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Abstract:

There are not necessarily dark matter and dark energy in the solar system, and dark energy cannot distribute uniformly in the whole space. Based on Dirac negative energy, Einstein mass-energy relation and principle of equivalence, we proposed the negative matter as the simplest model of unified dark matter and dark energy. All theories are known, only mass includes positive and negative. Because there is repulsion between positive matter and negative matter, so which is invisible dark matter, and repulsion as dark energy. It may explain many phenomena of dark matter and dark energy. We derive that the rotational velocity of galaxy is approximate constant, and an evolitional ratio between total matter and usual matter from 1 to present 11.82 or 7.88. We calculate the accelerated expansion at 9.760 billion years. Further, the mechanism of inflation is origin of positive-negative matters created from nothing, whose expansion is exponential due to strong interactions at small microscopic scales. We propose specifically some possible ways on observe dark matter in the Milky Way. Many observatories should be able to observe these results. Final, we research some basic problems in cosmology: Possible mechanism of missing antimatter, the origins of mass and charge, etc. The negative matter as a candidate of unified dark matter and dark energy is not only the simplest, and is calculable, observable and testable, and may be changed and developed.

Keywords: dark matter, dark energy, distribution, negative matter, unification, calculation, observation, Milky Way.

Introduction

Dark matter and dark energy as everyone knows are the greatest mysteries in astronomy and total physics. General hypothesis is that dark matter and dark energy are two different concepts.

Since 1970 to 1978, Rubin, et al. (1978), confirmed the existence of dark matter for ten spiral galaxies. Further, the dark matter in the Galaxy, in group of galaxies and cluster of galaxies, in the universe, is confirmed by the mass-to-light ratio and the galactic rotational curves, etc (Binney, & Tremaine, 1987).

Physicists have proposed many models on dark matter and dark energy, for example, weakly interacting massive particles (WIMPs), Quintessence, k-essence, Phantom, cosmic string, axion, brane cosmology, scaling dark energy, Holographic dark energy and so on. Recently, ultralight dark matter (ULDM) becomes a new important candidate (Van Tilburg et al., 2015; Ferreira, 2021).

For new data (Planck Collaboration, 2016; Tanabashi et al, 2018), usual visible matter is 4.84%, dark matter is 25.96%, and dark energy is 69.20%.
But, so far many models on dark matter and dark energy are not testability.

In this summary, we discuss distributions of dark matter and dark energy, and propose three basic principles of the negative matter as a candidate unified dark matter and dark energy, and derive some corresponding calculate results, and propose observed ways in the Milky Way.

**Distributions of Dark Matter and Dark Energy, and Negative Matter as Unified Dark Matter-Energy**

Dark matter and dark energy are the results of astronomical observations. They are amazing, but are not mysterious. Some believe that dark energy distributes uniformly in the whole space, and throughout the universe, even to us. Because dark matter is 25.96%, and dark energy is 69.2% in Universe (Planck Collaboration, 2016; Tanabashi et al, 2018), as long as there is some dark matter or dark energy in the solar system, general relativity, even Newtonian's gravity theory can not be so accurate, therefore, there are not necessarily dark matter and dark energy in the solar system. Recently, astronomers find more galaxies in the Universe without any dark matter. Guo, et al. reported 19 dwarf galaxies that could consist mainly of baryons, and provided observational evidence that could challenge the formation theory of low-mass galaxies within the framework of standard cosmology (Guo et al., 2020).

In 1928 Dirac (1930) predicted anti-particles and the negative energy state from his equation, and he emphasized: “we cannot ignore the negative energy states”. In order to prevent to jump continuously from positive energy state to negative energy state in the quantum theories, and keep the stability of world, Dirac proposed that as long as suppose that all the states of negative energy are occupied except perhaps a few of small velocity. The vacuum of the realistic world has already been filling with all negative energy states, such the Pauli exclusion principle will come into play and prevent more than one electron going into any one state, and avoid this jumping difficulty. It is namely the well-known Dirac negative energy sea and whose vacancy or hole is an anti-particle (or opposite particle). From this the annihilation and creation between positive and opposite particles may be predicted. There is exact description in <The Principles of Quantum Mechanics> (Dirac, 1958). But, it prevents only jump of fermions, but cannot be applied to bosons. Therefore, the stability problem exists still. In fact, the negative energy state appears in all relativity theories as

\[
E = \pm \sqrt{p^2 c^2 + m^2 c^4},
\]

equation also in the classical theory.

