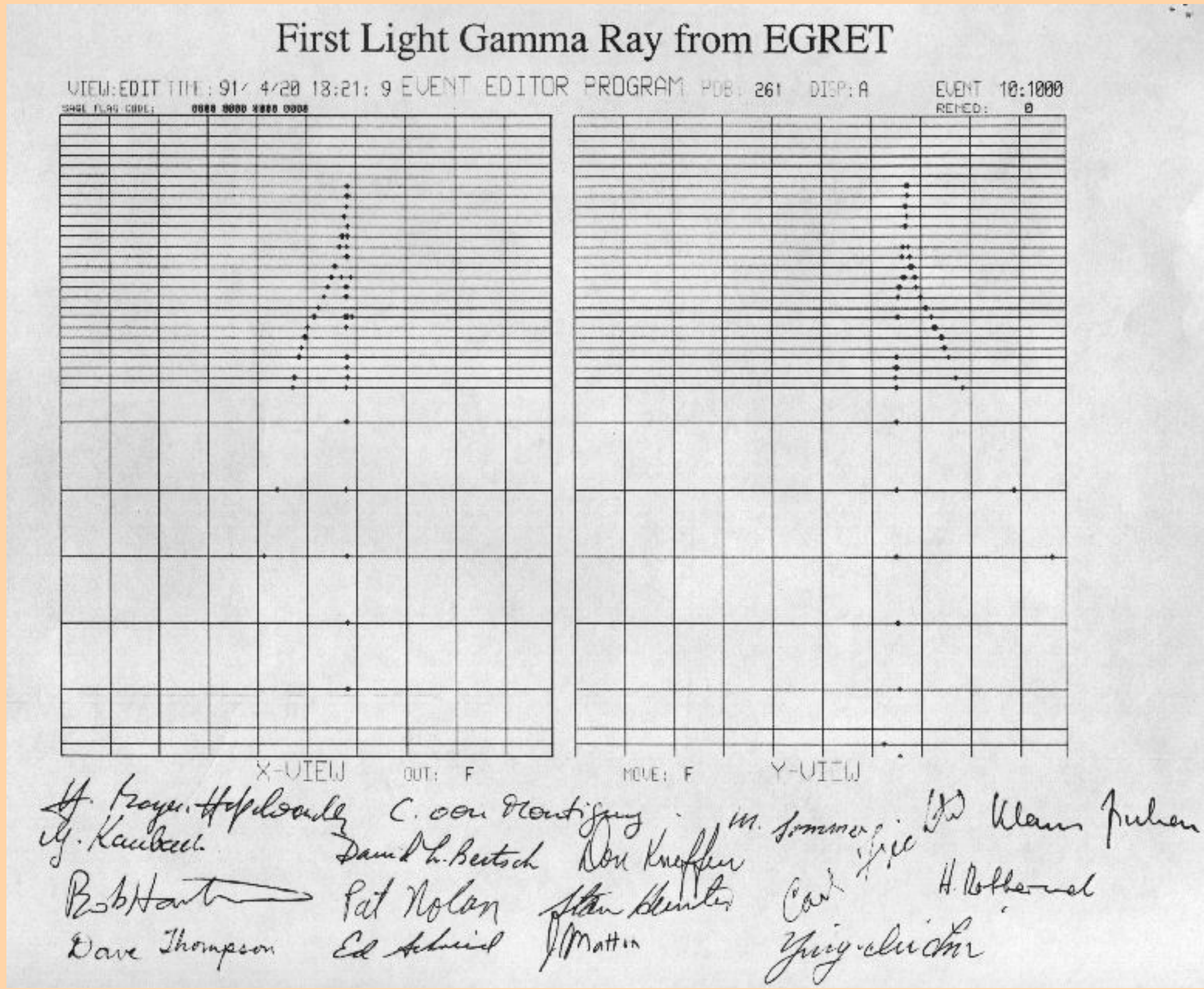
EGRET Results on AGNs

EGRET Characteristics

- 30 MeV - 30 GeV (little above 10 GeV for AGNs)
- Effective area ~1000 cm^2
- Energy resolution 8-15% (1 σ)
- Instrumental background negligible
- 2 year design lifetime, but operated full-time for 4.5 years, then 4.5 years part-time

EGRET Characteristics (continued)

- **Single photon detection, 15-20% efficiency**



EGRET Characteristics (continued)

