TACHYONS: FASTER THAN LIGHT PARTICLES

Robert W. Bly

" 'But, we'll be safe enough once we've made the jump into hyperspace.' He grinned knowingly. 'Can't nobody track another ship accurately at supralight speeds.' "

-Hans Solo to Luke Skywalker in **Star Wars**

A sticky point for science fiction writers is the fact that matter cannot travel faster than the speed of light. The velocity of light in free space, which we denote by the letter c, is about 186,000 miles per second (mps). If this is the ultimate speed limit, then the rapid interplanetary transportation which is taken for granted in so many science fiction stories would be just about impossible.

If we could travel at speeds close to c on Earth, it would be tantamount to instantaneous transportation. Flying at a velocity near c one could circle the Earth at the equator over seven times within one second. You could go anywhere on the planet within a fifth of a second.

When it comes to spanning the stars, however, c is more an approximation of a snail's pace than of the *Star Trek* transporter. Travelling at speeds near c it would take you 4.3 years to reach the nearest star (Alpha Centauri), 600 years to reach the Pole Star, and five million years to reach the Andromeda Galaxy. It seems as if we cannot go too far in the universe within a normal lifespan. Since this is due to that ultimate speed limit, let us take a look at where that limit comes from.

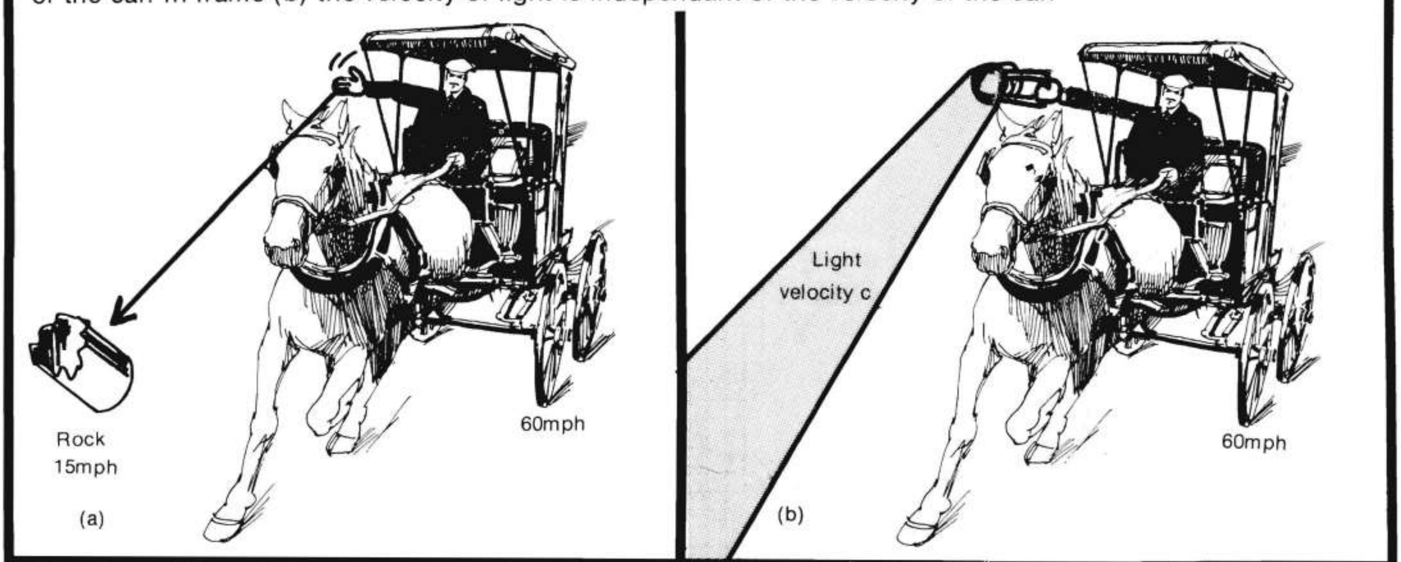
Einstein's Special Theory of Relativity has a postulate, which, in Einstein's own words is: "...light is always propogated in empty space with a definite velocity c which is independent of the state of motion of the emitting body." We can see what this means by way of an example.

