

# Solution of the Singularity Problem of Black Hole

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## Abstract

Singularity problem is a long-standing weak point in the theory of general relativity. Most scholars assume that the solution for this singularity consists in quantum mechanics. However, waiting for quantum gravity theory to be completed to solve the singularity problem in a black hole is wrong. Here we show that gravitational self-energy has a negative value can solve singularity problem and rescue general relativity. Black hole does not have a singularity and there exists a zone that has a uniform energy density within the black hole. Also, gravitational self-energy and  $R_{gs}$  guarantee uniform density due to repulsive gravity effect and this can be grounds for the expansion in the early universe and the uniform universe.

## I. Singularity problem of black hole

Generally, stars are under gravitational contraction by their own gravity and it is known that if this is contracted within a certain radius (like Schwarzschild radius), it makes a black hole which even lights cannot escape from. [1] [2] Since gravity is generally an attractive force, gravitational contraction continues to exist in the black hole, too. Thus, in the central part of black hole exists an area with infinite density of energy, which point we call singularity. [2] [3]

Such singularity denies application of the existing laws of physics and it is unnatural for a certain substantial object to have infinite density of energy. Besides, such singularity has never been observed as substance but is just a mathematical result of general relativity, which is considered a defect or limit of the theory. [4]

We assume that the solution for this singularity consists in quantum mechanics. [5] Though exact explanation is not available because quantum gravity theory in integration of quantum mechanics and gravity has not been completed yet.

## II. Gravitational self-energy and singularity of black hole

### 1. Gravitational self-energy

The concept of gravitational self-energy( $U_{gs}$ ) is the total of gravitational potential energy possessed by a certain object M itself. Since a certain object M itself is a binding state of infinitesimal mass dMs, it involves the existence of gravitational potential energy among these dMs and is the value of adding up these.  $M = \sum dM$ .

Gravitational self-energy or Gravitational binding energy( $-U_{gs}$ ) in case of uniform density is given by [6]

$$U_{gs} = -\frac{3}{5} \frac{GM^2}{R} \quad (1)$$

### 2. For black hole or singularity, never fail to consider gravitational self-energy.

In the generality of cases, the value of gravitational self-energy is small enough to be negligible, compared to mass energy  $mc^2$ . So generally, there was no need to consider gravitational self-energy. However the smaller R becomes, the higher the absolute value of  $U_{gs}$ . For this reason, we can see that  $U_{gs}$  is likely to offset the mass energy in a certain radius.

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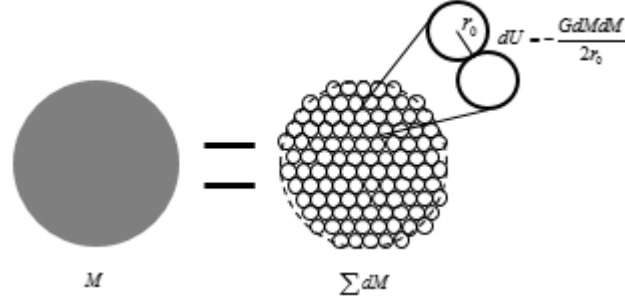


Figure 1: Since all mass  $M$  is a set of infinitesimal mass  $dM$ s and each  $dM$  is gravitational source, too, there exists gravitational potential energy among each of  $dM$ s. Generally, mass of an object measured from its outside corresponds to the value of dividing the total of all energy into  $c^2$ .

Thus, looking for the size in which gravitational self-energy becomes equal to rest mass energy by comparing both,

$$U_{gs} = \left| -\frac{3}{5} \frac{GM^2}{R_{gs}} \right| = Mc^2 \quad (2)$$

$$R_{gs} = \frac{3}{5} \frac{GM}{c^2} \quad (3)$$

This equation means that if mass  $M$  is uniformly distributed within the radius  $R_{gs}$ , gravitational self-energy for such an object equals mass energy in size. So, in case of such an object, mass energy and gravitational self-energy can be completely offset while total energy is zero. Since total energy of such an object is 0, gravity exercised on another object outside is also 0.

Comparing  $R_{gs}$  with  $R_S$ , the radius of Schwarzschild black hole,

$$R_{gs} = \frac{3}{5} \frac{GM}{c^2} < R_S = \frac{2GM}{c^2} \quad (4)$$

$$R_{gs} = 0.3R_S \quad (5)$$

This means that there exists the point where gravitational self-energy becomes equal to mass energy within the radius of black hole, and that, supposing a uniform distribution, the value exists at the point  $0.3R_S$ , a 30% level of the black hole radius.

Since this value is on a level not negligible against the size of black hole, we should never fail to consider “gravitational self-energy” for case of black hole.

### 3. Black hole does not have a singularity and there exists a zone that has a uniform energy density within the black hole.

From the equation above, even if some particle comes into the radius of black hole, it is not a fact that it contracts itself infinitely to the point  $R = 0$ . From the point  $R_{gs}$ , gravity is 0, and when it enters into the area of  $R_{gs}$ , total energy within  $R_{gs}$  region corresponds to negative values enabling anti-gravity to exist. This  $0.3R_B$  region comes to exert repulsive effects of gravity on the particles outside of it, therefore it interrupting the formation of singularity at the near the area  $R=0$ .

