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Primordial Nucleosynthesis in Hierarchical Antimatter Domains

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In a baryon-asymmetric Universe, primordial antimatter domains arise from inhomogeneous baryogenesis driven by the Pseudo-Nambu-Goldstone Boson field during inflation. Their evolution is governed by the competition between Hubble expansion and microphysical erosion of the domain boundary via annihilation with surrounding matter. The domain, however, is not homogeneous. Stochastic dynamics of the phase during inflation causes repeated recrossings of the potential barrier, producing a self-similar nested hierarchy: antimatter domains containing baryonic inclusions, which themselves contain antibaryonic inclusions, and so on down to the horizon scale at the end of inflation. The key consequence for nucleosynthesis is that annihilation proceeds throughout the volume, not on a single outer boundary. At t =100 s, free neutrons diffuse to the internal interfaces and annihilate there, suppressing primordial helium-4. High-energy photons from pion decay photodissociate helium-4 nuclei, significantly raising the helium-3 to helium-4 ratio, while nonthermal reactions overproduce lithium-6. This provides a unique chemical signature for antimatter astrophysical objects such as anti-stars or globular clusters. On the other side nonhomogeneity of antimatter domain facilitates formation of antimatter objects of stellar mass, which can be source of antihelium-4 in cosmic rays. Current models predict an anti-helium flux within reach of the AMS-02 experiment. Consistency with cosmic microwave background and diffuse gamma-ray observations sets a strict upper limit on the fraction of annihilated antimatter, imposing strong constraints on models of inhomogeneous baryogenesis.

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