Numerical Analysis of Cyclic Model in Bianchi-I Spacetime in Loop Quantum Cosmology

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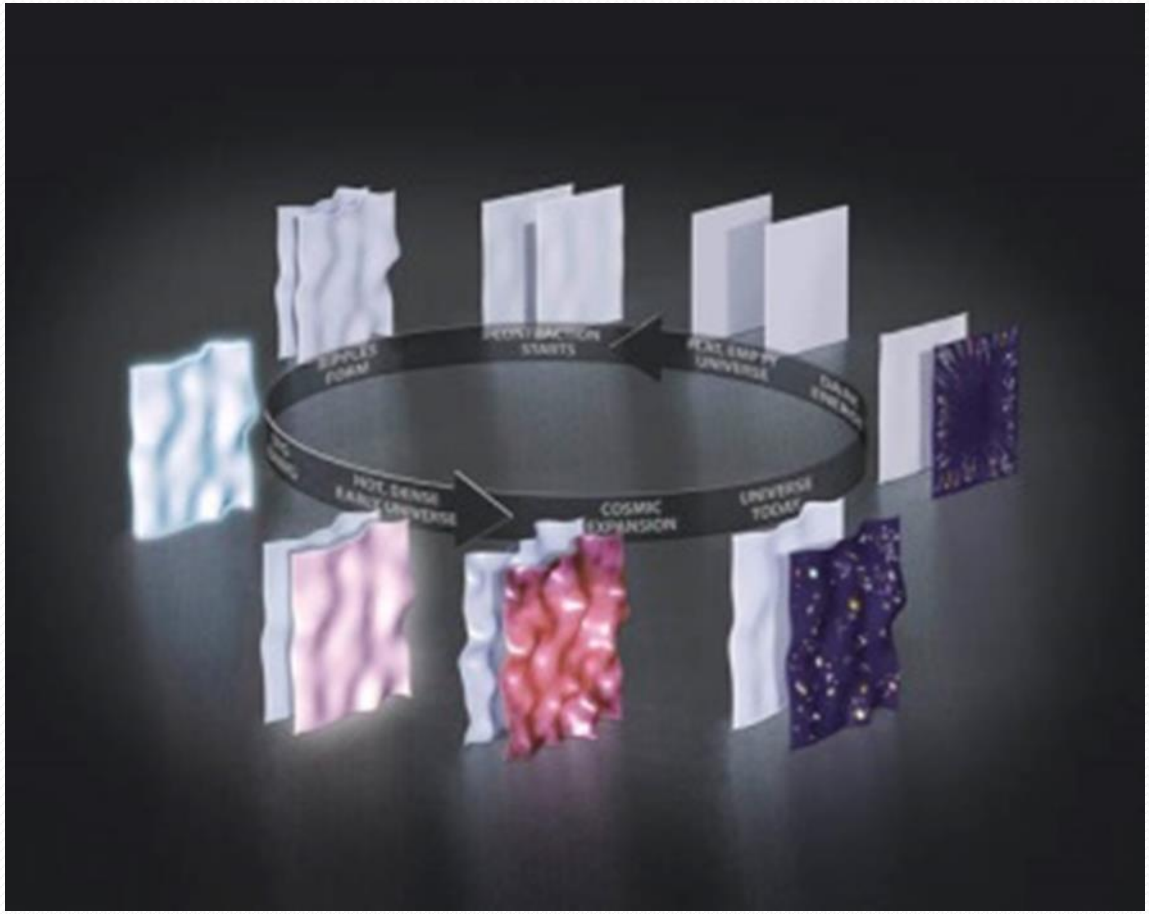
Background

- Bianchi-I spacetime is the simplest model of an anisotropic universe
  - Expands at different rates in different directions
- Loop Quantum Cosmology (LQC)
  - Applies ideas of Loop Quantum Gravity to the Big Bang model of the early universe
  - Replaces the Big Bang singularity with the Big Bounce

Cyclic Model

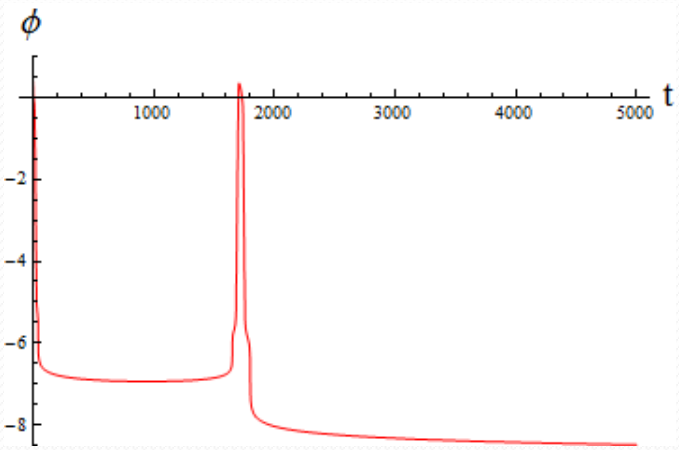
- Proposed by Steinhardt and Turok in the early 2000's as an alternative to inflation
- Draws on ideas from M-theory
- Universe goes through series of expansions and contractions which are governed by the inter-brane dynamics of two boundary branes
- Still had singularity when the two branes collided

