Gamma-ray Blazars in the COMPTEL Regime

W.Collmar
MPE, Postfach 1603, 85740 Garching, Germany

On behalf of the COMPTEL Collaboration

Abstract

After 5 years of operation COMPTEL has detected MeV-radiation from 8 γ-ray blazars discovered with EGRET at energies above 100 MeV. Because none had been observed at energies of a few MeV before, COMPTEL opened this field of γ-ray astronomy. The spectral results show that the COMPTEL energy range (0.75-30 MeV) is a transistion region for blazar spectra between a softer γ-ray spectrum and a harder X-ray spectrum.

I. Introduction

With the launch of the Compton Gamma-Ray Observatory (CGRO) on April 5, 1991 a new era of γ-ray astronomy began. This is especially true for the soft γ-ray range (photon energies around a few MeV), which was widely unexplored before the COMPTEL experiment on CGRO. Its sensitivity for MeV-radiation (0.75-30 MeV) together with the large exposure times available on satellite missions, resulted in a major improvement of our knowledge about the MeV-universe. A detailed description of the COMPTEL instrument can be found in Schönfelder et al. (1993).

With the detection of many blazar-type active galactic nuclei (AGN) at γ-ray energies above 100 MeV, EGRET widely opened the field of extragalactic γ-ray astronomy. Up to now EGRET has detected more than 50 γ-loud AGN (Thompson et al. 1995). Before COMPTEL no blazar was known to emit at MeV-energies. Now, after roughly 5 years of operation, COMPTEL has detected 8 of these EGRET blazars. In addition to these EGRET-type blazars, COMPTEL has observed so called "MeV-blazars" (Bloemen et al. 1995; Blom et al. 1995a), which show strong MeV-emission compared to the emission at hard γ-rays (EGRET range), and two - so far - unidentified objects (Williams et al. 1995; Iyudin et al. 1996) which might belong to this "MeV-blazar" class as well.

In this paper we concentrate on the "regular" EGRET-type blazars in the COMPTEL regime. Especially, we report more recent COMPTEL blazar results and also summarize their more general behaviour.

II. Some individual sources

II.1 Virgo region sources

Between April 1991 and October 1994 (Phases I, II, and III of the CGRO mission) COMPTEL was pointed towards the VIRGO sky region for $\sim$15 weeks in total. The quasar 3C 273 is observed to be the strongest MeV-source of the Virgo region (Fig. 1). In the sum of all Phase I-III data, 3C 273 is detected by COMPTEL with a significance of $\sim 9\sigma$ in the energy band 1 to 10 MeV (Collmar et al. 1996). Detections and non-detections along the course of the CGRO mission indicate a time-variable MeV-flux. The bending ("break")

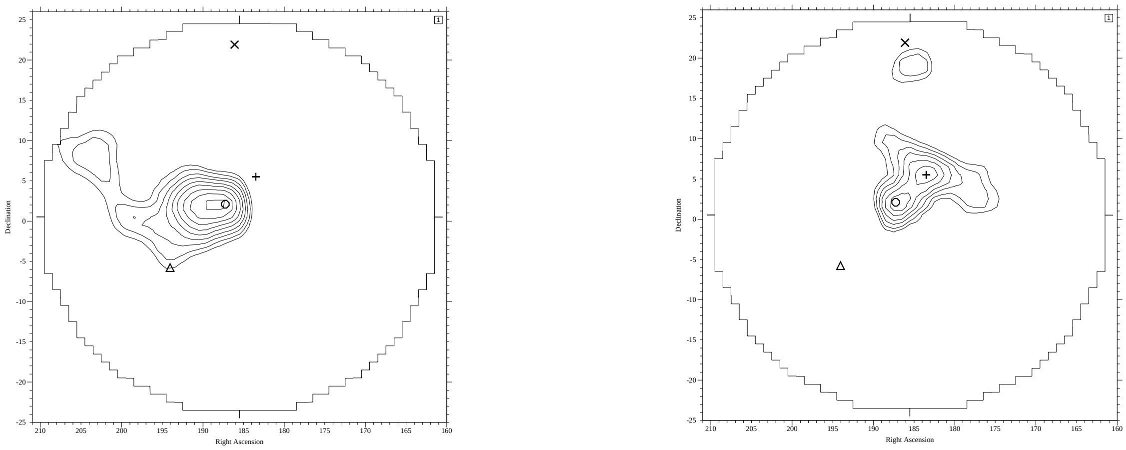

Figure 1: COMPTEL skymaps (detection significances) of the Virgo region for the sum of all Phase I-III data ($\sim$15 weeks of observation time). The contour lines start at a detection significance of 2.5σ with a step of 0.5σ (3 dof for an unknown source). The maps are generated in the 1-3 MeV (left), and the 3-10 MeV band (right). The locations of 3C 273 (**o**), 3C 279 (Δ) and 2EG J1224+2155 (**x**) are indicated. The most likely position of the new MeV-source GRO J1214+06 (**+**) is also marked. Apart from these four sources there are promising hints for further MeV-sources in the maps.

of the 3C 273 spectrum at MeV-energies (e.g. Lichti et al. 1995) is already indicated by the time-averaged COMPTEL spectral points between 0.75 and 30 MeV (Fig 2).

