

Discontinuous Spacetime with Vacuum Holes as Explanation for Gravitation, Quantum Mechanics and Teleportation

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Abstract—Hole Vacuum theory is based on discontinuous spacetime that contains vacuum holes. Vacuum holes can explain gravitation, some laws of quantum mechanics and allow teleportation of matter. All massive bodies emit a flux of holes which curve the spacetime; if we increase the concentration of holes, it leads to length contraction and time dilation because the holes do not have the properties of extension and duration. In the limited case when space consists of holes only, the distance between every two points is equal to zero and time stops - outside of the Universe, the extension and duration properties do not exist. For this reason, the vacuum hole is the only particle in physics capable of describing gravitation using its own properties only. All microscopic particles must 'jump' continually and 'vibrate' due to the appearance of holes (impassable microscopic 'walls' in space), and it is the cause of the quantum behavior. Vacuum holes can explain the entanglement, non-locality, wave properties of matter, tunneling, uncertainty principle and so on. Particles do not have trajectories because spacetime is discontinuous and has impassable microscopic 'walls' due to the simple mechanical motion is impossible at small scale distances; it is impossible to 'trace' a straight line in the discontinuous spacetime because it contains the impassable holes. Spacetime 'boils' continually due to the appearance of the vacuum holes. For teleportation to be possible, we must send a body outside of the Universe by enveloping it with a closed surface consisting of vacuum holes. Since a material body cannot exist outside of the Universe, it reappears instantaneously in a random point of the Universe. Since a body disappears in one volume and reappears in another random volume without traversing the physical space between them, such a transportation method can be called teleportation (or Hole Teleportation). It is shown that Hole Teleportation does not violate causality and special relativity due to its random nature and other properties. Although Hole Teleportation has a random nature, it can be used for colonization of extrasolar planets by the help of the method called 'random jumps': after a large number of random teleportation jumps, there is a probability that the spaceship may appear near a habitable planet. We can create vacuum holes experimentally using the method proposed by Descartes: we must remove a body from the vessel without permitting another body to occupy this volume.

Keywords—Border of the universe, causality violation, perfect isolation, quantum jumps.

I. INTRODUCTION

THE present theory is based on an hypothesis that spacetime is discontinuous according to Dedekind's and Clifford's definitions of continuity. According to Clifford, "continuity" is to be understood as the assumption that there are no physical, non-material gaps in the fabric of space [1].

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Dedekind has the same position [2], it is not necessary for space to be continuous. Dedekind said that space can be discontinuous with gaps of non-existence. In short, according to Dedekind's criterion, continuity is the absence of gaps. Thus, both fathers of the concept of continuity, Dedekind and Clifford, agree that continuity is the absence of the gaps of non-existence. Moreover, Dedekind admits that such discontinuous space-time with gaps may really exist and he created a precise definition of continuity that can serve as the basis for valid deductions. Thus, we propose a hypothesis that spacetime is discontinuous according to Dedekind's axiom of continuity and contains gaps of non-existence (vacuum holes). Such discontinuous spacetime with holes (or gaps of non-existence) deserves our attention because it can explain the gravitation, inertia, teleportation and quantum mechanics in the simplest possible way. Ockham's razor encourages us to select the simpler of two models, so long as both do an equivalently good job of matching the data. Imagine, one and the same process can explain gravitation, inertia, teleportation and quantum mechanics. According to Ockham's razor, we must choose the discontinuous spacetime called "Hole Vacuum" because it is the simplest explanation that can explain many fundamental phenomena.

Consider that we have a source of vacuum holes, for example a material body [3], [4]. Imagine that we collect all holes emitted by a material point-like source during a time unit (for example one second). In this case we will have a sphere with volume V and the radius r . Suppose that we have two bodies which emits during a second the total volume of holes V_1 and V_2 ; the radius of these spheres are r_1 and r_2 respectively; the distance between the sources is R [3], [4]. In this case the magnitude of the force F between these sources of holes will be:

$$F = G_v r_1^3 r_2^3 / R^2; R \gg r \quad (1)$$

where G_v is a gravitational constant equal to $G_v = 1.6653 \times 10^9$ N/m^4 (or $kg / m^3 s^2$), R is the distance between two point-like sources of holes (or between the centers of the mass of material bodies). However, the explanation of gravitation and inertia by vacuum holes has been published already in peer reviewed journals [3], [4]; therefore below, we describe teleportation and quantum mechanics only; there is no reason to repeat the published already ideas about gravitation in a hole vacuum.

II. DISCONTINUOUS SPACETIME AND QUANTUM MECHANICS

A. How to Create Holes (Gaps) in Spacetime

According to above definition, a gap of non-existence (called in this theory a "vacuum hole") is an absolute vacuum devoid of matter and spacetime. Therefore, to create a vacuum hole, we must remove from a vessel all material things, including spacetime. A similar experiment was described by Descartes, who wrote that if God removed from a vessel all the body (matter) contained in it without permitting another body to occupy its place then the sides of the vessel would come into proximity with each other [5]. Thus the main positions of Descartes theory are:

1. If we remove from a vessel all the matter contained in it, without permitting another material body to occupy its place, then, the sides of the vessel would come into proximity with each other [5].
2. It is absolutely contradictory that nothing (absolute vacuum) can possess extension [4], [5]. It means that the absolute Descartes vacuum does not have the property of extension (and time).

