General relativity as a unified fluid and field theory

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Abstract. Einstein’s dream for a unified field theory of Nature is attained with a classical fluid theory founded on space, time and spin, rather than on Einstein’s spacetime. An invariant quantum theory for the primordial fluid obeys the homogeneous Klein-Gordon equation, which is the same three-dimensional classical wave equation (CWE) initially tried by Schrödinger to formulate quantum mechanics (QM), but abandoned by linear superposition considerations. Primordial fluid pervades universe, obeys energy and momentum conservation, and is formed by saggins: energy-like, discrete, extended Planck-size objects of finite size, carriers of linear momentum and spin, moving in absolute 3D-curved space with speed C along straightest path. We briefly describe our novel non-harmonic and inherently quantized solutions for CWE in spherical coordinates, discovered in 1995. Solutions include a steady-state background field (possibly related to the CMB, to non-locality, and to action-at-a-distance), quantized helices, and inherently quantized functions exhibiting stable dynamic equilibrium, and isomorphism under many transformations, including the classical Doppler case, and the relativistic Lorentz, Poincaré, and Einstein transformations. Isomorphism pre-empts ab initio a few interpretative issues regarding relativistic and classical transformations. Mathematical fields represent the realistic physical temporal evolution of the primordial fluid in curved 3D-space.

1. Introduction: controversial questions in classical and quantum descriptions of Nature
Besides unprecedented technological progress, 20th century is characterized for abandoning cherished and fundamental notions rooted in Ancient Greece: logic, causality, space, and a careful distinction between the container and what is contained; inherently contradictory notions — as a vacuum with physical properties — are now common currency. Special relativity (SR) and quantum mechanics (QM) attributed an overemphasized role to the observer, leading to theories about how an observer sees Nature, rather than to how Nature behaves when the observer is not there as it was the case until the turn of 20th century. For Aristotle Earth was at the center of Ancient Cosmos, but a modern competitor has stronger claims: the anthropic principle places humankind at the center of universe, conveniently forgetting that tomorrow, on the geological scale, a collision with an asteroid may erase earth and humankind from the universe — event that would hardly affect the rest of cosmos. According to some views, the main open question in physics today is compatibility of quantum and gravity theories. Einstein dreams were more ambitious: only one Nature with all interactions described by a single theory. In the recent opinion of Gerard ‘tHooft, a unified theory should also address the question of “how matter behaves” [1]. Present paper outlines an approach that works: an objective, causal and Cartesian unified fluid and field theory, (hopefully) free of internal inconsistencies. As general context, let us mention two controversial aspects in Newton’s Principia [2]: (a) circular definition of mass, and (b) the notion of non-contact forces, in particular the notorious omission of a mechanism for generation and propagation of gravitational force. The latter omission led to the widely spread belief that Newton introduced action-at-a-distance (AAAD) in physics. Due to the high
predictive capability of Newtonian mechanics, defects (a) and (b) were pragmatically accepted or tolerated. Unfortunately, it is not generally known that in his private letters [3] Newton perseveringly and strongly argued for an ether (be it material, or immaterial) to explain gravity propagation [4]. An economic solution for issues (a) and (b) is provided by a Cartesian approach based on conservation of quantity of motion as a primitive notion [5-6] — thus downgrading force and mass from the role they have in Newtonian mechanics. A consistent kinematic definition of mass was proposed by Barré de Saint Venant around 1850 [7-8]. Without mentioning him, the method of Saint Venant is implemented in some modern textbooks [9]: stroboscopic photography to measure average velocity of two interacting bodies before and after a collision upon a pneumatic table. In contrast, the better-known operational definition of mass proposed by Mach around 1870 is based on mutually induced accelerations during the interaction of two bodies [8,10]. In criticizing the notions of instant velocity and instant acceleration fields, Russell [11] noted that to measure average velocity two observations at separate intervals of time are required, while an estimate for average acceleration requires at least three observations. From Ockham’s razor, Saint Venant’s more economical method is preferable to Mach’s approach. Our energy-like primordial fluid (PF) is a modern version of ether, which inherently carries an indestructible quantity of motion, thereby explaining propagation of the derived notion of force — which merely is the average exchange of quantity of motion in a collision. Such PF provides a causal and physically objective basis for the mathematical notion of field [4,12-13].

