# The Birth Mechanism of the Universe from Nothing and New Inflation Mechanism

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**Abstract**

There was a model claiming the birth of the universe from nothing, but the specific mechanism for the birth and expansion of the universe was very poor. According to the energy-time uncertainty principle, during $\Delta t$, an energy fluctuation of $\Delta E$ is possible, but this energy fluctuation should have reverted back to nothing. By the way, there is also a gravitational interaction during the time of $\Delta t$, and if the negative gravitational self-energy exceeds the positive mass-energy during this $\Delta t$, the total energy of the corresponding mass distribution becomes negative energy, that is, the negative mass state. Because there is a repulsive gravitational effect between negative masses, this mass distribution expands. Thus, it is possible to create an expansion that does not go back to nothing. Calculations show that if the quantum fluctuation occur for a time less than $\Delta t = \sqrt{\frac{3}{10}} t_P \approx 0.77 t_P$, then an energy fluctuation of $\Delta E > \sqrt{\frac{5}{6}} m_P c^2 \approx 0.65 m_P c^2$ must occur. But in this case, because of the negative gravitational self-energy, $\Delta E$ will enter the negative energy (mass) state before the time of $\Delta t$. Because there is a repulsive gravitational effect between negative masses, $\Delta E$ cannot contract, but expands. Thus, the universe does not return to nothing, but can exist. Gravitational Potential Energy Model provides a means of distinguishing whether the existence of the present universe is an inevitable event or an event with a very low probability. And, it presents a new model for the process of inflation, the accelerating expansion of the early universe. This paper also provides an explanation for why the early universe started in a dense state and solves the vacuum catastrophe problem. Additionally, when the negative gravitational potential energy exceeds the positive energy, it can produce an accelerated expansion of the universe. Through this mechanism, inflation, which is the accelerated expansion of the early universe, and dark energy, which is the cause of the accelerated expansion of the recent universe, can be explained at the same time.

## 1. Introduction

The now accepted Big Bang Cosmology suggests that all matter in the observable universe was once condensed in a very small space and was in thermal equilibrium at some point in the past. [1–3] There are several problems with the big bang model, and the accelerated expansion of the early universe was proposed to solve these problems. [4–7] However, in order to generate inflation, most models must introduce a new field, such as the Inflaton field. In addition, new factors such as false vacuum and phase transition are also assumed. [5] [6] Also, in terms of energy, Something, not Nothing, is firmly established. The problem of explaining the source of energy still exists.

How can Something come out of Nothing? Why did the universe expand after birth? Why didn't the universe become a black hole? How did the accelerated expansion of the early universe occur? Since these problems are important, I would like to propose an explanation through gravitational potential energy for these problems.

There are four types of basic forces, and there are many interactions in the universe. However, on a cosmic scale, gravity is the most powerful force, and it is important. In addition, although there are electric charges,

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spins, and various physical quantities, it is necessary to analyze the problem of expanding the universe due to gravitational interactions because the object will be a being with at least energy (mass) even in various situations.

### 1.1. Basic facts

First, we are currently observing the redshift of galaxies, and it seems reasonable to interpret this redshift as a receding velocity. Therefore, when we turn back time, we can think of a state in which most of the mass-energy in the observable universe is gathered in a very small space. This point of view is also recognized as a fact proven by cosmic microwave background radiation. [2] [3]

Second, one of the most fundamental physical quantities of all things is energy. Energy is a physical quantity equal to mass. Only the proportional constant is different ($E = mc^2$). In Newtonian mechanics, the source of gravity is mass, and in relativity, the source of gravity is the energy-momentum tensor. Therefore, we can think of it as the moment when mass or energy exists, and gravity also exists.

### 1.2. The logical structure of standard cosmology [8]

In the acceleration equation ($c \equiv 1$),

$$\frac{1}{R}(\frac{d^2R}{dt^2}) = -\frac{4\pi G}{3}(\rho + 3P) \tag{1}$$

For the universe to accelerate its expansion, the right hand side must be positive, and therefore $\rho + 3P$ must be negative. In the standard cosmology, the accelerating expansion of the universe is explained by introducing objects with positive mass density and negative pressure.

$$\rho_\Lambda + 3P_\Lambda = \rho_\Lambda + 3(-\rho_\Lambda) = -2\rho_\Lambda \tag{2}$$

However, if we expand the dark energy term, the end result is a negative mass density of $-2\rho_\Lambda$.

> *Negative Mass? Actually the firdt indication of the discovery!*
>
> *Day later... What does this mean? There cannot be negative mass, but would Einstein's Cosmological Constant explain this acceleration?* - From the Nobel Prize Lecture by Adam Riess [9]

Researchers who had aversion to negative mass introduced an entity that has positive energy density and exerts negative pressure, but this is considered to be a incorrect claim. Since pressure is related to kinetic energy or momentum, positive energy density produces positive kinetic energy, and thus, positive energy density produces positive pressure. Vacuum energy with a uniform positive energy density will not create negative pressure, but will create positive pressure. The cosmological constant appears to have a negative equivalent mass density, not a form that produces negative pressure with positive energy density. Also, $P = \frac{1}{3}\rho$ for light with the greatest kinetic energy compared to total energy. The claim that it($P_\Lambda = -\rho = -3(\frac{1}{3}\rho)$) has a kinetic energy component three times greater than that of light seems nonsensical.

Also, the negative pressure claim is an erroneous claim resulting from an erroneous application of $dU = -PdV$. Negative pressure is just an imaginary entity created by researchers who had an aversion to negative energy. To produce accelerated expansion in Friedmann equation, $\rho < 0$ or $P < 0$ must be present. The mainstream, which could not accept negative mass density, had to rely on $P < 0$ to somehow create the accelerated expansion of the universe. [10] [11]

One of the reasons researchers have abandoned negative mass density is because of false claims about negative mass that are widespread in academia. 1) The assertion that the low-energy state is stable and therefore spontaneous transition to the negative infinity level occurs, 2) Runaway motion 3) Perpetual motion problem 4) Spin 2 field problem, etc. are all false assertions. [11] Therefore, the possibility of our universe being in a negative energy (mass) state should be seriously considered.

When there is a lot of information, it is sometimes difficult to grasp the core of the information. We need to sort out the core logic of standard cosmology.

Let's look at the equation expressing $(\rho + 3P)$ as the critical density of the universe.
Matter + Dark Matter : $\rho_m \approx \frac{1}{3}\rho_c$
Dark Energy density : $\rho_\Lambda \approx \frac{2}{3}\rho_c$
Pressure of Matter + Dark Matter : $P_m \approx 0$
Pressure of Dark Enerrgy : $P_\Lambda = (-\rho_\Lambda) = (-\frac{2}{3}\rho_c)$

$$\rho + 3P \simeq \rho_m + \rho_\Lambda + 3(P_m + P_\Lambda) \simeq (\frac{1}{3})\rho_c + (\frac{2}{3})\rho_c + 3(-\frac{2}{3})\rho_c = (+1)\rho_c + (-2)\rho_c = (-1)\rho_c \quad (3)$$

$$\rho + 3P \simeq (+1)\rho_c + (-2)\rho_c = (-1)\rho_c \quad (4)$$

**Standard cosmology is a form of positive mass density of $+1\rho_c$ and negative mass density of $-2\rho_c$. So, finally, the universe has a negative mass density of "$-\rho_c$"**, so accelerated expansion is taking place. The current universe is similar to a state where the negative mass density is twice the positive mass density. And the total mass of the observable universe is the negative mass state. [8]

### 1.3. Attempts to explain the birth of the universe through quantum fluctuation

Edward Tryon proposed the Zero Energy Universe model, in which the universe arises from quantum fluctuations, where positive mass energy and negative gravitational potential energy are precisely balanced. Later, Alan Guth and Stephen Hawking, etc. argued or explained something similar to the basic concept of the zero energy universe.

However, Edward Tryon's paper only explains the basic concept, and there is no mechanism or process for how the universe could exist from quantum fluctuations. [12] The explanations of Alan Guth and Stephen Hawking are also at the level of explaining the concept. [13] [14] A model for the birth of the universe through quantum tunneling was discussed by Atkatz and Pagels, and by Alexander Branking. [15] [16] However, Alexander Branking's thesis uses various concepts and assumptions, making it difficult to determine whether the logic holds. **Despite the efforts of these pioneers, the mechanism for creating the universe from nothing still seems unclear.**

In this paper, since the propagation speed of the gravitational interaction is finite, I plan to explain how the amount of matter participating in the gravitational interaction and the gravitational potential energy change with time. Therefore, in the gravitational potential energy model, the total energy of the universe is not zero energy, but can change from positive to negative and from negative to positive. Through this, I will present a model that explains both inflation (the accelerating expansion of the early universe) and dark energy (causing the accelerating expansion of the current universe).

In addition, most of the existing inflation model introduces a new scalar field, but I plan to explain the accelerated expansion of the early universe through the known gravitational potential energy and present a very specific mechanism related to the birth of the universe from quantum fluctuations.

## 2. Gravitational potential energy and some forms of expansion

### 2.1. The initial state of the universe and the evolution of the range of gravitational interactions over time

The initial state of the universe is uncertain, and there is no agreed upon initial state. The early state of the universe, which we can now estimate, is a state in which all matter-energy existing in the observable universe is gathered in a very small space. Since there is no agreed-upon initial state of the universe, let's consider the early state a very short time after this initial state. In this paper, I plan to use the names of the initial state and early state.

In the early universe, an object with positive energy $E_1$ existed or was born in the local area. Since this chapter explains the characteristics of gravitational potential energy, it is explained in the situation where $E_1$ exists. In chapter 3, I will explain the condition without $E_1$ as well. Here, $E_1$ corresponds to an entity with energy in the local area. Since there is energy or mass, this is when gravity exists.

Even when we return the time of the observable universe to the past, we will encounter a time when the matter-energy in the observable universe is gathered in a very small space. Also, since $E_1$ represents a being with mass-energy, it is appropriate to look at the time when $E_1$ existed.

$E_1$ is the energy in the local domain. $E_T$ is the total energy of the range of possible gravitational interactions with each other when a finite amount of time has passed since the birth of the universe.

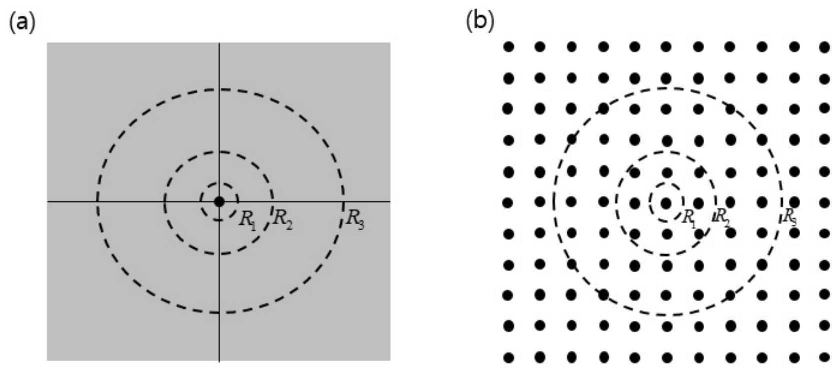


Figure 1: The range of gravitational interactions over time in the early universe. (a) Mass-energy distribution with uniform density, (b) is the distribution of beings with $E_1$ in the local area. Depending on the range of analysis, it may be non-uniform or uniform. For example, it is also a distribution corresponding to the discontinuous generation and extinction of energy at a specific location in space by quantum fluctuations. Images are one-dimensional, but think in three dimensions. $R_1(t_1)$, $R_2(t_2)$, $R_3(t_3)$ are the range (radius) of the gravitational interaction.

