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The Upper Limit of the Masses of Stable Black Holes and Evolution of a Black Hole

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Abstract Based on the cosmological model without singularity, this paper demonstrates that there is an upper limit of the mass of stable black holes. An unstable black hole could become quasar or an orphan quasar. When the mass of an unstable black hole increases to large enough so that the temperature of its central zone comes up to the highest temperature, the highest symmetry will be realized and then inflation will occur. Consequently, the black hole will transform into a new v-cosmic or a s-cosmic island inside the original s-cosmic island. This v-cosmic island seems to be a huge orphan quasar, and this s-cosmic island seems to be a huge quasar or white hole. This is because there is only a repulsive force between the s-particles and v-particles, and when the temperature is greater than the critical temperature, the s-particles and the v-particles must significantly transform from one to other. The more massive the black hole is, and the higher the density and temperature of the black hole are, the faster the transformation is. It is seen that the critical temperature and the highest temperature of the universe determine the mass of a stable black hole and evolution of an unstable black holes.

Keywords: *black holes, evolution of a black hole, quasar, orphan quasar, the highest temperature, critical temperature.*

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1. Introduction

Based on the cosmological model without singularity [1], this paper demonstrates that there is an upper limit of the mass of stable black holes, and unstable black holes could become quasars or, as their mass grows, they could inflate and become a new cosmic island.

Model [1] puts forward a new basic hypothesis that the universe is composed of *s*-matter and *v*-matter which are completely symmetric before symmetry breaking and the symmetry is $SU_S(5)\times SU_V(5)$, and whose contributions to Einstein tensor are opposite to each other. There is only the coupling of the s-Higgs field Ω_s and the *v*-Higgs field Ω_v. The masses of Ω_s and Ω_v are all very large and the coupling coefficient is positive. Thus, it can be concluded that there are two sorts of symmetry breaking, i.e., *s*- and *v*-symmetry breaking. When s-breaking occurs, i.e. $\langle\Omega_s\rangle\neq 0$, v-symmetry must remain, i.e. $\langle\Omega_v\rangle = 0$, and vice versa. Thus, when $\langle\Omega_s\rangle\neq 0$, the s-elementary particles must acquire their corresponding masses, and forming visible matter and dark matter; However, the masses of the v-elementary particles must be zero, forming color singlets of a large unified group, e.g., the $SU_V(5)$ color singlets, at low temperatures. In addition to the known universal gravitation, there is no other interaction among these color singlets so that they cannot form atoms, molecules or block masses, but can only diffusely distribute in space as the dark energy, and they have the effect of dark energy on the evolution of the universe. It is impossible to detect the *v*-color singlets in the universe with s-breaking. Therefore, this hypothesis is compatible with known theories and experiments.

Based on this model, the following results have been obtained.

A. The premise of hawking theorem is no longer valid in this model, so this model has no singularity.

B. There is the highest temperature in the universe.

C. The cosmological constant and the effective cosmological constant are both zero, and based on this, the evolution of the universe is explained [2];

D. The covariant definition of localized energy conservation in the general relativity is given [3];

E. The universe consists of infinite v-cosmic islands, infinite s-cosmic islands and transition zones. Each cosmic island is made up of huge holes and galaxies. It is impossible to communicate any information between a s-cosmic island and a neighboring v-cosmic island, so that every observer of a cosmic island thinks that his own cosmic island is the whole universe [4]. The cosmological principle holds firm for the universe as a whole, but it is not strictly valid for a cosmic island.

F. The gravity between two distant galaxies predicted by this model will be less than that predicted by general relativity [1], because there is a lot of v-color singlets between the two galaxies.

G. S-huge voids in a s-cosmic island are not empty, but full of v-color singlets. Thus a s-void has a repulsive effect on s-matter [1]. S-voids have the following characteristics.

a. S-matter and s-galaxies are very rare in a s-void;

b. A s-void has concave lens effect for s-light passing through the s-void.

c. The redshift of a s-galaxies in a s-voids is less than that of galaxies which are not in s-voids at the same distance. This is due to the repulsive effect of the v-color singlets on the s- photons.

d. The s-voids in a s-cosmic island is taking up more and more space than the s-galaxies.

e. The s-voids exerts pressure on the neighboring *s*-galaxies. This effect is combined with the gravitational effect of dark matter inside the s-galaxies, both are not easily distinguishable.

