Contribution ID: **36** Type: **Oral presentation**

Table-top high-energy quantum physics

Wednesday 11 July 2018 15:40 (20 minutes)

The existence of dark matter, or at least some interaction capable of mimicking its effects, is by now established beyond reasonable doubt. There is a huge spectrum of possibilities when it comes to answering the question of what is the nature of dark matter. One interesting possibility is that it is composed of very light scalar or pseudo-scalar particles, sometimes dubbed Weakly Interacting Slim Particles (WISPS). WISP dark matter can have masses ranging from 10^{-22} eV to a few eV, and models motivated by the strong-CP problem suggest that its coupling to ordinary baryonic matter is very weak. This implies that colliders are not necessarily the ideal experiments to search for these light particles. Here we report on the progress of an ongoing experiment aimed at searching new interactions of nature (so-called "fifth forces") mediated by WISPS. Our setup consists of a quantum optomechanical oscillator - a Silicon Nitride membrane - cooled near its ground state placed within micrometric distances from an optically levitated Silica microsphere in a high-finesse optical cavity. Motion of the membrane-microsphere system is monitored via a Pound-Drever-Hall scheme, and force and displacement sensitivities of up to 10^{-19} N/$\sqrt{\text{Hz}}$ (microsphere) and 10^{-15} m/$\sqrt{\text{Hz}}$ (membrane) are obtained. As we will show, the membrane-microsphere geometry presents several advantages in the search for sub-micron-range fifth forces and our setup is capable of placing interesting constraints on WISP dark matter candidates. Furthermore, we will discuss opportunities in the emerging field of "table-top"fundamental physics experiments, lying at the cross-borders of high-energy physics, quantum information and metrology.

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Session Classification: Parallel Section C Quantum Physics