1 Introduction

According to Ref. [1, 2], we consider a total {"massless" ($0 \rightarrow R_{\mathrm{BB}} \leq R \leq R_{\mathrm{Pl}}$) and massive ($R > R_{\mathrm{Pl}}$)} universe, where $R_{\mathrm{BB}} << R_{\mathrm{Pl}}$ and $R \leq R_{\mathrm{Pl}}$ describe the radius distance of the big bang (BB) and of the "massless" universe, whereas R_{Pl} and $R > R_{\mathrm{Pl}}$ are the Planck distance and the known scale factor, respectively. The denotation "massless" universe, we have applied because it contains mainly massless and nearly massless particles. It is determined by the gravitation [1, 2], whereas the massive universe is defined by a new inflation model [1-5] and the Friedmann-Lemaitre Equations [1-12]. In Refs. [2-5], we have shown that these universes have a Euclidian geometry.

In work [2], for the total ("massless" and massive) anti-universe, all assumptions derived from the known properties of the antiparticle, are completely correct. Unfortunately, in contrast to work [2], the work [1] gives a negative scale factor $-R$ as one incorrect assumption instead of the correct positive scale factor R for the anti-universe. Thus, we define once more the correct assumptions for the anti-universe in this work with starting point, universe, (see Sec. 3.10). We propose that the total ("massless" and massive)) anti-universe had its existence in the past, i.e. for a negative time direction $-\infty \leftarrow -t \leftarrow -t_{\mathrm{BB}} \leftarrow 0$. Thus, for the anti-universe, because of its negative time direction (from the big bang at $-t_{\mathrm{BB}}$ to the past), the Friedmann-Lemaitre Equations provide an expanding anti-universe with the scale factors greater than zero as well as the negative velocities $-c \leq -v \leq 0$ (see Table IV). For the universe, we have the positive time direction (from the origin (big bang at $+t_{\mathrm{BB}}$) to the future), so that the Friedmann-Lemaitre Equations yield an expanding universe with scale factors greater than zero as well as positive velocities $c \geq v > 0$. Thus, the Friedmann-Lemaitre Equations give a time reversal solution, in which anti-universe and universe result from two equivalent energy uncertainties via the uncertainty relation by one quantum fluctuation of the vacuum (origin).

In the works [1-4], we have uniquely estimated the rest energy of the light neutrinos and the supersymmetric grand unification particles. The works [1-4] show clearly that the massive universe (and anti-universe) are completely described by the (present), cosmological parameter values [1-12], which were also exactly estimated in Refs. [1, 2] via the light (anti)neutrino density parameters [1-5], multiplied by the different ratios of the relativistic energy and the rest energy of the supersymmetric grand unification (anti)particles [1-4]. On this way, it is also possible to calculate the rest energy and number density of the heavy and the sterile neutrinos [1-4], using the astronomical unit changing [1-5] and observed data of one sterile neutrino (as long-sought dark matter particle candidate [1-4, 13]).

At $R \leq R_{\rm Pl}$, for the "massless" universe and anti-universe, we must use the quantum cosmology or the quantum gravity. However, unfortunately, to this day, this quantum gravity is still highly incomplete and yields therefore no reliable predictions because the connection between the cosmological "constant" and the vacuum energy density is not clear [6]. Therefore, in the works [1, 2], for the "massless" universes, by aid of the virtual matter of the quantum vacuum, we have derived a simple solution for the long-sought four-dimensional quantum gravity. In works [1-3], we have derived generally the vacuum energy density for the total ("massless" and massive) universe and anti-universe, so that we solve generally the problem of the connection between the vacuum energy density and the cosmological "constant [1, 2]. These universes exist by the zero-point oscillations [1].

Thus, this four-dimensional quantum gravity, which is transferable to the massive universes, permits the determination of the parameters of the big bang and the evaluation of the lifetime of the sterile neutrinos via the transition from the final state of the universes in the direction to the big bang [1, 2]. Thus, we obtain a cyclic evolution of the total ("massless" and massive) universes as a result of the dark energy converted into photons and neutrino relics by the complete decay of the sterile neutrinos via the gravitation [1, 2]. Thus, this decay process must lead to an overheat of the final state of the universes because of the particle accumulation by deceleration, so that their heat death takes place [1]. Therefore, from these final states, we find to the "massless" universes and the big bang [1].

Using the expansion in opposite time directions from the big bang, the momentary beginning of the formation of the "massless" universe and anti-universe leads to a separation of the virtual particle-antiparticle pairs of the quantum vacuum into real particle pairs (matter) in the "massless" universe and antiparticle pairs (antimatter) in the "massless" anti-universe via the gravitational interaction. These separated particles and antiparticles are in a new thermal equilibrium with the photons, so that at the Planck length all real particles and antiparticles have the Planck energy $kT_{\rm Pl} = E_{\rm Pl}$ as relativistic energy for their start in the correspondingly separated massive universe and anti-universe [1, 2].

Consequently, at $R = R_{\rm Pl}$, all separated particles (universe) or antiparticles (anti-universe) have the Planck energy as relativistic energy, i.e. the non-separated particles and antiparticles can be formed only by interactions between the separated particles or antiparticles, so that these non-separated particles and antiparticles disappear again by annihilation. These interactions are determined by the known laws of nuclear physics or elementary particle physics. Because the statistical particle weights were derived by aid of these laws, the new thermal equilibrium has no influence on these statistical weights [1, 2]. In the old interpretation, where for the universe the non-separated particles and antiparticles are produced simultaneously by photons with the thermal energy of the sum of their rest energy in this old thermal equilibrium, so that this interpretation leads to difficulties at the explanation of the separation of matter and antimatter [1, 2].

