# The space-time-motion diagram: a relational model

Theodore J. St. John

## Abstract

The value of a geometric model is to provide an accurate representation of mathematical relationships and help visualize the nature of complex functions. Each component represents a concept that can be quantified so the quantities are mapped as lengths, areas, angles, etc. so that their relationships can be compared and interpreted. The Minkowski diagram of spacetime attempted to represent the relationship between space and time, but it was based on the 4D equation that unfolded one side of the equation (to fit the visual concept of space) without doing the same with the other. Therefore it represents a distorted map of a map, so the advantage of the geometric model is depleted if not destroyed. The purpose of this paper is to present a perspective on space, time and motion that is not biased by the presumption that time is already known to be 1D and to propose a space-time-motion (STM) model based on that perspective.

## Introduction

Physicists will tell you that spacetime is a continuum, but if you ask them what that means, you get an answer that describes a mixture rather than a continuum: "*Space really is 3 dimensional and time really is 1D. This is not an arbitrary division. Spacetime is unified in that different states of motion cause time and space to "mix", i.e. time moves at different rates to different observers. But a piece of paper is 2D because it takes two numbers to say where a point is. The room is thus 3D (3 numbers to describe position) and time is 1D because it takes only one number (the time) to say where you are in it*."

On the other hand, they also admit that they don't really understand what time actually is. In the January 2013 edition of Foundations of Physics, University of Pennsylvania physics professor Vijay Balasubramanian emphasized that *"time remains the least understood concept in physical theory. While we have made significant progress in understanding space, our understanding of time has not progressed much beyond the level of a century ago when Einstein introduced the idea of space-time as a combined entity.* (Balasubramanian, 2013)". He provides extensive references and a brief synopsis of the various perspectives on why there is an arrow of time, including geometric considerations (Minkowski vs. Euclidean), maximally supersymmetric four dimensional Yang-Mills theory, multi-dimensional string theory, and discusses numerous questions to illustrate his conclusion that "*We have more questions about time than answers*." One that serves to introduce this paper is the question: "*Why is there only one time?*"

The maieutic answer is: *Can we be certain that there is only one time if we don't even know what it is?* True, it only takes one number to describe time, but not because it is a one-dimensional entity — it's because everyone agreed upon a single time standard. Nothing prevents us from using a different clock for each direction of motion, giving time the same 3D character the spatial dimensions. Using the same standard clock has nothing to do with the nature of time; it only synchronizes it allowing a single symbol to represent it in every equation. Newton's predecessor, Isaac Barrow stated *the assumption* about time in his 1735 "Geometrical Lectures":

*"Time is commonly regarded as a measure of motion, and… consequently differences of motion (swifter, slower, accelerated, retarded) are defined by assuming time is known [emphasis added]; and therefore the quantity of time is not determined by motion but the quantity of motion by time: for nothing prevents time and motion from rendering each other mutual aid in this respect." (Burtt, 2003 p. 158)*

Einstein emphasized, in his paper "On the Electrodynamics of Moving Bodies (Einstein, 1905), that time is a *value* used to describe *motion* and that *events* are what we judge:

*"If we wish to describe the motion of a material point, we give the values of its co-ordinates as functions of the time. Now we must bear carefully in mind that a mathematical description of this kind has no physical meaning unless we are quite clear as to what we understand by 'time'. We have to take into account that all our judgments in which time plays a part are always judgments of simultaneous events."*

The purpose of this paper is to consider, as was done by Dan Shanahan (Shanahan), "*how Lorentz might have proceeded if informed by later insights as to the underlying wave nature of matter"* without the highly specialized language that has separated many physicists and isolated them to their own sub-fields (Mehta, 2008). The approach will be to present a perspective on space, time and motion that is not biased by the presumption that time is already known, as was the Minkowski space-time (ST) diagram, and to propose a space-time-motion (STM) model based on that perspective. The primary differences between the STM model and the ST model are

1) STM is based on the concept of motion so the origin of the coordinate system refers to the at-rest state.
2) The S and T axes of STM represent positive scalar values ($\Delta s$ and $\Delta t$) so there is no representation for zero space or zero time.
3) The axes on the STM model are scaled for both the inside and the outside of spherical wavefront. These scales are different as will be explained below.

## A particle/wave as a simple vector

The key point that was not yet known around the turn of the twentieth century was that a particle may be considered a particle if it is at rest, but as a wave[1], the very essence of a particle itself is motion (Morrison, 1990 p. 183). This particle/wave duality means that a complete model must include both the wave aspect and the particle aspect. The Schrödinger wave equation provided that model in 1926. (Anderson, 1982) (Morrison, 1990) (Goswami, 1992) Before quantum physics, the particle proper was modeled geometrically as a point in space, with zero dimensions, to represent its position in space and thus its point-wise particulate nature. The concept of Hilbert space was just introduced in the late 19th century, so state vectors had not been used and although vectors were used to describe particle motion, it was only in the sense that a particle *experiences* motion in 3D space with respect to inertial reference frames – not that it is motion itself[2].

Motion must be represented as having both magnitude and direction. Therefore, as a unit of motion, a particle will be represented in the STM model as an arrow (in standard vector format). However, *as an isolated particle at rest* (no reference point outside of itself) the word "motion" refers to an internal property. Direction in 3D space is irrelevant and meaningless for an isolated particle so the *direction* part of the vector will be called "outward" (similar to up spin where "inward" would refer to down spin). Instead of assuming a number of dimensions i.e. unfolding a space axis into 3 dimensions and leaving time as one, spacetime will be illustrated as a "space-time-motion" (STM) model. Similar to the ST model, the independence of space and time will be represented by perpendicular lines but their relation to motion will also be represented – as a third line perpendicular to the space-time "plane" – to accurately represent the definition of velocity as the derivative of space with respect to time. As an isolated particle, there is no reference frame to which motion can be referred, so space and time are only *concepts* (non-entities) that can be used later when *relative* motion is considered. Also, the words speed and velocity are used interchangeable to indicate scaled motion. Graphically, the particle is represented as vector $\boldsymbol{C}$ in the motion dimension with magnitude $c^2$, see Figure 1.