Passing now to open questions in QM, the completeness issue noted by Einstein still is there. Secondly, the Copenhagen interpretation of QM accepts the existence of undefined states of Nature between being and not-being — as the iconic Schrödinger’s cat, and Wigner’s friend. To stress the philosophical absurdity of the latter, Einstein used to pose the rhetorical question of whether the Moon existed when an observer was not looking at her! The Einstein-Podolsky-Rosen paradox and the ensuing Bell theorem are common knowledge. This writer agrees [14] with Einstein’s views on causality and objectivity. Finally, there is Born’s interpretation of the QM-wave-function as a probability. Since Jacob Bernoulli’s Ars Conjectandi (circa 1713), it is well-known that probability is not a physical magnitude, but a mere mathematical construct of human mind [15]. Further, present writer posits that the rest of Nature — as far as known on earth — does not conjecture about outcomes of forthcoming events. If there is little information, probability is subjective and is a mere (non-) informed guess; probability is less subjective if there is symmetry, or when it is viable to enumerate the (hopefully) complete list of physical trajectories leading to an outcome, as in Feynman’s continuous path integrals, or in discrete decision trees [16]. When long-term observations or controlled experimentation are viable, objective frequency-based probability is obtained. However, in any of the three previous scenarios probability is not a physical object.

In 1952 Louis de Broglie recalled [17] a distinction he made in the mid-1920s between the continuous solutions of the linear QM-equations and its interaction with a localized (presumably material) corpuscle in such wave field, leading to an objective and causal “dual solution”, that foreshadowed t’Hooft remarks [1] for eighty years. Since this mathematically coupled problem was difficult to solve, de Broglie settled for a simpler pilot-wave model: motion of a material corpuscle is controlled by the wave function $\Psi$. However, he also abandoned this proposal after realizing what we already said in previous paragraph: “$\Psi$ certainly is not a physical reality... it only is a representation of probabilities dependent upon the state of our knowledge” [17] (our literal translation from French, page 266). As alternative to the Copenhagen view of QM, de Broglie suggested in the 1950s a stochastic interpretation, where Schrödinger’s linear equation represents fluctuations of a fluid [18], but the fluid itself was proposed much earlier by Madelung [19-20].

The five-dimensional universe suggested by Klein in 1926, led de Broglie in 1927 [21] to an alternative for Schrödinger’s linear equation: the non-linear wave equation known today as Klein-Gordon equation (KGE). De Broglie also entered the long-standing controversy between Cartesian and Newtonians [3], and pointed out that a most appealing aspect of general relativity (GR) was to eliminate “the metaphysical concept of force from gravitational theory” [21]. In 1962 de Broglie insisted once again on non-linearity: “agreeing with some deep remarks by Einstein, all exchanges of
energy and linear momentum between corpuscles probably arise from transitory non-linear processes, whose description is beyond current linear theories” [22] (our translation from French, p 425). De Broglie also used a KGE in relativistic thermodynamics [23], soliton solutions of KGE are reported in [24], and a summary of de Broglie’s pilot-wave theory is in [25].

De Broglie consistently noted that all waves in his theory had physical reality, thus requiring an underlying physical fluid, often identified with Dirac’s ether [26]. In 1999 present author proposed a primordial fluid (PF) [27] similar to Dirac’s, but with two conceptual differences: (a) an unidirectional arrow of time from past to future, thus excluding reversibility, and science-fiction travels to the past, and (b) the fluid constituents were material 3D-extended preons. From Leibniz continuity principle stating that a change from state A to B has to go through all intermediate states, and considering the controversy on impenetrability of matter [28-30], we concluded that matter should have structure at all scales, so that the smallest bit of matter is divisible, but its components cannot possibly be material. So, instead of material preons, it is postulated here that the primordial fluid is formed by energy-like sagions, described as discrete, 3D-extended, spherical and Planck-size objects of radius R, carrying quantity of motion P, spin S, and moving with speed C along the straightest path [12]. Our fluid theory agrees with de Broglie’s relativistic QM and with the notion that matter has electromagnetic origin. In our theory the simplest entity of Nature is an energy-like sagion, rather than a material object as in the Leucippus and Democritus atom.

2. Reinterpretation of empirical evidence usually cited to support Einsteinian relativity

Next question: where does the primordial fluid exist? In a Newtonian context the sagion moves with speed C in absolute space, described in 1590 by Francesco Patrizi as physical space $\Sigma$ [31-32]. For Gauss, the geometrical nature of space was an empirical question, tackled by measuring the angles of a triangle defined by three mountain peaks in Germany. Gauss found a locally flat space up to his empirical accuracy. However, the observation of light-bending by Eddington in the 1919 solar eclipse suggests that, at a larger cosmological scale, space is positively curved.

