Quantum Nonlocality - Possible Cosmophysical Effects

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Abstract. Multiple experimental results indicate the existence of cosmophysical effects which influence parameters of nuclear decays and chemical reactions in lab. conditions. In particular, variations of nucleus $\alpha-$, $\beta-$decay parameters with amplitudes of the order $10^{-3}$ and periods of one year and solar day were detected. Significant influence of solar activity on nuclear decay and chemical reaction parameters also was reported. We argue that such deviations from radioactive decay law and other similar effects can be described by novel quantum nonlocality mechanism, which differs from EPR-Bohm nonlocality. Doebner-Goldin nonlinear Hamiltonian applied for the description of nuclear decay parameter variations.

keywords: quantum nonlocality, nonlinear quantum mechanics
1. Introduction

In the last decades, ample bulk of experimental results evidence for the existence of long-distance cosmophysical effects which presumably can’t be explained by standard physics. First observations of this kind were reported in the fifties by G. Piccardi, who has shown that parameters of some chemical reactions in lab. conditions correlate in time with solar activity, in particular, with intense solar flares, despite that chemical reactors were isolated from external electromagnetic fields [1]. Later, similar correlations of chemical reaction parameters with solar activity and other cosmophysical effects were reported by other groups [2, 3]. More recently influence of solar activity, in particular, intense solar flares on some nuclear decay parameters also was found [5, 4]. Besides, recent experiments have reported the periodic modulations of nuclear $\alpha$— and $\beta$—decay parameters of the order of $10^{-3}$ and with typical periods of one year, one day or about one month [5-9]. These and other related results, in particular, for cosmophysical influence on biological systems, reviewed below in more detail.

Until now theoretical discussion of these effects had quite restricted character. It was supposed that oscillations of $\beta$-decay rate is owed to anomalous interaction of solar neutrino flux with nuclei or seasonal variations of fundamental constants [5]. Yet, neither of these hypothesis can explain $\alpha$-decay parameter oscillations of the same order, because $\alpha$-decay should be insensitive to neutrino flux or other electro-weak processes. Really, $\alpha$— and $\beta$-decays stipulated by nucleon strong and weak interactions correspondingly. Therefore, observation of parameter oscillations for both decay modes supposes that some universal mechanism independent of particular type of nuclear interactions induces the decay parameter oscillations. Besides, chemical reactions performed via electromagnetic interactions, so it gives, in fact, additional arguments in favor of such hypothetical mechanism universality. It was proposed earlier that some of described effects can be explained by nonlinear interaction of classical gravitational field with quantum systems [10]. Some effects related to this nonstandard gravity interaction model also will be discussed here.

Nowadays, acknowledged universal physical theory is quantum mechanics (QM), so it’s worth to start from the analysis of its foundations, which can be related to discussed experimental results. In this framework, it’s notable that QM axiomatics implicates the existence of notorious quantum-mechanical nonlocality. This phenomenon was first formulated as famous EPR-Bohm paradox and later developed as Bell theorem [11, 12]. Now such nonlocal effects confirmed experimentally and applied in quantum communication and computing. In fact, this mechanism permits to realize specific form of nonlocal correlations (NC) or ‘action at the distance’ between distant parts of quantum system $S$. NC realization in EPR-Bohm variant demands that initially $S$ subsystems $S_1, \ldots, S_n$ should interact with each other, after such interaction seized and the subsytems departed, NC conserve the correlations of $\{S_i\}$ uncertain parameters at any distance between subsystems. Obviously, such conditions is impossible to fulfill for considered cosmophysical effects. Meanwhile, it was argued for long that quantum
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nonlocality can be more general concept than standard QM formalism admits and, in principle, some other NC effects, beyond EPR-Bohm paradox, can exist [13-17]. Their possible experimental tests in cosmophysical experiments were discussed in [18]. In this paper, we describe phenomenological NC model, which mechanism differs from EPR-Bohm one, and discuss its applications to some cosmophysical effects and biological problems. Note that this approach differs principally from hidden parameter theories [11, 12].

We’ll consider here NC effects for system internal states only, i.e. analogous to atomic or molecular states, and discuss first the conditions to which such NC mechanism should obey in general. Plainly, beside causality demands, such NC should agree with all standard invariance principles i.e. time, space shift and rotation symmetries. In addition, we’ll suppose that NC by itself can’t transfer the energy, momentum or orbital momentum between distant objects, such transfer can be performed basically by conventional fields only. Hence the system average energy, momentum and orbital momentum should not change at all during such communications, or change insignificantly in comparison with their initial expectation values. More complicated NC model variants where such conditions can be violated will be considered elsewhere.

