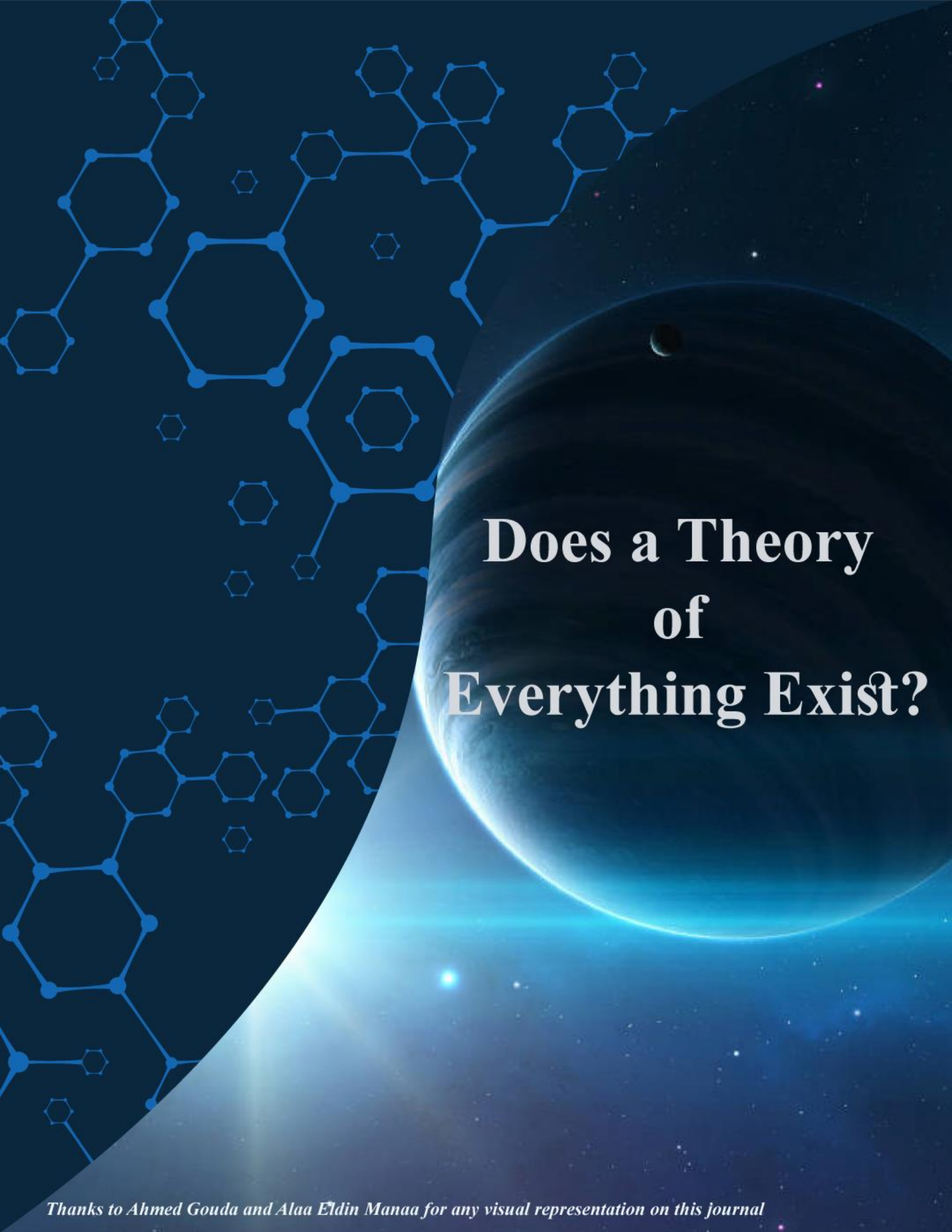

Does a Theory of Everything Exist?

Thanks to Ahmed Gouda and Alaa Eldin Manaa for any visual representation on this journal

Does a Theory of Everything Exist?

