Recent results on HESS J1632-478

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cherenkov telescope array

Abstract

HESS J1632-478 is an extended and still unidentified TeV source in the galactic plane.
In order to identify the source of the very high energy emission and to constrain its spectral energy distribution, we used a deep observation of the field obtained with XMM-Newton together with data from Molonglo, Spitzer and Fermi to detect counterparts at other wavelengths. The flux density emitted by HESS J1632-478 peaks at very high energies and is more than 20 times weaker at all other wavelengths probed. The source spectrum features two large prominent bumps with the synchrotron emission peaking in the ultraviolet and the external inverse Compton emission peaking in the TeV.
HESS J1632-478 is an energetic pulsar wind nebula with an age of the order of 10^4 year.
Its bolometric (mostly GeV-TeV) luminosity reaches 10% of the current pulsar spin down power.
The synchrotron nebula has a size of 1 pc and contains an unresolved point like X-ray source, probably the pulsar with its wind termination shock.

Observations

In the period from August to September 2008, XMM-Newton performed 9 observations of a field centered close to HESS J1632-478, collecting data for a total of 92 ks. Standard data reduction procedures were applied using XMM Science Analysis Software (SAS v.9) and selected for the energy ranges 0.2-12 keV for MOS and 0.2-15 keV for pn. Periods with enhanced background due to soft proton flares were disregarded in the analysis, resulting in a total filtered exposures of 87 ks and 62 ks for the MOS and pn cameras respectively. Merging together all the observations we obtained the mosaic image in Fig. 2a, where the extended source is highlighted with the white continuous ellipse.
Zooming inside this ellipse (see Fig. 2b) it is shown an unresolved point-like component with a black continuous line. The point and extended sources have a significances of 15 and 18 σ respectively. We fitted both the point-like and the extended source spectra with an absorbed power-law model and we reported the latter spectrum in Fig. 4.

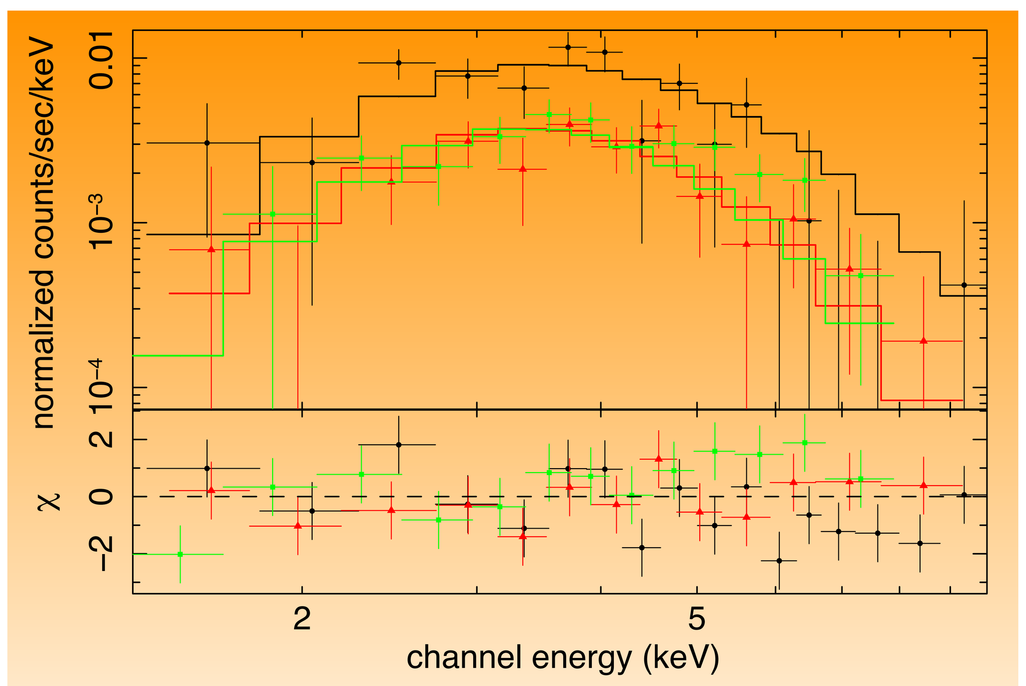

Figure 4. Best power-law fit of the spectra of the extended X-ray source obtained from the three EPIC cameras

The results of the best fit parameters for an absorbed power-law model are summarized in table 1.

Parameter	Point	Extended	Unit
N_H	13^{+6}_{-4}	$11^{+2.2}_{-2.7}$	10^{22} cm^{-2}
Γ	$2.6^{+1.3}_{-0.8}$	$3.4^{+0.6}_{-0.8}$	
$F_{2-10keV}$	$2.3^{+0.3}_{-1.0}$	$4.3^{+0.8}_{-0.4}$	10^{-13} erg cm^{-2} s^{-1}
χ^2_ν	1.8	1.9	

Table 1. Best fit parameters for an absorbed power-law model fitted to the three EPIC spectra on the point-like and extended sources.

