A simple model describing a pure QED universe

Stig Sundman
Dragonvägen 12 A 5, FIN-00330 Helsinki, Finland

March 11, 2009

Abstract

A particle model derived from Newton's second law pictures an electron in an expanding universe. The model unifies charge, spin, and expansion. Expansion causes gravity. Massive particles pick up energy released via radiation redshift, and a purely radiative, matter-free, universe is forbidden. Therefore, the universe is forced to undergo a series of matter-creating phase transitions—from literally nothing (phase 0), via decaying neutral spinless matter (phase 1), charged spinless matter (phase 2), and charged spinning matter (phase 3), to the strongly and weakly interacting stable matter of today (phase 4). The tauon-muon and muon-electron mass ratios tell how much the rest energies of the massive particles grew in phase 1 and phase 2, respectively. The model contains no adjustable parameters, and makes unambiguous predictions, such as $H_0 = 56.8\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ for the present-day Hubble expansion rate and $1/B\alpha = 205.759\,223$ (with $B = 0.666\,001\,731$) for the muon-electron mass ratio. To the zeroth-order predictions of the particle model must be added radiative contributions calculated using standard QED and electroweak theory. Thus, $m_\mu/m_e = 1/B\alpha + 1/(1-2B\alpha) = 206.769\,039$ is the muon-electron mass ratio of the pure QED universe (phase 3). This value is larger than the measured phase-4 value 206.768 283(6). A simple electroweak calculation shows that the appearance of the weak force caused a sudden decrease in lepton masses. Thus, a one-Higgs model adds $-0.000\,2076$ to m_μ/m_e. The corresponding decrease in tauon mass explains how the creation of the proton was energetically possible, and why the previously cold universe acquired a high temperature. The numerical value $1 + 2(m_p - m_\pi)/4(m_\pi - m_e) = 3.872 = 4 - 0.128$ informs that four Higgs bosons act to decrease the tauon mass, while a weak (presumably flavor-changing) effect slightly corrects the mass upward. It is concluded that the corresponding total weak correction to the muon-electron mass ratio is $-0.000\,2076\,(4 - 0.128 \log(m_\tau/m_\mu)) = -0.000\,755$, yielding $m_\mu/m_e = 206.768\,284$, which agrees with the measured value.

Preface. The results obtained here could be presented in a much briefer and more streamlined form. However, I have chosen to retain the main part of the paper (Sections 1 to 9 and Appendices A to E.7) in essentially the same form it had before my simulation experiment revealed that the energy principle plays a double role in physics. Instead, I have appended a list of detailed conclusions in Appendix G, which is intended to ensure that the model is internally consistent and neither conflicts with well-established dynamic theories nor contradicts astrophysical observations. Readers wishing a quick overview of the theory and its implications are recommended to jump to page 50 (Appendix G) after first reading Appendix E.8 on page 39.

Contents

1 Introduction and summary

In the beginning of the twentieth century, the universe was thought to be static, remaining in the same condition forever. When Albert Einstein wanted to apply his theory for gravity to the universe as a whole, he consequently added into his equation an artificial term representing a cosmological repulsion that counteracted gravity. Edwin Hubble's discovery that the universe is expanding made Einstein regret his lack of confidence in his original equation. If, instead of modifying it, he had drawn the logical conclusion from his equation, it would have led him to predict the expansion of the universe!

After the discovery of expansion, the cosmological constant Λ was no longer needed. It came to be regarded merely as a historical curiosity, and for several decades the "standard model of cosmology" was generally accepted. In effect, the model simply stated that gravity balances the expansion of the universe, and that the universe began as a singularity, i.e., as a point without extension. This "hot big bang" model successfully explained the nucleosynthesis believed to have produced the observed hydrogen and helium abundances.

In the 1970s, improved astronomical observations indicated that the truth might not be that simple. The theory of inflation was invented to fix the problem. In the 1990s, still better observations demonstrated new problems with the theory. Since then, physicists have attempted to patch the theory by adding to it more fixes, such as a revived cosmological constant, quintessence, dark energy, variable gravity, and varying constants of nature.

Naturally, many scientists have asked if the great complexity of today's new "standard model of cosmology" is an indication that it is fundamentally wrong. However, seldom questioned is Einstein's assumption that his theory of gravity applies, without modifications, to the universe as a whole. The weakness of this assumption can be demonstrated using a simple parallel: Euclid's plane geometry agrees very well with experiments. But if we try to apply it to the whole surface of the earth, we conclude that the earth is flat. Today, we know that Euclidean plane geometry cannot be applied to the earth as a whole. In contrast, Einstein's general relativity is a kind of geometry that physicists still believe is applicable to the universe as a whole.

The purpose of this paper is to demonstrate that a working alternative to Einstein's assumption may be constructed. I will show how the simplest conceivable field equation for an elementary particle inevitably leads to a simplified big-bang model that in a perfectly consistent way describes the origin of our present universe without resorting to fifth and sixth forces, inflation, or other artificial means. Best of all is that it demonstrates that even an extremely simple model for the universe may be capable of making unambiguous, testable predictions.

In Section 2, I discuss the Johnson-Baker-Willey (JBW) finite QED hypothesis, Dirac's large-number hypothesis, and Dirac's "new equation." My model for a QED universe implies that the two hypotheses should be true, and that the Dirac particle plays a crucial role in the model. Also, I point out that we have no means of testing experimentally that the $1/r$ law for the gravitational potential holds for very large cosmological distances, and that the theoretical consequences of a declining G have been investigated by Paul Dirac and others.

In Section 3, I show that, assuming maximum simplicity, the hydrodynamic equation for stationary flow has the solution

$$\rho = \rho_0 \left(1 - \frac{1}{f}\frac{v^2}{v_0^2}\right)^{f/2} . \tag{1.1}$$

Assuming that the field equation (1.1) may be applicable to a physical phenomenon, there exists only one reasonable choice. The simplest possible interpretation of the equation is that it describes the electron, or more generally, a charged lepton (electron, muon, or tauon). Thus, for the values 3, 2, and 1 of the number of degrees of freedom, f, it seems that Eq. (1.1) describes charge (which generates mass), spin, and expansion, respectively. Like the quantum wave function, the function in Eq. (1.1) has verifiable consequences, being in itself unobservable. Later, in Section 5, I show that the expansion of the universe implied by Eq. (1.1) causes a force similar to gravity. Thus Eq. (1.1) unifies charge, spin, expansion, and gravity. Gravity is but a side effect of the expansion, and expansion is a predetermined unperturbable feature of nature on the same footing with charge and spin.

In Section 4, it is seen that the mathematical consequences of the assumption that Eq. (1.1) describes, thus unifying, charge, spin, and expansion, may be summarized in the constant

$$B = 0.666\,001\,731, \tag{1.2}$$

and leads to the tentative assumption that

$$\frac{m_\mu}{m_e} = \frac{1}{B\alpha} = 205.759\,22 \tag{1.3}$$

holds for the ratio of the uncorrected (zeroth-order) muon-electron mass ratio. This value differs 0.5 % from the measured muon-electron mass ratio of 206.768 28(1).

In Section 5, the mathematical consequences of Eq. (1.1) are worked out, and instead of arriving at Newton's equation, $U = -Gm/r$, for the gravitational potential due to a point mass m, one obtains

$$U = -Gmr^{-1}\left(1 - \frac{r^2}{R^2}\right)^{-1}, \tag{1.4}$$

which appreciably differs from Newton's law only when the distance r approaches the radius R of the universe. The force caused by this potential is repulsive for distances $r > R/\sqrt{3}$. Further calculations lead to the large-number relations that Dirac deduced from observations, but which according to current cosmology are purely accidental (although attempts have been made to incorporate the relations by adding still more artificial fixes to the theory). Another result, with $H = c/R$ for the Hubble expansion rate (or Hubble's constant), is

$$\rho_u = \frac{3H^2}{4\pi G} \tag{1.5}$$

for the density of the universe.

In Section 6, possible implications for our actual universe are discussed.

In Section 7, the model's implications for the big-bang theory are investigated. By following the big bang backward in time we know that the early universe must have been quite hot. However, nothing suggests that the model universe should have been immensely hot at its birth. On the contrary, the principle of maximum simplicity demands that it should have had no temperature.

Consistent application of the principles of maximum simplicity and conservation of mass and energy suggests the following mechanism for the creation of our present universe. The breaking of the perfect symmetry of literally nothing led to a universe containing a neutral spinless particle. This neutral spinless particle should have been the massive particle described by Dirac's "new equation" of 1971 (which is discussed in Section 2).

In the first universe, neither charge, spin, nor strong or weak forces disturbed the symmetry. However, the universe was unstable (since matter was unstable), and in a second symmetry-breaking transition, real charged particles were created. In a third transition, spinning charged particles appeared. The fourth symmetry-breaking transition, finally, led to the creation of strong and weak forces and a stable universe (stable matter).

Mathematical investigation of the evolution of the first three phases leads to Eq. (1.3), thus explaining it. Also Hubble's constant,

$$H_0 = 56.8 \text{ km s}^{-1}\text{ Mpc}^{-1}, \tag{1.6}$$

is easily calculable.

In Section 8, the QED corrections to the muon-electron mass ratio are obtained to all orders in $B\alpha$. The result is a perturbation-theoretical series that may be summarized in

$$\bar{m}_\mu/m_e = 1/B\alpha + 1/(1 - 2B\alpha) = 206.769\,04, \tag{1.7}$$

where $\bar{m}_\mu$ is the QED-corrected muon mass. The corrected muon-electron mass ratio (1.7) differs less than 4 ppm from the measured ratio 206.768 28(1).

In Section 9, the reason for the strong and weak forces is explained. Since the lepton described by Eq. (1.1) cannot be equipped with any new attributes in addition to charge, spin, and expansion, a totally new kind of massive real particle had to appear in the fourth symmetry-breaking transition. We know that this particle must have been the proton. Application of the energy principle together with standard electroweak perturbation theory, shows that the proton's creation had to be accompanied by the creation of the Higgs boson (one of the particles predicted by the electroweak theory), which caused a slight decrease in the lepton masses and, thereby, in the total energy of the radiation via the virtual lepton pairs appearing in the photon propagator. In other words, the strong force could not appear alone, but had to be accompanied by the weak force. Assuming that the fourth transition produced a proton-antiproton pair with the antiproton immediately decaying, thus recreating the real electron and instantly heating the universe, a value of

$$n_\gamma/n_b \approx 2 \times 10^9 \tag{1.8}$$

is obtained for the initial ratio of the number of photons to the number of baryons (originally a ratio of about 2 billion photons to one proton, which represents the first baryon). This ratio should have remained largely unchanged until today, and agrees with observations within uncertainty limits.

In Section 10, a computer simulation of the early universe is attempted. Even if it fails to give definite values for the lepton mass ratios and α, it still leads to testable predictions. Thus, it suggests an initial photon-baryon number ratio of

$$n_\gamma/n_b = 2.447 \times 10^9. \tag{1.9}$$

Also, it gives an initial phase-4 value of 10.889 for the ratio between the rest energy of an electron pair and the average energy of the photons. A consequence of these results is that the muon-electron mass ratio becomes

$$m_\mu/m_e = 206.768\,22 \tag{1.10}$$

when weak corrections are added to the value given in Eq. (1.7).

In Section 11, some conclusions about the present universe (phase 4) are drawn, and what looks like an age or time paradox is discussed.

Appendices A, B, and C contain mathematical details, while Appendix D discusses the concept of pointless space. The space of the QED universe that preceded our present universe is assumed to be perfectly smooth or continuous, i.e., nongranular or pointless. It means that distance and direction cannot be defined. This indeterminacy of distance and direction in pointless space corresponds to quantum indeterminacy in dynamic field theories.

2 Dynamic theories

Interactions between charged leptons are described by quantum electrodynamics (QED), a field theory based on the wave function introduced by Erwin Schrödinger. Since QED is a purely dynamic theory, it cannot picture a static particle. In contrast, the stationary field equation presented in Section 3 shows a static picture of a particle but says nothing about the dynamics of interacting particles. Thus, the stationary field equation is a complement to QED and suggests answers to questions that the standard model of particle physics is unable to resolve.

The basic assumption underlying the stationary field equation is that some aspects of space can be described by the simplest conceivable solution to the fundamental hydrodynamic equation, an equation that in mathematical form expresses the law of conservation of momentum for a fluid. All subsequent assumptions are firmly founded on the principle of maximum simplicity [1]. One important consequence of this principle is symmetry. Another consequence is that physical models should contain as few arbitrarily adjustable parameters as possible (meaning no such parameter in the present case).[1]

To understand how the model fits in with current physical knowledge, one must first recall the Johnson-Baker-Willey (JBW) finite QED hypothesis, Dirac's new equation, and Dirac's large-number hypothesis.

The renormalization constants of QED (i.e., Z_1, Z_2, Z_3, and δm) are usually regarded to be divergent quantities. However, if Z_3 is nonzero, a suitable choice of gauge eliminates the divergence in $Z_1 = Z_2$. JBW [2] also shows that the avoidance of perturbation theory eliminates the divergences in δm, i.e., m equals δm and the bare mass m_0 is zero. Finally, the JBW finite QED hypothesis [2, 3, 4] states that Z_3 (in $\alpha = Z_3\alpha_0$) is finite and determined by $F_1(\alpha_0/4\pi) = 0$, where the function F_1 (with its first four coefficients obtained in 1935, 1950, 1967, and 1991, respectively [5]-[8]) is

$$F_1(x) = \frac{4}{3}x + 4x^2 - 2x^3 - 46x^4 + \cdots . \tag{2.1}$$

The JBW finite QED hypothesis implies that the lepton may be looked upon as a cloud of virtual photons (charge-generating carriers of the electromagnetic force), which has a mass of purely electrodynamic origin. Another implication is that the vacuum-polarization loops do not contribute to the lepton mass. The JBW hypothesis is a beautiful example of an application of the principle of maximum simplicity [1] since it, in addition to disposing of a number of infinities, in one stroke eliminates three otherwise unresolved (and possibly irresolvable) questions: the origin of the bare mass of the electron, the ratio of the electron's bare mass to its measured mass, and the contribution of the vacuum-polarization loops to the electron mass.

Paul Dirac is known for his spinor equation that he formulated in 1928, his prediction of the positron (1930) and the magnetic monopole (1931, 1948), and his large-number hypothesis (1937). However, his "new equation" published in 1971 [9] appears to be less known. This equation strongly resembles Dirac's usual spinor equation. In the interpretation of Biedenharn, Han, and van Dam [10], it describes a particle with nonzero mass and zero spin (generalized to arbitrary spin) that cannot interact with the electromagnetic field without destroying the consistency of the defining structure. A subset of the generalized equations describes a particle composed of two bosons, one or both of which bear electric charge. Evidently, Dirac's particle does not exist today.

The ratio of the electric to the gravitational force between electrons is about 10^{40}. Likewise, the ratio of the age of the universe to the time taken by light to traverse the classical electron

[1]See Appendix E.1 on page 35.

radius seems to be close to 10^{40}. The mass of the universe divided by the mass of the electron is about 10^{80}, i.e., 10^{40} squared. According to Dirac's large-number hypothesis [11, 12], these numbers are connected.

Dirac derived his large-number hypothesis (LNH) from observations. However, his hypothesis was abandoned because it conflicted with the generally accepted gravitation-expansion (GE) balance hypothesis, according to which gravity and expansion are unrelated phenomena that by chance happen to balance each other in a very delicate way (since otherwise the universe would have collapsed soon after its birth or expanded too rapidly for macroscopic structures to form). Still, the LNH relies on an observational basis, while the GE balance hypothesis has no such basis and indeed had to be repaired when it was found to contradict observations.

Finally, it must be remembered that a well-established theory is one that has been experimentally verified in a number of ways. Thus, Newton's theory of gravitation is well-established, although very precise experiments show that for large masses it must be replaced by Einstein's theory of general relativity (GR). However, these theories have been experimentally verified only for planetary or shorter distances. Still, current cosmological theories assume that, even for very large distances, the gravitational force falls off exactly like r^{-2} in the Newtonian limit of the theory. For obvious reasons, this very-long-range behavior of gravity has not been experimentally verified. Consequently, present cosmological models are not objectively well-established (i.e., experimentally verified) and their existence cannot be used as a scientific argument against rival models.

A declining G (consequence of the large-number hypothesis) seemingly violates GR. However, Dirac [11] and Canuto et al. [12] have shown that a variable G can be allowed for without compromising the validity of GR. Also note that theories have been proposed that challenge the special theory of relativity by assuming the speed of light to vary with time [13].

3 A hydrodynamic lepton model

Imagine the space of the QED model universe as a fluid, and imagine further a lepton as a whirl in this fluid. By combining the hydrodynamic equation for stationary flow with the adiabatic law, the equations

$$\rho = \rho_0 \left(1 - \frac{1}{f}\frac{\boldsymbol{v}^2}{v_0^2}\right)^{f/2} \tag{3.1}$$

and

$$\nabla \times \boldsymbol{v} = 0 \tag{3.2}$$

are obtained (see Appendix A.1 on page 29). These equations will be assumed to describe a charged lepton and to form the basis for the model universe. The equations can only provide a static picture of the lepton, which means that they cannot describe dynamic interactions mediated by photons.

Clearly, space must be something more elementary than an ordinary physical fluid. Therefore, no pressure and no temperature will be attributed to it. Also, the "density" ρ in Eq. (3.1) should be regarded as an unobservable property of space. Further, ρ_0 is the value of ρ at large distances from the particle, $\boldsymbol{v}$ is a field or "velocity," and f is the number of degrees of freedom.

In kinetic gas theory, f is the number of degrees of freedom of the molecules. In Eq. (3.1), however, f must have another meaning. Obviously, the only reasonable interpretation is that f somehow characterizes the field $\boldsymbol{v}$ or the whirl described by Eq. (3.1). One would thus expect a linear "velocity" to have a value of $f = 1$, and a two-dimensional cylindrically symmetric "rotation" to have a value of $f = 2$. Finally, the value $f = 3$ should be associated with a three-dimensional whirl. Assuming, therefore, three types of field, v, u, and w, associated with $f = 1$, 2, and 3, respectively, one obtains by superposition the final form of the hydrodynamic lepton equation,

$$\rho = \rho_0 \left(1 - \frac{v^2}{v_0^2}\right)^{1/2} \left(1 - \frac{1}{2}\frac{u^2}{u_0^2}\right) \left(1 - \frac{1}{3}\frac{w^2}{w_0^2}\right)^{3/2}. \tag{3.3}$$

The field w, corresponding to $f = 3$, is here thought to be a property of space, which can be mathematically compared to a spherically symmetric rotation with two possible directions of rotation that gives rise to energy and charge. The property u, having two degrees of freedom, $f = 2$, is thought to be comparable to a cylindrically symmetric rotation giving rise to spin and magnetic moment. The third property, v, having $f = 1$, is thought to be a motion of the space away from an energy distribution, the space source being proportional to the energy density. This effect should be responsible for the expansion of the universe and the gravitational force. Thus, via f, Eq. (3.1) unifies the electromagnetic and gravitational forces of the model universe.

Since w in the hydrodynamic lepton equation (3.3) was assumed to create energy, the energy of a single charged lepton may be written

$$E_0 = m_0 c^2 = \frac{1}{2} \int_V \rho w^2 \, \mathrm{d}V. \tag{3.4}$$

For the interaction energy between two electrons a distance a apart, one finds (see Appendix A.2 on page 29)

$$E_{\mathrm{int}} = \pm 4\pi \rho_0 w_0^2 r_0^4 / a \tag{3.5}$$

when

$$w = \pm w_0 r_0^2 / r^2 \tag{3.6}$$

is assumed. Fig. 3.1 shows the function (3.3) when the effects of v and u are ignored.

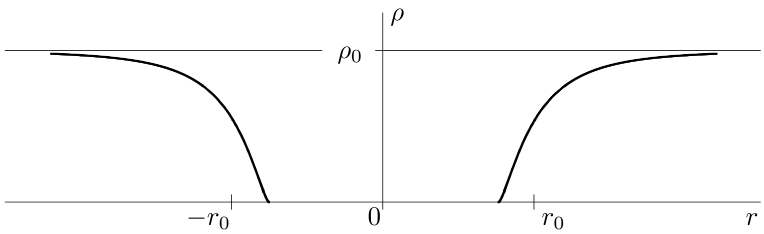

Figure 3.1: $\rho = \rho_0 \left(1 - \frac{1}{3}\frac{w^2}{w_0^2}\right)^{3/2}$ with $w = \pm w_0 r_0^2/r^2$. Note the cosmological radius $r_0/\sqrt[4]{3}$.

Since the interaction energy must be the same for, say, an electron and a muon as for two electrons, it follows that

$$w_e r_e^2 = w_\mu r_\mu^2 = w_\tau r_\tau^2. \tag{3.7}$$

Note that the radius r_0 characterizing the lepton may be either r_e, r_μ, or r_τ, and the corresponding w_0 either w_e, w_μ, or w_τ. In classical physics the interaction energy between two charged leptons is

$$E_{\mathrm{int}} = \pm e^2 / a \tag{3.8}$$

(setting $4\pi\epsilon_0 = 1$). Equating the hydrodynamic and the classical expressions for the interaction energy gives

$$4\pi \rho_0 w_0^2 r_0^4 = e^2, \tag{3.9}$$

which may be used to eliminate the unobservable parameter ρ_0.

Inserting Eqs. (3.6) and (3.9) into (3.4) and integrating over all space with real and positive ρ (note that the space disappears for $r < 3^{-1/4} r_0$, meaning that a cosmological radius appears inside the particle[2]), one obtains the relation

$$r_0 m_0 c^2/e^2 = B/2 \tag{3.10}$$

between the lepton's radius, mass, and charge. The lepton-structure constant characterizing this relation is

$$B = r_0 \int_0^{\pi/2} \sin\theta \, \mathrm{d}\theta \int (\rho/\rho_0) \, \mathrm{d}r/r^2. \tag{3.11}$$

After ρ/ρ_0 is eliminated using the hydrodynamic lepton equation (3.3), it is seen that the integration in Eq. (3.11) produces a well-defined numerical constant.

4 The lepton-structure constant *B*

To calculate the lepton-structure constant B defined in Eq. (3.11), the fields u and v appearing in the hydrodynamic lepton equation (3.3) must first be specified. Field w, creating charge, is already given in Eq. (3.6).

It was assumed, see discussion following Eq. (3.3), that the field u creates spin. The simplest non-trivial solution to Eq. (3.2) is in polar coordinates

$$u = u_0 r_0 / r \sin\theta. \tag{4.1}$$

Since $r \sin\theta$ is the perpendicular distance from the z axis, Eq. (4.1) describes an essentially two-dimensional cylindrically symmetric rotation. For the angular momentum, $s = \int r \sin\theta \, u \, \mathrm{d}m$, of the particle, one obtains

$$s = m_0 r_0 u_0. \tag{4.2}$$

If the third field, the linear "velocity" v, is neglected, Eq. (3.11) may be directly integrated to yield as a first approximation

$$B_1 = 0.669\,605\,309\,417. \tag{4.3}$$

See Eq. (B.7) on page 32.

Since the space created per unit time was assumed to be proportional to the energy density, see discussion following Eq. (3.3), the equation of continuity (the mathematical form of the law of conservation of mass) becomes

$$\nabla \cdot (\rho \boldsymbol{v}) = \rho_0 A \, \mathrm{d}E/\mathrm{d}V, \tag{4.4}$$

[2]Interestingly, the most symmetrical compactification of the ten-dimensional field of the spinning-string theory "induces a deSitter radius for spacetime that is about the same size as the internal six-dimensional space." [14]

where a new parameter, or constant of proportionality, A, is introduced. Eq. (4.4)[3] yields, via application of the divergence theorem,

$$m_0c^2 = \int\limits_V \frac{\mathrm{d}E}{\mathrm{d}V}\,\mathrm{d}V = \frac{1}{A\rho_0}\int\limits_V \nabla\cdot(\rho\boldsymbol{v})\,\mathrm{d}V = \frac{1}{A\rho_0}\oint\limits_S (\rho\boldsymbol{v})\cdot\mathrm{d}\boldsymbol{S} = \frac{4\pi}{A}\lim_{r\to\infty} r^2 v, \tag{4.5}$$

where S is the surface of a sphere with radius r. The obvious assumptions, compare with Eqs. (3.6) and (4.1),

$$\lim_{r\to\infty} v = v_0 r_0^2/r^2 \tag{4.6}$$

and

$$v_0 = c \tag{4.7}$$

mean that A, instead of being an adjustable parameter, is determined by

$$A = 4\pi\frac{r_0^2}{m_0 c}, \tag{4.8}$$

and thus eliminated from the calculations.

All three fields, w, u, and v, appearing in the lepton equation (3.3) are now known and the lepton-structure constant B may be computed. In Appendix B, it is shown how Eq. (4.4) may be transformed into an elliptic partial differential equation in two dimensions, with the help of which Eq. (3.11) may be iteratively integrated using B_1 of Eq. (4.3) as the initial approximation. The result is

$$B = 0.666\,001\,731\,498. \tag{4.9}$$

Now that the lepton constant B has been computed, one next wants to know if it might somehow be related to standard physical theory. Introducing the fine-structure constant

$$\alpha = e^2/\hbar c \tag{4.10}$$

(setting again $4\pi\epsilon_0 = 1$), one obtains from Eqs. (4.2) and (3.10)

$$s = B\alpha(u_e/c)\hbar/2 = \hbar/2, \tag{4.11}$$

since s must be equal to the lepton spin. Thus, the ratio u_e/c has the value $1/B\alpha = 205.759\,22$. This value is only 0.5 % less than the measured muon-electron mass ratio 206.768 28(1) [15]. Assuming tentatively that in the model the two ratios equal each other, one obtains

$$u_e/c = m_\mu/m_e \tag{4.12}$$

and

$$m_\mu/m_e = 1/B\alpha = 205.759\,22. \tag{4.13}$$

The hydrodynamic lepton model developed thus far cannot explain Eq. (4.13). In Section 7, however, this relation will appear naturally when the early phases of the model universe are considered.

[3] The fundamental equations used to describe the space of the model are the special form (3.1) of the momentum equation (A.1), which expresses conservation of momentum, and the continuity equation (4.4), which expresses conservation of mass. Thus, one may think of the space of the model as an unobservable fluid possessing six unobservable intrinsic properties: mass, momentum, density, and three types of velocity, but lacking such intrinsic properties as molecules, pressure, temperature, or energy. When space forms local disturbances (or "whirls"), these space whirls may interact. Consequently, a space whirl (i.e., a particle) may be detected by another space whirl. But although particles may "observe" other particles, the space itself remains unobservable.

5 The gravitation-expansion (GE) connection

In Sections 3 and 4, the small-scale aspects of the model were discussed, and several properties of the charged leptons were explained. Of course, this is not enough. Even a simple QED model for a universe must, to be credible, explain some of the large-scale behavior of the actual universe. The goal of this section is to show that the model can explain expansion and gravitation in a very simple way, and that Hubble's constant might be calculable. Some large-number connections [11] are also obtained.

Since, according to Section 3, space is continuously being created, the model universe must be expanding. Assuming that the masses in this universe are uniformly distributed (see discussion in Section 6), one expects them to be moving away from each other at the same average rate as the universe is expanding. A small group of N particles at $r = 0$ (a point mass in cosmological perspective, r now being a macroscopic distance) contributes $v = Ncr_0^2/r^2$ to the expansion at large r. See Eqs. (4.6) and (4.7). Adding to this velocity the contribution from the overall expansion of the universe, yields

$$v = Nc\frac{r_0^2}{r^2} + c\frac{r}{R}, \tag{5.1}$$

where the radius of the universe R is the distance at which the expansion of the universe would be equal to c if the expansion in a comparatively small volume were extrapolated sufficiently far. This means that the second term in Eq. (5.1) may be written as Hr, with H equal to the Hubble expansion rate

$$H = c/R. \tag{5.2}$$

Note that the modification to v in Eq. (5.1) does not affect the result in Eq. (4.5), which is obtained by considering a single particle with energy density $\mathrm{d}E/\mathrm{d}V$ falling off like r^{-4}.

