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The environment of pulsar 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, many theoretical efforts have been dedicated to understanding this source class. Indeed, assuming that they are probing the environment outside their parent supernova remnant (SNR), the gamma-ray emission hints at a confinement of high energy particles that challenges our current understanding of the CR transport in the average interstellar medium (ISM).
Recent hypotheses, including those proposed by Fang et al. 2020, suggest that such an assumption could be erroneous for middle-aged pulsars. Instead, these pulsars may be located in the downstream of the SNR, where turbulence freshly induced by shock activity significantly alters turbulence conditions.
To settle the issue of the position of the relative position of the pulsar, we propose an evolutionary model which coherently describes the evolution of the SNR as a function of the explosion energy and the ambient gas density and take into account the observed distribution of pulsar kick velocities. These quantities being subject to large variance over the Galaxy, we rely on a Montecarlo approach which gives as a result the probability of a pulsar of a given age to remain behind the SNR.
We also investigate more physically accurate models of pulsars being born in stellar wind bubbles and superbubbles to find the probability of a pulsar being inside a turbulent medium or in the ISM. Finally, considering the pulsar progenitor properties, we give the probability of pulsars of a representative Galactic population being in a turbulent medium as a function of their age.

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