

Physics in one dimension with perpendicular non-locality

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Abstract. A single momentum-carrying dimension connected by Lorentz transformations to a perpendicular non-local dimension having time but lacking spatial measures is applied to electromagnetic radiation, thermal radiation, the Schrödinger equation, Kepler's 3:rd law, the rotation curve of spiral galaxies, and the universe as a whole represented by the linear part of its apparent expansion. This is made possible by identifying and making local terms equal to non-local ones as prescribed by the geometry. For example, 1-D momentum, the oscillating orbited radius of a system and baryonic mass are local whereas field components, oscillation periods and the electron cloud of an atom are non-local. Accordingly, in thermal radiation the physical process of a single quantum transfer replaces field radiation intensity as a function value. The Schrödinger equation can be rearranged and split into factors of circulating current carried by electrons surrounding magnetic charge. The latter result derives from a suitable factorization of the Bohr atom. Based on the assumption that the geometrical framework is valid generally for the rest frame the so-called 'dark matter' of galaxies can be identified by analogy with black body radiation and with the electron cloud as being non-local as might be expected of a 'massive field'. The basic theory yields a radius that is the inverse of a line increment per unit length and per unit time as in Hubble's constant. A tentative numerical value of this line increment appears as a residue when the Bohr atom is factorized for the purpose of providing a circular current to the Schrödinger equation.

1. Introduction

Ever since the experimental discovery of Compton scattering it is agreed in the physics community that electromagnetic radiation has a forward-directed momentum component, notably above the transition from Thompson to Compton scattering at about $4 \times 10^{17} \text{ Hz} \approx 10^{26} \text{ m}^{-1}$ where the radiation starts to behave as particles. In the photon picture of electromagnetic radiation the forward Abraham and Minkowsky momenta now form the basis of quantitative applications [1] [2]. The existence of a forward momentum component can also be anticipated from the cross-product-Poynting vector based on Maxwell's description of the propagation of light [3] [4]. Since the latter is consistent with special relativity by the Faraday tensor most contemporary descriptions of electromagnetic radiation are based on Maxwell's equations. Nevertheless, many ambiguities are still unresolved and actively discussed in the literature. Maxwell's equations have been criticized for not providing a physical interpretation of the displacement current [5], for ambiguity regarding Coulomb and Lorentz gauge and for not dealing with signal source and sink events. Furthermore, they lack a conceptualization of the non-locality of the wave-front inferred from the self-interference of single quantum signals passing a double-slit. Non-locality in signal transmission has also been discussed in the context of polarization correlations and



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dismissed in the wave picture of the signal [6] whereas it persists in the photon picture. It is not known how the signal turns into local momentum upon absorption and then disappears from the entire wave-front, which in principle may span the entire galaxy or more. Any kind of non-locality which leads to instantaneous communication is considered unphysical in the geometrical framework of special relativity, which leads to still unresolved problems of fundamental importance in physics besides the need for a comprehensive quantitative picture of signal transmission.

These fundamental problems can only be solved from a broad perspective that includes the ontology of space-time, in other words, evaluating whether space-time exists on its own or if it appears as a consequence of its physical contents. It is not necessarily the case that the Cartesian coordinate system, invented in the 17:th century and later by special relativity adapted to the constant velocity of light, is the best geometrical framework for most processes in nature. In fact, the propagation of electromagnetic radiation carrying forward momentum and perpendicular electric and magnetic fields is not rotationally symmetric, adding to its wave-front non-locality which is unaccounted for in physics' descriptions even to this day. Even though electromagnetic radiation spans most of the universe's volume and would be a good candidate to determine the geometry of space-time the foundations of contemporary physics were laid in the 17:th and 18:th centuries based on our subjective impressions of the classical material 3-dimensional world. At the elementary level, however, the material world is made visible by the atom through its quantum interactions with light. The quantum transfers are discontinuous, which implies that on each quantum transfer the primordial atom redefines its momentum axis irrespective of whether the momentum is radial (head-on) or axial (curl or spin). In a typical quantum transfer the atom only accepts the proper head-on energy transfer in a probabilistic fashion without negotiating the energy of the signal based on incoming angle as is the case in classical momentum transfer. This means that the atom sees its surrounding on a one-dimensional axis different from our 3-dimensional world and all other dimensions will necessarily be non-local from *its* perspective. Hence, non-locality by reference to the momentum axis characterizes both the electromagnetic radiation and the atom and seems to be a fundamental property of space dictated by its physical contents. This idea will now be examined quantitatively by setting up a geometry that exhibits a momentum axis as well as non-locality, and applying this geometry at the quantum level in electromagnetic signal transfer, thermal radiation and the Schrödinger equation. It will also be shown that the geometry applies in the classical world based on examples from Kepler's 3:rd law, galaxy star rotation and even the entire universe.

