The universe and photons

Emmanuel Moulay *

Xlim (UMR-CNRS 6172) - Département SIC

Université de Poitiers - France

Abstract

In this article we show that the photon can be the primordial element of the physical evolution of the universe. Many results, based on well-established physical theories, support this assumption.

1 Introduction

Is there a fundamental building block of the universe? The string theory suggests that it is a string [10], and the loop quantum gravity that it is a space quantum [22]. Is it possible that there is a primordial element of the physical evolution of the universe rather than a building block of everything? This article suggests that this primordial element is the particle introduced by Albert Einstein in [7]: the photon.

A photon is an elementary particle, the quantum of the electromagnetic interaction and the basic unit of all forms of electromagnetic radiation. This is a particle without mass or charge whose energy is given by the formula:

$$E = h \cdot \nu \tag{1}$$

where h is the Planck constant and ν the frequency of the photon. For being the primordial elements in the universe, photons must account for the origin of fermionic matter and the fundamental interactions of the universe.

The paper is organized as follows. In section 2, we wonder if photons can emerge from the Big Bang. The section 3 is dedicated to fermionic matter. The section 4 deals with the fundamental interactions. A possible explanation for inflation is given in section 5. The wave-particle duality is discussed in section 6. Finally, a conclusion is given in section 7.

*e-mail: `emmanuel.moulay@univ-poitiers.fr`

2 Photons and the Big Bang

In this section, we wonder if photons can emerge from the Big Bang, an event which led to the formation of the universe. The Penrose-Hawking singularity theorems require the existence of gravitational singularities [13, 14]. A spacetime is a four dimensional Lorentzian manifold and a spacetime with a gravitational singularity is defined to be one that contains geodesics that cannot be extended in a smooth manner, what is also called “path incompleteness”. The end of such a geodesic is considered to be the gravitational singularity. In particular, the black holes which are areas of a spacetime with a gravitational field so intense that its escape velocity is equal to or exceeds the speed of light, contain a gravitational singularity. Stephen Hawking has shown in [12, 13] that a black body radiation, emitted from just beyond the event horizon, can get out of a black hole and can lead to black hole evaporation. The Hawking radiation is due to quantum fluctuations that are a temporary change in the amount of energy in a point in space. Due to the Heisenberg uncertainty principle:

$$\Delta E \cdot \Delta t \geq \frac{\hbar}{2} \tag{2}$$

where ΔE and Δt are the uncertainties in energy and time and $\hbar$ the reduced Planck constant, the conservation of energy can appear to be violated, but only for small times. Quantum fluctuations exist and they are for instance responsible for the Casimir effect. Thus, it is possible to “remove” a gravitational singularity with emission of a radiation having a black body spectrum. Nevertheless, the initial singularity is different from a conventional black hole because all timelike geodesics have no extensions into the past. If a charged particle goes out of a black hole then the conservation laws imply that the black hole has a charge. An hypothetical primordial radiation at the Planck epoch cannot be charged due to the conservation laws and because the Planck epoch does not cut the spacetime in two like the horizons of black holes. We suppose that there is a primordial radiation of photons at the Planck epoch. Actually, we know that there is a black body electromagnetic radiation filling the universe. This is the cosmic microwave background (CMB) radiation discovered in 1964 by American astronomers [21].

3 Photons and the fermionic matter

What is the origin of fermionic matter in the universe? Is it possible that fermionic matter came from photons, due to:

– the Einstein’s mass-energy equivalence:

$$E = \gamma \, m_0 \, c^2 \tag{3}$$

with $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$, v the velocity, m_0 the rest mass and c the speed of light in the vacuum;

– the physical conditions around the Big Bang?

We know that photons are emitted during a molecular, atomic or nuclear transition to a lower energy level, with various energy from infrared light to gamma rays. Moreover, the electron is able to move into an excited state with an absorption of a photon with an appropriate energy. So, fermionic matter can absorb or emit photons and this is a first information [8].

