Principle of Spacetime Black Hole Equivalence

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A new principle of spacetime black hole equivalence (SBHEP) is proposed. In addition to Einstein's general relativity and the cosmological principle, the SBHEP principle provides the third base for the black hole universe model that was recently developed by the author in attempt to model the universe, explain existing observations, and overcome cosmic problems and difficulties without relying on a set of hypothetical entities. A black hole universe does not have the horizon and flatness problems so that an inflation epoch is not required. Its origin from starlike and supermassive black holes removes the initial big bang singularity and magnetic monopole problems. A black hole or spacetime is static or in equilibrium when it does not accrete or merge with others, otherwise it becomes dynamic, expands, and emits. Gamma ray bursts, X-ray flares from galactic centers, and quasars can be self-consistently explained as emissions of dynamic starlike, massive, and supermassive black holes. Cosmic microwave background radiations are blackbody radiations of the black hole universe, an ideal blackbody. A black hole universe can accelerate if it accretes matter in an increasing rate, so that an explanation of the supernova measurements does not need dark energy.

1 Introduction

Cosmology is the study of the origin and development of the universe. The currently accepted standard big bang model of the universe (BBU) stands on two bases, which are (1) Einstein's general relativity (GR) that describes the effect of matter on spacetime and (2) the cosmological principle (CP) of spacetime isotropy and homogeneity that generates the Friedmann-Lemaître-Robertson-Walker (FLRW) metric of spacetime [1–4]. The Einstein field equation given in GR along with the FLRW metric of spacetime derived from CP produces the Friedmann equation (FE) that governs the development and dynamics of the universe. Although the big bang theory has made incredible successes in explaining the universe, there still exists innumerable problems and difficulties. Solutions of these problems and difficulties severely rely on an increasing number of hypothetical entities (HEs) such as dark matter, dark energy, inflation, big bang, and so on [5]. Therefore, the BBU consists of GR, CP, and innumerable HEs, *i.e.* BBU = {GR, CP, HE, HE, HE,....} (see the blue part of Fig. 1). Although it has only two bases (GR and CP), the BBU severely relies on an increasing number of HEs that have not yet been and may never be tested or falsifiable.

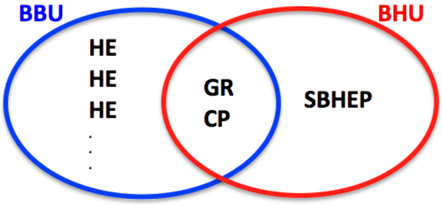

Fig. 1: The comparison of fundamentals between BBU and BHU (see Section 1 for details).

Describing the universe without relying on a set of HEs to explain observations and overcome cosmic problems and difficulties is essential to developing a physical cosmology. Recently, the author has developed a new physical cosmology called black hole universe (BHU) [6–7]. Instead of making many those HEs as the BBU did, the BHU proposes a new principle to the cosmology – the Principle of Spacetime Black Hole Equivalence (SBHEP) – in an attempt to explain all the existing observations of the universe and overcome all the existing problems and difficulties [8–12]. Standing on the three bases (GR, CP, and SBHEP), the new cosmological theory – BHU = {GR, CP, SBHEP} (see the red part of Fig. 1) – can fully explain the universe in various aspects as well as to conquer all the cosmic problems according to the well-developed physics without making any other HEs and including any other unsolved difficulties. GR and CP are common to both BBU and BHU. The BBU stands on two legs unstably so that needs many crutches for support, while the BHU stands on three legs stably without needing any other props. In the BHU, a single SBHEP removes all of innumerable HEs made in the BBU. This paper describes how this new black hole universe model explains the universe and conquers the cosmic difficulties with the principle of spacetime black hole equivalence.

2 Equivalence between spacetime and black hole

The effect of matter on spacetime can be obtained by solving Einstein's field equation provided in GR [13],

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} \tag{1}$$

where the subscripts μ and ν are the four-dimensional (4D) spacetime coordinate indices running through 0–3. $G_{\mu\nu}$ is

Einstein's curvature tensor, G is the gravitational constant, c is the speed of light in free space, and $T_{\mu\nu}$ is the 4D energy-momentum tensor. Adding a term of $\Lambda g_{\mu\nu}$ to the left hand side of (1), Einstein developed a static cosmology [14] and de Sitter developed a dynamic cosmology [15]. Here Λ is the cosmological constant and $g_{\mu\nu}$ is the metric of spacetime,

According to the cosmological principle, the universe, if it is viewed on a scale that is sufficient large, is homogeneous and isotropic. This principle implies that there is no special location and direction in the universe. The properties of the universe are the same for all observers in the universe. More strongly, physical laws are all universal. If a physical law is applicable to the Earth, then it can be applied to everywhere. The isotropic and homogeneous spacetime can be described by the FLRW metric [1–4],

$$\begin{aligned} ds^2 &= -g_{\mu\nu}dx^\mu dx^\nu \\ &= c^2dt^2 - R^2(t)\left[\frac{dr^2}{1-kr^2} + r^2\left(d\theta^2 + \sin^2\theta d\phi^2\right)\right], \end{aligned} \tag{2}$$

where $R(t)$ is the radius of curvature of the space and k is the curvature constant of the space.

