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Tachyons

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Let me begin by expressing my wholehearted admiration for the extraordinary genius and the wonderful personality of George Sudarshan. It was not only a great privilege but also a genuine pleasure working with him on the tachyon problem during our Rochester days.

Before the publication by Albert Einstein of his paper “Zur Elektrodynamik bewegter Körper” (“On the Electrodynamics of Moving Bodies”) in June 1905 [1], physicists had no reason to restrict their consideration of motions to velocities limited by that of light in vacuum. Some of such publications are listed in references [2-8]. One of the preeminent physicists who wrote extensively on electrons “moving in any given way” was Arnold Sommerfeld [5].

All such speculation came to an abrupt halt in 1905, after Einstein’s publication of June 1905, where he explicitly stated: “...speeds in excess of light have no possibility of existence...”. The main reasons for the $v > c$ restriction are:

- Even with infinite amount of energy v cannot exceed c : $v < c$.
- With $m = m_0(1 - v^2/c^2)^{-1/2}$ and a real, positive m , $v > c$ implies an “unphysical” imaginary proper mass m_0 .
- Causality violation : travel into the past would become possible.

The concept of an imaginary proper mass was dismissed offhand as “unphysical”. The need for an infinite amount of energy to accelerate a mass close to the velocity of light, the requirement for the mass traveling at $v > c$ to have an “unphysical” imaginary value, and the apparent possibility of traveling into the past at $v > c$ -- these three conundrums had a chilling effect on anybody who was impudent enough to take seriously the possibility of a particle moving faster than light in vacuum.

The causality violation by anything purportedly traveling backward in time was evocatively described in 1930 by Reginald Buller in his limerick:

*There was a young lady named Bright
Who traveled far faster than light.
She went out one day
In a relative way
And returned the previous night.*

Worldwide, until 1962, trying to publish anything that seemingly contradicted Einstein automatically ran the risk of being considered a crank. An interesting 1963 Spanish version of the above limerick is attributed to “Traductor Anonimo”. In 1974, when George Sudarshan and I published “*Beyond the Light Barrier*” in Russian in “Einsteinovskiy Sbornik 1973” (“Einstein Collection”), Acad.Sci.USSR, Moscow, 1974, we found an imaginative Russian version by a well-known poet S. Ya. Marshak.

To get the first paper on tachyons by George Sudarshan, his student V.K. Deshpande, and myself published – we had to resort to some diplomatic maneuvering. At a meeting of the American Physical Society in 1961, I spotted Walter Michels, the editor of the American Journal of Physics, chatting with the chairman of the Rochester Physics Department, Robert Marshak. I managed to join their conversation and found an opportunity to ask Bob Marshak to assure professor Michels that George Sudarshan and Oleksa Bilaniuk were respectable, *bona fide* physicists. Moreover, Bob Marshak asked Michels to examine our prospective submission on “Metarelativity” thoroughly and seriously, and not throw it automatically into the waste basket, which on first sight might appear the normal thing to do. As a result, our publication appeared in record time.

Our paper rapidly became widely quoted and a number of intrepid experimentalists started looking for faster-than-light particles, particularly after Gerald Feinberg published, in 1967, an attempt at quantization of our “metaparticles”, which he aptly renamed tachyons (from Greek *tachis*=swift).

But the acceptance was not universal. A challenge came, of all places, from the “dean” of science-fiction writers, Isaac Asimov, who published an article [12] on the subject, entitled “*Impossible, that’s all.*” Improbably, who came to our defense but another renowned science fiction writer, Arthur C. Clarke, with the article [13] “*Possible, that’s all.*”

In the end, Isaac Asimov wrote a contrite article [14] “*The Luxon Wall*”, in which he admitted that he had been “left flat-footed by the advance of physics.” He even called me and as a result he was invited to give a talk at Swarthmore. He was a sincere and deep-thinking person and we parted as best of friends.

On a more serious note, over 600 publication on tachyons, experimental and theoretical, appeared in the first 18 years following our 1962 “Metarelativity” paper. Please see Ref. 15 for a full listing. A number of these dealt with the resolution of the causality problem, which remained vexing for a while. In the end, it became clear that tachyons do not lead to causality violation either in the framework of special or of general relativity [16,17].