The main argument in favor of photons is a reaction called "pair production in two-photon collisions" that refers to the production of a stable elementary particle and its antiparticle from photons [9]. There exists an inverse process to pair production, called pair annihilation. This is a branch of physics called "two-photon physics" [1]. For instance, the electron e^- positron e^+ pair production is given by the "collision" of two photons γ:

$$\gamma + \gamma \rightarrow e^- + e^+ \tag{4}$$

at high energy [15, 18]. Let us recall that a photon is its own antiparticle. It is also possible to have a proton p antiproton $\overline{p}$ pair production [4]:

$$\gamma + \gamma \rightarrow p + \overline{p} \tag{5}$$

and more generally, a baryon-antibaryon pair production in two-photon "collisions" at high energy [6]. We also have a neutrino ν antineutrino $\overline{\nu}$ pair production by a photon:

$$\gamma \rightarrow \nu + \overline{\nu} \tag{6}$$

in a dense matter [19]. If the photon is the primordial element in the universe, then it is possible to obtain all fermion-antifermion pairs starting from photons [5, 17]. With this framework, the fundamental definition of masses is given by:

$$m_0 = h\frac{\nu}{\gamma c^2} \tag{7}$$

where m_0 is the rest mass of the produced elementary particle and ν the frequency of the photon involved in the pair production.

Nevertheless, there are practical problems with pair productions because two photons cannot really collide and light is quantized when interacting with matter. The experiments that take place in particle accelerators involve the use of matter, such as electrons, positrons and protons. They produce virtual particles which exist for a limited time and space due to the Feynman diagrams. We need pair productions of real particles for the production of fermionic matter. We may wonder if some physical conditions around the Planck epoch can start pair productions with photons only, avoiding the chicken or the egg causality dilemma between matter and light. It is possible to obtain pair productions of real particles with energetic photons, by using thermodynamic processes at very high temperature [24, Chapter 4]. This implies physical conditions that no longer exist in the universe. Different temperature thresholds correspond to different stable pair productions [24, p. 156]. The high temperature is provided by gravitational confinement around the Planck epoch.

Even if pair productions lead to the same quantity of matter and antimatter, the Sakharov conditions for the baryogenesis ensure that it is possible to produce matter and antimatter at different rates [23]. Then, pair productions can be favored with respect to pair annihilation.

4 Photons and the fundamental interactions

The aim of this section is to define a framework such that photons and physical conditions around the Big Bang lead to the fundamental interactions.

The gauge boson of the electromagnetic force is the photon γ. Let us consider the weak force whose gauge bosons are W^+, W^- and Z° bosons. If the photons' energy is above a certain threshold called the weak threshold, then photons are able to turn into massive W^+, W^- and Z° bosons following the pair productions [2]:

$$\gamma + \gamma \to W^+ + W^- \tag{8}$$

$$\gamma + \gamma \to Z^\circ + Z^\circ \tag{9}$$

Let us consider the strong force whose gauge bosons are the eight color-charged gluons. By using the Feynman diagrams, if the photons' energy is above a certain threshold called the strong threshold, then photons are able to turn into quarks q antiquarks $\overline{q}$ following the pair production [3]:

$$\gamma + \gamma \to q + \overline{q} \tag{10}$$

in association with gluon jet pair production [3, 16]. Once again, the pair productions in two-photon collisions can explain the origin of the electromagnetic, weak and strong interactions. Moreover, the masses of bosons are given by (7).

With this framework, we can define the elementary particles as the stable products of pair productions in two-photon collisions.

