Physics Related with Co-moving Coordinate System

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We derive the metric of an expanding universe with zero accelerations by pure kinematic method. By doing so we expatiate physics related with co-moving coordinate system in details. The most important discovery or our study is, in an expanding universe with zero accelerations, the red-shift of photons from distance galaxies is determined by the co-moving coordinate of the source galaxy instead of the scale factor’s time dependence. Our discovery is consistent with the current observed super-novae’s luminosity-distance v.s. red-shift relations.

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I. INTRODUCTION

The luminosity-distance v.s. red-shift relation of type Ia super-novae is the most direct evidence of dark energy’s existence see [2–6] for experimental literatures and [10–13] for theoretical explanations. The matter distribution power spectrum observed by SDSS [8] and cosmic microwave background anisotropy observed by WMAP [7] is indirect evidence of dark energy’s existence. We will provide a new explanation for super-novae’s luminosity-distance v.s. red-shift relation without assuming that the universe is accelerate-ly expanding. Our explanation will avoid almost all the main problems of standard cosmology before inflation is introduced into physics.

Our explanation resorts to new interpretation of physics related with co-moving coordinate system. As the first step, We would like to ask, if one focuses on a given direction of a non-perturbed universe, will he see an infinitely long, uniform and expanding galaxy line? If no, why? We consider only flat universe.

If yes, suppose this man/woman were put on galaxy O and were asked to measure the recession velocity of galaxy B and C, see FIG.1, what result will he/she get? (v, 2v) or (v, $\frac{2v}{\sqrt{2}}$)? $v$ is the relative recession velocity between two nearest galaxies. We insist the second answer, i.e., we insist that (i) cosmological principle is a local statement; (ii) the definition of simultaneity can only be relativistic.

If the one dimensional system in Figure.1 is uniformly expanding, the metric is

$$ds^2 = -dt^2 + a^2(t)d\bar{x}_{co}^2$$

when generalizing into (1+3)D space-time, we have

$$ds^2 = -dt^2 + a^2(t)(dr_{co}^2 + r_{co}^2[dr^2 + \sin^2\theta d\phi^2])$$

Some standard cosmologists claim that, the generalization of $(1+1)D \Rightarrow (1+3)D$ is ir-rationale. Because $(1+1)D$ gravitation theory is topological, its $G_{\mu\nu} = 0$, so no dynamical equations can be used to determine $a(t)$.

However if we know the $(1+1)D a(t)$ somehow, the generalization to $(1+3)D$ is rationale, because if we are considering a non-perturbed universe and if we are focusing on only a given direction, we will see the galaxy line in FIG. 1. Since the projection $(1+3)D \Rightarrow (1+1)D$ involves only kinematic, it involves no dynamics.

So our claiming is: if we know the $(1+1)D a(t)$ somehow, generalization of eq(1) into eq(2) is rationale, because the generalization only involves kinematic, it involves no dynamics. Although the $(1+1)D$ gravitation is topological, $G_{\mu\nu} = 0$, the $(1+3)D$ metric obtained by generalizing a pre-given $(1+1)D$ metric has non-zero $G_{\mu\nu}$. So non-trivial dynamics can appear in the generalized $(1+3)D$ space-time.

For example, if the system illustrated in FIG. 1 is expanding with zero acceleration, we can derive its metric $-(1+1)D$ form- by pure kinematic method then generalize the results into $(1+3)D$ space-time thus obtain the metric of an isotropic and homogeneous universe whose expansion has zero acceleration. The $(1+1)D$ metric we obtained by pure kinematic method has identically zero $G_{\mu\nu}$, but the generalized $(1+3)D$ metric has non-zero $G_{\mu\nu}$. So in the $(1+3)D$ space-time, non-trivial dynamic appears. On the other hand, if we know the energy momentum tensor corresponding with an expanding universe with zero accelerations as priors, directly solving the $(1+3)D$ dynamic equation will give us the same metric as that obtained by kinetic method of $(1+1)D$.

