Exploring the Inflation and Gravity of the Universe with Eyring's Rate Process Theory and Free Volume Concept

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Abstract

On the basis of the very successful free volume theory applicable to wide length scales from electrons to small molecules, macromolecules, colloidal particles and even granules, hypothetical particles dubbed "freevons" are proposed to fill up the free volume available in any system from microscopic atomic world to the macroscopic universe. The Eyring's rate process theory that has a wide applicability to many chemical and physical processes is assumed to govern the behaviors of freevons. It turns out that for keeping the universe to expand in an accelerated manner, the freevons must form the paired structures, like electrons paired in superconductivity state and helium-3 atoms paired in superfluidity state; It is also predicted that a temperature induced phase transition happening about at about 5 *K* and the Hubble's constant should dramatically increase, implying that the universe will inflate even further rapidly. The universe is therefore viewed as particles, the stars and galaxies, dispersed in the superfluidity freevon sea and the gravity is considered to be induced from the force density, usually defined as a negative gradient of pressure in fluid mechanics. The Newton's gravity equation is thus easily obtained under these assumptions, and similarly the Coulomb's Law can also be obtained using the same approach. In this superfluiditiy framework, the volumes rather than the masses of particles are found to be important in determining the gravitational forces. The expansion driving force comes from the activity or concentration gradient of freevons formed at the beginning of the big bang, and there is no need to postulate a mysterious dark energy or dark matter to be responsible for such an accelerated inflation; Freevons actually can do the job. Our approach may bridge various theories in astrophysics field and provide a possibility to use quantum mechanics to study the universe through exploring the quantum mechanics behaviors of freevons.

I. Introduction

Modern cosmology is built on Einstein's general relativity theory [1] with many additional modifications [2,3,4,5]. The astonishing success of those theories proved with the cosmological scale observations may indicate that the universe is undergoing accelerated expansion and the universe is originated from a big bang happened more than 13.8 billion years ago. The driving forces of the accelerated expansion is postulated as dark energy or dubbed dark matter that still remains a big mystery. As identified in the literature [6], the dark energy is usually resulted from the cosmological constant originally introduced by Einstein. However, the theoretical predictions pose a dramatic 123 orders of magnitudes difference compared with the observations [6,7]. The discrepancies propel more alternative theories proposed for better understanding the mystery of universe we have experienced so far [4].

In the special relativity, we may already know that mass actually is a function of speed [8]. Weightlessness is frequently observed in space where the gravity is reduced or becomes zero. These observations may imply that neither the weight nor the mass are intrinsic physical properties. Since the mass is strongly tied with the gravity and the gravity is something of unknown source, where and how the mass come from becomes a complicated issue, though Higgs mechanism is thought to be responsible for mass generation in the Higgs field [9]. However, the mass is the central concept in those gravitational theories and is used to determine the gravity at the same time, like something of using a mystery parameter to define another mystery one. If we don't take "mass" into the theoretical consideration, do we still run into the dilemma of dark energy or dark matter?

In this article, "mass" concept will not be used as a primary parameter for describing gravity. Instead, the volume will be used to derive the gravity. A particle, dubbed "freevon" occupying free volume in any spaces, is introduced in our theory to account for the gravity, dark energy, and dark matter. The material world we see every day and the unoccupied free spaces are filled up with invisible freevons. Current observations support that the universe is created from the big bang[10]. If this is correct, the involved tremendous explosive chemical and physical reactions could be described with Eyring's rate process theory. Eyring's rate process theory was first formulated in 1930s to describe the chemical reactions [11], but later extended to explain many other physical processes like viscosity, diffusion, and plasticity [12,13]. It not only can be applied to thermal systems, but also can be applied to athermal systems like granular powders [14], with the aid of powerful free volume concept [15,16,17]. Free volume is a spatial enclosure unoccupied by the packing of atoms, molecules, and macromolecular chains in various materials, or particles in colloidal suspensions and granular powders. It allows activated movements clearly correlated with temperature, thus many physical properties and relaxation phenomena are strongly related to how large the free volume available in the systems [18,19,20]. Since the free volume theory adequately resolves how large freedom the entities have, which addresses a space related issue, and Eyring's rate process theory adequately describes how fast the process is, which answers a time related question, we thus integrate these two theories together to describe many seemingly unrelated systems like glass liquids [18], colloids [21], granules [14,20], electrical conductivity [22], and Hall Effect [23] with great success. With the confidence of the wide applicability of our approach, we further extend this approach to treat the universe where time and space or simply space time are most important parameters.

II. Theory

1. Freevon concept and the view of our universe

As mentioned earlier, the idea of introducing "freevon" concept should attribute to the success of the free volume theory widely utilized in pure liquids, glassy liquids, colloidal suspensions, polymer solutions, polymer melts, and granular matter, to explain the universal viscosity equations governing these systems and glass transition temperatures [13,21,14,18,22,23] . As illustrated in Figure 1, the free volume is the unoccupied space in a system and exists everywhere from very small entities like in an atom and very large entities like our universe. It is the free volume available in these systems listed above that controls the viscosity, electrical, or other physical properties. These "empty" spaces are largely ignored, as it is not part of real "matter" that we are traditionally interested in; However, all evidences collected so far suggest that the free volume plays an active and critical role, and its relationships with temperature and particle volume fractions controls many phase transition phenomena, even the superconductivity of materials. We therefore need to adequately address the "free volume" and pay serious attentions on what is inside the free volume.

The free volume cannot be treated as "nothing" inside. The man-made vacuum systems contains virtual particles that could yield flashes of light [24]. It is clearly evident that we need to spend extra energy in order to create additional free space, especially when a system almost reaches its maximum packing points; beyond the maximum packing points, it becomes extremely difficult to further enlarge the free volume and often needs a huge effort. We therefore postulate that the free volume is actually occupied by "freevons", another kind of fundamental particles that exist in the free space in every system. Freevons should be one kind of Boson rather than Fermion, or originally a Fermion but can form a boson if two freevon pairs together, like Cooper pair formed by electrons in superconductors. We thus will posit that any matter from microscopic electronic scales to visible large scales is a composite of the real materials immersing in a sea of freevons. Freevons may permeate over to any tiny free space, even occupying the spaces left by electrons in atoms. With this multi-scale physical picture of freevons, one may easily understand why the same free volume theory works for all systems from microscopic to macroscopic scales. It is thus naturally to expand this theory to cosmological scales, as huge free volumes do exist in our universe, indeed. Figure 1 could be used as a simplified scheme of our universe, each particles may represent a galaxy; within a galaxy, we know that the free volume still exists between stars, therefore particles can be considered as highly porous ones and the free volume also exists inside each particle.

