Analyzing the Invariant Speed of Light

Edward G. Lake

Independent Researcher

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detect@outlook.com

Abstract: *There are a few experiments which appear to clearly demonstrate that a photon of light is received by a moving observer at c+v or c-v where v is the speed of the observer toward or away from the emitter, yet, in reality, light is always received at c. The purpose of this paper is to analyze and explain how the speed of light can be "invariant" and always be emitted and received at c, while a few experiments* <u>*appear*</u> *to show otherwise.*

Key words: Speed of Light; Time Dilation; Relativity; Energy; Doppler Effect.

I. Measuring the speed of light.

How can light be always emitted and received at *c* when some experiments seem to show otherwise? Mostly it is because the experiments are being misinterpreted.

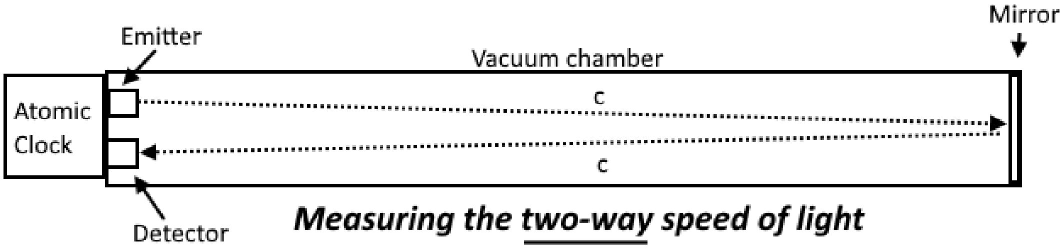

Figure 1

Figure 1 above shows a typical device for measuring the <u>two-way</u> speed of light. All you really need to know is the distance from the emitter & detector to the mirror at the opposite end of the device. A tiny burst of photons released by the emitter will travel at *c* down the vacuum chamber to the mirror, where the photons will be absorbed by atoms in the mirror and then <u>*instantly*</u> sent back to the detector. If you know the distance from the emitter & detector to the mirror, the speed of light is simply the time it takes for a tiny burst of photons to make the round trip. If the equipment is working properly, the speed of light will always be measured to be 299,792,458 meters per second, regardless of where the device is located. It could be in a laboratory at the equator, at the North Pole, on the moon, on Pluto, on the International Space Station, or moving at extremely high speeds through space. The same result will be measured.

Measuring the one-way speed of light that is received from some emitter is a *very* different situation. Early experiments which actually measured the one-way speed of light only got approximations. In 1676, the Danish astronomer Ole Roemer became the first person to measure the one-way speed of light, although that wasn't his intent. His intent was to use Jupiter's moon Io to measure "absolute time," which could then be used to determine the longitude of points on earth. Roemer measured the speed of light by timing eclipses of Jupiter's moon Io. Before then, it was generally assumed that the speed of light was either infinite or too fast to measure. Roemer determined that it took longer for light from Io to reach the earth when the earth was on the opposite side of the sun from Jupiter, versus when the earth was on the same side of the sun as Jupiter. That meant the speed of light was finite. Later, Dutch astronomer Christiaan Huygens did the arithmetic and he found the value for the speed of light to be equivalent to 131,000 miles per second. That value wasn't correct, but it was a good first approximation.[1]

Today, we measure the two-way speed of light and simply assume that the one-way speed of light is the same.

Understanding and measuring the "invariant speed of light" requires understanding exactly what is being measured. Such experiments do not measure the speed of photons of light, they compare the *energy difference* between outgoing and returning photons. And that change in energy is often erroneously interpreted as a change in speed. Adding to the confusion is the fact that many physicists insist that light consists of waves, not "particles."

II. What is Light?

The first point that must be understood is that light consists of photons. Photons are little packets of energy moving from one atom to another at the speed of light. If the two atoms are a trillion miles apart in empty space, a single photon will travel that distance just as it would if the atoms were next to each other or ten feet apart. It just takes a lot longer for the photon to get from one atom to the other if the atoms are a great distance away from one another.

The energy that a photon contains is in the form of oscillating electric and magnetic fields. Creating an illustration of a photon is problematic, since a photon only exists while traveling at the speed of light.

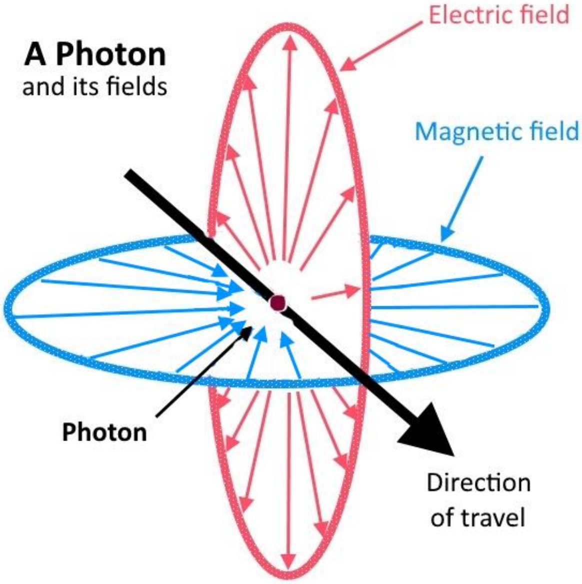

Figure 2

Figure 2 above shows what a photon might look like if it were possible to see it as a stationary object without using other photons to see it.

