The Supersymmetric Partners of the Quarks and Charged Leptons

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Symmetries are broken on the mass levels of three geometric sequences that descend from Planck scale and correspond with an extra-dimensional geometry. Partners resulting from broken symmetry take up a symmetrical arrangement about the mass level on which the symmetry is broken. The quark doublets lie in symmetrical arrangement about special mass levels, while isospin doublets are arranged symmetrically about sublevels. The pseudoscalar and vector mesons of the SU(5) multiplets lie in symmetrical arrangement with fundamental fermions of lower mass about mass levels. Such fermions include the valence quarks, charged leptons and a tower of 'level-states' that partner the short-lived isospin singlet and triplet mesons. Some level-states carry flavour and charge, and are identified with sea quarks.

1. Introduction

Signs of charged lepton-pseudoscalar meson supersymmetry were first seen several years ago [1]. Fitting the valence quarks into a supersymmetric scheme proved to be an intractable problem until improved quark mass evaluations were available. Some progress was then made [2], but it was with the subsequent discovery of the equations of the Planck Model, in which the scales of atomic and particle physics are related to Planck scale [3, 4, 5], that a clearer picture emerged [6, 7]. Some observations of quark-meson supersymmetry were made, partners taking up a symmetrical arrangement about a mass level. It was clear, though, that the short-lived singlet vector mesons ω, ϕ, $D_s{}^{*\pm}$ and $B_s{}^{*0}$, all with some strange quark content, lay in perfect symmetry not with the valence quarks but with 'level-states', allied to the valence quarks. Level-states occupy mass levels within Planck Sequence 2, which descends in geometric progression from the Planck Mass and is of common ratio $2/\pi$. Level-states carrying flavour will be identified with sea quarks.

In this paper, the pseudoscalar and vector mesons of the SU(5) multiplets will be shown to lie in symmetrical arrangement with charged leptons, valence quarks and level-states.

First, the Planck Model will be outlined. Then the quark doublets will be shown to lie in special symmetrical arrangement about mass levels within the 'Standard Model Mass Pattern'. The pseudoscalar meson isospin doublets, and $\pi^{\pm}$-π^0 triplet, will be shown to lie in

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symmetrical arrangement about mass sublevels. Moving on to supersymmetry, the charged leptons will be shown to lie in symmetrical arrangement with charged pseudoscalar mesons. Then, a trio of symmetrical arrangements amongst the lightest charged lepton (e), quark (u), charged pseudoscalar mesons ($\pi^{\pm}$) and vector mesons ($\rho^{\pm}$) will be presented. The symmetrical arrangement of quarks and mesons, and of level-states and mesons, will then be shown, and some rules governing the composition of superpartnerships will be formulated. A discussion follows, in which level-states will be shown to be components of hadrons.

In many of the figures, partnerships are shown within two sequences in a two-dimensional representation. In such cases, mass scales are constrained to lie on a straight line, shown in blue, since level numbers in the three Planck sequences are in constant ratio.

All lepton and hadron mass evaluations used here are those of the Particle Data Group [8].

2. The Planck Model

Particle mass scales lie upon the levels and sublevels of three geometric sequences that descend from the Planck Mass, 1.220932(73) x 10^{-19} GeV [9]. Sequences 1, 2 and 3 are of common ratio $1/\pi$, $2/\pi$ and $1/e$, respectively. The sequences may derive from the geometry of an $AdS_6 \times S^4$ spacetime with Planck-scale compactification radii [1].

Levels number sequentially from the Planck Mass, which is of level-number 0 in each sequence. Sublevels are of fractional level-number, usually multiples of 2^{-n}, where n is a positive integer, e.g. 97.5, 97.75, 97.875, etc. Multiples of 3^{-n} have been seen but are not featured here [1].

The Bohr radius is a key scale in the Planck Model [5]. It is given by

$$a_0 = \left(\frac{\pi}{2}\right)^{125} l_P \qquad (1)$$

where l_P is the Planck length, 1.616199(97) x 10^{-35} m [9]. From (1), a_0 = 0.529 x 10^{-10} m. The electron mass follows directly from (1). The up-type quark masses derive from the electron mass through symmetry and, like many other scales of atomic and particle physics, are related to Planck scale by way of multiplication by powers of $(2/\pi)^{25}$ and α, the fine structure constant. The down-type quarks derive from those of the up-type quarks through symmetry. The quark masses of the Planck Model are 2.18 MeV (up), 4.89 MeV (down), 96.1 MeV (strange), 1.271 GeV (charm), 4.275 GeV (bottom) and 174.1 GeV (top).

3. The quark doublets in symmetrical arrangement

The quark doublets lie in symmetrical arrangement about Type 2 superlevels (levels whose level-numbers are multiples of 5 [6]) in Sequences 2 and 3 [4]. The strange and charm quarks, as well as the electron and the Higgs VEV, mass equivalent, are arranged symmetrically about Level 45 in Sequence 3, at the three-sequence Type 2 superlevel close-coincidence (40, 100, 45). The whole arrangement, shown in Figure 1 on the mass levels of Sequences 2 and 3, will be called the Standard Model Mass Pattern.

