The New W, Z, H at 2, 3, 5 TeV

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Particles with masses of 2.1, 2.9 and 5.2 TeV, hints of which have been seen at the LHC, have been shown by Motl to be consistent with a left-right-symmetric extension of the Standard Model with a right-handed Higgs VEV of about 7.7 TeV. The hypothetical right-handed sector is shown to duplicate the left-handed sector in a sublime arrangement on the mass/energy levels of the Planck Model. The quarks are arranged in relation to both left and right-handed VEVs. Physics at TeV-scale is shown to be analogous to that on stellar mass scales by way of the 10D/4D correspondence.

1. Introduction

Gao et al [1] have shown that a leptophobic $SU(2)_L \times SU(2)_R \times U(1)_{B-L}$ model could explain hints seen at the LHC of particles with masses near 2 TeV and 3 TeV in terms of W' and Z'. Motl [2] found that the signals, and another corresponding to a particle mass near 5 TeV, could be explained by a left-right-symmetric extension of the Standard Model in which W' is of mass 2.1 TeV, Z' is of mass 2.9 TeV, H' is of mass 5.2 TeV and the right-handed Higgs VEV is ≈7.7 TeV. Here, we will show that W′, Z′ and H′ with the above masses and the values of both left and right-handed VEVs may be accommodated within the Planck Model [3]. We will show that the right-handed VEV is analogous, by way of the 10D/4D correspondence [4, 5, 6], to the Chandrasekhar limit. TeV-scale particles are shown to be analogous to stellar mass and intermediate mass black holes.

In the Planck Model, particles occupy mass levels that descend in geometric sequence from the Planck Mass. There are three sequences: Sequence 1 of common ratio 1/π, Sequence 2 of common ratio 2/π and Sequence 3 of common ratio 1/e. The sequences may derive from the geometry of ten-dimensional spacetime [7]. The levels of each sequence number from Planck scale (n=0). Levels of integer level-number are referred to as principal levels. Sublevels of fractional level-number also exist, e.g. half-levels and quarter-levels. Particles are shown plotted within two-dimensional representations of the mass level structure. Since the level-numbers in the three sequences are in constant ratio, and a particle will occupy a level or sublevel in each sequence, the particles will lie on a straight line in the representation. All values of particle mass used here, with the exception of those of W′, Z′ and H′, are the evaluations of the Particle Data Group [8].

The 10D/4D correspondence has been shown to relate the time at which an event occurred after the Big Bang with a characteristic mass scale [4]. On sub-Planckian mass scales ($\mathrm{m_{10}} < \mathrm{m_P}$ and $\mathrm{l_4} > \mathrm{l_P}$) the 10D/4D correspondence may be written as[1]

$$2\mathrm{m_{10}}^{-5} = \mathrm{l_4}^2 \tag{1}$$

Through symmetry [5], on super-Planckian mass scales ($\mathrm{m_4} > \mathrm{m_P}$ and $\mathrm{l_{10}} < \mathrm{l_P}$) the correspondence is written as

$$2\mathrm{l_{10}}^{-5} = \mathrm{m_4}^2 \tag{2}$$

By way of (1) and (2), we relate super-Planckian mass scales $\mathrm{m_4}$ to those of analogous sub-Planckian mass scales $\mathrm{m_{10}}$ through the equation

$$\mathrm{m_4}^2 = 2\mathrm{m_{10}}^{-5} \tag{3}$$

2. Signs of a left-right-symmetric world

The W and Z bosons are arranged symmetrically about the closely-coincident half-level intersection (34.5, 39.5) in Sequences 1 and 3 [3]. The neutral bosons Z and H are arranged symmetrically about Level 87 in Sequence 2 [9]. In the Planck Model, symmetrical arrangement about a mass level or sublevel is a feature of the isospin doublet, the triplet, e.g. $\pi^{\pm} - \pi^0$, the quark doublet and various other particles, e.g. the Λ and Σ^0 uds baryons. The W, Z and H bosons are shown in symmetrical arrangement on the levels and half-levels of Sequences 1 and 2 in Figure 1. W′, Z′ and H′ are arranged symmetrically about the levels of Sequence 2, as shown in Figure 2.

