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About Black Hole and Information Paradox

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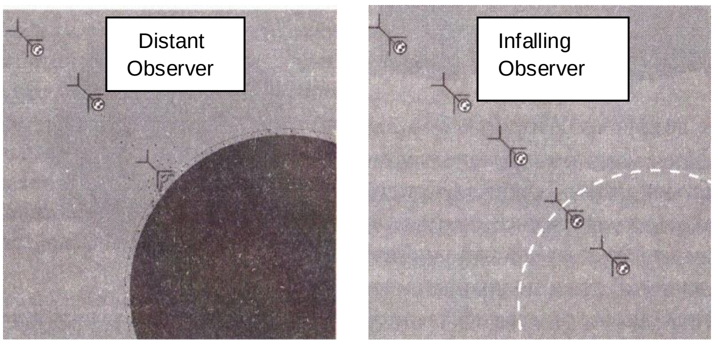
The black holes and their event horizons features are so far discussed in the scientific community. Particularly, as it was published, the so-called "information paradox", was recently discussed on the special meeting in CERN. The infalling system description duality in two different reference frames (distant and infalling ones) and the conjectures about the event horizon structure are closely related with this paradox.

In the present publication I state that, in fact, such the duality and information paradox do not exist.

1. Duality of the infalling massive particle description

As it is well known, a particle infalling onto black hole (BH) in a distant reference frame "slows" its motion and finally turns out to be "frozen" at the horizon and never crosses it. However, in the Kruskal coordinate system that overlaps all the spacetime (not only external region) the infalling particle continues freely its motion into BH before it meets the central singularity. The "naif" question appears: how can we reconcile the both descriptions?

In order to solve the situation L. Susskind proposed **[Susskind, 2008]** the idea of BH "complementarity" similar to the general Bohr complementarity principle. This idea states that the both descriptions (figs. 1a и 1b) are true. Any difference between them cannot be reached by some "superobserver" due to *the horizon existence*.



a) b)

Figure 1 **[Susskind, 2008]**.

However, regardless all the elegance of the complementarity idea I believe that it is redundant one. It turns out that, in fact, the particle infalling under the horizon is physically impossible!

My own investigation **[Shulman, 2009]** based on the known GR results has reached the intriguing picture of a BH creation when a material sphere of a finite size (not a point) is compressed. I choose the ratio ρ/ρ_0 (where ρ is the sphere actual density, ρ_0 is the critical density at which the gravitational collapse occurs) as the criterion of the state.

While this ratio is small, the pressure in the interior of the BH is strongly *positive* and is smoothly decreased from the sphere center to its periphery. However, the further compression of such the object near the collapse (at ρ/ρ_0 ~ 0.7025) leads to the essentially new situation: the pressure distribution in the interior of the BH is completely changed. It changes its sign at the center of the sphere and becomes *negative*, then inverts the sign while the *infinitely valued* bipolar rupture appears. As the ratio ρ/ρ_0 approaches unity this infinite bipolar rupture *is pushed* from the sphere center to its periphery; when the collapse happens this rupture turns to be exactly at the BH horizon and presents the *irresistible* barrier for any particle having the finite kinetic energy and trying to penetrate into the sphere interior (*under* its surface).

2. Dimensionality reduction

This fact forces me to propose the radical concept to describe BH in our Universe. It suggests that due to the gravitational collapse the *topology change* occurs at the BH boundary; the physical space itself disappears in interior of BH, and the black hole reduces to its boundary that takes the dimension 2 instead 3 (i.e., the dimensionality reduction occurs[1]).

Such the outlook is, in fact, not so surprising as one could expect. Since 70s of last century so-called “membrane paradigm” was commonly accepted in the BH theory. An *external* observer can strictly consider a BH as 2Dphysical membrane consisting in a viscous fluid having certain mechanical, electrodynamic, and thermodynamic features (**[Novikov and Frolov, 1989]**). These membrane features are determined by its surface gravitational and electric charges. In fact, this *mechanical* membrane comes to a dynamic *equilibrium* due to interaction between surface pressure, gravitation and centrifugal forces. *Electrodynamic* features of BH are specified by the complete similarity between the membrane and conductive sphere, and the electric field flux form of a charged particle near the event horizon of a non-rotating BH is the same one of this particle near above conductive surface. From the thermodynamic point of view the membrane surface area is similar to any usual body entropy: it increases or does not decreases (Hawking theorem). The membrane itself is defined by an effective temperature that is proportional to its surface gravitational charge. Finally, the famous Holographic Principle was formulated accordingly to which all the information is recorded on 2D-horizon. Maldacena in 1977 году established the complete isomorphism between these mathematical worlds **[Maldacena, 1998]**.

Note, recently the similar BH models were proposed where “interior region” and singularity were absent **[Mazur and Mottola, 2002]**, **[Mathur, 2013]**. The boundary between external Universe and BH are considered there as very thin (like planckian length), but finite.

I believe that the membrane paradigm is not an approximation, it is *absolutely exact*. All the BH mass is concentrated in this 2D region very uniformly, because there is no some difference depending on distance from the center. If the dimensionality reduction really takes place, then the complementarity conjecture is not needed, and holographic principle for BH turns out to be trivial statement.

3. The “information paradox” description

As it is known, S. Hawking theoretically discovered **[Hawking, 1975]** the BH thermal radiation. This radiation (as Hawking believes) is due to the virtual pairs “particle - antiparticle” creation; one member of the pair can tunnel under horizon, while another becomes the *real* one and is emitting into the external region. One thinks that this radiation leads to the paradoxical situation; e.g., the author of **[Anderson, 1996]** writes:

[1] ‘t Hooft was first who used this term in the close sense **[Hooft, 1993]**.

> Take a quantum system in a pure state and throw it into a black hole. Wait for some amount of time until the hole has evaporated enough to return to its mass previous to throwing anything in. What we start with is a pure state and a black hole of mass M. What we end up with is a thermal state and a black hole of mass M. We have found a process (apparently) that converts a pure state into a thermal state. But, and here's the kicker, a thermal state is a MIXED state (described quantum mechanically by a density matrix rather than a wave function). In transforming between a mixed state and a pure state, one must throw away information. For instance, in our example we took a state described by a set of eigenvalues and coefficients, a large set of numbers, and transformed it into a state described by temperature, one number. All the other structure of the state was lost in the transformation… In technical jargon, the black hole has performed a non-unitary transformation on the state of system. As you may recall, non-unitary evolution is not allowed to occur naturally in a quantum theory because it fails to preserve probability; that is, after non-unitary evolution, the sum of the probabilities of all possible outcomes of an experiment may be greater or less than 1.

Meanwhile, I propose below the arguments that (in my opinion) reject the information paradox existence.

4. Objections against the Hawking radiation mechanism

The Hawking radiation mechanism requires the tunneling of one virtual particle from the pair under the BH event horizon. However, as it was noted in the Section 1, there is the *infinite* barrier (i.e., the potential wall) at the “input” of BH; no particle can tunnel through such the wall. I have no any doubt that thermal Hawking radiation exists, but I believe, another mechanism is actual: in the BH gravitational field its effective radiation temperature (depending on the field stress) is determined by the surface gravitational charge and coincides with the Unruh temperature for an arbitrary gravity source; this temperature continuously transits to the Hawking temperature at the horizon (see **[Shulman, 2010]**). The BH entropy, Hawking radiation and temperature do not depend on the particle ability to penetrate into interior of BH.

5. When the “BH hair” appears

Even if we assume that a particle can penetrate into interior region of BH, this also cannot lead to the information paradox. In fact, very often the reference to the BH “no hair theorem” is made without account the presumption of BH *isolation*. We can read in the book **[Novikov and Frolov, 1989]**:

> Wheeler summarized the results of a large number of paper devoted to the final states of the black holes and formulated a conjecture that in its evolution to the stationary state, an isolated black hole sheds through radiation all those characteristics that radiation can remove. …
>
> An isolated black hole cannot be a source of any massive field since all the radiation modes are possible for such the fields … and accordingly to the Wheeler conjecture all from them have to be radiated during the transition into the stationary state.

If we now consider the quantum system penetration into an *isolated* BH, then it becomes clear that the BH isolation and stationarity turns out to be *disturbed*, and it will answer by a “*transitional”* radiation in order to *return* its stationarity. It is also clear that this *transitional* radiation *is not related* with stationary thermal Hawking radiation.

6. An infalling quantum system is *measured* by the BH external field

I am sure that the non-unitary evolution does not contradict to the quantum mechanics at all. In fact, the question is: does quantum mechanics give the reversible description only, or this is not the case.

Let us start from the classic mechanics. Very often one cites the irreversibility of the statistical mechanics against the reversibility of the Newton’s mechanics. However, as I believe, in general the Newton Law *is not reversible*. The second law of Newton one usually writes as

$$F = m\ddot{q}$$

where F is the external force, m is the mass, $\ddot{q}$ is the acceleration. Here, of course, one does not take into account some medium resistance and irreversible energy loss at motion. However, in a more general case one should include, for example, a friction into this equation, then we have

$$F = m\ddot{q} + D\dot{q} + ...$$

that is just irreversible. The friction is a *reaction* of the rest parts of the Universe on the considered particle motion, at this an irreversible energy redistribution occurs, so a new irreversible term will appear into system Hamiltonian.

Moreover, generally quantum systems may be specified by the coherence that could disappear during the *decoherence* process. Particularly, the decoherence happens while a particle interacts with a field that “measures” the particle state **[Zurek, 2002]**:

> If a particle is present, excitations of the field will scatter off the particle. The resulting “ripples” will constitute a record of its position, shape, orientation, and so on, and most important, its instantaneous location… [The equation for the particle density matrix evolution] naturally separates into three distinct terms, each of them responsible for a different aspect of the effectively classical behavior. The first term – the von Neumann equation (which can be derived from the Schrodinger equation) – generates reversible classical evolution of the expectation value of any observable that has a classical counterpart … The second term causes dissipation. The relaxation rate is proportional to the viscosity due to the interaction with the scalar field. That interaction causes a decrease in the average momentum and loss of energy. The last term also has a classical counterpart: It is responsible for fluctuations or random “kicks” that lead to Brownian motion.

Namely, the influence of the last term destroys with time the quantum coherence and eliminates the non-diagonal density matrix components.

So, it is incorrect to think about a system in the pure state thate penetrates into an *isolated* BH. In fact, the BH field *measures* the infalling system, and the system transits into the mixed (decohered) state just before the penetration into BH; at this no conjectures are required about the event horizon structure like **[Almheiri et al., 2013]**, where authors suppose that “the infalling observer burns up at the horizon”.

7. Can a distant observer see the BH growth?

I would like discuss one more interesting problem. Taking into account that signal propagation from the BH horizon up to a distant observer is infinitely slowed, it seems at first sight that a distant observer should see the BH just *in the first time point only*. However, the growing BHs absorb a *large amount of matter* that streams to the event horizon. When the accumulated mass around the horizon becomes dense enough, it collapses too. So the visible size of the BH increases still.

Acknowledgments

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