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Information Mechanics: The Dynamics of "It from Bit"

Dr. Zhi Gang Sha [α] & Rulin Xiu [σ]

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However, the process of "It from Bit" remains to be clarified. In this work, we propose *Information Mechanics*. We suggest that information determines observed phenomena. The interaction of the two basic elements making up information creates everything we observe. We introduce information space and time to be the basic elements. The interaction of information space and time creates everything we observe. Based on these assumptions, we derive an action, the information action, and the information function. The information action represents the maximum possibilities, i.e., information, in a system. Information action appears to be similar to the string action in string theory and superstring theory but with a different meaning. The information function calculates the possible states in a system. We demonstrate that elementary particles and their wave-particle duality, fundamental forces, dark matter, and dark energy can emerge from the information function. We show that it is possible to derive a value of the cosmological constant consistent with astrophysical observation. We demonstrate that one may derive the hierarchy between the weak scale and the Planck scale. We point out that one may study what is inside a black hole and deduce that the entropy of a black hole to an outside observer is proportional to the area of the event horizon. Based on the various problems Information Mechanics may address, we suggest that it could lead to the grand unification theory we seek.

Keywords: information mechanics, hierarchy problem, cosmological constant problem, dark matter, dark energy, black hole, it from bit, grand unification theory.

I. Introduction

The principles and laws of creation are sought in many disciplines, including sciences, philosophies, and ideologies. Current cosmology suggests that the creation of our universe is through a "big bang." However, the natural law that has led to the big bang waits to be explored further.

John Wheeler proposed [Refs 1, 2, 3] the idea "It from Bit." He suggested that information sits at the core of physics and every "it," whether a particle or field, derives its existence from observations. To show how everything comes to existence through observation, John Wheeler acknowledged [Ref 3] that time played an essential role, but this is not understood well enough.

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The Grand Unification Theory is an attempt to use one mathematical formula to explain everything, including all elementary particles, fundamental forces, dark matter, dark energy, and the macro structure of the universe, and to unify quantum physics with Einstein's general relativity theory about gravity. So far, string theory is the only mathematically consistent theory that can unify everything [Refs 4, 5]. However, current string theory is still limited in its ability to make predictions. Something is still missing.

In this paper, we propose *Information Mechanics*, in which information determines and creates everything we observe. We present the basic principles and formula about how information underlies all observed phenomena, including giving the emergence to elementary particles, fundamental forces, dark matter, dark energy, black holes, and the universe. We proffer two basic laws governing Information Mechanics. The First Law of Information Mechanics comes from quantum physics, indicating the information contained in our measurement determines the observed phenomena. The Second Law of Information Mechanics comes from the ancient Chinese wisdom about yin yang. It proposes that two basic elements, yin and yang, make up everything, including information, and that the interaction of these two elements creates all the observed physical phenomena. We will show that the interaction of two pairs of yin yang elements: space-time and exclusion-exclusion, create all elementary particles, forces, dark matter, dark energy, and the universe we observe.

We show that the laws of Information Mechanics give rise to an information action. Information action represents the maximum possibilities, i.e., information, in a system. Information action appears to be similar to string action. From the information action, one can define information function. Information function calculates the possible states in a system. *Information function* seems to be an extension of wave function in quantum mechanics. With information action and information function, we demonstrate that elementary particles and their wave-particle duality emerge from the Poincaré symmetry, fundamental forces come about due to the diffeomorphism symmetry, and classical equations of motion come from Weyl symmetry. Observation of dark matter and dark energy at the large scale of universe can be explained in Information Mechanics. We find that it is possible to calculate the

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cosmological constant consistent with the current astrophysical observation. The hierarchy problem regarding cosmological constant can be possibly explained and derived. We also demonstrate that it is plausible to deduce the large hierarchy between the weak symmetry breaking scale and Planck scale. We find that information action and function provide a way to study what is inside a black hole and also to derive the entropy of a black hole as seen by an outside observer to be proportional to the area of its event horizon.

II. Basic Principles and Laws of Information Mechanics

a) First Law of Information Mechanics

The observed phenomenon is determined by the information of the measurement.

The First Law of Information Mechanics comes from quantum physics, which indicates that the process of making a measurement determines the observed phenomenon.

For instance, quantum physics shows us that what detector we use and where we place the detector determines what phenomenon we observe.

b) Second Law of Information Mechanics

Everything is made of two basic elements. These two elements are opposite, relative, co-created, inseparable, and co-dependent. The interaction of these two elements creates everything.

The Second Law of Information Mechanics originates from ancient Chinese wisdom about yin yang [Ref 6, 7]. We keep the Chinese words here and call these two basic elements that make up everything: yin and yang.

