The Conclusion of the String Theory

Abhyuday Rai

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Bennett University

Abstract

String theory has been an interesting and attractive topic, and also controversial at the same time, from the past few decades. Though the theory has been seen successfully tackling problems that seemed unsolvable, it is yet to be proved right, while having many flaws. It does have many issues in it but at the same time offers hope, we can unify all the physics and have a theory of everything. So, the problem seems quite obvious, we have less idea about the conclusion of this theory, whether is it right or not.

Introduction

Humanity from the very beginning of has always tended towards unification, be it unification of concepts, unification of theories, equations and what not. Unification makes it easier for us to learn, when we have one concept that could define many other concepts then it becomes more efficient and easier to learn, understand, and remember that one concept over those smaller and multiple concepts that were used previously.

For centuries, scientists, physicists, and many other people have been trying to understand the functioning and the pattern of our universe. We have come a long way and we have made different concepts, subjects, theories, that could define different fields of our universe. But having so many different varieties of concepts make it very chaotic and hard to understand and learn everything.

From decades, in the scientific community the quest for finding a theory which could unify all smaller fragments of concepts our physics has and also is alone capable of defining the universe's working. A theory that could simplify and put all our known physics into one box and makes us see and understand the universe at all scales in a whole new and better perspective.

String theory is one such theory that seems capable of doing this seemingly impossible task. This theory might be the theory of everything and could unify all of the knowledge humanity has gained till now, in the field of physics, in one simple equation-like thing.

String theory in general terms talks about the structure, formation, and working of the universe at quantum scale i.e. the subatomic particles and strong nuclear force. It says that everything is made up of subatomic particles- electrons, protons, and neutrons, and these particles like protons when zoomed-in are made of quarks, now our conventional idea says that these quarks are the ultimate building particles and there's nothing beyond them, but Strings theory suggests that these infinitesimally small particles are ultimately made up of strings (or vibrations) of energy.

So, according to this theory, it works like this:

If we look at object around us and zoom into it, we will find that it is made of molecules or more precisely atoms of one or many types. Then if we expand these atoms which are mostly empty spaces, we will find that they consist of nucleons (protons, neutrons), and electrons, so now if we grab and zoom-into one of these nucleons we will see quarks which make up these, now finally at this scale when we look into these quarks, we see nothing but string-like filaments of energy that have their own certain fixed vibrations, just like the strings on a violin. So just as normal strings when plucked create vibrations and different notes, these strings of the energy when vibrate produce the particles themselves! It means that electrons are nothing but strings certain pattern and, quarks are strings vibrating in some other pattern. The patterns of the vibrations of the strings decide the what particle gets formed.

So, if this theory is right then probably deep inside of everything there is nothing but a dancing vibrating cosmic symphony of strings.

By far, String theory is humanities closest approach toward the presentation of the ultimate unified theory of everything. A theory which could explain the working of all of the nature’s fundamental forces.

This theory is a single mathematical framework, which describes how these strings propagate through space and interact with each other. It unifies the two most broad and extremely different worlds of physics, quantum mechanics and gravitation. Thus, it is also a theory of quantum gravity.

<u>The emergence of the String theory</u>

Albert Einstein, who unified space and time in his special and general theories of relativity pursued this goal for over thirty years, to produce a theory for everything, to unify gravity and quantum mechanics.

In the 1970s scientists after long experiments and researches, came upon a potential solution that could have made it easier to understand and explain **the strong nuclear force** that holds the nucleons together inside the nucleus of an atom. That solution was none other than, the string theory, it seemed to describe vibrating strings that would hold

Together the atomic constituents but within a few years while the string theory was being in development phase, new theories proved to be the right solution for understanding the strong nuclear force and so strings no longer seemed necessary, were soon discarded as a theory of the strong nuclear force and that made hundreds of scientists stop working on string theory. But still, few scientists who felt the beauty of the theory continued to research on it.

John H. SCHWARZ and J. SCHERK continued to explore the String theory, and found that this was something more than a theory for strong nuclear force. SCHWARZ proposed that string theory which had failed as a theory of strong nuclear force, was actually the solution to one of the biggest problems in all physics and that was unifying Gravity and Quantum Mechanics. But to this huge proposal no one paid any serious attention.

