Journal of Physical Science, Vol. 34(1), 21–26, 2023

Three Analytical Relations Giving The Speed of Light, The Planck Constant and The Fine-Structure Constant

Fabien Salmon

Université de Bordeaux, CNRS, Bordeaux INP, I2M, Bât A11, 351 cours de la Libération, 33400 Talence, France

Corresponding author: Salmon.Fabien@yahoo.com

Published online: 28 April 2023

To cite this article: Salmon, F. (2023). Three analytical relations giving the speed of light, the Planck constant and the fine-structure constant. *J. Phys. Sci.*, 34(1), 21–26. https://doi.org/10.21315/jps2023.34.1.2

To link to this article : https://doi.org/10.21315/jps2023.34.1.2

ABSTRACT: *The fundamental physical constants are at the root of physics theories, but no theoretical framework provides their experimental values. In addition, they are assumed to be independent of each other. Here, we present two valuable dimensionless numbers based on vacuum properties and fundamental constants. The value of these dimensionless numbers provokes questioning, since they are of order 10^1. In particular, they mean that it is possible to build a velocity and a parameter homogeneous to the Planck constant of the same order as the speed of light and the Planck constant respectively, only based on five well-known physical parameters. These formulas are very unlikely to be two coincidences and suggest that the parameters involved depend on each other. They also seem to indicate that light is a material wave and quantum mechanics is a deterministic theory. A link between these numbers and the fine-structure constant is also established.*

Keywords: fundamental constants, theoretical physics, speed of light, Planck constant, fine-structure constant

1. INTRODUCTION

Physics theories rely on fundamental physical constants. For instance, the speed of light, the Planck constant or the Boltzmann constant are often called fundamental physical constants. Their values are only measured and not theoretically predicted by any formula. One of the most studied constants is the fine-structure constant, which is without dimension.[1] Its value of approximately 1/137, bothered many physicists such as Pauli, Dirac, Eddington, or Feynman and is still an unsolved issue. In that sense, these fundamental constants remain a weakness of our understanding of physical laws. Besides, nobody can certify that they are truly constant.[2–4]

Here, we derive two dimensionless numbers from vacuum properties and fundamental constants. Their values are as intriguing as the fine-structure constant, since they are of order 10^1. That means that we can build a velocity of vacuum of the same order of magnitude as the speed of light. This is similar for the Planck constant. In addition, it is possible to express the fine-structure constant with another expression only based on both dimensionless numbers.

2. PHYSICS THEORIES AND FUNDAMENTAL CONSTANTS

Basically, the fundamental physics theories can be considered as composed of two parts: a mathematical framework relying on experimental observations and the interpretation of this framework. However, interpretation is not always easy because of the intrinsic bounds of theories.

For instance, Newton found his law of gravitation thanks to astronomical measurements. The gravitational constant, which appears in Newton's law, was measured by Cavendish in 1797. Newton's theory is based on this constant, but no theory explains its value. No theory explains why gravitation follows Newton's law, either. We only know that with $G \sim 6.674 \times 10^{-11} m^3 .kg^{-1} .s^{-2}$, this law describes the experimental observations. Thus, understanding the nature of gravitation from this law is not possible even if gravitational effects can be calculated and predicted.

The same consideration also holds for other theories such as relativity, which is based on the experimental limit of velocities, or quantum mechanics, which is based on the relation $E = hv$ and the de Broglie hypothesis. Scientists have made different interpretations of the mathematical framework of these theories, especially for quantum mechanics. From the same equation, some scientists consider that physical non-determinism exists, others claim that non-local hidden variables must exist to explain the observations.

All these theories rely on experimental laws based on parameters, often called fundamental constants, even though nobody has ever proved that they are truly constant. For instance, gravitation is based on *G*, relativity on the speed of light and quantum mechanics on the Planck constant *h*. By definition, no current theory can predict the value of fundamental constants, and they are considered to be independent of each other.

Therefore, these parameters are the Achilles heel of these theories. That is why scientists can disagree on their interpretations. To really understand reality and interpret it without any doubt, we must understand why the gravitational constant is approximately equal to $6.674 \times 10^{-11} m^3.kg^{-1}.s^{-2}$ and why gravitation acts as $1/r^2$. For example, why $E = h\nu$ with $h \sim 6.626 \times 10^{-34} kg.m^2.s^{-1}$, why time is relative and not absolute in the universe, etc.

