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The "Scattering of the Results of Measurements" of Processes of Diverse Nature is Determined by the Earth's Motion in the Inhomogeneous Space-Time Continuum. The Effect of "Half-Year Palindromes"

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As obtained in this experimental research, the sequence of the shapes of histograms (the spectra of the amplitudes of fluctuations), measured during an astronomical day from 6 h to 18 h of the local time, is very similar (with high precision of probability) to the sequence of the histogram shapes obtained during an astronomical night from 18 h to 6 h of the local time a half of year later in exact. We call the effect that the sequences of the histogram shapes in the same half of day measured a half of year later are similar after inversion the "effect of half-year palindromes". This means that the shapes of histograms are stable characteristics of a given region of space.

In the previous work [32], we considered the phenomenon of "palindromes", which stands for a high probability of similar histograms to be found upon comparison of two data series: first, representing the results of measurements of ^{239}Pu α-decay over astronomical day (since 6 to 18 h by local, longitude, time) and, second, measured over astronomical night (since 18 to 6 h, in continuation of the first series) and *inverted*. "Inverted" means that the order of histograms in the second series is reversed. The palindrome effect implies that (1) the shape of histograms depends on the spatial region passed by the axially rotating Earth over the period of measurements, and (2) the properties of this spatial region are not shielded by the Earth: whether in the daytime or nighttime, the histograms corresponding to the same spatial region are similar. In the course of the Earth's motion along the circumsolar orbit, i.e., upon its translocation into new spatial regions, histogram shapes change; the effect of palindromes, however, will manifest itself every new day.

A remark *It should be stressed that the shape of histograms depends on many factors: rotation of the Earth about its axis; motion of the Earth along the sircumsolar orbit; relative positions of the Earth, Moon and Sun; axial rotation of the Sun; motion of the Moon along the circumterrestrial orbit. In the past years, we revealed and described, more or less, most of these factors. It seems there is an hierarchy of causes (factors) that determine histogram shape. Among them, the axial rotation of the Earth and, correspondingly, the near-day periods in the change of histogram shapes are of primary importance. Because of such a multifactorness, the number of histogram shapes related to the effect of any single factor may amount to only a part of the total. In the case of palindrome effects, for example, this number is about 15–20% of the total possible shapes.*

As supposed by M. N. Kondrashova, the palindrome effect should also be revealed upon comparing histograms that have a half-year interval between them, i.e., histograms that correspond to the measurements made when the Earth was at the opposite ends of a diameter of the circumsolar orbit [33]. This supposition agrees with our earlier observation on similarity between the series of daytime histograms obtained on the days of vernal equinox and the series of nighttime histograms taken in the periods of autumnal equinox. However, in those experiments the "daytime" and "nighttime" terms were not associated with the rotational and translational motion of the Earth about its axis and along the circumsolar orbit, so the results were poorly reproducible. With the terms "daytime" and "nighttime" strictly defined (since 6 to 18 h and since 18 to 6 h by local time, respectively), the supposition was proved for different seasons, equinoctial periods and solstices. The daytime series of vernal equinox, for example, are highly similar to the inverse daytime and noninverse nighttime series of autumnal equinox.

Thus, there are "half-day" and "half-year" palindrome effects. This is illustrated in Figure 1.

The effect of "half-day" palindromes consists in the high probability of a series of nighttime histograms to be similar to the *inverse* series of daytime histograms measured on the same day (equally, noninverse daytime series are similar to the inverse nighttime ones). For example, the sequence "1-2-3-4-5" of the series of nighttime histograms is similar to the sequence "5-4-3-2-1" of the series of daytime histograms.

The effect of "half-year" palindromes results from the Earth's motion at two opposite points of the circumsolar orbit being directed oppositely during the same half of the day. This effect consists in the high probability of a series of nighttime histograms at a certain point of the circumsolar orbit to be similar to the *noninverse* series of daytime histograms at the opposite point of the orbit (the same holds true upon comparing a nighttime (daytime) series to the inverse nighttime (daytime) series at the opposite point of the orbit).

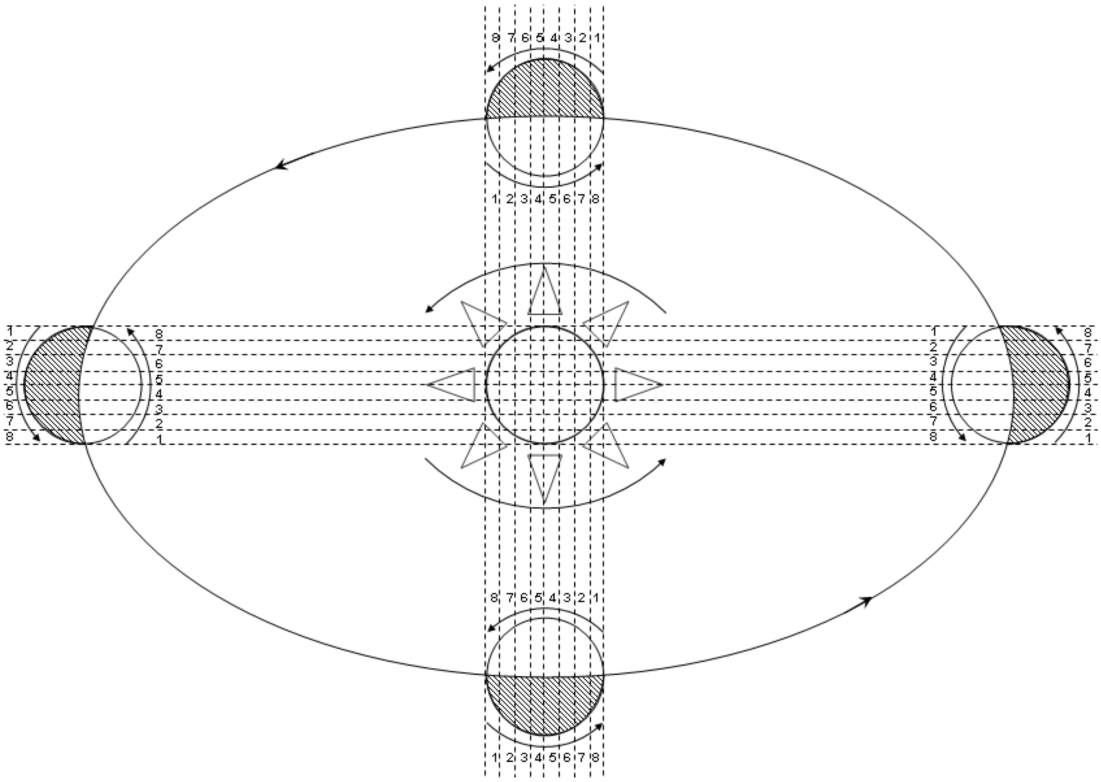

Fig. 1: A scheme illustrating "palindrome effects". With the Sun in the centre, the scheme shows four positions of the Earth on the circumsolar orbit. Both the Earth and the Sun are rotating counterclockwise; motion of the Earth along the circumsolar orbit is counterclockwise as well. As seen in the Figure, the Earth's rotational motion in the nighttime is co-directional to its motion along the circumsolar orbit and to rotation of the Sun. In the daytime, the direction of these motions is opposite. Hence, in the case of "backward" motion (in the daytime), the object measured passes in the inverse order the same spatial regions that it has passed in the direct order in the nighttime.

The half-year palindromes indicate, first of all, that certain features of the space continuum keep for a long time: after half a year we observe similar histograms. Obviously, a daytime picture of the stellar sky will correspond to the nighttime one after six months. The daytime series resembling the nighttime ones after half a year also means that the factors determining the shape of histograms are not shielded by the Earth.

As follows from these effects,

(1) the shape of histograms does not depend on the direction that a spatial region is scanned in during the Earth's motion (from right to left or vice versa);

(2) factors that determine histogram shape are not shielded by the Earth: both in the day- and nighttime, series of histograms turn out similar and dependent only on the region (vector) of space passed by the object measured at that moment;

(3) the shape of histograms is determined by the spatial regions being scanned in the course of rotational and translational motion of the Earth; in other words, the shape of histograms is a specific characteristic, which reflects peculiarities of the spatial region scanned during the measurement.

The fine structure of histograms resembles interferrential pictures [3–5, 15–17, 25]. This analogy may have a real significance: every spatial region is a result of interference of many gravitational waves, and the interferrential picture emerging can be reflected somehow in the shape of histograms.

Discovering the half-year palindromes, in addition to the half-day ones, allows us to consolidate all the previous findings and unify our views on the phenomenon of "macroscopic fluctuations", which stands for regular changes in the fine structure of sampling distributions (histograms) calculated from the results of measurements of processes of diverse (any) nature [2–16].

Now there is a good explanation for the high probability of a certain histogram shape to appear regularly, on a daily and yearly basis. The similarity of histograms obtained at different geographical points at the same local time becomes evident too.

As follows from all the data collected, our old conclusion — that alterations in the histogram shape are caused by the motion of the object studied along with the rotating and translocating Earth relatively to the "sphere of fixed stars" ("siderial day" and "sidereal year" periods) and the Sun ("solar day" and "near-27-day" periods) — is correct. The shape of histograms also depends on motion of the Moon about the Earth and changes in the relational positions of the Earth, Moon and Sun [10, 23–29]. Supplemented with the results of experiments, in which α-activity was measured with a collimator-based setup [24, 26–28], these data indicate, on the one hand, a sharp anisotropy of our world and, on the other hand, a relative stability of characteristics of the space continuum.

Discussion

In some way, the data presented above can be considered as a completion of the series of experiments that was started more than 50 years ago (the first paper was published in 1958 [1]). Over this period, the results obtained have been reviewed several times, and all the necessary references are provided in the correspondent reviews [3, 4, 12, 14, 15, 17, 25, 31]. Nevertheless, a brief consideration of the course of those studies would not be out of place.

The subject of this series of experiments was, basically, the "scatter of results", which will inevitably accompany any measurements. For most scientific and practical purposes, this "scatter" is a hindrance, impeding accurate evaluation of the parameters measured. To overcome undesirable influence of data scattering, researchers use a well-known and widely approved apparatus of statistical analysis, specifically designed to process the results of measurements. Different processes (of different nature) will be characterized by their own specific amplitude of data scattering, and they have even been classified according to this attribute. In biological processes, for example, the scatter (its mean-square estimate) can reach tens percent of the value measured. In chemical reactions, the scatter — if not resulted from trivial causes — would be smaller and amounts to several percent. In purely physical measurements, the scatter can be as small as several tenth or hundredth percent. There is a saying, popular in the scientific circles, that "biologists measure 'bad' processes with 'bad' devices, chemists measure 'bad' processes with 'good' devices, and physicists measure 'good' processes with 'good' devices". In fact, the relative amplitude of this unavoidable scatter of results is determined by deep causes, and among them is the subjection of the quantities (objects) measured to cosmophysical regularities. In this sense, the figurative "bad-good" assessment of natural processes changes its sign: the "best" (most sensitive) are biological processes; chemical processes are "somewhat worse"; and "much worse" (least sensitive) are processes like quantum generation or natural oscillations of piezoelectric quartz. From this viewpoint, a valuable and important process to study is radioactive decay, in which relative dispersion is equal, according to Poisson statistics, to $\sqrt{N}$, where N is the quantity measured.

Free of trivial errors, the scatter of the results of measurements has, usually, a purely stochastic character and, hence, will be described by a smooth, monotonously decreasing at both ends distribution, like Gaussian or Poisson functions. In reality, however, never do experimenters obtain such a smooth distribution. Whether the experimental distribution fits a theoretical one is decided by applying fitting criteria based on central limit theorems. These criteria are integral; they neglect the fine structure of distributions, which is considered casual.

The main result of our works consists in proving nonrandomness of the fine structure of sample distributions (i.e., histograms) constructed with the highest possible resolution. The proof is based on the following facts:

1. There is a high probability that at the same place and time, the fine structure of distributions obtained for different, independent processes will be similar;
2. The phenomenon is universal and independent of the nature of the process studied. Whether biochemical reactions or radioactive decay — if measured at the place and time, they will show similar histograms;
3. There exists a "near-zone effect", meaning that neighbour histograms calculated for non-overlapping segments of a time series of the results of measurements would be more similar than random far-apart histograms;
4. In the course of time, the shape of histograms changes regularly: similar histograms appear with periods equal to the sidereal and solar days, "calendar" and "sidereal" years [21];
5. At the same local time, similar histograms will appear at different geographical points: this is a so-called "effect of local time". This phenomenon was observed at both large and small distances between the objects measured. "Large distances" means that the measurements were carried out in different countries, in the Arctic and Antarctic, and on the board of ships sailing round the world. "Small distances" can be as short as 10 cm, as in V. A. Pancheluga's experiments with noise generators [27–30];
6. The "palindrome effects" discussed here and in the previous work [32] round off the set of proofs.

All these pieces of evidence were collected in the experiments with quite stochastic, according to the accepted criteria, processes.

The high quality of the apparatus for continuous, 24-hour measurements of α-activity constructed by I. A. Rubinstein enables us to collect long, non-non-interrupted data series for many years. On the basis of these data, accurate evaluation of the yearly periods has been made. A key step was conducting long-term measurements with I. A. Rubinstein's collimator-equipped detectors, which isolated beams of α-particles emitted in certain directions. Those experiments gave evidence that the shape of histograms depends on the spatial vector of the process. The sharpness of this dependence implies a sharp anisotropy of the space continuum [20, 22, 25].

In addition to the effects listed above, we have also found regularities that have been attributed to the relative positions of the Earth, Moon and Sun [10, 23, 26, 28, 32].

The whole set of these results is in agreement with the scheme in Figure 1.

Thus, the regularities found in the "scatter of results" of various measurements reflect important features of our world. The fine structure of histograms — spectra of amplitudes of fluctuations of the results of measurements of processes of diverse nature — is the characteristic of the inhomogeneous, anisotropic space-time continuum.

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The Length of the Day: A Cosmological Perspective

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We have found an empirical law for the variation of the length of the Earth's day with geologic time employing Wells's data. We attribute the lengthening of the Earth's day to the present cosmic expansion of the Universe. The prediction of law has been found to be in agreement with the astronomical and geological data. The day increases at a present rate of 0.002 sec/century. The length of the day is found to be 6 hours when the Earth formed. We have also found a new limit for the value of the Hubble constant and the age of the Universe.

1 Introduction

According to Mach's principle the inertia of an object is not a mere property of the object but depends on how much matter around the object. This means that the distant universe would affect this property. Owing to this, we would expect a slight change in the strength of gravity with time. This change should affect the Earth-Moon-Sun motion. It is found that the length of the day and the number of days in the year do not remain constant. From coral fossil data approximately 400 million years (m.y.) ago, it has been estimated that there were little over 400 days in a year at that time. It is also observed that the Moon shows an anomalous acceleration (Dickey, 1994 [1]). As the universe expands more and more matter appears in the horizon. The expansion of the universe may thus have an impact on the Earth-Moon-Sun motion. Very recently, the universe is found to be accelerating at the present time (Peebles, 1999 [2], Bahcall *et al.*, 1999 [3]). To account for this scientists suggested several models. One way to circumvent this is to allow the strength of gravity to vary slightly with time (Arbab, 2003 [4]). For a flat universe, where the expansion force is balanced by gravitational attraction force, this would require the universe to accelerate in order to avoid a future collapse. This can be realized if the strength of the gravitational attraction increases with time (Arbab, 1997 [5], 2003 [4]), at least during the present epoch (matter dominated). One appropriate secure way to do this is to define an effective Newton's constant, which embodies this variation while keeping the "bare" Newton's constant unchanged. The idea of having an effective constant, which shows up when a system is interacting with the outside world, is not new. For instance, an electron in a solid moves not with its "bare" mass but rather with an effective mass. This effective mass exhibits the nature of interaction in question. With the same token, one would expect a celestial object to interact (couple) with its effective constant rather than the normal Newton's constant, which describes the strength of gravity in a universe with constant mass. We, therefore, see that the expansion of the universe affects indirectly (through Newton's constant) the evolution of the Earth-Sun system. Writing an effective quantity is equivalent to having summed all perturbations (gravitational) affecting the system. With this minimal change of the ordinary Newton's constant to an effective one, one finds that Kepler's laws can be equally applicable to a perturbed or an unperturbed system provided the necessary changes are made. Thus one gets a rather modified Newton's law of gravitation and Kepler's laws defined with this effective constant while retaining their usual forms. In the present study, we have shown that the deceleration of the Earth rotation is, if not all, mainly a cosmological effect. The tidal effects of the Earth deceleration could, in principle, be a possible consequence, but the cosmological consequences should be taken seriously.

The entire history of the Earth has not been discovered so far. Very minute data are available owing to difficulties in deriving it. Geologists derived some information about the length of the day in the pats from the biological growth rhythm preserved in the fossil records (e.g., bi-valves, corals, stromatolites, etc.). The first study of this type was made by the American scientist John Wells (1963 [7]), who investigated the variation of the number of days in the year from the study of fossil corals. He inferred, from the sedimentation layers of calcite made by the coral, the number of days in the year up to the Cambrian era. Due to the lack of a well-preserved records, the information about the entire past is severely hindered. The other way to discover the past rotation is to extrapolate the presently observed one. This method, however, could be very misleading.

2 The model

Recently, we proposed a cosmological model for an effective Newton's constant (Arbab, 1997 [5]) of the form

$$G_{\text{eff}} = G_0 \left(\frac{t}{t_0}\right)^{\beta}, \tag{1}$$

where the subscript "0" denotes the present value of the quantity: G_0 is the normal (bare) Newton's constant and t_0 is the present age of the Universe. Here G_{eff} includes all perturbative effects arising from all gravitational sources. We remark here that G_0 does not vary with time, but other perturbations induce an effect that is parameterized in G_{eff} in the equation of motion. Thus, we don't challenge here any variation in the normal Newton's constant G_0. We claim that such a variation can not be directly measured as recently emphasized by Robin Booth (2002 [7]). It can only be inferred from such analysis. We remark here that β is not well determined ($\beta > 0$) by the cosmological model. And since the dynamics of the Earth is determined by Newton's law of gravitation any change in G would affect it. This change may manifest its self in various ways. The length of day may attributed to geological effects which are in essence gravitational. The gravitational interaction should be described by Einstein's equations. We thus provide here the dynamical reasons for these geological changes. We calculate the total effect of expansion of the universe on the Earth dynamics.

The Kepler's 2nd law of motion for the Earth-Sun system, neglecting the orbit eccentricity, can be written as

$$G_{\text{eff}}^2\left[(M+m)^2 m^3\right] T_{\text{eff}} = 2\pi L_{\text{eff}}^3, \tag{2}$$

where m, M are the mass of the Earth and the Sun respectively; L_{eff} is the orbital angular momentum of the Earth and T_{eff} is the period (year) of the Earth around the Sun at any time in the past measured by the days in that time. T_{eff} defines the number of days (measured at a given time) in a year at the epoch in which it is measured. This is because the length of day is not constant but depends on the epoch in which it is measured. Since the angular momentum of the Earth about the Sun hasn't changed, the length of the year does not change. We however measure the length of the year by the number of days which are not fixed. The length of the year in seconds (atomic time) is fixed. Thus one can still use Kepler's law as in (2) (which generalizes Kepler's laws) instead of adding other perturbations from the nearby bodies to the equation of motion of the Earth. We, however, incorporate all these perturbations in a single term, viz. G_{eff}. Part of the total effect of the increase of length of day could show up in geological terms. We calculate here the total values affecting the Earth dynamics without knowing exactly how much the contribution of each individual components.

The orbital angular momentum of the Earth (around the Sun) is nearly constant. From equation (2), one can write

$$T_{\text{eff}} = T_0\left(\frac{G_0}{G_{\text{eff}}}\right)^2, \tag{3}$$

where $T_0 = 365$ days and $G_0 = 6.67\times10^{-11}$ N m^{2}kg^{-2}.

Equations (1) and (3) can be written as

$$T_{\text{eff}} = T_0\left(\frac{t_0}{t_0 - t_p}\right)^{2\beta}, \tag{4}$$

where t_0 is the age of the universe and t_p is the time measured from present time backward. This equation can be casted in the form

$$x = \ln\left(\frac{T_{\text{eff}}}{T_0}\right) = 2\beta\ln\left(\frac{t_0 - t_p}{t_0}\right), \tag{5}$$

or equivalently,

$$t_0 = \frac{t_p}{(1 - \exp(-x/2\beta))}\,. \tag{6}$$

To reproduce the data obtained by Wells for the number of days in a year (see Table. 1), one would require $\beta = 1.3$ and $t_0 \backsimeq 11\times10^9$ years. This is evident since, from (Arbab, 2003 [4]) one finds the Hubble constant is related to the age of the Universe by the relation,

$$t_0 = \left(\frac{2+\beta}{3}\right) H_0^{-1} = 1.1\, H_0^{-1}, \tag{7}$$

and the effective Newton's constant would vary as

$$G_{\text{eff}} = G_0\left(\frac{t_0 - t_p}{t_0}\right)^{1.3}. \tag{8}$$

This is an interesting relation, and it is the first time relation that constrained the age of the Universe (or Hubble constant)from the Earth rotation. However, the recent Hipparcos satellite results (Chaboyer *et al.*, 1998 [8]) indicate that the age of the universe is very close to 11 billion years. Hence, this work represent an unprecedented confirmation for the age of the universe. One may attribute that the Earth decelerated rotation is mainly (if not only) due to cosmic expansion that shows up in tidal deceleration. Thus, this law could open a new channel for providing valuable information about the expansion of the Universe. The Hubble constant in this study amounts to $H_0 = 97.9$ km s^{-1}Mpc^{-1}. However, the Hubble constant is considered to lie in the limit, 50 km s^{-1}Mpc^{-1} $< H_0 <$ 100 km s^{-1} Mpc^{-1}. Higher values of H_0 imply a fewer normal matter, and hence a lesser dark matter. This study, therefore, provides an unprecedented way of determining the Hubble constant. Astronomers usually search into the space to collect their data about the Universe. This well determined value of β is crucial to the predictions of our cosmological model in Arbab, 2003 [4]. We notice that the gravitational constant is doubled since the Earth was formed (4.5 billion years ago).

From (3) and (8) one finds the effective number of days in the year (T_{eff}) to be

$$T_{\text{eff}} = T_0\left(\frac{t_0}{t_0 - t_p}\right)^{2.6}, \tag{9}$$

and since the length of the year is constant, the effective length of the day (D_{eff}) is given by

$$D_{\text{eff}} = D_0\left(\frac{t_0 - t_p}{t_0}\right)^{2.6}, \tag{10}$$

so that

$$T_0\, D_0 = T_{\text{eff}}\, D_{\text{eff}}\,. \tag{11}$$

Time*	65	136	180	230	280	345	405	500	600
solar days/year	371.0	377.0	381.0	385.0	390.0	396.0	402.0	412. 0	424.0

*Time is measured in million years (m.y.) before present.

Table 1: Data obtained from fossil corals and radiometric time (Wells, 1963 [7]).

Time*	65	136	180	230	280	345	405	500	600
solar days/year	370.9	377.2	381.2	385.9	390.6	396.8	402.6	412.2	422.6
length of solar day (hr)	23.6	23.2	23.0	22.7	22.4	22.1	21.7	21.3	20.7
Time*	715	850	900	1200	2000	2500	3000	3560	4500
solar days/year	435.0	450.2	456.0	493.2	615.4	714.0	835.9	1009.5	1434.0
length of solar day (hr)	20.1	19.5	19.2	17.7	14.2	12.3	10.5	8.7	6.1

*Time is measured in million years (m.y.) before present.

Table 2: Data obtained from our empirical law: equations (9) and (10).

We see that the variation of the length of day and month is a manifestation of the changing conditions (perturbation) of the Earth which are parameterized as a function of time (t) only. Thus, equation (7) guarantees that the length of the year remains invariant.

3 Discussion

The Wells's fossil data is shown in Table 1 and our corresponding values are shown in Table 2. In fact, the length of the year does not change, but the length of the day was shorter than now in the past. So, when the year is measured in terms of days it seems as if the length of the year varies. Sonett *et al.* (1996 [9]) have shown that the length of the day 900 m.y. ago was 19.2 hours, and the year contained 456 days. Our law gives the same result (see Table 2). Relying on the *law of spin isochronism* Alfvén and Arrhenius (1976 [10]) infer for the primitive Earth a length of day of 6 hours (p.226). Using coral as a clock, Poropudas (1991 [11], 1996 [12]) obtained an approximate ancient time formula based on fossil data. His formula shows that the number of days in the year is 1009.77 some 3.556 b.y. ago. Our law shows that this value corresponds rather to a time 3.56 b.y. ago, and that the day was 8.7 hours. He suggested that the day to be 5–7 hours at approximately 4.5 b.y. ago. Ksanfomality (1997 [13]) has shown that according to the principle of isochronism all planets had an initial period of rotation between 6–8 hours. However, our model gives a value of 6 hours (see Table 2). Berry and Baker (1968 [14]) have suggested that laminae, ridges and troughs, and bands on present day and Cretaceous bivalve shells are growth increments of the day and month, respectively. By counting the number of ridges and troughs they therefore find that the year contains 370.3 days in the late Cretaceous. According to the latest research by a group of Chinese scientists (Zhu *et al.* [15]), there were 15 hours in one day, more than 540 days, in a year from a study of *stromatolite* samples. We however remark that according to our law that when the day was 15 hours there were 583 days in a year 1.819 billion years ago. The difference in time could be due to dating of their rock.

Recently, McNamara and Awramik (1992 [16]) have concluded, from the study of *stromatolite*, that at about 700 m.y. ago the number of days in a year was 435 days and the length of the day was 20.1 hours. In fact, our model shows that this value corresponds more accurately to 715 m.y. ago. Vanyo and Awramik (1985 [17]) has investigated *stromatolite*, that is 850 m.y. old, obtained a value between 409 and 485 days in that year. Our law gives 450 days in that year and 19.5 hours in that day. This is a big success for our law. Here we have gone over all data up to the time when the Earth formed. We should remark that this is the first model that gives the value of the length of the day for the entire geologic past time.

The present rate of increase in the length of the day is 0.002 m s/century. Extrapolating this astronomically determined lengthening of the day since the seventeenth century leads to 371 days in the late Cretaceous (65 m.y. ago) Pannella (1972 [18]). The slowing down in the rotation is not uniform; a number of irregularities have been found. This conversion of Earth's rotational energy into heat by tidal friction will continue indefinitely making the length of the day longer. In the remote past the Earth must have been rotating very fast. As the Earth rotational velocity changes, the Earth will adjust its self to maintain an equilibrium (shape) compatible with the new situation. In doing so, the Earth should have experienced several geologic activities. Accordingly, one would expect that the tectonic movements (plate's motion) to be attributed to this continued adjustment.

We plot the length of day (in hours) against time (million years back) in Fig. (1). We notice here that a direct extrapolation of the present deceleration would bring the age of the Earth-Moon system t a value of 3.3 billion years. We observe that the plot deviates very much from straight line. The plot curves at two points which I attribute the first one to emergence of water in huge volume resulting in slowing down the rotation of the Earth's spin. The second point is when water becomes abundant and its rate of increase becomes steady.

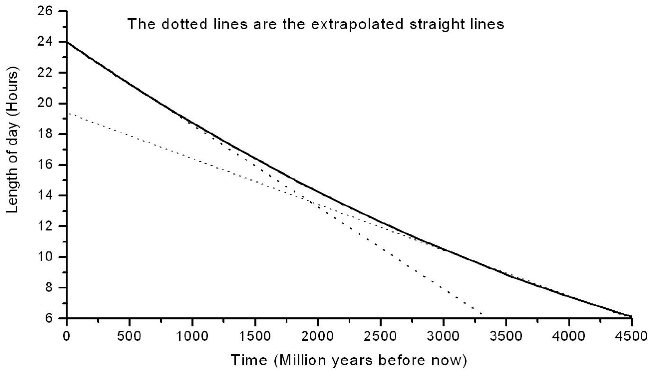

Fig. 1: The variation of length of day versus geological time.

These two points correspond to 1100 m.a. and 3460 m.a., and their corresponding lengths of day are 18.3 and 8.9 hours, respectively. As the origin of life is intimately related to existence of water, we may conclude that life has started since 3.4 billion years ago, as previously anticipated by scientists.

4 Conclusion

We have constructed a model for the variation of length of the day with time. It is based on the idea of an effective Newton's constant as an effective coupling representing all gravitational effects on a body. This variation can be traced back over the whole history of the Earth. We obtained an empirical law for the variation of the length of the day and the number of days in a year valid for the entire past Earth's rotation. We have found that the day was 6 hours when the Earth formed. These data pertaining to the early rotation of the Earth can help paleontologists to check their data with this findings. The change in the strength of gravity is manifested in the way it influences the growth of biological systems. Some biological systems (rythmites, tidalites, etc.) adjust their rhythms with the lunar motion (or the tide). Thus any change in the latter system will show up in the former. These data can be inverted and used as a geological calendar. The data we have obtained for the length of the day and the number of days in the year should be tested against any possible data pertaining to the past's Earth rotation. Our empirical law has been tested over an interval as far back as 4500 m.y. and is found to be in consistency with the experimental data so far known. In this work we have arrived at a generalized Kepler's laws that can be applicable to our ever changing Earth-Moon-Sun system.

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A Quantum Theory of Magnetism

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In this paper, a new Quantum Theory of Magnetic Interaction is proposed. This is done under a relaxation of the requirement of covariance for Lorentz Boost Transformations. A modified form of local gauge invariance in which fermion field phase is allowed to vary with each space point but not each time point, leads to the introduction of a new compensatory field different from the electromagnetic field associated with the photon. This new field is coupled to the magnetic flux of the fermions and has quanta called magnatons, which are massless spin 1 particles. The associated equation of motion yields the Poisson equation for magnetostatic potentials. The magnatons mediate the magnetic interaction between magnetic dipoles including magnets and provide plausible explanations for the Pauli exclusion principle, Chemical Reactivity and Chemical Bonds. This new interaction has been confirmed by numerical experiments. It establishes magnetism as a force entirely separate from the electromagnetic interaction and converts all of classical magnetism into a quantum theory.

1 Introduction

Quantum Electrodynamics (QED) is the most accurate theory available. The associated electromagnetic interaction, which is embodied in Maxwell's equations, is universally viewed as a unification of the electric force and the magnetic force. Such an interpretation, however, encounters difficulty when applied to a rather basic situation. Specifically, consider two electrons with parallel spins that are arranged spatially alongside each other ($\uparrow\uparrow$). From the theory of QED based on the Gordon decomposition [1, see p. 198], the electric charge of the electron along with its spin results in an electromagnetic interaction between the two particles which is made up of a dominant electric (Coulomb) repulsion and a weaker attractive magnetic component. That the magnetic component is attractive is stated explicitly by Fritzsch in his discussion of chromomagnetic forces among quarks [2, see p. 170]). This explains why orthopositronium, where the particle (electron and positron) spins are parallel and hence the magnetic component of the electromagnetic interaction is repulsive, has a higher energy state than parapositronium where the particle spins are anti-parallel and the magnetic component of QED is attractive. However, from the classical theory of magnetism, the magnetic moment of the two electrons results in a magnetic repulsion between the electrons rather than an attraction [3]. The commonplace occurrence of two bar magnets interacting with each other presents a further problem for the electromagnetic interaction since magnets, in general, carry a net zero charge and therefore cannot interact by exchanging photons. These examples appear to call into question the universally adopted practice of interpreting the magnetic force as part of the electromagnetic interaction and suggest the need for some level of re-examination. In attempting to address these problems associated with the magnetic interaction, we observe that according to the relativistic world-view, all physical laws of nature must have the same form under a proper Lorentz transformation [4]. With respect to quantum field theories, this means that the field equations describing the various interactions of elementary particles must be Lorentz-covariant, a requirement that places certain restrictions on the allowed interaction models. Lorentz covariance is however not an observed law of nature but is rather a mathematical requirement that is assumed to apply universally. We wish to relax the restrictions imposed by this condition and therefore advance the following postulate:

Postulate 1

Not all interactions are covariant under Lorentz boost transformations. On the basis of this conjecture, we develop a new model of the magnetic interaction. Postulate 1 is the only assumption used in this development and is no more far-fetched than any of the several assumptions of the widely considered superstring theory for which there is no firm supporting evidence and which includes (i) strings rather than particles as fundamental entities, (ii) supersymmetry, the interchangeability of fermions and bosons and (iii) 9 dimensional rather than 3 dimensional spatial existence! On the other hand, the validity of our model and the likely correctness of the postulate are demonstrated by the significant extent to which the consequences of the model accord with or provide plausible explanations for observed phenomena. In particular, the model achieves the following:

- It predicts the existence of a new massless vector particle different from the photon that satisfies the wave equation for magnetic fields. This particle mediates the magnetic interaction between magnetic dipoles thereby establishing the magnetic interaction as one separate from the electromagnetic interaction and converts all of classical magnetism into a quantum theory.

- It provides plausible explanations for a wide range of hitherto unexplained phenomena including phenomena associated with the Pauli exclusion principle, chemical reactivity and chemical bonds.

2 The electromagnetic interaction

At present, it is believed that the interaction of the electromagnetic field with charged point-like (Dirac) particles is governed by the Principle of Minimal Interaction [4]; all charged particles have only current-type interactions with the electromagnetic field given by $j^\mu A_\mu$ where A_μ is the 4-vector potential of the electromagnetic field and j^μ is the 4-vector current. The minimal concept implies that all electromagnetic properties can be described by this interaction and that no other interactions are necessary. The interaction involves both the charge of the particle and its magnetic moment resulting from its spin magnetic moment (SMM) derived from the Dirac theory and the quanta of the 4-vector electromagnetic field are spin 1 photons. Consider a "spinless" Dirac particle. For such a particle, the SMM is zero and hence electromagnetic interaction is only via the charge with the associated electric field being mediated by the 4-vector A_μ [5]. If on the other hand, the charge of the Dirac particle with spin goes to zero, the SMM again goes to zero and the interaction between the 4-vector A and the uncharged particle disappears. Roman [4, see p. 436] used the proton-photon interaction in the form $j^\mu A_\mu$ and the absence of a neutron-photon interaction (since the neutron is uncharged) to account for the experimental fact that the electromagnetic interaction destroys the isotropy of isospin space, an effect that Sakurai [6] considered as "one of the deepest mysteries of elementary particle physics".* It seems therefore that for neutrons, where the electric charge is zero but the magnetic moment is non-zero, interaction cannot be of the type $j^\mu A_\mu$ i.e. the associated magnetic field is not mediated by the 4-vector A_μ. The well-known absence of interaction between (relatively stationary) electric charges and magnets does perhaps suggest that different mediating quanta are involved in these interactions. We note from the electrodynamic equation $B = \nabla \times A_k$ that, unlike the electric field E that requires both the 3-vector potential A_k and a scalar potential ϕ for its definition, the magnetic field B is completely defined by A_k, which we know, satisfies [3]

$$\Box A_k = \mu J_k. \tag{2.1}$$

where J_k is current density, and which, as established by the Aharonov-Bohm Effect [7], has independent physical existence. We therefore ask, is the 3-vector A_k a magnetic interaction field that is separate from the 4-vector A_μ electromagnetic interaction field?

It is generally believed that all interactions are mediated by gauge fields and hence if A_k is an interaction field, then it should result from the gauge invariance principle [5]. According to this principle, changing the phase of a fermion locally creates phase differences, which must be compensated for by a gauge field if these differences are not to be observable. In other words, a gauge field results from fermion field phase changes. The electromagnetic field of QED and the gluon field of QCD (quantum chromodynamics) are examples of such compensating fields. Reversing this rule, we suggest that an independently created gauge field should produce local phase changes in the fermion field through interaction, i.e. fermion field phase changes should result from a gauge field. We believe that this is precisely what is demonstrated by the Aharonov-Bohm Effect [7]. Here, a 3-vector field A_k independently generated by an electric current, directly produces phase changes in a beam of electrons, in a region where the associated magnetic field B is zero. It follows, we believe, that A_k can be produced by an appropriate fermion field phase change, and that it represents an interaction field.

In order to model A_k as a gauge field, an appropriate conserved quantity, like electric charge, which will determine the strength of the coupling of A_k to the fermion, must be identified. In this regard, we note that an extensive quantum field theory describing magnetic monopoles carrying magnetic charges has been developed [8]. The quanta of this field theory are the quanta associated with the gauge field A_μ of QED, namely photons, which in this theory couple to both electric charge and magnetic charge. However magnetic monopoles have not been found despite strenuous efforts and therefore this theory remains unverified. Towards the development of a new theory having A_k as the gauge field, we adopt an approach sometimes employed in magnetostatics [3, see p. 325] and define a magnetic charge ν which, though physically unreal, is treated as the source of magnetic flux for the purposes of the development.

3 A gauge theory of magnetism

For a fermion with magnetic moment μ_m, we define [3]

$$\nu = \nabla \cdot \mu_m. \tag{3.1}$$

where we refer to ν as magnetic charge and regard it as the source of the magnetic flux associated with the magnetic moment μ_m. Now consider the Lagrangian density $L(x)$ of the fermion field $\psi(x)$ given by

$$L(x) = \bar{\psi}(x)(i\gamma^\mu \partial_\mu - m)\,\psi(x)\,. \tag{3.2}$$

*Using this same nucleon-photon interaction, Roman also proved that the electromagnetic interaction conserves the third component of isospin, T_3, a known experimental fact.

