Athens Journal of Sciences- Volume 6, Issue 3 – Pages 211-230

A Practical Model of Godel–Planck–Hubble–Birch Universe

By UVS Seshavatharam[*] & S Lakshminarayana[†]

By considering 'Planck mass' as a characteristic massive seed and by replacing big bang with a growing Planck ball, an evolving model of quantum cosmology can be developed. With reference to increasing support for large scale cosmic anisotropy, preferred directions, quantum mechanical demand of cosmic spin and by considering a decreasing trend of angular velocity, from the beginning of Planck scale, we have developed a procedure for estimating the trend of all cosmic physical parameters. From and about the baby universe, in all directions, cosmic acceleration can be understood with increasing expansion velocity and decreasing total matter density ratio. We would like suggest that, from the beginning of Planck scale, 1) Dark matter can be considered as a kind of cosmic foam responsible for formation of galaxies. 2) Cosmic angular velocity decreases with square of the decreasing cosmic temperature. 3) Increasing ratio of Hubble parameter to angular velocity plays a crucial role in estimating increasing cosmic expansion velocity and decreasing total matter density ratio. 4) There is no need to consider dark energy for understanding cosmic acceleration. With further study, cosmological nucleosynthesis and dark matter synthesis along with mass generation mechanism can be reviewed in a quantum cosmological approach.

Keywords: *Angular Velocity, Critical Density, Dark Matter, Expansion Velocity, Hubble's Law, Ordinary Matter, Planck Scale, Quantum Cosmology.*

PACS Nos: *04.20.-q, 04.60.-m, 04.50.Kd, 98.80.Qc, 98.80.Bp, 98.80.Es*

Introduction

According to the current notion of modern cosmology, if the known laws of physics are extrapolated to the highest density regime, the result is a singularity which is typically associated with the big bang (Gamow 1948a, 1948b). Unfortunate thing is that, pre or post conditions and parameters of big bang physics are absolutely unknown. In this critical scenario, in a quantitative approach, it may not be wrong to consider a 'growing' or 'evolving' phase of 'Planck scale'. Even though massive nature is unclear - with known physical laws, Planck scale can be assigned with certain 'mass', certain 'radius', certain 'volume', certain 'density', certain 'temperature' and certain 'pressure'. Clearly speaking, Planck mass can be considered as a characteristic massive seed of the evolving universe and big bang can be replaced with an evolving Planck ball. Planck mass can be called as the 'baby universe'. Thinking in this way, by

[*]Honorary Faculty, I-SERVE, Survey no-42, Hitech city, Hyderabad, India.
[†]Retired Professor, Department of Nuclear Physics, Andhra University, Visakhapatnam-03, India.

https://doi.org/10.30958/ajs.6-3-4 doi=10.30958/ajs.6-3-4

replacing big bang (Mitra 2011, 2014) with a growing Planck ball, in a hypothetical approach, an evolving model of quantum cosmology can be developed (Bojowald 2015, Padmanabhan 2005, Sivaram 2000). Since Planck scale is associated with Quantum theory and 'spin' is a basic property of quantum mechanics, it may not be wrong to consider a growing and rotating model of a Planck ball (Whittaker 1945, Gamow 1946, Godel 1949, Raychaudhuri 1955, Narlikar and Hoyle 1963, Hawking 1969, Birch 1982, Korotky and Obukhov 1995, Nodland and Ralston 1997, Kuhne 1997, Li 1998, Singh 1999, Obukhov 2000, Carneiro 2002, Panov and Kuvshinova 2004, Barrow and Tsagas 2004, Szydlowski and Godlowski 2005, Su and Chu 2009, Godlowski 2011, Longo 2011, Cai et al. 2013, Chechin 2016, 2017). Since nothing is known, it is absolutely not possible to simulate a big bang, but with future science, engineering and technology, it is certainly possible to simulate any 'Planck scale' physical event. Till that time, cosmic observations can be analyzed with a notion of 'growing Planck ball'. Center of the growing universe seems to depend on the location of the assumed Planck seed under consideration. In this paper, with reference to our recent paper (Seshavatharam and Lakshminarayana 2019), by modifying our proposed set of assumptions we try to cover up the Mach's principle (Arbab 2004, Annila 2012, Grahn et al. 2018) and show that, observable cosmic radius is a geometric mean of Schwarzschild radius and Hubble radius (Tatum et al. 2015a, Seshavatharam and Lakshminarayana 2015). It needs further study.

Important demerits of big bang notion can be understood with the following points:

1) Preconditions of big bang are absolutely unclear and unknown.
2) No quantitative description is available for the matter content associated with the big bang event.
3) Physical reasons that led to big bang are unclear and unknown.
4) Quantitative description for big bang bursting force or pressure is unclear and unknown.
5) Whether big bang followed known physical laws are not - is also unclear and unknown.
6) Quantum information associated with big bang is unclear and unknown.
7) Within a fraction of second, how, big bang allowed 'inflation' to happen? - is still a puzzling issue.
8) Applying Planck scale physics to big bang notion is a confusing issue.
9) Whether pre big bang or post big bang constitutes dark matter – is unclear and unknown.
10) Role of dark energy in big bang - is another complicated and questionable issue.

We would like appeal that, proposed decreasing trend of angular velocity, increasing trend of expanding speed (without dark energy), plotted graphs for understanding the smooth decreasing trend of density ratios of dark matter and ordinary matter, estimated non-inflationary cosmic radius of 14.772 Gpc, early stage fast cooling and later stage slow cooling seem to strengthen our proposed assumptions and semi empirical relations. Gamow's big bang model well established that, early stage nucleosynthesis plays a vital role in understanding the observed proportions of Hydrogen and Helium. Keeping this point in view, we plan to focus our future study on understanding Planck scale and nuclear scale baryonic and dark matter physical phenomena in a unified Gamow–Godel–Planck–Hubble–Birch universe.

Nomenclatures, Assumptions and Basic Relations

Nomenclatures

1) $H_t =$ Hubble parameter.
2) $\left(\rho_c c^2\right)_t \cong \left(3H_t^2 c^2/8\pi G\right) =$ Critical energy density.
3) $(\Omega_{OM})_t =$ Ratio of ordinary matter density to critical density.
4) $(\Omega_{DM})_t =$ Ratio of dark matter density to critical density.
5) $\omega_t =$ Cosmic angular velocity.
6) $\left(V_{\exp}\right)_t =$ Cosmic expansion velocity from and **a**bout the baby universe in all directions.
7) $(M_{OM})_t =$ Cosmic ordinary mass content.
8) $(M_{DM})_t =$ Cosmic dark matter content.
9) $(M_{OM} + M_{DM})_t \cong M_t =$ Total matter content = Total mass of evolving Planck ball.
10) $R_t =$ Cosmic radius associated with M_t = Radius of evolving Planck ball.
11) $T_t =$ Cosmic temperature.
12) $\gamma_t =$ Ratio of Hubble parameter to angular velocity.
13) $\left(d_g\right)_t =$ Galactic distance from and about the baby universe.
14) $\left(v_g\right)_t =$ Galactic receding speed from and about the baby universe.