II. $(1+1)D$ EXPANDING UNIVERSE WITH ZERO ACCELERATIONS

Take the galaxy line in FIG.1 as our experimental labs. Suppose the system is expanding with zero accelerations.

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Considering the following series

\[ v_B = v; \]
\[ v_C = \frac{v + v}{1 + v^2}; \]
\[ v_D = \frac{v + v_C}{1 + v \cdot v_C}; \]
\[ \vdots \]
\[ v_X = \frac{v + v_{X-1}}{1 + v \cdot v_{X-1}}; \]
\[ |AB| = 2a \]
\[ |OC| = 2a\sqrt{1 - v_B^2} \]
\[ |BD| = 2a\sqrt{1 - v_C^2} \]
\[ \vdots \]
\[ |X^+ - X^+| = 2a\sqrt{1 - v_X^2}. \]  

(3)

(4)

\( v, a \) are locally measured relative recession velocity and distance between two nearest galaxies respectively. Since we consider only the non-accelerate-ly expanding universe, so \( a = v \cdot t \). From series eqs(3) and (4) we get

\[ v_X = \frac{(1 + v)^X - (1 - v)^X}{(1 + v)^X + (1 - v)^X}; \]

\[ |OX| \sim a \sum_{N=0}^{X} \sqrt{1 - v_N^2} \]

\[ = l \int_{0}^{\infty} dx \sqrt{1 - v_x^2} \]

\[ = \frac{4a}{\ln(1 + v)} \left[ \arctg\left(\frac{1 + v}{1 - v}\right) + \frac{\pi}{4} \right]. \]  

(5)

(6)

From eq(6) using light velocity invariance principle, we can write down the metric of our (1+1)D non-accelerate-ly expanding universe as

\[ ds^2 = -dt^2 + \frac{4v^2t^2}{(e^{\sigma x} + e^{-\sigma x})^2} dx^2 \]

where \( \sigma = \frac{1}{2} \ln(1 + v) \frac{-1}{1 - v} \)  

or

\[ ds^2 = -dt^2 + a^2(t) dx^2, \quad a(t) = v \cdot t \]  

where \( x co = \frac{2}{\sigma} (\arctg[e^{\sigma x}] - \frac{\pi}{4}). \]  

(7)

(8)

(9)

(10)

We call the coordinate \( x \) in eq(7) natural coordinate, while the coordinate \( x co \) in eq(9) co-moving coordinate. Natural coordinate ranges in \( (-\infty, \infty) \), but co-moving coordinate only ranges in \( (-\frac{\pi}{2\sigma}, \frac{\pi}{2\sigma}) \). If \( v \to 0 \), natural coordinate coincides with co-moving coordinate. The co-moving coordinate definition of Standard cosmology emphasizes only one point: co-moving coordinate is a coordinate fixed on galaxies, the co-moving coordinate of a given galaxy does not vary as background universe expands. By this definition, natural coordinate is also co-moving coordinate.

But the difference between co-moving coordinate and natural co-ordinate is very important. Natural coordinate is related with physical coordinate through

\[ x_{ph} = \frac{2vt}{\sigma} (\arctg[e^{\sigma x}] - \frac{\pi}{4}). \]  

(11)

While co-moving coordinate is related with physical coordinate through

\[ x_{ph} = a(t) \cdot x_{co}, \quad a(t) = v \cdot t. \]  

(12)

Although the co-moving coordinate defined in eq(12) is very similar to that of standard cosmology, it has completely different interpretation from that of standard cosmology.

By standard cosmology’s definition \( x_{ph} = a(t) \cdot x_{co} \), if we have a photon emitted at \( (t, x_{co}) \) and detected at \( (t_0, 0) \), the red-shift of this photon is \( 1 + z = \frac{a(t_0)}{a(t)} \), it has nothing to do with the co-moving coordinate of source galaxy. But in the co-moving coordinate definition of eq(12), for the same photon, the red-shift is

\[ (1 + z) = \sqrt{\frac{1 + v_x}{1 - v_x}} = e^{\sigma x}. \]  

(13)

It is completely determined by the co-moving coordinate of source galaxy but has nothing to do with scale factor!