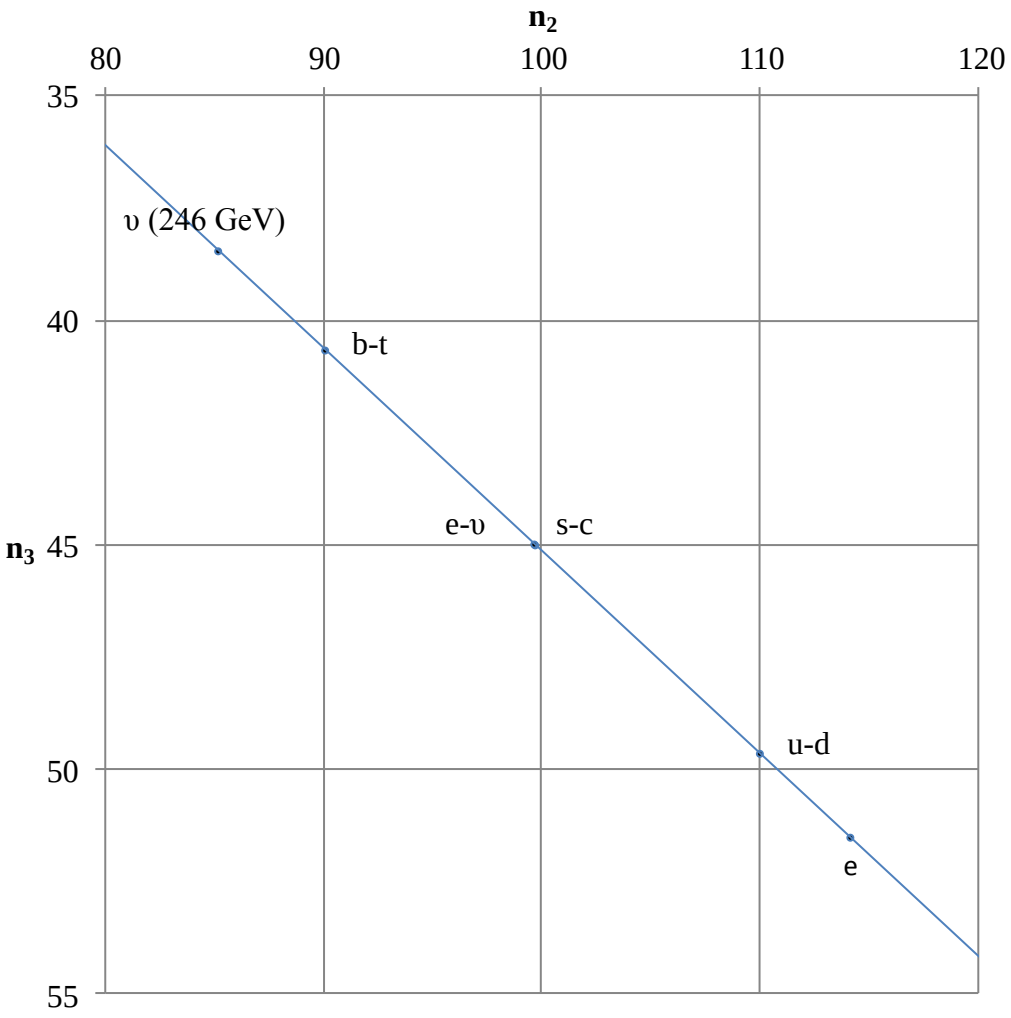

Figure 1: The quark doublets on the mass levels of Sequences 2 and 3. Each doublet is represented by the geometric mean of the two quark masses. The values of quark mass used here are the evaluations of the Particle Data Group, 2014 [8]. Mass scales are constrained to lie on the blue line since for any scale the corresponding level-numbers in Sequences 2 and 3 are in constant ratio. Also shown is the geometric mean of the electron mass and Higgs VEV, mass equivalent. The arrangement forms the Standard Model Mass Pattern.

4. Isospin doublets in symmetrical arrangement

Isospin doublets, in general, are arranged symmetrically about sublevels [10, 11]. The pseudoscalar meson isospin triplet $\pi^{\pm}$-π^{0} and the isospin doublets $K^{\pm}$-K^{0}, $D^{\pm}$-D^{0} and $B^{\pm}$-B^{0} are shown on the mass sublevels of Sequences 1 and 2 in Figure 2.

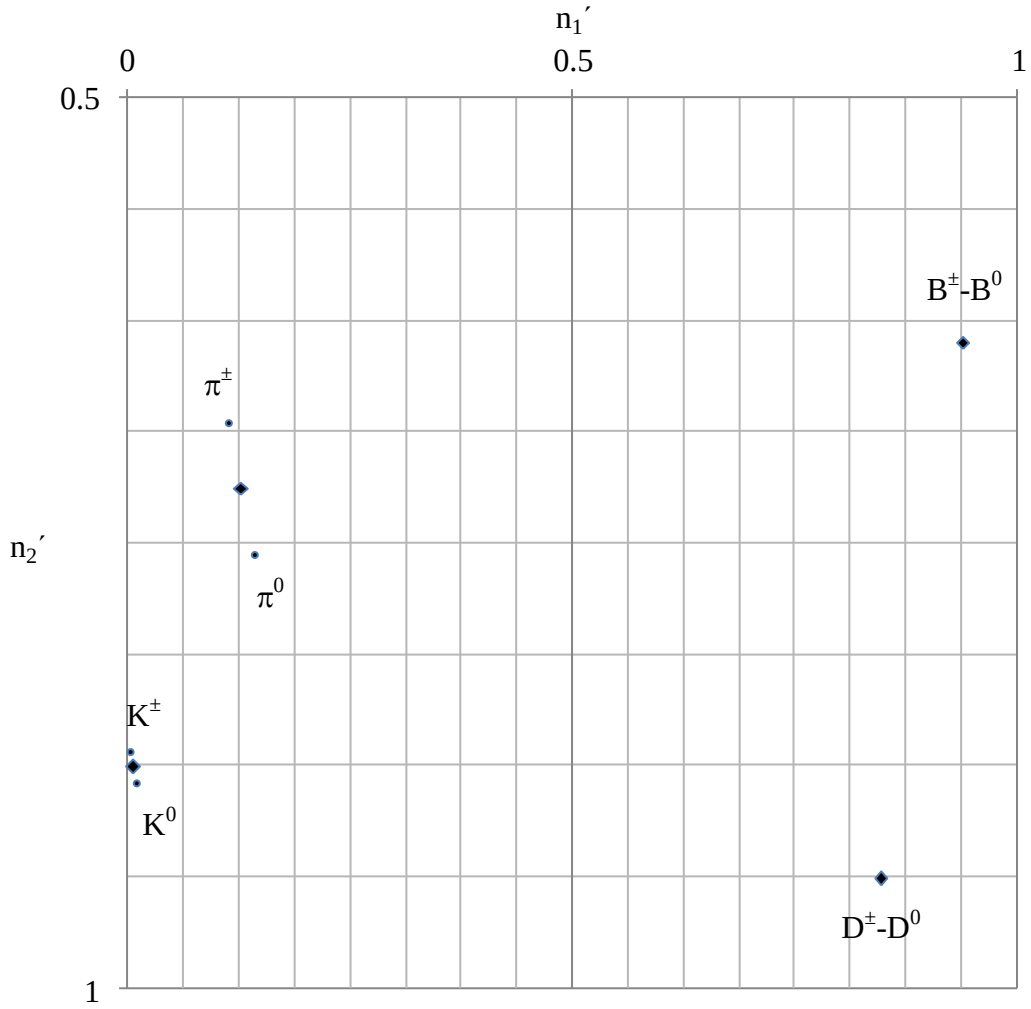

Figure 2: The pseudoscalar meson isospin triplet $\pi^{\pm}$-π^{0} and isospin doublets $K^{\pm}$-K^{0}, $D^{\pm}$-D^{0} and $B^{\pm}$-B^{0} on the mass sublevels of Sequences 1 and 2. So that the multiplets can all be shown on the same graph the integer part has been subtracted from each level-number. Each partnership is represented by the geometric mean of the two masses, which is marked by a diamond.

