SPONTANEOUS BREAKING OF THE QUANTUM SUPERPOSITION

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Abstract

In this work spontaneous (non-dynamical) breaking (effective hiding) of the unitary quantum mechanical dynamical symmetry (superposition) is considered. It represents an especial but very interesting case of the general formalism of the spontaneous symmetry breaking (effective hiding). Conceptual analogies with spontaneous breaking of the gauge symmetry in Weinberg-Salam’s electro-weak interaction are pointed out. Also, consequences of the spontaneous superposition breaking in the measurement process are discussed. Measurement can be considered as a typical Landau’s continuous phase transition with spontaneous superposition breaking (effective hiding) effectively corresponding to collapse. Here critical values of the order parameters are determined by Heisenberg’s uncertainty relations.

"Nothing is sure for me but what’s uncertain:
Obscure, whatever is plainly clear to see:
I’ve no doubt, except of everything certain:
Science is what happens accidentally:
I winn it all, yet a loser I’m bound to be:"

François Villon (1431. - 1463?),
Ballade: Du Concours De Blois

1 Introduction

As it is well-known, any dynamical symmetry transformation determines a reference system, i.e. referential frame for description of the dynamical processes. For this reason unbroken dynamical symmetry expresses the equivalence (relativity) of all referential frames, while breaking of a dynamical symmetry corresponds to preference (absoluteness) of some referential frame.
In the physics there are two principally different kinds of the breaking of a dynamical symmetry. First one represents the dynamical breaking and second one spontaneous (non-dynamical) breaking (effective hiding) [1]-[3].

Dynamical breaking of a dynamical symmetry represents, roughly speaking, the breaking of the dynamical symmetry by hidden dynamical terms. Precisely, by dynamical breaking of a dynamical symmetry there is one exact dynamics and an its approximation, i.e. approximate dynamics.

Exact dynamics yields an exact, i.e. with zero absolute error, deterministic description of corresponding physical process. Also, symmetries of the exact dynamics stand completely conserved during time.

Approximate dynamics represents, mostly, an approximate Taylor expansion of the exact dynamics statistically averaged over some terms. (For this reason given terms become effectively hidden in given approximate dynamics.) Consistent approximate dynamics needs that corresponding Taylor expansion is convergent globally, i.e. in whole space of the basic dynamical variables. Also, an interval statistical estimation [4] of the exact dynamics needs not only an average value, i.e. consistent approximate dynamics. It needs, also, a standard deviation (square root of the dispersion) that can be considered as as the absolute error of the approximate dynamics.

Consider a case when consistent approximate dynamics, i.e. convergent average value is sufficiently larger than standard deviation, i.e. absolute error of the approximate dynamics. Then it can be stated that approximate dynamics is self-complete. It means that, at the approximate level of the analysis, only approximate dynamics is sufficient for a complete, deterministic description of the physical process. Namely, here corresponding absolute error, that implies necessity of the statistical description, is negligible. (I.e. here statistical interval estimation can be approximately consistently reduced in the point statistical estimation.) In the same case symmetries of the approximate dynamics stand conserved during time.

Consider now the opposite case when consistent approximate dynamics, i.e. convergent average value becomes proportional or smaller than standard deviation, i.e. absolute error. Then approximate dynamics becomes self-incomplete. It means that approximate dynamics is not sufficient for complete approximate description of the physical process. Namely, here corresponding absolute error, that implies necessity of the statistical description, is not negligible. It implies that some of the symmetries of the approximate dynamics are unsatisfied for self-incomplete approximate dynamics.

It is possible that a self-complete approximate dynamics turns during time in a self-incomplete approximate dynamics. Namely, suppose that initially there is unique approximate dynamical state, i.e. dynamical state of the self-complete approximate dynamics. Also, suppose that this state represents a statistical mixture of the exact dynamical states, i.e. dynamical states of the exact dynamics. Given statistical mixture exactly dynamically evolves according to exact dynamics. It corresponds to approximate dynamical evolution of the approximate dynamical state according to approximate dynamics. Suppose that in a critical time moment self-complete approximate dynamics turns in the self-incomplete approximate dynamics. Precisely, suppose that then unique approximate dynamical state turns in a statistical mixture of the approximate dynamical states. Roughly speaking, initially hidden, i.e. implicit statistical mixture of the (exact) dynamical states becomes finally, i.e. in given critical time moment explicit (at the approximate level of the analysis). It corresponds to realization of the probabilistic events. Also, it corresponds to a typical Landau’s continuous phase transition [5]. In given phase transition critical values of the order parameters correspond to given critical time moment. Of course given phase transition includes a breaking of the symmetries of the self-complete approximate dynamics. Given breaking
is caused by exact dynamical terms. Given terms are hidden at the approximate level of the analysis corresponding to approximate dynamics. For this reason given symmetry breaking is called dynamical symmetry breaking.

Dynamical breaking of the dynamical symmetry exists, for example, by parity breaking in the weak (nuclear) interaction [2] etc. Also, dynamical breaking of the dynamical symmetries exists in the simple classical physical models of the different gambling games, e.g. tossing of a coin or playing at dice etc. Generally speaking, dynamical breaking of the dynamical symmetries represents one of the simplest physical model of the mathematical theory of the probability (statistics) [4].

Spontaneous breaking of a dynamical symmetry represents, roughly speaking, choice of an asymmetric solution of the dynamically symmetric equation. But it needs a more detailed explanation. By spontaneous breaking of a dynamical symmetry, also, there is one exact dynamics and an approximate dynamics. In any time moment exact dynamics is exactly satisfied and its symmetries are always exactly conserved.

Approximate dynamics, again, represents, mostly, an approximate Taylor expansion of the exact dynamics statistically averaged over some terms. Also, a standard deviation representing the absolute error of the approximate dynamics can be introduced. Meanwhile, approximate dynamics is here globally inconsistent or globally unstable. It means the following. At least for some values of the basic dynamical variables, or, at least in some domains in the space, approximate Taylor expansion of the exact dynamics diverges. However, approximate dynamics can be locally consistent, i.e. locally stable. It means that for some values of the basic dynamical variables or in some, local, domains of the space approximate Taylor expansion of the approximate dynamics converges. But, some principal characteristic, e.g. symmetries of the exact dynamics can forbid split of the approximate dynamical state in its simultaneously existing locally stable parts, i.e. locally stable approximate dynamical states. Nevertheless, an additional probabilistic, i.e. statistical approximation admits that a locally stable approximate dynamical state be effectively treated as a globally stable approximate dynamical state. Or, generally, globally unstable approximate dynamical state can be, by additional statistical approximation, i.e. with corresponding probability, effectively changed by, i.e. presented or projected in some globally stable approximate dynamical state. Last state corresponds to some locally stable approximate dynamical state too. In this way globally unstable approximate dynamical state and statistically obtained effective globally stable dynamical state exist simultaneously, but at the discretely different approximate levels of the analysis accuracy. First level does not admit a consistent approximate dynamical description of the physical system. Other level, whose definition includes some statistical methods, admits, effectively, consistent approximate dynamical description of the physical system. For this reason there is none dynamical transition from globally unstable in some effectively globally stable dynamical state. Realization of the probabilistic events corresponds simply to the change of the first by second approximate level of the analysis accuracy. In this way different effectively globally stable approximate dynamical states that appear with corresponding probabilities correspond implicitly to the same globally unstable approximate state or to exact dynamical state.

