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10 Progressing Beyond the Standard Models

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Abstract. The Standard Model of particle physics (SMPP) has enjoyed considerable success in describing a whole range of phenomena in particle physics. However, the model is considered incomplete because it provides little understanding of other empirical observations such as the existence of three generations of leptons and quarks, which apart from mass have similar properties. This paper examines the basic assumptions upon which the SMPP is built and compares these with the assumptions of an alternative model, the Generation Model (GM). The GM provides agreement with the SMPP for those phenomena which the SMPP is able to describe, but it is shown that the assumptions inherent in the GM allow progress beyond the SMPP. In particular the GM leads to new paradigms for both mass and gravity. The new theory for gravity provides an understanding of both dark matter and dark energy, representing progress beyond the Standard Model of Cosmology (SMC).

Povzetek. Standardni Model elektrošibke in barvne interakcije zelo uspešno opiše veliko pojavov v fiziki osnovnih delcev. Model imajo kljub temu za nepopoln, ker ne pojasni vrste empiričnih dejstev, kot je obstoj treh generacij leptonov in kvarkov, ki imajo, razen različnih mas, zelo podobne lastnosti. V prispevku obravnavamo osnovne predpostavke, na katerih so zgradili ta model in jih primerjamo s predpostavkami alternativnega modela, generacijskega modela. Generacijski model se v napovedih ujema z napovedmi standardnega modela za tiste pojave, ki jih slednji dobro opiše. Drugačne predpostavke omogočijo generacijskemu modelu napovedi, ki niso v dosegu standardnega modela: generacijski model ponudi drugačno paradigmo za maso in energijo. To vodi k novi teoriji gravitacije, ki ponuja novo razumevanje problemov temne snovi in temne energije, ter s tem k razširitvi standardnega modela kozmologije.

10.1 Introduction

The two models in the title are the Standard Model of Particle Physics (SMPP) and the Standard Model of Cosmology (SMC).

In this paper the SMPP [1] will be briefly described, indicating its *incompleteness* and the need for an improved model such as the Generation Model (GM) [2] in which the elementary particles of the SMPP have a substructure. During the last decade an alternative model, the GM, has been developed, although the current version has not changed since 2011. This model allows the elementary particles of the SMPP to have a substructure, suggested by indirect evidence. This version of the GM leads to new paradigms for both mass [3] and gravity [4]. In particular

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the new theory of gravity provides an understanding of both dark matter [5] and dark energy [6], and also solves the cosmological matter-antimatter asymmetry problem [7]. These represent progress beyond both the SMPP and the SMC.

10.2 Standard Model of Particle Physics

The SMPP [1,2] was developed throughout the 20th century, although the current formulation was essentially finalized in the mid-1970s following the experimental confirmation of the existence of quarks. The SMPP has enjoyed considerable success in describing the interactions of leptons and the multitude of hadrons (baryons and mesons) with each other as well as the decay modes of the unstable leptons and hadrons. However, the model is considered to be *incomplete* in the sense that it provides little understanding of several empirical observations: it does not explain the occurrence of three generations of the elementary particles: the first generation comprising the up and down quarks, the electron and its neutrino; the second generation comprising the charmed and strange quarks, the muon and its neutrino and the third generation comprising the top and bottom quarks, the tauon and its neutrino. Each generation behaves similarly except for mass. Second, it does not provide a unified description of the origin of mass nor describe the mass hierarchy of leptons and quarks. It also fails to describe the nature of gravity, dark matter, dark energy or the cosmological matter-antimatter asymmetry problem.

Because of the incompleteness of the SMPP, I have closely examined the basic assumptions upon which the SMPP has been erected [8]. There are three basic assumptions, which I consider to be dubious and also present major stumbling blocks preventing progress beyond the SMPP. These are (i) the assumption of a diverse complicated scheme of additive quantum numbers to classify its elementary particles; (ii) the assumption of weak isospin doublets in the quark sector to accommodate the universality of the charge-changing weak interactions and (iii) the assumption that the weak interactions are fundamental interactions described by a local gauge theory.

