H.E.S.S. observation of the Vela X nebula

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***Abstract*. Vela X is one of the nearest Pulsar Wind Nebulae (PWN) and has served as prototype for evolutionary studies. Associated with the pulsar B0833-45, Vela X has been observed at different wavelengths and in particular in and X-ray bands. The H.E.S.S. Cherenkov telescope array has observed Vela X in 2004 and 2005, discovering very high energy gamma-ray emission in this region, centered to the south of the pulsar, and contained within a region of 0.8 degrees radius. Additional observations from 2006 to 2009 allowed further investigation into the Vela X non-thermal emission. In this work the latest results on the Vela X gamma-ray emission are presented in the context of a multiwave-length analysis.**

***Keywords*: VelaX extension gamma**

I. Introduction

The H.E.S.S. array, a system of four large imaging atmospheric Cerenkov telescopes, which is operating since December 2003, has discovered a number of previously unknown gamma-ray sources at very high energy (VHE). A significant fraction of the new VHE Galactic sources observed by H.E.S.S. are Pulsar Wind Nebulae (PWN) ([1],[2]). The purpose of the PWN study is a diagnostic of the spatial and spectral distribution of the high energy electrons responsible of the TeV γ-ray production dominated by the Inverse Compton scattering off the well-known cosmic microwave background. The PWN Vela X is the bright flat spectrum radio component of the Vela SNR which is at a distance of about 290 pc ([3],[4]) and extented over a diameter of 8°. The Vela X region, within 2 degrees of the pulsar PSR B0833-45, has been observed by the H.E.S.S. γ-ray atmospheric Cherenkov detector in 2004 and 2005. A strong signal was seen from an extended region to the south of the pulsar ([5]), but within a smaller integration region of radius 0.8° around the position (α = $08^h35^m00^s$, δ = -45°36'). The VHE gamma excess observed by H.E.S.S., with intrinsic widths of 0.48° and 0.36° along the major and minor axes, coincides with a hard X-ray region. Such an asymmetric emission can be explained by an inhomogeneous medium, with higher density to the North of the pulsar position ([6]). The approximate full size of the Vela X PWN is about 3° in right ascension and 2° in declination. The actual volume of the VHE gamma cocoon emission is only 5% relative to the total volume of Vela X. This implies the need of further investigation all over the radio extension to better define the VHE gamma ray morphology of the Vela region even if we cannot expect an overall much larger flux than that from the cocoon. With such a purpose follow-up H.E.S.S. observations of the Vela X region have been performed in 2006, 2007, 2008 and 2009. The results of large scale emission are reported and discussed in this communication.

II. Observation and analysis methods

The investigation of the VHE size and morphology of the Vela X emission has an intrinsic limit due to the H.E.S.S. telescopes field of view (about 2.5°) which make it difficult to observe such an extended target. As a consequence, most of observation cannot be analyzed using a reflected background estimation: Vela X region is too close from the center of the field of view and no symmetric OFF-source region can be taken simultaneously. Therefore for the background subtraction a set of runs free of γ-ray sources and taken at the same conditions of the telescopes operations, same zenith and azimuth angles as for the pointing of the runs taken ON-Vela X were selected. Unfortunately residual differences between ON and OFF-runs are possible source of systematic uncertainties. Therefore, as a cross check, new observations were performed (since early 2008) with telescopes pointing 1.3° from the center of gravity of the Vela X cocoon as defined in [5], enabling to study emission till 1.2°. The cocoon, according to the first H.E.S.S. observations, was identified as a 0.8°-radius circular region centered at $\alpha = 08^h35^m$, $\delta = 45°36'$; while the investigated extended region corresponds to a ring between 0.8° and 1.2° around the same center. The total live time concerning the Vela X region after data quality cuts corresponds to about 58 hours taken since 2004 by the H.E.S.S. telescopes array.

Finally the X_{eff} procedure was used for the data analysis ([7]): a multivariate analysis method which allows for a competitive signal-to-background discrimination, important for searches of tiny signals and morphological study of extended sources. This method combines in a single estimator the main discriminating variables of the three reconstruction methods in use in the H.E.S.S. analysis: Hillas ([8]), Model ([9]), 3D-model ([10]). Shower direction and energy of γ events are also reconstructed by a combining procedure which relies on a composed estimator of the three angular and energy reconstructions coming respectively from the three methods in use. For cross-check purpose, independent Hillas analysis was also performed.