5. Supersymmetric partnerships

The charged leptons take up symmetrical arrangements with charged I=½ pseudoscalar mesons about mass levels in Sequences 1 and 2, as shown in Figure 3. The levels shown are Type 1 superlevels, whose level-numbers are multiples of 3 [6].

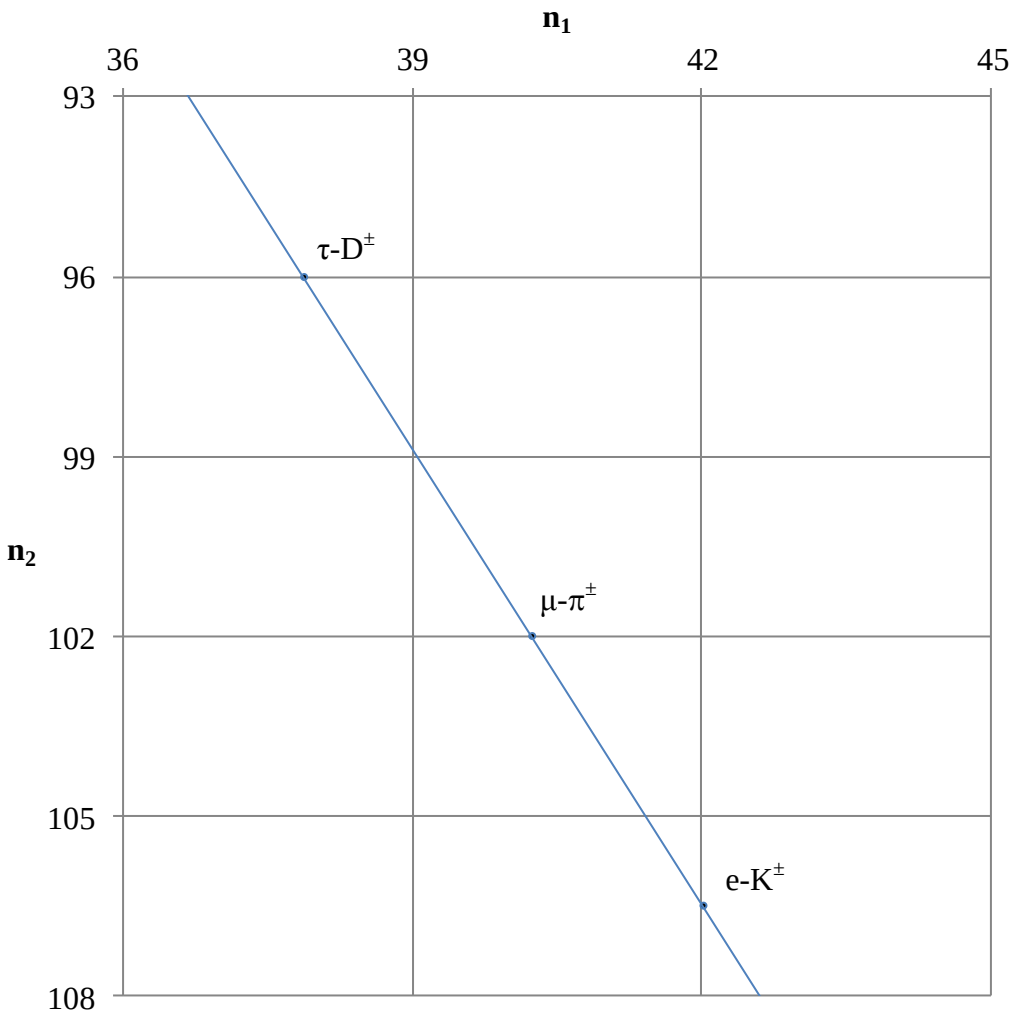

Figure 3: Charged lepton-pseudoscalar meson partnerships on the mass levels of Sequences 1 and 2. The levels shown are Type 1 superlevels, whose level-numbers are multiples of 3. Each partnership is represented by the geometric mean of the two masses.

The electron-charged K meson partnership is arranged symmetrically about Level 106.5 in Sequence 2, at the centre, (42, 106.5, 48), of a symmetrical arrangement of three-sequence coincident Type 1 superlevels, within Sequences 1, 2 and 3, that extends over many orders of magnitude [7]. The electron-charged K meson, up quark-charged pion and electron-rho meson partnerships are centred on adjacent mass levels in Sequences 2 and 3, respectively, as shown in Figure 4.

