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An analysis of oscillations in fuzzy dark matter cores

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Fuzzy dark matter (FDM) is a rapidly growing area of research which aims to alleviate the shortcomings of the current leading cold dark matter (CDM) model. On large cosmic scales, FDM recreates the large scale structure generated by CDM simulations; the two diverge on smaller scales, where CDM suffers the most. Where CDM requires the addition of baryonic feedback and other physics, one of the main attractive aspects of FDM is the inherent existence of a soliton core at the centre of the parent halo, which agrees with astronomical data of dwarf galaxy surveys. Given that the existence of the core is one of the foundational and fundamentally important aspects of FDM, it is of paramount importance that we understand the relevant dynamics and properties. Greater understanding and more accurate predictions of these dynamical behaviours will significantly assist in the search of smoking gun signals of FDM's existence, and may also constrain the properties of FDM, such as the boson mass.[1]

Simulations show that the soliton core exhibits dynamical behaviours in the form of a random walk within the potential well of the halo, as well as fixed period oscillations. We study the latter by performing a perturbative analysis of a generalised ground state soliton core using the empirical formula from [2], and compute an analytical expression for the oscillation frequency as a function of the soliton core's fundamental properties, inspired by the approach taken in [3]. We also numerically solve the Gross-Pitaevskii Poisson system of equations in 3D and separately using a spherically symmetric solver, to simulate the dynamical behaviour of a FDM soliton core. Our analytical study finds qualitative agreement with results from [3]—where instead of an accurate empirical formula, a Gaussian ansatz is used to model the core—with clear identifiable corrections and an improvement on agreement with our numerical simulations.

We henceforth generalise this analysis further to account for the possibility of self-interaction between the bosons through the use of the adjusted empirical formula from [4], and thus lay the foundations for further work to be done on self-interacting FDM.

References

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