Suppose a car is moving at 60 miles per hour (mph). The driver throws a rock out of the window in the same direction that the car is moving, at a velocity of 15 mph. Then the velocity of the rock with respect to the ground (or rest frame) is 60 mph + 15 mph = 75 mph. This is something common to our everyday experience: the velocities add vectorially.

Now consider the same car moving at the same velocity. The driver shines a flashlight so that the beam of light travels forward in the same direction as the car. The beam of light is moving, of course, with the velocity c. From everyday experience, one would expect that (as in the case of the rock) the velocities add, and that the velocity of light with respect to the ground will be c + 60 mph. But the postulate of Einstein says that the velocity of light *is independent of the state of motion of the emitting body*, so that the velocity of light relative to the ground *is still c*, and NOT c + 60 mph(see fig. I). (This phenomenon was actually observed experimentally by Michelson and Morely in the late nineteenth century.)

Einstein was able to relate the velocity c to certain phenomena which were noticeable only when a body's velocity was an appreciable fraction of the speed of light. When v approaches c, the body's mass

Figure I.
In frame (a) we see that the velocities are additive; the rock's velocity relative to the ground depends on the velocity of the car. In frame (b) the velocity of light is independant of the velocity of the car.



increases, length decreases, and time slows down for that body. These phenomena are expressed in the equations in Table I. Also since the mass M increases with speed, the energy E increases with speed because of the mass-energy equation (also in Table I).

Table I. Special Relativity Equations

Phenomenon	Equation
Mass-Energy Equivalence	$E=Mc^2$
Mass Increase	$M=Mo/(1-v^2/c^2)^{1/2}$
Length Contraction	$L=Lo(1-v^2/c^2)^{1/2}$
Time Dilation	$T=To(1-v^2/c^2)^{1/2}$

These equations show why we can never travel at speeds greater than or equal to c. Note they all contain the expression $(1-v^2/c^2)$. If velocity equals c, we see that this expression becomes zero. The mass M would become infinite and we would have a zero length. Since a body cannot have these properties, speeds equal to c (for ordinary matter) are strictly forbidden.

Something even more interesting happens if the velocity v exceeds c. Then, $(1-v^2/c^2)^{1/2}$ becomes a negative quantity, and in the equations in Table I we are taking square roots of negative numbers. Such numbers are called *imaginary numbers*. If we let the symbol i stand for the square root of negative one, then any imaginary number may be expressed as a real number multiplied by i. Now, while i makes good mathematical sense, it has no physical meaning. We cannot have i oranges, and you cannot weigh 80i kilograms. If a body travels at a speed exceeding c, it would have an imaginary mass, which is forbidden.

Matter as we know it must travel under the speed of light, and have real mass greater than zero. Particles which make up ordinary matter, such as protons, electrons and neutrons, are termed *tardyons*.

The mass that a particle has when it is at rest is termed the *rest mass* or *proper mass*, and is denoted by the symbol Mo. For another class of particles, called *luxons*, this rest mass equals zero. According to the equations in Table I, for Mo = 0, v must equal c. Thus, luxons always travel at velocities equal to (but never more or less than) c. Photons (of which light is composed) and neutrinos are examples of luxons.

Photons, neutrinos, electrons, and protons are all particles whose existences have been confirmed experimentally. There is a third type of particle which exits, for the moment, in theory only. These are *tachyons*, and they take their name from the Greek word *tachys*, meaning swift. They always travel at speeds faster than light.

Like tardyons, tachyons gain energy as their velocity approaches c. But remember, tachyons always travel faster than c. Thus, a tachyon gains energy as it slows down! If you push a tachyon and make it go faster, it loses energy, until at infinite speed its energy is zero (see Fig. II).

