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COMPTEL Observations of the Virgo Blazars 3C 273 and 3C 279

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Abstract. We report the main MeV properties (detections, light curves, spectra) of the Virgo blazars 3C 273 and 3C 279 which were derived from a consistent analysis of all COMPTEL Virgo observations between 1991 and 1997.

INTRODUCTION

The Virgo blazars 3C 273 and 3C 279 are well-known flat-spectrum radio quasars. Both sources have been detected at γ-ray energies by different instruments aboard the Compton Gamma-Ray Observatory (CGRO) from ~50 keV (OSSE) up to ~10-20 GeV (EGRET). In this paper we summarize their main MeV properties, which are derived from a consistent analysis of all COMPTEL observations between 1991 and 1997. A complete description of the analysis results, put into multifrequency perspective, is in preparation [1].

OBSERVATIONS AND DATA ANALYSIS

The imaging Compton Telescope COMPTEL - one of four experiments aboard CGRO - was sensitive to γ-rays in the energy range 0.75-30 MeV (for more details on COMPTEL see [2]). During 1991 and 1997 (i.e., CGRO observational phases I to VI) both sources were many times within the COMPTEL field-of-view (see Table 1). These data have been analysed – as a whole as well as individually – by using the standard COMPTEL maximum-likelihood analysis procedure including a filtering technique for background generation. Point spread functions assuming an E^{-2} power law shape for the source spectra were applied in our analyses.

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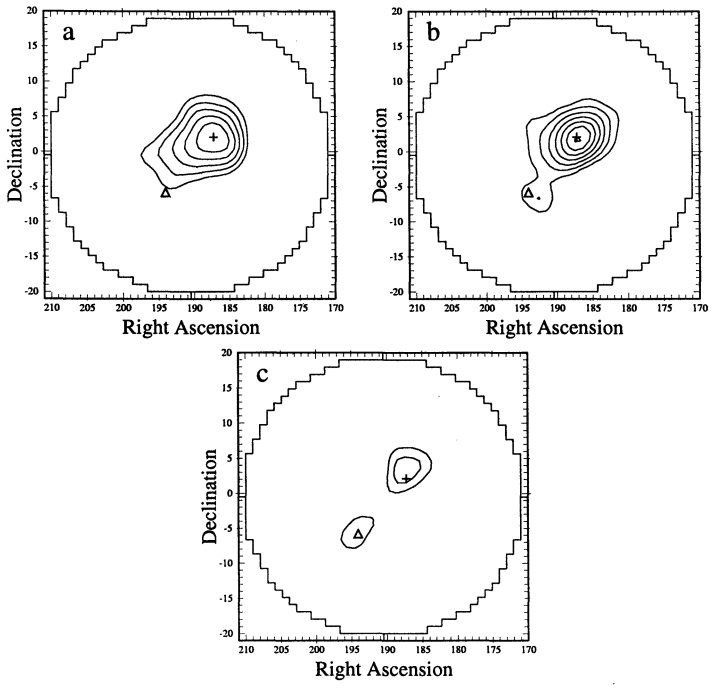

FIGURE 1. Time-averaged COMPTEL maximum-likelihood significance skymaps (1991 to 1997) of the Virgo region in 3 different bands (a: 1-3 MeV; b: 3-10 MeV; c: 10-30 MeV). The locations of the Virgo quasars 3C 273 (+) and 3C 279 (Δ) are given. The contour lines for all maps start at 4σ with a step of 1σ (χ^2_1-statistics for a known source).

TABLE 1. COMPTEL exposures on 3C 273 and 3C 279 during CGRO Phases I to VI (1991 - 1997). The time periods of the different phases, the total observation times (days within COMPTEL field-of-view), and the effective COMPTEL exposures of 3C 273 and 3C 279 are given.

CGRO Phase	Time Period mm/yy - mm/yy	Total Obs. Time [days]	3C 273 Eff. Exp. [days]	3C 279 Eff. Exp. [days]
I	05/91 - 11/92	27	8.95	10.12
II	11/92 - 08/93	21	5.58	5.51
III	08/93 - 10/94	64	10.85	13.90
IV	10/94 - 10/95	42	11.46	9.64
V	10/95 - 10/96	14	6.42	6.21
VI	10/96 - 11/97	49	15.08	12.07
Sum	05/91 - 11/97	217	58.3	57.5

RESULTS

3C 273

In the sum of the 1991 - 1997 data (Table 1), 3C 273 is significantly detected in the 3 standard COMPTEL bands above 1 MeV. The detection significances are $\sim 9\sigma$ in the 1-3 MeV, $\sim 9.5\sigma$ in the 3-10 MeV, $\sim 6\sigma$ in the 10-30 MeV band (Fig. 1), which make 3C 273 the most significant ($\sim 15\sigma$, 1 - 30 MeV) COMPTEL AGN overall. Evidence for the source is found in about 80% of the individual Virgo pointings (Fig. 2). Within uncertainties, no time variability is seen in each of the 3 bands on timescales of a few weeks.

