# Neutrinos Must be Tachyons

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## Abstract

The negative mass squared problem of the recent neutrino experiments[1-6] prompts us to speculate that, after all, neutrinos may be tachyons. There are number of reasons to believe that this could be the case. Stationary neutrinos have not been detected. There is no evidence of right handed neutrinos which are most likely to be observed if neutrinos can be stationary. They have the unusual property of the mass oscillation between flavors which has not been observed in the electron families. While Standard Model predicts the mass of neutrinos to be zero, the observed spectrum of $T_2$ decay experiments hasn't conclusively proved that the mass of neutrino is exactly zero. Based upon these observations and other related phenomena, we wish to argue that there are too many inconsistencies to fit neutrinos into the category of the ordinary inside light cone particles and that the simplest possible way to resolve the mystery of the neutrino is to change our point of view and determine that neutrinos are actually tachyons.

According to the so far confirmed physical data and the Standard Model, it is generally believed that neutrinos are massless and they travel at the speed of light. Actually this scenario fits close to most of the observed experimental results. The problem is that neutrino is a fermion and no other existing known fermions travel at the speed of light. And no other fermions violate the parity at the same time having the problem of mass oscillation. In this note, instead of attempting to define what neutrinos must be like, we wish to propose a scenario that neutrinos must be tachyons by showing how the behavior of a tachyon is physically consistent with the properties of neutrinos observed so far. In one of their pioneering works, Alan Chodos, Avi I. Hauser and V. Alan Kostelecky [7] have suggested in 1985 that at least one of the neutrinos may be tachyons within the field theoretical framework. The present report may be considered the generalization of their work largely based on the collective analysis of the widely scattered physical data concerning neutrinos.

Tachyon is a particle derivable from the energy invariance equation of special relativity exactly the same way as positron was predicted from it. In this solution, tachyons must travel always faster than the speed of light and have the negative mass squared. The total relativistic energy is still positive and it obeys Lorentz invariance. And any gauge theory based on Lorentz invariance will have it embedded in the theory. In that sense, it is not an unphysical particle any more than an electron or a positron. In other words, there is absolutely no physical law that prohibits the existence of tachyons. If we try to detect tachyons by a deliberate experiment, we would know it by measuring its negative mass squared value or its faster than the speed of light travel. Unlike gauge particles which have integer spin, tachyons have spin 1/2 and the conjugate anti-particle has the opposite sign of the mass and a lepton number may be assigned. The Dirac matrix, quantum mechanically extended from the relativistic energy relation, predicts about electron only that it has spin 1/2 and that it has the real mass with the possible existence of the conjugate anti-particle. The attachment of electric charge and the magnetic dipole moment for an electron is the result of the additional U(1) gauge symmetry that charged particles generally possess. Tachyon as a member of the fermion family has all the physical properties similar to that of electron except for the mass, charge and its speed of travel and other properties directly associated with them. In a similar manner, by the introduction of the gauge symmetry SU(2), tachyons acquire the properties of neutrinos which are governed by the weak interaction.

Since tachyons always travel faster than the speed of light, they never exist in the rest state. The closer its speed gets to the speed of light, the more energy it carries. The infinite speed tachyon will have zero energy and the one with the speed of light will carry infinite amount of energy exactly the same way as ordinary matter particles would. The absolute rest mass of a tachyon is defined by the energy of the tachyon when its speed is $\sqrt{2}$ times the speed of light. Therefore, usual large energy ($> MeV$) electron neutrinos are expected to have the velocity slightly larger than the speed of light which may also explain the earlier detection of neutrinos from the supernova prior to its visual confirmation, within the reasonable assumption that both the weak and the electromagnetic interactions occurred almost simultaneously at the time of the explosion.

It is not an ordinary particle in any sense of our physical intuition. However, it is as physical as any other particles we observe every day in the sense that Lorentz invariance and the gauge symmetry do not prohibit the existence of it. The fundamental physical laws of our universe have their strong foot hold on Lorentz and gauge invariance for various particle interactions. In fact, our elementary particle physics has evolved around these two invariances on top of the quantum principle. Since it is generally expected that an explosion would indicate a sudden increase of temperature and pressure inside the stellar object thereby ejecting radiation and debris at the same time, it is difficult to conclude that when 99 percent of the stellar energy is released in the form of neutrinos during the collapsing phase, the star can still have its original form intact and wait for one more day for an explosion only to emit photons. If we assume that the emission of neutrinos and lights have occurred almost simultaneously (within 1 hour period) at the time of the explosion, the early arrival of neutrinos from the supernova SN 1987A would prove unequivocally that the observed neutrinos are tachyons with its absolute rest mass 1.3 keV. This is based on the report by M. Aglietta et al. [8] where the light has traveled the distance of 50kps for 170,000 years and the first consecutive bursts of 5 neutrinos have an average energy of about 6.7 MeV with an advanced arrival time of 1.11 days prior to the light which has been confirmed by the subsequent visual detection of the supernova SN 1987A. This experimental data itself is in drastic contradiction to the assumption that the neutrino is massless and travels at the speed of light.