2. A geometrical construct exhibiting a momentum axis and perpendicular non-locality

A geometry with the required properties is obtained by performing a Lorentz transformation of the inverse of the number-flux vector at discrete time coordinates -1 and 0 defining an interval of observation:

$$(q_0, t_0) = \left(\frac{\sqrt{1 - \frac{v^2}{c^2}} m^2}{v} \frac{s}{s}, 0 \right); \quad (\bar{q}_0, \bar{t}_0) = \left(\frac{1}{v} \frac{m^2}{s}, -s \right) \quad (1)$$

$$(q_r, t_r) = \left(\frac{\sqrt{1 - \frac{v^2}{c^2}} m^2}{v} \frac{s}{s}, s \sqrt{1 - \frac{v^2}{c^2}} \right); \quad (\bar{q}_r, \bar{t}_r) = \left(\frac{1}{v} \frac{m^2}{s} - vs, 0 \right) \quad (2)$$

$$\overline{\Delta q} = -vs, \quad \overline{\Delta t} = \bar{t}_r - \bar{t}_0 = s \quad \Rightarrow \quad \overline{\frac{\Delta q}{\Delta t}} = -v \quad (3)$$

$$\Delta q = 0, \quad \Delta t = t_r - t_0 = s \sqrt{1 - \frac{v^2}{c^2}}. \quad (4)$$

Here, m is the unit of length and s the geometrized unit of time¹. This system of equations defines two observers located at the origin (un-barred) and at radius distance from the origin (barred observer). The latter observer is capable of observations along the momentum axis, Δq , and of measuring the unit of time while the observer at the origin only is aware of time and recognizes an angular velocity v . The two observers are space-like separated.

The directions of the axes is defined by analogy with the unit circle, $(\cos x)^2 + (\sin y)^2 = 1$, as

$$q_r^2 + \frac{1}{c^2} \frac{m^4}{s^2} = \frac{1}{v^2} \frac{m^4}{s^2} = \bar{q}_r^2 \quad (5)$$

or

$$\left(\frac{\Delta t}{s}\right)^2 + \left(\frac{\Delta q}{m}\right)^2 = 1 \quad (6)$$

so that line increment and time interval are perpendicular. The time interval measured by the momentum observer is also perpendicular to the momentum frame where it defines the tangential velocity as shown in eq. 3c.

The sign of the line increment (cf. eq. 3) shows that for $v > 0$ the radius of the observed object decreases in the time interval. An observer at the origin computes a contracted radius \bar{q}_0 similarly to the Lorentz-Fitzgerald case, $q_0 = \bar{q}_0 \sqrt{1 - v^2/c^2}$. Hence, the geometry can be understood as a circle space-like separated from a peripheral observer who detects it in the form of a line increment in the direction of observation after the passage of one unit of time. In physics, line increments in the direction of observation are known from the Bohr atom and the cosmological expansion which hints at concrete applications.

