EGRET HIGH-ENERGY GAMMA-RAY OBSERVATIONS OF AGN: ENERGY SPECTRA AND TIME VARIABILITY

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ABSTRACT. The Energetic Gamma Ray Experiment Telescope (EGRET) on the Compton Gamma Ray Observatory has detected more than 20 Active Galactic Nuclei (AGN) at photon energies above 30 MeV.

1. Introduction

Since the launch of the Compton Gamma Ray Observatory in April, 1991, EGRET has been mapping the high energy gamma ray sky. During the all-sky survey and in the

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observations since then, EGRET has identified 26 gamma-ray-bright AGN. All were detected with statistical significance of 5 σ or greater.

2. Identifications

Although EGRET source error boxes are relatively large (ranging from a few arcminutes to more than a degree in diameter), the number of high-energy gamma ray sources at high latitudes is modest; therefore, source confusion is not a serious problem. Gamma rays in the 100 MeV energy range are also inherently nonthermal, requiring high energy particles as their progenitors. The search for counterparts can focus on likely sites of particle acceleration. In the case of the EGRET sources, a very high fraction (more than 70%) of the high galactic latitude error boxes contain one particular type of AGN. These are characterized by their radio properties, particularly in the 1-5 GHz band: radio bright (more than 0.5 Jy), flat or nearly flat spectrum ($\alpha > -0.6$), and core dominated. An extrapolation of the Kühr et al. (1981) catalog indicates that there are fewer than 900 such sources in the sky. Such objects are generally thought to have jets, which provide the likely sites of particle acceleration to produce the gamma rays. Table 1 lists the EGRET detections, along with properties which indicate that many of these have characteristics of blazars.

3. Energy Spectra

Over at least the central part of the EGRET energy range (50 MeV to several GeV), all the AGN energy spectra can be well represented by power laws. As shown in Table 1, the photon number spectra range from -1.5 to -2.6. Combining the EGRET results with those from other frequencies (usually not contemporaneous) produces multifrequency spectra such as the example of Fig. 1. The gamma rays represent a major contributor to the total observed power of the source. In this example, the simultaneous EGRET (Hunter et al., 1993) and COMPTEL (Collmar, et al., 1993) observations show strong evidence for a spectral break near 10^{22} Hz.

4. Time Variability

Most of the EGRET-detected AGN show time variability on scales of days to months. An example is shown in Fig. 2. In addition to supporting the concept of a jet origin for the gamma radiation, the variability provides an important tool for modeling the physical processes in these jets. Correlations and time lags between gamma-ray flares and those seen at other wavelengths are crucial tests of models.

5. References

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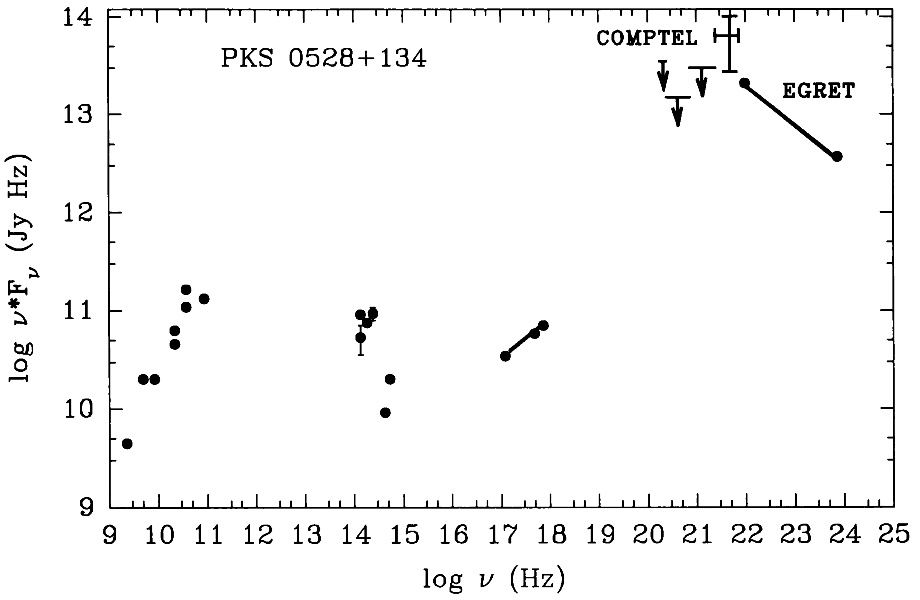

Fig. 1 -- Multifrequency spectrum of PKS 0528+134. The EGRET (Hunter et al., 1993) and COMPTEL (Collmar et al., 1993) observations were made in May, 1991. References to other observations are given by Hunter et al.