Figure 1. Free volume is the unoccupied space in a system and expressed in the blue color in this illustration. The spherical shape particles in the system could be electrons, atoms, molecules, particulates, or cosmological galaxies. Each particle may be highly porous and has free volume inside the particles, too.

2. Application of Eyring's rate process theory to freevons

As one may already know, the Eyring's rate process theory has been successfully employed to treat a broad spectrum of physical phenomena, like conductivity and electron transfer [21], viscosity of pure liquids, colloidal suspensions, polymer solution and melts, and granular particles [12,14,23]. It will be employed again in this article to treat freevons for elucidating the expansion of universe. Regarding Eyring's rate process theory, please go to Eyring's classic book for detailed information [25]. For avoiding redundancy, we will directly borrow the derived equations from the treatment on electrons with Eyring's rate process theory, and the velocity of freevons, replacing electrons in the equation, may be written as [21]:

$$v_f = K^+\lambda\left[exp\frac{\alpha w}{k_B T} - exp\frac{-(1-\alpha)w}{k_B T}\right] \qquad (1)$$

where v_f is the velocity of freevons, K^+ is the specific velocity rate in any direction for undisturbed systems, $K^+ = \frac{k_B T}{h} exp(-\Delta G/RT)$, k_B is the Boltzmann constant, T is temperature, h is Planck constant, R is the gas constant, λ is the distance between the initial equilibrium position to the final position, α is directly related to the coordinate number (c_n) of freevons in the system, $\alpha = 1/c_n$, and w is the amount of work needed in moving a freevon from one equilibrium position to the next. We assume that the velocity of freevons is related to how fast the whole system is going to expand. After the big bang, the volume of the universe, V, may be assumed to expand three dimensionally and evenly like a sphere showing in Figure 2. When the volume expands, the radius of the sphere expands, too. We thus may assume that the volume is the function of both the radius *r* and time *t*, $V = V(r,t)$. The volume change rate may be written as:

$$\frac{dV}{dt} = \frac{\partial V}{\partial t} + \frac{\partial V}{\partial r}\frac{dr}{dt} \qquad (2)$$

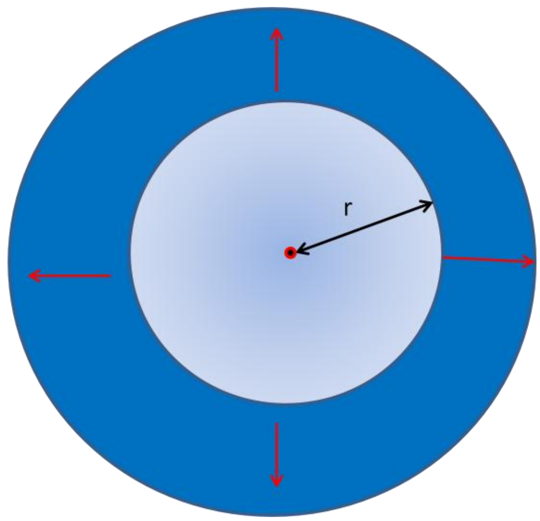


Figure 2 Schematic illustrations of universe expansions

Since $\frac{\partial V}{\partial r} = 4\pi r^2$, Eq. (2) may be re-written as:

$$dV = \frac{\partial V}{\partial t}dt + 4\pi r^2 dr \qquad (3)$$

According to the principal of total differentiation,

$$\frac{\partial^2 V}{\partial t \partial r} = 8\pi r \frac{dr}{dt} \qquad (4)$$

The left term of Eq.(4) is the expansion rate of universe, and $\frac{dr}{dt}$ should be equal to the velocity of freevons in the system, as freevon is supposed to move as fast as the expansion: whenever there is a free volume created, freevons are going to fill up immediately. Combining Eq. (1) and (4) leads to:

$$\frac{\partial^2 V}{\partial t \partial r} = 8\pi r K^+ \lambda \left[exp\frac{\alpha w}{k_B T} - exp\frac{-(1-\alpha)w}{k_B T} \right] \qquad (5)$$

Assuming $\frac{1}{\lambda}\frac{\partial^2 V}{\partial t \partial r} = v$, where *v* is the recessional velocity, Eq. (5) may be written as:

$$v = H_0 r \qquad (6)$$

with

$$H_0 = 8\pi K^+ \left[exp\,\frac{\alpha w}{k_B T} - exp\,\frac{-(1-\alpha)w}{k_B T}\right] \qquad (7)$$

Eq. (6) is the Hubble's law, if the recession of two-galaxy system can be assumed as one of the two galaxies is stationary and another galaxy is relatively moving away from the first one. In this scenario, the expansion may be considered as "spherical" expansion as shown in Figure 2, and $\frac{dr}{dt}$ may be called the linear expansions rate of the universe. Eq. (7) gives the Hubble's constant, indicating that the Hubble's constant actually isn't a constant, varying with temperature, the work needed for moving a freevon from equilibrium position to the next, the distance between the initial equilibrium position to the final position, the specific rate for the undisturbed system, and the parameter related to the coordinate numbers of freevons. However, at any measurement moment, these parameters could be reasonably assumed as "constants", for the sake of how we define the time and how the measurements are performed. Theoretically, the work *w* needed to move the freevon in a distance λ should be something related to the distance, and these two parameters aren't independent of each other. Based on how we generally define the "work" in physics, one may reasonably assume that $w = \Theta\lambda$ with Θ a constant in a system. Therefore, one may re-write Eq. (7) as:

$$H_0 = 8\pi K^+ \left[exp\,\frac{\alpha\Theta\lambda}{k_B T} - exp\,\frac{-(1-\alpha)\Theta\lambda}{k_B T}\right] \qquad (8)$$

Eq. (8) has four unknown parameters, $\alpha, \lambda, K^+,\ \Theta$. Apparently, if the expansion is accelerating, λ should increase, so does w.

