Appendix H

Elementary sub-atomic particles:
the earliest adaptive systems.

G. Blackwell

contact

ABSTRACT

Purpose

This paper considers a perspective on particulate matter as being formed from closed loops of waveform energy flow, consistent with observations by de Broglie, Schrödinger and others and supported by recent research findings. It demonstrates that all experimentally verified findings of Special Relativity (SR) may be derived directly from such a model. It further shows a clear form of auto-adaptive behaviour exhibited by such structures.

Design/methodology/approach

A generalised closed-loop energy flow model is analysed from first principles.

Findings

Motion-dependent time dilation, invariance of the measured speed of light, the Lorentz transformation, mass-energy equivalence ($E=mc^2$) and speed-related increase in apparent mass all follow naturally from this structure. Given this view of matter objective invariance of the speed of light relative to all inertial states of motion is an unnecessary and insupportable assumption. A unique objective rest frame (subject to Hubble expansion of space) is identified. All elementary sub-atomic particles owe their longevity to a non-destructive state-change response to energy input, referred to as 'motion'. A radically new perspective on time is presented. A possible causal explanation for particle-antiparticle asymmetry is identified.

Research implications

Closed timelike curves are not a possibility. Further implications for all fields of physics are very extensive.

Practical implications

No conflict between superluminal technologies and causality. Over and above this, possible practical implications are too extensive to be enumerated.

Originality/value

Totally original and of significant potential value in various respects.

Keywords: Relativity, particle, de Broglie, zitterbewegung, superluminal, time.
[N.B. keywords varied slightly by publisher on publication – see Paper URL: https://www.emerald.com/insight/content/doi/10.1108/03684921111118004/full/html]

Foreword

In order to address fundamental issues fully objectively this analysis avoids dependence on standard expressions that may nevertheless contain implicit assumptions (*e.g.* frame equivalence, embedded in formulae from Special Relativity but shown here to be open to question).

1   Introduction

Over recent years a great deal of research effort has been invested in unifying the various fundamental forces of nature, with considerable success (Glashow, 1980; Weinberg, 1980; Salam, 1980; 't Hooft, 2000; Veltman, 2000). Inclusion of the strong nuclear force and gravitation has focused on attempts to link them at the time of the Big Bang and show divergence of those forces as the universe expanded.

Perhaps surprisingly, no such major effort has been made to unify the two known types of physical entity created in that primordial event, photons of electromagnetic energy and the elementary particles from which all matter is formed. This is all the more remarkable as there is known to be a very strong link between those two entities: photons are constantly being emitted from and absorbed by particles of matter, transitioning between forming part of the energetic composition of an atom and existing as free energy; particle-antiparticle pairs are known to be capable of annihilating one another totally, transforming pure matter into pure energy (Cabibbo and Gatto, 1961; Cabibbo *et al.*, 1962; Di Vecchia and Greco, 1967; Schwitters and Strauch, 1976; Bernardini, 2004). The reverse process is also well established (Landau and Lifshits, 1934; Barbiellini *et al.*, 1974; Baldini *et al.*, 1979; Cooper, 1988; Ginzburg, 2006).

More than this, extensive evidence supports the premise of Special Relativity that every particle of matter has energy content proportional to its mass, whilst Quantum Mechanics defines a particle in terms of a wavefunction that has been shown to relate directly to its physical behaviour (Davisson and Germer, 1927).

Given these considerations it is highly pertinent to query why a one-off spontaneous event should so coincidentally generate two quite different types of entity that just happen to interact so effectively with one another. As with the fundamental forces, it is appropriate to consider whether they are, rather, different manifestations of essentially the same phenomenon.

The generally accepted view of the Big Bang creation event as starting with a singularity of infinitesimal size overwhelmingly dominated by high-energy photons offers very fertile ground for a virtually infinite variety of electro-magnetic constructs resulting from the tight confinement of those photons. (Stretching of photons by Hubble expansion of space indicates that spatial expansion is not a simple concomitant of photon propagation). In the first instants after that event motion would have necessarily been non-linear, giving rise to interactions – including self-interactions – resulting from electromagnetic field effects significantly more complex than those found in the familiar solution to Maxwell's equations that describes conventionally propagating electro-magnetic waves.

Of those accidental constructs many would not have survived under the conditions that prevailed at that time or since. Any that did would only have

done so by virtue of a structure that automatically accommodated frequent energy inputs and interactions with other energy constructs. In the immediate-post-big-bang field of unlimited possibilities it appears that this may indeed have been the case for a tiny proportion of those earliest photons, giving rise to auto-adaptive self-perpetuating energy patterns that we now refer to as 'particles'.

