Cosmology in 4-D Complex Space

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Abstract

Without relying on the cosmological principle, which has been the foundation of all the progress in physical cosmology such as the interpretation of Hubble's law, Friedman-Roberson-Walker (FRW) metric in general theory of relativity, the expanding of the universe in the Big Bang theory, etc., but still disputable for its validity as a principle in physical science, we can find comprehensive explanations in 4-D complex space for many unsolved problems such as the variation of fine-structure constant on cosmological scale, dark matter (hypothetical matter) in astrophysics, dark energy (hypothetical energy) in physical cosmology, and so on. With introducing new galactic dynamo process, the cosmological magnetic fields, which has been one of unsolved problems in astrophysics, is explained. For physical cosmology in 4-D complex space, new theory is introduced.

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Introduction

The 4-D complex space was introduced to get comprehensive explanations for fundamental questions in quantum physics and special theory of relativity, such as why light has the wave-particle duality, what the photon is, why the speed of light is constant in inertial frame of reference, what the length contraction is, what the time dilation is, etc. (Kim 1997).

For example, the particle-like property of light is shown in photoelectric effect; when a metal plate is irradiated with frequencies above a threshold frequency, electrons are released from the metal surface, in which the average kinetic energy of electrons is independent of the intensity of the light source but linearly proportional to the frequency of the light, and it is explained with introducing a constant h, which is known as Plank's constant ($h = 6.6260715\times10^{-34}\,\mathrm{J\cdot s}$), to express as $E_\gamma = h\nu$, in which ν is the frequency of the incident light, and $T_e = E_\gamma - W$, in which T_e is the kinetic energy of electron released from the metal surface; W, a work function expressed as $W = h\nu_o$ with a threshold frequency ν_o varying from metal to metal (Gasiorowicz 1974).

In the 4-D Complex Space, the Plank's constant (h) was interpreted as $h = p_\lambda \cdot \lambda$ that is the momentum being carried in one wave length times the wave length, which means one photon energy ($E_\gamma = p_\lambda c$) is corresponded to the energy in one wave length of travelling light (electromagnetic wave) with velocity of c ($c = 3\times10^8\,\mathrm{m}/s$) in free space, and in the model of light, which is a bunch of vacuum-particle-string vibrations in imaginary subspace of 4-D complex space, it is expressed as

$$h = 2\pi^2 m_e c\left(\frac{A^2}{d}\right), \tag{1}$$

in which A is the amplitude of the string vibration and d is the distance between adjacent vacuum particles in the string; the speed of light c is defined as $c = \sqrt{\frac{S}{\rho}}$ with the tension S and the mass density ρ in the string vibration $\left(\rho d = m_e\right)$; if the tension S is directly proportional to the density ρ, the light speed c can be supposed to be an invariant physical constant in inertial frame of references. As long as no energy loss is supposed in the propagation of light through the vacuum-particle-string vibrations with the speed of light c, the $m_e\left(\frac{A^2}{d}\right)$ in Eqn. (1) should be invariant; hence, Plank's constant h is supposed to be an invariant physical constant as well as the light speed c.

We can review the photoelectric effect with the model of light, vacuum-particle-string vibration in 4-D complex space, the light interaction with an electron being bounded in the metal plate occurs when one vacuum-particle-string wave is passing through the bounded electron for the time interval of $\Delta t \sim \frac{\lambda}{c} = \frac{1}{\nu}$. The selectivity of one vacuum-particle-string wave and the finite time window for the photoelectric interaction show the particle-like property of light.

As we know the saying that a picture is worth a thousand words, let's think of a picture as shown in Fig. (1), which can be compared with the similarity of photoelectric effect, as following: In a battle game, one strong soldier of group M is blocking the path of a gorge against the attacking from group P trying to pass through the gorge. Since the gorge path is so narrow that the soldiers in group P may have to pass through the gorge path in a line and the first soldier in the line have to fight alone with the group M soldier blocking the path, they need strong soldiers, at least one who is stronger than the group M soldier blocking the gorge path. Here, the narrow gorge path describes the microscopic interaction of light with a bounded electron in the metal plate, and correspondingly, the strong solder fighting alone with the one blocking the gorge path describes the threshold energy of photon ($E_\gamma \geq E_o = h\nu_o$).

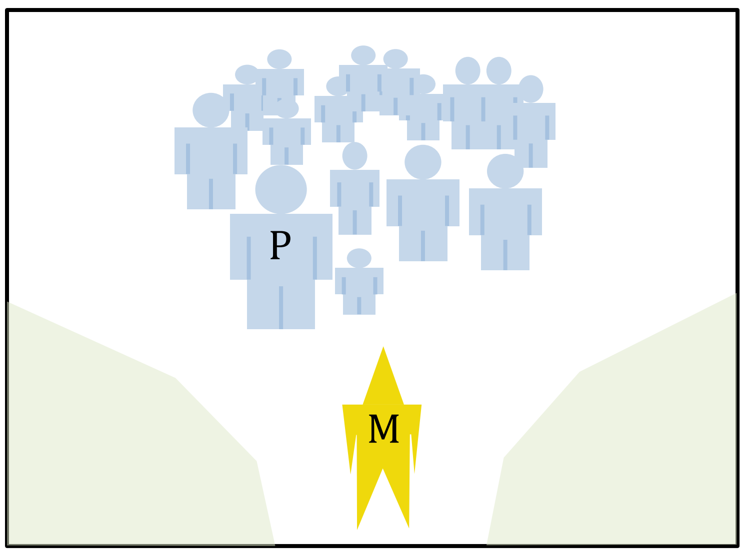

Fig. 1: photons (P) and the bounded electron (M) in photoelectric interaction

Let's review the vacuum particle distribution and physical interactions in 4-D complex space. The vacuum particles are bounded with a negative energy $\left(E_b \approx -m_e c^2\right)$ in 3-D imaginary subspace and participate in physical interactions such as gravitational interaction and electromagnetic interaction with the first principle given in 4-D complex space; vacuum particles are rearranged spontaneously for any disturbance to get the equilibrium in net mass density and net charge density, and the spins of vacuum particles are realigned spontaneously to restore any dynamic motion of electric charges and/or physical mass in phenomena (Kim 2008).