Substituting the FLRW metric of spacetime into the Einstein field equation of general relativity, one can have the Friedmann equation [16],

$$H^2(t) \equiv \frac{\dot{R}^2(t)}{R^2(t)} = \frac{8\pi G\rho(t)}{3} - \frac{kc^2}{R^2(t)}, \tag{3}$$

where $H(t)$ is the Hubble parameter or the expansion rate of the universe and ρ is the density of matter. The dot sign refers to the derivative of the quantity with respect to time, $\dot{R}(t) \equiv dR(t)/dt$. Including the cosmological constant, (3) has a term of $\Lambda/3$ on the right hand side.

According to the Schwarzschild field solution of (1) [17], the metric of spacetime surrounding a spherical body with mass M appears to be singular at the Schwarzschild radius $r_g = 2GM/c^2$, which divides the space into two disconnected patches. This indicates that a region of space, where matter accumulates up to a critical level such that the mass-radius (M-R) ratio reaches up to $M/R = c^2/(2G) \simeq 6.67 \times 10^{26}$ kg/m, forms a black hole and constructs its own spacetime, which is singular in space and non-causal in time to the outside. Therefore, it is reasonable to suggest or postulate that a black hole once formed constructs its own spacetime and a spacetime encloses its own unique black hole [6–7]. In other words, spacetime and black hole are equivalent. This postulate of the equivalence between spacetime and black hole plays a fundamental role in the modeling of the universe; therefore, we raise it as a new principle of the cosmology [18]. Without matter, a physical spacetime cannot be formed; without a spacetime, matter cannot become into existence. As a moral idea or belief, we cannot prove its correctness mathematically, but the truth for the principle of spacetime black hole equivalence can be justified and validated through explaining various observations of the universe, such as CMB and supernova measurements, *etc.*, and overcoming cosmic problems, such as dark energy and inflation problems, *etc.*, in accordance with the black hole model of the universe that is developed on the basis of this principle. In the following sections, we will demonstrate how the black hole model of the universe developed on the basis of this new principle to explain the observations of the universe and overcome the cosmic problems and difficulties.

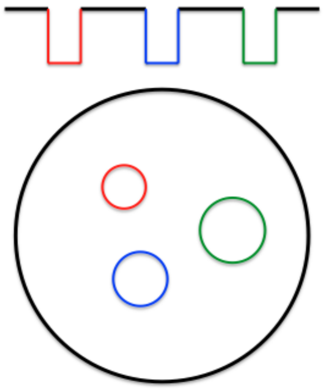

Fig. 2: The hierarchically layered structure of black hole universe. Inside our spacetime or black hole universe (the region represented or circled by the solid black lines), there are a number of subspacetimes (the regions represented or circled by the solid color lines), which are the observed star-like, massive, and supermassive black holes.

3 Black hole universe

From this principle of spacetime black hole equivalence, we understand that our universe, because it is constructed in a 4D spacetime, is or wraps a black hole, which is extremely supermassive and fully expanded. Its big radius and enormous mass can be determined in terms of the measurement of matter density of the universe as detailed below in the subsection 3.1. The inside observed star-like, massive, and supermassive black holes can be considered as subspacetimes (or called child universes) of our black hole universe (see Fig. 2). This hierarchically layered structure of spacetimes and subspacetimes genuinely overcomes the horizon problem, which was identified to exist in the big bang model of the universe primarily by Charles Misner in 1960s [19–20] and solved by Alan Guth in 1980s with the hypothesis of cosmic inflation [21] according to a field that does not correspond to any physical field. Therefore, in the black hole model of the universe, there does not exist the horizon problem at all.

3.1 Mass-radius relation and spacetime equilibrium

The boundary of a spacetime or black hole is determined, according to the Schwarzschild solution, by

$$\frac{2GM}{c^2R} = 1, \tag{4}$$

which is also the relation of the effective mass and radius of the universe according to Mach's principle [22–24] as well as the relation of the observable mass and radius of the universe according to observations. The mass and radius of a spacetime or black hole satisfy this Mach-Schwarzschild M-R relation. The space curvature constant of a closed spacetime or black hole is positive, *i.e.*

$$k = 1. \tag{5}$$

It is noted here that the big bang model suggests that the spacetime of the universe is flat (*i.e.* $k = 0$).

The cosmological principle expresses the matter inside a spacetime or black hole to be uniformly (*i.e.* isotropically and homogeneously) distributed in a scale which is sufficiently large (*i.e.* comparable rather than too small) in comparison with respect to the size of the spacetime. Then, the density of matter in a spacetime or black hole is given by

$$\rho \equiv \frac{M}{V} = \frac{3c^2}{8\pi G R^2} = \frac{3c^6}{32\pi G^3 M^2}, \tag{6}$$

which is inversely proportional to the square of radius or the square of mass. This square-law density expression (ρR^2 = constant or ρM^2 = constant) naturally removes the flatness problem of the universe, which was first pointed out by Robert Dicke in the BBU [25–26].