These two basic elements, yin and yang, make up the "Bit" of information. The Second Law of Information Mechanics suggests the interaction of yin and yang, the essential elements of information, creates everything.

III. Space and Time as the Fundamental Yin-Yang Pair

What are the basic yin yang elements that create the observed elementary particles, forces, dark matter, dark energy, and the universe?

We suggest that space and time are one of the fundamental pairs of yin-yang elements that create everything we observe.

We propose another meaning of space-time, which we call information space and time. Information space and time are related to two basic measurements we conduct. Information time relates to the measurement of movement and change. Information space relates to the measurement of stillness and solidity. For instance, the flow of sand in an hourglass and the movements of the sun and the moon have all been used as measurements of time. The duration of a day is based on the measurement of the rotation of the earth. The measurements of space, such as the length, height, and width of an object, are the measurement of its fixedness and stillness.

Information space and time are a yin-yang pair. They are opposite and relative. Change and stillness are opposites and relative. Space and time are co-created because whenever one measures change, one refers to something unchanged. Whenever one measures something as unchanged, one compares it with something one considers changing. Therefore, information space and time are inseparable and co-dependent.

According to quantum physics, it takes energy and momentum to measure time and space. How accurately time and space can be measured depends on the amount of energy and momentum used in the measurement. More specifically, to measure the time of duration $\Delta\tau$, it takes an energy of $\Delta E \sim \hbar/\Delta\tau$. To measure a space of size $\Delta\sigma$, it takes the momentum $\Delta p \sim \hbar/\Delta\sigma$.

If one takes gravity into consideration, according to general relativity, energy curves space-time. When one measures time interval $\Delta\tau$, the energy ΔE used for a time measurement will curve space-time. It will create a black hole with the horizon on the order of $G\Delta E/c^4$. When $\Delta\sigma$ is smaller than $G\Delta E/c^4$, no information can escape. Therefore, the measurable causal region is:

$$\Delta\sigma \geq G\Delta E/c^4.$$

Therefore, there exists the uncertainty relation between the measurable space $\Delta\sigma$ and measurable time $\Delta\tau$,

$$\Delta\sigma\,\Delta\tau \geq l_p\, t_p. \quad (1)$$

Here l_p is the Planck length and t_p is the Planck time. This uncertainty relation suggests that information space and time affect each other. They are not independent. They are a yin-yang pair.

Next, we propose that inclusion and exclusion are the other basic yin-yang pair in measurement. This is because, when one makes a measurement, one needs to give the information about what is included and what is excluded.

We propound, all measurements are based on these two basic yin-yang pairs: information space-time measurement and inclusive-exclusive measurement. To see this, one can examine all possible measurements, such as measurement of velocity, acceleration, energy, momentum, temperature, spin, electricity, magnetic field, mass, charge, and force. One can see that these measurements are various combinations of space and

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time measurement and inclusive and exclusive measurement.

IV. Derivation of Information Action

If all measurement is made of two basic measurements: space-time measurement and inclusion-exclusion measurement, according to the first and second laws of Information Mechanics, the interaction of the space and time yin-yang pair and the interaction of the inclusion and exclusion yin-yang pair should create all observed phenomena.

The simplest action created by the interaction of the information space time is:

$$A_1=\alpha\int\Delta\tau\Delta\sigma. \tag{2}$$

Here the symbol σ represents information space and the symbol τ represents information time. The integral symbol $\int$ represents the summation over information space and time, and α is a constant. From the uncertainty relation between information space and time (1), we get

$$\alpha=1/(l_p t_p).$$

To introduce the second yin-yang pair into the action, we need to include the inclusion and exclusion elements. To do this, we realize that corresponding to the inclusion and exclusion yin-yang pair, in nature there exist two types of particles, fermions and bosons. Fermions have half (1/2) spin. They repel each other. They cannot be in the same state. Bosons have integer spin. They tend to clump. The normal time and space coordinates τ and σ are of bosonic nature. If we assume each information space or time coordinate has both the fermion (yang, repulsive) and boson (yin, clumping) parts, each information time and space coordinate become two elements:

$$\tau \to (\tau, \theta_\tau) \tag{3}$$

$$\sigma \to (\sigma, \theta_\sigma). \tag{4}$$

Here we use θ_σ and θ_τ to represent the fermion part of information space and time coordinates σ and τ. The θ_σ and θ_τ can only take on the value of 0 or 1 because they are repulsive and refuse to stay at the same place. The four elements of the two yin-yang pairs are represented by σ, τ, θ_σ, and θ_τ.

