



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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SHORT ABSTRACT

This thesis investigates the longstanding cosmological puzzles of baryon asymmetry and dark matter, with a focus on probing their origins through stochastic gravitational wave (GW) signatures arising from early Universe dynamics. The persistent null results from conventional dark matter searches, direct detection experiments such as XENONnT, LUX-ZEPLIN, PandaX-II as well as large hadron collider (LHC) experiments and the inaccessibility of high-scale baryogenesis mechanisms in these experiments strongly motivate the exploration of gravitational wave astronomy as a complementary probe. In particular, first-order phase transitions (FOPT), associated with spontaneous symmetry breaking in the early Universe, are highlighted as natural sources of stochastic GW while simultaneously playing a crucial role in particle mass generation and asymmetry production. The thesis begins with a review of the observational evidences for dark matter and baryon asymmetry together with popular theoretical frameworks explaining their origins. It then introduces some of the mechanisms of gravitational wave production in the early Universe, with emphasis on FOPT, domain walls, and primordial black holes (PBH) generated signals within the reach of existing and near future detector sensitivity, such as NANOGrav, μ ARES, LISA, DECIGO, CE, LIGO, etc. Based on these foundations, we have investigated some production mechanisms of dark matter and baryon asymmetry connecting them to phase transitions associated with symmetry breaking that play an important role in the dynamics of the early Universe. A central concept discussed is the mass-gain mechanism, wherein particles remain massless in the symmetric phase and acquire mass upon crossing the bubble wall during a FOPT, thereby impacting efficiency of baryogenesis via leptogenesis and dark matter relic abundance. The thesis also explores the filtering effect during the expansion of true vacuum bubbles in a FOPT, where selective transmission of dark sector particles with non-zero chemical potential across the phase boundary can lead to the formation of PBH. Depending on their mass, such PBH may evaporate to produce dark matter particles or survive themselves as present day dark matter candidates. After showing the possibility of a doubly-peaked GW spectrum in a scenario with ultra-light PBH formation

during a FOPT, we also propose a novel filteredogenesis mechanism which connects PBH dark matter and visible sector asymmetry through selective transmission of dark fermions across expanding bubble walls. Furthermore, the thesis examines gravitational wave signals arising from topological defects, such as domain walls, generated via discrete symmetry breaking in scenarios like minimal Dirac seesaw and Left-Right Symmetric Models (LRSB). The annihilation of such domain wall networks can produce GW in the nano-Hz range, offering a compelling interpretation of recent PTA observations and a novel connection between neutrino mass generation, leptogenesis, and gravitational wave phenomenology.

