The Change of Gravitational Potential Energy And Dark Energy in the Zero Energy Universe

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Gravity is the force conquering the structure of the universe. By recognizing the components of the universe, we are estimating the quantity of components composing the universe through size of gravity and gravitational potential energy (GPE). In this paper, it is being shown that the universe can be born and expanded through pair creation of positive energy (mass) and negative energy (mass) from zero energy condition [1]. Also, GPE is composed by 3 units of U_{++}, U_{--}, and U_{-+} when negative and positive energy exists, U_{-+} (GPE between negative mass and positive mass) has positive values and is the component that makes repulsive gravitational effect [2]. U_{-+} corresponds with the inner energy of the system and can be interpreted as dark energy. The force by U_{-+} is $F = (\frac{4\pi G}{3})k_h(t)M\rho_r r = \frac{1}{3}\Lambda(t)Mc^2 r$ shaped. Also, situations in which U_{-+} has much higher value than $|U_{--}|+|U_{++}|$ depending on the distribution of negative mass and positive mass is possible. This doesn't mean that 72.1% of dark energy independently exists, but means that explanation from GPE occurring from 4.6% of negative energy, which is the same as 4.6% of positive energy, is possible. Moreover, 4.6% of negative energy is the energy which is inevitably required from zero energy, which is the most natural total energy value in the universe. This discovery implies that our belief that size of gravitational effect and size of components of the universe would always 1:1 correspond was wrong. We set up each model from the birth of universe to the present, and calculated GPE using computer simulation in each level. As a result, we could verify that pair creation model of negative mass and positive mass explains inflation of the early universe and decelerating expansion, and present accelerating expansion in time series.

PACS numbers: 95.36.+x, 95.35.+d, 98.80.Cq
Keyword: negative mass, negative energy, dark matter, dark energy, gravitational potential energy, antigravity, cosmological constant, cosmology, big bang, zero energy universe
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I. Introduction

Gravity is the force conquering the structure of the universe. By recognizing the components of the universe, we are estimating the quantity of components composing the universe through size of gravity and GPE.

In estimating some kind of unknown energy quantity of universe components, gravity has been a crucial part. For example, if the universe is composed of some materials and these materials are always moving in equal velocity, unknown repulsive energy to offset this attraction was needed and it was assumed that the size of this energy is the same as the size of the energy of materials and the direction should be the opposite.

From the observation on accelerating expansion of the universe in 1998 [3] [4], we assumed that a repulsive energy bigger than the total energy of visible matter need to exist and called this dark energy. Also, this dark energy has been accepted as an independent energy different from matter or dark matter [5].

We have trusted the above analysis on gravity and GPE had clear validity. However, through current numerical computation, we found that there was possibility of severe errors in this analysis through gravitational effect.

In 1957, Professor Bondi examined the characteristics of the negative mass and positive mass motions in General Relativity [6], and after, Forward looked into a propulsion method (diametric drive), using negative mass [7]. Also, there are researches that studied negative mass about to the recent cosmological phenomena [8–10].

Negative mass is stable at the state of high energy. So the "problem of the transition of the energy level of minus infinity" does not occur, and thus positive mass and negative mass can exist in the same space-time [2] [11].

In this paper, we show that the universe led to the current structure of the universe, if we assume pair creation of positive energy and negative energy in the early universe. We looked for size of GPE when negative and positive energy (mass) both exist and try to explain this GPE value regarding to the current size of dark energy.

II. Birth of the universe from zero energy state

[Video for Big bang Simulation] [1]

This is a computer simulation that shows you that the universe led to the current structure of the universe with pair creation of positive energy (mass) and negative energy (mass) from the zero energy state.

A. Birth of the Universe from "Nothing"

1)There was a pair creation of positive and negative energy in the early universe.

2)The total energy of universe is 0. Hawking and Guth et al. argued that GPE is negative energy, and that such GPE can offset all positive mass energy during a period of inflation [12].

3)The acceleration in the expansion of the universe observed suggests the existence of positive energy out of mass energy, and alternatively, it corresponds to what the overall GPE of the universe has positive value, indicating that GPE will not able to offset positive energy.

4)Nothing but the GPE doesn't completely offset mass energy. And for the birth of the universe from "nothing" and energy conservation at the birth of the universe, "negative mass", which corresponds to "negative energy", is needed.

5)The basic principle of physics of "lower state of energy is stable!" is wrong. So it should be modified to "lower state of energy as far as positive mass is concerned and higher state of energy as far as negative mass is concerned is stable!" [2] [11].

6)"Transition to the energy level of minus infinity", which was used to deny the existence of negative mass, did not occur, whereas a. Relativistic energy eq., b. Dirac eq., c. field equation existed [3], suggesting the existence of negative mass.

B. Structure of Void

1)The presence of primitive void due to a pair annihilation of positive mass and negative mass.

2)The presence of void due to gravitational contraction between positive mass and repulsive effect between negative mass.

C. Birth and Expansion of the Universe from singular point(or domain)

1)Even though all the mass of the universe come together in one small area on Big Bang, it does not have the same density as the black hole due to offsetting of density between positive mass and negative mass. Therefore it can be expandable.

2)The law of motion of positive mass and negative mass naturally explains that "expansion after birth" is the essential characteristics of the universe.

3)The expansion of the universe takes place in the state of total rest mass energy of "0" and, clusters of galaxies and the void structure can be achieved.

4)Energy conservation and momentum conservation exists without giving the initial velocity, and expansion of the universe occurs.

5)It does not require any other force except already known force, gravity.

III. Significant characteristics of dark energy and GPE

A. Simulation background and method

1) Physical background

a)Initial energy value of the universe It looks more natural when an initial energy value of universe is 0. Therefore, negative energy is needed to offset positive energy of matters.

If there was pair creation of positive and negative energy in the beginning of the universe, it is estimated that the total value of all positive energy will totally offset the total energy of all negative energy. If we consider only rest mass energy and GPE, the relation below will be valid [2].

$$\begin{aligned} E_T &= 0 = (+E) + (-E) = 0 \\ &= \sum (+m_+c^2) + \sum (-m_-c^2) + \sum U = 0 \end{aligned} \tag{1}$$

$(m_+ > 0, m_- > 0)$

b) $m_- = m_+$

To reach zero energy, size of m_+ and m_- should be different enough as the size of GPE, or GPE can be put as 0 through appropriate placement of particles while making m_- and m_+ equal.

The size of m_+ and m_- can be a different during pair creation [2], but this paper has purpose in showing possibility of various GPE values depending on the placement of particles which are pair produced, so the case in which m_+ is equal to m_- will be looked into.

c) GPE

If negative mass and positive mass coexist, GPE consists of the below three items [2].

$$U_T = U_{-+} + U_{--} + U_{++} \tag{2}$$

$$\begin{aligned} U_T = &\sum_{i,j}^{i=j=n} \left(-\frac{G(-m_{-i})m_{+j}}{r_{-+ij}}\right) \\ &+ \sum_{i,j,j>i}^{i=j=n} \left(-\frac{G(-m_{-i})(-m_{-j})}{r_{--ij}}\right) + \sum_{i,j,j>i}^{i=j=n} \left(-\frac{Gm_{+i}m_{+j}}{r_{++ij}}\right) \end{aligned} \tag{3}$$

$$\begin{aligned} U_T = &\sum_{i,j}^{i=j=n} \left(+\frac{Gm_{-i}m_{+j}}{r_{-+ij}}\right) \\ &+ \sum_{i,j,j>i}^{i=j=n} \left(-\frac{Gm_{-i}m_{-j}}{r_{--ij}}\right) + \sum_{i,j,j>i}^{i=j=n} \left(-\frac{Gm_{+i}m_{+j}}{r_{++ij}}\right) \end{aligned} \tag{4}$$

GPE between positive masses are negative value.

$$U_{++} = \sum_{i,j,j>i}^{i=j=n} (-\frac{Gm_{+i}m_{+j}}{r_{++ij}})$$

GPE between negative masses are negative value.

$$U_{--} = \sum_{i,j,j>i}^{i=j=n} (-\frac{Gm_{-i}m_{-j}}{r_{--ij}})$$

GPE between positive mass and negative mass are positive value.

$$U_{-+} = \sum_{i,j}^{i=j=n} (+\frac{Gm_{-i}m_{+j}}{r_{-+ij}})$$

When the number of negative mass is n_-, and the number of positive mass is n_+, total potential energy is given as follows.

$$U_T = (n_- \times n_+)U_{-+} + (\frac{n_-(n_- - 1)}{2}U_{--} + \frac{n_+(n_+ - 1)}{2}U_{++})$$

For example, two pairs exist.

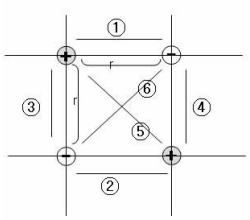


Figure 1: two pairs

$$U_T = (U_1+U_2+U_3+U_4)+(U_5+U_6) = 4U_{-+}+1U_{--}+1U_{++} \quad (5)$$

Gravitational potential shows significant characteristic when negative mass and positive mass both exist. While n^2 positive gravitational potential is produced above, $n^2 - n$ negative gravitational potential are produced. Therefore, total GPE can have various values.

d)Vacuum Energy

Vacuum energy value which is currently known is an energy value that is too big [13]. If this vacuum energy exists, it is difficult to explain why it isn't easily found around us.

In the hypothesis of the pair creation of negative mass and positive mass, Vacuum energy will become exactly 0 because vacuum is the space in which pair creation and pair annihilation of positive and negative energy occurs.

e)Characteristics of the negative mass

For characteristics of the negative mass, refer to below video.

[Video for characteristics of the negative mass] [14]

2)Simulation Program

To look into the characteristic of GPE, we used the simulation program (Demo Version) named Gravitation3D made by Roice Nelson [15]. Only phrase (Demo Version) is indicated on a screen, there is no functional limitation.

3)Simulation setting

a)Definition of parameter

A few parameters were needed to be defined for simulation.

Distance between pair creation negative energy and positive energy(distance of 1 pair) : d_0

Minimum distance between particle pairs for density modification during pair creation : d_m

Radius of pair creation range : R_0=500

Particle number of pair creation : N_0=2000ea (1000 pair)

b)Finding mean value

Through Gravitation3D program, 1000 particle pairs (total 2000ea particles) were produced by random and one mean value (GPE) of each distance value was found 5 times each.

c)Verification on program

To check if the calculated results of the program were correct, we calculated the GPE when 1, 2, and 3 pairs (consist of 15ea potentials) of particles existed by hand and confirmed that this value corresponded to the calculated results of the program.

B. Computer simulation

[Video for results of simulation] [16]

1) Distance=0.01

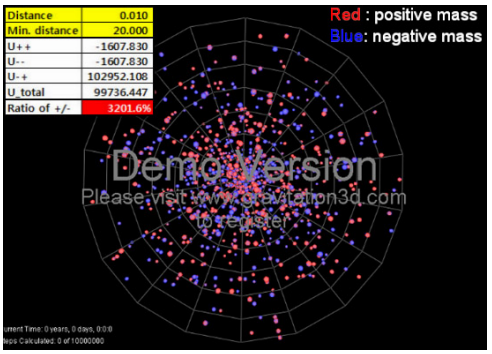


Figure 2: Distance 0.01

It was found out that U_{-+} value having positive value could be much higher than $|U_{++} + U_{--}|$. Thus, even though the size of positive mass and negative mass was equal, it could be known that repulsive GPE could be much higher than attractive GPE.

2) Distance =0.10

We will describe that an unknown repulsive energy U_{-+} higher that attraction of visible matter exists for the energy value of above.

3) Distance =0.19

According to the observance result of WMAP, it is predicted that current dark energy, dark matter, and matter is approximately 72.1%, 23.3%, and 4.6%, respectively [5].

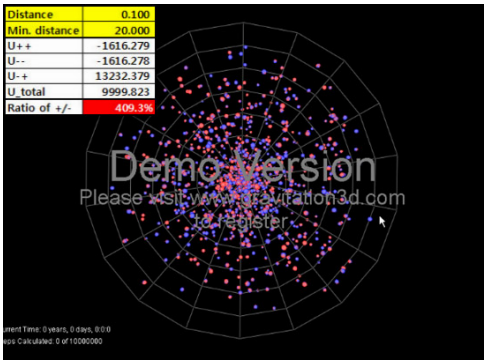


Figure 3: Distance 0.10

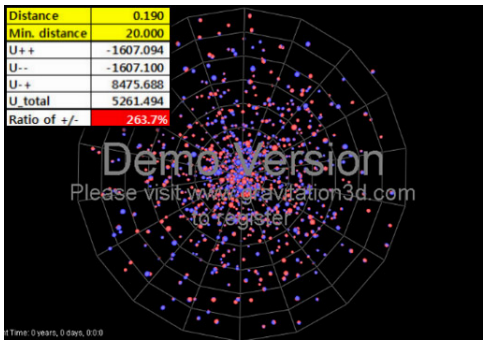


Figure 4: Distance 0.19

Dark matter and matter correspond to negative gravitational potential because they have attractive gravitational potential and dark energy correspond to positive gravitational potential because it produces repulsive effect.

Therefore, observation ratio of current universe is 72.1/27.9 = 2.584. Is shows similar condition to 2.63 which was found above. If conditions are changes, ratio of negative gravitational potential and positive gravitational potential can have various conditions close to 2.58.

4) Distance =1.00

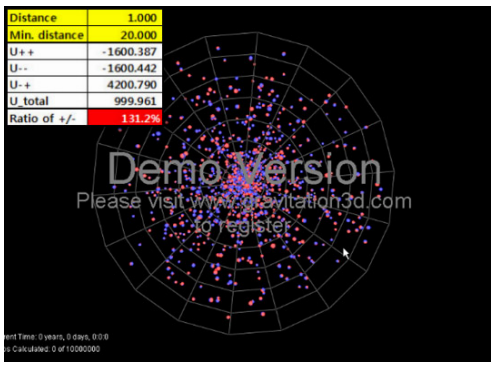


Figure 5: Distance 1.00

Particle pairs show to overlap (in the process being expressed in visible size) because of distance between negative mass and positive mass composing singular particle pairs are relatively close. Overlapping is unrelated to the calculation of GPE.

It can be known that distance between singular particle pairs are much smaller compared to the distance between other particle pairs. One particle pair corresponds to the cluster of galaxies in the universe structure. From movement characteristic of negative mass and positive mass, galaxies and cluster of galaxies have clustering structure of negative mass in the outside of the galaxy [2].

5) Distance =10.00

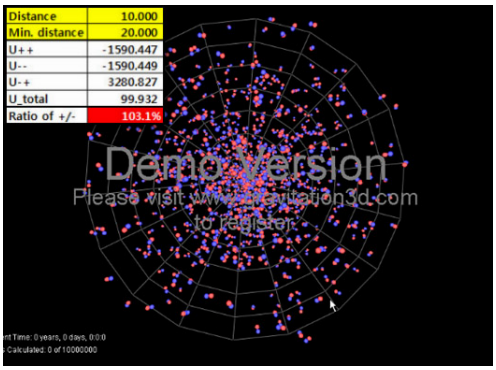


Figure 6: Distance 10.00

C. Expansion of the universe

Structure of galaxies or cluster of galaxies surrounding negative masses in the pair creation model of negative and positive mass is implied. refer to fig.7,8,9.