Therefore, the flatness (or fine-tuning) problem does not exist in the black hole model of the universe. Furthermore, by measuring the density, we can determine both the radius and mass of the universe. For the density of the present universe to be about the critical density $\rho_0 \sim \rho_c \equiv 3H_0^2/(8\pi G)$, we have the mass and radius of the present universe to be $M_0 \sim 8.8\times10^{52}$ kg (about a half hundred sextillions of solar masses) and $R_0 \sim 1.32 \times 10^{26}$ m (about forty-three hundred Mpc or one Hubble length). Here, according to measurements [27–30], the Hubble constant is chosen as $H_0 = 70$ km/s/Mpc. Therefore, the present universe is an extremely supermassive and fully expanded black hole with extremely low density and weak gravity. The gravitational field at its surface is $g_0 = GM_0/R_0^2 \sim 3 \times 10^{-10}$ m/s^2 and thus a 100-kg object at the surface or inside only weighs 3×10^{-8} N or less.

The big bang universe is an isolated system and the total energy or mass (though unknown) is a constant, so that the density is inversely proportional to the cube of radius (*i.e.* ρR^3 = constant). Fig. 3 plots the density of a black hole as a function of its radius in the unit of kilometers (the solid line) or a function of the mass in the unit of 0.337 solar masses (the same line). The dashed line plots the density of the big bang universe as a function of its radius with mass equal to M_0 (for a bigger mass, the line is shifted to a larger radius). The dotted line marks the density of the present universe (ρ_0) and its intersection with the solid line shows the mass (M_0), density (ρ_0), and radius (R_0) of the present universe. Three circles along the solid line represent a star-like black hole with three solar masses, a supermassive black hole with three billion solar masses, and the present black hole universe with mass M_0. The black hole universe is not an isolated system because its mass increases as it expands. The density decreases inversely proportional to the square of the radius (or the mass) of the black hole universe. Considering that matter can enter but cannot exit a black hole, we can suggest that the black hole universe is a semi-open system surrounded by outer space and matter. The entire space is infinite, existed forever, and isolated. It contains everything without outside and edge. Inside the entire space, any universe has outside space and matter and thus cannot be isolated.

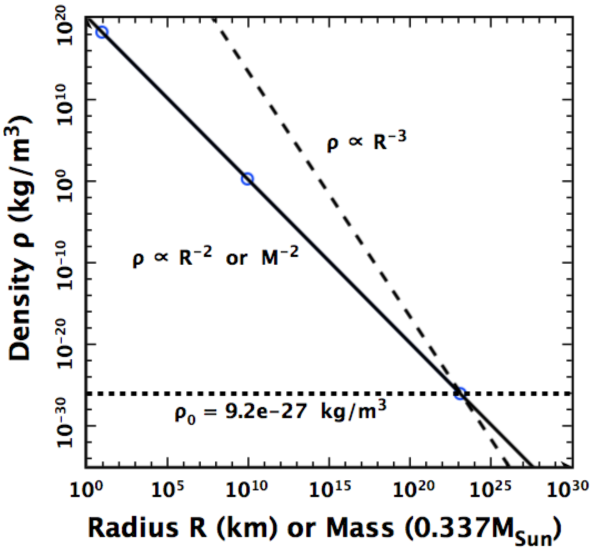

Fig. 3: The density of the black hole universe versus its mass and radius (the solid line). The dotted line refers to $\rho = \rho_0$, so that the intersection of the solid and dotted lines represents the density, radius, and mass of the present universe. The dashed line plots the density of the big bang universe, if it has mass M_0, as a function of the radius.

In the black hole universe model, we have that the effective and observable radii are the actual radius of the universe at all time, so that the black hole universe is always all observable and Mach's principle holds forever. In the big bang theory, the ratio between the effective radius and the radius of the universe increases as the universe expands and will reach the unity at a point, which is the present time if the universe has mass M_0. Before the point, the effective radius is less than the radius of the universe. While, after the point, the effective radius will be greater than the radius of the universe, at which Mach's principle does not hold, so that other physical laws neither hold.

According to GR and the stellar physics, a star with 20 or more solar masses, at the end of its life, will form a black hole after a supernova explosion [31]. Therefore, the black hole model of the universe does not need a big bang. The universe can be considered to originate from a star-like black hole (child universe) with several solar masses, which grows through a supermassive black hole with billion solar masses to the present universe with hundred-sextillion solar masses by accreting ambient matter and merging with other black holes. Which one was the first or initial black hole that the universe has grown up from is not critical or important to the present universe because the mass of the original one only takes one part of a sextillion in the present universe. This origin of the universe from black holes not only overcomes the fine-tuning problem but also conquer the difficulty of banging the universe out from nothing that violates the law of conservation of energy. This resolves the big bang singularity problem. In addition, if the universe originated from a star-like black hole, it would not be hot enough to create a magnetic monopole in any time period, thus solving the magnetic monopole problem. The recent discovery of gravitational waves confirms the existence and merger of black holes [32] and thus support this black hole model of the universe.

