TOWARDS A UNIFIED THEORY OF FORCES

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Abstract

A theoretical model is proposed that unifies the forces of gravitation, electromagnetism and the nuclear (strong) force. The classical electron radius, Dirac's Large Numbers and an explanation for electron spin follow from the model. The Mach relation of cosmology is derived and applications to modern astrophysics are indicated. These include an explanation for the accelerating expansion of the universe and a force equation for the higher order gravitational properties of binary pulsars.

Vers une théorie unifiée des forces

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Résumé

Un modèle théorique unifiant les forces de gravitation, l'électromagnétisme et la force nucléaire (forte) est proposé. Suivent le rayon classique de l'électron, les grands Nombres de Dirac et une explication du spin de l'électron à partir du model. La relation de Mach en cosmologie est dérivée et des applications d'astrophysique moderne sont indiquées. Ceux-ci incluent une explication pour l'expansion accélérée de l'univers et une équation de force pour les propriétés gravitationnelles d'ordre supérieure des pulsars binaires.

Hacia Una Unificada Teoría de las Fuerzas

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Extracto

Se propone un modelo teórico que unifica las fuerzas de gravitación, el electromagnetismo y la (fuerte) fuerza nuclear. Del modelo siguen el clásico radio del electrón, los Grandes Números de Dirac y una explicación de la revolución del electrón. Se deriva la relación de la cosmología Mach y se indican aplicaciones a las modernas astrofísicas. Éstas incluyen una explicación de la acelerante expansión del universo y una ecuación de fuerza para las propiedades gravitacionales de mayor orden de los pulsares binarios.

Para uma teoria unificada de forças

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Sumário

Um modelo teórico é proposto que unifica as forças de gravitação, do electromagnetismo e da força (forte) nuclear. O radius clássico do elétron, os Números Grandes de Dirac e uma explicação para a rotação do elétron seguem a partir do modelo. A relação da cosmologia do Mach é derivada e as aplicações à astrofísica moderna são indicadas. Estes incluem uma explicação para a expansão de aceleração do universo e uma equação da força para as propriedades gravitacionais de uma ordem mais elevada de pulsars binários.

Ansaetze zu einer vereinten Theorie der Kraefte

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Zusammenfassung

Es wird ein theoritisches Model vorgeschlagen, dass die Kraefte der Gravitation, des Elektromagnetismus und der starken Nuklearkraft vereinigt. Der klassische Elektronenradius, Diracs Grosse Zahlen und eine Erklaerung der elektronischen Drehung erscheinen in dem Model. Der Mach-Zusammenhang der Kosmologie folgt daraus und Anwendungen in der modernen Astrophysik werden angedeutet. Diese schliessen ein die beschleunigte Expansion des Universums und die Kraftgleichung fuer die hoehere Ordnung der Gravitationseigenschaften der binaeren Pulsare.

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1. Introduction

Modern physics distinguishes amongst four fundamental forces, i.e., forces that act differently under different conditions. They are the forces of gravitation and electromagnetism, the nuclear force and the weak force. Physicists have been successful in devising a model that incorporates the latter three forces, but the incorporation of gravitation remains elusive. A plethora of theories has been developed over the past forty years to include gravity, with string theory as the most popular recent candidate.[1] There are also supersymmetry and quantum gravity, but none of these models appear to be successful.

There is a firm belief among physicists that a single model of forces should exist, and the pursuit of such a model has been described as a search for the Holy Grail of physics. This model should be a single consistent mathematical formulation giving the properties of the four fundamental forces.

Such unification is desirable from a philosophical viewpoint. A fundamental tenet of mystical schools is that creation forms a unity, with the different forms the corporeal manifestations of a single, creative spirit. Our understanding of creation is driven by striving for such simplicity and beauty.

Another fundamental principle of the mystical schools is that of "As above, so below." Within a scientific context it implies that the very large should be reflected in the infinitesimally small. An example of this would be a model that describes both planetary motion and the motion of electrons in an atom.

We approach the problem by starting with a model of gravitation. In a previous paper in this journal[2] we presented a model, derived from Newton's ideas, which satisfies the three classical tests for a theory of gravitation.