SCHWARZ and Michael B. GREENE spent years developing the theory on their own, then in 1984 they achieved a breakthrough showing that the mathematics of string theory avoided potentially lethal technical issues and this time the community of physics heard them and string began rising and soon large number of scientists started working back on it, and it became a topic of research and high curiosity.

Our bonding with unification

Unification has always had been one of the key features in the development of physics. The physics that is taught to each of us, is a consequence of series of multiple unifications, of different concepts, that took place in the past.

Electromagnetism:

One of the earliest or the first of the steps of unification of our modern-day physics was that of putting electricity and magnetism together. About the history of this great unification, we get to know that Hans Christian Oersted in 1800s realized that if we had an electric current going through a wire, a magnet would move or in simpler words current causes magnetism. Later, Michael Faraday's brilliance took him develop this and observe that it was not only the current that affected magnets but also moving magnets could produce currents in neutral wire. These observations established connections between these two vast fields of physics, until Maxwell elaborated these connections between electricity and magnetism, by his set of 4 mathematical equations that could explain anything from these two topics and this was an absolutely huge and amazing discovery.

So, when we become better at technology, information and sources, we move on combining, streamlining, and unifying concepts and theories in form of mathematical notations, which could explain everything in a shorter, sharper and better manner. So, Maxwell incorporated these two fields and merged them into one topic – *'Electromagnetism'*.

$$
\begin{array}{lcc}
\nabla . E = \dfrac{\rho}{\epsilon_0} & (1) & \text{Gauss' law} \\
\nabla . B = 0 & (2) & \text{Magnetic monopoles} \\
\nabla \times E = -\dfrac{\partial B}{\partial t} & (3) & \text{Faraday's law} \\
\nabla \times H = J + \dfrac{\partial D}{\partial t} & (4) & \text{Ampere-Maxwell law}
\end{array}
$$

Space and time:

Albert Einstein took this unification to next heights, he realized that there were some inconsistences with the formulation of Maxwell's equations. And nobody could figure this out that waves needed medium to travel, so if light was a wave, according to Maxwell's equations then space had to be a medium with full transparency and no viscosity, and also had to be wight-less. But this kind of medium or matter was kind of magical and they called it 'ether', and many people including Maxwell tried to create models of the ether but could not succeed, as this kind of matter could simply not exist. In 1905 Einstein came up with his theory of special relativity and solved this problem and also unified space and time, which back then was one of the physics' biggest achievements. Later Einstein developed this theory by bringing in and unifying gravity with space and time, and this theory is known as 'General theory of relativity'. It showed how gravity acted as the curvature of space and also how it affects time and how time flows around heavy and strong masses. Einstein also during his proposal of Special theory of relativity came up with famous equation that unified mass and energy $E = mc^2$.

Electroweak unification:

Later to this, Electroweak Unification took place that unified Electromagnetism and weak nuclear forces (responsible for radioactive-decay, fission and fusion of nuclei).

The standard model:

With all these unifications of concepts and theories we have reached an equation which summarizes all our knowledge of particle physics! This equation is a description of all are fundamental particles that build up most of our universe be it mass, force or matter. These particles have been measured and observed in laboratories like the Large Hadron Collider at CERN, using huge and powerful machines. But this equation only describes the 3 of our 4 fundamental forces- electromagnetism, weak-nuclear force, and strong nuclear force. It does not contain any information about gravitation. So, this equation just covers the electroweak unification and thus fails to be the unified equation of everything. This mathematical formulation of the standard model of particle physics is called ***the equation of the standard model*** and the form in which this equation is written and represented is called the *Lagrangian.*

So, as we saw how unification has dominated our science, we go on for further unification, a unification that is capable of describing all the 4 forces, and now we arrive to the concept of string theory that seems capable of connecting the remaining dots. However, we will later see that this theory also opens the door for even bigger and extreme concepts that we could only dream of. So, for now this string theory unification is hypothetical, but at the same time also one our closest approaches to reach the final unification.

The string theory basically represents a major dream of theoretical physicists- a description of all forces and matter in one mathematical framework.

