Follow-up Geminga's Contribution to the Local Positron Excess with the HAWC Gamma-ray Observatory

Ramiro Torres Escobedo[1], Hao Zhou[1], for the HAWC collaboration
Mattia Di Mauro[2]
[1]Tsung-Dao Lee Institute & Department of Physics and Astronomy, Shanghai Jiao Tong University, [2]Istituto Nazionale di Fisica Nucleare (INFN) Torino

We acknowledge support by:

Abstract:
The PAMELA and AMS-02 experiments measured an anomalous local positron excess above energies of 10 GeV. The reason for this excess is not well understood but has been considered as indirect evidence of dark matter but could also be produced from nearby pulsars. The HAWC collaboration previously studied the extended gamma-ray emission of two nearby pulsars, Geminga and PSR 0656+14, but found these two pulsars did not contribute a significant amount to this excess. The previous study of HAWC led to the reinterpretation of our result and initiated the concept of inverse Compton (IC) halos. Fitting a new halo model together with 1343 days of data from the HAWC gamma-ray observatory may better constrain the contribution of these pulsars to the positron excess. This halo model utilizes 3D templates of gamma-ray emission from electron IC interactions to fit the diffusion coefficient and electron injection spectral index. This model can further help study the energy-dependent diffusion and incorporate anisotropic diffusion with the proper motion of the pulsar.

Sources & Model

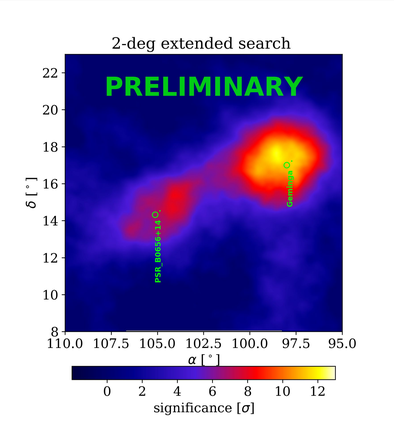

Figure 1: Significance of Geminga and PSR B0656+14 with 1343 days of HAWC data.

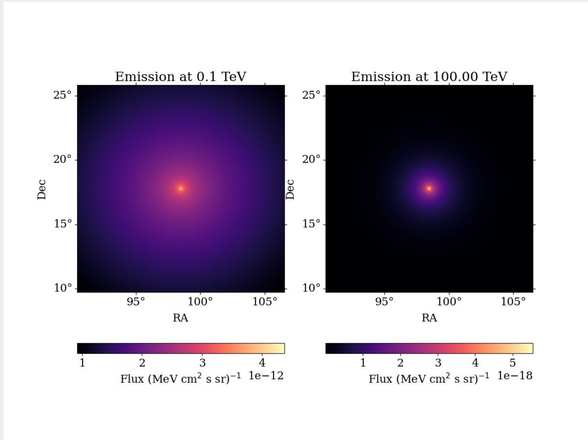

Figure 2: Gamma-ray emission from electron/positron IC interactions for a diffusion coefficient of 1.58×10^{26} cm^2/s at 1 GeV for a spectral index of 2.

Template Model:
- 3D templates of electron inverse Compton (IC) gamma-ray emission [2].
- Model assumes 100% conversion from pulsar spin down energy ($\dot{E}$) to electron/positron emission, $K(\dot{E} \rightarrow e^- e^+)$
- Model can incorporate proper motion of pulsar
- Model allows to study anisotropic diffusion

Analysis & Results

Halo Model:
- Multivariable interpolation of spectral index and diffusion coefficient
- Interpolation of energy, RA, and Dec to fit efficiency $K(\dot{E} \rightarrow e^-/e^+)$
- Diffusion coefficients 10^{25} - 10^{28} cm^{2}s^{-1} and spectral index values 1.5 - 2.4

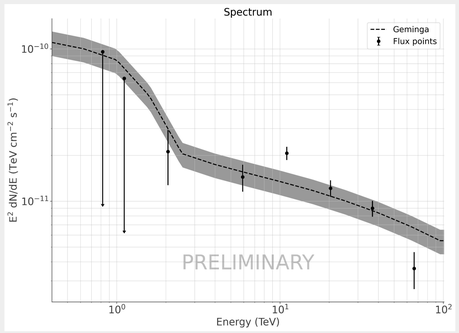

Figure 3: Spectrum for Geminga with new halo model. The fitting parameters for Geminga are diffusion coefficient, spectral index, and $K(\dot{E} \rightarrow e^- e^+)$. Gray band shows statistical error.

Geminga Fit

- $D_0 = (1.58 - 0.24 + 0.23) \times 10^{26}$ cm^2/s at 1 GeV
- $\alpha_e = 1.96 \pm 0.07$
- $K(\dot{E} \rightarrow e^- e^+) = (4.2 \pm 0.8) \times 10^{-2}$
- TS = 287

Comparison to HAWC's derived value [1]
- $D_{100} = (3.30 - 0.50 + 0.48) \times 10^{27}$ cm^2/s (current work)
- $D_{100} = (3.2 - 1.0 + 1.4) \times 10^{27}$ cm^2/s (HAWC, 2017)

Geminga and Monogem

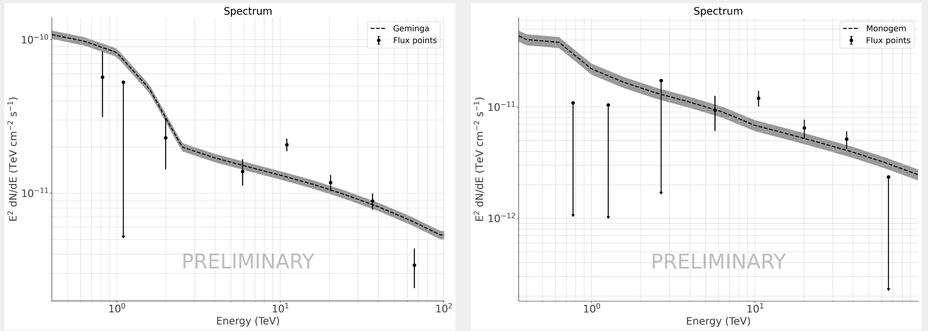

Figure 4: Spectra for joint fit of Geminga and Monogem. The diffusion coefficient and spectral index were fixed for joint fit of Geminga and Monogem to those from Figure 1. The fitting parameters are $K(\dot{E} \rightarrow e^- e^+)$ for Geminga and Monogem.

Geminga
- $K(\dot{E} \rightarrow e^- e^+) = (4.10 \pm 0.25) \times 10^{-2}$
- TS = 289

Monogem
- $K(\dot{E} \rightarrow e^- e^+) = (1.58 \pm 0.17) \times 10^{-2}$
- TS = 91.3

References

[1] U. Abeysekara et al. "Extended gamma-ray sources around pulsars constrain the origin of the positron flux at Earth". In:Science 358.6365 (2017). ISSN: 10959203. DOI:10.1126/science.aan4880.
[2] Mattia Di Mauro, Silvia Manconi, and Fiorenza Donato. "Detection of a γ-ray halo around Geminga with the Fermi-LAT data and implications for the positron flux". In:Physical Review D 100.12 (2019). ISSN: 24700029. DOI: 10.1103/PhysRevD.100.123015.