VERITAS and H.E.S.S. observations of the gamma-ray binary HESS J0632+057

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VERITAS and H.E.S.S. observations of the gamma-ray binary HESS J0632+057

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Abstract.
HESS J0632+057 has been recently identified as a new gamma-ray binary system. The source, located in the Monoceros region and associated with the massive Be star MWC 148, shows variability from radio to very high energy (VHE) gamma-rays, displaying a maximum of its non-thermal emission about 100 days after periastron passage (at orbital phases ~ 0.3). We present here the results obtained with the VERITAS and H.E.S.S Cherenkov telescopes spanning a wide time interval from 2004 to 2012. The source is detected at TeV gamma-rays at a high significance level at phases ~ 0.3. We also report for the first time TeV observations belonging to orbital phases never explored so far. The VHE gamma-ray results are discussed in a multiwavelength context, focusing on contemporaneous observations obtained with the *Swift*-XRT.

Keywords: binaries: general – gamma rays: observations – individual (HESS J0632+057)
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HESS J0632+057: A NEW GAMMA-RAY BINARY

The VHE gamma-ray source HESS J0632+057 [1] is a new member of the elusive class of gamma-ray binaries [2]. These objects are characterized by a peak in their broadband energy spectrum at MeV-GeV energies, showing variable and usually orbitally modulated high-energy emission. All known gamma-ray binaries are high-mass X-ray binaries, consisting of a compact object orbiting around a massive star of O or Be type. Besides HESS J0632+057, there are only a few binaries clearly identifed as VHE gamma-ray sources: PSR B1959-63/LS 2883 [3], LS 5039 [4], LS I +61 303 [5, 6]. In addition, a hint of a VHE flare from Cyg X-1 has been reported [7], and VHE emission from a direction consistent with that of the newly discovered binary 1FGL J1018.6-5856 [8] has been recently found [9].

HESS J0632+057 has been repeatedly observed at X-rays: XMM-Newton detected a hard and variable counterpart of HESS J0632+057 at the position of MWC 148 [2]. *Swift*-XRT observations showed a softer source [10] and the presence of X-ray outbursts each 321 ± 5 days [11]. An updated analysis of *Swift* data including observations up to March 2012 shows a somewhat shorter value of this periodic outburst, each ~ 315 days (See Fig. 1). X-ray pulsations from the source were not found in recent Chandra observations [12]. At radio wavelengths, VLT and GMRT observations of the source at 5 and 1.28 GHz detected a variable radio counterpart compatible with both the gamma-ray source and the MWC 148 star position [13]. EVN observations further showed spatially extended radio emission during the X-ray outburst, with the emission peak ≈ 10 times

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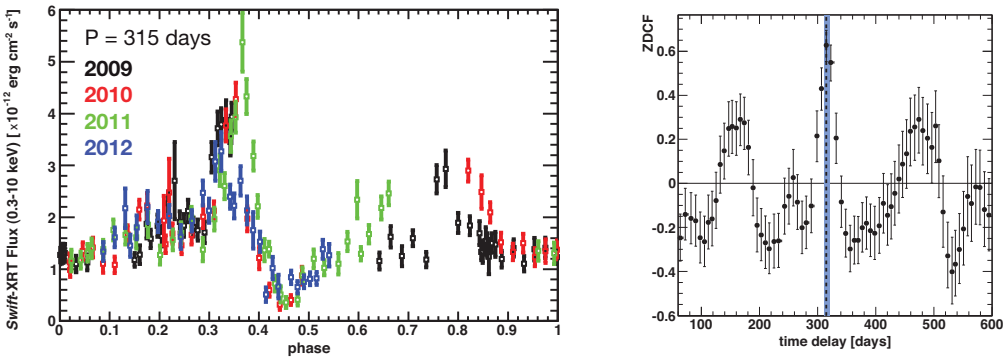

FIGURE 1. *Left*:Phase-folded X-ray lightcurve using a *Swift*-XRT data-set obtained from 2009 to 2012 (154 compared to 112 flux points in [11]). The X-ray peak at phase ~ 0.3 and the subsequent X-ray dip at phase ~ 0.45 are clearly seen. *Right*: A z-transformed discrete cross-correlation function analysis (ZCDF, Alexander 1997) provides an orbital period of P = 315^{+6}_{-4} days

larger than the orbit size [14]. In the optical band, observations with the Liverpool telescope have been used to obtain radial velocity measures. Fixing the orbital period to 321 days these data suggest a system with an eccentric orbit ($e \approx 0.83$ with periastron occuring at orbital phases ~ 0.97 [15].

