The 49 GeV Partner of the Higgs Boson

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The quantum/classical connection, found in an analysis of dark energy as vacuum energy, maps the radii of celestial bodies onto specific mass scales in the quantum world. The sun, owing to its location in the middle of the Main Sequence, is associated with a rich phenomenology. While the radius of Jupiter maps onto the mass of the Higgs boson, the radius of the sun maps onto the mass (49.4 GeV) of a particle that is symmetrically opposed to the Higgs boson on the mass levels of the Planck Model and is coupled to the Standard Model.

The Quantum/Classical Connection

The connection was found in an analysis of dark energy as vacuum energy [1, 2, 3].

Results ($\mathrm{H_0} = 67.8 \pm 0.9\ \mathrm{km.s^{-1}Mpc^{-1}}$; $\Omega_\Lambda = 0.692 \pm 0.012$) from Planck data [4] suggest that the dark energy density $\rho_\Lambda = \Omega_\Lambda \times 3\mathrm{H_0}^2/8\pi\mathrm{G}$ is of value $1.28 \pm 0.05 \times 10^{-123}$ in the natural units ($\hbar = c = G = 1$) used throughout this paper.

The zero point energy density at Planck scale ($1.220910(29) \times 10^{19}$ GeV, $1.616229(38) \times 10^{-35}$ m [5]) is notionally ½ in natural units. At the scale of the Bohr radius $\mathrm{a_0} = 0.529 \times 10^{-10}$ m – on the edge of the quantum world – the zero point energy, when contained in the 5-sphere of an $\mathrm{AdS_5} \times \mathrm{S^5}$ spacetime, gives rise to an energy density of

$$\rho_\Lambda = \frac{\mathrm{a_0}^{-5}}{2} \tag{1}$$

which has the value 1.33×10^{-123}.

In the classical world, the radius (14,300 Mpc [6]) of the observable universe, r_u, is of value 2.73×10^{61} in natural units (Planck Lengths). The dimensions of the dark energy density being $[\mathrm{L}]^{-2}$, one finds that $r_u{}^{-2} = 1.34 \times 10^{-123}$. It follows that

$$\rho_\Lambda = \mathrm{r_u}^{-2} \tag{2}$$

From (1) and (2),

$$2\mathrm{a_0}^5 = \mathrm{r_u}^2 \tag{3}$$

By conjecture, the *quantum/classical connection* holds generally and is written as

$$2\mathrm{m}^{-5} = \mathrm{r}^2 \tag{4}$$

where m is a ‘quantum’ mass/energy scale and r is a ‘classical’ length scale, specifically a radius. Specific quantum mass scales will be shown to be correlated with the radii of celestial bodies.

The Connection Between Stellar Radii and the Masses of Atomic Nuclei

Stellar radii map onto the masses of specific atomic nuclei by way of the quantum/classical connection [7]. Mass values corresponding to the confidently measured radii of the six stars – see Table 1 – within 15 light years of earth that have radii in the range 0.7-1.3 $R_{\odot}$ are shown on the mass levels and sublevels of Planck Sequences 1 and 3 in Figure 1. These geometric sequences descend from Planck scale with common ratios 1/π and 1/e, respectively, and may derive from a higher-dimensional geometry [8]. The mass values lie on a straight line since the level-numbers, n_1 and n_3, are in constant ratio. Five values of nuclear mass, characterised by mass numbers A, are shown on the levels of Sequences 1 and 3 in Figure 2 for comparison.

Star	Type	Radius ($R_{\odot}$)	Corresponding value of A
Sun	G	1	53.0
Alpha Centauri A	G	1.2234 ± 0.0053 [9]	48.9
Alpha Centauri B	K	0.8632 ± 0.0037 [9]	56.2
Epsilon Eridani	K	0.735 ± 0.005 [10]	59.9
Epsilon Indi A	K	0.732 ± 0.006 [10]	60.0
Tau Ceti	G	0.793 ± 0.004 [11]	58.1

Table 1: Values of corresponding mass number A calculated from the radii of nearby stars

The quoted stellar radius measurement uncertainties of ~0.5% correspond to an uncertainty in the corresponding value of A of ~0.1. The values of A in Table 1 have been calculated by dividing the mass values calculated from the stellar radii by 931.5 MeV, the atomic mass unit.

A Key Classical Length Scale

We have seen that stellar radii are correlated with specific values of atomic mass, the unit of which is the *atomic mass unit*, u, of value 931.5 MeV. In natural units – dividing by the Planck Mass in MeV – u has the value 7.63×10^{-20}. Can we assign a natural value to the Bohr radius, $a_0 = 0.529 \times 10^{-10}$ m, as the unit of length in the classical world? We know that $a_0 = (\pi/2)^{125}$ by dividing by the Planck Length in metres [1] but this is a characteristic of the quantum world, the Bohr radius marking the quantum/classical boundary. Is there a classical length scale l_C by which the Bohr radius may be divided to generate the natural classical unit of length?