The time-averaged COMPTEL MeV spectrum for the sum of the observations between 1991 and 1997 (Table 1) is shown in Fig. 3 in two representations. The left panel gives the spectrum in the 4 standard COMPTEL bands. The fluxes in these bands indicate a curved time-averaged MeV spectrum of 3C 273, which changes from a soft shape at upper COMPTEL energies to a harder one at lower energies. The emission maximum, and therefore the peak of the nonthermal inverse-Compton radiation of 3C 273 (for a multifrequency spectrum see e.g. [3]), is located in the 3-10 MeV band. A power-law fit to this summed spectrum results in an unacceptable χ^2-value of ~ 13 for 2 degrees of freedom, proving that a power law is not a viable model. The right panel shows a preliminiary 'high-resolution' (11 data points) spectrum of the same data which could be obtained because of the relatively high statistics for 3C 273. Again a spectral turnover at MeV energies is evident. This spectrum suggests that the spectral turnover of 3C 273 is on average broad and rather smooth. No spectral features (e.g., hints for a blueshifted annihilation line) are obvious.

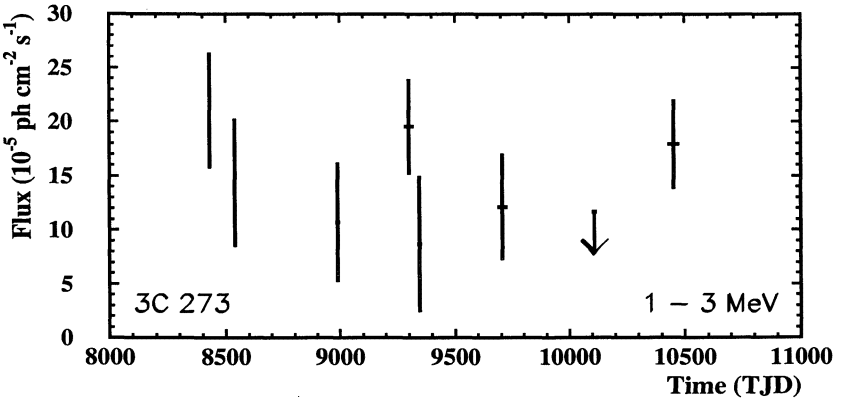

FIGURE 2. COMPTEL light-curves of 3C 273 in the 1-3 MeV band along the CGRO mission between 1991 and 1997. The blazar shows a rather stable γ-ray emission. The errors are 1σ and the upper limit is 2σ.

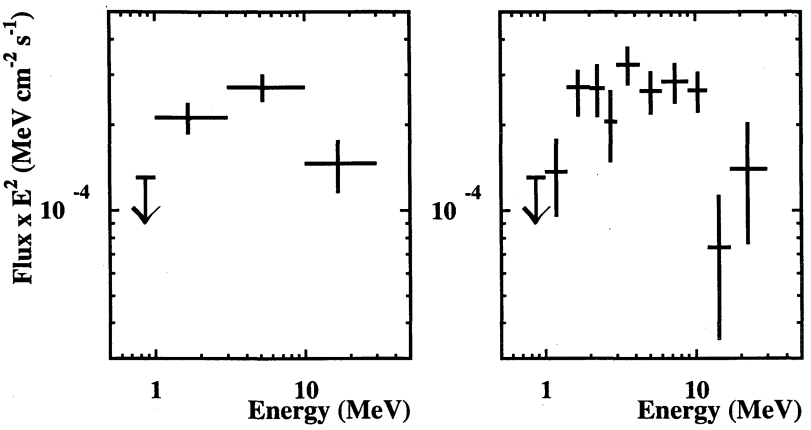

FIGURE 3. Time-averaged (i.e., for the sum of the observations in Table 1) COMPTEL MeV spectra of 3C 273. The left panel shows the spectrum in the 4 standard COMPTEL bands (0.75-1, 1-3, 3-10, 10-30 MeV), and the right one shows the same spectrum with increased spectral resolution (11 spectral points). The errors are 1σ and the upper limits are 2σ.

