Observations of the PWN HESS J1857+026 with *Fermi* LAT

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on behalf of the Fermi Large Area Telescope Collaboration

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Abstract :

HESS J1857+026 is a gamma-ray source detected by the HESS Čerenkov telescopes during the Galactic Plane Survey. The TeV source was recently identified as a pulsar wind nebula (PWN) after the discovery of the energetic pulsar PSR J1856+0245. Using more than two years of Fermi-LAT observations, we studied this TeV PWN in detail and detected significant emission coincident with this source. Results from the analysis of the source and the region of interest will be described in detail.

Introduction

HESS J1857+026 was discovered during the Galactic Plane Survey (Ref. 3) but remained unidentified despite multi-wavelength observations. The morphological analysis of the source assuming a 2D elongated Gaussian has shown significant extension of the source (~ 5σ) with a Gaussian intrinsic width of 0.1° in both axes. A power law fit of its spectrum between 600 GeV and 80 TeV yielded a spectral index of (2.39 ± 0.08).

The pulsar PSR J1856+0245 (Ref. 2) was discovered during the PALFA pulsar survey with the Arecibo Radio Telescope 7.31' from the position of HESS J1857+026. This detection lead to the association of HESS J1857+026 as a pulsar wind nebula (PWN) powered by the pulsar. PSR J1856+0245 is a young pulsar (characteristic age of 21 kyr) with a period of 81 ms and a spin-down luminosity of $\dot{E} = 4.6\times10^{36}\ erg/s$. The dispersion measure and NE2001 electron density model of the Galaxy (Ref. 4) assign PSR J1856+0245 a distance of ~ 9 kpc.

X-Ray counterparts of the PWN HESS J1857+026 were found during the ASCA Galactic Plane survey (Ref. 6) providing an opportunity for multi-wavelength studies. Two point sources were associated to the extended PWN and one to the pulsar.

The HESS PWN flux corresponds to a luminosity of $L^{\gamma}_{PWN} = 1.4\times10^{35}\ erg/s$ assuming a distance of 9 kpc which yields a γ-ray efficiency of 3.1 %.

The Region of Interest and W44

Data Set :

The analysis used 31 months of data collected from August 4, 2008, until March 2011. Only gamma-rays in the Pass 6 Diffuse class events were selected and we excluded those coming from a zenith angle larger than 100° because of possible contamination from secondary gamma-rays from the Earth's atmosphere (Abdo et al., 2009). We have used the P6_V11_Diffuse instrument response functions (IRFs).

The Galactic diffuse emission is modeled using the ring-hybrid model gll_iem_v02_P6_V11_DIFFUSE.fit. The instrumental background and the extragalactic radiation are described by a single isotropic component with a spectral shape described by the tabulated model isotropic_iem_v02_P6_V11_DIFFUSE.txt .

W44 :

The region analyzed here includes the bright 20 kyr old supernova remnant (SNR) W44, known to interact with its dense environment. Extended and only 1.3° from our source of interest, W44 could influence the quality of our fit and we decided to refit W44's shape.

SNR W44 was previously modeled with an elliptical ring (Ref. 1). Using more data, we fitted its morphology using the same assumption and its spectrum with a logarithmic parabola model.

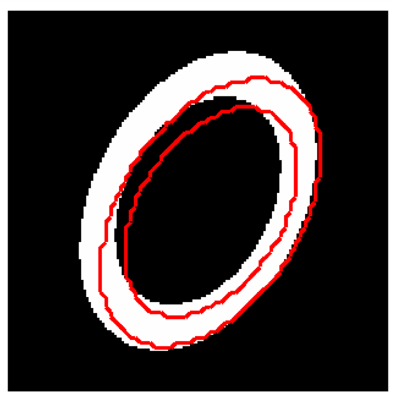

Figure 1 : Comparison between the shape obtained by the model of (Ref. 1) and the shape we derived with the new data set. The fit errors are not shown.

This preliminary analysis was important because W44 is very bright. The fit of W44 (Table 1) gave results consistent with (Ref. 1). This gave us confidence when fitting the diffuse emission normalization to minimize contamination of HESS J1857+026 by the bright SNR.

Model	RA(°)	DEC(°)	Semi Major Axis (°)	Semi Minor Axis (°)	Pos.Ang.(°)
Ref (1)	283,990	1,355	0,300	0,190	327
This Study	284,015 (+/-0,004)	1,392(+/-0,005)	0.335(+0,117/-0,086)	0.207 (+0,023/-0,021)	330 (+/- 25)

Table 1 : Results on the shape of W44 obtained with pointlike with statistical errors. Comparison with previous work (1). All the values are consistent in both cases.

