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QUANTUMLIKE BEHAVIOR OF CLASSICAL PARTICLES IN SPACETIMES WITH TIME MACHINES

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Abstract. A rough similarity between self-inconsistent evolutions of classical solid balls in spacetimes with wormholes (serving as time machines) and evolutions of quantum-mechanical microparticles is discussed. Within our discussion, wormholes are specified by a microscopic typical size of their mouths, and classical solid balls are divided into two categories: small and large balls. For geometric reasons, small balls can move through wormholes with microscopic mouths, while traverse of large balls through wormholes is forbidden. A new principle of self-consistency is suggested which admits partially inconsistent evolutions of small solid balls on closed timelike curves associated with wormholes. According to the new principle, evolutions of small solid balls on closed timelike curves can be self-inconsistent (they can violate conventional causality), but these evolutions change the past of small solid balls in the way keeping evolutions of large solid balls unambiguous. With the new principle, self-inconsistent evolutions of small classical balls in spacetimes with wormholes are roughly similar to unitary evolutions of quantum microparticles. Also, in a rough approximation, specific collisions between large and small classical balls - collisions each resulting in absorption of a small ball (having ambiguous trajectories that violate conventional causality) by a large ball - in spacetimes with wormholes are similar to quantum-mechanical measurement (wave function reduction) events.

1. INTRODUCTION

Quantum mechanics is a well developed and self sufficient branch of science, describing the matter at the atomic and subatomic scales; see, e.g., [1,2]. Besides, its representations and methods are widely exploited in other scientific areas, in particular, advanced materials science. One of remarkable examples of such a kind is use of density-functional calculations in examination of ideal strength of materials [3,4] and energy characteristics of generalized stacking faults [5-7], which serve as a basis for analysis of mechanical properties of nanocrystalline materials and nanowires [8-10]. At the same time, fundamentals of quantum mechanics are still under discussions; see, e.g., [11,12]. In particular, there are several interpretations and unsolved paradoxes of quantum mechanics [11,12]. One of the key problems in this area is in understanding the fundamental reasons for difference in the behavior between microscopic (quantum) and macroscopic (classical) particles. The problem in question dramatically manifests itself, in particular, in quantum-mechanical measurement (wave function reduction) events [11]. This paper discusses the problem. In doing so, the author (i) points out a rough similarity between evolutions of quantum microparticles and.self-inconsistent evolutions of classical solid balls in spacetimes containing wormholes; (ii) suggests a solution of a "size problem"

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concerning dramatic difference in the behaviors of large and small classical balls in spacetimes containing wormholes; and (iii) speculates that the suggested solution of the "size problem" may be useful in understanding the fundamental reasons for difference in the behavior between microscopic (quantum) and macroscopic (classical) particles in quantum mechanics.

Some time ago, it was theoretically revealed that time machines (closed timelike curves (CTCs)) can, in principle, exist in spacetimes with wormholes; see, e.g., [13-16]. In general, such CTCs allow one to travel to the past and thereby are capable of violating conventional causality through change of the past. Causality paradoxes of such a kind are well known in science fiction. A typical example is the "grandfather paradox" (a person traveled back in time and killed his biological grandfather before the latter met the traveler's biological grandmother); see, e.g., discussions in papers [17,18]. In order to avoid the causality violation attributed to the existence of CTCs, Friedman et al. [16] suggested the principle of self-consistency which admits the only self-consistent evolutions on CTCs in the sense that these evolutions change the past in the way keeping them (evolutions) unambiguous. More strictly, following Friedman et al [16], the principle of self-consistency states that "the only solutions to the laws of physics that can occur locally in the real Universe are those which are globally self-consistent" or, in other words, "this principle allows one to build a local solution to the equations of physics only if that solution can be extended to be part of a (not necessarily unique) global solution, which is well defined throughout the nonsingular regions of the spacetime." Other evolutions - self-inconsistent evolutions which by definition do not satisfy the principle of self-consistency - are considered as impossible in principle, because they violate the conventional causality [16]. The principle of self-consistency was successfully exploited in a mathematical analysis of time evolution of perfectly elastic solid balls ('billiard balls" serving as simple models of classical particles) and other classical systems in spacetimes with CTCs [19,20]. In terms of science fiction, the approach [16] is equivalent to "banana peal mechanism" preventing the grandfather paradox. That is, there always exists a strategically placed banana peal on which the prospective murderer slips as he pulls the trigger, thus spoiling his arm [18].

