Undecidability, uncomputability, and unpredictability - FQXI Essay Contest 2020

Is an Aether undecidable? By Marts Liena

Before we can answer that question, we first must look at how aether is defined. The meaning of the word aether has changed many times over the years since it was first mentioned in literature, and be sure when researching aether in English to include the other alternative spelling “ether” as well, keeping in mind that the latter spelling can be confused with the organic compound that was used as an anaesthetic to make people sleep.

In medieval times, aether was known as quintessence, the fifth classical element, the naming originally coming from Plato around 360 BC, after the Greek goddess of light, where in ancient Greece it meant the pure upper layers of the air that were believed to fill all space. Scientists in the 18th century named the medium that light travelled through, the luminiferous aether, and many scientists, up to the early 1920’s, believed this substance was all around us and that it also filled the vacuum of space. Another common definition of aether that was used last century was in reference to the radio spectrum, although this use of the word in this context has dropped out of vogue, in preference to the term “electromagnetic spectrum”.

Aether and “space”, thanks to Einstein, are sometimes used synonymously. Space is another word that has many meanings depending on context. Space can be the Newtonian mathematical 3-D shoebox that holds the aether and material objects, or sometimes space is defined as the contents of the shoebox: the vacuum or the aether. If we can imagine a small cube of empty space between galaxies, then the vacuum refers to the energy content of the cube’s passing constituents: electromagnetic radiation, the odd proton and electron, many neutrinos, some dark matter, and maybe the fluid aether within the cube. Sometimes this is referred to as the zero-point radiation, although this term can also have many meanings. Herein lies the complexity of trying to explain a concept that has a long history with many twists and turns.

In his 1905 paper on *‘The electrodynamics of moving bodies’* (ref.1), Einstein introduced the two postulates of special relativity:

1) Principle of Relativity –*“the laws of electrodynamics and optics will be valid for all frames of reference for which the equations of mechanics hold good”*. This is also known as the principle of covariance: physical laws must have the same mathematical form when observed in any inertial reference frame.
2) *“Light is always propagated in empty space with a definite velocity c, which is independent of the state of motion of the emitting body.”* This is sometimes stated as: the speed of light c, is a constant, independent of the relative motion of the source or observer.

A number of famous optical experiments were conducted from 1887 to the 1940’s to detect absolute motion, and these experiments, and many later ones, have so far been interpreted that no experiment has been able to show the absolute motion of the observer. It is generally thought that this is a consequence of the postulates of special relativity. That is special relativity leads us to conclude that absolute motion cannot figure in any law of physics. But if it is not in the laws and the laws determine what can be decided and what cannot be decided, then absolute motion cannot be. So no experiment will be able to detect the aether and thus the aether is undecidable!

Or so it was thought! But what if one of the postulates of special relativity has been misunderstood and misrepresented? Let us delve into this line of enquiry to see if it may be able to deliver an aether, despite the long list of experiments that have failed to detect an aether. We will now consider how experiment and interpretation of postulates can produce such a long standing misunderstanding.

Early attempts to detect an aether

The Michelson–Morley interferometer (MMI) experiment (ref.2) was a famous ‘failed’ attempt to detect the existence of the luminiferous aether, in that it was not able to detect a postulated aether wind. The experiment was performed between April and July 1887 by Albert Michelson and Edward W. Morley and compared the speed of light in perpendicular directions, in an attempt to detect the relative motion of matter through the stationary luminiferous aether. Because the light beam of the interferometer was two-way, the experiment was of second-order in that the fringe-shift (X_m) being searched for was thought to be proportional to the second power of the ratio of the Earth’s orbital velocity and the velocity of light *c*, ie. : $X_m \sim (v/c)^2$

Einstein wrote*, "If the Michelson–Morley experiment had not brought us into serious embarrassment, no one would have regarded the relativity theory as a (halfway) redemption.”*

In the paper on ‘The electrodynamics of moving bodies’ (a.k.a special relativity), Einstein noted *“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….”*. He later regretted his 1905 dismissal of the aether as “superfluous”.

