Quantum jumps: from foundational research to particle physics

2017 J. Phys.: Conf. Ser. 880 012033

(http://iopscience.iop.org/1742-6596/880/1/012033)

IOP Conf. Series: Journal of Physics: Conf. Series **880** (2017) 012033 doi:10.1088/1742-6596/880/1/012033

Quantum jumps: from foundational research to particle physics

Ignazio Licata[1,2] and Leonardo Chiatti[3]

[1]ISEM Institute for Scientific Methodology, Palermo (Italy)
[2]School of Advanced International Studies on Applied Theoretical and Non Linear Methodologies in Physics , Bari (Italy)
[3]ASL VT Medical Physics Laboratory, Viterbo (Italy)

E-mail: ignazio.licata@ejtp.info, leonardo.chiatti@asl.vt.it

Abstract. Since 1986 a vast body of experimental evidence has been accumulated of direct observation of quantum jumps in many physical systems. We can therefore assume that quantum jumps are genuine physical phenomena. On the other hand, substantial identity of "quantum jumps" and "collapses" induced by measurements can be admitted, both being represented by self-conjugate projection operators related to specific non-Hamiltonian aspects of micro-interactions. On this basis a model of quantum jump involving a single particle is discussed, and some consequences concerning hadronic physics (Hagedorn temperature, Regge trajectories) and quantum gravity are briefly sketched.

1. Introduction

Although the existence of quantum jumps (QJs) was rarely questioned by Bohr's time, the physics of these processes has never received much attention from researchers in foundations of quantum mechanics (QM). Despite of this, the direct observation of individual atomic QJs has become experimentally accessible since 1986 [1]. This observation has clearly evidenced that a QJ occurs as a discontinuous phenomenon whose duration is negligeable, not to be confused with the atomic transition (evolution of the atomic state vector from the initial state to the final state) ended by it. The transition, in fact, takes place in a finite time, which defines the process linewidth. A large experimental literature currently exists about QJs observation in many multi-level quantum systems, even macroscopic. These experimental facts compel us to consider in a new light the controversial "collapse of the wave function" associated with the measurement of a quantum observable. In fact, this collapse is also a discontinuous transformation represented by a projection operator on the final state of the process. It seems there are not essential differences between, for example, an atomic QJ and a collapse. As the atomic QJ is the projection of the time-dependent atomic orbital (solution of the time-dependent Schrödinger equation) on the final orbital, so the collapse is the projection of the time-dependent state vector of the system "apparatus + micro-object" on the final state associated with the actual result of the measurement. In other words, the collapse appears to be only a variant of QJ, a particular case of QJ. If this is true then, in accordance with the experimental results, the collapse must be a genuine physical phenomenon like the other QJs. So we have two consequences: 1) the objectivity of the collapse, which is a particular case of QJ and therefore a real physical phenomenon; 2) the cause of the collapse is the same as that of each other QJ: the coupling with an external field.

The very next question is what is the nature of the causal connection between the QJs. We can restrict ourselves to consider the connection between the QJ associated with the "preparation" of a quantum system and that, successive in time, relative to its "detection" in the final state. Cramer [2-4] suggested to see this pair of events as the two ends of a *transaction*, interpreting each of them as the emission of a wave signal Ψ towards the future and the concomitant emission of the conjugate signal Ψ^* toward the past. It is noteworthy that this is exactly the structure of the projector on the final state Ψ, which suggests an a-spatial description of the transaction as a loop connecting the two projectors associated with two events, we say $|\Psi\rangle\langle\Psi|$ and $|\Phi\rangle\langle\Phi|$. The statistics of these loops is then described by the transition amplitude $\langle\Psi|S|\Phi\rangle$ and its conjugate $\langle\Phi|S|\Psi\rangle$, where S is the time evolution operator [5]. This a-spatial concept of transaction, first formulated in [6], was promoted by Kastner [7] which underlined the difference from the original "spatiotemporal" reading proposed by Cramer. In our opinion, however, the existence of an additional level of the problem has to be considered. In fact, if the connection between the ends of a transaction is not attributable to the exchange of wave signals towards both the time directions within the light-cone, but is embodied in those time-simmetric a-spatial relations that we call loops, it is necessary considering that the latter are ultimately also a-temporal and indeed connected to an emergency process of time [5]. Transactions and QJs which represent their ends are thus structures that emerge from an a-spatial and a-temporal background through a *formal causation* process. The dynamic causality and temporal ordering, both essential aspects of the transactions, are emergent properties of this formal causation, rather than fundamental. It is then possible understand clearly that local interactions emerge from an *universal non-locality* which is much more extensive and radical than that involved in entangled states, which simply represents a particular manifestation of it [8]. In this context, the classical macroscopic reality can be seen as emergent from networks of QJs. In a cubic centimeter of ordinary matter at room temperature, a very high number of these events occur each second (think of the thermal noise and the constant interactions between atoms); and this is exactly what determines the appearance of that portion of matter as an object in the classical sense. In other words, the macro-objectification is an endogenous phenomenon. The border between classical and quantum is then defined by the fact that the average properties of large sets of QJs (the persistent "objects") can be described classically, while individual QJs or their direct connections require a more fundamental quantum description.