Louis de Broglie was the first physics Nobel laureate to be awarded this distinction on the strength of his PhD thesis, which proposed a wave function for an elementary particle (de Broglie, 1925). That wave function was given explicit form by Schrödinger to become the Quantum Mechanical description of matter The Copenhagen interpretation of that wave function regards it as simply a statistical description of particle behaviour, but de Broglie himself saw it as indicative of a deeper truth (de Broglie, 1927), as did Einstein (Einstein, 1926).

Schrödinger first identified a jittery motion ("zitterbewegung") in the behaviour of an electron (Schrödinger, 1930), a fluctuation in position at the speed of light around its median location. This phenomenon is clearly indicative of a cyclic component in the fundamental structure of an electron (Huang, 1952; Barut and Bracken, 1981; Hestenes, 1990).

It has now been demonstrated that zitterbewegung corresponds to a physical periodic oscillation in the substructure of an electron (Catillon *et al.*, 2008). It has also been shown analytically that a closed-loop electromagnetic wave construct could account for the characteristics of spin, magnetic moment and static charge as measured in an electron (Williamson and van der Mark, 1997). These observations create a compelling case for considering the compatibility of such a construct with other aspects of particle behaviour and its possible causative role in related well-established effects.

It is shown here that the cyclic-energy model of matter provides a complete explanation for all of the experimentally validated findings of Special Relativity (SR): motion-based time dilation; measured invariance of the speed of light from all inertial states of motion; Lorentz transformation; mass-energy relationship $E = mc^2$; speed-dependent increase in energy content (hence also effective mass) of any object.

It is further shown that the measured invariance of the speed of light is a direct consequence of that particle structure, a subjective experience of an object in motion rather than an absolute reality. From this it follows logically that the SR assumption of frame equivalence is not only redundant for explanation of observed phenomena, it is actually incompatible with this fully consistent perspective on the physical realm.

The existence of a unique objective reference frame, as shown here, and the subjective nature of perceived event sequencing from all other reference frames rules out any possibility of superluminal communication leading to breaches of causality, which depend on differing objective orderings of events in different frames.

The new view of time presented by this model also discounts any possibility of closed timelike curves (a subject of ongoing debate: Hawking, 1992; Sushkov, 1995; Bonnor, 2003; Friedman and Higuchi, 2006). Threats to causality from any future scientific or technological developments are thus nonexistent from this perspective.

2   Static charge

An electron exhibits wavelike behaviour when scattered off a crystal lattice (Davisson and Germer,1927). Since the destination of such a scattered electron, including its charge, is determined probabilistically from the quantum wave-function that describes the particle, it follows that the charge must be an integral feature of that wave. Rather than being some sort of 'nugget' tucked away inside the electron, charge must be an artefact of that waveform structure. *I.e.* static charge is the macroscopic net external effect of the time-varying electromagnetic fields that comprise the waveform nature of the electron.

Every one of the infinite variety of polarisation modes of a photon can be resolved into a linear combination of just two modes, left and right circular polarisation. In that respect these two modes can be seen as the fundamental polarisation modes of all electromagnetic radiation. Matching configurations of left and right circularly polarised cyclic (closed-loop) photons, with roles reversed, are ideal candidates for particle-antiparticle pairs.

It should now be noted that these two polarisation modes are not fully symmetric. Whilst the rotational pattern of each is a mirror image of the other, orientation of electrical and magnetic field components in one is *not* mirrored in the other – the juxtaposition of those field components is *the same* in both modes. There is, then, an intrinsic asymmetry in these fundamental elements of the structure of the universe.

Whilst phenomenological evidence for particle-antiparticle asymmetry is well documented (Nambu, 2008; Kobayashi, 2008; Maskawa, 2008), no causal explanation has yet been advanced for such asymmetry. The case for cyclic-photon formation of elementary particles is substantially strengthened by this clear cosmic structural asymmetry which could be responsible for observed effects.

Williamson and van der Mark (1997) describe how residual external field effects could account for the measured static charge associated with an electron formed from a closed-loop circularly polarised photon. In later work (Williamson, 2008) the authors introduce the novel concept of a 'pivot', modelled as a ponderous mass, to provide a focus for a closed-loop photon.

Since a photon carries zero charge it follows that any net external charge to a cyclic photon construct must be balanced by a net internal charge of opposite sign. In this sense an electron is not an electric monopole: the other pole of what is in fact a dipole is *inside* the electron.

This is totally analogous to a hollow spherical magnet with one pole on the outer surface and the other on the inner surface, albeit on a very small scale.

It is here proposed that the pivot introduced by Williamson and van der Mark could in fact be that internal charge, better envisaged as an electrical field effect acting from every point on the photon circuit upon every other point in that circuit. Field interactions across the interior of the photon circuit would necessarily create an asymmetry in the photon's electromagnetic wave function, resulting in a curved path that could well describe a self-perpetuating closed loop. Conditions in the initial infinitesimal-sized proto-universe would have been ideal for proliferation of such constructs.

