Analyzing the Fermi Bubbles with DArk Matter Particle Explorer

Zhao-Qiang Shen (zqshen@pmo.ac.cn), Kai-Kai Duan, Zun-Lei Xu, Xiang Li and Qiang Yuan
on behalf of the DAMPE Collaboration
Key Laboratory of Dark Matter and Space Astronomy, Purple Mountain Observatory, CAS, China

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MOTIVATION

Fermi bubbles consist of two bubble-shaped lobes, each of which is approximately 40° wide and extends to 55° above and below the Galactic center. They are first discovered by Fermi-LAT and thought to be related to the activities from the Galactic center [1,2]. DArk Matter Particle Explorer (DAMPE) is a space-borne high energy particle detector dedicated to measure cosmic rays and photons in a broad energy range [3]. In this work, we use 4.8 years of DAMPE γ-ray data to analyze the emission from the Fermi bubbles and provide an independent observation from the Fermi-LAT. Details can be found in [4].

DATA & METHOD

- **Data preparation**
  - ✓ DAMPE γ-ray data [5] from 2016-01-01 to 2020-10-01 at 2−200 GeV;
  - ✓ Discard the events when DAMPE is in SAA regions or strong solar flares happens;
  - ✓ Define the region of interest (ROI): $5^\circ \leq |b| \leq 60^\circ$ && $|l| \leq 60^\circ$ (see Fig. 1 for the counts map);
  - ✓ Mask 2° regions around the point sources presented in the preliminary DAMPE catalog [6].
- **Method**
  - ✓ Bin the photons into `nside=64` HEALPix projection spatial bins and 20 logarithmically spaced energy bins;

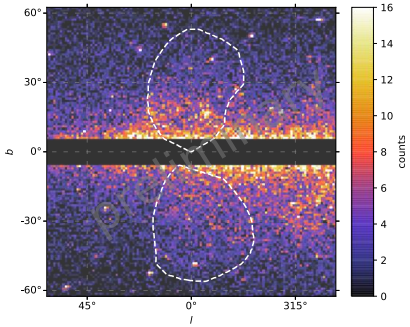

Figure 1. DAMPE counts map within the ROI from 2 GeV to 200 GeV. The point sources are not masked.

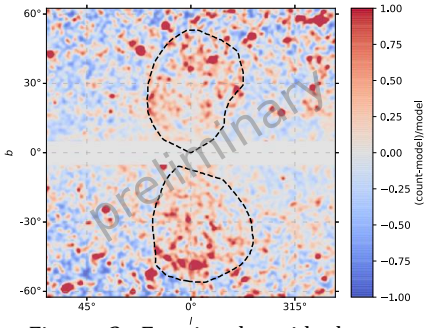

Figure 2. Fractional residual map when the template of Fermi bubbles is not included in the model.

- ✓ Construct the γ-ray model:
  1. Galactic diffuse emission (GDE) model `gll_iem_v02.fit` (LogParabola);
  2. Isotropic template (PowerLaw);
  3. Loop I template [7] (PowerLaw);
  4. Fermi bubbles template [1];
  5. Cocoon template [8] (PowerLaw);
- ✓ Convolve the templates with the IRFs defined in `DmpST` [9];
- ✓ Maximize the binned likelihood function.

RESULTS

- **Null model**

  The fractional residual map of the null model is shown in Fig. 2. An excess of counts is observed inside the Fermi bubbles.
- **Fermi bubbles**
  - ➢ PowerLaw (TS=330.8):
    - Index = -2.01 ± 0.05.
  - ➢ PowelawExpCutoff (TS=339.5):
    - Index = -1.7 ± 0.2;
    - Cutoff energy = 78 ± 40 GeV.

The Fermi bubbles are significantly detected in the DAMPE data (>18σ); the best-fit spectra are shown in Fig. 3; the spectrum is found to be slightly curved (2.9σ).

- **Cocoon**

  The TS value is 11.7 (3.0σ); the 95% confidence level upper limit is shown in Fig. 4.

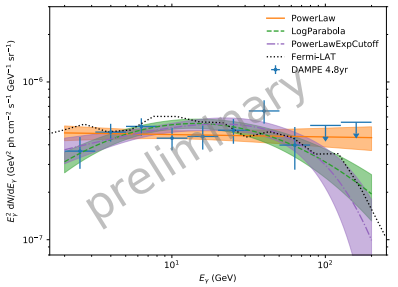

Figure 3. Averaged spectral energy distributions of Fermi bubbles. Upper limits are presented when the TS value is lower than 10.

- **Systematic uncertainty**

  We change GDE model to the templates calculated with the Galprop parameter set $^{S}L^{Z}4^{R}20^{T}150^{C}2$ [10] and refit the model (shown in Fig. 5). The TS values for the Fermi bubbles and cocoon are 281.4 (16.3σ) and 33.2 (5.4σ) respectively.

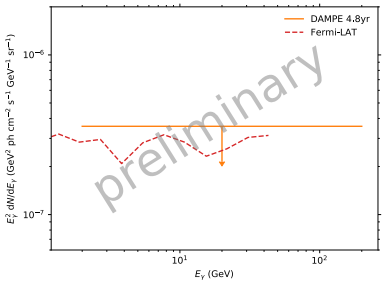

Figure 4. 95% confidence level upper limit on the spectrum of the cocoon. The Fermi-LAT flux is from [2].

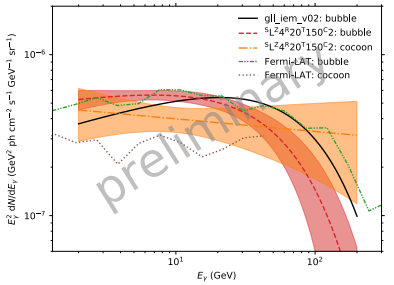

Figure 5. Spectra of the Fermi bubbles and cocoon derived with an alternative Galactic diffuse emission model [10].

References

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