1. Based on Dirac negative energy state, from 2007 we proposed that the negative matter may unify dark matter and dark energy (Chang, 2007; 2011; 2013; 2014a; 2014b; 2017; 2019; 2020; 2021; 2022a; 2023), in which the anti-(opposite) matter and the negative matter are different. The anti-matter is that some properties of matter are opposite, for instance, charge, baryon number, lepton number, strangeness number and so on, but their masses and total energy are still positive. These particles include positron and various anti-particles. The existence of these particles is already verified. Both positive and opposite matters meet to annihilate to photons with conservation of energy and zero-charge. A key of the negative matter is negative mass. According to the gravitational force:

\[
F = -\frac{G M_1 M_2}{r^2},
\]

there is still gravitational force between negative-negative matters, but it is universal repulsive force between the positive and negative matters. Therefore, the positive and negative matters are two regions of topological separation in general case by different interactions (Fug.1) (Chang, 2007; 2011).

Based on \( M \rightarrow M_+ - M_- \) and Eq.(1), all theories are all known. The positive and negative matters are two regions of topological separation in general case by different interactions, so the negative matter is invisible dark matter. Repulsion between positive matter and negative matter shows dark energy. This is the simplest candidate of dark matter, and can be unified dark energy, and may explain many phenomena of
dark matter and dark energy (Chang, 2007; 2011; 2013; 2014a; 2014b; 2017; 2019; 2020; 2021; 2022a; 2023), which should be in some group distributions. The negative matter should be a necessary development of Dirac theory.

![Figure 1. Positive and Negative Matters as Two Topological Separations](image)

II. According to the principle of equivalence in general relativity, inertial mass and gravitational mass must be equal always. Based on Eq.(1), there are only three cases: positive and positive matters, positive and negative matters, negative and negative matters (Chang, 2013; 2014a). But, for negative mass Bondi (1957) proposed three kinds of mass: inertial, passive gravitational, and active gravitational mass, and there are four cases. Such Bondi believes that the positive body will attract the negative one, etc. It is a fallacy with contradictions.

III. According to Einstein mass-energy relation $E = mc^2$, dark matter and dark energy should be unified, and it agrees with Occam's Razor (Chang, 2014b; 2021).

We found that some proofs of the positive mass theorem have all certain premises: an isolated gravitational system and infinite space, but both are all impossible. Therefore, the negative matter cannot be restricted. Further, we discussed some simple estimations of the positive matter theorem, which agree from astronomy to particles (Chang, 2022a).


### Basic Calculations of Negative Matter as Unified Dark Matter-Energy

In the modern cosmology (Dodelson, 2003; Weinberg, 2008), for a radiation-dominated universe of the big-bang cosmology, the total energy of usual matter is mainly the positive energy of photon $Me^2$. When the evolitional process from inflation and radiation-dominated
universe to the matter-dominated universe, the known total energy of usual baryon matter of non-relativity is:

\[ Mc^2 - \frac{GmM}{r}. \]  

(2)

The positive mass theorem is simplified to \( Mc^2 > \frac{GmM}{r} \), i.e., \( c^2 > \frac{Gm}{r} \). This constant \( \frac{c^2}{Gm} = 1.35 \times 10^{27} \text{kgm}^{-1} \) is very big.

In astronomy, Solar mass: Solar radius is \( M/R = 2.848 \times 10^9 \text{kgm}^{-1} \). For the solar system \( R \) is bigger, \( M/R \) is smaller. For black hole, \( r = 2Gm/c^2 \), so \( 1 > 0.5 \) hold always. For Galactic System

\[ \frac{M}{R} \approx 4 \times 10^{42} \text{kg}/2.85 \times 10^{21} \text{m} = 1.4 \times 10^{21} \text{kgm}^{-1} \]

The known total mass of Universe is \( M = 2 \times 10^{53} \text{kg} \), and corresponding scale is \( R = 4.2 \text{Gpc} = 1.3 \times 10^{26} \text{m} \) (Perkins, 2003), so \( \frac{M}{R} = 1.538 \times 10^{27} \text{kgm}^{-1} \). Both are comparable, and \( M/R \) is slightly big. It corresponds just to the acceleration of the universe and dark energy (Peebles, & Ratra, 2003).

