How can “137.036” be calculated?

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1 The four mystery numbers of physics

In theoretical physics, there are four fundamental numbers of unknown origin. Two of them,

$$m_\tau/m_\mu = 16.82 \tag{1.1}$$

and

$$m_\mu/m_e = 206.768, \tag{1.2}$$

are electron mass ratios.

> In addition to appearing in its familiar state with mass m_e, the electron may appear in two heavier, short-lived mass states.
>
> The heavy *muon* of mass $m_\mu = 206.768\, m_e$ was first observed in 1936. Its discovery came as a total surprise. *"Who ordered that?"* is a famous quote attributed to a physicist hearing about the finding.
>
> The superheavy *tauon* of mass $m_\tau = 3478\, m_e$ was discovered some 40 years later. Still today, the question asked among physiscists is *"Who ordered them?"*. Why should there be more than one generation, or family, of particles?

The third mystery number is the photon–baryon number ratio,

$$N_\gamma/N_b \approx 1.65 \times 10^9. \tag{1.3}$$

It is the number of photons (γ) in the universe divided by the number of protons (p) and neutrons (n) — so-called baryons.

The photon–baryon number ratio is equally mysterious as the electron mass ratios. It is related to the question of why the universe contains matter but not antimatter, a question that physicists still today are unable to answer.

> The universe should have been born with equal amounts of matter and antimatter — that is, with an equal amount of particles and antiparticles. So why didn't all particles and antiparticles annihilate each other? Why does a small amount of protons and neutrons remain, while all antiprotons ($\bar{p}$) and antineutrons ($\bar{n}$) have disappeared?

The fourth mysterious number is the fine-structure constant α. The inverse of alpha is

$$1/\alpha = 137.0360. \tag{1.4}$$

More precisely, in 2008, its value deduced from observations was reported to be 137.035 9991(1) with the uncertainty in the last digit shown in parenthesis.

There seems to be consensus among theoretical physicists that the value of alpha cannot be theoretically determined. It has gotten its value by chance is the best they can say about it.

> The fine-structure constant $\alpha = e^2/\hbar c$ is a measure of the strength of the electromagnetic force. Unlike the two mass ratios and the number ratio,

which are subject to corrections, α is expected to be a "pure" constant with the same value today as it has always had.

Ever since it was first measured, the value of alpha has fascinated people. Thus, back in the 1930s, a physicist tried to theoretically prove that its inverse was exactly $1/\alpha = 136$. When the experimental value was found to be very near to 137 and not 136, he managed to adapt his theory by adding a unit for reasons which only he was able to understand.

In the early 1960s, I read about these speculations and came up with my own suggestion: $10^2 + 6^2 + 1 + 6^{-2} + 10^{-2} = 137.038$, which seemed to fairly well match the experimental value of that time.

Today, after the accuracy of the experimental value has improved by several orders of magnitude, the chance of arriving in a seemingly logical and plausible way at an exactly matching value by playing with numbers is exceedingly small.

In the year 2016, physicists still do not understand these puzzling numbers, and cannot answer questions such as:

1. *What is the origin of the four mystery numbers?*
2. *What are the initial values of the electron mass ratios?*
3. *What is the initial value the photon–baryon number ratio?*
4. *What are the theoretical initial values of the electron mass ratios?*
5. *What is the theoretical initial value of the photon–baryon number ratio?*
6. *What is the exact theoretical value of* $1/\alpha$*?*

A maximally simple model (MxSM) of elementary particles attempts to answer these and other questions that have been regarded as unanswerable even in principle.

The hard core of MxSM is a simulation program coded in Fortran. The program tracks the evolution of the universe during its first phases. The revelations and predictions resulting from the simulation provide overwhelming proof that MxSM is far superior to the inflationary big-bang model, which for a long time has been the favored theory of cosmology.

2 Simulation of the universe's first phases

The source code of the Fortran program that simulates the early evolution of the universe is listed in physicsideas.com/Simulation.for [1].

The simulation program convincingly answers the first of the questions asked above, which is

1. *What is the origin of the four mystery numbers?*

Also it answers question 2 by stating that the initial, uncorrected, values of the electron mass ratios should be approximately

$$(m_\tau/m_\mu)^{\text{init}} = 16.919 \tag{2.1}$$

and

$$(m_\mu/m_e)^{\text{init}} = 151.136, \tag{2.2}$$

respectively.

Ideally, the simulation program should yield exact values (values calculable with any desired number of digits) for these quantities. As a bonus, with the exact value of the mass ratio in Eq. (2.2) known, one obtains an exact value for the inverse of alpha, namely

$$1/\alpha = (2B^2/B_0)(m_\mu/m_e)^{\text{init}}, \tag{2.3}$$

where

$$B = 0.666\ 001\ 731\ 498 \tag{2.4}$$

and

$$B_0 = 0.978\ 396\ 4019 \tag{2.5}$$

are well-defined, exactly computable numerical constants.

