Fascinating Super String Theory

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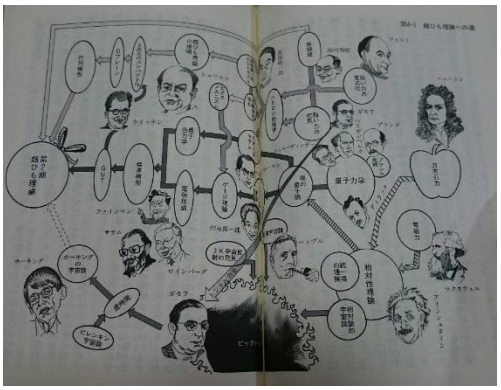
● Introduction

“Super String Theory”. What do you imagine when you hear “super string theory”? If you hear the word for the first time, you wouldn’t know about it at all. You may think “What is super?” “Does it mean great?” “Does the string mean string which use for packing?” “And then, what is it at all?” I first learned about super string theory when I watched a TV program on it. I was originally interested in elementary particles in physics and mechanism of the universe. I was attracted to some keywords in the TV program.
They were these words, ---“Einstein” “general theory of relativity” “Newton” “gravitation” “the theory which we can explain about everything in the universe” “the beginning and the end of the universe”. What do you think about it? Are you interested too?
Let’s get started on “Super String Theory”!



History chart of super string theory (*1)

1 SUPER STRING THEORY

● WHAT IS SUPER STRING THEORY

Super string theory is the theory which can explain all systems of the earth and universe. It is expected to become the goal for all physics so the theory is called “the ultimate theory”. It is also the long-cherished dream for physicists to complete super string theory. There are four forces in nature.

① Gravitational force
the weakest of the four fundamental force of nature. described by Newton’s universal theory of gravity, and subsequentry by Einstein’s general relativey.

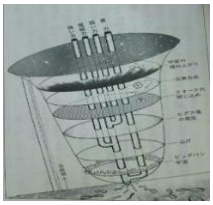
② Electromagnetic force
a union of the electric and magnetic forces

③ Weak force
best known for mediating radioactive decay

④ Strong force
the strongest of the four fundamental forces, responsible for keeping quarks locked inside protons and neutrons and for keeping protons and neutrons crammed inside of atomic nuclei

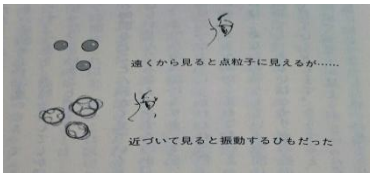
The unification of these four forces is closely connected to cosmology, because it is thought that just after the Big Bang the four forces were one. Then the forces branched with the expansion of the universe and the present four forces were born.
Regarding these four forces, electromagnetism and weak force has been already unified as “electroweak interaction”. “Grand unified theory” which is where electromagnetic, weak and strong forces are merged into one single force is not inspected experimentally but exists as a theory. That’s why we can understand and fully describe three of the four forces. Gravitational force still remains. Finally when we can fully understand the four forces including gravitational force, that’s the “theory of everything”. The best hope of “theory of everything” is “super string theory”.

Unification of four forces (*2)



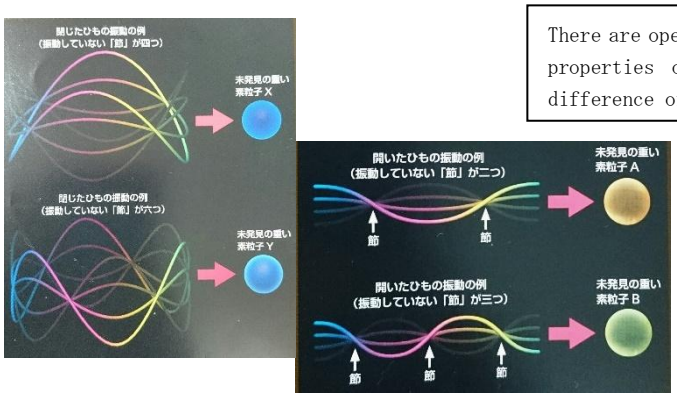
Let’s think about gravitational force which is a big problem for the completing super string theory. Gravitational force was discovered, at the very first, but it became a hindrance in the field of super string theory. Newton discovered gravity for the first time in history. Heestablished “the theory of universal gravitation”. Then Einstein developed the “general theory of relativity”. Nobody knew of weak force and strong force at this time, so he didn’t succed although he tried to to unify gravitational force and electromagnetic force for more than thirty years. By the way, “super” in super string theory means “super symmetry”. Super string theory is supersymmetric string theory.