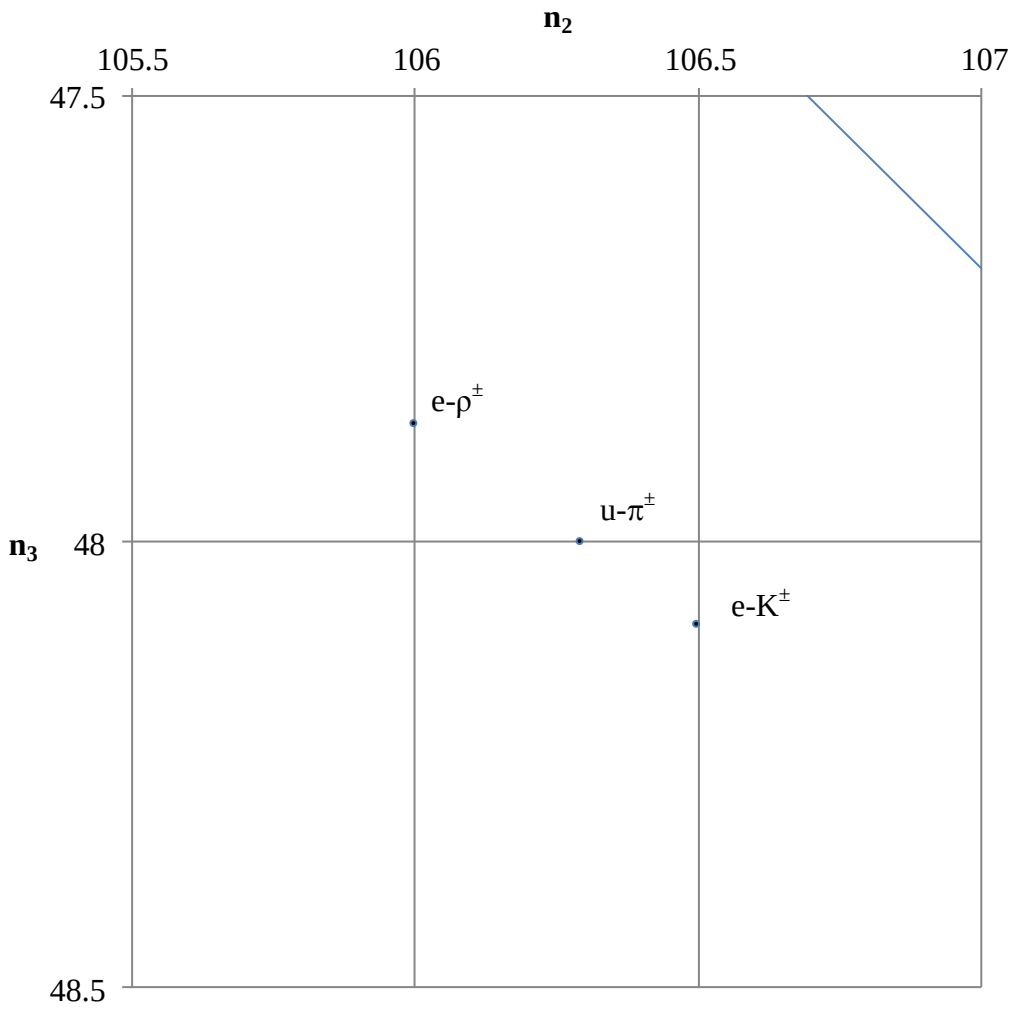

Figure 4: The lightest charged partnerships that are characterised by ΔJ=½, shown on the mass levels of Sequences 2 and 3. Each partnership is represented by the geometric mean of the two masses. The values of particle mass used here, with the exception of the up quark mass evaluation, are those of the Particle Data Group, 2014 [8]. The up quark mass (2.18 MeV) is that of the Planck Model [5].

The I=0 vector mesons ω, ϕ, $D_s^{*\pm}$ and B_s^{*0} are partnered by the hypothesised fermionic level-states L110 (u´, d´), L102 (s´), L97 (c´) and L94 (b´) [6], on the mass levels of Sequences 1 and 3, as shown in Figure 5. L110 occupies Level 110, which lies at the centre of the up-down quark doublet, in Sequence 2. L110 appears to carry both 'upness' and 'downness'. The strange, charm and bottom valence quarks lie adjacent to Levels 102 (120.9 MeV), 97 (1.156 GeV) and 94 (4.481 GeV), respectively, on which are located level-states L102, L97 and L94, which carry strangeness, charm and bottomness, respectively.

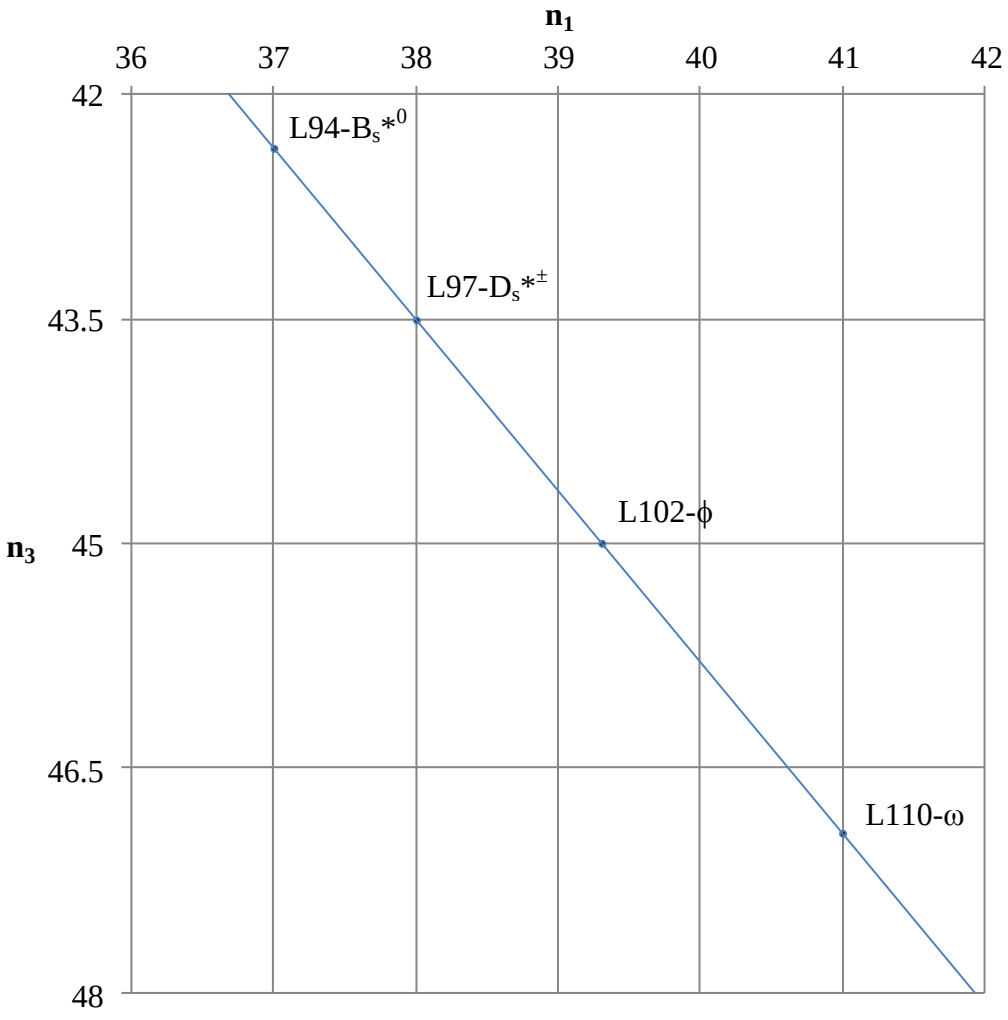

Figure 5: The partnerships of the hypothesised fermionic level-states L110, L102, L97 and L94 with I = 0 vector mesons, shown on the mass levels of Sequences 1 and 3. L110 partners ω. L102 partners π^0 and ϕ. L97 partners $Ds^{*\pm}$. L94 partners Bs^{*0}. Each partnership is represented by the geometric mean of the two masses. The values of particle mass used here are those evaluated by the Particle Data Group, 2014 [8].