The Lagrangian equation of the standard model:

$$
\begin{aligned}
&-\tfrac{1}{2}\partial_\nu g^a_\mu \partial_\nu g^a_\mu - g_s f^{abc}\partial_\mu g^a_\nu g^b_\mu g^c_\nu - \tfrac{1}{4}g_s^2 f^{abc}f^{ade}g^b_\mu g^c_\nu g^d_\mu g^e_\nu + \tfrac{1}{2}ig_s^2(\bar{q}^\sigma_i\gamma^\mu q^\sigma_j)g^a_\mu +\\
&\bar{G}^a\partial^2 G^a + g_s f^{abc}\partial_\mu\bar{G}^a G^b g^c_\mu - \partial_\nu W^+_\mu\partial_\nu W^-_\mu - M^2 W^+_\mu W^-_\mu - \tfrac{1}{2}\partial_\nu Z^0_\mu\partial_\nu Z^0_\mu - \tfrac{1}{2c_w^2}M^2 Z^0_\mu Z^0_\mu -\\
&\tfrac{1}{2}\partial_\mu A_\nu\partial_\mu A_\nu - \tfrac{1}{2}\partial_\mu H\partial_\mu H - \tfrac{1}{2}m_h^2 H^2 - \partial_\mu\phi^+\partial_\mu\phi^- - M^2\phi^+\phi^- - \tfrac{1}{2}\partial_\mu\phi^0\partial_\mu\phi^0 -\\
&\tfrac{1}{2c_w^2}M\phi^0\phi^0 - \beta_h[\tfrac{2M^2}{g^2} + \tfrac{2M}{g}H + \tfrac{1}{2}(H^2+\phi^0\phi^0+2\phi^+\phi^-)] + \tfrac{2M^4}{g^2}\alpha_h - igc_w[\partial_\nu Z^0_\mu(W^+_\mu W^-_\nu -\\
&W^+_\nu W^-_\mu) - Z^0_\nu(W^+_\mu\partial_\nu W^-_\mu - W^-_\mu\partial_\nu W^+_\mu) + Z^0_\mu(W^+_\nu\partial_\nu W^-_\mu - W^-_\nu\partial_\nu W^+_\mu)] - igs_w[\partial_\nu A_\mu(W^+_\mu W^-_\nu -\\
&W^+_\nu W^-_\mu) - A_\nu(W^+_\mu\partial_\nu W^-_\mu - W^-_\mu\partial_\nu W^+_\mu) + A_\mu(W^+_\nu\partial_\nu W^-_\mu - W^-_\nu\partial_\nu W^+_\mu)] - \tfrac{1}{2}g^2 W^+_\mu W^-_\mu W^+_\nu W^-_\nu +\\
&\tfrac{1}{2}g^2 W^+_\mu W^-_\nu W^+_\mu W^-_\nu + g^2c_w^2(Z^0_\mu W^+_\mu Z^0_\nu W^-_\nu - Z^0_\mu Z^0_\mu W^+_\nu W^-_\nu) + g^2 s_w^2(A_\mu W^+_\mu A_\nu W^-_\nu -\\
&A_\mu A_\mu W^+_\nu W^-_\nu) + g^2 s_w c_w[A_\mu Z^0_\nu(W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - 2A_\mu Z^0_\mu W^+_\nu W^-_\nu] - g\alpha[H^3 +\\
&H\phi^0\phi^0 + 2H\phi^+\phi^-] - \tfrac{1}{8}g^2\alpha_h[H^4 + (\phi^0)^4 + 4(\phi^+\phi^-)^2 + 4(\phi^0)^2\phi^+\phi^- + 4H^2\phi^+\phi^- +\\
&2(\phi^0)^2H^2] - gMW^+_\mu W^-_\mu H - \tfrac{1}{2}g\tfrac{M}{c_w^2}Z^0_\mu Z^0_\mu H - \tfrac{1}{2}ig[W^+_\mu(\phi^0\partial_\mu\phi^- - \phi^-\partial_\mu\phi^0) - W^-_\mu(\phi^0\partial_\mu\phi^+ -\\
&\phi^+\partial_\mu\phi^0)] + \tfrac{1}{2}g[W^+_\mu(H\partial_\mu\phi^- - \phi^-\partial_\mu H) - W^-_\mu(H\partial_\mu\phi^+ - \phi^+\partial_\mu H)] + \tfrac{1}{2}g\tfrac{1}{c_w}(Z^0_\mu(H\partial_\mu\phi^0 -\\
&\phi^0\partial_\mu H) - ig\tfrac{s_w^2}{c_w}MZ^0_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) + igs_w MA_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) - ig\tfrac{1-2c_w^2}{2c_w}Z^0_\mu(\phi^+\partial_\mu\phi^- -\\
&\phi^-\partial_\mu\phi^+) + igs_w A_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) - \tfrac{1}{4}g^2 W^+_\mu W^-_\mu[H^2 + (\phi^0)^2 + 2\phi^+\phi^-] -\\
&\tfrac{1}{4}g^2\tfrac{1}{c_w^2}Z^0_\mu Z^0_\mu[H^2 + (\phi^0)^2 + 2(2s_w^2-1)^2\phi^+\phi^-] - \tfrac{1}{2}g^2\tfrac{s_w^2}{c_w}Z^0_\mu\phi^0(W^+_\mu\phi^- + W^-_\mu\phi^+) -\\
&\tfrac{1}{2}ig^2\tfrac{s_w^2}{c_w}Z^0_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) + \tfrac{1}{2}g^2 s_w A_\mu\phi^0(W^+_\mu\phi^- + W^-_\mu\phi^+) + \tfrac{1}{2}ig^2 s_w A_\mu H(W^+_\mu\phi^- -\\