However, in its first approximate version, the simulation program cannot by itself predict anything. Instead, the values shown in Eqs. (2.1) and (2.2) are used to calibrate the simulation of phases 1 and 2 of the newborn universe.

The program's output from phase 1 is used as input for phase 2. Similarly, its output from phase 2 is used as input for phase 3. In spite of the uncertainties in the output of phases 1 and 2, the program's prediction for the end of phase 3,

$$N_\gamma/N_b = 2\ 786\ 275\ 000, \tag{2.6}$$

is quite precise. The reason for this precision is that phase 3 lasts for a significantly longer time than phases 1 and 2, and therefore is insensitive to small variations in the output from these earlier phases.

2.1 Insights and predictions resulting from the simulation

The simulation program fails to produce the exact theoretical values of the four "mystery numbers" of physics. But, more importantly, it demonstrates why the electron appears in three mass states (or generations) and shows that the four numbers are in principle computable, well-defined constants.

> Compared to what the simulation has already achieved, the exact values of the mystery numbers are of minor interest.
>
> There already exists a value for α — theoretically computed from the electron anomalous magnetic moment (a_e) — that is more precise than the directly measured value.
>
> Similarly, the original simulation program already produces a value for the muon–electron mass ratio [2],
>
> $$m_\mu/m_e = 206.768\ 283\ 185(78) \tag{2.7}$$
>
> that is obtained theoretically from $1/\alpha$ and is far more precise than the directly measured 2006 CODATA value,
>
> $$m_\mu/m_e = 206.768\ 2823(52). \tag{2.8}$$
>
> The most interesting number to know would be an exact prediction for the tauon–muon mass ratio (m_τ/m_μ), which lacks connection to precisely known physical constants.

Already in its original version, the simulation program is able to reveal all details that reasonably can be known about the evolution of particles and forces in the early phases of the universe.

> The simulation tells that the universe begins in a quantum leap from the perfectly symmetric, timeless and spaceless state of literally nothing to the simplest possible material world consisting of a neutral and spinless particle — the "D particle" that was first described by Paul Dirac in 1971. See physicsideas.com/Dparticle.pdf [3] and references therein. This event constitutes the first symmetry-breaking phase transition in the history of the universe.
>
> The next particle that enters the physical scene is the electron, however not in its present form, but in the form of a charged "spinless tauon" ($\tau_0^\pm$). In the shape of a dielectron, or ditauon ($\tau_0^+\tau_0^-$), the spin-0 tauon replaces the D particle as bearer of the universe's matter.
>
> The spin-0 tauon is soon succeeded by a second-generation spin-0 electron, or "spinless muon" ($\mu_0^\pm$) appearing in the form of a dimuon ($\mu_0^+\mu_0^-$).
>
> Next, in a transition where the electron in its various mass states acquires spin, the spinless muon is replaced by the familiar third-generation electron ($e^\pm$), which in its role as sole bearer of the universe's mass appears in the shape of a quadelectron ($e^+e^-\ e^+e^-$).
>
> The main feat of the simulation program is its detailed explanation of how the mass-bearing matter–antimatter symmetric quadelectron is replaced

with the matter-only proton–electron pair (pe^-), or the hydrogen atom. It tells why this replacement could only be achieved with assistance from a number of weakly interacting particles — a spin-0 Higgs boson (H), two spin-1 bosons (the neutral Z and charged $W^{\pm}$) and a neutral spin-$\frac{1}{2}$ fermion, or neutrino (ν) — at the same time as it reveals their respective roles in the process.

But this is not all. The details of the simulation also show that a small particle–antiparticle asymmetry is created in the process, which explains puzzling asymmetries observed in neutral K and B meson decays.

2.2 Shortcomings of the simulation program

A perfected version of the simulation program should be self-contained and produce exact theoretical results for the initial values of the two electron mass ratios, the initial photon–baryon number ratio, and the constant $1/\alpha$. Compare with Eqs. (2.7), (1.2), (1.3), and (1.4), respectively. For several reasons, the program in Ref. [1] fails to do this.

One shortcoming of the program in its original form is that it is based on the assumption that the universe begins in the form of a ditauon $(\tau_0^+\tau_0^-)$, and doesn't take into account that the ditauon originates from a D particle.

Also, the program assumes that, viewed from the end of phase 1 when the last ditauon annihilates and radiation rematerializes, each particle may be regarded as the first, primordial particle. By following all these particles as a collective from time $t = 1$, the simulation gives an adequate overall picture of the evolution, whose fine details, however, cannot be discerned.

Regarding the number N at each instant in time as a whole number (an integer $N \geq 0$) leads to another shortcoming. It results from the fact that (in the global picture of the simulation) the particle lifetime τ increases with time, which makes it impossible to know what precisely the effective lifetime of the particles should be.

