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Citation: [AIP Conf. Proc. 1505](#), 502 (2012); doi: 10.1063/1.4772307

View online: <http://dx.doi.org/10.1063/1.4772307>

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Flat Spectrum Radio Quasars: MAGIC results and unexpected features

G. De Caneva^{*}, U. Barres de Almeida[†], J. Becerra Gonzalez^{**,‡}, K. Berger^{**,‡}, E. Lindfors[§], D. Mazin^{†,¶}, D. Paneque[†], K. Saito[†], C. Schultz^{||}, J. Sitarek^{¶,††}, A. Stamerra^{‡‡}, F. Tavecchio^{§§}, for the MAGIC Collaboration and M. Hayashida^{¶¶,***} for the *Fermi*-LAT Collaboration

^{*}*Deutsches Elektronen-Synchrotron (DESY), D-15738 Zeuthen, Germany*

[†]*Max-Planck-Institut für Physik, D-80805 München, Germany*

^{**}*Inst. de Astrofísica de Canarias, E-38200 La Laguna, Tenerife, Spain*

[‡]*Depto. de Astrofísica, Universidad de La Laguna, E-38206 La Laguna, Spain*

[§]*Finnish Centre for astronomy with ESO (FINCA), University of Turku, Finland*

[¶]*IFAE, Edifici Cn., Campus UAB, E-08193 Bellaterra, Spain*

^{||}*Università di Padova and INFN, I-35131 Padova, Italy*

^{††}*University of Łódź, PL-90236 Lodz, Poland*

^{‡‡}*Università di Siena, and INFN Pisa, I-53100 Siena, Italy*

^{§§}*INAF National Institute for Astrophysics, I-00136 Rome, Italy*

^{¶¶}*KIPAC, SLAC National Accelerator Laboratory 94025, CA, U.S.A.*

^{***}*Department of Astronomy, Kyoto University, 606-8502, Kyoto, Japan*

Abstract.

The detection of Flat Spectrum Radio Quasars (FSRQs) in the Very High Energy (VHE, $E > 100$ GeV) range is challenging, mainly because of their steep soft spectra. Often neither the emission nor the variability features of recently discovered VHE-FSRQs can be explained with the models developed so far for BL Lacs. Here we present the latest MAGIC results for all the three FSRQs known to be VHE emitters. We start with the 2010 discovery of PKS 1222+21 ($z = 0.432$), whose fast variability challenges simple one-zone emission models, requiring a more complicated scenario. Second, we present the latest results on 3C 279, the most distant AGN ($z = 0.536$) and first FSRQ detected in very high energies. It was observed in 2011, first during a monitoring campaign and later observations were triggered by a flare detected with *Fermi*-LAT. Finally, we report the 2012 detection of PKS 1510-089 ($z = 0.36$). This summary of VHE observations is the first step for a forthcoming study of multiwavelength spectral properties of these sources aimed at identifying the physical processes responsible for their emission and at explaining their observed variability.

Keywords: Gamma rays:galaxies - Flat Spectrum Radio Quasars:individual: PKS 1510-089, PKS 1222+216, 3C 279

PACS: 98.54.Aj, 95.55.Ka, 95.85.Pw

FLAT SPECTRUM RADIO QUASARS

Among more than fifty blazars detected in very high energy (VHE) γ -rays, only three belong to the subclass of Flat Spectrum Radio Quasars (FSRQs): PKS 1510-089, PKS 1222+216 and 3C 279, all detected with the MAGIC telescopes. FSRQs are characterized by broad and luminous emission lines in the optical spectrum and have highest luminosities among blazars. Their spectral energy distribution has two peaks, one in the optical/UV and one in the MeV/GeV energy range and often shows a “big blue bump”

FIGURE 1. Distribution of the squared angular distance (θ^2) between the source position and the reconstructed arrival direction of the γ -ray events for the blazar PKS 1510-089.

in the optical-UV region from the accretion disk. Due to the presence of UV and optical radiation from the accretion disk and broad line region (BLR), VHE emission may be internally absorbed.

PKS 1510-089

PKS 1510-089 has been discovered by H.E.S.S. in 2009, after a major outburst in the high energy and the optical regime ¹. In late January 2012, it was detected in a high activity state in the *Fermi*-LAT energy range (100 MeV to 10 GeV) triggering MAGIC follow up observations from February 2012 [1] until April, for a total of ~ 21 h. An excess of 509 γ -like events was found (Fig. 1) corresponding to a statistical significance of 5.7σ (calculated with equation 17 of [2]) above 190 GeV. MAGIC observations are part of a large multiwavelength campaign spanning from Radio to VHE whose data interpretation is still ongoing.

