On the origin of particles

2011-11-30/stigS

History

The Ptolemaic cosmology was growing toward “maximum complexity” for a long time until it was replaced with “maximum simplicity” in the form of Newton’s gravitational potential $U = -Gm/r$. After that, simplicity became theoretical physicists’ new guiding-star, which led the way to theories such as Einstein’s general relativity (GR) based on the equivalence principle, Bohr’s atomic model, and quantum field theory (QFT). Cosmology remained simple until the introduction of an inflationary phase caused it to explode in theoretical complexity and diversity. Today, physicists are forced to admit that cosmology is in trouble. See, for instance, Paul J. Steinhardt, Scientific American, April 2011, front page and pp. 18-25, *Quantum Gaps in Big Bang Theory: Why our best explanation of how the universe evolved must be fixed — or replaced.*

The root of cosmology’s trouble

The problems of present cosmology can be traced back to the idea that the universe begins in the form of an infinitely hot and dense singularity – an already (at time zero) chaotic and highly complex world. Since this newborn universe is mathematically unspecifiable, its early evolution is unpredictable; and so are the lepton mass ratios, the fine-structure constant alpha, et cetera.

Back to simplicity

The *principle of maximum simplicity* (see pp. 94–96 in James Bjorken’s and Sidney Drell’s classic Relativistic Quantum Fields) suggests an alternative, *least-symmetry-breaking* scenario. In it, the universe begins in the form of a neutral and spinless particle — a single-particle world in which only space, time, and mass (equivalent to energy) break the perfect simplicity and symmetry of *literally nothing* (term introduced by Alexander Vilenkin in 1982). This primordial particle — which is its own antiparticle — is described by *Dirac’s new equation* published by Paul Dirac in 1971. Dirac’s new particle is characterized by some unique properties that only the very first particle may possess.

Properties of Dirac’s universe

According to Biedenharn, Han, and van Dam (1973), Dirac’s neutral spinless particle represents a relativistic harmonic oscillator which can only exist alone (that is, in a universe void of charged particles and photons carrying electric force) at the same time as it may be viewed as “a realization on” two oppositely charged bosons. Therefore, the D particle may (in analogy with Schrödinger’s cat) simultaneously be alive in its original massive shape and dead after annihilating into a pair of massless photons and in addition (unlike Schrödinger’s cat with only one life) live a second life after decaying into a pair of massive charged bosons (which, in turn, annihilates into a massless pair of photons).

The beginning

Our observations undeniably demonstrate that a material universe is possible. Therefore, the probability for a transition from literally nothing to a material universe cannot be exactly zero. Consequently, a transition must occur. Since no time exists in literally nothing, the spontaneous symmetry breaking must occur at the beginning of time. The principle of maximum simplicity suggests that as few symmetries as possible should be broken in the transition. That is, the universe should appear in the form of a single, spinless and neutral particle on which no forces act (forces are mediated by particles, so-called gauge bosons such as the photon).

Predictable early evolution

In a one-particle universe there cannot exist kinetic energy or heat. As a consequence, during its early phases — of which the observed tauon-muon mass ratio (16.82), muon-electron mass ratio (206.768), and photon-baryon number ratio (a few billion) bear testable evidence — the universe continues to be perfectly cold and its evolution, which is governed by the principle of least symmetry breaking and a few conservation laws [see Conservation laws], mathematically predictable. Also, the universe remains perfectly particle-antiparticle symmetric until — in the process of forming the first proton-antiproton pair — there appears a tiny pion-antipion asymmetry, which today reveals itself in the CP-violating "superweak force" observed in the decay of neutral K (kaon) and B mesons.

The big bang

With proton-antiproton annihilation forbidden by conservation laws [see Global conservation of energy], the antiproton is forced to decay into an electron plus radiation in a nuclear explosion that transforms antimatter (the antiproton) into matter (an electron) and heats matter (proton plus electron) to a very high temperature. This finite, antimatter-fueled big bang signals the beginning of the world as we know it.

The Higgs photon

The theory of an initially cold Dirac universe predicts a very weakly interacting, light, neutral, and spinless *weak photon* that comes in precisely defined and theoretically calculable mass states. This particle is described by the Feynman rules for the so-called Higgs boson. Several observations have been reported that convincingly demonstrate the existence of a light spinless photon [see page 11, Observations of virtual and real Higgs bosons].

Conservation laws

Behind the "extended standard model" (xSM) lies the discovery that the laws of conservation of momentum and energy govern the universe's evolution. The law of conservation of energy applies both locally and globally. In our familiar local picture of the universe, the law says that particle rest energy (mc^2) is constant as are the speed of light (c) and particle lifetimes (τ). In contrast, the global version of the law states that the total energy in a cosmic volume coexpanding with the universe is conserved, which in turn implies that both c and τ grow over time with τ proportional to c. The naive objection that a given distance $d = c\tau$ cannot be constant in one picture and increase in another is invalid in a quantum universe (as, for instance, the so-called spooky action at a distance demonstrates).

Global conservation of energy

The global law of conservation of energy forbids the existence of a matter-free expanding universe (that would lose its energy through photon redshifting) and forces the universe to undergo a series of symmetry-breaking transitions in which matter is repeatedly recreated or transformed:

D particle → spinless tauons $\tau_0^\pm$
→ spinless muons $\mu_0^\pm$
→ spin-$\frac{1}{2}$ electrons $\mathrm{e}^\pm$ (with the virtually existing muon and tauon acquiring spin, too)
→ pions $\pi^\pm$ (a brief "pion parenthesis" when weak and superweak forces appear)
→ proton-antiproton pair $\mathrm{p\bar{p}}$
→ proton-electron pair pe^- [see above, The big bang]

Expansion

The law of conservation of momentum governs the unperturbable expansion of the universe [see Dirac's large-number hypothesis (LNH)].

Gravity

Gravity is a by-product of the expansion and does not affect the universe's overall expansion. Newton's gravitational potential $U = -mG/r$ is replaced by $U = -mG/r(1 - r^2/R^2)$, where R is the radius of the universe. The gravitational force is proportional to $\mathrm{d}U/\mathrm{d}r$ and becomes repulsive for distances greater than $R/\sqrt{3}$.

Dirac's large-number hypothesis (LNH)

For a cosmic volume V coexpanding with the universe, $\mathrm{d}V/\mathrm{d}t = \text{constant}$ in the global picture, which implies that LNH holds true in this picture. In the local picture, where time differs from global time and the universe's age from its global age, the naive conclusions drawn from LNH about time dependence of gravity and rate of expansion are incorrect.

