On the Kinetic Origin of Mass

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Rotating rings (or toroidal plasma filaments) are associated with singularities in space-time in two limits: when the rotation velocity approaches c and zero, respectively. The resulting geometry incorporates a constant relationship between surface and energy for the kinetic energy of the rotation, as well as the rest-masses of the rings. This relation provides the missing link that unifies the electric and gravitational forces. The geometry generates configurations similar to vortex rings in hydrodynamics, and leads to a model of elementary particle masses. An interpretation of the thermodynamics of de Broglie is given in which the cosmic background radiation and other cases of radiation in space are identified as due to energy exchanges between particles and the vacuum.

Introduction

Various interpretations have been given of de Broglie's original hypothesis that elementary particles are periodic, *i.e.* clock-like, structures with an internal frequency in phase with the frequency of a physically real pilot wave that propagates in a sub-quantum medium having the properties of a hidden thermostat (de Broglie 1970). This internal particle frequency has been depicted as either the rotation of a Yukawa hypertube with a period determined by the Compton wavelength (Vigier 1982) or, alternatively, as the vibration of an extended periodic disturbance with a velocity-dependent wavelength and frequency corresponding to one of the natural frequencies of the sub-quantum medium (Wignall 1985).

However, attempts to model the hidden thermostat, for example as a superfluid of fermion-antifermion pairs (Sinha & Sudarshan 1978, Sinha *et al.* 1976), a stochastic ether-like medium (Cufaro Petroni 1981, Gueret 1979, Halbwachs *et al.* 1982), or spinor field (Nambu & Jona-Lasinio 1961), have achieved only limited success. The hypothesis developed here is that the concept of charged ring configurations in the subquantum medium combined with a new fundamental constant relating particle rest mass to internal kinetic energy via vacuum interaction surfaces can provide a viable model of elementary particle structures and interactions.

It is known that de Broglie's thermodynamics implies a variation of proper mass by a certain quantity, representing an exchange of heat between the particle and the thermostat (de Broglie 1970). The idea of an uncertainty or statistical fluctuation in global particle masses has also been suggested by other authors (Lawrence & Szamosi 1974, Hayakawa & Tanaka 1961), although the concept has not been developed. In earlier work (Broberg 1981, 1982), I postulated an energy exchange between particles and the sub-quantum medium indicating a quantization of the vacuum energy on the order of hH. This result is very similar to earlier work by Browne (1962), who proposed that the cosmological redshift may be due to a gravitational interaction between photons, where photon energy is quantized as an integer number of gravitons, which in turn would be made up of neutrino-antineutrino pairs. The exceedingly small value of this energy unit (~10^{-66} gm) may be compared with results obtained by Hokkyo for a fundamental mass (Hokkyo 1968), or predicted values of a "photon rest mass" (for a review, see Vigier 1990).

The model presented here was developed from the vacuum energy quantization concept. Particle restmass is conceived as arising from charged rings on the subquantum level analogously to the appearance of discrete eigenmodes in electromagnetic waves propagating in a torus (Sita Janaki & Dasgupta 1990). On the assumption that the electron is composed of a plasma filament confined in a toroidal geometry, the quantized nature of its mass appears as a natural consequence, resembling the phenomenon of charge quantization discussed by Lehnert (1985). When the charge is equal to the charge quantum e, the formulae yield energies in agreement with observed particle masses to four significant figures, with the approximations made. Furthermore, the de Broglie thermostat results from a definite relation between absorbing and radiating surfaces in the particle geometry. This radiation has been calculated to about 3°K when particles are considered as perfect sinks for graviton energy.

Comparisons with particle masses and other phenomena give good grounds to believe that a new constant relationship of general validity has been found. The constant is expressed as a ratio between surface and energy applicable to self-contained quantum oscillator systems. We conclude that this ratio is a fundamental constant of nature, and that it is the missing link needed for a unified description of the forces and the particles.

Geometric considerations

In setting up our quantum system, we do not normalize the Schroedinger equation arbitrarily, as, for example, in the case of the Higgs field. I have shown elsewhere (Broberg 1984, 1991) that proper normalization implies a definite relationship between surface and energy, which is assumed constant for all self-contained quantum systems (*i.e.* a stability constraint, comparable to a radiationless condition (Hokkyo 1965)). The surface is thus the equivalent of the probability density of the Schroedinger equation, and may be similar to local energy confinement in the Schwarzschild singularity or the "bag confinement" of quarks. The same principle may also apply to the photon, which is usually considered to have energy of a purely kinetic origin.

Since the mid-80s superstring theories, first introduced by Scherk and Schwartz (1974), have been widely used in attempts to describe and unify the concepts of physics. The strings are supposed to represent particles, and they can be open or curved lines. With time, in the space-time geometry, the strings generate surfaces, or world-sheets. The significance of the latter to particles has been discussed by Hawking (1987).

The world-sheet of a closed string is a cylinder, while its cross-section is a flat disk, for example a circle, representing the position (or rather the probability density of the position) of the string (or particle) as a function of time. When particles absorb each other, their strings and world-sheets become joined. Thus, a particle can be modeled as a wave traveling along the string world-sheet, while the string vibrates.