The simplest action created by these two yin-yang pairs is:

$$A_2=\alpha'\int\Delta\tau\Delta\sigma\Delta\theta_\tau\Delta\theta_\sigma. \tag{5}$$

We will call the action A_1 and A_2 the information action.

One can see that the action A_1 is basically the action of bosonic string and the action A_2 is the action of the super string[Ref 4, 5]. It is interesting to see that from the basic laws of Information Mechanics we can derive string action [Ref 4, 5].

There is a fundamental difference in the meaning and function between information action and string action. For instance, suppose the integration of τ and σ is over (0, T) and (0, L). We can see that T and L correspond to the time and space scale involved in our measurement in Information Mechanics. They are different in different measurements. If our measurement and observation is the whole universe, T and L should be the age and horizon length of the universe. This is different from string theory, in which L is set to be the string length and T is set to be infinite.

The information actions A_1 and A_2 in equations (2) and (5) give the amount of the information in a system with the observation scale (0, T) and (0, L). Information action expresses the possible states that can be observed in a system. Seth Lloyd derived a similar result in his paper [Ref 8], viz. that the maximum observable information in a system is represented by (2).

V. Two Types of Space-Time

To derive the observable phenomena in Information Mechanics, it is necessary to realize that there exist two types of space time. One is the information space time associated with the fundamental yin-yang pair (τ, σ). It is related to the basic elements of information. We call it information space and time. The other is the physical measurement of space distance and time duration or physical location of space time X^μ. Let's call X^μ physical space and time.

The physical space and time X^μ is a projection from the information space and time (τ, σ),

$$X^\mu: (\tau, \sigma) \to X^\mu(\tau, \sigma).$$

Suppose in this projection, the total information is unchanged. The action A_1 becomes:

$$A_1' = \alpha \int d\tau\, d\sigma\, (-\det h_{ab})^{1/2}. \tag{6}$$

Here, $h_{ab} = \partial_a X^\mu \partial_b X_\mu$.

In the following, for the sake of the simplicity of illustration, we will work with the "bosonic string,"

$$A_1 = \alpha\int_0^T d\tau \int_0^L d\sigma.$$

One can follow and extend the same discussion to the general case of "superstring,"

$$A_2 = \alpha' \int_0^T d\tau \int_0^L d\sigma d\theta_\tau d\theta_\sigma.$$

VI. Definition of Information Function

Now let's define the information function Ψ:

$$\Psi=\exp(i\,A). \tag{7}$$

Here A is the information action. We can see that the information function Ψ is related to the amount of information I in a system through the formula:

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$$I = A = -i\ln\Psi. \quad (8)$$

Suppose the information function at $\tau = 0$ and $\sigma = 0$ is Ψ_0. The information Ψ at $\tau = T$ and $\sigma = L$ is

$$\Psi = \exp(iA_1)\Psi_0. \quad (9)$$

Here $A_1 = \alpha\int_0^T d\tau \int_0^L d\sigma$ or $A_2 = \alpha\int_0^T d\tau \int_0^L d\sigma d\theta_\tau d\theta_\sigma$.

Using the action A_1' in (6), the information function at $\tau = T$ and $\sigma = L$ now becomes

$$\Psi = \exp(iA_1)\Psi_0 = \int \mathcal{D}X \exp(iA_1')\, \Psi_0.$$

Here $A_1' = \alpha\int_0^T d\tau \int_0^L d\sigma\,(-\det h_{ab})^{1/2}$.

Here $\int \mathcal{D}X$ represents summing over all possible X, similar to Feynman's path integral definition [Ref 9].

Compare to the wave function in quantum physics:

$$\Psi(T) = \int \mathcal{D}X \exp(iS)\, \Psi_0.$$

Here $S = \int_0^T dt\, \mathcal{L}(x(t), \dot{x}(t))$.

One can see that the information function is a natural extension of the wave function in quantum physics. The action in Information Mechanics integrates over both time and space while the action in quantum physics integrates over time.

Information Mechanics is also different from quantum field theory. The action of Information Mechanics integrates over two-dimensional information space and time, while in quantum field theory the action integrates over four-dimensional physical space time. The main task of quantum field theory is to calculate the correlation function and scattering cross-sections. In Information Mechanics, the correlation function and, thus, scattering cross-section can be obtained through the information function in the equation (9). Note that the wavelength and frequency in quantum field theory are now replaced with the measurement scales T and L in Information Mechanics. We will discuss the correspondence between the calculations of Information Mechanics with those of quantum field theory in more detail in future work.