Let’s discuss now what quantum systems will be most vulnerable to such NC influence. Suppose that the states of two distant systems $S_1, S_2$, evolving during time interval $\{t_0, t_f\}$, due to their reciprocal NC influence would differ from $S_1, S_2$ final states in standard QM. From described assumptions it follows that according to QM rules the initial $S_1, S_2$ states can’t be stationary and non-degenerate, because such states are ground ones and possess the minimal possible energy, and only some essential energy transfer can make them to evolve to another ones which are excited states. Hence the only reasonable possibility is that $S_1, S_2$ are degenerate systems, i.e. they have several states with the same energy and during $\{t_0, t_f\}$ can evolve from its initial state to another one with the same energy. In this case, due to anticipated reciprocal $S_1, S_2$ NC influence some $S_1, S_2$ parameters, in principle, can deviate from standard QM predictions. The simple example is the particle at energy level $E$ confined in symmetric double well potential divided by potential wall of the maximal height $U_m$ such that $E < U_m$. Suppose that system $S_1$ has two degenerate orthogonal states $g_1, g_2$ in these wells with the energy $E$ and at $t_0$ it’s in the state $g_1$ confined in one well. Thereon, due to under-barrier tunneling it would spread gradually into other well [12], so that it will evolve with the time to some $g_1, g_2$ superposition. In this case, hypothetical $S_2$ NC influence on $S_1$, in principle, can change the final state parameters, in particular, resulting $g_1, g_2$ probabilities at $t_f$. Analogous evolution would occur in $S_2$, if it possesses similar structure. If this is the case, $S_1, S_2$ parameter measurements would indicate distinctions from QM predictions. Such state degeneration is typical for many molecular and nuclear systems, in this paper, model of such NC processes involving quantum tunneling will be considered, its mathematical formalism was formulated first in [10].
2. Experimental motivations

First results, indicating the deviations from exponential $\beta$-decay rate dependence, were obtained during the precise measurement of $^{32}$Si isotope life-time \cite{6}. In addition to standard decay exponent, sinusoidal annual oscillations with the amplitude about $6 \times 10^{-4}$ relative to total decay rate and maxima in the end of February, were found during 5 years of measurements. Since then, the annual oscillations of $\beta$-decay rate for different heavy nuclei from Ba to Ra were reported, for most of them the oscillation amplitudes are of the order $5 \times 10^{-4}$ with their maximum on the average at mid-February \cite{5}. Lifetime of short-living $\alpha$-decayed isotopes $^{212}$Po, $^{213}$Po, $^{214}$Po was measured directly, the annual and daily oscillations with amplitude of the order $7 \times 10^{-4}$, with annual minima at February-March for different isotops and daily maxima around 6 a.m. were found during 6 years of measurements \cite{8}. It was shown also that decay rates of $^{53}$Mn, $^{55}$Fe $\gamma$-capture and $^{60}$Co $\beta$-decay correlate with solar activity, in particular, with intense solar flare moments, preceding them for several days; in this case, observed decay variations are of the order $10^{-3}$ \cite{5,4}.

Parameters of some chemical reactions also demonstrate the similar dependence on solar activity and periodic cosmophysical effects \cite{1-3}. First results were obtained for bismuth chloride hydrolysis, its reaction rate was shown to correlate with solar Wolf number and intense solar flare moments \cite{1}. It was demonstrated that for biochemical unithiol oxidation reaction its rate correlates with solar activity, in particular, with intense solar flares and it also grows proportionally to Wolf number. Besides, it was found that its rate correlates with periodic Moon motion and Earth axis nutation \cite{3}. Takata biochemical blood tests also indicate strong influence of solar activity and Sun position in the sky \cite{19}. It performed via human blood reaction with sodium carbonite $\text{Na}_2\text{CO}_3$ resulting in blood flocculation. Its efficiency parameter demonstrates fast gain for the blood samples taken from organism starting from 6-8 minutes before astronomic sunrise moment, this gain continues during next 30 min. Such parameter behavior is independent of mountain or cloud presence at eastern horizon sector, which can screen the Sun at that time. This parameter demonstrates approximate invariance during the solar day and gradual decline after sunset, such daily dependence conserved even in complete isolation from electromagnetic fields and solar radiation. This parameter also demonstrates the gain for larger solar Wolfe numbers and for the test location shifted in the direction of Earth equator. Significant parameter correlation with Sun eclipse moments also was observed; some of these results were confirmed by other researchers \cite{20, 21, 22, 23}. Similar daily variations of deuterium diffusion rate into palladium crystal were reported \cite{24}. Possible connection of these effects with NC mechanism for chemical reactions discussed in final section.

Experiments of other kind also exploited some biochemical and organic-chemical reactions, the example is reaction of ascorbic acid with dichlorphenolindophenol \cite{2,25}. Authors noticed first that dispersion of reaction rates can change dramatically from day to day, sometimes by one order of value, whereas average reaction rate practically
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doesn’t change [2, 26]. Further studies have shown connection of this effect with some cosmophysical factors, like solar activity, Wolf numbers, solar wind and orbital magnetic field. In particular, average rate dispersion becomes maximal during solar activity minima of 11 year solar cycle [2]. Shielding of exploited chemical reactors in iron and permalloy boxes practically don’t change these effects, hence such cosmophysical influence can’t be transferred by electromagnetic fields. Individual nuclear decay or chemical reaction acts normally are independent of each other [29]; such stochastic processes are described by Poisson probability distribution [27]. For this distribution, at any time interval $dT$ the dispersion of decay count number $\sigma_p = N^{1/2}$, where $N$ is average count number per $dT$. If the resulting dispersion $\sigma < \sigma_p$, it means that this process becomes more regular and self-ordered and described by sub-Poisson statistics with corresponding distribution [28]. For $\sigma \rightarrow 0$ the time intervals between events tend to be fixed. If on the opposite $\sigma_p < \sigma$, it corresponds to super-Poisson statistics, which is typical to collective chaotic processes; in both cases it can be supposed that solar activity acts on reaction volume as the whole, similarly to crystal lattice excitations. For quantum systems such dispersion variations are typical for squeezed states [28], this approach will be considered for our model below. It’s notable that this analysis evidences that high solar activity makes molecular system to perform chemical reactions in more self-ordered and regular way. In general, analogous considerations are applicable to arbitrary statistical distributions of studied systems not only Poisson-like ones.