A problem with the current superstring theories is that they have become increasingly complicated and require many more than the normal four dimensions of space-time to work consistently. They have not yet had the anticipated success in explaining the particle properties.

In the following, the concept of rings, rather than strings, will be used. We will analyze singularities generated by a rotating closed ring, much like the core in a superfluid vortex ring (Bergman 1991).

Toroidal ring structures have already been used in models of the electron by Bergman and Wesley (1990) and Carroll (1991), and apparently all quantum states of the electron can be satisfied with these models. Bergman has extended his model to particles in general (Bergman 1991). Putterman (1974), meanwhile, has described how ions become coupled to superfluid vortex rings and concludes that superfluidity is accompanied by the formation of a quantized vortex ring attached to the ion. On the astronomical scale, Wells (1990) has shown that the semimajor axes of the nine major planets, as well as their velocity ratios (the Titius-Bode series), can be explained by assuming that the solar system emerged from a cylindrical volume of plasma that has relaxed to a "minimum energy" state, with planets developing from gas vortex rings that have rolled up into balls.

What is significant about the new type of singularities defined here is that they are initially independent of Planck's constant as well as current gravitational parameters. When we look at quantized systems on different scales, we will find that Newton's "constant" is not at all the only constant of its kind.

To set up the surface-energy relation, we first model a local singular quantum system as a rotating configuration of energy.

Consider a thin rotating ring with rest mass m_0 and rotation velocity v_r. Its kinetic energy is, therefore

$$m_0 c^2(\gamma_r - 1)$$

or in mass terms

$$m_0(\gamma_r - 1)$$

In the following, energy will be expressed as a mass equivalent.

If the ring rotates with velocity v_r and a period t, the surface across the ring can be expressed as

$$\phi_K = \pi\left(\frac{v_r\tau}{2\pi}\right)^2 = \pi r^2$$

The relationship between the surface and kinetic energy is therefore

$$A = \frac{\pi\left(\frac{v_r\tau}{2\pi}\right)^2}{m_o(\gamma_r - 1)}$$

We will treat A as a constant parameter.

This expression can then be developed to

$$Am_0\gamma_r = \frac{\pi(\gamma_r + 1)}{\gamma_r}\cdot\left(\frac{c\tau}{2\pi}\right)^2$$

And we have

$$\lim_{v_r \to 0}(Am_o) = 2\pi\left(\frac{c\tau}{2\pi}\right)^2$$

and

$$\begin{cases} Am_k = \pi\left(\frac{c\tau}{2\pi}\right)^2 \\ m_k = \underbrace{\lim(m_0\gamma_r)}_{\substack{m_o \to 0 \\ \gamma_r \to \infty}} \end{cases}$$

Therefore, for a fixed cycle-time or frequency, we have identified two limits differing by a factor of 2.

In one limit, the peripheral velocity and radius of the rotating ring shrink to zero, while we still find a surface corresponding to the rest state of the ring mass. In another limit, the peripheral velocity goes to c, and therefore the circumference—but not the radius—of the ring shrinks to zero due to Lorentz-contraction; the surface in this case corresponds to the relativistic mass of the quantum.

If the ring translates in space on an open or closed path, a point on the ring will describe a spiral pattern, thus creating an extended tube or a toroidal structure. When the translation velocity is v_L, the rotational velocity is v_r, the tube length is L, and the point moves over N loops with velocity c along the spiral, we have

$$\begin{cases} v_r^2 + v_L^2 = c^2 \\ (2\pi r N)^2 + L^2 = (c\tau)^2 \end{cases}$$

Hence, $c/v_r = \gamma_L$ and $c/v_L = \gamma_r$.

We assume that each loop on the spiral is associated with a ring. When the main toroid contains only one ring and its radius r is much smaller than R it will rotate with a low velocity, approaching zero. On the other hand, if we have N rings and N is large (the spiral loops are tightly packed) or the tube length is short compared to the ring radius, each loop will rotate faster, and when $N \to \infty$, the loop rotation velocity will approach c. In this limit, from a purely kinetic point of view, the rest mass of the tube may be given as the sum of the relativistic ring-masses.

We will assume that the spiral corresponds to a charge current (Carroll 1991), while the rings contribute to the mass of the system.

The division of the system into rings will reach a limit number due, on the one hand, to a decrease in the ring's radius and velocity when its energy content is reduced due to the subdivision of the tube energy over a greater number of loops, and, on the other hand, to an increase of velocity when the number of loops increases. This process will lead to a fixed limit of energy at a certain number of spiral loops, which has a certain relation to the fine structure constant in the electron-system. However, this will not prevent the individual rings from setting up their own spiral structures on the sub-ring level, *etc.*, to the level of the gravitational radius of the system.

Higher energies set up subsystems on the electron tube. This process will lead to the creation of single electromagnetic rings, which still respect the toroidal geometry.

Photon, quantum volume and spin-factor

The photon will be treated as a ring in the case where the rotation velocity approaches zero, while the forward velocity of its ring-spiral system approaches c. In the background system the photon can be modeled as a sphere Lorentz-contracted to a flat disk with the two sides superimposed on each other. The wavelength of the photon will be written here in a form consistent with the Compton wavelength for any particle. Hence, we have $\lambda = cT_c$.

