DETECTION OF VHE GAMMA-RAYS FROM MRK 501 WITH THE CAT IMAGING TELESCOPE

A. Barrau, R. Bazer-Bachi, H. Cabot, L.M. Chounet, G. Debiais, B. Degrange, J.P. Dezalay, A. Djannati-Ataï, D. Dumora, P. Espigat, B. Fabré, P. Fleury, G. Fontaine, R. George, C. Ghesquière, P. Goret, C. Gouiffes, I.A. Grenier, L. Iacoucci, S. Le Bohec, I. Malet, C. Meynadier, F. Munz, T.A. Palfrey, E. Paré, Y. Pons, M. Punch, J. Québert, K. Ragan, C. Renault, M. Rivoal, L. Rob, P. Schovanek, D. Smith, J.P. Tavernet and J. Vrana

1 Centre d’Etudes Nucléaire de Bordeaux-Gradignan, France
2 Centre d’Etudes Spatiales des Rayonnements, Toulouse, France
3 Laboratoire de Physique Corpusculaire, Collège de France, Paris, France
4 Laboratoire de Physique Nucléaire de Haute Énergie, École Polytechnique, Palaiseau, France
5 Laboratoire de Physique Nucléaire de Haute Énergie, Universités de Paris VI et VII, France
6 Service d’Astrophysique, Centre d’Études de Saclay, France
7 Groupe de Physique Fondamentale, Université de Perpignan, France
8 Nuclear Center, Charles University, Prague, Czech Republic
9 Université Paris VII
10 Department of Physics, Purdue University, Lafayette, IN 47907, U.S.A
11 JLO Ac. Sci. & Palacky University, Olomouc, Czech Republic

*IN2P3/CNRS
‡INSU/CNRS
‡DAPNIA/CEA
†Deceased

ABSTRACT

The CAT imaging telescope on the site on the former solar plant Thémis has been observing γ-rays from Mrk501 above 220 GeV in March and April 1997. This source is shown to be highly variable and the light curve is presented. The detected γ-ray rate for the most intense flare is in excess of 10 per minute.

INTRODUCTION

The CAT imaging telescope was recently built on the site of the former solar plant “Thémis” (French Pyrénées). The detector has a trigger threshold for γ-rays of ~220 GeV near the zenith, with excellent source-location and energy-resolution capabilities. The detector has been operational since October, 1996. The active galactic nucleus (AGN) Markarian 501 was the second extragalactic source detected in the VHE domain, by the Whipple group (Quinn et al., 1996) with a flux level of a tenth that of the Crab. In 1996 observations, some flaring activity was noted (Weekes, 1997).

OBSERVATIONS

The CAT imaging Cherenkov telescope has observed Mrk 501 in March and April of 1997. The total observing time on-source is 50 h, with 18 h of data off-source, i.e. on a control region of the sky following the same trajectory as the source. Data were taken under clear-sky, moonless conditions. At the latitude of the Thémis site, Mrk501 passes close to the zenith, thus providing a low threshold for atmospheric Cherenkov detection.

DATA-ANALYSIS

The data were analysed using both the standard moment-based analysis and the model-based
maximum likelihood method developed by the CAT group (Le Bohec, 1996) which takes advantage of the fine resolution of the CAT imaging camera. The latter method has the advantage of providing the point of origin on the sky (in two dimensions) of each individual γ-ray, and gives an estimate of the γ energy.

RESULTS
For the two months of observation, a strong signal was seen from Markarian 501. For the moment-based analysis, Figure 1 shows the distribution of the orientation angle (α) for those events which pass the shape cuts, for all of the on-source observations at a zenith angle less than 30°. It can be seen that there is a strong signal at small α values, as expected for a point source, and that the control region shows no excess. The model-based maximum likelihood method also shows a strong signal, as shown in Figure 2; in this case α is defined as the angle at the image centre between the source position and the estimated point of origin of the γ-ray. In Figure 3, the 2-dimensional binned distribution of the estimated γ-ray origins for the on-source data minus the off-source data is plotted. The position of maximum emission is clearly seen to be at the position of Markarian 501. Given that this source is known to have flaring episodes, the night-to-night variation in the event rate was investigated, using a moment-based analysis. The cuts efficiency for gamma rays is of the order of 40%. Figure 4 shows the resulting nightly γ-ray rate, for events passing all cuts. The source is seen to exhibit rapid variations of an order of magnitude, in contrast to the Crab Nebula which was seen to be steady from October 1996 to January 1997. At the same site in April 1997, the Themistocle array (Djannati-Atai et al., 1995) has simultaneously observed flaring activity from Mrk 501 above about 1.5 TeV; we are currently analysing a sample of common events.

CONCLUSIONS
In spring of this year, Markarian 501 has exhibited intense and highly-variable flaring activity, becoming at times the brightest known source in the VHE γ-ray sky. We are now investigating the spectral shape of Markarian 501.

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Fig. 1: The $\alpha$-plot of Mrk501 using the moment-based analysis. The bin width is $3^\circ$ and the zenith angle for this data set is less than $30^\circ$.

Fig. 2: The $\alpha$-plot of Mrk501 using the model-based analysis of LeBohec (1996). The bin width is $3^\circ$ and the zenith angle for this data set is less than $30^\circ$. 
Fig. 3: The ON-OFF plot of Mrk501 in RA,DEC coordinates as obtained with the method of LeBohec (1996). The bin size is $0.1 \times 0.1 \, \text{deg}^2$. 
Fig. 4: The γ-ray rate from Mrk501 on a night to night basis after shape and orientation cuts. The horizontal line shows the average Crab rate.