Probing spectral curvature for the distant blazar PG1553+113

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Abstract: PG 1553+113 is a well-known TeV blazar, whose redshift is still uncertain (z>0.4, [1]). The source has been monitored in VHE gamma-rays by MAGIC since February 2005 and has been detected on a regular basis in a quiescent state with modest flux variations, lying in the range from 4% to 11% of the Crab Nebula flux above 150 GeV (Aleksic et al. 2012). The source has remained as well in quiescent state in the Fermi energy band since the beginning of its operation. However, in March and April 2012, strong VHE gamma-ray flaring activity was detected with the MAGIC telescopes. The flux at ∼100 GeV reached an unprecedented level for PG 1553+113 (∼Crab Nebula flux). An intense multiwavelength campaign was carried out during the whole period in optical by the KVA telescope, in optical-UV by Swift/UVOT, in X-rays by Swift/XRT, in infrared by the REM telescope as well as in gamma-rays by Fermi/LAT. The source was observed for ∼18 hours with the MAGIC telescopes and due to the high state of the source, the high statistics of the detection allows a very detailed spectral study. The observed spectrum cannot be described by a simple power-law. This is the most distant blazar for which spectral curvature has been found. This spectral feature can have an intrinsic origin or can be produced by the interaction of VHE gamma-ray photons with the Extragalactic Background Light (EBL) photon field. Considering a redshift of z=0.4 the spectral curvature is most likely due to the absorption effect by EBL. Therefore, the VHE observations together with Fermi simultaneous observations provide a unique set of data to probe the intrinsic properties of the source, the EBL and the Intergalactic Magnetic Field (IGMF). In addition, the multiwavelength behaviour is interesting in order to test the standard emission models. In this talk we will present detailed results of the MAGIC observations together with the results of the MWL campaign, as well as the implications on EBL and emission models.

Keywords: Gamma-rays: galaxies-BL Lacertae objects: individual: PG1553+113

1 Introduction

The blazar PG1553+113 was discovered as a very high energy (VHE, E>100 GeV) gamma-ray emitter by H.E.S.S. [4] and MAGIC [5] in 2005 and monitored by MAGIC since then [2]. Only small-scale variability has been observed in VHE γ-rays since its discovery, with a flux varying from 4% to 11% of the Crab Nebula flux above 150 GeV. The VHE spectrum from the source is well described by a simple power-law with a photon index ∼4, and no significant variability on the spectral index has been measured until now, all measurements being compatible within the experimental errors.

This blazar is classified as a BL Lac object, showing significant optical variability [6] and a featureless optical spectrum [7] as typical for this kind of objects. Therefore, the measurement of its redshift is challenging. The most recent estimation, based on the Ly alpha forest method, gives a lower limit z>0.40 [1]. Also upper limits have been estimated from the VHE gamma-ray spectra, z<0.42 [8] and z<0.66 [9].

A new multiwavelength campaign lead by MAGIC was organized, from February up to June 2012, including instruments from radio to gamma-rays. The preliminary results from this observational campaign are presented in this contribution.

2 MAGIC Observations and Data Analysis

MAGIC system consists of two 17 m diameter Imaging Atmospheric Cherenkov Telescopes (IACT) situated on the

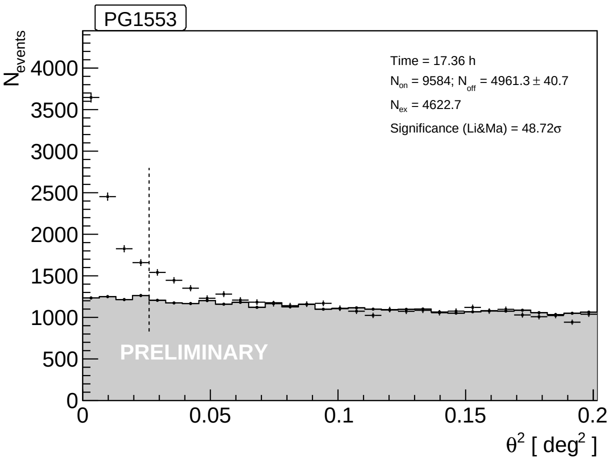

Fig. 1: Detection plot of PG1553+113 for E>100 GeV.

