The Unified Electro-Gravity (UEG) Theory Applied to Cosmology

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The Unified Electro-Gravity (UEG) theory is extended for the unique conditions of cosmology, which may support a possible reversal of the current expansionary phase of the universe, explain the current accelerated expansion of the universe without need for any dark energy, and also explain the signatures of the baryon acoustic oscillation (BAO) in the cosmic microwave background (CMB) and in the correlation function of galaxy distribution, without any dark matter. UEG effects due to the the CMB radiation in the recent universe, and in the ionized environment before recombination, as well as those due to anticipated star lights in the future universe, are modeled with suitable cosmological assumptions. This may provide a new theoretical paradigm, which can potentially answer some of the most fundamental questions in cosmology today.

I. INTRODUCTION

The Unified Electro-Gravity (UEG) Theory has been successfully applied to model elementary particles [1, 2], quantum mechanics [3], stars [4] and galaxies [5]. In the simplest form, the UEG theory introduces a new gravitational field in proportion to the energy density of radiation [1], with the UEG constant γ as the constant of proportionality. This simple form applies only for small levels of energy density, having an ideal spherical symmetry. Suitable modification is needed to model non-spherical distributions of energy density in a binary star [4], and a spiral galaxy [5], or for higher levels of energy density seen in elementary particles [2]. Based on the past successes of the UEG theory under the diverse conditions, we may expect that the UEG theory, with suitable extensions to account for the unique conditions of cosmology, would help to answer different unresolved questions in cosmology today. A fundamental question may be opened: is the big bang just a fortuitous one-time event for our universe, or it could be only one of the natural sequence of big bounces in a cyclic universe (e.g. [6]), with periodic expansion and contraction? The answer to this question would hinge on a satisfactory theory that could support reversal of the current expansion of the universe, back to a contracting phase, to be followed by a natural big crunch and a bounce, which the cyclic model would presume. Another basic question would be, what is the physical basis for the apparent accelerated expansion [7, 8] of the current universe? Any new physics is expected to emulate the hypothetical dark energy, which is invoked by scientists today to explain the accelerated expansion [7, 8]. The new physics is also expected to emulate the hypothetical dark matter, which apparently explains the signature of the baryon acoustic oscillations (BAO) in the cosmic microwave background (CMB) [9–11] as well as in the large-scale correlation function of galaxy distribution [12]. With the success of the UEG theory in modeling the flat rotation curves in spiral galaxies [5], without any need for the hypothetical dark matter, the current theory for the BAO and CMB signatures based on the dark matter may no longer be tenable.

We attempt in this paper to answer some of the basic questions, based on the UEG theory, with suitable assumptions and extensions to accommodate unique cosmological conditions, which might not have been encountered in the other problems [1]-[5] solved by the UEG theory. We would assume an ideal homogeneous, isotropic universe, and propose a cyclic universe that anticipates future events. The present expansionary state of the universe is assumed to have been adjusted over repeated cycles in the past, such that together with the future anticipated events it would result in a reversal of its current expansion, leading to a complete cyclic process. Any energy density associated with the CMB radiation, or with any present and future star lights, would produce new UEG forces. These new forces, in addition to the Newtonian gravity due to conventional matter content of the universe, would constitute the complete physical basis for the current expansion, possible future contraction, and the geometry of the universe, without need for any fictitious dark energy or dark matter. The new UEG model could potentially explain important cosmological observations, such as (a) the supernova distance-redshift measurements [7, 8] without any dark energy or dark matter, and (b) the basic BAO signature in the CMB [10, 11] without any dark matter, as well as (c) support a possible reversal of the current expansion of the universe, in order that the universe can contract and then cycle back to maintain a periodic process. The regime of big-bang nucleo-synthesis (BBN) [13, 14], when nuclei of light elements are believed to have been synthesized in the early universe, is assumed to be unaffected by the UEG theory. This is possibly because in the BBN regime the photons in the cosmic radiation would remain tightly coupled to the highly ionized material environment, which may not contribute to any significant UEG forces. In addition, in this regime when the universe is dominated by radiation, any UEG effect may have been highly diluted over a larger effective region of universe far beyond the observable universe. Accordingly, all successful predictions of the BBN may remain largely unaffected by the new UEG theory.

All the above proposed physics is expected to be based on a UEG theory that is applicable at a relatively low level of energy density. The theory in principle may be extended in the regime of high energy density, as was the case for modeling elementary particles, to model very early universe. The UEG theory may be extended to the highest level of energy density, beyond the levels applicable to model elementary particles, where the gravitation may transition from its usual attractive to a new repulsive nature. This reversal of gravitation could provide a definitive physical basis for the reversal from a previously contracting (big crunch) to the currently expanding (big bounce) universe, supporting an inflation-like [15] or any other suitable form of expansion (or contraction) in the transitional phase.

We have used available cosmological parameters for different estimations in this paper, that may have been adopted from the Wilkinson Microwave Anisotropy Probe (WMAP) 9 year results [10] or from early Planck Mission (2013) results [11], as appropriate and adequate for particular purposes. All parameters are specified, for proper interpretation of results with respect to variation of the parameters. Any variations based on more recent results of the Planck Mission (2015) [16] may not materially change the results or conclusions from the study.

II. BASIC THEORY

A. UEG Acceleration Due to the CMB Radiation

The UEG acceleration a_u, associated with the energy density of the current CMB radiation at temperature $T = 2.725^0 K$ may be estimated, assuming a nominal value of the UEG constant $\gamma_0 = 0.6 \times 10^3$ (m/s^2)/(J/m^3) derived from a UEG model of elementary particles [1, 2].

$$\begin{aligned} a_u = \gamma_0 W_\tau = \gamma_0 (4\sigma/c) T^4 = 2.5 \times 10^{-11} \mathrm{m/s^2}, \\ \gamma_0 = 0.6 \times 10^3 (\mathrm{m/s^2})/(\mathrm{J/m^3}), \\ \sigma = 5.670 \times 10^{-8} \mathrm{W/(m^2K^4)},\ \mathrm{T{=}2.725^0K}. \end{aligned} \tag{1}$$

The σ is the Stefan-Boltzman constant, and the c is the speed of light in empty space. The UEG acceleration a_u may be compared with the cosmological acceleration a_0 at the boundary of the observable universe of radius $R \simeq 46.3\ GLy$ [17], approximated using the current value of the Hubble constant $H \simeq 67.8$ (km/s)/Mpc.

$$\begin{aligned} a_0 = \tfrac{1}{2} H^2 R = 1.057 \times 10^{-9} \mathrm{m/s^2}, \\ H = 67.8\ \mathrm{(km/s)/Mpc,\ R{=}46.3\ BLy}, \\ \mathrm{Mpc{=}3.0857 \times 10^{22}m,\ 1\ BLy{=}9.4607 \times 10^{24}m}. \end{aligned} \tag{2}$$

The a_u is smaller than the a_0 by about a factor of 40. Assuming the matter (baryonic) density of the universe to be 4.9% of the critical density to maintain the current expansion rate associated with the Hubble constant H_0, we may estimate the acceleration a_g at the boundary of the observable universe $r = R$, attributed to the Newtonian gravitation. The UEG acceleration a_u due to the CMB radiation is about half of the Newtonian acceleration a_g at $r = R$ due to matter (baryonic) content of the universe. The a_u is a fundamental parameter, which would shape any cosmological model based on the UEG theory.

$$\begin{aligned} a_g = (0.049) \times a_0 = 5.179 \times 10^{-11} \mathrm{m/s^2}, \\ a_u = (2.5/5.179) a_g = 0.483 a_g. \end{aligned} \tag{3}$$

B. UEG Acceleration Due to any Present or Future Star Lights

The Newtonian acceleration a_g may be directly expressed using Newton's law of gravitation, in terms of the energy density $w = \rho_v c^2$ associated with the matter density ρ_v.

$$\begin{aligned} a_g = \tfrac{4\pi G \rho_v R}{3} = 1.36 w,\ w = \rho_v c^2, \\ G = 6.67 \times 10^{-11} (\mathrm{m^3/s^2})/\mathrm{kg}, \\ \mathrm{R{=}46.3\ BLy} = 4.409 \times 10^{26} \mathrm{s}. \end{aligned} \tag{4}$$

