Perturbations in Loop Quantum Cosmology

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Motivation

For now there is no empirical evidence of quantum gravity.
We have e.g. LQG, CDT but theory without an experiment is a pure mathematics. Can it change in the near future?

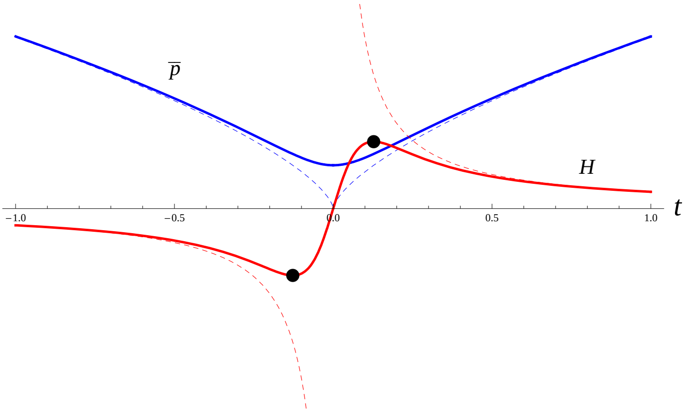
LHC reach 14 TeV (presently up to 1 TeV at Tevatron) while we need 10^{16} TeV (Planck energy). We never reach it with the present generation of accelerators.

Other possibilities → "Natural experiments":

- Photons time delay from Gamma Ray Bursts.
- Collapsing stars - QG inducted energy flux.
- Footprints on Cosmic Microwave Background.

In particular gravitational waves produced during quantum epoch can survive till now living frozen on the super-horizontal scales! During the period of recombination they can produce CMB polarization due to the Thomson scattering.

LQG → Loop Quantum Cosmology → Big Bounce



Background dynamics → Effective Friedmann equation:

$$H^2 \equiv \left(\frac{1}{2\overline{p}}\frac{d\overline{p}}{dt}\right)^2 = \frac{8\pi G}{3}\rho\left(1 - \frac{\rho}{\rho_c}\right)$$

Perturbations

We perturb basic variables around a spatially flat FRW background

$$
\begin{aligned}
E &= \bar{E} + \delta E \\
A &= \bar{A} + \delta A
\end{aligned}
$$

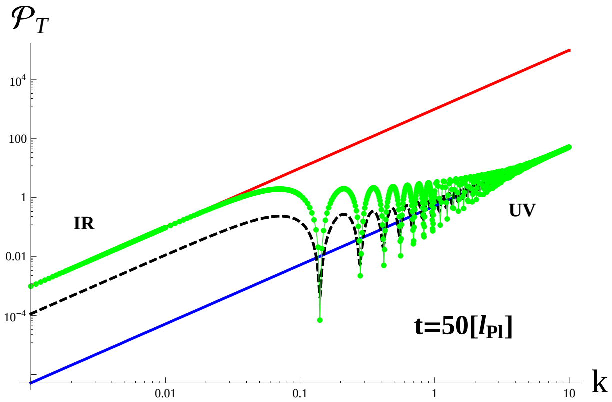
Perturbations $(\delta A, \delta E)$ can be splitted for the

- scalar (coupled with a scalar field - fairly complicated system)
- vector (simple but less interesting - decaying modes)
- tensor (gravitational waves - relatively simple)

Equation for tensor modes

$$\frac{d^2}{d\eta^2} h^i_a + 2\bar{k} \frac{d}{d\eta} h^i_a - \nabla^2 h^i_a + \tilde{T}_Q h^i_a = 0$$

Tensor power spectrum



Correlation function:

$$\langle 0|\hat{h}^a_b(\mathbf{x},\eta)\hat{h}^b_a(\mathbf{y},\eta)|0\rangle = \int \frac{dk}{k}\mathcal{P}_T(k,\eta)\frac{\sin kr}{kr}$$

More realistic evolution - Inflation in LQC

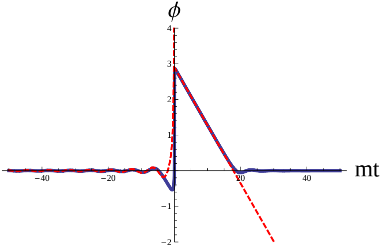
Since now we have considered only isolated bounce phase. However further stage of evolution, namely inflation, should be also taken into account.

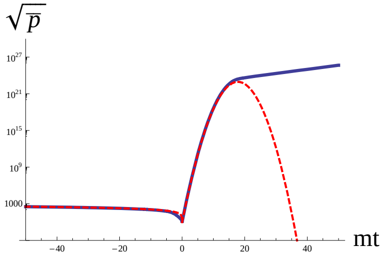
In order to produce inflation we consider a model with massive potential

$$V(\phi) = \frac{m^2}{2}\phi^2$$

then EOM is given by

$$\ddot{\phi} + 3H\dot{\phi} + m^2\phi = 0.$$





Summary and Outlook

- Transparent effects of the LQC induced bounce phase: oscillations in the power spectra and suppression of the spectra at super-horizontal scales.
- Are these oscillations survive the phase of inflation? Can they give footprints on the CMB?
- Suppression of spectra potentially leads to damping of the CMB at low multipoles.
- A lot of work still to be done ...
- Priority: Scalar perturbations (problems with quantum anomalies).
- CMB polarization.
- Non-Gaussian effects.