Substituting Eq. (5.1) in the hydrodynamic lepton equation (3.3), and neglecting the fields u and w (corresponding to $f = 2$ and 3, and responsible for the short-range spin and electromagnetic forces acting between particles), one obtains

$$\frac{\rho}{\rho_0} = \left(1 - N^2\frac{r_0^4}{r^4} - 2N\frac{r_0^2}{Rr} - \frac{r^2}{R^2}\right)^{1/2}. \tag{5.3}$$

It is seen that the third term under the square root would give rise to a pull on every mass surrounding the N-particle "point mass." The strength of this pull would be proportional to the mass on which it acts and inversely proportional to the square of the distance between the N particles and the mass. This force must, therefore, be identical with gravitation. However, the pull of gravitation on a mass is also proportional to the mass of the particles giving rise to this force. Thus,

$$\frac{r_{eg}^2}{m_e} = \frac{r_{\mu g}^2}{m_\mu} = \frac{r_{\tau g}^2}{m_\tau} \tag{5.4}$$

must hold, and the gravitational radius r_{0g} (compare with Appendix D) must be distinguished from the electromagnetic radius r_0 (i.e., r_e, r_μ, or r_τ), for which holds, according to Eq. (3.10),

$$r_e m_e = r_\mu m_\mu = r_\tau m_\tau. \tag{5.5}$$

The second term in Eq. (5.3) would give rise to a strong attractive force. In general, however, the strength of the pull exerted by one mass on a second mass would be different from the pull exerted on the first mass by the second mass. Such a non-mutual force is not physically permissible and the term must be omitted. Similarly, all other terms in the series expansion of the square root in Eq. (5.3) must be excluded if they contain higher powers of r_{0g} than r_{0g}^2. See Section 6.

Retaining only the physically permissible terms in the series expansion of Eq. (5.3), the series can be summed up in (see Appendix E.2 on page 36)

$$\frac{\rho}{\rho_0} = \left(1 - \frac{r^2}{R^2}\right)^{1/2} - N\left(1 - \frac{r^2}{R^2}\right)^{-1/2} \frac{r_{0g}^2}{Rr}. \tag{5.6}$$

Eq. (5.6) means that the energy of a particle with mass m_0 at a distance r from the point mass (group of N particles) is modified according to, compare with Eq. (3.4),

$$E = m_0 c^2 \left(1 - \frac{r^2}{R^2}\right)^{1/2} \left[1 - N\left(1 - \frac{r^2}{R^2}\right)^{-1} \frac{r_{0g}^2}{Rr}\right]. \tag{5.7}$$

The square root in Eq. (5.7) can be written as $(1 - v_{\text{exp}}^2/c^2)^{1/2}$, where v_{exp} is the rate of expansion of the universe at the distance r from the observer. Thus, Eq. (5.7) implies that the observed mass m_0 should be multiplied by $(1 - v_{\text{exp}}^2/c^2)^{1/2}$. According to the special theory of relativity, this mass should, however, be divided by the same square root in order to account for the kinetic energy of the mass due to its velocity away from the observer. The effect of the square root in Eq. (5.7) is, thus, seen to cancel the effect of special relativity on a cosmic scale. In other words, the energy potential derived from Eq. (3.1) contains a factor that exactly cancels the kinetic energy of a distant mass moving away from the observer with the speed of the expanding universe. However, an alternative interpretation is obtained by simply omitting the square root in Eq. (5.7), and concluding that there exists no kinetic energy resulting from the expansion of the universe.

Choosing for practical reasons the latter interpretation, Eq. (5.7) is replaced by

$$E = m_0 c^2 \left[1 - N\left(1 - \frac{r^2}{R^2}\right)^{-1} \frac{r_{0g}^2}{Rr}\right]. \tag{5.8}$$

The second term in Eq. (5.8) gives rise to a force $F = \mathrm{d}E/\mathrm{d}r = m_0\,\mathrm{d}U/\mathrm{d}r$ with gravitational potential

$$U = -Gmr^{-1}\left(1 - \frac{r^2}{R^2}\right)^{-1} \tag{5.9}$$

due to a point mass m. The force between m and another point mass is proportional to $\mathrm{d}U/\mathrm{d}r$, and is seen to become repulsive when r exceeds the distance to the "turning point" (see Fig. 5.1 and Appendix E.3 on page 36)

$$r_{\text{tp}} = R/\sqrt{3} = 0.577\,R = 0.577\,c/H. \tag{5.10}$$

Since there is no kinetic energy connected with the expansion, the total force, which the rest of the universe exerts on a particle, must vanish. See Section 6.

For all practical measurements of gravitational forces, r^2/R^2 in Eq. (5.9) may be set to zero, and Newton's gravitational potential

$$U = -Gmr^{-1} \tag{5.11}$$

is obtained.

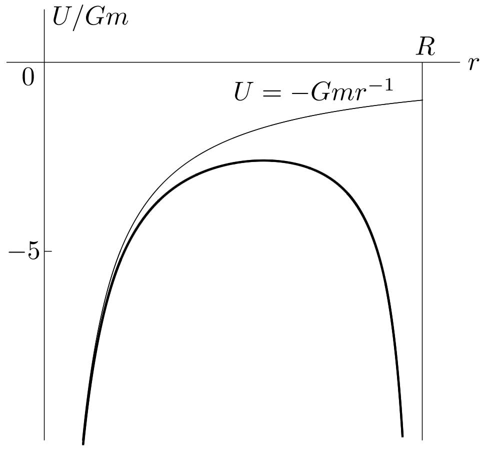

Figure 5.1: $U = -Gmr^{-1}(1 - r^2/R^2)^{-1}$.

Now, instead of a point mass (again assuming mass to be uniformly distributed in the model universe), consider a large sphere of radius r containing a mass M_r. With M_r/m_0 equal to the number, N, of particles contributing to its expansion, the sphere should expand according to

$$\frac{\mathrm{d}r}{\mathrm{d}t} = c\frac{M_r}{m_0}\frac{r_{0g}^2}{r^2}. \tag{5.12}$$

Choosing $r = R$, which means that $\mathrm{d}r/\mathrm{d}t = c$, one obtains one of the famous large-number relations,

$$\frac{M}{m_0} = \frac{R^2}{r_{0g}^2}, \tag{5.13}$$

where $M = \frac{4}{3}\pi\rho_u R^3$, and ρ_u is the density of the universe.

For the gravitational force between a lepton and a mass m, Eqs. (5.8) and (5.9) give $mc^2 r_{0g}^2/Rr^2 = Gm_0 m/r^2$ ($r \ll R$), or another large-number relation,

$$R = \frac{c^2 r_{0g}^2}{Gm_0}. \tag{5.14}$$

Eliminating r_{0g}^2 from Eqs. (5.13) and (5.14), and using $H = c/R$ for the Hubble expansion rate, one obtains the density

$$\rho_u = \frac{3H^2}{4\pi G} \tag{5.15}$$

of the universe. Eq. (5.15) contains no adjustable parameter. It implies a density twice as high as it is commonly believed to be. Dynamic effects may, however, modify this value. See Section 6.

Since, according to Eq. (3.10), r_e is $B/2$ times the classical electron radius $r_{\mathrm{cl}} = e^2/m_e c^2$,

$$\frac{1}{H_0} = \frac{R}{c} = \left(\frac{r_{eg}}{r_e}\right)^2 \frac{B^2 r_{\mathrm{cl}}^2 c}{4Gm_e} = \left(\frac{r_{eg}}{r_e}\right)^2 \times 138\,\mathrm{Gyr} \tag{5.16}$$

is obtained from Eqs. (5.2) and (5.14) for the inverse of the present-day Hubble expansion rate. Eq. (5.16) contains what appears to be a freely adjustable parameter, namely r_{eg}/r_e. However, in Section 7, a unique value will be obtained for it.

6 Quantum gravity and the quantum universe

The results obtained in Section 5 suggest that general relativity cannot, without modifications, be applied to the entire volume of the universe. The situation may be analogous to the case of Euclidean plane geometry which, even if it perfectly agrees with observations on a small scale, has to be modified into spherical geometry before it can be applied to the entire surface of the earth.

The field equation (3.1) treats space as a classical fluid. Still (see Appendix D), the space of the QED universe is assumed to be pointless, lacking properties like pressure and temperature. Now, pointless space in the static model (picturing a stationary charged lepton) corresponds to quantum theory in dynamic models. Although the static model is a complement to the established dynamic theories, and very different from them, there are many analogues and points of contacts.

The wave function of quantum theory is unobservable, and so is the field appearing in Eq. (3.1). For both cases, it holds that only by interpreting the field equation properly may its consequences be calculated and compared with reality.

To explain gravity, dynamics had to be introduced into the static picture in the form of an overall expansion of the universe. Thus, the simple static picture of a single lepton no longer suffices, and artificial manipulation of the square root in Eq. (5.3) is required to obtain a self-consistent description. Again, a direct analogue can be found in quantum theory. Dirac derived his linear spinor equation by treating the square root in the Hamiltonian function of a relativistic free particle [16],

$$H = \left(p^2c^2 + m^2c^4\right)^{1/2}, \tag{6.1}$$

in much the same manner as the square root in Eq. (5.3) is treated in Section 5. In both cases, the purely classical description has to be modified, and, in both cases, the modifications are justified by the result. When attempting to develop a viable quantum gravity, this analogue might be worth noting.

There are more things that may be worth stressing. Gravity is repulsive for large cosmological distances and, being but a consequence of an unperturbable expansion, it must balance itself. In other words, self-consistency requires that the sum of the forces from all masses in a given solid angle must be zero. Further, the radius of the universe, R, should appear in the equations of quantum gravity. Also, the cosmological radius inside leptons, mentioned in the parenthesis before Eq. (3.10), might be of interest and possibly suggest a remedy for the infinities plaguing some quantum-gravity theories.

It was assumed in Section 5 that the masses are moving away from each other at the same average rate as the universe is expanding. In the pointless space of the QED universe, position in space cannot be defined. Therefore, G of the model should be a universal constant varying only with time. In our present universe, which no longer is in an indefinite quantum state, this need not be true. If space behaved similar to a classical physical fluid, one would expect the rate of expansion to be higher near large masses and consequently the value of G to differ inside and outside a galaxy. As a consequence, Eqs. (5.15) and (5.16) would require modification.

7 The particle generations

The simplest possible model universe has no temperature. Possible radiation in this simple universe would lose energy because of the redshift caused by the expansion. Since there is no other way of compensating for this loss (the rate of expansion being predetermined and unperturbable), conservation of energy must imply that the decrease in energy of the radiation is balanced by an increase in rest energy of the massive particles. An immediate consequence is that such a universe cannot exist without matter being present. This result, in turn, suggests that the young universe may have run through several phases, each phase forming the simplest possible universe (fulfilling the initial conditions it inherited from the previous phase) and ending when the decay of its last massive particle forces a matter-recreating phase transition.

Next, details in the time development of the early model universe will be investigated, which requires some results from previous sections. In Section 4, the lepton-structure constant $B = 0.666\,001\,731\,5$ was computed. If the particles of Section 3 are spinless, field u in the hydrodynamic lepton equation (3.3) vanishes and Eq. (4.4) transforms into an ordinary differential equation, with the help of which Eq. (3.11) may be integrated. The resulting structure constant for "spinless leptons" is

$$B_0 = 0.978\,396\,401\,9. \tag{7.1}$$

As discussed in Appendix D, the lepton radius may have different values in different connections. Thus, one must distinguish between the lepton's spin radius r_{0s} and its electromagnetic radius r_0, and Eq. (4.2) on page 10 should read

$$s = m_0 r_{0s} u_0 = \hbar/2. \tag{7.2}$$

Since the same spinning photon can produce all three types of lepton pairs, it is natural to assume that the three spin radii have the same common value. The conclusions drawn thus far about the lepton radius may thus be summarized in

$$r_e m_e = r_\mu m_\mu = r_\tau m_\tau = Be^2/2c^2, \tag{7.3}$$

$$\frac{r_{eg}^2}{m_e} = \frac{r_{\mu g}^2}{m_\mu} = \frac{r_{\tau g}^2}{m_\tau}, \tag{7.4}$$

and

$$r_{es} = r_{\mu s} = r_{\tau s}. \tag{7.5}$$

From Eqs. (3.10) and (7.2), it follows that

$$\alpha = \frac{e^2}{\hbar c} = \frac{1}{B}\frac{r_0}{r_{0s}}\frac{c}{u_0}. \tag{7.6}$$

Now, suppose that the universe began as a neutral particle formed by a pair of oppositely charged "spinless tauons" in an otherwise pointless and empty (and therefore distanceless and timeless) space. This event was the first phase transition. It broke the perfect symmetry of literally nothing by creating a universe containing a neutral spinless particle (compare with Alexander Vilenkin's "quantum tunneling from literally nothing" [17]). Let the initial mass of the spinless tauon be $m_\tau^0 = m_1$. Because of quantum effects, clones of the particle pair appeared on the horizon as the tiny universe expanded. See Appendix E.4 on page 36. There were no strong or weak forces. Since the tauons were spinless and the tauon pairs outward neutral, no universally defined spin or charge existed (charge and spin were not quantized). The "spinless tauon" pair should have formed the neutral particle (D) described by Dirac's new equation [9, 10] and possible only in the newborn universe. See the discussion in Section 2 (page 7) of Dirac's new equation and his large-number hypothesis.

In **phase 1**, the tauon pairs annihilated rapidly into pairs of entangled photons until only one tauon pair remained. When the last tauon pair was about to annihilate, the mass of the tauon had reached (see beginning of this section)

$$m_\tau^0 = c_1 m_1, \tag{7.7}$$

where c_1 is a, presently unknown, numerical constant. The annihilation of the last tauon pair forced the universe to freeze, and matter to be recreated in the form of spinless muons with the spinless tauons reappearing as virtual particles. Because the energy was conserved, the muons acquired the mass $m_\mu^0 = m_2 = m_1$ with the corresponding radius $r_\mu = r_2$. Using Eq. (7.7), one obtains

$$m_\tau / m_\mu = c_1, \tag{7.8}$$

which also should hold for spinning particles. Since the tauon-muon mass ratio is 16.8, the model universe must have contained considerably more than 16 photon pairs when the second phase transition occurred.

In **phase 2**, where two types of charged particles existed, the charge e was now fixed as a universal constant, and the particles were spinless bosons described by the Klein-Gordon equation. The spinless muon acquired the natural

$$w_\mu = u_\mu = v_\mu = c. \tag{7.9}$$

See Eqs. (3.3) on page 9 and (4.7) on page 11. These spinless-muon pairs annihilated producing photon pairs, and at the moment when the last pair annihilated, the spinless muon had the mass

$$m_\mu^0 = c_2 m_2 \tag{7.10}$$

and the radius $r_\mu = r_2/c_2$, with c_2 a numerical constant. See Eq. (7.3).

In a third phase transition, matter was recreated in the form of spinning electrons with the spinless tauon and muon reappearing as virtual, now spinning, leptons. Thus, spin had become a universal (quantized) constant, and the universe was a charge-symmetric QED world with particles described by Dirac's spinor equation.[4] Since this time one spin-1 photon produced two spin-$\frac{1}{2}$ electrons (an electron-positron pair), the electron acquired the mass $m_e = m_3 = \frac{1}{2} m_2 = \frac{1}{2} m_1$. With the introduction of spin, the tauon and muon masses changed by the factor B/B_0. Thus, $m_\mu^0 = c_2 m_2$ in Eq. (7.10) became $m_\mu = c_2 m_2 B/B_0$, and the muon-electron mass ratio is

$$m_\mu / m_e = 2 c_2 B / B_0. \tag{7.11}$$

Since lepton spin was introduced by the birth of the electron, the natural relation

$$r_{es} = r_e \tag{7.12}$$

must hold. From Eq. (7.2), one obtains $m_e r_{es} u_e = m_\mu r_{\mu s} u_\mu$, and using Eqs. (7.5) and (7.9), $u_e = c m_\mu / m_e$. Together with Eqs. (7.6) and (7.12), this equation yields

$$\alpha = \frac{1}{B} \frac{m_e}{m_\mu}, \tag{7.13}$$

[4]Note that there exists an alternative formulation of Dirac's spinor equation. Like the Klein-Gordon equation, this is an explicitly charge-symmetric second-order differential equation naturally derivable using Feynman's method of path integrals [18].

meaning that Eq. (4.13) can finally be explained.

Fig. 7.1 summarizes the first three phases of the universe. N_1, N_2, and N_3 are the number of photon pairs at the end of phase 1, phase 2, and phase 3, respectively. N_1 is expected to be of the order 10^2, and N_3 of the order 10^9. The photons γ_τ and γ_μ, associated with the spinless tauon and muon, respectively, differed from each other and from the photon γ of today.

Phase	Beginning of phase	End of phase
1	$1 \times \mathrm{D}$	$N_1 \times \gamma_\tau\gamma_\tau$ + virtual τ_0 loops
2	$N_1 \times \mu_0^+\mu_0^-$	$N_2 \times \gamma_\mu\gamma_\mu$ + virtual μ_0 and τ_0 loops
3	$N_2 \times (\mathrm{e}^+\mathrm{e}^-\ \mathrm{e}^+\mathrm{e}^-)$	$N_3 \times \gamma\gamma$ + virtual e, μ, and τ loops

Figure 7.1: The origin of the lepton generations.

In **phase 3**, the annihilation of electron pairs went on until the expanding universe contained $N_3 - 1$ photon pairs and one pair of electron pairs. With charge and spin fixed as universal constants, no new lepton species was allowed to form. Instead, in the fourth phase transition the last remaining electron-positron pairs annihilated into a photon pair that instantly transformed into a pair of antiproton-proton pairs. With repeated pair annihilation forbidden, the antiprotons were forced to decay into electrons and photons: $\mathrm{p\bar{p}\,p\bar{p}} \to \mathrm{pe}^-\gamma\,\mathrm{pe}^-\gamma$ (grand unified theories, GUTs, predict proton decay into a positron plus radiation, a process that, however, has not been observed). As a result, the present universe was initially heated to a temperature that was high enough for the nucleosynthesis to proceed exactly as in conventional big-bang cosmologies.

In **phase 4**, the creation of the proton meant the birth of the strong and weak forces. Since the newborn proton was a baryon, the original baryon number was $n_b = 2$, and the original value of the photon-baryon number ratio was $n_\gamma/n_b = n_\gamma/2 = N_3$, which until today may have remained largely unchanged. The strong and weak forces, and the possibility of theoretically calculating the photon-baryon number ratio, will be discussed in Section 9.

The ratio r_{eg}/r_e, appearing in the expression for Hubble's constant, Eq. (5.16), must still be determined. The newborn spinning electron of phase 3 received half the mass of the newborn spinless muon of phase 2, i.e., $m_e = m_3 = \frac{1}{2}m_2$. With $r_e m_e = r_2 m_2$ (see Eq. (7.3)) one therefore obtains

$$r_e = 2r_2, \tag{7.14}$$

while Eq. (7.4) yields $r_{eg}^2/m_e = r_2^2/m_2$, or

$$r_{eg}^2 = r_2^2/2. \tag{7.15}$$

From Eqs. (7.14) and (7.15), it follows that

$$\frac{r_{eg}}{r_e} = \frac{1}{\sqrt{8}} \tag{7.16}$$

for the newborn electron, and this relation is assumed to still hold.

From Eq. (5.16), it now follows that

$$\frac{1}{H_0} = \frac{R}{c} = \frac{B^2 r_{\mathrm{cl}}^2 c}{32 G m_e} = 17.2\,\mathrm{Gyr}, \tag{7.17}$$

or

$$H_0 = 56.8\ \mathrm{km\,s^{-1}\,Mpc^{-1}}, \tag{7.18}$$

which means that the model yields a definite, testable prediction for the present-day Hubble expansion rate.

From Eq. (5.12), one obtains

$$\int_0^r r^2\,\mathrm{d}r = c\frac{M_r}{m_e}\int_0^t r_{eg}^2\,\mathrm{d}t \tag{7.19}$$

or (letting r_{eg} = constant)

$$r^3 = 3c\frac{M_r}{m_e} r_{eg}^2 t, \tag{7.20}$$

and, after division of Eq. (5.12) by (7.20) and noting that $H = v_{\mathrm{exp}}/r = c/R$,

$$v_{\mathrm{exp}} = \mathrm{d}r/\mathrm{d}t = r/3t, \tag{7.21}$$

$$H = 1/3t, \tag{7.22}$$

and

$$R = 3ct, \tag{7.23}$$

involving the age t of the universe. From Eqs. (5.14), (7.22), and (7.23), it follows that H and G should change with time according to

$$\dot{H}/H = \dot{G}/G = -1/t = -3H. \tag{7.24}$$

Eq. (7.24) implies an age, $t = 1/3H$, of the universe that is too low—only about 5 billion years. Also, the predicted change in G exceeds the upper limit obtained from observations. Interestingly, however, the first equality in (7.24) implies that H should change very slowly with time, because G, as observations demonstrate, may change only slowly. In other big-bang models this behavior of H would be interpreted as an indication that the universe is accelerating (with H constant in time, the speed $v_{\mathrm{exp}} = Hr$ of a galaxy at a distance r away from us increases with growing r as the galaxy recedes, see Appendix E.5 on page 37).

In summary, the predictions of the model are good except when the age of the universe is calculated, i.e., in the last equality in Eq. (7.24). This fact seems to indicate that in a dynamic theory the time scale for the early universe has to be modified. During the evolution of our present universe, the masses of the electron and the original proton have increased about a million times and atomic dimensions correspondingly decreased (see Section 10). Supposedly, it was during the early period of the universe, when masses grew rapidly, that the time scale was affected in such a way that it made the universe older than Eq. (7.24) predicts. An interesting consequence is that the large-scale structures in the universe may have formed during a very long period and that the existence of stars older than $1/H$ cannot be ruled out.

Note, finally, that the process described here need not be the simplest possible. For instance, instead of assuming that masses increase with time, one may assume that c increases in such a way that the loss in photon energy $E_\gamma = hc/\lambda$ due to the redshift (increase in wavelength λ), is compensated for by an increase in particle rest energy $E = mc^2$. See Appendix E.6 on page 37. With α, h, and m constant, this assumption implies that the charge e also changes with time.

In this picture, c^2 grows by a factor of order one million (n_γ/n_b divided by the proton-electron mass ratio 1836) in phase 4. In any case, the (dimensionless) electromagnetic, weak, and strong coupling constants should have remained unchanged since they first appeared.

It should be a straightforward task to clarify the age problem, or "time paradox," via computer simulation of the evolving universe.

8 QED corrections to the muon mass

The spinning leptons of phase 3 were the same as today's electron ($e^\pm$), muon ($\mu^\pm$), and tauon ($\tau^\pm$). Their interaction with the photon (γ) is described by the one-photon vertex of spinor QED. The interaction between the spinless muon ($\mu_0^\pm$) of phase 2 and its corresponding photon (γ_μ) is described by scalar QED [19]. In the Feynman graphs of scalar QED, both one-photon and two-photon vertices appear. See Fig. 8.1.

The one-photon vertex (upper left in Fig. 8.1) is the building block of spinor QED (or QED for short). It appears twice in the vacuum-polarization (v-p) loop (lower left) in which the photon forms a transient electron-positron pair, or electron pair for short (the positron is an antielectron, i.e., a positively charged electron). The two-photon "seagull" vertex (upper right) is an additional feature in scalar QED. It appears twice in the "sunset" graph (lower right), in which the photon emits a spinless muon and its antiparticle, and recaptures them later in time.

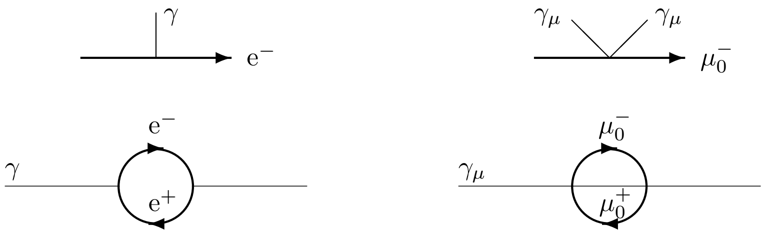

Figure 8.1: Graphs in QED. Thick lines with arrows designate massive particles (electrons or muons). Time runs from left to right. Right arrows indicate particles, and left arrows indicate antiparticles (since the positively charged electron, say, may be regarded as an ordinary electron moving backward in time). Photons are shown as thinner lines without arrows (since the photon is its own antiparticle).

Fig. 8.2 shows an alternative way of drawing the sunset graph.

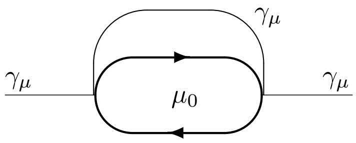

Figure 8.2: An alternative view of the sunset graph.

The photon is a spin-1 particle that may (or may not) have an orbital angular momentum that cancels out its spin. Being end products of spinless-muon pair annihilation, the real photons of phase 2 formed outward spinless pairs. Simplicity requires that the individual real photon had no orbital angular momentum. Therefore, it possessed a nonzero total angular momentum identical with its spin. Since angular momentum is a conserved quantity in physics, such a photon cannot disintegrate into a pair of spinless muons. It can only form spinless-muon loops via the two-photon vertex of scalar QED.

Fig. 8.3 illustrates the third phase transition, when the phase-2 photons (γ_μ) materialized as pairs of spinning electrons in phase 3. The vertical line indicates the instant of transition.

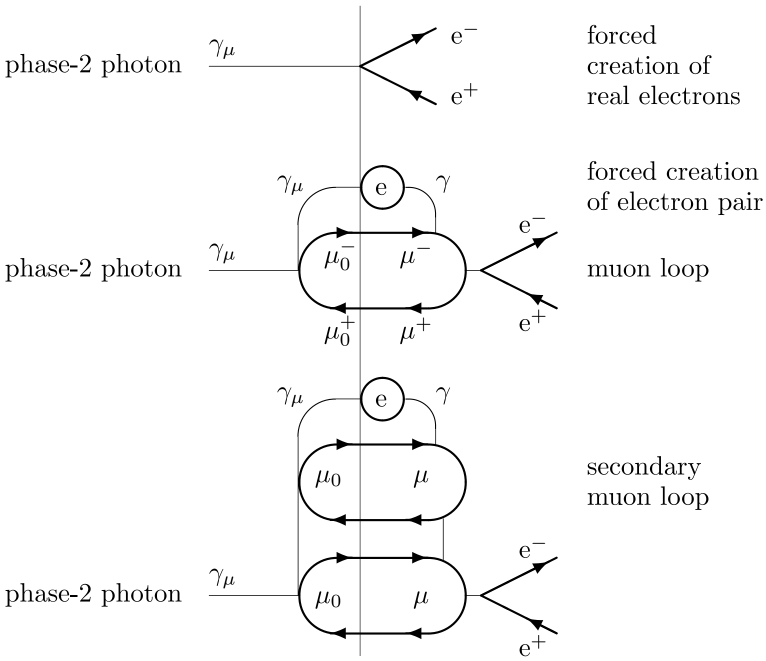

Figure 8.3: The third phase transition.

In the first case (top of Fig. 8.3), the real phase-2 photon materializes into an electron and a positron.

In the second case, the phase-2 photon emits a muon pair. The muons acquire spin and an initial natural mass m_μ. But instead of recapturing the pair of spinless muons it emitted in phase 2, the photon itself is, after materializing into an electron pair that again annihilates into a photon, captured by the spinning muon of phase 3, thus adding the mass $2m_e$ (created in the materialization of the photon) to the mass of the muon pair. Therefore, the muon pair possesses a mass of $2m_\mu + 2m_e$ when it annihilates forming a real phase-3 photon that materializes into a pair of real electrons.

In the third case (bottom of Fig. 8.3), the photon emits two muon pairs in phase 2, and is itself absorbed by the phase-3 muon of the secondary muon loop. The materialized mass, $2m_e$, affects the final mass of the primary (bottom) muon pair in proportion m_e to m_μ, since it is transferred to it via the secondary muon loop (with associated mass $2m_\mu$) ending in a phase-3 photon (with associated mass $2m_e$). Therefore, the diagram's contribution to the mass of the bottom muon pair is $(m_e/m_\mu)2m_e$.