Evolutions of quantum-mechanical systems in spacetimes with CTCs were considered in paper [21]. In particular, it was found that self-inconsistent evolutions of quantum systems do not occur in the Everetts' multiworld interpretation of quantum mechanics. In doing so, the pairs of seemingly inconsistent events occur in "different" universes, and thereby these events are interpreted as consistent [21] (see also a discussion in papers [17,18]). In this context, following Deutsch [21], the Everetts' multiwold interpretation can be experimentally distinguished from other interpretations of quantum mechanics in spacetimes with CTCs. Also, note that the Deutsch approach [21] is similar to multiworld interpretations of seemingly inconsistent classical events (e.g., birth of a person and "this person kills his young grandfather" event) at time loops associated with time machines in science fiction; see, e.g., [18]. In the classical multiworld interpretation, the pairs of seemingly inconsistent events occur in "different" universes, and thereby they are not in contradiction.

In this paper, we will focus our consideration on self-consistent and self-inconsistent evolutions of classical objects (solid balls) in spacetimes with wormholes, taking into account sensitivity of these evolutions to finite sizes of wormhole mouths. In contrast to the approach [16] excluding all self-inconsistent evolutions from classical physics, we think that self-inconsistent evolutions are worth being considered as possible as well. Though such evolutions violate the conventional causality, they are roughly similar to evolutions of quantum microparticles. The main aim of this paper is to theoretically examine the specific features of self-inconsistent and unambiguous evolutions of classical solid balls, with their sensitivity to geometric sizes of wormhole mouths and causality paradoxes taken into account. We point out quantumlike behavior of classical small balls in spacetimes with wormholes, in which case self-inconsistent evolutions of such balls are roughly similar to unitary evolutions of quantum microprticles. In the framework of the suggested approach, small and large classical ball exhibit different behaviors due to their geometric sizes allowing and do not allowing them to traverse through wormholes, respectively. The difference in the behavior between small and large classical balls in spacetimes with wormholes is roughly similar to difference in the behavior between quantum microparticles and classical particles in quantum mechanics. (In this paper focused on the causality aspects only, we do not consider other problems (like the negative energy problem; see, e.g., [22,23]) related to the existence of wormholes in spacetimes.)

2. SELF-CONSISTENT AND SELF-INCONSISTENT EVOLUTIONS OF CLASSICAL SOLID BALLS IN SPACETIME WITH A STATIC WORMHOLE

First, following the approach [16], let us illustrate the conventional principle of self-consistency in the case of a perfectly elastic solid ball which moves in a spacetime with a CTC associated with a static wormhole (Fig. 1). The wormhole has two mouths A and B, spherical holes (shown as cross-hatched circles in Fig. 1) characterized by the same radius *R* and distant by *D* from each other in a three-dimensional space. The mouths are connected by a short handle with the negligibly small length $l << D$. For the aims of this paper, it is logical to assume that $l = 0$. The spacetime is a flat spacetime everywhere except for the wormhole mouths and their vicinities. There are CTCs which involve traverse through the wormhole. The traverse means that, when a solid ball with radius $r < R$ enters the wormhole mouth A, the ball appears from the mouth B in the past.