Elementary particle is a string (*3)



● ABOUT STRING THEORY

If you divide everything which forms the nature into small pieces again and again and again, you would finally discover an extremely small string. This is “string theory”. It says our body, our desk and blackboard in the classroom, heavenly bodies in the universe like the sun, everything is made of numbers strings.
The smallest particle which composes a matter in nature is called an elementary particle. It is thought that there are many unknown elementary particles.
According to string theory, if you enlarge an elementary particle, you could find a small string. Moreover, if you enlarge any particle, you could find the same string. The different properties of elemenrtary particles are created by differences in the vibration of their strings. What size do you think is a string? It is the smallest in nature. The thickness is zero but it has a length. We don’t know about it for certain. It is the minus thirty four power of ten meter. That is it is about one ten billionth of 1 millimeter of one ten billionth of 1 millimeter of one ten billionth of 1 millimeter. The size is far beyond imagination. There are two kinds of strings. One is an open string like a hair, the other is a closed string like a rubber band. Both ends of an open string can stick together and become a closed string. A closed string can be cut and become an open string. Two kinds of strings, they are basically the same. These strings keep acting and never stop. In the case of the open string, it has a motion like spinning at high speed. In the case of closed string, it is vibrating while swelling and shrinking. The exercise speed can become velocity of light.



There are open strings and closed strings. The different properties of elemenrtary particles are created by difference of vibration of strings. (*4)

● ABOUT SUPERSYMMETRY

Modern physics needs symmetry. Symmetry means that even if you did some kind of operation, the laws of motion never change. The four forces are different. So each force is asymmetric. The unification of all four forces needs higher symmetry in nature. Super string theory needs supersymmetry as higher symmetry. Symmetry doesn’t exist in observable nature. Just after the Big Bang, the time four forces were one, it is thought that there was symmetry. At that time there was extremely high energy in the universe. You could see symmetry under those conditions with full of high energy. High energy changes into particles with mass. At this point a pair of particles (particle and antiparticle) is born. These two particles are with equal mass and opposite electric charges. It is thought that in the days of Big Bang, the same number of particles and antiparticles were born. It is thought if a particle crashes with its antiparticle, both of them are destroyed. So the same number of particles and antiparticles should have been destroyed. However in the early days of Big Bang, only particles were stayed a little a lot by somehow mechanism and formed today’s universe. If symmetry existed in our daily lives, you could see another you who looks like exactly you in front of yourself. We can’t see such phenomenon now, that’s why we have to say that we can’t confirm symmetry in usual space.

2 EXTRA DIMENSIONS

● ABOUT BRANEWORLD THEORY

Braneworld is a hypothesis and it is derived from super string theory. It says there is a brane through whole space. It means the brane floats in the high-dimensional space (including three-dimensional space, space-time and hidden dimensions). In that case, human bodies and matters like cars and houses and even light, they can move like sliding over the brane but can’t leave the brane.
Elementary particles which form all matter are made of open strings. Both ends of string
stick to the brane (three-dimensional brane) and never fly to the high-dimensional space. We also can’t leave the brane. Light can’t leave the brane either and we see the world through the light. This is one of the reasons we can’t notice the high-dimensional space. On the other hand, a graviton is made of a closed string. A graviton Is an elementary particle that mediates the force of gravitation. Closed string doesn’t have its end to stick to the brane and can fly to the high-dimensional space. Only gravitation can leave and move freely in the high-dimensional space. If there is another universe except for our universe in the high-dimensional space, it would be possible to catch the gravitation of heavenly bodies existing in another universe.

Image of braneworld (*5)

● ABOUT HIGH-DIMENSIONAL SPACE

Super string theory is a theory without contradiction in ten-dimensional space and time. If super string theory is

correct, it would be the case that our world is in ten-dimensional space, according to theoretical calculations.
What is ten-dimensional space? It is difficult to picture, it should have six-dimensions except for length, width, height and time. Actually these six-dimensions are curled up and out of sight. It exists as hidden dimensions. The size of the hidden six-dimensions is one ten billionth of 1 millimeter of one ten billionth of 1 millimeter, the same size as a string in string theory. According to super string theory, such hidden dimensions exist in the same places any places high-dimensional space.
The shape of extra dimensions is represented by calabi-yau manifold. Manifold is a mathematics term and it has the meaning of space.