Aberration

In physics and astronomy, aberration, as investigated by Bradley in 1725, is a phenomenon which produces an apparent motion of celestial objects about their true positions, dependent on the latitude and hence velocity of the observer on Earth, over a period of time. Stellar or annual aberration, is the change in aberration angle over the course of a year as the Earth's velocity changes as it revolves around the Sun. It reaches a maximum angle of approximately 20 arcseconds in right ascension or declination. In 1727 using measurements for eight different stars, Bradley was able to estimate the constant of aberration at 20.2 arcseconds and with this was able to estimate the speed of light at 295,000 km per second.

It is so important in relativistic physics that Einstein discussed it in his 1905 paper “On the electrodynamics of moving bodies”. Einstein's result is the same as Bradley's original equation except for an extra factor of Υ, where $\Upsilon=\surd(1-v^2/c^2)$, because of relativistic velocity addition. Lorentz had previously theorized in 1892 that objects undergo "length contraction" by a factor of Υ in the direction of their motion through the aether. In this way, aberration and related optical phenomena can be accounted for in the context of an immobile aether. Selleri (ref.3) goes further in developing transformations for a privileged system and concludes that “If the absolute aberration angle is the same for all *S*, also the aberration angle observed between two moving systems *S* and *S ’* has to be the same! …Thus the above explanation of aberration in terms of (Earth’s) absolute motion provides the resolution of a longstanding problem of the relativistic approach.”

Variable speed of light

In the ten years between the years of 1905 and 1915 when he published his masterwork “The General Theory of Relativity”, Einstein grappled with the principle of equivalence and his new relativity theory almost continuously. However, he did considerable thinking about the constancy of the speed of light and late in 1907 he suggested that clocks need not necessarily run at the same speed, in an article in the German yearbook of ‘Radioactivity and Electronics’. He further elaborated on this idea in his 1911 paper (ref.4) published in Annalen der Physik: *“Nothing forces us to assume* *that clocks in different gravitational potentials have to be seen as running at the same speed."* This important paper has generally been overlooked from the point of view of variable speed of light theories, partially because it contained a fundamental mistake and partially because it was soon overtaken by his General Relativity in 1915, whose mathematics had corrected the mistake.

Einstein had concluded that light passing in a gravitational field must experience curvature, and so it became that this deflection was to become a precisely tested prediction of relativity. Famously, British astronomer Arthur Eddington organised expeditions where observations were to be made of the total solar eclipse of May 1919, with the aim to measure the gravitational deflection of starlight passing near the Sun. These were carried out by two expeditions, one to the West African island of Príncipe, and the other to the Brazilian town of Sobral. The value of this deflection had been predicted incorrectly by Einstein in 1911, but a corrected estimate of deflection was one of the tests he proposed for his General Theory of Relativity. On 3 June 1919, despite clouds that had reduced the quality of the photographic plates, Eddington recorded in his notebook*: "... one plate I measured gave a result agreeing with Einstein."* Later at a Royal Astronomical Society dinner he opined (and the rest is history):

"*Oh leave the Wise our measures to collate*
One thing at least is certain, light has weight
One thing is certain and the rest debate
Light rays, when near the Sun, do not go straight".

In an analogy to the situation in dielectric media such as water, where a shorter wavelength λ , by means of c = νλ , leads to a lower speed of light, Einstein assumed that clocks in a gravitational field run slower, whereby the corresponding frequencies are influenced by the gravitational potential:

$$\nu_1 = \nu_2 \left(1 + \frac{GM}{rc^2}\right).$$

Einstein commented: *"Given ... that the speed of light is a function of position, it is easily deduced from Huygen's principle that light rays propagating at right angles to the gravity field must undergo deflection."* In a subsequent paper in 1912 (ref.5) he concluded that: *"The principle of the constancy of the speed of light can be kept only when restricting to spacetime regions of constant gravitational potential."*

Einstein had deduced a light deflection at the sun of 0.85 arcsecond, which is just one-half of the correct value later derived by his theory of general relativity. While the correct value was measured by Eddington in 1919, Einstein gave up his VSL theory for reasons relating to general relativity which he was developing, where both space and time measurements are influenced by nearby masses.

