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Planck Quantized bending of light leads to the CMB temperature

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Abstract

We will demonstrate that if the curvature of photons is quantized and linked to the Planck length, then the bending of a photon in a gravitational field must likely be the Planck length per photon wavelength. If we apply this concept to the Hubble sphere, the longest possible wavelength that can be bent into the Hubble sphere correspond to a wavelength equal to the energy that very precisely predicts the CMB temperature. This leads us to the ability to predict not only the CMB temperature, but also provides a potential mechanism linked to the Planck scale for explaining why the CMB temperature is what it is. We further discuss how this is related recent theoretical findings related to the CMB temperature. It seems like more and more theoretical evidence points towards a solid foundations for that the CMB temperature clearly can be presicely predicted, not only measured as commonly assumed.

Keywords: Quantized light bending, Planck length, Hubble sphere, CMB temperature.

1 Background on basic circle tangent geometry

As the distance from the tangent to the circumference of the circle will play an important role in our analysis, we will quickly go through a refreshment on this, even though it is naturally well-known. In Figure 1, if we want to find the distance b , which is the distance between the tangent and the circumference of the circle with radius r , then we must have that:

$$b = r - r' \tag{1}$$

Now based on Pythagoras theorem we must have:

$$r'^2 = r^2 - \left(\frac{a}{2}\right)^2 \tag{2}$$

Replacing this value for r' back into equation (1) gives us the formula for the distance b from the tangent (tip) to the circumference:

$$b = r - \sqrt{r^2 - \left(\frac{a}{2}\right)^2} = r - \sqrt{r^2 - \frac{a^2}{4}} \tag{3}$$

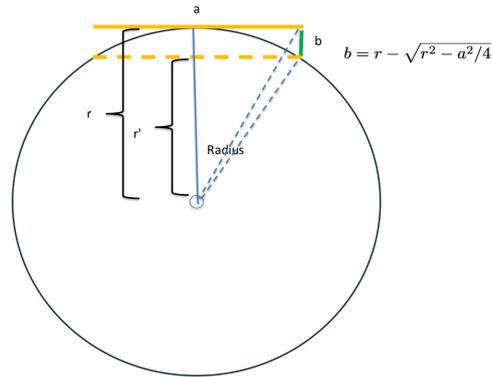


Figure 1: The figure illustrate the basic of the geometry of a tangent to a circle and how we can find the length b if we know r and a as well as a if we know r and b .

The distance b also represents how much the line a must bend over its own distance in each direction to follow or become part of the circumference of the circle. Furthermore, if b is known, then we can solve equation 3 for a , which gives:

$$a = 2\sqrt{2br - b^2} \quad (4)$$

We will in the next section heavily rely on this simple and well known geometry principles in deriving a formula for predicting the CMB temperature based on that a photon if bent in a gravitational field must minimum be bent by the Planck length.

2 Quantized bending of light leads to the CMB temperature

Many physicists [1–4] assume the Planck [5, 6] length is the minimum length and also that quantum gravity must be related to the Planck scale. Based on this we will conjecture that a wavelength in a gravitational field must in gravitational field must bend minimum the Planck length over its own wavelength. If the gravitational field is too weak to bend it a full Planck length then the photon will not be bent. This we have tried to illustrated in figure 2. The only difference between A) and B) in the figure is that we have drawn the bending as smooth-bending in B).

So we will conjecture that if a photon is bent in a gravitational field it must be bent with minimum the Planck length over its own photon wavelength. This could even be the maximum in addition to the minimum a photon can be bent over its own wavelength. To be bent two Planck length the photon must travel two photon wavelength in the gravitational field etc. This seems to be somewhat line with basic logic reasoning from quantum gravity in that even bending of light must be quantized and linked to the Planck scale, even if we not can see this particular point have been discussed. However to be more than a conjecture it should lead to testable predictions, and to our own surprise it seems to do so as we will come to in this section.

