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Remarks on Quantum Gravity*

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Abstract. Quantum gravity is analyzed from an axiomatic point of view. Under some general conditions imposed on the asymptotic structure of space–time a rigorous proof of the CPT theorem and a general discussion of the axiomatic approach to quantum gravity are presented.

I. Introduction

In this paper we analyze in detail a set of axioms for quantum gravity recently proposed by Hawking [1–3]. The interest of such an axiomatization is twofold: on the one hand it allows us to make general statements about quantum gravitational effects and to analyze what type of principles and results of ordinary quantum field theory apply to quantum gravity; and on the other hand it may give a more definitive answer to the question of whether the inclusion of nontrivial topological configurations of the gravitational field generate loss of quantum coherence, i.e. evolution of pure to mixed states. This possibility was suggested shortly after the discovery that black holes can emit particles in a thermal spectrum [4, 5]. The semiclassical calculation carried out so far in the presence of a black hole seems to suggest that such a process might take place. These arguments led Hawking to infer that such an evolution from a pure to a mixed state could also occur on a microscopic level due to quantum fluctuations of the metric. Since these gravitational bubbles can have nontrivial topologies, the virtual geometries they describe will not be globally hyperbolic, and thus, they could generate acausal poles in the Green's functions of fields propagating through them [6–8]. Hence, it seems plausible that an acausality intrinsic to quantum gravity, might generate the loss of quantum coherence. Equivalently, one may interpret the quantum gravitational bubbles as virtual black holes which form and evaporate.

Without a rigorous theory of quantum gravity, the most reasonable way to assess the validity of the above conclusions is to try to formulate a minimal set of

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