From LQC to CMB

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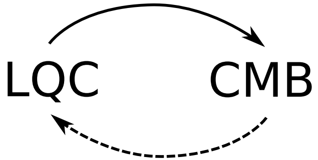
LQC - loop quantum cosmology gives an applicative framework to investigate evolution of the Universe at the Planck epoch (When the characteristic energies are of the order 10^{19}GeV). This theory base on the non-perturbative approach to quantise gravitational degrees of freedom, called loop quantum gravity (LQG).

CMB - cosmic microwave background (radiation)

We derive predictions from the theory and then we try to confront them with observational data.



This can give us the feedback on the theory and can learn us something about the Planck scale physics.

Problems of the standard cosmology:
1) Initial Big Bang singularity.
2) Initial conditions for inflation.

Solutions given by LQC:
1) The initial singularity is replaced by the quantum Big Bounce.
2) A bounce gives mechanism to set the proper initial conditions for inflation.

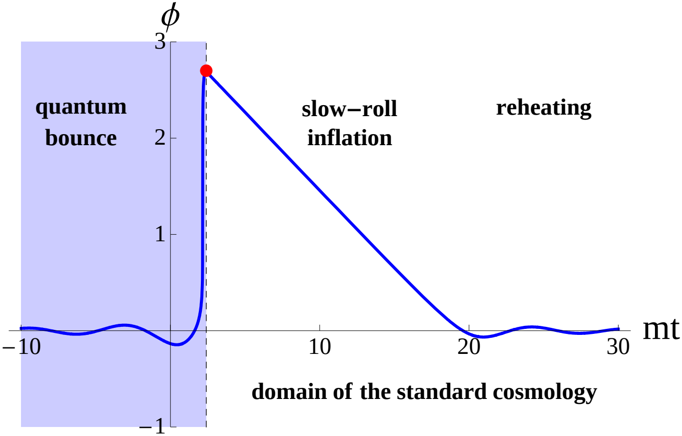
Effective Friedmann equation:

$$H^2 = \frac{8\pi G}{3}\rho\left(1 - \frac{\rho}{\rho_c}\right),$$

where the critical energy density is given by

$$\rho_c = \frac{\sqrt{3}}{16\pi^2\gamma^3} m_{Pl}^4 \simeq 0.82 m_{Pl}^4.$$

Inflation in LQC - the *shark fin* scenario



Dynamics of the massive *inflaton* field is governed by:

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

Gravitational waves in LQC

$$\frac{d^2}{d\eta^2}h^i_a + 2aH\frac{d}{d\eta}h^i_a - \nabla^2 h^i_a + m_Q^2 h^i_a = 0,$$

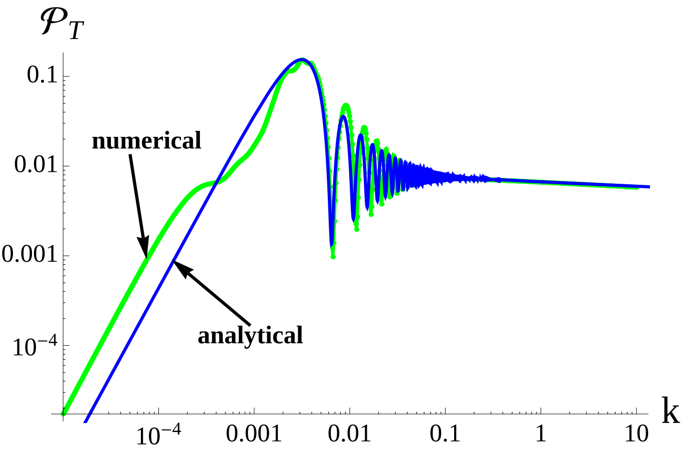
where $h^1_1 = -h^2_2 = h_\oplus$, $h^1_2 = h^2_1 = h_\otimes$ in the TT gauge. The quantum gravitationally induced "effective mass" is given by

$$m_Q^2 := 16\pi G a^2 \frac{\rho}{\rho_c}\left(\frac{2}{3}\rho - V\right).$$

Quantization promotes the field h^i_a to be the operator $\hat{h}^i_a$. The correlation function of the $\hat{h}^i_a$ field is defined as follows

$$\langle 0|\hat{h}^a_b(\mathbf{x},\eta)\hat{h}^b_a(\mathbf{y},\eta)|0\rangle = \int_0^\infty \frac{dk}{k}\mathcal{P}_T(k,\eta)\frac{\sin kr}{kr}.$$

Power spectrum of gravitational waves.



In the IR region the spectra behave as $\mathcal{P}_{\rm T} \propto k^2$ while in the UV region they behave as $\mathcal{P}_{\rm T} \propto k^{-2\epsilon}$, where $\epsilon \ll 1$ is the slow-roll parameter. Here $m = 10^{-2} m_{\rm Pl}$.

Polarization of the CMB

The way to produce polarization:

Gravitational waves $\mapsto$ Fluctuations of density $\mapsto$ Thomson scattering $\mapsto$ Polarization of the CMB photons

We are interested in B-type polarization which is directly related with tensor power spectrum.

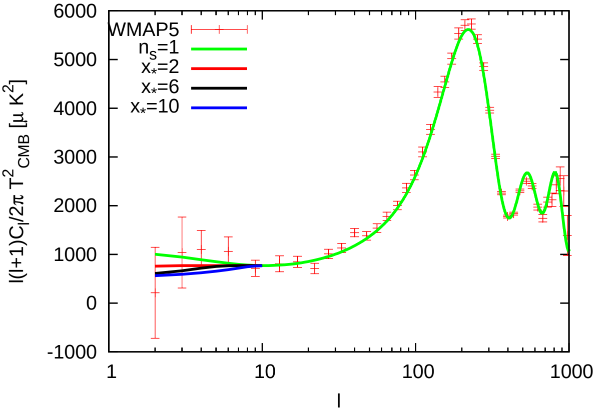
At present, we have only upper constraints on amplitude of this type polarization, as

$$\left. \frac{l(l+1)C_l^{BB}}{2\pi} \right|_{l=2\ldots7} \leq 0.055\mu\text{K}^2 \text{ (95\% CL)}$$

from the 7-year observations of WMAP satellite. However, even based on this, we can put constraint on $\mathcal{P}_{\text{T}}$ and then constrain the parameters ρ_{c} and m. The resulting bounds are weak, however can eliminate some possible scenarios.

Temperature anisotropy of the CMB

One can assume that the modifications of the spectrum of the scalar perturbations are similar to those in case of tensor modes. Then, we can investigate the possible effects on the temperature anisotropy of the CMB.



References

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