Multiwavelength observations of PKS 2155-304 with H.E.S.S., *Fermi*-LAT, RXTE, Swift and ATOM.

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***Abstract*. In August 2008, the first joint observing campaign between a ground-based Very High Energy (VHE) γ-ray telescope (H.E.S.S.) and the *Fermi*-LAT took place, with simultaneous observations of the AGN PKS 2155-304. This 11-day multi-wavelength campaign also included RXTE and ATOM for the X-ray and optical coverage, respectively, and a trigger of Swift observations in the final nights. PKS 2155-304, which is one of the brightest AGN at VHE, was found to be in a low state close to the quiescent state but nonetheless provided us with precious and unexpected information. Indeed, for the first time, a quantitative correlation was measured between the VHE and the optical fluxes variabilities of an AGN. In contrast to what was observed during the 2006 flare, no correlation between X-ray and VHE fluxes was measured, which is interpreted as Klein-Nishina effects preventing the highest energy electrons to scatter via Inverse Compton. If the double peak structure of the SED is well reproduced by a one zone homogeneous SSC models, this simple picture fails to explain the correlation pattern observed between different waveband and its flux level dependency.**

***Keywords*: γ-ray, AGN, multiwavelength**

I. Introduction

Active Galactic Nuclei are variable objects emitting over the entire electromagnetic spectrum. For these reasons, simultaneous multiwavelength campaigns are crucial to improve our understanding of those objects, Indeed, the accelerations mechanisms in the blazar's jets can be probed by matching the emission model's spectral and temporal prediction with data. At VHE, the detection of such objects generally happens during a flaring episode. But with the new generation of Cherenkov telescopes VHE low flux states of some AGN became accessible. PKS 2155-304, a blazar at z=0.116, is a source whose VHE quiescent state as been observed and recently characterized (see [4] and [5]) and is detectable by H.E.S.S. within one hour. This bright source, extensively covered from radio to TeV energies over the past 20 years (see [6] and refereces therein) is an ideal and sure target for multiwavelength observations. Nonetheless, given the lack of sensitive observatories in the GeV domain, the emission models still predict a wide variety of fluxes in the 100MeV–10TeV energy range. Crucial information is expected from the *Fermi* Gamma-ray Space Telescope whose sensitivity is greatly improved over EGRET's one.

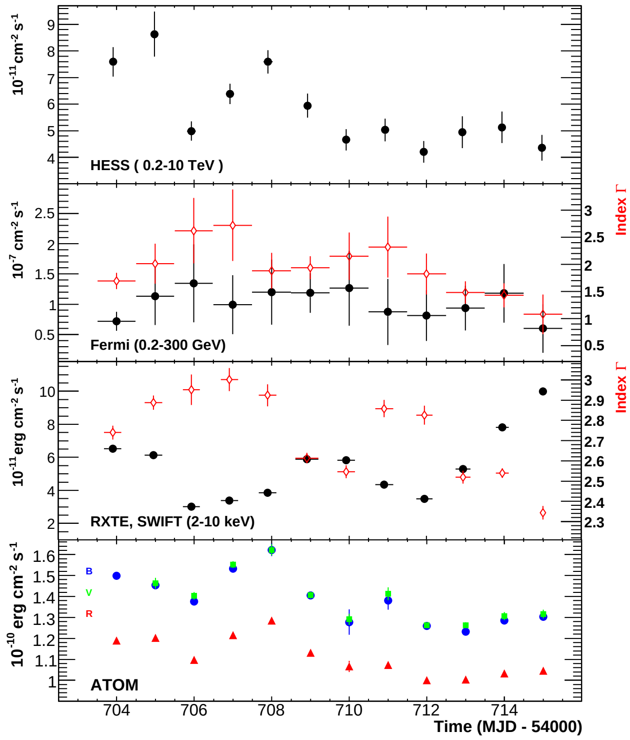

Fig. 1. Nightly lightcurves of, from top to bottom: H.E.S.S. (32.9 hours), *Fermi*-LAT ($7.7 \times 10^8 \mathrm{cm}^2\,\mathrm{s}$ exposure), RXTE (75 ks) and *Swift* (5 ks) and ATOM (106 observations, B: blue circles, V: green squares, R: red triangles). The *Fermi* and RXTE/*Swift* panels also show the nightly spectral index measurements (red). Vertical bars show statistical errors only. Horizontal bars shown only on *Fermi* and RXTE/*Swift* panels represent the integration time.