VERITAS AND H.E.S.S. OBSERVATIONS

VERITAS and H.E.S.S. are ground-based gamma-ray observatories, each consisting of four imaging atmospheric Cherenkov telescopes. The instruments have similar performance, with large effective areas ($> 10^5$ m^2) over a wide energy range (100 GeV to 30 TeV) and good energy (15-20%) and angular ($\leq 0.1^\circ$) resolutions. The high sensitivity of H.E.S.S. and VERITAS enable the detection of sources with a flux of 1% of the Crab Nebula in less than 30 hours of observations.

VERITAS observed HESS J0632+057 for a total of 162 h between 2006 December and 2012 January. About 144 h of data passed quality selection criteria. All observations were taken with the source at a fixed offset of 0.5° from the camera center. The energy threshold after analysis cuts ranges between 220 GeV and 450 GeV. The most recent observations, taken in 2011/2012, amount to a total of 34.3 h between November 2011 to January 2012. The analysis of these data provides 163 excess events, implying a detection with a statistical significance of 9.8 σ

H.E.S.S. observed the source yearly from 2004 to 2012. The full dataset consists of 47.3 h of observations, which were performed over a large range of zenith angles (28°-58°). In the 2011/2012 campaign, H.E.S.S. observed the source in December 2011 and February 2012, providing a total of 8.2 h of good quality data-set. Bad weather prevented however most of the observations close to the expected peak. We also report here archival

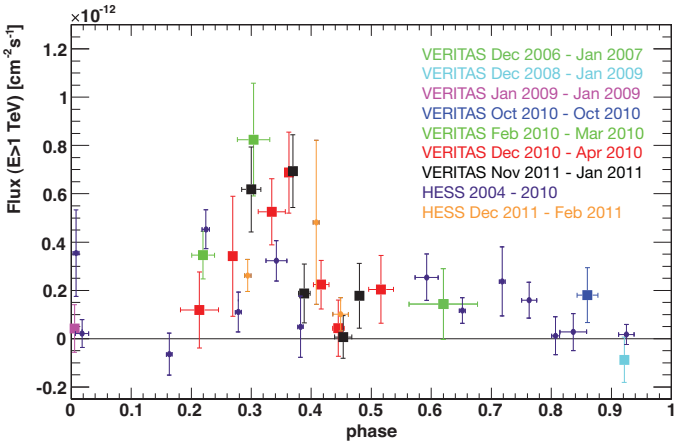

FIGURE 2. VHE fluxes above 1 TeV from H.E.S.S. (purple and orange filled circles) and VERITAS (filled squares; vertical scale on the left) measurements, folded with the orbital period of 315 days. The marker colors indicate different periods of observations. Error bars show 1σ statistical uncertainties.

TABLE 1. VERITAS and H.E.S.S. results for the different data-sets

	Obs. time [h]	**N_{on}**	**N_{off}**	**excess**	**significance [σ]**
VERITAS					
All data	144.2	1525	18310	544	15.5
2011/2012	34.3	367	2388	163.5	9.8
HESS					
All data	47.3	823	11032	270.0	10.4
2011/2012	8.2	148	1787	53.9	4.9
phase $\in [0.7-0.8]$	7.1	93	1228	33.9	4.1

H.E.S.S. observations corresponding to orbital phases unexplored so far. In particular we show new data in the phase range [0.7 - 0.8] (using an orbital period of 315, see above) which were taken in March 2007, January 2008 and October 2009 and amount to ~ 7 h of observing time. Using the *Model analysis* technique [16] with *standard cuts*, a 4.1σ deviation from the background level is found. A cross-check using a boosted-decision-tree-based Hillas analysis [17] for the same run list, which also makes use of an independent calibration of the raw data, provides compatible results, with a somewhat higher significance of 4.8σ in this phase range.

SUMMARY AND CONCLUSIONS

VERITAS and H.E.S.S. observations of HESS J0632+057 provide a wide data-set with more than 190 h of observations covering a large fraction of the system orbital phases. The source is detected at TeV energies at a high significance level around phase 0.3. Results are consistent in this phase with observations taken from 2004 to 2012, as

well as with recent results reported by the MAGIC Collaboration [18]. Archival data taken with H.E.S.S show a 4.1σ deviation from background events from the direction of HESS J0632+057 at phases $\sim 0.7 - 0.8$, or about half an orbital period later than the peak at phase ~ 0.3. Additional TeV data are however required to provide more solid conclusions in this phase range. Finally, an updated X-ray data-set provides a refined system period of P = 315 $^{+6}_{-4}$ days. In addition, an updated z-CDF analysis (see, e.g. [19]) with the newest data shows a $\sim 4\sigma$ correlation of the X-ray and VHE fluxes.

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