In the sum of all data, there is also evidence for the quasar 3C 279 at a significance level $\sim 3.4\sigma$ in the 1-3 MeV band. Along the course of the CGRO mission, 3C 279 was detected by COMPTEL several times: during a γ-ray flaring period at the beginning of the CGRO mission at energies above 3 MeV (e.g. Williams et al. 1995), and during a long observational period in Phase III (8 weeks) at energies below 3 MeV (Collmar et al. 1995) indicating a spectral change. Again, detections and non-detections indicate a time-variable MeV-flux.

In addition to these two quasars, there is evidence for previously unknown MeV-sources in Virgo. One of them is spatially consistent with the EGRET source 2EG J1224+2155 which is identified with the quasar PKS 1222+216 (Thompson et al. 1995). The significance of the COMPTEL detection at the EGRET position is $\sim 3\sigma$. The other new source - GRO J1214+06 - was detected at a level of $\sim 4.5\sigma$ by COMPTEL. Without an obvious counterpart, it remains an unidentified object yet. The energy spectrum seems to peak in the 3-10 MeV energy range, similar to what we have seen so far from other AGN detected by COMPTEL. Apart from these published sources there are promising hints for further MeV-emitting objects in Virgo. In general, the Virgo sky region contains several MeV-emitting objects. All of them are showing considerable time variability indicated by detections and non-detections during different viewing periods. So, no MeV-maps of this region have ever looked the same.

II.2 PKS 0528+134

Like the Virgo sky region the galactic anticenter was in the COMPTEL field-of-view sev-

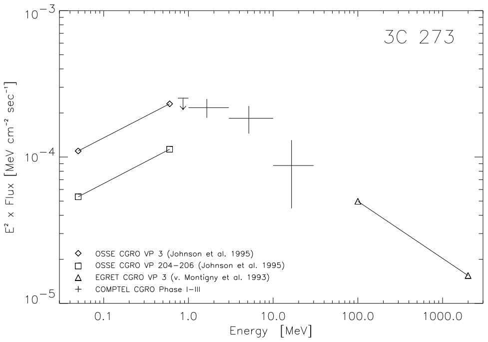

Figure 2: Combined OSSE, EGRET and COMPTEL spectrum of 3C 273, plotted as differential flux $\times$ E^2, which represents a power per decade of energy plot. The spectra are not measured contemporaneously. The COMPTEL error bars are 1σ and the upper limit is 2σ. The spectral turnover at a few MeV is evident. For the references of the EGRET and OSSE measurements see Collmar et al. (1996).

eral times. During Phase I-III (analysed in detail by Collmar et al. 1997) the quasar PKS 0528+134 was within 30^o of the COMPTEL pointing direction for $\sim$17 weeks. In the sum of all data, PKS 0528+134 is detected throughout the whole COMPTEL energy range, however most significantly at energies above 3 MeV. The average spectrum is well represented by a power-law shape with a photon index of $\sim$-2. Detections and non-detections along the mission indicate a time-variable MeV-flux. Variations at the highest COMPTEL energies follow strictly the trend as seen by EGRET above 100 MeV. Combining simultaneous COMPTEL- and EGRET data for γ-ray flare phases, a spectral break at MeV-energies becomes evident (Fig. 3). Including observations from lower waveband regions shows that for PKS 0528+134 the power per frequency decade peaks at MeV-energies (Fig. 3).