Note that for the Eyring's rate process theory to be applicable to freevons, there must be an external field that may induce the freevons to move at certain directions; Or, the activity of freevons should be non-uniform at the very early beginning and there is an activity gradient existing in the universe. Otherwise, freevons may move to all random directions in three dimensional (3D) spaces, there is no "net" expansions to happen, as the possibility of freevons to move to any direction, including backwards and forwards, should be equal. So the parameter *w* is related to an external field that exerts on freevons to move at certain direction, like an electrical field that imposes on electrons and induces conductions at certain directions; Or, it is related to the activity gradient, like the diffusion process observed in our daily life. Since one cannot imagine there is another external field exerting on freevons to move meaningfully in a sense of "net" activities, one must posit that there should be a highly concentrated freevons region at the very early beginning in our universe. For this regards, one may need to assume that at the singularity where the big bang starts to happen, the freevons should be already there, with a extremely high activity or concentration; when the big bang happens, freevons starts to fill up the voids created during the explosion or expansion; if the space is infinite, the freevons activity gradient should exist all the time for ensuring the expansion to continue without a stop. Therefore, for the universe to expand and obey the Eyring's rate process theory, the universe must expand in preferential one direction for maintaining activity gradient. In consequence, the universe must evolve into a flat shape due to this requirement. The recent observation confirms that the universe is pretty flat with the spatial curvature less than 0.005, indeed [26].

The equilibrium constant of the universe expansion process could be estimated with Eq. (8). The equilibrium constant is typically defined as the activity or concentration ratio of the final products to the reactants. Since freevons may be considered as one kind of Bosons and the extremely high activity gradient of freevons must be maintained, the equilibrium constant of the Eyring's activation process during the expansion must be very small. Here we will give an estimation on the equilibrium constant based on what we know so far. According to the definition, $K^+ = \frac{k_B T}{h} exp\left(-\frac{\Delta G}{RT}\right)$ and ΔG is the standard Gibbs free energy of the activation process from the literature [25], Eq. (8) thus could be rearranged as:

$$H_0 = 8\pi \frac{k_B T}{h} exp\left(-\frac{\Delta G}{RT}\right)\left[exp\frac{\alpha\Theta\lambda}{k_B T} - exp\frac{-(1-\alpha)\Theta\lambda}{k_B T}\right]$$

$$= AT\left[exp\frac{\alpha\Theta\lambda}{k_B T} - exp\frac{-(1-\alpha)\Theta\lambda}{k_B T}\right] \qquad (9)$$

with

$$A = 8\pi \frac{k_B}{h} exp\left(-\frac{\Delta G}{RT}\right) \qquad (10)$$

The parameter A is $5.24{\times}10^{11}\ s^{-1}K^{-1}$ if the equilibrium constant, $K_c = 1$, where $K_c = exp\left(-\frac{\Delta G}{RT}\right)$, the highest possible number when the universe reaches the equilibrium status and there is no more expansion happening. When $K_c = exp\left(-\frac{\Delta G}{RT}\right) = 1$, then $K^+ = \frac{k_B T}{h}$. From the literature [27], one may find that $K^+ = \tau K_c$, hence $K^+ = \tau$ in this case, where τ is the relaxation time related parameter of freevons. Therefore, $\tau = \frac{k_B T}{h}$, implying that freevons may have a very high frequency even at very low temperature close to 1 Kelvin, let alone at extremely high temperatures when big bang starts. In addition, in reality $K_c \ll 1$ for the reason of the high activity gradient, the frequency is even much higher, making the freevons very hard observable.. The latest measurement of the Hubble's constant indicates that it is about 73 km/s /megaparsec, equivalent to $2.36{\times}10^{-18}\ s^{-1}$ [28], which results in the term $K_c T\left[exp\frac{\alpha\Theta\lambda}{k_B T} - exp\frac{-(1-\alpha)\Theta\lambda}{k_B T}\right] = 4.5{\times}10^{-30}$, a very small number. This may indicate that K_c could be a very small number, too, about $4.5{\times}10^{-30}$, if $T\left[exp\frac{\alpha\Theta\lambda}{k_B T} - exp\frac{-(1-\alpha)\Theta\lambda}{k_B T}\right] = 1$. Such a small equilibrium constant indicates that the activity gradient of freevons is extremely high, which may be the reason that the universe keeps expanding.

The Hubble's constant could be evaluated against temperature and the coordinate number related parameter using Eq. (8). According to the definition of the parameter α, $\alpha = 1$, if freevons form pairs, then Eq. (9) will be simplified as:

$$H_0 = AT\left[exp\frac{\Theta\lambda}{k_B T} - 1\right] \quad (10)$$

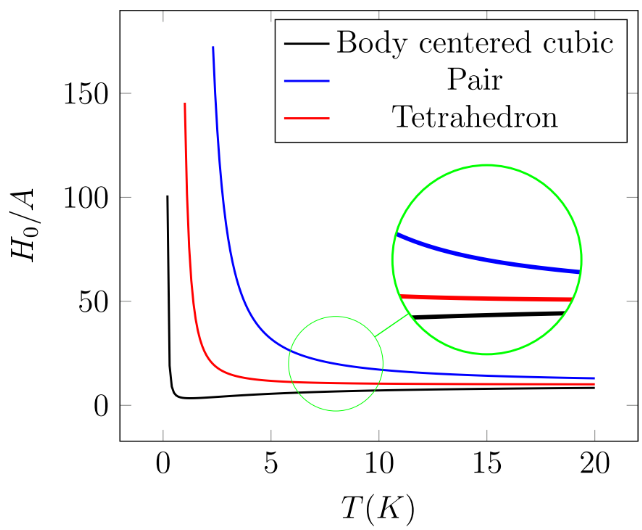
If freevons form a tetrahedral lattice structure, $\alpha = 1/4$, Eq. (9) may be written as:

$$H_0 = AT\left[exp\frac{0.25\Theta\lambda}{k_B T} - exp\frac{-0.75\Theta\lambda}{k_B T}\right] \quad (11)$$