VII. Emergence of Elementary Particles and Fundamental Forces

As discovered in particle physics, the basic constituents of everything are elementary particles and fundamental forces. It is found that elementary particles have wave-particle duality, meaning that they behave like a wave but each elementary particle has its own specific mass and spin, no matter where and when one makes the measurement. The wave-particle duality of elementary particles and fundamental forces was proposed by Einstein and Niels Bohr and indicated by experiments [Ref10, 11]. However, it is never derived from the first principle in theoretical physics.

In the following, we show how the wave-particle duality of elementary particles and fundamental force se merge in Information Mechanics.

To do this, first notice, as shown in string theory [Ref 4,5],it is possible to introduce a metric tensor γ^{ab} and rewrite the action A_1' in (6) in the form:

$$A_1''[X, \gamma] = \alpha \int d\tau\, d\sigma\, (-\det\gamma_{ab})^{1/2}\gamma^{ab}\partial_a X^\mu \partial_b X_\mu. \quad (10)$$

In Information Mechanics, the possibility to introduce tensor γ^{ab} is due to the relativity between the yin yang, the information time and space (τ, σ).

The action A_1'' is invariant under the following three transformations:

1. D-dimensional Poincaré transformation

$$X'^\mu(\tau,\sigma) = \Lambda^\mu_\nu X^\mu(\tau,\sigma) + a^\mu$$

$$\gamma'_{ab}(\tau,\sigma) = \gamma_{ab}(\tau,\sigma) \quad (11)$$

2. Diffeomorphism transformation

$$X'^\mu(\tau,\sigma) = X^\mu(\tau,\sigma)$$

$$\frac{\partial\sigma'^c}{\partial\sigma'^a}\frac{\partial\sigma'^d}{\partial\sigma'^b}\gamma'_{cd}(\tau',\sigma') = \gamma_{ab}(\tau,\sigma) \quad (12)$$

3. Two-dimensional Weyl transformation

$$X'^\mu(\tau,\sigma) = X^\mu(\tau,\sigma)$$

$$\gamma'_{ab}(\tau,\sigma) = \exp\big(2\omega(\tau,\sigma)\big)\gamma_{ab}(\tau,\sigma). \quad (13)$$

Information action has three symmetries: Poincaré symmetry, diffeomorphism symmetry, and Weyl symmetry.

VIII. Emergence and Observation of Elementary Particles Due to Poincaré Symmetry

In Information Mechanics, the observed world is made of a certain amount of information, which represents different possibilities in a system. The observation of the same elementary particles regardless of physical space and time is due to the Poincare symmetry. The observed elementary constituents should be invariants of Poincaré transformation. From group theory, one knows that mass and spin are the two invariants under Poincaré transformation. Because of this, the basic constituents, elementary particles, are specified by mass and spin.

The wave aspect of elementary particles is represented by the information function. It comes from the basic assumption that everything we observe comes from information. Information represents different possibilities. In this way, the wave-particle duality of

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elementary particles and fundamental forces emerge in Information Mechanics.

IX. Emergence of Gravity and Gauge Force Due to Diffeomorphism Symmetry

In Information Mechanics, the emergence of gravity and gauge interaction is due to diffeomorphism symmetry (12). Diffeomorphism invariance(12) suggests one can introduce the physical space-time metric tensor $G_{\mu\nu}(X^{\mu})$and anti-symmetric tensor $B_{\mu\nu}(X^{\mu})$ in the action (10):

$$A_1^{'''}\,[X, \gamma, G_{\mu\nu}, B_{\mu\nu}] =$$
$$\alpha \int d\tau\, d\sigma\, (-\det \gamma_{ab})^{\frac{1}{2}} (\gamma^{ab} G_{\mu\nu} + \varepsilon^{ab} B_{\mu\nu}) \partial_a X^{\mu} \partial_b X^{\nu}. \quad (14)$$

The action $A_1^{'''}$ [X, $\gamma, G_{\mu\nu}$, $B_{\mu\nu}$] *has* the diffeomorphism invariance in physical space-timeX^{μ}:

$$\frac{\partial X'^{\alpha}}{\partial X'^{\mu}} \frac{\partial X'^{\beta}}{\partial X'^{\nu}} G'_{\alpha\beta}(X'^{\mu}) = G_{\mu\nu}(X^{\mu})$$

$$\frac{\partial X'^{\alpha}}{\partial X'^{\mu}} \frac{\partial X'^{\beta}}{\partial X'^{\nu}} B'_{\alpha\beta}(X'^{\mu}) = B_{\mu\nu}(X^{\mu}).$$

The introduction of physical space-time tensor metric $G_{\mu\nu}(X^{\mu})$and anti-symmetric tensor $B_{\mu\nu}(X^{\mu})$can induce gravity and gauge interaction in physical space-time.

