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### Comptel observations of the quasar PKS 0528+134

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## COMPTEL OBSERVATIONS OF THE QUASAR PKS 0528+134

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### ABSTRACT

During Phase I and Phase II of the CGRO-mission, the quasar PKS 0528+134 was in the field of view of the COMPTEL instrument during several viewing periods. The quasar was detected by COMPTEL mainly at energies above 10 MeV. Below 10 MeV there is evidence for the source during some CGRO viewing periods, while below 3 MeV no signal is detected. The detections and non-detections during different viewing periods follow the trend seen by EGRET, thereby indicating a time-variable MeV-flux of the quasar. The COMPTEL spectral results together with the simultaneously measured EGRET spectrum, indicate a spectral break in the upper part of the COMPTEL energy range at energies between 10 MeV and 30 MeV.

### INTRODUCTION

PKS 0528+134 was originally detected at  $\gamma$ -ray energies (mainly above 100 MeV) by the EGRET experiment (Kanbach et al. 1991) during two CGRO pointings towards the galactic anticentre at the beginning of the mission (April and May 1991). Located in the same field as the well-known sources Crab and Geminga, this new  $\gamma$ -ray source was identified with the radio source PKS 0528+134, and confirmed as a quasar, after positional analysis and after an optical spectrum revealed a redshift of 2.07 for this object (Hunter et al. 1993).

A search in the COMPTEL data (0.75 - 30 MeV) for AGN detected by EGRET led to the discovery of PKS 0528+134 also at low energy  $\gamma$ -rays (Collmar et al. 1993a). Preliminary results from the early viewing periods have been presented by Collmar et al. (1993b). In this paper we review the latest COMPTEL results on PKS 0525+134. Being work in progress (especially for the CGRO Phase II observations), the quantitative results should be considered as preliminary.

### OBSERVATIONS

Up to the end of Phase II (August 1993) of the CGRO-mission, the quasar PKS 0528+134 (l:  $191^{\circ}.37$ , b:  $-11.^{\circ}01$ ) was in the COMPTEL field of view several times.

During 5 viewing periods (VP) the source was located within  $20^\circ$  of the COMPTEL pointing direction. The relevant data of these observations are given in Table I.

For VP 2.5 (Target of Opportunity observation of the sun) no results have been derived yet (COMPTEL was operating in a special mode to detect solar neutrons). This observation period will be included in future work.

Table I: COMPTEL observations of PKS 0528+128 ( $< 20^\circ$  pointing direction)

VP	Observation Time	Observation Duration (days)	Angular distance to point. direction ( $^\circ$ )	VP target
0	April 22 - May 7, 91	15	$\sim 8$	CGRO verific. <sup>1</sup>
1	May 16 - May 30, 91	14	6.2	Crab pulsar
2.5	June 8 - June 15, 91	7	5.1	Sun, ToO <sup>2</sup>
213	March 23 - March 29, 93	6	9.0	Crab pulsar
221	May 13 - May 24, 93	11	6.3	Crab pulsar

## DATA ANALYSIS

The COMPTEL data analysis package (COMPASS) includes for mapping and source analysis the Maximum-Entropy-Method (MEM) described by Strong et al. (1992) and the Maximum-Likelihood-Method (MLM) described by de Boer et al. (1992). Both methods can be used for the generation of skymaps, but - in the current setup of the COMPTEL data analysis system - source significances, fluxes and error regions are derived by the MLM.

The COMPTEL data analysis for PKS 0528+134 is complicated by its proximity to the Crab (l:  $184^\circ.56$ , b:  $-5^\circ.979$ ). The Crab is only  $8^\circ$  away and is the brightest source in the COMPTEL energy range. Figure 1a shows a MLM-map of the Crab region in the 10-30 MeV band. The image is clearly dominated by the Crab, though emission from PKS 0528+134 is also evident. The contour lines are elongated in direction of the Parkes quasar. From this figure it is apparent that a flux estimate for PKS 0528+134 can not simply be derived by reading off the relevant values from the map, because the two sources are not clearly resolved, and the Crab outshines the quasar by about a factor of 5 or more.