Substituting the Mach-Schwarzschild M-R relation (4) (or density (6)) and positive space curvature constant (5) into the Friedmann equation (3), we have $\dot{R} = 0$ and $\dot{M} = 0$ – a zero rate of change in radius or mass. This indicates that a spacetime or black hole is static [7,33] when it neither accretes matter from the outside nor merges with other black holes. In the static state, the spacetime reaches equilibrium because the positive curvature balances the gravity entirely. A spacetime with the curvature radius R can hold the matter with mass equal to $c^2R/(2G)$ in equilibrium. Hawking [34] theorized the surface radiation of a static black hole with the quantum effect. For a star-like or more massive black hole, the Hawking radiation is negligibly weak and ultra-cold, which leads to the entropy of a static black hole to be 20 orders higher than its massive parent star. Including the cosmological constant, (3) determines Λ in the static state as $\Lambda = 3H^2$, which is $\sim 1.55 \times 10^{-35}$ s^{-2}.

3.2 Expansion and acceleration of spacetime

When a spacetime or black hole accretes its ambient matter or merges with other black holes, it becomes dynamic and expands. The rate of expansion or Hubble parameter is given by

$$H = \frac{\dot{R}}{R} = \frac{\dot{M}}{M}, \tag{7}$$

and the deceleration parameter is given by

$$q = -\frac{R\ddot{R}}{\dot{R}^2} = -\frac{M\ddot{M}}{\dot{M}^2}. \tag{8}$$

Here, the double dot symbol refers to the second order derivative of the parameter with respect to time. A spacetime or black hole expands if it gains matter, *i.e.* $\dot{M} > 0$, and accelerates if it gains matter in an increasing rate, *i.e.* $\ddot{M} > 0$. The expansion of spacetime is physical and outward without violating Einstein's light-speed upper limit and conservation of energy. A spacetime or black hole grows its space as it accretes matter by taking the outside space rather than by stretching the space of itself geometrically.

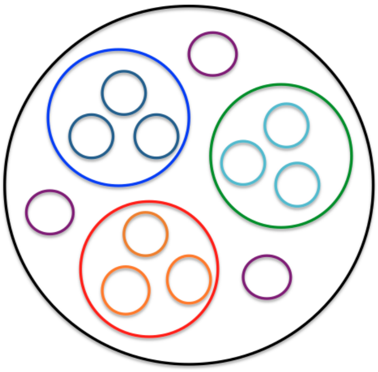

Fig. 4: A simple sketch of the innermost three layers of the entire space that is structured hierarchically. The black circle represents the mother universe. Our black hole universe is coded as red, in which three child universes (*i.e.* star-like or supermassive black holes) were drawn. Parallel to our universe, there are sister universes. Here two adult sister universes (blue and green circles) and three little sister universes (brown circles). The adult sister universes have also their child or baby universes, but the little sister universes are too young to have their babies.

For a spacetime or black hole including our black hole universe to expand, it must have an outside, where matter is available for accretion. The black hole model of the universe suggests that the entire space is structured with layers, hierarchically and family-like. Fig. 4 sketches the innermost three layers of the black hole universe including the mother universe (black circle), our universe itself (red circle), and child or baby universes (*i.e.* star-like or supermassive black holes). We have only drawn three child universes (yellow circles). We have also drawn two adult sister universes (blue and green circles) and three little sister universes (brown circles), which are universes parallel to our black hole universe. The adult sister universes have also their child universes. There should have a number of child universes and may also have many sister universes. A child universe grows by accreting material from its outside or by merging with other child universes. This universe grows up by accreting material from the mother universe or by merging with sister universes. The mother universe will also grow up if it has outside; otherwise, it is static. If the whole space is finite, then the number of layers is finite. Otherwise, it has infinite layers and the outermost layer corresponds to the limit of zero Kelvin for the absolute temperature, zero for the density, and infinite for the radius and mass.

From the data of type Ia supernova measurements, Daly et al. obtained the deceleration parameter of the present universe to be $q_0 \sim -0.48$ for the flat spacetime (for a closed spacetime, q_0 is smaller, *e.g.* $q_0 = -0.6$) [35]. Riess et al. and Perlmutter et al. explained the acceleration of the universe by suggesting the big bang universe to be dominated by dark energy up to about $\sim 73\%$ [36–37]. In the black hole universe model, however, the universe accelerates because it inhales the outside matter in an increasing rate, *i.e.* a positive $\ddot{M} > 0$. To have $q_0 = -0.48$, the present black hole universe only needs to inhale the outside matter in an increasing rate at $\ddot{M}_0 = -q_0 M_0 H_0^2 \sim 2.2 \times 10^{17}$ kg/s^2 (or about 220 solar masses per year square).

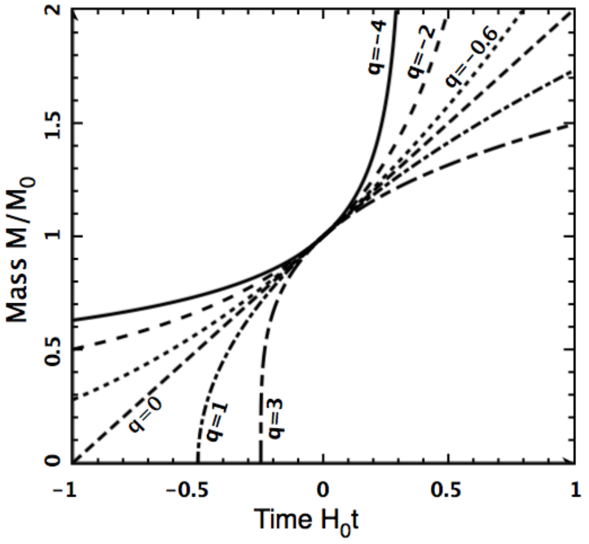

Fig. 5: Mass of black hole universe versus time with various deceleration parameters $q = -4, -2, -0.6, 0, 1, 3$.

