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String Theory in Cosmology – A Brief Review

K Sreelatha[1], T P Vinu[2]

[1, 2] Department of Physics, NSS Hindu College Changanacherry, Kerala, India

Abstract: ***String theory requires super symmetry which works in eleven dimensions. The simulation of black hole made by Stephen Hawking and Jacob Bekenstien in 1970s was proved by Stromineer and Vafa in 1996, using this theory. Super symmetry also proposes the reasons of red shift and dark matter. The T-duality in super string theory proposes pre big bag form of Universe. Inflation, accelerating universe and event horizon are some active areas of research in this field.***

Keywords: String theory, cosmology, T duality, Big Bang, Super symmetry

1. Introduction

The strings of string theory are unimaginably small. Average string, is about 10^{-33}centimetres long. That's a millionth of a billionth of a billionth of a billionth of a centimeter. If an atom were magnified to the size of the solar system, a string would be the size of a tree.

2. String Theory

String theory is a theoretical proposition in which the point like particles and packets of "elementary particle physics" are substituted with one dimensional object known as strings. String theory describes the ways in which the string moves and interacts with each other in space. On distance scales larger than string scale, a string looks just like an ordinary particle. It possesses properties like mass, charge and other properties. These properties are determined by the vibrational state of the string. In string theory one of the vibrational states of string corresponds to „graviton", a hypothetical elementary particle that mediates the force of gravitation in the framework of quantum field theory. Thus string theory is the theory of quantum gravity.

3. String Theory and Cosmology

3.1 Limiting the dimensions of the universe

Einstein postulated theory of gravity about 100 years ago and this is the only theory that does not go well with laws of quantum mechanics. Einstein's theory of relativity opened up the universe to a multitude of dimensions, because there was no limit on how it functioned. Relativity worked just as well in four dimensions as in forty. But string theory only works in ten or eleven dimensions. The extra dimensions could conceivably be too large for us to measure; our four dimensions could be curled up exceedingly small inside of these larger dimensions.

3.2 Search for Evidence

In 1996, physicists Andrew Strominger, of the Institute for Theoretical Physics in Santa Barbara, and Cumrun Vafa at Harvard, simulated a black hole with an excessive amount of disorder, or entropy. Such a black hole had been earlier, simulated two decades ago by physicists Jacob Bekenstein and Stephen Hawking. At that time, no one could figure out why a black hole might harbour so much entropy.

The theoretical black hole created by Strominger and Vafa was not created like conventional black holes seen at the centre of galaxies such as the Milky Way. Instead, they relied on string theory to simulate it, providing a link between the complex theory and the fundamental force of gravity that drives black holes.

By basing its foundation on string theory instead of conventional particles, they lent more credibility to the potentially unifying theory. Whether string theory is the "ultimate" theory or the theory of everything, is still not clear. But it is a strong contender for explaining the inner workings of the universe

3.3 Low Energy String Cosmology

A big complicating factor in understanding string cosmology is understanding string theories. Most of the mass in our Universe appears to occur in the form of dark matter. One leading candidate for the composition of this dark matter is something called a WIMP, a Weakly Interacting Massive Particle. One strong candidate for the WIMP comes from super symmetry

The Minimal Supersymmetric Standard Model (MSSM) predicts the existence of spin 1/2 fermions called neutralinos that are the fermionic super-partners of the neutral gauge bosons and Higgs scalars. Neutralinos would have a high mass but interact very weakly with other particles. They could make up a significant portion of the mass density of the Universe without emitting light, so that makes them good candidates for the mysterious source of dark matter in the Universe

Today the vacuum energy we measure is 120 orders of magnitude smaller than the one the quantum theory predicts and this is the biggest embarrassment of modern theoretical physics. For this reason, the "dark energy" measurement is the most radical input from cosmology for theorists to interpret and explain. A related puzzle is the black-hole information puzzle: quantum mechanics and gravity clash, as they make opposite claims concerning the fate of information in black holes. This clash is subtler today than it was 20 years ago, but it still remains

String theories require super-symmetry, so in principle, if neutralinos were discovered to make up cosmic dark matter, that would be good. But if supersymmetry were unbroken, fermions and bosons would be exactly matched in the Universe, and that's not the way things are.

