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Tachyonic gravitational dark matter production after inflation

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Abstract

We propose a novel gravitational mechanism for the non-thermal production of dark matter driven by curvature-induced tachyonic instabilities after inflation. Departing from the commonly studied non-minimal couplings to gravity, our framework considers a real scalar field coupled quadratically to spacetime curvature invariants. We show that the rapid reorganization of spacetime curvature at the end of inflation can dynamically render the dark matter field tachyonic, triggering a short-lived phase of spontaneous symmetry breaking and explosive particle production. As a concrete and theoretically controlled example, we focus on the Gauss–Bonnet combination. By combining analytical estimates with fully non-linear 3+1 classical lattice simulations, we track the out-of-equilibrium evolution of the system and compute the resulting dark matter relic abundance. We find that this purely gravitational mechanism can robustly reproduce the observed dark matter density over a wide range of masses and inflationary scales, providing also simple fitting functions that enable a lattice-independent application of our results.

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