Further, based on this model, we may calculate simply some results.

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**Figure 2. In Andromeda Galaxy the Curve of the Rotational Velocity with Distance. The Red Curve is the Theoretical Calculated Prediction of the No-Dark Matter, and the white Curve is the Measured Curve**

In Fig.2 the difference between the two curves is one of the key evidence for the existence of dark matter. According to classical mechanics the rotational velocity is:

\[ V^2 = \frac{GM}{R} \approx \text{constant}. \]  

(4)

If the negative matter is introduced \( M \rightarrow M_+ - M_- \), the equation (3) will become:

\[ \frac{G}{R^2} (M_+ - M_-) = \frac{1}{R} V^2. \]  

(5)
The total mass of the spherality galaxy inside radius \( R \) is:

\[
M(R) = M_+ - M_- = \int_0^R (\rho_+ - \rho_-) dV = (\rho_+ - \rho_-) \int_0^R 4\pi r^2 dr = \frac{4\pi}{3} R^3 (\rho_+ - \rho_-).
\]

(6)

\[
\frac{dV}{dt} = -\frac{G}{R^2} (M_+ - M_-) = -\frac{4\pi}{3} GR (\rho_+ - \rho_-).
\]

(7)

For the plane disk-like galaxy

\[
M(R) = (\rho_+ - \rho_-) \int_0^R 2\pi rdr = \pi R^2 (\rho_+ - \rho_-).
\]

(8)

\[
\frac{dV}{dt} = -\pi G (\rho_+ - \rho_-).
\]

(9)

If \( \rho_+ \approx \rho_- \) and \( M_+ \approx M_- \), \( dV/dt \approx 0 \), integral derive \( V \) and \( V^2 \) are approximate constants (Fig.1), the expansion rate is unchanged.

When \( \rho_+ - \rho_- > 0 \), \( M_+ - M_- > 0 \), \( dV/dt < 0 \), the expansion rate is deceleration. If \( \rho_+ - \rho_- < 0 \), \( M_+ - M_- < 0 \), \( dV/dt > 0 \), the expansion rate is acceleration.

We searched some results and tests of the negative matter as dark matter, in which a judgment test is an opposite repulsive lensing, but usual cases are gravitational lensing for huge massive matter. We supposed that dark matter-energy is completely the negative matter, then may calculated a ratio between negative mass and baryon mass, which agree with new observed value. We discussed advantage the negative matter as dark energy, for example, unified mass and energy in relativity, determined space-time scales on inflation, and phantom must be a type of the negative matter, and it is similar with weakly interacting massive particles (WIMPs), etc (Chang, 2019).

In the modern cosmology (Dodelson, 2003; Weinberg, 2008) the usual total energy of radiation-dominated universe is energy of photon \( M_{\gamma} c^2 \). The total energy of positive and negative matters is \( M_+ c^2 - M_{\gamma} c^2 \). Because inflation is origin of nothing, the total energy should be zero, i.e., \( M_+ = M_- \).

When the evolutional process from radiation-dominated universe to the matter-dominated universe, the known total energy of usual baryon matter of non-relativity is:

\[
M_+ c^2 - \frac{GM_+^2}{R_+}.
\]

(10)

Assume that dark matter and dark energy are completely the negative matter, so the total energy includes three parts: one of the positive matter, one of negative matter, and their repulsion force:

\[
E_t = M_+ c^2 - \frac{GM_+^2}{R_+} + (-M_- c^2 - \frac{GM_-^2}{R_-}) + \frac{GM_+ M_-}{R_+}.
\]

(11)

Both ratio is:

\[
\frac{-3GM_+^2}{2R_+} + (-M_- c^2 - \frac{GM_-^2}{R_-}) + \frac{GM_+ M_-}{R_+}.
\]

(12)

Since the gravitation is negative energy, so the ratio will increase along time and scale \( R \). This will show that the expanding universe leads to increasing numbers of the negative energy-dark energy.

We suppose that for early inflation cosmology the positive matter and the negative matter have the same mass \( M_+ = M_- = M \), and both are separated. In order to simplify assume that positive and negative matters form two identical spheres, respectively, so \( R_+ = R_- = R, R_+ = 2R \).

