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Einstein Classical Program Revived

Andrea Carati[a*] *& Luigi Galgani*[a]

[a] *Department of Mathematics, Università degli Studi di Milano, Via Saldini 50, 20132 Milan, Italy*

***Corresponding author:** Andrea Carati, Email: andrea.carati@unimi.it

Abstract

The Einstein Classical Program is well known: to prove that, at least in the domain of atomic physics, quantum mechanics can be recovered from a theory presenting some "realistic character". Here we address an extreme form of the program in which the realistic theory is just classical electrodynamics of point charges, and give concrete examples in which typical "quantum phenomena" are explained. Namely, spectral lines (in the case of ionic crystals) and chemical bond (in the case of the H_2^+ ion of the Hydrogen molecule). Additionally, an explanation is given of a phenomenon (existence of polaritons in ionic crystals), for which a quantum explanation is still lacking. Concerning the general objection that a classical theory would be impossible because of radiative collapse (radiation emission by accelerated charges), we illustrate how it is removed for charges in a medium, in virtue of the Wheeler-Feynman cancellation. The impact of such results for the general reductionistic program is also commented.

Keywords: microscopic electrodynamics, Wheeler-Feynman absorber theory, IR crystal spectrum, H_2^+ bond

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Introduction

The modern reductionist approach is dominated by mechanism, i.e. by the prejudice that every phenomenon may ultimately be explained as due to the motion of ultimate components, namely, for what concerns atomic physics, by the motions of atoms and molecules. The motion of such components is governed by the laws of quantum mechanics. Thus, such theory ideally holds up the whole conceptual building of modern science. However, quantum mechanics, beyond its known interpretative paradoxes, is not without problems: in particular, nobody has yet succeeded in building up a quantum theory of fields in a self-consistent way, nor in providing a rigorous theoretical basis for statistical quantum mechanics, perhaps the most important step for carrying up a self-consistent mechanistic program. In other words, while many formulas "explain" a multitude of observed phenomena, such formulas remain, in the spirit of the familiar P.A.M. Dirac's comment at the end of his treatise, at the level of "valid rules" of a "workable theory". This state of things was felt by some physicists, first of all Einstein himself (Schlipp 1949), as unsatisfactory, and as a clue that, perhaps, quantum mechanics may be nothing but a "shortcut" leading to an explanation of phenomena that would require, in the still unknown ultimate theory, a long deductive work. In other words, quantum mechanics might be deduced as a theorem from a more complete theory.

In our approach, we travel an alternative route. Instead of trying to deduce the quantum theory, we aim at reproducing phenomena considered impossible to explain outside of the quantum paradigms, such as spectra and chemical bond. The theory we consider

is just classical electrodynamics of point charges, as developed from the times of Planck, Abraham and Lorentz, through the works of Dirac and then of Wheeler and Feynman, up to the present days.

Now, it has always been stated that such extreme version of the program would be impossible since, according to classical electromagnetism, accelerated charges should radiate energy away, and for example electrons would fall on nuclei within 10-8 seconds (instability of the Rutherford atom). We will refer to such objection as the *radiative collapse*. However, this is proven for a single charge, or a system of few charges, while completely isolated. Instead, the charges are in fact immersed in a medium, constituted by a huge number of charges subject to mutual electromagnetic interactions, with their characteristic long-range reach. This global feature—that we inherit from the Wheeler-Feynman approach to classical electrodynamics in a medium—is indeed a key point also for our approach to the relations between quantum and classical mechanics. Now, it will be seen that, as a consequence of the Wheeler-Feynman theory, in general the medium produces a cancellation of the radiations emitted by the single charges. Thus, the radiative-collapse objection is removed, and it would rather seem as if the presence of a medium necessarily had to be taken into account, even in quantum mechanics.

So, how does it happen that the common local approach used in quantum mechanics, in which single isolated systems are considered as if the medium did not exist, in fact works? Think of the computation of the energy levels of an atom, with its implication for the spectra. Now, whereas a justification does not seem to exist in a quantum framework, it will be shown here that the situation is different in a classical setting. Indeed, a local approach for computing the electromagnetic forces was recently justified in the case of ionic crystals, through a fulfillment of the Wheeler-Feynman theory. So it is now made plausible that, within a classical framework, an analogous property may be proven to occur in general cases, for example in the case of gases.

