Multiwavelength view of the TeV Blazar RGB J0152+017

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***Abstract*. VHE gamma-ray emission was discovered from the high-frequency-peaked BL Lac object RGB J0152+017 by the Cherenkov telescope array H.E.S.S. in November 2007. The instantaneously triggered multiwavelength observations with the X-ray satellites Swift and RXTE, the optical telescope ATOM and the radio telescope Nançay provided the first simultaneous SED for RGB J0152+017. The subsequent observations with Swift (X-ray and UV-optical telescopes) and ATOM (optical) show flux variations on several time scales. This longterm monitoring demonstrates that the shape of the synchrotron spectrum changes. Moreover indication of VHE variability on monthly time scales was detected. In optical observations variation on very short time scales was detected which demonstrate that at least part of the non-thermal emission results from a very compact emission region.**

***Keywords*: AGN; VHE γ-rays; multiwavelength**

I. Introduction

RGB J0152+017 is a BL Lac object located at α_{J2000} =1h 52m 39.6s, $\delta_{J2000} = 1°47'17.2''$ ([1]) with a redshift of $z = 0.08$. It was discovered in November 2007 in the VHE domain using the H.E.S.S. experiment ([2]). Based on the instantaneously triggered multiwavelength observations with Swift, RXTE, ATOM and Nançay the spectral energy distribution (SED) of RGBJ0152+017 was derived. The SED of RGBJ0152+017 based on these simultaneous observations allows RGB J0152+017 to be classified as a high-frequency-peaked BL Lac object ([2]).

II. Temporal Analysis

After the discovery of VHE emission and the instantaneously triggered multiwavelength campaign in November 2007, follow-up observations with the X-ray satellites Swift (XRT [3], UVOT [4]) and RXTE (PCA [5]) were obtained in Dec 2007 and Jan 2008 and with the Cherenkov telescope array H.E.S.S.([6]) in Dec 2007, Aug and Oct 2008. The optical telescope ATOM ([7]) monitored RGB J0152+017 from June 2008 to Jan 2009. The observations by the X-ray satellite RXTE are not taken into account due to contamination of the data obtained by the non-imaging PCA detector by nearby bright X-ray sources ([8]).

The H.E.S.S. experiment consists of four imaging atmospheric Cherenkov telescopes, located in the Khomas Highland, Namibia. The Swift X-ray telescope covers an energy range from 0.2 to $10\ \mathrm{keV}$ and the UV-optical telescope measures the emission in the bands (central wavelengths): uvw2 (188 nm), uvm2 (217 nm), uvw1 (251 nm), u (345 nm), b (439 nm) and v (544 nm). The ATOM telescope is an optical 75-cm telescope located at the H.E.S.S. site with which observations of RGB J0152+017 in the R-band (640 nm) and B-band (440 nm) are obtained.

The results of these broadband simultaneous observations from Nov 2007 to Jan 2008 are shown in Fig. 1. No evidence for variability on short time scales ($\Delta t < 1$ day) was found at high energies. Therefore a nightly binning was chosen to focus on the long-term variation. The very high energy (VHE) flux measured by H.E.S.S. show no significant variation and a flux of $I(> 300\ \mathrm{GeV}) \approx 2.6 \times 10^{-12}\mathrm{cm}^{-2}\ \mathrm{s}^{-1}$ is detected in Nov 2007 and $I(> 300\ \mathrm{GeV}) \approx 1.4 \times 10^{-12}\mathrm{cm}^{-2}\ \mathrm{s}^{-1}$ in Dec 2007 (see Fig. 3). The X-ray and UV flux varies on time scales of ~ 10 days indicating that the emission region is compact. The spectral shape of the X-ray spectra does not change significantly (average photon index ≈ 2.3 for a power-law [8]). Instead the denser sampling of the optical R-band measurements with ATOM show significant intra-day variability (IDV) in the Nov 2007 data, e.g. night from 12 to 13 Nov 2007 (see Fig. 2). This IDV is statistically significant in comparison with the lightcurves of the reference stars. The absolute magnitudes of the R-band measurements by the ATOM telescope contain a systematic uncertainty of $\sim 0.03\ \mathrm{mag}$. The significant variation in relative flux ($\sim 30\%$) on very short timescales of ~ 1 hour leads to the conclusion that the emission region must be very compact ($R < 2 \times 10^{14}\mathrm{cm}$,[9]) and that a non-negligible contribution of the optical radiation can be described by synchrotron radiation. The subsequent monitoring with one observation per night shows a longterm increase of the relative flux over a period of ≈ 25 days by $\sim 20\%$ and $\sim 15\%$ for B- and R-band fluxes, respectively.