> This is the reason for my experimenting with values of τ taken about half-way between the time $t = t_N$ when the previous decay took place and $t = t_N + \Delta t$ when the next decay will occur. See table on page 46 in physicsideas.com/Paper.pdf [4].

2.3 Logic of the original program

The logic of the simulation can hardly be simpler. Assuming global validity of the law of conservation of energy, it repeatedly applies the well-known rule for radioactive decay,

$$(\Delta t)_{N\to N-1} = \tau/N, \tag{2.9}$$

to the universe's matter-bearing particles.

> Eq. (2.9) gives the average time that elapses between successive decays of unstable particles in a sample of radioactive material. N is the number of remaining unstable particles and τ the lifetime of the particles. For more details about radioactive decay, see Section 3 below. 12

The starting point of the program in physicsideas.com/Simulation.for [1] is the assumption that the universe pops into existence as a "dielectron" consisting of an entangled pair ($\tau_0^+\tau_0^-$) of charged spinless tauons.

> From the results of the simulation, it is concluded that the primordial particle is not a ditauon (built from two oppositely charged component particles) but an even simpler particle — the neutral D, which may be conceived as a relativistic harmonic oscillator [3]. However, this revelation of the simulation is not taken into account in the program code.

Another reason why the program cannot produce precise predictions on its own is the assumption that the universe always contains an integral number of particles — that is, N in Eq. (2.9) is taken to be an integer.

The simulation in Ref. [1] is based on the asumption that an expanding sphere of radius r and volume $V = \frac{4}{3}\pi r^3$ grows at a rate proportional to its energy content E_V. With energy conserved, this means that

$$\mathrm{d}V/\mathrm{d}t = \text{constant}. \tag{2.10}$$

The calculation on page 44 in physicsideas.com/Paper.pdf [4] led me to assume that (with t_0, r_0, and R_0 set equal ro 1)

$$r = (Nt)^{1/3}, \tag{2.11}$$

$$R = t, \tag{2.12}$$

and

$$N = R^2, \tag{2.13}$$

which give the physically meaningful connection

$$N = t^2 \tag{2.14}$$

between the number of particles (N) in the early quantum-indeterminate universe and the age (t) of it.

2.4 Suggested improvements

The program should take into account what happens to the primordial, maximally symmetric D particle.

Time begins running at $t = 0$, and the physical universe is born at a time set equal to 1 in the program. Between $t = 0$ and $t = 1$, the D particle builds up in an oscillation. It then attempts to disappear in a similar fashion as it appeared — that is, with a lifetime of $\tau = 1$ annihilate into literally nothing. However, forbidden to do this by the law of conservation of energy that comes into existence at the same time as the particle, it is forced to transform into a new and less symmetric type of massive particle.

> Naively, one might think — as I used to do — that the D particle annihilates in about the same way as the ditauon. However, the path-integral description of quantum physics implies that — until the decay physically takes place — an unstable particle and its decay product coexist in a state of superposition. Now, the massive D particle can never annihilate into massless radiation because there are no photons coexisting with it. In fact, it cannot even exist in the same universe as the ditauon ($\tau_0^+\tau_0^-$) and the photon (γ_τ), which mediates the electric force that binds together the ditauon's two component particles [3].

In Appendix A below, a more detailed repetition of the calculation performed 21
on page 44 in Ref. [4] yields the relations

$$r^3 - r_0^3 = 3cNr_0^2(t - t_0) \tag{2.15}$$

and

$$R = 3c(t - t_0) + r_0^3/R^2. \tag{2.16}$$

The hydrodynamic calculation in the appendix is classical. However, the universe is not classical — it's a quantum world. Therefore, these relationships shouldn't necessarily be taken at face value, but be regarded as indicative only.

> This is so because position and distance are undefinable concepts in the early universe that exists in a state of cosmic quantum indeterminacy. Therefore, r and R must not be regarded as radii of specific lengths, but as practically usable auxiliary variables defined in terms of t and N.
>
> Similarly, c in Eq. (2.16) cannot be a velocity because "velocity" implies that particles are moving relative to each other. And, in a universe where position and distance are undefinable concepts, also velocity is an undefinable concept. Thus, in the simulation of the early universe, the role of the variable c is to connect the massive particle's increasing self-energy E (with $E \propto c^2$) to the radiation energy E_r — with $E_r \propto 1/\lambda$, where λ is the photon wavelength, which in the program is set equal to r (an imagined radius of an expanding volume containing a given number of particles).

So, how should the relation $R = 3c(t-t_0)+r_0^3/R^2$ in Eq. (2.16), be interpreted?

