Article

Not peer-reviewed version

The Photon Energy Density Parameter Ω_γ of the Universe Exactly Derived

Espen Haug *

Posted Date: 27 March 2024

doi: 10.20944/preprints202403.1663.v1

Keywords: Photon energy density parameter; Friedmann equation; critical density; Thermodynamical Friedmann equation

Article

The Photon Energy Density Parameter Ω_γ of the Universe Exactly Derived

Espen Gaarder Haug

Norwegian University of Life Sciences, Christian Magnus Falsensvei 18, Aas, Norway Ås, Norway; espenhaug@mac.com

Abstract: We will demonstrate that the photon energy density parameter Ω_γ of the universe can be derived exactly in $R_h = ct$ cosmology. We find that it must be $\Omega_\gamma = \frac{1}{5760\pi} \approx 5.52621330180192 \times 10^{-5}$. This indicates that there is no uncertainty in the radiation density within at least some sub-classes of $R_h = ct$ cosmology.

Keywords: photon energy density parameter; Friedmann equation; critical density; thermodynamical Friedmann equaiton

---

Deriving the Photon Energy Density Parameter Ω_γ

The photon energy density: ρ_γ is normally found by doing the following integral:

$$\rho_{\gamma,0}c^2 = \int_0^\infty h v n(v) dv = a_b T_0^4 \tag{1}$$

which mean we have:

$$\rho_{\gamma,0} = \frac{a_b T_0^4}{c^2} \tag{2}$$

where the radiation density constant: a_b is given by:

$$a_b = \frac{8\pi^5 k_b^4}{15c^3h^3} = \frac{4}{c}\sigma \tag{3}$$

In 1978, Emslie and Green [1] presented the photon energy density relative to the critical Friedmann energy density as:

$$\begin{aligned} \Omega_{\gamma,0} &= \frac{\rho_\gamma}{\rho_c} \\ \Omega_{\gamma,0} &= \frac{\frac{aT_0^4}{c^2}}{\frac{3H_0^2}{8\pi G}} \end{aligned} \tag{4}$$

Haug and Tatum [2] have recently shown that the Friedmann [3] equation can be expressed in thermodynamic form, indicating that the critical density must be given by:

$$\rho_{c,0} = \frac{3H_0}{8\pi G} = T_0^4 \frac{23040\pi}{c^3}\sigma \tag{5}$$

By replacing this into equation (4) one get:

$$\begin{aligned} \Omega_{\gamma,0} &= \frac{\frac{aT^4}{c^2}}{T^4\frac{23040\pi}{c^3}\sigma} \\ \Omega_{\gamma,0} &= \frac{4\sigma}{23040\pi\sigma} \\ \Omega_{\gamma,0}, &= \frac{1}{5760\pi} \approx 5.52621330180192 \times 10^{-5} \end{aligned} \tag{6}$$

This implies that the photon density parameter remains exact for all cosmic time epochs. This consistency aligns with at least two potential types of $R_h = ct$ cosmological models. It is conceivable within growing black hole models, as exemplified in [4], and also within steady-state black hole cosmology, where the metric from general relativity suggests that density inside the black hole varies as one approaches the center, as discussed in [5,6]. Additionally, this holds true in the extremal universe scenario, where the density inside the black hole's Hubble sphere varies, as indicated in [7]. The idea of black hole cosmology goes at least back to 1972 by Pathria [8] and is actively discussed to this day [9–17], even if the Λ-CDM model currently takes most headlines.

When observing the black hole (Hubble sphere), it resembles a growing black hole model due to the density change along the radius in the steady-state black hole.

In $R_h = ct$ black hole cosmology in earlier epochs of the universe, we must have:

$$\rho_{\gamma,t} = \frac{a_b T_0^4 (1+z)^4}{c^2} = \frac{a_b T_t^4}{c^2} \tag{7}$$

Furthermore, we must have a critical density, as demonstrated by Haug and Tatum [2,18], of:

$$\rho_{c,t} = \frac{3H_t}{8\pi G} = T_0^4 (1+z)^4 \frac{23040\pi}{c^3}\sigma = T_t \frac{23040\pi}{c^3}\sigma \tag{8}$$

By substituting these into the equation below, we obtain:

$$\begin{aligned}
\Omega_{\gamma,t} &= \frac{\rho_\gamma}{\rho_{c,t}} \\
\Omega_{\gamma,t} &= \frac{\frac{aT_t^4}{c^2}}{T_t^4 \frac{23040\pi}{c^3}\sigma} \\
\Omega_{\gamma,t} &= \frac{4\sigma}{23040\pi\sigma} \\
\Omega_{\gamma,t} &= \frac{1}{5760\pi} \approx 5.52621330180192 \times 10^{-5}
\end{aligned} \tag{9}$$

In a black hole growing $R_h = ct$ cosmology during the entire cosmic epoch, the photon radiation density ratio remains constant and exact. This is likely inconsistent with the predictions of the Λ-CDM model in earlier times, but it should be correct for the current time as well.