In Figure 1, If the matter or energy within the radius $R_1$ interacted gravitationally at the age $t_1$ of the universe, the matter or energy within the radius $R_2$ will interact gravitationally at a later time $t_2$.

As the universe ages, the matter and energy participating in gravitational interactions change, resulting in changes in the energy composition of the universe.

The total energy $E_T$ of the system is

$$E_T = \sum_i m_i c^2 + \sum_{i<j} -\frac{Gm_i m_j}{r_{ij}} = Mc^2 - \frac{3}{5}\frac{GM^2}{R} \tag{5}$$

Since there is an attractive component (Mass or Energy) and a repulsive component (Gravitational potential energy or Gravitational self-energy), it contains elements that can explain the accelerated expansion and decelerated expansion of the universe. [8]

### 2.2. Some forms of expansion due to gravitational potential energy

#### 2.2.1. Binding energy in the mass defect problem [10]

When two masses form a bonded state, a stable bonded state is achieved only when energy is released to the outside of the system as much as the binding energy.

In (b), the total energy of the two particle system is

$$E_{T_1} = 2mc^2 - \frac{Gmm}{r} \tag{6}$$

In the dimensional analysis of energy, $E$ has $kg(m/s)^2$, so all energy can be expressed in the form of $(mass)X(velocity)^2$. So, $E = Mc^2$ holds true for all kinds of energy. Here, $M$ is the equivalent mass. If we introduce the negative equivalent mass $-m_{gp}$ for the gravitational potential energy,

$$-\frac{Gmm}{r} = -m_{gp}c^2 \tag{7}$$

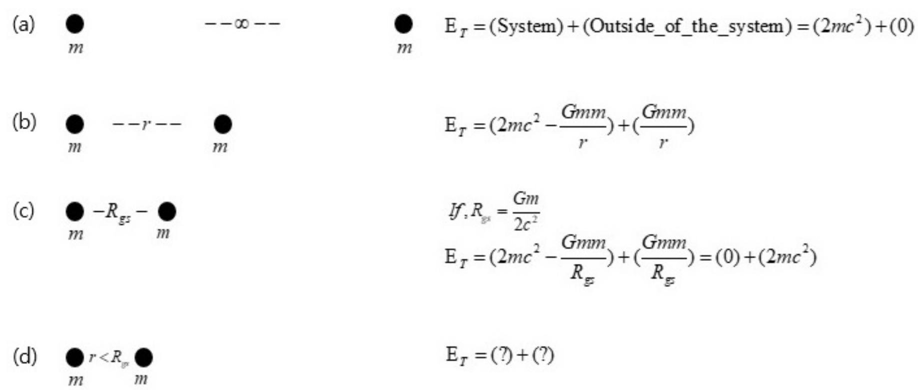


Figure 2: In order for a system to form a bond state, a mass defect equal to the binding energy must occur.

$$E_{T_1} = 2mc^2 - \frac{Gmm}{r} = 2mc^2 - m_{gp}c^2 = (2m - m_{gp})c^2 = m^*c^2 \tag{8}$$

**The gravitational force acting on a relatively distant third mass $m_3$ is**

$$F = -\frac{Gm^*m_3}{R^2} = -\frac{G(2m - m_{gp})m_3}{R^2} = -\frac{G(2m)m_3}{R^2} - \frac{G(-m_{gp})m_3}{R^2} \tag{9}$$

That is, **when considering the gravitational action of a bind system, not only the mass in its free state but also the binding energy term ($-m_{gp}$) should be considered.** Alternatively, the gravitational force acting on the bind system can be decomposed into a free-state mass term and an equivalent mass term of binding energy. [10]

While we usually use the mass $m^*$ of the bind system, we forget that $m^*$ is "$m - m_{binding-energy}$". Gravitational potential energy is also a kind of binding energy. Therefore, the gravitational potential energy, which is the binding energy, must also be considered in the universe.

Look at the second term again, it is the repulsive force (anti-gravity) term.

$$F_{gp} = +\frac{G(m_{gp})m_3}{R^2} \tag{10}$$

What if, in the observable universe, the second term is greater than the first term?

**2.2.2. Gravitational Potential Energy or Gravitational Self Energy** [8] [17]

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 spherical uniform distribution is given by

$$U_{gs} = -\frac{3}{5}\frac{GM^2}{R} \tag{11}$$

The gravitational self-energy is proportional to $-\frac{M^2}{R}$. Therefore, as the mass increases, the gravitational self-energy value increases.

For some celestial bodies, calculating the gravitational self-energy value,
In the case of Moon, $U_{gs-Moon} = (-1.89 \times 10^{-11})M_{Moon}c^2$
In the case of Earth, $U_{gs-Earth} = (-4.17 \times 10^{-10})M_{Earth}c^2$
In the case of the Sun, $U_{gs-Sun} = (-1.27 \times 10^{-4})M_{Sun}c^2$
In case of a Black hole, $U_{gs-Black-hole} = (-3.0 \times 10^{-1})M_{Black-hole}c^2$

$$U_{gs-Black-hole} = -\frac{3}{5}\frac{GM^2}{R} = -\frac{3}{5}\frac{GM^2}{(\frac{2GM}{c^2})} = -\frac{3}{10}Mc^2 \tag{12}$$

It can be seen that as the mass increases, the ratio of gravitational self-energy increases. Surprisingly, in the case of a black hole, it can be seen that the negative gravitational potential energy is 30% of the positive mass energy, which cannot be ignored. [17]

So, now we can ask the following question. What about the universe with much greater mass?

Since gravitational potential energy (or gravitational field energy) can generate repulsive force on a cosmic scale, we need to apply gravitational potential energy to two periods in our universe where repulsive force is needed. The two periods are the inflation period, the accelerated expansion of the early universe, and the dark energy period, the recent accelerated expansion of the universe.

#### 2.2.3. Some Forms of Expansion

##### 2.2.3.1. Expansion in space with no cosmological constant or no vacuum energy and with uniform energy (mass) density

In Figure 1, in space with a uniform mass density, the range of gravitational interactions increases as the universe ages.

A situation with a uniform mass density could exist for several reasons. For example, one can imagine a situation in which, when the universe is born, some creation field propagates, creating a uniform density throughout space. Another example would be if there were quantum fluctuations everywhere in space, it would be like a uniform mass density. It is also thought that uniform density is naturally achieved when negative energy (i.e. anti-gravity) is present.

$$F = -\frac{G(-M_-)m}{r^2} = -\frac{G(-\frac{4\pi r^3\rho_-}{3})m}{r^2} = +m(\frac{4\pi G\rho_-}{3}r) \tag{13}$$

Since the acceleration is of the form $a = +kr$, a uniform density effect is estimated. Regardless of the cause, it is conceivable that the universe would have uniform density at some point in the early universe, even when the current observable universe is rolled back.

Instead of assuming uniform density, it is also possible to introduce a density $\rho(r,t)$ that depends on coordinates and time. In this case, too, the mass participating in the gravitational interaction changes over time, and expansion occurs accordingly. The core argument doesn't change.

###### 2.2.3.1.1. The total energy of a gravitationally interacting system

Mass energy : $E_{ME} = Mc^2$

Gravitational potential energy (Gravitational self-energy) : $U_{gs} = -\frac{3}{5}\frac{GM^2}{R}$

$$E_T = \sum_i m_i c^2 + \sum_{i<j} -\frac{Gm_i m_j}{r_{ij}} = Mc^2 - \frac{3}{5}\frac{GM^2}{R} \tag{14}$$

In this model, over time, the positive mass energy participating in the gravitational interaction grows, but the negative gravitational potential energy (gravitational self-energy) also grows. Let's consider the change in magnitude of two terms in a uniform density state.

$$\frac{U_{gs}}{E_{ME}} = \frac{-\frac{3}{5}\frac{GM^2}{R}}{Mc^2} = -(\frac{4\pi G\rho}{5c^2})R^2 = -kR^2 \simeq -kc^2t^2 \tag{15}$$

As the universe ages, the age of the universe increases, and the range of gravitational interactions, $R$ (approximately assumed to be $R = ct$), increases. In the case of uniform density, the negative gravitational potential energy increases faster than the positive mass energy.

That is, even if a region is initially in a positive energy (mass) state, as time elapsed, the gravitationally interacting region could be converted to a negative energy (mass) state and accelerated expansion.

**2.2.3.1.2. When R changes, the ratio of increase in gravitational self-energy to increase in mass energy** [8]

$$\frac{d(Mc^2)}{dR} = 4\pi R^2 \rho c^2 \tag{16}$$

$$\frac{d(U_{gs})}{dR} = -\frac{16\pi^2 G}{3} R^4 \rho^2 = (-\frac{4\pi R^3 \rho G}{3Rc^2})(4\pi R^2 \rho c^2) = -\frac{GM}{Rc^2}(\frac{d(Mc^2)}{dR}) \tag{17}$$

$$\frac{d(U_{gs})}{dR} = -\frac{R_S}{2R}\frac{d(Mc^2)}{dR} \tag{18}$$

$R_S$ is the Schwarzschild radius of the black hole formed by the observable universe.
The size of the event horizon formed by the mass distribution of observable universe 46.5 Gly is 477.8 Gly.

$$\frac{d(U_{gs})}{dR} = -\frac{R_S}{2R}(\frac{d(Mc^2)}{dR}) = -\frac{477.8Gly}{2(46.5Gly)}(\frac{d(Mc^2)}{dR}) = -(5.14)(\frac{d(Mc^2)}{dR}) \tag{19}$$

If the particle horizon increases and a positive mass is increases by $\Delta M$, the equivalent mass of negative gravitational potential energy is increases by $-5.14\Delta M$. This value is not a fixed value, it depends on the density and the size of the particle horizon. [8]

When applied to the observable universe, we get surprising results.
To find the ratio $-\frac{R_S}{2R}$ according to $R$,

$$\frac{\frac{d(U_{gs})}{dR}}{\frac{d(Mc^2)}{dR}} = -\frac{R_S}{2R} \tag{20}$$

| $R(Gly)$ | $R_S(Gly)$ | $-R_S/2R$ |
|---|---|---|
| 10 | 4.80 | -0.238 |
| 15 | 16.0 | -0.533 |
| 20 | 38.0 | -0.950 |
| 25 | 74.2 | -1.48 |
| 30 | 128 | -2.13 |
| 35 | 204 | -2.91 |
| 40 | 304 | -3.80 |
| 45 | 433 | -4.81 |
| 50 | 594 | -5.94 |

The density used the current critical density($\rho_c = 8.50\times10^{-27}[kgm^{-3}]$), but the density is a variable. Please see the approximate trend. The rate of increase of gravitational potential energy tends to be greater than the rate of increase of mass energy. Therefore, at some point, a situation arises in which dark energy becomes larger than matter and dark matter.

When the size $R$ of the observable universe passes 20 to 25 $Gly$, it turns out that the transition from decelerating expansion to accelerating expansion occurs. And, this period is about 5 billion years ago, which is similar to the observations. [8] Therefore, the above analysis results suggest that gravitational potential energy is dark energy.

**2.2.3.1.3. The inflection point at which the magnitudes of mass energy and gravitational potential energy are equal**

If we find the magnitude at which the positive mass energy and the negative gravitational potential energy are equal, [10]

$$E_T = \sum_i m_i c^2 + \sum_{i<j} -\frac{Gm_i m_j}{r_{ij}} = Mc^2 - \frac{3}{5}\frac{GM^2}{R} = 0 \tag{21}$$

$$\rho = \frac{5c^2}{4\pi G R^2} \tag{22}$$

$$R_{gs} = \sqrt{\frac{5c^2}{4\pi G \rho}} \tag{23}$$

If the mass density of the early state of the universe is $\rho_0$, then the size of the universe where the positive mass energy and negative gravitational self-energy are equal, $R_{gs}$, is

$$R_{gs} = \sqrt{\frac{5c^2}{4\pi G \rho_0}} \tag{24}$$

In the case of uniform density, if the radius $R$ of the gravitational interaction is smaller than $R_{gs}$, the region is in a state of decelerating expansion, since the positive mass energy is greater than the negative gravitational potential energy.