In contrast to Einstein, Robert Dicke in his 1957 paper (ref.6) assumed not only the frequencies to vary, but also the wavelengths. Since c = νλ, this resulted in a relative change of *c* twice as much as considered by Einstein in 1911. Dicke correctly assumed a refractive index :

$$n = \frac{c}{c_0} = 1 + \frac{2GM}{rc^2}$$

and proved it to be consistent with the observed value for light deflection. Maxwell's equations show us that the refractive index of electromagnetic radiation equals: n = √εμ where ε is the relative permittivity and μ is the relative permeability. As most materials are non-magnetic at optical frequencies, we can approximate n = √ε , as μ is very close to 1. Thus the value $(n^2 -1) = (\varepsilon- \varepsilon_0) = \Delta\varepsilon$, which comprises the contribution of the particles present in a dielectric medium (ε) less the contribution of aether without particles (ε_0).

Varying speed of light (VSL) cosmologies have been recently proposed independently by Jean-Pierre Petit in 1988, John Moffit in 1992, and the team of Andreas Albrecht and João Magueijo in 1998 to explain the horizon problem of cosmology and propose an alternative to cosmic inflation, and again by Lockie Cresswell in 2013.

In Petit's VSL model, the first VSL paper to be published since Dicke, the variation of *c* accompanies variations in all physical constants throughout cosmological evolution in space and time, so that all equations and measurements of these constants remain unchanged. The Einstein field equations remain invariant through convenient joint variations of *c* and *G* in Einstein's constant.

Moffat had to make a conjecture that the *Lorentz invariance* — the basic symmetry of special relativity — was somehow spontaneously broken in the early universe, to get his theory to work. Magueijo came up with a similar theory, in collaboration with Albrecht. Their approach, developed without any knowledge of Moffat's work, was very similar involving abandoning the conservation of energy.

Cresswell noted in a public presentation (ref.7) in 2013 that according to his definition of time, that the speed of light through a cubic volume of space is proportional to the energy embodied in that space divided by the area of a side bounding the cubic volume, ie. $c \sim kE/L^2$, and that maybe therefore c was very much faster in the early Universe. If the expansion of the Universe is achieved just by expanding aether (visualise an aether particle growing in size like a balloon being blown up), and a unit length (Planck length) is defined as the size of an aether particle, and then if a volume of space is doubled it in size, its energy density decreases by a factor of 8. Thus the speed of light, c, decreases by a factor of 4. ie. the real Universe is growing much faster than the observable universe! This very nicely circumvents inflation during the Big Bang (ie. no need for inflation). If the speed of light was faster in the past, then Universe may be much younger than we think it is now, since modern science treats it as a constant. Since our understanding of the Universe hinges on the constancy of the speed of light, this change with time is an important thing to measure. Now rather than talking about energy (which could be kinetic or gravitational), if we just consider gravitational mass because it uses terms in common use, we have $GM \sim L^3T^{-2} = Lc^2 = Tc^3$, and hence $T = kGM/c^3$ (Note that Dicke had $GM=(k-1(rc^2))/2$ and Einstein had $GM=k'-1(rc^2)$ which are both dimensionally Lc^2, as expected!). Again, it can be seen that if the tick of the clock in the early Universe was small, c will be very much faster! Cresswell's model is similar to Petit's in many ways but holds the unit charge constant. It predicts that the magnetic permeability of free space will have been changing, as according to Maxwell's equation, $c = \sqrt{(1/\mu\varepsilon)}$. Assuming the permittivity of free space is constant (constant charge), then for every doubling in the size of the Universe, μ_0 increases by a factor of 16. This may provide a stronger test on the constancy of the speed of light.

Professor George Ellis expressed concerns that a varying c would require a rewrite of much of modern physics to replace the current system which depends on a constant c. Any new physics, incorporating VSL, would need to revise Maxwell's equations, the metric tensor in general relativity, cosmological evolution including age and size of the universe, in a consistent manner. Whether these concerns apply to the proposals of Einstein (1911), Dicke (1957) and Cresswell (2013) is a matter of debate, though VSL cosmologies still remain out of mainstream physics.