About 3/4-th of the matter content of the universe is made of hydrogen [13, 18], and only a negligible percentage of the hydrogen have been used for hydrogen fusion in the stars. Most of the hydrogen content remain unused outside of the stars in inter-stellar and intergalactic space, waiting for possible right conditions to locally collapse and light up in the form of stars and galaxies of the future. If we ideally allow all the hydrogen to, at once, form light radiation through hydrogen fusion today, the density of the light radiation would be about 0.7% of the energy density [19] $(3/4)w = (3/4)\rho_v c^2$ associated with the hydrogen mass density $(3/4)\rho_v$. The UEG acceleration a'_u produced by this star radiation may be expressed in terms of the w, and then compared with the Newtonian acceleration a_g of (4).

$$\begin{aligned} a'_u = w \times 0.007 \times \gamma_0 \times 0.75 = 3.15 w, \\ a'_u = (3.15/1.36) a_g = 2.3 a_g = (2.3/0.483) a_u = 4.8 a_u, \\ a'_u = 4.8 \times 2.5 \times 10^{-11} = 1.2 \times 10^{-10} \mathrm{m/s^2}. \end{aligned} \tag{5}$$

The UEG acceleration a'_u due to light radiation of the possible future stars is 2.3 times the Newtonian acceleration a_g at $r = R$ due to matter (baryonic) content of the universe. Like the UEG acceleration $a_u = 0.483 a_g$ due to the CMB radiation, the $a'_u = 2.3 a_g = 4.8 a_u$ due to the future star lights is also a fundamental parameter, which would shape any cosmological model based on the UEG theory. Assuming that only a negligible fraction of the total primordial hydrogen has so far been used in all the stars, the UEG acceleration due to all the current star lights is negligible compared to the a'_u or the a_g.

C. Equivalent UEG Mass and Energy for Cosmological Modeling

The UEG accelerations a_u and a'_u would be uniform everywhere, in proportion to the associated uniform energy densities W_τ and W'_τ, respectively, as per the UEG theory applied in a simple form [1]. In contrast, the acceleration a_g due to the Newtonian gravitation increases linearly with distance, assuming a uniform mass density. Accordingly, the simple UEG model would produce much larger acceleration at smaller distances, compared to the Newtonian acceleration, leading to a possible non-uniform expansion which would be clearly incompatible with the fundamental assumption of a uniform, isotropic universe. The simple UEG theory may have to be properly revised for cosmology, requiring basic UEG parameters to be properly redistributed in proportion to the respective parameters from the Newtonian gravity. Equivalently, there may be some new physics at cosmological scale, which would transform the basic non-uniform expansion due to the UEG gravitation into the expected uniform expansion, leading to effectively the same results as the redistribution model suggested above.

We will follow a redistribution model for the UEG theory, which would confirm to the fundamental assumption of a uniform or homogeneous universe. Basic UEG parameters, such as equivalent UEG mass and energy, may be redistributed in proportion to the respective quantities expected from the Newtonian gravity, such that certain total measure of the UEG parameters are conserved.

A simple objective measure of conservation may be to ensure the total integration of a UEG parameter over the volume of the observable universe of radius $r = R$ to remain fixed. Here, the volume of the observable universe is a naturally objective region. However, the above measure of conservation would truncate the integration of the conserved parameter abruptly at $r = R$, which may seem arbitrary. Instead, conserving a weighted integration over the observable universe, with the weighting factor at a location proportional to the red-shift factor associated with the location, may be physically meaningful. The weighting factor would gradually de-emphasize the conserved integrand from its reference unit value at the center $r = 0$, to zero at the edge of the observable universe.

The equivalent mass density associated with the uniform UEG acceleration a_u has a ρ_0/r distribution. This may be redistributed with a uniform mass density ρ_{uv}, such that the total mass M_u integrated over the observable universe with a weighting function $(1-r/R)^2$ is conserved. The selected weighting function may be shown to be the red-shift factor for an ideal universe with a critical material density, which is assumed to be approximately valid for the proposed redistribution. The equivalent UEG mass density ρ_{uv} may now be compared with the material density ρ_v, which is related to the Newtonian acceleration a_g at $r = R$. The relation (3) between the a_u and a_g may be used here. The weighted material mass M enclosed in the sphere of radius $r = R$ would be related to the M_u by the same ratio between the respective mass densities ρ_v and ρ_{uv}.

$$
\begin{aligned}
M_u &= \int_0^R \left(\frac{\rho_{u0}}{r}\right)\left(1-\frac{r}{R}\right)^2 4\pi r^2 dr = \int_0^R \rho_{uv}\left(1-\frac{r}{R}\right)^2 4\pi r^2 dr \\
&= \frac{4\pi}{12}\rho_{u0}R^2 = \frac{4\pi}{30}\rho_{uv}R^3,\ \rho_{uv} = \frac{5\rho_{u0}}{2R} = \frac{5a_u}{4\pi GR}, \\
a_u &= \frac{G}{R^2}\int_0^R \left(\frac{\rho_{u0}}{r}\right)4\pi r^2 dr = 2\pi G\rho_{u0},
\end{aligned} \tag{6}
$$

$$
\begin{aligned}
\rho_v &= \frac{3a_g}{4\pi GR},\ \rho_{uv} = \frac{5a_u\rho_v}{3a_g} = (5/3)\times 0.483\rho_v = 0.8\rho_v, \\
M &= \int_0^R \rho_v\left(1-\frac{r}{R}\right)^2 4\pi r^2 dr = \frac{4\pi}{30}\rho_v R^3,\ M_u = 0.8M.
\end{aligned} \tag{7}
$$

Similarly, the equivalent uniform mass density ρ'_{uv} associated with the UEG acceleration a'_u, and its weighted mass M'_u may also be expressed, and compared with respective material parameters ρ_v and M.

$$
\rho'_{uv} = \frac{5a'_u\rho_v}{3a_g} = (5/3)\times 2.3\rho_v = 3.83\rho_v,\ M'_u = 3.83M. \tag{8}
$$

Using the same weighting factor used above for calculating equivalent cosmological mass parameters, we may also find equivalent kinetic energy parameters of expansion W_u, W'_u and W, associated with the UEG masses M_u, M'_u and the material mass M, respectively.

$$
\begin{aligned}
W_u &= \int_0^R \frac{1}{2}v^2\frac{\rho_{u0}}{r}\left(1-\frac{r}{R}\right)^2 4\pi r^2 dr \\
&= \int_0^R \frac{1}{2}(Hr)^2\frac{\rho_{u0}}{r}\left(1-\frac{r}{R}\right)^2 4\pi r^2 dr \\
&= \frac{4\pi}{120}H^2\rho_{u0}R^4 = \frac{1}{10}(HR)^2 M_u = \frac{1}{10}(H\times 46.3BY)^2 M_u c^2 \\
&= \frac{1}{10}\left(\frac{67.8}{3.0587}\times 10^{-19}\times 1.46\times 10^{18}\right)^2 M_u c^2 = 1.048M_u c^2, \\
W'_u &= 1.048M'_u c^2.
\end{aligned} \tag{9}
$$

The relationship in (6) between M_u and the UEG mass-density coefficient ρ_{u0} is used in the above derivation. Similarly,

$$
\begin{aligned}
W &= \int_0^R \frac{1}{2}v^2\rho_v\left(1-\frac{r}{R}\right)^2 4\pi r^2 dr \\
&= \int_0^R \frac{1}{2}(Hr)^2\rho_v\left(1-\frac{r}{R}\right)^2 4\pi r^2 dr \\
&= \frac{4\pi}{210}H^2\rho_v R^5 = \frac{1}{7}(HR)^2 M = \frac{1}{7}(H\times 46.3BY)^2 Mc^2 \\
&= \frac{1}{7}\left(\frac{67.8}{3.0587}\times 10^{-19}\times 1.46\times 10^{18}\right)^2 Mc^2 \\
&= 1.496Mc^2.
\end{aligned} \tag{10}
$$

