New Observations of AGN with Specific Instruments

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COMPTON OBSERVATORY OBSERVATIONS OF AGN

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ABSTRACT. The principal results on active galactic nuclei from the Phase 1 observations by the *COMPTON Gamma Ray Observatory* are presented. These include the detection of a new class of high-energy gamma ray sources by the EGRET instrument and extensive observations of Seyfert galaxies in low-energy gamma rays by OSSE. The identified EGRET sources are associated with core-dominated radio loud objects, OVV's and BL Lacs. EGRET has not detected any Seyfert galaxies. OSSE observes a thermal-like spectrum from NGC 4151, and the low-energy gamma ray spectra of other Seyferts are significantly softer than the spectra below 50 keV, suggesting that a thermal emission mechanism is characteristic of these objects. OSSE has not detected any positron annihilation radiation from any Seyfert, and neither OSSE nor COMPTEL have detected an MeV excess from these sources.

1. Introduction

Prior to the launch of the *COMPTON Observatory* there were only four extragalactic sources which had been detected above 100 keV: Cen A, NGC 4151, MCG 8-11-11 and 3C 273 (Levine et al. 1984). AGN observed in the 1-50 keV energy band by HEAO, EXOSAT and Ginga were generally well fit with a "canonical" power-law spectrum with an a spectral index of about -1.7, although Ginga analyses did provide evidence for iron line emission and an additional reflected component above 10 keV. It was clear that the spectra of Seyfert galaxies had to break above several hundred keV in order not to overproduce the diffuse gamma ray background. However, MeV emission consistent with the hard x-ray spectrum extending to above 1 MeV was reported for two Seyferts: NGC 4151 (Perotti et al. 1981a) and MCG 8-11-11 (Perotti et al. 1981b). Only one extragalactic source, the nearby quasar 3C 273, was detected above 50 MeV by COS-B (Swanenburg et al. 1978). Finally, observations dating from the late 1960's had detected a diffuse gamma ray background at energies from 20 keV to several hundred MeV. The origin of this gamma ray background has been the focus of intense theoretical work, but remains a mystery. Although AGN contribute to the diffuse gamma ray background, the fraction of this background which is attributable to AGN is unknown.

The *COMPTON Gamma Ray Observatory* was launched on 5 April 1991. It carries four instruments which undertake gamma ray observations from 20 keV to 20 GeV. The overall capabilities and characteristics of these instruments are described in a series of papers (Johnson et al. 1993, Thompson et al. 1993, Schoenfelder et al. 1993, Fishman et al. 1989). Briefly, the EGRET instrument observes gamma rays in the 30 MeV-20 GeV region by converting incident gamma rays into electron-positron pairs and uses the path of the pairs through a multiple spark chamber to determine the direction of the incident gamma ray. COMPTEL uses the compton scattering process to "image" 1-30 MeV gamma rays. Both EGRET and COMPTEL have broad fields-of-view and the first 18 months (Phase 1) of the mission were used to undertake a full sky

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survey with these two instruments. This was accomplished with a series of two and three week viewing periods (VP) during which the attitude of the observatory remained fixed. OSSE operates in the 50 keV -10 MeV region, has a 3.7° x 11.4° field-of-view (non-imaging), and is used to study one object at a time. The BATSE instrument consists of eight broad field-of-view detectors which provide all sky coverage for transient phenomena such a cosmic gamma-ray bursts and solar flares. Strong sources can be observed by BATSE in an Earth occultation mode, and the strongest active galactic nuclei are monitored on a nearly continual basis (Paciesas et al. 1993)

