On the possible role of Mach's principle and quantum gravity in modern quantum cosmology

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Abstract: Based on Mach's principle and quantum gravity, we imagine our universe as a best quantum gravitational sphere and assume that, at any stage of cosmic evolution: 1) Planck scale Hubble parameter plays a crucial role. 2) Space-time curvature follows, $GM_t \cong R_t c^2$ where M_t and R_t represent the ordinary cosmic mass and radius respectively. 3) Both, cosmic radius and expansion velocity, are proportional to the ratio of dark matter density and ordinary matter density. 4) Cosmic temperature is proportional to the ratio of ordinary matter density and critical density. With further research, a unified model of 'quantum cosmology' with evolving dark energy or evolving vacuum energy can be developed.

Keywords: Big bang; Quantum gravity; Planck scale Hubble parameter; Mach's principle; Observational cosmology;

1 Introduction

Assuming that universe is a best possible quantum gravitational sphere [1,2], we define the Planck scale Hubble parameter, $H_{pl} \cong \sqrt{\frac{c^5}{G\hbar}} \cong 1.854921 \times 10^{43}$ $\mathbf{sec}^{-1}$ and apply it to current cosmological data fitting in the form of $\gamma_t \cong \left[1 + \ln\left(\frac{H_{pl}}{H_t}\right)\right]$ where H_t is the time dependent Hubble parameter. Proceeding further, with reference to the currently believed cosmic density break up and Planck scale critical density, we proposed semi-empirical relations for predicting the quantitative percentages of past cosmic density breakups. By considering the Mach's principle [2], proposed set of assumptions and proposed cosmic density break up relations, we make an attempt to fit and understand the current cosmological physical parameters.

1.1 To choose the magnitude of H_0

As per the 2015 Planck data [3]: $H_0 \cong (67.31 \pm 0.96)$ km/sec/Mpc and $T_0 \cong (2.722 \pm 0.027)$ K. With reference to the reported current CMBR temperature and with our proposed set of assumptions, in this paper, we choose, $H_0 \cong 64.5\,\text{km/sec/Mpc} \cong 2.0903 \times 10^{-18} sec^{-1}$.

1.2 Nomenclature

At the Planck scale,

1. $H_t \cong H_{pl}$ and $\gamma_{pl} = 1$.
2. $(\Omega_{OM})_{pl}$ = Defined Planck scale ratio of ordinary matter density and critical density $= \frac{1}{2}$.
3. $(\Omega_{DM})_{pl}$ = Defined Planck scale ratio of dark matter density and critical density $= \frac{1}{2}$.
4. $(\Omega_{DE})_{pl}$ = Defined Planck scale ratio of dark energy density and critical energy density = 0.
5. H_{pl} = Defined Planck scale Hubble parameter $= \sqrt{\frac{c^5}{G\hbar}}$.
6. R_{pl} = Planck scale cosmic radius $= \sqrt{\frac{G\hbar}{c^3}}$.
7. M_{pl} = Planck scale cosmic mass $= \sqrt{\frac{\hbar c}{G}}$.
8. $(\lambda_{max})_{pl}$ = Planck scale cosmic thermal wavelength $= \left(\frac{1}{(\Omega_{pl})_{OM}}\right) R_{pl} \cong 2\sqrt{\frac{G\hbar}{c^3}}$.
9. T_{pl} = Planck scale cosmic temperature $= \frac{2.898 \times 10^{-3} K.m}{(\lambda_{max})_{pl}} = \frac{(\Omega_{pl})_{OM}}{4.96511423} \frac{hH_{pl}}{k_B}$
10. V_{pl} = Planck scale cosmic expansion velocity = c.

At any stage of cosmic evolution,

1. $\gamma_t \cong \left[1 + \ln\left(\frac{H_{pl}}{H_t}\right)\right]$ = Defined new number.

2. $(\Omega_{OM})_t$ = Ratio of ordinary matter density and critical density.
3. $(\Omega_{DM})_t$ = Ratio of dark matter density and critical density.
4. $(\Omega_{DE})_t$ = Ratio of dark energy density and critical energy density.
5. H_t = Hubble parameter, M_t = Ordinary cosmic mass and R_t = Cosmic radius.
6. $(\lambda_{max})_t$ = Cosmic thermal wavelength and $T_t = \frac{2.898\times10^{-3}K.m}{(\lambda_{max})_t}$ = Cosmic temperature.
7. z = Cosmic redshift.
8. V_t = Cosmic expansion velocity.
9. $(d_g)_0$ = Current galactic distance from and about the point of big bang.
10. $(v_g)_0$ = Current galactic receding speed from and about the point of big bang.