In fact, it is the description of the main properties of vacuum holes: after appearance, a hole collapses as soon as possible; also, a hole in spacetime does not possess the properties of extension and duration (time);

The lifetime of a vacuum hole is $T_h > 0$, because the surrounding particles cannot fill this void instantaneously due to the existence of the universal speed limit c . In other words, since the speed of the surrounding particles is limited by the speed of light c , therefore, they cannot fill the void instantaneously due to the hole's lifetime, $T_h > 0$. Thus, the theory suggests two methods of creation of absolute vacuum:

1. Holes in spacetime appear if we quickly remove from a vessel all the body contained in it, without permitting another material body to occupy its place;
2. We can obtain large holes by expanding the small holes.

There are some physical processes which are able to produce the absolute void or Descartes' vacuum, where the material particles disappear instantaneously, for example the annihilation of particle-antiparticle, decays, and inelastic scattering. Imagine, for example, a particle moving at near-light speed that strikes together with another particle. In that case, a particle is *thrown out instantaneously at nearly light speed from the occupied volume*, as a Descartes vacuum appears for a short time. The Descartes' void appears also at the annihilation of particle-antiparticle pairs and decays because there initial particles disappear (probably instantaneously). We can verify this hypothesis experimentally by the help of two high precision atomic clocks: Descartes' void is always accompanied by the time retardation effects. Consequently, we will observe the time retardation effects if the described above processes, generate holes.

B. The Border of the Universe

We can define the Universe as a collection of all material things that exist, including matter and spacetime. In this case, material things outside of the Universe do not exist; it is the

absolute nothing in an absolute sense [6]. It is the absolute void which does not have the properties of extension and duration (time); let us call it a vacuum hole. The imaginary line between material things and nothingness is called the "edge of the Universe".

The edge of the Universe is an impenetrable, non-material barrier through which matter cannot pass. These virtual, microscopic, ubiquitous "walls" in space prevent the classical motion of particles at small scales and cause them to have quantum behavior. In other words, the edge of the Universe [6], [7] behaves as a barrier of some kind that forbids the classical motion at small scales and impedes our motion because the holes are the sources of inertia and gravitation.

Imagine that spacetime is a mixture of elementary volumes dV and holes. Then imagine the motion of a material particle P through such discontinuous spacetime with holes.

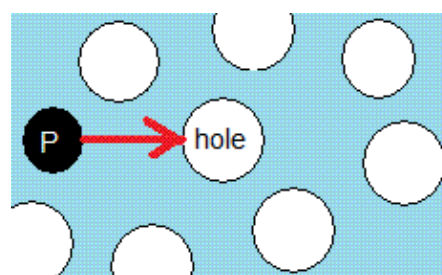


Fig. 1 The discontinuous spacetime with holes does not allow straight mechanical motion for particles

You see, the normal straight mechanical motion of the particle P is not possible because space is discontinuous and contains the impassable "walls" in space (holes). Therefore, a particle is not able to travel mechanically and in a straight line because one cannot move through the impassable holes. The further mechanical motion is impossible because a hole is a total absence of space (the property of length) and time.

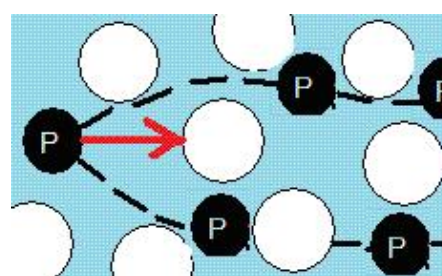


Fig. 2 Particles can move in discontinuous spacetime with the help of "jumps" only

There is a single way to move through such discontinuous space with holes: a particle must "jump" continually in order to overcome the vacuum holes. In other words, this particle must be "smeared out" over some region of space and move through many trajectories simultaneously as a cloud. Such a concept is very close to the notion of wave properties of the microscopic particles. It is shown below that such "jumps" are the cause of quantum behavior. All particles must jump continually in order to overcome the impassable obstacles,

such as vacuum holes. These holes also explain why quantum particles do not have trajectories, because it is impossible to trace a line in such space with holes, since space contains the impassable walls. Microscopic particles cannot move mechanically and straightforward, and therefore, they do not have trajectories.

The macroscopic bodies are capable to move mechanically because these holes have the microscopic sizes. It has been shown [6], [7] that if we increase the size of holes, then the macroscopic bodies will exhibit the quantum behavior.

Imagine the macroscopic body in spacetime, for example a metal sphere with mass 10 kg and speed 1 m/s. It has the classical behavior because vacuum holes are very small. Now imagine that we increase the sizes of the holes by N times to 0.5 meters. If near a metal sphere a hole appears, one fills a hole by itself and moves with immense acceleration to the center of the hole. If vacuum holes arise chaotically in the different places, then this sphere will move chaotically as a Brownian particle. Further, imagine that a vacuum hole appears just in the volume occupied by a sphere. In this case, a sphere will be ejected (thrown) by a hole from its volume. Further, if the “landing area” is occupied by another hole, then this sphere will exist in several places simultaneously in the form of a “cloud”. Notice, now we are not able to see this sphere because one is “smeared out” over a large region of space, and therefore, one does not have a definite position. Since vacuum holes appear continually, it means that our sphere also will exist in the form of the cloud continually. It has been shown already [6], [7] that the existence of a macroscopic object in the form of a cloud (as described above) displays the wave properties like diffraction and interference. Thus, vacuum holes are capable to delocalize particles, and therefore, it can explain the nature of de Broglie wavelength.

