

# Possible Relations of Cosmic Microwave Background with Gravity and Fine-Structure Constant

Qinghua Cui

Department of Biomedical Informatics, Peking University, Beijing, China

Email: [cuiqinghua@hsc.pku.edu.cn](mailto:cuiqinghua@hsc.pku.edu.cn)

**How to cite this paper:** Cui, Q.H. (2022) Possible Relations of Cosmic Microwave Background with Gravity and Fine-Structure Constant. *Journal of Modern Physics*, 13, 1045-1052.

<https://doi.org/10.4236/jmp.2022.137058>

**Received:** May 29, 2022

**Accepted:** July 3, 2022

**Published:** July 6, 2022

Copyright © 2022 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

---

## Abstract

Gravity is the only force that cannot be explained by the Standard Model (SM), the current best theory describing all the known fundamental particles and their forces. Here we reveal that gravitational force can be precisely given by mass of objects and microwave background (CMB) radiation. Moreover, using the same strategy we reveal a relation by which CMB can also precisely define fine-structure constant  $\alpha$ .

## Keywords

Gravity, Gravitational Constant, Cosmic Microwave Background, Fine-Structure Constant

---

## 1. Introduction

Gravity, called also gravitational force, represents a fundamental and universal force because of mass and always acts as attraction between all matters. Although dominantly developed by Issac Newton several centuries ago and then by Albert Einstein one century ago, the gravitational force is still one of the most mysterious forces in the universe as it cannot be described by the standard model, the current best theory explaining all the known forces well except gravity [1]. Given the critical role of gravity in the universe and its linear relation with the gravitational constant  $G$ , one of the most fundamental constants of nature, it is quite important to get the precise knowledge of gravity and  $G$ . During the past two centuries, more than 300 experimental  $G$  values have been measured [2]; however, gravity is still the least precisely known constant due to its extreme weakness and non-shieldability [3].

Here we reveal a quantitative relation between gravity and the cosmic micro-

wave background (CMB), a kind of radiation almost evenly filling the universe [4]. We propose an equation among which the gravitational force and the gravitational constant  $G$  can be well determined by the frequency  $f$  or temperature  $T$  of CMB, which suggests that the gravitational force could be from the interaction between matter and CMB. Based on this finding, the “gravitational waves” are explained as periodic or non-periodic signals of gravity variation in nature. Moreover, this theory can easily interpret why the gravitational force is always attractive and why the “gravitational waves” travel at the speed of light. Moreover, using the same strategy, we reveal that CMB can also precisely predict fine-structure constant  $\alpha$ .

## 2. Gravitational Force Given by the Cosmic Microwave Background

It is well known that the Boltzmann constant  $k$  links the average kinetic energy  $E$  of gas particles with its temperature  $T$  as the following equation,

$$E = \frac{3}{2}kT \quad (1)$$

It is well known that photons have only two physical degrees of freedom. Thus, the expected average energy of CMB photons will be

$$E = \frac{2}{2}kT = kT \quad (2)$$

Moreover, the energy of CMB photons can be given by

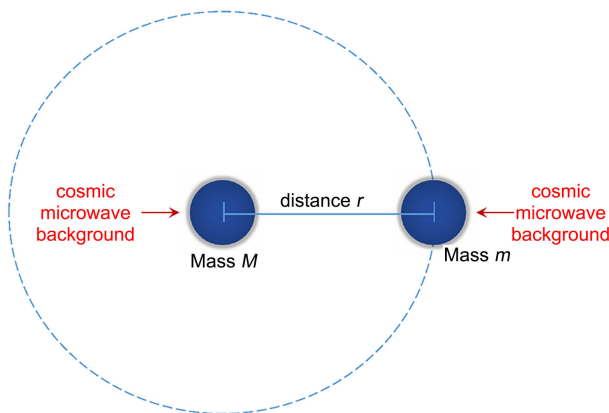
$$E = hf \quad (3)$$

where  $h$  is the Planck constant and  $f$  is the frequency of the CMB photons. Then, the expected average frequency  $f$  of CMB photons is expressed as

$$f = \frac{kT}{h} \quad (4)$$

A widely accepted experimental value of the CMB temperature is  $T = 2.73$  K (*Kelvin*) [5], then the expected average frequency of CMB will be  $f = 5.688397 \times 10^{10}$ .