III. RESULTS

A. Global analysis

The X_{eff} analysis of the Vela X region was performed both with two options 80 and 200 photoelectrons (p.e.) charge thresholds. In both cases the analysis provides good results in terms of statistical significance and background rejection. The new data reveal gamma-ray emission up to a radius of about 1.2° from the previously defined center position.

TABLE I: Statistical results with X_{eff}. The On region is a circle of radius 1.2°.

p.e. cut	N_{On}	N_{Off}	γ excess	σ	S/B
80	39794	32242	7611	28.4	0.2
200	12212	7036	5156	37.3	0.7

The X_{eff} methods allows to improve the lower energy sensitivity for spectral analysis and the investigation of possible features in the source morphology.

B. The large scale emission

In the outer ring with inner and outer radii of 0.8° and 1.2°, with 80-pe cut in charge and On/Off analysis, significance of the excess is equal to 11σ for 2106 events and reaches 14.6σ for 1341 events at 200-pe cut in charge. Using a reflected method for background subtraction, the best value is 5.1σ. The preliminary spectrum (see Fig. 1) is well fitted by a power law with exponential cutoff, has spectral index equal to $\Gamma = 1.4 \pm 0.2_{stat} \pm 0.3_{sys}$, an energy cut off $13 \pm 5_{stat} \pm 4_{sys}$ TeV. A previous analysis on the cocoon has been done on data from 2004 to 2005, using Hillas method for reconstruction and event selection (see [8]) and On/Off background subtraction. The spectrum was well fitted by a power law function with index $\Gamma = 1.45 \pm 0.09_{stat} \pm 0.2_{sys}$ and an exponential cut off at an energy of $13.8 \pm 2.3_{stat} \pm 4.1_{sys}$ TeV. The new spectral fit for the ring is compatible with the previous one for the cocoon, confirming the fact that emission observed in the ring also comes from Vela X.

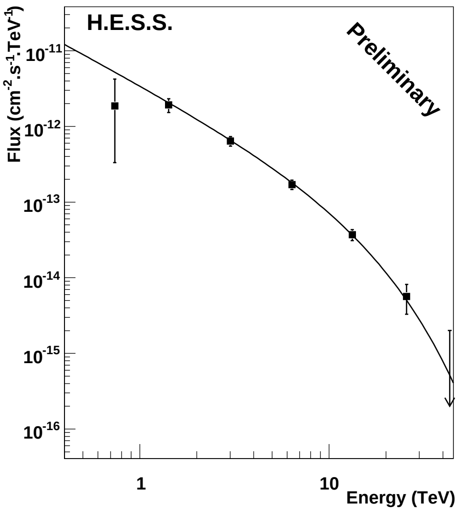

Fig. 1: Spectrum in TeV band of emission from the ring, fitted by a power law function with exponential cut off.

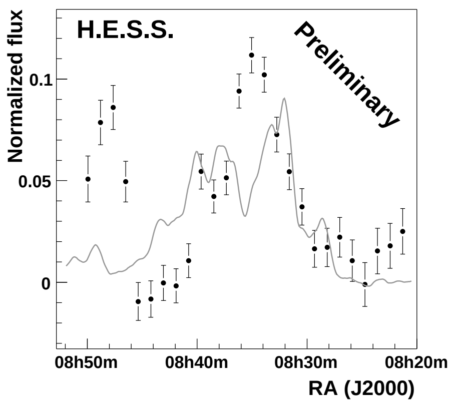

Fig. 2: TeV flux profile in Vela X region along right ascension. The grey line shows the 4.85 GHz radio profile as observed by PMN ([11]), appropriately smoothed for comparison. The peak on the left side of the profile is due to the rim of the supernova remnant RX J0852.0-4622.

C. multiwavelength comparison

A radio map of the Vela X region at 4.85 GHz was obtained in the Parkes-MIT-NRAO Southern Survey ([11]). Fig. 2 shows the radio and TeV profiles of the emission along right ascension. Each TeV flux point is computed by the integration of excess events in boxes of 0.2° width (along the right ascension axis), extending in declination from -46.54° to -44.94°. These plots show that the TeV emission (black dots) extends over essentially the full extent of the radio emission (grey line) of Vela X.

IV. Conclusion

H.E.S.S. observations of the Vela X region since 2004 to 2009 have allowed for a deep investigation of this PWN in the TeV regime. Thanks to the increased observation time, it was possible to detect significant emission in a larger region than the cocoon to 1.2° from the center of gravity. The energy spectrum of photons in such a ring is compatible with the cocoon ones in terms of spectral index and the high energy cut-off, while integrated flux is about a factor 3 less important.

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