In a gravitational field the Schwarzschild [7] solution predict light bending of

$$\theta = \frac{4GM}{c^2 r} \quad (5)$$

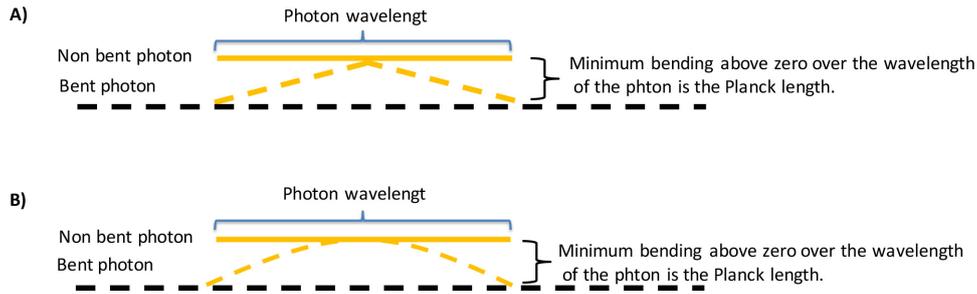


Figure 2: We assume a photon if it is changing direction in a gravitational field (is bent) minimum must bend (curve) minimum the Planck length. The two figures above illustrates the same, one smoothly bent and one bent jut at the middle.

For a black hole, we have a radius equal to the Schwarzschild radius $r = r_s = \frac{2GM}{c^2}$, and then the light bending becomes

$$\theta = \frac{4GM}{c^2 r_s} = 2 \quad (6)$$

This means the light beam is bent around 360 degrees. One interpretation of this could be that photons get trapped in the event horizon or close to it and travel around the black hole. Alternatively, the more standard solution would be that they fall into the black hole and end up in the central singularity.

In the recent exact solution to Einstein's [8] field equation given by Haug and Spavieri [9], the light bending (when charge is set to zero) is given by

$$\theta = \frac{4GM}{c^2 r} - \frac{2G^2 M^2}{c^2 r^2} \quad (7)$$

However, the event horizon for a black hole under this metric is $r_h = \frac{GM}{c^2} = \frac{1}{2}r_s$, so this leads to a light bending at the horizon of the black hole of

$$\theta = \frac{4GM}{c^2 r_h} - \frac{2G^2 M^2}{c^2 r_h^2} = 2 \quad (8)$$

So, just as in the Schwarzschild metric, it seems like a light beam is bent 360 degrees around the black hole. There is an additional factor that makes this more likely under the Haug and Spavieri metric. The orbital velocity in the Haug-Spavieri metric at the event horizon is given by:

$$v_o = \sqrt{\frac{GM}{r_h}} = \sqrt{\frac{GM}{\frac{GM}{c^2}}} = c \quad (9)$$

This supports the view that photons could end up orbiting the black hole at the event horizon itself or very close to it.

Next, we will move on to cosmology. Since the break through discovery by Hubble [10] and Lemaître [11] the Hubble constant, Hubble radius and the Hubble sphere has played an important role in cosmology. Even in the Λ -CDM model, the Hubble radius plays a central role, particularly in the critical solution of the Friedmann equation [12]. However, also in other cosmological models, the Hubble radius plays an important role as well. One class of such models is the so-called $R_H = ct$ type cosmological models that are actively discussed to this day (see [13–18]). Another class of cosmological models assumes that the Hubble sphere

is actually a special kind of black hole-type universe. This idea was suggested at least as early as 1972 by Pathria [19] and again in 1994 by Stuckey [20]. Despite being in conflict with the Λ -CDM model, the black-hole universe idea is actively discussed to this day [21–23]. It's important to note that there are many metrics to study here; the Schwarzschild metric is the best known solution, but can be seen as just a start. We also have for example the Reissner-Nordström [24, 25] metric, the Kerr [26] metric, the Kerr-Newman [27, 28] metric, and also the latest Haug-Spavieri metric and also other metrics. There is also the possibility to combine concepts from $R_H = ct$ cosmology with growing black holes, as, for example, done under the Schwarzschild metric by Tatum et al. [29]. Our point is simply that it is too early to claim what one will consider to be the best cosmological model in the future. At this stage, we would personally say that the best approach is to continue investigation of the Λ -CDM model, but also the less known alternative cosmological models. Over time, many researchers can fully explore the different solutions of Einstein's field equation, as well as how different quantum gravity models can fit into cosmology, first then we will likely be able to reach some type of optimal cosmological model. We hope this paper can be a small, but important step in that direction. What we will present is quite general and could be consistent with a series of different cosmological models.