2.1. On the two different principles of equivalence

In contrast, for Einstein light-bending was a strong support for GR [33]. In his correspondence during the Swiss years [34], Einstein mentions three possible methods to confirm GR: (1) examination of existing solar photographs, (2) observation of stars near the sun in full daylight, idea suggested by astronomer Erwin Freundlich-Finlay (EFF) of Berlin Observatory, and (3) observation of star light during the 1914 solar eclipse in an expedition of EFF to Russia that was abruptly ended by the outbreak of World War I [35]. Einstein mentions light-bending in a letter to EFF dated September 1/1911 from Prague (L281 = letter 281 in [34]); correspondence with EFF on this subject continued on September 21/1911 (L287), January 8/1912 (L336), October 27/1912 (L420), mid-August 1913 (L468), August 26/1913 (L472), December 7/1913 (L492), and January 20/1914 (L506). Einstein also corresponded on light-bending with astronomer George Hale on October 16/1913 (L477) and November 8/1913 (L483).

In L448 sent to Ernst Mach in June 25/1913 Einstein stated [34]: “Next year, during the solar eclipse, we shall learn whether light rays are deflected by the sun, or in other words, whether the underlying fundamental assumption of the equivalence of the acceleration of the reference system, on the one hand, and the gravitational field, on the other hand, is really correct”. This is a clear statement of Einstein’s principle of equivalence of acceleration and gravity (EP-A henceforth) mentioned by Einstein five years before in a letter to Arnold Sommerfeld dated January 5/1908 (L72 in [34]). According to Ginzburg [36-37] EP-A was formulated in 1907 [38]. In the opinion of the present writer, EP-A contains the deepest physical and philosophical implications of Einstein’s GR, and has everyday manifestations easily seen in the laboratory [39]. Hence, there is no need to invoke light-bending as empirical proof for EP-A.

There is a different, although related, question: is the ratio between inertial mass and gravitational mass a constant, independent of the composition of matter? This is the equivalence principle for mass...
EP-M. For Newton, EP-M was an empirical question that he answered with pendulum experiments described in book III, proposition VI of the Principia [2] (see p 108 in [3]). For Einstein EP-M was also an empirical question, and in July 10/1912 he asked help from Prof. Wilhelm Wien to carry out two “quite easy” experiments involving (a) two pendulums, and (b) a torsion balance (L413, p 319-320 in [34]). It seems that Einstein was unaware of the earlier experiment by Eötvös involving torsion balances carried out in Hungary in the 1890s [40], and published around 1910 [41]. A re-analysis of Eötvös data by the Fischbach group in 1986 [42-44] shows that gravitational mass depends on the number and distribution of protons and neutrons in the atomic nucleus. Fischbach fitted the dashed line in Figure 1 to Eötvös observations with their Yukawa-type gravity model, and the correlation was poor. The anomaly remained unexplained [41] until in 2011 present writer separately analyzed the P-series and the Cu-series in Eötvös experiments (Figure 1a). Taking into account orbital electrons plus the binding energy of protons and neutrons in the nucleus, an atomic-like pushing gravity model was obtained [45-46], which is consistent with Eötvös data at 92% correlation coefficient (Figure 1b). The only adjustable parameter turned out to be, as expected, the electron/proton mass ratio.

Summarizing, EP-A and EP-M are two different questions; this may clarify some controversies regarding Einstein’s equivalence principle [36-37, 47-49]; also note that Einstein suggested different and separate empirical methods to verify EP-A and EP-M. In our view, EP-A is locally valid, but EP-M is not. We also depart from Einstein’s interpretation of star light-bending; instead, it is curvature of absolute 3D-space in the local region from star to earth.

![Figure 1. Relative torsion in Eötvös experiment depends on composition: (a) nuclear composition effect analysed by Fischbach [42-44], (b) atomic composition effect analysed by Múnera [45-46].](image)

### 2.2. On the evidence against absolute space

Einstein rightly rejected the far-fetched properties of electromagnetic ether models in the second half of the 19th century, but he erred in his 1905 general dismissal of ether, including Newton’s [2] (possibly immaterial) fluid-like ether [4]. In our view, when Einstein formulated EP-A in 1907 [38] he immediately sensed that he was a prisoner of his 1905 dismissal. Indeed, in L73 to Sommerfeld dated January 14/1908 Einstein wrote from Bern [34]: “If the Michelson-Morley experiment had not put us in the worst predicament, no one would have perceived the relativity theory as a (half) salvation”. In L448 to Mach dated June 1913 Einstein considered the physics inside a shell rotating “relative to the fixed stars (‘Restsystem’)”, which to an unaware reader sounds very similar to Newton’s ideas. According to Kostro [50], Einstein reintroduced ether around 1916, but it seems that the seeds for such reinstatement were planted around 1907. At any rate, Einstein explicitly said at Leyden in 1920: “Newton might no less well have called his absolute space ‘Ether’; what is essential is merely that besides observable objects, another thing, which is not perceptible, must be looked upon as real, to
enable acceleration or rotation to be looked upon as something real” [51]. Surprisingly, Einstein did not distinguish between the container (absolute space) and its contents (ether). In the mid-1990s present author uncovered several weaknesses in Michelson-Morley experiment (MMX) [52]. Most significant was that only the fractional part of the fringe-shift was recorded, leading to under-estimation of fringe-shift amplitude [53], which should be of several fringes as calculated with modern values of solar velocity [54]. This prompted us to repeat the MM experiment at CIF in Bogota (Colombia) in a continuous manner during two years (2003-2005). As usual in second-order experiments, two velocities of sun relative to a preferred frame were obtained from our data: (a) CIF-S: VS = 500 km/s, R.A. = 16h-40m, Dec = -75º (southern celestial hemisphere) [55], and (b) CIF-N: VS = 365 km/s, R.A. = 5h-24m, Dec = 79º (northern celestial hemisphere) [56]. Our solar velocities are compatible with other observations supporting absolute motion [57].

