Title

SEARCH METHODS FOR ULTRALIGHT SCALAR FIELD DARK MATTER WITH GRAVITATIONAL-WAVE DETECTORS AND ITS DETECTABILITY

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Abstract

Although Weakly Interacting Massive Particles (WIMPs) are promising candidates of dark matter, null results from various experiments cast doubt on WIMPs, implying the need to search for other candidates. Ultralight scalar field is one of the other dark matter candidates that is motivated by string theory [1]. Interestingly, if it couples with Standard Model particles, it oscillates mirrors in gravitational-wave detectors and generates detectable signals [2]. To extract information on ultralight scalar field dark matter from real data as much as possible, we studied its signal's characteristics in detail and developed a suitable data-analysis method [3].

As a result, we found that the morphology of the signal's spectra is characterized by the frequency dispersion of the scalar field in the Galaxy and the period of the detector's motion. Then, we proposed two data analysis methods for that signal: (1)Incoherent sum of the spectra and (2)Narrow band stochastic gravitational-wave background search. We found that our analysis methods improve the previously estimated constraints on the coupling between the scalar field and the Standard Model particles by a factor of about 7, at ground-based gravitational-wave detectors' frequency range. Finally, we estimated its detectability with our analysis methods. We found that our methods can improve the existing constraints given by fifth-force experiments on one of the scalar field's coupling constants by a factor of ~ 30, ~ 100 and ~ 350 for $m_\phi = 2 \times 10^{-17}$ eV, 10^{-14} eV and 10^{-12} eV respectively, where m_ϕ is the scalar field's mass. Our study also demonstrated that experiments with gravitational-wave detectors play a complementary role to the Equivalence Principle tests.

References

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