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Time and Black Holes

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Abstract

The conception of "parametric" Time for increasing Black Hole is used. This Time is hardly linked with the Black Hole event horizon's radius, because of that it is the same for both external and internal observers. A solution of Einstein-Friedmann's equation for Black Hole internal region is given. Since the Black Hole continuously absorbs a matter or/and energy from external world, a White Hole is required inside this Black Hole as a channel of such absorption.

Introduction

Two fundamental difficulties exist in the conception of Time used in the General Relativity and Black Hole Physics. The first consists in bad understanding of Time attributes. The temporal component of metrics differs from spatial ones by opposite sign and imaginary factor, but it is not clear at all what means the *irreversible time currency*.

It is bad as such, but leads one more problem. When one considers a transition trough light barrier or event horizon, some roles exchange occurs between a spatial component and a temporal one. In this case one says about *non-stationary* and *uni-directed* evolution in such inverted domain, however, one is again based on a vague meaning of time currency.

A test body dynamics is usually studied at a sufficiently small time scale, when *event horizon radius is considered as a given (constant) value*. Additionally, the known collision appears when the arrival time (to the horizon) is finite at a distant reference time, but is infinite at the other one that is hardly related with the arriving body. In order to describe these processes Penrose's diagrams use "other" universes that sometimes are considered as Past or Future of our own Universe. However, their temporal distance from us must be *infinite*, and this contradicts to the fact that our Universe has a finite age.

Below I propose a new conception of Time that I develop since 1993.

Parametric Time for Black Hole

As was noted above, the modern physics of Black Holes (BH) uses different Time conceptions for observers who are inside and from outside of the event horizon. Due to the impossibility of any information exchange the time synchronization problem seems to be insoluble. Is it really the case?

BH's remarkable feature consists in the objective existence and principal measurability of its main parameters – mass, electric charge and angular momentum. Together these parameters determine the BH event horizon area and allow us to find a *radius* (size) of BH. We will consider below only neutral and non-rotating holes (Schwarzschild's BH). We also will ignore the Hawking's radiation. The gravitational radius of a Schwarzschild's BH is proportional to its mass M: $R = 2GM/c^2$, where G is the gravity constant, c is velocity of light. As it is well known, the BH event horizon area never decreases (Hawking's theorem), so we have a fine universal label *marking* BH's evolution – its size that is the same for *both external and internal observers*.

When we consider a sufficiently large (at cosmological scale) evolution period of a BH, we can *parametrize* the set of its sequential states[1] using its global size. This statement correlates with the known link between BH event horizon area and BH's entropy. Any other reference frames may be made consistent with the frame that we have selected.

Dynamics of BH's internal region

The proposed choice of Time allows us to get the full description of BH evolution with usual Einstein-Friedmann's equation solution, where at the one side we have the momentum-energy tensor, and at the other side there is some spacetime geometry tensor. We have two coordinates: the current global BH's radius R and unambiguously related with him its cosmological age that we set t = R/c, c is velocity of light.

We suppose that BH is spatially uniform, then the Einstein-Friedmann's equations can be written in the usual form:

$$k(c/R)^2 + (R'/R)^2 - 2(R''/R) = - 8\pi GP/c^2$$
$$k(c/R)^2 + (R'/R)^2 = 8\pi G\rho/3,$$

where G is gravity constant, ρ is mean dencity, P is a matter pressure inside BH, k = 1 (in this case we assume a positive curvature). Here the upper stroke (') denotes the differentiation on time.

Furthermore, our BH has to be born during collapse, i.e. at high density of its matter. Before collapse this high density created high *pressure* inside BH's "ancestor", hence we will not a priori believe that pressure is equal to zero or to choice a sign of that value. It is very important while searching correct solution.

And we should take in account the most important moment. In order to integrate on time the Einstein-Friedmann's equations we have to decide, do we can use the full matter/energy conservation law? Since the BH's mass increases by definition, the answer is negative. Thus, one has to consider BH as *open* system limited by a semi-permeable membrane. Note, the geometric features of BH evolve too hence the premises of the *Noether's theorem* are not accomplished.

