Philosophy Study, July 2021, Vol. 11, No. 7, 517-526
doi: 10.17265/2159-5313/2021.07.002

Development of Matter and Testable Negative Matter as Unified Dark Matter and Dark Energy

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Dark matter and dark energy as two basic problems of modern science are very important in philosophy. But, some models of them are not testability in epistemology. Based on Dirac's negative energy, we propose that the negative matter and opposite matter are different. They can form a perfect symmetrical world. The negative matter may be the simplest model of unified dark matter and dark energy. It is the mechanism of inflation as origin of positive-negative matters created from nothing. We calculate an evolutional ratio between total matter and usual matter, and propose a judgment test of the negative matter as dark matter is an opposite repulsive lensing, and other eight possible tests. This is a testable and calculable model.

Keywords: philosophy of science, dark matter, dark energy, negative matter, repulsion, inflation

Introduction

Matter is a very important basic concept in philosophy. It is well-known that some progress is matter and energy unified by $E = mc^2$ in relativity, matter-energy-information composes the most basic material world, and matter developed to anti-matter by Dirac et al. Now dark matter and dark energy are two basic problems in astronomy, cosmology, science and philosophy. Some ancient Greek words ("Fifth Element" and "Quintessence") are used in the study of dark matter and dark energy. Recently, both become hot topics of philosophy, such as dark energy as philosophy of cosmology on 24 May 2018; *Philosophy Talk: Dark Matter and Dark Energy* by Devon Strolovitch on 4 June 2019. Specially, epistemology of the Large Hadron Collider (LHC) and the Lichtenberg Group for History and Philosophy of Physics are organising *Workshop on the Philosophy of Dark Matter* on 29 and 30 March 2021. Speakers are: Simon Allzén and Siska de Baerdemaeker (Stockholm University, Sweden), Antonis Antoniou (University of Bristol, UK), Niels Martens (University of Bonn & RWTH Aachen University, Germany), Helen Meskhidze and William L. Vanderburgh (University of California, USA).

General hypothesis is that dark matter and dark energy are two different concepts. But, so far some models on dark matter and dark energy are not testability in epistemology. Philosophy of science basically follows the logical positivism, mainly causality, logical self-consistency, observability, scalability, repeatable verification and other characteristics. From 2007, we proposed that the negative matter developed the Dirac negative energy may unify dark matter and dark energy, and both are unified due to relativity (Chang, 2007; 2011; 2013; 2014; 2017; 2019; 2020b). This is a testable and calculable. Then some searched the models of negative matter.

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Dark Matter, Dark Energy and Negative Matter

The dark matter in the Galaxy, in group of galaxies and cluster of galaxies, in the universe, is confirmed (Binney & Tremaine, 1987). The dark matter seems to have mass and may become huge conglomeration. The dark matter is possibly the weakly interacting massive particles (WIMP). The simplest kind of dark matter model is to add phenomenally a real scalar field φ as the dark matter field in the standard model (McDonald, 1994; Barger, Langacker, McCaskey, Ramsey-Musolf, & Shaughnessy, 2008). Clowe et al. (2006) discussed directly an empirical proof of the existence of dark matter.

The dark energy as a huge repulsive force is proposed in order to explain the accelerating universe discovered from observes of supernovae (Perlmutter et al., 1998; Riess et al., 1998; Peebles & Bharat, 2003), and may unify many different results of observations. The dark energy seems to be the energy of vacuum, and be zero mass. It distributes uniformly in the whole space, and its interactions are repulsive. Usually assume that the dark energy connects with the cosmological constant Λ (Weinberg 1989), and is a dynamical scalar field (quintessence model). In the parameterization of dark energy, eight basic parameters for density are too much. Scherrer (2004) proposed a new *k*-essence models in which the universe fills a kind of invisible fluid, and can serve as a unified model for dark matter and dark energy. Mortonson, Hu, and Huthree (2010) predicted the testable dark energy from current data. But, the tests of some known theories are very difficult.