L is clearly invariant under the transformation

$$\psi^{'}(x) = e^{-i\nu a}\psi(x)\,, \tag{3.3}$$

where α is a constant and ν is the magnetic charge of the fermion. From Noether's theorem [4], it follows that the magnetic charge is conserved i.e.

$$\partial_t \nu = \partial_t \left\{ \sum \nu_i \int \bar{\psi}_i \gamma^0 \psi_i d^3x \right\} = 0. \tag{3.4}$$

In practical terms, this means that magnetic flux is conserved. Thus, like electric charge, the conservation of magnetic charge (flux) can be viewed as a consequence of the invariance of the fermion Lagrangian density under the global transformation (3.3). Towards the generation of A_k through local phase changes, we recall that the electromagnetic field is the gauge field which guarantees invariance of the Lagrangian density under space-time local $U(1)$ gauge transformations, i.e. α is a function of space $\bar{x}$ and time t. Here, noting that the electron interference pattern produced by A_k in the Aharonov-Bohm effect varies spatially as A_k is changed, we let the parameter α, in (3.3) be a function of space $\bar{x}$, $\alpha = \alpha(\bar{x})$ i.e. it may have different values at different points in space but continues to be the same at every time t. Considering a neutron field ψ_n say, (3.3) becomes

$$\psi^{'}(x) = e^{-i\nu\alpha(\bar{x})}\psi(x). \tag{3.5}$$

Under this space-local transformation, the Lagrangian density is not invariant. Invariance is achieved by the introduction of a 3-vector massless field A_k, $k = 1, 2, 3$, such that

$$L = \bar{\psi_n}(i\gamma^\mu \partial_\mu - m)\,\psi_n - \nu\,\bar{\psi}_n \gamma^k \psi_n A_k\,, \tag{3.6}$$

where $A_k \rightarrow A_k + \frac{\partial \alpha(\bar{x})}{\partial \bar{x}}$ as

$$\psi_n \rightarrow e^{-i\nu\alpha(\bar{x})}\,\psi_n\,. \tag{3.7}$$

The quantity $\bar{\psi}_n \gamma^k \psi_n$ varies like a vector under space rotation and space inversion but not under a Lorentz boost. However, under postulate 1, such a term is allowed in the interaction. Hence, by demanding space-local invariance, a 3-vector field A_k is introduced. When we add to the fermion Lagrangian density a term representing kinetic energy of A_k [4], we arrive at the equation of motion for A_k given by

$$\Box A_k = \nu\,\bar{\psi}_n \gamma^k \psi_n\,. \tag{3.8}$$

This is a 3-vector Klein-Gordon equation whose associated quanta have spin 1 charge 0 and mass 0. Variation of (3.6) with respect to ψ_n gives

$$(i\gamma^\mu \partial_\mu - m)\psi_n = -\,\nu\,\gamma^k A_k \psi_n\,, \tag{3.9}$$

which is the modified Dirac equation in the presence of the field A_k. Analogous to the electromagnetic case, we associate the quantity $\nu\bar{\psi}_n \gamma^k \psi_n$ with current density J_k such that

$$\Box A_k = \mu J_k\,, \tag{3.10}$$

where μ is the permeability constant. This is equation (2.1) of classical electrodynamics. In the case of magnetic material, the equivalent current density is referred to as magnetization or Amperian current density J_m [3, see p. 315] given by

$$J_m = \nabla \times M\,, \tag{3.11}$$

where M is the magnetic dipole moment/unit volume or magnetization . Equation (3.10) is the well-known wave equation for magnetic potentials. [3]. If the magnetic charge distribution is time-independent, the wave equation (3.10) reduces to

$$\nabla^2 A_k = -\,\mu J_k\,. \tag{3.12}$$

Equation (3.12) is the Poisson equation for magnetostatic potentials that contains all of classical magnetism. It leads, under appropriate conditions, to the inverse square law for magnetic poles as well as an inverse higher-order law for magnetic dipoles given by

$$F = \frac{3\mu\mu_1\mu_2}{4\pi r^4}\,, \tag{3.13}$$

where the dipoles are parallel and spatially opposite each other ↑↑ [4, see p. 311, problem 19.10]. Thus, J_k is the source of the potential A_k and we interpret A_k as the magnetic gauge field with quanta of spin 1, mass zero, charge zero and odd parity which we shall call magnatons. It is the gauge field which guarantees invariance under space-local $U(1)$ gauge transformations. The conservation of magnetic charge is directly associated with the universality of the magnetic coupling constant for all particles with a magnetic moment and the strength of the coupling is the magnetic charge (flux) of the particle. Thus, while for electrically charged particles the interaction with an electromagnetic field — the Quantum Electrodynamic Interaction or electromagnetic interaction — is mediated by the photon and involves the electric charge and the associated SMM, the interaction of a "magnetically charged" particle with a magnetic field is mediated by the magnaton and involves the particle's magnetic moment. This is a new quantum interaction, which we shall refer to as the Quantum Magnetodynamic Interaction or magnetic interaction. It is in general different from the magnetic component of the electromagnetic interaction. To demonstrate this difference, consider again two electrons with parallel spins (↑↑). Recall, from the theory of QED, (e.g. [1, see p. 198]), that the electric charge of the electron along with its spin results in an electromagnetic interaction between the two particles which is made up of a dominant electric repulsion and a weaker attractive magnetic component. In the new theory, the magnetic moment of the two electrons results in a magnetic repulsion given by (3.13) consistent with the classical theory of magnetism and different from the magnetic component of the electromagnetic force, which is attractive. Since the potential of the magnetic interaction is of the form $1/r^3$, its effect will not generally be noticed in QED interactions where the potential is of the form $1/r$, but becomes dominant at short distances. Experimentally, in electron-positron high-energy scattering for example, there are indeed sharp resonances as well as novel asymmetries in the angular distributions, which cannot be accounted for in the QED perturbation theory, which Barut [9] has considered to be possibly of magnetic origin. In fact, Barut points out that in perturbation theory, the short distance behaviour of QED is completely unknown since the forces involved change completely at high energies or short distances. We believe that it is the magnetic interaction mediated by the magnaton, which becomes effective at short distances, that is the operative mechanism. We conclude then that the observed magnetic interaction between magnetic dipoles and magnets is mediated not by photons as is widely believed, but by magnatons. Because magnatons are massless vector particles, the associated magnetic field is long-range and results in interactions that are both attractive and repulsive, all in agreement with observation.

4 Application of the quantum magneto-dynamic interaction

The quantum magnetodynamic interaction effectively converts all of classical magnetism into a quantum theory and is therefore supported by 400 years of scientific discovery in magnetism, started by Gilbert in 1600. We expect new detailed predictions from the theory because of its quantum mechanical nature but defer this substantial exercise. Instead, we examine simple and direct tests of the model and show that it offers plausible explanations in precisely those areas where there are no simple answers. The larger the number of applications where it provides a persuasive account, the greater will be our confidence in its correctness and consequently our preparedness to engage in more detailed analysis. In the following sub-sections, three areas are discussed: The Pauli exclusion principle, chemical reactivity and chemical bonds.

4.1 The Pauli Exclusion Principle

The Pauli Exclusion Principle is an extremely important principle in science [10]. It is the cornerstone of atomic and molecular physics and all of chemistry. It states that two electrons (or other fermions) cannot have the same spatial wave function unless the spins are anti-parallel ($\uparrow\downarrow$) i.e. apart from the electric repulsion, parallel spin electrons tend to repel each other while anti-parallel spin electrons tend to attract each other. The operative force of attraction/repulsion is unknown. It cannot be the magnetic component of the electromagnetic force since it has the wrong sign and because of the inability to identify this so-called "Pauli Force", the tendency is to label this behaviour a "quantum-mechanical effect, having no counterpart in the description of nature according to classical physics" [10, see p. 564]. We suggest that the tendency for parallel spin electrons to repel each other and anti-parallel spin electrons to attract each other arises as a result of the quantum magnetodynamic interaction. The magnetic moment of an electron is aligned with its spin, making it effectively a tiny magnet. Therefore, parallel spin electrons will experience mutual repulsion according to equation (3.13) arising from the exchange of magnatons, while anti-parallel spin electrons will experience mutual attraction. This, of course, is consistent with classical magnetism represented by (3.13).

Periodic Table of Elements

An immediate application of the magnetic attraction between anti-parallel spin electrons is in the energy levels of atoms. The attractive magnetic force in the anti-parallel spin electrons accounts for the anti-parallel pairing of electrons in atomic orbitals where the electrons are close together, this leading to the Periodic Table of elements. We further suggest that the attractive component of the long-range electromagnetic force between parallel spin electrons accounts for the experimental fact that unpaired electrons in different atomic orbitals having the same energy are parallel spin-aligned.

Solidity of matter

In solids, inter-atomic and inter-molecular forces are in general considered to be manifestations of the electromagnetic interaction between the constituents, and the electric (Coulomb) component plays the dominant role. This interaction provides an attractive force that holds the constituent atoms in a regular lattice. This is very evident in solids such as sodium chloride. For small inter-atomic distances such that the orbitals of inner electrons overlap, a repulsive force component arises. This repulsive force at short distances is called the repulsive core and is a general feature of atomic interaction. It prevents the interpenetration of atoms and thereby provides the solidity of matter [11]. The repulsive core is attributed to the Pauli Exclusion Principle and Gillespie explains this as follows [12, see p. 69]: "... because of the Pauli principle, in any region of space around a nucleus in which there is a high probability of finding a pair of electrons of opposite spin, there is only low probability of finding any other electrons. Since most molecules have an equal number of electrons of opposite spin, no other electrons can penetrate into each other to a significant extent." Again no force is identified and in fact Gillespie refers to the unknown Pauli forces as apparent forces that are not real. We propose that the quantum magnetodynamic interaction between the magnetic fields of the orbiting anti-parallel electron pairs in the various atoms is the missing component in Gillespie's explanation and that this along with the electric force prevents collapse in solids. The magnetic interaction neutralizes the associated magnetic field of the anti-parallel pair such that there is no magnetic interaction (which could be attractive) between the pair and the magnetic field of other electrons. As a result the electric field of the pair repels other electrons and prevents them from penetrating to any significant extent. This, we suggest, is responsible for the solidity of matter with the magnetic neutralization being a critical feature of the process. The existence of the magnetic interaction in the repulsive core mechanism is supported by Earnshaw's theorem [13] according to which a system of only interacting electric charges cannot be stable.

4.2 Chemical reactivity

Chemical reaction generally involves the union or separation of atoms. While the Coulomb force is a dominant feature of this activity, we suggest that the primary basis of chemical reactivity is the magnetic interaction. This interaction explains why atoms and molecules with unpaired electrons in the valence shell like the alkali metals, the halogens and free radicals, tend to be highly reactive. The unpaired electrons in such substances have a magnetic field that interacts with the magnetic field of unpaired electrons of other atoms and molecules. The hydroxyl radical (OH) is an example of an odd electron molecule or free radical having an unpaired electron. It is extremely reactive because the radicals can combine with each other or with odd electron carriers, each contributing an electron to form pairs with the constituents drawn together and bound by the magnetic interaction. The magnetic interaction causes unpaired electrons to be points of high reactivity and hence free radicals have no more than a fleeting existence at room temperature [14]. The presence of this magnetic field in substances with unpaired electrons is evident in nitric oxide, boron and oxygen, all of which have one or more unpaired valence electron and are paramagnetic. Liquid oxygen will actually cling to a magnet. On the other hand, atoms and molecules with paired electrons like the noble gases of Group 8 on the Periodic Table tend to be unreactive. This occurs because the paired electrons in such substances are anti-parallel in spin alignment and this results in a substantial neutralization of the overall magnetic field associated with the pair. Since this magnetic field is being proposed as the agent responsible for promoting reactions, such substances would be expected to be less chemically reactive, as is observed. Because of this unavailability of unpaired electrons, the atoms of the members of Group 8 all exist singly.

Experimental confirmation

Important numerical experiments carried out by Greenspan [15] provide strong confirmation of this magnetic interaction and the attraction it produces between anti-parallel electron pairs. This researcher found that classical dynamical calculations for the ground-state hydrogen molecule using a Coulombic force between the bond electrons along with spectroscopic data yielded a vibrational frequency of 2.20×10^{14} Hz, which was a significant deviation from the experimentally determined value of 1.38×10^{14} Hz. By assuming the force between the electrons to be fully attractive rather than fully repulsive, Greenspan obtained the correct vibrational frequency. This approach was successfully tested for the following ground-state molecules: H^1_2, H^2_2, H^1H^2, H^1H^3, and Li^7_2. In all, these cases, deterministic dynamical simulations of electron and nuclei motions yielded correct ground-state vibrational frequencies as well as correct molecular diameters under the assumption that the binding electrons attract. In another paper [16] Greenspan showed that the assumption of electron attraction also yields the correct vibrational frequencies and average molecular diameters for ground-state molecules Li^7_2, B^{11}_2, C^{12}_2, and N^{14}_2. Obtaining correct ground-state results for both vibrational frequencies and average molecular diameters in this large number of molecules was most unexpected and is an extremely strong indication of the correctness of the magnetic interaction model proposed in this paper.

4.3 Chemical bonds

Chemical bonding is due to the attraction of atoms for the electrons of other atoms toward their unfilled orbitals. We suggest that the basis of this attraction is the magnetic interaction between the unpaired electrons associated with these unfilled orbitals. Here we consider ionic bonds, covalent bonds and the concept of the rule-of-two that is central to chemistry.

Ionic bonds

In ionic bonds, donor atoms such as sodium tend to lose electrons easily while acceptor atoms such as chlorine tend to acquire additional electrons. When atoms of these two kinds interact, a re-arrangement of the electron distribution occurs; an electron from the donor atom migrates to the acceptor atom thereby making the acceptor atom negatively charged and the donor atom positively charged. The Coulomb interaction between these ions then holds them in place in the resulting crystal lattice. [11]. In this explanation of the formation of an ionic bond, while the role of the Coulomb force is clear, it is not clear what makes the electron from the donor atom migrate to the acceptor atom. We suggest that apart from the action of the electric force, the migration of the electron from a donor atom to an acceptor atom during a chemical reaction results from the magnetic interaction. As the chemicals are brought together, the electron of the donor atom is close enough to interact with the electron of the acceptor atom via their magnetic fields. The operative quantum magnetodynamic interaction causes the electron of the donor atom and the electron of the acceptor atom to be drawn together in an anti-parallel spin alignment consistent with magnetic attraction. The resulting magnetically bound pair becomes attached to the acceptor atom because of its greater electric attraction (electronegativity), precisely as observed.

Covalent bonds

While some bonds are ionic, the majority of chemical bonds have a more or less covalent character. This bond is the foundation of organic chemistry and is the basis of the chemistry of life as it binds DNA molecules together. According to the current understanding [11], atoms with incomplete shells share electrons, with the electrons tending to concentrate in the region between the atoms. This concentration of electrons exerts a Coulombic attraction on the positive nuclei of the two atoms and this gives rise to a covalent bond. What is not evident in this explanation though is why the shared electrons cluster between the atoms, despite their mutual electric repulsion. The accepted approach is to solve the Schrodinger equation arising from the application of wave mechanics to the system and on this basis attempt to show that the electrons occupy the region where they are observed to cluster. This approach to the explanation of the nature of the covalent bond has been described by Moore [17] as the most important application of quantum mechanics to chemistry. However, this quantum-mechanical method is at best only an approximation as the only atoms that can be described exactly by wave mechanics are hydrogenic (single-electron) atoms such as H, He^{+1} and Li^{+2}. As a result, most of the claimed predictions are really systematized experimental facts as pointed out by Luder [18]. Moreover, wave mechanics does not identify the force that causes the clustering. The quantum magnetodynamic interaction offers an immediate explanation for this clustering: the two electrons involved in a covalent bond always have opposite spin arising from the interaction of the associated magnetic fields and this results in magnetic attraction between them, and hence the clustering. The strong directional characteristic of covalent bonds is a significant indicator of the magnetic nature of the bond, and the close proximity of the associated electron orbitals is consistent with dominant magnetic interaction. The general saturable nature of this bond and the empirical fact that an electron pair cannot normally be used to form more than one covalent bond arise because the intensity of the magnetic field of the anti-parallel electron pair constituting the bond is significantly reduced due to the anti-parallel alignment. This reduction in reactivity resulting from magnetic field neutralization in the anti-parallel pair has already been observed in the noble gases where only electron pairs exist.

To illustrate covalent bond formation based on the magnetic interaction, we examine the covalent bonds in hydrogen gas (like atoms) and hydrogen chloride (unlike atoms). The hydrogen atom has one electron in the 1s orbital. Consider the approach of two hydrogen atoms in the formation of a hydrogen molecule. If the electron spins are parallel (triplet state), then there will be magnetic (and electric) repulsion between the electrons as their orbitals overlap. This repulsive state with spin-aligned electrons in triplet state hydrogen atoms is spectroscopically detectable, thus confirming the overall correctness of this description. Magnetic repulsion along with electric repulsion between the nuclei prevents the formation of a stable molecule. If the electron spins are anti-parallel (singlet state), then for sufficient electron orbital overlap, the resulting magnetic attraction between the electrons is enough to overcome the electric repulsion between them (as well as between the nuclei), and the electrons cluster in a region between the two nuclei. The electric force of attraction between this electron cluster and the two nuclei establishes the covalent bond and a stable hydrogen molecule H_2 results. It is an observed fact [19] that atomic hydrogen is highly unstable as the atoms tend to recombine to form H_2 molecules. We attribute this to the action of the magnetic interaction between the unpaired electrons as described. Similar action occurs in chlorine and oxygen molecules. As a second example, consider the formation of hydrogen chloride from an atom of hydrogen and an atom of chlorine. Hydrogen has one unpaired electron in the K shell in a spherical orbital and chlorine has seven valence electrons in the M shell, 2 filling the 3s orbital and 5 in the 3p orbitals comprising 3 orthogonal dumbbell-shaped orbitals about the nucleus. Two of these 3p orbitals are filled with paired electrons while the remaining 3p orbital has a single unpaired electron. When a hydrogen atom and a chlorine atom approach, the spherical orbital of the hydrogen overlaps with the unfilled elliptical orbital of the chlorine and the magnetic interaction between the unpaired electrons in these two orbitals causes these 2 electrons to cluster between the 2 atomic nuclei in an anti-parallel spin formation. The elliptical shape of the chlorine's 3p orbital is altered in the process. This magnetic interaction between these unpaired elections establishes the covalent bond and the consequent formation of hydrogen chloride (HCl). The arrangement is shown in Figure 1.

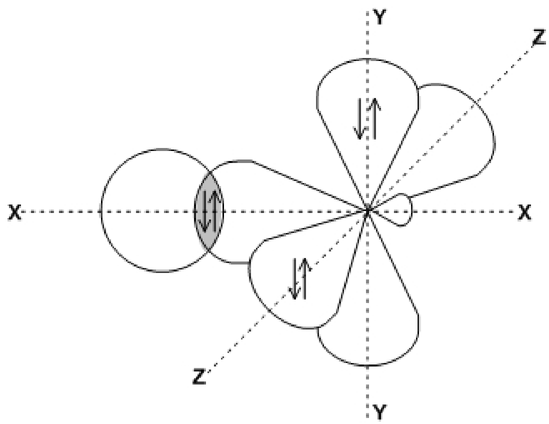

Fig. 1: Covalent bond formation in hydrogen chloride: the s orbital of the hydrogen atom overlaps with a p orbital of the chlorine atom.

The bound electrons are situated closer to the chlorine atom because of its higher electronegativity though they are not completely transferred to the chlorine atom as in sodium chloride. This imbalance causes the HCl molecule to be polar with a positive pole near the hydrogen atom and a negative pole near the chlorine atom. Thus, both the ionic bond and the covalent bond involve a magnetically bound (anti-parallel spin-aligned) electron pair that is attracted to two positively charged atomic nuclei by Coulomb forces. The relative strength of these two electric forces in a specific bond determines the exact position of the electron pair between the atomic nuclei and hence its location along the bonding continuum represented by pure covalent (H_2)-polar covalent (HCl)-ionic (NaCl) bonding.

Rule-of-two

The "rule of two" [12] is a central concept in chemistry that is more significant than the well-known "rule-of-eight" or stable octet for which there are many exceptions. It is recognition of the observational fact that electrons are generally present in molecules in pairs, despite their mutual electric repulsion. We attribute this tendency to electron pair formation to the magnetic attraction between the two anti-spin aligned electrons forming the pair as verified by the Greenspan data. The new magnetic interaction therefore explains the universal "rule-of two" simply and naturally.

5 Conclusion

In this paper, we have proposed a new magnetic interaction — quantum magneto-dynamics or QMD — that is mediated by massless spin 1 quanta called magnatons. These mediators are different from photons, the quanta of the electromagnetic interaction in QED. QMD is associated with the magnetic moment of the fermions and accounts for all magnetic interactions between magnets. Magnatons are massless vector particles that give the magnetic field its long-range attractive/repulsive character. They satisfy the Poisson equation of classical magnetism and are, we believe, the transmission agents in the Aharanov-Bohm effect. QMD provides plausible explanations for various hitherto unexplained phenomena including the Pauli exclusion principle, chemical reactivity and chemical bonds. It explains the "Pauli Force" that leads to electron pairing in atomic orbitals. It also explains covalent bonds which are the foundation of organic chemistry as well as the "rule of two" according to which electrons are present in molecules in pairs with only a few exceptions, despite their mutual electric repulsion. Greenspan [15, 16] has confirmed this attractive magnetic force between anti-parallel spin aligned electrons for several molecules in important numerical experiments. The effects of QMD are not evident in low-energy QED interactions because the potential of the magnetic interaction is of the form $1/r^3$ but become dominant at high energies or short distances. The extent to which the new quantum theory of magnetism accords with observation and its success in providing simple answers in several areas where relativistic models provide none all strongly suggest that the theory may be right and that a more detailed investigative programme should be pursued. Issues that need to be explored include:

1. The renormalizability of the new interaction to enable calculations;
2. Quantitative application of the magnetic interaction to the Pauli Exclusion phenomenon, chemical reactivity and chemical bonds;
3. Application to molecular geometry;
4. Analysis of the new interaction in order to reveal new quantum mechanical phenomena such as may occur in electron-positron high-energy scattering [9], polarised proton-proton collisions [20] and elastic electron-neutron scattering [5].

We have been led to this new interaction by breaking away from the excessively restrictive idea of Lorentz covariance. An alternative modification of U(1) gauge invariance explored in ([21], where we demand that the Lagrangian density be invariant under a time-local (rather than space-local) $U(1)$ gauge transformation $\psi \to \psi^{'} = U\psi$ with U being time-dependent (rather than space-dependent), generated a scalar spin0 field (rather than a 3-vector spin1 field) which we identify as the gravitational field (instead of the magnetic field). This field satisfies a wave equation, which contains the Poisson equation for gravitational potentials and hence 300 years of Newtonian gravitation. This is a further indication that the basic approach may be valid. In future research, therefore, we intend to pursue the modified gauge invariance approach used in this paper and demand that nucleon interaction be invariant under an isotopic gauge transformation $\psi \to \psi^{'} = U\psi$ with U being a space-dependent isospin rotation $U(\bar{x})$. The hoped-for result is massless rho-mesons which when unified with the spin1 magnatons are given mass through spontaneous symmetry breaking thereby yielding massive rho-mesons. Such an approach in [22] involving a time-dependent isospin rotation $U(t)$ and unification with spin0 gravitons yielded pi-mesons!

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The Planck Vacuum

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This paper argues that there is a polarizable vacuum state (the Planck vacuum) that is the source of the quantum vacuum; the free particles; the gravitational, fine structure, and Planck constants; the gravitational field and the spacetime of General Relativity; the Maxwell equations and the Lorentz transformation; and the particle Compton relations and the quantum theory.

1 Introduction

This is an unusual paper that needs to be put into perspective to be understood because the definitions contained herein evoke preconceived ideas that get in the way of the reader. For example, the words "bare charge" mean something very specific to the quantum-field-theory specialist that evoke notions of renormalization and Feynman diagrams. The definition of these words given here, however, mean something quite different; so this preface is intended to provide a setting that will make the paper easier to understand.

About ten years ago the author derived the gravitational ($G = e_*^2/m_*^2$), Planck ($\hbar = e_*^2/c$), and also fine structure ($\alpha = e^2/e_*^2$) constants in a somewhat confused and mixed-up manner. Although their derivation at that time left something to be desired, the simple elegance and connectedness of these three fundamental equations has provided the motivation behind the search for their explanation. Thus it was the "leading" of these three constants that resulted in the paper that is about to be read. The intent at the beginning of the investigations was not some urge to discover a grand theory that unifies diverse areas of physics, although the search for the physics behind the constants appears to be doing just that.

The Planck vacuum (PV) state is envisioned as an infinite, invisible (not directly observable), omnipresent, uniform, and homogeneous negative energy state somewhat analogous to the Dirac "sea" in quantum mechanics. The quantum vacuum, on the other hand, consists of virtual particles that appear and disappear at random in free space, the space where free particles and the rest of the universe are observed. The source of this quantum vacuum is assumed to be the PV, where the fields of the quantum vacuum are analogous to non-propagating induction fields with the PV as their source. The PV is also assumed to be the source of the free particles.

The charge of the Planck particle is called the bare charge, and it is this bare charge that is the true, unscreened, charge of the electron and the rest of the charged elementary particles. The polarizability of the PV is shown to be responsible for the fact that the observed electronic charge e has a smaller magnitude than the bare charge e_*.

The PV theory is not derived from some pre-existing theory, e.g. the quantum field theory — it is assumed to be the source of these pre-existing theories. The simple calculations in the paper lead to the above constants and from there to the many suggestions, assumptions, speculations, and handwaving that necessarily characterize the PV theory at this early stage of development. It is expected, however, that the theory will eventually lead to a "sea change" in the way we view fundamental physics. So let's begin.

The two observations: "investigations point towards a compelling idea, that all nature is ultimately controlled by the activities of a single *superforce*", and "[a living vacuum] holds the key to a full understanding of the forces of nature"; come from Paul Davies' popular 1984 book [1] entitled *Superforce: The Search for a Grand Unified Theory of Nature*. This living vacuum consists of a "seething ferment of virtual particles", and is "alive with throbbing energy and vitality". Concerning the vacuum, another reference [2] puts it this way; "we are concerned here with virtual particles which are created alone (e.g., photons) or in pairs (e^+e^-), and with the vacuum — i.e., with space in which there are no real particles". This modern vacuum state, as opposed to the classical void, is commonly referred to as the quantum vacuum (QV) [3]. The virtual particles of this vacuum are jumping in and out of existence within the constraints of the Heisenberg uncertainty principle ($\Delta E \Delta t \sim \hbar$); i.e., they appear for short periods of time (Δt) depending upon their temporal energy content (ΔE), and then disappear. The QV, then, is an ever-changing collection of virtual particles which disappear after their short lifetimes Δt, to be replaced by new virtual particles which suffer the same fate, ad infinitum.

Among other things, the following text will argue that the source of the QV is the Planck vacuum (PV) [4] which is an omnipresent degenerate gas of negative-energy Planck particles (PP) characterized by the triad (e_*, m_*, r_*), where e_*, m_*, and r_* ($\lambda_*/2\pi$) are the PP charge, mass, and Compton radius respectively. The charge e_* is the bare (true) electronic charge common to all charged elementary particles and is related to the observed electronic charge e through the fine structure constant $\alpha = e^2/e_*^2$ which is one manifestation of the PV polarizability. The PP mass and Compton radius are equal to the Planck mass and length [5] respectively. The zero-point (ZP) random motion of the PP charges e_* about their equilibrium positions within the PV, and the PV dynamics, are the source of both the QV and the free particles. The PV is held together by van der Waals forces. In addition to the fine structure constant, the PV is the source of the gravitational ($G = e_*^2/m_*^2$) and Planck ($\hbar = e_*^2/c$) constants. The non-propagating virtual fields of the QV are assumed to be real fields appearing in free space which are analogous to induction fields with the PV as their source.

A charged elementary particle is characterized by the triad (e_*, m, r_c), where m and r_c are the particle's mass and Compton radius. The field *intrinsic* to the particle is the bare Coulomb field $e_*\mathbf{r}/r^3$, where $\mathbf{r}$ is the radius vector from the particle to the field point. All other fields, classical or quantum, associated with the particle and its motion arise from this fundamental field and its interaction with the PV.

Section 2 traces the concept of the PV from the first observation of the initial paragraph after the preface to the derivation of the fine structure, gravitational, and Planck constants; to the Compton relation of the PP; and to the free-space permittivities. A rough heuristic argument shows the binding force of the vacuum to be van-der-Waals in nature.

The ultimate PV-curvature force is derived in Section 2 from Newton's gravitational equation. This ultimate force is shown in Section 3 to be tied to the Riemannian spacetime of General Relativity (GR) which, therefore, is related to the real physical curvature of the PV. As a consequence, GR describes the *spacetime* curvature of the PV.

Using the Coulomb field of the bare charge, the polarizability of the PV, and an internal feedback mechanism intrinsic to the PV; Section 4 derives the relativistic electric and magnetic fields associated with the charge, and infers the Lorentz transformation and constancy of the speed of light from the results.

The electromagnetic vacuum (EV) consists of the virtual photons mentioned in the first paragraph which lead collectively to the ZP electromagnetic field with which Section 5 argues that the EV has its origin in the PV.

A free charged particle distorts the PV in two ways. Its bare Coulomb field polarizes the vacuum, and its mass exerts a van-der-Waals attractive force on the PPs of the PV. Section 6 shows how these two vacuum-distorting forces lead to the quantum mechanics and, by inference from Section 5, to the quantum field theory (QFT).

Section 7 summarizes and comments on the ideas presented in Sections 1 through 6.

2 Planck particle and vacuum

The idea from Davies' first observation that a single superforce controls all of nature is interpreted here to mean that the ultimate strengths of nature's fundamental forces are identical, whether those forces are actually realizable or just asymptotically approachable. The static Coulomb and gravitational forces between two like, charged elementary particles are used in this section to derive the fine structure constant, the ultimate Coulomb force, the ultimate gravitational force, the gravitational constant, and the ultimate PV-curvature force. Using a new expression (4) for the gravitational force, and the results from the above; the Compton relation of the PP, and the free-space permittivities (the dielectric constant and magnetic permeability) are derived. These derivations utilize three normalization constants to isolate the ultimate forces. The three constants correspond to charge normalization (e_*), mass normalization (m_*), and length normalization (r_*). These constants start out as normalization constants, but end up defining a new fundamental particle (the PP) and a fundamental vacuum state (the PV).

The static Coulomb force between two like, charged particles can be expressed in the following two forms:

$$F_{\mathrm{el}} = \frac{e^2}{r^2} = \alpha \left(\frac{r_*}{r}\right)^2 F'_* \,, \tag{1}$$

where r is the distance between particles, $\alpha \equiv e^2/e_*^2$, and $F'_* \equiv e_*^2/r_*^2$. If e_* is assumed to be the maximum particle charge (the electronic charge unscreened by a polarizable vacuum state), and r_* is assumed to be some minimum length ($r_* < r$ for all r); then F'_* is the ultimate Coulomb force.

The static gravitational force of Newton acting between two particles of mass m separated by a distance r can be expressed in the following forms:

$$-F_{\mathrm{gr}} = \frac{m^2 G}{r^2} = \frac{m^2}{m_*^2}\left(\frac{r_*}{r}\right)^2 F_* \,, \tag{2}$$

where G denotes Newton's gravitational constant, and $F_* \equiv m_*^2 G/r_*^2$. If m_* is the maximum elementary particle mass, and r_* is the minimum length, then F_* is the ultimate gravitational force as m_*/r_* is the maximum mass-to-length ratio.

Adhering to the idea of a single superforce implies that the force magnitudes F'_* and F_* must be equal. This equality leads to the definition of the gravitational constant

$$G = \frac{e_*^2}{m_*^2} \tag{3}$$

in terms of the squared normalization constants e_*^2 and m_*^2.

The gravitational force in (2) can also be expressed as

$$-F_{\mathrm{gr}} = \frac{(mc^2/r)^2}{c^4/G} \tag{4}$$

by a simple manipulation where c is the speed of light. The ratio mc^2/r has the units of force, as does the ratio c^4/G. It can be argued [6] that c^4/G is a superforce, i.e. some kind of ultimate force. The nature of the two forces, mc^2/r and c^4/G, is gravitational as they emerge from Newton's gravitational equation; but their meaning at this point in the text is unknown. As an ultimate force, c^4/G can be equated to the ultimate gravitational force F_* because of the single-superforce assumption. Equating c^4/G and F_* then leads to

$$\frac{c^4}{G} = \frac{m_*\,c^2}{r_*} \tag{5}$$

for the ultimate force c^4/G. It is noteworthy that the form m_*c^2/r_* of this force is the same as that ratio in the parenthesis of (4), which must be if c^4/G is to represent an ultimate force of the form mc^2/r. That (5) is an ultimate force is clear from the fact that m_* is the ultimate particle mass and r_* is the minimum length, roughly the nearest-neighbor distance between the PPs constituting the PV.

Invoking the single-superforce requirement for the ultimate force c^4/G from (5) and the ultimate Coulomb force F'_* leads to

$$\frac{m_*c^2}{r_*} = \frac{e_*^2}{r_*^2} \tag{6}$$

or

$$r_*m_*c = \frac{e_*^2}{c} \equiv \hbar\,, \tag{7}$$

where e_*^2/c defines the (reduced) Planck constant. Furthermore, if the reasonable assumption in made that the minimum length r_* is the Planck length [5], then m_* turns out to be the Planck mass [5]. Noting also that (7) has the classic form of a Compton relation, where r_* is the Compton radius ($\lambda_*/2\pi$), it is reasonable to assume that the triad (e_*, m_*, r_*) characterizes a new particle (the PP). Thus the Compton radius r_* of the PP is $r_* = e_*^2/m_*c^2$.

The units employed so far are Gaussian. Changing the units of the first equation in (7) from Gaussian to mks units [7] and solving for ϵ_0 leads to

$$\epsilon_0 = \frac{e_*^2}{4\pi r_* m_* c^2} \qquad \text{[mks]} \tag{8}$$

where ϵ_0 is the electric permittivity of free space in mks units. Then, utilizing $\epsilon_0\mu_0 = 1/c^2$ leads to

$$\mu_0 = 4\pi\,\frac{r_*m_*}{e_*^2} \qquad \text{[mks]} \tag{9}$$

for the magnetic permittivity. The magnitude of μ_0 is easy to remember — it is $4\pi\times10^{-7}$ in mks units. Thus r_*m_*/e_*^2 in (9) had better equal 10^{-7} in mks units, and it does (e_* in Gaussian units is obtained from (3) and G, or from (7) and $\hbar$; and then changed into mks units for the calculation).

Shifting (8) and (9) out of mks units back into Gaussian units leads to

$$\epsilon = \frac{1}{\mu} = \frac{e_*^2}{r_*m_*c^2} = 1 \tag{10}$$

for the free-space permittivities in Gaussian units. Considering the fact that the free-space permittivities are expressed exclusively in terms of the parameters defining the PP, and the speed of light, it is reasonable to assume that the free-space vacuum (the PV) is made up of PPs. Furthermore, the negative-energy solutions to the Klein-Gordon equation or the Dirac equation [3], and the old Dirac hole theory [3], suggest that a reasonable starting point for modeling the PV may be an omnipresent gas of negative-energy PPs.

The PV is a monopolar degenerate gas of charged PPs. Thus the PPs within the vacuum repel each other with strong Coulombic forces, nearest neighbors exerting a force roughly equal to

$$\frac{e_*^2}{r_*^2} = \left(\frac{5.62\times10^{-9}}{1.62\times10^{-33}}\right)^2 \sim 10^{49} \quad \text{[dyne]} \tag{11}$$

where r_* is roughly the nearest-neighbor distance. The question of what binds these particles into a degenerate gas naturally arises. The following heuristic argument provides an answer. Using the definition of the gravitational constant ($G = e_*^2/m_*^2$), the gravitational force between two *free* PPs separated by a distance r can be written in the form

$$-\frac{m_*^2G}{r^2} = -\frac{e_*^2}{r^2} \tag{12}$$

leading to a total gravitational-plus-Coulomb force between the particles equal to

$$(-1+\alpha)\,\frac{e_*^2}{r^2} \tag{13}$$

where the Coulomb force ($\alpha e_*^2/r^2$) comes from (1). This total force is attractive since the fine structure constant $\alpha \approx 1/137 < 1$. The total force between two PPs *within* the PV must be roughly similar to (13). Thus it is reasonable to conclude that the vacuum binding force is gravitational in nature.

3 General Relativity

Newton's gravitational force acting between two particles of mass m_1 and m_2 separated by a distance r can be expressed as

$$\begin{aligned} F_{\text{gr}} = -\frac{(m_1c^2/r)(m_2c^2/r)}{c^4/G} &= \\ &= \frac{(-m_1c^2/r)(-m_2c^2/r)}{-m_*c^2/r_*}\,, \end{aligned} \tag{14}$$

where (5) has been used to obtain the second expression. Although the three forces in the second expression must be gravitational by nature as they come from the gravitational equation, their meaning is unclear from (14) alone.

Their meaning can be understood by examining two equations from the GR theory [5], the Einstein metric equation

$$G_{\mu\nu} = \frac{8\pi T_{\mu\nu}}{c^4/G} = \frac{8\pi T_{\mu\nu}}{m_*c^2/r_*} \tag{15}$$

and the Schwarzschild equation

$$ds^2 = -\left[1-2n(r)\right]c^2dt^2 + \frac{dr^2}{\left[1-2n(r)\right]} + r^2\,d\Omega^2 \tag{16}$$

where the n-ratio is

$$n(r) \equiv \frac{mc^2/r}{c^4/G} = \frac{mc^2/r}{m_*c^2/r_*} \tag{17}$$

and where $G_{\mu\nu}$ is the Einstein curvature tensor, $T_{\mu\nu}$ is the energy-momentum density tensor, ds is the Schwarzschild line element, and dt and dr are the time and radius differentials. The remaining parameter in (16) is defined in [5]. The line element in (16) is associated with the curvature of spacetime outside a static spherical mass — in the particle case the equation is only valid outside the particle's Compton radius [8]. For a vanishing mass ($m = 0$), the n-ratio vanishes and the metric bracket $[1 - 2n(r)]$ reduces to unity; in which case (16) describes a flat (zero curvature or Lorentzian) spacetime.

As mc^2/r in (16) and (17) is a spacetime-curvature force, (14) implies that m_1c^2/r and m_2c^2/r are PV curvature forces. The ultimate curvature force m_*c^2/r_* appears in the denominators of (14), (15), and (17). Thus it is reasonable to conclude that the theory of GR refers to the *spacetime*-curvature aspects of the PV. The forces m_1c^2/r and m_2c^2/r are attractive forces the masses m_1 and m_2 exert on the PPs of the PV at a distance r from m_1 and m_2 respectively.

According to Newton's third law, if a free mass m exerts a force mc^2/r on a PP within the PV at a distance r from m, then that PP must exert an equal and opposite force on m. However, the PP at $-r$ exerts an opposing force on m; so the net average force the two PPs exert on the free mass is zero. By extrapolation, the entire PV exerts a vanishing average force on the mass. As the PPs are in a perpetual state of ZP agitation about their average "r" positions, however, there is a residual, random van der Waals force that the two PPs, and hence the PV as a whole, exert on the free mass.

Puthoff [9] has shown the gravitational force to be a long-range retarded van der Waals force, so forces of the form mc^2/r are essentially van der Waals forces. The ZP electromagnetic fields of the EV are the mechanism that provides the free-particle agitation necessary to produce a van der Waals effect [9]. But since the source of the EV is the PV (see Section 5), the PV is the ultimate source of the agitation responsible for the van-der-Waals-gravitational force between free particles, and the free-particle-PV force mc^2/r.

4 Maxwell and Lorentz

The previous two sections argue that curvature distortions (mass distortions) of the PV are responsible for the curvature force mc^2/r and the equations of GR. This section argues that polarization distortions of the PV by free charge are responsible for the Maxwell equations and, by inference, the Lorentz transformation. These ends are accomplished by using the bare Coulomb field of a free charge in uniform motion, a feedback mechanism intrinsic to the PV [10], and the Galilean transformation; to derive the relativistic electric and magnetic fields of a uniformly moving charge.

The bare Coulomb field $e_*\mathbf{r}/r^3$ intrinsic to a free bare charge e_* polarizes the PV, producing the Coulomb field

$$\mathbf{E}_0 = \frac{e\mathbf{r}}{r^3} = \frac{e}{e_*}\frac{e_*\mathbf{r}}{r^3} = \alpha^{1/2}\frac{e_*\mathbf{r}}{r^3} = \frac{e_*\mathbf{r}}{\epsilon' \, r^3} \tag{18}$$

observed in the laboratory, and creating the effective dielectric constant ϵ' $(\equiv e_*/e = 1/\sqrt{\alpha})$ viewed from the perspective of the bare charge, where α is the fine structure constant. In terms of the fixed field point (x, y, z) and a charge traveling in the positive z-direction at a uniform velocity v, the observed field can be expressed as

$$\mathbf{E}_0 = \frac{e\,[x\widehat{\mathbf{x}} + y\widehat{\mathbf{y}} + (z - vt)\,\widehat{\mathbf{z}}]}{[x^2 + y^2 + (z - vt)^2]^{3/2}}\,, \tag{19}$$

where the charge is at the laboratory-frame origin $(0, 0, 0)$ at time $t = 0$. This expression assumes that the space-time transformation between the charge- and laboratory-coordinate frames is Galilean.

The observed field produces an effective dipole at each field point. When the charge moves through the vacuum, the dipole rotates about the field point and creates an effective current circulating about that point. The circulating current, in turn, produces the magnetic induction field*

$$\mathbf{B}_1 = \boldsymbol{\beta} \times \mathbf{E}_0 = \frac{e\beta\,(z - vt)}{r^3}\,\boldsymbol{\phi}\,, \tag{20}$$

where $\beta = v/c$, $\boldsymbol{\beta} = \beta\,\widehat{\mathbf{z}}$, $\boldsymbol{\phi}$ is the azimuthal unit vector, and $r^2 = x^2 + y^2 + (z - vt)^2$ is the squared radius vector $\mathbf{r}\cdot\mathbf{r}$ from the charge to the field point. The field $\mathbf{B}_1$ is the first-step magnetic field caused by the bare charge distortion of the PV.