Of significant interest is the compatibility of our results with two contemporary experiments: (1) de Haan [58] experiments involving standing waves and a Fabry-Perot interferometer, and (2) Lipa vertical interferometer at Stanford in 2002 [59], temperature controlled to a micro-Kelvin accuracy, that was interpreted as a “null” MMX. Applying procedure described in [54], absolute velocity of surface of earth at Stanford University (Palo Alto, California) was calculated for dates of Lipa’s experiment using our CIF-S value for solar velocity. Figure 2 shows projection of our calculated absolute velocity upon Lipa’s laboratory floor for May 30/2002. The observed frequency variations recorded by Lipa on same date [59] exhibit correlation coefficients at 99.8% with absolute speed, and 99.1% with absolute direction of motion, which imply that EM frequency may be affected by absolute motion, contrary to Lipa’s interpretation. The paradox is easy to explain: Lipa attributed observed frequency variations to unexplained “mechanical disturbances”, subtracted them, and obtained a noise of zero amplitude. Hence, they got the reported “null” result!

![Figure 2. Projection of absolute velocity on the floor of the laboratory at Stanford University in May 30/2002. Observed frequency variations on same day [59] are highly correlated with absolute motion.](image)

3. New solutions for the homogeneous Klein-Gordon equation or classical wave equation

Empirical evidence sketched in previous section implies absence of evidence against absolute space; in Einsteinstein mood, the Michelson-Morley experiment no longer puts us in any predicament. It is postulated that a primordial fluid entirely pervades the curved 3D-absolute space \( \Sigma \), and that it obeys conservation of total energy, and linear and angular momentum. In regions of universe devoid of matter, the fluid is locally described by the homogeneous Klein-Gordon equation (1), which is the same classical wave equation; the physical potential field \( \Pi \equiv (\phi, A) \) contains a scalar potential \( \phi \) (conservation of total energy) and a vector potential \( A \) (conservation of linear momentum), whose dimensions \( ML^{-1}T^{-2} \) correspond to density of total energy, and to flow of linear momentum per unit area (or, equivalently, density of angular momentum flow) respectively. Equation (1) represents De Broglie’s pilot wave [21-23], and also complies with classical electrodynamics [60]:

\[
\Box \Pi = \left( \frac{\partial^2}{\partial t^2} - \nabla^2 \right) \Pi = 0 \text{, where } w \equiv C^* t \text{, } \Pi \equiv (\phi, A).
\]

Time is treated as length \( w \) with \( C^* \) being the local average speed of primordial fluid. In presence of matter, right hand side is non-zero due to elastic and inelastic sagion-matter interactions; a complete
(3+1+1) formulation requires Dirac’s equations containing spin, characterized by a positive/negative absolute sense of rotation: counterclockwise/clockwise. In isotropic absolute space all directions \((\theta,\phi)\) are equivalent, and linear motion becomes one-dimensional along arbitrary ray \((r,t)\), or \((r,w)\). Thus, we use spherical coordinates \((r,w,\theta,\phi)\) to solve equation (1). The standard separation of variables in equation (2) leads to harmonic solutions, with \(F(r,w)\) being the one-dimensional travelling wave equation found by D’Alembert in the 18th century:
\[
\Pi(r,w;\theta,\phi) = F(r,w)D(\theta,\phi), F(r,w) = R(r)T(w), D(\theta,\phi) = Y(\theta,\phi,\ell,m),
\]

where \(\ell > m\), \(m^2 \geq 0\).