3. Theoretical NC model

Here we’ll consider possible NC properties for large systems like the set of metastable nuclei or molecules. In standard QM framework, the system evolution operator defined mainly by quantum-to-classical correspondence, for NC effects such guidelines are absent and we’ll construct it basing only on general QM principles and discussed experimental results. We’ll construct here phenomenological model of NC effects, it can’t describe directly discussed experimental results, but simulate analogous effects for simple quantum systems.

For the start let’s consider NC model for the set of $N$ identical, $\alpha$-decaying nucleus $\{A_i\}$, its initial state is $\{A_i\}$ product state. In fact, the similar considerations are applicable to the evolution of arbitrary metastable system, like atom or molecule, yet for nucleus $\alpha$-decay its description is most simple. Gamow theory of nucleus $\alpha$-decay supposes that in initial nucleus state, free $\alpha$-particle already exists inside the nucleus, but its energy $E$ is smaller than maximal height of potential barrier $U_m$ constituted by nuclear forces and Coulomb potential [30]. Hence $\alpha$-particle can leave nucleus volume only via quantum tunneling through this barrier. Therefore, alike for considered double well example, $\alpha$-particle energy is the same inside and outside nucleus, and corresponding inside-outside states $\psi^i_{0,1}$ are degenerate and orthogonal to each other. Hence such degeneration permits, in principle, for hypothetical NC mechanism to change nucleus decay rate without any energy transfer to $\alpha$-particle, but just changing the
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barrier transmission rate, such mechanism described in the next section. Gamow α-particle Hamiltonian for $A_i$ nucleus

$$H_i = \frac{\vec{P}^2}{2m} + U_N(r_i)$$

(1)

where $m$ is α-particle mass, $\vec{P}$ is its momentum operator, $U_N$ is nucleus barrier potential, $r_i$ is the distance from nucleus center [31]. If at $t_0$ α-particle was in initial state $\psi^i_0$, then the Shroedinger equation solution gives for decay probability rate at given decay moment $t$ for nucleus $A_i$

$$p_i(t) = \lambda \exp[-\lambda(t - t_0)]$$

(2)

here $p_i$ is the absolute value of time derivative of total decay probability from $t_0$ to $t$; resulting nucleus life-time is proportional to $\lambda^{-1}$. Hence at $t \to \infty$ nucleus state evolves to final state $\psi^i_1$, so that $<\psi^i_0|\psi^i_1> = 0$, so that $p_i(t)$ is the expectation value of transition rate for such system transformation [30]. Note that in chemical reactions, the reagents pass over potential barriers mainly due to thermal fluctuations which transfer to them the kinetic energy larger than barrier height, the role of tunneling mechanism supposed to be negligible. However, they also would suffer barrier scattering, hence it’s possible that analogous model can be applied for them also.

Our main model assumption, which below implemented in NC Hamiltonian ansatz, is that intensity of NC effects induced by some system $S_1$ will be proportional to $S_1$ transition rate from its initial internal state $\psi_{in}$ to final one $\psi_f$, such that $<\psi_{in}|\psi_f> = 0$. In particular, NC influence intensity of nucleus $A_i$ on another distant nucleus is proportional to $p_i(t)$. It was argued that the stationary states should be insensitive to NC influence, in the same vein, since NC influence should be reciprocal, it reasonable to suppose that such $S_1$ influence on some $S_2$ system would change $S_2$ transition rate, and vice versa for $S_2$ NC influence on $S_1$. It’s notable that some standard QM interactions are also induced by analogous transition processes, example is charged transition current in weak interactions, it stipulates, in particular, neutron $\beta$-decay [29]. Additional arguments in favor of this assumption prompted by QM formalism will be considered below. According to this hypothesis, thermonuclear reactions in the Sun result in production of unstable isotopes [29], hence variation of their total decay intensity supposedly can induce NC influence on nuclear decay parameters on the Earth [4-7]. In addition, experimental results discussed in previous section indicate that NC influence can make system evolution less chaotic and more regular, in particular, can result in squeezed states with sub-Poisson statistics. It’s notable that self-ordering is quite general feature of quantum dynamics, examples are crystal lattices or atomic spins in ferromagnetic. Besides the system self-ordering, other forms of system state symmetrization induced by standard QM dynamics. Example is elastic particle scattering, in that case, the final state possesses larger angular symmetry than incoming plane wave state [33]. These analogies together with cited experimental data permits to suppose that for unbound system evolution such NC influence tends to make its evolution more symmetric and self-ordered, our choice of NC Hamiltonians will be
prompted by this hypothesis. Such tendency supposedly would result in symmetrization of decay moment distributions and analogous event distributions on time axe. For example, enlargement of metastable system life-time can be treated as the growth of evolution symmetry, because the event moment distribution $p(t)$ becomes more homogeneous in time, its asymptotic limit is $p(t) \rightarrow \text{const}$ for $t > t_0$. It’s notable that experimental results reviewed above demonstrate enlargement of nucleus life-time induced by enhanced solar activity [5, 4].