Suppose that an exact dynamical state initially can be approximated by a globally stable approximate dynamical state. Suppose that this exact dynamical state exactly dynamically evolves during time. It corresponds to approximate dynamical evolution of globally stable approximate dynamical state. Suppose that in a critical time moment exact dynamical state, in corresponding approximation, becomes a globally unstable approximate dynamical state. Further consistent approximate dynamical description of the exact dynamical state needs, in the practically same critical time moment, mentioned change of the first by the second level of the analysis accuracy.
it needs mentioned non-dynamical change of the globally unstable approximate dynamical state by one statistically obtained effectively globally stable dynamical state. Complex change of the initial globally stable approximate dynamical state by final effectively globally stable approximate dynamical state includes both approximate dynamical evolution and change of the approximate levels of the analysis accuracy. Such change corresponds to a typical Landau’s continuous phase transition [5]. In given phase transition critical values of the order parameters correspond to given critical time moment. Of course given phase transition includes a breaking of the symmetries of the approximate dynamics. Given breaking is non-dynamical, i.e. it is not caused by exact dynamical terms hidden within given approximation. It is practically caused by a non-dynamical change of the first by the second approximate level of the analysis accuracy. For this reason given non-dynamical symmetry breaking is called spontaneous symmetry breaking, i.e. effective hiding. It means that here approximate dynamical symmetry is not really broken at the first level of the approximate analysis accuracy. It is only effectively hidden by statistical change of the first by the second level of the approximate analysis accuracy.

Spontaneous breaking (effective hiding) of the dynamical symmetry exists, for example, by Heisenberg’s ferromagnetics, by Weinberg-Sallam’s electro-weak interaction, etc. [1]-[3]. (There is wide-spread phrase that Higgs boson breaks gauge symmetry in the electro-weak interaction. It, seemingly, implies that gauge symmetry is dynamically broken by Higgs boson. Meanwhile, as it is well-known [1]-[3], given phrase represents a simplification only. Appearance of the Higgs boson represents, in fact, a consequence but not a cause of the spontaneous breaking, i.e. effective hiding of the gauge symmetry. As it has been shown by t’Hooft [6] only exactly unbroken gauge symmetry admits re-normalization of the electro-weak interaction. Vice versa, any dynamical breaking of the gauge symmetry causes a principal non-re-normalizability of the electro-weak interaction. Similarly, comparison of the spontaneous gauge symmetry breaking with really dynamical symmetry breaking by simple classical mechanical systems, eg. a pellet in the bottle with a rotating double well bottom, has only a limited validity. Spontaneous breaking of the gauge symmetry is really caused, on the one hand, by local divergence of the small perturbation approximation of the quantum field dynamics within a small vicinity of the field corresponding to false vacuum. On the other hand it is caused by local convergence of the same approximate dynamics within a small vicinity of the field corresponding to degenerate minimum of the potential energy density. Or, spontaneous breaking or effective hidding of the gauge symmetry exists only within small perturbation approximation of the quantum field dynamics. It can be added and pointed out that exact solution of given dynamics cannot be practically obtained.) It is not hard to see that spontaneous breaking (effective hiding) of the dynamical symmetries represents a consistent physical model of the mathematical theory of the probability (statistics) [4].

In this work an especial but very interesting case of the general formalism of the spontaneous symmetry breaking (effective hiding) will be considered. Concretely, spontaneous (non-dynamical) breaking (effective hiding) of the unitary quantum mechanical dynamical symmetry, precisely superposition of the weakly interfering wave packets will be considered. Conceptual analogies with spontaneous breaking of the gauge symmetry in Weinberg-Sallam’s electro-weak interaction are pointed out. Also, consequences of the spontaneous superposition breaking in the measurement process will be discussed. Namely, it is well-known [7],[8] the following. Any dynamical breaking (by some hidden dynamical terms, so-called hidden variables) of the unitary quantum mechanical dynamical symmetry (superposition), i.e. collapse in the quantum measurement must be either inconsistent (contradictory to experimental data) or physically implausible (superluminal). It will be demonstrated that quantum measurement can be consistently and physically plausible
considered as a typical Landau’s continuous phase transition. Or, collapse by measurement can be considered as the spontaneous breaking of the unitary quantum mechanical dynamical symmetry (superposition). Here critical values of the order parameters are determined by Heisenberg’s uncertainty relations.

2 Spontaneous superposition breaking on a simple quantum mechanical system

As it is well-known within standard quantum mechanical formalism [12]-[15] Schrödinger’s equation

$$\hat{H}\Psi = (\frac{\hat{p}^2}{2m} + \hat{V})\Psi = \hat{E}\Psi$$

(1)

represents the exact (non-relativistic) dynamical equation of a simple (without subsystems) quantum system. Here \(\hat{H} = (\frac{\hat{p}^2}{2m} + \hat{V})\) represents the Hamiltonian observable of given system, \(\hat{p} = -ih\frac{\partial}{\partial x}\) - momentum observable of given system, \(\hat{V} = \hat{V}(x)\) - potential energy observable of given system, \(\hat{E} = \hat{V}(x)\) - total energy observable of given system, \(m\) - mass of given system, \(\hat{\Psi} = \hat{\Psi}(\hat{x})\) - coordinate observable of given system, \(t\) - time moment, \(\hbar\) - reduced Planck’s constant, and, \(\Psi = \Psi(x,t)\) - exact quantum mechanical dynamical state of given system. This state belongs to Hilbert’s space \(H\) and satisfies unit norm condition

$$\int |\Psi|^2 dx = 1$$

(2)

(For reason of the simplicity, without any diminishing of the generality of the basic conclusions, only one-dimensional, along \(x\) axis classically speaking, dynamics of the conservative (with time independent \(\hat{V}\)) quantum system will be considered.) General solution of (1), in common with initial condition

$$\Psi(x,0) = \Psi_0$$

(3)

determines unambiguously (neglecting constant phase factor) the quantum mechanical dynamical state in any time moment. It, formally, can be presented by

$$\Psi(x,t) \equiv \hat{U}\Psi = \exp[\frac{\hat{H}}{i\hbar}]\Psi_0$$

(4)

where \(\hat{U} = \exp[\frac{\hat{H}}{i\hbar}]\) represents the unitary quantum mechanical dynamical evolution operator.