The $c\bar{c}$ states η_c and J/Ψ both partner level-state L100, the partnerships being centred on Level 44 in Sequence 3, as shown in Figure 6. The $b\bar{b}$ states η_b and Y both partner level-state $L45_3$, the partnerships being centred on Level 96 in Sequence 2. Level 100 in Sequence 2 and Level 45 in Sequence 3, homes of the L100 and $L45_3$ level-states, intersect at the centre of the Standard Model Mass Pattern, shown in Figure 1. The partnership of the tau lepton with the pseudoscalar mesons $D^{\pm}$ shares a mass level with the composite $L45_3$-$b\bar{b}$ partnership.

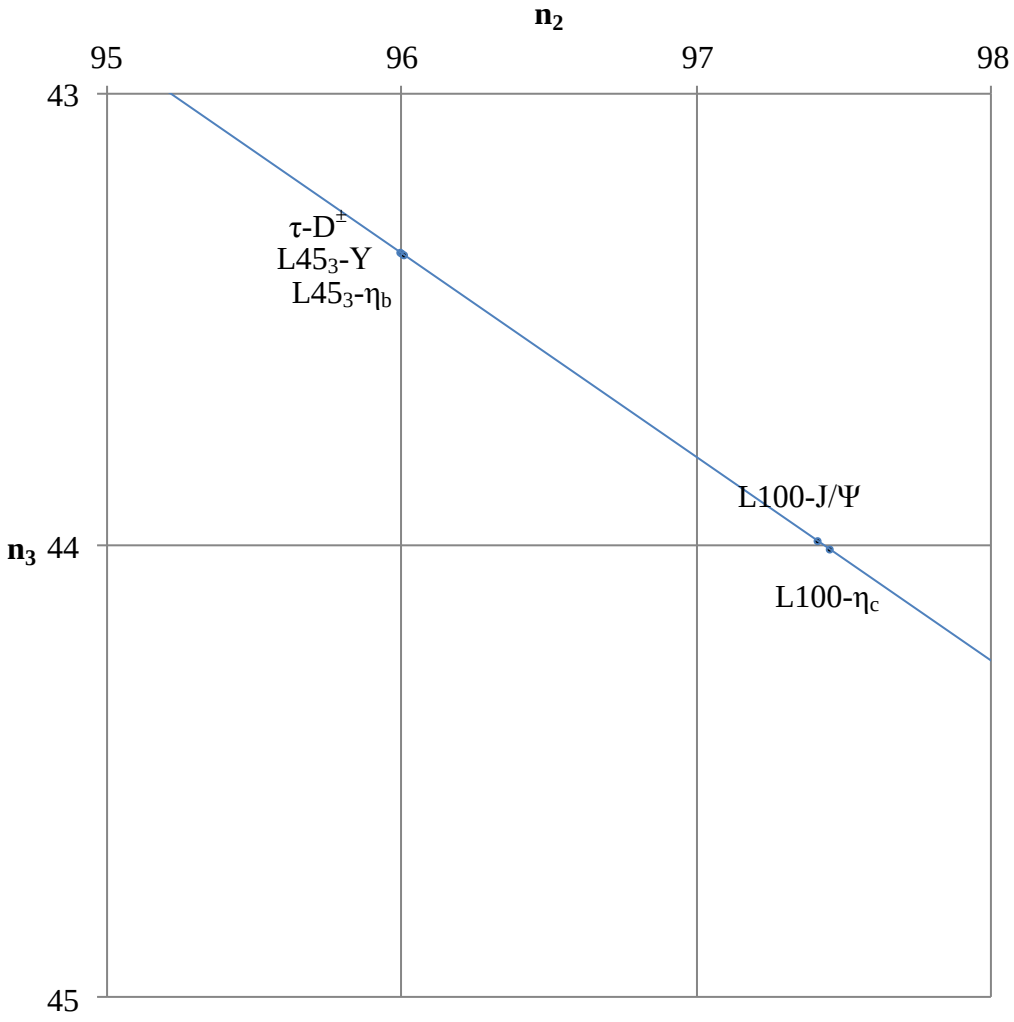

Figure 6: The composite partnership of level-state L100 with the pseudoscalar meson η_c and vector meson J/Ψ, and the composite partnership of level-state $L45_3$ with the pseudoscalar meson η_b and vector meson Y, on the mass levels of Sequences 2 and 3. Also shown is the partnership of the tau lepton with the pseudoscalar mesons $D^{\pm}$. Each partnership is represented by the geometric mean of the two masses.

The charm quark, of mass 1.271 GeV [5], is partnered by the $D_s^{\pm}$ pseudoscalar mesons, and the bottom quark, of mass 4.275 GeV [5], is partnered by the B_s^0 and $B_c^{\pm}$ pseudoscalar mesons. The partnerships are shown on the mass levels of Sequences 1 and 3 in Figure 7. The $D_s^{*\pm}$ and B_s^{*0} vector mesons, which partner level-states L97 (c´) and L94 (b´), respectively, also occupy Levels 38 and 37 in Sequence 1, as was shown in Figure 5.