Now, we need to consider what if the distance d in Eqn. (1), which is the distance between vacuum particles, can be changed in free space or inertial frame of reference in physics? If the distance d is changed due to whatever reason, it is natural that the strength of physical interactions, electromagnetic interaction and gravitational interaction, should be changed since the physical interactions are supposed to be based on the first principle given in 4-D complex space. Correspondingly, some physical constants or parameters in physical laws can be adjusted, too. In addition, the energy scale in physical vacuum space should be changed because the vacuum particles are supposed to be bounded in the imaginary subspace in 4-D complex space, which means that the mass of vacuum particles is changed; nevertheless, the electric charge of vacuum particles is invariant. Here, we need to discuss more about the mass, which is the energy scale in space.

In special relativity, the relativistic effects such as time dilation and length contraction appear with γ factor expressed as $\gamma(\upsilon)=\frac{1}{\sqrt{1-\left(\frac{\upsilon}{c}\right)^2}}$ between two inertial frames of reference moving with a relative velocity υ to each other; the γ factor is used to explain the relativistic Doppler effect and the mass-energy relation as $E=mc^2$ in which the mass m is rest mass m_o times relativistic effect γ as $m=m_o\gamma$. In a nuclear physics, the mass defect after a nuclear fission process is corresponded to the energy released from the fission, which was in a form of mass inside a nucleus in the fission process. In special relativity, the mass is just one of energy forms.

However, the relativistic effects also appear in the theory of general relativity, for example, in gravitational redshift and in Schwarzschild metric (Schutz 1990) under the gravitational field in which a gravitational potential is given as $\Phi=-\frac{GM}{r}$; thus, the metric is expressed as $ds^2=-c^2d\tau^2=-\left(1+\frac{2\Phi}{c^2}\right)c^2dt^2+\left(1+\frac{2\Phi}{c^2}\right)^{-1}dr^2+r^2d\Omega^2$, if time interval dt or length segment in radial direction dr is compared with in the inertial frame of reference $\left(r\to\infty,\ \Phi=0\right)$ with $d\Omega=0$.

In conjunction with the first principle in 4-D complex space, the relativistic effect in special relativity is the same as in general relativity in the respect of space geometry of vacuum particles; the distance d between vacuum particles is closely related to the strength of physical interactions such as, at least, electromagnetic interaction and gravitational interaction; thus, the change of d should be related to the energy scale in space. In short, if the distance d is changed, of course in average in space, the energy scale in space as well as the strength of physical interactions is supposed to be different from what we have known on the earth, which means the bounding energy of vacuum particles in 4-D complex space is also changed.

A physical constant, such as $h,\ c,\ G,\ \varepsilon_o,\ \mu_o,\ \alpha,$ etc., is not a fixed numerical value but determined through numerous measurements with uncertainties at different locations and times; hence, the physical constant (in a limit of measurement uncertainty) should be same everywhere all the time as expected for physical laws – universality of physical laws. However, if a physical constant has been changed in time or is different at a remote area in space, which means that a physical law including the physical constant is not universal any more, it should be asked why and how it is different from what we have known. In fact, since more than half a century ago the variation of physical constant such as the fine structure constant α has been mentioned and reported in astrophysics (Versfeld 2013, SCI NEWS 2020).

In 1930s, astronomers found that the mass discrepancy in clusters of galaxies and the flatness in the rotation curve of a typical spiral galaxy couldn't be explained with the conventional gravitational law. It has been a big question in astrophysics and still not answered clearly despite that several explanations have been suggested with introducing a hypothetical invisible mass -- dark matter (Metcalfe 2021, Jaco de Swart 2017) or modifying the theory of general relativity or Newtonian gravity, MOND (Milgrom 1983), etc.

According to the interpretation of gravitational and electromagnetic interactions in 4-D complex space (Kim 2008, 2017), anyhow, the idea of dark matter cannot be possible because the dark matter is supposed to participate only in gravitational interaction not in electromagnetic interaction, and the MOND (Modifying Newtonian dynamics) is also not acceptable because there is no reason to modify the strength of gravitational interaction and the gravitational interaction only. Without introducing the hypothetical mass, we can find a comprehensive explanation in the 4-D complex space defined for physical space.

In addition, the black hole (Shapiro and Teukolsky 1983) with the so-called space-time singularity, which means that the black hole has infinity mass density at the singularity and it is an empty space as its name implies, is not possible in 4-D complex space because vacuum particles interacting in gravitational interaction cannot be packed into one specific point in the space due to the finite size of vacuum particles and the distance d between vacuum particles.