An iterative feedback process is assumed to take place within the PV that enhances the original electric field $\mathbf{E}_0$. This process is mathematically described by the following two equations [10]:

$$\nabla \times \mathbf{E}_n = -\frac{1}{c}\frac{\partial \mathbf{B}_n}{\partial t} \tag{21}$$

and

$$\mathbf{B}_{n+1} = \boldsymbol{\beta} \times \mathbf{E}_n\,, \tag{22}$$

where n $(= 1, 2, 3\ldots)$ indicates the successive partial electric fields $\mathbf{E}_n$ generated by the PV and added to the original field $\mathbf{E}_0$. The successive magnetic fields are given by (22). Equation (21) is recognized as the Faraday equation.

The calculation of the final electric field $\mathbf{E}$, which is the infinite sum of $\mathbf{E}_0$ and the remaining particle fields $\mathbf{E}_n$, is conducted in spherical polar coordinates and leads to [10]

$$\mathbf{E} = \frac{(1 - \lambda)\,\mathbf{E}_c}{\left(1 - \beta^2\sin^2\theta\right)^{3/2}}\,, \tag{23}$$

where λ is the infinite sum of integration constants that comes from the infinity of integrations of (21) to obtain the $\mathbf{E}_n$, and θ is the polar angle between the positive z-direction and the radius vector from the charge to the field point. The field $\mathbf{E}_c$ is the observed static field of the charge, i.e. equation (19) with $v = 0$. The final magnetic field is obtained from $\mathbf{B} = \boldsymbol{\beta} \times \mathbf{E}$.

*The polarization vector $\mathbf{P} = \chi_e\mathbf{E}_0 = (\epsilon' - 1)\mathbf{E}_0/4\pi$ rotating about a field point in the PV produces an effective current proportional to $\beta\sin\theta$ which leads to the magnetic induction field $\mathbf{B}_1 = \boldsymbol{\beta} \times \mathbf{E}_0$.

Finally, the constant λ can be evaluated from the conservation of electric flux [10] (the second of the following equations) which follows from Gauss' law and the conservation of bare charge e_* (the first equation):

$$\int \mathbf{D} \cdot \mathbf{dS} = 4\pi e_* \longrightarrow \int \mathbf{E} \cdot \mathbf{dS} = 4\pi e \tag{24}$$

where $\mathbf{dS}$ is taken over any closed Gaussian surface surrounding the bare charge, and where $\mathbf{D} = \epsilon' \, \mathbf{E} = (e_*/e)\mathbf{E}$ is used to bridge the arrow. Inserting (23) into the second equation of (24) and integrating yields

$$\lambda = \beta^2 \tag{25}$$

which, inserted back into (23), leads to the relativistic electric field of a uniformly moving charge [7]. The relativistic magnetic field is $\mathbf{B} = \boldsymbol{\beta} \times \mathbf{E}$. The conservation of electric flux expressed by the second equation of (24) is assumed as a postulate in [10]. The first equation shows that the postulate follows from Gauss' law and the conservation of bare charge.

The relativistic field equations $\mathbf{E}$ and $\mathbf{B}$ for a uniformly moving charge are derived above from the Coulomb field $e_*\mathbf{r}/r^3$ of the bare charge in (18), an assumed PV feedback dynamic given by (21) and (22), and the *Galilean* transformation. Of course, the relativistic equations can also be derived [7] from the Coulomb field $e\mathbf{r}/r^3$ (where $r^2 = x^2 + y^2 + z^2$) of the observed electronic charge e at rest in its own coordinate system, and the *Lorentz* transformation. It follows, then, that the Lorentz transformation is a mathematical shortcut for calculating the relativistic fields from the observed charge e $(= e_* \sqrt{\alpha})$ without having to account directly for the polarizable PV and its internal feedback dynamic. Furthermore, it can be argued that the constancy of the speed of light c from Lorentz frame to Lorentz frame, which can be deduced from the resulting Lorentz transformation, is due to the presence of the PV in the photon's line of travel.

If there were no polarizable vacuum, there would be no rotating dipole moments at the field points (x, y, z); and hence, there would be no magnetic field. A cursory examination of the free-space Maxwell equations [7] in the case where the magnetic field $\mathbf{B}$ vanishes shows that the equations reduce to $\nabla \cdot \mathbf{E} = 4\pi\rho_*$, and to the equation of continuity between e_* and its current density. Thus it can be argued that the Maxwell equations owe their existence to the polarizable PV.

5 Electromagnetic vacuum

The EV is the photon part of the QV mentioned at the beginning of the Introduction, i.e. the virtual photons that quickly appear and dissappear in space. This section argues that the EV has its origin in the PV.

The virtual photons of the EV lead to the ZP electric field (see [9] for detail)

$$\mathbf{E}_{zp}(\mathbf{r}, t) = \mathrm{Re} \sum_{\sigma=1}^{2} \int d\Omega_k \int_0^{k_{c*}} dk\, k^2\, \widehat{\mathbf{e}}_\sigma \left\{A_k\right\} \times \\ \times \exp\left[i\left(\mathbf{k}\cdot\mathbf{r} - \omega t + \Theta\right)\right] \tag{26}$$

the spectrum of which Sakharov [11] has argued must have an upper cutoff wavenumber k_{c*} that is related to the "heaviest particles existing in nature". In the present context, the heaviest particles existing in nature are clearly PPs. Puthoff [9, 12] has calculated the wavenumber to be $k_{c*} = \sqrt{\pi c^3/\hbar G}$, which can be expressed as $k_{c*} = \sqrt{\pi}/r_*$ by substituting the constants $\hbar = e_*^2/c$ and $G = e_*^2/m_*^2$ and using the PP Compton relation. The cutoff wave number is characteristic of the minimum length r_*, the Compton radius of the PP, associated with the PV.

The amplitude factor in (26) is [9]

$$A_k = \left(\frac{\hbar\omega}{2\pi^2}\right)^{1/2} = e_* \left(\frac{k}{2\pi^2}\right)^{1/2}, \tag{27}$$

where $\hbar = e_*^2/c$ and $k = \omega/c$ are used to obtain the second expression. This result implies that bare charges are the source of the ZP field, for if e_* were zero, the amplitude factor would vanish and there would be no field. It is reasonable to assume that these bare charges reside in the PV.

Equation (26) can be expressed in the more revealing form

$$\mathbf{E}_{zp}(\mathbf{r}, t) = \left(\frac{\pi}{2}\right)^{1/2} \frac{e_*}{r_*^2}\, \mathbf{I}_{\mathrm{zp}}(\mathbf{r}, t)\,, \tag{28}$$

where $\mathbf{I}_{\mathrm{zp}}$ is a random variable of zero mean and unity mean square; so the factor multiplying $\mathbf{I}_{\mathrm{zp}}$ in (28) is the root-mean-square ZP field. Since $m_* c^2/r_*^3$ is roughly the energy density of the PV, the ZP field can be related to the PV energy density through the following sequence of equations:

$$\frac{m_* c^2}{r_*^3} = \frac{e_*^2/r_*}{r_*^3} = \left(\frac{e_*}{r_*^2}\right)^2 \approx \langle \mathbf{E}_{\mathrm{zp}}^2 \rangle\,, \tag{29}$$

where the PP Compton relation is used to derive the second ratio, and the final approximation comes from the mean square of (28). The energy density of the PV, then, appears to be intimately related to the ZP field. So, along with the k_{c*} and the A_k from above, it is reasonable to conclude that the PV is the source of the EV.

6 Quantum theory

A charged particle exerts two distortion forces on the collection of PPs constituting the PV, the curvature force mc^2/r and the polarization force e_*^2/r^2. Sections 2 and 3 examine the PV response to the curvature force, and Section 4 the response to the polarization force. This section examines the PV response to both forces acting *simultaneously*, and shows that the combination of forces leads to the quantum theory.

The equality of the two force magnitudes

$$\frac{mc^2}{r} = \frac{e_*^2}{r^2} \quad \Longrightarrow \quad r_c = \frac{e_*^2}{mc^2} \tag{30}$$

at the Compton radius r_c of the particle appears to be a fundamental property of the particle-PV interaction, where m is the particle mass. This derivation of the Compton radius shows the radius to be a particle-PV property, not a property solely of the particle.

The vanishing of the force difference $e_*^2/r_c^2 - mc^2/r_c = 0$ at the Compton radius can be expressed as a vanishing tensor 4-force [7] difference. In the primed rest frame ($\mathbf{k}' = \mathbf{0}$) of the particle, where these static forces apply, this force difference $\Delta F'_\mu$ is ($\mu = 1, 2, 3, 4$)

$$\Delta F'_\mu = \left[\mathbf{0},\; i\left(\frac{e_*^2}{r_c^2} - \frac{mc^2}{r_c}\right)\right] = [0,\; 0,\; 0,\; i\,0]\,, \tag{31}$$

where $i = \sqrt{-1}$. Thus the vanishing of the 4-force component $\Delta F'_4 = 0$ in (31) is the source of the Compton radius in (30) which can be expressed in the form $mc^2 = e_*^2/r_c = (e_*^2/c)(c/r_c) = \hbar\omega_c$, where $\omega_c \equiv c/r_c = mc^2/\hbar$ is the Compton frequency associated with the Compton radius r_c. As an aside: the transformation of the force difference (31) to the laboratory frame using $\Delta F_\mu = a_{\mu\nu}\Delta F'_\nu$ leads to a $\Delta F_3 = 0$ from which the de Broglie radius ($\lambda_d/2\pi$), $r_d \equiv r_c/\beta\gamma = \hbar/m\gamma v$, can be derived.

In what follows it is convenient to define the 4-vector wavenumber tensor

$$k_\mu = (\mathbf{k}, k_4) = (\mathbf{k}, i\,\omega/c)\,, \tag{32}$$

where $\mathbf{k}$ is the ordinary vector wavenumber, and $i\omega/c$ is the frequency component of k_μ. This tensor will be used to derive the particle-vacuum state function, known traditionally as the particle wavefunction.

The vanishing of the 4-force component $\Delta F'_4$ from (31) in the rest frame of the particle leads to the Compton frequency ω_c. Thus from (32) applied to the prime frame, and $\mathbf{k}' = \mathbf{0}$, the equivalent rest-frame wavenumber is $k'_\mu = (\mathbf{0}, i\,\omega_c/c)$.

The laboratory-frame wavenumber, where the particle is traveling uniformly along the positive z-axis, can be found from the Lorentz transformation $k_\mu = a_{\mu\nu}k'_\nu$ [7] leading to

$$k_z = \gamma k'_z - i\beta\gamma k'_4 \quad \text{and} \quad k_4 = i\beta\gamma k'_z + \gamma k'_4\,, \tag{33}$$

where

$$a_{\mu\nu} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \gamma & -i\beta\gamma \\ 0 & 0 & i\beta\gamma & \gamma \end{pmatrix} \tag{34}$$

is used, $\beta = v/c$ and $\gamma^2 = 1/(1-\beta^2)$, and where the x- and y-components of the wavenumbers vanish in both frames. With $k'_z = 0$ and $k'_4 = i\,\omega_c/c$, the laboratory-frame wavenumber from (32) and (33) becomes

$$k_\mu = (0,\; 0,\; \beta\gamma\omega_c/c,\; i\gamma\omega_c/c) = (0,\; 0,\; p/\hbar,\; iE/c\hbar)\,, \tag{35}$$

where $p = m\gamma v$ and $E = m\gamma c^2$ are the relativistic momentum and energy of the particle. The second parenthesis in (35) is derived from the first parenthesis and $\omega_c = mc^2/\hbar$, from which $k_z = p/\hbar$ and $k_4 = i\,E/c\hbar = i\,\omega_z/c$ emerge.

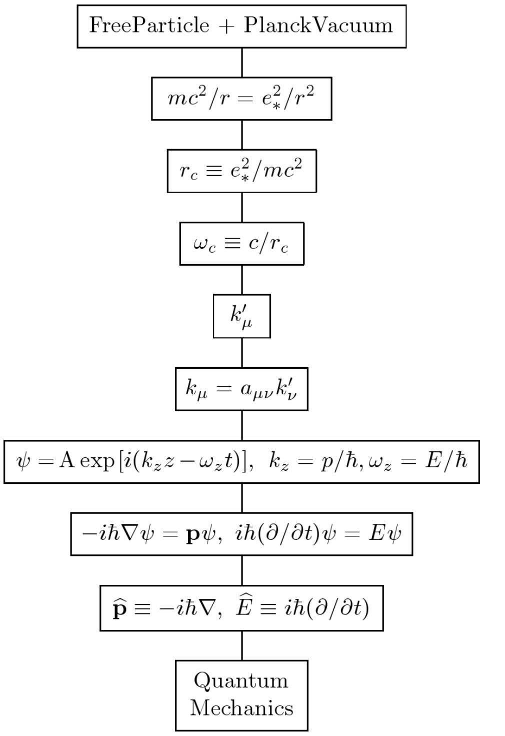

Fig. 1: The flow-diagram traces the particle-vacuum interaction to the Compton radius r_c and the Compton frequency ω_c. From there, the corresponding four-vector wavenumber k'_μ and the Lorentz transformation lead to the particle-vacuum wavefunction ψ, the gradient and time derivative of which then yield the momentum and energy operators, and the quantum mechanics.

The relativistic momentum p and energy E in $k_z = p/\hbar$ and $\omega_z = E/\hbar$ characterize the classical particle motion, and suggest the simple plane-wave

$$\psi = \mathrm{A}\exp\left[i(k_z z - \omega_z t)\right] = \mathrm{A}\exp\left[i(pz - Et)/\hbar\right] \tag{36}$$

as a suitable state function to characterize the wave behavior of the particle-PV system. This laboratory-frame state function reduces to the state function $\psi = \mathrm{A}\exp\left(-imc^2t/\hbar\right)$ in the particle rest frame where $v = 0$. The $S(z,t) \equiv pz - Et$ in the exponent of (36) are particular solutions (for various nonvanishing m) of the free-particle, relativistic Hamiltonian-Jacobi equation [8, p.30] although this fact is not used here in deriving the state function.

Since $-i\hbar\nabla\psi = \mathbf{p}\psi$ and $i\hbar(\partial/\partial t)\psi = E\psi$ from (36), it is clear that the momentum ($\widehat{\mathbf{p}} \equiv -i\hbar\nabla$) and energy ($\widehat{E} \equiv i\hbar(\partial/\partial t)$) operators have their origin in the vacuum perturbation caused by the two forces mc^2/r and e_*^2/r^2 as these two forces are responsible for the wavefunction (36). Once the operators $\widehat{\mathbf{p}}$ and $\widehat{E}$ are defined, the quantum mechanics follows from the various classical (non-quantum) energy equations of particle dynamics. A flow-diagram of the preceding calculations is given in Figure 1.

The preceding calculations leading from the particle-PV interaction to the quantum mechanics are straightforward. Tracing the QFT [12] of the massive particles to the PV is less clearcut however. Nevertheless, as Section 5 shows the PV to be the source of the EV, it is easy to conclude that the PV must also be the source of the massive-particle-vacuum (MPV) part of the QV, and thus the QFT.

7 Summary and comments

This paper presents a new theory in its initial and speculative stage of development. Sections 2 through 6: show that the fine structure constant, the gravitational constant, and the Planck constant come from the PV; derive the free-space permittivities in terms of the PP parameters, showing that the free-space vacuum and the PV are one and the same; show that the previously unexplained force mc^2/r is a curvature force that distorts both the PV and the spacetime of GR, and that GR describes the spacetime aspects of the PV; show the PV to be the source of the Maxwell equations and the Lorentz transformation; show that the QV has its origin in the PV; show that the PV is the source of the Compton relations ($r_c mc = \hbar$) and the quantum theory.

The Compton radius r_c ($= e_*^2/mc^2$) is traditionally ascribed to the particle, but emerges from the PV theory as a particle-PV interaction parameter. Inside r_c ($r < r_c$) the polarization force dominates ($e_*^2/r^2 > mc^2/r$) the curvature force, while outside the reverse is true. Both the EV and MPV parts of the QV are omnipresent, but inside r_c the MPV is responsible for the particle *Zitterbewegung* [3, p.323] caused by "exchange scattering" taking place between the particle and the MPV, resulting in the particle losing its single-particle identity inside r_c.

The development of the PV theory thus far is fairly simple and transparent. The theory, however, is fundamentally incomplete as particle spin is not yet included in the model. Calculations beyond the scope and complexity of those here are currently underway to correct this deficiency.

Even in its presently incomplete state, the PV theory appears to offer a fundamental physical explanation for the large body of mathematical theory that is the vanguard of modern physics. The predictive ability of the QFT, or the modern breakthroughs in astrophysics made possible by GR, are nothing less than spectacular; but while the equations of these theories point toward a fundamental reality, they fall short of painting a clear picture of that reality. Most students of physics, for example, are familiar with the details of the Special Theory of Relativity, and a few with the differential tensor calculus of GR. In both cases, however, the student wonders if there is a real physical space related to these mathematically-generated spacetimes, or whether these spacetimes are just convenient schematic diagrams to help visualize the mathematical artifacts in play. The present paper argues that there is indeed a real physical space associated with spacetime, and that space is the free-space PV.

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The Source of the Quantum Vacuum

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The quantum vacuum consists of virtual particles randomly appearing and disappearing in free space. Ordinarily the wavenumber (or frequency) spectrum of the zero-point fields for these virtual particles is assumed to be unbounded. The unbounded nature of the spectrum leads in turn to an infinite energy density for the quantum vacuum and an infinite renormalization mass for the free particle. This paper argues that there is a more fundamental vacuum state, the Planck vacuum, from which the quantum vacuum emerges and that the "graininess" of this more fundamental vacuum state truncates the wavenumber spectrum and leads to a finite energy density and a finite renormalization mass.

1 Introduction

The quantum vacuum (QV) [1] consists of virtual particles which are created alone (photons) or in massive particle-antiparticle pairs, both of which are jumping in and out of existence within the constraints of the Heisenberg uncertainty principle ($\triangle E \Delta t \sim \hbar$); i.e., they appear in free space for short periods of time (Δt) depending upon their temporal energy content (ΔE) and then disappear. So the QV is an ever-changing collection of virtual particles which disappear after their short lifetimes Δt to be replaced by new virtual particles that suffer the same fate, the process continuing ad infinitum. The photon component of the QV is referred to here as the electromagnetic vacuum (EV) and the massive-particle component as the massive particle vacuum (MPV).

The quantum fields ascribed to the elementary particles are considered to be the "essential reality" [2] behind the physical universe; i.e., a set of *fields* is the fundamental building block out of which the visible universe is constructed. For example, the vector potential for the quantized electromagnetic field can be expressed as [1, p. 45]

$$\mathbf{A}(\mathbf{r},t) = \sum_{s=1}^{2}\sum_{\mathbf{k}} \left(\frac{2\pi c\hbar}{kV}\right)^{1/2} \times \times \left[a_{\mathbf{k},s}(t)\exp\left(i\mathbf{k}\cdot\mathbf{r}\right) + \mathrm{h.c.}\right]\mathbf{e}_{\mathbf{k},s}\,, \tag{1}$$

where the first sum is over the two polarizations of the field, $k = |\mathbf{k}|$, $V = L^3$ is the box-normalization volume, $a_{\mathbf{k},s}(t)$ is the photon annihilation operator, $h.c.$ stands for the Hermitian conjugate of the first term within the brackets, and $\mathbf{e}_{\mathbf{k},s}$ is the unit polarization vector. This is the quantized vector potential for the EV component of the QV. The vector potential satisfies the periodicity conditions

$$\mathbf{A}(x+L, y+L, z+L, t) = \mathbf{A}(x,y,z,t) \tag{2}$$

or equivalently

$$\mathbf{k} = (k_x, k_y, k_z) = (2\pi/L)(n_x, n_y, n_z)\,, \tag{3}$$

where the n_i can assume any positive or negative integer or zero. Since the Planck constant $\hbar$ is considered to be a primary constant, the field in (1) is a fundamental field that is not derivable from some other source (e.g. a collection of charged particles). This paper argues that $\hbar$ is not a primary constant and thus that there is a more fundamental reality behind the quantum fields.

The most glaring characteristic of the EV (and similarly the MPV) is that its zero-point (ZP) energy [1, p. 49]

$$\sum_{s=1}^{2}\sum_{\mathbf{k}} \frac{\hbar\omega_k}{2} = c\hbar \sum_{\mathbf{k},s} \frac{k}{2} \tag{4}$$

is infinite because of the unbounded nature of the $\mathbf{k}$ ($|k_i| < \infty$) in (3). The sum on the right side of the equal sign is an abbreviation for the double sum on the left and $\omega_k = ck$. Using the well-known replacement

$$\sum_{\mathbf{k},s} \longrightarrow \sum_{s}\left(\frac{L}{2\pi}\right)^3 \int d^3k = \frac{V}{8\pi^3}\sum_{s}\int d^3k \tag{5}$$

in (4) leads to the EV energy density

$$\frac{c\hbar}{V}\sum_{\mathbf{k},s}\frac{k}{2} = \frac{c\hbar}{2\pi^2}\int_0^\infty k^3\,dk = \infty\,, \tag{6}$$

where the infinite upper limit on the integral is due to the unbounded $\mathbf{k}$ in (3).

The present paper does two things: it identifies a charged vacuum state (the PV [3]) as the source of the QV; and calculates a cutoff wavenumber (based on an earlier independent calculation [4]) for the integral in (6). The PV model is presented in the Section 2. In a stochastic-electrodynamic (SED) calculation [4] Puthoff derives the particle mass, the cutoff wavenumber (in terms of the speed of light, the Planck constant, and Newton's gravitational constant), and the gravitational force. The Puthoff model is reviewed in Section 3 and the resulting cutoff wavenumber changed into a form more useful to the present needs by substituting derived relations [3] for the Planck and gravitational constants.

Section 4 argues that the QV has its source in the PV. It accomplishes this result by comparing the PV and QV energy densities. The reader is asked to excuse the course nature of the comparisons used to make the argument. Section 5 comments on the previous sections and expands the PV theory somewhat.

The de Broglie radius is derived in Appendix A to assist in the calculations of Section 4. The derivation is superficially similar to de Broglie's original derivation [5], but differs essentially in interpretation: here the radius arises from the two-fold perturbation the free particle exerts on the PV.

2 Planck vacuum

The PV [3] is an omnipresent degenerate gas of negative-energy Planck particles (PP) characterized by the triad (e_*, m_*, r_*), where e_*, m_*, and r_* $(\lambda_*/2\pi)$ are the PP charge, mass, and Compton radius respectively. The charge e_* is the bare (true) electronic charge common to all charged elementary particles and is related to the observed electronic charge e through the fine structure constant $\alpha = e^2/e_*^2$ which is a manifestation of the PV polarizability. The PP mass and Compton radius are equal to the Planck mass and length respectively. In addition to the fine structure constant, the particle-PV interaction is the ultimate source of the gravitational $(G = e_*^2/m_*^2)$ and Planck $(\hbar = e_*^2/c)$ constants, and the string of Compton relations relating the PV and its PPs to the observed elementary particles and their bare charge e_*

$$r_* m_* c^2 = \cdots = r_c m c^2 = \cdots = e_*^2\,, \tag{7}$$

where the charged elementary particles are characterized by the triad (e_*, m, r_c), m and r_c being the mass and Compton radius $(\lambda_c/2\pi)$ of the particle. Particle spin is not yet included in the theory. The ZP random motion of the PP charges e_* about their equilibrium positions within the PV, and the PV dynamics, are the source of both the free particles and the QV.

The Compton relations (7) have their origin in the two-fold perturbation of the PV by the free particle which polarizes and "curves" (in a general relativistic sense) the PV. The particle-PV interaction is such that the polarization force (e_*^2/r^2) and the curvature force (mc^2/r) are equal at the Compton radius r_c [3]:

$$\frac{e_*^2}{r^2} = \frac{mc^2}{r} \quad \longrightarrow \quad r_c m c^2 = e_*^2\,, \tag{8}$$

where the second equation can be expressed in its usual form $r_c m c = \hbar$. The requirement that the force equality in (8) hold in any Lorentz frame leads to the momentum $(\widehat{\mathbf{p}} = -i\hbar\nabla)$ and energy $(\widehat{E} = i\hbar\partial/\partial t)$ operators and to the de Broglie radius (Appendix A). The so-called "wave-particle duality" of the particle follows from the coupling of the free particle to the (almost) continuous nature of the PV whose continuum supports the wave associated with the wave property ascribed to the particle.

3 Puthoff model

One of the charges in the product e_*^2 terminating the chain of Compton relations (7) belongs to the free particle while the other represents the magnitude of the PP charges making up the PV. The fact that the bare charge is common to all the charged elementary particles depicted by (7) suggests that perhaps e_* is massless, and that the mass m in the particle triad (e_*, m, r_c) results from some reaction of the charge to the ZP fields. In a seminal paper [4] Puthoff, in effect, exploits the idea of a massless charge to derive the particle mass, the wavenumber k_{c*} truncating the spectrum of the ZP fields, and the Newtonian gravitational force. This section reviews Puthoff's SED calculations and casts them into a form convenient to the present needs. Some minor license is taken by the present author in the interpretation behind equations (12) and (13) concerning the constant A.

The Puthoff model starts with a particle equation of motion (EoM) for the mass m_0

$$m_0 \ddot{\mathbf{r}} = e_* \mathbf{E}_{zp}\,, \tag{9}$$

where m_0, considered to be some function of the actual particle mass m, is eliminated from (9) by substituting the damping constant

$$\Gamma = \frac{2e_*^2}{3c^3 m_0} \tag{10}$$

and the electric dipole moment $\mathbf{p} = e_* \mathbf{r}$, where $\mathbf{r}$ represents the random excursions of the charge about its average position at $\langle \mathbf{r} \rangle = 0$. The force driving the particle charge is $e_* \mathbf{E}_{zp}$, where $\mathbf{E}_{\rm zp}$ is the ZP electric field (B5). Equation (9) then becomes

$$\ddot{\mathbf{p}} = \frac{3c^3\Gamma}{2}\,\mathbf{E}_{\rm zp}\,, \tag{11}$$

which is an EoM for the charge that, *from here on*, is considered to be a new equation in two unknowns, Γ and the cutoff wavenumber k_{c*}. The mass m of the particle is then defined via the stochastic kinetic energy of the charge whatever that may be. A reasonable guess is the kinetic energy of the discarded mass m_0

$$mc^2 \sim \left\langle \frac{m_0 \dot{\mathbf{r}}^2}{2} \right\rangle = \frac{\langle \dot{\mathbf{p}}_2^2 \rangle}{3c^3\Gamma} \tag{12}$$

realizing that, at best, this choice is only a guide to predicting what parameters to include in the mass definition. The dipole variation $\dot{\mathbf{p}}_2$ is explained below. The simplest definition for the mass is then

$$m \equiv \frac{1}{c^2}\frac{A\,\langle \dot{\mathbf{p}}_2^2 \rangle}{3c^3\Gamma}\,, \tag{13}$$

where A is a constant to be determined, along with Γ and k_{c*}, from a set of three experimental constraints.

The three constraints used to determine the three constants Γ, k_{c*}, and A are: 1) the observed mass m of the particle; 2) the perturbed spectral energy density of the EV caused by radiation due to the random accelerations experienced by the particle charge e_* as it is driven by the random force

$e_*\mathbf{E}_{zp}$; and 3) Newton's gravitational attraction between two particles of mass m.

The dipole moment $\mathbf{p}$ in (11) can be readily determined using the Fourier expansions [6]

$$\mathbf{p}(t) = \int_{-\infty}^{\infty} \widetilde{\mathbf{p}}(\Omega) \exp\left(-i\Omega t\right) d\Omega/(2\pi)^{1/2} \tag{14}$$

and

$$\mathbf{E}_{zp}(\mathbf{r}, t) = \int_{-\infty}^{\infty} \widetilde{\mathbf{E}}_{zp}(\Omega) \exp\left(-i\Omega t\right) d\Omega/(2\pi)^{1/2}, \tag{15}$$

where $\widetilde{\mathbf{p}}(\Omega)$ and $\widetilde{\mathbf{E}}_{zp}(\Omega)$ are the Fourier transforms of the dipole moment vector $\mathbf{p}$ and the field $\mathbf{E}_{zp}$ respectively.

The mass of the particle is defined via the planar motion of the charge normal to the instantaneous propagation vector $\mathbf{k}$ in (B5) and results in (Appendix B)

$$\left\langle \dot{\mathbf{p}}_2^2 \right\rangle = 2 \left\langle (\widehat{\mathbf{x}} \cdot \dot{\mathbf{p}})^2 \right\rangle = \frac{3\hbar c^5 \Gamma^2 k_{c*}^2}{2\pi}, \tag{16}$$

where $\widehat{\mathbf{x}}$ is a unit vector in some arbitrary x-direction and the factor 2 accounts for the 2-dimensional planar motion. When the average (16) is inserted into (13), the constant

$$\Gamma = \frac{2\pi m}{A\hbar k_{c*}^2} \tag{17}$$

emerges in terms of the two as yet unknown constants A and k_{c*}.

Acceleration of the free bare charge e_* by $\mathbf{E}_{zp}$ generates electric and magnetic fields that perturb the spectral energy density of the EV with which $\mathbf{E}_{zp}$ is associated. The corresponding average density perturbation is [4]

$$\overline{\Delta\rho'(k)} = \frac{\hbar c^3 \Gamma^2 k}{2\pi^2 R^4} = \frac{2m^2 c^3 k}{A^2 \hbar k_{c*}^4 R^4}, \tag{18}$$

where (17) is used to obtain the final expression, and where R is the radius from the average position of the charge to the field point of interest. An alternative expression for the spectral energy perturbation

$$\Delta\rho(k) = \frac{\hbar k}{2\pi^2 c^3} \left(\frac{mG}{R^2}\right)^2 \tag{19}$$

is calculated [4] from the spacetime properties of an accelerated reference frame undergoing hyperbolic motion, and the equivalence principle from General Relativity. Since the two perturbations (18) and (19) must have the same magnitude, equating the two leads to the cutoff wavenumber

$$k_{c*} = \left(\frac{2\pi c^3}{A\hbar G}\right)^{1/2}, \tag{20}$$

where G is Newton's gravitational constant.

The final unknown constant A in (20) is determined from the gravitational attraction between two particles of mass m calculated [4] using their dipole fields and coupled EoMs, resulting in Newton's gravitational equation

$$F = -\frac{\hbar c^3 \Gamma^2 k_{c*}^2}{\pi R^2} = -\frac{2m^2 G}{AR^2}, \tag{21}$$

where (17) and (20) are used to obtain the final expression. Clearly $A = 2$ for the correct gravitational attraction, yielding from (20) and (17)

$$k_{c*} = \left(\frac{\pi c^3}{\hbar G}\right)^{1/2} \left[= \frac{\pi^{1/2}}{r_*}\right] \tag{22}$$

and

$$\Gamma = \frac{\pi m}{\hbar k_{c*}^2} = \frac{mG}{c^3} \left[= \left(\frac{r_*}{r_c}\right)\frac{r_*}{c}\right] \tag{23}$$

for the other two constants. The expressions in the brackets of (22) and (23) are obtained by substituting the PV expressions for the gravitational constant ($G = e_*^2/m_*^2$), the Planck constant ($\hbar = e_*^2/c$), and the Compton relation in (8). The bracket in (22) shows, as expected, that the cutoff wavenumber in (B5) is proportional to the reciprocal of the Planck length r_* (roughly the distance between the PPs making up the PV). The bracket in (23) shows the damping constant Γ to be very small, orders of magnitude smaller than the Planck time r_*/c. The smallness of this constant is due to the almost infinite number ($\sim 10^{99}$ per cm^3) of agitated PPs in the PV contributing simultaneously to the ZP field fluctuations.

An aside: zitterbewegung

SED associates the *zitterbewegung* with the EV [7, p. 396], i.e. with the ZP electric and magnetic fields. In effect then SED treats the EV and the MPV as the same vacuum while the PV model distinguishes between these two vacuum states. Taking place within the Compton radius r_c of the particle, the particle *zitterbewegung* can be viewed [1, p. 323] as an "exchange scattering" between the free particle and the MPV on a time scale of about $r_c/2c$, or a frequency around $2c/r_c$. The question of how the particle mass derived from the averaging process in (13) can be effected with the charge appearing and disappearing from the MPV at such a high frequency naturally arises. For this averaging process to work, the frequency of the averaging must be significantly higher than the *zitterbewegung* frequency. This requirement is easily fulfilled since $ck_{c*} \gg 2c/r_c$. To see that the averaging frequency is approximately equal to the cutoff frequency ck_{c*} one needs only consider the details of the average $\left\langle (\widehat{\mathbf{x}} \cdot \dot{\mathbf{p}})^2 \right\rangle$ in (13) which involves the integral $\int_0^{k_{c*}} k\, dk \approx \int_0^{10^{33}} k\, dk$. Ninety-nine percent of the averaging takes place within the last decade of the integral from 10^{32} to 10^{33} (the corresponding frequency ck in this range being well beyond the Compton frequency c/r_c of any of the observed elementary particles), showing that the effective averaging frequency is close to ck_{c*}.

4 EV and MPV with truncated spectra

The non-relativistic self force acting on the free charge discussed in the previous section can be expressed as [1, p. 487]

$$e_* \mathbf{E}_{\text{self}} = \frac{2e_*^2}{3c^3} \frac{d\ddot{\mathbf{r}}}{dt} - \ddot{\mathbf{r}}\, \delta m \tag{24}$$

where the radiation reaction force is the first term and the renormalization mass is

$$\delta m = \frac{4e_*^2}{3\pi c^2} \int_0^{k_{c*}} dk \tag{25}$$

assumed here to have its wavenumber spectrum truncated at k_{c*}. An infinite upper limit to the integral corresponds to the box normalization applied in Section 1 to equation (3) where $|n_i| < \infty$ is unbounded. However, if the normal mode functions of the ZP quantum field are assumed to be real waves generated by the collection of PPs within the PV, then the number of modes n_i along the side of the box of length L is bounded and obeys the inequality $|n_i| \leqslant L/2\sqrt{\pi}\, r_*$, where r_* is roughly the separation of the PPs within the PV. Thus the cutoff wavenumber from the previous section ($k_{c*} = \sqrt{\pi}/r_*$) that corresponds to this n_i replaces the infinite upper limit ordinarily assumed for (25). So it is the "graininess" ($r_* \neq 0$) associated with the minimum separation r_* of the PPs in the PV that leads to a bounded k_i and n_i for (3), and which is thus responsible for the finite renormalization mass (25) and the finite energy densities calculated below.

Electromagnetic vacuum

Combining (4) and (5) with a spectrum truncated at k_{c*} leads to the EV energy density [1, p. 49]

$$\frac{c\hbar}{V} \sum_{\mathbf{k},s} \frac{k}{2} = \frac{2c\hbar}{8\pi^3} \int d^3k\, \frac{k}{2} = \frac{c\hbar}{4\pi^3} \int d\Omega_k \int_0^{k_{c*}} dk\, k^2\, \frac{k}{2} =$$
$$= \frac{4\pi c\hbar}{4\pi^3} \int_0^{k_{c*}} dk\, k^2\, \frac{k}{2} = \frac{c\hbar}{2\pi^2} \frac{k_{c*}^4}{4} = \frac{c\hbar}{8r_*^4} = \frac{1}{8} \frac{e_*^2/r_*}{r_*^3}\,, \tag{26}$$

where the 2 in front of the triple integral comes from the sum over $s = 1, 2$; and where $k_{c*} = \sqrt{\pi}/r_*$ and $c\hbar = e_*^2$ are used to obtain the final two expressions. If the energy density of the PV (excluding the stochastic kinetic energy of its PPs) is assumed to be roughly half electromagnetic energy ($\sim e_*^2/r_*$) and half mass energy ($\sim m_* c^2$), then

$$\frac{e_*^2/r_* + m_* c^2}{r_*^3} = 2\frac{e_*^2/r_*}{r_*^3} \tag{27}$$

is a rough estimate of this energy density. Thus the energy density (26) of the EV (the virtual-photon component of the QV) is at most one sixteenth ($1/16$) the energy density (27) of the PV. Although this estimate leaves much to be desired, it at least shows the EV energy density to be less than the PV energy density which must be the case if the PV is the source of the EV.

Massive particle vacuum

The energy density of the ZP Klein-Gordon field is [1, p. 342]

$$\frac{\langle 0|H|0\rangle}{V} = \frac{1}{2V} \int d^3k E_k\, \delta^3(0) =$$
$$= \frac{\delta^3(0)}{2V} \int d\Omega_k \int_0^{k_{c*}} dk\, k^2 E_k = \frac{1}{4\pi^2} \int_0^{k_{c*}} k^2 E_k\, dk =$$
$$= \frac{e_*^2}{4\pi^2} \int_0^{k_{c*}} k^2 \left(k_c^2 + k^2\right)^{1/2} dk\,, \tag{28}$$

where $\delta^3(0) = V/8\pi^3$ is used to eliminate $\delta^3(0)$ and $E_k = e_*^2 \sqrt{k_c^2 + k^2}$ comes from (A5). Equation (28) leads to

$$\frac{\langle 0|H|0\rangle}{V} = \frac{e_*^2 k_c}{4\pi^2} \int_0^{k_{c*}} k^2 \left[1 + \left(\frac{k}{k_c}\right)^2\right]^{1/2} dk =$$
$$= \frac{e_*^2/r_c}{4\pi^2} \int_0^{k_{c*}} k^2 \left[1 + (r_c k)^2\right]^{1/2} dk =$$
$$= \frac{e_*^2/r_c}{4\pi^2 r_c^3} \int_0^{r_c k_{c*}} x^2 (1 + x^2)^{1/2} dx =$$
$$= \frac{1}{16} \frac{e_*^2/r_*}{r_*^3} \left(1 + \frac{r_*^2}{\pi r_c^2} + \cdots\right) \approx \frac{1}{16} \frac{e_*^2/r_*}{r_*^3}\,, \tag{29}$$

where $k_c = 1/r_c$ is used in the first line. The final integral is easily integrated [8] and leads to the expansion in the second-to-last expression. The final expression follows from the fact that the second ($r_*^2/\pi r_c^2 \sim 10^{-40}$) and higher-order terms in the expansion are vanishingly small (the ratio $r_*/r_c \sim 10^{-20}$ is used as a rough average for the ratio of the Compton radii of the PP and the observed elementary particles). So the energy density in (29) is one thirty-second ($1/32$) of the PV energy density in (27).

The k^2 term under the radical sign in (28) corresponds to the squared momentum of the massive virtual particles contributing to the average vacuum density described by (28). The second term in the large parenthesis of (29) is approximately the relative contribution of the virtual-particle mass to the overall energy density as compared to the coefficient in front of the parenthesis which represents the energy density of the virtual-particle kinetic energy. Thus the kinetic energy of the virtual particles in the MPV dominates their mass energy by a factor of about 10^{40}.

5 Conclusion and comments

The conclusion that the PV is the source of the quantum fields is based on the fact that $\hbar$ $(= e_*^2/c)$ is a secondary constant, where one of the e_*s in the product e_*^2 is the particle charge and the other is the charge on the PPs making up the PV; and that the amplitude factor A_k in the ZP electric field (B5) is proportional to the charge on the PPs in the PV. The ubiquitous nature of $\hbar\omega = e_*^2 k$ in the quantum field equations, whether k is an electromagnetic wavenumber or a de Broglie wavenumber, further supports the conclusion.

The Compton relations (7) and the Puthoff model in Section 3 both suggest that the particle charge e_* is massless. To be self-consistent and consistent with the Puthoff model, the PV model for the Compton relations must assume that the Compton radius $r_c = r_c(m) = e_*^2/mc^2$ is larger than the structural extent of the particle and the random excursions of the charge leading to the mass (13).