In accordance with the discussion in the preceding section, the surface associated with the photon radius R_{ph} shall be proportional to its energy, and we define this surface as:

$$\pi \cdot R_{ph}^2 = A\frac{h}{c \cdot cT_c}$$

As the photon moves in space, its surface will cover a certain volume during each cycle:

$$A\frac{h}{c \cdot cT_c} \cdot cT_c \Rightarrow A\frac{h}{c} \equiv V_0$$

We will treat this volume as fundamental for all quantum oscillators, expressing it as follows:

$$V_0 = \frac{Ah}{c}$$

A "stationary" disk with the same Compton wavelength as the photon will have in total half this surface, because its rotation velocity approaches c. Therefore, if it is a two-sided disk, each surface will have one quarter of the surface of the photon. It will cover one half quantum volume during one cycle:

$$2\pi R_{rest}^2 \cdot cT_c = \tfrac{1}{2} V_0$$

Hence, for the latter system we have the oscillator frequency given by:

$$4\pi\left(\frac{c\tau}{2\pi}\right)^2 \cdot cT_c = V_0$$

or

$$\pi\left(\frac{c}{\frac{1}{2}\omega}\right)^2 \cdot cT_c = V_0$$

The resulting factor $s = ½$ applied to the particle frequency is the internal particle spin-factor.

We know from the pair-building effect that a photon of sufficient energy, whose forward momentum is absorbed by a heavy nucleus, produces a pair of half-spin particles. Hence, the two particles, when seen as two-sided disks, will together have the same surface-to-energy relationship as the original photon.

Consider instead the case when each particle of the pair can be treated as a spherical system in its rest-state. Each particle has ideally (when the "kinetic" energy is zero) half the energy of the original photon. In order to conserve the surface-to-energy parameter, each particle will therefore need twice the distance in the time-dimension compared to the original photon to set up one quantum volume over its surface. When the space-time coordinate is expressed as a Compton wavelength we have for this case:

$$4\pi R_{sphere}^2 \cdot cT_c = V_0$$

Each spherical particle system will also have spin factor $s = ½$.

A stationary (local) spin-one particle-system can therefore be composed of two two-sided disks, which together set up one quantum volume over their Compton wavelengths, while a local half-spin particle-system can be built either from one spherical surface, which sets up one quantum volume over the particle Compton wavelength, or from four one-sided surface-components, which together set up one quantum volume over the particle Compton wavelength.

In general, for the above defined systems we have:

$$Am \cdot cT_c = V_0$$

A stationary, or local, system will be more complex than a photon and have an internal geometry; the quantum is trapped in a spiral-structure, which can be treated as an assembly of rings. Given a certain Compton wavelength for the system, each surface on one side of a fast-rotating ring in the spiral will correspond to one Nth of the surface of the quantum system. Hence we have:

$$N \cdot \pi r^2 \cdot cT_c = V_0$$

The spiral velocity along the tube is slow when the rings rotate fast. Hence, the tube can form a one-ring system itself. This can be achieved if the thin spiral-tube curls up and closes itself over the large circle of a sphere. The relation between the radii of the tube and the sphere becomes:

$$r = \frac{2}{\sqrt{N}} \cdot R$$

Using this geometric form, the length of the spiral becomes:

$$\ell^2 = (2\pi R)^2 + (2\pi r)^2 N^2$$

This yields:

$$\ell^2 = \pi Am\sqrt{1+4N}$$

When such a spiral-ring system is formed, each loop or ring in the tube-structure will share its surfaces on both sides with its neighbours. Consequently, the spiral is glued together by surface-energy shared by consecutive rings. All the surfaces inside the spiral will therefore be absorbed internally, gluing each other together. The curvature of the system will transform the tube into a toroid-like shape—the same curvature bending the surfaces on the two sides of the toroid into a spherical shape.

The interaction-surfaces resulting from our introductory treatment of surface in relation to kinetic energy are therefore non-zero surfaces corresponding to what is seen in the idealized form ($v_r \to c$) as "singularities" in three spatial dimensions. However, as a result of the formation of mass inside the systems, the particles will not be truly point-like in three spatial dimensions either, but have certain non-vanishing surfaces for their interactions with the exterior.

For a particle at rest, the quantum volume is a three-dimensional object in four-dimensional space-time. The volume of the toroid-like spiral-tube is the three-dimensional surface of a four-dimensional space-time sphere. Our model is, therefore, constructed in four-dimensional space. The surface of the sphere in the model can thus be treated as a vector composed of four orthogonal surface components in four-dimensional space-time.

The Electron

The concept of a charged spiral, adhering to the geometry of a stationary particle set out above, can be used to describe a system that has the quantum properties of the electron. This has already been discussed by Carroll (1991), as well as by Bergman and Wesley (1990).

The quantization of the charge has been analyzed by Lehnert (1987), who has also presented a Lorentz invariant extended formulation of Maxwell's equations leading to the prediction of a longitudinal purely electric wave *in vacuo*, in addition to the transverse electromagnetic wave (Lehnert 1985). The latter paper also predicts the formation of steady states *in vacuo*, in which electromagnetic radiation becomes subject to a self-confinement, leading to values of particle charge, spin and the product of magnetic momentum and mass of the same order of magnitude as those observed for the electron and the proton.