It is known that gravity is always attractive and gravitational waves travel at speed of light, which triggers us to obtain the idea and hypothesis that CMB could have a role in gravity. As shown in **Figure 1**, we assume there are two astrophysical objects with mass of  $M$  and  $m$ , and with a distance of  $r$ . It is thus not difficult to understand that CMB crashes into the two objects at all directions except the direction along the line connecting them (**Figure 1**). Therefore, the force by CMB collision will be cancelled out at all directions except the direction along the line connecting them. That is, the inner side of both objects does not receive collision and the corresponding outer side of each object receives the collision (force), thus resulting in an attractive force, that is, the gravitational force, between the two objects along the line connecting them. Then, the gravitational force can be given by the following equation:



**Figure 1.** A diagram for the role of cosmic microwave background (CMB) in the gravitational force between two astrophysical objects with mass of  $M$  and  $m$ , and with a distance of  $r$ . In the diagram, CMB plays a role in gravitation as some necessary “stimulus” but not mechanical force of unseen tiny particles as Le Sage’s theory of gravitation suggested.

$$F = \frac{Mm}{4\pi r^2} \times \frac{hf}{\lambda} \times f \times 2 \tag{5}$$

where  $\frac{Mm}{4\pi r^2}$  is the matter interaction of the two objects.  $hf$  and  $\lambda$  are the expected average energy and wavelength of CMB, respectively. Then,  $\frac{hf}{\lambda}$  represents the force doing such a work (energy) in a distance of  $\lambda$  (collision) by one CMB-wave. And in unit time (second), there are  $2f$  times of collisions in unit mass for object pairs. Given that the speed of light in free space is  $c = \lambda f$ , the above gravitational force equation then can be given by the frequency  $f$  or by the CMB temperature  $T$  as follows:

$$\begin{cases} F = \frac{hf^3}{2\pi c} \frac{Mm}{r^2} \\ F = \frac{k^3 T^3}{2\pi ch^2} \frac{Mm}{r^2} \end{cases} \tag{6}$$

Therefore, the Newton’s gravitational constant  $G$  can be expressed as

$$\begin{cases} G = \frac{hf^3}{2\pi c} \\ G = \frac{k^3 T^3}{2\pi ch^2} \end{cases} \tag{7}$$

As a result, the gravitational constant determined by the current value  $T$  and constants  $h$ ,  $c$  and  $k$  will be  $G = 6.474792 \times 10^{-11} \text{ m}^3 \cdot \text{kg}^{-1} \cdot \text{s}^{-2}$ , which is close to the current measured value ( $6.674184 \times 10^{-11}$ ) [3], however, tension still exists. Given this observation, we have to revisit the temperature of CMB. It should be pointed out that this theory is different from Le Sage’s theory of gravitation, which represents the kinetic gravitational theory presented by Nicolas Fatio de Duillier in 1690 and by Georges-Louis Le Sage in 1748. Le Sage’s theory ex-

plained Newton's gravitational force as mechanical force of unseen tiny particles, however, in this theory CMB contribute to gravity as some necessary stimulus but not mechanical force as it is too weak to explain gravitation.

On the other hand, using Equation (7) and the current experimental value of  $G$ , it is not difficult to obtain the corresponding CMB temperature  $T = 2.757741$  K. Historically, the experimental and estimated  $T$  value does vary [6] [7], for example from [2.64, 2.77] [8] to [2.710, 2.728] [4]. In addition, it is well known that the CMB temperature  $T$  displays slight anisotropies [9]. Moreover, it was reported CMB radiation is warmer in the past space-time [10]. For example,  $T$  at redshift  $z = 2.3371$  could be between 6.0 and 14 K, much higher than the temperature at present space-time [10]. As the cooling of our universe,  $G$  continuously decreases, which can easily interpret why astrophysical objects are far away from each other. Moreover, given the non-shieldability of gravity and big distance of astrophysical objects, it makes sense that  $T$  at the scale of measured gravity will be a little bit higher than the one (2.73 K) at present space-time. Therefore, for something with shieldability and small measurement scale, it is expected that the temperature of CMB will be a little bit smaller, for example 2.71 K.