Chose a time dependent basis \(B(t) = \Psi_n \equiv \Psi_n(x,t) = \hat{U}\Psi_n(x,0), \forall n \text{ in } H\). Obviously, given basis dynamically evolves analogously to (4). It implies that (1) can be equivalently transformed in

$$\sum_n(\Psi_n,\Psi)(\frac{\hat{p}^2}{2m} + \hat{V})\Psi_n = \sum_n(\Psi_n,\Psi)\hat{E}\Psi_n$$

(5)

Here superposition coefficients \((\Psi_n,\Psi)\) for \(\forall n\) satisfy the unit norm condition corresponding to (2)

$$\sum_n |(\Psi_n,\Psi)|^2 = 1$$

(6)

as well as condition of the time independence

$$(\Psi_n(x,t),\Psi(x,t)) = (\hat{U}\Psi_n(x,0), \hat{U}\Psi(x,0)) = (\Psi_n(x,0),\Psi(x,0)) = \text{const} \quad \text{for } \forall n$$

(7)
Obviously $B(0)$ can be chosen quite arbitrarily. It implies, practically, that exact unitary quantum mechanical dynamics conserves the superposition of the states from any complete basis in $H$. Or, more generally, it means that all bases in $H$ represent the equivalent referential frames for description of the exact quantum mechanical dynamics. Also, between two bases in $H$ there is one-to-one mapping by corresponding unitary transformation. It means that invariance of the exact quantum mechanical dynamics in respect to arbitrary unitary transformation (representing, roughly speaking, a ”rotation” in the Hilbert’s space), called unitary symmetry, represents a basic exact dynamical symmetry of the exact quantum mechanical dynamics.

It can be observed that, in some degree, interference terms in (8), (9) are similar to Goldstone modes in the physical theories with spontaneous symmetry breaking [1]-[3]. Namely, as it has been discussed previously, interference terms point out implicitly on the existence of the unitary symmetry of the quantum mechanical dynamics. Given symmetry represents, roughly speaking, a symmetry in respect to ”rotations” in Hilbert space. Similarly, Goldstone modes point out implicitly on the rotational symmetry in different physical theories with spontaneous symmetry breaking. Also, choice of the eigen basis of given observable within which interference terms disappear is, in some degree, similar to Higgs mechanism. It represents the choice of an especial rotating referential frame within which Goldstone modes disappear. But existence of a more detailed conceptual similarity between quantum mechanics and physical theories with spontaneous symmetry breaking needs an additional analysis. Especially, it needs a discussion on the possibility of the spontaneous breaking of the unitary symmetry, i.e. superposition within some approximation of the quantum mechanical dynamics.

Consider, now, quantum mechanical dynamical state $\Psi$ from orbital Hilbert’s space $H_{ORB}$. Orbital Hilbert’s space $H_{ORB}$ represents an especial sub-space of the usual Hilbert’s space $H$. Over this sub-space only such observable $\hat{A}$ acts that represents an analytical function of the coordinate or/and momentum observable. As it is well-known, average value and standard deviation of $\hat{A}$ in $\Psi$ are given by expressions

$$<\hat{A}> = (\Psi, \hat{A}\Psi) = \int \Psi \* \hat{A}\Psi dx$$  \hspace{1cm} (8)

$$\Delta \hat{A} = (\langle \hat{A}^2 \rangle - \langle \hat{A} \rangle^2)^{\frac{1}{2}}$$  \hspace{1cm} (9)

Average value of an observable, including $\hat{A}$, in $\Psi$ has numerically identical values in all bases. But this average value can be consistently interpreted as the statistical average value only in the eigen basis of given observable. In this basis interference terms, i.e. nondiagonal elements do not exist. In all other bases, where corresponding interference terms exist, given average value cannot be interpreted consistently statistically. It refers on the expressions (8),(9) too.

According to (8), Schrödinger’s exact quantum mechanical dynamics for quantum state (1),(3) can be changed by equivalent Ehrenfest’s exact quantum mechanical dynamics for average values

$$m \frac{d <x>}{dt} = <\hat{p}>$$  \hspace{1cm} (10)

$$\frac{d <\hat{p}>}{dt} = -<\frac{\partial \hat{V}(x)}{\partial x}>$$  \hspace{1cm} (11)

$$(\Psi(x,0), x\Psi(x,0)) = (\Psi_0, x\Psi_0) \equiv x_0$$  \hspace{1cm} (12)

$$(\Psi(x,0), \hat{p}\Psi(x,0)) = (\Psi_0, \hat{p}\Psi_0) \equiv p_0$$  \hspace{1cm} (13)

Here (10),(13) represent corresponding initial conditions.
Exact solution of the system (10)-(13) considers general solution of (10),(11) and introduction of the initial conditions (12),(13) in this general solution. But this exact solution is, mostly, mathematically very complicated. For this reason only some simple approximate solutions of (10)-(13) are appropriate for consideration. For example it can be supposed that $\hat{A}$ represents a function of $x$ only (dependence of $\hat{p}$ can be formally neglected without any diminishing of the generality of the basic conclusions). Then (8) can be Taylor expanded in a relatively small vicinity of $\langle x \rangle$, i.e. within the following coordinate interval

$$X(\Psi) = (\langle x \rangle - \frac{\Delta x}{2}, \langle x \rangle + \frac{\Delta x}{2})$$

(14)

It yields

$$\langle \hat{A} \rangle = A(\langle x \rangle) + \left[ \frac{\partial A(\langle x \rangle)}{\partial \langle x \rangle} \right] (x - \langle x \rangle^2) + \frac{1}{2} \left[ \frac{\partial^2 A(\langle x \rangle)}{\partial \langle x \rangle^2} \right] (x - \langle x \rangle^2)^2 + \cdots =$$

$$= A(\langle x \rangle) + \frac{1}{2} \left[ \frac{\partial^2 A(\langle x \rangle)}{\partial \langle x \rangle^2} \right] \Delta x^2 + \cdots$$

(15)

