30TH INTERNATIONAL COSMIC RAY CONFERENCE

ICRC 2007 Proceedings - Pre-Conference Edition

Successful ToO triggers on the extragalactic sources with the MAGIC telescope

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Abstract: The MAGIC collaboration has been performing Target of Opportunity (ToO) observations whenever alerted that known or potential very high energy gamma-ray emitting extragalactic sources were in a high flux state in the optical, X-ray band or/and in the TeV energy range. Here we report on MAGIC triggered observations, results of the analysis, and possible optical-TeV correlation seen in the data. Among other sources, detections as well as spectral and temporal characterestics of Mkn 180 and PKS 2155-304 will be reported.

Introduction

The search for very high energy (VHE, defined as E $>$ 100 GeV) γ-ray emission from Active Galactic Nuclei (AGN) is one of the major goals for ground-based γ-ray astronomy. New detections open the possibility of a phenomenological study of the physics inside the relativistic jets in AGN, in particular to understand both the origin of the VHE γ-rays as well as the correlations between photons of different energy ranges (from radio to VHE). The number of reported VHE γ-ray emitting AGN has been slowly increasing and is currently 17 (May 2007). Eight of them have been seen by MAGIC: Mkn 421 [5], Mkn 501 [8], Mkn 180 [2], 1ES1959+650 [3], 1ES2344+514 [4], 1ES1218+304 [1], and PG1553+113 [6], and BL Lac [7].

The known VHE γ-ray emitting AGN are variable in flux in all wavebands. Correlations between X-ray-γ-ray emission have been found (e.g. [13]) although the relationship has proven to be rather complicated with γ-ray flares being also detected in the absence of X-ray [16] and vice versa [17]. The optical-TeV correlation has yet to be studied, but the optical-GeV correlations seen in 3C 279 [14] suggest that at least in some sources such correlations exist. Using this as a guideline, the MAGIC collaboration has been performing Target of Opportunity (ToO) observations whenever being alerted that sources were in high flux state in the optical and/or X-ray band.

In this paper we present the first detection of VHE γ-ray emission fromMarkarian 180 (Mkn 180) and results on PKS 2155-304.

Markarian 180

The AGN Mkn 180 (1ES 1133+704) is a well-known high frequency peaked BL Lac (HBL) at a redshift of z = 0.045 [10]. The spectral energy distribution (SED) of HBLs exhibits a generic two-bump structure: one peak with a maximum in the X-ray band and the other peak located in the GeVTeV band. The radiation is produced in a highly beamed plasma jet, which is almost aligned with the observer's line of sight. A double peaked SED is normally attributed to a population of relativistic electrons, where one peak is due to synchrotron emission in the magnetic field of the jet, and the second peak is caused by inverse Compton (IC) scattering of low energy photons by the same parent relativistic electron population.

The observation of Mkn 180 was triggered by a brightening of the source in the optical on 2006 March 23. The alert was given as the core flux increased by 50% from its quiescent level value as

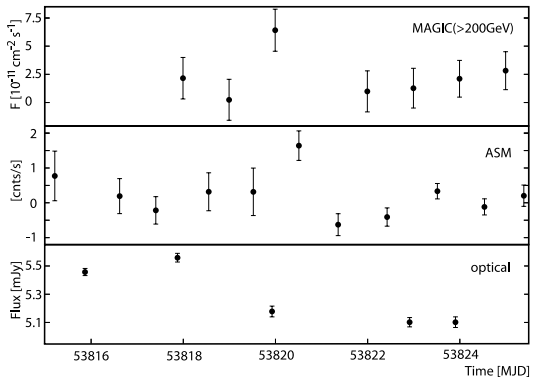

Figure 1: Lightcurve of Mkn 180 for MJD=53815-53825 (March 21 to March 31). Upper panel: VHE γ-rays measured by MAGIC above 200 GeV. Middle panel: ASM count rate. Lower panel: optical flux measured by KVA.

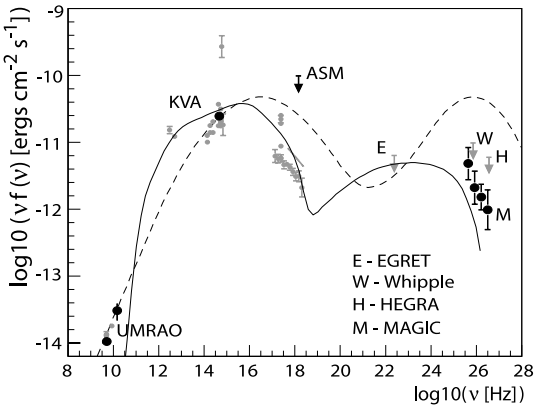

Figure 2: The Spectral Energy Distribution of Mkn 180. Simultaneous data (UMRAO, KVA, ASM, and MAGIC) are noted in black. Grey points represent historical data. The arrows denote the upper limits fromASM, EGRET, Whipple, and HEGRA. The solid line is from [9] and the dashed line is from [12].

determined from over three years of data recording. The simultaneous MAGIC, ASM[1] and KVA[2] lightcurve is shown in Fig 1. Around this time Mkn 180 was also observed as part of the AGN monitoring program by the University of Michigan Radio Observatory (UMRAO). The 4.8 GHz flux density was 0.21±0.02 Jy and the 14.5 GHz flux density was 0.22±0.06 Jy from 2006 Jan 1. - Apr. 13. No evidence for flaring was found between January and April 2006.

