Applied Physics Research; Vol. 7, No. 6; 2015
ISSN 1916-9639 E-ISSN 1916-9647
Published by Canadian Center of Science and Education

On Einstein's Program and Quantum Mechanics

Claude Elbaz[1]

[1] Academie Europeenne Interdisciplinaire de Science (A.E.I.S.), Paris, France

Correspondence: Claude Elbaz, Academie Europeenne Interdisciplinaire de Science (A.E.I.S.), Paris, France. E-mail: claude.elbaz@science-inter.com

Received: November 13, 2015 Accepted: November 18, 2015 Online Published: November 19, 2015

doi:10.5539/apr.v7n6p126 URL: http://dx.doi.org/10.5539/apr.v7n6p126

Abstract

The Einstein's program forms a consistent system for universe description, beside the standard model of particles. It is founded upon a scalar field propagating at speed of light c, which constitutes a common relativist framework for classical and quantum properties of matter and interactions. Matter corresponds to standing waves. Classical domain corresponds to geometrical optics approximation, when frequencies are infinitely high, and then hidden. Quantum domain corresponds to wave optics approximation. Adiabatic variations of frequencies yield electromagnetic interaction. They lead also to Classical and Quantum Mechanics equations, with unification of first and second quantifications for interactions and matter, and to the wave-particle duality, by space reduction of the introduced space-like amplitude function u(r,t), which completes the usual time-like function ψ(r,t).

Keywords: Einstein's Program, Quantum Mechanics, Adiabatic invariant, hidden variables, wave-particle duality.

1. Introduction

Quantum mechanics forms the base of the Standard Model of particles, as a consistent theoretical system. From an experimental point of view, it has been validated in 2012 by the detection of the B.E.H, or Higgs, boson, which represents its crowning. It describes the whole universe as constituted of particles, both for matter or for interactions. They behave either as waves or as particles, and derive from relativist quantum fields.

The wave-particle problem had much mobilized physicists, especially, in 1920 years, for elaboration of quantum mechanics, in a probabilistic and non relativistic framework.

The Standard Model, which privileges particle aspect of universe leaves unsolved many problems. For instance, it can be shown explicitly that the Compton equations, which plays a basic role, and is usually considered as proof of particle behavior of light, exhibits physical consequences less complete than the wave point of view. On another hand, Planck parameters, do not only define a very brief epoch in the earliest time following the universe emergence, before all material particles were created at nucleo-synthesis era, 13,8 billion years ago. They rather continue to apply at present time, in order to determine the extreme boundary limits for a fundamental particle of matter, between its particle aspect and its wave aspect (Elbaz, 2014).

More generally, the formalism of the Standard Model leaves open many questions, since it is implicitly based on point particles of matter: singularities of the field for special relativity (Landau L. & Lifchitz E, 1965, 48), and "point-like" particles with zero dimension for quantum theory. For instance, a "fundamental particle", like a quark, or an electron, has no measurable size. Its mass-energy density is then infinite. In addition, the concept of material particle is characterized by a double discontinuity, in space and in time. In space, by determining an inner « full » part, and an outer « empty » part. In time, by determining a prior time before its creation, and a posterior time after, during which its life is either limited or unlimited.

From a physical point of view, it is obvious that a particle cannot be strictly point-like, since its energy density would be infinite. As the size is not of prime importance, it does not figure usually beside mass and electric charge. On another hand, the basic models are physically and mathematically opposed and complementary, since the waves are extended through space while the particles are concentrated.

In extension of general relativity and of his different discoveries, including in quantum physics, such as the stimulated emission, Einstein had proposed a consistent approach for physics, symmetrical to the standard model, in order to circumvent these difficulties. He privileged a classical continuous field.

«*We have two realities: matter and field. ….We cannot build physics on the basis of the matter concept alone. But the division into matter and field is, after the recognition of the equivalence of mass and energy, something artificial and not clearly defined. Could we not reject the concept of matter and build a pure field physics? …We could regard matter as the regions in space where the field is extremely strong. In this way a new philosophical background could be created….Only field-energy would be left, and the particle would be merely an area of special density of field-energy. In that case one could hope to deduce the concept of the mass-point together with the equations of the motion of the particles from the field equations- the disturbing dualism would have been removed… One would be compelled to demand that the particles themselves would everywhere be describable as singularity free solutions of the completed field-equations. Only then would the general theory of general relativity be a complete theory….One could believe that it would be possible to find a new and secure foundation for all physics upon the path which had been so successfully begun by Faraday and Maxwell.*» (Einstein & Infeld, 1938, 256-257).