Within this simplest scheme, one can distinguish self-consistent and self-inconsistent evolutions of the ball. Following the approach [16], a typical example of self-consistent evolution is schematically presented in Fig. 1a. The ball moves along the trajectory α, undergoes self-collision at point O (the collision with "older itself"), moves along the trajectory α' and reaches the wormhole mouth A at the end of the trajectory α' (Fig. 1a). The ball enters the mouth A, then appears from the wormhole mouth B in the past, moves along the trajectory β, collides with "younger itself" at point O, and then moves along the trajectory β'. The ball trajectories α and β meet at point O where the ball collides with itself. As a result of this self-collision, the ball moving along trajectories α and β drives itself to move along trajectories α' and β', respectively, in which case the trajectory α' ends at the wormhole mouth A and thus forms a closed self-consistent evolution curve Oα'ABβ O (Fig. 1a). Besides, the ball moves along the trajectory β' towards the future (Fig. 1a). If details of the self-consistent evolution on the CTC are not interesting, one can consider it as that occurring within a black box with the trajectory α coming into the box from the past and the trajectory β' moving from the box towards the future (Fig. 1b).

Now let us discuss, following the approach [16], a typical example of self-inconsistent evolution (Fig. 2a). The ball moves along the trajectory α and enters the wormhole mouth A at the end of this trajectory (Fig. 2a). Then the ball appears from the mouth B in the past and moves along the trajectory β (Fig. 2a). The ball trajectories α and β meet at point O where the ball collides with itself. As a result of this self-collision, the ball moving along trajectories α and β drives itself to move along trajectories δ and γ, respectively, in which case both the trajectories γ and δ do not end at the wormhole mouth A (Fig. 2a). If it is so, the ball does not move along the wormhole handle AB, does not appear at the mouth B, does not collide with itself at point O; and, as a corollary, the ball moves along the trajectory α, enters the mouth A at the end of this trajectory, and so on (Fig. 2a). To summarize, the ball enters the wormhole mouth A, if and only if it does not enter the wormhole mouth A. Thus, the self-inconsistent evo-

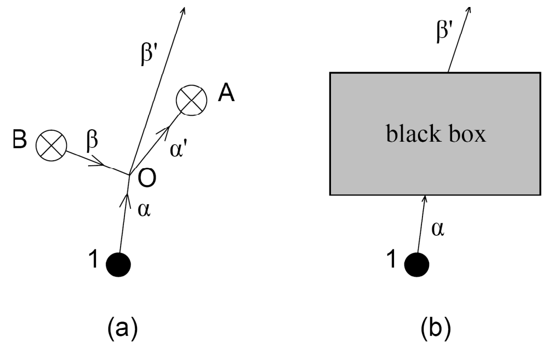

Fig. 1. A typical example of self-consistent evolution of a classical solid ball in spacetime with a wormhole. (a) The solid ball (full circle) moves along the trajectory α, collides with older itself at point O, moves along the trajectory α' and reacheas the wormhole mouth A (cross-hatched circle) at the end of the trajectory α'. The ball enters the mouth A, then appears from the wormhole mouth B (cross-hatched circle) in the past, moves along the trajectory β, collides with younger itself at point O, and then moves along the trajectory β'. The ball trajectories α and β meet at point O where the ball collides with itself. As a result of this self-collision, the ball moving along trajectories α and β drives itself to move along trajectories α' and β', respectively, in which case the trajectory α' ends at the wormhole mouth A and thus forms a closed self-consistent evolution curve Oα'ABβ O. Besides, the ball moves along the trajectory β' towards the future. (b) If details of the self-consistent evolution on the CTC (associated with the wormhole) are not interesting, one can consider it as that occurring within a black box with the trajectory α coming into the box from the past and the trajectory β' moving from the box towards the future.