For observations towards the origin along the radius in the local frame of observation, the magnitude of the line increment is summed from Δq per unit length, m , to the unit length proper, m , per radius, \bar{q}_0

$$\frac{-\Delta q}{m} = \frac{m}{\bar{q}_0} \Leftrightarrow \bar{q}_0 \Delta q = -m^2 \quad (7)$$

as can be derived from eqs. 1b and 3c. Here, the velocity of light, m/s , limits the radial extension of the geometry to $|\bar{q}_0|$ ($v \leq c$ as required by $\sqrt{1 - v^2/c^2}$). In eq. 7 the radius and the line increment define the unit of length so that each unit length comes with a line increment as well as a radius whereas eq. 3a shows that the line increment also can be interpreted as a rate. Because of eq. 3 and 4, observations can only be made from the laboratory frame at the periphery towards the origin of space and time coordinates. The observer at the origin is non-local in the sense of performing all observations solely on the time axis (eq. 4b)

Summarizing the above,

1. Each length in the local frame comes with a line increment, a momentum.
2. This line increment is the inverse of a radial length in the momentum frame.

¹ using non-standard notation for the purpose of distinguishing the two units

3. Time is perpendicular to the momentum axis. The time axis harbors the non-local observer. Because of the absence of spatial measures in the non-local frame the geometry is not rotationally symmetric like the Euclidean-Cartesian one. Besides the absence of spatial measure and the two frames being perpendicular the non-locality is also evident from the space-like separation of the local and the non-local observer.

4. The two observers are located either at the origin or at the end of a radial length.

5. The line increment per unit time equals a perpendicular velocity (eq 3).

6. The time dilatation of special relativity is preserved (eqs. 2a and 4b).

7. There is a length contraction of the same magnitude as a Lorentz-Fitzgerald contraction applied to the radius, which is confined to the non-local observer's frame (eq. 2). This contraction is not visible in the local frame of observation where it is known from special relativity theory that Lorentz contractions can indeed not be observed [7] [8].

8. There is a relativistic horizon obtained by adding line increments linearly to each unit length until the sum of these increments adds up to the velocity of light. However, there are no relativistic effects in the local frame (eq. 3) since the atom either responds to or does not respond to the signal depending on its internal structure in its rest frame without taking into account relativistic alternatives. The relativistic distortions take place prior to the quantum transfer and make the signal fit or not fit to transfer its momentum coming from a moving or stationary source.

3. From quantum to classical in a one-dimensional material world with perpendicular non-locality

In as much as known physical processes can be interpreted within the geometrical framework defined above it is a valid framework for these processes and the framework consequently has 'physicality' with regard to these processes. The property 5 above is most useful for evaluating this since it implies that some factors assigned to the local frame are equal to other factors in the non-local frame. A quantitative example to start with can then easily be obtained by rearranging the thermal Planck distribution [9], placing local factors to the left and non-local ones to the right, as

$$h\nu \exp\left(\frac{-h\nu}{kT}\right) = \frac{c^3}{8\pi} U(\nu) d\nu^{-1} \tau^2 \left(1 - \exp\left(\frac{-h\nu}{kT}\right)\right) . \quad (8)$$

The left side contains the momentum transfer to and from the matter, $h\nu$, and the exponential term which is interpreted classically as a probability that the excited state of the matter decays. The exponential term was extensively characterized in the early 20:th century, e.g. [9] [10] [12] [13]. The right side contains the complementary probability that the electromagnetic field transfers energy to the matter. Furthermore, the right side contains the field intensity per frequency component, which is known to result from a squared probability amplitude, and the oscillation period τ of the radiation squared. In accordance with the present geometrical framework and with the well-established directions of the electric and magnetic fields of electromagnetic radiation these components are perpendicular to the momentum axis. Hence, the geometry embeds in a natural way thermal radiation. It is noteworthy that in the present case the field intensity appears as a function variable rather than as a function value like in the well-established approaches to Planck's equation. Letting the amplitude work jointly with the squared oscillation period to establish the radiation field like in eq. 8 is consistent with many known exceptions from the Bohr-Einstein energy level rules [14] [15]. In the present case the actual physical event, the momentum transfer, appears as a function value, supporting the conjecture that the geometrical framework is a 'natural' or 'physical' one. The form and interpretation of eq 8 given here applies at equilibrium when any absorption of radiation is immediately emitted or the radiation intensity is low in comparison with spontaneous emission. A conventional analysis of stimulated

emission similarly to eq. 8 can be found in [16].