The Hubble radius can represent different things in different cosmological models; it is a black hole event horizon in some pure black hole cosmological models. It could also simply be an information horizon of some sort in several cosmological models such as in some classes of $R_H = ct$ models. The following analysis likely best fits the black-hole type models of the universe, but at this stage, other models such as Λ -CDM should not be excluded.

If the minimum light bending above zero for a photon per photon wavelength is the Planck length, then for a photon to be able to orbit the Hubble sphere or not escape the Hubble sphere, it must have a length as illustrated in Figures 3 and 4.

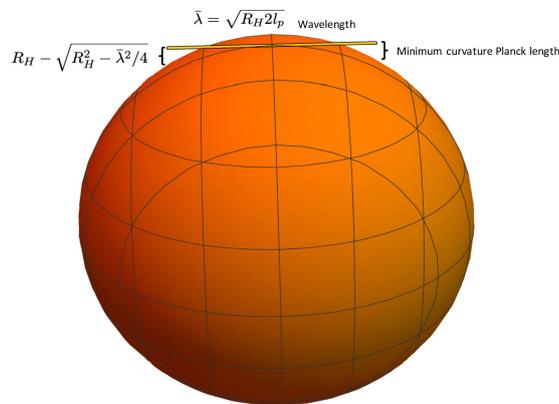


Figure 3: A photon is passing just along the horizon (surface) of the Hubble sphere. To follow the sphere a photon with wavelength $\bar{\lambda}$, the photon needs to curve at least the Planck length while moving its own photon wavelength to follow the surface.

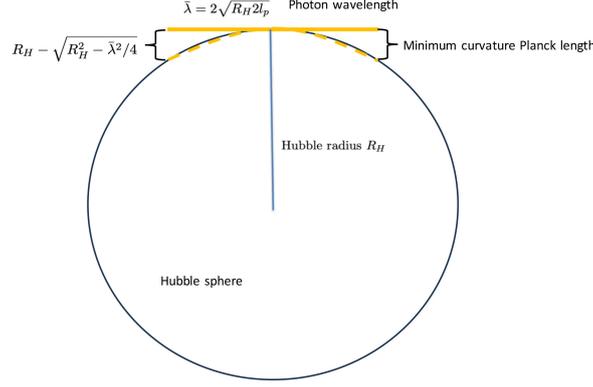


Figure 4: The same as the figure 3 but the important details are easier to understand if we just focus on the Hubble circumference. So for a photon to stay inside the Hubble sphere it must bend minimum the Planck length while moving its own wavelength to stay inside the Hubble sphere. This wavelength we can calculate from basic geometry given in section 1, and it is $\bar{\lambda} = 2\sqrt{R_H 2l_p}$.

Based on section one this means we have the following equation

$$\begin{aligned} b &= r - \sqrt{r^2 - a^2/4} \\ l_p &= R_H - \sqrt{R_H^2 - \bar{\lambda}^2/4} \end{aligned} \quad (10)$$

where $R_H = \frac{c}{H_0}$ is the Hubble radius and l_p is the Planck length that here represent the minimum curvature over the wavelength of the photon (particle). Solved for the wavelength we get

$$\bar{\lambda} = 2\sqrt{R_H 2l_p} \quad (11)$$

This could mean longer wavelengths than that can likely escape out of the Hubble sphere. The temperature related to the energy given by this predicted special wavelength in equation (11) is given by

$$T = \hbar f \frac{1}{k_b} = \hbar \frac{c}{\bar{\lambda}} \frac{1}{k_b} = \hbar \frac{c}{2\sqrt{R_H 2l_p}} \frac{1}{k_b} \approx 17.11k \quad (12)$$

