

Preface

General Relativity (GR) is a very successful theory and is the best formalism we have to describe the geometrical properties of the spacetime. It has passed all the experimental and observational scrutinies so far, ranging from local tests like perihelion precession and bending of light to precision tests using pulsars.

In spite of these outstanding successes there still remain some unresolved issues, suggesting that general relativity is not complete. The most important reason is the presence of singularities in many physical situations leading to a loss of predictability. Another reason has to do with the fact that the horizons in general relativity possess thermodynamic properties like temperature and entropy. Within the framework of general relativity, there is no natural explanation for this “thermodynamic” interpretation and it provides motivation to take a fresh look at the theory. A third reason arises from the fact that all the other known interactions (electromagnetic, weak and strong) are described by quantum theories, while gravity alone is still described by a classical theory. This laid the foundation of the belief that “quantum theory of gravity” awaits discovery. The attempts to obtain a perturbative quantum general relativity, taking a cue from the quantization of the other forces, has not succeeded. This has the unavoidable conclusion: we need to modify our understanding of quantum field theory or the understanding of general relativity or both.

In this thesis, we try to understand the thermodynamic nature of general relativity better by taking a closer look at the structure of general relativity and its higher curvature cousins, collectively called Lanczos-Lovelock gravity. If one can derive a result in the context of Lanczos-Lovelock gravity, the result for general relativity is encompassed by it as well. We shall analyze the geometrical structure of Lanczos-Lovelock gravity (which has general relativity as a special case) leading to the inescapable connection between gravity and thermodynamics. We will also have occasion to talk about Virasoro algebra associated with an arbitrary null surface and associated entropy in this context.

As a complementary approach towards a quantum theory of gravity, we study some aspects of quantum field theory in curved spacetime. The specific issues addressed in this context include: (a) What can we say about classical singularities

from the viewpoint of quantum theory? This specifically requires one to probe quantum fields inside the black hole horizon. (b) Is the retrieval of information from an evaporating black hole possible? (We will show that distortions to the thermal spectra of a particular kind, referred to as non-vacuum distortions can be used to fully reconstruct a subspace of initial data.) (c) Can Rindler effect be present for geodesic observers? We illustrate for a specific (1+1) black hole spacetime, there are geodesic observers who are confined to a flat region of the spacetime and hence will experience Rindler effect.

Finally, in order to capture some quantum gravity effects, we have introduced a zero point length to the spacetime and have discussed its geometrical consequences. In particular, we have shown that at the Planck scale the spacetime becomes essentially two-dimensional.

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