At this stage we need to clarify our use of the terms 'model' and 'theory.' By a model we understand the body of mathematics that describes a system, and by theory we also include the postulates and assumptions on which the mathematical body is constructed. A model is constructed from postulates, assumptions, and the appropriate mathematical tools, and yields specific results or predictions. A theory tells us how that model is constructed.

Our paper is mainly descriptive and we shall limit its mathematics to an essential minimum. We shall avoid calculus where possible. The mathematical detail can be found in Ref. 3. However, no discussion on a unified theory can be sensible without some mathematics. As stated by Richard Feynman (1918-1988):[4] "People who wish to analyze nature without using mathematics must settle for a reduced understanding." For the scientist an elegant mathematical formulation represents its version of beauty.

Correct mathematics is one of the requirements for a model of physics. The other requirements are valid postulates or presumptions, consistency of argument, and agreement with observation. We aver that the proposed model satisfies all these requirements.

We must emphasize that our model is strictly based on standard, conventional physics, and specifically on the principles of Hamiltonian dynamics and special relativity theory.

2. The Newtonian model

Our Newtonian-type model of gravitation is based on a Lagrangian [see eq. (17) of Ref. 2],

$$L = -m_0(c^2 + v^2)\, e^{R/r}, \tag{1}$$

where

m_0 = gravitational mass of a particle,
c = speed of light,
R = Schwarzschild radius = $2GM/c^2$,
G = gravitational constant,
M = mass of a massive, central body,

v = speed of the test particle relative to the central body,
R = distance of the test particle from the central body.

A Langrangian is a compact mathematical expression from which we can derive the properties of a system, such as the energy and the forces acting on the system. It will also give the equations of motion of a particle, i.e., how it moves under the forces acting on the system. We call the actions due to a force the *dynamics* of a system.

In the rest of the text 'the Lagrangian' shall refer to the Lagrangian of (1).

The energy E of a particle can be derived from the Lagrangian (see Ch.3 of Ref. 3) as

$$E = m_0 c^2 \frac{e^{R/r}}{\gamma^2}, \tag{2}$$

where $\gamma = 1/\sqrt{1 - v^2/c^2}$.

It will be convenient, and more general, to write the above equation in terms of the gravitational potential $\Phi = GM/r = Rc^2/2r$. The above equation then becomes

$$E = m_0 c^2 \frac{e^{2\Phi/c^2}}{\gamma^2} . \tag{3}$$

It is also useful to define a variable *gravitational mass*,

$$m = m_0/\gamma^2 , \tag{4}$$

so that (2) and (3) can be rewritten as

$$E = mc^2 e^{R/r} = mc^2 e^{2\Phi/c^2} . \tag{5}$$

It must be noted that m decreases with velocity.

For the systems described in Ref. 2, the Lagrangian describes two types of motion. The first one is that of a particle with non-zero mass moving about the central body. In the case of a planet, such as Mercury, it describes, not only an elliptical path for the planet, but also a precession of the ellipse.

The second type of motion is for a particle of zero mass, i.e., for a photon, or particle of light. In this case the Lagrangian predicts a hyperbolic path, which results in the bending of a light ray by the sun.

Both the above predictions conform with observation. These two phenomena are *dynamical* in origin.

With the foregoing in mind we can state our first postulate:

***Postulate 1**: The dynamics of a system of particles subject to gravitational forces is determined by the Lagrangian of (1).*

3. Gravitational redshift

The third test is that of gravitational redshift. This effect implies that the *frequency* of a photon will decrease with increasing strength of a gravitational field. For example, the frequency of a photon moving closer to a star will decrease, i.e., its frequency is shifted towards the weaker, or red side, of the spectrum. In order to accommodate this effect in the Newtonian model we make an important assumption. To understand this assumption we first look at the tenets of Special Relativity.

4. Special relativity

Special relativity (SR), as formulated by Einstein (1879-1955) in 1905, can be represented by the metric,

$$ds^2 = c^2 d\tau^2 = c^2 dt^2 - dr^2 ,$$

where

ds = invariant Minkowskian metric,
τ = the proper time as measured on a clock (the proper clock) *carried* by the test particle,
t = the coordinate time as measured on the *different clocks* (the coordinate clocks) as the test particle passes them.