Currently, the dominant idea is to say that the fundamental constants are universal constants of the universe, and that they are "input parameters" of nature. There would be no particular reason for the speed of light to be approximately equal to $2.998 \times 10^8 m.s^{-1}$. This discussion would also hold for the gravitational constant, Planck's constant, Boltzmann's constant, etc. There is even a theory, initially developed by Alan Guth and Andreï Linde (fined-tune universe), that assumes that there is an infinite number of universes with different values of fundamental constants, and we would be in the one presenting these values.

Basically, there are these two possible hypotheses about fundamental constants; either the fundamental constants are absolute parameters of the universe and there is nothing that explains the experimental observations previously mentioned, or there exist unknown theories that explain these parameters and their values. The results presented in section 3, based on a dimensional analysis, favour the second way of thinking.

3. RESULTS AND DISCUSSION

We start from a basic idea; since vacuum presents continuous properties such as the propagation of waves (light and gravitational) or a non-zero permittivity, could some fundamental constants actually be given by relations involving vacuum properties? We look for such possible relations thanks to a dimensional analysis.

We assume that the following fundamental constants and vacuum properties could be involved in the calculation. The critical density $\rho_c = \frac{3H^2}{8\pi G} \sim 9.2 \times 10^{-27} kg.m^{-3}$ (with H the Hubble constant and G the gravitational constant) naturally appears in cosmology through the Friedmann equations.[5] This corresponds to the density associated to a flat universe. If the average density of the universe is smaller than the critical density, then the universe is hyperbolic. If it is greater, the universe is a three-dimensional sphere (surface of a four-dimensional ball). Measurements show that the average density of the universe is approximately equal to the critical density (some atoms per cubic meter), which avoids scientists to settle the question.[6] However, this allows us to consider the critical density as the average density of vacuum in our dimensional analysis where only matters orders of magnitude. Considering that many measurements do not agree on the value of the Hubble constant, we assume $H \sim 70 km.s^{-1}.MPc^{-1}$ because this corresponds to an average of the observations.[7–10] The cosmic microwave background is electromagnetic radiation originating from an early epoch of the universe (approximately 370,000 years after the Big Bang).[11] It fills all the space and has a temperature of about 2.73 K, which can thus be considered as the temperature of vacuum. We finally consider that the fundamental constants are the Boltzmann constant $k_B \sim 1.381 \times 10^{-23} kg.m^2.s^{-2}.K^{-1}$, the Planck constant $h \sim 6.626 \times 10^{-34} kg.m^2.s^{-1}$, the vacuum permittivity $\varepsilon_0 \sim 8.854 \times 10^{-12} m^{-3}.kg^{-1}.s^4.A^2$, the elementary charge $e \sim 1.602 \times 10^{-19} A.s$, and the speed of light $c \sim 2.998 \times 10^8 m.s^{-1}$. The values of these parameters are gathered in the CODATA database.[12]

From all these parameters, exactly two dimensionless numbers can be constructed:

$$\Pi_1 = \frac{c^2 \rho_c}{(\varepsilon_0 e^{-2})^3 (k_B T_{CMB})^4} \sim 10 \tag{1}$$

$$\Pi_2 = \frac{(\varepsilon_0 e^{-2})^{5/2} (k_B T_{CMB})^2 h}{\sqrt{\rho_c}} \sim 21.7 \tag{2}$$

These dimensionless numbers could mean that we can build two variables with the same dimensions and orders of magnitude as two fundamental constants from the same set of parameters, i.e., the vacuum properties and some fundamental constants.

For instance, only from $\varepsilon_0 e^{-2}$, k_BT and ρ_c, we can create a variable that is equal to the speed of light and a variable that is equal to the Planck constant:

$$c \sim \sqrt{10 \frac{(\varepsilon_0 e^{-2})^3 (k_B T)^4}{\rho_c}} \sim 3.0 \times 10^8 m.s^{-1} \tag{3}$$

$$h = \frac{21.7 \sqrt{\rho_c}}{(\varepsilon_0 e^{-2})^{5/2} (k_B T)^2} \sim 6.6 \times 10^{-34} J.s \tag{4}$$

Like the fine-structure constant, both dimensionless numbers (1) and (2) are of a reasonable order of magnitude, 10^1, whereas all the involved constants and properties present very disparate values. Moreover, both dimensionless numbers are based on the same set of parameters which are assumed to be independent from each other. Therefore, the probability that two such relations exist tends to zero according to the current physics theories.