***By astronomical standards*, EGRET had:**

*** Huge field of view (nearly 1 steradian)**

➔always many objects in FOV, including several blazars

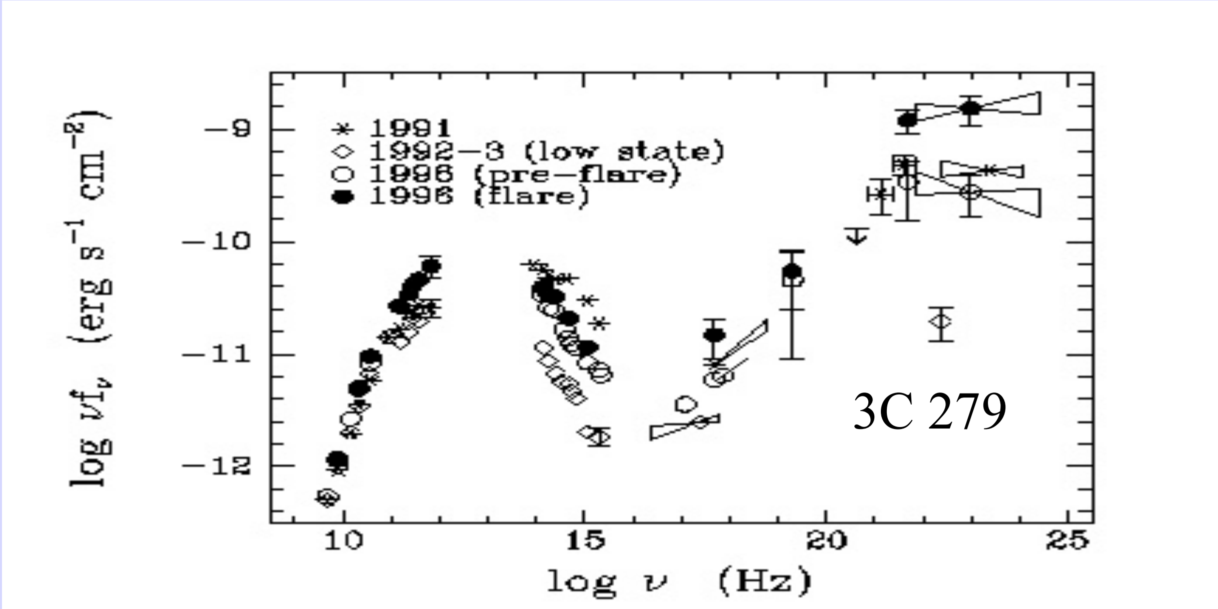
*** Very poor angular resolution**

(~5º at 100 MeV, ~0.5º at 10 GeV)

Sources localized to 0.1º-1.0º

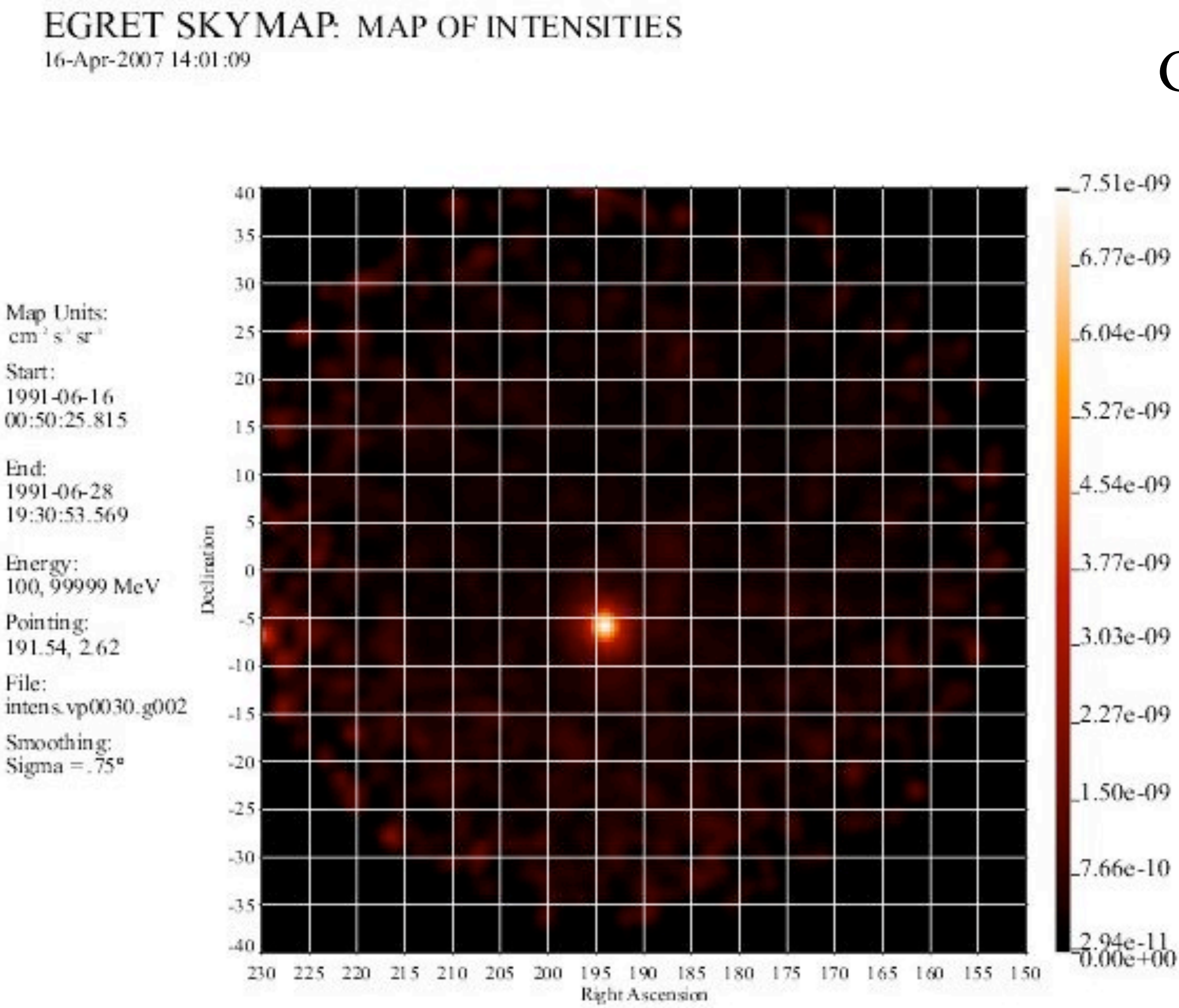
GLAST LAT will have better angular resolution (esp. at high energies), larger effective area (esp. at high energies), and a larger field of view, but (possibly) some instrumental background.

