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White Hole existence on the inverse universe

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Abstract

The existence of White Hole (WH) has been suggested by Schwarzschild solution to the Einstein field equation as a time-reversed Black Hole (BH), besides there has not been observational evidence for their existence yet. Our idea of the "inverse universe", in which we introduce the time-reversed kinematics as another geometric state, can explain that WH should appear in such a geometry after a matter falls into a BH. In this work, we present a new operation for WH conversion from BH, and by using it the nearly infinity point on the universe, for instance the inside of BH, is geometrically connected to the inside of WH on the inverse universe. Such a conversion is useful to provide the simple solution to the problem of "information loss" in BH. Furthermore, we find another conversion point as the prior geometric state to the Big Bang, and we propose a new cosmology of cyclic universe.

Keywords: White hole; Black hole Information Loss; Dark Energy; Cyclic Universe.[**]

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1. Introduction

Black hole (BH) [1] has been known as the mysterious object; the general relativity predicts an object with extremely strong gravity that nobody can directly observe since a light can not escape from its inside (whose boundary is denoted as event horizon). We then expect BH existence from the observation of phenomena around BH, where strong gravitational force creates the extreme events, for instance the strong X-ray radiation from a matter captured by BH's gravity [2] [3]. The Schwarzschild solution [4], which is the exact solution of Einstein equation in the general relativity under a circumstance without rotation and charge, mathematically describe BH's geometry, but it does not explain a naïve question: "What happens to a matter fallen in the BH? Exactly speaking, where is matter going inside an event horizon?" [5] [6] [7]. Theoretically, inside an event horizon, any physical objects, even a light, are not allowed to go outside due to distorted geometry and eternally fall towards the singularity, in which the curvature becomes infinity. This implies that the kinematics behind an event horizon is compelled to an only direction to a singularity at timelike infinity [8]. On the other hand, BH will be eventually evaporated by Hawing radiation with the only light emission, and this is then consequent on a paradox, in which the initial information of matter, *e.g.* spin, is reduced to the three types of property, *i.e.* mass, electric charge and angular momentum, involving the Hawking radiation, seemingly the final matter violates a time-reversibility of the quantum mechanics.

Although a white hole (WH) [8] has been also theoretically predicted so far as the time-reversed BH solution of Einstein equation in which the physical object is compelled to outside of event horizon, no evidence of WH has been observed yet. We also come up with a question: "Why has a WH not been observed in our universe?". The general relativity is successful at the description of the gravitational geometry and establishes its validity with several observations and experiments below the Plank scale, except for a prediction of WH. This is also a cosmological issue.

In this article, we propose a new idea to address both issues: matter loss in BH and non-existence of WH, by introducing the "inverse universe" where its time-flow is reversed from that in our universe, like a mirror universe [9]. In our model, the matter fallen in BH is converted to anti-matter as a consequence of time-reversed operation, and it is then emitted from WH in the inverse universe. Therefore the total amount of matter including information is preserved in the whole universe, our universe and the inverse universe.

Furthermore considering another infinity point in the inverse universe as another conversion to the beginning of our universe, *i.e.* Big Bang, we can also provide the explanation of the fundamental issue of cosmology: "What is before Big-Bang?". Our cosmological model has an advantage to economically explain

