INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
PhD-17 SHORT ABSTRACT OF THESIS

Name of the Student	:	Suresh Chand
Roll Number	:	176121102
Programme of Study	:	Ph.D.

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Name of Thesis Supervisor(s)	:	Dr. Debasish Borah, Dr. Pankaj Kumar Mishra
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SHORT ABSTRACT

The nature of dark matter (DM) and the origin of the baryon asymmetry of the Universe (BAU) remain two of the most compelling open questions in contemporary particle physics and cosmology. Since the proposal of dark matter in 1933 by Fritz Zwicky, and its subsequent confirmation through observations of galaxy clusters, the cosmic microwave background (CMB), and large-scale structure, the search for a viable DM candidate has remained a central focus of modern cosmology. In parallel, the observed matter–antimatter asymmetry of the Universe continues to challenge the Standard Model (SM), motivating a variety of baryogenesis mechanisms, including leptogenesis.

This thesis presents a unified framework that connects low-scale leptogenesis with the dark matter sector. We consider a minimal extension of the Standard Model involving three right-handed neutrinos, a charged scalar, and a neutral fermion. In this setup, the decay of right-handed neutrinos, together with interactions in the dark sector, can simultaneously account for the observed baryon asymmetry and the present-day dark matter relic abundance. CP-violating effects arising from both visible and dark sector interactions play a central role in generating the required asymmetry.

The model unifies leptogenesis and dark matter production within a single framework. In particular, feeble interactions between dark sector states and right-handed neutrinos allow successful low-scale leptogenesis for right-handed neutrino masses of order ~2 TeV, without requiring the resonant enhancement typically invoked in high-scale scenarios. Furthermore, the framework naturally accommodates asymmetric dark matter, where dark sector dynamics contribute to the generation of the final lepton asymmetry.

This establishes a direct dynamical relation between the dark sector and baryogenesis, providing a coherent explanation for both the BAU and DM relic density.

This thesis is structured as follows. Chapter 1 introduces the observational evidence and theoretical foundations of DM and BAU. Chapter 2 discusses the limitations of the Standard Model and reviews relevant beyond-the-Standard-Model (BSM) scenarios. Chapter 3 presents the proposed minimal extension and its role in generating both the baryon asymmetry and dark matter abundance. Chapter 4 provides a detailed analysis of leptogenesis with CP phases induced by dark matter interactions, along with phenomenological implications and collider signatures.

Chapter 5 summarizes the results and concludes the thesis, outlining possible directions for future work.

This study aims to provide a unified explanation of two fundamental problems in physics, potentially linking early-Universe cosmology with testable predictions at high-energy colliders such as the Large Hadron Collider (LHC).