Errata: A simple model describing a pure QED universe

[physicsideas.com/Paper.pdf (March 11, 2009)]

Stig Sundman

June 27, 2016

(1) Proton parity (bottom of page 41)

Contrary to what is stated on page 41, the antiproton has negative parity.

(2) Higgs contribution to the lepton mass (pages 6, 23, 33-34, 39-44)

The result in Appendix C is wrong: the Higgs boson's contribution to the mass of the charged lepton is positive — not negative. Consequently, the conclusion in Appendix E.8 that the appearance of the heavy Higgs particle causes a decrease in lepton mass and an increase in quark energy is wrong, too. For a correct derivation of the Higgs boson's contribution to the lepton mass, see page 27 below. 27

In phase 3, the mass of the charged lepton (τ, μ, e) is of purely electromagnetic origin, generated entirely by massless virtual photons. When new particles (H, Z^0, ν, $W^{\pm}$) contributing to the mass of the already existing charged lepton appear, the energy of the virtual photons drops so that the lepton's mass remains unchanged as required by the law of conservation of energy. Therefore, when the Higgs first appears, the lepton mass splits into an electromagnetic mass component and a small component generated by virtual Higgs particles, which acquire masses that equal their contributions to the lepton mass [1]:

$$\begin{aligned} m_{H_\tau} &= 0.505 \text{ MeV}, \\ m_{H_\mu} &= 106.085 \text{ eV}, \\ m_{H_e} &= 12.0006\ \mu\text{eV}. \end{aligned} \tag{0.1}$$

Energy is transported from the background radiation to the quarks by the light Higgs (H_τ, H_μ, H_e). After being emitted by the leptons appearing in the propagators of the background photons, the Higgs particles are absorbed by the quarks, which use their energy to build first the pion and later the proton.

Soon after the first appearance of the light Higgs, the heavy Higgs (with mass about 125 GeV) shows up with the task of generating the neutral Z boson's mass (91.19 GeV).

In summary, the simulation of the universe's first femtoseconds suggests that the perfect symmetry of literally nothing is broken by the appearance of the massive, neutral, and spinless Dirac particle — a kind of relativistic harmonic oscillator built up in the time t_c, and attempting to annihilate itself in the same time. Consequently, the lifetime of the D particle equals the initial age of the physical universe, $t_c \approx 10^{-19}$ s.

With a massless expanding universe forbidden by the law of conservation of energy, the unstable matter content of the expanding universe undergoes repeated symmetry-breaking transformations until a stable proton–electron pair ($p\,e^-$) finally appears when the age of the universe is nearly 40 000 t_c, or approximately 4×10^{-15} second:

$$
\begin{array}{ccccccccccccccccc}
D & \rightarrow & \tau_0^+\tau_0^- & \rightarrow & \underline{\mu}_0^+\underline{\mu}_0^- & \rightarrow & \mu_0^+\mu_0^- & \rightarrow & \underline{e}^+\underline{e}^- & \rightarrow & e^+e^- & \rightarrow & HZ\nu W \text{ mechanism} & \rightarrow & p\bar{p} & \rightarrow & pe^- \\
1 & & 9 & & 0 & & 23 & & 0 & & 37\,293 & & 1000 & & 0 & & \infty \\
1 & & 10^2 & & 10^2 & & 10^3 & & 2\times10^3 & & 3\times10^9 & & & & & &
\end{array}
$$

The underlined symbols indicate newborn, "frozen" particles, which immediately turn into dynamically interacting particles. The first row of numbers shows the duration of existence of the particle pairs in units of t_c. The next row indicates the number of particles at the beginning and end of each phase. Thus, phase 1 begins with one D particle and ends with almost 100 photon pairs resulting from tauon-pair annihilation ($\tau_0^+\tau_0^- \rightarrow \gamma_\tau\gamma_\tau$). Phase 2 begins with nearly 100 spinless-muon pairs and ends with about 1000 photon pairs. Phase 3, in turn, begins with about 2000 electron pairs (rematerialized pairwise from pairs of photons: $\gamma_\mu\gamma_\mu \rightarrow e^+e^-\ e^+e^-$) and ends with approximately 3×10^9 background photons (γ).

No transfer of energy or mass takes place in the first three phases. However, the final transition from four mass-bearing electron pairs to one electron–proton pair requires repeated transport of energy from the background photons to the proton-building quarks. This is where the Higgs–neutrino (or $HZ\nu W$) mechanism comes in:

$$
\begin{array}{ccccccccccccc}
e^+e^-e^+e^- & \rightarrow & \underline{\pi}^+\underline{\pi}^-\underline{\pi}^+\underline{\pi}^- & \xrightarrow{H} & \pi_-^+\pi_-^-\pi_-^+\pi_-^- & \rightarrow & \pi_-^+\pi_-^- & \xrightarrow{Z} & \pi_+^+\pi_-^- & \rightarrow & \pi_+^+\pi_+^- & \xrightarrow{\nu W} & p_+\bar{p}_+ \rightarrow p_+e_+^- \\
 & & 0 & & 10^{-5} & & 10^{-5} & & 10^3 & & 10^{-5} & & 10^{-5} \qquad \infty
\end{array}
$$

Again, the numbers indicate time duration, suggesting that the process takes about $10^3\,t_c$, or 10^{-16} second. The uppermost row shows in which reaction each weakly interacting particle first appears.

After the last two electron pairs have transformed into equally heavy "frozen" pion pairs (underlined), the mass (or rest energy — no kinetic energy exists) needed to turn the pions into dynamically interacting physical particles is brought by the Higgs from the background radiation. That is, the Higgs is forced to appear on the scene, extract mass from virtual leptons appearing in the propagators of the background photons, and hand it over to u and d quarks forming four massive real pions.

Within less than 10^{-5} time units t_c (with $t_c \approx 10^{-19}$ s) from its creation, one of the pion pairs annihilates via strong interaction.

After a lapse of another $10^{-5}\,t_c$, the imminent annihilation of the remaining pion pair is prevented by the neutral Z boson (whose mass is generated by the heavy Higgs) coming to the rescue — switching the intrinsic parity (indicated by subscript: $\pi_-^+ \rightarrow \pi_+^+$) of one of the pions, thereby making strong decay of the pair impossible. However, in about $10^3\,t_c$, the weak parity-switching force introduced by the Z causes a second change of pion intrinsic parity, which again enables strong decay of the pion pair.

The comparatively long time ($10^3\, t_c$) that elapses between the two parity-switching events introduces a particle–antiparticle asymmetry (point 4.27 on page 60 in Section G.2) that should reveal itself in various ways, as a kind of "superweak" effect. Presumably, the CP-violating "superweak force" acting in kaon and B-meson decay is a consequence of this matter–antimatter or, more precisely, d–$\bar{d}$ asymmetry.

With the last real pion pair doomed to disappear, its natural replacement is a real proton–antiproton pair. Consequently, the mass transport has to be repeated three more times.

Part of the delivered mass remains unused by the quarks and must be restored to the leptons — the natural alternative in an indeterminate quantum universe where kinetic energy does not exist. The unused mass is returned by spin-$\frac{1}{2}$ neutrinos that, to be able to travel from quarks to leptons, require help of both the Z particle and yet another new type of particle — the charged W boson, with the bulk of its mass generated by the heavy Higgs.

With the matter of the universe concentrated in a single proton–antiproton pair, the pair's annihilation is forbidden by the law of conservation of energy. Therefore, the antiproton is forced to transform into an electron — an event that finally results in a viable world containing stable proton–electron matter. The parity, which the antiproton inherits from the pion, has the wrong sign because protons and antiprotons (appearing as virtual particles at the same time as the real pions are formed) have positive and negative parity, respectively. Therefore, the antiproton's decay does not involve a change of parity, and the fact that the decay takes place does not prove that ordinary antiprotons or protons should be able to decay, too.

The decay of the heavy antiproton into a light electron and radiation gives the electron a high speed. Consequently, it leads to the introduction of kinetic energy and heat, and thereby to activation of the second law of thermodynamics as well as to activation of the gravitational force, which has no role to play as long as the universe remains in an indefinite quantum state, where position, motion, and kinetic energy are not defined.