A right-handed Higgs VEV υ_R of 7.7 TeV would be related to GUT scale (2.1×10^{16} GeV) by a factor $\pi^{-25.0}$. Precise powers of $(\pi/2)^{-25}$ feature widely in the Planck Model. The VEV is shown on the levels of two sequences that descend from GUT scale in sequences of common ratio $1/\pi$ and $2/\pi$ in Figure 3. The sequences are incorporated within Sequences 1 and 2. Included in Figure 3 are the electroweak symmetry breaking scale of ~2300 TeV, determined using the 10D/4D correspondence [4], and the electron, which is precisely of mass $M_{GUT}/(\pi/2)^{100}$ [3].

[1] where c=G=ħ=1

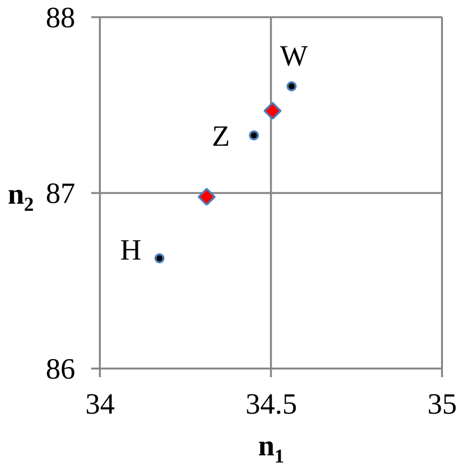

Figure 1: The W, Z and H bosons on the levels of Sequences 1 and 2. The geometric means of the W & Z masses, and of the Z & H masses, are marked with diamonds.

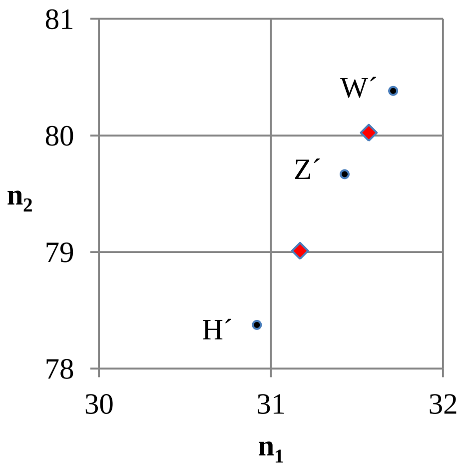

Figure 2: The W´, Z´ and H´ bosons on the levels of Sequences 1 and 2. The geometric means of the W´ & Z´ masses, and of the Z´ & H´ masses, are marked with diamonds.