The photon consists of oscillating electric and magnetic fields, fields that extend at right angles to one another. In figure 2 it can be imagined that the electric field has <u>expanded</u> to about half its full size while the magnetic field has <u>contracted</u> to about half its full size at the moment it is observed. The distance a photon travels between one fully expanded electric field and the next fully expanded <u>electric</u> field is the photon's "wavelength."

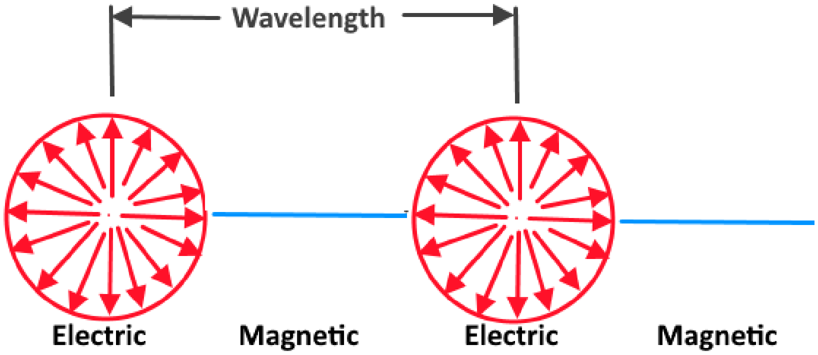

Figure 3

Figure 3 above illustrates how the oscillating fields of a moving photon produce a "wavelength" even though there are no actual <u>spreading</u> waves involved. Figure 4 below shows how wavelengths differ for different types of photons.

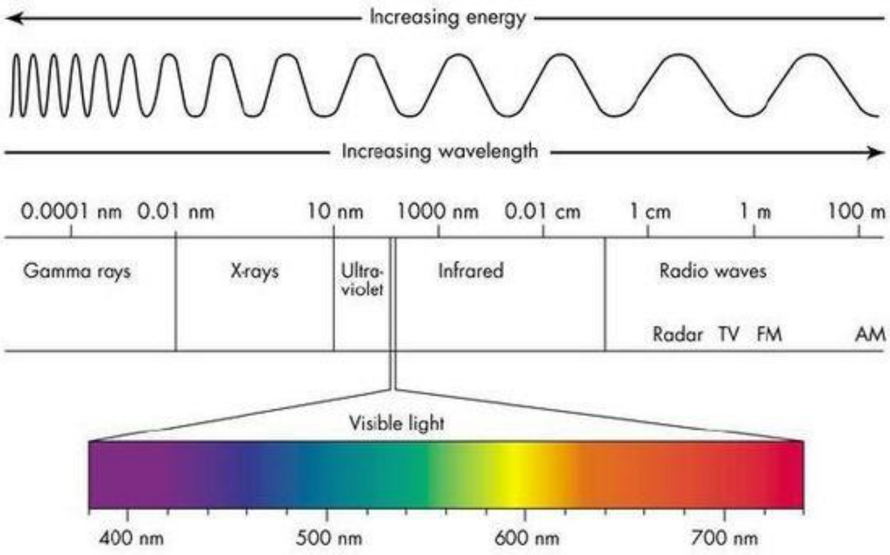

Figure 4

Figure 4 also shows how the energy of a photon relates to its wavelength, which in turn relates to the frequency of the photon's field oscillations. The more energy a photon contains, the shorter its wavelength. If the photon in Figure 2 is a yellow light photon with a wavelength of 600 nanometers, that also means that the photon's electric field oscillates at a rate of 499,654,096,666,667 times per second. By the way of contrast, a photon from a typical police radar gun has an electric field oscillation frequency of 35,000,000,000 times per second, and a wavelength of 8,565,499 nanometers. And if you tune your AM radio to a frequency of 1200 kilohertz, the radio will receive photons that were created with electromagnetic fields that oscillate 1,200,000 times per second and have a wavelength of about 300 meters.

III. What is Time?

Time is evidently a property of particles <u>with mass</u>, such as protons, neutrons and electrons which combine to form atoms. Each proton, neutron and electron is like a tiny clock that ticks at a specific rate and thereby creates time. The "ticks" are in the form of the particle's oscillating electric and magnetic fields. While each <u>type</u> of particle may "tick" at a different rate, they all "tick" at a constant rate <u>per second</u>. Aging and decay are chemical processes which are an effect of time.

Photons have no mass, they always travel at the speed of light, and they do not experience time.

Further evidence that time is a property of particles with mass is Time Dilation, i.e., the slowing of time due to the speed of an atom or the atom's altitude relative to some gravitational mass. The fact that time can be slowed means time simply cannot be a sequence of events. Time must be some physical thing that can be affected by changes in motion and/or gravity.