2. High Energy Sources

As noted earlier, 3C 273 was the only extragalactic high-energy gamma ray source detected prior to the launch of GRO. 3C 273 and the Virgo region were scheduled to be viewed in VP11, about 5 months into the mission. However, the occurrence of a Type 1a supernova in NGC 4527, SN 1991t, resulted in an early change to the viewing program which enabled the Virgo region to be viewed in VP3 (June 1991). Surprisingly, 3C 273 was not observed by EGRET as an intense source, but the nearby OVV quasar 3C 279 was. 3C 279 was the first quasar for which superluminal motion was observed, and it had been recognized as a good candidate for gamma ray emission. Remarkably, EGRET observed significant variability in 3C 279's high-energy gamma-ray emission during the two week observation (Hartman et al. 1991). The source was observed to increase by a factor of 3 over a period of one week, and then decreased by a factor of 3 over a period of only two days. At a redshift of 0.538, the apparent γ-ray luminosity of the source is 1 x 10^{48} erg/s if isotropic emission is assumed. This luminosity is an order of magnitude larger that the luminosity in any other spectral band. The short term variability and the luminosity strongly indicate the high-energy gamma ray emission originates in relativistic jets with the radiation beamed toward the Earth. The short term variability probably results from the emission originating relatively close (a few light days) to the central compact object, and the intrinsic gamma ray luminosity is reduced from the apparent luminosity by the beaming factor.

The energy spectrum of 3C 279 is observed to be a power law in the EGRET energy range. During June 1991 when the strong flaring activity occurred, the photon spectral index was -1.9. Several months later, when the source was in a somewhat lower intensity state, the spectrum was slightly steeper, spectral index = -2.1. Ginga observed this source several days prior to the EGRET observations in June, 1991, so contemporaneous x-ray observations are available. Broad-band *Compton* spectral results on this and other sources will be discussed later in this paper.

During Phase 1 of the *COMPTON* mission, EGRET has reported the detection of 22 extragalactic sources at greater that 5σ (Fichtel et al. 1993a). These are listed in Table 1. All of these sources belong to the class of radio loud active galactic nuclei. Fourteen are classified as flat spectrum quasars and four are BL Lacs. Six of the sources are associated with radio objects which exhibit superluminal characteristics. Identifications have been made with optical and/or radio objects in all but four cases. These identifications are based on the EGRET error box associated with each object and the most likely candidate from a pre-selected list of AGN (Fichtel et al. 1993b). Short term variability has been observed for several of these sources where the detection is sufficiently significant to perform temporal studies. In all cases, the spectra can be adequately

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Table 1: AGN Detected by EGRET during Phase 1