In this work, for a better intelligibility, we give firstly a detailed review for the transition from the final state of the universes in the direction "big bang" as a start of an eternal cyclic evolution, so that these two states are bound with each other. The reason of this final state is a mean negative acceleration [1-5] interpreted as Pioneer anomaly [1-5, 14, 15]. We confirm the parameters of the big bang and the lifetime of the sterile neutrinos, so that we can corroborate the eternal cyclic evolution of the universes, whereat we derive a time reversal solution for anti-universe and universe, in which they begin their existence via two equivalent energy uncertainties by one quantum fluctuation of the vacuum. Secondly, we describe the dark matter and dark energy by the special properties of the sterile neutrinos. Thirdly, on the basis of all these results, we propose a solution of following important problems.

The existence of the new thermal equilibrium is supported by the light neutrinos.

We estimate the rest energy of the photons and the gravitons in accordance with their limiting values [16]. The existence of the rest energy of the photons, which is probably identical with the rest energy of the gravitons, is confirmed by the measured general galactic magnetic field [9, 17] and the theoretical magnetic neutrino moment [1-5, 10, 18].

Theoretical data, derived via the rest energy of the photons, permit far-reaching conclusions about the Hubble "constants". The Hubble expansion rate $H_0 = 67.3\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$, which in Ref. [7] was assumed as the present Hubble "constant" of the universe, is interpreted in this work as the present "Hubble constant" of the cosmic microwave background (CMB), since it was derived by the Planck observations [12] from the measurement of the cosmic back ground radiation, which was formed at $3.72 \cdot 10^5$ years after the big bang [7], so that this new Hubble "constant" $H_0 = 67.3\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ can be used further as basis for all hitherto existing considerations for the evolution of the universe, i.e. it must also determine all Hubble "constants" of the universe (see Sec. 7).

Thus, in the ΛCDM model, we assume that this present CMB value $H_0 = 67.3\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ must also yield a new Hubble constant for the beginning of the "present" accelerated (acc) expansion of the universe, where we expect this new Hubble "constant" with a larger value $H_{\mathrm{acc}} > H_0$. After the accelerated expansion, we have a slow linear (lin) expansion [1, 2] with the new Hubble "constant" $H_{\mathrm{lin}} << H_0$, derived by aid of the astronomical unit changing [1-5, 19]. The accelerated expansion is decelerated, so that presently we must observe the present Hubble "constant" $H_{\mathrm{acc},0}$ with the condition $H_{\mathrm{acc}} > H_{\mathrm{acc},0} > H_0$. The calculated value $H_{\mathrm{acc},0}$ is excellently confirmed by the most recent observations of Riess [20] in 2019.

Via time-dependent vacuum energy densities or cosmological "constants" (see, e.g., Ref. [21]), we solve generally the discrepancy between the vacuum energy of the Planck scale and the present dark energy as a continuous transition in accordance with the quantum field theory. The same solution is obtained from the big bang to the final state of the universe, using again the Planck scale. We demonstrate this behaviour from the big bang to the Planck scale as well as from Planck scale to the final state of the massive universes via the X, Y gauge bosons [1-5], the Higgs boson and the electron.

Thus, this work is organized as follows. In Sec. 2, we summarize the necessary equations and parameters. In Sec. 3, for a better intelligibility of this work, we give a detailed review for the universe and the time-reversal anti-universe as an eternal cycle of evolution, whereat we derive the transition from the final state of the massive universes in the direction to the big bang of the massless universe (Sec. 3.1), the lifetime of the sterile neutrinos (Sec. 3.2), the constant volume of the sterile neutrinos (Sec. 3.3), the heat accumulation in the final state of the universe as a result of the very high energy density (Sec. 3.4), the mean (maximum) energy of the "massless" and massive universe (Sec. (3.5), the zero-point oscillations as an existence form of the massless universes (Sec. 3.6), the particle horizon and the zero-point oscillations for the early and late massive universe (Sec. 3.7), the greatest possible gravitational energy and the hypothetical superforce of the particle interactions (Sec. 3.8), the very high temperature of the big bang (Sec. 3.9), the time reversal solution for anti-universe and universe (Sec. 3.10) as well as the eternal cyclic evolution for anti-universe and universe (Sec. 3.11). In Sec. 4, we explain the present dark matter and dark energy via the special properties of the sterile neutrinos. In Sec. 5, we give a reasonable argument for the new thermal equilibrium via the light neutrinos. In Sec. 6, we estimate the rest energy of photons and gravitons including conclusions. In Sec. 7, we calculate the different Hubble "constants" as a function of the cosmic evolution epochs. In Sec. 8, the time dependence of the cosmological "constant" is derived. In Sec. 9, we give a short summary. The values of physical constants, used in this work, are given in Refs. [7, 10].

2 The necessary equations and parameters

In Refs. [2-5], we have generally derived $\mathrm{k}=0$ by $\Omega_{\mathrm{tot}}=1$ and $\Omega_{\mathrm{tot}}(z)=1$, so that in the $\Lambda\mathrm{CDM}$ model the Friedmann-Lemaitre Equations are given by

$$H^2=\left(\frac{\dot{R}}{R}\right)^2=\frac{8\pi G_N}{3}\rho+\frac{c^2}{3}\Lambda \tag{2.1}$$