# The Planck Model

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The Planck Model is summarised and some new observations are made. The fundamental particles are shown in systematic arrangement on mass levels. Hadrons are arranged on sublevels. Length and mass scales of atomic and particle physics are shown to derive from Planck scale. 100 years after the publication of Niels Bohr's atomic model, the Bohr Radius has been found to be a constant of the Planck Model with implications for dark energy.

## 1. Introduction

This is a summary of work published between 2003 and 2013. The phenomena, as now understood in the light of improved experimental data, are described. The paper is intended to provide a lucid introduction to the Planck Model. Important developments have taken place during 2013, after the discovery that the Bohr Radius is a constant of the model: these are included.

First, the quarks, charged leptons, weak gauge bosons and hadrons are shown to occupy mass levels that descend in geometric progression from the Planck Mass. Special arrangements of particles on the mass levels are highlighted. Equations relating the Bohr Radius, the electron and quark masses, and various other scales of atomic and particle physics to Planck scale are then presented. Finally, a link is demonstrated between zero-point energy at Planck scale and dark energy. The paper ends with a brief discussion.

## 2. Mass levels

There are three principal sequences of mass levels, each of which has the Planck Mass, $M_P$ = 1.220932(73) x $10^{19}$ GeV [1], as first term. The sequences descend in geometric progression and are of common ratio $1/\pi$ (Sequence 1), $2/\pi$ (Sequence 2) and 1/e (Sequence 3) [2, 3, 4]. Mass levels within the three sequences are given the level-numbers $n_1$, $n_2$ and $n_3$. For example, level-number $n_2$ = 100 refers to a level of mass $(2/\pi)^{100}.M_P$ within Sequence 2. All massive particles occupy levels within each sequence. Level-numbers within the three sequences are in constant ratio. Levels of integer level-number are occupied by the quarks and charged leptons. Levels of fractional level-number, known as sublevels, are occupied by the hadrons and weak gauge bosons. The sublevels shown here are of half-integer, quarter-integer, eighth-integer, etc, level-number.

The particle mass evaluations of the Particle Data Group [5] have been used throughout.

## 3. The occupation of mass levels

Particles are shown on the levels, or sublevels, of either one or two sequences in each figure. In the two-dimensional representations, the levels are plotted perpendicular to each other. Since the level-

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numbers within any two sequences are in constant ratio, particles are constrained to lie on a straight line within the representation. Mass level coincidences occur on the straight line.

***Quarks***

The quark weak isospin doublets take up symmetrical arrangements about mass levels within Sequences 2 and 3, as shown in Figure 1. Each quark doublet is represented here by the geometric mean of the two masses. The doublets are said to occupy levels. The symmetrical arrangement is characteristic of isospin doublets in general. The level-numbers of the occupied levels are multiples of 10 in Sequence 2 and a multiple of 5 in Sequence 3; such levels are called superlevels. The doublets lie close to superlevel coincidences.

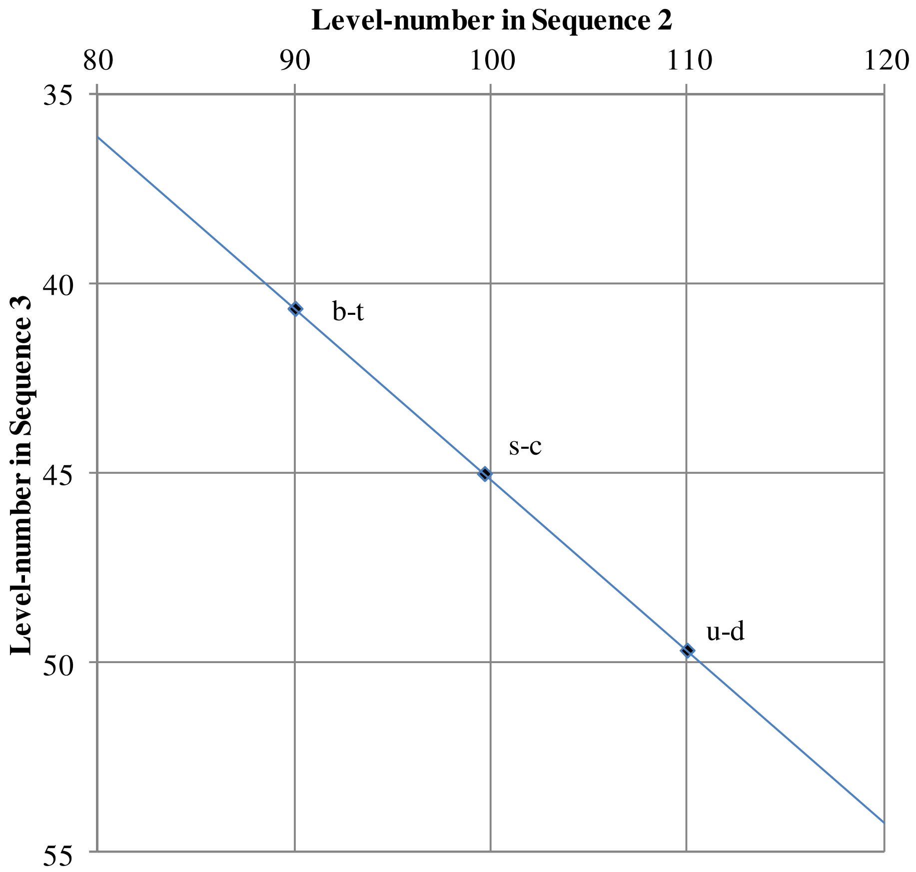


**Figure 1:** Quark doublets on the mass levels of Sequences 2 and 3. Sequences 2 and 3 descend in geometric sequence from the Planck Mass and are of common ratio 2/π and 1/e, respectively. Each doublet is represented by the geometric mean of the two central values of Particle Data Group evaluation [5]). Particles are constrained to lie on the blue line.

