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THE MESON MASS SYSTEM

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The neglected 35 MeV/c^2 particle mass quantization hypothesis has recently been reassessed for all known meson states. The rule is found to be statistically relevant, once the states are grouped by quark composition and J^{PC}, with slightly different mass units for each group. In certain groups the mass unit is spin-dependent. Also the mass units are linearly quantized, with highly structured correlation patterns. The baryon masses are organized along similar lines. These results support an indication that hadrons might be shell-structured.

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1. Masses and the particle physics timeline paradox

The particle mass spectrum is a mystery, and to put it in perspective it is interesting to compare the discovery timelines of atomic and particle physics. Dalton established the atomic nature of chemistry (1808), Mendeleyev charted the taxonomy with the periodic table (1869) and Balmer discovered the spectral rules (1885). All this happened well before Bohr's model (1913) and the theory of quantum mechanics (1925-26) were proposed. In the end, only a few months after the formulation of the Schroedinger equation, the spectral rules, the periodic table, and chemistry, were readily understood.

Mainstream particle physics enjoys accurate quark-based CKM chemistry, a plausible but incomplete taxonomy, no comprehensive mass rules, a clunky model, and a glorified theory that has been around for a few decades but does not explain the chemistry nor computes the masses. Particle physics had its Diracs already, while we are still in the Mendeleyev-Balmer time frame. One possible explanation for this paradoxical situation is that we are on the wrong track, most likely because of a simplistic identification of valences with constituents. Actually, the same mixup occurred in the early days of chemistry.

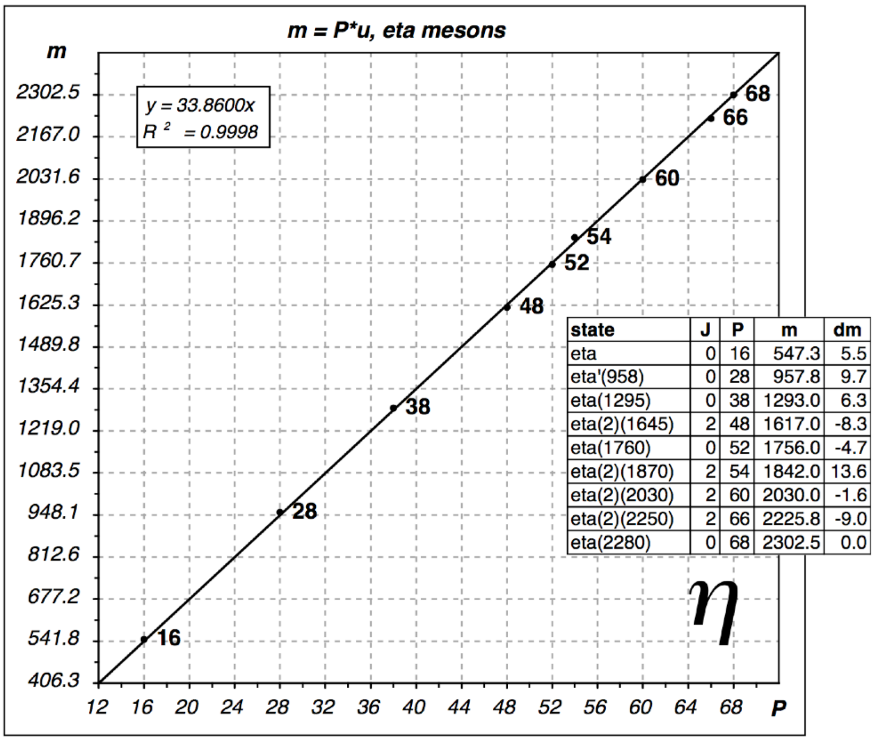
2. Old mass rules, known and less known

Particle physics textbooks mention the Chew-Frautschi plot, a linear relationship of spin versus mass squared in particles of the same family (Regge trajectories), and the GMO formula for particles in the same SU(3) multiplets. Both rules are considered marginal, and the PDG RPP no longer quotes them. Whatever the model and the theory, it would seem interesting to analyze the mass spectrum, hunting for yet-undetected numerical regularities that just must be there. The dominant approach in the community is rather to try and retrofit the masses from the theory, and discourage Balmerian mass analyses by making it difficult to publish such results. Unknown to most, there is a recurring mass rule thread which did not make it to the common body of knowledge: the 35 MeV/c^2 quantum. It has been observed that meson masses are even multiples of about 35 MeV/c^2, baryons (and unstable leptons) odd multiples, hence mass differences among similar particles are quantized by 70 MeV/c^2. Y. Nambu noticed this fact in 1952 already [1], but did not pursue it, while M. H. Mac Gregor studied this rule extensively from the early ’70s [2] to the present time [3] for his research on particle models. A few more authors mentioned it, with or without a physics interpretation (please see Ref. 4 for a historical account).

