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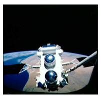
Summary of all Centaurus A Observations with CGRO COMPTEL



Compton
Gamma-Ray Observatory
(CGRO)

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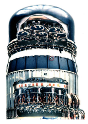

COMPTEL

Journal of Cen A Observations

VP	target	dates	exp.	C	B	O	E
12.0	Cen A	91-10-17 to 91-10-31	4.22	x	x	p	x
14.0	Eta Car	91-11-14 to 91-11-28	1.19	x	x		x
23.0	Cir X-1	92-03-19 to 92-04-02	1.32	x	x		x
27.0	4U1543-47	92-04-28 to 92-05-07	0.77	x	x		x
32.0	NGC 3783	92-06-25 to 92-07-02	0.73	x	x		x
207.0	IC 4329A	93-01-12 to 93-02-02	3.55	x	x		x
208.0	NGC 4507	93-02-02 to 93-02-09	1.45	x	x		x
215.0	Cen A	93-04-01 to 93-04-06	1.01	x	x	p	x
217.0	Cen A	93-04-12 to 93-04-20	1.61	x	x	p	x
314.0	Gal 304-01	94-01-03 to 94-01-16	2.10	x	x		x
315.0	Gal 304-01	94-01-16 to 94-01-23	1.01	x	x		x
316.0	Cen A	94-01-23 to 94-02-01	2.40	x	x	p	x
402.0	GPlane 310	94-10-18 to 94-10-25	0.82	x	x		x
402.5	GPlane 310	94-10-25 to 94-11-01	0.85	x	x		
424.0	Cen A	95-07-10 to 95-07-25	3.92	x	x	p	x
531.0	PSR B1055-52	96-10-03 to 96-10-15	0.89	x	x		
619.0	Cir X-1	97-05-06 to 97-05-14	1.09	x	x		
619.4	Cir X-1	97-05-20 to 97-05-28	1.09	x	x		
619.7	Cir X-1	97-06-04 to 97-06-10	0.82	x	x		
627.0	PSR 1055-52	97-09-02 to 97-09-09	0.86	x	x		x
630.0	PSR 1055-52	97-09-23 to 97-10-07	1.46	x	x		x
632.1	Carina-1	97-10-07 to 97-11-03	2.68	x	x		
705.0	PSR B1509-58	97-12-09 to 97-12-16	1.41	x	x		
706.0	PSR B1509-58	97-12-16 to 97-12-23	1.20	x	x		
707.0	PSR B1509-58	97-12-23 to 97-12-30	1.11	x	x		
717.0	Cen X-3	98-04-14 to 98-04-22	0.93	x	x		
718.0	Cen X-3	98-04-22 to 98-04-29	0.88	x	x		
719.0	Cen X-3	98-04-29 to 98-05-05	0.81	x	x		
729.5	J1550-564	98-09-25 to 98-10-06	1.51	x	x		
808.5	J1550-564	99-03-16 to 99-03-23	0.93	x	x		
817.5	N Vel 1999	99-05-27 to 99-06-08	1.67	x	x		
819.5	N Vel 1999	99-06-08 to 99-06-22	2.30	x	x		
821.0	PSR 1509-58	99-07-06 to 99-07-13	1.20	s	x		
822.0	PSR 1509-58	99-07-13 to 99-07-20	1.23	s	x		
823.0	PSR 1509-58	99-07-20 to 99-07-27	1.41	s	x		
824.0	PSR 1509-58	99-07-27 to 99-08-03	1.13	s	x		
825.0	PSR 1509-58	99-08-03 to 99-08-10	0.96	s	x		
826.0	PSR 1509-58	99-08-10 to 99-08-17	0.99	s	x		
830.5	N Vel 1999	99-09-28 to 99-10-05	0.86	s	x		
912.5	N Vel 1999	00-03-01 to 00-03-21	2.74	s	x		

Table 1

Note:
VP = viewing period; dates are given in the form yy-mm-dd;
exp. = effective exposure time (see text); p= primary target;
C = COMPTEL; B = BATSE; O = OSSE; E = EGRET;
(19)91-10-17 = TJD 8546; (20)00-03-21 = TJD 11624;
the colored viewing periods have been combined for Fig. 2.