However, it still can perform the function as black hole because  $R_{gs}$  is only 30% of  $R_S$  with a large difference in volume and, comparing total mass, it still can correspond to a very large quantity of positive mass. Therefore, it still can perform the function as black hole on the objects outside of  $R_S$ .

### 4. Waiting for quantum gravity theory to be completed to solve the singularity issue in a black hole is wrong as it was made by our stereotypes.

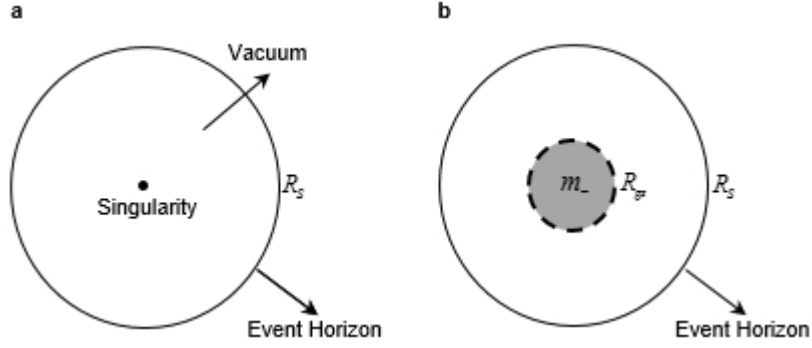


Figure 2: a.Existing Model. b.New Model. The area of within  $R_{gs}$  has gravitational self-energy of negative value, which is larger than mass energy of positive value. This area (within  $R_{gs}$ ) exercises anti-gravity on all particles entering this area, and accordingly prevents all masses from gathering to  $r=0$ . Therefore the distribution of internal energy can't be reduced to at least radius  $R_{gs} = 0.3R_S$ .

When there occurred a problem in singular “point”, one dimensional idea that problems should be solved from  $\lambda$ , wavelength that has a little bigger than “point” was partially acted. Of course, we should try to establish a quantum gravity theory for other reasons.

We can think of a black hole of big size and approach this problem by reducing the mass of this black hole. In other words, we should form a certain internal structure of usual size and apply the experience that we had applied the limit.

$$\lim_{M \rightarrow small} R_{gs}$$

If you are still uncomfortable with  $R_{gs}$ , think about a black hole with the size 10 billion times bigger than the solar mass. [7] [8] Schwarzschild radius of this black hole is  $R_S = 3 \times 10^{10} km$  and  $R_{gs}$  of this black hole  $1 \times 10^{10} km$ . Is it a size that requires quantum mechanics? Is it a high density state that requires quantum mechanics? Black hole of this size is Newtonian mechanics' object and therefore, gravitational potential energy must be considered.

Let's reduce the mass of this black hole gradually and approach three times the solar mass, the smallest size of black hole where stars can be formed!

In case of the smallest black hole with three times the solar mass, [9]  $R_S = 9km$ .  $R_{gs}$  of this object is as far as 3km. In other words, **even in a black hole with smallest size that is made by the contraction of a star, the distribution of internal energy can't be reduced to at least radius 3km.**

### 5. The minimal size of existence

[ Existence = the sum of infinitesimal existences composing an existence ]

A single mass M for some object means that it can be expressed as  $M = \sum dM$  and, for energy,  $E = \sum dE$ . The same goes for elementary particles, which can be considered a set of dMs, the infinitesimal mass.

The equation (2) above means that if masses are uniformly distributed within the radius  $R_{gs}$ , the size of negative binding energy becomes equal to that of mass energy. This can be the same that the rest mass, which used to be free for the mass defect effect caused by binding energy, has all disappeared. This means the total energy value representing “some existence” coming to 0 and “extinction of the existence”. **Therefore,  $R_{gs}$  is considered to act as “the minimal radius” or “a bottom line” of existence with some positive energy.**

### III. Expansion of the general relativity and cosmology

1. We can solve the problem of singularity by separating the term( $-M_{gs}$ ) of gravitational self-energy from mass and including it in the solutions of field equation.

In the Schwarzschild solution,

$$ds^2 = -(1 - \frac{2GM}{c^2 r})c^2 dt^2 + \frac{1}{(1 - \frac{2GM}{c^2 r})} dr^2 + r^2 d\theta^2 + r^2 \sin^2 \theta d\phi^2 \quad (6)$$

For the sphere with uniform density,

$$-M_{gs} = -\frac{3}{5} \frac{GM^2}{Rc^2} \quad (7)$$

$M \rightarrow M + (-M_{gs})$ ,

$$ds^2 = -(1 - \frac{2G(M - M_{gs})}{c^2 r})c^2 dt^2 + \frac{1}{(1 - \frac{2G(M - M_{gs})}{c^2 r})} dr^2 + r^2 d\theta^2 + r^2 \sin^2 \theta d\phi^2 \quad (8)$$

1) If  $M \gg |-M_{gs}|$ , we get the Schwarzschild solution.