Particle-antiparticle annihilation follows logically from this description. As soon as an electron and a positron are coincident in the same space (drawn to that position by their opposing charges), their respective internal electrical charges cancel out (as do their external charges) and there is nothing to hold either of the two formative photons in their cyclic path. As a result two conventional linear photons of identical energy content to their particulate counterparts are released (in opposite directions, so conserving linear momentum).

3   Motion-dependent time dilation

If a particle is formed from a cyclic energy flow then when that particle is set in motion its formative energy flow will follow a form of spiral path. In the simplest case, if the formative energy of a static particle traces out a circular closed loop then giving the particle a linear motion perpendicular to that loop would result in the energy flow describing a helical path whose central axis is the particle's direction of motion (Fig. 1).
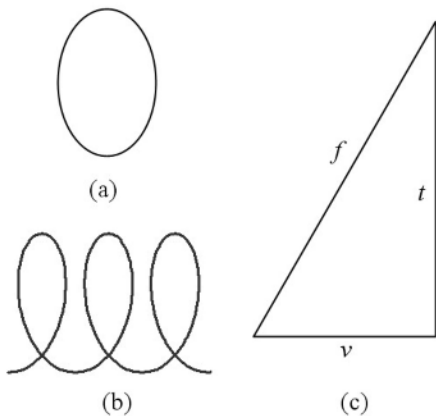

Figure 1

(a) Repeated circular motion in a vertical plane.

(b) Repeated circular motion as in (a), combined with linear motion perpendicular to the plane of circular motion.

(c) Spiral motion as in (b), unwound to show vertical turn and horizontal velocity components, t and v, of overall flow/flight speed f.

Using the analogy of a mosquito in flight: if a mosquito is tracing out a vertical circle, repeatedly, at top speed (Fig. 1a) and is then induced by some means to move horizontally perpendicular to that vertical plane, whilst still flying in the same sized circles*, it will describe a helical path as shown in Fig. 1b.

Moreover it will now trace out fewer circles per minute than it did whilst not moving horizontally as some of its flying time is taken up with the linear component of its flight path. [*There is no reason to suppose that a particle may change its dimensions perpendicular to its direction of travel simply as a result of adopting a state of motion. Such a conjecture can be shown to be incompatible with the SR hypothesis of frame equivalence, eliminating the possibility of either of these proposals being proved on the basis of assumption of the other. Invariance of lateral dimensions under motion is implicitly supported by its satisfaction here of a wide range of observed phenomena.]

By 'unrolling' the mosquito's flight path, considering it as a straight line in the direction of the helix angle – effectively tangential to that helix – it can be seen that the cyclic (vertical) component and linear (horizontal) component of that path form two sides of a right-angled triangle of which the unrolled helical path forms the hypotenuse (Fig. 1c). In other words the rotational turn component t, the linear horizontal velocity component v and the composite flight component f are linked by the Pythagorean relationship: $f^2 = t^2 + v^2$.

Returning now to the circular-path formative energies of that simplest-case particle: when that particle is in motion as above, the cyclic (intrinsic) flow component – labelled t for reasons given below – and the (extrinsic) linear velocity component v form that same Pythagorean triple with the overall energy flow speed f, namely: $f^2 = t^2 + v^2$. This follows directly from consideration of the mosquito analogy.

If a particle is formed from a cyclic energy flow then any time-based effects within that particle must be disseminated around its structure by that energy flow – there is nothing else. Likewise interactions between that particle and its environment must be mediated by that energy flow. For that particle its formative energy flow *is* the flow of time.

It follows that if for any reason its rate of cyclic energy flow changes then the rate of time experience will change correspondingly for that particle. Halve the number of cycles per second described by that energy flow and time will run at half-speed for that particle. Every second ticked by a clock made from particles so affected, be it mechanical, quartz oscillator or atomic, will last twice as long.

And there we have motion-dependent time dilation. A particle in motion experiences less cycles per second of its formative energies than that same particle at rest in accordance with the Pythagorean triple given above, where t now represents rate of time experience. That reduction in cycle rate leads to a corresponding reduction in the rate of time experience. If t_0 represents the rate of time experience for a static particle, *i.e.* $v = 0$, so that $t_0 = f$, then we have:
$$t/t_0 = \surd(1 - v^2/f^2).$$

Translating this into the conventional form for time dilation, increase in actual duration of each second ticked by a clock moving at speed v is given by time dilation factor $1/\surd(1 - v^2/f^2)$. This corresponds to the Lorentz factor γ, as used in SR, with the speed of light c replaced by energy flow speed f.

The result derived here for a particle formed from a circular energy loop, moving linearly in a direction perpendicular to that circular path, can be shown to hold for any closed-loop particle structure, of any complexity, moving in any direction. Rather than simply assuming energy flow speed f to be equal to c, this is shown to be the case in the next section, bringing this result into complete agreement with the well-proven SR time dilation factor.