The fact that $G_{\mu\nu}(X^{\mu})$ and $B_{\mu\nu}(X^{\mu})$ describe the gravity and gauge interaction in physical space-time can be further confirmed by the equations of motion associated with$G_{\mu\nu}(X^{\mu})$ *and* $B_{\mu\nu}(X^{\mu})$. In the following, we will show that, from the Weyl invariance, one can obtain the equations of motion regarding $G_{\mu\nu}$ *and* $B_{\mu\nu}$, which shows that $G_{\mu\nu}$ *and* $B_{\mu\nu}$ follow the equations of motion associated with gravity and gauge force.

X. Weyl Invariance, Holography, and Classical Equations of Motion

The Weyl invariance (13) is automatically preserved at the first order in information action. However, higher-order corrections could possibly violate it. For instance, in [Refs 4, 5], it is shown that there are the following second-order corrections to the information action:

$$\beta^{G}{}_{\mu\nu} = \alpha\, R_{\mu\nu} + \alpha/4\, H_{\mu\lambda\omega} H_{\nu}{}^{\lambda\omega} + O(\alpha^2) \quad (15)$$

$$\beta^{B}{}_{\mu\nu} = -\,\alpha/4\, \nabla^{\omega} H_{\mu\lambda\omega} + O(\alpha^2). \quad (16)$$

The preservation of Weyl Invariance at the higher orders requires that:

$$\beta^{G}{}_{\mu\nu} = \beta^{B}{}_{\mu\nu} = 0.$$

Notice that $\beta^{G}{}_{\mu\nu} = 0$ leads to the generalized Einstein's equation with the source terms from the anti-symmetric tensor. The equation $\beta^{B}{}_{\mu\nu}=0$ is the anti symmetric generalization of Maxwell's equations.

We can see that requiring Weyl invariance, one is able to obtain classical equations of motion including Einstein's general relativity and gauge interactions. In this way, Information Mechanics includes classical physics.

In Information Mechanics, all the physical phenomena are projected from a two-dimensional information space time. The two-dimensional information space time has Weyl invariance. This means that the two-dimensional information space time is a hologram from which all observed phenomena, including physical space time, elementary particles, gravity, and gauge interactions emerge. Classical equations of motion come from the holographic nature, the Weyl invariance of information space time.

XI. Emergence of Dark Energy and Dark Matter

The observed accelerated expansion and large structure of our universe [Refs12, 13, 14, 15, 16]indicates an unknown source of energy, dark energy, and an unknown source of matter, dark matter. There are many proposals about the potential candidates for dark matter and dark energy.

In the following, we will show that Information Mechanics may explain the observation of dark energy and dark matter. Dark matter and dark energy can emerge from information function.

Dark energy and dark matter are phenomena observed in the large structure of the universe. To see what matter and energy emerges in the large structure of universe, we need to study the information function:

$$\Psi = \exp(iA_1^{''}) = \int \mathcal{D}X \exp(i\, A_1^{''}).$$

Here

$$A_1^{''} = \alpha \int_0^T d\tau \int_0^L d\sigma\, (-\det \gamma_{ab})^{\frac{1}{2}} (\gamma^{ab} G_{\mu\nu} + \varepsilon^{ab} B_{\mu\nu}) \partial_a X^{\mu} \partial_b X^{\nu},$$

where T is the age of the universe and L is the length of the horizon of the universe.

One may notice that in the information function Ψ, there exist vibrations in the energy state (n, m) with the frequency ν_n= n/T and wavelength λ_m = L/m. The frequency and wavelength of some of these vibrations have a frequency and wavelength on the order of 1/T and L. These vibrations are almost impossible to detect at this moment. This is because, to observe them, it takes a detector as large as the universe or it takes time as long as the age of the universe. These vibrations are very "dark" due to this innate difficulty to be observed by detectors. They can only be observed on the large structure of the universe. They are natural possible candidates for dark matter and dark energy.

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XII. Calculation of Cosmological Constant

The cosmological constant is the simplest possible form of dark energy. The current standard model of cosmology, the Lambda-CDM model, assumes a non-zero cosmological constant as the source of dark energy. It is found that, in terms of the Planck unit, and as a natural dimensionless value, the cosmological constant is calculated to be on the order of 10^{-122} [Ref 15, 16]. The large discrepancy between the natural energy scale, Planck scale, and the observed value of 10^{-122} in terms of Planck scale is the so called cosmology constant problem.

In the following, we will estimate the vacuum energy of the information function. Surprisingly, we are able to obtain a value for the cosmological constant consistent with the observation.

To calculate the vacuum energy of the universe, we use the fact that the energy at state (n, m) with the frequency $\nu_n = n/T$ and wavelength $\lambda_m = L/m$ is:

$$E_{n,m} = (n + ½)\, \hbar/T.$$

The lowest energy of the vacuum fluctuation is $E_{0n,m} = \hbar/2T$.

