A first step in evolving quantum cosmology

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Abstract. Implementing Mach's principle and Planck scale simultaneously in entire cosmic evolution can be considered as a first step in quantum cosmology. In this context, we propose a simple model of quantum cosmology without dark energy. Our assumptions are: 1) Universe is a quantum gravitational object. 2) Planck scale and Mach's principle play a combined role in entire cosmic evolution. 3) Cosmic thermal wavelength is inversely proportional to ordinary matter density ratio. 4) Ordinary matter density ratio and dark matter density ratio play a combined role in estimating cosmic expansion velocity. 5) Critical energy density and dark energy density are equal in magnitude and physically there exists no dark energy.

1. Introduction

By considering 'Planck scale' [1-4] as a characteristic limit of the evolving universe and considering 'Mach's principle' [5] as a deep cosmic probe, an 'evolving model' of quantum cosmology can be developed. In this paper, by fitting the current ordinary matter density ratio with current cosmic temperature and current Hubble parameter, we try to estimate the current cosmic mass, radius and expansion velocity. We noticed a simple relation for estimating the total matter density ratio. Proceeding further, we proposed a simple method for understanding the non-existence of dark energy.

1.1 Motivating points

- a) Mach's principle is one of the iconic principles underlying general theory of relativity (GTR) and can be given a priority in developing a workable or unified model of cosmology.
- b) Cosmic expansion, Lambda term, dark matter, cosmic temperature, inflation, cosmic acceleration and dark energy and vacuum energy are different concepts, by using which alternative models of GTR are emerging and are being extended in many ways. In this sequence, Quantum gravity can also be given some consideration.
- c) Quantum gravity is a wide range physical model intended for understanding the in-built cosmological quantum phenomena on small scale as well as large scale distances. So far, progress in this direction is very nominal and 'GTR' needs a serious review with reference to 'quantum cosmology'. In this context, Planck scale and Mach's principle seem to play a crucial role in entire cosmic evolution.
- d) With reference to particle physics, current technological limits on particle colliding energy, unidentified/unseen particles, unknown particle interactions and incomplete final unification scheme to some extent, one can hopefully believe in the existence of dark matter [6].
- e) Basically, 'dark energy' was proposed for understanding cosmic acceleration. Careful analysis of improved supernovae data suggets that universe is coasting at constant veleocity and evidence for acceleration is only marginal [7,8]. In this context, now a days, a great debate has been initiated

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among mainstream copsmologists on the existence of dark energy [9-12]. According to a new study [13], the nature of dark energy is 'dynamic' and conceptually seems to deviate from the famous cosmological constant or vaccum energy. According to another new study [14,15], evidence for dynamical dark energy is very poor.

- f) Density perturbations [12] and interaction between dark mtter and baryons [11] seem to play a crucial role in understanding observed cosmic acceleration and there exists no need of introducing dark energy.
- g) Even though redshift is an index of cosmic expansion, without knowing the actual galactic distances and actual galactic receding speeds, with 100% confidence level, it may not be possible to decide the absolute nature of cosmic expansion rate.

2. Concepts and relations pertaining to quantum cosmology

2.1 Nomenclatures

 Ω_{OM} = Ratio of ordinary matter density to critical density.

 Ω_{DM} = Ratio of dark matter density to critical density.

- H = Hubble parameter.
- V_{exp} = Cosmic expansion velocity.
- M_{OM} = Cosmic ordinary mass.

 M_{DM} = Cosmic dark matter.

 M_{tot} = Cosmic total matter.

R =Cosmic radius associated with M_{tot} .

 $(\lambda_{max}) =$ Cosmic thermal wavelength and

$$T = \text{Cosmic temperature } = \frac{2.898 \times 10^{-3} \,^{\circ} \text{K.m}}{(\lambda_{max})} \,.$$

Note-1: For the above symbols, subscript t denotes time dependent value, 0 denotes current value and pl denotes Planck scale value.

Note-2: $\beta \cong A$ new number related with quantum constants $\cong 4.96511423 \left(\frac{45}{128\pi^7}\right)^{\frac{1}{4}} \cong 0.51572.$

2.2 Basic assumptions

- 1) Universe is a quantum gravitational object.
- 2) Planck scale and Mach's [15] play a crucial role in entire cosmic evolution.
- 3) Cosmic thermal wavelength is inversely proportional to ordinary matter density ratio [16].
- 4) Ordinary matter density ratio and dark matter density ratio play a combined role in estimating cosmic expansion velocity.
- 5) Critical energy density and dark energy density are equal in magnitude and physically there exists no dark energy.