Obviously, any number of muon loops may appear in diagrams of the type described. In the path-integral formulation of quantum theory, a particle simultaneously takes all possible paths. Adding, therefore, the contributions from all diagrams, one obtains $2m_\mu + 2m_e + (m_e/m_\mu)2m_e + (m_e/m_\mu)^2 2m_e + \cdots$ for the mass of the first muon pair. Note that α, being essentially a measure of the electron-muon mass ratio, is not defined for phase 2. Therefore, the natural phase-2 probability amplitude is 1.

For each secondary loop running clockwise (like the one in Fig. 8.3, third case), there is another loop running counterclockwise. Consequently, the contribution to the mass of the primary muon pair from all diagrams is $2\bar{m}_\mu = 2m_\mu + 2m_e + 2(m_e/m_\mu)\, 2m_e + 2^2(m_e/m_\mu)^2\, 2m_e + \cdots$, and the mass of one muon becomes

$$\begin{aligned}\bar{m}_\mu &= m_\mu + m_e + 2(m_e/m_\mu)m_e + 2^2(m_e/m_\mu)^2 m_e + 2^3(m_e/m_\mu)^3 m_e + \cdots \\ &= m_\mu + m_e/(1 - 2m_e/m_\mu),\end{aligned} \tag{8.1}$$

which is equivalent to

$$\begin{aligned}\bar{m}_\mu/m_e &= 1/B\alpha + 1 + 2B\alpha + 4(B\alpha)^2 + 8(B\alpha)^3 + \cdots \\ &= 1/B\alpha + 1/(1 - 2B\alpha) \\ &= 206.769\,04,\end{aligned} \tag{8.2}$$

where $\bar{m}_\mu$ is the QED-corrected muon mass.

Interestingly, the QED-corrected value in Eq. (8.2) is greater than the measured value 206.768 28(1). Thus, weak and/or strong perturbative corrections are expected to add a negative contribution of about −0.000 76 to the theoretical muon-electron mass ratio.

9 The strong-weak (SW) connection

The model universe does not explain the strong and weak forces. It does explain, however, why a new nonleptonic particle had to appear in the fourth phase transition. Since this particle must be the strongly interacting proton, it also explains why the strong force appeared. Since the proton was much heavier than the positron from which it originated, and the energy of the universe had to be conserved, a sudden decrease in the photon energy must have accompanied the birth of the proton. A credible model must explain this decrease in photon energy.

The appearance of the strong force introduced hadronic vacuum-polarization (v-p) loops into the photon propagator, thereby causing a slight increase in the photon's energy. Strong effects cannot, therefore, explain the decrease that must have occurred.

In the JBW finite QED model [2, 3, 4], the leptonic v-p loops do not contribute to the mass of the charged lepton. In the high-energy limit, hadronic v-p loops behave like lepton loops, and the JBW model, therefore, implies that the strong force does not modify the lepton mass. Consequently, the appearance of the strong force could not indirectly have caused a decrease in the photon energy via modification of the masses in the leptonic v-p loops.

It follows that only a fourth force appearing simultaneously with the strong force can explain the required sudden decrease in photon energy. Obviously, this fourth force should be identified with the weak force.

Since, in the JBW theory, the tauon's bare mass is zero, the lowest-order QED contribution to its mass comes from the graph on the left in Fig. 9.1. In electroweak theory, there exists a

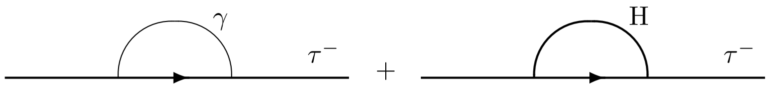

Figure 9.1: $\delta m_\tau^{(2)} = \delta m_\tau^{(\gamma)} + \delta m_\tau^{(H)}$.

similar graph in which the massless spin-1 photon (γ) is replaced by the massive spin-0 Higgs boson (H). The contributions to the tauon mass from both the photon graph and the Higgs graph are divergent in perturbation theory. They are, however, comparable with each other, and may be written as a sum of two finite terms multiplyed by a divergent logarithm. In Appendix C, it is shown that in the standard model the sum of the two contributions is

$$\delta m_\tau^{(2)} = \delta m_\tau^{(\gamma)} + \delta m_\tau^{(H)} \propto \frac{3}{2}\left(\frac{\alpha}{\pi}\right)\ln\Lambda\left[1 - \frac{G_F m_\tau^2}{4\sqrt{2}\pi\alpha}\right], \tag{9.1}$$

where G_F is the Fermi coupling constant. Consequently, the relative change in tauon mass caused by the appearance of the Higgs is

$$\frac{\Delta m_\tau}{m_\tau} = -\frac{G_F m_\tau^2}{4\sqrt{2}\pi\alpha} = -2.84\times 10^{-4}. \tag{9.2}$$

Note here the use of the conventional $\hbar = c = 1$, meaning that $G_F m_\tau^2$ is actually short for $G_F m_\tau^2 c^4/(\hbar c)^3$.

Since the photon forms virtual lepton pairs (lepton v-p loops) with probability amplitude α, a decrease Δm_τ in the tauon mass implies a relative decrease $\alpha\Delta m_\tau/m_\tau$ in the photon's energy. See Appendix E.7 on page 38. Ignoring the comparatively small contributions from the muon and electron loops, the relative decrease in energy, $(n_\gamma - 2)\alpha\Delta m_\tau/m_\tau$, of $N_3 - 1 = n_\gamma/2 - 1$ photon pairs should counterbalance the increase in mass, $n_b(2m_p - 2m_e)$, caused by the transformation of the last $n_b = 2$ electron-positron pairs into antiproton-proton pairs. See discussion following Eq. (7.13) on page 17. Assuming for simplicity that every photon had the energy $m_e c^2$, one obtains $\Delta E = (n_\gamma - 2)m_e c^2 \alpha G_F m_\tau^2/4\sqrt{2}\pi\alpha = 2n_b(m_p c^2 - m_e c^2)$, or approximately,

$$\frac{n_\gamma}{n_b} G_F m_\tau^2 \approx 8\sqrt{2}\pi\frac{m_p}{m_e}. \tag{9.3}$$

Insertion of Eq. (9.2) and $m_p/m_e = 1836$ in Eq. (9.3) yields

$$\frac{n_\gamma}{n_b} \approx 1.77\times 10^9, \tag{9.4}$$

which is of the expected order of magnitude [20].

Eq. (9.3) contains several uncertainties. Second-order perturbation theory has been used to derive it, and the effect of the hadronic v-p loops has been ignored. The standard model has been assumed, and, therefore, a three-Higgs model would imply a correspondingly lower n_γ/n_b. Finally, due to the cosmological redshift, the average energy of the photons was probably considerably lower than $m_e c^2$ (it was originally twice this energy), and, therefore, n_γ/n_b should be correspondingly larger. If one wants to compare the photon-baryon number ratio in Eq. (9.3) with the present-day ratio, it must also be borne in mind that the ratio increases with time because of photon splitting and other ongoing processes, and that black holes may have swallowed most of the baryons at a time when G was much stronger than at present.

10 Computer simulation of the early universe

An experimental FORTRAN program was written to simulate the evolution of the universe. Because of approximations made in the program, it executes in seconds on a PC, but cannot produce exact results.

When attempting to mathematically follow the development of the decaying universe of phase 1, it turns out that initially the lifetime τ (the inverse of the decay constant) of the primordial particle pair must have been 1, in units of t_c, where t_c is the age of the universe at its creation (the primordial particle popping up in an expanding spacetime bubble with initial radius r_c and initial time t_c).

In **phase 1**, spinless-tauon pairs annihilated into pairs of photons. Because of the redshift effect, the photons lost energy as the universe expanded. Thus, the photon energy was proportional to $1/\lambda$, where λ is the photon wavelength, which increases with the expansion of space.

Since energy is a conserved quantity in physics, the energy content of an expanding volume V, containing a fixed number of particle pairs, must be constant. Therefore, c was forced to increase to make the rest energy mc^2 (with constant mass, m) of the remaining massive particles grow in order to compensate for the decrease in photon energy caused by the expansion.

The computer simulation experiment shows that, for the model to remain simple and consistent, it is necessary to assume that the lifetime τ grows at the same rate as c.

From Eqs. (5.13) and (7.23), it follows that the number of particles in the universe should be

$$N \propto t^2. \tag{10.1}$$

When the total increase in particle rest energy in phase 1 is calculated from the known tauon-muon mass ratio, the requirement in Eq. (10.1) is found to be approximately fulfilled if the number of particle pairs at the end of phase 1 is $N_1 = 86$.

In **phase 2**, there were initially N_1 spinless-muon pairs. Because of energy conservation, the particle pairs acquired the same initial rest energy as the primordial particle had at time t_c (the beginning of time). This means that c and τ were reset to their initial values. The downward jump in c^2, in turn, forced a corresponding jump upward in (the hitherto constant) mass of the now virtual tauon, thus allowing the tauon to retain the rest energy it had gained in phase 1.

At the end of phase 2, there were roughly $N_2 = 1000$ particle pairs in the universe, and the age of the universe was approximately $t = 33$ (in units of its initial age t_c).

Surprisingly, the simulation of the first two phases indicates that Eq. (10.1) should be replaced by

$$N = (t - 1)^2, \tag{10.2}$$

with the age t measured in units of the initial age t_c. It turns out that this unexpected result has a logical explanation. Thus, Eq. (10.2) implies that the primordial particle (D) was a particle of its own that, due to its properties (see Section 2), was predestined to live alone in the universe. Therefore, when at t = 2, it decayed into a pair of tauons, there was but one particle pair present in the universe, not four of them as suggested by Eq. (10.1).

Alternatively, the D particle did not decay directly into a tauon pair, but indirectly via a photon pair, which was forced to materialize into a tauon pair. Such a process would be analogous to the rematerialization processes occurring in the two later phase transitions, and would imply that the primordial particle lived in a phase of its own, the first phase out of five.

In **phase 3**, the conditions had changed. The leptons were spinning, and the Planck constant h had appeared. Its existence caused the photon energy, now expressible as hc/λ, to decrease at a much slower rate than in the first two phases, because this time the constancy of h caused the increase in c to partly compensate the decrease in $1/\lambda$. If $\tau = (2\pi^2\alpha^2)^{-1}$ (obtained via mathematical experimentation) is assumed,

$$N_3 = n_\gamma/2 = 2.447 \times 10^9 \tag{10.3}$$

holds for the number of photon pairs at the end of phase 3 and at the beginning of phase 4. Correspondingly, the rest energy of the electron had grown by a factor of about

$$x = 10.889, \tag{10.4}$$

and the age of the universe was approximately 49 470. The equation for the energy balance in the fourth phase transition may now be written as (compare with Eq. (9.3))

$$(n_\gamma - 2)\frac{2m_e c^2}{x}\alpha\frac{y}{4\sqrt{2}\pi\alpha}G_F m_\tau^2 = n_b(2m_p c^2 - 2m_e c^2), \tag{10.5}$$

or, with good accuracy,

$$(n_\gamma/n_b)y\,G_F = 4\sqrt{2}\pi x(m_p/m_e - 1)m_\tau^{-2}, \tag{10.6}$$

where y is a measure of the weak contribution to the tauon mass. For the one-Higgs model studied in Appendix C, $y = 1$. From Eq. (10.6), the actual value of y can be calculated, and is found to be

$$y = 3.94. \tag{10.7}$$

The same y value should multiply the correction (C.6) to the muon-electron mass ratio. Therefore, this correction becomes $-0.000\,82$, and the final predicted value is

$$m_\mu/m_e = 206.768\,22, \tag{10.8}$$

which is slightly less than the measured value 206.768 28(1).

Eq. (10.7) suggests that the Higgs should cause a correction factor of $y = 4$. This factor seems quite plausible. Thus, for instance, the electroweak model discussed in Ref. [21] contains a Higgs doublet and an additional Higgs triplet with, in all, four physical Higgs bosons in the spectrum.

The remaining discrepancies, 0.000 06(1) between measured and calculated muon-electron mass ratios, and 0.06 between $y = 4$ and $y = 3.94$ in Eq. (10.7), suggest the following tentative interpretation:

First, assume that the hadronic v-p loops appearing in the phase-4 photon propagator cause a small upward jump in the energy of the photons. Also, note that a new form of energy may result from the appearance in phase 4 of exotic matter, such as the lightest supersymmetric (SUSY) particle (LSP). Now, supposing that this additional increase in energy totals n_b times 19 MeV on the right in Eq. (10.5), the correction factor becomes $y = 3.98$ for the tauon.

Further, assume that the difference between the factor 4 (due to the Higgs effect) and 3.98, i.e., 0.02, derives from a positive contribution (maybe caused by some weak flavor-changing coupling) that is relatively proportional to the lepton mass (while the negative Higgs contribution is relatively proportional to the square of the lepton mass). Then, the corresponding difference in connection with muons would be 0.02 times the tauon-muon mass ratio, or $0.02 \times 17 = 0.34$. With y = 3.66, the value in Eq. (10.8) changes to $206.769\,04 - 3.66 \times 0.000\,207\,6 = 206.768\,28$ (see Eqs. (8.2) and (C.6)) in agreement with the measured ratio.

In **phase 4**, energy conservation requires that, with a proton, an electron, and N_3 photons in an expanding volume V,

$$(m_p + m_e)c^2 + N_3(2m_e c_i/x)\,c\,(t/t_i)^{-1/3} = E_0 \tag{10.9}$$

must be constant if processes caused by gravity and other forces are ignored. With the initial values $t_i = 49\,470$ and $E_0 = (m_p + m_e)c_i^2 + 2N_3 m_e c_i^2/x$ (and choosing, say, without loss of generality, $c_i = 1$ and $m_p + m_e = 1$), the evolution of the volume may be tracked until present time, t_0, when the temperature of the cosmic background radiation (CBR) has fallen to its observed value of about $T_0 = 2.725$ K and c has grown by a factor of 494.3.

Using $\tau = c$ (with initial value $\tau = t_c = 1$) for the time-dependent time increment dt, and counting the number of time increments required to reach t_0, one obtains $t_0 = 3 \times 10^{21}$ and $k = 1.000\,32$ for the total number of time increments times the present-day time increment 494.3 divided by the age t_0.

The picture presented here is the **global picture** in the sense that the energy principle holds true globally. In the global picture, the age of the universe is t_0, and τ grows with time, which means that the atomic clock ticked faster in the early days of the universe. In the beginning of phase 4, the clock tick was 494 times shorter than today. Therefore, much happened in a short time.

In our practical **local picture** (or atomic-clock picture), the clock ticks define a constant time unit, and c, particle lifetimes, and atomic dimensions are constant. In the local picture, the age of the universe is $kt_0 > t_0$, and the universe stayed young a comparatively long time. Therefore, much had time to happen.

The global and local pictures complement each other. In the local picture, the conservation of rest energy (mc^2) simplifies practical physical calculations, while the nonconservation of total energy in a volume coexpanding with the universe makes cosmological calculations impractical. In the global picture, the opposite is true.

Note that in a classical world the two pictures would be incompatible with each other, while in a quantum world, where absolute distance measures are not definable, there is no conflict between them. See discussion in Appendix D.

When computing t_0 and k, it was assumed that the proton, electron, and photons in the volume V did not interact with other particles. This assumption is, of course, highly unrealistic. We know that protons and electrons have combined to form macroscopic structures, such as black holes, stars, planets, and cosmologists. Also, considerable amounts of neutrinos and high-energy cosmic rays have been produced. In a realistic simulation, the balance equation (10.9) would be replaced by a complicated set of equations. One would expect that a realistic simulation results in $k \gg 1$ and t_0 several magnitudes greater than 10^{21}.

That gravity decreases with time, see Eq. (7.24), suggests that primordial black holes were created in large numbers. Today, the gravitational force between electrons is roughly 10^{40} times weaker than the electric force. When the black holes began to form, gravity may have been, say, 10^{30} times stronger than it is today. Consequently, most of the energy in the initially very dense universe should have been rapidly trapped in black holes.

The seeds of the black holes were formed from matter (protons, neutrons, and electrons). Thus, the photon-baryon number ratio, n_γ/n_b, increased from its initial value in Eq. (10.3). However, once the seeds had formed, n_γ/n_b began to decrease, because proportionally more of the fast-moving photons than of the slower-moving baryons hit the black holes. The end result might well be that today n_γ/n_b is of the same order of magnitude as it was originally.

The expansion in combination with the rapid decrease in G saved the universe's matter and radiation from being converted entirely into black holes.

When gravity weakened, the black holes lost their grip on the part of the surrounding matter that wasn't eventually swallowed by them. As a result, the vast majority of the black holes should today be "naked" and impossible to directly observe. Since low-mass black holes would be difficult to detect even via microlensing [22, 23], there may be huge amounts of unseen black holes inhabiting the intergalactic regions of the universe.

11 Conclusions

The particle model presented in Section 3 pictures an expanding universe inhabited by "static electrons," which are described by a stationary hydrodynamic equation. One may say that the picture provides a quantum-electrostatic (QES) description of the charged leptons that complements the dynamic theory, QED. Even if the QES model cannot describe the dynamics of the universe, a number of conclusions can be drawn from it.

According to QES, the lepton's mass derives from its charge, that is, from the virtual photons of QED. Thus, the mass of the bare lepton should be zero in agreement with the JBW model. The universe must appear the same in all directions. Because distance cannot be defined in empty space, the particles coming into view on the horizon must be indistinguishable from particles elsewhere in the universe. The vacuum energy (the zero point field caused by quantum fluctuations) does not affect the expansion. The process of nucleosynthesis should be much the same as in conventional big-bang cosmologies. The initially strong gravity may have produced the black holes of Michael Hawkins' microlensing theory [22, 23]. The observed structures may have had time to form.

In the computer simulation discussed in Section 10, various approximations were made, and the results are not exact. However, the several detailed predictions already produced by the simulation suggest that it should be possible to obtain precise numerical values for the uncorrected tauon-muon and muon-electron mass ratios, and, via Eq. (7.13), a precise prediction for α.

The computer simulation suggests that τ and c are functions of the time, t, i.e., of the global time of the particle model. In our standard definition of time, τ and c are constant because of the way we measure time—using atomic clocks that tick at a pace proportional to the lifetime of particles.

Since the beginning of phase 4, matter self-energy and c^2 have grown by a factor of order 10^6 (the initial energy of the $2N_3$ photons divided by the initial energy of the two proton-electron pairs) in the global picture. Consequently, the increase in c and τ is of the order 10^3, and the age of the universe is, when measured using an atomic clock, considerably higher than a naive interpretation of Eq. (7.24) would imply.

Seen from the static picture's point of view, QES and QED might be two sides of the same coin. However, from a dynamical point of view, it seems more logical to assume that in the first three phase transitions the new particles were born stationary (the universe "froze," which means that all time-dependent processes came to a halt and space was momentarily described by the stationary version (A.3) of the momentum equation) but instantly turned dynamic, beginning to interact via virtual photons. During the particles' transition from static to dynamic objects, properties like charge, spin, and mass were conserved. Therefore, results obtained using Eq. (3.1) should still hold for the dynamic universe.

Also, the fact, revealed by the simulation program, that the primordial particle must have been a particle of its own, makes perfect sense, since the initial particle cannot reasonably have been a product of the freezing of a space that did not exist—an idea implicitly present in the original assumption. More plausible seems the idea that the primordial particle was comparable to a (necessarily dynamic) oscillator. Quoting Ref. [10]: "In a very real sense, the (generalized) new Dirac equation constitutes an explicit and precise solution to that much abused object, the relativistic harmonic oscillator."

The good agreement between theory and observations suggests that the only massive particle inhabiting phase 3 was the electron. Thus, it seems to exclude the possibility that the universe of phase 3 was described by some subset of the supersymmetry (SUSY) theory, say.

Gravity is a force acting on "classical," macroscopic objects between which distances can be defined. In an indeterminate quantum universe having no temperature, and with undefinable distances between particles, there should be no gravitational effects. Therefore, one would expect that pure spinor QED provides the full description of phase 3.

A static particle model cannot tell what the dynamic theory describing our present universe should look like, whether its space should be smooth or granular, etc. However, the QES model suggests a number of boundary conditions for a theory of everything (TOE). Since the output from phase 3 should equal the input to phase 4, properties like:

- the number of extended spatial dimensions (3),
- the number of particle generations (3),
- the two lepton mass ratios (206.8 and 16.8),
- the value of α (1/137.0),
- the number of basic forces (4), and
- the relation in Eq. (9.3) between the Fermi constant and the proton mass

should be input to the TOE and probably not calculable from it. Expansion should play a central role, i.e., $R = c/H$ should appear in the equations for quantum gravity. Also, particles are expected to possess an intrinsic cosmological radius. See parenthesis before Eq. (3.10) on page 10.

A Derivations

A.1 The hydrodynamic equation

The fundamental hydrodynamical equation, better known as the momentum equation, follows from the law of conservation of momentum (Newton's second law of motion). For a nonviscous fluid it is [24]

$$\frac{\partial \boldsymbol{v}}{\partial t} + \frac{1}{2}\nabla \boldsymbol{v}^2 - \boldsymbol{v} \times (\nabla \times \boldsymbol{v}) + \frac{1}{\rho}\nabla p = 0 \tag{A.1}$$

in the absence of external forces. Assuming the flow to be irrotational (or potential), that is,

$$\nabla \times \boldsymbol{v} = 0, \tag{A.2}$$

and stationary ($\partial \boldsymbol{v}/\partial t = 0$), Eq. (A.1) simplifies to

$$\frac{1}{2}\nabla \boldsymbol{v}^2 + \frac{1}{\rho}\nabla p = 0. \tag{A.3}$$

In an adiabatic process, heat does not enter or leave the system. For an ideal gas, the adiabatic law states that [25]

$$p\rho^{-\gamma} = p_0\rho_0^{-\gamma}, \tag{A.4}$$

where γ is a numerical constant and p_0 and ρ_0 are the undisturbed pressure and density far away from the whirl. Because normal rules of derivation apply to the gradient (meaning that in Eq. (A.3) the ∇ symbol may be replaced by $\mathrm{d}/\mathrm{d}x$), $\rho^{-1}\nabla\rho^{\gamma} = \frac{\gamma}{\gamma-1}\nabla\rho^{\gamma-1}$ (since derivation shows that both expressions equal $\gamma\rho^{\gamma-2}\nabla\rho$), and insertion of Eq. (A.4) in (A.3) yields

$$\frac{1}{2}\nabla \boldsymbol{v}^2 + \frac{\gamma}{\gamma-1}p_0\rho_0^{-\gamma}\nabla\rho^{\gamma-1} = 0. \tag{A.5}$$

Introducing v_0 and f via

$$v_0^2 = \gamma p_0/\rho_0, \tag{A.6}$$

which holds for the velocity of sound in a gas [25], and

$$\gamma = 1 + 2/f, \tag{A.7}$$

which holds for an ideal gas [26], Eq. (A.5) may be written

$$\frac{1}{2}\nabla \boldsymbol{v}^2 + \frac{f}{2}v_0^2\rho_0^{-2/f}\nabla\rho^{2/f} = 0, \tag{A.8}$$

which on integration (with $\boldsymbol{v} = 0$ for $\rho = \rho_0$) yields

$$\rho = \rho_0\left(1 - \frac{1}{f}\frac{\boldsymbol{v}^2}{v_0^2}\right)^{f/2}. \tag{A.9}$$

A.2 The electric force

Let there be two particles, one at $z = 0$ and the other at $z = -a$. Suppose, first, that both give rise to cylindrically symmetric rotations with axes of rotation parallel with the x axis. Consider a point in the yz plane at a distance $\boldsymbol{r}_1$ from the first and $\boldsymbol{r}_2$ from the second particle (i.e., $\boldsymbol{r}_1 = \boldsymbol{a} + \boldsymbol{r}_2$). The square of the sum of the two velocities is

$$w^2 = (\boldsymbol{w}_1 + \boldsymbol{w}_2)^2 = (\boldsymbol{\omega}_1 \times \boldsymbol{r}_1 + \boldsymbol{\omega}_2 \times \boldsymbol{r}_2)^2. \tag{A.10}$$

If, instead, $\boldsymbol{w}_1$ and $\boldsymbol{w}_2$ represent the corresponding radial velocities, then

$$w^2 = (\boldsymbol{w}_1 + \boldsymbol{w}_2)^2 = (w_1 \boldsymbol{r}_1/r_1 + (w_2 \boldsymbol{r}_2/r_2)^2 \tag{A.11}$$

holds. Since the velocities of the first case are perpendicular to the velocities of the second case, the resulting w^2 is the same for the two cases.

Assume, therefore, that for the three-dimensional rotation (which is a mathematical generalization that cannot be visualized) the same correspondence holds, and that, consequently, Eq. (A.11) may be used in the calculations. With $w_i = \pm w_0 r_0^2/r_i^2$ $(i = 1, 2)$ according to Eq. (3.6) and $\boldsymbol{r}_1 = \boldsymbol{r}$, Eq. (3.4) then yields for the interaction energy

$$\begin{aligned} E_{\text{int}} &= \pm\frac{1}{2}\int \rho \frac{2\, w_1 w_2}{r r_2} \boldsymbol{r} \cdot \boldsymbol{r}_2 \,\mathrm{d}V \\ &= \pm \int \rho \frac{w_0^2 r_0^4}{r^3 \mid \boldsymbol{r} - \boldsymbol{a} \mid^3} \boldsymbol{r} \cdot (\boldsymbol{r} - \boldsymbol{a}) \,\mathrm{d}V \\ &= \pm w_0^2 r_0^4 \rho_0 \int_0^{2\pi} \mathrm{d}\varphi \int_0^{\pi} \sin\theta \,\mathrm{d}\theta \int_0^{\infty} \frac{r + a\cos\theta}{(r^2 + a^2 + 2ra\cos\theta)^{3/2}} \,\mathrm{d}r \\ &= \pm 4\pi \rho_0 w_0^2 r_0^4 / a, \end{aligned} \tag{A.12}$$

since $\rho = \rho_0$ may be assumed for $a \gg r_0$.

B The constant B

Using Eqs. (3.4), (3.6), (3.9), (3.10), and (4.8), one obtains from Eq. (4.4),

$$B\,\nabla\cdot(\rho\boldsymbol{v}) = c\rho r_0^3/r^4. \tag{B.1}$$

Eq. (3.2) implies that

$$B\boldsymbol{v} = -cr_0\nabla f, \tag{B.2}$$

where f is a dimensionless scalar function chosen such that

$$\lim_{r\to\infty} f = Br_0/r \tag{B.3}$$

according to Eq. (4.6). Insertion of Eq. (B.2) in (B.1) yields

$$\nabla^2 f + \frac{1}{\rho}\nabla\rho\cdot\nabla f + \frac{r_0^2}{r^4} = 0. \tag{B.4}$$

Using Eqs. (3.3), (3.6), (4.1), and (B.2), ρ/ρ_0 is expressed as a function of f and the polar coordinates r and θ. In a coordinate system with $\alpha = 2^{-1/2}r_0/r$ and $\beta = \cos\theta$, the elliptic partial differential equation (B.4) may be written as

$$af_{\alpha\alpha} + cf_{\beta\beta} + ef_\alpha + gf_\beta = p + d, \tag{B.5}$$

where

$$\begin{aligned}
&a = \alpha^2 \quad\rightarrow\quad \frac{5}{2}\alpha^2 \ \text{ for } \alpha = (3/4)^{1/4},\\
&c = 1-\beta^2,\\
&e = -8\alpha^5\left(1-\frac{4}{3}\alpha^4\right)^{-1} - 2\alpha^3\left(1-\beta^2-\alpha^2\right)^{-1} \quad\rightarrow\quad 0 \ \text{ for } \alpha = (3/4)^{1/4},\\
&g = -2\beta - 2\alpha^2\beta\left(1-\beta^2-\alpha^2\right)^{-1},\\
&p = -2\alpha^2, \quad \text{and}\\
&d = 2B^{-2}\alpha^2\left[1-2B^{-2}\alpha^2\left(\alpha^2 f_\alpha^2 + (1-\beta^2)f_\beta^2\right)\right]^{-1}\\
&\quad\times\left[2\alpha^3 f_\alpha^3 + (1-\beta^2)f_\beta^2(\alpha f_\alpha - \beta f_\beta) + \alpha^4 f_\alpha^2 f_{\alpha\alpha}\right.\\
&\quad\left.+\,2\alpha^2(1-\beta^2)f_\alpha f_\beta f_{\alpha\beta} + (1-\beta^2)^2 f_\beta^2 f_{\beta\beta}\right]
\end{aligned}$$

and the boundaries and boundary conditions are

$$\begin{aligned}
&\alpha = 0: && f = \text{ constant (e.g., } f = 0);\\
&\beta = 0: && f_\beta = 0);\\
&\alpha = (3/4)^{1/4}: && f_\alpha = 0;\\
&\alpha^2+\beta^2 = 1: && \alpha f_\alpha + \beta f_\beta = 0.
\end{aligned}$$

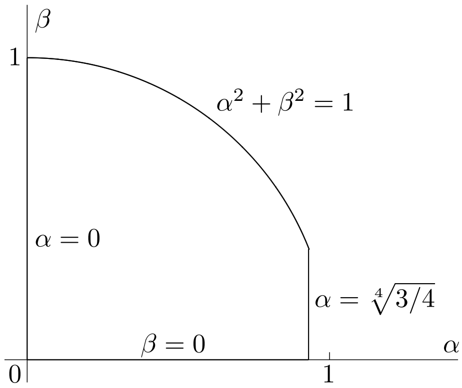

Figure B.1: Boundaries of Eq. (B.5).