2. The Upper Limit of the Masses of Stable Black Holes and Evolution of Unstable Black Holes

2.1. Definition of Stable Black Holes

When the distribution of s-matter around a s-black hole is constant, the s-energy absorbed by the s-black hole is equal to the released v-energy. The explanation for this definition is as follows:

When the s-mass of a s-black hole is large enough, the temperature T_{sC} of its central zone can be higher than a critical temperature $T_{\varphi cr}$ (see below). In this case, the s-particle in the central zone can significantly transform into v-particles. It is seen that a sufficiently massive s-black hole is composed of a large number of s-particles and a small number of v-particles. S-black holes do not emit s-particles, butthey emit v-particles. The larger the density and the higher the temperature in the central zone of the black hole, the more s-particles transform into v-particles, more v-particles are radiated. A s-black hole with its s-mass M_s absorbs s-energy E_s from the s-matter around it, E_s transforms into v-energy $E_v = E_s$, E_v is radiated out. In this way, the total energy and the s-energy of the s-black hole do not change. It is called a stable black hole. The temperature T in present paper is the conventional thermodynamic temperature.

2.2. S-particles Significantly Transform into v-particles when $T_{sC} > T_{\varphi cr}$

According to model [1], there are the Higgs fields $\mathbf{\Omega}_a, \mathbf{\Phi}_a$ and χ_a , $a = s, v$. $\mathbf{\Omega}_a, \mathbf{\Phi}_a = \sum_{i=1}^{24} (T_i / 2)\varphi_{ai}$ and χ_a are respectively 1, 24, 5 dimensional representations of the $SU(5)$ group, $T_i^{'}s$ are the $SU(5)$ generators [5,6]. Temperature will rise when space contracts. When the temperature effect is considered, the Higgs potentials become.

$$V_S = -\frac{1}{2}\mu^2\Omega_s^2 + \frac{1}{4}\lambda\Omega_s{}^4 - \frac{1}{2}w\Omega_s^2 Tr\Phi_s^2 + \frac{1}{4}a\left(Tr\Phi_s^2\right)^2 + \frac{1}{4}bTr\Phi_s^4 - \frac{1}{2}\zeta\Omega_s^2\chi_s^+\chi_s + \frac{1}{4}\xi\left(\chi_s^+\chi_s\right)^2, \quad (1a)$$

$$V_V = -\frac{1}{2}\mu^2\Omega_v^2 + \frac{1}{4}\lambda\Omega_v^4 - \frac{1}{2}w\Omega_v^2 Tr\Phi_v^2 + \frac{1}{4}a\left(Tr\Phi_v^2\right)^2 + \frac{1}{4}bTr\Phi_v^4 - \frac{1}{2}\zeta\Omega_s^2\chi_v^+\chi_v + \frac{1}{4}\xi\left(\chi_v^+\chi_v\right)^2, \quad (1b)$$

$$V_{SV} = \frac{1}{2}\Lambda\Omega_s^2\Omega_v^2 + \frac{1}{2}p\Omega_s^2 Tr\Phi_v^2 + \frac{1}{2}q\Omega_s^2\chi_v^+\chi_v + \frac{1}{2}p\Omega_v^2 Tr\Phi_s^2 + \frac{1}{2}q\Omega_v^2\chi_s^+\chi_s, \quad (1c)$$

$$V = V_S + V_V + V_{SV} \quad (1d)$$

[1] has proven that there is the highest temperature $T_{\max}$ at which the expectation values of all Higgs fields are equal to zero, i.e., $\langle\omega_a\rangle = 0$, $\omega = \Omega$, Φ and χ. Consequently, s-particles and v-particles can significantly transform from each to other so that $T_s = T_v = T_{\max}$. In this case, $V(\omega_a) = V_0 = V_{\max}$, space inflation occurs. Then the highest symmetry $SU_S(5)\times SU_V(5)$ will break to $SU_S(3)\times SU_2(2)\times U_S(1)\times SU_V(5)$ or $SU_S(5)\times SU_V(3)\times SU_V(2)\times U_V(1)$ (finally $SU(3)\times SU(2)\times U(1)\to SU(3)\times U(1)$ or $U(1)$ in low temperatures [5,6]), and the reheating process occurs. Let a cosmic island is in s-breaking, i.e. there be symmetry $SU_S(3)\times U_S(1)\times SU_V(5)$.