*Charged leptons*

The charged leptons are shown in partnership with charged pseudoscalar mesons on the mass levels of Sequences 1 and 2 in Figure 2. The level-numbers are multiples of 3; the levels are superlevels.

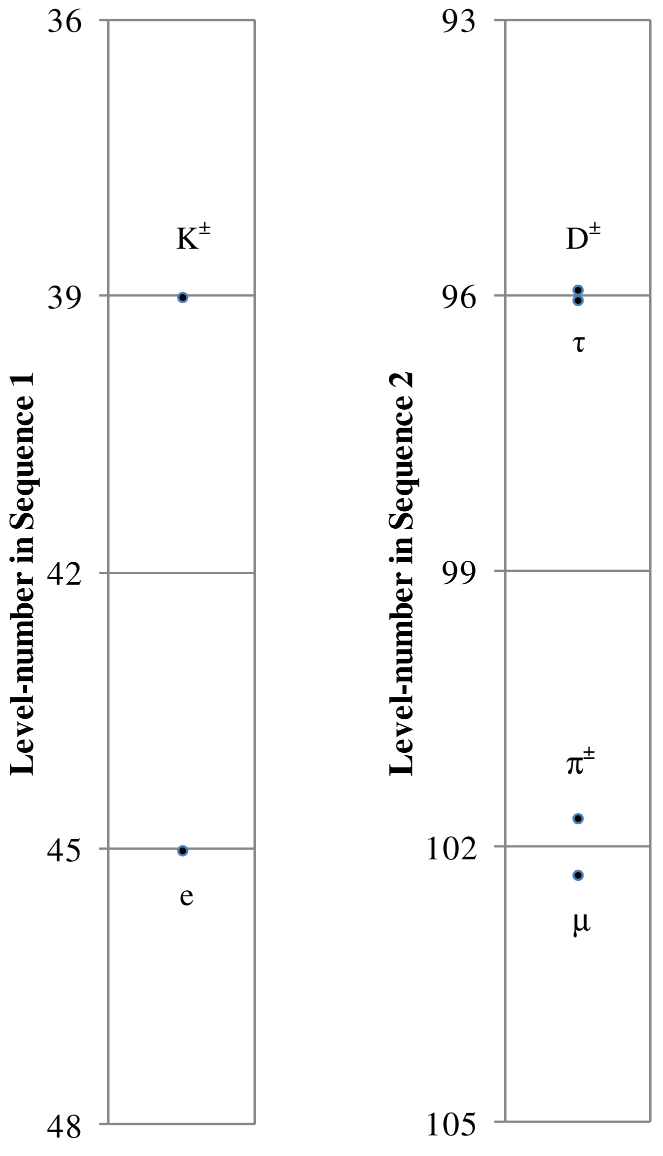


**Figure 2:** The charged leptons and their pseudoscalar partners on the mass levels of Sequences 1 and 2.

The electron and the charged K-mesons occupy coincident superlevels within Sequences 1 and 2, as shown in Figure 3. The geometric mean of the two masses lies close to coincident superlevels within Sequences 1 and 3. Also shown is the most precise superlevel coincidence that occurs at known particle mass scales: (93, 42) in Sequences 2 and 3. It lies at 7.0 GeV.