The differential equation is integrated numerically by placing a rectangular grid over the area within the boundary, defining a linear equation for each mesh point, and solving the resulting matrix equation [27]. External points near the curved boundary are related to the internal points through the normal derivative.

In Step 1, the matrix is factorized and the equation solved for the vector f, assuming $d = 0$. Then, B is found from, compare with Eq. (3.11),

$$B = B_1 - D, \tag{B.6}$$

where

$$\begin{aligned} B_1 &= 2^{1/2} \int_0^{(\frac{3}{4})^{1/4}} \left(1 - \frac{4}{3}\alpha^4\right)^{3/2} \mathrm{d}\alpha \int_0^{(1-\alpha^2)^{1/2}} \left(1 - \frac{\alpha^2}{1-\beta^2}\right) \mathrm{d}\beta \\ &= 0.669\,605\,309\,417\,211 \end{aligned} \tag{B.7}$$

and

$$D = 2^{1/2} B^{-2} \int_0^{(\frac{3}{4})^{1/4}} \left(1 - \frac{4}{3}\alpha^4\right)^{3/2} \mathrm{d}\alpha \int_0^{(1-\alpha^2)^{1/2}} \left(1 - \frac{\alpha^2}{1-\beta^2}\right) H(\alpha,\beta)\, \mathrm{d}\beta, \tag{B.8}$$

with

$$H(\alpha,\beta) = (r_0 \nabla f)^2 \left(1 + \left[1 - B^{-2}(r_0\nabla f)^2\right]^{1/2}\right)^{-1}, \tag{B.9}$$

in which

$$(r_0\nabla f)^2 = 2\alpha^4 f_\alpha^2 + 2\alpha^2(1-\beta^2) f_\beta^2. \tag{B.10}$$

In Step 2, the vector d is calculated using the previously obtained values for f and B. Using the new d, the matrix equation is again solved for f, and an improved value is calculated for B. This step is repeated until the desired precision has been attained.

The results are better behaved if a rectangular boundary is used. Such a boundary may be obtained by introducing the new variables $x = \alpha$ and $y = \beta(1-\alpha^2)^{-1/2}$. Computation of B using an increasing mesh density now leads to a series of values converging toward the value in Eq. (4.9).

C Weak contributions to the lepton mass

Following Ref. [28] (see page 244, Eq. (4.19)), the second-order QED contribution to the muon mass may be written (with $U = 1, V = m_\mu^2 z_1 + m_2^2 z_2 - m_\mu^2 z_1 A_1$, and $A_1 = z_2 = 1 - z_1$)

$$\begin{aligned}
\delta m_\mu^{(\gamma)} &= \frac{1}{2} m_\mu \left(\frac{\alpha}{\pi}\right) \int_0^1 \mathrm{d}z_1 \int_{\lambda^2}^{\Lambda_\mu^2} z_2 \, \mathrm{d}m_2^2 \frac{2 - A_1}{U^2 V} \\
&= \frac{1}{2} m_\mu \left(\frac{\alpha}{\pi}\right) \int_0^1 \mathrm{d}z_1 (1 + z_1) \ln \frac{m_\mu^2 z_1^2 + \Lambda_\mu^2 (1 - z_1)}{m_\mu^2 z_1^2 + \lambda^2 (1 - z_1)} \\
&= \frac{3}{2} \left(\frac{\alpha}{\pi}\right) m_\mu \left(\ln \frac{\Lambda_\mu}{m_\mu} + O(1)\right),
\end{aligned} \tag{C.1}$$

where m_μ is the renormalized muon mass, Λ_μ the photon ultraviolet (UV) cutoff in connection with muons, and λ the infinitesimal photon mass.

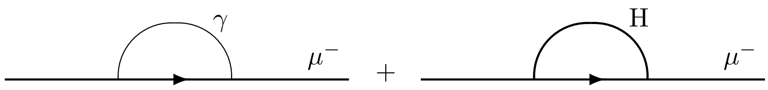

Figure C.1: $\delta m_\mu^{(2)} = \delta m_\mu^{(\gamma)} + \delta m_\mu^{(H)}$.

The Higgs scalar exchange diagram gives a contribution proportional to the square of the lepton mass. In the standard model, it may be obtained by replacing the vertex $-ie\gamma^\alpha$ by $-igm_\mu/2M_W$ (where $g^2 = 4\sqrt{2}M_W^2 G_F$) and $-g_{\alpha\beta}$ by 1 in the photon propagator of the muon QED self-mass graph [29]. These modifications amount to replacing $(\alpha/2\pi)(2-A_1)$ in Eq. (C.1) by $-(G_F m_\mu^2/8\sqrt{2}\pi^2)(1 + A_1)$. The resulting divergent term is

$$\delta m_\mu^{(H)} = -3 \frac{G_F m_\mu^2}{8\sqrt{2}\pi^2} m_\mu \left(\ln \frac{\Lambda_\mu^H}{m_\mu} + O(1)\right), \tag{C.2}$$

where Λ_μ^H is the Higgs UV cutoff in connection with muons. Note here the use of the conventional $\hbar = c = 1$. Introducing the dimensionless cutoff constant Λ and assuming (see discussion below) that $\Lambda_\mu^H \propto \Lambda_\mu$, i.e.,

$$\ln \Lambda = \ln \frac{\Lambda_\mu^H}{m_\mu} = \ln \frac{\Lambda_\mu}{m_\mu} + O(1), \tag{C.3}$$

one obtains in second order the divergent contribution

$$\begin{aligned}
\delta m_\mu^{(2)} = \delta m_\mu^{(\gamma)} + \delta m_\mu^{(H)} &= \frac{3}{2} \left(\frac{\alpha}{\pi}\right) \ln \Lambda \left[1 - \frac{G_F m_\mu^2}{4\sqrt{2}\pi\alpha}\right] m_\mu \\
&= \frac{3}{2} \left(\frac{\alpha}{\pi}\right) \ln \Lambda \left[1 - 1.004\,05 \times 10^{-6}\right] m_\mu.
\end{aligned} \tag{C.4}$$

In the JBW model [2, 3, 4], and in the nonperturbative scheme of Delbourgo and West [30, 31], the bare mass of the lepton is zero. Thus, Eq. (C.4) represents the lowest-order muon mass. Assuming that perturbation theory is valid in this context, Eq. (C.4) states that the Higgs boson causes a relative change of

$$\Delta m_\mu / m_\mu = -1.004\,05 \times 10^{-6} \tag{C.5}$$

in the muon mass. Since the relative decrease is proportional to the square of the lepton mass, the change in electron mass is negligible. Thus,

$$\Delta(m_\mu/m_e) = \Delta m_\mu/m_e = -0.000\,207\,6. \tag{C.6}$$

Similarly, the Higgs correction to the tauon mass is

$$\Delta m_\tau/m_\tau = -\frac{G_F m_\tau^2}{4\sqrt{2}\pi\alpha} = -2.84 \times 10^{-4}. \tag{C.7}$$

Evidently, higher-order calculations are necessary before any definite conclusions about the weak mass corrections can be drawn. Obviously, one can imagine four possibilities. Consistent higher-order perturbation-theoretical calculations: (1) are not possible, (2) are possible for all weak models, (3) are possible only for some specific model, or (4) become possible if some assumption, e.g., Eq. (C.3), is modified. A consistent result might be that the higher-order leading terms contain the same square bracket that appears in the second-order term (C.4).

D Sizeless leptons

In Sections 3 and 4, the "principle of maximum simplicity" is extensively used. It is one of the leading principles in physics; e.g., used in the development of quantum field theory [1]. In the spirit of this principle, imagine the space of the QED universe as a homogeneous fluid (a fluid not made of points) that completely filled the universe. Without points, coordinate systems (origins, axes) cannot be defined, and therefore distance and direction are meaningless concepts in a pointless space. This picture is in agreement with quantum theory. Compare it, for example, with the EPR paradox [32, 33] when the opposite spins of two "entangled" particles are undefined until one of the particles has been in touch with a (macroscopic) coordinate system (i.e., a measuring apparatus).

Another example that is applicable is the famous double-slit experiment [34, 35]. One may label the screen near the slits with, say, "A" and "B," but the empty pointless space inside the slits cannot be labeled or marked in any way. Thus, both slits contain the same empty space traversed by the particle. An obvious conclusion is that, seen from a macroscopic coordinate system, it appears that a particle simultaneously takes all possible paths. As is well known, particles behaving in this way are described by path integrals and Feynman diagrams.

The particles described in Section 3 were assumed to be leptons. In a pointless space these particles must be sizeless, and their unobservable radius may have different numerical values in different connections. Thus, one should distinguish between the lepton's electromagnetic radius r_0, its spin radius r_{0s}, and its gravitational radius r_{0g}.

E Details

E.1 The principle of maximum simplicity

The principle of maximum simplicity [1] is seldom mentioned by name. Still, this principle has rather important consequences, with the most important consequence stating that physics can be described by mathematical methods.

Other aspects of the principle include reductionism, Occam's razor, and nature's preference for beauty and symmetry. The principle provides the basis for mathematics and physics, and is extensively used in real-life situations (common sense).

One rule suggested by common sense and applicable in physics is: Check the simplest hypothesis first!

E.2 Derivation of the gravitational potential

From Eq. (5.3), one obtains, with $x = r/R$, $a = Nr_{0g}^2/Rr$, and ignoring a^2 and higher powers of a,

$$
\begin{aligned}
\frac{\rho}{\rho_0} &= [1-(x+2a)]^{1/2} \\
&= 1 - \frac{1}{2}(x+2a) - \frac{1}{2\cdot 4}(x+2a)^2 - \frac{1\cdot 3}{2\cdot 4\cdot 6}(x+2a)^3 \\
&\quad - \frac{1\cdot 3\cdot 5}{2\cdot 4\cdot 6\cdot 8}(x+2a)^4 - \cdots \\
&= 1 - \frac{1}{2}(x+2a) - \frac{1}{2\cdot 4}(x^2+2x\cdot 2a) - \frac{1\cdot 3}{2\cdot 4\cdot 6}(x^3+3x^2\cdot 2a) \\
&\quad - \frac{1\cdot 3\cdot 5}{2\cdot 4\cdot 6\cdot 8}(x^4+4x^3\cdot 2a) - \cdots \\
&= 1 - \frac{1}{2}x - \frac{1}{2\cdot 4}x^2 - \frac{1\cdot 3}{2\cdot 4\cdot 6}x^3 - \frac{1\cdot 3\cdot 5}{2\cdot 4\cdot 6\cdot 8}x^4 - \cdots \\
&\quad - a\left(1 + \frac{1}{2}x + \frac{1\cdot 3}{2\cdot 4}x^2 + \frac{1\cdot 3\cdot 5}{2\cdot 4\cdot 6}x^3 + \cdots\right) \\
&= (1-x)^{1/2} - a(1-x)^{-1/2} \\
&= \left(1-\frac{r^2}{R^2}\right)^{1/2} - N\left(1-\frac{r^2}{R^2}\right)^{-1/2}\frac{r_{0g}^2}{Rr}.
\end{aligned}
\tag{E.1}
$$

E.3 Where gravity turns repulsive

From Eq. (5.9), according to which $U \propto -r^{-1}\left(1-r^2/R^2\right)^{-1}$, it follows that

$$
\begin{aligned}
F &\propto \frac{\mathrm{d}U}{\mathrm{d}r} \propto \frac{\mathrm{d}}{\mathrm{d}r}\left[-r^{-1}\left(1-\frac{r^2}{R^2}\right)^{-1}\right] \\
&= r^{-2}\left(1-\frac{r^2}{R^2}\right)^{-1} + r^{-1}\left(1-\frac{r^2}{R^2}\right)^{-2}\frac{-2r}{R^2} \\
&= r^{-2}\left(1-\frac{r^2}{R^2}\right)^{-1} - 2R^{-2}\left(1-\frac{r^2}{R^2}\right)^{-2} \\
&= \left[r^{-2}\left(1-\frac{r^2}{R^2}\right) - 2R^{-2}\right]\left(1-\frac{r^2}{R^2}\right)^{-2} \\
&= r^{-2}\left(1-3\frac{r^2}{R^2}\right)\left(1-\frac{r^2}{R^2}\right)^{-2}.
\end{aligned}
\tag{E.2}
$$

Therefore, $F \leq 0$ for $r \geq R/\sqrt{3}$.

E.4 The horizon of the universe

The concept "behind the horizon" is not definable. We see the universe being born on the horizon. "Beyond the horizon" would mean "before the universe was created," i.e., "before time began," which is an impossible concept. Physics stops on the horizon.

The question of how more and more particles come into sight on the horizon is a quantum theoretical problem that is common to all big-bang models. For instance, proposing an inflationary phase would only accentuate the problem, not remove it.

E.5 Imperceptible deceleration vs. acceleration

If the universe is decelerating very slowly, the Hubble expansion rate appears to be constant in time. A constant H, in turn, means that the universe is accelerating.

For the rate of expansion one obtains by definition $v_{\mathrm{exp}} = \mathrm{d}r/\mathrm{d}t = Hr$, or $\mathrm{d}r/r = H\,\mathrm{d}t$. With $H =$ constant, integration yields $\log r - \log r_1 = H(t - t_1)$, or $r = r_1 \exp[H(t - t_1)]$, from which follows

$$v_{\mathrm{exp}} = \mathrm{d}r/\mathrm{d}t = r_1 H \mathrm{e}^{H(t-t_1)}, \tag{E.3}$$

with the corresponding acceleration

$$a = \mathrm{d}^2r/\mathrm{d}t^2 = r_1 H^2 \mathrm{e}^{H(t-t_1)} > 0. \tag{E.4}$$

Thus, a decelerating ($a < 0$) universe in which the deceleration is imperceptibly small (no decrease in H over time is observed) appears to be accelerating ($a > 0$).

From $t - t_1 = H^{-1} \log(r/r_1)$, it follows that a universe beginning as a singularity ($r_1 = 0$ when $t_1 = 0$) and expanding with constant expansion rate would be infinitely old. Therefore, if nothing is known about the time dependence $\mathrm{d}H/\mathrm{d}t$ of the Hubble expansion rate, no conclusion about the upper limit of the age of the universe can be drawn from the presently observed value of H.

E.6 Time-dependent and time-independent "universal constants"

The "universal constants" appear to be the same independently of where we measure them; directly locally or indirectly in distant galaxies.

Some of these universal constants are believed to remain unchanged also over cosmological time scales. To these belong the dimensionless constants "137" $= \alpha^{-1}$, "207" $= m_\mu/m_e$, and "17" $= m_\tau/m_\mu$.

The photon energy $E_\gamma = hc/\lambda$ decreases because of the redshift (its wavelength λ increases). To compensate for this loss of energy, the energy of the massive particles must increase. Therefore, the electron rest energy, $E_e = m_e c^2$, must grow (as well as the rest energy of the nucleons). With $\alpha = e^2/\hbar c$ constant in time, this requirement suggests that m_e increases, while e^2, $\hbar$, and c are constant. From Eq. (3.10), it follows that $r_e \propto 1/m_e$ decreases over time.

An alternative is that $\hbar$ and m_e are constant, but c increases in such a way that E_γ still decreases while E_e grows. In this case, $e^2 \propto c$ increases with time while $r_e \propto 1/c$ decreases. In both cases, atomic dimensions decrease with r_e:

- the classical electron radius, $r_{\mathrm{cl}} = e^2/m_e c^2 = 2r_e/B$,
- the Compton wavelength, $\lambda_0 = r_{\mathrm{cl}}\alpha^{-1}$, and
- the Bohr radius of the hydrogen atom, $a_0 = \lambda_0 \alpha^{-1}$.

E.7 Energy decrease caused by the appearance of the weak force (the Higgs)

The photon γ forms a short-lived electron pair with probability α about equal to 1/137 (the "fine-structure constant" α being a measure of the strength of the electromagnetic interaction). With the same probability that the photon forms electron pairs, it also forms muon and tauon pairs. See Fig. E.1.

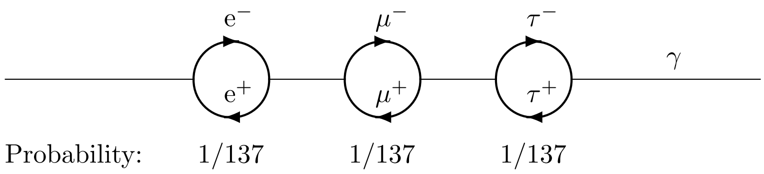

Figure E.1: The photon propagator

The energy change of a photon with energy $m_e c^2$ forming a tauon pair at the time of the fourth phase transition is, from Eq. (9.2),

$$m_e c^2 \frac{\Delta m_\tau}{m_\tau} = -m_e c^2 \frac{G_F m_\tau^2}{4\sqrt{2}\pi\alpha}. \tag{E.5}$$

Consequently, the change in energy of $n_\gamma \approx 10^9$ photons of which one out of 137 is in the tauon state is

$$\Delta E = -\alpha \frac{n_\gamma}{n_b} \frac{G_F m_\tau^2}{4\sqrt{2}\pi\alpha} m_e c^2, \tag{E.6}$$

where $n_b = 1$ is the number of baryons.

E.8 Corrections

In the computer simulation described in Appendix F, it is assumed that two proton-antiproton pairs were created from the last two annihilating electron-positron pairs of phase 3.

Realizing that the "frozen pion" must have played a role similar to the roles played in earlier phases by the "frozen spinless muon" and the "frozen electron" (see points 1.30, 2.19, and 3.19 in Appendix G), it becomes evident that the universe must have existed in an intermediate state where pions were the carriers of matter.

The existence of a "pion phase" preceding the "proton phase" implies that, in the process of creating stable matter, acquisition of energy had to be carried out twice. It turns out that only one proton-antiproton pair was originally created, because two pairs would have required seven Higgs bosons while the muon-electron mass ratio indicates that there are only four of them. The same conclusion follows from the observation that nothing forbade one of the pion pairs to annihilate into two photons—only the annihilation of the last pair was forbidden.

The creation of a stable proton-electron pair from an electron-positron pair was a multi-step process that two times had to be supplied with fresh energy.

First, to fuel the dynamic interactions of four initially "frozen" pions formed (with mass and energy conserved) from the last two electron pairs, the energy

$$E_1 = 4(m_\pi - m_e)c^2 = 556.236 \text{ MeV} \tag{E.7}$$

was drawn from the $n_\gamma = 2N_3$ background photons via the appearance of a one-Higgs electroweak force. See Appendix E.7.

Then, to supply the energy

$$E_2 = 2(m_p - m_\pi)c^2 = 1597.404 \text{ MeV} \tag{E.8}$$

needed in the conversion of the last pion pair into a proton pair, three more Higgs bosons were required. The excess energy, $3E_1 - E_2 = 71.304$ MeV corresponding to $0.128E_1$, was restored to the photons via the appearance of a flavor-changing mechanism that caused a slight increase in the tauon's mass. Thus, a total energy of $(1 + 3 - 0.128)E_1 = 3.872E_1$ was tapped off from the background photons. It implies that the change in tauon mass caused by the electroweak force is

$$y = 1 + E_2/E_1 = 4 - 0.128 = 3.872 \tag{E.9}$$

times the negative one-Higgs mass correction obtained in Appendix C.

The Higgs boson causes a relative decrease in lepton mass that is proportional to the square of the lepton's mass (see Appendix C). Thus, for the negative contribution to the muon mass, it holds that

$$\Delta m_\mu^{(-)}/m_\mu = (m_\mu/m_\tau)^2 \Delta m_\tau^{(-)}/m_\tau. \tag{E.10}$$

The corrective positive contribution's dependence on mass is unknown, but there is no reason to believe that it should be much more complex than the negative contribution's mass dependence. In fact, assuming a simple dependence, and requiring agreement with observations, there is but one possible choice, namely

$$\Delta m_\mu^{(+)}/m_\mu = (m_\mu/m_\tau)^2 \log{(m_\tau/m_\mu)} \Delta m_\tau^{(+)}/m_\tau. \tag{E.11}$$

Consequently, when the total change in tauon mass is $y = 4 - 0.128 = 3.872$ times the contribution from one Higgs boson, the corresponding change in muon mass is

$$y_\mu = 4 - 0.128 \log{(m_\tau/m_\mu)} = 4 - 0.362 = 3.638 \tag{E.12}$$

times the one-Higgs contribution to the muon mass. For the corrected muon-electron mass ratio it gives $m_\mu/m_e = 206.769\,039 - 3.638 \times 0.000\,2076 = 206.768\,284$.

A more precise calculation yields $m_\mu/m_e = 206.768\,283\,185(77)(7)(5)(5)$ with the uncertainties coming from errors in $\alpha^{-1} = 137.035\,999\,084(51)$, G_F, m_π, and m_τ, respectively. This theoretical value,

$$m_\mu/m_e = 206.768\,2832(1), \tag{E.13}$$

agrees with the measured value 206.768 2837(56) in Ref. [15] and is nearly two orders of magnitude more accurate.

In the beginning, a phase transition broke the perfect symmetry of literally nothing and gave birth to an expanding spacetime bubble of initial age t_c. Its space was oscillating, and the bubble formed a single-particle universe: the Dirac particle—a matter-antimatter neutral "relativistic harmonic oscillator" on which no forces acted. After the "D particle" had appeared at time t_c, the law of conservation of energy governed the evolution of the universe. Particles multiplied and decayed, with the result that matter rapidly transformed into pure radiation. Since global conservation of energy forbids the existence of an expanding universe void of matter (see beginning of Section 7 on page 16), the decay of the last massive particle triggered (in another symmetry-breaking phase transition) creation of an electric force whose sole purpose was to recreate matter from radiation. Repetitive decay triggered the creation of two more matter-recreating forces. See Fig. E.2.

Force	Matter	Constant	Dynamics
Electric	$\mu_0^+\,\mu_0^-$	m_τ/m_μ	Scalar QED
Electromagnetic	$\mathrm{e}^+\,\mathrm{e}^-$	$m_\mu/m_e,\ \ \alpha^{-1}$	Spinor QED
Strong	$\pi^+\,\pi^-,\ \ \mathrm{p}\,\bar{\mathrm{p}}$	$m_\pi/m_e,\ \ m_p/m_\pi$	QCD

Figure E.2: Matter-creating forces. The latter two forces still exist.

The electroweak force differed from the matter-creating forces. Its purpose was to furnish the strong force with the energy it needed to create a proton-antiproton pair from the last annihilating pair of electron pairs. The required energy was tapped off from background photons forming transient lepton pairs (see Appendix E.7).

The consistency of the theory may now be checked. Upon correction, the simulation in Appendix F should give the same y value ($y = 3.872$) as the direct calculation yields. Consequently, the computation should be redone with the balance equation (F.7) replaced by

$$2N_3(2/x)m_e c^2 y G_F m_\tau^2/4\sqrt{2}\pi = 4(m_\pi - m_e)c^2 + 2(m_p - m_\pi)c^2. \tag{E.14}$$

Unlike the rest of the model's parameters, which are unambiguously derived or have the natural value of one, the τ coefficient used for phase 3 in Appendix F was conjectured on the assumption that it should be simple. Sticking to the same assumption, the only value consistent with Eq. (E.14) appears to be

$$\tau_3 = \frac{1}{8\pi}\alpha^{-2} = 747.1873 \tag{E.15}$$

for the initial annihilation lifetime in phase 3. Comparison with parapositronium's lifetime, 1.25×10^{-8} s, which is proportional to α^{-5}, suggests that τ_3 should be about $\alpha^3\times1.25\times10^{-8}$ s, that is, of the order of magnitude 10^{-16} s (when measured in "local seconds," τ has not changed since phase 3).

As noted on page 48, it should be possible to calculate the τ_3 coefficient from standard QED theory. However, it is not the actual coefficent in Eq. (E.15) one obtains, but its ratio to the corresponding coefficient for scalar QED. In the simulation, both coefficients are expressed in units of the universe's initial age, t_c, whose value in seconds is unknown. Division of 10^{-16} s by τ_3 suggests that t_c should be about 10^{-19} s.

Repeating the simulation, using the corrected balance equation and the τ coefficient of Eq. (E.15), gives $N_3 = 1.393\times10^9$, or

$$n_\gamma/n_b = 2.786\times10^9 \tag{E.16}$$

with $n_b = 1$, and a growth in electron self-energy of $x = 10.535$. Using these values, $y = 3.844$ is obtained from the balance equation.

At first sight, one might be tempted to conclude that the difference between the two y values,

$$\Delta y = 3.872 - 3.844 = 0.028, \tag{E.17}$$

indicates that assumption (E.15) is wrong. However, a detailed analysis instead supports the assumption, demonstrating that the y discrepancy discloses pertinent information about the process that led to stable protons.

To understand the result, it must be remembered that the higher value, $y = 3.872$, is calculated in our standard (local) picture, where c and particle energies and lifetimes are conserved, while the simulation is performed in the global picture, where these quantities increase over time. Thus, the increase in pion rest energy means that the longer the universe stayed in the pion phase, the larger part of the energy brought by the additional three Higgs bosons was needed to fuel the conversion of pions into protons. In other words, an energy fetch of 2.844 times the contribution from one Higgs boson would have sufficed if the pion-to-proton transformation had taken place immediately after the creation of the pions. A little later, when it actually took place, the conversion needed $2.872/2.844 = 1.010$ times more energy.

The pion belongs to the hadrons—strongly interacting particles. Assuming that the newborn pion pairs annihilated by strong interaction in about 10^{-24} s (which is a typical lifetime of resonances—strongly interacting particle states), the result in Eq. (E.17) implies that, after one pion pair had almost instantly annihilated, the only remaining pair acquired a lifetime of 0.216 times the phase-3 lifetime assumed in Eq. (E.15). In other words, it lived maybe 10^8 times longer than the first pair. For details, see added FORTRAN code in program Simulation.for.

How can the prolonged life of the last pion pair be explained? The following chain of logic demonstrates that an explanation may be readily found.

The creation of the strong force was accompanied by a "Higgs force," which was mediated by a single Higgs boson, and whose sole purpose was to supply the strong force with the energy it needed to transform the frozen pions into dynamic systems of quarks—the pions we observe today.

Most elementary particles have a definite intrinsic parity that may be positive or negative [36]. Particles of interest here are,

- with negative parity (-1): e^+, μ^+, τ^+, π^+, π^-, π^0, γ, and
- with positive parity $(+1)$: e^-, μ^-, τ^-, p, $\bar{p}$.

