confirmed the derivation of the quantum gravity [1, 2] by the gravitation via the particle-antiparticle pairs of the quantum vacuum [1, 2].

Besides, this solution corroborates the correctness of the estimation of the parameters of the big bang [1, 2], the new inflation model [1-5], the (light [1-5], heavy [1-4] and sterile [1-4]) neutrinos as well as the SUSY GUT particles (X and Y gauge bosons [1-5] as well as magnetic monopoles [1-5]). Consequently, the conception of the SUSY GUT is now well established within the theories of the early universe.

Using the data of Tables III to V, the results, derived in this Sec. 8 for the massless and massive universe, are also valid for the massless and massive anti-universe.

9 Summary

We have derived the transition from the final state of the universe and anti-universe to the big bang (origin) via the complete sterile (anti)neutrino decay and the quantum gravity. With that, we have solved precisely and uniquely this fundamental problem, whereat we have confirmed the explanation that the present dark matter and dark energy can be attributed to the invisible decay and breakup products of the sterile neutrinos. We have proved that the massless universe and anti-universe exist by zero-point oscillations. Finally, we have also shown that the massive universe and anti-universe can be explained reasonably by zero-point oscillations.

By aid of the time-dependent vacuum energy densities or cosmological "constants", we confirm the predictions of the quantum field theory.

The final age of the universe and the anti-universe was confirmed to $t_{f2} = 6883\,\mathrm{Gyr}$, derived in Refs. [1, 2]. The lifetime $\tau_{\hat{\nu}}$ of the sterile neutrinos [1, 2] was also confirmed to $\tau_{\hat{\nu}} = 35.11\,\mathrm{Gyr}$ [1, 2]. The rest energy of the photons was estimated to $E_0(\gamma) \cong 1.563 \cdot 10^{-35}\,\mathrm{eV}$. This estimation is confirmed by the measured general galactic magnetic field. It was assumed that the rest energy of the gravitons has probably the same value as at the photons.

In the framework of the ΛCDM model, we determine various values of the Hubble "constant" in the evolution of the universes as a function of the present CMB Hubble constant $H_0 = 67.3 \pm 1.2\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ so that we can determine the present Hubble constant of the accelerated expansion to $"H_{\mathrm{acc},0}" = 74.0^{+2.0}_{-2.6}\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ in excellent agreement with its most recent observed value $74.03\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ by Riess et al. in 2019, i.e. we need no new physical assumptions. However, the accelerated expansion began with a large Hubble constant $H_{\mathrm{acc}} = 95.0\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$, so that the accelerated expansion is decelerated. In future, this result is in accordance with a slow linear expansion, which has the small Hubble constant $H_{\mathrm{lin}} = 0.843\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$.

For the big bang, we have confirmed the distance $R_{\mathrm{BB}} = 2.069 \cdot 10^{-98}\,\mathrm{m}$ and the time $t_{\mathrm{BB}} = 6.901 \cdot 10^{-107}\,\mathrm{s}$ of Refs. [1, 2]. The vacuum energy density or the cosmological "constant" of the big bang were also confirmed to $\rho_{\mathrm{vac}}(R_{\mathrm{BB}})c^2 = 4.227 \cdot 10^{247}\,\mathrm{eV\,cm^{-3}}$ and $\Lambda = 1.406 \cdot 10^{192}\,\mathrm{m^{-2}}$ (see Refs. [1, 2]). The very high temperature $\widetilde{T}_{\mathrm{BB}} = \widetilde{E}_{\mathrm{BB}}/k \cong 5.52 \cdot 10^{94}\,\mathrm{K}$ was estimated for the hot big bang. Therefore, for the direct investigation of the big bang, ultrahigh-energy accelerator experiments, which under terrestrial conditions also in the near future have not the necessary energies, are utopian. Thus, for example, they should be stopped in favour of the neutrino physics.