Anyway, in the case of ionic crystals a theoretical computation of infrared spectra was performed through a completely classical treatment within statistical mechanics, according to Kubo's linear response theory. The result, illustrated in Figure 1, shows that the experimental data are reproduced in an astonishingly good way, and in fact even better than through a quantum computation. Additionally, still in the case of ionic crystals a phenomenon was proved, i.e. the existence of polaritons. This plays an essential role in explaining transparency properties of crystals, but, being due to retardation of the electromagnetic forces, could not yet be proved in a quantum framework.

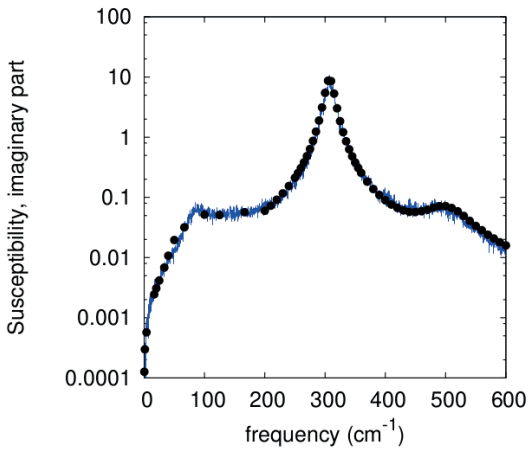

Figure 1: Infrared spectrum of the Lithium Fluoride crystal. Imaginary part of susceptibility vs. frequency, at room temperature. Comparison between calculations (solid line) and experimental data taken from Palik 1998 (points).

In Section 1, the Wheeler-Feynman theory is illustrated. In Section 2, it is described how such theory, formulated by them at a formal level, received a "rigorous" formulation in the particular case of ionic crystals. In the conclusive Section, some general comments are given. In particular, it is pointed out how the Wheeler-Feynman approach has apparently devastating consequences for the general problem of reductionism in science, since it leads to equations of motion in which the familiar deterministic Laplacian character is apparently lost.

1. The Wheeler-Feynman Theory

The Wheeler-Feynman theory can be illustrated as an invention of them to eliminate a paradoxical feature of classical electrodynamics. This shows up when a material medium is conceived as constituted by a multitude of microscopic charges (rather than as a

continuum) with mutual electromagnetic interactions. The paradox is that in an infinite medium classical electrodynamics of charges could not exist, since the total electromagnetic forces on each of them apparently diverge. Wheeler and Feynman showed it through a very simple argument (Wheeler-Feynman, 1945, see also Wheeler-Feynman, 1949), with the aim of explaining the origin of the damping force acting on accelerated charges. In fact, the theory of Wheeler and Feynman is a fulfillment of the great Dirac's contribution of 1938 (Dirac, 1938). Without it, such theory would not exist.

1.1 The Paradox of Wheeler and Feynman

The paradox says that *if, contrary to what occurs in optics, the electromagnetic field would propagate in a medium with the speed of light in vacuum c, then the forces between the charges would diverge*. Thus, removing the paradox not only allows one to explain phenomena (optics), but it is even a founding fact of the microscopic theory itself, since otherwise the latter would be contradictory.

To understand this fact, consider a plane wave propagating in the medium: every charge will suffer a force, and thus an acceleration a_i proportional to it. As it is well known, an accelerating charge radiates. The point is that its radiation field decreases very slowly with distance, i.e., as $1/r$, in a much slower way than the Coulomb field, which decreases as $1/r^2$. Therefore, for the total electric field created by all the radiating particles, one obtains the expression,

$$E_{tot} = \sum_i \frac{e_i^2}{c^2} \frac{(a_i \wedge n_i) \wedge n_i}{r_i} \quad .$$

Here c is the speed of light, while e_i is the charge of i-th particle, and a_i its acceleration. Moreover r_i is the distance between the i-th charge and the point at which the field is computed, while n_i is the unit vector in the direction of the i-th charge. All quantities are to be computed at the retarded time.