&W^-_\mu\phi^+) - g^2\tfrac{s_w}{c_w}(2c_w^2-1)Z^0_\mu A_\mu\phi^+\phi^- - g^1 s_w^2 A_\mu A_\mu\phi^+\phi^- - \bar{e}^\lambda(\gamma\partial + m_e^\lambda)e^\lambda -\\
&\bar{\nu}^\lambda\gamma\partial\nu^\lambda - \bar{u}^\lambda_j(\gamma\partial + m_u^\lambda)u^\lambda_j - \bar{d}^\lambda_j(\gamma\partial + m_d^\lambda)d^\lambda_j + igs_w A_\mu[-(\bar{e}^\lambda\gamma^\mu e^\lambda) + \tfrac{2}{3}(\bar{u}^\lambda_j\gamma^\mu u^\lambda_j) -\\
&\tfrac{1}{3}(\bar{d}^\lambda_j\gamma^\mu d^\lambda_j)] + \tfrac{ig}{4c_w}Z^0_\mu[(\bar{\nu}^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar{e}^\lambda\gamma^\mu(4s_w^2 - 1 - \gamma^5)e^\lambda) + (\bar{u}^\lambda_j\gamma^\mu(\tfrac{4}{3}s_w^2 -\\
&1 - \gamma^5)u^\lambda_j) + (\bar{d}^\lambda_j\gamma^\mu(1 - \tfrac{8}{3}s_w^2 - \gamma^5)d^\lambda_j)] + \tfrac{ig}{2\sqrt{2}}W^+_\mu[(\bar{\nu}^\lambda\gamma^\mu(1+\gamma^5)e^\lambda) + (\bar{u}^\lambda_j\gamma^\mu(1 +\\
&\gamma^5)C_{\lambda\kappa}d^\kappa_j)] + \tfrac{ig}{2\sqrt{2}}W^-_\mu[(\bar{e}^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar{d}^\kappa_j C^\dagger_{\lambda\kappa}\gamma^\mu(1+\gamma^5)u^\lambda_j)] + \tfrac{ig}{2\sqrt{2}}\tfrac{m_e^\lambda}{M}[-\phi^+(\bar{\nu}^\lambda(1 -\\
&\gamma^5)e^\lambda) + \phi^-(\bar{e}^\lambda(1+\gamma^5)\nu^\lambda)] - \tfrac{g}{2}\tfrac{m_e^\lambda}{M}[H(\bar{e}^\lambda e^\lambda) + i\phi^0(\bar{e}^\lambda\gamma^5 e^\lambda)] + \tfrac{ig}{2M\sqrt{2}}\phi^+[-m_d^\kappa(\bar{u}^\lambda_j C_{\lambda\kappa}(1 -\\
&\gamma^5)d^\kappa_j) + m_u^\lambda(\bar{u}^\lambda_j C_{\lambda\kappa}(1+\gamma^5)d^\kappa_j] + \tfrac{ig}{2M\sqrt{2}}\phi^-[m_d^\lambda(\bar{d}^\lambda_j C^\dagger_{\lambda\kappa}(1+\gamma^5)u^\kappa_j) - m_u^\kappa(\bar{d}^\lambda_j C^\dagger_{\lambda\kappa}(1 -\\
&\gamma^5)u^\kappa_j] - \tfrac{g}{2}\tfrac{m_u^\lambda}{M}H(\bar{u}^\lambda_j u^\lambda_j) - \tfrac{g}{2}\tfrac{m_d^\lambda}{M}H(\bar{d}^\lambda_j d^\lambda_j) + \tfrac{ig}{2}\tfrac{m_u^\lambda}{M}\phi^0(\bar{u}^\lambda_j\gamma^5 u^\lambda_j) - \tfrac{ig}{2}\tfrac{m_d^\lambda}{M}\phi^0(\bar{d}^\lambda_j\gamma^5 d^\lambda_j) +\\
&\bar{X}^+(\partial^2 - M^2)X^+ + \bar{X}^-(\partial^2 - M^2)X^- + \bar{X}^0(\partial^2 - \tfrac{M^2}{c_w^2})X^0 + \bar{Y}\partial^2 Y + igc_w W^+_\mu(\partial_\mu\bar{X}^0 X^- -\\
&\partial_\mu\bar{X}^+ X^0) + igs_w W^+_\mu(\partial_\mu\bar{Y}X^- - \partial_\mu\bar{X}^+ Y) + igc_w W^-_\mu(\partial_\mu\bar{X}^- X^0 - \partial_\mu\bar{X}^0 X^+) +\\
&igs_w W^-_\mu(\partial_\mu\bar{X}^- Y - \partial_\mu\bar{Y}X^+) + igc_w Z^0_\mu(\partial_\mu\bar{X}^+ X^+ - \partial_\mu\bar{X}^- X^-) + igs_w A_\mu(\partial_\mu\bar{X}^+ X^+ -\\
&\partial_\mu\bar{X}^- X^-) - \tfrac{1}{2}gM[\bar{X}^+ X^+ H + \bar{X}^- X^- H + \tfrac{1}{c_w^2}\bar{X}^0 X^0 H] + \tfrac{1-2c_w^2}{2c_w}igM[\bar{X}^+ X^0\phi^+ -\\
&\bar{X}^- X^0\phi^-] + \tfrac{1}{2c_w}igM[\bar{X}^0 X^-\phi^+ - \bar{X}^0 X^+\phi^-] + igMs_w[\bar{X}^0 X^-\phi^+ - \bar{X}^0 X^+\phi^-] +\\
&\tfrac{1}{2}igM[\bar{X}^+ X^+\phi^0 - \bar{X}^- X^-\phi^0]
\end{aligned}
$$