In addition, under the proposed framework, we can revisit some famous issue in gravity, e.g. gravitational waves. In Albert Einstein's theory of general relativity, gravity is not a force but modeled as a curvature in space-time. A famous prediction of the general relativity is that accelerating astrophysical objects with mass will produce "gravitational waves" [11], that is, fluctuations in the space-time, which were directly detected for the first time by LIGO recently [12]. Here we try to re-interpret "gravitational waves" using the proposed theory. According to Equation (6), any changes in the parameters ( $M$ ,  $m$ ,  $r$ , and  $T$ ) will change the gravitational force from original  $F$  to new  $F'$ . Then, the variation of the gravitational force  $F_v$  will be

$$F_v = F - F' = \frac{k^3}{2\pi ch^2} \left( \frac{MmT^3}{r^2} - \frac{M'm'T'^3}{r'^2} \right) \quad (8)$$

This equation describes the "gravitational waves". If any value of  $M$ ,  $m$ ,  $r$ ,  $c$ , or  $T$  changes dramatically enough, the "gravitational waves"  $F_v$  would be observed. It is thus not difficult to infer that the "gravitational waves" will travel at the speed of the CMB radiation, that is, the speed of light.  $F_v$  could be periodic or non-periodic, but obviously in most cases it is non-periodic because the parameters in Equation (10) show less periodicity.

### 3. Fine-Structure Constant Given by the Cosmic Microwave Background

Fine-structure constant  $\alpha$ , called also Sommerfeld's constant, is a dimensionless physical constant, which characterizes the strength of the electromagnetic interaction between elementary charged particles [13]. Given its central importance to the foundations of physics, this constant has been measured using various

methods [14] [15] [16], but still remains one of the mysterious constants of nature. Here we try to describe fine-structure constant using CMB using the same strategy as above. Fine-structure constant is defined as the ratio of the tangential velocity of the electron in the lowest-energy orbit of the hydrogen atom to the speed of light. Using the same strategy as above, the force  $F_e$  between the electric charges of the electron and the proton can be given by the following equation:

$$F_e = \frac{e^2}{4\pi r^2} \times 2f = \frac{e^2 f}{2\pi r^2} \quad (9)$$

where  $e$  is the elementary charge ( $e = 1.602176634 \times 10^{-19} \text{C}$ ),  $r$  is the Bohr radius ( $r = 5.2917721067 \times 10^{-11} \text{m}$ ), and  $f$  is the frequency of CMB. Unlike the gravitational force, electric force is the unit interaction ( $e^2/4\pi r^2$ ) of charges in unit time (second). Therefore,  $F_e$  is described by Equation (9) as the  $2f$  times (in one second) of unit interactions of paired charges. Besides the electric force, there could also exist the gravitational force  $F_g$  between the electron and the hydrogen nuclei, which can be given by Equation (10):

$$F_g = \frac{hf^3}{2\pi c} \frac{m_n m_e}{r^2} \quad (10)$$

where  $m_n$  and  $m_e$  are the rest mass of the electron ( $m_e = 9.109 \times 10^{-31} \text{kg}$ ) and the hydrogen nuclei ( $m_n = 1.67 \times 10^{-27} \text{kg}$ ), respectively. In addition, the central force  $F_c$  for the electron with a tangential velocity  $v$  at the Bohr orbit can be given by:

$$F_c = \frac{m_e v^2}{r} \quad (11)$$

In a steady state,  $F_e + F_g = F_c$ . That is,

$$\frac{e^2 f}{2\pi r^2} + \frac{hf^3}{2\pi c} \frac{m_n m_e}{r^2} = \frac{m_e v^2}{r} \quad (12)$$

Using the present frequency  $f$  of CMB and other parameters in Equation (12), we can obtain that the electronic force  $F_e$  is much greater ( $2.36 \times 10^{39}$  times) than the gravitational force  $F_g$ . In this case, the force between the electron and the hydrogen nuclei can be precisely given by the electronic force  $F_e$ . Hence, the Equation (12) can be simplified to the following equation in a high precision.