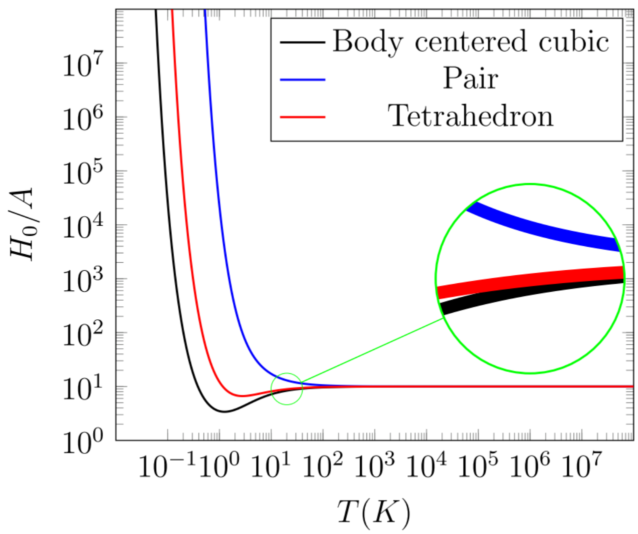
If freevons form a body-centered cubic lattice structure, $\alpha = 1/8$, Eq. (9) may be written as:

$$H_0 = AT\left[exp\frac{0.125\Theta\lambda}{k_B T} - exp\frac{-0.875\Theta\lambda}{k_B T}\right] \quad (12)$$

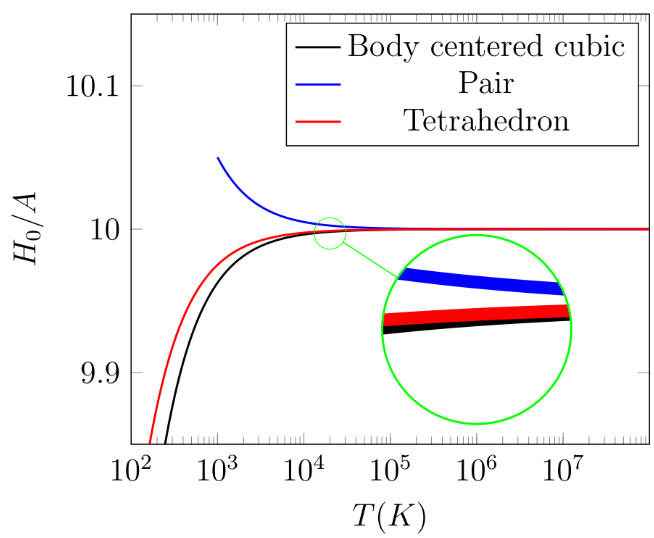
Using Eq. (10), (11), and (12), one may plot the normalized Hubble constant H_0/A against temperature under the assumption $\frac{\Theta\lambda}{k_B} = 10$, which is shown in Figure 3. If the universe really



(a)



(b)



(c)

Figure 3. The normalized Hubble constant $\frac{H_0}{A}$ *is plotted against temperature under assumption* $\frac{\Theta\lambda}{k_B} = 10$ *based on Eq. (10), (11), and (12). For clearly demonstrating the relationship, the graphs are plotted at several different scales: (a) Very low temperature range from 0 to 20 K; (b) very wide temperature range from 0.01 to* 10^8 *K; (c) Very wide temperature range but very small normalized Hubble constant range.*

follows the Eyring's rate process and the free volume theory, then it must obey what has been demonstrated in Figure 3: 1) If the freevons form the pair structures, the universe is going to expand in an accelerated manner, slowly accelerating from the temperature about 100 million *K* when the big bang starts, maintaining at such paces for a wide temperature range, and dramatically accelerating when the universe cools down to the current cosmologic temperature about 2.73 *K* [29]; 2) However, if the freevons form the body centered cubic or tetrahedron structures rather than the pairs, the universe is going to expand in a decelerated mode after the big bang, which is obviously contradictory to the current observations, though both two cases eventually would lead to a dramatic expansion when the temperature is low enough, very close to 1 *K* based on Figure 3b. Those two cases will not be discussed further due to their unrealistic natures. Note that the value of the term $\frac{\Theta\lambda}{k_B}$ is arbitrarily chosen as 10 in the calculation for simplicity; we have tried to render different values for this term and found that the different numbers can only move the normalized Hubble constant $\frac{\mathrm{H}_0}{\mathrm{A}}$ up and down along y axis and will not change the transition temperature points; 3) When freevons form the pair structures and the temperature reaches about 5 *K* as shown in Figure 3a, the normalized Hubble constant seems to go through a transition point and then dramatically speeds up. Since our current cosmological temperature is about 2.73 *K*, well below the transition temperature, we should observe even more dramatically accelerated expansion nowadays, if this prediction is correct. In a word, the freevons must form pair structures in the universe, which is the direct consequence of the Eyring's rate process theory and free volume concept.

The temperature induced phase transition predicted in our expansion process due to the pairing of freevons is very similar to superconductivity transition where electrons form the Cooper pair structures [21] and superfluidity of helium-3 where helium-3 atoms form pair structures [30,31]. In addition, for maintaining accelerated expansions, our prediction requires the freevons to form pairs at the very early stage. Superfluidity was believed to exist inside neutron stars even at extremely high temperatures [32,33]. Since freevons forms pairs and the current cosmological temperature is low enough, it is therefore reasonably to postulate that our current universe is in superfluidity state. Clearly, this is the direct consequence of the current framework utilizing the Eyring's rate process theory and the free volume concept. Our postulate is consistent with the previous hypothesis that the non-removable background of the universe could be considered as a superfluidity or Bose–Einstein condensate, proposed in the superfluidity vacuum theory that intends to unify the quantum mechanics and gravity in 1976 [34] and further evolved to be called the logarithmic BEC (Bose–Einstein condensate) vacuum theory [35]. The recent theoretical calculation indicates that if the spacetime is a liquid, the viscosity must be very close to zero, a superfluid [36], further supporting our result. Since our universe is in the superfluidity state, there should be no viscous dragging force caused by the freevons. We therefore will treat the universe as a zero viscosity fluid in next section, for the purpose of correlating this superfluidity state of freevons with gravity.