Note-3: Based on these assumptions, from the beginning of Planck scale, a) With a 'decreasing' trend of total matter density ratio, cosmic expansion velocity can be shown to be increasing. b) With an 'increasing' trend of total matter density ratio, cosmic expansion velocity can be shown to be decreasing. c) With a constant trend of total matter density ratio, cosmic expansion velocity can be shown to be shown to be constant.

2.3 Choosing the Magnitude of H_0

1) As per the 2015 Planck data [17]: $H_0 \simeq (67.31 \pm 0.96)$ km/sec/Mpc and the present temperature of

the CMB radiation is, $T_0 \cong (2.722 \pm 0.027)$ K.

- 2) According to the advanced observational data analysis by [18], current best value of $H_0 \simeq (73.24 \pm 1.74)$ km/sec/Mpc.
- 3) With reference to $T_0 \cong 2.722$ K and our proposed set of concepts, in this paper, we choose, $H_0 \cong 70$ km/sec/Mpc $\cong 2.26853 \times 10^{-18} sec^{-1}$. This value seems to lie in between (67.31 and 73.24) km/sec/Mpc.

2.4 Role of the Planck scale in entire cosmic evolution

So far no mainstream cosmological model implemented Planck scale in current cosmic evolution. In this complicated situation, in a positive approach, we make an attempt to implement the 'Planck scale' in the entire cosmic evolution. With further study, our approach can be developed for a better understanding. Based on quantum gravity, we define the Planck scale Hubble parameter,

 $H_{pl} \cong \sqrt{\frac{c^5}{G\hbar}} \cong 1.855 \times 10^{43} \text{ sec}^{-1}$. To proceed further, we define that,

$$\left(\frac{3H_t^2c^2}{8\pi G\left(aT_t^4\right)}\right)^{\frac{1}{2}} \cong \gamma_t \cong \left[1 + \ln\left(\frac{H_{pl}}{H_t}\right)\right]$$
(1)

where H_t is the time dependent Hubble parameter.

If defined $H_{pl} \cong 1.854921 \times 10^{43} \text{ sec}^{-1}$, one can choose different values of γ in between $\gamma_{pl} \cong 1$ and $\gamma_0 \cong 141.2564$. For each value of γ , one can get a corresponding H and all other physical parameters can be estimated.

2.5 Relation between temperature and ordinary matter density ratio

With reference to the set of concepts, at any stage of cosmic evolution, we choose the following set of 'semi empirical model relation'. One can modify them for a better understanding. At any arbitrary point of time, let,

$$(M_{OM} + M_{DM})_t \cong (M_{tot})_t$$

$$\cong \left[(\Omega_{OM})_t + (\Omega_{DM})_t \right] \left(\frac{3H_t^2}{8\pi G} \right) \left(\frac{4\pi}{3} R_t^3 \right)$$

$$(2)$$

$$G(M_{OM} + M_{DM})_t \cong G(M_{tot})_t \cong R_t c^2$$
(3)

$$R_{t} \cong \frac{G(M_{OM} + M_{DM})_{t}}{c^{2}} \cong \frac{G(M_{tot})_{t}}{c^{2}}$$

$$\tag{4}$$

3. Cosmic physical parameters

3.1 Cosmic temperature and ordinary matter density ratio

1) Temperature of the CMB radiation,

$$\left(\lambda_{max}\right)_{t} \cong \frac{1}{\left(\Omega_{OM}\right)_{t}} \left(\frac{c}{\sqrt{H_{pl}H_{t}}}\right) \text{ and}$$

$$T_{t} \cong \frac{2.898 \times 10^{-3} \text{ }^{\circ}\text{Km}}{\left(\lambda_{max}\right)_{t}} \cong \left(\Omega_{OM}\right)_{t} \times \frac{h\sqrt{H_{pl}H_{t}}}{4.965114k_{B}}$$

$$\cong \left[1 + \ln\left(\frac{H_{pl}}{H_{t}}\right)\right]^{-\frac{1}{2}} \left(\frac{3H_{t}^{2}c^{2}}{8\pi Ga}\right)^{\frac{1}{4}} \cong \left[\gamma_{t}\right]^{-\frac{1}{2}} \left(\frac{3H_{t}^{2}c^{2}}{8\pi Ga}\right)^{\frac{1}{4}}$$

$$(5)$$

where $\left(\frac{c}{\sqrt{H_{pl}H_{t}}}\right)$ can be called as the Planck-Hubble mean length.