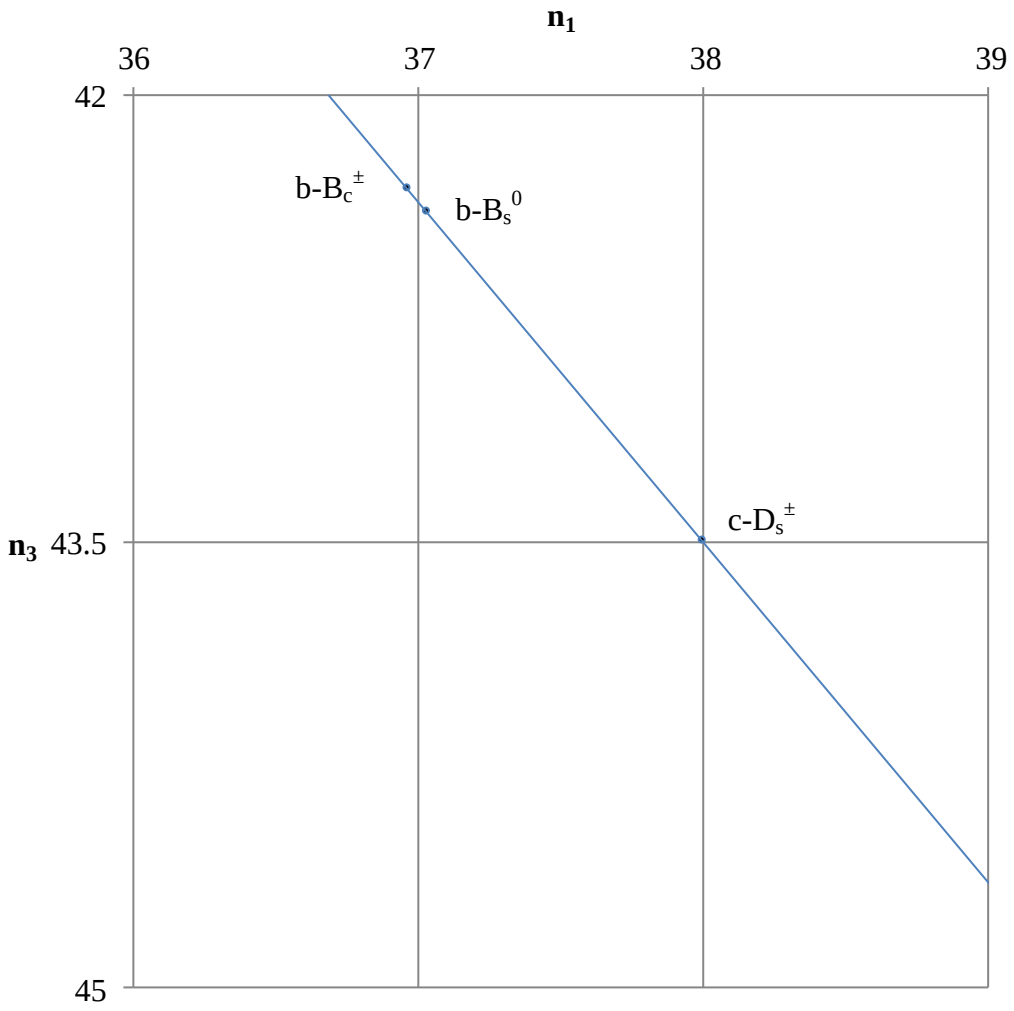

Figure 7: The partnership of the charm quark with the $D_s^{\pm}$ pseudoscalar mesons, and of the bottom quark with the B_s^0 and $B_c^{\pm}$ pseudoscalar mesons. The charm and bottom quark masses used here (1.271 GeV and 4.275 GeV) are those of the Planck Model [5].

Level-state L110 (u´, d´) is partnered by ω on Level 41 in Sequence 1, as was shown in Figure 5. The down quark, of mass 4.89 MeV [5], partners both K^0 and η, the two partnerships being arranged symmetrically about Level 41, as shown in Figure 8.