We will now discuss the mass-aspect of the electron. For magnetic permeability μ_0 of vacuum space and charge e, the energy of the magnetic field stored inside the toroid tube is:

$$E=\frac{1}{2}\mu_0\left(\frac{iN}{L}\right)^2 V,$$

where V is the volume of the toroid. When the spiral completes one turn (N loops) around the toroid, the charge travels a distance

$$\ell = 2\pi r N\left(1+\left[\frac{L}{2\pi r N}\right]^2\right)^{1/2}$$

and the current is

$$i=\frac{ec}{\ell}$$

We have also:

$$\left(\frac{L}{2\pi r N}\right)^2 \equiv \frac{1}{4N}$$

Thus

$$N\cdot i=\frac{ec}{2\pi r\left(1+\frac{1}{4N}\right)^{1/2}}$$

and the magnetic energy is:

$$E=\frac{1}{2}\mu_0\frac{e^2c^2V}{(2\pi r)^2\left(1+\frac{1}{4N}\right)\ L^2}$$

In its mass equivalent form, the energy can be written

$$m=\frac{\mu_0 e^2}{8\pi L\left(1+\frac{1}{4N}\right)}$$

We have also $Am=4\pi R^2$.

By eliminating R, we obtain a value for the rest mass of the system:

$$m=\frac{1}{4\pi}\left(\frac{\left[\mu_0 e^2\right]^2}{A\left(1+\frac{1}{4N}\right)^2}\cdot\right)^{1/3}$$

We assume that this represents the electron mass, which is thus made up entirely of magnetic energy (to be qualified further on in the text), when N is large. The result is consistent with a value of the relation between surface and mass given by the electron mass:

$$\begin{cases} m_e \approx 9.108\cdot 10^{-31}[Kg] \approx 0.511[MeV] \\ A\approx 0.70\left[M^2/Kg\right]\approx 1.25\cdot 10^{-26}\left[cm^2/MeV\right] \end{cases}$$

The radius is then

$$R=\frac{1}{4\pi}\left(\frac{A\mu_0 e^2}{\left(1+\frac{1}{4N}\right)}\right)^{1/3} \rightarrow\approx 2.25\cdot 10^{-16}\ m$$

and the toroidal tube length is:

$$L=\frac{1}{2}\left(\frac{A\mu_0 e^2}{1+\frac{1}{4N}}\right)^{1/3} \rightarrow\approx 1.413\cdot 10^{-15} m$$

The above numerical value for A will be used in the following for all particles and fields.

If each one of the loops has a fraction (one Nth) of the charge on its surface, the potential electric energy of the associated rings is:

$$E=\frac{1}{4\pi\varepsilon_0}\cdot\frac{\left(\frac{e}{N}\right)^2}{r}\equiv\frac{1}{8\pi\varepsilon_0}\cdot\frac{e^2}{N\sqrt{NR}}$$

When we sum over all the loops, we get:

$$\sum_{n=1}^{N} E=\frac{1}{8\pi\varepsilon_0}\cdot\frac{e^2}{\sqrt{NR}}$$

In other words, the electric potential energy of the loops disappears when N is large. The electric force acting on consecutive rings produces an expansive force on the spiral. This force corresponds to a stored energy equivalent to the magnetic energy stored in the spiral, calculated above, when the field-lines are parallel to the electron tube. This should be the case, because we have assumed that the spiral-tube curves with the space. The tension of the magnetic field in the spiral-tube system therefore cancels the electric expansion-force between consecutive rings. The electrostatic potential energy on the toroid, finally, cancels out by the surface energy potential in the system, as explained further on in the section on "force action in the quantum system". Consequently, the magnetic field itself makes the only contribution to the mass.

The muon

The mass of the muon is given by the electron geometry in the case of one of the four surface-components from the electron-system (or the cross-section of the spherical system). The spiral has one loop, or ring. The spiral-length (time) from the reduced electron system times the cross-section sets up one quarter of a quantum volume. In this case, due to the single loop, both the electric and the magnetic fields come into play. Hence, we have an electromagnetic system with the mass given by:

$$Am_\mu \cdot \underbrace{L\{N=1\}\sqrt{1+4N}}_{\ell} = \tfrac{1}{4}V_0$$

The Compton wavelength of the muon is therefore 4ℓ.

The particle mass is:

$$m_\mu = \frac{h}{4cL\{N=1\}\sqrt{1+4N}}$$

$$\equiv \frac{h}{2c}\cdot\left(\frac{1+\frac{1}{4}}{A\mu_0 e^2}\right)^{1/3}\frac{1}{\sqrt{5}}$$

and finally:

$$m_\mu = 1.883\cdot 10^{-28}\,Kg\,(105.55\,MeV)$$

This mass agrees to four significant figures with the observed mass.

Force action in the quantum system

We will regard the vacuum energy as being glued together by consecutive rings in the manner discussed above for the electron.