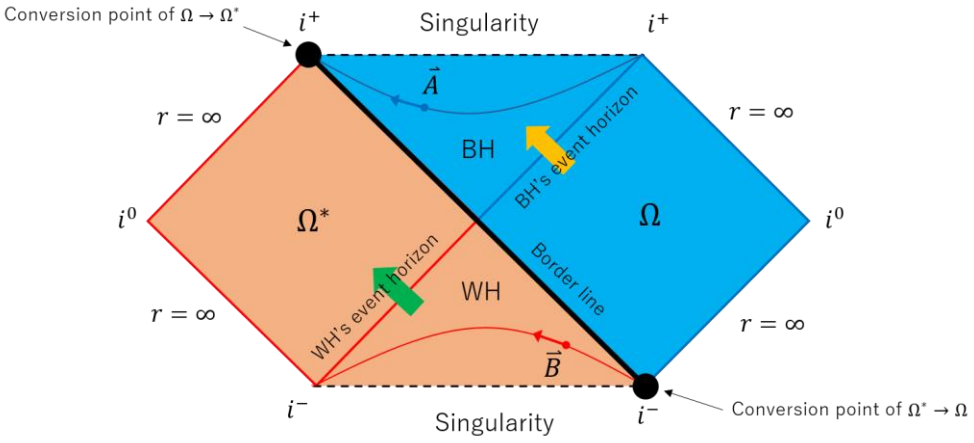

Figure 1. Penrose diagram, showing the maximal extension of Schwarzschild metric and border line between **Ω** and **Ω***. There are two one-way directions such as from outside to inside of BH on **Ω** and from inside to outside of WH on **Ω*** across the event horizon. In this metric, there are two singularities of BH and WH (top and bottom lines respectively). The timelike infinity point represents "$\mathbf{i}^+$" as end-point (infinite future) and "$\mathbf{i}^-$" as start-point (infinite past). There is a border line between **Ω** and **Ω*** where the kinematical transformation is strictly restricted except its end-points at near infinity points, $\mathbf{i}^+$ and $\mathbf{i}^-$ called as conversion points explained in a text.

several cosmological problems over the other cyclic cosmology [10] [11] and mirror universe [9].

2. Conversion from Black Hole to White Hole

We first consider the kinematical transformation from p to q on the gravitational space-time (Minkowski geometry) Ω,

$$\Omega: p \Rightarrow q, \tag{1}$$

where physical object moves from outside to inside of BH's event horizon. This transformation happens in that physical object at timelike point p on Schwarzschild metric is dragged by the gravitational force of BH into inside of Schwarzschild radius, in which the metric is changed as spacelike point q. According to the maximal extension of Schwarzschild metric (Kruskal-Szekeres coordinate [12] [13]), there is a region of negative time, defined as the extended geometry Ω*, wherein the kinematics advance to the past, taken by the time-reversed transformation. In a contrast to BH solution, for WH solution regarded

as the time-reversed BH solution to Einstein equation, the kinematical transformation on Ω^* is

$$\Omega^*: q^* \Rightarrow p^*, \tag{2}$$

from inside q^* to outside p^* of WH's event horizon. The superposition of "*" represents state after the time-reversed operation is taken. In Figure 1, one can see that transformation $p \Rightarrow q$ shows the arrow crossing BH's event horizon on Ω, and after that q follows metric directing to timelike infinity i^+ inside BH. On the other hand, $q^* \Rightarrow p^*$ shows another arrow on Ω^* in which q^* on WH follows metric directing to outside WH's event horizon.

No evidence of WH observation in our universe indicates that there is a border between Ω and Ω^* in which matter is mostly prohibited to cross its border, except the connection in nearly infinity points, i^+ and i^- (see below). This means the conversion from BH to WH happens inside BH's event horizon (see Figure 1), where we have no way to detect the existence of WH unless we enter the inside of BH's event horizon.

Here we also introduce the extremely large potential wall, but not infinity, in Ω and Ω^* boarder. Considering the quantum tunneling, due to the quantum fluctuation in the vacuum, the open threshold for the connection between Ω and Ω^* appears despite the extremely small probability. On the path to i^+ (triangle region of BH in Figure 1), however, this event should occur since inside the event horizon its time scale is infinitely extended. Observing the matter fallen in BH from the outside of event horizon, a matter seems to disappear, but in our model, whose information is transited into the inverse universe through WH.

Such an idea is useful for the solution to the problem of disappearance of matter and its information inside BH; we can interpret that those are taken by the geometrical transformation from Ω to Ω^* and information loss is independent of BH evaporation. As a result, total amount of matter and its information should be conserved on the two geometries, Ω and Ω^*.