This perspective on time is supported by three observations from SR:

(1) The mathematics of spacetime show effects of time as perpendicular to all spatial dimensions. The above analysis showing spatial velocity and time experience varying as the two mutually perpendicular sides of a right angled triangle, regardless of the direction of spatial motion, shows why this would be so. Note that this mathematical relationship does not require or imply that time is itself a 'direction' as is generally supposed.

(2) In SR the time co-ordinate is subject to a factor of i ($= \sqrt{-1}$). This requirement, marking time as an imaginary dimension (in the mathematical sense) indicates that the SR interpretation may be in some way back-to-front, a mirror image of the true reality. This matches well with the above proposal that, rather than objects moving through time as in SR, time in fact moves through those objects in the form of cyclic energy flows.

(3) The 4-dimensional formalisation of spacetime requires measurements in the time dimension to be multiplied by c, indicating that time in some sense has a speed c. This is shown here to be literally true since time effects are carried through material objects at the speed f of their formative energy flows, shown below to be equal to c.

In brief: whilst interactions in space and time are well described by a 4-dimensional mathematical model, attributing time effects to a physical pseudospatial dimension is arguably an unwarranted extrapolation from that model. Without such a physical time dimension closed timelike curves could not exist.

4   Invariance of the Speed of Light

The invariance of the speed of light as measured from all inertial frames of reference has been well established for over a century. This central postulate of SR has been interpreted as meaning that the speed of light is objectively absolute, with the knock-on consequence that all inertial reference frames are taken to be equivalent. The cyclic photon description of matter offers an analytical derivation of that invariance requiring no such assumptions.

Events affecting a moving object are necessarily evaluated and assimilated in terms of their appearance and behaviour relative to that moving object. This statement of the apparently obvious requires clarification in the context of a perspective that doesn't implicitly assume frame equivalence.

In the SR perspective a car travelling along a road and being confronted by a stationary tree across that road may equally well be viewed as a section of

landscape that includes a tree across a road sweeping along to encounter a stationary car. Both interpretations are considered to be equally valid, since motion is seen as a wholly relative state. This mundane example illustrates a principle regarded as operating at all scales of size and speed, from the sub-microscopic to the cosmic.

In the cyclic photon view on particle structure a static object has no extrinsic (linear) component to its constituent energy flows, which are wholly intrinsic, describing cycles that form the particles making up that object (setting aside any internal motions of particles within the object). By contrast a moving object would include extrinsic components to all of its constituent particle energy flows in the object's direction of motion. It is shown in Section 5 that this is not a reciprocal relationship, *i.e.* that roles of static and moving object are objectively defined by their respective energy flows (though subjective impressions may indicate otherwise).

Even though positions of objectively static and moving object are not inter-changeable, it is nevertheless the case that the car moving along that road will experience its interaction with the tree in much the same way as if it were static and the tree were moving. That perspective must then be evaluated in the light of the fact that the energetic makeup of the affected object (the car in this case) differs from that of the same object when static.
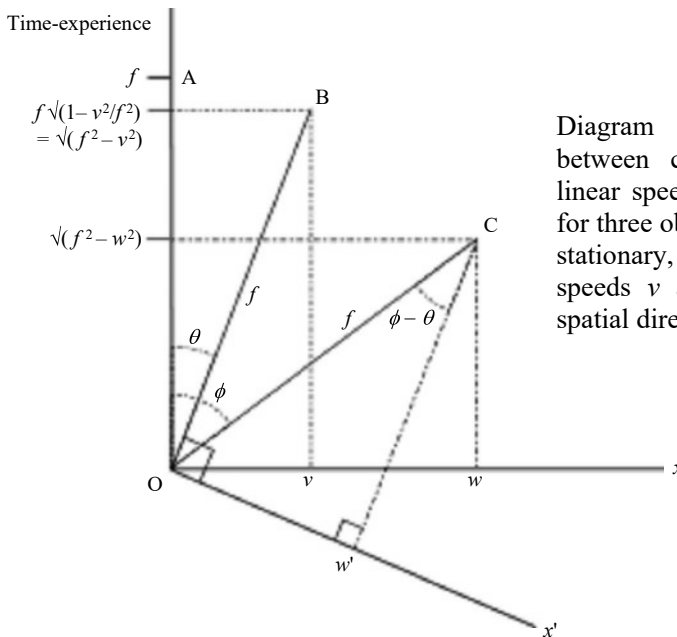

Figure 2

Diagram showing relationship between cyclic energy flow f, linear speed and time experience for three objects A, B and C. A is stationary, B and C are moving at speeds v and w respectively in spatial direction x.