Black holes

From LNH, it follows that G decreases with time. Therefore, when the universe's antimatter disappeared in the big bang [see above, The big bang], the universe was very dense and gravity very strong (maybe 10^{30} times stronger than it is today). Therefore, a large part of the matter and radiation in the universe quickly coalesced into small black holes. As the universe expanded and gravity weakened, the lightest black holes released their content and fed the remaining black holes with new material. The result is that today the bulk of the universe consists of "Jupiter-mass objects" — black holes that reveal their existence via the microlensing effect that has been studied by Mike Hawkins of the Royal Observatory in Edinburgh [New Scientist, 8 June 1996, pp. 30-33]. Proof that the microlensing effect is caused by black holes is provided by another observation made by Hawkins [New Scientist, 10 April 2010, p. 13].

> One objection to Hawkins' conclusions was that no mechanism for the production of small primordial black holes could be thought of (in a universe where G is assumed to be constant). Another objection was that his observations suggested that there exists such a large number of black holes that they would give the universe a density that exceeds the

> so-called critical density $\rho = 3H^2/4\pi G$. Also this objection is invalidated by xSM, which predicts a density of the universe that is twice the "critical density" [which isn't critical in any way; see above, Gravity].

Accelerated expansion: an illusion

The Chandrasekhar limit is about 1.4 solar masses. The limit, which is proportional to $G^{-3/2}$, specifies the critical mass at which white dwarfs explode and form type Ia supernovae. Billions of years ago, gravity was stronger and the Chandrasekhar limit lower than today. Therefore, since there was less material fueling an explosion, and less matter the explosion could eject, old type Ia supernovae shone less brightly than younger ones do.

It should be easy to estimate the rate of decrease in G that is required to explain the illusory acceleration. Further, since Dirac's LNH implies that $\dot{H}/H = \dot{G}/G$, it should be possible to obtain a consistent distance scale and a value for the present-day Hubble expansion rate that hopefully matches the theoretically obtained value of $H = 56.8$ km/s/Mpc.

Formation of structure

According to presently favored hypotheses, gravity does not change over time. Which suggests that the young universe expanded uniformly and cooled rapidly. Consequently, when the universe was about a million years old, its temperature would have fallen to about 3000 K — the so-called decoupling temperature at which matter in the form of hydrogen becomes transparent to photon radiation. Around this time, the first black holes supposedly appeared as the result of stars undergoing gravitational collaps, and galaxies and galaxy clusters began to form. However, the "standard" cosmological models have failed to predict the existence of superclusters and hyperclusters — recently observed "aggregations of galaxies stretching for more than 3 billion light years" [see Stephen Battersby, *Universe seems too clumpy for comfort*, New Scientist, 25 June 2011, p. 8].

If one accepts that gravity decreases with time according to Dirac's LNH (that is, $G \propto 1/t$ as deduced by Paul Dirac from observations that still hold true), the picture changes drastically. After the black holes had formed very soon after the birth of the universe [see above, Black holes] and swallowed most of the universe's matter and radiation, they combined into structures that grew in size and complexity as the universe expanded. The structures were tightly bound by the strong gravity and did not participate in the overall expansion of the universe.

Since the structures did not expand, the photons contained within them were not cooled via expansion-induced redshifting. Instead, a slow cooling may have been produced by the evaporation of tiny black holes (a process speeded up by the rapidly decreasing G), which had swallowed high-energy photons and now released low-energy photons.

Only the relatively few photons, which were traveling through the stretching, sparcely-populated voids between structures, contributed to the cooling of the universe via redshifting.

As a result, instead of a million years, it may have taken a hundred billion years for the universe to cool to the 3000 K decoupling temperature at which photons became able to escape from the interior of galaxies and galaxy clusters. After that, the temperature of the cosmic microwave background radiation (CMB) fell rapidly to its present value of 2.7 K.

The age of the universe

Upon the elimination — enforced by the law of conservation of energy — of antimatter through antiproton decay, the uniformly expanding universe consisted of matter in the form of a proton-electron pair with rest energy $(m_p + m_e)c^2 = 1837.15\, m_e c^2 = 938.8$ MeV and radiation in the form of 2786 million photons of energy $E_\gamma = h\nu = 0.190\, m_e c^2 = 97\ 000$ eV. In other words, less than 4 ppm of the universe was matter.

Today, the energy of the background photons has decreased to nearly zero (less than 0.001 eV). If bound structures had not been formed and the universe had continued to expand uniformly, matter rest mass (mc^2) and c^2 would — in the global picture — have rapidly increased by a factor of $2786 \times (97\ 000\ \text{eV})/(938.8\ \text{MeV}) = 288\ 000$, and c and particle lifetimes τ (with $\tau \propto c$) by a factor of about 500. This would not have affected our local view of the universe's age — only for the very early, unobservable evolution of the universe the "local second" would appear to be much longer than the "global second."

However, since the early formation of structures inhibited most of the photons from participating in the universe's expansion, only a small percentage of the photon radiation underwent redshifting before the decoupling took place. Therefore, c and τ may have grown, say, a hundred times. Which implies that, because most of the loss of radiation energy took place relatively late in history, the universe's local age divided by its global age should be closer to 100 than to 1.

> Note that the increase in c also affects the baryons (quarks) and leptons (charged and neutral) that are trapped in black holes. (Singularities are mathematical abstractions that do not exist in the physical world. Therefore, quarks and leptons are not crushed out of individual existence at the centers of black holes.)

The size of the universe

R defined as $R = c/H$ is the radius and $t = R/3c = 1/3H = 5.7$ Gyr is the age which the universe would have in the absence of radiation undergoing redshift caused by the expansion. The actual age of the universe is much greater than $1/3H$. Also, the horizon of the universe is very far away, at a distance $R_h \gg c/H$. Consequently, the actual volume of the universe, $V = \frac{4}{3}\pi R_h^3$, is very large.

The fractal universe

"FRACTAL UNIVERSE — Giant patterns in the sky are shaking the foundations of cosmology" (New Scientist's cover story, 10 March 2007, Amanda Gefter).

"The universe may have a fractal structure, looking similar at all scales" (New Scientist, 25 June 2011, p. 8, Stephen Battersby quoting Francesco Sylos).

After the first proton-electron pair had appeared, it was joined by more pairs coming within sight as the horizon receded when the originally very rapid expansion decelerated. After first repelling the newcomers, the gravitational force began to attract them, and soon the first micro black hole had formed, gathering around itself a miniature galaxy of protons and electrons in a dense sea of photons. After more galaxies had come within sight and within attractive gravitational reach of each other, they combined into the first tiny cluster of microgalaxies. Then, after more clusters had appeared on the horizon, a small cluster of clusters began to form.