Expansion of the universe means increase of the distance between cluster of galaxies or the galaxy while the sizes of individual galaxies are the same.

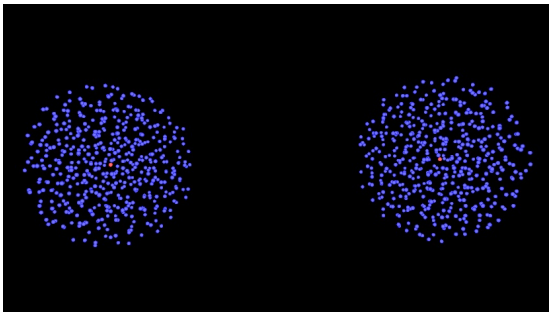


Figure 7: In the structure negative mass surrounds galaxy composed of positive mass, arrangement of particles is fixed and distance between galaxies increases.

D. Change of the GPE followed by the density difference between negative mass and positive mass

Potential energy can have various values depending on the density difference of negative and positive mass.

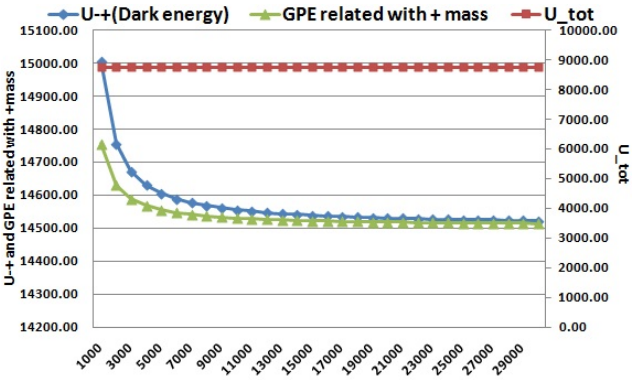


Figure 8: As R, which corresponds to the distance of the galaxy, increases, absolute values of GPE(U_{++}, U_{--}, U_{-+}, GPE related with + mass ($U_{++} + U_{-+}$)) decrease while the total GPE is maintained constant.

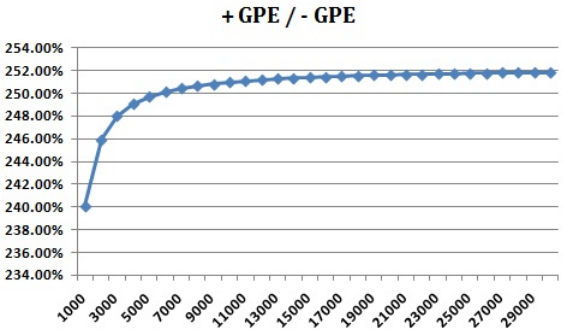


Figure 9: However, ratio of positive gravitational potential (Dark Energy) and negative gravitational potential increases as the universe expands and this is seen to mean that percentage of repulsive effect increases compared to the attractive effect of ordinary matter.

There is also difference in acceleration of negative and positive mass, and this brings change in potential energy.

Negative mass expands faster than positive mass in situations when density of negative mass is higher than positive mass density. It could be confirmed through the simulation of even distribution condition passing [16].

E. Future of the universe

1)As the pair creation hypothesis of negative and positive mass predicts that dark energy is conserved and density of dark energy decreases following the expansion of the universe, it is predicted that the universe will expand like Figure 10.c.

2)Density difference of negative and positive mass and movement difference of negative and positive mass implies the possibility of vibration expansion standard to total GPE of 0. Therefore, Figure 10.b model above is possible [17].

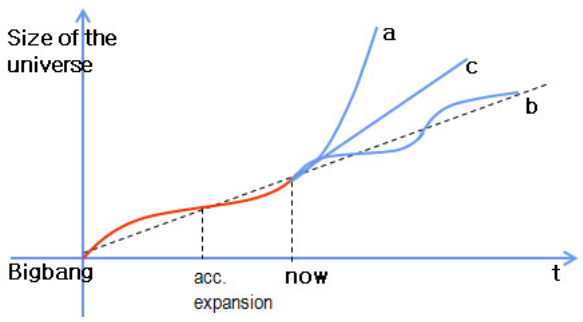


Figure 10: Accelerating expansion and decelerating expansion followed by the density difference between negative mass and positive mass.

F. Centripetal force effect in the galaxy from dark matter(negative mass) halo out of the galaxy

[Video for Centripetal force effect from negative mass] [18]

If the negative mass is disposed at the outline, the test mass vibrates, and a kind of restoring force (This corresponds to the centripetal force when considering rotation of the galaxy) exists.

This suggests that the halo, dark matter (negative mass) of the external galaxy could get additional effects of centripetal force to the inner galaxy.

G. Maybe, dark energy is constant

Currently, dark energy is being observed as though it has a constant value. Generally, density of subjects that have local energy distribution should change to $1/r^3$, so this model is difficult to explain the constant value. Therefore, it is easy to consider it as a wrong model.

Distance	0.30	0.01	
Min distance	1.00	1.00	
Radius	200.00	400.00	
U++	-5061.60	-2564.88	
U--	-5059.32	-2564.90	
U-+	13454.50	104909.24	
U_tot	3333.58	99779.45	
Ratio of +/-	132.94%	2045.10%	
V	33,510,293	268,082,347	800.0%
U++ + U-+	-10120.92	-5129.78	50.7%
|ρ--+ρ++|	0.000302	0.000019	6.3%
ρ-+	0.000402	0.000391	97.5%
ρ_tot	0.000099	0.000372	374.1%
Ratio -/+	132.94%	2045.10%	1538.4%

Figure 11: Where R_0=200, it is the situation where the radius has increased in double to R=400 when the distance of the particle pairs has decreased to 1/30. It is the result randomly producing 1000 particle pairs and finding GPE value.

Looking into the above results (fig.11), the ρ_{-+} value

that corresponds to the repulsive GPE density (dark energy density) is almost being maintained as a constant even though the volume was increase to 8 times.

In the above mechanism, particle A (positive mass) and particle B (negative mass) is evenly distributed, and particle A and particle B do change by $1/r^3$, but any physical quantity that comes out of their relation is possible by constant value.

Of course, dark energy in our model is a variable that essentially depends on time (refer to fig.30). [2]

H. Observation value of WMAP

1)Pair Creation

Assuming pair creation of negative and positive energy in the beginning of the universe, it is seen that law of conservation of energy should be valid for each pairs for law of conservation of energy to be valid. According to calculation of the previous paper, it is predicted that size of negative can bigger than size of positive. [2]

2)Some interpretation

According to the observance result of WMAP, it is predicted that current dark energy, dark matter, and matter is approximately 72.1%, 23.3%, and 4.6%, respectively [5].

Now, let's correspond to the GPE as follows.

Matter = U_{++} = Negative GPE

Dark Matter = U_{--} = Negative GPE

Dark Energy = U_{-+} = Positive GPE

a) $|-m_-| > m_+$: fig.12

			Ratio
Matter	U++	4.6	1
Dark matter	U--	23.3	5.065
Dark Energy	U-+	72.1	15.674
Ratio of +/-		2.584	

-m-	-2.25	
m+	1.00	
Distance	1.38	
R	7000.00	
Min. distance	20.00	Ratio
U++	-146.76	1
U--	-742.98	5.063
U-+	2290.88	15.610
U_tot	1401.14	
Ratio of +/-	2.575	

Figure 12: In condition of $-m_- = -2.25m_+$, results shown above were gained. This doesn't prove that the size of current negative mass is 2.25 times as positive mass. However, the above result implies that there is possibility to explain that the size ratio of the 3 predicted energy by using the "hypothesis of pair creation of negative and positive mass."

b) $|-m_-| = m_+$: fig.13

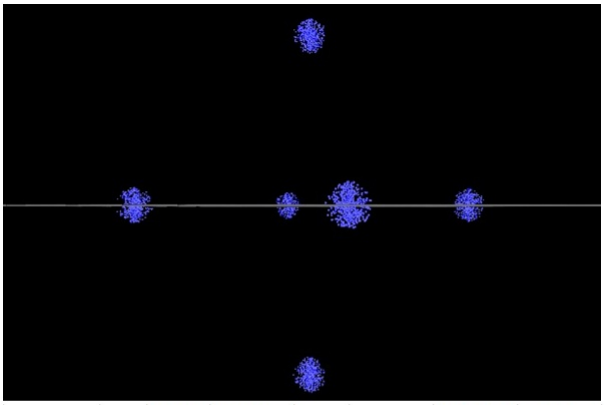
When total rest mass =0, we get below ratio.

Matter = U_{++} = -83.2 (ratio: 1)

Dark Matter = U_{--} = -459.6 (ratio: 5.523)

Dark Energy = U_{-+} =+1286.9 (ratio : +15.463) : repulsive gravitational effect

It is similar the ratio of matter(4.6% : 1):dark matter(23.3% : 5.06):dark energy(72.1% : +15.67 : repulsive gravitational effect).



		WMAP	Ratio
Matter	U++	4.6	1
Dark Matter	U--	23.3	5.065
Dark Energy	U-+	72.1	15.674
Ratio +/-			2.584

	Simulation	Ratio
U++	- 83.2	1
U--	- 459.6	5.523
U-+	1286.9	15.463
Ratio +/-		2.371

Figure 13: m+ = +100 X 6 = + 600. (±1200,0,0), (0,±1200,0), (0,0,±1200), each 100. $-m_-$ = (-0.2 X 500) X 6 = - 600. Negative mass distribution : center(±1200,0,0), center(0,±1200,0), center(0,0,±1200), negative mass is spread within R=3-120, md=8. [19]

Through the distribution of a negative mass and a positive mass when total mass energy is at the state of 0, we could obtain a similar result to WMAP observation or predicted ratio.

In this model, the currently predicted energy ratio comes from the distribution that negative masses are surrounding the galaxy or the galaxy clusters.

I. Results of simulation

1) Even though negative and positive mass have the same size, total GPE can have $+, 0, -$ values depending on the placement of each.

2) U_{-+} value is higher as d_0 is smaller and the total GPE also have a high positive value.

3) Looking into the numerical calculation of B-1)$\sim$ B-4), it can be seen that positive gravitational potential value U_{-+} can have much higher values than negative gravitational potential values.(138% - 3,201%) If we consider the distance of Planck length level, this value can have very high values enough to explain inflation. From the observation result of WMAP, we know that dark energy value, which generates repulsion, is 2.58 times the total of matter and dark matter. Until now, it is predicted that dark matter produces attraction. Closely look into numbers B-3).

4) Because we judge components of the universe by gravity or GPE, it can be assumed that there is dark energy of 2.63 times or inner energy of 2.63 times regarding the situation of U_{-+} value having approximately 2.63 times U_{++} and U_{--} values in number B)-3). There are several situations satisfying 2.58 times. Even if 100ea

(unit mass +10) positive masses exist and 1000ea (unit mass −1) negative masses exist, it satisfies about 2.58 times.

5) The above results show that 72.1% of dark energy doesn't exist independently, but implies that there is possibility that negative energy having the same size of positive energy can emerge.

6) This "increase of dark energy" doesn't come from a newly generated space, but shows feature of GPE which is made by negative mass and positive mass.

IV. Antigravity is the source of dark energy

For the following three reasons, we have been doubtful if dark energy has antigravity.

1) Gravity is the force which has ruled the macroscopic movement of the universe.

2) Dark energy's scale is similar to the magnitude of gravity generated from ordinary matters. (About 15 times)

3) Dark energys effect is repulsive.

However, nobody is sure whether dark energy truly originates from antigravity, for other several reasons as follows.

1) No antigravity has been observed in laboratories or around the earth, thus far.

2) Contrary to that the force coming from dark energy is $F = +kr$ shaped as a $\vec{F_\Lambda} = \frac{1}{3}\Lambda mc^2 r\hat{r}$ shape [20], antigravity is $F = +\frac{k}{r^2}$ shaped.

3) As dark energy is an unknown effect itself, there is a possibility that other unknown force different from existing ones exists.

Since we still have no idea about the source of dark energy, it's been hard to call dark energy "antigravity", even though it was possible to call it "anti-gravitational effect", in the way that its effect is repulsive.

This paper is going to induce a dark energy term from antigravity, and demonstrate that antigravity is the source of dark energy.

A. GPE, when antigravity exists.

We are aware of what gravitational self-energy (gravitational binding energy) as the sum of GPE is displayed as follows, when matters show a three-dimensional spherical distribution.

$$U_S = -\frac{3}{5}\frac{GM^2}{r} \tag{6}$$

(r: radius, M: the mass of the sphere)

Because we are planning to apply this to cosmology,

Assumption: For simple modeling, we will suppose that antigravity source has a uniform distribution on a cosmological scale of a level of cluster of galaxies.

When gravitational self-energy by ordinary matters is as below in our universe,

$$U_M = -\frac{3}{5}\frac{GM^2}{r} \tag{7}$$

Because we don't know how big GPE by antigravity is, let's introduce and indicate a constant k_h(hyoyoung constant) which is easy for comparison as below, for a simple comparison. Stricity speaking, k_h is function of the time.

$$U_{DE} = k_h\frac{GM^2}{r} \tag{8}$$

[2]

B. Force generated by positive GPE.

$$\vec{F} = -\nabla U_{DE} = -\frac{\partial U_{DE}}{\partial r}\hat{r} = -\lim_{\Delta r\to 0}\frac{U_{DE}(r+\Delta r) - U_{DE}(r)}{\Delta r}\hat{r} \tag{9}$$

$$U_{DE}(r) = k_h\frac{GM^2}{r} = k_h\frac{G(\frac{4\pi}{3}r^3\rho_r)^2}{r} = k_hG(\frac{4\pi}{3})^2{\rho_r}^2r^5 \tag{10}$$

$$U_{DE}(r+\Delta r) = k_hG(\frac{4\pi}{3})^2{\rho_{r+\Delta r}}^2(r+\Delta r)^5 \tag{11}$$

When considering the law of conservation of mass-energy,

$$\rho_r r^3 = \rho_{r+\Delta r}(r+\Delta r)^3 \tag{12}$$

$$\rho_{r+\Delta r} = \rho_r(\frac{r}{r+\Delta r})^3 = \rho_r(1 - 3\frac{\Delta r}{r} + 6(\frac{\Delta r}{r})^2...) \tag{13}$$

$${\rho_{r+\Delta r}}^2 = {\rho_r}^2(1 - 6\frac{\Delta r}{r} + 21(\frac{\Delta r}{r})^2...) \tag{14}$$

$$(r+\Delta r)^5 = r^5(1+\frac{\Delta r}{r})^5 = r^5(1+5\frac{\Delta r}{r} + 10(\frac{\Delta r}{r})^2 + \cdots) \tag{15}$$

$$F = -\lim_{\Delta r\to 0}\frac{k_hG(\frac{4\pi}{3})^2[{\rho_{r+\Delta r}}^2(r+\Delta r)^5 - \rho_r^2r^5]}{\Delta r} \tag{16}$$

$$F \approx -\lim_{\Delta r\to 0} k_hG(\frac{4\pi}{3})^2{\rho_r}^2r^5[-\frac{1}{r} + (\frac{\Delta r}{r^2})] \tag{17}$$

$$F \approx +k_h G(\frac{4\pi}{3})^2 {\rho_r}^2 r^5 [\frac{1}{r}] \tag{18}$$

$$\begin{aligned} \vec{F} &= +k_h G(\tfrac{4\pi}{3})^2 {\rho_r}^2 r^5 [\tfrac{1}{r}]\hat{r} \\ &= +k_h G(\tfrac{4\pi}{3})(\tfrac{4\pi}{3}\rho_r r^3)\rho_r r^2 [\tfrac{1}{r}]\hat{r} \\ &= +k_h G(\tfrac{4\pi}{3}) M \rho_r r \hat{r} \end{aligned} \tag{19}$$

Therefore, the force generated from positive GPE by antigravity source which uniformly distributes

$$\vec{F} = +(\frac{4\pi G}{3}) k_h M \rho_r r \hat{r} \tag{20}$$

As a $\vec{F} = +k\hat{r}$ shape, this force is repulsive force, and is proportional to r like dark energy.