The Einstein's Program has been implicitly supported, and validated, by the International Legal Metrology Organization, by shifting from material standards of space and time to field standards. The speed of light in vacuum is admitted as a "pure", or primary, fundamental constant in experimental physics, with its numerical value strictly fixed. The standard for measures of time is based on the period an electromagnetic wave frequency.

In previous articles (Elbaz, 2010, 2012, 2013), we showed how the Einstein's program forms a consistent system for universe description, beside the standard model. It allows us to complete the universe grasp, like both eyes give us access to tridimensional vision, or both ears to stereophonic audition. Starting from a scalar field propagating at light velocity, matter corresponds to standing waves, and interactions to their adiabatic variations. In the geometrical optics approximation, when frequencies are infinitely high, the oscillations are hidden. This holds at one and the same time in classical relativistic and quantum frameworks, yielding their descriptions being incomplete.

In this article we propose to show how the Einstein's program, allows us to retrieve the main basic equations of quantum mechanics, like Schrödinger's equation, Dirac's distribution, Heisenberg's relations, all resulting from adiabatic variations or almost standing waves. We point out the role of the amplitude function, acting also implicitly in quantum mechanics, and then hidden. In the geometrical approximation, when constant frequency is very high, it leads to the free particle concept, both in classical and quantum mechanics. When frequency is almost constant, it leads to the interacting particle concept. From its small variations derive electromagnetic interaction and adiabatic invariant constant, formally identical with the Planck's constant.

This article appears as paving the way towards reexamination of typical quantum experiments, such as double-slit interference, or entanglement, raised by E.P.R Einstein's article in 1935.

2. The Einstein's Program

We restrict to summarize some equations deduced from Einstein's program without their demonstrations, available elsewhere (Elbaz, 2010, 2012, 2013), in order to show how they are related to main equations of quantum mechanics, otherwise widely documented.

2. 1 Kinematical Properties of Standing Fields

In previous articles we showed how the variations of the light velocity c yield general relativity and gravitational interaction. Here we will restrict to c constant, restricting to special relativity.

From the d'Alembertian's equation describing a scalar field ε propagating at light velocity c

$$\varepsilon = \Delta\varepsilon - (1/c^2)(\partial^2\varepsilon/\partial t^2) = 0, \qquad \partial^\mu\partial_\mu\,\varepsilon = 0 \tag{1}$$

derive two kinds of elementary harmonic solutions with constant frequency ω_0, with different kinematical properties. The progressive waves, either retarded $\cos(\omega_0 t_0 - k_0 x_0)$, or advanced $\cos(\omega_0 t_0 + k_0 x_0)$, are in motion with light velocity $c=\omega_0/k_0$. The standing waves, where space and time variables are separated, oscillate locally: $\varepsilon_0(x_0,t_0) = u_0(k_0x_0)\psi_0(\omega_0 t_0) = \cos(\omega_0 t_0)\cos(k_0 x_0)$. They allow to define a system of coordinates at rest (x_0,t_0).

They may be considered as resulting from superposition of progressive waves

$$\cos(\omega_0 t_0 + k_0 x_0) + \cos(\omega_0 t_0 - k_0 x_0) = 2\cos(\omega_0 t_0)\cos(k_0 x_0). \tag{2}$$

When, in a system of reference (x,t), the frequencies of opposite progressive waves are different

$$\cos(\omega_1 t - k_1 x) + \cos(\omega_2 t + k_2 x) = 2\cos(\omega t - \beta k x)\cos(kx - \beta\omega t), \tag{3}$$

where $\omega=(\omega_{1+}\omega_2)/2=kc$, and $\beta=(\omega_1-\omega_2/\omega_{1+}\omega_2)$. By identification with (2), they form a standing wave in motion with a speed $v=\beta c=(\omega_1-\omega_2/\omega_{1+}\omega_2)c$, with frequency $\omega=(\omega_{1+}\omega_2)/2=kc$, and $\omega_0=\sqrt{\omega_1\omega_2}$ at rest, defining the Lorentz transformation between the systems of reference(x_0,t_0) and (x,t).