In addition, equation (3) is homogeneous to $c \propto \sqrt{\frac{P_{vacuum}}{\rho_{vacuum}}}$, hich looks like the definition of the speed of a material wave. It would be such a great coincidence to be able to derive the velocity of a material wave from the vacuum properties equal to the speed of electromagnetic waves in vacuum.

For all these reasons, it is highly probable that the speed of light and the Planck constant are not fundamental constants of the universe, but are given by relations (3) and (4).

Eventually, we note the following relation between the fine-structure constant and both dimensionless number (1) and (2):

$$\alpha^{-1} = \frac{2\varepsilon_0 hc}{e^2} = 2\sqrt{\Pi_1}\,\Pi_2 \sim 137.035 \quad (5)$$

4. CONCLUSION

From a dimensional analysis, we have built two dimensionless numbers based on fundamental constants and vacuum properties. Both dimensionless numbers (1) and (2) present an order of magnitude of 10^1 in spite of the great disparity between the involved parameters. This order of magnitude is very likely not a coincidence. Relations (1) and (2) can actually be written as two formulas giving the speed of light and the Planck constant. The speed of light formula is homogeneous to the classical relation for the speed of a material wave. This highly suggests that electromagnetic waves are basically material waves, contrary to the current scientific consensus. The relation giving the Planck constant highly suggests that quantum mechanics basically relies on hidden variables, since the Planck constant can be expressed with vacuum properties. This is also opposite to the current scientific consensus. Finally, both relations explain the value of the fine-structure constant, which was still a mystery.

5. REFERENCES

1. Tiesinga, et al. (2021). Inverse fine structure constant, CODATA recommended values of the fundamental physical constants: 2018. *J. Phys. Chem. Ref. Data*, 50(3), 033105. https://doi.org/10.1063/5.0064853
2. Uzan, J. P. (2003). Tests of gravity on astrophysical scales and variation of the constants. *Ann. Henri Poincaré*, 4, 347–369. https://doi.org/10.1007/s00023-003-0927-9
3. Garcia-Berro, et al. (2007). Astronomical measurements and constraints on the variability of fundamental constants. *Astron. Astrophys. Rev.*, 14, 113–170. https://doi.org/10.1007/s00159-006-0004-8
4. Flambaum, V. V. (2008). Variation of fundamental constants in space and time: Theory and observations. *Eur Phys J Spec Top*, 163, 159–171. https://doi.org/10.1140/epjst/e2008-00817-5
5. Friedmann, A. (1999). On the curvature of Space. *Gen. Relativ. Gravit.,* 31, 1991–2000. https://doi.org/10.1023/A:1026751225741
6. Ade, P. A. R et al. (2014). *Planck* 2013 results. XXVI. Background geometry and topology of the Universe. *Astron. Astrophys.*, 571. https://doi.org/10.1051/0004-6361/201321546
7. Riess, R. G. et al. (2019). Large Magellanic Cloud Cepheid Standards provide a 1% foundation for the determination of the Hubble Constant and stronger evidence for Physics beyond LambdaCDM. *Astrophys. J.*, 876(1), 85. https://doi.org/10.3847/1538-4357/ab1422
8. Planck collaboration (2014). Planck 2013 results. I. Overview of products and scientific results. *Astron. Astrophys.*, 571, A1. https://doi.org/10.1051/0004-6361/201321529
9. Hotokezaka, K. et al. (2019). A Hubble constant measurement from superluminal motion of the jet in GW170817. *Nat. Astron.*, 3, 940–944. https://doi.org/10.1038/s41550-019-0820-1
10. Freedman, W. L. et al. (2019). The Carnegie-Chicago Hubble Program. VIII. An independent determination of the Hubble Constant based on the Tip of the Red Giant Branch. *Astrophys. J.*, 882(1), 34. https://doi.org/10.3847/1538-4357/ab2f73
11. Sunyaev, R. A. (1974). The thermal history of the universe and the spectrum of relic radiation. In M. S. Longair (Ed.). *Confrontation of Cosmological Theories with Observational Data.* Netherlands: Springer, 167–173. https://doi.org/10.1007/978-94-010-2220-0_14
12. Mohr, et al. (2016). CODATA recommended values of the fundamental Physical Constants: 2014. *Rev. Mod. Phys.*, 88(3), 035009. https://doi.org/10.1103/RevModPhys.88.035009