Fermi-LAT Data Analysis

Search for pulsation :

For the timing analysis, a set of photons with energies over 0.1 GeV was selected within a radius of 1.0° with respect to the radio pulsar position (l = 36.0°, b =0.06°) using a cone of energy-dependent radius. This choice takes into account the instrument performance and maximizes the signal to noise ratio over a broad energy range.

The arrival times of events were corrected to the Solar System Barycenter using the JPL DE405 Solar System ephemeris, and the events have been folded using a radio ephemeris from the Jodrell Bank Telescope. A total of 76 observations spanning MJDs 54590 to 55666 were made in a band centred at 1.5 GHz to build the timing solution.

No significant pulsation was detected with the current statistics.

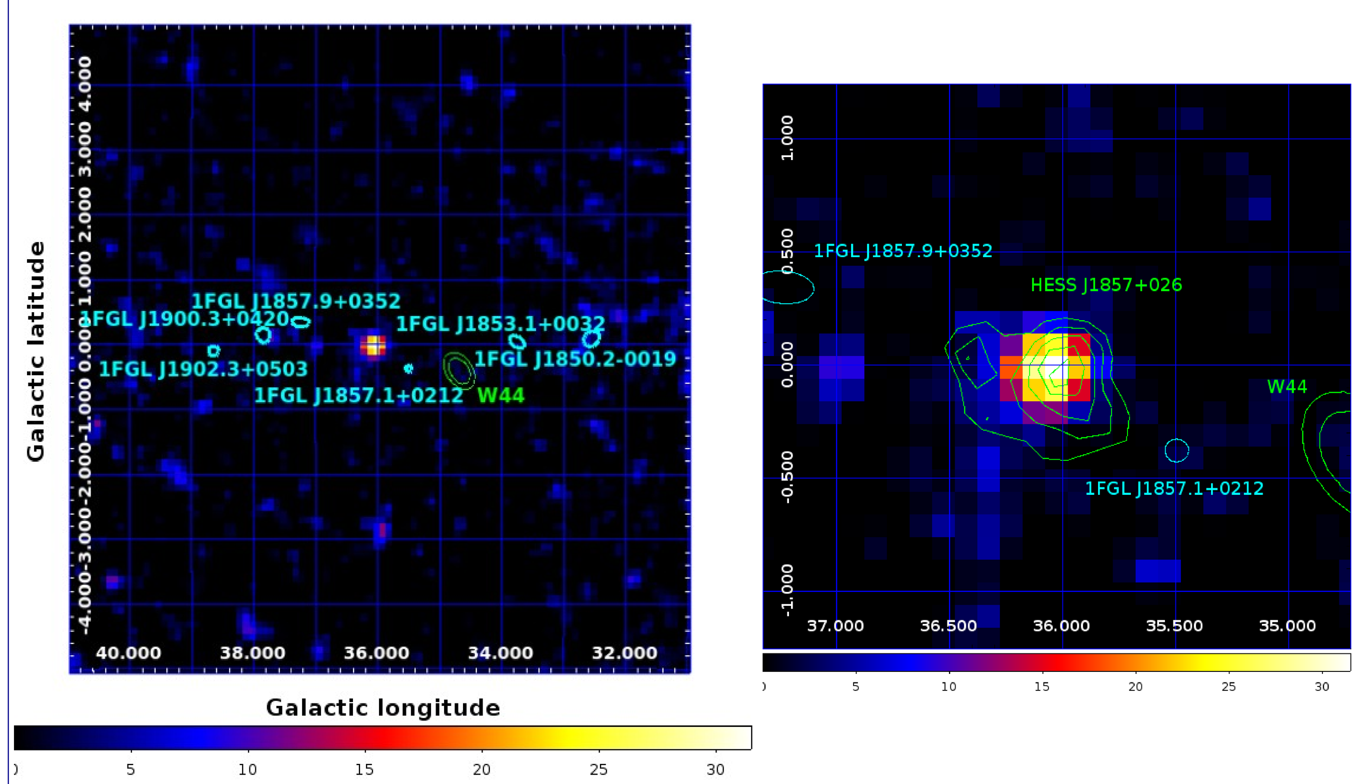

Figure 2 : Excess Test Statistic (TS) map of the source above 10 GeV. The TS was evaluated by placing a point-source at the center of each pixel, Galactic diffuse emission and nearby sources (except HESS J1857+026) included in the fit. **Left :** a region of 8° X 8° with 1FGL Catalog Sources superimposed. **Right :** Zoom up view (X4) centered on HESS J1857+026 with HESS contours in green.

Test for extension (HESS J1857+026) :

To avoid any contamination from other sources or diffuse emission from the Galactic plane we tested for extension above 10 GeV.

In this test all sources from the previous work (W44 left panel) were included in the model. We tested three different shapes for HESS J1857+026 : a point source, a disk and a Gaussian distribution.