We analyzed also the radio energy band using the 2nd Molonglo Galactic Plane Survey (MGPS-2) at 843 MHz [1]. The position of the extended XMM-Newton source lies in a large negative area, caused by artifacts of the image reconstruction, so integrating the excess counts based on a conservative detection threshold of the MGPS-2 survey yields to an upper limit for the flux density of 25 mJy.
This radio excess (see Fig. 1) corresponds well to the position and size of the extended X-ray source, indicated by the white ellipse.
In the infrared energy band between 3.6 and 8 μm we have taken into account the Galactic Legacy Infrared Mid-Plane Survey Extradinaire (GLIMPSE) [2] and we did not find any sign for diffuse infrared emission corresponding to the X-ray and radio counterparts. We extracted a flux density upper limit of ~ 25 mJy at 3.6 μm.
We looked for possible high energy counterpart in the Fermi-LAT first year Catalogue [3], and found two unidentified GeV sources in the neighborhood of HESS J1632-478. Both these sources are flagged with the letter "c", indicating that they are to be considered as potentially confused with interstellar diffuse emission or perhaps spurious detection. It is therefore very unclear if any of these Fermi sources could be a counterpart of HESS J1632-478.
The HESS ellipse is extended with a semi-major axis of (12±3)' and it is parallel to the line joining the two Fermi sources, lying close to the extremity of that ellipse. If the two Fermi sources are real and radiate in the TeVs, the extension and inclination of HESS J1632-478 could be significantly affected by confusion. The VHE spectrum, between 0.2 and 4.5 TeV, can be fitted with a power-law model, yielding a photon index Γ = 2.12 ± 0.20 and a flux above 200 GeV of (28.7 ± 5.3) × 10^{-12} ph cm^{-2} s^{-1}. [4]
Figure 3 shows an extraction from the MIPSGAL survey at 24 μm, in which are reported the position of the diffuse X-ray source (white continuous ellipse), the HESS source extension (white dashed ellipse) and the 95% confidence region for the two FERMI detections.