Figure 2 shows diagrammatically the relationship between linear speed, time experience and cyclic energy flow speed, for a stationary object A, an object B moving at speed v in direction x and a third object C also moving in direction x.
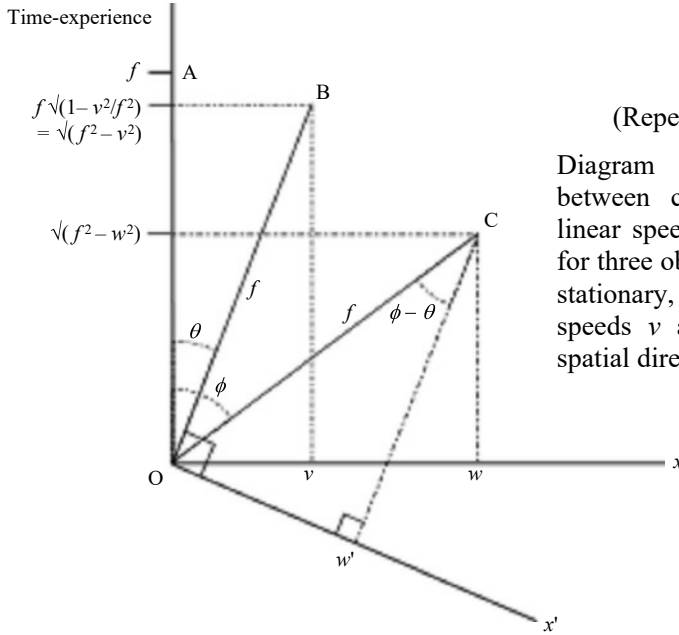
Time-experience

Figure 2

(Repeated for reference)

Diagram showing relationship between cyclic energy flow f, linear speed and time experience for three objects A, B and C. A is stationary, B and C are moving at speeds v and w respectively in spatial direction x.

Being in a state of motion, B will experience everything from the oblique 'helix-angle' of its formative energy flows, *i.e.* as if its personal energy flow orientation (shown as OB in Fig. 2) is the time-experience axis for a static object (as OA is). It will thus interpret its own subjective axis x', at 90° to OB, as the true spatial axis, and so evaluate C's speed based on w', the projection of C's personal energy flow OC onto that axis.

From Fig. 2 it is apparent that: $w' = f \sin(\phi - \theta)$

However B's state of motion also leads it to experience a time dilation factor of: $1/\sqrt{(1 - v^2/f^2)}$, equal to sec θ, giving:

$$\text{B's perception of C's speed} = f(\sin\phi - \tan\theta\cos\phi) = w - v\sqrt{\frac{f^2 - w^2}{f^2 - v^2}} \qquad (1)$$

This is not identical to the corresponding expression from SR, which is based on an implicit assumption of frame equivalence. However it gives similar consequences in terms of relative speeds. First, if v and w are small compared to f then:

B's perception of C's speed $w - v$

I.e. at low speeds compared to energy flow speed f, B's experience of C's speed is the conventional expected relative speed.

However as w^2 approaches f^2 the term in v diminishes, reducing to zero in the limit when $w = \pm f$. *I.e.* when C's actual speed is the speed of the cyclic energy flows making up material particles, then:

B's perception of C's speed $= w = f$

regardless of B's own speed.

In other words, an energy flow moving in a wholly linear spatial direction with no cyclic component (and so also no time experience) would be experienced by all other objects, regardless of their own speed, as if it were moving at speed f relative to them. [This result, proved here for energy flows collinear with object motion, can be shown to hold for energy incident on a moving object at any angle relative to object motion.]

This quality, which is known to apply to light, can only hold for one such speed – the mathematics do not permit otherwise. It thus follows that cyclic energy flows forming particles of matter travel at c, the speed of light *in vacuo*. c will therefore be used in place of f throughout the rest of this paper.

The measured invariance of the speed of light is thus shown to be a result of the structure of material particles rather than an intrinsic property of light itself. This analysis also shows why light is regarded as not experiencing any passage of time.

5   Asymmetry of states of motion. Unique objective reference frame. Compatibility of superluminal communication and causality.

Equation 1 in Section 4 shows how simple analysis of the cyclic-photon model of matter leads directly to results for perceived relative speeds, of motion both at low speeds and at the speed of light, that are supported by extensive empirical evidence. That equation also shows that this model neither requires nor supports the SR view of all inertial reference frames as being equivalent.

If $w = 0$ in Equation 1, *i.e.* object C corresponds to stationary object A, then that equation gives B's perception of A's speed as: $-v/\sqrt{(1 - v^2/c^2)}$, which is *not* equal and opposite to A's perception of B's speed. *I.e.* A's frame and B's frame are not symmetric.

This has significant implications for the SR perspective on the Lorentz Transformation, which SR regards as a symmetric rotation in spacetime. That perspective is apparently supported by the skew-symmetric transformations from x to x' and t to t' as reproduced below. However that symmetry implicitly assumes the very thing that it appears to prove, in that the value to be used in place of v is assumed to be $-v$ rather than some other value v'.