Source	Type	Redshift (z)	Observ. Dates	Flux (E>100 MeV) (10^{-7} γ/cm^2-s)	Photon Index
PKS 0202+149 (4C+15.05)	Quasar		2/20 - 3/5 1992 4/23 - 4/28 1992 5/7 - 5/14 1992	0.25 ±0.08 <1.4 <0.4	2.5±0.1
PKS 0208-512	Quasar	1.003	9/5 - 9/12 1991 9/19 - 10/3 1991 11/7 -11/14 1991	0.17±0.07 1.07±0.08 0.53±0.12	1.7±0.1
0219+428			11/28-12/12 1991 8/11- 8/20 1992 9 /1 - 9/17 1992	0.17±0.04 <0.2 <0.4	
0234+285			11/28-12/12 1991 8/11- 8/20 1992 9 /1 - 9/17 1992	0.17±0.05 <0.6 <0.3	
PKS 0235+164 (OD+160)	BL Lac	0.94	11/28-12/12 1991 2/20 - 3/5 1992	<0.3 0.86±0.12	2.0±0.2
0420-014 (OA 129)	Quasar	0.92	5/16 - 5/30 1991 6/8 - 6/15 1991 2/20 - 3/5 1992 5/14 - 6/4 1992	<0.11 <0.11 0.44±0.13 <0.4	
PKS 0446+112	Quasar		5/16 - 5/30 1991 6/8 - 6/15 1991 8/11 - 8/20 1992 9/1 - 9/17 1992	<0.14 <0.14 0.96±0.18 <0.5	1.8±0.3
0454-234			5/14 - 6/4 1992	0.62±0.15	
PKS 0454-463		0.858	7/26 - 8/8 1991 9/19 - 10/3 1991 12/27/91-1/10/92 5/14 - 6/4 1992	0.27±0.07 <0.2 <0.3 <0.2	
PKS 0528+134	Quasar	2.06	5/16 - 5/30 1991 6/8 - 6/15 1991 8/11 - 8/20 1992	}0.84±0.10 <0.6	2.6±0.1
PKS 0537-441	BL Lac	0.894	7/26 - 8/8 1991 8/22 - 9/5 1991 12/27/91-1/10/92 5/14 - 6/4 1992	0.33+0.08 <0.2 <0.5 <0.3	2.0±0.2
0716+714	BL Lac		1/10 - 1/23 1992 3/5 - 3/19 1992 6/11 - 6/25 1992	0.18±0.04 0.52±0.13 <0.5	1.8±0.2 2.4±0.3
0836+710 (4C+71.07)	Quasar	2.17	1/10 - 1/23 1992 3/5 - 3/19 1992 6/11 - 6/25 1992	0.13±.03 0.43±0.11 <0.3	2.4±0.2 1.9±0.4
1101+384 (Mrk 421)	BL Lac	0.031	6/28 - 7/12 1991 9/17 - 10/8 1992	0.14±0.05 0.22±0.07	1.9±0.1
1226+023 (3C 273)	Quasar	0.158	6/15 - 6/28 1991 10/3 -10/17 1991	0.26±0.04 0.13±0.04	2.4±0.1

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Source	Type	Redshift (z)	Observ. Dates	Flux (E>100 MeV) (10^{-7} γ/cm^2-s)	Photon Index
1253-055 (3C 279)	Quasar	0.538	6/15 - 6/28 1991 10/3 -10/17 1991 10/17 -10/31 1991 4/2 - 4/16 1992	2.6±0.1 0.85±0.07 1.02±0.27 0.56±0.20	1.9±0.1 2.1±0.1
1606+106 (4C +10.45)	Quasar	1.23	9/12 - 9/19 1991 12/12 -12/27 1991 4/2 - 4/23 1992	<0.3 0.53±0.12 0.29±0.07	2.2±0.3
1633+382 (4C +38.41)	Quasar	1.81	9/12 - 9/19 1991	0.95±0.08	1.9±0.1
2022-077 (NRAO 629)	Quasar		8/15 - 8/22 1991 10/31 - 11/7 1991 1/23 - 2/6 1992 2/6 - 2/20 1992 10/28 - 11/3 1992	0.67±0.12 <0.13 0.25±0.08 <0.16 <0.7	1.5±0.2
PKS 2052-474	Quasar	1.489	8/6 - 8/13 1992 8/27 - 9/1 1992 10/15 -10/29 1992	<1.1 <0.4 0.28±0.06	
2230+114 (CTA 102)	Quasar	1.037	1/23 - 2/6 1992 4/23 - 4/28 1992 5/7 - 5/14 1992 8/20 - 9/3 1992	0.25±0.05 <1.2 0.39±0.17 0.48±0.17	2.6±0.2
2251+158 (3C 454.3)	Quasar	0.859	1/23 - 2/6 1992 4/23 - 4/28 1992 5/7 - 5/14 1992 8/20 - 9/3 1992	0.78±0.08 1.1±0.3 0.43±0.13 1.23±0.18	2.2±0.1

described by a single power law, although there may be a suggestion for high energy steepening above 1 GeV in several of the sources. The range of redshifts extends to $z > 2$. This is also consistent with a subset from a population of objects in which the emission is beamed toward the observer.

This discovery of a class of high-energy gamma ray sources associated with active galactic nuclei is one of the early surprises of the *COMPTON* mission, and has enabled a new observational approach to the study of AGN. It has also made clear the importance of obtaining broad band coverage, from radio through high-energy gamma rays for these very intriguing sources. Results from such multi-wavelength campaigns are the subject of other talks at this conference.