RADIO

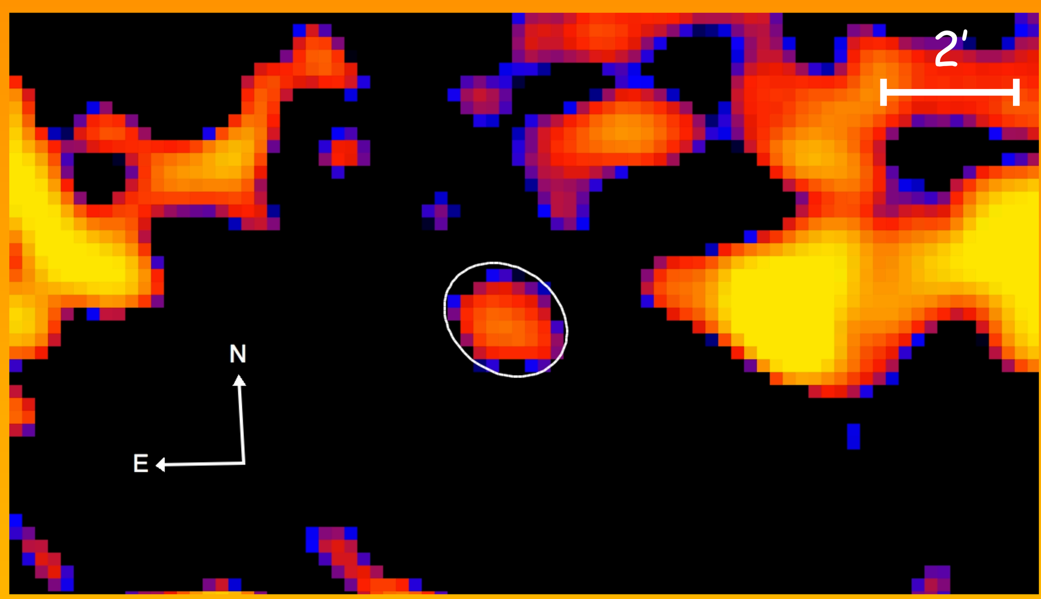

FIGURE 1

X-RAY

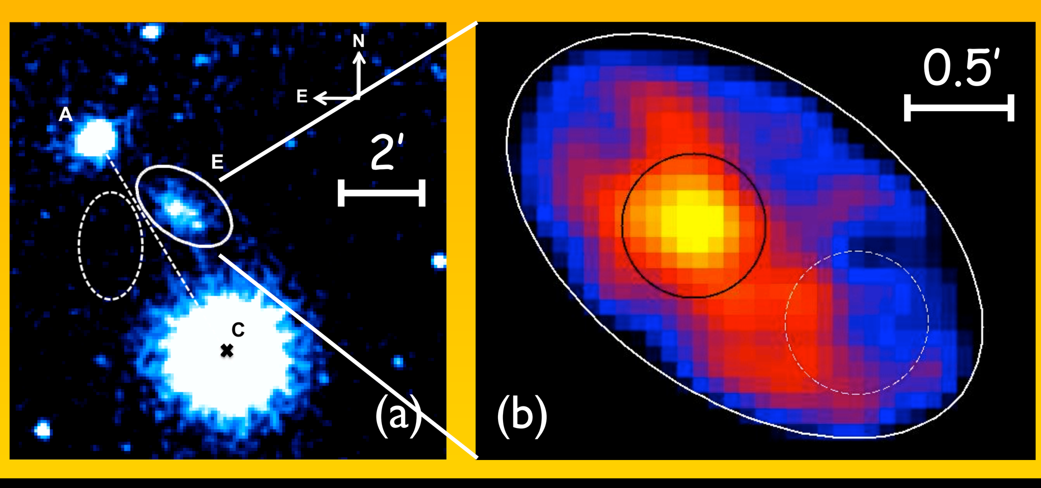

FIGURE 2

INFRARED

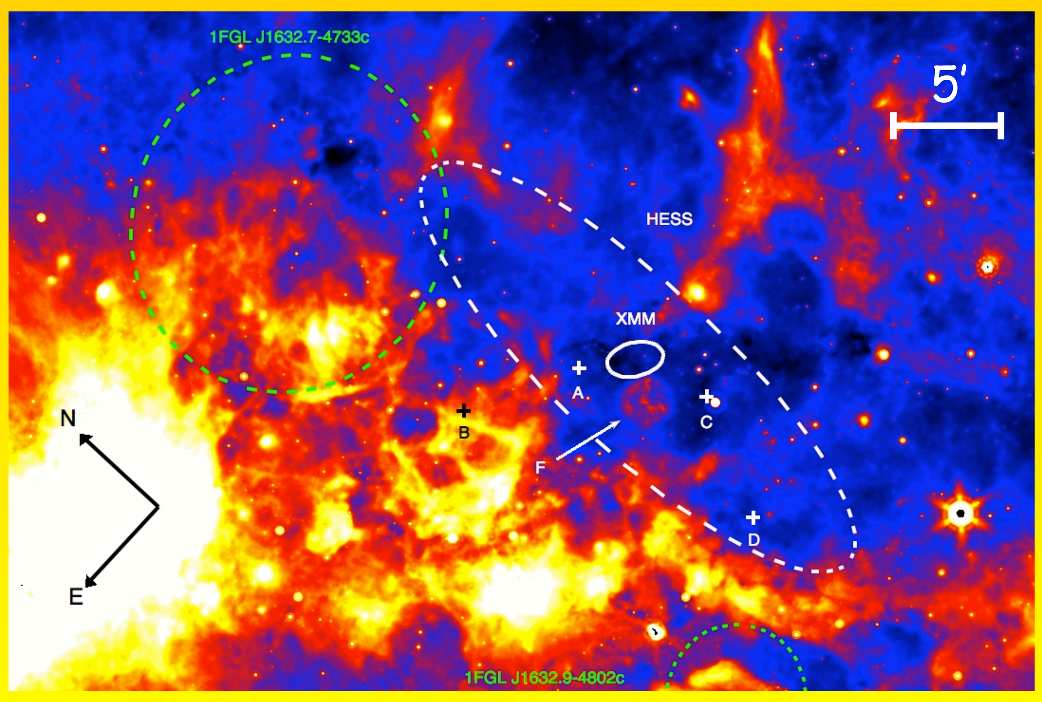

FIGURE 3

Modelling

The XMM-Newton and H.E.S.S. spectra clearly indicate the presence of two spectral bumps matching the expected synchrotron and inverse Compton emission of a Pulsar Wind Nebula. We used a phenomenological description of the electron energy distribution given by Spitkovsky (2008) [5], recently adopted by Fang & Zhang (2010) [6] to model the SED of a sample of PWNs:

$$n(\gamma) = \begin{cases} K\left(\frac{\gamma}{\gamma_c}\right)\exp\left(\frac{\gamma}{\gamma_c}\right) = n_0(\gamma) & \gamma \leq \gamma_1 \\ n_0(\gamma) + K_1\left(\frac{\gamma}{\gamma_c}\right)^{-\alpha}\exp\left(\frac{\gamma}{\gamma_{c1}}\right) & \gamma > \gamma_1, \end{cases}$$

where γ_c is the Lorentz factor of the electrons at the termination shock and we fixed [5] γ_1 = 7γ_c. The resulting SED was obtained using a well tested code [7] and is reported in Fig. 5.