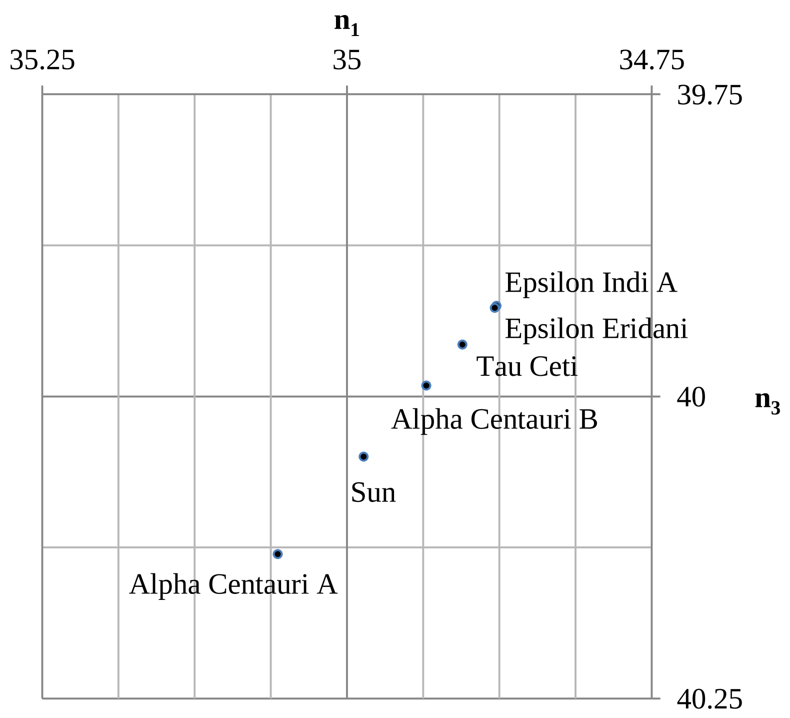

Figure 1: Mass scales calculated from the radii of all six stars within 15 light years of earth that have radii in the range 0.7-1.3 $R_{\odot}$. Shown on the mass levels and sublevels of Planck Sequences 1 and 3.

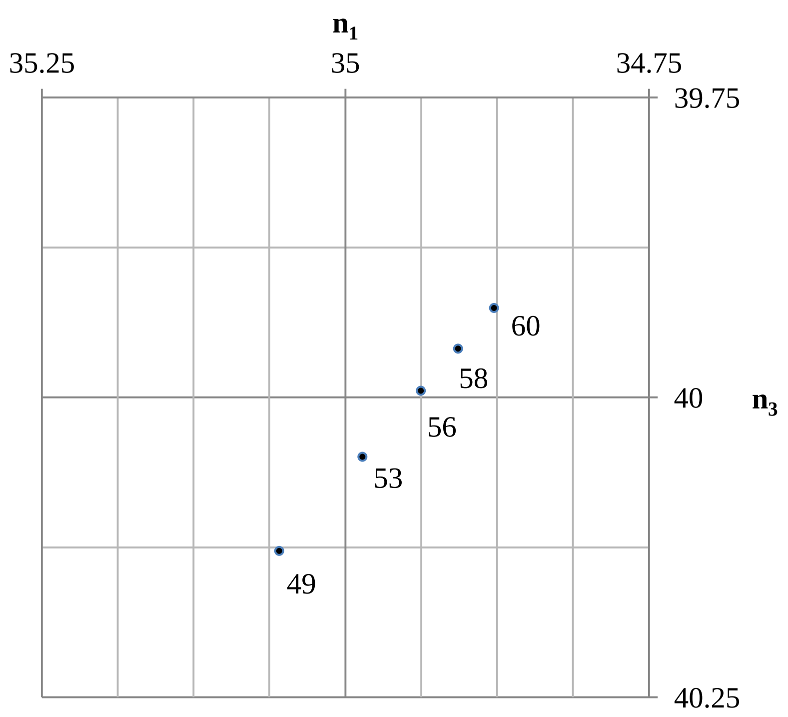

Figure 2: The occupation of the mass levels of Planck Sequences 1 and 3 by atomic nuclei with the mass numbers (A) shown. For comparison with Figure 1.

By conjecturing that $\mathrm{u}/\mathrm{M_P} = \mathrm{a_0}/l_\mathrm{C}$ one finds that l_C = 6.94 × 10^5 km, or 0.997 $R_\odot$. This curious result, $l_\mathrm{C} \sim R_\odot$, signifies that the solar radius, 6.957 × 10^5 km [12], is a key classical length scale, perhaps reflecting the current location of the sun in the middle of the Main Sequence.