If we accept eqs(11)+(13), then even without assuming that the universe is accelerate-ly expanding, we can give the observed luminosity-distance v.s. red-shift relation of super-novas a very beautiful explanation. Of course, if one would like to, he can replace the velocity \( v \) in eqs(7), (9), (11) and (12) with a time dependent function \( v(t) = v + pt + \frac{pt^2}{2} + ... \), and the factor \( a(t) = v \cdot t + \frac{pt}{2} + \frac{pt^2}{6} + ... \) thus obtain appropriate relations in an accelerate-ly expanding universe. In this case eq(13) will be changed so that more free parameters enter, hence more precise fitting with experiments can be obtained.

### III. GENERALIZATION INTO (1+3)D SPACE-TIME

Generalizing eqs(7) or (9) into (1+3)D space-time, we obtain

\[ r_{ph} = \frac{2vt}{\sigma} (\arctg[e^{\sigma r}] - \frac{\pi}{4}) \]

(14)

\[ ds^2 = -dt^2 + \frac{v^2t^2}{\cosh^2 \sigma r} (dr^2 + r^2[\theta^2 + \sin^2 \theta d\phi^2]) \]  

(15)

\[ r_{ph} = a(t) \cdot r_{co}, \quad a(t) = vt, 0 \leq r_{co} \leq \frac{\pi}{2\sigma} \]  

(16)

\[ ds^2 = -dt^2 + a^2(t) (dr_{co}^2 + \frac{t^2}{\cosh^2 \sigma r} [\theta^2 + \sin^2 \theta d\phi^2]) \]  

(17)

The parameter \( v \) now should be understood as the average recession velocity between two nearest galaxies. If we
take a limit $v \to 0$, co-moving coordinate reduce to natural coordinate, eq(17) becomes (15). Note, we consider only galaxies which are performing Hubble recensions relative to each other. We do not consider galaxies bounded in the galaxy clusters.

Just the same as (1+1)D case, eq(17) is very similar to standard cosmology’s FRW metric, but the two has completely different physical interpretations. E.g. if we have a photon emitted at $(t, r_{co}, \theta, \phi)$ and detected at $(t_0, 0, \theta, \phi)$. By standard cosmology, the red-shift of this photon is $(1 + z) = \frac{dt}{d\tau}$, but by our explanation of eq(17), the red-shift is

$$(1 + z) = \sqrt{\frac{1 + vr}{1 - vr}} = e^{\sigma r} \tag{18}$$

Although our starting point, the (1+1)D metric eqs(7) and (9) are topological theory, it has no dynamics. When we generalize them into (1+3)D case, eqs(15) or (17), non-trivial dynamics appears. By Einstein equation, we can calculate the energy momentum tensor corresponding with them. The results are respectively

$$8\pi GT_{\mu\nu, na} = -G_{\mu\nu, na} = -\text{diag}$$

$$\{-(6v^2 r + 5\sigma^2 r - \sigma^2 r \cosh[2\sigma r] + 4\sigma \sinh[2\sigma r])$$

$$\left(\frac{2v^2 r^2}{\sigma^2 r \sinh[2\sigma r]} \right)$$

$$, \left(\sigma^2 + v^2 \right) \text{sech}^2[\sigma r] + \sigma (\sigma - \frac{2\tanh[\sigma r]}{r})$$

$$, r^2 (\sigma^2 + v^2) \text{sech}^2[\sigma r] + \sigma r \tanh[\sigma r],$$

$$\sin^2 \theta \left[ r^2 (\sigma^2 + v^2) \text{sech}^2[\sigma r] + \sigma r \tanh[\sigma r] \right]\} \tag{19}$$

$$8\pi GT_{\mu\nu, co} = -G_{\mu\nu, co}$$

$$=-\text{diag}\{\frac{3}{r^2}, v^2, v^2 r_{co}, v^2 r_{co} \sin^2 \theta \} \tag{20}$$