Introduction

The elliptical galaxy NCG 5128 is the stellar body of the giant double radio source Centaurus A (Cen A). It contains a jet with a large inclination ($\sim 70^\circ$) to the line-of-sight which is detected in all wavelength bands where the spatial resolution is sufficient. The dust lane, which obscures the nucleus at optical wavelengths (Fig. 3), is thought to be the remnant of a recent ($10^7 - 10^8$ years ago) merger of the elliptical galaxy with a smaller spiral galaxy (Thomson 1992).
Its proximity of < 4 Mpc (Hui et al. 1993) makes Cen A the closest active galaxy and therefore, NGC 5128 is very well studied and frequently observed in all wavelength bands. Its emission is detected from radio to high-energy gamma-rays (Johnson et al. 1997; Israel 1998) making it the **only** radio galaxy detected in MeV gamma-rays. All other AGN detected in MeV gamma-rays (and identified) are blazars (Collmar et al. 1999).
Variability of Centaurus A is reported in many wavelength regimes. In hard and in soft X-rays, observations of Cen A have revealed intensity variability greater than an order of magnitude (Bond et al. 1996).

Observations

During more than 9 years in orbit on board the Compton Gamma-Ray Observatory (CGRO), COMPTEL has observed Centaurus A in the energy range 0.75 - 30 MeV during 40 CGRO pointings which had Cen A closer than 32° from the center of the wide COMPTEL field-of-view. Table 1 lists all this observations. The effective observing time (in days) of an observation listed in Table 1 is dependent on the pointing duration, the offset of Cen A from the pointing direction and off-times of the instrument due to passages through the South Atlantic Anomaly (SAA) and the Earth in the field-of-view. The total effective observing time of all 40 observations was 60 days. Indicated in Table 1 are also simultaneous observations with the OSSE and EGRET experiments also on board of CGRO. BATSE, which was an omnidirectional instrument, continuously monitored Cen A in hard X-rays (see Fig. 1).

Light Curves

The BATSE 20 - 200 keV 10 day average light curve in Fig. 1 shows (when compared to previous observations by other experiments as listed in Bond et al. (1996)) that Cen A was in an intermediate intensity state at the beginning of the CGRO observations and stayed in a low emission state for the remainder of the mission with two intervals of slightly enhanced emission in between. Light curves in all COMPTEL standard energy bands (0.75 - 1 MeV, 1 - 3 MeV, 3 - 10 MeV, and 10 -30 MeV) have been derived as well as in the total 1 - 30 MeV energy band. Several (short) viewing periods which had similar observation conditions and were close together in time, have been combined to enhance statistics. Those groups are marked in Table 1.
The example light curve in Fig. 2 (1 - 30 MeV; upper limits are 2 σ including statistical and systematic errors) derived from the COMPTEL measurements does not show significant changes. The same is also true for the other enery bands.

Spectra

When all spectra of Cen A obtained by COMPTEL in the energy range 0.75 - 30 MeV are analyzed, it turns out, that all exept one, are similar. The exeption is the first observation (VP 12), when Cen A was in an intermediate emission state (Fig. 4). All other observations can be merged into the average low state spectrum shown in Fig. 5. In this figure, the high-energy part of a spectral energy distribution (SED) from radio to gamma-rays obtained during a simultaneous multiwavelength campaign (Steinle et al. 1999) is included in green. In both figures the COMPTEL data points are colored red. The additional data are from OSSE (50 keV - 1 MeV) and EGRET (> 50 MeV).
The spectra taken in the intermediate and low state observations are different, as they show the two break energies in a doubly broken power-law fit at significantly different locations. Also the spectral slopes are different as is the total luminosity in the two emission states. The derived spectral properties when fitting a doubly broken power-law to the combined OSSE, COMPTEL, and EGRET data (photon spectrum; see Steinle et al. 1998) are the following:

Spectral Properties of Cen A

Parameter	Intermediate State	Low State
E_{b_1}	150 keV	140 keV
E_{b_2}	16.7 MeV	0.59 MeV
α_1	1.74	1.73
α_2	2.3	2.0
α_3	3.3	2.6
L_γ	5×10^{42} erg^{-1}	3×10^{42} erg^{-1}

Table 2

(We used H_0 = 50 km s^{-1} Mpc^{-1}, z = 0.0006 (3.5 Mpc), and $q_0 = 0.5$ to calculate the luminosity assuming isotropic emission.)

Summary and Conclusions

The detection of Centaurus A in gamma-rays up to MeV (and GeV) energies with the COMPTEL (and EGRET) instrument(s) on board CGRO makes this AGN unique, as all other AGN detected in high energy gamma-rays are of the blazar type. As Cen A is viewed from an large angle with respect to the jet axis, it may well be, that we do not see jet emission from this AGN (misaligned blazar) but emission from the nuclear region and that we detect Cen A only because it is so close.
Observed continuously with CGRO over more than 9 years, Cen A did not show the large intensity variations recorded in the past. At the beginning of the observations, Cen A was in an intermediate emission state before its intensity declined to the low emission state which lasted for the reminder of the mission. Therefore only one spectrum had been measured with COMPTEL in an emission state other than the low state. This intermediate state spectrum differs significantly from the average low state spectrum as can be seen in Table 2 and by comparing Figs. 4 and 5.
A lot of interesting data have been collected by the gamma-ray sensitive instruments on board CGRO, but still many open questions exist and many important high energy measurement have to be made. Among the most interesting observations still missing are simultaneous multiwavelength measurements of the SED in a high and intermediate emission state, and their correlation with the spectral shape, as well as MeV observations with high enough spatial resolution to resolve jet and nucleus in gamma-rays.

References

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Light Curves

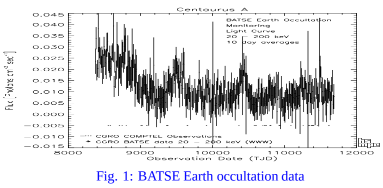


Fig. 1: BATSE Earth occultation data

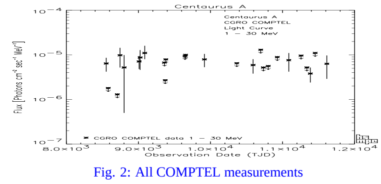
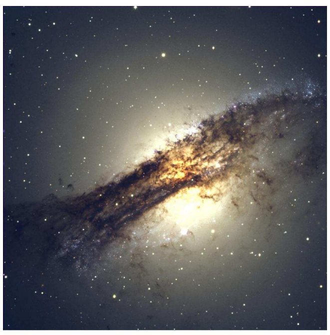


Fig. 2: All COMPTEL measurements

Centaurus A - NGC 5128



Centaurus A Radio Galaxy (VLT KUEYEN + FORS2)

Fig. 3: Optical image of NGC 5128 (Cen A)

Spectra

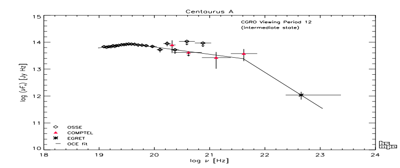


Fig. 4: Intermediate state spectrum (viewing period 12)

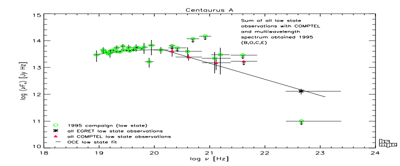


Fig. 5: Low state spectrum (all other viewing periods) and data from the multiwavelength campaign 1995

For more information on Centaurus A see: http://www.mpe.mpg.de/Cen-A/

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