As soon as it became evident that no laws of physics prohibit the existence of faster-than-light objects, experimentalists, as if mindful of Gell-Mann’s witty “Totalitarian Principle” [18], envisioned searches for the mystifying tachyons.

Another jocular aphorism, the “Alvarez Criterion”, may be quoted to envision the considerations which the potential tachyon searchers must have before embarking on their experiments. The Alvarez criterion is stated in terms of : $\mu = P \times \sigma$ where μ = merit of an experiment, P = probability of its success, and σ = significance of the result. For tachyons, $P=0$ and $\sigma =$ infinity, so that $\mu = 0 \times$ infinity, which is indeterminate. The outcome of tachyon experiments being indeterminate, the decision rested with the gumption of the experimenters. Considering the number of tachyon search experiments (see a partial list in Refs. 19-31), the gumption was indeed high.

The searches included: 1. search for tachyonic magnetic monopoles, 2. tachyon Michelson experiment, 3. missing mass searches in bubble chamber and emulsion records. There were over 300 papers during 1967-1980 on the quantum mechanics of tachyons. For a full bibliography, please see Ref. 15. Indications that electron neutrinos may be tachyonic was published in 1985, by Alan Chodos, Avi I. Hauser and V. Alan Kostelecky in 1985 [22], and other papers exploring this hypothesis, have re-energized

both the experimental and theoretical interest in tachyons.

Preliminary results of measurements of the endpoint of the electron energy spectrum of tritium decay yield negative values of (neutrino mass)² = -27 ± 20 eV . This would indicate that the proper mass of the neutrino is imaginary and that the neutrino is in fact a tachyon. Experimenters now face the challenge to obtain a result which would prove beyond any doubt that the mass of

the electron neutrino is indeed imaginary. A summary of experimental results for (neutrino mass)², obtained in 1991 – 2000 is given in the following table:

EXPERIMENT	MEASURED M ²	FORMAL LIMIT	C.L. %	YEAR
Mainz	$-1.6 \pm 2.5 \pm 2.1 \text{ eV}^2$	2.2	95	2000
Troitsk	$-1.0 \pm 3.0 \pm 2.1 \text{ eV}^2$	2.5	95	2000
Zurich	$-24 \pm 48 \pm 61 \text{ eV}^2$	11.7	95	1992
Tokyo INS	$-65 \pm 85 \pm 65 \text{ eV}^2$	13.1	95	1991
Los Alamos	$-147 \pm 68 \pm 41 \text{ eV}^2$	9.3	95	1991
Livermore	$-130 \pm 20 \pm 15 \text{ eV}^2$	7.0	95	1995
China	$-31 \pm 75 \pm 48 \text{ eV}^2$	12.4	95	1995
Average of PDG (98)	$-27 \pm 20 \text{ eV}^2$	15.0	95	1998

Another approach to ascertain if electron neutrinos are tachyons involves verifying if the “knee” in the cosmic ray spectrum is due to high-energy proton decay

$p \rightarrow n + e^+ + \nu$, with concomitant emergence of a neutron spike where ν would have negative energy in proton’s rest frame, hence would be tachyonic. The possibility of the “knee” being due to such “tachyonic” proton decay has been discussed in a number of papers, including Ref. [31].

The examination of the relativistic velocity addition $v = (u + v) (1 + uv/c^2)^{-1/2}$ involving superluminal velocities leads to a curious conclusion. If there is a parallel tachyonic universe, all velocities within that universe would be seen by us as greater than c , but would be seen as less than c by the inhabitants of that universe. Conversely, to the inhabitants of that universe, all velocities within our world would appear to be tachyonic.

Tachyons have so far eluded physicists, but not enterprising vendors. There is a number of “tachyonized” products on sale and books that provide guidance how to stay healthy by using tachyons [32-33]. Astrologers too seem to have a keen interest in tachyons. In their Australian journal *Alternate Universe* they have published an article “*Tachyon Universe Discovered*”. But in contrast to the tachyon vendors, they give a clue that this discovery should not be taken too seriously: The date of the publication is April 1, 2006.

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