2. Quantum jumps

This section briefly summarize the QJ model we discussed elsewhere, referring the reader to the original papers for the necessary insights [9,10,11,12]. Let us consider a QJ in a system consisting of a single elementary particle, following which such a particle is released in the state Ψ. As we have seen, from the transactional point of view this QJ is represented by the action of the operator $|\Psi\rangle\langle\Psi|$ which, acting on a generic state $|\Psi\prime\rangle$, produces a new state proportional to $|\Psi\rangle$. A natural interpretation of the projector $|\Psi\rangle\langle\Psi|$ is the following: the shutdown of the component $|\Psi\rangle$ of $|\Psi\prime\rangle$ (section $\langle\Psi|$ of the projector) can be seen as the switching off of its de Broglie phase factor or, in other words, as the transfer of the particle rest energy to the vacuum: the component $|\Psi\rangle$ enters a condition in which "there is not motion in time." This condition is, from the point of view of the external time of the laboratory, a-temporal and then a-spatial, as a result of the relativistic relationship between spatial and temporal coordinates. The restart of the component $|\Psi\rangle$ (section $|\Psi\rangle$ of the projector) must then be interpreted as the restoration of the de Broglie phase factor or the transfer of an amount of energy (equal to the particle rest energy) from the vacuum to the particle. This component exits from the a-spatial and a-temporal condition to reappear as the particle state vector, undergoing the dynamical evolution in laboratory time. In this sense in a QJ we have the annihilation of the state Ψ followed by its re-creation. All the factors of the state vector $|\Psi\rangle$ other than the de Broglie phase factor (which express the dependence on the position, spin, and so on) remain unchanged. An important detail is that since only the QJ is observable (because it involves an energy transfer from one field to another through the vacuum), the component $|\Psi\prime\rangle - |\Psi\rangle$ of $|\Psi\prime\rangle$ remains counterfactual. The projector $|\Psi\rangle\langle\Psi|$ can act on its right transforming the component $|\Psi\rangle$ in $|\Psi\rangle$, or on its left transforming the component $\langle\Psi|$ in $\langle\Psi|$. In other words it can be seen as the concomitant emission of the state Ψ towards the future and its conjugated Ψ^* towards the past, according to Cramer's interpretation. Therefore, the algebraic or topological transformation that represents the QJ has to preserve the information associated with the de Broglie temporal phase factor of the state Ψ, recoding it in a form "frozen" with respect to the flow of external time t. We assume that in the background condition the information associated with the state Ψ is encoded in a kind of "internal wavefunction" inaccessible by direct observation. Let us introduce a background "internal time" which will be denoted by $\tau\prime$. The internal wavefunction associated with the particle will contain a factor $\Phi(\tau\prime)$, real and harmonic in $\tau\prime$, null at the boundary and outside the interval $[-\theta_0/2, +\theta_0/2]$. The reality condition must be satisfied for the absence of a temporal direction, which implies $\Phi = \Phi^*$. The following equation is a consequence of this postulate:

$$-\hbar^2 \frac{\partial^2}{[\partial(2\pi\tau')]^2}\Phi = (M_{sk}c^2)^2\Phi \tag{1}$$

with the condition $\Phi = 0$ for $\tau' \leq -\theta_0/2$, $\tau' \geq +\theta_0/2$, where M_{sk} is the original (skeleton) component of the particle mass. From Eq. (1) it follows that:

$$M_{sk}c^2 = n' \frac{\hbar}{\theta_0} \tag{2}$$

where $n\prime = 0, , 1, 3/2, ...$ is an integer for odd solutions, a half-integer for even solutions. A second postulate states that each oscillating solution of Eq. (1) is globally characterized by a second variable T (which is dimensionally a temperature) such that the not normalized probability of a given value of that variable is expressed by

