Why There Are Only Four Fundamental Forces: A Possible Explanation

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Abstract

It is known that there are exactly four fundamental forces of nature: gravity forces, forces corresponding to weak interactions, electromagnetic forces, and forces corresponding to strong interactions. In this paper, we provide a possible explanation of why there are exactly four fundamental forces: namely, we relate this number with the dimension of physical space-time.

1 Formulation of the Problem

Fundamental forces of nature: a brief reminder. According to modern physics (see, e.g., [1, 2]), there are four fundamental forces that describes our Universe. Here the forces are listed in the increasing order of their strength:

- gravity forces,
- forces corresponding to weak interactions,
- electromagnetic forces, and
- forces corresponding to strong interactions.

Let us briefly remind the readers what are these forces:

- Everyone knows what gravity and electromagnetism are.
- Strong forces are the ones that keep protons and neutrons in the atoms' nuclei. Without the strong forces, protons in a nucleus would fly away – they have the same charge, so electromagnetic charges will move them apart.
- Weak forces are responsible for other processes inside the nucleus, such as *beta-decay*, when a neutron decays into a proton, a positron, and an anti-neutrino.

Comment. Even people who are not very familiar with weak interactions have probably heard about radiocarbon dating – a technique which is commonly use to date fossils. This technique is based on the fact that fossils contain Carbon (C), and in nature, part of Carbon is radioactive – corresponding to the isotope C^{14}.

- When a creature is alive, it constantly exchanges carbon with the surrounding media, and as a result, its proportion of C^{14} remains the same.
- However, after death, the exchange stops, and, due to beta-decay, the remaining C^{14} atoms decay.

Thus, by the proportion of C^{14} remaining in a fossil, we can tell how long ago the corresponding creature died.

Why four fundamental forces? A natural question is: why there are four fundamental forces and not three or five or whatever?

In this paper, we provide a possible explanation for this empirical fact.

2 Our Explanation

Main idea. Our idea is that the fact that we have four fundamental forces is related to the fact that space-time is four-dimensional: each space-time event can be uniquely determined:

- by its three spatial coordinates x, y, and z, and
- by the moment of time t.

Our explanation. In the simple Newtonian approximation, each interaction is described by one scalar field – the potential: we have gravity potential, we have electrostatic potential, etc.

So, the potentials of these four forces are four functions

$$f_1(x, y, z, t), \ldots, f_4(x, y, z, t)$$

of four variables. Thus, for each combination of the values $v_1, \ldots, v_4$ of these potentials, we can solve the corresponding system of four equations with four unknowns

$$f_i(x, y, z, t) = v_i, \quad i = 1, 2, 3, 4,$$

and, thus, express the space-time coordinates in terms of the values $v_1, \ldots, v_4$.

In principle, we could have another force, characterized by a different potential $v_5 = f_5(x, y, z, t)$. However, since we can represent all four coordinates x, y, z, and t as functions of $v_1, \ldots, v_4$, we can therefore conclude that v_5 can be represented as a a function of $v_1, \ldots, v_4$:

$$v_5 = F(v_1, \ldots, v_4),$$

for some function F.

So, every other observed force can be reduced to these four fundamental forces. In this sense, the main four forces are fundamental.

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References

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