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[1] Louis de Broglie introduced the theory of electron waves in 1924.

[2] Vectors themselves had only recently been discovered. In 1837, William Rowan Hamilton (1805-1865) showed that complex numbers could be considered abstractly as ordered pairs of real numbers. It wasn't until 1843 when Hamilton realized that a pure number (scalar term) could be added to a set of directed line segments (three rectangular components, or projections on three rectangular axes) that he called a VECTOR to represent a quaternion. The first book on modern vector analysis in English, "Vector Analysis" was written in 1901 and the idea of multidimensional Hilbert space was introduced shortly thereafter. http://www.math.mcgill.ca/~labute/courses/133f03/VectorHistory.html and http://en.wikipedia.org/wiki/Hilbert_space#History

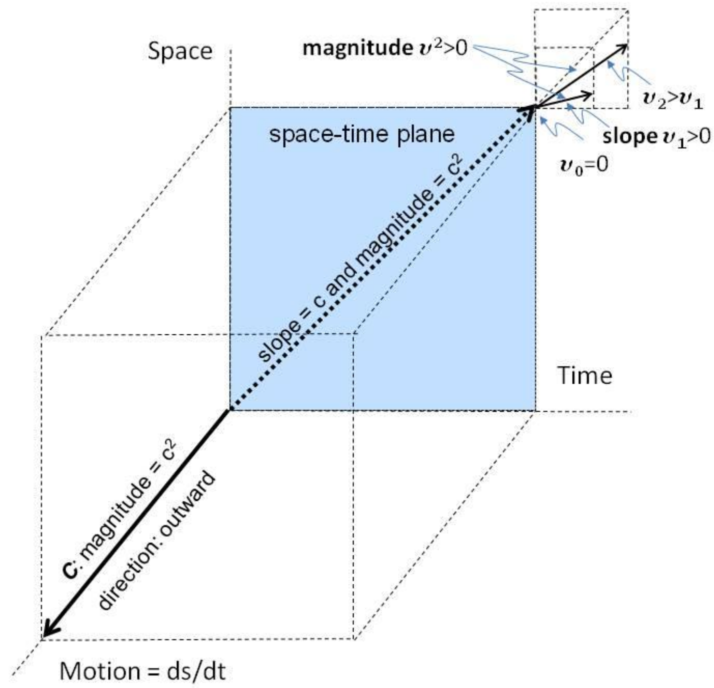



**Figure 1 The space-time-motion (STM) model. An isolated particle is represented as a vector, *C* and its relation to space and time only exists *in-potentia* as the slope of an imaginary projection of C onto the ST plane, until a separate reference frame is selected from which its relative motion can be measured.**

There is no such thing as a truly isolated particle and there exists an infinite number of inertial reference frames in the universe from which the particle could be referenced[3]. Therefore, the concepts of space and time exist *in potentia* and motion $\boldsymbol{C}$ can be represented in terms of $S$ and $T$ as the slope $c$ of the diagonal line on the $ST$ plane. This line is *conceptually* projected as a potential onto the plane with the same magnitude as $\boldsymbol{C}$, i.e. $c^2$. It is represented by the diagonal (natural units[4]) because there is no preferred scale for either space or time. Actual measurements will require scales ("unnatural" gauges that assign scalar values to $s$ and $t$) to be defined, but they are arbitrary and introduce an artificial skew to the geometric representation. In natural units (Jaffe, 2007), the value of $c = \frac{s}{t}$ is 1 and $c^2 = 1$.

Any one of the infinite moving reference frames, whose velocity is represented by the vector with slope $v$ and magnitude $v^2$ in Figure 1, would be located outside of the particle's surface, at the tip of $\boldsymbol{C}$**.** The smallest possible distance in space, $s$ from the particle's center represents the surface of the particle at $c^2$, which of course is the particle's *at-rest* reference

[3] There is no need for an absolute reference frame or an ether.

[4] see http://stuff.mit.edu/afs/athena/course/8/8.06/spring08/handouts/units.pdf and http://superstringtheory.com/unitsa.html for an explanation of natural units.

frame[5], i.e. $\boldsymbol{v} = 0$. All possible *moving* reference frames[6] (relative to the particle) are represented by $\boldsymbol{v}_n > 0$ and the maximum value of $v$, which would be oriented along the diagonal, is $c$.

This model represents measurable quantities; therefore numerical values (measurement scales represented by the dummy variables $s$ and $t$) are inherently dependent upon the natural internal motion of the particle. Because the slope of the diagonal represents the change in space (i.e. displacement) per unit time $(\Delta t \equiv 1)$, *it is numerically equal to the magnitude of one unit of space*, $\Delta s_0$ as shown in Figure 2a. Therefore, because relative velocity is referenced to the same gauge (*unit time*), the scale for external motion is numerically assigned to the same change in space (per unit time), which is *c*. The Lorentz factor therefore translates relative velocity $v$, to the natural scale defined by $c$, via the angle $\theta$ shown in Figure 2a and b, as follows:

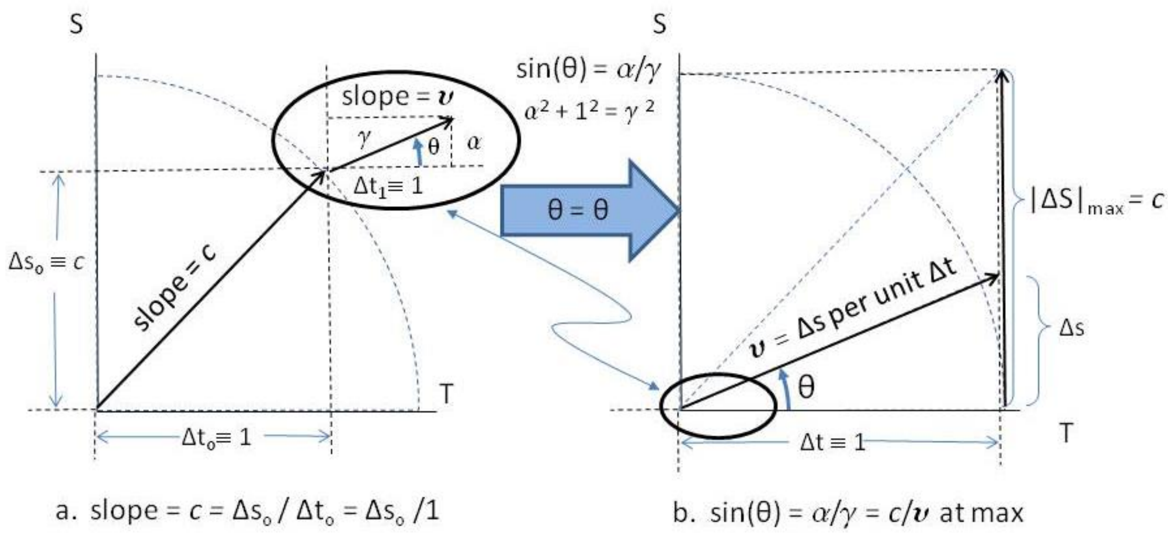



**Figure 2 (a) The speed of light (internal motion of a particle) sets the scale for space/time in terms of length per unit time. In natural units, light travels one unit of space, *c* per unit of time so the vector *C* is constant in magnitude and direction (out of the page) while $v$ can vary from 0 to *c*. (b) The Lorentz factor translates a measure of relative velocity to a fractional value of the maximum possible motion in one unit of time.**

[5] The fact that the at-rest reference frame is one (out of an infinite number) that seems to be shared by every visible object gives rise to the notion that there should exist some preferred ether. However, each object, no matter how small or large, has its own unique at-rest frame. Superimposing frames is a perspective that allows one to see the unity or continuity in discreteness.

[6] Even though Figure 1 represents an isolated particle at rest, the point $(s, t) = (1,1)$ which represents the surface of the particle, could be interpreted as a separate point particle that moves with time $(t)$ but remains at a constant distance $(s)$ from the origin. If it is measured, it appears to be a point particle, an electron, orbiting (i.e. motion at a constant distance) its own center.

As a separate system, in Figure 2a, the magnitude of relative velocity is labeled as $\gamma$ and the displacement in one unit of time is $\alpha$. If expressed as a fraction of its motion $\left(\frac{\alpha}{\gamma}\right)$, the numeric value of displacement $\alpha$ is the same at slow speed as it is at the maximum speed, $c$. Therefore, the same fraction, written in terms of $v$ and $c$, (i.e. $\frac{v}{c}$ ) provides the inherent gauge to which relative motion can be referenced:

$$\sin(\theta) = \frac{\alpha}{\gamma} = \frac{v}{c}.$$

The two terms on the right can also be squared and written as

$$\left(\frac{\alpha}{\gamma}\right)^2 = \left(\frac{v}{c}\right)^2 \quad \text{or} \quad \gamma^2 v^2 = \alpha^2 c^2$$

Because both time scales $\Delta t_0$ and $\Delta t_1$ are synchronized to a common time scale, one unit of time is the same for both vectors. Thus the sides of the small triangle (relative velocity) are related by

$$\alpha^2 + 1 = \gamma^2$$

or

$$\alpha^2 = \gamma^2 - 1.$$

Substituting for $\alpha^2$

$$\gamma^2 v^2 = (\gamma^2 - 1)\, c^2$$

$$\gamma^2 v^2 = \gamma^2 c^2 - c^2$$

$$c^2 = \gamma^2 c^2 - \gamma^2 v^2 = \gamma^2 (c^2 - v^2).$$

Thus

$$\gamma^2 = \frac{c^2}{(c^2 - v^2)}$$

and

$$\gamma = \sqrt{\frac{1}{1 - \frac{v^2}{c^2}}} \qquad (1)$$

which is the Lorentz factor. Thus the STM model provides a geometric representation of the Lorentz transformation from the at-rest perspective to the in-motion perspective of another inertial reference frame as required by special relativity. (Jackson, 1975 p. 515)

## Modifying the Minkowski model

The Minkowski space-time (ST) formalism developed in 1908 by Hermann Minkowski[7] is commonly used as an illustration of the properties of space and time as a continuum, so it will not be covered in detail here. J. D. Jackson calls it a "*fruitful concept in special relativity*" to describe "space-like" and "time-like" separations between two events, but it has attracted criticism over the years in its application. (Jackson, 1975 p. 518) Scott Walter described its initial presentation in 1908 and the "significant confusion" caused by the three-dimensional hyperboloid embedded in Minkowski's four-dimensional space (Walter, 1999). Brown and Pooley describe similar contradictions and call it "a glorious non-entity" in the sense that Leibniz considered space and time to be non-entities: "*Nonentities do not act, so for Leibniz space and time can play no role in explaining the mystery of inertia*." (Brown, 2004)

