Physical Time and Quantum Gravity

Abstract

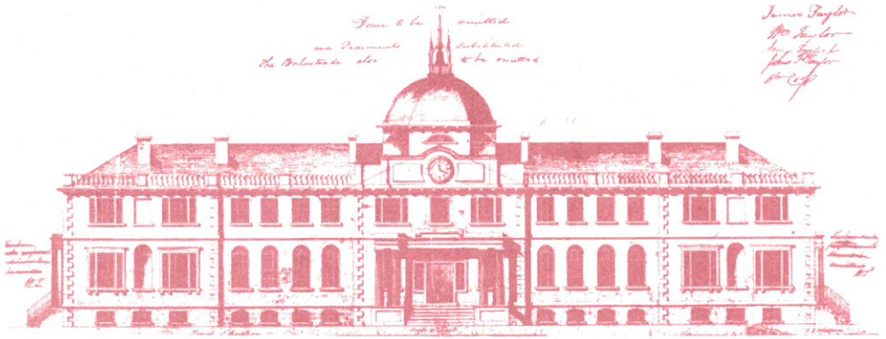
In this thesis, we explore the quantum gravity Universe using physical time.

First, we consider a Friedmann-Lemaitre-Robertson-Walker (FLRW) Universe with a massive scalar field. We polymer quantize the scalar field and use the number of efolds of inflation as physical time. We look at the semiclassical dynamics of this system assuming that the scalar field is described by a Gaussian state. We find that there is a `polymer inflation' phase that continues into the infinite past, followed by slow-roll inflation, and then reheating. We also show that sub-Planckian initial data can lead to significant inflation.

Second, we expand the previous model to include a pressureless dust field. The scalar field is polymer quantized, and we use dust as physical time. We find that there is an early time polymer inflationary phase, followed by slow-roll inflation, and an exit into late time classical dynamics. The value of the dust energy density controls the amount of polymer inflation with smaller values giving more inflation.

Third, we look at the Cosmological Constant (CC) problem as viewed from the physical Hamiltonian framework, where we first identify a physical time. We show that vacuum energy depends on the choice of time, is generally a square root and time-dependent, and is a function of the observed CC. We explicitly calculate it for various choices of time. We also discuss why the conventional CC problem is ill-posed, and formulate the question `Does vacuum gravitate?' We find that there is no CC problem when viewed from this framework.

Finally, we construct the path integral for a closed FLRW Universe with a CC and dust. We use dust as physical time, and numerically evaluate the integral using Markov Chain Monte Carlo (MCMC) techniques. We calculate the no-boundary wavefunction of the Universe, as well as correlation functions and mean volume. We find that the wavefunction is peaked on zero volume Universes. For a positive CC, we discuss two methods of making the integral convergent. We find that a smaller CC leads to a greater probability of large Universes.



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UNIVERSITY OF NEW BRUNSWICK
SCHOOL OF GRADUATE STUDIES

ORAL EXAMINATION

Syed Moeez Hassan

IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

Ph.D. Candidate

Syed Moeez Hassan

Graduate Academic Unit

Mathematics & Statistics

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January 7, 2019

2:30 p.m.

Forestry & Geology Bldg.
Room 202

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BIOGRAPHY

Universities attended (with dates & degrees obtained):

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Publications:

• *Universe as an oscillator*, Masooma Ali, Syed Moeez Hassan, Viqar Husain
Phys. Rev. D 98, 086002 (2018) [arXiv:1807.03864]

• *Quantum gravitational collapse as a Dirac particle on the half line*, Syed Moeez Hassan, Viqar Husain, Jonathan Ziprick
Phys. Rev. D 97, 104032 (2018) [arXiv:1707.02585]

• *Semiclassical cosmology with polymer matter,* Syed Moeez Hassan, Viqar Husain
Class. Quantum Grav. 34 084003 (2017) [arXiv:1705.00398]

• *Polymer inflation*, Syed Moeez Hassan, Viqar Husain, Sanjeev S. Seahra
Phys. Rev. D 91, 065006 (2015) [arXiv:1409.6218]

Selected Conference Presentations:

• *Is There a Cosmological Constant Problem?*
Canadian Association of Physicists (CAP) Congress 2018, Dalhousie University, Halifax, Canada, June 2018

• *Simulating Quantum Gravity: A Cosmological Model*
Atlantic General Relativity, St.F.X. University, Antigonish, Canada, June 2018

• *A Dusty Polymery Universe*
Atlantic General Relativity, Memorial University Newfoundland, Saint Johns, Canada, May 2017

• *Polymer Inflation*
16th Canadian Conference on General Relativity and Relativistic Astrophysics, Simon Fraser University, Vancouver, Canada, July 2016

• *Rainbow metrics from Quantum Gravity?*
Atlantic General Relativity, UNB, Fredericton, Canada, May 2015