But, what about gravitation? The General Relativity is the most fundamental theory of space and time that links the spacetime geometry with energy and momentum [11]. Gravitation is different from the other interactions because it is a deterministic continuous nonrenormalizable theory and it does not really exist in a given spacetime. It is given by the Riemann curvature tensor of the spacetime. What exists? It is a background spacetime whose metric changes with energy and momentum. So, gravitation cannot emerge from photons when they are considered as particles in a given spacetime. The propagation of photons in vacuum, when they are considered as waves, provides a limit on the possibility of motion for matter and is a kind of “universal clock” for time. Indeed, the notion of time comes from the possibility of motion for matter relative to the possibility of motion for photons in vacuum which is the speed of light c [20]. Moreover, photons are also a kind of “universal rule” for measuring distances and also the cosmic distance scales with the redshift. Space and time are defined and measured relative to photons. We suppose that there are only photons at the Planck epoch which is the “primordial light epoch”. Thus, the notion of time falls down. The Planck epoch becomes a singular domain because geodesics cannot be extended into the past, keeping the universe outside an hypothetical initial singularity where all physical values become infinite. Somehow, we “remove” the mathematical initial singularity with photons. Time starts with the first pair production in two-photon collisions at the Planck epoch. Then, the complexity and the entropy increase.

5 Photons and inflation

In order to resolve several problems, the Big Bang cosmology needs an exponential expansion of the early universe. This is the theory of inflation. Nevertheless, the detailed physics mechanism responsible for inflation is not known. At the Planck epoch, we suppose that we have only photons. We also have enough energy to produce all fundamental particles. In this framework, inflation corresponds to the violent period of fermionic matter and antimatter pair productions. Due to the Pauli exclusion principle, all fermions and antifermions exhibit space-occupying behavior that violently inflate the universe. If we start with photons only, we have a period of fermionic matter and antimatter pair production and this period is inflation.

6 Photons and the wave-particle duality

Wave-particle duality is the concept that matter and light exhibit the behaviors of both waves and particles. The metaphor of the cylinder is an example of an object that shares two apparently irreconcilable properties. At first sight, it is incongruous to assert that an object has the properties of a circle and the properties of a rectangle on a map. Let us consider a cylinder. A projection on the axis of the cylinder gives a circle, and a projection perpendicular to this axis gives a rectangle, as shown in Figure 1. We have an object having both properties, but it is neither one nor the other.

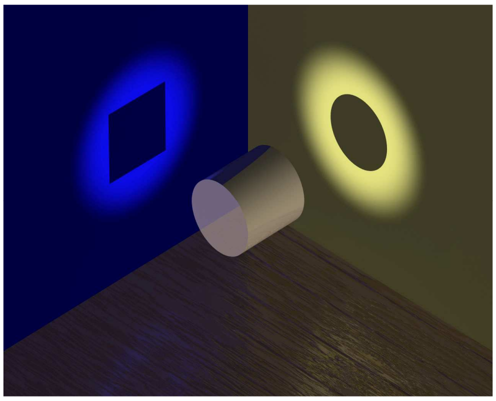

Figure 1: The metaphor of the cylinder

"Waves" and "particles" are mathematical ways of seeing things and not things in themselves. If the photon is the primordial element in the universe, then it explains the wave-particle duality of matter and it implies that the universe is both continuous and discrete at the most fundamental level. Indeed, photons are themselves both continuous, as waves, and discrete, as particles. They are an important link between the General Relativity and the Quantum Mechanics [8, 11], and this paper suggests that this link is the fundamental one. This theory provides an alternative solution to quantum gravity concerning the problems of the unity of Physics and of the beginning of the universe. If the photon is the primordial element of the physical evolution of the universe then the universe is both continuous and discrete at the most fundamental level, due to the wave-particle duality. Continuous physical theories could not be completely associated with discrete ones although there are links between them, exactly as geometry and algebra in Mathematics. Thus, the continuous/discrete duality of the universe and the unity of Physics may be preserved until the Big Bang into the wave-particle duality of photons.

7 Conclusion

This article raises the question of whether the photon is the primordial element of a physical evolution of the universe. Many results are consistent with this assumption. The photon has in its blood the laws of quantum theory and relativity.

This requires a change in philosophical perspective because the universe can be both discrete and continuous at the most fundamental level.