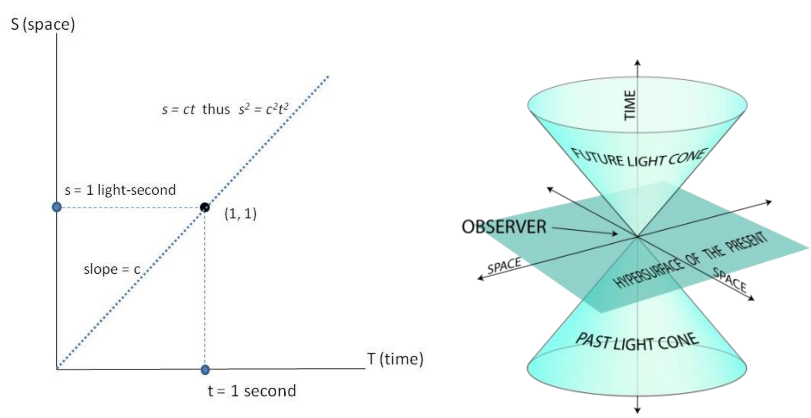
An explanation of the ST diagram might begin with time and space considered equally with one variable representing three-dimensional space (as a single dimension, $S$) and one representing time (as another, independent dimension, $T$), since $S = ct$ see Figure 3a. One unit on the time axis is shown as one second and one unit on the space axis is one light-second, or the distance in natural units that light travels in one second (Jaffe, 2007). So we imagine a flash of light at the origin ($t = 0, s = 0$) that expands at the speed of light and plot the point (1, 1).

A "light cone" in Figure 3b is formed by revolving the line ($c$ in Figure 3a) that connects the origin with the point (1, 1) around the $T$ axis to represent the limit of causality (causal influences such as signals cannot travel faster than the speed of light) and the intersection of the time axis with the space plane is said to represent the *event horizon* – the boundary of a theoretical black hole. Since any material particle must have a velocity less than the speed of light, its path in space and time is represented by a path along the time axis (called a world line) inside the light cone.

Mirroring the $T$ axis to represent the past as negative time provides a sense of distinction - an appearance of past, present and future as we seem to experience time, but it will be shown below that it also serves to hide the important relationship that gives meaning to time in the context of motion. The same effect of wiping away relationships occurred when the equation for spacetime was written by Einstein in his original paper (Einstein, 1905) as a four-vector ($x^2 + y^2 + z^2 - c^2t^2 = 0$) with space unfolded into three dimensions while time was left

[7] Reference http://en.wikipedia.org/wiki/Minkowski_diagram which references Minkowski's "Space and Time" english translation provided by Meghnad Saha at http://en.wikisource.org/wiki/Space_and_Time_(Saha)

as one. Why was it written like this rather than $s^2 = c^2t^2$? Partly because a model of 3D space and 1D time is engrained in our way of thinking, but in the 1890s, sophisticated techniques of non-Euclidean geometry had recently been invented and were being used in many areas to solve dynamic problems. (Walter, 1999)[8]. 3D space and 1D time is so obvious that it is usually the starting point of analysis, considered to be *a priori* knowledge. In fact Einstein didn't even bother to mention it before discussing the transformation of coordinates between stationary and moving coordinate systems. His derivation started with, "*To any system of values x, y, z, t, which completely defines the place and time of an event in the stationary system…*" (Einstein, 1905 p. 5)




a. b.

**Figure 3 (a) A normalized plot of time vs. space that illustrates the point that light travels one unit of distance (light-second) in one unit of time (second) (b) Minkowski's time vs. space diagram, (source: http://en.wikipedia.org/wiki/Minkowski_space) expanded to include the past as negative time and the future as positive time. This is an abstract representation since space is shown as two dimensions, the event horizon, an "hyperspace" of the present.**

But it is not necessary to unfold space into 3D. It is mathematically correct to leave the equation $(x^2+y^2+z^2 = c^2t^2)$ as the symmetrical version, $(s^2 = c^2t^2)$. The disadvantage to unfolding one side of the equation (to fit the visual geometrical model) without doing the same with the other is that it complicates the math, requiring parametrization in terms of hyperbolic functions (Jackson, 1975 p. 517) not to mention introducing a symmetry-break without a cause. Furthermore, the geometric approach that is supposed to help us visualize the nature of complex functions (Kreysig, 1979) becomes a distorted map of a map, so the advantage of the geometric model is depleted if not destroyed.

[8] Scientific readers appreciate sophisticated methods and once introduced, they become fashionable. For example, Steven Weinberg attributed Einstein's mistakes to his reliance on the principle of aesthetics and simplicity. "Since Einstein's time," said Weinberg, "we have learned to distrust this sort of aesthetic criterion. Our experience in elementary particle physics has taught us that any term in the field equations of physics that is allowed by fundamental principles is likely to be there in the equations." (Weinberg, 2005)

On the other hand, if space and time are symbolized as *concepts* with dummy variables[9], $S = s^2$ and $T = t^2$, then $s^2 = c^2t^2$ can be written as

$$S = Tc^2.$$

What this *means* is that space and time are equivalent, yet measurably different aspects of motion, just as $E = mc^2$ means that mass and energy are equivalent, yet measurably different forms of the same process. The variables $s$ and $t$ are simply the measurable scales and $c^2$ is simply the conceptual factor that relates the units of measurement.

The value of a geometric model is that it is supposed to provide an accurate visual representation of a mathematical model. It is a scale model of the components in an equation; each component represents a concept that can be quantified. The length of a line segment in a geometric model corresponds to a quantity so the relationship between it and other components, also modeled (or mapped) as the length of line segments, can be visually compared on the graph. The model has nothing to do with the physical size of the components being modeled, unless that component actually represents physical size. It has everything to do with the relationship of the quantities. The visual model serves as a kind of experiment that verifies the math and gives visual clues about the meaning of results, such as interactions of components, by showing the relationships between them. However, the map of an analytic function onto a hypersurface is only conformal (angle-preserving) at points where the derivative is not zero (Kreysig, 1979 p. 599). So when a function such as motion is reduced to scaled quantities, the scales must be discontinuous at the point where the function (which is the derivative of the scales) is zero.