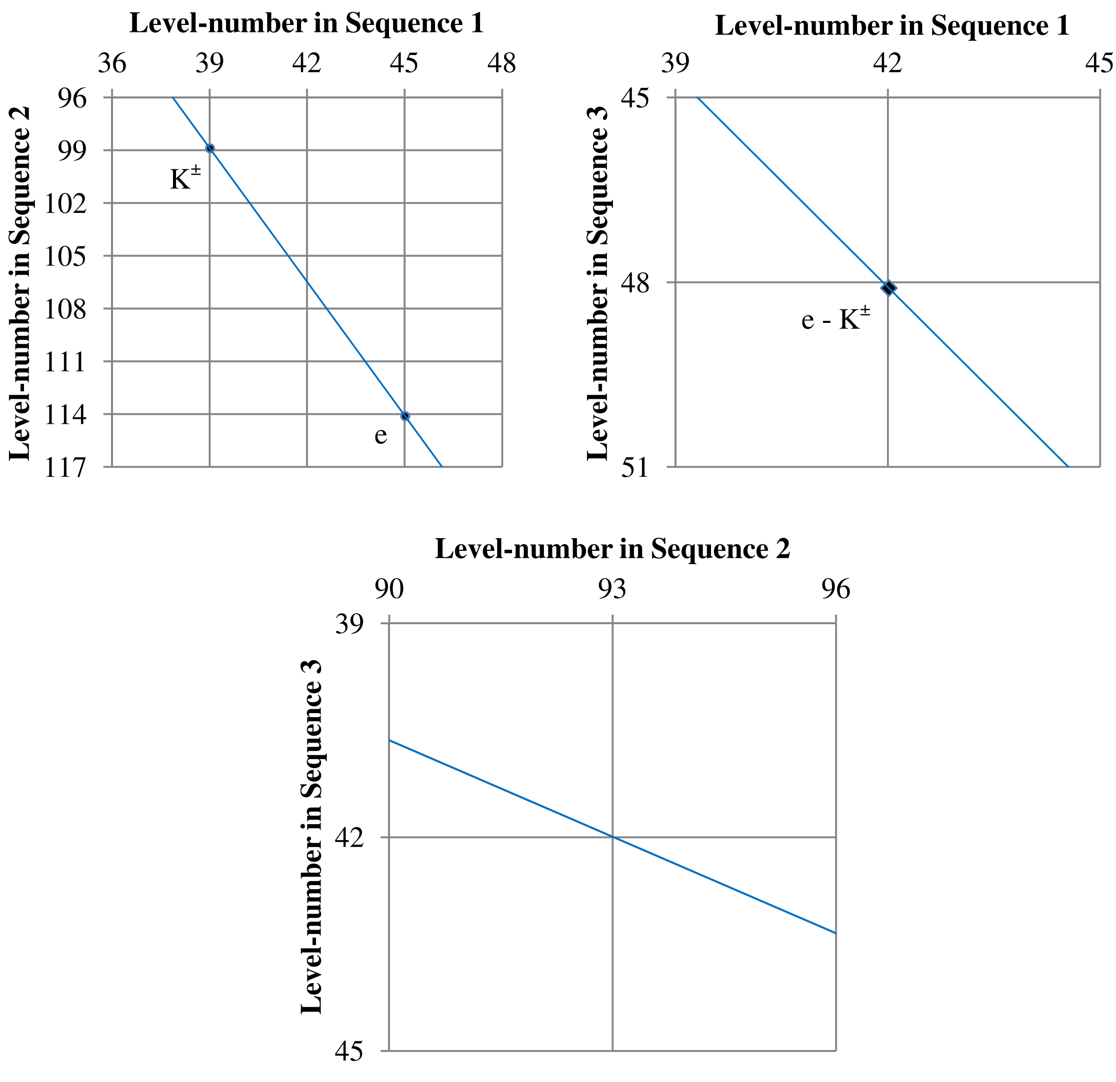


**Figure 3:** Superlevel coincidences in Sequences 1, 2 and 3. The geometric mean of the masses of the electron and the charged K-mesons is shown by a diamond. The vacant superlevel coincidence at (93, 42) in Sequences 2 and 3 occurs at 7.0 GeV and is the most precise superlevel coincidence at known particle mass scales.

### *Weak gauge bosons*

The weak gauge bosons $W^{\pm}$ and $Z^0$ are symmetrically arranged about closely coincident sublevels of half-integer level-number within Sequences 1 and 3, as shown in Figure 4. The sublevel coincidence at (34.5, 39.5), in Sequences 1 and 3, lies close to a sublevel of half-integer level-number (87.5) within Sequence 2. Such a close triple 'half-level' coincidence as that at (34.5, 87.5, 39.5) is a rare phenomenon. No closer such coincidence occurs at known particle mass scales.

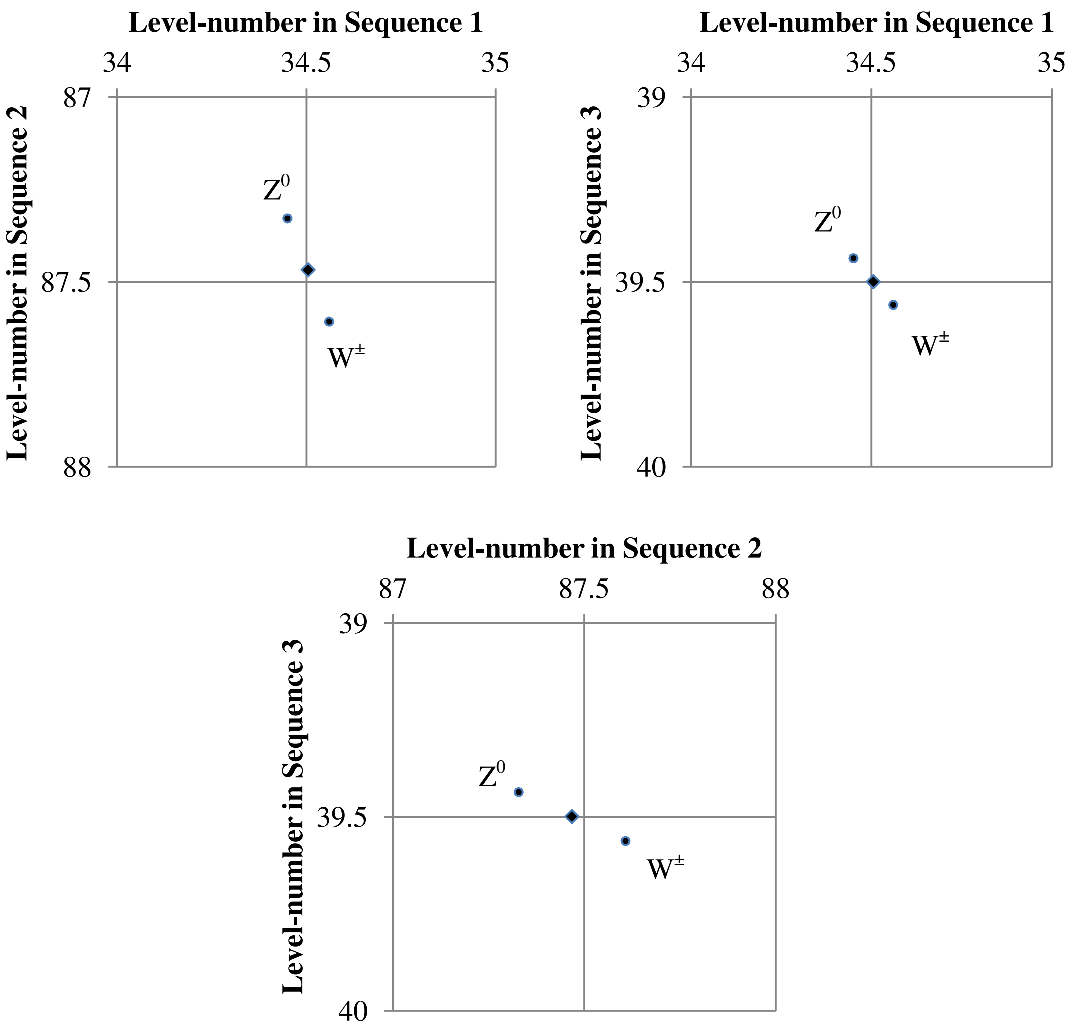


**Figure 4:** The weak gauge bosons on the mass sublevels of Sequences 1, 2 and 3. The geometric mean of the two central values of Particle Data Group evaluation [5] is shown by a diamond.