The W_u, W'_u and W are the kinetic energies of the current universe at the expansion velocity v, associated with a critical mass density ρ_{vc}. It may be useful to find the corresponding kinetic energies, W_{u0}, W'_{uo} and W_0, if the expansion velocity were $v_0 = \sqrt{0.049} \times v$. The v_0 is the expansion velocity associated with the current material density ρ_v, which is about 4.9% of the critical mass density ρ_{vc}.

$$\begin{aligned} W_{u0} &= 0.049 W_u = 1.048 M_u c^2 \times (0.049), \\ W'_{u0} &= 0.049 W'_u = 1.048 M'_u c^2 \times (0.049), \\ W_0 &= 0.049 W = 1.496 M c^2 \times (0.049), \\ v_0^2 &= v^2 \times (0.049) \ . \end{aligned} \tag{11}$$

III. A UEG MODEL IN ANTICIPATION OF A FUTURE CONTRACTION OF THE UNIVERSE

As mentioned, the universe may be anticipating future star light due to fusion of existing hydrogen content, mostly unused to date. If the star burst ideally happens today, all at once, the total mass content would be $M + M_u + M'_u$, consisting of the UEG masses M_u and M'_u due to CMB radiation and star light, in addition to the material mass M. This would be associated with a critical expansion velocity v'_0, which may be related to the velocity v_0 defined in (11). The critical velocity v'_0 is the threshold velocity less than which eventual contraction would be possible. We assume that that UEG acceleration would reduce as $1/\alpha^{4.5}$, as the scale factor α increases, in contrast with a $1/\alpha^2$ variation for the Newtonian acceleration. Integration of the acceleration with the scale factor would be proportional to the the respective contributions to the squared critical velocity, which would be associated with integration coefficients 1/3.5 and 1, respectively. This fundamentally assumes that the equivalent mass/energy of the UEG field due to radiation is modeled as pressure-less, unlike the mass/energy of conventional radiation which is associated with radiation pressure. Otherwise, the above integration coefficient for the UEG contribution would have been 1, the same as that for the Newtonian gravitation due to conventional matter.

$$\begin{aligned} {v'_0}^2 &= (1 + \tfrac{M_u + M'_u}{M} \times \tfrac{1}{3.5}) v_0^2 \\ &= (1 + \tfrac{\rho_{uv} + \rho'_{uv}}{\rho_v} \times \tfrac{1}{3.5}) v_0^2 = 2.32 v_0^2. \end{aligned} \tag{12}$$

The $1/\alpha^{4.5}$-dependence of the UEG acceleration, assumed above, may be explained as follows. As the universe expands, the energy density of radiation would reduce with a $1/\alpha^4$ variation, which would directly contribute to the reduction of the UEG acceleration. The horizon of the observable universe is assumed to expand in excess of the scale factor, proportional to $\alpha^{0.5}$, which may contribute to an additional factor of $1/\alpha^{0.5}$ in the reduction of the UEG acceleration, according to the redistribution model of section II C to determine the UEG acceleration. The $\alpha^{0.5}$ dependence of the horizon in excess of the scale factor is valid for an ideal condition of a matter-only, flat universe, but is assumed to be approximately valid in the present model, representing a small exponent in the UEG acceleration in addition to the primary $1/\alpha^4$ dependence.

The total kinetic energy W'_0 associated with the threshold velocity v'_0 may be expressed as,

$$\begin{aligned} W'_0 &= 2.32(W_0 + W_{u0} + {W'}_{u0}) = 2.32 W_0 \times (1 + \tfrac{W_u + W'_u}{W}) \\ &= 2.32 W_0 \times (1 + \tfrac{1.048(M_u + M'_u)}{1.496 M}) \\ &= 2.32 \times 0.049 W \times (1 + 3.24) \\ &= 0.482 W = 0.73 M c^2. \end{aligned} \tag{13}$$

Now, the total energy W_2 available in the future universe at the threshold of possible contraction, after the ideal star burst phase, may be calculated. This is obtained by adding the threshold kinetic energy W'_0 to the equivalent mass-energies of the Newtonian mass M, and of the UEG masses M_u, M'_u due to the CMB radiation and star lights, respectively. Similarly, the total energy W_1 in the current universe may be obtained, by adding the kinetic energies W and W_u to the mass-energies associated with the Newtonian mass M and the UEG mass M_u due to the CMB radiation.

$$\begin{aligned} W_2 &= (M + M_u + M'_u)c^2 + W'_0 \\ &= (M + M_u)c^2 + 3.83 M c^2 + 0.73 M c^2, \\ W_1 &= (M + M_u)c^2 + W + W_u \\ &= (M + M_u)c^2 + 1.496 M c^2 + 1.048 \times 0.8 M c^2, \\ W_2 &> W_1, \ \gamma = \gamma_0 = 0.6 \times 10^3 (\mathrm{m/s^2})/(\mathrm{J/m^3}). \end{aligned} \tag{14}$$

Note that the W_2 is greater then the W_1, which means the excess kinetic energy in the current universe may not be enough to guarantee continuation of the expansion. The above calculations assume a nominal value of $\gamma = \gamma_0$. We may trace the above calculations with $\gamma = \alpha\gamma_0$, and find the required γ for the current universe to lead to a future universe just at the threshold of possible contraction, as per the ideal model, by solving a quadratic equation of α.

$$\begin{aligned} & W_2 = W_1, \ \gamma = \alpha\gamma_0, \\ & 1.496 M c^2 + 1.048 \times 0.8 \alpha M c^2 \\ &= 3.83 M c^2 \alpha + 0.049 \times 1.496 (1 + 1.32\alpha)(1 + 3.24\alpha) M c^2, \\ & 1 + 0.56\alpha = 2.56\alpha + 0.049(1 + 1.32\alpha)(1 + 3.24\alpha), \\ & 0.21\alpha^2 + 2.22\alpha - 0.951 = 0, \\ & \alpha = \tfrac{-2.22 + \sqrt{4.93 + 0.8}}{0.42} = 0.41, \\ & \gamma > \alpha\gamma_0 = 0.41\gamma_0 = 0.25 \times 10^3 (\mathrm{m/s^2})/(\mathrm{J/m^3}). \end{aligned} \tag{15}$$

Essentially, the above model predicts a lower limit of the $\gamma > 0.25 \times 10^3$ $(\mathrm{m/s^2})/(\mathrm{J/m^3})$, in anticipation of a future contraction that would lead to a cyclic universe. The predicted lower limit is consistent with the the $\gamma = \gamma_0$ deduced from a UEG model of elementary particles [1, 2]. Conversely, if the value of the γ is given to be equal to γ_0, the above model may be extended into the future for estimation of an effective timing for the anticipated star-burst event in the future.

IV. A UEG MODEL FOR THE ACCELERATED EXPANSION OF THE UNIVERSE

We will model the expansion velocity v as it changes with the scale factor $\alpha < 1$, or its associated redshift factor $z > 0$, of the universe. The velocity v may be normalized with its unit reference equal to the total velocity of the current universe, at time $t = t_0$.

$$
\begin{gathered}
v = \frac{\dot{\alpha}}{\dot{\alpha}(t{=}t_0)} = \frac{\dot{\alpha}}{H_0},\ \dot{\alpha} = \frac{d\alpha}{dt}, \\
v^2(z) = v_g^2(z) + v_u^2(z) + v_\Delta^2(z),\ \alpha = \frac{1}{1+z}. \qquad (16)
\end{gathered}
$$

The squared-velocity v^2 may be expressed consisting of three parts. The first two parts, v_g^2 and v_u^2, are contributed from the critical velocities that could be supported by the Newtonian gravity and the new UEG field, respectively. The contribution from the Newtonian gravity of conventional matter is $\Omega_b(1+z)$, where $\Omega_b = 0.049$ is the fractional density of the conventional matter, with respect to the critical density necessary to support the observed expansion of the current universe. The functional dependence of the UEG contribution v_u^2 was explained in section III.