Fine Structure Constant α

In quantum physics, the photoelectric effect represents the interaction of electrons in metal plate with photons, which means that each bounded electron in the metal plate interacts with a photon; on the other hand, the fine structure constant α, which is the dimensionless physical constant represented as $\alpha = \frac{e^2}{4\pi\varepsilon_o} \cdot \frac{1}{\hbar c} \approx \frac{1}{137}$, in which e is the electron's charge; ε_o, the permittivity of free space; $\hbar = \frac{h}{2\pi}$, is the strength measure of electromagnetic interaction, for example, in hydrogen atom the electromagnetic interaction of the bounded electron with a photon ($E_\gamma = h\nu$). In spite of the dimensionless, interestingly, it has been reported that the fine structure constant α is varying in time, at spatial location, and with energy scale (Wiki-fine-structure-constant), which means that the strength of electromagnetic interaction can be changed depending on environmental conditions (John K. Webb 1999, 2011, A. Hees 2020).

As mentioned in Introduction, in 4-D complex space, the strength of electromagnetic interaction can be varied on the distance d of vacuum particles filled in imaginary space; thus, it might be thought that the variation of fine structure constant should be caused by the permittivity of free space ε_o because the other physical constants such as the charge of electron, Plank's constant, and the speed of light in the fine structure constant are supposed to be invariant; however, the cause can be found in other physical constants too since the energy scale in space can be changed. As long as we believe in, actually we want to believe, that the physical laws are invariant always anywhere, the variation of the fine structure constant is supposed to be caused by the change of energy scale in space.

All in all, we can suppose that the physical vacuum in 4-D complex space can be different in galaxies those of which are remote far away from others in the universe, which makes the fine structure constant varying. In other words, the distance d between vacuum particles in imaginary space can be different, which means that the binding energy of the vacuum particles in the imaginary space is different. Hence, in a far away galaxy the binding energy of vacuum particles can be expressed as

$$E_b = E_{be} + \Phi_{sp} \tag{2}$$

in which the $E_{be} \approx -m_e c^2$ on the earth, the Φ_{sp} is a space potential function representing the intrinsic property of space depending on the distance d of vacuum particles, in which the distance d should be related to the energy distribution in real space[2]. Then, as we can expect, the space potential function $\Phi_{sp} = 0$ on the earth, and the E_b in Eqn. (2) can be different from E_{be} on the earth as long as $E_b \leq 0$. For the space with $E_b = 0$, we can expect 'Nothingness' in phenomenological world and only electric charges in physical vacuum with zero binding energy, which is, let's say, the grand equilibrium state in 4-D complex space. To understand the energy scale in space, the mass in space can be expressed as

$$\xi_{sp} \equiv \frac{m_{sp}}{m_E} = 1 - \frac{\Phi_{sp}}{m_E^{rest}} \tag{3}$$

in which ξ_{sp} is the energy scale factor in space; m_{sp}, mass in space; m_E, mass on the earth; m_E^{rest}, the rest mass of m_E; and Φ_{sp}, space potential function. Fig. (2) shows a schematic drawing representing the binding energy distributions of vacuum particles in a galaxy and intergalactic space connected to the galaxy; E_b is the average binding energy of vacuum particles in the galaxy,

[2] mass energy and all other kinds, such as electric energy, magnetic energy, etc.

and the vacuum particles participate in physical interactions in phenomena; the blue ball is representing physical objects in real space.

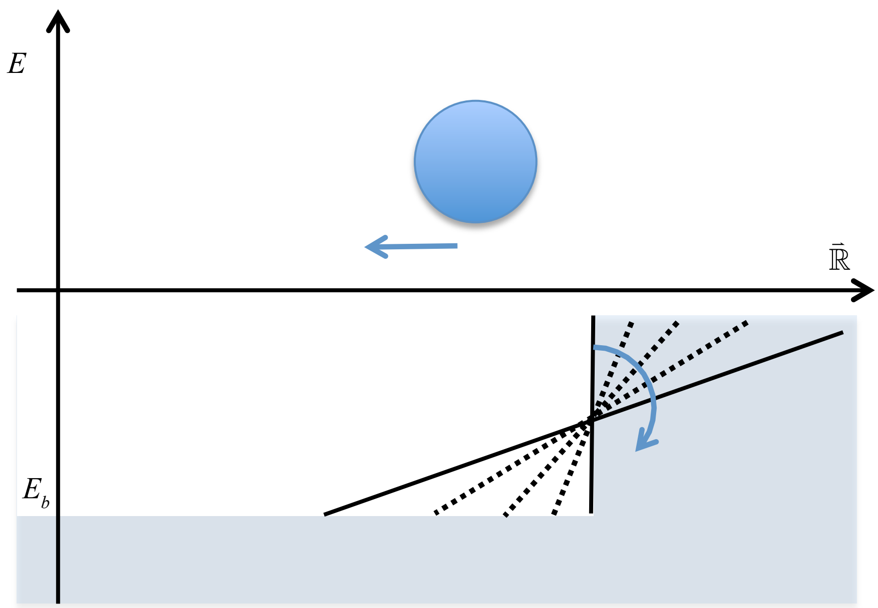

Fig. 2: biding energy distribution of vacuum particles in a galaxy

In the consideration of the first principle in 4-D complex space, the binding energy distribution at the edge of the galaxy in Fig. (2) is supposed to be varying with time while the physical objects in the galaxy are being pushed back, which means that the galaxy itself is moving away from the intergalactic space, and which suggests, one step further, that all the distant galaxies in the universe are moving away from others, in general.

Hubble's Law

Hubble's law (Hubble 1929, Hubble and Tolman 1935) is the empirical relation between the distance of galaxies and their apparent receding velocity from us, which is expressed as $\upsilon = \mathrm{H}_0 \cdot d$, where υ is the velocity of galaxy in km/s; H_0, Hubble constant in km/s/Mpc (Garner 2019, Sutter 2021); d, the distance of the galaxy in Mpc. With the cosmological principle, isotropy and homogeneity, those of which are assumed to be valid in space at a sufficiently large scale and accepted in general, the Hubble's law has been interpreted as the universe is expanding and the speed of the expanding is being accelerated (Morrow 2017).