If we substitute $v = dr / dt$, the above equation can be written as

$$\gamma\, d\tau = dt, \tag{6}$$

the time-dilation formula of SR.

Since the proper time is measured at one position on one body it will be the same for all observers, whether they are fixed at various points in the coordinate frame or moving with the proper clock. We call such a quantity an *invariant*. The energy E in (2) is similarly an invariant.

In Fig. 1 the coordinate clocks A and B are fixed in some reference frame, whereas the proper clock moves from one coordinate clock to the other. SR states that the time interval $\Delta\tau = \tau_2 - \tau_1$, as measured on the proper clock, will be shorter than the time interval $\Delta t = t_2 - t_1$ between the two coordinate clocks. For infinitesimal small intervals the difference is given by (6), where v is the relative velocity between the proper and coordinate clocks.

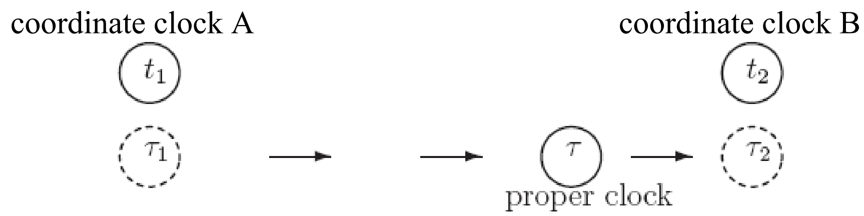

Figure 1: Proper clock passing coordinate clocks.

A fundamental requirement of SR is that the relative velocity between the coordinate and proper clocks must be constant, which also implies motion along a straight line. The description of such motion, as well as any others, is called *kinematics*. Kinematics only tells us how a particle moves in space with time, without referring to the forces giving rise to the motion.

SR is a pure kinematical theory. The early challenge of gravitation theory was to incorporate the results of SR into the dynamics of gravitation. Einstein's first efforts were along this line.[5]

In this paper we shall show how such incorporation can be achieved.

5. The red-shift formula

SR is not only a kinematical theory; it is also a theory of electromagnetism. This is indicated by the title of Einstein's paper: *Zur Elektrodynamik bewegter Körper*. Incorporating SR into our theory of gravitation will then provide the link between gravitation and electromagnetism. For this we need the red-shift formula.

Frequency is the inverse of time, so that the inverses of (6) give the Doppler shift for frequency:

$$\gamma\nu = \nu_p, \tag{7}$$

where ν and ν_p are respectively the frequencies of a coordinate clock and a proper clock. By substituting for γ from (2) we find

$$\nu = A\nu_p e^{-R/2r}, \tag{8}$$

where

$$A = \sqrt{E/m_0c^2}. \tag{9}$$

Since both A and ν_p are invariants we may define another invariant frequency as

$$\nu_0 = A\nu_p. \tag{10}$$

Equation (8) can then be written as

$$\nu \;=\; \nu_0 e^{-R/2r}\,, \tag{11}$$

$$\approx \nu_0(1 - R/2r)\,, \tag{12}$$

which gives the observed values for gravitational redshift.

One of the perplexities of astrophysics is the relation between Doppler shift and gravitational redshift. The above relations clarify this relation.

Multiplying (11) by Planck's constant *h* on both sides gives an energy equation,

$$\widetilde{E} \;=\; h\nu_0\, e^{-R/r}\,,$$

where

$$\widetilde{E} = h\nu \tag{13}$$

has the form for the energy of a photon. A significant aspect of the equation is that it contains the quantum mechanical *h* and the gravitational *G* in one equation.

Since both *E* and $h\nu_0$ are invariants, they are related by a constant. Since these invariants do not have any absolute values at this stage, we may set the constant equal to unity.

Therefore

$$E = \widetilde{E}e^{R/r}\,. \tag{14}$$

With the foregoing in mind we now formulate our second postulate:

Postulate 2*: Special Relativity is valid instantaneously and locally at all points in the reference system of the central massive body.*

This is also a standard assumption in relativity theory. It implies that the time-dilation formula of (6) is valid locally at all points in space. The time difference between the proper clock and the coordinate clocks varies with γ, or equivalently, with the velocity. But, since γ is related to the gravitational potential according to (3), the time differences also depend on the gravitational potential at the point where the measurement is made.