It’s natural to suppose that NC effect for any system of restricted size grows with the number of system constituents $N_c$ involved into reactions. For the case of two nearby systems $S_1, S_2$ it supposed that due to NC effects $S_1$ evolution transforms its own state and influences $S_2$ in the similar way and vice versa. For the case of two systems of which one of them $S_1$ is large and other one $S_2$ is small, for them NC effects supposedly realized in master regime, i.e. $S_1$ can significantly influence $S_2$ state and make it evolution more ordered, whereas $S_2$ practically doesn’t influence $S_1$ state evolution. It can be assumed also that in this case, $S_2$ self-influence NC effect is insignificant in comparison with $S_1$ NC influence. Then, resulting NC effect in $S_2$ should depend on $S_1$ evolution properties and $S_1, S_2$ distance $R_{12}$.

Typical experimental accuracy of nuclear decay time measurement $\Delta t$ is several nanoseconds [29]. Formally, such measurement described as the sequence of multiple consequent state measurements divided at least by $\Delta t$ interval. If first one shows that nucleus is in $\psi_0$ state, and next one that it’s in the state $\psi_1$, it means that nucleus decay occurred during this time interval; note that Zenon effect can be neglected for nucleus decays [32, 33]. In QM formalism, a general state of quantum system $S$ described by density matrix $\rho$, for pure states $\rho = |\psi><\psi|$. If $A_1, A_2$ nuclei are its components, the partial $A_{1,2}$ density matrixes $\rho_{1,2}$ can be defined. For each $A_i$ it turns out that if some other $S$ components are also measured, then its decay probability rate would differ from eq. (2) and becomes

$$\gamma_i(t) = \frac{\partial}{\partial t} Tr \rho_i(t) P_i^i$$

(3)

where $P_i^i$ is projector on $A_i$ final state [32].

4. Nonlinear QM formalism

It was supposed that NC effects should not change the system average energy, however, if the corresponding NC Hamiltonian is linear operator then for $\alpha$-decay in Gamow model this condition is violated [34]. It will be shown here that some nonlinear Hamiltonian can satisfy much better to this condition and so it’s sensible to apply it for NC effect description. Nonlinear QM Hamiltonians were used initially in effective theories describing collective effects, but now it’s acknowledged that such hypothetical nonlinear corrections to standard QM can exist also at fundamental level [35]. In nonlinear QM
formalism, particle evolution described by nonlinear Schroedinger equation of the form

\[ i\hbar \partial_t \psi = -\frac{\hbar^2}{2m} \nabla^2 \psi + U(\vec{r}, t)\psi + F(\psi, \bar{\psi})\psi \]  

(4)

where \( m \) is particle mass, \( U \) is system potential, \( F \) is arbitrary functional of system state. Currently, the most popular and elaborated nonlinear QM model is by Doebner and Goldin (DG) \[36, 37\]. In its formalism, simple variant of nonlinear term is

\[ F = \frac{\hbar^2}{m} \Gamma \Phi \]

where \( \Phi = \nabla^2 + \frac{|\nabla \psi|^2}{|\psi|^2} \)  

(5)

is nonlinear operator, \( \Gamma \) is real or imaginary parameter which, in principle, can depend on time or other external factors, here only real \( \Gamma \) will be exploited. With the notation

\[ H^L = -\frac{\hbar^2}{2m} \nabla^2 + U(\vec{r}, t) \]

(6)

we abbreviate (1) to \( i\hbar \partial_t \psi = H^L \psi + F \psi \) where in our case, \( H^L \) is Gamow Hamiltonian.

Main properties of eq. (4) were studied in [36, 10], for constant \( \Gamma \) they can be summarized as follows: (a) The probability is conserved. (b) The equation is homogeneous. (c) The equation is Euclidian- and time-translation invariant for \( U = 0 \). (d) Noninteracting particle subsystem remain uncorrelated (separation property). (e) For \( U = 0 \), plane waves \( \psi = \exp[i(\vec{k}_0 \cdot \vec{r} - \omega t)] \) with \( \omega = E/\hbar, |\vec{k}_0|^2 = 2mE/\hbar^2 \) are solutions both for real and imaginary \( \Gamma \). Writing \( Q > = \int \bar{\psi} \hat{Q} \psi d^3x \) for operator expectation value, in particular, since \( \int \bar{\psi} F \psi d^3x = 0 \), the energy functional for solution of (4) is

\[ < i\hbar \partial_t > = < H^L >. \]

Hence the average system energy would change insignificantly if not at all if \( F \) added to initial Hamiltonian, therefore, it advocates DG ansatz application in NC models. In particular, it will be shown that in WKB approximation, which is the main ansatz for decay calculus, the energy expectation value doesn’t change in the presence of such nonlinear term.

It’s notable that nonlinear term \( F \) in particle Hamiltonian can modify the particle tunneling rate through the potential barrier. In particular, analytic solution of this problem was obtained for rectangular potential barrier, in that case, the barrier transmission rate depends exponentially on \( \Gamma \) \[10\]. To calculate corrections to Gamow model for arbitrary potential \( U \), WKB approximation for nonlinear Hamiltonian of (1) can be used. In this ansatz, 3-dimensional \( \alpha \)-particle wave function reduced to \( \psi = \frac{1}{r} \exp(i\sigma/\hbar) \); function \( \sigma(r) \) can be decomposed in \( \hbar \) order \( \sigma = \sigma_0 + \sigma_1 + ... \), here \( r \) is the distance from nucleus centre \[12, 33\]. Given \( \alpha \)-particle with energy \( E \), one can find the distances \( R_0, R_1 \) from nucleus centre at which \( U(R_{0,1}) = E \). Then, for our nonlinear Hamiltonian the resulting equation for \( \sigma_0 \)

\[ \left( \frac{1}{2m} - \Lambda \right) \left( \frac{\partial \sigma_0}{\partial r} \right)^2 = E - U(r) \]