2) Ordinary matter density ratio,

$$\left(\Omega_{OM}\right)_{t} \cong \left(\frac{\left(M_{OM}\right)_{t}}{\frac{4\pi}{3}R_{t}^{3}}\right) \div \left(\frac{3H_{t}^{2}}{8\pi G}\right) \cong \frac{0.51572}{\sqrt{\gamma_{t}}} \cong \frac{\beta}{\sqrt{\gamma_{t}}}$$
(6)

3.2 Relation between ordinary matter density ratio and dark matter density ratio With reference to current observed dark matter density ratio, we noticed that,

$$\left(\Omega_{DM}\right)_{0} \approx \left(\frac{1}{\gamma_{0}}\right)^{\frac{1}{4}} - \left(\Omega_{OM}\right)_{0} \approx \left(\frac{1}{\gamma_{0}}\right)^{\frac{1}{4}} - \frac{\beta}{\sqrt{\gamma_{0}}}$$

$$\text{and } \left[\left(\Omega_{OM}\right)_{0} + \left(\Omega_{DM}\right)_{0}\right] \approx \left(\frac{1}{\gamma_{0}}\right)^{\frac{1}{4}}$$

$$(7)$$

Based on this coincidence, we assume that, at any stage of cosmic evolution, $\begin{bmatrix} 1 \\ 1 \end{bmatrix}$

$$\begin{bmatrix} \left(\Omega_{OM}\right)_{t} + \left(\Omega_{DM}\right)_{t} \end{bmatrix} \cong \left(\frac{1}{\gamma_{t}}\right)^{\frac{1}{4}} \text{ and}$$

$$\left(\Omega_{DM}\right)_{t} \cong \left(\frac{1}{\gamma_{t}}\right)^{\frac{1}{4}} - \left(\Omega_{DM}\right)_{t} \cong \left(\frac{1}{\gamma_{t}}\right)^{\frac{1}{4}} - \frac{\beta}{\sqrt{\gamma_{t}}}$$

$$(8)$$

This relation needs further study. We are working on understanding its physical significance. Interesting point to be noted is that, without consideing dark matter density ratio, with this relation, total matter density ratio can be estimated. See the following picture-1. With reference to critical density, green curve represents the trend of ordinary matter density ratio and black curve represents the trend of dark matter density ratio.

3.3 Cosmic radius, expansion velocity, total matter

1) Cosmic radius,

$$R_{t} \cong \sqrt{\frac{2}{\left[\left(\Omega_{OM}\right)_{t} + \left(\Omega_{DM}\right)_{t}\right]}} \left(\frac{c}{H_{t}}\right) \cong \sqrt{2\gamma_{t}^{1/4}} \left(\frac{c}{H_{t}}\right)$$
(9)

2) Cosmic expansion velocity,

$$\left(V_{\exp}\right)_{t} \cong R_{t}H_{t} \cong \sqrt{\frac{2}{\left[\left(\Omega_{OM}\right)_{t} + \left(\Omega_{DM}\right)_{t}\right]}} c \cong \sqrt{2\gamma_{t}^{1/4}} \left(c\right)$$
(10)



Figure 1: Decreasing trend of ordinary and dark matter density ratios

3) Cosmic total matter,

$$\left[\left(M_{OM} \right)_{0} + \left(M_{DM} \right)_{0} \right] \cong \left(M_{tot} \right)_{t} \cong \left(\frac{c^{2} \left(V_{\exp} \right)_{t}}{GH_{t}} \right)$$
(11)

4) Cosmic ordinary matter content,

$$(M_{OM})_{t} \simeq \left[\frac{(\Omega_{OM})_{t}}{(\Omega_{OM} + \Omega_{DM})_{t}}\right] \left(\frac{c^{2}(V_{exp})_{t}}{GH_{t}}\right)$$
(12)

5) Cosmic dark matter content,

$$\left(M_{DM}\right)_{t} \cong \left[\frac{\left(\Omega_{DM}\right)_{t}}{\left(\Omega_{OM} + \Omega_{DM}\right)_{t}}\right] \left(\frac{c^{2}\left(V_{\exp}\right)_{t}}{GH_{t}}\right)$$
(13)

4. To show a method for understanding the non-existence of dark energy Kinetic energy of the expanding universe can be represented by

$$K_t \simeq \frac{1}{2} \left(M_{OM} + M_{DM} \right)_t \left(V_{\exp} \right)_t^2 \simeq \frac{1}{2} \left(M_{tot} \right)_t \left(V_{\exp} \right)_t^2$$
(14)

For a moment, assume that, critical energy itself is driving the entire universe with an expansion velocity $(V_{exp})_{r}$.