Directional component \(D(\theta,\phi)\) is the same for the linear non-relativistic Schrödinger equation and for the relativistic Klein-Gordon equation (1). Thus, the Lorentz invariance of the KGE is fully contained in the one-dimensional motion \(F(r,w)\) along arbitrary ray \(r\), which is equivalent to Einstein’s special relativity motion along arbitrary X-axis (axes Y and Z being ignored in practice). In QM, directional solution \(D(\theta,\phi)\) is restricted to \(m^2 \geq 0\), and reduces to usual spherical harmonics \(Y(\ldots)\). In the mid-1990s we studied the (usually neglected) inherently quantized helicoidal functions \(H(\theta,\phi)\) that appear for \(m^2 < 0\) [12, 61-64]. There are two families of helices spiraling inward/outward on the surface of quantized cones shown in Figure 3. Inward growth has been observed in circular micro-pyramids of \(\text{YBa}_2\text{Cu}_3\text{O}_6\) at the 125 nanometer scale [65], and silicon carbide crystals at the 100 micrometer scale [66]; at a larger scale, swirls, tornados and hurricanes are everyday examples. On the contrary, snail- and sea-shells display outward spiral growth. Whether spiral galaxies grow inwards or outwards is left open.

![Figure 3. Helicoidal solutions for equation (1) with \(m^2 < 0\) for counter-clockwise upward motion. Panel (a): Two families of cones around Z-axis; the vertex angle is inherently quantized. Panel (b): Outward spirals grow from \(x = 1\) outwards. Panel (c): Inward spirals grow from \(x = 1\) inwards towards the Z-axis.](image-url)

Searching for longitudinal non-harmonic solutions for \(F(r,w)\) in electromagnetic contexts, we re-wrote the one-dimensional travelling wave as \(M(r,q)\), where the novel independent variable \(q\) intermingles spatial distance \((r)\) and time \((w)\) in an intimate un-separable manner. But, in contrast to
SR, variable \( q \) is a mere mathematical manipulation of physical magnitudes without ontological implications regarding space and time, which remain two separate notions:

\[
\Pi(r,w,\theta,\phi) = M(r,q)D(\theta,\phi) = (N(r) + Q(q))D(\theta,\phi) = B(r,\theta,\phi) + U(q,\theta,\phi),
\]

(3)

Separation of functions \( N(r) \) and \( Q(q) \) in the differential equation for \( M(r,q) \) generates a new quantum number \( \eta \) that appears in the generic solution for \( Q(q) \) in terms of \( Q \)-functions of the first, second and third kind, related to associate Legendre functions. \( Q \)-functions were first described in [61], further details appear in [12, 62-63]:

\[
B(r,\theta,\phi) = N(r)D(\theta,\phi),
\]

\[
U(q,\theta,\phi) = Q(q)D(\theta,\phi),
\]

(4)

As usual in the theory of time-dependent differential equations, the background field \( B(r,\theta,\phi) \) in equation (3) is a particular solution of equation (1). This time-independent steady-state background may provide an alternative interpretation to the origin of cosmic microwave background radiation, and yield a causal explanation for action-at-a-distance and non-locality features in QM and EM theory, along the lines discussed in [67]. New universal field \( U(q,\theta,\phi) \) depends on only three explicit dimensionless ratios of length, viewed as cosines of time \((q)\) and spatial direction \((\theta,\phi)\). Then, velocity dependent function \( f(\beta) \) cancels in numerator and denominator of any transformation of moving coordinates leading to the remarkable property of isomorphism, outlined in equations (5):

\[
s \rightarrow s' = f(\beta)(s - \beta w), \quad w \rightarrow w' = f(\beta)(w - \beta r), \quad s = x, y, z, r, \quad \text{where} \quad \beta = V / C.
\]

Isomorph: \[
\begin{pmatrix} w \\ s \\ r \end{pmatrix} = \begin{pmatrix} q, \cos \theta \\ q', \cos \theta' \end{pmatrix} = \begin{pmatrix} w - \beta r \\ s - \beta w \\ r - \beta w \end{pmatrix}, \quad \text{where} \quad \cos \theta = s / r,
\]

(5)

Doppler: \( f(\beta) = 1 \), Lorentz: \( f(\beta) = \gamma \), Pointcaré: \( f(\beta) = \gamma l(\beta) \),

where \( \gamma = \left(1 - \beta^2\right)^{-1/2} \).

The practical implication is that four competing transformations are equivalent: (1) Doppler formed by the classical Galilei transformation for distance \( r \), and the local time defined by Voigt in 1887 [68], and also mentioned by Poincaré in 1900 [69], (2) Poincaré [70-71], (3) Lorentz [72], (4) Einstein [72]. There is a four-fold repetitive pattern in \( Q_l(q,l) \) functions (see Figure 4) according to \( l = 4n - 1, 4n, 4n + 1, 4n + 2 \), where \( n \) is the number of stable spherical surfaces of dynamic equilibrium [12]. The latter easily explain atomic structure [73], and Titius-Bode rule in both solar and exoplanetary systems with coefficients of correlation usually above 99% [74-75]. In far-field \((r \to \infty)\) \( Q_l \) is monotonous and tends asymptotically to nonzero for odd-\( l \).