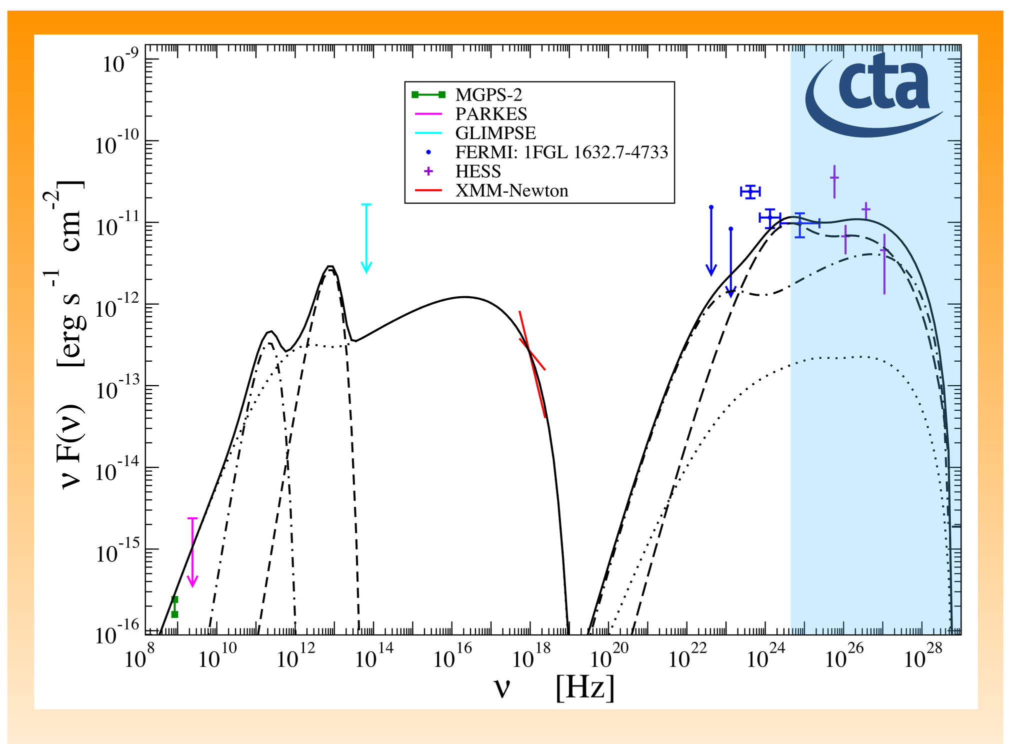

Figure 5. SED of HESS J1632-478. The continuous line indicates the prediction of the model used to represent the emission. CTA energy range is also highlighted in blue.

We reproduced both the synchrotron self Compton and the external Compton emission, assuming a one-zone (post terminal shock) homogeneous emitting region.
The parameters of the model used to represent the emission are reported in table 2.

	Parameter	Value	
Electron distribution	γ_c	1.6×10^5	
	γ_{c1}	1.6×10^8	
	α	2.4	
	N	7.0×10^{-8}	e^-/cm^3
	R	$1.6{\times}10^{18}$	cm
Synchrotron	B	1	μG
External Compton	U^{CMB}_{rad}	0.25	eV/cm^3
	U^{IR}_{rad}	2	eV/cm^3

Table 2. Parameters of the emission model representing the SED of HESS J1632-478 assuming a distance of 3kpc

Conclusions

We observed the unidentified TeV source HESS J1632-478 with XMM-Newton and looked for counterparts in the GeV, infrared and radio bands. An extended faint X-ray source is detected close to the centroid of the H.E.S.S. ellipse. A radio excess corresponding to the X-ray source is found in the Molonglo sky survey. Upper limits have been derived from Spitzer and Parkes data. The GeV image obtained by Fermi shows two close-by sources, but none of them corresponds to the X-ray source. The flux density emitted by HESS J1632-478 at very high energies is at least 20 times larger than observed at the other wavebands probed. The source shape and spectral energy distribution suggests a pulsar wind nebula and can be used to constrain a one zone model for the post terminal shock region of the pulsar wind nebula. The assumed relativistic electron distribution is Maxwellian (γ ~ 10^5) with a non thermal tail extending to γ ~ 10^8. The synchrotron nebula is faint because of the low magnetic field (3 μG).
The point-like X-ray source, detected in the synchrotron nebula, is probably the signature of the pulsar and of the termination shock. The age of the pulsar is estimated as some 10^4 years.
As of today, we only know about one hundred of Galactic sources emitting in the TeV band, and a large part of them are still classified as unidentified. CTA with its better angular resolution and deeper sensitivity, will significantly enrich the current scarce TeV source population, detecting many hundreds of new Galactic sources during its Galactic Plane Survey.

References

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