If we know the energy momentum tensor describing the cosmological fluid is $T^\mu_\nu = \text{diag}(\rho, \frac{1}{3} \rho, \frac{1}{3} \rho, \frac{1}{3} \rho)$ in the co-moving coordinate, i.e. $T^\mu_\nu$ expressed in eq(20) times $g^\mu\nu$, then starting from a general ansatz $ds^2 = -dt^2 + a(t)(dr^2 + r^2 d\Omega^2)$, using Einstein equation, we can also derive out the function form of $a(t) = v \cdot t$. This is just the routine of standard cosmology. But this routine slides over all physics related with the definition of co-moving coordinate system, see eq(18) and the related remarks.

From eq(20), we can see that in the co-moving coordinate system, for a non-accelerately expanding universe, its cosmological fluid has pressure $p = -\frac{1}{3} \rho$. Note it is $T^\mu_\nu$, not $T_{\mu\nu}$, that is directly related with energy density and pressure, $T^\mu_\nu = pu^\mu u_\nu + p(u^\nu u_\nu + \delta^\mu_\nu)$. We have two reasons to accept this negative pressure.

The first reason is, we can think it originates from dark energy, e.g., $T^\mu_\nu = (\rho, \frac{1}{3} \rho, \frac{1}{3} \rho, \frac{1}{3} \rho)$, so no negative pressure also exists as a result of gravitations. Imagine an infinitely long uniform galaxy line, if one of the composite galaxies is less weighted than others, then all galaxies on the left hand side of this less weighted galaxy will collapse and move to the left, while all galaxies on the right hand side of this less weighted galaxy will collapse and move to the right. So, the less weighted galaxy receives gravitations which have intentions to split it into two parts. This intention can be understood as the origin of negative pressure. A less weighted galaxy is just an auxiliary object to illustrate the effects negative pressure. When all galaxies are equal weighted, negative pressure also exists as a result of gravitations.

If we accept the first reason, i.e., negative pressure originates from dark energy, then we will have to accept that our metric eqs(15) and (17) only describe our universe in a very short period of time. Because \( \rho_m \propto a^{-3}(t) \), while \( \rho_de \propto a^{-3(1+w)}(t) \). If \( \rho_m \sim \rho_de \) today, then in the far past, \( \rho_de \) must be much less than \( \rho_m \), so negative pressure provided by dark energy will not be able to prevent the universe from decelerate-ly expanding. If we accept the second reason, i.e. dark energy originates from gravitations between different parts of the universe, then our metric eqs(15) and (17) can be used to describe the universe in any eras when the gravitation is the main interaction between different parts of the universe.

Of course, at very early times, galaxies do not exist, so the parameter $v$ cannot be understood as the average recession velocity between two nearest galaxies, but according to the hierarchical clustering scenario, before galaxies appear, stars exist, before stars appear, nucleon exists, before nucleon appears, electron and protons exists, ... So, as long as we accept that inter-gravitations among different parts of the universe produce negative pressures, while the average velocity of relative recession between two nearest composite object is $v$, then eqs(15) and (17) can be used to describe our universe at times as early as big-bang nucleon synthesis, even primordial singular point. While God, need only calculate and assign value to one parameter $v$, so that when the universe is 137Gyr old, human appears.