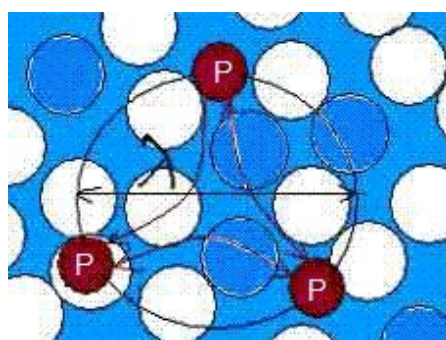


Fig. 3 Holes are capable to delocalize particles

Let a hole appear near particle P. Now a particle must fill the void, consequently, a force appears that tries to move this particle: therefore, the momentum Δp of a particle changes. In the next moment of time a particle fills the hole – it is a change of position Δx . Thus, because of the appearance of holes, the position and momentum of all particles fluctuates continually. Since holes are capable of influencing other particles, this action must be quantized. So, let us quantize the action of a vacuum hole: the action of a vacuum hole is equal to the Plank constant. In this case, we have $\Delta x \Delta p \geq \hbar N/2$,

where N is the number of elementary holes acting together on the object as a whole, in one direction. Let us consider another case when a hole appears just in the volume occupied by a particle in space (particle P on the left corner of Fig. 3). It means that a particle will be thrown out of its volume by a hole. Taking into account that the action of all elementary holes is constant (quantized) and equal to Plank constant, consequently, a hole will eject, for example, light particles on long distances and heavy particles on small distances; thus, we have a relation $\lambda = \hbar N/p$; or $\lambda = \hbar N/mv$ for a non-relativistic case, where N – is the number of holes acting together (in one direction) on a given object as a whole. It means that if we increase the number of holes acting together near an object M, then we increase the quantum (wave) properties of this object M. Further, if a particle is ejected by a hole, one should appear in another (landing) place. Imagine that the landing place also is occupied by another hole; in such case a particle must exist in several places, simultaneously, as a cloud (Fig. 3). You see that due to existence of the vacuum holes, quantum particles must exist in the form of a cloud, existing in two or more places simultaneously. Thus, according to Hole Vacuum theory, all microscopic particles are “smeared out” over some region of space by holes: de Broglie matter waves have a direct physical interpretation as a particle “smeared out” – one exists in many places simultaneously in the form of a “cloud”.

C. The Hole Nature of Quantum Nonlocality

Quantum mechanics violates a principle formulated by A. Einstein, known as the principle of locality or local realism, which states that changes performed on one physical system, should have no immediate effect on another spatially separated physical system. We have to explain why Quantum mechanics is unavoidably nonlocal, and why particle behavior can correlate across vast distances.

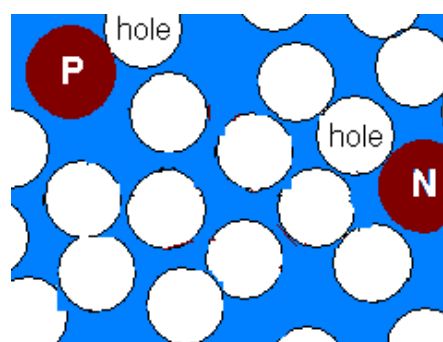


Fig. 4 Quantum Non-locality: all particles are close neighbors due to existence of holes

It is easy to show that Quantum Nonlocality is a “built in” effect in the present Hole Vacuum Theory because vacuum holes exist everywhere through the Universe; there are holes (or a border of universe) near every particle. Therefore, every particle is “close” to every other distant particle from the Universe through a vacuum hole. In other words, the distance between every two distant particles is zero through a hole; therefore, every entangled “particle is in communication with

its distant partner through a hole. Every particle in every star and galaxy may "know" about the existence of every other particle through a hole.

Imagine that a particle P is placed in Andromeda galaxy and particle N is near you. First of all, note that: 1) holes exist in every point of Universe, and particularly near P and N; 2) the extension property of a hole tends to zero. Consequently, these particles are close "neighbors" through a hole, and therefore, spatially separated quantum systems can instantaneously influence one another. In fact, every particle in the Universe may "feel" other distant particles through a hole; it explains long-distance nonlocal quantum correlations. There is a more detailed explanation below: spatially separated particles can influence one another using instantaneous hole teleportation or quantum jumps. In fact, holes act as non-traversable "shortcuts" from one region of spacetime to another: the motion of matter and fundamental fields is forbidden through a hole, because it is a region without the properties of extension and time. Matter and fundamental fields cannot move outside of the real Universe. In other words, holes are some kind of non-traversable "shortcuts", but not wormholes. Therefore, changes performed on one physical system should have no immediate effect on another spatially separated system. The quantum jumps like Hole Teleportation are allowed only through the holes which have absolute isolation. It is shown below that hole teleportation is a fundamental property of matter and all quantum phenomena like wave-particle duality, quantum correlations etc, are based on these instantaneous quantum jumps. For example, a particle from this computer is placed "close" to other particles from the Andromeda galaxy through a hole, because the same holes exist both near you and near every other objects of Universe. On the other side, a hole is a perfect isolator; therefore, material objects are not able to interact through a hole using fundamental interactions. It preserves the principle of locality and explains why objects in our daily lives behave "normally": physical processes occurring at one place should have no immediate effect on the elements of reality at another location. The quantum jumps like Hole Teleportation are allowed only through absolutely isolated "shortcuts" as holes. Such nonlocal quantum jumps cause quantum correlations, entanglement, and wave-particle duality. It will be shown below that all quantum mechanics is based on vacuum holes and quantum jumps like Hole teleportation. The world is nonlocal because of the existence of holes in spacetime.