One of the puzzling discrepancies in this line of argument is in the fact that the observed upper limit of the absolute mass squared values of neutrinos from the recent experiments [1-6] are much smaller than the one predicted from the supernova. However, their results have been estimated from the assumption that neutrinos are inside light cone particles which may have contributed to the smaller mass squared value than the actual one. The continuous, down to zero energy spectrum of the neutrino makes it almost impossible to distinguish it from the behavior of a photon, which explains the general consensus that neutrino is a particle with zero mass which travels at the speed of light. Also, the imaginary neutrino mass would allow the electron energy spectrum from $T_2$ decay experiments to have the long end tail with no specific structure suggesting the non existence of the real rest mass.

Determining the dark matter content using the neutrino mass also has to be viewed from a different perspective since the rest mass can no longer be real. In this case, the average energy density of the neutrinos emitted at the time of the big bang must be used instead. Because of its weak interaction with matter and faster than the speed of light travel, neutrino would not lose its energy during the expansion and cool down phase of the universe since the reduction of its speed would mean the spontaneous increase of its energy which violates the conservation of energy principle. Therefore, assuming that neutrinos are actually tachyons, it is possible to consider neutrinos as a strong candidate for the dark matter in the universe since the total mass-energy of neutrinos contributes directly to the matter content. The faster than the speed of light travel also makes it unlikely that neutrinos may be captured near massive gravitating stars to be detected. It is more likely that neutrinos will be uniformly distributed throughout the universe regardless of the local gravitational force as the energy of the neutrino gets close to zero. The concept of the imaginary mass of neutrinos also makes it more likely that they can exist in the inter-transitional states between different flavors due to the phase oscillation. Furthermore, there is no way of detecting both helicities of a particle traveling faster than the speed of light, which is an another refreshing evidence that neutrinos are tachyons.

The investigation so far indicates that tachyons do not violate the observed experimental data concerning neutrinos. Our traditional belief that a particle's rest mass should be real and it must travel equal to or less than the speed of light doesn't help to solve the mystery of neutrino. On the historical side of the problem, the positron has already set an example that the reality of the rest mass has nothing to do with the reality of the particle itself. If neutrinos are tachyons as they seem to be, it widely opens a completely different perspective of the universe. The main puzzling consequence of this result may be that some type of energy can in fact be transferred faster than the speed of light as far as the particles that carry the energy have the negative mass squared. Of course, the problem is that energy in general form has no way to be transferred faster than the speed of light at will without invoking weak interactions unless other control mechanisms for such interaction are created. It is also conceivable that the solar neutrino deficiency problem which is an yet another mystery associated with neutrinos may also be due to the fundamental assumption that neutrinos are normal inside light cone particles in the standard solar model in addition to their flavor oscillation problem.

As pointed out by H. Van Dam, Y. J. NG and L. C. Biedenharn, [9] one may need to extend the usual framework of field theory to include the nonscalar tachyonic particles. However, we do not believe this is an insurmountable barrier compared to the fundamental conceptual difficulties one faces by putting neutrinos into the category of the normal light cone particles in our field theory. As indicated by Alan Chodos, Avi I. Hauser and V. Alan Kostelecky, [7] the need for such an extension cannot be used to exclude apriori existence of tachyons, rather it suggests that more theoretical work is required to determine physically acceptable modification of the usual non-tachyonic quantum field theory.

Based on the above discussions we conclude that neutrinos are tachyons which have all the major physical properties required for the observed neutrinos. Before we explore other gauge symmetries for neutrinos, it must be carefully investigated to see if all the observed experimental facts on neutrinos fit into the predicted behavior of tachyons. The ultimate test of this scenario may depend on at least one order of magnitude higher resolution and statistics in the future $T_2$ decay experiments as well as on the reanalysis of the past experimental data in light of the tachyonic particle's point of view.

## References


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