Non singular initial stages of the universe

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ABSTRACT

Initial conditions of the universe is the challenging aspect for the physical and mathematical theories. To deliver the aspects of the initial conditions of the universe, the big bang singularity is employed. The classical singularity can't explain the divergences occurred in matter density, pressure and curvature. Hence quantum cosmological models are deployed to solve such discrepancies in classical theory. Non singular beginning of the universe, and quantum mechanical analysis of big bang singularity are reported in this work. Tactics from loop quantum cosmology is implemented in this work.

Keywords : big bang, singularity, loop quantum cosmology, vacuum, non singular beginning

1 INTRODUCTION

Initial conditions of the universe is a long standing problem for physical theories. The initial stages of the universe is scrutinized with numerous theories. In most of the theories the initial stages of the universe cope with singularity[1]. In classical framework the initial singularity cannot be analysed and avoided. The singularity is the region where all physical theories fail. The singularity is characterized with zero scale factor, diverged energy density, pressure and scalar curvature. Many attempts have been taken to resolve the singularity. Some approaches skips the initial singularity. On the other hand quantum mechanics deals the miniature level problems. The weird nature of subatomic particle level is revealed by the quantum mechanics. The quantum mechanics is applied to the initial stages of the universe. Such formalism is referred as the loop quantum cosmology which implements the formalism of loop quantum gravity[2]. The initial stages of the universe is resolved by the loop quantum cosmology. Such singularity resolution provides possible resolution of extension of geodesics beyond the singularity. The standard cosmological models hold the big bang cosmological model[3]. The model found the initial conditions of the universe as dense, hot and tiny. From that initial point, the universe cooled and expanded to present stages of the observable universe [4],[5]. The non singular universe is also proposed with the universe from nothing models. The universe is analysed quantum mechanically. The initial conditions of the universe can be treated as quantum vacuum fluctuations [7]. By the inflation scenario the universe is predicted as the expanded state from the quantum vacuum .The expansion is predicted as inflation scenario [12]. The evolution of the universe is treated as cyclic manner which is proposed as conformal cyclic cosmology [8]. By connecting these models,the quantum treatment the universe can be analysed. In this work the big bang singularity is analysed. The similarity resolution from loop quantum cosmology is discussed. Emergence of universe from vacuum is also discussed. Emergence of non singular universe is analysed from this work .

2 BIG BANG AND INITIAL SINGULARITY

The expansion of the universe have been observed by various analysis [9], [10],[11]. They provide the result that initial stages of the universe must be in the state of isotropic and homogeneous. Those results are predicted from the general relativity. The Hubble expansion didn't offer the current expansion scenario of standard cosmological model. The general relativistic principles provide the homogeneous and isotropic solution for the universe in large scales. The big bang model has been formulated in 1940 by the work of Gamow and his collaborators. For the relic abundance of elements of current scenario of the universe, the earlier universe must begin from the state of very hot and dense initial conditions . That state of the universe is cooled to current observational state of the universe [4][5]. The first direct evidence for this model was the presence of low temperature background [6]. Thus the background temperature with 3K is direct consequence from the big bang, where the initial stages of the universe must be a ultra dense and hot singular universe.

The Robertson Walker metric is

$$ds^2 = dt^2 - R^2(t)[\frac{dr^2}{1-kr^2}(d\theta^2 + \sin^2\theta d\phi^2)] \quad (1)$$

Here k is the curvature constant which takes values −1,0,+1 for open flat and closed universes correspondingly. This could be re-expressed as

$$ds^2 = dt^2 - R^2(t)[d\chi^2 + S^2(\chi)(d\theta^2 + \sin^2\theta d\phi^2)] \quad (2)$$

Where modified function acts as χ,sinχ,sinhχ for k=0,+1,−1 models. Proper distances in terms of comovimg coordinates are determined by the scale factor. The Friedman equation determines the equations of motion of the universe. Those equations are derived from Einstein's equation.

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = \frac{8\pi G}{c^2}T_{\mu\nu} + \Lambda g_{\mu\nu} \tag{3}$$

Where $R_{\mu\nu}$ curvature tensor , *R* Ricci scalar, $T_{\mu\nu}$ stress energy tensor, $g_{\mu\nu}$ is the metric. The solutions of Einstein's equation leads to Friedman equation

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G\rho}{3} - \frac{k}{a^2} + \frac{\Lambda}{3} \tag{4}$$

and

$$\frac{\ddot{a}}{a} = \frac{\Lambda}{3} - \frac{4\pi G}{3}(\rho + 3p) \tag{5}$$

Here *H* Hubble constant. The critical density when universe stops expansion is defined as

$$\rho_c = \frac{3H^2}{8\pi G} \tag{6}$$

The critical density is obtained for k=0 and Λ=0. The critical energy density is related to the total energy density as

$$\Omega_{tot} = \frac{\rho}{\rho_c} \tag{7}$$

Hence the Friedman equation can be rewritten as

$$\frac{k}{a^2} = H^2(\Omega_{tot} - 1) \tag{8}$$

The equation can be restated as

$$\frac{k}{a^2} = H_0^2(\Omega_m - \Omega_r - \Omega_v - 1) \tag{9}$$

Which represents the present value of Hubble parameter ,matter density, radiation density and vacuum density.