However, as time passes, i.e. as the universe ages, the radius $R$ of the gravitational interaction becomes larger than $R_{gs}$, From this point on, the negative gravitational potential energy becomes greater than the positive mass energy, so the region becomes negative energy state, and accelerates expansion.

By setting $R = ct$(depending on the dominant constituent, the coefficients vary), we can get the approximate time for the universe to transition to the accelerated expansion phase.

$$R_{gs} = \sqrt{\frac{5c^2}{4\pi G \rho_0}} \simeq ct \tag{25}$$

$$t_{gs} = \sqrt{\frac{5}{4\pi G \rho_0}} \tag{26}$$

$t_{gs}$ is the time when the gravitational self-energy equals the mass energy, and $\rho_0$ is the average density at this time.

**2.2.3.2. Expansion with no cosmological constant or no vacuum energy and constant total mass**

Consider the expansion model in which the total mass is constant. This is the case when positive mass in an expanding system is conserved.

$$E_{ME} = M_0 c^2 = \frac{4\pi\rho(t)R(t)^3}{3}c^2 = \frac{4\pi c^2}{3}\rho R^3 \tag{27}$$

$$U_{gs} = -\frac{3}{5}\frac{G{M_0}^2}{R(t)} = -\frac{3}{5}\frac{G{M_0}^2}{R} \tag{28}$$

The positive mass energy is constant even when $R$ increases. On the other hand, negative gravitational self-energy is inversely proportional to $R$, and decreases as $R$ increases (over time).

$$\frac{U_{gs}}{E_{ME}} = \frac{-\frac{3}{5}\frac{G{M_0}^2}{R}}{M_0 c^2} = (-\frac{3}{5}\frac{GM_0}{c^2})\frac{1}{R} = -\frac{k}{R} \tag{29}$$

When $R$ doubles, the negative energy drops to half the positive energy. In this model, if the total energy of the region is in a positive energy (mass) state, that is, if it is in a decelerating expansion state, it continues to decelerate expansion.

This suggests that even though the region was in a negative energy (mass) state, i.e., in an accelerating expansion state, it changes to a decelerating expansion state over time. This mechanism could be used to end the inflation mechanism.

In the early universe, as in chapter 2.2.3.1, the universe accelerates as the range of gravitational interactions increases. As $R$ increases due to this accelerated expansion and the materials are accelerated, the average density may decrease. Then, the universe will go into an expansion similar to chapter 2.2.3.2, and the universe will enter a period of decelerating expansion.

Thus, it will be possible to build a model that includes the beginning and end of the inflation mechanism.

**2.2.3.3. Expansion in space where there is no cosmological constant or no vacuum energy, when the expansion velocity of matter and the propagation velocity of gravitational interaction are different**

We can consider the case where there is no cosmological constant or no vacuum energy, but the propagation velocity of gravitational interaction is faster than the expansion velocity of matter. In this case, it is a form of influx of new mass-energy within the range of gravitational interaction.

In this case, the mass energy also increases, and the magnitude of the gravitational potential energy also increases. **Depending on the amount of mass newly entering the range of gravitational interaction, both accelerated expansion and decelerated expansion are possible.**

I have done some analysis of these expansions in pages 13-14 of this paper [8] .This is not covered in this paper and is a subject for future research.

**2.2.3.4. When vacuum energy exists and the velocity of expansion of matter and the velocity of transfer of gravitational interaction are the same**

When vacuum energy exists, the total amount of matter within the range of gravitational interaction is conserved.

$$M_0 = \frac{4\pi}{3}\rho_{m,0}{R_0}^3 = \frac{4\pi}{3}\rho_{m,t}{R_t}^3 \tag{30}$$

$$\rho_{m,t} = (\frac{R_0}{R_t})^3\rho_{m,0} \tag{31}$$

$$E_{ME} = M(t)c^2 = \frac{4\pi c^2}{3}(\rho_{m,t} + \rho_{ve}){R_t}^3 = \frac{4\pi c^2}{3}((\frac{R_0}{R_t})^3\rho_{m,0} + \rho_{ve}){R_t}^3 \tag{32}$$

$$U_{gs} = -\frac{3}{5}\frac{GM(t)^2}{R(t)} = -\frac{3}{5}\frac{GM(\frac{4\pi {R_t}^3(\rho_{m,t}+\rho_{ve})}{3})}{R_t} = -\frac{4\pi GM{R_t}^2(\rho_{m,t} + \rho_{ve})}{5} \tag{33}$$

Strictly speaking, if density is a function of time, then the gravitational self-energy equation is presumed to be different from the uniform density equation. (The gravitational self-energy density depends on the process by which the mass gathers.) This is left for future research, and here I will consider only the beginning and end of the process. Since both the beginning and the end have uniform density, applying the uniform density equation,

$$\frac{U_{gs}}{E_{ME}} = \frac{-\frac{4\pi GM(t)R(t)^2(\rho_m(t)+\rho_{ve})}{5}}{M(t)c^2} = -\frac{4\pi G({R_t}^2\rho_{m,t} + {R_t}^2\rho_{ve})}{5c^2} \tag{34}$$

$$\frac{U_{gs}}{E_{ME}} = -(\frac{3GM_0}{5c^2}\frac{1}{R_t} + \frac{4\pi G}{5c^2}{R_t}^2\rho_{ve}) \tag{35}$$

When the vacuum energy density $\rho_{ve}$ is 0, this equation is the same as the result in 2.2.3.2 chapter. As $R$ increases, the first term goes to 0, but the second term increases in proportion to $R^2$. In other words, the vacuum energy term becomes more important as time goes on.

A model like this can also be used to solve the current dark energy problem. Note that, in the Gravitational Potential Energy Model, vacuum energy does not have negative pressure. Although energy density always remains constant, positive energy density does not have negative pressure because pressure is related to momentum or kinetic energy. [8] Since the gravitational potential energy is a negative energy component, there is no need to artificially assume a negative pressure.

# 3. Estimation of the birth of the universe and the early universe

There are many assumptions and speculations about the birth of the universe. In particular, since there are few facts verified through experiments, we have no choice but to rely more on assumptions and inferences. Therefore, there are many unexplained and inexplicable things. Nonetheless, since I wish to go a step further regarding the origin of the universe, I describe the following speculation with this wish in mind.

Regarding the origin of energy in the universe, we can build a model that assumes or asserts that all energy existed in the first place, or we can build a model in which energy is also born. Each model has its strengths and weaknesses. However, what I felt during my research is that the total energy of the system changes due to the propagation time of the gravitational interaction and the range of the interaction. In addition, it is known that there is no global energy conservation equation in the current general theory of relativity, and the concept of dark energy in the standard model is also a concept in which the total energy of the system is not conserved. [18]

Therefore, since the total energy of the universe is not a conserved physical quantity, it is not necessary to select a model in which the early universe must have all the energy of the current universe. In addition, since these models still have the problem of explaining the initial energy, I believe that they are unlikely to be the ultimate solution to the origin of the universe or the origin of energy.

### 3.1 The logical structure of standard cosmology and negative energy

In order to explain the birth of energy out of nothing, an introduction to negative energy is indispensable. Many scientists think that the total energy of the universe is positive, and most seem to think that the total energy of any object cannot be negative. However, these thoughts may be wrong.

We have to think about the logic behind standard cosmology.
Let's go back to what we discussed in the introduction.

$$\frac{1}{R}(\frac{d^2R}{dt^2}) = -\frac{4\pi G}{3}(\rho + 3P) \tag{36}$$

$$\rho + 3P \simeq \rho_m + \rho_\Lambda + 3(P_m + P_\Lambda) \simeq (\frac{1}{3})\rho_c + (\frac{2}{3})\rho_c + 3(-\frac{2}{3}\rho_c) = (+1)\rho_c + (-2)\rho_c = (-1)\rho_c \tag{37}$$

$$\rho + 3P \simeq (+1)\rho_c + (-2)\rho_c = (-1)\rho_c \tag{38}$$

**Standard cosmology is a form of positive mass density of $+1\rho_c$ and negative mass density of $-2\rho_c$. So, finally, the universe has a negative mass density of "$-\rho_c$"**, so accelerated expansion is taking place. The current universe is similar to a state where the negative mass density is twice the positive mass density. And the total mass of the observable universe is the negative mass state. [8]

One of the teachings of relativity and quantum mechanics is that we shouldn't judge nature by the knowledge we acquire in everyday life. You shouldn't try to fit the universe into your stereotyped mold. Thinking that the universe would naturally slow down expansion, we introduced the deceleration parameter $\beta$ to account for this. Already, the accelerating expansion of the universe itself, the problem itself, is a case where our stereotypes have failed, and is evidence.

Since the current observable universe is very likely to be in a negative energy state, we should put aside our reluctance to introduce negative energy or negative mass and think about the following models.

### 3.2. Creation of pairs of negative and positive energy

#### 3.2.1. Starting at zero energy, including negative and positive energy

$$E_T(t = 0) = 0 \tag{39}$$

$$E_T(t = t_0) = (+E) + (-E) = \sum +m_+c^2 + \sum -m_-c^2 = 0 \tag{40}$$

$$E_T(t > t_0) = \sum +m_+c^2 + \sum -m_-c^2 + \sum U \tag{41}$$

$t_0$ is a time infinitely close to $t = 0$.

In this model, negative energy $(-E)$ and positive energy $(+E)$ pairs are initially created from nothing, so the initial energy starts at zero. A model in which various interactions occur over time, including gravitational interactions.

$E_T(t = 0)$ or $E_T(t = t_0)$ is 0, but $E_T(t > t_0)$ can be negative, 0, or positive. Since space-time is transformed by the energy momentum tensor, at the same time that energy is born, time is also born.

In this model, the total gravitational potential energy term is

$$\begin{aligned} U_T = \sum_{i<j}(-\tfrac{Gm_{+i}m_{+j}}{r_{++ij}}) + \sum_{i<j}(-\tfrac{Gm_{-i}m_{-j}}{r_{--ij}}) + \sum_{i,j}(+\tfrac{Gm_{-i}m_{+j}}{r_{-+ij}}) \\ = U_m + U_d + U_\Lambda \end{aligned} \tag{42}$$

The first term is the gravitational potential energy term of matter, the second term is the gravitational potential energy term of dark matter, and the third term is the repulsive force term. Since the third term can be greater than the first and second terms, we can produce accelerated expansion. [19]

#### 3.2.2. Starting from zero energy, including negative and positive energy and gravitational potential energy

$$E_T(t = 0) = 0 \tag{43}$$

$$E_T(t = t_0) = \sum +m_+c^2 + \sum -m_-c^2 + \sum U = 0 \tag{44}$$

$$E_T(t > t_0) = \sum +m_+c^2 + \sum -m_-c^2 + \sum U \tag{45}$$

This model initially starts from nothing ($E_T(t = 0) = 0$), but over time, various interactions, including gravitational interactions, occur. $E_T(t = 0)$ or $E_T(t = t_0)$ is 0, but $E_T(t > t_0)$ can be negative, 0, positive.

Since a pair of negative and positive mass is created from nothing, looking at the case of creating one pair,

$$E_T = 0 = (+m_+c^2) + (-m_-c^2) + (-\frac{G(+m_+)(-m_-)}{r}) = 0 \tag{46}$$

$$|-m_-| = m_+ + \frac{Gm_+m_-}{rc^2} \tag{47}$$

Normally, when creating a pair of negative and positive mass, it is assumed that the two masses will be exactly the same size, but this guess is incorrect.