The additive quantum numbers allotted in the SMPP to classify the six leptons and the six quarks, which constitute the elementary matter particles of the SMPP, are charge Q, lepton number L, muon lepton number L_μ and tau lepton number L_τ for the leptons, and charge Q, baryon number A, strangeness S, charm C, bottomness B and topness T for the quarks. Antiparticles have opposite quantum numbers to the corresponding particle.

It should be noted that except for charge, leptons and quarks have different kinds of quantum numbers so that this classification is *non-unified*. Each of the additive quantum numbers is conserved in any interaction, except for S, C, B and T, which may undergo a change of one unit in weak interactions.

I consider that the basic problem with the SMPP is this classification of its elementary particles employing a diverse complicated scheme of additive quantum numbers, some of which are not conserved in weak interaction processes; and at the same time failing to provide any physical basis for this scheme.

Another problem with the SMPP concerns the method it employs to accommodate the universality of the charge-changing (CC) weak interactions. The CC weak interactions are mediated by the *W* bosons which have zero additive quantum numbers apart from charge.

In the SMPP, the observed universality of the CC weak interactions in the lepton sector is described by assuming that the mass eigenstate leptons form weak isospin doublets. The leptons have weak isospin 1/2, whose third component is related to both charge and lepton number. Restricting the discussion in this paper to only the first two generations for simplicity, means that the two neutrinos interact with their corresponding charged leptons with the full strength of the CC weak interaction and do not interact at all with the other charged lepton. This is guaranteed by the conservation of lepton numbers.

On the other hand the universality of the CC weak interactions in the quark sector is treated differently. It is assumed that the u and c quarks form weak isospin doublets with so-called weak eigenstate quarks d' and s', respectively, where

$$d' = d\cos\theta + s\sin\theta,$$

and

$$s' = -d\sin\theta + s\cos\theta,$$

and θ is a mixing angle introduced by Cabibbo in 1963 into the transition amplitudes prior to the development of the quark model in 1964. In the quark case the third component of weak isospin is related to both charge and baryon number.

The SMPP assumes that the u and c quarks interact with d' and s', respectively, with the full strength of the CC weak interaction and that the u and c quarks do not interact at all with s' and d', respectively. However, this latter assumption is dubious since, unlike the lepton sector, there are no conserved quantum numbers to guarantee this.

A third problem with the SMPP concerns the origin of mass. In the SMPP, the masses of hadrons arise mainly from the energy content of their constituent quarks and gluons, in agreement with Einstein's 1905 conclusion. On the other hand the masses of the elementary particles, the leptons, the quarks and the *W* and *Z* bosons are interpreted differently, arising from the existence of the so-called Higgs field [9,10]. The Higgs field was introduced mathematically to spontaneously break the U(1) x SU(2) local gauge symmetry of the electroweak interaction to generate the masses of the *W* and *Z* bosons. The Higgs field also cured the associated fermion mass problem: by coupling, with appropriate strength, originally massless fermions to the scalar Higgs field, it is possible to produce the observed fermion masses and to maintain local gauge invariance.

I consider that there are several problems with the SMPP's interpretation of the origin of mass. First, there is no clear evidence for the existence of the hypothetical Higgs field. Second, the model provides no *unified* origin of mass. Third, the fermion-Higgs coupling strength is dependent upon the mass of the fermion so that a new parameter is introduced into the SMPP for each fermion mass. In fact fourteen new parameters are required, if one includes two more parameters to describe the masses of the W boson and the Higgs particle. Fourth, the Higgs mechanism does *not provide any physical explanation* for the origin of the masses of the elementary particles.