$$\frac{e^2 f}{2\pi r^2} = \frac{m_e v^2}{r} \quad (13)$$

Then, the tangential velocity  $v$  of the electron with the Bohr radius can be given by:

$$v = e \sqrt{\frac{f}{2\pi r m_e}} \quad (14)$$

Then, fine-structure constant will be

$$\alpha = \frac{v}{c} = \frac{e}{c} \sqrt{\frac{f}{2\pi r m_e}} \quad (15)$$

Given the shieldability effect analyzed above, the temperature of CMB in an

atom would be a little bit smaller than the observed one ( $\sim 2.73$  K), for example 2.71 K. As a result, using this CMB temperature ( $\sim 2.73$  K), we have calculated fine-structure constant to be  $\alpha^{-1} = 137.036804055$ , which is quite close to the experimental values, for example the values by Smiciklas *et al.* (137.03599955) [17], by Morel *et al.* (137.035999206) [14], by Pachucki *et al.* (137.0360011), by Parker *et al.* (137.035999046), and by Aoyama *et al.* (137.0359991491) [18]. This finding suggests that CMB has a critical connection with fine-structure constant. On the other side, if we take the average (137.03599961) of the above five experimental values, the corresponding temperature of CMB will be  $\sim 2.710032$  K. In addition, given that the Bohr radius is given by

$$r = \frac{4\pi\epsilon_0 \left(\frac{h}{2\pi}\right)^2}{m_e e^2} \quad (16)$$

where  $\epsilon_0$  is vacuum permittivity. Then, Equation (14) can be further described by

$$\alpha = \frac{e^2}{hc} \sqrt{\frac{f}{2\epsilon_0}} \quad (17)$$

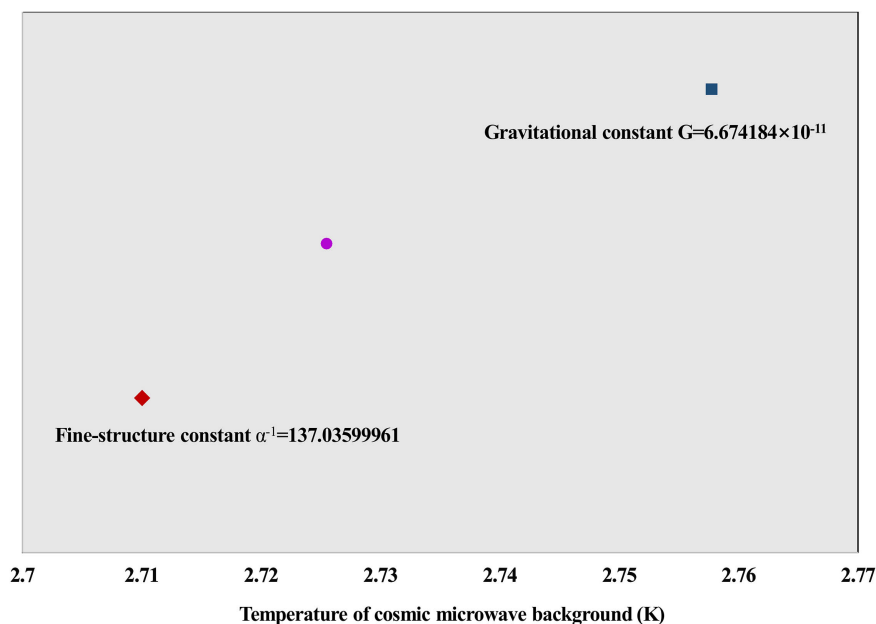
Moreover, it is well known that  $\alpha = e^2/(2\epsilon_0 hc)$ . Therefore, it is not difficult to obtain  $\epsilon_0 = 1/(2f)$ , suggesting that vacuum permittivity could be the time used for once stimulus on the interacting charges by CMB. Finally, fine-structure constant can be further expressed as the frequency of temperature of CMB with a number of other constants, as follows:

$$\begin{cases} \alpha = \frac{e^2 f}{hc} \\ \alpha = \frac{e^2 kT}{h^2 c} \end{cases} \quad (18)$$

From the above analysis, we know that based on the temperature of CMB  $T = 2.757741$  K and  $T = 2.710032$  K, the predicted  $G$  value and  $\alpha$  value match the experimental values with very high precision. However, at present, the widely accepted temperature is 2.72548 K, indicating that the temperature of CMB is variable at different space-time scale or conditions (e.g. shieldability or non-shieldability) [9]. For example, it was reported that the temperature of CMB at a past time (redshift  $z = 2.3371$ ) is between 6.0 and 14 K. We summarized the relations of CMB with gravitational constant and fine-structure constant (**Figure 2**).