(7)

where \( \Lambda = \frac{2\Sigma}{m} \) for \( R_0 \leq r \leq R_1 \), \( \Lambda = 0 \) for \( r < R_0, r > R_1 \) \[10\]. Its solution for \( R_0 \leq r \leq R_1 \) can be written as

\[ \psi(r) = \frac{1}{r} \exp(i\sigma_0/\hbar) = \frac{C_r}{r} \exp[-\frac{1}{\hbar} \int_{R_0}^{r} q(\epsilon) d\epsilon] \]

(8)
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where \( C_r \) is normalization constant,

\[
q(\epsilon) = \frac{1}{\hbar} \left( \frac{2m[U(\epsilon) - E]}{1 - 4\Gamma} \right)^{\frac{1}{2}}
\]  

(9)

Account of higher order \( \sigma \) terms doesn’t change transmission coefficient which is equal to

\[
D = \exp \left[ -\frac{2}{\hbar} \int_{R_0}^{R_1} q(\epsilon) d\epsilon \right] = \exp \left[ -\frac{\phi}{(1 - 4\Gamma)^{\frac{1}{2}}} \right] \simeq \exp \left[ -\phi(1 + 2\Gamma) \right]
\]  

(10)

here \( \phi \) is constant, whereas \( \Gamma \), in principle, can change in time, assuming that its time scale is much larger than the barrier transition time. Note that \( \Lambda \) term induced by nonlinearity doesn’t change the average particle energy in comparison with initial linear ansatz. To calculate nucleus life-time, \( D \) multiplied by the number of \( \alpha \)-particle kicks into nucleus potential wall per second \( n_d \), so it gives \( \lambda = n_d D \) [30], for DG model \( n_d \) doesn’t depend on \( F \) term [10].

Consider two nucleus systems \( S_1, S_2 \) with the average distance \( R_{12} \) between \( S_1, S_2 \) elements, supposedly it’s much larger than \( S_1, S_2 \) size. \( S_1 \) is the set of \( N_1 \) unstable nuclei \( \{A_1\} \) prepared at \( t_0 \) with decay probability rate described by eq. (2). \( S_2 \) includes just one unstable nuclide \( B \) prepared also at \( t_0 \), its evolution normally described by Gamow Hamiltonian \( H^L \) ansatz of (6). Its decay constant \( \lambda_b \), in principle, can differ from \( \lambda \) of eq. (2) if for \( B \neq U_N \) of eq. (1). In such set-up presumably NC effects induced by \( S_1 \) would influence \( B \) evolution and perturb also its own evolution as well. Hence for \( S_1 \) nuclei their initial decay probability rate can change to some \( p_i^v(t) \). Suppose that all geometric factors of such NC influence on \( B \) for given \( S_1 \) described by real function \( \chi(R_{12}) \) which absolute value grows with \( N_1 \) and diminishes with \( R_{12} \), i.e. \( \chi \) is phenomenological NC propagation function. Resulting corrections to \( H^L \) are supposed to be small and so can be accounted only to the first order of \( \chi \). Basing on assumptions discussed above, in particular, that resulting NC effect proportional to \( S_1 \) total transition rate, it follows that if no measurements of \( S_1 \) states performed, then corrected \( B \) Hamiltonian becomes

\[
H^d(t) = H^L + \frac{\hbar^2}{m} \chi(R_{12}) p_i^v(t) \Phi
\]  

(11)

where \( \Phi \) is nonlinear operator of (5) for \( B \alpha \)-particle. It means that in this case, \( \Gamma = \chi p_i^v(t) \), substituting it in eq. (10), in WKB approximation it gives \( B \) decay probability

\[
p'(t) = C_b \exp\{-[(t - t_0)\xi(t)]\}
\]  

(12)

here \( C_b \) is normalization constant

\[
\xi(t) = \exp\{[1 + \frac{\hbar^2}{m} \chi(R_{12}) p_i^v(t)] \ln \lambda_b\}
\]  

(13)

Hence for such ansatz, \( B \) probability rate \( p'(t) \) depends on \( S_1 \) nuclei decay rate and can differ from \( B \) probability rate \( p_b(t) \) in Gamow model. It can be assumed for the start that \( p_i^v(t) \approx p_i(t) \) of eq. (2), because in our model typical \( S_1 \) NC self-influence expected
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to be small. Note that $B$ kinematic parameter $n_d$ practically doesn’t change in this case.