6. The photo-electric effect

Einstein received the Nobel Prize for his 1905 paper on the photo-electric effect. This relation relates the kinematical energy $\widetilde{E}$ of SR to the frequency of a photon:

$$\widetilde{E} \;=\; \widetilde{m}c^2 \;=\; h\nu\,, \tag{15}$$

where

$$\widetilde{m} \;=\; \gamma\,\widetilde{m}_0\,. \tag{16}$$

The quantity $\widetilde{m}$ is the *electromagnetic mass* of a particle, and it varies relative to its rest mass $\widetilde{m}_0$ according to (16). The difference between the gravitational mass *m* and the electromagnetic mass $\widetilde{m}_0$ is fundamental to our theory.

The above relations for $\widetilde{E}$, as well as the link between electromagnetism and the kinematics of SR, persuades us to associate $\widetilde{E}$ with the *electromagnetic energy* of a system.

From (14), (15) and (16) we get

$$E = \widetilde{m}_0 c^2 \frac{e^{R/2r}}{\sqrt{1 - v^2/c^2}} = \widetilde{m} c^2 e^{R/2r} , \tag{17}$$

or, in terms of Φ,

$$E = \widetilde{m}_0 c^2 \frac{e^{\Phi/c^2}}{\sqrt{1 - v^2/c^2}} = \widetilde{E} e^{\Phi/c^2} . \tag{18}$$

The corresponding Lagrangian for the above energy can be derived as [3]

$$L = -\widetilde{m}_0 c^2 \sqrt{1 - v^2/c^2}\, e^{\Phi/c^2} . \tag{19}$$

7. The Hydrogen atom

Expanding (18) gives

$$\begin{aligned} E = {} & \widetilde{m}_0 c^2 + \widetilde{m}_0 v^2/2 + \widetilde{m}_0 \Phi + \widetilde{m}_0 \Phi v^2 / 2c^2 \\ & + \widetilde{m}_0 \Phi^2 / 2c^2 + \widetilde{m}_0 v^2 \Phi^2 / 4c^4 + \ldots \end{aligned} \tag{20}$$

Consider the first three terms on the right-hand side (RHS) of the above equation:

$$E = m_0 c^2 + m_0 v^2/2 + m_0 \Phi . \tag{21}$$

In order for the motion of the system to be bounded, the last term must not only be inversely proportional to *r*, but also negative. To ensure this we let

$$\widetilde{m}_0 \Phi = -e^2/r , \tag{22}$$

where *e* is an arbitrary constant.

This is a significant result as the constant *e* eventually turns out to be the charge on an electron. Its existence is a mathematical requirement for bound motion. Alternately, a positive sign in (22) results in unbounded, repulsive motion.

Since $\Phi = Rc^2 / 2r$, (22) can also be written as

$$\widetilde{m}_0 c^2 = -e^2 / r_e , \qquad (23)$$

where

$$r_e = R / 2 . \qquad (24)$$

In this case R is the Schwarzschild radius of the proton.

Eq. (23) has the same form as the expression for the classical electron radius. In standard physics this expression is an *ad hoc* defined quantity, whereas in our model it is derived from the properties of the system.

Eq. (17) can now be written as

$$E = \widetilde{m}_0 c^2 e^{r_e / r} . \qquad (25)$$

8. Hydrogen spectrum

In mathematical physics we use a perturbation method when a quantity, such as the energy above, is expressed in a convergent series. To apply this method to E above, we need to express the energy in terms of the momentum. From SR,

$$\widetilde{E}^2 = m_0{}^2 c^4 + p^2 c^2 , \qquad (26)$$

where $\vec{p} = \widetilde{m} \vec{v}$ is the classical momentum of a particle.