Cyclic Model



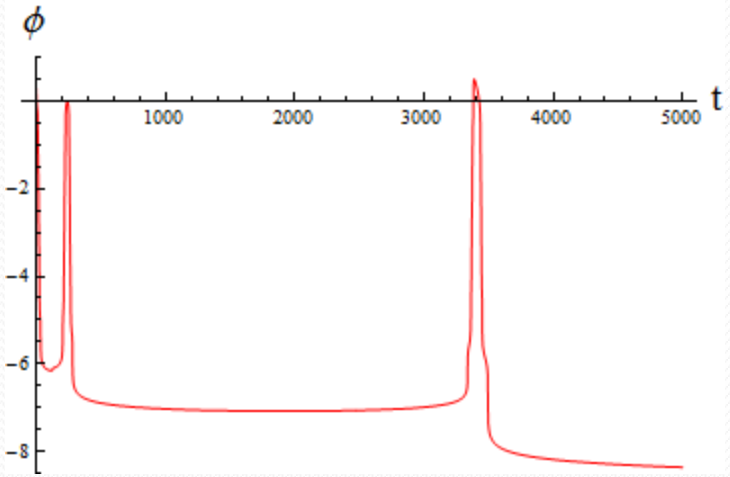
Further Background

- Since then, LQC has been applied to the cyclic model
  - Brane interaction described as a potential of the scalar field
- Has been shown that there do exist sets of initial values that produce a turnaround of the scalar field when the branes collide instead of a singularity



Purpose

- Goal of my project was to explore the parameter space and find initial values that resulted in multiple turnarounds of the scalar field



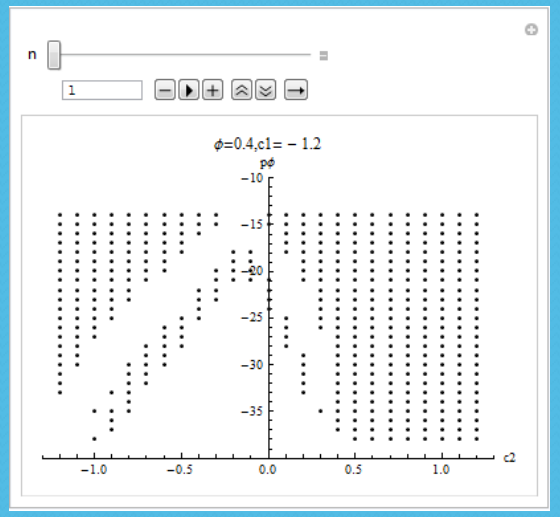
Methods

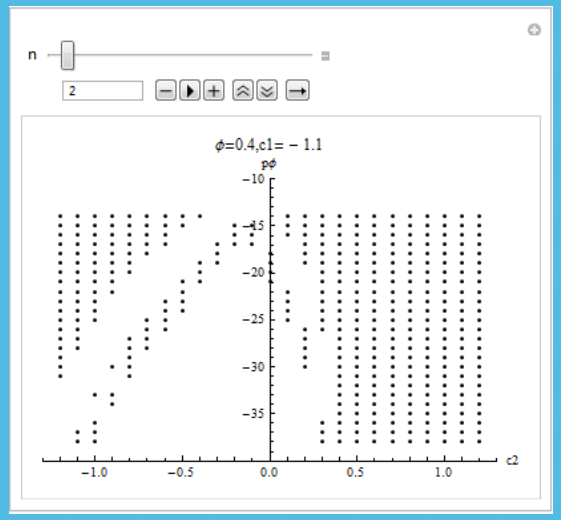
- Bianchi-I spacetime described with eight variables p_1, p_2, p_3, c_1, c_2, c_3, ϕ, p_ϕ
- Eight first order differential equations
  - Time derivatives of eight variables
- Want to vary c_1, c_2, ϕ, p_ϕ

