The γ-ray emission toward HESS J1813-178 with *Fermi*-LAT

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Abstract

HESS J1813-178 is one of the brightest and most compact objects detected by the HESS Galactic Plane Survey and MAGIC observations. A young supernova remnant (SNR) G12.8–0.0 locates within the TeV extent of HESS J1813-178. And a pulsar wind nebula (PWN) driven by an energetic X-ray pulsar PSR J1813-1749 is embedded in the SNR, together with a young stellar cluster, C1 1813-178, detected in this region. The origin of the γ-ray emission from HESS J1813-178 is still not clear. Previous studies show that the GeV emission around HESS J1813-178 is much more extended than its TeV emission. With the *Fermi*-LAT data analysis, we did a detailed morphological and spectral analysis in the region of HESS J1813-178 and found that the GeV γ-ray morphology above 20 GeV is much smaller, which is close to the TeV γ-ray contours. Meanwhile, the GeV spectrum above 20 GeV is hard with an index of $\sim$ 2.07, which connects smoothly with that of HESS J1813-178.

Overview Of HESS J1813-178

HESS J1813-178 was detected to be nearly point-like by HESS, and the TeV γ-ray emission shows a power-law spectrum with a rather hard photon index of 2.09$\pm$0.08. HESS J1813-178 is positionally coincident with a young shell-type SNR G12.8-0.0. And deep X-ray observations revealed a PWN embedded in the SNR, which is powered by an energetic pulsar PSR J1813-1749. Meanwhile, a young stellar cluster, C1 1813-178, is discovered in this region, which is associated with SNR G12.7-0.0 and G12.8-0.0 at a kinematic distance of 4.8 kpc, together with the TeV γ-ray emission region of HESS J1813-178. It is still not clear for the origin of the γ-ray emission from HESS J1813-178. Fang & Zhang (2017) predicted that the TeV γ-ray emission is mainly originated from the PWN, although the contribution from the SNR shell could be enhanced with a denser medium. With the *Fermi*-LAT data, Araya (2018) found a much extended GeV γ-ray emission (radius $\sim$ 0.6°) around HESS J1813-178. The global γ-ray spectrum in the energy range of 0.5 - 500 GeV with an index of 2.14$\pm$0.04 is not consistent with the IC emission characteristic from leptons in a PWN. And Araya (2018) argued that the extended GeV emission may be related to the star-forming regions around HESS J1813-178, like W33.

References

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Data Reduction

The following analysis is performed using the latest Pass 8 data with "Source" event class from 2008 August 4 (MET 239557418) to 2021 January 4 (MET 631411205). To avoid a too large point spread function (PSF) in the lower energy band, only events from 1 GeV to 1 TeV are selected. In addition, the events whose zenith angle larger than 90° are excluded to minimized the contamination from Earth Limb. The analysis is performed in a 14° $\times$ 14° square region, and the latest standard LAT analysis software *Fermitools* is adopted. All sources in the fourth *Fermi*-LAT source catalog (4FGL) are included in the model, together with the Galactic (modeled by `gll_iem_v07.fits`) and isotropic (modeled by `iso_P8R3_SOURCE_V2_v1.txt`) diffuse backgrounds. The binned likelihood analysis method with *gtlike* is adopted to fit the data.

Data Results

In the 4FGL catalog, an extended source named 4FGL J1813.1-1737e described by an uniform disk with a radius of 0.6°, is regarded as the GeV counterpart of HESS J1813-178. Using the spatial model recommended in 4FGL, we first investigate the spectrum of 4FGL J1813.1-1737e by dividing the data into 15 equal logarithmic energy bins from 1 GeV to 1 TeV. And The resulting spectral energy distribution (SED) of 4FGL J1813.1-1737e is shown as the black dots in the left panel of Figure 1, and the black arrows represent the 95% upper limits for energy bins with TS values smaller than 4.0. The SED shows a spectral upturn in the energy of $\sim$ 20 TeV. And then we divided the global energy range into two parts: 1 GeV - 20 GeV and 20 GeV - 1 TeV.
For the γ-ray emission in 1 GeV - 20 GeV, we refitted the spatial size of 4FGL J1813.1-1737e using *fermipy*, a `PYTHON` package that automates analyses with the Fermi Science Tools. Adopting the spatial template of an uniform disk, the radius is fitted to be 0.561° at the centroid of (RA., Dec. = 273.379°, -17.677°), which is similar to the values in 4FGL. The spectrum of 4FGL J1813.1-1737e in the energy range of 1 GeV - 20 GeV can be well fitted by a power-law model with an index of 2.49$\pm$0.04, which is shown as the green butterfly in the left panel of Figure 1. And the corresponding photon flux is calculated to be (1.77$\pm$0.06) $\times 10^{-8}$ph cm^{-2} s^{-1}. For the data analysis in 20 GeV - 1 TeV, the γ-ray centroid is fitted to be (RA., Dec. = 273.421°, -17.814°). And the spatial size of 4FGL J1813.1-1737e is much smaller, with a radius of 0.232°. The right panel of Figure 1 shows the γ-ray emission of 4FGL J1813.1-1737e above 20 GeV. And the γ-ray morphology is consistent with the TeV emission from HESS J1813-178 marked as the cyan contours. With the smaller spatial size, the γ-ray spectrum of 4FGL J1813.1-1737e in the energy range of 20 GeV - 1 TeV is hard, with an index of 2.07$\pm$0.20 for a power-law model. And the corresponding photon flux is (1.56$\pm$0.28) $\times 10^{-10}$ph cm^{-2} s^{-1}. The global spectrum is shown as the cyan butterfly in the left panel of Figure 1. And it can be connected smoothly with the TeV spectrum of HESS J1813-178 by HESS and MAGIC, which suggests that the GeV γ-ray emission above 20 GeV may has the same origin with HESS J1813-178.