● ABOUT BLACK RING

In the four-dimensional space, the shape of black hole is sphere. Dr. Hawking proved it mathematically by using the Einstein equation. However in high-dimensional space this equation is not correct. In 2002 Emparan and Reall discovered a black ring in five-dimensional space. The black ring is a ring-shaped black hole like a donut. Black ring turns anticlockwise. All black rings turn all the time. The shape of a black hole without turning is that of an absolute sphere, if they are in four-dimensional or high-dimensional space.

3 THE FUTURE OF SUPER STRING THEORY

● PROBLEM OF SUPER STRING THEORY

Super string theory has no way to form testable predictions, to prove or disprove itself through experiments and observations. This is a big problem. A string in the super string theory is extremely small, so it is very difficult to build a hypothesis and substantiate.
According to super string theory, there may be cosmic strings floating in the universe. Cosmic strings were made in the early universe became as extremely long strings. Just right after the Big Bang, the universe was extremely high temperature and density and there was a huge outbreak of strings of extremely high energy. Physicists think those strings got stuck to each other and became cosmic strings. They say the length may be more than ten billion light-years. We can't observe it with a telescope. But they think we can confirm the existence of cosmic string indirectly with a gravitational wave detector, because if a cosmic string moves, it would shake the space around it and be observable as a gravitational wave.
It is difficult to test super string theory through experiments. But it is extremely fascinating to attempt testing by astronomical observation.

● IF SUPER STRING THEORY IS PROVED

If super string theory is proved, we could unify two major theories (general theory of relativity and quantum theory). If super string theory is completed, it can explain all the happenings of nature. It can also explain every piece of matter and every mechanism at work in the universe. Then we will understand about the origin and the end of the universe. It solve the problems like "Is our universe the only one?" "Does space just exist without a beginning at all?".How do we understand the beginning of the universe if super string theory is proved? At the moment of the Big Bang, there was huge mass, but originally it was an extremely small size. The general theory of relativity handles large mass and the quantum theory handles small size. That's why a theory combining these two is necessary.

(*1,2,3)　はじめての＜超ひも理論＞　川合光　講談社現代新書より
(*4,5)　ニュートン別冊　現代物理学３大理論　ニュートンプレスより
(*6)　宇宙の謎に挑む　ブレーンワールド　白水徹也　化学同人より

4 EXTRACTS FROM INTERVIEWS WITH PFYSICISTS AT CAMBRIDGE UNIVERSITY

● Dr. Mahdi Godazgar

① I've heard you have been researching on the black hole based on the superstring theory. Is it true?

Yes, I've worked on is gravitational theory, it is a classical gravity which means the basically theory of Einstein's without any matters of gravity. But in higher dimensions and also gravitational theory called super gravity and the super gravity theory basically like Einstein's theory of gravity but also they have matter, they have special matter which are properties called super symmetry. The whole theory has a special symmetry and so both these theories, both gravity in high dimensions and super gravity were motivated super string theory.
So the super in superstring theory, means "supersymmetric" which assist super gravity.
And what this is is that it's basically an equation which says something about how curve space and time off. So in Einstein's theory space and time come together you have four dimensions, one time and 3 spaces, and the way the space is curved it depends on the multi content you have. But even if you don't have any matter, it doesn't mean that you just have a flat space. So black holls are important.

② What is the difference between the black hole based on the superstring theory and a regular black hole?

The black hole based on the superstring theory. Basically any gravitational theory will have black hole solutions. In my black hole solutions, basically solutions of the theory which contain a region of space time in which common communicate with an outside.
So I'm just thinking about if you have an object it's very dance and very massive then it's going to be hot to get out of this object's influence of orbit. So just like for example we live on earth, it's very hard to be out of orbit, because you know if we jump, we fall back down. Nothing can escape. That's the black hole. Essentially all black holes have characteristic problems.

③ What have you recently found out about the superstring theory?

At the moment most people work on a basically relations between one part of the theory and another. String theory has of all symmetries which people called dualities. In superstring theory there must be a special kind of symmetry called supersymmetry. Supersymmetric partners have not been observed in experiments. A lot of people believe this is because supersymmetric partners are too massive to be detected.
All of the main issues with the string theories are to try to understand how we control string theory experiments. This is obviously very hard.
The hope is someway you can inform a certain aspects of the theory to relate to cosmology all particle physic's experiments.
And so far this hasn't.

