The accelerated expansion of the Universe as a result of quantum effects

Suraj K,¹ and Ng Shao Chin Cindy²

Department of Physics, Faculty of Science, National University of Singapore

10 Kent Ridge Road, Singapore 117546

ABSTRACT

We review an approach towards explaining the accelerated expansion of the universe as a result of quantum cosmological effects. In this approach, the quantized Friedmann-Lemaître-Robertson-Walker (FLRW) model minimally coupled to a free massless scalar field was studied. In an earlier paper, solutions of this model were obtained after employing Gaussian superpositions of negative and positive modes solutions of the Wheeler-DeWitt equation and quantum bohmian trajectories had been observed in the Bohn-de Broglie interpretation of quantum cosmology. In this approach however, another different class of Gaussian packets and their quantum bohmian trajectories were analysed. It was shown that in this new class, the trajectories initially behave classically, i.e. with a decelerated expansion, then undergoes an expansion in the middle of its evolution due to quantum effects during this time and finally returns to the classical decelerated expansion in the future.

Introduction

The recent data collected from high redshift supernovae experiments indicate that the present expansion of the universe is an accelerated one and not decelerated as one would

¹ Student
² Lecturer
expect from Hubble’s observations and from the results of classical General Relativity (GR). Assuming the validity of classical GR and Friedmann’s equations, the only way to explain this acceleration was to consider the existence of some ‘dark energy’ which imparts a negative pressure into these equations. There are a few possible candidates to explain this dark energy, the most obvious one being the cosmological constant introduced by Einstein and/or the quantum fluctuations of fields in vacuum. However, the estimated zero-point energies of these quantum fields are 55 orders of magnitude smaller than the critical density value, thereby raising the question as to why the many contributions to the effective value of the cosmological constant cancel out to give a number 55 orders of magnitude smaller than expected (the cosmological constant problem). One candidate that was proposed to explain this cancelling out and thereby the acceleration of the universe was a very light, evolving scalar field called quintescence.

Another different approach to explain this problem would be to assume that at present, classical GR is not valid at cosmological scales. So one could look for physical reasons for the modification of the left-hand-side of Einstein’s equations instead of introducing the negative pressure fluid on the right hand side. This paper aims to show that it is possible to ‘mimic’ the effects of such a negative pressure fluid using quantum cosmological effects and thereby explain the positive acceleration of the universe. Using the model considered in earlier works of Colistete Jr., Fabris and Pinto-Neto, an additional Gaussian superposition is taken of negative and positive modes solutions to the Wheeler-DeWitt equation. Writing the Bohm guidance equations and reducing them to a dynamical system, the bohmian trajectories are again analysed. Two cases are seen, depending on the initial conditions: oscillating universes without singularities and
relatively small amplitudes, and universes which arise classically from a singularity, then undergo quantum effects in the middle of its expansion and later for large scale factor values return to the classical behaviour. Since the quantum effects are to be studied, the acceleration during the epoch where these play a role are studied and its behaviour as a function of the free massless scalar field $\phi$ and of the logarithm of the scale factor $\ln(a)$ is explored. A positive acceleration of the universe is obtained in this model as a quantum effect, with the mechanism being driven by the quantum potential appearing in the modified quantum Einstein-Hamilton-Jacobi equation. It is to be noted however that the acceleration is not forever and that in the future the universe would recover its classical decelerated expansion. Thus, this approach presents itself as an alternative explanation for the accelerated expansion of the Universe seen today.

**Future Aims**

In the latter half of the project, we aim to compare the quantum acceleration of the Universe’s expansion with the acceleration due to the presence of the cosmological constant in the classical model and also try and reproduce the results of the comparison of the curve relating the luminosity distance with redshift in the quantum model with the corresponding curve obtained using the classical model as was attempted in the original paper by Santini and Pinto-Neto.

**References**

Ryden, Barbara; *Introduction to Cosmology* (2003).