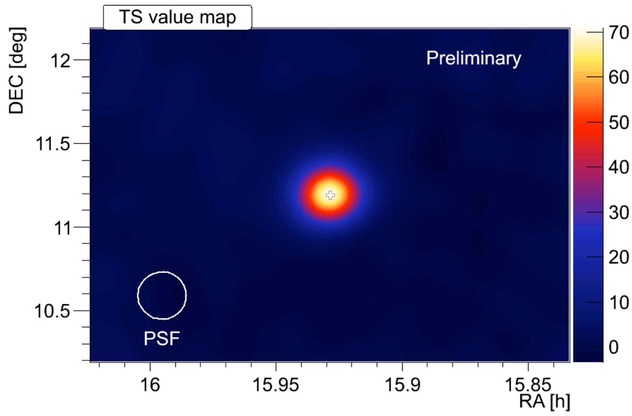

Fig. 2: Significance skymap of PG1553+113 for E>100 GeV.

Roque de los Muchachos, in the Canary island of La Palma (28°46′ N, 17°53′ W), at the height of 2200 m a.s.l. Its low energy threshold ∼50 GeV and its sensitivity (0.76% Crab Nebula flux for E>290 GeV in 50 h of observations [10]), makes the system an excellent instrument for observations of extragalactic sources.

PG1553+113 was observed by MAGIC from February 26 to May 2, 2012 in stereo mode. We collected ∼17.4 hours of good quality data, covering a zenith angle range ∼ 17°-34°. The observations have been performed in the so-called wobble mode (i.e. with the source offset by 0.4° from the camera center), which provides a simultaneous estimate of the background from the same data set [11]. The analysis of the data has been performed using the standard MAGIC analysis software package [12].

In Fig. 1 and 2 the detection plots are shown: the θ^2 distribution and the skymap. The source has been detected with high statistics ∼48.7σ. As shown in the skymap (Fig. 2), the source is compatible with a point-like source centered at the position of PG1553+113. We have detected flux variations in nightly time scales with the MAGIC telescopes (see lower panel in Fig. 4). During the first part of the observations we detected the source in high state, and therefore an astronomical telegram was issued [13]. Later on, during the night of April 19-20th (MJD 56037) a flare of the source was detected reaching the Crab Nebula flux level at ∼100 GeV [3], and was followed up by MAGIC for several nights.

3 Spectrum

The differential VHE spectrum corrected for instrumental effects making use of the Tikhonov unfolding algorithm [18] is shown in Fig. 3. The observed spectrum is represented in the figure by black points showing spectral curvature. A simple power-law fit is very unlikely with a probability of $P = 1.9 \cdot 10^{-6}$ ($\chi^2/d.o.f. = 39.1/7$). In turn, the differential spectrum can be well fitted from ∼90 GeV to 620 GeV by a power-law with an exponential cut-off with a probability of $P = 0.5$ ($\chi^2/d.o.f. = 5.04/6$):

$$\frac{dF}{dE} = f_0 \cdot (\frac{E}{200GeV})^{-\Gamma} \cdot e^{\frac{-E}{E_0}} \qquad (1)$$

with a normalization constant at 200 GeV of $f_0 = (2.8 \pm 1.3) \cdot 10^{-9}\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{TeV}^{-1}$, a photon index of $\Gamma = 2.1 \pm 0.4$ and $E_0 = 130 \pm 40$ GeV.

The VHE spectrum can also be well described by a log-parabola:

$$\frac{dF}{dE} = f_0 \cdot (\frac{E}{200GeV})^{-a-b\cdot\log\frac{E}{200GeV}} \qquad (2)$$

where the parameters are given by a flux normalization constant at 200 GeV of $f_0 = (6.1 \pm 0.3) \cdot 10^{-10}\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{TeV}^{-1}$, $a = 3.74 \pm 0.07$, $b = 1.9 \pm 0.4$. The goodness of the fit is given by $\chi^2/d.o.f. = 2.2/6$ (probability $P = 0.9$).