The simplest alternative is my original assumption that Eqs. (2.11) and 8
(2.12) hold true. These relations imply that $R = 1$ and $N = 1$ at time $t = 1$,

while $R = 2$ and $N = 4$ at time $t = 2$ when the ditauon replaces the D particle as bearer of matter. However, the results of the original simulation suggest that $N \approx (t-1)^2$ for $N = R^2 \gg 1$, which conflicts with Eq. (2.14) and thereby apparently excludes this alternative.

> It seems that consistency between the simulations of phase 1 and phase 2 requires that $N = (t-1)^2$ for large values of t. See conclusion at bottom of page 46 in Ref. [1].

Another possibility is that Eqs. (2.15) and (2.16) are used as such with t_0, r_0, and c set equal to 1 in the simulation program:

$$r = (1 + 3(t-1))^{1/3}, \tag{2.17}$$

$$R = 3(t-1) + 1/R^2. \tag{2.18}$$

These equations imply that $r = R = 1$ at $t = 1$, while $r = 4^{1/3} = 1.587$ and $R = 3.104$ when the D particle is succeeded by the ditauon at $t = 2$.

> Equation (2.18) may be solved for R through iteration. Example of Fortran code:

```
        t      = 2
        R      = 1
        do 10    k = 1,100
C                To check convergence, remove C from col 1:
C                write (*,*) 'iterating R:', k-1, R, R**2
C                write (9,*) 'iterating R:', k-1, R, R**2
10      R      = (3*(t - 1)*R**2 + 1)**(1/3.0)
```

> With $R = 1$ as start value, $R = 3.103803$ and $R^2 = 9.633596$ are obtained after 46 iterations.
>
> Note again that V, r, and R are auxiliary variables without physical content, whose purpose is to help visualize the connections between the physically meaningful variables N, t, and $c = \tau$.
>
> The initial values of r and R are irrelevant, and may for simplicity be set equal to 1 in the program. Also, as demonstrated in the original program [1], r and R may be eliminated from the calculations.

From Eq. (2.13) or Eq. (A.3), it now follows that the total number of particles 8, 21
in the universe at $t = 2$ is $N = R^2 = 9.634$.

However, also this alternative conflicts with the prediction of the original simulation suggesting that $N = R^2 \rightarrow (t-1)^2$ for $R \rightarrow \infty$. A third alternative may therefore be that

$$r = (1 + (t-1))^{1/3}, \tag{2.19}$$

$$R = t - 1 + 1/R^2, \tag{2.20}$$

which for $t = 1$ have the solutions $r = 1$ and $R = 1$, respectively, and satisfy the prediction $N = (t-1)^2$ for $t \rightarrow \infty$. In this case, iteration of the equation

$$R = ((t-1)R^2 + 1)^{1/3}$$

for $t = 2$ with $R = 1$ as the start value yields $R = 1.466$ and $N = R^2 = 2.148$.

Whatever the relation between N and t might be, it should result in predictions for the "mystery numbers" that match the actually observed numbers.

The relation connecting N to t should either be obtained theoretically via quantum theoretical considerations or experimentally through trial and error, using relations that look simple and plausible. (My method was very primitive. I experimented more or less blindly. Then, when a result looked meaningful, I tried to interpret it as best I could.)

Another question has to do with the properties of the D particle. How does D differ from the still existing particles that succeeded it? For instance, does it create space at the same rate as the particles of today do, or at a slower or faster rate?

> The particles that succeed the D particle as bearers of the universe's matter have energies $E \propto c^2$ and create space according to $\mathrm{d}V/\mathrm{d}t \propto E$. But what if the self-energy of the D particle — a "relativistic harmonic oscillator" [3] — isn't proportional to c^2, but to c^k with $k \neq 2$?

3 On radioactive decay

Unstable particles decay at unpredictable times. However, they have precisely defined lifetimes (τ) that tell how long they live on average (a particle's lifetime is also known as its mean life, or average life).

For a sample containing unstable particles, the time Δt, which on average elapses between two decay events, is given by

$$\Delta t = \tau / N, \tag{3.1}$$

where N is the number of unstable particles left in the sample after the first of the two events has taken place.

In connection with radioactive decay, one often talks about a particle's half-life defined as

$$T_{1/2} = \tau \log 2 \tag{3.2}$$

with $\log 2 = 0.693\ 147$.

To understand the connection between half-life and lifetime, assume that there are $N = 2p$ unstable nuclei in a radioactive sample. On average, the time between the previous and the next decay is $\Delta t = \tau/N = \tau/2p$. All unstable particles in the sample decay within $(\frac{1}{2p} + \frac{1}{2p-1} + \frac{1}{2p-2} + \ldots + \frac{1}{2} + 1)\,\tau = (\log 2p + C)\,\tau$, where the equality sign holds for $p \to \infty$, and $C = 0.557\ 2157$ is Euler's constant.
The last p particles decay within $(\frac{1}{p} + \frac{1}{p-1} + \frac{1}{p-2} + \ldots + \frac{1}{2} + 1)\,\tau = (\log p + C)\,\tau$. Consequently, the first p particles decay within $(\log 2p + C - \log p - C)\,\tau = \log(2p/p)\,\tau = \tau \log 2$. That is, $T_{1/2} = \tau \log 2 = \tau \times 0.693\ 147\ 181$.