Thus, when a photon produces short-lived vacuum-polarization loops, e.g. via $\gamma\to e^+e^-\to\gamma$, parity is conserved: $-1 = (-1)(+1) = -1$.

The newborn pions (the real and virtual π^+ and π^- and the virtual π^0) acquired negative parity. Since $(-1)^2 = +1$, pion pairs and photon pairs had the same positive parity, which allowed pion pairs to rapidly annihilate into two photons.

After the first pair had annihilated, the remaining pair—the only existing matter—was not allowed to follow suit. Its annihilation had to be avoided. Therefore, in a symmetry-breaking transition, the Higgs force was turned into a parity-violating "weak force" with sole purpose to switch the parity of one of the pions from negative to positive, and, thereby, inhibit the imminent pair annihilation from being realized.

Since $(+1)(-1) \neq (-1)^2$, parity conservation now inhibited the "mixed-parity" pion pair from annihilating into photons, and the existence of matter (the pion pair) was guaranteed for the time being.

When it initially appeared, the parity-violating weak force had to choose as its first target either the pion or the antipion. Thereby, it added to the original weak force a subtle matter-antimatter asymmetry—a "superweak" CP-violating effect observed in kaon and B meson decay. Compare with point 4.27 on page 60.

The parity-violating force had come to stay, and when the remaining pion pair had lived maybe 10^8 times longer than the first pair (about 10^{-16} s, instead of 10^{-24} s), the weak force also caused the second pion to change parity. After this event, the pair was able to repeat its attempt to quickly annihilate (since now $(+1)^2 = (-1)^2$).

The neutral pion is observed to decay into two photons ($\pi^0 \to \gamma\gamma$, violating parity conservation) with a lifetime of $0.84(6) \times 10^{-16}$ s. It should be possible to theoretically compare its lifetime with the lifetime of the unique mixed-parity pion pair that preceded the creation of the proton. If the lifetimes were the same, it would imply a phase-3 annihilation lifetime (τ_3) of about $(0.84/0.216) \times 10^{-16}$ s $= 4 \times 10^{-16}$ s.

Because the pion pair remained the sole carrier of matter, its annihiliation was still forbidden and had to be inhibited. The introduction of the weak parity-switching force had required no additional energy. Since (evidently) no more similar tricks were physically possible, only energy-consuming means remained. The remedy was to once again turn to Higgs for help with acquisition of fresh energy. The request resulted in the creation of three more Higgs bosons and the introduction of a mechanism for disposing of the surplus energy that was not consumed in the process of transforming the pion-antipion pair into a proton-antiproton pair.

The proton and antiproton (p and $\bar{\text{p}}$) inherited the positive parity of the real pions from which they were formed (virtual pions still held negative parity). To inhibit the threatening annihilation of the proton pair, the antiproton decayed into a negative electron ($\bar{\text{p}} \to \text{e}^-$) without change of intrinsic parity (+1).

The fact that the antiproton was forced to transform back into an electron proves that the proton pair was the only carrier of matter, since otherwise its annihilation into two photons would have been allowed. Thus, if stable exotic matter, such as the lightest supersymmetric particle (LSP), exists, it may have been created at the earliest in the process that transformed the antiproton into an electron.

In summary, direct calculation of the energies involved in the transformation of an electron pair into a proton pair combined with a detailed simulation of the same process—a brief episode in the early evolution of the universe—explains the complexity of the energy-transferring electroweak force and makes several unambiguous predictions. Thus, the theory:

- Explains that at first one, and soon after, another three Higgs bosons appeared.
- Demands the existence of a parity-switching weak force (observed).
- Suggests matter-antimatter asymmetry of this force (CP violation observed in K and B meson decay).

- Predicts that a weak mechanism causes a positive correction to the lepton masses.
- Predicts for the tauon a ratio of 0.128 between the positive mass change and a one-Higgs negative mass change.
- Predicts for the muon a corresponding ratio of $\log\left(m_\tau/m_\mu\right) \times 0.128$.
- Predicts for the muon-electron mass ratio a value of 206.768 283 185(78), which agrees with the measured value 206.768 2837(56), the uncertainties being 0.4 ppb (parts per billion) and 27 ppb, respectively.

F Computer simulation of the universe

Summary of the hydrodynamic model for space

The universe is expanding because space is created inside particles and is flowing out from them. The amount of space created per unit time by a particle is proportional to the particle's energy. Consider a sphere with radius r and volume $V = \frac{4}{3}\pi r^3$ that grows at the same rate as space is created by a particle at its center. Because the space created is proportional to the particle's energy, the volume grows at a steady rate. In other words, $\mathrm{d}V/\mathrm{d}t$ is constant. With a suitable definition of the "particle radius," r_0, one may write $\mathrm{d}V/\mathrm{d}t = 4\pi c r_0^2$, or

$$\mathrm{d}r/\mathrm{d}t = c r_0^2/r^2, \tag{F.1}$$

valid for $r \gg r_0$.

Suppose next that V, instead of containing one particle, contains N particles, which means that

$$\mathrm{d}r/\mathrm{d}t = cNr_0^2/r^2. \tag{F.2}$$

Particles on the horizon of the universe recede with velocity $\mathrm{d}r/\mathrm{d}t = c$, and the distance to the horizon is given by the universe's radius, $R = c/H$, where H is the Hubble expansion rate. Letting V be the volume of the entire universe (i.e., setting $\mathrm{d}r/\mathrm{d}t = c$ and $r = R$), the number of particles in the universe is given by

$$N = R^2/r_0^2. \tag{F.3}$$

From Eq. (F.2), one obtains via integration $\int_0^r r^2 \mathrm{d}r = cNr_0^2 \int_0^t \mathrm{d}t$, or

$$r^3 = 3cNr_0^2 t, \tag{F.4}$$

where t is the age of the universe. Division of Eq. (F.2) by Eq. (F.4) gives $\mathrm{d}r/\mathrm{d}t = r/3t$, and, choosing $r = R$,

$$R = 3ct, \tag{F.5}$$

which implies that the radius of the universe grows linearly with time.

Thus, a volume containing a fixed number of particles grows like t, whereas the volume of the universe grows like t^3.

From Eqs. (F.3) and (F.5), it follows that

$$N \propto t^2, \tag{F.6}$$

where N is the number of particles in the universe, and t is the age of the universe.

The early universe

It is assumed that the universe was created as a single spinless and outward neutral particle (a pair of "spinless tauons"), which popped up in a finite spacetime volume in a phase transition that broke the perfect symmetry of literally nothing. Thus, in phase 1, the universe initially contained $N_0 = 1$ particle pairs occupying a volume V_0.

As space expanded, the number of particles in the universe grew according to Eq. (F.6), at the same time as the massive particle pairs annihilated into pairs of massless photons. When the last spinless-tauon pair was about to annihilate (and thereby trigger the rematerialization of radiation in a second phase transition), the volume of the universe was V_1, and it contained

N_1 particle pairs. Quantum indistinguishability means that each one of them originated from the very first particle pair.

In phase 2, history repeated itself, now with the spinless muon playing the leading role. By the end of phase 2, the volume of the universe had grown from V_1 to V_2, and the number of particle pairs from N_1 to N_2.

In phase 3, history repeated itself once more, but now with the spinning electron in the leading role. Initially, phase 3 contained $2N_2$ electron pairs, since, in the third phase transition, every photon had rematerialized as two electrons (an electron-positron pair). At the end of phase 3, when the last pair of electron pairs were about to annihilate, the universe's volume had grown to V_3, and it contained $N_3 - 1$ photon pairs in addition to the remaining two electron pairs.

Computer simulation of the first three phases

Use the index c to refer to the value of a quantity at the time of creation (the first phase transition), i to refer to its initial value in a phase, and f to refer to its final value, when the next phase transition is triggered.

For each phase, assume a value for the final number of particle pairs, N_f, and calculate the time it takes for all pairs to annihilate. Addition of this time interval to the time t_i, when the phase began, gives the time t_f (i.e., the age of the universe) when the phase ends. At this point in time, $N_f = (t_f/t_c)^2$ should hold as required by Eq. (F.6). If necessary, repeat the calculation using another value of N_f, and continue until the requirement (F.6) is met as closely as possible.

If the model is good, the self-energy of the final massive particles should have grown by a factor of 16.919, 151.136 31, and order of 10, in phase 1, 2, and 3, respectively.

Since, by the end of phase 3, the universe should have exploded from a single-particle universe to one containing billions of particles, the final outcome of the simulation is sensitive to variations in the initial assumptions. Mathematical experimentation suggests the following scenario.

In phases 1 and 2, the photon energy is given by a constant divided by the photon's wavelength. As the universe expands and the wavelength λ increases, the velocity of light grows, which causes the self-energy mc^2 (with m constant) of the spinless-lepton pairs to grow in such a way that the energy content of any given expanding volume is conserved.

In the phase transitions, energy conservation makes the rematerialized particle acquire the original energy of its predecessor, or, in the case of the electron, half this energy. It means that c jumps back to its original value, thereby (because of conservation of rest energy) forcing an upward jump in mass of the, now virtual, predecessor(s).

In the first two phases, the lepton rest energy grew rapidly with c^2. In phase 3, however, the conditions were different. The Planck constant h (which did not exist in previous phases) had appeared, and its existence caused the photon energy, hc/λ, to decrease at a much slower rate than in previous phases, since the constancy of h now meant that the increase in c partly compensated the decrease in $1/\lambda$.

Mathematical experiments

The tentative assumption that the lifetime τ (also called mean life or average life) of the particle pairs is constant in each phase, means that in phase 1 it should have a value of about 2.045 (in units of t_c) for $N \propto t^2$ to be satisfied. Similarly, in phase 2, its value should be about 4.78. These values are not easily understood.

Assuming instead that $\tau \propto c$, it is seen that $N \propto t^2$ holds approximately if the initial lifetime in the three phases is 1, 1, and $(2\pi^2\alpha^2)^{-1}$, respectively. The maximum simplicity of the first two values strongly supports this assumption.

When the lifetime is assumed to stay constant, the calculation is rather trivial. That (as computations indicate) τ grows with c, complicates the calculation.

The table summarizes the results of various experiments. E_f is the final rest energy of the massive particle in units of its initial rest energy. The first five entries show the results when various averages involving τ ($<\tau>$, $<\tau^2>$, etc.) over the time interval Δt between two annihilation events is used to calculate Δt, i.e., when $\Delta t = \tau/N$ is replaced by $\Delta t = (<\tau^k>)^{1/k}/N$ or $\Delta t = \exp<\log\tau>/N$, where N now denotes the number of remaining massive particle pairs. When using averages, iteration of a numerical integration is performed, except in the case of $<\tau^2>$, when analytical integration may be performed (but iteration is still needed).

For phase 3, no averaging is done. Also, to speed up the calculation, approximations are made with the result that only the first 4 figures in N_3 are reliable.

The universe's age t_f at the end of a phase, is not shown in the table, but is typically (with initial age $t_c = 1$) about 10, 33, and 49 470, respectively.

	N_f			$t_f - \sqrt{N_f}$			E_f		
Method	1	2	3	1	2	3	1	2	3
$<\log\tau>$	86	1019	2447240000	1.031	1.035	1.042	16.855	151.044	10.888
$<\tau>$	86	1013	2447000000	1.068	1.273	0.579	16.930	151.265	10.887
$<\tau^{-1}>$	87	1029	2447500000	0.990	0.798	0.200	16.978	151.139	10.889
$<\tau^2>$	86	1006	2446700000	1.103	1.505	1.055	17.002	151.197	10.886
$<\tau^{-2}>$	87	1037	2447700000	0.952	0.546	0.729	16.899	151.190	10.890
$\tau(t_N)$	99	1220	2453500000	-0.289	-4.929	-0.815	16.872	151.166	10.916
$\tau(t_N + \Delta t)$	78	905	2440500000	2.118	6.034	4.129	16.846	151.345	10.858
$\tau(t_N + \frac{1}{2}\Delta t)$	85	999	2446600000	1.151	1.676	0.848	16.890	151.127	10.885
$\tau(t_N + x_1\Delta t)$	96	1167	2452233000	0.000	-3.590	0.000	16.919	151.096	10.911
$\tau(t_N + x_2\Delta t)$	86	1016	2447412300	1.004	1.000	1.000	16.845	151.019	10.889
$\tau(t_N + x_3\Delta t)$	86	1010	2447604900	1.000	1.000	1.000	16.839	149.771	10.890
$\tau(t_N + x_4\Delta t)$	87	1023	2447189200	1.000	1.000	1.000	17.046	151.998	10.888
Target value							16.919	151.136	O(10)

The last seven examples show experiments in which the value of τ used in the calculation is taken to be its value at the beginning of the time interval (i.e., $\tau = \tau(t_N)$), at the end of the interval (when $t = t_N + \Delta t = t_{N-1}$), at its midpoint ($t_N + \frac{1}{2}\Delta t$), or at some point $t_N + x_n\Delta t$ with $x_n < 1$: $x_1 = 0.0875$, $x_2 = 0.43855$, $x_3 = 0.437$, and $x_4 = 0.4386$.

The fourth example from below (with $x_1 = 0.0875$) shows that if N_1 and N_2 are both adjusted to lie as close as possible to the target values, x_n can only be adjusted to make $t_f - \sqrt{N_f} = 0$ for one of the first two phases. Also, the value of x_1 seems to be unrealistically low.

The next example (with $x_2 = 0.43855$) shows that it is possible to instead adjust x_n so that $t_f - \sqrt{N_f} = 1$ is nearly satisfied for both phases. In the last two examples, x_n is adjusted to make $t_f - \sqrt{N_f} = 1$ in both phases, with E_1 and E_2 closely below their target values (next to last example), and closely above them (last example).

These results suggest that, instead of $N = t^2$ (in units where $t_c = 1$), $N = (t-1)^2$ connects the number of particles N to the age t of the universe. In other words, mathematical experiments, which use target values obtained from the measured m_τ/m_μ and m_μ/m_e, indicate that $\sqrt{N} \propto t-1$ should replace Eq. (F.6). This observation suggests that the primordial particle was a particle of its own, which did not interact electromagnetically, and which, therefore, was predestined to spend its life alone in the universe. A candidate for this primordial particle should be the spinless massive particle (D) described by Dirac's "new equation." According to Biedenharn, Han, and van Dam [10], Dirac's equation is a realization on two bosons. Also, interaction with the electromagnetic field destroys the consistency of the defining structure.

Thus, the universe was born at the initial age of 1 (the D particle popping up in an expanding spacetime bubble of unit dimensions), and when it was 2, the D disintegrated into a pair of tauons (either directly, or via a pair of photons that "froze" into a pair of massive spinless tauons). Therefore, at the age of $t = 2$, the universe contained $N = 1$ particle pairs, and the relation $N = (t-1)^2$ holds true.

The calculation leading to Eq. (F.6) is based on classical fluid dynamics. The result is that Dirac's large-number hypothesis [11, 12] is rediscovered. Naturally, this simple model cannot tell anything about the dynamics of the universe (such as interactions between particles and possible time-dependence of c).

Conclusions

Even if the experiments fail to provide exact results, the predictions $N_3 = 2447$ million and an increase in electron rest energy of about $x = 10.889$ are precise enough to give useful information about the lepton mass corrections caused by the appearance of the weak force in the third phase transition.

The energy balance, which was assumed in the derivation of Eq. (9.3), namely $\Delta E = (n_\gamma/n_b)m_e c^2 \alpha G_F m_\tau^2/4\sqrt{2}\pi\alpha = 2(m_p c^2 - m_e c^2)$, can now be corrected to read

$$(n_\gamma/n_b)(2/x)m_e c^2 y G_F m_\tau^2/4\sqrt{2}\pi = 2(m_p c^2 - m_e c^2), \tag{F.7}$$

from which the corrected Eqs. (9.3) and (9.4) are found to be

$$\frac{n_\gamma}{n_b} G_F m_\tau^2 \approx \frac{x}{2y} 8\sqrt{2}\pi \frac{m_p}{m_e}, \tag{F.8}$$

and

$$\frac{n_\gamma}{n_b} \approx \frac{x}{2y} 1.77 \times 10^9, \tag{F.9}$$

respectively.

The quantity $(2/x)m_e c^2$ represents the average photon energy. It was originally $2m_e c^2$, and did not change appreciably during phase 3. But relative to the electron rest energy, which increased $x = 10.889$ times, it is now correspondingly smaller.

The factor y is unknown, and depends on the model used for weak interactions. For a one-Higgs model, y = 1. Use of this value, however, resulted in a correction to the muon-electron mass ratio that was too small by a factor of about 3.66 for the corrected ratio to match the measured ratio.

Inserting into Eq. (F.9), $n_\gamma/n_b = n_\gamma/2 = N_3 = 2.447 \times 10^9$ and $x = 10.889$, gives $y = 3.94$. When the one-Higgs correction to the muon-electron mass ratio, $-0.000\,207\,6$, is multiplied by y, the expected actual correction is found to be $-0.000\,818$. Thus, the corrected muon-electron mass ratio is predicted to be $206.769\,04 - 0.000\,82$, or

$$m_\mu/m_e = 206.768\,22, \tag{F.10}$$

which should be compared with the measured value

$$m_\mu^{\mathrm{m}}/m_e = 206.768\,28(1). \tag{F.11}$$

Can the fine-structure constant α be calculated?

In summary, even if the mathematical experiment so far has failed to produce definitive theoretical values for the uncorrected tauon-muon and muon-electron mass ratios, and via them α, a good prediction for the corrected muon-electron mass ratio is obtained.

The values of three physical constants had to be conjectured. Still, the very simplicity of two of them ($\tau_1 = \tau_2 = 1$), and the quite plausible[5] expression for the third one, $\tau_3 = (2\pi^2\alpha^2)^{-1}$, suggest that the computer simulation gives an essentially correct picture of the evolution of the early universe.

Also, nothing seems to forbid an exact mathematical description of the evolution of the first phases. Supposedly, path integrals have to be used, and the actual computation performed numerically via Monte Carlo methods.

The target value, 151.136 31, for the final E_f of phase 2 (given as 151.136 in the table of results) is obtained via division of $\alpha^{-1} = 137.036$ by the numerical constant $2B^2/B_0 = 0.906\,704\,696$ (where $B = 0.666\,001\,731$ and $B_0 = 0.978\,396\,402$). Conversely, if E_f of phase 2 can be computed with high accuracy, multiplication by the same numerical constant should give an accurate theoretical (and purely numerical) value for α^{-1}.

Computer simulation of phase 4

Consider a volume V containing a proton, an electron, and N_3 photons. For simplicity, assume that the particles do not interact with each other. Energy conservation implies that

$$(m_p + m_e)c^2 + N_3(2m_e c_i/x)\, c\, (t/t_i)^{-1/3} = E_0 \tag{F.12}$$

must stay constant. With $t_i = 49\,470$ and $E_0 = (m_p + m_e)c_i^2 + 2N_3 m_e c_i^2/x$ (and choosing, say, $c_i = 1$ and $m_p + m_e = 1$), the evolution of the volume may be followed until present time, t_0, when the temperature of the cosmic background radiation (CMB) has fallen to about $T_0 = 2.725$ K and c has grown by a factor of 494.3.

Using $\tau = c$ (with initial value equal to $t_c = 1$) for the time increment dt, and counting the number of time increments required to reach t_0, one obtains $t_0 = 3 \times 10^{21}$ for the present age of the universe, and $k = 1.000\,32$ for the total number of time increments times the present-day time increment 494.3 divided by the age t_0.

In a more realistic simulation, allowing for the formation of neutrons, atoms, and macroscopic structures, one might expect that t_0 should be several orders of magnitude greater than 10^{21}, and $k \gg 1$.

The picture presented here is a "global" picture of the world in the sense that the energy principle holds true globally, which is a necessity for the picture to be consistent and the universe calculable. Thus, from Eq. (F.5), one obtains

$$t = R/3c = 1/3H \tag{F.13}$$

for the global age of the universe, with its present value $t_0 = 1/3H_0 \approx 6 \times 10^9$ yr.

[5] The lifetime for pair annihilation depends on the dynamics of the particles. The cross section for the annihilation into two photons of a positron of given energy with a (negative) electron at rest was obtained by Dirac in 1930[37]. When the positron has a low velocity, v, the cross section σ is, in the Born approximation [38], $\sigma = \pi r_0^2/v$ with $r_0 = \alpha/m_e$. Thus, $\tau \propto (\pi\alpha^2)^{-1}$. However, this process differs from the annihilation process of phase 3, in which an entangled pair of electron pairs annihilates into an entangled photon pair. Comparison of the spinor-QED calculation with the corresponding scalar-QED calculation should explain the ratio between the two τ values, $(2\pi^2\alpha^2)^{-1}$ and 1.

However, in our practical (local) system of measurement, we define τ and c to be constant in time. (The global and local pictures complement each other. In a quantum world, where no absolute measure of distance exists, there is no conflict between them. Compare with what Einstein called "the spooky action at a distance.") Thus, instead of directly measuring (global) time, we count atomic-clock ticks. Consequently, in our local picture, the age of the universe appears to be $kt_0 \gg t_0$. And, since τ (the atomic-clock tick) of the young universe was many hundred times shorter than it is today, it appears that the universe stayed young for a very long period of time.

From Eq. (F.13), one obtains

$$\dot{H}/H = -1/t \tag{F.14}$$

for the Hubble expansion rate. However, because the local age is much greater than the global age, measurements (relying on atomic clocks) of $\dot{H} = \mathrm{d}H/\mathrm{d}t$ indicate that H decreases so slowly that it appears to be constant. A constant H, in turn, implies an accelerating universe (which is evident from $\mathrm{d}r/\mathrm{d}t = Hr$).

G Detailed conclusions

Two discoveries, both of them resulting from simple mathematical experiments, led up to the present cosmological theory.

The first experiment (described in Appendix H) revealed that the classical momentum equation, which connects a fluid's velocity ($\boldsymbol{v}$) and pressure (p) to its density (ρ), may be written in a form where the variable p is replaced by a parameter (f) denoting number of degrees of freedom. Applied to space, the pressureless momentum equation implies position undefinability, since absence of pressure implies absence of molecules and, thereby, absence of coordinate points. The equation has a stationary solution, which is interpreted as a snapshot of an electron formed from—and being part of—expanding space.

In the second experiment (described in Appendix F), a computer program was used to simulate the evolution of the early universe. It revealed that the energy principle (conservation of energy) serves a double purpose in physics. Thus, in addition to governing local physical processes (for instance, by requiring that $E = mc^2 =$ constant), it governs the evolution of the universe by demanding that the energy in a volume coexpanding with the universe be constant. Classically, such a double role implies an unresolvable time paradox (see below). But thanks to position undefinability (suggested by the first experiment), the energy principle's two roles do not conflict with each other in the quantum world.

The computer simulation (see Section 10 and Appendix F) indicates that the three phases, which are summarized in Fig. G.1, preceded the present phase 4 of the universe. The numbers in the second and fourth columns indicate the approximate age (t) of the universe in units of its initial age (t_c).

Phase	Beginning of phase		End of phase	
#	t	Particles	t	Particles
1	1	$1 \times \mathrm{D}$	10	$10^2 \times \gamma_\tau\gamma_\tau$ + virtual τ_0 loops
2	10	$10^2 \times \mu_0^+\mu_0^-$	33	$10^3 \times \gamma_\mu\gamma_\mu$ + virtual μ_0 and τ_0 loops
3	33	$10^3 \times \mathrm{e^+e^-\ e^+e^-}$	37 325	$10^9 \times \gamma\gamma$ + virtual e, μ, and τ loops

Figure G.1: The origin of the lepton generations.

The first phase transition broke the perfect symmetry of literally nothing and led to the creation of matter in the form of a massive particle (D) that, incapable of interactions, lived single till it decayed into an unstable pair of spinless tauons ($\tau_0^+\tau_0^-$) or directly into a photon pair ($\gamma_\tau\gamma_\tau$). In the next phase transition, there appeared unstable pairs of spinless muons. In the third phase transition, unstable pairs of (ordinary) spinning electrons were created when radiation (in the form of muon photons γ_μ) rematerialized. The numbers of particle pairs (10^2, 10^3, and 10^9) indicate order of magnitude. In summary, the primordial particle evolved according to $\mathrm{D} \to \tau_0^+\tau_0^- \to \gamma_\tau\gamma_\tau \to \mu_0^+\mu_0^- \to \gamma_\mu\gamma_\mu \to \mathrm{e^+e^-\ e^+e^-} \to \gamma\gamma$, with also direct decay $\mathrm{D} \to \gamma_\tau\gamma_\tau$ possible.

G.1 Level 1. Brief listing of points of interest

An asterisk (*) indicates that a point is discussed in more detail on level 2 below. The same numbering system applies to both levels.

General
0.01. Base all reasoning on the principle of maximum simplicity.*
0.02. Let V be a volume coexpanding with the universe. Assume that*

$$\mathrm{d}V/\mathrm{d}t = \text{ constant}, \tag{G.1}$$

implying an unperturbable expansion of space, and that

$$\text{the energy in } V \text{ is conserved}, \tag{G.2}$$

implying that energy is globally conserved.

Phase 1: the tauon generation*
1.01. The universe popped up as a tiny spacetime bubble of unit dimensions.
1.02. Thus, at the instant of creation, the age of the universe was $t_c = 1$.*
1.03. Its birth spontaneously broke the absolute symmetry of literally nothing.*
1.04. The newborn universe had no temperature.
1.05. It contained one single particle, the massive "D particle."
1.06. The D particle is described by Dirac's "new equation" published in 1971.*
1.07. No electromagnetic, strong, weak, or gravitational forces acted in the universe.*
1.08. In particular, Dirac's particle was unable to produce virtual photons.
1.09. The D particle was predestined to remain single.
1.10. It was unstable with lifetime (or mean life) $\tau = 1$.
1.11. For times $t < 2$, the lone D particle was in a dual state.
1.12. It existed both as a decayed (dead) and an undecayed (live) particle.*
1.13. It may be compared to Schrödinger's famous cat in its unopened box.*
1.14. At $t = 2$, the live D transformed into a pair of spinless tauons ($\mathrm{D} \to \tau_0^+\tau_0^-$).*
1.15. The D particle's transformation and its decay were irreversible processes.
1.16. Energy was conserved in these processes.
1.17. Photons are carriers of the electromagnetic force.
1.18. Thus, the decay of the D particle created the electromagnetic force.
1.19. The spinless tauons ($\tau_0^\pm$) that succeeded the D are described by scalar QED.*
1.20. They interacted via virtual photons (γ_τ).
1.21. When the universe expanded, more tauon pairs came in sight of each other.*
1.22. The tauon pairs were indistinguishable from each other.
1.23. The tauon pairs were unstable and annihilated into photon pairs ($\gamma_\tau\gamma_\tau$).
1.24. The photons lost energy as the universe expanded.
1.25. To counterbalance the energy loss, the tauon rest energy, $m_{\tau_0}c^2$, grew.
1.26. The tauon mass, m_{τ_0}, remained constant while c grew.*
1.27. The annihilation of the last tauon pair forced space to freeze.
1.28. In the process, c jumped back to its initial value.
1.29. Conservation of tauon rest energy caused an upward jump in m_{τ_0}.
1.30. The photon pairs materialized into pairs of "frozen" spinless muons: $\gamma_\tau\gamma_\tau \to \mu_0^+\mu_0^-$.*
1.31. The frozen particles immediately transformed into dynamically interacting particles.
1.32. In the transformation, the particles' charge and mass were conserved.