Incidentally, by employing, as a natural unit of atomic mass, $\mathrm{u_{nat}} = \mathrm{m_{proton}} - 2\mathrm{m_u} - \mathrm{m_d}$ = 929.2 ± 0.7 MeV, one finds that l_C = 0.9995 ± 0.0008 $R_\odot$. The particle masses used here and throughout the paper are the evaluations of the Particle Data Group [13].

The Solar System and the Quantum/Classical Connection

Mass/energy scales derived from the radius of the sun, the geometric mean $r_{GM(G)}$ (39,930 km) of the radii of the four gas giant planets and the geometric mean $r_{GM(R)}$ (4,226 km) of the radii of the four rocky planets [12] are shown on the levels of Planck Sequences 1 and 3 in Figure 3. Volumetric mean radii have been used.

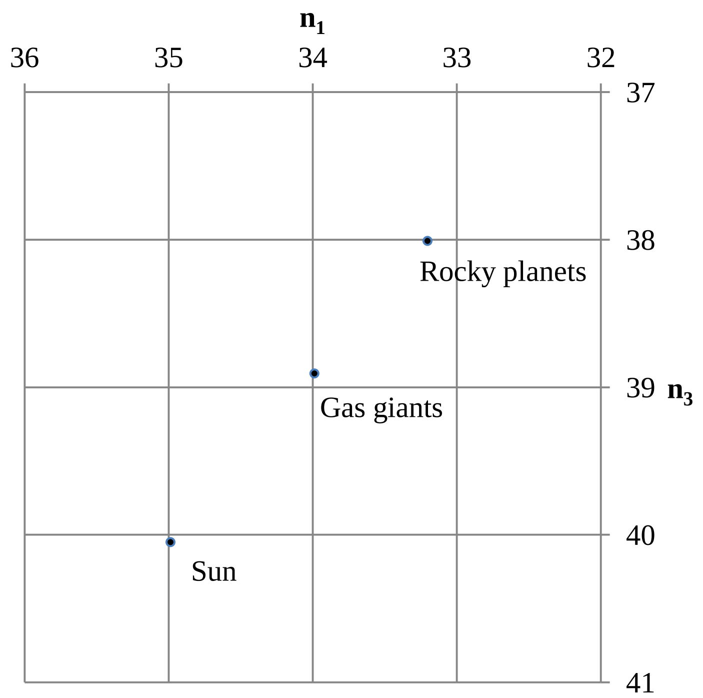

Figure 3: Mass scales corresponding, through the quantum/classical connection, to the radius of the sun, the geometric mean $\mathrm{r_{GM(G)}}$ of the radii of the four gas giants and the geometric mean $\mathrm{r_{GM(R)}}$ of the radii of the four rocky planets. Shown on the mass levels of Planck Sequences 1 and 3.

The occupation of levels by the three mass scales suggests that the solar system is a promising arena for the exploration of the quantum/classical connection. Solar system length scales (radii) are also related within a network of levels associated with the Planck Model, as seen in Figure 4.

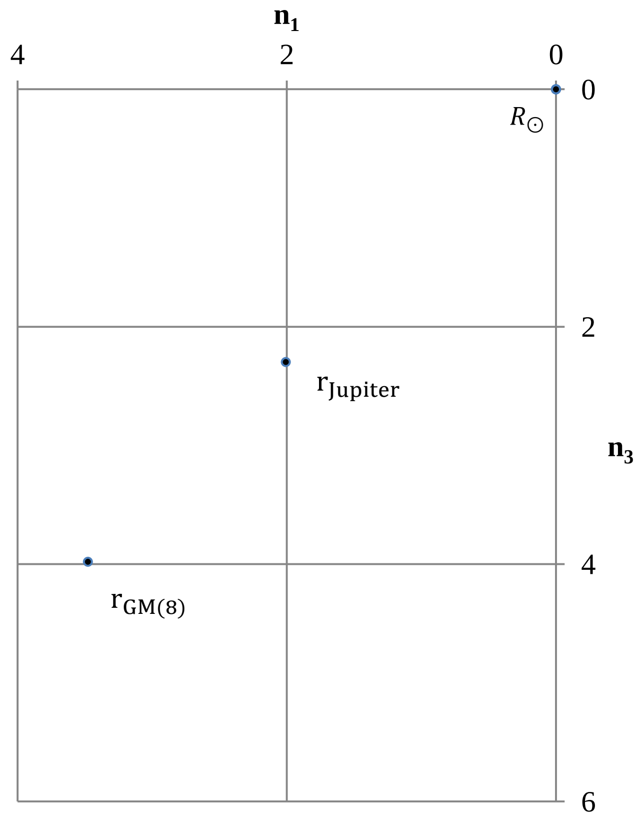

Figure 4: The radius of Jupiter r_{Jupiter} and the geometric mean radius $r_{\mathrm{GM(8)}}$ (12,992 km) of all eight planets on levels of length scale that descend from the solar radius within sequences with common ratios, 1/π and 1/e, that are equal to those of Planck Sequences 1 and 3, respectively.