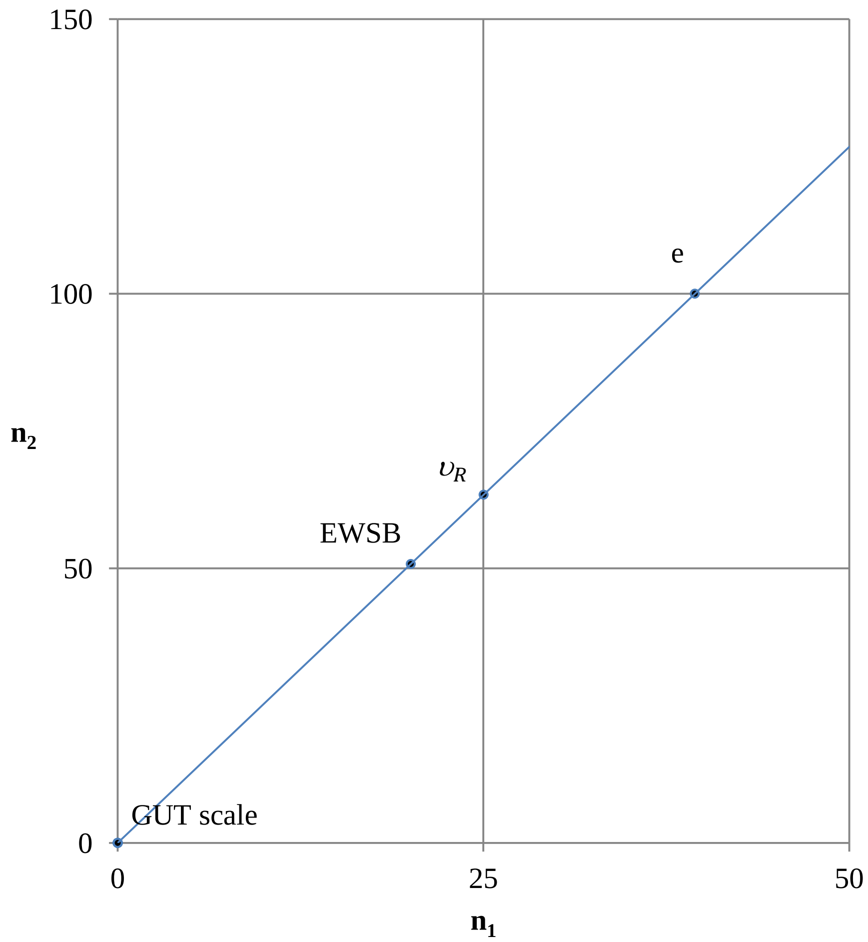

Figure 3: The right-handed Higgs VEV, υ_R, the electroweak symmetry breaking scale ~2300 TeV [4], EWSB, and the electron, e, on levels that descend from 2.1×10^{16} GeV in sequences of common ratio $1/\pi$ and $2/\pi$, i.e. they are incorporated within Sequences 1 and 2.

The right-handed VEV is located prominently within the Planck Model, as shown in Figure 3, while the left-handed VEV υ_L lies on the intersection of levels that descend from υ_R within Sequences 1 and 2, as shown in Figure 4. Included on the levels and half-levels of Figure 4 are the 'doublets'[2] W′-Z′, W-Z and b-t, each represented by the geometric mean of the two masses.