See page 25 below for a summary of the information about the muon mass 25
that is given by the simulation of the universe's early phases. For a discussion
of the Higgs boson, see page 8. 8

(3) The age of the universe (page 19)

The relation between the Hubble expansion rate H and the gravitational constant G obtained in Section 7 is

$$H = \frac{c}{R} = \frac{32Gm_e}{B^2 r_{cl}^2\, c} = 56.8\ \mathrm{km\,s^{-1}\,Mpc^{-1}}, \qquad (7.17)$$

where R is the "radius of the universe" defined via $H = c/R$. Alternatively expressed,

$$1/H = 17.2 \text{ Gyr}. \tag{7.18}$$

This theoretical result, which is independent of the history of the universe, roughly agrees with the value deduced from observations. However, the theoretically and observationally obtained values are not directly comparable because astrophysicists' assumption that the gravitational force is constant over time by necessity affects distance determination and leads to a corrupted observational value.

> The Chandrasekhar limit is about 1.4 solar masses. This limit, which is proportional to $G^{-3/2}$, specifies the critical mass at which white dwarfs explode and form so-called standard-candle type Ia supernovae used to calibrate distance measurements. Variations in G will cause variations in brightness of the type Ia supernovae and introduce errors in distance measurements if these are based on the assumption that G is constant over time.

On the other hand, the connection $t = 1/H$ shown in Eq. (7.22) is obviously wrong, since it predicts an age of $t = 5.7$ Gyr for the universe, which observations prove cannot be younger than about 13 Gyr.

The reason why the theoretically predicted age differs from the observed age is that so-called primordial black holes (PBHs) appear soon after the first proton–electron pair has formed. The mass trapped in the PBHs is effectively removed from the universe and no longer contributes to its expansion. That is, when the first PBHs appear, the value of the energy $E_r = M_r c^2$ in the equation

$$\frac{\mathrm{d}r}{\mathrm{d}t} = \frac{1}{c}\frac{E_r}{m_0}\frac{r_{0g}^2}{r^2} \tag{5.12}$$

suddenly falls and continues to decrease as the PBHs grow in mass. Consequently, the expansion $\mathrm{d}r/\mathrm{d}t$ of the cosmic sphere containing E_r slows down.

Primordial black holes (pages 26, 27, 54, 61)

At the beginning of the present phase of the universe, the proton and electron take over the role of matter-bearing particles. The electron and two photons, which are created in the forced disintegration of the antiproton, possess kinetic energy, while the proton remains at rest in a calm sea of pairwise entangled photons. The introduction of kinetic energy means that the universe leaves its original state of quantum indeterminacy — a state characterized by undefinable velocities and distances between particles — and enters a state in which particles interact through the long-range gravitational and electromagnetic forces.

The proton forms a heavy "nucleus of condensation" toward which the pairwise entangled background photons fall until they become packed together by gravity into a "primordial black hole" (PBH) that is sufficiently heavy and dense to prevent even massless radiation from escaping.

It is well known that gravitational time dilation has the effect that — in the eyes of a distant observer — processes in an object falling toward a black hole appear to slow down until time stops ticking when the object reaches the surface of the black hole, the so-called event horizon. This fact suggests that a black hole, instead of being the hole in space it is generally believed to be, in reality is a compact object consisting of densely packed particles (in the case of the first PBH, three quarks and a large number of photons) "hibernating" in a frozen, timeless state with their individuality preserved. Also, it is clear that no forces exist inside a black hole because forces are mediated by gauge particles, and exchange of particles (which implies motion of particles) cannot take place in the timeless interior of a PBH.

The gravitational force was originally very strong and a small fraction of the 2786 million photons (see Eq. (E.16) on page 41 in Appendix E8) surrounding the first proton sufficed to build the first PBH.

> The calculations in Section 7 apply to a universe in which no black holes appear. In such a universe, $G \propto 1/t$, and today's gravity corresponds to an age of $t = 1/3H = 5.7$ Gyr. See Eqs. (7.17) and (7.22) on page 19 in Section 7. Division of this age with the age of about 4×10^{-15} s (see page 2 above) when the proton is born and gravity begins to act yields 2
> $5.7 \times 10^9 \times 31\ 557\ 000$ s$/4 \times 10^{-15}$ s $= 4.5 \times 10^{31}$. That is, the gravitational force was originally 4.5×10^{31} times stronger than today.
>
> The simulation (discussed in Appendix F, page 44) of the universe's first phases shows that the average energy of the background photons is $2m_e/10.535 = 97\ 010$ eV (see line following Eq. (E.16) on page 41) when the first proton–electron pair appears and the gravitational force begins to act on particles. The minimum mass of a black hole coincides with the so-called Planck mass,
>
> $$M = \sqrt{\hbar c/G}, \qquad (0.2)$$
>
> where $\hbar = h/2\pi$ is the reduced Planck constant, and h is Planck's quantum of action. Today, $G/\hbar c = 6.708 \times 10^{-39}$ $(\mathrm{GeV}/c^2)^{-2}$, which gives $M = 1.22 \times 10^{19}$ GeV$/c^2$ (equal to 2.2 micrograms).
>
> According to Eq. (E.16) on page 41, there are $N_\gamma = 2.786 \times 10^9$ photons surrounding the original proton–electron pair. With $E_\gamma = 97\ 010$ eV, one obtains $N_\gamma E_\gamma = 2.70 \times 10^5$ GeV for the total energy of the photons. For the proton and electron, together with their surrounding photons, to be able to form a black hole, the initial force of gravity must have been $(M/N_\gamma E_\gamma = 1.22 \times 10^{19}\ \mathrm{GeV}/2.70 \times 10^5\ \mathrm{GeV})^2 = (4.52 \times 10^{13})^2$ $= 2 \times 10^{27}$ times stronger than today. Since the force should have been 22 500 times stronger than that (4.5×10^{31} times stronger than today), and since the background radiation consisted of entangled photon pairs at rest, the logical conclusion is that the photons immediately condensed into a primordial black hole (PBH) with the three quarks (uud) of the proton at its center.
>
> The newborn black hole attempts to grow and swallow as many of the photons surrounding it as possible. However, the gravitational force is

a result of the expansion of the universe. And the expansion, in turn, is caused by elementary particles producing space in proportion to their energy content. The particles swallowed by the black hole are isolated from the outer world, and cannot contribute any more to the universe's expansion. Consequently, the larger the portion of the background photons in the black hole is, the more the expansion and the gravitational force decrease.

If, at a given point of time, there are N photons outside the black hole and $N_\gamma - N$ photons inside it, gravity will be N/N_γ as strong as it was before the PBH formed. When the hole has reached its maximum size, evaporation from it will prevent gravity from weakening any further. The balance condition is

$$(N_\gamma - N)E_\gamma/c^2 = \sqrt{\hbar c/(N/N_\gamma)G_0}. \tag{0.3}$$

With $G_0 = 4.5\times10^{31}\, G$, where G is the present-day gravitational constant, the condition is fulfilled when the ratio N/N_γ has decreased to

$$N/N_\gamma = 0.000\ 045, \tag{0.4}$$

which means that the very first black hole grows until only 45 ppm of the photons remain free outside the event horizon.

Denote $N/N_\gamma = x$ and $E_\gamma/c^2 = M_\gamma$. Write Eq. (0.3) in the form

$$1/x = (1-x)^2(N_\gamma M_\gamma)^2 G_0/\hbar c, \quad \text{or} \tag{0.5}$$

$1/\text{x} = (1-x)^2 \times (2\ 786\ 000\ 000 \times 97\ 010 \times 10^{-9})^2 \times 4.5 \times 10^{31} \times 6.708 \times 10^{-39}$
$= (1-x)^2 \times 2.205 \times 10^4$,
and solve it iteratively with $1 - x = 1$ initially:
$(1-x)^2 = 1$: $1/x = 22\ 050$, $x = 0.000\ 045$, $(1-x)^2 = 0.9999$;
$(1-x)^2 = 0.9999$: $1/x = 22\ 048$, $x = 0.000\ 045$.

The radius $R = c/H$ may be taken to define the radius of the "visible" universe. By definition,

$$H = r^{-1}\mathrm{d}r/\mathrm{d}t. \tag{0.6}$$

According to Eq. (5.12), this means that

$$H \propto E_r/r^3, \tag{0.7}$$

where r is the radius of an arbitrary cosmic volume (V) expanding with the universe, and E_r the active energy in this volume. Since the build-up of the first PBH is a swift process, the simultaneous growth in r is negligible. Consequently, the radius R increases by a factor of about $1/0.000\ 045 = 22\ 000$ during the process. That is, the visible universe, with its matter originally carried by a single proton–electron pair, rapidly "inflates" in size until it contains about $22\ 000^3$, or roughly 10^{13}, identical pairs of positively charged black holes and negatively charged free electrons.