One sees that every shell of radius R contains a number of charges proportional to R^2. Therefore, it contributes in absolute value with a term of order R to the sum, and so the sum diverges, in absolute value, for macroscopic bodies (i.e., when one lets R tend to infinity). How can it be possible that this field is instead rather small in ordinary circumstances? The point is that, for a generic propagating plane wave, one can show that there will be a destructive interference among all the spherical waves emitted by the charges (i.e. the series converges). One should observe however that a destructive interference could occur only if the plane waves propagate with a speed less than c, otherwise, an infinite number of terms in the sum would have equal phases, the field would diverge, and an inconsistency would appear.

1.2 The Wheeler-Feynman Identity

According to Wheeler and Feynman, such fact has a great impact on microscopic electrodynamics. Indeed, by considering the electromagnetic field produced by all charges in the medium, i.e., the field,

$$F^{ret}_{\mu,\nu} = \sum_{all\,k} F^{ret,k}_{\mu,\nu}$$

(written in relativistic notations), they arrive to the conclusion that

$$\sum_{all\,k} F^{ret,k}_{\mu,\nu} = \sum_{all\,k} F^{adv,k}_{\mu,\nu} \quad ,$$

where the advanced fields

$$F^{adv,k}_{\mu,\nu}$$

are the standard solutions of the Maxwell's equations with a given source. The difference is that, instead of involving the "retarded" time t-r/c, they involve the "advanced" one t+r/c, as if the solution would depend on the future position of the source. In fact, the difference,

$$\sum_{all\,k} \left(F^{ret,k}_{\mu,\nu} - F^{adv,k}_{\mu,\nu} \right)$$

that Dirac *calls radiation field* (the reason will be explained later), is a solution of the free Maxwell equations (i.e., without sources), so that it propagates at the speed of light c, and thus, by consistency, has to vanish. In other terms, in order to have a self-consistent microscopic electrodynamics in a medium, the *Wheeler-Feynman identity*

$$\sum_{all\ k}\left(F^{ret,k}_{\mu,\nu}-F^{adv,k}_{\mu,\nu}\right)=0 \qquad (1)$$

has to hold. In their paper, Wheeler and Feynman, working at a formal level (i.e. neglecting convergence problems of the series defining the electromagnetic forces acting on each charge) give strong arguments indicating that their identity should hold "generically" for infinite systems of charges. Still within a formal approach, a proof was given in a paper (Carati, 2014) under a conspicuous condition. In fact, the identity is proven, for an infinite system, if the motions of the particles are assumed to satisfy a decorrelation property, analogous to those considered in the usual treatments of statistical mechanics. Instead, in the case of ionic crystals, following a method introduced by Ewald in 1917 (inspired to a work by Riemann), the series could be summed (see Lerose, 2014), and the identity was proven in a "rigorous" way.

1.3 The Wheeler-Feynman equations of motion

What impact does the Wheeler-Feynman identity produce on the dynamics of particles? An apparently devastating one indeed, since the equations of motion then turn out to take the form (see below)

$$m_i \ddot{x}^{\nu}_{i,\mu}=e_i \dot{x}^{\nu}_i \sum_{k\neq i}\frac{F^{ret,k}_{\mu,\nu}+F^{adv,k}_{\mu,\nu}}{2} \qquad (2)$$

Here the dot denotes derivative with respect to proper time, while m_i and e_i are mass and charge of the i-th particle. Now, this is a system of equations for which the usual Cauchy problem no more makes sense: indeed the retarded field

$$F^{ret,k}_{\mu,\nu}$$

depends on the whole past history of the k-th particle, whereas the advanced field

$$F^{adv,k}_{\mu,\nu}$$

depends on its future history, so that the force turns out to be undetermined, unless the whole trajectories of all particles are assigned (for all times). In this sense, the equations of motion are not evolution equations but compatibility equations among all histories of the single particles. In fact, one considers the set of all possible trajectories (in the configuration space of the whole system), and the good ones are those for which the compatibility conditions are satisfied. Laplacian determinism receives here a big hit, indeed.