D.No Rest in the Micro-World

There is no rest for microscopic particles due to the continuous appearance of holes. For this reason, all physical systems and objects, even at absolute zero temperature, vibrate and have a zero-point energy that is always greater than zero. For example, since vacuum holes appear near the atoms and force them to vibrate, the Helium-4 remains liquid at atmospheric pressure, in spite of the fact that the temperature is close to absolute zero [6]. According to the Hole Theory, the large holes decay into particle-antiparticle pairs, which annihilate and disappear. Thus, the appearance of the vacuum

holes cause the electron to execute rapid oscillatory motions; for this reason the electron is "smeared out" and exists in the form of a cloud. Vacuum holes cause vibration of the entire Universe, including spacetime and all material particles.

Although, vacuum holes can explain also other quantum laws, we cannot describe it here due to the limited space of this paper. Readers can find a detailed description of these ideas in [6], [7].

III. HOLE TELEPORTATION

A. Classical Description of Hole Teleportation

Hole Teleportation exploits the geometrical properties of the Universe as a whole in order to reduce the (distance) path between the start and destination points. In other words, Hole Teleportation is faster than light because it shortens the path between the start and destination points, but not due to exceeding the speed of light.

What is outside of the Universe? Mathematical theories like topology do not help us here: the examples of unbounded spaces and other mathematical objects that have no boundary are not applicable to the Universe as a whole, because spacetime is not continuous. We can define the Universe as a collection of all material things that exist, including matter and spacetime. In this case, outside of the edge of the Universe is nothing in an absolute sense – no matter, no spacetime, no fundamental fields [6], [8]. It is the absolute void which does not have the properties of extension (length) and duration (time); let us call it a vacuum hole. The imaginary line between material things and the nothingness is called the border (edge) of the Universe. However, the border of the Universe cannot exist in a single place or point, because the principles of cosmological would then be violated. It is the principle according to which there cannot be places or directions privileged towards another place or direction of the Universe. For this reason, the edge of the Universe must pass through every point of spacetime [8]; it means that the microscopic virtual holes must appear and disappear continually in every point of the Universe.

This space with holes or "Hole Vacuum" has some important properties that allow teleportation of material bodies:

1. The experimenters have access to the edge of the Universe, since virtual holes exist at every point of the Universe.
2. The extension and duration does not exist as the properties outside of the Universe. Consequently, material objects cannot exist outside of the Universe (inside of hole sphere) – since a hole cannot contain matter by definition. What would happen if we sent a material body outside of the Universe? For this purpose, we must surround (envelop) a body with a closed surface consisting of vacuum holes for a short time dT [8]. In such a way we create around the body the macroscopic border of the Universe. Then we ask, where was the body during that time dT that it was surrounded by holes? As far as a material body cannot really exist outside of the

Universe, therefore one must return back instantaneously to the real Universe. Since inside of the hole sphere the matter cannot exist therefore a body had been existing at another point in the Universe already. Taking into account that holes exist at every point of the Universe, it follows that the body may appear in a random place. Since a body disappears in one place and reappears in another place without traversing the physical space between them, therefore such transfer satisfies the definition of teleportation.

B. Teleportation by Curving the Spacetime

Instead of increasing the speed of motion, the better way is to reduce the path between the start and destination points (or volumes). Another explanation of Hole Teleportation is based on General Relativity. According to Einstein's theory of General Relativity, energy curves spacetime. So a very strong gravitation may curve the spacetime until the two distant points coincide, thereby forming a shortcut between them. It is similar to folding spacetime like a piece of paper so that two distant points coincide. For teleportation to be possible, it would be necessary to create the geometry similar to that of a black hole, where the start point coincides with the endpoint.

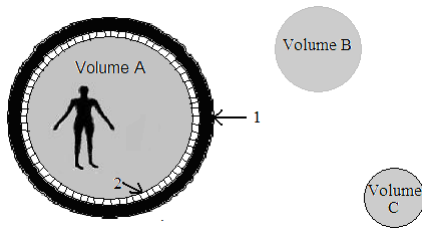


Fig. 5. Stationary teleportation station with internal hole production, where 1 - is the equipment to produce holes; 2 - vacuum holes

It was shown already that, in fact, a vacuum hole represents gravitation [3], [4]. In other words, we can simply think of a vacuum hole as another name for gravitation. For this reason, if we create a closed hole surface, actually, we create the strongest gravitational field in the universe, the same as in a black hole. Another possible explanation for Hole Teleportation is that the strongest gravitational field in the Universe curves spacetime in such a way that the distant volumes A, B, C... coincide. Since the start volume A and destination volumes B, C... coincide, it follows that at teleportation the body exists simultaneously in multiple locations A, B, C... If we destroy the hole surface, we destroy in this way, the channel that connect these points, and therefore, a body remains in some random volume – therefore such a transfer satisfies the definition of teleportation.

Although HT uses a short “passage” in spacetime that directly connects two distant regions of the Universe, it was shown that HT is not a traversable wormhole [9]. We suspect that inside the closed hole surface is a hyperbolic geometry called the Poincare ball model.

C. Quantum Description of Hole Teleportation

There are the following signs that Hole Teleportation may have the quantum nature [6], [8]:

- 1) By definition, Hole Teleportation envelopes an object with absolutely an impenetrable hole surface which cuts all causal and physical interactions with the environment. In other words, the essence of HT is the creation of absolute isolation from the environment. However, quantum mechanics tell us that all quantum behaviors exist due to the fact of isolation. Decoherence theory states that all isolated quantum systems may always maintain their quantum nature (independent of their size or mass), but that it becomes increasingly difficult to guarantee this isolation for large (macroscopic) objects. For this reason, we suspect that Hole Teleportation is a quantum mechanical phenomenon.
- 2) As described above, the process of Hole Teleportation requires that the object must exist simultaneously in two or more places. It reminds us of the behavior of an electron in the double-slit experiment, which exists simultaneously in two places. For this reason, we may suppose that both phenomena have the same physical origin (quantum nature).