If there is a relatively small number N of decaying particles present in the sample, such as 2, 4, 10, 100, 1000, or 10 000, $\log 2 = 0.693\ 147$ is replaced by
$\frac{1}{2} = 0.5$,
$\frac{1}{4} + \frac{1}{3} = 0.583$,
$\frac{1}{10} + \ldots + \frac{1}{5} = 0.646$,
$\frac{1}{100} + \ldots + \frac{1}{51} = 0.688$,
$\frac{1}{1000} + \ldots + \frac{1}{501} = 0.692\ 647$, and
$\frac{1}{10\ 000} + \ldots + \frac{1}{5001} = 0.693\ 097$, respectively.

One may conclude that both lifetime and half-life are statistical concepts. But where lifetime is defined for any number of particles, the definition of half-life, $T_{1/2} = \tau \log 2$, only holds for many particles.

In our familiar, local picture of the world, where the speed of light (c) is constant, particle lifetimes are constant, too. The fact that a particle's lifetime — its mean life, or average life — is τ implies that its probability, p, for decaying within a time interval of $\Delta t = \tau$ is $1/2$.

Consequently, the probability that the particle still exists after that time is $1 - \frac{1}{2}$, and its probability for decaying within the next interval τ is $(1 - \frac{1}{2}) \times \frac{1}{2} = \frac{1}{4}$. Thus, the probability that it has decayed within $2\,\tau$ is $\frac{1}{2} + \frac{1}{4} = \frac{3}{4}$. And the probability that it still exists and will decay within the next time interval $\Delta t = \tau$ is $(1 - \frac{3}{4}) \times \frac{1}{2} = \frac{1}{8}$. In this manner, the particle's "statistical decay" proceeds through successive intervals $\Delta t_i = \tau$ $(i = 1, 2, 3, \ldots)$ with forever decreasing probabilities $p_i = 1/2^i$. Only after an infinite time will the probability that the particle actually has decayed become exactly $\sum_{i=1}^{\infty} 1/2^i = 1$.

In the simulation of the early phases of the universe, one must regard the number of unstable particles not as an integer, but as a fractional (or real), continuously varying number.

For time increments $\mathrm{d}t$ that are fractions of the lifetime — that is, $\mathrm{d}t = \tau/n$, where n is an integer unrelated to the actual (fractional) number N of particles — one obtains for the probability that a given particle decays within the interval between t_{i-1} and t_i with $t_i = i\,\mathrm{d}t$ ($i = 1, 2, 3, \ldots$), the expression

$$p_i = x(1-x)^{i-1}, \tag{3.3}$$

where

$$x = 1 - 2^{-1/n}. \tag{3.4}$$

For the summed probabilities $(p_1 + p_2 + p_3 + \ldots)$ that the particle has decayed by the time t_i, one similarly obtains

$$s_i = 1 - (1-x)^i. \tag{3.5}$$

Proof. Let t_0 be the time of creation of the unstable particle and $p_1 = x$ its probability of decaying before $t_1 = t_0 + \tau/n$. Thus, the summed probabilities for the particle's decay up to t_1 is $s_1 = p_1 = x$. For increasing times $t_i = t_0 + i\tau/n$, one finds
$t = t_0$: $p_0 = 0$, $s_0 = 0$;
$t = t_0 + \tau/n$: $p_1 = x$, $s_1 = x = 1 - (1-x)$;
$t = t_0 + 2\tau/n$: $p_2 = x(1-s_1) = x(1-x)$, $s_2 = s_1 + p_2 = x + x(1-x) = 2x - x^2 = 1 - (1 - 2x - x^2) = 1 - (1-x)^2$;
$t = t_0 + 3\tau/n$: $p_3 = x(1-s_2) = x(1-2x+x^2) = x(1-x)^2$, $s_3 = s_2 + p_3 = 2x - x^2 + x - 2x^2 + x^3 = 1 - (1 - 3x + 3x^2 - x^3) = 1 - (1-x)^3$.
After calculating p_4, s_4, p_5, and s_5, I conclude that the general expression for the probability p_i of decay between t_{i-1} and t_i is $x(1-x)^{i-1}$. Similarly, the total probability for decay between t_0 and t_i must be $1 - (1-x)^i$.
Since the probability for the particle to decay before $t = t_0 + \tau$ is $\frac{1}{2}$, one obtains the equation $s_n = 1 - (1-x)^n = \frac{1}{2}$ with solution $x = 1 - 2^{-1/n}$.