3. Two particle systems—gravity equation and Coulomb's law

Let's consider two particles, one large and one small, dispersed in a sea of freevons that form pair structure of zero viscosity. The volume of the small particle is V_1, and that of the large one is V_2, and they are separated with a distance r. The force density concept used in fluid mechanics will be borrowed to describe the field between those two particles. For an inviscid ideal superfluid, the force F in a volume V enclosed by a surface area S may be expressed as:

$$F = -\oint P\,\mathbf{n}\mathrm{d}S \tag{13}$$

where P is the pressure, a function of both time and position, $P(t, x, y, z)$. According to Gauss' law [37], Eq. (13) may be re-written as:

$$F = -\oint P\,\mathbf{n}\mathrm{d}S = -\int_{\mathrm{V}} \nabla \mathrm{P}\mathrm{d}\mathrm{V} \tag{14}$$

where ∇ is the a vector operator, $\nabla = \mathbf{x}\frac{\partial}{\partial x} + \mathbf{y}\frac{\partial}{\partial y} + \mathbf{z}\frac{\partial}{\partial z}$. Therefore, the force density, f, may be written as:

$$f = \frac{dF}{dV} = -\nabla P \tag{15}$$

It is the negative pressure gradient of a flow field. Again, P is the pressure, F is the force and V is the volume. For simplicity, the pressure is assumed to be independent of time and it only varies with the space. Every particle in the freevons sea will experience a force on the surface due to the pressure gradient, and larger particles will have larger pulling forces due to their larger volumes, as illustrated in Figure 4. Relatively, a gravitational potential field seems to be created around every particle thanks to the pressure gradient. Assume that the large particle will experience a force, F_2, which would create the pulling force to the small particle. This force exerts on the large particle surface and assumedly starts to change from the center of the particle. It of course originates from the negative pressure gradient and may have a similar relationship with depth or distance as the hydraulic pressure does, $F_2 \propto -\nabla P \propto -U_2 r$, where U_2 may be termed the gravitational field potential and r is the relative distance. It may be re-written as

$$U_2 = -\frac{F_2}{r} \tag{16}$$

for gaining an universal and consistent "potential" name as we use in the electric field, where the local electric field potential is the charge quantity divided by the distance. The parameter U_2 should be a constant relative to the large particle but may be inversely proportional to the distance relative to the small particle. One may further assume that there is an imaginary sphere based on the distance and the force density on the imaginary sphere surface will be:

$$f_r = \frac{dF}{dV} = \frac{dF_2/dr}{dV/dr} = -\frac{U_2}{4\pi r^2} \tag{17}$$

where f_r is the imaginary force density at the distance r, $V = \frac{4}{3}\pi r^3$. Under the influence of the force density from the large particle, a gravitational force F will exert on the small particle and may be expressed as:

$$F = f_r V_1 = -\frac{U_2 V_1}{4\pi r^2} \qquad (18)$$

Where V_1 is the volume of small particle. We know that the gravitational force exerted on the small particle from the large particle should be identical to that exerted on the large particle from the small particle. Therefore, Eq. (18) may be written as:

$$F = -\frac{U_2 V_1}{4\pi r^2} = -\frac{U_1 V_2}{4\pi r^2} \qquad (19)$$

For satisfying both Eq. (18) and Eq. (19), the constant U_1 and U_2 must have the form $U_2 = A_2 V_2$ or $U_1 = A_1 V_1$, where A_1 and A_2 are the particle related constants. Eq. (19) now can be re-written as:

$$F = -\frac{A_2 V_1 V_2}{4\pi r^2} = -\frac{A_1 V_1 V_2}{4\pi r^2} = -\frac{C V_1 V_2}{4\pi r^2} \qquad (20)$$

In this form, the gravitational forces from the small particle or from the large particle gain an identical expression and the parameters A_1 must equal to A_2 , $A_1 = A_2 = C$. The parameter C is a gravitational force related constant. Essentially, Eq. (20) is identical to the Newton's gravity equation, if the mass of the particle is defined as $m = Vd$, the product of the density and the volume and d is the density of the particles. In this case, Eq. (20) may be re-written as:

$$F = -\frac{C}{d_1 d_2}\frac{m_1 m_2}{4\pi r^2} = -G\frac{m_1 m_2}{r^2} \qquad (21)$$

where m_1 and m_2 are the mass of the small and large particles, and d_1 and d_2 is the density of the small and large particle, respectively. The parameter G is the regular gravitational constant and has the relationship with another parameter C:

$$G = \frac{C}{4\pi d_1 d_2} \qquad (22)$$

or $C = 4\pi d_1 d_2 G$. As one may see, the "mass" concept is not used in the derivation and it only appears in the end for comparison purpose with the Newton's gravitation equation. According to Eq. (20), the gravitational force is related to the volumes of both particles, which makes sense as the gravitational field can be assumed as a flow field with a pressure gradient; the force exerted on the particles are related to the pressure gradient, the particle density, and the volumes of the particles. Since the parameter C is known, then the gravitational field strength of both the small and large particles may be expressed as:

$$U_1 = 4\pi d_1 V_1 d_2 G,\ U_2 = 4\pi d_1 V_2 d_2 G \qquad (23)$$

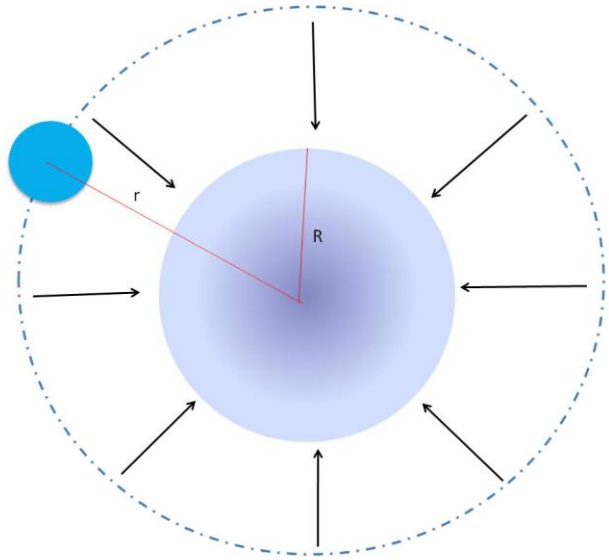


Figure 4 The schematic diagram of two particles in the space.