Now this NC effect will be considered on more fundamental level beyond master regime. Let’s suppose that for system $S_1 N_1 = 1$ and nuclei $A_1, B$ states described by wave functions $\psi_1, \psi_b$ correspondingly. Then for the same initial conditions as above, the system initial wave function $\psi_s = \psi_0^1 \psi_0^b$. It was assumed that $A_1$ NC influence on $B$ state evolution is proportional to $A_1$ transition rate from its initial state to final one and so for conjugal $B$ NC influence on $A_1$ evolution. In QM framework, $A_1$ transition rate described by the operator $Q_1^a = \frac{dP_1^a}{dt}$, where $P_1^a$ is projector on $A_1$ final state, $Q_1^b$ is corresponding derivative for projector on $B$ final state; they can be calculated from Erenfest theorem \[12\]. Therefore $A_1, B$ Hamiltonian in first $\chi$ order can be chosen as

$$H_s(t) = H_L + \frac{\hbar^2}{m} \chi(R_{12}) Q_1^a \Phi + H_1 + \frac{\hbar^2}{m} \chi(R_{12}) Q_1^b \Phi_1 \quad (14)$$

where $\Phi_1$ is nonlinear operator of eq. \[5\] for $A_1$, $R_{12}$ is $A_1, B$ distance. It follows that for our system $< Q_1^a \Phi > = p_1(t)$ of eq. \[2\]. Since $A_1, B$ operators commute, transition rate operators can be replaced by their expectation values

$$H_s(t) = H_L + \frac{\hbar^2}{m} \chi(R_{12}) p_1(t) \Phi + H_1 + \frac{\hbar^2}{m} \chi(R_{12}) p_b(t) \Phi_1 \quad (15)$$

Therefore, obtained ansatz supports the use of eq. \[11\] for NC influence calculations for large $S_1$ systems. Solution of evolution equation for Hamiltonian of eq. \[14\] gives transition rate for $B$ decay at $t$ described by eq. \[12\] with $p_1(t)$ of eq. \[2\]. Since $A_1, B$ operators commute, transition rate operators can be replaced by their expectation values

Under NC influence for $\chi > 0$ resulting $A_1, B$ nucleus life-times becomes larger than initial one. Such $S_1, S_2$ evolution modification can be interpreted as the growth of $S_1, S_2$ evolution symmetries such that resulting decay probabilities $p_1'(t), p_2'(t)$ becomes more homogeneous in time in comparison with initial $A_1, B$ decay probabilities. It can be supposed also that inverse process, i.e. $A_1$ nucleus synthesis via reaction of $\alpha$-particle with remnant nucleus would induce the opposite NC effect on $B$, reducing $B$ nucleus life-time and so reducing its evolution symmetry. Hence proposed NC mechanism can change, in principle, the evolution symmetry in both directions enlarging or reducing it. Proposed model exploits NC dynamics based on nonlinear $\alpha$-decay Hamiltonian, which, in fact, is used as effective Hamiltonian demonstrating how the decay rates can change under NC influence. It was assumed above that NC doesn’t change any subsystem average energy, in our model this condition fulfilled for WKB approximation.
5. Squeezed State Production

Now let’s consider NC model, which describes self-ordering symmetry growth, resulting in sub-Poisson event statistics. For that purpose multiple time formalism for evolution operator calculation will be used. Remind that solution of QM evolution equation for the system state prepared at $t_0$

$$\psi(T) = W(T)\psi(t_0)$$

where integral evolution operator

$$W(T) = \exp\left[-\frac{i}{\hbar} \int_{t_0}^{T} H(\tau) d\tau \right]$$ (16)

for $H(t)$ system Hamiltonian [33]. Consider for illustration the system of two independent nuclei $A_1, A_2$, its initial state $\psi_A = \psi_0^1\psi_0^2$ where formally $\psi_0^{1,2} = \psi_0$. If their evolution is independent, then operator $W(T)$ will be just the product of two right side terms of eq. (16), but it can be also formally written as

$$W(T) = C_t \exp\left\{ -\frac{i}{\hbar(T - t_0)} \int_{t_0}^{T} \int_{t_0}^{T} [H_1(t_1) + H_2(t_2)] dt_1 dt_2 \right\}$$ (17)

where $H_{1,2}$ are $A_{1,2}$ Gamow Hamiltonians of eq. (11) with corresponding notations, $C_t$ is time-ordering (chronological) operator [33]. In a sense, here the second integration for each term is dummy giving just multiplier $T - t_0$, yet such ansatz is used here because below NC effects will be treated via time-dependent Hamiltonians [33]. Note that for that example $H_{1,2}$, in fact, don’t depend on time, their time parameter just indicates on which of time parameters $t_1$ or $t_2$ $H_{1,2}$ integration was truly performed.

Let’s consider just one system $S$ of $N$ nuclei, as was supposed, due to conjugal NC influence between $S$ elements, its evolution would become more regular and self-ordered without significant life-time change. Due to it, $S$ evolution can differ from the case of independent nuclei and would result in the temporary correlation between $S$ decays. Let’s start from the simplest case $N = 2$ with $A_1, A_2$ nuclei prepared at $t_0$ at the distance $R_{12}$. $S$ evolution operator can be chosen from the analogy with squeezed photon production in atomic resonance fluorescence [28]. In that case, the photon production rate is suppressed if the time interval between two consequently produced photons is less than some fixed $\Delta T$. Due to it, the resulting photon registration becomes more regular, and hence their statistics would become sub-Poissonian. Suppose that $A_1$ NC influence rate on $A_2$ characterized by some scalar function $k(R_{12})$, its absolute value supposedly diminishes as $R_{12}$ grows, the same function describes $A_2$ NC influence on $A_1$. Analogously to ansatz of eq. (15), let’s suppose that $A_2$ NC correlation with $A_1$ evolution is proportional to $A_1$ transition rate and vice versa, but integrated over some time interval. For the simplicity, we assume that NC correlation of $A_1, A_2$ decay moments is such that their evolution ansatz can be factorized into $A_1, A_2$ terms. For
example, if no measurement of $A_1$ state is done, then resulting phenomenological $A_2$ Hamiltonian supposedly becomes