For new data, in the universe, usual visible matter is only 4.84%, the dark matter is 25.96%, and the dark energy is 69.2% (Planck Collaboration, 2016; Tanabashi & Particle Data Group, 2018). Recently, Elahi and Khatibi (2019) discussed multi-component dark matter in a non-Abelian dark sector. Kim, Lane, Lee, Lewis, and Sullivan (2020) searched for dark photons with maverick top partners.

In 1928, Dirac predicted anti-particles and the negative energy state from his equation, further, he emphasized: “we cannot ignore the negative energy states” (Dirac, 1930, p. 360). 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 the vacuum of the realistic world has already been filling with all negative energy state; such the Pauli Exclusion Principle will prevent more than one electron going into any one state. It is the Dirac negative energy sea, whose hole is namely an anti-particle (or opposite particle). There is exact description in *The Principles of Quantum Mechanics* (Dirac, 1958). But, it prevents only jumping of fermions, but cannot be applied to bosons. Therefore, the stability problem still exists. In fact, the negative energy state appears in all relativity theories, even also in the classical theory.

We think 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 and lepton number, etc., 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. The negative matter has a negative mass and total energy. The creation of negative matter is difficult, but its existence will be stable.

Based on Dirac’s negative energy state, we proposed the negative matter, whose key is negative mass. According to the gravitational force:

$$F = -\frac{G}{r^2} m_1 m_2 \tag{1}$$

there is still a gravitational force between negative-negative matters, but it is universal repulsive force between the positive and negative matters (Chang, 2007; 2011). Such the positive and negative matters are two regions of topological separation in general case by different interactions, so the negative matter is invisible. This is the simplest candidate of dark matter, and can be unified dark energy due to the repulsive force between the positive and negative matters. It may explain their some phenomena of dark matter and dark energy (Chang 2007; 2011; 2013; 2014; 2017; 2019; 2020b). The negative matter is a necessary development of Dirac theory, and is also a new paradigm of matter (Kuhn, 1962).

For negative mass, Bondi (1957) proposed three kinds of mass: inertial, passive gravitational, and active gravitational mass, and there are four cases. Bondi believes that the positive body will attract the negative one, etc. But, it is wrong. According to the principle of equivalence in general relativity, inertial mass and gravitational mass must always be equal. Based on Eq. (1), there are only three cases of interactions: positive and positive matters, positive and negative matters, negative and negative matters (Chang, 2007; 2011). The well-known Hawking evaporation hypothesis of black hole is based on the simultaneous production of positive and negative particles. The negative matter also is not a mathematical problem. Probably it agrees with the first law proposed by Clarke (1989). Positive energy of gravity just corresponds to that repulsion is negative energy.

Negative Matter as Mechanism of Inflation

Cosmos and its origin are always important problem in philosophy. In cosmology, Guth (1981) first proposed inflation is an important progress, whose time origin is from 10^{-32} s, and cosmic scale factor exponential expansion $a(t) \approx e^{Ht}$. The universe has expanded at least 10^{26} times. Inflation explains the flatness and horizon, etc. problems. But, it has many questions, for example, the inflation origin is near absolute zero temperature, the vacuum energy is almost zero, etc. It must be very high energy. Next Linde (1982; 1983) and Albrecht and Steinhardt (1982) proposed the chaotic inflation. The universe first was inflation, and slowed down 11 billion years ago. Then, it has been accelerated expansion for five billion years. The inflation model is a new result of the combination of modern quantum field theory and cosmology, and it is a big development of very early cosmology. But, so far this has not a reasonable mechanism of inflation, and only introduces phenomenally a scalar field.

We proposed that the mechanism of inflation cosmology due to a huge repulsive force between the positive matter and negative matter created at the same time in quantum fluctuations. This corresponds to the cosmological mode created from nothing to all things from vacuum (Chang, 2007; 2013). At very small scale, it is similar to the strong repulsion field, and produces quantum effect, and the interaction between positive-negative matters is nonlinear, which may obtain chaos, which may form the Linde chaotic inflation, but both differences are different scales and times.

According to this model of the negative matter, inflation should end on a strong interaction scale $R_e = R_i e^N \approx 10^{-13}$ cm, so $N = \ln(R_e/R_i) = 20\ln 10 = 46$. This is only 65% of now hypothesis $N = 70$. For $N = 70 = 30\ln 10$, the scale should extend to origin on 10^{-43} cm or end on 10^{-3} cm.