The assumption that the weak interactions are fundamental interactions arising from a local gauge theory, unlike both the electromagnetic and strong colour interactions, is at variance with the experimental facts: both the W and Z particles, mediating the weak interactions, are massive, and this conflicts with the requirement of a local gauge theory that the mediating particles should be massless in order to guarantee the gauge invariance. I consider this assumption very dubious, especially since it leads to more problems than it solves. It also leaves several questions unanswered: *How does the spontaneous symmetry breaking mechanism occur within the electroweak theory? What is the principle that determines the large range of fermion masses exhibited by the leptons and quarks?*

10.3 Generation Model of Particle Physics

The GM of particle physics [2,8] overcomes many of the problems inherent in the SMPP. In the GM the three dubious assumptions of the SMPP discussed previously are replaced by three different and simpler assumptions. These are (i) the assumption of a *simpler unified* classification of leptons and quarks; (ii) the assumption that the *mass eigenstate quarks* form weak isospin doublets and that hadrons are composed of *weak eigenstate quarks* and (iii) the assumption that the weak interactions are *not fundamental interactions*.

Table 10.1 shows the additive quantum numbers allotted to both leptons and quarks in the GM. This is a much simpler and unified classification scheme involving only three additive quantum numbers: charge Q, particle number p and generation quantum number g. All three quantum numbers are conserved in all interactions. In particular this classification scheme allows the development of a composite model of leptons and quarks, which I consider a necessary condition for a simpler model.

particle	Q	p	g	particle	Q	p	g
ν_e	0	-1	0	u	$+\frac{2}{3}$	$\frac{1}{3}$	0
e^-	-1	-1	0	d	$-\frac{1}{3}$	$\frac{1}{3}$	0
ν_μ	0	-1	± 1	c	$+\frac{2}{3}$	$\frac{1}{3}$	± 1
μ^-	-1	-1	± 1	s	$-\frac{1}{3}$	$\frac{1}{3}$	± 1
ν_τ	0	-1	$0, \pm 2$	t	$+\frac{2}{3}$	$\frac{1}{3}$	$0, \pm 2$
τ^-	-1	-1	$0, \pm 2$	b	$-\frac{1}{3}$	$\frac{1}{3}$	$0, \pm 2$

Table 10.1. GM additive quantum numbers for leptons and quarks.

The conservation of the generation quantum number in weak interactions was only achieved by making two postulates, which means that the GM differs fundamentally from the SMPP in two more ways. First the GM postulates that it is the mass eigenstate quarks of the same generation, which form weak isospin doublets: (u, d) and (c, s). Thus the GM assumes, in the two generation approximation, that the u and c quarks interact with d and s, respectively, with the *full* strength of the CC weak interaction and that the u and c quarks do *not* interact at all with s and d, respectively. This is guaranteed by the conservation of the generation quantum number. Second, the GM postulates that hadrons are composed of weak eigenstate quarks such as d' and s' rather than the corresponding mass eigenstate quarks, d and s, as in the SMPP. Essentially, in the GM the roles of the mass eigenstate quarks and the weak eigenstate quarks are interchanged from that in the SMPP. These two postulates overcome the second dubious assumption of the SMPP.

The GM assumes that the leptons, quarks and the W and Z bosons are *composites*. Consequently, the weak interactions are *not* fundamental interactions arising from an SU(2) local gauge theory. They are residual interactions of the strong colour interaction binding the constituents of the leptons, quarks and the W and Z bosons together. This strong colour interaction is completely analogous to that of QCD in the SMPP. The composite nature of leptons, quarks and the W bosons overcomes the dubious assumption of the SMPP that the weak interactions are fundamental.

10.4 Composite Generation Model

In 2005 I began construction of a GM in which the leptons and quarks are composite particles. This composite GM was based on the unified classification scheme and also on early 1979 composite models of Harari [11] and Shupe [12]. The current composite GM was proposed in 2011 and is described in detail in Chapter 1 of the book *Particle Physics* published by InTech in 2012 [2] and in a review paper published in *Advances in High Energy Physics* in 2013 [8]. Unfortunately, today I have only the time to indicate some of the features of the composite GM (CGM) that are relevant for today's talk.

In the CGM the elementary particles of the SMPP have a *substructure* consisting of massless "rishons" bound together by strong colour interactions, mediated by massless hypergluons. Each rishon carries a colour charge: red, green or blue like a quark in the SMPP. This model is very similar to the SMPP in which hadrons have a *substructure* consisting of quarks bound together by strong colour interactions, mediated by massless gluons. Today I shall only have time to give a very brief outline of the development of the CGM.