The number of EGRET detected blazars was much greater than anticipated, because (at least during flares) the GeV emission can be far higher than predicted by synchrotron self-Compton models.



But in the beginning, we didn't know that. Since the earlier γ-ray telescope COS-B had detected only one AGN, 3C 273, that was what we expected to see. The first chance came very early in the CGRO mission, because of the nearby supernova 1991T (only a few degrees from 3C 273 – remember, large FOV). Here's what we saw:

Great! There it is.

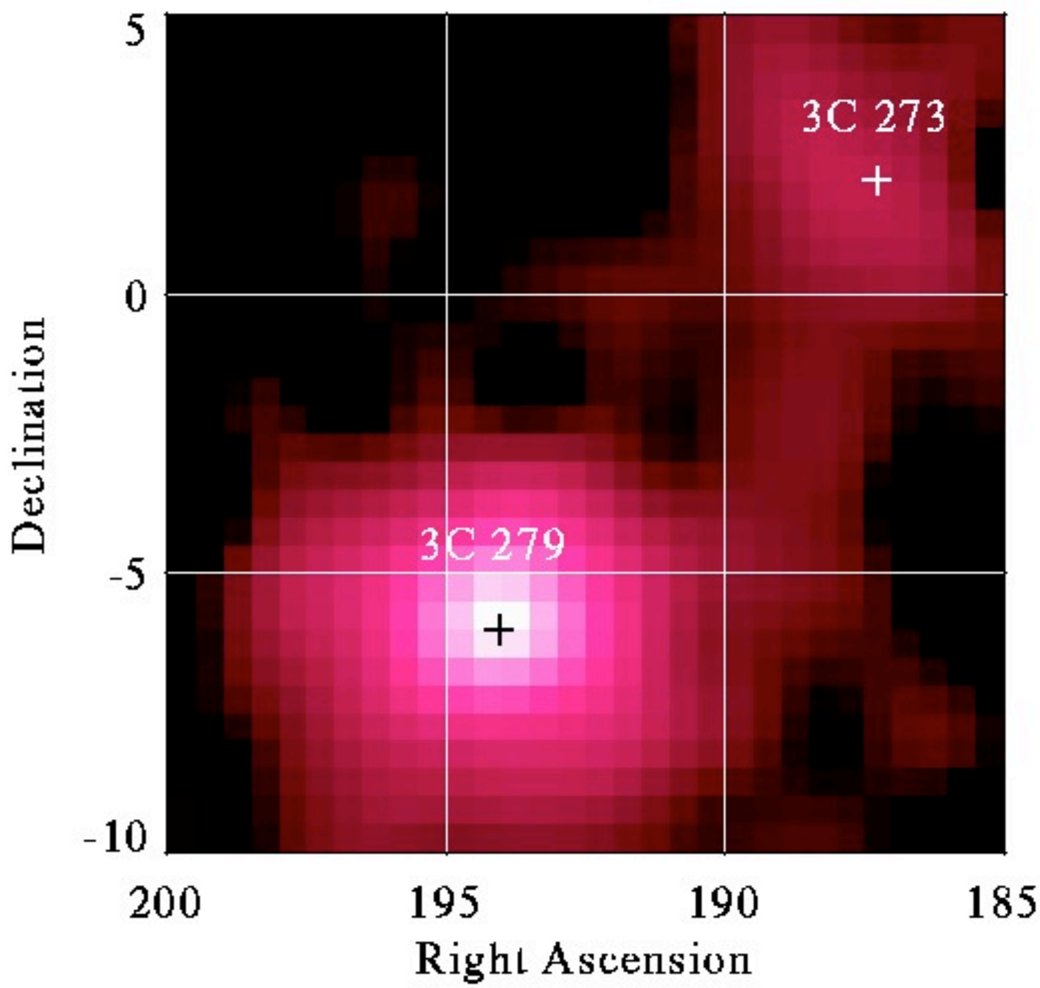


Oops…

Eventually, somebody thought to look up the 3C 273 coordinates. They were 10º from the source we were seeing! Could the spacecraft aspect be off that much? We were firmly advised "No Way" (and we already knew from earlier observations that the Crab and Geminga pulsars were seen in the right place). So what was that bright source? And what happened to 3C 273?