In general case series (15) diverges. But series (15) can converge for some exact quantum mechanical dynamical state $\Psi$ during some finite but relatively large time interval $T$. Especially for some exact quantum mechanical dynamical state $\Psi$, during $T$, for any observable $\hat{A}$ that acts over $H_{ORB}$ it can be satisfied

$$\langle \hat{A} \rangle \simeq A(\langle x \rangle)$$

(16)

or, equivalently,

$$\langle \hat{A}^2 \rangle \simeq \langle \hat{A} \rangle^2$$

(17)

and

$$| \langle \hat{A} \rangle | \gg \Delta \hat{A}$$

(18)

Given approximation conditions (16)-(18) define well-known wave packet approximation [13],[14]. Exact quantum mechanical dynamical state $\Psi$ that satisfies (16)-(18) represents approximately a wave packet. Given wave packet, i.e. $\Psi$ in the wave packet approximation will be denoted $\Psi_{WP}$. For a wave packet (see for example detailed analysis in [13],[14]) Heisenberg’s uncertainty relation obtains the following form

$$\Delta x \Delta \hat{p} \simeq \hbar$$

(19)

It means that wave packet is practically certainly placed in $X(\Psi)$ so that (8) can be approximated by

$$\langle \hat{A} \rangle \simeq (\Psi_{WP}, \hat{A}\Psi_{WP}) \simeq \int_{X(\Psi)} \Psi_{WP} \ast \hat{A} \Psi_{WP} dx \simeq A(\langle x \rangle) |\Psi_{WP}|^2 \Delta x \simeq A(\langle x \rangle)$$

(20)

Additionally it can be supposed that $\langle \hat{A} \rangle$ is significantly time dependent while $\Delta \hat{A}$ is practically time independent so that wave packet dissipates extremely slowly. Then continuously time dependent $\langle \hat{A} \rangle$ can be considered as an order parameter. Simultaneously $\Delta \hat{A}$ can be considered as a practically constant critical value of the order parameter. When absolute value of given order parameter $\langle \hat{A} \rangle$ is larger than its critical value $\Delta \hat{A}$, i.e. when (16)-(18) are satisfied, approximate wave packet dynamics is self-complete. But, in the opposite case, when absolute value of given order parameter $\langle \hat{A} \rangle$ is smaller than its critical value $\Delta \hat{A}$, i.e. when (16)-(18) are
unsatisfied, approximate wave packet dynamics becomes self-incomplete. It admits a typical Landau’s continuous phase transition, by continuously time decreasing absolute value of $\langle \hat{A} \rangle$, from self-complete approximate wave packet dynamics in the self-incomplete approximate wave-packet dynamics. And vice versa.

In this way within wave packet approximation equations (10),(12),(13) stand practically unchanged while equation (11) turns in the following equation

$$\frac{d \langle \hat{p} \rangle}{dt} = -\frac{\partial V(\langle x \rangle)}{\partial \langle x \rangle} \tag{21}$$

Simultaneously approximate dynamics determined by (10),(12),(13),(21) becomes an effective dynamics. It corresponds, obviously, to Newton’s classical mechanical dynamics for a particle with coordinate $\langle x \rangle$ and momentum $\langle \hat{p} \rangle$ for classical mechanical force $-\frac{\partial V(\langle x \rangle)}{\partial \langle x \rangle}$.

It can be observed that within wave packet approximation unitary symmetry of the exact quantum mechanical dynamics is not broken. But it becomes implicit since average value of a quantum mechanical observable does not depend of the choice of the basis in the (orbital) Hilbert’s space.

Thus, exact quantum mechanical dynamics is always exactly globally stable in the orbital Hilbert’s space. Also, within wave packet approximation, quantum mechanical dynamics can be presented effectively by self-complete classical mechanical dynamics globally stable within usual coordinate space. Vice versa, when wave packet approximation is unsatisfied exact quantum mechanical dynamics cannot be approximated classical mechanically dynamically globally stable in the usual coordinate space. Finally, transition from the situation when wave packet approximation is satisfied in the discretely different situation when wave packet approximation is unsatisfied, and vice versa, can be presented as a typical Landau’s continuous phase transition. In this transition order parameters have critical values determined by Heisenberg’s uncertainty relation. From effective classical mechanical view point $|\hat{A}|$ represents the statistically perturbed, i.e. with some absolute error proportional to $\Delta \hat{A}$, estimated value of a classical variable $A$. It can be additionally supposed that $|\hat{A}|$, in distinction from $\Delta \hat{A}$, depends intensively of time and quantum mechanical dynamical state $\Psi$. For this reason satisfaction of (18) in the better and better approximation can be interpreted in sense that absolute error of the statistical estimation of the ”exact” value of the classical mechanical variable $A$ is smaller and smaller. And vice versa.

Further, suppose that there are two quantum states $\Psi_1$ and $\Psi_2$ from $H_{ORB}$ that both satisfy wave packet approximation. Then wave packets corresponding to these quantum states, $\Psi_{1WP}$ and $\Psi_{2WP}$, are weakly interfering, i.e. satisfy additional weak interference approximation, if the following approximation condition is satisfied

$$X(\Psi_1) \cap X(\Psi_2) = \emptyset \tag{22}$$

where $\cap$ represents cross of the intervals and $\emptyset$- empty interval. This condition can be presented in the equivalent form

$$|\langle x \rangle_1 - \langle x \rangle_2| \geq \frac{\Delta_1 x + \Delta_2 x}{2} \tag{23}$$

where

$$\langle x \rangle_n = (\Psi_n, x \Psi_n) \quad for \quad n = 1, 2 \tag{24}$$

$$\Delta_n x = (\langle x^2 \rangle_n - \langle x \rangle_n^2)^{1/2} \quad for \quad n = 1, 2 \tag{25}$$
In further approximation
\[ \Delta_n x \simeq \Delta x \simeq \text{const} \quad \text{for} \quad n = 1, 2 \]  
(26) turns in
\[ |< x >_1 - < x >_2| \geq \Delta x \]  
(27)

Obviously, two weakly interfering wave packets are classical mechanically distinguishable.