Considering the temperature effect, the one-loop correction of the gauge fields and $\langle\Omega_v\rangle_0 = \langle\Phi_v\rangle_0 = 0$ in the S-breaking, ignoring the one loop corrections of the fermions and the Higgs fields, the terms proportional to λ^n $(n>1)$ and the term s irrelevant to Ω_a and Φ_a, only considering Ω_a and the breaking components $Diagonal(1,1,1,-3/2,-3/2)\varphi_a$ of Φ_a for brevity ($a = s, v$, when χ_v is considered as well, the following inferences are still qualitatively valid), let $p \sim w < g^4 < C = (76/16)(kg)^2$ and $(15/16)(15a+7b) \equiv (11/3)B$, $B = \left(5625/1024\pi^2\right)g^4$, here g and k are the gauge coupling constant of the $SU(5)$ gauge fields and the Boltzmann constant, (here $k=1$), respectively, we get [7,8,9].

$$V_{a,eff}^{(1)T} = -\frac{1}{2}\left(\mu^2 - \frac{\lambda}{4}T_a^2\right)\Omega_a^2 - \frac{1}{4}\lambda\Omega_a^4 - \frac{15}{4}w\Omega_a^2\varphi_a^2 + B\varphi_a^4\left(\ln\frac{\varphi_a^2}{\sigma^2} - \frac{1}{2}\right) + CT_a^2\varphi_a^2, \sigma \sim 10^{15}\text{GeV}, \quad (2a)$$

$$V_{SV} = \frac{1}{2}\Lambda\Omega_s^2\Omega_v^2 + \frac{15}{4}p\Omega_s^2\varphi_v^2 + \frac{15}{4}p\Omega_v^2\varphi_s^2, \quad (2b)$$

Let $v_a \equiv \langle\Omega_a\rangle_0$, It is seen from (2) that there are the three critical temperatures $T_{\varphi scr}$ and $T_{\varphi scr1}$, $T_{\varphi scr} < T_{\varphi scr1} < T_{\max}$ in the S-breaking in which $v_{\Omega v} = v_{\varphi v} = 0$. $T_{\varphi scr}$ satisfies

$$\begin{aligned} &\frac{\partial}{\partial\Omega_s}V_{s,eff}^{(1)T}(\Omega_s,\varphi_s) = \frac{\partial}{\partial\varphi_s}V_{s,eff}^{(1)T}(\Omega_s,\varphi_s) = 0, \\ &\frac{\partial^2}{\partial\varphi_s^2}V_{s,eff}^{(1)T} > 0, \frac{\partial}{\partial\Omega_s}V_{s,eff}^{(1)T} > 0, \end{aligned} \quad (3a)$$

$$V_{s,eff}^{(1)T}(\Omega_s,\varphi_s) = V_{s,eff}^{(1)T}(0,0), \quad (3b)$$

$$v_{\Omega s}^2 = \left(\mu^2 + \frac{15}{2}wv_{\varphi s}^2 - \frac{\lambda}{4}T_{\varphi scr}^2\right)/\lambda, \quad (3c)$$

$$v_{\varphi s}^2 = \sigma^2 e^{1/2}, \text{ or } v_{\varphi s}^2 = 0, \text{ when } T_s = T_{\varphi vcr} = T_v, \quad (3d)$$

$$T_{\varphi scr}^2 = \left(\mu^2 + \frac{15}{2}wv_{\varphi s}^2\right)/\lambda\left(\frac{4C}{15w} + \frac{1}{4}\right). \quad (3e)$$