This form of the Planck distribution with the quantum-momentum left and non-local factors right agrees geometrically with the trivial example of electromagnetic radiation *per se* mentioned in the Introduction, which can be illustrated by the Poynting vector²

$$\mathbf{S} = \mathbf{B} \times \mathbf{E} \quad (9)$$

The Schrödinger equation for a free particle, at left in

$$\frac{p^2}{2M_e} \Psi = -i\hbar \frac{\partial}{\partial t} \Psi \Rightarrow \frac{\hbar}{2} \left(\frac{\partial}{\partial x} \right)^2 \Psi = -iM_e \frac{\partial}{\partial t} \Psi, \quad (10)$$

yields the form at right where local terms (length measures) are on the left side and non-local ones (electron cloud and time) on the right side, which agrees with the notion of Property 5 in Section 2 that physical processes in general are composed of equally large local and non-local terms. Furthermore, the imaginary term, $-i$, makes the non-local terms perpendicular to the momentum frame as prescribed in Section 2.

The Bohr atom in the ground state with its oscillating radius defined by the circulating non-local electron provides further justification for the proposed geometry. The Bohr atom can be factorized such as to give a concrete physical-geometrical meaning to the Schrödinger equation. First, write the Bohr atom, $a_0 = 4\pi\epsilon_0\hbar^2/(e^2m_e)$, as

$$\left[a_0 \frac{\alpha m_e}{\hbar} \right] \left(\frac{e^2}{4\pi\epsilon_0\alpha} \right) = \hbar \Rightarrow 2.4113 \times 10^{-53} \frac{e^2 c^2}{4\alpha^2} = \hbar \Rightarrow \frac{2\overline{\Delta q}}{\pi \text{Ampere}} \frac{ec}{2\alpha} = \sqrt{\hbar} \quad (11)$$

where geometrized units have been used except in the case of the factor c of magnetic charge because of charge invariance. The square-bracketed term becomes unity and can be omitted whereas the number in the middle is interpreted as $4\overline{\Delta q}^2/\pi^2$ where $\overline{\Delta q} = 7.714 \times 10^{-27} \text{ m}^{-3}$. Use is thus made of the substitution

$$\sqrt{\hbar} = \frac{2\overline{\Delta q}}{\pi \text{Ampere}} \frac{ec}{2\alpha} \quad (12)$$

which is inserted into the linear Schrödinger equation for a free particle in the form at the right side of eq. 10 to give

$$(\overline{\Delta q})^2 \left(\frac{ec}{2\alpha} \right)^2 \left(\frac{\partial}{\partial x} \right)^2 \Psi = i 2M_e \frac{\partial}{\partial t} \Psi \left(\frac{\pi}{2} \text{Ampere} \right)^2 s^{-2}. \quad (13)$$

Here the non-local right side has a circular ($\pi/2$) electric current carried by a pair of electrons surrounding on the left local side a squared magnetic charge⁴ (possibly two charges of opposite sign) that are associated with a squared line increment interpretable as angular momentum.

² The ambiguity of the Poynting vector and Maxwell's equations, much discussed in the literature, cf. e.g. [3] [4], is left aside here.

³ The numerical value of $\overline{\Delta q} = 7.714 \times 10^{-27} \text{ s}^{-1}$ (equal to $71.36 \text{ km/second/Mparsec}$), agrees within errors with the Hubble constant in astrophysics obtained by two independent measuring methods [17] [18] [19]. The inverse of the line increment prescribed by Property 2 in Section 2 is $1.296 \times 10^{26} \text{ m}$ and a light signal would take 13.7 billion years to travel between the endpoints of this radial length. Since the line increment refers to the unit length by eq. 7 and is taken per unit time by eq. 3c it has the same dimension as Hubble's constant, which is m/ms . In the present paper though the chosen numerical value has a quantum-physical justification on its own as shown subsequently.

⁴ The magnetic charge monopole was originally identified as a one-dimensional entity [11]

While the Schrödinger equation previously has been criticized for being purely mathematical the substitution using eq. 12 shows that it may actually *define* the structure of the atom in terms of a non-local charged electron pair surrounding the nucleus. The physical interpretation of eq. 13 with several but not all terms squared invites further theory.