The point of this lengthy discussion on VSL theories is to firstly show that Einstein and many others have considered a variable speed of light, and secondly to show that a VSL needs to be considered at the same time as the second postulate of special relativity (namely that the speed light c, is a constant in free space, independent of the relative motion of the source or observer) with respect to all experiments designed to confirm or deny the existence of an aether.

It should be duly noted that most of these experiments were not performed in "free space", but had optical paths of varying dielectric constants, ie. permittivities that allow a varying speed of light. As far as I can determine V.V.Demjanov (ref.8) is the only physicist to factor this into MMI experiments and he claims the horizontal projection of the Earth's velocity relative to luminiferous aether found by his experiments lies in the range 140 km/s to 480 km/s depending on the time of the day, at the latitude of his experimental setup in Russia.

First order experiments

By first order I mean a dependency on v/c, whereas by second order I mean a dependency on v^2/c^2, where v might be the velocity of the MM interferometer (MMI), or the Earth, or the privileged inertial frame.

It is nowadays considered that all MMI experiments with two way travel in a vacuum (ε_0) have second order effects that cancel to produce a "null" reading. Most of the previous MMI experiments from the 1880's to the 1960's (with a noticeable exception) produced extremely small fringe shifts that were always considered to be evidence of a null reading.

However, in more recent times, experiments have been designed to explore first order effects, and these experiments all seem to be successful at detecting motion with respect to an absolute or privileged frame.

Demjanov has reported positive fringe shifts in a Michelson-Morley experiment involving optically dense media (ref.s 8 and 9). According to his paper the fringe shift disappeared when the optically dense medium was replaced by a vacuum because of second-order length contraction of the arm that is parallel to the direction of motion of the apparatus. He found linear dependence of fringe shift Xm on $\Delta\varepsilon$ in the range $0:000006 < \Delta\varepsilon < 0:01$ where $\Delta\varepsilon = \varepsilon_1 - \varepsilon_0$ and $\varepsilon_0 = 1$ in a vacuum, which led him to study the signal to noise ratio of differing dielectric permittivities and thus unlock his reason why previous MMI experiments produced null results.

In a 2005 paper (ref.10), Eugene Shtyrkov commented: *"The ether drift due to motion of the Earth has been discovered in the process of tracking of a geostationary satellite. The average annual velocity of the orbital component of the ether drift found to be 29.45 km/s that almost coincides with the known value of orbital velocity of the Earth (29.765 km/s). Parameters of galactic motion of the solar system were also measured, and the values for the Sun apex right ascension (270°) and declination (89.5 °) are also in a close agreement with data accepted in observational astronomy. Such results are direct evidence that the velocity of a uniformly moving system can be measured with a device having the source of radiation (geostationary satellite) and detector (antenna of the telescope) fixed with respect to each other and the system itself. Evidently, this fact is reason for the hypotheses of light speed constancy* ***with respect to the observer*** *to be revised."*

In a 2012 paper (ref.12) titled "Successful Search for Ether Drift in a Modified Michelson-Morley Experiment Using the GPS", Stephen Gift gives results of a modified Michelson-Morley experiment employing synchronised GPS clocks instead of an interferometer for direct measurement of light travel times along the arms of the system. The light travel times were directly determined and were therefore essentially immune to the second-order length contraction phenomenon, that occurs in conventional Michelson-Morley experiments. His data indicated an aether drift arising from the Earth's rotation, again calling the interpretation of special relativity into question.