For a constant acceleration expansion universe, the time-dependent mass can be analytically solved from (8) as [10],

$$\frac{M}{M_0} = \left[(q+1)H_0 t + 1\right]^{1/(q+1)}. \tag{9}$$

To quantitatively see how the mass $M(t)$ varies with time and depends on the deceleration parameter q, we plot in Fig. 5 according to (9) the mass as a function of time with various values of $q = -4, -2, -0.6, 0, 1, 3$. The lines with negative q are concave upward, which show that the mass increases in an increasing rate and the universe accelerates. The lines with positive q are concave downward, which show that the mass increases in a decreasing rate and the universe decelerates. For $q = 0$, the black hole universe accretes matter or increases its mass in a constant rate and thus expands uniformly.

The cosmological redshift of light from a source in an expanding spacetime is determined by

$$1 + Z = \frac{R_0}{R} = \frac{M_0}{M}. \tag{10}$$

The luminosity distance of the light source depends on the redshift as [10,38–39],

$$\begin{aligned} d_L &= (1+Z)M_0 \sin\left[\int_t^0 \frac{cdt}{M}\right] \\ &= (1+Z)R_0 \sin\left[\frac{c^3}{2GM_0H_0}\frac{1-(1+Z)^{-q}}{q}\right]. \end{aligned} \tag{11}$$

Here we have applied (9) and (10) to complete the integration. Eq. (11) reduces to the Hubble law, $H_0 d_L = cZ$, at Z $\ll$ 1 [40] and perfectly explains the type Ia supernova measurements if the universe accretes matter in an increasing rate of $q = -0.6$ [34]) or $\ddot{M} \sim 3 \times 10^{17}$ kg/s^2 in average [10].

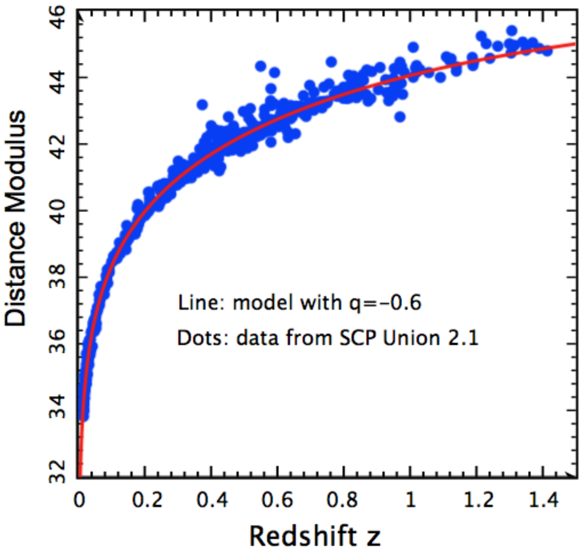

Fig. 6: Luminosity distance-redshift relation of type Ia supernovae. Blue dots are measurements credited by the Union2 compilation of 580 SNeIa data from Supernova Cosmology Project [41–42]. Red line is analytical results from this study with $q = -0.6$. The distance modulus is plotted as a function of the cosmological redshift.

Fig. 6 plots the luminosity distance-redshift relation (red line) along with the type Ia supernova measurements (blue dots), which are credited by the Union 2.1 compilation of 580 SNIA data from Supernova Cosmology Project [41–42]. In this plot the Hubble constant is chosen to be $H_0 = 70$ km/s/Mpc and the deceleration parameter is chosen to be $q = -0.6$. The distance modulus, which is defined by $\mu = 5\log_{10} d_{\rm L} - 5$ with $d_{\rm L}$ in parsecs, is plotted as a function of redshift. The chi-square statistic is very close to unity [10]. Therefore, the black hole universe model can perfectly explain the measurements of type Ia supernovae without dark energy, which is needed to take $\sim 73\%$ in the big bang universe [36–37].

3.3 Temperature of spacetime and background radiation

The temperature inside a spacetime or black hole depends on the state and density of matter enclosed and hence depends on the radius or mass. The stellar physics has shown that a neutron star can reach trillions of Kelvin at the moment of its birth and then quickly cools down to hundred millions of Kelvin due to strong radiation and neutrino emissions. Since it is compact as a neutron star, a star-like black hole should also initially reach trillions of Kelvin but statically holds this hotness due to lack of significant emissions to the outside (the Hawking radiation is negligible). The thermal radiation inside a spacetime or black hole is the blackbody radiation governed by the Planck law, from which one can derive the total energy of blackbody radiation inside a spacetime or black hole with radius R and temperature T to be

$$U_\gamma = \alpha R^3 T^4. \tag{12}$$

Here, the constant α is given by, $\alpha \equiv 32\pi^6 k^4/(45h^3c^3) \sim 3.2\times10^{-15}$ J/m^3/K^4, with k the Boltzmann constant and h the Planck constant.