Author: Aia M. Harby

Abstract

The Theory of Everything is a set of equations capable of describing all phenomena that have been observed, or that will ever be observed. During the past two centuries, physicists were curious about unifying the 4 fundamental forces in the universe, which are: electric, magnetic, weak, and strong forces. Through many researches and experiments, they have reached some unification theories such as Maxwell's theory of electromagnetism, electroweak theory, grand unification theories, and some other theories which may be considered as theories of everything such as the M-Theory. By the way, researchers will be still working on this aspect until they can find a final theory that may describe our mysterious universe without any challenges.

Keywords: Theory of Everything (TOE), General Relativity, Quantum Mechanics, Unification Theories

I. Introduction

A theory of everything (TOE) is a hypothetical, theoretical framework that explains and links all the physics phenomena of this universe. It has been one of the major unsolved physics problems. However, there are actually some theories that have been proposed as Theories of everything such as the String Theory.

Over the past centuries, researchers have developed two theoretical frameworks which, together, can be considered as a TOE and these theories are Einstein's General Relativity & Quantum Mechanics. General relativity focuses only on the gravitational force, but on the other hand, Quantum Mechanics focuses on the other non-gravitational forces: electromagnetic, weak, and strong forces, and it has succeeded in implementing a standard model for describing them. Each of these two theories could describe its own respective area of inquiry —the smallest and the most massive bodies of the universe— with excellent accuracy, but both of them failed to be applied to each other's subject matter. Therefore, quantum gravity, which is the unified gravity with the other three interactions, has become an important area of research lately. Some researchers believed that the string theory could be proposed as a theory of everything as it assumes that at the beginning of the cosmos, all the four major interactions were defined as a single fundamental force. [1]

In this paper, some major theories, which played important roles through the evolution of the theory of everything until now, have been shown ranging from the electromagnetic idea to the string theory.

II. Electro-Magnetic Unification

In June 1865, Maxwell's unification revolutionary scientific paper: "A Dynamical Theory of the Electromagnetic Field" was published. It described how electricity and magnetism are closely connected, besides, by changing one of them, the other must respond or exist, even it was not there before. His discoveries have been simplified in a

mathematical form, known as Maxwell's equations of electromagnetism, and they are:

1. $\nabla \cdot \mathbf{D} = \rho_v$ Gauss' Law
2. $\nabla \cdot \mathbf{B} = 0$ Magnetic Monopoles
3. $\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$ Faraday's Law
4. $\nabla \times \mathbf{H} = \frac{\partial \mathbf{D}}{\partial t} + \mathbf{J}$ Ampere-Maxwell Law

where ∇ is the divergence operator, D is the electric flux density, ρv is the electric charge density, B is the magnetic flux density, E is the electric field, H is the magnetic field, and J is the electric current density. Using these equations, Maxwell found wavelike solutions that spread through any kind of media, including pure vacuum, and move at the known speed of light. So, he reached the revolutionary conclusion that electromagnetic waves are the same thing as light, in all of its forms and frequencies. [2]

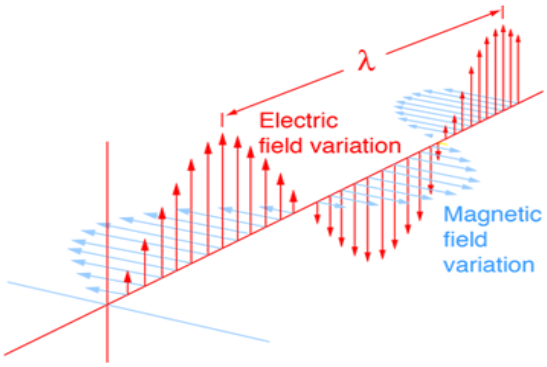

Figure (1): Electromagnetic waves

Therefore, this theory was considered as the 1st true unification theory that brought electricity, and magnetism together; and provided us with the first accurate understanding of light.