Using the Friedmann equation as well as the known properties of particles and antiparticles, we have found a time reversal solution for the anti-universe $(-t_{\mathrm{f2}} \leftarrow -t \leftarrow -t_{\mathrm{BB}} \leftarrow 0)$ and the universe $(0 \rightarrow t_{\mathrm{BB}} \rightarrow t \rightarrow t_{\mathrm{f2}}.)$, since they expand in the opposite time direction by scale factors greater than zero and at velocities with opposite sign (see Table IV). The beginning of the anti-universe (antimatter) and the universe (matter) is a result of two equivalent energy uncertainties by one quantum fluctuation of the vacuum according to the uncertainty relation in form of $\widetilde{E}_{\mathrm{BB}} = -\hbar/2(-t_{\mathrm{BB}})$ and $\widetilde{E}_{\mathrm{BB}} = \hbar/2t_{\mathrm{BB}}$, respectively. The total energy $E_{\mathrm{BB}} = 2\widetilde{E}_{\mathrm{BB}} = \hbar/t_{\mathrm{BB}}$, which must yield the vacuum, is used for the excitation of the zero-point oscillations. At $t = 0$ (origin), these two energy uncertainties disappear by annihilation.

. With that, we have simply solved the fundamental problem of the separation of antimatter and matter because the unknown anti-universe must be existent in the past, whereas the known universe exists in the future. Besides, we have shown that the existence of the anti-universe and the universe is determined by an eternal cyclic cosmic evolution, for which is responsible the transition from their final state in the direction to the big bang.

. If we go in direction to the end of the universes, we have shown that we have an enormous increase of the energy density and the temperature because of the relationship "final state of the universe and big bang". To this day, in these processes, at the dark energy, the complete sterile neutrino decay was not considered, so that this work yields a strongly improved picture of the universe and the corresponding anti-universe in contrast to the hitherto existing big bang models.

In these hitherto existing big bang models [6-12], where the physics of the early universe ($t \leq 10^{-6} s^{-1}$) is still very uncertain, their theories are not well established [6]. They predict, e.g., for the elusive dark matter, the existence of many exotic particles [6, 8, 11], for which however there is no experimental evidence [6].

In contrast to these theories, by aid of time-dependent vacuum energy densities or cosmological "constants" [1, 2], this work yields new contributions for the picture of the universe and the corresponding anti-universe by the derivation of the parameters of the big bang (as a result of the complete sterile (anti)neutrino decay) via the results of the quantum gravity [1, 2], which was derived by the gravitation via the particle-antiparticle pairs of the quantum vacuum, using the new thermal equilibrium between photons and particles [1-3] as well as the new inflation model [1-3].

By these new contributions, the SUSY GUT transition is now well established at the theories of the early universe. These new arguments are based on (convincing) direct experimental observations as the 3-neutrino oscillation parameters (see, e.g., Ref. [10]), the Planck 2013 results (see, e.g., Refs. [7, 12]), "the sterile neutrino decay" (see, e.g., Refs. [13, 22-26]), "the Pioneer anomaly" (see, e.g., Refs. [14, 15]), the general galactic magnetic field [9, 17],"the astronomical unit changing" (see Ref. [19]) and the present Hubble "constant" [20] as well as "well" established theories as the neutrino statistics (see, e.g., Refs. [6-11]), "the magnetic neutrino moments of the standard

$SU(2) \times U(1)$ model" (see, e.g., Refs. [10, 18]), the hot big bang model (see, e.g., Refs. [6-12]) and "the SUSY GUT transition" (see, e.g., Ref. [7]), used in Refs. [1-5], which are the fundamental basis of this work.

The "dark energy" was not introduced a priori in the ΛCDM model. This dark energy is based on the convincing experimental observation of the expansion of the universe by Hubble because by this discovery Einstein' cosmological constant Λ, introduced by him to get a static universe, has obtained a Renaissance via the quantum field theory as vacuum energy density (negative pressure), which in the works [1, 2] was thus connected with the cosmological "constant" and the dark energy as variable quantities. This work supports once more this hypothesis [1, 2] by the transition to a time-dependent vacuum energy density or cosmological "constant" in the eternal cyclic evolution of the total (massless and massive) universe and anti-universe. This assumption is confirmed by discovery of the present accelerated cosmic expansion [7], defined as the corresponding "present dark energy" [1, 2].

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