3C 279

In the sum of all 1991 - 1997 data there is evidence for 3C 279 at energies above $\sim$1 MeV, more significantly above $\sim$3 MeV (Fig. 1). The detection significances for this period are $\sim 3.5\sigma$, $\sim 4.5\sigma$, and $\sim 4.5\sigma$ in the 1-3 MeV, 3-10 MeV, and 10-30 MeV COMPTEL bands, respectively. The detections and non-detections along the course of the mission indicate time variability (Fig. 4). This is most obvious by the high flux in the 10-30 MeV band during CGRO VP 511.5 (February '96), which is about 3σ above the previous flux measurement and the upper limit in the next observational period, and which is simultaneous to the largest γ-ray flare ever observed from 3C 279 by EGRET. There is the trend, that 3C 279 becomes visible in the uppermost COMPTEL band, when EGRET observes a strong flaring event (Fig. 4).

The COMPTEL MeV spectra of 3C 279 can be well represented by power-law shapes. The 6-year time-averaged spectrum is consistent with a power-law shape ($E^{-\alpha}$) with a photon index α of 1.78 ± 0.15 (Fig. 5). The spectra for the individual time periods are less well determined, but they indicate the trend of a spectral hardening with EGRET-measured flux. To investigate this trend, we subdivided the COMPTEL data according to the γ-ray state (high vs. low) above 100 MeV, and generated MeV spectra for the sum of both states (Fig. 5). These two spectra show different spectral shapes with a crossover at $\sim$2 MeV. This indicates that the 'EGRET flares' are a high-energy γ-ray (>3 MeV) phenomenon, and that the peak of the inverse-Compton emission changes with source flux in 3C 279.

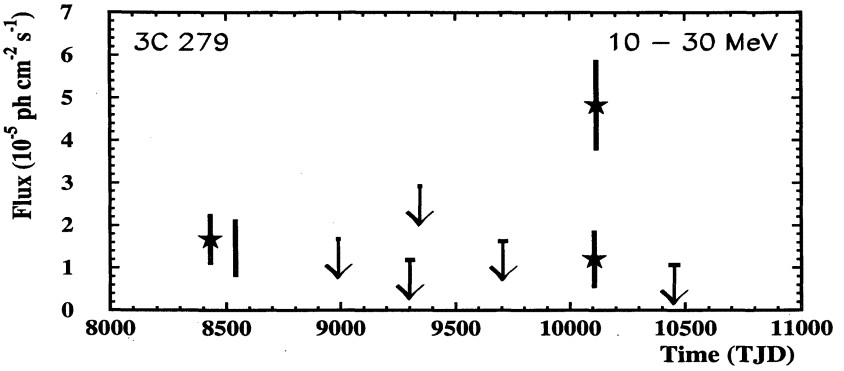

FIGURE 4. COMPTEL light curve of 3C 279 in the 10-30 MeV band from 1991 to 1997. The detections and non-detections indicate time variability. The blazar is always detected by COMPTEL when EGRET reports γ-ray flaring (i.e, high fluxes) at energies above 100 MeV. These periods are marked by a '$\star$'.

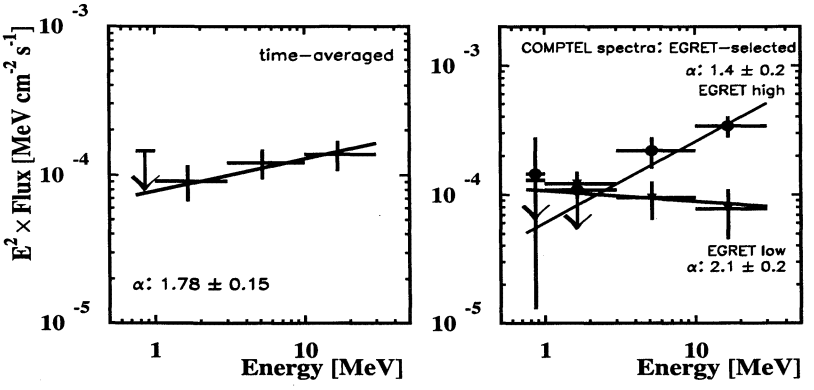

FIGURE 5. Time-averaged COMPTEL spectra of 3C 279. The left panel shows the spectrum averaged over the sum of the '91 to '97 data, while the right panel shows spectra averaged over times of γ-ray flaring ('EGRET high') and γ-ray quiescent ('EGRET low') periods. The spectral difference is obvious.

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