The attractive non-zero far field of the \( l = 4n - 1 \) group easily explains the flat rotation rate of galaxies, without ad hoc dark matter, while the repulsive non-zero far field of the \( l = 4n + 1 \) group is similar to nuclear and sub-nuclear confining forces. The far field is zero for even-\( l \), for \( l = 4n \) it is attractive as in Newton and Coulomb forces, and for \( l = 4n + 2 \) it is repulsive as in Coulomb force between equal sign charges. \( Q \)-functions are very similar to Boscovich unified force [76], which is inherently quantized in near field \((r \to 0)\) as Thomson [77] noted before inception of QM. Spherical surfaces of dynamic equilibrium lead to a simple method to solve the three-body problem, and to construct Trojans orbits [74].
Figure 4. Function $Q_i$ for $n = 2$. Note stable intercepts along horizontal axis for the gravitational potential $\ell = 4n = 8$ (graphs plotted by C E Cedeño).

References

[1] ‘t Hooft G 2002 Determinism beneath quantum mechanics Preprint arXiv:0212095v1
[2] Newton I 1687 Philosophiae Naturalis Principia Mathematica (Madrid: Editorial Tecnos, 1987)
[3] Thayer H S 1953 Newton’s Philosophy of Nature—Selections from his Writings (New York: Hafner Publishing) pp 183 198
[4] Múnera H A 2015 From the classical ethers of Descartes and Newton to cosmons and sagions Apeiron 20 2 pp 1-67
[5] Lindsay R B 1961 Physical Mechanics (Princeton NJ USA: Van Nostrand)
[6] Desloge E A 1989 Empirical foundation of classical dynamics Am. J. Phys. 57 pp 704-706
[7] De Saint Venant B 1845 Memoire sur les sommes et les différences géométriques et sur leur usage pour simplifier la mécanique Comptes rendus Académie des Sciences (Paris) 21 620
[8] Jammer M 1961 Concepts of Mass in Classical and Modern Physics (Harvard: Harvard University Press) (Republished in Mineola NY USA: Dover 1997) pp 90, 92
[9] Eisberg R M and Lerner L M 1981 Physics: Foundations and Applications (USA: McGraw-Hill) ch 4
[10] Mach E 1883 The Science of Mechanics translated from German ed 1908, 1912, 1921, 1933 by T J McCormack (La Salle Ill USA: Open Court) p 303
[11] Russell B 1902 The Principles of Mathematics 2nd (New York: W.W. Norton 1938)
[12] Múnera H A 2016 Interconnection of all forces of nature via the energy and momentum equations for a fluid aether ed R L Amoroso et al pp 247-267
[13] Amoroso R L, Kauffman L H and Rowlands P 2016 Unified Field Mechanics: Natural Science Beyond the Veil of Spacetime (Singapore: World Scientific)
[14] Múnera H A 2002 Bell’s-type inequalities revisited: new constraints from objective reality Momento 25 pp 3-27 (Preprint http://www.revistas.unal.edu.co/index.php/momento/article/view/44239)
[15] Laplace P 1814 A Philosophical Essay on Probabilities translated from French by F W Truscott and F L Emory (New York: Dover 1995)
[16] Múnera H A 1992 A deterministic event tree approach to uncertainty, randomness and probability in individual chance processes Theory and Decision 32 pp 21-55
[17] De Broglie L 1952 Sur la possibilité d’une interprétation causale et objective de la mécanique ondulatoire Comptes rendus Académie des Sciences (Paris) 234 pp 265-268
[18] Bohm D and Vigier J P 1954 Model of the causal interpretation of quantum theory in terms of a fluid with irregular fluctuations Physical Review 96 1 pp 208-217
[19] Madelung E 1926 Eine anshauliche Deutung der Gleichung von Schrödinger Naturwissenschaften 14 45 1004
[20] Madelung E 1927 Quantentheorie in hydrodynamischer Form Zeit. Phys. 40 322-6