In Information Mechanics, with the space and time measurement scale at T and L, the total number of possible states N is:

$$N = TL/(l_p t_p).$$

If we assume each of the possible states can contribute to vacuum fluctuation energy of $E_{0n,m} = \hbar/2T$, then the total vacuum energy is:

$$E_{vac} = \hbar /2T \times TL/ l_p^2 = \hbar L/(2\, l_p^2).$$

The vacuum energy density in three-dimensional observed space is:

$$\rho_{vac} = E_{vac}/(4\pi L^3/3) = \rho_p 3 l_p^2/(8 \pi L^2).$$

Here ρ_p is the Planck energy density,

$$\rho_p = E_p/l_p^3,$$

and E_p is the Planck energy $E_p = \hbar/t_p = 1.956 \times 10^9$ Joule.

The cosmological constant Λ_c is: $\Lambda_c = 8\pi\, \rho_{vac}$. Therefore

$$\Lambda_c = 8\pi\, \rho_{vac} = 3\rho_p\, l_p^2/L^2.$$

We know that:

$$l_p^2/L^2 = t_p^2/t_u^2 = 10^{-122}.$$

Here t_u is the age of the universe. We use:
$t_u = 13.799$ billion years $= 4.35 \times 10^{17}$ seconds.
From this, we obtain:

$$\Lambda = 3 \times 10^{-122} \rho_p. \quad (17)$$

According to results published by the Planck Collaboration in 2018 [Refs 15,16], the cosmological constant is 2.888 x 10^{-122} in Planck units. The result in (17), $\Lambda = 3 \times 10^{-122} \rho_p$, is consistent with the data from the Planck Collaboration in 2018 [Refs 15, 16].

Information Mechanics seems to be able to address the large hierarchy problem regarding the cosmological constant.

XIII. Emergence of the Electroweak Scale and Planck Scale Hierarchy

There are two outstanding hierarchy problems in physics. One is the cosmological constant problem. The other is to derive the large difference between weak force and gravity, or equivalently between Higgs mass and Planck mass [Ref 17, 18, 19, 20]. We have shown above that Information Mechanics may help address the cosmological constant problem; next, we will explore how it may help cope with the second hierarchy problem.

To derive the weak scale and Higgs mass in Information Mechanics, we study the information action A_2 and write *it* in terms of complex coordinates, z, $\bar{z}$, θ, and $\bar{\theta}$ [Ref 4, 5]:

$$A_2 = \alpha' \int dz d\bar{z}\, d\theta\, d\bar{\theta} = \alpha \int d^2z\, d^2\theta.$$

We introduce observable space-time $X^\mu(z, \bar{z}, \theta, \bar{\theta})$ in superspace, which includes both bosonic spacetime $X^\mu(Z, \bar{z})$ and its fermionic counterpart $\psi^\mu(Z, \bar{z})$ and $\tilde{\psi}^\mu(z, \bar{z})$:

$$X^\mu(z, \bar{z}, \theta, \bar{\theta}) = X^\mu(Z, \bar{z}) + \theta\psi^\mu(Z, \bar{z}) + \bar{\theta}\tilde{\psi}^\mu(z, \bar{z}) + \theta\bar{\theta}F^\mu.$$

The term F^μ is the auxiliary field, which can usually be eliminated through equations of motion. We suggest that bosonic space time $X^\mu(z, \bar{z})$ corresponds to observable spacetime coordinates and the fermionic spacetime $\psi^\mu(z, \bar{z})$ and $\tilde{\psi}^\mu(z, \bar{z})$ correspond to elementary particles. In superspace $X^\mu(z, \bar{z}, \theta, \bar{\theta})$, there is supersymmetry, which is the invariance under the transformation between space-time bosonic coordinates and fermion coordinates. After integrating over fermion coordinates $(\theta, \bar{\theta})$, the action A_2 including metric tensor $G_{\mu\nu}$ and anti symmetric tensor $B_{\mu\nu}$ becomes [Ref 4, 5]:

$$A_2 = \alpha \int d^2z[(G_{\mu\nu} + B_{\mu\nu})\, \partial_z X^\mu \partial_{\bar{z}} X^\nu + G_{\mu\nu}(X)(\psi^\mu D_{\bar{z}}\psi^\nu + \tilde{\psi}^\mu D_z\tilde{\psi}^\nu) + ½\, R_{\mu\nu\rho\sigma}(X)\psi^\mu\psi^\nu\tilde{\psi}^\rho\tilde{\psi}^\sigma]. \quad (18)$$