### *Reductionism as a model-making process*

Reductionism is an important part of the scientific method. It is a technique that *refers* a complex concept to measurable quantities (i.e. quantizing). It must be followed by *inferring* meaning from the relationships. Reducing to measurable quantities is an effective starting point but a measurable quantity is a scalar, i.e. a single dimension that is mathematically represented (modeled) in physics as a single symbol. In modifying the model for spacetime, it is important to emphasize the point that models (coordinate systems, variables and equations) symbolically represent *concepts that can be quantified and distinguished from one another*. For example, $R$, could represent the total number of people in a room. But a person can be a boy or a girl so $R$ also represents the sum of mutually exclusive concepts (complementary antonyms): $X$ girls and $Y$ boys. All three variables can be graphically represented by line segments whose lengths (scalar magnitudes) correspond to the quantities that $X$, $Y$, and $R$ represent. As a linear

[9] Concepts, like experiences, are unmeasurable, multidimensional (esoteric) whereas mathematical symbols, including dummy variables represent scalar, measurable (exoteric) values

combination, $X + Y = R$ so the $X$ and $Y$ line segments can be *lined up end-to-end* and a physical measurement of the length of the resulting line should be $R$. If it is, it experimentally verifies the math.

If $R$ represents a set of concepts that are different but *not* mutually exclusive, such as height and weight as measures of size — it can be represented as a symbol that is *understood* to have more than one dimension. In this case, $R$ could be drawn as a two-dimensional surface, (or hypersurface) for example, by substituting a *dummy variable pair*, $rr = r^2 = R$. The dummy pair conceptually represents the same concept as $R$ - size - but the pair is only used to give $R$ a dual aspect. Each aspect is measureable and has a different meaning, but the individual $r$'$s$ have no meaning except as relational place-holders. If however, the $r$'$s$ are symbolized differently as, say $x$ and $y$, then the two-dimensional concept, $R$, can be expressed graphically, represented as different, orthogonal dimensions, e.g. vertical and horizontal. However, they can never be represented as equals, even if the quantity is zero[10] since they are conceptually different. Thus it must be understood and reemphasized that the axes and the quantities together represent the concepts. The axes are *scaled* using the same sized quantities (the numbering system) because numbers can be related geometrically, but they do not actually intersect.

So even though $R$ is not measureable directly, reducing it to measurable quantities and observing the relational quality allows one to derive a *sense* of the non-measurable size $R$ (a *continuum* that spans among four extremes: tall and thin, tall and fat, short and thin or short and fat). That *sense* of the relationship *emerges* from the overall shape of the two-segment graphic, which can itself be expressed as the slope of the *imaginary* line from the tip of one to the tip of the other. In a very simple way, this answers one of Balasubramanian's questions: *Can time be emergent from the dynamics of a timeless theory?* (Balasubramanian, 2013)

The imaginary line from the tip of one to the tip of the other is imaginary only in the sense that it does not actually lie on the same plane as height and weight. It is transcendent, i.e. its meaning transcends the meaning of the individual measurables. There is no need for a real line because its essence – the quality that it represents – is effectively projected (conformally mapped) onto the plane of measurables by their relative sizes. The two individual quantities (variables $x$ and $y$) have independent meaning and are mathematically related to $R$, but not by a linear relationship. They are one-dimensional concepts so adding them together does *not* give the two-dimensional concept, $R = r^2$ or the dummy variable $r$. Instead $x + y$ gives a quantity that is meaningless. However, $x$ and $y$ are also concepts themselves and every concept has a dual aspect — for every concept, there is an opposite: not-$x$ and not-$y$. In this case, since the concepts are measurable, their opposites are *gradable* antonyms, i.e. they have meanings that

[10] If the quantity is zero then the model no longer applies because zero means there is nothing to model.

lie on a continuous spectrum, like hot and cold. If that duality is represented as a sum (geometrically as positive and negative axes), then the axes will be assumed to pass right through the origin and the discontinuity at zero will be hidden[11]. However, by representing the duality as a product, (as geometric areas), $X = x^2$ and $Y = y^2$, then their sum $(x^2 + y^2)$ is equal to the area, $r^2 = R$.[12] As areas they can be added linearly to give the original concept; $x^2 + y^2 = r^2 = X + Y = R$, so they can be symbolically represented and geometrically related.

## The Space-Time-Motion (STM) Model

Look again at the $ST$ diagram, shown in Figure 4a. It represents the concept of motion, which is a form of energy, reduced to measurable quantities, $s$ and $t$. The graph on a two-dimensional plot is a collection of individual points, $(s, t)$ and the imaginary line that connects one point to another represents the magnitude of change between the two points. However, it's the slope that gives the *sense* of the emergent quality, motion. Symbolically, the slope is represented by the dummy variable, $c$, which is only one side of a square surface $c^2$ – the "motion plane". The one-dimensional line is a projection that *refers to* or *implies* motion but motion is not actually part of the *S-T* plane. Motion is what is *inferred from* the plane by the change (derivative) of space with respect to time. Therefore, in order to graphically illustrate it as a related concept it must be represented as a *tangent dimension* as it is in the $STM$ diagram in Figure 4. Since relative motion is what is actually experienced, even when an object is perceived as being at rest, it is conceptually *projected* onto the $ST$ plane as *potential* motion — a one-dimensional dummy variable.

[11] It seems trivial, and beyond the fundamentals class it is treated as being trivial, that a measureable quantity such as length (L), is actually a difference (L=x_1-x_0) rather than an absolute. It must be referred to a reference but if the reference is defined as zero, it is easy to ignore. The problem with that is significant: ignoring the reference creates an illusion, i.e. the apparent existence of an absolute reality.

[12] This also serves as a proof for the Pythagorean Theorem. (see http://en.wikipedia.org/wiki/Pythagorean_theorem).