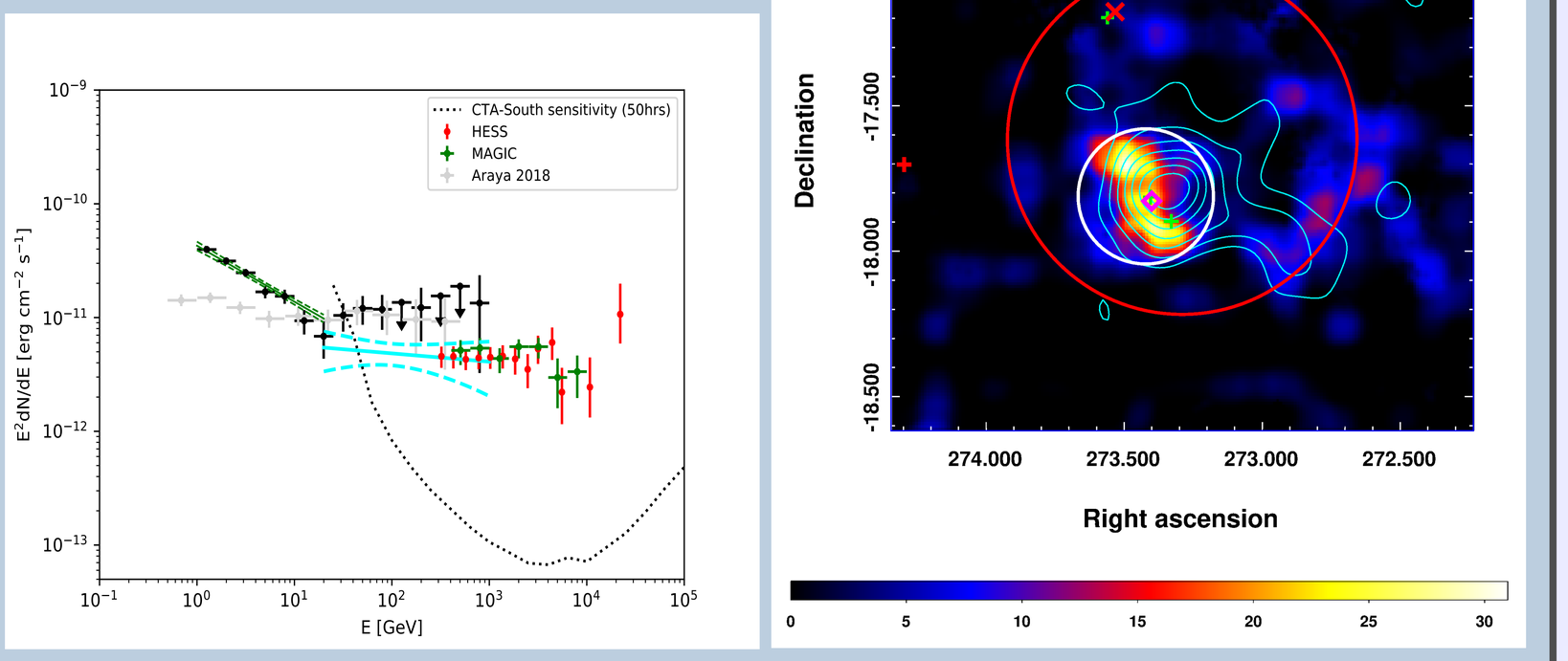

Figure 1: Left: The SED of HESS J1813-178. The black dots depict the results of *Fermi*-LAT data in the energy range of 1 GeV - 1 TeV. The global best-fitting power-law spectra with 1σ statistic errors in the range of 1 GeV - 20 GeV and 20 GeV - 1 TeV are shown as the green and cyan butterflies, respectively. The gray dots are from Araya (2018). The observational data by HESS and MAGIC are marked by the red and green dots. The black dotted line shows the differential sensitivity of Cherenkov Telescope Array in the south hemisphere (CTA-South; 50 hr). Right: TS map for a region of 2.0° $\times$ 2.0° above 20 GeV. The positions of 4FGL sources are shown as the red pluses, and the spatial size of 4FGL J1813.1-1737e is marked by the red circle. The red cross represents 4FGL J1814.1-1710, which is suggested to be associated with SNR G13.5+0.2. The smaller spatial size with the data above 20 GeV is shown as the white circle. The centroid position of the TeV γ-ray emission from HESS J1813-178 detected by HESS is marked by the magenta diamond, and the cyan contours represent the TeV γ-ray emission from HESS J1813-178 detected by MAGIC. Three SNRs in this region (G12.8-0.0, G12.7-0.0, G13.5+0.2) are marked by the green pluses.