In the considered case we have R' = c, R'' = 0, so the equations can be solve easy. The more, we can directly express a matter dencity and pressure as dependences on the spatial curvature:

$$\rho = 3c^2 / (4\pi GR^2)$$
$$P = - c^4/(4\pi GR^2)$$

The "state equation" for the BH's internal region is:

$$P = - \rho c^2/3.$$

Revealed solution's features

As follows from made assumption (R' = c), we found out a solution for continuosly increaing world inside BH. Some "Hubble's parameter" H = c/R appears for it, this parameter is inversely proportional to the BH's radius and age.

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[1] The concept of parametric Time as measure of an arbitrary object variability was formulated in works of prof. A. Levich (See, for example, **[Levich, 1988, 1995]**).

Since we did not set a pressure equal to zero, then we find out the following result: our solution corresponds with a *positive* curvature of a 4-sphere, mean matter dencity inside BH is *always* $\rho = 2\rho_{cr}$, where $\rho_{cr} = 3H^2/(8\pi G)$ is critical value for "flat" metrics in the Einstein-Friedmann's model. Because of that the BH's mass (product of density and volume) is finally proportional to the first power of radius R (BH's size) and to Time, as we supposed.

Some non-zero cosmological constant Λ is absent in this solution. Instead we have a *negative* pressure P evolving in Time that gives the linear BH's expansion. By this way we exclude some non-uniform (accelerated or decelerated) rise of BH. Also, we have not some "horizon problem" since the event horizon expansion rate is exactly equal to the BH's expansion rate.

In such expanding BH's model all its resting points have to "move" away one from another during Time. In other words, an *absolute* frame system has to appear in every BH's spatial point corresponding to the "true" state of rest. And when some material body really moves inside BH relative to "true" state of rest, then such motion must be in principle experimentally measurable.

A White Hole is required inside expanding Black Hole

So, we have in our Universe some increasing BH that works like "vacuum cleaner" or "energy pump" and continuously accepts a matter or/and energy from our Universe. An external observer can see a BH as an event horizon, any information cannot arrive from inside to such observer. And what can "see" an internal observer located inside BH?

An observer located inside BH (at least neutral and non-rotating) may in principle see in his expanding world a continuous arrival of matter and/or energy, or some kind of "White Hole" (WH).

A possible connection between BH and WH is very interesting. It is clear that Black Holes (if they exist at all) either existed since beginning the Universe (primordial BH) or appeared later (BH having solar mass, super-massive BH in the core of galaxies[2], quantum BH, etc.).

In the book **[Novikov and Frolov, 1989]** White Holes are defined formally as an analog of solution for BH but with increasing (not decreasing) T-region. It is stated there that it is the case of a sphere expanding from under event horizon, however, one cannot say that the matter expansion appeared *after* singularity. These events are not linked by a timelike interval, because of that one simply formulates that "a nature of spacelike singularity generates the matter expansion in the vacuum". One concludes that WH cannot appear due to the gravitational collapse of some object, but may exist perpetually. One also states that single perpetual BH can exist only together (in pair) with single perpetual WH.

As we can see, our interpretation differs a little. Particularly, we consider an increasing BH inside our Universe, maybe without included BH of the "next" level. However, at least one perpetual WH must exist inside this BH from which a matter and/or energy arrives at this world.

It is also very interesting how an internal observer sees that "maternal" WH (some kind of a umbilical cord connecting the increasing BH with our Universe). Here one can consider two speculative possibilities.

First, the WH seems to be a spherical region somewhere inside BH like a centre of the universe for it. This picture is similar to the picture of BH seen outside of it – the

[2] There is an information about super-massive Black Hole in the core of Galaxy having the mass approximately 3 - 5 millions of solar mass and consuming external matter up to 2 Earth's mass per hour [http://lenta.ru/news/2009/05/28/blackhole/].

event horizon that is a perpetual generator (not consumer) of information. An external observer believes that BH has the same internal 3D metric structure as the external world.

On the other hand, an external observer sees only BH's 2D event horizon *surface*, its entropy (and hence a set of its possible states) is determined exclusively by the area of that surface, *not* by the BH's *volume*. So, one can say that BH is a *real* hole in our world, absolutely *nothing* is under this 2D event horizon surface. Hence, the *second* speculative possibility appears. When one transits in his mind through an event horizon, then the BH's internal region's dimension decreases to the unit, so for an internal observer each spatial point of BH *contacts* with the maternal Universe. In other words, for such observer WH and the event horizon are present everywhere. The energy and information are born at all points of the BH, and the process is associated with BH's uniform expansion. In principle, such contacts may provide some "non-local" interaction (via external world) between particles inside BH.