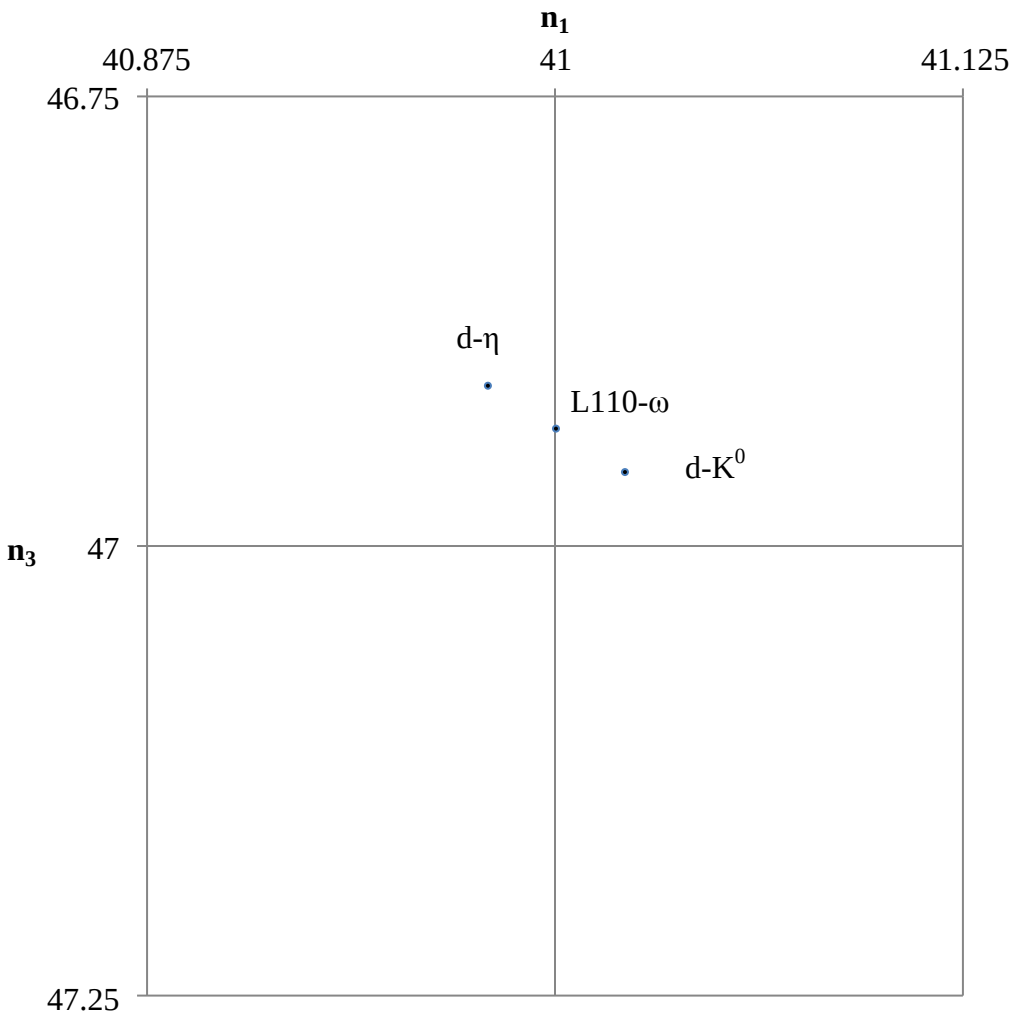

Figure 8: Level-state L110 (u´, d´) in partnership with ω, and the down quark in partnership with both K^0 and η on the mass levels of Sequences 1 and 3. Each partnership is represented by the geometric mean of the two masses. The values of meson mass used are those evaluated by the Particle Data Group, 2014 [8]. The down quark mass (4.89 MeV) is that of the Planck Model [5].

Level state L102 (s´) is partnered by the pseudoscalar meson π^0 and the vector meson ϕ. The strange quark, of mass 96.1 MeV [5], is partnered by both K^{*0} and η'. The μ-$\pi^{\pm}$ partnership is centred on Level 102 in Sequence 2. The partnerships are shown on the mass levels of Sequences 2 and 3 in Figure 9.

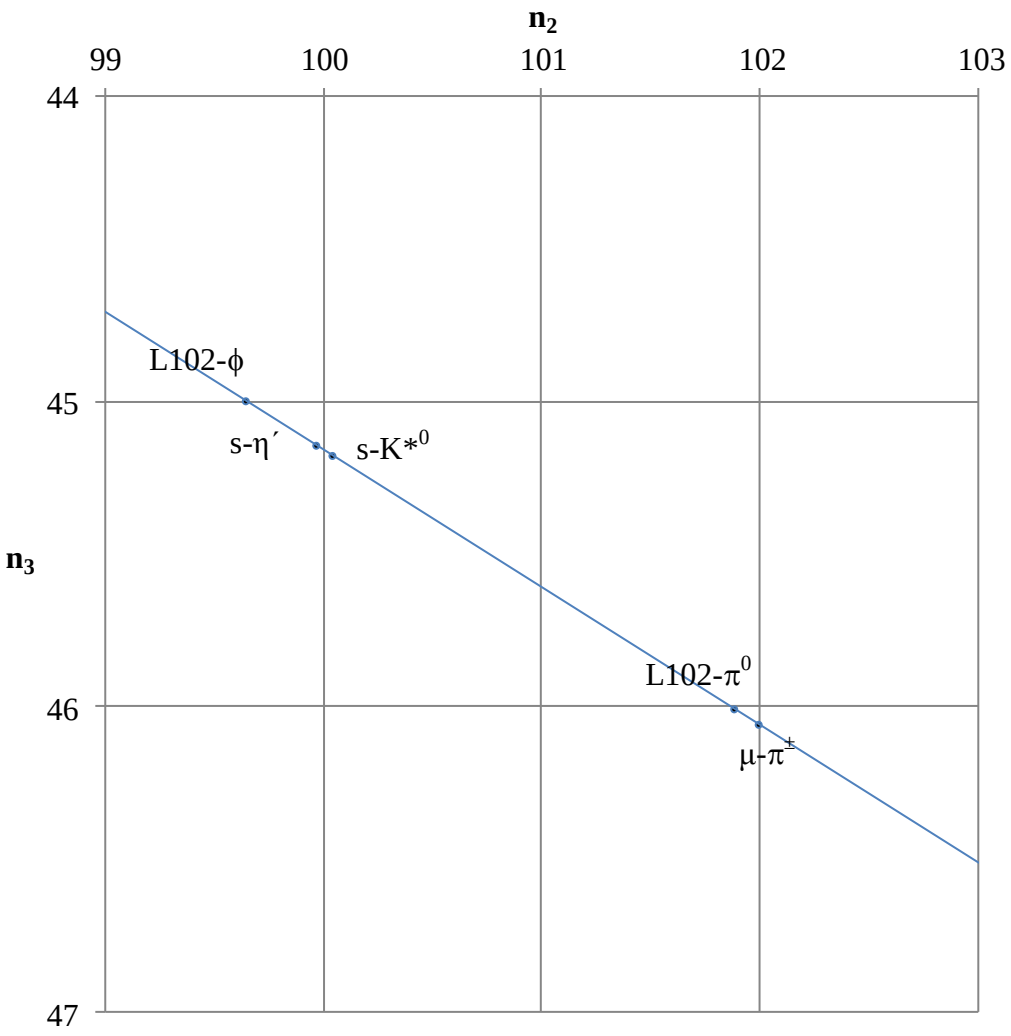

Figure 9: Partnerships adjacent to the Type 2 superlevel coincidence, (100, 45) in Sequences 2 and 3, at the centre of the Standard Model Mass Pattern, and to (102, 46) in Sequences 2 and 3. Level state L102 is partnered by both π^0 and ϕ. The strange quark is partnered by both K^{*0} and η'. The μ-$\pi^{\pm}$ partnership is centred on Level 102 in Sequence 2. Each partnership is represented by the geometric mean of the two masses. The values of meson and lepton mass used are those evaluated by the Particle Data Group, 2014 [8]. The strange quark mass (96.1 MeV) is that of the Planck Model [5].

6. Rules governing superpartnerships

A list of the superpartnerships identified in this paper is presented in Table 1.

J = ½	J = 0
u	$\pi^{\pm}$
d	η, K^0
L102 (s´)	π^0
s	η'
L100	η_c
c	$D_s^{\pm}$
$L45_3$	η_b
b	B_s^0, $B_c^{\pm}$

J = ½	J = 1
e	$\rho^{\pm}$
L110 (u´, d´)	ω
L102 (s´)	ϕ
s	K^{*0}
L100	J/Ψ
L97 (c´)	$D_s^{*\pm}$
$L45_3$	Y
L94 (b´)	B_s^{*0}

Table 1: The pseudoscalar and vector mesons of the SU(5) multiplets, together with their quark and level-state partners. Level-states lie in Sequence 2, with the exception of $L45_3$, which lies in Sequence 3. L100 and $L45_3$ are found at the centre of the Standard Model Mass Pattern, shown in Figure 1. Partnerships shown in the same colour share a mass level.