[21] De Broglie L 1927 L'univers a cinq dimensions et la mécanique ondulatoire Le Journal de Physique et le Radium series VI 8 2 pp 65-73 and 242-4
[22] De Broglie L 1962 Remarques sur l'interprétation de la dualité des ondes et des corpuscles Cahiers de Physique 16 147 pp 425-45
[23] De Broglie L 1970 The reinterpretation of wave mechanics Foundations of Physics 11 pp 5-15.
[24] Gueret P and Vigier J P 1982 Non-linear Klein-Gordon equation carrying a nondispersive soliton-like singularity Lettre al Nuovo Cimento 35 8 pp 256-9
[25] Chebotarev L V 2000 The de Broglie-Bohm-Vigier approach to quantum mechanics Jean-Pierre Vigier and the Stochastic Interpretation of Quantum Mechanics ed S Jeffers et al (Montreal: Apeiron) pp 1-17
[26] Cufaro-Petroni N and Vigier J P 1983 Dirac's aether in relativistic quantum mechanics Foundations of Physics 13 2 pp 253-285.
[27] Múnera H A 2000 A realistic four-dimensional hydrodynamic aether interpreted as a unified field equation Lorentz Group, CPT and Neutrinos ed A E Chubykalo et al (Singapore: World Scientific) pp 425-33
[28] Hankins T L 1965 18th-century attempts to resolve the vis viva controversy Isis 56 281-97
[29] Grant E 1978 The principle of the impenetrability of bodies in the history of concepts of separate space from the Middle Ages to the seventeenth century Isis 69 249 551-71
[30] Grmek M D 1996 La méthodologie de Boscovich Revue d'Histoire de Science 49 4 pp 379-400
[31] Patrizi F 1593 Nova de Universis Philosophia Translated by Brickman (Venice, Italy)
[32] Brickman B 1943 On physical space: Francesco Patrizi Journal for History of Ideas 4 224-45
[33] Einstein A 1911 Ueber der Einfluss der Schwerkraft auf die Ausbreitung des Lichtes Annalen der Physik 35 pp 898-908
[34] Beck A and Howard D 1995 The Collected Papers of Albert Einstein Volume 5 The Swiss Years: Correspondence, 1902-1914 (Princeton NJ USA: Princeton University Press)
[35] Speziali P 1994 Albert Einstein Correspondencia con Michele Besso translated into Spanish by M Puigcerver from Correspondence (1903-1955) (Paris: Hermann 1979) (Barcelona, Spain: Tusquets Editores) p 106
[36] Ginzburg V L and Eroshenko Y N 1996 Commens on paper below Physics-Uspekhi 39 1 81-2
[37] Logunov A A, Mestvirishvili M A and Chugreev Y V On incorrect formulations of the equivalence principle Physics-Uspekhi 39 1 73-9
[38] Einstein A 1907 Jahrbuch der Radioaktivität und Elektronik 4 411
[39] Múnera H A 2010 The Principle of Equivalence: Demonstrations of Local Effective Vertical and Horizontal The Physics Teacher 48 131-3
[40] Von Eötvös R, Pekár D and Fekete E 1922 Beiträge zum Gesetze Proportionalität von Trägheit und Gravität Annalen der Physik series 4 68 9 pp 12-66.
[41] Nieto M M, Hughes R J and Goldman T 1989 Actually, Eötvös did publish his results in 1910, it's just that no one knows about it.... Am. J. Phys. 57 pp 397-404
[42] Fischbach E, Sudarsky D, Szafer A and Talmadge C 1986 Reanalysis of the Eötvös experiment. Phys. Rev. Lett. 56 pp 3-6
[43] Fischbach E, Sudarsky D, Szafer A, Talmadge C and Aronson S H 1988 Long-range forces and the Eötvös experiment Annals of Physics 182 pp 1-89
[44] Fischbach E and Talmadge C L 1999 The Search for Non-Newtonian Gravity (New York: Springer Verlag)
[45] Múnera H A 2011 A Le Sagian atomic-type model for propagation and generation of gravity Should the Laws of Gravitation be Reconsidered?–The Scientific Legacy of Maurice Allais ed H A Múnera (Montreal: Apeiron) pp 385-422
[46] Múnera H A 2013 The empirical basis for the equivalence principle: the Eötvös, Pekár and
Fekete experiment revisited - Once again Proc. of Natural Philosophy Alliance 10 pp 204-212