If the time is the current inflation time, it will be new interactions, such as weaker interactions at smaller scales, which also increase by only two to three orders of magnitude. If the positive and negative matters may continually produce or annihilate for different positions and evolutional times of cosmos and galaxies, it will obtain the very complex relations between the positive and negative masses. This will have continual start of the Big Bang and the creation from nothing. This is not a vacuum, and is a case of complete opposite positive and negative matters. It seems to correspond to the origin of Big-Bang Universe.

We assume that positive matter and negative matter are respectively the same gravitation fields only with different positive or negative mass (Chang, 2007; 2013), and correspond to Riemannian geometry and closed universe. The positive and negative matters are repulsion each other, which is probably Lobachevskian geometry and open universe, and derived cosmic accelerated expansion.

Negative Matter Is the Simplest Model of Unified Dark Matter and Dark Energy

The modern cosmology (Dodelson, 2003; Weinberg, 2008) includes an early inflation cosmology. In a radiation-dominated universe of the big-bang cosmology, the usual total energy is mainly energy of photon M_+c^2. The total energy of positive and negative matters is:

$$M_+c^2 - M_-c^2 \tag{2}$$

Because inflation is origin of nothing, the total energy should be zero, i.e., $M_+ = M_-$.

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

$$M_+c^2 - \frac{GM_+^2}{R_+} \tag{3}$$

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

$$E_t = M_+c^2 - \frac{GM_+^2}{R_+} + (-M_-c^2 - \frac{GM_-^2}{R_-}) + \frac{GM_+M_-}{R_\pm} \tag{4}$$

Both ratio is:

$$\frac{M_+c^2 - \frac{GM_+^2}{R_+} + (-M_-c^2 - \frac{GM_-^2}{R_-}) + \frac{GM_+M_-}{R_\pm}}{M_+c^2 - \frac{GM_+^2}{R_+}} \tag{5}$$

We suppose that for early inflation cosmology the positive matter and the negative matter have the same mass $M_+ = M_- = M$, and in order to simplify assume that positive and negative matters form two identical spheres, respectively, so $R_+ = R_- = R$, $R_\pm = 2R$, Eq. (5) is simplified to:

$$\frac{-\frac{3GM^2}{2R}}{Mc^2 - \frac{GM^2}{R}} = \frac{3}{2}\frac{GM}{GM - Rc^2} \tag{6}$$

It is known that the total mass of Universe is $M = 2 \times 10^{53}$ kg, and corresponding scale is $R = 4.2Gpc = 1.3 \times 10^{26}$ m (Perkins, 2003), so

$$Rc^2 = 1.17\times10^{43} m^3s^{-2}, \text{ and } GM = 1.34\times10^{43} m^3s^{-2} \tag{7}$$

A simple calculation obtains $\frac{3}{2}\frac{GM}{GM - Rc^2} = 11.82$. 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, ratio between usual matter, total matter and dark energy is 4.84:30.8:69.2 (Planck Collaboration, 2016; Tanabashi & Particle Data Group, 2018), so 30.8/4.84 = 6.36, and 69.2/4.84 = 14.3.

It is kwon that the gravitational field equations with the cosmological constant are:

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + \Lambda g_{\mu\nu} = 8\pi k T_{\mu\nu} \quad (8)$$

We proposed the field equations of general relativity on the negative matter (Chang, 2013):

$$G_{\mu\nu} = 8\pi k (T_{\mu\nu} - T'_{\mu\nu}) \quad (9)$$

So, the cosmological constant Λ corresponds to the negative matter, i.e., $\Lambda = 8\pi k T'_{\mu\nu}/g_{\mu\nu}$. Here $\Lambda g_{\mu\nu}$ corresponds to the negative energy state and vacuum energy (Dirac sea), and is consistent with conformal gravity theory (Mannheim, 1992).

