INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

Name of the Student	:	Soumen Kumar Manna
Roll Number	:	196121028
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Aspects of (pseudo) Nambu-Goldstone Bosons in Physics Beyond the Standard Model

Name of Thesis Supervisor(s)	:	Prof. Arunansu Sil
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SHORT ABSTRACT

This thesis explores the phenomenology of two prominent pseudo-Nambu-Goldstone bosons, the Majoron and the Axion-like Particles (ALPs), as an effective and minimal way to address some of the most profound puzzles in particle physics and cosmology, such as the nature of dark matter, the origin of neutrino masses, and the existence of matter-antimatter asymmetry of the Universe. These light and feebly interacting particles naturally emerge from the spontaneous breaking of approximate global symmetries, establishing themselves not only theoretically appealing, but also highly relevant for experimental searches. We first explore Majorons, the pseudo-Nambu-Goldstone bosons associated to global lepton number symmetry breaking, as a viable freeze-in dark matter, where dimension-5 lepton number violating terms play the central role not only in producing the dark matter Majoron over a broader mass range (in keV-GeV), but also in facilitating high-scale resonant leptogenesis via right-handed neutrino mass splitting. In the next part, we turn our attention to ALPs, a generalization of the QCD axion, which was originally introduced to resolve the strong CP problem in the Standard Model. Although ALPs do not necessarily solve the strong CP problem, they offer a much wider parameter space to explore, as their mass and decay constant are independent parameters, in contrast to the QCD axion. In this context, we first examine their evolution as coherently oscillating dark matter via the well-known misalignment mechanism in presence of a Standard Model Higgs boson-assisted global symmetry breaking interaction, which results into a significantly enhanced allowed parameter space, and further achieve low-scale spontaneous leptogenesis, driven by ALP-induced CPT violation and an inert Higgs doublet assisted lepton number breaking interaction. Lastly, we explore an ALP-portal fermionic dark matter scenario at electron-positron colliders, emphasizing on the distinctive mono-photon plus missing energy signature. Across these studies, explicit symmetry breaking operators play a crucial role in solving some of the open problems of particle physics and cosmology, while preserving the models theoretically economical.