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Rishon Constituents of Higher-Generation Leptons and a Global Conservation Law

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This paper offers a model-independent approach for the rishon assignments of higher-generation leptons and simultaneously a conservation law that seems to account for all the particle decays observed so far without considering the baryon and several lepton conservation laws.

Recently there has been a great deal of interest in the subcomponent model for quarks and leptons (Harari, 1979; Shupe, 1979; Nelson, 1980; Pati and Salam, 1974). We consider here the Harari–Shupe (1979) type of model with two rishons T and V. Every quark and lepton in the first generation corresponds to some allowed combination of rishon or antirishon and the model accounts successfully for the charge, color, and spin of the composite system. The rishon contents of higher generation leptons and quarks are, however, not yet well established. Several models have been proposed but none is unique. In this paper, we offer a model-independent approach for assigning rishons to the members of higher generations. Our approach entails a conservation law that seems to account for all the particle decays without considering the baryon and several lepton conservation laws.

In the rishon model (Harari, 1979, Shupe, 1979), the rishon contents of quarks and leptons of the first generation and the three vector bosons (W^+, W^-, Z^0) are given as

$$e^- = 3\bar{T}, \qquad \nu_e = 3V, \qquad d = \bar{T}2\bar{V}, \qquad u = 2TV$$

and

$$W^+ = 3T3V, \qquad W^- = 3\bar{T}3\bar{V}, \qquad Z^0 = 3V3\bar{V}$$

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where T and V are two spin-half objects (rishons) with electric charge $Q(T)=1/3$, $Q(V)=0$. It is well known that the baryon and the lepton numbers are additive quantum numbers. In the quark model (Gell-Mann and Ne'eman, 1964), we assign $B=1/3$ to each quark such that all the baryons and mesons can have, respectively, $B=+1$ and $B=0$. Thus while there is a baryon number ($B=1/3$) for any quark, and three lepton numbers L_e, L_μ, L_τ for the leptons of three generations, it is interesting to note that the rishons T and V (which under different combinations yield both the quarks and leptons) can be provided with neither baryon nor lepton number. This fact in turn stimulates us to assign a new quantum number N (say) to the rishons so that both the quarks and leptons can have a common quantum number. In the rishon model, the quarks and leptons are supposed to be generated by at least three rishons in each case and so we prescribe the value of N for the T and V rishons arbitrarily as $N(T)=N(V)=1/3$ and for the antirishons $N(\bar{T})=N(\bar{V})=-1/3$. Then apart from the usual quantum numbers, the value of N for the quarks and leptons of the first generation and the same for the intermediate bosons are found to be

$$N(d)=-1, \qquad N(u)=+1, \qquad N(e^-)=-1, \qquad N(\nu_e)=+1 \tag{1a}$$

$$N(W^-)=-2, \qquad N(W^+)=+2, \qquad N(Z^0)=0 \tag{1b}$$

Needless to say, $N(\bar{d})=+1$, $N(\bar{u})=-1$, $N(e^+)=+1$, $N(\bar{\nu}_e)=-1$. Further, we suppose that for the γ particles, $N(\gamma)=0$. The values of N for the pions and nucleons are given as

$$\begin{aligned} &N(P)=N(uud)=+1, && N(n)=N(udd)=-1, \\ &N(\pi^+)=N(u\bar{d})=+2, && N(\pi^-)=N(\bar{u}d)=-2, \\ &N(\pi^0)=N(u\bar{u} \text{ or } d\bar{d})=0 \end{aligned} \tag{2}$$

It is now significant to note that from the decay of the neutron, $n \to P+e^-+\bar{\nu}_e$, we find $\Delta N=0$. The most expected decay mode for proton, viz. $P\to e^+ + \pi^0$ predicted in the grand unification scheme such as $SU(5)$ (Georgi and Glashow, 1974), also gives $\Delta N=0$. But what about other (involving members of higher generations) decay modes? An encouraging indication is that if one assigns $N(s)=-1$, $N(c)=+1$, $N(\mu^-+\bar{\nu}_\mu)=-2$, $N(\tau^-+\bar{\nu}_\tau)=-2$, then all the experimentally observed decay modes of different particles (Particle Data Group, 1982) are found to satisfy $\Delta N=0$ without a single exception.

As regards the b quark, it has now been seen in combination with an antiquark not of its own flavor. All the evidence (Behrends et al., 1983) supports the view that the b quark decays by emitting a W^-. Furthermore, there are indications that most of the time it turns into a c quark rather than a u quark, i.e., $b\to c+W^-$. The values $N(W^-)=-2$, $N(c)=+1$

Table I. The Rishon Contents of Leptons and Quarks as Proposed by Elbax *et al.* (1981)

Leptons		Quarks	
ν_e	VVV	u, d	$TTV, \bar{T}\bar{V}\bar{V}$
e^+	TTT	c	$2TV+K_2(T\bar{T})+K_2'(V\bar{V})$
ν_μ	$3V(3V3\bar{V})$	s	$2\bar{V}\bar{T}+r_2(T\bar{T})+r_2'(V\bar{V})$
μ^+	$3T(3T3\bar{T})$	W^+, W^-	$3T3V, 3\bar{T}3\bar{V}$
ν_τ	$3V(6V6\bar{V})$	Z_0	$3V3\bar{V}$
τ^+	$3T(6T6\bar{T})$	Gluon	$2T2\bar{T}V\bar{V}$ or $2V2\bar{V}T\bar{T}$

Table II. The Rishon Contents of Leptons in the Present Model

ν_e	$3V$	e^-	$3\bar{T}$
ν_μ	$3\bar{V}(3V3\bar{V})$	μ^-	$3\bar{V}(3\bar{T}3\bar{V})$
ν_τ	$9\bar{V}(3V3\bar{V})$	τ^-	$9\bar{V}(3\bar{T}3\bar{V})$

together with $\Delta N=0$ then yield $N(b)=-1$. The decay of the b quark demands that the b quark share a doublet with the t quark. Now since $N(b)=-1$, it is very likely to presume that $N(t)=+1$ so that one can define for the doublets, $N(d, u)=N(s, c)=N(b, t)=(-1, +1)$. Thus, if one accepts the quantum number N and its conservation $\Delta N=0$, then the experimental facts allow one to define the value of N for the quarks and leptons of each generation as follows:

$$N(d)=-1, \qquad N(u)=+1, \qquad N(e^-)=-1, \qquad N(\nu_e)=+1 \tag{3a}$$

$$N(s)=-1, \qquad N(c)=+1, \qquad N(\mu^-+\bar{\nu}_\mu)=-2 \tag{3b}$$

$$N(b)=-1, \qquad N(t)=+1, \qquad N(\tau^-+\bar{\nu}_\tau)=-2 \tag{3c}$$

It is gratifying to note that the rishon constituents of the quarks and leptons of higher generations proposed in several models (Elbaz et al., 1981; Harari and Seiberg, 1981) also satisfy the equation (3). Here we keep the rishon contents of the second- and third-generation quarks the same as proposed

Table III. Rishon Number (N) for the Quarks and Leptons

Leptons		Quarks	
$N(\nu_e)=+1,$	$N(e^-)=-1$	$N(u)=+1,$	$N(d)=-1$
$N(\nu_\mu)=-1,$	$N(\mu^-)=-3$	$N(c)=+1,$	$N(s)=-1$
$N(\nu_\tau)=-3,$	$N(\tau^-)=-5)$	$N(t)=+1,$	$N(b)=-1$

by Elbaz et al. (1981) or in any other possible manner that would always give $N(s)=-1$, $N(c)=+1$, $N(b)=-1$, $N(t)=+1$.

But in the case of leptons, if we accept $N(\mu^-)=-1$, $N(\nu_\mu)=+1$, $N(\tau^-)=-1$, $N(\nu_\tau)=+1$ [as found from the model (Table I)], it appears that although the single conservation law $\Delta N=0$ can explain all the particle decays, the need for considering the several lepton conservation laws remains inevitable to explain the nonoccurrence of the decays like $\mu^- \to e^- + e^+ + e^-$, $\mu^- \to e^- + \bar{\nu}_e + \nu_e$, $\tau^- \to e^- + \bar{\nu}_e + \nu_\mu$, etc. However, this difficulty can be overcome and in fact, $\Delta N=0$ would be a unique conservation law provided we find that the values of N for μ^- ν_μ, τ^-, ν_τ are somewhat different from that given above and at the same time satisfy the constraints $N(\mu^-)+N(\bar{\nu}_\mu)=N(\tau^-)+N(\bar{\nu}_\tau)=-2$ [equation (3)]. Needless to say, such a possibility emerges when the rishon constituents of the said particles are different from that given by the previous model (Elbaz et al., 1981).

Any subcomponent model for quarks and leptons must supply some mechanism for binding the subcomponents together and for this purpose, the concept of hypercolor force is introduced. In addition to their electric charge and color, the rishons are assumed to carry hypercolor. The antirishons are supposed to have antihypercolor. Only combinations of three rishons or three antirishons are neutral with respect to hypercolor. The assignment of hypercolor thus explains the rule for forming composite rishon systems. If each hypercolor rishon is counted as a separate particle, there are 18 rishon varieties altogether. So, without violating the exclusion principle, we may propose (although heuristic) another possibility of the rishon constituents of the second and third generation leptons as

$$\nu_\mu = 3\bar{V}(3V3\bar{V}), \qquad \mu^- = 3\bar{V}(3\bar{T}3\bar{V}) \tag{4a}$$

$$\nu_\tau = 9\bar{V}(3V3\bar{V}), \qquad \tau^- = 9\bar{V}(3\bar{T}3\bar{V}) \tag{4b}$$

so that they consistently remain hypercolorless, colorless, electrically neutral (ν_μ, ν_τ), integrally charged (μ^-, τ^-), and have half-spin angular momentum. We like to point out at this moment that our rishon assignments for higher generations are different from that given by Elbaz et al. (1981). Elbaz increases the rishon contents for higher generations in steps of $3V3\bar{V}$ for ν's and $3T3\bar{T}$ for l's. Our assignments, on the other hand, are in steps of $6\bar{V}$ both for ν's and l's.

The usual internal quantum numbers, viz. lepton number (L), isospin (I_3), and charge (Q) of the leptons of each generation are expressed in terms of rishons as

$$L_g = \frac{1}{3+6(g-1)} \Sigma R \tag{5a}$$

with

$$\Sigma R = [n(T) + n(\bar{T}) + n(V) + n(\bar{V})],$$

$$I_3 = \tfrac{1}{6}[n(T) - n(\bar{T}) + n(V) - n(\bar{V})] + (g-1) \tag{5b}$$

and

$$Q_g = 2(g-1) - k/3 \tag{5c}$$

with $k = n(\bar{T}) + n(\bar{V})$, so that one can obtain the Gell-Mann-Nishijima relation

$$Q = I_3 + Y/2, \qquad Y = -L \tag{6}$$

In the above relations, g represents the generation number and stands as $g = 1, 2, 3$, respectively, for the first, second, and third generations.

According to equation (4), the values of N for the second and third generation leptons turn out to be

$$N(\nu_\mu) = -1, \qquad N(\mu^-) = -3, \qquad N(\nu_\tau) = -3, \qquad N(\tau^-) = -5 \tag{7}$$

Now from equation (7), we find $N(\mu^-) + N(\bar{\nu}_\mu) = -2$, $N(\tau^-) + N(\bar{\nu}_\tau) = -2$, as expected from experimental results [equation (3)]. Thus it may be stated that the rishon assignments for the higher-generation leptons given in equation (4) are consistent from the experimental side as well as from the standpoint of their internal quantum numbers.

In conclusion, we would like to give a short account of the results of the above discussions. The rishon model reveals the existence of a new quantum number N. Its conservation $\Delta N = 0$ is found to be true for any decay mode involving the members of first generation. We have then assumed that the proposed $\Delta N = 0$ is a unique conservation law and would be true for any observed decay involving members of any generation. In fact, such an assumption is relevant because the consideration of three conservation laws just for six particles in the lepton group seems unusual inasmuch as there remains only one conservation law (baryon conservation) in the large hadron group. Moreover, this conservation law $\Delta N = 0$ can overcome the need for considering the mysterious conservation of $(B-L)$ instead of global baryon conservation in the unified models of quarks and leptons. However, as discussed above, the existence of relation such as $\Delta N = 0$ implies a need for assigning the rishons to the higher-generation leptons. The assignments proposed by Elbaz et al. (1981) do not fulfil the purpose. In view of this fact, we have assigned rishons to the higher-generation leptons in such a way that the single conservation law $\Delta N = 0$ might be treated as a substitute of the baryon and three lepton conservation laws. Alternatively, it can be stated that the rule $\Delta N = 0$ together with the constraints $N(\mu^-)+N(\bar{\nu}_\mu)=N(\tau^-)+N(\bar{\nu}_\tau)=-2$ [obtained from experiments (equation (3))] have given us a clue to find the rishon contents of higher-generation leptons. This paper mainly concerns the rishon assignments for the higher generations. We differ from Elbaz et al. in this regard. Elbaz increases the rishon contents for higher generations, in steps of $3V3\bar{V}$ for ν's and $3T3\bar{T}$ for l's. Our assignments, on the other hand, are in steps of $6\bar{V}$ for both ν's and l's. Elbaz has to have alternating parities for (e, μ, τ) but same parity for $(\nu_e, \nu_\mu, \nu_\tau)$. We do not have this problem. Moreover, the proposed selection rule $\Delta N=0$ demands that out of some recently suggested decay modes, viz.,

$$P \to e^+ + \pi^0 \tag{8a}$$

$$P \to e^+ + k^0 \tag{8b}$$

$$P \to \mu^+ + k^0 \tag{8c}$$

$$\mu^- \to e^- + \gamma \tag{8d}$$

$$\tau^- \to \mu^- + \gamma \tag{8e}$$

only the decay modes (8a) and (8b) could be allowed. The forbidding of the hypothetical process $P \to \mu^+ + k^0$, $\mu^- \to e^- + \gamma$, $\tau^- \to \mu^- + \gamma$, of course, does not undermine our proposed selection rule because some theories (Nelson, 1984; Mitra, 1983) also straight way forbid them. In fact, the quantum number N distinguishes the three-generation leptons from one another which look observationally alike. Further, the proposed selection rule provides an explanation for maintaining their relative stabilities against mutual transition ($\mu \not\to e\gamma$, $\tau \not\to \mu\gamma$) (Mitra, 1983). This paper thus presents one possibility of the rishon constituents of the higher-genration leptons and simultaneously a conservation law that can rule out many unwanted decays.

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