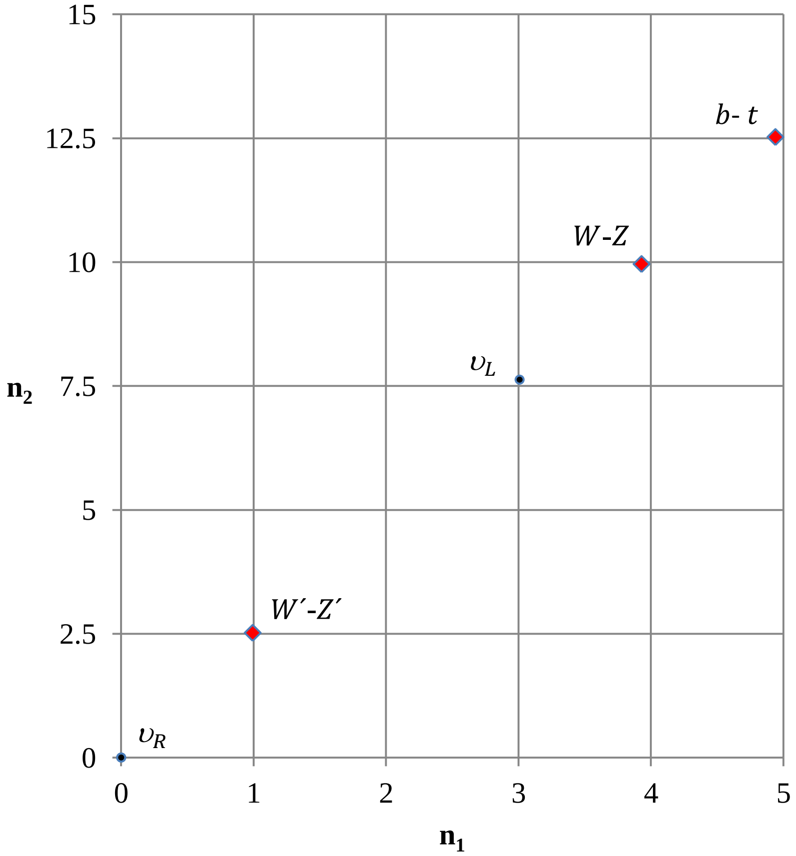

Figure 4: The right and left-handed Higgs VEVs and high mass particles. Diamonds mark the geometric means of the masses of the particles in a doublet (see footnote). The levels shown descend from 7.7 TeV in sequences of common ratio 1/π and 2/π, i.e. they are incorporated within Sequences 1 and 2.

The pattern of Figure 4, continued to lower mass/energy scales, includes the u-d doublet, which, together with the s-c doublet, is shown on levels that descend from υ_R within Sequences 2 and 3 in Figure 5. The mass scale representing the s-c doublet, which lies at the heart of the quark mass range [3], is equal to υ_R/e^{10}. With the exception of the down quark, which shares a sublevel with the up quark, the individual quarks lie on levels and sublevels that descend from υ_R within Sequences 2 and 3, as shown in Figure 6.

[2] The Planck Model does not distinguish between W^+ and W^-.

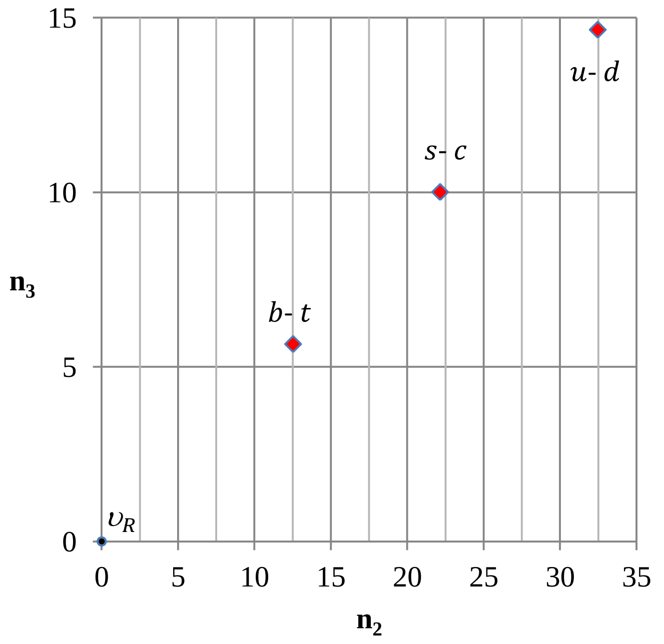

Figure 5: The quark doublets on mass levels that descend from the right-handed Higgs VEV (7.7 TeV) and are incorporated within Sequences 2 and 3. The doublets are represented by the geometric mean of the two masses.

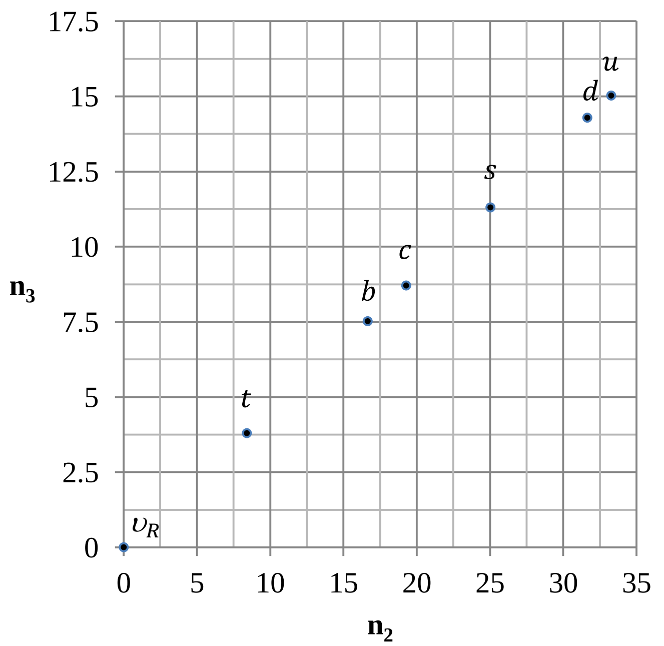

Figure 6: The quarks on mass levels that descend from the right-handed Higgs VEV (7.7 TeV) and are incorporated within Sequences 2 and 3.

