

A Thought Experiment Suggests a Simple Interpretation of Quantum Entanglement

Qinghua Cui

Wuhan Institute of Physical Education, Wuhan, China
Email: cuiqinghua@bjmu.edu.cn

How to cite this paper: Cui, Q.H. (2025) A Thought Experiment Suggests a Simple Interpretation of Quantum Entanglement. *Journal of Modern Physics*, 16, 286-293.
<https://doi.org/10.4236/jmp.2025.162014>

Received: December 24, 2024

Accepted: February 17, 2025

Published: February 20, 2025

Copyright © 2025 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

Quantum entanglement is a bizarre, counterintuitive phenomenon which shows that entangled subatomic particles remain related even when they are far apart, which was described by Einstein as “spooky action at a distance”. Although this phenomenon could be interpreted by a few theories, for example, the famous Copenhagen interpretation which describes that these states exist simultaneously by a wave function, however, there is still no unquestioned theory and it continues to puzzle people around the world. Here we propose a hypothesis that gravity cuts out stop functioning between subatomic particles based on the observations of a thought experiment. It is well known that the Universe is filled with various subatomic particles (e.g. cosmic neutrino background, CvB) and gravity is a universal force making any particle in the Universe attract any other. Based on these observations, it is expected that the CvB particles walking abreast will be combined together by their gravity after some time/distance, which will thus result in a greatly uneven distribution of CvB. However, the observational evidence showed that CvB is highly isotropic and homogenous, suggesting that gravity would no longer work at the subatomic scale. Thus, the relation of the paired subatomic particles would become some pure correlation of mass (or equivalent energy) status. In this case, time would be not required anymore due to the ineffectiveness of gravity. The proposed new interpretation matches the experimental observations well and finally possible thought experiments are presented to test this theory.

Keywords

Quantum Entanglement, Gravity, Cosmic Neutrino Background, Subatomic Particles

1. Introduction

Quantum entanglement describes a bizarre, counterintuitive phenomenon which shows that entangled subatomic particles such as photons or electrons remain connected even when they have vast distances. For dozens of years, quantum entanglement represents the heart property that makes quantum physics different from classical physics, however, continues to puzzle people around the world [1]. On the Copenhagen interpretation of quantum mechanics, the state of a particle can be given by a Schrödinger's *wave function*, which describes probabilities of the particle in a location or a state of motion [2]. A measurement will cause the probabilities (superposition) to collapse to the state measured. Then, for paired (or grouped) entangled particles, the measured state of each particle will be correlated, which is independent of their locations and distances. However, quantum entanglement was described by Einstein as "spooky action at a distance" because its information can be transmitted faster than the speed of light, which is impossible and cannot be accepted by classical physics. And the above interpretation was rejected by Einstein *et al.* [3], and they proposed hidden-variable theories to explain quantum entanglement as well. In 1964, John Bell derived Bell's inequality from Einstein's separability and locality assumptions [4], which provided a possibility to test the above interpretations. After that, a number of experiments based on Bell's inequality have been performed. For example, Gisin *et al.* showed that the collapse of the *wave function* exceeds the speed of light by at least four orders of magnitude [5]. Recently, more studies observed significant violations of the Bell inequality, which rejects local realism that does not permit physical influences to travel faster than the speed of light [6] [7]. Currently, one critical problem is what the nature of quantum entanglement is. Quantum nonlocality represents just one possible way to violate Bell's inequalities, and new theories are still expected to interpret the nature of quantum entanglement [2].

