What is GQuEST?

September 4, 2023

Quantum Gravity probes the long-standing conundrum of Quantum Mechanics and General Relativity at the Planck scale. Theoretical work is challenged by the vast scale difference between theories and direct observations. Kathryn Zurek leads an international collaboration of theorists to pursue ways to observe signatures of quantum gravity. This work incorporates entanglement of quantum states on surfaces that define regions of space. Just as temperature emerges from the motion of many particles, gravity emerges from this entanglement.

These states are not directly observable. However, an essential part of the theory is accessible to experimental tests: the metric appears as a breathing mode of a sphere controlled by a scalar field ϕ

$$ds^2 = -dt^2 + (1 - \phi)(dr^2 + r^2 d\Omega^2). \tag{1}$$

Effects of this scalar field ϕ will be measured (or excluded) by the GQuEST experiment.

Compared to the standard case ($\phi = 0$), a photon accumulates changes in phase while propagating according to the metric defined in Equation 1. In principle, a monochromatic light source at frequency $\nu_0 = c/\lambda_0$ could be measured after propagating distance L. Any observed deviation from phase at distance L is evidence for fluctuations caused by the scalar field ϕ. In practice, that approach is experimentally infeasible, but a Michelson Interferometer is ideal!

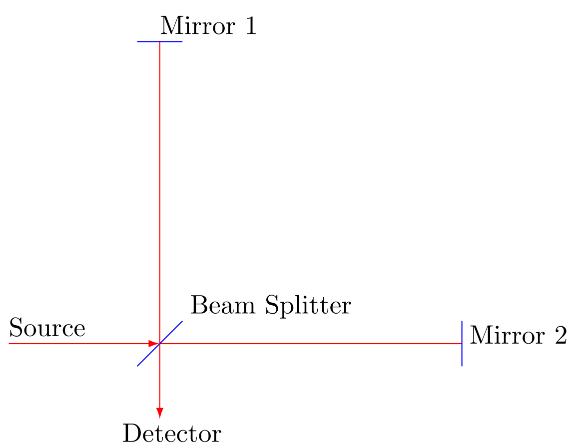

Figure 1: Schematic of an Interferometer

An interferometer (Figure 1) is sensitive to the phase difference between two paths. The distances L_1, L_2 are the distances between the Beam Splitter and Mirror 1, Mirror 2. A typical operating mode sets the difference $L_1 - L_2$ to emit a fraction of the total power in the interferometer to the detector at the dark port. Variations in $L_1 - L_2$ cause variations in the relative phases, which manifest as variations in detected power. Poisson statistics of the detected photons dominate the variation in measured power. In principle, relatively long integration times would reveal effects due to phase fluctuations due to the scalar field ϕ. GQuEST will use a novel technique for reading out the detector.

Our strategy is to filter out the majority of the photons from the output port before they reach a photon counting detector. We will use narrow-band resonant cavities tuned to detect side-bands of the source frequency. In our nominal design we use cavities offset from ν_0 by $\epsilon = \mathcal{O}(10\text{ MHz})$. These cavities pass signal photons at $\nu_0 + \epsilon$ while attenuating carrier photons at ν_0 by over 100 dB. These cavities can be tuned within a range of offset frequencies. Instrumental effects from the interferometer will be present in narrow bands in this range. Scanning offset frequencies allow us to characterize these effects while measuring (or excluding) the broad band signal spectrum.

Continuing theoretical work characterizes the expected amplitude of ϕ, the dependence of detection sensitivity on interferometer geometry, and correlations between multiple interferometers.