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Novel signatures of dark matter in laser-interferometric gravitational-wave detectors

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Dark matter may induce apparent temporal variations in the physical "constants", including the electromagnetic fine-structure constant and fermion masses. In particular, a coherently oscillating classical dark-matter field may induce apparent oscillations of physical constants in time, while the passage of macroscopic dark-matter objects (such as topological defects) may induce apparent transient variations in the physical constants. We point out several new signatures of the aforementioned types of dark matter that can arise due to the geometric asymmetry created by the beam-splitter in a two-arm laser interferometer. These new signatures include dark-matter-induced time-varying size changes of a freely-suspended beam-splitter and associated time-varying shifts of the main reflecting surface of the beam-splitter that splits and recombines the laser beam, as well as time-varying refractive-index changes in the freely-suspended beam-splitter and time-varying size changes of freely-suspended arm mirrors. We demonstrate that existing ground-based experiments already have sufficient sensitivity to probe extensive regions of unconstrained parameter space in models involving oscillating scalar dark-matter fields and domain walls composed of scalar fields. In the case of oscillating dark-matter fields, Michelson interferometers — in particular, the GEO\,600 detector — are especially sensitive. The sensitivity of Fabry-Perot-Michelson interferometers, including LIGO, VIRGO and KAGRA, to oscillating dark-matter fields can be significantly increased by making the thicknesses of the freely-suspended Fabry-Perot arm mirrors different in the two arms. Not-too-distantly-separated laser interferometers can benefit from cross-correlation measurements in searches for effects of spatially coherent dark-matter fields. In addition to broadband searches for oscillating dark-matter fields, we also discuss how small-scale Michelson interferometers, such as the Fermilab holometer, could be used to perform resonant narrowband searches for oscillating dark-matter fields with enhanced sensitivity to dark matter. Finally, we discuss the possibility of using future space-based detectors, such as LISA, to search for dark matter via time-varying size changes of and time-varying forces exerted on freely-floating test masses.

Reference: H. Grote and Y. V. Stadnik, arXiv:1906.06193

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