There are numerous models in the literature. However, the CGM is based on the 1979 two-particle schematic models of Harari and Shupe, which are very similar and provide arguably the most economical and impressive description of the first generation of leptons and quarks. Both models treat leptons and quarks as composites of two kinds of spin-1/2 particles that Harari named "rishons" from the Hebrew for primary. The two kinds of rishons are labelled T with charge $Q = 1/3$ and V with $Q = 0$.

Table 10.2 shows the structures given to the first generation of leptons and quarks. It should be noted that no composite particle involves mixtures of rishons and antirishons. Also it should be noted that quarks contain mixtures of the two types of rishons, whereas leptons do not. Essentially, the Harari-Shupe model (HSM) describes the charge character of the first generation of particles.

particle	structure	Q
e^+	TTT	$+1$
u	TTV, TVT, VTT	$+\frac{2}{3}$
$\bar{d}$	TVV, VTV, VVT	$+\frac{1}{3}$
ν_e	VVV	0
$\bar{\nu}_e$	$\bar{V}\bar{V}\bar{V}$	0
d	$\bar{T}\bar{V}\bar{V}, \bar{V}\bar{T}\bar{V}, \bar{V}\bar{V}\bar{T}$	$-\frac{1}{3}$
$\bar{u}$	$\bar{T}\bar{T}\bar{V}, \bar{T}\bar{V}\bar{T}, \bar{V}\bar{T}\bar{T}$	$-\frac{2}{3}$
e^-	$\bar{T}\bar{T}\bar{T}$	-1

Table 10.2. HSM of first generation of leptons and quarks.

The CGM is a major extension of the HSM: the introduction of a *third* kind of rishon (U) and all three additive quantum numbers are allotted to each kind of rishon (see Table 10.3).

rishon	Q	p	g
T	$+\frac{1}{3}$	$+\frac{1}{3}$	0
V	0	$+\frac{1}{3}$	0
U	0	$+\frac{1}{3}$	-1

Table 10.3. CGM additive quantum numbers for rishons.

Table 10.4 gives the structures of the first generation of leptons and quarks in the CGM. Antiparticles are denoted in the usual manner by a "bar" placed above the particle identifier. The u-quark has $p = 1/3$ since it contains two T-rishons and one $\bar{V}$-rishon. It is essential that the u-quark should contain an $\bar{V}$-rishon rather than a V-rishon as in the HSM, since its particle number is required to agree with its baryon number 1/3. It should be noted that leptons are composed of three rishons, while quarks are composed of one rishon and one rishon-antirishon pair. Each lepton of the first generation is *colourless*, composed of three rishons carrying different colours. Each quark of the first generation is *coloured*, composed of one rishon and one colourless rishon-antirishon pair. The first generation of particles are all built out of T and V rishons and their antiparticles so that each particle has $g = 0$. The second and third generations are identical to the first generation plus one and two *colourless* rishon-antirishon pair(s): $\bar{U}V$ or $\bar{V}U$ with $Q = p = 0$ but $g = \pm 1$ so that the second and third generations have $g = \pm 1$ and $g = 0, \pm 2$, respectively. This gives *three repeating patterns*.

particle	structure	Q	p	g
e^+	TTT	$+1$	$+1$	0
u	$TT\bar{V}$	$+\frac{2}{3}$	$+\frac{1}{3}$	0
$\bar{d}$	$T\bar{V}\bar{V}$	$+\frac{1}{3}$	$-\frac{1}{3}$	0
ν_e	$\bar{V}\bar{V}\bar{V}$	0	-1	0
$\bar{\nu}_e$	VVV	0	$+1$	0
d	$\bar{T}VV$	$-\frac{1}{3}$	$+\frac{1}{3}$	0
$\bar{u}$	$\bar{T}\bar{T}V$	$-\frac{2}{3}$	$-\frac{1}{3}$	0
e^-	$\bar{T}\bar{T}\bar{T}$	-1	-1	0

Table 10.4. CGM of first generation of leptons and quarks.

