Uncover a New Scenario for Fine-Structure Constant

Tong Wang

Abstract

The fine-structure constant is an important constant in physics. It has already had several well-known physical interpretations. In this study we wish to propose another interpretation, which connects the Planck mass and the elementary charge.

Keywords: Fine-Structure Constant; Planck Mass

1. Introduction

The fine-structure constant, commonly denoted by α, is a fundamental physical constant. It is defined as follows

$$\alpha = \frac{e^2}{4\pi\varepsilon_0\hbar c}, \quad (1)$$

where e is the elementary charge, ε_0 is the vacuum permittivity, $\hbar$ is the reduced Planck constant, c is the speed of light.

It has several interpretations in physics. Mostly it is concerned with the strength of the electromagnetic interaction between elementary charged particles. However, here we present a new interpretation which connects the magnitude of gravitational potential energy between Planck masses and the magnitude of the electromagnetic potential energy between elementary charged particles.

2. Methodology

Let us compare the gravitational potential energy between Planck masses and the electromagnetic potential energy between elementary charged particles, with the same spatial separation.

First, by definition Planck mass is

$$m_p = \sqrt{\frac{\hbar c}{G}}, \quad (2)$$

where m_p is the Planck mass. Therefore, the magnitude of the gravitational potential energy (U_p) between two Planck masses is

$$|U_p| = G\frac{m_p(m_p)}{r}, \quad (3)$$

where r is the spatial distance between the two Planck masses.

Plugging Eq. (2) into Eq. (3), we have

$$|U_p| = G\frac{\hbar c}{Gr} = \frac{\hbar c}{r}. \quad (4)$$

Next, the magnitude of the electromagnetic potential energy (U_e) between elementary charged particles is

$$|U_e| = \frac{e(e)}{4\pi\varepsilon_0 r} = \frac{e^2}{4\pi\varepsilon_0 r}, \quad (5)$$

by assumption the r has the same value as that in Eq. (4).

We have calculated the magnitude of gravitational potential energy and electromagnetic potential energy separated by the same distance. Let us compare their relative strength (the ratio of them).

$$\frac{|U_e|}{|U_p|} = \frac{\frac{e^2}{4\pi\varepsilon_0 r}}{\frac{\hbar c}{r}} = \frac{e^2}{4\pi\varepsilon_0 \hbar c}\,. \tag{6}$$

Plugging Eq. (1) into Eq. (6), we have

$$\frac{|U_e|}{|U_p|} = \alpha. \tag{7}$$

3. Results

It concludes that the ratio, of the electromagnetic potential energy between elementary charged particles to the gravitational potential energy between Planck masses, is the fine-structure constant.

4. Discussion

The fine-structure constant is an important physics constant, playing many roles in the strength of the electromagnetic interaction between elementary charged particles. The Planck mass also plays pivotal roles in the String theory. In this study we establish a connection between elementary charge and Planck mass via the fine-structure constant. It is worth pursuing this direction further to find deeper relationship between them.