Mkn 180 was observed by MAGIC in 2006 during 8 nights (from March 23 to 31), for a total of 12.4 hours, at zenith angles ranging from 39° to 44°. After the standard analysis, a clear excess corresponding to a 5.5 σ was determined. No evidence for flux variability was found. The fit to the nightly integrated flux is consistent with a constant emission (χ^2 = 7.1, 6 degrees of freedom). Fig. 1 shows the VHE lightcurve together with the ASM daily averages and the R-band by KVA flux data. The X-ray flux of the source is generally below the ASM sensitivity, but on March 25 a 3 σ excess was observed, which suggests that the source was also active in X-rays. The optical flux reached its maximum in the night MAGIC started the observations (March 23) and began to decrease afterwards. The measured energy spectrum of Mkn 180 can be well described by a power law:

$$\frac{\mathrm{d}N}{\mathrm{d}E} = (4.5 \pm 1.8) \times 10^{-11} \times \left(\frac{E}{0.3\,\mathrm{TeV}}\right)^{-3.3\pm0.7} \frac{1}{\mathrm{TeV\,cm^2\,s}}$$

The observed integral flux above 200 GeV is $F(E > 200\ \mathrm{GeV}) = (2.25 \pm 0.69) \times 10^{-11}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, which corresponds to $1.27 \times 10^{-11}\,\mathrm{ergs\,cm}^{-2}\mathrm{s}^{-1}$ resp. 11% of the Crab Nebula flux measured by MAGIC.

PKS 2155-304

PKS 2155-304 is a well-known HBL object, located in the Southern hemisphere at a redshift of z = 0.117 [11]. MAGIC observations were triggered by the Astronomer's Telegram 867 [9] reporting historically high fluxes of VHE γ-rays from PKS 2155-304. The VHE activity was supported by an optical brightening of the source and an increased X-ray activity.

1. All-Sky-Monitor on-board the RXTE satellite, see http://heasarc.gsfc.nasa.gov/xte_weather/
2. See http://tur3.tur.iac.es/

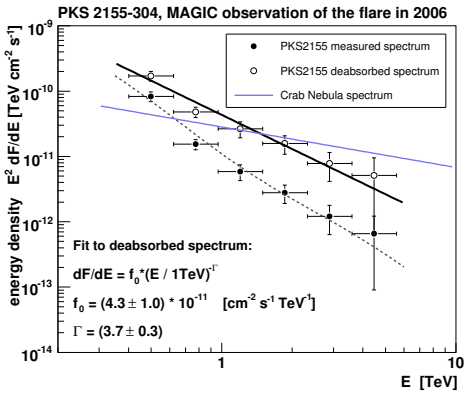

Figure 3: Averaged energy spectrum of PKS 2155-304 for MJD=53944-53949 (2006 July 28 to August 2). The Crab Nebula spectrum is shown for comparison.

MAGIC observed PKS 2155-304 for 6 nights in July August 2006 at high zenith angles ranging from 58° to 68°. A clear signal corresponding to 11 σ excess was determined. Due to the high zenith of observation, the energy threshold is higher. The analysis energy threshold for this data set is at about 600 GeV. An averaged energy spectrum of PKS 2155-304 is shown in Figure 3. Themeasured spectrum is consistent with a power law with a soft slope of $\Gamma = 4.0$, whereas the deabsorbed energy spectrum [15] has a slope of $\Gamma = 3.7 \pm 0.3$. The soft slope confirms findings by H.E.S.S. (private communication) and points to a IC peak position below 200 GeV. No significant flux variations were found in 30 min time bins along the 6 nights of observations with MAGIC.

Conclusions

The discovery of VHE γ-ray emission from Mkn 180 was triggered by an optical flare, but no significant variations in the VHE regime were found. The short observation period and the small signal do not allow to carry out detailed studies. It is therefore not possible to judge whether the detected VHE flux level represents a flaring or a quiescent state of the AGN.

The rather steep slope of the VHE spectrum of Mkn 180 suggests an IC peak position well below 200 GeV, while the non-detection by EGRET gives a lower limit of $\sim$ 1 GeV for the peak position [**?**]. This is in agreement with the SSC model of [**?**] suggesting the IC peak position at around 10 GeV. The overall IC luminosity, however, is underestimated in this model: the observed integral flux above 300 GeV is a factor 30 larger than predicted. An explanation for this discrepancy could be the models underlying assumption of a quiescent state synchrotron spectrum to obtain the IC flux. This could indeed suggest that our measurement was made during a high state.

The detection of PKS 2155-304 with the MAGIC telescope proved the capability of the instrument to observe distant extragalactic γ-ray sources under large zenith angle if the sources are in a flaring flux state. Especially for multiwavelength campaigns, MAGIC observations are crucial in order to obtain independent energy spectra and light curves measurements at VHE.

The discovery of VHE emission from Mkn 180 during an optical outburst as well as an optical activity during the PKS 2155-304 VHE outburst make it very tempting to speculate about the connection between the two energy bands. Since Mkn 180 has not been observed prior to the outburst with MAGIC and the upper limits from other experiments are above the observed flux level, further observations are needed.

Acknowledgements

We would like to thank the IAC for the excellent working conditions at the ORM in La Palma. The support of the German BMBF and MPG, the Italian INFN, the Spanish CICYT, the ETH Research Grant TH 34/04 3 and the Polish MNiI Grant 1P03D01028 is gratefully acknowledged. We also thank H. D. and M. F. Aller, Univ. of Michigan Radio Observatory, for providing the UMRAO data.

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