After the appearance of the first PBH and the sudden decrease in E_r and H, the universe forms a calm sea of pairwise entangled photons in which positively charged PBHs are floating. Through this sea, negatively charged electrons are racing. For each electron, there are in addition two free (non-entangled) photons traveling at the speed of light.

As the universe continues its now comparatively slow expansion with E_r in Eq. (5.12) constant, its rate of expansion, $H \propto E_r/r^3$, continues to slow down when r increases. As a result, $G \propto H$ decreases, the minimum black-hole mass $M \propto 1/\sqrt{G}$ increases, and the lightest PBH explodes when its mass falls below M.

The explosion of the PBH leads to a sudden increase in E_r that is accompanied by an equally abrupt increase in H and G. The particles released in the explosion provide food for the remaining PBHs, which grow fatter at the same time as E_r diminishes. As a result, the rate of expansion and the value of G resume their decrease, and the minimum black-hole mass M increases until the lightest of the remaining PBHs becomes supercritical and explodes.

The cycle repeats itself over and over with the result that G continues to decrease until the expansion of the universe has all but stopped, the gravitational force has become even weaker than it is today, and the masses of the PBHs greater than their present minimum mass.

At the beginning of the universe's early epoch characterized by exploding black holes, the repulsive force between PBHs caused by their positive charge outbalances the gravitational attraction between them and keeps them apart. However, sooner or later, a free electron will hit a PBH and merge with it. The resulting neutral black hole will attract neighboring PBHs and, together with them, form a system of black holes orbiting each other.

Black holes circling each other cause tidal effects on their surfaces that enable photons to escape into freedom. The freed particles cause an increase in E_r and an accompanying increase in G that counterbalances its decrease caused by the expansion and the increase in mass of solitary black holes.

The still numerous and densely packed black holes begin to collide and merge with each other. In these collisions, black holes of ever-growing size are produced at the same time as part of their trapped particles are released.

After a time, most of the energy originally contained in PBHs has been freed, and the period of decreasing gravity comes to an end. From now on, E_r in $H \propto E_r/r^3$ grows faster than r^3. As a result, the rate of expansion of the universe increases — the universe "accelerates" — and the force of gravity increases in strength.

Today, the the originally very tiny PBHs have merged into giant black holes at the center of galaxies, and the particles freed in the collisions supply material for the stars of the galaxies.

> Today, collisions between giant black holes are rare because of the large distances between them, but particles in black holes are still continuously being freed in systems where two black holes orbit each other. In contrast, solitary black holes are constantly trapping particles in their immediate vicinity. It seems plausible that more energy is released in the form of photons than is being captured in the form of mostly massive particles. If that is so, G may still be increasing. However, the effect of black holes on the rate of expansion of the universe, and thereby on the strength of

> gravity, will in the long perspective become negligible, and the universe will return to its mode of expansion before the appearance of PBHs — that is, a constantly decelerating expansion with H and G proportional to $1/r^3$.

In the intense flashes of exploding black holes, heavy particles were created that might constitute the unseen so-called dark matter. See discussion about dark matter below. 12

The Higgs particle

In phase 2, the particles of the universe are bosons described by scalar electrodynamics (scalar QED). In the phase transition — enforced by the law of conservation of energy — that terminates phase 2, the mass-bearing particles rematerialize in the form of spin-$\frac{1}{2}$ electrons. This means that the universe of phase 3 is a pure QED world described by spinor electrodynamics (spinor QED). The electron of phase 3 may be envisaged as a hole in space (as suggested by Figure 3.1 on page 9 in Section 3), which gives the particle a "bare mass" of $\delta m = 0$ (as required by the JBW theory mentioned on page 7 in Section 2), and which is surrounded by short-lived virtual photons that provide the electron with a dynamically generated mass.

In the prelude of today's phase 4, the electron mass was split up into a photonic component providing the bulk of the mass and a Higgs component adding a minor contribution to it.

The photon may be regarded as an open, vibrating string with its energy ($E_\gamma = h\nu$) determined by the frequency (ν) of its vibrations.

Now, the Feynman diagrams as well as the principle of maximum simplicity 26, 16
indicate that the photon and the Higgs are closely related. This relationship between the massless spin-1 photon and the massive spin-0 Higgs, together with the fact that the two particles generate the mass of the electron, suggest that the Higgs may be thought of as a photon bent into a ring: a standing wave forming a closed non-rotating string with its frequency of vibration determining its mass.

> The spinning string theory has its origin in Regge pole theory and the Veneziano dual resonance theory. A spinning string is the quantum mechanical counterpart of a classical, extended object. Different vibration modes of the string correspond to resonances with different masses. The string may be closed and rotating.
>
> After its introduction in the 1970s the theory never made any real breakthrough. However, in the 1980s it attracted renewed interest, although this time no longer as a particle theory but as a theory of everything (TOE). The demand that string theory should provide a self-contained TOE — a theory of all particles and all forces — has prevented theorists from attempting to apply it to individual particles such as the Higgs.

The comparison with the photon suggests that the Higgs may carry any mass and energy assigned to it in reactions in which it is created.

When emitted by tauons, muons, and electrons, respectively, it takes on the masses shown on page 1 above. Similarly, when emitted by a W particle, it 1
acquires a mass of approximately $M_{H_W} = 125$ GeV, which is the mass of the heavy Higgs particle that generates the mass of the Z boson and the bulk of the mass of the W boson (which, being electrically charged, also contains a photon-generated mass component).

When created in other reactions, such as photon–photon collisions in the sun, the Higgs may appear in a continuous mass spectrum. See discussion about dark matter below. 12

A look at a listing of Feynman vertices shows that the Higgs mimics the 26
photon in its interaction with matter (electrons and down and up quarks). The only visible difference between vertex 1 and vertex 2 in the listing is that the massless photon boson is designated by a thin line, and the mass-carrying Higgs boson by a thick line.

This observation has interesting implications. An electron may, without violating the laws of nature, permanently emit a photon. In contrast, an electron that emits a Higgs particle loses mass that it must — forced by the law of conservation of mass — recapture within a time Δt determined by the Heisenberg uncertainty relation

$$\Delta E \, \Delta t \geq \frac{1}{2}\hbar, \tag{0.8}$$

which in the present case may be replaced by $\Delta E \, \Delta t = \hbar$ with $\Delta E = m_H c^2$. (Compare with the relation $\Gamma\tau = \hbar$, which connects the so-called decay width Γ of an unstable particle to its lifetime τ.)

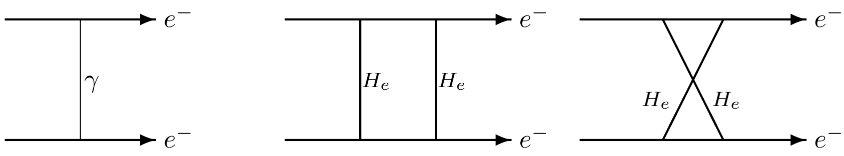
A consequence of this observation is that a Higgs particle cannot decay into a pair of real electrons ($e^- e^+$). However, nothing prevents the Higgs from annihilating through a virtual electron loop (a short-lived $e^- e^+$ pair).

Similarly, a Higgs cannot decay into a pair of quarks (that is, a neutral pion, π^0), but it may annihilate through a quark loop, such as a $d\bar{d}$ loop.

A comparison between the Higgs and photon Feynman diagrams suggests that the Higgs-mediated force between two charged particles is repulsive, independent of the signs of the charges, whereas the photon-mediated electromagnetic force is attractive or repulsive depending on whether the charges are of opposite or equal sign, respectively.

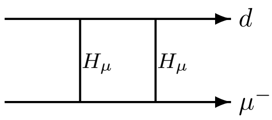
The fact that no repulsive electric (i.e., static) force attributable to the Higgs has been observed means that the Higgs-mediated force is of a purely dynamic nature, presumably resembling the photon-mediated magnetic force generated by an electric current flowing through a copper coil. Thus, the magnetic Higgs force will mainly affect particles orbiting each other at relativistic speeds.