### *Hadrons*

The uds, udc and udb $J^P=½^+$ baryons are shown on the levels and sublevels of Sequence 2 in Figure 5. The uds baryons Λ and $\Sigma^0$ are symmetrically arranged about Level 97, in a partnership configuration. The mass difference of these two baryons is 79.959 ± 0.030 MeV, for which $n_2$ = 103.000 ± 0.002. Other pairs of strange hadrons sharing some quantum numbers, but not necessarily spin, are characterized by a mass difference equal to the mass of a level in Sequence 2 [2]. The udc and udb $J^P=½^+$ singlet states $\Lambda_c^+$ and $\Lambda_b^0$ occupy mass levels of half-integer level-number.

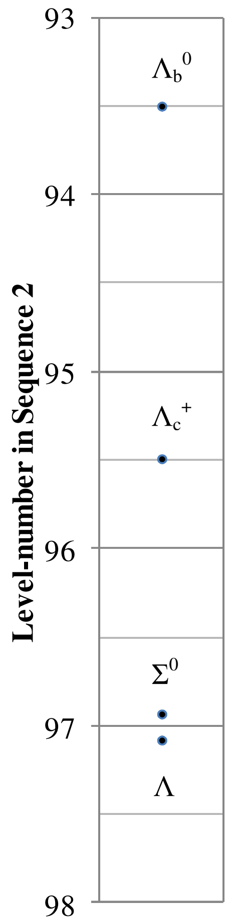


**Figure 5:** The uds, udc and udb $J^P=½^+$ baryons on the mass levels and sublevels of Sequence 2.

The charged pions lie in symmetrical arrangement with the neutral pion about coincident sublevels within Sequences 1 and 2, as shown in Figure 6. The K-meson isospin doublets lie immediately adjacent to Level 39 in Sequence 1, and are symmetrically arranged about a sublevel in Sequence 2.

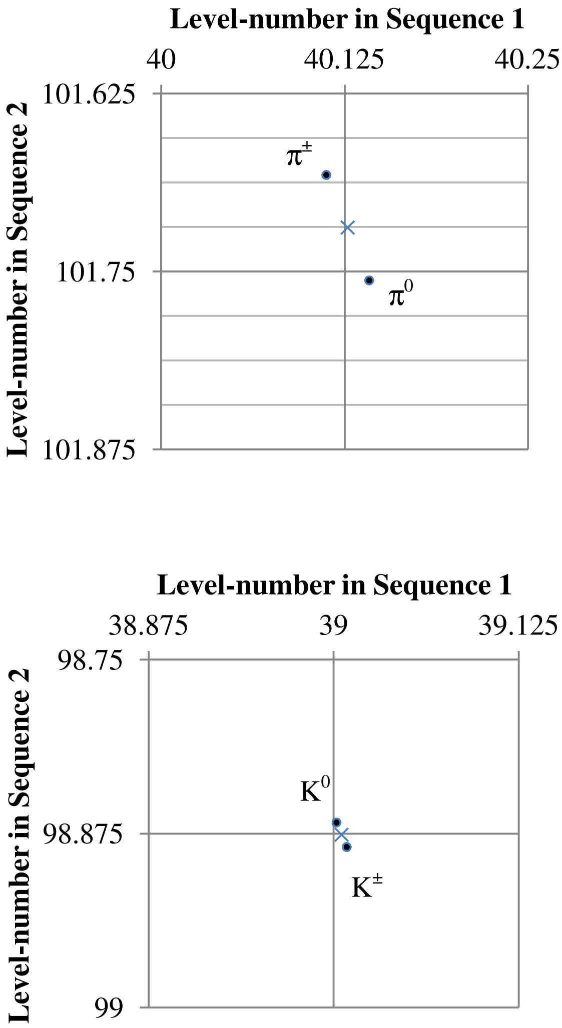


**Figure 6:** The pion isospin triplet and K-meson isospin doublets on the mass levels and sublevels of Sequences 1 and 2. For both pions and K-mesons, the geometric mean of the two central values of Particle Data Group mass evaluation [5] is shown by a cross.

The proton-neutron and K*-meson isospin doublets are symmetrically arranged about sublevels in Sequence 2, as shown in Figure 7. The ϕ-meson, a singlet state, occupies a sublevel within Sequence 2.