Such Eq.(12) is simplified to:

\[
\frac{-3GM_+^2}{2R} = \frac{3GM}{2GM - Rc^2}.
\]

(13)

It forms a changeable and continuously increased dark matter-energy field. It is known that the total mass of Universe is \( M = 2 \times 10^{53} kg \), and corresponding scale is \( R = 4.2 Gpc = 1.3 \times 10^{26} m \) (Perkins, 2003), so
And
\[ GM = 1.34 \times 10^{43} \text{ m}^3 \text{s}^{-2}. \]  
\[ Rc^2 = 1.17 \times 10^{43} \text{ m}^3 \text{s}^{-2}, \]

A simple calculation obtains
\[ \frac{3GM}{2GM - Rc^2} = 11.82. \]

Of course, the actual situations are more complicated. But, this is a model that can be computed and compared, and may also be developed.

According to new data (Planck Collaboration, 2016; Tanabashi, et al., 2018), ratio between usual matter, total matter and dark energy is 4.84:30.8:69.2, so 30.8/4.84=6.36, and 69.2/4.84=14.3.

If \( R = R_c \), positive matter and negative matter are mix together in the same volume, so Eq.(12) is simplified to:
\[ -\frac{G M c^2}{R} + \frac{G M c^2}{R} \pm R_c^2 = 7.88 \]  
(15)

We supposed that for early inflation cosmology the positive matter and the negative matter have the same mass \( M_+ = M_- = M \), and \( R_+ = R_- = R \). So Eq.(16) becomes to:
\[ E_t = -\frac{2G M^2}{R} + \frac{G M^2}{R} \pm R_c^2 \]  
(17)

Corresponding force is:
\[ F = -\frac{G M^2}{R^2} (2R_\mp^2 - R^2) = -\frac{G M^2}{R^2} \sqrt{2R_\mp^2} (\sqrt{2R_\mp^2} - R). \]  
(18)

If \( R < \sqrt{2R_\mp} \), it is gravitation; if \( R > \sqrt{2R_\mp} \), it is repulsion. \( R = \sqrt{2R_c} \) is the inflection point for the accelerated expansion of the universe.

First, it is qualitatively consistent. The positive and negative matters in the early universe were dominated by gravitation, respectively. Later the velocities slow down, the repulsion appears at the inflection point, but it is not in the exponential form.

In Cosmology the distance \( R \) is proportional to time \( T = R/v \), which corresponds to the light cone \( ds^2 = dr^2 - c^2 dt^2 = 0 \), \( R = cT \). So \( R = \sqrt{2R_c} \) corresponds to \( T = \sqrt{2T_0} \). If \( T = 13.8 \) billion years is the current cosmic time, so an inflection point appeared at \( T_0 = T/\sqrt{2} = 13.8/\sqrt{2} = 9.760 \) billion years. This is the same with accelerated expansion at 9.7 billion years.

Of course, the actual situations are more complicated. But, this is a model that can be computed and compared, and may also be developed.

**Negative Matter in Cosmology, and Inflation**

It is known that the gravitational field equations with the cosmological constant are:
\[ G_{\mu\nu} + \Lambda g_{\mu\nu} = R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + \Lambda g_{\mu\nu} = 8\pi k T_{\mu\nu}. \]  
(19)

We proposed the field equations of general relativity on the negative matter (Chang, 2007; 2011; 2013; 2014a; 2014b; 2017; 2019; 2020; 2021; 2022a; 2023):
\[ G_{\mu\nu} = 8\pi k (T_{\mu\nu} - T'_\mu T'_\nu). \]  
(20)

So the cosmological constant \( \Lambda \) corresponds to the negative matter, i.e., \( \Lambda = 8\pi k T_{\mu\nu} / g_{\mu\nu} \). Here \( Ag_{\mu\nu} \) corresponds to the negative energy state and vacuum energy (Dirac sea), and is consistent with conformal gravity theory.

Caldwell (2002) proposed phantom as cosmological consequences of a dark energy component with super-negative equation of state, whose cosmic energy density has negative pressure. The total energy is negative, so it is
namely a type of negative matter. Then phantom becomes an important dark energy model.