First of all, without applying the cosmological principle, we can interpret the Hubble's law naively with the Doppler effect appeared between two objects moving to each other; if a galaxy is moving away from us and we see the light signal coming from the galaxy, the light signal is supposed to be emitted in the past, which means that the receding velocity υ in the Hubble's law is the information at $t=-\frac{d}{c}$ in the past[3]; thus, the receding velocities of galaxies we measure are getting slow down with time, which is a deceleration contrastingly not the acceleration in the standard theory of cosmology (Peebles). However, if the receding velocities can be explained with the Doppler effect from peculiar motions of the galaxies, the receding speed can be greater than the speed of light according to the Hubble's law, which is impossible in special theory of relativity. Anyhow, we can be sure, at least, the galaxies we can observe on the earth are receding from us.

If the expanding of the universe is accelerating in reality (Perlmutter 2003), we need to know how it is possible in the standard model of cosmology. Now, let's review the cosmological principle, saying that at a large scale the space is the same everywhere and no directional difference. The homogeneity and isotropy in the cosmological principle means that the physical system in cosmology is invariant under the translational and rotational transformations, which is so ideal that may not be realistic although it is very convenient for people studying cosmology on the desk; hence, which would be rather a human's dogmatic attitude toward nature. Only possible condition of the universe for the homogeneity and isotropy in the cosmological principle should be an edgeless or infinite space without any directional event at such large scale (Caldwell 2008, Corless 2019, Nathan Secrest 2021). Nevertheless, in the standard cosmological model, it has been believed valid, at least, in an approximation.

According to the cosmological principle the Hubble's law is applicable with expecting the same result at any location in space because there is no preferred location and no preferred direction in space at a sufficiently large scale. To explain the generalization of Hubble's law in the universe, Friedman-Roberson-Walker (FRW) metric has been introduced as

$$ds^2 = c\ dt^2 + a(t)\left(\frac{dr^2}{1-kr^2} + r^2 d\Omega^2\right), \text{ in which } d\Omega^2 = d\theta^2 + \sin^2\theta\ d\phi^2 \text{ (Rowan-Robinson 1996).}$$

In fact, it was just phenomenological adaptation for the cosmological principle because any corresponding physical reality for the scale factor $a(t)$ in the FRW metric was not explained. To explain the scale factor people used to make an analogy of a muffin-like universe, but the space is not like a muffin batter being baked in the oven or a rubber band to be stretched.

There is even more controversial concept in physical cosmology than the expanding space in the FRW metric. The Big Bang theory says that the space and time has been created from nothing but energy. However, if energy can create space, the space should be dependent on the energy, and by the same token the space should be annihilated if the energy is disappeared from the space. Then, the space creation and space annihilation can be happened anytime anywhere locally in space; then, we should have observed the effect of space creation or space annihilation as well as the global expanding of the universe.

Although there should have been the philosophical discussion of whether the space and time is

[3] if $d \sim \text{Mpc}$, $t \sim -6.5\times10^5\text{ly}$ ago.

dependent of physical phenomena or not, the space and time itself is independent of physical phenomena in 4-D complex space. Then, we need to know how it is possible if the space is expanding uniformly and being accelerated. In other words, it need to be explained what the scale factor in the FRW metric is.

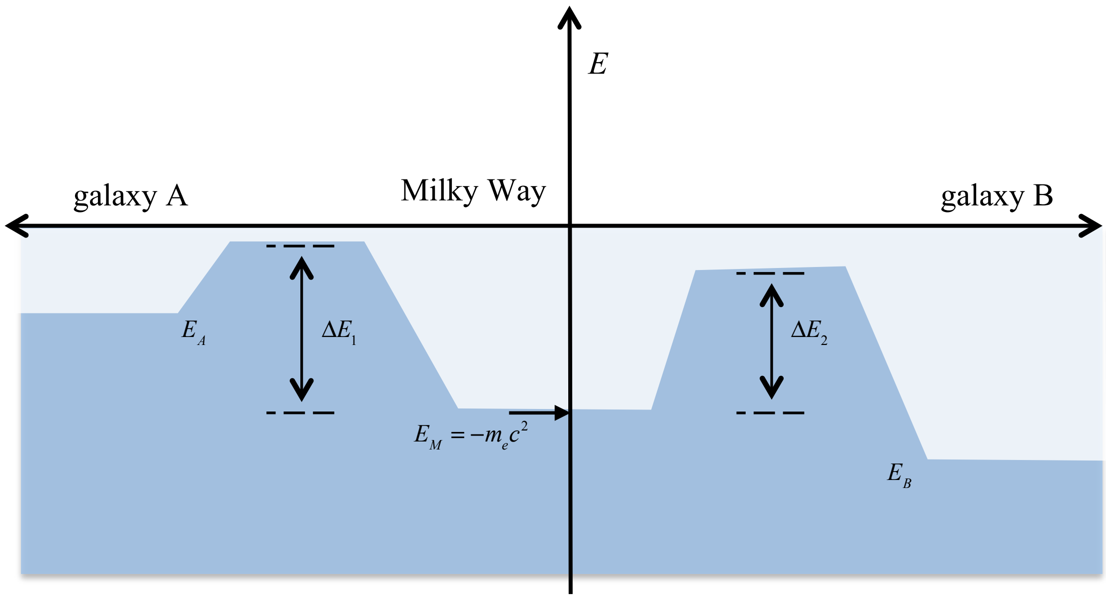

Fig. 3: the binding energy of vacuum particles in far distant galaxies

If the distance d between adjacent vacuum particles is not a constant but different in far away galaxies[4] from our Milky Way galaxy, as mentioned in Introduction, the strength of physical interactions should be changed, and the energy scale (e.g. electron mass) is changed as shown in Fig. (3) since the binding energy of vacuum particles also depends on the distance d. In the schematic drawing in Fig. (3), the galaxy A, Milky Way galaxy, and galaxy B are moving away from others as shown in Fig. (2); the binding energy differences ΔE_1 and ΔE_2 in intergalactic spaces will be reduced with time. Meanwhile, the strength of physical interactions in galaxy A is smaller than in Milky Way galaxy; the strength of physical interactions in Milky Way galaxy, smaller than in galaxy B.