3 RESOLUTION OF CLASSICAL SINGULARITY

The classical singularity are assumed to be non solvable in any classical theories. The classical singularity has divergence in energy density ,pressure and temperature. Similarly it has divergence in curvature also. At singularity the volume approaches to zero. From such situation the universe has been emerged out as big bang theory predicts. The singularity should be treated quantum-mechanical in order to obtain the initial stages of the universe precisely. So the loop quantum cosmological formalism implemented to analyse the quantum mechanical behavior of the singularity.[13].The loop quantum cosmological formalism is introduced with loop quantum gravity solutions.[2]. The loop quantum cosmology attempts to quantize the gravity. The loop quantum gravity theory is a background Independent and diffomorphism invariant theory. Hence the loop quantum gravity is background independent, it has been used to analyse the singularity as a quantum mechanical perspective. The loop quantum cosmology has there canonical variables, which represent the curvature and scale factors.

$$\{c, p\} = \frac{\mathcal{K}\gamma}{3} \tag{10}$$

Here *c* represents the curvature component, and *p* represents the scale factor component. The Ashtker connection variable and its co triad has been introduced as

$$A_a^i = C\Lambda_I^i \omega_a^I \tag{11}$$

and

$$E_i^a = p\Lambda_i^I \chi_I^a \tag{12}$$

Where Λ_I is internal *SU*(2) dreibein. ω^I act on space manifold $\sum$. The volume operator is determined has with eigenvalues

$$V_j = (\gamma l_p^2)^{\frac{3}{2}} \sqrt{\frac{1}{27} j(j+\frac{1}{2})(j+1)} \tag{13}$$

The volume operator determines the volume of the universe at earlier stages. As per the classical big bang theory the volume approaches zero value at the singularity. This scenario is resolved with the loop quantum cosmology. The scale factor is introduced as operator. The inverse scale factor is related to the volume operator. The inverse scale factor value approaches minimum as the eigenvalues tends to minimum. That provides non zero values for scale factor and volume at singularity level.

$$M_{IJ} = \frac{q_{IJ}}{\sqrt{detq}} = \frac{e_I^i e_J^i}{(dete)} = \frac{1}{a}\delta_{IJ} \tag{14}$$

Similarly for for any given quantum state the evolution of universe can be viewed as collection of histories. As the universe is treated with the scalar potential as its internal time ,the evolution near the singularity can be viewed as forward and backward evolutions. From the loop quantum cosmological scenario , the existence of conformal cyclic cosmological model has been proven. Also this model suggests the initial stages of the universe as big bounce instead of existing big bang. Which means that once the universe approaches the critical density, it will bounce back to the future evaluational cycles of the universe. Various singularities from classical theories are also resolved from LQG models.

4 CONCLUSION

The initial stages of the universe consist many challenging aspects. From the conformal cyclic cosmology ,it has been introduced that the universe evolves as cyclic manner. Thus the end of a universe will be a beginning for future universes. Regarding this approach the initial stage universe is treated as quantum vacuum. the universe starts from big bang, expends until it reaches the critical density ,then it compress back into singularity. In this contracting phase the universe loose all of its constituents into singularity. Matter, radiation ,even dark matter also will be last into singularity. From this initial point the universe will start its evolution once again. The emergence of universe at this point is referred as spontaneous creation of universe from quantum vacuum [14]. The quantum mechanical universe is originated from the quantum vacuum fluctuations [7].The universe will be created out of quantum vacuum into a flat space [*15*]. The occurrence of universe emerging out of quantum vacuum resembles like quantum tunnelling. The universe pass through the quantum potential and the leakage causes the creation of universe out of nothing . There is no consequences are required for this phenomena. This process happens as like radioactive decay. The vacuum energy is translated as the cosmological constant in many physical theories. Thus the expansion of the universe is dominated by the cosmological constant. That parameter rules the initial stages of the universe also. The universe which emerges out of quantum vacuum is compared with the big bounce [16]. From such scenario the initial stages of the universe ,that derived from Wheeler Dewitt solutions is related to the loop quantum cosmological solutions. The loop quantum cosmological resolution of earlier stages of the universe removes the singularity. Thus it provides non-zero eigenvalues for the scale factor and volume. The singularity can be analysed quantum mechanically. The singularity resolution equations provides nonsingular initial stages of the universe over the theorems which hold absence of singularity . Hence it has been proven that the existence of nonsingular beginning of the universe is plausible. Apart from Big bang model the cycle cosmological model provides numerous information about the initial stages of the universe. Hence non singular beginning of the universe by quantum mechanical approach is possible.

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