$T_{\varphi scr1}$ satisfies

$$\frac{\partial}{\partial\Omega_s}V_{s,eff}^{(1)T}(\Omega_s,\varphi_s) = \frac{\partial}{\partial\varphi_s}V_{s,eff}^{(1)T}(\Omega_s,\varphi_s) = 0, \quad (4)$$

$$\frac{\partial^2}{\partial\varphi_s^2}V_{s,eff}^{(1)T} = 0, \frac{\partial}{\partial\Omega_s}V_{s,eff}^{(1)T} = 0, \quad (5)$$

When $T_{\varphi cr1} > T_s > T_{\varphi cr}$, there is the relative minimum of $V_{\varphi s}^{(1)T}(\bar{\varphi}_s, T_s)$ and V_0 is the absolute minimum of $V_{\varphi s}^{(1)T}(\bar{\varphi}_s, T_s)$. When $T_s > T_{\varphi cr1}$, there is no relative minimum of $V_{\varphi s}^{(1)T}(\bar{\varphi}_s, T_s)$ and V_0 is still the minimum of $V_{\varphi s}^{(1)T}(\bar{\varphi}_s, T_s)$. When $T_s = T_{\max}$, the vacuum expectation values of all Higgs fields are zero so that the highest symmetry realized and inflation will occurs [1].

Thus, when $T_s > T_{\varphi cr}$, $v_{\Omega s} \neq 0$ but $|v_{\Omega s}|$ is very small, $v_{\Omega v} = v_{\varphi v} = 0$. In this case, the masses of all s-fermions, v-fermions, s-gauge particles and v-gauge particles are zero.

$$\begin{aligned} &m_{\Omega s}^2 = 2\lambda v_{\Omega s}^2 = 2\left(\mu^2 + \frac{15}{2}wv_{\varphi s}^2 - \frac{\lambda}{4}T_s^2\right), \\ &v_{\varphi s} = 0 \textit{ when } T_s > T_{\varphi cr} \end{aligned} \quad (6)$$

$$m_{\Omega v}^2 = -\left(\mu^2 - \frac{\lambda}{4}T_v^2\right) + \frac{\Lambda}{\lambda}\left(\mu^2 + \frac{15}{2}wv_{\varphi s}^2 - \frac{\lambda}{4}T_s^2\right), \quad (7)$$

$$m_{\varphi s}^2 = -\frac{15}{2}w\left(\mu^2 + \frac{15}{2}wv_{\varphi s}^2 - \frac{\lambda}{4}T_s^2\right) + 2CT_s^2, \quad (8)$$

$$m_{\varphi v}^2 = \frac{15}{2}p\left(\mu^2 + \frac{15}{2}wv_{\varphi s}^2 - \frac{\lambda}{4}T_s^2\right) + 2CT_v^2, \quad (9)$$

It is easily seen from (6)-(9), that the masses of the Higgs particle are very small and $m(\Omega_s) \sim m(\Omega_v)$, and the masses of all gauge particles and all fermions are equal to zero when $T_s > T_{\varphi cr}$. Consequently, s-particles and v-particles can significantly transform from one to other, so that $T_s \simeq T_v$. The higher the temperature is, the faster the transformation is. When $T_s < T_{\varphi cr}$, the transformation of s-particles and v-particles from one to other may be ignored.

When $T_s > T_{\varphi cr}$, although s-particles and v-particles can significantly transform from one to other, the s-total mass M_s is still more than the v-total mass M_v inside the black hole. This is because $v_{\Omega v} = v_{\varphi v} = 0$ inside and outside the s-black, and there is the repulsive force on the v-particles coming from s-matter so that the v-particles can easily get out of the black hole. In contrast with the v-particles, it is hard that v-particles to fly out of a black hole the, because $\left|\langle\omega_s\rangle_O\right| \gg \left|\langle\omega_s\rangle_i\right| > 0$ and the strong gravitation coming from s-black hole on the s-particles, here $\langle\omega_s\rangle_o$ and $\langle\omega_s\rangle_i$ are the expectation values of the s-Higgs fields outside and inside the s-black hole, $\omega = v_\Omega$, v_φ, respectively.