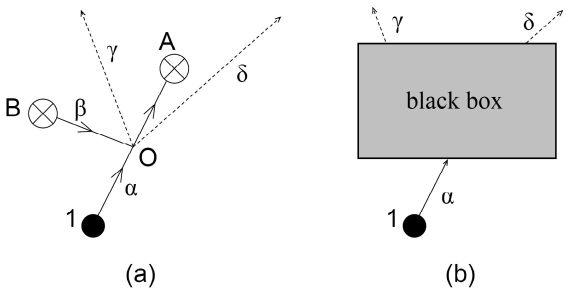

Fig. 2. A typical example of self-inconsistent evolution of a classical solid ball in spacetime with a wormhole. (a) The solid ball (full circle) moves along the trajectory α and enters the wormhole mouth A (cross-hatched circle) at the end of this trajectory. Then the ball appears from the wormhole mouth B (cross-hatched circle) in the past, moves along the trajectory β. The ball trajectories α and β meet at point O where the ball collides with itself. As a result of this self-collision, the ball moving along trajectories α and β drives itself to move along trajectories δ and γ, respectively, in which case both the trajectories γ and δ do not end at the wormhole mouth A. If it is so, the ball does not move along the wormhole handle AB, does not appear at the mouth B, does not collide with itself at point O and, as a corollary, moves along the trajectory α, enters the mouth A at the end of this trajectory, and so on. That is, the ball enters the wormhole mouth A, if and only if it does not enter the wormhole mouth A. (b) If details of the self-inconsistent evolution on the CTC (associated with the wormhole) are not interesting, one can consider it as that occurring within a black box with the unambiguous trajectory α coming into the box from the past and the two ambiguous trajectories γ and δ moving from the box towards the future (for details, see text).

lution (Fig. 2a) produces the paradox (called the Polchinskii' paradox [16]) which serves as an analog of the grandfather paradox in science fiction. With the Polchinskii' paradox, the authors [16] concluded that the self-inconsistent evolutions are impossible in principle, because they violate the conventional causality.

If details of the self-inconsistent evolution along a CTC are not interesting, one can consider it as that occurring within a black box with the trajectory α coming into the box from the past and both the trajectories γ and δ (whose realizations are uncertain in accordance with the Polchinskii' paradox) moving from the box towards the future (Fig. 2b). Hereinafter we denote the trajectories γ and δ as "ambiguous trajectories" in order to distinguish them from classical (unambiguous) trajectories. Also, the same term "ambiguous trajectory" will designate any uncertain trajectory resulted from a self-inconsistent evolution of a classical ball in a spacetime with wormholes.

3. QUANTUMLIKE CHARACTER OF SELF-INCONSISTENT EVOLUTIONS OF CLASSICAL SOLID BALLS IN SPACETIME WITH A STATIC WORMHOLE

The existence of the two ambiguous trajectories (γ and δ) of one classical solid ball (Fig. 2) is roughly similar to quantum-mechanical uncertainty in spatial localization of quantum objects like electrons in the textbook experiment with electrons moving through two slits of a screen. As with the case of electrons whose spatial coordinates in the mentioned experiment are uncertain, one can not unambiguously identify spatial coordinates of the classical ball having the two ambiguous trajectories (Fig. 2) in a spacetime with a wormhole. In the context discussed, self-inconsistent evolution of one classical solid ball at its ambiguous trajectories can be treated as a rough analog of unitary evolution of a quantum microparticle.

More than that, within the description of behavior of classical balls in spacetimes with CTCs, one can define also approximate analogs of quantum-mechanical measurement (wave function reduction) events. To start their discussion, let us consider the specific features of evolutions of classical solids balls divided into two categories: small and large balls, depending on their radii in a spacetime with a wormhole. All the small solid balls have the same mass m and radius r smaller than the wormhole mouth radius R. The small solid balls with radius r can in principle move through the wormhole with radius $R > r$. In this context, if small solid balls move through the wormhole, their evolutions can be self-inconsistent, as with evolution of the previously considered solid ball (Fig. 2) having the two ambiguous trajectories γ and δ.

