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Acceleration and Transport of the Unstable Cosmic-ray Isotope 60Fe in Supernova-Enriched Environments

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The unstable isotope ^{60}Fe, with a half-life of 2.6 million years, is produced primarily in supernova explosions. The observed presence of ^{60}Fe in cosmic rays and its detection in deep-sea crusts and sediments suggest two possible scenarios: either the direct acceleration of ^{60}Fe from supernova ejecta or its enrichment in the circumstellar material surrounding supernova progenitors, which indicates cosmic ray production in clusters of supernovae. Focusing on the latter scenario, we consider an environment shaped by successive supernova explosions, reminiscent of the Local Bubble around the time of the most recent supernova explosion. We independently tracked the evolution of the ^{60}Fe mass ratio within the Local Bubble using passive scalars. To investigate the spectra of protons and ^{60}Fe, we explicitly modelled cosmic-ray acceleration and transport at the remnant of the last supernova by simultaneously solving the hydrodynamical equations for the supernova outflow and the transport equations for cosmic rays, scattering turbulence, and large-scale magnetic field, using the time-dependent acceleration code RATPaC. The main uncertainty in our prediction of the local ^{60}Fe flux at about $pc = 1$ GeV/nuc is the magnetic-field structure in the Local Bubble and the cosmic-ray diffusion beyond the approximately 100 kyr of evolution covered by our study. We found that if the standard galactic propagation applies, the local ^{60}Fe flux would be around 3% of that measured. If there is a sustained reduction in the diffusion coefficient at and near the Local Bubble, then the expected ^{60}Fe flux could be up to 30% of that measured.

Collaboration(s)

Author: SHI, Xinyue (DESY)

Co-authors: POHL, Martin; Dr SCHULREICH, Michael

Presenter: POHL, Martin

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