The lowest-order diagrams for electron–electron scattering illustrate the difference between the electromagnetic force (left) and the Higgs force (middle and right with the crossing Higgs lines not touching each other):

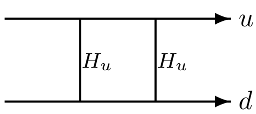


Since the law of conservation of mass forbids a permanent exchange of a single Higgs particle between two electrons, there is no Higgs parallel to the first-order photon-exchange diagram to the left in the figure.

Similarly, the repulsive quark–muon force — that presumably is responsible for the proton radius discrepancy [5] — is described to the lowest order by diagrams such as:



The repulsive force between quarks, which may lie behind a number of hitherto unexplained so-called anomalies in nuclear physics [1], is described to lowest order by diagrams such as:



The strength of the Higgs–fermion interaction is proportional to the mass of the fermion (see 2, 6, and 7 in the list of vertices). Since the lowest-order diagrams 26
describing the magnetic Higgs force between two fermions (f_1 and f_2) contain four vertices (are said to be of second order), the Higgs force is proportional to the fourth power of the mass of the fermion with which the virtual Higgs boson of the Feynman diagram is associated (say, $F_H \propto m_{f_1}^4$).

This fact suggests that the Higgs force between light and relatively slow-moving electrons in atoms is too weak to be experimentally detected. Most clearly the consequences of the repulsive magnetic force are expected to show up in protons and neutrons in which distances are short and the quarks orbit each other at relativistic speeds.

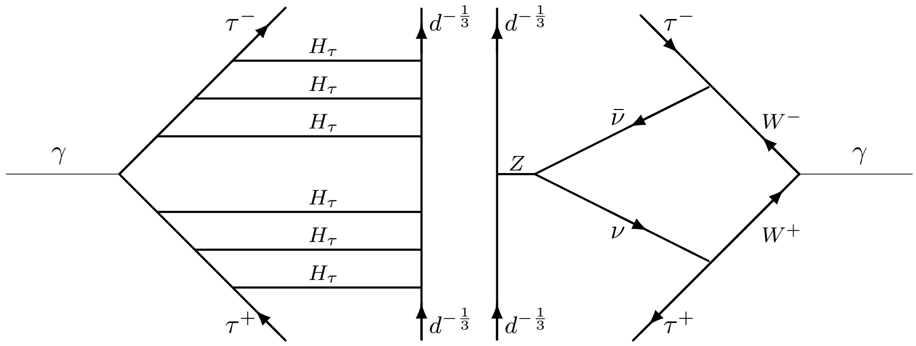
The neutrino

The simulation of the evolution of the universe during its first few femtoseconds reveals that the Higgs boson transported energy from background photons to quarks, while the neutrino fermion transported unused energy from the quarks back to the photons.

The fact that the two particles performed similar tasks suggests that the neutrino is closely related to the Higgs particle and consequently may be imagined as a rotating Higgs ring with its spin of $\frac{1}{2}\hbar$ originating from its rotation.

If that is so, the neutrino should, in analogy with the Higgs, be able to bear any mass and energy that is assigned to it in the reaction in which it is created. Compare with the discussion about dark matter below. 12

The figure illustrates transport of mass from a tauon loop to a down quark and the subsequent return of excess energy from the quark to a tauon pair:



A puzzling question remains. How is the neutrino formed that returns the unused energy to the photon from which it was borrowed? To be able to give over its energy load (which, according to Eq. (E.9) on page 39 in Appendix E.8, is equivalent to 0.128 times the mass of the corresponding Higgs particle) to the photon, this particular neutrino must be able to interact with all three charged leptons (τ, μ, and e) via the reactions $\tau + \nu \rightarrow W$, $\mu + \nu \rightarrow W$, and $e + \nu \rightarrow W$, respectively.

Observations show that neutrinos created in the sun in the form of electron-state neutrinos (ν_e) may transform into muon-state (ν_μ) or tauon-state neutrinos (ν_τ) on their way to the earth.

Might it be possible that the vibrational frequency of the closed neutrino string determines which one of the charged leptons it interacts with through mediation of a W, and that this frequency continuously varies? If that is so, the rotation of the string must vary, too, for the mass and spin angular momentum of the neutrino to be conserved.

Dark matter

The Higgs boson is unstable and annihilates through virtual vacuum-polarization loops, such as:

In opposite reactions, Higgs particles may be created from colliding photons. Heavy Higgs particles have a very short lifetime, while the lifetimes of particles of vanishingly small masses tend to infinity [1].

During the universe's early epoch characterized by exploding black holes, very light Higgs particles may have been produced in large numbers, and many of them may still exist. Unlike background photons and neutrinos that have decoupled from matter, the Higgs particles continue to interact with matter and acquire the temperature of their surroundings. In spite of their vanishingly small mass, the long-lived Higgs particles may, therefore, carry comparatively high energies. Consequently, it cannot be excluded that these weakly interacting massive particles (WIMPs) constitute a considerable part of the dark matter of the universe.

Heavy so-called sterile neutrinos may have been produced in large numbers in the intense radiation of exploding primordial black holes. Due to the expansion of the universe, these WIMPs have lost practically all of their initial kinetic energy, which means that most of them by now have been trapped by gravity and accumulated in galaxies and clusters of galaxies in which they may form the bulk of the dark matter that astrophysicists have been looking for [1].

Summary of the maximally simple model (MxSM)

1.1. The maximum simplicity principle (MxSP) is used as the leading guideline in the development of a maximally simple model (MxSM) of the universe. For a discussion of the principle of maximum simplicity, see Appendix E.1 (p. 35).

1.2. Observations show that the universe is expanding. According to MxSM, the expansion of the universe implies that the total number of particles (N) it contains are increasing as well.

1.3. Extrapolating the expansion backward in time, one ultimately reaches the "time of creation" (t_c), when $N = 1$ and the universe consists of a massive, neutral spin-0 boson that (being alone) cannot possess kinetic energy or temperature.

1.4. This is the only possible beginning of a universe that obeys the principle of maximum simplicity because other values of N generate questions without simple, unequivocal answers.

1.5. There is but one plausible candidate for the first particle: the "D particle" described by Paul Dirac in 1971. See page 5 in Section 1 and page 47 in
Appendix F. Also, see PIECE 2 below. 17

1.6. The D particle is unstable with a lifetime τ that, as required by MxSP, has to be $\tau = t_c$. This equality also follows from the properties of the D particle
(see page 1 above). 1

1.7. Simplicity requires that the law of conservation of momentum, which has proved its general validity in many ways, should be universally applicable. That is, this law should apply, not only to elementary particles, but also to space itself.

1.8. Thus, when the momentum equation (which is also known as the fundamental hydrodynamic equation) is applied to space, it leads to a very simple model of a stationary elementary particle. Although this model cannot describe the dynamically interacting particles of the real world, it may be used to picture particles at the exact moment of their first appearance; that is, before they begin to interact with neighboring particles.

1.9. The applicability of the model is demonstrated by the fact that the numerical constant B (see page 24 below), which characterizes the static model of the 24
electron, provides the basis (in combination with the fine-structure constant α)
for the theoretically obtained value of the muon–electron mass ratio (page 25 25
below).

1.10. Remarkably, the model furnishes a simple explanation of why the universe is expanding: energy creates space. And, even more remarkable, it shows that the gravitational force is but a side effect of the creation of space caused by individual particles combined with the unperturbable overall expansion that results from space created by the totality of particles in the universe. Thus, gravity's pull on neighboring particles must be compensated for by its push on distant particles. Or, expressing it differently, assuming all particles are evenly distributed throughout the universe, the total gravitational force (resulting from all particles in a solid angle) that acts on a given particle must by necessity be zero. See the thick line in Figure 5.1 on page 14 in Section 5.

2.1. Simplicity requires that the law of conservation of energy holds true. This law forbids the existence of a purely radiative, expanding universe. Consequently, when the D particle's last massive decay product — a pair of entangled, charged spin-0 bosons possessing the same lifetime $\tau = t_c$ as its predecessor — annihilates, the law of conservation of energy forces the radiation to materialize and form pairs of entangled, charged spin-0 bosons similar to the pairs created in the decay of the D particle.