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$$K_t \cong \frac{1}{2} (M_{tot})_t \left(V_{\exp} \right)_t^2 \cong \left\{ \left(\frac{3H_t^2 c^2}{8\pi G} \right) \left[\frac{4\pi}{3} R_t^3 \right] \right\}$$
(15)

Current scale	Planck scale
$H_0 \cong 70 \mathrm{km/sec/Mpc} \cong 2.26853 \times 10^{-18} \mathrm{sec^{-1}}$	$H_{pl} \cong \sqrt{\frac{c^5}{G\hbar}} \cong 1.855 \times 10^{43} \text{ sec}^{-1}$
$\gamma_0 \cong \left[1 + \ln\left(\frac{H_{pl}}{H_0}\right)\right] \cong 141.2564$	$\gamma_{pl} \cong \left[1 + \ln \left(\frac{H_{pl}}{H_{pl}} \right) \right] \cong 1$
$\left(\Omega_{_{OM}}\right)_{_{0}}\cong\left(\beta\big/\sqrt{\gamma_{_{0}}}\right)\cong0.0434$	$\left(\Omega_{_{OM}}\right)_{_{pl}}\cong\left(\beta\big/\sqrt{\gamma_{_{pl}}}\right)\cong0.51572$
$\left(\Omega_{_{OM}}\right)_{_{0}}+\left(\Omega_{_{DM}}\right)_{_{0}}\cong\left(\frac{1}{\gamma_{_{0}}}\right)^{\frac{1}{4}}\cong0.290$	$\left(\Omega_{OM}\right)_{pl} + \left(\Omega_{DM}\right)_{pl} \cong \left(\frac{1}{\gamma_{pl}}\right)^{\frac{1}{4}} \cong 1.0$
$\left(\Omega_{DM}\right)_{0} \cong \left(\frac{1}{\gamma_{0}}\right)^{\frac{1}{4}} - \frac{\beta}{\sqrt{\gamma_{0}}} \cong 0.2467$	$\left(\Omega_{DM}\right)_{pl} \cong \left(\frac{1}{\gamma_{pl}}\right)^{\frac{1}{4}} - \frac{\beta}{\sqrt{\gamma_{pl}}} \cong 0.48428$
$T_0 \cong \left(\beta / \sqrt{\gamma_0}\right) \times \frac{h \sqrt{H_{pl} H_0}}{4.965114 k_B} \cong 2.722 \text{ K}$	$T_{pl} \cong \left(\beta / \sqrt{\gamma_{pl}}\right) \times \frac{hH_{pl}}{4.965114k_B} \cong 9.247 \times 10^{31} \text{ K}$
$R_{0} \cong \sqrt{\frac{2}{\left[\left(\Omega_{OM}\right)_{t} + \left(\Omega_{DM}\right)_{t}\right]}} \left(\frac{c}{H_{0}}\right)$	$R_{pl} \cong \sqrt{\frac{2}{\left[\left(\Omega_{OM}\right)_{pl} + \left(\Omega_{DM}\right)_{pl}\right]}} \left(\frac{c}{H_{pl}}\right)$
$\approx 3.47 \times 10^{26} \text{ m} \approx 11.246 \text{ Gpc}$	$\cong 2.286 \times 10^{-35} \mathrm{m}$
$\left(V_{\exp}\right)_{0} \cong R_{0}H_{0} \cong \sqrt{\frac{2}{\left[\left(\Omega_{OM}\right)_{0} + \left(\Omega_{DM}\right)_{0}\right]}}(c)$	$\left(V_{\exp}\right)_{pl} \cong R_{pl}H_{pl} \cong \sqrt{\frac{2}{\left[\left(\Omega_{OM}\right)_{pl} + \left(\Omega_{DM}\right)_{pl}\right]}}(c)$
$\cong \sqrt{2\gamma_0^{1/4}} \left(c \right) \cong 2.6256c$	$\cong \sqrt{2\gamma_{pl}^{1/4}} \left(c \right) \cong 1.414c$
$\left(M_{OM}\right)_{0} \cong \left[\frac{\left(\Omega_{OM}\right)_{0}}{\left(\Omega_{OM} + \Omega_{DM}\right)_{0}}\right] \left(\frac{c^{2}\left(V_{\exp}\right)_{0}}{GH_{0}}\right)$	$\left(M_{OM}\right)_{pl} \cong \left[\frac{\left(\Omega_{OM}\right)_{pl}}{\left(\Omega_{OM} + \Omega_{DM}\right)_{pl}}\right] \left(\frac{c^2 \left(V_{\exp}\right)_{pl}}{GH_{pl}}\right)$
$\cong 6.99 \times 10^{52} \text{ kg}$	$\approx 1.539 \times 10^{-8} \text{ kg}$
$\left(\left(M_{DM} \right)_{0} \cong \left[\frac{\left(\Omega_{DM} \right)_{0}}{\left(\Omega_{OM} + \Omega_{DM} \right)_{0}} \right] \left(\frac{c^{2} \left(V_{\exp} \right)_{0}}{GH_{0}} \right) $	$\left(M_{DM}\right)_{pl} \cong \left[\frac{\left(\Omega_{DM}\right)_{pl}}{\left(\Omega_{OM} + \Omega_{DM}\right)_{pl}}\right] \left(\frac{c^2 \left(V_{\exp}\right)_{pl}}{GH_{ll}}\right)$
$\simeq 3.974 \times 10^{53} \text{ kg}$	$\simeq 1.539 \times 10^{-8} \text{ kg}$
$\left[\left(M_{OM}\right)_{0}+\left(M_{DM}\right)_{0}\right]\cong\left(\frac{c^{2}\left(V_{\exp}\right)_{0}}{GH_{0}}\right)$	$\left[\left(M_{OM} \right)_{pl} + \left(M_{DM} \right)_{pl} \right] \cong \left(\frac{c^2 \left(V_{exp} \right)_{pl}}{GH_{pl}} \right)$
$\cong 4.673 \times 10^{53} \text{ kg}$	$\approx 3.08 \times 10^{-8} \text{ kg}$