Phase 2: the muon generation

2.01. The rematerialized universe contained initially about 86 spinless-muon pairs.
2.02. The spinless muons ($\mu_0^{\pm}$) are described by scalar QED.
2.03. They interacted via virtual photons (γ_μ).
2.04. The τ_0 and γ_τ reappeared in the form of virtual particles.*
2.05. Tauons (τ_0) could not produce muon photons (γ_μ).
2.06. Muons (μ_0) could not produce tauon photons (γ_τ).
2.07. Thus, the two species of "spinless leptons" did not interact with each other.*
2.08. When the universe expanded, more muon pairs came in sight of each other.
2.09. The muon pairs were indistinguishable from each other.
2.10. The muon pairs were unstable and annihilated into photon pairs ($\gamma_\mu\gamma_\mu$).
2.11. The photons lost energy as the universe expanded.
2.12. To counterbalance the energy loss, the muon rest energy, $m_{\mu_0}c^2$, grew.
2.13. Similarly, the virtual tauons' rest energy, $m_{\tau_0}c^2$, grew.
2.14. The masses m_{μ_0} and m_{τ_0} remained constant while c grew.
2.15. The annihilation of the last muon pair forced space to freeze.
2.16. In the process c jumped back to its initial value.
2.17. Conservation of muon rest energy caused an upward jump in m_{μ_0}.
2.18. Similarly, an upward jump in m_{τ_0} occurred.
2.19. The photons materialized into pairs of "frozen" electrons: $\gamma_\mu\gamma_\mu \to \mathrm{e}^+\mathrm{e}^-\ \mathrm{e}^+\mathrm{e}^-$.
2.20. When this happended, the universe contained about 1000 photon pairs.
2.21. The frozen electrons immediately transformed into dynamically interacting particles.
2.22. In the transformation, the electron's charge, spin, and mass were conserved.

Phase 3: the electron generation

3.01. The rematerialized universe contained initially about 2000 electron pairs.
3.02. The spin-$\frac{1}{2}$ electrons ($\mathrm{e}^{\pm}$) are described by QED (that is, spinor QED).
3.03. They interact via virtual photons (γ).
3.04. The spinless muons reappeared in the form of virtual spin-$\frac{1}{2}$ muons ($\mu^{\pm}$).
3.05. The virtual spinless tauons reappeared in the form of virtual spin-$\frac{1}{2}$ tauons ($\tau^{\pm}$).
3.06. The tauon, muon, and electron interacted via the same photon, γ.
3.07. The three species of leptons therefore interacted with each other.
3.08. When the universe expanded, more electron pairs came in sight of each other.
3.09. The electron pairs were indistinguishable from each other.
3.10. The electron pairs were unstable and annihilated into photons: $\mathrm{e}^+\mathrm{e}^- \to \gamma$.
3.11. The electron pairs annihilated synchronously pairwise.*
3.12. The photons lost energy as the universe expanded.
3.13. To counterbalance the energy loss, the electron rest energy, $m_e c^2$, grew.
3.14. Similarly, the virtual muons' and tauons' rest energies grew.
3.15. The lepton masses remained constant while c grew.
3.16. The annihilation of the last electron pairs triggered a transition.*
3.17. One of the last two electron pairs transformed into a proton pair: $\mathrm{e}^+\mathrm{e}^- \to \mathrm{p}\bar{\mathrm{p}}$.
3.18. The transformation proceeded stepwise.
3.19. First, the electrons transformed into "frozen" pions: $\mathrm{e}^+\mathrm{e}^-\ \mathrm{e}^+\mathrm{e}^- \to \pi^+\pi^-\ \pi^+\pi^-$.*
3.20. The particle masses were conserved in the transition.
3.21. This event signaled the end of simplicity.

Phase 4: the present universe

4.01. The present universe contained initially about 2 786 275 000 photons.
4.02. The frozen pions with mass m_e disintegrated into dynamic systems of quarks.*
4.03. This process meant the birth of the strong force.*
4.04. Three families of quarks matched the three generations of leptons.
4.05. Quark and pion masses are dynamically determined.*
4.06. The transformation required an energy of $E_1 = 4(m_\pi - m_e)c^2$.*
4.07. The photons were the only available source of energy.
4.08. The appearance of the strong force did not affect the photon energy.
4.09. Therefore, another means was required to tap the photons for energy.
4.10. The trick was performed by a simultaneously appearing Higgs force.
4.11. The Higgs interaction was mediated by a Higgs boson.
4.12. Like the electromagnetic and strong forces, the Higgs force conserved parity.
4.13. The creation of the Higgs boson caused a decrease in tauon mass.*
4.14. Part of the photons were in the tauon state—forming virtual tauon loops.*
4.15. The virtual tauons' energy loss counterbalanced the increase E_1 in matter energy.
4.16. One of the pion pairs almost instantly annihilated into two photons.
4.17. Pions and photons have negative intrinsic parity (-1).*
4.18. The annihilation process $(\pi^+\pi^- \to \gamma\gamma)$ conserved parity: $(-1)^2 = (-1)^2$.
4.19. Global energy conservation forbade the remaining pion pair's annihilation.
4.20. A switch of parity could inhibit an attempted annihilation: $(+1)(-1) \neq (-1)^2$.
4.21. A forced symmetry breaking turned the Higgs interaction into a "weak interaction."
4.22. This interaction violated parity invariance.
4.23. Its introduction caused one of the pions to switch parity.
4.24. Choosing one of the pions meant choosing between matter and antimatter.
4.25. The choice introduced a "superweak" matter-antimatter asymmetric effect.
4.26. The weak parity-violating force had come to stay.
4.27. Eventually, it caused the second pion to switch parity.*
4.28. Fast annihilation was again allowed: $(+1)^2 = (-1)^2$.
4.29. To avoid annihilation, the pion pair was forced to transform into a proton pair.
4.30. The additional energy needed was $2(m_p - m_\pi)c^2$.
4.31. Creation of three more Higgs bosons provided $3E_1 = 12(m_\pi - m_e)c^2$ of energy.
4.32. This was $0.128E_1$ more energy than the process demanded.*
4.33. The excess energy was restored to the tauons.*
4.34. In all, proton creation consumed $(1 + 3 - 0.128)E_1 = 3.872E_1$ of energy.
4.35. No exotic matter was created.
4.36. Proton-antiproton annihilation would have produced a matter-free universe.
4.37. Therefore, annihilation of the unstable proton pair was forbidden.
4.38. Instead, the antiproton was forced to decay back into an electron.
4.39. This process created stable matter and therefore a stable universe.
4.40. The antiproton decay released $m_pc^2 - m_ec^2 = 937.761$ MeV of energy.
4.41. The energy of the background photons was $2m_ec^2/10.535 = 0.097$ MeV.
4.42. The $n_b = 1$ proton was the first baryon (protons and neutrons are baryons).*
4.43. Thus, the initial photon-baryon number ratio was $n_\gamma/n_b = 2.786 \times 10^9$.
4.44. The total photon energy was about 300 000 times higher than the matter energy.*
4.45. The photons lose energy as the universe expands.
4.46. Similarly, all other fast-moving particles lose energy.
4.47. To balance this energy loss, matter rest energy grows.
4.48. Rest masses remain constant while c grows.

The temperature of the universe

A.01. In its first three phases, the universe was in an indeterminate quantum state.
A.02. No collisions between real particles took place.
A.03. Therefore, temperature (T) was not definable when phase 3 ended.
A.04. The antiproton decay heated the massive particles (electron and proton).
A.05. The energy released in the decay corresponds to $T = 1.09 \times 10^{13}$ K.*
A.06. The energy of the background photons corresponded to $T = 1.126 \times 10^{9}$ K.*

Apparent time paradox

B.01. In our local picture, energy is locally conserved: mc^2 = constant.
B.02. In the local picture, c and the atomic-clock tick, τ, are constant.
B.03. In the global picture, energy is globally conserved: $\mathrm{d}V/\mathrm{d}t$ = constant.
B.04. In the global picture, c and the atomic-clock tick, τ, are changing.
B.05. A trivial redefinition of time may convert a constant c to a changing c.*
B.06. Classically, one would require that the distance $c\tau$ remains invariant.
B.07. Thus, an increase in c would be counterbalanced by a decrease in τ.
B.08. Surprisingly, in the global picture both c and τ grow: $\tau \propto c$.
B.09. In classical physics such a behavior violates logic.
B.10. A given distance cannot both be constant and change with time.
B.11. However, in our actual world, which is a quantum world, there is no conflict.
B.12. This is so, because distance is undefinable in a pointless space.
B.13. Compare with the "spooky action at a distance."*
B.14. In the global picture, the present age of the universe is $t_0 = 1/3H_0 = 5.7$ Gyr.
B.15. In our local picture, it is much older, $t_0 \gg 5.7$ Gyr.
B.16. Therefore, gravity's predicted variation ($\dot{G}/G = -1/t$) is difficult to observe.

Black holes

C.01. G is inversely proportional to the age t of the universe.*
C.02. Therefore, gravity was initially very strong.
C.03. Consequently, black holes were abundantly produced in the young universe.
C.04. First, seeds of black holes formed from matter (baryons and electrons).
C.05. In this process, the photon-baryon number ratio (n_γ/n_b) grew.*
C.06. Fast-moving photons quickly hit black holes once these existed in abundance.
C.07. Slow-moving massive particles were captured at a comparatively slow rate.
C.08. Therefore, n_γ/n_b began to decrease.
C.09. Part of the black holes merged into giant black holes that can still be observed.
C.10. Most black holes remained comparatively small.
C.11. Today, Jupiter-mass or smaller black holes contain the bulk of dark matter.*
C.12. Most of the original photons were quickly captured by the black holes.
C.13. The remaining free photons lost energy because of the expansion.
C.14. Soon, the decreasing G caused the lightest black holes to evaporate.
C.15. The evaporating black holes released bursts of high-energy photons.*
C.16. Effectively, the light black holes functioned as temporary photon stores.
C.17. While stored in black holes, the photons were unaffected by the expansion.
C.18. Thus, light black holes temporarily saved photons from losing energy.
C.19. They delayed the transfer of energy from radiation to matter.
C.20. Thereby they delayed the growth of c and the atomic-clock tick τ.
C.21. They delayed the cooling of the photons.
C.22. Thus, the universe was old when the photon temperature reached $T_d \approx 3000$ K.

C.23. T_d is the "decoupling" temperature of the photons (or microwaves) from matter.
C.24. At the time of decoupling, large structures had already formed.
C.25. Large-scale fluctuations in the cosmic microwave background (CMB) had arisen.

The apparently accelerating universe
D.01. Because of the apparent time paradox, no decrease in G is observed.
D.02. Because of the apparent time paradox, no decrease in H is observed.
D.03. A constant H implies acceleration.
D.04. This is evident from the definition of H: $\mathrm{d}r/\mathrm{d}t = Hr$.
D.05. Therefore, the universe appears to be accelerating.
D.06. In the past, gravity was stronger than today.
D.07. Consequently, distant stars shine slightly brighter than nearby stars.
D.08. This effect strengthens the illusion of an accelerating universe.

The fundamental unit of time
E.01. The mass of the universe is $M = c^3/HG$. Today, $M_0 = 2.20 \times 10^{53}$ kg.*
E.02. Originally, the photon pairs of phase 4 had the energy $4m_e c^2/10.535$.
E.03. Division of $M_0 c^2$ by this energy yields $N_0 = 6.36 \times 10^{83}$.*
E.04. Thus, $t_0 = \sqrt{N_0}\, t_c = 0.80 \times 10^{42}\, t_c$.
E.05. In the global picture, the age of the universe is $t_0 = 1/3H_0 = 1.81 \times 10^{15}$ s.*
E.06. Equating the two expressions for t_0 yields $t_c = 2.3 \times 10^{-27}$ s.
E.07. In this calculation, the increase in c has been ignored.
E.08. A more realistic estimate of the initial age of the universe is $t_c = 10^{-30}$ s.*
E.09. Also this value is probably too high. A better value may be $t_c \approx 10^{-31}$ s.*
E.10. Measured in our familiar "local seconds," $t_c \approx 10^{-19}$ s.*

Planck time
F.01. Electric charge comes in multiples of e (the charge of the electron).
F.02. Similarly, action comes in multiples of $\frac{1}{2}\hbar$ (the spin of the electron).*
F.03. In analogy, physicists predict the existence of a "Planck time," t_P.
F.04. The Planck time appears in quantum gravity theories.*
F.05. $N = (t/t_c - 1)^2$ suggests that t is only defined for integral numbers N.
F.06. It might mean that $t_P/t_c = \sqrt{N+1} - \sqrt{N} = 1/2\sqrt{N}$.*
F.07. If so, both G and t_P decrease with time (with increasing $\sqrt{N}$).
F.08. Today, t_P may be of the order 10^{-76} s.*

The four forces
G.01. There were no forces present in the newborn universe.*
G.02. There were no strong or weak forces in its first three phases.*
G.03. There were no gravitational effects in its first three phases.*
G.04. Gravity provides the long-range repulsive force acting in the universe.*
G.05. There is no fifth force.*
G.06. The apparent acceleration is a measure of $\dot{G}$.*
G.07. Via $\dot{H}/H = \dot{G}/G$ it indicates the value of $\dot{H}$.

The quantum universe
H.01. The absence of "molecules" in a "fluid" means the absence of a coordinate system.
H.02. In such a perfectly smooth (pointless) "fluid," position is a meaningless concept.
H.03. The undefinability of position implies quantum indeterminacy.*

H.04. The “frozen” space at the beginning of phases 2 and 3 was perfectly smooth.

The three lepton generations and α

I.01. The theory explains why there are three lepton generations (τ, μ, and e).
I.02. It predicts for the muon-electron mass ratio:*
205.759 223 = theoretical value obtained from the momentum equation. Eqs. (4.13), (7.13)
206.769 039 = value including an early scalar-QED contribution (+1.009 816). Eq. (8.2)
206.768 209 = value including a four-Higgs correction (-0.000 830). Page 39
206.768 283 = value including a positive electroweak correction (+0.000 074). Eq. (E.13)
206.768 284(6) is the measured value (for reference). Ref. [15]
I.03. It yields estimates for the tauon-muon and muon-electron mass ratios.*
I.04. Precise values for the lepton mass ratios and α may be computable.*

G.2 Level 2. Explanatory details

General

0.01. In its broad sense, the principle of maximum simplicity implies that physics can be logically understood. In other words, it implies that physics may be described in mathematical terms. On a more detailed level, the principle implies symmetry and beauty, Occam's razor, the applicability of common sense, etc. Common sense, in turn, advices us to always test the simplest hypothesis first.

0.02. Assumption (G.1) is suggested by a stationary solution (a solution not involving time, t) to the momentum equation. Assumption (G.2), implying global energy conservation, forces cosmology to be built on the same solid pillar on which other branches of physics securely rest.

Phase 1

1.00. There are a couple of good reasons why one should use the word "tauon" instead of "τ" or "τ particle." One reason is that an elementary particle should have a name of its own. Compare with the electron and the muon, which are seldom referred to as "the e" or "the μ." Another reason is that the terms "τ lepton" and "τ particle" are ambiguous, because they are applicable both to the heavy charged tauon (τ^- with antiparticle τ^+) and to the light (nearly massless) neutral tauon neutrino (ν_τ with antiparticle $\bar{\nu}_\tau$).

1.02. The computer simulation of the early evolution of the universe makes sense only provided that the universe is initially finite (has a nonzero size) and is maximally simple. It is practical to measure the universe's age t and radius r in units of their values (t_c and r_c) at the instant of creation.

1.03. Our observations undeniably demonstrate that a material universe is possible. Therefore, the probability for a transition from literally nothing to a material universe cannot be exactly zero. Consequently, a transition must occur. Since no time exists in literally nothing, the spontaneous symmetry breaking must occur at the beginning of time, $t = t_c$ (or $t = 1$ when t is measured in units of t_c).

1.06. Supposedly, the primordial particle (D) is the massive, neutral, and spinless particle described by Paul Dirac's "new equation" (proposed in December 1970 and published in 1971 [9]). The particle has an interesting property:

Dirac in Ref. [9]: "One may try the usual way of introducing an electromagnetic field .... One finds that the equations are no longer consistent except in the special case ..., which means no field."

Biedenharn, Han, and van Dam in Ref. [10]: "Most remarkable of all is the fact that the conserved particle current cannot interact with the electromagnetic field without destroying the consistency of the defining structure."

Initially, the universe did not know massless particles (photons or radiation). No means of communication existed. The velocity of light (c) was not defined, and the size of the universe was not definable (no "radius" ct is definable if c does not exist). Since, for a sizeless universe, "expansion of the universe" cannot be defined, the D particle could not multiply. It was foredoomed to spend its life in splendid isolation.

1.07. Dirac's "new equation" shows that a massive one-particle universe without forces is conceivable. The principle of maximum simplicity (with Occam's razor as one of its manifestations), in turn, requires that the number of forces acting in the newborn universe should be as small as possible. Therefore, a single D particle formed the initial universe.

1.12. The simulation experiment suggests that the decay process started at $t = 1$ and continued uninterrupted until the last of about 86 particle pairs had annihilated. However, it also suggests that $N = (t - 1)^2$, implying that the multiplication of particles in the universe began at age $t = 2$. If the conclusion is correct, it means that between $t = 1$ and $t = 2$, the D particle

was alone in its universe and partly decayed.
1.13. Like Schrödinger's cat, the D particle was both dead and alive. The radiative remains of the dead D shrank and lost weight as the photon wavelength increased, and at the same time the live D prospered and grew fatter.
1.14. Ref. [10]: Dirac's equation "constitutes an explicit and precise solution to the ... relativistic harmonic oscillator" that "is a realization on two bosons" with a conserved particle current that "cannot interact with the electromagnetic field without destroying the consistency of the defining structure."

Thus, Dirac's equation suggests that the D particle may transform into a pair of spinless tauons ($\mathrm{D} \to \tau_0^+\tau_0^-$) with the same probability that it may decay into a pair of tauon photons ($\mathrm{D} \to \gamma_\tau\gamma_\tau$).

Supposedly, it was the existence of the photon (γ_τ) together with the universe's growing (and now well-defined) size that forced the live D's final transformation into a tauon pair at $t = 2$. Also, see point I.04 below.
1.19. The theory of scalar QED, or the quantum electrodynamics of spinless bosons (bosons are particles with integral spin), is presented for instance in W. Greiner, J. Reinhardt, Quantum Electrodynamics, 2nd edition, Springer, Berlin, 1996, pages 383–398. On page 383, the authors note: "In contrast to the case of spinor electrodynamics, however, the importance of this theory is limited, because there are no elementary charged scalar particles in nature."
1.21. This is a quantum effect. See Appendix E.4 on page 36. Note that an electron can emit a photon and later capture it. During its brief existence the ("virtual") photon may disintegrate into a pair of electrons, which again recombine to form a photon. Thus, the electron has the ability to make copies of itself. The same is true for muons and tauons, and was true for their spinless predecessors as well. Unlike the spinless tauon, Dirac's particle was unable to emit and capture photons and to reproduce itself.

Because of the ability of the spinless muon and tauon to generate virtual copies of themselves, they left to future generations their portraits in the form of (today spinning) virtual muons and tauons. Dirac's particle was not able to leave behind any similar image of itself.
1.26. An increase in particle rest energy might be caused by either an increase in particle mass or an increase in the speed of light (c). Computer simulation rules out the first alternative. Thus, c increases with time.
1.30. The classical momentum equation (A.1) connects a fluid's velocity ($\boldsymbol{v}$) and pressure (p) to its density (ρ). After the pressure p has been eliminated, the momentum equation reads

$$\frac{\partial \boldsymbol{v}}{\partial t} - \boldsymbol{v} \times (\nabla \times \boldsymbol{v}) + \frac{1}{2} v_0^2 \nabla \left(\left(\frac{\boldsymbol{v}}{v_0} \right)^2 + f \left(\frac{\rho}{\rho_0} \right)^{2/f} \right) = 0. \tag{G.3}$$

In the rematerializations producing massive leptons from radiation, the space of the universe "freezes" and all time-dependent processes come to a halt. It means that the newborn massive particle should be described by the solution (see Appendix A.1 on page 29),

$$\rho = \rho_0 \left(1 - \frac{1}{f} \frac{\boldsymbol{v}^2}{v_0^2} \right)^{f/2}, \tag{G.4}$$

to the stationary ($\partial \boldsymbol{v}/\partial t = 0$) form of Eq. (G.3). From Eq. (G.4), two particle equations may be constructed. One of them,

$$\rho = \rho_0 \left(1 - \frac{v^2}{v_0^2} \right)^{1/2} \left(1 - \frac{1}{3} \frac{w^2}{w_0^2} \right)^{3/2}, \tag{G.5}$$

describes a spinless particle (a spin-0 muon or a spin-0 tauon). The other,

$$\rho = \rho_0 \left(1 - \frac{v^2}{v_0^2}\right)^{1/2} \left(1 - \frac{1}{2}\frac{u^2}{u_0^2}\right) \left(1 - \frac{1}{3}\frac{w^2}{w_0^2}\right)^{3/2}, \tag{G.6}$$

describes a spin-$\frac{1}{2}$ particle (electron, muon, or tauon). The two particle equations demonstrate that charge, spin, and expansion (with accompanying gravity) are intimately connected via the degrees-of-freedom parameter f.

The two equations provide instantaneous "static" pictures of the rematerialized particles. The static picture is immediately destroyed as dynamic interactions resume.

The classical momentum equation (G.3) cannot reasonably describe dynamically interacting elementary particles. However, an unknown momentum equation may provide the general equation for space—an equation in which time is quantized. And it may well be that the classical equation and the quantum equation have a common stationary solution—Eq. (G.4).

Phase 2

2.04. The mass ratio $m_{\tau_0}/m_{\mu_0} \approx 16.919$ recorded information about the energy gain of the spinless tauon in phase 1. Because of electroweak corrections, today's tauon-muon mass ratio, m_τ/m_μ, is slightly lower (about 16.818).

2.07. The fact that spinless muons could not generate virtual tauons explains the simplicity of the coefficients in the series expansion (8.2).

Phase 3

3.11. The electron pairs originally materialized in pairs from pairs of entangled photons: $\gamma_\mu\gamma_\mu \to \mathrm{e}^+\mathrm{e}^-\ \mathrm{e}^+\mathrm{e}^-$. Therefore, the electron pairs were pairwise entangled, and conservation of the system's energy E and momentum $\boldsymbol{p}$ (which in particle physics are the components of a four vector—the "four momentum" p) caused the annihilation of one pair to trigger the annihilation of the second pair.

In other words, conservation of the system's four momentum inhibited one electron pair from annihilating into a single photon while the other pair retained its mass. Annihilation into three photons was allowed, but this "orthopositronium decay" is a comparatively very slow process.

3.16. This time, the annihilation into photons was never brought to an end. If it had been, the indistinguishability of the photons would have caused all photon pairs to rematerialize, thus creating a fourth "lepton" species. This particle would have been lighter than the electron. Its nonexistence may indicate that such a particle is not physically conceivable.

3.19. Supposedly, the electron pairs initially transformed into frozen pion pairs with the frozen pion described by another stationary solution to Eq. (G.3). This solution should describe the charged pion as a kind of electron with its spin cylinder bent into a ring (like a smoke ring). Compare with Georg Joos in Ref. [24], page 206:

"The remarkable properties of circular vortex rings—their indestructability, indivisibility, &c.—led Sir W. Thomson to formulate the ingenious theory that atoms are vortices in the ether. This idea was developed by Sir J. J. Thomson in an Adams Prize Essay (1883). The matter is only of historical interest now."

Also, note that the idea of a primeval matter conceived as revolving in a vortex can be traced back to Anaximander (about 611–547 B.C.) [39].

Phase 4

4.02. Dynamically, the charged pions are formed from up and down quarks (π^+ from $\mathrm{u\bar{d}}$ and π^- from $\mathrm{d\bar{u}}$), which suggests that quarks are closed spinning strings.

4.03. The strong force is described by quantum chromodynamics (QCD). It acts between quarks via the exchange of gluons. Thus, the birth of the pion—or rather, the birth of its constituent particles, the quarks—meant the birth of the strong force.
4.05. Assuming that the electron transformed into a pion that disintegrated into an up and a down quark, $m_u + m_d = m_{\pi^\pm} = m_e = 0.511$ MeV/c^2 should hold initially. These "frozen" masses may be compared with the actual pion mass, $m_{\pi^\pm} = 139.57$ MeV/c^2, the "current" quark masses, $m_u = 4$ MeV/c^2 and $m_d = 8$ MeV/c^2 (deduced from current algebra), and with the "constituent quark masses," in terms of which $2m_u + m_d \approx m_p = 938.3$ MeV/c^2. See Ref. [20], pages 2 and 13.
4.06. For details, see Appendix E.8, page 39.
4.13. A purely electroweak and rather trivial standard-model calculation demonstrates that the mass correction is negative and that the tauon contribution dominates. See Appendix C.
4.14. See Appendix E.7 on page 38.
4.17. Elementary particles have intrinsic parity. Thus, a negative parity (-1) is associated with the particles e^+, μ^+, τ^+, π^+, π^-, π^0, and γ, while a positive parity ($+1$) is associated with e^-, μ^-, τ^-, p, $\bar{\text{p}}$, n, and $\bar{\text{n}}$ [36].
4.27. Two effects introduced a slight asymmetry between the two parity-switching events. Particle rest energy ($E \propto c^2$) grew by one percent ($2.872/2.844 = 1.010$, see page 41) and particle lifetimes ($\tau \propto c$) increased by 0.5 percent.
4.32. Using $m_e = 0.511$ MeV/c^2, $m_\pi = 139.570$ MeV/c^2, and $m_p = 938.272$ MeV/c^2 [15], one obtains $E_1 = 4(m_\pi - m_e)c^2 = 556.236$ MeV, and the excess energy is $3E_1 - 2(m_p - m_\pi)c^2 = (14m_\pi - 2m_p - 12m_e)c^2 = 71.304$ MeV $= 0.1282E_1$. This result holds in the local picture where particle rest energies are constant. The dynamic picture shows a slightly different result. See page 41.
4.33. Presumably, the energy left unused by the proton pair was returned to the tauons via the appearance of neutrino rest masses and a weak flavor-changing mechanism.
4.42. Baryons are composed of three quarks (antibaryons of three antiquarks).
4.44. With $n_\gamma = 2.786 \times 10^9$ photons of energy $E_\gamma = 2m_ec^2/10.535$ and $n_b = 1$ electron-proton pair of energy $E_m = 1837m_ec^2$, one obtains the ratio $n_\gamma E_\gamma / n_b E_m = 288\,000$.

The temperature of the universe
A.05. The Penguin Dictionary of Physics [40]: Boltzmann's formula, $n = n_0 \exp(-E/kT)$, shows the number of particles (n) having an energy (E) in a system of particles in thermal equilibrium.

Thus, $E = kT$ relates energy E to thermodynamic temperature T. With $m_p - m_e = 937.76$ MeV/c^2 and the Boltzmann constant $k = 8.617 \times 10^{-5}$ eV K^{-1} (Ref. [15], page 91), one obtains $T = 1.09 \times 10^{13}$ K.
A.06. With $m_e = 0.511$ MeV/c^2 and $k = 8.617 \times 10^{-5}$ eV K^{-1}, one obtains $T = 2m_ec^2/10.535k = 1.126 \times 10^9$ K.

Apparent time paradox
B.05. João Magueijo in Ref. [13], page 198: "After all, you could also regauge your clocks so that the speed of light becomes variable even in circumstances in which it is normally taken to be a constant. A simple way to do this would be to stupidly take a grandfather clock on a space mission. On the Moon, a pendulum clock ticks more slowly (since gravity is weaker), and if you insist that grandfather clocks are the correct way to keep time, then naturally you would find that the speed of light on the Moon is much higher."
B.13. The "spooky action at a distance," or the Einstein–Podolsky–Rosen (EPR) paradox (see Appendix D), signifies that the measurement of the state of one photon in a pair of "entan-

gled"photons instantaneously affects the state of the other photon—even if the two photons are at very large distances from each other. The effect, finding practical use in quantum cryptography, has been experimentally verified for distances of many kilometers. The obvious conclusion is that macroscopically well-defined distances are undefinable in the microscopic quantum world.

Black holes

C.01. From Eq. (7.24), i.e., $\dot{G}/G = -1/t$ or $\mathrm{d}G/G = -\mathrm{d}t/t$, it follows that $\log G = -\log t + \log \mathrm{constant} = \log(\mathrm{constant}/t)$. That is, $G \propto 1/t$.

