Proposal for the Analysis of Baryon and Lepton coupled Ultralight Dark Matter using Accelerometers

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Since the early 20th century, dark matter has been implicated in a variety of gravitational phenomena that existing theories cannot adequately explain. However, the nature of dark matter remains largely unknown. One outstanding property that is very poorly known is its mass, with current bounds allowing it to lie in the broad range of $10^{-22}\,\mathrm{eV}$ to tens of solar masses. The quest to identify this elusive particle requires a multifaceted approach, involving various experiments and studies targeting specific subsets of this extensive mass range.

In the ultralight regime of this mass range ($\sim 10^{-22}\,\mathrm{eV} - 1\,\mathrm{eV}$), dark matter could manifest as a vector-like particle. Given its theoretical bosonic nature and local density, it is expected to display classical wavelike behavior. This form of dark matter could arise from a novel $U(1)$ symmetry, with prominent candidates involving the gauging of various combinations of baryon (B) and lepton (L) numbers.

If dark matter exists as an ultralight particle, we can use its wavelike behavior to detect it using accelerometers. Considering that the gauging depends on a combination of baryon and lepton numbers, accelerometers constructed from different materials would exhibit distinct charge responses to such an ultralight field. This difference in acceleration would be noticeable when exposed to an incoming dark matter wave.

The Windchime experiment represents one such approach to actively explore the detection of dark matter using accelerometers. However, to date, there have been limited studies on distinguishing dark matter originating from different choices of conserved charges, specifically various B and L combinations. The existing promoted accelerometer profiles (including only 2 different materials) provide only the acceleration difference without revealing the true nature of the charge. This semester, I aim to delve into this aspect, aiming to differentiate between dark matter scenarios associated with specific B and L combinations.

During the last semester, I looked into the signal that would be generated by such vector, wavelike dark matter on an axial sensor, accounting for the stochastic nature of the signal and the rotation of the Earth. This semester, my focus will be on utilizing this signal model to predict the signals produced by various gauged charges. I aim to explore how different materials, along with different multi-sensor profiles, can be employed to differentiate between various dark matter models.

To achieve this, I will conduct a signal analysis, including Monte Carlo simulations of the signal and Fourier analysis for different types of charges. Additionally, I will investigate how sensors made of diverse materials contribute to the overall detection process. With the detector models, I will be looking into noise signatures of such detection and draw boundary lines based on the analysis. I would also like to see if any boundary lines can be drawn based on current experiments that utilize accelerometers such as LIGO and MICROSCOPE. This approach is designed to enhance our understanding of dark matter.