$$\exp\left(-\frac{\hbar/\theta_0}{kT}\right) \tag{3}$$

for $kT \geq \hbar/\theta_0$, 0 otherwise, where k is the Boltzmann constant and $T \geq 0$. Assuming $\tau\prime\prime = \hbar/kT$ this probability becomes the square modulus of a second factor of the internal wavefunction:

$$\Lambda = \exp\left(-\frac{\tau''}{2\theta_0}\right) \tag{4}$$

If we assume that while in the background condition the particle is in a state of superposition of different values of $\tau\prime\prime$ we have:

$$-\imath\hbar \frac{\partial}{[\partial(\imath\tau'')]}\Lambda = \frac{\hbar}{2\theta_0}\Lambda \tag{5}$$

for $0 \leq \tau\prime\prime \leq \theta_0$, $\Lambda = 0$ otherwise. The creation of the wavefunction associated with the particle state Ψ exiting from the background can be considered as the passage from Eq. (3) to a probability identically equal to 1 for any value t of the "external" time accessible to the observer. This probability will be the square modulus of a factor that we can write as:

$$\Lambda \propto \exp\left(-\imath\frac{\tilde{\tau}}{2\theta_0}\right) \tag{6}$$

We can imagine this factor to derive from Eq. (4) by the Wick rotation $\tau'' \to \imath\tilde{\tau}$; simultaneously to this transformation, the factor $\Phi(\tau')$ must disappear. The quantity $\tilde{\tau}/2\theta_0$ can be interpreted as the external time t measured in units of the oscillation period of the old factor Φ, i.e. θ_0/n'. Therefore:

$$\frac{\tilde{\tau}}{2\theta_0} = \pm\frac{t}{(\frac{\theta_0}{n'})} \Rightarrow \tilde{\tau} = \pm 2n't \tag{7}$$

And thus:

$$\Lambda \to \exp\left(\pm\frac{-\imath n't}{\theta_0}\right) = \exp\left(\mp\imath M_{sk}c^2\frac{t}{\hbar}\right) \tag{8}$$

i.e. the de Broglie's temporal phase factor. Annihilation is represented by the inverse process. It is immediately clear that (1) and (5) are two wave equations, respectively, in the real component τ' and the imaginary component $\imath\tau''$ of a complex internal time $\tau = \tau' + \imath\tau''$, which thus becomes the "precursor" of time t measured in the laboratory; this last physical quantity is thus emerging. The frequency of the "hidden" oscillation Φ becomes the frequency of the de Broglie's phase factor, experimentally accessible as the particle mass. The transformation (8) is, at the same time, algebraic (because it involves a Wick rotation) and topological (because it involves, on the complex plane of the variable τ, the transformation of a rectangular domain in a circumference [11]). Clearly, the entire model dissolves in the limit $\theta_0 \to 0$. The interval θ_0 must be a time scale characterizing the realm of elementary particles, and this leads to the conclusion that it is $c\theta_0 \approx 10^{-13}$ cm, and therefore $\hbar/\theta_0 \approx$ 50-100 MeV. Consideration should be given to the fact that this time scale is not a minimum time interval, nor does $c\theta_0$ define a minimum spatial interval. An estimation of θ_0 can be derived from the observation that the particle mass m should consist of the skeleton mass renormalized by perturbative effects (self-interaction) limited to the interaction vertex where the state Ψ is created [11,13]. This vertex coincides naturally with the QJ. If $n' = 0$, only the term of self-interaction survives in m. Only a fraction of the energy $\hbar/\theta_0$ needed to locate the particle in a temporal extension θ_0 is used, expressed by the dimensionless self-coupling constant $(g^2/\hbar c)$. This energy is therefore $g^2/(c\theta_0)$, and the particle is delocalized to a dressing region $\hbar c/g^2$ times larger than $c\theta_0$. This is the situation of lighter particles, i.e. electrons and neutrino mass eigenstates, whose masses are certainly lower than $\hbar/\theta_0$. With electrons, the self-interaction will be essentially electrostatic and therefore the self-interaction energy will be $e^2/c\theta_0$, where e is the elementary electric charge. Equating this expression to the rest energy of the electron, we obtain $c\theta_0$ is the classical radius of the electron. As a result, the fundamental skeleton mass interval $\hbar/\theta_0$ in Eq. (2) amounts approximatively to 70 MeV. Consequently, the interval θ_0 coincides (unless a factor 2/3) with the "chronon" introduced by Caldirola in its classical electron theory [14]. To our knowledge, this is the only classical electron theoretical description which is not affected by troubles with self-energy divergence or runaway solutions or violations of causality (pre-accelerations).