Now, suppose that \( B(t) = \Psi_n \equiv \Psi_n(x,t) = \hat{U}\Psi_n(x,0) \), \( \forall n \) represents a basis in \( H_{ORB} \) whose all quantum states satisfy wave packet approximation. Suppose too that wave packets \( \Psi_{nWP} \) for \( \forall n \) corresponding to quantum states from \( B(t) \) are all mutually weakly interfering. It means that the following approximation conditions are satisfied
\[ (\Psi_n, \hat{A}\Psi_m) \simeq (\Psi_{nWP}, \hat{A}\Psi_{mWP}) \simeq A(< x >_n)\delta_{nm} \quad \text{for} \quad \forall n, m \]  
(28)

where
\[ < \hat{D} >_n = (\Psi_n, \hat{D}\Psi_n) \quad \text{for} \quad \forall n \]  
(30)

and
\[ \Delta_n \hat{D} = (< \hat{D}^2 >_n - < \hat{D} >^2_n)^{1/2} \quad \text{for} \quad \forall n \]  
(31)

for arbitrary observable \( \hat{D} \), eg. \( x \), that acts over \( H_{ORB} \). Here \( \delta_{nm} \) represents well-known Kronecker’s symbol. Then exact quantum mechanical dynamical state \( \Psi = \Psi(x,t) \) can be exactly quantum mechanically presented as the following superposition of the quantum states from \( B(t) \)
\[ \Psi = \sum_n (\Psi_n, \Psi)\Psi_n = \sum_n c_n \Psi_n \]  
(32)

Here
\[ c_n = (\Psi_n, \Psi) \quad \text{for} \quad \forall n \]  
(33)

represent superposition coefficients. It will be supposed that \( \Psi \) does not belong to \( B(t) \) so that superposition (32) is nontrivial. Or, it will be supposed that at least two superposition coefficients in (32) are different from zero. Then it can be simply proved that \( \Psi \), i.e. a nontrivial superposition of the wave packets, does not represent any wave packet (does not satisfy the wave packet approximation). Namely, according to suppositions, it follows
\[ < \hat{A}^2 > \simeq \sum_n |c_n|^2 \hat{A}^2(< x >_n) \]  
(34)
\[ < \hat{A} >^2 \simeq \sum_n |c_n|^2 \hat{A}(< x >_n) < \hat{A} > \]  
(35)

Here, in general case, superposition coefficients and their absolute values must be independent of \( A(< x >_n) \) for \( \forall n \). Since \( \hat{A} \) can be arbitrary observable that acts over \( H_{ORB} \) it can be chosen that
\[ A(< x >_n) > 0 \quad \text{for} \quad \forall n \]  
(36)

But then wave packet approximation condition (17) can be satisfied only for an especial condition
\[ A(< x >_n) \simeq < \hat{A} > \quad \text{for} \quad \forall n \]  
(37)

I.e. (17) cannot be satisfied for all observable that act over \( H_{ORB} \) and satisfy (36). It, simply, means that \( \Psi \) cannot satisfy wave packet approximation. Or, it means that \( \Psi \), that exactly represents
a quantum mechanically dynamically globally stable state, represents a classical mechanically dynamically globally unstable state.

Nevertheless $\Psi$ represents the superposition of the weakly interfering, i.e., classically speaking, separated in the coordinate space, wave packets. For this reason $\Psi$ can be considered as classical mechanically dynamically locally stable in a small vicinity of any wave packet. Precisely, $\Psi$ is classical mechanically dynamically stable within coordinate intervals

$$X_{\text{red}}(\Psi_n) = (\langle x \rangle_n - \frac{\Delta_{\text{nred}}x}{2}, \langle x \rangle_n + \frac{\Delta_{\text{nred}}x}{2})$$

for $\forall n$. (38)

representing reductions of the coordinate intervals $X(\Psi_n)$ for $\forall n$. Obviously, $X_{\text{red}}(\Psi_n)$ and $X(\Psi_n)$ have the same centrum $\langle x \rangle_n$ (which implies that within both intervals the same wave packet dynamics, that explicitly depends of the average value of the coordinate, is satisfied) for $\forall n$. But it will be supposed that width of $X_{\text{red}}(\Psi_n)$, $\Delta_{\text{nred}}x$, is smaller than width of $X(\Psi_n)$, $\Delta_n x$, i.e. that it represents a reduction of $\Delta_n x$, for $\forall n$. Then, according to wave packet approximation, it follows

$$\langle x \rangle_n \gg \Delta_n x > \Delta_{\text{nred}}x \text{ for } \forall n$$

which means that supposed local reductions of the wave packets widths are unobservable for wave packet dynamics. Simply speaking, in difference from exact quantum mechanical dynamics wave packet dynamics cannot differ wave packet and reduced wave packet (wave packet in corresponding reduced coordinate interval).

It will be supposed that by given local reductions the following condition of the local conservation of the average value is satisfied

$$|c_n|^2 A(\langle x \rangle_n) \Delta_n x = A(\langle x \rangle_n) \Delta_{\text{nred}}x \text{ for } \forall n$$

It, on the one side, determines widths of the reduced coordinate intervals according to suppositions

$$\Delta_{\text{nred}}x = |c_n|^2 \Delta_n x < \Delta_n x \text{ for } \forall n$$

On the other hand it yields

$$|c_n|^2 = \frac{\Delta_{\text{nred}}x}{\Delta_n x} \text{ for } \forall n$$

It represents a very interesting result. Namely $\Delta_{\text{nred}}x$ represents the measure of $X_{\text{red}}(\Psi_n)$ while $\Delta_n x$ represents the measure of $X(\Psi_n)$ for $\forall n$. It admits, in common with normalization condition

$$\sum_n |c_n|^2 = 1,$$

that $|c_n|^2$ for $\forall n$ be consistently considered as “geometrically” defined probabilities [5].

Now, the meaning of the events corresponding to given probabilities will be explained. Firstly, it can be pointed out that given superposition of the weakly interfering wave packets cannot be simply split in the simultaneously existing wave packets with corresponding intensities. Namely, splitting of the weakly interfering wave packets in the simultaneously existing wave packets with corresponding intensities smaller than 1 implies unambiguously exact breaking of the unitary symmetry of the quantum mechanical dynamics. More precisely, such splitting breaks the unit norm of the quantum dynamical state. So, conservation of the unitary symmetry of the exact quantum mechanical dynamics forbids definitely splitting of the superposition of the weakly interfering
wave packets in the simultaneous existing wave packets with corresponding intensities, i.e. norms smaller than 1. In this way mentioned probabilistic events cannot be explained by splitting of the superposition of the weakly interfering wave packets in the simultaneously existing wave packets.