Table-1: Current and Planck scale cosmic physical parameters

Inserting relations (9) and (11) in relation (15), it is possible to show that,

$$(V_{\exp})_t \cong R_t H_t \cong \sqrt{\frac{2}{(\Omega_{OM} + \Omega_{DM})_t}}(c)$$
 (16)

Thus, based on the above relations, if one believes in critical energy, there is no need to believe in the existence of dark energy.

5. Current and Planck scale cosmic physical parameters

See table-1 for various cosmic physical parameters associated with current and Planck scales.

6. Cosmic scale factor and redshift

With reference to the proposed concepts and relations and with reference to the current definitions of cosmic redshift and scale factor, it is possible to show that,

$$\left(\frac{1}{a} \cong (z+1) \cong \frac{T_t}{T_0}\right) \cong \sqrt{\frac{\gamma_0 H_t}{\gamma_t H_0}} \cong \sqrt{\frac{\gamma_0}{\gamma_t}} \exp\left(\frac{\gamma_0 - \gamma_t}{2}\right)$$
(17)

We are working on interpreting this relation and it needs further study.

7. To estimate the current cosmic age

From the beginning of cosmic evolution, based on the proposed cosmic expansion velocities, cosmic age can be approximated with the following relation.

$$t \simeq \frac{\left(R_t - R_{pl}\right)}{\left[\left(\left(V_{\exp}\right)_t + \left(V_{\exp}\right)_{pl}\right)/2\right]}$$
(18)

where $\left[\left(\left(V_{\exp}\right)_{l} + \left(V_{\exp}\right)_{pl}\right)/2\right]$ can be considered as average expansion velocity.