The PV theory has progressed to this point without addressing particle spin — its success without spin suggesting perhaps that spin is an acquired, rather than an intrinsic, property of the particle. A circularly polarized ZP electric field may, in addition to generating the mass in (13), generate an effective spin in the particle. This conclusion follows from a SED spin model [7, p. 261] that uses a circularly polarized ZP field in the modeling process — in order to avoid too much speculation though, one question left unexplored in this spin model is how the ZP field acquires the circular polarization needed to drive the particle's spin. Perhaps the ZP field acquires its circular polarization when the magnetic field probing the particle (a laboratory field or the field of an atomic nucleus) induces a circulation within the otherwise random motion of the PP charges in the PV, these charges then feeding a circular polarization back into the ZP electric field $\mathbf{E}_{zp}$ of the EV, thus leading to the particle spin.

Appendix A de Broglie radius

A charged particle exerts two distorting forces on the collection of PPs constituting the PV [3], the polarization force e_*^2/r^2 and the curvature force mc^2/r. The equality of the two force magnitudes at the Compton radius r_c in (8) is assumed to be a fundamental property of the particle-PV interaction. The vanishing of the force difference $e_*^2/r_c^2 - mc^2/r_c = 0$ at the Compton radius can be expressed as a vanishing tensor 4-force [9] difference. In the primed rest frame of the particle where these static forces apply, this force difference $\Delta F'_\mu$ is ($\mu = 1, 2, 3, 4$)

$$\Delta F'_\mu = \left[\mathbf{0},\ i\left(\frac{e_*^2}{r_c^2} - \frac{mc^2}{r_c}\right)\right] = [\,0,\ 0,\ 0,\ i\,0\,], \tag{A1}$$

where $i = \sqrt{-1}$. Thus the vanishing of the 4-force component $\Delta F'_4 = 0$ in (A1) is the source of the Compton relation in (8) which can be expressed in the form $mc^2 = e_*^2/r_c = (e_*^2/c)(c/r_c) = \hbar\omega_c$, where $\omega_c \equiv c/r_c = mc^2/\hbar$ is the Compton frequency corresponding to the Compton radius r_c.

The 4-force difference in the laboratory frame, that is $\Delta F_\mu = a_{\mu\nu}\Delta F'_\nu = 0_\mu$, follows from its tensor nature and the Lorentz transformation $x_\mu = a_{\mu\nu}\,x'_\nu$ [9], where $x_\mu = (x, y, z, ict)$,

$$a_{\mu\nu} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \gamma & -i\beta\gamma \\ 0 & 0 & i\beta\gamma & \gamma \end{pmatrix} \tag{A2}$$

and $\mu, \nu = 1, 2, 3, 4$. Thus (A1) becomes

$$\begin{aligned} \Delta F_\mu &= \left[0,\ 0,\ \beta\gamma\left(\frac{e_*^2}{r_c^2} - \frac{mc^2}{r_c}\right),\ i\gamma\left(\frac{e_*^2}{r_c^2} - \frac{mc^2}{r_c}\right)\right] = \\ &= \left[0,\ 0,\ \left(\frac{e_*^2}{\beta\gamma r_d^2} - \frac{mc^2}{r_d}\right),\ i\left(\frac{e_*^2}{\gamma r_L^2} - \frac{mc^2}{r_L}\right)\right] = \\ &= [\,0,\ 0,\ 0,\ i\,0\,] \end{aligned} \tag{A3}$$

in the laboratory frame. The equation $\Delta F_3 = 0$ from the final two brackets yields the de Broglie relation

$$p = \frac{e_*^2/c}{r_d} = \frac{\hbar}{r_d} = \hbar k_d \tag{A4}$$

where $p = m\gamma v$ is the relativistic particle momentum, $r_d \equiv r_c/\beta\gamma$ is the de Broglie radius, and $k_d = 1/r_d$ is the de Broglie wavenumber.

Using (8) and (A4), the relativistic particle energy can be expressed as

$$\begin{aligned} E_{k_d} &= \left(m^2c^4 + c^2p^2\right)^{1/2} = \\ &= \left(e_*^4 k_c^2 + c^2\hbar^2 k_d^2\right)^{1/2} = e_*^2\left(k_c^2 + k_d^2\right)^{1/2}, \end{aligned} \tag{A5}$$

where $mc^2 = e_*^2/r_c$, $k_c = 1/r_c$, and $c\hbar = e_*^2$ are used to obtain the final two expressions.

The equation $\Delta F_4 = 0$ from (A3) leads to the relation $p = \hbar/r_L$, where $r_L \equiv r_c/\gamma$ is the length-contracted r_c in the ict direction. The Synge primitive quantization of flat spacetime [10] is equivalent to the force-difference transformation in (A3): the ray trajectory of the particle in spacetime is divided (quantized) into equal lengths of magnitude $\lambda_c = 2\pi r_c$ (this projects back on the "ict" axis as $\lambda_L = 2\pi r_L$); and the de Broglie wavelength calculated from the corresponding spacetime geometry. Thus the development in the previous paragraphs provides a physical explanation for Synge's spacetime quantization in terms of the two perturbations e_*^2/r^2 and mc^2/r the free particle exerts on the PV.

Appendix B Charge EoM with the self force

Combining (24) and (25) leads to the charge's self force

$$e_*\mathbf{E}_{\text{self}} = \frac{2e_*^2}{3c^3}\left(\frac{d\ddot{\mathbf{r}}}{dt} - \omega'_*\ddot{\mathbf{r}}\right) \tag{B1}$$

with $\omega'_* \equiv 2c/\sqrt{\pi}\,r_*$. Adding (B1) to the right side of (9) then yields the x-component of the charge's acceleration corresponding to (11):

$$\ddot{x} = \Gamma\left(\frac{d\ddot{x}}{dt} - \omega'_*\ddot{x}\right) + \frac{3c^3\Gamma}{2e_*}\,\widehat{\mathbf{x}}\cdot\mathbf{E}_{zp} \tag{B2}$$

which can be solved by the Fourier expansions

$$x(t) = \int_{-\infty}^{\infty}\widetilde{x}(\Omega)\exp\left(-i\Omega t\right)d\Omega/(2\pi)^{1/2} \tag{B3}$$

and

$$E_x(\mathbf{r}, t) = \int_{-\infty}^{\infty}\widetilde{E}_x(\Omega)\exp\left(-i\Omega t\right)d\Omega/(2\pi)^{1/2} \tag{B4}$$

where $E_x \equiv \widehat{\mathbf{x}}\cdot\mathbf{E}_{zp}$, and where the ZP electric field $\mathbf{E}_{zp}$ is assumed to have an upper cutoff wavenumber k_{c*} [3, 4]:

$$\begin{aligned} \mathbf{E}_{zp}(\mathbf{r}, t) = \text{Re}\sum_{\sigma=1}^{2}\int d\Omega_k\int_0^{k_{c*}} dk\,k^2\,\widehat{\mathbf{e}}_\sigma(\mathbf{k})A_k\,\times \\ \times\,\exp\left[\,i\left(\mathbf{k}\cdot\mathbf{r} - \omega t + \Theta_\sigma(\mathbf{k})\right)\right], \end{aligned} \tag{B5}$$

where Re stands for "real part of"; the sum is over the two transverse polarizations of the random field; the first integral is over the solid angle in k-space; $\widehat{\mathbf{e}}_\sigma$ is the unit polarization vector; $A_k = \sqrt{\hbar\omega/2\pi^2} = e_* \sqrt{k/2\pi^2}$ is the amplitude factor which is proportional to the bare charge e_* of the PPs in the PV; $\omega = ck$; and Θ_σ is the random phase that gives $\mathbf{E}_{zp}$ its stochastic character.

The inverse Fourier transform of E_x from (B4) works out to be

$$\begin{aligned}\widetilde{E}_x(\Omega) = \left(\frac{\pi}{2}\right)^{1/2} \sum_{\sigma=1}^{2} \int d\Omega_k \int_0^{k_{c*}} dk\, k^2\, \widehat{\mathbf{x}} \cdot \widehat{\mathbf{e}}_\sigma(\mathbf{k}) A_k \times \\ \times \left\{ \delta(\Omega - \omega) \exp\left[\, i\, (\mathbf{k} \cdot \mathbf{r} + \Theta_\sigma(\mathbf{k}))\right] + \right. \\ \left. + \,\delta(\Omega + \omega) \exp\left[-i\, (\mathbf{k} \cdot \mathbf{r} + \Theta_\sigma(\mathbf{k}))\right] \right\}\end{aligned} \tag{B6}$$

in a straightforward manner, where $\delta(\Omega-\omega)$ and $\delta(\Omega+\omega)$ are Dirac delta functions. Equation (B6) is easily checked by inserting it into (B4) and comparing the result with $\widehat{\mathbf{x}} \cdot \mathbf{E}_{zp}$ from (B5).

Calculating $\ddot{\mathbf{x}}$ and $d\ddot{\mathbf{x}}/dt$ from (B3) and inserting the results, along with (B4), into (B2) leads to the inverse transform

$$\widetilde{x}(\Omega) = -\frac{\left(3c^3\Gamma/2e_*\right)\, \widetilde{E}_x(\Omega)}{(1 + \Gamma\omega'_*)\Omega^2 + i\,\Gamma\Omega^3} \tag{B7}$$

for $x(t)$. Then inserting (B7) into (B3) yields

$$\begin{aligned}x(t) = -\left(\frac{3c^3\Gamma}{2e_*}\right) \mathrm{Re} \sum_{\sigma=1}^{2} \int d\Omega_k \int_0^{k_{c*}} dk\, k^2\, \widehat{\mathbf{x}} \cdot \widehat{\mathbf{e}}_\sigma(\mathbf{k}) A_k \times \\ \times \frac{\exp\left[\, i\, (\mathbf{k} \cdot \mathbf{r} - \omega t + \Theta_\sigma(\mathbf{k}))\right]}{(1 + \Gamma\omega'_*)\omega^2 + i\,\Gamma\omega^3}\end{aligned} \tag{B8}$$

for the random excursions of the charge.

Differentiating (B8) with respect to time while discarding the small Γ terms in the denominator leads to the approximation

$$\begin{aligned}\dot{x}(t) = \left(\frac{3c^3\Gamma}{2e_*}\right) \mathrm{Re} \sum_{\sigma=1}^{2} \int d^3k\, \widehat{\mathbf{x}} \cdot \widehat{\mathbf{e}}_\sigma(\mathbf{k}) \times \\ \times \frac{A_k\, i\omega \exp\left[\, i\, (\mathbf{k} \cdot \mathbf{r} - \omega t + \Theta_\sigma(\mathbf{k}))\right]}{\omega^2}\end{aligned} \tag{B9}$$

for the x-directed velocity, from which the dipole average (16)

$$\left\langle \dot{\mathbf{p}}_2^2 \right\rangle = 2 \left\langle (\widehat{\mathbf{x}} \cdot \dot{\mathbf{p}})^2 \right\rangle = 2e_*^2 \left\langle \dot{x}^2(t) \right\rangle = \frac{3\hbar c^5 \Gamma^2 k_{c*}^2}{2\pi} \tag{16}$$

follows, where $e_*^2 = c\hbar$ is used to eliminate e_*^2, and

$$\int d^3k = \int d\Omega_k \int_0^{k_{c*}} dk\, k^2 \tag{B10}$$

is used to expand the triple integral during the calculation.

Differentiating (B8) twice with respect to the time leads to the dipole acceleration that includes the charge's self force:

$$\begin{aligned}\ddot{\mathbf{p}} = \frac{3}{2} \left(\frac{r_*}{r_c}\right)^2 r_c c^2\, \mathrm{Re} \sum_{\sigma=1}^{2} \int d\Omega_k \int_0^{k_{c*}} dk\, k^2\, \widehat{\mathbf{e}}_\sigma(\mathbf{k}) \times \\ \times \frac{A_k \exp\left[\, i\, (\mathbf{k} \cdot \mathbf{r} - \omega t + \Theta_\sigma(\mathbf{k}))\right]}{1 + \Gamma\omega'_* + i\,\Gamma ck},\end{aligned} \tag{B11}$$

which differs from (11) only in denominator on the right side of (B11). The last two terms in the denominator are orders of magnitude smaller than one: $\Gamma\omega'_* < r_*/r_c \sim 10^{-20}$ and $\Gamma ck < \Gamma ck_{c*} = \sqrt{\pi}\, r_*/r_c \sim 10^{-20}$. Thus the charge's self force is not a significant consideration in the definition (13) of the particle's mass.

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A Unified Theory of Interaction: Gravitation, Electrodynamics and the Strong Force

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A unified model of gravitation and electromagnetism is extended to derive the Yukawa potential for the strong force. The model satisfies the fundamental characteristics of the strong force and calculates the mass of the pion.

1 Introduction

A unified theory of interaction, as it is generally understood, implies a description of the four fundamental forces — gravitation, electromagnetism, the strong interaction and the weak force — in terms of a single mathematical formulation. It has been shown [1–3] that a unified model of gravitation and electromagnetism can be derived by starting from a Lagrangian for gravitation,

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

where

m_0 = *gravitational rest mass* of a test body moving at velocity $\mathbf{v}$ in the vicinity of a massive, central body of mass M,

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

$R = 2GM/c^2$ is the Schwarzschild radius of the central body.

This Lagrangian characterizes the *dynamics* of a system.

Applying the canonical equations of motion, the following conservation equations follow:

$$\begin{aligned} E &= mc^2e^{R/r} = \text{total energy = constant}\,, && (2)\\ L^2 &\equiv M^2e^{2R/r} = \text{ constant}, && (3)\\ L_z &\equiv M_z e^{R/r} = e^{R/r}m_0r^2\sin^2\theta\,\dot\phi, && (4)\\ &= z \text{ component of } \mathbf{L} = \text{constant}, \end{aligned}$$

where $m = m_0/\gamma^2$ and

$$\mathbf{M} = (\mathbf{r}\times m_0\mathbf{v}) \tag{5}$$

is the total angular momentum of the test body.

The *kinematics* of the system is determined by assuming the local and instantaneous validity of special relativity (SR). This leads to a Lagrangian characterizing the kinematics of the system,

$$L = -\,\tilde m_0c^2\sqrt{1-v^2/c^2}\,\exp(r_e/r)\,. \tag{6}$$

giving the following conservation equations:

$$\begin{aligned} E_e &= \tilde m c^2 e^{r_e/r} = \text{constant}, && (7)\\ L^2 &\equiv M^2\exp(2r_e/r) = \text{constant}, && (8)\\ L_z &\equiv M_z\exp(r_e/r) = \text{constant}, && (9) \end{aligned}$$

where

$$\begin{aligned} r_e &= R/2\,, && (10)\\ \tilde m &= \gamma\tilde m_0\,, && (11)\\ \mathbf{M} &= \mathbf{r}\times\tilde m\mathbf{v}\,. && (12) \end{aligned}$$

For the hydrogen atom, R = Schwarzschild radius of the proton, r_e = classical electron radius $= R/2 = -\,e^2/\tilde m_0c^2$, while $\tilde m_0$ is the *relativistic* or *kinematical* rest mass of the electron and $\mathbf{M}$ is the total angular momentum of the orbiting electron.

We also note that

$$E_e = \tilde E\,e^{r_e/r}\,, \tag{13}$$

where $\tilde E = \tilde m c^2$ is the total relativistic energy.

The common factor between the gravitational and electromagnetic interactions is the radius constant, $R = 2r_e$. These two radii are related in terms of electromagnetic masses $\tilde m$ by $N_p \approx 10^{40}$, one of the numbers of Dirac's Large Number Hypothesis (LNH).

2 Basic properties of nuclear interaction

Any theory of the strong interaction must satisfy certain basic properties of the force. They are:

(1) the force is charge independent,

(2) it only acts over a range $\sim 10^{-13}$ cm,

(3) the form of its potential is

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

(4) where the coupling constant $Q^2/\hbar c \sim$ 1–15,

(5) r_q is related to the mass of a pion by $r_q \sim h/m_\pi c$.

The above items describe the fundamental properties of the strong force and we shall limit ourselves to showing how these are accommodated in our model.

3 Derivation of an energy relation for the strong interaction

The energy equation (2) can be rearranged in a unique form for $r \approx R$ as follows:

$$\begin{aligned} E &= mc^2 \exp(R/r)\,, \\ &\approx mc^2(1+R/r)\,, \\ &= mc^2(r/R+1)R/r\,, \\ &\approx mc^2 R/r\exp(r/R)\,. \end{aligned} \tag{14}$$

The mathematical condition for the approximate equality of (2) and (14) is found by equating the two equations:

$$\begin{aligned} \exp(R/r) &\cong R/r\,\exp(r/R) \\ \Rightarrow R/r &\cong \exp\left[(R^2-r^2)/rR\right]. \end{aligned} \tag{15}$$

The approximate equality of the two exponential forms therefore holds uniquely for $r^2 \cong R^2$.

Repeating the above procedure for the electromagnetic energy (7) we find

$$E_e \approx \widetilde{m}c^2 r_e/r\,\exp(r/r_e)\,. \tag{16}$$

We rewrite the classical electron radius r_e as

$$\widetilde{m}_{e0}\,c^2 = -\,e^2/r_e\,, \tag{17}$$

where we now write $\widetilde{m}_{e0}$ for the electromagnetic rest mass of the electron.

Substituting (17) in (16) gives

$$E \approx -\,\widetilde{m}c^2\left(\frac{e^2}{\widetilde{m}_{e0}\,c^2}\right)\frac{1}{r}\,\exp\left[r/(-\,e^2/\widetilde{m}_{e0}\,c^2)\right]. \tag{18}$$

Defining

$$r_q = |r_e|\,, \tag{19}$$

(18) can be written as

$$E \approx -\,\widetilde{m}c^2\,\frac{r_q}{r}\,\exp(-r/r_q) \tag{20}$$

$$= -\,\frac{Q^2}{r}\,\exp(-r/r_q)\,, \tag{21}$$

where Q^2 is defined as

$$Q^2 = \widetilde{m}c^2 r_q = \widetilde{E}r_q\,. \tag{22}$$

Eq.(21) has the form of the Yukawa potential. The corresponding gravitational form is given by (14).

3.1 Model for the strong interaction

It was seen that a Yukawa-type potential exists at $r = R$ for gravitational interaction as well as at $r = r_e = R/2$ for electromagnetic interaction. The two related energy equations are respectively (14) and (16). Since our model postulates the concurrent action of gravitation and electromagnetism we have to find a model for the nuclear force that reconciles both these equations simultaneously.

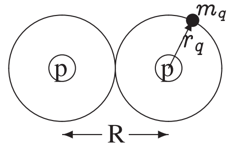

Fig. 1: Model of a deuteron. Two protons are separated at a distance R from each other. A particle of mass $\widetilde{m}_q$ and charge $-e$ moves in a figure eight pattern alternatively about each of them at a radius of $r = r_q = |r_e|$ from each proton.

Consider the model of a deuteron depicted in Figure 1.

The two protons are bound by a gravitational force according to the energy given by (2). Each proton moves in the gravitational field of the other, with the total kinetic energy expressed in terms of their reduced mass. The form of this energy is not relevant at this stage. At the same time, a charged particle of mass $\widetilde{m}_q$ moves at a radius of $r = r_q$ alternately about each proton, causing alternative conversions from proton to neutron and vice-versa. Only this hybrid form simultaneously and uniquely satisfies both the conditions for the two Yukawa-type potentials. This is possible, as can be seen from Figure 1, because $R = 2r_q$.

We provisionally call the charged, orbiting particle a q-particle.

3.2 Determination of the mass $\widetilde{m}_q$

The mass $\widetilde{m}_q$ cannot be determined independently without using some boundary condition. For gravitation, the Newtonian form in the weak-field limit was used, and for electromagnetism the condition for bound motion was applied. Both conditions are derived from observation. In this case we apply the experimental value for Q^2 and assume

$$\frac{Q^2}{\hbar c} \approx 1\,. \tag{23}$$

The q particle orbiting the protons spends half of its period about each proton. In considering the proton-q particle electromagnetic interaction, we must therefore assume that the mass $\widetilde{m}_q$ is spread over both protons. Its electromagnetic energy $\widetilde{E}$ is therefore equal to $\widetilde{m}_q c^2/2$ for a single proton-q particle interaction.

Applying this condition to (22) and using (17) we get

$$\begin{aligned} Q^2 &= \widetilde{E}r_q\,, \\ &= \frac{1}{2}\,\widetilde{m}_q c^2\,\frac{e^2}{\widetilde{m}_{e0}\,c^2}\,, \\ &= \frac{\widetilde{m}_q\,\alpha\hbar c}{2\widetilde{m}_{e0}}\,, \end{aligned} \tag{24}$$

where $\alpha = e^2/\hbar c$ is the fine-structure constant.

The condition $Q^2/\hbar c = 1$ then yields

$$\widetilde{m}_q = \frac{2\widetilde{m}_{e0}}{\alpha}\,. \tag{25}$$

The mass $\widetilde{m}_q$ is therefore equal to the mass of the π^- meson, namely

$$\widetilde{m}_q = 274\,\widetilde{m}_{e0} = \widetilde{m}_\pi\,. \tag{26}$$

We henceforth refer to the q particle as the π^- meson or pion, and use $\widetilde{m}_\pi$ for $\widetilde{m}_q$, and $\widetilde{m}_0$ for $\widetilde{m}_{e0}$.

3.3 Comparison with characteristics of the strong interaction

In Section 2 we listed the characteristics of the strong interaction. Comparing these with the results of our model we find:

1. The attractive force between the nucleons is gravitational and therefore charge independent. It must be remembered that the gravitational force acts on the *gravitational masses* of the protons, which are reduced to the magnitude of the electromagnetic masses by the LNH factor;
2. The strong interaction appears in its unique form at $r = R = 2r_q \approx 10^{-13}$ cm;
3. The Yukawa potential is given by (21);
4. The value of the coupling constant had to be assumed to calculate the mass of the orbiting particle;
5. The expression for r_q follows from (17), (25) and $\alpha = e^2/\hbar c$:

$$r_q = \frac{e^2}{\widetilde{m}_0\, c^2} = \frac{2e^2}{\alpha\,\widetilde{m}_\pi\, c^2} = \frac{2\hbar}{\widetilde{m}_\pi\, c}\,. \tag{27}$$

4 Discussion

The above derivations are in accord with Yukawa's model of nucleon interaction through the exchange of mesons. Eq.(21) confirms the experimental result that nuclear forces only act in the region $r \cong r_q \cong 10^{-13}$ cm. Conversely, forces that only manifest in this region are describable by the Yukawa potential, which is a unique form for *both* the gravitational and electrodynamic energy equations in this region. In terms of our unified model it implies that nuclear forces only appear different from the gravitational force because experimental observations at 10^{-13} cm confirm the form of the Yukawa potential.

One of the main obstacles to the unification of gravity and the strong force has been the large difference in their coupling constants. The foregoing derivations overcomes this difficulty by the special form of the energy equations at distances close to the Schwarzschild radius.

Since the strong force appears to be a special form of gravity at small distances it explains why the strong force, like gravity, is attractive. The occurrence of repulsion at the core of the nucleus is presently little understood and if this is to be explained in terms of our model one would have to look at the form of the general energy equation in the region $r < r_q$.

It was previously shown [2, 3] how gravitational and electromagnetic energies could respectively be expressed as a power series in R/r or r_e/r. However, the form of (21) shows that this cannot be done for the energy arising from nuclear forces since $r \approx r_q$.

Our analysis of the three fundamental forces shows that the forces are all manifestations of one fundamental force, manifesting as universal gravitation. Electrodynamics arises as a kinematical effect and the nuclear force as a particular form at a distance equal to the classical electron radius. The weak force is not yet accommodated in this model, but analogously it is expected to be described by the energies of (2) and (7) in the region $r < R$.

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The Logarithmic Potential and an Exponential Mass Function for Elementary Particles

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The assumption that elementary particles with nonzero rest mass consist of relativistic constituents moving with constant energy pc results in a logarithmic potential and exponential expression for particle masses. This approach is put to a test by assigning each elementary particles mass a position on a logarithmic spiral. Particles then accumulate on straight lines. It is discussed if this might be an indication for exponential mass quantization.

1 Introduction

The approach of fitting parts of elementary particle mass spectra involving logarithmic potentials has been subject to research in the past decades. In this paper the simple assumption of relativistic constituents moving with constant energy pc in a logarithmic potential is discussed. A similar approach has already been presented in one of the early papers by Y. Muraki et al. [1], where the additional assumption of circular quantized orbits results in an empiric logarithmic mass function with accurate fits for several meson resonance states.

Besides the basic assumption of constant energy pc of the constituents and a resulting logarithmic potential, however, the physical approach in this paper differs and results in an exponential mass function with elementary particle masses proportional to ϕ^n, where n are integers. ϕ is a constant factor derived and thus not empirical chosen to fit particle masses.

The mass function results in points on a logarithmic spiral lining up under a polar angle φ and being separated by the factor ϕ. Elementary particle masses following this exponential quantization thus would, when placed on the spiral, be found on straight lines. Even slight changes of the value ϕ would change the particle distribution on the spiral significantly. Linear distributions for particle masses on the spiral thus would give hints if the logarithmic potential is an approach worth being further investigated to explain the wide range of elementary particle masses.

2 Physical approach

Elementary particles with mass m consist of confined constituent particles, which are moving with constant energy pc within a sphere of radius R. For this derivation it is not essential to define further properties of the constituents, e.g. if they are rotating strings or particles in circular orbits.

The only assumption made is that the force F needed to counteract a supposed centrifugal force $F_Z \propto c^2/R$ acting on each constituent is equal or proportional to pc/R, thus $F = F_Z = a_1/R$, regardless of the origin of the interaction. The potential energy needed to confine a constituent therefore is

$$E = \int \frac{a_1}{R}\, dR = a_1 \int \frac{1}{R}\, dR = a_1 \ln \frac{R}{R_a}\,, \qquad (2a)$$

where R_a is the integration constant and a_1 a parameter to be referred to later. The center of mass of the elementary particle as seen from the outside and thus the mass that is assigned to the system is

$$m = \frac{\hbar}{cR}\,. \qquad (2b)$$

The logarithmic potential energy in Eq. (2a) is assumed to be proportional to m/R, yielding

$$E = \frac{a_2 m}{R}\,. \qquad (2c)$$

Both parameters a_1 and a_2 are supposed not to be a function of R, but to depend on constituent particle properties and coupling constants, resp. For example, a_1/a_2 could be set equal c^2/γ (γ is the gravitational constant), but such a constraint is not required. Inserting m from Eq. (2b) into Eq. (2c) yields

$$E = a_2 \frac{\hbar}{cR^2}\,. \qquad (2d)$$

The angular momentum of the system is assumed to be an integer multiple n of $\hbar$, with a ground state of radius R_0.

$$E_n = a_2 \frac{\hbar}{cR_n^2} = a_2 \frac{(n+1)\hbar}{cR_0^2}, \quad n = 0, 1, 2 \ldots \qquad (2e)$$

From Eq. (2a) and Eq. (2e) it follows that

$$\ln \frac{R_a}{R_n} = -(n+1)\frac{R_a^2}{R_0^2} \quad \text{with} \quad R_a = \left(\frac{a_2 \hbar}{a_1 c}\right)^{\frac{1}{2}}, \qquad (2f)$$

assigning the integration constant R_a a value. For $n = 0$ the value for R_n is set to R_0, allowing to calculate the ratio R_a/R_0 using Eq. (2f)

$$x = e^{-x^2} \quad \text{with} \quad x = \frac{R_a}{R_0}\,,$$

and with defining $\phi = 1/x$ resulting in

$$\phi = 1.53158. \qquad (2g)$$

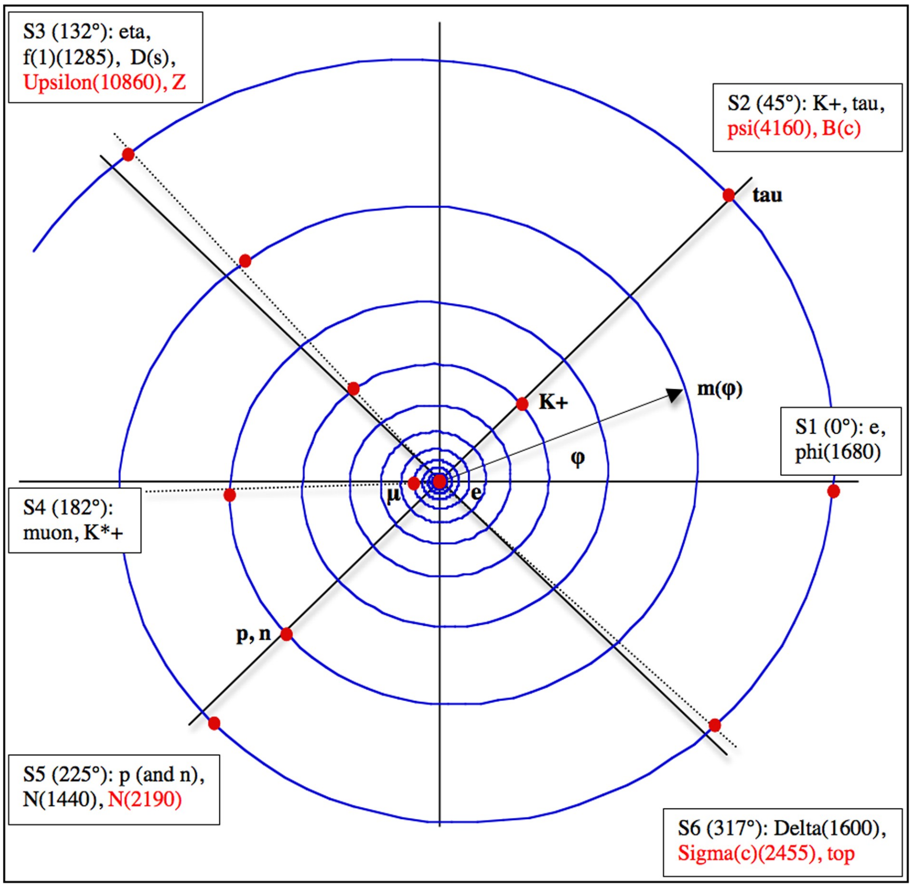

Fig. 1: The masses of elementary particles placed on the spiral and listed for each resulting sequence starting from the center. The solid lines are seperated by 45°. The red dot in the center is the electron at 0°. The outer limit of the spiral at 135° is about 2 GeV. Particles allocated on a sequence, but with masses too large for this scale are marked red in the attached listings of sequence particles. The top for example is far outside on S6 at 317°.

Since $\ln\phi = 1/\phi^2$ it follows that

$$R_n = R_a e^{(n+1)\ln\phi}\,. \tag{2h}$$

With Eq. (2b) and Eq. (2f) R_a can be written as

$$R_a = R_0\alpha\,, \tag{2i}$$

where

$$R_0 = \frac{\hbar}{m_0 c} \quad \text{with} \quad \alpha = m_0\left(\frac{a_2 c}{a_1\hbar}\right)^{\frac{1}{2}}$$

and inserting R_a into Eq. (2h) yields

$$R_n = R_0 e^{k\varphi_n} \quad \text{where} \quad k = \frac{1}{2\pi}\ln\phi\,, \tag{2j}$$

and

$$\varphi_n = 2\pi(n+1) + \varphi_s \quad \text{and} \quad \varphi_s = 2\pi\,\frac{\ln\alpha}{\ln\phi}\,.$$

Eq. (2j) applies to particle masses by inserting R_n into Eq. (2b). Thus with

$$m_n = \frac{\hbar}{R_n c} \quad \text{and} \quad m_0 = \frac{\hbar}{R_0 c}$$

it follows that

$$m_n = m_0 e^{k\varphi_n}\,. \tag{2k}$$

In Eq. (2k) $-k$ is substituted by k, which just determines to start with m_0 as the smallest instead of the biggest mass and thus turning the spiral from the inside to the outside instead vice versa. This has no influence on the results. m_n are elementary particle masses and points on a logarithmic spiral lining up at an angle φ_s as defined in Eq. (2j). These points are referred to as a particle sequence $S(\varphi_s)$. The angle φ_s should not be the same for all elementary particles since it is a function of the parameters a_1 and a_2.

To determine whether elementary particle masses tend to line up in sequences first of all a logarithmic spiral

$$m(\varphi) = m_0 e^{k\varphi}$$

with continues values for φ is calculated. m_0 is the initial mass and thus starting point of the spiral at $\varphi = 0$. The starting point $m_0 = m(\varphi = 0)$ is set so that as a result the electron is placed at the angle $\varphi = 0$.

One turn of the spiral $m(\varphi) \to m(\varphi + 2\pi)$ corresponds to multiplying $m(\varphi)$ by ϕ, yielding $m(\varphi)\phi = m(\varphi + 2\pi)$. Spiral points lining up at the same polar angle φ differ by a factor ϕ.

In a second step for each elementary particle mass pro-

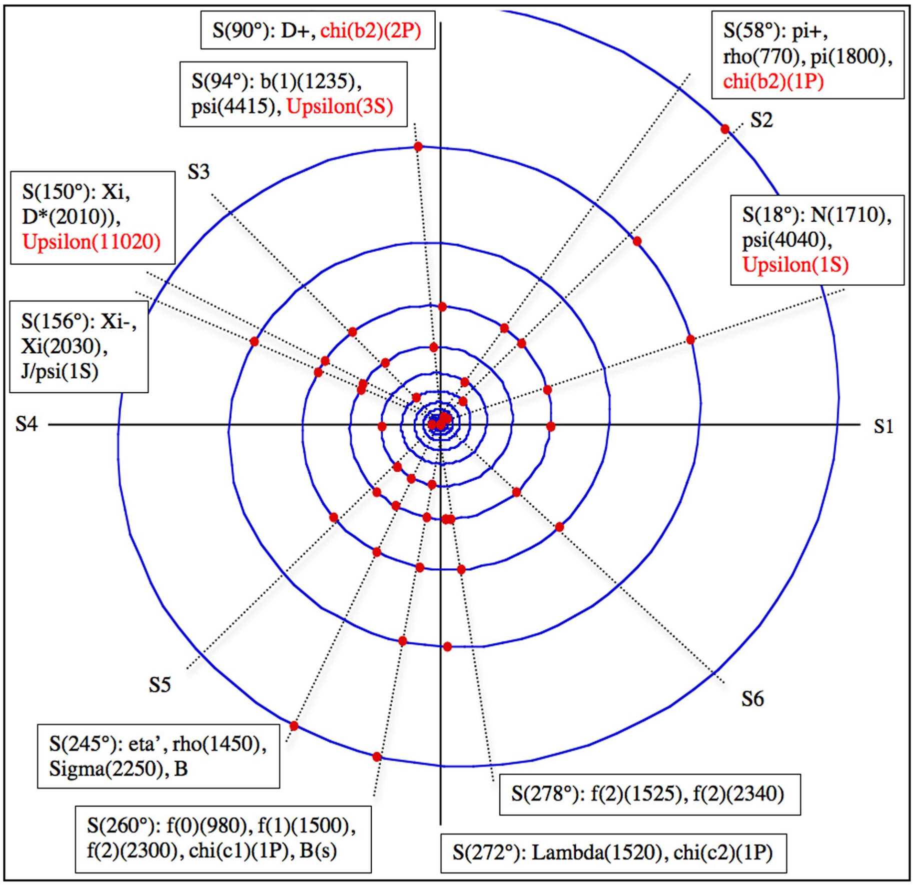

Fig. 2: Additional sequences shown within a mass range of 6.5 GeV. See Fig. 1 for listings of S1-S6.

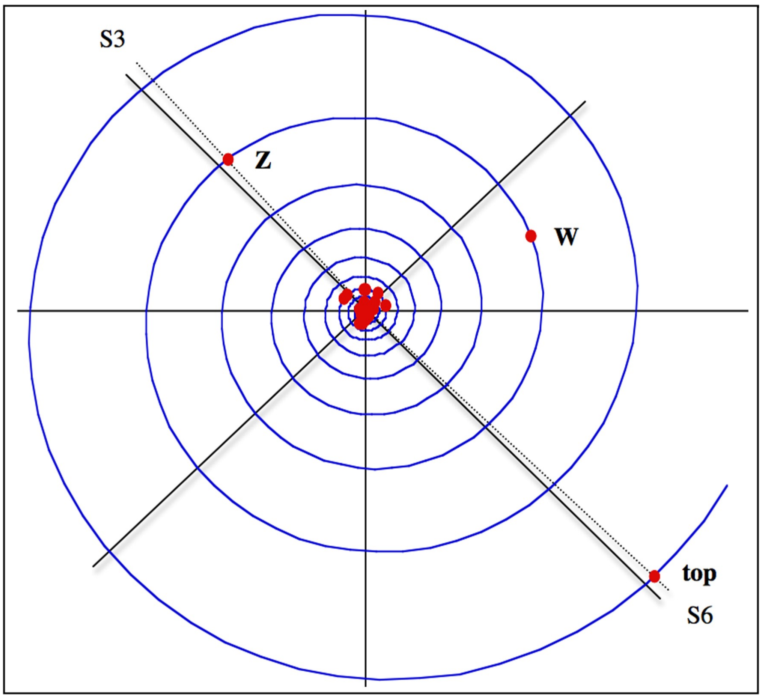

Fig. 3: At a mass range of 175 GeV the Z and top align with S3 and S6, resp., as listed in Fig. 1.

vided by the PDG table 2004 [2, 3] the resulting angle φ_s in the logarithmic spiral is calculated using Eq. (2k) with m_0 as the electron mass and φ_s as defined in Eq. (2j). This results in polar coordinates (m_n, φ_s) and thus a point on the spiral for each elementary particle.

After all elementary particles are entered as points into the spiral it is analyzed if sequences $S(\varphi_s)$, thus particle masses m_n lining up in the spiral in the same direction φ_s are found.

3 Results

The results for particle sequences are shown step by step for mass ranges from 2 GeV to 175 GeV to provide a clear overview. Elementary particles which are part of a sequence, but out of the shown mass range and thus not displayed as red dots in the spiral are marked red in the list of sequence particles, which is attached to each sequence.

All allocations of elementary particle masses to sequences are accurate within at least $\Delta m/m = 4\times10^{-3}$. All sequence positions are fitted and accurate within $\varphi_s \pm 0,5^\circ$.

Fig. 1 shows the results within a mass range of 2 GeV from the center to the outer limit of the spiral. The position of the electron is set to 0° as the starting point of the spiral, the muon then is found to be at 182°. Also on these sequences are the phi (1680) and the K* (892), resp.

The K+, tau, psi (4160) and B (c) are at 45°. The proton, N (1440) and N (2190) opposite at 225°. The eta, f (1)(1285), D (s), Upsilon (10860), Z-boson are at 132° and the Delta (1600), Sigma (c)(2455) and the top opposite at 317°, resp. Calculating the Planck mass with $m_{pl} = (\hbar c/\gamma)^{1/2}$ results in a position on sequence S6.

In Fig. 2 additional sequences within a mass range of 6.5 GeV are shown, e.g. the pi+, rho (770), pi (1800) and chi (b2)(1P) are aligned at S (58°).

Also the f (0)(980), f (1)(1500), f (2)(2300), chi (b2)(1P) and B (s) are aligned precisely in a sequence at 260°. The f (2)(1525) and f (2)(2340) align at 278°.

Other sequences are as follows, at 150° (Xi, D* (2010), Upsilon (11020)), at 156° (Xi-, Xi (2030), J/psi (1S)) and at 245° (eta', rho (1450), Sigma (2250), B). Also the psi (4040), psi (4415), Upsilon (1S) and Upsilon (3S) are found in sequences.

A picture of the mass range of elementary particles at 175 GeV is shown in Fig. 3, with the Z and top aligning in the sequences S3 and S6, resp., as listed in Fig. 1.

4 Discussion and conclusion

In this simple model the mass distribution of elementary particles strongly depends on the derived quantization factor ϕ. Even slight changes $\Delta\phi/\phi \approx 5\times10^{-4}$ disrupt the particle sequences. Thus of interest are the symmetric sequences S1-S6 with precise positions for the electron, muon, kaon, proton and tau. Also the eta, K (892), D (s), B (c), Upsilon (10860), Z and top are placed on these sequences. Other sequences align particles like f's, pi's and Xi's.