3. Mini big-bangs

The square modulus of Eq. (4):

$$|\Lambda(\tau'')|^2 = \exp\left(-\frac{\hbar/\theta_0}{kT}\right) = \exp\left(-\frac{\tau''}{\theta_0}\right) \tag{9}$$

describes the background as a set of thermostats at different absolute temperatures $T \in [\hbar/k\theta_0, \infty)$. When a particle with rest energy Mc^2 interacts with this background in a QJ, each thermostat gives a contribution:

$$dQ = Mc^2 \frac{\exp(-\frac{\tau''}{\theta_0})d\tau''}{\int_0^{\theta_0} \exp(-\frac{\tau''}{\theta_0})\, d\tau''} \tag{10}$$

to this energy. In the case of a contact interaction, that is confined within the QJ, as the strong interaction between hadrons is, each particle "sees" a single equivalent thermostat, with which it exchanges a thermal contribution equal to the sum of the thermal contributions exchanged with the various thermostats, and an entropy equal to the sum of the entropies exchanged with the various thermostats. Such exchanges are reversible due to the time simmetry of the QJ; the temperature T_H of the equivalent thermostat is thus defined by the relation:

$$\int_{\tau''=0}^{\tau''=\theta_0} dQ/T = \frac{\int_{\tau''=0}^{\tau''=\theta_0} dQ}{T_H} \tag{11}$$

This relation provides $kT_H = 160$ MeV, which is exactly the Hagedorn temperature [15,16]. It is also possible to see that the mass spectrum of the hadronic states implied by (9) is the same as that derived from the Hagedorn statistical bootstrap model, when the deconfinement temperature of the charge centres (quarks) is taken as T_H [15 ,16]. We can conclude by observing that the value of T_H is defined by θ_0, and $c\theta_0$ is the maximum value of the confinement radius of charge centres (de Sitter radius of the micro-particle universe [11]). The Hagedorn temperature is then connected to confinement. The "thermal" description of QJ outlined in this section is very similar to that proposed by us for the big bang [17,18]. The expression "mini big bangs" in use today with reference to interaction vertices involving real particles seems therefore particularly significant.

4. Regge trajectories

The introduction of the chronon θ_0 allows the definition of a moment of inertia of the particle of the order of $\hbar\theta_0$. This moment of inertia is not associated with a geometric extension of the particle or a mass distribution in the classical sense. It is simply a factor converting the frequency j/θ_0 (where j is the eigenvalue of particle total spin) in the spin $j\hbar$. The "granularity" of the particle temporal localization in a QJ, expressed by the chronon, pesents some observable consequences in the case of hadrons. Hadrons can be generated in strong interactions whose range is of the order of $c\theta_0$. As we can see from Eq. (2), when a hadron exits from the interaction sphere of radius $c\theta_0$ where it has been formed, it has a definite skeleton mass m, where $\theta_0/n\prime = \hbar/mc^2$ (the effective mass will also contain contributions from internal degrees of freedom and perturbative effects). The newly formed mass m is therefore associated with a moment of inertia $mc^2\theta_0^2$ with respect to the centre of the sphere. The natural angular pulsation of the new-born hadron is $n\prime/\theta_0$, or more generally its integer submultiple $n\prime/n\theta_0$), so that the quantity of angular momentum transferred from the interaction vertex to the hadron is given by:

$$\Delta J = \Delta[(mc^2\theta_0^2)(\frac{n\prime}{n\theta_0})] = \Delta[(mc^2\theta_0^2)(\frac{mc^2}{n\hbar})] = \Delta[(mc^2)^2(\frac{\theta_0^2}{n\hbar})] \tag{12}$$

Bearing in mind that $J = j\hbar$ we obtain, for n constant, the Regge trajectory:

$$(mc^2)^2 = jn(\hbar/\theta_0)^2 + \sigma \tag{13}$$

Here σ, which can be positive, zero or negative, represents the intercept of the trajectory [19]. Pulsations which are greater than $n\prime/\theta_0$ obviously have no relevance, because the hadron temporal localization makes the higher harmonics lose their physical meaning. Pulsations which are lower than $n\prime/\theta_0$ should be its submultiples, because angular motion is sampled by strong

IOP Conf. Series: Journal of Physics: Conf. Series **880** (2017) 012033 doi:10.1088/1742-6596/880/1/012033

interactions with a maximum frequency given by the inverse of the hadron temporal extension. In other words, n/θ_0 becomes a Nyquist frequency. Eq. (13) defines a rectilinear Regge trajectory whose slope is quantized, because n is an integer. For a discussion about experimental evidences of quantization the reader should consult ref [20].