The mass/energy scales corresponding, through the quantum/classical connection, to the three values of radius in Figure 4 are shown on the levels and sublevels of Planck Sequences 1 and 3 in Figure 5. The Higgs field vacuum expectation value (VEV; 246 GeV), the Higgs boson H^0 (125 GeV) and a particle, provisionally x, of mass 49.4 GeV, for which evidence will be provided, are shown on the mass/energy levels of Sequences 1 and 3 in Figure 6. A comparison of Figures 5 and 6 indicates that the quantum/classical connection gives rise to the mappings:

$$r_{\mathrm{GM(8)}} \rightarrow \text{Higgs VEV} \tag{5}$$

$$r_{\mathrm{Jupiter}} \rightarrow m_{\mathrm{H}^0} \tag{6}$$

$$r_{\mathrm{Sun}} \rightarrow m_{\mathrm{x}} \tag{7}$$

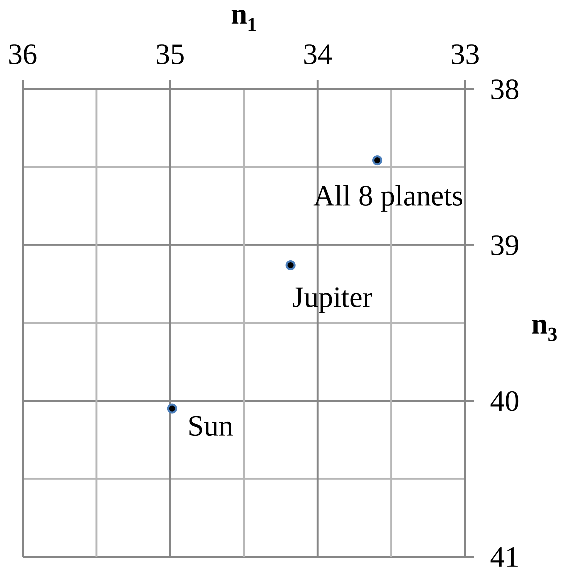

Figure 5: Mass scales corresponding to the radii of the sun and Jupiter, and to the geometric mean radius $r_{GM(8)}$ of all eight planets. Shown on the levels and sublevels of Planck Sequences 1 and 3.

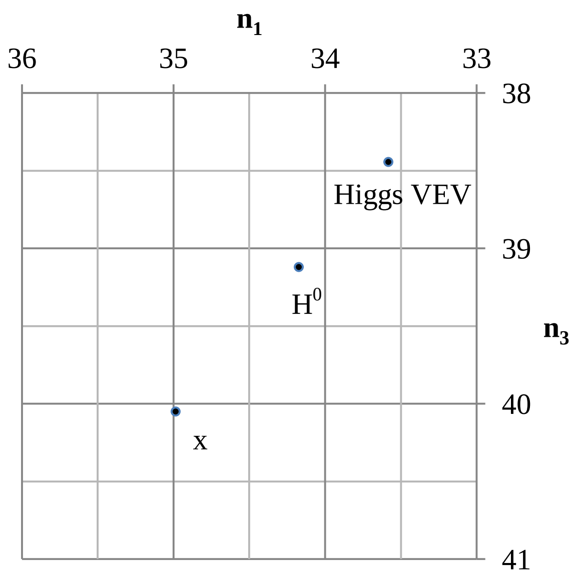

Figure 6: The occupation of the mass/energy levels of Planck Sequences 1 and 3 by particle x (49.4 GeV), the Higgs boson H^0 (125 GeV) and the Higgs VEV (246 GeV). For comparison with Figure 5.

Particle x and the Higgs boson take up a symmetrical arrangement about almost coincident levels that descend from the Higgs VEV, and are incorporated in Planck Sequences 1 and 2, as shown in Figure 7. Planck Sequence 2 is of common ratio 2/π [8].