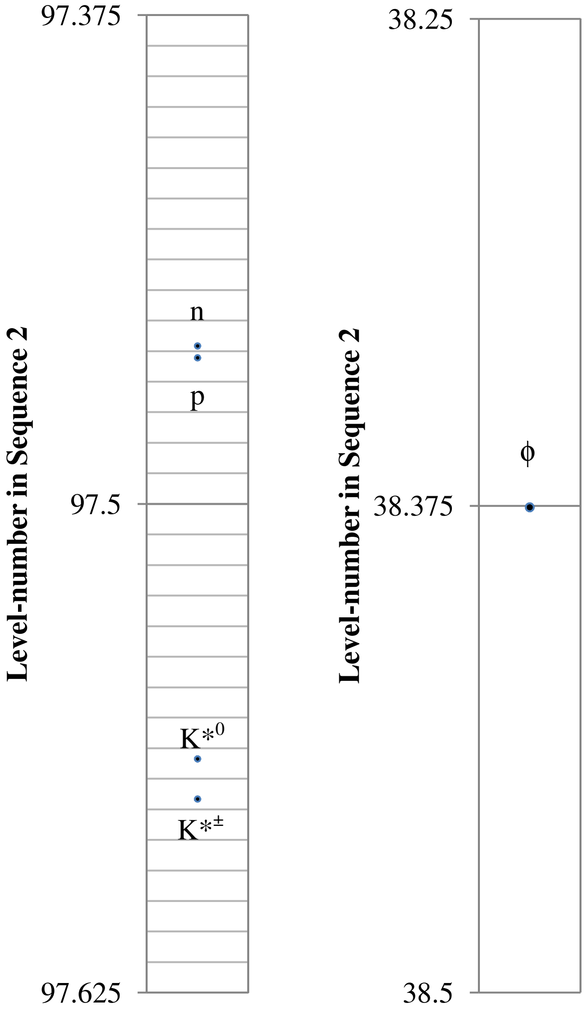


**Figure 7:** The occupation by hadrons of the mass sublevels of Sequence 2. The proton-neutron and K*-meson isospin doublets are arranged symmetrically about sublevels. The ϕ-meson occupies a sublevel.

The proton lies close to the triple coincidence at (38.5, 97.5, 44), as shown in Figure 8.

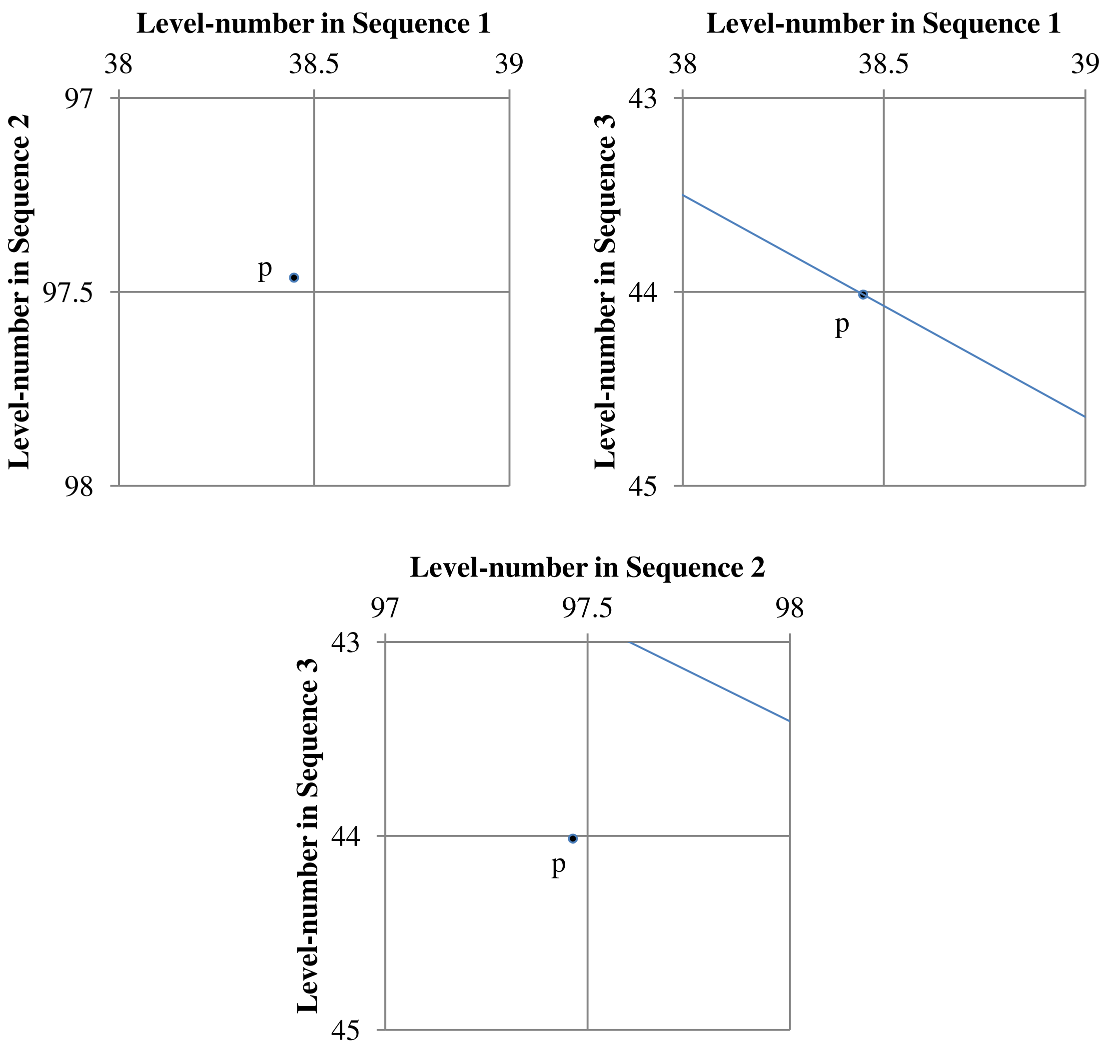


**Figure 8:** The proton on the mass levels of Sequences 1, 2 and 3.

## 4. The GUT and Higgs sequences

Incorporated within Sequences 1, 2 and 3 are three sequences of identical common ratio but of first term equal to GUT scale (2.1 x $10^{16}$ GeV). The Higgs field vacuum expectation value (246.22 GeV) lies at the triple coincidence (28, 71, 32) within the incorporated sequences, as shown in Figure 9. There is no closer triple coincidence at greater mass scales.