In the above, we consider the conversion from BH to WH, which is the connection of geometry at the nearly infinity point from i^+ on Ω to i^- on Ω^* showing the left-upper corner to right-bottom corner of Penrose diagram (see

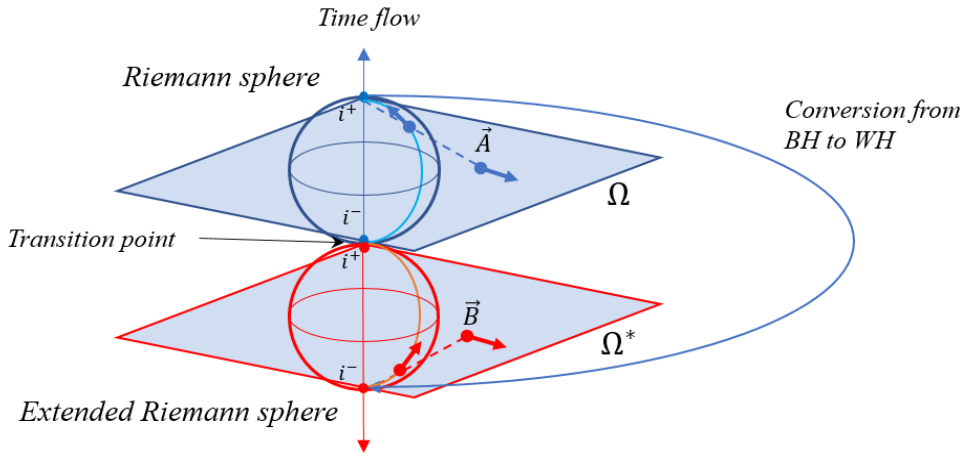

Figure 2. Riemann sphere and extended Riemann sphere. North pole of Riemann and extended Riemann spheres represent infinity point $\mathbf{i}^+$, and south pole is $\mathbf{i}^-$. The conversion from BH to WH can connect the north pole of Riemann sphere and south pole of the extended Riemann sphere. The time-flow showing vertical arrow has opposite direction since the extended Riemann sphere is a consequence of time reversed. The vector $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$ represent kinematical transformations of physical object on geometry of $\boldsymbol{\Omega}$ and $\boldsymbol{\Omega}^*$, and those points can be projected onto Riemann and extended Riemann sphere. Assuming that $\vec{\mathbf{A}}$ is located inside the event horizon of BH, the corresponding transformation $\vec{\mathbf{B}}$, which is inside event horizon of WH appears through the conversion. The connected point of both Riemann spheres is transition point from the Big Crunch to the Big Bang.

Figure 1). The other side, *i.e.* the connection from i^- on Ω^* to i^+ on Ω, then regards a geometrical transformation from the end of the inverse universe (Big Crunch) to the beginning of universe (Big Bang). This is considered of a sort of the cyclic cosmology model [10] [11]. We discuss more details later.

3. Representation of the extended Riemann Sphere

Next we discuss the representation of gravitational space-time Ω with a complex plane, and define it in Riemann sphere by the stereographic projection; now the north pole corresponds to the infinity point i^+ (see Figure 2). In this picture, we can also figure out that there is a reversed sphere defined as the extended Riemann sphere [14] [15][††], which consists with the geometry of the inverse universe Ω^*. So that the conversion from BH to WH can be interpreted

[††] We used a nomenclature "converse" in those references instead of "inverse".

as that the south pole on the extended Riemann sphere is connected to the north pole on the Riemann sphere. Consequently, the kinematics on the extended Riemann sphere regards the time-reversed kinematics on the Riemann sphere. Here we define "time-flow" on Ω as a time sequence, and it is then opposite flowing sequence on Ω^*; the time-flow towards i^+ on the Riemann sphere corresponds to the time-flow towards i^- on the extended Riemann sphere (see Figure 2). Considering the kinematics on those spheres, the directions are same, *i.e.* both vectors $\vec{A}$ and $\vec{B}$ in Figure 2 are transformed from south to north on surface of both spheres, however $\vec{B}$ is observed as opposite kinematics from $\vec{A}$ since the time-flow is opposite.