The absorption effect due to the interaction of the γ-ray photons with EBL has been tested making use of different state-of-the-art EBL models: [15], [17] and [16]. Since the redshift of PG 1553+113 is unknown, we calculated the optical depth for each VHE γ-ray energy interval for each model at a redshift z=0.4 which is the most recent lower limit of its redshift [1]. We found that the spectrum corrected by the EBL effect can be well fitted by a simple power-law:

$$\frac{dF}{dE} = f_0 \cdot (\frac{E}{200GeV})^{-\Gamma} \qquad (3)$$

which parameters in the case of [16] are given by a normalization flux at 200 GeV is $f_0 = (1.05 \pm 0.03) \cdot 10^{-9}\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{TeV}^{-1}$ and a photon index of $\Gamma = 2.33 \pm 0.05$. The EBL corrected spectrum is shown in Fig. 3 in blue squared points while the blue shaded area represents the uncertainty due to the use of the different EBL models.

4 Multiwavelength behavior

We present the preliminary results of the most extensive multiwavelength study of PG1553+113 ever performed. As shown in Fig. 4, the source has been observed from radio to VHE gamma-rays making use of the following instruments: radio by Metsähovi and OVRO, in optical by KVA telescope, optical-UV by *Swift*/UVOT, X-rays by *Swift*/XRT, infrared by REM telescope, Fermi/LAT in high energy (HE, E>100 MeV) gamma-rays as well as optical polarization measurements by Liverpool telescope. A clear increasing

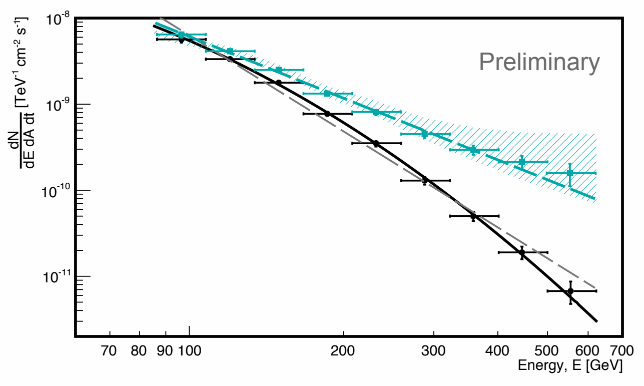

Fig. 3: Differential energy spectrum of PG 1553+113 as measured by MAGIC during the 2012 flaring episode. Differential fluxes are shown as black points. The gray dashed line represent the simple power-law fit while the solid black line represents the best fit to a logarithmic parabola. The absorption corrected spectrum using the EBL model by [16] is shown by the cyan squares; the dashed cyan line is the best-fit power law. The shaded cyan area account for the uncertainties derived by the used of different EBL models ([15], [17], [16] and Franceschini*1.3 [14].

trend during the flare state has been found between optical, X-rays and VHE gamma-rays, and the correlation among them is being studied. For HE gamma-rays an increase of the flux has been measured, however due to the poor statistics from *Fermi*/LAT a strict correlation cannot be found. Moreover, changes in the optical polarization and the polarization angle have been found during the flaring period.

5 Conclusions

In this contribution we present the preliminary results on the highest state ever detected for the BL Lac PG1553+113 at VHE gamma-rays. The source shows clear variability in nightly time scales. Moreover, the most extensive campaign of simultaneous multiwavelength data of this source so far has been carried out. The detected variability together with the multiwavelength observations coverage are an extraordinary data sample in order to test the emission models. Also taking into account the polarization measurements the study of the source which is in process contribute to the better understanding of the acceleration mechanism in relativistic jets.

Besides, given the high emission state of the source and therefore, the high statistics of its detection with the MAGIC telescopes, and considering the fact that PG1553+113 is a distant source ($z > 0.4$) the collected data set is very useful to test not only the intrinsic characteristics of the source, but also to probe the cosmological backgrounds. PG1553+113 is the most distant source showing curvature in its VHE spectrum mainly caused by the interaction with the low energy photons from the Extragalactic Background Light (EBL).