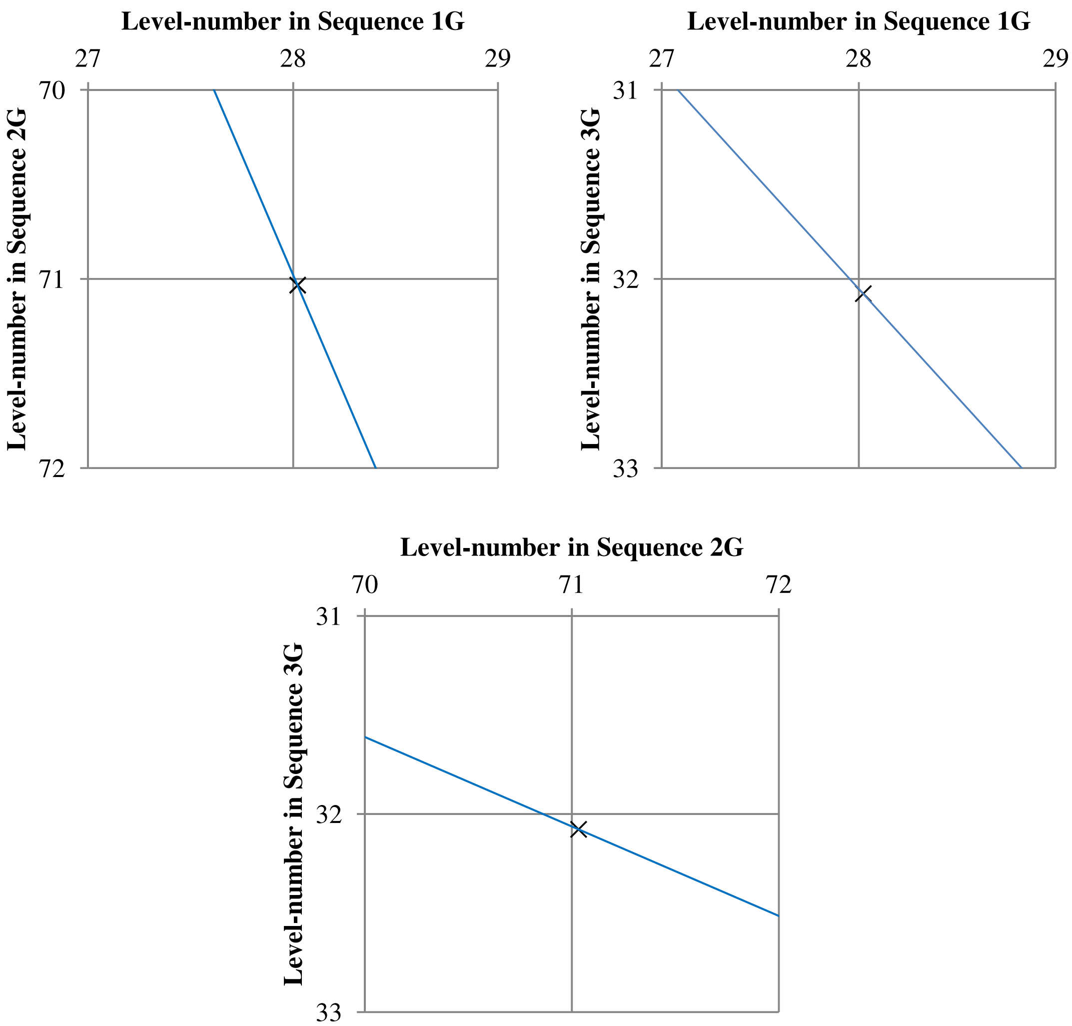


**Figure 8:** The Higgs field VEV (246.22 GeV), marked with a cross, at the triple coincidence (28, 71, 32) within Sequences 1G, 2G and 3G, that descend from GUT scale (2.1 x $10^{16}$ GeV) with common ratios 1/π, 2/π and 1/e, respectively.

The lightest charged particles of each kind (lepton, quark, meson, baryon and gauge boson) lie on the levels of two sequences that descend from the Higgs field VEV and are incorporated within Sequences 2 and 3, as shown in Figure 10. The full significance of the common ratios, $(2/\pi)^{2.5}$ and $(1/e)^{1.875}$, is unclear, although they do ensure that close level coincidences, such as those occupied by the up – down quark doublet and the proton, occur.