The u-d and b-t quark doublets are arranged about levels that descend from υ_L within Sequence 2, as shown in Figure 7, as well as about levels that descend from υ_R (Figure 5). The s-c doublet lies close to a level, although precisely upon a principal level (Level 45) in Sequence 3 [3]. Individually, only the light quarks are closely associated with mass levels that descend from υ_L, as shown in Figure 8. The up and down quarks share a level and the strange quark occupies a sublevel. Strange hadrons also occupy the levels and sublevels that descend from υ_L within Sequence 2 [10].

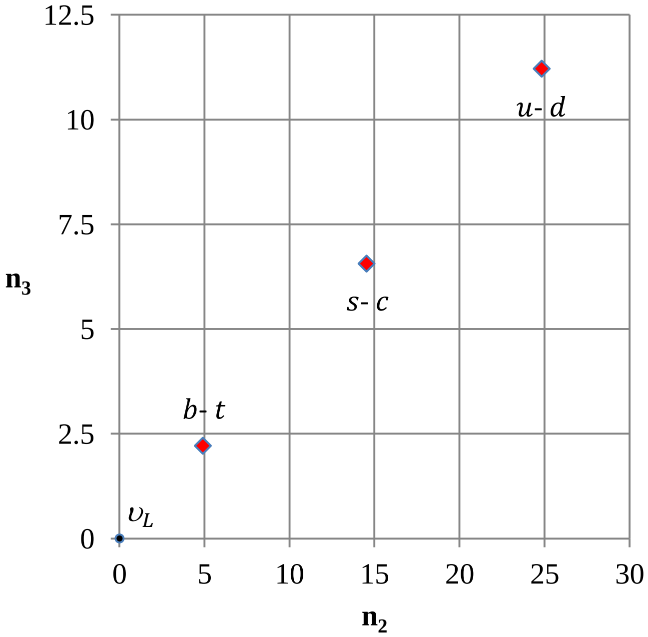

Figure 7: The quark doublets on mass levels that descend from the left-handed Higgs VEV (246 GeV) and are incorporated within Sequences 2 and 3. The doublets are represented by the geometric mean of the two masses.

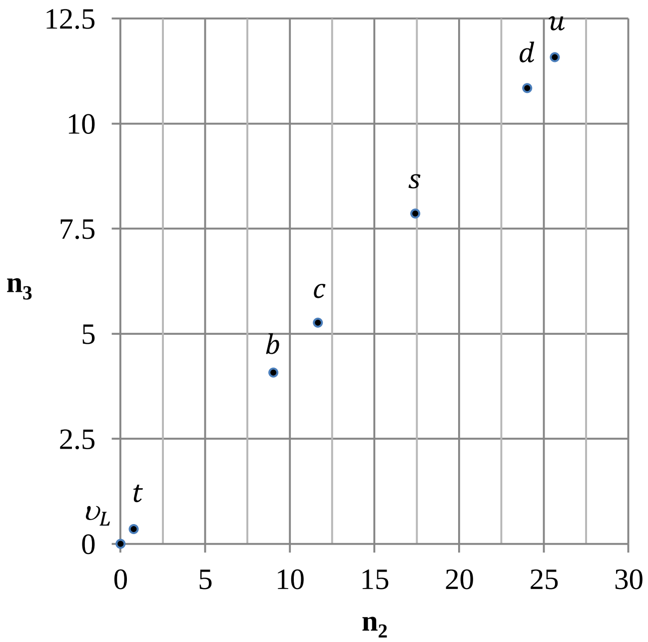

Figure 8: The quarks on mass levels that descend from the left-handed Higgs VEV (7.7 TeV) and are incorporated within Sequences 2 and 3.