And so the process of forming ever bigger and more complex fractal structures continued until a point when the universe had expanded and gravity weakened so much that it was unable to bind together still larger structures.

Later, as the gravitational force continued to weaken, the largest bound structures began to disintegrate. Today, galaxies are still held together by the gravitational force, but the clusters they form have begun to participate in the overall expansion of the universe, which means that the galaxies are drifting apart.

> Galaxies are not affected by the universe's expansion. *"But clusters of galaxies, which are only loosely bound by gravity, will feel this effect."* See Zeeya Merali quoting Richard Price in New Scientist, 1 October 2005, p. 13: *Why the universe is expanding without us.*

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:

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

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 which α is the fine-structure constant with $1/\alpha = 137.035\ 999\ 084(51)$ and $B = 0.666\ 001\ 731\ 498$ characterizes the simplest possible solution to the pressureless form of the momentum equation.

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 $\mathrm{e}^\pm$ (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 ($\mathrm{e}^+\mathrm{e}^-\ \mathrm{e}^+\mathrm{e}^-$).

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.

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 carrier of the universe's mass.

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 ($\mathrm{p}\bar{\mathrm{p}}$).

A pressureless solution to the momentum equation

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

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

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

The **pressureless** form of the momentum equation

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

A pressureless **stationary** solution

characterized by

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

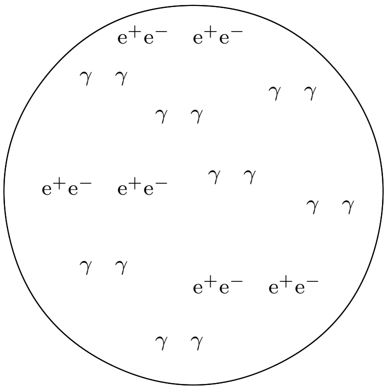
No pressure = no heat = no molecules = no reference points
= position, distance, and direction undefinability
= quantum indeterminacy

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

Global conservation of energy

Volume coexpanding with the universe

Consider a volume V, which contains N_e electron pairs (e^+e^-) and N_γ photons and grows at the same rate as the universe expands. As the electron pairs annihilate ($e^+e^- \to \gamma$), N_e decreases and N_γ increases, but their sum $N = N_e + N_\gamma$ does not change.



Volume V grows

Photon wavelength λ increases
Speed of light c increases

Electron pairs annihilate ($e^+e^- \to \gamma$)

The law of conservation of energy applies "globally" to the volume and forces c to grow over time to compensate for the decrease in radiation frequency $\nu = c/\lambda$ resulting from the stretching of the photon wavelength λ — the so-called redshift that is caused by the universe's expansion. That is, the law requires that

$$E = N_\gamma hc/\lambda + N_e 2m_e c^2 = \text{constant},$$

where $N = N_\gamma + N_e = \text{constant}$, the Planck constant h and the electron mass m_e are fundamental constants of nature, N_e and $\nu = c/\lambda$ decrease with time, and N_γ, λ, and c increase.

In a classical world, global conservation of energy would conflict with the familiar local conservation of energy (c constant). However, the universe is a quantum world, which means that there is no conflict — thanks to distance undefinability (or quantum indeterminacy).

The annihilation of the last electron pairs is forbidden by the law of conservation of energy because it would lead to a pure photon universe and a steadily decreasing E ($N_e = 0$ in the equation). Consequently, the attempted final annihilation of matter provokes a chain reaction leading to creation of quarks and several types of weakly interacting particles.

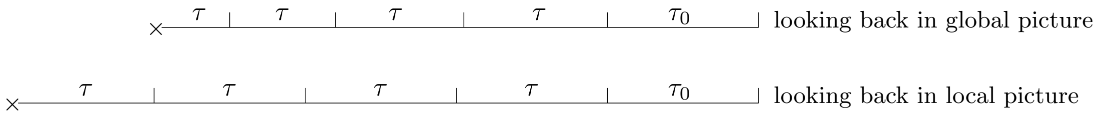
The end result is that the unstable positron-electron pair (e^+e^-) is replaced by the stable proton-electron pair (pe^-) as carrier of the universe's matter.

Global time versus local time

When we study the physical world, we see a picture in which particle mass m, particle rest energy $E = mc^2$, and (consequently) the speed of light c are conserved. In this familiar **local picture**, also particle lifetime (τ) is conserved. For instance, the lifetime (or mean life) $\tau \approx 10^9$ years or 1 Gyr of uranium-235 is constant. (Its half-life is $T_{1/2} = \tau \log 2 \approx 700$ million years.)

In the **global picture**, the total energy content of a cosmic volume coexpanding with the universe is conserved. The global law of conservation of energy requires that both τ and c grow over time.

In the global picture, the universe looks younger than it does in the local picture. The figure illustrates the difference:

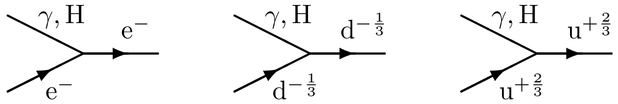


Observing a gamma-ray burst (×) means looking back in time. Letting, at a given epoch in the history of the universe, the lifetime τ take on the value $\tau_0 = 10^9$ yr (1 Gyr) in both the local and global pictures, the figure indicates that the gamma-ray burst took place 4 Gyr earlier in the global picture and 5 Gyr earlier in our conventional, local picture.

Observations of virtual and real Higgs bosons

Several observations have been reported that cannot be explained within the frame of the standard model of elementary particles (SM) as long as one presumes that the spinless neutral elementary particle — the so-called Higgs boson — appearing in SM theory is very heavy.

The picture changes if one takes the Feynman diagrams of SM at face value and accepts that they say exactly what they seem to be saying — that the Higgs particle (H) is a massive but very light and weakly interacting spin-0 photon that accompanies and mimics the massless spin-1 photon (γ) in its interactions with the building blocks of ordinary matter (up and down quarks and electrons):



identical-looking diagrams
picture photon and Higgs

[Although the neutral spin-1 Z^0 particle couples graphically to quarks and charged leptons in the same way as the photon and Higgs do, it differs significantly from them because it also couples to the neutrino (ν), which is a neutral lepton.]