In this work, we first provide a hypothesis that gravity cuts out and stop functioning between subatomic particles through a thought experiment. It is well known that cosmic neutrino background (CvB) is one of the most abundant subatomic particles in our Universe [8]. The thought experiment is, if gravity works between subatomic particles, the CvB particles walking abreast would be combined together by their gravity after some time/distance. This thus will lead to greatly uneven distribution of CvB, and even forming neutrino stars. However, current observational evidence shows that CvB is quite isotropic and homogenous. The above conflict suggests that gravity may no longer work between subatomic particles. In this case, we further hypothesized that the relation of two or more entangled subatomic particles will become some pure interaction of mass (or equivalent energy) status, which thus does not require time and speed anymore due to the ineffectiveness of gravity. As a result, this interprets quantum entanglement as some form of interaction of mass (or equivalent energy) status without time and speed limitation. We further showed that the predictions by this interpretation matched the experimental observations well. Finally, two putative experiments

were proposed to validate this interpretation.

2. A Thought Experiment on Gravity between Subatomic Particles

Gravity is a universal force and always attractive between two objects even for antimatter objects [9]. As the weakest of all known fundamental forces, the smallest measurement of gravity ever recorded is between two gold spheres of 1 millimetre (mm) radius [10], which revealed a smaller gravitational constant G . However, it still remains unclear about gravity for objects between smaller scale including subatomic particles, for example, CvB particles. Standard cosmology stated that neutrinos should be the most abundant particles in the Universe. Here we propose a thought experiment on the gravity between two CvB particles. For simplicity, here we use the Newton's gravity equation, then the gravity between two CvB particles walking abreast is described by

$$F = G \frac{m_v^2}{r^2} \quad (1)$$

where G is the Newtonian's gravitational constant, m_v is the mass of the CvB particle (here we assume the two CvB particles have the same mass), which is estimated to be ~ 1 eV ($\sim 1.78 \times 10^{-36}$ kg) and r is the distance between the two particles. It is estimated that the number density of CvB is 112 neutrinos per cc. Then, we assume a typical distance between two CvB particles is $r_0 = \sim 1.0 \times 10^{-3}$ meters. In addition, it is estimated the diameter of the neutrino is around the scale of $r_1 = 1.0 \times 10^{-20}$ meters. Next, let's start with the distance of 1.0×10^{-3} m and simulate how long these particles will combine together (from r_0 to r_1). The distance s of the two CvB particles moving by gravity can be described by the following equation,

$$s = g_v t^2 \quad (2)$$

where t is the time and g_v is the gravitational acceleration. Here g_v is also variable with s by the following relation,

$$g_v = \frac{Gm_v}{(r_0 - s)^2} \quad (3)$$

According to Equations (2) & (3), we can obtain Equation (4) to calculate the time t ,

$$t = \sqrt{\int_0^{r_0-r_1} \frac{s(r_0 - s)^2}{Gm_v} ds} \quad (4)$$

Then,

$$\begin{aligned} t &= \sqrt{\frac{1}{Gm_v} \left(\frac{(r_0 - r_1)^4}{4} - \frac{2r_0(r_0 - r_1)^3}{3} + \frac{r_0^2(r_0 - r_1)^2}{2} \right)} \\ &= 2.648737 \times 10^{16} \text{ (second)} \end{aligned} \quad (5)$$

The simulation was run using R. As a result, the value of t is about 840 million years, suggesting that it will take ~ 840 million years for the two CvB particles

walking from the distance of $1.0\text{e-}3$ m to $1.0\text{e-}20$ m, that is their combination. **Figure 1** shows the computer simulated combination process of two putative CvB particles with the distance of $1.0\text{e-}3$ m to $1.0\text{e-}20$ m.