$$H_2^c(T) = H_2 + \frac{\hbar^2}{m} \int_{t_0}^{T} k(R_{12}) \varphi(T - t)Q_1^1 dt \Phi_2 \tag{18}$$

with $Q_1^1$ operator defined above. $\Phi_{1,2}$ are $A_{1,2}$ nonlinear operators of eq. (5) with corresponding notations. $\varphi$ is causal Green function

$$\varphi(\tau) = \gamma(t) - \gamma(t)$$

its possible dependence on $A_1, A_2$ distance supposedly accounted in $k(R_{12})$. Thus, corresponding NC time dependence described as the difference of two step functions $\gamma(t) = \{0, \tau < 0; 1, \tau > 0\}$ which is simple variant of such ansatz [27]. $\nu > 0$ is NC parameter, it corresponds to the time range in which $A_1, A_2$ decay acts are correlated; $\nu$ supposed to be much larger than the barrier transition time [31]. Hence $A_2$ Hamiltonian $H_2^c$ is time-dependent, at given time moment $T$ it depends on $A_1$ decay rate during time interval $\nu$ previous to $T$. Analogous modification occurs for $A_1$ Hamiltonian with corresponding index change. In general, such $S_1$ NC influence on $A_1, A_2$ Hamiltonians results in $W(T)$ nonlinear modification in comparison with eq. (17)

$$W(T) = C_t \text{exp}\{-\frac{i}{\hbar(T - t_0)} \int_{t_0}^{T} [H_1(t_1) + H_2(t_2) + (T - t_0)G(t_1, t_2)] dt_1 dt_2\} \tag{19}$$

Third term in this equality is NC dynamics term, it suprresses nucleus decays at small time intervals between them. Due to $A_1, A_2$ operator commutativity, the operators $Q_1^{1,2}$ in first $k$ order can be replaced by their expectation values, therefore

$$G(t_1, t_2) = \frac{\hbar^2}{m} k(R_{12})[\varphi(t_1 - t_2)\gamma_2(t_2)\Phi_1 + \varphi(t_2 - t_1)\gamma_1(t_1)\Phi_2]$$

where $\Phi_{1,2}$ are of eq. (5). Note that the second right-side term corresponds to $H_2^c$ Hamiltonian of eq. (18) where operator $Q_1^1$ replaced by its expectation value $\gamma_i$ of eq. (3). If no measurement of $A_i$ state was performed for $t_f < T$, then $\gamma_i(t_i) = p_i(t_i)$ of eq. (2). Otherwise, if such measurement was done at some $t_f$ and $A_i$ was found to be in the final state, then for $t_a > t_f$ it follows that $\gamma_i(t_a) = 0$. Under these conditions, kinematic factor $n_{d\alpha}$ for $\alpha$-particle motion inside nucleus changes insignificantly. Then, in WKB approximation for our nonlinear evolution operator the joint $A_{1,2}$ decay probability $p_s$ for $k > 0$ will differ from independent decay case when $p_s(t_1, t_2) = p_1(t_1)p_2(t_2)$ and is equal to

$$p_s(t_1, t_2) = C_1^2 \exp[-g(t_1, t_2)(t_1 + t_2 - 2t_0)]$$

where $C$ is normalization constant, analogously to eq. (13)

$$g(t_1, t_2) = \exp[(1 + 2\theta) \ln \lambda] \tag{20}$$

where $\lambda$ is from eq. (2)

$$\theta = \frac{\hbar^2}{m} k(R_{12})[\eta(t_1 - t_2)\varphi(t_1 - t_2)\gamma_2(t_2) + \eta(t_2 - t_1)\varphi(t_2 - t_1)\gamma_1(t_1)]$$
Due to it, if the time interval between two decay moments is less than $\nu$, the nucleus decay rate will be suppressed, and resulting decay event distribution will become more regular. For independent nucleus decays their joint decay probability corresponds to Poissonian process, whereas NC dynamics term in eq. (19) would transform it into sub-Poissonian one, resulting in less stochastic and more ordered event distribution. Note that in the considered case, $A_1, A_2$ states are correlated, but aren’t entangled. For $N > 2$ the considered NC dynamics term in $W(T)$ would change to $G(t_1, \ldots, t_N)dt_1\ldots dt_N$ with corresponding integration over $N$ independent time parameters. As the result, for analogous $G$ ansatz the joint decay probability of two arbitrary consequent decays will be suppressed for small time intervals between them, and the decay event distribution will be sub-Poissonian.

Here only system self-ordering NC effect resulting in sub-Poisson event statistics was studied, however, some distant system $S_m$ can induce, in principle, analogous NC evolution symmetrization in system $S$, as experimental results evidence [2, 26]; such formalism will be considered in forcoming paper. It can be supposed that analogous NC effect description is applicable also to chemical reactions and other atomic and molecular systems. It’s possible also that two considered evolution symmetrization mechanisms, i.e. life-time enlargement and event ordering can coexist and act simultaneously for some systems.