A parallel calculation of the photon and Higgs contributions to the mass of the electron suggests that the Higgs comes in one of three mass states depending on which one of the three charged leptons (electron, muon, or tauon) it is associated with:

- H_e possessing a mass of 12.0007 μeV/c^2 corresponding to a photon of frequency 2.9018 GHz,
- H_μ possessing a mass of 106.086 eV/c^2, and
- H_τ possessing a mass of 0.505 MeV/c^2.

[In this respect the spin-0 Higgs resembles the spin-$\frac{1}{2}$ neutrino. However, being simpler than the neutrino, the Higgs cannot oscillate between its three mass states as the neutrino does.]

Experimental evidence suggests that the spinless photon is revealing its presence in:

- the Brookhaven E821 muon $g-2$ experiment (H_μ),
- the Pioneer anomaly (H_e),
- GPS measurements taken to indicate that neutrinos travel faster than light (H_e),
- observed correlations between solar flares and radioactive decay rates (H_μ, H_τ),
- measurements of the proton radius (H_μ),
- the proton “spin crisis” (H_e, H_μ, H_τ),
- the smoke effect observed by Eugene Podkletnov (H_e).

Taken together, these observations seem to confirm the prediction that the Higgs particle of the Feynman diagrams is very light with the actual mass of the electron-type Higgs lying near its theoretical value of 12 μeV/c^2.

They suggest that muon and tauon-type Higgs particles arriving from the sun behave similarly to neutrons in the moderator of a nuclear reactor: are slowed down in the interior of the earth, become thermal, and diffuse up to the planet's surface where they speed up the decay of unstable isotopes before they leak out into space.

The Brookhaven E821 muon experiment demonstrates that a light ($m_{H_\mu} < m_\mu$) Higgs particle interacts with the muon [see page 13, The Brookhaven muon experiment].

The Pioneer anomaly gets a natural explanation if the electron-type Higgs (H_e) appearing in parallel with the photon (γ) in the photon's propagator (where all existing electrically charged elementary particles form short-lived vacuum-polarization loops) has a mass near the theoretically predicted 12 $\mu\mathrm{eV}/c^2$, which corresponds to the energy of a 2.90 GHz photon [see page 14, Higgs delay].

CERN's OPERA experiment, which seems to indicate that the observed neutrinos travel faster than light — a physical impossibility, can be explained in exactly the same way as the Pioneer anomaly [see page 14, Higgs delay].

The variation in radioactive decay rates apparently caused by solar flares is of particular interest because the observed effect requires the existence of a free real Higgs particle and provides information about the particle's interaction with matter [see page 16, Increased radioactive decay rates].

The measurements of the proton radius, which yield a higher value for ordinary hydrogen than for muonic hydrogen (where the electron that orbits the proton is replaced by a muon), demonstrate that a repulsive Higgs force appears between muon and proton [see page 17, Higgs force].

The proton spin crisis similarly shows that a repulsive Higgs force tends to push apart the proton's constituent particles (one down and two up quarks), thereby forcing them to circle as far away from each other as the strong force allows them to do. The result should be that the quarks' orbital angular momenta together with their measured spin angular momenta add up to the proton's spin [see page 17, Higgs force].

The smoke effect reported by Podkletnov might be caused by a dynamic electroweak force mediated by the electron-type Higgs. Because of the low mass of this particle, it is conceivable that the force has sufficiently long range to cause an observable push on air molecules close to the cryostat containing the 12-inch superconducting disk fabricated by Podkletnov [see page 17, Higgs force].

The Brookhaven muon experiment

The E821 muon $(g-2)$ experiment at Brookhaven yielded a very precise value for the muon's anomalous magnetic moment, a_μ (which is half of the muon's so-called $g-2$: $a_\mu = (g-2)/2$). The value obtained is

$$a_\mu^{\mathrm{exp}} = 0.001\ 165\ 920\ 80(63).$$

If the particle (H_μ) appearing in the one-loop Higgs correction to a_μ is considerably lighter than the muon ($m_{H_\mu} \ll m_\mu$), it contributes theoretically with

$$a_\mu(\mathrm{H}_\mu) = \frac{3G_F m_\mu^2}{8\sqrt{2}\pi^2} = 0.000\ 000\ 003\ 50$$

to the value of a_μ. Together with the rest of the contributions, it gives

$$a_\mu^{\mathrm{th}} = 0.001\ 165\ 921\ 28(61)$$

for the theoretical a_μ value. The difference

$$\Delta a_\mu = a_\mu^{\mathrm{exp}} - a_\mu^{\mathrm{th}} = -0.000\ 000\ 000\ 48(88)$$

indicates good agreement between the theoretically predicted and experimentally measured values. Note that the uncertainties are added in quadrature ($63^2 + 61^2 = 88^2$).

If instead the Higgs particle H_μ is much heavier than the muon, its effect is negligible, which implies that the results no longer match each other:

$$\Delta a_\mu = a_\mu^{\mathrm{exp}} - a_\mu^{\mathrm{th}} = +0.000\ 000\ 003\ 02(88).$$

In other words, the experiment demonstrates that the Higgs particle contributing to a_μ is lighter than the muon; that is, $m_{H_\mu} < m_\mu = 105.66\ \mathrm{MeV}/c^2$.

Higgs delay

Photons traveling through a transparent medium or substance (solid, liquid, gas, or plasma) interact electromagnetically with the charged particles of the substance. The result is an electromagnetic delay of the photon ray, which means that the signal speed is less than the speed of light in vacuum (c). For some extensively used photon frequencies, the relation between frequency and signal speed in various substances has been thoroughly investigated. For other frequencies, the relation has not been experimentally checked.

A photon jumping between two charged particles in a transparent medium will occasionally be accompanied by two additional photons or by a single Higgs boson. For most frequencies, the appearance of a Higgs particle in the photon ray doesn't cause any measurable delay. However, when the energy of the photon is in the vicinity of the Higgs rest energy, the virtual Higgs particle that happens to accompany the massless photon in its jump between, say, two protons in the solar plasma may be only slightly off mass-shell and have an energy that approximately equals its rest energy. When this occurs, the Higgs has low kinetic energy and moves with a speed that may be much lower than c, thus causing an "anomalous," electroweak signal delay.

The neutrinos differ from photons in that they very rarely interact with other particles. Therefore, a neutrino effectively travels with its vacuum speed from the moment it is created to the moment it is annihilated in a collision with another particle. Since all experimentally observed neutrinos have energies that are very much higher than their rest energies, they travel with a speed that for practical purposes may be taken to equal c.

A report "*By CERN, Geneva, Switzerland* — Published: September 26, 2011" states that "OPERA results indicate that the neutrinos travel at a velocity 20 parts per million above the speed of light".