2 Semi empirical relations connected with cosmic density breakup

At any stage of cosmic evolution:

1. $(\Omega_{OM})_t \cong \left(\frac{1}{1+\gamma_t}\right)\left(\frac{1+\sqrt{\gamma_t}}{2}\right)$ and $(\Omega_{OM})_0 \cong 0.04528$
2. $(\Omega_{DM})_t \cong \left(\frac{1}{1+\gamma_t}\right)\left(\frac{1+\sqrt{\gamma_t}}{2}\right)^2$ and $(\Omega_{DM})_0 \cong 0.2918$
3. $(\Omega_{DE})_t \cong 1-[(\Omega_{OM})_t+(\Omega_{DM})_t]$ and $(\Omega_{DE})_0 \cong 0.66292$.
4. $\frac{(\Omega_{DM})_t}{(\Omega_{OM})_t} \cong \left(\frac{1+\sqrt{\gamma_t}}{2}\right)$ and $\frac{(\Omega_{DM})_0}{(\Omega_{OM})_0} \cong 6.4443$.
5. $\sqrt{\left(\frac{3H_0^2c^2}{8\pi G\left(aT_0^4\right)}\right)} \approx \gamma_t \Rightarrow H_0 \approx 70$ km/sec/Mpc.

3 Important relations and results

At any stage of cosmic evolution:

1. $\frac{V_t}{c} \cong \frac{(\Omega_{DM})_t}{(\Omega_{OM})_t} \cong \left(\frac{1+\sqrt{\gamma_t}}{2}\right)$ and $V_0 \cong 6.4443c$.
2. $R_t \cong \left[\frac{(\Omega_{DM})_t}{(\Omega_{OM})_t}\right]\left(\frac{c}{H_t}\right) \cong \frac{V_t}{H_t}$ and $M_t \cong \left(\frac{c^2R_t}{G}\right) \cong \frac{c^2V_t}{GH_t}$. $R_0 \cong 97.70\,\text{Gly} = 29.97\,\text{Gpc}$; $M_0 \cong 1.245\times10^{54}$ kg.
3. $(\lambda_{max})_t \cong \left(\frac{1}{(\Omega_{OM})_t}\right)\frac{c}{\sqrt{H_tH_{pl}}}$ and $T_t \cong \frac{2.898\times10^{-3}\,\text{Km}}{(\lambda_{max})_t} \cong \left(\frac{(\Omega_{OM})_t}{4.96511423}\right)\frac{h\sqrt{H_tH_{pl}}}{k_B}$. $(\lambda_{max})_0 \cong 1.0634\,mm$ and $T_0 \cong 2.7252$ K.
4. $(z+1) \cong \frac{T_t}{T_0} \cong \frac{(\lambda_{max})_0}{(\lambda_{max})_t} \cong \left(\frac{(\Omega_{OM})_t}{(\Omega_{OM})_0}\right)\sqrt{\frac{H_t}{H_0}} \cong \left(\frac{(\Omega_{OM})_t}{(\Omega_{OM})_0}\right)\exp\left(\frac{\gamma_0-\gamma_t}{2}\right)$.
5. Hubble parameter associated with $(z+1)$ can be expressed as: $H_t \cong \left(\frac{(\Omega_{OM})_0}{(\Omega_{OM})_t}\right)^2(z+1)^2H_0$
6. Observed anisotropy in current CMBR temperature:
    (a) For any galaxy, $(T_0)_{galaxy}$ is on higher side, if $[(\Omega_{OM})_0]_{galaxy} > \left(\frac{1}{1+\gamma_0}\right)\left[\left(\frac{1+\sqrt{\gamma_0}}{2}\right)\right]$
    (b) For any galaxy, $(T_0)_{galaxy}$ is on lower side, if $[(\Omega_{OM})_0]_{galaxy} < \left(\frac{1}{1+\gamma_0}\right)\left[\left(\frac{1+\sqrt{\gamma_0}}{2}\right)\right]$
7. At present, from and about the point of big bang, galactic receding speeds can be approximated with $(v_g)_0 \cong \left(\frac{(d_g)_0}{R_0}\right)V_0 \cong \left(\frac{V_0}{R_0}\right)(d_g)_0 \cong H_0\,(d_g)_0$.