For the current case,

$$t_{0} \approx \frac{\left(R_{0} - R_{pl}\right)}{\left[\left(\left(V_{\exp}\right)_{0} + \left(V_{\exp}\right)_{pl}\right)/2\right]}$$

$$\approx \frac{2R_{0}}{\left(\left(V_{\exp}\right)_{0} + \left(V_{\exp}\right)_{pl}\right)} \approx 18.16 \text{ BillionYears}$$
(19)

]

Based on relation (18), for the Planck scale, $t_{pl} \cong 0$. For a temperature of 3000 K, it is possible to show that,

$$H_{3000K} \cong 2.49 \times 10^{-12} \text{ sec}^{-1}$$

$$\gamma_{3000K} \cong 1 + \ln\left(\frac{H_{pl}}{H_{3000K}}\right) \cong 127.34774$$

$$\sqrt{\frac{\gamma_0}{\gamma_{3000K}}} \exp\left(\frac{\gamma_0 - \gamma_{3000K}}{2}\right) \cong 1103.407 \approx 1100$$
(20)

Cosmic age corresponding to a temperature of T=3000K can be estimated to be,

$$t_{3000K} \cong \frac{\left(R_{3000K} - R_{pl}\right)}{\left[\left(\left(V_{\exp}\right)_{3000K} + \left(V_{\exp}\right)_{pl}\right)/2\right]} \cong 16467.55 \text{ Years}$$
(21)

where $(V_{exp})_{3000K} \cong 2.592c$ and $R_{3000K} \cong 3.12 \times 10^{20}$ m.

This age estimation is roughly 23 times less than the current estimations and needs a review with reference to current and future observations pertaining to formation of early galaxies. We would like to suggest that, in our model, cooling is very fast in the early phase.

8. Velocity-distance relation

At present, from and about the hypothetical point of Planck scale or big bang, galactic receding speeds can be approximated with,

$$\left(v_{g}\right)_{0} \cong \left(\frac{\left(d_{g}\right)_{0}}{R_{0}}\right) \left(V_{\exp}\right)_{0} \cong \left(\frac{\left(V_{\exp}\right)_{0}}{R_{0}}\right) \left(d_{g}\right)_{0} \cong H_{0}\left(d_{g}\right)_{0}$$
(22)

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When $(d_g)_0 \to R_0$, $(v_g)_0 \cong H_0 R_0$. This can be compared with currently believed Hubble's law for the current expanding universe.

9. Discussions and conclusions

9.1 Cosmological constant problem

With reference to proposed concepts, ratio of the Planck scale critical density to the current critical density is,

$$\left(\frac{3H_{pl}^2c^2}{8\pi G}\right) \div \left(\frac{3H_0^2c^2}{8\pi G}\right) \cong \left(\frac{H_{pl}}{H_0}\right)^2 \cong 6.685 \times 10^{121}$$
(23)

We wish to appeal that, this idea can be considered as a characteristic tool for constructing a model of 'quantum gravity' with cosmic evolution.

9.2 Horizon problem

The 'horizon problem' is a problem with the standard cosmological model of the Big Bang. It points out that different regions of the universe have not 'contacted' each other because of the large distances between them, but nevertheless they have the same temperature and other physical properties like behavior of gravity, behavior of matter and speed of light. If one is willing to consider the concept of 'matter causes the space-time to curve', 'horizon problem' can be understood. According to big bang model, during its evolution, as the universe is expanding, thermal radiation temperature decreases and matter content increases. As matter content increases, based on Mach's principle, at any stage of

evolution, it is possible to have an increasing radius of curvature, $R_t \cong \frac{G}{c^2} \Big[(M_{OM})_t + (M_{DM})_t \Big]$. For the

current case, $R_0 \cong \frac{G}{c^2} \Big[(M_{OM})_0 + (M_{DM})_0 \Big] \cong 11.25$ Gpc and there is no scope for 'causal disconnection' of distant visible matter.

9.3 Cosmic inflation

Cosmologists proposed different starting mechanisms for initiating and fine tuning the believed 'inflation' and a great debate is going on its existence [19-22]. In this context, we are trying to understand the basics of inflation in a quantum gravitational approach.

9.4 CMBR fluctuations

Temperature fluctuations are directly proportional to actual galactic ordinary matter density fluctuations. Clearly speaking, observed hot spots and cold spots can be interpreted with higher and lower (ordinary) matter densities pertaining to galactic surroundings.

