Cosmic Phase Transitions and Gravitational Waves: a quest for physics beyond the Standard Electroweak Model

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ABSTRACT

The first detection of Gravitational Waves (GWs) in 2015 has opened a new window into the early Universe, providing a powerful tool to explore phenomena beyond the reach of electromagnetic observations. This dissertation explores cosmic First-Order Phase Transitions (FOPTs) as a compelling source of GWs, which also offers a plausible explanation to a key shortcoming of the Standard Model (SM) of particle physics, the observed matter-antimatter asymmetry of the Universe, via electroweak baryogenesis (EWBG) mechanism. In parallel, this thesis explores another fundamental open question, the nature of dark matter (DM), with particular attention to Weakly Interacting Massive Particles (WIMPs). The SM neither predicts a FOPT, essential for the EWBG mechanism, nor provides a viable particle DM candidate, despite strong astrophysical and cosmological evidence for the latter.

To address these limitations, this dissertation investigates three well-motivated beyond-the-Standard-Model (BSM) scenarios, focusing on the two interconnected aspects of the early Universe: FOPTs and DM production, with particular emphasis on the possibility of multi-component WIMP DM frameworks. With the upcoming GW detectors like LISA, BBO, DECIGO and its variants, we analyse GW signals arising from strong FOPTs using both the conventional and improved novel methods, aiming to constrain viable BSM parameter spaces. By examining the complementary insights from various DM direct and indirect experiments, relic abundance and GW observatories, alongside collider searches, this thesis refines the landscape of the BSM scenarios and offers robust predictions to distinguish between BSM models in future experiments across different energy frontiers.

References

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