4 Possible implications of our proposed set of assumptions/results

1. **About the cosmological constant problem**: With reference to assumption-2, ratio of Planck scale critical density to current critical density is, $\left(\frac{3H_{pl}^2c^2}{8\pi G}\right) \div \left(\frac{3H_0^2c^2}{8\pi G}\right) \cong \left(\frac{H_{pl}}{H_0}\right)^2 \cong 7.875\times10^{121}$. We wish to appeal that, our assumption-1 can be considered as a characteristic tool for constructing a model of 'quantum gravity'.
2. **About the horizon problem**: The 'horizon problem' or 'homogeneity problem' is a problem with the standard cosmological model of the hot Big Bang. It points out that different regions of the universe have not 'contacted' each other because of the great distances between them, but nevertheless they have the same temperature and other physical properties. If one is willing to consider the concept of 'matter causes the space-time to curve', 'horizon problem' can be understood. According to hot big bang model, during its evolution, as universe is expanding, thermal radiation temperature decreases and matter content increases. As matter content increases, based on Mach's principle [4], at any stage of evolution, it is possible to have an increasing radius of curvature, $R_t \cong \frac{GM_t}{c^2}$. Clearly

speaking, for the current case, as there exists no matter outside of $R_0 \cong \frac{GM_0}{c^2}$, there is no scope for 'causal disconnection'.

3. **About cosmic inflation**: Mainstream cosmologists believe that the superluminal expansion period of the universe (called "cosmic inflation") ended by 10^{-32} seconds (a tiny fraction of a second) after the hot big bang [4,5]. Since that time, they believe, expansion initially decelerated (from gravity) and then, after about 6 billion years, began very slowly to accelerate (from dark energy). Many cosmologists proposed different starting mechanisms for initiating and fine tuning the believed 'inflation'. In this context, we would like to stress the fact that, with $R_0 \cong \left(\frac{1+\sqrt{\gamma_0}}{2}\right)\left(\frac{c}{H_0}\right)$, estimated current cosmic radius is 97.70 Gly=29.97 Gpc and is just twice of the modern estimate [6]! Clearly speaking, considering our proposed assumptions, currently believed cosmic inflation can be reviewed.

4. **About Hawking's black hole temperature formula**: With reference to Hawking's black hole temperature formula [7], cosmic temperature can be estimated with $T_t \cong \left(\frac{1}{\gamma_t+1}\right)\frac{h\left(\sqrt{cV_t}\right)^3}{xk_B G\sqrt{M_t M_{pl}}}$ where $x = 4.96511423$.

5. **About CMBR anisotropy**: Observed anisotropy in current CMBR temperature can be understood with the relational condition: $(\Omega_{OM})_0$ is greater than or less than $\left[\left(\frac{1+\sqrt{\gamma_0}}{2}\right)\left(\frac{1}{1+\gamma_t}\right)\right]$.

6. **About the evolving vacuum energy**: Based on the proposed set of assumptions and cosmic density break up relations, it is possible to imagine that, as the universe is evolving, decreasing matter density and increasing cosmic volume, both, paves a way for increasing vacuum content. Thinking in this way, from the beginning of cosmic evolution, dark energy can be identified with evolving vacuum energy [8].

7. **Planck scale radiation redshift**: Redshift associated with Planck scale can be expressed with $(z+1)_{pl} \cong \left(\frac{T_{pl}}{T_0}\right) \cong \left(\frac{(\Omega_{OM})_{pl}}{(\Omega_{OM})_0}\right)\exp\left(\frac{\gamma_0-1}{2}\right) \cong 3.29\times 10^{31}$.

5 Conclusion

In any model of cosmology [9], fundamental questions to be solved are: 1) Why do 'dark matter' and 'visible matter' have their measured values of $\approx 33\%$ of critical energy? 2) Why do 'dark energy' has its measured values of $\approx 68\%$ of critical energy? 3) How to estimate their past and future magnitudes? In this context, we appeal that, our set of assumptions and relations can be given some consideration and with further research, their scope and workability can be scrutinized and validated.

Acknowledgements

It is great pleasure to express our deep gratitude to Dr.Shankar Hazra, Dr.Abhas Mithra, Dr.E.Terry Tatum, Dr.L.M.Chechin and Dr.Serkan Zorba for their valuable technical discussions and kind encouragement. We are very much thankful to the anonymous reviewers for guiding us in improving the quality and presentation of this paper. Author Seshavatharam is indebted to professors shri 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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