C.05. The baryon number, B, is conserved in particle reactions (protons and neutrons have $B = 1$, while their antiparticles have $B = -1$; quarks have $B = \frac{1}{3}$, antiquarks $B = -\frac{1}{3}$). However, when matter disappears into black holes, B is not conserved. Thus, an evaporating black hole, which has originally swallowed baryonic (and leptonic) matter, spews out its energy content (its mass) in the form of radiation and matter-antimatter neutral particle pairs.

C.11. See Section 10, last paragraph.

C.15. A Dictionary of Science [41]: Hawking process: "However, for a 'mini' black hole, such as might have been formed in the early universe, with a mass of order 10^{12} kg (and a radius of order 10^{-15} m), the temperature would be of order 10^{11} K and the hole would radiate copiously (at a rate of about 6×10^{9} W) a flux of gamma rays, neutrinos, and electron-positron pairs."

Ref. [20], page 447: Black holes of mass M radiate as black bodies with temperature proportional to $1/GM$.

When the formation of black holes had passed its peak and gravity (maybe still 10^{20} times stronger than today) grew weaker, first the lightest black holes (maybe weighing a few μg), and later successively heavier ones, rapidly evaporated, producing bursts of photons of high energy (partly via electron-positron pairs that subsequently annihilated into photons). Because of this release of energetic radiation, the energy of the background photons decreased much more slowly than it would have done in the absence of black holes. The process explains why c and τ have continued to appreciably change during a long period of time, with the result that today the local age of the universe is much higher than its global age. Which, in turn, explains why thus far no change in gravity ($\dot{G}/G = -1/t$) has been experimentally detected.

A numerical exercise may illustrate the effect of black holes on the evolution of the photon-baryon number ratio. Consider 1000 baryons (neutrons, or protons plus electrons) and assume that there were originally 2786 G (with G—for giga—denoting 10^{9}) photons per 1000 baryons. Over time, the numbers (which only are intended as qualitative suggestions to indicate the trend) may have changed in the following manner:

n_γ	n_b	n_γ/n_b	
2786 G	1000	2.786 G	Originally
2700 G	900	3.0 G	After most black-hole seeds had formed
100 G	100	1.0 G	Before light black holes began to evaporate
129 G	85	1.5 G	After all light black holes had evaporated
128 G	80	1.6 G	Today

The fundamental unit of time

E.01. For the mass $M = \frac{4}{3}\pi\rho_u R^3$ of the universe, one obtains, using Eqs. (5.2) and (5.15), the expression

$$M = c^3/HG. \tag{G.7}$$

With $c = 3 \times 10^{8}$ m/s and $G = 6.674 \times 10^{-11}$ m^3/kg s^2 (Ref. [15], page 91), this gives $M_0 = 2.20 \times 10^{53}$ kg for the present mass of the universe. It corresponds to the mass of

1.31×10^{80} electron-proton pairs.
E.03. At the beginning of phase 4, the number of photon pairs was $N = (t/t_c)^2$ (for $t \gg t_c$). Today, with most of the original photons trapped in black holes, N may be regarded as a kind of "photon-pair equivalent."
E.05. The value follows from Eqs. (7.17) and (7.24), with 1 yr $= 3.156 \times 10^7$ s (Ref. [15], page 92), when today's values of the global or cosmic second and the local or atomic second (defined in terms of atomic-clock ticks and initially much shorter than the cosmic second) are taken to be the same.
E.08. In phase 3, c increased by a factor of $\sqrt{10.535} = 3.25$. Without interference from black holes, c would until today have further increased by a factor of 494.3 in phase 4 (see Appendix F). When these two factors are considered, $t_c = 1.4 \times 10^{-30}$ s.
E.09. Most of the energy of the original photons was transferred to the massive particles (protons, electrons, and neutrons) before black holes began to form. Thus, most of the mentioned increase in c happened early. Later, black holes built up from massive baryons (and low-energy photons). Their subsequent evaporation meant that matter was converted into high-energy radiation, which, in turn, gave over its energy to matter as the universe continued its expansion. As a result, t_c should be less than 1.4×10^{-30} s, maybe of the order 10^{-31} s.
E.10. In our local picture (which shows a universe that is much older than $1/3H_0$), particle lifetimes and t_c have not changed, and t_c is directly related to present-day annihilation lifetimes. See page 41).

Planck time
F.02. It is not $\frac{1}{2}\hbar$, but the Planck constant, $h = 2\pi\hbar$, that is named Planck's quantum of action. This is because Max Planck discovered that the photon's energy is quantized according to $E_\gamma = h\nu$. If one replaces the frequency (ν) by the angular frequency, $\omega = 2\pi\nu$, the formula reads $E_\gamma = \hbar\omega$. Also, $\hbar$ is the quantum of action that appears in quantum mechanical calculations of orbital angular momenta, while the still smaller quantum of action, $\frac{1}{2}\hbar$, appears in calculations involving spin. This smallest quantum of action also appears in the uncertainty principle discovered by Werner Heisenberg ($\Delta p_x \times \Delta x \geq \frac{1}{2}\hbar$ and $\Delta E \times \Delta t \geq \frac{1}{2}\hbar$).

Also, note that the photon has spin $\hbar$ and that it may (or may not) have an orbital angular momentum $\hbar$, which—when it exists—counterbalances the spin (never doubles it), giving the photon zero total angular momentum.
F.04. João Magueijo in Ref. [13], page 234: "Quantizing gravity therefore means quantizing space and time. There should be indivisible, smallest amounts of length and duration: fixed quanta making up any period or separation. Such quanta are called the Planck length (L_P) and Planck time (t_P), and no one really knows what they are except that they must be minute."
F.06. $t_P = \sqrt{N+1} - \sqrt{N} = \sqrt{N}((1 + 1/N)^{1/2} - 1) = \sqrt{N}(1/2N + \cdots) = 1/2\sqrt{N}$.
F.08. Assuming $N_0 = 10^{90}$ and $t_c = 10^{-31}$ s, $t_P = 0.5 \times 10^{-76}$ s.

The four forces
G.01. The principle of maximum simplicity suggests that the newborn universe was nothing but matter in its simplest possible form: a massive D particle incapable of interaction and therefore living single till it decayed.
G.02. In the first and second phases, the interactions were described by scalar QED, and in the third phase by (spinor) QED.
G.03. Gravitation is a force acting on macroscopic objects, between which distances are well-defined. As long as particles only appeared entangled in pairs, distance was not definable, and no gravitational effects existed.
G.04. The gravitational force is attractive over all distances where its effect may be observed.

However, it turns repulsive when distances approach the radius of the universe. See Eq. (5.9) and Fig. 5.1 on page 14.

G.05. Because of the time paradox, the deceleration is much slower than expected from a naive interpretation of Dirac's large-number hypothesis. When the predicted deceleration was not observed, physicists explained it as an effect caused by a repulsive fifth force and revived Einstein's cosmological constant (Λ).

However, the declining force of gravity (G decreasing very slowly over time) makes distant stars look slightly brighter than nearby stars, which creates the illusion of acceleration. The effect forced physicists to replace the constant cosmological repulsion by a new and mysterious force (referred to as dark energy or quintessence), which was allowed to vary over time in such a way that it could be adapted to explain any observed change in the universe's expansion rate.

G.06. That no change in G has been directly observed means that H, too, changes at an imperceptibly slow rate and should appear to be constant. Therefore, what is interpreted as a measure of acceleration in inflationary cosmology is in reality a measure of $\dot{G}$. A detailed computer simulation should yield an unambiguous prediction for $\dot{G}$ matching the value derived from observations of how type Ia supernovae (astronomy's "standard candles") vary in brightness with distance.

The quantum universe

H.03. See Appendix D.

The three lepton generations and α

I.02. See Appendix E.8. For a more precise calculation, see Simulation.for.

I.03. This is indirectly demonstrated by the simulation experiment discussed in Section 10 and Appendix F.

I.04. See discussion following Eq. (F.11) on page 47. The methods described in Appendix F cannot yield unambiguous results. Here follows an example of a systematic approach yielding an unambiguous and precise—but incorrect—value for the fine-structure constant α.

First, calculate the time interval Δt between two annihilation events using $\Delta t = \tau_N/N$. Then, divide Δt in 10 000 (say) time increments, dt (d$t = \Delta t/10\,000$), and build a new Δt by adding the increment dt 10 000 times to the age t, each time multiplying the original dt by $c(t)/c(t_N)$ to account for the increase in lifetime τ that accompanies the increase in velocity of light, c.

Using this method to calculate the effective Δt, run the simulation program to find the values of N_1 and N_2 that make $t_f - \sqrt{N_f}$ lie as close as possible to, but still below, 1. The results are 16.579 (vs. expected 16.919) and 136.426 (vs. expected 151.136) for the original mass ratios. The latter value corresponds to $1/\alpha = 136.426 \times 2B^2/B_0 = 123.698$ (vs. measured 137.036).

Assuming that the universe is in a physical state only for descrete values of its age t when N in $t = 1 + \sqrt{N}$ is an integer number (compare with the discussion of Planck time), the final annihilations are slightly deferred, and the results are 16.585 and 136.417 for the original mass ratios, the latter value corresponding to $1/\alpha = 123.690$.

Even if α may be uniquely determined and its value found to agree with observation, it will not disprove the "anthropic principle"—the idea that our universe is specially designed to foster physicists able to observe it. Some other (strong or electroweak) parameters may still be determined by chance. Therefore, as long as these parameters haven't been uniquely derived from basic principles, one cannot dismiss the idea of a multiverse in which the majority of an infinite number of universes are unsuitable for life.

FORTRAN code used to obtain the previous results:

```
      B          = 0.6660017315
      B0         = 0.9783964019
      taui       = 1
      invals     = 10000
c                                           Input to phase 1:
      Nf         = 85
      t          = 1
c                                           Do for phase 1 and phase 2:
      do 150     iphase = 1,2
      N          = Nf
      Em         = Nf
      Er         = 0
      Em1        = 1
c                                           Beginning of loop.
110   continue
c                                           Calculate Delta = time to next pair
c                                           annihilation. Note that Em1 = c**2.
      tauN       = taui*sqrt(Em1)
      Delta      = tauN/N
      call       itere (invals, Er, Em, N, t, tauN, Delta)
      t          = t + Delta
c                                           Photon wavelength proportional to r
c                                           proportional to t**(1/3), that is,
c                                           Er proportional to t**(-1/3).
      DelEr      = Er*(1 - ((t - Delta)/t)**(1/3.0))
c                                           Em + Er = Nf conserved:
      Er         = Er - DelEr
      Em         = Em + DelEr
c                                           Rest energy of one massive pair:
      Em1        = Em/N
c                                           Annihilation. If final, jump.
      if         (N.eq.1) go to 130
      N          = N - 1
      Em         = Em - Em1
      Er         = Er + Em1
      go to 110
c                                           End of phase.
130   continue
c                                           Assume annihilation at 1 + sqrt(Nf):
c     tf         = 1 + sqrt(Nf*1.0)
c     if         (t.gt.tf) go to 140
c     DelEr      = Er*(1 - (t/tf)**(1/3.0))
c     Er         = Er - DelEr
c     Em         = Em + DelEr
c     t          = tf
140   write      (*,*) 'Em =', Em
```

```
c                                                  Input to phase 2:
       Nf           = 948
c
150    continue
       write        (*,*) '1/alpha =', Em*2*B**2/B0
       stop
       end
c
c                   Calculate effective Delta.
c
       subroutine   itere (invals, Er, Em, N, tN, tauN, Delta)
c
c      Step 1.      Delta = tauN/N. Initial Delta value obtained at time = tN.
c      Step 2.      dt = Delta/10000 (example with invals = 10000).
c      Step 3.      Do 10000 times t = t + dt*c/cN with c = c(t) and cN = c(tN).
c      Step 4.      Delta = t - tN = final Delta.
c
       Em1          = Em/N
       cN           = sqrt(Em1)
       Delta        = tauN/N
       t            = tN
       dt           = Delta/invals
       do 110       i = 1,invals
       DelEr        = Er*(1 - (tN/t)**(1/3.0))
       Em1          = (Em + DelEr)/N
       c            = sqrt(Em1)
110    t            = t + dt*c/cN
       Delta        = t - tN
       return
       end
```

G.3 Conservation of energy and momentum in physics

Classical physics is based on two conservation principles: conservation of energy and conservation of momentum. In relativistic physics, they are one single principle: conservation of four momentum.

In classical physics, three-component vectors are used to specify coordinates. Thus, the vector $\boldsymbol{x} = (x_1, x_2, x_3)$ specifies position in a three-dimensional rectangular coordinate system with axes x_1, x_2, and x_3 (or x, y, and z). Correspondingly, the vector $\boldsymbol{p} = (p_1, p_2, p_3)$ specifies magnitude and direction of momentum.

In relativistic physics, a four vector $x = (x^0, x^1, x^2, x^3) = (ct, \boldsymbol{x})$ may similarly be used to specify a spacetime coordinate, and $p = (p^0, p^1, p^2, p^3) = (E/c, \boldsymbol{p})$ may specify four momentum. The velocity of light, c, is commonly set equal to 1, which simplifies the notation somewhat: $x = (t, \boldsymbol{x})$ and $p = (E, \boldsymbol{p})$. (In actual calculations, there is an additional distinction between vectors with upper indices and vectors with lower indices.)

Conservation of four momentum means that each of the four components is separately conserved. QED provides a good example of the importance of conservation of four momentum—much of its mathematics consists of manipulating various expressions involving four momentum.

Conservation laws explain the universe

Two discoveries led up to the present cosmological theory that makes detailed testable predictions.

- Conservation of momentum determines the expansion of the universe and explains gravity.
- Conservation of energy caused the formation of three lepton generations. Then, it forced the creation of the proton and the Higgs bosons. This process led to a stable universe with matter dominating over antimatter.

The importance of energy and momentum conservation has long been recognized in physics. Why then haven't the recent discoveries been made earlier?

The main reason seems to be the fact that energy is not conserved in general relativity (GR) in an expanding universe. The belief in GR is so firm that physicists haven't thought about checking the consequences for cosmology (and for GR) if global energy conservation is assumed in spite of what GR suggests.

When applying energy conservation to particle physics, two different pictures emerge—both equally true.

- In the local picture, energy is locally conserved. For instance, a particle's rest energy, mc^2, doesn't change with time. In the local picture, energy is not globally conserved.
- In the global picture, the energy in a volume, V, coexpanding with the universe is conserved. In this picture, energy is not locally conserved.

In our local—standard—picture, we assume that particle lifetimes (τ) and c do not change over time. In fact, we take the unit of time to be the tick of an atomic clock, and we define c to be constant.

However, in the global picture, it turns out that c must grow with time for the energy in the volume V to remain constant. This is because photons lose energy due to their redshift caused by expansion, and this energy loss can only be compensated for by an increase in the rest energy mc^2 of massive particles (c grows, m being constant).

In classical physics, a growing c presents no problem. It is enough to redefine the unit of time (decoupling it from τ) in such a way that the distance $r = c\tau$ remains invariant in the two pictures. Which it may do, if τ decreases as c grows.

Here, however, comes a surprise. In the global picture, a particle's lifetimes does not decrease as $1/c$. Instead, it grows so that $\tau \propto c$.

In classical physics this is an impossible result. A distance $r = c\tau$ cannot both be constant in time and increase with time. So, how can the result be explained?

To understand this apparent paradox, one must return to the principle of conservation of momentum. When applied to a fluid, the principle takes the form of the "momentum equation," which connects a fluid's velocity ($\boldsymbol{v}$) and pressure (p) to its density (ρ). Now, the momentum equation may be written in a form, where p no longer appears. Assuming that it may be applied to space, the pressureless momentum equation implies position undefinability, because absence of pressure implies absence of molecules and, thereby, absence of coordinate points.

And if position cannot be defined, so cannot distance. In other words, the momentum equation implies that distance (r) is an undefinable concept in empty space.

Now, this result shouldn't have come as a surprise. Einstein's famous "spooky action at a distance" demonstrated long ago that distance is undefinable in the quantum world. What is surprising, is that its consequences for global energy conservation hasn't been understood before.

Conservation laws rule the world

- Local conservation of energy governs physical and chemical processes. In addition, it keeps the rest energy (mc^2) of particles constant over time.
- Global conservation of energy keeps the total energy constant over time in a volume coexpanding with the universe.
- Conservation of momentum, when applied to space, implies position undefinability (or quantum indeterminacy—exemplified by the "spooky action at a distance"), thereby reconciling the principles of global and local energy conservation, which in classical physics are mutually exclusive.

The conservation laws provide constraints, which make the world predictable and help to integrate cosmology with particle physics.

Thus, in the early universe, global conservation of energy caused the formation of three generations of leptons, and controlled the creation of the proton and the Higgs boson along with their strong and weak forces.

The momentum equation determines the expansion of the universe and explains the gravitational force.

According to our local picture of the world, energy is not conserved in general relativity (GR) in an expanding universe. However, in the global picture of the universe, conservation of energy must hold in theories for quantum gravity—GR's generalization.

H Historical note

The idea of matter originating from eternal motion—matter being vortices or whirls in a kind of "perfect fluid," "ether," or "primeval matter"—is very old. See discussion of point 3.19 on page 59.

By observing the behavior of spinning tennis balls, one may conclude that two stationary spinning balls on a table should repel each other if they spin in the same direction, and attract each other if they have opposite spin directions. In analogy with the tennis ball, I imagined that the charge of an electron is a kind of spherically symmetric rotation with velocity w that generates the particle's energy and causes the electrostatic force between (positively or negatively charged) electrons. Similarly, I assumed that an ordinary cylindrically symmetric rotation with velocity u pictures the electron's spin.

Clearly, if elementary particles were whirls in a sort of fluid, this "fluid" had to be simpler than the physical fluids we know, and could not conceivably possess molecules, heat, or pressure (p). Therefore, p had to be eliminated from the momentum equation (A.1), which connects a fluid's density, ρ, to its pressure, p, and velocity, v. Thus, substitution of $v_0^2\,\nabla\rho$ for ∇p in Eq. (A.3) led to the density function (May 1964)

$$\rho = \rho_0 \exp\left(-\frac{1}{2}\frac{w^2}{w_0^2} - \frac{1}{2}\frac{u^2}{u_0^2}\right), \quad w = \pm w_0 r_0^2/r^2, \quad u = \pm u_0 r_0/r\sin\theta. \tag{H.1}$$

Mathematical investigation of the function demonstrated that it causes a force similar to the electrostatic force between two electrons. Fig. H.1 shows that the density, ρ, of the imagined fluid goes to zero when the particle's radius $r \to 0$, so that its energy $E = \frac{1}{2}\int \rho w^2 \mathrm{d}V$ remains finite.

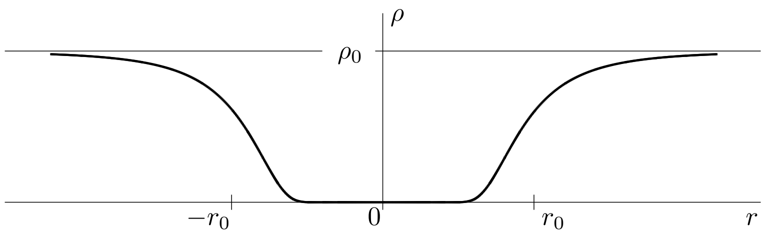

Figure H.1: $\rho = \rho_0 \exp\left(-\frac{1}{2}\frac{w^2}{w_0^2}\right)$ with $w = \pm w_0 r_0^2/r^2$

The particle's mass is proportional to an integral that evaluates to $B_1 = 0.755\,777$. Since the model is assumed to picture an electron with spin $\frac{1}{2}\hbar$, it can be seen that u_0/c must equal $1/B_1\alpha = 181.318$. This value is of the same order of magnitude as the measured muon-electron mass ratio $m_\mu/m_e = 206.768$. Assuming that in the model the two quantities equal each other (i.e., $u_0/c = m_\mu/m_e$), one obtains for the muon-electron mass ratio the prediction,

$$m_\mu/m_e = 181.318, \tag{H.2}$$

which is about 12 % smaller than the actual value.

In summary, the mathematical experiment showed that a simple hydrodynamic model may:

- picture the electron's charge and rest energy,
- picture the electron's spin, and
- predict the muon-electron mass ratio.

However, a big problem was that the model introduced more questions than it answered, questions such as:

- Why should p be eliminated via $\nabla p = v_0^2 \, \nabla \rho$?
- How can the model be developed further without new ad hoc assumptions?
- How can other forces of nature be introduced in the model?

Thus, the experiment demonstrates the problem with ad hoc assumptions in general. They may explain some features, but for every question they answer, they generate a number of new questions. A good theory should answer more questions than it generates.

If elementary particles really could be explained in the way suggested by the experiment, the density function had to be derived in a more logical way. The problem was how to rid the momentum equation of p in such a manner that both the process and its result were convincing. Eventually, physical reasoning led to (November 1966)

$$\rho = \rho_0 \left(1 - \frac{1}{f} \frac{v^2}{v_0^2} \right)^{f/2} . \tag{H.3}$$

See Appendix A.1 on page 29.

It was immediately clear that the number of degrees of freedom had to be $f = 3$ for the three-dimensional spherically symmetric rotation w, and that $f = 2$ should characterize the essentially two-dimensional cylindrically symmetric rotation u. No other values for f could be advocated, especially since (using these values) the new predicted mass ratio,

$$m_\mu / m_e = 1/B_1 \alpha = 204.652, \tag{H.4}$$

was only 1 % smaller than the measured value, 206.768.

And, as one would expect from a physically sound model, the improved model answered more questions than it generated. Even the obvious new question:

- If f may be 3 or 2, should not $f = 1$ be an option, too?

had a most obvious answer:

- $f = 1$ characterizes a one-dimensional velocity (v).

The existence of the velocity v, in turn, can only mean that the particle's energy (or energy in general) creates space. Therefore, Eq. (H.3) provides the explanation for why the universe is expanding.

Also, a short calculation immediately showed that v causes a force of attraction that becomes repulsive for very vast cosmic distances—a force that only can be identified with the force of gravitation.

In summary, one single and very simple equation, Eq. (H.3) expressing Newton's second law of motion, explained the origin of charge, spin, gravitation, and the expansion of the universe. Also, it eliminated the need to introduce a repulsive fifth force, and predicted that the expansion will go on forever at a steadily decreasing rate.

I Discussions

This is intended to be a temporary appendix, which will not be in the final version of the paper. The aim of the discussions is to convince the reader that the new "predictive cosmology" presented earlier in the paper is superior to the presently dominating "inflationary cosmology," which is based on the idea that the universe began as a singularity—an infinitely hot and dense point.

I.1 About the paper's mathematics

The paper contains no advanced mathematics. The pressureless form

$$\rho = \rho_0 \left(1 - \frac{1}{f}\frac{\boldsymbol{v}^2}{v_0^2}\right)^{f/2}. \tag{I.1}$$

of the momentum equation is essentially all there is to the theory. since everything else follows logically from it. To understand the derivation in Appendix A.1 (page 29) of Eq. (I.1), no detailed knowledge of vector analysis is needed. One need only know that, except for defining direction of the slope via the components of the unit vector $\mathbf{e}$, the gradient of a function $f(x,y,z)$ (defined as $\operatorname{grad} f = \nabla f = \frac{\partial f}{\partial x}\mathbf{e}_x + \frac{\partial f}{\partial y}\mathbf{e}_y + \frac{\partial f}{\partial z}\mathbf{e}_z$) is similar to the derivative $\frac{\mathrm{d}f}{\mathrm{d}x}$ of a function $f(x)$. Therefore, it is enough to replace grad or ∇ by $\frac{\mathrm{d}}{\mathrm{d}x}$ and use standard rules of derivation. These rules may be found in text books, or, for instance, in H. B. Dwight, *Tables of Integrals and other Mathematical Data*, fourth edition 1961, where formula 66 provides the applicable rule: $\frac{\mathrm{d}f(u)}{\mathrm{d}x} = \frac{\mathrm{d}f(u)}{\mathrm{d}u} \cdot \frac{\mathrm{d}u}{\mathrm{d}x}$.

B_0 of Eq. (4.3) on page 10 is an approximation of the constant B, in which the effect of expansion (v) is ignored. Its computation poses no problem, and the integral and its value are shown in Eq. (B.7) on page 32.

B does not differ much from B_0, and as long as B's precise value isn't required, there is no need to know more than its first couple of digits. Still, the calculation of B is not difficult. The divergence theorem used in Eq. (4.5) is fundamental in vector analysis and may be found in any text book. Obtaining Eq. (B.5) is a straightforward but somewhat tedious task. Programming the numerical integration from scratch is laborious, but with the aid of a suitable program package it should be fast and simple.

The calculation in Appendix C of the weak correction to the lepton masses is very simple—basically one elementary integration. The disadvantage of the method is that it requires knowledge of the Feynman-parametric formulation of perturbation theory for QED, which was developed by Toichiro Kinoshita and Predag Cvitanović, and is taught in Ref. [28] and in a series of three articles in Phys. Rev. D 10 (1974); 3978, 3991, and 4007. However, to see the crucial point—that the Higgs causes a decrease in lepton masses—it is enough to note that the scalar particle propagator (of the Higgs) and the massless vector propagator (of the photon) have opposite signs. See, for instance, Table 2.2 on page 47 in Ref. [20].

The rest of the calculations are simple and straightforward. The details given in Appendix E will probably be seen as superfluos by readers using calculus daily.

The simulation program, which led to the discovery of the double role of the energy principle, can hardly be simpler. Essentially, it consists of nothing but continuous summing of two types of energy—particle rest energy and radiative energy.

I.1.1 Experimental mathematics and simplicity

The main features of the present "predictive cosmology"—the roles of the momentum equation, weak interaction, and global energy conservation—were discovered more or less accidentally via mathematical experiments.

The rest follows naturally via application of the principle of maximum simplicity. Thus, the theory contains many in principle freely adjustable parameters, but their values are assumed to be exactly one, since this is the only value that can be advocated when maximum simplicity is used as guide.

Most of the assumptions have parallels in the standard model (SM). For instance, the assumption (3.7) on page 9 is equivalent to saying that the charges of the electron, muon, and tauon have identical values. In SM, this assumption is necessitated by simplicity, since without it, the theory of QED would be mathematically intractable. Consequently, it is not surprising if the assumption has become to be regarded as a proven fact.

I.1.2 What the computer simulation predicts

For many years, my numerous attempts to simulate the early evolution of the universe invariably failed. At first, I assumed that the increase in rest energy of the massive particles was caused by a growth in rest mass. Using this hypothesis, the expected increase in tauon and muon rest energies could somehow be understood, but for phase 3 it led to an increase in electron rest energy that was many orders of magnitude greater than the required order of 10.

Then, I realized that the increase in particle rest energy ($E = mc^2$) could just as well be caused by a growing c. For the first two phases, the situation didn't change. The rest energy of the spinless particles still increased rapidly as the photon's energy ($E_\gamma \propto 1/\lambda$) decreased when its wavelength λ grew as the universe expanded. However, the appearance of the Planck constant h in phase 3 forced the growing c to partly compensate the decrease caused by the growing λ, so that the photon energy (for which now holds that $E_\gamma = hc/\lambda$) decreased at a much slower rate than in the previous two phases. Thus, the appearance of the spinning electron with accompanying global constant h (Planck's quantum of action) explains why phase 3 evolved in a way which differed radically from that of phases 1 and 2.

Although the observation that in phases 3 and 4 the growing c slowed down the decrease in photon energy meant a breakthrough in the understanding of the early universe, the detailed simulation still didn't make sense. Already to make the simulation of phases 1 and 2 agree with observations, it was necessary to introduce two arbitrarily adjustable lifetimes τ with values about 2.045 and 4.78 (see Appendix F). This result suggested that no model in which particle lifetimes were constant could fit observational data.

Suddenly, everything made sense. Experiments in which the particle-pair lifetime τ was allowed to vary over time indicated that $\tau \propto c$. When this condition was satisfied, the computer program suggested that

- $\tau = 1$ initially in phase 1,
- $\tau = 1$ initially in phase 2, and
- $\tau = (2\pi^2\alpha^2)^{-1}$ initially in phase 3 (see footnote 5 on page 48).