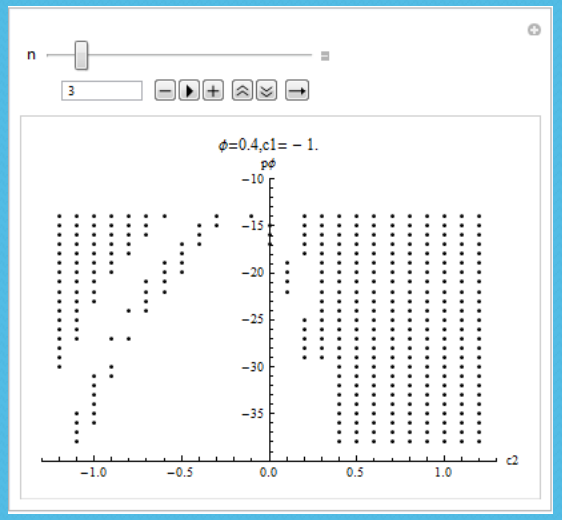
Methods

- Used Mathematica
  - Set initial values using Hamiltonian constraint
  - Numerically solved set of differential equations
  - Analyzed behavior of ϕ
- Ran code on LSU HPC Philip
  - Parallelized to run multiple sets of equations simultaneously
  - Run for longer times

Results

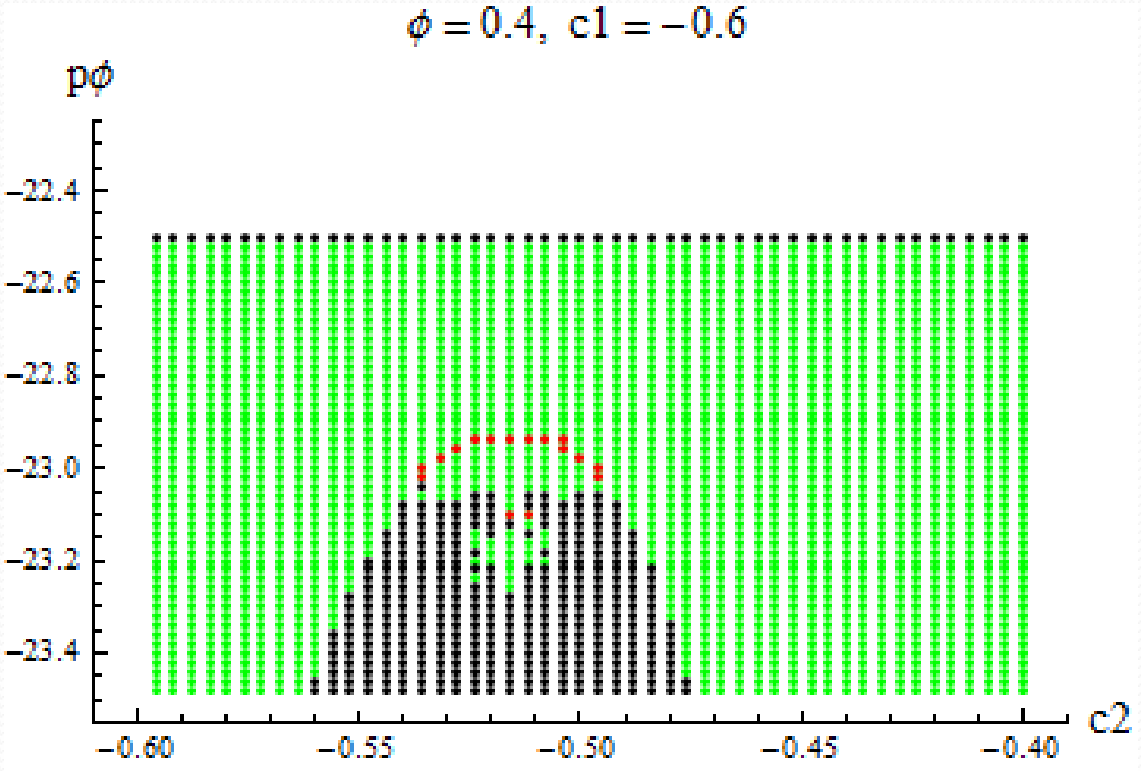






- For each set of four values (ϕ, c_1, c_2, p_ϕ) we determined if there was none, one, or multiple turnarounds in the scalar field

Results



- No turnaround
- One turnaround
- Multiple turnarounds

Conclusions

- Rough patterns of values that will produce a model where the scalar field turns around
- Initial values of the variables that produce a model with multiple turnarounds fall within very precise ranges
- Further research is needed to draw more valuable conclusions
  - changing the parameters of the potential, increasing the precision of values, and increasing range of values

References

- P.J. Steinhardt, N. Turok. “A Cyclic Model of the Universe.” Science Vol. 296 no. 5572 pp. 1436-1439 (24 May 2002)
- T. Cailleteau, P. Singh and K. Vandersloot, “Nonsingular Ekpyrotic/Cyclic model in Loop Quantum Cosmology,” Phys. Rev. D 80, 124013 (2009)

Any Questions?