This is because there is a binding energy or potential energy between negative and positive mass. Since this potential energy has either a negative or positive sign, the magnitudes of the negative mass and the positive mass are different. [11]

When a negative mass and a positive mass are pair-created, the negative mass moves in the direction of the positive mass, and the positive mass moves away from the negative mass, resulting in runaway motion.

However, since the acceleration is determined by the size of the other party's mass, the magnitude of the acceleration of negative mass and positive mass is different. As a result, the negative mass and the positive mass have the effect of moving further and further apart, so that the negative mass and the positive mass do not annihilate, and can exist in a state where the pair is broken. [11]

This logic can be the theoretical basis for the existence of two masses after pair creation and without pair annihilation. 1)The law of conservation of energy, 2)the mass difference between negative and positive mass due to potential energy, 3)repulsive gravitational effect. [11]

#### 3.2.3. Starting from zero energy, including positive energy and gravitational potential energy

This model creates a zero energy state in which positive mass energy and negative gravitational potential energy cancel each other out. To formalize the content of Edward Tryon's 1973 paper [12]

$$E_T(t=0)=0 \tag{48}$$

$$E_T(t=t_0)=\sum_i +m_i c^2+\sum_{i<j} -\frac{Gm_i m_j}{r_{ij}}=0 \tag{49}$$

$$E_T(t>t_0)=\sum_i +m_i c^2+\sum_{i<j} -\frac{Gm_i m_j}{r_{ij}} \tag{50}$$

Period of accelerated expansion of the early universe, period of inflation

$$E_T(t_2>t>t_0)=\sum_i +m_i c^2+\sum_{i<j} -\frac{Gm_i m_j}{r_{ij}}<0 \tag{51}$$

$t_1$ is the inflection point, $t_1$ is the entry time for accelerated expansion, and $t_2$ is the end time for accelerated expansion.

In the case of this model, as the range of gravitational interaction increases after birth, a situation in which the gravitational potential energy exceeds the mass energy is possible, and can immediately enter the accelerating expansion period.

Edward Tryon argued for a zero energy universe in which positive mass energy and gravitational potential energy cancel not only at the birth of the universe, but also today. [12]

I can accept starting from the zero energy state at birth, but I believe that as time goes on, the range of gravitational interaction changes, and thus the mass-energy that participates in gravitational interaction changes. Thus, the total energy of the universe is not conserved, it varies. I claim that negative gravitational potential energy can explain the acceleration expansion in the early days of the universe and the current acceleration expansion.

When $t>t_0$, the situation is similar to the analysis situation in 3.3. chapter.

#### 3.2.4. Starting from negative energy, including positive energy and gravitational potential energy

$$E_T(t=0)=0 \tag{52}$$

$$E_T(t=t_0)=\sum_i +m_i c^2+\sum_{i<j} -\frac{Gm_i m_j}{r_{ij}}<0 \tag{53}$$

$$E_T(t>t_0)=\sum_i +m_i c^2+\sum_{i<j} -\frac{Gm_i m_j}{r_{ij}} \tag{54}$$

Since chapter 3.3 covers the case of starting from positive energy, let's also consider starting from negative energy.

If the object is in a negative energy state from the beginning, it accelerates and expands right after birth because there is a repulsive gravitational effect between the negative masses. $E_T(t>t_0)$ can be less than, equal to, or greater than zero. It changes depending on the size and circumstances of the mass that participates in the gravitational interaction. For example, initially accelerated expansion, but may switch to decelerated expansion when the expansion described in Chapter 2.2.3.2 occurs.

If additional mass gains exist, it may enter a period of accelerated expansion again. Any additional mass increase is due to a new mass-energy increase in the range of gravitational interactions. This can be achieved by the cosmological constant or vacuum energy, and in a space with a uniform material distribution, a mass-increasing effect can occur when the expansion rate of matter and the transfer rate of gravitational interaction are different.

### 3.3. Positive energy (mass) birth model
#### 3.3.1. Estimating from the Planck Scale

$$E_T(t=0)=0 \tag{55}$$

$$E_T(t=t_0)=\sum_i +m_ic^2>0 \text{ or } E_T(t=t_0)=\sum_i +m_ic^2+\sum_{i<j}-\frac{Gm_im_j}{r_{ij}}>0$$

$$E_T(t>t_0)=\sum_i +m_ic^2+\sum_{i<j}-\frac{Gm_im_j}{r_{ij}} \tag{56}$$

Inflection point, when inflation starts

$$E_T(t=t_1)=\sum_i +m_ic^2+\sum_{i<j}-\frac{Gm_im_j}{r_{ij}}=0 \tag{57}$$

Period of accelerated expansion of the early universe, period of inflation

$$E_T(t_2>t>t_1)=\sum_i +m_ic^2+\sum_{i<j}-\frac{Gm_im_j}{r_{ij}}<0 \tag{58}$$

Let's assume that the universe was born or existed with uniform density $\rho_0$ at $t_0$, and when time $t_1$ has elapsed, the range of gravitational interaction has reached $R_{gs}$ (the point at which the magnitudes of positive mass energy and negative gravitational potential energy are equal).

Since it is a process of building a rough model, using $R\simeq ct$ for the range of gravitational interactions,

$$R_{gs}=\sqrt{\frac{5c^2}{4\pi G\rho_0}}\simeq ct_1 \tag{59}$$

$$t_1=\sqrt{\frac{5}{4\pi G\rho_0}} \tag{60}$$

The above expression means that when an object with a certain uniform density $\rho_0$ passes time $t_1$, the positive mass energy and negative gravitational self-energy become equal, After time longer than this $t_1$, the region reaches a negative energy state, suggesting accelerated expansion. The higher the density, the smaller the radius at which the negative gravitational potential energy cancels out the positive mass energy. This also reduces the time $t_1$ at which the universe enters accelerated expansion.

In the beginning of the universe, if we assume that the time to enter accelerated expansion is the Planck time,

$$R_{gs}=\sqrt{\frac{5c^2}{4\pi G\rho_0}}\simeq ct_1=ct_P=\sqrt{\frac{\hbar G}{c^3}} \tag{61}$$

$$\rho_0=\frac{5}{4\pi G{t_1}^2}=\frac{5}{4\pi G{t_P}^2}=2.05\times10^{96}kgm^{-3} \tag{62}$$

In the denominator, the time $t_1$ passes through the inflection point from decelerating expansion to accelerating expansion is entered. It can be seen that when the density is high, the accelerated expansion starts relatively quickly, and when the density is low, the accelerated expansion starts relatively late.

$$M=\frac{4\pi R^3}{3}\rho_0=\frac{4\pi(ct_P)^3}{3}(\frac{5}{4\pi G{t_P}^2})=\frac{5c^3}{3G}t_P=\frac{5}{3}m_P \tag{63}$$

Looking at the meaning of these values,

A uniform mass distribution with energy density $\rho_0$ passes through the point where the negative gravitational potential energy equals the positive mass energy at Planck time $t_P$, When time is greater than $t_P$, the expansion accelerates. At this time, the minimum mass of the region entering accelerated expansion is $\frac{5}{3}m_P$.

**When the age of the universe reaches the Planck time, it becomes possible to build a model of the accelerated expansion of the universe. By changing the initial density, we can change the time it takes to enter accelerated expansion.**

### 3.3.2. Birth and expansion of the universe from the Uncertainty Principle

$$\Delta x \Delta p \geq \frac{\hbar}{2} \tag{64}$$

$$\Delta E \Delta t \geq \frac{\hbar}{2} \tag{65}$$

#### 3.3.2.1. Uncertainty Principle + Expansion in Planck time

If we consider the energy (mass) change during the Planck time, if $\Delta t = t_P$

$$\Delta E \geq \frac{\hbar}{2\Delta t} = \frac{\hbar}{2}\frac{1}{\sqrt{\frac{\hbar G}{c^5}}} = \frac{1}{2}m_P c^2 \tag{66}$$

According to the uncertainty principle, it is possible to change or create more than $\frac{1}{2}m_P c^2$ energy during Planck time $\Delta t$.

In chapter 3.3,1, I found the magnitude of the mass when the mass distribution reaches a negative mass state(i.e. when the universe enters accelerated expansion) in the Planck time. This value is $\frac{5}{3}m_P$. By the way, when the mass distribution of an object is approximated in the form of a spherical mass distribution, $\Delta x$ from the uncertainty principle corresponds to the diameter, not the radius. thus, $\Delta x = 2R' = c\Delta t$

$$R_{gs}' = \sqrt{\frac{5c^2}{4\pi G \rho_0'}} \simeq \frac{ct_1}{2} = \frac{ct_P}{2} = \frac{1}{2}\sqrt{\frac{\hbar G}{c^3}} \tag{67}$$

$$\rho_0' = \frac{5c^2}{4\pi G (\frac{ct_1}{2})^2} \tag{68}$$

$$M' = \frac{4\pi R'^3}{3}\rho_0' = \frac{4\pi (\frac{ct_P}{2})^3}{3}(\frac{5}{4\pi G(\frac{t_P}{2})^2}) = \frac{1}{2}\frac{5c^3}{3G}t_P = \frac{5}{6}m_P \tag{69}$$

This value is $\frac{1}{2}$ times the mass value obtained in 3.3.1 Chapter.

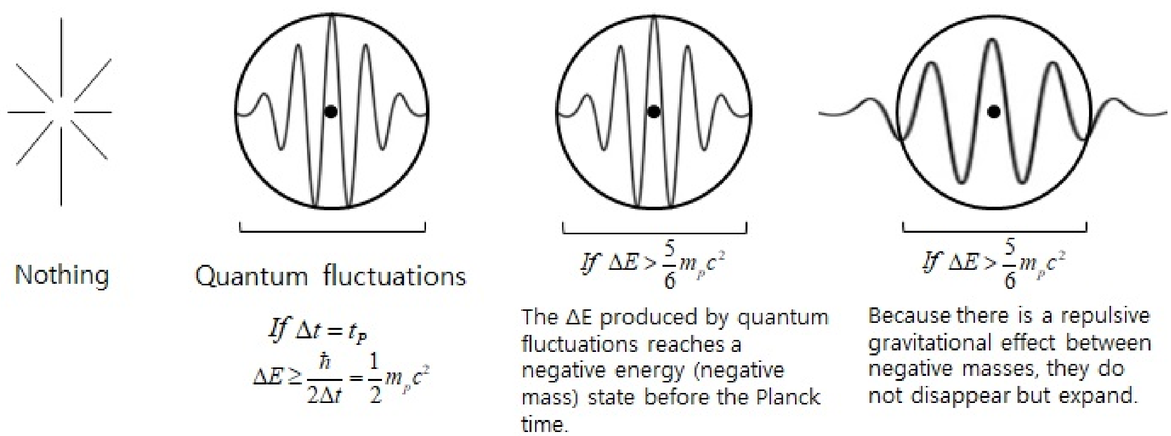


Figure 3: According to the uncertainty principle, If $\Delta t = t_P$, $\Delta E \geq \frac{\hbar}{2t_P} = \frac{1}{2}m_P c^2$. By the way, what if the energy fluctuation occurs more than $\frac{5}{6}m_P c^2$ ?

**According to the uncertainty principle, during the Planck time, energy fluctuation of more than $\frac{1}{2}m_P c^2$ are possible, By the way, if an energy fluctuation of more than $\frac{5}{6}m_P c^2$, which is slightly**

**larger than the minimum, occurs, the total energy reaches a negative energy (mass) state in $t_P$ time, in which quantum fluctuation can exist. However, there is a repulsive gravitational effect between negative masses. Therefore, since the mass distribution is in a negative mass state, the mass distribution will expand instead of contract.** [2] **Thus, the quantum fluctuations generated from the uncertainty principle cannot return to nothing, but can expand and become the present universe.**

* Motion of positive mass due to negative gravitational potential energy,

$$F_{gp} = -\frac{G(-m_{gp})m_3}{R^2} = +\frac{G(m_{gp})m_3}{R^2} \tag{70}$$

The force exerted by a negative (equivalent) mass on a positive mass is a repulsive (anti-gravity) force, so the positive mass accelerates and expands.