However, the redshift of receding (mutual moving away among the galaxies) is different from the conventional Doppler effect that is about the relative motion between two physical objects; rather, it can be similar to the gravitational redshift because the redshift is coming from the distance d changing of vacuum particles at the edge of galaxy as in the distance d variation of vacuum particles in gravitational field. Therefore, the redshift in the Hubble's law is not from the apparent receding velocity although the peculiar motions are also accompanied; in fact, galaxies are not receding as such apparent velocity estimated from the redshift, so-called cosmological redshift,

[4] It takes 2.5×10^4 light year to get the nearest galaxy.

and the scale factor $a(t)$ in FRW metric is not describing physical reality (Kitching 2018).

In Fig. (3), although galaxy A and galaxy B both are receding from us in Milky Way galaxy, the light signal from galaxy A is blueshifted because the distance d of vacuum particles in galaxy A is supposed to be bigger than in Milky Way galaxy, which means, $E_A > E_M \Rightarrow d_A > d_M$. In fact, it has been known that light signals from some galaxies are blueshifted, such as Andromeda galaxy and M90, M86, and M98 in Virgo Cluster.

In addition, there are a couple of points interesting about the ΔE_1 and ΔE_2 in the intergalactic spaces in Fig. (3) and for the vacuum-particle-string vibration at the edge of galaxies during the process of pushing away among galaxies. Firstly, ΔE, which is the binding energy difference in intergalactic space, represents the physical reality that can explain for the cosmological constant Λ in the Einstein's static universe (Wiki-Einstein-static-universe, Silk 1989) and for the dark energy in the standard cosmology. The second, the vacuum-particle-string vibration might be the source of the CMBR (Sciama 1993) or the background radiation in space in general because an electromagnetic radiation should be accompanied with the vacuum energy fluctuation.

Galactic Rotation Anomaly - Dark matter?

For almost a century the dark matter (Bertone and Hooper 2018, Nasa Science 2021) has been one of most important topics in astrophysics and cosmology. Fig. (4)[5] shows the galactic rotation anomaly: in a typical spiral galaxy, the relation of rotation velocity vs. distance is predicted as in graph (A) but observed as in graph (B), which cannot be explained with physical laws in convention such as Newton's law of gravitation or general theory of relativity.

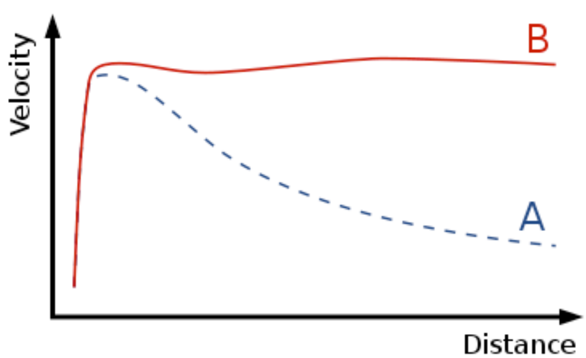

Fig. 4

If the mass density in the typical spiral galaxy is given as $\rho \propto \frac{1}{r^2}$ even in far remote from the galactic core, the flatness in the observed rotational velocity in graph (B) can be explained with the conventional law of gravitation as $\upsilon = \sqrt{\frac{GM(r)}{r}}$ in which $M(r) \propto r$. Hence, the hypothetical mass became to be introduced with the name 'dark matter' because it is not visible matter. However, it has been searched fruitlessly. Also, there have been many alternative explanations instead of the dark matter, but none of them seems to have been successful.

[5] Wikipedia

To find a comprehensive explanation for the galactic rotation anomaly, we need to consider the binding energy distribution of vacuum particles $E_b(r)$ in a spiral galaxy because the slope of binding energy distribution generates the physical force as shown in Fig. (2). Therefore, the space potential function $\Phi_{sp}(r)$ in Eqn. (2) should be added in the gravitational potential energy.

The schematic drawing for the binding energy distribution in a spiral galaxy arms is shown in Fig. (5). In which the binding energy distribution should be related with the energy distribution in real space, and the hump-shaped pattern in the binding energy distribution between two adjacent spiral arms are lessened, which is shown with the blue dash line in Fig. (5), due to the electric charge distributions induced: negative charges are induced inner sides of spiral arms facing to the galactic center and positive charges are located at the other sides of spiral arms alternatively.

