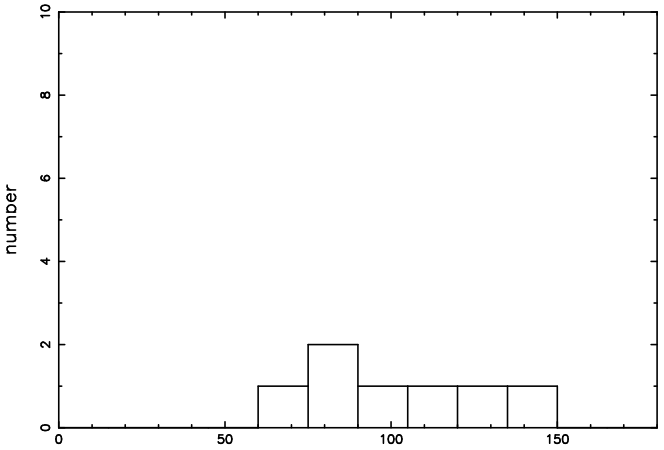

Fig. 2. The ΔPA (°) distribution of EGRET-detected BL Lacs

The VLBI polarization images revealed that the direction of the magnetic field tends to be parallel to the VLBI structure axis in quasars, while it tends to be perpendicular to the jet axis in BL Lac objects (Cawthorne et al. 1993). This may indicate that the γ-ray emission is related to the magnetic field.

It is also possible that the different ΔPA distribution between EGRET-detected quasars and EGRET-detected BL Lac objects may be related to the properties of central objects. We are still not clear if the detection of γ-ray emission is dependent upon

the magnetic field in the jet, opaque medium surrounding the central engine, and so on. VLBI polarization observations are strongly encouraged to find the relationship.

In conclusion, the results presented in this paper may well contribute to a better understanding of different blazar types and the AGN unification scheme. Much more radio observations are expected to be done to get the sample as complete as possible for further study.

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References

Antonucci R. R. J. and Ulvestad J. S., 1985, ApJ 294, 158. AN85
Appl S., Sol H., and Vicente L., 1996, A&A 310, 419. AP96
Baath L. B., 1987, in: Superluminal Radio Sources, eds. J. A. Zensus and T. J. Pearson (Cambridge: Cambridge Univ. Press), p. 206. BA86
Blandford R. D. and Rees M. J., 1974, MNRAS 165, 395
Bloom S. D. and Marscher A. P., 1993, in Proceeding of the Compton Symp., eds. N. Gehrels and M. Friedlander, New York, AIP, p. 578
Bondi M., Padrielli L., Fanti R. et al., 1996, A&A 308, 415. BO96
Browne I. W. A., 1987, in: Superluminal Radio Sources, eds. J. A. Zensus and T. J. Pearson (Cambridge: Cambridge Univ. Press), p. 129. BR86
Browne I. W. A., Clark R. R., Moore P. K. et al., 1982, Nature 299, 788. BR82
Cawthorne T. V., Wardle J. F. C., Reborts D. H., and Gabuzda D. C., 1993, ApJ 416, 519
Conway J. E. and Murphy D. W., 1993, ApJ 411, 89
Dermer C. D. and Schlickeiser R., 1992, Sci 257, 1642
Dermer C. D. and Schlickeiser R., 1993, ApJ 416, 458
Fey A. L., Clegg A. W., and Fomalont E. B., 1996, ApJS 105, 299. FE96
Fey A. L. and Charlot P., 1997, ApJS 111, 95. FE97
Gabuzda D. C., Wardle J. F. C., Roberts D. H., 1989, ApJ 338, 743, GA89
Ghisellini G., Maraschi L. and Dondi L., 1996, A&AS, Special issue third Compton symposium, 120, 503
Hooimeyer J. R. A., Barthel P. D., Schilizzi R. T., and Miley G. K., 1992, A&A 261, 18. HO92a
Hooimeyer J. R. A., Schilizzi R. T., Miley G. K., and Barthel P. D., 1992, A&A 261, 25. HO92b
Keel W. C., 1986, ApJ 302, 296. KE86
Lichti G. G., et al., 1995, A&A 298, 711
Mattox J.R., Schachter J., Molnar L. et al., 1997, ApJ 481, 95
Maraschi L., Ghisellini G., and Celotti A., 1993, ApJ 397, L5
Melia F. & Konigl A., 1989, ApJ 340, 162
Montigny von C., Bertsch D. L., Chiang J. et al., 1995, ApJ 440, 525
Murphy D. W., Browne I. W. A., and Perley R. A., MNRAS 1993, 264, 298. MU93
Mutel R. L., 1990, in: Parsec-scale Radio Jets, eds. J. A. Zensus and T. J. Pearson (Cambridge: Cambridge Univ. Press), p. 98. MU90
Pauliny-Toth I. I. K., Porcas R. W., Zensus A. et al., in: IAU Symposium 110, VLBI and Compact Radio Sources, eds. R. Fanti, K. Kellermann, and S. Setti (Dordrecht: Reidel), p. 149. PA84
Perley R. A., 1982, AJ 87, 859. PE82
Pearson T. J. and Readhead A. C. S., 1988, ApJ 328, 114. PE88
Pohl M., Reich W., Krichbaum T. P. et al., 1995 A&A 303, 383. PO95
Preston R. A., Jauncey D. L., Meier D. L. et al., 1989, AJ 98, 1. PR89
Reich W., et al., 1993, A&A 273, 65
Romney J., Padrielli L., Barthel N. et al., 1984, A&A 135, 289. RO84
Rusk R. E., 1988, PhD. thesis, Univ. Toronto. RU88
Scheuer P. A. G., 1974, MNRAS 166, 513
Schlickeiser R., 1996, A&ASS 120, 481
Sikora M., Begelman M. C., and Rees M. J., 1994, ApJ 421, 153.
Thompson D. J., Bertsch D. L., Dingus B. L. et al., 1995, ApJS 101, 259
Thompson D. J., Bertsch D. L., Dingus B. L. et al., 1996, ApJS 107, 227
Tingay S. J., Edwards P. G., Costa M. E. et al., 1996, ApJ 464, 170. TI96
Ulvestad J. S., Johnston K. J., and Weiler K. W., 1983, ApJ 266, 18. UL83
Unwin S. C., 1987, in: Superluminal Radio Sources, eds. J. A. Zensus and T. J. Pearson (Cambridge: Cambridge Univ. Press), p. 34. UN86
Wardle J. F. C., Robert D. H., and Brown L. F. et al., in: Parsec-scale Radio Jets, eds. J. A. Zensus and T. J. Pearson (Cambridge: Cambridge Univ. Press), p. 20. WA90
Wehrle A. E., Cohen M. H., Unwin S. C. et al., 1992, ApJ 391, 589. WE92
Weinberg, S., Gravitaion And Cosmology, 1972, John Wiley & sons, New York, Printed in United States America.
Witzel A., 1987, in: Superluminal Radio Sources, eds. J. A. Zensus and T. J. Pearson (Cambridge: Cambridge Univ. Press), p. 83, WI86
Xu W., Readhead A. C. S., and Pearson T. J. et al. 1994, in: Compact Extragalactic Radio Sources, eds. J.A. Zensus and K. I. Kellermann, p. 7
Xu W., Readhead A. C. S., and Pearson T. J. et al., 1995, ApJS 99, 297. XU95

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