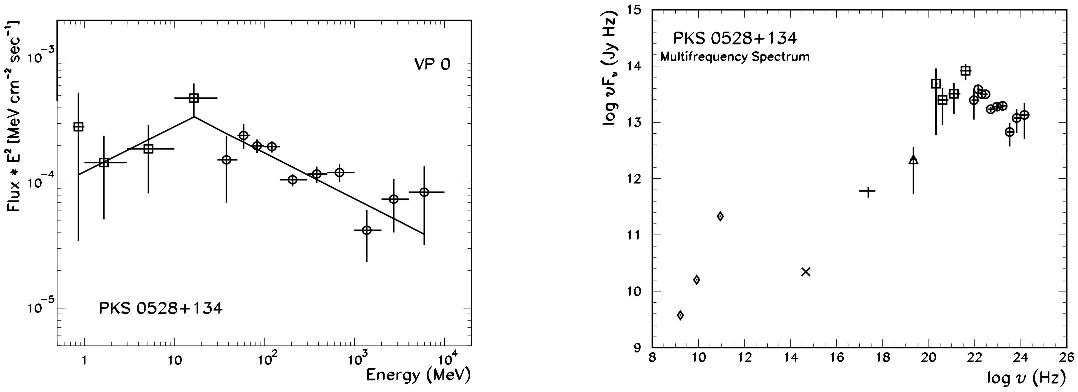

Figure 3: Left: Simultaneous COMPTEL($\square$) and EGRET ($\circ$) spectrum of PKS 0528+134 for the CGRO verification phase (April 1991). The solid line represents the best-fitting broken PL-function. The spectral turnover at MeV-energies is evident (Collmar et al. 1997). Right: Broad band spectrum for the same observational period. Only the EGRET and COMPTEL data are contemporaneous. The luminosity peaks at MeV-energies. For references of the low energy points see Collmar et al. (1997).

III. Summary

COMPTEL has positively detected 8 (3C 273, 3C 279, PKS 0528+134, 3C 454.3, CTA 102, PKS 0208-512, PKS 1222+216, PKS 1622-297) of the EGRET blazars. All of them are quasars. No BL Lac-object is detected by COMPTEL yet. Despite the fact that the anlyses for the individual sources have been carried out in different detail, some general results are apparent. All blazars seem to be time-variable at MeV-energies on the order of months to years as is indicated by detections during some individual viewing periods and non-detections during others. Within individual viewing periods (~2-3 weeks), time variability was not observed for any source yet. Probably only because of the generally low detection significances. Apart from 3C 273, which has a soft spectrum ($\alpha <$ -2) and PKS 1222+216, whose MeV-spectrum is undefined (only one positive spectral point), all other blazars tend to have hard ($\alpha >$ -2) spectra. Comparing the COMPTEL spectral measurements with the EGRET ones, spectral breaks become obvious. Except for 3C 273 none of the COMPTEL blazar spectra allow a simple extrapolation of the simultaneously measured EGRET power laws. For 3C 273 a combination of OSSE and COMPTEL data requires the break (Fig. 4). This indicates that the COMPTEL energy range is a transition region for the blazar spectra between a softer γ-ray spectrum in the EGRET energy range and a harder spectrum in the X-ray range. The multiwavelength spectra generated for some of the sources show that for PKS 0528+134 (e.g. Collmar et al. 1997), 3C 454.3 and CTA 102 (Blom et al. 1995b) the energy output per frequency decade peaks at MeV-energies. For 3C 273 a comparable amount of radiation energy is released at UV-energies ("blue bump") (e.g. Lichti et al. 1995).

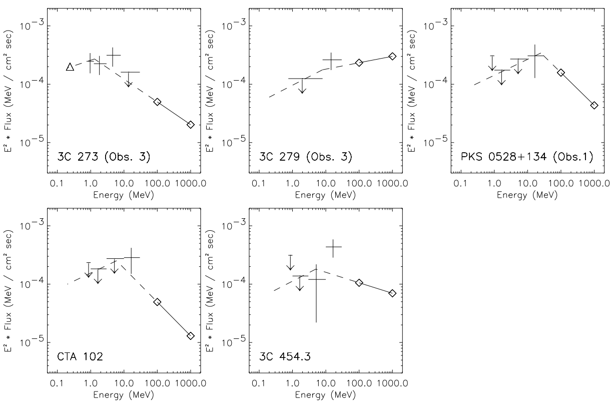

Figure 4: Illustration of spectral breaks at MeV-energies found by COMPTEL for 5 AGN. The solid lines (framed with diamonds) represent the spectral shapes of the sources as measured by EGRET. The spectral points or upper limits represent the COMPTEL measurements. Eye fits to the breaks are indicated by the dashed lines. For references of the individual spectra see Schönfelder et al. (1996).

IV. Conclusion

After 5 years in orbit, COMPTEL has provided new and interesting results on γ-ray blazars improving our knowledge about these powerful sources. Because COMPTEL is still "healthy" and will stay (probably) in operation for some more years, more and improved results on blazars are expected for the future. Due to increasing exposure time and improved background reduction techniques the COMPTEL sensitivity for MeV-observations will increase as well.

V. References

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