3. Low Energy Sources

Unlike EGRET and COMPTEL, OSSE has a smaller non-imaging field-of-view and undertakes observations of isolated objects one at a time. OSSE observed 35 active galaxies during phase 1. These sources comprise 14 Seyfert Type 1's, 9 Seyfert Type 2's, 4 BL Lacs, 5 QSOs, 1 radio galaxy, and 2 starburst galaxies. Table 2 provides a list of the QSOs and BL Lacs which were OSSE targets. The rather small number of QSOs reflects the Phase 1 observation plan prior to the

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EGRET discovery of the high energy AGN as well as the large number of Seyferts which had been observed with hard spectra in previous hard x-ray surveys (Rothschild et al. 1983).

Table 2: QSOs and BL Lacs Observed by OSSE during Phase 1

Source	Type	Observ. Dates	Detection Signif. (σ)	Flux @ 70 keV (10^{-3} γ/cm^2-s-MeV)	Photon Index (above 50 keV)
3C 273	QSO	6/15 - 6/28 1991	34.77	23.9±0.82	1.69±.05
		8/22 - 9/5 1991	6.86	76.2±1.29	1.59±0.23
		10/3 - 10/17 1991	6.66	5.94±0.9	1.63±0.23
		8/12 - 8/20 1992	6.41	23.6±3.94	2.33±.39
		9/1 - 9/17 1992	12.57	29.2±2.32	1.84±0.14
QSO 0736+016	QSO	6/15 - 6/28 1991	0.24		
3C 279	QSO	9/19 - 10/3 1991	9.34	10.2±1.26	2.10±0.25
		9/17 - 10/8 1992	0.66		
PKS 0528+134	QSO	10/8 - 10/15 1992	0.61		
		11/3 - 11/17 1992	1.03		
QSO 0834-201	QSO	10/8 - 10/15 1992	-0.22		
		11/3 - 11/17 1992	0.20		
Mrk 421	BL Lac	7/12 - 7/26 1991	-0.63		
		7/26 - 8/8 1991	-0.01		
		9/12 - 9/19 1991	-1.08		
PKS 0548-322	BL Lac	6/11 - 6/25 1992	2.08	6.82±3.72	2.92±1.64
4C 04.77	BL Lac	8/20 - 8/27 1992	0.84		
PKS 2155-304	BL Lac	10/15-11/17 1992	4.96	7.47±1.67	2.01±0.44

Table 3 lists the Seyfert galaxies which were OSSE Phase 1 targets. The strongest Seyfert galaxy observed by OSSE is NGC 4151. These results have been reported by Maisack et al. (1992). The spectrum for NGC 4151 observed in July 1991 is shown in Fig. 1. This spectrum is well fit by thermal spectra (thermal bremsstrahlung or Sunyaev-Titarchuk model) but is not consistent with a single power-law. A single power law fit to the data gives a spectral index of -2.72 ± 0.07 in the 65-800 keV region (Maisack et al. 1993), which is much harder than that observed at lower energies. This clear evidence for a spectral break and the best fit thermal temperature of about 40 keV supports thermal models of Seyfert sources, and is similar to the spectra observed for galactic black hole candidates such as Cyg X-1 and GRO J0422+34. No evidence for a positron annihilation feature or an excess MeV emission is observed raising doubts about non-thermal models that were developed for these sources following earlier reports of MeV emission for NGC 4151 and MCG 8-11-11. The OSSE and COMPTEL upper limits in the 1-10 MeV region are more than an order of magnitude below the level reported by Perotti et al. (1981a) from a balloon-borne observation.