5. Side effects on quantum gravity

The skeleton mass is the energy associated with the localization of the particle in an interaction vertex as a real particle incoming or outgoing that vertex. Experimentally, the entities that propagate from a QJ to another are the particles, not their charge centres (for example hadrons, not quarks). As we know from the equivalence principle, the gravitational charge of a particle is proportional to its inertial mass which in turn is derived from the skeleton mass. Consequently, this charge, as the skeleton mass, is a global property of the particle instead of individual charge centres. Now, the particle is coupled with external non gravitational fields through its charge centres (which, when coinciding with quarks, are also the sources of internal color field) and we know that the energy exchanged in such couplings does not present some known upper limit. This suggests that charge centres are pointlike. The particle that contains them has instead a finite radius $c\theta$ (with $\theta \leq \theta_0$). The gravitational field is however coupled with the particles through their mass. There is therefore an upper limit to the energy E that the gravitational field can exchange with the particles in a single interaction: when E exceeds $\hbar/\theta$ the gravitation "does not see" the particle, but only a fraction $(\hbar/\theta E)^3$ of it. For $E \gg \hbar/\theta$ the particle is completely decoupled from gravitation. For example, for an electron is $\theta = e^2/mc^3$, where m is the electron mass [11-13], thus the electron decoupling starts at 70 MeV. For other particles the decoupling begins to higher energies. In gravitational collapse leading to the formation of a black hole, nucleons and electrons overlap and at a certain moment in a volume of radius $\approx c\theta_0$ will be concentrated a mass M whose gravitational self-energy is of the order of 70 MeV. At about this point the decoupling of matter by the gravitational field begins. This occurs at the critical density ρ_0 defined by the equation:

$$\frac{GM^2}{c\theta_0} = \frac{G[\rho_0(c\theta_0)^3]^2}{c\theta_0} \approx 70MeV \tag{14}$$

where G is the gravitational constant. When this density is reached the collapse continues due to inertia, but it is slowed by the pressure and eventually reverses; of consequence, the density decreases. When the density again reaches the critical value, the gravitation reappears. Oscillations around a stable point likely occur. The singularity is not formed, remaining an object of density comparable to that critical. From (14) we have $\rho_0 \approx 10^{32}$ g/cm^3, a value that is 62 orders of magnitude lower than the Planck density, given by the ratio between the mass of Planck and the cube of the Planck length: $M_{Planck}/(l_{Planck})^3 \approx 10^{-5}$ g/$(10^{-33}$ cm$)^3 = 10^{94}$ g/cm^3. The density of the collapsed object exceeds that of a neutron star of about 17 orders of magnitude. We must therefore assume that this object has gone through its own Schwarzschild radius so becoming a black hole. Ultimately, it is conceivable that a finite chronon could prevent the formation of singularities in gravitational collapse.

6. Conclusions

Our intent was to elucidate some possible connections between the foundational research in QM and current topics in particle physics. We can not hide that part of our motivation was to oppose the current trend of progressive isolation of this kind of research in an epistemological and philosophical scope removed from the confrontation with the cutting-edge research. The main results presented here can be summarized for points as follows:

(i) The external (laboratory) time is an emergent property at the particle scale;

(ii) the particle bare (skeleton) mass is finite;
(iii) it is also quantized;
(iv) the quantum of skeleton mass is $\hbar/\theta_0$, where θ_0 is a new constant of Nature;
(v) derivation (from θ_0) of the Hagedorn temperature $T_H = 160$ MeV;
(vi) Regge trajectories do exist, with quantized slopes;
(vii) θ_0 (probably) prevents the formation of singularities in gravitational collapse.

The derivation of these results and their relevant connections becomes possible only when we cease to see the dynamical causality as fundamental, and start to conceive it as an emerging aspect of a formal causation connecting the phenomenal domain to an a-spatial and a-temporal "background". The quantum formalism then becomes, how correctly guessed by Bohm many years ago [21], a (still partial) mathematical description of this causation. We have tried to enrich this description by adding a minimal model of QJ. In this model a time interval appears, the chronon, already known from the Caldirola work, which plays an essential role in the derivation of results listed above. The top-down structure of this approach, the exact opposite to that, bottom-up, of the conventional dynamical approach [22], expresses the fundamental nature of the non-local aspect of the physical world, of which the entanglement phenomena only represent the emerging peak.