When a spacetime or black hole accretes matter and radiation from its outside, it becomes dynamic and expands. Considering that the gain of matter and radiation inside is equal to the loss of matter and radiation outside, we have [8]

$$\frac{dT}{dR} = -\frac{3T}{4R}\left[1 - \left(\frac{T_p}{T}\right)^4\right], \tag{13}$$

where T is the temperature inside and T_p is the temperature outside. This equation governs the thermal history of the black hole universe from its origin as a star-like black hole with several solar masses and growing through a supermassive black hole with billions of solar masses to the present state with hundred sextillions of solar masses. Since the temperature outside is always less than that inside, $T_p < T$, the temperature of a spacetime or black hole decreases with its radius. As the black hole universe grows in size from a star-like black hole to the present state, its temperature decreases from trillions of Kelvin to about 3 K [8]. The cosmic microwave background radiation (CMB) is explained as the blackbody radiation of the black hole universe – an ideal blackbody – rather than the fireball leftover of the big bang universe.

Considering the black hole universe to decrease its relative temperature in a rate slightly faster than the mother universe, we have [8]

$$T_p = aT^b, \quad \text{or} \quad T_p/T = aT^{b-1} \tag{14}$$

Here b is a constant slightly less than 1 and a can be derived from b according to the temperature and radius of the present universe (T_0 and R_0). Then, (13) can be analytically solved as

$$T = R^{-3/4}\left(a^4 R^{3-3b} + T_s^{4-4b} R_s^{3-3b}\right)^{1/(4-4b)}, \tag{15}$$

where the constant a is given by

$$a = \left[T_0^{4-4b} - \left(\frac{R_s}{R_0}\right)^{3-3b}\right]^{1/4}. \tag{16}$$

Choosing b appropriately (or slightly less than 1), we can completely determine the thermal history of the black hole universe that evolved from a hot star-like black hole with temperature T_s and radius R_s to the present universe with temperature T_0 and radius R_0. In Fig. 7, the temperature of the black hole universe is plotted as a function of the universe radius with $b = 0.93$. Here we have chosen $T_0 = 2.725$ K, $R_0 = 1.32 \times 10^{26}$ m, $R_s = 8.9$ km, and $T_s = 10^{12}$ K.

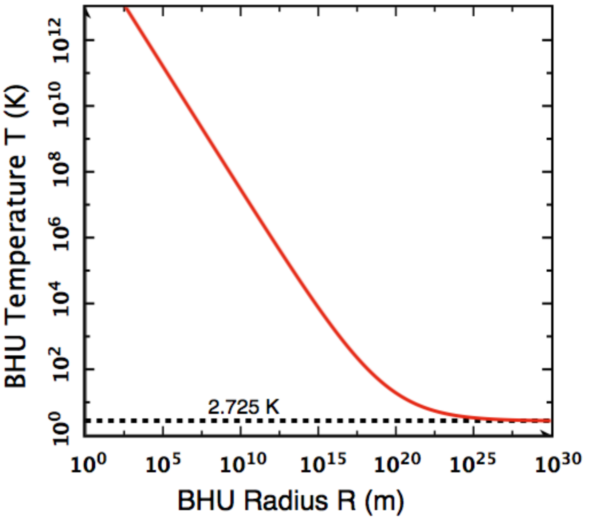

Fig. 7: The possible thermal history of the black hole universe. A hot star-like black hole with $T_s = 10^{12}$ K expands to the size of the present universe and cools down to $\sim$ 2.725 K. The temperature line is curved by concaving upward and approaches $\sim$ 2.725 K at the present time as the black hole universe expands to the present size.

It is seen that the temperature line is concave upward and approaches $\sim$ 2.725 K as the black hole universe expands to the present size. The initial temperature of the star-like black hole T_s is not critical to the present universe. The reason is because most matter and radiation are from the mother universe. This reason also explains why all other physical properties of the star-like black hole, including its size (or mass), angular momentum, and charge, and the evolution of the early universe are not critical to the present universe. Furthermore, the early process of material accretion and black hole mergers do not have significant leftover in the present universe.

The above explanation of the CMB of this universe requires a decreasing temperature outside, *i.e.* an expanding mother universe. To have an expanding mother universe and explain its CMB with a decreasing temperature, there needs an expanding grandmother universe, and so forth. Therefore, the entire space is eternal and infinite, containing everything with infinite layers (Fig. 8). Nothing can be outside the entire space. The star-like or supermassive black holes called child universes belong to the innermost layer. They are subspacetimes of our black hole universe (the second innermost layer) that we live in. Our black hole universe is a subspacetime of the mother universe (the third innermost layer). The mother universe may contain a great number of child universes that are parallel to (and hence sisters of) our black hole universe. Mathematically, we can use an infinite large family tree that contains infinite generations or an infinite large set that contains infinite subsets to represent the relationships among different generations of black hole universes. The outermost layer called grand universe is infinitely large in size, mass, and entropy but has zero limits for both the density and absolute temperature.