The existence of more than one sequence implies that α in Eq. (2i), i.e. the ratio of parameters a_1 and a_2, has several values within the elementary particle mass spectrum.

Randomly chosen values for ϕ other than the derived one do not provide symmetric and precise results, but rather uniform distributions, as should be expected. The results of the precise and specific sequences in the derived logarithmic spiral still might be a pure coincidence. But they also could be an indication for constituent particles moving in a logarithmic potential, resulting in an exponential quantization for elementary particle masses. Then the results would suggest the logarithmic potential to be considered an approach worth being further investigated to explain the wide range of elementary particle masses.

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A Note of Extended Proca Equations and Superconductivity

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It has been known for quite long time that the electrodynamics of Maxwell equations can be extended and generalized further into Proca equations. The implications of introducing Proca equations include an alternative description of superconductivity, via extending London equations. In the light of another paper suggesting that Maxwell equations can be written using quaternion numbers, then we discuss a plausible extension of Proca equation using biquaternion number. Further implications and experiments are recommended.

1 Introduction

It has been known for quite long time that the electrodynamics of Maxwell equations can be extended and generalized further into Proca equations, to become electrodynamics with finite photon mass [11]. The implications of introducing Proca equations include description of superconductivity, by extending London equations [18]. In the light of another paper suggesting that Maxwell equations can be generalized using quaternion numbers [3, 7], then we discuss a plausible extension of Proca equations using biquaternion number. It seems interesting to remark here that the proposed extension of Proca equations by including quaternion differential operator is merely the next logical step considering already published suggestion concerning the use of quaternion differential operator in electromagnetic field [7, 8]. This is called Moisil-Theodoresco operator (see also Appendix A).

2 Maxwell equations and Proca equations

In a series of papers, Lehnert argued that the Maxwell picture of electrodynamics shall be extended further to include a more "realistic" model of the *non-empty vacuum*. In the presence of electric space charges, he suggests a general form of the Proca-type equation [11]:

$$\left(\frac{1}{c^2}\frac{\partial}{\partial t^2} - \nabla^2\right) A_\mu = \mu_0 J_\mu, \qquad \mu = 1, 2, 3, 4. \tag{1}$$

Here $A_\mu = (A, i\phi/c)$, where A and ϕ are the magnetic vector potential and the electrostatic potential in three-space, and:

$$J_\mu = (j,\ i c\bar{\phi})\,. \tag{2}$$

However, in Lehnert [11], the right-hand terms of equations (1) and (2) are now given a new interpretation, where $\bar{\phi}$ is the nonzero electric charge density in the vacuum, and j stands for an associated three-space current-density.

The background argument of Proca equations can be summarized as follows [6]. It was based on known definition of derivatives [6, p. 3]:

$$\left.\begin{aligned} \partial^\mu &= \frac{\partial}{\partial x^\mu} = \left(\frac{\partial}{\partial t}; \frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z}\right) = \left(\partial^0; -\nabla\right) \\ \partial_\mu &= \frac{\partial}{\partial x^\mu} = \left(\partial^0; \nabla\right) \end{aligned}\right\}, \tag{3}$$

$$\partial_\mu a^\mu = \frac{\partial a^0}{\partial t} + \nabla \vec{a}\,, \tag{4}$$

$$\partial_\mu \partial^\mu = \frac{\partial^2}{\partial t^2} - \frac{\partial^2}{\partial x^2} - \frac{\partial^2}{\partial y^2} - \frac{\partial^2}{\partial z^2} = \partial_0^2 - \nabla^2 = \partial^\mu \partial_\mu\,, \tag{5}$$

where ∇^2 is Laplacian and $\partial_\mu\partial^\mu$ is d'Alembertian operator. For a massive vector boson (spin-1) field, the Proca equation can be written in the above notation [6, p. 7]:

$$\partial_\mu \partial^\mu A^\nu - \partial^\nu(\partial_\mu A^\mu) + m^2 A^\nu = j^\nu. \tag{6}$$

Interestingly, there is also a neat link between Maxwell equations and quaternion numbers, in particular via the *Moisil-Theodoresco* D operator [7, p. 570]:

$$D = i_1 \frac{\partial}{\partial x_1} + i_2 \frac{\partial}{\partial x_2} + i_3 \frac{\partial}{\partial x_3}\,. \tag{7}$$

There are also known links between Maxwell equations and Einstein-Mayer equations [8]. Therefore, it seems plausible to extend further the Maxwell-Proca equations to biquaternion form too; see also [9, 10] for links between Proca equation and Klein-Gordon equation. For further theoretical description on the links between biquaternion numbers, Maxwell equations, and unified wave equation, see Appendix A.

3 Proca equations and superconductivity

In this regards, it has been shown by Sternberg [18], that the classical *London equations* for superconductors can be written in differential form notation and in relativistic form, where they yield the Proca equations. In particular, the field itself acts as its own charge carrier [18].

Similarly in this regards, in a recent paper Tajmar has shown that superconductor equations can be rewritten in terms of Proca equations [19]. The basic idea of Tajmar appears similar to Lehnert's extended Maxwell theory, i.e. to include *finite photon mass* in order to explain superconductivity phenomena. As Tajmar puts forth [19]:

> "In quantum field theory, superconductivity is explained by a *massive photon*, which acquired mass due to gauge symmetry breaking and the Higgs mechanism. The wavelength of the photon is interpreted as the London penetration depth. With a nonzero photon mass, the usual Maxwell equations transform into the so-called Proca equations which will form the basis for our assessment in superconductors and are only valid for the superconducting electrons."

Therefore the basic Proca equations for superconductor will be [19, p. 3]:

$$\nabla \times \bar{E} = -\frac{\partial \bar{B}}{\partial t}\,, \tag{8}$$

and

$$\nabla \times B = \mu_0 \bar{j} + \frac{1}{c^2}\frac{\partial \bar{E}}{\partial t} - \frac{1}{\lambda^2}\bar{A}\,. \tag{9}$$

The Meissner effect is obtained by taking curl of equation (9). For non-stationary superconductors, the same equation (9) above will yield second term, called London moment.

Another effects are recognized from the finite Photon mass, i.e. the photon wavelength is then interpreted as the London penetration depth and leads to a photon mass about 1/1000 of the electron mass. This furthermore yields the Meissner-Ochsenfeld effect (shielding of electromagnetic fields entering the superconductor) [20].

Nonetheless, the use of Proca equations have some known problems, i.e. it predicts that a charge density rotating at angular velocity should produce huge magnetic fields, which is *not observed* [20]. One solution of this problem is to recognize that the value of photon mass containing charge density is different from the one in free space.

4 Biquaternion extension of Proca equations

Using the method we introduced for Klein-Gordon equation [2], then it is possible to generalize further Proca equations (1) using biquaternion differential operator, as follows:

$$(\Diamond\bar{\Diamond})A_\mu - \mu_0 J_\mu = 0\,, \qquad \mu = 1,2,3,4, \tag{10}$$

where (see also Appendix A):

$$\Diamond = \nabla^q + i\nabla^q = \left(-i\,\frac{\partial}{\partial t} + e_1\,\frac{\partial}{\partial x} + e_2\,\frac{\partial}{\partial y} + e_3\,\frac{\partial}{\partial z}\right) + \\ + i\left(-i\,\frac{\partial}{\partial T} + e_1\,\frac{\partial}{\partial X} + e_2\,\frac{\partial}{\partial Y} + e_3\,\frac{\partial}{\partial Z}\right). \tag{11}$$

Another way to generalize Proca equations is by using its standard expression. From d'Alembert wave equation we get [6]:

$$\left(\frac{1}{c^2}\frac{\partial}{\partial t^2} - \nabla^2\right)A_\mu = \mu_0 J_\mu\,, \qquad \mu = 1,2,3,4, \tag{12}$$

where the solution is Liennard-Wiechert potential. Then the Proca equations are [6]:

$$\left[\left(\frac{1}{c^2}\frac{\partial}{\partial t^2} - \nabla^2\right) + \left(\frac{m_p c}{\hbar}\right)^2\right]A_\mu = 0\,, \quad \mu = 1,2,3,4, \tag{13}$$

where m is the photon mass, c is the speed of light, and $\hbar$ is the reduced Planck constant. Equation (13) and (12) imply that photon mass can be understood as charge density:

$$J_\mu = \frac{1}{\mu_0}\left(\frac{m_p c}{\hbar}\right)^2. \tag{14}$$

Therefore the "biquaternionic" extended Proca equations (13) become:

$$\left[\Diamond\bar{\Diamond} + \left(\frac{m_p c}{\hbar}\right)^2\right]A_\mu = 0\,, \qquad \mu = 1,2,3,4. \tag{15}$$

The solution of equations (12) and (12) can be found using the same computational method as described in [2].

Similarly, the generalized structure of the wave equation in electrodynamics — *without* neglecting the finite photon mass (Lehnert-Vigier) — can be written as follows (instead of eq. 7.24 in [6]):

$$\left[\Diamond\bar{\Diamond} + \left(\frac{m_p c}{\hbar}\right)^2\right]A_\mu^a = RA_\mu^a\,, \quad \mu = 1,2,3,4. \tag{16}$$

It seems worth to remark here that the method as described in equation (15)-(16) or ref. [6] is not the only possible way towards generalizing Maxwell equations. Other methods are available in literature, for instance by using topological geometrical approach [14, 15].

Nonetheless further experiments are recommended in order to verify this proposition [23, 24]. One particular implication resulted from the introduction of biquaternion differential operator into the Proca equations, is that it may be related to the notion of "active time" introduced by Paine & Pensinger sometime ago [13]; the only difference here is that now the time-evolution becomes nonlinear because of the use of 8-dimensional differential operator.

5 Plausible new gravitomagnetic effects from extended Proca equations

While from Proca equations one can expect to observe gravitational London moment [4, 22] or other peculiar gravitational shielding effect unable to predict from the framework of General Relativity [5, 16, 22], one can expect to derive new gravitomagnetic effects from the proposed extended Proca equations using the biquaternion number as described above.

Furthermore, another recent paper [1] has shown that given the finite photon mass, it would imply that if m is due to a Higgs effect, then the *Universe is effectively similar to a Superconductor.* This may support De Matos's idea of dark energy arising from superconductor, in particular via *Einstein-Proca* description [1, 5, 16].

It is perhaps worth to mention here that there are some indirect observations [1] relying on the effect of Proca energy (assumed) on the galactic plasma, which implies the limit:

$$m_A = 3\times 10^{-27} \text{ eV}. \tag{17}$$

Interestingly, in the context of cosmology, it can be shown that Einstein field equations with cosmological constant are approximated to the second order in the perturbation to a flat background metric [5]. Nonetheless, further experiments are recommended in order to verify or refute this proposition.

6 Some implications in superconductivity research

We would like to mention the Proca equation in the following context. Recently it was hypothesized that the creation of superconductivity at room temperature may be achieved by a resonance-like interaction between an everywhere present background field and a special material having the appropriate crystal structure and chemical composition [12]. According to Global Scaling, a new knowledge and holistic approach in science, the everywhere present background field is given by oscillations (standing waves) in the universe or physical vacuum [12].

The just mentioned hypothesis how superconductivity at room temperature may come about, namely by a resonance-like interaction between an everywhere present background field and a special material having the appropriate crystal structure and chemical composition, seems to be supported by a statement from the so-called ECE Theory which is possibly related to this hypothesis [12]:

> "... One of the important practical consequences is that a material can become a superconductor by absorption of the inhomogeneous and homogeneous currents of ECE space-time ... " [6].

This is a quotation from a paper with the title "ECE Generalizations of the d'Alembert, Proca and Superconductivity Wave Equations ... " [6]. In that paper the Proca equation is derived as a special case of the ECE field equations.

These considerations raises the interesting question about the relationship between (a possibly new type of) superconductivity, space-time, an everywhere-present background field, and the description of superconductivity in terms of the Proca equation, i.e. by a massive photon which acquired mass by symmetry breaking. Of course, how far these suggestions are related to the physical reality will be decided by further experimental and theoretical studies.

7 Concluding remarks

In this paper we argue that it is possible to extend further Proca equations for electrodynamics of superconductivity to biquaternion form. It has been known for quite long time that the electrodynamics of Maxwell equations can be extended and generalized further into Proca equations, to become electrodynamics with finite photon mass. The implications of introducing Proca equations include description of superconductivity, by extending London equations. Nonetheless, further experiments are recommended in order to verify or refute this proposition.

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Appendix A: Biquaternion, Maxwell equations and unified wave equation [3]

In this section we're going to discuss Ulrych's method to describe unified wave equation [3], which argues that it is possible to define a unified wave equation in the form [3]:

$$D\phi(x) = m_\phi^2 \cdot \phi(x), \tag{A.1}$$

where unified (wave) differential operator D is defined as:

$$D = \left[(P - qA)_\mu \left(\bar{P} - qA \right)^\mu \right]. \tag{A.2}$$

To derive Maxwell equations from this unified wave equation, he uses free photon expression [3]:

$$DA(x) = 0, \tag{A.3}$$

where potential A(x) is given by:

$$A(x) = A^0(x) + jA^1(x), \tag{A.4}$$

and with electromagnetic fields:

$$E^i(x) = -\partial^0 A^i(x) - \partial^i A^0(x), \tag{A.5}$$

$$B^i(x) = \in^{ijk} \partial_j A_k(x). \tag{A.6}$$

Inserting these equations (A.4)-(A.6) into (A.3), one finds Maxwell electromagnetic equation [3]:

$$\begin{aligned} &-\nabla \bullet E(x) - \partial^0 C(x) + ij\nabla \bullet B(x) - \\ &- j(\nabla x B(x) - \partial^0 E(x) - \nabla C(x)) - \\ &- i(\nabla x E(x) + \partial^0 B(x)) = 0. \end{aligned} \tag{A.7}$$

For quaternion differential operator, we define quaternion Nabla operator:

$$\begin{aligned} \nabla^q \equiv c^{-1}\frac{\partial}{\partial t} + \left(\frac{\partial}{\partial x}\right) i + \left(\frac{\partial}{\partial y}\right) j + \left(\frac{\partial}{\partial z}\right) k = \\ = c^{-1}\frac{\partial}{\partial t} + \vec{i} \cdot \vec{\nabla}. \end{aligned} \tag{A.8}$$

And for biquaternion differential operator, we may define a diamond operator with its conjugate [3]:

$$\Diamond\bar{\Diamond} \equiv \left(c^{-1}\frac{\partial}{\partial t} + c^{-1}\,i\,\frac{\partial}{\partial t}\right) + \{\vec{\nabla}\}* \tag{A.9}$$

where Nabla-star-bracket operator is defined as:

$$\begin{aligned}\{\vec{\nabla}\}* \equiv \left(\frac{\partial}{\partial x} + i\,\frac{\partial}{\partial X}\right) i \,+ \\ + \left(\frac{\partial}{\partial y} + i\,\frac{\partial}{\partial Y}\right) j + \left(\frac{\partial}{\partial z} + i\,\frac{\partial}{\partial Z}\right) k\,.\end{aligned} \tag{A.10}$$

In other words, equation (A.9) can be rewritten as follows:

$$\begin{aligned}\Diamond\bar{\Diamond} \equiv \left(c^{-1}\frac{\partial}{\partial t} + c^{-1}\,i\,\frac{\partial}{\partial T}\right) + \left(\frac{\partial}{\partial x} + i\,\frac{\partial}{\partial X}\right) i \,+ \\ + \left(\frac{\partial}{\partial y} + i\,\frac{\partial}{\partial Y}\right) j + \left(\frac{\partial}{\partial z} + i\,\frac{\partial}{\partial Z}\right) k\,.\end{aligned} \tag{A.11}$$

From this definition, it shall be clear that there is neat link between equation (A.11) and the Moisil-Theodoresco D operator, i.e. [7, p. 570]:

$$\begin{aligned}\Diamond\bar{\Diamond} \equiv \left(c^{-1}\frac{\partial}{\partial t} + c^{-1}\,i\,\frac{\partial}{\partial t}\right) + \left(D_{xi} + i\,D_{Xi}\right) = \\ = \left(c^{-1}\frac{\partial}{\partial t} + c^{-1}i\frac{\partial}{\partial T}\right) + \left[i_1\frac{\partial}{\partial x_1} + i_2\frac{\partial}{\partial x_2} + i_3\frac{\partial}{\partial x_3}\right] + \\ + i\left[i_1\frac{\partial}{\partial X_1} + i_2\frac{\partial}{\partial X_2} + i_3\frac{\partial}{\partial X_3}\right].\end{aligned} \tag{A.12}$$

In order to define biquaternionic representation of Maxwell equations, we could extend Ulrych's definition of *unified differential operator* [3,17,21] to its biquaternion counterpart, by using equation (A.2) and (A.10), to become:

$$\{D\}* \equiv \left[\left(\{P\}* - q\{A\}*\right)_\mu \left(\{\bar{P}\}* - q\{A\}*\right)^\mu\right], \tag{A.13}$$

or by definition $P = -i\hbar\nabla$, equation (A.13) could be written as:

$$\{D\}* \equiv \left[\left(-\hbar\{\vec{\nabla}\}* - q\{A\}*\right)_\mu \left(-\hbar\{\vec{\nabla}\}* - q\{A\}*\right)^\mu\right], \tag{A.14}$$

where each component is now defined in term of biquaternionic representation. Therefore the biquaternionic form of the *unified wave equation* [3] takes the form:

$$\{D\} * \phi(x) = m_\phi^2 \cdot \phi(x)\,, \tag{A.15}$$

which is a wave equation for massive electrodynamics, quite similar to Proca representation.

Now, biquaternionic representation of free photon fields could be written as follows:

$$\{D\} * A(x) = 0\,. \tag{A.16}$$

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Phase Transitions in Even-Even Palladium Isotopes

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The positive and negative parity states of the even-even palladium isotopes were studied within the frame work of the interacting boson approximation model (IBA-1). The energy spectra, potential energy surfaces, electromagnetic transition probabilities, back bending and staggering effect have been calculated. The potential energy surfaces show smooth transition from vibrational-like to gamma-soft and finally to rotational-like nuclei. Staggering effectle, has been observed between the positive and negative parity states in palladium isotopes. The agreement between theoretical predictions and experimental values are fairly good.

1 Introduction

The region of neutron-excess nuclei at mass $A \cong 100$ is an area of interest to many authors because of the observation of the phase transitions. Three phase transitional regions are well known where the structure changes rapidly. Nd-Sm-Gd and Ru-Pd regions where the change is from spherical to well deformed nuclei when moving from lighter to heavier isotopes. But, Os-Pt regions the change is from well deformed to γ-soft when moving from lighter to heavier isotopes.

The structure of these transitional nuclei has been the subject of many experimental and theoretical studies. Experimentally, levels of ^{102}Pd were populated from the decay of ^{102}Ag populated in the ^{89}Y (^{16}O,3n) reaction [1] and their properties were studied through γ spectroscopy. Also, measurements were performed using an array of eight HPGe detectors on gamma multiplicity gated on proton spectra of $^{102\text{-}104}$Pd which have been measured [2] in the ^{12}C + ^{93}Np reaction E(^{12}C) = 40 MeV, at backward angles.The cross-section along with the angular momentum and excitation energy are populated.

Theoretically, the transitional regions and phase transitions in palladium isotopes have been analyzed in the frame work of the IBA-2 model [3–7]. From the analysis of energies, static moments, transition rates, quadrupole moments and mixing ratios, they were able to identify states having large mixed - symmetry components.

Cranked Strutinsky Method [8], Geometric Collective Model [9] (GCM) and the Relativistic Mean Field Theory [10] have examined palladium series of isotopes to find examples displaying the characteristics of E(5) critical point behavior [11]for the shape transition from spherical vibrator to a triaxially soft rotor.

In this article, we carried out a microscopic study of the Yrast and negative parity states, electromagnetic transition rates, $B(E1)$, $B(E2)$, potential energy surfaces, $V(\beta,\gamma)$, for $^{100\text{-}116}$Pd nuclei employing the interacting boson model.

2 Interacting boson approximation model (IBA-1)

2.1 Level energies

IBA-1 model [12–14] was applied to the positive and negative parity states in even-even $^{100\text{-}116}$Pd isotopes. The Hamiltonian employed [15] in the present calculation is:

$$\begin{aligned} H &= EPS\cdot n_d + PAIR\cdot(P\cdot P) + \\ &+ \frac{1}{2}\,ELL\cdot(L\cdot L) + \frac{1}{2}\,QQ\cdot(Q\cdot Q) + \\ &+ 5OCT\cdot(T_3\cdot T_3) + 5HEX\cdot(T_4\cdot T_4)\,, \end{aligned} \tag{1}$$

where

$$P\cdot p = \frac{1}{2}\left[\begin{array}{l} \left\{(s^\dagger s^\dagger)^{(0)}_0 - \sqrt{5}(d^\dagger d^\dagger)^{(0)}_0\right\} x \\ \left\{(ss)^{(0)}_0 - \sqrt{5}(\tilde{d}\tilde{d})^{(0)}_0\right\} \end{array}\right]^{(0)}_0, \tag{2}$$

$$L\cdot L = -10\sqrt{3}\left[(d^\dagger\tilde{d})^{(1)} x\,(d^\dagger\tilde{d})^{(1)}\right]^{(0)}_0, \tag{3}$$

$$Q\cdot Q = \sqrt{5}\left[\begin{array}{l} \left\{(S^\dagger\tilde{d} + d^\dagger s)^{(2)} - \frac{\sqrt{7}}{2}\,(d^\dagger\tilde{d})^{(2)}\right\} x \\ \left\{(s^\dagger\tilde{d} + +\tilde{d}s)^{(2)} - \frac{\sqrt{7}}{2}\,(d^\dagger\tilde{d})^{(2)}\right\} \end{array}\right]^{(0)}_0, \tag{4}$$

$$T_3\cdot T_3 = -\sqrt{7}\left[(d^\dagger\tilde{d})^{(2)} x\,(d^\dagger\tilde{d})^{(2)}\right]^{(0)}_0, \tag{5}$$

$$T_4\cdot T_4 = 3\left[(d^\dagger\tilde{d})^{(4)} x\,(d^\dagger\tilde{d})^{(4)}\right]^{(0)}_0. \tag{6}$$

In the previous formulas, n_d is the number of boson; $P\cdot P$, $L\cdot L$, $Q\cdot Q$, $T_3\cdot T_3$ and $T_4\cdot T_4$ represent pairing, angular momentum, quadrupole, octupole and hexadecupole interactions between the bosons; EPS is the boson energy; and $PAIR$, ELL, QQ, OCT, HEX is the strengths of the pairing, angular momentum, quadrupole, octupole and hexadecupole interactions.

nucleus	EPS	$PAIR$	ELL	QQ	OCT	HEX	$E2SD(eb)$	$E2DD(eb)$
^{100}Pd	0.6780	0.000	0.0095	−0.020	0.0000	0.0000	0.1020	−0.3817
^{102}Pd	0.5840	0.000	0.0115	−0.0200	0.0000	0.0000	0.1270	−0.3757
^{104}Pd	0.5750	0.0000	0.0225	−0.0200	0.0000	0.0000	0.1210	−0.3579
^{106}Pd	0.5630	0.0000	0.0230	−0.0200	0.0000	0.0000	0.1220	−0.3609
^{108}Pd	0.5180	0.0000	0.0235	−0.0200	0.0000	0.0000	0.1170	−0.3461
^{110}Pd	0.4950	0.0000	0.0235	−0.0200	0.0000	0.0000	0.1110	−0.3283
^{112}Pd	0.4950	0.0000	0.0235	−0.0200	0.0000	0.0000	0.08770	−0.2594
^{114}Pd	0.52200	0.0000	0.0235	−0.0200	0.0000	0.0000	0.0612	−0.1810
^{116}Pd	0.5700	0.0000	0.0216	−0.0200	0.0000	0.0000	0.0742	−0.2195

Table 1: Parameters used in IBA-1 Hamiltonian (all in MeV).

2.2 Electromagnetic transition rates

The electric quadrupole transition operator [15] employed in this study is:

$$T^{(E2)} = E2SD \cdot (s^\dagger \tilde{d} + d^\dagger s)^{(2)} + \\ + \frac{1}{\sqrt{5}} E2DD \cdot (d^\dagger \tilde{d})^{(2)} . \qquad (7)$$

The reduced electric quadrupole transition rates between $I_i \to I_f$ states are given by

$$B(E_2, I_i - I_f) = \frac{[< I_f \parallel T^{(E_2)} \parallel I_i >]^2}{2I_i + 1} . \qquad (8)$$

3 Results and discussion

3.1 The potential energy surfaces

The potential energy surfaces [16], $V(\beta,\gamma)$, as a function of the deformation parameters β and γ are calculated using:

$$\begin{aligned} &E_{N_\Pi N_\nu}(\beta,\gamma) = \, <N_\pi N_\nu; \beta\gamma \,|H_{\pi\nu}| N_\pi N_\nu; \beta\gamma> \\ &= \zeta_d (N_\nu N_\pi)\beta^2(1+\beta^2) + \beta^2(1+\beta^2)^{-2} \times \\ &\times \left\{ k N_\nu N_\pi [4 - (\bar{X}_\pi \bar{X}_\nu)\beta \cos 3\gamma] \right\} + \\ &+ \left\{ [\bar{X}_\pi \bar{X}_\nu \beta^2] + N_\nu(N_\nu - 1)\left(\frac{1}{10} c_0 + \frac{1}{7} c_2\right)\beta^2 \right\} , \end{aligned} \qquad (9)$$

where

$$\bar{X}_\rho = \left(\frac{2}{7}\right)^{0.5} X_\rho \quad \rho = \pi \text{ or } \upsilon . \qquad (10)$$

The calculated potential energy surfaces, $V(\beta,\gamma)$, are presented in Fig. 1. It shows that $^{100-110}$Pd are vibrational-like nuclei while ^{112}Pd is a γ-soft where the two wells on the oblate and prolate sides are equal. ^{114,116}Pd are prolate deformed and have rotational characters. So, ^{112}Pd is thought to be a transitional nucleus forming a zone between soft vibration side and nearly deformed nuclei in the other side.

3.2 Energy spectra

The energy of the positive and negative parity states of palladium series of isotopes are calculated using computer code PHINT [17]. A comparison between the experimental spectra [18–26] and our calculations for the ground state and $(-ve)$ parity states are illustrated in Fig. 2. The model parameters given in Table 1 are free parameters and adjusted to reproduce as closely as possible the excitation energy of the $(+ve)$ and $(-ve)$ parity levels. The agreement between the calculated levels energy and their correspondence experimental values for all nuclei are slightly higher for the higher excited states. We believe this is due to the change of the projection of the angular momentum which is due mainly to band crossing.

Unfortunately there is no enough measurements of electromagnetic transition rates $B(E1)$ or $B(E2)$ for these series of nuclei. The only measured $B(E2, 0_1^+ \to 2_1^+)$'s are presented, in Table 2 for comparison with the calculated values. The parameters $E2SD$ and $E2DD$ are displayed in Table 1 and used in the computer code NPBEM [17] for calculating the electromagnetic transition rates after normalization to the available experimental values.

No new parameters are introduced for calculating electromagnetic transition rates $B(E2)$, (Table 1), and $B(E1)$, (Table 2), of intraband and interband. The values of the ground state band are presented in Fig. 3 and show bending at $N = 64$ which means there is an interaction between the $(+ve)$ ground state and the $(-ve)$ parity states.

The moment of inertia I and angular frequency $\hbar\omega$ are calculated using equations (11, 12):

$$\frac{2J}{\hbar^2} = \frac{4I - 2}{\Delta E(I \to I - 2)} , \qquad (11)$$

$$(\hbar\omega)^2 = (I^2 - I + 1)\left[\frac{\Delta E(I \to I-2)}{(2I-1)}\right]^2 . \qquad (12)$$

The plots in Fig. 4 show upper bending at $I^+ = 12$ and lower bending at $I^+ = 14$ for $^{100\text{-}116}$Pd. It means, there is a crossing between the ground and the $(-ve)$ parity states.

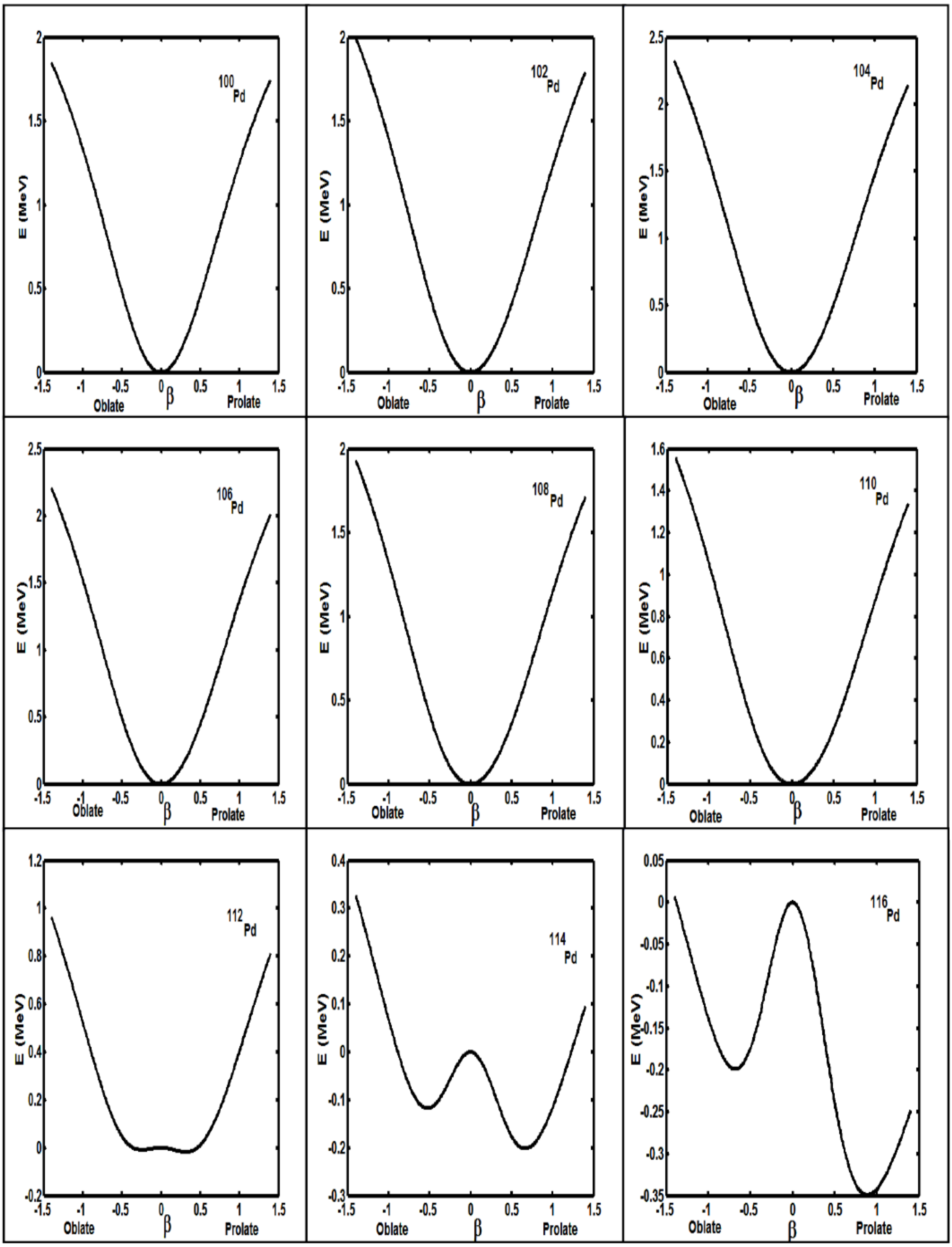

Fig. 1: Potential energy surfaces for $^{100-116}$Pd nuclei.

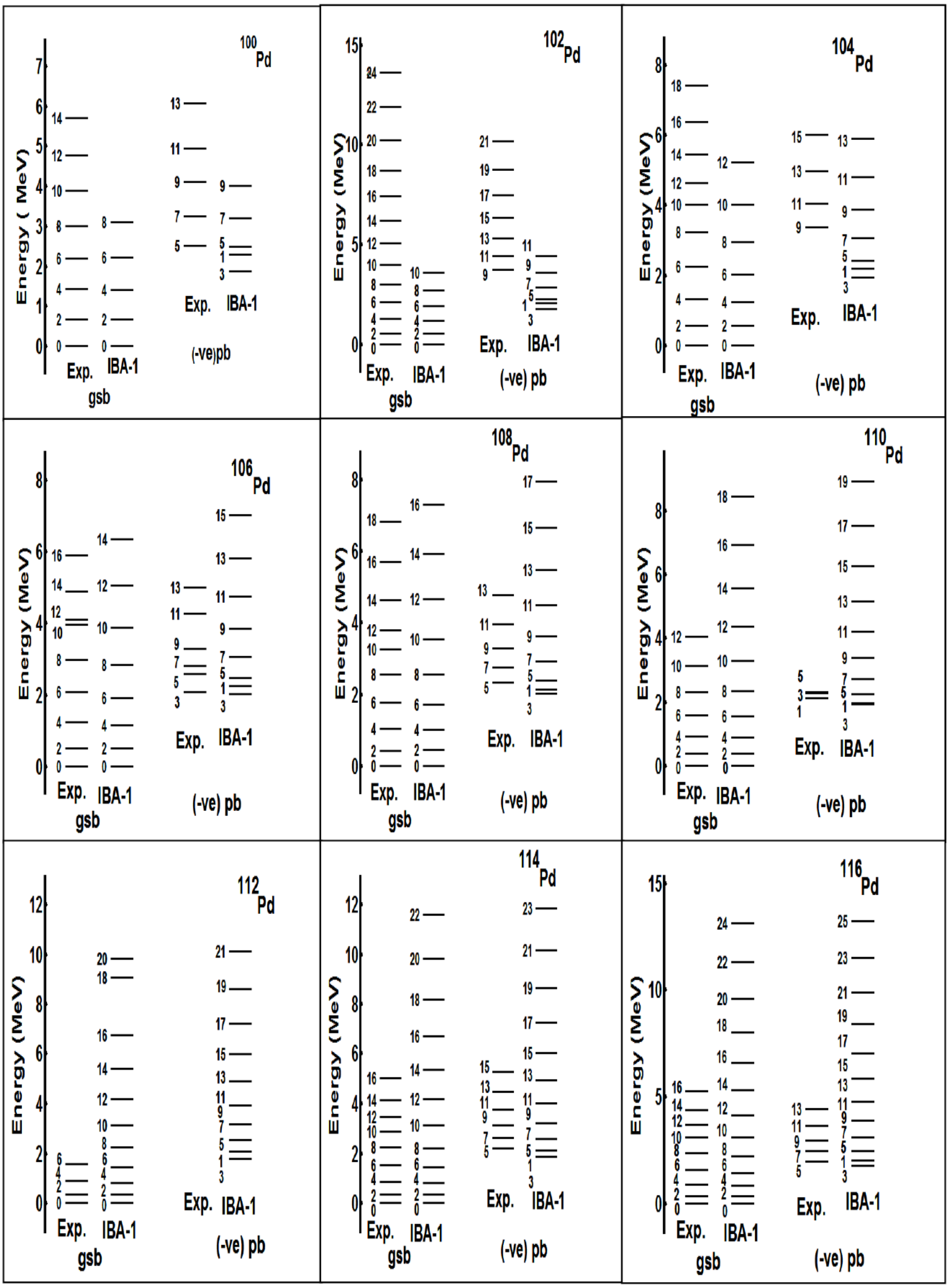

Fig. 2: Comparison between exp. [18–26] and theoretical (IBA-1) energy levels.

I_i^+ I_f^+	^{100}Pd	^{102}Pd	^{104}Pd	^{106}Pd	^{108}Pd	^{110}Pd	^{112}Pd	^{114}Pd	^{116}Pd
0_1 Exp*. 2_1	——	0.460(30)	0.535(35)	0.660(35)	0.760(40)	0.870(40)	0.660(11)	0.380(20)	0.620(18)
0_1 Theor. 2_1	0.2275	0.4657	0.5317	0.6663	0.7672	0.8631	0.6640	0.3804	0.6237
2_1 0_1	0.0455	0.0931	0.1063	0.13333	0.1534	0.1726	0.1328	0.0761	0.1247
2_2 0_1	0.0001	0.0004	0.0007	0.0013	0.0023	0.0034	0.0029	0.0017	0.0028
2_2 0_2	0.0199	0.0395	0.0449	0.0582	0.0738	0.0925	0.0785	0.0481	0.0819
2_3 0_1	0.0000	0.0000	0.0000	0.0000	0.0001	0.0004	0.0007	0.0006	0.0010
2_3 0_2	0.0286	0.0669	0.0822	0.1051	0.1126	0.1100	0.0704	0.0356	0.0576
2_3 0_3	0.0045	0.0082	0.0095	0.0128	0.0180	0.0270	0.0260	0.0166	0.0292
2_4 0_3	0.0012	0.0044	0.0074	0.0129	0.0234	0.0423	0.0462	0.0317	0.0570
2_4 0_4	0.0335	0.0602	0.0640	0.0755	0.0744	0.0702	0.0398	0.0182	0.0279
4_1 2_1	0.0702	0.1545	0.1846	0.2396	0.2943	0.3265	0.2535	0.1463	0.2429
4_1 2_2	0.0071	0.0137	0.0156	0.0202	0.0249	0.0300	0.0245	0.0150	0.0264
4_1 2_3	0.0117	0.0278	0.0346	0.0449	0.0492	0.0492	0.0323	0.0168	0.0277
6_1 4_1	0.0711	0.1756	0.2236	0.3011	0.3635	0.4188	0.3244	0.1878	0.3153
6_1 4_2	0.0098	0.0177	0.0195	0.0241	0.0273	0.0304	0.0233	0.0139	0.0244
6_1 4_3	0.0062	0.0191	0.0261	0.0353	0.0384	0.0380	0.0250	0.0131	0.0218
8_1 6_1	0.0476	0.1559	0.2225	0.3180	0.3950	0.4613	0.3599	0.2102	0.3574
8_1 6_2	0.0107	0.0184	0.0197	0.0236	0.0252	0.0266	0.0198	0.0116	0.0205
8_1 6_3	——	0.0094	0.0169	0.0253	0.0288	0.0295	0.0201	0.0109	0.0185
10_1 8_1	——	0.0969	0.1835	0.2936	0.3849	0.4629	0.3679	0.2183	0.3769
10_1 8_2	——	0.0178	0.0187	0.0219	0.0224	0.0229	0.0166	0.0096	0.0171

Table 2: Values of the theoretical reduced transition probability, $B(E2)$ (in $e^2\,b^2$).
*Ref. 27.

