Despite tremendous success of the standard model of cosmology (see for example [1; 2; 3]), in explaining ‘recession of galaxies’, ‘Big Bang Nucleosynthesis’ (BBN), the origin of ‘Cosmic Microwave Background Radiation’ (CMBR) etc., it fails to solve the horizon problem, flatness problem, monopole problem and the singularity problem related to the early universe. It was soon realized that the singularity problem may be alleviated only after replacing general theory of relativity (GTR) by a quantum theory of gravity at the Planck scale. Attempts in this line was initiated by Utiyama and De-Witt [4]. All such attempts ended up with the understanding that General Theory of Relativity is non-renormalizable and for a renormalized theory, Einstein–Hilbert action should be replaced by adding higher order curvature invariant terms. However, it was Stell [5], who first provided a renormalized theory of gravity in 4-dimension but at the cost of losing unitarity. It is now known that gravity does not provide a renormalized theory in 4-dimension. It is now hoped that a modified version of string theory or supergravity theory might provide a well behaved quantum theory of gravity in future. In the absence of a successful quantum theory of gravity, study of quantum cosmology was initiated with an understanding that it might provide new physics to understand the situation better at the Planck’s scale. One such attempt was invoked by suggesting wormholes [6], which is one of our topics. To get a better understanding of quantum cosmology it is also required to provide a formalism in connection with canonical formulation of higher order curvature invariant terms. However, such attempt is possible only if supplementary boundary terms associated with such scalar curvature invariants are available. In this regard, there has been much attempt in the literature to make such formulation for curvature-squared action. However, viable quantum description of curvature-squared action via non-perturbative canonical approach has been presented by Sanyal [7]. Here, in this present dissertation, following Sanyal’s prescription [7] canonical formulation of the scalar curvature-squared action in the presence of a lapse function has also been presented. Later, it has been extended to arbitrary higher dimensions. These are the main topics which have been included in this dissertation.

Although the issue of singularity is still far from being resolved, other problems of standard model had been addressed successfully in the past. In the Eighty’s, Alan Guth and others [8] - [12] suggested an early inflationary regime to resolve the three problems, viz., horizon, flatness and unwanted relics, monopoles in particular. Note that the problems of homogeneity and isotropy are bye products of the horizon problem. With lot of evidence it is now accepted that the universe had experienced an inflationary regime prior to the hot big bang, which must not be thought of as a singularity now, rather is a hot soup of plasma required to explain BBN, CMBR, large scale structure formation etc. In the process, the singularity has been pushed back even earlier, where as already mentioned GTR should be replaced by an appropriate Quantum theory of gravity. We would also like to mention that any such theory of Quantum gravity contains scalar curvature squared term in the action under weak energy limit and such a term automatically results in inflation without phase transition [12]. Such a term also solves the problem of graceful exit through reheating giving way to the hot big-bang required for nucleosynthesis, Baryogenesis, structure formation etc.

Once the theory of Inflation has been accepted being confirmed by certain experiments, it was thought that the major problem has been resolved since the late time cosmic evolution appeared
to be perfectly in tune with the standard model prior to late nineties. However, recent SNe Ia supernovae observation [13] - [16] convincingly suggested that the universe is undergoing a late time accelerating era. There are also some other observational evidences for cosmic acceleration. So, presently it is a challenge to the physicists to solve the puzzle. It is clear that the root of such an accelerating epoch is the presence of negative pressure caused by of some sort of exotic matter or field which is not admissible in the standard cosmological model as it requires violation of energy conditions. We therefore have to go beyond the standard model, once again. In the literature, there are numerous proposals of non-standard models, viz., cosmological constant (ΛCDM) model, scalar-field model, modified theory of gravity, particle creation at expense of gravitational field etc. to address this late time acceleration. In this dissertation we have addressed two such models, viz., modified theory of gravity and particle creation phenomena.

The scheme of the present dissertation is the following. Standard model of cosmology and its consequent problems in different era have been discussed in chapter-1. The singularity problem, inflationary paradigm, some recent celebrated observations and there outcomes, dark energy and its different sources have also been discussed in the same chapter. Chapter-2 is devoted to discuss some aspects of $F(R)$ theory. In chapter-3, it has been shown that late time acceleration may be achieved without dark energy via particle (CDM) creation mechanism. Canonical formulation of the curvature-squared action in the presence of lapse function has been presented in chapter-4. A detailed study of quantum and semiclassical Euclidean wormholes for Einstein’s theory with a minimally coupled scalar field has been performed for a class of potentials in chapter-5. Finally, we end up with conclusion in chapter-6.

Bibliography