Substituting this expression in (18), we get

$$E = (p^2 c^2 + m_0{}^2 c^4)^{1/2} \; e^{\Phi / c^2} . \qquad (27)$$

We take the finite radius of the proton into account by changing r to $r - g r_e$, where g has a value between 0 and 1. The potential function can then be written as

$$\exp(\Phi / c^2) = \exp(r_e / (r - g r_e)) , \qquad (28)$$

which can be expanded as

$$\exp(\Phi / c^2) = 1 + \frac{r_e}{r} + w \frac{r_e{}^2}{r^2} + (w^2 - 1/4) \frac{r_e{}^3}{r^3} + \cdots , \qquad (29)$$

where

$$w = (g + 1/2) . \qquad (30)$$

With this form for the potential, and using $\widetilde{m}_0 c^2 r_e = -e^2$ from (23), (27) can be expanded as

$$E = \underbrace{\tilde{m}_0 c^2}_{E_0} + \underbrace{\frac{p^2}{2\tilde{m}_0} - \frac{e^2}{r}}_{E_1} - \underbrace{\frac{p^4}{8\tilde{m}_0{}^3 c^2}}_{E_2} + \underbrace{\frac{p^2 r_e}{2\tilde{m}_0 r}}_{E_3} + \underbrace{w\frac{r_e{}^2 \tilde{m}_0 c^2}{r^2}}_{E_4} + \underbrace{w\frac{p^2 r_e{}^2}{2\tilde{m}_0 r^2}}_{E_5} - \underbrace{\frac{p^4 re}{8\tilde{m}_0{}^3 c^2 r}}_{E_6}$$

$$+ \underbrace{\tilde{m}_0 c^2 (w^2 - 1/4)\frac{r_e{}^3}{r^3}}_{E_7} + \cdots \qquad (31)$$

Each of the braced terms has a specific physical meaning, and each one can be quantized according to the unperturbed Bohr theory (see section 8.3.3 of Ref. 3). We then find the following expressions:

$E_0 = \tilde{m}_0 c^2$	:	rest mass energy
$E_1 = -R_e / n^2, \quad n = 1, 2, \cdots$	:	Bohr energy
$E_2 = -\frac{\alpha^2 R_e}{n^2}\left[\frac{1}{k} - \frac{3}{4n}\right], \quad k = 1, 2, \cdots n$	:	"relativistic correction" of the Bohr- Sommerfeld model
$E_3 = \frac{\alpha^2 R_e}{n^3}\left[\frac{2}{k} - \frac{1}{n}\right]$	:	orbital magnetic energy
$E_4 = w2\alpha^2 R_e \frac{1}{n^3 k} = w\alpha^4 \tilde{m}_0 c^2 \frac{1}{n^3 k} = \pm\frac{e^8 \tilde{m}_0}{2\hbar^4 c^2}\frac{1}{n^3 k}$	:	quantum mechanical spin energy
$E_5 = \pm\frac{1}{2}\left(\frac{v^2 e^4}{2\tilde{m}_0 c^4 r^2}\right)\left(\frac{\tilde{m}}{m_0}\right)^2$	:	radiative reaction

The constant $R_e = \alpha^2 \tilde{m}_0 c^2 / 2$ is the Rydberg constant, $\hbar = h/2\pi$, and $\alpha = e^2/\hbar c$ is the fine-structure constant. The value $w = \pm 1/2$, which corresponds to the quantum values of electron spin, arises from truncating the series after E_6, which implies setting E_7 and higher order energies equal to zero. In physical terms this implies a limit to the resolution of our observational apparatus.

The sum of the first three terms gives the fine-structure spectrum of the hydrogen atom:

$$(E_0 + E_1 + E_2)/\tilde{m}_0 c^2 \cong 1 - \frac{\alpha^2}{2n^2}\left[1 + \frac{\alpha^2}{n}\left(\frac{1}{k} - \frac{3}{4n}\right)\right]. \qquad (32)$$

The sum of the remaining terms E_3 and E_4 represents the total spin-orbit energy. This energy is related to higher order effects such as the Lamb shift. Details about these effects can also be found in Ref. 3. The calculated value of the Lamb shift differs by an order of 10 from the observed value. However, since the Lamb shift is a third order perturbation of the hydrogen spectrum, the discrepancy could possibly be resolved by a second order correction to the effective nuclear radius.

For $k=1$ the expression for E_4 is equal to the Darwin term of the Dirac theory.[6]

9. The Large Number Coincidences

Dirac postulated that the large dimensionless ratios ($\sim 10^{40}$) of certain universal constants underlie a fundamental relationship between them. A theoretical explanation for these ratios has not yet been found, but it became known as Dirac's Large Number Hypothesis (LNH).[7] Some of these relations are derivable from (24).