I_i^- I_f^+	^{100}Pd	^{102}Pd	^{104}Pd	^{106}Pd	^{108}Pd	^{110}Pd	^{112}Pd	^{114}Pd	^{116}Pd
1_1 0_1	0.0009	0.0020	0.0033	0.0052	0.0091	0.0148	0.0213	0.0255	0.0259
1_1 0_2	0.1290	0.1248	0.1299	0.1314	0.1340	0.1360	0.1369	0.1379	0.1384
3_1 2_1	0.1268	0.1228	0.1235	0.1246	0.1309	0.1414	0.1530	0.1605	0.1617
3_1 2_2	0.0267	0.0361	0.0395	0.0443	0.0501	0.0566	0.0645	0.0719	0.0771
3_1 2_3	0.0006	0.0018	0.0030	0.0053	0.0108	0.0190	0.0268	0.0311	0.0335
3_2 2_1	0.0093	0.0031	0.0016	0.0012	0.0014	0.0028	0.0053	0.0079	0.0099
3_2 2_2	0.0912	0.0278	0.0190	0.0153	0.0136	0.0146	0.0172	0.0196	0.0193
3_2 2_3	0.1132	0.2103	0.2247	0.2243	0.2172	0.2109	0.1827	0.1686	0.1599
5_1 4_1	0.2660	0.2582	0.2578	0.2576	0.2637	0.2747	0.2873	0.2959	0.2979
5_1 4_2	0.0260	0.0392	0.0457	0.0530	0.0604	0.0670	0.0736	0.0801	0.0861
5_1 4_3	0.0002	0.0010	0.0018	0.0032	0.0058	0.0088	0.0111	0.0125	0.0137
7_1 6_1	0.415*	0.4035	0.4005	0.3982	0.4025	0.4121	0.4236	0.4319	0.4341
7_1 6_2	0.0163	0.0325	0.0419	0.0515	0.0598	0.0663	0.0722	0.0781	0.0844
9_1 8_1	0.5714	0.5561	0.5489	0.5439	0.5454	0.5524	0.5617	0.5689	0.5709
9_1 8_2	——	0.0187	0.0318	0.0436	0.0533	0.0604	0.0664	0.0725	0.0792
11_1 10_1	——	0.7143	0.7015	0.6933	0.6914	0.6950	0.7017	0.7073	0.7088

Table 3: Values of the theoretical reduced transition probability, $B(E1)$ (in $\mu\,e^2 b$).

This fact has confirmed by studying the staggering effect to palladium isotopes which presented in Fig.5.

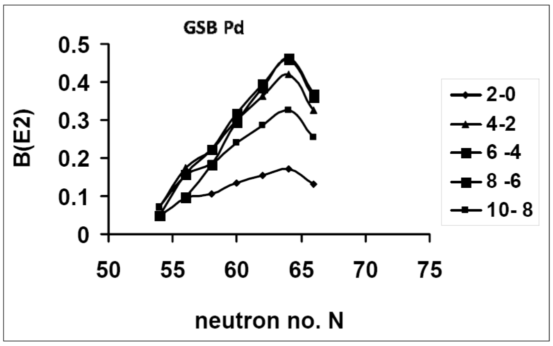

Fig. 3: The calculated $B(E2)$'s for the ground state band.

3.3 The staggering

The presence of $(+ve)$ and $(-ve)$ parity states has encouraged us to study staggering effect [28–30] for $^{100-116}$Pd series of isotopes using staggering function equations (15, 16) with the help of the available experimental data [18–26].

$$Stag(I) = 6\Delta E(I) - 4\Delta E(I-1) - 4\Delta E(I+1) + \Delta E(I+2) + \Delta E(I-2)\,, \quad (13)$$

with

$$\Delta E(I) = E(I+1) - E(I)\,. \quad (14)$$

The calculated staggering patterns are illustrated in Fig. 5 which show an interaction between the $(+ve)$ and $(-ve)$ parity states of $^{100-104}$Pd and $^{112-1116}$Pd nuclei at $I^+ = 12$. Unfortunatelly, there is no enough experimental data are available for $^{106-110}$Pd to study the same effect.

3.4 Conclusions

IBA-1 model has been applied successfully to $^{100-116}$Pd isotopes and we have got:

1. The levels energy are successfully reproduced;
2. The potential energy surfaces are calculated and show vibrational-like to $^{100-110}$Pd, γ-soft to ^{112}Pd and rotational characters to $^{114-116}$Pd isotopes where they are mainly prolate deformed nuclei;
3. Electromagnetic transition rates $B(E1)$ and $B(E2)$ are calculated;
4. Upper bending for $^{100-106}$Pd has been observed at angular momentum $I^+ = 12$ and lower bending at $I^+ = 14$ for all palladium isotopes;
5. Electromagnetic transition rates $B(E1)$ and $B(E2)$ are calculated;and

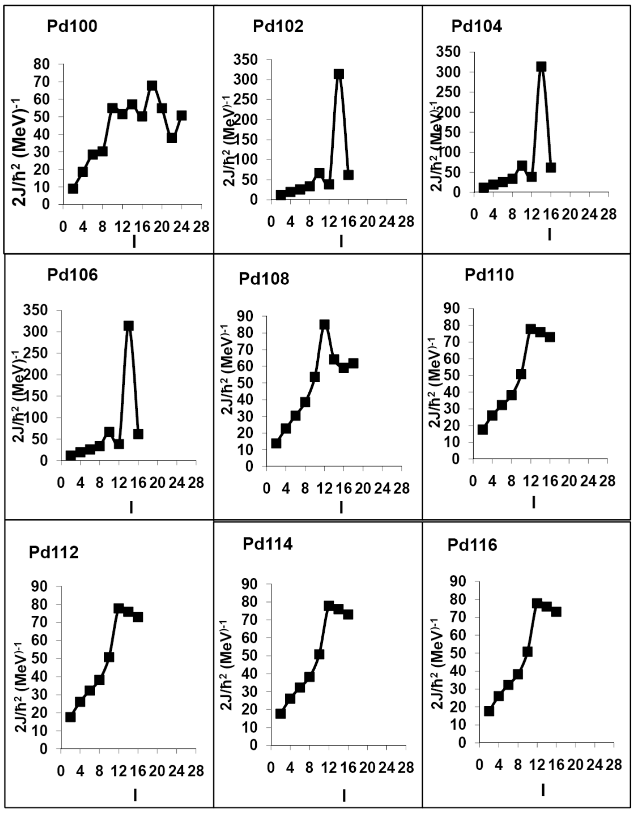

Fig. 4: Angular momentum I as a function of $2J/\hbar^2$.

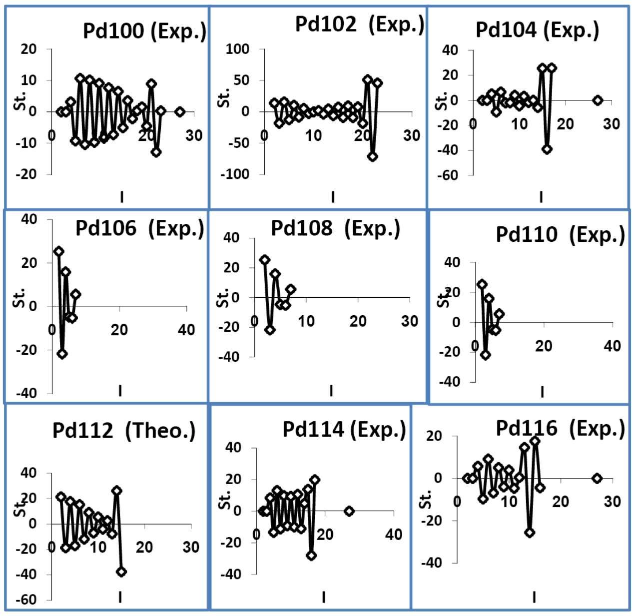

Fig. 5: $\Delta I = 1$, staggering patterns for $^{100-116}$Pd isotopes.

6. Staggering effect and beat patterns are observed and show an interaction between the $(-\mathrm{ve})$and $(+\mathrm{ve})$ parity states at $I^+ = 12$ for palladium isotopes except for $^{106\text{-}110}$Pd where scarce experimental data are available.

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The Apparent Lack of Lorentz Invariance in Zero-Point Fields with Truncated Spectra

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The integrals that describe the expectation values of the zero-point quantum-field-theoretic vacuum state are semi-infinite, as are the integrals for the stochastic electrodynamic vacuum. The unbounded upper limit to these integrals leads in turn to infinite energy densities and renormalization masses. A number of models have been put forward to truncate the integrals so that these densities and masses are finite. Unfortunately the truncation apparently destroys the Lorentz invariance of the integrals. This note argues that the integrals are naturally truncated by the graininess of the negative-energy Planck vacuum state from which the zero-point vacuum arises, and are thus automatically Lorentz invariant.

1 Introduction

Sakharov [1] hypothesized that Newton's gravitational constant is inversely proportional to a truncated integral over the momenta of the virtual particles in the quantum vacuum [2] (QV), and that the cutoff wavenumber "...determines the mass of the heaviest particles existing in nature..." according to a suggestion by M. A. Markov. Inverting the Markov suggestion, the Planck vacuum (PV) model [3, 4] assumes that these "heaviest particles" are the Planck particles (PPs) constituting the degenerate negative-energy PV state, and that it is the separation between these PPs that leads to the cutoff wavenumber. Puthoff [4, 5] furthers the Sakharov argument by calculating the cutoff wavenumber to be

$$k_{c*} = \left(\frac{\pi c^3}{\hbar G}\right)^{1/2} \quad \left[= \frac{\pi^{1/2}}{r_*}\right], \tag{1}$$

where G is Newton's gravitational constant and r_* is the Planck length. The ratio in the bracket is derived by substituting the constants $\hbar = e_*^2/c$, $G = e_*^2/m_*^2$, and the Compton relation $r_* m_* c^2 = e_*^2$ from the PV model, where m_* is the Planck mass and e_* is the bare (true) charge common to the charged elementary particles.

It is accepted knowledge that the truncation of the vacuum integrals destroys their Lorentz invariance. For example, a stochastic electrodynamic version of the zero-point (ZP) electric field can be expressed as [5]

$$\mathbf{E}_{zp}(\mathbf{r},t) = \mathrm{Re} \sum_{\sigma=1}^{2} \int d\Omega_k \int_0^{k_{c*}} dk\, k^2\, \mathbf{e}_\sigma(\mathbf{k})\, A_k \times$$
$$\times \exp\left[\, i\left(\mathbf{k}\cdot\mathbf{r} - \omega t + \Theta_\sigma(\mathbf{k})\right)\right], \tag{2}$$

where the cutoff wavenumber k_{c*} apparently destroys the Lorentz invariance of the field. The accepted Lorentz-invariant version of (2) replaces k_{c*} by ∞. By giving the cutoff wavenumber an interpretation different from a momentum wavenumber, however, this note argues that (2) is Lorentz invariant as it stands. The next section presents this argument.

The virtual-particle field consists of virtual photons and massive virtual-particle pairs, the collection being the QV. It is assumed that the structure of the PV and the ZP agitation of its PPs are responsible for the structure of the virtual-particle field, the corresponding average of the photon field being the ZP electric field in (2). While the negative-energy PV is assumed to be invisible (not directly observable), it offspring the QV appears in free space and interacts with the free particles therein. The argument in the next section assumes this perspective.

2 Cutoff wavenumber

The set of orthogonal modes associated with a continuous medium contains an infinite number of eigenfunctions. If the medium is quasi-continuous like the PV, however, the number is finite. Using this fact, the development of the ZP electric field is reviewed below to show that the cutoff wavenumber is associated with the number of PPs per unit volume in the PV and is not fundamentally a momentum wavenumber for the QV fields. Thus being associated with the PP density, the cutoff wavenumber is not dependent upon the free-space Lorentz frames observing the QV.

The ZP electric field can be expressed as [6, p.73]

$$\mathbf{E}_{\mathrm{zp}}(\mathbf{r},t) = \left(\frac{8\pi^3}{V}\right)^{1/2} \times$$
$$\times\ \mathrm{Re} \sum_\sigma \sum_{\mathbf{n}} \mathbf{e}_{\mathbf{k},\sigma} A_k \exp\left[\, i\left(\mathbf{k}\cdot\mathbf{r} - \omega t + \Theta_{\mathbf{k},n}\right)\right], \tag{3}$$

where the first sum is over the two polarizations of the field, $k = |\mathbf{k}|$, $V = L^3$ is the box-normalization volume, $\mathbf{e}_{\mathbf{k},\sigma}$ is the polarization vector,

$$\pi^2 A_k^2 = \frac{\hbar\omega}{2} = \frac{e_*^2 k}{2} \tag{4}$$

yields the amplitude factor A_k which is proportional to the bare charge e_* of the PPs in the PV, and Θ_σ is the random phase that gives $\mathbf{E}_{\text{zp}}$ its stochastic character. The two ratios in (4) are the ZP energy of the individual field modes. The field satisfies the periodicity condition

$$\mathbf{E}_{\text{zp}}(x+L,\ y+L,\ z+L,t) = \mathbf{E}_{\text{zp}}(x,y,z,t) \tag{5}$$

or equivalently

$$\mathbf{k} = (k_x,k_y,k_z) = (2\pi/L)(n_x,n_y,n_z) = (2\pi/L)\,\mathbf{n}\,, \tag{6}$$

where $k = (2\pi/L)\,n$, and where ordinarily the n_i can assume any positive or negative integer and zero.

An unbounded mode index n_i in (6) leads to the infinite energy densities and renormalization masses that plague both the quantum field theory and the stochastic electrodynamic theory. However, if the normal mode functions of the ZP field are assumed to be waves supported by the collection of PPs within the PV [4], then the number of modes n_i along the side of the box of length L is bounded and obeys the inequality $|n_i| \leqslant (L/2\pi)\,k_{c*} = L/2\sqrt{\pi}\,r_*$. So it is the "graininess" ($r_* \neq 0$) associated with the minimum separation r_* of the PPs that leads to a bounded k_i and n_i for (6), and which is thus responsible for finite energy densities and renormalization masses [4]. Unfortunately this truncation of the second sum in (3) leads to apparently non-Lorentz-invariant integrals for the "continuum" version of that equation developed below.

Using the replacement [6, p.76]

$$\sum_\sigma \sum_{\mathbf{n}} f(\mathbf{k}_{\mathbf{n}}, \mathbf{e}_{\mathbf{n},\sigma})\,a_{\mathbf{n},\sigma} \longrightarrow \tag{7}$$

$$\longrightarrow \left(\frac{V}{8\pi^3}\right)^{1/2} \sum_\sigma \int d^3k\, f(\mathbf{k}, \mathbf{e}_\sigma(\mathbf{k}))\,a_\sigma(\mathbf{k}) \tag{8}$$

in (3) and truncating the field densities at $k_{c*} = \sqrt{\pi}/r_*$ leads to [4, 5]

$$\begin{aligned}\mathbf{E}_{\text{zp}}(\mathbf{r},t) &= \text{Re}\sum_\sigma \int d^3k\,\mathbf{e}_\sigma(\mathbf{k})\,A_k \,\times \\ &\times \exp\left[\,i\,(\mathbf{k}\cdot\mathbf{r} - \omega t + \Theta_\sigma(\mathbf{k}))\,\right] = \\ &= \text{Re}\sum_\sigma \int d\Omega_k \int_0^{k_{c*}} dk\,k^2\,\mathbf{e}_\sigma(\mathbf{k})\,A_k \,\times \\ &\times \exp\left[\,i\,(\mathbf{k}\cdot\mathbf{r} - \omega t + \Theta_\sigma(\mathbf{k}))\,\right],\end{aligned} \tag{9}$$

where $d\Omega_k$ is the k-space solid-angle differential. As shown below in (10) and(11) this cutoff wavenumber k_{c*} is fundamentally related to the number of PPs per unit volume constituting the PV.

The ZP electromagnetic energy density of the QV calculated from (8) is

$$\frac{\langle \mathbf{E}_{\text{zp}}^2 \rangle}{4\pi} = \int_0^{k_{c*}} \frac{e_*^2 k}{2}\cdot\frac{k^2\,dk}{\pi^2}\,, \tag{10}$$

where the first ratio under the integral sign is the ZP energy of the individual modes. The second ratio is the number of modes per unit volume between k and $k+dk$; so the number of modes in that range is $k^2V\,dk/\pi^2$. If the total number of PP oscillators (with three degrees of freedom each) in the volume V is N, then the total number of modes in V is [7]

$$\int_0^{k_{c*}} \frac{k^2V\,dk}{\pi^2} = 3N\,, \tag{11}$$

which provides an estimate for N/V. Integrating (10) gives

$$\frac{N}{V} = \frac{k_{c*}^3}{9\pi^2}\ \left[= (9^{1/3}\pi^{1/6}r_*)^{-3} \approx \frac{1}{(2.5\,r_*)^3}\right] \tag{12}$$

for the number of PPs per unit volume. The equation outside the brackets shows that k_{c*} is proportional to the cube root of this PP density. The ratio in the bracket shows that the average separation of the PPs is approximately 2.5 times their Compton radii r_*, a very reasonable result considering the roughness of the calculations.

From (11) the previous paragraph shows that the cutoff wavenumber k_{c*} in (8) and (9) is associated with the mode counting in (10) taking place within the invisible PV. Since the number of these PV modes is not influenced by the free-space Lorentz frame observing the QV, the k_{c*} in (8) and (9) must be independent of the Lorentz frame. Thus (8) and (9) are Lorentz invariant as they stand since k_{c*} is frame independent and the integrands are already Lorentz invariant [8]. That is, when viewed from different Lorentz frames, the wavenumber k_{c*} remains the same; so the integrals are Lorentz invariant.

3 Review and comments

From the beginning of the ZP theory the medium upon which calculations are based is the free-space continuum with its unbounded mode density. So if the spectral density is truncated, the ZP fields naturally lose their Lorentz-invariant character because the truncation and the Lorentz viewing frames exist in the same space. This contrasts with the development in the preceding section where the truncation takes place in the invisible PV while the viewing is in the free space containing the QV.

One way of truncating in free space without losing Lorentz invariance [9, 10] is to assume that the so-called elementary particles are constructed from small sub-particles called partons, so that the components of the parton driving-field $\mathbf{E}_{\text{zp}}$ with wavelengths smaller than the parton size ($\sim r_*$) are ineffective in producing translational motion of the parton as a whole, effectively truncating the integral expressions at or near the Planck frequency c/r_*. The parton mass turns out to be

$$m_0 = \frac{2}{3}\left(\frac{m_*^2}{m}\right) = \frac{2}{3}\left(\frac{r_c}{r_*}\right) m_* \sim 10^{20}\,m_* \tag{13}$$

where m_* is the Planck mass, m is the particle mass, and r_c is the particle Compton radius. The parenthetical ratio in the second expression is roughly 10^{20} for the observed elementary particles; i.e., for the observed particles, the parton mass is about twenty orders of magnitude greater than the Planck mass.

It is difficult to explain the inordinately large ($10^{20} m_*$) parton mass in (12) that is due to the equation of motion

$$m_0 \ddot{\mathbf{r}} = e_* \mathbf{E}_{\mathrm{zp}} \tag{14}$$

at the core of the Abraham-Lorentz-Dirac equation used in [9], where $\ddot{\mathbf{r}}$ is the acceleration of the mass about its average position at $\langle \mathbf{r} \rangle = 0$. Equation (13) is easily transformed into the equation of motion

$$e_* \ddot{\mathbf{r}} = \frac{3c^3 \Gamma}{2} \mathbf{E}_{\mathrm{zp}} \tag{15}$$

for the charge e_*, where $\ddot{\mathbf{r}}$ is the charge acceleration. If the time constant Γ is treated as a constant to be determined from experiment [4, 5], then solving (14) leads to

$$\Gamma = \left(\frac{r_*}{r_c} \right) \frac{r_*}{c} \sim 10^{-20} \, \frac{r_*}{c} \,, \tag{16}$$

where r_*/c is the Planck time. Unlike the m_0 in (12) and (13), this inordinately small time constant can be accounted for: it is due to the large number ($N/V \sim 10^{97}$ per cm^3) of agitated PPs in the PV contributing simultaneously to the ZP field fluctuations described by (8). It is noted in passing that the size of the parton ($\sim r_*$) is not connected to its mass m_0 by the usual Compton relation (i.e., $r_* m_0 c^2 \neq e_*^2$) as is the case for the PP ($r_* m_* c^2 = e_*^2$).

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On the Tidal Evolution of the Earth-Moon System: A Cosmological Model

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We have presented a cosmological model for the tidal evolution of the Earth-Moon system. We have found that the expansion of the universe has immense consequences on our local systems. The model can be compared with the present observational data. The close approach problem inflicting the known tidal theory is averted in this model. We have also shown that the astronomical and geological changes of our local systems are of the order of Hubble constant.

1 Introduction

The study of the Earth-Moon-Sun system is very important and interesting. Newton's laws of motion can be applied to such a system and good results are obtained. However, the correct theory to describe the gravitational interactions is the general theory of relativity. The theory is prominent in describing a compact system, such as neutron stars, black hole, binary pulsars, etc. Einstein theory is applied to study the evolution of the universe. We came up with some great discoveries related to the evolution of the universe. Notice that the Earth-Moon system is a relatively old system (4.5 billion years) and would have been affected by this evolution. Firstly, the model predicts the right abundance of Helium in the universe during the first few minutes after the big bang. Secondly, the model predicts that the universe is expanding and that it is permeated with some relics photons signifying a big bang nature. Despite this great triumphs, the model is infected with some troubles. It is found the age of the universe determined according to this model is shorter than the one obtained from direct observations. To resolve some of these shortcomings, we propose a model in which vacuum decays with time couples to matter. This would require the gravitational and cosmological constant to vary with time too. To our concern, we have found that the gravitational interactions in the Newtonian picture can be applied to the whole universe provided we make the necessary arrangement. First of all, we know beforehand that the temporal behavior is not manifested in the Newton law of gravitation. It is considered that gravity is static. We have found that instead of considering perturbation to the Earth-Moon system, we suggest that these effect can be modeled with having an effective coupling constant (G) in the ordinary Newton's law of gravitation. This effective coupling takes care of the perturbations that arise from the effect of other gravitational objects. At the same time the whole universe is influenced by this setting. We employ a cosmological model that describes the present universe and solves many of the cosmological problems. To our surprise, the present cosmic acceleration can be understood as a counteract due to an increasing gravitational strength. The way how expansion of the universe affects our Earth-Moon system shows up in changing the length of day, month, distance, etc. These changes are found in some biological and geological systems. In the astronomical and geological frames changes are considered in terms of tidal effects induced by the Moon on the Earth. However, tidal theory runs in some serious difficulties when the distance between Earth and Moon is extrapolated backwards. The Moon must have been too close to the Earth a situation that has not been believed to have happened in our past. This will bring the Moon into a region that will make the Moon rather unstable, and the Earth experiencing a big tide that would have melted the whole Earth. We have found that one can account for this by an alternative consideration in which expansion of the universes is the main cause.

2 Tidal theory

We know that the Earth-Moon system is governed by Kepler's laws. The rotation of the Earth in the gravity field of the Moon and Sun imposes periodicities in the gravitational potential at any point on the surface. The most obvious effect is the ocean tide which is greater than the solid Earth tide. The potential arising from the combination of the Moon's gravity and rotation with orbital angular velocity (ω_L) about the axis through the common center of mass is (Stacey, 1977 [1])

$$V = -\frac{Gm}{R'} - \frac{1}{2}\,\omega_L^2 r^2\,, \tag{1}$$

where m is the mass of the Moon, and from the figure below one has

$$\left.\begin{aligned} R'^2 &= R^2 + a^2 - 2aR\cos\psi \\ r^2 &= b^2 + a^2\sin^2\theta - 2ab\cos\psi \end{aligned}\right\}, \tag{2}$$

where $\cos\psi = \sin\theta\cos\lambda$, $b = \frac{m}{M+m}R$, while a is the Earth's radius.

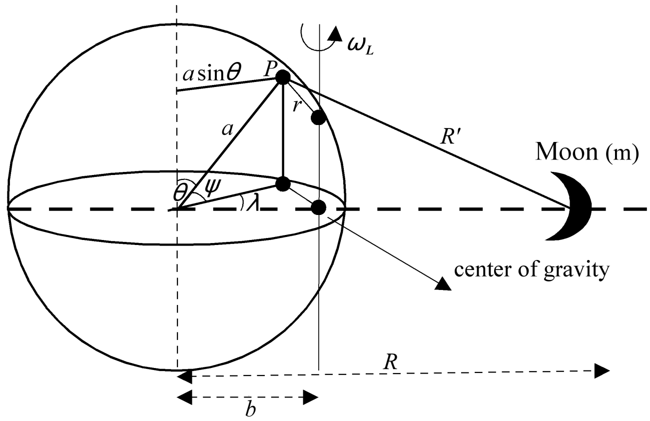

Fig. 1: The geometry of the calculation of the tidal potential of the Moon and a point P on the Earth's surface.

From Kepler's third law one finds

$$\omega_L^2 R^3 = G(M+m)\,, \tag{3}$$

where M is the Earth's mass, so that one gets for $a \ll R$

$$V = -\frac{Gm}{R}\left(1+\frac{1}{2}\frac{m}{M+m}\right) - \\ -\frac{Gma^2}{R^3}\left(\frac{3}{2}\cos\psi - \frac{1}{2}\right) - \frac{1}{2}\,\omega_L^2 a^2 \sin^2\theta\,. \tag{4}$$

The first term is a constant that is due to the gravitational potential due to the Moon at the center of the Earth, with small correction arising from the mutual rotation. The second term is the second order zonal harmonics and represents a deformation of the equipotential surface to a prolate ellipsoid aligned with the Earth-Moon axis. Rotation of the Earth is responsible for the tides. We call the latter term tidal potential and define it as

$$V_2 = -\frac{Gma^2}{R^3}\left(\frac{3}{2}\cos\psi - \frac{1}{2}\right). \tag{5}$$

The third term is the rotational potential of the point P about an axis through the center of the Earth normal to the orbital plane. This does not have a tidal effect because it is associated with axial rotation and merely becomes part of the equatorial bulge of rotation. Due to the deformation an additional potential $k_2 V_2$ (k_2 is the Love number) results, so that at the distance (R) of the Moon the form of the potential due to the tidal deformation of the Earth is

$$V_T = k_2 V_2 = k_2\left(\frac{a}{R}\right)^3 = -\frac{Gma^5}{R^6}\left(\frac{3}{2}\cos\psi - \frac{1}{2}\right). \tag{6}$$

We can now identify ψ with ϕ_2: the angle between the Earth-Moon line and the axis of the tidal bulge, to obtain the tidal torque (τ) on the Moon:

$$\tau = m\left(\frac{\partial V_T}{\partial\psi}\right)_{\psi=\phi_2} = \frac{3}{2}\left(\frac{Gm^2a^5k_2}{R^6}\right)\sin 2\phi_2\,. \tag{7}$$

The torque causes an orbital acceleration of the Earth and Moon about their common center of mass; an equal and opposite torque exerted by the Moon on the tidal bulge slows the Earth's rotation. This torque must be equated with the rate of change of the orbital angular momentum (L), which is (for circular orbit)

$$L = \left(\frac{M}{M+m}\right) R^2\omega_L\,, \tag{8}$$

upon using (3) one gets

$$L = \frac{Mm}{M+m}(GR)^{\frac{1}{2}}\,, \qquad L = \frac{MmG^{\frac{2}{3}}}{(M+m)^{\frac{1}{3}}}\,\omega_L^{-\frac{1}{3}}\,. \tag{9}$$

The conservation of the total angular momentum of the Earth-Moon system (J) is a very integral part in this study. This can be described as a contribution of two terms: the first one due to Earth axial rotation ($S = C\omega$) and the second term due to the Moon orbital rotation (L). Hence, one writes

$$J = S + L = C\omega + \left(\frac{Mm}{M+m}\right) R^2\omega_L\,. \tag{10}$$

We remark here to the fact that of all planets in the solar system, except the Earth, the orbital angular momentum of the satellite is a small fraction of the rotational angular momentum of the planet. Differentiating the above equation with respect to time t one gets

$$\tau = \frac{dL}{dt} = \frac{L}{2R}\frac{dR}{dt} = -\frac{dS}{dt}\,. \tag{11}$$

The corresponding retardation of the axial rotation of the Earth, assuming conservation of the total angular momentum of the Earth-Moon system, is

$$\frac{d\omega}{dt} = -\frac{\tau}{C}\,, \tag{12}$$

assuming C to be constant, where C is the axial moment of inertia of the Earth and its present value is ($C_0 = 8.043\times 10^{37}$ kg m^{-3}). It is of great interest to calculate the rotational energy dissipation in the Earth-Moon system. The total energy (E) of the Earth-Moon system is the sum of three terms: the first one due to axial rotation of the Earth, the second is due to rotation of the Earth and Moon about their center of mass, and the third one is due to the mutual potential energy. Accordingly, one has

$$E = \frac{1}{2}C\omega^2 + \frac{1}{2}R^2\omega_L^2\left(\frac{Mm}{M+m}\right) - \frac{GMm}{R}\,, \tag{13}$$

and upon using (3) become

$$E = \frac{1}{2}C\omega^2 - \frac{1}{2}\frac{GMm}{R}\,. \tag{14}$$

Thus

$$\frac{dE}{dt} = C\omega\frac{d\omega}{dt} - \frac{1}{2}\frac{GMm}{R^2}\frac{dR}{dt}\,, \tag{15}$$

using (8), (11) and (12) one gets

$$\frac{dE}{dt} = -\,\tau(\omega - \omega_L)\,. \tag{16}$$

3 Our cosmological model

Instead of using the tidal theory described above, we rather use the ordinary Kepler's and Newton law of gravitational. We have found that the gravitation constant G can be written as (Arbab, 1997 [2])

$$G_{\text{eff}} = G_0 f(t)\,, \tag{17}$$

where $f(t)$ is some time dependent function that takes care of the expansion of the universe. At the present time we have $f(t_0) = 1$. It seems as if Newton's constant changes with time. In fact, we have effects that act as if gravity changes with time. These effects could arise from any possible source (internal or external to Earth). This variation is a modeled effect due to perturbations received from distant matter. This reflects the idea of Mach who argued that distant matter affects inertia. We note here the exact function $f(t)$ is not known exactly, but we have its functional form. It is of the form $f(t) \propto t^n$, where $n > 0$ is an undetermined constant which has to be obtained from experiment (observations related to the Earth-Moon system). Unlike Dirac hypothesis in which G is a decreasing function of time, our model here suggests that G increases with time. With this prescription in hand, the forms of Kepler's and Newton's laws preserve their form and one does not require any additional potential (like those appearing in (5) and (6)) to be considered. The total effect of such a potential is incorporated in G_{eff}. We have found recently that (Arbab, 1997 [2])

$$f(t) = \left(\frac{t}{t_0}\right)^{1.3}, \tag{18}$$

where t_0 is the present age of the universe, in order to satisfy Wells and Runcorn data (Arbab, 2004 [3]).

3.1 The Earth-Sun system

The orbital angular momentum of the Earth is given by

$$L_S = \left(\frac{M}{M + M_\odot}\right) R_E^2 \Omega\,, \tag{19}$$

or equivalently,

$$\left.\begin{aligned} L_S &= \left(\frac{M M_\odot}{M + M_\odot}\right) (G_{\text{eff}} R_E)^{\frac{1}{2}} \\ L_S &= \left(\frac{M M_\odot}{M + M_\odot}\right)^{\frac{1}{3}} \left(\frac{G_{\text{eff}}^2}{\Omega}\right)^{\frac{1}{3}} \end{aligned}\right\}, \tag{20}$$

where we have replace G by G_{eff}, and Ω is the orbital angular velocity of the Earth about the Sun. The length of the year (Y) is given by Kepler's third law as

$$Y^2 = \left(\frac{4\pi^2}{G_{\text{eff}}(M_\odot + M)}\right) R_E^3\,, \tag{21}$$

where R_E is the Earth-Sun distance. We normally measure the year not in a fixed time but in terms of number of days. If the length of the day changes, the number of days in a year also changes. This induces an apparent change in the length of year. From (20) and (21) one obtains the relation

$$L_S^3 = N_1 G_{\text{eff}} Y^2\,, \tag{22}$$

and

$$L_S^2 = N_2 G_{\text{eff}} R_E\,, \tag{23}$$

where N_1, N_2 are some constants involving (m, M, $M_\odot$). Since the angular momentum of the Earth-Sun remains constant, one gets the relation (Arbab, 2009 [4])

$$Y = Y_0 \left(\frac{G_0}{G_{\text{eff}}}\right)^2, \tag{24}$$

where Y is measured in terms of days, $Y_0 = 365.24$ days. Equation (23) gives

$$R_E = R_E^0 \left(\frac{G_0}{G_{\text{eff}}}\right), \tag{25}$$

where $R_E^0 = 1.496\times10^{11}$ m. To preserve the length of year (in terms of seconds) we must have the relation

$$D = D_0 \left(\frac{G_{\text{eff}}}{G_0}\right)^2, \tag{26}$$

so that

$$Y_0 D_0 = Y D = 3.155\times10^7 \text{ s}\,. \tag{27}$$

This fact is supported by data obtained from paleontology. We know further that the length of the day is related to ω by the relation $D = \frac{2\pi}{\omega}$. This gives a relation of the angular velocity of the Earth about its self of the form

$$\omega = \omega_0 \left(\frac{G_0}{G_{\text{eff}}}\right)^2. \tag{28}$$

3.2 The Earth-Moon system

The orbital angular momentum of the Moon is given by

$$L = \left(\frac{M}{M + m}\right) R^2 \omega_L \tag{29}$$

or,

$$\left.\begin{aligned} L &= \left(\frac{Mm}{M + m}\right) (G_{\text{eff}} R)^{\frac{1}{2}} \\ L &= \left(\frac{Mm}{M + m}\right)^{\frac{1}{3}} \left(\frac{G_{\text{eff}}^2}{\omega_L}\right)^{\frac{1}{3}} \end{aligned}\right\}, \tag{30}$$

where we have replace G by G_{eff}, and ω_L is the orbital angular velocity of the Moon about the Earth. However, the length of month is not invariant as the angular momentum of the Moon has not been constant over time. It has been found found by Runcorn that the angular momentum of the Moon 370 million years ago (the Devonian era) in comparison to the present one (L_0) to be

$$\frac{L_0}{L} = 1.016 \pm 0.003\,. \tag{31}$$

The ratio of the present angular momentum of the Moon (L) to that of the Earth (S) is given by

$$\frac{L_0}{S_0} = 4.83\,, \tag{32}$$

so that the total angular momentum of the Earth-Moon system is

$$J = L + S = L_0 + S_0 = 3.4738\times10^{34}\ \text{Js}\,. \tag{33}$$

Hence, using (17) and (18), (28), (30) and (31) yield

$$\left.\begin{aligned} & L = L_0\left(\frac{t}{t_0}\right)^{0.44} \\ & \omega = \omega_0\left(\frac{t_0}{t}\right)^{2.6}, \quad \omega_L = \omega_{0L}\left(\frac{t}{t_0}\right)^{1.3} \end{aligned}\right\}, \tag{34}$$

where $t = t_0 - t_b$, t_b is the time measured from the present backward. The length of the sidereal month is given by

$$T = \frac{2\pi}{\omega_L} = T_0\left(\frac{t_0}{t}\right)^{1.3}, \tag{35}$$

where $T_0 = 27.32$ days, and the synodic month is given by the relation

$$T_{sy} = \left(\frac{T}{1-\frac{T}{Y}}\right). \tag{36}$$

We notice that, at the present time, the Earth declaration is -5.46×10^{-22} rad/s^2, or equivalently a lengthening of the day at a rate of 2 milliseconds per century. The increase in Moon mean motion is 9.968×10^{-24} rad/s^2. Hence, we found that $\dot\omega = -54.8\,\dot n$, where $n = \frac{2\pi}{\omega_L}$. The month is found to increase by 0.02788/cy. This variation can be compared with the present observational data.

From (34) one finds

$$\omega\,\omega_L^2 = \omega_0\,\omega_{0L}^2\,. \tag{37}$$

If the Earth and Moon were once in resonance then $\omega = \omega_L \equiv \omega_c$. This would mean that

$$\left.\begin{aligned} & \omega_c^3 = \omega_0\,\omega_{0L}^2 = 516.6\times10^{-18}\ (\text{rad/s})^3 \\ & \omega_c = 8.023\times10^{-6}\ \text{rad/s} \end{aligned}\right\}. \tag{38}$$

This would mean that both the length of day and month were equal. They were both equal to a value of about 9 present days. Such a period has not been possible since when the Earth was formed the month was about 14 present days and the day was 6 hours! Therefore, the Earth and Moon had never been in resonance in the past.

Using the (11) and (34) the torque on the Earth by the Moon is (Arbab, 2005 [4, 5])

$$\tau = -\frac{dL}{dt} = -\frac{dS}{dt}\,, \qquad \tau = -\,\tau_0\left(\frac{t}{t_0}\right)^{0.56}, \tag{39}$$

where $\tau_0 = 3.65\times10^{15}\,\mathrm{N\ m}$. The energy dissipation in the Earth is given by

$$P = \frac{dE}{dt}\,, \quad \frac{dE}{dt} = \frac{d}{dt}\left(\frac{1}{2}\,C\,\omega^2 - \frac{1}{2}\,\frac{G_{\text{eff}}Mm}{R}\right), \tag{40}$$

where R, ω is given by (30) and (34).

We remark that the change in the Earth-Moon-Sun parameters is directly related to Hubble constant (H). This is evident since in our model (see Arbab, 1997 [2]) the Hubble constant varies as $H = 1.11\,t^{-1}$. Hence, one may attribute these changes to cosmic expansion. For the present epoch $t_0 \sim 10^9$ years, the variation of ω, ω_L and D is of the order of H_0 (Arbab, 2009 [4, 5]). This suggests that the cause of these parameters is the cosmic expansion.

Fossils of coral reefs studied by John Wells (Wells, 1963 [7]) revealed that the number of days in the past geologic time was bigger than now. This entails that the length of day was shorter in the past than now. The rotation of the Earth is gradually slowing down at about 2 milliseconds a century. Another method of dating that is popular with some scientists is tree-ring dating. When a tree is cut, you can study a cross-section of the trunk and determine its age. Each year of growth produces a single ring. Moreover, the width of the ring is related to environmental conditions at the time the ring was formed. It is therefore possible to know the length of day in the past from palaeontological studies of annual and daily growth rings in corals, bivalves, and stromatolite. The creation of the Moon was another factor that would later help the planet to become more habitable. When the day was shorter the Earth's spins faster. Hence, the Moon tidal force reduced the Earth's rotational winds. Thus, the Moon stabilizes the Earth rotation and the Earth became habitable. It is thus plausible to say that the Earth must have recovered very rapidly after the trauma of the Moon's formation. It was found that circadian rhythm in higher animals does not adjust to a period of less than 17–19 hours per day. Our models can give clues to the time these animals first appeared (945–1366 million years ago).

This shortening is attributed to tidal forces raised by the Moon on Earth. This results in slowing down the Earth rotation while increasing the orbital motion of the Moon. According to the tidal theory explained above we see that the tidal frictional torque $\tau \propto R^{-6}$ and the amplitude of tides is $\propto R^{-3}$. Hence, both terms have been very big in the past when R was very small. However, even if we assume the rate $\frac{dR}{dt}$ to have been constant as its value now, some billion years ago the Earth-Moon distance R would be very short. This close approach would have been catastrophic to both the Earth and the Moon. The tidal force would have been enough to melt the Earth's crust. However, there appears to be no evidence for such phenomena according to the geologic findings. This fact places the tidal theory, as it stands, in great jeopardy. This is the most embarrassing situation facing the tidal theory.

4 Velocity-dependent Inertia Model

A velocity — dependent inertial induction model is recently proposed by Ghosh (Gosh, 2000 [8]) in an attempt to surmount this difficulty. It asserts that a spinning body slows down in the vicinity of a massive object. He suggested that part of the secular retardation of the Earth's spin and of the Moon's orbital motion can be due to inertial induction by the Sun. If the Sun's influence can make a braking torque on the spinning Earth, a similar effect should be present in the case of other spinning celestial objects. This theory predicts that the angular momentum of the Earth (L'), the torque (τ'), and distance (R') vary as

$$\left.\begin{aligned} L' &= \frac{mM}{(M+m)^{\frac{1}{3}}}\, G_{\text{eff}}^{\frac{2}{3}}\, \omega_L^{-\frac{1}{3}} \\ \tau' &= -\frac{L'}{3\omega_L}\,\dot{\omega}_L \\ \dot{R} &= -\frac{2}{3}\,\frac{R}{\omega_L}\,\dot{\omega}_L \end{aligned}\right\} . \tag{41}$$

The present rate of the secular retardation of the Moon angular speed is found to be $\frac{d\omega_L}{dt} \equiv \dot{\omega}_L \approx 0.27{\times}10^{-23}$ rad s^{-2} leaving a tidal contribution of $\approx -0.11{\times}10^{-23}$ rad s^{-2}. This gives a rate of $\frac{dR}{dt} \equiv \dot{R} = -0.15{\times}10^{-9}$ m s^{-1}. Now the apparent lunar and solar contributions amount to $\approx 2.31{\times}10^{-23}$ rad s^{-2} and $\approx 1.65{\times}10^{-23}$ rad s^{-2} respectively. The most significant result is that $\frac{dR}{dt}$ is negative and the magnitude is about one tenth of the value derived using the tidal theory only. Hence, Ghosh concluded that the Moon is actually approaching the Earth with a vary small speed, and hence there is no close-approach problem. Therefore, this will imply that the tidal dissipation must have been much lower in the Earth's early history.