1.3.1 From Equations of Motion to Compatibility Equations

One starts up with equations of motion of the usual form, in which the product mass times the (four) acceleration of a particle is set equal to the sum of the forces acting on it. These are on the one hand the (generalized) Lorentz force due to the electromagnetic retarded fields produced by the other particles, and on the other hand the damping force due to the radiation emission by the particle, i.e., the force acting on a charge, that takes into account the energy it radiates away due to its acceleration. This problem was first discussed by Planck in a phenomenological way and then by Abraham and Lorentz through models of the charges. A definitive answer was eventually given by Dirac, who expressed the damping force in terms of the fields, as

$$K_{i,\mu}=e_i \dot{x}^{\nu}_i \frac{F^{ret,i}_{\mu,\nu}-F^{adv,i}_{\mu,\nu}}{2} \ .$$

One has thus the equations of motion

$$m_i \ddot{x}^{\nu}_{i,\mu}=e_i \dot{x}^{\nu}_i \sum_{k\neq i} F^{ret,k}_{\mu,\nu}+K_{i,\mu} \ .$$

So, inserting the Dirac expression for the damping force, and expressing the retarded force as semi-sum plus semi-difference, one obtains

$$m_i \ddot{x}^{\nu}_{i,\mu}=e_i \dot{x}^{\nu}_i \sum_{k\neq i}\frac{F^{ret,k}_{\mu,\nu}+F^{adv,k}_{\mu,\nu}}{2}+e_i \dot{x}^{\nu}_i \sum_{all\,k}\frac{F^{ret,k}_{\mu,\nu}-F^{adv,k}_{\mu,\nu}}{2}$$

that reduces to the stated equation in virtue of the Wheeler-Feynman identity (1).

1.4 The Radiative Collapse Removed: Application to Plasma Physics

But the most important consequence of the Wheeler-Feynman identity for us is the failure of the fundamental objection against the use of charges' trajectories in atomic physics, i.e., the instability of the Rutherford atom or more in general the radiative collapse. In fact Dirac shows (see Dirac 1938) that

$$F^{ret,k}_{\mu,\nu} - F^{adv,k}_{\mu,\nu}$$

represents the field radiated by charge k. So, if the Wheeler-Feynman identity holds, it means that the total radiated field vanishes, i.e. that the energy of the system remains constant. The energy that a particle loses by radiation is compensated by the energy it absorbs from the fields due to the remaining particles. So persistent motions, of the type required in the Rutherford model, can exist. Examples of this type of persistent motions were exhibited in several papers (Lerose, 2014; Carati, 2003; Marino, 2007).

This fact has a relevant impact in plasma physics too, in connection with what is commonly called *the reabsorption problem*. Indeed, in fusion machines electrons are confined by strong magnetic fields that keep them gyrating about magnetic lines. But this is the same situations of electrons orbiting about nuclei. So, according to common wisdom, in fusion machines electrons should collapse, emitting an incredibly huge radiation, whereas this is not the case, and such instability in general does not occur. In our opinion, the reason is again the validity of the Wheeler-Feynman identity (see Carati, 2021). In fact, this is proven only in the case of not too large densities. An instability is indeed observed at large densities, and this fact too seems to be theoretically justified in the present approach.

2. The Infrared Spectrum of Ionic Crystals

In the previous Section it was shown how the Wheeler-Feynman identity allows one to overcome the fundamental objection (radiative collapse) to a realistic description of atomic physics through particles' trajectories. Here we illustrate how, using particle trajectories, typical "quantum phenomena" are in fact explained, starting with the absorption spectrum of a substance, in the case of ionic crystals.

To this end the first thing to do would obviously be to make available such trajectories as solutions of the equations (2). But, as already mentioned, the Wheeler-Feynman theory has a formal character, inasmuch as it doesn't discuss the convergence problem of the series defining the electromagnetic force acting on a charge. Indeed such series are not absolutely convergent, so that they make no sense, unless some suitable procedure is introduced. To our knowledge, no solution to this problem exists in the general case, whereas a solution was provided in the case of ionic crystals, as illustrated below.

