Blazar Observations in the TeV energy range with the MAGIC Telescope

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The study of very high energy (VHE, $E \geq 100$ GeV) $\gamma$-ray emission from active galactic nuclei (AGN) is one of the major goals of ground-based $\gamma$-ray astronomy. The sensitivity of the current imaging air Cerenkov telescopes (IACT) enables phenomenological studies of the physics inside the relativistic jets in blazars, and in particular advances in understanding both the origin of the VHE $\gamma$-rays as well as the relations between photons of different energies (from radio to VHE).

Except for the radio galaxy M87, all 18 currently known VHE gamma-ray emitting AGNs are blazars, which are characterized by a close orientation of the jets with the line of sight, a highly variable electromagnetic emission on all energy scales from radio to $\gamma$-rays, and spectra dominated by non-thermal emission that consists of two distinct broad components. While the low energy bump, located at optical to X-ray energies, is unisonously explained by synchrotron emission of electrons, the origin of the high-energy part of the spectrum is still debated. Leptonic models ascribe it to inverse Compton processes that either up-scatter synchrotron photons, or to external photons that originate from the accretion disk, from nearby massive stars, or are reflected into the jet by surrounding material. In hadronic models, interactions of a highly relativistic jet outflow with ambient matter, proton-induced cascades, or synchrotron radiation off protons, are responsible for the high energy photons.

The 17 m diameter MAGIC telescope, Located on the Canary Island of La Palma (2200 m a.s.l.), is a unique instrument for the study of very high energy $\gamma$-rays. Its energy range spans from 60 GeV (trigger threshold at small zenith angles) up to tens of TeV. MAGIC has a sensitivity of $\sim 2\%$ of the Crab Nebula flux in 50 observation hours. Observations during moderate moonshine enable a substantially extended duty cycle, which is particularly important for blazar observations. Parallel optical observations are performed with the KVA 35 cm telescope. In this contribution highlights from recent blazar observations are presented.

MAGIC observed the blazar Mkn 501 for 24 nights during six weeks in summer 2005. About 18 hours out of the total 30 observation hours were performed in the presence of (moderate) moonshine. During most of the observations the source was in a rather low flux state, corresponding to $30\%$ of the Crab nebula flux at $E \geq 200$ GeV. In two nights (one with moon present), however, Mkn 501 was reaching up to four times the Crab nebula flux. For the flare nights, a clear peak in the spectrum is seen, which in leptonic models it can be identified with the “Inverse Compton peak”, now for the first time is seen unambiguously in VHE range for blazars. A closer look at the two flare nights reveals rapid flux changes with doubling times as short as 3 minutes or less.

In fall 2005, MAGIC saw a clear $1\sigma$ excess from the direction of IES 2344+514. The measured flux corresponds to $10\%$ of the Crab nebula flux ($E > 200$ GeV). For the first time a diurnal measurement of the emission of this blazar was possible, yielding no strong evidence for significant variability on timescales of days and thus giving first insights to the day-scale properties of a low blazar emission state.

BL Lacertæ ($z = 0.069$) is the historical prototype of the BL Lac class of AGNs. Unlike for the up to recently known “VHE blazars” with their synchrotron peaks in the X-ray domain, the peak of its synchrotron emission is located in the sub-millimeter to optical band. 22.2 hours of MAGIC observations of BL Lacertæ from August to December 2005 resulted in a $5.1\sigma$ VHE $\gamma$-ray signal. Above 200 GeV, an integral flux of $(0.6 \pm 0.2) \times 10^{-11} \text{ cm}^{-2} \text{s}^{-1}$ was measured, corresponding to approximately $3\%$ of the Crab nebula flux. No significant evidence of flux variability was found. The differential spectrum between 150 and 900 GeV was found to be rather steep, with a photon index of $\alpha = -3.6 \pm 0.5$.

MAGIC 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.

After entering a high optical flux state Mkn 180 was observed by MAGIC in 2006 during 8 nights in 2006 March for a total of 12.4 hours, resulting in a clear excess corresponding to $5.5 \sigma$, was determined. The fit to the nightly integrated flux is consistent with a constant emission ($\chi^2_\nu = 7.1/6$). A differential energy spectrum for the source could be deduced, following a pure power law with a spectral index of $\alpha = -3.3 \pm 0.7$.

Regular monitoring of the blazar 1ES 1011+496 showed on 2007 March 12 the highest optical state ever observed during the monitoring. VHE observations, triggered by the optical flare, were conducted for a total of 26.9 hours and yielded a $\gamma$-ray signal on the $6.21 \sigma$ significance level. Within statistical errors, a 14-day light curve consistent with a constant emission of $F(E > 200\text{GeV}) = (1.58 \pm 0.32) \cdot 10^{-11} \text{ cm}^{-2} \text{s}^{-1}$ was found, and a differential energy spectrum described by a pure power law with $\alpha = -4.0 \pm 0.5$ was found. The redshift of 1ES 1011+496 was determined to be $z = 0.212 \pm 0.002$, which makes this blazar the most distant extragalactic source currently detected to emit VHE $\gamma$-rays.