The gravitational force acting between negative masses is attractive($F = -\frac{G(-m)(-m)}{r^2} = -\frac{Gmm}{r^2}$), but since the inertial mass is negative in the case of negative mass, the gravitational effect is repulsive($F = -ma$, $a = -\frac{F}{m}$ ). So the distribution of negative energy or the distribution of negative equivalent mass is inflated.

At this time, the Planck time is the time when individual masses or individual events enter accelerated expansion, and the time when the entire universe enters explosive acceleration is when the surrounding matter or energy also comes within the range of gravitational interaction, thus, it may be slightly larger than the Planck time.

Since $\Delta E = \frac{1}{2}m_P c^2$ is a minimum, we can try putting in a larger value, e.g. the total mass energy [3] of the observable universe or the total mass energy of the entire universe. In addition, here, the time to enter accelerated expansion is set as the Planck time, but this time can be adjusted. Depending on the observation results, it is necessary to adjust the time to enter accelerated expansion.

**3.3.2.2. The magnitude at which the minimum energy produced by quantum fluctuations equals the energy required for accelerated expansion**

In the analysis above, the minimum energy of quantum fluctuations possible during the Planck time is $\Delta E \geq \frac{1}{2}m_P c^2$, and the minimum energy fluctuation for which expansion after birth can occur is $\Delta E > \frac{5}{6}m_P c^2$. Since $\Delta E > \frac{5}{6}m_P c^2$ is greater than $\Delta E \geq \frac{1}{2}m_P c^2$, the birth and coming into existence of the universe is a probabilistic event. More precisely, a single event is a probabilistic event, but in a situation where the entire universe has uniform density, this event also becomes a inevitable event. This is because as time passes, the mass energy participating in the gravitational interaction increases. It will inevitably pass through the inflection point $R_{gs}$.

**For those unsatisfied with probabilistic event, consider the case where the birth of the universe was an inevitable event.**

If, $\Delta t = kt_P$

$$\Delta E \geq \frac{\hbar}{2\Delta t} = \frac{\hbar}{2}\frac{1}{k\sqrt{\frac{\hbar G}{c^5}}} = \frac{1}{k}(\frac{1}{2}m_P c^2) \tag{71}$$

$$R_{gs}{}' = \sqrt{\frac{5c^2}{4\pi G\rho_0{}'}} \simeq \frac{ct_1}{2} = \frac{c(kt_P)}{2} \tag{72}$$

$$\rho_0{}' = \frac{5}{4\pi G(\frac{kt_P}{2})^2} = \frac{4}{k^2}\rho_0 \tag{73}$$

$$M' = \frac{4\pi R'^3}{3}\rho_0{}' = k(\frac{5}{6}m_P) \tag{74}$$

[2]Stated another way, it expands because the repulsive force due to the negative gravitational self-energy is greater than the attractive force due to the positive energy (mass) distribution.

[3]Here, the meaning of the total mass energy is the value excluding the gravitational potential energy created by the mass energy

$$\frac{1}{k}(\frac{1}{2}m_P c^2) = k(\frac{5}{6}m_P c^2) \tag{75}$$

$$k = \sqrt{\frac{3}{5}} \simeq 0.77 \tag{76}$$

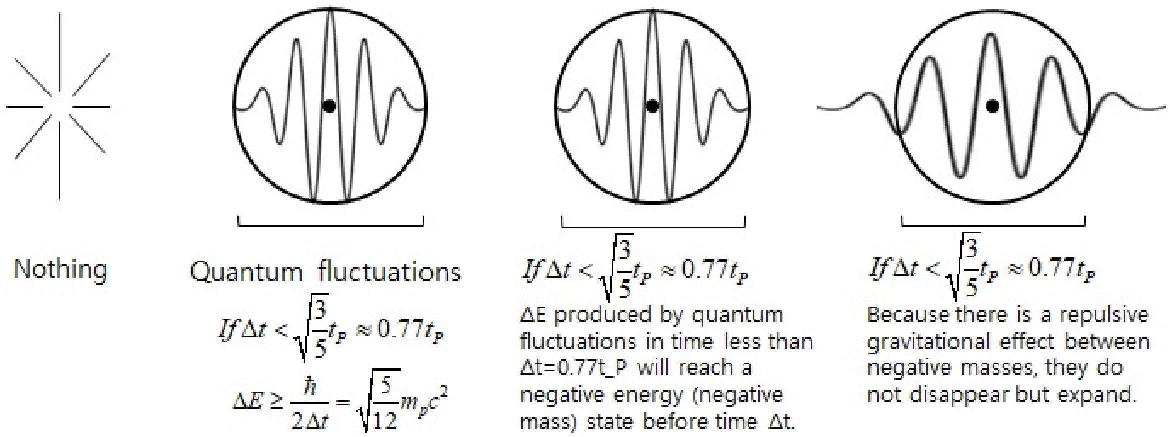


Figure 4: **If a quantum fluctuation occurs with $\Delta t$ less than $\sqrt{\frac{3}{5}}t_P = 0.77t_P$, The situation in which the universe is born and expands may be an inevitable situation.**

To summarize,

If $\Delta t \leq \sqrt{\frac{3}{5}}t_P \approx 0.77t_P$, then $\Delta E \geq \frac{\hbar}{2\Delta t} = \sqrt{\frac{5}{12}}m_P c^2$ is possible. And, the minimum magnitude at which the energy distribution reaches a negative energy state by gravitational interaction within $\Delta t$ is $\Delta E = \sqrt{\frac{5}{12}}m_P c^2$. Thus, when $\Delta t < \sqrt{\frac{3}{5}}t_P$, a state is reached in $\Delta t$ where the total energy of the system is negative.

In other words, **when quantum fluctuation occur where $\Delta t$ is smaller than $\sqrt{\frac{3}{5}}t_P = 0.77t_P$, the corresponding mass distribution reaches a state in which negative gravitational potential energy exceeds positive mass energy within $\Delta t$. Therefore, it can expand without disappearing.**

In this case, the situation in which individual mass distribution expand after birth becomes an inevitable event.

**3.3.2.3. Uncertainty Principle + when inflation starts at $10^{-36}s$**

In the existing cosmology, inflation starts at about $10^{-36}s$ [1], so let's think about what results come out when the uncertainty principle is combined at this time.

$$\Delta m \geq \frac{\hbar}{2c^2\Delta t} = \frac{\hbar}{2c^2(10^{-36}s)} = 5.89 \times 10^{-16}kg = 2.7 \times 10^{-8}m_P \tag{77}$$

$$\rho_1{}' = \frac{5}{4\pi G(\frac{t_1}{2})^2} = 2.39 \times 10^{82}kgm^{-3} \tag{78}$$

$$M' = \frac{4\pi R'^3}{3}\rho_1' = 0.33kg \tag{79}$$

According to the energy-time uncertainty principle, during $\Delta t = 10^{-36}s$, more than $\Delta E \geq \frac{\hbar}{2\Delta t} = (5.89 \times 10^{-16}kg)c^2$ energy fluctuation or creation is possible.

However, if there is an energy fluctuation of more than $\Delta E = (0.33kg)c^2$ during $\Delta t = 10^{-36}s$, the total energy passes through the point where the negative gravitational self energy exceeds the positive mass energy before $\Delta t = 10^{-36}s$, and accelerates expansion. Thus, a situation may occur in which the energy fluctuation expands rather than contracts.

In this case, there is a difference of approximately $10^{15}$ times between the minimum energy $(5.89\times10^{-16}kg)c^2$ that can be created by quantum fluctuations and the minimum energy $(0.67kg)c^2$ at which the mass distribution enters accelerated expansion. Therefore, in this case, the existence of the universe or the event that the universe expands after its birth can be regarded as a low-probability event.

It should be noted that this analysis is based on a single event. It is also necessary to build a model that sets the inflation time to $10^{-36}s$ assuming multiple energy birth events.

Whether the birth of the universe (a situation in which the universe is born from quantum fluctuations and does not disappear) is an inevitable event or a low-probability event can be determined by creating a precise cosmology that applies the mechanism of this paper and comparing it with observational data.

**The combined model of the uncertainty principle and gravitational potential energy can provide an explanation for why the early universe was dense and why it was born in a dense state.** Energy fluctuations are possible for a short time due to the uncertainty principle, and if the total energy of the gravitational interaction range becomes negative during this short time, the energy expands and can exist. At this time, high density is required in order for the gravitational potential energy to exceed the mass energy. In other words, it is possible to achieve a state in which the total energy is negative energy within a small $\Delta t$ only in the case of a high-density state.

Existing "Something from Nothing" models are complex in many processes, and it is often difficult to identify even if there are problems during the process. However, the gravitational potential energy model is very simple. In addition, the coupled model of the uncertainty principle and gravitational potential energy explains the birth of the universe from nothing (zero energy) and its accelerated expansion after birth without introducing a new physical quantity such as inflaton.

### 3.4. Does the same creation and expansion as in the early universe occur in the current vacuum?

I think that the current situation is different from the situation in the early universe when space-time, fields, and forces were born, and therefore, the accelerated expansion of the early universe suggested by this model was only once when the universe was first born.

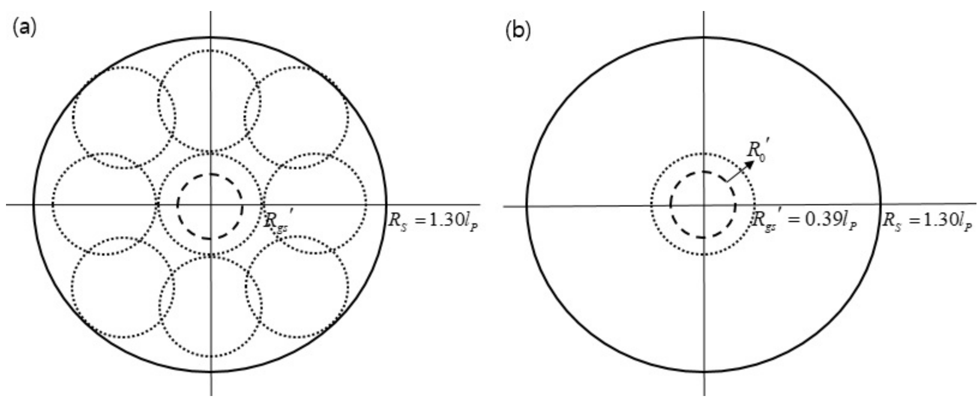


Figure 5: (a) the vacuum of the early universe, when the density of quantum fluctuations is high; (b) the current vacuum, when the density of quantum fluctuations is low. If the density of quantum fluctuations is high, as in (a), expansion beyond the event horizon is possible, which is formed by single quantum fluctuations. Uniform density approximation possible. As in (b), if the density of quantum fluctuations is low, the quantum fluctuations cannot cross the event horizon they form and return to the zero state.

Let's find the size of the event horizon formed by a single mass $\sqrt{\frac{5}{12}}m_P \approx 0.65m_P$,

$$R_{gs}{}' = \frac{c\Delta t}{2} = \frac{c\sqrt{\frac{3}{5}}t_P}{2} \simeq 0.39l_P \tag{80}$$

$$\rho_0{}' = \frac{5}{4\pi G(\frac{kt_P}{2})^2} = 1.37 \times 10^{97} kgm^{-3} \tag{81}$$

$$R_S = \frac{2GM}{c^2} = \frac{2G(\sqrt{\frac{5}{12}}m_P)}{c^2} = 2.096 \times 10^{-35} m \simeq 1.30l_P \tag{82}$$

In figure (b), since the event horizon formed by single quantum fluctuation is $R_S = 1.30l_P$ ($l_P$ is the Planck length), and the energy (mass) distribution is $R_{gs}{}' = 0.39l_P$, This mass distribution gets trapped inside the black hole it forms and returns to zero energy due to its gravitational properties. Since the expansion is greater than the mass distribution region, from then on, the total mass is conserved expansion. Therefore, as R increases, the negative gravitational potential energy decreases, and it converges around the point ($R = R_{gs}$) where the negative gravitational potential energy and the positive mass energy become equal.