9.5 Cosmic expansion velocity

Now a days, main stream cosmologists are seriously working on 'eternal light speed expansion' [23-25], Melia et al 2016). In this context, by considering a decreasing trend of ordinary matter density and dark matter density, starting from the Planck scale, it is possible to get an expression for increasing cosmic expansion velocity. It can be expressed as follows.

$$\frac{\left(V_{\exp}\right)_{t}}{c} \cong \sqrt{\frac{2}{\left[\left(\Omega_{OM}\right)_{t} + \left(\Omega_{DM}\right)_{t}\right]}}$$
(24)

Based on this expression, for the Planck scale, $(V_{exp})_{pl} \cong \sqrt{2}c$ and for the current scale, $(V_{exp})_0 \cong 2.626c$. Interesting point to be noted is that, after 18 billion years of cosmic expansion, increment in expansion velocity seems to be only $[(V_{exp})_0 - (V_{exp})_{pl}] \cong 1.212c$. See the following picture-2.



Figure 2: Increasing trend of cosmic expansion velocity

Before 1990s, most of the cosmologists thought that the cosmic expansion would be decelerating due to the gravitational attraction of the matter in the universe. In between 1995 and 1998, as space technology was advancing, based on the available supernovae redshift data, cosmologists noticed that, rather than slowing down, universe was expanding with increasing rate [18,24]. Even though it was a shocking news for most of the science community, confirmatory evidence has been found in baryon acoustic oscillations and other cosmological observations [28]. Considering the updated supernovae redshift data, in 2016, cosmologists noticed that, universe is coasting at constant speed rather than acceleration [7]. In this context, now a days, a great debate has been initiated among various groups of cosmologists on 'cosmic acceleration' [29-32].

From figure-2, it is very clear that, right from the beginning of cosmic evolution, cosmic expansion velocity seems have an increasing trend. To some extent, this can be compared with currently believed cosmic acceleration concept. Interesting point to be noted is that, current expansion velocity seems to

depend on $\{(\Omega_{OM})_0 + (\Omega_{DM})_0\}$. In near future, if decrease in $\{(\Omega_{OM})_0 + (\Omega_{DM})_0\}$ is found to be significant, one can expect acceleration and if decrease in $\{(\Omega_{OM})_0 + (\Omega_{DM})_0\}$ is found to be insignificant, one can expect cosmic constant rate of expansion. It is for further study.

10. Conclusions

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We would like to suggest that:

- 1) Implementing Mach's principle and Planck scale simultaneously in entire cosmic evolution can be considered as a first step in quantum cosmology.
- 2) Total matter density ratio seems to be inherently connected with the ratio of Planck scale and time dependent Hubble parameters.
- 3) Independent of existing methods and in a quantum gravity approach, we have proposed a very simple and very efficient method for co-relating the current Hubble parameter and current cosmic temperature. Even though it is very interesting, it is also true that the proposed concepts and relations are speculative and peculiar. By using the proposed relations and applying them in fundamental cosmic physics, in due course, their role or existence can be verified.
- 4) Current cosmic radius is about 11.25 Gpc and can be compared with current observations of 14 Gpc. Current cosmic sphere seems to constitute around 18 Hubble spheres and needs further study with respect to the Bayesian model average estimate of >251 Hubble spheres proposed by [32-34].
- 5) When critical energy itself is able to drive the universe at $(V_{exp})_{t} \cong R_{t}H_{t} \cong \sqrt{\frac{2}{\left[(\Omega_{OM}), + (\Omega_{DM})\right]^{2}}}(c)$,

practically there is no need to introduce 'dark energy'.

- 6) Without knowing the trend of past and future matter densities, it may not be possible to understand the actual rate of cosmic expansion. In a quantum gravitational approach, we are working on developing various relations for understanding the trend of total matter density ratio.
- 7) Independent of galactic redshift data, we are working on finding alternative tools for understanding the cosmic expansion rate. In future, with advanced science, engineering and technology, by considering $\frac{d(T_0)}{dt}$ or $\frac{d(H_0)}{dt}$ or $\frac{d(\Omega_{DM})_0}{dt}$ or $\frac{d(\Omega_{DM})_0}{dt}$ or $\frac{d(\Omega_{DM} + \Omega_{DM})_0}{dt}$ absolute cosmic rate of expansion can be estimated

Acknowledgements

It is great pleasure to express our deep gratitude to Dr. E. Terry Tatum for his valuable technical discussions and kind encouragement. Author Seshavatharam is indebted to professors brahmashri M. Nagaphani Sarma, Chairman, shri K.V. Krishna Murthy, founder Chairman, Institute of Scientific Research in Vedas (I-SERVE), Hyderabad, India and Shri K.V.R.S. Murthy, former scientist IICT (CSIR), Govt. of India, Director, Research and Development, I-SERVE, for their valuable guidance and great support in developing this subject.

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