<u>The working and insights of the String Theory</u>

String theory changes the standard perspective we use to see and understand the world around us. It replaces all matter and forces particles with tiny vibrating strings, that twist and turn in complicated ways, that from our view look like particles.

One of the most major problems string theory tends to describe is that of how gravity works with tiny objects like the electrons and nucleons. General relativity describes gravity as reaction of large objects in space. So, of the four forces in nature, only gravity lacks this description from the perspective of small particles.

When theorists tried to predict what might happen when gravity particles- '*gravitons*' smash together, they got infinite energy packed into a small space, as result. This result showed that we were missing some mathematics here. So, theorists in 1970s introduced strings of string theory to get rid of problematic, point-like graviton particles, as only & only strings could collide and rebound cleanly without implying physically impossible infinites.

<u>Ten-dimensional universe:</u>

According to the theory, a string of a particular length striking a particular note gains the properties of a photon, another string folded and vibrating with a different frequency plays the role of quark, and the same goes on for other particles. This framework also proved attractive for its potential to explain fundamental constants like electron's mass. So, if we get the right way to describe the folding and movement of these strings, theorists hope, we will be able to solve greatest of the problems in physics. But for this explanation, our familiar 4 dimensions (three of space, and one of time) are not sufficient. For understanding and explaining the behavior of these strings we require 6 additional dimensions which are visible only to these tiny strings. This makes it a total of 10 dimensions, which then puts up a hypothesis of a **10-dimensional universe**.

Multiple dimensions (beyond 4) can be thought this way, as to a man a power line (wire that carries electricity, connecting the poles) looks like 1-dimensional line, but for an ant who is crawling on the wire, the wire becomes a 3-dimensional cylinder. So, similarly these multiple unknown dimensions could be very small or very big which we humans cannot observe in our lives.

To solve these complexities physicists in mid 1980s came up with five different conflicting versions of string theory, and a String theory conference was held at University of Southern California, 1995, led by Edward Witten, theorist at Institute for Advanced Study in Princeton, New Jersey. The most accepted theory among these theories was the M-theory, which was the closest of them all to be the super-string theory and the theory of everything. In the conference the five theories showed up sharing much data in common and also that they were shadows of single parent theory and highlighted connections called dualities, which have proven to be a major contribution, to mathematics and physics.