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

Proposed Assumptions

With respect to our earlier and recent publications (Seshavatharam and Lakshminarayana 2015, 2017, 2018a, 2018b), in this paper, we revise the proposed four assumptions for a better understanding and simplification.

1) Ratio of Hubble parameter to angular velocity is, $\gamma_t \cong \left(\frac{H_t}{\omega_t}\right) \cong \left[1 + \ln\left(\frac{H_{pl}}{H_t}\right)\right] \cong \sqrt{\frac{3H_t^2 c^2}{8\pi G\left(aT_t^4\right)}}$.

2) $\left(V_{\exp}\right)_t \cong R_t H_t \cong \gamma_t^{1/4} c$ can be considered as the increasing cosmic expansion velocity.
3) Total matter density ratio can be expressed with $\left(\Omega_{OM} + \Omega_{DM}\right)_t \cong \frac{c}{\left(V_{\exp}\right)_t} \cong \frac{1}{\gamma_t^{1/4}}$
4) Dark matter can be considered as a kind of cosmic foam responsible for formation of galaxies (Verlinde 2017, Levkov et al. 2018, Montes and Trujillo 2019, https://www.forbes.com[1]).

Note points-2:

(1) Assumption 1 indicates the role of Planck scale in entire cosmic evolution. Using the number γ_t, density ratios of dark matter and ordinary matter can be studied.
(2) Assumption 2 can be considered as a simplified form of Hubble's law applied to the expanding universe as whole. $\left(V_{\exp}\right)_t \cong \gamma_t^{1/4} c$ can be understood in terms of cosmic kinetic energy and temperature in the following way. During cosmic evolution,
   a) Kinetic energy of matter is inversely proportional to cosmic temperature.
   b) Based on assumption 1, cosmic temperature can be shown to be inversely proportional to $\sqrt{\gamma_t}$.
   c) Hence, cosmic expansion velocity can be shown to be proportional to $\gamma_t^{1/4}$.
(3) Assumption 3 plays a crucial role in estimating cosmic matter content.
(4) Assumption 4 may help in studying the nature of dark matter.

Role of the Planck Scale in Entire Cosmic Evolution

We make an attempt to implement the 'Planck scale' in the entire cosmic evolution. We define the Planck scale Hubble parameter, $H_{pl} \cong \sqrt{\frac{c^5}{G\hbar}} \cong 1.854921\times 10^{43}\ \sec^{-1}$. To proceed further, we assume that,

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

$$\frac{3\omega_t^2 c^2}{8\pi G} \cong aT_t^4 \quad \text{and} \quad \omega_t \cong \sqrt{\frac{8\pi G\left(aT_t^4\right)}{3c^2}} \tag{2}$$

[1]https://www.forbes.com/sites/startswithabang/2019/02/22/the-wimp-miracle-is-dead-as-dark-matter-experiments-come-up-empty-again/#18c618f26dbc.

Based on relation (1), if defined $H_{pl} \cong 1.854921\times10^{43}$ sec^{-1} , one can choose different values of γ in between $\gamma_{pl} \cong 1$ and $\gamma_0 \cong 141.2564$ where $H_0 \cong 70\text{km/sec/Mpc} \cong 2.26853\times10^{-18}$ sec^{-1} (Planck Collaboration 2015, Riess 2016). For each assumed value of H_t, one can get a corresponding γ_t and all other physical parameters can be estimated.

For the Planck scale, $\gamma_{pl} \cong 1$ and $\omega_{pl} \cong \frac{H_{pl}}{\gamma_{pl}} \cong H_{pl} \cong 1.855\times10^{43}$ rad/sec.

For the current case, $\gamma_0 \cong 141.2564$ and $\omega_0 \cong \frac{H_0}{\gamma_0} \cong 1.606\times10^{-20}\ \frac{\text{rad}}{\text{sec}}$ $\cong 5.068\times10^{-13}\ \frac{\text{rad}}{\text{year}}$

This value can be compared with other estimates (Birch 1982).

In a simplified form, cosmic temperature can be expressed as,

$$T_t \cong \frac{1}{\sqrt{\gamma_t}}\left(\frac{3H_t^2c^2}{8\pi Ga}\right)^{\frac{1}{4}} \cong \left\{\frac{0.652632\hbar\sqrt{\omega_{pl}\omega_t}}{k_B}\right\} \tag{3}$$

Estimating the Trend of Density Ratios of Ordinary Matter, Dark Matter and Total Matter

With the help of defined $\left(\frac{H_t}{\omega_t}\right) \cong \gamma_t \cong \left[1+\ln\left(\frac{H_{pl}}{H_t}\right)\right]$ and with reference to the current observed values of $(\Omega_{OM})_0$ and $(\Omega_{DM})_0$, we are making an attempt to estimate the past values of $(\Omega_{OM})_t$ and $(\Omega_{DM})_t$.

Unless we know the physical nature and properties of dark matter, it may not be possible to thoroughly analyze the density ratios of dark matter and ordinary matter. Keeping the current values of $(\Omega_{OM})_0$ and $(\Omega_{DM})_0$ in view and guessing that, there exists $(\Omega_{OM})_{pl}$ and $(\Omega_{DM})_{pl}$ at Planck scale, we propose the following very simple 'model' relations. We ask readers not to show more focus on relations (4), (5) and (6). With further study, other such kind of relations can be developed in a verifiable approach and percentages of dark matter and ordinary matter can be explored (Verlinde 2017).

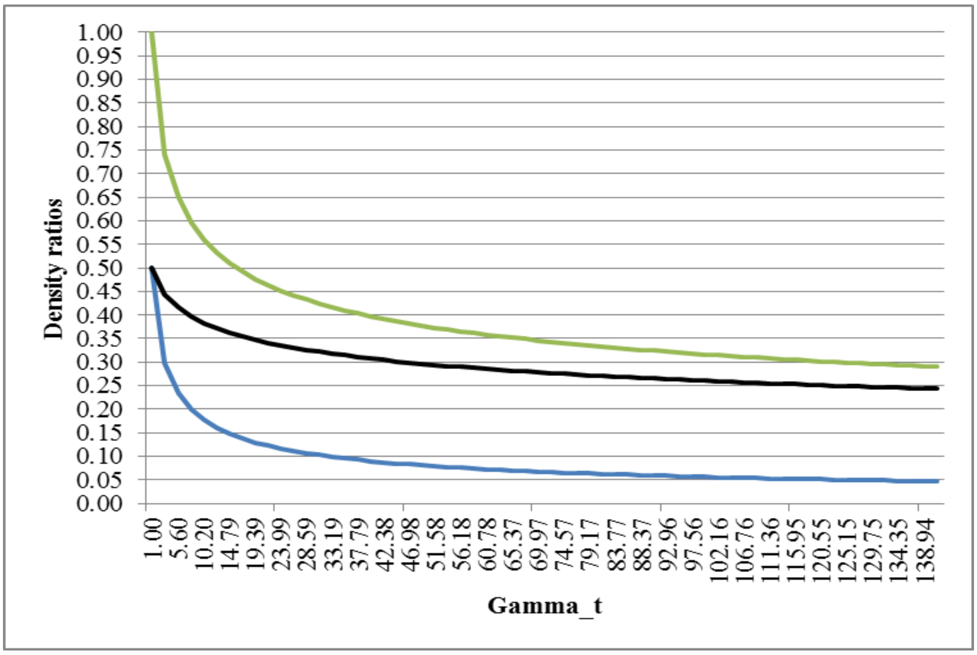
$$\frac{(\Omega_{DM})_t}{(\Omega_{OM})_t} \cong \gamma_t^{1/3} \tag{4}$$