In cosmology it is an important progress that Guth proposed inflation whose time origin is from $10^{-32}$ s, and cosmic scale factor exponential expansion $a(t) \approx e^{tn}$. Then Linde and Albrecht, et al., proposed the chaotic inflation. We proposed the mechanism of inflation as origin of positive-negative matters created from nothing at the same time, whose quantum fluctuations correspond just to the chaotic inflation (Chang, 2007; 2011; 2013; 2014a; 2014b; 2017; 2019; 2020; 2021; 2022a; 2023). It is a Planck time $10^{-43}$ s, and length $10^{-33}$ cm. At this very small space the positive matter and negative matter are the very strong repulsive interaction, and the exponential inflation is just a form of the strong interaction

$$F = -g^2 \frac{e^{4r}}{r^2},$$

in which the positive matter is $g$, and the negative matter is $-g$, so $F>0$ is a huge strong repulsive force for the length inside $10^{-13}$ cm. When the scale is bigger than one of the strong interaction, the inflation finishes, and the positive matter and opposite matter will form two regions of topological separation repulsed each other (Fig.1).

Some Possible Ways on Observe Dark Matter in the Milky Way

In 2007, COSMOS obtained first three-dimensional distribution map of dark matter on world (Massey, Rhodes, & Ellis, 2007). We researched the most complete theory of the negative matter, and its quantum theory, and corresponding Lobachevskian geometry. We proposed a judgment test for the negative matter as dark matter, and other possible tests (Chang, 2013; 2014a; 2014b; 2017; 2019; 2020; 2021).

There must have dark matter in the Milky Way. We should closely observe the dark regions of the Milky Way (Fig.5), which could be three categories: vacuum, black hole, or dark matter. The black holes form some spherical regions, while vacuum and dark matter may not be completely regular. When the Earth is in different positions throughout the year, the background stars of these regions will be respectively constant, gravitational lensing, or...
opposite repulsive lensing if negative matter as
dark matter. The both angles of deflection are:

\[ \Delta \varphi = \frac{4G(\pm M)}{c^2 R}, \]  

(22)

in which R is the same for a black hole, while R 
for negative matter is not necessarily the same. 
Many observatories should be able to observe 
these differences. We look forward to the early 
results of the astronomers.

Panek (2011) described some possible observe 
ways on dark matter and dark energy. Siegel 
(2016) in Beyond the Galaxy collected some 
pictures of astronomical observations on dark 
matter. Recently, astronomers observed a super-
huge hole about 2 billion light-years scale (Fig.6). 
This is most likely an invisible region of the 
negative matter, because its form is irregular, and 
cannot be origin of black hole with spherical 
symmetry. Fig.6 as a negative matter should be 
able to see the image of the repulsion lensing. 
These may be linked to the spiral gravitational 
len 2237+0305 (Trott et al., 2010) and Virgo 
giant clusters Abell 1689, etc.

Figure 5. VISTA gigapixel mosaic of the central parts of the Milky Way 
(European Southern Observatory)

Figure 6. A super-huge hole in Universe
Some Problems in Cosmology

Because of the repulsion of the negative matter, the universe accelerates its expansion, and is even less likely to big shrink and big rebound, so the universe cannot circulate.

It is known that matter is far greater than antimatter. It may be linked to CP nonconservation, etc. We propose a possible mechanism of missing antimatter when the attraction of the positive and negative charge is greater than the repulsion of positive and negative masses. We extend the total energy to the case with electromagnetic interactions. Only the simplest electrostatic forces are considered, assume that e is negative charge and Q is positive charge:

\[ E_T = (M_+ c^2 - \frac{GM_+^2}{R_+} + \frac{e_+ Q_+}{R_+}) + (-M_- c^2 - \frac{GM_-^2}{R_-} + \frac{e_- Q_-}{R_-}) + (\frac{GM_+ M_-}{R_+ R_-} + \frac{e_+ e_- Q_+ Q_-}{R_+ R_-}). \]  

(23)

Specifically, it is known that the present existence is the proton p and electron e, which constitute hydrogen. Their antimatters are the negative proton p and positron e. Assume that the presence of proton p and electron e in the negative matter. A mass m in antimatter has charge q, and a mass –M in the negative matter has opposite charge –Q. As long as the attraction qQ of the positive and negative charge is greater than the repulsion of positive and negative masses, i.e., qQ > GmM, such the opposite charged antimatter and negative matter can annihilate and decrease when fluctuations. Probably it may explain the puzzle of missing antimatter. Some new predictions can be obtained: 1. The known world is mainly positive matter. 2. Very little antimatter. 3. There are more remaining, mainly neutral antimatter and negative matter. The most basic protons and the electrons are charged particles, and the neutrons are unstable, so more remainders are neutral particles, especially neutrinos and photons, and neutrons. It accords also with Sakharov’s three conditions. Further, we should consider the motion of the charged particles and the corresponding electromagnetic theory and electrodynamics, and QED. This is Dirac genius prediction (Dirac, 1930; 1958): The sea of negative matter is occupied full, at present it is 96%, and is widely distributed. The antimatter is only vacancy (hole), so very little.