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Parameters for Viability Check on Gravitational Theories Regarding the Experimental Data

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Parameterized post-Newtonian formalism requires an existence of a symmetric metric in a gravitational theory in order to perform a viability check regarding the experimental data. The requirement of a symmetric metric is a strong constraint satisfied by very narrow class of theories. In this letter we propose a viability check of a theory using the corresponding theory equations of motion. It is sufficient that a connection exists, not necessarily a metrical one. The method is based on an analysis of the Lorentz invariant terms in the equations of motion. An example of the method is presented on the Einstein-Infeld-Hoffmann equations.

1 Introduction

The parameterized post-Newtonian (PPN) formalism is a tool used to compare classical theories of gravitation in the limit of weak field generated by objects moving slowly compared to c. It is applicable only for symmetric metric theories of gravitation that satisfy the Einstein equivalence principle.

Each parameter in PPN formalism is a measure of departure of a theory from Newtonian gravity represented by several parameters. Following the Will notation [1], there are ten parameters: γ, β, ξ, α_1, α_2, α_3, ζ_1, ζ_2, ζ_3, ζ_4; γ is a measure of space curvature; β measures the nonlinearity in superposition of gravitational fields; ξ is a check for preferred location effects, i.e. a check for a violation of the strong equivalence principle (SEP) whether the outcomes of local gravitational experiments depend on the location of the laboratory relative to a nearby gravitating body; α_1, α_2, α_3 measure the extent and nature of preferred-frame effects, i.e. how much SEP is violated by predicting that the outcomes of local gravitational experiments may depend on the velocity of the laboratory relative to the mean rest frame of the universe; ζ_1, ζ_2, ζ_3, ζ_4 and α_3 measure the extent and nature of breakdowns in global conservation laws. The PPN metric components are

$$\begin{aligned} g_{00} &= -1+2U-2\beta U^2-2\xi\Phi_W+(2\gamma+2+\alpha_3+\zeta_1-2\xi)\,\Phi_1+ \\ &+ 2\,(3\gamma-2\beta+1+\zeta_2+\xi)\,\Phi_2+2\,(1+\zeta_3)\,\Phi_3+ \\ &+ 2\,(3\gamma+3\zeta_4-2\xi)\,\Phi_4-(\zeta_1-2\xi)\,A-(\alpha_1-\alpha_2-\alpha_3)w^2U- \\ &- \alpha_2 w^i w^j U_{ij}+(2\alpha_3-\alpha_1)\,w^i V_i+O(\epsilon^3)\,, \end{aligned} \tag{1.1}$$

$$\begin{aligned} g_{0i} &= -\tfrac{1}{2}\,(4\gamma+3+\alpha_1-\alpha_2+\zeta_1-2\eta)\,V_i- \\ &- \tfrac{1}{2}\,(1+\alpha_2-\zeta_1+2\xi)\,W_i- \\ &- \tfrac{1}{2}\,(\alpha_1-2\alpha_2)\,w^i U-\alpha_2 w^j U_{ij}+O(\epsilon^{5/2})\,, \end{aligned} \tag{1.2}$$

$$g_{ij} = (1+2\gamma U)\,\delta_{ij}+O(\epsilon^2)\,, \tag{1.3}$$

where w^i is the coordinate velocity of the PPN coordinate system relative to the mean rest-frame of the universe and U, U_{ij}, Φ_W, A, Φ_1, Φ_2, Φ_3, Φ_4, V_i and W_i are the metric potentials constructed from the matter variables and have similar form as the Newtonian gravitational potential [1, 2].

The theories that can be compared using PPN formalism are straightforward alternatives to GR. The bounds on the PPN parameters are not the ultimate criteria for viability of a gravitational theory, because many theories can not be compared using PPN formalism. For example, Misner et al. [3] claim that Cartan's theory is the only non-metric theory to survive all experimental tests up to that date and Turyshev [4] lists Cartan's theory among the few that have survived all experimental tests up to that date. There are general viability criteria [5] for a gravitational theory: (i) is it self-consistent? (ii) is it complete? (iii) does it agree, to within several standard deviations, with all experiments performed to date?

For a symmetric metric theory, the answer of (iii) is consisted in checking the PPN parameters. But, for a non-symmetric or a non-metric theory there is not a convenient method. So, we propose a method for checking (iii) even in the cases when the PPN formalism can not be applied such as non-symmetric metric and non-metric theories. It is based on a Lorentz invariance analysis of all terms in the equations of motion of the corresponding theory. Since there is no general equations of motion formula for all theories, we give an example of the method on the Einstein-Infeld-Hoffmann (EIH) equations. However, the general principle of the method can be applied to any other theory in which the equations of motion can be derived, no matter whether the theory includes a metric or not.

2 Lorentz invariant terms in the EIH equations

Given a system of n bodies, the equations of motion of the j-th body is

$$\frac{d^2\vec r_j}{dt^2} = \sum_{i\neq j}\frac{(\vec r_i-\vec r_j)Gm_i}{r_{ij}^3}\Bigg[1-\frac{3}{2c^2}\frac{[\dot{\vec r}_i\cdot(\vec r_j-\vec r_i)]^2}{r_{ij}^2} - \frac{2(\beta+\gamma)}{c^2}\sum_{k\neq j}\frac{Gm_k}{r_{jk}} - \frac{2\beta-1}{c^2}\sum_{k\neq i}\frac{Gm_k}{r_{ik}} + \frac{1}{2c^2}(\vec r_i-\vec r_j)\,\dot{\vec v}_i - \frac{2(1+\gamma)}{c^2}\,\dot{\vec r}_i\dot{\vec r}_j + \gamma\Big(\frac{v_j}{c}\Big)^2 + (1+\gamma)\Big(\frac{v_i}{c}\Big)^2\Bigg] + \frac{1}{c^2}\sum_{i\neq j}\frac{Gm_i}{r_{ij}^3}\Big((\vec r_j-\vec r_i)\cdot\big((2+2\gamma)\dot{\vec r}_j-(1+2\gamma)\dot{\vec r}_i\big)\Big)\times(\dot{\vec r}_j-\dot{\vec r}_i) + \frac{3+4\gamma}{2c^2}\sum_{i\neq j}\frac{Gm_i}{r_{ij}}\,\dot{\vec v}_i\,, \tag{2.1}$$

where $\vec r_s$ is the radius-vector of the s-th body, $\vec v_s = \dot{\vec r}_s$ is the velocity of the s-th body and upper dot marks the differentiation with time. Formula (2.1) can be rearranged in the form

$$\frac{d^2\vec r_j}{dt^2} = \sum_{i\neq j}\frac{(\vec r_i-\vec r_j)Gm_i}{r_{ij}^3}\Bigg[1-\frac{3}{2c^2}\frac{[\dot{\vec r}_i\cdot(\vec r_j-\vec r_i)]^2}{r_{ij}^2} + \frac{1}{c^2}\sum_{k\neq i}\frac{Gm_k}{r_{ik}} + \frac{1}{2c^2}(\vec r_i-\vec r_j)\,\dot{\vec v}_i - \frac{2}{c^2}\,\dot{\vec r}_i\dot{\vec r}_j + \Big(\frac{v_i}{c}\Big)^2\Bigg] + \frac{1}{c^2}\sum_{i\neq j}\frac{Gm_i}{r_{ij}^3}\Big((\vec r_j-\vec r_i)\cdot(2\dot{\vec r}_j-\dot{\vec r}_i)\Big)(\dot{\vec r}_j-\dot{\vec r}_i) + \frac{3}{2c^2}\sum_{i\neq j}\frac{Gm_i}{r_{ij}}\,\dot{\vec v}_i + \gamma\Bigg[\sum_{i\neq j}\frac{(\vec r_i-\vec r_j)Gm_i}{r_{ij}^3}\times\Bigg(-\frac{2}{c^2}\sum_{k\neq j}\frac{Gm_k}{r_{jk}} + \frac{1}{2c^2}(\vec r_i-\vec r_j)\,\dot{\vec v}_i + \frac{1}{c^2}(\dot{\vec r}_i-\dot{\vec r}_j)^2\Bigg) + \frac{2}{c^2}\sum_{i\neq j}\frac{Gm_i}{r_{ij}^3}\Big((\vec r_j-\vec r_i)\cdot(\dot{\vec r}_j-\dot{\vec r}_i)\Big)(\dot{\vec r}_j-\dot{\vec r}_i) + \frac{2}{c^2}\sum_{i\neq j}\frac{Gm_i}{r_{ij}}\,\dot{\vec v}_i\Bigg] - \beta\,\frac{2}{c^2}\Bigg[\sum_{i\neq j}\frac{(\vec r_i-\vec r_j)Gm_i}{r_{ij}^3}\times\Bigg(\sum_{k\neq j}\frac{Gm_k}{r_{jk}} + \sum_{k\neq i}\frac{Gm_k}{r_{ik}}\Bigg)\Bigg]. \tag{2.2}$$

The second and the third term are of order c^{-2} and each of them is Lorentz invariant, neglecting the terms of order c^{-4} and smaller, i.e. they take same values in all inertial systems. So, (2.2) means

$$\frac{d^2\vec r_j}{dt^2} = \sum_{i\neq j}\Bigg\{-\frac{(\vec r_j-\vec r_i)Gm_i}{r_{ij}^3}\Bigg[1-\frac{3}{2}\frac{[\vec v_i\cdot(\vec r_j-\vec r_i)]^2}{r_{ij}^2c^2} + \frac{v_i^2}{c^2} - 2\,\frac{\vec v_i\cdot\vec v_j}{c^2}\Bigg] + \frac{Gm_i}{r_{ij}^3c^2}\,(\vec v_j-\vec v_i)\big[(\vec r_j-\vec r_i)\cdot\vec v_j\big]\Bigg\} + \text{Lorentz invariant terms.} \tag{2.3}$$

Every single Lorentz invariant term in (2.2), i.e. in (2.3), can be replaced by a term proportional to the corresponding Lorentz invariant term, so

$$\frac{d^2\vec r_j}{dt^2} = \sum_{i\neq j}\Bigg\{-\frac{(\vec r_j-\vec r_i)Gm_i}{r_{ij}^3}\Bigg[1-\frac{3}{2}\frac{[\vec v_i\cdot(\vec r_j-\vec r_i)]^2}{r_{ij}^2c^2} + \frac{v_i^2}{c^2} - 2\,\frac{\vec v_i\cdot\vec v_j}{c^2}\Bigg] + \frac{Gm_i}{r_{ij}^3c^2}\,(\vec v_j-\vec v_i)[(\vec r_j-\vec r_i)\cdot\vec v_j] + A\,\frac{(\vec r_i-\vec r_j)Gm_i}{r_{ij}^3}\,\frac{(\vec v_i-\vec v_j)^2}{c^2} + B\,\frac{(\vec r_i-\vec r_j)Gm_i}{r_{ij}^3c^2}\times[(\vec r_i-\vec r_j)\cdot\dot{\vec v}_i] + C\,\frac{Gm_i}{r_{ij}c^2}\,\dot{\vec v}_i + D\,\frac{Gm_i}{r_{ij}^3c^2}\,(\vec v_j-\vec v_i)\times[(\vec r_j-\vec r_i)\cdot(\vec v_j-\vec v_i)] + E\sum_{k\neq i,j}\frac{(\vec r_i-\vec r_j)Gm_i}{r_{ij}^3}\,\frac{Gm_k}{r_{ki}c^2} + F\sum_{k\neq i,j}\frac{(\vec r_i-\vec r_j)Gm_i}{r_{ij}^3}\,\frac{Gm_k}{r_{kj}c^2}\Bigg\}. \tag{2.4}$$

The bounds on the parameters A, B, C, D, E and F can be determined directly from the experimental data. Now, the viability check of any gravitational theory regarding the agreement on the experimental data would be consisted in checking how the theory fits in the bounds of the new parameters.

3 Conclusion

In this letter we introduced a new approach of viability check of gravitational theories regarding the experimental data, based on the analysis of the Lorentz invariance of the equations of motion. An example is given for the EIH equations. This method can be applied on any theory that has a connection regardless it is metrical or not. The bounds of the new parameters can be determined directly from the experimental data.

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An Asymptotic Solution for the Navier-Stokes Equation

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We have used as the velocity field of a fluid the functional form derived in Casuso (2007), obtained by studying the origin of turbulence as a consequence of a new description of the density distribution of matter as a modified discontinuous Dirichlet integral. As an interesting result we have found that this functional form for velocities is a solution to the Navier-Stokes equation when considering asymptotic behaviour, i.e. for large values of time.

1 Introduction

The Euler and Navier-Stokes equations describe the motion of a fluid. These equations are to be solved for an unknown velocity vector $\vec{u}(\vec{r}, t)$ and pressure $P(\vec{r}, t)$, defined for position $\vec{r}$ and time $t \geqslant 0$. We restrict attention here to incomprenssible fluids filling all real space. Then the Navier-Stokes equations are: a) Newton's law $\vec{f} = m\vec{a}$ for a fluid element subject to the external force $\vec{g}$ (gravity) and to the forces arising from pressure and friction, and b) The condition of incompressibility. A fundamental problem in the analysis is to find any physically reasonable solution for the Navier-Stokes equation, and indeed to show that such a solution exists. Many numerical computations appear to exhibit blowup for solutions of the Euler equations (the same as Navier-Stokes equations but for zero viscosity), but the extreme numerical instability of the equations makes it very hard to draw reliable conclusions (see Bertozzi and Majda 2002 [1]). Important progress has been made in understanding weak solutions of the Navier-Stokes equations (Leray 1934 [2], Khon and Nirenberg 1982 [3], Scheffer 1993 [4], Schnirelman 1997 [5], Caffarelli and Lin 1998 [6]). This type of solutions means that one integrates the equation against a test function, and then integrates by parts to make the derivatives fall on the test function. In the present paper we test directly the validity of a solution which was obtained previously from the study of turbulence.

2 Demonstration of validity of the asymptotic solution

We start from the Navier-Stokes equation for one-dimension:

$$\frac{\partial u_x}{\partial t} + u_x \frac{\partial u_x}{\partial x} = \nu \frac{\partial^2 u_x}{\partial x^2} - \frac{\partial P}{\partial x} + g\,, \tag{1}$$

where ν is a positive coefficient (viscosity) and g means a nearly constant gravitational force per unit mass (an externally applied force).

Taking from Casuso, 2007 [7], the functional form derived for the velocity of a fluid

$$u_x = -\sum_k \frac{\sin(x_k t)}{it^2}\, e^{it(x+k)} + \text{const}, \tag{2}$$

where $-x_k \leqslant x + k \leqslant x_k$, k describe the central positions of real matter structures such as atomic nuclei and x_k means the size of these structures. Assuming a polytropic relation between pressure P and density ρ via the sound speed s we have:

$$P = s^2 \rho = \frac{s^2}{\pi} \sum_k \int \frac{\sin(x_k t)}{t}\, e^{it(x+k)} dt\,. \tag{3}$$

Puting equations (2) and (3) into equation (1) we obtain:

$$A + B = C + g\,, \tag{4}$$

where

$$A = -\sum_k \left[\frac{\cos(x_k t)}{it^2}\, x_k + \frac{(x+k)}{t^2} \sin(x_k t) + \right.$$
$$\left. + 2\,\frac{\sin(x_k t)}{t^3} \right] e^{it(x+k)}\,, \tag{5}$$

$$B = \left[-\sum_k \frac{\sin(x_k t)}{it^2}\, e^{it(x+k)} + \text{const} \right] \times$$
$$\times \left[-\sum_k \frac{\sin(x_k t)}{t}\, e^{it(x+k)} \right], \tag{6}$$

$$C = \nu \left[-\sum_k i \sin(x_k t)\, e^{it(x+k)} \right] -$$
$$- \frac{is^2}{\pi} \sum_k \int \sin(x_k t)\, e^{it(x+k)}\, dt\,. \tag{7}$$

Now taking the asymptotic approximation, at very large time t, we obtain

$$\nu \sin(x_k t)\, e^{it(x+k)} = -\frac{s^2}{\pi} \int \sin(x_k t)\, e^{it(x+k)} dt + g\,, \tag{8}$$

and differentiating and taking only the real part, we have

$$x_k \cos(x_k t) = -\frac{s^2}{\pi\nu} \sin(x_k t)\,, \tag{9}$$

which is the same as

$$-\frac{x_k \pi \nu}{s^2} = \tan(x_k t) \tag{10}$$

then, in the limiting case (real case) $x_k \to 0$ and, again at very large time t, we have the solutions

$$x_k t = 0, \pi, 2\pi, 3\pi, \ldots, n\pi \tag{11}$$

with n being any integer number. So we have demonstrated that the equation (2) is a solution for the Navier-Stokes equation in one dimension.

Now, for the general case of 3-dimensions we have to generalize the functional form which describes the nature of matter in Casuso, 2007 [7], in the sense of taking a new form for the density

$$\rho = \frac{1}{\pi} \sum_k \int \frac{\sin(r_k t)}{t} \, e^{it(r+k)} \, dt \,, \tag{12}$$

where $r = \sqrt{x^2 + y^2 + z^2}$, and applying the continuity equation

$$\frac{\partial \rho}{\partial t} = -\frac{\partial}{\partial x}(\rho u_x) - \frac{\partial}{\partial y}(\rho u_y) - \frac{\partial}{\partial z}(\rho u_z). \tag{13}$$

Using the condition of incompressibility included in Navier-Stokes equations

$$\mathrm{div}\vec{u} = 0 \tag{14}$$

and assuming isotropy for the velocity field $u_x \simeq u_y \simeq u_z$, we have

$$u_x = u_y = u_z = -\frac{r}{\pi(x+y+z)} \times \\ \times \sum_k \frac{\sin(r_k t)}{it^2} \, e^{i\,t(r+k)} + \mathrm{const}, \tag{15}$$

where $-r_k \leqslant r + k \leqslant r_k$. Including this expression for the velocity in the 3-dimensional Navier-Stokes main equation (taking into account the condition $\mathrm{div}\vec{u} = 0$)

$$\frac{\partial}{\partial t} u_x = \nu \left[\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} \right] u_x - \frac{\partial P}{\partial x} + g \,, \tag{16}$$

we obtain

$$-\frac{r}{\pi(x+y+z)} \sum_k e^{it(r+k)} \times \\ \times \left[\frac{r_k \cos(r_k t)}{i\,t^2} + \frac{(r+k)\sin(r_k t)}{t^2} - \frac{2\sin(r_k t)}{i\,t^3} \right] = \\ = \nu \Delta u_x - \frac{\partial P}{\partial x} + g \,, \tag{17}$$

where Δ means $\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$. Again taking the approximation of very large time, we have

$$\frac{\partial P}{\partial x} = g \,, \tag{18}$$

i.e.

$$i \, \frac{s^2 x}{\pi r} \sum_k \int \sin(r_k t) \, e^{it(r+k)} dt = g \,. \tag{19}$$

Taking the partial derivative with respect to time we obtain

$$i \, \frac{s^2 x}{\pi r} \sum_k \sin(r_k t) \, e^{it(r+k)} = 0 \tag{20}$$

or (which is the same),

$$e^{it(r+k)} \sin(r_k t) = 0 \,, \tag{21}$$

i.e.

$$(\cos[(r+k)t] - i \sin[(r+k)t]) \sin(r_k t) = 0 \,. \tag{22}$$

Taking only the real part

$$\sin(r_k t) \cos[(r+k)t] = 0 \,. \tag{23}$$

So, we have two solutions: (a) $r_k t = 0, \pi, 2\pi, \ldots, n\pi$, and (b) $(r+k)\,t = \frac{\pi}{2}, 3\frac{\pi}{2}, \ldots, (2n+1)\frac{\pi}{2}$. We must note that the solution (a) is similar to the 1-dimension solution.

3 Conclusions

By using a new discontinuous functional form for matter density distribution, derived from consideration of the origin of turbulence, we have found an asymptotic solution to the Navier-Stokes equation for the three dimensional case. This result, while of intrinsic interest, may point towards new ways of deriving a general solution.

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On PT-Symmetric Periodic Potential, Quark Confinement, and Other Impossible Pursuits

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As we know, it has been quite common nowadays for particle physicists to think of six impossible things before breakfast, just like what their cosmology fellows used to do. In the present paper, we discuss a number of those impossible things, including PT-symmetric periodic potential, its link with condensed matter nuclear science, and possible neat link with Quark confinement theory. In recent years, the PT-symmetry and its related periodic potential have gained considerable interests among physicists. We begin with a review of some results from a preceding paper discussing derivation of PT-symmetric periodic potential from biquaternion Klein-Gordon equation and proceed further with the remaining issues. Further observation is of course recommended in order to refute or verify this proposition.

1 Introduction

As we know, it has been quite common nowadays for particle physicists to think of six impossible things before breakfast [1], just like what their cosmology fellows used to do. In the present paper, we discuss a number of those impossible things, including PT-symmetric periodic potential, its link with condensed matter nuclear science, and possible neat link with Quark Confinement theory.

In this regards, it is worth to remark here that there were some attempts in literature to generalise the notion of symmetries in Quantum Mechanics, for instance by introducing CPT symmetry, chiral symmetry etc. In recent years, the PT-symmetry and its related periodic potential have gained considerable interests among physicists [2, 3]. It is expected that the discussions presented here would shed some light on these issues.

We begin with a review of results from our preceding papers discussing derivation of PT-symmetric periodic potential from biquaternion Klein-Gordon equation [4–6]. Thereafter we discuss how this can be related with both Gribov's theory of Quark Confinement, and also with EQPET/TSC model for condensed matter nuclear science (aka low-energy reaction or "cold fusion") [7]. We also highlight its plausible implication to the calculation of Gamow integral for the (periodic) non-Coulomb potential.

In other words, we would like to discuss in this paper, whether there is PT symmetric potential which can be observed in Nature, in particular in the context of condensed matter nuclear science (CMNS) and Quark confinement theory.

Nonetheless, further observation is of course recommended in order to refute or verify this proposition.

2 PT-symmetric periodic potential

It has been argued elsewhere that it is plausible to derive a new PT-symmetric Quantum Mechanics (PT-QM; sometimes it is called pseudo-Hermitian Quantum Mechanics [3, 9]) which is characterized by a PT-symmetric potential [2]

$$V(x) = V(-x)\,. \tag{1}$$

One particular example of such PT-symmetric potential can be found in sinusoidal-form potential

$$V = \sin\varphi\,. \tag{2}$$

PT-symmetric harmonic oscillator can be written accordingly [3]. Znojil has argued too [2] that condition (1) will yield Hulthen potential

$$V(\xi) = \frac{A}{(1-e^{2i\xi})^2} + \frac{B}{(1-e^{2i\xi})}\,. \tag{3}$$

Interestingly, a similar periodic potential has been known for quite a long time as Posch-Teller potential [9], although it is not always related to PT-Symmetry considerations. The Posch-Teller system has a unique potential in the form [9]

$$U(x) = -\lambda \cosh^{-2} x\,. \tag{4}$$

It appears worth to note here that Posch-Teller periodic potential can be derived from conformal D'Alembert equations [10, p.27]. It is also known as the second Posch-Teller potential

$$V_\mu(\xi) = \frac{\mu(\mu-1)}{\sinh^2\xi} + \frac{\ell(\ell+1)}{\cosh^2\xi}. \tag{5}$$

The next Section will discuss biquaternion Klein-Gordon equation [4, 5] and how its radial version will yield a sinusoidal form potential which appears to be related to equation (2).

3 Solution of radial biquaternion Klein-Gordon equation and a new sinusoidal form potential

In our preceding paper [4], we argue that it is possible to write biquaternionic extension of Klein-Gordon equation as follows

$$\left[\left(\frac{\partial^2}{\partial t^2}-\nabla^2\right)+i\left(\frac{\partial^2}{\partial t^2}-\nabla^2\right)\right]\varphi(x,t)= \\ =-m^2\varphi(x,t)\,, \qquad (6)$$

or this equation can be rewritten as

$$\left(\diamondsuit\bar{\diamondsuit}+m^2\right)\varphi(x,t)=0 \qquad (7)$$

provided we use this definition

$$\diamondsuit=\nabla^q+i\nabla^q=\left(-i\,\frac{\partial}{\partial t}+e_1\frac{\partial}{\partial x}+e_2\frac{\partial}{\partial y}+e_3\frac{\partial}{\partial z}\right)+ \\ +i\left(-i\frac{\partial}{\partial T}+e_1\frac{\partial}{\partial X}+e_2\frac{\partial}{\partial Y}+e_3\frac{\partial}{\partial Z}\right), \qquad (8)$$

where $e_1,\ e_2,\ e_3$ are *quaternion imaginary units* obeying (with ordinary quaternion symbols $e_1=i,\ e_2=j,\ e_3=k$):

$$i^2=j^2=k^2=-1\,,\quad ij=-ji=k\,, \qquad (9)$$

$$jk=-kj=i\,,\quad ki=-ik=j\,, \qquad (10)$$

and quaternion *Nabla operator* is defined as [4]

$$\nabla^q=-i\,\frac{\partial}{\partial t}+e_1\frac{\partial}{\partial x}+e_2\frac{\partial}{\partial y}+e_3\frac{\partial}{\partial z}\,. \qquad (11)$$

Note that equation (11) already included partial time-differentiation.

Thereafter one can expect to find solution of *radial* biquaternion Klein-Gordon Equation [5, 6].

First, the standard Klein-Gordon equation reads

$$\left(\frac{\partial^2}{\partial t^2}-\nabla^2\right)\varphi(x,t)=-\,m^2\varphi(x,t)\,. \qquad (12)$$

At this point we can introduce polar coordinate by using the following transformation

$$\nabla=\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial}{\partial r}\right)-\frac{\ell^2}{r^2}\,. \qquad (13)$$

Therefore by introducing this transformation (13) into (12) one gets (setting $\ell=0$)

$$\left(\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial}{\partial r}\right)+m^2\right)\varphi(x,t)=0\,. \qquad (14)$$

By using the same method, and then one gets radial expression of BQKGE (6) for 1-dimensional condition as follows [5, 6]

$$\left(\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial}{\partial r}\right)-i\,\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial}{\partial r}\right)+m^2\right)\varphi(x,t)=0\,. \qquad (15)$$

Using Maxima computer package we find solution of equation (15) as a new potential taking the form of sinusoidal potential

$$y=k_1\sin\left(\frac{|m|\,r}{\sqrt{-i-1}}\right)+k_2\cos\left(\frac{|m|\,r}{\sqrt{-i-1}}\right), \qquad (16)$$

where k_1 and k_2 are parameters to be determined. It appears very interesting to remark here, when k_2 is set to 0, then equation (16) can be written in the form of equation (2)

$$V=k_1\sin\varphi\,, \qquad (17)$$

by using definition

$$\varphi=\sin\left(\frac{|m|\,r}{\sqrt{-i-1}}\right). \qquad (18)$$

In retrospect, the same procedure which has been traditionally used to derive the Yukawa potential, by using radial biquaternion Klein-Gordon potential, yields a PT-symmetric periodic potential which takes the form of equation (1).

4 Plausible link with Gribov's theory of Quark Confinement

Interestingly, and quite oddly enough, we find the solution (17) may have deep link with Gribov's theory of Quark confinement [8, 11]. In his Third Orsay Lectures he described a periodic potential in the form [8, p.12]

$$\ddot{\psi}-3\sin\psi=0\,. \qquad (19)$$

By using Maxima package, the solution of equation (19) is given by

$$\left.\begin{aligned} x_1&=k_2-\frac{\int\frac{1}{\sqrt{k_1-\cos(y)}}\,dy}{\sqrt{6}} \\ x_2&=k_2+\frac{\int\frac{1}{\sqrt{k_1-\cos(y)}}\,dy}{\sqrt{6}} \end{aligned}\right\}, \qquad (20)$$

while Gribov argues that actually the equation shall be like nonlinear oscillation with damping, the equation (19) indicates close similarity with equation (2).

Therefore one may think that PT-symmetric periodic potential in the form of (2) and also (17) may have neat link with the Quark Confinement processes, at least in the context of Gribov's theory. Nonetheless, further observation is of course recommended in order to refute or verify this proposition.

5 Implication to condensed matter nuclear science. Comparing to EQPET/TSC model. Gamow integral

In accordance with a recent paper [6], we interpret and compare this result from the viewpoint of EQPET/TSC model which has been suggested by Prof. Takahashi in order to explain some phenomena related to Condensed matter nuclear Science (CMNS).

Takahashi [7] has discussed key experimental results in condensed matter nuclear effects in the light of his EQPET/TSC model. We argue here that his potential model with inverse barrier reversal (STTBA) may be comparable to the periodic potential described above (17).

In [7] Takahashi reported some findings from condensed matter nuclear experiments, including intense production of helium-4, ^{4}He atoms, by electrolysis and laser irradiation experiments. Furthermore he [7] analyzed those experimental results using EQPET (Electronic Quasi-Particle Expansion Theory). Formation of TSC (tetrahedral symmetric condensate) were modeled with numerical estimations by STTBA (Sudden Tall Thin Barrier Approximation). This STTBA model includes strong interaction with negative potential near the center.

One can think that apparently to understand the physics behind Quark Confinement, it requires fusion of different fields in physics, perhaps just like what Langland program wants to fuse different branches in mathematics.

Interestingly, Takahashi also described the Gamow integral of his STTBA model as follows [7]

$$\Gamma_n = 0.218\left(\mu^{1/2}\right)\int\limits_{r_0}^{b}\left(V_b - E_d\right)^{1/2} dr\,. \tag{21}$$

Using $b = 5.6$ fm and $r = 5$ fm, he obtained [7]

$$P_{4D} = 0.77, \tag{22}$$

and

$$V_B = 0.257 \text{ MeV}, \tag{23}$$

which gave significant underestimate for 4D fusion rate when rigid constraint of motion in 3D space attained. Nonetheless by introducing different values for λ_{4D} the estimate result can be improved. Therefore we may conclude that Takahashi's STTBA potential offers a good approximation (just what the name implies, STTBA) of the fusion rate in condensed matter nuclear experiments.

It shall be noted, however, that his STTBA lacks sufficient theoretical basis, therefore one can expect that a sinusoidal periodic potential such as equation (17) may offer better result.

All of these seem to suggest that the cluster deuterium may yield a different inverse barrier reversal which cannot be predicted using the D-D process as in standard fusion theory. In other words, the standard procedure to derive Gamow factor should also be revised [12]. Nonetheless, it would need further research to determine the precise Gamow energy and Gamow factor for the cluster deuterium with the periodic potential defined by equation (17); see for instance [13].

In turn, one can expect that Takahashi's EQPET/TSC model along with the proposed PT-symmetric periodic potential (17) may offer new clues to understand both the CMNS processes and also the physics behind Quark confinement.

6 Concluding remarks

In recent years, the PT-symmetry and its related periodic potential have gained considerable interests among physicists.

In the present paper, it has been shown that one can find a new type of PT-symmetric periodic potential from solution of the radial biquaternion Klein-Gordon Equation. We also have discussed its plausible link with Gribov's theory of Quark Confinement and also with Takahashi's EQPET/TSC model for condensed matter nuclear science. All of which seems to suggest that the Gribov's Quark Confinement theory may indicate similarity, or perhaps a hidden link, with the Condensed Matter Nuclear Science (CMNS). It could also be expected that thorough understanding of the processes behind CMNS may also require revision of the Gamow factor to take into consideration the cluster deuterium interactions and also PT-symmetric periodic potential as discussed herein.

Further theoretical and experiments are therefore recommended to verify or refute the proposed new PT symmetric potential in Nature.

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LETTERS TO PROGRESS IN PHYSICS

LETTERS TO PROGRESS IN PHYSICS

An Explantion of Hubble Redshift due to the Global Non-Holonomity of Space

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In General Relativity, the change of the energy of a freely moving photon should be the solution to the scalar equation of the isotropic geodesic equations, which manifests the work produced on the photon being moved along the path. I solved the equation in terms of physical observables (Zelmanov, *Physics Doklady*, 1956, v. 1, 227–230), and in the large scale approximation, i.e. with gravitation and deformation neglected in the space, while supposing the isotropic space to be globally non-holonomic (the time lines are non-orthogonal to the spatial section, a condition manifested by the rotation of the space). The solution is $E = E_0 \exp(-\Omega^2 a\, t/c)$, where Ω is the angular velocity of the space (it meets the Hubble constant $H_0 = c/a = 2.3\times10^{-18}\ \text{s}^{-1}$), a is the radius of the Universe, $t = r/c$ is the time of the photon's travel. So a photon loses energy with distance due to the work against the field of the space non-holonomity. According to the solution, the redshift should be $z = \exp(H_0\, r/c) - 1 \approx H_0\, r/c$. This solution explains both the redshift $z = H_0\, r/c$ observed at small distances and the non-linearity of the empirical Hubble law due to the exponent (at large r). The ultimate redshift, according to the theory, should be $z = \exp(\pi) - 1 = 22.14$.

In this short thesis, I show how the Hubble law, including its non-linearity with distance, can be deduced directly from the equations of the General Theory of Relativity.

In General Relativity, the change of the energy of a freely moving photon should be the solution to the scalar equation of isotropic geodesics, which is also known as the equation of energy and manifests the work produced on the photon being moved along the path. In terms of physically observable quantities — chronometric invariants (Zelmanov, 1944), which are the respective projections of four-dimensional quantities onto the time line and spatial section of a given observer — the isotropic geodesic equations are presented with two projections onto the time line and spatial section, respectively [1–3]

$$\left.\begin{aligned} &\frac{d\omega}{d\tau} - \frac{\omega}{c^2}\, F_i\, c^i + \frac{\omega}{c^2}\, D_{ik}\, c^i c^k = 0 \\ &\frac{d(\omega c^i)}{d\tau} - \omega F^i + 2\omega\left(D^i_k + A^{\cdot i}_{k\cdot}\right) c^k + \omega \triangle^i_{nk} c^n c^k = 0 \end{aligned}\right\},$$

where ω is the proper frequency of the photon, $d\tau$ is the interval of physically observable time, c^i is the vector of the observable velocity of light ($c_k c^k = c^2$), F_i is the gravitational inertial force, A_{ik} is the angular velocity of the space rotation due to the non-holonomity of space (the non-orthogonality of the time lines to the spatial section), D_{ik} is the deformation of space, $\triangle^i_{nk}$ are the three-dimensional Christoffel symbols. Integration of the scalar equation should give a function $E = E(t)$, where $E = \hbar\omega$ is the proper energy of the photon. However, integration of time in a Riemannian space is not a trivial task. This is because the observable interval of time $d\tau = \sqrt{g_{00}}\, dt - \frac{1}{c^2}\, v_i dx^i$ depends on the gravitational potential along the path, on the linear velocity $v_i = -\frac{c g_{0i}}{\sqrt{g_{00}}}$ of the rotation of space (due to the non-holonomity of it), and on the displacement dx^i of the observer with respect to his coordinate net during the measurement in process. The result of integration depends on the integration path, so time is not integrable in a general case. We consider the "large scale approximation", where distances are close to the curvature radius of the Universe; so gravitation and deformation are neglected in the space ($g_{00} = 1$ and $D_{ik} = 0$, respectively), and the observer is resting with respect to his coordinate net ($dx^i = 0$). In such a case, integration of time is allowed, and is simple as $d\tau = dt$. We also suppose the isotropic space, the "home space" of photons, to be globally non-holonomic ($v_i \neq 0$). With these, the gravitational inertial force F_i, losing the gravitational potential $\mathrm{w} = c^2(1 - \sqrt{g_{00}}) = 0$, consists of only the second term, which is due to the space non-holonomity

$$F_i = \frac{1}{\sqrt{g_{00}}}\left(\frac{\partial \mathrm{w}}{\partial x^i} - \frac{\partial v_i}{\partial t}\right) \simeq -\frac{\partial v_i}{\partial t}\,.$$

We consider a single photon travelling in the x-direction ($c^1 = c,\ c^2 = c^3 = 0$). With the "large scale approximation" in a globally non-holonomic isotropic space, and assuming the linear velocity of the space rotation to be $v_1 = v_2 = v_3 = v$, and be stationary, i.e. $\frac{\partial v}{\partial t} = B = \text{const}$, the scalar equation of isotropic geodesics for such a photon takes the form

$$\frac{dE}{dt} = -\frac{B}{c}\, E\,.$$

This is a simplest uniform differential equation of the 1st order, like $\dot{y} = -\,k\,y$, so that $\frac{dy}{y} = -\,k\,dt$ or $d(\ln y) = -\,k\,dt$. It solves as $\ln y = -kt + \ln C$, so we obtain $y = y_0\,e^{-kt}$. As a result, the scalar equation of isotropic geodesics (the equation of energy), in the "large scale approximation" in the globally non-holonomic space, gives the solution for the photon's energy (frequency) and the redshift $z = \frac{\omega_0 - \omega}{\omega}$ as depending on the distance $r = ct$ travelled from the observer

$$E = E_0\,e^{-kt}, \qquad z = e^{kt} - 1\,,$$

such that at small distances of the photon's travel, i.e. with the exponent $e^x = 1 + x + \frac{1}{2}\,x^2 + \ldots \simeq 1 + x$, takes the form

$$E \simeq E_0\,(1 - kt)\,, \qquad z \simeq kt\,,$$

where $k = \frac{1}{c}\,B = \frac{1}{c}\,\frac{\partial v}{\partial t} = \text{const}$. Thus, according to our calculation based on the General Theory of Relativity, a photon being moved in a non-holonomic space loses its proper energy/frequency due to the work produced by it against the field of the space non-holonomity (or the negative work produced by the field on the photon).

It is obvious that, given a stationary non-holonomity of the isotropic space, we can express k through the angular velocity Ω and the curvature radius $a = \frac{c}{H_0}$ of the isotropic space connected to our Metagalaxy (we suppose this is a constant curvature space of sperical geometry), as

$$k = \frac{1}{c}\,\Omega^2 a\,,$$

where H_0 is the Hubble constant. So for the galaxies located at a distance of $r \simeq 630$ Mpc* (the redshift observed on them is $z \simeq 0.16$) we obtain

$$\Omega = \sqrt{\frac{z\,c}{a\,t}} = \sqrt{\frac{z\,c^2}{a\,r}} \simeq 2.4\times10^{-18}\ \text{sec}^{-1},$$

that meets the Hubble constant $H_0 = 72\pm8\times10^5$ cm/sec×Mpc $= 2.3\pm0.3\times10^{-18}$ sec^{-1} (according to the Hubble Space Telescope data, 2001 [4]).

With these we arrive at the following law

$$E = E_0\,e^{-\frac{H_0 r}{c}}, \qquad z = e^{\frac{H_0 r}{c}} - 1\,,$$

as a purely theoretical result obtained from our solution to the scalar equation of isotropic geodesics. At small distances of the photon's travel, this law becomes

$$E \simeq E_0\left(1 - \frac{H_0\,r}{c}\right), \qquad z \simeq \frac{H_0\,r}{c}\,.$$

As seen, this result provides a complete theoretical ground to the linear Hubble law, empirically obtained by Edwin Hubble for small distances, and also to the non-linearity of the Hubble law observed at large distances close to the size of the Metagalaxy (the non-linearity is explained due to the exponent in our solution, which is sufficient at large r).

