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BARYON NUMBER AND LEPTON NUMBER CONJUGATION SYMMETRY*

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SUMMARY: Lepton number conjugation symmetry leads to e-μ universality and the Konopinski-Mahmoud classification scheme. A similar doubling of states might also occur for the baryons.

In our galaxy there is a large preponderance of baryons over antibaryons. But there is another, lesser-noted asymmetry, namely that all protons have the same baryon number, $B = 1$. Why do there not also exist positively-charged protons with $B = -1$? The protons in some other galaxy could all have $B = -1$, and everything would be identically the same, except they could annihilate with ordinary protons. They would not obey the usual Gell-Mann-Nishijima formula, but rather

(1) $$Q = I_3 + \frac{1}{2} Y , \qquad Y = S - B.$$

Apparently, these states do not exist, and so the symmetry must be broken. But how?

Let ψ be the proton field and

(2) $$\hat{\psi} = C_B \, \psi \, C_B^{-1}$$

be the same field with just the baryon number reversed.

(3) $$\mathcal{L} = -\frac{1}{2} (\partial_\mu \phi)^2 - \frac{1}{2} \mu^2 \phi^2 - \bar{\Psi} \gamma \cdot \partial \Psi - \frac{1}{2} (m + \hat{m}) \bar{\Psi} \Psi - \frac{1}{2} (m - \hat{m}) \lambda^{-1} \bar{\Psi} \tau_3 \Psi \phi$$

is the Lagrangian for

(4) $$\Psi \equiv \begin{pmatrix} \psi \\ \hat{\psi} \end{pmatrix}$$

interacting with a neutral scalar meson which couples to baryon number. If ϕ has a nonzero vacuum expectation value

(5) $$\langle 0 \,|\, \phi \,|\, 0 \rangle = \lambda ,$$

we get the mass terms

$$(6) \qquad -m\bar{\psi}\psi - \hat{m}\hat{\bar{\psi}}\hat{\psi} .$$

If one of the masses, say m, should turn out to be negative, we can define a new field, $\gamma_5\psi$, which has opposite parity to ψ.

The following scheme emerges: For every fermion there is a conjugate fermion which is identical except that it has opposite B and L, and it can have a different mass and parity.

Conjugate baryons could decay strongly via

$$(7) \qquad \hat{N} \to \bar{\Xi} , \qquad \hat{\Lambda} \to \bar{\Lambda} , \qquad \hat{\Sigma} \to \bar{\Sigma} ,$$

which conserve Y and B but not S. Symbolically, we have assumed that $\hat{N}$ and N have opposite parity, but they could also have the same parity. Possible candidates for $\hat{\bar{\Xi}}$ are the $N^*(1470)$, (1535), (1700), and (1780). Also, the $Z_0^*(1830)$ might be the $\hat{\bar{\Omega}}$.

The symmetry is more clearly realized by the leptons. We simply get the old Konopinski-Mahmoud [1] scheme where ν_e, e^-, $\bar{\nu}_\mu$, μ^+ all have $L = 1$. The left-handed component of a massless four-component spinor is ν_e, while $\bar{\nu}_\mu$ is the right-handed component. This scheme is consistent with observation [2]. The reactions

$$(8) \quad \Sigma^- \to p\mu^- e^- , \qquad \nu_\mu p \to e^+ n$$

are allowed by L conservation, but they require $\Delta Q = 2$ and V + A currents, respectively.

The scalar meson was introduced into the Lagrangian as an artifice for splitting the masses. By letting $\mu \to \infty$, it would have no other physical effects. On the other hand, $\mu = 0$ would give

us long-range fields coupled to B and L, so that these conservation laws would not be transcended in gravitational collapse. The experimental equivalence of gravitational and inertial mass puts severe limits on the coupling constant $\Delta m/\lambda$.

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FOOTNOTES AND REFERENCES

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1. E. J. KONOPINSKI and H. M. MAHMOUD, Phys. Rev. 92, 1045 (1953).

2. See S. P. ROSEN, Particles and Fields - 1971, Proceedings of the Rochester Meeting of APS/DPF, 1971, edited by A. C. MELISSINOS and P. F. Slattery (AIP, 1971), p. 226.

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