$$(\Omega_{OM})_t \cong \left[\left(1+\gamma_t^{1/3}\right)\gamma_t^{1/4}\right]^{-1} \tag{5}$$

$$(\Omega_{DM})_t \cong \left[\left(1+\gamma_t^{-1/3}\right)\gamma_t^{1/4}\right]^{-1} \tag{6}$$

See Figure 1 plotted with relations (4) and (6). Blue curve represents a decreasing trend of ordinary matter density ratio, black curve represents a decreasing trend of dark matter density ratio and green curve represents a decreasing trend of total matter density ratio. Here, it is very important to note that, even though density ratios of ordinary matter and dark matter are assumed to have a decreasing trend, their mass content can be shown to be increasing with increasing cosmic volume. In terms of $(\Omega_{OM})_t$ and $(\Omega_{DM})_t$,

Figure 1. *Decreasing Trend of Density Ratios of Ordinary Matter, Dark Matter and Total Matter*



$$M_t \cong \left[(\Omega_{OM})_t+(\Omega_{DM})_t\right]\left(\frac{3H_t^2}{8\pi G}\right)\left(\frac{4\pi}{3}R_t^3\right) \cong \left(\frac{c\left(V_{\exp}\right)_t^2}{2GH_t}\right) \tag{7}$$

$$(M_{OM})_t \cong \left[\frac{(\Omega_{OM})_t}{(\Omega_{OM}+\Omega_{DM})_t}\right]\left(\frac{c\left(V_{\exp}\right)_t^2}{2GH_t}\right) \cong (\Omega_{OM})_t\left(\frac{\left(V_{\exp}\right)_t^3}{2GH_t}\right) \tag{8}$$

$$(M_{DM})_t \cong \left[\frac{(\Omega_{DM})_t}{(\Omega_{OM}+\Omega_{DM})_t}\right]\left(\frac{c\left(V_{\exp}\right)_t^2}{2GH_t}\right) \cong (\Omega_{DM})_t\left(\frac{\left(V_{\exp}\right)_t^3}{2GH_t}\right) \tag{9}$$

$$\left.\begin{array}{l} \left(V_{\exp}\right)_t \cong \sqrt{\dfrac{2GM_tH_t}{c}} \quad \text{and} \\ R_t \cong \gamma_t^{1/4}\left(\dfrac{c}{H_t}\right) \cong \sqrt{\left(\dfrac{2GM_t}{c^2}\right)\left(\dfrac{c}{H_t}\right)} \end{array}\right\} \tag{10}$$

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.

$$t \cong \frac{(R_t - R_{pl})}{\left[\left((V_{\exp})_t + (V_{\exp})_{pl}\right)/2\right]} \tag{11}$$

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

For the current case, $t_0 \cong 21.656 \text{ BillionYears}$.

For a temperature of 3000 K, it is possible to show that,

$$\left.\begin{aligned} H_{3000K} &\cong 2.49\times10^{-12} \text{ sec}^{-1} \\ \gamma_{3000K} &\cong 1+\ln\left(\frac{H_{pl}}{H_{3000K}}\right) \cong 127.34774 \\ Z_{3000K} &\cong \sqrt{\gamma_{3000K}} - 1 \cong 10.285 \\ z_{3000K} &\cong \sqrt{\frac{\gamma_0}{\gamma_{3000K}}\exp\left(\gamma_0 - \gamma_{3000K}\right)} - 1 \cong 1102.407 \end{aligned}\right\} \tag{12}$$

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

$$t_{3000K} \cong \frac{(R_{3000K} - R_{pl})}{\left[\left((V_{\exp})_{3000K} + (V_{\exp})_{pl}\right)/2\right]} \cong 19613.65 \text{ Years} \tag{13}$$

where, $R_{3000K} \cong 4.0445\times10^{20}$ m and $(V_{\exp})_{3000K} \cong 3.36c$. This estimation is 19.37 times less than the current estimations and needs further study with respect to early stage formation of galaxies.

Cosmic Scale Factor and Red Shift

With reference to the proposed relations (1) and (3) and with reference to the current definitions of cosmic redshift and scale factor, it is possible to show that,

$$\left.\begin{aligned}&\left(\frac{1}{a}\cong(z+1)\cong\frac{T_t}{T_0}\right)\cong\sqrt{\frac{\gamma_0 H_t}{\gamma_t H_0}}\cong\sqrt{\frac{\gamma_0}{\gamma_t}}\sqrt{\frac{H_t}{H_0}}\\&\cong\sqrt{\frac{\gamma_0}{\gamma_t}}\left\{\exp\left(\frac{\gamma_0-\gamma_t}{2}\right)\right\}\cong\sqrt{\left(\frac{\gamma_0}{\gamma_t}\right)\exp(\gamma_0-\gamma_t)}\end{aligned}\right\} \tag{14}$$

$$z\cong\sqrt{\left(\frac{\gamma_0}{\gamma_t}\right)\exp(\gamma_0-\gamma_t)}-1 \tag{15}$$