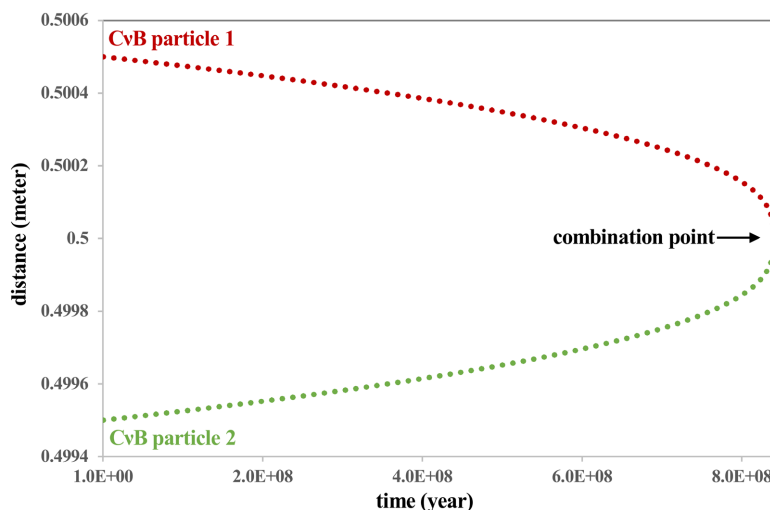


Figure 1. A computer simulated combination process of two putative CvB particles. It shows how the distance (the y axis) of the two side-by-side particles decreases from $1.0\text{e-}3\text{m}$ to $1.0\text{e-}20\text{m}$ with time (the x axis) due to the attraction force of gravity.

It is well known that CvB consists of relic neutrinos from the Big Bang ~ 13.8 billion years ago. It is thus a quite short time for 840 million years compared to the Universe's age. Therefore, if gravity works between the subatomic particles, the currently observed CvB will be greatly uneven. Up to now, however, the observational evidence showed that the distribution of CvB is highly isotropic and homogenous [8], suggesting that gravity may cut out and stop functioning between CvB particles and thus other subatomic particles.

3. A Simple Interpretation of Quantum Entanglement

Based on the above thought experiment, we proposed that gravity does not function anymore between subatomic particles. Here we further propose a hypothesis, in this case, the interaction between subatomic particles will be some pure correlation of mass (or equivalent energy) status. Here we provided some clues about how we got the above idea. We previously revealed a connection between gravity and cosmic microwave background (CMB), among which gravity can be mathematically calculated by Equation (6) [11].

$$F = \frac{hf^3}{2\pi c} \frac{Mm}{r^2} \quad (6)$$

where f is the expected frequency of CMB. This suggests that CMB could take part in the creation of gravity. As CMB is also electromagnetic wave, diffraction would occur between masses whose size is small enough. In this case, CMB would no longer all contribute to gravity and then the gravitational constant G will decrease

between small masses. We showed this hypothesis matches the real world well in a recent paper [12]. For example, this hypothesis predicted the gravitational constant G will decrease to $5.96 \times 10^{-11} \text{ m}^3 \cdot \text{kg}^{-1} \cdot \text{s}^{-2}$ between masses whose diameter are 2 millimetres (0.002 metres), which is quite consistent with the measured one $((6.04 \pm 0.06) \times 10^{-11} \text{ m}^3 \cdot \text{kg}^{-1} \cdot \text{s}^{-2})$ by experiments, however, the authors explained this is resulted from the known systematic uncertainties [10]. Thus, here we further hypothesize that CMB will not contribute to gravity (that is, gravity will not exist any longer) when the mass size decreases small enough (e.g. at the subatomic scale). Based on the above analysis, mathematically, here we then remove the gravitational constant G from Equation (1) and Equation (6) due to the ineffectiveness of gravity and add two variables representing the status of the two subatomic particles. Thus, for a pair of entangled subatomic particles, some form of interaction I_{qe} between their quantum status could be expressed as