How to explain HT using the laws of quantum mechanics? We have the following hypothesis: For teleportation to be possible, we must force a body to disappear in the start place A and reappear in another place B. The chain of reasoning producing teleportation runs as follows: According to Bohr's Complementarity principle, we cannot observe the material object as a “particle” and “wave” simultaneously in the one and same experiment. Consequently, if we could somehow transform the particle-like body into a wave then it must disappear for observers. In other words, at teleportation the body is “smeared out” over a large region of space and therefore cannot be observed.

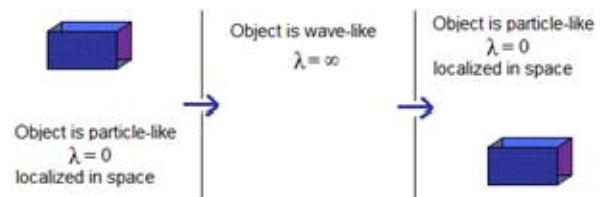


Fig. 6 The transformation particle-wave-particle looks as teleportation

Fig. 6 shows the transformation "particle-wave-particle". First, we observe the body as a particle-like object in the “start” position. Then we convert it into a wave with the wavelength $L \rightarrow \infty$ (the body was smeared out over a large region of space). Next, this wave collapses and we see again the body as a particle-like object. The wave collapse may be caused either by the destruction of the closed hole surface or by the detection, because it is a localized particle-like object. Such transformation may be caused by the destruction of the closed hole surface. This chain of transformations “particle-wave-particle” looks as teleportation because the body

disappears in one place A and reappears in another place B without traversing the physical space between them. We suppose that at teleportation the body's de Broglie wavelength tends to infinity and therefore it is "smeared out" over a large region of the Universe.

The teleportation device (teleporter) can be with internal and external production of holes. First is called a stationary teleporter and the second is a mobile teleporter. Accordingly, the stationary station has a spherical room where a material body can be introduced for teleportation. The other option would be for body to produce a hole's surface around itself, therefore this station can repeatedly teleport itself to a random points of the Universe. In this case, the equipment to produce holes and the source of energy is placed inside of the teleporter.

D. The properties of Hole Teleportation

1. HT has the probabilistic nature; after teleportation a body appears in a random place (volume) of the Universe.
2. A body in uniform rectilinear motion can pass an infinite distance without any energy expenses; consequently, the energy expenditure for Hole Teleportation at any distances will always be equal to zero. The only expenditure of energy in HT is the energy that will be needed to create holes in spacetime.
3. The conservation laws require that at teleportation the speed and the direction of body's motion (momentum) must remain unchanged. In other words, after teleportation the body may appear on one of its possible trajectories.
4. At teleportation, a body would reappear in a place that did not violate the energy conservation laws. The potential of the force field must be the same at the both points, otherwise it violates the conservation laws and we would have a "perpetual motion machine" that would be having energy arising from nothing. For example, imagine that at teleportation a body disappears from the surface of the Earth and reappears at altitude $h = 100$ m above the Earth's surface. Further, this body falls and its gravitational potential energy mgh is converted to kinetic energy $mv^2/2$. After the body hits the ground, its kinetic energy is converted into heat. Then we repeat the entire process: we teleport this body to any altitude h above ground level, whereupon it falls again. We see that every cycle of teleportation leads to the release of energy. Since Hole Teleportation does not require energy for transportation of a body from point A to B, it means that we have the "perpetual motion machine" that produces work without the input of energy. To prevent such a violation of conservation laws, at teleportation a body could only appear in such a place where these processes were not possible.
5. The teleportation between moving frames is forbidden by the conservation laws and relativistic effects. The explanation is that, by definition, at teleportation the virtual hole surfaces (spheres) appear in the start and destination places. It is self-evident that all these virtual

spheres must be identical and congruent. It means that you can lay one on top of the other and they match exactly. However, if two frames are in motion, then the hole spheres in the start and destination places will have different sizes and shapes due to the length contraction effects; since these hole spheres cannot match, it follows therefore that teleportation between moving frames is not possible.

Another restriction comes from the time dilation effect. The HT is instantaneous and simultaneous by definition; it means that teleportation is possible only between such frames where teleportation can remain simultaneous and instantaneous. However, if two frames are in motion then teleportation cannot be simultaneous and instantaneous because time runs at different rates, and therefore, we cannot synchronize the clocks using the Einstein's clock synchronization procedure. For this reason, hole teleportation is possible only between frames of reference that are at rest with respect to one another; in this case, time flows at the same rates in both frames, and therefore, teleportation can be simultaneous and instantaneous.

6. The events "disappearance" of body (send) and "reappearance" of body (receive) are simultaneous in Hole Teleportation. To illustrate it, let us imagine the process of Hole Teleportation. If we create the closed hole surface in the point A, we curve the spacetime in such a way that some distant points A, B, C... coincide. Therefore, this hole sphere (and body) exist in many places simultaneously. Suppose that all clocks in these points A, B, C... are synchronized (they are at rest in respect to each other). At teleportation all observers in points A, B, C... cannot see the body because it is hidden by the impenetrable hole surface, therefore, they do not know where the body is. In the next moment all the hole spheres decay simultaneously, and therefore, observer A notices the disappearance of the body in point A, and some observer C simultaneously sees the appearance of the body in the point C. For this reason, both observers A and C agree that the events "disappearance" and "appearance" of body at teleportation are simultaneous, according to their synchronized clocks. Consequently, the teleportation events "disappear" (send) and "appear" (receive) cannot be interpreted as "cause" and "effect" in the classical sense.