IV. Time Dilation.

Time Dilation, which has been confirmed by many well-known experiments, tells us that the length of a second varies with an atom's velocity and altitude. If you move an object, time will slow down for that object, which means the field oscillation rates of all of its particles will slow down. The same thing happens if you move an object closer to a gravitational mass - the field oscillation rate of all of its particles slows down. Doing the opposite, i.e., slowing down an object or moving the object away from a gravitational mass, has the opposite effect: it speeds up the oscillation rates and thereby speeds up time.

If radiant energy in the form of a photon is added to an atom, energy that the atom cannot retain, the atom will get rid of the excess energy by emitting a new photon. While a photon travels at the speed of light and does not experience time, its electric and magnetic fields will oscillate at a rate per second that is governed by the type of atom that originally created it. Additionally, a fast moving atom will emit a photon that oscillates slower, and a slow moving atom will emit a photon that oscillates faster, although the oscillation rate per second will be the same.

Therein lies the "invariance of *c*." The speed of light is always the same rate per second for every photon or atom in the universe, even though the length of a second is different for virtually every photon or atom in the universe.

V. Stationary Points in Space.

Before discussing experiments which verify that light photons are always emitted and received at *c*, it is important to understand that photons of light are always emitted from "stationary points in space."

When you look at a distant star, you do not see it where it is currently located, you see it where it was located when it emitted the photons you see. Each of those photons came to your eyes in a straight line from "a stationary point in space."

This is part of the origin of the fictitious "luminiferous ether" that mathematicians created to solve problems with understanding how light works. Having a "luminiferous ether" not only created a way to have stationary points in space, it also provided a medium through which "waves of light" could move. Einstein's idea that light is simply emitted from stationary <u>points</u> in space eliminated the need for a "luminiferous ether." Einstein stated it this way in the introduction from his 1905 paper "*On the Electrodynamics of Moving Bodies*"**[2]**:

> The introduction of a "luminiferous ether" will prove to be superfluous inasmuch as the view here to be developed will not require an "absolutely stationary space" provided with special properties, nor assign a velocity-vector to a point of the empty space in which electromagnetic processes take place.

Einstein's theory of Special Relativity (which originated from that 1905 paper) says that light is emitted from stationary <u>points</u> in space, but not from any "absolutely stationary space" with special properties.

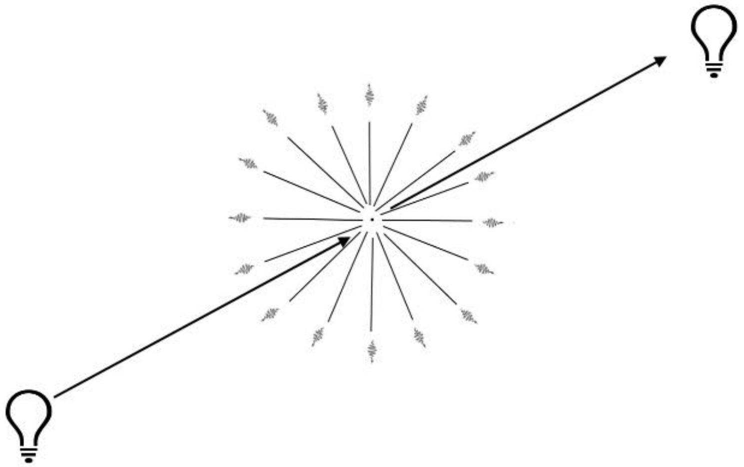

Figure 5

Figure 5 illustrates how light photons travel away from a moving light bulb at the speed of light in all directions if the moving lightbulb only emitted light photons for an instant. During that instant light photons were emitted at *c* in all directions like an expanding sphere. The moving light bulb was, in effect, at a stationary point in space when all the photons were emitted. And the trajectories of all those photons will trace back in straight lines to the stationary point in space where they were created.

The key point to be understood here is that, since photons are emitted from "stationary points in space," <u>they cannot carry any *kinetic* energy resulting from motion by the ***emitter***</u>. Einstein stated it this way as his Second Postulate:

> light is always propagated in empty space with a definite velocity *c* which is independent of the state of motion of the emitting body.**[3]**

The "emitting body" for a photon is an atom. The postulate (a "postulate" is something that must be understood and assumed to be true in order to understand his theory) says that the speed of the atom that emits a photon of light does not change the speed of that photon. Light is always emitted at *c,* just as illustrated in Figure 5 above.

VI. Transferring Energy and "The Doppler Effect."

Energy comes in six basic forms: chemical, electrical, radiant, mechanical, thermal and nuclear. There are also combinations of these basic forms. Radiant energy, also known as electromagnetic radiation (EMR), is energy transmitted without the movement of mass. Photons consist entirely of radiant energy.

Electric companies turn the chemical energy stored in coal and other fuels into electric energy. When you turn on a light switch in a room, you allow the transfer of electric energy from the electric company to the tungsten filament of a light bulb. The tungsten atoms in the filament heat up and emit photons to get rid of the excess energy that the atoms cannot hold. The photons spread out and illuminate the room by hitting atoms in the walls and objects in the room, which in turn send photons of different types to your eyes, enabling you to see those objects.

