INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

Name of the Student	:	RAJESH MONDAL
Roll Number	:	206121024
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Name of Thesis Supervisor(s)	:	Prof. Debaprasad Maity
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SHORT ABSTRACT

We are currently in the era of precision cosmology, which offers us a unique opportunity to investigate beyond the Standard Model (SM) of physics. Toward this endeavor, the inflaton and Dark Matter (DM) are assumed to be natural new physics candidates. It is believed that reheating takes place right after inflation, during which all the SM particles are produced. Interestingly, reheating not only explains the cosmic origin of visible matter but also provides a mechanism for the production of other cosmological relics, such as DM. Furthermore, reheating can also affect the observational predictions of the preceding phase of inflation. Thus, reheating offers a promising playground for the phenomenological study of inflation and DM within a unified framework, which has been studied extensively in this thesis. Wefirst studied the dynamics of reheating for a general inflaton equation of state (EoS), considering both gravitational and non-gravitational interactions between the inflaton and radiation. We showed that, depending on the EoS and the nature of the inflaton's decay products (radiation), thermal effects can play a significant role in the reheating process. We have constrained key microphysical parameter, namely the non-gravitational inflaton coupling, in terms of the inflaton EoS, the reheating temperature, and the CMB spectral index. Furthermore, we analyzed the implications of the reheating dynamics for the DM phenomenology, considering both thermal and non-thermal production of DM. The non-trivial expansion and thermal history during reheating significantly impact the viable DM parameter space, potentially enlarging the regions accessible to future experiments. This opens a promising, indirect window to probe the early Universe in laboratory settings. Then, we explored the impact of the latest observation of Planck and BICEP/Keck data on the inflaton phenomenology. Due to the lack of direct experimental probes, both the inflationary and post-inflationary parameters, like inflationary e-folding number, reheating temperature, inflaton couplings, etc, remain largely unconstrained. Using the latest constraints on CMB from Planck+BICEP/Keck, we derived detailed phenomenological constraints on inflationary and post-inflationary parameters. Finally, we propose a novel reheating scenario governed by the right-handed neutrinos (RHNs) in the well-known Type-I seesaw framework embedded in the SM. Our scenario represents the most minimal possible framework, as it does not introduce any new interactions beyond the SM, except for gravity. We call this scenario gravitational neutrino reheating, abbreviated as νGRe. Interestingly, νGRe not only offers successful reheating but also solves the well-known neutrino mass and baryon asymmetry problems. This vGRe constrains a large class of inflation models, RHN masses, and predicts a non-vanishing lightest active neutrino mass. Overall, this thesis demonstrates how reheating serves as a unifying bridge between inflation, dark matter, and particle physics, allowing these seemingly disparate sectors to be constrained within a single framework. By combining theoretical modeling with state-of-the-art cosmological observations, it shows how precision cosmology can indirectly probe physics at energy scales far beyond the reach of terrestrial.