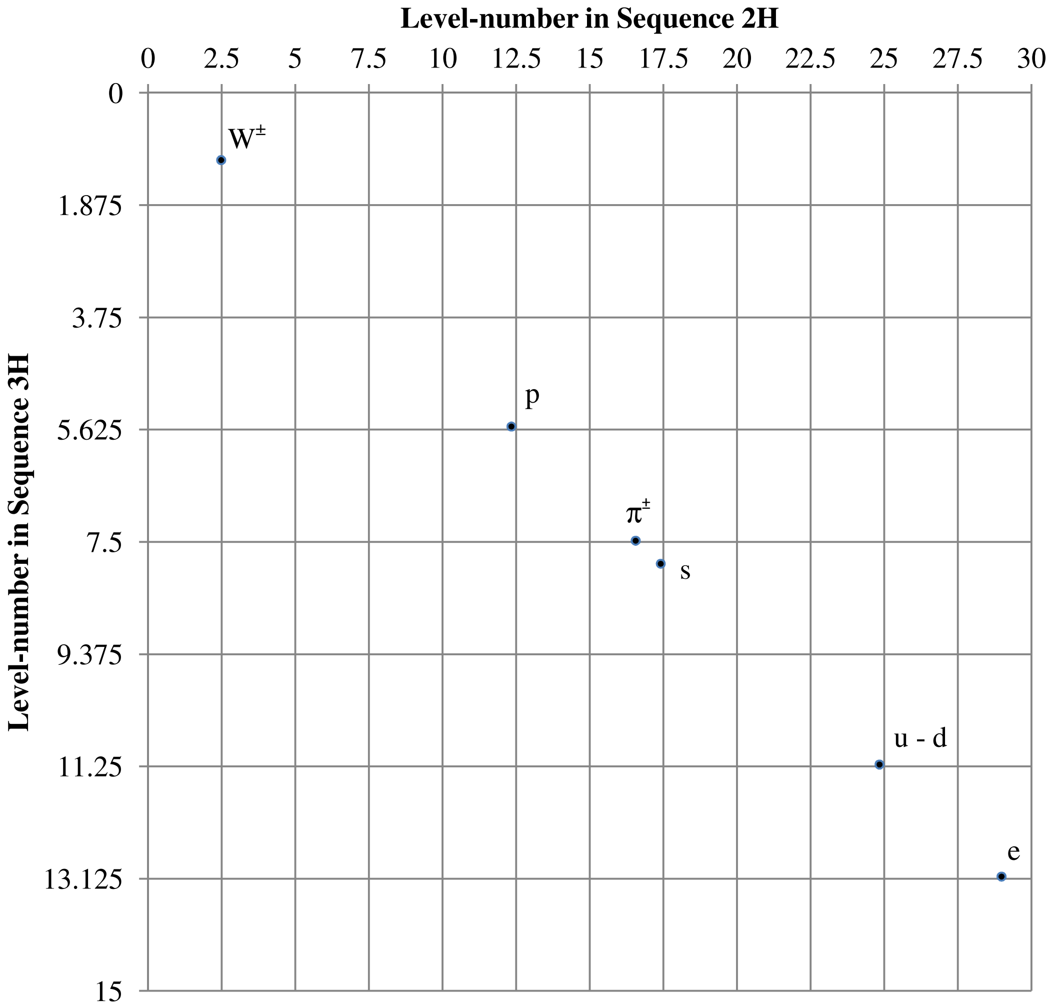


**Figure 9:** The lightest charged particles of each kind on the mass levels of Sequences 2H and 3H that descend from the Higgs field VEV with common ratios $(2/\pi)^{2.5}$ and $(1/e)^{1.875}$, respectively, and are incorporated within Sequences 2 and 3. Central values of Particle Data Group evaluation [5] have been used for all particles. The up-down quark doublet is represented by the geometric mean of the two masses.

## 5. The scales of atomic and particle physics

Following the discovery of the relationship between the Bohr Radius and the Planck Length (1.616199(97) x $10^{-35}$ m [1]), shown in Table 1, various other scales of atomic and particle physics have been found to be related to Planck scale in a similar manner [6]. In each case, the two scales are related through multiplication by integer powers of $(\pi/2)^{25}$ and $\alpha$, the fine structure constant.

Equations for the Reduced Compton Wavelength, Classical Electron Radius, electron mass and Hartree Energy follow immediately from the equation for the Bohr Radius. The other equations, for the up-type quark masses, the pion charge radius and the GUT scale, have been found by inspection.

| Scale | Value | Relationship to Planck Scale in the Planck Model | Value in the Planck Model |
|---|---|---|---|
| Bohr Radius | 0.5292 x $10^{-10}$ m [1] | $a_0 = \left(\frac{\pi}{2}\right)^{125} l_{Planck}$ | 0.5290 x $10^{-10}$ m |
| Reduced Compton Wavelength | 0.3862 x $10^{-12}$ m [1] | $\frac{\lambda}{2\pi} = \alpha \left(\frac{\pi}{2}\right)^{125} l_{Planck}$ | 0.3861 x $10^{-12}$ m |
| Classical Electron Radius | 2.818 x $10^{-15}$ m [1] | $r_e = \alpha^2 \left(\frac{\pi}{2}\right)^{125} l_{Planck}$ | 2.817 x $10^{-15}$ m |
| electron mass | 0.5110 MeV [5] | $m_{electron} = \alpha^{-1} \left(\frac{\pi}{2}\right)^{-125} M_{Planck}$ | 0.5111 MeV |
| Hartree Energy | 27.21 eV [1] | $E_h = \alpha \left(\frac{\pi}{2}\right)^{-125} E_{Planck}$ | 27.22 eV |
| up quark mass | $2.3^{+0.7}_{-0.5}$ MeV [5] | $m_{up} = \alpha \left(\frac{\pi}{2}\right)^{-100} M_{Planck}$ | 2.177 MeV |
| charm quark mass | 1.275 ± 0.025 GeV [5] | $m_{charm} = \alpha^2 \left(\frac{\pi}{2}\right)^{-75} M_{Planck}$ | 1.271 GeV |
| top quark mass | 173.07 ± 0.52 ± 0.72 GeV [5] | $m_{top} = \alpha \left(\frac{\pi}{2}\right)^{-75} M_{Planck}$ | 174.1 GeV |
| pion charge radius | 0.672 ± 0.008 x $10^{-15}$ m [5] | $r_\pi = \left(\frac{\pi}{2}\right)^{100} l_{Planck}$ | 0.6614 x $10^{-15}$ m |
| GUT scale | 2.1 x $10^{16}$ GeV | $E_{GUT} = \alpha^{-1} \left(\frac{\pi}{2}\right)^{-25} E_{Planck}$ | 2.092 x $10^{16}$ GeV |

**Table 1:** Scales of atomic and particle physics in the Planck Model.

It has been possible to calculate the masses of the down-type quarks since the quark doublets lie in symmetrical arrangement about the levels of Sequences 2 and 3, as shown in Figure 1. The down-type quark masses of the Planck Model are shown in Table 2.