After a considerable amount of confusion (a bunch of physicists trying to become astronomers), we looked around to see what could possibly be so bright. 3C 279 turned up as the obvious candidate, later confirmed by correlated variations.

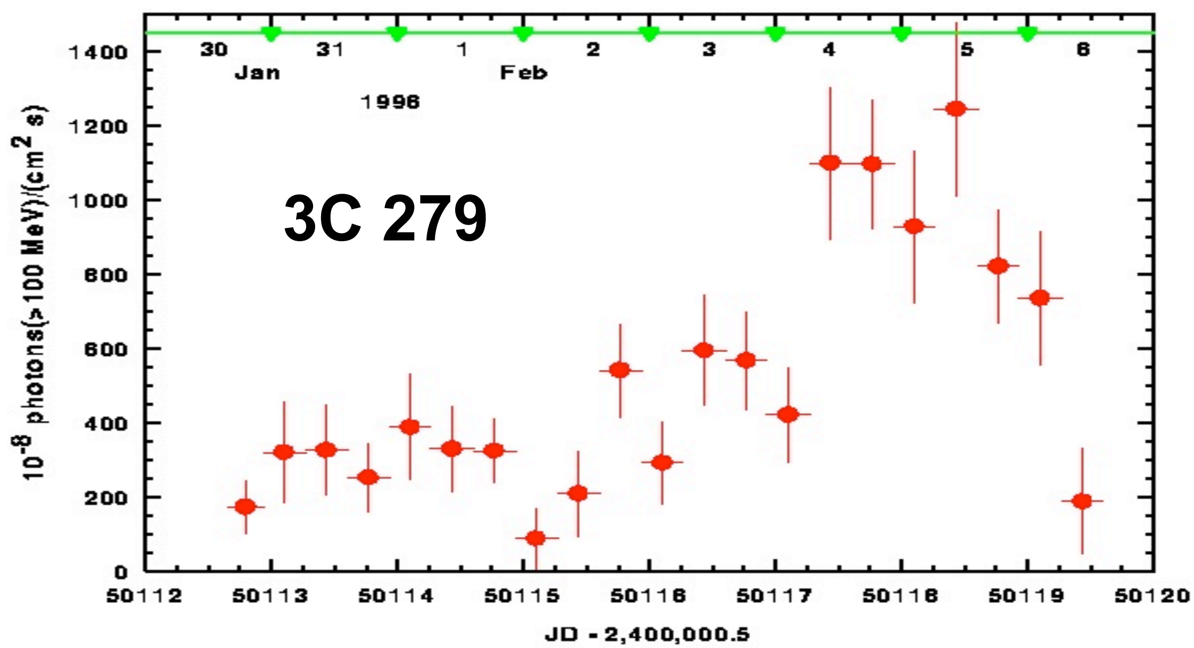
But where was 3C 273? After several days, somebody happened to convert the intensity scale to logarithmic: ➔


5
0
-5
-10
Declination
3C 273
3C 279
200
195
190
185
Right Ascension

EGRET AGN Detections

- About 75 blazars with rather high confidence
  - about 75% FSRQs
  - about 25% BL Lacs, including 4 HBLs (Mrk 421, Mrk 501, 2005-489, 2155-304)
- Probable detection of 3 radio galaxies
- About 55 sources which *might* be blazars
- About 50 unidentified sources with $|b| > 10^{o}$
- 2 or 3 likely blazars in $|b| < 10^{o}$