The OSSE observation of NGC 4151 raises the question whether other Seyfert galaxies have similar spectra, and if so, what is the implication for the contribution of Seyferts to the diffuse gamma ray background. NGC 4151, detected at a sensitivity level of about 60σ, is the only Seyfert observed thus far for which a distinction between spectral models can clearly be made

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(Maisack et al. 1993). Johnson et al. (1994) have studied the summed spectra of many of the lower intensity OSSE Seyferts and find that the summed spectrum is consistent with a thermal model, and not consistent with a power law model. This can be seen, in part, by inspecting Table 3 where the spectral indices for each of the Seyfert observations are given. Note that by excluding NGC 4151, the average spectral index of the six Seyferts (3C 111, 3C 390.3, IC 4329A, MCG - 6-30-15, MCG 8-11-11, and NGC 4388) detected with a significance above 6σ is 2.50. This is significantly harder that the 'canonical' spectral index observed for these sources below 50 keV, suggesting that a thermal-like spectrum may be typical of Seyfert galaxies.

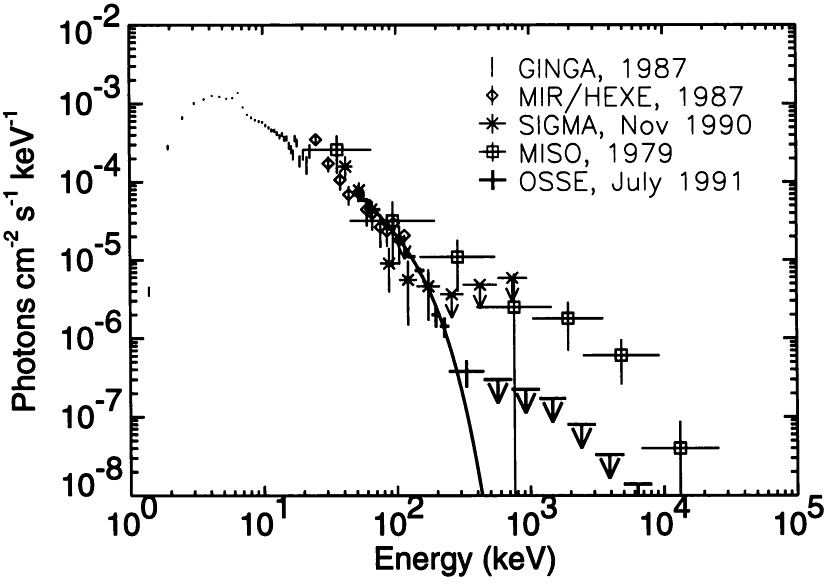

Figure 1. OSSE spectrum of NGC 4151 observed in July, 1991. The best fit Sunyaev-Titarchuk thermal comptonization model is shown. Previous x-ray and gamma ray results are also shown.

4. Broad-Band *COMPTON Observatory* Spectra

One of the objectives of the *Compton Observatory* is to obtain broad band γ-ray coverage of a variety of sources. Brown et al. (1994) have presented preliminary spectra for several AGN over the gamma ray band from 0.1 MeV to 10 GeV. These are shown in Figure 2 and include spectra for 3C 273, 3C 279, PKS 0528-134 and Mrk 421, which have been detected by EGRET at high energies and for which OSSE and/or COMPTEL observations have been made or for which significant low-energy upper limits exist. By broad-band spectra, we limit these to GRO data only. Other papers in these proceedings go into considerably more detail on the very broad band observations of AGN, from radio to gamma rays, which is the focus of this meeting .