Here, covariant derivatives are:

$$D_{\bar{z}}\psi^\nu = \partial_{\bar{z}}\, \psi^\nu + [\, \Gamma^\nu{}_{\rho\sigma}(X) + \tfrac{1}{2}H^\nu{}_{\rho\sigma}(X)\,]\, \partial_{\bar{z}} X^\rho \psi^\sigma$$

$$D_z\tilde{\psi}^\nu = \partial_Z\tilde{\psi}^\nu + [\, \Gamma^\nu{}_{\rho\sigma}(X) - \tfrac{1}{2}H^\nu{}_{\rho\sigma}(X)\,]\, \partial_Z X^\rho\, \tilde{\psi}^\sigma.$$

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Here $\Gamma^{\nu}{}_{\rho\sigma}(X)$ is the Christoffel connection. It is related to the gravitational interaction. And $H^{\nu}{}_{\rho\sigma}(X)$ is the anti-symmetric tensor field strength.

To see how the hierarchy between Higgs mass and Planck mass emerges, we use the similarity between Higgs mechanism and superconductivity. The Higgs mechanism was originally suggested in 1962 by Philip Anderson when he noticed the similarity between electroweak symmetry breaking and superconductivity [Ref 21, 22]. In the following, we show that in Information Mechanics, one may use superconductor theory, BCS theory, to induce the large hierarchy between Planck mass and Higgs mass.

Notice the observable space-time coordinates $X^{\mu}(Z, \bar{z})$consist of a series of vibrations. Similar to the phonons in a superconductor interacting with fermions through electromagnetic force, $X^{\mu}(Z, \bar{z})$ vibrations interact with fermions, gravity, and gauge interactions, as indicated in the information action (18) through the interaction terms:

$$V_{int} = \mathbf{G_{\mu\nu}(X)}\psi^{\mu} [\Gamma^{\nu}{}_{\rho\sigma}(X) + \tfrac{1}{2}H^{\nu}{}_{\rho\sigma}(X)]\, \partial_{\bar{z}}X^{\rho}\psi^{\sigma} + \mathbf{G_{\mu\nu}(X)}$$

$$\tilde{\psi}^{\mu}[\Gamma^{\nu}{}_{\rho\sigma}(X) - \tfrac{1}{2}H^{\nu}{}_{\rho\sigma}(X)]\, \partial_{Z}X^{\rho}\, \tilde{\psi}^{\sigma}$$

$$+ \tfrac{1}{2} R_{\mu\nu\rho\sigma}(X)\psi^{\mu}\psi^{\nu}\tilde{\psi}^{\rho}\tilde{\psi}^{\sigma}. \qquad (19)$$

As discovered in BCS theory, these interactions can add a negative potential energy which leads to a ground state with the formation of coherent fermion pairs. This ground state energy results in a non-zero gauge field, which breaks the gauge symmetry.

In the interaction terms (19), the gauge interaction is proportional to $\partial_{\bar{z}}X^{\rho}$ and $\partial_{Z}X^{\rho}$. This indicates that the ground state with the formation of fermion pairs will not only break gauge symmetry but also space-time translational symmetry. This means that it can lead to space-time compactification and also super symmetry breaking. This may be a natural non-perturbative mechanism for gauge symmetry breaking, space-time compactification, and super symmetry breaking.

According to the BCS mechanism, the non-perturbative ground state potential energy in the weak interaction limit is on the order of [Ref 21, 22]:

$$W = - n_c\hbar\omega\exp[-\tfrac{1}{NV}].$$

Here N is the state density and V is the interaction potential. The energy term$\hbar\omega$corresponds to the energy of space-time vibration. It can be on the order of the space-time compactification scale, which may be of the same energy scale as the super symmetry breaking. One can see that the Higgs mass is exponentially smaller than the space-time compactification scale.

Because of the exponential form of the non-perturbative potential energy in the ground state, the large hierarchy between Higgs mass and compactification scale and thus Planck scale can be easily generated. We will expand the detailed model, calculation, and discussion of this possible scheme in future work.

XIV. Black Holes

Any fundamental physics theory including gravity should be able to address what is happening inside a black hole. Let's take a look at how Information Mechanics could help us study what is inside a black hole.

A black hole is created when the gravity force becomes stronger than the fermionic exclusion force, and matter is collapsed by gravity to the point that all matter including light is confined to a limited space and time [Ref 23, 24]. Thus, we propose that a black hole is related to physical space-time compactification in the observable four-dimensional space-time.

