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Is the Holy Grail in sight?

So what is Stephen Hawking doing in Mumbai anyway?'
We know that he is here to attend a high level, international Physics conference going on at TIFR (Tata Institute of Fundamental Research), which is in Colaba, Mumbai. Some of us even know that Stephen Hawking is the great guru of theoretical Physics and the author of the bestseller, "A Brief History of Time", and there is talk about the work he has done in STRING THEORY. But what is this all about?

The string theory is where physicists have reached in the quest for the grand unification of "the basis of physical reality", a journey that has often sallied into metaphysics and aesthetics. But have they got there yet, or how near are they?

The beginning

The journey really started with Isaac Newton, when he first 'unified' the findings of Copernicus and Galelio, in their studies of the motion of the planets and laid down the famous 'Newton's Laws of Motion'. The 'laws' have since been tested and applied in countless ways and whole fields of modern living, in fact depend on the exact application of the knowledge of these laws, from the motor car to airplanes, dams and power stations, machines of every kind, including the engines of war.

The other great discovery of Newton was the law of gravitation, which, along with the laws of motion, raised the status of human knowledge to almost divine stature, in that man now understood the very guiding principles of the movement of heavenly bodies!

Close on Newton’s heels came further discoveries of other physical phenomena, the gas laws, the kinetic theory, and finally the laws of electromagnetism; and so closely did the laws enmesh and agree with each other, that it did appear that all knowledge had been gained! The ‘grand unification’ was at hand!

At least till the discovery of new and yet unexplained things – radioactivity, the structure of the atom, atomic spectra, and as if this were not enough, the Theory of Relativity.

The Theory of Relativity turned on its head the very ideas of time and space, and particularly implied that Newtonian mechanics was but an approximation of the reality of nature. Anomalies in how the ‘classical field theory’ explained the way warm objects radiated heat necessitated a new way of thinking about how energy was transferred, not continuously, but in 'bursts' or 'quanta'. The nucleus of atoms were found to have a structure and matter was found to consist of many types of fundamental particles, components of the atoms themselves.

The 20 the century was then again unprecedented in its fecundity of intellectual discovery. With the development of quantum mechanics, which was the new way of looking a matter in very small dimensions, when ‘quantum effects’ become important, came the great new discoveries of transistors and lasers and nuclear power (and bombs). When quantum mechanics, electromagnetic theory and the Special Theory of Relativity were combined, a powerful computational method called quantum electrodynamics was discovered, which led again to startling insight into the very internals of matter, with the prediction and discovery in experiment, of a whole Noah’s arc of fundamental particles.

Again, it began to look like Physics was on the point of ‘all knowledge’, but for disturbing discoveries, this time on the cosmic scale!

Einstein’s Theory of Relativity is in fact two theories, the Special Theory and the General Theory. The special Theory deals primarily with the ‘relative’ nature of space and time, and let to the celebrated “E=mc2”, the equation at the heart of atomic power! Einstein then extended the theory to include mass and gravity and developed the General Theory of Relativity. This theory views mass and gravity as curvature in a ‘4 dimensional space’ and explains the observed acceleration of a particle when it is near a mass as nothing but ordinary motion along space which has been curved due to the presence of the mass!

These results of the General Theory, in fact, have been verified by observing that stars hidden behind the solar disc actually become visible during a solar eclipse, because the light from the stars travel along a curved space when they pass the sun!

The General Theory of Relativity, when applied to cosmology and the evolution of stars leads to startling results, like the ‘expanding universe’ and ‘Black Holes’, or stars so dense that even their radiant light is unable to escape their gravity!

In this realm of Physics, again, like in the beginning of the last century, the existing view of reality begins to break down, with some results of the theories resulting in ‘singularities’, which are ultimately, ‘absurdities’. One way of looking at the difficulties is that quantum electrodynamics works and appears to be all right so long as we can consider gravitational effects to be negligible. And then, the General Theory of Relativity, for all its spectacular predictions about the universe, does not recognize the existence of quantum effects!

String Theory is an attempt at bridging the gap.

String Theory

Physics, for all its ‘quanta’ and ‘quarks’ and ‘strange particles’ and other mumbo-jumbo, in fact is averse to theories that smack of ‘magic’ or ‘wizardry’. To that extent, physicists have never been really comfortable with the fact that an electric charge, or a magnetic pole, can have an effect at a distance, without any medium seeming to connect the two points!

It was to get around this problem of ‘action at a distance’ that it was necessary to introduce the idea of a ‘field’, although this was nothing but saying the same ‘magic’ thing in another way. The development of quantum field theory in the last century, particularly the work of Richard Feynman, came up with the concept that forces were due to the ‘exchange’ of a particle that ‘carried the force’. This was philosophically satisfactory, except, if only the ‘carrier’ particles were detected…! One of the properties of such particles would be that they have ‘even numbers of units of spin’, which is a quality that enables more than one particle to occupy the same point. The ‘carrier’ for the electromagnetic force is the photon, which behaves well enough, but for the gravitational field, it becomes necessary to introduce the ‘graviton’ and to derive its properties, at least in principle.

The properties of the graviton, even in principle then lead to irreducible difficulties. A consistent quantum theory for gravity would require a graviton to have zero mass and two units of ‘spin’. It is also necessary that particle interactions, even gravitational, should take place at a single point in the ‘4 dimensional space’. Now if when a ‘graviton’ is introduced into quantum field theory, the mathematics at the ‘single point', which is, at ‘zero distance’ begins to yield absurd results!

Enter String Theory: string theory gets around this difficulty by proposing that the interaction occurs not at zero distance but at a very small distance.

String Theory uses an idea of 'excited states' of a 'string'. If a violin string is plucked, it vibrates in a series of harmonic frequencies. In String Theory, particles are treated as the ‘excitations' in ' elementary strings' of dimensions of the order of ‘quantum gravity’ or the ‘Plank length’, which is $\sim 10^{-33}$ cms, (or 1/10 with 33 zeroes). With this postulate, it becomes possible to develop string theories that permit the existence of gravitons in quantum theory, but without generating the problems at the 'zero distance'.

The difficulty with the theory is that no experimental methods are known by which we could detect particles at such dimensions. A part of string theory research is thus about devising theoretical stratagems to validate the theory even without experimental test!

String theories, in fact exist in different flavours, of whether the strings are closed or open and also whether or not they include particles with an ‘odd number of units of spin’. The particles with an ‘even’ number’, like the graviton, are called Bosons (named after Satyen Bose) and these are the particles that transmit forces. The particles with ‘odd number’ of units of spin are ‘Fermions’ (named after the Italian, Enrico Fermi) are the particles that matter consists of.

When Fermions are included in String Theories, it becomes necessary to introduce a ‘supersymmetry’ which means that for every ‘Boson’ there has to be a corresponding ‘Fermion’.

Quantum Physics had predicted that for every particle there had to be an ‘antiparticle’ with the same properties, except the charge.

The discovery of the ‘positron’, the antiparticle of the electron was a major discovery that validated the quantum theory.

In similar fashion, if the supersymmetric partners of existing particles were discovered, it would validate string theory as well. Supersymmetric partners of existing particles are still too massive to detected in present day accelerators. But accelerators available in a decade may be able to answer many questions about String Theory and its consequences!

It does appear that the quest for the Holy Grail must go on!