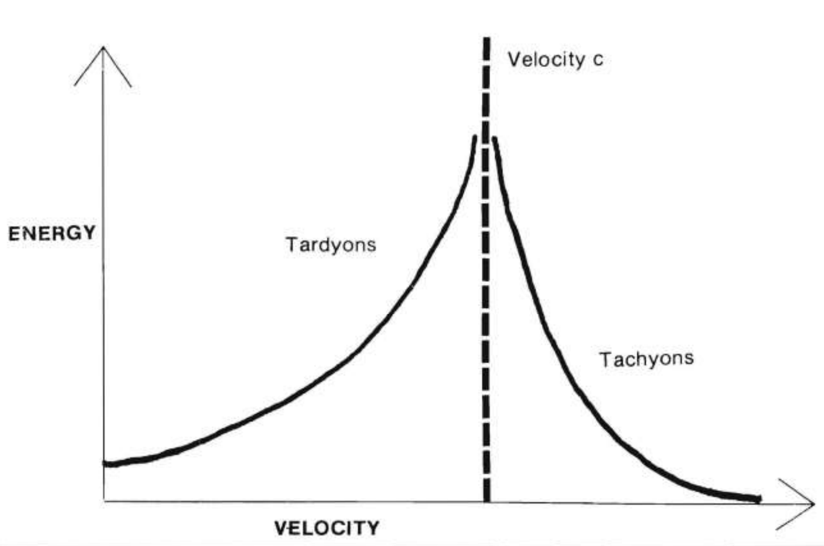
You might object to tachyons on the basis of the equations in Table I. After all, you would have M as an imaginary number if the particle travels faster than light. This problem was resolved in 1962 by three physicists at the University of Rochester, who proposed that tachyons do indeed have imaginary rest masses. They pointed out the fact that while an imaginary rest mass does indeed have no physical meaning, the term *rest mass* itself has no physical meaning for a tachyon, since the tachyon is *never at rest*, travelling always at speeds exceeding c. Therefore, the rest mass Mo of a tachyon need not be a real quantity, and an imaginary rest mass is allowed. Special Relativity prohibited speeds greater than c because Einstein was thinking in terms of particles at rest which would accelerate past the lightspeed barrier, and not particles which were always in motion at speeds already above lightspeed.

The properties of the tachyon caused some sticky theoretical problems besides this, however. Consider two places, *A* and *B*. A tachyon is emitted by *A*, and this is noted by a stationary observer. Some time later, the observer sees the tachyon absorbed at *B*. The tachyon, like all particles, has positive energy. Now as a consequence of relativity, an observer moving very fast with respect to the stationary observer will observe the following: He will see the tachyon, with *negative* energy, being absorbed by *B* *before* being emitted by *A*. Now, according to the Theory of Special Relativity, the event of the tachyon being emitted and absorbed should be valid in all frames of reference. But to the speedy observer, two things have happened which violate physical law.

The first is that the tachyon was absorbed before it was even emitted. It has violated the *causality principle*, which tells us that cause must come before effect. Also, the tachyon had negative energy, which is not allowed. If it was allowed, then there would be nothing to prevent pairs of particles being created where one had negative energy and the other had positive energy. Letting those particles with negative energy go away, we would have an unlimited source of positive energy, and would be getting something for nothing. This violates our fundamental understanding of the way the universe is run, so it can't happen without a major revision in physics.

It would appear that tachyons are nothing more than a nice concept, after all. This was the case until G. Feinberg resolved the problem in 1967. The speedy observer saw station *B* absorb tachyon T (which possessed negative energy) before it was emitted by station *A*. Feinberg said that the speedy observer could just as well describe the picture as: station *B* emits tachyon T (which now has positive energy) and, some time later, tachyon T is absorbed by station *A*. Feinberg's picture (presented here in a

Figure II.
Both tradyons and tachyons gain infinite energy as they approach the speed of light.



much simplified form) resolved the biggest theoretical dilemma facing our tachyon.