Since the host-galaxy contribution of the R- and B-band measurements is non-variable, an upper limit for the host-galaxy can be derived from the detected variations. The resulting upper limit for the host-galaxy contribution is 15.5 mag for the R-band and 16.3 mag for the B-band. This result is compatible with [10], where an extended host galaxy up to $20''$ was detected in very deep R-band observations with ≈ 16 mag within the inner $5''$.

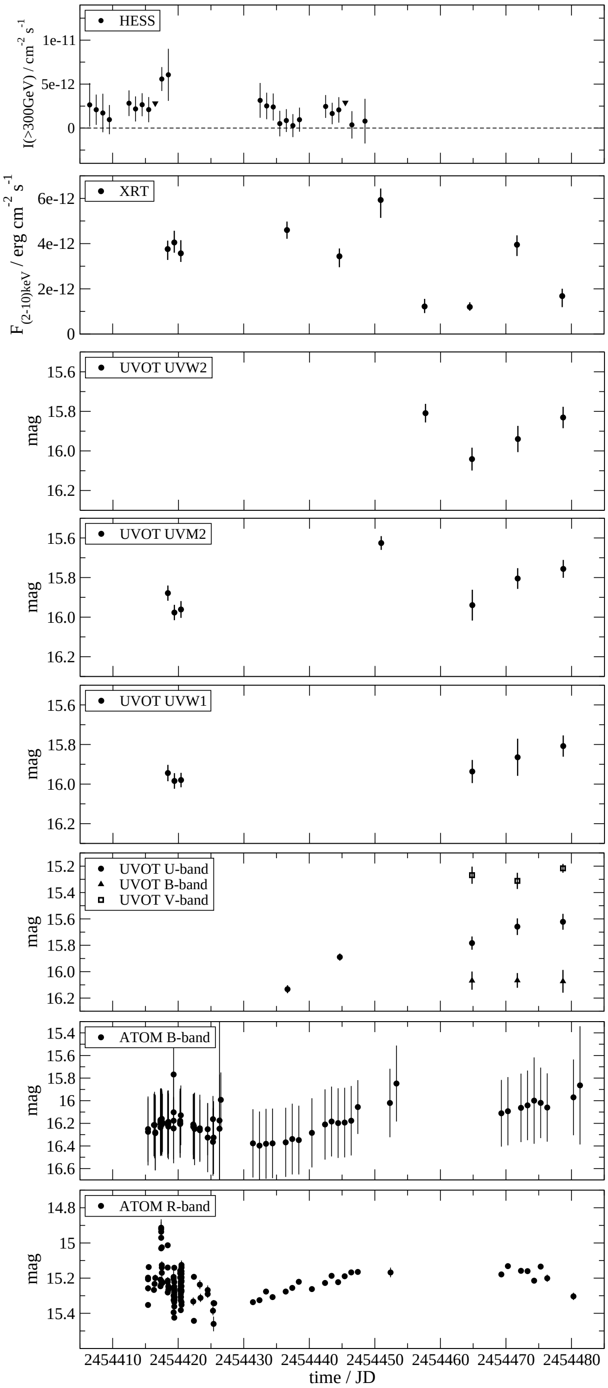

Fig. 1. H.E.S.S., Swift/XRT, Swift/UVOT and ATOM lightcurves of RGB J0152+017. For the H.E.S.S. and Swift measurements nightly averages are shown because no variability on short timescales was found. The triangles in the H.E.S.S. lightcurve represent upper limits at 99% confidence level calculated using [11]. For the ATOM R-band measurements only the statistical uncertainties are shown.