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. Then, phantom becomes an important dark energy model. Piao and Zhang (2004) researched phantom inflation and primordial perturbation spectrum. Hong, J. Lee, T. H. Lee, and Oh (2008) considered a higher dimensional gravity theory with a negative kinetic energy phantom field and a cosmological constant. Scherrer and Sen (2008) examined phantom dark energy models produced by a field with a negative kinetic term. Chimento, Forte, Lazkoz, and Richarte (2009) discussed the dark energy density derived from the three-scalar phantom field, and its negative component plays the role of the negative part of a classical Dirac field. González and Guzmán (2009) presented the full nonlinear study of a phantom scalar field accreted into a black hole, which includes that the total energy of the space-time is positive or negative. The total energy is negative, so phantom is namely a type of negative matter.

Dirac (1958) pointed out, the physical laws are symmetrical between the positive and negative charge. Further, the physical laws should also be symmetrical between the positive and negative matters. It forms just the most perfect symmetrical world that four matters on positive, opposite, and negative, negative-opposite particles exist together (Chang, 2017). If the negative matter is verified, a new and complete world will be exhibited (see Figure 1).

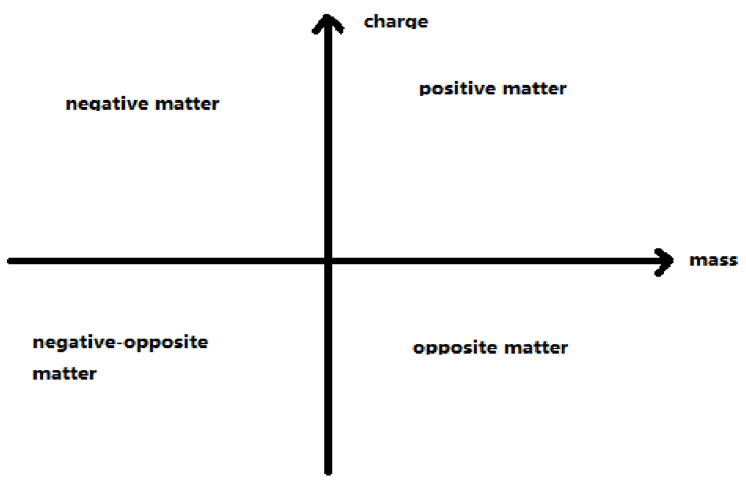

Figure 1. A new most perfect symmetrical world.

Symmetry forms a beautiful world. We researched the symmetrical structure on change of entropy which includes entropy decrease (Chang, 2020a). Cui (2021) searched for a general system theory on the philosophical ontology.

Judgment Test and Other Eight Tests on Negative Matter as Dark Matter

Based on observations of a remarkable cosmic structure called the bullet cluster, Clowe et al. (2006) discovered that this structure is actually two clusters of galaxies passing through one another. Past observations have shown that only a very small percentage of mass in the universe can be explained by regular matter. The new research is the first to detect luminous matter and dark matter independent one another, with the luminous matter clumped together in one region and the dark matter clumped together in another. These observations demonstrate that there are two types of matter: one visible and one invisible. In 2007, COSMOS obtained the first three-dimensional distribution map of dark matter in the world (Massey et al., 2007). In May 2011, Atacama cosmology telescope found the trace of dark energy in the cosmic microwave background (Sherwin et al., 2011), and in which found the weak lens phenomenon (CMB lensing) (Das et al., 2011).

The negative matter is completely symmetry with positive matter, and it as dark matter should agree with the principle of cosmology and is uniform on a large scale. But, it is groups, so it is impossible that the whole universe is full of dark matter. General relativity is very precise in the solar system, in which there cannot have dark energy and dark matter.