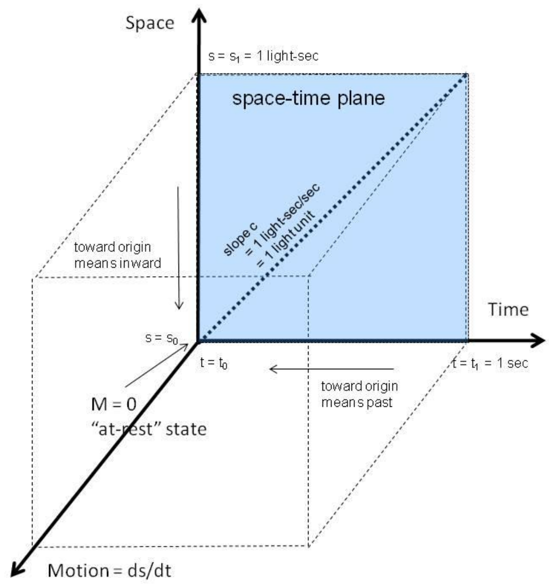



**Figure 4 The Space-Time-Motion (STM) diagram**

By definition, motion is a *change* in space. Time is just the name of the factor that scales it. Motion is what is ultimately real and space/time are merely the two scales that gauge motion. The difference in the two is that space plays the role as numerator, i.e. it numerates (quantifies or quantizes) motion whereas time denominates the quantity as a fraction of some reference. So motion is a fractional change in space in any direction. The denominator that it is referenced to (also quantified as "per unit time") is an arbitrary scale that was once measured by motion of the sun, moon, sand in an hour glass, etc. and eventually standardized to a device that moves more consistently[13].

Graphically, the quantity of motion is represented by the slope of the space-vs-time plot – numerically it is the fractional change in the reference dummy variable, $s$, with respect to the scale, $t$, so it could never exceed a value of one-to-one, which is graphically represented by 45$^{\circ}$. The region above 45$^{\circ}$ ("elsewhere" in Minkowski terminology) is meaningless in terms of speed. Instead, it refers to the inverse concept, call it lapse: the change in time with respect to space. It's not a very useful concept, but physically, it would be equally correct to say a car drives at a speed of 60 miles/hour (1 mile/minute) or a lapse of $\frac{1}{60}$ hours/mile (1 minute/mile). A passenger in the car could perceive the experience in one of three ways: 1) as stillness – zero motion (his unmeasurable reality) by closing his eyes, or he could choose to compare himself to his surroundings (his measurable perception); 2) as speed - referencing space by looking out the window at the mile markers and taking glimpses at his watch, "space-like"; or 3) as lapse -

[13] The decay of cesium is measured by the movement of a particle to a detector, so time is still measured by motion.

referencing time by looking at his watch and taking glimpses out the window, "time-like". His perception, and therefore his experience would be a function of his choice of perspective.

All three of these perspectives are represented on the STM diagram. In contrast to the Minkowski ST diagram none of the axes in the STM diagram intersect or extend in the negative direction because they represents change, which is quantified and modeled by positive increments on the axes. Just as the radius of a sphere is a positive measure from the center outward to the surface of a sphere, positive $s$ values represent outward-directed change in any direction in space. Similarly, positive $t$ values represent forward-directed change in time. Regardless of which "direction" it happens, the fact that it happens means that it is positive[14]; it can never "un-happen". Mathematically, it is not incorrect to use negative dummy variables ($s = -\, s'$ and $t = -t'$) because the magnitudes of $S = s^2$ and $T = t^2$ gives the same result: a mirror image of outward expansion.

On the STM diagram, a negative direction on the $ST$ axes (from the tip of the arrow toward the origin) represents inward, toward the center of the sphere – where the light flash originated at some position, $s_0$ and time, $t_0$. What appears to be an intersection is neither zero time nor zero space; it represents the zero-motion perspective or "at-rest" state. The word *state* is used to mean the same kind of state as that used in quantum mechanics. The at-rest state of a light flash is what the light sphere itself would see if it could measure itself. From its perspective, it is not expanding or moving. Instead, it sees the flash bulb along with the coordinate scales on the $ST$ axes shrinking or collapsing into its infinite center.

So rather than making "past" time and "future" time point in opposite directions as Minkowski did, the STM model represents the present (here and now: position, $s_1$ and time, $t_1$ in Figure 5) as the event point of reference. It corresponds to Minkowski's "Event Horizon" but it is modeled as a point at the coordinate (here, now). Conceptually it simply sets and resets the reference.

"Outside" of the event horizon, a linear scale is used to illustrate measureable increments of change in space and in time. For example in Figure 5, *Event 1* represents the flash and *Event 2* represents the measurement of the light reaching 1 light-second in 1 second. Every event that came <u>before</u> *Event 1* is represented as a point closer to the origin. Therefore events that have "passed" must be represented on a non-linear, inverse scale. It is an inverse scale because, from the future perspective, a previous event horizon would be drawn with a radius whose magnitude is the inverse of the linear-scale number. If event 1 is plotted at (1, 1), and event 2 is at (2, 2), then event 1 is plotted on the $S$ and $T$ axes at one-half the value as event 2.

[14] If it is desired to model direction in space, then the space axis can be unfolded, which would hide the time axis from the 3D representation. Effectively, it would be understood or "collapsed" into the mind as information (Matzke, 2002).

A measurement of event 2 would mathematically reduce it or conceptually/graphically *collapse* it to (1, 1), i.e. the present moment

- 2 light-sec/2 sec = 1 light-sec/sec = 1 light-unit= ½ light-units/ ½ units.

Ergo, event 2 collapses to (1, 1) and event 1 collapses to (½, ½).

Both events are created by the same light unit, yet they can be distinguished (perceived) as separate events because they are measured and plotted on space and time scales that are conceptually different. The non-linear scale makes it look like the axes in Figure 5 *bend* into the page, which if interpreted as actual space rather than a concept, could be considered a black hole[15]. But because this is just a conceptual model, it simply represents information that "collapses" into the infinitesimal center of the light sphere, beneath the hypersurface of the present and into the past, becoming an integral part of the particle. On the other hand, the motion – the vector that graphically projects out of the page — is linear. It is the quality of the experience that can be sensed but requires two antonymous dimensions (a vector, i.e $c^2$ ) to be described.