In the global picture, where the particle lifetime increases with time at the same rate as c increases (with $\tau = c$ in the program), the situation is more complex.

However, the time increments may still be calculated in the local picture, after which they are translated into global time increments through multiplication by c (with initial value 1).

In the simulation program, let l be the local time and t its corresponding global time.

During what might be called the universe's phase 0, between $t = 1$ and $t = 2$ when the D particle is alone in the universe, no annihilation of particles takes place. Consequently, c and τ retain their original values of 1, and global and local times coincide: $t = l$ and $\mathrm{d}t = \mathrm{d}l$.

At the end of phase 0, at time $t = l = 2$, the D particle transforms through a quantum leap into a ditauon. By this time, the volume containing the single D particle has expanded at a constant rate and doubled in size with its radius r

increasing from $r = 1$ to $r = 2^{1/3} = 1.260$ if either one of Eqs. (2.11) or (2.19) 8, 10
holds true.

Since the universe increases in size at a faster rate than V expands (with $R \propto t$ and $r \propto t^{1/3}$, respectively), the initial number of ditauons (N) is a fractional number greater than 1.

> If Eq. (2.20) holds true, then at time $t = 2$, R has increased from its 10
> initial value of 1 to 1.466, and the number of particles in the universe from $N = 1$ to $N = R^2 = 2.148$.

Unlike the D particle, the ditauon annihilates into radiation (diphotons). At local time $2 + \mathrm{d}l$ and global time $2 + \mathrm{d}t$, a small fraction of the N ditauons has (statistically) annihilated.

The local and global times are now updated by adding to them their corresponding time increments:

```
l = l + dl
t = t + dt
```

The local time increment $\mathrm{d}l$ doesn't change with time, but the global time increment $\mathrm{d}t = c\,\mathrm{d}l$ changes when c and $\tau = c$ increase as a result of the redshifting of the photon wavelength caused by the expansion.

If one considered only the particles in V, updating t by adding to it $\mathrm{d}t = c\,\mathrm{d}l$ would suffice, and one could continue the calculation using the constant $\mathrm{d}l$ and an increasing global time differential, $dt = c\,\mathrm{d}l$. However, the particles in the universe must be treated as a collective. Consequently, for each step $\mathrm{d}l$ and $\mathrm{d}t$ forward in time, one must also update the number N of particles considered.

Therefore, each time increment must be accompanied by an update of the volume V, which again should be set equal to the volume of the entire universe. That is, new values of R and $N = R^2$ must be computed, and a new value of $\mathrm{d}l$ calculated.

In this way, the annihilation of matter is tracked until the remaining fraction of massive particles reaches the value 0.5, when (statistically) the last remaining particle annihilates.

The global lifetime τ and global speed of light c are initially 1, and grow as the self energy of the massive ditauon increases at the same time as the energy of its decay product, the diphoton, decreases. Setting the mass m of the ditauon equal to 1, its self energy $E = mc^2$ simplifies to $E = c^2$, and the relationship $\tau = c = E^{1/2}$ holds generally.

The law of global energy conservation implies that the total energy contained in the expanding volume V is constant and may in the program be set equal to the total number of particles, N, contained in V. That is, energy balance implies that

$$E_m + E_r = E_V = N, \tag{3.6}$$

where E_m is the energy of the undecayed fraction of ditauons ($\tau_0^+\tau_0^-$) and E_r the energy of their annihilation product — that is, radiation in the form of diphotons ($\gamma_\tau\gamma_\tau$).

Since the radiative energy E_r is inversely proportional to the photon wavelength λ, which in turn is proportional to the radius r of the expanding spherical volume V, energy conservation implies that

$$f_m c^2 + f_r/r = 1. \tag{3.7}$$

In this equation, r is the radius (initially $r = 1$ at $t = 1$) of the expanding volume, f_m the remaining massive fraction of the dielectrons with total energy $f_m N c^2$, and $f_r = 1 - f_m$ their annihilated fraction with total energy $f_r N/r$.

4 Fortran source code

Here follows an outline of a Fortran program intended as a starting point for checking various hypotheses. I haven't tested the code, which therefore may contain errors, from trivial misprints to serious logical flaws.

Standard Fortran convention is used: variables beginning with the letters `i`, `j`, `k`, `l`, `m`, and `n` are integers, while all other variables are reals (in practice meaning fractional numbers). For example N and l (denoting number of particles and local time, respectively) are in the program written as `fN` and `tl`.

Also note that $\Delta t = \tau/N$ is translated into `Delta = tau/fN`, and similarly $\mathrm{d}t = \tau/Nn$ into `dt = tau/fN/n` and $\mathrm{d}l = 1/Nn$ into `dtl = 1/fN/n`.