2.1 Results Obtained Through Linearization: The Case of Ionic Crystals

The reason why the divergence problem can be concretely dealt with in the case of crystals, is that their equations of motion admit in a quite natural way an approximated treatment through linearization, since by definition crystals present a stable equilibrium, about which a linearization is feasible. The solutions of the linearized model are searched in the form of propagating waves. In the linear approximation, the field created by the ions turns out to be equal to that generated by a lattice of oscillating dipoles placed at their rest positions. As just mentioned, in such case Ewald was able to sum the series, so that a finite expression can be found both for the retarded and for the advanced fields.

Ewald found that each field can be thought of as the sum of two series having physical characters of completely different types. The first series forms the near field. This name is due to the fact that the only relevant terms in the series are those due to the charges located near the point at which the field is evaluated. Such field is obtained as a sum of spherical waves outgoing from any dipole and propagating with the speed of light c: however, since only the nearest charges are involved, the delays can be neglected, and, with a good approximation, that field can be dealt with as an instantaneous one. Instead, the second series, also absolutely rapidly convergent, is summed over the wave vectors k of the lattice. Such series represents a macroscopic field, and is due to the far charges. It can be represented as a combination of plane electromagnetic

waves, each propagating with a given phase velocity equal to $\omega(k)/|k|$ rather than with the speed of light c.

Following such Ewald procedure, in the work (Lerose, 2014), a rigorous study could be performed for an ionic crystal model. It was shown that there exist traveling wave solutions, with a well definite dispersion relation $\omega(k)$ (with a certain number of branches), and that for such solutions the Wheeler-Feynman identity holds. Moreover, since the quantity $\omega(k)/|k|$ could be computed, such result shows that an evaluation of the refractive index can actually be produced in a purely theoretical way.

Additionally, it was shown that the dispersion relation $\omega(k)/|k|$ presents two further branches, with respect to a pure mechanical model of crystal (i.e. a model involving no delays, as occurs for c tending to infinity). Such additional branches, called *polaritonic branches*, were experimentally observed in the years seventies of the last century. For the occurring of such branches (due to the retardation of the forces), a quantum mechanical deduction is still lacking.

Concerning the model, a key remark is that, if one looks for the most relevant feature of ionic crystals, i.e., their behavior in the infrared, then the motion of the electrons can be ignored, and the force due to the electromagnetic fields produced by them on the ions can be approximated through a mechanical "effective potential" having a short range character. This is one of the approximations usually performed in ionic crystal models (even in the quantum case), that goes back to the work of Born and Oppenheimer, and to the previous one of Born and Heisenberg for the classical case (see the works Born, 1924 and Born, 1927). So, in the equations of motion (2) for the ions (dealt with as point charges) such further short-range forces of a mechanical type due to the electrons come in. Moreover, due to the large mass of the ions, their equations of motion are taken in the *non-relativistic approximation*. In order for the equations to describe a crystal, an equilibrium point of the system has to exist, in which the rest positions of the ions form a well definite lattice. For example, in the case of Lithium Fluoride a cubic, face-centered lattice occurs with two ions, one of Lithium and one of Fluorine, in the primitive cell. So, if the displacements q_k from their rest positions are assumed to be small, in a first approximation the forces can be linearized, neglecting all terms nonlinear in the displacements, thus obtaining the system of equations

$$m_i \ddot{q}_i = F_i^{mech} + e_i \sum_{k \neq i} \frac{E^{ret,k} + E^{adv,k}}{2}, \qquad (3)$$

where F_i^{mech} is a force of a mechanical type (the electric field due to the electrons and of the Coulomb field due to the lattice of ions at rest), whereas the electric fields $E^{ret,k}$ and $E^{adv,k}$ are those generated by a dipole of moment $p_k = e_k\, q_k$ located at the equilibrium position of the k-th charge and evaluated at the equilibrium position of the i-th one (rather than at its actual position). Notice that the Lorentz force due to the magnetic fields is at least of a quadratic order in the displacements from the equilibrium positions, so that the magnetic field does not enter the equation, in the considered order of approximation. This approximation leads to an enormous simplification of the problem, since now the delays (and the anticipations) are fixed, rather than depending on the motions of the charges. However, one is still dealing with a formidable problem of infinitely many differential equations with delay and anticipation, for which existence and uniqueness theorems are unknown.