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

Table 1. *Current and Planck Scale Cosmic Physical Parameters*

Current scale	**Planck scale**
$H_0 \cong 70\text{km/sec/Mpc}$ $\cong 2.26853\times10^{-18}\,sec^{-1}$	$H_{pl}\cong\sqrt{\frac{c^5}{G\hbar}}\cong1.855\times10^{43}\ \text{sec}^{-1}$
$\gamma_0\cong\left[1+\ln\left(\frac{H_{pl}}{H_0}\right)\right]\cong141.2564$	$\gamma_{pl}\cong\left[1+\ln\left(\frac{H_{pl}}{H_{pl}}\right)\right]\cong1$
$(\Omega_{OM})_0\cong0.04673$	$(\Omega_{OM})_{pl}\cong0.5$
$(\Omega_{DM})_0\cong0.2433$	$(\Omega_{DM})_{pl}\cong0.5$
$(\Omega_{OM})_0+(\Omega_{DM})_0\cong0.290$	$(\Omega_{OM})_{pl}+(\Omega_{DM})_{pl}\cong1.0$
$T_0\cong\left(\frac{1}{\sqrt{\gamma_0}}\right)\left(\frac{3H_0^2c^2}{8\pi Ga}\right)^{\frac{1}{4}}\cong2.721\,\text{K}$	$T_{pl}\cong\left(\frac{1}{\sqrt{\gamma_{pl}}}\right)\left(\frac{3H_{pl}^2c^2}{8\pi Ga}\right)^{\frac{1}{4}}$ $\cong9.247\times10^{31}\ \text{K}$
$R_0\cong\gamma_0^{1/4}\frac{c}{H_0}\cong4.556\times10^{26}\ \text{m}$ $\cong14.772\ \text{Gpc}$	$R_{pl}\cong\gamma_{pl}^{1/4}\left(\frac{c}{H_{pl}}\right)\cong1.616\times10^{-35}\,\text{m}$
$(V_{\exp})_0\cong R_0H_0\cong3.4475c$	$(V_{\exp})_{pl}\cong R_{pl}H_{pl}\cong c$
$(M_{OM})_0\cong1.7035\times10^{53}\ \text{kg}$	$(M_{OM})_{pl}\cong5.441\times10^{-9}\ \text{kg}$
$(M_{DM})_0\cong8.87195\times10^{53}\ \text{kg}$	$(M_{DM})_{pl}\cong5.441\times10^{-9}\ \text{kg}$
$\left[(M_{OM})_0+(M_{DM})_0\right]$ $\cong M_0\cong1.0575\times10^{54}\ \text{kg}$	$\left[(M_{OM})_{pl}+(M_{DM})_{pl}\right]$ $\cong M_{pl}\cong1.0882\times10^{-8}\ \text{kg}$
$t_0\cong\frac{R_0}{\left[\left((V_{\exp})_0+(V_{\exp})_{pl}\right)/2\right]}$ $\cong21.656\ \text{BillionYears}$	$t_{pl}\cong0$

Velocity and Distance Relation

In all directions, from and about the hypothetical baby universe, current galactic receding speeds can be approximated with,

$$\left(v_g\right)_0 \cong \left(\frac{\left(d_g\right)_0}{R_0}\right)\left(V_{\exp}\right)_0 \cong \left(\frac{\left(V_{\exp}\right)_0}{R_0}\right)\left(d_g\right)_0 \cong H_0\left(d_g\right)_0 \tag{16}$$

a) Relation (16) can be compared with currently believed Hubble's law for any receding galaxy in the current expanding universe.
b) For a distance of $\frac{c}{H_0}$, receding speed is c.
c) When, $\left(d_g\right)_0 \to R_0$, $\left(v_g\right)_0 \cong H_0 R_0$

Results and Discussion

Cosmological Constant Problem

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

$$\left(\frac{3H_{pl}^2c^2}{8\pi G}\right) \div \left(\frac{3H_0^2c^2}{8\pi G}\right) \cong \left(\frac{H_{pl}}{H_0}\right)^2 \cong 6.685\times 10^{121} \tag{17}$$

This idea can be considered as a characteristic tool for constructing a model of 'quantum gravity' with cosmic evolution.

Horizon Problem

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, at any stage of evolution, it is possible to have an increasing radius of curvature. For the current case, $R_0 \cong \gamma_0^{1/4}\left(\frac{c}{H_0}\right) \cong \sqrt{\left(\frac{2GM_0}{c^2}\right)\left(\frac{c}{H_0}\right)} \cong 14.772 \text{ Gpc}$ and there is no scope for 'causal disconnection' of distant visible matter (Vardanyan 2011).

Cosmic Inflation

In our model, without considering 'inflation' concepts (Guth 1981, Linde 1982, Steinhardt 2011, Ijjas et al. 2014), starting from the Planck scale, it is possible to have a current cosmic radius of 14.772 Gpc and it is consistent with current observations of 14.25 Gpc. Our estimated cosmic age corresponding to 2.7 K is around 21.66 billion years whereas big bang model estimation is 13.8 billion years. At lower time scales, our estimated cosmic age corresponding to 3000 K is around 19,614 years whereas big bang model estimation is 3,80,000 years.

Point to be discussed in depth is, with big bang and inflation, after 3,80,000 years of evolution, cosmic temperature is 3000 K where as in our model, without big bang and inflation, after 19,614 years of cosmic evolution, temperature is 3000K. From this, it is very clear to say that, compared to big bang and inflation, in our model, temperature drop is faster in the beginning and slower in the later stages. This can be considered as a hint for the observed large scale 'Isotropic' nature of Cosmic microwave back ground radiation (CMBR).

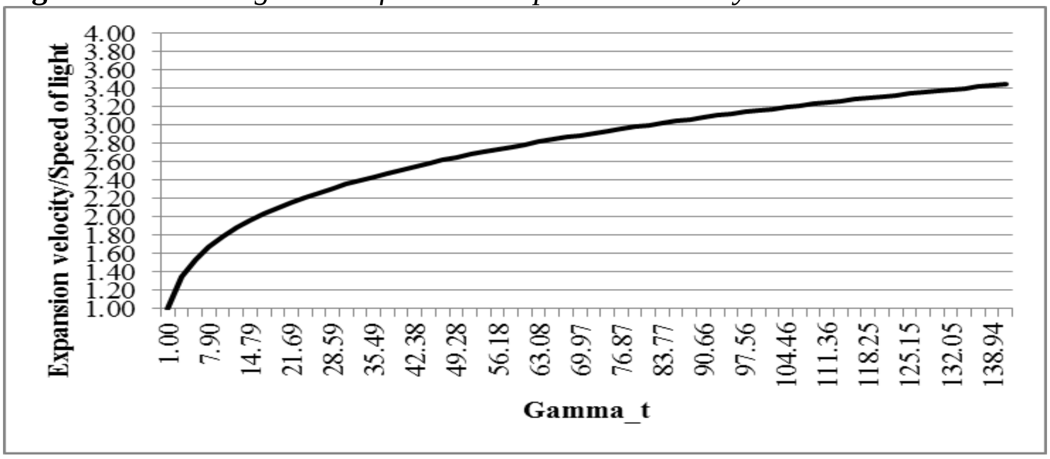
Cosmic Acceleration and Expansion Velocity

By considering a decreasing trend of ordinary matter and dark matter density, starting from the Planck scale, it is possible to get an expression for cosmic expansion velocity. It can be expressed as follows.

$$\frac{\left(V_{\exp}\right)_t}{c} \cong \gamma_t^{1/4} \cong \left[1+\ln\left(\frac{H_{pl}}{H_t}\right)\right]^{1/4} \cong \left(\frac{3H_t^2c^2}{8\pi G\left(aT_t^4\right)}\right)^{1/8} \cong \frac{1}{(\Omega_{OM})_t+(\Omega_{DM})_t} \tag{18}$$

Based on this expression, for the Planck scale, $\left(V_{\exp}\right)_{pl} \cong c$ and for the current scale, $\left(V_{\exp}\right)_0 \cong 3.4475c.$ After 21.66 billion years of cosmic expansion, increment in expansion velocity seems to be $\left[\left(V_{\exp}\right)_0-\left(V_{\exp}\right)_{pl}\right] \cong 2.45c.$ (See Figure 2).