If we assume that this force is the same as the existing force related to dark energy,

$$(\frac{4\pi G}{3}) k_h M \rho_r r = \frac{1}{3}\Lambda M c^2 r \tag{21}$$

$$\Lambda = \frac{4\pi G k_h \rho_r}{c^2} \tag{22}$$

Here, the total mass, M was used, as the force by GPE affects all particles in the three-dimensional sphere.

Then, let's figure out constant k_h from the current observation results, and verify whether Λ calculated by us is a right value.

Not mass-energy, we are measuring a gravitational effect from the observation of the universe, and supposing the existence of mass-energy corresponding to the gravitational effect.

The ratio of magnitude of gravitational effects of the present dark energy and matters can be yielded as below.
$\frac{DarkEnergy}{Matter} \approx \frac{72.1}{4.6} = 15.67 = |\frac{U_{-+}}{U_{++}}|$

$$k_h = 15.67 \times \frac{3}{5} = 9.40 \tag{23}$$

$$\Lambda = \frac{4\pi G k_h \rho_r}{c^2} = 3.64 \times 10^{-52} [\frac{1}{m^2}] \tag{24}$$

This value is in accord with the dimension of cosmological constant that is being inferred from the existing observation results, and is similar with the prediction, too.

According to this hypothesis that our universe consists of negative energy and positive energy of the same scale, it appears that the total mass accelerated by GPE is 2M. Thus, cosmological constant value can be reduced by 1/2.

Anyways, we can see that the force generated from GPE by antigravity has the same shape as the force by dark energy, and that it is possible to accurately explain its magnitude and repulsive effect.

Moreover, we figured out the secondary term to verify whether this model would be right,

The force generated from GPE by antigravity can be indicated like
$F = (\frac{4\pi G}{3}) k_h(t) M \rho_r r = \frac{1}{3}\Lambda(t) M c^2 r$

C. Meanings including proof

1) The essence of dark energy (accelerating expansion) is antigravity.

2) The force by U_{-+}(GPE between negative mass and positive mass, positive GPE) is
$\vec{F} = (\frac{4\pi G}{3}) k_h(t) M \rho_r r \hat{r} = \frac{1}{3}\Lambda(t) M c^2 r \hat{r}$
shaped, and it is needed to conduct an observatory experiment of $\Lambda(t)$, for verification of this model.

3) The above evidence explains why dark energy looks like a constant.

4) "Negative mass" and "antimatter with a possibility of generating antigravity" [21] can be candidates of antigravity source.

5) The above evidence only considered forms of matters, but implies that dark energy is a function of time, considering radiation or the secondary term. There is a need of figuring out a relativistic formula including radiation.

6) Even if mass-energy of antigravity source is equal to mass-energy of gravity source, the repulsive gravity effect could be 15 times bigger than the gravitational effect resulting from gravity source.

7) We can answer the CCC(Cosmological Constant Coincidence) problem of "Why does dark energy have the similar scale with matters?". It is because it has the same gravitational effect as them.

8) We can consider a general shape, $U = kr^n$ (n is real number) as a cause for dark energy, and thus there is a high possibility that it is no accident that the above evidence is valid.

9) While the existing cosmological constant or vacuum energy is a concept not to conserve energy, GPE is conserved.

V. Inflation, decelerating expansion and accelerating expansion

We made a program that is able to calculate GPE from locations of each particle.

It can not simulate the whole process from the big bang to the present due to the limit of personal computer that the numbers of particles to be simulated is limited, but we can obviously examine the change.

This simulation is showing incredible results. It not only explains the total energy of the universe, flatness, and the essence (Zero energy, Pair creation of negative mass and positive mass) of the process of birth of the universe, but it explains inflation, decelerating expansion in

the early stage, accelerating expansion in the late stage, and dark matter through the only term, negative energy. Moreover, this negative energy is one that is essentially required by the law of energy conservation.

A. Birth of the universe from zero energy state

[Simulation Video] [19]

1) computer simulation

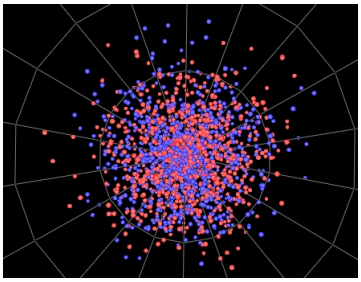


Figure 14: m_+=+1 (1,000ea), $-m_-$ = −1 (1,000ea), U_{++} = −5190.4707907, U_{--} = −5308.0373689, U_{-+} = +10499.2712222, U_{tot} = 0.7630625

Total rest mass energy is zero. Total GPE (U_{tot}) is +0.7630625.

$|\frac{U_{tot}}{U_{-+}}| = 0.0000726$, so U_{tot} is almost zero.

We could not make $U_{tot} = 0$ for there were too many particles. Therefore, we simulated dividing the value of U_{tot} into two parts which are when it is little bit bigger than 0 (+0.76306) and when smaller than 0 (−0.53277), and we could gain almost similar results. (Attached 1, 2)

2) Accelerating expansion of the universe (inflation)

It can be confirmed that even though the total energy starts with 0, the universe expands and positive masses combine one another due to attractive interaction among themselves, while negative masses can not form massive mass structure because of repulsive interaction.

The pair creation model of negative mass and positive mass explains "energy conservation" in times of the birth of the universe and "expansion after the birth" naturally, and it does not need institution of new mechanism or field like inflaton or inflation itself [22], and it explains this effect with only gravity.

3) Change of GPE

The graph above is that the change of GPE related with positive mass and U_{tot} drawn through graph.

As we have observed activities of only positive masses, "GPE related with positive mass ($U_{++} + U_{-+}$)" has a significant meaning.

a) Nevertheless the value of U_{tot} changes from 0 to negative value, the universe expands for GPE related with positive mass has + value.

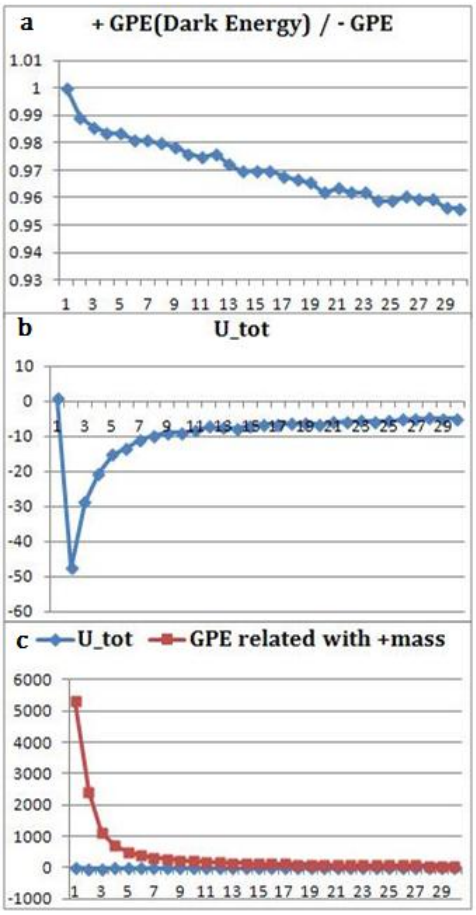


Figure 15: Fig.15-a.The ratio of negative GPE to positive GPE of the early universe. We can confirm that as the universe expands, (+GPE/−GPE) ratio decreases, and U_{tot} gets to be negative value. Fig.15-b. Total GPE of the early universe. Fig.15-c. U_{tot} of the early universe and GPE related with positive mass. It looks almost like a straight line for the size of U_{tot} is relatively small.

b) Note that nevertheless the total energy is 0, GPE related with positive mass has very big positive value, and this value approaches to 0 very rapidly. This explains the dramatic expansion like the early universe inflation and the finish of this inflation mechanism.

c) The thing we can notice by this and the next simulation is that if time goes bit more, U_{tot} and GPE related with positive mass both have negative values, and the universe is converted to the decelerating expansion stage.

d) In order to explain the flatness of the universe, typical researchers assume the inflation mechanism and explain it using this. But Zero Energy Universe does not need institution of new field for it guarantees flatness itself, and additionally, the simulation above means that the accelerating expansion of the early universe can be explained with gravity without instituting new field.

4) Change of GPE related with positive mass and U_{tot} in three initial value

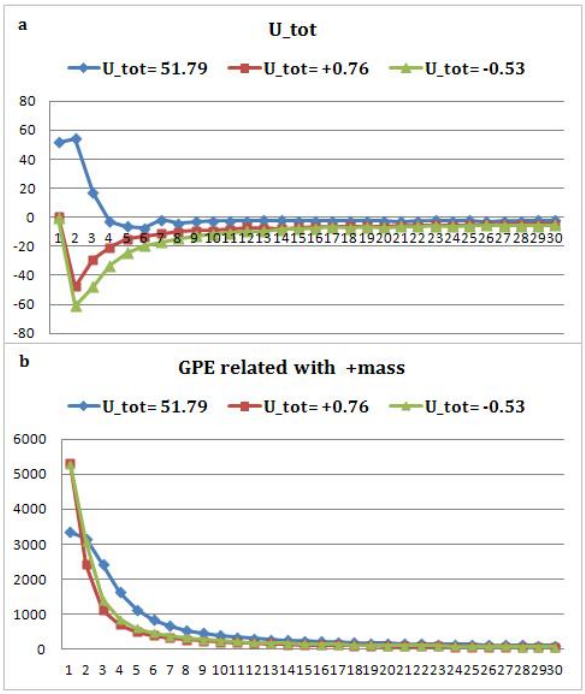


Figure 16: Fig16-a. Total rest mass energy=0, U_{tot}(initial value)= +51.79 / +0.76 / −0.53. Time scale=0.5, Step scale(+51.79,−0.53)=200, Step scale(+0.76)=250, Fig16-b. Change of GPE related with positive mass in three cases

GPE related with positive mass has very big positive value, and this value approaches to 0 very rapidly.

B. GPE among distant galaxies and accelerating expansion

1) When positive mass is spread through relatively large area

[Simulation Video] [23]

After the birth of the universe, positive masses bind together by attractive interaction. Meanwhile, negative masses are being almost uniformly distributed because of repulsive interaction. Negative masses are gravitational bounded to massive positive masses (Galaxy or Galaxy cluster) for massive positive mass has attractive effect on negative mass. [2]

a) The ratio of +GPE to − GPE of distant galaxy

i) Early status is that positive GPE is smaller than negative GPE, and the U_{tot} has negative value. This negative GPE status results from gravitational binding of positive masses.

ii) As time goes by, binding of positive mass increases due to attractive interaction, and the absolute value of negative gravity potential reaches maximum.

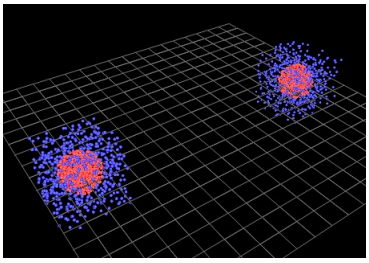


Figure 17: Distant galaxy the structure that negative mass surrounds galaxy composed of positive mass. m_+ = (1 X 500) + (1 X 500) = + 1000, center1(−1000,0,0), center2(+1000,0,0), R=150, $-m_-$ = (−1 X 500) +(−1 X 500) = −1000, negative mass distribution : $-250 \leq (x \pm 1000), y, z \leq +250$. We simulated having it has unit mass of positive mass and negative mass.

iii) The absolute value of negative GPE decreases due to positive mass has a gravitational binding and negative mass does gravitational contraction and U_{tot} is converted to positive value as a result. Center of gravitational contraction of negative masses is galaxy or galaxy cluster.

iv) U_{tot} and GPE related with positive mass both are converted to positive value. Therefore, the universe gets to an era of accelerating expansion again.

v) On the simulation above, we can confirm that +GPE increases 200% the value of −GPE, and for we deduce the universal components through GPE, we will guess that repulsive dark energy increases 200% the value of attractive mass energy (matter + dark matter, as a general deduction).

b) U_{tot} and GPE related with positive mass on distant galaxy

i) In the early universe, GPE related with positive mass had very big + value, but this value gets smaller as positive masses binds together and comprise of galaxy structure. On the simulation above, it still has positive value, and so it is in the status of accelerating expansion.

ii) We can notice that U_{tot} and GPE related with positive mass both are converted to negative value by gravitational binding of positive masses. Therefore, the universe gets to an era of decelerating expansion.

iii) GPE related with positive mass is converted to positive value due to negative mass does gravitational contraction around massive positive mass(Galaxy or Galaxy Cluster). Therefore, the universe gets to an era of accelerating expansion again.

iv) The decelerating expansion and accelerating expansion is naturally explained through "pair creation model of negative mass and positive mass", and the conversion from accelerating expansion to decelerating expansion and from decelerating expansion to accelerating expansion is explained in sequence.