Surprisingly, the gravitational field strength is not only dependent on the physical properties of the particle itself, but also dependent on the density of the second particle! The only explanation may be that the local flow field created by the first particle could be distorted again due to the presence of the second particle; Both $V_1 d_2$ and $d_1 V_2$ may be considered "buoyancy" forces hat the particles may experience. Again, the gravitational field can be approximated as a flow field that can be distorted easily by the particles dispersed into it; in such a flow field, only the volume and density matter.

The same principle may be employed to derive the Coulomb's law for the interaction between two stationary charges. The force density concept may be defined as the same as before; It is this force that exerts on the small particle and generate the attractive or repulsive forces between those two charges. In analogy to Eq. (18), one may write down the same equation below for electrostatic interaction force:

$$F = f_r V_1 = -\frac{U_2 V_1}{4\pi r^2} \tag{24}$$

In the case that the electrostatic charge interaction takes place between two charge entities, the charged particles usually are considered as "point" charges with spherically symmetric distribution. It is thus reasonable to assume that the charge quantity q on the particles may be directly proportional to the volume of the particles, as the charges need to distribute evenly on the particle surfaces due to the repulsive forces between them. Hence one may assume $q_1 = k_1 V_1$. Under this assumption, one may obtain:

$$F = -\frac{U_2 q_1}{4\pi k_1 r^2} \quad (25)$$

Since the force exerted on the small particle from the field of the large particle should be identical to the force exerted on the large particle from the small particle, one may write the similar equations in analogy to Eq. (19):

$$F = -\frac{U_2 q_1}{4\pi k_1 r^2} = -\frac{U_1 q_2}{4\pi k_2 r^2} \quad (26)$$

Again, for satisfying Eq. (26), the parameters of both U_1 and U_2 should meet $U_1 = \frac{q_1}{k_1}$ and $U_2 = \frac{q_2}{k_2}$, thus Eq. (26) may be written as:

$$F = -\frac{q_1 q_2}{4\pi k_1 k_2 r^2} \quad (27)$$

Apparently, Eq. (27) is the Coulomb's law for the interaction between two charged particles. Both Newton's gravity law and Coulomb's law are obtained under same assumptions that the force density of the large particle may "emit" volumetrically and the reduction rate of the force exerted on the second particle may be directly proportional to the force density. In both cases, the volume under discussion seems to be extremely important. Note that the derivations above don't take the time variation into account and they are limited to the conditions where all objects under consideration are stationary, or the moving speed is negligible. Otherwise, Einstein's relativity and the relativistic hydrodynamics involving Euler's equations should be used [38].

It's worth to mention that we haven't used the concept of "mass" so far in our derivations. The mass could be defined using the Newton's second law and Euler's equation if the systems are considered as ideal superfluids without viscous force, which is the case due to the super fluidity nature of paired freevons. In case that a fluid of velocity **v**, mass *m*, and under a force **F**, $\mathbf{F} = m\frac{d\mathbf{v}}{dt}$. Since the velocity **v** is the function of both time and space, one may write:

$$d\mathbf{v}_1 = \frac{\partial \mathbf{v}}{\partial t} dt \quad (28)$$

referring to the velocity variation at a fixed space point during time interval *dt*. And

$$d\mathbf{v}_2 = \frac{\partial \mathbf{v}}{\partial x} dx + \frac{\partial \mathbf{v}}{\partial y} dy + \frac{\partial \mathbf{v}}{\partial z} dz \quad (29)$$

referring to the velocity variation at a given time between two points separated by d**r**. By definition, Eq. (29) may be simply expressed as:

$$d\mathbf{v}_2 = (d\mathbf{r} \cdot \nabla)\mathbf{v} \quad (30)$$

where ∇ is the Del operator. The total velocity variation may be written as: $d\mathbf{v} = d\mathbf{v}_1 + d\mathbf{v}_2 = \frac{\partial \mathbf{v}}{\partial t} dt + (d\mathbf{r} \cdot \nabla)\mathbf{v}$ **.** Thus, the force may be written:

$$\mathbf{F} = m\frac{d\mathbf{v}}{dt} = m(\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla)\mathbf{v}) \qquad (31)$$

The term $\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla)\mathbf{v}$ is the acceleration of the motion. Based on Eq. (14), one may easily obtain:

$$m = -V\nabla P/[\left(\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla)\mathbf{v}\right)] \qquad (32)$$

or

$$\left[\left(\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla)\mathbf{v}\right)\right] = -\frac{1}{\rho}\nabla P \qquad (33)$$

where $\rho = \frac{m}{V}$, the fluid density. Eq. (33) is the Euler equation. In this article, both volume and force density are considered primary parameters rather than the mass, Eq. (32) tells us that the mass is directly proportional to the product of the volume and the force density, i.e., the force exerted on the particle divided by the acceleration that is the function of the velocity rate and the divergence in the space. Clearly, the mass may only be a constant when the velocity is extremely high and the volume and the force density remain a constant, too. If an electric field and a magnetic field exist in the space, Eq. (33) should be re-written as [39]:

$$\left[\left(\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla)\mathbf{v}\right)\right] = -\frac{1}{\rho}[\nabla P + q(E + \mathbf{v} \times \mathbf{B})] \qquad (34)$$

III. Discussion

Freevons are hypothetically introduced in this article on the basis of the very successful free volume concept that has been utilized to help us understand many physical phenomena like phase transitions, glass transitions, and diffusions; Many important physical properties such as viscosity and conductivity can be well described with the free volume concept. It can be used to treat the systems containing entities as small as electrons, simple molecules like water, macromolecules such as polymers, colloidal particles, and even large particles as big as granules. It is therefore naturally to postulate that the free volume concept may be applicable to cosmological entities like galaxies and the whole universe. Freevons are supposed to quickly fill up the free volume available from microscopic atomic world to macroscopic universe, providing the possibility that a single theory on freevons could be applicable to all length scales and thus the principles and laws govern the microscopic and macroscopic worlds could be unified, which is the original driving force for us to work on this problem.