The Lorentz transformation, fundamental in special relativity, is specific of c-field standing waves, particularly through the coefficient $\sqrt{(1-\beta^2)}$. It implies necessarily two frequencies, so that v, the moving speed of matter, as a relative difference, is strictly inferior to c. The four-dimensional Minkowski's formalism expresses that the stability properties of a standing wave in its rest system, hold when they move uniformly with a speed $v=\beta c<c$. It defines invariant quantities, obtained from four-dimensional quantities, such as coordinates $x_\mu x^\mu=x_0^2$ or $x_\mu x^\mu=c^2t_0^2$, and functions $u_\mu u^\mu=u^2(x_0)$ or $\psi_\mu\psi^\mu=\psi^2(t_0)$. Their space-like or time-like characters are absolute, according to their depending coordinate variation in the rest system.

Since the functions $u_0(k_0x_0)$ and $\psi_0(\omega_0t_0)$ are independent, the frequency ω_0 is necessarily constant in

$$(1/u_0)\Delta_0u_0=(1/\psi_0)(\partial^2\psi_0/c^2\partial t_0^2)=-k_0^2=-\omega_0^2/c^2. \quad (4)$$

The function of space $u_0(k_0x_0)$, which obeys the Helmholtz's equation at rest $\Delta_0u_0+k_0^2u_0=0$, becomes $\Delta u-(1/c^2)(\partial^2u/\partial t^2)+k_0^2u=0$ in motion. It describes geometric properties of standing waves. It verifies Bessel spherical functions solutions, and particularly its simplest elementary solution, with spherical symmetry, finite at origin of the references system, which represents a lumped function,

$$u_0(k_0r_0)=(\sin k_0r_0)/(k_0r_0). \quad (5)$$

In geometrical optics approximation, when the frequency is very high, and tends towards infinity $\omega_0=k_0c\rightarrow\infty$, the space function tends towards Dirac's distribution $u_0(k_0r_0)\rightarrow\delta(r_0)$. The standing wave of the field behaves as a free classical material particle isolated in space (Elbaz, 2013).

From a kinematical point of view, the central extremum of an extended standing wave, either at rest or in motion, is appropriate to determine its position $x_0=r_0=0$ in cartesian coordinate system of reference, exactly like the centre of mass in mechanics. It verifies, for instance from (5),

$$\boldsymbol{\nabla}_0u_0(\mathbf{x}_0)=0. \quad (6)$$

In order to point out the constant frequency of a standing field, we express it as

$$\varepsilon(\omega t,kx)=u(kx,\beta\omega t)\exp i(\omega t-\beta kx) \qquad \varphi=\omega t-\beta kx \quad (7)$$

The equations of special and general relativity are based on mass-points, as singularities, moving on trajectories, deriving then directly from geometrical optics approximation. The periodic equations, generic of standing fields, are hidden. The space coordinates x_α, involved in the space-time metric, are point-like dynamical variables, and not field variables r, which would describe an extended amplitude repartition in space. Then, the kinematic properties of standing waves for a scalar field propagating at light velocity c, with constant frequency ω and velocity v, reduce formally to kinematical properties of isolated point-like matter.

2.2 Dynamical Properties of Standing Fields

Instead of appeal to heterogeneous material boundaries in order to limit the c-field, we rather consider homogeneous boundaries provided by wave packets.

Two progressive waves with different frequencies ω_1,ω_2 propagating in the same direction at light velocity, give rise to a wave packet propagating in the same direction at light velocity. Its main wave with frequency $\omega=(\omega_{1+}\omega_2)/2$, is modulated by a wave with frequency $\beta\omega=(\omega_1-\omega_2)/2=\Delta\omega/2=\Delta kc/2$, wavelength $\Lambda=2\pi/\beta k$, and period $T=\Lambda/c$. Since $\beta<1$, the modulation wave acts as an envelope with space and time extensions $\Delta x=\Lambda/2$, $\Delta t=T/2$, yielding well known Fourier relations $\Delta x.\Delta k=2\pi$ and $\Delta t.\Delta\omega=2\pi$.Then, Fourier relations represent homogeneous boundary conditions for the scalar field ε. From a physical point of view, they must necessarily supplement the d'Alembertian's equation (1) in order to emphasize that the field cannot extend to infinity with respect to space and time.