$$
\begin{gathered}
v_g^2(z) = \Omega_b(1+z), \\
v_u^2(z) = \Omega_u(1+z)^{3.5} = \frac{\rho uv}{\rho v}\Omega_b\frac{(1+z)^{3.5}}{3.5}, \\
\Omega_u = \frac{\rho uv}{\rho v} \times \frac{1}{3.5}\Omega_b = 0.8 \times \frac{1}{3.5}\Omega_b = 0.23\Omega_b. \qquad (17)
\end{gathered}
$$

The third term v_Δ^2 in (16) is the contribution of the excess velocity v_Δ. The v_Δ^2 is the total squared-velocity in excess of the first two terms that are critically supported by the Newtonian gravity and the UEG field, respectively. The excess squared-velocity is $1 - \Omega_b - \Omega_u$ at $t = t_0$, and is required to change with the scale factor with the following basic condition. The kinetic energy associated with the excess velocity, enclosed inside a co-moving spherical volume, with its radius changing in proportion with the scale factor, with a current reference radius equal to the current horizon distance, is required to be conserved independent of the scale factor. The kinetic energy over any given spherical volume is defined such that the ratio of the kinetic energy to the mass in the volume at a given time, for a unit reference velocity at the spherical boundary, is equal to that over the entire volume of the observable universe, at the particular time. The ratios $W/M = 1.496c^2$ and $W_u/M_u = 1.048c^2$ between the kinetic energies and the respective masses for the conventional gravity and the UEG field, respectively, as derived in (9,10) for the current universe, would apply for all scale factors for a unit normalized squared-velocity (normalized to a unit value for the current universe at r=R). Accordingly, the excess kinetic energies W_Δ and $W_{u\Delta}$ may be expressed in terms of the associated masses M and M_u, respectively, proportional to the excess squared-velocity v_Δ^2

$$
\begin{gathered}
W_\Delta(z) + W_{u\Delta}(z) = 1.496M(z)c^2v_\Delta^2(z) + 1.048M_u(z)c^2v_\Delta^2(z) \\
= W_\Delta(z=0) + W_{u\Delta}(z=0) \\
= 1.496M(z=0)c^2v_\Delta^2(z=0) + 1.048M_u(z=0)c^2v_\Delta^2(z=0), \\
v_\Delta^2(z) = v_\Delta^2(z=0) \times \frac{1.496M(z{=}0)+1.048M_u(z{=}0)}{1.496M(z)+1.048M_u(z)} \\
= (1 - \Omega_b - \Omega_u) \times \frac{1+0.7M_u(z{=}0)/M(z{=}0)}{1+0.7M_u(z)/M(z{=}0)}. \qquad (18)
\end{gathered}
$$

The relationship (7) between the M_u and M in the current universe, and the associated relationship (17) between the Ω_b and Ω_u, may be used in the above expression. The conventional mass M in the observable universe, which is associated with a $1/\alpha^2 = (1+z)^2$ dependence of its acceleration due to Newtonian gravity, remains constant with the scale factor α. Whereas, the equivalent UEG mass M_u, which is associated with a $1/\alpha^{4.5} = (1+z)^{4.5}$ dependence of the UEG acceleration, would change with a $1/\alpha^{2.5} = (1+z)^{2.5}$ dependence.

$$
\begin{gathered}
v_\Delta^2(z) = (1 - 1.23\Omega_b) \times \frac{1+0.7\times0.8}{1+0.7\times0.8(1+z)^{2.5}} \\
= \Omega_\Delta \times \frac{1.56}{1+0.56(1+z)^{2.5}}, \\
M(z) = M(z=0),\ M_u(z) = M_u(z=0)(1+z)^{2.5}, \\
M_u(z=0) = 0.8M(z=0), \\
\Omega_\Delta = 1 - \Omega_b - \Omega_u = 1 - 1.23\Omega_b = 0.94\ . \qquad (19)
\end{gathered}
$$

Combining (19,17) in (16), the total normalized velocity $v(z)$ may be expressed.

$$
\begin{gathered}
v^2(z) = \Omega_b(1+z) + \Omega_u(1+z)^{3.5} \\
+ (1 - \Omega_b - \Omega_u)[\frac{1.56}{1+0.56(1+z)^{2.5}}] \\
= 0.049(1+z) + 0.011(1+z)^{3.5} \\
+ 0.94[\frac{1.56}{1+0.56(1+z)^{2.5}}]. \qquad (20)
\end{gathered}
$$

The above derivations assumes a specific set of available cosmological parameters, with the Hubble constant $H_0 = 67.8$ (km/s)/Mpc and $\Omega_b = 0.049$. Any variations due to changes of the parameters may be similarly traced by introducing additional factors for the different parts, in terms of fractional changes of the appropriate parameters, which may be expressed in terms of the fractional change $h_{67.8}$ of the measured Hubble constant H_0 with respect to the best value of $H_0 = 67.8$ (km/s)/Mpc currently available.

$$
\begin{aligned}
v^2(z) &= \Omega_b h_{67.8}^{-2}(1+z) + \Omega_u h_{67.8}^{-1}(1+z)^{3.5} \\
&+ (1 - \Omega_b h_{67.8}^{-2} - \Omega_u h_{67.8}^{-1})[\tfrac{1+0.56h_{67.8}}{1+0.56h_{67.8}(1+z)^{2.5}}] \\
&= 0.049 h_{67.8}^{-2}(1+z) + 0.011 h_{67.8}^{-1}(1+z)^{3.5} \\
&+ (1 - 0.049 h_{67.8}^{-2} - 0.011 h_{67.8}^{-1})[\tfrac{1+0.56h_{67.8}}{1+0.56h_{67.8}(1+z)^{2.5}}], \\
h_{67.8} &= \frac{H_0}{67.8\ \mathrm{kms^{-1}Mpc^{-1}}}. \qquad (21)
\end{aligned}
$$

The normalized squared-velocity v^2 as derived above is compared in Fig.1 with those from the standard cosmological model, where $v^2 = \Omega_M(1+z) + \Omega_\Lambda/(1+z)^2 + (1 - \Omega_M - \Omega_\Lambda)$. The acceleration in the standard model due to the dark-energy term, with its fractional density Ω_Λ, is emulated in the UEG model without any need for the hypothetical dark-energy. Further, only the conventional matter with the fractional density Ω_b is used in the UEG model, without need for any additional dark matter. Whereas, the standard model uses the mass fraction of $\Omega_M = \Omega_b + \Omega_{dm}$, which includes the density Ω_b of the conventional baryonic mass and additional density Ω_{dm} of dark matter. Unlike the mass M due to the conventional baryons or dark matter, the equivalent UEG mass M_u is reduced as the universe expands. This results in an effective outward acceleration as the universe expands, so that the kinetic energy in the observable universe due to the excess velocity is conserved, as the UEG model requires. This effective acceleration is seen only in the current and recent past of the universe ($z < 1$ from Fig.1) when the excess velocity is significantly larger than the critical velocity that can be supported by the conventional and UEG masses. In the past, the UEG mass M_u was larger, and consequently the excess velocity to conserve the excess kinetic energy was smaller. In sufficient past, the smaller excess velocity, as compared to the critical velocity in the current universe, was even much smaller than the larger critical velocity that could be supported at the time. This would result in having the effective outward acceleration associated with the smaller excess velocity, due to the kinetic-energy conservation discussed above, to be much smaller than the normal gravitational deceleration (inward acceleration) in the sufficient past associated with the larger critical velocity supported at the time. Accordingly, the expansion of the universe was effectively decelerating in the sufficient past ($z > 1$ from Fig.1), while it is accelerating only currently and in recent past ($z < 1$ from Fig.1), as per the UEG model, which would be consistent with the standard model with $\Omega_\Lambda \sim 0.76$.

The luminosity distance D_L [20] derived from the velocity function $v(z)$ is plotted in Fig.2, which shows the UEG model with $\Omega_b = 0.49$ is comparable to the standard model with $\Omega_\Lambda = 0.76$, for $z < 2$. The results from the UEG model and the standard model with the $\Omega_\Lambda = 0.76$, are plotted in Fig.3 in relative magnitudes with respect to a nearly empty universe with $\Omega_M = 0.2$, $\Omega_\Lambda = 0$, which are consistent with measurements of high-z supernovae from [7]. The theoretical results from the UEG and standard models over a larger range of redshift are shown in Fig.4, which maybe similarly compared with results from [21] that include measurements of gamma-ray bursts (GRB). In summary, the UEG model with no dark matter or dark energy is shown to be consistent with measurements of high-z supernovae, and possibly GRBs, emulating the standard model with the hypothetical dark matter and dark energy. That is a remarkable development.