Various positive matter and black hole exhibit the gravitational lensing effect. The negative matter will be the repulsive lensing phenomena. Both are different in observations. The celestial body with huge massive matter has the gravitational lensing effect (see Figure 2):

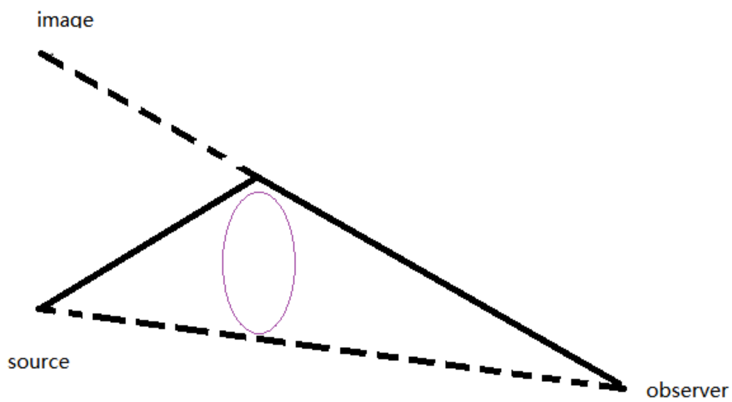

Figure 2. Gravitational lensing.

Since usual light under interaction of negative matter is repulsive deflection, so it will show the repulsive lensing effect. We proposed that a judgment test for the negative matter as dark matter (Chang, 2019) is an opposite repulsive lensing (see Figure 3). Microlensing Observations in Astrophysics team and Optical Gravitational Lensing Experiment team (Chae et al., 2002; Copeland et al., 2006) have searched widely for dark stars and exoplanets by microlensing. Their results should provide possible data.

At present, Giannini (2019) proposed that Chang developed the field equations (Chang, 2007; 2013) describing the repulsive interaction, which is another possibility being explored is the repulsive force of negative mass and its potential relation to dark matter in unified positive and negative mass sources all scales.

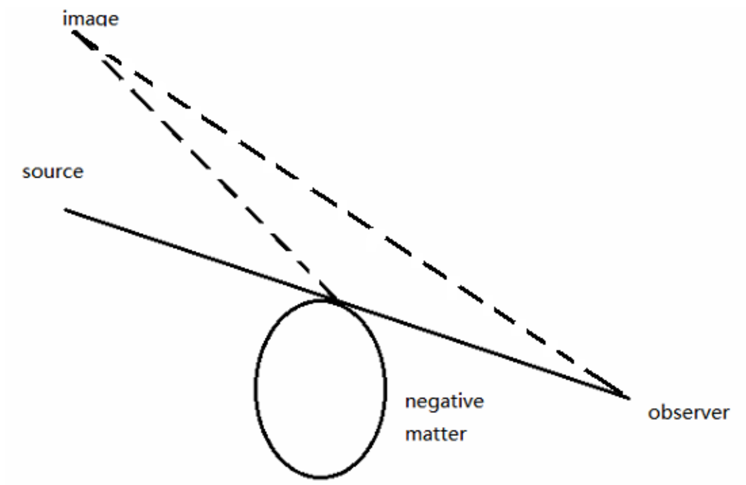

Figure 3. Repulsive lensing.

The numerical simulations of cold dark matter predicted that there are many dark matter halos. Gentile, Famaey, Zhao, and Salucci (2009) discussed universality of galactic surface densities within one dark halo scale-length. These halos around the galaxy are expected to observe many satellite galaxies (Kravtsov, 2010). The actual observation of satellite galaxies is far less than theoretical predictions.

Generally, we proposed other eight possible tests of this hypothesis (Chang, 2020b): (1) In a large scale space, if there is a negative mass cluster in positive matter, some positive matter will be screened, and the other visible matter will be changed by repulsion lensing. As a result, visible matter appears less, and the negative matter and its screened positive matter will appear as invisible dark matter. According to this assumption, the visible celestial phenomena and dark matter will be slightly different because the screened and distorted parts are different for those observations from different positions of the Earth in the solar system. The season effects of this dark matter are observable. (2) There is repulsive force between positive and negative matters, and which obey the square inverse ratio repulsive law according to the Newtonian law. This agrees with the shape of dark matter as the Galactic halo (Gentile et al., 2009; Bernabei et al., 2013). (3) General photons are reflected by the negative matter, which exhibits a type of dark matter. (4) When the move speeds between positive and negative matters are very big, and the kinetic energy is bigger than the potential energy, their colliding result will be a complete annihilation, whose leftover is only a mass-difference of positive and negative matters. These may indicate very high energy phenomena in astronomy. (5) The negative matter may represent the cosmic repulsion and the fast expansion. (6) The positive and negative matters under some exceeding conditions may be created from nothing to all things; at the same time, both are a huge repulsion and rapid expansion, which derives the inflation universe (Chang, 2007; 2013; 2014; 2017; 2020b). (7) It must exist that some repulsion field regions obey Lobachevskian geometry with curvature $R < 0$. (8) The negative matter is similar to invisible black hole, but is repulsive force for matter, and its mass is invariant.