When the difference of frequencies $\beta\omega=(\omega_1-\omega_2)/2=\Delta\omega/2<<\omega$ is very small, it can be considered as a perturbation with respect to the main frequency, $\beta\omega=\delta\omega$. Then a wave packet can be assimilated to a progressive monochromatic wave with frequency $\Omega=\omega\pm\delta\omega$, inside the limits fixed by the component frequencies $\omega_1=\omega+\delta\omega$ and $\omega_2=\omega-\delta\omega$. By difference with standing waves frequencies, which must be constant and monochromatic, progressive fields solutions of (1), may be more complex, with frequencies varying with space and time. We will characterize an almost monochromatic wave by a frequency $\Omega(x,t)$, varying very little around a constant ω

$$\Omega(x,t)=K(x,t)c=\omega\pm\delta\Omega(x,t) \qquad \delta\Omega(x,t)<<\omega \qquad \omega=\text{constant}. \quad (8)$$

We recognize the definition of an adiabatic variation for the frequency (Landau & Lifchitz, 1960,154). Consequently, all following properties of almost fields arise inside such a process. The necessarily constant frequency of a standing wave must be considered, not as a given data, but rather as the mean value, all over the field, of different varying frequencies $\Omega(x,t)$. The perturbation frequencies $\delta\Omega(x,t)$ of modulation waves propagating at light velocity, behave as interactions between main waves, which yield the mean frequency ω to remains practically constant all over the space-time.

Such a behavior authorizes mathematically to derive almost fields properties from monochromatic ones, through the variation of constants method (Duhamel principle). Instead of (8), we express it, as

$$\varepsilon(x,t) = U(x,t)\exp i\phi(x,t) \qquad \phi(x,t)= \Omega(x,t)t - \mathbf{K}(x,t).\mathbf{x} +2n\pi, \tag{9}$$

where products of second order $\delta\Omega dt\approx0$ and $\delta\mathbf{K}.d\mathbf{x}\approx0$, defined modulo 2π, are neglected at first order of approximation. This is equivalent to incorporate directly the boundary conditions defined by Fourier relations, in almost monochromatic solutions,

$$d\phi(x,t)=\Omega(x,t)dt - \mathbf{K}(x,t).d\mathbf{x} \approx \omega dt-\mathbf{k}.d\mathbf{x}. \qquad U(x,t)=u(x,t)\pm\delta U(x,t) \tag{10}$$

Following (1), the field $\varepsilon(x,t)$ defined by (9) verifies,

$$\partial^\mu\partial_\mu U- U\partial^\mu\phi\partial_\mu \phi =0 \qquad \text{or} \qquad \partial^2U/c^2\partial t^2-\nabla^2U- U[(\partial\phi/c\partial t)^2-(\nabla\phi)^2]=0 \tag{11}$$

$$\partial^\mu (U^2\partial_\mu \phi)=0 \qquad \text{or} \qquad \partial(U^2\Omega)/c^2\partial t+ \nabla.(U^2\beta\mathbf{K}) =0 \tag{12}$$

These relations apply to progressive waves for $\beta=\pm1$, to standing waves at rest for $\beta=0$ and in motion for $\beta<1$, to monochromatic waves for ω and $\mathbf{k}$ constant, to almost monochromatic waves for varying $\Omega(x,t)$ et $\mathbf{K}(x,t)$. They lead to dynamical properties for energy-momentum conservation, and to least action principles, for standing fields and almost standing fields (Elbaz, 2013).

For a standing wave with constant frequency ω, either at rest or in motion, (12) reduces to

$$\partial u_0^2/\partial t_0 = 0. \qquad \partial u^2/\partial t +\nabla.u^2\mathbf{v}=0 \qquad \text{or} \qquad \partial_\mu w^\mu =0 \tag{13}$$

where $w^\mu=(u^2,u^2\mathbf{v}/c)=u_0(x_0)^2(1,\mathbf{v}/c)/\sqrt{(1-\beta^2)}$ is a four-dimensional vector. This continuity equation for u^2 is formally identical with Newton's equation continuity for matter-momentum energy density

$$\partial\mu/\partial t +\nabla.\mu\mathbf{v}=0. \qquad \text{with} \qquad u^2 =\mu c^2 . \tag{14}$$

By transposition, we can then admit that u^2 represents the energy density of the standing field.

