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Gravitational Waves and Primordial Black Holes in First-Order Phase Transitions

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Many extensions to the Standard Model are expected to yield first-order phase transitions (FOPTs) which could produce detectable signals of gravitational waves (GWs) and observable abundances of primordial black holes (PBHs). We study such FOPTs within conformal $B - L$ models, which naturally accommodate stronger GW signals due to supercooling. By scanning large regions of parameter space, we compute GW spectra across symmetry breaking scales and find signals spanning the sensitivities of planned experiments including THIEA, LISA and aLIGO. We correlate these spectra with PBH abundances to identify viable multi-messenger benchmarks.

Whereas many analyses rely on approximate criteria for horizon formation or fixed density-contrast thresholds in determining PBH collapse, we employ a relativistic method originally developed by Blau, Guendelman, and Guth (1987). This approach maps the dynamics of false-vacuum remnants onto an effective one-dimensional potential, where the turning point marks the onset of collapse. Using this formalism, we obtain a reliable connection between microscopic particle physics and macroscopic PBH formation at a low computational cost. Together with the GW analysis, this framework provides a systematic and testable bridge between early-universe physics and present-day observations.

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