IV. SUPERLUMINAL PARADOXES

In this section, we are going to show that Hole Teleportation is a paradox-free theory due to its special properties. To prove this, we will consider below some examples of superluminal paradoxes. If a superluminal theory generates paradoxes, it is a sure sign that it is wrong and incorrect. The wrong superluminal theories can generate various paradoxes which can violate, for example, the principle of causality and the principle of locality (cosmological locality). In fact, the cosmological locality is a variation of the principle of locality: a region of the universe is only directly influenced by its immediate surroundings. An example of superluminal paradox that violates the principle of

locality (and cosmological locality) is the "Open Tunnel paradox" [9].

Let us begin with violation of causality by superluminal travel methods. It is useful to distinguish between "passive" causality violation (the possibility to observe a cause-effect inversion in a suitable moving system) and "active" causality violation (the possibility that an effect triggers the disabling of its own cause) [10].

A. Tolman's Experiment, Two Way Example

For a start, let us consider first the original Tolman's paradox [11], [12], which is usually considered as an example of strong violation of causality. The numerical two-way communication example is a demonstration of active violation of causality, because the effect can influence the cause.

Since Tolman's paradox is well known, we only quote a few important propositions; a detailed description of the Tolman's paradox (numerical two-way communication example) can be found in [12].

Imagine that two observers, for example Alice and Bob, who are aboard rockets moving inertially with a relative speed v , for example $v=0.8c$. Each observer also has a tachyon transmitter aboard their rocket, which sends out signals that move at $v=2.4c$ in the rocket's own frame [12]. After that, 300 days have elapsed since Alice passed next to Bob, she uses the tachyon transmitter to send a message to Bob.

Tolman used a tachyon-like superluminal carrier of information in his original thought experiment [11]. There is no evidence that such superluminal carrier [11] really exists. The main error in Tolman's paradox is very simple: Since he introduces a superluminal tachyon-like carrier of information with non-physical properties in his experiment, therefore he obtains the non-physical results as violation of causality. In all thought experiments, we must use only correct particles (or carriers of information) obeying the laws of nature. Even if a theorist introduces a new carrier of information, or a new particle, it must be consistent with the laws of nature – otherwise the imaginary experiment will be wrong by definition. It is self-evident that a thought experiment becomes physically meaningless if it uses the magic particles that violate the laws of nature.

What is the difference between fairy tales and scientific experiments? For example, the experimenters may use the vampires or goblins in the role of carriers of information. However, we do not use the magic heroes in the scientific experiments because they violate the laws of nature. As a matter of fact, the tachyons also violate the laws of nature. In fact, the only difference between magic vampires and tachyons is that the word "tachyon" sounds more "scientific" than "vampire". A thought experiment that uses the magic particles goes beyond the rational and enters into the mystery. Therefore, Tolman's paradox is neither correct nor scientific because it uses the non-existing particles that violate the laws of nature. It is generally known that the tachyon is a hypothetical particle invented by theorists, and therefore, this concept may be wrong. In particular, the properties of tachyon were not deduced logically from any real phenomena, and

therefore, can be considered as a phantom of imagination. The following properties of tachyons are wrong: a) The superluminal signaling between moving frames of references must be forbidden because it leads to violation of causality. For example, in Hole Teleportation theory, this ability is prevented by its random nature and conservation laws. It looks like the theorists endowed the tachyons with the signaling ability only because it is very comfortable for their thought experiments. b) The notion of tachyon's speed is the next doubtful property. It is very strange that the tachyon can have some finite speed, for example $2.4c$. In contrast, HT can be instantaneous only, and therefore, the events "send" and "receive" are simultaneous. Although all tachyon's properties are doubtful, a full treatment of the tachyon concept is beyond the scope of this paper.

We conclude that the question about superluminal transportation (Tolman's paradox) is actually not solved correctly. What is the correct answer anyway? Let us think critically: If superluminal phenomena exist, then they do not violate the laws of nature (including causality). Consequently, in order to prove that the superluminal transportation of energy and information is possible, it is enough to show at least one example of superluminal transportation that does not violate the laws of nature; such superluminal transport obeying the laws of nature is shown below, it is Hole Teleportation. Thus, the original Tolman's paradox is wrong and leads to the violation of causality because it uses the magic tachyon-like carriers with unphysical properties. To prove this, we will replace tachyon-like carriers with the correct superluminal carrier of energy/information as Hole Teleportation.

Now, let us consider the correct version of Tolman's paradox (the numerical example with two-way communication), which does not violate causality. Two observers, Alice and Bob, are aboard a rocket moving inertially with a relative speed $v=0.8c$. Each one also has a superluminal Hole Teleportation transmitter aboard their rocket. After that, 300 days have elapsed since Alice passed next to Bob, she tries to send a superluminal message to Bob. Since Hole Teleportation has a random nature, the probability $P(A)$ that this superluminal message may appear just next to Bob is vanishingly small. Let us calculate this probability: Suppose that the radius of teleportation is limited by the distance $L=0.1$ Mpc. It means that at teleportation, the body may appear inside of the sphere with the radius $R=0.1$ Mpc only. According to astronomical observations, this volume is mostly empty so that the matter only fills a vanishingly small percentage of the space. If we ignore the presence of matter in this sphere, the number of total outcomes possible in an equiprobable sample space will be $N=V_{\text{sphere}}/V_{\text{spaceship}}=1.2 \times 10^{64}$. Consequently, the probability $P(A)$ that Alice's superluminal message may appear just next to Bob is $P(A)=1/1.2 \times 10^{64}$. However, experimenters must receive at least two superluminal messages for active violation of causality: When Bob receives the superluminal message from Alice; he immediately uses his own superluminal transmitter to send a follow-up message back to Alice [12].