III. Electroweak Force

Electroweak theory is the theory that describes the unification of the two fundamental forces: electromagnetic and the weak forces; these interactions are generally quite different from each other as the weak force acts only across distances smaller than the atomic nucleus while the electromagnetic force may extend through great distances. Besides, the comparison between these two interactions at some point between two protons indicates that the weak force is 10 million times weaker than the electromagnetic force. One of the major discoveries in the 20th century is that the electromagnetic force and the weak force are two different branches of the same interaction, i.e., the electroweak force as it arose as a result of the efforts done to produce a self-consistent gauge theory for the weak force, in analogy with QED (quantum electrodynamics) through considering the two basic requirements for the gauge theory of the weak force, which are: exhibiting an underlying mathematical symmetry, called gauge invariance and the theory should be renormalizable; it should not contain nonphysical infinite quantities. Sheldon Lee Glashow, Abdus Salam, and Steven Weinberg were awarded the Nobel Prize to appreciate their efforts in discovering — independently— that they could construct a gauge-invariant theory of the weak force, providing that they also included the electromagnetic force. There were some requirements for their experiments, which are: two electrically charged and two neutral massless carriers in order to mediate the unified electroweak interaction. However, the short range of the weak force indicates that it is carried by massive particles. This implies that the underlying symmetry of the theory is hidden by a mechanism that gives mass to the exchanged particles in weak interactions but not to the photons exchanged in electromagnetic interactions. This mechanism is called the Higgs field. [3] A mathematical foundation used to renormalize the unified electroweak theory was provided in the early 1970s. Therefore, this led to more general acceptance of the electroweak theory. In addition, the characteristics of the

unified electroweak force and more information are generally summarized in the Standard Model of particle physics.

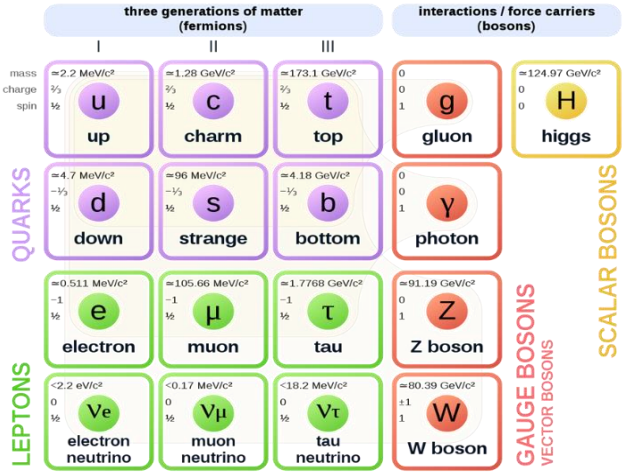

Figure (2): Standard Model of Particle Physics

IV. Grand Unification Theory (GUT)

A Grand Unification Theory (GUT) is an assumption in which the three interactions: the electromagnetic, weak, and strong forces are unified into a single force. During the 1970s, a theory, which is quite similar to the researches done on the electroweak interaction but for the strong force, called quantum chromodynamics (QCD), was developed. In QCD, quarks interact through the exchange of particles called gluons, but, is there what could be called a GUT or not? This is actually the goal of many physicists nowadays to be discovered.

The experiments had confirmed that at high energies, the electromagnetic and the weak forces could be unified into a single electroweak interaction, meanwhile, there is evidence that the strengths of the different forces vary with energy in such a way that they unite at high energies. However, the energies involved with the strong force are extremely high, in comparison to the energy scale of electroweak unification. So, the prior GUT models just predicted that, at even higher energies, the strong force could be unified with the electroweak force into a single interaction.