It is now possible to determine the time-constant which sets up a quantum volume on the surface of a disk with the Planck radius

$$\begin{cases} \pi R_{Pl}^2 = \dfrac{2\pi G h}{c^3} \\ \pi R_{Pl}^2 \cdot cT = V_0 \end{cases}$$

The time constant corresponding to the surface is given by the quantum volume

$$V_0 = \frac{Ah}{c}$$

This gives:

$$cT = \frac{Ac^2}{2\pi G} = 1.5\cdot 10^{26}\ m\,(16\cdot 10^9\ ly)$$

a figure in good agreement with the accepted value of the so-called Hubble radius (c/H). This indicates the existence of a minimal energy quantum, possibly a graviton, which has a positional uncertainty equal to the Hubble radius (for further discussion, see (Broberg 1981, 1982).

If this particle is indeed the graviton, the true value of Hubble's "constant" should be:

$$H = \frac{1}{T} \equiv \frac{2\pi G}{Ac} \approx 2.00\cdot 10^{-18}\,s$$

This value corresponds to a Hubble time of approximately 1.6×10^{10} years, which is borne out by observations of the cosmological redshift.

The mass corresponding to the surface is then:

$$m_{Pl} = \frac{\pi R_{Pl}^2}{A} \equiv \frac{hH}{c^2} \approx 1.47\cdot 10^{-68}\,Kg$$

$$\approx 8.25\cdot 10^{-39}\,MeV$$

This mass has a positive or a negative value, depending on whether the Planck radius is imaginary or not. If it is imaginary, the "graviton mass" is a "hole" in the vacuum space, thus transferring negative momentum corresponding to an attractive force. An absorption of energy by a particle from the vacuum would be equivalent to the emission of such a vacuum hole.

If we continue the analogy with the electron and introduce a constant G_e in the electron system with a function analogous to Newton's constant in the large-scale universe, we find the following relation to be true:

$$G_e = \frac{Ac^2}{R_e}$$

The force between two quanta of mass m_e becomes

$$F = G_e\frac{(m_e)^2}{R^2}$$

Inserting the expressions for G_e, m_e and R_e from the electron model above when $N\to\infty$ gives:

$$R^2F = \frac{Ac^2}{\left(\frac{1}{4\pi}\left[A\mu_0 e^2\right]^{1/3}\right)}\cdot\left(\frac{1}{4\pi}\left[\frac{\left(\mu_0 e^2\right)^2}{A}\right]^{1/3}\right)^2$$

$$\equiv \frac{c^2\mu_0 e^2}{4\pi}$$

When the number of loops in the spiral structure is small we get instead:

$$R^2F = \frac{c^2\mu_0 e^2}{4\pi}\cdot\frac{1}{\left(1+\frac{1}{4N}\right)^{2/3}}$$

It follows from this that the "gravitational" or attraction force law in the electron system is of equivalent form and magnitude to Coulomb's Law when $N\to\infty$. (When $N\to 0$ we have the case of a slowly rotating ring in a "relativistic" particle. It is therefore possible to find a value of N which gives the proper relation between the Universal force of gravitation and the electric force.) In the electron-system the force laws can be written in the unified form:

$$F = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q_1Q_2}{R^2}$$

$$\equiv G_e\frac{(n_1 m_e)\cdot(n_2 m_e)}{R^2}$$

Accordingly, the force laws can be given in a more general form, as follows [N.B.: the energy density of the force field (ρ_g) is expressed in terms of the vacuum background density(ρ_0) of force-carrying quanta, the interaction surface (Φ) of each particle and the surface of their common space (D^2)]:

$$\rho_g = \rho_0 \cdot \left(\frac{\Phi_1}{D^2}\right) \cdot \left(\frac{\Phi_2}{D^2}\right)$$

The product of the normalized particle surfaces can be understood as the probability that a force quantum will interact with both particle quanta simultaneously. Newton's law of gravitation also adheres to this more general formula.

We may therefore conclude that the potential electric energy of the charged toroid inside the electron system disappears, and, therefore, only the magnetic energy stored inside will contribute to the mass. To determine what is meant by "inside" the electron, we calculate the counterpart to the Schwarzschild radius in the electron system, using G_e instead of Newton's G:

$$R_{Ge} = \frac{2G_e \cdot m_e}{c^2} \equiv 2L$$

This value is equal to the "classical" electron radius:

$$2L = \frac{\mu e^2}{4\pi m_e}$$

Therefore, electrical energy from a charge on the surface of a sphere with the "classical radius" would be transformed into stored magnetic energy in the electron mass, fall inside the counterpart of a Schwarzschild singularity in the electron system, and acquire the spiral structure described above.

The relation to the gravitation in the Universe occurs when N becomes so large that the radius of rings, or subrings, in the electron-system is equal to the gravitational radius of the electron. Using the relations defined in the section on the electron, the mass of the electron can be given as:

$$m_e = \frac{\pi r^2}{A} \cdot N$$

The gravitational radius, using the expression for G above becomes:

$$\begin{cases} R_G = \dfrac{2Gm_e}{c^2} \equiv \dfrac{r^2}{cT} \cdot N \\ R_G = r \end{cases}$$

Hence,

$$cT = r \cdot N.$$

The relation between the universal mass-field and the electron mass therefore becomes:

$$m_e = \frac{\pi (cT)^2}{A} \cdot \frac{1}{N}$$

In short, there are as many electron masses in the universal mass-field as there are rings on the level of the gravitational radius in the electron-system. In its own mass-field, the electron toroid is the one ring in the counterpart to a "universe" that contains only one electron mass.