Nevertheless, there is a possibility that superposition of the weakly interfering wave packets is represented by arbitrary wave packet. Such really local representation, i.e. projection, can be approximately, i.e. effectively presented as a global representation by means of characteristic probabilistic, i.e. statistical methods. Precisely, as it has been pointed out previously, in difference from exact quantum mechanical dynamics wave packet dynamics does not differ wave packet and its local reduction. For this reason, from aspect of the wave packet dynamics, change of the globally unstable superposition of the weakly interfering wave packet by a locally stable reduced wave packet can be effectively presented as change of given superposition by corresponding globally stable wave packet. Moreover, it is not hard to see that quotient of the coordinate interval of a wave packet and coordinate interval corresponding to superposition (representing, in fact, union of the coordinate intervals of all wave packets) is equivalent to quotient of the coordinate interval of corresponding reduced wave packet and coordinate interval of given wave packet (42). This quotient, of course, represents probability of the event that from aspect of the wave packet dynamics globally unstable superposition of the wave packets is changed by one locally stable reduced wave packet, i.e. effectively by corresponding globally stable wave packet.

It is very important to be pointed out that given events exist, i.e. can occur, only effectively, within wave packet approximation. Appearance of given events within given approximation is called self-collapse. Without given approximation, i.e. completely exactly, quantum mechanically, self-collapse does not exit at all. For this reason self-collapse does not any influence (change) on the exactly existing globally stable quantum mechanical dynamical state $\Psi$ (32).

Thus, superposition of the weakly interfering wave packets and superposition breaking, i.e. self-collapse, exist simultaneously but on the discretely different levels of the analysis accuracy, exact and approximate. It represents a typical "relativistic" effect in sense that the dynamical concepts depend significantly from the level of the analysis accuracy [16],[17]. Similar situation exists in the general theory of relativity. Here, exactly speaking, there is no gravitational force in the absolute Euclidian space and time, but there is an Einstein's gravitational field in corresponding curved Riemanian space-time. Nevertheless, in the approximation of the weak gravitational field Newton's gravitational force in the absolute Euclidian space and time effectively appears.

It is not hard to see that self-collapse can be considered as the spontaneous (non-dynamical) unitary symmetry, i.e. superposition breaking (effective hiding). In this sense self-collapse represents an especial case of the general theory of the spontaneous, i.e. nondynamical symmetry braking (effective hiding) [1]-[3].

More precisely, here expression (43) determines the a-priory probabilities of potential events. Given probabilities, for a nontrivial superposition, are smaller than 1. But, by spontaneous realization of the events, a-priory probabilities turn in the a posteriori probabilities. Then a-posteriori probability of the spontaneously realized event equals 1 while a-posteriori probabilities of the unrealized events equal 0. In this way unit norm of the quantum dynamical state is conserved. I.e. norm of the superposition of the weakly interfering wave packets as well as norms of the spontaneously realized wave packet equal 1. (Now it can be observed that condition on the unit norm of the quantum dynamical state represents a more precise form of the early expression "indivisibility of the quant of action" and similar [17]. Of course, this condition represents more precise form of the atomistic concepts in the antique.)

However, it seems that "final" wave packet is principally different from "initial" superposition
of the weakly interfering wave packets. For this reason it seems that here “initial” superposition is ”finally” broken as well as unitary symmetry. Meanwhile such breaking is non-dynamical, i.e. spontaneous (accidental) in full agreement with general theory of the spontaneous symmetry breaking [1]-[3]. Or, here exact quantum mechanical superposition is not exactly broken. It is only effectively hidden in spontaneously realized wave packet by statistical methods within wave packet approximation. Without given approximation, i.e. exactly quantum mechanically dynamically, superposition of the weakly interfering wave packets is completely conserved. In other words, quantum system is always exactly quantum mechanically dynamically described by superposition of the weakly interfering wave packets. Simultaneously, but within wave packet approximation, it is described by one, spontaneously realized, wave packet. For this reason superposition of the weakly interfering wave packets and spontaneously realized wave packet do not belong to the same level of the analysis accuracy. It implies that spontaneously realized wave packet represents the most appropriate representation, i.e. projection of the exact superposition of the weakly interfering wave packets at approximate level of the analysis accuracy. Or, all wave packets represent different representations, i.e. projections of the same exact superposition of the weakly interfering wave packets at the approximate level of the analysis accuracy. In other words, unique exact superposition of the weakly interfering wave packets corresponds to a degenerate set of its projections, i.e. wave packets at the approximate level of the analysis accuracy.

Finally, it is very important to be pointed out that basis of the weakly interfering wave packets represents unique basis over which superposition breaking occurs within wave packet approximation. Namely, any other basis, principally different from given basis, holds quantum mechanical states that represent nontrivial superposition of the weakly interfering wave packets. For this reason, within wave packet approximation, any quantum mechanical state from any other basis, principally different from given basis, turns spontaneously (non-dynamically and probabilistically) in a wave packet from basis of the weakly interfering wave packets.

3 Spontaneous superposition breaking on a quantum mechanical super-system. Measurement as a Landau’s continuous phase transition

Suppose that there is a quantum mechanical super-system, 1+2, that holds two quantum mechanical sub-systems, 1 and 2. Suppose that quantum mechanical dynamical state of 1 + 2 represents the following non-trivial correlated (entangled) quantum state (non-trivial super-systemic superposition)

$$\Psi^{1+2} = \sum_n c_n \Psi^1_n \otimes \Psi^2_n$$

from Hilbert’s space of the quantum states of 1 + 2, $H_{1+2} = H_1 \otimes H_2$. Here $B_1 = \Psi^1_n, \forall n$ represents a basis in the Hilbert’s space of the quantum states of 1, $H_1$, $B_2 = \Psi^2_n, \forall n$ - a basis in the Hilbert’s space of the quantum states of 2, $H_2$, $\otimes$ - tensorial product, $c_n$ for $\forall n$ - superposition coefficients that satisfy unit norm condition

$$\sum_n |c_n|^2 = 1$$

According to standard quantum mechanical formalism [12]-[15], its usual interpretations [16],[17] as well as later theoretical [6] and experimental analysis [7], $\Psi^{1+2}$ describes exactly (completely) and dynamically stable 1 + 2 inseparable in 1 and 2.
Suppose that $H_2$ represents the orbital Hilbert’s space, $H_{2ORB}$, and that $B_2$ represents the basis of the weakly interfering wave packets so that conditions analogous to (28),(29)

$$(\Psi_n^2, \hat{A}_2\Psi_n^2) \simeq (\Psi_{nWP}^2, \hat{A}_2\Psi_{nWP}^2) \simeq A_2(< x_2 >_n)\delta_{nm} \text{ for } \forall n, m$$

(46)

is satisfied, where $\hat{A}_2$ represents arbitrary observable, eg. $x_2$ that acts over $H_{2ORB}$. Also, suppose that $H_1$ can be any Hilbert’s space and $B_1$ any basis in $H_1$.