2.2 The Instantaneous Approximation: The Infrared Spectra of Ionic Crystals

However, the linearized model has limitations: first, in a certain band of frequencies it is absolutely opaque (the electromagnetic field cannot propagate), whereas in the complementary band it is absolutely transparent, i.e. the field propagates with no absorption at all.

Therefore, if one aims at computing, for example, the absorption coefficient, one has to go beyond the linear approximation. Taking non linearities into account, in a direct way without approximations, is at the moment impracticable. We resorted to study numerically the problem using a system of 4096 charges placed in a box, with periodic boundary condition. Now, we recall that the radiation reaction term is canceled for an infinite system, and moreover that the (retarded plus advanced) electromagnetic field is necessarily split into the sum of a near field, in which the delay is extremely small and can be ignored, and of a far field that instead presents the character of an external electromagnetic wave.

However, the propagation character of such wave are inappreciable in our model, because it can be felt only if the system has dimensions comparable to the infrared wavelengths (some microns), while the dimensions of our system (4096 ions) correspond to some tenths of Angstrom.

So, in the work (Carati, 2014) we proceeded with the apparently brutal approximation of working at a purely Coulomb level (i.e. with delays completely neglected), and so with purely Newtonian equations of motion. At such level, the electric susceptibility can be computed as the Fourier transform of the auto correlation of polarization, expressed in term of the position of the ions. Figure 1, taken from the work (Carati, 2018), reports the theoretical imaginary part of electric susceptibility, and the experimental data, for the main absorption line of Lithium Fluoride in the infrared. The most evident feature of the figure is that the computed values reproduce the data within about five orders of magnitude. It thus appears that the propagating wave plays no significant role for the computation of electric susceptibility (and thus of spectra). Propagation effects might however play a role for other phenomena.

2.3 Enters the Electron: The Chemical Bond in the H_2^+ Ion

We have seen that a pure Newtonian model allows one to reproduce the spectra of ionic crystals. One can ask whether it can reproduce other typical "quantum phenomena", in particular the chemical bond, a key ingredient in the ionic crystal model, since it accounts for the inter-ionic force due to the electrons. In light of the cancellation property that is expected to be produced by the Wheeler-Feynman identity, we proceed as is done in quantum mechanics, by neglecting the medium at all, and considering only the system of interest, as if the medium did not exist.

As at the moment we are unable to treat models with several electrons, we consider the case of the H_2^+ ion, i.e., a system with a single electron and two protons, that is the paradigmatic case in which a chemical bond (between protons) is formed. The idea, that goes back to Born and Heisenberg, is that, due to the small electron mass with respect to the proton mass, the electron moves much faster than the protons, which thus appear as "static". So the force the electron produces on the protons can be averaged along (a piece of) the trajectory, thus giving rise to an effective static attractive force between the two protons.

This was implemented in the paper (Carati, 2020), the most relevant result of which is shown in figure 2. The figure shows the effective potential between the protons due to the electron, as a function of distance (continuous curve), together with the results of quantum computations (crosses). The agreement is very good up to quite large distance, actually the double of the molecule size. Further investigations are needed for understanding the discrepancy at larger distances.

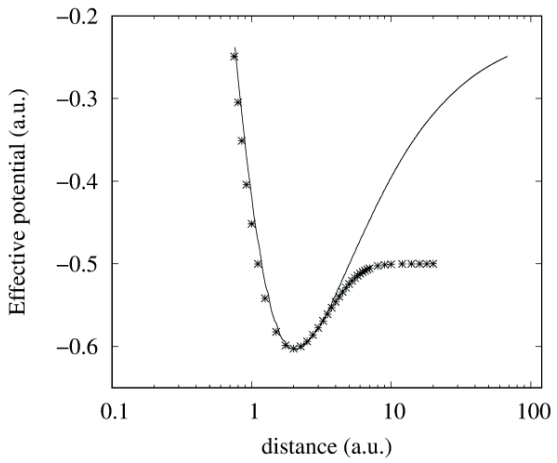

Figure 2: The result for H_2^+. Effective potential as a function of proton distance, computed for suitably chosen initial data (continuous line), together with the quantum potential in the Born-Oppenheimer approximation (stars). Distance and potential are given in atomic units (a.u.). Logarithmic scale is on the horizontal axis.