2.2. The particles of phase 2 are described by the Feynman diagrams and rules of scalar electrodynamics (scalar QED).

3.1. When the last pair of massive particles annihilates at the end of the universe's phase 2, history repeats itself with the difference that the rematerialized particles inhabiting the universe's phase 3 have acquired spin and appear, not as pairs, but as pairs of pairs of ordinary spin-$\frac{1}{2}$ electrons ($e^+e^-\ e^+e^-$).

3.2. At the exact instant of its rematerialization, the electron is pictured by Eq. (3.3) on page 9 in Section 3. When this initially static particle immediately turns into a dynamically interacting particle, its spin, charge, and mass are conserved, which means that the results obtained from calculations based on Eq. (3.3) continue to hold true.

3.3. The universe of phase 3 is a pure QED world described by the well-known Feynman diagrams and rules of spinor electrodynamics (spinor QED).

3.4. This universe remains in an indeterminate quantum state, which means that distances between particles are undefinable, and the gravitational force still inactive.

4.1. If history had repeated itself once more, all electron pairs would have annihilated, and a fourth generation of electron-type particles (that is, electrically charged leptons) would have been created. Evidently, this was not a viable alternative because the unstable electron–positron pairs, which acted as bearers of matter in phase 3, were instead replaced by stable electron–proton pairs.

4.2. The replacement of the positron with a proton was a rather complex process, which required help from a number of auxiliary, weakly interacting particles that had to be created specifically for this purpose. See summary of the Higgs–neutrino mechanism in the middle of page 2 above. 2

4.3. After the law of conservation of energy had forced the antiproton to decay and the universe to leave its initial state of quantum indeterminacy and position undefinability, the proton became a nucleus of condensation around which the first primordial black hole began to form.

4.4. This event signaled the beginning of a long "black interlude" in which PBHs played the dominating role. Today we can see the result of their interactions with each other and with the electrons they were unable to capture.

> Note that hot big bang's (HBB's) initial, mathematically unspecifiable, swarm of immensely hot particles is in the present maximally simple model (MxSM) replaced by a lone, temperatureless, and mathematically well-defined primeval particle. HBB's rapid inflation of the universe to enormous proportions followed by a sudden return to "normal" expansion is in MxSM replaced by an abrupt retardation of the expansion followed by a period in which the expansion is very slow before it again accelerates, the photons decouple from matter, and the first generation of stars ignite.

The pieces of the puzzle

The simple model of the universe presented here is based on equations and principles in physics that have been known for a long time. No new pieces of the physics puzzle have been introduced. Instead, existing (but sometimes forgotten) pieces are fitted together in a new way.

Among the fundamental questions a sound theory of cosmology should be able to answer are:

1. *What is the universe like at the exact instant of its birth?*
2. *How long did it take the universe to come into being?* (*)
3. *What makes the universe expand?* (*)
4. *What is the cause of the gravitational force?*
5. *Why is the universe a quantum world?*
6. *Why does the electron come in three mass states?*
7. *Why are there three forces in addition to gravity?*
8. *Why is there more matter than antimatter?*
9. *How were giant black holes formed?*

(*) In big-bang theories, questions 2 and 3 are replaced with: *What fueled the initial explosion (the hot big bang)?*

PIECE 1. The maximum-simplicity principle (MxSP).

The term "principle of maximum simplicity" was coined by James Bjorken and Sidney Drell on page 95 in their epoch-making book, "Relativistic Quantum Fields", published in 1965. On page 94, the authors write: "We use simplicity as a final although less physical guide"; and on page 96: "Experiment and simplicity are our main guides in constructing interactions". However, the effort to picture the world in as simple terms as possible is much older than that. For instance, the Ptolemaic cosmology was an attempt to describe the movements of the planets in a way that could be easily understood.

Perhaps simplicity's most beautiful triumph took place when the Ptolemaic cosmology was replaced with Newton's gravitational potential $U = -MG/r$, which was believed to provide a perfect description of the orbits of celestial objects.

> Note that Newton's well-known equation for the force (F) between the mass M and another mass (m) is m times the derivative of the gravitational potential of M. That is, $F = mdU/dr = mMG/r^2$, where the masses M and m are pointlike or, alternatively, spherically symmetric.

In its ultimate interpretation, MxSP requires that the universe in every phase of its development is maximally simple. The most important consequence of

MxSP is that the world can be understood, which in practice means that it can be logically and consistently described in mathematical terms. MxSP demands that one should try to find a maximally simple explanation to a given phenomenon. That is, using Occam's razor one should cut away all assumptions that are not absolutely essential. Thus, the principle says that one should not make more assumptions than are necessary to describe things; for instance by not introducing more forces than necessary.

PIECE 2. The *D* particle.

In 1971, Paul Dirac published an equation for which no use was found, and which soon fell into oblivion. It formally resembles his relativistic wave equation for the electron of 1928, which today is referred to as Dirac's Equation. In its simplest form, Dirac's forgotten equation describes a massive, neutral, and spinless particle (here referred to as the "*D* particle"). The properties of this maximally simple object make it the ideal candidate for a newborn material universe. Thus, the answer to the first of the previously listed questions is: 16

1. At the exact instant of its birth, the universe is mathematically described by Dirac's equation of 1971.

The *D* particle may be regarded as a relativistic harmonic oscillator, which suggests that it takes one upward oscillation to build the particle. Consequently, the universe is born at the "time of creation" (t_c), which is determined by the frequency of "Dirac's oscillator" and defines the basic universal time unit. Thus, the answer to the second question is:

2. It took the universe one universal time unit, t_c, to come into being.

> After all pieces of the puzzle have been fitted together, t_c is seen to be about 10^{-19} s.

PIECE 3. The flow equation.

A critical piece of the puzzle is the "flow equation", which describes the motion of fluids. Its use in weather forecasting and other areas of the physical sciences makes it one of the world's most exploited equations.

MxSM starts by demonstrating that the flow equation may be written without referencing pressure or temperature, or any other variables related to molecules in the fluid it describes. Assuming that the flow equation in this "pressureless" form can be applied to space, its straightforward interpretation suggests that it may be used to model a stationary particle equipped with spin and electric charge — a kind of "space whirl", which may be identified with the electron. Interestingly, the same equation suggests that the depicted particle generates space that flows out from its interior, thus providing a natural explanation for why the universe is expanding. And, even more remarkable, when the flows of space from two particles are combined with the universe's overall expansion, the two particles are attracted to each other by a force that may be identified with the force of gravitation.

In summary, the "pressureless space equation" has a solution that may be used to model a charged spinning electron contributing to a universal expansion that causes a gravitational force. Thereby, the second piece of MxSM answers two of cosmology's fundamental questions:

3. Particles create space and thereby make the universe expand.

4. The gravitational force is caused by the universe's expansion.

The fact that the equation used to describe space (the "space equation") does not contain references to molecules, or "points" — space is "pointless" — means that there is no way in which position in empty space can be defined.

This observation necessitates the introduction of a fourth piece that explains the quantum nature of the universe — a piece that theoretical physicists have managed to close their eyes to for over a century:

PIECE 4. Pointless space.

Space is pointless. That is, space is a physical reality, not a mathematical abstraction. The nonexistence of "space points" implies undefinability of position, distance, direction, and size. For instance, the electron should not be viewed as a point particle, but as a particle that possesses internal structure but nonetheless lacks any definitive size due to the undefinability of distance in space.

In short, a pointless space is equivalent to a quantum world. Thus, the answer to the fifth question is:

5. The universe is a quantum world because position in space is undefinable.

PIECE 5. The principle of conservation of energy.

Thanks to the constraints imposed by the law of energy conservation, it is possible to mathematically describe physical processes and predict their outcome. Without energy conservation, the world would be chaotic — there would be neither chemistry nor theoretical physics.

When the energy principle is applied to local processes studied in laboratories, the result is the familiar "local picture" of the world in which particle lifetimes and the speed of light are constant.

In contrast, when one applies the energy principle to a volume (V) expanding with the universe, it results in a "global picture" of the world in which particle lifetimes and the speed of light (c) grow with time. In this picture, the rest energy (Mc^2) of the massive particles (with total mass M) in the volume V (which might be, for example, a group of galaxy clusters) grows to compensate for the energy loss suffered by the volume's free radiation, which is stretched and "redshifted" by the expansion.