While the probability that the first act of teleportation may hit the target is $P(A) = 1/1.2 \times 10^{64}$, the experiment requires that two acts of teleportation must hit their targets in succession (in the same experiment). Hence, the joint probability that two teleportation events $P(A)$ and $P(B)$ hit their targets will be $P(AB) = P(A) P(B) = 1/1.5 \times 10^{128}$. The average number of trials (acts of teleportation) until first success (to hit both targets) is $1/p = 1.5 \times 10^{128}$. Suppose that experimenters are capable to send one superluminal message per minute continually. In this case, calculations show that this event $P(AB)$ is so improbable that it is expected to occur only once in every 2.8×10^{122} years, assuming one minute cycles. By comparison, the age of the Universe is only 13.82×10^9 years. In other words, if the experimenters try to violate causality by the help of Hole Teleportation, the average duration of this experiment will exceed the age of the Universe by 10^{112} times. So, it is not really feasible.

Let us calculate the energy requirements for teleportation – experimenters must expend energy in order to create a closed hole surface. Suppose that the amount of energy required for teleportation is equivalent to 0.001 kg. In such a case, the amount of energy required for 1.5×10^{128} acts of teleportation is $\sim 10^{125}$ kg. For comparison, the mass of observable Universe is only 10^{53} kg; there is not enough mass in the observable Universe to supply the energy requirements for this experiment. So, again, it is not possible to violate causality by the help of HT.

In order to violate causality, the experiment also requires that the moving observer must fly $\sim 2.8 \times 10^{122}$ years with the relativistic speed $v = 0.8c$. In this case, he passes the distance 2×10^{122} light years moving in a straight line, while the commoving distance from Earth to the edge of observable Universe is only 4.65×10^{10} light years. If the observer goes beyond the edge of observable Universe, then he will not be able to communicate with other observers, therefore he must return back. Even if the moving observer (for example Bob) has the ideal rocket that is fueled by antimatter, calculations show that there is not enough mass in the observable Universe to supply the energy he would need to fly 2.8×10^{122} years near Alice. Also, take into consideration that the radius of HT has been limited artificially to 0.1 Mpc in this experiment, whereas usually the radius of HT can be very large, and therefore, all the above listed numbers must increase. Thus, it is physically impossible to violate causality with the help of HT.

Although we can continue to list problem after problem, we hope that we have convinced you that the random teleportation cannot be used for superluminal communication and violation of causality. If you are still not convinced, then take into consideration that HT has an additional property that prevents the violation of causality: the superluminal signaling between moving frames of references is forbidden. Remember that Alice and Bob are aboard spaceships moving inertially with a relative speed of $0.8c$. Since the observers are in motion in respect to each other, therefore superluminal communication (Hole Teleportation) between them is not possible. In fact, Tolman's paradox is based on superluminal communication

and relativity of simultaneity. Since the experimenters cannot receive superluminal messages, they cannot violate causality. We conclude that HT has the double (absolute) protection against active violation of causality.

B. The Passive Violation of Causality

How about the passive violation of causality? An example of passive violation of causality is the “one way example” (Tolman's paradox) [11], [12]: A superluminal signal is sent from A to B. Then the authors introduce the inertial frame moving with relative velocity v , where the effect arises before its cause [12].

There are the following errors in the “one way” Tolman's paradox: The author uses again the magic particles (tachyons) with unphysical properties – therefore, it is a science fiction story but not a scientific experiment. The experiment will be valid only when we use the real particles that respect the laws of nature. If we replace the tachyons by Hole Teleportation then it resolves the paradox: the superluminal signals do not violate causality. It is absolutely impossible to violate causality by help of Hole Teleportation and we ask all readers to send to author at least one example of active violation of causality by Hole Teleportation. Tachyons violate causality because they are non-physical fantasies. Let us demonstrate it again for passive violation of causality: the experimenters try to send a superluminal signal from A to B in the “one way” Tolman's paradox. The probability that random teleportation may hit the target is $P(A) = 1/1.2 \times 10^{64}$. The event $P(A)$ is so improbable that it is expected to occur only once in every 2.3×10^{58} years, assuming one minute cycles. Also, the total amount of energy required for 1.2×10^{64} acts of teleportation is $\sim 10^{61}$ kg, while the mass of observable Universe is only 10^{53} kg. In addition, the moving observer needs even more energy in order to fly 2.3×10^{58} years with relativistic speed near points A and B. We conclude that it is physically impossible to violate causality by help of HT.

Let us consider another error in Tolman's paradox. The author writes that the impossibility of a $> c$ seems to be proven [11], [12].

Let us pay attention to the fact that the principle of causality was deduced from the observation of the subluminal world, and therefore, it cannot judge the superluminal phenomena. In my opinion, it is physically incorrect to transfer our subluminal experience to the superluminal world, because some principles (or laws) of subluminal physics may be different in the superluminal world. Besides, take into account that the events “send” and “receive” are simultaneous in HT, and therefore, cannot be interpreted as “cause” and “effect”. For this reason, the inversion of acausal events is not a paradox at all – actually the moving observer sees the inversion of acausal events send-receive, but not the inversion of cause-effect.