In order to describe the kinematical behavior of a standing field, we may restrict to one of its particular point such as its center of amplitude, with position x_0 defined by (6), especially when experimental conditions lead us to consider that it reduces to a point. The position x_0 of the energy density verifies

$$\nabla_0u_0^2=0 \qquad \nabla u^2 +(\partial u^2\mathbf{v}/c^2\partial t)=0 \qquad \nabla\times\mathbf{v}=0 \qquad \text{or} \qquad \pi^{\mu\nu}=\partial^\mu w^\nu-\partial^\nu w^\mu=0, \tag{15}$$

The standing wave energy density u^2 is spread in space. It corresponds then to a potential energy density, so that. $\mathbf{F}= -\nabla u^2 =-\nabla w_P=$ is a density force, and $\partial u^2\mathbf{v}/c^2\partial t$ a density momentum. $\pi^{\mu\nu}$ is a four-dimensional force density. In (15), the vanishing four-dimensional force density tensor $\pi^{\mu\nu}$ of a standing wave, asserts that its space stability remains in uniform motion, and that the energy-momentum density four-vector w^μ is four-parallel, or directed along the motion velocity $\mathbf{v}$.

Equation (15) is mathematically equivalent to the least action relation, in which energy density w^μ is a four-dimensional gradient $\partial^\mu a$,

$$\delta\int da=0 \quad \delta\int\partial^\mu a dx_\mu =0 \qquad \text{with} \qquad w^\mu = \partial^\mu a. \tag{16}$$

When we transpose the mass density $\mu=u^2/c^2$, and we take into account the identities $\nabla P^2=2(\mathbf{P}.\nabla)\mathbf{P}+2\mathbf{P}\times(\nabla\times\mathbf{P})$ and $d\mathbf{P}/dt=\partial\mathbf{P}/\partial t+(\mathbf{v}.\nabla)\mathbf{P}$ for c and v constant, after integration with respect to space, we get the equation for matter

$$d\mathbf{p}/dt=-\nabla mc^2+\{\nabla(mv)^2\}/2m \qquad d\mathbf{p}/dt=\nabla L_m=-\nabla m_0c^2\sqrt{(1-\beta^2)}. \tag{17}$$

We retrieve the relativistic Lagrangian of mechanics for free matter $L_m=-m_0c^2\sqrt{(1-\beta^2)}$.

2.3 Electromagnetic Interaction

The continuity equation of an almost standing wave, applies to the total energy density, $W=U^2\Omega=w+\delta W$, sum of the mean standing wave w and of the interactions δW. Relation (15) becomes

$$\Pi^{\mu\nu}=\partial^\mu W^\nu-\partial^\nu W^\mu=0 \quad \text{or} \quad \Pi^{\mu\nu}=\pi^{\mu\nu}+\delta\Pi^{\mu\nu}=0 \tag{18}$$

By difference with the null four-dimensional density force $\pi^{\mu\nu}$ for a standing wave, only the total density force $\Pi^{\mu\nu}$ for an almost standing wave vanishes. In the first case, this asserts the space stability of an isolated moving standing wave, while in the second case, the space stability concerns the whole almost standing wave. It behaves as a system composed of two sub-systems, the mean standing field with high frequency $\Omega(x,t)\approx\omega$, and the interaction field with much lower frequency $\delta\Omega(x,t)$, each one exerting an equal and opposite non vanishing density force $\pi^{\mu\nu}=-\delta\Pi^{\mu\nu}$ against the other. The mean energy-momentum density tensor $\pi^{\mu\nu}$, no longer vanishes in (18), as previously in (15). This comes from the mean energy-momentum density four-vector w^μ, which is no longer parallel, because of the opposite density force $\delta\Pi^{\mu\nu}$ exerted by the interaction.

It appears that an almost standing field behaves as a whole system in motion which can be split in two sub-systems, the mean standing field and the interaction field. Both are moving with velocity v, while exerting each other opposite forces in different directions, including perpendicularly to the velocity v. The perturbation field, arising from local frequency variations $\delta\Omega(x,t)$, introduces orthogonal components in interaction density force and momentum.