Start of program. To begin with, open a disk file to which the output of the program may be written:

```
      open    (9,file='temp0.tXt',status='new')
```

The computation is repeatedly executed using a successively smaller time incre-
ment, $\mathrm{d}l = \Delta l/n$, or (according to Eq. (2.9) with τ in the local picture constant 8
and set equal to 1) $\mathrm{d}l = 1/Nn$, where n is an integer that may be doubled
each time the overall program loop is executed. If the program works properly,
its output should converge toward a well-defined value when $\mathrm{d}l$, which may be
regarded as a time differential, tends to zero as $n \to \infty$:

```
      do 900  i = 0,imax
      n     = 2**i
```

When testing various assumptions, `imax` may be less than 5. Only when high-precision results are desired, values greater than 10 or 15 need to be used.

Phase 0. The simulation is trivial because no annihilation takes place in
phase 0, and c as well as $\tau = c$ are constant. The only question is how the
universe expands during the brief "D parenthesis". If the radius R of the uni-
verse (`Ru` in the program) increases as suggested in Eq. (2.20), its value at time 10
$t = l = 2$ may be iterated:

```
      t     = 2
C                              Try 2nd of 3 alternatives:
C1    Ru    = t
      Ru    = 1
      do 10   k = 1,100
10    Ru    = ((t - 1)*Ru**2 + 1)**(1/3.0)
C3    Ru    = 1
C3    do 10   k = 1,100
C3 10 Ru    = (3*(t - 1)*Ru**2 + 1)**(1/3.0)
      fN    = Ru**2
```

Phase 1. Track the massive ditauon's increase in self-energy in the global picture.

The simulation of phase 1 is no longer trivial because now the ditauon (the successor of the D particle as bearer of the universe's matter) annihilates into pure radiation (that is, a massless diphoton) with the result that the ditauon's self-energy c^2 (with the particle's mass set equal to 1 in the program) increases to counterbalance the decrease in photon energy caused by the expansion of the volume V. See Eqs. (3.6) and (3.7). The initial values of phase 1 are: 14, 15

```
      tl    = 2
      t     = 2
C                                Use 2nd of 3 alternatives:
C1    r     = (fN*t)**(1/3.0)
      r     = (1 + fN*t)**(1/3.0)
C3    r     = (1 + 3*fN*t)**(1/3.0)
      rsave = r
      c     = 1
      tau   = 1
      Em    = fN
      Er    = 0
      fm    = 1
      fr    = 0
```

where f_m is the undecayed fraction of the massive particles and $f_r = 1 - f_m$ the fraction that has annihilated into radiation. Compare with Eq. (3.7). In 15
addition, the initial values in phase 1 of R and $N = R^2$ are obtained as output from phase 0.

Next, start the program loop in which the evolution of the particles of phase 1 is traced:

```
      do 120  j = 1,6*n
```

If the program works properly, it should exit the loop before the counter `j` reaches its maximum value specified in the `do` statement. This happens when the last massive particle annihilates. See 1.6 below.

An uninterrupted loop would indicate that the expansion causes particles to multiply too rapidly for all matter to disappear, which has the consequence that the particle-antiparticle symmetric universe of phase 1 is stable.

1.1. In the local picture (where $\tau = c = 1$ is constant), calculate the probability (p_1) that a fractional (or differential) part of the ditauons annihilates in the interval $\mathrm{d}l$ between l and $l + \mathrm{d}l$. Update accordingly f_m and f_r, which are the same in the global as in the local picture.

With $\mathrm{d}l = \Delta l/n$ and $\Delta l = 1/f_m N$ (see Section 2.3), and with the help of 8
Eqs. (3.3) and (3.4), one obtains: 13

```
      dtl   = 1/(fm*fN)/n.
      x     = 1 - 1/2**(1.0/n)
      p1    = x
      dfm   = fm*p1
      fm    = fm - dfm
      fr    = 1 - fm
      tl    = tl + dtl
```

1.2. Look at the annihilation of ditauons from the global perspective:

```
      dt    = c*dtl
      dEm   = Em - fm*fN*c**2
      t     = t + dt
```

1.3. Look at the radiation redshift from the global perspective:

```
C                            Use 2nd of 3 alternatives:
C1    r     = (fN*t)**(1/3.0)
      r     = (1 + fN*t)**(1/3.0)
C3    r     = (1 + 3*fN*t)**(1/3.0)
      dEr   = Er*(1 - rsave/r)
C     rsave = r              See 1.7 below.
```

1.4. Update the energies of the decayed and undecayed particles.

```
      Er    = Er + dEm - dEr
      Em    = Em - dEm + dEr
```

1.5. Update c according to Eq. (3.7): 15

```
      c     = sqrt((1 - fr/r)/fm)
```

1.6. If the number of remaining massive particles is 0.5 or less, exit loop:

```
      if     (fm*fN.le.0.5) go to 130
```