> Take a given distance d to be $d = c\tau$, where τ is the lifetime of a radioactive isotope. In the local picture, d is constant in time. In the global picture, where τ and c grow with time, d instead increases over time. In a classical world, the two pictures are mutually exclusive. However, in our quantum universe, there is no conflict between the two pictures. This is so because position and distance are not definable in a space lacking reference points. See discussions under PIECE 3 and PIECE 4. 17, 18

The constraints imposed by global energy conservation have far-reaching consequences because they lead to the conclusion that an expanding universe in which the last massive particles have decayed into radiation (resulting in a purely radiative universe) is forbidden by the law of energy conservation. (This is because, in the case of a purely radiative universe, the massless electromagnetic radiation is redshifted as the universe expands, resulting in a universal decrease of energy with time.) Consequently, the law forces the radiation to rematerialize. A computer simulation of the evolution of the early universe shows that three rematerializations have taken place. Therefore, the answer to the sixth question is:

6. The three mass states of the electron are the result of early phase transitions in which the law of energy conservation forced the universe's radiation to rematerialize.

Further, the simulation explains why the electromagnetic, strong, and weak forces successively appear in the originally force-free universe. Thereby it answers the seventh question:

7. Why are there three forces in addition to gravity?

> Note that forces are carried by particles (such as photons). Consequently, in a universe consisting of a single D particle, forces cannot exist because force-carrying particles do not exist.

Finally, the simulation shows that the universe's present phase (phase 4) begins when the law of conservation of energy forces the negatively charged antiproton to decay into an electron and radiation. In this "nuclear big bang", the matter-antimatter (proton-antiproton) symmetric universe is transformed into a universe built from matter (proton and electron) with no antimatter present. Thus, the simulation answers the eighth question:

8. Why is there more matter than antimatter?

PIECE 6. The standard model of particle physics (SM).

The standard model, as framed by the Feynman diagrams and rules, makes it possible to calculate the interactions of all presently existing elementary particles. For it to be able to describe all particle interactions that have taken place since the birth of the universe, Dirac's forgotten equation should be included as part of SM.

PIECE 7. The JBW finite QED theory.

The JBW finite QED theory, also referred to as pure QED (where QED stands for quantum electrodynamics), was developed in the early 1960s by Kenneth Johnson, Marshall Baker, and Raymond Willey; it is sometimes called the Johnson–Baker–Willey model of QED or simply the JBW theory. It makes the divergent (or infinite) "renormalization constants" appearing in QED finite. In particular, the JBW theory states that the so-called bare mass (m_0) of the electron is zero, which means that the electron's mass (m) is of purely dynamic origin and equals its self-mass (δm) created by virtual particles surrounding its empty interior — a hole in space. As a result, the ratio $m(H)/m(\gamma)$ of the contributions of Higgs particles and photons to the electron mass, m, can be calculated and the Higgs particle's contribution, $m(H)$, determined.

The simulation program shows that $m_H = m(H)$ must hold. That is, the mass, m_H, of the Higgs particle appearing in the electron's self-mass Feynman diagrams equals the particle's contribution to the electron mass. It turns out that m_H is very small, which means that the heavy Higgs boson observed in CERN's LHC (Large Hadron Collider) experiment is accompanied by three similar, but very much lighter, Higgs bosons — one for each electron generation (e, μ, τ).

What the maximally simple model predicts

The maximally simple model (MxSM) of particle physics leads to many predictions, of which some should be relatively easy to check [1].

The most interesting result is the theoretically calculated muon–electron mass ratio of $(m_\mu/m_e)^{\text{th}} = 206.768\ 283\ 185(78)$, which is generally believed to 25
be incalculable even in principle. Since the value agrees with the experimentally measured value of $m_\mu/m_e = 206.768\ 2823(52)$, it constitutes a successful postdiction of MxSM. In addition, being 67 times more precise than the experimental value, it predicts the outcome of more accurate experiments that hopefully will be performed in the future.

Another result of great theoretical interest is the superweak effect mentioned on page 3 above. It reveals itself in the form of a discrepancy presented 3
in Eq. (E.17) on page 41 in Appendix E.8. As concluded in the discussion on pages 41–43, the superweak force is caused by a small particle–antiparticle asymmetry that arises in the brief "pion parenthesis" that precedes the present "proton–electron phase". The information provided by the simulation program should enable theorists to predict the magnitude of the particle–antiparticle asymmetries occurring in the decay of mesons containing a down quark or one of its heavier counterparts (strange or bottom quark).

> Maybe the observed matter-antimatter asymmetry can be explained as follows. Let E_{π^+} be the rest energy of the pion when a parity-switching force, f_{π^+}, causes it to flip its intrinsic parity ($\pi^+_- \rightarrow \pi^+_+$). Denote by E_{π^-} and f_{π^-} the corresponding rest energy and force when a little later the antipion flips its parity ($\pi^-_- \rightarrow \pi^-_+$). As mentioned on page 41 in Appendix E.8, the pion rest energy grows by about 1 % (a factor of 0.010) during the time interval between the two parity-switching events. Thus, $E_{\pi^-} > E_{\pi^+}$, which means that
>
> $$f_{\pi^+}/E_{\pi^+} > f_{\pi^-}/E_{\pi^-} \tag{0.9}$$
>
> holds if the force remains constant ($f_{\pi^-} = f_{\pi^+}$) or increases at a slower rate than the rest energy does. Interpreted in the local picture, where particle rest energy is constant, Eq. (**??**) implies that $f_{\pi^+} > f_{\pi^-}$. Therefore, one expects that $f_{\bar{K}^0} > f_{K^0}$, since both π^+ and $\bar{K}^0$ contain a positively charged down antiquark. Consequently, the antikaon should transform into a kaon more often than the kaon transforms into an antikaon.

Of more immediate and practical interest is the model's prediction that the dark matter of the universe consists of weakly interacting massive particles (WIMPs) in the form of long-lived, practically massless Higgs particles and heavy sterile neutrinos, which are expected to contribute the bulk of the dark matter.

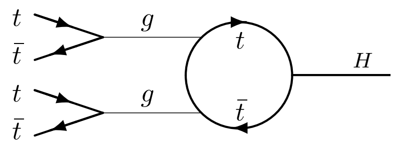
Collisions between sterile neutrinos may explain puzzling observations of x-ray and gamma radiation emanating from the center of the Milky Way galaxy.

Also, the prediction of MxSM that the Higgs particle may carry any mass it receives in a reaction between particles suggests that very heavy Higgs particles should show up in high-energy experiments.

And indeed, on 15 December 2015, a surprising discovery was announced by CERN. A 750-GeV boson, six times heavier than the 125-GeV Higgs boson discovered a few years earlier, had very likely been observed through its decay into a pair of photons, a so-called diphoton:

> "Tuesday, 15 December 2015 — A new boson at 750 GeV?
> ATLAS and CMS presented today a summary of the first LHC results obtained from proton collisions with 13 TeV center-of-mass energy. The most exciting news was of course the 3.6 sigma bump at 750 GeV in the ATLAS diphoton spectrum, roughly coinciding with a 2.6 sigma excess in CMS."

Since MxSM allows Higgs particles of any mass to exist, the observation may have a simple explanation: in the experiment, a tetraquark consisting of two top–antitop pairs is occasionally produced. It rapidly decays into a pair of gluons ($t\bar{t}\,t\bar{t} \to gg$), which through a virtual quark loop decays into a Higgs particle:



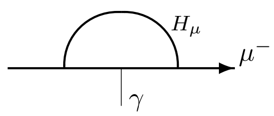
Next, the Higgs annihilates into a pair of photons through a virtual W or fermion (most likely, top) loop.

Note that the value 750 GeV/4 = 187.5 GeV agrees with the mass of the top quark whose measured value is reported to lie in the vicinity of 186 GeV.

If the explanation is correct, one might expect similar bumps to show up near 17 GeV and 5 GeV that — since the masses of the bottom and charm quarks are around 4.3 GeV and 1.3 GeV, respectively — should be the approximate energies of the $b\bar{b}\,b\bar{b}$ and $c\bar{c}\,c\bar{c}$ tetraquarks.

In an article titled "A light Higgs particle explains physics mysteries" [1], I list seven puzzling observations that might be explained by the existence of the light virtual Higgs boson predicted by MxSM.