The $\pi^{\pm}$ mesons also partner the muon. The $K^{\pm}$ and $\rho^{\pm}$ mesons partner the electron. The $D^{\pm}$ mesons partner the tau lepton. The ρ^0 meson forms a same-spin partnership with ω on Level 97.875, a sublevel, in Sequence 2 [12].

From Table 1 and Figure 3, two rules governing the composition of fermion-meson partnerships have been formulated.

1. I=0 mesons partner level-states. The charmed level-state (L97) is partnered by charged mesons. All other level-states are partnered by neutral mesons.

2. I=½ and I=1 mesons, and those mesons (η, K^0; η', K^{*0}; B_s^0, $B_c^{\pm}$) that participate in composite flavoured superpartnerships, partner valence quarks or charged leptons.

7. Discussion

The partners of the quarks and charged leptons have been identified. Simple rules govern the composition of superpartnerships. A flavoured valence quark and a level-state that carries the same flavour are of different mass and are partnered by different mesons. The valence quarks and the charged leptons are partnered, in the main, by long-lived pseudoscalar mesons, which decay through weak interactions. The level-states, some of which have been identified with the short-lived virtual-state sea quarks, are partnered by the short-lived isopin singlet mesons, pseudoscalar and vector, which decay principally by strong and electromagnetic interactions.

The partnership of a quark, level-state or charged lepton with a meson is arranged symmetrically about a mass level in one of the three Planck sequences. Coincident levels and superlevels are favoured locations. Partnerships are arranged about mass levels between Levels 37 and 42 in Sequence 1, which in turn are arranged about the centre of the Standard Model Mass Pattern.

We have seen that level-states are partnered by short-lived pseudoscalar and vector mesons, and mostly lie on the mass levels of Sequence 2, which is of common ratio $2/\pi$. Using central values of Particle Data Group evaluation [8], we find that

$$\frac{m_{H^0}}{m_{W^\pm}} = \frac{\pi}{2} \tag{2}$$

to within 1 part in 200, suggesting that the short-lived Higgs scalar boson and $W^\pm$ vector boson may both partner level-states, the two partnerships being centred on the same mass level. The $W^\pm$ and Z^0 vector bosons form a same-spin partnership [12].

Besides partnering other short-lived states, level-states are also components of hadron mass, and again are seen to carry flavour. Level-states are found on mass sublevels as well as levels of integer level-number. In equations (3)–(10), the mass of a short-lived hadron is produced from the mass of another hadron by the addition of one or two level-states. The Particle Data Group's evaluation of hadron mass is shown in brackets.

In (3), the mass of K^{*0} ($d\bar{s}$) is related to the mass of the ρ^- ($d\bar{u}$) vector meson. Level-state L102 carries the strangeness that replaces the 'upness' of ρ^- The mass of the heavier of two isospin doublet states results from the equation; this seems to be a rule [10].

$$m_{K^{*0}} = m_{\rho^-} + m_{L102(s')} = 896.17\pm0.25 \text{ MeV} \quad (895.81\pm0.19 \text{ MeV}) \tag{3}$$

In (4), the level-state does not carry flavour and there is consequently no change in flavour

$$m_{\Sigma^0} = m_{\Lambda} + m_{L103} = 1192.66\pm0.01 \text{ MeV} \quad (1192.642\pm0.024 \text{ MeV}) \tag{4}$$

In (5) and in (6), two excited baryons are related in mass to each other. Here, strangeness is supplied by level-state L101.5. The ground state Δ baryons are clustered around a sublevel in Sequence 2, of mass 1232.09 MeV, which has been taken to be the mass of $\Delta(1232)^+$.

$$m_{\Sigma(1385)^0} = m_{\Delta(1232)^+} + m_{L101.5(s')} = 1383.63\pm0.12 \text{ MeV} \quad (1383.7\pm1.0 \text{ MeV}) \tag{5}$$

$$m_{\Xi(1530)^-} = m_{\Sigma(1385)^0} + m_{L101.5(s')} = 1535.2\pm1.1 \text{ MeV} \quad (1535.0\pm0.6 \text{ MeV}) \tag{6}$$

In (7), (8), (9) and (10), the masses of the ground state $s\bar{s}$, $c\bar{c}$, $b\bar{b}$ and $s\bar{b}$ neutral vector mesons are related to those of other mesons. In (10), as in (5) and (6), strangeness has been supplied by level-state L101.5.

$$m_{\phi} = m_{\omega} + 2m_{L102(s')} = 1024.47\pm0.12 \text{ MeV} \quad (1019.461\pm0.019 \text{ MeV}) \tag{7}$$

$$m_{J/\psi} = m_{\omega} + 2m_{L97(c')} = 3095.21\pm0.12 \text{ MeV} \quad (3096.916\pm0.011 \text{ MeV}) \tag{8}$$

$$m_{\Upsilon} = m_{K^0} + 2m_{L94(b')} = 9460.6\pm0.5 \text{ MeV} \quad (9460.30\pm0.26 \text{ MeV}) \tag{9}$$

$$m_{B_s{}^{*0}} = m_{\omega} + m_{L94(b')} + m_{L101.5(s')} = 5415.69\pm0.12 \text{ MeV} \quad (5415.4+2.4/-2.1 \text{ MeV}) \tag{10}$$

As constituents of hadrons, level-states can be unflavoured or they can carry the strangeness (L102), charm (L97) or bottomness (L94) of an adjacent valence quark. They can also carry electric charge, as shown in (3), (5) and (6), in which a strange quark appears to replace an up quark. Previously thought to be valence quarks [2, 10], those level-states that carry flavour are now reckoned to be sea quarks. As short-lived virtual states, their masses do not necessarily equal those of the valence quarks.

Level-states exist momentarily. During its brief existence, a level-state has a supersymmetric partner. The partner of a level-state is usually an excited, and shorter-lived, version of the partner of the corresponding valence quark.

The discovery of level-states, and the identification of some level-states with sea quarks, has cast some light on particle phenomena, and on supersymmetry in particular.

8. References

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