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Long-term gamma-ray lightcurves and high state probabilities of Active Galactic Nuclei

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Abstract. Current neutrino detectors are approaching a sensitivity that allows one to detect Active Galactic Nuclei (AGN) in their high state. However, the expected signals might be too weak to result in a significant detection. One possibility to increase the detection chance is to focus the searches during states of high electromagnetic activity, especially in the very high energy (VHE) gamma-ray regime. In this context a good knowledge of the phenomenology of gamma-ray flux variability of the known VHE AGN is crucial. Here, we present our effort in archiving and combining VHE gamma-ray lightcurves and first results including a lightcurve of Mrk 421 spanning 15 years and the estimation of an average observed high state rate.

1. Introduction

Apart from a variety of studies using simultaneous data in different electromagnetic wavelength bands (multi-wavelength), efforts are also on-going in current neutrino detectors to combine neutrino observations with electromagnetic data (multi-messenger, see, e.g. [5, 14]). In this work, steps toward a collection of available VHE data on AGN, a general approach for lightcurve combination, and an estimation of average high state rates are presented in view of future and on-going multi-messenger studies with neutrino detectors.

2. Gamma-Ray Data Collection

A Large amount of observations of extragalactic objects were carried out by different VHE gamma-ray telescopes. We have started a collection and archivation of all available data. For the effective use of observations from different experiments, a common data format and methods for cross-normalization are necessary. The data archive, format definitions and first publications or notes can be found at http://www-zeuthen.desy.de/multi-messenger/GammaRayData/index.html. The data used in the present work were taken from [1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17]. One of the most studied objects in the VHE regime is Mrk 421. A combined long-term lightcurve for this object using data from several experiments is shown in Figure 1. This lightcurve spans 15 years and contains more than 1500 effective observation hours. This lightcurve is the biggest combined data set in the VHE regime up to now. The most prominent AGN in neutrino astronomy is 1ES 1959+650 because of the possible detection of an *orphan flare* by the Whipple collaboration [8]. A combined lightcurve from this object containing the data collected so far is shown in Figure 2. The distribution of the flux states of Mrk 421 is shown in Figure 3. The distribution essentially follows an exponential as expected from a stochastic outburst population.

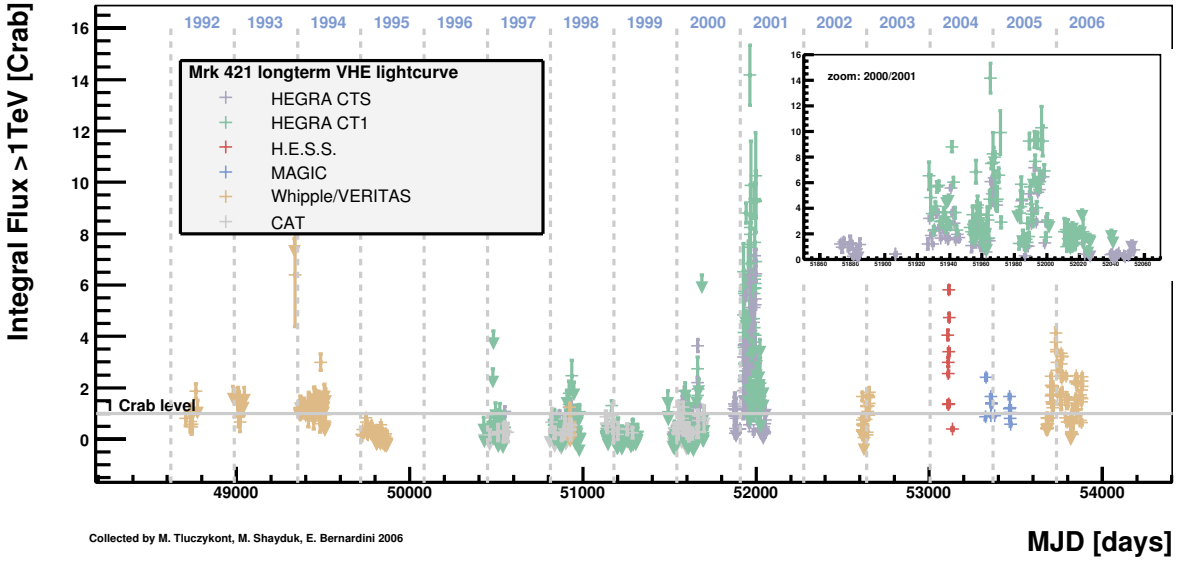

Figure 1. Long-term gamma-ray lightcurve (integral flux, E >1 TeV) of Mrk 421.

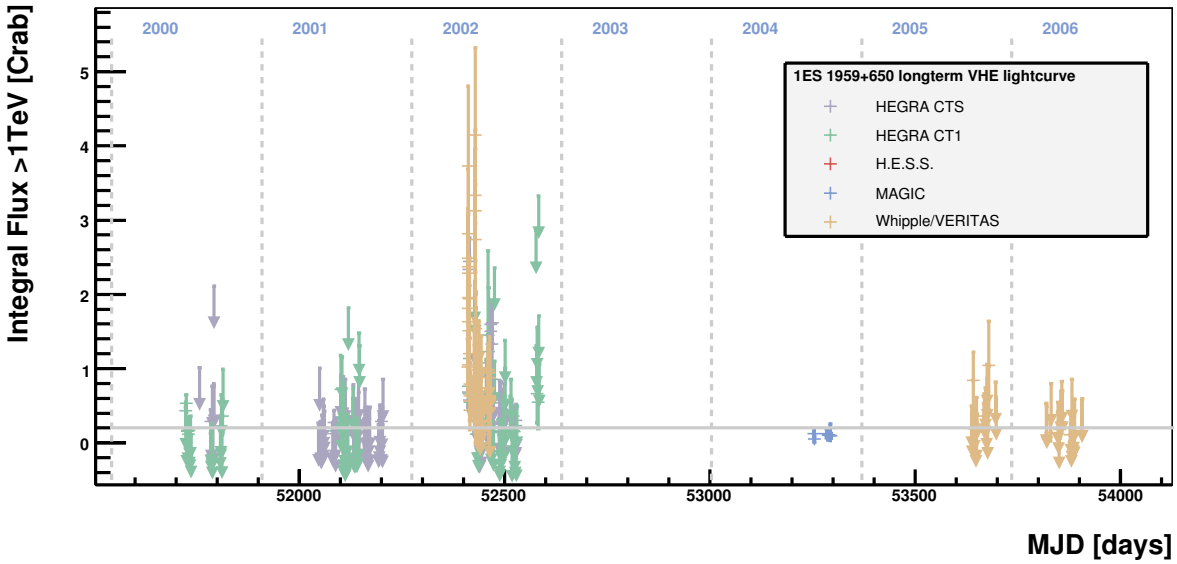

Figure 2. Long-term gamma-ray lightcurve (integral flux, E >1 TeV) of 1ES 1959+650.

A zoom on low flux states is shown in Figure 4. A baseline might be visible at a flux of 0.3 Crab. However, at low fluxes sensitivity thresholds of the detectors can easily lead to biases.

3. Results

An average observed high state rate R_{HS} for a given flux threshold F_{thr} can be derived from the ratio of high state occupancy ($F > F_{thr}$) to the total observation time. This observed average high state rate is shown for Mrk 421 in Figure 5. R_{HS} can also be derived from the slope of the flux state distribution (Figure 3). This is work in progress and first estimates of R_{HS} using this

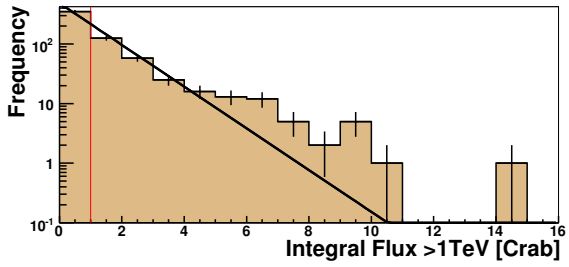

Figure 3. Distribution of observed flux levels of Mrk421. The fit of an exponential shows that the distribution is essentially of stochastic nature. However, the observations are biased towards high flux states because of external and self triggering on high states. Most high states above 4 Crab occurred during the 2000/2001 season.

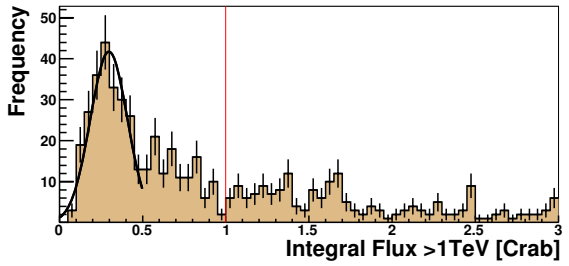

Figure 4. Distribution of low flux levels of Mrk421 (upper limits excluded) fitted by a Gaussian with a mean at 0.3 Crab that might be interpreted as a baseline flux. However, at low fluxes the data is limited by the sensitivity of the detectors. The vertical line indicates the 1 Crab flux value.

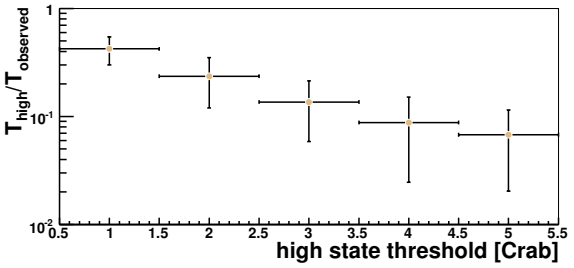

Figure 5. Observed average high state rate R_{HS} as a function of flux thresholds F_{thr}. R_{HS} was derived from the ratio of high state time to total observation time. One has to note that R_{HS} is an average observed quantity.

method are available at the web page mentioned in Section 2.

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