As a result, a quite accurate prediction, $n_\gamma/n_b = 2.447 \times 10^9$, was obtained for the initial photon-baryon number ratio. Also, the muon-electron mass ratio changed to 206.768 22, thereby closing in on the observed value 206.768 28.

The final breakthrough, however was the observation that the growth in particle lifetimes resolves the time paradox and explains why no decrease in G or H has been observed in spite of the prediction of Eq. (7.6) that $\dot{H}/H = \dot{G}/G = -1/t$.

From the same observation, it follows that the energy principle plays a double role in physics. Thus, local energy ($E = mc^2$, say) is conserved when time is measured in units of atomic-clock ticks, and global energy is conserved when time is measured in such a way that the growing c keeps the energy constant in a volume coexpanding with the universe ($E = mc^2$ increasing to counterbalance the decrease in $E_\gamma = hc/\lambda$). Global energy conservation provides the constraints that turn cosmology into a science capable of making detailed unambiguos and refutable predictions.

I.1.3 Computation of the fine-structure constant α

It is generally agreed that it is not possible to determine α within a purely electrodynamical context. The issue is discussed in detail by Stephen Adler in Ref. [3].

When the muon was discovered in the 1930s, the empirical relation $m_e \approx \frac{2}{3}\alpha m_\mu$ led to speculations that α and the electron-muon mass ratio might be closely connected.

Now, the momentum equation has provided a connection between the two quantities. First, empirically in Eq. (4.13), and then, with the help of the energy principle, theoretically in Eq. (7.13).

With the connection known, the question is no longer whether α is calculable, but whether m_μ is calculable. The calculation in point I.04 on page 63 leads to an unambiguous but obviously incorrect result. Could it be that the only problem is how to calculate the effective lifetime τ between two consecutive annihilation events? Or, does the problem's solution require a deeper quantum-theoretical analysis?

Another possibility is that a very simple solution exists. Compare with the calculation of the final (positive) correction to the muon-electron mass ratio, which in the global picture is far from simple, but in the local picture turns out to be trivial (see derivation of Eq. (E.12) on page 39).

I.2 Briefly about predictive cosmology

Present cosmology is based on the idea that nothing ever heated the universe—that it was born infinitely hot in the form of a "singularity," i.e., an infinitely dense point. The notion of an initially infinitely dense and infinitely hot universe is problematic, because infinity (∞) is a mathematical concept that is very loosely defined (thus, for instance, $\infty + 2 = \infty$, $\infty \times 2 = \infty$, $\infty \times \infty = \infty$, and $\infty^\infty = \infty$) and cannot be used as starting-point for any detailed calculations. The consequence of building cosmology on this mathematically intractable idea is that the originally simple theory has exploded into a myriad of competing inflationary and other (such as the Albrecht-Magueijo-Barrow varying speed of light, VSL) theories. These theories have necessitated the further introduction of multiverses (multiple universes), dark energy or quintessence (a repulsive force that varies in strength in an unpredictable manner as the universe expands), etc.

The reason for the existence of the forces acting in nature is not understood. The strengths of the forces are—for want of a better explanation—assumed to be determined by chance. And so are a number of particle mass ratios and other "freely adjustable parameters."

A new theory remedies the lack of explanations and complements the well-established dynamic theories of the standard model of particle physics (SM) by showing a snapshot—a stationary picture—of particles at the exact instant of their creation.

The solid basis for the new theory is the principle of energy conservation. Thus, energy is doubly conserved—locally in our laboratories or in our galaxy, and globally in large volumes coexpanding with the universe. In classical physics, this double role of the energy principle is inconceivable—in quantum physics it is natural. Global energy conservation provides constraints, which turn cosmology into a science that makes refutable predictions.

The theory's starting point is the momentum equation, which connects a fluid's velocity ($\boldsymbol{v}$) and pressure (p) to its density (ρ). A particular stationary solution (a solution not involving time, t) to the momentum equation contains, instead of p, a degrees-of-freedom parameter (f). The solution,

$$\rho = \rho_0 \left(1 - \frac{1}{f}\frac{\boldsymbol{v}^2}{v_0^2}\right)^{f/2}, \tag{I.2}$$

is assumed to show an instantaneous picture of space. Via f—taking on the values 3, 2, and 1, respectively—it unifies a particle's charge and spin with space creation that makes the universe expand and causes the particle's gravity.

No pressure means no "molecules" and, consequently, no definable coordinate points. Thus, the absence of pressure implies distance undefinability and quantum indefiniteness. This, in turn, is the secret behind the energy principle's double role in physics.

The principles of global and local energy conservation provide the constraints that are needed to unambiguously determine particle masses, strengths of forces, and the evolution of the universe. Thus, by demanding energy conservation both locally in laboratories and globally in volumes that are coexpanding with the universe, it becomes evident that the universe must have gone through three short-lived phases before it entered its present stable phase.

Directly from Eq. (I.2), it follows that a volume V containing a given amount of energy expands according to $\mathrm{d}V/\mathrm{d}t =$ constant. Thus, the universe is forever expanding at a steadily decreasing rate. This mode of expansion implies that the large-number hypothesis (LNH), which Dirac deduced from observations, holds true and that later theories about inflation and accelerating expansion must be wrong. There is no fifth force in the theory, because gravity itself provides a very-long-range repulsion that counterbalances the cosmological effect of its shorter-range attraction.

Also, Eq. (I.2) indirectly explains why there are three generations of leptons (electron, muon, and tauon), why the proton with accompanying strong force exists, why the weak force exists, and why there is stable matter (that is, why there is more matter than antimatter).

The theory yields unambiguous predictions for the density of the universe (ρ_u), the Hubble expansion rate (H), the initial photon-baryon number ratio (n_γ/n_b), and the muon-electron mass ratio (m_μ/m_e). It also suggests that the tauon-muon mass ratio (m_τ/m_μ) and the fine-structure constant (α) might be readily computable.

From Dirac's large-number hypothesis (LNH), it follows that $G \propto t^{-1}$, which implies a very strong early gravity. It goes without saying that mini black holes must have been produced abundantly at a time when gravity was more than, say, 10^{20} times stronger than today. In fact, only the universe's rapid expansion with accompanying rapid decrease in G saved matter and radiation from being converted entirely into black holes.

And what heated the universe initially, before the appearance of black holes? The answer is: the same antiproton decay that transformed the originally symmetric but unstable universe into the stable matter-antimatter asymmetric world we observe today.

I.2.1 Things the theory explains

There is a surprising mass of information that derives from the momentum equation's special form (I.2). Thus, the equation explains, directly or indirectly:

- The reason why there are three particle generations (global conservation of energy)
- The lepton mass ratios (determined by energy conservation)
- The value of the fine-structure constant α (determined via m_e/m_μ)
- The purpose of the electromagnetic force (recreate matter from radiation)
- The purpose of the strong force (create stable matter—the proton)
- The purpose of the electroweak force (transfer energy from leptons to quarks)

- The purpose of weak parity (P) switching (stabilize matter)
- The cause of charge-parity (CP) violation (global energy conservation)
- The purpose of weak flavor mixing (transfer energy back to leptons)
- The reason for the existence of the gravitational force (expansion of space)
- The repulsive force (gravity's "other side")
- The age and flatness of the universe (the expansion obeys $\mathrm{d}V/\mathrm{d}t$ = constant)
- The reason why antimatter disappeared (the antiproton's decay into an electron)
- The origin of the universe's early heat (antiproton decay)
- The homogeneity of the background radiation
- The large photon-baryon number ratio (n_γ/n_b)

I.2.2 Predictions

- 206.768 283 185(78) for m_μ/m_e, a value 67 times more precise than the measured value, 206.768 2823(52)
- 4 physical Higgs bosons
- $\Omega = 2$, or a density of the universe twice as high as it is commonly believed to be
- $H_0 = 56.8$ km/s/Mpc for the present-day Hubble expansion rate
- $n_\gamma/n_b = 2.786 \times 10^9$ photons per baryon (original value)

I.2.3 To do in particle physics

- Calculate α. See end of Appendix G.2 (I.04 on page 63) for a failed attempt.
- Develop the QED theory for the (primordial) D particle proposed by Dirac in 1971.
- Improve the scalar perturbation calculation in Section 8.
- Perform the QED calculations suggested in footnote 5 on page 48. See Eq. (E.15).
- Reinvestigate the JBW hypothesis in the light of the Higgs calculation (Appendix C).
- Clarify what restrictions are put on electroweak models by the requirement that weak corrections to the lepton masses be calculable to all orders in perturbation theory.
- Further develop the treatment in Appendix C of the Higgs correction.
- Investigate consequences of the predicted four physical Higgs bosons.
- Find the electroweak model that is consistent with the scenario described in Appendix E.8.
- Predict the outcome of CERN's LHC experiment.
- Examine the effect of hadronic v-p loops appearing in the phase-4 photon propagator.
- Investigate consequences of the internal cosmological radius of elementary particles (see footnote 2 on page 10).
- Study consequences for string theory of the external conditions discussed at the end of Section 11.
- Consider the implications for quantum-gravity theories of the close connection between charge, spin, and expansion/gravity.
- Research the effect on general relativity (GR) of global energy conservation.
- Investigate the effect on GR of the modified gravitational potential. See Eq. (5.9).
- Clarify if the Pioneer anomaly may be a "spooky" effect due to distance indeterminacy.

I.2.4 To do in astrophysics

- Estimate the distribution of black holes in the universe.
- Estimate their average size and compare them with the Jupiter-mass black holes, which according to Michael Hawkins' observations constitute 99 percent of the universe.
- Estimate the rate of decrease of G and H.
- Obtain the corresponding $\dot{G}$ and $\dot{H}$ from type Ia supernova observations.
- Investigate the effect of a slowly declining G on the luminosity of distant stars.
- Correct the distance scale assuming a slowly decreasing gravity.
- Clarify if G declines fast enough to save the earth when the sun turns into a red giant.

I.3 Recent observations reported in *New Scientist*

During the past 20 years many critical articles have been written about the direction cosmology has taken. However, the criticism has led to no change in the theory's course toward ever increasing complexity. Evidently, this is because no plausible alternative has been proposed to the hypothesis that the big bang began as an infinitely dense and hot point in spacetime—a singularity. "Infinity" and "singularity" are unphysical concepts that theoretical physicists borrowed from pure mathematics and began to regard as physical concepts. The old "steady state" theory, which still has its supporters, is no better in this respect. It replaces infinite density by another infinity: an infinite age of the universe.

After the idea of an early inflationary period was introduced to explain observations that conflicted with theory, new observations forced additional repairs to the hot-big-bang model. Thus, the multiverse was introduced, and Einstein's constant cosmological repulsion first reintroduced and later replaced by a mysterious repulsive long-range force (dark energy or quintessence), which appears to vary with time in an unpredictable manner.

Recently, however, observational evidence has accumulated, which challenges the presently favored cosmological model and seems to support the new "predictive" cosmology. I will present some of these observations via excerpts from articles published in New Scientist.

I.3.1 Stars older than the universe

> There have been reports about stars "older than the universe." Of course, a star cannot be older than the universe. Consequently, all observations suggesting the existence of stars older than about 14 Gyr have had to be explained in some alternative way.

End of the beginning (*Cover story, New Scientist, 2 July 2005, pp 30-35*)

Is it time to admit that the idea of a big bang just doesn't stack up? **Marcus Chown** meets the doubters thinking the unthinkable

WHAT if the big bang never hapened? Ask cosmologists this and they'll usually tell you it is a stupid question. . . .

Or are they? A small band of researchers is starting to ask the question no one is supposed to ask. . . .

"Look at the facts," says Riccardo Scarpa of the European Southern Observatory in Santiago, Chile. "The basic big bang model fails to predict what we observe in the universe in three major ways." The temperature of today's universe, the expansion of the cosmos, and even the presence of galaxies, have all had cosmologists scrambling for fixes. "Every time the basic big bang model has failed to predict what we see, the solution has been to bolt on something new — inflation, dark matter and dark energy," Scarpa says.

For Scarpa and his fellow dissidents, the tinkering has reached an unacceptable level. All for the sake of saving the notion that the universe flickered into being as a hot, dense state. "This isn't science," says Eric Lerner who is president of Lawrenceville Plasma Physics in West Orange, New Jersey, and one of the conference organisers. "Big bang predictions are consistently wrong and are being fixed after the event." So much so, that today's "standard model" of cosmology has become an ugly mishmash comprising the basic big bang theory, inflation and a generous helping of dark matter and dark energy.

The fact that the conference went ahead at all is an important step forward, say its organisers. Last year they wrote an open letter warning that failure to fund research into big bang alternatives was suppressing free debate in the field of cosmology (*New Scientist*, 22 May 2004, p 20).

The trouble, says Lerner, who headed the list of more than 30 signatories, is that cosmology is bankrolled by just a few sources, and the committees that control those purse strings are dominated by supporters of the big bang. Critics of the standard model of cosmology are not just uncomfortable about the way they feel it has been cobbled together. They also point to specific observations that they believe cast doubt on cosmology's standard model.

...

The Spitzer galaxies have red shifts that correspond to a time when the universe was between about 600 million and 1 billion years old. Galaxies this young should be full of newborn stars that emit blue light because they are so hot. The galaxies should not contain many older stars that are cool and red. "But they do," says Lerner.

Spitzer is the first telescope able to detect red stars in faraway galaxies because it is sensitive to infrared light. This means it can detect red light from stars in high-red-shift galaxies that has been pushed deep into the infrared during its journey to Earth. "It turns out these galaxies aren't young at all," says Lerner. "They have pretty much the same range of stars as present-day galaxies."

And that is bad news for the big bang. Among the stars in todays galaxies are red giants that have taken billions of years to burn all their hydrogen and reach this bloated phase. So the Spitzer observations suggest that some of the stars in ultra-distant galaxies are older than the galaxies themselves, which plunges the standard model of cosmology into crisis.

Not surprisingly, cosmologists have panned Lerner's theories. They put the discrepancy down to large uncertainties in estimating the ages of galaxies. But Lerner has a reply. He points to other distant objects that appear much older than they ought to be. "At high red shift, we also observe clusters and huge superclusters of galaxies," he says, arguing that it would have taken far longer than a billion years for galaxies to clump together to form such giant structures.

...

My comment: The observations strongly support the predictions of the new cosmology. They indicate that gravity was stronger in the past (G declining) and that the universe is older than it appears to be in our local picture—exactly as the computer simulation predicts.

I.3.2 On type Ia supernovae and the fate of the earth

The new cosmology predicts (as did Dirac's large-number hypothesis) that the gravitational force decreases with time. Thus, because of the once stronger gravity, early stars were more compact, bright, and short-lived than present stars. This effect should show up in studies of very distant objects.

Supernova blow to dark energy studies (*New Scientist, 13 October 2007, p 14*)

DAVID SHIGA

EFFORTS to discover the nature of the mysterious force known as dark energy have been thrown into disarray by the discovery that the supernovae are not as predictable as had been assumed.

Because the average brightness of the stellar explosions known as type Ia supernovae was thought to stay the same over the universe's history, astronomers have treated them as "standard candles". In other words, they have used their apparent brightness as seen from Earth as a yardstick for measuring how far away they are, and from this they have estimated the rate of expansion of the universe.

Now an investigation of supernovae by Andrew Howell of the University of Toronto, Canada, and colleagues has thrown the basis for such measurements into doubt.

The researchers examined data from the Supernova Legacy Survey and the Hubble Higher-z Supernova Search. This showed that type Ia supernovae, thought to signal the deaths of white dwarf stars, were about 12 per cent brighter 8 billion years ago than they are now (*The Astrophysical Journal Letters*, vol 667, p 37). ...

...

Why the early universe had more of the brighter type Ia supernovae remains a mystery. However, ...

> **My comment**: In the predictive cosmology, where $\mathrm{d}V/\mathrm{d}t$ is constant and gravity the only very-long-range intergalactic force, things are simple. Both the Hubble expansion rate H and the gravitational constant G decrease, but too slowly for the effects to be directly measurable. However, very far back in time the slightly stronger gravity made stars burn appreciably faster than today and type Ia supernovae shine brighter. Thus, the reported 12 % decrease in supernova brightness over the past 8 billion years is an indirect measure of $\dot{G}$ (that is, $\mathrm{d}G/\mathrm{d}t$) and $\dot{H}$ (obtained from $\dot{G}$ via $\dot{H}/H = \dot{G}/G$ according to Eq. (7.24)).

The end of the world as we (now) know it (*New Scientist, 1 March 2008, p 20*)

EARTH'S future looks bright — but not in the way you might hope. The slim chance our planet will survive when the sun begins its death throes has been ruled out.

In about seven billion years, the sun will fuse the last of its hydrogen into helium and expand into a red giant 250 times its current size. At first, the sun's loss of mass as it sheds its outer layers will loosen its gravitational pull on Earth, which will allow the planet to migrate to a wider orbit. This process has led some researchers to speculate that the Earth might escape destruction — but survival now seems impossible, says Peter Schröder of the University of Guanajuato in Mexico and Robert Smith of the University of Sussex in the UK.

They created the most detailed model to date of the sun's transition to a red giant, based on observations of six nearby red giant stars. ...

...

The work has been accepted in *Monthly Notices of the Royal Astronomical Society* (www.arxiv.org/abs/0801.4031).

> **My comment**: The model's prediction may change if the decrease in G, which is suggested by the supernova observations, is taken into consideration. From the observed decrease in brightness of the type Ia supernovae—12 % in 8 billion years—one would expect a further decrease of about 10 % in the coming seven billion years. Astrophysicists

should be able to estimate the corresponding decrease in G and its effects on the properties of the red giant and on the orbit of the earth.

I.3.3 On black holes

Black holes have long been considered a candidate for the invisible part of the universe's mass—the so-called dark matter. The idea is supported by studies of light from distant quasars, which suggest an abundant existence of Jupiter-mass black holes.

Bright light, black hole (*New Scientist, 8 June 1996, pp 30-33*)

Is space chock-a-block with mini black holes, enough to bring the Universe to a violent end? *Marcus Chown* weighs up the evidence

ASK any astronomer what a black hole is, and you'll usually get the same answer: the shrunken remains of a star much more massive than the Sun, which can suck in matter like a cosmic vacuum cleaner. But one astronomer has found the first signs that black holes may have been born long before the stars. Mike Hawkins of the Royal Observatory in Edinburgh claims that space is teeming with tiny black holes—almost small enough to get your arms around—that were manufactured just moments after the big bang. The nearest might be only 30 light years away—a mere stone's throw in astronomical terms.

Ironically, the clues do not come from studies of dark objects but from quasars, the brightest objects in the Universe. Quasars are typically as bright as hundreds of normal galaxies, yet they generate all their energy in a region about the size of the Solar System. Most astronomers believe that they are powered by supermassive black holes, typically as heavy as a billion Suns. The light would then come from an "accretion disk" of gas, which is heated to millions of degrees as it swirls down into the hole.

Since quasars were discovered in 1963, astronomers have found that they sometimes fluctuate in brightness. Some rare quasars vary their light output over a very short time—months or even hours. Most astronomers agree that these short-term fluctuations are probably due to "hot spots" in the accretion disc, perhaps caused when stars from a surrounding galaxy collide with the disc. But quasars also fluctuate on longer timescales of between 5 and 10 years, and no one knows why. "In the 30-odd years since quasars were discovered, we have amassed an enormous amount of data, but we still don't really understand what they are," says astronomer Bohdan Paczynski of Princeton University.

Without any obvious mechanism for the long-term fluctuations, astronomers have tended to put them down to unknown changes within the quasar or overlying galaxy. "The prejudice of most astronomers was that such changes are intrinsic to quasars," says Hawkins. "There was no plausible explanation for the cause but no one doubted that one would eventually turn up."

However, over the past couple of years, Hawkins has followed up a controversial alternative. He suggests that the long-term variations do not arise within the quasars themselves, but that they are illusions caused by bodies passing between quasars and the Earth. If he is right, then the Universe may be chock-a-block full of black holes, only about a metre across, left over from the big bang.

...

This was an astonishing conclusion. For at least one object to be lensing every quasar, the Universe would have to contain a truly enormous population of Jupiter-mass objects. In fact, they would have to make up the vast majority of the mass in the Universe. James Gunn and William Press of the California Institute of Technology in Pasadena had made this crystal clear back in 1973 when they studied how much matter would have to be put in compact bodies spread throughout the Universe to ensure that every quasar was lensed (*Astrophysical Journal*, vol 185, p 397). It turned out that the combined mass of all the lenses would have to be several hundred times the mass we see in visible galaxies.

If Hawkins's idea was true, this would be revolutionary. All these Jupiter-mass objects would give the Universe more than a "critical mass", enough to one day halt its expansion and force it to collapse in a big crunch. The lensing objects could also solve one of the central mysteries of cosmology—the identity of dark matter. The Universe is dominated by nonluminous matter, which reveals itself only by its gravitational effect on visible stars and galaxies. "Most of the dark matter is made of these Jupiter-mass objects," says Hawkins. "The nearest body could be only 30 light years from Earth."

> **My comment**: Note that the new cosmological model predicts a mass of twice the "critical mass" of inflationary cosmology (without, of course, predicting any "big crunch"). See Eq. (5.15) on page 14.

. . .

Hawkins could think of only one other possibility for his Jupiter-mass objects—black holes formed in the first moments of creation. The idea sounds crazy, as black holes are usually thought to form when the gravity crushing a very massive star overwhelms the outward pressure of its hot matter. This only happens for stars many times as massive as the Sun—it is impossible to make a Jupiter-mass hole in this way through the pull of gravity alone.

Yet according to some theorists, the fury of the big bang fireball may well have been enough to crush matter together to form these mini black holes. In the 1980s, David Schramm and Matt Crawford of the University of Chicago suggested that the right conditions occurred a mere millionth of a second after the big bang. At this time, the Universe consisted of a hot "soup" of free quarks. . . .

. . .

> **My comment**: Michael Hawkins has written a book about his research, *Hunting Down the Universe: The Missing Mass, Primordial Black Holes, and other Dark Matters* (1997). From the front flap of his book (which is Ref. [23] in my paper), I copy the beginning:
>
> In 1993, astronomer Michael Hawkins came to the startling conclusion that about 99 percent of the universe consists of tiny primordial black holes, formed within the maelstrom of the first microsecond of the big bang. In ***Hunting Down the Universe***, Hawkins recounts the twenty-year odyssey that led him to this compelling and provocative conclusion, describing in the process the accumulation of evidence that solved the greatest mystery of modern cosmology: the problem of "dark matter" or the missing mass of the universe.
>
> Although Hawkins's theory has won the support of many distinguished astrophysicists, most are reluctant to believe it. And not because of a wealth of scientific evidence to the contrary, but for very unscientific reasons like jealousy and preservation of the status quo. . . .
>
> Another obvious reason why Hawkins's theory didn't receive much support is that theoreticians couldn't devise a plausible mechanism for the formation of his black holes, because they assumed that gravity has always been as weak as it is today. This assumption is contradicted by Dirac's large-number hypothesis (LNH), which says G decreases with time, but which was discarded because no change in G was observed. See Section 2 for a brief discussion of the LNH. Naturally, with gravity once being, say, 10^{20} times stronger than today, there is no need for fanciful speculations about matter being crushed together by "the fury of the big bang fireball."

Did black hole fireworks light up the cosmos? (*New Scientist, 7 June 2008, p 12*)

LONG before the first stars were born, something else may have lit up the darkness — gamma rays from a swarm of microscopic "primordial" black holes, each weighing no more than a small asteroid and forged in the violence of the big bang.

Physicists predict that primordial black holes would have spewed out radiation, including high-energy gamma rays, while shrinking and becoming even hotter.

Katherine Mack of Princeton University in New Jersey and Daniel Wesley of Cambridge University think that such gamma rays would have warmed the soup of hydrogen gas that filled the universe at the time. Future radio observatories may be able to measure this temperature signature indirectly. ...

...

Avi Loeb of Harvard University says that the existence of primordial black holes is still speculative. "But nevertheless, it's a legitimate possibility that one should explore the consequences of," he says. Spotting the gamma-ray signature could also confirm that black holes do evaporate, which has yet to be observed. *David Shiga*

I.3.4 On inflation

> Inflation was introduced to repair the problems brought about by the—not very well-founded—assumption that the big-bang universe was initially infinitely hot. In the predictive cosmology (with moderate initial heat caused by antiproton decay) there is no place for inflation, because none of the problems that were fixed by the inflation hypothesis exists in the new theory.

Inflation deflated (*Cover story, New Scientist, 7 June 2008, pp 30-33*)

Our best theory of the early universe is starting to look a tad insecure. Could this mean we've got it all wrong, asks **Michael Brooks**

... "It was the most boring talk you've ever heard," says Benjamin Wandelt, a cosmologist at the University of Illinois, Urbana-Champaign.

And Wandelt should know — he was doing the talking. Speaking at a conference on the first moments of the universe, held last December in Cambridge, UK, he described how satellite measurements of the cosmic microwave background radiation (CMB), the echo of the big bang, seem to contradict the predictions of inflation. Wandelt claims his analysis puts inflation to its most precise test yet — and that the theory seems to have failed.

Most physicists find this hard to swallow, so to get anyone to even think about accepting his analysis Wandelt had to spend his allotted hour refuting a seemingly endless litany of possible flaws. That's why his talk was so dull. "I had to examine effect after effect after effect," he says. It was worth the effort, though. Wandelt's analysis was published last month in the prestigious journal *Physical Review Letters* (vol 100, p 181301), an outcome that will surprise anyone who thought inflation was ironclad. It is, in fact, one of a number of recent setbacks for inflation, which is starting to look a little vulnerable.

...

I.3.5 Upcoming CERN experiments

POWER UP (**Cover story** | Large Hadron Collider, *New Scientist, 30 August 2008, pp 26-33*)

After years dreaming of what the biggest atom smasher ever built will produce, the time has come to find out, says **Matthew Chalmers**

. . .

The LHC's microscopic fireball is the closest we can get to recreating conditions last seen less than a trillionth of a second after the big bang, when the particles and forces that shape today's universe began to emerge. The higher the collision energy, the more massive the particles created in the debris. So a host of hitherto unseen particles could materialise from the firestorm, providing physicists with important new leads in the quest to unite all the forces of nature, including gravity, into one "theory of everything".

The LHC might help us to finally crack what are arguably the biggest mysteries in physics, starting with the origin of mass and the disappearance of antimatter. It could reveal what makes up the majority of matter in the universe, the so-called dark matter that is invisible to our telescopes. And it might tell us about the very nature of space-time itself. Do extra dimensions of space exist in addition to the three we live in? Are there mini-black holes? The LHC is more than a machine. It is the intellectual quest of our age.

> **My comments**: The young universe was never as hot as the colliding particles produced by the LHC will be. The antiproton decay heated matter to less than 0.94 GeV (point 4.40 on page 53) while the LHC will produce energies up to 14 000 GeV (14 TeV).
>
> The LHC will detect the Higgs boson. Presumably, four physical Higgs bosons will show up. See paragraph following Eq. (10.8) on page 25 and point I.02 on page 56.
>
> The LHC will not say anything about the bulk of dark matter, since this is nothing but black holes. See Appendix I.3.3. However, it is possible that a small part of the dark matter consists of exotic matter, such as the lightest superpartner (LSP) predicted by the supersymmetry (SUSY) theory discussed in the article.
>
> The LHC will not answer the question "Why is there no antimatter?" The answer to this question is simply that matter and antimatter annihilate each other, and if there are equal amounts of them, the end result is inevitably a universe without matter. The energy principle forbids such a purely radiative universe and forces the radiation to materialize. Three unstable matter-antimatter symmetric phases preceded the present asymmetric, and therefore stable, fourth phase. We are reminded of the universe's initial three phases by the tauon, muon, and electron, respectively. Another thing is that the LHC experiment should shed light on the process that led up to the present matter-antimatter asymmetry. The details of this process, in which the strong and weak forces were created, remain to be investigated. See Appendix E.8.

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