[47] Ohanian H C 1977 What is the principle of equivalence? Am. J. Phys. 45 10 903-9
[48] Walstad A 1979 The equivalence principle Am. J. Phys. 47 6 565-6
[49] Ohanian H C 1979 Reply to Professor Walstad Am. J. Phys. 47 11 p 1006
[50] Kostro L 2000 Einstein and the Ether (Montreal: Apeiron)
[51] Einstein A 1983 Sidelines on Relativity (New York: Dover) p 17
[52] Múnera H A 1998 Michelson-Morley experiments revisited: systematic errors, consistency among different experiments, and compatibility with absolute space Apeiron 5 (1-2) 371-6
[53] Múnera H A 2006 The evidence for length contraction at the turn of the 20th century: Non-existent Einstein and Poincaré: The Physical Vacuum ed V V Dvoeglazov (Montreal: Apeiron Press) pp 87-102
[54] Múnera H A 2002 The effect of solar motion upon the fringe-shifts in a Michelson-Morley interferometer à la Miller Annales de la Fondation Louis de Broglie 27 3 463-84
[55] Múnera H A, Hernández-Deckers D, Arenas G and Alfonso E 2007 Observation of a significant influence of earth’s motion on the velocity of photons in our terrestrial laboratory Proceedings of SPIE 6664 66640K.
[56] Múnera H A, Hernández-Deckers D, Arenas G, Alfonso E and López I 2009 Observation of a non-conventional influence of earth’s motion on the velocity of photons, and calculation of the velocity of our galaxy Proc. of PIERS 2009 Progress in Electromagnetics Research Symp. Beijing (23-27 March 2009)
[57] Múnera H A 2009 Towards the reinstatement of absolute space, and possible cosmological implications ICFAI University Journal of Physics 2 2-3 pp 9-24
[58] De Haan V O 2015 Experiments to test special relativity Proc. of International Scientific Meeting PIRT-2015 Moscow (29 June-02 July) 131-9
[59] Lipa J A, Nissen J A, Wang S, Stricker D A and Avaloff D 2003 A new limit on signals of Lorentz violation in electrodynamics Physical Review Letters 90 060403
[60] Malet H 1926 Sur la synthèse mathématique des lois de l’électrodynamique Comptes rendus Académie des Sciences (Paris) 183 pp 191-193
[61] Múnera H A, Buriticá D, Guzmán O and Vallejo J I 1995 Non-conventional solutions for the travelling wave equation (in Spanish) Revista Colombiana de Física 27 215-8
[62] Múnera H A and Guzmán O 1997 New explicit nonperiodic solutions of the homogeneous wave equation Foundations of Physics Letters 10 1 pp 31-41
[63] Múnera H A 2000 New closed solutions in spherical coordinates for the 3D-homogeneous wave equation (in Spanish) Momento 20 1-30 (Preprint http://www.revistas.unal.edu.co/index.php/momento)
[64] Múnera H A 2017 Neo-Cartesian Unified Fluid Theory: From the Classical Wave Equation to De Broglie’s Lorentzian Quantized Mechanics and Quantized Gravity Proc. of Vigier X Symp. ed R L Amoroso (Singapore: World Scientific) in the press
[65] Stäuble-Pümpin B, Mendoza G A, Guzmán O, Clavijo J, Prieto P. and Dam B 2001 Two-component model to describe the growth of physical-vapour-deposited YBa2Cu3O7 films Physica C 356 161
[66] McGraw-Hill 1977 Encyclopedia of Science and Technology (New York: McGraw-Hill) 3 636
[67] Chubykalo A, Espinoa A and Alvarado-Flores R 2016 Helmholtz theorems, gauge transformations, general covariance and the empirical meaning of gauge conditions Journal of Modern Physics 7 1021-44 (Preprint http://dx.doi.org/10.4236/jmp.2016.79092)
[68] Voigt W 1887 On the Doppler’s principle (in German) Nachrichten von der Königlichen Gesellschaft der Wissenschaften und der Georg-Augusts Universität zu Göttingen 2 pp 41-51
[69] Poincaré H 1900 Théorie de Lorentz et principe de réaction Archives Neerlandaises 5 252-78
[70] Poincaré H 1905 Sur la dynamique de l’électron Compt. Rend. Acad. Sci.(Paris) 140 1504-8
[71] Poincaré H 1906 Sur la dynamique de l’électron Rend. Circolo Matematico Palermo 21 129-76
[72] Pustovoit V I 2013 On the problems of experimental verification of general relativity Proc. Int. Scientific Meeting PIRT-2013 pp 462-68
[73] Múnera H A 2016 Unified field theory from classical wave equation: application to atomic and nuclear structure. AIP Conf. Proc. 1753 030015
[74] Múnera H A 2016 Novel approach to gravitation from fluid theory: Titius-Bode structures, flat rotation rate of galaxies, and other predictions. Astronomy in Focus-XXIX ed P Benvenuti (Cambridge, UK: Cambridge University Press)
[75] Múnera H A 2017 Gravity from classical fluid theory: prediction and retrodiction of quantized planetary structures. The Galileo of Palomar: Essays in memory of Halton Arp ed C C Fulton and M Kokus (Montreal: Apeiron)
[76] Boscovich R J 1758 Theory of Natural Philosophy tr J M Child (Chicago: Open Court, 1922)
[77] Thomson J J 1907 Corpuscular theory of matter (New York: Charles Scribner) p160