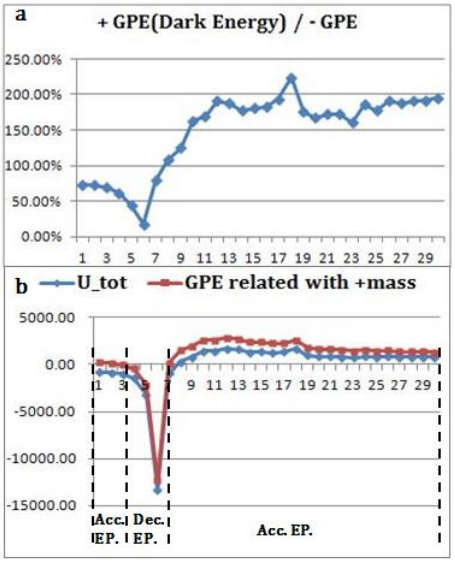


Figure 18: Fig.18-a.The ratio of +GPE to − GPE of distant galaxy. Fig.18-b. U_{tot} and GPE related with positive mass on distant galaxy. Note that GPE value related with positive mass changes from positive value to negative value, and to positive value again. This represents acceleration expansion − > deceleration expansion − > acceleration expansion of the universe.

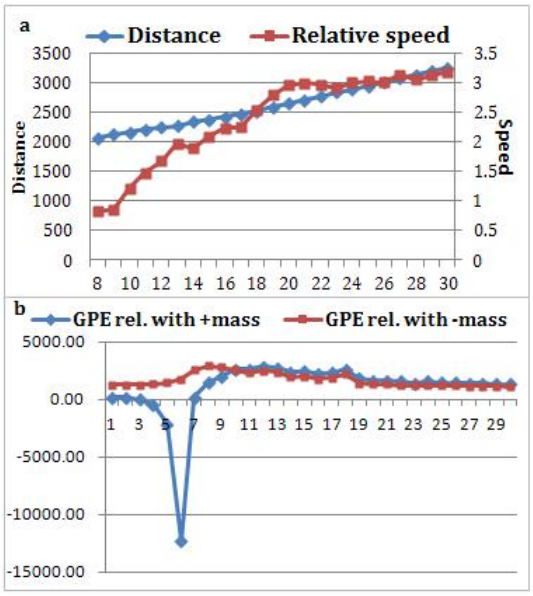


Figure 19: Figure19-a.The change of distance and relative speed among distant galaxies. Figure19-b. GPE related with positive mass and negative mass

v) The conversion from negative value to positive value shall be done more smoothly than the graph above for there exist thousands of billions of galaxies in our universe.

c) The change of distance and relative speed among distant galaxies

Massive positive mass is given a birth from the 8th stage due to gravitational contraction. We calculated distance between the two massive positive masses (corresponding to the galaxy or galaxy cluster) and relative speeds of the two from then.

We can notice that there exits positive acceleration, and it corresponds to accelerating expansion.

d) GPE related with positive mass and negative mass

Positive mass and negative mass have different GPE value each other, therefore their movements are different each other.

2) When positive mass is spread through relatively small area

[Simulation Video] [19]

The reason why we set the unit mass of positive masses bigger than that of negative masses is that positive masses increased through gravitational binding due to attractive interaction, while mass increase mechanism of negative masses is limited due to repulsive interaction.

a) The ratio of +GPE to −GPE of distant galaxy

It is same with the analysis of "1)When positive mass is spread through relatively large area" above. We can confirm that repulsive +GPE increased to 300% the level of −GPE. Considering that the present universe dark energy rates 258% of attractive energy, we can notice that this model can explain the present dark energy problem.

b) U_{tot} and GPE related with positive mass on distant galaxy.

It is same with the analysis of B−1) above, and it is confirmed that U_{tot} and GPE value related with positive mass both are converted to positive value, as negative mass does gravitational contraction around massive positive mass. This means that our universe is naturally

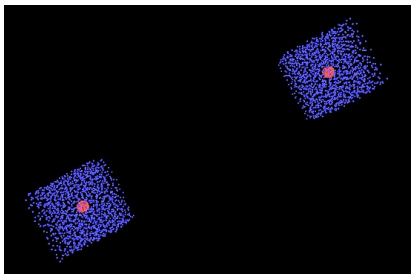


Figure 20: Distant galaxy the structure that negative mass surrounds galaxy composed of positive mass. When positive mass is spread through relatively small area. m_+ = (1 X 300) + (1 X 300) = + 600, center1(−1000,0,0), center2(+1000,0,0), within R=40, $-m_-$ = (−0.2 X 1500) +(−0.2 X 1500) = −600, negative mass distribution : $-250 \leq (x \pm 1000), y, z \leq +250$.

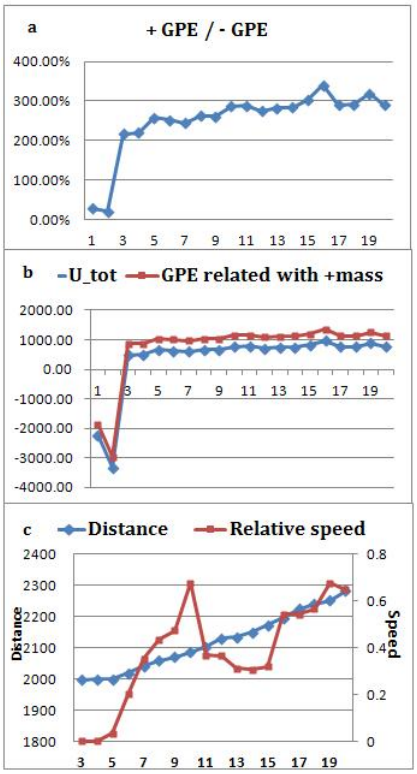


Figure 21: Fig.21-a.The ratio of +GPE to −GPE of distant galaxy. Fig.21-b. U_{tot} and GPE related with positive mass on distant galaxy. Fig.21-c. Distance and relative speed of distant galaxy.

converted from decelerating expansion to accelerating expansion.

c) Distance and relative speed of distant galaxy

Massive positive mass is given a birth due to gravitational contraction. We calculated distance between the two massive positive masses and relative speeds of the two from then.

It is appearing to be greatly affected by the movements of the individual particles, but in overall, it is showing accelerating expansion effect.

C. Change of GPE among close galaxies

[Simulation Video] [19]

1)The ratio of +GPE to −GPE of close galaxies

a) It is a status that positive GPE is smaller than negative GPE and so U_{tot} has negative value. This negative GPE status results from gravitational binding of positive masses.

b) As time goes by, positive masses bind due to attractive interaction.

c) During 10–12 stages, gravitational potential value increase momentarily due to movements of the two massive positive masses.

d) As negative mass does gravitational contraction

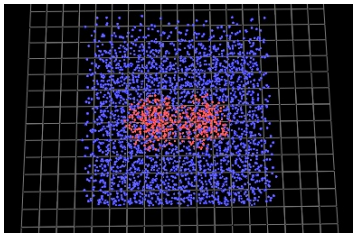


Figure 22: Close galaxies and negative mass distribution. $m_+ = (1\ \text{X}\ 300) + (1\ \text{X}\ 300) = +600$, center1(−150,0,0), center2(+150,0,0), Positive mass is spread within R=180. $-m_- = -0.2\ \text{X}\ 3000 = -600$, negative mass distribution: $-500 \leq x, y, z \leq +500$

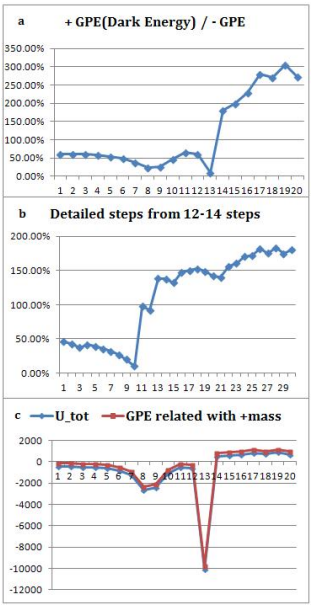


Figure 23: Fig.22-a.The ratio of +GPE to −GPE of close galaxies. Fig.22-b. Is a result of simulating the detailed steps from 12-11 steps to 13-20 steps after dividing 12 14 steps into 20 steps. Fig.22-c. U_{tot} and GPE related with positive mass on closed galaxy.

around massive positive mass, value of +GPE increased, and U_{tot} value is converted to positive value as a result.

2) The change of U_{tot} and GPE related with positive mass among close galaxies

a) It is shown that as negative mass does gravitational contraction around massive positive mass, U_{tot} and GPE value related with positive mass both are converted to positive value. This means that our universe is converted from decelerating expansion to accelerating expansion.

b) The change of expansion acceleration of the universe takes place by positive masses and negative masses, doing gravitational binding and forming galactic structure.

D. Gravitational contraction due to positive

mass and negative mass

1) When positive mass does gravitational contraction

The structure that negative mass surrounds galaxy composed of positive mass.

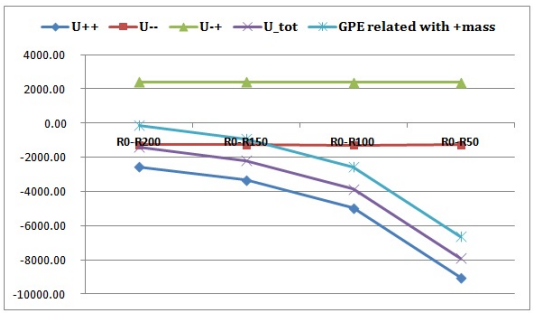


Figure 24: $-m_-$= (−1 X500)+(−1 X500)= -1000, negative mass distribution: center1(−1000,0,0), center2(+1000,0,0), within R=220∼250. m_+ = (+1X500) + (+1X500)= +1000, positive mass distribution : center1(−1000,0,0), center2(+1000,0,0), within a)R0 ∼ R200, b)R0 ∼ R150, c)R0 ∼ R100, d)R0 ∼ R50

It is shown that as positive mass does gravitational contraction, U_{tot} and GPE value related with positive mass both gradually smaller (negative value).

This means that our universe is converted from accelerating expansion (inflation) in the early universe to decelerating expansion.

2) When negative mass does gravitational contraction

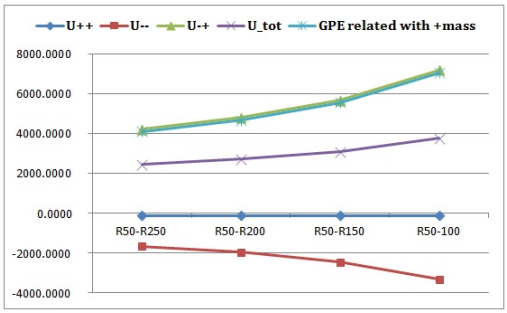


Figure 25: m_+ = (500 X1) + (500 X1)= 1000, positive mass distribution: center1(-1000,0,0), center2(+1000,0,0). $-m_-$ = (-1X500) + (-1X500)= -1000, negative mass distribution : center1(-1000,0,0), center2(+1000,0,0), within a)R50 ∼ R250, b)R50 ∼ R200, c)R50 ∼ R150, d)R50 ∼ R100

It is shown that as negative mass does gravitational contraction around massive positive mass, U_{tot} and GPE value related with positive mass both are bigger.

This means that our universe is converted from decelerating expansion to accelerating expansion (Dark Energy).

E. Distant six galaxies

[Simulation Video] [19]

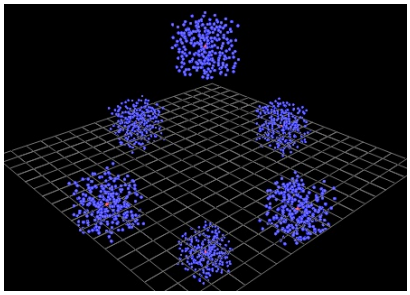


Figure 26: Distant six galaxies. $m_+ = +100$ X 6 = +600. Each +100 at $(\pm 1000, 0, 0)$,$(0, \pm 1000, 0)$,$(0, 0, \pm 1000)$. $-m_- = (-0.4$ X 250) X 6 = − 600, center$(\pm 1000, 0, 0)$, center$(0, \pm 1000, 0)$, center$(0, 0, \pm 1000)$ negative mass is spread within $-250 \leq x, y, z \leq +250$

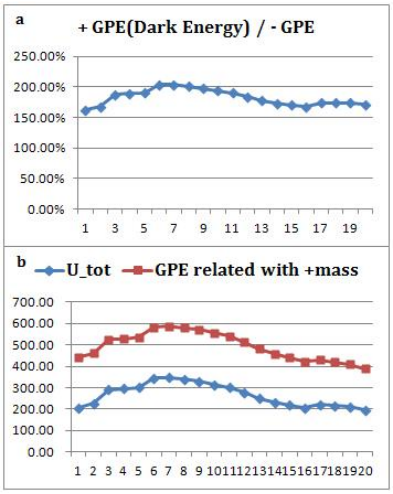


Figure 27: Fig.27-a.The ratio of +GPE to −GPE on six galaxies. Fig.27-b. U_{tot} and GPE related with positive mass on six galaxies.

1) The ratio of +GPE to −GPE and GPE related with positive mass on six galaxies (fig.27)

U_{tot} and GPE related with positive mass both have a positive value. Therefore, expansion of universe is accelerating.

2) The change of distance and relative speed among six galaxies (fig.28)

We can notice that there exits positive acceleration, and it corresponds to accelerating expansion.

F. The change of GPE in the whole time of the universe

1) The ratio of +GPE/-GPE of universe according to time. Even if the total GPE is 0, +GPE/-GPE can have diverse values in the early universe. But it is assumed that it would have similar graph as time goes.

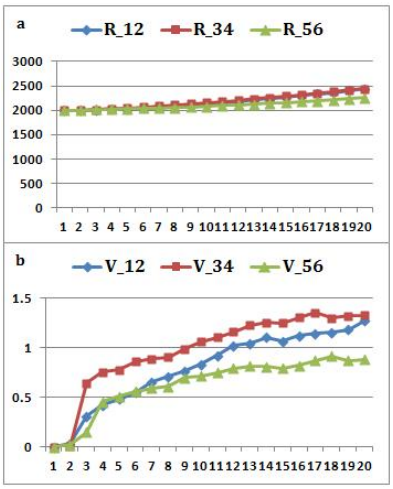


Figure 28: Fig.28-a. The change of distance. Fig.28-b. Relative speed among six galaxies

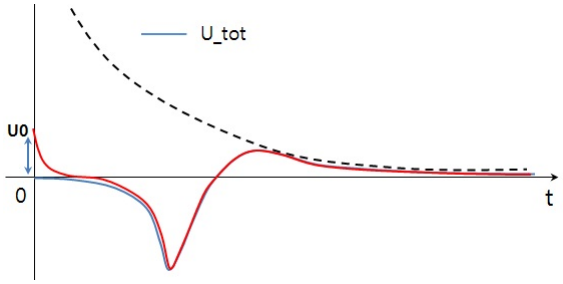


Figure 29: The change of U_{tot} of universe according to time. Refer to Fig.15-b, 16-a, 18-b, 21-b, 23-c, 27-b.

2) The change of U_{tot} of universe according to time.

a) GPE approaches to 0 at last as universe gets larger for it is in proportion to 1/r.

b) U_{tot} can have diverse values in the early universe. But it is assumed that it would have similar graph as time goes.

c) It seems that U_{tot} more likely has 0 or positive value. The homogeneous distribution of negative energy and positive energy makes U_{tot} have positive value (red line).