It may be noted that, unlike the conventional matter which is associated with a definitive mass density, the equivalent UEG mass density is not a definitive quantity, but is modeled in relation to the horizon distance of the observable universe, as per the redistribution model developed in section II C. The above derivations use an approximate formulation for the dependence of the horizon distance of the observable universe on the scale factor. We assume that the horizon distance expands with a $\alpha^{0.5}$ dependence as an excess factor, multiplied to the scale factor α of normal expansion of the universe. This dependence is the ideal case for a matter-only universe. It is used in the derivations only as an effective dependence of the horizon, as a good reference, which may work in an overall average sense over a range of the scale factor. A more accurate formulation may require the above dependence to be modeled with a variable exponent of the scale factor, that varies as a function of the scale factor. Refinement of the reference analysis may be possible by estimating the exponent under different specific conditions, and revising the associated formulations accordingly. However, it may require a involved numerical computation process, in order to rigorously model the horizon distance and incorporate it into the UEG model.

V. A UEG MODEL FOR THE ACOUSTIC HORIZON AND DARK MATTER BEFORE RECOMBINATION

Based on the comparisons with the standard model, in consistency with the current observations, the above model for the UEG mass based on the size of the observable universe appears to be reasonably valid in the recent universe, covering redshifts of the order of $z \sim 10$ possibly even larger. However, for much larger redshifts questions may arise about the fundamental validity of the redistribution model of section II C, based on the size of the observable universe. The radial distance of the observable universe may be referred to as the "matter horizon", which is the farthest distance the matter produced in the earliest universe would appear to be located to a current observer. The universe is assumed to be expanding with a gravitational deceleration (or acceleration toward the reference origin), due to the conventional

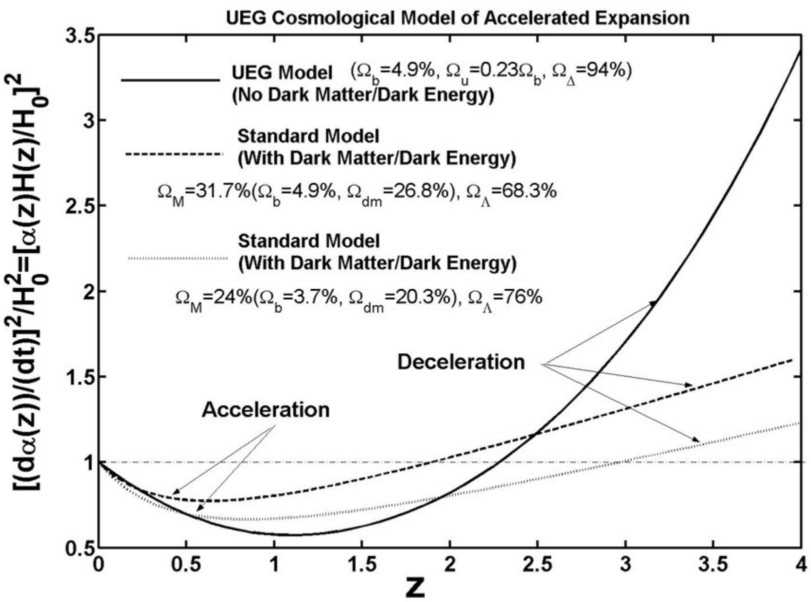

FIG. 1.

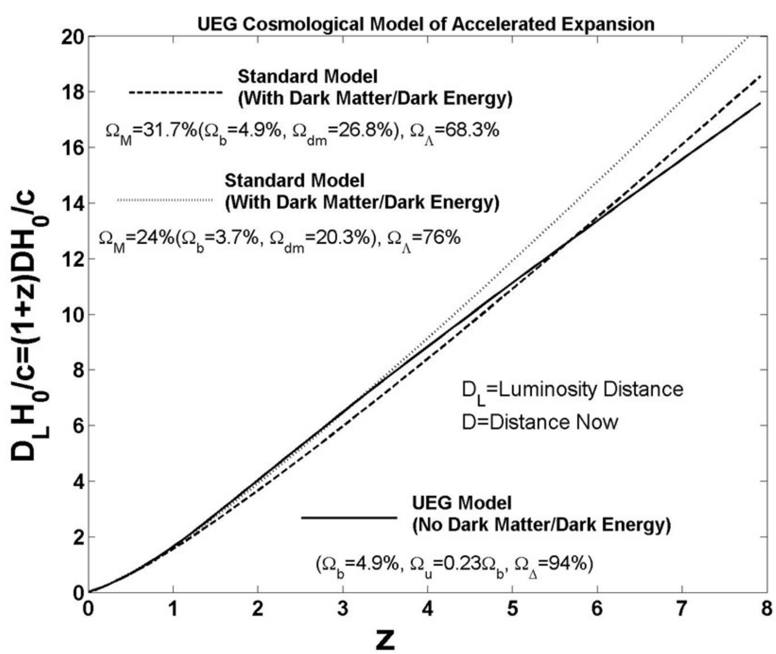

FIG. 2.

attractive form of gravity, since the time of the earliest matter formation. However, before the era of matter formation, the earliest radiation-only universe might have undergone an inflationary phase [15] with gravitational acceleration (away from the reference origin), possibly following a big crunch, and supported by a form of repulsive gravity based on a UEG theory at the highest level of energy density. The horizon associated with this gravitationally repulsive phase of accelerated expansion, which may be referred to as the “radiation horizon,” is expected to be much farther than the “matter horizon”. It is conceivable that the effective UEG mass may have to be modeled differently for different scale factor of expansion, based on the matter horizon, or the radiation

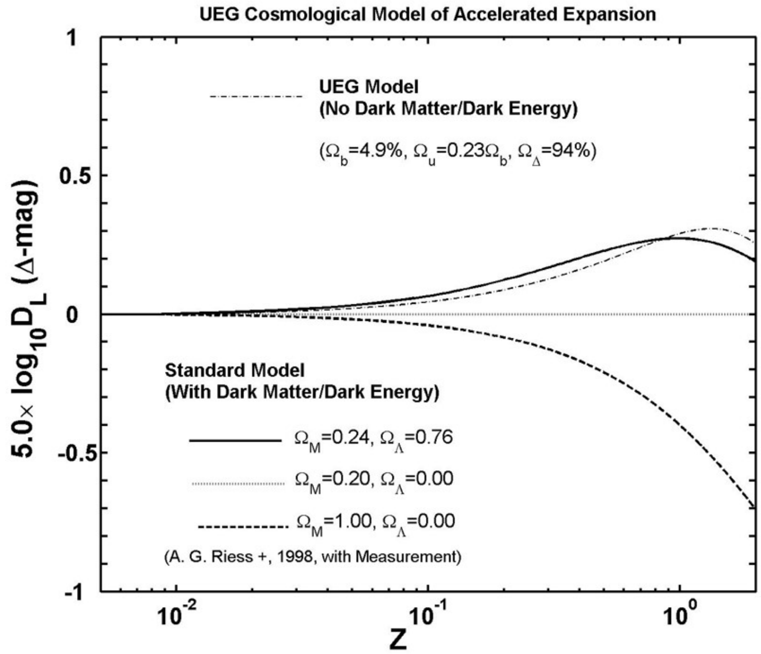

FIG. 3.

horizon, or possibly a combination of the both, depending on the relative matter and radiation contents of the universe. In the current universe, which is matter dominated, the conventional matter horizon appear to determine the UEG physics accurately. However, as one gets close to the scale of recombination ($z \sim 1100$), the radiation density would be comparable to the matter (baryonic) density, in which case the UEG model applicable in the current universe may not be valid.