Conflicts of Interest: The author declare no conflict of interest.

Data Availability Statement: No data was used for this study.

References

1. A. G. Emslie and R. M. Green. Can the Einstein-de sitter model adequately describe the universe at any epoch. *Astrophysics and Space Science*, 58(1):181, 1978.
2. E. G. Haug and E. T. Tatum. Planck length from cosmological redshifts solves the Hubble tension. *Research-Gate.org*, 2024. URL https://www.preprints.org/manuscript/202403.1241/v1.
3. A. Friedmann. Über die krüng des raumes. *Zeitschrift für Physik*, 10:377, 1922. URL https://doi.org/10.1007/BF01332580.
4. E. T. Tatum, U. V. S. Seshavatharam, and S. Lakshminarayana. The basics of flat space cosmology. *International Journal of Astronomy and Astrophysics*, 5:116, 2015. URL http://dx.doi.org/10.4236/ijaa.2015.52015.
5. E. G. Haug and G. Spavieri. Mass-charge metric in curved spacetime. *International Journal of Theoretical Physics*, 62:248, 2023. URL https://doi.org/10.1007/s10773-023-05503-9.
6. E. G. Haug and G. Spavieri. New exact solution to Einstein's field equation gives a new cosmological model. *Researchgate.org Pre-print*, 2023. URL http://dx.doi.org/10.13140/RG.2.2.36524.44161.

doi:10.20944/preprints202403.1663.v1

7. E. G. Haug. The extremal universe exact solution from Einstein's field equation gives the cosmological constant directly. *Journal of High Energy Physics, Gravitation and Cosmology*, 10:386, 2024. URL https://doi.org/10.4236/jhepgc.2024.101027.
8. R. K. Pathria. The universe as a black hole. *Nature*, 240:298, 1972. URL https://doi.org/10.1038/240298a0.
9. P. Christillin. The Machian origin of linear inertial forces from our gravitationally radiating black hole universe. *The European Physical Journal Plus*, 129:175, 2014. URL https://doi.org/10.1140/epjp/i2014-14175-2.
10. T. X. Zhang and C. Frederick. Acceleration of black hole universe. *Astrophysics and Space Science*, 349:567, 2014. URL https://doi.org/10.1007/s10509-013-1644-6.
11. N. Popławski. The universe in a black hole in Einstein–Cartan gravity. *The Astrophysical Journal*, 832:96, 2016. URL https://doi.org/10.3847/0004-637X/832/2/96.
12. T. X. Zhang. The principles and laws of black hole universe. *Journal of Modern Physics*, 9:1838, 2018. URL https://doi.org/10.4236/jmp.2018.99117.
13. D. A. Easson and R. H. Brandenberger. Universe generation from black hole interiors. *Journal of High Energy Physics*, 2001, 2001. URL https://doi.org/10.1088/1126-6708/2001/06/024.
14. E. Gaztanaga. The black hole universe, part i. *Symmetry*, 2022:1849, 2022. URL https://doi.org/10.3390/sym14091849.
15. Z. Roupas. Detectable universes inside regular black holes. *The European Physical Journal C*, 82:255, 2022. URL https://doi.org/10.1140/epjc/s10052-022-10202-6.
16. E. Siegel. Are we living in a baby universe that looks like a black hole to outsiders? *Hard Science, Big Think, January 27*, 2022. URL https://bigthink.com/hard-science/baby-universes-black-holes-dark-matter/.
17. C. H. Lineweaver and V. M. Patel. All objects and some questions. *American Journal of Physics*, 91(819), 2023.
18. E. G. Haug and E. T. Tatum. Planck length from cosmological redshifts solves the Hubble tension. *ResearchGate.org*, 2024. URL 1https://doi.org/0.13140/RG.2.2.21825.98407.