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New bounds on macroscopic scalar-field topological defects from non-transient signatures due to environmental dependence and spatial variations of the fundamental constants

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We point out that in models of macroscopic topological defects composed of one or more scalar fields that interact with standard-model fields via scalar-type couplings, the back-action of ambient matter on the scalar field(s) produces an environmental dependence of the fundamental constants of nature, as well as spatial variations of the fundamental constants in the vicinity of dense bodies such as Earth due to the formation of a "bubble-like" defect structure surrounding the dense body. In sufficiently dense environments, spontaneous symmetry breaking may be inhibited altogether for ϕ^2 interactions, potentially delaying the cosmological production of topological defects to rather late times. We derive bounds on non-transient variations of the fundamental constants from torsion-pendulum experiments that search for equivalence-principle-violating forces, experiments comparing the frequencies of ground- and space-based atomic clocks, as well as ground-based clocks at different heights in the recent Tokyo Skytree experiment, and measurements comparing atomic and molecular transition frequencies in terrestrial and low-density astrophysical environments. Our results constrain the present-day mass-energy fraction of the Universe due to a network of infinite domain walls produced shortly after the BBN or CMB epochs to be $\Omega_{\mathrm{walls},0} \ll 10^{-10}$ for the symmetron model with a ϕ^4 potential and ϕ^2 interactions, improving over CMB quadrupolar temperature anisotropy bounds by at least 5 orders of magnitude. Our newly derived bounds on domain walls with ϕ^2 interactions via their effects of non-transient variations of the fundamental constants are significantly more stringent than previously reported clock- and cavity-based limits on passing domain walls via transient signatures and previous bounds from different types of non-transient signatures (by about 10 orders of magnitude for wall thicknesses comparable to the size of Earth), under the same set of assumptions.

Reference: [Stadnik, PRD **102**, 115016 (2020)]

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