If T_0 is the "Hubble time", the above relation would give the electron mass by the factor $1/N$ applied to a total universal energy-mass field with the energy:

$$M_0 = \frac{\pi (cT_0)^2}{A} \approx 1.0 \cdot 10^{53} [Kg]$$

As a comparison with observation, such a mass is approximately equal to the mass of 10^{11} galaxies, each having the mass of 10^{11} stars, if the average mass of a star is about the same as the mass of our sun.

A general conclusion from the discussion above is that there is strong evidence in favour of a hypothesis that the force laws in the Universe are linked to each other via the quantum surface-energy relation expressed by the constant A.

Mesons

Charged pion

The fundamental mesons and baryons are found when time-sheets obtained from the electron-system are used to set up the quantum volume.

We have already seen in the case of the muon that the electric field is liberated when the electron string has one loop only; the result is an electromagnetic particle. The mass of the pion quark can be related to the "classical electron-radius", as defined above. Suppose that we have a quantum with the Compton time corresponding to the counterpart of the circumference of the Schwarzschild singularity in the electron-system, *i.e.* a wave on the surface of the electron-system. This quantum will have the mass:

$$m_q = \frac{h}{4\pi cL}$$

Two such quanta will have the mass:

$$m_{\pi\pm} = \frac{h}{2\pi cL} \equiv \frac{h}{\pi c \left(A \mu_0 e^2\right)^{1/3}}$$

$$m_{\pi\pm} \approx 2.489 \cdot 10^{-28} Kg (139.5 MeV)$$

This mass is identical to the mass of the charged pion to about four significant figures' accuracy. The two quanta in the pion-system are assumed to correspond to the quark-structure.

The system may be regarded as one charged ring of radius L, where the time-component is folded twice, like a Moebius strip. It has then sunk to the level in the Schwarzschild-like "singularity" where all of the potential electric energy has been transformed into an electromagnetic mass-field of energy.

We have not undertaken further analysis of the charge and spin relations of the quanta; we have merely established a comparison of the mass with the geometric concept of structure identified in the analysis of the electron.

A more in-depth study of the quark structure and its conciliation with this geometry should be undertaken in a later essay.

Neutral pion

The neutral pion can be treated as an electromagnetic quantum-time system.

This surface corresponds to the surface of a tube where the length and the circumference are both equal to $(c\tau)$. We thus obtain:

$$\begin{cases} m_q = \frac{1}{2}\frac{h}{c(c\tau)} \\ m_{\pi_o} = \frac{h}{c(c\tau)} \\ Am_q = (c\tau)^2 \end{cases}$$

$$m_{\pi_o} = \left(\frac{2h^2}{Ac^2}\right)^{1/3} \approx 2.407 \cdot 10^{-28}\ kg \quad (135.0\ MeV)$$

This mass agrees to four significant figures with the observed mass.

Meson resonances

A large number of other meson masses have been calculated as resonances to the ground states found above (Broberg 1991). The spin particles are separated from non-spin particles by degrees of freedom in the 2-oscillator (quark) system.

Nucleons

Neutron

The neutron quark structure corresponds to three pairs of interacting rings where each ring surface is

$$Am_q = 4\pi r^2$$

Each ring occupies one spherical quantum volume equal to one-sixth of the quantum volume v_0. Hence the volume is:

$$\frac{4}{3}\pi r^3 = \frac{Ah}{c}\cdot\frac{1}{6}$$

This yields an equation system

$$\begin{cases} Am_n = 4\pi r^2 \cdot 6 \\ \frac{Ah}{c} = \frac{4}{3}\pi r^3 \cdot 6 \end{cases}$$

And the mass of the ring system becomes

$$m_n = 6 \cdot \left(\frac{\pi h^2}{Ac^2}\right)^{1/3}$$

$$\approx 1.6785 \cdot 10^{-27}\ kg\ (941.716\ MeV)$$

The system mass is the same as if all the surfaces of the ring components and volumes were folded over each other, with the total calculated as the mass of one ring quantum, for which A is divided by 6—a surface manifold of sixth order.

This figure agrees with the neutron mass with three figures' accuracy. If four electron masses are deducted from the above calculated mass we get 939.67 MeV, which gives about four figures' accuracy for the neutron mass. The reason for this difference may be that the creation of the neutron has to include the subtraction of these sub-quantities from the four space-time vectors of the system.

Proton

The proton mass can be obtained from a quantum-time system as follows. Each quark, or subsystem, is set up in the same way as for the charged pion, with the difference that it contains one ring based on the electron-system with charge $e/3$.

The proton-mass is found when three pion-like quark-structures are added together, each one containing two one-loop waves around the Schwarzschild-like "singularity" of the electron-system. The total assembly thus carries the charge e. The total mass is:

$$m_p = \frac{3h}{\pi c}\frac{1}{\left(A\mu_0\left[\frac{e}{3}\right]^2\left[\frac{1}{1+\frac{1}{4}}\right]\right)^{1/3}}$$

$$= 1.672 \cdot 10^{-27}\ kg\ (938.07\ MeV)$$

This gives an accuracy of three to four figures.