All the large balls are similar to each other. The mass of each large ball highly exceeds the mass m of a small ball. Also, large balls are characterized by the same large radius R_L larger than the radii of the wormhole mouths and small balls: $R_L>R>r$. As a corollary, in contrast to small balls, large balls can not move through the wormhole with the mouth radius $R < R_L$. In these circumstances, one logically concludes that large balls always have unam-

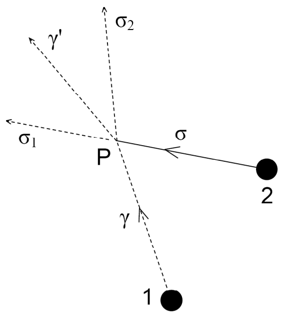

Fig. 3. A collision of two small solid balls in the situation where one of these balls initially (before the collision) has ambiguous trajectories in spacetime with a wormhole. The ambiguous trajectory (dashed line) γ of the small ball 1 (full circle) meets the unambiguous trajectory (solid line) σ of small ball 2 (full circle) at some point P of the spacetime. Due to uncertainty in realization of the ambiguous trajectory γ of the ball 1, its collision with another solid ball at point P is uncertain, too. As a corollary, the initially (before the collision) unambiguous trajectory of the ball 2 at point P transforms into two ambiguous trajectories σ_1 and σ_2.

biguous evolutions in the spacetime with the wormhole.

Thus, for geometric reasons (expressed in inequality $R>r$), small solid balls can have self-inconsistent evolutions on CTCs associated with wormholes, and thereby their past can change producing the Polchinskii' paradox. In contrast, for geometric reasons (expressed in inequality $R_L>R$), large solid balls can not evolve on the CTCs, and thereby their evolutions are always unambiguous.

We briefly discussed behaviors of isolated small and large balls in spacetimes with CTCs. Let us consider their collisions and sensitivity of such collisions to the presence of CTCs. Since large balls always have unambiguous evolutions, collisions between large balls in a spacetime with CTCs are not influenced by the presence of CTCs. Such collisions are identical to collisions between classical balls in a spacetime free from CTCs.

Now let us consider a collision of two small balls in the situation where one of these balls has ambiguous trajectories. Let a small solid ball (hereinafter denoted as the ball 1) have the two ambiguous trajectories γ and δ in a spacetime with a wormhole (Fig. 2). Let the ambiguous trajectory γ of the small ball 1 meet a trajectory σ of another small ball (hereinafter denoted as the ball 2) at some point P of the spacetime (Fig. 3). Due to uncertainty in realization of the ambiguous trajectory γ of the ball 1, its collision with another solid ball at point P is uncertain, too. In these circumstances, after the ball 2 has reached point P, its evolution has become uncertain. The trajectory of the ball 2 at point P transforms into the two ambiguous trajectories σ_1 and σ_2 (Fig. 3). (Roughly speaking, the trajectory σ_1 corresponds to the Polchinskii' paradox "cycle" at which the ball 1 does not move in the future, and, as a corollary, the balls 1 and 2 do not collide at point P; see Figs. 2 and 3. The trajectory σ_2 corresponds to the Polchinskii' paradox "cycle" at which the ball 1 moves along the two trajectories in the future, and, as a corollary, the balls 1 and 2 collide at point P; see Figs. 2 and 3.) Thus, a collision of a small ball having ambiguous trajectories and a small ball having a classical unambiguous trajectory results in transformation of the unambiguous trajectory of the second ball into the two ambiguous trajectories (Fig. 3).

Note that, if the ball 1 moves through the wormhole and thereby has ambiguous trajectories, the collision of the two small balls (Fig. 3) does not forbid traverse of the small ball 1 through the wormhole in the past. That is, the collision does not prevent change in the past of the solid ball 1 having self-inconsistent evolution.

The situation is dramatically different for collisions of another kind, the namely collisions between small and large balls with associated absorption of small balls by large balls. As to details, let us consider the small ball 1 which moves along ambiguous trajectories γ and δ; collides with the large ball 3, when its ambiguous trajectory γ meets the classical trajectory of the large ball 3; and then is absorbed by the ball 3 (Fig. 4a). Due to the absorption, the small ball 1 looses its individuality. The ball 1 becomes a part of the large ball 3. Since large balls can not traverse through the wormhole and have the unambiguous evolutions, the absorbed small ball 1 (Fig. 4a) as a part of the large ball 3 can not traverse through the wormhole and should have the unambiguous evolution. In other words, the absorption event (Fig. 4a) changes the past in the sense that the absorbed small ball 1 can not move through the wormhole in the past, and thereby the ball 1 does not experience the Polchinskii' paradox after the absorption.