Assuming a point source we fitted its position and assuming a diffuse source we fitted its center and extension.

Results are shown in Table 2. We found that the point source model best describes HESS J1857+026 with a centroid at :

$$RA = 284.28° \qquad DEC = 2.74°$$

Which is consistent with the HESS position :

$$RA = 284.3° \qquad DEC = 2.68°$$

Hypothesis	Point	Gaussian	Disk
TS	33.38	41.35	42.21
Δ TS	-	7.97	8.83

Table 2 : Test Statistic obtained by pointlike above 10 GeV for three shape hypotheses (Point, Gaussian, Disk) for HESS J1857+026. No significant extension was found.

Fig. 2 shows an excess Test Statistic Map with HESS contours.

Discussion

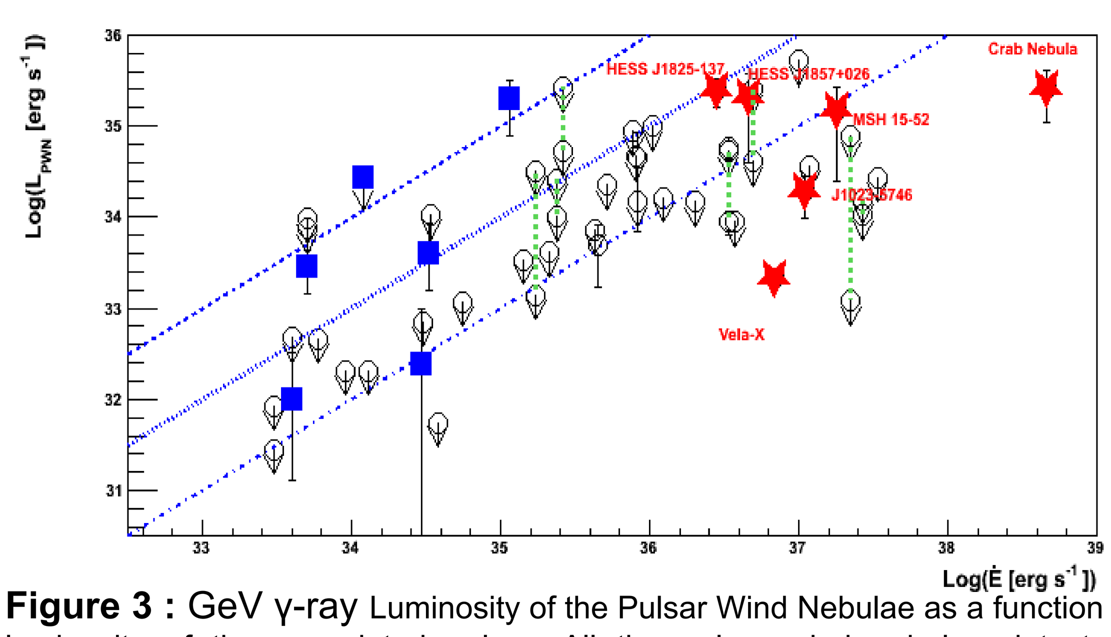

Figure 3 : GeV γ-ray Luminosity of the Pulsar Wind Nebulae as a function of the spin-down luminosity of the associated pulsar. All the pulsar wind nebulae detected by Fermi are associated with young and energetic pulsars. Pulsar wind nebulae detected by Fermi are marked with red stars (✶). Blue squares (■) represent pulsars for which GeV γ-ray emission seems to come from the neutron star magnetosphere, and not from the nebula.

Population Study :

As for other PWNe detected by Fermi, HESS J1857+026 is powered by a young (Age ≤21 kyr) and energetic pulsar ($\dot{E} = 4.6\times10^{36}\ erg/s$). Assuming a distance of 9 kpc, the γ-ray flux obtained using Fermi-LAT data corresponds to a γ-ray luminosity of $L^{\gamma}_{PWN} = 2.05\times10^{35}\ erg/s$ and yields a γ-ray efficiency of 4.4 %.

Although this is one of the highest PWN efficiencies observed in the GeV range by Fermi it is still in the range of expected values and very close to the estimate obtained in the TeV band (~ 3.1 %) using the HESS data.

Fig. 3 is an update of Figure 7 of (Ref. 7) on which we added HESS J1857+026 and HESS J1825-137 (Ref. 8). Pulsar wind nebulae detected by Fermi are marked with red stars. Blue squares represent pulsars showing a plausible magnetospheric emission. Error bars take into account both the statistical uncertainties on the luminosity and the uncertainty on the pulsar distance. Lines correspond to constant γ -ray efficiency: 100% (dashed), 10% (dotted), and 1% (dot-dashed).

References

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