For determination of the flux associated with the quasar, we have adopted the following procedure: emission models of the Crab and PKS 0528+134 have been generated by convolution of assumed (or known in case of Crab) source parameters with the COMPTEL response. These source models have been included into the null hypothesis of the likelihood fitting process so that their flux values are allowed to vary while their positions are kept fixed. This approach leads to a simultaneous determination of the Crab and PKS 0528+134 fluxes, together with the generation of an overall skymap with the two sources removed. We believe that this method should be best suited for this analysis. However, some systematic effects may still remain, and may possibly be larger at lower

<sup>1</sup>VP 0 was used for data analysis from April 28 to May 7, 1991 after COMPTEL had reached a stable observation configuration

<sup>2</sup>Target of Opportunity observation

energies, because the angular resolution is decreasing with energy (Schönfelder *et al.* 1993), resulting in a broadening of the Crab signal. An investigation of possible systematic effects is in progress.

In the present analysis only point spread functions assuming an  $E^{-2}$ -power law spectrum for PKS 0528+134 have been applied. Though this may not correspond to the true spectral slope of the quasar, the impact of this specific choice on our flux estimates is considered to be small.

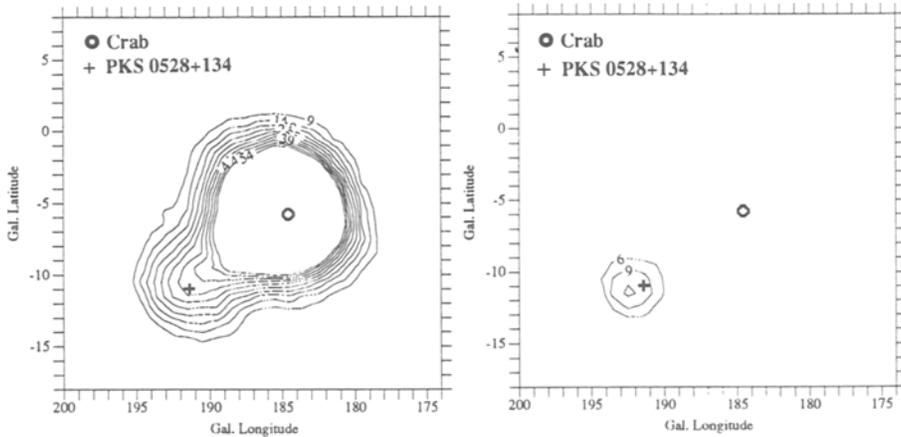


Fig. 1. Maximum-likelihood skymaps of the Crab region in the 10-30 MeV band from combined VP 0, 1, 213. Fig. 1a shows the Crab and the evidence for PKS 0528+134. Crab dominates the map. The likelihood ratio contours start at a value of 9 with a step of 5, and are cut off at a value of 54. Fig. 1b shows the likelihood map of the same region with the Crab removed (a model of the Crab was included in the null hypothesis of the likelihood fitting procedure). The remaining feature is evidence for PKS 0528+134.

## RESULTS

Four CGRO viewing periods have been analysed with respect to PKS 0528+134. Using a combination of data from VP 0, 1, and 213 (roughly 30 days of gross observation time), the quasar is detected by COMPTEL at energies above 10 MeV. Though masked by the nearby presence of the Crab, the 10-30 MeV skymap clearly reveals the source (Fig. 1). Applying the analysis method described above, a statistical detection significance of  $3.3\sigma$  is found. Below 10 MeV the combined skymaps yield no positive detection, though there is some evidence for emission in the 3-10 MeV band during two individual VP.

In individual VP the main signal is also seen at energies above 10 MeV (e.g. during VP 0 and VP 1 at about the  $2\sigma$  level each). Below 10 MeV the best evidence is found during VP 213 in the 3-10 MeV range. Figure 2 shows the 3-10 MeV skymap of VP 213 (Crab removed) giving evidence for PKS 0528+134 at a level of about  $2.1\sigma$ . For VP 221

only a "quick-look" analysis has been carried out to date. No evidence could be found for PKS 0528+134 in the different COMPTEL energy bands.

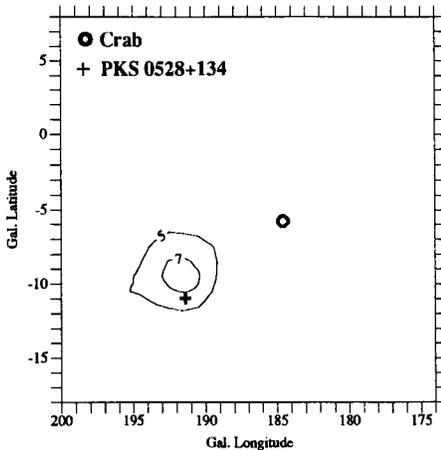


Fig. 2. 3-10 MeV likelihood map of the Crab region for VP 213. The Crab is removed. A  $2.1\sigma$  excess at the position of PKS 0528+134 is visible.