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Table 3: Seyfert Galaxies Observed by OSSE During Phase 1

Source	Type	Observ. Dates	Detection Signif. (σ)	Flux @ 70 keV (10^{-3} γ/cm^2-s-MeV)	Photon Index (above 50 keV)
3C 111	SY 1	6/28 - 7/12 1991 5/14 - 6/4 1992	6.15 1.89	5.23±0.97	2.03±0.37
3C 390.3	SY 1	10/17-10/31 1991 5/14 - 6/4 1992	6.09 4.89	6.86±1.20 5.41±1.09	2.60±0.45 2.30±0.46
Mrk 279	SY 1	3/5 - 3/19 1992	4.01	4.12±1.13	2.38±0.62
IC 4329A	SY 1	10/8 - 10/15 1992 11/3 - 11/17 1992	3.67 8.26	8.64±2.33 11.4±1.47	2.25±0.59 2.85±0.38
MCG -6-30-15	SY 1	10/8 - 10/15 1992 11/3 - 11/17 1992	3.38 6.91	4.80±1.70 6.72±1.12	2.28±0.77 2.39±0.40
Mrk 509	SY 1	10/28 - 11/3 1992	3.21	6.14±2.08	3.83±1.28
3C 120	SY 1	5/14 - 6/4 1992 6/4 - 6/11 1992 7/2 - 7/16 1992	2.62 -0.31 3.14	5.08±1.89 3.32±1.16	1.59±0.58 1.81±0.57
MCG +8-11-11	SY 1	6/11 - 6/25 1992	7.65	6.15±0.90	2.70±0.41
Mrk 841	SY 1	4/16 - 4/23 1992	-0.19		
NGC 3783	SY 1	6/25 - 7/2 1992	2.08	4.04±1.90	1.62±0.68
ESO 141-55	SY 1	8/27 - 9/1 1992 10/15-10/29 1992	3.17 -0.19	4.12±1.94	1.75±0.74
Mrk 335	SY 1	4/23 - 4/28 1992 5/7 - 5/14 1992 8/20 - 9/3 1992	-0.54 0.92 -0.17		
NGC 5548	SY 1.2	8/15 - 8/22 1991 10/17-10/31 1991 10/31 -11/7 1991	3.47 2.38 2.74	6.49±2.00 8.42±2.99 8.21±3.20	3.36±1.05 3.68±1.37 1.73±0.65
NGC 4151	SY 1.5	6/28 - 7/12 1991 4/2 - 4/9 1991 4/9 - 4/16 1991	64.41 5.82 5.57	41.5±0.83 34.4±6.85 42.6±7.77	2.42±.05 2.22±0.45 2.07±0.38
NGC 4593	SY 1.9	8/12 - 8/20 1992 9/1 - 9/17 1992	-0.99 -0.94		
NGC 7314	SY 1.9	4/28 - 5/7 1992	1.31		
NGC 7582	SY 2	12/12-12/27 1991 4/2 - 4/9 1992 4/9 - 4/16 1992 4/16- 4/23 1992	3.44 3.04 0.13 -0.31	7.80±2.32 8.00±3.24	3.07±0.96 5.26±1.66
NGC 1275	SY 2	11/28-12/12 1991	2.81	2.75±0.92	2.49±0.83
NGC 2992	SY 2	6/4 - 6/11 1992 7/2 - 7/16 1992	0.94 0.19		
MCG -5-23-16	SY 2	8/6 - 8/12 1992 8/12 - 8/20 1992 8/27 - 9/1 1992	4.14 -0.62 3.80	5.55±1.68 7.55±2.38	1.89±0.52 2.08±0.63
NGC 1068	SY 2	2/20 - 3/5 1992	0.07		
NGC 4388	SY 2	9/17 -10/8 1992	11.51	10.9±1.00	2.37±0.22
MCG +5-23-16	SY 2	8/12 - 8/20 1992 9/1 - 9/17 1992	-0.51 -0.22		