In Information Mechanics, to study black holes, we can start with the action (18):

$$A_2 = \alpha\int d^2z[(G_{\mu\nu} + B_{\mu\nu})\, \partial_z X^{\mu}\partial_{\bar{z}}X^{\nu} + \mathbf{G_{\mu\nu}(X)}(\psi^{\mu} D_{\bar{z}}\psi^{\nu} + \tilde{\psi}^{\mu}D_z\tilde{\psi}^{\nu})$$

$$+ \tfrac{1}{2} R_{\mu\nu\rho\sigma}(X)\psi^{\mu}\psi^{\nu}\tilde{\psi}^{\rho}\tilde{\psi}^{\sigma}].$$

In the case of a black hole, $G_{\mu\nu}$ and $R_{\mu\nu\rho\sigma}(X)$ become very large, and we assume this leads to compactification of space-time in the observable four-dimensional space-time. This means that:

$$X^0 \cong X^0 + D^0,$$

$$X^i \cong X^i + D^i,\ i = 1,2,3.$$

Inaction A_2(18), this space-time compactification will lead to a positive kinetic energy:

$$(G_{\mu\nu} + B_{\mu\nu})\, \partial_z X^{\mu}\partial_{\bar{z}}X^{\nu} \cong (G_{\mu\nu} + B_{\mu\nu})\, \frac{1}{D^{\mu}}\frac{1}{D^{\nu}} \qquad (19)$$

This additional kinetic energy term will balance the negative potential energy from the gravity and gauge interaction term:

$$G_{\mu\nu}(X)\psi^{\mu} [\Gamma^{\nu}{}_{\rho\sigma}(X) + \tfrac{1}{2}H^{\nu}{}_{\rho\sigma}(X)]\, \partial_{\bar{z}}X^{\rho}\psi^{\sigma} + G_{\mu\nu}(X)\tilde{\psi}^{\mu}[\Gamma^{\nu}{}_{\rho\sigma}(X) -$$

$$\tfrac{1}{2}H^{\nu}{}_{\rho\sigma}(X)]\, \partial_{Z}X^{\rho}\, \tilde{\psi}^{\sigma} + \tfrac{1}{2} R_{\mu\nu\rho\sigma}(X)\psi^{\mu}\psi^{\nu}\tilde{\psi}^{\rho}\tilde{\psi}^{\sigma} \qquad (20)$$

The balance between the kinetic energy in (19) and the potential energy in (20) could lead to a new stable ground state. It indicates that the internal structure of a black hole is similar to a crystal, or liquid crystal, or some other ordered and coherent state. The action A_2 can enable us to study the detailed dynamics inside a black hole with matter, space-time, gravity, and gauge interactions all present in one formula. We will defer the detailed calculation and discussion to future work.

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To study the dynamics outside of the black hole, the measurement scale L is larger than the horizon of the black hole. For an observer outside a black hole, a black hole appears as a particle with specific mass and spin.

Like everything, a black hole carries information. For an outside observer, the entropy of a black hole is the unknown information or possibilities associated with the black hole. Since the outside observer can't receive any information beyond the horizon of a black hole, the information space scale, L, for the observation of a black hole is the black hole's horizon. The information time scale associated with the external observation of a black hole is L/c. According to the equation (2), the maximum amount of unknown information associated with the observation of a black hole for an outside observer is:

$$S = \frac{L^2}{l_p^2}.$$

It's interesting that, in Information Mechanics, one may derive the result that the entropy of a black hole is proportional to the area of the event horizon in units of Planck scale.

The holographic principle [Ref 25, 26, 27]emerges in Information Mechanics, but in a different way. Here the maximum information is proportional to the area covered by the information space-time, not the physical space-time. In three-dimensional space, the area covered by the physical space could be the same as or proportional to the area of information space-time. This coincidence only happens in four-dimensional physical space-time.

XV. Discussion and Conclusion

In this paper we introduce Information Mechanics and its two basic principles and laws. We propose that information determines the observed phenomena. The interaction of basic yin yang elements making up information and everything creates the observed phenomena. We derive the information action and information function. We show that the observed phenomena, such as physical space time, elementary particles and their wave-particle duality, fundamental forces, classical equations of motion, dark matter, and dark energy, may emerge from the information action and information function. We show how classical physics, quantum physics, quantum field theory, and string theory may emerge in information Mechanics. We discover that it is possible to derive a value of the cosmological constant consistent with astrophysical observation. We suggest a plausible scheme to derive the hierarchy between the weak scale and the Planck scale using information action. We indicate that one can study what is inside a black hole and deduce that the entropy of a black hole to an outside observer is proportional to the area of the event horizon.

Information Mechanics appears to be promising to address various challenging problems facing theoretical physics. More detailed calculations and further investigation are still needed. We welcome more people to participate in this project.

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