ABSTRACT

This thesis is dedicated to the young field of extragalactic **V**ery **H**igh **E**nergy (VHE) γ-ray astrophysics. In particular, to extragalactic sources like the **A**ctive **G**alactic **N**ucleus (AGN), one of the most powerful sources of energy known so far in the Universe, which are studied in detail in the energy range from 70 GeV to 10 TeV with the **M**ajor **A**tmospheric **G**amma **I**maging **C**herenkov (MAGIC) telescopes. This type of extragalactic sources contain a **S**uper **M**assive **B**lack **H**ole (SMBH) inside of the mass of $(10^6 - 10^{10})M_\odot$. It is believed that a SMBH converts the potential energy of matter in an accretion process to radiation and collimated jets with an particle outflow. As of now, there exist various subclasses of AGNs. The most numerous detected subclass, where the objects present one jet oriented at small angles with respect to the line of sight of an observer, is known as a blazar. Until today, most of the blazars in the VHE regime have been discovered within the last ten years of ground based telescopes using the **I**maging **A**ir **C**herenkov **T**echnique (IACT). The three major IACT experiments are MAGIC, **H**igh **E**nergy **S**tereoscopic **S**ystem (H.E.S.S.) and **V**ery **E**nergetic **R**adiation **I**maging **T**elescope **A**rray **S**ystem (VERITAS). The numerous discoveries of AGNs among others have been possible thanks to permanent improvements in sensitivity and the extension of the energy range of these instruments.

This thesis is focused on a study of blazars and their redshift dependent properties, starting from the very first discovery of these sources in the TeV range. In particular, the research study presented in this work can be divided into an experimental/analytical and a phenomenological part, the former conducted as a member of the MAGIC Collaboration. The first part of this work is dedicated to a long-term study of the blazar 1ES 1959+650 during a seven year survey of the MAGIC observation. Furthermore, new blazar discoveries and detections of 1ES 0033+595, B3 0133+388 and PKS 1717+177 in the VHE γ-ray range are presented. In the second part of the thesis the results of the phenomenological work are reported, where a population study for all (since today) known blazars (with well known spectral parameters) is performed with a special focus on the evolution of the Universe.

1ES 1959+650 one of the closest ($z = 0.48$) known VHE γ-ray emitting blazars was observed regularly with the MAGIC telescopes from 2005 to 2012. In this

long-term study, the data collected from 2009 to 2012 is combined with previous observations (from 2005 to 2008). This very extended survey makes 1ES 1959+650 one of the longest and unique studied blazar at energies above 300 GeV. A conclusion of this long-term study is that the overall flux above 300 GeV from 2005 to 2012 shows only a modest variability on yearly timescale within a factor 3 corresponding to a variation between 4% to 12% of the Crab Nebula flux. Only one distinct "flare" (strong flux enhancement) on May 30th 2009 has been detected during the long-term study. The integral flux of this flare corresponds to ~70% of the Crab Nebula flux. Interestingly evidence for a correlation with a delay of 1-2 days (where γ-radiation appear to lead radio) between the flux levels in simultaneously taken radio and VHE γ-ray data during the flare has been found. This result strongly indicates that the nearly coincident flux enhancement in both wavelengths have a common emission region which is undoubtedly produced in the jet region and not in the **B**road **L**ine **R**egion (BLR).

In the case of the uncertain distance (HBL) object 1ES 0033+595 the discovery at VHE γ-ray (E>100 GeV) is reported. 1ES 0033+595 was detected at clear significance level of 5.5 σ. The temporal study yields a low flux level of (2.2±0.4)% of the Crab Nebula flux above 150 GeV with no significant variability. Since the redshift of this source is uncertain, a new value of $z = 0.34 \pm 0.5$ has been derived using an empirical approach based on comparing the spectral slopes in the **H**igh **E**nergy (HE) and VHE γ ranges.

Within the framework of this thesis, the discovery of a second blazar known as B3 0133+388 (RGB 0136+3905) with an unknown redshift is reported. This blazar is currently still not fully classified as a **H**igh frequency peaked **BL** Lac (HBL) class object. Different authors argue that this source should be classified as a **I**ntermediate frequency peaked **BL** Lac (IBL) object due to it's synchrotron peak at $\nu_{\mathrm{peak}} = 10^{16.59}$ Hz. As a result of the data analysis in this work B3 0133+388 has been detected at significance level of 5.6 σ. However, no significant variability could be detected and the temporal study yields a flux level of (3.6±0.9)% of the Crab Nebula flux above 150 GeV. Similar to 1ES 0033+595 a new redshift estimation was performed on the HE and VHE γ-ray spectra. The new redshift was calculated to be $z = 0.46 \pm 0.05$.

The final experimental and analytical part of this thesis deals with the **L**ow frequency peaked **BL** Lac (LBL) object PKS 1717+177. This source was detected at a significance level of 6 σ in the observation period between April to August 2009 in stand-alone mode with M I. It is one of only four LBL objects currently seen in the VHE γ-ray range. A preliminary temporal study indicates a flux

level of ~4% of the Crab Nebula flux above 200 GeV.

The phenomenological part of this thesis consist of a population study off all currently known LBL, IBL and HBL objects in low state with a well measured VHE γ-ray spectra. The spectral properties of the observed sources are compared and correlated with each other. The main results are:

1. A strong correlation of the spectral softening and the source distance has been found. Reasonable explanations could be on the one hand the evidence of VHE γ-ray absorption on the **E**xtragalactic **B**ackground **L**ight (EBL) and on the other an artifact due to TeV blazar selection bias.

2. The obtained γ-**R**ay **h**orizon (GRH) shows that in most cases the IACT observations are indeed detecting a decreasing flux with larger redshifts given by the GRH feature. The estimations from different EBL models show that the Universe is more transparent to VHE γ-rays than previously thought and that further investigation of the EBL in order to understand the opacity of VHE γ-ray photons when traveling throughout the Universe evolution are needed.

The improved sensitivity due to the stereoscopic upgrade of the MAGIC telescopes was crucial in order to discover new blazars in the low energy range (70 – 250 GeV) of the VHE γ-ray regime and thus in obtaining a unique population study during this work. Future observations with sensitivity improved IACT instruments like the **C**herenkov **T**elescope **A**rray (CTA) have the potential to probe the here arose questions in a more quantitative manner.