CSU PHYSICS COLLOQUIUM

"Precision measurements aiding the search for dark matter and gravitational-waves"

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Lory Student Center (Room 308)

Abstract

Low-energy experiments have recently emerged as the next testbeds to investigate big physics questions like (a) Is there physics beyond the standard-model? (b) Do gravitons exist? What is the nature of gravitational forces between quantum systems? (c) What is dark matter made up of? (d) What happened before the dark ages? In this talk, I will focus on precision measurement experiments searching for gravitational waves (GWs) and axions.

Squeezed states are special quantum states of light which have been engineered to redistribute the uncertainty from one observable into the complementary non-commuting observable. GW observatories like LIGO and VIRGO now deploy squeezed states in regular operation to detect GWs below the standard quantum limit (SQL). The SQL arises from both the photon shot noise as well as from quantum radiation pressure noise. This radiation-pressure interaction can also be used to generate squeezed states, i.e., optomechanical squeezing, but is often challenging to achieve due to presence of thermal motion. I will show recent measurements of optomechanical squeezing in the audio-frequency band at room temperature and describe the design considerations that enabled this squeezer.

In the second part of my talk, I will describe another precision-measurement experiment (ARIADNE) to look for spin-dependent forces mediated by the axion. The axion is a solution to the strong-CP problem (i.e., unnaturally small dipole moment of the neutron) and also happens to be an excellent dark matter candidate. To solve the strong -CP problem, the QCD axion must mediate forces between nucleons. We will test for one such force in the form of a monopole-dipole coupling by looking for interaction between an unpolarized tungsten source mass and highly polarized He-3 gas. This interaction can be quantified as being equivalent to measuring an effective magnetic field of 10^-20 T at 100 Hz. I will describe the experiment's concept, a subset of the technical challenges that must be overcome to look for this effect, and recent progress towards realizing the experiment.

While these experiments are well-motivated to answer fundamental science questions in the short term, they also pave the way for future, even more challenging precision measurement experiments. I will show snapshot ideas of a few such future experiments.

Biography

Nancy Aggarwal received her bachelor's degree in engineering physics from IIT Bombay and PhD in physics from MIT. As a student at the LIGO group with Prof. Nergis Mavalvala, she focused her research primarily on optomechanical squeezing. She received the 2019 GWIC thesis prize for her PhD thesis and has published her doctoral work in Nature and Nature Physics.

Gravitating towards the hunt for axions, she joined Prof. Andrew Geraci's group at Northwestern as a postdoc fellow and holds joint appointments at Center for Fundamental Physics (CFP) and Center for Interdisciplinary and Exploratory Research in Astronomy (CIERA). She is working on an axion experiment (ARIADNE) as well as a miniature gravitational-wave detector based on levitated nanoparticles. She has also started a new global initiative to identify methods to look for ultra-high-frequency gravitational waves, for which she published a review article in Living Reviews of Relativity.