In these tests, the season effect may explain DAMA observed the annual modulation 8.9σ (Bernabei, Belli, Cerulli, & DAMA collaboration, 2000, Barger, Langacker, McCaskey, Ramsey-Musolf, & Shaughnessy, 2008). DAMA/LIBRA (Bernabei et al., 2013) obtains a final model independent result of DAMA/LIBRA-phase. CoGeNT Collaboration observed possible signs of light dark matter particles, and had similar annual modulation (CoGeNT Collaboration, 2010; Aalseth et al., 2011). But, CDMS experiments measured electronic and phonon signals caused by dark matter scattering (Ahmed & CDMS Collaboration, 2009), and XENON100 experiments detected luminous and ionizing signals after dark matter scattering (Aprile, 2011), both were not found in DAMA results. Probably, dark matter does not generate these signals.

As a two-dimensional plane, this corresponds to gravitational and electromagnetic fields determined by mass M and charge Q, respectively. Further, we combine strong interaction ("running" coupling constants $G > 0$) and weak interaction ($G < 0$) with short-range unified through the asymptotic freedom ($G = 0$), then three-dimensional space can uniformly describe the four basic interactions (Chang, 2020c).

The philosophical meaning of dark matter and dark energy is even given a mysterious soul, aura, etc. But both are inseparable from the mass-energy. Even if there is soul-Reiki which is massless or mass at least very small, it is impossible to produce such huge mass-energy.

We proposed the complete theory of negative matter (Chang, 2020b), and its correspondence principle is also a philosophical method. The negative matter as a candidate of unification of dark matter and dark energy is not only the simplest, and may explain inflation and be calculated and tested. It agrees with Occam's razor.

References

Aalseth, C. E., Barbeau, P. S., Colaresi, J., Collar, J. I., Diaz Leon, J., Fast, J. E., … Yocum, K. M. (2011). Search for an annual modulation in a P-type point contact germanium dark matter detector. Retrieved from https://arxiv.org/abs/1106.0650

Ahmed, Z., & CDMS Collaboration. (2009). Results from the final exposure of the CDMS II experiment. Retrieved from https://arxiv.org/abs/0912.3592

Albrecht, A., & Steinhardt, P. J. (1982). Cosmology for grand unified theories with radiatively induced symmetry breaking. *Physical Review Letters, 48*(17), 1220-1223.

Aprile, E., & The XENON100 Collaboration. (2011). Dark matter results from 100 live days of XENON100 data. *Physical Review Letters, 107*(13), 131302.

Barger, V., Langacker, P., McCaskey, M., Ramsey-Musolf, M. J., & Shaughnessy, G. (2008). CERN LHC phenomenology of an extended standard model with a real scalar singlet. *Physical Review, 77*(3), 035005.

Bernabei, R., Belli, P., Cappella, F., Caracciolo, V., Castellano, S., Cerulli, R., … Ye, Z. P. (2013). Final model independent result of DAMA/LIBRA—Phase1. *The European Physical Journal C, 73*(2648), 1-11.

Bernabei, R., Belli, P., Cappella, F., Cerulli, R., Dai, C. J., d'Angelo, A., … Ye, Z. P. (2008). First results from DAMA/LIBRA and the combined results with DAMA/NaI. *The European Physical Journal C, 56*, 333-355.

Bernabei, R., Belli, P., Cerulli, R., & DAMA Collaboration. (2000). Search for WIMP annual modulation signature: Results from DAMA/NaI-3 and DAMA/NaI-4 and the global combined analysis. *Physics Letters, 480*(1-2), 23-31.