$R < R_{gs}$ : system is in negative energy (mass) state. Since the repulsive force component is greater than the attractive force component, the mass distribution expands.

$R > R_{gs}$: The system is in a positive energy (mass) state. Since the attractive force component is greater than the repulsive force component, the mass distribution undergoes deceleration expansion and contraction.

Therefore, the mass distribution becomes stable at $R = R_{gs}$ while oscillating around $R = R_{gs}$. The point where $R = R_{gs}$ is the point where the total energy of the system is zero.

Therefore, it is estimated that the current universe will not undergo accelerated expansion after birth as in the early universe.

The situation in Figure (a) is one in which there are multiple quantum fluctuations in $R_S$. This can be compared to the case where $R_S$ is full with uniform density $\rho_0{}'$. Therefore, let's find the size of the event horizon formed when the entire $R_S$ is filled with a mass distribution with density $\rho_0{}'$.

The size of the event horizon $R_S$ is proportional to its mass. When $R_S$ is filled with uniform density, since the volume increases $(\frac{R_S}{R_{gs}{}'})^3$ times, the mass also increases $(\frac{R_S}{R_{gs}{}'})^3$ times.

$$(\frac{R_S}{R_{gs}{}'})^3 = (\frac{1.3l_P}{0.39l_P})^3 \simeq 37.04 \tag{83}$$

$$R_S{}' \simeq 37.04R_S \tag{84}$$

Therefore, the event horizon $R_S{}'$ formed by the mass distribution filling $R_S$ with uniform density $\rho_0{}'$ becomes 37 times larger than the original $R_S$. Accordingly, the space in which the matter can expand also increases by approximately $(37)^3 \simeq 5 \times 10^4$ times. Because there is also an increase in mass that participates in gravitational interactions in this increased space, expansion into ever-larger space becomes possible.

$\Delta E = \sqrt{\frac{5}{12}}m_P c^2$ is the minimum value at which accelerated expansion occurs. Thus, we can think of the birth of a larger initial mass energy. It is also possible to build models in which the total mass energy of the observable universe or the entire universe is born in $\Delta t$. In this case, a faster accelerated expansion will occur because the negative gravitational self-energy is much greater than the positive mass energy.

**On the other hand, this suggests that the mass distribution born in the early universe still exists within the radius of the cosmic black hole. In other words, we have not yet escaped the black hole created by the total mass of the universe, and we exist inside the cosmic black hole. [20]**

If the critical density of the current observable universe is set at $\rho_c = 8.50 \times 10^{-27} [kgm^{-3}]$, and the size of the event horizon formed by the observable universe is calculated, $R_S = 478Gly$. It is roughly 10 times the size of the observable universe $R = 46.5Gly$. [20] In other words, the current observable universe also exists inside the black hole (or event horizon) formed by its own mass distribution.

Arranging the logic,

In the case of high density of quantum fluctuations in the early universe (the level at which other quantum fluctuations exist within the event horizon that a single quantum fluctuation forms, or birth with a uniform density ${\rho_0}'$ ), mass influx over time exists and, therefore, the event horizon grows, it is possible that the universe also grows. The situation in which the observable universe exists inside the event horizon created by the mass distribution of the observable universe is consistent with the interpretation of this model.

In another case, suppose the total mass energy of the entire universe was born in time $\Delta t$. Since the early universe was a situation in which space-time was born out of nothing, it is thought of as a different situation from the current vacuum.

However, in the current case, when quantum fluctuations are generated at a low density compared to the early universe (a level where no other quantum fluctuations exist within the event horizon formed by a single quantum fluctuation, or when quantum fluctuations are sparsely generated), a single quantum fluctuation is trapped inside the event horizon formed by its own mass, and annihilates to zero energy due to the nature of its negative gravitational potential energy.

**3.5. The density range in which quantum fluctuation is not confined to the event horizon formed by their own mass**

From the energy-time uncertainty principle,

$$\Delta E = \frac{4\pi R^3}{3}\rho' c^2 = \frac{4\pi (\frac{c\Delta t}{2})^3}{3}(\rho' c^2) = (\frac{\pi}{6}(\Delta t)^3 \rho' c^3)c^2 = m^* c^2 \tag{85}$$

$$m^* = \frac{\pi}{6}(\Delta t)^3 \rho' c^3 \tag{86}$$

$$\rho' \geq \frac{3}{\pi}\frac{\hbar}{c^5 (\Delta t)^4} \tag{87}$$

The condition that the mass distribution is not confined to the event horizon created by its own mass is

$$R_S < {R_0}' = \frac{c\Delta t}{2} \tag{88}$$

$$R_S = \frac{2GM}{c^2} = \frac{2G(\frac{\pi}{6}(\Delta t)^3 {\rho_0}' c^3)}{c^2} = \frac{\pi}{3}G(\Delta t)^3 {\rho_0}' c \tag{89}$$

$$\frac{\pi}{3}G(\Delta t)^3 {\rho_0}' c < \frac{c\Delta t}{2} \tag{90}$$

$${\rho_0}' < \frac{3}{2\pi}\frac{1}{G(\Delta t)^2} \tag{91}$$

Consequently,

$$\frac{3}{\pi}\frac{\hbar}{c^5 (\Delta t)^4} \leq {\rho_0}' < \frac{3}{2\pi}\frac{1}{G(\Delta t)^2} \tag{92}$$

To find the minimum value at which the equation holds,

$$\frac{3}{\pi}\frac{\hbar}{c^5 (\Delta t)^4} < \frac{3}{2\pi}\frac{1}{G(\Delta t)^2} \tag{93}$$

$$\Delta t > \sqrt{\frac{2G\hbar}{c^5}} = \sqrt{2}t_P \tag{94}$$

If, $\Delta t = k t_P$

$$\frac{3}{\pi}\frac{\hbar}{c^5 (k t_P)^4} \leq \rho' < \frac{3}{2\pi}\frac{1}{G(k t_P)^2} \tag{95}$$

$$\frac{1}{k^4}\frac{3}{\pi}\frac{c^5}{\hbar G^2} \leq \rho' < \frac{1}{2k^2}\frac{3}{\pi}\frac{c^5}{\hbar G^2} \tag{96}$$

Expressed using the Planck density $\rho_P = \frac{m_P}{{l_P}^3} = \frac{c^5}{\hbar G^2}$,

$$\frac{1}{k^4}\frac{3}{\pi}\rho_P \leq \rho' < \frac{1}{2k^2}\frac{3}{\pi}\rho_P \tag{97}$$

In this chapter, $\rho'$ is the density of quantum fluctuation created by the uncertainty principle when they are distributed over the event horizon created by their mass. Since there is an upper bound in the inequality, it can be seen that even if masses significantly greater than the minimum are produced, they will be confined to the event horizon.

If, $\Delta E = 10^8 m_P c^2$, $\Delta t = t_P$

$$R_S = \frac{2GM}{c^2} = \frac{2G(10^8 m_P)}{c^2} = 2 \times 10^8 (\frac{Gm_P}{c^2}) = 2 \times 10^8 l_P \tag{98}$$

$$R = \frac{c\Delta t}{2} = \frac{ct_P}{2} = \frac{1}{2}l_P \tag{99}$$

Since $R < R_S$, the mass distribution lies inside the event horizon of its own formation.

### 3.6. The Vacuum Catastrophe Problem or Cosmological Constant Problem

The vacuum catastrophe problem or the cosmological constant problem is a problem in which there is a large difference between the theoretical prediction of vacuum energy proposed by quantum field theory and the observed value. It is known that there is a difference of about $10^{120}$ between theoretical predictions and observed values.

Strictly speaking, the vacuum energy model is only one of the dark energy models, so the observed (or estimated from observed results) dark energy density may not be the density of vacuum energy. Therefore, the actual vacuum energy density can be the dark energy density, or zero, or negative. However, if the density of vacuum energy is greater than the dark energy density, it will have a larger effect than the dark energy term, so it can be excluded by observational results. Therefore, the upper limit of the observed vacuum energy density is approximately the dark energy density, and there is still a difference of more than $10^{120}$ times between the theoretical prediction value and the actual vacuum energy density value.

First, looking at the claims of the vacuum energy model, [1]

> *We can crudely estimate the value of the energy density of the vacuum using the uncertainty principles $\Delta x \Delta p \approx \hbar$(Eq. 5.19) and $\Delta E \Delta t \approx \hbar$ (Eq. 5.20). The vacuum can be modeled as a place where matter-antimatter pairs of particles are constantly being created and annihilated. These particles cannot be directly observed and their energy cannot be tapped; they are known as virtual particles. They borrow their rest energy $\Delta E$ from the vacuum and are annihilated in such a short time $\Delta t$ that they escape detection.*
>
> *Let's consider a virtual particle of mass $m \approx (\Delta E)/c^2$ confined to a cubical box of side $L \approx \Delta x$ with a particle lifetime of*
>
> $\Delta t \approx \hbar/\Delta E \approx \hbar/mc^2$
>
> *In addition, the particle's speed is approximately*
>
> $v \approx \frac{\hbar}{m\Delta x} \approx \frac{\hbar}{mL}$
>
> *(see Example 5.4.2). Since the farthest the particle can travel in time $\Delta t$ is $v\Delta t$, we set $L = v\Delta t$ to be certain the particle's motion does not carry it outside the box. Thus*
>
> $L = v\Delta t \approx \frac{\hbar}{mL}\frac{\hbar}{mc^2}$
>
> *Solving for L, we find*
>
> $L \approx \frac{\hbar}{mc}$

*The energy density of the vacuum must be capable of creating a pair of particles in the box so that conservation rules can be maintained (such as electric charge). That is, the energy density of the vacuum must be at least*

$u_{vac} \approx \frac{2mc^2}{L^3} \approx \frac{2m^4c^5}{\hbar^3}$

*The energy density of the vacuum must be capable of creating a pair of particles in the box so that conservation rules can be maintained (such as electric charge). That is, the energy density of the vacuum must be at least*

$u_{vac} \approx \frac{2mc^2}{L^3} \approx \frac{2m^4c^5}{\hbar^3}$

*The greatest mass for each particle in the pair may be taken to be the Planck mass,* $m_P = \sqrt{\hbar c/G}$ *(Eq.30.4). Our estimate of the energy density of the vacuum is thus*

$u_{vac} \approx \frac{2{m_P}^4c^5}{\hbar^3} \approx \frac{2c^7}{\hbar G^2}$

*Or* $u_{vac} \approx 10^{114} Jm^{-3}$*. Of course this is only a rough estimate. More sophisticated calculations (which also invoke an arbitrary cut-off to avoid an infinite answer) result in a value of* $u_{vac} \approx 10^{111} Jm^{-3}$.

Since there is energy $\Delta E$ or $u_{vac}$, which is one of the sources of gravity, and there is time $\Delta t$ for gravity to propagate, the gravitational self-energy must also be considered in this problem. So, to look at the mainstream estimates in terms of my model, let's do some calculations.

We have an equation for calculating the total gravitational potential energy in the case of a spherical, uniform distribution. This value is called the gravitational self-energy. In the vacuum energy model, calculations were performed as a regular hexahedron with one side L. If we consider a spherical space inside a regular hexahedron, the value of the vacuum energy density will be the same in this case. Since there is an expression for gravitational self-energy already calculated for spherical space, to utilize it, let's consider a spherical energy (mass) distribution with $R = \frac{L}{2}$.

