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Interstellar Magnetic Field Effects on the Asymmetric Structure of Pulsar Halos

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There has been ongoing debate about the potential unconfirmed asymmetric structure of the diffuse γ -ray emission of the Geminga halo. In this work, we adhere to first principles, injecting and propagating individual cosmic ray (CR) electrons in 3D realizations of turbulent magnetic fields characterized by Kolmogorov turbulence and Bohm diffusion. The particle motion is governed by the Lorentz force, and their energy losses are accounted for through synchrotron and inverse Compton scattering. Furthermore, we consider potential regular magnetic field and the inclination angle between the line of sight (LOS) and the magnetic field lines (MFLs) direction, calculating the resulting gamma-ray emission, comparing it with the HAWC surface brightness measurements. We confirmed that the coherence length L_c could be constrained around 1 pc as previous work suggested, the $\chi^2/\text{d.o.f.}$ fitting findings using the HAWC data suggest that the presence of a regular magnetic field has a marginal improvement over a purely turbulent magnetic field. Since Bohm diffusion corresponds to the cosmic-ray-driven instability case, which represents more tangled MFLs and isotropic CRs densities around the injection location, performs worse than Kolmogorov turbulence. This results suggest the possibility of potential filamentary structure inside the Geminga halo, while limited by the resolution of very-high-energy (VHE) detectors, the inner asymmetry structure may be invisible. In extreme situation, such as a large L_c is superimposed with a strong regular magnetic field, when the LOS is coincidentally parallel to the direction of the MFL, the resulting pulsar halo morphology is overall isotropic. However, our results suggest that even in this scenario, the intrinsic filamentary structure would not be disrupted.

Collaboration(s)

Author: LI, Yuan

Co-authors: Prof. GIACINTI, Gwenaél (Tsung-Dao Lee Institute); Prof. LÓPEZ-COTO, Rubén (Instituto de Astrofísica de Andalucía)

Presenter: LI, Yuan

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