Taking R as the Schwarzschild radius of the proton, $R_p = 2GM_p/c^2$, we rewrite (24) as

$$-\frac{e^2}{\tilde{m}_0 c^2} = \frac{GM_p}{c^2} ,$$

or

$$-\frac{e^2}{GM_p \tilde{m}_0} = 1 . \qquad (33)$$

Defining the relationship between the *gravitational mass* M_p of a proton and its *electromagnetic rest mass* $\tilde{m}_{0p}$, as

$$M_p = N_D \tilde{m}_{0p} , \qquad (34)$$

where N_D is a dimensionless number, we can write (33) as

$$-\frac{e^2}{G\tilde{m}_{0p}\tilde{m}_0} = N_D . \qquad (35)$$

Taking the absolute value of the above equation gives the basic relationship of the LNH. Further LNH derivations are derived in Ref. 3.

10. A unified force model

One can derive the forces acting on a particle by applying the Euler-Lagrange equations to the Lagrangian of the system. From the Lagrangian of (19) we find a Lorentz-type force equation (see 7.4 of Ref. 3):

$$\dot{\vec{p}} = \tilde{m}_0 [k\vec{E} + \vec{v} \times \vec{H}] \ , \qquad (36)$$

where for

Gravitation: $k = -1$,
Electromagnetism: $k = +1$.

The same equation gives either planetary or atomic motion, where the vectors $\vec{E}$ and $\vec{H}$ are respectively given by

$$\vec{E} \ = \ \hat{r}\frac{GM}{r^2} \ = \ \hat{r}\frac{r_e c^2}{r^2} \ , \qquad (37)$$

$$\vec{H} \ = \ \frac{GM(\vec{v} \times \vec{r})}{c^2 r^3} \ = \ \frac{r_e(\vec{v} \times \vec{r})}{r^3} \ . \qquad (38)$$

11. Interim summary

We have shown in a descriptive way that the Newtonian-type Lagrangian (1) gives both the gravitational and electromagnetic equations of motion. In particular, we can derive the paths of planets and the spectrum of the hydrogen atom from this fundamental Lagrangian. The model is further confirmed from the fact that both the classical electron radius and Dirac's Large Number Relations are inherently part of the model.

The distinguishing feature from other attempts to unification is the distinction between the gravitational mass m and the electromagnetic mass $\tilde{m}$ of a particle. This distinction is discussed further in section 14.

The Lorentz-type force offers a description of higher order gravitational properties such as geodetic precession and frame dragging of binary pulsars.

12. The nuclear (strong) force

Any theory of the nuclear, or strong interaction, must satisfy certain basic requirements concerning the properties of the force. They are briefly (see Ch.17 of Ref. 8):

(a) The force is charge independent,
(b) it only acts over a range $\sim 10^{-13}$ cm,
(c) the form of its potential is $-Q^2 / r \exp(-r / r_q)$,
(d) where the coupling constant $Q^2 / \hbar$ could range from 1 to 15,
(e) r_q is related to the mass m_π of a pion by $r_q \sim h / m_\pi c$.

At $r \approx R$ the gravitational energy equation (5) can be rearranged in a unique form as:[3]

$$E \ \approx \ (mc^2 R / r) \exp(r / R) \ . \qquad (39)$$

Repeating the same procedure for the electrodynamic energy (25) we find that at $r \approx r_e$,

$$E \approx (\tilde{m}c^2 r_e / r)\exp(r / r_e) \ . \tag{40}$$

Both (39) and (40) are accommodated in the model for a deuteron as depicted in Fig. 2. We also use $\tilde{m}_q$ for $\tilde{m}$.

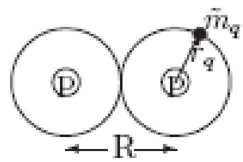

Fig. 2: Model of a deuteron. Two protons are separated at a distance *R* from each other. A particle of mass $\tilde{m}_q$ and charge –*e* moves in a figure eight pattern about each of them, alternately at a radius of $r = r_q = |r_e|$ from each proton.

For this case we write (23) as

$$\tilde{m}_{e0} c^2 = -e^2 / r_e \ , \tag{23}$$

where $\tilde{m}_{e0}$ is the electromagnetic rest mass of the electron.