Then, as it is not hard to see, in a complete analogy with previous discussion, it can be consistently concluded the following. Within wave packet approximation, discretely different from the exact quantum mechanical description, globally dynamically unstable state corresponding to super-systemic non-trivial superposition (43) can be changed spontaneously (non-dynamically) by some non-correlated (non-entangled) state $\Psi_1^n \otimes \Psi_{nWP}^2$ with probability $|c_n|^2$ for $\forall n$. Also, within given approximation, non-correlated state $\Psi_1^n \otimes \Psi_{nWP}^2$ admits a separation of $1 + 2$ in 1 and 2. By this separation 1 is described effectively exactly quantum mechanically (without any numerical approximation of the quantum state) by $\Psi_1^n$ while 2 is described effectively within wave packet approximation by $\Psi_{nWP}^2$ for $\forall n$. In this way here a sub-systemic spontaneous (non-dynamical) superposition breaking, i.e. self-collapse on the one subsystem (eg. 2) occurs if condition of the weakly interfering wave packet approximation is satisfied sub-systemically. Simultaneously, relatively, i.e. in respect to self-collapsed quantum mechanical sub-system (eg. 2), other quantum mechanical sub-system (eg. 1) is described by an effectively exact (without any numerical approximation of the quantum state) mixture of the quantum mechanical states from correlated basis. Or, it can be stated that on this sub-system a relative (in respect to the self-collapsed first sub-system) superposition breaking. i.e. collapse appears. For this reason given relative superposition breaking, i.e. relative collapse represents an effective exact (without any numerical approximation) quantum mechanical phenomenon on corresponding subsystem (eg. 1).

Now, according to some previous ideas [9]-[11], it will be proved that sub-systemic spontaneous (non-dynamical) superposition breaking, i.e. self-collapse and relative collapse on the correlated quantum mechanical sub-systems, can be used for the consequent and consistent description of the measurement process [8],[12],[16],[17].

Suppose that 1 represents the measured quantum object. Suppose that, before measurement, 1 is exactly quantum mechanically described by quantum mechanical dynamical state

$$\Psi^1 = \sum_n c_n \Psi_n^1$$

(48)

where $B_1 = \Psi_n^1$, $\forall n$ represents a time independent eigen basis of the measured observable. Also suppose that 2 represents the measuring apparatus. Suppose that, before measurement, 2 is exactly quantum mechanically described by quantum mechanical dynamical state

$$\Psi^2 = \Psi_0^2$$

(49)

where $itB_2 = \Psi_n^2$, $\forall n$ represents, on the one hand, a time dependent eigen basis of so-called pointer observable and, on the other hand, basis whose states represent the wave packets. Then, before measurement, $1 + 2$ is exactly quantum mechanically described by the following non-correlated (non-entangled) quantum mechanical dynamical state

$$\Psi^1 \otimes \Psi^2 = \sum_n c_n \Psi_n^1 \otimes \Psi_0^2.$$  

(50)
Further, suppose that exact quantum mechanical dynamical interaction between 1 and 2 can be presented by von Neumann unitary quantum mechanical dynamical evolution operator $\hat{U}_{1+2}$ determined by

$$\hat{U}_{1+2}\Psi_n^1 \otimes \Psi_m^2 = \Psi_n^1 \otimes \Psi_m^2 + n \text{ for } \forall n, m.$$  \hspace{1cm} (51)

More precisely, it can be supposed that, during some relatively small time interval $\tau$, $\hat{U}_{1+2}$ changes the initial quantum mechanical state $\Psi_n^1 \otimes \Psi_m^2$ in the final quantum mechanical state $\Psi_n^1 \otimes \Psi_m^2 + n$ for $\forall n, m$. Then, after given interaction, precisely after time interval $\tau$ or in time moment $\tau$, 1 + 2 is exactly quantum mechanically described by the following correlated (entangled) quantum mechanical dynamical state

$$\Psi_{1+2} = \sum_n c_n \Psi_n^1 \otimes \Psi_n^2.$$  \hspace{1cm} (52)

Simply speaking by exact quantum mechanical dynamical interaction between 1 and 2, i.e. during time interval $t$, an extension of the superposition from 1 on 1 + 2 occurs.

Suppose that given interaction between 1 and 2 is chosen in such way that after this interaction, i.e. after time moment $\tau$, conditions of the weak interference between wave packets from $B_2$, (46), (47), become satisfied. More precisely, suppose that absolute values of the order parameters $<x_2>_n - <x_2>_m$ for $\forall n, m$, according to appropriately chosen exact quantum mechanical dynamics, i.e. $\hat{U}_{1+2}$, increase continuously during time. Suppose, further, that after time moment $\tau$, their absolute values become larger than critical value $\Delta x_2$ determined, implicitly, by Heisenberg’s uncertainty relations. Then within wave packet approximation (52) can be changed spontaneously (non-dynamically) by some non-correlated (non-entangled) state $\Psi_n^1 \otimes \Psi_{nW}^2$ with probability $|c_n|^2$ for $\forall n$. In this way, within given approximation, during time interval $\tau$, a typical Landau’s continuous phase transition with spontaneous (non-dynamical) superposition breaking (effective hiding), precisely with self-collapse on 2 and relative collapse on 1, occurs.