Although the total GPE starts with 0 or positive value in the early stage, it change to negative value as time goes by, and positive masses forms galaxies binding themselves, and as negative mass does gravitational contraction, it is converted to positive value. This provides natural explanation about accelerating expansion of the early universe, decelerating expansion in the first half, and accelerating expansion in the second half.

3) The change of U_{tot} and GPE value related with positive mass according to time.

In early universe, Even if the total GPE is 0, the universe can expand in acceleration. The typical matter we observe in the universe is positive mass, and this is because there are two GPE categories (U_{++}, U_{-+}) related with positive masses.

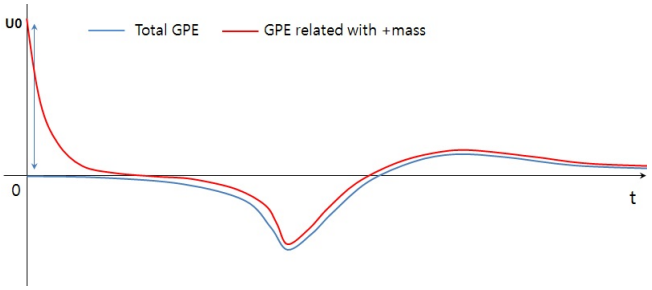


Figure 30: The change of U_{tot} and GPE value related with positive mass according to time. Refer to Fig.15-b,c,16-a,b,18-b,21-b,23-c,27-b

Although U_{tot} and GPE value related with positive mass can have values that have large difference in the early universe, as time goes by, U_{tot} and GPE value related with positive mass have values and shapes similar to each other.

VI. For the new field equation

Einstein's field equation :

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = 8\pi G T_{\mu\nu} \tag{25}$$

We need making new Friedmann eq. and Field eq., on the assumption that negative energy(mass) and positive energy(mass) coexist.

If negative energy and positive energy coexist, gravitational potential energy consists of the below three terms.

$$U_T = U_{++} + U_{--} + U_{-+}$$
$$= \sum_{i>j} -\frac{Gm_{+i}m_{+j}}{r_{++ij}} + \sum_{i>j} -\frac{Gm_{-i}m_{-j}}{r_{--ij}} + \sum_{i,j} +\frac{Gm_{-i}m_{+j}}{r_{-+ij}}$$

Positive matter : $\sum_{i>j} -\frac{Gm_{+i}m_{+j}}{r_{++ij}} \rightarrow 8\pi G({}^{++}T_{\mu\nu})$

Negative matter : $\sum_{i>j} -\frac{Gm_{-i}m_{-j}}{r_{--ij}} \rightarrow 8\pi G({}^{--}T_{\mu\nu})$

Dark Energy : $\sum_{i,j} +\frac{Gm_{-i}m_{+j}}{r_{-+ij}} \rightarrow 8\pi G({}^{-+}T_{\mu\nu})$

Therefore, new field equation (Hyoyoung's field eq.)

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = 8\pi G({}^{++}T_{\mu\nu} + {}^{--}T_{\mu\nu} + {}^{-+}T_{\mu\nu}) \tag{26}$$

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = 8\pi G({}^{++}T_{\mu\nu} + {}^{--}T_{\mu\nu} - \frac{\Lambda(t)}{8\pi G}g_{\mu\nu}) \tag{27}$$

At this time, we should considering the structure that negative mass surrounds galaxy or galaxy cluster composed of positive mass. Refer to Fig13, Fig20, Fig26.

VII. Conclusion

From the simulation result of chapter II and accelerating expansion of the universe, there is possibility that our universe is composed of negative and positive energy (mass). From analysis results of chapter III, total GPE has 3 components and it is known that the total of this GPE can have positive, negative and zero values.

No one has seen dark energy or dark matter. We must remember that we only recognize it through gravitational effect.

When we judge the components of the universe, we judge the components by gravitational effect rather than mass energy.

Therefore, when GPE U_{-+} exists larger than GPE U which is generated by materials, we will be confused to think that some mass energy bigger than the mass energy of materials exists.

This discovery implies that our belief that size of gravitational effect and size of components of the universe would always 1:1 correspond was wrong.

This model starts with a single assumption that is "There was a pair creation of negative mass and positive mass in the early universe", and in other word, "The law of energy conservation came into existence when the universe was birthed."

This single assumption explains all of the total energy of the universe, flatness, inflation, decelerating expansion, dark energy, and dark mass.

Diverse momentary assumptions that the typical theories (the momentum of inflation, cosmological constant, vacuum energy, dark matter like WIMP) have are not needed, and negative energy is the essential energy to satisfy energy conservation at the time of birth of the universe.

Therefore, it is necessary to try to calculate and observe negative mass more strictly, laying aside the abstract aversion of negative mass.

Acknowledgments

Thank you very much for Nembo Buldrini and Roice Nelson who has helped us with computer simulation.

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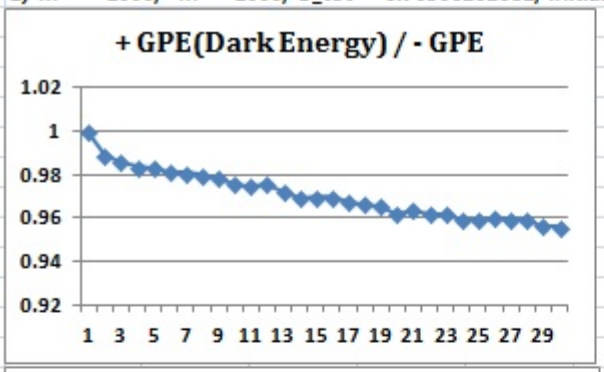
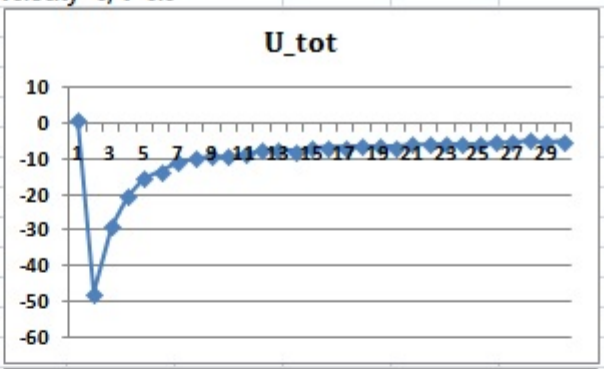
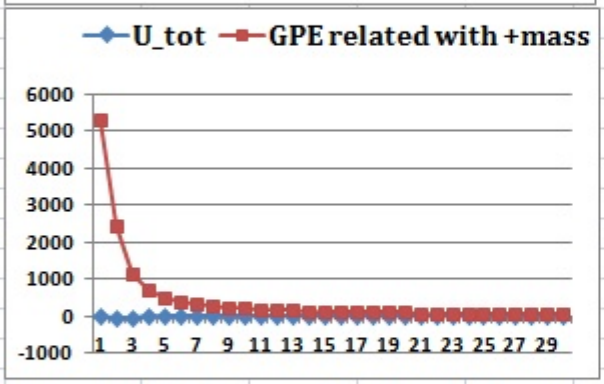
#1. A simulation of U_tot being adjacent to 0 in the early universe (+0.76306252081)

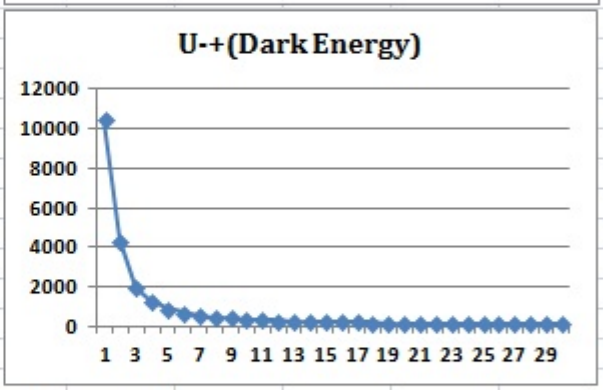
	1	2	3	4	5	6	7	8	9	10
Step	250.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00
U++	-5190.47	-1928.14	-876.47	-549.03	-396.16	-310.05	-253.47	-214.63	-186.43	-165.30
U--	-5308.04	-2463.70	-1144.00	-713.25	-512.53	-398.30	-325.04	-274.28	-237.10	-208.72
U-+	10499.27	4344.13	1991.56	1241.61	893.51	694.99	567.42	479.07	414.40	365.04
U_tot	0.76	-47.72	-28.91	-20.67	-15.18	-13.37	-11.09	-9.84	-9.13	-8.98
(U-+)+(U++)	5308.80	2415.99	1115.09	692.59	497.35	384.94	313.95	264.44	227.97	199.74
+GPE/-GPE	100.01%	98.91%	98.57%	98.36%	98.33%	98.11%	98.08%	97.99%	97.84%	97.60%
(U-+)+(U--)	5191.23	1880.43	847.55	528.36	380.98	296.69	242.38	204.79	177.30	156.32
	11	12	13	14	15	16	17	18	19	20
Step	250.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00
U++	-148.20	-133.56	-122.92	-113.71	-105.17	-97.90	-91.97	-86.62	-81.84	-78.05
U--	-186.36	-168.28	-153.38	-140.88	-130.26	-121.13	-113.18	-106.20	-100.03	-94.53
U-+	326.10	294.60	268.62	246.84	228.32	212.40	198.54	186.34	175.57	165.99
U_tot	-8.47	-7.24	-7.67	-7.76	-7.11	-6.63	-6.61	-6.48	-6.30	-6.59
(U-+)+(U++)	177.89	161.04	145.70	133.12	123.15	114.50	106.57	99.73	93.73	87.94
+GPE/-GPE	97.47%	97.60%	97.22%	96.95%	96.98%	96.97%	96.78%	96.64%	96.54%	96.18%
(U-+)+(U--)	139.74	126.32	115.24	105.95	98.06	91.28	85.36	80.14	75.54	71.46
	21	22	23	24	25	26	27	28	29	30
Step	250.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00	250.00
U++	-73.81	-70.50	-67.14	-64.59	-61.88	-59.08	-56.80	-54.65	-53.03	-51.20
U--	-89.61	-85.17	-81.14	-77.48	-74.13	-71.06	-68.23	-65.62	-63.20	-60.95
U-+	157.43	149.75	142.63	136.22	130.41	124.99	119.97	115.39	111.15	107.22
U_tot	-5.98	-5.91	-5.65	-5.85	-5.60	-5.15	-5.06	-4.88	-5.08	-4.94
(U-+)+(U++)	83.62	79.25	75.49	71.63	68.53	65.91	63.17	60.74	58.13	56.01
+GPE/-GPE	96.34%	96.20%	96.19%	95.88%	95.88%	96.04%	95.95%	95.94%	95.63%	95.59%
(U-+)+(U--)	67.83	64.58	61.49	58.74	56.28	53.93	51.74	49.77	47.95	46.26

1) Production of 1000s for each positive mass and negative mass within R=200.
2) m+=+1000, -m-=-1000, U_tot=+0.76306252081, initial velocity=0, t=0.5









1) Even if the total energy of the universe is 0, matters can be generated.

$$E_T = 0 = (+E) + (-E) = 0 = \sum +m_+c^2 + \sum -m_-c^2 + \sum U = 0$$

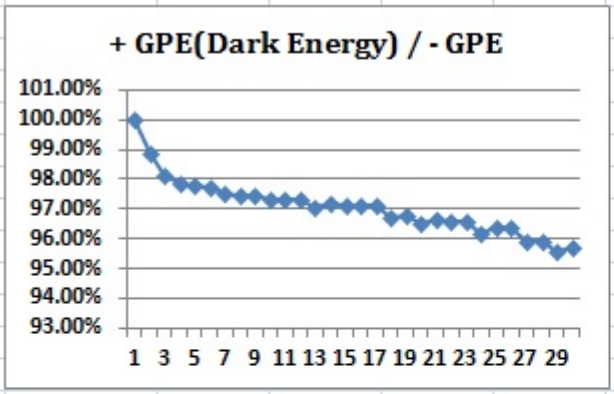
2) Even when U_tot is 0, there exists very huge GPE value related with positive mass in the early universe, and this is the cause of inflation (accelerating expansion in the early universe).
3) In the early universe, GPE value related with positive mass approaches to 0 very rapidly, mechanism. and this represents the termination of inflation
4) U-+ explains Inflation and the present Dark Energy at the same time.
5) Expansion problem from the status of exceeding density of black hole doesn't take place because of an offset of positive energy and negative energy.

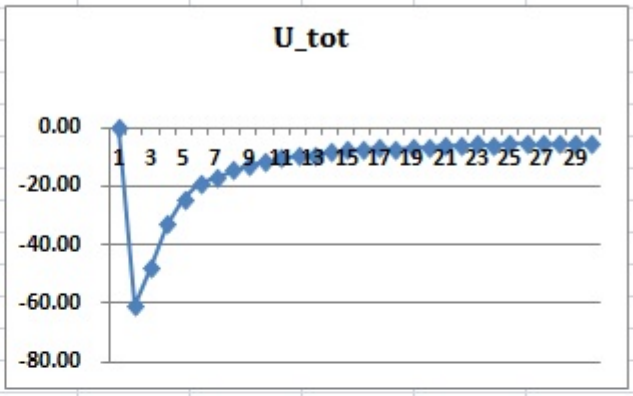
Figure 31:

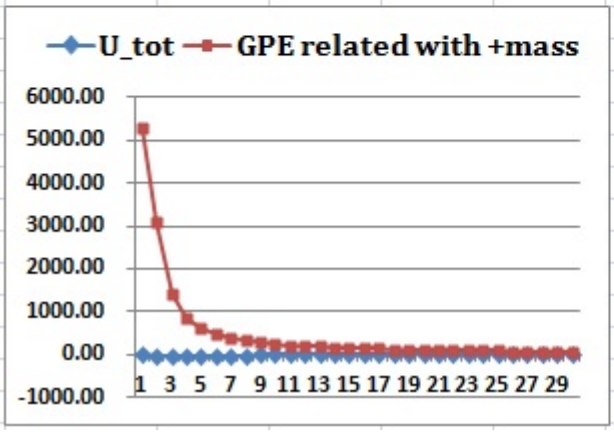
#2. A simulation of U_tot being adjacent to 0 in the early universe (-0.5327703949)