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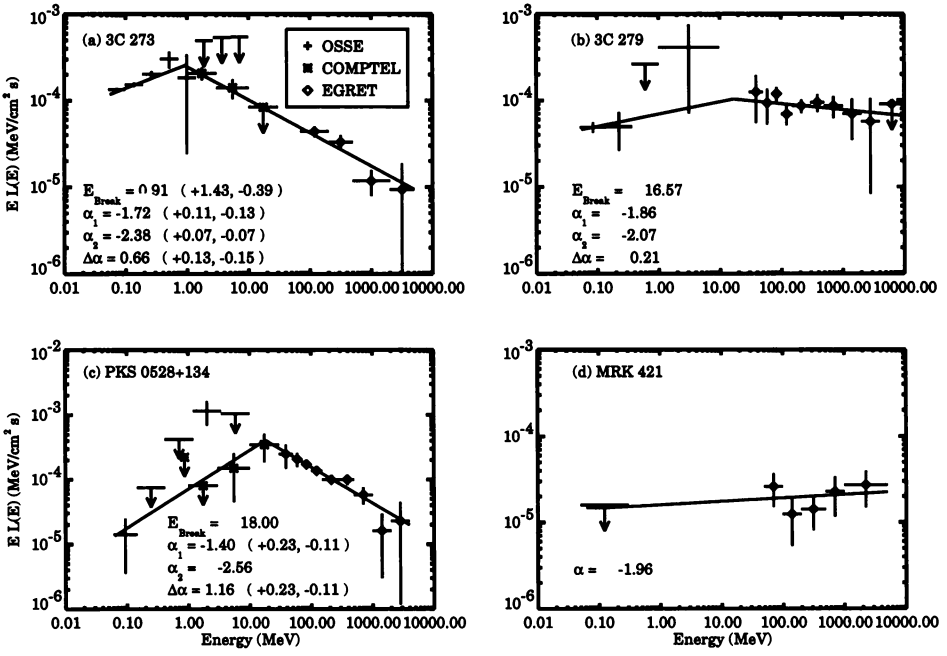

Figure 2: 0.1 MeV - 10 GeV spectra for four AGN: (a) 3C 273, (b) 3C 279, (c) PKS 0528+134, and (d) Mrk 421.

The GRO spectrum of 3C 273 in June, 1991 is shown in Figure 2a. During this observation, 3C 273 was relatively weak in high-energy gamma rays compared to the COS-B observation, and was also weak in low-energy gamma rays compared to historical data. The spectrum is characterized by a broken power law with a break near 2 MeV, and a change in spectral index of 0.66.

The spectrum for 3C 279 is shown in Figure 2b. The reader is cautioned that the data from the GRO instruments are not simultaneous. The EGRET data were taken in VP11 when OSSE was not observing the source. These are compared with OSSE data from VP10. It should also be noted that the high-energy gamma ray emission during VP3 showed clear variability, raising further caution about over-interpreting these data. Nevertheless, the EGRET data during VP3 and VP11 showed little change in intensity at the lower energy of the EGRET band (100 MeV). A broken power law fit to the VP10/VP11 data suggests only a small change in index in the GRO energy range, and the combined data are consistent with a single power law of index about -2.0

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The spectrum for PKS 0528+134 is shown in Fig. 2c. This QSO, at a redshift of 2.08, has been detected by EGRET and COMPTEL, but OSSE only has upper limits for a non-contemporaneous observation. This source exhibits one of the softer spectra observed by EGRET (α = -2.6). COMPTEL observes a weak signal, which requires a spectral break near 20 MeV. A spectral break of $\delta\alpha \geq 1.0$ is also required by OSSE limits in the 0.1-1.0 MeV region.

The spectrum of the nearby BL Lac, Mrk 421, is shown in Fig 2d. Mrk 421 is the only extragalactic source observed at TeV energies by ground-based gamma ray detectors (Punch et al. 1992). EGRET has obtained a spectrum with a power law index of -2.0 which agrees with the TeV data when extrapolated to higher energies. The OSSE upper limits at 100 keV are not constraining on the spectrum, so it is possible that this α= -2.0 power law extends unbroken from 0.1 MeV to 1 TeV.