The first *Fermi* and H.E.S.S. simultaneous observations targeted PKS 2155-304. This 11-day campaign – involving ATOM, RXTE and Swift for the optical and X-ray observations respectively – provided the first continuous MeV–TeV spectral energy distribution resolving the Inverse Compton (IC) or hadronic peak. Also, PKS 2155-304 was caught in a low flux state which offers the possibility to compare its behaviour with that observed during the previous campaign, in 2006, while the source was flaring.

II. Observations and Analysis

PKS 2155-304 was observed during 11 days from August 25 to September 6 (MJD 54704-54715). For details and technical issues please see [1]. The resulting lightcurves are presented in Fig. 1. Nightly flux variability is detected in the VHE, X-ray and Optical bands. Spectral variability is observed for the *Fermi* spectrum, and for the X-ray band a clear hardening of the spectrum when the flux increases is measured on daily basis.

The H.E.S.S. ($>$ 200 GeV) averaged spectrum is compatible with those measured when the source was in a comparable flux level in 2003 (see [2] and [3]) and between 2005 and 2007 (see [4]). The differential flux at the fit decorrelation energy $E_0 = 350\mathrm{GeV}$ is $I_0 = (10.4 \pm 0.24_{\mathrm{stat}} \pm 2.08_{\mathrm{sys}}) \times 10^{-11}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\mathrm{TeV}^{-1}$ and the spectral index $\Gamma = 3.34 \pm 0.05_{\mathrm{stat}} \pm 0.1_{\mathrm{sys}}$. No spectral variability is detected. During these observations, unlike during the 2006 flare, the VHE flux was not correlated with the X-ray flux, but, for the first time, a clear indication for correlation between Optical and VHE fluxes was measured (Pearson's correlation coefficient $\rho = 0.77 - 0.86$ with uncertainties ≤ 0.09).

The *Fermi* ($0.2 - 300$ GeV) average spectrum over the campaign duration is well fitted by a power law with flux at $E_0 = 943\,\mathrm{MeV}$ equal to $I_0 = (2.42 \pm 0.33_{\mathrm{stat}} \pm 0.16_{\mathrm{sys}}) \times 10^{-11}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\mathrm{MeV}^{-1}$ and $\Gamma = 1.8 \pm 0.11_{\mathrm{stat}} \pm 0.09_{\mathrm{sys}}$. Though the HE flux is compatible with a constant, a nightly variation of the spectral index is observed and correlates with the X-ray flux, with a Pearson's correlation coefficient $\rho = -0.80 \pm 0.15$. Since the flux level of the source was consistent with that of the campaign, and in order to increase the statistics, data from August 4 to October 4 have been used to derive to HE spectrum. For this dataset, a broken power law is preferred with a probability of 97%. The break is at $E_{br} = 1.0 \pm 0.3\,\mathrm{GeV}$ with a low-energy photon index of $\Gamma_{\mathrm{L}} = 1.61 \pm 0.16_{\mathrm{stat}} \pm 0.17_{\mathrm{sys}}$ and a high-energy photon index of $\Gamma_{\mathrm{H}} = 1.96 \pm 0.08_{\mathrm{stat}} \pm 0.08_{\mathrm{sys}}$. This spectrum is used for the SED modeling.