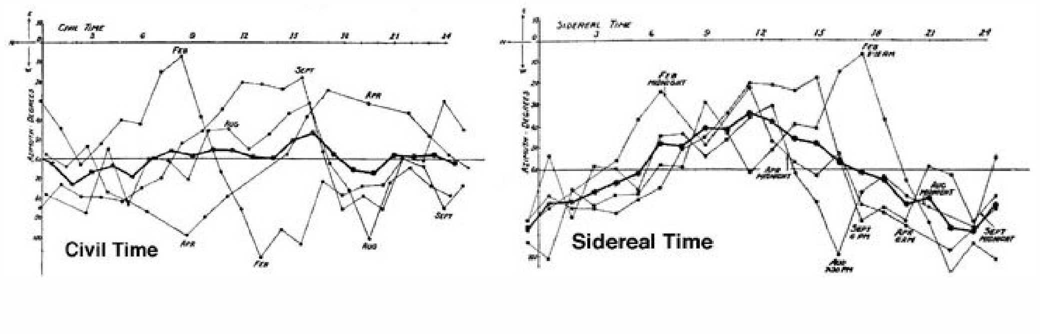
What I am suggesting is that the experimental pillars of special relativity, that have supported Einstein's inductive reasoning, need to be reconsidered with respect to optical aberration, with respect to time dilation and/or length contraction factors that take into account the true astronomical motion of the Earth with respect to the Cosmic Microwave Background (CMB), as well as a varying speed of light due to gravitational fields and the varying permittivities of various experimental optical paths. Historical data also needs to be reviewed where possible to include estimates of the noise floor characteristic of the particular experiment. This will alter the results of the classical Michelson-Morley experiments which found that the total time required for light to traverse a distance L and return is independent of its direction (ie. there is no privileged inertial frame of reference).

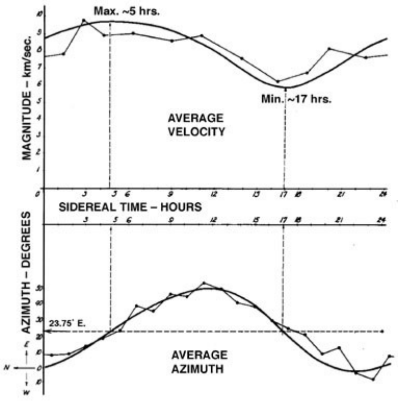
The notable exception

Following the initial Michelson-Morley interferometer experiment of 1887, MMI experiments were conducted over many decades, first by Edward Morley and Dayton Miller, and then by Miller alone, with a 64-meter interferometer that was three times more sensitive than the original 1887 MMI (ref.13).

The dense protective wood cover over the instrument and the stone-basement shield, Miller felt would unfortunately slow down the movement of an entrained aether. These various problems, along with a relatively short light-path, and placement at a relatively low altitude basement location, virtually guaranteed only a small (but never "null") measured result. So Miller decided to move the experiment to a higher altitude atop Mt Wilson in 1925 and insulated it well from draughts, hoping these steps eliminated any significant influences of ambient temperature differences upon the apparatus and the air within the light-beam path, but still allowed the movement of aether-drift.

A typical Miller data sheet recorded over 20 turns of the interferometer, and over 300 of these data sheets were recorded by Miller at Mt. Wilson alone, covering more than 6000 turns of the interferometer. Some graphs of global aether drift**,** from Dayton Miller's Mount Wilson aether-drift experiments, 1925-26, are shown below. The Sidereal Time graph above plots data from four separate months or epochs, measured at different times of the year and organized by sidereal time, shows a definite periodic curve, unlike the Civil Time graph. The heavy lines are the mean of all four epochs. This demonstrates that the detected axis and periodicity of aether drift is the same for different times of year, but can only be seen when the data is viewed within a cosmological, sidereal coordinate system. (From Miller 1928, p.362)





Average velocity and azimuth of global aether drift**,** from Dayton Miller's Mount Wilson Ether Drift Experiments, 1925-26.

Top Graph: Average variations in observed magnitude of ether-drift from all four epochs of measurement. Maximum velocity occurs at around 5 hours sidereal time and minimum velocity occurs around 17 hours sidereal. While Miller's 1933 paper assumed the Earth was pushing through the aether and moving towards Dorado, near the southern pole of the Plane of the Ecliptic, the movement and direction of aether-drift past the interferometer was exactly opposite to this, towards Draco near the northern pole of the Plane of the Ecliptic (17 hours right ascension, declination of +68°). It is important, from the standpoint of his working theory, to clarify the concepts of the "net motion of the Earth" versus the "direction of aether-drift". However, if the aether itself is in motion, acting as a cosmic prime-mover, the direction of aether-drift and the net motion of the Earth would be identical, though at different velocities.