	1	2	3	4	5	6	7	8	9	10
Step	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00
U++	-5312.00	-2427.38	-1085.15	-666.37	-475.41	-368.51	-301.52	-254.43	-220.04	-194.11
U--	-5299.87	-3133.38	-1458.40	-889.94	-629.62	-484.60	-392.86	-329.88	-284.05	-249.28
U-+	10611.33	5499.69	2495.73	1523.02	1080.41	833.74	677.27	569.56	491.19	431.66
U_tot	-0.53	-61.06	-47.82	-33.29	-24.62	-19.37	-17.12	-14.74	-12.90	-11.73
(U-+)+(U++)	5299.34	3072.31	1410.58	856.65	605.00	465.23	375.74	315.13	271.15	237.55
+GPE/-GPE	99.99%	98.90%	98.12%	97.86%	97.77%	97.73%	97.53%	97.48%	97.44%	97.35%
(U-+)+(U--)	5311.47	2366.32	1037.34	633.08	450.79	349.14	284.41	239.69	207.13	182.38
	11	12	13	14	15	16	17	18	19	20
Step	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00
U++	-173.56	-156.60	-143.69	-131.74	-122.05	-113.49	-105.88	-100.30	-94.36	-89.75
U--	-222.02	-200.09	-182.06	-166.99	-154.22	-143.23	-133.70	-125.36	-117.99	-111.43
U-+	384.90	347.22	316.21	290.31	268.25	249.30	232.75	218.28	205.51	194.16
U_tot	-10.69	-9.47	-9.54	-8.42	-8.02	-7.42	-6.83	-7.38	-6.84	-7.02
(U-+)+(U++)	211.34	190.61	172.51	158.57	146.20	135.81	126.87	117.98	111.15	104.41
+GPE/-GPE	97.30%	97.34%	97.07%	97.18%	97.10%	97.11%	97.15%	96.73%	96.78%	96.51%
(U-+)+(U--)	162.88	147.13	134.15	123.32	114.03	106.07	99.05	92.92	87.52	82.73
	21	22	23	24	25	26	27	28	29	30
Step	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00
U++	-84.78	-80.85	-76.91	-74.19	-70.64	-67.71	-65.71	-63.17	-61.32	-59.01
U--	-105.56	-100.27	-95.49	-91.14	-87.16	-83.52	-80.17	-77.08	-74.21	-71.55
U-+	184.01	174.88	166.52	158.96	152.06	145.74	139.91	134.54	129.56	124.94
U_tot	-6.34	-6.24	-5.88	-6.37	-5.74	-5.49	-5.97	-5.71	-5.97	-5.62
(U-+)+(U++)	99.22	94.03	89.61	84.77	81.43	78.03	74.20	71.37	68.24	65.93
+GPE/-GPE	96.67%	96.55%	96.59%	96.15%	96.36%	96.37%	95.91%	95.93%	95.60%	95.69%
(U-+)+(U--)	78.45	74.61	71.03	67.82	64.90	62.21	59.74	57.46	55.35	53.38

1) Production of 1000s for each positive mass and negative mass within R=200.
2) m+=+1000, -m-=-1000, U_tot=-0.5327703949, initial velocity=0, t=0.5







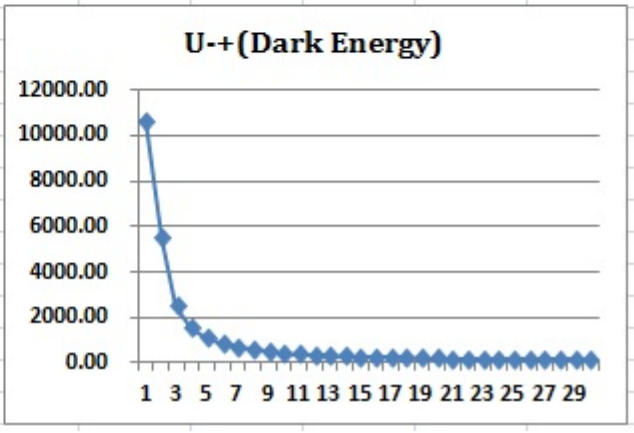
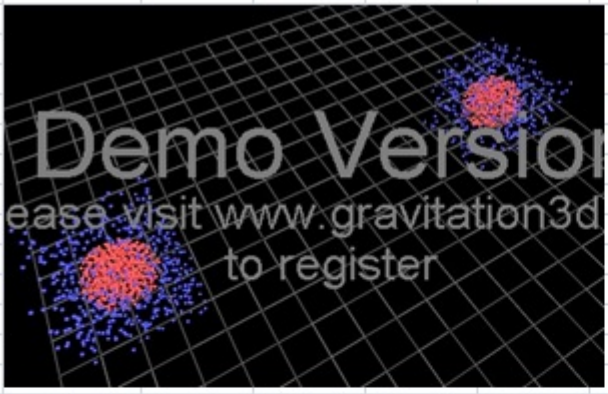


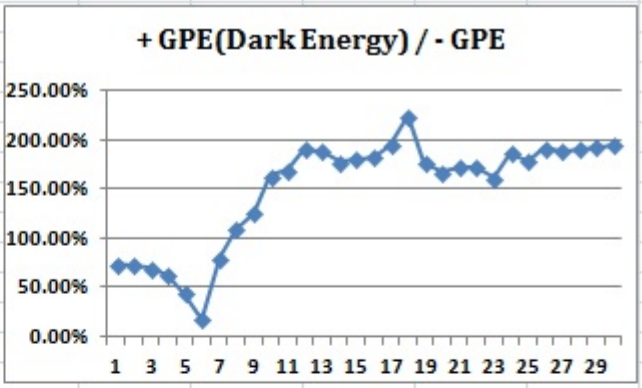
Figure 32:

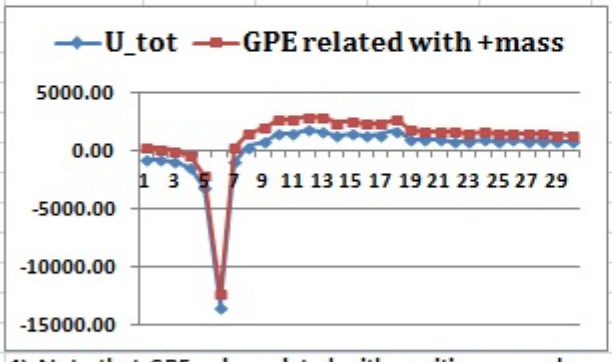
#3. Distant galaxy1 – The structure that negative mass surrounds galaxy composed of positive mass.
When positive mass is spread through relatively large area

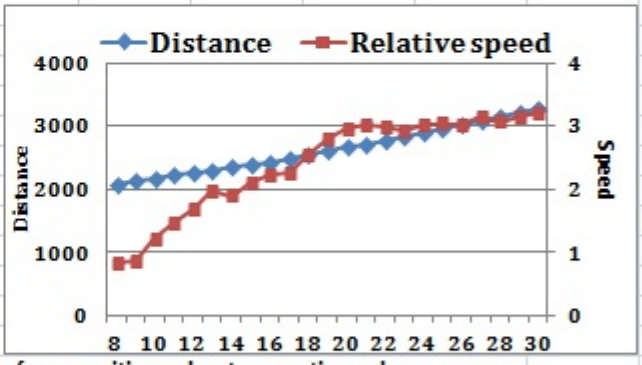
	1	2	3	4	5	6	7	8	9	10
Step	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
U++	-2054.72	-2111.39	-2310.93	-2806.92	-4656.23	-15145.36	-3448.72	-2576.34	-1961.77	-1088.25
U--	-1008.53	-1010.68	-1017.36	-1029.51	-1049.22	-1082.03	-1113.76	-1156.71	-1180.30	-1189.36
U-+	2254.21	2266.23	2304.39	2377.59	2511.79	2856.40	3637.00	4052.07	3943.43	3710.07
U_tot	-809.03	-855.84	-1023.89	-1458.83	-3193.66	-13370.99	-925.48	319.02	801.36	1432.46
(U-+)+(U++)	199.50	154.84	-6.54	-429.33	-2144.44	-12288.96	188.28	1475.73	1981.66	2621.82
+GPE/-GPE	73.59%	72.59%	69.24%	61.97%	44.02%	17.60%	79.72%	108.55%	125.50%	162.89%
(U-+)+(U--)	1245.68	1255.55	1287.04	1348.08	1462.57	1774.37	2523.24	2895.36	2763.13	2520.71
	11	12	13	14	15	16	17	18	19	20
Step	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
U++	-883.82	-748.34	-719.01	-613.70	-652.92	-522.95	-495.91	-472.04	-427.50	-469.13
U--	-1163.89	-1148.67	-1124.22	-1076.98	-1040.33	-991.78	-944.01	-894.71	-842.93	-803.35
U-+	3467.10	3623.23	3462.74	2999.03	3063.79	2767.53	2793.19	3059.27	2236.29	2127.17
U_tot	1419.39	1726.22	1619.51	1308.34	1370.54	1252.79	1353.28	1692.52	965.87	854.70
(U-+)+(U++)	2583.29	2874.89	2743.73	2385.33	2410.87	2244.58	2297.28	2587.22	1808.79	1658.05
+GPE/-GPE	169.3%	191.0%	187.9%	177.4%	180.9%	182.7%	194.0%	223.8%	176.0%	167.2%
(U-+)+(U--)	2303.21	2474.57	2338.52	1922.05	2023.46	1775.74	1849.19	2164.56	1393.36	1323.83
	21	22	23	24	25	26	27	28	29	30
Step	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
U++	-433.22	-398.70	-493.85	-351.03	-412.21	-331.04	-332.58	-338.17	-320.26	-300.16
U--	-765.42	-727.78	-693.29	-668.20	-640.33	-615.17	-590.47	-567.47	-548.00	-531.19
U-+	2064.24	1941.95	1910.78	1896.44	1868.57	1810.98	1736.10	1729.48	1667.43	1621.83
U_tot	865.59	815.47	723.65	877.21	816.04	864.78	813.06	823.83	799.17	790.49
(U-+)+(U++)	1631.01	1543.24	1416.94	1545.41	1456.36	1479.95	1403.53	1391.31	1347.17	1321.68
+GPE/-GPE	172.2%	172.4%	161.0%	186.1%	177.5%	191.4%	188.1%	191.0%	192.0%	195.1%
(U-+)+(U--)	1298.81	1214.17	1217.50	1228.24	1228.24	1195.82	1145.64	1162.00	1119.44	1090.64

1) center1(-1000,0,0), center2(-1000,0,0), Positive masses(each 500) are spread within R=150.
2) m+=+1000, -m-=-1000, Total rest mass-energy=0, U_tot=-809.034683, initial velocity=0, t=0.2









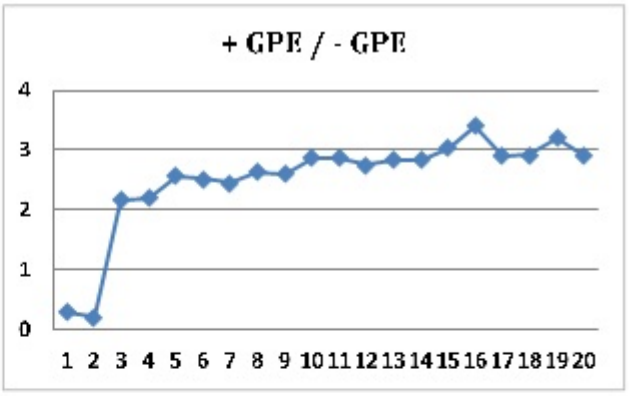
1) Note that GPE value related with positive mass changes from positive value to negative value, and to positive value again.
This represents 'acceleration expansion --> deceleration expansion --> acceleration expansion' of the universe.
2) Even if U_tot is negative number, acceleration expansion can take place.
3) Positive mass and negative mass have different GPE value each other, and therefore their movements are different each other.
4) After two huge positive masses are formed, the distance between them is getting far from each other, and this seems to represent the expansion of the universe.

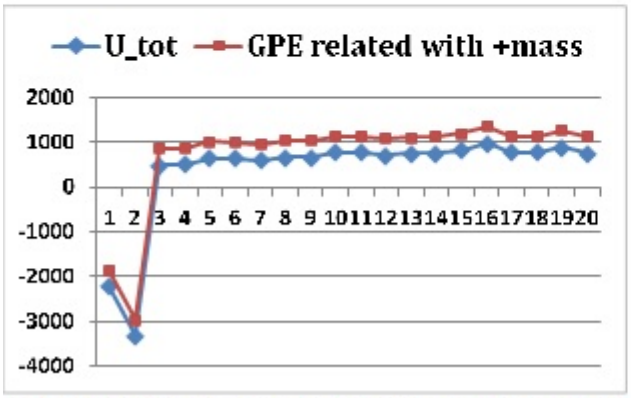
Figure 33:

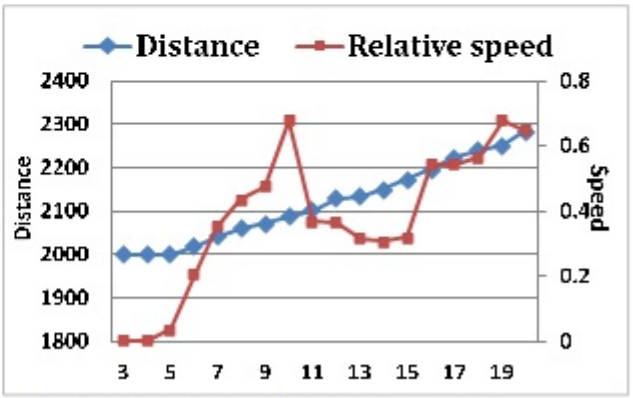
#4. Distant galaxy2 – the structure that negative mass surrounds galaxy composed of positive mass.
When positive mass is spread through relatively small area

	1	2	3	4	5	6	7	8	9	10
Step	0.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
U++	-2743.78	-3846.75	-45.02	-45.02	-44.96	-44.16	-43.22	-42.61	-42.18	-41.67
U--	-369.38	-369.57	-370.16	-371.19	-372.51	-370.55	-368.18	-368.24	-369.69	-371.75
U-+	890.29	892.86	901.28	919.24	1074.68	1045.11	1006.78	1079.97	1076.27	1183.83
U_tot	-2222.86	-3323.46	486.09	503.02	657.21	630.40	595.39	669.12	664.40	770.42
(U-+)+(U++)	-1853.48	-2953.89	856.25	874.22	1029.72	1000.95	963.56	1037.36	1034.09	1142.17
+GPE/-GPE	28.60%	21.18%	217.08%	220.86%	257.43%	252.01%	244.72%	262.86%	261.31%	286.36%
(U-+)+(U--)	520.91	523.29	531.11	548.05	702.17	674.56	638.60	711.73	706.58	812.09
	11	12	13	14	15	16	17	18	19	20
Step	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
U++	-41.04	-39.94	-39.76	-39.15	-38.27	-37.51	-36.60	-36.14	-35.79	-34.90
U--	-370.93	-366.89	-369.73	-369.98	-369.17	-368.79	-366.30	-366.55	-367.94	-363.47
U-+	1187.17	1120.32	1158.80	1160.72	1239.91	1383.19	1166.00	1176.04	1290.16	1155.99
U_tot	775.20	713.49	749.31	751.60	832.47	976.89	763.10	773.34	886.43	757.62
(U-+)+(U++)	1146.13	1080.38	1119.04	1121.57	1201.64	1345.68	1129.40	1139.89	1254.37	1121.09
+GPE/-GPE	288.17%	275.38%	282.98%	283.71%	304.32%	340.43%	289.40%	292.04%	319.56%	290.18%
(U-+)+(U--)	816.24	753.43	789.07	790.75	870.74	1014.40	799.70	809.49	922.22	792.53

1) center1(-1000,0,0), center2(-1000,0,0), Positive masses(each 300) are spread within R=40.
2) m+=(1X300)+(1X300), -m-=(-0.2X1500)+(-0.2X1500), 250≤(x±1000),y,z≤250, almost uniformly distribution.
3) Total rest mass energy=0, initial velocity=0, t=0.1







1) It's appearing to be greatly affected by the movements of the individual particles, but in overall, it's showing accelerating expansion effect.