In 1978, work by Werner Nahm showed that the maximum number of space-time dimensions in which one can formulate a constituent supersymmetric theory is 11. In the conference Edward suggested that al the 5 super string theories were in fact just different limiting cases of a single theory in **11 space-time dimensions**.

Super Symmetric String Theory

Standard model of physics is the theory, most used and also proved, which we use to learn and understand our physical world. This theory work descent with most of the things we see around, but fails to explain certain problems in physics.

Supersymmetry is one of the most used and accepted ideas/principles that are taken into consideration for solving these kinds of complex problems in physics.

The standard model describes 17 fundamentals particles of matter and forces that make up everything.

Supersymmetry if explained din one line is an idea where force equations and matter equations are identical.

Force equations = **Matter equations**

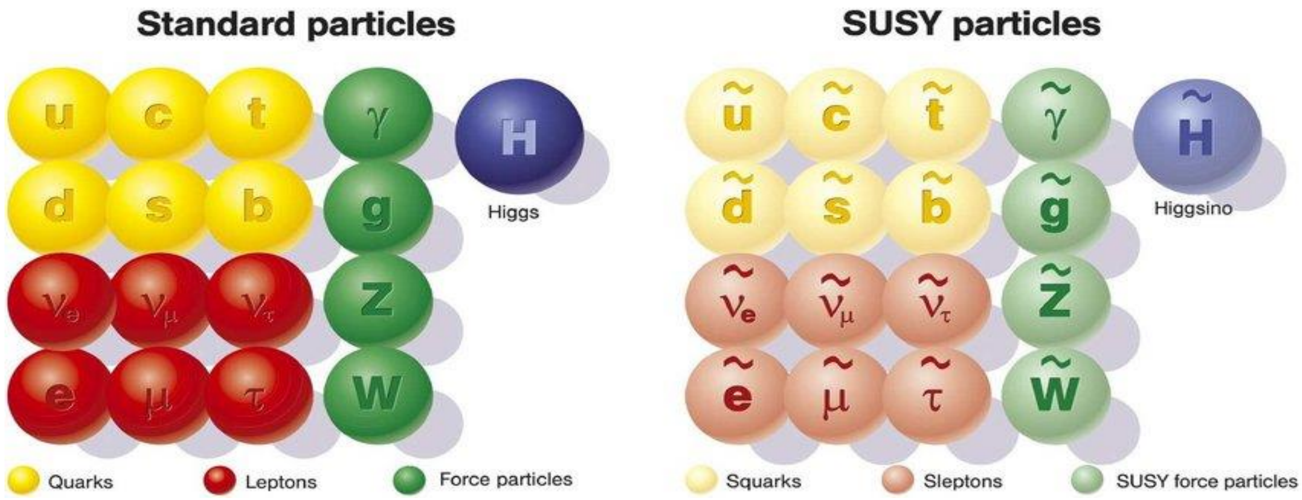
If any theory includes supersymmetry in it, it is called Supersymmetric.

Supersymmetry is an idea which treats both force and matter equally, though the mathematics in supersymmetry cannot be proved to govern the universe, still supersymmetry explains many prominent problems left untouched by the standard model, some of which are:

- Why gravity is so weak?
- Presence of Higgs boson
- Dark matter

Now our string theory includes this concept of supersymmetry and thus it is *supersymmetric theory*.

Supersymmetry predicts the existence of a cousin particle (supersymmetric particle) for each fundamental particle we have, so if now we know 17 fundamental particles to be existing, according to supersymmetry there are 17 more cousin particles of them. However, till now we have not been able to detect any of these cousin particles and that raises a question upon the correctness of this concept.



Why string theory?

- It provides a path to a mathematically consistent way to integrate gravity with other fundamental forces and elementary particles in quantum mechanics.

- It, in principle, gives a first principles way of calculating all of experimentally measured physical constants of the standard model.

- It has the capabilities to might reveal the physics that is important at extremely high energies, such as those present in the first moments after the Big-Bang.

- It provides a potential foundation for a 'theory of everything' that reduces all of the fundamentals of physics, currently addressed by the Standard model and General relativity, to the properties of fundamental strings.