I leave the final word to Albert Einstein[1]:

All the fifty years of conscious brooding have brought me no closer to the answer to the question, "What are light quanta?" Of course today every rascal thinks he knows the answer, but he is deluding himself.

References

[1] S. J. Brodsky. Photon–photon collisions — past and future. *Acta Physica Polonica B*, 37(3):619–632, 2006.

[2] S. J. Brodsky and P. M. Zerwas. High energy photon-photon collisions. *Nuclear Instruments and Methods in Physics Research Section A*, 355(1):19–41, 1995.

[3] Jiří Chýla. Heavy quark production in $\gamma\gamma$ collisions. In *International Conference on the Structure and Interactions of the Photon, World Scientific Publishing*, pages 103–108, Ascona Switzerland, 2001.

[4] L3 Collaboration. Proton-antiproton pair production in two-photon collisions at LEP. *Physics Letters B*, 571(1-2):11–20, 2003.

[5] L3 Collaboration. Muon-pair and tau-pair production in two-photon collisions at LEP. *Physics Letters B*, 585(1-2):53–62, 2004.

[6] B. Echenard and L3 Collaboration. Baryon-antibaryon pair production in two-photon collisions at LEP. *Physics Letters B*, 126:307–312, 2004.

[7] A. Einstein. Über einen die erzeugung und verwandlung des lichtes betreffenden heuristischen gesichtspunkt. *Annalen der Physik*, 17:132–148, 1905.

[8] R. P. Feynman. *The Feynman Lectures on Physics*. Addison Wesley, 2005.

[9] R. P. Feynman. *QED: The Strange Theory of Light and Matter*. Princeton University Press, 2006.

[10] M. Gasperini. *The Universe Before the Big Bang: Cosmology and String Theory*. Springer, 2009.

[11] O. Grøn and S. Hervik. *Einstein's general theory of relativity: with modern applications in cosmology*. Springer, 2007.

[1] Letter to Michele Besso, 1951

[12] S. W. Hawking. Black hole explosions? *Nature*, 248:30–31, 1974.

[13] S. W. Hawking. Particle creation by black holes. *Communications in Mathematical Physics*, 43(3):199–220, 1975.

[14] S. W. Hawking and R. Penrose. The singularities of gravitational collapse and cosmology. *Proceedings of the Royal Society A*, 314, 1970.

[15] J. H. Hubbell. Electron positron pair production by photons: A historical overview. *Radiation Physics and Chemistry*, 75(6):614–623, 2006.

[16] K. Kajantie and R. Raitio. Gluon jet pair production in e^+ e^- initiated photon-photon collisions. *Physics Letters B*, 87(1-2):133–135, 1979.

[17] B. A. Kniehl, A.V. Kotikov, Z. V. Merebashvili, and O. L. Veretin. Heavy-quark pair production in polarized photon-photon collisions at next-to-leading order: Fully integrated total cross sections. *Physical review D*, 79(11), 2009.

[18] E. Liang. Intense laser pair creation and applications. *High Energy Density Physics*, 6(2):219–222, 2010.

[19] A.E. Lobanov. Neutrino-antineutrino pair production by a photon in a dense matter. *Physics Letters B*, 637(4-5):274–278, 2006.

[20] E. Moulay. The nature of time. *cel-00511837*, 2010.

[21] A. A. Penzias and R. W. Wilson. A measurement of excess antenna temperature at 4080 mc/s. *Astrophysical Journal*, 142:419–421, 1965.

[22] C. Rovelli. *Quantum Gravity*. Cambridge Monographs on Mathematical Physics, 2007.

[23] A. D. Sakharov. Violation of CP invariance, C asymmetry, and baryon asymmetry of the universe. *Journal of Experimental and Theoretical Physics*, 5:24–27, 1967.

[24] S. Weinberg. *The First Three Minutes: A Modern View Of The Origin Of The Universe*. Basic Books, 1993.