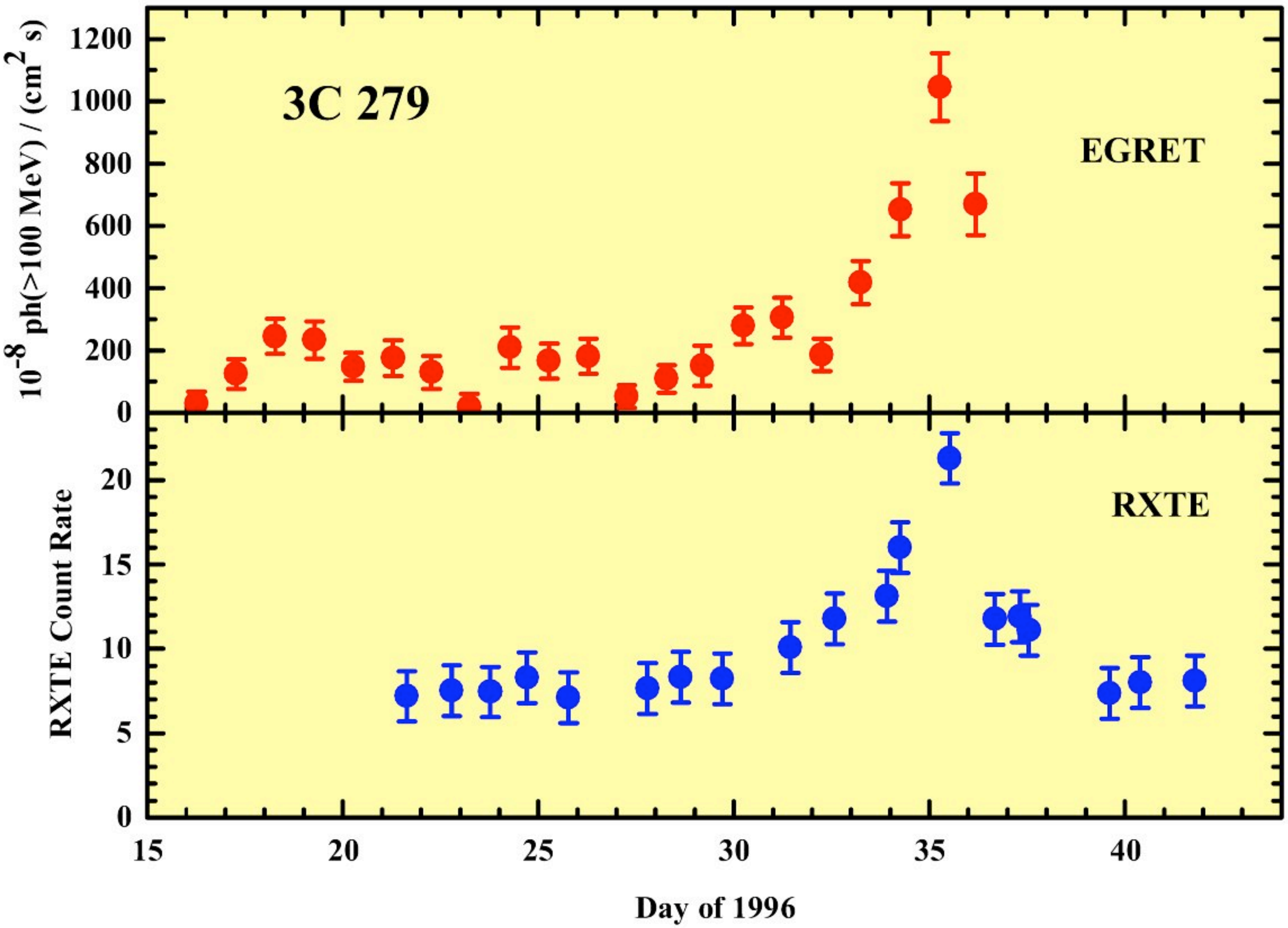
1622-297 and 3C 279 showed EGRET flux variations by factors of 50-100, and doubling & halving times as short as 3-8 hours (limited by counting statistics).



Most EGRET detections were of flaring blazars – many observations of specific objects yielded no detection. 3C 279 was detected every time it was observed, but just barely during the very low state in winter 1992-93. Several other FSRQs, including 0208-512 and 3C 454.3, were detected every time there was significant exposure to them, but did not vary much in flux. 0528+134 varied by at least an order of magnitude, but was detected every time there was significant exposure. It is not clear whether those objects were ever seen in quiescence. As seen by EGRET, the HBL Mrk 421 didn't vary appreciably, but it flared dramatically in X-rays and TeV γ-rays during the EGRET era.

A number of multiwavelength campaigns were carried out: several on 3C 279 and 3C 273 (same FOV), but 0528+134, 1156+295, 0716+714, Mrk 421, 3C 454.3 and CTA 102 (same FOV), 2155-304, OJ 287, 1219+285, 0208-512, Mrk 501 and 3C 345 (same FOV), 0235+164, BL Lacertae, 1622-297, etc., were all studied to varying degrees. (3C 345 was never detected by EGRET, even during a big radio/optical flare.)

Although long-term time correlations between γ–rays and lower frequencies were rather clear, short-term correlations were scarce. The only really clear short-term correlation seen was between the EGRET flux and the RXTE X-ray flux during the large 3C 279 flare in early February, 1996. (There was no detectable time lag either way.)