Because particles cannot travel faster than light (if one ignores quantum fluctuations that are smoothed out in macroscopic time-of-flight measurements), and velocity is measured as distance per time: $v = d/t$, the result of the OPERA experiment shows that there is an error in the measurements. Since atomic clocks are very accurate and easy to synchronize, the only possibility is an error in the distance measurement. The simplest explanation for this error is that the microwave radio signals used by the global GPS positioning system experience an unexpected and previously unnoticed Higgs delay as they travel through the proton-rich plasma of the inner Van Allen belt.

As long as one and the same frequency is used in communications with satellites, a systematic error in distance measurements caused by electroweak delay in interplanetary plasma is difficult to notice because it does not affect position determination. An exception is the position determination of very distance objects, which experience a decreasing Higgs delay because of the thinning out of the interplanetary plasma.

Pioneer 10 and Pioneer 11 are such objects.

New Scientist 20 July 2002 p. 28: "Today, Pioneer 10 is 80 times as far from the Sun as Earth is, and it's 400,000 kilometres behind schedule".

In other words, the radio signal covers a distance of $d = 80 \times 150 \times 10^6$ km $= 12 \times 10^9$ km in a time that is $\Delta t = (400\ 000 \text{ km})/(300\ 000 \text{ km/s}) = 4/3$ s shorter than expected. The anomaly may be explained by assuming that the signal travels $r = 1/6$ of the distance with a speed of $v = 0.999\ 96\ c$ (that is, $\Delta v = c - v = 4 \times 10^{-5}\ c$, meaning a 40 ppm delay) and the remaining distance with speed c:

$t = rd/v + (1-r)d/c$ $\qquad$ $t = d/v - \Delta t$

Idealized actual situation $\qquad$ Assumed — believing $v = c$

By setting $r = 1/6$, $\Delta t = 4/3$ s, and $d = 12 \times 10^9$ km in the equation

$$rd/(c - \Delta v) + (1-r)d/c = d/(c - \Delta v) - \Delta t,$$

which simplifies to $1/(1 - \Delta v/c) = 1 + c\Delta t/(1-r)d$, or approximately for small $\Delta v/c$,

$$\frac{\Delta v}{c} = \frac{\Delta t}{1-r}\frac{c}{d},$$

one obtains a relative delay of $\Delta v/c = (2/5) \times 10^{-4} = 40$ ppm. For $r \to 0$, one gets a theoretical but unrealistic minimum of 33 ppm, while no precise maximum can be inferred from the cited information.

For spacecraft telemetry, GPS uses a frequency of 2.2275 GHz, which lies between the frequencies of about 2.11 and 2.29 GHz that were used in communication with Pioneer 10 and 11.

GPS is said to reserve its 1.2276 GHz frequency for military use. Assuming that OPERA's precision distance measurement was done using this frequency, one may conclude that in the vicinity of the earth, the electroweak relative delay of 1.2 GHz signals is about 20 ppm while 2.2 GHz signals are delayed at least twice this much.

Consequently, the OPERA and Pioneer observations agree with the prediction that microwave signals experience a Higgs delay that reaches its maximum somewhere around 2.9 GHz.

Increased radioactive decay rates

In “Stanford Report, August 23, 2010” titled *“The strange case of solar flares and radioactive elements,”* Dan Stober reports that researchers have found that the radioactive decay of some elements seems to be influenced by activities inside the sun.

More information on the subject is presented in an article titled *“Radioactive decay rates can change”* written “By Davide Castelvecchi” on “November 22nd, 2008; Vol.174 #11 (p. 20)”.

The experiments described in the articles provide convincing evidence for the existence of free, real Higgs particles.

Muon and tauon-type Higgs particles interact with quarks of atomic nuclei but not with electrons. These weakly interacting particles are expected to be produced in large numbers inside the sun. Arriving at the earth, they should be able to penetrate deep into the planet. Thus, light Higgs particles emanating from the sun might provide a natural explanation for the observed variations in radioactive decay rates.

The fact that no correlation between power production and distance from the sun has been reported for spacecraft using radioactive material as energy indicates that solar Higgs particles do not directly cause measurable variations in decay rates. Instead, it suggests that the earth moderates and accumulates the hot muon and tauon-type Higgs particles that hit it. After becoming thermal, the particles gradually diffuse to the surface of the earth and out into space, triggering immediate decay of unstable isotopes they happen to interact with during their random walk.

An experiment performed in the 1980s at the Brookhaven National Laboratory in Upton, N.Y., and another at the PTB — the National Metrology Institute of Germany — in Braunschweig about 1300 km farther to the north, are reported to show seasonal variations in radioactive decay rates with the peaks and troughs shifted with respect to each other by about a month. This shift appears to be a natural consequence of the fact that in January and July (when the earth-sun distance reaches its minimum and maximum, respectively), the relative altitude of the sun changes more rapidly in Northern Germany than in New York.

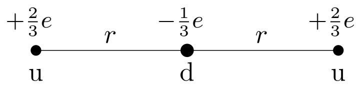
The Higgs force

In New Scientist, 26 March 2011, pp. 50–53, “Nuclear bad boys,” Kate McAlpine reports that measurements using muonic hydrogen gives a value of 0.8418 fm for the proton radius. Earlier measurements using ordinary hydrogen had given the proton a radius of 0.877 fm. The 4 percent discrepancy can be explained within the framework of the standard model if the muon-type Higgs particle mediates a repulsive force between muon and proton. For this force to be of sufficiently long range (exceeding 125 fm), the Higgs must be much lighter than the muon.

On page 52 in the same article, Richard Webb (“ALL IN A SPIN”) tells about another mystery, the so-called spin crisis, that has been puzzling physicists since 1988.

The proton’s spin is the sum of the orbital and spin angular momenta of its constituent particles (quarks and gluons). However, experiments indicate a gap between the sum of the observed individual angular momenta and the proton’s spin angular momentum. A Higgs force affecting the dynamics of the quarks might help to explain the discrepancy.

Asymptotic freedom implies that the strong force that glues quarks together tends to zero for $r \to 0$, where r is the distance between the quarks. In the figure, the strong force is ignored and the two up quarks circle the down quark situated at the proton’s center:



$$F_{ud} \propto -(+\tfrac{2}{3}e)(-\tfrac{1}{3}e)/r^2 = +\tfrac{2}{9}e^2/r^2 \qquad F_{uu} \propto -(+\tfrac{2}{3}e)^2/(2r)^2 = -\tfrac{1}{9}e^2/r^2$$

The figure, which shows a net inward electromagnetic force ($F_{ud} + F_{uu} \propto +e^2/9r^2$) acting on the up quarks, indicates that the three quarks may stick closely together at the center of the proton. Which, in turn, suggests that the quarks should have vanishingly small orbital angular momenta. Now, the repulsive electroweak force mediated by all three types of Higgs may well outweigh the electromagnetic attraction between the quarks and force them to move in as wide orbits as allowed by the strong force (which, like the force of a rubber band, increases with growing r). Consequently, their angular momenta might be considerable larger than they would be in the absence of electroweak Higgs forces.

