Testing Fundamental Properties of Space with the Fermilab Holometer

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Abstract. Precision length measurements provide valuable insights about the fundamental properties of space-time. The Holometer is a research program to both experimentally probe signatures of the Planck scale and to extend the accessible frequency range from kHz up to MHz for gravitational wave searches. The instrument consists of separate yet identical 39-meter Michelson interferometers operated at Fermi National Accelerator Laboratory, which can reach length sensitivities better than $10^{-20}\mathrm{m}/\sqrt{\mathrm{Hz}}$ within the 1-10 MHz frequency range. The Holometer is fully operational with 130 of hours of science quality data obtained during the first observational campaign.

1. Introduction

The Holometer experiment was built and operated at Fermi National Accelerator Laboratory. The instrument consists of two 39 meter power-recycled Michelson Interferometers. Each interferometer has separate yet identical vacuum systems, lasers, electronics, signal detectors and digitizers [1]. By 2014, the construction and commission was completed. Each interferometer operates with cavity powers greater than 2 kW, which produces an instantaneous length sensitivity of $10^{-20}\mathrm{m}/\sqrt{\mathrm{Hz}}$ at frequencies above 1 MHz. The first observing campaign obtained 130 hours of science data during the summer of 2015. This dataset was used to perform two different scientific searches - Holographic Noise and MHz gravitational waves.

2. Holographic Noise

A new noise has been proposed as a consequence of fluctuations at the Planck-scale, which would introduce an imprecision in the location of an object. The predicted additional RMS length noise would be 2×10^{-17} m, for a 39 m Michelson Interferometer due to the scaling relationship of the Planck length (10^{-35} m) and the length of the instrument[2]. The first model of the spectral shape and scaling amplitude of how this new noise will show up in a 39 m Michelson Interferometer was tested. This model was ruled out at 5σ significance by using 130 hours of science data [3].

3. Gravitational Waves

The unique frequency range of the Holometer enables an extension of the gravitational wave spectrum from kHz up to a broad range of MHz frequencies. Early universe remnants such as primordial black holes and cosmic super-strings are capable of radiating at these high of frequencies. Constraints on the stochastic gravitational wave background and a first search for primordial black holes binaries at MHz frequencies has been performed using the 130 hour dataset. [4]

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4. References

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