IV. OBSERVATIONS OF SUPER-NOVAE

From theoretical aspects, the basis of eqs(15) and (17) is very simple and concrete, (i) cosmological principle is a local statement; (ii) the definition of simultaneity can only be relativistic. However, will experimental observations support it? The luminosity-distance v.s. red-shift relation of super-novae is the most direct evidence that the universe is accelerate-ly expanding. But this statement is based on ignoring of physics related with co-moving coordinate system discovered in this paper. We will show that when considering physics related with co-moving coordinate system, the observational result can be explained even without assuming that our universe is accelerate-ly expanding.
If we consider physics related with co-moving coordinate system, the red-shift of photons coming from distant galaxies will be changed remarkably comparing with standard cosmology. When the universe is assumed expanding with zero acceleration, photons emitted from a super-nova at position \( (t, r, \theta, \phi) \) have red-shift

\[
(1 + z) = \frac{1 + v_r}{1 - v_r} = e^{\sigma r}. \tag{21}
\]

Considering Lorentz dilating, the photons emitted in period \( \delta t \) can only reach us in period \( \delta t e^{\sigma r} \). So we get the luminosity-distance v.s. red-shift relation as

\[
d_l = (1 + z) \cdot \frac{2v \cdot H_0^{-1}}{\sigma} \left[ \arctg(1 + z) - \frac{\pi}{4} \right]. \tag{22}
\]

Please refer to [1], section 14.4, eqs(14.4.11-14) for detailed derivation of eq(22).

\[\text{FIG. 2: The luminosity distance v.s. red-shift relation of super-novae. Red(solid) line is the prediction of this paper; Black(dot) line is the prediction of \( \Lambda \)CDM cosmology, in which } \Omega_m = 0.27, \Omega_{\Lambda} = 0.73, H_0 = 71 \text{ km/(s} \cdot \text{Mpc); Blue(dash) line is the prediction of standard CDM cosmology, in which } \Omega_m = 1.0, H_0 = 71 \text{ km/(s} \cdot \text{Mpc).}\]

\[\text{From FIG. 2, we can see that when considering physics related with co-moving coordinate system, even without assuming that our universe is accelerate-ly expanding, theoretical predictions are very close to predictions of } \Lambda \text{CDM cosmology. From best fitting observational results of [6], we get } v = 0.79/3000, H_0 = 60 \text{ km/(s} \cdot \text{Mpc), } \chi^2 = 303 \text{ (186Golden+Silver sample) or } v = 0.899/3000, H_0 = 60 \text{ km/(s} \cdot \text{Mpc), } \chi^2 = 237 \text{ (157Golden sample).}\]

\[\text{Only judging from numerical fitting qualities, our prediction eq(22) may be not as good as standard cosmology. But our theoretical frame-work has only two free parameters, } v \text{ and } H_0, \text{ while standard cosmology actually uses three parameters, } \Omega_m, H_0 \text{ and } w. \text{ The superiority of our frame-work over standard cosmology is mainly on theoretical aspects.}\]

\[\text{Standard cosmology does not give any explanation of negative pressure’s producing mechanism, so the equation of state coefficient } w \text{ of dark energy must be counted as a free parameter. But we provide a possible negative pressure producing mechanism, it can produce } p = -\frac{1}{3} \rho. \]

\[\text{We will discuss this problem in more details in the discussion section. Since we do not resort to dark energies to explain the luminosity-distance v.s. red-shift relation of super-novae, our universe contains only matters today, so our cosmological frame-work has no coincidence problem [9].}\]

\[\text{Since in our cosmological frame-work, universe expands with zero acceleration, the size of the observable universe is always equal to the particle horizon of the universe. So our frame-work has no horizon problem. Since our cosmological frame-work has no horizon problem, quantum fluctuations inside the horizon will provide the primordial seeds for latter structure formations. So our frame-work has no primordial structure formation seeds problem [14–16].}\]

\[\text{Considering physics related with co-moving coordinate system, the global topology of the universe is not related with the energy density of the universe through a simple Friedmann equation } \frac{\dot{a}^2}{a^2} + k = \frac{8\pi G}{3} \rho_{tot}. \text{ We have not found the metric of a closed/open universe by kinematical method. Probably, eq(17) is the only solution of the real universe. If that is the case, our cosmological frame-work has no flatness problem at all.}\]

\[\text{V. DISCUSSIONS}\]