2.3. The Upper Limit of the Masses of Stable Black Holes and Evolution of Unstable Black Holes

Let there be a s-black hole H_S in s-cosmic island, and the distribution of s-matter around H_S be determined. H_S is spherical and the density of s-matter is uniform in the θ and φ angular directions. It is obvious that the temperature T_{sC} in the centre of the $s-black$ hole is the highest in the s-black hole. The zone in which the temperature $T_s \simeq T_{sC}$ is defined as the central zone. Let the radius of the central zone be r_{sc}, the total s-mass of the s-black hole be M_s, the s-mass and the v-mass in the central zone be $\tilde{M}_s$ and $\tilde{M}_v$, respectively. The s-black hole absorbs the s-matter around it so that its mass to increase. $\tilde{M}_v$ will decrease because v-particles can easily escape from the s-black hole. $\tilde{M}_s$ and $\tilde{M}_v$ will change because s-particles and v-particles can transform from one to other. Taking these factors into account, the changes of M_s and $\tilde{M}_v$ can be obtained,

$$\frac{dM_s}{dt} = K_s\left(M_s - \tilde{M}_v\right) - K_{sv}\tilde{M}_s + K_{vs}\tilde{M}_v, \quad (11)$$

$$\frac{d\tilde{M}_v}{dt} = -K_v\left(M_s - \tilde{M}_v\right)^\alpha \tilde{M}_v + K_{sv}\tilde{M}_s - K_{vs}\tilde{M}_v. \quad (12)$$

Here $\left(M_s - \tilde{M}_v\right)$ is the effective gravitational mass, the coefficient K_s is determined by the gravitational constant G and the distribution of s-matter encircling H_S so that K_s is a function of time. $K_{sv}\tilde{M}_s$ is such s-matter which transform into v-matter; $K_{vs}\tilde{M}_v$ is such v-matter which transform into s-matter. $K_v\left(M_s - \tilde{M}_v\right)^{\alpha}\tilde{M}_v$ is the repulsive force coming from $\left(M_s - \tilde{M}_v\right)$, the repulsive force causes the v-particles in the central zone to fly out of the black hole. The coefficients K_{sv} will increase as T_s and the density ρ_s ; K_{vs} will all increase as T_v and the density ρ_v . When the heat balances, T_s and ρ_s monotonously increase as M_s; T_v and ρ_v monotonously increase as $\tilde{M}_v$ increase. The parameter α is a is positive and undetermined. Here the transformation of s-particles and v-particles from one to other outside the central zone is ignored.

When $T_{sC} < T_{\varphi cr}$ and the distribution of s-matter encircling H_S is determined, the transformation of s-particles and v-particles from one to other may be ignored, so that $\tilde{M}_v$ may be ignored. Thus, (10) is simplified as $dM_s / dt = K_s M_s$ so that M_s monotonously increases. T_{sC} and r_{sc} will increase as M_s increases.

According to the conventional theory about black holes, the mass of a black hole monotonously increases always. In contrast with the conventional theory, according to the model [1], when M_s is large enough so that $T_{sC} > T_{\varphi cr}$, s-particles and v-particles can conspicuously transform from one to other. In the case, the change of M_s and $\tilde{M}_v$ are described by (10)-(11). When the distribution of s-matter is determined, K_s is determined. According to the definition of stable black holes, $dM_s / dt = 0$. In order to $dM_s / dt = 0$, it is necessary $dM_v / dt = 0$. In this case, (10)-(11) is simplified as

$$0 = K_s\left(M_s - \tilde{M}_v\right) - K_{sv}\tilde{M}_s + K_{vs}\tilde{M}_v, \qquad (12)$$

$$0 = -K_v\left(M_s - \tilde{M}_v\right)^{\alpha}\tilde{M}_v + K_{sv}\tilde{M}_s - K_{vs}\tilde{M}_v. \qquad (13)$$

From (12) - (13) we have

$$\left[K_s - K_v\tilde{M}_v\left(M_s - \tilde{M}_v\right)^{\alpha-1}\right]\left(M_s - \tilde{M}_v\right) = 0. \qquad (14)$$