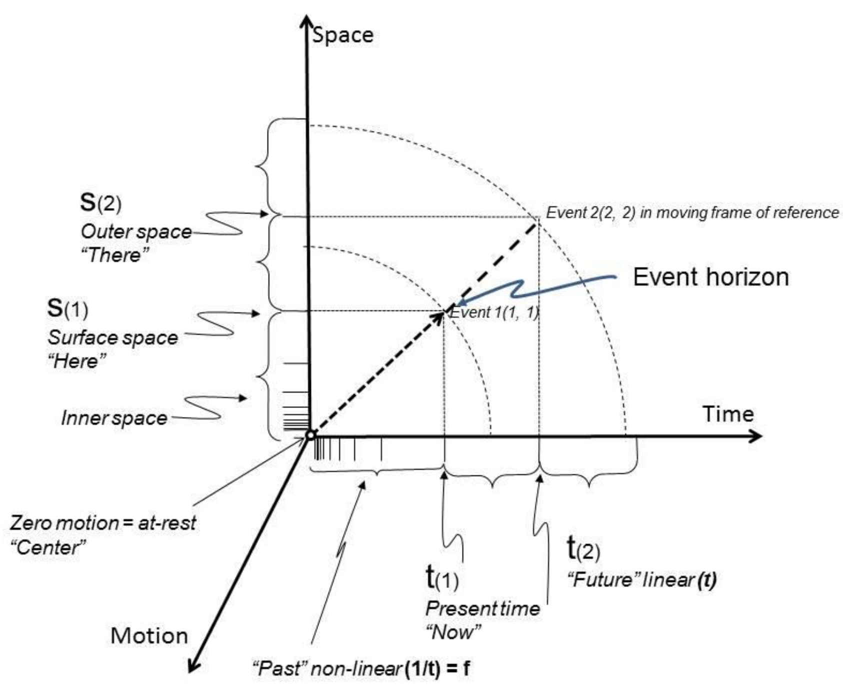



**Figure 5 Event horizon from the at-rest perspective of the flash bulb**

[15] Interpreting this singularity as a physical hole in space is thus a map-territory error

The major advantage of the STM diagram is that it graphically represents energy of motion as a continuum that can be perceived as the superposition of the at-rest and in-motion perspectives, as functions of space and time, as well as functions of energy and frequency, all on appropriately scaled axes. The origin represents the Lorentz-translated reference for the particle/wave inertial frame (its surface) to which other particles can be measured moving in space and time. It also represents the infinitesimal center of the particle/wave as mass and since the two angles that separate the diagonal from the T and S axes can be expressed as $\omega t$ and $ks$ a wave equation can represent the particle using Euler's equation (an eigenfunction) in space and time

$$\Psi(s,t) = e^{-i(\omega t - ks)}$$

where are the complementary angles $[(\omega t - ks) = \frac{2\pi}{\lambda}(ct - s) = \frac{p}{\hbar}(ct - s)]$ contain all the variables needed for operators in quantum mechanics.

As a quantum particle at rest it has $E_o = mc^2 = hf$ , where $E_o$ is the rest energy, $m$ is the mass, $h$ is Planck's constant, and $f$ is frequency. As discussed above, frequency is simply the inverse of the time scale and the natural scale of the "past" inside the event horizon. The relationship $\frac{E_o}{f} = h$ is revealed by the STM diagram in Figure 6 as the same relationship as velocity, but instead of representing motion as the ratio of space per unit time, it is represented as energy per unit frequency. Plank's constant is seen to be the scaling factor that relates the two just as *c* is the scaling factor that relates space and time. From the relations $c = \frac{\omega}{k} = \lambda f$, and $p = \frac{h}{\lambda}$, the relation between the two can be found to be $h = \frac{p}{f}c$.

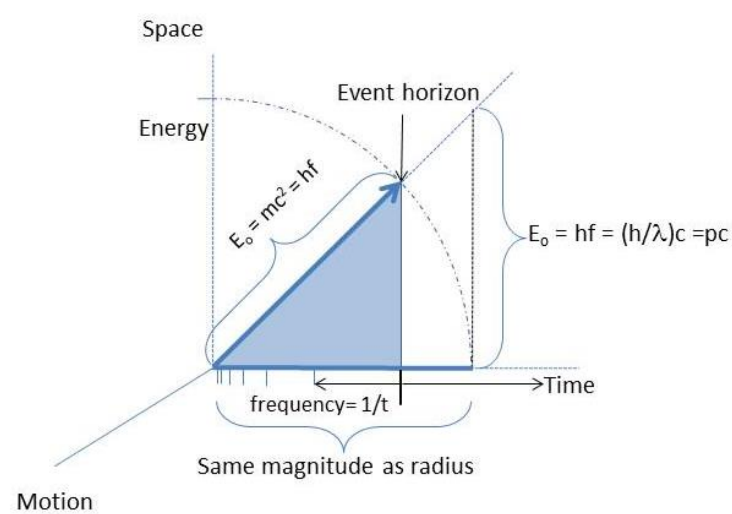



**Figure 6 Energy and frequency are naturally represented inside the event horizon in the STM diagram**

In graphical terms, $h$ is the slope of the diagonal on the $E$ vs $f$ part of the diagram – the same slope as $c$ only de-magnified by the scale $\frac{p}{f}$. In terms of space and time, the slope $h$ is the derivative with respect to time, $\frac{\partial}{\partial t}$. Thus projections on the STM diagram represent elements of quantum mechanics such as the Energy operator - the product of the magnitude (normalized to a unit cycle) $\frac{h}{2\pi}$ and the slope $h$ with the unit vector $-i$ to indicate projection as a rotation: $\hat{E} = -i\hbar\frac{\partial\Psi}{\partial t}$

Using the same reasoning as that used to justify the conclusion that the vertical leg in Figure 2 has magnitude $c$, the vertical projection in Figure 6 has the magnitude $E_o = hf = \frac{hc}{\lambda} = pc$.