After the observations in 2007, RGB J0152+017 was monitored by H.E.S.S. in August and October 2008. A month by month lightcurve was derived using the whole dataset of observations (see Fig. 3). The fit by a constant of this lightcurve has a probability of 3.3%. This is the first indication of variability for the VHE emission.

The further monitoring with the optical telescope ATOM shows a nearly constant flux of ≈ 15.3mag in the R-band observations from June 2008 to Jan 2009.

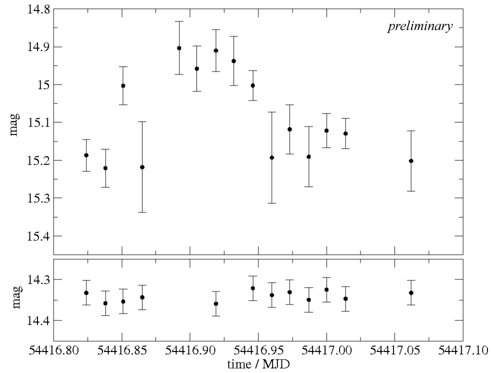

Fig. 2. Optical R-band lightcurve of the night 12.-13. Nov 2007 obtained with ATOM. The upper panel show the flux of RGB J0152+017 in relation with one reference star. For comparison the lightcurve of this reference star is given in the lower panel. Significant variations on time scales of hours can be seen.

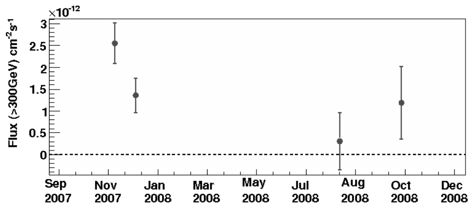

Fig. 3. H.E.S.S. month by month lightcurve covering the whole dataset of observations.

III. VHE GAMMA-RAY SPECTRUM

RGB J0152+017 was observed by H.E.S.S. in Nov, Dec 2007, Aug and Oct 2008 with a total exposure of 47.4 hours and a mean zenith angle of $27°$. After the standard H.E.S.S. data quality selection, 39.2 hours live time remains. An excess of 272 γ is measured with a significance of 6.4σ ([12]) at the position of RGB J0152+017. The time-averaged photon spectrum (see Fig.4) was derived using a forward-folding maximum likelihood method described in ([13]). Over the energy range covered (300 GeV to 8 TeV), the spectral shape of RGB J0152+017 is well described by a power-law function of the form $\mathrm{d}N/\mathrm{d}E = I_0(E/E_0)^{-\Gamma}$ where $E_0 = 560$ GeV is the decorrelation energy. The differential flux at this energy is $I_0 = (1.51 \pm 0.27_{\rm stat} \pm 0.30_{\rm sys}) \times 10^{-12} \rm cm^{-2}\ s^{-1}\ TeV^{-1}$ and the spectral index $\Gamma = 3.15 \pm 0.46_{\rm stat} \pm 0.2_{\rm sys}$.