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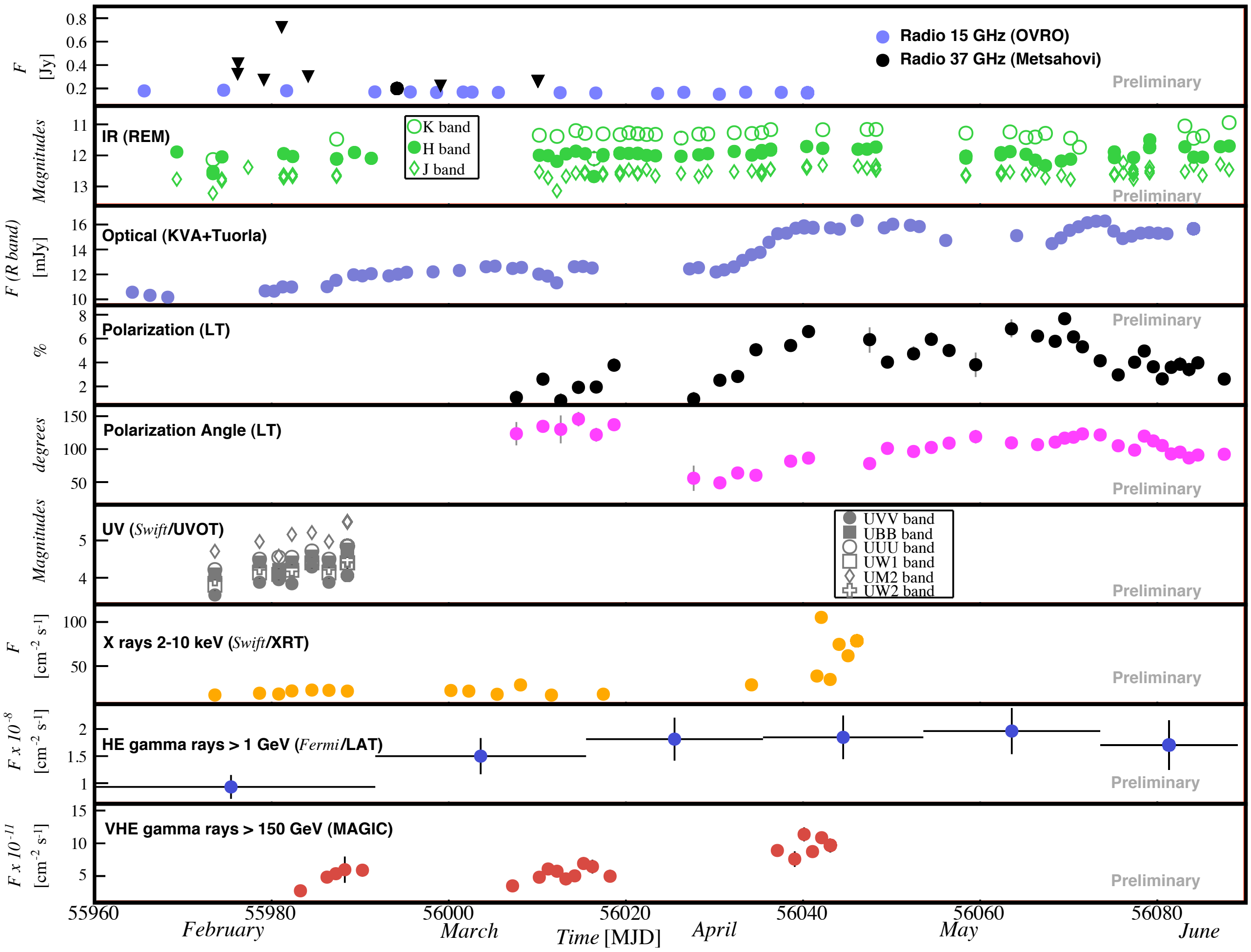

Fig. 4: Multiwavelength light curve of PG1553+113 from radio up to VHE gamma-rays.