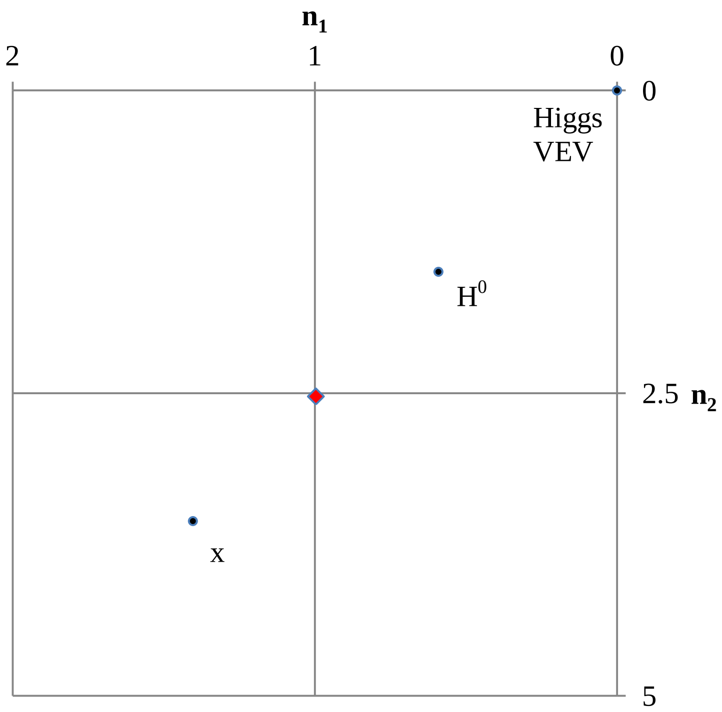

Figure 7: Particle x (49.4 GeV) and the Higgs boson H^0 (125 GeV) on mass/energy levels that descend from the Higgs VEV within Planck Sequences 1 and 2. A diamond marks the geometric mean of the H^0 and x masses.

The symmetrical arrangement of two particles about a level or sublevel is characteristic of a partnership. Isospin doublets take up such arrangements in the Planck sequences, as do the quarks of each generation and various hadrons, e.g. the uds baryons Λ and Σ^0, with some quantum numbers in common [14]. Certain pairs of particles with spin-difference ½ also take up a symmetrical arrangement about a level, e.g. the charged leptons partnered by charged pseudoscalar mesons [15].

The value of $\mathrm{m_{H^0}/m_x}$, like that of the vector boson mass ratio $\mathrm{m_Z/m_{W^\pm}}$ and the first generation quark mass ratio $\mathrm{m_u/m_d}$, approximates to the level-number ratio in the two sequences in which the partners are symmetrically arranged. The Higgs boson H^0 (mass 125.09(24) GeV [13] and particle x (mass 49.354(3) GeV, calculated from the solar radius) are arranged symmetrically about a level in Higgs Sequence 1 (of common ratio 1/π), closely adjacent to a half-level in Higgs Sequence 2 (of common ratio 2/π). The level-number ratio in Sequences 1 and 2 is equal to $ln(\pi)/ln(\pi/2)$, which has the value 2.535. The value of $\mathrm{m_{H^0}/m_x}$, is 2.535.

The $W^{\pm}$ and Z vector bosons are arranged symmetrically about a half-level in Planck Sequence 1 (of common ratio $1/\pi$), closely adjacent to a half-level in Planck Sequence 3 (of common ratio 1/e), as shown in Figure 8. The level-number ratio in Sequences 1 and 3 is equal to $ln(\pi)$, which has the value 1.145. The value of $m_Z/m_{W^{\pm}}$ is 1.134.

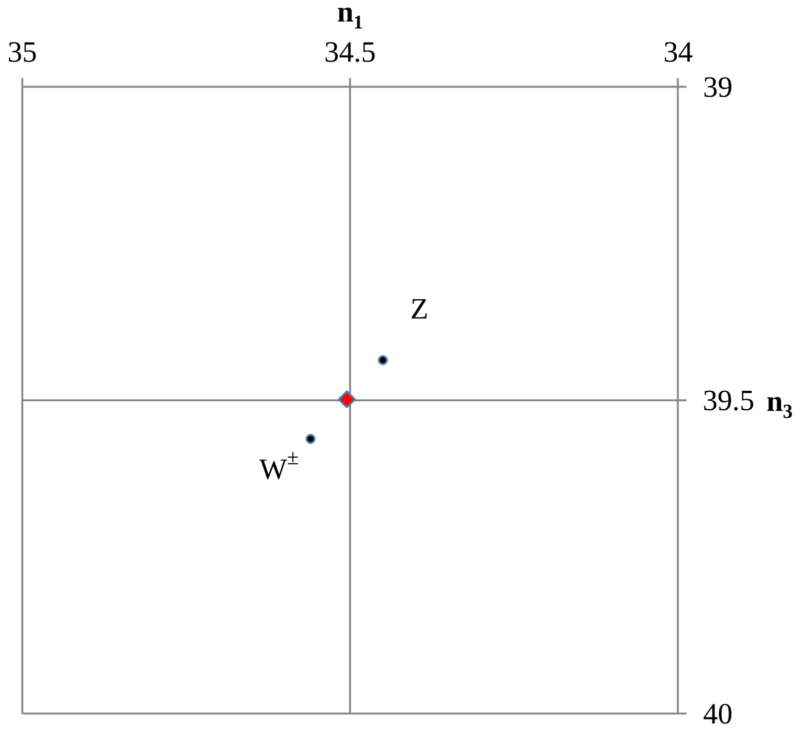

Figure 8: $W^{\pm}$ and Z in Planck Sequences 1 and 3. A diamond marks the geometric mean of the two masses.

