SHORT COMMUNICATIONS

MASSES OF THE QUARKS: AN ESTIMATION FROM $(1/2)^+$ BARYON DATA

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QUARKS were originally proposed in the early sixties by Gell-Mann[1] and others to bring some order into the confusing world of the hundreds of the so-called "elementary" particles and resonances observed by that time. The total number of quarks is at present believed to be six and they are denoted by the symbols u,d,s,c,b and t. These quarks are believed to be the ultimate constituents of all hadrons. Although it has not yet been possible to observe the quarks experimentally[2], the success of the quark model[3] has led to a tremendous number of theorectical investigations into the properties of these elusive particles. In the present note, we estimate the masses of the quarks from the masses of the J^P $(1/2)^+$ baryons by extending a very simple model proposed by Jenkovszky.

Recently Jenkovszky put forward the hypothesis[4] that the mass $\mathbf{m}_{ab}$ of the meson made up of the quarks a and b is given by the sum of the individual quark masses $\mathbf{m}_a$ and $\mathbf{m}_b$ and a quark spin-spin interaction as follows:

$$\mathbf{m}_{ab}=\mathbf{m}_a+\mathbf{m}_b+\frac{C}{\mathbf{m}_a\mathbf{m}_b}\,.S_a.S_b. \qquad (1)$$

In (1), S_a and S_b are the spins of the quarks a and b, respectively, while C is a constant.

We generalize this hypothesis to cover the case of the $(1/2)^+$ baryons. It is well known from quark models that the quantum numbers of these baryons can be accounted for by assuming that they are made up of three quarks with the spins of the two quarks pointing up, while that of the third pointing down. By extending the hypothesis of Jenkovszky, we propose that the mass $\mathbf{m}_{abc}$ of a baryon made up of the three quarks a, b and c with the spins S_a, S_b and S_c, respectively, is given by the relation

$$\mathbf{m}_{abc}=\mathbf{m}_a+\mathbf{m}_b+\mathbf{m}_c+\frac{C}{\mathbf{m}_a\mathbf{m}_b}\,S_a.S_b+\frac{C}{\mathbf{m}_b\mathbf{m}_c}\,S_b.S_c+\frac{C}{\mathbf{m}_a\mathbf{m}_c}\,S_a.S_c \qquad (2)$$

For simplicity, we ignored the three quark interaction and assumed the same constant of proportionality C for all spin-spin interactions.

To estimate the masses of the quarks from (2), we use the following data on $(1/2)^+$ baryon masses as input:

$$\begin{aligned} P(u\uparrow u\downarrow d\uparrow)&=0.9383\ \text{GeV},\\ \Lambda_c^+\,(u\uparrow d\uparrow c\downarrow)&=2.282\ \text{GeV},\\ \Xi^0\,(u\uparrow s\uparrow s\downarrow)&=1.315\ \text{GeV},\\ \Omega^0_{cl}(s\uparrow s\downarrow c\downarrow)&=2.75\ \text{GeV},\\ \Sigma^0_b\,(u\uparrow s\uparrow b\downarrow)&=5.68\ \text{GeV},\\ \Sigma^0_t\,(u\uparrow s\uparrow t\downarrow)&=20.29\ \text{GeV}, \end{aligned} \qquad (3)$$

In (3) the particle symbols have been used to indicate the masses of the corresponding particles, while the constituent quarks and the directions of their spins are shown in the parentheses. The masses of P, Λ^+_c and Ξ^0 are taken from the available latest experimental data[5]. For the remaining particles, we have used the recent estimates by Tiwari and co-workers[6], since these baryons have not yet been observed.

Using the mass data of (3) into (2), we get the following estimates for the quark masses and the constant C:

$$\begin{aligned} \mathbf{m}_u&=\mathbf{m}_d\,0.282\ \text{GeV},\\ \mathbf{m}_s&=0.496\ \text{GeV},\\ \mathbf{m}_c&=1.72\ \text{GeV},\\ \mathbf{m}_b&=4.91\ \text{GeV},\\ \mathbf{m}_t&=19.5\ \text{GeV}.\\ C&=-5\text{-}85\times10^{-3}\,(\text{GeV})^3. \end{aligned} \qquad (4)$$

In deriving these values, we have assumed that $\mathbf{m}_u=\mathbf{m}_d$, since the quarks u and d form an isospin doublet and their masses should be equal.