Since energy can neither be created nor destroyed, that means energy can only be held or transferred. When the chemical energy in gasoline is used to move an automobile, much of that chemical energy is turned into mechanical energy. Mechanical energy consists of potential energy and kinetic energy. Potential energy is the energy an object possesses due to the energy in the atoms that comprise the object. Kinetic energy is defined as "the energy which a body possesses by virtue of being in motion." The more chemical energy you use to move an automobile, the faster the automobile travels and the more kinetic energy the automobile and every atom comprising the automobile will carry.

Kinetic energy is commonly transferred by collisions. The type of collision of importance here is the collision when a moving atom collides with a photon. The atom has mass, the photon doesn't. If a photon had mass while traveling at 670,616,629 miles per hour (mph), it would smash apart any atom it hit. Since a photon has no mass, the photon and its energy are usually absorbed by any atom it hits. If it is a stable atom, as most atoms are, the atom will not be able to hold the added energy from the photon, and it will then immediately get rid of that excess energy by emitting a new photon.

This is where "The Doppler Effect" enters the picture. With sound waves, the Doppler Effect can be measured by both the emitter and the receiver. If you are a stationary receiver listening to the whistle from an approaching train, that whistle will seem to have a higher pitch as the train approaches you, and then the whistle will drop to a lower picture after the train passes and begins moving away from you. That is because the sound waves are closer together when the train is approaching an observer, and farther apart when the train is receding away from an observer, as shown in Figure 6 below.

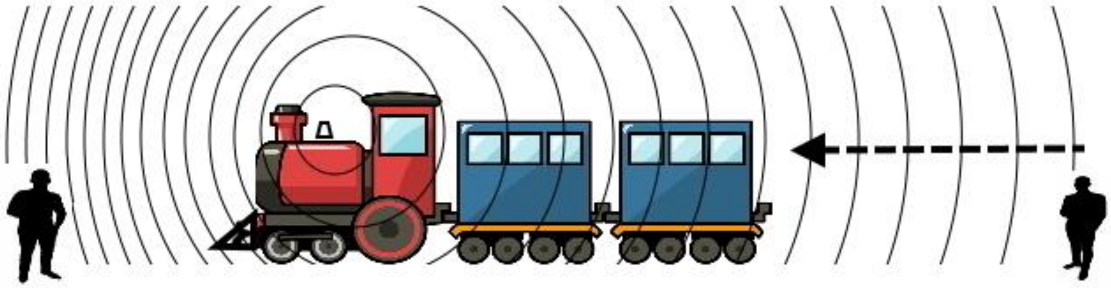

Figure 6

If you are aboard the train and pass by a clanging warning bell where a road crosses the railroad tracks, you will hear the bell clangs closer together as you approach and farther apart as you move away from the crossing, even though the bell actually clangs at a constant rate, as shown in Figure 7 below.

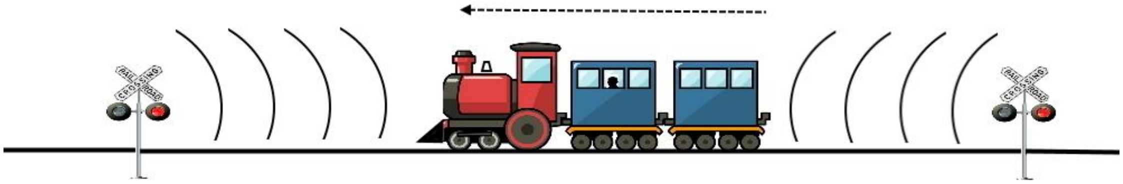

Figure 7

With light, because photons are emitted from "stationary points in space," there can be no Doppler Effect situation like that shown in Figure 6. You can only get a Doppler Effect when an observer approaches or moves away from an emitter, as in Figure 7.

More importantly, when a photon collides with an atom in an oncoming object, the kinetic energy possessed by the atom is combined with the radiant energy of the photon. When the atom emits a new photo to get rid of the excess energy it cannot contain, the amount of energy in the new photon includes the kinetic energy, too.

This is where *c*+*v* and *c*-*v* are often mistakenly believed to occur. It is not *c*+*v*, where *c* is the speed of light and *v* is the speed of an object, it is actually *Qe*+*KE*, where *Qe* is the radiant energy of the photon and *KE* is the kinetic energy of a moving atom. And, of course, *Qe*-*KE* is the reduction of an atom's kinetic energy from the radiant energy contained by a photon.

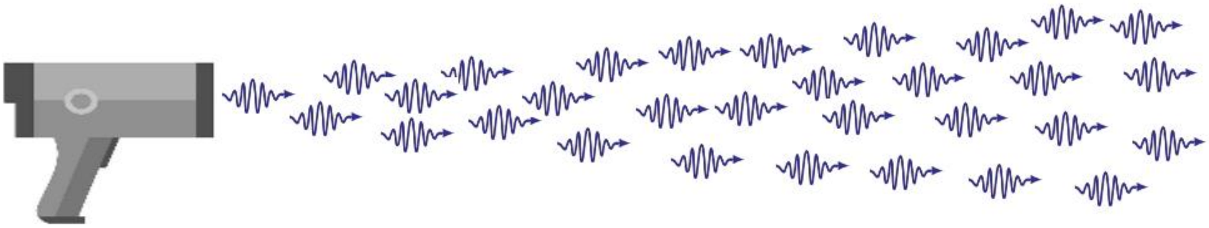

Figure 8

Police radar guns seem to be the best example of using kinetic energy to measure the speed of an object. When the trigger of a police radar gun is pulled, the gun transfers energy from a battery to a metal filament that produces photons which oscillate in a radio frequency range instead of visible light frequencies. Those photons are emitted through a cone-shaped transmitter, much like turning on a flashlight. Figure 8 above depicts a cone of photons, except of course, that there would be many billions of them and the photons would be much more crowded together at the exit from the gun, spreading out in the cone as they travel.