Figure 2. *Increasing Trend of Cosmic Expansion Velocity*



From Figure 2, it is very clear that, right from the beginning of cosmic evolution, cosmic expansion velocity seems to have an increasing trend.

Interesting point to be noted is that, expansion velocity seems to depend on $\frac{1}{(\Omega_{OM})_t + (\Omega_{DM})_t}$. In near future, if decrease in $(\Omega_{OM})_t + (\Omega_{DM})_t$ is found to be insignificant, one can expect cosmic 'constant rate of expansion' (Nielsen et al. 2016, Colin et al. 2018, Dam et al. 2017) and if decrease in $(\Omega_{OM})_t + (\Omega_{DM})_t$ is found to be significant, one can expect 'acceleration' (Haridasu et al. 2017). It is for further study.

Cosmic Angular Velocity

With reference to our assumptions and relations, defined Planck scale angular velocity is 1.855×10^{43} rad/sec and current angular velocity seems to be $\omega_0 \cong 1.606\times10^{-20}$ rad/sec $\cong 5.068\times10^{-13}$ rad/year. Here, interesting point to be noted is that, cosmic angular velocity decreases with decreasing cosmic temperature and decreasing Hubble parameter. The first experimental evidence of the Universe rotation was done by Birch in 1982 evidently. According to Birch, there appears to be strong evidence that the Universe is anisotropic on a large scale, producing position angle offsets in the polarization and brightness distributions of radio sources. These can probably be explained on the basis of a rotation of the Universe with an angular velocity of approximately 10^{-13} rad/year. Observational effects of current cosmic rotation can be understood with the works of Obukhov (2000), Godlowski (2011) and Longo (2011). Nowadays Chechin (2016, 2017) is seriously working on cosmic rotation.

About Dark Matter

Considering the very nature of Dark matter, new studies suggest that, a) Dark matter can be eliminated with emerging gravity concept (Verlinde 2017). b) Dark matter can be considered as a Bose-Einstein condensate (Levkov et al. 2018). c) Dark matter distribution can be understood through the distribution of intracluster light (Montes and Trujillo 2019). d) Evidence for considering dark matter as a characteristic weakly interacting massive particle (WIMP) is getting ruled out (https://www.forbes).[2] In this critical situation, our proposal of considering dark matter as a kind of 'galactic foam' can be given some consideration. With further study, mystery of 'dark matter density ratio' can be explored with respect to different theoretically extended ideas of general theory of relativity or quantum cosmology.

[2]https://www.forbes.com/sites/startswithabang/2019/02/22/the-wimp-miracle-is-dead-as-dark-matter-experiments-come-up-empty-again/#18c618f26dbc.

General Discussion

Schwarzschild radius (Seshavatharam 2010, Tatum et al. 2015b) is one of the iconic relation underlying general theory of relativity and can be given a priority in developing a workable or unified model of cosmology. We would like to suggest that, by considering a relation of the, $R_t \cong \gamma_t^{1/4}\left(\frac{c}{H_t}\right) \cong \sqrt{\left(\frac{2GM_t}{c^2}\right)\left(\frac{c}{H_t}\right)}$ currently believed 'horizon' problem can be reviewed and resolved.

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 cosmology can also be given some consideration.

Quantum cosmology 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'.

When universe is able to give birth to atoms, elementary parrticles and photons that show quantrum behaviour, universe can certainly be considered as a quantum gravitational object for ever.

What to quantize? How to quantize? When to quantize? and What to measure? are some interesting questions in current quantum cosmology and need a special focus. In this context, cosmic temperature can be considered as a characteristic feature of quantum cosmology.

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 (Barkana 2018).

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. In this context, now a days, a great debate has been initiated among mainstream cosmologists on the existence of dark energy (Haridasu et al. 2017, Racz et al. 2017, Berezhiani et al. 2017, Smoller 2017). According to a recent study (Zhao et al. 2017), 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 (Wang and Meng 2017), evidence for dynamical dark energy is very poor.

Density perturbations and interaction between dark mtter and baryons seem to play a crucial role in understanding observed cosmic acceleration and need of introducing dark energy seems to be ad-hoc.

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.

If the universe is the same in all directions, as the big bang models require, the hot spots and cold spots of CMBR in the afterglow of the big bang should be randomly splattered about the sky - the big temperature splotches and the small temperature goose pimples should have no preferred direction. The fact that they are aligned along the axis of evil leads Land and Magueijo (2005) to suggest that, may be the assumptions behind the big bang models are wrong. In other words, the Universe is not the same in all places or directions, but has a special direction.

Considering a sample of 355 optically polarized quasars with accurate linear polarization measurements, (Jain et al. 2004, Hutsemekers et al. 2005), demonstrated that quasar polarization angles are definitely not randomly oriented over the sky. Polarization vectors appear coherently oriented over very large spatial scales, in regions located at both low and high redshifts and characterized by different preferred directions. These characteristics make the alignment effect difficult to explain in terms of local mechanisms, namely a contamination by interstellar polarization in our Galaxy.

According to Ghosh et al. (2016) - The tantalizing possibility that the cosmological principle may be violated is indicated by many observations. The most prominent of these effects is the so-called Virgo alignment, which refers to a wide range of phenomena indicating a preferred direction pointing towards Virgo. The Square Kilometer Array has the capability to convincingly test several of these effects. These include the dipole anisotropy in radio polarization angles (Jain and Ralston 1999), the dipole in the number counts and sky brightness (Blake and Wall 2002, Singal 2011, Gibelyou and Huterer 2012, Tiwari and Jain 2015a, Rubart and Schwarz 2013) and in the polarized number counts and polarized flux (Tiwari and Jain 2015b). These observations may indicate that we need to go beyond the standard Big Bang cosmology. Alternatively they may be explained by pre-inflationary anisotropic and/or inhomogeneous modes (Aluri and Jain 2015, Rath et al. 2013). In either case, confirmation of this alignment effect is likely to revolutionize cosmology.

According to Zhao and Santos (2015) - The foundation of modern cosmology relies on the so-called cosmological principle which states a homogeneous and isotropic distribution of matter in the universe on large scales. However, recent observations, such as the temperature anisotropy of the cosmic microwave background (CMB) radiation, the motion of galaxies in the universe, the polarization of quasars and the acceleration of the cosmic expansion, indicate preferred directions in the sky. If these directions have a cosmological origin, the cosmological principle would be violated, and modern cosmology should be reconsidered.