The examples given show that several quantum processes of fundamental importance can be advantageously interpreted in the proposed geometrical framework composed of a single spatial dimension and a non-local frame. Subsequently it will be shown that many classical systems also are compatible with the proposed geometry such that quantum and classical worlds exist on an equal footing within the same framework. This is also a result that has been obtained with conventional geometry and quantum mechanics [20] [21]. For example, Kepler's 3:rd law supplemented with the gravitational constant may be rearranged and written (T = orbital period, r = orbital radius = an oscillating length with period T , local factors left, non-local ones (M , T and v^{-1}) right

$$r = G M_{\text{sun}} \frac{T^2}{4\pi^2 r^2} \quad (14)$$

whereas Galilee's acceleration may be written (L = length displacement at the observed velocity, a = acceleration, t = time passed, s = unit of time)

$$L = a t s . \quad (15)$$

The latter may be adapted to the apparent cosmological expansion, which *a priori* is linear in the present geometry, so that by analogy with eq. 15 (m = meter, r = radius) the universe accelerates onto the local unit length,

$$m = \frac{\overline{\Delta q}}{s^2} \left(\frac{r_{\text{universe}}}{m} s \right) s , \quad (16)$$

where, tentatively, $\overline{\Delta q}/ms = H_0$. As is well known the linearity prevails over quite long distances before the measures are obscured by relativistic effects and by the long time intervals ΔT between astrophysical observation and actual event leading to cosmological model-dependence. If one ignores that only radial endpoints are allowed in this geometry it basically holds that

$$\sum \overline{\Delta q} = H_0 \Delta T \quad (17)$$

since each unit length comes with a line increment and the universe is assumed to have the same space-time structure everywhere along its radius unaffected by relativistic effects. This agrees with the trivial case in standard cosmology where, however, the present acceleration of the distant origin onto the local unit length is seen in the reverse as a literal expansion from a local origin. In eqs. 14 - 16 the acceleration acts like an operator from the non-local to the local frame whereby the former has a squared term like in the quantum world (eqs. 8, 10, 13).

Finally, the rotation of stars in spiral galaxies adapted from the baryonic Tully-Fischer relation [22] [23] and rearranged by analogy with thermal radiation as in eq. 8 yields

$$v_{\text{bar}}^2 = v_{\text{obs}}^2 \left(1 - \exp \left(- \sqrt{\frac{v_{\text{bar}}^2}{Rg^\dagger}} \right) \right) \quad (18)$$

indicating by analogy with the previous examples in this paper that the robust baryons contained in the term v_{bar} (baryonic velocity) are local and stable (no exponential term) whereas

so called 'dark matter' contained in the term v_{obs} (observed velocity) is non-local.

These examples from the classical world show that it too can be seen from the perspective of a one-dimensional observer immersed in a non-local dimension, not just in the manner that the tiny atom sees a signal but on a macroscopic scale as well.

4. Discussion

In this paper, the physicality of a geometrical construct composed of one spatial dimension embedded in a perpendicular non-local field, like in electromagnetic signal propagation, has been evaluated. It has been shown that such a geometry naturally accommodates thermal radiation and provides physical meaning to the Schrödinger equation including its complex terms based on a suitable factorization of the Bohr atom. Furthermore, the solar system given by Kepler's 3:rd law, the apparent cosmological expansion and the velocity distribution of stars in spiral galaxies conform to the geometry. Besides providing a tentative general framework for the rest frame evidenced by these applications the coexistence of our 3-dimensional world with a hidden, quantitatively well defined non-local frame of observation implies a kind of manifest 'duality' which has not previously been documented⁵. The non-local frame may in a very concrete fashion harbor all kinds of physics descriptions that have previously only been thought of as merely mathematics, like e.g. particle-field duality, superpositions, path integrals, number theory, permutations and the like.

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⁵ The word 'duality' in the sense intended here has previously been used in philosophy (Descartes) and physics (de Broglie). In quantum physics various 'pictures' usually denote how the same phenomenon can be described with different mathematical approaches.

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