Even though the spectra of AGN observed by EGRET can be fit with power laws, broad band GRO data indicate that spectral breaks occur at energies ranging from less that 0.1 MeV to above 1 GeV. In the case of PKS 0528+134 the magnitude of the break is $\delta\alpha \geq$ 1.0 and occurs near 20 MeV, while in 3C273 the spectral break, $\delta\alpha$ = 0.66, occurs at lower energy, ~2 MeV. The energy and magnitude of the spectral break should provide information about the emission mechanism and/or geometry of the relativistic beams in these sources.

5. Future Plans for COMPTON/GRO

During Phase 1 the EGRET and COMPTEL instruments completed a full sky survey for gamma radiation above 1 MeV. Guest Investigations were started in Phase 2 and in the current phase (Phase 3) over one half of the observation time is devoted to GI observations. Starting with the next phase (November 1994) all observing time will be competed. Several key projects have been allocated time in the current phase for in-depth study of AGN. Several regions of the sky will be viewed by COMPTEL and EGRET to monitor a large number of the AGN which were discovered during the sky survey. New sources will also certainly be discovered based on the variability which seems to be commonplace in these objects. There is also a deep survey of the Virgo region to be undertaken in Phase 3 which will provide 8 weeks of coordinated observations with the OSSE, EGRET and COMPTEL instruments. Coordinated observations at other wavelengths are also being organized in connection with the Virgo survey. Finally, there will be a multi-wavelength campaign to observe NGC 4151 in December, 1993.

6. Summary

The COMPTON Observatory has made several important contributions to the understanding of AGN during the first 1-1/2 years of the mission. These include:

1. Discovery of a new class of high-energy gamma ray emitting AGN associated with radio loud, core-dominated sources. The short term variability, power-law spectra, and large apparent radiated power suggest that the emission arises in relativistic jets that are beamed toward the observer.

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2. Measurements of the low-energy gamma ray spectra of Seyfert galaxies. These spectra, typified by NGC 4151, are much steeper above 50 keV than below 50 keV. No evidence for positron annihilation features or MeV excesses reported previously have been observed. This seems to suggest a thermal origin for the radiation, similar to that observed in several galactic black hole candidates.

3. Broad-band spectra of several radio loud objects with spectral indices and spectral break energy covering a wide range of these parameters. Further observations and characterization of these should help in understanding the emission mechanism and perhaps the geometry associated with these beamed sources. It is clear that much progress in understanding AGN will come from such multi-wavelength campaigns, and we expect that the *COMPTON Observatory* will contribute to a large number of such campaigns in the future.

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References

Brown, K., et al., 1994, to be published in Proc. Second *COMPTON* Symposium.
Fichtel, C.E., et al., 1993a, presented at the 182nd AAS meeting, private communication.
Fichtel, C.E., et al., 1993b, AIP Conference Proceeding **280**, 461.
Fishman,G.J. et al. 1989, Proceedings of the GRO Science Workshop, 2-39.
Hartman, R.C. et al., 1992 Ap. J., **385**, L1
Johnson, W.N. et al., 1994, to be published in Proc. Second *COMPTON* Symposium.
Johnson, W.N., et al., 1993, Ap. J. Supp. **86**, 693.
Levine, A.M., et al., 1984, Ap. J. Supp., **54**, 581.
Maisack, M., et al., 1993 Ap. J. **407**, L61.
Paciesas, W.S., et al. 1993, AIP Conference Proceeding **280**, 473.
Perotti, F, et al., 1981a, Ap. J. **247**, L63.
Perotti, F., et al., 1981b, Nature, **292**, 133.
Punch, M., et al., 1992, Nature **358**,477.
Rothschild, R.E., et al., 1983. Ap. J. **269**, 423.
Swanenburg, B.N., et al., 1978, Nature **275**, 298.
Schoenfelder, V., et al., 1993, Ap. J. Supp. **86**, 657.
Thompson, D. J., et al., 1993, Ap. J. Supp. **86**, 629.

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