It is not hard to see that given phase transition possesses all necessary characteristics of the real measurement process. Namely, 2, i.e. measuring apparatus, is described effectively classical mechanically by a statistical mixture of the eigen states of the pointer observable only. Also, 1, i.e. measured quantum object, is described effectively quantum mechanically by a statistical mixture of the eigen states of the measured observable only. Statistical weights, i.e. probabilities of the events, in both mixtures are numerically, i.e. quantitatively determined by superposition coefficients of the exact quantum mechanical dynamical state of 1, i.e. measured quantum object before measurement (48) exclusively. But, qualitatively, statistical or probabilistic characteristics of corresponding superposition coefficients represent intermediate consequences of the self-collapse that appears on 2, i.e. measuring apparatus exclusively. For this reason spontaneous superposition breaking, i.e. self-collapse on 2 and relative collapse on 1, yield a consistent and consequent formalization of the measurement. Exact quantum mechanical dynamical interaction between measured quantum object and measuring apparatus on the one hand, and, measurement as the spontaneous superposition breaking on the other hand, exist simultaneously but on the discrete different levels of the analysis accuracy, exact and approximate. (It represents a consequent formalization and consistent explanation of the Bohr’s concept of the complementarity, i.e. relative boundary between measured object and measuring apparatus [16],[17].) Meanwhile, by usual measurements, where measuring apparatus represents a macroscopic system, there are extreme technical difficulties (eg. decoherence by interactions with environment) for immediate experimental studying of the existing dynamical interaction between measured quantum object and measuring apparatus, or, roughly speaking, mesoscopic and macroscopic superposition. Nevertheless, there are many realizable or realized experiments [18],[19] that affirm or would affirm existence of the mesoscopic
or macroscopic superposition. Or, given experiments affirm or would affirm less or more explicitly existence of the correlated quantum mechanical dynamical state of the quantum mechanical super-system (measured quantum object + measuring apparatus). For example, in [18] is theoretically discussed a potentially realizable experiment at extremely small temperatures (necessary for elimination of the environmental decoherence). Within given experiment there is a quantum mechanical super-system that holds two sub-systems. First one represents a photon that can be considered as 1. Second one represents a movable mesoscopic mirror of a typical Michelson’s interferometer that can be considered as 2. Roughly speaking exact quantum mechanical dynamical interaction between photon and mirror periodically correlates (entangles) and decorrelates (deentangles) given sub-systems. During a correlation period all conditions for spontaneous superposition breaking, i.e. self-collapse on the mirror and relative collapse (absence of the superposition) on the photon, are satisfied. But during next decorrelation period a superposition on the photon appears. It implies that in the previous correlation period super-system photon+mirror has been really in a correlated state, i.e. in the state of a super-systemic superposition. (Detailed discussion of [18] from aspect of the spontaneous superposition breaking concept is given in [9].) In [19] a mesoscopic quantum mechanical superposition on a super-system is realized without decoherence.

Generally speaking, concept of the spontaneous superposition breaking is able to solve all open problems of the foundations of the quantum mechanics [8]. Especially, on the one hand, \( \hat{U}_{1+2} \) or correlations between \( B_1 \) and \( B_2 \) are exactly quantum mechanically uniquely determined (neglecting constant phase factors). On the other hand, self-collapse on 2 within localization of the weakly interfering wave packets approximation appears over \( B_2 \) exclusively. For this reason within given measurement any observable that does not commute with measured observable or whose eigen basis is different from \( B_1 \) cannot be measured at all. In other words two or many noncommuting observable cannot be simultaneously statistically distributed. It implies that within standard quantum mechanical formalism, including measurement as the spontaneous superposition breaking, an inequality analogous to Bell’s inequality for hidden variables [7] cannot be consistently formulated (for details see [10]). Simply speaking quantum mechanics represents a local theory, in full agreement with existing experimental data [8]. (Usually used term ”quantum nonlocality” refers, in fact, only on the hypothetical hidden variables theories that should satisfy existing experimental data.)

4 Conclusion

In conclusion the following fundamental principles of the standard quantum mechanical formalism can be shortly repeated and pointed out. Hilbert’s space represents exactly the fundamental physical space. All bases in this space represent exactly the fundamental referential frames (reference systems). Any referential frame can be exactly transformed in some other by corresponding unitary transformation (representing, roughly speaking, a ”rotation” in the Hilbert’s space). Quantum mechanical system is exactly and completely described by unitary symmetric (that conserves superposition and does not prefer any referential frame as the absolute) quantum mechanical dynamical state (of the unit norm). This state and its dynamical evolution is determined unambiguously (neglecting constant phase factor) by Schrödinger’s equation (or equivalent equations) and initial condition only. Physical characteristics of given quantum mechanical system in its quantum mechanical dynamical state are exactly represented by average values of corresponding Hermitian operators, observable. Given characteristics evolve exactly deterministically during time according to exact quantum mechanical dynamics, i.e. Ehrenfest’s equations. There is none other funda-
mental principle of the standard quantum mechanics so that quantum mechanics represent an objective, deterministic and local (without Bell’s inequality analog) physical theory.

Measurement, as it has been suggested in [16],[17], represents only an effective phenomenon. It can be consequently modeled by spontaneous (nondynamical) superposition breaking with inherent statistical (probabilistic) characteristics. It considers the self-collapse that appears exclusively over eigen basis of the pointer observable on the effectively classical mechanical described measuring device. Simultaneously it considers the relative collapse that appears exclusively over eigen basis of the measured observable at the effectively quantum mechanically described measured quantum object. Thus preference of the eigen basis of the measured observable occurs really by measurement. But given preference is implicitly formulated even by a demand that average value of given observable in the quantum mechanical dynamical state of the measured quantum object has form of a statistical average value. Namely, numerical value of an observable, including measured observable, is the completely same in any basis. It expresses unitary symmetry of the quantum mechanical dynamics. Meanwhile in a basis different from eigen basis of the measured observable interference terms appear. They, on the one hand, point out that unitary symmetry is exactly conserved, i.e. that ”rotation” from one in the other referential frame is still possible. But, on the other hand, theirs presence forbids that given average value be presented in the form of the statistical average value in given basis different from eigen basis of the measured observable. It is not hard to see that given interference terms in the standard quantum mechanical formalism in some degree are analogous to Goldstone modes in the general formalism of the spontaneous symmetry breaking [1]-[3].

So, spontaneous (nondynamical) superposition breaking points out, intermediately, that fundamental unitary symmetry of the quantum mechanical dynamics cannot be exactly broken but only effectively hidden in the approximate measurement process. Or, instead of one (absolute) referential frame (basis of the measured observable by collapse) there are all possible (relative) referential frames (bases in the Hilbert’s space) that describe equivalently the unitary symmetric quantum mechanical dynamics. It is in full agreement with the following Bohr’s words: ”Before concluding I should still like to emphasize the bearing of the great lesson derived from general relativity theory upon the question of physical reality in the field of quantum theory. In fact, notwithstanding all characteristic differences, the situation we are concerned with in these generalizations of classical theory presents striking analogies which have often been noted. Especially, the singular position of measuring instrument in the account of quantum phenomena, just discussed, appears closely analogous to the well-known necessity in relativity theory of upholding an ordinary description of all measuring processes, including sharp distinction between space and time coordinates, although very essence of this theory is the establishment of new physical laws, in comprehension of which we must renounce the customary separation of space and time ideas. The dependence of the reference system, in relativity theory, of all readings of scales and clocks may even be compared with essentially uncontrollable exchange of the momentum or energy between the objects of measurement and all instruments defining the space-time system of the reference, which in quantum theory confront us with the situation characterized by the notion of complementarity. In fact this new feature of natural philosophy means a radical revision of our attitude as regards physical reality, which may be paralleled with the fundamental modification of all ideas regarding the absolute character of physical phenomena, brought about general theory of relativity.” [16]
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