If this conclusion is correct, the existence of light scalar Higgs bosons might explain the proton’s missing-spin mystery within the framework of SM.

The smoke effect reported by Eugene Podkletnov might belong to the same category as the proton crisis and the proton radius discrepancy.

When Podkletnov's team *"was carrying out tests on a rapidly spinning disc of superconducting ceramic suspended in the magnetic field of three electric coils, all enclosed in a low-temperature vessel called a cryostat"* (according to Robert Matthews and Ian Sample), they observed that *"pipe smoke rose in a column above the superconducting disc"* (Charles Platt).

If sufficiently strong electric currents were induced in the superconducting disk, and if the distance between disk and the nearest air molecules above the cryostat was sufficiently short, an upward pressure on the air may have resulted.

Comments added on 2012-05-04:

In February 2012, the OPERA team reported that errors in the experiment cast doubt on their conclusion that neutrinos seemingly travel faster than light. Now, the Pioneer anomaly suggests that the appearance of flyweight Higgs bosons in the photon propagator should cause errors in distance measurements based on satellite-relayed microwaves. However, if the GPS positioning system has been properly calibrated, the effect might be invisible in earthbound experiments employing GPS.

The ICARUS experiment (http://arxiv.org/abs/1203.3433 v3, 29 March 2012) found good agreement between neutrino speed and the speed of light. Interestingly, whereas the OPERA team used GPS for determination of the neutrino baseline, the ICARUS team used the more direct method of optical triangulation to measure it.

If the Higgs delay noticeably compromises GPS distance measurements, there might be a significant mismatch between values for the distance CERN–Gran Sasso obtained via GPS and triangulation methods. Consequently, before final conclusions about the "OPERA anomaly" are drawn, two questions need to be answered:

How well do the OPERA and ICARUS distance measurements agree with each other?

Has the corresponding MINOS neutrino baseline been measured through triangulation?

> Independent of the answer to the questions, the signal speed in various media (such as the interplanetary plasma) of microwaves with freqencies in the vicinity of 2.9 GHz should be checked by comparing it to the speed of visible light.

About varying radioactive decay rates

According to Castelvecchi's article, both silicon-32 with a half-life of at least 60 years and chlorine-36 with a half-life of about 300 000 years "had rates of decay that varied with the season, about 0.3 percent."

At perihelion on about 3 January, the earth is approximately $r = 147$ million km from the sun, and at aphelion on about 3 July, some $r = 152$ million km from it. The number of solar Higgs particles arriving from the sun should be proportional to $1/r^2$. That is, there should be a variation of almost seven percent ($n \propto 1/r^2$ gives $dn/n = -2dr/r = -10/150 = -1/15$) in the number of Higgs particles reaching the earth. Assuming for simplicity that the seasonal variation in the decay rate of Cl-36 is 0.2 percent, one finds (solving $0.2/x = -dn/n = 1/15$) that the flux of Higgs particles from the sun should cause a total increase in decay rates of 3.0 percent.

At high altitude (and on the surface of the earth, if the atmosphere is transparent to thermal Higgs particles leaking out from the earth's interior), all thermal Higgs particles hitting a given sample of radioactive material come from below. Therefore, the change in decay rate of the sample should be only half of the change that the same sample experiences in the earth's interior, where it is hit by thermal Higgs particles approaching from all directions. In other words, the decay rate of Cl-36 should increase by 3.0 percent when the measurement, for instance, is repeated deep in a mine shaft.

Another possibility that might be worth investigating is that the virtual or real Higgs particles supposed to be abundantly produced in microwave ovens may accelerate the decay rates of radioactive isotopes such as U-235. Microwaves of various frequencies should be tested, from the 2.45 GHz (12.2 cm) waves of commonly used kitchen microwave ovens to waves with the maximum frequency that can be reached using microwave ovens or similar devices.

About the Higgs force

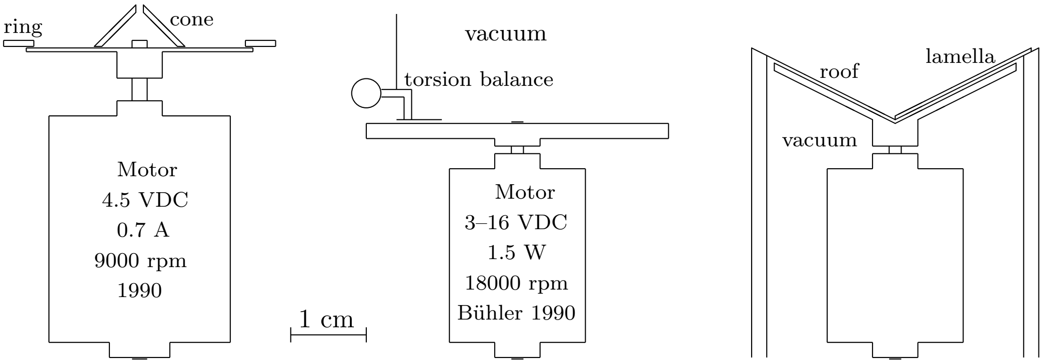
The rising-air effect observed by Podkletnov may be naturally explained if one assumes that the currents, which the three electric coils induced in the 12-inch levitating disk, acted as electron-driven pumps that forced the disk to release its hold of the air molecules adhering to its surface. This means that the currents must have caused a relatively strong short-range repulsive force on the air immediately above the disk. Evidently, such an effect is only possible if the bulk of the electrons that form the induced currents circulate on or very near the surface of the disk. Experiments suggest that this is indeed the case. See Makoto Tsuda, Haigun Lee, So Noguchi, Yukikazu Iwasa, *"Electromaglev" ("active-maglev") – magnetic levitation of a superconducting disk with a DC field generated by electromagnets. Part 4: theoretical and experimental results on supercurrent distributions in field-cooled YBCO disks,* Cryogenics 39 (1999) 893–903.

Also, Podkletnov's team found that the effect increased when they rotated the disk. And, to be sure, a straightforward calculation suggests that a rotating disk should induce a repulsive Higgs force that might enable it to act as a pump producing a readily detectable air flow — provided that the air does not circle with the disk, which the force produced by the induced currents may have prevented it from doing in Podkletnov's experiment.