Nature loves symmetry. Subject of cosmic ‘rotation’ is not new and not against to General theory of relativity. Quantum mechanics point of view, ‘spin’ is a basic and characteristic property. Quantum gravity point of view, it is reasonable to review the currently believed ‘standard cosmology’ with reference to cosmic rotation.

Proposed coefficient γ_t seems to have an attractive feature of connecting the density ratios of ordinary matter and dark matter throught the cosmic evolution. With further study, such kind of other coefficients can also be developed with possible physics.

Without considering the currently belived dark energy, cosmic expnasion velocity can be shown to be increasing with a drcreasing trend of total matter density ratio. To some extent, this can be compared with currently believed cosmic acceleration concept (Riess et al. 1998, Perlmutter et al. 1999, Weinberg et al. 2013).

Considering the updated supernovae redshift data, in 2016, cosmologists noticed that, universe is coasting at constant speed rather than acceleration. In this way, nowadays, a great debate is going on among various groups of cosmologists on 'cosmic acceleration' (Li et al. 2011, Rubin and Hayden 2016). Another group of cosmologists are developing models with speed of light (Tsagas 2011, Wei et al. 2015, Melia and Fatuzzo 2016, John 2016, Tutusaus et al. 2018). In this context, we would like suggest that, observationally, by finding the trend of total matter density ratio, actual expansion speed can be figured out.

Dark matter may exist or may not exsit, gravity may be emerging or may not be emerging, based on assumption 3 and Figure 1, observationally believed current total matter density ratio can be fitted and can be extrapolated to past and future in a verifiable approach. With further study, mystery of 'total matter density ratio' can be explored with respect to different theoretically extended ideas of general theory of relativity or quantum cosmology.

The discovery of the accelerating universe in the late 1990s was a radical idea in modern cosmology. To account for the observed cosmic acceleration, cosmologists hypothesized the presence of a hidden and dominating energy reservoir of the universe and called it as 'Dark energy'. Evidence for dark energy, the new component that causes the acceleration, has since become extremely strong, owing to an impressive variety of increasingly precise measurements of the expansion history and the growth of structure in the universe. Very unfortunate thing is that, till today, no one could understand the mechanism for the observed cosmic acceleration. It is one of the central challenges of modern observational cosmology (Huterer and Shafer 2018). Another puzzling issue is that, even though the standard Friedmann-Lemaitre-Robertson-Walker cosmological model (FLRW) is gaining a great success in explaining most of the modern observations, till today, observationally no one could identify a probable means or carrying agent for the well believed dark energy. It casts a serious doubt on the actual physical existence of dark energy and raises a general doubt on the scope of FLRW model to cosmic acceleration. In this context, our proposed method of 'increasing cosmic expansion velocity connected with decreasing total matter density ratio', i.e. relation (18) can be given some consideration in reviewing and relinquishing (Buchert et al. 2018) the currently believed dark energy concept.

In a cosmological approach, so far no physical model is successful in understanding the mass generation and proliferation mechanism for the observed photons, leptons, neutrinos, baryons, mesons and Higgs bosons from the cosmic energy reservoir. In this context, one can see a great initiative taken by Schwinger (1998), Bulnes (2018) and Robson (2017).

Conclusions

By considering the proposed concepts, asumptions, relations, result oriented discussion and general discussion, an outline picture of a workable model of quantum cosmology can be developed. With further study, nucleosynthesis and dark matter synthesis along with mass generation mechanism can be reviewed in a quantum cosmological approach. We are working in this direction and it will be published elsewhere.

Acknowledgements

Author Seshavatharam is indebted to Dr. E. Terry Tatum for his kind technical and helpful discussions, to Profs Brahmashri M. Nagaphani Sarma, Chairman, Shri K.V. Krishna Murthy, to Founder Chairman, Institute of Scientific Research in Vedas (I-SERVE), Hyderabad, India and to 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. Both authors are very much thankful to the anonymous reviewers for their helpful suggestions in improving the quality and presentation of this subject.

References

Aluri PK, Jain P (2012) Large Scale Anisotropy due to Pre-Inflationary Phase of Cosmic Evolution. *Modern. Physical Letters A* 27(4).

Annila A (2012) Probing Mach's Principle. *Monthly Notices of Royal Astronomical Society* 423(2).

Arbab AI (2004) Quantization of Gravitational System and its Cosmological Consequences. *Gen. Rel. Grav. Grav* 36(Jan): 2465-2479.

Barkana R (2018) Possible Interaction between Baryons and Dark-matter Particles Revealed by the First Stars. *Nature* 555(Feb): 71-74.

Barrow JD, Tsagas CG (2004) Dynamics and Stability of the Godel Universe. *Classical and Quantum Gravity* 21(7): 1773-1790.

Berezhiani L, Khoury J, Wang J (2017) Universe without Dark Energy: Cosmic Acceleration from Dark Matter-baryon Interactions *Physical Review* 95(12-15): 123530.

Birch P (1982) Is the Universe rotating? *Nature* 298(Jul): 451-454.

Blake C, Wall J (2002) A Velocity Dipole in the Distribution of Radio Galaxies. *Nature* 416(6877): 150-152.

Bojowald M (2015) Quantum Cosmology: A Review. *Reports on Progress in Physics* 78(2): 023901

Buchert T, Coley AA, Kleinert H, Roukema BF, Wiltshire DL (2016) Observational Challenges for the Standard FLRW Model. *International Journal of Modern Physics* 25(3): 1630007.

Bulnes F (2018) Gravity, Curvature and Energy: Gravitational Field Intentionality to the Cohesion and Union of the Universe. In T Zouaghi (ed), *Gravity - Geoscience*

Applications, Industrial Technology and Quantum Aspect. http://dx.doi.org/10.5772/intechopen.71037.

Cai RG, Ma YZ, Tang B, Tuo ZL (2012) Constraining the Anisotropic Expansion of the Universe. *Physical Review D* 87(12).

Carneiro S (2002) Open Cosmologies with Rotation. *General Relativity and Gravitation* 34(6): 793-805.

Chechin LM (2016) Rotation of the Universe at Different Cosmological Epochs. *Astronomy Reports* 60(6): 535-541.

Chechin LM (2017) Does the Cosmological Principle Exist in the Rotating Universe? *Gravitation and Cosmology* 23(4): 305-310.

Colin J, Mohayaee R, Rameez M, Sarkar S (2018) Apparent Cosmic Acceleration due to Local Bulk Flow. arXiv:1808.04597v1.

Dam LH, Heinesen A, Wiltshire DL (2017) Apparent Cosmic Acceleration from Type Ia Supernovae. *Monhtly Notices of the Royal Astronomical Society* 472(1): 835-851.

Gamow G (1946) Rotating Universe? *Nature* 158(4016): 549.