3. The right-handed Higgs field and atomic hydrogen

Interestingly, the proton mass and hydrogen K-shell binding energy, 13.6 eV, lie on levels that descend from υ_R within Sequences 2 and 3, as shown in Figure 9. Binding energy in a unified model was the subject of a recent paper [11].

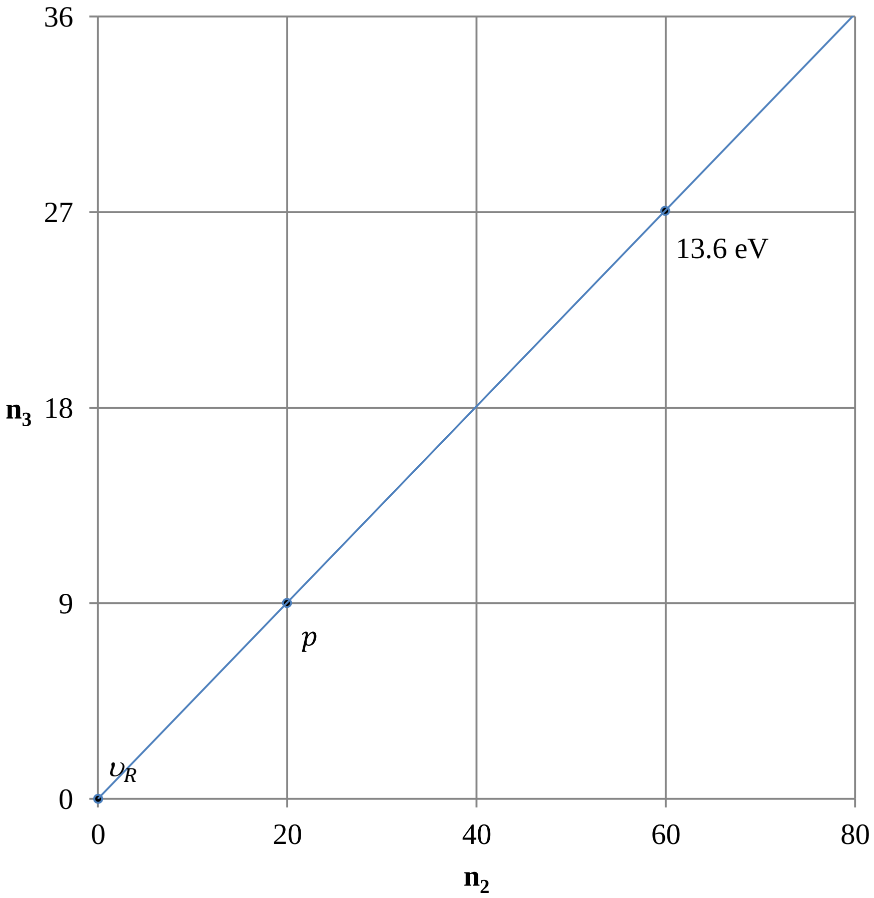

Figure 9: The proton and the hydrogen K-shell binding energy on levels that descend from 7.7 TeV in sequences of common ratio 1/π and 2/π, i.e. they are incorporated within Sequences 1 and 2.

4. The right-handed sector and black holes

By way of the 10D/4D correspondence we have identified the particle analogues of gravitationally bound objects of super-Planckian mass [5, 6]. Atomic nuclei, which are known to occupy mass levels [12], have been found to be the analogues of supermassive black holes. The analogue of the ultraluminous X-ray source M82 X-1, which is thought to be an intermediate black hole of mass 428±105 $M_\odot$ [13], lies on closely coincident half-levels in Sequences 1 and 2: a rare and conspicuous location in the Planck Model. The analogue of M82 X-1, of mass 0.81 TeV, is shown within the overarching left-right arrangement in Figure 10.