Substituting (23) in (40) gives

$$E \approx -\tilde{m}c^2 \left(\frac{e^2}{\tilde{m}_{e0} c^2} \right) \frac{1}{r} \exp\left[r / (-e^2 / \tilde{m}_{e0} c^2) \right] . \tag{41}$$

Defining

$$r_q = |r_e| \ , \tag{42}$$

(41) can be written as

$$E \approx -\tilde{m}c^2 \frac{r_q}{r} \exp(-r / r_q) \, , \tag{43}$$

$$= -\frac{Q^2}{r} \exp(-r / r_q) \, , \tag{44}$$

where Q^2 is defined as

$$Q^2 = \tilde{m}c^2 r_q = \tilde{E} r_q \, . \tag{45}$$

Eq. (44) has the form of the Yukawa potential. The mass $\tilde{m} = \tilde{m}_q$ is then equal to the pion mass m_π.

Property (e) for the pion mass can be derived from the above relations by assuming property (d) as a boundary condition (see Ch.7 of Ref. 3).

13. The weak force

The weak force cannot yet be incorporated explicitly in the model as no classical equivalent of this force exists. This force gives rise to radioactivity, in particular β-decay. It acts over distances $r < R = 2r_e$ and we therefore expect that our Lagrangian (1) must be adapted for this range.

14. Possible implications for cosmology

Einstein was deeply influenced by the ideas of Ernest Mach (1838-1916), in particular that the local properties of matter should be determined by the properties of the distant, massive stars. He wrote:[9]

> *But in the second place the theory of relativity makes it appear probable that Mach was on the right road in his thought that inertia depends upon a mutual action of matter. For we will show in the following that, according to our equations, inert masses do act upon each other in the sense of the relativity of inertia, even if only very feeble. What is to be expected along the lines of Mach's thought?*

The principle implies that changes in the distant universe will cause changes in local properties, such, for example, as the mass of an electron. We shall not be able to measure this change as it is a relative change, and our measuring apparatus will be changed equivalently. This effect has become known as the Mach effect.

Dennis Sciama (1926-1999) proposed an *ad hoc* formulation for this effect as[10]

$$G \cong Lc^2 / M. \qquad (46)$$

where

L = radius of the universe,

M = mass of the universe ≅ mass of the distant stars.

This relation can be found (see Ch.10 of Ref. 3) by applying the energy relation of (2) to the system of Fig. 3:

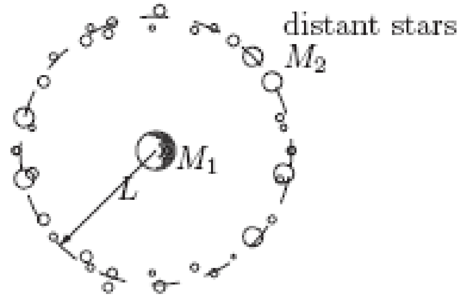

Fig. 3: Mutual gravitational interaction between a central mass M_1 and the distant stars of total mass M_2.

The potential at M_2 due to M_1 is $\Phi_1 = GM_1 / L = R_1 c^2 / 2L$ and the potential of the shell at M_1 is $\Phi_2 = GM_2 / L = R_2 c^2 / 2L$. Furthermore, since M_1 and M_2 are in relative motion, the value of γ will be the same for both of them. Applying (2) then gives

$$E = M_1 c^2 \exp(R_2 / L) = M_2 c^2 \exp(R_1 / L) \ .$$

Since $L > R_2 >> R_1$ we can realistically approximate the exponential to first order in R_2/L. After some algebra we then get $R_2 \approx L$, which gives the Mach relation $2GM_2/Lc^2 \approx 1$.

One of the mysteries of modern astrophysics is the accelerating expansion of the universe. This can be explained in terms of the conversion of radiation energy into mass.

We note from (4) that *m decreases* with increasing velocity, implying that mass is converted into kinetic energy. Alternatively, if the masses *m* of two bodies are increased through the conversion of radiation energy into mass, then the masses will repel each other according to (5). For example, if the mass *m* of a test body in the vicinity of a central mass *M* is increased, then the distance *r* between them will increase equivalently to keep *E* constant. The rate of repulsion will depend on the rate of conversion of energy into mass. This conversion is the opposite to the conversion of mass into energy as is found in nuclear fission.