The path to enter the inverse universe is a way with conversion from BH to WH, and in this way the matter including energy is converted into the anti-matter in the extended Riemann sphere, which is a consequence of time-reversed operation; the particles are changed to the anti-particles, for instance, proton and electron are converted to anti-proton and positron respectively. So that, while in our universe the particles are dominated, in the inverse universe anti-particles are dominated, namely anti-hydrogen composed by positron and anti-proton is a fundamental atom. Furthermore the time-reversed operation for gravitational force makes a change of attractive force to the repulsive force, and it then results that the star can not be constructed in the inverse universe and particles are afloat without any cluster. The important ingredient is the dark energy [16] [17], which is currently considered as 70% dominant repulsive force in our universe to explain the acceleratingly expanding universe observed from *e.g.* type Ia supernova [18] [19], expected to be a stem of the cosmological constant, but have not been directly observed yet, is changed to interactive force in the inverse universe (here it is called "anti-dark energy") through BH/WH conversion. In the inverse universe, anti-dark energy plays an important role of shrinking the space-time to transition point, which is a cross point between Riemann and extended Riemann spheres in Figure 2. This ends up with the Big Crunch in the inverse universe. Our model of cosmology will be discussed in the next section.

4. Cosmology of the inverse universe

Now we can discuss a cosmology of the inverse universe. Starting from soon after the Big Bang in our universe, the first BH was created by collapsed massive star by the gravitational force and its amount increased following the time-flow. The matter including dark energy in Riemann sphere Ω is transformed into the extended Riemann sphere Ω^* through BH/WH conversion. Increasing the number of BH, the amount of matter and dark energy decreases in Ω, and the speed of expansion of our universe will be reduced since the ingredient to control the scale of universe decreases. At the end, our universe will be totally

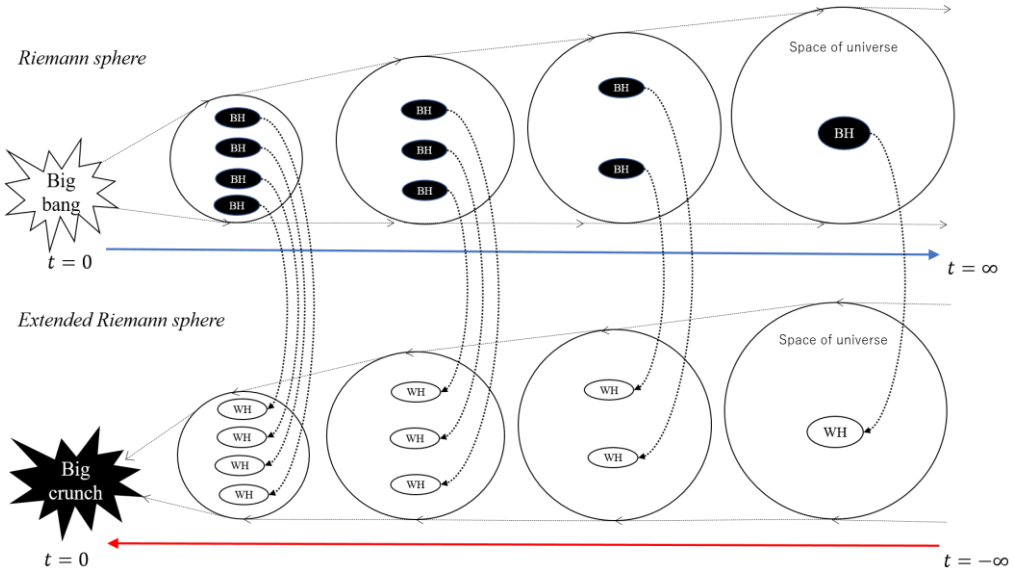

Figure 3. Time-flow of the universe and the inverse universe. On Ω, the BHs increasingly appear in the universe since the matter is rich. The space size has also been expanded by the dark energy. Expansion speed has been reduced because the amount of dark energy has also decreased due to increase of BHs. The matter and energy fallen in BHs have been transited onto Ω^* via WHs, and the amount of anti-matter on Ω^* has increased. The BHs are collapsed and disappear for a while, and eventually whole energy is transited onto Ω^* and nothing (exactly speaking a light appeared in BH evaporation is remnant) in the universe after all. On the other hand, on Ω^*, first there is only space, and once the WHs appear, energy increases and space is shrunk by anti-dark energy. Eventually the universe ends up to Big Crunch.

filled by BH, and eventually the universe becomes void space, where a light created by Hawking radiation of BH evaporation [20] remains.