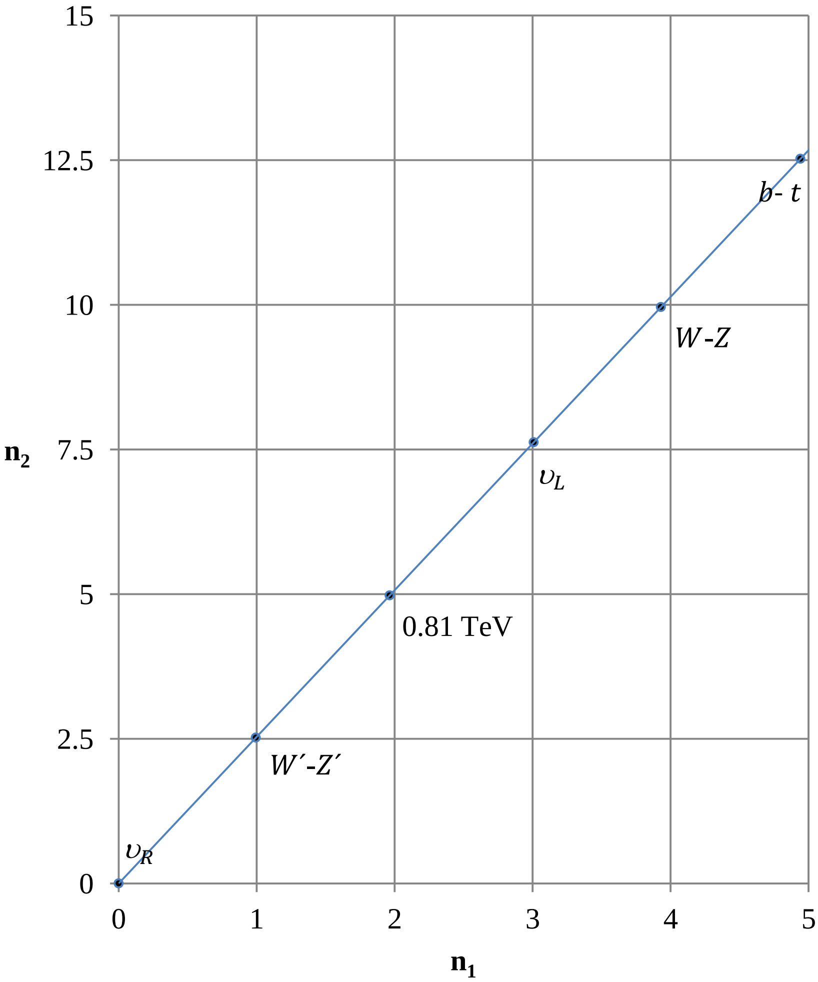

Figure 10: The analogue particle(s), at a mass scale of 0.81 TeV, of the intermediate black hole M82 X-1 (428 $M_\odot$); inserted into the arrangement of Figure 4. The levels shown descend from 7.7 TeV in sequences of common ratio 1/π and 2/π, i.e. they are incorporated within Sequences 1 and 2.

The analogue mass scales (7.8 TeV, 4.8 TeV and 3.1 TeV) of the lightest neutron stars (~1.5 M_Θ), ≈Chandasekhar limit, and the least massive (~5 M_Θ) and most massive (~15 M_Θ) stellar mass black holes are shown on the levels of Sequences 2 and 3 in Figure 11. The right-handed VEV υ_R, H´ and Z´ are shown for comparison on the levels of Sequences 2 and 3 in Figure 12.