The origin of Universe is always an attracting science questions (Weinberg, 1977; Sternglass, 1997; Clegg, 2011; 2019). In the modern cosmology (Dodelson, 2003; Weinberg, 2008) we think that two evolutional processes are very important, in which inflation produces the positive-negative matters and mass, and the matter-dominated universe in the visible region produces the opposite matters and charges. Both introduce the gravitational constant G, and the fine-structure constant \( \alpha \), respectively. While the negative matter region is invisible and hard to know.

Conclusion

This is known that the big bang and black hole contracts to singularities are two opposite processes at different scales. When the energy decreases, the inversion process of neutron star formation corresponds probably to the generation of charges in the universe. It is the evolutional process from radiation-dominated universe to the matter-dominated universe, the universe first forms neutrons, and then the neutron decay \( n \rightarrow p + e^- + \nu_e \), and produces simultaneously different charges, and derive three basic fermions proton p, electron e, and neutrino, which correspond to three elements of strong, electromagnetic, and weak interactions (Chang, 2022b). So far the high energy experiments in the past sixty years have shown that the smallest mass fermions are proton, electron, neutrino and photon, which form the simplest model of particles. These fermions seem to be inseparable truth elements, because further experiments derive particles with bigger mass. They correspond to four interactions, and are also only stable particles. The final simplest theory is based on leptons \( (e^- \nu_e) \) and nucleons \( (p-n) \) or \( (u-d) \) in quark model with SU(2) symmetry and corresponding Yang-Mills field.
Other particles and quark-lepton are their excited states (Chang, 2022b).

For mass we derive Eq.(1). For charge and $\alpha$, the Rosen-Ross mass formula of leptons-meson is derived (Chang, 1989):

$$M = m_e(1 + \frac{n}{2a}).$$

(24)

When $n=3$, $M=206.554m_e = 105.55MeV \approx m(\mu^\pm)(105.66)$; $n=4$, $M=275.072m_e = 140.56MeV \approx m(\pi^\pm)(139.57)$.

According to the superstring model, matter produces, corresponding string produces. Usual string has two moving states: oscillation and rotation, so we proposed corresponding potential and the equation of the emergence string:

$$\frac{d^2\psi}{dr^2} + \left[ -\frac{K(K+1)}{r^2} + 2m(E - U) \right] \psi = 0.$$  

(25)

Its energy spectrum is the GMO mass formula and a modified accurate mass formula (Chang, 1989; 2012; 2018):

$$M = M_0 + AS + B[I(I + 1) - S^2 / 2].$$

(26)

These are some relations between the string and observable experimental data.

For the $J^p=1^+ / 2$ baryon octet, let $M_0 = 910.75$, $A=-222.04$ and $B=38.43MeV$, so

$$m(n) = 939.5725, m(A) = 1115.6, m(\Sigma^0) = 1192.46, m(\Xi^0) = 1314.89MeV.$$  

(27)

Therefore, Eq.(26) agrees completely with the experimental data of the neutral baryons (Tanabashi, et al., 2018).

For the $J^p=0^+$ meson octet, let $A=0$, $M_0 = 549.4$ and $B = -207.22$ MeV, so

$$m(\pi^0) = 134.96, m(K^0) = 497.6, m(\eta) = 549.4 MeV.$$  

(28)

The neutral mesons agree completely within the range of error (Tanabashi, et al., 2018). (27) and (28) are all neutral hadrons, and baryon and meson can be unified by $M=m$. From (24) and (26) we may calculate the basic mass spectrum, which are all composed of first generation of lepton-quark ($u$-$d$ and $e$-$\nu_e$) extended to a part of second generation ($s$ and $\mu$) in particle astrophysics (Perkins, 2003).

Moreover, in 1929 a physicist Ivar Waller of Sweden has proposed that the negative energy is an integral part of quantum theory.

In a word, the negative matter as a candidate of unified dark matter and dark energy is not only the simplest, and is calculable, observable and testable, and may be changed and developed.

References


