



Poster number: 3

Quantum state of universe before big bounce

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Motivation

Quantum gravitational effects are dominant at the Planck scale.

Question: Is the initial singularity of the Universe avoided by quantum gravitational effects?



We need a quantum theory of the Universe.

Problem: Time evolution of wave function and observable is lost in quantum gravity.

“Problem of time and observable”

Our work

(i) construct a quantum theory free from the problem

We quantize the **flat FRW model with dust** by using the **reduced phase space method**, which is different from the famous Dirac method.

(ii) analyze the dynamics of the Universe

We numerically evolve a wave function of the universe and evaluate the **expectation value of** $|P| \propto a^2$, where a is the scale factor.

- The range of P is the whole real line.
- The sign of P determines the orientation of triads.

Results

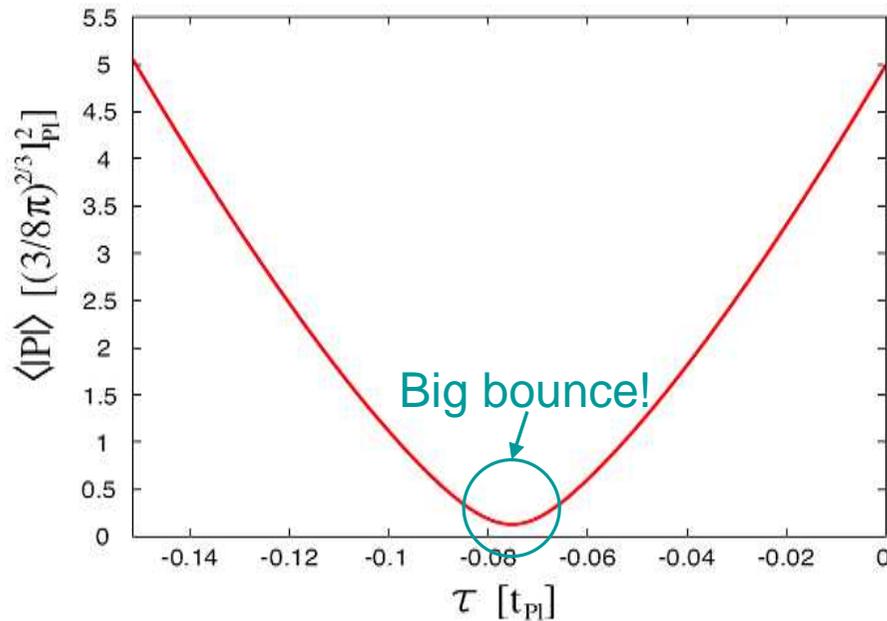


Fig.1 Expectation value of $|P|$

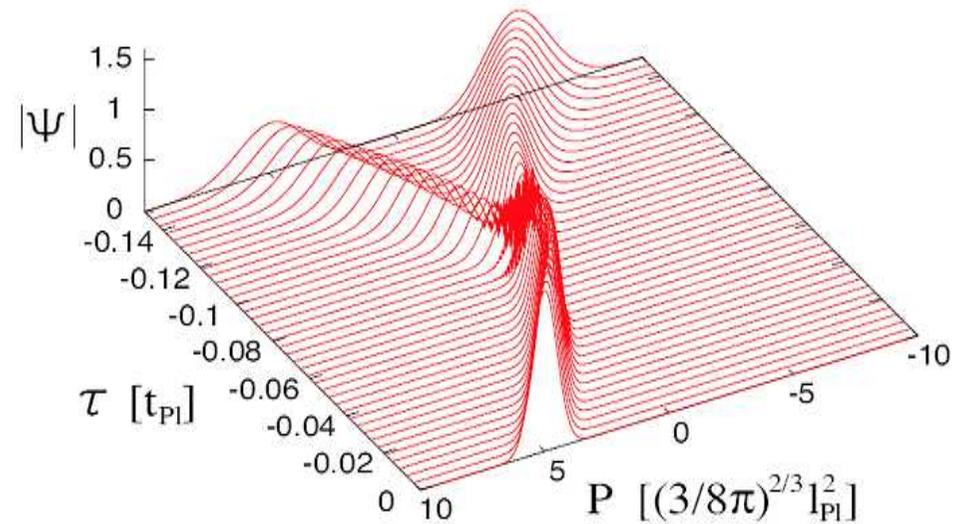


Fig 2. Absolute value of the wave function

- The initial singularity is replaced by a big bounce.
- The universe has been in a superposition of states representing right-handed and left-handed systems before the big bounce.

Summary

- Gauge-invariant construction of quantum cosmology has been proposed.
- The quantization has provided a possible resolution to the problem of time and observable.
- Initial singularity of the Universe has been avoided by quantum gravitational effects.
- If the present Universe is in the right-handed state, the past state was in superposition of the right-handed and left handed states.