Project 4.1 Scalar field dark matter from an ultracold atomic physics perspective (theoretical)

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Background:

Bose-Einstein condensates of ultracold atoms are famous for being the coldest known matter in the universe, though the amount of matter is small, dilute and has so far been produced only in high vacuum in a few high technology laboratories. Remarkably, one of the models for dark matter, so called „fuzzy" or wave dark matter which has received a lot of attention recently, also postulates that the dark matter that accounts for most of the matter of the universe is nothing but a condensate with a wavelength on the order of the size of a galaxy. In this project, we want to take advantage of the many parallels between the now very developed description of matter waves in atomic Bose-Einstein condensates and the fuzzy dark matter model to obtain a more nuanced and accurate representation of the postulated fuzzy dark matter.

In particular, wave dark matter simulations to date have not included higher energy, lower wavelength modes far outside of the main condensate. Generally the study of coherence and other quantum properties of wave dark matter is in its infancy, and has only started to go beyond the zero temperature approximation. We will work with the group of prof. Nick Proukakis in Newcastle University who have recently carried out pioneering studies of wave dark matter from this angle.

Aim:

We will apply the wave matter descriptions developed to describe condensates of ultracold atoms to include the effect of the neglected higher energy waves into dark matter simulations. The approach is based on stochastic nonlinear Schrödinger equations, where the noise part is responsible for nonzero temperature. By including these shorter wavelength phenomena we plan to get a more accurate picture of the fuzzy dark matter. There are also many quantum effects to explore in the wave dark matter model generally, which have not been taken into account previously. We hope that the new results will also allow us to investigate how such waves of fuzzy dark matter would affect „small" tracer particles such as globular clusters or dwarf galaxies. If the effect is observable, it might allow for real astronomical observations to distinguish between the predictions of fuzzy dark matter and the more standard dark matter model to determine which of them is closer to reality.

Requirements:

- research experience in theoretical physics, cosmology, or theoretical astronomy,
- good programming skills or a strong willingness to learn them,
- experience with ultracold gases, cosmology, or quantum physics will be a strong advantage, as will experience with numerical calculations, particularly in writing programs to solve differential equations,
- Master's degree in physics or astronomy (or an equivalent that qualifies one for PhD studies in physics in the country of issue).
- sufficient proficiency in the English language for efficient scientific interaction.

Funding:

Scholarship: grant funding for 48 months – 5000 PLN per month (4250 PLN net) in the first two years, later 6000 PLN per month (4550 PLN net), from an NCN Preludium Bis project.

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