6. Conclusion

Considered experimental results and theoretical analysis evidence that novel communication mechanism between distant quantum systems can exist. It’s based on specific form of QM nonlocality, principally different from well-known EPR-Bohm mechanism. In this paper, NC effect studied for metastable internal states of quantum systems, in particular, $\alpha$-decay nuclei ensemble. Application of nonlinear Hamiltonian terms for NC description permits to construct its simple model, NC formalism for arbitrary quantum systems will be considered elsewhere. Analogous NC mechanism supposedly can influence chemical reaction rates. Besides the results discussed in sect. 2, additional arguments in favor this hypothesis provide Takata blood test studies. Taking blood samples at different altitudes up to several km and analyzing them together with results cited in sect. 2, authors concluded that the influence source isn’t the Sun itself, but Earth atmosphere at the altitude larger than 6 km [19, 40]. It’s established now that during solar day from sunrise to sunset the intense photochemical reactions occur at such altitudes, in particular, SO$_2$, NO$_2$ molecule destruction by ultraviolet solar radiation, which results in ozone and other compound synthesis [11]. Hence it can be supposed that those chemical reactions induce NC influence which changes blood activity in distant organisms promptly, in its turn such changes influence the results of blood reaction with sodium carbonate. In particular, it explains the start of reaction rate gain 6-8 min before astronomic sunrise, because at that time solar radiation already reach Earth atmosphere at such altitudes.
Such hypothetical nonlocal influence supposedly is universal, so beside nuclear decays and chemical reactions, such temporary variations of system parameters can be observed, in principle, for other systems in which metastable states and tunneling play important role. In particular, it’s well known that development and functioning of biological systems performed quite consistently even at relatively large distances between their parts. For example, the kidney and liver cells, blood erythrocytes identify and attract the proper partner cells and reject wrong ones at the distance of several microns, which are much larger than the range of chemical forces. Another notorious example is morphogenesis problem, i.e. proportional and optimal growth of plants and organisms. Up to now the mechanism which regulates spontaneous cell division in optimal way at significant distances between them is poorly understood. It’s difficult to admit that such long-distance effects can be achieved via chemical messengers only, so it was argued long ago that some other physical mechanism can be responsible for that. Some authors proposed already that long-distance correlations inside cells and living organisms can be induced by QM nonlocality. However, standard EPR-Bohm mechanism can’t induce NC in dense and warm media, which is characteristic for biological systems. It isn’t obvious how NC model considered here can be extended on biological systems which are quite complex, yet there is no direct obstacles for that as well, some options discussed in [34].

In the same vein, multiple publications indicate that some cosmophysical effects can influence also biological system properties (see [45, 46] and refs. therein). Of them, it’s worth to notice specially influence of moon tide gravity variations $\delta g$ on seedling bioluminescence rate and tree stem diameter variations. There is no consistent explanation up to now how such small gravitational force variations $\frac{\delta g}{g} \sim 10^{-7}$ can perturb subtle biological processes. It’s worth to notice specially that bioluminescence data show the essential intensity dependence on $\delta g$ time derivative. Meanwhile, the model of nonlinear gravitational field interaction with quantum systems predicts similar gravity influence on arbitrary quantum systems, in particular, it describes in this framework the observed life-time and decay rate variations of unstable nuclear isotopes. It’s established now that such bioluminescence stipulated mainly by biochemical reactions of protein oxidation. Hence it can be assumed that observed $\delta g$ time derivative dependence owed to nonlinear gravity interaction with molecular states involved in these reactions.

Analogously to gravity, such quantum NC influence supposedly has universal character, such analogy seems to deserve further analysis. In particular, such nonlocal communications between two systems $S_1, S_2$ can appear if they are the systems of scattering particles. However, for metastable systems NC effects are expected to be more easily accessible for experimental observation due to their relatively long duration. It’s worth to stress that in this nonrelativistic model nonlinear Hamiltonian terms describe nonlocal effects only, whereas local interactions are linear. EPR-Bohm paradox and Bell inequalities demonstrate that quantum measurement dynamics is essentially nonlocal. However, it seems doubtful that dynamics of quantum measurements differs
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principally from the rest of QM dynamics, more reasonable is to expect that both of them can be described by some universal formalism, hence the presence of nonlocal terms in it would be plausible [17, 38]. Information-theoretical analysis of quantum measurements supports this hypothesis [39]. Concerning with causality for NC communications, at the moment it’s still possible to assume that such NC can spread between systems with velocity of light. But even if this spread is instant, it’s notable that usually superluminal signalling in QM discussed for one bit yes/no communications [13, 14]. In our case, to define the resulting change of some continuous parameter expectation value, one should collect significant event statistics which can demand significant time, so it makes causality violation quite doubtful possibility. In addition, NC dependence on the distance between two systems expressed by $\chi$ function can be so steep that it also would suppress effective superluminal signalling. Situation can be similar to QFT formalism where some particle propagators spread beyond light cone, but due to analogous factors, it doesn’t lead to superluminal signalling [49]. Note that some nonlinear QM models by themselves permit superluminal signalling, but it doesn’t constitute serious contradiction with our nonlocal ansatz [37].

In general, experimental results for nuclear decay and chemical reaction parameter variations and considered biological effects demonstrate ample bulk of different cosmophysical effects which supposedly influence them. Currently, it seems possible that mentioned nonlinear gravity mechanism and NC mechanism can be appropriate for description of different cosmophysical effects. In particular, gravity mechanism can fit with good accuracy periodic variations of $\alpha-$, $\beta-$decay parameters related to Earth orbital motion [10]. Supposedly it can induce also biological effect variations related to moon tide gravity influence. Nuclear and electromagnetic processes in the Sun related to variable solar activity supposedly induce NC influence on nuclear decay and chemical reaction parameters. It’s possible also that in some cases such NC mechanism can interfere with gravity or electromagnetic field influence resulting in some combined effects.

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