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Abstract. Using the COMPTEL data of the first 5 years of the CGRO mission we have derived the average pulsed spectrum of the Crab Pulsar, as well as phase-resolved spectra of the pulsed emission of the Crab Pulsar. The spectra in the COMPTEL energy range (0.75 to 30 MeV) are compared to those in the neighbouring energy bands. The pulsed flux has been examined for its stability. Pulsed lightcurves have been derived for different energy intervals. Preliminary results of this analysis are presented.

INTRODUCTION

For our analysis of COMPTEL data we have selected all Crab viewing periods (VPs) out of the first 5 years of the CGRO operation, where the Crab Nebula was within 30° of the pointing direction. In total there are 19 viewing periods, namely: 0, 1, 31, 36, 36.5, 39, 213, 221, 310, 321.1 321.5, 337, 412, 413, 419.1, 419.5, 420, 426, 502. This adds up to a total exposure of the Crab Nebula of $1.09 \cdot 10^9$ s cm^2 in the 1-3 MeV energy band.

ANALYSIS

The timing analysis was performed with the pulsar analysis subsystem of the COMPTEL Processing and Analysis Software System (COMPASS) using contemporary Crab radio observations (Arzoumanian et al. 1992). Lightcurves
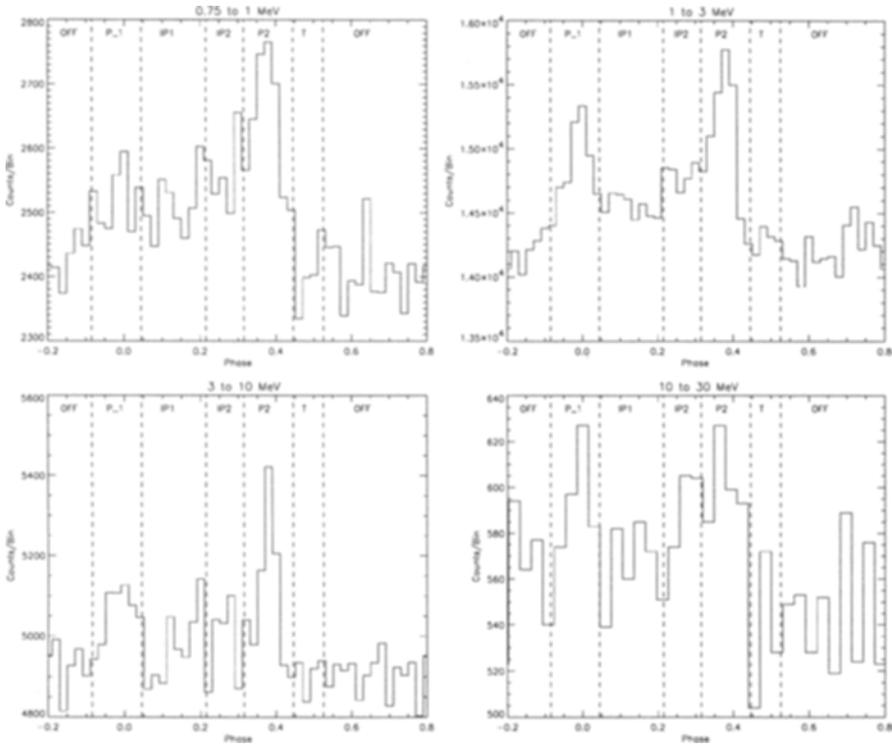
FIGURE 1. The Crab lightcurves of the combined observations for the four standard energy intervals.

were created for the combined observations by folding the photon arrival times with the pulsar period once they were transformed to the Solar System Barycentre.

We used a maximum likelihood ratio method to calculate the source flux with its associated statistical uncertainty (Bloemen *et al.* 1994). COMPTEL cannot resolve the Crab pulsar from the surrounding nebula. Therefore we used phase selection to disentangle the unpulsed and pulsed emission assuming that the unpulsed emission remains constant over the full pulsar period.

The pulsed emission Φ_{Δ_p} was determined by calculating the total (i.e. pulsed plus unpulsed) flux $(\Phi_{total})_{\Delta_p}$ in a pulsed phase interval Δ_p with subsequent subtraction of the unpulsed component $\Phi_{\Delta_{up}}$:

$$\Phi_{\Delta_p} = (\Phi_{total})_{\Delta_p} - \Phi_{\Delta_{up}} \cdot \frac{\Delta_p}{\Delta_{up}}$$

where Δ_p/Δ_{up} is the ratio of the width of the pulsed phase to the width of the unpulsed phase interval.

Phase-resolved photon spectra of the pulsed emission were calculated for the

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Phase	Phase Interval	I_0 $10^{-4} ph/cm^2/MeV$	α	χ^2 (5 dof)
P1	0.915-0.445	2.59±0.41	-2.22±0.18	7.2
IP1	0.045-0.215	1.89±0.45	-2.65±0.35	1.7
IP2	0.215-0.315	2.73±0.50	-2.63±0.35	3.1
P2	0.315-0.445	4.57±0.43	-2.31±0.13	3.8
tot. pulsed	0.445-0.525	2.52±0.28	-2.37±0.15	1.6

TABLE 1. Results of powerlaw fitting of the 5-year averaged spectra. All fluxes are instantaneous.

smaller phase intervals indicated in Fig. 1. The phase definitions used earlier by Nolan *et al.* (1993) and Much *et al.* (1995) were adopted.