$$I_{qe} = \frac{E_1 E_2}{r^2} |S_1\rangle |S_2\rangle \quad (7)$$

where E is the energy or equivalent mass of each entangled particle and r is the distance of the two particles. Here we introduce $|S_1\rangle$ and $|S_2\rangle$ as some quantum status (e.g. spin) of the two entangled particles. Given that we hypothesize gravity does not work in this case, Equation 6 obviously does not require time or speed anymore as it is well known gravity travels at the speed of light. In addition, according to Equation (7), distance will not determine whether I_{qe} occurs, but distance length would play a role in the strength of the entanglement. Distant entangled particles will have weaker strength of entanglement, which could explain why it is more difficult for making entanglement between more distant particles [13]. As a result, this kind of interaction of quantum status is present and independent of time. To maintain its conservation, if the status of one particle changes (e.g. $|S_1\rangle$), that of the other (e.g. $|S_2\rangle$) should change at the same time as well. Given that spin naturally does not contribute to the energy of the system, the change of spin should not change the value of I_{qe} . As a result, this kind of relation can always occur because it is only dependent on status but not I_{qe} value much. This relation is then the so-called quantum entanglement. However, Equation (7) clearly shows that if the conservation of I_{qe} is broken dramatically, the entanglement between the two particles will be broken. Firstly, I_{qe} can be easily disturbed as the energy of the two particles can be easily affected by a number of factors for example magnetic field and electronic field. Meanwhile, I_{qe} is also largely affected by the distance between the entangled particles. Obviously, when the distance is large enough, tiny changes in ‘energy’ would lead to significant effects on I_{qe} , which can easily destroy the entanglement as well. Indeed, up to now it is still a quite difficult task for long-distance entanglement [14]. The above theoretical analysis is consistent with the fact that “entanglement is fragile and hard to maintain” [15]. Finally, according to the above analysis and Equation (7), we can make the following main predictions:

- quantum entanglement can only occur between particles whose size is small

enough, for example, subatomic particles, between which gravity cuts out stop functioning;

- quantum entanglement is independent of time but relies on distance, and the smaller the distance the easier the entanglement generation and measurement;
- quantum entanglement is dependent on the “energy” status of the entangled particles, and the higher the “energy” the easier the entanglement;
- quantum entanglement is dependent on the circumstance of the entangled particles, any obvious change in the “energy” (e.g. by magnetic field, electronic field, etc.) along their travel paths would break the entanglement;
- Based on the previous prediction, it is thus expected uncharged particles should be more easily entangled than the charged particles under similar other conditions, as the later ones are more easily affected by circumstance (e.g. by magnetic field, electronic field, etc.).

4. Putative Experiments to Test the New Interpretation of Quantum Entanglement

The above hypothesis could be validated by experiments designed according to the above five predictions. Moreover, to validate the proposed new interpretation of quantum entanglement, here we present two putative experiments. According to Equation (8), we predicted that quantum entanglement is highly dependent on the “energy” status of the entangled particles, and the higher the “energy”, the easier the entanglement generation and measurement. So, the first putative experiment is performing quantum entanglement experiments for paired photons with different energy, for example, paired photos from red light to violet or even ultra-violet light under the same conditions. The next is to check whether “energy” affects the difficulty of forming and breaking entanglement.

The second putative experiment is on one pair of electrons in an even magnetic field. It is known that the energy difference between the two states (in a magnetic field or not in a magnetic field) of one electron can be expressed as

$$E = 2\mu_B B \quad (8)$$

where μ_B is the Bohr magneton and B is the magnetic field strength. That is, magnetic field will increase the energy of the electron within it. And then we can tune the magnetic field with different intensities, from small to big. According to the new interpretation, it will be expected that it is easier for the two electrons in stronger magnetic field to be entangled, and vice versa. This experiment can also be used to test the proposed interpretation.

5. Conclusion

In conclusion, we reveal that quantum entanglement could be resulted from some interaction of mass/energy status of paired or grouped subatomic particles, between which we revealed that gravity will no longer function by a thought experiment. This is based on our previous observation, CMB contributes to gravity and would not work between masses small enough, such as subatomic particles.

Moreover, this new interpretation revealed that quantum entanglement is independent of time. This kind of interaction does not require time or speed, which thus allows immediate communication at a distance. However, it suggests that quantum entanglement is dependent on distance and “energy” status of the particles. It thus seems theoretically impossible to implement quantum entanglement between particles very far away from each other. This study probably presents a new theory for the interpretation of the nature of quantum entanglement. Finally, two putative experiments are designed for future tests on quantum entanglement and this theory.