After generalizing relations (17) by constants variation method for mass $M(x,t)=m\pm\delta M(x,t)$, we get

$$\nabla Mc^2+\partial P/\partial t=0 \qquad \nabla\times P=0 \qquad dP/dt=-\nabla Mc^2+(\nabla P^2)/2M. \tag{19}$$

The density force $\delta\Pi^{\mu\nu}\neq 0$ exerted by the interaction is formally identical with the electromagnetic tensor $F^{\mu\nu}=\partial^\mu A^\nu-\partial^\nu A^\mu\neq 0$. We can set them in correspondence $\delta\Pi^{\mu\nu}=eF^{\mu\nu}$, through a constant invariant charge e, with $\delta M(x,t)=eV(x,t)/c^2$ and $\delta P(x,t)=eA(x,t)/c$. The double sign for mass variations corresponds to the two signs for electric charges, or to emission and absorption of electromagnetic energy by matter. We retrieve the minimum coupling of classical electrodynamics, $P^\mu(x,t)=p^\mu+eA^\mu(x,t)/c$, with $M(x,t)c^2=mc^2+eV(x,t)$, and $P(x,t)=p+eA(x,t)/c$, where electromagnetic energy exchanged with a particle is very small compared to its own energy $eA^\mu(x,t)/c=\delta P^\mu(x,t)<<p^\mu$ (Landau L. & Lifchitz E., 1965, 102). Electromagnetic interaction is then directly linked to frequencies variations of the field ε.

Relation (19) yields the relativistic Newton's equation for charged matter with the Lorentz force

$$dP/dt=-\nabla m_0c^2\sqrt{(1-\beta^2)}+e(E+v\times H/c). \tag{20}$$

2.4 Adiabatic Invariant

For an almost standing wave, the relation (11) leads to

$$[\partial U^2/\partial t+\nabla.U^2\mathbf{v}]/U^2+\delta[\partial\Omega/\partial t+\nabla.\Omega\mathbf{v}]/\Omega=0 \quad \text{or} \quad (\partial_\nu W^\nu)/W+\delta(\partial_\nu\Omega^\nu)/\Omega=0 \tag{21}$$

with energy density $W=w\pm\delta W=\mu c^2=\mu c^2\pm\delta\mu c^2$, four-dimensional energy density $W^\nu=w^\nu\pm\delta W^\nu$, frequency $\Omega=\omega\pm\delta\Omega$, and four-dimensional frequency $\Omega^\nu=(\Omega,\Omega\mathbf{v}/c)$, leading to

$$W^\nu=I\Omega^\nu \quad \text{and} \quad \delta W^\nu=I\delta\Omega^\nu \tag{22}$$

when we take into account the double sign in frequency variation $\delta\Omega$. The constant I is an adiabatic invariant density. Integrations with respect to space of μ and I densities, lead to relations between four-energy and four-frequency through the adiabatic invariant H, formally identical with the Planck's constant h.

$$E^\nu=m_0c^2u^\nu=(mc^2,\mathbf{p}c)=H\omega^\nu=H\omega_0u^\nu=H(\omega,\mathbf{k}c) \tag{23}$$

For the standing wave corresponding to matter, adiabatic variations of its frequency Ω lead to electromagnetic interaction constituted by progressive waves. The energy of electromagnetic interaction derives from mass variation $dE=c^2dm$. It leans directly upon the wave property of matter: its energy $dE= hd\nu= c^2dm$ derives from variations of matter energy $E=h\nu=mc^2$.

3. Applications to Quantum Mechanics

The Einstein's program provides a common framework which allows us to retrieve the main basic assumptions , and equations, of quantum mechanics. Instead of starting from the beginning the point-like particle as fundamental, in order to fit to experiment, it derives its properties and behaviours from a continuous extended field propagating at light velocity. Localized particles derive in the geometrical optics approximation. It is well known that carrying out an approximation leads to different final results, depending it occurs at the beginning, or at the end of a demonstration. In the first case, the neglected properties and data, hidden along the calculus process, yield a less complete result.

3.1 Classical Mechanics

Classical mechanics, based on mass-points for Newton or singularities for relativity, moving on trajectories, leans from the beginning upon the geometrical optics approximation of the c-field (5). The prevailing macroscopic environment is very much greater than the main wavelength $\lambda=2\pi/k$ and the perturbation wavelength $\Lambda=2\pi/\delta K$, which acts as a boundary concentrating the extended field in space. Both are hidden for an isolated particle. The amplitude space function $u_0(k_0x_0)$, solution of the Helmholtz's equation at rest $\Delta_0u_0+ k_0^2u_0 =0$, such as (5), reduces to a Dirac's distribution $\delta(r_0- \mathbf{x}_0)$. Consequently, the total energy of the underlying almost standing field is entirely concentrated in the Cartesian central extremum $\mathbf{x}_0$ of $u_0(k_0x_0)$, defining its position $\mathbf{x}_0= r_0=0$. Such a concentration at $\mathbf{x}_0$ coordinate is clearly represented by the implicit Dirac's distribution $\delta(\mathbf{x}_0)$. By integration all over space, the mass is totally recovered. No mass-energy remains outside the position $\mathbf{x}_0$.