When $\left(M_s - \tilde{M}_v\right) \neq 0$ and let $\alpha = 1$ for simplicity, we have $\tilde{M}_v = K_s / K_v \equiv \tilde{M}_{v0}$. M_s which satisfies (12) - (13) when $\tilde{M}_v = \tilde{M}_{v0}$ is called the mass of a stable s-black hole and is denoted by M_{s0} . When the heat balances, M_s and $\tilde{M}_v$ determine T_{sC} , T_{vC}, ρ_s and ρ_v, and from this determine K_{sv}, K_{vs} and r_{sc}. When $M_s \neq M_{s0}$, H_S is not a stable black hole.

It is possible that $M_s\left(t_0\right) \neq M_{s0}$, $T_{sC} > T_{\varphi cr}$ and K_{sv} is large enough, or $K_s\left(M_s - \tilde{M}_v\right)$ is small, so that $dM_s / dt < 0$. K_s can decrease because s-matter encircling H_S decreases. Higher T_{sC} is, larger K_{sv} is. When $T_{sC} > T_{\varphi cr}$, $\tilde{M}_s$ conspicuously transforms into $\tilde{M}_v$ so that M_s decreases. When $M_s < M_{s0}$, H_S is no longer a black hole. On the other hand, there is the strong repulsive force between M_s and $\tilde{M}_v$ so that the gravitation of the black hole H_S on the s-particles. Thus, H_S emits a lot of s-particles so that H_S becomes a quasar. Simply put, this is what happens when a black hole loses its gravitational constraints.

It is possible that $\left(M_s - \tilde{M}_v\right)$ is small enough so that the gravitation of the black hole H_S is small enough and $dM_s / dt < 0$. In the case, H_S becomes an orphan quasar.

When $M_S > M_{s0}$ and the s-matter around H_S is plentiful enough, $dM_s / dt > 0$, $dM_v / dt \neq 0$ is possible. In the case, M_s will increase so that T_{sC} and r_{sc} increase. Consequently H_S becomes a huge black hole.

When M_s continues to increase so that $T_{sC} = T_{\max}$, the s-particles and the v-particles are perfectly symmetrical, i.e. the highest symmetry will be restored, and inflation will occurs. Consequently, the s-black hole H_S will transform into a v-cosmic or s-cosmic island. This is because the v-particles can easily escape out from the s-black hole so that $T_v \lesssim T_S = T_{\max}$. Thus, the state with the highest potential and symmetry will possibly jump to the state in v-breaking and forms a small v-cosmic island in the s-cosmic island, even though H_S is inside s-cosmic island. The small v-cosmic island does not attract s-celestial bodies, but can emit a lot of s-particles. Consequently, the small v-cosmic island seems to be an huge orphan quasar. When H_S with the highest temperature $T_{\max}$ jumps to the state with s-breaking, H_S becomes a s-cosmic island which seems to be an huge quasar or white hole.

The discussion above is only qualitative. These coefficients K_s, K_v , K_{sv}, K_{vs}, α and r_{sc} require further study and astronomical observations to determine.

3. Conclusions

Based on the cosmological model without singularity, this paper demonstrates that there is an upper limit of the mass of stable black holes. An unstable black hole could become quasar or an orphan quasar. When the mass of an unstable black hole increases to large enough so that the temperature of its central zone comes up to the highest temperature, the highest symmetry will be realized and then inflation will occur. Consequently, the black hole will transform into a new v-cosmic or a s-cosmic island inside the original s-cosmic island. This v-cosmic island seems to be a huge orphan quasar, and this s-cosmic island seems to be a huge quasar or white hole. This is because there is only a repulsive force between the s-particles and v-particles, and when the temperature is greater than the critical temperature, the s-particles and the v-particles must significantly transform from one to other. The more massive the black hole is, and the higher the density and temperature of the black hole are, the faster the transformation is. It is seen that the critical temperature and the highest temperature of the universe determine the mass of a stable black hole and evolution of an unstable black holes.

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