In general, the absorption of the small ball 1 by the large ball 3 (Fig. 4a) is not a definite event, because the small ball 1 has ambiguous trajectories γ and δ. In these circumstances, the small ball 1 moving along ambiguous trajectories γ and δ can be absorbed by the large solid ball 4 (Fig. 4 b), as with the large ball 3 (Fig. 4a). That is, with ambiguity of

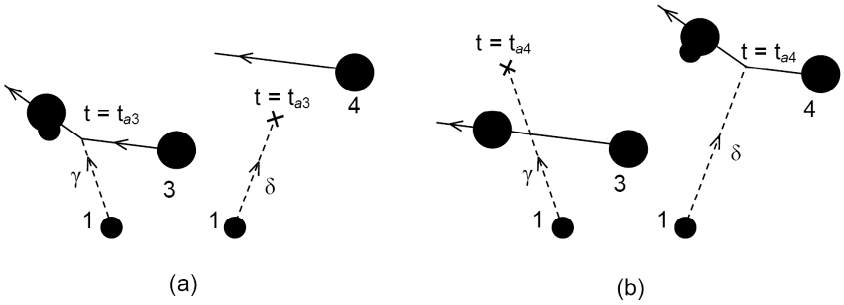

Fig. 4. A quantum-measurement-like event of collision of a small solid ball (having two ambiguous trajectories) with a system consisting of two large balls in spacetime with a wormhole. Two versions of the absorption event are possible. (a) The small ball 1 (small full circle) moves along ambiguous trajectories γ and δ, collides with the large ball 3 (large full circle) and is absorbed by it. Due to the absorption, the small ball 1 looses both its individuality (it becomes a part of the large ball 3) and thereby capability of moving through the closed timelike curve in the past. (b) The small ball 1 (small full circle) moves along ambiguous trajectories γ and δ, collides with the large ball 4 (large full circle) and is absorbed by it. Due to the absorption, the small ball 1 looses both its individuality (it becomes a part of the large ball 4) and thereby capability of moving through the closed timelike curve in the past.

the trajectories γ and δ taken into account, both the absorptions presented in Figs. 4a and 4b can come into play. (Hereinafter, the absorption events shown in Figs. 4a and 4b will be denoted as absorption A and absorption B, respectively.) However, the large balls can have only unambiguous trajectories. Thus, we have the two statements/conclusions: (i) both the absorption events A and B can come into play; (ii) the large balls can have only unambiguous trajectories. These statements are not in conflict, if only one of the absorption events (Figs. 4a and 4b) occurs. That is, the absorption of a small solid ball having ambiguous trajectories by a large solid ball having a classical unambiguous trajectory results in transformation of the ambiguous trajectories into one unambiguous trajectory of the small ball (Fig. 4). In doing so, selection of either the absorption A or the absorption B as a real event is not a definite. The selection can not be prescribed in advance due to ambiguity of the trajectories γ and δ of the small ball taking part in the absorption. This situation roughly resembles a quantum-mechanical measurement at which a macroscopic device initially (before the measurement event) has two classically distinguished states, and the selection of one of these states in the measurement event can not be prescribed, because it is made by "uncertain interaction" of the macroscopic device with a quantum microparticle.

To summarize, the small ball 1 moves along ambiguous trajectories γ and δ, collides with either the large ball 3 or the large ball 4, and is absorbed by the ball 3 or 4, respectively (Fig. 4). Due to the absorption, the small ball 1 looses both its individuality (it becomes a part of the large ball 3 or 4) and thereby capability of moving through the wormhole. In other words, the absorption changes the past in the sense that the absorbed ball 1 can not move through the wormhole in the past, and thereby the ball 1 does not experience the Polchinskii' paradox. In this context, the absorption of the small ball 1 by one of the large balls (Fig. 4) can be treated as a rough analog of a quantum-mechanical measurement of a spatial coordinate of a microparticle (being a rough analog of the small ball 1) due to its interaction with a macroscopic device (being a rough analog of the system consisting of the large balls 3 and 4).