Figure 34:

#5. Close galaxies -the structure that negative mass surrounds galaxy composed of positive mass.

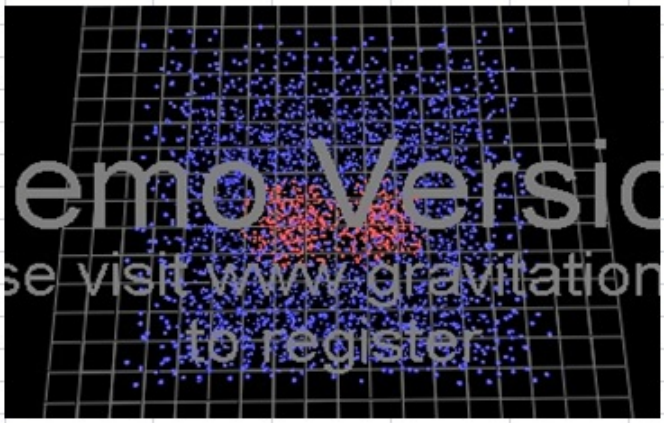
	1	2	3	4	5	6	7	8	9	10
Step	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00
U++	-902.98	-912.14	-941.29	-996.70	-1094.40	-1284.28	-1746.55	-3193.65	-2988.68	-1654.56
U--	-324.15	-324.29	-324.72	-325.46	-326.51	-327.92	-329.73	-332.04	-334.42	-336.53
U-+	756.05	757.09	760.29	765.82	774.08	785.72	802.04	825.80	860.72	919.42
U_tot	-471.08	-479.34	-505.72	-556.34	-646.83	-826.48	-1274.24	-2699.89	-2462.38	-1071.67
(U-+)+(U++)	-146.93	-155.05	-181.00	-230.88	-320.32	-498.56	-944.51	-2367.85	-2127.96	-735.14
+GPE/-GPE	61.61%	61.23%	60.05%	57.92%	54.48%	48.74%	38.63%	23.42%	25.90%	46.18%
(U++)+(U--)	431.90	432.80	435.57	440.37	447.57	457.80	472.31	493.76	526.30	582.89

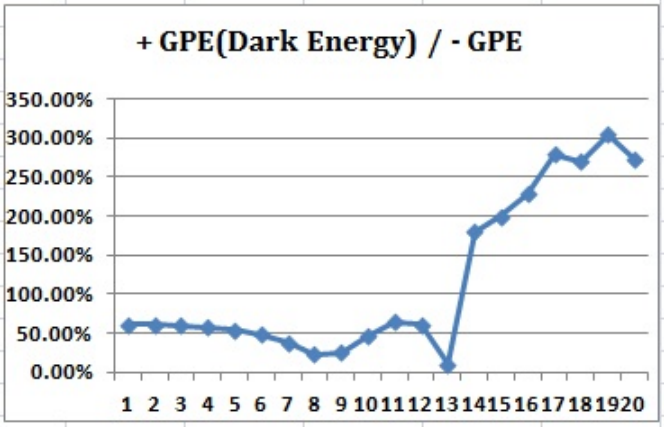
	11	12	13	14	15	16	17	18	19	20
Step	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00
U++	-1215.62	-1326.07	-10928.07	-282.17	-246.42	-166.69	-121.31	-105.30	-113.83	-88.55
U--	-336.17	-334.82	-335.93	-332.59	-328.16	-316.56	-314.87	-302.69	-302.73	-296.64
U-+	1009.79	1020.13	1137.46	1106.53	1148.28	1105.96	1218.44	1103.16	1267.80	1051.08
U_tot	-541.99	-640.76	-10126.54	491.76	573.70	622.71	782.26	695.16	851.24	665.89
(U-+)+(U++)	-205.82	-305.94	-9790.61	824.35	901.86	939.27	1097.13	997.85	1153.97	962.53
+GPE/-GPE	65.07%	61.42%	10.10%	179.99%	199.85%	228.86%	279.35%	270.39%	304.35%	272.87%
(U++)+(U--)	673.63	685.31	801.53	773.93	820.12	789.39	903.57	800.47	965.08	754.44

1) m+=(1 X 300) + (1 X 300) = +600, center1(-150,0,0), center2(+150,0,0), Positive mass is spread within R=180.

2) -m- = -0.2 X 3000 = -600, negative mass distribution: -500≤x,y,z≤500 0‖, -m-=-0.2, total 3000ea

3) Total rest mass energy=0, initial velocity=0, t=0.1





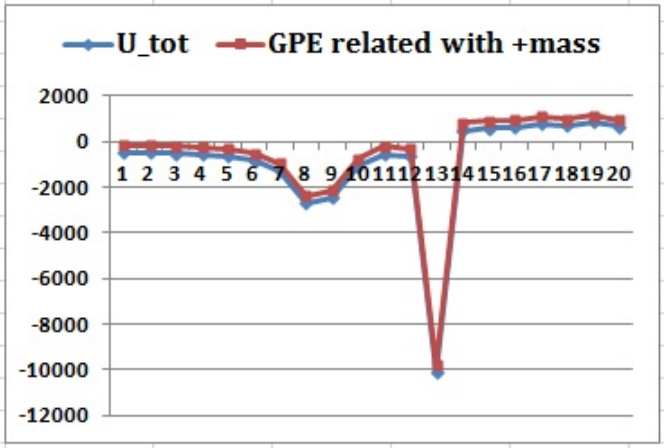


Figure 35:

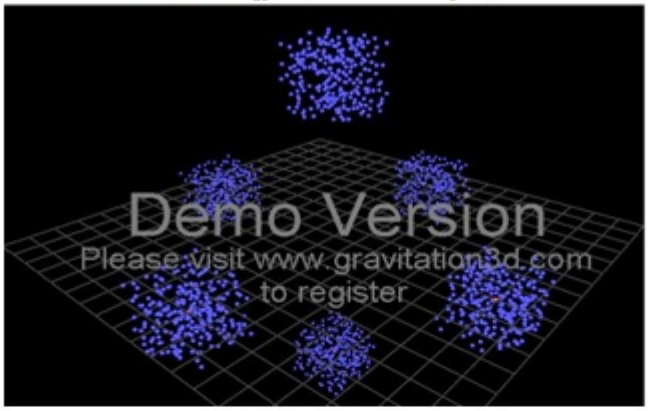
#6. Distant six galaxies -the structure that negative mass surrounds galaxy composed of positive mass.

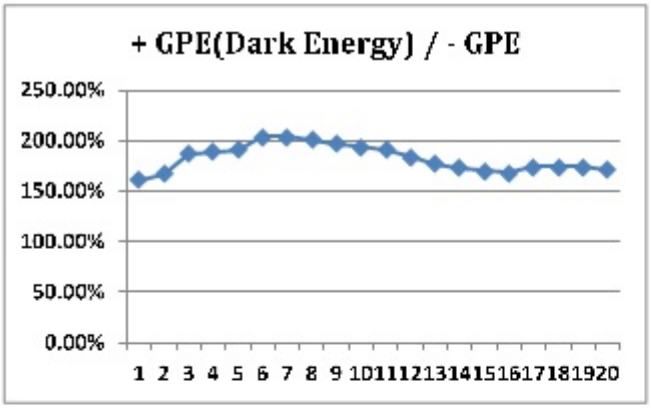
	1	2	3	4	5	6	7	8	9	10
Step	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
U++	-99.85	-99.85	-98.80	-98.32	-97.48	-96.85	-96.15	-95.39	-94.52	-93.61
U--	-234.91	-235.43	-233.93	-233.48	-234.16	-235.87	-238.42	-241.08	-242.26	-241.95
U-+	541.63	560.92	624.16	627.31	632.18	677.92	683.10	676.04	665.49	650.76
U_tot	206.87	225.63	291.43	295.51	300.54	345.20	348.53	339.57	328.70	315.20
(U-+)+(U++)	441.78	461.07	525.36	528.99	534.70	581.07	586.95	580.65	570.97	557.14
+GPE/-GPE	161.79%	167.30%	187.59%	189.06%	190.62%	203.75%	204.17%	200.92%	197.60%	193.93%
(U-+)-(U--)	306.72	325.48	390.23	393.83	398.02	442.05	444.68	434.96	423.23	408.81
	11	12	13	14	15	16	17	18	19	20
Step	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
U++	-92.65	-91.61	-90.53	-89.41	-88.27	-87.14	-85.96	-84.76	-83.54	-82.31
U--	-240.40	-236.88	-232.84	-227.75	-222.07	-216.37	-210.71	-205.03	-198.86	-193.16
U-+	634.12	605.28	572.75	548.70	527.73	510.02	516.64	505.38	492.41	472.04
U_tot	301.07	276.79	249.38	231.55	217.39	206.51	219.97	215.60	210.01	196.57
(U-+)+(U++)	541.47	513.67	482.22	459.29	439.46	422.88	430.68	420.62	408.87	389.73
+GPE/-GPE	1.90	1.84	1.77	1.73	1.70	1.68	1.74	1.74	1.74	1.71
(U-+)-(U--)	393.71	368.40	339.91	320.95	305.67	293.65	305.94	300.35	293.55	278.88

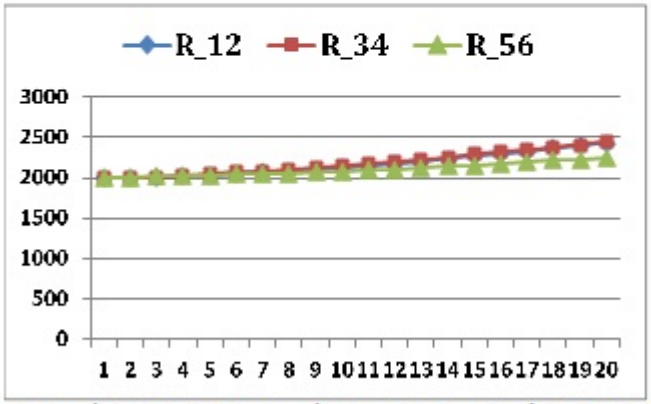
1) center(±1000,0,0), center(0,±1000,0), center(0,0,±1000), m+=+100X6=+600

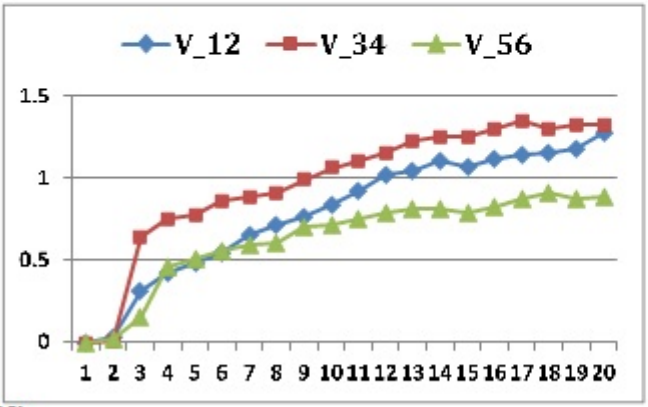
2) negative mass: center(±1000,0,0), center(0,±1000,0), center(0,0,±1000), -250 ≤ x,y,z ≤ 250, -m-=(-0.4 X 250)X6=-600

3) Total rest mass energy=0, initial velocity=0, t=0.3









1) X-axis(R_56, V_56), Y-axis(R_34,V_34), Z-axis(R_12,V_12)

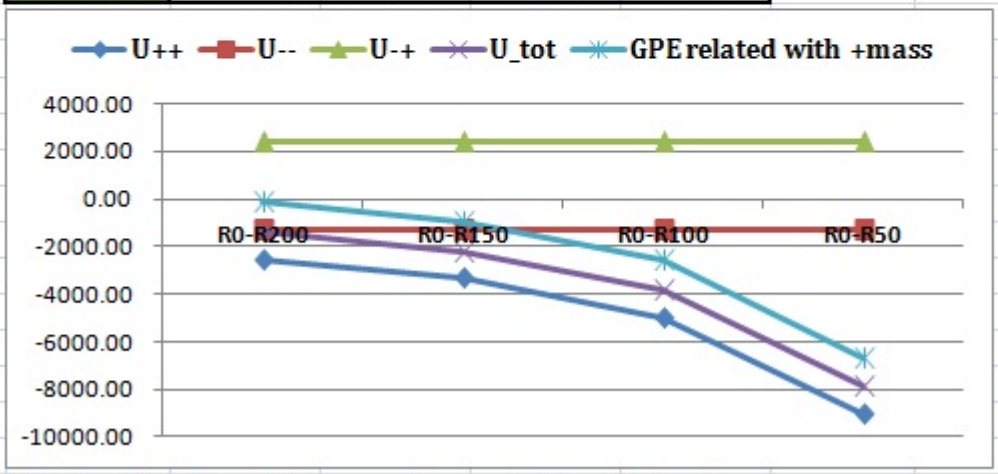
2) We can notice that there exits positive acceleration, and it corresponds to accelerating expansion of universe.

Figure 36:

#7. Gravitational contraction due to positive mass and negative mass

1) When positive mass does gravitational contraction

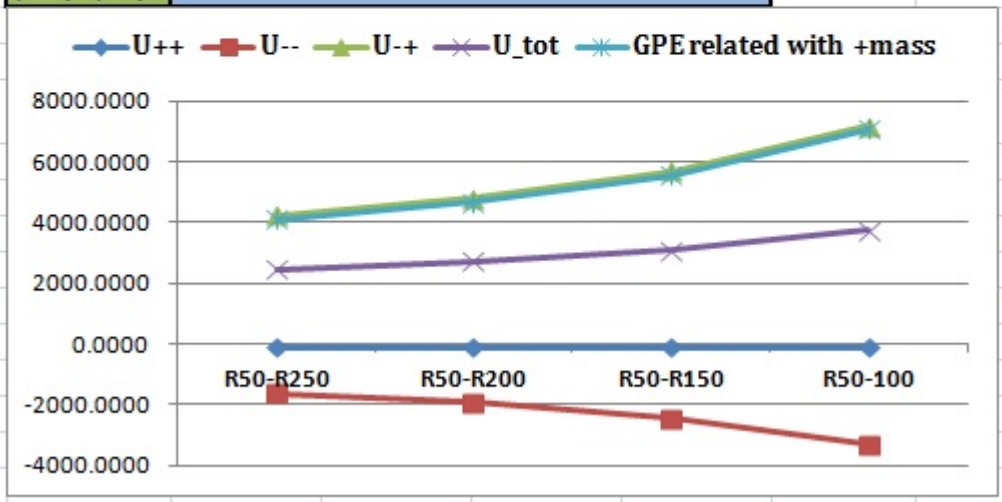
-m-	center1(-1000,0,0), center2(+1000,0,0),R220-250			
m+	R0-R200	R0-R150	R0-R100	R0-R50
U++	-2549.43	-3330.91	-4963.22	-9025.24
U--	-1258.82	-1256.70	-1281.29	-1255.27
U-+	2417.44	2402.33	2388.49	2384.24
U_tot	-1390.81	-2185.29	-3856.02	-7896.26
(U-+)+(U++)	-131.99	-928.59	-2574.72	-6641.00
+GPE/-GPE	63.48%	52.37%	38.25%	23.19%
(U-+)+(U--)	1158.62	1145.63	1107.20	1128.98



It is shown that as positive mass does gravitational contraction,
U_tot and GPE value related with positive mass both gradually smaller (negative value).

