Proceedings of the 30th International Cosmic Ray Conference
Rogelio Caballero, Juan Carlos D'Olivo, Gustavo Medina-Tanco,
Lukas Nellen, Federico A. Sánchez, José F. Valdés-Galicia (eds.)
Universidad Nacional Autónoma de México,
Mexico City, Mexico, 2008
Vol. 3 (OG part 2), pages 1025–1028

30TH INTERNATIONAL COSMIC RAY CONFERENCE

Long term monitoring of bright TeV Blazars with the MAGIC telescope

F. GOEBEL[1], M. BACKES[2], T. BRETZ[3], M. HAYASHIDA[1], C. HSU[1], K. MANNHEIM[3], A. MORALEJO[4], W. RHODE[2], K. SATALECKA[4], M. SHAYDUK[1,5], M. TESHIMA[1], R. WAGNER[1]
FOR THE MAGIC COLLABORATION
[1]*Max-Planck-Institut für Physik, Munich, Germany*
[2]*Universität Dortmund, Germany*
[3]*Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Germany*
[4]*Institut de Fisica d'Altes Energies (IFAE), Barcelona, Spain*
[5]*DESY, Zeuthen, Germany*
[6]*Humboldt Universität zu Berlin, Germany*
fgoebel@mppmu.mpg.de

Abstract: The MAGIC telescope has performed long term monitoring observations of the bright TeV Blazars Mrk421, Mrk501 and 1ES1959+650. Up to 40 observations, 30 to 60 minutes each have been performed for each source evenly distributed over the observable period of the year. The sensitivity of MAGIC is sufficient to establish a flux level of 25% of the Crab flux for each measurement. These observations are well suited to trigger multiwavelength ToO observations and the overall collected data allow an unbiased study of the flaring statistics of the observed AGNs.

Introduction

The extra-galactic GeV/TeV γ-ray sources Mrk421, Mrk501 and 1ES1959+650 are blazars, i.e. Active Galactic Nuclei (AGNs) containing jets (plasma outflows moving at relativistic velocities) pointing towards the Earth. They belong to the subclass of High frequency-peaked BL Lac (HBL) objects. These blazars exhibit no emission lines but a continuous Spectral Energy Distribution (SED) with a peak in the UV to soft X-ray band and a second peak in the GeV-TeV range. These objects show prominent time variabilities on various time scales at all frequencies. In the Very High Energy (VHE: 100 GeV - 100 TeV) range variations larger than one order of magnitude and flux doubling times of less than 10 minutes have been observed.

Synchrotron-Self Compton (SSC) models, which attribute the low energy peak to Synchrotron radiation of relativistic electrons and the high energy peak to inverse Compton radiation of the same electron population, have been successfully used to describe most of the existing multiwavelength data. However, the existing data are not sufficient to distinguish between different models describing the emission processes and the formation and structure of the jets. In particular models in which hadronic acceleration plays a decisive role are an attractive alternative. These models predict emission of high energy neutrinos and may be more suitable than simple SSC models to explain the observed orphan TeV flares of 1ES1959+650.

The sources Mrk421 (z=0.030), Mrk501 (z=0.034) and 1ES1959+650 (z=0.047) are bright and close blazars and therefore well suited to study the intrinsic properties of these objects.

AGN monitoring

Monitoring the variable flux states of AGNs in VHE γ-rays using Imaging Atmospheric Cherenkov Telescopes (IACTs) is in many ways a valuable tool to study the jet physics of AGNs. The measurement of the long term flux variability of blazars is interesting in its own right and can provide input to constrain theoretical models. The determination of flaring state probabilities is also essential to estimate the statistical significance of possible correlations between flaring states and other observables such as neutrino events [1, 2]. The selected AGNs are in the FoV and some of the prime targets of the neutrino observatory Amanda/IceCube which is observing the northern hemisphere with a yearly improving sensitivity.

In order to obtain an unbiased distribution of the flux level states it is important to schedule the monitoring observations used for these studies independently of any a priori knowledge of the flux state. In particular observations triggered by observed high flux states in the X-ray or γ-ray band should not be used for such studies.

Very importantly, AGN monitoring also allows one to trigger Target of Opportunity (ToO) observations which require a high flux level in the VHE range. Observations during high flux states are particularly interesting since on the one hand these correspond to the most violent states of the AGNs and on the other hand the high flux levels allow very precise and high statistics observations. The ToO observations may be performed by the same IACT issuing the ToO trigger but may also include other IACTs in order to increase the time coverage of the observations. The ToO may also include multiwavelength observations e.g. together with X-ray satellites.

The usual procedure to trigger AGN flare ToOs relies on X-ray monitoring. This procedure has a few disadvantages, besides obvious technical advantages. Although a general correlation between X-ray and γ-ray flares cannot be denied, a strategy which only relies on X-ray triggers is biased and will never detect the very interesting orphan flares, which are characterized by high γ-ray states without a simultaneous high state in X-rays.

Finally, the combined data obtained during unbiased monitoring observations can be used to perform detailed AGN studies which require high statistics at various flux levels. In particular VHE observations of AGNs during low flux states are still rare.

AGN monitoring strategies

VHE γ-ray astronomy is currently a very dynamic field with many new detections of exciting galactic and extra-galactic objects every year. The observation time of IACTs is thus very precious and can only to a small extent be devoted to AGN monitoring programs. Previous generation IACT which are still operational have therefore been used to continuously monitor known AGNs [3] and dedicated, small inexpensive IACT are under discussion.

Here we present a monitoring program using the MAGIC telescope, a high sensitivity latest generation IACT. Short observations are scheduled evenly distributed over the observable period of the year. Each of these sampling observations should be long enough to detect a given minimum flux level, taking into account the sensitivity of the telescope. Typically, 20 to 60 min observations are sufficient to detect moderate flaring states of nearby TeV blazars. These observation times are short enough to keep the impact on the overall observation schedule low. In the case of MAGIC, observations can be scheduled during partial moon or modest twilight. This further decreases the impact on high priority, deep observations, while the sensitivity under these observational conditions is only slight reduced [4] for the purposes of the monitoring program.

Continuous observation programs with moderate sensitivity IACTs are only sensitive to variations of the flux level averaged over longer observation times. On the other hand short sampling observations with high sensitivity IACTs are sensitive to considerably shorter flares but the duty cycle is much lower.

AGN monitoring program using the MAGIC telescope

MAGIC [5] is currently the largest single dish Imaging Atmospheric Cherenkov telescope (IACT) for high energy γ-ray astronomy with the lowest energy threshold among existing IACTs. It is installed at the Roque de los Muchachos on the Canary Island La Palma at 2200 m altitude and has been in scientific operation since summer 2004. The 17 m diameter parabolic shaped mir-

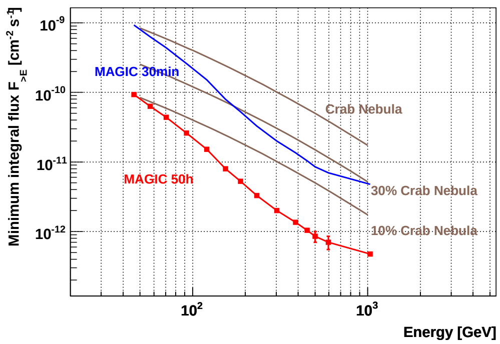

Figure 1: Sensitivity of MAGIC for 50 h and 30 min observations

ror preserves the time structure of the Cherenkov light signals. The camera is equipped with 576 photo-multiplier tubes (PMTs). The analog signals are transfered via optical fibers to the trigger and FADC electronics. The energy threshold of MAGIC is $\sim$60 GeV. A source emitting γ-rays at a flux level of 2.5% of the Crab Nebula can be detected with 5 sigma significance within 50 h observation time. The sensitivity is sufficient to establish a flux level of 25% of the Crab flux above 300 GeV for a 20 min observation. A quick online analysis estimates the flux level of each source during data taking. The sensitivity of the online analysis allows to detect a flux of 30% of the Crab flux within 30 min (see Figure 1).

The bright TeV blazars Mrk421, Mrk501 and 1ES1959+650 haven been selected for a long term monitoring program with the MAGIC telescope using the above mentioned sampling strategy. Up to 40 short observations, evenly distributed over the respective observable time during the MAGIC Cycle II observation period, have been scheduled of each of these sources. For the brighter sources Mrk421 and Mrk501 30 min have been scheduled for each observation while for the less bright blazar 1ES1959+650 60 min have been scheduled. The observation times are enough to establish a flare using the online analysis and can be used to trigger ToO observations.

First results

Preliminary results of the blazar monitoring data recorded between April 2006 and January 2007 are displayed in Figures 2, 3 and 4. The plots show the light curves of the Mrk421, Mrk501 and 1ES1959 during the period observed with the monitoring program. The data have been processed with the standard MAGIC analysis tools. Some observation days have been removed due to poor observation conditions. On the other hand data taken during multiwavelength observations [6] have been included in the plots as green points. These observations had been scheduled in advance and can therefore also be considered as unbiased measurements. Due to longer observation times the errors on the flux level are however much smaller. The background rate for each night are shown in the lower plots. A flaring state may be defined as 2 times the Crab flux in the case of Mrk421 and Mrk501 and 0.5 times the Crab flux in case of 1ES1959 as indicated in the plots. According to this definition Mrk 421 was observed in flaring state during the commissioning phase of monitoring program in April/May 2006. A statistical analysis of the flux level based on the above data is ongoing.

Acknowledgments

We would like to thank the IAC for excellent working conditions. The support of the German BMBF and MPG, the Italian INFN and the Spanish CICYT, the Swiss ETH and the Polish MNiI is gratefully acknowledged.

References

[1] Bernardini, E., et al., internal Amanda/ICECube proposal

[2] Leier, D., Becker, J., Groß, A., Rhode, W., internal Amanda/IceCube report

[3] Horan, D., 2007 AAS/AAPT Joint Meeting 209, #109.09

[4] Albert, J., astro-ph/0702475v1, Submitted to Astroparticle Physics

[5] E. Lorenz, *New Astron. Rev.* **48** (2004) 339;

[6] Hayashida, M., this proceedings

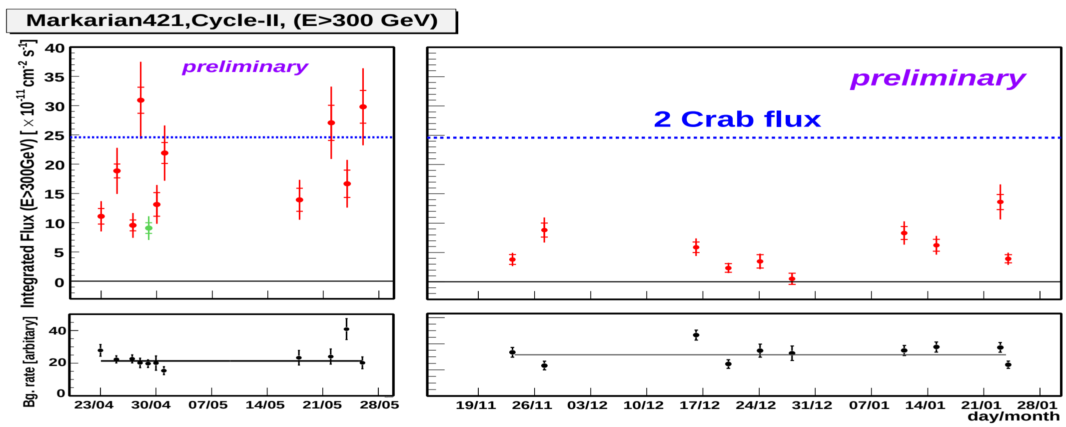

Figure 2: Light curves of Mrk421 observed between April 2006 and January 2007

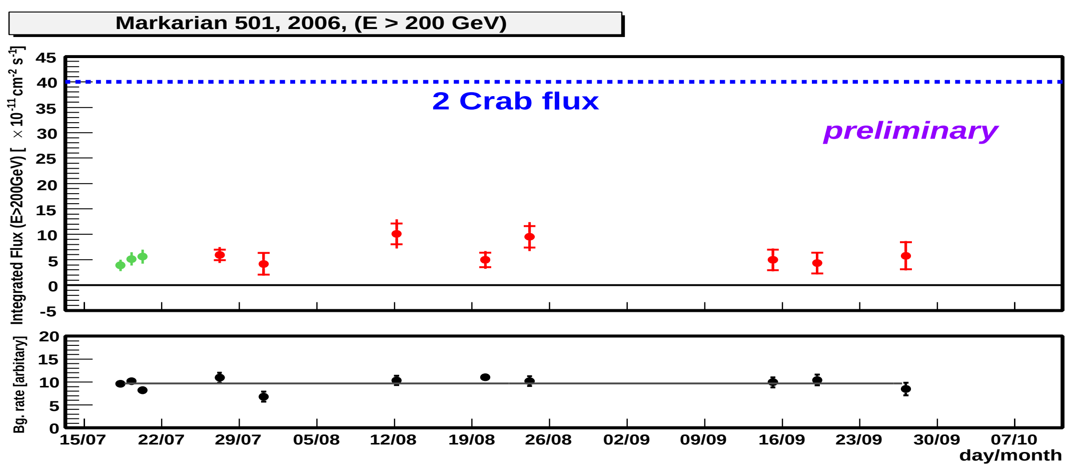

Figure 3: Light curves of Mrk501 observed between July and October 2006

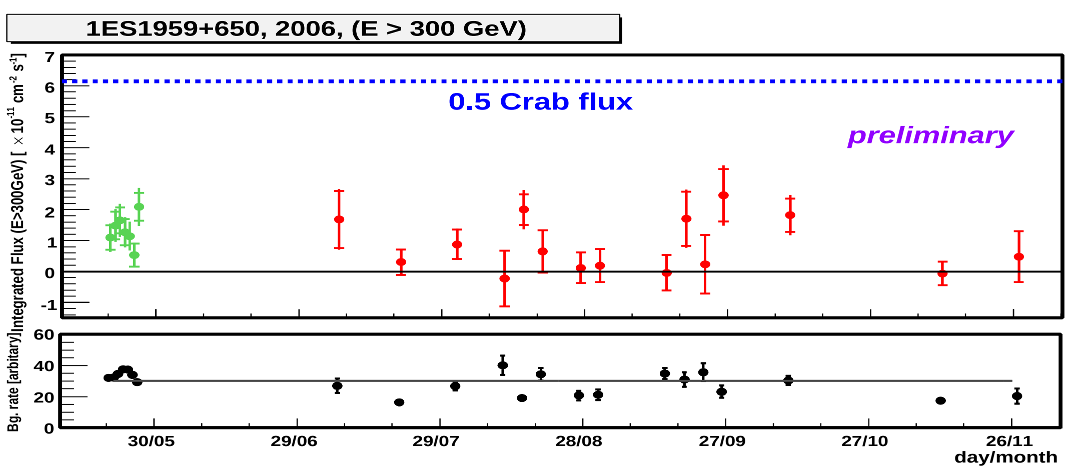

Figure 4: Preliminary light curves of 1ES1959 observed between May and November 2006