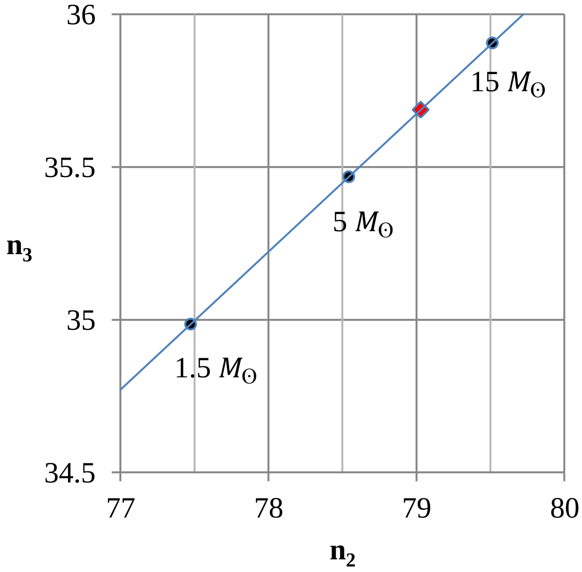

Figure 11: The analogue mass scale (7.8 TeV) of the lightest neutron stars, 1.5 M_Θ (≈Chandrasekhar limit), and of 5 M_Θ (4.8 TeV) and 15 M_Θ (3.1 TeV) stellar mass black holes. Mid-range stellar mass black holes (8.7 M_Θ; 3.9 TeV) are represented by a diamond.

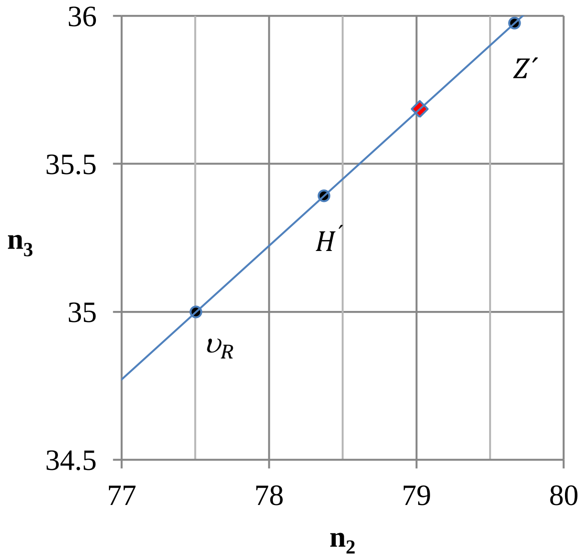

Figure 12: The right-handed Higgs VEV (7.7 TeV) and the neutral bosons Z' and H', shown on the levels of Sequences 2 and 3. The geometric mean of the two boson masses (3.9 TeV) is marked by a diamond.

The right-handed Higgs VEV is analogous, by way of (1), to the Chandrasekhar limit. At mass scales below the VEV, the analogue particles of neutron stars and black holes exist. At mass scales above the Chandrasekhar limit, stellar collapse may give rise to a neutron star or black hole. The Z´-H´ doublet, represented by the geometric mean of the two masses, is analogous to the stellar mass black hole.

5. Discussion

The existence of Sequences 1, 2 and 3, which descend from Planck scale, and the population of their levels by particles of all kinds, indicates that the mass of a particle may derive ultimately from its location relative to the Planck brane in a higher-dimensional space. Couplings with the Higgs fields derive from the location of the particle relative to the right-handed and left-handed Higgs branes, both of which are located in relation to the GUT brane within the higher-dimensional space. W, Z, H and W´, Z´, H´ are closely aligned with the Higgs sequences but also with the Planck sequences.

Across the Planck divide, the Planck sequences are made up of levels of length scale. Astrophysical mass scales correspond, through (2), to sub-Planckian length scales, which occupy levels that oppose the particle mass levels across the divide. To say that a particle is the analogue of, for example, a black hole is to say that the particle occupies an equivalent location in a ten-dimensional manifold of spacetime to that occupied by the black hole in a dual ten-dimensional manifold of energy-momentum. The model developed is a realisation of Born reciprocity [14]: a symmetry between space and momentum. Bolognesi has espoused Born reciprocity with his theory of trans-Planckian duality [15, 16].

6. References

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