What sorts of problems are there now?

As I said, the main problem is trying to understand how string theory can relate or can be related to the world. So string theory will be depending on how it exists in either 10 or 11 dimensions. And in order to relate 11 dimensional or 10 dimensional theory, we have to sort of imagine extra dimensions somehow they compactified on a very small scale. The point is how you know the mechanism to compact dimensions.

④ The braneworld is known to be the cause of the birth of space. Do you think this is true?

The braneworld theory is another way of think of sort of invading our world in this high dimentional world. The original way, you could get four dimensional world from this high dimensional theory and this is by compactification. But another alternative way, it's the sort of think about our universe, our four dimensional universe somehow living on the slice of this high dimensional world and to slice in which all physical

interaction somehow constraint beyond this blaneworld except for gravity.
Gravity can always reach out. In fact this is a motivation for studying high dimensional gravity. This is one of the main motivations. It's because if it is true we live on the sort of slice of the high dimensional world, then we should be able to defer this from a certain gravitation. In resent particle physics experiments, they haven't enabled to find evidence that seemed to suggest to solve blaneworld slices.

⑤ Is every string the same length and width?

Yes and important difference between strings is closed strings and open strings. Strings can have various kinds of boundary conditions. For example closed strings have periodic boundary conditions. Open strings can have 2 different kinds of boundary conditions called Neumann and Dirichlet boundary conditions. With Neumann boundary conditions the endpoint is free to move. With Dirichlet boundary conditions the endpoint is fixed to move only on some manifold. It is called D-brane.

⑥ Can you cut or attach the string?

You can cut the closed string to make open string. The end of single open string can come together to make closed string.

⑦ What are you researching now?

At the moment, I'm looking at black holes. I'm trying to understand the symmetries the one has various limits so I've recently work on trying to understand what sort of symmetry if you go very close to a black hole. So I deal with the understanding the Symmetries you can basically describe how black holes perform and what would happened traditionally one thinks of black holes, its mass, its rotation. There's the way you distinguish one black hole from another. Recently people have been investigating the differences you can sort of see and sort of imprinted on the surface of black holes.

● Professor Harvey Reall

① Does the black hole exist? (one theoretically and one observational)

In nature? Yes. Yes. I think we have very good evidence that like all the system in nature. Evidence from very plight of jet in the sky meeting X-rays ways the black hole discovery the first. This is believed when we have black hole and a normal star near it and black hole is putting metal off the star which from the this grand of black hole who did appreciate with gradually get some very hot as the matter so black hole eventual falls in … and get so hot the limits X-rays … X-rays in detective so it's good evidence insistent black holes coming from this kind of observation. Recently people have studied stars near the center of galaxy and people have been able to follow the movement of individual stars around the center of galaxy and from the shapes the obvious of the stars. We know there are very massive objects and with the math about 4million times math and the object to confined to very small regent … regent smaller than solar system. And everything we can think of called very large math small regent of black halls recently characteristic properties black hall they can be very massive and very small combination. And so there is a very good evidence so there is a black hole at the center of the galaxy. There is also evidence for black holes at the center of other galaxies. Very recently, just last year we found a new way of detective black holes using gravitational waves. So you probably heard about this exciting discovery which detected gravitational waves in gravitational field predicted by Einstein's theory of general relativity.

② Why is the 5th dimensional black hole that you've discovered in the shape of a ring?

We saw equations of general relativity I've been found on your solution with its property. It's unusual because before that all black holes that people had found were circle and they were failure miss signed at four dimensions of space time. The black hole has to be so. So people thought the same was probably true in higher dimensions. Then we made this discovery actually that's not true, that's high dimension's black hole don't have to be so because surprise by that.

③ Does the black ring have any connections with the superstring theory?

Yes, in some ways. So superstring theory predicts that there are extra dimensions and in our universe we know that there are four large dimensions, three spaces and one time. So the extra dimensions would have to be small. But we can also imagine of study other universes in string theory when you have four dimensions of spaces and one of time in charge. People often think about these other universes just test consistence of the theory. So was it the theory can explain for example properties of black holes and so one thing people interested entropy of black hole. This is a photonomic idea like a gas as entropy. But we know for gas the entropy comes from the indivisual walcules. We know the black holes also have entropy. So they should be something. Microscope of description of black hole which explains. Black rings and another type of black holes try to calculate using superstring theory. If you have a theory of quantum gravity, you can test it by trying to calculate the entropy of black holes. And so black rings or another type of black hole, and so we can test string theory by trying to calculate the entropy of black ring using string theory.

