Tachyons: Properties and way of detection *

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The presently observed accelerating universe suggests that there is a possibility of the real existence of 'Tachyons' - a Boson class particle theorized to exceed the maximum speed of electro magnetic radiation. Theory suggests that Tachyons do not violate the theory of Special Relativity despite having a speed greater than that of light in vacuum. But their existence is not confirmed by experiment. In this article, possible properties of tachyons are discussed which would be helpful to test their existence and detection. Two thought experiments are proposed to detect them.

Keywords: ***Accelerating universe; Properties of Tachyons; Detection of Tachyons; Dark energy***

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1. Introduction

It once was thought that the speed of light was infinite. Albert Einstein's Special Relativity theory [1] established that the speed of light in vacuum is the highest that can be can be attained by a matter particle - so they will never be able to attain a speed greater than that of light. A very high number experiments have confirmed Special Relativity theory with increasing precision. An example being the bending of light by heavy massive objects is experimentally proved [2]. There is also experimental proof that light speed in a vacuum is finite. LIGO gravitational wave detection in very recent years [3, 4] from an inspiraling binary black hole is the latest experimental proof for Einsteins Special Relativity theory.

But, Relativistic mechanics believers are still in search of particles having speed greater than that of light, termed as tachyon [5, 6, 7, 8], something not possible by strict observance of Relativistic mechanics. The discovery of the accelerating expansion [9, 10, 11] of the universe provides fresh breath for people with these views. With new theories and experimental setups the Classic interpretation of Relativity becomes contestable in three different ways:

- **First**,General relativity theory does not explain the accelerating expansion of the universe. So is the theory complete? Are additions possible that would contribute to Cosmological theory that are not currently in Special relativity?

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- **Second**, As the expansion of the universe is accelerating there would be a possible time for a galaxy when its speed would be greater than the speed of light. This is strictly a non-relativistic concept. But, it is possible. Not only that, the discovery of GN-z11 galaxy [12, 13] incorporate more discrepancies. According to Big Bang, GN-z11 galaxy travels 13.4 billion light year distance in 400 million year time. Thus, if it travels with equal speed all along its path, it should have a speed of $33.5c$ where c is the speed of light in vacuum. [13] If, GN-z11 started from 0 speed its speed should be more than $33.5c$. Thus, if we consider that Big Bang theory is true, the existence of tachyon should also be true.
- **Third**, Dark energy [14, 15, 16, 17, 18, 19] which is considered as hidden force behind the accelerating expansion of the universe may itself be a candidate for tachyon [20, 21, 22, 23].

Sommerfield [24] first discussed the existence of a particle having a speed faster than the speed of light in pre-relativistic age. But it is discouraged by the followers due to the growing success of Special relativity theory which excludes such possibilities. In 1962, a group lead by Sudarshan in the University of Rochester of New York devoted themselves to justify any such possibility within relativistic approach [25]. They reported that if tachyon exists, that should not violet Special relativity theory. Since then, several attempts were made to prove their existence including experiments to detect. Theory has advanced significantly [26, 27], but, not the experiment [28, 29] so far. In present article, possible properties of tachyon are discussed and a thought experiment is proposed to detect it

2. What separates us from the world of tachyon?

Derivation of relativistic theory includes two restrictions

- (i) In any frame of reference the energy of a particle must be positive.
- (ii) Laws of particle dynamics must be independent of frame of reference.

Condition (i) is imposed to satisfy our common experiences bound by Newtonian mechanics. Condition (ii) is considered to satisfy experiences of a non-relativistic regime. But, these two conditions restrict ourselves to go beyond our common experiences. If negative energy state exists, we would never be able to find it out using this theory. If every particle has its opposite counterpart which is known as anti-particle, like electron and positron, then why energy would not have its opposite one? It may be a negative energy state or an imaginary energy state.