When one of the photons hits an atom in a target, the receiving atom will momentarily absorb the photon, become unstable, and then immediately emit a NEW photon to get rid of that excess energy. If the receiving atom is some relatively shiny material, such as silver, aluminum or chrome, it will tend to emit the new photon back in the direction from which the old photon was received, otherwise the photons could be emitted off in some random direction. But, even then, since there are many photons, a few could still be emitted back toward the radar gun.

This is where *Qe* and *KE* enter the picture. A stationary radar gun emits photons with *Qe* energy traveling at original *c.* A photon hits an atom with *KE* energy in an oncoming target moving at velocity *v*. The photon hits the target atom at Time Dilated *c*, and the *KE* energy of the atom is added to the new photon that is then emitted at Time Dilated *c* by the atom. The new photon with the original *Qe* energy plus the additional *KE* energy is returned to the radar gun. The radar gun receives the photon at original *c*, and the radar gun compares the *Qe* energy of the photons it emitted to the *Qe*+*KE* energy of the photons it received back. The energy difference (known as the "beat" frequency[4] when doing the calculations) is directly convertible to the speed of the target because the energy difference, as a percentage of twice the photon's original energy (i.e., 2 times its original wavelength or frequency), is the same percentage that the speed of the target is to the speed of light.

A. Original frequency: 35,000,000,000 Hz.
B. Return frequency: 35,000,010,416.666664 Hz.

C. Difference: 10,416.666664 Hz.
D. The speed of light: 670,616,629 mph.

C as a percentage of 2xA: 0.000014880952377285714%

That percentage of D = 99.79414119564882 mph, which rounds to 100 mph.

It is unclear why the original frequency must be multiplied by 2, but it appears to relate to the fact that a photon's actual energy frequency consists of an oscillating electric field and an oscillating magnetic field, but only the electric field's oscillations are being counted by a radar gun.

It is also important to understand how Einstein's Second Postulate affects the transfer of energy. Once again, Einstein's Second Postulate states:

> light is always propagated in empty space with a definite velocity *c* which is independent of the state of motion of the emitting body.[2]

I underlined a key word: "emitting." The emitting body emits light at *c* with all of its energy. Movement by the emitted body does *not* add kinetic energy to the photons. It just lengthens the duration of a second so that the same amount of energy is measured in a slightly longer period of time. It is always the receiving body that adds the kinetic energy to the photon. A stationary radar gun emitting photons at a moving target registers the speed of that target because the target added kinetic energy to the photons it received. A moving radar gun pointed at a stationary object registers the speed of the radar gun because the moving radar gun adds kinetic energy to the photons it receives.

VII. Kinetic energy and the "cosine effect".

While an object moving at 100 mph has the same amount of kinetic energy no matter in what direction it is moving, the amount of energy its atoms will transfer to oncoming photons depends upon the angle at which the photons arrive.

Full kinetic energy will be added to the returning photon if the original photon hits an approaching target at an angle of zero degrees. No kinetic energy will be added to a returning photon if that photon hits the target at a 90 degree angle. Full kinetic energy will be subtracted from a returning photon that hit the target at a 180 degree angle, i.e., a target that is moving directly away from the oncoming photon. It is called "the cosine effect."[3] Here are examples of speeds that a radar gun will display depending on the angle to a target moving at 100 mph:

0 degree angle = 100 mph. 180 degree angle = -100 mph.

5 degree angle = 99.6 mph.	175 degree angle = -99.6 mph.
10 degree angle = 98.5 mph.	170 degree angle = -98.5 mph
20 degree angle = 94 mph.	160 degree angle = -94 mph.
30 degree angle = 86.6 mph.	150 degree angle = -86.6 mph.
40 degree angle = 76.6 mph.	140 degree angle = -76.6 mph.
50 degree angle = 64.3 mph.	130 degree angle - -64.3 mph.
60 degree angle = 50 mph.	120 degree angle = -50 mph.
70 degree angle = 34.2 mph.	110 degree angle = -34.2 mph.
80 degree angle = 17.4 mph.	100 degree angle = -17.4 mph.
85 degree angle = 8.7 mph.	95 degree angle = -8.7 mph.
90 degree angle = 0 mph.	

Radar guns do not show negative numbers, so if a target is racing away from the radar gun at 100 mph, the gun will simply show the target's speed to be 100 mph.

VIII. "Invariant Speed of Light" Experiments.

1. Radar guns.

Radar guns may be the simplest and best way to demonstrate that light is always emitted at *c* and is always received at *c*, but the amount of energy contained within the photon can change due to the Doppler Effect. Kinetic energy is added or subtracted if the receiver is moving toward or away from the "stationary point in space" where the photons were emitted. Radar guns have already been thoroughly discussed.