We have not undertaken a detailed study of the *uud* quark-structure of the proton. Our goal is simply to find the particle masses. However, in a more complete analysis the quark structure should be developed further.

Particle geometry and the fine-structure constant

The fine structure constant is given by:

$$\alpha = \frac{\mu_0 e^2}{2\frac{h}{c}}$$

The relation between the time constant in the electron system and the particle mass can be established as follows.

If we use the length of the electron spiral as the time constant in our metric system and the time in the particle system is defined by $cT = \hbar/cm$, we have:

$$\begin{cases} \left(\dfrac{\hbar}{cm_e}\right)^2 = \pi A m_e (1+4N) \\ m_e^3 = \dfrac{1}{(4\pi)^3} \cdot \dfrac{(\mu e^2)^2}{A\left(1+\dfrac{1}{4N}\right)^2} \end{cases}$$

The result is:

$$\begin{cases} \alpha = \dfrac{1}{\sqrt{N}}\left(1+\dfrac{1}{4N}\right)^{½} \\ \alpha = \dfrac{r}{2R}\left(1+\dfrac{1}{4N}\right)^{½} \end{cases},$$

This can be compared with the most energetic photon quantum emitted from the hydrogen atom, which has the energy:

$$\frac{m_e \alpha^2}{2} \Rightarrow \frac{m_e}{2N_e}$$

This finding is in line with the quantized nature of the electromagnetic spectrum.

We may conclude that the fine structure constant is a parameter relating a number of consecutive rings in the electron-system to each other:

$$\alpha = \frac{r}{2R} = \frac{4\pi L}{\lambda_C} = \frac{\lambda_C}{2\pi R_B} = \frac{4\pi R_B}{\lambda_{Ryd}},$$

where λ_C is the Compton wavelength of the electron, R_B is the inner orbit in the Bohr model of the hydrogen atom and λ_{Ryd} is the wavelength of the most energetic photon-quantum emanating from the hydrogen spectrum. The classical radius of the electron radius is equal to $2L$, while $L = 2\pi R$ and r are geometric properties from the electron model introduced here. Hence, every second ring rotates with a velocity equal to or close to c, while the remaining rings rotate with a velocity close to zero when compared with c. This indicates that what we see are ring structures from a spiral pattern which repeats itself over and over again. Whether or not the same pattern occurs from the level of the electron gravitational radius and all the way up to the Hubble radius is an open but fascinating question.

The relation between r and R indicates the possibility that the masses of the heavier particles may result from the creation of charges, for example electron-positron pairs, on the subquantum level (r) in the electron system.

The "vacuum thermostat" and the cosmic background radiation

We now return to de Broglie's thermodynamics, which, as noted earlier, implies an exchange of energy between particles and the vacuum via a "vacuum thermostat". This idea can be developed as follows.

We saw earlier that the electron can be described by a model incorporating a spherical surface for interactions with the surrounding space.

This surface seems to be the locus of interactions at the quark level. It is also the site where particle charge quanta are stored; it is the core of rest-mass particles. The surface determines the inner structure of a counterpart of a Schwarzschild singularity in the quantum space-time of particles. We will therefore treat this area as an absolute sink for vacuum energy. This is in accordance with the analysis of Carroll (1991) who concludes that "in addition to the motion of particle spin, there exists a source-sink flow at right angles to the motion of spin—through the vortex centre".

We assume that the vacuum space has an energy density ρ_0 (in terms of mass).

It was established above, in the section dealing with the force action, that the vacuum tube corresponds to a surface which has a radius equal to the Plank radius. We can therefore also calculate the corresponding "graviton" mass density in the vacuum from the relation between surface and mass:

$$A = \frac{Surface}{Mass} = \frac{\Phi_{Pl}}{\Phi_{Pl} \cdot cT_0 \cdot \rho_0}$$

We thus have

$$A \cdot cT_0 \cdot \rho_0 = 1$$

The density is:

$$\rho_0 = \frac{1}{A \cdot cT_0} \equiv \frac{2\pi G}{A^2 c^2}$$

The energy inflow through the absorbing surface is:

$$\frac{dm_e}{dt} = c\rho_0 \cdot A m_e$$

The increase of energy causes the quantum-system's temperature to increase, and at an equilibrium temperature it will radiate off energy with a Planck spectrum.

As the radiating surface, we will use the surface corresponding to the time constant in the electron system defined in the preceding section on the fine structure constant. This time constant is assumed to be equal to the length of the spiral in the electron system. The radiating surface is consequently based on the quantum counterpart of the Compton wavelength:

$$\Phi_{rad} = \frac{1}{\pi}\ell^2 \equiv \frac{1}{\pi}\left(\frac{\hbar}{cm_e}\right)^2$$

The radiation temperature depends on the relation between the absorbing and the radiating surfaces:

$$\frac{\Phi_{abs}}{\Phi_{rad}} = \frac{Am_e}{\frac{1}{\pi}\ell^2} \equiv \frac{\alpha^2}{4}$$

The temperature can be calculated with Stefan-Boltzmann's law:

$$T = \sqrt[4]{\frac{\frac{\mathrm{d}m}{\mathrm{d}t}\cdot c^2}{\sigma\cdot\Phi_{rad}}} \equiv \sqrt[4]{\frac{c^3\rho_0}{\sigma}\cdot\frac{\Phi_{abs}}{\Phi_{rad}}}$$

The radiation temperature is, finally:

$$T = \sqrt[4]{\frac{2\pi Gc}{\sigma A^2}\cdot\frac{\alpha^2}{4}} \approx 2.8^{\circ}[K]$$

This temperature is in good agreement with the background microwave-radiation from space. The de Broglie "thermostat" therefore appears to be a very realistic notion.