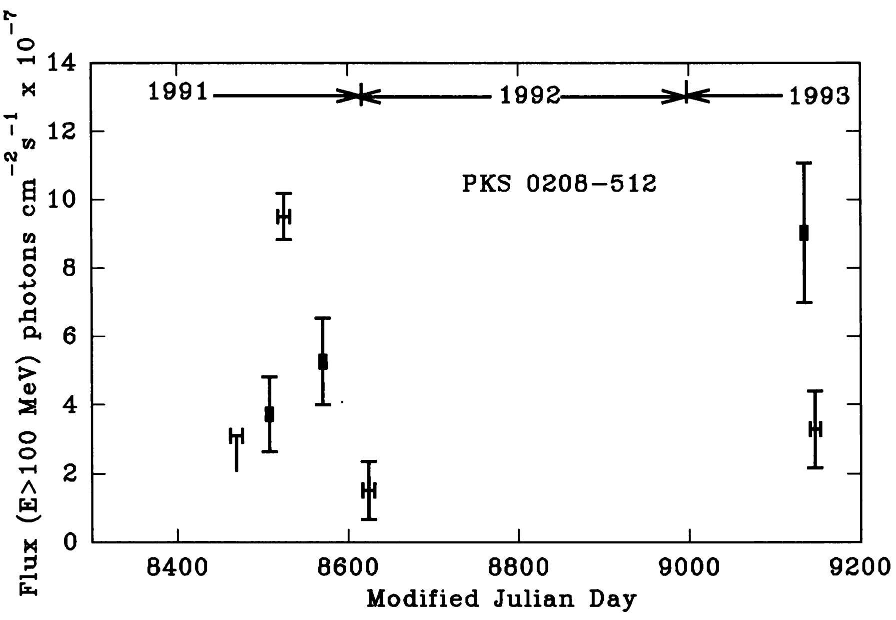

Fig. 2 -- Time variability of E > 100 MeV gamma rays from PKS 0208-512 as seen by EGRET. Data points from 1991-1992 are from Bertsch et al. (1993).

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Table 1 -- EGRET High Energy Gamma Ray Observations of AGN

Source ID and characteristics		OVV	BL Lac	super lum.	radio bright	flat radio[1]	opt. pol.	flux (10^{-6} cm^{-2} s^{-1}) (E>100 MeV)	photon spectral index	z	relative luminosity[2]
0202+149	(4C+15.05)				√	√	√	0.3±0.1	-2.5±0.1	. . .	. . .
0208-512	PKS				√	√	√	0.4 to 0.9	-1.7±0.1	1.00	2
0219+428	(3C 66A)		√		√	√	√	0.17±0.05		0.444	0.03
0234+285				√	√	√	√	0.17±0.05		1.213	0.3
0235+164	(OD+160)		√	?	√	√	√	0.8±0.1	-2.0±0.2	0.94	2.0
0420-014	(OA 129)	√			√	√	√	0.4±0.1	-1.9±0.3	0.92	0.4
0446+11					√	√		1.0±0.2	-1.8±0.3		
0454-463	PKS				√	√		0.25±0.1		0.86	0.3
0528+134	PKS	√			√	√		0.4 to ~ 3	-2.6±0.1	2.06	4 to 13
0537-441	PKS		√		√	√	√	0.3±0.1	-2.0±0.2	0.894	0.2
0716+714			√	?	√	√	√	0.20±0.06	-1.8±0.2	. . .	. . .
0827+243		√			√	√		0.20±0.04		2.05	
0836+710	(4C+71.07)	√		√	√	√		0.15±0.04	-2.4±0.2	2.17	1.1
1101+384	(Mrk 421)		√	√	√	√		0.14±0.03	-1.9±0.1	0.031	0.0002
1156+295	(4C+29.45)	√		√	√	√	√	0.63±0.15		0.729	
1226+023	(3C 273)	√		√	√	√	√	0.30±0.05	-2.4±0.1	0.158	0.008
1253-055	(3C 279)	√		√	√	√	√	0.6 to 4.9	-2.0±0.1	0.54	0.3 to 2
1406-076	PKS				√	√		0.25±0.1		0.86	0.3
1606+106	(4C+10.45)				√	√		1.0±0.1		1.49	
1611+343		√			√	√		0.33±0.06		1.40	
1633+382	(4C+38.41)	√		√	√	√		0.4 to 1.4	-1.9±0.1	1.81	3 to 11
1739+522	(4C+51.37)				√	√		0.3 to 0.5		1.38	
2022-077	(NRAO 628)				√	√		0.7±0.1	-1.5±0.2	. . .	. . .
2052-474					√	√		0.3±0.1		1.489	0.6
2230+114	(CTA 102)			?	√	?	√	0.24±0.07	-2.6±0.2	1.037	0.5
2251+158	(3C 454.3)	√		√	√	√	√	0.8±0.1	-2.2±0.1	0.859	0.5

1. Flat spectrum radio sources: $\alpha_r > -0.5$ (2-5 GHz band).
2. The source luminosity for the observed energy range (0.1 GeV<E<5 GeV), computed using the known redshift assuming $H_0 = 75$ km s^{-1} Mpc^{-1} and $q_0=1/2$, is equal to the relative luminosity times (10^{48} erg s^{-1})f, where f is an unknown beaming factor. Typically f is thought to be in the range from 10^{-2} to 10^{-3}.