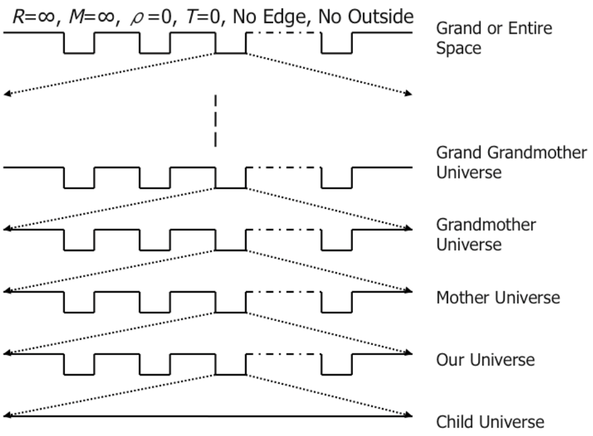

Fig. 8: The entire space with infinite layers or subspacetimess [8]. The bottom layer is a child universe or an empty spacetime. The child universe is a subspacetime of the universe in which we live in. Similarly, our universe is a subspacetime of the mother universe, and so on. The top layer is the entire space of all subspacetimes.

Each layer or black hole universe tends to absorb its outside matter and radiation and takes its outside space and expands outward. When our black hole universe expands to be one as large as the mother universe, the inside star-like and supermassive black holes will have merged and grown up into a black hole universe that is similar to the present one. This process is irreversible with neither a beginning nor an end. The evolution of black hole universe is iterative – beginningless and endless. When one black hole universe is expanded out, a new similar black hole universe is formed from inside child universes [7]. The black hole model of the universe is complete because it can address our universe not only at the present as well as its inside, but also in the past and future as well as its outside.

The total radiation energy inside the black hole universe is plotted in Fig. 9 as a function of the radius. It is seen that a young black hole universe with radius less than 10^{15} m or mass less than some hundred billions of solar masses remains the total radiation energy as a constant. This characteristic allows us to explain the activities and emissions of dynamic star-like and supermassive black holes observed in the universe.

3.4 Emissions of dynamic black holes

For a star-like black hole with several solar masses to grow through a supermassive black hole with billion solar masses, the temperature outside is negligibly lower than the temperature inside, *i.e.* $T_p \ll T$. In this case, (13) can be solved as

$$R^3 T^4 = \text{Constant}, \tag{17}$$

which implies that the total radiation energy inside a spacetime or black hole with mass about billions of solar masses or less remains the same amount as shown in Fig. 9. Therefore, accreting outside matter and radiation or merging with other black holes into a single one, a black hole not only becomes dynamic and expands but also intensively emits its inside hot and hence high-frequency blackbody radiation out of its horizon, which has been disturbed or broken by the accretion or merger in order for the total energy of its inside radiation to remain as a constant.

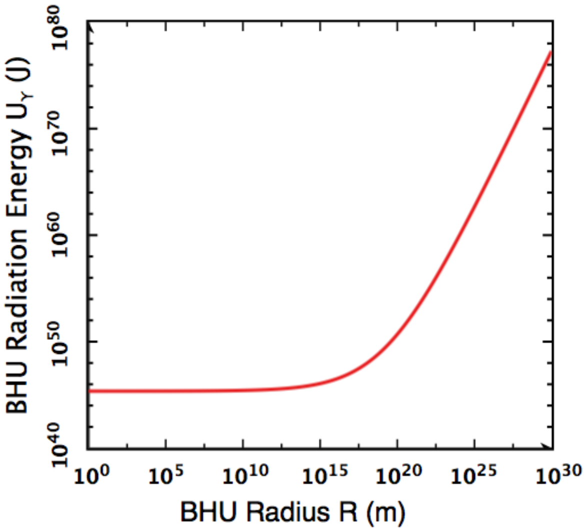

Fig. 9: Radiation energy of the black hole universe. As a hot star-like black hole with $T_s = 10^{12}$ K expands to the size of the present universe and cools down to ∼ 2.725 K, its radiation energy first remains as a constant and then rapidly increases with radius when it grows into a supermassive black hole with radius greater than about thousand billions of kilometers or mass greater than about hundred billions of solar masses.

This emission mechanism of dynamic black holes can self-consistently explain the observed gamma ray bursts, X-ray flares from galactic centers, and quasar emissions as emissions of dynamic star-like, massive, and supermassive black holes, respectively (the details on these have been described in [9,11–12]). Dynamic star-like black holes with trillions of Kelvin radiate gamma rays and produce gamma ray bursts, while dynamic massive or supermassive black holes with millions to billions of Kelvin radiate X-rays such as X-ray emissions from quasars and X-ray flares from Sgr A* (a massive black hole at the Milky Way center). The energetic events associated with black holes are activities of child universes. The author has shown that a child universe with radius $R \gtrsim 10^{18}$ m or mass $M \gtrsim 3 \times 10^{14}$ solar masses does not emit [9], but can strongly attract and accrete its ambient matter including galaxies, which may help us to understand great attractors observed with thousand trillions of solar masses, *e.g.* the Norma Cluster. On the other hand, quasars if electrically charged may have a significant electric redshift as illustrated by [43]. The merger of star-like black holes if missing mass may release significant gravitational waves as recently detected by LIGO [32].