The above analysis makes it clear that this is not a valid assumption and that, as derived from the cyclic energy flow perspective on matter, the full Lorentz Transformation is not symmetric*. It further points logically to a unique rest-frame in which the formative energy flows of all static objects are wholly intrinsic (cyclic) with no extrinsic linear velocity component. All objects apparently static in any other reference frame include a linear velocity component in their formative energy flows.   [* But see end-note following references]

This unique reference frame, denoted **R** here, is likely to be comoving with the rest-frame of the Cosmic Microwave Background Radiation (CMBR). **R** (spatial axes indeterminate) is the definitive frame for objective ordering of cosmic events and objective assessment of speed of any object.

Given this unique objective ordering, time travel as allowed by SR in the event of superluminal communication is not in fact a possibility. Hence there is no risk of superluminal communication undermining the universal principle of causality.

6 The Lorentz Transformation [See also footnote, below]

For the purposes of derivation of this transformation use is made of Einstein's illustrative example of a long high-speed train travelling at constant speed on a straight railway track. As the train passes through a station, the guard at the back of the train and the stationmaster in his office both set their watches to zero at the instant that one passes the other. A short time later the stationmaster flashes a light up the track to reach a signal box, a distance x up the line, at time t.

Based on the times shown on his watch when the light first passes him and again when it is reflected back to him from the signal box, the guard calculates the time of arrival of that light at the signal box as t' and his distance from the box at that instant as x'. Using only the results already established, *i.e.*:

(a) motion-dependent time dilation, and

(b) perceived invariance of the speed of light

the guard's calculations can be shown to give the results:

$$t' = \gamma(t - vx/c^2)$$
$$x' = \gamma(x - vt)$$

where γ is the conventional Lorentz factor: $1/\sqrt{(1 - v^2/c^2)}$.

These two correspond to the equation (non-matrix) form of the Lorentz Transformation as used in SR. However to these must be added:

$$v' = -\gamma v \qquad \text{[perceived speed of original frame]}$$

as explained in Section 5. These three equations yield the inverse transformation:

$$t = \gamma't' - (v'/c^2)x' \,, \quad x = \gamma'x' - v't' \,, \quad v = -v'/\gamma' \quad \text{where: } \gamma' = \sqrt{(1 + v'^2/c^2)} \ [\, = \gamma \,]$$

7 Inertia. The elementary particle as an adaptive system.

The energetic structure of an elementary particle is held together by the electromagnetic interactions within that structure. This is implicit in the concept of a particle formed from a closed-loop energy flow. It follows that a variation in the rate of energy flow – the energy flux rate – is likely to compromise the integrity of particle structure. Of the possibly extensive variety of such photon-based structures that may have been formed in the immediate aftermath of the Big Bang, those that did not automatically adjust to changes in energetic circumstances would have literally come unravelled in very short order.

Injection of energy in a certain direction – a linear photon – into a cyclic-photon particle structure would certainly upset the dynamic balance of that structure. It would only survive such an upset if it were to automatically shift to a new state of dynamic equilibrium that accommodated that additional energy.

Footnote: Since publication of this paper the author has shown that, although actual interaction between a moving object and a static object is asymmetric, such interaction appears, as a direct consequence of the subjective experience of a moving object, to be symmetric. The symmetric Lorentz Transformation is therefore applicable for most practical purposes (despite actual objective asymmetry) – see 'Looking back to the Lorentz Transformation' in Chapter 5.

This would necessarily be due to self-compensating electromagnetic field effects which, once brought about by chance in the laboratory of the primordial proto-universe, would also be self-perpetuating. The likelihood of that ultra-dynamic environment resulting in one in every few billion photons forming stable elementary particles is consistent with the form of the universe as we now find it.

Considering matters now from the alternative perspective: a particle in motion experiences a reduced effective speed of cyclic energy flow, since a component of its formative energy flow is acting linearly as particle velocity. As structural integrity is likely to be dependent on cyclic energy flux rate, that reduced cyclic flow speed would need to be balanced by a corresponding increase in flux density, which is proportional to the frequency of that waveform energy flow. Specifically, the cyclic flow speed component is reduced by a factor of $1/\gamma$, so frequency would need to be increased by a factor of γ.

This relationship between speed and energy content corresponds to the SR perspective, and so also to its practical implementation in energy required in particle accelerator experiments. A speed-dependent frequency component consistent with this view was confirmed by Davisson and Germer over 80 years ago (1927).

[Williamson and van der Mark (1997) show that increased cyclic-photon frequency, so also increased energy content, of a moving particle may be resolved into 'time-like' and 'space-like' components. Those components correspond to the intrinsic (cyclic) and extrinsic (linear) components of the particle's formative energy flow as referred to in this paper (frequency components map directly to speed components). Since any space-like/extrinsic component would not be apparent (and so also would be inaccessible) to an observer travelling at the same velocity as a moving particle, only the intrinsic frequency component – the component responsible for the structural integrity of the particle – would be perceptible to that observer.]