The really hard part of any supersymmetric theory is to break the supersymmetry without losing all the advantages of having had the supersymmetry to begin with.

One of the reasons particle and string physicists have liked supersymmetric theories is that they predict zero total vacuum energy, because the fermions and boson vacuum energies cancel each other out. When supersymmetry is broken, the fermions and bosons don't exactly match any more, the cancellation doesn't occur any more. There seems to be pretty good evidence from the red shifts of distant supernovae that the expansion of our Universe is accelerating due to something like a vacuum energy or a cosmological constant.

So whatever path by which supersymmetry is broken in string theory needs to lead at the end to the right amount of vacuum energy to account for this observed acceleration. This is a theoretical challenge, because supersymmetry breaking seems to give too large a contribution.

The T duality symmetry has led to an interesting proposal for pre-Big Bang cosmology where the stringy Universe starts out flat, cold and very large instead of curved, hot and very small. This early Universe is unstable and starts to collapse and contract until it reaches the self dual point, where it heats up and starts to expand to give the expanding Universe we observe today. One advantage to this model is that it incorporates the very stringy behaviour of T duality and the self dual point, so it is a very inherently stringy cosmology.

3.4 Inflation Vs the giant brane collision

A current model to inflation is the giant brain collision model, also known as the Ekpyrotic Universe, or the Big Splat. This intriguing model starts out with a cold, static five-dimensional space-time that is close to being perfectly supersymmetric. The four space dimensions are bounded by two three-dimensional walls or three branes, and one of those three-dimensional walls makes up the space that we live on. The other brane is hidden from our perception.

According to this theory, there is a third three brane loose between the two bounding branes of the four dimensional bulk, and when this brane hits the brane we live on, the energy from the collision heats up our brane and the Big Bang occurs in our visible Universe.

3.5 The problem with acceleration

There is a problem with an accelerating Universe that is fundamentally challenging to string theory, and even to traditional particle theory. In eternal inflation models and most quintessence models, the expansion of the Universe accelerates indefinitely. This indefinite acceleration leads to situation where a hypothetical observer travelling forever through the Universe will be eternally blocked from seeing any evidence of most of the Universe. The boundary of the region beyond which an observer can never see is called that observer's event horizon.

But a cosmological event horizon is a major technical problem in high energy physics, because of the definition of relativistic quantum theory in terms of the collection of scattering amplitudes called the S Matrix. One of the fundamental assumptions of quantum relativistic theories of particles and strings is that when incoming and outgoing states are infinitely separated in time, they behave as free non-interacting states.

But the presence of an event horizon implies a finite Hawking temperature and the conditions for defining the S Matrix cannot be fulfilled. This lack of an S Matrix is a formal mathematical problem not only in string theory but also in particle theories.

One recent attempt to address this problem invokes quantum geometry and a varying speed of light. This remains, an active area of research. But most experts doubt that anything so radical is required.

4. Conclusion

Einstein proposed relativity theory and gravity about a century ago. This theory does not go well with laws of quantum mechanics. String theory tries to provide a link between the complex theory and the fundamental force of gravity that drives black holes. As string theory basing on strings instead of conventional particles, it lent more credibility to the potentially unifying theory. Whether the string theory is the "ultimate" theory or the theory of everything, is still not clear, but is an active area of research. This paper just gives an outline to this vast subject.

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Author Profile

Dr Sreelatha K, working as Asst Professor in Post Graduate Department of Physics, NSS Hindu College, Changanacherry (Under Mahatma Gandhi University, Kottayam, Kerala)

Dr Vinu T P, working as Asst Professor in Post Graduate Department of Physics, NSS Hindu College, Changanacherry (Under Mahatma Gandhi University, Kottayam, Kerala)