4 Discussion and conclusions

In addition to above issues that have been addressed in details in the early papers [7–12,39], the black hole model of the universe can also self-consistently illustrate various other problems of the universe such as why the redshifts of galaxies are quantized, how the galaxies and clusters are formed, why the expansion of the universe can be anisotropic, how the elements are synthesized, why the universe increases its entropy extremely without significantly increasing its disorder, how the heavy-ion enriched objects are formed in extremely deep fields or the young universe, what the great attractor is, why the voids exist, and so on. Preliminary results on some of them have been presented in a sequence of AAS (213rd-215th, 217th, 219th-224th, 228th) meetings and the details on all these problems will be addressed in future in full length papers.

The BHU stands on three bases, which are (1) GR of describing matter effect on spacetime, (2) CP of spacetime homogeneity and isotropy, and (3) SBHEP of spacetime black hole equivalence. We have not yet explored the quantum effect on this model to pop up baby universes and holes. In this model, baby or child universes are star-like and supermassive black holes, which are formed from stars and galaxies. To appropriately explain CMB, the entire space is favored to be infinite and eternal and includes infinite universes, which are layered hierarchically and evolved iteratively. Due to gravity and Jeans collapse criterion, matter forms stars, which then, if massive, end as black holes or child universes. A black hole, once formed, will grow and expand by accreting its ambient matter and merging with other black holes. A galaxy (usually including a massive black hole at its center), once most stars run out their fuels and died as dwarfs, neutron stars, and black holes, will eventually form a supermassive black hole (or quasar) by accreting all galactic matter and objects, and merging all stellar black holes into the massive black hole at the center. LIGO recently discovered the gravitational wave that confirms the existence of black holes and their merger [32]. A black hole universe can be considered to be originated or born from a star-like black hole (or child universe) without a big bang singularity, flatness, horizon, and magnetic monopole problems. It gradually grows or expands by accreting outside matter or merging with other black holes without dark energy and inflation problems. Each star-like black hole or supermassive black hole is usually rotating with significant angular momentum. But when many randomly rotating black holes merge to form a large universe like our present universe, the net angular velocity may be negligibly small. Inside a fully expanded or grown universe, objects formed from the collapse of matter (*e.g.* planets, stars, galaxies, clusters, *etc.*) can rotate globally. Gamow speculated that the rotations of these objects might be due to the cosmic rotation [44] and Godel obtained a cosmological solution of Einstein's field equation for rotating universes [45]. The black hole model of the universe is a model with multiverses (infinite or uncountable), which are hierarchically layered. It is different from other models of multiverse such that the many-world (or universes) interpretation of quantum physics proposed by [46] and the branes model of multiverse that suggested the visible 4D spacetime universe to be restricted inside a higher-dimensional space [47].

The three bases of BHU (GR, CP, and SBHEP) with well-developed physics theories and laws such as the conservation of energy, Planck's radiation, and so on can derive some laws or regularities of the BHU such as the spacetime equilibrium, the spacetime expansion and acceleration, the conservation of blackbody radiation, the increase of entropy, and so on that regulate and govern the development and dynamics of black hole universes. These laws or regularities can help us to explain and describe the origin, structure, expansion, evolution, acceleration of the universe, CMB, quasar, Sgr A* X-ray flare, *etc.* and meantime to overcome problems such as the horizon, flatness, monopole, dark matter, dark energy, low initial entropy, redshift quantization, big bang, old objects in the young universe, entropy, and so on. The BHU does not have unknowns. Both the charge and angular momentum are zero ($Q = 0$ and $J = 0$). The mass M is the only or key parameter. The radius or scale factor R, the temperature T, and the entropy S are derived from M according to the relations given by (4), (13), and entropy equations of thermodynamics. Measuring density tells us the radius R, and thus T and S. Measuring the Hubble parameter H tells the rate of change in $\dot{M}$, and thus $\dot{R}$, $\dot{T}$, $\dot{S}$. Measuring the deceleration parameter q tells us the double rate of change in mass $\ddot{M}$, and thus radius $\ddot{R}$, temperature $\ddot{T}$, entropy $\ddot{S}$. Measuring CMB, supernovae, *etc.* also tells us R and thus M, T, S, so that finds how the universe expands, *e.g.* acceleration or not.

As a consequence, installing one more leg (or fundamental) – the Principle of Spacetime Black Hole Equivalence – to the cosmology, we can attempt to fully explain the universe and simply overcome the difficulties according to the well-developed physics without needing to make other hypotheses such as inflation, dark energy, and so on. The black hole model of the universe is robust by only needing one stroke (the single postulate or principle SBHEP) rather than relying on an increasing number of hypothetical entities (HEs) as done in the big bang model [5] to explain the universe and solve the cosmic problems.

Acknowledgements

This work was partially supported by the NSF HBCU-UP, REU (PHY-1263253), and AAMU Title III programs.

Submitted on August 1, 2016 / Accepted on September 9, 2016

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