1.7. Consider the expansion of the whole universe.

If one wanted to follow the decay of the fixed number of particles in V, one would calculate p_2 from Eq. (3.3) and repeat the calculations in 1.1 to 1.5. 13
However, all particles in the universe must be looked upon as a collective, which means that, since the spherical volume V is expanding at a slower rate than the universe (with $r \propto t^{1/3}$ versus $R \propto t$), new values of r (that is, `rsave`) and N must be calculated each time l is incremented:

```
      fNsav = fN
C                             Use 2nd of 3 alternatives:
C1    Ru    = t
      Ru    = r
      do 110  k = 1,100
110   Ru    = ((t - 1)*Ru**2 + 1)**(1/3.0)
C3    Ru    = r
C3    do 110  k = 1,100
C3 110 Ru   = (3*(t - 1)*Ru**2 + 1)**(1/3.0)
      rsave = Ru
      fN    = Ru**2
      Em    = Em*fN/fNsav
      Er    = Er*fN/fNsav
```

After exiting the loop simulating phase 1, write c^2 equal to the predicted value for $(m_\tau/m_\mu)^{\text{init}}$ together with the current values of the local and global times and the number of particles in the universe:

```
120   continue
C
130   write   (*,*) 'tl, t, fN, c**2:', tl, t, fN, c**2
      write   (9,*) 'tl, t, fN, c**2:', tl, t, fN, c**2
```

Phase 2. Track in the global picture the increase in self-energy of the massive dimuon.

The logic of phase 2 is identical to the logic of phase 1. Initially, the variables c and $\tau = c$ are reset to 1, while the variables l, t, and N retain their values obtained at the end of phase 1.

Only after the simulation of phase 1 has produced a value that agrees with the uncorrected value of the tauon–muon mass ratio — that is, $c^2 = (m_\tau/m_\mu)^{\text{init}} = 16.919$ according to Eq. 2.1 — phase 2 needs to be simulated. 4
Still, when experimenting with different alternatives, a comparison of the outputs from phases 1 and 2 might help determine which alternative works best and thereby help zooming in on the correct values of the two electron mass ratios and $1/\alpha$.

In particular, one would expect that an incorrect value of N at the end of phase 0 leads to a relative error in phase 2 that is smaller than the corresponding relative error in phase 1.

After exiting the loop simulating phase 2, write c^2 equal to the predicted value for $(m_\mu/m_e)^{\text{init}}$ together with the current values of the local and global times and the number of particles in the universe:

```
230   write   (*,*) 'tl, t, fN, c**2:', tl, t, fN, c**2
      write   (9,*) 'tl, t, fN, c**2:', tl, t, fN, c**2
```

Finally, write the predicted value for $1/\alpha$: 4

```
       B      = 0.666001731498
       B0     = 0.9783964019
C
       write   (*,*) ’1/alpha =’, 2*B**2/B0*c**2
       write   (9,*) ’1/alpha =’, 2*B**2/B0*c**2
C
900    continue
C
990    close   (9)
       stop
       end
```

A The hydrodynamic model for space

Here I repeat the derivations on page 44 (first page of Appendix F) in physicsideas.com/Paper.pdf with the difference that the integrations over r and t now go from r_0 to r and from t_0 to t, respectively (instead of from 0 as they do in Paper.pdf).

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

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

valid for $r \gg r_0$.

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

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

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 defined as $H = r^{-1}\mathrm{d}r/\mathrm{d}t$. Letting V be the volume of the entire universe (i.e., setting in Eq. (A.2) $\mathrm{d}r/\mathrm{d}t = c$ and $r = R$), the number of particles in the universe is given by

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

From Eq. (A.2), one obtains via integration $\int_{r_0}^{r} r^2\mathrm{d}r = cNr_0^2\int_{t_0}^{t}\mathrm{d}t$, or

$$r^3 - r_0^3 = 3cNr_0^2(t - t_0), \tag{A.4}$$

where t is the age of the universe. Division of Eq. (A.2) by Eq. (A.4) gives $\mathrm{d}r/\mathrm{d}t = (r^3 - r_0^3)/3r^2(t - t_0)$, and, choosing $r = R$,

$$R = 3c(t - t_0) + r_0^3/R^2, \tag{A.5}$$

which implies that, for $R^2 \gg r_0^2$ and $t \gg t_0$, 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. (A.3) and (A.5), it follows that

$$N = (3c(t - t_0)/r_0 + r_0^2/R^2)^2, \tag{A.6}$$

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

References

[1] Stig Sundman, physicsideas.com/Simulation.for.

[2] Stig Sundman, physicsideas.com.

[3] Stig Sundman, physicsideas.com/Dparticle.pdf.

[4] Stig Sundman, physicsideas.com/Paper.pdf.