10.5 Mass

Since the mass of a hadron arises mainly from the energy of its constituents, the CGM suggests that the mass of a lepton, quark or vector boson arises from a characteristic energy E associated with its constituent rishons and hypergluons, according to $m = E/c^2$. Thus the CGM provides a *new paradigm* and a *unified* description for the origin of *all* mass: the mass of a body arises from the energy content E of its constituents. The mass is given by $m = E/c^2$ in agreement with Einstein's 1905 conclusion, so that there is no need for the existence of a Higgs field with its accompanying problems. A corollary of this idea is: *If a particle has mass, then it is composite.*

The CGM suggests that the mass hierarchy of the three generations arises from the substructures of the leptons and quarks. The mass of each composite particle is expected to be *greater* if the constituents are on average more widely spaced: this is a consequence of the nature of the strong colour interactions, which are stronger for larger separations of the colour charges, and higher generation particles are more massive than lower generations. Particles with two or more charged rishons will have larger structures due to electric repulsion.

Qualitatively, for the same generation, one expects that (i) a charged lepton will have a greater mass than the corresponding neutral lepton; (ii) a $Q = +2/3$ quark will have a greater mass than the corresponding $Q = -1/3$ quark. These are both generally true: (i) the electron has a larger mass than its corresponding neutrino, and (ii) the top quark mass (175 GeV) is > the bottom quark mass (4.5 GeV), the charmed quark mass (1.3 GeV) is > the strange quark mass (200 MeV), although the up quark mass (5 MeV) is < the down quark mass (10 MeV). The first generation quarks seem to present an anomaly since the proton consists of two up quarks and one down quark while the neutron consists of two down quarks and one up quark so that the proton is only stable if the down quark ($Q = -1/3$) is more massive than the up quark ($Q = +2/3$). In the CGM, this anomaly is accounted for by the constituents of hadrons being weak-eigenstate quarks rather than mass-eigenstate quarks. The proton is stable since the weak eigenstate quark d' has a larger mass than the up quark, containing about 5% of the strange quark mass.

10.6 Gravity

Let us now consider the nature of gravity within the framework of the GM. It is envisaged that the rishons of each colourless lepton, i.e., a particle with total colour charge zero, are very strongly localized since to date there is no direct evidence for any substructure of these particles. The rishons are expected to be distributed according to quantum-mechanical wave functions, for which the product wave function is significant for only an extremely small volume of space so that the corresponding colour fields are almost cancelled. It should be noted that the colour fields would only cancel completely if each of the rishons occupied the same position, but quantum mechanics prevents this. This raises a question: *What is the residual interaction arising from the incomplete cancellation of the strong interactions?*

Between any two colourless leptons (electrons) there will be a very weak residual interaction, arising from the colour interactions acting between the rishons of one lepton and the rishons of the other lepton. In two papers [3,4] I suggested that this residual interaction gives rise to the usual gravitational interaction. There will be a similar residual interaction between any two colourless hadrons such as neutrons and protons, each containing three differently coloured quarks.

Gravity acts between bodies with mass. The mass of a body of ordinary matter is essentially the total mass of its constituent electrons, neutrons and protons. In the GM, each of these three particles is composite and colourless. Indeed, all three particles are in a three-colour antisymmetric state so that their behaviour with respect to the colour interactions is basically the same. This suggests that the residual colour interactions between electrons, neutrons and protons have several properties associated with the usual gravitational interaction: universality, very weak strength and attraction.

In the GM gravity essentially arises from the residual colour forces between all electrons, neutrons and protons. This leads to a *new law of gravity*: the residual colour interactions between any two bodies of masses m_1 and m_2, separated by a distance r, leads to a universal law of gravitation, which closely resembles Newton's original law given by: $F = H(r) m_1 m_2 / r^2$, where Newton's gravitational constant (G) is replaced by a function of r, $H(r)$.

The new gravitational interaction of the GM is based upon the residual colour interactions acting between electrons, neutrons and protons. The GM assumes that the colour interactions acting between rishons have the same characteristics as the colour interactions acting between quarks in the SMPP. These colour interactions have two important properties that differ from the Newtonian interaction: (i) asymptotic freedom and (ii) colour confinement. These determine the nature of the function $H(r)$.