Mathematically, the reduction of the extended space function $u(r_0)$, with respect to spherical coordinate r_0 to a point-like $\delta(\mathbf{x}_0)$, where r_0 is no longer present and characterized only by its Cartesian position $\mathbf{x}_0$, represents a collapse. Nevertheless, it must be emphasized that the geometrical optics approximation does not imply any physical collapse of a lumped function such as (5) following a measurement. The energy extended outside the extremum does not appear experimentally when it is measured, only because it is too slight, and then undetectable with regards to the means used. Such an approximation is well known, and usual, in electromagnetic signal technology.

These properties remain unchanged in motion, except that the Helmholtz's equation, which becomes $\Delta u-(1/c^2)(\partial^2u/\partial t^2)+k_0^2u =0$, with plane wave solution $u= \exp i(\mathbf{k.x}-\beta\omega t)$, admits as extremum postion $(\mathbf{x}-\mathbf{v}t)/\sqrt{(1-\beta^2)}$ instead of $\mathbf{x}_0$. By comparison with spherical field variables r describing the space repatition of u, the position $\mathbf{x}$ is a dynamical Cartesian variable. In special and general relativity, the equations are based on particles, as singularities, moving on trajectories. They lean then directly upon geometrical optics approximation. The periodic equations, generic of standing fields, are hidden. The space coordinates x_α , involved in the metric, are point-like dynamical variables, and not field variables r which would describe an extended repartition in space.

Consequently, the least action relation (16), which describes the centre of energy motion as point-like (15), derives from the whole extended amplitude function u. Then, it takes implicitly into account the very slight hidden energy, acting outside localized mass. Since centuries, it is known that this outside hidden informative action had intrigued physicists: following the least action principle, how a well localized particle was aware of far boundaries in order to adjust and minimize its path? From Einstein's program (16), we notice that the instantaneous energy repartition in space (5), expresses only that u represents the resulting stationary space-like part of a field ε which had propagated at light velocity c.

3.2 Quantum Mechanics

3.2.1 Wave and Geometrical Optics Approximations

In quantum mechanics, the geometrical optics approximation holds only for the main wavelength $\lambda=2\pi/k$, with main energy mc^2. Matter behaves as made of particles. The microscopic acting environment, with dimensions around $\Lambda=2\pi/\delta K$, yield wave approximation to become into sight for kinetic energy $mv^2/2$, linked to electromagnetic interactions. The underlying almost standing field $\varepsilon(x,t)$, for matter in (9), verifies simultaneously the geometrical optics approximation for its main frequency ω, and the wave approximation for the interacting frequency $d\Omega(x,t)=d\delta\Omega(x,t)$, according to (8). Following (11-17) and (22), a material particle is characterized by constant point-like energy E and momentum $\mathbf{p}$, with its motion governed by wave-like interactions.

Such a double approximation was clearly set down at the beginning of quantum theory. In Bohr's atom, an electron, as a mass-point, moved along a trajectory around a nucleus, while exchanging with it electromagnetic wave. Because of admitted energy quantification, its path exhibited periodical sequences, instead of being monotonous.

By comparison with classical mechanics, the least action principle, which asserts that the motion occurs locally along the speed **v**, was replaced by a circular integral, which asserts that the phase is defined modulo 2π in (9).

3.2.2 Schrödinger Equation.

This appears also, either in the Schrödinger equation

$$(ih/2\pi)\partial\psi/\partial t = -(h^2/8\pi^2 m)\Delta\psi \tag{24}$$

admitted as fundamental, or which is equivalent, in the operators acting on ψ function

$$E \rightarrow (ih/2\pi)\partial/\partial t \quad \mathbf{p} \rightarrow -(ih/2\pi)\nabla \tag{25}$$

In both cases, the framework is non relativist. The energy considered restricts to the kinetic energy of the particle $E_k = p^2/2m$, instead of its main energy $E=mc^2 \approx E_k + E_0$.This emphasizes that the rest energy $E_0 = m_0c^2$, admitted as remaining constant in whole processes involved afterwards, is eluded, or hidden. The mass of a particle like an electron, is admitted as unaffected by its motion and by its interactions. Like in classical physics, the mass-energy extended outside the point-particle in neglected, and hidden. Nevertheless, its underlying action continues to operate in that case, but as a second order wave approximation.