3C 279
EGRET
RXTE
10^{-8} ph(>100 MeV) / (cm^2 s)
RXTE Count Rate
Day of 1996
0
200
400
600
800
1000
1200
0
5
10
15
20
15
20
25
30
35
40

EGRET AGN Detections (& possibles)

- **The next slide shows all of the firmly identified AGNs, as well as the AGNs possibly associated with EGRET sources. In the ID column, "S-E" refers to the work of Sowards-Emmerd, Romani, and Michelson.**
- **Note that essentially all of the objects listed have flat radio spectra. For the firm IDs, this is a real correlation, but for the rest, it is partly because the flat-spectrum objects are thought to be the most likely IDs.**
- **For the firm IDs, the flat spectrum is not just over 1.4-2.7-4.85-8 GHz (where flatness has historically been judged) but extends to 90 GHz or higher.**

EGRET AGN Detections (continued)

- The 3 detected radio galaxies are listed in green. 3C 111 does not have a flat radio spectrum, but it shows moderate superluminal motion. NGC 6251 is known as a radio galaxy, but it is flat over (at least) 1-60 GHz, with a blazar-like SED.
- The final 3 columns, H(igh) P(olarization), S(uper)L(uminal), and BL (Lac) are incomplete. Updates are welcome.

Name	ID?	Other Name	Max Sign.	F_{max} >100MeV 10^{-8} cm^{-2} s^{-1}	Photon Index	z	F S	H P	S L	B L
0036-099	S-E	TXS,PMN	4.1	38 ± 16	2.7±0.4	2.102	Y			
0119+041	?	OC +033	4.5	20 ± 6	2.6±0.7	0.637	Y	Y		
0130–171	S-E	PKS	4.9	14 ± 7	2.5±0.3	1.022	Y			
0202+149		4C +15.05	5.3	53 ± 26	2.2±0.3	0.405	Y	Y	5	
0208–512		PKS	29.0	134 ± 25	2.0±0.1	1.003	Y	Y		
0210+119	S-E?	87GB	4.4	18 ± 5	2.0±0.6	0.252	Y			
0219+428		3C 66A	7.9	25 ± 6	2.0±0.1	0.444	Y	Y	10-19	L
0234+285	?	4C +28.07	6.3	31 ± 12	2.5±0.2	1.213	Y	Y	Y	
0235+164		OD +160	10.0	65 ± 9	1.9±0.1	0.940	Y	Y	19-30	L
0239+175	S-E?	87GB	4.2	26 ± 8	2.6±0.4	0.551	Y			
0322+222	S-E	87GB	4.2	29 ± 17	2.6±0.3	2.060	Y			
0336–019		CTA26	8.6	178 ± 37	1.8±0.3	0.852	Y	Y	5-12	
0414–189		PKS	4.5	50 ± 16	3.3±0.7	1.536	Y			
0415+379		3C 111	5.3	77 ± 50	?	0.048	NO		3.5	
0419+175	S-E?	87GB	6.5	64 ± 34	2.4±0.2	0.908	?			
0420–014		OA+129	6.8	64 ± 34	2.4±0.2	0.915	Y	Y	6	
0430+289		87GB	8.7	76 ± 22	1.9±0.1	?	Y	?	?	?
0440–003		NRAO 190	10.9	86 ± 12	2.4±0.2	0.844	Y	Y	10	
0446+112		PKS	7.7	110 ± 19	2.3±0.2	1.207	Y			
0454–234		OF –292	4.4	15 ± 4	3.1±0.5	1.003	Y	Y		L
0454–463		PKS	4.3	23 ± 7	2.8±0.4	0.858	Y			
0458–020	?	4C –02.19	5.5	68 ± 41	2.5±0.3	2.286	Y	Y	9	
0459+060	?	OF +99.3	4.5	34 ± 18	2.4±0.4	1.106	Y			
0506-612	?	PKS	4.8	29 ± 12	2.4±0.3	1.093	Y	NO		Y
0510+559	S-E?	87GB	7.0	56 ± 24	2.2±0.2	2.190	Y			
0521-365	?	PKS	21.4	32 ± 7	2.6±0.4	0.055	?	Y		L