According to the mass-energy equivalence principle, it is possible to define the equivalent mass ($m = \frac{E}{c^2}$) for all energies. Therefore, in this paper, the terms equivalent mass energy or mass energy or mass are sometimes used for objects with positive energy.

#### 3.6.1. Vacuum energy in space $R = \frac{L}{2}$

$$E_{vac} = \frac{4\pi R^3}{3} u_{vac} = \frac{4\pi (\frac{L}{2})^3}{3} (\frac{2c^7}{\hbar G^2}) = \frac{4\pi (\frac{\hbar}{2m_P c})^3}{3} (\frac{2c^7}{\hbar G^2}) = \frac{\pi}{3} m_P c^2 \tag{100}$$

$$E_{vac} = \frac{\pi}{3} m_P c^2 \simeq +1.047 m_P c^2 \tag{101}$$

#### 3.6.2. The gravitational potential energy of the vacuum energy of space $R = \frac{L}{2}$

$$U_{gs} = -\frac{3}{5}\frac{GM^2}{R} = -\frac{3}{5}\frac{G(\frac{\pi}{3}m_P)^2}{\frac{L}{2}} = -\frac{3}{5}\frac{G(\frac{\pi}{3}m_P)^2}{(\frac{\hbar}{2m_P c})} = -\frac{2\pi^2}{15} m_P c^2 \tag{102}$$

$$U_{gs} = -\frac{2\pi^2}{15} m_P c^2 \simeq -1.316 m_P c^2 \tag{103}$$

#### 3.6.3. The event horizon created by vacuum energy $E_{vac} = \frac{\pi}{3} m_P c^2$

$$R_S = \frac{2GM}{c^2} = \frac{2G(\frac{\pi}{3}m_P)}{c^2} = \frac{2\pi}{3} l_P \simeq 2.094 l_P \tag{104}$$

#### 3.6.4. The radius $R_{gs}$ at which the magnitudes of positive mass energy and negative gravitational potential energy are equal

$$|\frac{U_{gs}}{E_{vac}}| = |\frac{-\frac{3}{5}\frac{G(\frac{\pi}{3}m_P)^2}{R}}{\frac{\pi}{3}m_P c^2}| = |\frac{\frac{\pi}{5}\frac{Gm_P}{c^2}}{R}| = 1 \tag{105}$$

$$R_{gs} = \frac{\pi}{5}l_P = 0.628l_P \tag{106}$$

#### 3.6.5. Physical meaning of calculated $R$ values

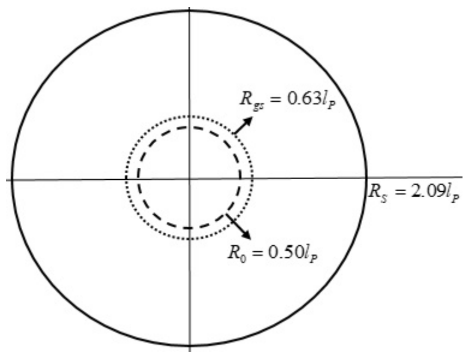


Figure 6: $R_0$, $R_{gs}$, $R_S$ created by the vacuum energy density $u_{vac}$

$$E_T(t = \Delta t) = E_{vac} + U_{gs} = \frac{\pi}{3}m_P c^2 - \frac{2\pi^2}{15}m_P c^2 \simeq -0.269m_P c^2 < 0 \tag{107}$$

Initially, since the negative gravitational potential energy is greater than the positive mass energy, the mass distribution at $R_0 = \frac{L}{2}$ will expand.

If there is no additional mass influx (or if mass is held constant), when the expanding mass distribution passes $R_{gs}$, the negative gravitational potential energy equals the positive mass energy.

When the mass distribution becomes larger than $R_{gs}$, since the positive mass energy is greater than the negative gravitational potential energy, the system switches to the positive mass state, and thus the situation in which the attractive force acts. Thus, the mass distribution will contract back to $R_{gs}$.

Mass energy is of the form $E = Mc^2$ and remains constant. On the other hand, the gravitational potential energy is of the form $U_{gs} = -\frac{3}{5}\frac{GM^2}{R}$, and the absolute value decreases as $R$ increases. Therefore, when the mass distribution expands, only the absolute value of the negative gravitational potential energy term decreases, so the system switches to the positive mass state after $R = R_{gs}$. The reduced gravitational potential energy will be converted into kinetic energy.

For example, if the mass in the system is constant and $R$ ($R$ is the radius of the mass distribution) doubles from $R_0$ to $2R_0$, it can be seen that the absolute value of the gravitational self-energy is reduced by a factor of $\frac{1}{2}$.

$$U_{gs}(R = R_0) = -\frac{3}{5}\frac{GM^2}{R_0} \tag{108}$$

$$U_{gs}(R = 2R_0) = -\frac{3}{5}\frac{GM^2}{2R_0} = \frac{1}{2}U_{gs}(R = R_0) \tag{109}$$

$R < R_{gs}$ : system is in negative energy (mass) state. Since the repulsive force component is greater than the attractive force component, the mass distribution expands.

$R > R_{gs}$: The system is in a positive energy (mass) state. Since the attractive force component is greater than the repulsive force component, the mass distribution undergoes deceleration expansion and contraction.

Therefore, the mass distribution becomes stable at $R = R_{gs}$ while oscillating around $R = R_{gs}$. The point where $R = R_{gs}$ is the point where the total energy of the system is zero.

One of the important characteristics is that it vibrates (repeating acceleration and deceleration expansion) based on $R = R_{gs}$, and finally stabilizes at $R = R_{gs}$. This is because the $R = R_{gs}$ point is the point where the positive and negative energy components are equal, and the total energy of the system is zero. Although we are analyzing the process in detail, the time interval between these events is approximately $t_P \sim 10^{-44}s$.

As a rough estimate, if there is no additional mass density generation within the $1l_P$(approximately $2(0.50l_P)$) range, the mass distribution will converge to $R_{gs}$ where the positive mass energy equals the negative gravitational potential energy. As a result, the mass distribution returns to the zero-energy state because the magnitudes of the positive mass energy and the negative gravitational self-energy in $R_{gs}$ are equal.

Also, since the event horizon $R_S = 2.09l_P$ formed by the mass distribution of $R_0$ is greater than $R_{gs} = 0.63l_P$, the mass distribution exists inside the event horizon. Therefore, the mass distribution does not escape the event horizon, converges to $R_{gs}$, and finally returns to nothing.

And, as a problem of consideration, when a stellar black hole forms, the space-time outside the black hole is affected and curved during the process of forming the black hole. By the way, after forming the black hole, if the location of the mass distribution changes inside the black hole, does this also affect the space-time outside the black hole?

It is estimated that gravity due to changes in the distribution of mass inside the black hole will not be able to escape the black hole. Even when gravity due to changes in the mass distribution inside the black hole affects the geometry of space-time outside the black hole, the effect is zero or very close to zero because of the gravitational properties of negative gravitational potential energy and positive mass energy described above.

As in previous theoretical calculations, if the vacuum had an enormous energy of $u_{vac} \approx 10^{111} \sim 10^{114} Jm^{-3}$, it should be observable around us. However, we are not detecting the presence of these enormous energies from the vacuum. Even if quantum fluctuations occur in vacuum according to existing theoretical assumptions, since $\Delta E$ and $\Delta t$ exist, their own gravitational interactions must also be taken into account. Therefore, considering the gravitational self-energy, the vacuum energy density is likely to be zero, unless the frequency of quantum fluctuations in the vacuum is extremely high.

If the frequency of occurrence of quantum fluctuations is less than approximately 1 within the range of radius $l_P$ during the $5t_P$, it can be estimated that the total energy of the quantum fluctuations produced will be in the zero energy.

For example, as a rough estimate, let's assume that 1 quantum fluctuation occurs within a radius of $1l_P$ in $100t_P$ time. Even in this case, it suggests a return to the zero energy state by the above mechanism.This is the case assuming an enormous number of quantum fluctuations. This situation corresponds to the assumption of approximately $10^{147}$ ($100t_P \approx 10^{-42}s$, $2(1l_P) \approx 10^{-35}m$, $Volume \propto 10^{-105}m^3$) quantum fluctuations per second, in a space of $1m^3$.

**Thus, vacuum energy is not a source of dark energy.**

If the problem is a simple situation that cannot explain the difference in density of $10^{120}$, the possibility remains that the difference in density can be explained by some mechanism at some point in the future. But,

**The real problem with vacuum energy model is**,

First, that positive energy density (positive inertial mass density) and negative pressure are logically contradictory because the source of pressure is momentum or kinetic energy.

Second, even in the case of light with the greatest momentum or kinetic energy component relative to the total energy, the pressure is $P = \frac{1}{3}\rho$. The claims of the vacuum energy model require a being with a momentum or kinetic energy three times ($P_\Lambda = -\rho_\Lambda = -3(\frac{1}{3}\rho_\Lambda)$) greater than that of light.

Third, it is a problem related to the logic of $\rho_\Lambda + 3P_\Lambda = \rho_\Lambda + 3(-\rho_\Lambda) = -2\rho_\Lambda$. Mass density $\rho$ and pressure $P$ are properties that an object has. Also, mass density $\rho$ and pressure $P$ are the sources of gravity. However, even if the volume does not expand or contract and maintains a constant size, it means that the gravitational force of $\rho_\Lambda + 3P_\Lambda = -2\rho_\Lambda$ is applied. That is, it suggests that the object (or energy density) has a gravitational force with a negative mass density of $-2\rho_\Lambda$. This is different from a vacuum, which we think has a positive energy density $+\rho_\Lambda$.

Fourth, it also seems that there is a problem in applying $dU = -PdV$ to vacuum energy. See this paper for a debate on negative pressure. [8]

Proponents of standard cosmology should think about the real reason standard cosmology appears to be successful, the core logic.

$$\rho + 3P \simeq (+1)\rho_c + (-2)\rho_c = (-1)\rho_c \tag{110}$$

**3.7. Does the second law of thermodynamics hold throughout the history of the universe?**

The second law of thermodynamics is the law that governs the achievement of thermal equilibrium in a closed system. I do not agree with the claim that the second law of thermodynamics holds for all events in the entire universe.

As shown in this paper, I believe and assert that the first law of thermodynamics does not hold in the entire universe. The cosmological constant or vacuum energy introduced in standard cosmology is also an object that does not conserve the total energy of the system. [18]

So, if the first law does not hold, should the second law hold?

In principle, entropy is proportional to the system's state function (or multiplicity). However, when the energy value changes, the total number of state functions of the system also changes. However, if negative energy exists, the total amount of energy itself is reduced. This is a phenomenon in which the sum of the state functions is reduced.

Should the entropy of negative energy be defined as a positive number? Should it be defined as negative number? As the energy decreases, the number of state functions also decreases. Entropy is estimated to decrease. By setting the entropy of negative energy to be positive, it is unclear whether the law of entropy increase can be maintained. But, even with this definition, is there any need to uphold this law?

The law of increasing entropy is not a law that holds throughout the whole history of the universe.

# 4. Explaining inflation and dark energy simultaneously

In the current cosmological constant and vacuum energy model, since the energy density is a constant, two constant values are needed to account for the current accelerated expansion and the early universe's accelerated expansion. [1] [21] [22] And, the two periods have a very large density difference. These are characteristics that contradict their usual definition or nature. On the other hand, in the gravitational potential energy or gravitational self-energy model, since it is a form that depends on the mass density value in both situations, different values can be explained in the two situations.