LIGHTCURVES

Figure 1 shows the lightcurves we obtained for the combined observations in the four COMPTEL standard energy intervals (0.75 to 1 MeV, 1 to 3 MeV, 3 to 10 MeV and 10 MeV to 30 MeV). The lightcurves show two peaks with a phase separation of 0.4. Compared to energies above 50 MeV (Nolan *et al.*, 1993), there is relatively significant interpulse emission. The peak intensities change within the COMPTEL energy band relative to each other. Towards higher energies the intensity of the first peak increases relative to the second peak. This is to be expected considering the shape of the lightcurve measured above 30 MeV by EGRET, where the first peak dominates.

SPECTRAL ANALYSIS

All derived COMPTEL spectra (both total pulsed and phase-resolved), when fitted alone, can be described with a simple powerlaw, $I_0/1.65$ MeV$\cdot E^\alpha$. Our fit results are listed in Table 1.

Total Pulsed Spectrum

The total pulsed emission for the COMPTEL standard energy intervals was calculated for each VP. For the interval with the best statistics (1-3 MeV) the Crab pulsar's emission is shown as a funtion of time (TJD) in Fig. 2. The flux is compatible with a constant flux, except for the combination of VP 412+413, where we only received an upper limit. Further analysis of these VPs are required.

The spectrum of the total pulsed emission is shown in Fig. 3 as measured by

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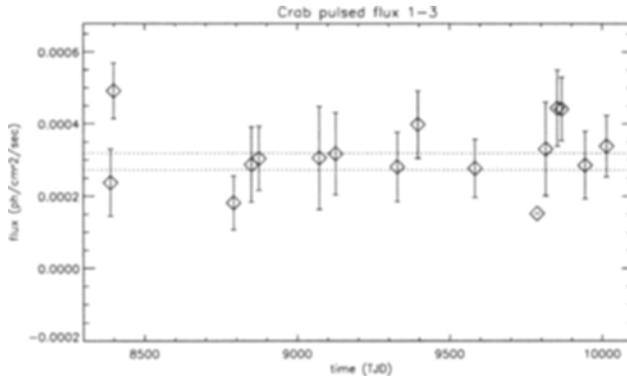
FIGURE 2. Instantaneous flux of the Crab pulsar in the 1-3 MeV energy band measured in the different VPs. The two horizontal lines indicate the $\pm\,1\sigma$ uncertainty of the average flux in the entire period. The data point without error-bar is an upper limit (sum of VPs 412+413).

OSSE, COMPTEL and EGRET. However the OSSE, EGRET and COMPTEL spectra are not contemporaneous. Nevertheless the total pulsed spectra as measured by OSSE, COMPTEL and EGRET connect smoothly.

Phase-Resolved Spectra

The phase-resolved spectra for the first peak (P1), first and second inter-pulse (IP1 and IP2) and for the second peak (P2) were calculated. We compared the COMPTEL spectrum with the EGRET spectra obtained by Nolan et al (1993). The data have to be interpreted carefully, as the EGRET data are not contemporaneous with the COMPTEL data. However the constancy of the COMPTEL total pulsed flux (Fig 2.) and the smooth connection of the total pulsed spectrum (Fig 3.) suggest that a comparison is valid.

Although our results are preliminary (e.g. the P1 spectrum requires further analysis), the following conclusions can already be drawn from the phase-resolved spectra.

- the COMPTEL P2 spectrum smoothly connects to EGRET

- the IP1 and IP2 spectra clearly require a change in slope between the COMPTEL and the EGRET data

SUMMARY

- In the COMPTEL energy range the ratio of the intensities of the two main peaks of the lightcurve changes, namely, with increasing energy the first peak becomes more dominant relative to the second peak.

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- The total pulsed emission can be described by a single powerlaw
- Combining the COMPTEL with the EGRET phase-resolved spectrum shows that
  - the phase-resolved spectrum of the second pulse connects smoothly to EGRET
  - the IP1 and IP2 spectra require a change in slope between the COMPTEL and the EGRET data

ACKNOWLEDGMENTS

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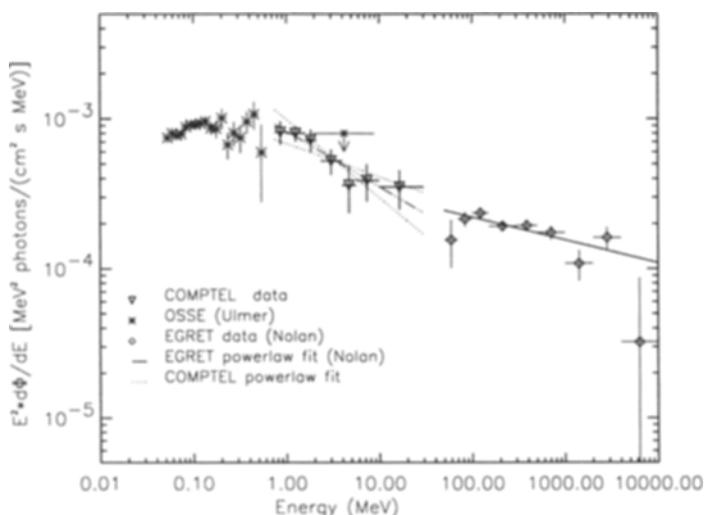
FIGURE 3. Instantaneous spectrum of the Crab total pulsed emission of the combined observations. The OSSE and EGRET spectra shown are not contemporaneous. Nevertheless the spectra of the three instruments connect smoothly.