Acknowledgments
The authors whish to thank Giuseppe Vitiello and Thomas Elze for their encouragement and stimulating atmosphere of DICE 2016, and Elinor Ruth Kastner and Erasmo Recami for fruitful discussions over the years.

References

[1] Bergquist J C, Hulet R G, Itano W M and Wineland D J 1986 Observations of quantum jumps in a single atom *Phys. Rev. Lett.* **57**(14) 1699-1702
[2] Cramer J G Generalized absorber theory and the Einstein-Podolsky-Rosen paradox 1980 *Phys. Rev.* D **22**(2) 362-376
[3] Cramer J G The Transactional interpretation of quantum mechanics 1986 *Rev. Mod. Phys.* **58** 647-687
[4] Cramer J G 2015 The transactional interpretation of quantum mechanics and quantum nonlocality *Preprint* arXiv:1503.0039 [quant-ph]
[5] Chiatti L 2013 The transaction as a quantum concept *Int. Journ. Res. App. Sci.* **16**(4) 28-47 (*Preprint* arXiv:1204.6636 [gen-ph])
[6] Chiatti L 2005 *The archetypal structures of physical world* (Roma: Di Renzo)
[7] Kastner R E 2013 *The Transactional interpretation of quantum mechanics: the reality of possibility* (Cambridge: Cambridge University Press)
[8] Licata I 2014 Transaction and non locality in quantum field theory *EPJ Web of Conferences* **70** 00039
[9] Chiatti L and Licata I 2017 Fluidodynamic representation and quantum jumps *Quantum structural studies; classical emergence from the quantum level*, eds R E Kastner, J Jeknic-Dugic and G Jaroszkiewicz (Singapore:World Scientific) pp 201-224
[10] Chiatti L 2016 Is Bohr challenge still relevant? *Beyond peaceful coexistence: the emergence of space, time and quantum*, ed I Licata (Singapore:World Scientific) pp. 545-557
[11] Licata I and Chiatti L 2015 Timeless approach to quantum jumps *Quanta* **4**(1) 10-26
[12] Chiatti L and Licata I 2016 Particle model from quantum foundations *Quant. Stud. Math. Found.* DOI 10.1007/s40509-016-0094-6
[13] Chiatti L 2012 A possible model for the mass spectrum of elementary particles *Phys. Ess.* **25**(3) 374-386 (*Preprint* arXiv:0905.3794)
[14] Caldirola P 1980 The introduction of the chronon in the electron theory and a charged-lepton mass formula *Lett. Nuovo Cim.* **27**(8) 225-228
[15] Hagedorn R and Rafelski J 1981 From hadron gas to quark matter I *Statistical mechanics of quarks and hadrons*, ed H Satz (Amsterdam:North Holland) pp.237-251

IOP Conf. Series: Journal of Physics: Conf. Series **880** (2017) 012033 doi:10.1088/1742-6596/880/1/012033

[16] Rafelski J and Hagedorn R 1981 From hadron gas to quark matter II *Statistical mechanics of quarks and hadrons*, ed H Satz (Amsterdam:Noorth Holland) pp.253-272

[17] Licata I and Chiatti L 2010 Archaic universe and cosmological model: big-bang as nucleation by vacuum *Int. Jour. Th. Phys.* **49**(10) 2379-2402

[18] Licata I and Chiatti L 2009 The archaic universe: big bang, cosmological term and the quantum origin of time in projective cosmology *Int. Journ. Theor. Phys.* **48**(4) 1003-1018

[19] Collins P D B 1977 *An introduction to Regge theory and high energy physics* (Cambridge:Cambridge University Press)

[20] Chiatti L 2014 A simple quantization rule for the slopes of Regge trajectories *Phys. Ess.* **27** 143-145

[21] Bohm D, Hiley B J and Stuart A E G 1970 On a new mode of description in physics *Int. Jour. Theor. Phys.* **3** 171-183

[22] Hiley B J 2016 Some remarks on the evolution of Bohm's proposals for an alternative to standard quantum mechanics (*Preprint* http://www.bbk.ac.uk/tpru/BasilHiley/History_of_Bohm_s_QT.pdf; retrieved 16/11/2016)