The UEG model in the time frame around the recombination may require the knowledge of the radiation horizon, which is not available without a definitive model of the inflationary phase. However, considering that the radiation horizon would be much farther than the matter horizon, it may be assumed that the effective UEG mass in this time frame would be much smaller than that modeled using the matter horizon, as it was done in the UEG model for the current universe. The effective UEG mass at the recombination may emulate the hypothetical dark matter in the standard model. Accordingly, we may assume the effective UEG mass enclosed inside the matter universe, or its associated matter density, to be larger than the respective baryonic parameters by a factor of $\Omega_{dm}/\Omega_b = 0.268/0.049 = 5.47$, as a reference, effective over the duration of recombination. The Ω_b and Ω_{dm} are the baryonic and dark matter fractions of the current universe, respectively, used in the standard model. The ratio of the baryonic and dark matter is assumed to remain constant over all different time scales, in accordance with the dark-matter characteristic of the standard model.

The above effective UEG mass density is assumed to be valid just after and sufficiently during the recombination process. However, before the recombination the universe was ionized and opaque to radiation. Therefore, unlike in the current universe, there would not have been any CMB radiation available before the recombination to produce UEG forces. Accordingly, the effective UEG mass density sufficiently before the recombination would have been zero, but it increased to be effectively about 5.47 times the baryonic matter density after the recombination, which may be considered a relatively abrupt process. This is similar to the possible increase of UEG effects in the current universe due to anticipated future star lights, modeled in section III. As the similar case in the current universe, the expansion velocity before the recombination would have been larger than the critical velocity that could be supported by the baryonic and radiation mass densities, in anticipation of the increased UEG mass and associated kinetic energy after the recombination. We will follow a formulation similar to that in section III, in order to find the expansion velocity before the recombination.

For convenience, all parameters used in the following modeling will refer to the recombination time scale as the current reference with zero redshift or unit scale factor, and the final results may be properly scaled back to the actual current universe as needed. Distinct from the actual current universe, the universe at the recombination would have appreciable mass density of radiation (photon) and neutrino, as compared to the baryon mass density, and all parameters associated with the conventional photon radiation would be referred to with a subscript r', and those associated with total relativistic

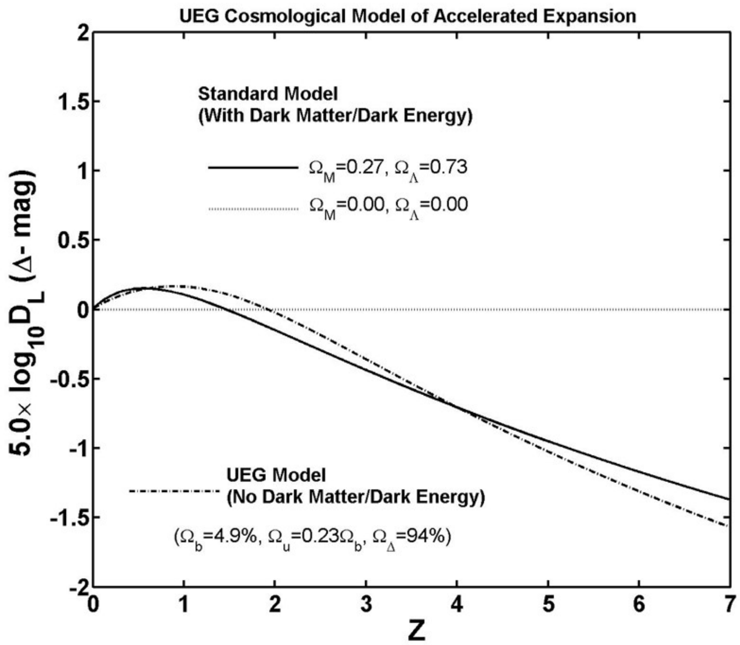

FIG. 4.

particles (photon and neutrino) with a subscript r. v_0 is the reference critical velocity supported by the baryonic matter content, and the associated kinetic energy of the baryons is W_0. Unlike the matter horizon, the radiation horizon can be shown to expand proportional to the scale factor. Assuming that the UEG model at the recombination would be based dominantly on the radiation horizon, as discussed earlier, all special adjustments (with 0.5 exponent of scale factor used for modeling in the current universe) to account for variation of the horizon distance may not be needed for modeling in the recombination phase. Accordingly, the UEG acceleration, associated critical squared velocity which is obtained by integration of the UEG acceleration with the scale factor α, and the effective UEG mass or mass density, would have a $1/\alpha^4$, $1/(3\alpha^3)$, and $1/\alpha^2$ dependence for modeling in the recombination phase. This is in contrast with the $1/\alpha^{4.5}$, $1/(3.5\alpha^{3.5})$, and $1/\alpha^{2.5}$ for the respective dependencies used for modeling in the current universe. Further, the distance to the radiation horizon, which is assumed to be the effective horizon for the UEG modeling in the recombination phase, is much farther than the conventional matter horizon. Therefore, in the recombination phase, the effective kinetic energy due to the expansion velocity, which linearly increases with distance, would be much larger than the mass-energy enclosed by the effective horizon. Accordingly, different mass-energies may be ignored in the computation of the total energy enclosed by the horizon, for the present derivation in the recombination phase.

The squared-velocity ${v_0'}^2$ just after recombination, which is the total critical squared-velocity supported by the baryonic and radiation masses, and any equivalent UEG mass due to the radiation at the recombination, may be expressed in terms of the v_0^2. As discussed above, the squared-velocity due to the UEG mass would require a factor 1/3. This is the factor needed in the derivation of the squared-velocity, implemented as the integration of the $1/\alpha^4$-dependent UEG acceleration with the scale factor.

$$\begin{aligned}{v_0'}^2 &= (1 + \tfrac{M_r}{M} + \tfrac{M_u}{M} \times \tfrac{1}{3})v_0^2 = (1 + \tfrac{\rho_{rv}}{\rho_v} + \tfrac{\rho_{uv}}{\rho_v} \times \tfrac{1}{3})v_0^2 \\ &= (1 + \tfrac{\Omega_r}{\Omega_b} + \tfrac{\Omega_{dm}}{\Omega_b} \times \tfrac{1}{3})v_0^2. \qquad (22)\end{aligned}$$

The $\Omega_{dm}/\Omega_b = 5.47$ is the ratio of the dark and baryonic masses, whose value is maintained independent of the scale factor, and $\Omega_r/\Omega_b = 25/12$ is the ratio of the radiation (photon) and baryonic masses at the scale of recombination. The kinetic energy of expansion W_0' after the recombination may be expressed in terms of the kinetic energy W_0 of the baryonic matter associated with the reference velocity v_0. The W_0' is also approximately equal to the total energy W_2 after the recombination. The same relationships (9,10) between the energy W and mass M for the baryonic mass, and the W_u and M_u for the UEG mass (equivalent to dark matter content at recombination), in the current universe is also used here as a rough estimate, although the associated redistribution weighting factor (see section II C) may not apply as well at the recombination phase.

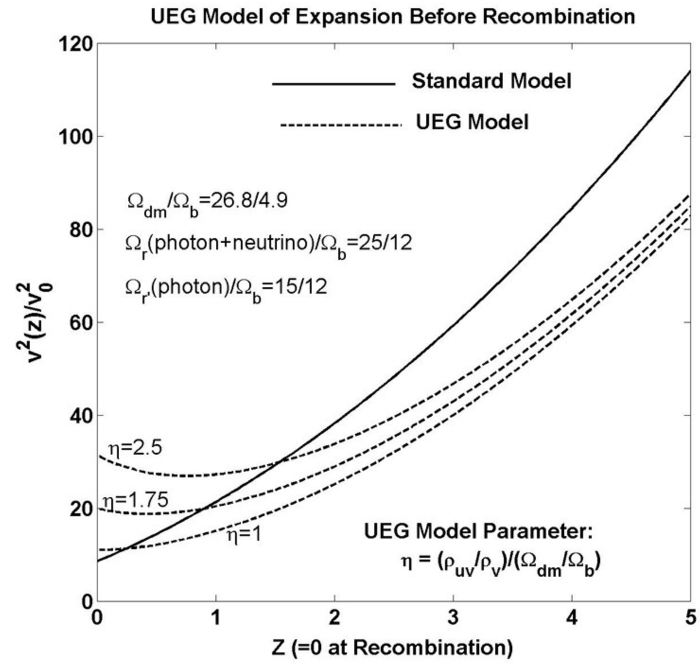

FIG. 5.