Condition (ii) is more influential than condition (i). Let us take a very funny example, a person is trying to catch a fish by a harpoon in the sea. The person is on a boat which is at the same speed as the fish. From common experience we can say, the person and the fish have a relative speed 0. If the person throws his harpoon successfully to hit the fish perpendicular to the direction of movement and parallel to their line of joining he must observe that the harpoon hit the fish in an angle to the line of joining. But, if similar event occurs when they are completely at rest with respect to the lake(or say Earth) harpoon will hit with an angle of 0 with respect to their line of joining. This discrepancy is due to the negligence of the effect of the reference frame. When the event occurs at rest, harpoon doesn't carry any momentum except its direction of throwing. Thus, when it crosses the inter face of the two reference frames no momentum or energy dispersion would occur. Thus, there is no reference frame effect. But, when the event occurs with existing relative speed, to a third reference frame which is in contact with both the frames under observation, the harpoon has extra momentum perpendicular to its direction of throw with respect to the third frame. Thus, when it crosses the interface of two reference frames, its energy and momentum must change which makes impact on our observation. If a camera is used instead of a harpoon, we shall observe no difference in two photos if the distance is small. But, if the distance is sufficiently large we should observe a significant difference. Thus, travel time through the interacting media is also important. Some one may not be convinced by this example but should agree with me that any measurement process is accompanied with media which is associated with momentum and energy. Thus, when an observer tries to measure a property of an event which is in a different reference frame then the measurement media (say a signal) should cross the interface of the two reference frame twice with a time gap say δt hence the measured value should be influenced. If say, two observers from two different reference frames measure a common property of an event on a third reference frame at the same time they should get different results which should not be equivalent unless we add the interaction of reference frame with the measurement media. In this case, two observers should come to the conclusion that other one violets the basic laws of physics. Thus, for the consistency of the law of particle dynamics, one should include an extra term which should carry the information of the reference. If still there is any doubt, we may give an argument against the restriction (i). If we initially assume that particle dynamics is independent of reference frame then it would be very difficult to know the effect of reference frames on the dynamics of a particle if it exists in reality. Thus, a derivation of Special relativity theory without any restriction is very important and demanding to explain present observations satisfactorily. We may use any restriction only for the special cases. Of course, the derivation of the Special relativity theory without any restriction is very difficult. But, that is the only way to examine whether the speed of a particle higher than the speed of light is possible or not.

3. Difficulties regarding the detection of tachyon

There are several proposals to detect tachyon [30, 31]. Experiments are performed to prove the existence of tachyon. Still success is far away. Reason is precisely due to the lack of proper knowledge about the properties of tachyon which restrict to design proper detector. Thus, we may split our job as follows -

- (i) search for proper properties.
- (ii) search proper way to convert tachyon to an object of our known universe.
- (iii) design proper experimental setup.

3.1. properties of tachyon

So far only one property of tachyon is confirmed that its speed is grater than the speed of light. Nothing else are confirmed, though there are lots of proposals like open string field property [32, 33, 34], inflation property [35], matter property [36] and others [37]. In general, mass of tachyon is considered as imaginary. But, recently Hill and Cox [38] showed that mass of tachyon may be real. In present work mass of tachyon is considered as real. Though it is necessary that tachyons would be anti-gravity particle *ie.* instead of gravitational attraction, two tachyons repel each other. Few more properties of tachyon are proposed here.

- **Nature** It is obvious that tachyon should differ from matter and electromagnetic wave. Could it be something originated from all these component? For the time being, let us consider that tachyon is a composite of wave particle compound phase including exclusive incorporation of space. Let us elaborate this idea. **A particle like something having a mass like property ($m = 0$ or $m \neq 0$) moving with a speed, higher than the speed of light, due to the strong gravitational repulsion and creating compression and elongation of space along its direction of propagation with oscillating electric and magnetic**

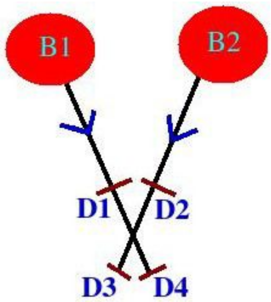
field perpendicular to its propagation is called tachyon. This is purely a postulate considered in present article. This assumption states that tachyon has electromagnetic component and space component. Thus, decoherence of tachyon should yield electromagnetic radiation (say photon) and space. If it is massive, we also get matter. Thus, we may conclude that tachyon is the fundamental particle from which present universe is formed. If this statement is true, then its existence should be confined to the pre Big Bang area or inside a Black hole. The compression of space by the tachyon is the reason behind its super luminal speed. But, compression of space is only possible for a particle having extreme high gravity (here it is anti-gravity). If tachyon has extrema high anti-gravity, its own electromagnetic oscillation should be frozen on it. Thus, it should not interact with electromagnetic radiation. Thus, dark matter may be a candidate for tachyon. According to the present postulate we have three properties of tachyon which may be exploit for its detection - gravitational force, gravitational wave and electromagnetic radiation obtained from the decoherence of tachyon.