Bottom Graph: Average variations in observed azimuth readings according to sidereal time. This graph uses the same average data curve from the top graph published by Miller in 1928 (p.363) but at the time was given a different baseline average. The same graph is presented here, using Miller's revised seasonal averages as published in 1933 (ref.14), which help define the axis of aether-drift. The independent averages for the four epochs provided by Miller (Feb.=-10° west of north, April=+40° east, Aug.=+10° east, Sept.=+55° east) together yield *a mean displacement 23.75° east of north.* This is very close to the Earth's axial tilt of 23.5°, and can hardly be coincidental. (Graphic adapted from Miller 1928, p.363 and Miller 1933 p.235)

According to Wikipedia, *"His {Miller} measurements in the 1920s amounted to approximately 10 km/s instead of the nearly 30 km/s expected from the Earth's orbital motion alone. He remained convinced this was due to partial entrainment or aether dragging, though he did not attempt a detailed explanation. He ignored critiques demonstrating the inconsistency of his results and the refutation by the Hammar experiment. Miller's findings were considered important at the time, and were discussed by Michelson, Lorentz and others at a meeting reported in 1928. There was general agreement that more experimentation was needed to check Miller's results. Miller later built a non-magnetic device to eliminate magnetostriction, while Michelson built one of non-expanding Invar to eliminate any remaining thermal effects. Other experimenters from around the world increased accuracy, eliminated possible side effects, or both. So far, no one has been able to replicate Miller's results, and modern experimental accuracies have ruled them out."*

Although Miller's interferometer experiments were based on second order effects (v^2/c^2), which have been shown in other second order experiments to consistently produce null results, it is possible that some first order permittivity effects have crept in, such as varying air pressure and density, which have revealed themselves in his extremely long run of experimental data. Indeed

Demjanov has shown (ref.9) that the hypothetical relative amplitude of the fringe shift for Dayton Miller's 1926 year data exceeded the estimated noise floor of his data for several hours per day.

Considerations of some Nobel Laureates

Robert B. Laughlin, Nobel Laureate in Physics, endowed chair in physics, Stanford University states: *"It is ironic that Einstein's most creative work, the general theory of relativity, should boil down to conceptualizing space as a medium when his original premise [in special relativity] was that no such medium existed [..] The word 'ether' has extremely negative connotations in theoretical physics because of its past association with opposition to relativity. This is unfortunate because, stripped of these connotations, it rather nicely captures the way most physicists actually think about the vacuum..."*

Another Nobel Laureate in Physics, Frank Wilczek, wrote in his 2008 book *The Lightness of Being: Mass, Ether and the Unification of Forces (ref.15)*: *"No presently known form of matter has the right properties [to play the role of the ether]. So we don't really know what this new material ether is. We know its name: the Higgs condensate [or Higgs field], after Peter Higgs, a Scots physicist who pioneered some of these ideas. The simplest possibility … is that it's made from one new particle, the so-called Higgs particle. But the ether could be a mixture of several materials. … There are good reasons to suspect that a whole new world of particles is ripe for discovery, and that several of them chip in to the cosmic superconductor, a.k.a the Higgs condensate."*

Wilczek argues from many lines of evidence that there is in fact an aether that underpins space, which he calls alternately the Grid or the "cosmic superconductor or the ether."

My Conclusion

I conclude that although the status of the aether is currently, by consensus, considered undecided, it definitely is not undecidable! A better understanding of time dilation and variability in the speed of light in various dielectric mediums, both kinematical and gravitational, will pave the way to a plethora of new and different interferometer type experiments that will eventually sway the scientific community to pronounce the aether as a real and most important entity, particularly in the study of gravity.

Notes regarding Einstein's view on the Aether (ref.s 16-18)

Einstein himself has been quoted on many occasions as to the necessity of an aether and on the properties of an aether.

Beyond 1915, Einstein's own thinking had evolved to the point where he realized that some type of (relativistic) aether was theoretically necessary after all. Einstein called this his "new ether," but changed his terminology over time.