Then, proceeding from our solution, we are able to calculate the ultimate redshift, which is allowed in our Universe. It is, according to the exponential law,

$$z_{\max} = e^{\pi} - 1 = 22.14\,.$$

In the end, we calculate the linear velocity of the rotation of the isotropic space, which is due to the global non-holonomity of it. It is $\breve{v} = \Omega\,a = H_0\,a = c$, i.e. is equal to the velocity of light. I should note, to avoid misunderstanding, that this linear velocity of rotation is attributed to the isotropic space, which is the home of isotropic (light-like) trajectories specific to massless light-like particles (e.g. photons). It isn't related to the non-isotropic space of sub-light-speed trajectories, which is the home of mass-bearing particles (e.g. galaxies, stars, planets). In other words, our result doesn't mean that the visible space of cosmic bodies rotates at the velocity of light, or even rotates in general. The space of galaxies, stars, and planets may be non-holonomic or not, depending on the physical conditions in it.

A complete presentation of this result will have been held at the *April Meeting 2009 of the American Physical Society* (May 2–5, Denver, Colorado) [5], and also published in a special journal on General Relativity and cosmology [6].

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*1 parsec $= 3.0857\times10^{18}$ cm $\simeq 3.1\times10^{18}$ cm.

LETTERS TO PROGRESS IN PHYSICS

A Few Remarks on "The Length of Day: A Cosmological Perspective"

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An interesting hypothesis concerning the varying length of day has been formulated in this edition, proposed by A.I. Arbab, based on a proposition of varying gravitational constant, G. The main ideas are pointed out, and alternative frameworks are also discussed in particular with respect to the present common beliefs in astrophysics. Further observation is of course recommended in order to refute or verify this proposition.

1 Introduction

An interesting hypothesis has been formulated in this edition, proposed by A. I. Arbab [1,2], based on a proposition of varying gravitational constant, G. The main ideas are pointed out, and alternative frameworks are also discussed in particular because the idea presents a quite different approach compared to the present common beliefs in astrophysics and cosmology, i.e. that the Earth is not expanding because the so-called Cosmological expansion does not take place at the Solar system scale.

2 Basic ideas of Arbab's hypothesis

Arbab's hypothesis is mainly an empirical model based on a set of observational data corresponding to cosmological expansion [1]. According to this model, the day increases at a present rate of 0.002 sec/century. His model started with a hypothesis of changing gravitational constant as follows [1]:

$$G_{\text{eff}} = G_0 \left(\frac{t}{t_0}\right)^{\beta}. \tag{1}$$

We shall note, however, that such a model of varying constants in nature (such as G, etc.) has been discussed by numerous authors. The idea itself can be traced back to Dirac, see for instance [3].

What seems interesting here is that he is able to explain the Well's data [4, 5]. In a sense, one can say that even the coral reef data can be considered as "cosmological benchmark". Furthermore, from this viewpoint one could expect to describe the "mechanism" behind Wegener's idea of tectonic plate movement between continents [6]. It can be noted that Wegener's hypothesis has not been described before in present cosmological theories. Moreover, it is also quite safe to say that: "There has been no consensus on the main driving mechanism for the plate tectonics since its introduction" [7].

It is worth noting here that the idea presented in [1, 2] can be considered as quite different compared to the present common beliefs in astrophysics and cosmology, i.e. that the Earth is not expanding because the so-called Cosmological expansion does not take place at the Solar system scale. Apparently in [1] the author doesn't offer any explanation of such a discrepancy with the present beliefs in astrophysics; nor the author offers the "physics" of the causal relation of such an expansion at the Solar system scale. Nonetheless, the empirical finding seems interesting to discuss further.

In the subsequent section we discuss other alternative models which may yield more-or-less similar prediction.

3 A review of other solutions for cosmological expansion

In this regards it seems worth noting here that there are other theories which may yield similar prediction concerning the expansion of Earth. For instance one can begin with the *inhomogeneous scalar field cosmologies* with exponential potential [8], where the scalar field component of Einstein-Klein-Gordon equation can be represented in terms of:

$$\phi = -\frac{k}{2} + \log(G) + \psi\,. \tag{2}$$

Alternatively, considering the fact that Klein-Gordon equation is neatly related to Proca equation, and then one can think that the right terms of Proca equation cannot be neglected, therefore the scalar field model may be expressed better as follows [9]:

$$(\Box + 1)\, A_\mu = j_\mu + \partial_\mu \left(\partial_\nu j^\nu\right)\,. \tag{3}$$

Another approach has been discussed in a preceding paper [10], where we argue that it is possible to explain the lengthening of the day via the phase-space relativity as implication of Kaluza-Klein-Carmeli metric. A simpler way to predict the effect described by Arbab can be done by including equation (1) into the time-dependent gravitational Schrödinger equation, see for instance [11].

Another recent hypothesis by M. Pitkanen [12] is worth noting too, and it will be outlined here, for the purpose of stimulating further discussion. Pitkanen's explanation is based on his TGD theory, which can be regarded as generalization of General Relativity theory.

The interpretation is that cosmological expansion does not take place smoothly as in classical cosmology but by quantum jumps in which Planck constant increases at particular level of many-sheeted space-time and induces the expansion of space-time sheets. The accelerating periods in cosmic expansion would correspond to these periods. This would allow also avoiding the predicted tearing up of the space-time predicted by alternative scenarios explaining accelerated expansion.

The increase of Earth's radius by a factor of two is required to explain the finding of Adams that all continents fit nicely together. Increases of Planck constant by a factor of two are indeed favoured because p-adic lengths scales come in powers of two and because scaling by a factor two are fundamental in quantum TGD. The basic structure is causal diamond (CD), a pair of past and future directed light cones forming diamond like structure. Because two copies of same structure are involved, also the time scale $T/2$ besides the temporal distance T between the tips of CD emerges naturally. CD's would form a hierarchy with temporal distances $T/2^n$ between the tips.

After the expansion the geological evolution is consistent with the tectonic theory so that the hypothesis only extends this theory to earlier times. The hypothesis explains why the continents fit together not only along their other sides as Wegener observed but also along other sides: the whole Earth would have been covered by crust just like other planets.

The recent radius would indeed be twice the radius that it was before the expansion. Gravitational force was 4 time stronger and Earth rotated 4 times faster so that day-night was only 6 hours. This might be visible in the biorhythms of simple bacteria unless they have evolved after that to the new rhythm. The emergence of gigantic creatures like dinosaur and even crabs and trees can be seen as a consequence of the sudden weakling of the gravitational force. Later smaller animals with more brain than muscles took the power.

Amusingly, the recent radius of Mars is one half of the recent radius of Earth (same Schumann frequency) and Mars is now known to have underground water: perhaps Mars contains complex life in underground seas waiting to the time to get to the surface as Mars expands to the size of Earth.

Nonetheless what appears to us as a more interesting question is whether it is possible to find out a proper metric, where both cosmological expansion and other observed expansion phenomena at Solar-system scale can be derived from the same theory (from a Greek word, *theoros* — "to look on or to contemplate" [13]). Unlike the present beliefs in astrophysics and cosmological theories, this seems to be a continuing journey. An interesting discussion of such a possibility of "generalized" conformal map can be found in [14]. Of course, further theoretical and experiments are therefore recommended to verify or refute these propositions with observed data in Nature.*

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* At the time of writing, we are informed that Arbab's forthcoming paper will discuss a more comprehensive and theoretical approach of his hypothesis [15]. Our remarks here are limited to his papers discussed in this issue, and also in his earler paper [16].

LETTERS TO PROGRESS IN PHYSICS

Israel L. Bershtein (1908 – 2000) — the Founder of the Theory of Fluctuations in Self-Oscillating Systems

(In Commemorating the 100th Birthday Anniversary)

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Israel L. Bershtein (1908–2000) was one of the famous radio physicists in the world. He had constructed the theory of amplitude and frequency fluctuations for the electromagnetic wave generators working in the radio and optical scales. He also had developed numerous methods for precise measurement of the fluctuations, which also can be applied to ultimate small mechanical displacements. Besides these he was the first person among the scientists, who had registered the Sagnac effect at radiowaves.

Fig. 1: I. L. Bershtein in 1930 (the left corner in the picture), being a 5th grade university student at the Low Current Lab (a common name for a radio laboratory in those years). This photo is interesting from the historical viewpoint, because the background of a radio laboratory of the 1930's.

In November, 2008 we celebrate the 100th Birthday Anniversary of Israel Lazarevich Bershtein, Doctor of Science in Physics and Mathematics, a distinguished radio physicist, the author of theoretical and experimental research methods for fluctuations of radio and optical electromagnetic oscillators. The paper deals with I. L. Bershtein's basic scientific achievements.

I. L. Bershtein started his scientific activities when radiophysics originated and broke new ground, so he took a part in its development. I. L. Bershtein was born on November 22, 1908 in the Mogilyov city of the Russian Empire (nowadays the Republic of Belarus). After graduating from school he studied physics at the Electromechanical Faculty of the Leningrad Polytechnical Institute (1926–1930). A. F. Ioffe, V. F. Mitkevich, D. D. Rozhansky, A. A. Chernyshev, and M. A. Shatelen were among his teachers. A well-known debate concerning the nature of electric current, electric and magnetic fields and also the long-range action problem between V. F. Mitkevich, the full member of the USSR Academy of Sciences, and Ya. I. Frenkel, the corresponding member of the Academy, took a place in 1929–1930 at the Polytechnical Institute. P. Ehrenfest was invited by A. F. Ioffe to participate in two sessions of the debate. I. L. Bershtein took a part in all three sessions of these.

After graduating from the Polytechnical Institute in 1931 I. L. Bershtein was employed at the Central Military Research Radio Laboratory (later — the Frunze Factory). He however preferred scientific activities. In 1930 N. D. Papaleksi, the corresponding member of the Academy, paid attention to the talented student. On his advice I. L. Bershtein addressed Prof. A. A. Andronov who agreed to become his scientific supervisor. In 1933 I. L. Bershtein was enrolled for A. A. Andronov's in-service training postgraduate course. His task was to obtain expressions for amplitude and frequency fluctuations of a self-oscillating system (by the example of valve oscillator) close to its periodic motion. I. L. Bershtein managed to show that frequency fluctuations of the generator "blurred" the infinitely narrow radiation line of an ideal oscillator and it acquired width, while amplitude fluctuations created a rather wide but low "pedestal" of the generation line. Results of this work were recommended to publishing by L. I. Mandelstam, the full member of the Academy, and they were published in *Soviet Physics — Doklady* [1]. Paper [1] considerably exceeded the maximum permissible volume and A. A. Andronov reached an agreement with the Editor-in-Chief S. I. Vavilov, the full member of the Academy, on publishing [1] in total. In 1939 I. L. Bershtein under supervision of A. A. Andronov defended a Ph.D. thesis. The official opponents were M. A. Leontovich and G. S. Gorelik. In 1941 I. L. Bershtein

Fig. 2: I. L. Bershtein in 1938, among the research scientists and professors of the Gorky Physics and Technical Institute (GPTI). In the 1st row (from left to right): unknown person; unknown person; Prof. S. M. Rytov; I. L. Bershtein; Prof. Jakov N. Nikolaev; Kholodenko. In the 2nd row (from left to right): Prof. Alexandra G. Lyubina; Prof. Victor I. Gaponov (the husband of Prof. Maria T. Grekhova, the Director of GPTI, and the father of A. V. Gaponov-Grekhov, the full member of the Academy); unknown person.

published a more detailed statement of the theory of fluctuations in valve oscillator [2]. The original theoretical results he had obtained required experimental validation, however the Fascist Germany aggression upon the USSR forced I. L. Bershtein to postpone his fundamental research.

During the World War II I. L. Bershtein developed radio receiving equipment for the Soviet army and aviation needs. In 1946 I. L. Bershtein stopped his industrial activity and was employed at the Gorky Physics and Technical Institute (GPTI) in G. S. Gorelik's department, and held a post of Assistant Professor and Full Professor of radioengineering at the newly organized Radiophysical Faculty of the Gorky State University. Nevertheless, until 1952 he continued to supervise the development and production of radio equipment at a factory. At that time I. L. Bershtein starts to develop experimental methods for measuring amplitude and frequency fluctuations of valve oscillator. In particular, he was the first person who suggested to process measurement of small phase fluctuations by the so-called method of triangle, based on the interference of the measured and reference signals having an insignificant constant phase shift relative to each other and close amplitude values. The experimental measurement carried out by I. L. Bershtein in [3, 4] completely verified his earlier theoretical results [1, 2]. His paper [4] was awarded the Mandelstam Prize presented to L. I. Bershtein at a session of the USSR Academy of Sciences by N. I. Vavilov, the President of the Academy.

In papers [3, 4] I. L. Bershtein managed to measure the lowest level of periodic phase modulation of the order 10^{-8} rad in the frequency band 1 Hz. This permitted to carry out a very interesting physical experiment, i.e., to measure the Sagnac effect at radio waves employing a cable of the 244 m length coiled round a barrel [5]. The radio wavelength was 10 m and the angular velocity of the barrel's rotation was 1–1.3 revolutions per second. Since the phase difference of counter-running waves caused by the rotation is inversely proportional to the wavelength, it is evident that the Sagnac interferometer sensitivity at radio waves is 10^7 lower than the sensitivity under the other equal conditions expected in the optical range.

I. L. Bershtein's papers on fluctuations and the Sagnac effect [3–5] brought him world-wide popularity. He became a leading Soviet scientist on fluctuation measurement. In 1954 he measured extremely small mechanical displacements employing the interference method, and recorded a displacement of the order 10^{-3} Å (see [6]). (It should be noted that, in 1998, one of I. L. Bershtein's disciples, namely — V. M. Gelikonov, managed to increase the measurement accuracy of mechanical displacements by 4 orders to it. See [7] for detail.) That year I. L. Bershtein defended a Dr.Sci. thesis (his opponents were G. S. Landsberg, Yu. B. Kobzarev, S. M. Rytov, and G. S. Gorelik) and after G. S. Gorelik's departure for Moscow he headed a scientific department in GPTI. In the same time he became a Full Professor at the Radioengineering Faculty of the Gorky State University.

In 1957 I. L. Bershtein and his department were transferred to the Radiophysical Research Institute (RRI), where he studied klystron oscillators and matched their frequencies to the frequencies of a quartz oscillator and an ammonia maser,

Fig. 3: I. L. Bershtein in 1948. This is the time of the upper point of his scientific achievements.

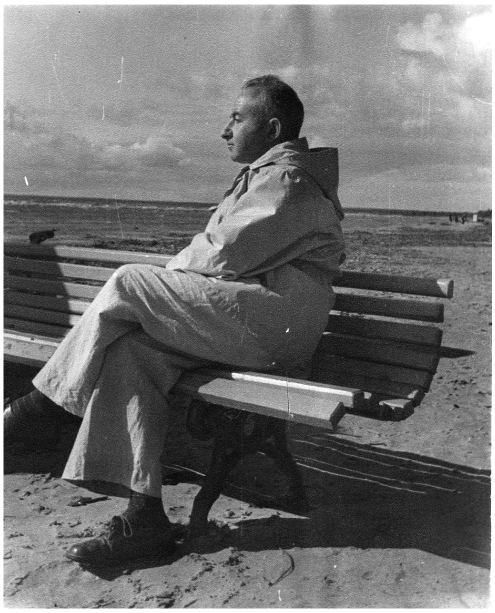

Fig. 4: The mid-60's. I. L. Bershtein being taking relax at the coast of the Black Sea.

then investigated the oscillator fluctuations in AFC system operation. In the mid-60's I. L. Bershtein's department started developing a subject related to the pioneering experimental and theoretical studies in the field of fluctuation processes in gas lasers with Fabry-Pérot and ring resonators, including gas lasers with an absorbing cell used for elaboration of the optical frequency standards. At that time I. L. Bershtein developed a heterodyne method for frequency fluctuation measurement, enabling his disciples Yu. I. Zaitsev and D. P. Stepanov to be first persons in the world who measured frequency fluctuations of a gas laser at the wavelength $0.63\,\mu$ [8]. In 1969 I. L. Bershtein was invited to held a lecture on his department's activities at P. L. Kapitsa's workshop in Kapitza's Institute for Physical Problems in Moscow.

In 1970 the so-called polarization resonances in counterrunning waves in an amplifying laser tube at the wavelength $3.39\,\mu$ [9] were discovered with the participation of L. I. Bershtein. He also studied the influence of the light backscattering on laser operation and reciprocal capture of the counterrunning wave frequencies in a ring gas laser. The AFC systems for laser generation developed by I. L. Bershtein permitted his disciples to discover new effects in gas lasers with an absorbing cell. The new effects they have discovered were the dynamic self-stabilization of the generation frequency which occurs not only at the centre of the transition line of the absorbing gas, but also at the boundaries of the entire non-uniformly broadened absorption line, the dependence of the self-stabilization coefficient on the modulation frequency [10], and the so-called dispersion resonances they have recorded.

I. L. Bershtein was a member of the Editorial Board of the journal *Soviet Radiophysics* published in RRI for about twenty years (1958–1976).

From 1977 to 1986 I. L. Bershtein headed a research laboratory at the Institute of Applied Physics dealing with fiber-optic interferometers. From 1987 to 1999, being a leading consulting scientist, he continued his studies in the field of fiber-optic gyroscopy and semiconductor radiation sources for fiber optics. I. L. Bershtein died on August 16, 2000.

The life and scientific activity of I. L. Bershtein is a worthy example of service to science. His work in the field of self-oscillating system fluctuations and micro phase metering are the classics of science, and are extremely valuable for radiophysics. He is the author of more than 60 scientific publications and many inventions certified by patents. He was also awarded several prizes provided by the USSR Government [11].

Under careful leading of I. L. Bershtein three persons have got a Ph.D. degree. Those were I. A. Andronova, Yu. I. Zaitsev, and L. I. Fedoseev (the last person was led by I. L. Bershtein commonly with V. S. Troitsky, the corresponding member of the Academy). Many other research scientists were also I. L. Bershtein's disciples: Yu. A. Dryagin, D. P. Stepanov, V. A. Markelov, V. V. Lubyako, V. A. Rogachev. The next generations of research scientists were also I. L. Bershtein's disciples. Those are I. A. Andronova's disciples, namely — I. V. Volkov, Yu. K. Kazarin, E. A. Kuvatova, Yu. A. Mamaev, A. A. Turkin, G. V. Gelikonov, and Yu. I. Zaitsev's disciples — V. M. Gelikonov, V. I. Leonov, G. B. Malykin, and also D. V. Shabanov who was V. M. Gelikonov's disciple, and also L. M. Kukin, who was Yu. A. Dryagin's disciple. I. L. Bershtein patiently transferred all his scientific experience to the aforementioned persons, who are actually his disiples and followers in science.

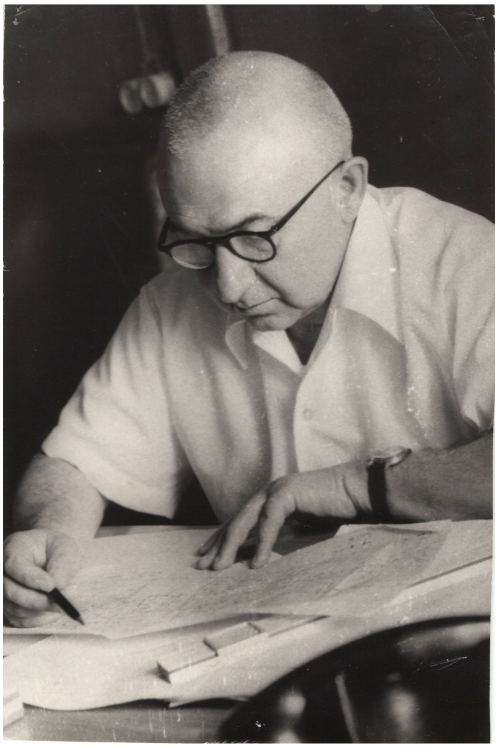

Fig. 5: I. L. Bershtein at the working desk in his cabinet. This photo, pictured in 1967, is very specific to his nativity of a man who spent his life in science.

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LETTERS TO PROGRESS IN PHYSICS

Frank Robert Tangherlini — the Founder of an Alternative Relativistic Kinematics

(On the Occasion of His 85th Birthday)

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Already fifty years ago, Frank Robert Tangherlini, an American theoretical physicist, suggested an original procedure which, targeting the synchronization of clocks located in two different inertial reference frames of the space, was different from that Einstein had introduced. As a result of these, Tangherlini had deduced the so-called the Tangherlini transformations, which are a sort of the transformations of the spatial coordinates and time being moved from one inertial reference frame into another one. The Tangherlini transformations differ from the Lorentz transformations (which can be meant classic ones in the theory of relativity) and, in particular, suggest the velocity of light to be anisotropic in a moving inertial reference frame. The Tangherlini transformations being applied provide adequate explanations to all well-known interference experiments checking of the Special Theory of Relativity.

In this paper I have to present, to the scientific community, the life and scientific achievements of Frank Robert Tangherlini, the prominent American theoretical physicist who meets his 85th birthday on Saturday, March 14, 2009. He started his scientific carrier with a blessed theoretical result, known later as the *Tangherlini transformations*, which was shadowed and unknown to the scientific community for about twenty years. I also give here the direct and inversion Tangherlini transformations, and tell the story how his famous PhD thesis [1] containing the transformations, was written, and how he got a PhD degree on the basis of the thesis.

Frank Robert Tangherlini was born on March 14, 1924, in Boston (Massachusetts, USA) in the family of a worker. His father, Emiliano Francesco Tangherlini (1895–1979) was an Italian-born immigrant: being a young boy, Emiliano was carried out from Italy into the USA by his father Luigi, a marble sculptor assistant. In his young years, Emiliano was employed as an instrumental worker at a machine factory, then, in the years of the Great Depression, he happily found some employment at the Boston Shipyard. What is interesting, one of the flats in the house at Beacon Hill near Massachusetts State House, where Emiliano Tangherlini had residence, was owned by the Kennedy family — the great American family which gave John Fitzgerald Kennedy (1917–1963), the thirty-fifth President of the United States. (Also, John Kennedy's grandfather from the mother's side was the Major of Boston city). In 1947–1952, despite the big difference in the age and in the social status of John Kennedy, Emiliano Tangherlini found a friendship from the side of him when walked somewhere in the park near the home. They spent much time together when talking about everything at the walks. Many years later, when becoming the US President, John Kennedy visited Emiliano Tangherlini when doing an official visit to Boston: John Kennedy stopped his car escort, then went to Emiliano Tangherlini through the crowding people who met him on the street, and shacked Emiliano's hand on the public.

The grandfather of Frank Robert Tangherlini from the mother's side, Barnett Rubinovich (he has changed his family name to Robinson when becoming a US citizen), was born in Krolevetz — a small town near Nezhin city of Chernigov Gubernya of the Russian Empire. He immigrated to the USA in the end of the 19th century, and settled in New York city where he later owned a clothes shop. His daughter, Rose (1894–1953) was born a few years later he arrived in the USA. In 1919 Rose changed her religion from Judaism and took Catholic belief, in order to get marry with Emiliano Tangherlini. She was employed as a bookkeeper then, in the years of the Great Depression, as a waitress in order to survive in the hard conditions of the economical crisis.

In June 1941, Frank Robert Tangherlini completed his high school education, by getting a silver medal (he also had got a bronze medal in the field of the world history). Then, in the Autumn of 1941, he became a student at Boston Jesuit College, where he took education in electrical engineering during five semesters. Being a student, he was set free of military service. He actually had a possibility to continue this "free-of-war time" until the actual end of the World War II. Such a behaviour was not in his habit. In July 1943 he volunteered to the US army, and had the basic training during one year at Fort Beining, Georgia. In the Autumn, 1944, he was sent to Liverpool, England. Being in England he, in common with his two close friends, volunteered to a parachute

Fig. 1: Frank Robert Tangherlini with two paratrooper friends in Auxerre, France, Summer 1945. From left to right: Sergeant Frank Tangherlini, Private James Barlow (he died in Connecticut, in October 2007), Private Joe Rhiley (later he was a major in the US Airforce, and was killed in an aviation accident in Japan while on a training mission with a Japanese pilot; there is an airfield in Nebraska, his home state, named after him). Tanghelini called his youngest son Riley (without "h") in honour of his late friend.

training school at Hungerford, Berkshire, 60 miles West from London city. When visiting London in free time, Tangherlini saw the great destruction in the city and many people killed due to the ballistic missiles V-2 launched from the Fascist Germany through the strait. He observed the people, who actually lived at the London underground railways during many weeks without seeing sunshine, in order to survive under the Nazi's air attacks.

A few months later, the paratrooper corps where Tangherlini continued military service was dispatched into France. Tangherlini had got five parachute jumps into the battle, then was a machine-gunner, and participated in many bloody battles in France, Belgium, Germany. In particular, he fought at the Battle for Ardennes, where many Americans were killed. Many his friends-in-battle were killed there. He met the end of the World War II in Europe being a Paratrooper Sergeant. It was in Ulm, Germany, the patrimony of Albert Einstein. His paratrooper corps was moved to Austria, in order to keep the Austrian-Italian border safely. Then they started preparation to a very risky dispatch known as the "jump at Tokyo", which was happily cancelled due to the capitulation of Japan.

Fig. 2: Paratrooper Sergeant Frank Tangherlini (right) and his youngest brother Burt (left). Los Angeles, the Spring of 1946.

In January, 1946, Frank Robert Tangherlini returned to the USA, and retired from military service. He has several military orders from the US Government.

In close time after his coming back to the USA, Tangherlini continued his education. He moved to Harvard University, where he studied sciences in the same grade that Robert Francis Kennedy (the US Attorney General in the future). Tangherlini was graduated as a BSc at Harvard, then — as MSc at the University of Chicago. In the years 1952–1955 he was employed as a research engineer in Convair-General Dynamics Company, San Diego. It was some ierony that his scientific supervisor was a German engineer, who worked for the Fascist Germany at the Peenemunde Rocket Centre during the World War II, and participated in the V-2 launches at London.

In 1959 Tangherlini got a PhD degree from Stanford University. He continued his post-doctorate studies in Copenhagen (1958–1959), at the Institute of Theoretical Physics headed by Niels Bohr. Then Tangherlini continued his studies at the School of Theoretical and Nuclear Physics, the Naples University (1959–1960). In the same time many other physicists, famous in the future, continued their post-doctorates there. They were Francis R. Halpern (1929–1995), Murray Gell-Mann (b. 1929), and the Japanese physicist Susunu Okubo (b. 1930).

In the years 1960–1961 Frank Robert Tangherlini was employed as a research scientist at the Institute of Field Physics, University of North Carolina. In 1961–1964 he was Assistant Professor at Duke University, North Carolina, then in 1964–1966 — Associate Professor at The George Washington University (four blocks from the White House, Washington, DC). In 1966–1967 he was a research scientist at Danish Space Research Institute, Copenhagen, and in the same time

Fig. 3: Some people pictured at the Institute of Theoretical Physics (now — Bohr Institute). Copenhagen, the fall of 1959. Top row: nine persons to the right, the tall person is Sheldon Glashow of the later Glashow-Weinberg-Salam electroweak theory. Just below him slightly to the right is Eugen Merzbacher, the author of a text on quantum mechanics. The second person in the same row, going to the right, is Frank Tangherlini. Go down two rows to the person almost directly below Tangherlini, with a beard, then move one person to the right , that is "Ben" Sidorov (Veniamin A. Sidorov) who later became the full member of the Russian Academy of Sciences and Director of the Accelerator Centre in Novosibirsk. Now go down two more rows to the first row. In the centre is Niels Bohr. Next to him, to your left, is Felix Bloch, whom Tangherlini had for nuclear physics when he was at Stanford. Four persons to the left of Bloch is Aage Bohr, one of Bohr's sons. Next to Aage Bohr, to your left is Ben Mottelson, who worked with Aage Bohr on nuclear physics. Go back to Niels Bohr, and count three persons to your right, that is Leon Rosenfeld who co-laborated with Bohr, particularly later on Complementarity. Finally, the next to the last person on the right is Magnusson. He was from Iceland, and worked with Prof. Møller on the gravitational energy-momentum tensor. Møller himself is not in the photo because he was then Director of NORDITA, a separate institute devoted mainly to assistance in research of Scandinavian physicists.

— a lecturer at the Technical University of Denmark. A long time from 1967 to 1994 he was Associate Professor at the College of the Holy Cross, Worcester (Massachusetts). Commencing in 1994 he is retired. He has residence in San Diego, California, where he is still active in science and sport.

Frank Robert Tangherlini is a member of the American Physical Society, and is also a member of several other civil and sport clubs. He is enthusiastic in tennis and foot racing. In particular, he participated, until the least time, in the annual marathon runs in California. He journalist reports are requested to publish by San Diego Union-Tribune. In 1947 he published a roman [2]. He survives by four children and seven grandchildren (four girls and three boys).

Frank Robert Tangherlini has a wide field of scientific interests: the Special Theory of Relativity, the General Theory of Relativity, relativistic cosmology, Mach's principle, and many others. He authored many publications in the peer review scientific journals. W. K. H. Panofsky (1919–2007) was one of his co-authors in science [3].

In already 1951, Tangherlini paid interest to the possibility of the superluminal objects — the objects whose velocity exceeds the velocity of light. He discussed this problem in 1951–1956 with Hermann Weyl (1885–1955), Gregor Wentzel (1898–1978), Wolfgang Pauli (1900–1958), John Wheeler (1911–2008), Julian Schwinger (1918–1994). He also had a talk with George Gamov (1904–1968), on the connected theme — the ultimate high ratio "signal/noise" which could be possible in radiowaves. All those considerations concerning the principal possibility of superluminal motions have led Tangherlini, in the future, to his own version of the transformations of the spatial coordinates and time being moved from one inertial reference frame into another one, which is different from the Lorentz transformations.

These transformations — at now they are known as the *Tangherlini transformations* — were deduced in 1958 while Frank Robert Tangherlini worked on his PhD thesis, and were

Fig. 4: Frank Tangherlini in 1959 at Copenhagen, after he has defended his PhD thesis where the Tanghelini transformations and the other important results were first introduced into theoretical physics.

the main part of the thesis. Tangherlini himself called these the *absolute Lorentz transformations*.

His PhD supervisor was Sidney D. Drell (b. 1926), who had became the best friend of Andrew D. Sakharow many years later. At the initially stage of the development, Tangherlini had also another supervisor who consulted him: it was Leonard Isaac Shiff (1915–1971), with whom Tangherlini closely co-laborated commencing in 1955.

June of 1958 was met by Tangherlini at Stanford University. He gave a public presentation of his PhD thesis [1] then, in September, he put his thesis on the desk of the Physics Section of the Graduate Division, Stanford University. Positive review on his PhD thesis were given from the side of Sidney D. Drell and Leonard Isaac Shiff, while Albert H. Bouker, the Dean of the Graduate Division, clarified that the PhD thesis is enough ready to be defended. Tangherlini's PhD thesis was considered in the absence of the author himself, because at that time he, in common with Drell, was with Niels Bohr in Copenhagen, in the Institute of Theoretical Physics (this Institute was called later Bohr Institute). On December 9, 1958, Florine H. McIntosh, the Secretary Committee on Graduate Study, informed Tangherlini that his PhD thesis has met a positive reaction from the side of the Committee's members — Joshua L. Soske (Geophysics), chairman, Walter E. Meyerhof (Physics), and Menaham M. Schiffer (Mathematics) — who considered the thesis. On January 9, 1959, Harvey Hall, the Registar of the Committee, provided a hardcopy of the Stanford PhD Diploma to Tangherlini. Later Tangherlini produced a microfilm of his PhD thesis [1], then gave presentations, based on the microfilm, at Copenhagen. In particular he provided the microfilm to several theoretical physicists such as Oscar Klein (1894–1977), who noted that he met a similar method of the synchronization of clocks while he read the lectures at Stockholm [4].

Being in 1959 at Copenhagen, Tangherlini composed a detailed paper on the basis of his PhD thesis, then submitted the paper to *Annals of Physics* (New York). Philip McCord Morse (1903–1985), the founder and first editor of the journal, however declined Tangherlini's paper. He argued that this paper was so large (it was 76 pages of the typewriting) for such a journal, and suggested, in his letter to Tangherlini sent on September 23, 1959, that Tangherlini should truncate it or, alternatively, split into two segregate papers. In his next letter to Tangherlini (September 28, 1959), Morse hoped that the requested version of the paper will be submitted in close time. Unfortunately, there was no chance to do it, because Tangherlini was very hurry of time while his post-doctorate studies at Naples. Undoubtedly, it was a big mistake made by Tangherlini that he ignored such a lucky chance. If that paper would have been published in that time, the end of the 1950's, his theory [1] was wide known to the scientific community so that the next fifty years of his life and scientific carrier were much glorious than it was in his real life.

Meanwhile, a very brief contents of his main scientific results, in particular — the direct and inverse Tangherlini transformations, were published in 1961, in a very short Section 1.3 of his large paper [5] spent on the applications of Mach's principle to the theory of gravitation. This paper got so much attention from the side of the scientific community, that was translated into Chinese by Prof. P. Y. Zhu, the famous Chinese theoretical physicist, then published in China [6]. A short description of Tangherlini's PhD thesis was also given in Appendix to his paper of 1994 [4].

The direct and inverse Tangherlini transformations are introduced on the case, where the clocks, located in two different inertial reference frames, are synchronized with each other by the signals of such a sort that they travel at infinite velocity (for instance, these can be superluminal-speed tachyons, the hypothetical particles). One regularly assumes that such an instant synchronization is impossible in practice. However this becomes real in the case where all clocks of the resting and moving reference frames are located along the same single line. To do it, one can use the so-called "light spot" B. M. Bolotovskiĭ and V. L. Ginzburg suggested [7], because it has to travel at a superluminal phase velocity. (In paper [8], I already considered the problem how two clocks, distantly located from each other, can be synchronized by means of such a "light spot", and also the auxiliary problems connected to it.) In his PhD thesis [1], Tangherlini suggested also another method how to synchronize the clocks: this is so-called the "external synchronization", where the clocks, distantly located from each other, become synchronized in a resting ("preferred") inertial reference frame, then these already synchronized clocks are used for synchronization of the other clocks, which are located in the moving inertial reference frames distant from each other. With these, each of the moving clocks are synchronized at that moment of time, when they meet the resting clocks. This method of synchronization leads however to the non-equality of different inertial reference frames: the "preferred" inertial reference frame is such that got the first synchronization of the clocks. The direct and inverse Tangherlini transformation are

$$\left.\begin{array}{ll} x' = \gamma(x - vt), & x = \gamma^{-1}x' + \gamma v t', \\ y' = y, & y = y', \\ z' = z, & z = z', \\ t' = \gamma^{-1}t, & t = \gamma t, \end{array}\right\} \qquad (1)$$

where v is the velocity (it is directed along the x-axis) of the inertial reference frame K' with respect to the preferred inertial reference frame K, $\gamma = 1/\sqrt{1 - v^2/c^2}$ is the Lorentz-factor, while c is the velocity of light.

It is obvious that the direct Tangherlini transformations have the sequel that time t' of a moving inertial reference frame has to delay in γ times with respect to t that is the same that the transverse Doppler-effect in the Special Theory of Relativity. The direct Tangherlini transformations (1) differ from the Lorentz transformations in only the transformation of time (this is due to the difference in the synchronization method for the clocks in different inertial frames). Proceeding from (1), Tangherlini obtained the velocity of light in vacuum, c', measured in the moving inertial reference frame K' [1]

$$c' = \frac{c}{1 + \frac{v}{c}\cos\alpha'}\,, \qquad (2)$$

where the angle α' is counted from the x'-axis in the moving inertial frame K'. Formula (2) means that the velocity of light in the moving inertial frame K', i.e. the quantity c', is anisotropic to the angle α'. This is a direct result of the synchronization procedure suggested by Tangherlini [1].

Tangherlini's formula (2) gives an explanation to the results obtained in the Michelson-Morley experiment [9] and also in the Kennedy-Thorndike experiment [10], because, according to Tangherlini's formula, the common time of the travel of a light beam toward and backward doesn't depend on the velocity v the inertial reference frame K' moves with respect to the "preferred" inertial reference frame K. Moreover, it is possible to show that the Tangherlini transformations provide an explanation to all interferention experiments checking the Special Theory of Relativity, in particular — Sagnac's experiments [11]. (Read more on the Sagnac effect and explanations of it in my recent papers [12, 13].) It should also be noted that the Lorentz transformations lead to the relation $c' = c$, which differs from Tangherlini's formula (2). Another important sequel of the Tangherlini transformations is that they keep Maxwell's equations to be invariant [1].

Fig. 5: Prof. Frank Robert Tangherlini at the present days. San Diego, California.

First time after Frank Robert Tangherlini suggested these transformations, they met actually no attention from the side of the scientific community. However just the anisotropy of the cosmic microwave background was found in 1977, the scientists have understood that fact that our inertial reference frame, connected to the Earth, moves with a velocity of about 360 km/sec with respect to a "preferred" inertial reference frame, where the microwave background radiation is mostly isotropic so that the common momentum of all space masses of our Universe is zero. After that experimental discovery, many suppositions concerning the anisotropy of the velocity of light were suggested, and the Tangherlini transformations became requested. The first persons who called the Tangherlini transformations in order to explain the Michelson-Morley result in the presence of the anisotropy of the velocity of light were R. Mansouri and R. U. Sexl [14]. Then many papers concerning the Tangherlini transformations were published.

There were several papers produced by the other authors where the Tangherlini transformations were "re-discovered" anew. Just two examples with the papers by S. Marinov, 1979 [15], and by N. V. Kupryaev, 1999 [16]. What is interesting, Frank Tangherlini met Stefan Marinov at the *General Relativity 9th Meeting* in Jena, in 1980. Tangherlini wrote me in his private letter on October 14, 2006, how this happened [17]:

> "I met Marinov under a most curios circumstance: He had put up over doorway of a hall where many of passed through, a poster of about 1/3 meter width and about 2 meter long in which he criticized me, in artistic calligraphy, for not having folloved on my transformation. I

> found this very strange behaviour. After all why did't write to me, or arrange a meeting at conference? So I suspect than he was somewhat crazy, although possibly artistically talented. In any crazy, one should't spend too much time on him except as an example of how people in science, just as in every day life, can astray."

During more than the hundred years after the Special Theory of Relativity was constructed, the most researchers were filled in belief that the Lorentz transformations originate in two postulates of the Special Theory of Relativity: the equality of all inertial reference frames, and the isotropy of the velocity of light in all inertial reference frames, including the independence of the velocity of light from the velocity of the source of light. If however using another procedure synchronizing the clocks, we obtain other transformations of the coordinates and time. In particular, if using the procedure synchronizing the clocks through the infinite-speedy signals, as Tangherlini suggested [1], we obtain the Tangherlini transformations. In other word, the synchronizing procedure suggested by Tangherlini leads to the kinematic relativistic transformations of the spatial coordinates and time (1), which are unexpected, but very adequate in the description of the transfer from one inertial reference frame into another one.

In this concern, I would emphasize the very important difference between the Tangherlini transformations and the Lorentz transformations. In the Tangherlini transformations, c' (2) is the velocity of light in the inertial reference frame K' measured by an observer who is located in the inertial reference frame K. An observer located in the inertial reference frame K' will found that $c' = c$. On the contrary, in the Lorentz transformations, given any inertial reference frame (K', K, or any other inertial frame), there is $c' = c$ and, hence, the velocity of light in the inertial frame K, being measured by the observers located in the inertial frames K' and K is always the same. The anisotropy of the coordinate velocity of light $c' = c$ in the inertial reference frame K' is the fee paid for the absolute simultaneity in all inertial reference frames [18].

The author thanks Frank Robert Tangherlini for the complete text of his PhD thesis [1] and the other papers useful to me, and also for friendly discussions. I also thank V. V. Kocharovski, for useful notes, and N. V. Roudik and E. G. Malykin who helped me. Special thank goes to D. Rabounski for assistance. This work was partly supported by the Council on President's Grants of the Russian Federation for Leading Scientific Schools (project no. NSh. 1931.2008.2).

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