EGRET has detected this source during VP 0 and VP 1 (Kanbach et al. 1992). PKS 0528+134 was redetected by EGRET during VP 213 at a very high intensity level (Sreekumar et al. 1993). No evidence for PKS 0528+134 could be found by EGRET during VP 221 (Nolan et al. 1993).

The COMPTEL results for the individual VP follow the intensity behaviour of PKS 0528+134 as measured by EGRET. For the VP when the source is detected by EGRET (VP 0, VP 1, VP 213), there is also evidence in the COMPTEL data at a significance level of about  $2\sigma$  each. For VP 221 when PKS 0528+134 is not detected by EGRET; the COMPTEL data also do not show any hint for the source. So in general, COMPTEL measures the same intensity behaviour as EGRET, indicating a time-variable MeV-flux of the quasar.

During VP 213 EGRET detects the source at its highest intensity level ever measured in  $\gamma$ -rays. At energies above 100 MeV, PKS 0528+134 is as bright or even brighter than the Crab pulsar (Sreekumar et al. 1993). The COMPTEL flux results for VP 213 indicate that the quasar was also brightest in the COMPTEL energy during this viewing period. Unfortunately, this VP lasted only for 6 days resulting in enlarged statistical errors. It can be stated however, that in the COMPTEL energy range the source was weaker than the Crab pulsar. This fact indicates that during VP 213, PKS 0528+134 had either a different spectrum than the Crab pulsar and/or a spectral break above the COMPTEL energy range has occurred. In any case, a comparison of the EGRET and COMPTEL results of VP 213 will be very interesting.

Figure 3 shows the COMPTEL and EGRET spectra of VP 1. The EGRET spectrum is from Hunter et al. (1993). The COMPTEL results together with the EGRET spectrum indicate a spectral break in the upper part of the COMPTEL energy range, probably at energies between 10 MeV and 30 MeV. EGRET spectra for other VP are not publicly available at the present time.

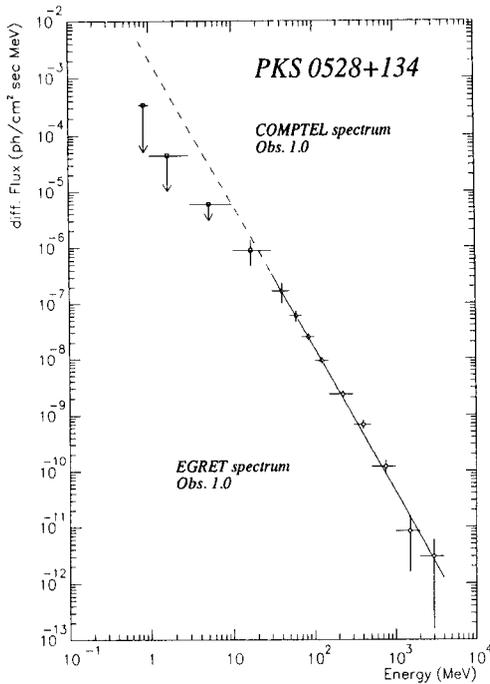


Fig. 3. Contemporaneous COMPTEL and EGRET energy spectra of PKS 0528+134 during VP 1. The COMPTEL upper limits are  $2\sigma$ . The EGRET spectrum is from Hunter et al. (1993). The dashed line represents the extrapolation of the EGRET spectrum throughout the COMPTEL energy range. The evidence for a spectral break is visible.

## SUMMARY

The COMPTEL data of four CGRO viewing periods containing PKS 0528+134 within  $20^\circ$  of the pointing direction have been analysed. The source was clearly detected with a significance of  $3.3\sigma$  at energies above 10 MeV combining data of three VP. Below 10 MeV evidence for the source could be found only in the 3-10 MeV band during VP 213 and VP 0 at a significance level of the order of  $2\sigma$  and  $1\sigma$ , respectively. In general, the long term intensity behaviour measured by COMPTEL follows the trend as seen by EGRET, thereby indicating a time-variable MeV-flux. Combining the EGRET and COMPTEL energy spectra for VP 1 (the only EGRET spectrum publicly available at the present time), a spectral break in the energy range between 10 MeV and 30 MeV is indicated.

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