PKS 1222+216

The blazar PKS 1222+216 (4C +21.35) was discovered at VHE γ -rays by MAGIC on June 17th 2010 [3] during follow up observations triggered by high activity in γ -rays in the *Fermi*-LAT range. We measured a soft spectrum with a photon index $\Gamma = 3.75 \pm 0.27_{stat} \pm 0.2_{sys}$ in the energy range from 70 GeV to 400 GeV. Complementing our measurements with *Fermi*-LAT observations (Fig. 2), the simultaneous GeV and VHE (corrected for EBL absorption) spectra are consistent with a single power law with an index of $\sim 2.7 \pm 0.3$ between 3 GeV and 400 GeV, without a strong intrinsic cutoff. This strongly suggests that the γ -ray emission is located beyond the BLR [4]. Also more exotic scenarios, as the presence of axion like particles have been invoked

¹ <http://www.mpi-hd.mpg.de/hfm/HESS/pages/home/som/2012/06/>

FIGURE 2. PKS 1222+21, flare of 2010 June 17th: high-energy SED and light curve above 100 GeV, in 6 minutes bins.

[5]. The VHE light curve (Fig. 2) shows a doubling time of the flare of the order of minutes ($8.6^{+1.1}_{-0.9}$ min), among the fastest variations ever detected for sources of this class, implying a compact emission region, which is difficult to reconcile with a scenario where the γ -ray emission is not produced inside the BLR. Also models which invoke acceleration of ultra high energy cosmic-rays UHECR proton in the inner jet [6] have been proposed.

3C 279

The FSRQs 3C 279 was observed by the MAGIC telescopes in 2011 from February to April collecting ~ 20 h for monitoring, and in June for ~ 10 h during follow-up observations triggered by a high state in the optical and the *Fermi*-LAT energy ranges. Both periods do not provide any detection, consequently we computed two differential flux upper limits at 147 GeV and 304 GeV. The obtained values, corrected for extragalactic background light (EBL) absorption using [7], are presented together with *Fermi*-LAT spectral points in Fig. 3. Comparing the observations in the two energy ranges, we cannot exclude the presence of a break in the γ -ray spectrum. The interpretation of multi-wavelength data from this campaign is ongoing and will be presented elsewhere. The historical behavior of this source was different in various flaring episodes, and it is difficult to find a general trend [8],[9].

OUTLOOK

MAGIC detected all three FSRQs known to emit in VHE γ -rays. With the observations at our disposal, it is difficult to deduce a general trend among the few representatives of this class and an ultimate model to explain their emission. From this preliminary work, it is evident that follow up observations are necessary for detecting flaring states and discoveries of new sources. Furthermore, simultaneous multiwavelength data are fundamental for understanding the physical processes involved.

FIGURE 3. Spectral energy distribution of 3C 279 measured with *Fermi*-LAT and MAGIC (corrected for EBL absorption using [7]) 2011 observations. Previous MAGIC results are also shown [8],[9].

ACKNOWLEDGMENTS

The MAGIC Collaboration would like to thank the Instituto de Astrofísica de Canarias for the excellent working conditions at the Observatorio del Roque de los Muchachos in La Palma. The support of the German BMBF and MPG, the Italian INFN, the Swiss National Fund SNF, and the Spanish MICINN is gratefully acknowledged. This work was also supported by the CPAN CSD2007-00042 and MultiDark CSD2009-00064 projects of the Spanish Consolider-Ingenio 2010 programme, by grant DO02-353 of the Bulgarian NSF, by grant 127740 of the Academy of Finland, by the DFG Cluster of Excellence “Origin and Structure of the Universe”, by the DFG Collaborative Research Centers SFB823/C4 and SFB876/C3, and by the Polish MNiSzW grant 745/N-HESS-MAGIC/2010/0.

The *Fermi*-LAT Collaboration acknowledges support from a number of agencies and institutes for both development and the operation of the LAT as well as scientific data analysis. These include NASA and DOE in the United States, CEA/Irfu and IN2P3/CNRS in France, ASI and INFN in Italy, MEXT, KEK, and JAXA in Japan, and the K. A. Wallenberg Foundation, the Swedish Research Council and the National Space Board in Sweden. Additional support from INAF in Italy and CNES in France for science analysis during the operations phase is also gratefully acknowledged.

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