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The Scattering of Spin-1 Particles by Quantum Gravitational Bubbles

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Abstract. Quantum gravitational bubbles may be used to obtain a non-perturbative approximation to the path integral of quantum gravity. There are three basic types of bubbles CP^2, $S^2 \times S^2$, and $K3$, and in this paper the propagation of elementary spin-1 particles in CP^2 is investigated. To date information about the propagation of particles other than scalars has been obtained by making approximations to the basic bubble types. The work presented here represents the first exact calculation. It is found that spin-1 particles scatter very strongly, particularly at low energies, which is at odds with both physical observation and the earlier work on this subject. Possible explanations for this discrepancy are offered.

1. Introduction

The idea of spacetime foam is that the dimensional character of the gravitational constant allows very large fluctuations of the metric and even the topology on scales less than the Planck length. Such a foamlike structure cannot be handled by ordinary perturbation theory but it might be treated by a different approximation scheme, that of gravitational bubbles [1, 2]. In these references the authors use gravitational bubbles to calculate the behaviour of particles of spins 0, $\frac{1}{2}$, and 1 in the quantum gravitational vacuum. In this paper, I shall discuss a similar calculation, the results of which are at odds with those of Hawking et al. In order to appreciate the discrepancies and possible resolutions it is necessary to discuss how one arrives at the foam model.

Consider some fields, ϕ, propagating through a gravitational vacuum from some "in" region to some "out" region. In keeping with the usual assumptions of quantum field theory, I shall assume that there are such "in" and "out" regions which are asymptotically flat, and where the interactions and fluctuations may be turned off. The scattering amplitude for this propagation may be evaluated via the Euclidean path integral

$$\langle \phi_{\text{out}} | \phi_{\text{in}} \rangle = \int \mathscr{D}[g, \phi] \exp(-I[g, \phi]), \tag{1.1}$$

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