2) When negative mass does gravitational contraction

m+	center1(-1000,0,0), center2(+1000,0,0)			
-m-	R50-250	R50-200	R50-150	R50-100
U++	-125	-125	-125	-125
U--	-1645.63	-1944.42	-2456.66	-3301.23
U-+	4214.19	4794.12	5666.22	7176.04
U_tot	2443.56	2724.69	3084.57	3749.81
(U-+)+(U++)	4089.19	4669.12	5541.22	7051.04
+GPE/-GPE	238.00%	231.66%	219.48%	209.44%
(U-+)+(U--)	2568.56	2849.69	3209.57	3874.81



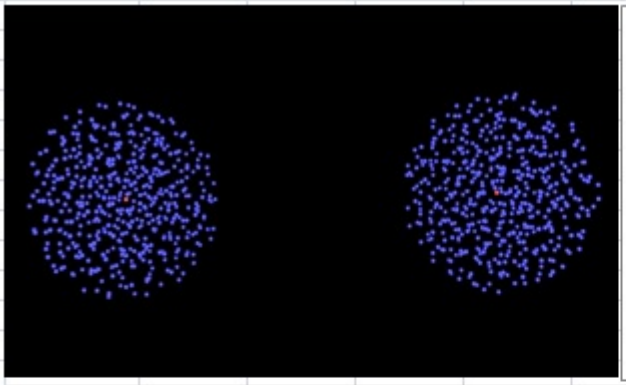
It is shown that as negative mass does gravitational contraction around massive positive mass,
U_tot and GPE value related with positive mass both are bigger.

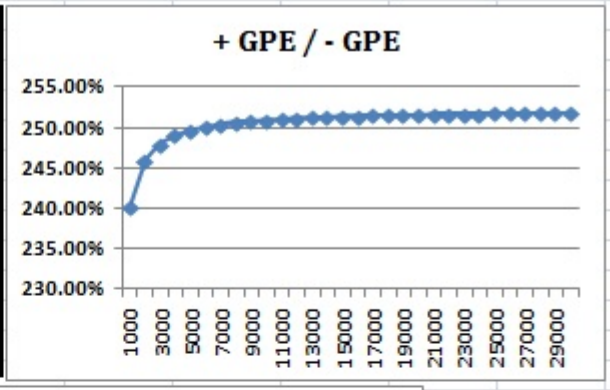
Figure 37:

#8. In the structure negative mass surrounds galaxy composed of positive mass, arrangement of particles is fixed and distance between galaxies increases.

R	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000
U++	-250.00	-125.00	-83.33	-62.50	-50.00	-41.67	-35.71	-31.25	-27.78	-25.00
U--	-5999.83	-5874.76	-5833.07	-5812.24	-5799.73	-5791.40	-5785.45	-5780.98	-5777.51	-5774.73
U-+	15005.82	14755.75	14672.40	14630.73	14605.73	14589.06	14577.16	14568.23	14561.28	14555.73
U_tot	8756.00	8756.00	8756.00	8756.00	8756.00	8756.00	8756.00	8756.00	8756.00	8756.00
(U-+)+(U++)	14755.82	14630.75	14589.07	14568.23	14555.73	14547.40	14541.44	14536.98	14533.51	14530.73
+GPE/-GPE	240.10%	245.94%	248.00%	249.04%	249.68%	250.11%	250.42%	250.65%	250.83%	250.97%
(U-+)+(U--)	9006.00	8881.00	8839.33	8818.50	8806.00	8797.66	8791.71	8787.25	8783.77	8781.00
R	11000	12000	13000	14000	15000	16000	17000	18000	19000	20000
U++	-22.73	-20.83	-19.23	-17.86	-16.67	-15.63	-14.71	-13.89	-13.16	-12.50
U--	-5772.46	-5770.56	-5768.96	-5767.59	-5766.40	-5765.36	-5764.44	-5763.62	-5762.89	-5762.23
U-+	14551.18	14547.39	14544.19	14541.44	14539.06	14536.98	14535.14	14533.50	14532.04	14530.73
U_tot	8756.00	8756.00	8756.00	8756.00	8756.00	8756.00	8756.00	8756.00	8756.00	8756.00
(U-+)+(U++)	14528.45	14526.56	14524.96	14523.58	14522.39	14521.35	14520.43	14519.62	14518.88	14518.23
+GPE/-GPE	251.09%	251.19%	251.27%	251.35%	251.41%	251.46%	251.51%	251.55%	251.59%	251.63%
(U-+)+(U--)	8778.72	8776.83	8775.23	8773.85	8772.66	8771.62	8770.70	8769.89	8769.15	8768.50
R	21000	22000	23000	24000	25000	26000	27000	28000	29000	30000
U++	-11.90	-11.36	-10.87	-10.42	-10.00	-9.62	-9.26	-8.93	-8.62	-8.33
U--	-5761.63	-5761.09	-5760.60	-5760.15	-5759.73	-5759.35	-5758.99	-5758.66	-5758.35	-5758.06
U-+	14529.54	14528.45	14527.47	14526.56	14525.73	14524.96	14524.25	14523.58	14522.97	14522.39
U_tot	8756.00	8756.00	8756.00	8756.00	8756.00	8756.00	8756.00	8756.00	8756.00	8756.00
(U-+)+(U++)	14517.63	14517.09	14516.60	14516.14	14515.73	14515.34	14514.99	14514.66	14514.35	14514.06
+GPE/-GPE	2.51657	2.51686	2.51712	2.51736	2.51757	2.51778	2.51796	2.51814	2.51830	2.51845
(U-+)+(U--)	8767.90	8767.36	8766.87	8766.41	8766.00	8765.61	8765.26	8764.93	8764.62	8764.33

1) As R, which corresponds to the distance of the galaxy, increases, absolute values of GPE(U++, U--, U-+, GPE related with + mass) decrease while the total GPE is maintained constant.
2) Ratio of +GPE (Dark Energy) and -GPE increases as the universe expands and this is seen to mean that percentage of repulsive effect(DE) increases compared to the attractive effect of ordinary matter.





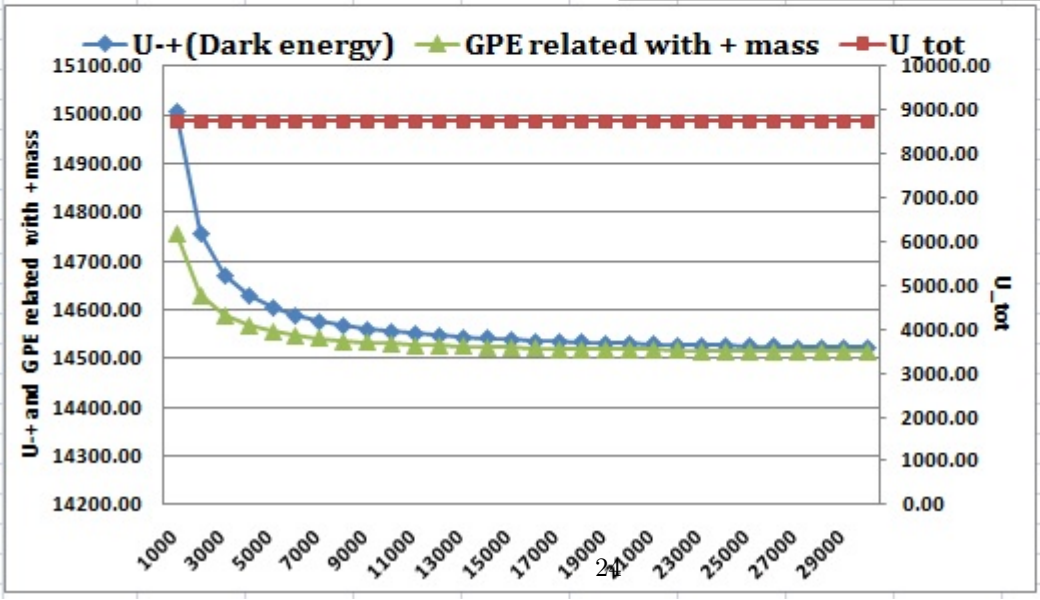
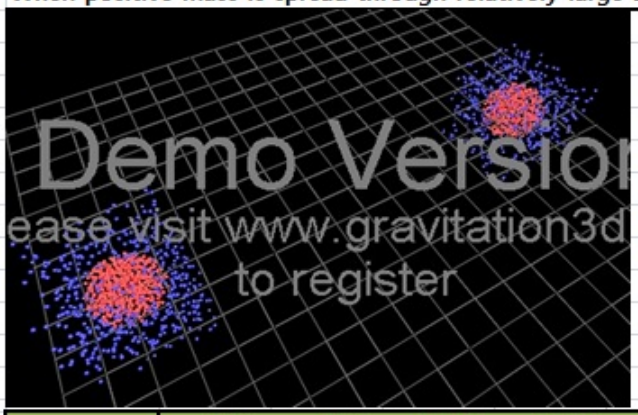
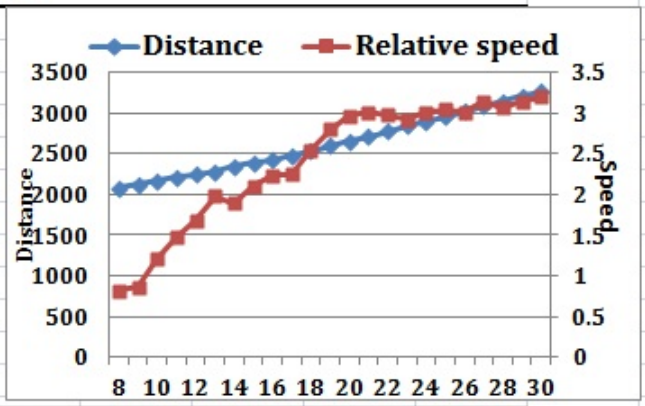


Figure 38:

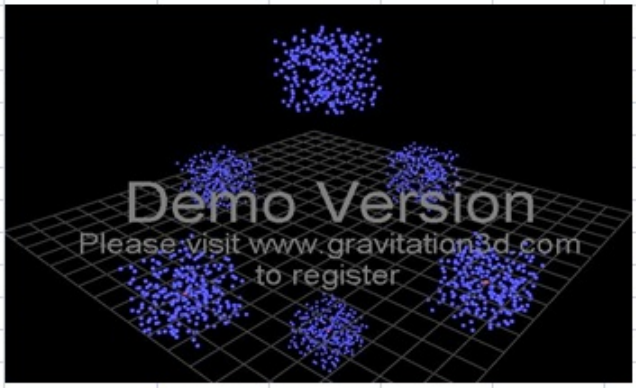
#3-1. Distant galaxy1 – The structure that negative mass surrounds galaxy composed of positive mass.
When positive mass is spread through relatively large area

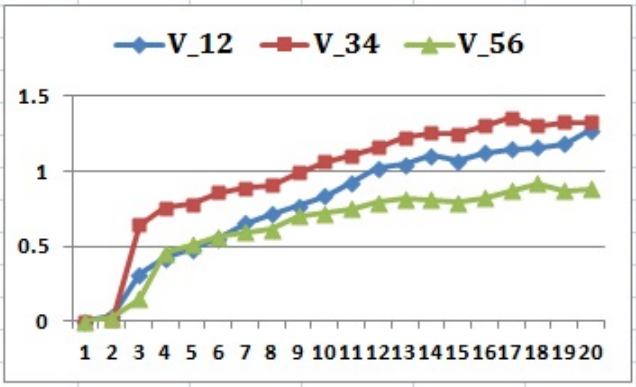




	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00
R	2077.63	2125.73	2167.08	2211.37	2244.67	2277.89	2347.78	2383.62	2423.15
V_rel	0.82	0.86	1.22	1.47	1.68	1.97	1.89	2.10	2.23
	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00
R	2471.57	2528.28	2599.84	2654.25	2711.35	2776.12	2840.46	2896.85	2955.97
V_rel	2.25	2.54	2.79	2.96	3.00	2.98	2.92	3.01	3.03
	26.00	27.00	28.00	29.00	30.00				
R	3013.79	3082.17	3141.56	3200.19	3261.13				
V_rel	3.01	3.14	3.06	3.14	3.19				

#6-1. Distant six galaxies -the structure that negative mass surrounds galaxy composed of positive mass.





	1	2	3	4	5	6	7	8	9	10
R_12	2000	2000.10	2011.49	2021.13	2033.78	2048.28	2064.83	2083.36	2104.93	2127.22
V_12	0	0.03	0.31	0.42	0.48	0.55	0.65	0.71	0.77	0.84
R_34	2000	1999.94	2012.16	2028.16	2046.27	2064.67	2084.81	2106.82	2129.71	2153.40
V_34	0	0.01	0.64	0.76	0.78	0.86	0.89	0.91	0.99	1.06
R_56	2000	2000.13	2016.13	2020.10	2033.53	2040.22	2047.53	2055.82	2066.93	2079.95
V_56	0	0.02	0.15	0.45	0.51	0.56	0.59	0.61	0.70	0.72
	11	12	13	14	15	16	17	18	19	20
R_12	2151.75	2179.21	2207.93	2237.93	2268.67	2299.79	2332.10	2365.01	2400.46	2437.00
V_12	0.92	1.02	1.05	1.11	1.07	1.12	1.15	1.16	1.18	1.27
R_34	2178.06	2204.33	2232.24	2261.65	2290.79	2319.51	2350.48	2381.31	2411.80	2441.99
V_34	1.10	1.16	1.23	1.26	1.25	1.31	1.36	1.30	1.32	1.33
R_56	2094.00	2108.89	2124.71	2141.24	2158.47	2175.99	2194.60	2215.06	2235.14	2255.66
V_56	0.75	0.79	0.82	0.81	0.79	0.82	0.87	0.92	0.87	0.88

Figure 39: