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GENERATION NUMBERS AND COMPOSITE MODELS OF LEPTONS AND QUARKS

L. PALGI. GENERATSIOONIARVUD NING LEPTONITE JA KVARKIDE LIITMUDELID

Л. ПАЛЬГИ. ГЕНЕРАЦИОННЫЕ ЧИСЛА И СОСТАВНЫЕ МОДЕЛИ ЛЕПТОНОВ И КВАРКОВ

(*Presented by P. Kard*)

It is convenient to introduce leptons and quarks in three generations [1]:

first generation: ν_e, e^-, u, d,
second generation: ν_μ, μ^-, c, s,
third generation: ν_τ, τ^-, t, b.

These generations are formed so that the masses increase with added generations. There is a clear experimental evidence for the existence of the first and second generations of fundamental fermions and for the existence of the τ-lepton. The study of τ-decay gives indirect evidence for the existence of ν_τ. The upsilon as $b\bar{b}$ state serves as such for the existence of the b-quark. Although t-quark remains to be discovered, the existence of t-quark is strongly suggested by theory. How many generations are there? It remains to be seen.

Although there are a lot of open problems (an excellent survey may be found in ref. [1]), a simple picture of the world is consistent with experimental data: the $SU(2)\times U(1)$ standard theory [2–4]. The electroweak interaction of quarks and leptons is described by the spontaneously broken $SU(2)\times U(1)$ gauge theory with six quarks and six leptons in left-handed doublets

$$\begin{pmatrix}\nu_e\\ e^-\end{pmatrix},\quad \begin{pmatrix}\nu_\mu\\ \mu^-\end{pmatrix},\quad \begin{pmatrix}\nu_\tau\\ \tau^-\end{pmatrix}$$

$$\begin{pmatrix}u\\ d\end{pmatrix},\quad \begin{pmatrix}c\\ s\end{pmatrix},\quad \begin{pmatrix}t\\ b\end{pmatrix}$$

and right-handed singlets of charged fermions [2–5]. Each charged lepton couples via the same weak current to its own neutrino. Weak transitions will normally connect u to d, c to s, and t to b while Cabibbo-like mixing with other generations is strongly suppressed. At the same time *a priori* there are no theoretical prescriptions of how to choose the lepton and quark doublets.

It is remarkable that each generation is similar to other generations and the pattern of quarks is very similar to that of leptons. So the old μ-e puzzle, instead of being solved, is modified to the generation puzzle and to that of the quark-lepton symmetry.

In this note, in order to emphasize the quark-lepton symmetry, we introduce an additive quantum number for sequent lepton and quark generations: the generation numbers n_l and n_q as positive integers for generations and negative integers for antigenerations. The generation numbers are defined in Table 1.

Table 1

Generation Numbers

Leptons and Antileptons	n_l	Quarks and Antiquarks	n_q
e^-, ν_e	1	u, d	1
μ^-, ν_μ	2	c, s	2
τ^-, ν_τ	3	t, b	3
$e^+, \overline{\nu}_e$	—1	$\bar{u}, \bar{d}$	—1
$\mu^+, \overline{\nu}_\mu$	—2	$\bar{c}, \bar{s}$	—2
$\tau^+, \overline{\nu}_\tau$	—3	$\bar{t}, \bar{b}$	—3

The analogy between quarks and leptons is immediately expressed by using the generation numbers. The allowed charged hadron currents satisfy $\Delta n_q=0$, and the allowed charged lepton currents satisfy $\Delta n_l=0$. The currents with $\Delta n_q\neq0$ are Cabibbo-suppressed hadron currents [4,5]. Although there is no experimental evidence, in principle no prohibition to $\Delta n_l\neq0$ leptonic currents exists. The corresponding Cabibbo-like angles are very small but not necessarily zero. The currents with $\Delta n_q\neq0$, $\Delta n_l\neq0$ are the hypothetical ones responsible for baryon number nonconservation.

In what follows we examine generation numbers from the point of view of composite models. A composite model of quarks and leptons was outlined by H. Harari and M. A. Shupe in two very similar papers [6,7]. The set of building blocks consists of two $J=1/2$ objects, rishons (further H. Harari's notation will be used [6]): one charged particle T and one neutral particle V. Their antiparticles are $\overline{T}$ and $\overline{V}$. The quarks and leptons can be constructed from three rishons. The quarks and leptons of the first generation are the ground states of the corresponding composite systems and a higher generation must contain the same rishons at higher energy values.

Here we introduce quantum numbers to characterize the composite rishon lepton and quark states, N_l and N_q, respectively (see Tables 2 and 3).

In Tables 2 and 3 n_R is a conserved number — the net number of rishons minus the net number of antirishons. It is useful to define n_C as the number of possible arrangements of rishons: $n_C=1$ for a lepton and $n_C=3$ for a quark. Now it is possible to express the generation numbers via the composite model numbers and the electric charge:

$$n_{q,l}=-N_{q,l}(-1)^{n_R+Qn_C}. \quad (1)$$

Table 2

Leptons and Antileptons

Rishon Structure	First Gen. N_l		Second Gen. N_l		Third Gen. N_l		Q	n_R	n_C
TTT	e^+	1	μ^+	2	τ^+	3	1	3	1
VVV	ν_e	1	ν_μ	2	ν_τ	3	0	3	1
$\bar{V}\bar{V}\bar{V}$	$\bar{\nu}_e$	—1	$\tilde{\nu}_\mu$	—2	$\bar{\nu}_\tau$	—3	0	—3	1
$\bar{T}\bar{T}\bar{T}$	e^-	—1	μ^-	—2	τ^-	—3	—1	—3	1

Table 3

Quarks and Antiquarks

Rishon Structure	First Gen. N_q		Second Gen. N_q		Third Gen. N_q		Q	n_R	n_C
TTV, TVT, VTT	u	1	c	2	t	3	2/3	3	3
TVV, VTV, VVT	$\bar{d}$	1	$\bar{s}$	2	$\bar{b}$	3	1/3	3	3
$\bar{T}\bar{V}\bar{V}$, $\bar{V}\bar{T}\bar{V}$, $\bar{V}\bar{V}\bar{T}$	d	—1	s	—2	b	—3	—1/3	—3	3
$\bar{T}\bar{T}\bar{V}$, $\bar{T}\bar{V}\bar{T}$, $\bar{V}\bar{T}\bar{T}$	$\bar{u}$	—1	$\bar{c}$	—2	$\bar{t}$	—3	—2/3	—3	3

The third component of the weak isospin of left-handed doublet states is in composite model numbers

$$(t_3)_{q,l} = -1/2(-1)^{n_R+Qn_C}. \qquad (2)$$

A number of fenomenological consequences are common in the model of refs. [6,7] and in R. Raitio's model [8] for which it is possible to define the above-introduced composite model numbers as well.

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