2. Mirrors on the Moon.

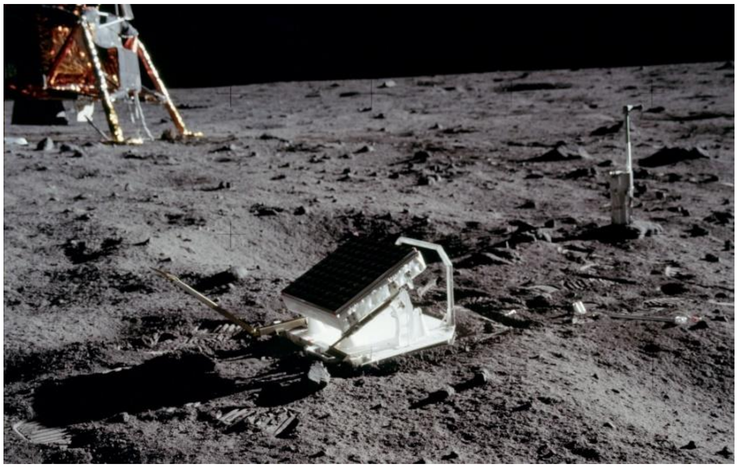

Figure 9

One experiment which has been used to claim that light hits an approaching target at $c+v$ was documented in a paper titled "*Lunar Laser Ranging Test of the Invariance of c*."**[6]** The paper was written by NASA scientist Daniel Y. Gezari who was working on his own, not as a NASA scientist, and who made his paper public via Cornell University's arXiv.org library web site. He used data collected by the Apache Point Lunar Laser Ranging Operation facility at the Apache Point Observatory in New Mexico. The abstract for Mr. Gezari's paper reads as follows:

> The speed of laser light pulses launched from Earth and returned by a retro-reflector on the Moon was calculated from precision round-trip time-of-flight measurements and modeled distances. The measured speed of light (c) in the moving observer's rest frame was found to exceed the canonical value c = 299,792,458 m/s by 200±10 m/s, just the speed of the observatory along the line-of-sight due to the rotation of the Earth during the measurements. This result is a first-order violation of local Lorentz invariance; the speed of light seems to depend on the motion of the observer after all, as in classical wave theory, which implies that a preferred reference frame exists for the propagation of light. However, the present experiment cannot identify the physical system to which such a preferred frame might be tied.

In plain English, what Mr. Gezari measured was the speed of an observatory on the rotating earth as that observatory moved toward mirrors left on the moon by the Apollo astronauts (example shown in Figure 9 above).

Mr. Gezari states that such a measurement means the returning light photons from the moon arrived at $c+v$ where v was the speed of the observatory on the rotating earth as that observatory moved toward the moon (see Figure 10 below).

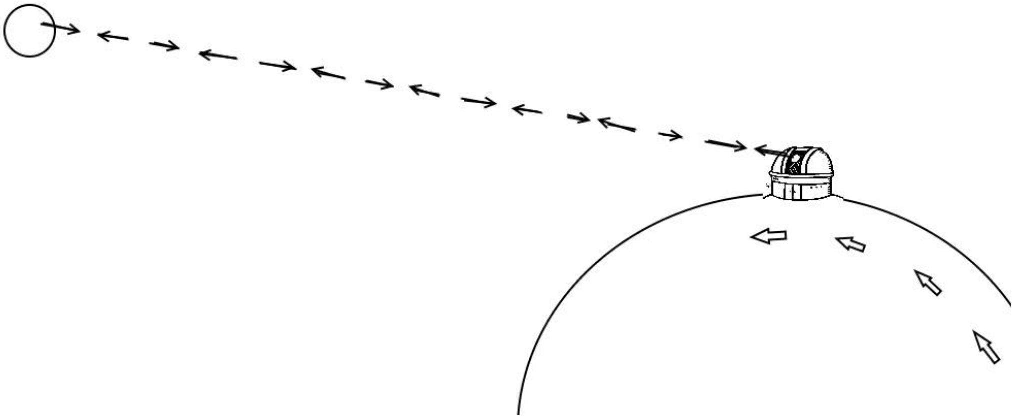

Figure 10

Mr. Gezari's argument appears to be that the round-trip speed of light as measured from the earth's "rest frame" should be equal to what the speed of light would be if the moon and earth were stationary relative to one another. Instead, the light returned faster than that because the light had less distance to travel on the return trip than on the outgoing trip. That means – according to Mr. Gezari – that the speed of light must depend upon the motion of the observer. And, if that is so, then "a preferred reference frame" must exist for the propagation of light.

Mr. Gezari is correct about that. His computed speed for the earth resulted from the fact that light photons are emitted from "stationary points in space," which Mr. Gezari would probably consider to be "a preferred reference frame." And an observer moving relative to that "stationary point in space" will receive light at *c*, but it will be a time dilated *c*. Mr. Gezari dismisses time dilation as being too small to measure in this situation. It's not too small, it just has nothing to do with the problem of how the observatory on earth was measured to be traveling at 200±10 m/s toward the mirrors on the moon. The answer to that problem is that light was emitted from "a stationary point in space" (the mirrors on the moon) and received by a moving observer on earth traveling at 200±10 m/s toward the mirrors on the moon. The light traveled at speed *c* from a stationary point and the observer moved at speed *v* toward the oncoming light.

