QUANTUM OPTICAL DETECTION OF THE HOLOGRAPHIC PRINCIPLE

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This paper proposes a quantum optical method for the detection of length fluctuations due to the holographic principle. This optical interferometric alternative to the atomic interferometry proposed by Y. Jack Ng [1] would be simpler for an experimentalist to conduct.

Key words: quantum gravity fluctuations, holographic principle, atomic physics, virtual black holes, single atom laser, interferometry.

1. INTRODUCTION

It is commonly thought that quantum gravity is a domain of physics that is completely inaccessible to experimental detection. This is because the length scale is very small, and energy required to probe this scale is $10^{19}$ GeV. However, it may be illustrated that there are subtle influences of quantum gravity that can be detected on a large scale. This is the case with measuring the length fluctuations due to the holographic principle. Y. Jack Ng demonstrated that quantum gravity fluctuations according to the holographic principle results in length fluctuations that may be detected by atomic interferometry [1]. This short paper demonstrates that this same experiment may be conducted with atomic physics measurements and optical interferometry. This puts fewer demands on the requirements for the experimental protocol.
2. THE HOLOGRAPHIC PRINCIPLE

Black holes in the early days were called by the Russians frozen stars. This is because the radiation emitted by matter falling towards the hole emit photons that "climb" out of the gravity field are shifted to larger wave lengths, and the apparent clock on this matter slows down. As this matter approaches the event horizon it appears to become frozen above this surface, as well as darkened into blackness by gravitational red shifting. This means that a black hole has layers of fields and quantum information pasted just above the horizon as seen by an exterior observer. It would then appear that in principle all the fields and particles that compose a black hole may be observed if enough effort is made. However, these field theoretic geological layers are compressed into a membrane one Planck length above the event horizon. What is observed are the quantum modes associated with the quantum gravity, and quanta emitted by other fields are red shifted to \( \sim 10^{36} \) times their wavelength. For practical purposes the only field information available left is gravitational mass and electric charge.

This does pose the interesting conjecture that all quantum gravitational information exists on an event horizon. This posits that in going and out coming fields with respect to an event horizon are projected onto the horizon and determined there. The upper bound on the number of degrees of freedom in a spacetime volume is given by the number of Planck units of area bounding this volume. Hence an event horizon contains all field theoretic information of the black hole. An \( SO(2,1) \) Lorentz algebra is derived for operators that describe fields that scatter off event horizons [2]. The total field theoretic information pinned on event horizons defines the entropy of the black hole. Boltzmann’s H-theorem and the use of statistics was what lead to an understanding of the underpinning of thermodynamics. As black holes are thermodynamic, much the same should obtain with quantum gravity. A Planck scale black hole of mass \( M = \sqrt{\hbar c/G} \) and temperature \( T \approx \sqrt{\hbar c^5/G/k_b} \approx 10^{36^0} k \), indicates that the maximum entropy in a region of radius \( R \) is \( S = R^2/4Gk_b \). Given a partition function \( Z = e^{-E/k_bT} \) with

\[
S = k_B T (\partial Z/\partial T)|_R,
\]

the number of required states in this region must grow exponentially with \( R \). However, the quantum modes in a region of space are determined by the area bounding that volume. This is the case for an event horizon bounding a black hole, or the cosmological event horizon that bounds the observable universe.

In a volume of spacetime the quantum gravity information is then determined simply by the area bounding this volume. This then means that quantum gravity fluctuations in a volume are determined by field modes on the area bounding that volume. This means that metric