2) If  $M \ll |-M_{gs}|$ ,

$$ds^2 \simeq -(1 + \frac{2GM_{gs}}{c^2 r})c^2 dt^2 + \frac{1}{(1 + \frac{2GM_{gs}}{c^2 r})} dr^2 + r^2 d\theta^2 + r^2 \sin^2 \theta d\phi^2 \quad (9)$$

In the domain of  $0 \leq r < R_{gs}$ ,

The area of within  $R_{gs}$  has gravitational self-energy of negative value, which is larger than mass energy of positive value. Negative mass has gravitational effect which is repulsive to each other. [10] So, we can assume that  $-M_{gs}$  is almost evenly distributed. Therefore  $\rho_{gs}$  is constant. And we must consider the Shell Theorem.

$$-M_{gs} = -\frac{4\pi r^3}{3} \rho_{gs} \quad (10)$$

$$(1 + \frac{2GM_{gs}}{c^2 r}) = 1 + \frac{2G(\frac{4\pi}{3} r^3 \rho_{gs})}{c^2 r} = 1 + \frac{8\pi G \rho_{gs} r^2}{3c^2} \quad (11)$$

$$ds^2 \simeq -(1 + \frac{8\pi G \rho_{gs} r^2}{3c^2})c^2 dt^2 + \frac{1}{(1 + \frac{8\pi G \rho_{gs} r^2}{3c^2})} dr^2 + r^2 d\theta^2 + r^2 \sin^2 \theta d\phi^2 \quad (12)$$

If  $r \rightarrow 0$ ,

$$ds^2 \simeq -c^2 dt^2 + dr^2 + r^2 d\theta^2 + r^2 \sin^2 \theta d\phi^2 \quad (13)$$

There is no singularity.

#### 2. Kretschmann scalar

For Schwarzschild black hole, the Kretschmann scalar [11] is,

$$R^{\mu\nu\rho\sigma} R_{\mu\nu\rho\sigma} = \frac{48G^2 M^2}{c^4 r^6} \quad (14)$$

In the preexisting model, if  $r \rightarrow 0$ , it does diverse.

However, this model is

$$R^{\mu\nu\rho\sigma} R_{\mu\nu\rho\sigma} = \frac{48G^2 (M - M_{gs})^2}{c^4 r^6} \approx \frac{48G^2 (-M_{gs})^2}{c^4 r^6} = \frac{(16\pi G \rho_{gs})^2}{3c^4} \quad (15)$$

It does not diverse. Therefore, black hole doesn't have singularity.

**3. Gravitational self-energy can provide the concept of minimal size, one of the reasons for introducing string theory.**

To remove singularity, considering gravitational self-energy is only enough without need to assume some minimal unit like a string. Thus, the existing relations need to be transformed so that they may include the minimal length by dint of gravitational self-energy.

$$\Delta x \sim \frac{\hbar}{\Delta p} \tag{16}$$

$$\Delta x \sim \frac{\hbar}{\Delta p} + R_{gs} \geq \frac{3}{5} \frac{GM}{c^2} = \frac{3}{5} \frac{GE}{c^4} \tag{17}$$

Since the increase of momentum is put into the increase of energy and mass,  $\Delta x$  cannot go to 0. Therefore, we can introduce the minimal length naturally and work out the problems of singularity or infinity.

**4. The source of uniformity and expansion**

The mainstream physics assumes inflation to explain about the uniformity, flatness and horizon of the universe. [2] [12] [13]

However, if the universe starts from the high density state ( $0 < R < R_{gs}$ ), as the negative gravitational potential energy is bigger than the positive mass energy in the area of  $0 < R < R_{gs}$ , there exists a anti-gravity effect. Therefore, matter distribution is essentially closer to a uniform density within the radius of  $R_{gs}$ . Thus inevitably the universe expands in uniform density. This can be a strong explanation for the fact that the universe that we observe has almost a uniform density.

Also, the universe that was born in high density state does not have a singularity by gravitational collapse, but can be one explanation for the fact that the universe expands.

**5.  $R_{gs}$  of the present universe**

From the equation (3),

$$R_{gs} = \sqrt{\frac{5c^2}{4\pi G\rho}} \tag{18}$$

Use to the Planck data('2013, h=0.678), [14]

$$\rho_{c,0} = \frac{3H_0^2}{8\pi G} = 8.64 \times 10^{-27} kgm^{-3} \tag{19}$$

$$R_{gs} = \sqrt{\frac{5c^2}{4\pi G\rho}} = 2.49 \times 10^{26} m = 26.3Gly \tag{20}$$

If the universe that was born in high density state, universe does not a singularity by gravitational collapse, but must expands to the  $R_{gs}(26.3Gly)$  at least.

Gravitational self-energy can solve singularity problem and rescue general relativity that collapses itself. Also it can be grounds for the expansion in the early universe and the uniform universe.

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**Supplementary information**

This paper is a paper that is rearranged in a single topic (singularity problem) among my articles.

(<https://www.researchgate.net/publication/287217009> & <https://www.researchgate.net/publication/309786718>).