Conflicts of Interest

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

References

- [1] Kumar, M. (2008) Quantum: Einstein, Bohr and the Great Debate about the Nature of Reality. Icon Books.
- [2] Vedral, V. (2010) Quantum Physics: Hot Entanglement. *Nature*, **468**, 769-770. <https://doi.org/10.1038/468769a>
- [3] Einstein, A., Podolsky, B. and Rosen, N. (1935) Can Quantum-Mechanical Description of Physical Reality Be Considered Complete? *Physical Review*, **47**, 777-780. <https://doi.org/10.1103/physrev.47.777>
- [4] Bell, J.S. (1964) On the Einstein Podolsky Rosen Paradox. *Physics Physique Fizika*, **1**, 195-200. <https://doi.org/10.1103/physicsphysiquefizika.1.195>
- [5] Salart, D., Baas, A., Branciard, C., Gisin, N. and Zbinden, H. (2008) Testing the Speed of ‘Spooky Action at a Distance’. *Nature*, **454**, 861-864. <https://doi.org/10.1038/nature07121>
- [6] Giustina, M., Versteegh, M.A.M., Wengerowsky, S., Handsteiner, J., Hochrainer, A., Phelan, K., *et al.* (2015) Significant-Loophole-Free Test of Bell’s Theorem with Entangled Photons. *Physical Review Letters*, **115**, Article ID: 250401. <https://doi.org/10.1103/physrevlett.115.250401>
- [7] Shalm, L.K., Meyer-Scott, E., Christensen, B.G., Bierhorst, P., Wayne, M.A., Stevens, M.J., *et al.* (2015) Strong Loophole-Free Test of Local Realism. *Physical Review Letters*, **115**, Article ID: 250402. <https://doi.org/10.1103/physrevlett.115.250402>
- [8] Ringwald, A. (2009) Prospects for the Direct Detection of the Cosmic Neutrino Background. *Nuclear Physics A*, **827**, 501c-506c. <https://doi.org/10.1016/j.nuclphysa.2009.05.109>
- [9] Anderson, E.K., Baker, C.J., Bertsche, W., Bhatt, N.M., Bonomi, G., Capra, A., *et al.* (2023) Observation of the Effect of Gravity on the Motion of Antimatter. *Nature*, **621**, 716-722. <https://doi.org/10.1038/s41586-023-06527-1>
- [10] Westphal, T., Hepach, H., Pfaff, J. and Aspelmeyer, M. (2021) Measurement of Gravitational Coupling between Millimetre-Sized Masses. *Nature*, **591**, 225-228. <https://doi.org/10.1038/s41586-021-03250-7>
- [11] Cui, Q. (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>
- [12] Cui, Q. (2025) The Gravitational Constant g May Decrease between Millimetre-Sized

-
- Masses. *Journal of Modern Physics*, **16**, 133-139.
<https://doi.org/10.4236/jmp.2025.161005>
- [13] Yin, J., Li, Y., Liao, S., Yang, M., Cao, Y., Zhang, L., *et al.* (2020) Entanglement-Based Secure Quantum Cryptography over 1,120 Kilometres. *Nature*, **582**, 501-505.
<https://doi.org/10.1038/s41586-020-2401-y>
- [14] Li, B., Cao, Y., Li, Y., Cai, W., Liu, W., Ren, J., *et al.* (2022) Quantum State Transfer over 1200 km Assisted by Prior Distributed Entanglement. *Physical Review Letters*, **128**, Article ID: 170501. <https://doi.org/10.1103/physrevlett.128.170501>
- [15] Riordon, J.R. and Temming, M. (2022) Experiments on ‘Entangled’ Quantum Particles Won the Physics Nobel Prize.
<https://www.snexplores.org/article/physics-nobel-prize-2022-quantum-entanglement-particles-tech>