0527-359	S-E?		“	“ “	“	4.172				
0528+134		OG +147	33.4	351 ± 37	2.5±0.1	2.060	Y		8-24	
0529+483	S-E?	87GB	5.5	33 ± 17	2.6±0.2	1.162	Y			
0537+251	S-E?	87GB	5.1	74 ± 35	2.7±0.2	0.623	Y			
0537-286	?	OG –263	4.2	35 ± 12	2.5±0.6	3.104	Y			
0537–441		PKS	10.6	91 ± 15	2.4±0.1	0.894	Y	Y		L
0539–057	?	PKS	4.4	67 ± 20	?	0.839	Y	Y		
0616-116		PMN	4.6	48 ± 16	2.7±0.4	0.970	Y			
0716+714		S5	10.9	46 ± 11	2.2±0.1	~0.300	Y	Y	11-15	L
0735+178		OI +158	6.1	29 ± 10	2.6±0.3	>0.424	Y	Y	7	L
0738+548		87GB	8.1	42 ± 8	2.0±0.2	0.723	Y			Y
0803+514	?	87GB	4.3	23 ± 14	2.8±0.3	1.136	Y			
0804+499	?	OJ +508	5.1	15 ± 6	2.2±0.5	1.430	Y	Y		
0805-077	?	PKS	5.8	40 ± 13	2.3±0.3	1.837	Y			
0827+243		OJ +248	8.2	111 ± 60	2.4±0.2	0.939	Y		25-27	
0829+046		OJ +49	4.1	34 ± 16	2.5±0.4	0.180	Y	Y	3-11	L
0836+710		4C+71.07	6.6	33 ± 9	2.6±0.2	2.172	Y		14	
0847-120		PMN	5.2	44 ± 12	1.6±0.6	0.566	?			
0851+202		OJ +287	4.2	16 ± 7	2.0±0.4	0.306	Y	Y	5-8	L
0917+449	?	B3,S4	8.6	34 ± 10	2.2±0.1	2.190	Y		9	
0954+556		4C +55.17	6.7	47 ± 16	2.1±0.2	0.896	Y	Y		
0954+658		S4	6.3	18 ± 9	2.1±0.2	0.368	Y	Y	Y	L
1011+496	?	87GB	4.0	13 ± 8	1.9±0.4	0.200	Y			Y
1055+567	?	87GB	4.7	16 ± 10	2.5±0.5	0.143	Y			L
1101+384		Mrk 421	9.9	27 ± 7	1.6±0.2	0.031	Y		1.3,2	H
1127-145	?	OM – 146	6.6	62 ± 18	2.7±0.3	1.184	Y	?	10-20	
1130+009	S-E	PKS	4.3	52 ± 24	2.7±0.6	1.640	Y			
1156+295		4C +29.45	6.2	163 ± 41	2.0±0.2	0.729	Y	Y	9-14	
1219+285		ON +231	7.7	54 ± 14	1.7±0.2	0.102	Y	Y	0.6-2.8	L
1219-164	S-E?	PMN	4.2	30 ± 11	2.5±0.5	?	?			
1222+216		4C +21.35	9.3	48 ± 15	2.3±0.1	0.435	Y		8.5-15	
1226+023		3C 273	10.1	48 ± 12	2.6±0.1	0.158	Y		2.3-11	
1229–021		4C +02.55	5.1	16 ± 4	2.9±0.3	1.043	Y			
1236+049	?	87GB	4.7	15 ± 9	2.5±0.5	1.762	Y			
1243–072		ON –73	5.2	44 ± 30	2.7±0.2	1.286	Y			
1253–055		3C 279	42.2	1045 ± 108	2.0±0.1	0.538	Y	Y	3.5-6	
1310-041	S-E?	PKS	5.0	24 ± 13	2.3±0.2	0.825	Y			
1313–333	?	OP –322	7.1	32 ± 19	2.3±0.2	1.210	Y			Y
1322–427	?	Cen A	6.2	39 ± 15	2.6±0.3	0.002	NO		NO	
1324+224		B2	5.9	68 ± 23	1.9±0.4	1.400	Y			
1331+170		OP +151	4.2	33 ± 19	2.4±0.5	2.084	Y			
1334–127		OP –158.3	4.1	20 ± 12	2.6±0.4	0.539	Y	Y		L
1340+289	S-E?	B2	4.2	21 ± 7	2.5±0.6	0.905	Y			
1406–076		OQ –10	16.2	128 ± 23	2.3±0.1	1.494	Y		18-28	
1417+385	S-E?	B2	4.4	21 ± 8	3.2±0.5	1.831	Y			
1424–418		PKS	6.8	55 ± 16	2.1±0.2	1.522	Y	Y		
1454-354	S-E	PKS	4.4	30 ± 14	3.0±0.4	1.422	Y			
1501-343	S-E	PMN	“	“ “	“	?	Y			
1456-179	S-E?	PMN	4.3	37 ± 12	2.7±0.4	?	Y			
1504-166	?	OR –102	4.4	33 ± 10	?	0.876	Y	Y		
1510–089		OR –017	5.6	49 ± 18	2.5±0.2	0.360	Y	Y	4-9	
1514–241	?	AP Lib	4.2	37 ± 18	2.7±0.4	0.049	Y	Y		L