So, the round trip was shorter than Mr. Gezari expected due to his mistaken assumption that, when the speed of light is said to be "invariant," that means it cannot take a different amount of time for light to travel from Emitter-A to Receiver-B than from Emitter-B to Receiver-A. In reality, if the stationary point in space that is Emitter-A emits light to stationary Receiver-B, the light will have to travel the full distance between A and B. However, if "stationary point in space" Emitter-B then sends light to approaching Receiver-A, that light will travel a shorter distance equal to the distance Receiver-A moved while the light is traveling from A to B and then from B back to A. Moving at a speed of 200±10 meters per second, which is 447 miles per hour, means the observatory earth travelled 447 miles closer to the mirrors on the moon while the light is making the round trip.

3. The Sagnac Effect.

The Sagnac effect,[7] as shown in Figure 11 below, is another experiment which is sometimes used to claim that light arrives at a moving observer at *c+v* or *c-v*. In reality, the Sagnac effect just puts a tiny version of Mr. Gezari's experiment onto a turntable. Photons with a known amount of energy are emitted by a light source on the rotating table, but they are also emitted from "stationary points in space," since the rotating table does not add to the speed of the photons. The photons pass through half-silvered mirrors also on the table until they hit a moving detector/receiver that is also on the rotating table. The result is an addition (or subtraction) of kinetic energy for the received photons that is translatable to the speed of the object toward (or away from) the point of emission.

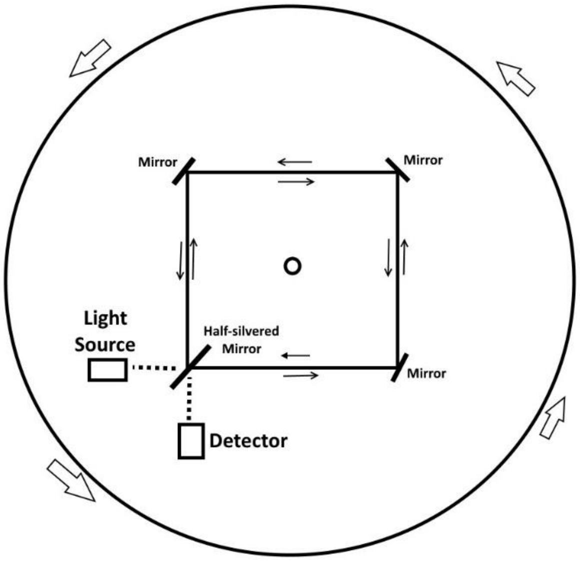

Figure 11

4. Pulsars.

Figure 12 below shows the pulsar "experiment."[8][9] Electromagnetic pulses from the stationary pulsar will hit the earth with more energy in June, and with more pulses per unit of time, when the earth is moving toward the pulsar, than in December, when the earth is moving away from the pulsar.

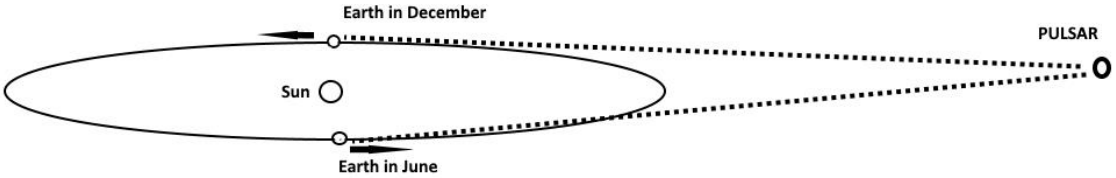

Figure 12

While the one way speed of light cannot be measured, it can be assumed that the pulses travel at c away from stationary points in space, and thus the difference in the oscillation frequency of the photons will directly relate to the energy the moving earth, as a receiver, adds to or subtracts from the photons arriving from the pulsar. And you simply receive more pulses per unit of time if you are moving toward the source of the pulses.