In the previous paper [8], I presented the cosmological constant term obtained by the gravitational potential energy model. Strictly speaking, the cosmological constant does not exist in the gravitational potential energy model, and the gravitational potential energy plays the role of negative pressure or negative energy density. Since many numbers are obtained through standard cosmology, the cosmological constant term is introduced into the explanation to aid understanding.

$$\frac{\Lambda(t)c^2}{3} = 3(\frac{2\pi GR(t)\rho(t)}{5c})^2 \tag{111}$$

$$\Lambda(t) = (\frac{6\pi GR(t)\rho(t)}{5c^2})^2 \simeq (\frac{6\pi Gct\rho(t)}{5c^2})^2 = (\frac{6\pi Gt\rho}{5c})^2 \tag{112}$$

Also, it was shown that this value can explain the current value of the cosmological constant.

**4.1. In the gravitational potential energy model, the cosmological constant value at Planck time**

Let $R = ct$, $\rho_0 = \frac{5}{4\pi G t_P{}^2}$, let's calculate the value of the cosmological constant in Planck time.

$$\Lambda(t) = (\frac{6\pi G R(t)\rho(t)}{5c^2})^2 \simeq (\frac{6\pi G ct(\frac{5}{4\pi G t^2})}{5c^2})^2 = (\frac{3}{2ct})^2 \tag{113}$$

$$\Lambda(t_P) = 8.66 \times 10^{69} m^{-2} \tag{114}$$

$$\Lambda(t_{now}) = 1.1056 \times 10^{-52} m^{-2} \tag{115}$$

$$\frac{\Lambda(t_P)}{\Lambda(t_{now})} = \frac{8.66 \times 10^{69} m^{-2}}{1.1056 \times 10^{-52} m^{-2}} = 7.83 \times 10^{121} \tag{116}$$

It was about $10^{121}$ times bigger in Planck time than it is now.

In either the gravitational potential energy model or the gravitational self-energy model, the repulsive force component is a function of $R(t)$ and $\rho(t)$. [8] Thus, very large values in the early universe and very small values in the present can be explained at the same time.

**4.2. At $10^{-36}s$, the value of the cosmological constant**

In the existing inflation model, the start time of accelerated expansion is approximately $10^{-36}s$ [1], so if we find the value at this time,

$$\Lambda(t = 10^{-36}s) = (\frac{6\pi G R(t)\rho(t)}{5c^2})^2 \simeq (\frac{9}{4c^2})\frac{1}{(10^{-36}s)^2} = 2.52 \times 10^{55} m^{-2} \tag{117}$$

$$\frac{\Lambda(t = 10^{-36}s)}{\Lambda(t_{now})} = \frac{2.52 \times 10^{55} m^{-2}}{1.1056 \times 10^{-52} m^{-2}} = 2.28 \times 10^{107} \tag{118}$$

## 5. Why the universe was born

Why was the universe born? Wouldn't it have been okay to stay in nothing? Why did the change happen? We cannot yet give an exact answer to this question. Also, logically, without any premise, it seems impossible to create something out of nothing. However, since it is an important issue, I would like to write my personal thoughts with the hope of going one step further than in the past.

Let's look at the following expression. This is a conservation equation.

$$A = 0 = (+B) + (-B) = 0 \tag{119}$$

A certain physical quantity $A = 0$, which is nothing, is a physical quantity that is conserved at the beginning and end. However, in order for this physical quantity $A$ to be conserved in all circumstances of space and time, it must be conserved in the form of $A = (+B) + (-B) = 0$.

In other words, in order for physical quantity $A$ to be in the nothing state in many situations (or all situations), new physical quantities $+B$ and $-B$ must be created, which must be conserved in space-time. However, the newly born $+B$ and $-B$ create new changes. It is thought that this was in the process of the birth of the universe.

Let's look at how pair production occurs from photon.

$$A = 0 = (+Q) + (-Q) = 0 \tag{120}$$

The total charge of a photon is zero. When photon do pair creation, photon do not conserve charge by creating beings with zero charge, but by creating $+Q$ and $-Q$ to preserve zero. That is, in all cases, in all circumstances, in order to satisfy or maintain nothing, this equation of the form $(+Q) + (-Q) = 0$ must hold. This may be because "0" is not representative of all situations and is only a subset of $(+Q) + (-Q) = 0$ .

At the beginning and end of the process, the total charge is conserved, but in the middle process $+Q$ and $-Q$ are created, which in turn create the presence of one another, including a force or field by the presence of charges.

Another example is the case of gauge transformation for scalar potential $\Phi$ and vector potential $A$ in electromagnetic fields.

$\Phi \to \Phi - \frac{\partial \Lambda}{\partial t}$, $\mathbf{A} \to \mathbf{A} + \nabla \Lambda$

Maxwell equations of electromagnetism hold them in the same form for gauge transformation. After all, the existence of some symmetry or the invariance that the shape of a certain physical law must not change requires a gauge transformation, and this leads to the existence of new physical quantities ($\Lambda$ ,$\frac{\partial \Lambda}{\partial t}$ , $\nabla \Lambda$) that did not exist in the beginning.

This can be interpreted as requiring the birth of a new thing in order for the conserved physical quantity to be conserved and not change. The condition that should not change is what makes change.

Why was the universe born? Why is there something rather than nothing? Why did the change happen?
It changes, but does not change!
It changes not to change! [23]

Something that wants to change creates change.
Something that does not want to change also creates change.

What does not change ($A = 0$) also creates changes in order not to change in various situations (Local, Grobal, phase transformation...). This is because only the self ($A$) that does not want to change needs to be preserved.

The change of the universe seems to have created a change by the nature of not changing. The universe created Something (space-time, energy, mass, charge, spin, force, field, potential...) to preserve Nothing. By the way, as this something was born, another something was born, and the birth of something chained like this may still preserve the first nothing, and in some cases, the first nothing itself may also have changed.

# 6. Verification method and future research

In this paper, a model for the birth and accelerated expansion of the universe based on gravitational potential energy (gravitational self-energy) is presented. The core logic is that during $\Delta t$, it is possible to change or create $\Delta E$, and then $\Delta E$ itself undergoes a gravitational interaction during $\Delta t$. At this time, it is argued that when the negative gravitational potential energy becomes larger than the positive energy, that is, when the total energy of system reaches a negative energy state, there is a repulsive gravitational effect and expansion occurs.

If the acceleration expansion time of the early universe is determined, the average density $\rho_0$ value of the early universe can be obtained through the equation in which the gravitational potential energy equals the mass energy.

Once this value of $\rho_0$ is determined, then the behavior of the universe is determined by the existing dynamics.

At this time, the equation of motion must include an equivalent mass term of gravitational potential energy or gravitational field energy. In Chapter 2.2.3, I have presented several types of expansion, the basically important expansions are 2.2.3.1., 2.2.3.2. and 2.2.3.3. Due to my lack of knowledge, I explained it in terms of gravitational potential energy, but if you are capable, you can also describe it in terms of the energy of the gravitational field. Considering the Shell theorem or Birkoff's theorem, the gravitational potential energy may be more appropriate than the energy of the gravitational field.

Chapter 2.2.3.1 is the mechanism for making accelerated expansion, and chapter 2.2.3.2 is the mechanism for making decelerated expansion. Chapter 2.2.3.3 can make both accelerated and decelerated expansions, depending on the size of the new mass participating in the gravitational interaction. You can also add a cosmological constant or vacuum energy term to this. However, at this time, when the density of vacuum energy is positive, the pressure is not negative pressure, but has a positive pressure of $0 \sim +\frac{1}{3}\rho$. [8]

In a simple model, the inflection point at which the universe transitions to accelerated expansion is determined by the equation

$$E_T = \sum_i m_i c^2 + \sum_{i<j} -\frac{G m_i m_j}{r_{ij}} = Mc^2 - \frac{3}{5}\frac{GM^2}{R} = 0 \tag{121}$$

At this time, the following relationship is established between the density and the time to enter accelerated expansion.

$$R_{gs} = \sqrt{\frac{5c^2}{4\pi G\rho_0}} \simeq ct \tag{122}$$

Because there are strong constraints, we can validate the model right or wrong.

According to the uncertainty principle, $\Delta E \geq \frac{\hbar}{2\Delta t}$ holds. Therefore, $\Delta E$ ranges from $\frac{\hbar}{2\Delta t}$ to $\infty$. We can start with a model that assumes mass production at the Planck mass level in time $\Delta t$, or we can start with the total mass energy of the observable universe or the total mass energy of the entire universe in time $\Delta t$.

Furthermore, it will be possible to verify through the dark energy term obtained through gravitational potential energy and the new Friedmann equation.
Acceleration equation obtained by Gravitational Potential Energy Model [8]

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}(\rho + \frac{3P}{c^2}) + 3(\frac{2\pi GaR\rho}{5c})^2 \tag{123}$$

Dark energy term obtained by Gravitational Potential Energy Model [8]

$$\frac{\Lambda(t)c^2}{3} = 3(\frac{2\pi GR(t)\rho(t)}{5c})^2 \tag{124}$$

The dark energy term is a function of time, specifically the extent $R(t)$ of the gravitational interaction. and density $\rho(t)$
Researchers who have a good understanding of the observational results need to use the ideas in this paper to create and analyze the equations of motion to describe inflation. As these precise models emerge, the number of factors that can verify the correctness of the model will increase.

# 7. Conclusion

Most of the existing inflation models are forms in which the scalar potential exists independently in addition to the material distribution in the universe. On the other hand, gravitational potential energy is a physical quantity that comes from the distribution of matter itself. It is not the introduction of something new and independent. What we should have reflected in the calculation is reflected in the calculation.

In this paper, I present an idea that can solve the accelerated expansion problem of the early universe and the current accelerated expansion problem through gravitational potential energy. Gravity takes time to propagate and, therefore, changes in the amount of matter and energy that participates in gravitational interactions as the universe ages.

The total energy of a gravitationally interacting system has the form
$E_T(t) = \sum_i m_i c^2 + \sum_{i<j} -\frac{G m_i m_j}{r_{ij}}$
For a spherical uniform distribution, this equation can be simply expressed as the gravitational self-energy equation.

$E_T = \sum_i m_i c^2 + \sum_{i<j} -\frac{G m_i m_j}{r_{ij}} = Mc^2 - \frac{3}{5}\frac{GM^2}{R}$

While mass energy is proportional to $M$, gravitational potential energy is proportional to $-\frac{M^2}{R}$. Thus, as the universe ages, the radius R of the gravitational interaction increases, and the mass M participating in the gravitational interaction increases. However, in the case of a uniform distribution, negative gravitational potential energy increases faster than positive mass energy. Therefore, as the universe ages (time passes), it passes through an inflection point where the negative gravitational potential energy exceeds the positive mass energy, and from this point on, the universe enters a period of accelerated expansion. Through this gravitational potential energy, it is possible to create an accelerated expansion of the early universe.

There have been models claiming that positive energy is born from quantum fluctuations, but in most cases, no specific mechanism for the birth and expansion has been suggested.

According to the energy-time uncertainty principle, during $\Delta t$, the energy variation of $\Delta E$ is possible. However, this energy fluctuation had to go back to the original nothingness. By the way, there is also a gravitational interaction during $\Delta t$, and if the negative gravitational potential energy exceeds the positive energy during this $\Delta t$, the corresponding energy (mass) distribution is placed in a negative energy (mass) state. Because there is a repulsive gravitational effect between negative masses, this mass distribution expands. Thus, it is possible to exist without returning to nothingness. Also, it is explained that through the energy density $\rho_0$ generated at this time, the acceleration expansion time and the form of expansion in the early universe can be determined.

The gravitational potential energy model explains the dark energy phenomenon [8]and the inflation phenomenon at the same time. It also solves the singularity problem of black holes [17]and provides an explanation for the birth of the universe from quantum fluctuation.

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