If freevons really obey the Eyring's rate process theory, freevons must form pairs and behave very similarly to the paired electrons in superconductivity state, or paired atoms in superfluidity state, to account for the accelerated expansion of the universe. There should be a phase transition occurring at very low temperatures and the Hubble's constant is predicted to dramatically increase in the future as the universe continues to cool down, which could be used to examine if freevons really exist. Note that there is no "vacuum" state in our framework, as it is filled up with freevons, which substantially differs our theory from the superfluidity vacuum theory and the logarithmic BEC (Bose–Einstein condensate) vacuum theory. Our approach actually substantiates the hypothetical superfluidity theory, bridging the accelerated expansions of the universe with the superfluidity and most importantly building up the connections between gravity and the accelerated expansions.

Freevons should be a kind of Bosons rather than Fermions, as one cannot imagine that they are distinguishable. As shown earlier, freevons should have a very high frequency dependable on temperature, $\tau = \frac{1}{K_c}\frac{k_B T}{h}$, thus high energy, too. They may carry a mass, as they generate pressure gradient and induce "superficial" gravity observed in our daily life. They could represent the dark matter and dark energy in the universe, if we really need those two terms. Note in our framework, the dark matter and dark energy are unnecessary concepts and the driving force of the universe expansion or inflation is the activity gradient of freevons created at the big bang point. If freevons really exist as high energy particles, their behaviors should be described with quantum mechanics, providing the possibilities of explaining many intriguing cosmological phenomena with quantum mechanics, too.

We haven't touched the black hole issue yet. But if the universe is filled with superfluidity freevons, the traditional spacetime could be considered an inviscid fluid; Therefore, the black holes could simply be heterogeneous regions where there are sinkholes in the bottom of the liquid; Everything could be spirally sucked into the holes, like what we have already seen the water flow pattern in a water tank with a drainage hole at the bottom. The gravitational waves [40] detected in 2016 could be the splash waves generated when one huge particle passes through a black hole or when two particles coalesce together.

The universe could be analogously considered as a well dispersed colloidal suspension, where the particles, i.e. the stars and galaxies, dispersed in a superfluidity liquid. Since there is no viscous force in this system, the particles may move endlessly in their original obits or speeds; the particles may occasionally coalesce together due to strong interparticle forces, or due to the suction effect arisen from the local uneven velocity distributions of the superfluidity liquid. We actually are living in the "freevon sea" of superfluidity property, generating pressure to any particles dispersed in this liquids and inducing "gravity" accordingly; In the mean while, the fluidity of these freevons will surely create expansion of universe, due to the nature of the very high frequency of freevons.

IV. Conclusions

On the basis of the successful free volume theory applicable to many systems containing entities from as small as electrons to as large as granules, freevons are hypothetically proposed to fill up any free volume available in any system at any length scales. Under the assumption that the freevons would still obey the Eyring's rate process theory as we observed in atomic, molecular, colloidal, and granular systems, the accelerated expansion of the universe only becomes possible when freevons form pair structures and the freevons are in superfluidity state; there should be a phase transition at about 5 *K*, below this point the Hubble constant is predicted to even more dramatically increase, implying that the expansion will accelerate even further. The driving force of the universe expansion is the extremely high activity gradient of freevons that must be maintained at a certain preferential direction due to the requirement of the Eyring's rate process theory. Therefore, the universe must evolve into a flat shape. The universe could be considered as particles dispersed in the superfluidity freevons sea, and the gravity is thus induced by the negative pressure gradient in the system. Under this physical picture, the Newton's gravity equation and Coulomb's law for electrical charge interactions can be easily obtained.

The approach employed in this article is exactly same as utilized in electronic, molecular, colloidal particles, and granular systems; All those systems from electronic to cosmological scales are therefore unified and treated with a single theoretical framework: the combination of the Eyring's rate process theory and free volume concept. It may shed light on many mysteries in our universe, simplify many difficult theories, and build up the connections between them.

Acknowledgement: The authors greatly appreciate colleagues and reviewers' constructive comments and suggestions that make this paper more logical and readable.

References:

1. A. Einstein. Kosmologische Betrachtungen zur allgemeinen Relativitätstheorie (Cosmological Considerations in the General Theory of Relativity). *Preussische Akademie der Wissenschaften, Sitzungsberichte* **1917,** 142–152.

2. A. Friedman. Über die Krümmung des Raumes. English translation in: Friedman, A. (1999). "On the curvature of space". General Relativity and Gravitation 31 (12): 1991–2000. *Zeitschrift für Physik* **1922,** *10* (1), 377–386.

3. S. Weinberg. The cosmological constant problem. *Rev. Mod. Phys.* **1989,** *61*, 1-23.

4. T. Clifton, P. G. Ferreira, A. Padilla, C. Skordis. Modified gravity and cosmology. *Phys. Rep.* **2012,** *513* (1-3), 1–189.

5. G. Lemaître. Un univers homogène de masse constante et de rayon croissant rendant compte de la vitesse radiale des nébuleuses extragalactiques". Annals of the Scientific Society of Brussels (in French). *Annals of the Scientific Society of Brussels (in French)* **1927,** *A47*, 49-59.