5. Michelson-Gale.

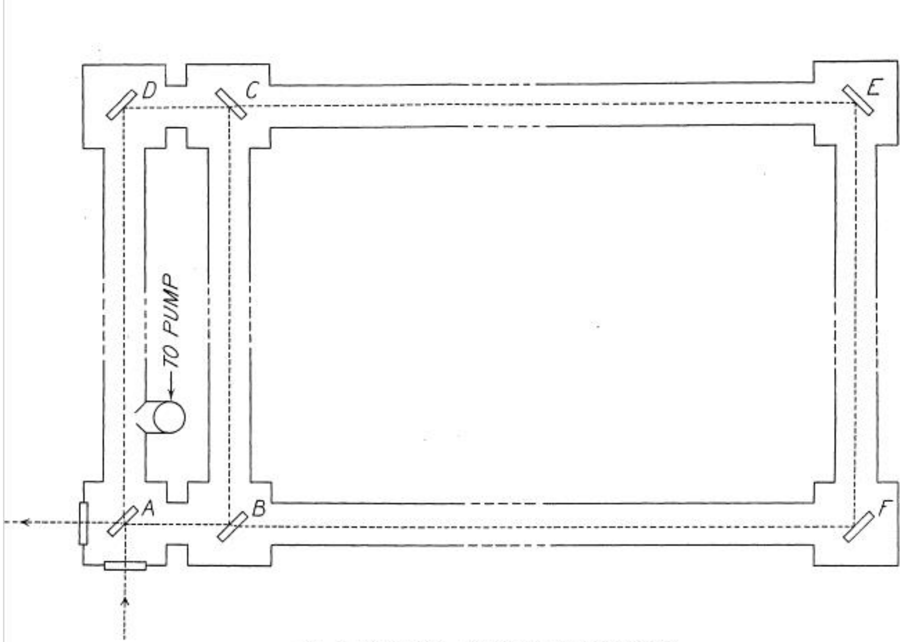

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Fig. 1.—Ground plan, showing arrangement of mirrors

Figure 13

The Michelson-Gale Experiment[10][11][12] is similar to the Sagnac Effect. However, instead of measuring the kinetic energy added by the motion of a turntable, the Michelson-Gale experiment evidently measured the kinetic energy added by the rotation speed of the earth.

The Michelson-Gale experiment, like the Michelson-Morley experiment,[13] was an attempt to measure the speed of the earth through the "luminiferous ether" which was believed to fill the universe and provide the medium for the creation of light waves. If such an ether existed, the speed of light should be significantly different when the light is emitted in the direction of travel through the ether as the earth moves at 67,000 miles per hour around the sun, versus when light is simply moving at a right angle to earth's direction of travel through the ether. The Michelson-Morley experiment involved a device that could fit in a relatively small room. The Michelson-Gale device was much bigger.

Figure 13 above shows the Michelson-Gale experiment layout as illustrated in their paper. It is roughly 1112 feet from Mirror A to Mirror D and 2007 feet from Mirror A to Mirror F. West is to the left, East is to the right. Light sent from Mirror A to D to E to F and back to A (light sent at right angles to the "ether wind") was compared to light sent from Mirror A to B to C to D and back to A (light sent directly into the ether wind).

Sending photons around the device eliminated the need to create exact duplicate frequency emitters at points D and F. Instead, the emission frequency is guaranteed to be the same because it all originates with one emitter. The configuration just means that the frequency of light traveling from Mirror D to Mirror A was compared to the frequency of light traveling from Mirror F to Mirror A.

The experiment supposedly demonstrated that light traveling east to west on our rotating Earth travels at a slightly different speed than light traveling from north to south, but the speed difference was nowhere near the 67,000 mph difference that would be measured if the "luminiferous ether" actually existed. The measured speed difference of 0.3 kilometers per second or 671 miles per hour vaguely corresponded with the rotation speed of the earth at the location of the device near Chicago. It was assumed the difference was due to light traveling at *c* from Mirror D to Mirror A, while light traveled at *c+v* from Mirror F to Mirror A.

In reality, light is emitted at *c* from Mirror F and is received at *c* by Mirror A, but kinetic energy is added to the light that is received by moving Mirror A. The emitter and receiver may be stationary relative to one another, but the photons are emitted from "stationary points in space" at Mirror F, while the receiver/observer Mirror A is moving with the rotating earth. That means the photons also had added measurable kinetic energy when they are received. The effect was not measurable when photons traveled north to south, only when traveling east to west.

6. GPS satellites.

GPS satellites are moving relative to a point on the Earth where the signals are received, and the spinning Earth is moving relative to the satellite which sent the signals. That means that the signals from a GPS satellite are emitted from "stationary points in space" and will arrive with added kinetic energy (and a higher frequency) if a receiver/observer on the spinning Earth is moving toward the satellite, and with negative kinetic energy if the receiver/observer is moving away from the satellite. Signals from GPS satellites do not arrive at *c+v* or *c-v* as some science papers claim.[14][15] Figure 9 showed the moving earth and the moon. Although the moon is a different kind of satellite than a GPS satellite, that makes no difference, since it is only the moving receiver which measures the Doppler Effect on light.

IX. Conclusions.

Is the speed of light "invariant"? Hendrik Lorentz and Albert Einstein considered it to be so, since light is always emitted and received at *c*, which is 299,792,458 meters per second. But both of them understood that the length of a second will vary for an object that is moving versus a stationary object. And the faster an object moves, the longer a second will be for that object. Additionally, the length of a second varies with altitude because Time is affect by gravity. This means that the "invariant speed of light" is different virtually everywhere. Light from every star in the visible universe arrives at 299,792,458 meters per second, but the length of a second is almost certainly different for the receiver than for virtually every emitter.

Additionally, experiments which claim to show that light can arrive at $c+v$ or $c-v$ where v is the speed of the observer, actually show that light will be received with more kinetic energy if the observer/receiver is moving toward the emitting source of the light, and with less kinetic energy if the receiver is moving away from the emitting source of the light. The experiments do not actually measure the speed of light.

So, the answer to the question "Is the speed of light invariant?" totally depends upon your definition of "invariant."

X. References.

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