The author writes that “the effect arises before the cause”. Suppose that we found a moving frame C, where “the effect arises before the cause in this frame”. What do these terrible words mean? It means only that the light from the event “receive” comes to the observer C before the light from the

event “send”. However, it is clear that all the causal chains have a direction from cause to effect in this frame C. In other words, these distant teleportation events cannot change the chronological order of events in the moving frame C. In fact, the moving observer C may violate causality only if he sends a superluminal signal to Alice that commands the destruction of the teleportation transmitter when this message is received. But the laws of HT forbid the teleportation between moving frames; therefore, the moving observer C is not able to send any superluminal messages to Alice until he is in motion in respect to Alice. Consequently, the moving observer can observe only these distant superluminal events, but he is not able to influence them. In other words, the effect cannot influence the cause with the help of HT.

V. THE ADVANTAGES OF HOLE TELEPORTATION

Although HT cannot be used for superluminal communication due to its random nature, instead we can use HT to explore the deep Universe and colonize the extra-solar planets. Hole teleportation has the following advantages:

1. In contrast to wormholes and warp drives, Hole Teleportation does not require exotic matter, black holes or enormous energies comparable to Jupiter's mass. HT needs only vacuum holes which can be created by the help of usual physical processes such as annihilation, decay, and particle scattering. Hole Teleportation seems to be the only valid superluminal proposal that can be practically realized, because holes can be created in the laboratory [13]. In addition, the energy expenses for (hole) teleportation of a human being cannot exceed 10 grams – we must create a hole sphere with the diameter 1 – 2 meters.
2. HT allows interstellar one-way travel in a human lifetime: we can teleport (throw) spaceships into deep space. For example, the spaceship may appear next to Barnard's star.
3. We can find and colonize the extra-solar planets by help of mobile teleportation stations. According to astronomical observations, planets exist everywhere, and for this reason, we can find and colonize the habitable planets by help of random teleportation jumps. The mobile station produces the hole's surface around itself which could then allow it to teleport itself repeatedly to random places in the Universe. After a large number of teleportation jumps, there is a probability that the teleportation station may appear next to an Earth-like habitable planet. If the crew observes the good planet in its immediate surroundings, they can land using the rocket technologies. At the very least, it is far better to use random teleportation than to use spaceships – Hole Teleportation can convey a spaceship to the extra-solar planets during some hours only.

VI. CONCLUSIONS

The discontinuous spacetime with holes can explain gravitation, inertia, quantum mechanics, teleportation of matter in the simplest possible way and therefore this theory

deserve attention. Moreover, Hole Teleportation is the only superluminal carrier of information and energy which does not violate causality. It is absolutely impossible to prove the violation of causality by superluminal Hole Teleportation.

REFERENCES

- [1] J. G. Petronic, “Concepts of continuity: William Kingdon Clifford's empirical conception of continuity in mathematics (1868-1879)”, *Philosophia Scientia, Actes de la 17e Novembertagung d'histoire des mathematiques*, pp. 45-83, 2006.
- [2] R. Dedekind, *Essays on the Theory of Numbers, "Continuity and Irrational Numbers,"* Dover, New York, ISBN 0-486-21010-3.
- [3] C. Leshan, "Vacuum Holes as Cause of Gravitation and Inertia", *Acta Physica Polonica B*, Vol. 41, No. 11, 2010.
- [4] C. Leshan, “Descartes' vacuum in hole gravitation theory”, *Concepts of Physics*, Vol.6, No. 4, 2009, pp. 567, Retrieved October 09, 2016 from http://merlin.phys.uni.lodz.pl/concepts/2009_4/2009_4_567.pdf
- [5] R. Descartes, *The Principles of Philosophy*, Blackmask Online, 2002, (translated by Veitch John).
- [6] C. Leshan, “Hole interpretation of quantum mechanics”, *FQXi Essay Contest - Is reality Digital or Analog?*, 2011, Retrieved October 09, 2016 from <http://fqxi.org/community/forum/topic/874>
- [7] C. Leshan, "Heisenberg Compensator - teleportation as particle-wave duality", *Quantum Magic*, Vol.5, No.2, 2008, pp. 2132.(in Russian).
- [8] C. Leshan, "Teleportation in hole vacuum", *Journal of Theoretics*, Vol.1, No.5, 1999, Retrieved October 09, 2016, from <http://www.journaloftheoretics.com/articles/1-5/leshan%20teleport%20final.htm>
- [9] C. Leshan, *The open tunnel paradox (wormholes), Hole Physics, teleportation and levitation*, V1, N3, 2005. (in Russian), Retrieved October 09, 2016, from <http://holevacuum.narod.ru/2/par.htm>
- [10] G. Modanese, "Velocity requirements for causality violation", *arXiv:1304.5522 (physics.gen-ph)*, 2013.
- [11] R. C. Tolman, "Velocities greater than that of light. The theory of the Relativity of Motion". University of California Press, 1917.
- [12] R. W. Anderson, “The Cosmic Compendium: Interstellar Travel”, *Lulu.com*, 2015.
- [13] C. Leshan, "How to create an absolute vacuum and a perfectly isolated system", *FQXi Essay Contest - What's ultimately possible in physics?* 2009, Retrieved October 09, 2016, from <http://fqxi.org/community/forum/topic/481>