- **Distribution** What is the distribution function of tachyon? So far no such proposal is reported. Its distribution function is very important. Thus, here few postulates are described on tachyon's distribution function -
  - Tachyon may have negative integral spin values like -1, -2, etc.
  - As tachyon has only one type of spin but with negative sign, it may follow Bose-Einstein statistics with additional negative sign. This is a guess on the basis of sign. Exact distribution law may be different. The search is going on.
  - For tachyon statistics, temperature (T) should be replaced by space vibration frequency (S).
  - For tachyon, so called higher energy like states may be more populated than lower states.
  - As space is a component along with electromagnetic part, an energy like state of tachyon must be a matrix.
- **Dynamics** Tachyon dynamics is studied mostly in the string field theory formalism [39, 40, 41, 42]. Now the question is, if tachyon belongs to a space where speed is not limited, how could we apply laws of physics of a space where speed is limited by c? There is another issue, how could we use the so called *energy* for tachyon? Thus, to study dynamics of tachyon, we have to use new laws which are free of any restrictions discussed earlier. Few postulates may be very important to derive any dynamical law for tachyon.
  - Inclusion of space explicitly makes tachyon dynamics reference dependent.
  - Both energy like and momentum like properties should be defined newly. In previous section, it is mentioned that energy like states of tachyon is a matrix and energy like property is a tensor of rank three. Here it could be postulated that momentum like property is also a matrix.

3.2. Conversion of tachyon to tardyon and luxon

Until we have any detector to detect tachyon directly, we have to covert tachyon to tardyon or luxon to perform indirect detection of tachyon. It is discussed in section 3.1 that energy like property of tachyon includes electromagnetic part and space part. Thus, a head-on collision between two tachyons may produce luxon or tardyon due to

Fig. 1: Experiment for tachyon detection using collision



interference like phenomenon. If such event occurs, only then we can detect the existence of tachyon with our present detector. There is another way we can convert tachyon to luxon or tardyon. By trapping tachyon in a confined space and allowed for decoherence like incident to occur, we may reach to our goal.

3.3. Thought experiments for tachyon detection

Two thought experiments are proposed here for the detection of tachyon. Experiment-1 exploits the effect of collision between two tachyons and Experiment-2 exploits trapping and decoherence like phenomenon of it.

3.3.1. Experiment-1

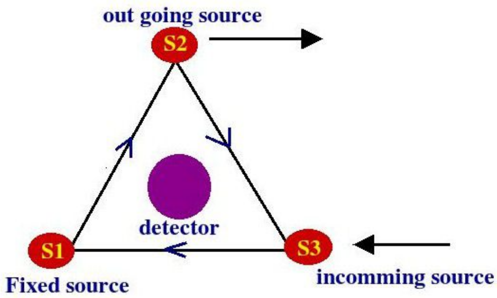
A proposed experiment for tachyon detection based on tachyon collision is presented in Figure 1. B_1 and B_2 are two sources of tachyon (may be two Black holes). D_1, D_2, D_3 and D_4 are four detectors. These detectors are capable to measure electromagnetic energy intensity or gravitational wave intensity. If, there is no existence of tachyon, energy difference (or gravitational wave intensity) between D_1 and D_4 should be same as calculated by present laws. Similar is true for D_2 and D_3. if we face any discrepancy, we may conclude that B_1 and B_2 are sources of tachyon and tachyons have properties similar to our postulates described in section 3.1. Though a negative result of this experiment may be due to different property of tachyon.

3.3.2. Experiment-2

Experiment-2 is based on tachyon decoherence. A proposed experimental setup is shown in Figure 2. In this experiment, we allow tachyons to react among themselves for infinite time period which may yield electromagnetic wave or gravitational wave due to decoherence type phenomenon of tachyons. Then by measuring electromagnetic wave or gravitational wave we may test the existence of tachyon.

In Figure 2, S_1, S_2 and S_3 are three source of tachyon among which S_2 and S_3 are stretching away and coming back symmetrically such that at every definite time interval, say Δt, these three sources forms a equilateral triangle. If these sources are coherent source of tachyon, we may have interference like phenomenon which would be very much periodic, as a result, the area enclosed by this triangle should enriched by tachyon. Increase of tachyon density may leads to decoherence like event which may produce luxon or tardyon. Thus, a detector placed in the center of this equilateral triangle,

Fig. 2: Experiment for tachyon detection using decoherence



if records increase of energy or gravitational wave intensity, we could conclude that those sources emit tachyon. Positive result of this experiment also proves decoherence like property of tachyon.

4. Conclusion

In conclusion, it could be said that in this article probable properties of tachyon is reported. Experiments are also proposed qualitatively but the mathematical formulation is not done. Such study is going on. But, a proper derivation of general relativity theory without any restriction may disclose the mystery of tachyon. Present article may be helpful for designing of new experiments for tachyon detection.

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Declaration

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