Binney, J., & Tremaine, S. (1987). *Galactic dynamics*. Princeton: Princeton University Press.

Bondi, B. (1957). Negative mass in general relativity. *Reviews of Modern Physics, 29*(3), 423-428.

Caldwell, R. R. (2002). A phantom menace? Cosmological consequences of a dark energy component with super-negative equation of state. *Physics Letters B, 545*, 23-29.

Chae, K. H., Biggs, A. D., Blandford, R. D., Browne, I. W. A., De Bruyn, A. G., Fassnacht, C. D., … York, T. (2002). Constraints on cosmological parameters from the analysis of the cosmic lens all sky survey radio-selected gravitational lens statistics. *Physical Review Letters, 89*(15), 151301.

Chang Y. F. (2020a). Development of entropy change in philosophy of science. *Philosophy Study, 10*(9), 517-524.

Chang Y. F. (2020b). Negative matter as unified dark matter and dark energy: Simplest model, theory and nine tests. *International Journal of Fundamental Physical Sciences, 10*(4), 40-54.

Chang, Y. F. (2007). Negative matter, repulsion force, dark matter, phantom and theoretical test—Their relations with inflation cosmos and Higgs mechanism. Retrieved from https://arxiv.org/abs/0705.2908

Chang, Y. F. (2011). Negative matter, dark matter and theoretical test. *International Review of Physics, 5*(6), 340-345.

Chang, Y. F. (2013). Field equations of repulsive force between positive-negative matter, inflation cosmos and many worlds. *International Journal of Modern Theoretical Physics, 2*(2), 100-117.

Chang, Y. F. (2014). Astronomy, black hole and cosmology on negative matter, and qualitative analysis theory. *International Journal of Modern Applied Physics, 4*(2), 69-82.

Chang, Y. F. (2017). Negative matter as unified dark matter and dark energy, and possible tests. *Hadronic Journal, 40*(3), 291-308.

Chang, Y. F. (2019). Negative matter as dark matter, and its judgment test and calculation of ratio. *International Journal of Modern Applied Physics, 9*(1), 1-12.

Chang, Y. F. (2020c). Unification of strong-weak interactions and possible unified scheme of four-interactions. *European Journal of Applied Sciences, 8*(5), 28-45.

Chimento, L. P., Forte, M., Lazkoz, R., & Richarte, M. G. (2009). Internal space structure generalization of the Quintom cosmological scenario. *Physical Review, 79*(4), 043502.

Clarke, A. C. (1989). *Astounding days: A science fictional autobiography.* London: Gollancz.

Clowe, D., Bradac, M., Gonzalez, A. H., Markevitch M., Randall S. W., Jones C., & Zaritsky D. (2006). A direct empirical proof of the existence of dark matter. Retrieved from https://arxiv.org/abs/astro-ph/0608407

CoGeNT Collaboration. (2010). Results from a search for light-mass dark matter with a P-type point contact germanium detector. Retrieved from https://arxiv.org/abs/1002.4703

Copeland, E. J., Sami, M., & Tsujikawa, S. (2006). Dynamics of dark energy. *International Journal of Modern Physics, D15*(11), 1753-1935.

Cui, W. C. (2021). On the philosophical ontology for a general system theory. *Philosophy Study, 11*(6), 443-458.

Das, S. et al. (2011). Detection of the power spectrum of cosmic microwave background lensing by the Atacama cosmology telescope. *Physics Review Letter*. *107*(2), 021301.

Dirac, P. A. M. (1930). The theory of electrons and protons. *Proceedings of the Royal Society of London Series A, 126*(801), 365-369.

Dirac, P. A. M. (1958). *The principles of quantum mechanics*. Oxford: Clarendon Press.

Dodelson, S. (2003). *Modern cosmology*. Amsterdam, Netherlands: Academic Press.

Elahi, F., & Khatibi, S. (2019). Multi-component dark matter in a non-Abelian dark sector. *Physical Review D, 100*(1), 015019.

Gentile, G., Famaey, B., Zhao, H., & Salucci, P. (2009). Universality of galactic surface densities within one dark halo scale-length. *Nature, 461*(7264), 627-628.