Since the time-flow of the extended Riemann sphere is reversed from that of Riemann sphere, in the inverse universe a WH first appears in void space, and anti-matter and anti-dark energy are emitted from WH. Here the universe shrinks due to the dominance of attractive force of anti-dark energy, and time-flow is then directed to the Big Crunch (see Figure 3). The matter including information fallen in the BH is emitted from the WH, and following time-flow, WH's size becomes small, and eventually disappears by Hawking radiation (see Figure 4).

Once the Big Crunch happens, assuming the transition from Big Crunch to Big Bang at the nearly infinity point i^+ in the inverse universe, anti-matter and anti-dark energy are transformed to normal ones as in our universe. Back to

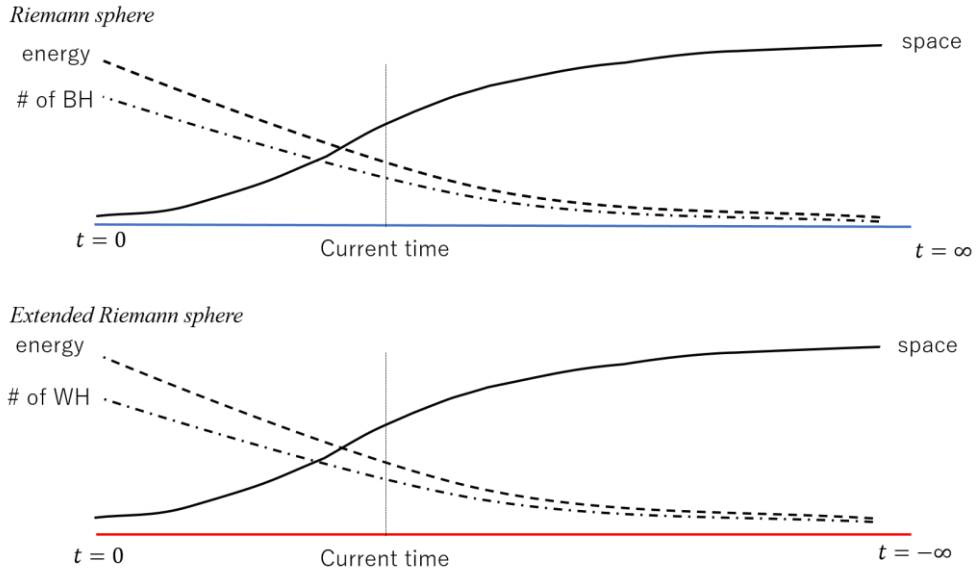

Figure 4. The amount of energy (or information), BH (top) and WH (bottom), and size of space on **Ω** (top) and **Ω*** (bottom) as a function of time flow. Total amount of energy is invariant, while, on each side, the energy flows from **Ω** to **Ω*** through BH and WH. A space of **Ω** has been initially spread since repulsive force of dark energy is rich, but its speed is gradually reduced since the dark energy has been transformed by BH/WH conversion. On the other hand, a space of **Ω*** is decreased since an attractive force of anti-dark energy has been increase through BH. Current out position is relatively close to Big Bang, and the universe is still expanding due to rich dark energy.

Figure 2, one can see that the kinematics on the extended Riemann sphere approach infinity i^+ at the north pole, and through the transition point, the kinematics start from the south pole on Riemann sphere. This model provides the new cyclic cosmology. From the perspective of Riemann and the extended Riemann sphere, the matter circulates in two universes with different time-flow through the polarity of Riemann spheres.