$$W_0' = \frac{v_0'^2}{v_0^2} W_0 \times (1 + \tfrac{M_r}{M} + \tfrac{1.048 M u}{1.496 M})$$
$$= \frac{v_0'^2}{v_0^2} W_0 \times (1 + \tfrac{\Omega_r}{\Omega_b} + \tfrac{1.048\Omega_{dm}}{1.496\Omega_b}),\ W_2 = W_0'. \quad (23)$$

The squared-velocity $v^2(z)$ may be expressed as a function of the redshift $z > 0$, with reference zero redshift at the recombination. It consists of two principal parts, which are the critical squared-velocities supported by the baryonic and radiation contents, and the additional term v_Δ^2 in excess of the principal parts. The total energy W_1 just before recombination ($z = 0^+$), which is approximately equal to the total kinetic energy as discussed, may be expressed using the $v^2(z = 0^+)$.

$$v^2(z > 0) = v_0^2(1 + z) + v_0^2 \tfrac{\Omega_r}{\Omega_b}(1 + z)^2 + v_\Delta^2(z),$$
$$v^2(z = 0^+) = v_0^2 + v_0^2 \tfrac{\Omega_r}{\Omega_b} + v_\Delta^2(z = 0), \quad (24)$$

$$W_1 = \frac{v^2(z=0^+)}{v_0^2} W_0 \times (1 + \tfrac{M_r}{M})$$
$$= \frac{v^2(z=0^+)}{v_0^2} W_0 \times (1 + \tfrac{\Omega_r}{\Omega_b}). \quad (25)$$

The excess squared-velocity $v_\Delta^2(z = 0)$ just before recombination may be solved by enforcing energy conservation with $W_2 = W_1$.

$$W_2 = W_1,\ \frac{v_0'^2}{v_0^2} W_0 \times (1 + \tfrac{\Omega_r}{\Omega_b} + \tfrac{1.048\Omega_{dm}}{1.496\Omega_b})$$
$$= \frac{v^2(z=0^+)}{v_0^2} W_0 \times (1 + \tfrac{\Omega_r}{\Omega_b}),$$
$$(1 + \tfrac{\Omega_r}{\Omega_b} + \tfrac{\Omega_{dm}}{\Omega_b} \times \tfrac{1}{3})(1 + \tfrac{\Omega_r}{\Omega_b} + \tfrac{1.048\Omega_{dm}}{1.496\Omega_b})$$
$$= (1 + \tfrac{\Omega_r}{\Omega_b} + \frac{v_\Delta^2(z=0)}{v_0^2})(1 + \tfrac{\Omega_r}{\Omega_b}),$$
$$\frac{v_\Delta^2(z=0)}{v_0^2} = \frac{(1+\frac{\Omega_r}{\Omega_b}+\frac{\Omega_{dm}}{\Omega_b}\times\frac{1}{3})(1+\frac{\Omega_r}{\Omega_b}+\frac{1.048\Omega_{dm}}{1.496\Omega_b})}{(1+\frac{\Omega_r}{\Omega_b})}$$
$$- (1 + \tfrac{\Omega_r}{\Omega_b}). \quad (26)$$

The sum of the kinetic energies $W_\Delta(z)$ and $W_{r\Delta}(z)$ of the baryonic and radiation masses, respectively, associated with the excess velocity $v_\Delta(z)$ may be required to be conserved for all redshifts. This would lead to expressing the z-dependence of the squared-velocity $v_\Delta^2(z)$, in terms of the $v_\Delta^2(z = 0)$ solved above. Using this result in (24) would provide a complete expression for the $v^2(z > 0)$ before recombination.

$$W_\Delta(z) + W_{r\Delta}(z) = \frac{v_\Delta^2(z)}{v_0^2}(W_0 + W_0 \tfrac{\Omega_r}{\Omega_b}(1 + z))$$
$$= W_\Delta(z = 0) + W_{r\Delta}(z = 0)$$
$$= \frac{v_\Delta^2(z=0)}{v_0^2}(W_0 + W_0 \tfrac{\Omega_r}{\Omega_b}), \quad (27)$$

$$v_\Delta^2(z) = v_\Delta^2(z=0)\frac{(1+\frac{\Omega_r}{\Omega_b})}{(1+\frac{\Omega_r}{\Omega_b}(1+z))}. \tag{28}$$

In the above derivation we ideally assumed the ratio of the UEG and baryonic masses or the respective mass densities $M_u/M = \rho_{uv}/\rho_v$ to be equal to Ω_{dm}/Ω_b, abruptly after the recombination, and equal to zero in the ionized environment before the recombination. However, in reality the UEG effect would gradually transition as the ionization changes during this phase. In order that this transitional UEG effect emulates the effect of the dark matter of the standard model, which is maintained at its constant value throughout the phase, the above ratio of the UEG and baryoninc masses may have to be sufficiently larger than the ratio Ω_{dm}/Ω_b by a factor $\eta > 1$. With introduction of this factor, the complete function $v^2(z > 0)$ is expressed as follows.

$$\begin{aligned} v^2(z>0) &= v_0^2(1+z) + v_0^2\frac{\Omega_r}{\Omega_b}(1+z)^2 + v_\Delta^2(z) \\ &= v_0^2(1+z) + v_0^2\frac{\Omega_r}{\Omega_b}(1+z)^2 \\ &+ v_0^2[\frac{(1+\frac{\Omega_r}{\Omega_b}+\eta\frac{\Omega_{dm}}{\Omega_b}\times\frac{1}{3})(1+\frac{\Omega_r}{\Omega_b}+\eta\frac{1.048\Omega_{dm}}{1.496\Omega_b})}{(1+\frac{\Omega_r}{\Omega_b})} - (1+\frac{\Omega_r}{\Omega_b})] \\ &\times [\frac{(1+\frac{\Omega_r}{\Omega_b})}{(1+\frac{\Omega_r}{\Omega_b}(1+z))}]. \end{aligned} \tag{29}$$

For comparison, the squared-velocity function $v^2(z)$ from the standard model is expressed in the following form.

$$\begin{aligned} v^2(z>0) &= v_0^2(1+z) + v_0^2\frac{\Omega_{dm}}{\Omega_b}(1+z) \\ &+ v_0^2\frac{\Omega_r}{\Omega_b}(1+z)^2, \end{aligned} \tag{30}$$

where $\Omega_r/\Omega_b \sim 25/12$ is the ratio of the radiation (photon and neutrino) and baryon masses at the time of recombination.

Fig.5 shows the normalized velocity function $v^2(z)/v_0^2$ of (29) for different values of the parameter η, that are compared with the corresponding function (30) from the standard model.

The sound horizon distance r_s at the recombination, scaled back in the current universe, may be derived using the $v(z)/v_0$ functions of (29,30), in terms of the Hubble constant $H_0 = 67.8$ (km/s)/Mpc and the fractional matter content $\Omega_b = 0.049$ in the current universe, the scale factor $\alpha_c = 1/(1+z_c) = 1/1100$ at the recombination, and the sound speed $c_s(z)$ in the photon-baryon plasma.

$$\begin{aligned} r_s &= \frac{1}{H_0\sqrt{0.049(1+z_c)}}\int_{z=0}^{\infty}\frac{c_s(z)dz}{[v(z)/v_0](1+z)}, \\ c_s(z) &= \frac{c}{\sqrt{3(1+\frac{3\Omega_b}{4\Omega_{r'}(1+z)}}}, \end{aligned} \tag{31}$$

where $\Omega_{r'}/\Omega_b = 15/12$ is the ratio of radiation (photon) and baryon mass densities at the recombination. The values of the r_s from the UEG model with variable UEG mass-density, defined by the parameter $\eta = (\rho_{uv}/\rho_v)/(\Omega_{dm}/\Omega_b)$, are compared in Fig.6 with those from the standard model with the fixed parameter $\Omega_{dm}/\Omega_b = 5.47$ for the dark matter. The reference value for the parameter $\eta = 1$ corresponds to $\rho_{uv}/\rho_v = \Omega_{dm}/\Omega_b = 5.47$. The results show that the UEG model using only baryon and radiation contents, and UEG effect of the radiation, but without any dark matter, would emulate the standard model that includes the baryon and radiation, and additional dark-matter, with a reasonable adjustment of the parameter $\eta \sim 1.75, \eta > 1$, as we expected.