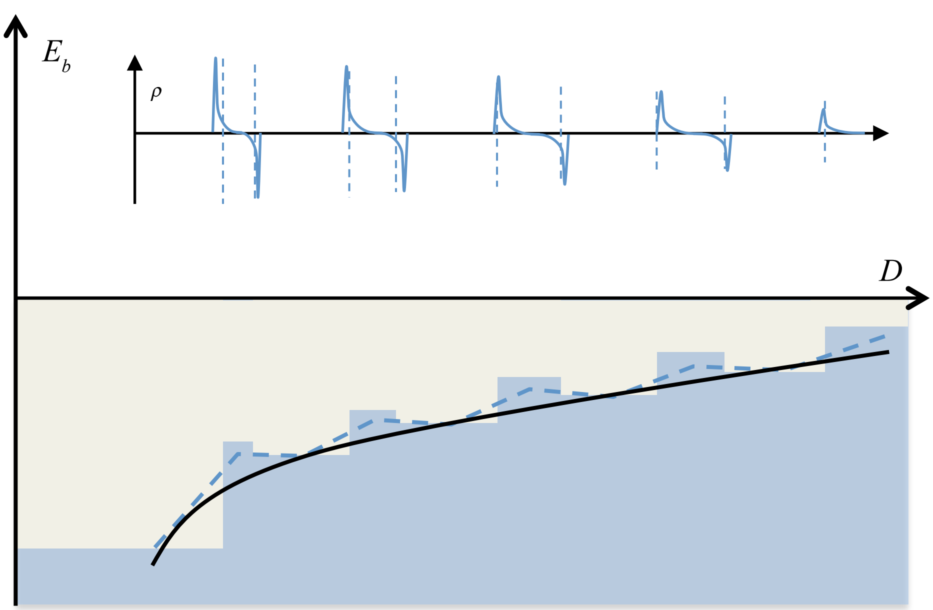

Fig. 5: binding energies in a spiral galaxy arms

To make it simple, let's say, a circular motion in the galactic plane under the gravitational field of mass M at the center of the galaxy. Then, the rotational velocity at radius r is expressed as

$$\frac{\mathrm{G}M}{r^2} + \frac{d}{dr}\Phi_{sp}(r) = \frac{\upsilon^2}{r}, \tag{4}$$

in which r is the distance from the center of the galaxy. If the space potential function $\Phi_{sp}(r)$ is given as $\Phi_{sp}(r) = A\ln(r) - B$ with positive constants A and B for the $E_b(r)$ as shown with the solid black line in Fig. (5), the rotating velocity $\upsilon = \sqrt{\frac{GM}{r} + A}$ from Eqn. (4); thus, $\upsilon \sim \sqrt{A}$ for $r >> 0$.

Galactic dynamo process

Magnetic fields can be present anywhere as long as the sources for the magnetic fields persist. However, on cosmological scale - e.g., in galaxies and galaxy clusters the existence of magnetic fields has been a puzzle in astrophysics with the questions of what the source of the magnetic fields is and where it is.

In 4-D complex space, the mass in physics interacts with electric charges (mass-charge interaction) and the primitive virtual negative charge is assigned for the mass as $Q_v \sim 10^{-19} M$ in MKSA units through the comparison of the interaction strengths in electromagnetic interaction and gravitational interaction on the earth (Kim 2008). Therefore, for a mass object in space, positive charges are attractive and negative charges are repulsive, which makes the electric charge separation in the space surrounding the mass object. In addition, if the mass object is huge on such large scale, the physical movement of mass object itself can generate a significant PVN current, which can generate the magnetic fields in space, too, which can explain the connection of gravity and magnetic field for the discovery of a helical magnetic field around the Orion molecular cloud (Sanders 2006).

For the galactic dynamo process that creates the cosmological scale magnetic fields, a possible mechanism is suggested as following: to see the crucial process in the dynamo process, let's make it simple, only mechanical interactions, such as gravitational interaction, mass-charge interaction, and electromagnetic process, are considered with the perfect conductivity[6] for the gas and dust in plasma state; however, for the complete description of galactic dynamo process in the MagnetoHydroDynamics (MHD) the mass-charge interaction should be included as the source of electric fields.

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[6] magnetic Reynolds number $R_m \to \infty$

Now, let's start with a core object such as a supernova remnant[7] ($M > 3M_{\odot}$) rotating with angular velocity ω and interstellar gas and dust being collapsed into the core with differential rotations. Since positive charges are attractive toward the core and negative charges are being pushed outward, to make an electric equilibrium with the core object, a positive charge distribution is made on the surface of the core; however, negative charges, mainly electrons, are being pushed out and almost free from the core object. Now, the magnetic field is generated by the charge distributions of the positive charges on the surface of the core object and PVN charges of the core object itself; however, the PVN charge effect can be ignored in the magnetic field generation. For the core object, the process of charge separation continues and the magnetic field grows until the electrostatic force generated from the positive charge accumulation cancel out the Lorentz force as $\vec{E}_s + \vec{\upsilon} \times \vec{B} = 0$ where $\vec{\upsilon} = \vec{\omega} \times \vec{r}$.

In astrophysics, some people have considered the so-called Biermann battery (Zweibel 2013) for a seed magnetic field generation in galactic dynamo process and searched possible mechanisms for the Biermann battery effect in space. However, we can say, the mass itself of the core object produces the Biermann battery effect.

As long as the mass accretion continues in the rotating core object, more positive charges attract to the core; the magnetic field increases until the positive charge accumulation makes a dynamic equilibrium with the Lorentz force and some stationary negative charges (electrons) should be located outside due to the excess electric field made by the Lorentz force; for the rotating core object, an oblate positive charge distribution forms on the surface of the core, and for the interstellar gas and dust being collapsed an accretion disk develops along the equatorial plane that is perpendicular to the rotating axis.