The up and down quarks, of mass $2.2^{+0.6}_{-0.4}$ MeV and $4.7^{+0.5}_{-0.4}$ MeV [13], respectively, are arranged symmetrically about a superlevel[1] in Planck Sequence 2 (of common ratio 2/π), closely adjacent to a superlevel in Planck Sequence 3 (of common ratio 1/e), as shown in Figure 9. The level-number ratio in Sequences 2 and 3 is equal to $ln(\pi/2)$, which has the value 0.452. The Particle Data Group's evaluation of m_u/m_d is 0.38 – 0.58 [13]. The value of m_u/m_d found using the up and down quark masses of the Planck Model (2.2 MeV and 4.9 MeV) [15] is 0.45.

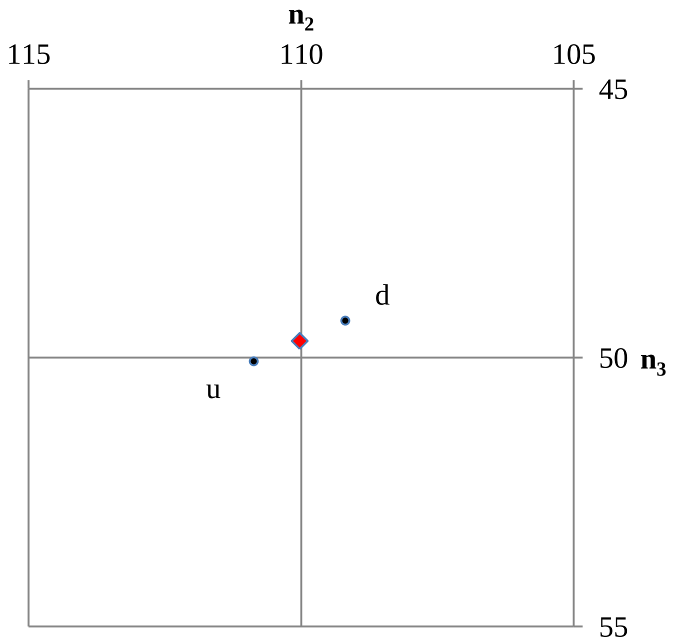

Figure 9: The up and down quarks in Planck Sequences 2 and 3. A diamond marks the geometric mean of the two masses. Central values of Particle Data Group evaluation (2.2 MeV and 4.7 MeV) have been used.

[1] In this case a level whose level-number is a multiple of 5 [15]

In the Standard Model of particle physics the mass of a particle arises out of its coupling with the Higgs field. In the Planck Model [15] particles occupy mass levels that descend from the Higgs VEV (246 GeV) and are incorporated in the Planck sequences. The values of the Higgs field coupling constants derive from the locations of the particles relative to the location of the VEV within the Planck sequences.

The locations of the $W^{\pm}$, Z and H^0 bosons and particle x in Higgs Sequences 2 and 3 are shown in Figure 10.