Basically, the function ψ defined by (24) or (25) verifies

$$\psi = a\ \exp\text{-}i\varphi \quad \varphi = (h/2\pi)(E_k t - \mathbf{p.x}) \tag{26}$$

Where the three terms, amplitude a, energy E_k and momentum **p** are constant. This corresponds directly to the standing field relation (7), through Planck-Einstein-de Broglie relations $E=h\nu=mc^2$ (Broglie, 1924, 21). Such a plane wave (26) is not appropriate to describe a particle. The space concentration of ψ is implicitly carried out by the variation of constants method, without going into details, after admitting that the constant terms vary slightly. Usually, only the mathematical process, in agreement with experiment, is given importance.

In wave mechanics, the solution of the Schrödinger equation is extended from of a plane wave (26), to a more complex wave packet, involving implicit variations δE_k for energy and δp for momentum around their constant values. They behave as virtual, so that the phase φ in (26), no longer monochromatic describing a motion at the speed v of the matter particle,

$$\delta E_k / \delta p = mv\delta v/m\delta v = v \tag{27}$$

In experiments, the particle appears with practically constant values E_k and p for its energy and momentum. They are affected only by second order virtual, and then aleatory, variations δE_k and δp, which do not change the phase variation dφ in (26). The second order relations $\delta E_k dt = \delta p dx = nh$, where n=0,1,….is an integer, correspond to the Heisenberg relations.

In quantum mechanics, the amplitude a is no longer constant, but varies with respect to space and time. However, these variations are very slight with respect to E_k and **p**, so that they do not hold when operators (25) are applied to $\psi=a(x,t)\exp\text{-}i(h/2\pi)(E_k t-\mathbf{p.x})$ in order to retrieve the Schrödinger equation (24). The absolute phase φ, which cannot be measured, is eluded in products involving ψ and its conjugate $\psi^*=a(x,t)\exp_{+}i(h/2\pi)(E_k t-\mathbf{p.x})$, yielding experimentally observables quantities (Quigg, 1983, 41).

For instance, the well known continuity relation deduced from the Schrödinger equation

$$\partial\psi^*\psi/\partial t + \nabla.[-(ih/2m)(\psi^*\nabla\psi-\nabla\psi^*\ \psi)=0 \quad \text{or} \quad \partial a^2/\partial t+\nabla.a^2\mathbf{v}=0 \tag{28}$$

shows that the $\psi^*\psi= a^2(x,t)$ moves with the particle with the speed v. The normalization condition

$$\int\psi^*\psi dx=1 \quad \text{or} \quad \int a^2dx=\int\dot{\rho}(x)dx=1 \quad \text{like} \quad \int\delta(x)dx=1 \tag{29}$$

permits to identify $a^2(x)= \dot{\rho}(x) =\delta(x)$ with a point-like probability density. Since it accompanies the particle in its motion, it is defined in its system of reference, by a space-like function.

Such a relativist property for the function a(x) goes beyond its introduction from the non relativist Schrödinger equation. It is consistent with, and derives from, the operators (25), which remain valid in the relativist case. The phase becomes $\varphi= (h/2\pi)(Et-\mathbf{p.x})$ for the function $\psi=a\ \exp\text{-}i\varphi$. If, in one hand we admit that E and p, and in other hand that the amplitude a, are not rigorously constant, we are led to identify the space-like amplitude a(x,t) with the space-like amplitude U(x,t) of an almost stationary c-field (9).

The normalisation condition confirms then that, in addition to the non relativist approximation, quantum mechanics leans on point-like approximation of the Einstein's scalar c-field according his program.

4. Concluding Remarks

Taking account of the space-like amplitude a(x,t) in quantum mechanics, paves the way towards reexamination of typical quantum experimental behaviors, such as double-slit interference, or E.P.R entenglement, raised in 1935 by Einstein.

Acknownledgments

Even though I mentionned that the related works in quantum mechanics are well documented, and impossible to be all cited, I thank a referee for pointing out that, the best possible references are due to Nobel Prize in Physics laureates, particularly for modern optics and spectroscopy works by C. Cohen-Tannoudji, S. Haroche, A.B.Mc Donald, A.L. Schawlow, C.H.Townes, and D.J. Wineland.

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