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Lessons from HAWC PWNe Observations: The Diffusion Constant is Not a Constant; Pulsars Remain the Likeliest Sources of the Anomalous Positron Fraction; Cosmic Rays are Trapped for Long Periods of Time in Pockets of Inefficient Diffusion

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Recent TeV observations of nearby pulsars with the HAWC telescope have been interpreted as evidence that diffusion of high-energy electrons and positrons within pulsar wind nebulae is highly inefficient compared to the rest of the interstellar medium. If the diffusion coefficient well outside the nebula is close to the value inferred for the region inside the nebula, high-energy electrons and positrons produced by the two observed pulsars could not contribute significantly to the local measured cosmic-ray flux. The HAWC collaboration thus concluded that, under the assumption of isotropic and homogeneous diffusion, the two pulsars are ruled out as sources of the anomalous high-energy positron flux. Here, we argue that since the diffusion coefficient is likely not spatially homogeneous, the assumption leading to such conclusion is flawed. We solve the diffusion equation
with a radially dependent diffusion coefficient, and show that the pulsars observed by HAWC produce potentially perfect matches to the observed high-energy positron fluxes. We also study the implications of inefficient diffusion within pulsar wind nebulae on Galactic scales, and show that cosmic rays are likely to have very long residence times in regions of inefficient diffusion. We describe how this prediction can be tested with studies of the diffuse Galactic emission.

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