Gerhard, O. E., & Silk, S. (1996). Baryonic dark halos: A cold gas component? *The Astrophysical Journal, 472*(1), 34-45.

Giannini, J. (2019). Feasibility of constructing a unified positive and negative mass potential. *International Journal of Modern Theoretical Physics, 8*(1), 1-16.

González, J. A., & Guzmán, F. S. (2009). Accretion of phantom scalar field into a black hole. *Physical Review D, 79*(12), 121501.

Guth, A. G. (1981). The inflationary universe: A possible solution to the horizon and flatness problems. *Physical Review D, 23*(2), 347-356.

Hong, S. T., Lee, J., Lee, T. H., & Oh, P. (2008). Higher dimensional cosmological model with a phantom field. *Physical Review D, 78*(4), 047503.

Kim, J. H., Lane, S. D., Lee, H. S., Lewis, I. M., & Sullivan, M. (2020). Searching for dark photons with maverick top partners. *Physical Review D, 101*(3), 035041.

Kravtsov, A. (2010). Dark matter substructure and dwarf galactic satellites. Retrieved from https://arxiv.org/abs/0906.3295

Kuhn, T. S. (1962). *The structure of scientific revolution.* Chicago: University of Chicago Press.

Linde, A. D. (1982). A new inflationary universe scenario: A possible solution of the horizon, flatness, homogeneity, isotropy and primordial monopole problems. *Physics Letters B, 108*(6), 389-393.

Linde, A. D. (1983). Chaotic inflation. *Physics Letters B, 129*(3-4), 177-181.

Linde, A. D. (1994). Hybrid inflation. *Physical Review D, 49*(2), 748-754.

Lucchin, F., & Matarrese, S. (1985). Power law inflation. *Physical Review D, 32*(6), 1316.

Mannheim, P. D. (1992). Conformal gravity and the flatness problem. *Astrophysical Journal, 391*, 429-435.

Massey, R. et al. (2007). Dark matter maps reveal cosmic scaffolding. *Nature*. *445*(7125), 286-290.

McDonald, J. (1994). Gauge singlet scalars as cold dark matter. *Physical Review D, 50*, 3637-3649.

Mortonson, M. J., Hu, W., & Huthree, D. (2010). Testable dark energy predictions from current data. *Physical Review D, 81*(6), 063007.

Peebles, P. J. E., & Bharat, R. (2003). The cosmological constant and dark energy. *Reviews of Modern Physics, 75*(2), 559-606.

Perkins, D. (2003). *Particle astrophysics* (2nd ed.). Oxford: Oxford University Press.

Perlmutter, S., Aldering, G., Valle, M. D. et al. (1998). Discovery of a supernovae explosion at half the age of the Universe. *Nature, 391*, 51-54.

Piao, Y., & Zhang, Y. (2004). Phantom inflation and primordial perturbation spectrum. *Physical Review D, 70*(6), 063513.

Planck Collaboration. (2016). Planck 2015 results. *Astron & Astrophys, 594*, A1-A13.

Riess, A. G., Filippenko, A. V., Challis, P., Clocchiatti, A., Diercks, A., Garnavich, P. M., … Tonry, J. (1998). Observational evidence from supernovae for an accelerating universe and a cosmological constant. *Astronomical Journal*, *116*(3), 1009-1038.

Scherrer, R. J. (2004). Purely kinetic k essence as unified dark matter. *Physical Review Letters, 93*(1), 011301.

Scherrer, R. J., & Sen, A. A. (2008). Phantom dark energy models with a nearly flat potential. *Physical Review D, 78*(6), 067303.

Sherwin, B. et al. (2011). Evidence for dark energy from the cosmic microwave background along using the Atacama cosmology telescope lensing measurements. *Physics Review Letter. 107*(2), 021302.

Tanabashi, M., & Particle Data Group. (2018). Particle data group. *Physical Review D, 98*(3), 030001.

Weinberg, S. (1989). The cosmological constant problem. *Reviews of Modern Physics, 61*(1), 1-23.

Weinberg, S. (2008). *Cosmology*. Oxford: Oxford University Press.