The equations of motion considered are a semi-relativistic extension of the standard three body problem with Coulomb forces, since the electron, due to its high speed, has to be treated relativistically.

No free parameters enter the model, except for the initial data. So an interesting point is to understand how Planck's constant $\hbar$ enters the problem. The point is that a bond, i.e. an effective potential, can be formed only if the motions are of a sufficiently ordered type, for perturbation theory to apply. Now, sufficiently ordered motions occur when the electron's angular momentum about the line through the protons is sufficiently large. And this is found to occur for an angular momentum of the order of $\hbar$.

Conclusions

We have shown cases where typical "quantum phenomena" (infrared spectra, chemical bond) can be explained in terms of trajectories of charges, solutions of Newton equations. Additionally, a phenomenon was explained (existence of polaritons, at the basis of the transparency properties of crystals), not yet explained in a quantum framework.

The approach used has a characteristic global feature, inasmuch as one deals with a macroscopic medium constituted by charges with mutual long-range electromagnetic interactions. In fact, the presence of the medium allows one to remove the main objection generally raised against the use of charges' trajectories in atomic physics, namely the radiative collapse of the charges, due to radiation emission caused by their accelerated motions. Such removal is in fact the main consequence of the Wheeler-Feynman identity, proposed by them through heuristic arguments, and now proven at least in the particular case of ionic crystals. By the way, it would be interesting to understand why such consequence was not drawn explicitly by Wheeler and Feynman themselves.

For what concerns the reductionist problem, one should point out that the results illustrated were obtained at the cost of dealing with Newton equations involving electromagnetic forces in a very special way, i.e. as semi-sum of retarded and of advanced forces. Consequently, the familiar Laplacian type of determinism (in which the present determines both future and past) is lost, and the problem of what determines what remains opaque. It should be mentioned that, nevertheless in their second work Wheeler and Feynman (Wheeler & Feynman, 1949) discuss such problem with nonchalance, as if it were somehow irrelevant. We are confident that the concrete applications presented here, with their impact on the relations between quantum and classical mechanics, may solicit the scientific community to take seriously into account the Wheeler-Feynman theory that apparently was ignored.

However, at least one exception exists. This concerns the works performed by J. Cramer in the years 1980 (see Cramer 1980 and 1986, and also Kestner 2012), that were brought to our attention by a referee. Such works are indeed relevant for our approach, and are addressed here through a final short comment, leaving possible further contributions for future work. Cramer's approach seems to be complementary to ours. Indeed, as explicitly stated even in the titles of his papers, his primary concern is with the *interpretation* of quantum mechanics. Instead, we work in the spirit of the extreme version of the Einstein Classical Program, aiming at *explaining* quantum mechanics in a completely classical framework, somehow as if it did not exist. To this end we start with concentrating on the explanation of concrete paradigmatic "quantum phenomena". Now, Cramer's argumentation is substantially based on the original version of the Wheeler-Feynman theory, which deals with classical electrodynamics of charges. On the other hand, the severest objection to the use of Newtonian trajectories in atomic physics–i.e. the radiative collapse—was eventually removed, and typical "quantum phenomena" were explained in terms of classical charges, just in virtue of the Wheeler-Feynman theory. Thus, it becomes at least conceivable that Cramer's interpretation may produce a relevant progress towards implementing the Einstein Classical Program itself in its extreme version, which aims at reducing quantum mechanics to pure classical electrodynamics.

These verifications could be the driving force for a transformation in a more inclusive sense of human consciousness as a whole.

Dedication

This paper is in memory of Giuseppe Pastori Parravicini, who suggested that the result obtained in the work (Carati, 2003) might be extended to a realistic model, in order to explain the phenomenon of polaritons, whose explanation in a quantum framework was lacking. In such way our research on the relations between quantum and classical mechanics passed, from the domain of ideal paradigmatic models, to the concrete one of theoretical predictions to be compared with experimental data, as occurred with the infrared spectra of ionic crystals, with polaritons and with the chemical bond in the H_2^+ ion.

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