In our model, total amount of matter is invariant on $\Omega + \Omega^*$; however individually it is changed along the time-flow. As shown in Figure 4, matter on Ω is transformed to Ω^* through BH/WH conversion, and it then decreases on Ω and increases on Ω^*. The size of space, which is affected by the attractive force and repulsive force of matter (anti-dark energy) and dark energy (anti-matter) in our universe (inverse universe), respectively, is consistently changed on both Ω and Ω^*. On Ω, initially there filled the repulsive force of dark energy in the early universe and space was quickly spread. The number of BH increases after collapsed massive star, and simultaneously increasing the amount of matter and dark energy fallen in BH, the energy is reduced in Ω. So that the size of space is

asymptotically close to a constant when the amount of matter and dark energy in Ω is reduced to be zero. On Ω^*, initially a WH appears and repulsive force of anti-gravitational force of anti-matter is filled in the inverse universe, and it then spreads a space. Increasing anti-dark energy which comes through BH in Ω, the attractive force increases, while WHs disappear due to evaporating its energy. As a consequence, a space starts shrinking and disappears in Big Crunch, and its matter backs to a normal one starting from Big Bang.

5 Discussion and summary

In this article we propose the new idea to solve the cosmological problems, BH information loss, WH non-existence and before Big Bang, by introducing the inverse universe and BH/WH conversion. Our idea is that the matter behind the event horizon of BH is directed to the infinity point in which the time-reversed operation is taken and converted to the anti-matter, eventually emitted from WH in the inverse universe. Now the information in BH is just transformed onto that in the inverse universe via WH. In our model, WH should exist in the inverse universe as a pair of BH, and matters fallen in BH are converted to anti-matter in the inverse universe. Considering the representation of our model with Riemann sphere, we also derive a new cyclic cosmology in which Big Crunch in the inverse universe is connected to Big Bang in our universe at the nearly infinity point. Here the anti-dark energy plays an important role to shrink the universe with its attractive force, as an opposite role of dark energy. We comment that our solution to the BH information loss is retained in classical gravity and no assumption of unitarity violation of quantum mechanics. Behind the event horizon of BH, the reversibility of initial and final state is regarded as the BH/WH conversion, and ensemble of final state is transformed into the inverse universe. In addition, we argue that for its solution it is possible to separate between quantum effect and gravity, namely such an issue is nothing to do with the argument of holography [21].

Here one also has a question: “How can we experimentally observe the inverse universe?”. We consider such an observation will be the new phenomena of breaking time-reversal symmetry in our universe. In Figure 1, we assume a hard border of geometry between Ω and Ω^*, however taking into account a quantum effect, besides extremely small probability, the extra particle possibly appears from the inverse universe by penetrating through such a hard border (like a quantum tunneling) even in the outside of event horizon. Such a phenomenon can be seen as asymmetry of particle and anti-particle in our universe. Note that to observe it, we experimentally need a high energy insertion to amplify the probability to access the inverse universe.

Now we propose that a reason of "why is particle richer in our universe than anti-particle?" (known as a baryon asymmetry problem [22]) is an emergence of the extra particle from the inverse universe due to quantum effect in the early universe. At the beginning of Big Bang, the number of particle and anti-particle was exactly same and annihilated each other, however its symmetry was accidentally broken by extra particle of the inverse universe. At last, after expanding and cooling down our universe, such an extra particle remains and constitutes stars and us (such an accidental event simultaneously happened and oppositely anti-particle became richer in the inverse universe.). In this scenario, an appearance of extra particle should be detected in the search of time-reversal symmetry breaking (same as CP violation) in the microscopic scale, *e.g.* non-zero electric dipole moment of particle [23]. Although there have been many models to explain the time-reversal symmetry breaking in high energy physics [24], those models need to assume the new particles, for instance supersymmetry particles, despite no evidence of those detection. On the other hand, our scenario does not assume any new particles even in high energy scale (over TeV scale), and simply such a breaking will occur within the framework of the standard model of particle physics. In a current situation of no discovery of the new particle beyond the standard model even in Large Hadron Collider experiment over 1 TeV energy [25], our scenario is rather reasonable compared to high energy models.

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