If we divide this by 2π , we get a temperature of approximately $2.72k$. Despite not being ideal, it is far from abnormal to adjust the end result with a factor like 2π . Adler et al. [30], for example, did so in a paper related to Hawking [31] temperature and simply called it a “calibration factor.” This is even how the reduced Planck constant came into being, also known as the Dirac constant. Dirac needed an adjustment of 2π and divided the Planck constant by 2π , which is why it is also known as the Dirac constant. After adjusting for the “calibration factor,” we get

$$T_{CMB} = \hbar f \frac{1}{k_b 2\pi} = \hbar \frac{c}{\bar{\lambda}} \frac{1}{k_b 2\pi} = \hbar \frac{c}{\sqrt{R_H 2l_p}} \frac{1}{k_b 4\pi} \approx 2.72^{+0.082}_{-0.069}k \quad (13)$$

we have here used a Hubble parameter in calculation of R_H given by the recent published study by Kelly and et. al [32] of $66.6^{+4.1}_{-3.3} (km/s)/Mpc$. The estimated CMB temperature is very close to measured CMB temperatures, see for example [33–36]. We are here focusing on the CMB temperature now, that is from z close to zero. If we examine the Cosmic

Microwave Background (CMB) temperature from a distance, specifically when the redshift (z) is significantly higher than zero, we naturally encounter the well-known rule $T_k = T_{CMB}(1+z)$, which has been extensively tested up to a cosmological redshift of approximately $z = 6$. However, the uncertainty in CMB temperature measurements from distant observations is notably high. For instance, Riechers et al. [37] predicts the CMB temperature based on measurements at $z = 6.34$. The one standard deviation estimate then spans a wide range, from 16.4 to 30.2 Kelvin.

In a recent paper, Haug and Tatum [38] come to the same result simply by conjecturing that the CMB temperature is the geometric mean temperature of the minimum and maximum temperature in the Hubble sphere, by considering the minimum and maximum wavelengths. They simply assume the maximum wavelength in the Hubble sphere is equal to the diameter of the Hubble sphere or alternatively the circumference. Furthermore, they assume the minimum wavelength is the Planck length or alternatively the circumference of a Schwarzschild micro black hole. These two geometric approaches do not seem to contradict each other but rather appear to be complementary.

This also takes us back to the interesting formula published by Tatum and Seshavatharam [39, 40] in 2015, which was

$$T_{CMB} = \frac{\hbar c^3}{k_b 8\pi G \sqrt{M_c m_p}} = \frac{\hbar c}{k_b 4\pi \sqrt{R_H 2l_p}} \approx 2.72^{+0.082}_{-0.069} k \quad (14)$$

where M_c is the critical Friedmann universe mass $M_c = \frac{c^3}{2GH_0}$, and we use the same Hubble constant prediction as given above. The last part of this formula is identical to the formula we have derived here. If one has a formula that can also predict the CMB temperature and not only measure the CMB temperature, then this clearly must be a breakthrough in cosmology. However, naturally, only if such a formula is based on a solid foundation. Tatum et al applied the formula to a growing black hole universe rooted in the Schwarzschild metric.

Tatum et al. arrived at this formula somewhat heuristically (as is often done at an initial break through) by modifying the Hawking temperature formula $T_{Hw} = \frac{\hbar c^3}{k_b 8\pi GM}$, by replacing M with $\sqrt{M_c m_p}$. This has hardly gained any attention in the research community. The reason for this is likely that they had demonstrated no derivation of their formula so it was unclear if it truly could be correct despite giving the correct CMB temperature. Further it was published in a very low-ranked journal. Now, eight years after its first publication, we know this formula is consistent with simple geometric approaches rooted in sound reasoning, such as a photon minimum must be bent by the Planck length if it is bent in a gravitational field. Additionally, the formula has recently been proven to be derived by the Stefan-Boltzmann law, see [41]. We shortly below list the recent findings in CMB temperature that:

3 Conclusion

If one assumes that a photon, when bent in a gravitational field, must be bent by the Planck length, then in the Hubble sphere, it seems like photons with microwavelengths are unlikely to move out of the Hubble sphere. They are trapped inside the sphere and may even be possibly captured from the outside of the sphere. This geometric quantum approach seems to lead to a formula that can very precisely predict the CMB temperature.

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Declarations

Conflict of interest

The author declares no conflict of interest.