The agreement of the sound horizon r_s from the standard model with the UEG model for $\eta \sim 1.75$ means that all signatures of the baryon acoustic oscillation (BAO) in the current universe (in the CMB [10, 11] and in the correlation distance of galaxy density [12]) predicted by the standard model, that are based on the horizon distance r_s as a reference "ruler", would be emulated in the UEG model for the given η. In addition, this value of $\eta \sim 1.75$, which is reasonably larger than unity, means that the UEG mass during the transition phase of recombination could potentially emulate the effective gravity of the dark matter in acoustic oscillations before the recombination. Therefore, the signature of the dark matter in the CMB could also be replicated by the UEG effects. The characteristics of the BAO in the ionized environment before recombination [22] needs to be reviewed, by properly including the new UEG effects, in order to make a more definitive evaluation. In any case, the present results indicate that all essential signatures of the BAO observed in the current universe could be potentially explained by the UEG theory without need for any dark matter, in consistency with the standard model predictions that require the hypothetical dark matter. That is a significant development.

Furthermore, even a somewhat different value of the Hubble constant $H_0 \neq 67.8$(km/s)/Mpc, that can be consistent with the CMB observations as well as recent measurement of the H_0 in the local universe [23, 24], could be accommodated in the present UEG theory, by suitable adjustment of the parameter η. This is significant as well, in order to overcome any tension between the CMB signature and the local H_0 measurement, which is getting increasingly difficult to resolve based on a conventional dark-energy model using a cosmological constant [23, 24].

VI. DISCUSSION AND CONCLUSION

The UEG theory, originally developed for modeling elementary particles [1, 2], is applied under special conditions to cosmology. The new theory explains the accelerating expansion of the recent universe, consistent with supernova measurements [7, 8]; explains the expansion of

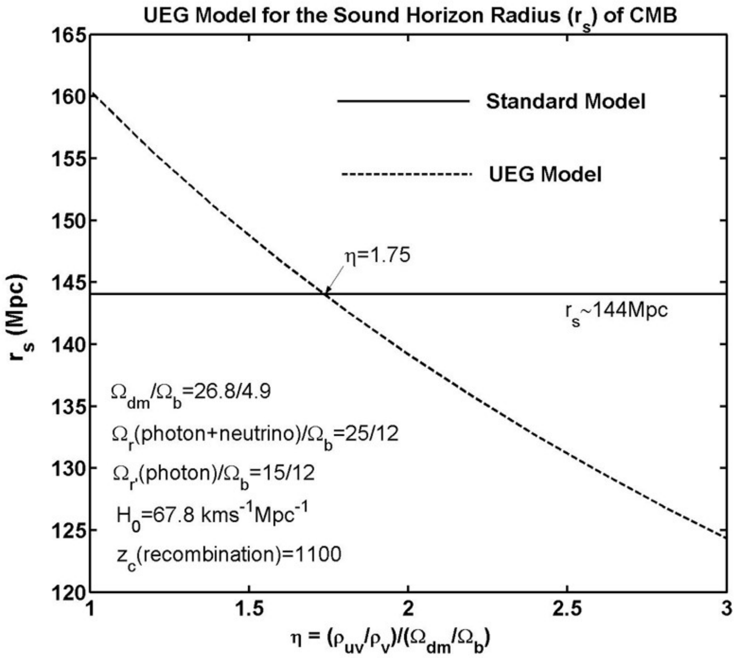

FIG. 6.

the universe before recombination, consistent with measured signatures of BAO in galaxy distributions [12] and in the CMB [10, 11]; could resolve a potential tension between different measured values of the Hubble constant, consistent with the CMB signatures as well as recent local measurements of the H_0 [23, 24]; and the theory supports a future contraction of the universe presumably leading to a cyclic process. The theory is based on gravitation of conventional matter in the universe, with additional acceleration and equivalent mass due to new UEG effects of the CMB radiation and any future star lights, without need for hypothetical dark matter or dark energy. As per the UEG theory, the energy density associated with any radiation, such as the CMB radiation or star lights, would produce new gravitational acceleration. The new UEG acceleration is modeled in terms of an equivalent mass distribution, just like conventional gravitational acceleration is modeled in terms of a conventional mass distribution as its source. The UEG mass distribution may also be treated like any distribution of conventional inertial mass, and accordingly be associated with its rest as well as kinetic mass-energy based on special relativity. These are significant new understandings on the basic principles of gravity, mass and energy, in the context of the new UEG theory.

The above new UEG effects are to be adopted in consistency with the basic cosmological assumption of a homogeneous and isotropic universe. However, the UEG theory, when applied in its simple form, would lead to a uniform acceleration independent of the radial distance from a center of observation. The uniform acceleration is associated with a uniform energy distribution of the CMB radiation, or with a uniform distribution of star lights produced from a uniform galaxy distribution. The equivalent mass associated with the uniform UEG acceleration, based on a simple UEG theory, can be shown to be non-uniform in distribution. This would be in contradiction with a uniform mass distribution, with associated gravitational acceleration linearly increasing with radial distance, that would be expected in consistency with the basic cosmological assumption of a homogeneous universe. In order that the UEG theory be consistent with the basic cosmological assumption, suitable adjustment in the simple UEG theory is needed. A new model is proposed and implemented in the paper, in the form of an effective UEG model for cosmology. Based on the success of the proposed approach, validated in consistency with measured observations, the effective model might be accepted as a fundamental new UEG theory for cosmology. Alternatively, some new physical process in the cosmological scale may allow readjustment of the expansion and mass distribution of the universe, in response to the uniform UEG accelerations supported by the simple UEG theory, which may ultimately lead to the same outcome as predicted from the effective UEG model. Both the above possibilities would be theoretically equivalent to each other.

The effective UEG model proposes suitable redistribution of the UEG mass and energy enclosed inside a spherical volume, defined by a “particle horizon” associated with first creation of conventional matter, or possibly by a “radiation horizon” (much farther than the particle horizon) associated with the early radiation-dominated inflationary universe, or even by a suitable combination of the above two horizons based on the mass and radiation content of the universe at a given time. The particle or radiation horizon would carry fundamental significance in the proposed UEG theory of cosmology, having critical theoretical as well as philosophical implications. The effective UEG model in the present work is implemented using a physically reasonable redistribution model, that may be adequate for certain objectives. However, further theoretical or observational development may be needed for a more definitive and rigorous UEG redistribution model. In addition, the physics of the BAO [22] may need to be re-evaluated based on the proposed UEG model, in order to properly account for any UEG effects on the CMB signature. The UEG effects in the ionized environment before recombination could potentially emulate effects of the hypothetical dark matter, as we have assumed in section V. A focused study of the BAO physics, based on the new UEG theory, would be needed for a rigorous understanding and analysis, beyond the scope of the present work.

Aside from the possible fundamental advancement in the proposed UEG theory of cosmology, as discussed above, some analytical or numerical refinement in the proposed UEG model could be implemented in principle. For analytical simplicity we may have assumed certain functional variation for the horizon distance of the observable universe, at different scale lengths or associated red-shifts. These assumptions may be effective in an average sense over a range of scale lengths, with adequate validity for the specific results presented. For accurate results in general applications, the functional variation of the horizon distance may have to be accurately tracked, using a more involved numerical computation.

With evident success in answering some of the key questions in cosmology today, as presented in this paper, the UEG theory may provide a new theoretical framework for any future advancement in physical cosmology. With successful prior application of the UEG theory in particle physics [1, 2], quantum mechanics [3], and stellar and galactic modeling [4, 5], the present extension of the UEG theory to cosmology may help to establish a complete, unified theory of physics, fundamentally integrating gravity, electromagnetics, as well as quantum mechanical concepts, with validity in in the smallest (elementary particles) to the largest (cosmology) domains of the nature.

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