| Scale | Value | Relationship to Planck Scale in the Planck Model | Value in the Planck Model |
|---|---|---|---|
| down quark mass | $4.8^{+0.5}_{-0.3}$ MeV | $m_{down} = \alpha^{-1} \left(\frac{\pi}{2}\right)^{-120} M_{Planck}$ | 4.888 MeV |
| strange quark mass | 95 ± 5 MeV | $m_{strange} = \alpha^{-2} e^{-90} \left(\frac{\pi}{2}\right)^{75} M_{Planck}$ | 96.13 MeV |
| bottom quark mass | 4.18 ± 0.03 GeV | $m_{bottom} = \alpha^{-1} \left(\frac{\pi}{2}\right)^{-105} M_{Planck}$ | 4.275 GeV |

**Table 2:** Masses of the down-type quarks in the Planck Model.

The ratios of various scales, as indicated by the Planck Model and as calculated from experimental values, are presented in Table 3.

| Ratio | Value in Planck Model | Value from experiment |
|---|---|---|
| $\frac{m_d}{m_e}$ | $\left(\frac{\pi}{2}\right)^{5}$ | $\left(\frac{\pi}{2}\right)^{5.0(2)}$ |
| $\frac{m_b}{m_d}$ | $\left(\frac{\pi}{2}\right)^{15}$ | $\left(\frac{\pi}{2}\right)^{15.0(2)}$ |
| $\frac{m_t}{m_u}$ | $\left(\frac{\pi}{2}\right)^{25}$ | $\left(\frac{\pi}{2}\right)^{24.9(5)}$ |
| $\frac{m_u c^2}{E_h}$ | $\left(\frac{\pi}{2}\right)^{25}$ | $\left(\frac{\pi}{2}\right)^{25.1(6)}$ |
| $\frac{a_0}{r_\pi}$ | $\left(\frac{\pi}{2}\right)^{25}$ | $\left(\frac{\pi}{2}\right)^{24.97(3)}$ |
| $\frac{Higgs\ VEV}{(m_u m_d)^{1/2} c^2}$ | $\left(\frac{\pi}{2}\right)^{25}$ | $\left(\frac{\pi}{2}\right)^{24.8(4)}$ |
| $\frac{E_{GUT}}{m_e c^2}$ | $\left(\frac{\pi}{2}\right)^{100}$ | $\left(\frac{\pi}{2}\right)^{100.0(1)}$ |
| $\frac{(m_e m_t)^{1/2}}{M_{Planck}}$ | $\left(\frac{\pi}{2}\right)^{-100}$ | $\left(\frac{\pi}{2}\right)^{-100.01(1)}$ |

**Table 3:** Ratios in the Planck Model in comparison with those calculated from experimental values [5]. The up-down quark doublet is represented by the geometric mean, $(m_u m_d)^{1/2}$, of the two masses. The geometric mean of the electron and top quark masses, $(m_e m_t)^{1/2}$, is representative of particle mass scales in general.

## 5. Dark energy

The WMAP 9-year six-parameter ΛCDM fit [7] suggests that the dark energy density, $\rho_\Lambda$, which is responsible for the cosmological constant, has the value 1.27 ± 0.07 x $10^{-123}$ in Planck units [8]. This value may be written as 0.48 ± 0.02 x $(\pi/2)^{-625}$.

Assuming dark energy is zero-point energy (vacuum energy), its value at Planck scale is $\frac{1}{2}\hbar\omega_{Planck}$, or 0.5 in Planck units. The experimental value of dark energy density, ~ 0.5 x $(\pi/2)^{-625}$, is $(a_0/l_{Planck})^5$ times smaller than the theoretical value at Planck scale, since the Bohr Radius, $a_0 = (\pi/2)^{125}\ l_{Planck}$. The possibility suggests itself that the positive cosmological constant is caused by vacuum energy residing within the $S^5$ of $AdS_5$ x $S^5$ at the scale of the vacuum, conjectured to be the Bohr Radius; the $S^5$ is of radius equal to the Bohr Radius [8].

## 6. Discussion

Particles occupy mass levels, sublevels and superlevels. Levels have been related to boundaries in an extra-dimensional geometry. The mass of the level derives from the location of the boundary in an extra dimension [4, 9]. The mass of a sublevel may derive from an off-boundary location [10]. Superlevels may be related to boundaries in covering spaces.

All fields except gravity are confined to 3-branes at the end of, and perpendicular to, an extra dimension of length π/2 in Planck units. Gravity is localised towards the Planck brane. The configuration is similar to that of the Randall and Sundrum RS1 model [11]. In the Planck Model, particles live on 3-branes in the covering space. The mass scale on the brane is transformed from Planck scale by an exponential factor $(\pi/2)^{-n_2}$, where $n_2$, a level-number in the Planck Model, is a winding number. Many particles clearly lie upon mass level or sublevel coincidences. In the extra dimensional geometry, the particles live at the intersections of branes that lie perpendicular to extra dimensions.

Most, or all, particles have partners. An isospin doublet is a form of partnership. Other partnerships involve particles of the same or different spin [2]. The charged leptons are partnered by charged pseudoscalar mesons.

Several scales of atomic and particle physics are related through multiplication by powers of (π/2). The locations corresponding to the related scales are identified with each other in an extra dimension of length π/2 in Planck units.

'Higgs sequences' have been identified. Higgs field coupling constants are incorporated within the Planck Model.

Dark energy may be vacuum energy diluted in density from its value at Planck scale to that at the length scale of the vacuum (the Bohr Radius). The dark energy resides within the $S^5$ of $AdS_5$ x $S^5$. The dark energy density is of constant value and, by gravity, which is free to propagate in the bulk, gives rise to the cosmological constant that we measure in the four-dimensional world.

## 7. References


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