The more mass the core is getting, the more charges are accumulated: positive charges on the core object and negative charges outside, and then the more magnetic field increases. The accretion disk is extended, and the collapsed interstellar medium starts being cooled down. A donut shaped ring forms surrounding the core and rotates making the balance with the gravity of the core object. The space between the core and the donut shaped ring gets empty due to the mass accretion into the core; the negative charge distribution is located inside the ring now and contributes to generate the magnetic field in the space between the core and the ring. It is like two magnetic dipoles in which one is embedded in the other as shown in Fig. (6) in which the positive charge distribution on the core object is shown with the red color; the negative charge distribution, the blue color.

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[7] It has been known that black holes exist at the center of almost all galaxies, and it is the initial conditions for the formation of black hole.

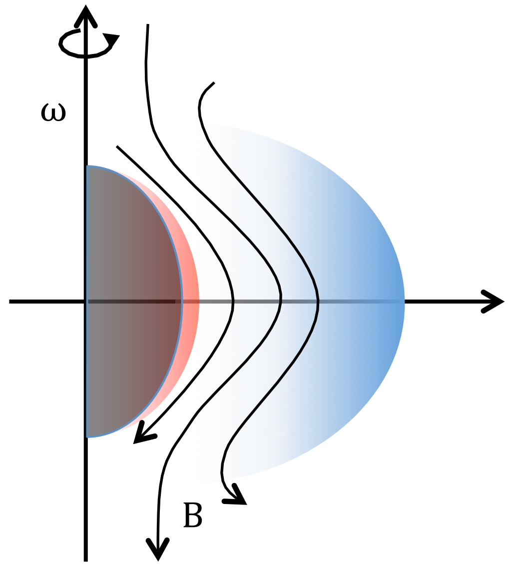

Fig. 6: galactic dynamo with two magnetic dipoles

If the core object turns to be a black hole, the positive charge distribution should be located outside the event horizon of the black hole due to the positive electric potential in the distribution. Through the mass accretion if the black hole mass increases, more positive charges nearby the core and corresponding negative charges outside are accumulated; then, magnetic field is supposed to be increased but also squeezed by the core gravity; then, some positive charges, those of which have been excited by the energy released from mass objects falling into the core, are released along the magnetic field lines with electromagnetic radiations to lessen the magnetic pressure, which should be the black hole jet stream along the rotating axis.

In Fig. (6) the magnetic field lines are reaching out to the galactic disk plane where the electric charge distribution is supposed as shown in Fig. (5), in which negative charge distributions are inner edges of the spiral arms and positive charge distributions are outer edges, and the charge distributions are moving together with the spiral arms. Then, it is not such difficult to figure out how the large-scale pattern, which is parallel to the spiral arms, is formed in the galactic magnetic fields including local magnetic fields generated by the induced charge distributions moving together in the galactic disk plane. In addition, the local magnetic fields could be related to the generation of the galactic spiral arms and the star formation in the spiral arms (Shklovskii 1978, D. R. Beck 2007, Beck and Wielebinski 2021).

Cosmology in 4-D Complex Space

Physical cosmology is talking about the history of the universe, which cannot be proved at this time and predicting the future of the universe, which also cannot be confirmed in our time scale. With the limiting data of observations on the earth, the system of the universe in such huge scale including us cannot be compared with any other physical system. Therefore, the physical cosmology doesn't have to be strict such as a scientific theory does, in general. Besides, considering the history of cosmology, the cosmology is not independent of the philosophy of nature (The Metaphysics Research Lab 2017).

There is an interesting view of natural philosophy in the Chun-Bu-Kyung, which has been handed down to people those who are living mainly in Korean Peninsula in East Asia (LEE 2020). It is the scripture saying that everything in nature keeps making changes, being changed, and repeated over and over; however, its fundamental nature in ontology is unique and immutable.

It seems that ancestors were wiser than people living now; they didn't say the word, 'start' or 'end' separately, but did implied consistently a circle of the changes, which means that the fundamental nature has always been out there apart from its phenomenological features. Then, what is the unique and immutable nature or essence in natural science? With that in mind, let's start the cosmology in 4-D complex space that is endless in time and limitless in size, in which physical phenomena in real space interact with vacuum particles in imaginary space.

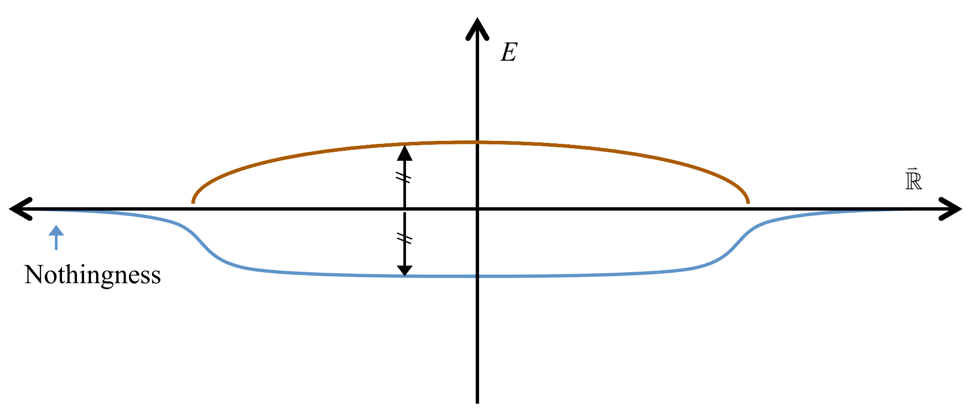

Fig. 7: average energy distribution in real space and in imaginary space

Fig. (7) shows the schematic drawing of the average energy distribution in real space and the corresponding vacuum particle energy distribution in imaginary space in 4-D complex space. Here, the universe is all matters and energies in real space and corresponding vacuum energies in imaginary space. The Nothingness in Fig. (7) represents no energy in real space and in imaginary space either, which is the grand equilibrium state in Eqn. (2) with $E_b = 0$. Now, if the Nothingness is corresponded to the fundamental nature in the scripture, the Chun-Bu-Kyung, we can suppose that for the energy distribution in real space, correspondingly the same amount but negative energy distribution should be in imaginary space as shown in Fig. (7). If a celestial object approaches to the Nothingness in Fig. (7), it will be pushed back owing to the first principle in 4-D complex space as shown in Fig. (2). Therefore, the universe in real space for physical phenomena is not expanding forever regardless of what energy density it has in real space.