Strong support for the existence of a Higgs particle that is lighter than the muon (with a mass of $m_\mu = 105.6584$ MeV) and interacts with muons comes from the "muon $(g-2)$ experiment" at Brookhaven, which was performed in the years from 1997 to 2001. In this experiment, physicists measured the anomalous magnetic moment of the muon, to which the Higgs contributes a small correction through the Feynman diagram:



If the Higgs particle (H_μ) appearing in the diagram is light ($m_{H_\mu} \ll m_\mu$), the difference between experimental and theoretical values lie well within the margin of error. If instead H_μ is heavy ($m_{H_\mu} \gg m_\mu$), maybe identical to the observed 125-GeV Higgs, the discrepancy between experimental and theoretical values is 3.5 times the error margin.

Another puzzling effect, the so-called flyby anomaly, may be explained by H_e particles of mass 12 μeV appearing in radio signals of frequency near $\nu =$ 2.9 GHz, which corresponds to a photon energy of $E_\gamma = h\nu = 12$ μeV. Since much information has already been gathered about this effect, physicists with access to the material should be able to check whether the explanation proposed by MxSM is plausible or not.

Most clearly the Higgs force is expected to show up in atomic nuclei. Thus, it may explain unexpected results in measurements of the proton's spin, the nucleon's magnetic moment, and the proton radius.

In addition, the article [1] lists several observations that might be explained by the appearance of real Higgs particles. To these belong the neutron lifetime discrepancy, the tritium endpoint anomaly, and the high temperature of the sun's corona.

In summary, MxSM provides a highly successful model of the early universe — at least if one compares it to the hot-big-bang model, which is unable to answer even one of the questions posed on page 16 above. 16

What the flow equation reveals about nature

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

Flow equation for a nonviscous
fluid in the absence of external forces

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

The **pressureless** form of the flow equation

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

A pressureless **stationary** solution

characterized by

$\underline{B = 0.666\ 001\ 731\ 498}$

No pressure = no heat = no molecules = no reference points
= position, distance, and direction undefinability
= quantum indeterminacy

$f = 3$: charge e, energy $E = mc^2$
$f = 2$: spin $\frac{1}{2}\hbar$, magnetic moment
$f = 1$: expansion with $dV/dt \propto E$, gravitation with $U = -Gmr^{-1}(1 - r^2/R^2)^{-1}$

Secrets revealed by the muon–electron mass ratio

Let V be an arbitrarily large volume that coexpands with the universe. Denote by E the total energy of the particles within the volume. Leaning on two assumptions,

$$\mathrm{d}V/\mathrm{d}t = \text{constant} \quad \text{and} \quad E = \text{constant},$$

the universe's evolution may be simulated. Two measured mass ratios,

$$m_\tau/m_\mu = 16.8183(27) \quad \text{and} \quad m_\mu/m_e = 206.768\,2823(52),$$

are used to check and calibrate the simulation. With the help of data produced by the simulation, a theoretical value is obtained for the latter ratio:

$$(m_\mu/m_e)^{\text{th}} = 206.768\,283\,185(78),$$

which is nearly two orders of magnitude more precise than the experimental value used in the calibration. The muon–electron mass ratio contains detailed information about the history of elementary particles:

$$m_\mu/m_e = 205.759\,223 + 1.009\,816 - 0.000\,208 - 0.000\,623 + 0.000\,074 = 206.768\,283$$

1966

$1/B\alpha = 205.759\,223$ is the basic ratio. In it, $B = 0.666\,001\,731\,498$ characterizes the simplest possible solution to the pressureless form of the momentum equation, while α is the fine-structure constant with $1/\alpha = 137.035\,999\,084(51)$.

2007

The contribution $1/(1 - 2B\alpha) = 1.009\,816$ to the muon mass derives from photons that materialize when the spinless muon is succeeded by the spinning electron as bearer of the universe's mass.

1999

The small negative correction ($-0.000\,2076$) to the mass ratio is a result of the Higgs appearing and conveying mass from the virtual charged leptons $\tau^\pm$, $\mu^\pm$, and $e^\pm$ (which appear in the background photon propagators) to the real quarks forming two pion pairs ($\pi^+\pi^-\ \pi^+\pi^-$) that replace the last decaying electron pairs ($e^+e^-\ e^+e^-$).

2008

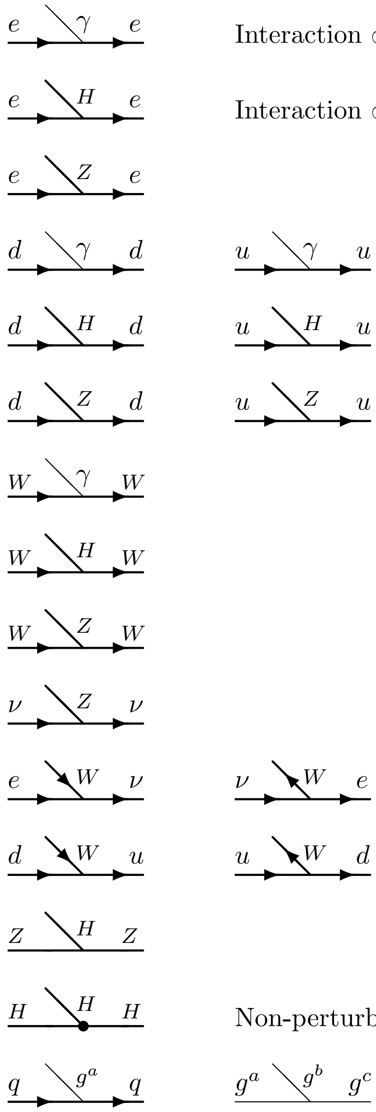
The second negative correction ($-0.000\,6228$) to the mass ratio is a result of Higgs particles conveying three times more mass from the leptons to the quarks when the last decaying pion pair ($\pi^+\pi^-$) is replaced by a proton pair ($p\bar{p}$).

2008

The mass brought by the Higgs particles is more than the quarks need to build the proton pair. The neutrino restores the excess mass to the leptons.

Feynman vertices in the standard model

The three-legged ghost-free vertices of SM are [6]:



1 — Interaction $\propto \sqrt{\alpha} \propto e$

2 — Interaction $\propto m_e$

3

4, 5 — Interactions $\propto \sqrt{\alpha} \propto e$

6, 7 — Interactions $\propto m_d,\ m_u$

8, 9

10

11

12

13

14, 15

16, 17

18

19 — Non-perturbative for large M_H

20, 21 — Quark–gluon, gluon–gluon interactions

Right-pointing arrows indicate particles (W^+, e^-, d, u, and ν). Similarly, left-pointing arrows are used to indicate antiparticles (W^-, e^+, $\bar{d}$, $\bar{u}$, and $\bar{\nu}$), which may be regarded as particles moving backward in time.

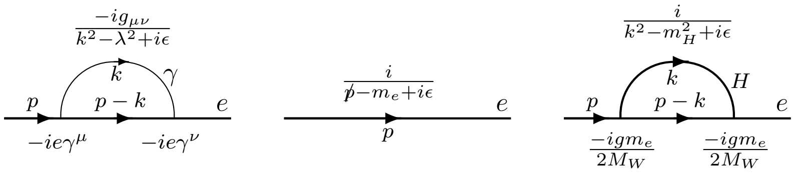
Calculation of mass correction

The expression for the second-order photon and Higgs contributions to the lepton mass,

$$\delta m^{(2)}(\gamma) + \delta m^{(2)}(H) = \ln \frac{\Lambda}{m} \left(\frac{3\alpha}{2\pi} - \frac{3G_F m^2}{8\sqrt{2}\pi^2} \right) m, \tag{0.10}$$

obtained in Appendix C was derived in an indirect way that requires knowledge of the Feynman-parametric formulation of QED [2], which was developed by Toichiro Kinoshita and Predag Cvitanović in 1974. To understand how Eq. (0.10) may be obtained from first principles — that is, from the Feynman rules of SM — one must take a look at these rules.

In the figure, the propagators for the photon, electron, and Higgs are shown above their corresponding particle lines, while the expressions for the photon–electron and Higgs–electron vertices are shown below the electron line:



The notation follows the convention established by James Bjorken and Sidney Drell in the first [3] of their two standard-setting textbooks on quantum field theory (QFT) published in 1964 and 1965, respectively.