> I use as the starting point the reported proton-radius discrepancy of about 0.8418 fm vs. 0.877 fm obtained for muonic and ordinary hydrogen, respectively and take the Higgs force between nucleons (protons or neutrons) to be about 10 percent of the corresponding force between muon and proton. Also, I assume that the force is proportional to the radial acceleration of the nuclei, that is, $F \propto \omega^2 r$, where $\omega = v/r = 2\pi\nu$ is the angular velocity of the disk. When I make the additional, but unrealistic, assumption that the Higgs force obeys the inverse square law, which it would do if the Higgs boson was massless, I conclude that the force should be strong enough to be detectable over millimeter-long distances. For the assumed electron-type Higgs of mass 12 $\mu\mathrm{eV}/c^2$, the force should be appreciable over nanometer-long distances.

For the Podkletnov effect to be of practical interest, one should devise methods via which the effect can be produced without resorting to superconductor techniques.

Left in the figure, an experiment is suggested in which an electric motor rotates a disk with its upper surface preferably coated with a heavy material such as gold:



The fixed cone and ring should touch the upper surface of the rotating disk in order to prevent air dragged along by the central and peripheral parts of the disk from spreading to the part of the disk acting as the pump.

The apparatus should be enclosed in a vacuum chamber, which is evacuated before the motor is started. When the disk rotates at full speed, the chamber is filled with air or some other fluid such as water. If the disk rotates with sufficiently high speed, the Higgs force should be strong enough to prevent the fluid's molecules from adhering to the disk. The result should be a laminar inward and upward flow.

The experiment suggested in the middle of the figure should be performed in vacuum. If the surface of the disk is sufficiently smooth and the thin horizontal plate that is part of the torsion balance is sufficiently close to the surface of the disk, there should be a radial inward force acting on the plate. A light beam reflected by the plane horizontal mirror helps to detect even very small forces.

Since one expects the Higgs force to be directed radially inward, a disk of the conical shape indicated right in the figure may work better than a flat disk. Here, motor and disk are assumed to be enclosed in a vacuum chamber with a thin roof (ideally consisting of a minimum number of graphene layers) supported by thin radially running lamellae, of which one of maximum length is shown in the figure.

The electric motors described in the figure are far from ideal. With five times higher rotational speed and four times larger disk diameter, the force should be a hundred times stronger (assuming that $F \propto \omega^2 r$).

If the suggested Higgs pump is capable of producing an appreciable flow of air, water, or other fluids, it might find use in applications that require the flow to be laminar.

Possibly several small pumps could be coupled both in parallel and in series to produce a strong flow of air, thereby fulfilling the dream of many people: a silent leaf blower.

2012-05-22:

A closer study of the OPERA (http://arxiv.org/abs/1109.4897 v2, 17 Nov 2011) and ICARUS (http://arxiv.org/abs/1203.3433 v3, 29 Mar 2012) reports shows that both teams use the same value for the CERN–Gran Sasso distance. In vacuum, distances may be directly and precisely measured as $d = ct$ using electromagnetic signals and atomic clocks. In other media, such direct measurements, which are unaffected by signal refraction and delay, can only be done with the aid of neutrino beams. Therefore, the ICARUS experiment provides the hitherto most precise direct measurement of a geographic distance. The uncertainty in measured neutrino travel time reported by ICARUS is about 10 ns, which means that an approximate distance of 730 km, previously measured indirectly using GPS, has been verified to an accuracy of about 3 m.

Thermal neutral particles leaking out from the sun's upper atmosphere cannot cause the observed linkage between solar activity and rate of decay of some radioactive isotopes. A more plausible explanation should be that neutrinos arriving from the sun's core may produce "spinless photons" through (possibly weak-model dependent) interactions with matter in the earth's interior. Even with a lifetime of less than one microsecond, a muon-type Higgs with an energy of several thousand times its predicted rest energy of 106 eV may exist long enough to interact with a very large number of atomic nuclei. Traveling practically with the speed of light, it covers, for example, a distance of 300 m in 1 μs and 300 km in 1 ms.

Conclusions added on 2012-08-14:

On proton decay

A reader informed me about an error on page 14 in http://www.physicsideas.com/Universe.pdf, pointing out that the proton and the antiproton have opposite parity. However, the fact that the antiproton has negative parity does not alter the conclusion — in parenthesis — on the last line of the same page. Instead, it implies that the first real proton pair, with both of its component particles inheriting positive parity from the last real pions, was not physically viable and would have annihilated immediately if the result — a massless universe — had been allowed. Since annihilation was forbidden, the universe underwent a phase transition that obeyed the principle of least symmetry breaking. That is, with charge, spin, and positive parity conserved, the negatively charged component of the particle pair was forced to transform into an electron. Now, every enforced transition introduces a new element or feature that adds to the complexity of the universe. This time, the law of conservation of energy caused introduction of motion and, thereby, kinetic energy and heat. As a consequence, the second law of thermodynamics entered the scene. The transition was a unique, non-repeatable leap from a forbidden, unphysical state to the nearest allowed physical state. Because no physical channel for (anti)proton decay was created, the proton is stable.

The corrected Higgs-neutrino mechanism for mass transport may be summarized as

$$\mathrm{e}^+\mathrm{e}^-\;\mathrm{e}^+\mathrm{e}^- \rightarrow \underset{0}{\underline{\pi}^+\underline{\pi}^-\;\underline{\pi}^+\underline{\pi}^-} \xrightarrow{\mathrm{H}} \underset{10^{-5}}{\pi^+_-\pi^-_-\;\pi^+_-\pi^-_-} \rightarrow \underset{10^{-5}}{\pi^+_-\pi^-_-} \xrightarrow{\mathrm{Z}} \underset{10^{3}}{\pi^+_+\pi^-_-} \rightarrow \underset{10^{-5}}{\pi^+_+\pi^-_+} \xrightarrow{3\mathrm{H}\nu\mathrm{W}} \underset{0}{\mathrm{p}_+\bar{\mathrm{p}}_+} \rightarrow \underset{\infty}{\mathrm{p}_+\mathrm{e}^-_+}$$

where the lifetime of the unphysical proton pair is zero, and the positive parity of the final mass-carrying particles is indicated. For details, see page 3 in Universe.pdf.