For stars there is stellar life cycle, and for galaxies, galactic life cycle, otherwise there should be; as such, for local parts of the universe, one of which we are living in, they have their own life cycles. Hence, the universe keeps being changed but recycled in small scales and big scales; however, there is only one universe as a whole and total energy in real space is invariant.

Summary

In physics, physical constants are supposed to be invariant at any place and anytime. Therefore, if the variation of physical constant is observed, there should be a reason to be explained; otherwise, the corresponding physical law itself doesn't make sense as a physical law.

The fine-structure constant α is a measure of the strength of electromagnetic interaction. If the fine-structure constant is changed, the strength of electromagnetic interaction is changed; however, the strength of gravitational interaction is supposed to be changed too because gravitational interaction is under the same physical interaction mechanism as electromagnetic interaction in 4-D complex space. Since the strength of physical interaction depends on the vacuum particle distance d in imaginary space, the binding energy of vacuum particles in imaginary space is changed; thus, energy scale is changed in space. In short, physical environment is changed in vacuum space.

The galaxy-to-galaxy interaction among far remote galaxies is interpreted as the repulsive interaction based on the first principle in 4-D complex space, which is not by the so-called space expansion in FRW metric in general theory of relativity and thus the apparent receding velocity estimated by the cosmological redshift should not be true. The origin for the cosmological constant Λ introduced in Einstein's static universe and the dark energy in the standard model of cosmology is found in the binding energy distribution of vacuum particles in space. Moreover, the source of the background radiation corresponding to the CMBR is expected from the vacuum particle energy fluctuation in intergalactic space, which is being made in the galaxy-to-galaxy interaction.

Without introducing the dark matter (hypothetical matter), the galactic rotation anomaly in a typical spiral galaxy is explained with the space potential function that is based on the binding energy distribution of vacuum particles in space. Since the mass itself in 4-D complex space can be a source of electromagnetic interaction, new galactic dynamo process is introduced to explain the galactic magnetic fields.

To investigate the behavior of a heavenly body in astrophysics, we need to consider the mas-charge interaction in MHD as well as others, such as gravity, electromagnetism, thermodynamics, plasma physics, etc., which means that the electromagnetic interaction is always accompanied with the gravitational interaction in the universe, and vice versa. In addition, the space potential function Φ_{sp} in Eqn. (2) or space energy distribution in general should be included in the theory of general relativity in physical cosmology.

In the schematic drawings of binding energy distributions in Fig. (2) and Fig. (3), the slope near the edge of intergalactic space is not smooth, exaggerated a little though, which is supposed to be due to the negative charge distribution being pushed out of the mass distribution in galaxy. For the same reason, the electric charge distribution in the spiral arms is expected as in Fig. (5).

Finally, the theory of cosmology in 4-D complex space is introduced, in which only one universe exists as a whole with the conservation of total energy in real space. The universe is not static universe or steady universe but keeps being changed in timeless and edgeless 4-D complex space.

In this paper, nothing has been proved quantitatively; however, for many questions in astrophysics and physical cosmology comprehensive explanations are given in 4-D complex space with the first principle.

Discussion

If we say 'space' in physical science, the space is an abstract concept in which physical reality is; it means that the space itself is 'emptiness' or 'nothingness' at least in classical physics, and it should be distinguished with the space in mathematics to describe the physical reality. However, the 4-D complex space represents physical phenomena in its real subspace and the ontological reality, which is interacting with the phenomena, in its imaginary subspace in which vacuum particles are confined with negative energies; which means that the space itself is independent of the physical phenomena.

In physical cosmology based on Newtonian physics or general theory of relativity, the mass density in space or average energy density in general is, has been believed, the critical factor to decide whether the universe keeps expanding or not, and the average energy density in space should be estimated through the observations on the earth; then, with the cosmological principle it can be generalized for the average energy density in the universe. Hence, the cosmological principle has been a foundational assumption in physical cosmology. However, now we don't have to enforce the disputable and impractical cosmological principle; then, why don't we let it go and see the universe as it is?

In books and websites on the Internet, people keep saying that the Hubble's observation is the empirical evidence for the expanding of the universe. However, strictly speaking, that is not true: The scale of distance in Edwin Hubble's observation – Hubble scale, in fact, was much less than the cosmological scale in which the cosmological principle make sense – CP scale (Hubble 1929), which means that the Hubble's law is independent of the cosmological principle and thus the cosmological principle cannot be applied in the Hubble scale. Therefore, the Hubble's observation cannot be the evidence for the expanding universe or the cosmological principle.

If we remember the quote following: "If the first button in a shirt is put wrong, then every button will be wrong." — Unknown, we can say, for almost a century the physical cosmology has worn the wrongly buttoned shirt, and ironically the Big Bang theory, which is the most popular model in physical cosmology, has been under the spotlight with wearing the shirt.

Now, we need to consider the scientific consensus and the quote as "In the sciences, the authority of thousands of opinions is not worth as much as one tiny spark of reason in an individual man."
— Galileo Galilei.

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