IV. BROADBAND SPECTRAL VARIATION

The strictly simultaneous X-ray and UV observations give the possibility to study the synchrotron spectrum of this high-frequency-peaked BL Lac in detail. The different variation in both bands leads to the conclusion that the shape of the synchrotron spectrum changes. To quantify these spectral changes, a log-parabolic fit was chosen for describing the UV and X-ray spectra taken with the Swift satellite. The log-parabolic model

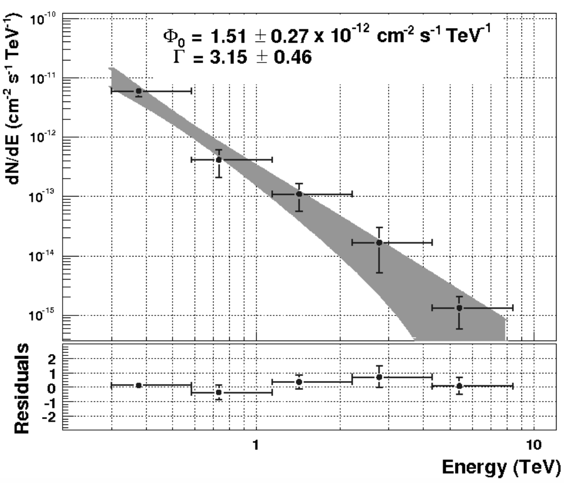

Fig. 4. Average VHE gamma-ray spectrum obtained by H.E.S.S. from observations in Nov, Dec 2007, Aug and Oct 2008 shown with a power law fit. The shaded area corresponds to the 1σ confidence level limit given by the maximum likelihood method. The residuals consist of the ratio between the number of measured and expected events. The spectral points are derived by combining these residuals with the fitted spectral form, simply to illustrate the statistical error of the energy bin.

can be expressed by $F(E) = K(E/E_1)^{-(a+b\log(E/E_1))}$ where $E_1 = 1\,\mathrm{keV}$, a is the photon index of a power law at E_1 and b is the curvature parameter. To obtain the intrinsic spectra of RGB J0152+017, the X-ray spectra are corrected for the galactic absorption ($n_{\mathrm{H}} = 2.72\times10^{20}\ \mathrm{cm}^{-2}$,[14]) and the UV spectra for the dust absorption. The amount of dust absorption could be derived from the hydrogen column density following [15]. Using the resulting $E(B-V) = 0.033$ and the $A_\lambda/E(B-V)$ from [16] the UV spectra could be corrected for the absorption by dust. The influence of the host galaxy in the UV data is negligible in comparison with the extinction. Instead for the optical observations the influence of the host galaxy is much higher, hence they are not included for the log-parabolic fit.

In Fig. 5 the spectra from 15. Nov and 30. Dec 2007 are shown with the corresponding log-parabolic fit. It is clearly visible that the peak energy of the synchrotron spectrum is shifted to lower energies with time while the peak flux are comparable. In comparison with other VHE Blazars [17], RGB J0152+017 has one of the lowest peak energy ($\approx 0.001-0.05$ keV) of the synchtrotron spectrum while most of them show peak energies > 0.1 keV.

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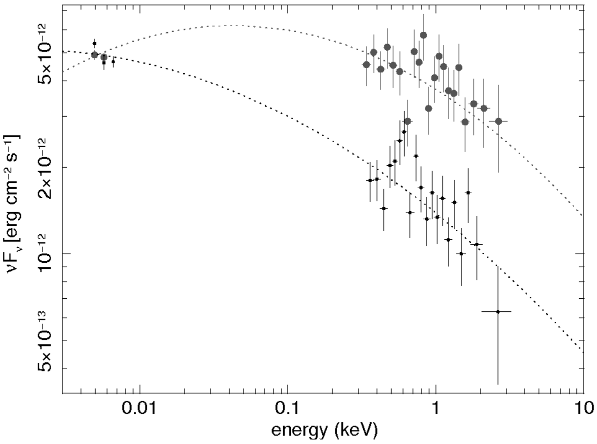

Fig. 5. Strict simultaneous UV and X-ray spectra from 15. Nov (grey, large circle) and 30. Dec 2007 (black) corrected for absorption. The dotted lines correspond to the log-parabolic fit to the spectra.

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