The resulting triangle accurately depicts the well-known relationship for total energy of a particle:

$$E^2 = (pc)^2 + (mc^2)^2. \tag{2}$$

It is identical to one commonly used as a mnemonic device (Halliday, et al., 1993) to illustrate the components in Special Relativity. This is shown in Figure 7 as the hypotenuse of the in-motion triangle represents total energy $E = mc^2 + KE$ where $KE$ is the relativistic kinetic energy

$$KE = mc^2(\gamma - 1). \tag{3}$$

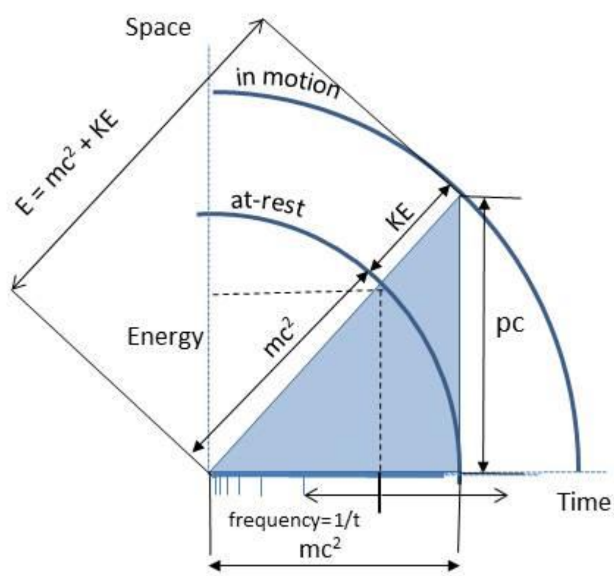



**Figure 7 The difference between the at-rest and in-motion diagrams is**

Combining equations, the total energy is

$$E = mc^2 + KE = mc^2 + mc^2(\gamma - 1) = mc^2 + mc^2(\gamma) - mc^2. \quad (4)$$

or

$$E = mc^2(\gamma). \quad (5)$$

Therefore the projection of total energy (both actual and potential motion of the particle represented by the hypotenuse of the large triangle) onto the space-time plane is de-magnified or *condensed* into space (projected onto the space axis) emerging as a spherical particle that may be perceived at rest, as a bundle of energy in a particular position ($x$), or in motion with momentum ($p$). The Heisenberg uncertainty principle is also revealed to be a restatement of the relationship $h = \frac{p}{f}c$. By substituting $f = \frac{c}{\lambda}$ and $\lambda = 2\pi\Delta x$, where $\Delta x$ is one unit of space in any scale, $h = \frac{pc}{c/\lambda} = p\lambda = 2\pi\Delta xp$ or $\Delta xp = \frac{h}{2\pi}$. In essence, it is the same as the speed limit for physical particles.

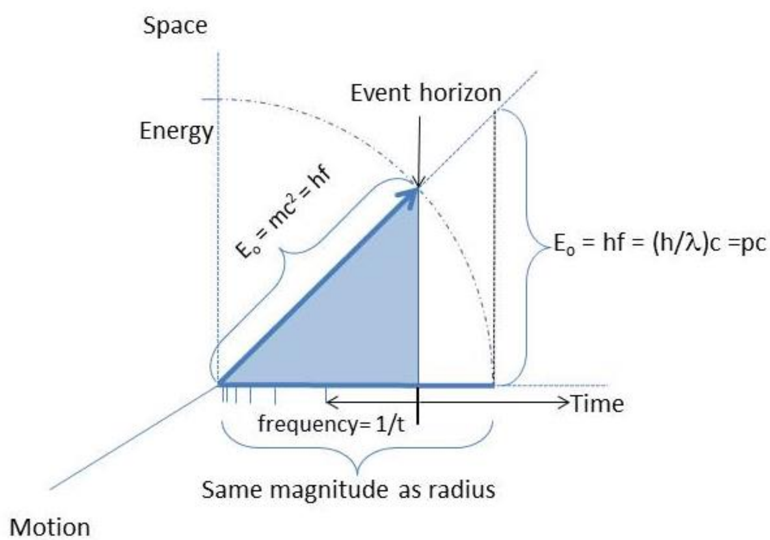



**Figure 8 STM diagram shows the relationship between Energy and frequency**

## Conclusion

Physics was originally based on the idea that there exists an observer-independent reality and that time was something that exists (Condon, 1960). But close examination of physical objects and the mystery of time is has led to ambiguities, paradoxes and claims of failure (Smolin, 2006). However, the recent turn to a relational approach to physics, often referred to the process philosophy of Alfred North Whitehead. (Epperson, 2009) (Epperson, et al., 2013) (Clayton, 2004) (Eastman, et al., 2004) (Cahill, 2003) (Cahill) Process philosophy is a position that "*pledges itself to explain the physical world by the aid of motion alone*." (Keeton, 2004). The word "process" is a metaphysical word[16] in that its meaning contains *both* spatial and temporal components as integral parts of motion as an *experience*. This is in contrast with the reductionist philosophy that considers complex systems to be nothing more than the sum of their parts, which *assumes* that there are permanent "parts" to sum. In process philosophy, "experiential units" are considered basic elements of reality. "*Time is not an incidental aspect of reality, added on to fundamentally static things; instead, temporal change is a fundamental feature of the physical world itself.*" (Clayton, 2004)

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[16] Metaphysics should not be a source of concern in a physics paper. It simply refers to meanings, relationships and concepts that transcend the physical components that interact. Cosmology is now considered a scientific study, because it has forced nearly everything into the standard physical model, but it is actually a branch of metaphysics in that it deals with both physical and non-physical nature of the universe.

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