On the origin of mass

It is generally recognized that the Higgs mechanism for mass creation is not the last word. For instance, on page 179 in *Gauge Theory of Weak Interactions* (2nd ed. 1996) Walter Greiner and Berndt Müller write:

“Owing to the large mass difference between leptons and intermediate bosons, the whole procedure seems to be very artificial. It is therefore appropriate to view the Higgs mechanism as a theoretical tool, which must eventually be replaced by a more fundamental theory for the generation of rest masses. Such an underlying theory may well yield an explanation for the large mass ratios. The development of a theory of this kind is one of the important tasks of particle physics.”

On 4 July 2012, CERN reported observation of what is believed to be a heavy Higgs particle possessing a mass of about 125 GeV/c^2. The discovery suggests the following scenario:

Time begins with the appearance of a massive D particle, which decays into a pair of charged spinless particles. The law of conservation of energy prevents the universe from losing all of its mass through particle-antiparticle annihilation. In phase 3, the universe’s mass is carried by electron-positron pairs and is generated by the electromagnetic or photon field. In the present phase 4, the Higgs field accompanies the photon field as generator of particle masses.

The Higgs-neutrino mechanism for mass transport between leptons and quarks (see above, bottom of page 21) answers the whys of weak interactions. For instance, it explains why the neutrino exists, has mass, and must be able to change its mass. However, it does not explain the details of the underlying weak model. Still, it provides valuable information that should help theorists discover the correct model:

In the process of building the pion pair, a heavy spin-0 boson (H_Z) appears and creates the Higgs field. It is accompanied by a light spin-0 Higgs particle (H_τ, H_μ, H_e) and a heavy neutral spin-1 boson (Z). The mass of the Z boson has been measured, and is about 91.2 GeV/c^2. The mass of the nascent light Higgs is calculable from the pion-electron mass difference, and is about 0.505 MeV/c^2, 106 eV/c^2, or 12.0 μeV/c^2 depending on whether the Higgs is ejected by a tauon, muon, or electron, respectively. With any one of these masses known, the Fermi constant G_F is calculable from $m_H/m = G_F m^2/4\sqrt{2}\pi\alpha$, where m is the mass of the lepton associated with the Higgs of mass m_H.

When the proton pair succeeds the pion pair as carrier of the universe’s mass, the neutrino fermion (ν) is formed together with the charged spin-1 boson (W), which has a mass of about 80.4 GeV/c^2. With the masses of the light Higgs boson known, the masses of the neutrino at the instant it is ejected from the quarks are calculable from the proton-pion mass difference, and are found to be 0.128 times the Higgs masses. When the muon-type neutrino is absorbed by the muon, its mass has grown by a factor of $\log(m_\tau/m_\mu)$. The total neutrino mass delivered to the leptons should equal the total mass ejected by the quarks.

Finally, the detailed simulation of the universe’s early evolution (see physicsideas.com) reveals the existence of a small matter-antimatter asymmetry, which presumably is responsible for the so-called superweak force whose presence has been observed in kaon and B meson decays. See page 15 in Universe.pdf.

On radioactive decay rates 2013-01-22

The first Higgs particle was assigned the task of extracting mass from the charged lepton and handing it over to the down and up quarks, which built the first pion and proton pairs. Consequently, a light Higgs, ejected by an electron, strips the electron of a small part of its mass, while a captured Higgs adds the same amount of mass to the electron. Therefore, since the electron's mass is a conserved quantity, electrons cannot absorb Higgs radiation, only delay and refract it. The maximum time a Higgs may be kept by an electron is determined by the Heisenberg uncertainty relation $\Delta t \Delta E = \hbar$, and is $\Delta t = \hbar / m_{H_e} c^2 = 6.582 \times 10^{-16}$ eV s/12×10^{-6} eV = 0.055 ns. In this time, the lightest Higgs particle may travel a distance of $c\Delta t = 3 \times 10^8$ m s^{-1} $\times\ 5.5 \times 10^{-11}$ s = 16 mm, which gives an estimate of the maximum range of the Higgs-mediated weak force.

Even if real Higgs particles cannot be created or annihilated by electrons, they can be created and annihilated by down and up quarks, which may be compared to closed rotating strings possessing internal kinetic energy that contributes to their mass. Thus, light Higgs particles may be produced in collisions between neutrinos and quarks. Also, a quark may absorb a light Higgs, convert its mass to kinetic energy, and — by spreading the total energy brought by the Higgs to other quarks — flip the nucleus into an excited state.

Since the original task of the light Higgs was to transfer mass (or rest energy) from the charged leptons to the down and up quarks, it does not interact with heavier quarks. Consequently, it primarily decays via virtual loops formed by charged leptons or light quarks. That is, when appearing in its lightest mass state, the Higgs most often decays through a d-quark, u-quark, or electron loop. An attempt to estimate its lifetime suggests that it is on the order of 10 hours. As a thermal particle of energy $kT = 8.617 \times 10^{-5}$ eV K^{-1} $\times$ 293.15 K = 0.0253 eV, it would live $0.0253/12 \times 10^{-6} = 21\ 000$ times longer than a particle at rest, or long enough for particles in the earth to either be absorbed by atomic nuclei or disappear into space before decaying.

Unless they are rapidly absorbed by atomic nuclei or quickly leak out into space, both the cold Higgs particles created in the earth by background neutrinos, the hot solar particles hitting the earth, and the high-energy particles produced by solar neutrinos will become thermal via elastic collisions with nuclei. Because the Higgs in its lightest mass state has a vanishingly small mass, the relation $p = E/c$ connects its momentum to its energy. For a particle that reverses its direction in a collision with an atomic nucleus at rest, conservation of momentum implies that $p = -(p - \Delta p) + Mv$, where M is the mass of the nucleus. Since the particle's loss of momentum, Δp, is negligible (compare with a small ping-pong ball hitting a big iron ball), $2p = Mv$, or $2E/c = Mv$. For the kinetic energy received by the nucleus, one obtains $T = \frac{1}{2}Mv^2 = (Mv)^2/2M = (2E/c)^2/2M = 2E^2/Mc^2$, and for the maximum fractional energy loss of the light Higgs, $T/E = 2E/Mc^2$. Since $E \ll Mc^2$, hot particles lose, and cold particles gain energy at a comparatively slow rate. For instance, if the Higgs has an energy of 0.025 eV and collides with a nucleus of mass $M = 50$ GeV/c^2 (compare with the neutron's mass of 0.94 GeV/c^2) at rest, the maximum fractional energy loss suffered by the light particle is $T/E = 2 \times 0.025/50 \times 10^9 = 10^{-12}$. Consequently, the earth may contain a large number of light Higgs particles with energies forming a broad continuous spectrum.