1915 was a momentous year for Einstein, with the publishing of his general theory of relativity, which showed a very different conception of space and time than that in his 1905 paper on special relativity. In general relativity, space has no independent existence; rather, it is a consequence of the various fundamental energy fields. Shortly after his paper on general relativity was published, he exchanged letters with his old mentor Hendrik Lorentz, the Nobel Prize-winning physicist, on the topic of the aether. Lorentz had argued throughout his career that some concept of the aether was necessary for a valid description of reality. Einstein conceded eventually that indeed a non-material aether was necessary to explain inertia and acceleration. Einstein first described his "new ether" in a

1916 letter to Lorentz: *"I agree with you that the general theory of relativity is closer to the ether hypothesis than the special theory. This new ether theory, however, would not violate the principle of relativity, because the state of this ether would not be that of a rigid body in an independent state of motion, but every state of motion would be a function of position determined by material processes."* Some years later Einstein wrote to Lorentz commenting again on the aether: *"It would have been more correct if I had limited myself, in my earlier publications, to emphasizing only the non-existence of an ether velocity, instead of arguing the total non-existence of the ether, for I can see that with the word ether we say nothing else than that space has to be viewed as a carrier of physical qualities."*

In 1918, Einstein published a letter to his critics of special and general relativity. In this letter Einstein writes that the "diseased man" of physics (the aether) is in fact alive and well, but that it is a relativistic aether, in that no motion may be ascribed to it. By 1920, Einstein regarded that the aether was a necessary medium by which acceleration and rotation may be judged, independently of any frame of reference: "*To deny the ether is ultimately to assume that empty space has no physical qualities whatever. The fundamental facts of mechanics do not harmonize with this view. For the mechanical behaviour of a corporeal system hovering freely in empty space depends not only on relative positions (distances) and relative velocities, but also on its state of rotation, which physically may be taken as a characteristic not appertaining to the system in itself. In order to be able to look upon the rotation of the system, at least formally, as something real, Newton objectivises space. Since he classes his absolute space together with real things, for him rotation relative to an absolute space is also something real. Newton might no less well have called his absolute space "ether"; what is essential is merely that besides observable objects, another thing, which is not perceptible, must be looked upon as real, to enable acceleration or rotation to be looked upon as something real. … The conception of the ether has again acquired an intelligible content, although this content differs widely from that of the ether of the mechanical wave theory of light … According to the general theory of relativity, space is endowed with physical qualities; in this sense, there exists an ether. Space without ether is unthinkable; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of space and time (measuring-rods and clocks), nor therefore any spacetime intervals in the physical sense.*"

In some of his later papers, Einstein gave a new definition of the aether by identifying it with "properties of space", and this aether can be called absolute, as long its state cannot be influenced by matter. So he argued that Newton's absolute space can be considered as an "absolute aether", and that the four-dimensional spacetime of special relativity, which replaces the absolute space of Newton, would also be some sort of absolute aether, as its states cannot be influenced by matter as well. However, Einstein also said that in general relativity the aether is not absolute anymore, as the gravitational field and therefore the structure of spacetime depends on the presence of matter. It must be noted that Einstein's use of the word aether to represent 'properties of space' was not accepted by the contemporary scientific community.

Einstein noted in 1924: "*Because it was no longer possible to speak, in any absolute sense, of simultaneous states at different locations in the ether, the ether became, as it were, four dimensional, since there was no objective way of ordering its states by time alone. According to special relativity too, the aether was absolute, since its influence on inertia and the propagation of light was thought of as being itself independent of physical influence....The theory of relativity resolved this problem by establishing the behaviour of the electrically neutral point-mass by the law of the geodetic line, according to which inertial and gravitational effects are no longer considered as separate. In doing so, it attached characteristics to the ether which vary from point to point, determining the metric and the dynamic behaviour of material points, and determined, in their turn, by physical factors, namely the distribution of mass/energy. Thus the ether of general relativity* *differs from those of classical mechanics and special relativity in that it is not 'absolute' but determined, in its locally variable characteristics, by ponderable matter."*

It was only by the mid 1930's after much work on his unified field theories that Einstein had considered the aether to be synonymous with space, when thinking deeply on the physical meaning of general relativity. With respect of the metric g_{uv} , he wrote that *"it can only be determined by specifying physical laws which it satisfies. Thus it was determined that the metrical field was the gravitational field. Thus the geometric structure of this space is dependent on physical factors".* I would argue here that he neglected to include magnetic fields that thread the Universe, as equally important in determining the metric. But later in an article published in *Mein Weltbild*, Einstein wrote: *"Physical space and ether are only different terms for the same thing; fields are physical states of space. If no particular state of motion can be ascribed to the ether, there do not seem to be any grounds for introducing it as an entity of a special sort alongside space."*