The suggested scenario for evolutions of small and large balls corresponds to the new principle of self-consistency, which admits partially inconsistent evolutions of small solid balls on CTCs in spacetimes with wormholes. According to the new principle, small solid balls on CTCs can have self-inconsistent evolutions with ambiguous trajectories. However, these self-inconsistent evolutions of small solid balls change their past in the only way keeping evolutions of large solid balls unambiguous.

Note that, though large balls can not move through wormholes, their behavior is influenced by wormholes. It is because large balls interact with small balls whose behaviors are dramatically affected by wormholes. The quantum-measurement-like event – absorption of a small ball by a large ball (Fig. 4) – makes connection between unambiguous classical world of large balls and ambiguous trajectories of small solid balls involved in the Polchinskii' paradox.

4. CONCLUDING REMARKS

Thus, quantumlike behavior is exhibited by systems of small and large solid balls in spacetimes with wormholes. The key geometric difference between small and large balls is in typical values of their radii: a typical radius r of a small solid ball is lower than the wormhole mouth radius R which, in its turn, is lower than a typical radius R_L of a large solid ball ($r < R < R_L$). As a corollary, large balls can not move through wormholes, while small balls are capable of moving through wormholes. Due to traverse of a small solid ball through a wormhole, evolution of the small ball can be self-inconsistent in the sense that it violates conventional causality and has two ambiguous trajectories. In doing so, one can not unambiguously identify spatial coordinates of the classical small ball having the two ambiguous trajectories (Fig. 2). The considered uncertainty in spatial coordinates of a classical solid ball in a spacetime with a wormhole resembles quantum-mechanical uncertainty in spatial coordinates of quantum microparticles (such as electrons moving through two slits of a screen). In the context discussed, self-inconsistent evolution of a classical small ball at its ambiguous trajectories can be treated as a rough analog of unitary evolution of a quantum microparticle in quantum mechanics.

In contrast, evolutions of large balls in a spacetime with wormholes are always unambiguous. Thus, small classical balls can have self-inconsistent evolutions with ambiguous trajectories, while large balls always have unambiguous evolutions in a spacetime with wormholes. In order to describe cooperative evolution of small and large classical balls in one spacetime with wormholes, the author suggested the new principle of self-consistency. According to the new principle, evolutions of small solid balls on CTCs (related to wormholes) can be self-inconsistent, but these evolutions change the past of small solid balls in the way keeping evolutions of large solid balls unambiguous.

Note that the new principle generalizes and modifies the conventional principle of self-consistency. The conventional principle [16] describes the situation where all classical balls are capable of moving through wormholes. The conventional principle [16] admits only self-consistent evolutions resulting in unambiguous trajectories of classical balls. All self-inconsistent evolutions (resulting in ambiguous trajectories) of classical balls are treated as impossible [16]. The new principle deals with the situation where small balls can traverse through wormholes, while large balls can not. The new principle admits self-inconsistent evolutions of small balls, if they keep evolutions of large balls unambiguous.

With the new principle of self-consistency, absorption of a small ball (having a self-inconsistent evolution) by a large ball in a spacetime with wormholes transforms the self-inconsistent evolution of the small ball into one of the unambiguous evolutions of two large balls (Fig. 4). In doing so, since the small ball has two ambiguous trajectories, only one of two different absorption events A and B (see Figs. 4a and 4b, respectively) can come into play in the real world. Selection of one of the absorptions A and B as the real event is not definite; it is probabilistic. The selection can not be unambiguously prescribed in advance. The selection of the absorption A is specified by some probability, as with the absorption B. This situation roughly resembles a quantum-mechanical measurement at which a macroscopic device initially (before the measurement event) has two classically distinguished states, and the selection of one of these states in the measurement event can not be unambiguously prescribed in advance, because it is made by “uncertain interaction” of the macroscopic device with a quantum microparticle.

