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The environment of TeV halo progenitors

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Since the discovery of TeV halos around the Geminga and B0656+14 pulsars by the HAWC experiment in 2017, and around J0622+3749 by LHAASO in 2021, several theoretical efforts have been dedicated to understanding this source class. Surprisingly, the gamma-ray emission hints at a strong confinement of high-energy electron-positron pairs around the pulsar, which challenges our current understanding of the transport of cosmic particles in Galactic environments. Making sense of pulsar halos requires first and foremost knowing the nature of the medium that pairs are released into. In this work, we aim at providing such an information from a population perspective.

We compute semi-analytically the evolution of pulsars and supernova remnants in both star clusters and wind-blown bubbles environments and generate a full Galactic population from a Monte-Carlo sampling of the main parameters of the problem (kick velocities, cluster membership, etc). We eventually produce statistics about the medium where pulsars are to be found at any given age, which can be useful in addressing the question of the origin of TeV halos since some environments can naturally be expected to be more turbulent than others. We specifically examine known nearby pulsars from the ATNF catalog, and give their probability of being inside their parent remnants or superbubbles. We find that most galactic pulsars escape into the interstellar medium at more than 200 kyr instead of the fiducial $lesssim$60 kyr value often quoted in the literature. We discuss the possible implications of these findings on the likelihood that a pulsar develops a TeV halo and on its detectability with current and future gamma-ray detectors, as well as the possible impact on the release of lepton pairs in the Galaxy in connection with the so-called positron excess.

Collaboration(s)

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