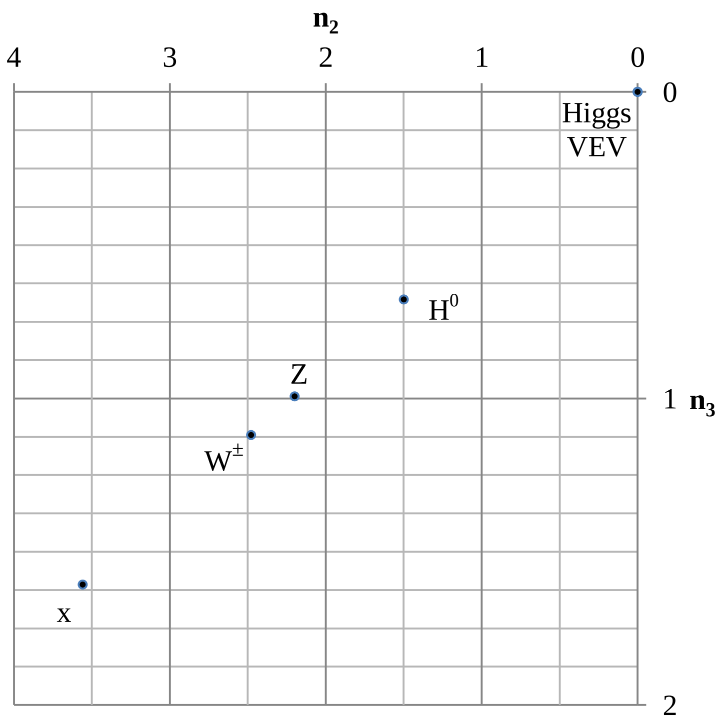

Figure 10: The Higgs boson H^0, the vector bosons $W^{\pm}$ and Z and particle x on the mass/energy levels of Higgs Sequences 2 and 3, which descend from the Higgs VEV with common ratios $2/\pi$ and $1/e$, respectively, and are incorporated in Planck Sequences 2 and 3.

The lightest charged lepton (electron), quarks (up and down as a doublet), unflavoured and strange mesons (π^0 and $K^{\pm}$) and baryon (proton) also occupy the levels and sublevels of Higgs Sequences 2 and 3, as shown in Figure 11.

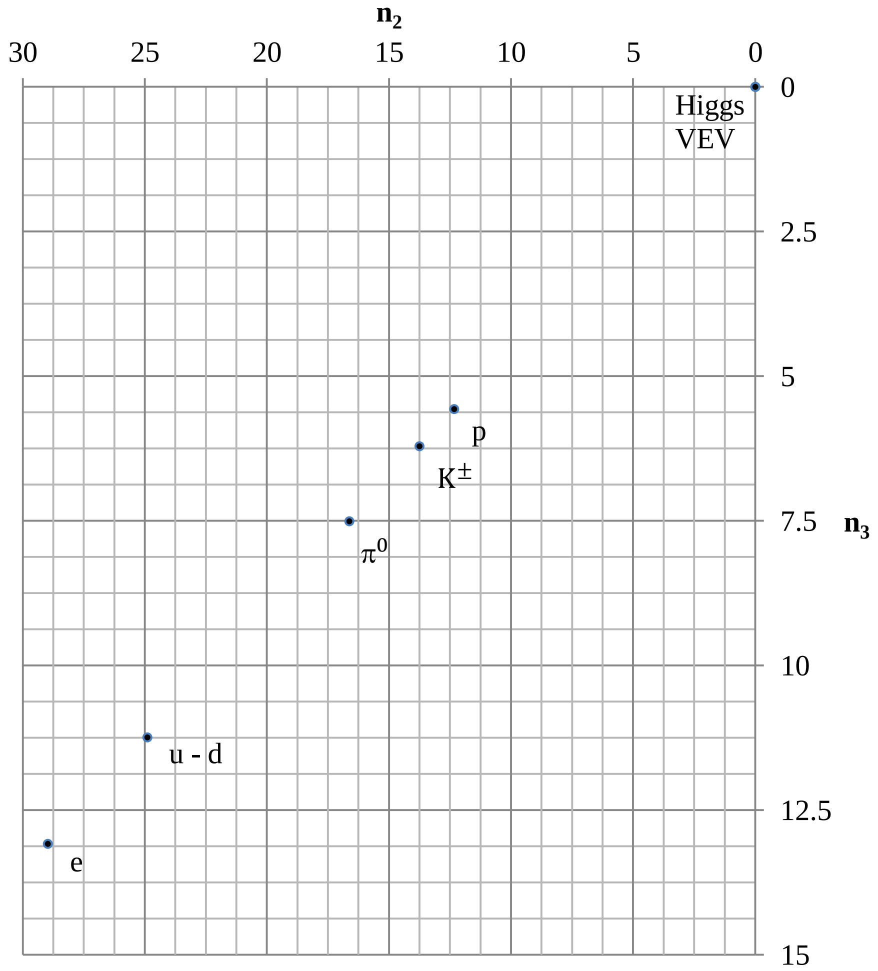

Figure 11: The lightest charged lepton (electron), quarks (up and down as a doublet represented by the geometric mean of the two masses), unflavoured and strange mesons (π^0 and $K^{\pm}$) and baryon (proton) in Higgs Sequences 2 and 3.

The particles of Figure 11 also occupy the levels of the x-sequences, which descend from the mass of particle x and are incorporated in the Planck sequences, as shown in Figure 12. The particles occupy levels whose level-numbers are multiples of 2 in x-Sequences 1 and 3. The up and down quarks now clearly occupy separate levels, potentially with implications for the nature of the coupling to particle x.