1529-230	S-E?	PMN	4.7	94 ± 28	2.7±1.0	2.290	Y			
1604+159		4C +15.54	4.7	42 ± 12	2.1±0.4	0.357	Y	Y		L
1606+106		4C +10.45	7.9	62 ± 13	2.6±0.2	1.226	Y		>2	
1611+343		OS +139	8.7	69 ± 14	2.4±0.2	1.401	Y		8-24	
1622-253		OS –237.8	7.5	82 ± 35	2.2±0.1	0.786	Y			
1622-297		PKS	24.7	1700 ± 300	2.2±0.1	0.815	Y		4-11	
1625-141	S-E?	PKS	4.5	70 ± 40	2.1±0.2	1.100				
1626-172	S-E?	PMN	4.1	99 ± 32	?	?	Y?			
1633+382		4C +38.41	17.3	108 ± 10	2.2±0.1	1.814	Y		7-10	
1637+826	MHM	NGC 6251	4.1	12 ± 4	2.3±0.5	0.025	Y			
1642-076	S-E?	PMN	4.1	67 ± 28	2.4±0.4	0.139	?			
1652+398		Mrk 501	5+*			0.034	Y	Y	1.5	H
1714-336	S-E	PMN	5.2	84 ± 43	2.6±0.2	3.180	Y			
1716-771	?	PKS	4.3	41 ± 23	2.7±0.4		Y			
1725+044		PKS	5.1	30 ± 19	2.7±0.3	0.296	Y			
1730-130		NRAO 530	12.1	105 ± 35	2.2±0.1	0.902	Y		7-9	
1735-150	S-E?	PMN	5.4	196 ± 49	3.2±0.8	?	Y?			
1739+522		4C +51.37	6.4	45 ± 27	2.4±0.2	1.375	Y	Y		
1741–038		OT –68	4.6	49 ± 20	2.4±0.4	1.054	Y	Y		
1759–396	?	PMN	6.0	146 ± 49	3.1±0.4	0.296	Y			
1804-502		PMN	4.3	62 ± 20	2.9±0.4	1.606	?			
1823+017	S-E	PMN	6.8	132 ± 24	2.8±0.4	1.771	Y			
1825+344	S-E	87GB	4.0	29 ± 9	2.0±0.5	1.814	Y			
1830-211		PKS	7.8	99 ± 25	2.6±0.1	2.507	Y			
1845-273	S-E	PMN	4.2	90 ± 30	2.3±0.5	?	N			
1902-119	S-E	PMN	5.6	76 ± 33	2.6±0.2	?	Y			
1908–201		OV -213	7.2	37 ± 20	2.4±0.2	1.119	Y		10	Y
1920–211	?	OV -235	4.4	29 ± 8	?	0.874	Y			
1933–400		PKS	5.2	94 ± 31	2.9±0.4	0.965	Y			
1936–155		OV –161	4.0	55 ± 19	3.5±1.3	1.657	Y	Y		
2002-233		PMN	5.3	44 ± 13	2.3±0.4	0.830	Y	Y		
2005+642	S-E	87GB	4.9	25 ± 11	2.4±0.3	1.574	Y			
2005-489		PKS	4+*		hard	0.071	Y			H
2013+370	HEM	TXS,NVSS	6.4	83 ± 27	2.1±0.1	0.025	Y			
2022–077		NRAO 629	7.6	74 ± 13	2.4±0.2	1.388	Y			
2023+335	S-E?	B2	5.8	99 ± 29	2.3±0.2	0.219	Y			
2027-308	S-E	PKS	4.0	32 ± 20	3.4±0.8	?	Y			
2032+107		OW +154	4.9	36 ± 15	2.8±0.3	0.601	Y	Y		L
2047+098	S-E	PKS	4.1	40 ± 18	2.2±0.5	?	Int			
2052–474		PKS	5.0	35 ± 21	2.0±0.4	1.489	Y			
2105+598	?	4C +59.33	5.3	33 ± 10	2.2±0.3	?	Y			
2155-304		PKS	5.9	30 ± 8	2.4±0.3	0.116	Y		Y	H
2200+420		BL Lac	10.6	40 ± 12	2.6±0.3	0.069	Y	Y	2.2-6	L
2206+650	?	87GB	5.2	31 ± 13	2.3±0.3	1.120	Y			
2209+236		PKS	4.3	46 ± 20	2.5±0.5	1.125	Y			
2230+114		CTA 102	8.5	52 ± 15	2.5±0.1	1.037	Y	Y	9-12	
2250+194	?	87GB	4.0	62 ± 22	2.4±0.6	0.284	Y			
2251+158		3C 454.3	17.9	116 ± 18	2.2±0.1	0.859	Y	Y	4-16	
2255–282		PKS	9.6	140 ± 27	1.7±0.2	0.926	Y			
2320–035		PKS	5.1	38 ± 10	?	1.410	Y			
2346+385	?	S3	4.8	38 ± 10	2.5±0.7	1.032	Y			
2351+456		4C +45.51	4.6	43 ± 20	2.4±0.4	1.992	Y			
2356+196		OZ +193	4.2	26 ± 9	2.1±0.4	1.066	Y			