Thus, in Feynman's slash notation, $\not{p}$ is the inner product of the four vector γ and the four momentum p, or

$$\not{p} = \gamma \cdot p = \gamma^\mu p_\mu = \gamma_\mu p^\mu, \tag{0.11}$$

where the convention of summing over repeated indices is used (e.g., $\gamma^\mu p_\mu = \gamma^0 p_0 + \gamma^1 p_1 + \gamma^2 p_2 + \gamma^3 p_3$). For the time component of a four vector such as p, it holds that $p^0 = p_0$, and for its space components, $p^i = -p_i$ ($i = 1,\ 2,\ 3$). The components p_1, p_2, and p_3 form the momentum vector $\boldsymbol{p}$. The same rules apply to the four vector γ ($\gamma^0 = \gamma_0$ and $\gamma^i = -\gamma_i$ with $(\gamma_1,\ \gamma_2,\ \gamma_3) = \boldsymbol{\gamma}$).

The arrows shown in the figure indicate four momentum — p for the electron, and k for the photon and Higgs. The indices μ and ν indicate that summation over photon and electron polarizations must be performed for the photon–electron loop, while no similar summation is needed for the Higgs–electron loop (the reason for the difference being that the photon is a spin-1 boson and the Higgs a spin-0 boson). For computational reasons, the photon is attributed an infinitesimal mass (λ) that is set equal to zero in final results.

Moving clockwise around the loops and multiplying the expressions with each other, compare with Eq. (8.34) in Ref. [3], one obtains for the integrand associated with the left (photon–electron) loop,

$$I(\gamma) = \frac{-ig_{\mu\nu}}{k^2 - \lambda^2 + i\epsilon} \left(-ie\gamma^\nu\right) \frac{i}{\not{p} - \not{k} - m_e + i\epsilon} \left(-ie\gamma^\mu\right), \tag{0.12}$$

and for the integrand associated with the right (Higgs–electron) loop,

$$I(H) = \frac{i}{k^2 - m_H^2 + i\epsilon}\left(-ig\frac{m_e}{2M_W}\right)\frac{i}{\not{p} - \not{k} - m_e + i\epsilon}\left(-ig\frac{m_e}{2M_W}\right). \quad (0.13)$$

The symbol $g_{\mu\nu}$ appearing in the photon propagator is given by the 4×4 matrix [3, p. 281]

$$g_{\mu\nu} = g^{\mu\nu} = \begin{bmatrix} 1 & & & \\ & -1 & & \\ & & -1 & \\ & & & -1 \end{bmatrix},$$

where only the nonzero elements of the matrix are explicitly shown. Similarly, the components of the four vector γ are the Dirac matrices [3, p. 282]

$$\gamma^0 = \begin{bmatrix} 1 & & & \\ & 1 & & \\ & & -1 & \\ & & & -1 \end{bmatrix}, \gamma^1 = \begin{bmatrix} & & & 1 \\ & & 1 & \\ & -1 & & \\ -1 & & & \end{bmatrix}, \gamma^2 = \begin{bmatrix} & & & -i \\ & & i & \\ & i & & \\ -i & & & \end{bmatrix}, \gamma^3 = \begin{bmatrix} & & 1 & \\ & & & -1 \\ -1 & & & \\ & 1 & & \end{bmatrix}.$$

The fundamental property of the γ matrices is the anticommutation relation

$$\gamma^\mu\gamma^\nu + \gamma^\nu\gamma^\mu = 2g^{\mu\nu}, \quad (0.14)$$

that is, $2g^{\mu\nu}I$ with the unit matrix I not explicitly shown.

From (0.14) the rest of the properties of the γ matrices may be derived using the fact that $g_{\mu\nu}$ lowers the index of a four-vector component while $g^{\mu\nu}$ raises it:

$$g_{\mu\nu}\gamma^\nu = \gamma_\mu, \quad g^{\mu\nu}\gamma_\nu = \gamma^\mu, \quad g_{\mu\nu}p^\nu = p_\mu, \quad g^{\mu\nu}p_\nu = p^\mu. \quad (0.15)$$

For instance, multiplication of Eq. (0.14) by $p_\mu q_\nu$ yields

$$\not{p}\not{q} + \not{q}\not{p} = 2p_\mu q^\mu = 2p \cdot q \quad (0.16)$$

(since, being scalar quantities, p_μ and q_ν commute with γ matrices; $\gamma^\nu p^\mu = p^\mu\gamma^\nu$). With $q = p$, the relation simplifies to

$$\not{p}^2 = p^2. \quad (0.17)$$

Also, readily obtained are the relations

$$\gamma_\mu\gamma^\mu = 4, \quad \gamma_\mu\not{p}\gamma^\mu = -2\not{p}, \quad (0.18)$$

the latter via $\gamma_\mu\not{p}\gamma^\mu = \gamma_\mu\gamma_\alpha p^\alpha\gamma^\mu = (2g_{\mu\alpha} - \gamma_\alpha\gamma_\mu)\gamma^\mu p^\alpha = (2\gamma_\alpha - \gamma_\alpha\gamma_\mu\gamma^\mu)p^\alpha = -2\gamma_\alpha p^\alpha$.

Ignoring the infinitesimal constant ϵ, using $g_{\mu\nu}\gamma^\nu = \gamma_\mu$, and introducing the fine-structure constant α and the Fermi coupling constant G_F via the relations [4, p. 159]

$$e^2 = 4\pi\alpha, \quad G_F/\sqrt{2} = g^2/8M_W^2, \tag{0.19}$$

the integrands may be written

$$I(\gamma) = -4\pi\alpha \frac{\gamma_\mu(\not{p} - \not{k} + m_e)\gamma^\mu}{(k^2 - \lambda^2)((p-k)^2 - m_e^2)} \tag{0.20}$$

and

$$I(H) = \sqrt{2}G_F m_e^2 \frac{\not{p} - \not{k} + m_e}{(k^2 - m_H^2)((p-k)^2 - m_e^2)} \tag{0.21}$$

when the electron propagator is rewritten according to

$$\frac{1}{\not{p} - m_e} = \frac{1}{\not{p} - m_e} \times \frac{\not{p} + m_e}{\not{p} + m_e} = \frac{\not{p} + m_e}{\not{p}^2 - m_e^2} = \frac{\not{p} + m_e}{p^2 - m_e^2}. \tag{0.22}$$

Before the integrands can be weighed against each other, the numerator in Eq. (0.20) must be simplified. With the aid of Eq. (0.18), the integrand becomes

$$I(\gamma) = 8\pi\alpha \frac{\not{p} - \not{k} - 2m_e}{(k^2 - \lambda^2)((p-k)^2 - m_e^2)}. \tag{0.23}$$

Integration over the four momentum k produces a divergent result for k approaching infinity — hence the UV cutoff mass Λ in Eq. (0.10). The fact that m_H^2 and m_e^2 appear alongside k^2, and m_e alongside k, explains why no particle masses appear in the divergent part of the expression for $\delta m^{(2)}$ (since $m_e/\gamma k$, m_e^2/k^2, and $m_H^2/k^2 \to 0$ for $k \to \infty$).

Division of Eq. (0.21) by Eq. (0.23) shows that in the limit when $k \to \infty$ (and the integral diverges), the ratio between the two integrands is

$$\frac{I(H)}{I(\gamma)} = \frac{G_F m_e^2}{4\sqrt{2}\pi\alpha}, \tag{0.24}$$

which is the same ratio as in Eq. (0.10), but with opposite sign. Consequently, the result obtained in Eq. (0.24) demonstrates a mistake in the original calculation.

References

[1] S. Sundman, *A light Higgs particle explains physics mysteries*, physicsideas.com/Article3v2.pdf (2016).

[2] T. Kinoshita, in *Quantum Electrodynamics*, edited by T. Kinoshita (World Scientific, Singapore, 1990), pp. 218–321.

[3] J. D. Bjorken and S. D. Drell, *Relativistic Quantum Mechanics* (McGraw-Hill, New York, 1964).

[4] W. Greiner and B. Müller, *Gauge Theory of Weak Interactions*, 2nd ed. (Springer, Berlin, 1996).

[5] Randolf Pohl *et al.*, *The size of the proton*, Nature **466**, 213 (2010).

[6] M. Veltman, *Diagrammatica: The Path to Feynman Diagrams* (Cambridge University Press, 1994), pp. 259–272.