In March 1949, answering a letter from his friend Maurice Solovine, Einstein wrote: *"You imagine that I regard my life's work with calm satisfaction. But a close look yields a completely different picture. There is not a single concept of which I am convinced that will remain, and I am uncertain that I was even on the right track."*

And again in March 1952, Einstein wrote to Solovine:*"You find it strange that I think of the comprehensibility of the world as a miracle or as an eternal mystery. Well, a priori, one should expect the world to be chaotic, not to be grasped by the mind in any way. One could (indeed one should) expect that the world to be subjected to law only so far as we grasp it through our intelligence. This would be a sort of order like the alphabetical order of words of a language. By contrast, the kind of order created by Newton's gravitational theory, for instance, is of a very different character. Even if the axioms of the theory are proposed by man, the success of such a project supposes in the objective world a high degree of ordering, which we are in no way entitled to expect a priori. That is the "miracle" which becomes more and more evident as our knowledge develops. And here is the weak point of positivists and professional atheists, who are elated because they think that they have preempted not only the world of the divine but also of the miraculous."*

References

(1) On the electrodynamics of moving bodies; Einstein, Albert; Annalen der Physik, 17 891-921, (1905).

(2) On the Relative Motion of the Earth and the Luminiferous Ether*;* Michelson, Albert A.; Morley, Edward W.; American Journal of Science. 34 (203): 333–345 (1887).

(3) Recovering the Lorentz Ether; Selleri, F.; Apeiron, 11, 246, (2004).

(4) On the Influence of Gravitation on the Propagation of Light; Einstein, Albert; Annalen der Physik, 35, pp. 898-908, (1911).

(5) Speed of light and statics of the gravitational field; Einstein, Albert; Annalen der Physik. **38** (7): 355–369 (1912).

(6) Gravitation without a Principle of Equivalence; Dicke, Robert; Reviews of Modern Physics 29(3):363-376, (1957).

(7) The Future of Physics (Part 2); Cresswell, Lockie; AstroNetworks Vic, (2013).

(8) Michelson Interferometer Operating at Effects of First Order with Respect to v/c (the third method of measuring the speed of "aether wind"); Demjanov, V.V.; arXiv:quant-ph/0103103v3 (2010).

(9) What and how the Michelson Interferometer measures; Demjanov, V.V.; arXiv:physics.gen-ph/1003.2899v6 (2011).

(10) Observation of Ether Drift in Experiments with Geostationary Satellites; Shtyrkov, E.I.; Proceedings of the Natural Philosophy Alliance, pp201-205, 12th Annual Conference, Storrs CT, (2005).

(11) Equation of the GPS; Gift, S.J.G.; Applied Physics Research, 3, 110, (2011).

(12) Successful Search for Ether Drift in a Modified Michelson-Morley Experiment Using the GPS; Gift, S.J.G.; DOI:10.5539/apr.v4n1p185 Corpus ID:56296937 (2012).

(13)Ether-Drift Experiments at Mount Wilson; Miller, Dayton C.; Proceedings of the National Academy of Sciences. 11 (6): 306–314. (1925).

(14) The Ether-Drift Experiment and the Determination of the Absolute Motion of the Earth; Miller, Dayton C.; *Reviews of Modern Physics*. 5 (3): 203–242 (1933).

(15) The Lightness of Being: Mass, Ether and the Unification of Forces; Wilczec, Frank; Basic Books, New York, (2008).

(16) Ideas And Opinions; Einstein, Albert; New York: Random House, (1995).

(17) Einstein: His Life and Universe; Isaacson, Walter; New York: Simon and Schuster, (2008).

(18) Letters to Solovine, 1906 – 1955; Einstein, Albert; Open Road Media, United States (2015).

(19) Einstein and the Ether; Kostro, Ludwig; Apeiron (2000).

(20) The Physics Surrounding the Michelson-Morley Experiment and a New Aether Theory; Perez, I.; arXiv:1004.0716v3 [physics.gen-ph] (2010).