Gamow G (1948a) The Evolution of the Universe. *Nature* 162(4122): 680=682.

Gamow G (1948b) The Origin of Elements and the Separation of Galaxies. *Physical Review* 74(4): 505.

Ghosh S, Jain P, Kashyap G, Kothari R, Nadkarni-Ghosh S, Tiwari P (2016) Probing Statistical Isotropy of Cosmological Radio Sources using Square Kilometre Array *Journal of Astrophysics and Astronomy* 37(4): 25.

Gibelyou C, Huterer D (2012) Dipoles in the Sky. *Monthly Notices of the Royal Astronomical Society* 427(3): 1994-2021.

Godel K (2000) An Example of a New Type of Cosmological Solutions of Einstein's Field Equations of Gravitation. *General Relativity and Gravitation* 32(7): 1409-1417.

Godlowski W (2011) Global and Local Effects of Rotation: Observational Aspects. *International Journal of Modern Physics* 20(9): 1643-1673.

Grahn P, Annila A, Kolehmainen, E *(*2018) On the Carrier of Inertia. *AIP Advances* 8(3): 035028.

Guth AH (1981) Inflationary Universe: A Possible Solution to the Horizon and Flatness Problems. *Physical Review D* 23(2): 347-356.

Haridasu BS, Lukovic VV, D'Agostino R, Vittorio N (2017) Strong Evidence for an Accelerating Universe. *Astronomy & Astrophysics* 600. Doi: 10.1051/0004-6361/201730469.

Hawking SW (1969) On the Rotation of the Universe *Monthly Notices of the Royal Astronomical Society* 142(2): 129-141.

Huterer D, Shafer DL (2018) Dark Energy Two Decades After: Observables, Probes, Consistency Tests. *Reports on Progress in Physics* 81(1): 016901.

Hutsemekers D, Cabanac R, Lamy H, Sluse *D* (2005) Mapping Extreme-Scale Alignments of Quasar Polarization Vectors. *Astronomy & Astrophysics* 441(3): 915-930.

Ijjas A, Steinhardt PJ, Loeb A (2014) Inflationary Schism. *Physics Letters B* 736(Sep): 142-146.

Jain P, Ralston JP (1999) Anisotropy in the Propagation of Radio Polarizations from Cosmologically Distant Galaxies. *Modern Physics Letters A* 14(6): 417-432.

Jain P, Panda S, Sarala S (2004) Pseudoscalar-Photon Mixing and the Large Scale Alignment of QSO Optical Polarizations. *PRAMANA Journal of Physics* 62(3): 679-682.

John MV (2016) Realistic Coasting Cosmology from the Milne Model. arXiv:1610.09885.

Korotky VA, Obukhov YN (1995) Polarization of Radiation in a Rotating Universe. JETP

108: 1889-1898.
Kuhne RW (1997) On the Cosmic Rotation Axis. *Modern Physics Letters A* 12(32): 2473-2474.
Land K, Magueijo J (2005) Examination of Evidence for a Preferred Axis in the Cosmic Radiation Anisotropy. *Physical Review Letters* 95(7): 071301.
Levkov DG, Panin AG, Tkachev II (2018) Gravitational Bose-Einstein Condensation in the Kinetic Regime. *Physical Review Letters* 121(15): 151301.
Li LX (1998) Effect of the Global Rotation of the Universe on the Formation of Galaxies. General Relativity and Gravitation 30(3): 497-507.
Li Z, Wu P, Yu H (2011) Examining the Cosmic Acceleration with the Latest Union2 Supernova Data. *Physics Letters B* 695(1-4): 1-8.
Linde AD (1982) A New Inflationary Universe Scenario: A Possible Solution of the Horizon, Flatness, Homogeneity, Isotropy and Primordial Monopole Problems. *Physics Letters B* 108(6): 389-393.
Longo MJ (2011) Detection of a Dipole in the Handedness of Spiral Galaxies with Redshifts z ~ 0.04. *Physics Letters B* 699(4): 224-229.
Melia F, Fatuzzo M (2016) The Epoch of Reionization in the R_h=ct Universe. *Monthly Notices of Royal Astronomical Society* 456(4): 3422-3431.
Mitra A (2011) Why the Big Bang Model Cannot Describe the Observed Universe Having Pressure and Radiation. *Journal of Modern Physics* 2(12): 1436-1442.
Mitra A (2014) Why the Rh = ct Cosmology is Unphysical and in fact a Vacuum in Disguise Like the Milne Cosmology. *Monthly Notices of Royal Astronomical Society* 442(1): 382-387.
Montes M and Trujillo I (2019) Intracluster Light: A Luminous Tracer for Dark Matter in Clusters of Galaxies. *Monthly Notices of Royal Astronomical Society* 482(Oct): 2838-2851.
Narlikar J V, Hoyle F (1963) Newtonian Universes with Shear and Rotation. *Monthly Notices of Royal Astronomical Society* 126(2): 203-208.
Nielsen JT, Guffanti A, Sarkar S (2016) Marginal Evidence for Cosmic Acceleration from Type Ia Supernovae. *Scientific Reports* 6(Oct): 35596.
Nodland B, Ralston JP (1997) Indication of Anisotropy in Electromagnetic Propagation over Cosmological Distances. *Physical Review Letters* 78(16): 3043-3046.
Obukhov YN (2000) On Physical Foundations and Observational Effects of Cosmic Rotation Colloquium on Cosmic Rotation. In M Scherfner, T Chrobok, M. Shefaat (eds). Colloquium on Cosmic Rotation, 23. Berlin: Wissenschaft und Technik Verlag.
Padmanabhan T (2005) Dark Energy: the Cosmological Challenge of the Millennium. *Current Science* 88: 1057.
Panov VF, Kuvshinova EV (2004) Quantum Birth of the Universe with Rotation. *Gravitation & Cosmology* 10: 37-38.
Perlmutter S, Aldering G, Goldhaber G, Knop RA, Nugent P, Castro PG, Deustua S, Fabbro S, Goobar A, Groom DE, Hook IM, Kim AG, Kim MY, Lee JC, Nunes NJ, Pain R, Pennypacker CR, Quimby R, Lidman C, Ellis RS, Irwin M, McMahon RG, Ruiz-Lapuente P, Walton N, Schaefer B, Boyle BJ, Filippenko AV, Matheson T, Fruchter AS, Panagia N, Newberg HJM, Couch WJ (1999) Measurements of Ω and Λ from 42 High-Redshift Supernovae. *The Astrophysical Journal* 517(2): 565.
Planck Collaboration (2015) Planck 2015 Results XIII Cosmological Parameters.
Racz G, Dobos L, Beck R, Szapudi I, Csabai I (2017) Concordance Cosmology without Dark Energy. *Monthly Notices of Royal Astronomical Society Letters* 469(1): L1-L5.
Rath PK, Mudholkar T, Jain P, Aluri PK (2013) Direction Dependence of the Power Spectrum and its Effect on the Cosmic Microwave Background Radiation. *Journal of*