This, then, is inertia: the requirement for a consistent cyclic energy flux rate to maintain structural integrity. If that structural integrity is threatened by an injection of energy then self-regulating mechanisms within a particle will cause it to move to a new stable state, a state of (altered) motion. This change of state is a direct physical consequence of the alteration in balance of the electromagnetic forces described in Section 2. Without such an energy injection the particle will continue in its present stable state, whatever that may be.

8   E = mc²

It is apparent from the previous section that the inertial response – what is termed 'the inertial mass' – of any object will vary in accordance with the variation in its energy content, as derived in that section.

I.e. if m_0, E_0 are object rest-mass and rest-energy respectively, and m_v, E_v are effective mass and energy at speed v, then: $m_v = \gamma m_0$, just as $E_v = \gamma E_0$.

Newton's Second Law for a dynamically varying mass gives:

$$F = \frac{\mathrm{d}(m_v v)}{\mathrm{d}t} = \frac{\mathrm{d}}{\mathrm{d}v}\left(\frac{m_0 v}{\sqrt{1 - v^2/c^2}}\right)\frac{\mathrm{d}v}{\mathrm{d}t} = \frac{m_0}{(1 - v^2/c^2)^{3/2}}\, v\,\frac{\mathrm{d}v}{\mathrm{d}x}$$

Now:
$$E_V = E_0 + \int_0^{X_V} F\,\mathrm{d}x = E_0 + \int_0^{V}\frac{v m_0}{(1 - v^2/c^2)^{3/2}}\,\mathrm{d}v$$

=>
$$\gamma E_0 = E_0 + (\gamma - 1)m_0 c^2$$

giving: $E_0 = m_0 c^2$, and correspondingly: $E_v = m_v c^2$.

9   Conclusion

The cyclic-photon perspective on particulate matter has been shown to account fully for all verifiable tenets of Special Relativity, in a manner that is consistent with a wide range of other experimental findings. It further shows every long-lived elementary particle to be an auto-adaptive structure in which self-balancing electromagnetic field effects automatically ensure transitions between stable states in response to energy exchanges with its environment. This, virtually by definition, makes the elementary particle the earliest adaptive system in the universe.

The notion of inertial frame equivalence, as assumed in Special Relativity, has been shown to be not only unnecessary but also incompatible with this fully consistent explanation of a substantial body of experimental evidence. A unique objectively static reference frame has been identified, setting aside any possibility of conflict between superluminal communication and the principle of causality.

A radically new and coherent perspective on the nature of time has been shown to also be consistent with this view of particle structure and with that supporting evidence. A possible causal explanation has been advanced for particle-antiparticle asymmetry, consistent with the structure of matter proposed here and the extensive scientific evidence supporting that proposal.

This new insight into the nature of material structure offers very significant opportunities for scientific and technological developments in a wide variety of arenas.

References

Baldini Celio R., Capon G., Del Fabbro R., De Santis P., Grilli M., Iarocci E., Mencuccini C., Murtas G.P., Spinetti M., Valente V., Bacci C., De Zorzi G., Penso G., Stella B. (1979), "Experimental results on photon-photon interactions at ADONE", *Phys. Lett. B*, Vol. 86 No. 2, pp. 239-242.

Barbiellini G., Orito S., Tsuru T., Visentin E., Ceradini F., Conversi M., d'Angelo S., Ferrer M.L., Paoluzi L., Santonico R. (1974), "Muon Pair Production by Photon-Photon Interactions in e^+e^- Storage Rings", *Phys. Rev. Lett.*, Vol. 32 No. 7, pp. 385 – 388.

Barut A.O. and Bracken A.J. (1981), "Zitterbewegung and the internal geometry of the electron", *Phys. Rev. D*, Vol. 23 No.10, pp. 2454-2463.

Bernardini, C. (2004), "AdA:The First Electron-Positron Collider", *Physics in Perspective*, Vol. 6 No. 2, pp. 156-183.

Bonnor, W.B. (2003), "Closed timelike curves in general relativity", *Int. J. Mod. Phys. D*, Vol. 12, pp. 1705-1708.

Cabibbo N. and Gatto R. (1961), Electron Positron Colliding Beam Experiments, *Phys. Rev.*, Vol. 124, pp. 1577-1595.

Cabibbo N., Da Prato G., De Franceschi G., Mosco U. (1962), "New method for producing and analyzing linearly polarized gamma-ray beams", *Phys. Rev. Lett.*, Vol.9 No. 6, pp. 270-272.