6. R. G. Vishwakarma. Einstein's gravity under pressure. *Astrophys Space Sci* **2009,** *321,* 151–156.

7. M. Li, X. Li, S. Wang, and Y. Wang. *Dark Energy;* World Scientific Publishing Co, 2014.

8. A. Einstein. Zur Elektrodynamik bewegter Körper (On the Electrodynamics of Moving Bodies). *Annalen der Physik* **1905,** *322* (10), 891-921.

9. P.W. Higgs. Broken Symmetries and the Masses of Gauge Bosons. *Phys. Rev. Lett.* **1964,** *13* (16), 508–509.

10. R. P. Kirshner. *The Extravagant Universe: Exploding Stars, Dark Energy, and the Accelerating Cosmos;* Princeton University Press: Princeton, 2002.

11. H. Eyring. The Activated Complex in Chemical Reactions. *J. Chem. Phys.* **1935,** *3* (2), 107–115.

12. H. Eyring. Viscosity, Plasticity, and Diffusion as Examples of Absolute Reaction Rates. *J. Chem. Phys* **1936,** *4,* 283-291.

13. H. Eyring and J. O. Hirschielder. The theory of the liquid state. *J. Phys. Chem.* **1937,** *41,* 249-257.

14. T. Hao. Analogous Viscosity Equations of Granular Powders Based on Eyring's Rate Process Theory and Free Volume Concept. *RSC Adv.* **2015,** *5,* 95318-95333.

15. D. Turnbull, D. and M.H. Cohen. Free-Volume Model of the Amorphous Phase: Glass Transition. *J. Chem. Phys.* **1961,** *34,* 120-124.

16. M.H. Cohen and D. Turnbull. Molecular transport in liquids and glasses. *J. Chem. Phys.* **1959,** *31,* 1164-1169.

17. H. Fujita. Notes on Free Volume Theories. *Polymer J.* **1991,** *23,* 1499-1506.

18. T. Hao. Unveiling the relationships among the viscosity equations of glass liquids and colloidal suspensions for obtaining universal equations with the generic free volume concept. *Phys. Chem. Chem. Phys.* **2015,** *17,* 21885-21893.

19. T. Hao. Derivation of stretched exponential tap density equations of granular powders. *Soft Matter* **2015,** *11* (15), 3056-3061.

20. T. Hao. Tap density equations of granular powders based on the rate process theory and the

free volume concept. *Soft Matter* **2015,** *11,* 1554-1561.

21. T. Hao. Electrical conductivity equations derived with the rate process theory and free volume concept. *RSC Adv.* **2015,** *5,* 48133-48146.

22. Tsu-Sen Chow. *Mesoscopic Physics of Complex Materials;* Springer, 2000.

23. T. Hao. Viscosities of liquids, colloidal suspensions, and polymeric systems under zero or non-zero electric field. *Adv. Coll. Interf. Sci.* **2008,** *142,* 1-19.

24. Q. C. Choi. A vacuum can yield flashes of light. *Nature* **2013,** doi:10.1038/nature.2013.12430.

25. S. Glasstone, K. Laidler, and H. Eyring. *The theory of rate process;* McGraw-Hill: New York, 1941.

26. Planck Collaboration; P. A. R. Ade, N. Aghanim, M. Arnaud, et.al. Planck 2015 results. XIII. Cosmological parameters. *Astronomy & Astrophysics* **2016,** *594,* A13.

27. T. Hao. Integer, Fractional, and Anomalous Quantum Hall Effect Explained with Eyring's Rate Process Theory and Free Volume Concept. *viXra:1611.0357* **2016**.

28. A. G. Riess, L. M. Macri, S. L. Hoffmann, D. Scolnic, S. Casertano, A. V. Filippenko, B. E. Tucker, M. J. Reid, D. O. Jones, and J. M. Silverman. A 2.4% determination of the local value of the Hubble constant. *The Astrophys. J.* **2016,** *826* (1).

29. D. J. Fixsen. The Temperature of the Cosmic Microwave Background. *The Astrophys. J.,* **2009,** *707* (2), 916-920.

30. A. J. Leggett. Interpretation of Recent Results on He3 below 3 mK: A New Liquid Phase? *Phys. Rev. Lett.* **1972,** *29* (18), 1227–1230.

31. D. D. Osheroff, W. J. Gully, R. C. Richardson, D. M. Lee. New Magnetic Phenomena in Liquid He3 below 3 mK. *Phys. Rev. Lett.* **1972,** *29* (14), 920–923.

32. A. B. Migdal. Superfluidity and the Moments of Inertia of Nuclei. *Soviet Phys. JETP* **1960,** *37* (10), 176-185.

33. U. Lombardo and H. -J. Schulze. Superfluidity in Neutron Star Matter. *Physics of Neutron Star Interiors. Lecture Notes in Physics* **2001,** *578,* 30-53.

34. K. P. Sinha, C. Sivaram, and E. C. G. Sudarshan. The superfluid vacuum state, time-varying cosmological constant, and nonsingular cosmological models. *Foundations of Phys.* **1976,** *6*

(6), 717–726.

35. A. V. Avdeenkov and K. G. Zloshchastiev. Quantum Bose liquids with logarithmic nonlinearity: Self-sustainability and emergence of spatial extent. *J. Phys. B: At. Mol. Opt. Phys* **2011,** *44*, 195303.

36. S. Liberati and L. Maccione. Astrophysical Constraints on Planck Scale Dissipative Phenomena. *Phys. Rev. Lett.* **2014,** *112*, 151301.

37. P. K. Kundu, I. M. Cohen, and D. R. Dowling. *Fluid Mechanics, 5th Edition;* Academic Press, 2011.

38. L. Rezzolla and O. Zanotti. *Relativistic Hydrodynamics;* Oxord University Press, 2013.

39. W.J. Maciel. *Hydrodynamics and Stellar Winds: An Introduction;* Springer International Publishing Switzerland , 2014.

40. B. P. Abbott et al. (LIGO Scientific Collaboration and Virgo Collaboration). Observation of Gravitational Waves from a Binary Black Hole Merger. *Phys. Rev. Lett.* **2016,** *116*, 061102.