At the Big Bang the universe consisted of radiation only. As this radiation was converted into mass, the masses repelled each other. This process is still continuing, and according to our model, accounts for the accelerating expansion of the universe.

Higher order gravitational effects are becoming increasingly relevant in the study of binary pulsars.[11] [12] Astrophysicists are looking for confirmation of the Einstein-Mach effects predicted by General Relativity theory. These effects include geodetic precession and frame dragging, or Thirring effect. We are presently looking at applying (36) to calculate these effects.

15. Conclusion

The equivalence of planetary and atomic motion is in accord with the axiom of "As above, so below." Similarly, Mach's Principle also appeals to the mystical scientist. Changes in the universe cause changes in the locally small. Since we are part of this change, we are not aware of it. This also casts light on the meaning of absolute time. Absolute time is the time interval between two coordinate clocks fixed in the reference frame of the universe. This interval will change according to the properties of the universe, or equivalently, to those of the distant stars.

A fundamental feature of the model is the distinction between the dynamics and kinematics of a system. This is reflected in the two postulates. The Lagrangian of (1) specifies the *dynamics* of a system. It describes a gravitational force that causes particles to move, specifically in accelerated motion. The way the particles move is described by the *kinematics* of the system. There is no reference to forces. Kinematics is described by special relativity, which, at speeds much less than that of light, gives the classical Newtonian equations of motion. Special relativity also describes the electrodynamics of a system, which depends on the velocities of the particles. The velocity of a particle changes according to the magnitude of the force acting on it, but our postulate 2 stipulates that the velocity remains constant within infinitesimally small intervals of time and space. This is a standard assumption in physics. It allows the global validity of special relativity, and therefore also that of the Maxwell equations of electrodynamics at all points in space under the influence of gravitation.

The electrodynamical force therefore results from the motion induced by the gravitational force determined by the Lagrangian. The two forces are linked by the relations of the LNH.

Postulates 1 and 2, therefore, form the foundation of a unified model of gravitation and electrodynamics.

The model is also characterized by two different types of masses: a gravitational mass m and an electromagnetic mass $\tilde{m}$. These two masses are related by the relations of the LNH. Different types of masses for the electron are not unusual in modern physics. Quantum electrodynamics, the theory of the electron and photon, is plagued by conceptual problems of mass renormalization (see p. 217 of Ref. 13). It must still be seen to what extent our model could resolve the ambiguities of this procedure.

We have mentioned that m decreases with velocity, and it is well known that $\tilde{m}$ increases with velocity. The first effect is consistent with our closed particle model of gravitation. As velocity, or kinetic energy, increases, it must be at the expense of mass, which is converted into energy. This does not apply to electrodynamic systems that are not closed: energy is applied from an outside source, and part of the energy is converted into mass to impede the acceleration of a charged particle. This is equivalent to the Lenz effect.

An intriguing aspect is the possibility of demonstrating gravitational repulsion in the laboratory. The theoretical mechanism is explained in section 14. A suggestion of how this can be applied appears in the work of Roger Jennison.[14]

The paper shows that there is possibly only one force in nature, that of gravitation. The electromagnetic force arises from the kinematics induced by the gravitational force, and the strong force is a unique form for gravitation at a separation equal to the Schwarzschild radius of a nucleon. No expression has yet been found for the weak force, but we can deduce that it would have a form for the gravitational force in a region smaller than the Schwarzschild radius of a nucleon.

The proposed Lagrangian is general enough to be applied, in principle, to all dynamical systems. Equivalently, the Lorentz-type force of (36) offers more direct applications. It should simplify the present mathematical formulations to describe the higher order gravitational effects of binary pulsars.

The proposed model has a rigid structure with a consistent mathematical formulation. Change the form of the classical electron radius and the perihelion precession of Mercury is affected. All assumptions are well established in physics and all predictions, with the exception of the Lamb shift, agree with observation. The discrepancy of the Lamb shift should be resolvable with a closer look at the effective nuclear radius of the hydrogen atom. Taking all these conditions into consideration we must conclude that the proposed model satisfies the basic requirements for a unified model of forces.

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