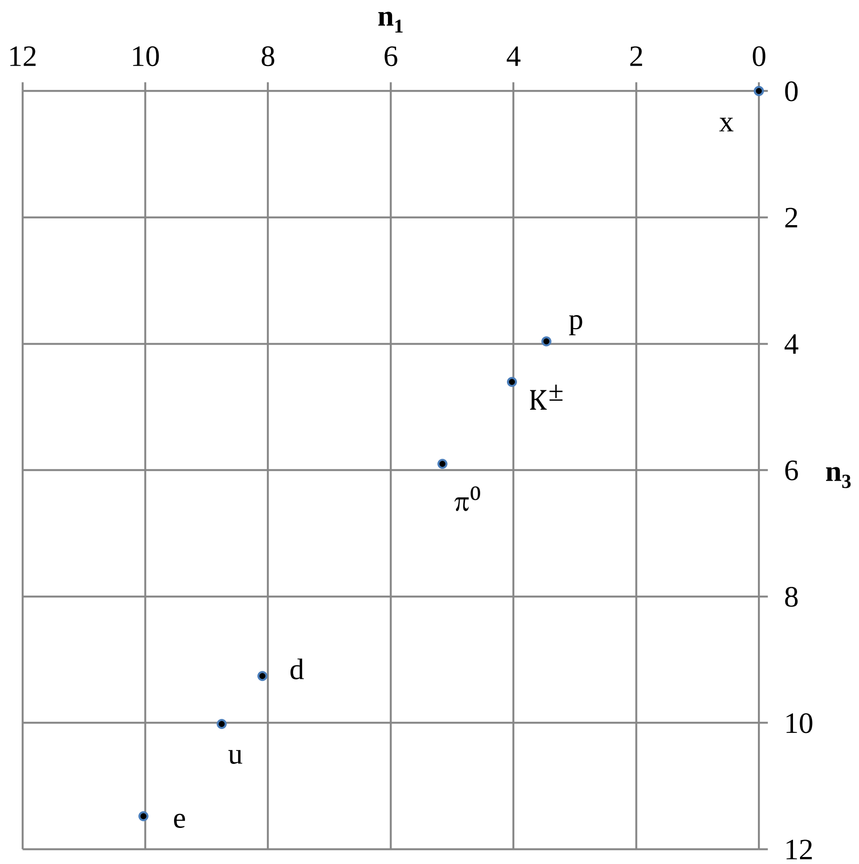

Figure 12: The lightest charged lepton (electron), quarks (up and down), unflavoured and strange mesons (π^0 and $K^{\pm}$) and baryon (proton) in x-Sequences 1 and 3, which descend from the mass scale (49.4 GeV) of particle x with common ratios $1/\pi$ and $1/e$, respectively.

Discussion

The sun is currently about halfway through the stable phase of its evolution. As a G-type star it is located in the middle of the Main Sequence. A star of the sun's radius, that of a medium-sized G-type star, corresponds, through the quantum/classical connection, to a particle with a mass that places it at a special location within the mass level network of the quantum world. That location, (35, 40) in Sequences 1 and 3, is associated with stability. Level 35 in Sequence 1 is occupied by an atomic nucleus with A=52, while Level 40 in Sequence 3 is occupied by an atomic nucleus with A=56. Both mass numbers pertain to stable nuclei, i.e. ^{52}Cr and ^{56}Fe. The sun's radius corresponds to the mass scale of an atomic nucleus with A=53. As a star such as the sun evolves, its radius will change and consequently the corresponding (through the quantum/classical connection) quantum mass scale will change. Since stellar radii have been shown to correspond to the masses of specific atomic nuclei, one would expect the size of the star to remain constant over long periods followed by sudden changes of radius. For a star of the sun's size, a change in the corresponding value of A from 53 to 52 would result from an increase in radius of ~5%.

The planetary system of the sun has formed in such a way that the radii of the planets are distributed in a symmetrical pattern [16]. The pattern is centred on a length scale of $2.0\,\mathrm{R_{Earth}}$, at the centre (geometrically) of the gap in radius between the gaseous and rocky planets. Such a radius gap could be common in planetary systems. Using data for 2025 Kepler planets from the CKS Survey, evidence has been found for a radius gap at 1.5-2.0 $\mathrm{R_{Earth}}$ [17]. The length scale $2.0\,\mathrm{R_{Earth}}$ corresponds, through the quantum/classical connection, to the Higgs VEV.

It is a particular length scale, equal to the geometric mean of the solar system planetary radii, and not the radius of a specific celestial body that corresponds to the Higgs VEV. It is the radii of celestial bodies, i.e. the sun and Jupiter, that correspond to the masses of particle x and the Higgs boson, respectively. However, the solar radius is of equal size to a key classical length scale that may set the scales of stellar radii. The Higgs boson and particle x form a partnership. The two particles are arranged symmetrically in the Higgs sequences and their mass ratio suggests they are closely related. The particles of the Standard Model couple to the Higgs field and also to particle x.

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