- It helps physicists to evaluate and make most probable predictions for the solutions to unsolved mysteries of physics and universe.

The issues with String theory

As we got see how string theory looked beneficial for mankind, here are some flaws or issues in string theory that pull down the probability of string theory to be the right concept.

- **Multiverse** and Number of solutions: To construct models of particles physics based on string theory, physicists typically begin by specifying a shape for the extra dimensions of space-time (as predicted by string theory). Each of these different shapes corresponds to a different possible universe or *vacuum state*, with different collection of particles and forces. String theory currently predicts an enormous number of vacuum states, which is estimated to be around $\mathbf{10^{500}}$ and

these might be sufficiently diverse to accommodate almost any phenomenon that might be observed at low energies.
So the possibility of presence of these many universes, raises a concern regarding the string theory.

- The supersymmetry: String theory is supersymmetric as it predicts the correctness of supersymmetry, but as predicted by supersymmetry we have not been able to find a single cousin particle out of the 17 cousin particles of the 17 fundamental particles.

- Multiple dimensions: String theory fails to fit-in four essential forces of physics together in four dimensions, rather it requires multiple models of string theory having 10 dimensions each to fit together the four models of physics. To put and make these different versions of string theory work together, we require 11th dimension and understanding these many dimensions and visualizing them is just beyond the scope of any technology we have at present.

- No experimental data: it is sometimes said that string theory has strayed too far from experiments and observations. In the present times, from decades to now, physicists have not been able to conduct experiments on string theory which could provide any real data about its existence.

- The complexity: String theory has a hugely complicated and poorly understood high-energy scale behavior, it is seemingly capable of producing a very wide range of possible observable effects, none of which have been seen. It has so many versions of itself that using one version for everything is not possible without creating a total mess.

<u>The conclusion of string theory</u>

A computation shows string theory is **98.5%** likely to be correct, going on to claim that the actual probability is higher over **99.7%**! So, despite being such complex and messy, this theory with numerous flaws and misleading facts, still cannot be discarded and called a wrong or failed theory.

Here is why we can still hope string theory to be right and be a promising contender for the place of *the theory of everything*.

We saw there were many issues with the theory, which definitely cannot be neglected but this is a fact that many of these flaws themselves are not still proven to be right.

The only reason that could that could explain the absence of ant technical or experimental data for string theory, might be our limiting technology, we saw how complex and deep this theory is and so for carrying out experiments, we require extremely powerful and giant machines, which we are not having any access to, currently. Because our present technology is totally based on our standard model and general relativity, so these machines can hardly be used to perform experiments for a theory which is much ahead of these theories themselves.

The present technology is not capable of visualizing the extra dimensions and that too 11 of them. Also, it is also a limitation over not being able to detect the supersymmetric particles, as they require much powerful tech, which we currently lack. So, this is the reason we cannot erase the fundamentals of string theory.

We don’t have any knowledge or idea or even the technology that could describe the concept of multiverse as suggested by the string theory. But it also really opens doors to fictional worlds, we can imagine how parallel universe would look like and how interesting that would be. Apart from this imagination we don’t have any solid proof that can be used to explain the existence of multiple universes. But still, if cannot detect or we don’t have the tools to detect these multiple universes, we cannot neglect string theory on this basis.

We also saw how advantageous the strings can be, be it the field of physics or mathematics strings have helped in solving various problems, also they help us understand the randomness and weirdness of our universe. Plus, String theory has got no flaw in it, that is technically proven.

Still, unless we have the access to the powerful technologies that could help us perform experiments regarding the theory, we cannot conclude it be correct but yes, even in the future if the theory is proved to be wrong, many of its parts would still help in coming up with the solutions to major physics problems. But unless we don’t have the evidences that demonstrate string theory to be wrong, people will continue to pursue researches on it, because ultimately it is a very interesting topic that also expands our thinking and make us think about infinite possibilities our universe has.

So, finally we can say that the String theory still stands as one of the most powerful and attractive contenders for our quest of finding the ultimate theory, a theory for everything.

References:

- www.space.com
- www.realclearscience.com
- en.m.wikipedia.org
- astronomy.com
- www.forbes.com
- physics.stackexchange.com
- www.britannica.com
- https://youtube.com/c/fermilab
- https://youtube.com/c/WorldScienceFestival
- https://youtu.be/YtdE662eY_M
- https://youtube.com/c/pbsspacetime