Cosmology and Astroparticle Physics 2013(Apr).
Raychaudhuri AK (1955) Relativistic Cosmology I. *Physical Review* 98(4): 1123-1126.
Riess AG, Filippenko AV, Challis P, Clocchiatti A, Diercks A, Garnavich PM, Gilliland RL, Hogan CJ, Jha S, Kirshner RP (1998) Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant *The Astronomical Journal* 116(3): 1009-1038.
Riess AG, Macri LM, Hoffmann SL, Scolnic D, Casertano S, Filippenko AV, Tucker BE, Reid MJ, Jones DO, Silverman JM, Chornock R, Challis P, Yuan W, Brown PJ, Foley RJ (2016) A 2.4% Determination of the Local Value of the Hubble Constant. *The Astrophysical Journal* 826(1): 56.
Robson BA (2017) Cosmological Consequences of a Quantum Theory of Mass and Gravity. In AJ Capistrano de Souza (ed), *Trends in Modern Cosmology*. http://dx.doi.org/10.5772/intechopen.68410.
Rubart M, Schwarz DJ (2013) Cosmic Radio Dipole from NVSS and WENSS. *Astronomy & Astrophysics* 555(Jul): 117.
Rubin D, Hayden B (2016) Is the Expansion of the Universe Accelerating? All Signs Point to Yes. *The Astrophysical Journal Letters* 833(2): L30.
Schwinger J (1998) Particles, Sources, and Fields. In *Advanced Book Program* 1. USA: Perseus Books.
Seshavatharam UVS (2010) Physics of Rotating and Expanding Black Hole Universe. *Progress in Physics* 2(Apr): 7-14.
Seshavatharam UVS, Lakshminarayana S (2015) Primordial Hot Evolving Black Holes and the Evolved Primordial Cold Black Hole Universe. *Frontiers of Astronomy, Astrophysics and Cosmology* 1(1): 16-23.
Seshavatharam UVS, Lakshminarayana S (2017) Toy Model of Spinning Quantum Cosmology. *Physical Science International Journal* 15(4): 1-13.
Seshavatharam UVS, Lakshminarayana S (2018a) On the Eternal Role of Planck Scale in Machian Cosmology. *SF J Astrophysics* 1:5.
Seshavatharam UVS, Lakshminarayana S (2018b) Toy Model of Evolving and Spinning Quantum Cosmology – A Review. *International Journal of Astronomy Astrophysics and Space Science* 5(1): 1-13.
Seshavatharam UVS, Lakshminarayana S (2019) An Outline Picture of a Growing and Rotating Planck Universe with Emerging Dark Foam. *Asian Journal of Research and Review in Physics* 2(2): 1-13.
Singal AK (2011) Large Peculiar Motion of the Solar System from the Dipole Anisotropy in Sky Brightness due to Distant Radio Sources. *The Astrophysical Journal* 742(2): L23-L27.
Singh S (1999) Cosmological Models with Shear and Rotation. *Journal of Astrophysics and Astronomy* 20(1-2): 67-77.
Sivaram C (2000) Some Implications of Quantum Gravity and String Theory for Everyday Physics. *Current Science* 79(4): 413-420.
Smoller J, Temple B, Vogler Z (2017) An Instability of the Standard Model of Cosmology Creates the Anomalous Acceleration without Dark Energy. *Proceeding of the Royal Society A* 473(2207): 20160887. Doi: 10.1098/rspa.2016.0887.
Steinhardt PJ (2011) The Inflation Debate: Is the Theory at Heart of Modern Cosmology Deeply Flawed? *Scientific American* 304(4): 1-25.
Su SC, Chu MC (2009) Is the Universe Rotating? *The Astrophysical Journal* 703(1): 354.
Szydlowski M, Godlowski W (2005) Dynamics of the Universe with Global Rotation. *General Relativity and Gravitation* 37(5): 907-936.
Tatum ET, Seshavatharam UVS, Lakshminarayana S (2015a) Thermal Radiation Redshift in Flat Space Cosmology. *Journal of Applied Physical Science International* 4(1): 18-26.

Tatum ET, Seshavatharam UVS, Lakshminarayana S (2015b) The Basics of Flat Space Cosmology. *International Journal of Astronomy and Astrophysics* 5(2): 116-124.

Tiwari P, Jain P (2015a) Dipole Anisotropy in Integrated Linearly Polarized Flux Density in NVSS Data. *Monthly Notices of Royal Astronomical Society* 447(3): 2658-2670.

Tiwari P, Jain P (2015b) Extracting Spectral Index of Intergalactic Magnetic Field from Radio Polarizations. *Monthly Notices of Royal Astronomical Society* 460(3): 2698-2705.

Tsagas C (2011) Apparent Cosmic Acceleration due to Large-scale Peculiar Motions. *J. Phys: Conf. Ser.* 283(1): 012040.

Tutusaus I, Lamine B, Blanchard A (2018) Model-Independent Cosmic Acceleration and Type Ia Supernovae Intrinsic Luminosity Redshift Dependence. *Astronomy & Astrophysics* 625(A15): arXiv:1803.06197.

Vardanyan M (2011) Applications of Bayesian model Averaging to the Curvature and Size of the Universe. *Monthly Notices of Royal Astronomical Society Letters* 413(1): L91-L95.

Verlinde E (2017) Emergent Gravity and the Dark Universe. *SciPost Phys.* 2, 016.

Wang D, Meng XH (2017) No Evidence for Dynamical Dark Energy in Two Models. *Physical Review D* 96(10): 103516.

Wei JJ, Wu XF, Melia F, Maier RS (2015) Comparative Analysis of the Supernova Legacy Survey Sample with ΛCDM and the Rh=ct Universe. The Astronomical Journal 149(3).

Weinberg DH, Mortonson MJ, Eisenstein DJ, Hirata C, Riess AG, Rozo, E (2013) Observational probes of cosmic acceleration. *Physics Reports* 530(2): 87-255.

Whittaker ET (1945) Spin in the Universe. *Yearbook of Royal Society*. Edinburgh: 5-13.

Zhao GB, Raveri M, Pogosian L, Wang Y, Crittenden RG, Handley WJ, Percival WJ, Beutler F, Brinkmann J, Chuang CH, Cuesta AJ, Eisenstein DJ, Kitaura FS, Koyama K, L'Huillier B, Nichol RC, Pieri MM, Rodriguez-Torres S, Ross AJ, Rossi G, Sánchez AG, Shafieloo A, Tinker JL, Tojeiro R, Vazquez JA, Zhang H (2017) Dynamical Dark Energy in Light of the Latest Observations. Nature Astronomy 1(9): 627-632.

Zhao W, Santos L (2015) The Weird Side of the Universe: Preferred Axis. *International Journal of Modern Physics: Conference Series* 45: 1760009.