● Professor Nick Dorey

① What have you recently found out about the superstring theory?
What sorts of problems are there now?

String theory is an attempt to insist theory which just ally forces, particles and attraction and nature. Unification is the idea that different aspects explain by single theory. Hope is that one can find completely unify description all of forces of particles, particular the thing it has been very difficult for the theorists absence like Einstein describe the gravity. Gravity is the force but it's not just the force, curving space of time. His theory works beautiful picture of what gravity is. So big goal is interfiling to unify the theory describing gravity together with other forces. Problem is it's very hard to try to reconcile gravity the other forces. Trying combining mechanic of gravity, it's very hard to write down. String theory is really far successful attempt.

② According to the superstring theory, when the big bang happened it made a string which gradually grew bigger and is now floating in a space.

That's a very spectacular idea. Wide strings could be discovered. We believe that the universe just after the big bang expanded very very rapidly to very very large scale. Strings were around the universe. It's possible some strings are stretched out to very large size. People are about to try looking for such things with no success so far but who knows. I think it's by no means clear that such thing should be there. Generally one of the problems of string theory is to test experimentally. It's very difficult. The reason is because if you are going to attempt to unify gravity with the other forces, then effects witch distinguish very very high energy in small scales much smaller than we can really hard to observe in experiments possibly indirect ways by cosmolozy. To explain more about I work on I have to say I trace string theory. String theory came about to attempt to concentrate gravity. But actually also has a lot tellers about more conventional aspects of physics. So initially string theory was divided the way beyond quantum field theory. You can actually learn a lot about quantum field theory by studying string theory. In particular string theory teaches us new ways to think about quantum field theory.

③ Tell me about the super symmetry theory in the superstring theory.

Super symmetry turns out superstring theory to be a useful theory that makes sense. Super symmetry relates Bosons particles and Fermions particles. String theory

definitely needs super symmetry. However in the real world we don't see super symmetry. In very low energy symmetry is no visible because it's been broken somewhy. When you go to very high energy symmetry is restored over and over again in nature. It reminds possible the super symmetry is a real symmetry in nature if you go to very small distances in very high energy. When you go to low energy in large distance scales, symmetry is broken. Theorists work with allow for this kind of phenomenon.

④ I've heard open strings can't go away from D-brain.

That's right. In string theory open strings naturally end on the surface called brains. So people are trying to make a model in a real world involving string theory. The model where we live in universe which is ten dimensional, string theory requires extra dimension. But we live on a surface called a brain in that high dimensional space. It's an idea that may turn out to be useful and that's way that's futuristic string theory that contains these special surface called D-brain. We learn a lot about string theories by studying different figurations of these brains.

⑤ If the superstring theory is proved to be true, I've heard that it will mean the some theory can prove the beginning and end of space.

That's very expectancy. One of the reasons we want to how the theory recruit gravity like string theory. If so we can understand what happened after Big Bang. Because in Einstein theory gravity works very well when you have large universe which has curved space and time gentle. You have gentle gravitational forces. When the gravitational forces become very strong, Einstein's theory has to break down, has to be described by something else. Only candidate the moment for such theory is string theory. In principal string theory could be applied to understand what happened in the very very beginning of time, and also what might happen in the far future. But it is very speculative and people are not really able to do honest conflations to understand that.

⑥ Are you researching super string theory?

I'm researching quantum field theory. Quantum field theory is the theory that describes the interactions of all particles. So it's something that we know describes very well the standard model particle of physics. But still many things we don't understand about quantum field theory. So particular I mention this phenomina of confine of quarks we know it must happen in the real world but no one is able to prove it. My work is mainly trying to study those aspects of quantum field theory. Technically, in quantum field theory you usually have a number called coupling constant. It describes how strong force is between particles. When the force is small then you can calculate instructions by drawing pictures. Each picture caused bond to mathematical expression which comes multiply of number of coupling constant. My work is really trying understand those kinds of aspects of quantum field theory that's we don't understand but trying different type of methods. One of the most useful ideas has been actually to understand quantum field theory interns string theory.