3. New results on meson masses

In several of the papers dealing with the 35 MeV/c^2 mass unit, the evaluation of the statistical relevance of the results is either missing or incorrect. To clarify the issue, the present author has recently reassessed this hypothesis for the mesons [4]. In this analysis, all the states listed in the PDG RPP are considered (including exotics), apart from those with a large measurement error on the mass, and the best value of the mass unit u is derived from the data with a correlated Diophantine minimization procedure. The statistical significance of the result is expressed by p, the probability of the null hypothesis, i.e. that a random sample of as many masses in the same range exhibits the same correlation or better, and is computed by Montecarlo. The procedure is described in Ref. 4, and the results show that:

- for all particles with mass below 1 GeV/c^2 , mesons, baryons and the muon considered together, the rule is statistically significant (p = 0.03), but in its simple form with a single mass unit it breaks down at higher masses;
- grouping all mesons in 19 families defined by quark composition and J^{PC}, the hypothesis is statistically significant separately for each group, only with different mass units all in the vicinity of 35 MeV/c^2, with average p = 0.05 and several cases where it is just a few per mil (see Fig. 1, the η mesons, with p_η = 0.001);
- some scalar and vector families, but no pseudoscalar, show also a linear dependence of the mass unit from the spin of about 0.25 MeV/c^2 per unit of J ;
- the mass units of the various families are quantized on a grid of 12 intervals of about 0.25 MeV/c^2 centered around 35.4 MeV/c^2, and their location on the grid shows intriguing correlations with the quantum numbers (Fig. 2).



state	J	P	m	dm
eta	0	16	547.3	5.5
eta'(958)	0	28	957.8	9.7
eta(1295)	0	38	1293.0	6.3
eta(2)(1645)	2	48	1617.0	-8.3
eta(1760)	0	52	1756.0	-4.7
eta(2)(1870)	2	54	1842.0	13.6
eta(2)(2030)	2	60	2030.0	-1.6
eta(2)(2250)	2	66	2225.8	-9.0
eta(2280)	0	68	2302.5	0.0

Fig. 1. Mass multiplicity plot for the η mesons: $m_i = u * P_i$, with the mass unit u and the even integer multiplicities P_i obtained by minimization; the fit residuals dm_i are small in comparison with the interval [-33.86, 33.86], and correspond to a significance $p_\eta = 0.001$; no spin dependence is observed; four η states with large errors on the mass are not used in the procedure.

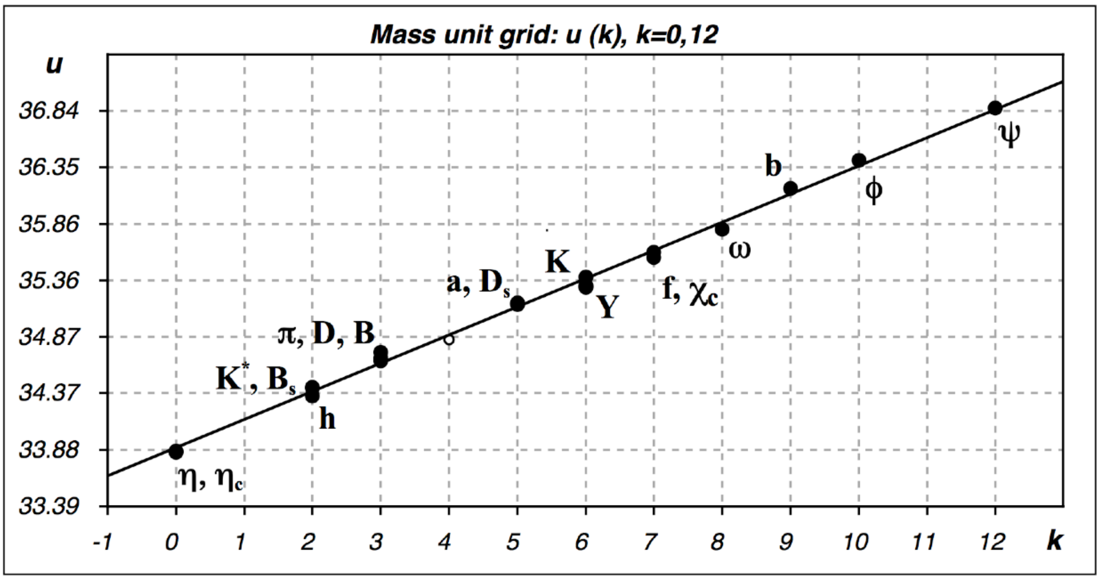


Fig. 2. Meson mass unit grid $u_k = u_0 + k * du$, k = [0..12]; the labels above the line refer to the q-qbar asymmetric meson families, the q-qbar symmetric are listed below the line; the open point at k = 4 corresponds to the unstable leptons; the radius of the points is the average error on u.

In Fig. 2, notice the η and η_c both in *u*-grid position 0, the vector mesons in positions 6, 8, 10 and 12, and further correlations of the grid position with the quark composition and the quantum numbers [4]. These results show that the meson mass system is multi-linear with three parameters, possibly only 2. The baryon masses show very similar regularities based on the same parameters [5].

4. Shell model, constituents, interaction

This analysis was performed to support a conjecture that mesons and baryons might be shell-structured [6]. Combining the results of Ref. 4, summarized here, with a mass-lifetime correlation analysis, indicative of shell-structured hadrons [6], it appears that nuclear and mesonic shells have very similar population sequences [7]. In addition, the mesonic mass unit quantization patterns of Fig. 2 suggest solid-phase partonic bound states on an fcc lattice, with light spin-1/2 partons of charge 0, +1 and -1 in anti-parallel spin coupling, and positive binding energy [7]. This interpretation strengthens the mesons-nuclei shell analogy through the fcc nuclear model of N. D. Cook [8].

A possible choice for the constituents compatible with these results (and the only one with non-fictitious particles), are the stable leptons, as suggested by A. O. Barut in a different context, with short-distance electro-magnetism acting as the strong interaction [9]. This is in agreement with M. H. Mac Gregor's observation that particle masses and lifetimes are α-quantized [10], therefore related to electro-magnetism, although his results are quoted in conjunction with a different particle model.

Acknowledgments

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