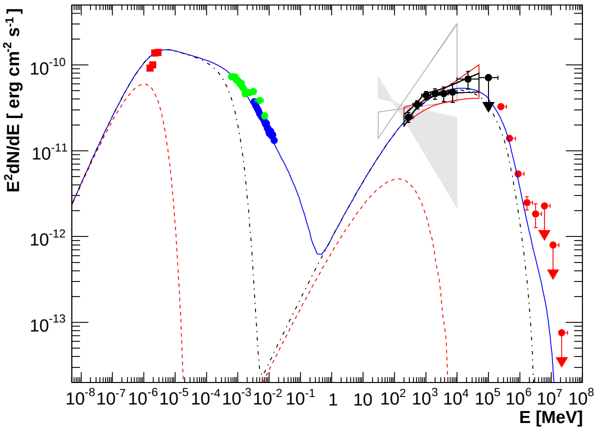

Fig. 2. PKS 2155-304's SED. Black and red butterflies are *Fermi* spectrum covering MJD 54682-54743 and restricted to MJD 54704-54715, respectively. The black circles are the power-law-fit-estimated differential flux in limited energy bins. They are found to be consistent within 1σ with the fit over the extended dataset (Aug. 4 – Oct. 4) . The gray butterflies are EGRET measurements. The solid line is a 1-zone SCC model. In red dashed line and in black dot-dashed line, the same model without electron above γ_1 and above γ_2, respectively. The VHE part is absorbed with the $P0.45$ extragalactic background model (see [7])

III. Discussion

A simple one zone synchrotron self-Compton (SSC) model is used to fit the broadband time-averaged spectrum (see Fig. 2). Within this model, the electron density is described by a triple power law with two breaks at $\gamma_1 = 1.4 \times 10^4$ and $\gamma_2 = 2.3 \times 10^5$ and a maximal energy $\gamma_{\mathrm{max}} = 10^{6.5}$. The magnetic field is 18mG.

The electrons with $\gamma > \gamma_2$ are responsible for the X-ray emission (see the blue dot-dashed line in Fig. 2). Omitting these electrons in the SSC calculation doesn't significantly change the VHE flux, because these electrons are deep into the Klein-Nishina regime. The lack of correlations observed between the VHE and X-ray fluxes can therefore be expected within this model.

The electrons with $\gamma_1 < \gamma < \gamma_2$ are responsible for the optical, HE and VHE emissions (see the red dashed line in Fig. 2). Correlation between the optical and VHE fluxes is observed. If the same population of electrons drives these emissions then the optical/HE and HE/VHE fluxes should also be correlated. The correlation pattern of the source during this campaign cannot be reproduced by this model.

IV. Conclusion

The first multiwavelength campaign with *Fermi*-LAT and an ACT instrument caught PKS 2155-304 in a low flux state. The results of these observations strongly challenge the standard models for these objects. Though a simple 1-zone SCC model can reproduce the SED, such a model is ruled out by the observed variability pattern. Comparing the results of this campaign to that of previous ones, the correlation properties of the source seem to be flux-level dependent. Such a two-fold behaviour depending on the flux level in also apparent in the spectral evolution of the source (see [4]). If this behaviour is confirmed, the nature of the differences between the quiescent state and the flaring episodes need to be addressed. Through these broadband observations, PKS 2155-304 provided a new precious piece of the puzzle, to refine the description of emission mechanisms in blazar jets.

References

[1] F. Aharonian , A.A. Abdo et al. (H.E.S.S. and *Fermi* Collaborations), ApJ Let., 696, L150-155, (2009)
[2] F. Aharonian et al. (H.E.S.S. Collaboration), A&A, 430, 865, (2005)
[3] F. Aharonian et al. (H.E.S.S. Collaboration), A&A, 442, 895, (2005)
[4] F. Aharonian et al. (H.E.S.S. Collaboration), in preparation (2009)
[5] J.-P. Lenain et al., AIPC, 1085, 415 (2008)
[6] D. Sanchez, 44th Rencontres de Moriond (2009)
[7] F. Aharonian et al. (H.E.S.S. Collaboration), Nature, 440, 20, (2006)