Physicists are interested in the question of whether tardyons and tachyons can interact with one another. Here an analogy is drawn between this interaction and the force between electrons. Einstein suggested that the Coulomb force between electrons could be regarded as composed of photons. Moving electrons emit photons, and if an electron absorbs a photon it effects its state of motion. Similarly, two tardyons might exchange tachyons between each other, creating a new kind of force. This would imply that a moving tardyon could emit a tachyon, and here we have one possible mechanism for the creation of tachyons.

It is thought that some tachyons (if not all) carry an electrical charge. Then the simplest way for tachyons to be created would be in pairs of equal and opposite charges using a photon source. But let us say that you do create charged tachyons in this fashion, and then they immediately go flying off at speeds we can't even guess at. Unlike a tardyon you can't slow down a tachyon. So how do you observe one?

P. Cerenkov noted that charged particles travelling faster than light in a given medium give off radiation. Now, while the speed of light is a constant speed in a vacuum, light can be slowed down in a medium such as oil or water. So, if light travels at 170,000 mps in medium H, and a tardyon travels at 180,000 mps in medium H, the tardyon will emit *Cerenkov radiation*.

This radiation is the analog of the sonic boom which occurs when a jet breaks the sound barrier. The sonic boom is a shockwave emitted when a body (the jet) exceeds the speed s of sound in a meduim (the air). In the case of a charged tachyon, the particle *always* exceeds the speed of light in any medium, including free space, since the tachyon is travelling faster than c. Thus, the charged tachyon always emits Cerenkov radiation. In one exoeriment, the charged tachyon source was subjected to a stong electric field in order to give the tachyons enough energy for the Cerenkov radiation to be visible as ordinary light. The experiment gave no evidence of photons, hence there was no evidence for the existence of tachyons.

The theoreticians have done their job as far as the tachyon is concerned, and it is up to experimental physicists to confirm or deny the tachyon's existence. But while they are at it, we can have some fun with theoretical speculations.

It has been suggested that maybe there are no tachyons in our own universe, but there are two seperate universes, one of tachyons and one of tardyons. They are separated by a luxon wall. The problem with this picture is its lack of symmetry. Science writer Isaac Asimov has suggested that while there are two universes separated by a luxon wall, which is which depends on your point of view. From our viewpoint, we are in the tardyon universe and the other is the tachyon universe. From the other side of the luxon wall, we are the tachyon universe and they are composed of tardyons. This intuitive picture is pleasing in that it has the symmetry which physics looks for in nature. Physicist O. Bilaniuk, one of the three UR scientists who cleared up the problem of the tachyon's imaginary mass, has constructed a rigid mathematical model of the two universes which supports Asimov's picture.

What about the possibility of travel faster than light? Well, the lightspeed barrier is still a true barrier to tardyons, of which we are composed. We will never be able to travel faster than light. Now, we know tardyons may be converted to luxons and then converted back to tardyons (electron + proton = gamma ray = electron + proton). Similarly, there is no theoretical objection to converting tardyons to tachyons and then converting them back again. We might be converted to tachyons, transmitted across the galaxy at speeds billions of times faster than light, and have the tachyons captured and converted back to tardyons again. We haven't worked out how this can safely be done to objects and people, and it may very well never be done. But this kind of transporter is not totally out of the realm of the possible.

Science fiction writer Ursula K. LeGuin predicts that while we will never be able to travel faster than light, we *will* be able to communicate instantaneously to any point in the universe with a device she calls the ansible. Perhaps this is more feasible—a transmission of information tachyons. The problem here is that even if we find charged tachyons, they lose energy so rapidly through Cerenkov radiation that it may be impossible to transmit any pattern through them. Remember Fig. II, and you'll see that a loss of energy for a tachyon implies an increase in speed. Thus, the problem in using tachyons to transmit information faster than light is to make sure they don't go *too* fast, or they will lose their energy!

Einstein once wrote that "...velocities greater than that of light...have no possibility of existence..." And for all our tachyon theory, we have not yet found physical evidence contrary to his statement.

But what if...

Copy deadline for our next issue is November 10.