It should be noted that the above approximate relation for radiation temperature will give about the same result for a proton which radiates off its energy via the electron layers in the hydrogen atom.

The relation between the absorbing and radiating surfaces has a basic form, *i.e.* a function only of constants directly related to the vacuum space. The background radiation could therefore also arise from sub-vacuum activities, such as the spontaneous creation and absorption of electron-positron pairs in accordance with the Dirac ether theory. The background radiation would then be the visible sign of these processes, as well as the Universal gravitational interaction.

If this is true, vacuum space itself could function as an absorbing medium for electromagnetic energy. Whenever a photon intercepted a vacuum "hole" it would lose one elementary quantum of energy while interacting with the quantum volume that contains the "hole". One consequence of this is that the cosmological redshift should be enhanced when electromagnetic waves pass through areas of spacé with strong gravitational interactions, such as in galaxies. This effect has been observed and has been analyzed by Jaakkola (1977).

Astrophysical implications

Much of the electromagnetic radiation from stars could arise from the same process that creates the cosmic background radiation; energy could be absorbed by the particles in a star from the vacuum and radiated back out over the star's surface, thus explaining both the low neutrino rate in the radiation from the sun and the origin of the energy that can fuse the particles in a star together beyond the heavy elements, up to the level of a neutron star.

If this process actually takes place, the fusion processes in stars are only responsible for part of the radiation from the stars when they are young, while later on in their cycle the radiation would be mainly due to the release of residual energy after fusion has absorbed part of the energy radiation from the particle quanta, caused by their interaction with the vacuum space.

Thus, if gravitation is induced by the particle-vacuum interaction, the radiation from celestial bodies would be a visible sign of the gravitational process in the Universe.

Continuing this line of thought, we may find an energy-based "ecology" in the Universe, where energy is transferred and transformed between the different states of vacuum, particles and electromagnetic radiation.

Galactic structure presents similarities to the geometry described here for the electron. Galaxies normally have a spiral shape. A star of average size corresponds to a ring with a radius approximately equal to the gravitational radius of the galaxy. The sum of all such ring radii in a galaxy becomes about equal to the Hubble length. The ring radius of a star is calculated from the mass:

$$r \propto \sqrt{\frac{Am_{\odot}}{4\pi}} \approx 10^{15}[m]$$

This is the radius a star would have if all its particle masses were joined in one quantum. It is of the same magnitude as the average distance between stars in the galaxy, or the distance to the Oort cloud of meteorites around the solar system.

One is tempted to speculate that the radius of a "star-ring" could be the equilibrium extension of a star-gas, when the star has undergone gravitational collapse and goes through the states of a supernova, later becoming a white dwarf. The Oort cloud could, therefore, be the vestige of a former phase in our sun's life cycle.

Discussion

With the development of the particle-ring concept, the thermodynamics of de Broglie has been made explicit. We have shown that the vacuum thermostat is to be identified with an interaction surface that is characteristic of each quantum system. Through this surface, each particle remains in constant contact with the vacuum energy and maintains an equilibrium temperature and mass. A development of this concept has led to definite predictions with regard to the cosmic background radiation and other radiation from material bodies, and leads to further insights into the relations between the particles and the forces, as well as to the role of the fine structure constant. The cosmological redshift may be explained by the same principle.

As early as 1919, Einstein (1919) indicated the "possibility of a theoretical construction of matter out of gravitational field and electromagnetic field alone", noting that particle energies might be accounted for by means of a modification to the field equations of general relativity. More specifically, in a discussion of the electron, he proposed that the gravitational constant ("the scalar of curvature") could have another value in the system of a particle than in the space outside the particle. The model presented here is based on the same fundamental idea.

With regard to particles, it should be noted that this analysis is mainly an empirical comparison between geometric concepts and particle energies, and consequently does not conform in detail with the quark model. A more thorough study of this problem should be undertaken.

However, the differences between the inner structures of the quantum components in the models presented here for the different families of particles are quite real (one component for leptons, two for mesons and three for baryons).

The particle mass formulae given here must be seen as approximations due to the fact that the one-way vibration velocity has been assigned the value c, whereas in reality the velocity would be slightly less, *i.e.* the de Broglie group velocity, if the rings are not infinitely thin. A deeper study of this concept may yield more accurate results for the masses.

The geometry used for the particles and the force fields bears a strong resemblance to superfluid vortex rings (Putterman 1974). The results presented here, together with Lehnert's prediction (Lehnert 1985) of a purely electric wave in vacuo, suggest that it may at last be possible to develop a complete theory of superconductivity.

Finally, the evolution of stars, galaxies and other large-scale astronomical structures may ultimately be understood better in the light of the quantum ring model proposed in this study.

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