\[\text{There are two worries about our considering of physics related with co-moving coordinate system. The first is, since we use special relativity velocity addition rules to calculate recession velocity of galaxies on a given observational direction, some people worry that our theory will contradict the basic fact of Hubble’s discovery, the recession velocity of a galaxy is proportional to the distance the galaxy being away from us, } v \propto H_0 \cdot x_{ph}. \text{ First let me explain that, even for this basic fact, different standard cosmologists could give us different interpretations.}\]

\[\text{The first class standard cosmologists say that this is an empiric formulae only valid at low red-shift. Because if it is valid at very high red-shift, or on very large physical distances, super-light velocity of recessions would appear, which is anti-relativity. The second class standard cosmologists say that, } v \propto H_0 \cdot x_{ph} = \text{ a basic principle valid on any scales; super-light recession velocity on super-horizon scales introduces no problem, so is allowed. We support the first class of standard cosmologists, i.e., } v \propto H_0 \cdot x_{ph} \text{ is an empiric formulae only valid on low red-shift or small (compare with observational horizon of the universe) scales.}\]

\[\text{Still take the one-dimensional galaxy line in FIG. 1 as our experimental labs. Consider the recession velocity and the physical distance of a galaxy located at } (t, x) \text{ relative to us, } x \text{ is the natural coordinate of that galaxy,}\]

\[
v_x = \frac{e^{\pi x} - e^{-\pi x}}{e^{\pi x} + e^{-\pi x}}; \tag{23}
\]
Obviously, only when \( v_x << 1 \), i.e. \( \sigma x << 1 \), \( v_x \propto x_{ph} \). Obviously, regardless how large is \( x \), the recession velocity \( v_x \) cannot be larger than 1, the light velocity.

The second worry about our cosmological picture is, since we assume that the average value of relative recession velocity between two nearest galaxies is time independent. The Hubble parameter is also time independent. This is just an illusion. Still take the one-dimensional galaxy line as our experimental labs. Obviously, since the distance between two nearest galaxies increases linearly with time, Hubble parameter, decreases as \( t^{-1} \) as time passes by. This is the same as standard cosmology’s matter/radiation dominated era’s Hubble parameter evolution rules. So if we use eq(17) to trace back the history of our universe, we will not get result inconsistent with Big Bang Nucleon-synthesis of standard cosmology.

Our final discussion is about the negative pressure \( p = -\frac{1}{3}\rho \)'s producing mechanism. As the first step, let me ask if we have a one-dimensional infinitely long uniform galaxy line, and if the system is at rest initially, will it collapse at self-regravitations? Professor Ed. Witten once told me, Einstein contemplated similar questions. He considered a three-dimensional uniform lattice system, by poisson equation \( \nabla^2 \phi = \rho \) (in general relativity, there are similar equations which will give us the same conclusions), the system has a solution \( \phi = \frac{1}{2}\rho x^2 \).

So for any galaxy not on the \( x = 0 \) plane, it will receive a force pointing to that plane. As a result the system will collapse to that plane. Of course, the system could also has solution like \( \phi = \frac{1}{2}\rho(x-x_0)^2 \), which means that the system should collapse to the \( x = x_0 \) plane. So Einstein concludes that an isotropic and homogeneous matter dominated universe cannot have static solution. This is why Einstein introduced cosmological constant into his basic equations to get static solutions, as early as before Hubble discovered that our universe is expanding.

However, we wish to express a modest suspicion that, Einstein may ignore an important thing. In a infinitely long uniform galaxy line, inter-gravitations among different galaxies can produce negative pressures. Imagine that, there is a galaxy in the line containing less matters comparing with other galaxies. In this case, galaxies on the left hand side of this less weighted galaxy will collapse and move to the left, while galaxies on the right hand side of this less weighted galaxy will collapse and move to the right. So the less weighted galaxy will receive gravitations from both sides, which have intentions to split this galaxy into two parts. This intention can be understood as origins of negative pressure \( p = -\frac{1}{3}\rho \).

Then why is the equation of state coefficient \( \frac{1}{3} \)?