#### 4. Conclusion and Discussion

We have revealed and quantified possible relations of the cosmic microwave background (CMB) with gravity and fine-structure constant. These relations can easily interpret a number of observations. For example, the gravitational force is always attractive and the gravitational wave travels at the speed of light. Moreover, as CMB is continuously cooling, the gravitational constant is expected to decrease as the CMB temperature, which can easily explain why astrophysical objects are far away from each other. In addition, we noted that although the



**Figure 2.** Cosmic microwave background (CMB) can precisely predict the current measured value of fine-structure constant at 2.710032 K and the current measured value of gravitational constant at 2.757741 K. The y-axis value has no meaning but just to separate the data points.

proposed equations match the observation data well but the original dimensions do not match consistently. Therefore, some traditional dimensions should be removed or new dimension should be introduced. Although clear relations of CMB with gravity and fine-structure constant have been revealed, exact explanations are still needed. In addition, it should be noted that besides CMB photons, the cosmic background may also include large amounts of neutrinos and gravitons. Therefore, it is important to investigate whether these “particles” contribute to gravity. Finally, although the proposed equations match the observations well, more data and especially new experiments are needed to further support the proposed findings.

### Acknowledgements

This work has been supported by the grant from the Natural Science Foundation of China (62025102).

### Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

### References

- [1] Virdee, T.S. (2016) *Philosophical Transactions of the Royal Society A Mathematical Physical and Engineering Sciences*, **374**, Article ID: 20150259. <https://doi.org/10.1098/rsta.2015.0259>

- 
- [2] Li, Q., *et al.* (2014) *Philosophical Transactions of the Royal Society A Mathematical Physical and Engineering Sciences*, **372**, Article ID: 20140141. <https://doi.org/10.1098/rsta.2014.0141>
- [3] Li, Q., *et al.* (2018) *Nature*, **560**, 582-588. <https://doi.org/10.1038/s41586-018-0431-5>
- [4] Klimenko, V.V., Ivanchik, A.V., Petitjean, P., Noterdaeme, P. and Srianand, R. (2020) *Astronomy Letters*, **46**, 715-725. <https://doi.org/10.1134/S1063773720110031>
- [5] Fixsen, D.J. (2009) *Astrophysical Journal*, **707**, 916-920. <https://doi.org/10.1088/0004-637X/707/2/916>
- [6] Konar, K., Bose, K. and Paul, R.K. (2021) *Scientific Reports*, **11**, Article No. 1008. <https://doi.org/10.1038/s41598-020-80195-3>
- [7] Traunmüller, H. (2020) *F1000Research*, **9**, 261. <https://doi.org/10.12688/f1000research.22432.3>
- [8] Amici, G.D., Bensadoun, M., Bersanelli, M., Kogut, A., Levin, S., Smoot, G.F. and Witebsky, C. (1990) *Astrophysical Journal*, **359**, 219. <https://doi.org/10.1086/169052>
- [9] de Bernardis, P., *et al.* (2000) *Nature*, **404**, 955-959. <https://doi.org/10.1038/35010035>
- [10] Srianand, R., Petitjean, P. and Ledoux, C. (2000) *Nature*, **408**, 931-935. <https://doi.org/10.1038/35050020>
- [11] Vitale, S. (2021) *Science*, **372**, eabc7397. <https://doi.org/10.1126/science.abc7397>
- [12] Abbott, B.P., *et al.* (2016) *Physical Review Letters*, **116**, Article ID: 061102.
- [13] Müller, H. (2020) *Nature*, **588**, 37-38. <https://doi.org/10.1038/d41586-020-03314-0>
- [14] Morel, L., *et al.* (2020) *Nature*, **588**, 61-65. <https://doi.org/10.1038/s41586-020-2964-7>
- [15] Pachucki, K. and Yerokhin, V.A. (2010) *Physical Review Letters*, **104**, Article ID: 070403. <https://doi.org/10.1103/PhysRevLett.104.070403>
- [16] Parker, R.H., *et al.* (2018) *Science*, **360**, 191-195. <https://doi.org/10.1126/science.aap7706>
- [17] Smiciklas, M. and Shiner, D. (2010) *Physical Review Letters*, **105**, Article ID: 123001. <https://doi.org/10.1103/PhysRevLett.105.123001>
- [18] Aoyama, T., Knoshita, T. and Nio, M. (2018) *Physical Review D*, **97**, Article ID: 036001. <https://doi.org/10.1103/PhysRevD.97.036001>