The rough similarity in question is of particular interest in the situation where the wormhole mouth radius R is in the microscopic range typical for real quantum-mechanical microparticles. In this situation, there is the microscopic “structural” scale R of the spacetime with the wormhole, and this scale naturally differentiates behaviors of large (macroscopic) and small (microscopic) classical objects. In the situation under discussion, one may speculate on a new interpretation of quantum mechanics in terms of evolutions of small and large classical balls in a spacetime with a wormhole having microscopic mouths.

REFERENCES

[1] C. Cohen-Tannoudji, *Quantum Mechanics* (Wiley Interscience, New York, 2006).

[2] N. Zetilli, *Quantum Mechanics: Concepts and Applications* (John Wiley & Sons, Chichester, 2009).

[3] C.R. Krenn, D. Roundy, M.L. Cohen, D.C. Chrzan and J.W. Morris, Jr. // *Phys. Rev. B* **65** (2002) 134111.

[4] J.W. Morris, Jr., D.M. Clatterbuck, C.R. Krenn, W. Luo and M.L. Cohen // *Mater. Sci. Forum* **426-432** (2003) 4429

[5] J. Hartford, B. von Sydow, G. Wasnstrom and B.I. Lundqvist // *Phys. Rev. B* **58** (1998) 2487.

[6] G. Lu, N. Kioussis, V.V. Bulatov and E. Kaxiras // *Phys. Rev. B* **62** (2000) 3099

[7] J.A. Yan, C.-Y. Wang and S.-Y. Wang // *Phys. Rev. B* **70** (2004) 174105.

[8] S.G. Srivansan, X.Z. Liao, M.I. Baskes, R.J. McCabe and Y.T. Zhu // *Phys. Rev. Lett.* **94** (2005) 125502.

[9] M.Yu. Gutkin and I.A. Ovid'ko // *Acta Mater.* **56** (2008) 1642.

[10] S.V. Bobylev and I.A. Ovid'ko // *Phys. Rev. Lett*. **103** (2009) 135501; *Phys. Rev. B* **83** (2011) 054111.

[11] R. Penrose*, Shadows of the Mind: A Search for the Missing Science of Consciousness* (Oxford University Press, Oxford, 1994)

[12] *Time in Quantum Mechanics*, Lecture Notes in Physics, Vol. 734, edited by G. Muga, R.S. Mayato and I. Egusquiza (Springer, Berlin, 2008)

[13] M.S. Morris, K.S. Thorne and U. Yurtsever // *Phys. Rev. Lett*. **61** (1988) 1446

[14] M.S. Morris and K.S. Thorne // *Am. J. Phys*. **56** (1988) 395.

[15] V.P. Frolov and I.D. Novikov // *Phys. Rev. D* **42** (1990) 1057.

[16] J. Friedman, M.S. Morris, I.D. Novikov, F. Echeverria, G. Klinkhammer, K.S. Thorne and U. Yurtsever // *Phys. Rev. D* **42** (1990) 1915.

[17] P.G. Grove // *Found. Phys*. **32** (2002) 567.

[18] A. Everett // *Phys. Rev. D* **69** (2004) 124023.

[19] F. Echeverria, G. Klinkhammer and K.S. Thorne // *Phys. Rev. D* **44** (1991) 1077.

[20] I.D. Novikov // *Phys. Rev. D* **45** (1992) 1989.

[21] D. Deutsch // *Phys. Rev. D* **44** (1991) 3197.

[22] L.H. Ford and T.A. Roman // *Phys. Rev. D* **53** (1996) 5496.

[23] M. Vesser, S. Kar and N. Dadhich // *Phys. Rev. Lett.* **90** (2003) 201102.