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Primordial Black Hole Formation for Scalar Field - Perfect Fluid Dominated Systems with Full General Relativity: The Case of a Scalar Field Dominated Universe

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In this work, we introduce a numerical code that solves the Misner-Sharp formalism for a spherically symmetric cosmological model containing both a scalar field and a perfect fluid. While the code is capable of exploring general scenarios involving an uncoupled scalar field and perfect fluid, our current research focuses on the regime where the scalar field dominates the dynamics. As an initial application, we investigate a post-inflationary scalar field-dominated scenario, in which the universe is governed by a rapidly oscillating scalar field for an extended period. We analyse the threshold for PBH formation under quadratic and quartic potentials, considering perturbations that are initially on superhorizon scales. Our results confirm that a quartic potential behaves analogously to a radiation-dominated universe, resulting in a PBH formation threshold close to the well-established value in radiation backgrounds. Conversely, in the quadratic potential case, we observe a significant deviation from dust-like behaviour, where wave-like effects counteract gravitational collapse. While numerical limitations prevent us from evolving a wide range of initial conditions to determine a precise threshold for PBH formation, our findings suggest that PBH formation may be suppressed in this scenario, potentially allowing the formation of stable solitonic structures instead. This study highlights the importance of properly accounting for wave dynamics in oscillating scalar fields when determining PBH formation criteria.

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