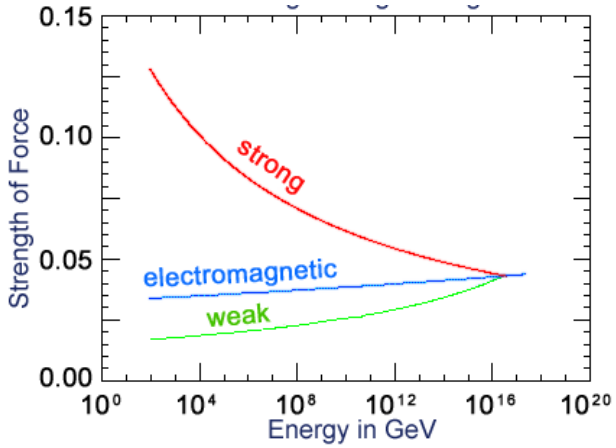

Figure (3): Forces Merge at High Energies

There is also evidence that the strengths of the forces do not congregate exactly unless new effects come into play at higher energies such as the supersymmetry.

There is no hard evidence until now that nature is described through a GUT, however, one of the few possible real experiments of the grand unified theory is the proton decay. [4]

V. String Theory & Towards a TOE

String theory is considered to be a major dream of theoretical physicists as it is a description of all forces and matter in one mathematical picture. It helped in exploring the standard description of the universe by replacing all matter and force particles with just one element: tiny vibrating strings that twist and turn in complicated ways. The theory describes how these strings spread through space and interact with each other. On large distances, a string looks just like an ordinary particle, with its mass, charge, and other characteristics determined by the vibrational state of the string. The string theory is considered to be a theory of quantum gravity as one of the many vibrational states of the string corresponds to the graviton, i.e., a quantum mechanical particle that carries gravitational force. [5]

In 1995, Edward Witten discovered the new version of the string theory, which is called the M-theory —the mother of all the string theories—, but until now, no one knows what mathematical form it might take. "The 'M' is likely inspired by higher-dimensional objects called membranes, but since the theory has no concrete mathematical equations, the 'M' remains a placeholder with no official meaning." Marika Taylor

The sequence of all the events shown in the whole paper led the scientists to consider the M-Theory as a theory of everything even as its exact definition remains unknown. But what are actually the challenges that still face the M-Theory? First, string theory does not have a satisfying definition in all circumstances. Another challenge is that the theory is thought to describe a huge landscape of possible universes, and this seemed to be complex to develop the particle physics based on the string theory.

VI. Conclusion

Finding a theory of everything would be a great scientific achievement, finally making sense of all the weird stuff in our universe. For decades, many scientists worked hard to prove the existence of this theory passing from the 1st real unified theory which is the electromagnetic idea through Einstein's general law of relativity to the unification theories of particle physics. These Grand Unification Theories are still mysterious because of the difficulty to examine them practically, but there were some pieces of evidence that could prove their validity. However, any excellent GUT model would not include the gravity, so another theory was needed to achieve the unification of all the 4 fundamental forces. M-Theory – so-called the theory of everything predicts that at the beginning of the universe, all the four fundamental forces were one single fundamental force. This theory is considered as the most one that really makes sense, but some challenges are still needed to be solved before finally considering it as a TOE.

VII. References

[1] Laughlin, R. B., & Pines, D. (2000). The Theory of Everything. *Proceedings of the National Academy of Sciences, 97(1), 28–31.* doi:10.1073/pnas.97.1.28

[2] Tombe, Frederick. (2006). The Unification of Electricity and Magnetism.

[3] Salam, A. (1994). Weak and electromagnetic interactions. *World Scientific Series in 20th Century Physics, 244–254.*doi:10.1142/9789812795915_0034

[4] Escultura, E. E. (2008). The grand unified theory. *Nonlinear Analysis: Theory, Methods & Applications, 69(3), 823–831.*doi:10.1016/j.na.2008.02.043

[5] Vimal, R. L. P. (2010). Towards a Theory of Everything Part III: Introduction of Consciousness in Loop Quantum Gravity and String Theory and Unification of Experiences with Fundamental Forces. *NeuroQuantology, 8(4).*doi:10.14704/nq.2010.8.4.303