From the estimated masses given in (4), we get the values

$$\begin{aligned} \mathbf{m}_c/\mathbf{m}_s&=3.46,\\ \mathbf{m}_b/\mathbf{m}_c&=2.86,\\ \mathbf{m}_t/\mathbf{m}_b&=3.98, \end{aligned} \qquad (5)$$

for the ratios of the masses of successively heavier quarks. We observe that the first two ratios are fairly close to three, a value expected on theoretical grounds by Jenkovszky[4] and many other workers. Moreover, from (4), we have $\mathbf{m}_u/\mathbf{m}_s=0.57$, which is quite close $\mathbf{m}_u/\mathbf{m}_s=0.63$ derived by Lipkin[7].

Our estimates of the quark masses also are in good agreement with the values obtained by other workers using much more sophisticated theoretical models.

For example Aubrecht and Scott derived[8] $m_u = m_d =$ 0.298 GeV, $m_s = 0.497$ GeV, $m_c = 1.54$ GeV, $m_b = 4.73$ GeV and $m_t = 14.7$ GeV. On the other hand Aerts and Heller[9] recently applied the Born-Oppenheimer approximation to the MIT bag model and obtained $m_s = 0.571$ GeV, $m_c = 1.872$ GeV and $m_b = 5.237$ GeV.

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A CONTRIBUTION TO THE FLORAL ANATOMY OF *PHRYMA LEPTOSTACHYA* L.

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THE herbaceous monotypic genus *Phryma* L., with bicentric distribution in moist, deciduous or mixed forests of eastern North America and South East Asia, seems to be of somewhat uncertain taxonomic position. It was referred to the Verbenaceae[1-3]. It was also assigned[4,5] to an independent family Phrymaceae on the basis of the presence of single ovule in the unilocular ovary. This treatment was followed and it was included in Lamiales[6]. The morphoanatomical features of *Phryma leptostachya* L. was studied[7] in a casual way and this work embodies very few observations concerning the genesis of floral parts and their vasculature. There is, however, no other published work so far on the floral anatomy of *Phryma*. The present work, therefore, was undertaken to amplify details of the features of vasculature of the flower of *Phryma leptostachya* L. and to clarify the systematic status of the genus.

The flowers are grouped in both terminal and axillary long pedunclate spikate racemes. The flowers are bracteate, bracteolate, complete, hypogynous and tetracyclic with floral formula $K_{(5)}$, $C_{(5)}$, A_4, $G_{(2)}$. The sympetalous calyx is persistent and 2-lipped displaying 3 and 2 condition (figure 19) and accrescent in fruit. The upper lip of sympetalous tubular corolla comprises two members and encloses the tripartite lower lip (figures 20–22). The four epipetalous stamens are included and the anthers are 4-sporangiate; the posterior stamen being completely suppressed. The posterolateral stamens are shorter than the antero-lateral ones and the anthers stand out at different levels. The 2-carpellary syncarpous pistil is 1-ovulate (figures 15, 16). The ovule is sub-basal and is borne on the placenta, which is fused with the ovary wall along the anterior side. The filiform glabrous terminal style is included in the flower and terminates in a bifid stigma.

The two bracteoles, which are almost opposite to one another, arise above the 3-stranded bract and at slightly successive levels on the floral axis, receive a trace from each of the corresponding stele/vascular bundle of the 2-steled/bundled floral axis (figures 1 & 2). The two prominent steles/vascular bundles after giving off those to the corresponding bracteoles (figures 1 & 2), fuse to organise a closed ring of main stele, the simple siphonostele (figure 2). Five strong sepal traces emerge symmetrically from the main stele (figures 3–5) and prior to their entry into the base of the sepals, each trace branches into a median and pair of lateral traces (figure 6). Thus, the sepals are 3-traced and the sepal laterals originate conjointly with the midribs (figures 6 & 7). At a slightly higher level of the sepaline vasculature from the axial cylinder a second whorl of five traces alternating with the sepaline traces depart for the petals (figures 6–8). Four staminal traces are then produced alternating with the petaline traces from the main stele (figures 9–11). There is no external or anatomical evidence of the suppressed posterior stamen (figures 9 & 10). The nine (5 petal and 4 staminal) traces enter the corolla tube (figures 9–11). The petaline bundles remain unsegmented in the greater part of the corolla tube (figures 9–12), but at its throat each bundle gives rise to a petal dorsal and a pair of petal laterals (figures 13 & 14). At the level of divergence of the filaments no branches of the staminal traces are left behind in the corolla tube and traces depart from the ring and enter the filaments, ultimately ending in the connective (figures 17-19).