"Internal" Black Holes

Let us consider now some expanding BH (we will call it "maternal" universe). Inside this universe new "daughter" BH can appear and expand. In fact, although the *mean* matter density inside the maternal universe is $2\rho_{cr}$, the matter distribution in the volum may by very nonuniform, so a large "void" region can surround a compact collapsing object.

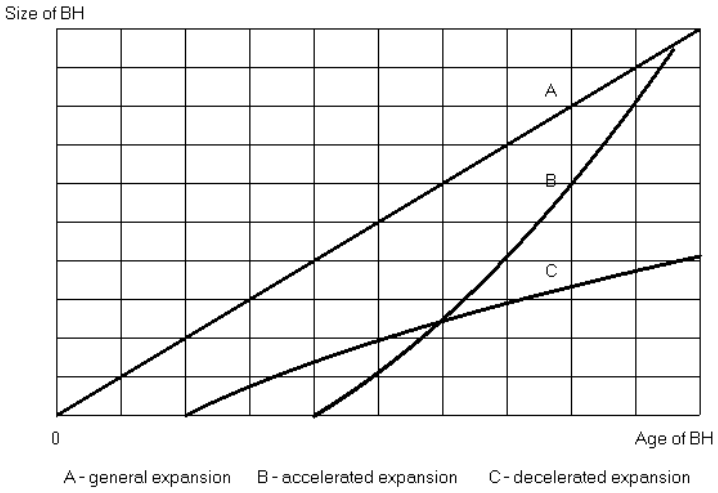

Figure 1.
Dependences Size-Age for the maternal universe (A) and "daughter" BH (B, C)

The dependence Size-Age for the maternal universe is linear by definition (curve A in Fig. 1). What about daughter BH, they can appear (due to collapse) at different "maternal" points of time and have in general different rate. For example, curve B in Fig.1 corresponds with accelerated rate, and curve C represents decelerated rate, so their own "parametric" time scales can differ from maternal time scale. Note, if an internal BH expands with acceleration, it have to become equal to the maternal universe and absorb it.

Conclusion

Let us to sum up. We consider Black Holes appeared in our Universe after Big Bang and evolving due to mass rise during the next cosmological stages. For such BH

we suppose to introduce a special parametric time (current cosmological age of BH) unambiguously related with a current BH's event horizon radius using standard factor – velocity of light. Then the BH's dynamics can be described by the usual Einstein-Friedmann's equations, however, two circumstances must be taken in account. Firstly, we do not refuse a priori a pressure of matter (it can be even a negative one) inside BH. Secondly, since BH's mass increases due to an external mass and energy consuming, we cannot use a conservation law while integration of the equation. Then we find out some "creationistic" solution that describes expanding world inside BH. Such picture is close to this one available to an observer in our Universe.

In fact, the author since 1993 developed Time conception connected with namely our Universe expansion, above solution was found out just for it **[Shulman, 2007]**. However, any discussion with scientific community was interrupted when I supposed to refuse the global energy/matter conservation law in the cosmological scale, hence – to consider our Universe as an *open* system. Only by degrees I understood that our Universe may present something like BH which consumes an *external* matter/energy (I do not consider now some speculations about possible BH's hierarchy). I don't know, is the new point of view a convincing one for the scientific community.

References:

[Levich, 1988] Levich A.P. Metabolic time of natural systems // System Studies. Annual edition. 1988. Moscow: Nauka. 1989. Pp.304-325 (in Russian). Pp.117-126 (in Russian).

[Levich, 1995] Levich A.P. Time as Variability of Natural Systems: Ways of Quantitative Description of Changes and Creation of Changes by Substantial Flows // On the Way to Understanding the Time Phenomenon: the Constructions of Time in Natural Science. Part 1. Interdisciplinary Time Studies. Moscow: Singapore, New Jersey, London, Hong Kong: World Scientific. 1995b. Pp.149-192. Available at: http://www.chronos.msu.ru/EREPORTS/levich1.pdf

[Novikov and Frolov, 1989] Novikov I.D., Frolov V.P. Physics of Black Holes. Dordrecht, Kluwer Acad., 1989.

[Shulman, 2007] Shulman M.H. *Cosmology: a New Approach*. Available at: http://www.timeorigin21.narod.ru/eng_time/Cosmology.pdf