Cattilon P., Cue N., Gaillard M.J., Genre R., Gouanère M., Kirsch R.G., Poizat J.-C., Remillieux J., Roussel L., Spighel M. (2008), A Search for the de Broglie Particle Internal Clock by Means of Electron Channeling, *Found. Phys.*, Vol. 38 No. 7, pp. 659-664.

Cooper S. (1988), "Meson Production in Two-Photon Collisions", *Annu. Rev. Nucl. Part. Sci.*, Vol. 38, pp. 705-749.

Davisson C.J. and Germer L.H. (1927), "Diffraction of Electrons by a Crystal of Nickel", *Phys. Rev.*, Vol. 30, pp. 705-740.

de Broglie L. (1925), «•Recherches sur la théorie des quanta » [Thèse de doctorat, 1924], *Annales de Physique*, l0-ème série, t. III, pp. 22-128.

de Broglie L. (1927), Preface to German translation of PhD thesis: „*Untersuchungen zur Quantentheorie*", Becker, W. (trans.), Aka. Verlag., Leipzig, p. v.

Di Vecchia P. and Greco M. (1967), "Double Photon Emission in e^+e^- Collisions", *Nuovo Cimento A*, Vol. 50 No.2, pp. 319-332.

Einstein A. (1926), "Letter to Max Born (4 December 1926)", Born, I. (trans.), "*The Born-Einstein Letters*", Walker and Company, New York (pub. 1971).

Friedman J.L. and Higuchi A. (2006), "Topological censorship and chronology protection", *Annalen Phys.*, Vol. 15 No. 1, pp. 109-128.

Ginzburg I.F. (2006), "About earlier history of two-photon physics", *Acta Phys. Pol. B*, Vol. 37 No. 3, pp. 657-662.

Glashow S.L. (1980), "Towards a unified theory: Threads in a tapestry" (1979 Nobel lecture), *Rev. Mod. Phys.*, Vol. 52 No. 3, pp. 539-543.

Hawking S.W. (1992), "The chronology protection conjecture", *Phys. Rev. D*, Vol. 46 No.2, pp. 603-611.

Hestenes D. (1990), "The Zitterbewegung Interpretation of Quantum Mechanics", *Found. Phys.*, Vol. 20 No. 10, pp. 12-32.

Huang K. (1952), "On the zitterbewegung of the Dirac electron", *Am. J. Phys.*, Vol. 20 No. 8, pp. 479-84.

Kobayashi M. (2008), "CP Violation and Flavour Mixing", (Nobel lecture), *The Nobel Foundation*.

Landau L.D. and Lifshits E.M. (1934), "On the production of electrons and positrons by a collision of two particles", *Sov. Phys.*, Vol. 6, p. 244.

Maskawa T. (2008), **"**What Does CP Violation Tell Us?**"** (Nobel lecture), *The Nobel Foundation*.

Nambu ,Y. (2008) "Spontaneous Symmetry Breaking in Particle Physics: a Case of Cross Fertilization" (Nobel lecture), *The Nobel Foundation*.

Salam A. (1980), "Gauge Unification of Fundamental Forces." (1979 Nobel lecture), *Rev. Mod. Phys.*, Vol. 52 No. 3, pp. 525 – 538.

Schrödinger E. (1930), „Über die Kraftfreie Bewegung in der Relativistischen Quantenmechanik", *Sitzungb. Preuss. Akad. Wiss. Phys.-Math. Kl.*, Vol. 24, pp. 418-428.

Schwitters R.F. and Strauch K. (1976**),** "The Physics of e⁺e⁻ Collisions", *Annu. Rev. Nucl. Sci.***,** Vol. 26, pp. 89-149.

Sushkov, S.V. (1995), "Quantum complex scalar field in two-dimensional spacetime with closed timelike curves and a time-machine problem", *Class. Quantum Grav.*, Vol. **12**, pp. 1685-1697.

't Hooft G.. (2000), "A confrontation with infinity" (1999 Nobel lecture), *Rev. Mod. Phys.*, Vol. 72 No. 2, pp. 333-339.

Veltman M. (2000), "From weak interactions to gravitation" (1999 Nobel lecture), *Rev. Mod. Phys.*, Vol. 72 No. 2, pp. 341-349.

Weinberg S. (1980), "Conceptual foundations of the unified theory of weak and electromagnetic interactions" (1979 Nobel lecture), *Rev. Mod. Phys.*, Vol. 52 No. 3, pp. 515-523.

Williamson J.G. and van der Mark M.B. (1997), "Is the electron a photon with toroidal topology?", *Ann. Fond. L. de Broglie*, Vol. 22 no.2, pp. 133-160.

Williamson J.G. (2008), "On the nature of the electron and other particles", formerly at http://www.cybsoc.org/electremdense2008v4.pdf . A PDF of this paper is now available at:
https://www.researchgate.net/publication/267370968_On_the_nature_of_the_electron_and_other_particles   (accessed Oct 2021).