Asymptotic freedom is rather a misnomer. A better term is antiscreening as used by Wilczek in his 2004 Nobel lecture. Antiscreening arises from the self-interactions of the hypergluons mediating the residual colour interactions. These antiscreening effects lead to an increase in the strength of the residual colour interactions acting so that H becomes an increasing function of r. The 'flat' rotation curves observed for galaxies imply that $H(r) = G(1 + kr)$.

10.7 Galaxy Rotation Problem and Dark Matter

For galaxies there is a major gravitational problem [5], which has been around for about forty years. It was found that the rotation curves for galaxies disagreed with Newton's gravitational law for large r: the stars and gas were rotating much faster than expected from Newton's law and their orbital velocities were roughly constant. These observations implied that either Newton's law was incorrect at large distances or some considerable mass was missing.

The rotation curve for a galaxy is the dependence of the orbital velocity of the visible matter in the galaxy on its radial distance from the centre of the galaxy. What the observations showed was that the rotation curves were essentially 'flat' at the extremities of the visible matter, i.e., at large distances. This implies gross disagreement with Newton's universal law of gravitation, which predicts a fall-off as $1/\sqrt{r}$ as in the solar system.

Two solutions, which have been very successful, are first the *dark matter hypothesis* that proposes that a galaxy is embedded within a giant halo of dark matter. This matter is considered to be non-atomic but otherwise its nature is unknown and so far has not been detected. The second solution is the *Modified Newtonian Dynamics* (MOND) hypothesis: in 1983 Milgrom [13] proposed that gravity varies from Newton's law for low accelerations. This is an empirical hypothesis without physical understanding.

It was found that the *new law of gravity* is essentially equivalent to the MOND hypothesis so that the GM gravitational interaction provides a physical basis for the MOND hypothesis. In my opinion, the continuing success [14,15] of the MOND hypothesis is a strong argument against the existence of undetected dark matter haloes, consisting of unknown matter embedding galaxies.

In the GM $H(r) = G(1+kr)$ arises from the self-interactions of the hypergluons mediating the gravitational interaction and explains the dark matter problem of the galaxy rotational curves: for small r, $H(r)$ is approximately G and gravity is approximately Newtonian; for large r, $H(r)$ is approximately Gkr and gravity is approximately $1/r$ rather than $1/r^2$, and the $1/r$ dependence gives the flat rotation curves observed.

10.8 Dark Energy Problem

Colour confinement is the phenomenon that colour charged particles (e.g., quarks in the SMPP, rishons in the GM) cannot be isolated and consequently form colourless composite particles (e.g., mesons and baryons in the SMPP and also leptons in the GM). Colour confinement leads to another phenonmenon analogous to the 'hadronization process', i.e., the formation of hadrons out of quarks and gluons in the SMPP and implies $H(r) = 0$ for sufficiently large r in the GM.

In the GM, $H(r) = 0$ arises if the gravitational field energy is sufficient that it is energetically favourable to produce the mass of a particle-antiparticle colourless pair rather than the colour field to extend further. This implies that gravity ceases to exist for sufficiently large cosmological distances.

The strong colour interaction is known to have a finite range of approximately 10^{-15}m. Gravity is about 10^{-41} times weaker at 10^{-15}m [16] than the strong colour interaction. This suggests that the 'hadronization process' for gravity occurs at about 10^{26}m, i.e., roughly ten billion light years.

The new law of gravity implies that gravity ceases to exist for cosmological distances exceeding several billion light years, resulting in less slowing down of galaxies than expected from Newton's law. This result agrees well with observation [17,18] of distant Type Ia supernovae, which indicate the onset of an accelerating expansion of the universe at about six billion light years.

10.9 Summary and Conclusion

The GM allows progress beyond the Standard Models of both particle physics and cosmology by the development of a composite model of the elementary particles of the SMPP. This led to (i) a unified description of all mass and a qualitative understanding of the mass hierarchy of the three generations of leptons and quarks and (ii) a new law of gravity and an understanding of both dark matter and dark energy.

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