Before answering this question, let us first imagine that, if what we illustrated in FIG. 1 is not a galaxy line, but an electron-line. Will the system expand at self-repulsion? According to the same poisson equation analysis of Einstein, the system should not expand at self-repulsion, but should collapse at self-repulsions! This is un-acceptable. So, maybe Einstein, and almost all standard cosmologists since Einstein, were cheated by their intuitions: an infinitely long uniform galaxy line will collapse at self-gravitations. They analyzed this problem by first ignoring pressures originated from the inter-gravitations(or static electronic repulsions) among the composite objects of the system then using the so-called dynamic equations (Einstein equation or Poisson equation) so get their conclusions.

Our point of view is, to answer the question that, will an infinitely long uniform galaxy line collapse at self-gravitations, or an electron line expanding at self-repulsions? We should not use dynamic equations at the condition of ignoring pressures originated from interactions among different composite objects. Otherwise, we will get un-acceptable conclusions, e.g., an infinitely long uniform electron-line will collapse at self-repulsions.

We think the reasonable conclusion should be, from symmetry analysis, any galaxy on the line receives gravitations from both sides. The two-side gravitations cancel each other, so any galaxy on the line will not run close to its neighbors, i.e., the system will not collapse or expanding at self-gravitations or self-repulsions. If we insist this analysis, then an initial expanding non-perturbed universe will keep expanding at the same speed for ever. For such a universe, we have used kinematic method and derived its metric in eq(17), by Einstein equation, the energy momentum tensor corresponding with metric has pressure \( p = -\frac{1}{3}\rho \).

We must claim that, when we say Einstein and his following standard cosmologists were cheated by their intuitions, we only want to express our modest suspicion. We have received many many criticisms and lampoons for our suspicion. But we think this suspicion is worth being kept in mind. After all, this suspicions has given us a possible explanation of the luminosity-distance v.s. red-shift relation of type Ia super-novae. We wish further exploration of this suspicion, for example, perturbing eq(15) or (17) and studying the structure formation or cosmic micro-wave background anisotropy problem then comparing with experimental observations such as SDSS [8] and WMAP [7] will tell us whether our suspicion can be fact or not.

VI. CONCLUSIONS

We derive the metric of an expanding universe with zero accelerations by pure kinematic method. By doing so we expatiate physics related with co-moving coordinate system in details. The most important discovery of our study is, in an expanding universe with zero accelerations, the red-shift of photons from distance galaxies is determined by the co-moving coordinate of the source galaxy instead of the scale factor ratio \( \frac{a(t_i)}{a(t)} \). Our discovery is consistent with the current observed super-novae’s
luminosity-distance v.s. red-shift relations.
We also discuss that, an expanding universe with zero accelerations has no horizon problem, (probably) no flatness problem, no primordial structure formation’s seed problem. By Einstein equation, we find that to assure an expanding universe with zero accelerations, then energy momentum tensor of the underlying cosmological fluid must have $p = -\frac{1}{3}\rho$. We discuss that such a negative pressure can originate from the inter-gravitations among different composite objects of the universe — the galaxies.

Acknowledgement

Originally, this paper appears as an answering letter to criticisms on our works [17]. When we finish the first version of that paper, we send it to professor E. Witten, G. ’t Hooft, P. J. Steinhardt and other peoples for comments and criticisms. They read our paper and give comments seriously. We thank them very much for their comments or criticisms on our work in that paper. Their reactions encourage us very much.

The current version of this paper include results of discussions with professor L. Liu, S.-y Pei. They inquire me to give a talk on the topic discussed in [17] at Beijing Normal University. When I finish the demonstrating document for the talk, I find the document itself may express my ideals more clearly than the original paper. So I decide to update the answering letter with the current paper — in fact— the demonstrating document of talk to be given in BNU.

Although I ask so many people to read my paper and give comments or criticisms on it, and they indeed do so. This does not mean that they agree with me on my opinions. So none of these people is to take responsability for the errors in the paper. But if there is any reasonable points in the paper, I must owe the credit to all of them.

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