Particles as the Analogues of Black Holes

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By way of the 10D/4D correspondence we have identified atomic nuclei as the particle analogues of supermassive black holes. We now specify the nuclear analogues of the supermassive black holes of the Milky Way and M31 galaxies and show that they occupy mass levels in the Planck Model. We show that the particle analogue of the ultraluminous X-ray source M82 X-1, which is thought to be an intermediate mass black hole, would be of mass 0.8 TeV. The particle analogues of stellar mass black holes would have masses in the region of 3-5 TeV. The 10D/4D correspondence may have implications for the black hole information paradox.

1. Introduction

On the basis of the 10D/4D correspondence [1], we found a relationship, on the mass levels of the Planck Model [2], between the range of nuclear mass from that of ^{1}H to that of the tightly bound ^{56}Fe and the range of supermassive black hole (SMBH) mass [3]. On sub-Planckian mass scales ($l_4 > l_P$ and $m_{10} < m_P$) the 10D/4D correspondence is written as

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

while, by symmetry, on super-Planckian mass scales ($m_4 > m_P$ and $l_{10} < l_P$) the correspondence is written as

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

Here and throughout the paper, c = G = ħ = 1. Taken together, (1) and (2) relate the super-Planckian mass m_4 of a gravitationally bound celestial object to an analogous sub-Planckian mass scale m_{10} derived from the geometry of ten-dimensional spacetime [4]:

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

Values of m_{10} corresponding through (3) to the masses of the SMBHs of the Milky Way and M31 are shown to lie on the mass levels of the Planck Model. Such levels are occupied by subatomic particles, including atomic nuclei [5]. Values of m_{10} calculated for the two galaxies also lie on the sub-Planckian mass levels and reveal a specific connection between galaxies and particles. We show that the particle analogue of the intermediate mass black hole candidate M82 X-1 would occupy a conspicuous location, at TeV scale, within the mass level structure of the Planck Model. The particle analogues of stellar mass black holes would also be found at TeV scale.

In the Planck Model, mass levels descend from Planck scale in three geometric sequences, of common ratio 1/π (Sequence 1), 2/π (Sequence 2) and 1/e (Sequence 3). The levels in each sequence are numbered sequentially from Planck scale ($n = 0$). Principal levels are of integer level-number. Sublevels of fractional[1] level-number also exist. Throughout the paper, mass scales and particles are shown plotted within two-dimensional representations of the mass level structure. Since the level-numbers n_1, n_2 and n_3 in Sequences 1, 2 and 3 are in constant ratio, all mass scales and particles lie on a straight line within each representation.

2. SMBHs of the Milky Way and M31

SMBHs generally range in mass from ~5×10^5 solar masses to ~10^{10} solar masses. The corresponding range of sub-Planckian mass scales, m_{10} in (3), lies between the mass of the proton and that of the ^{56}Fe nucleus [3], as shown in Figures 1 and 2. The sub-Planckian mass scales corresponding to the masses of the SMBHs of the Milky Way (4.4×10^6 solar masses [6]) and M31 (1.4×10^8 solar masses [7]), the two most massive galaxies in the Local Group, are shown within Sequences 1 and 3 of the Planck Model in Figure 1. Each value of m_{10} lies close to a principal mass level. The mass number of the nuclear analogue of each SMBH may be calculated from the mass value of the level. Level 41 in Sequence 3, of mass 19 GeV, is associated with the SMBH of the Milky Way. Level 37 in Sequence 1, of mass 4.9 GeV, is associated with the SMBH of M31. The nuclear analogues are of mass number A≈20 (Milky Way) and A≈5 (M31), as shown in Figure 2.

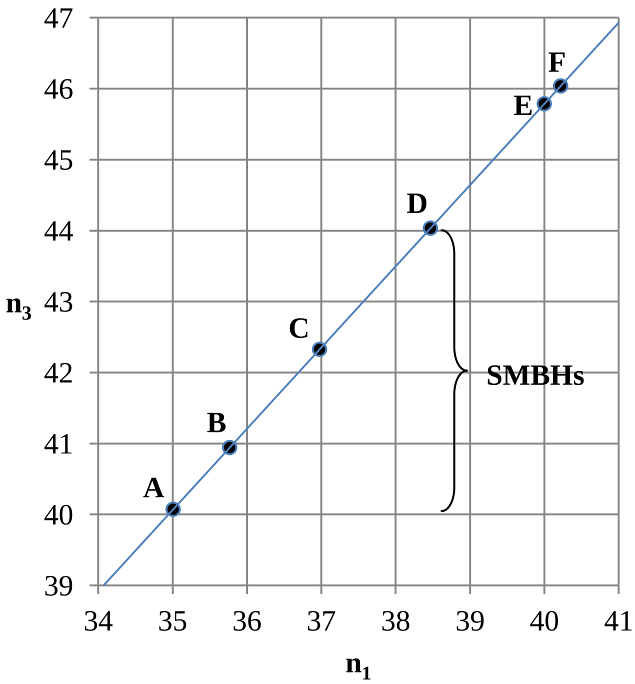
3. The Milky Way and M31 Galaxies

The sub-Planckian mass scales corresponding through (3) to the masses of the Milky Way ($0.8^{+0.4}_{-0.3}\times10^{12}$ solar masses [8]) and M31 ($1.5^{+0.5}_{-0.4}\times10^{12}$ solar masses [8]) lie on principal levels in Sequences 1 and 3, as shown in Figures 1 and 3. The sub-Planckian mass scale corresponding to the geometric mean (1.1×10^{12} solar masses) of the two central values of galaxy mass is 140 MeV, i.e. the mass of the charged pions, as shown in Figure 4. The galaxy pair constitutes a doublet of sorts in the Planck Model, in which isospin doublets are arranged symmetrically about mass sublevels [5]. The charged pions are the analogue particles of the galactic doublet.

4. The Intermediate Mass Black Hole M82 X-1

The sub-Planckian mass scale (0.81 TeV) corresponding through (3) to the mass (428 solar masses [9]) of the ultraluminous X-ray source M82 X-1, which is thought to be an intermediate mass black hole, lies on closely coincident low order[2] sublevels in each of the three sequences, as shown in Figures 5 and 6.

[1] Half-integer, quarter-integer, eighth-integer etc
[2] Levels of half-integer and quarter-integer level-number



A: 5×10^5 solar masses.

B: Milky Way SMBH, 4.4×10^6 solar masses

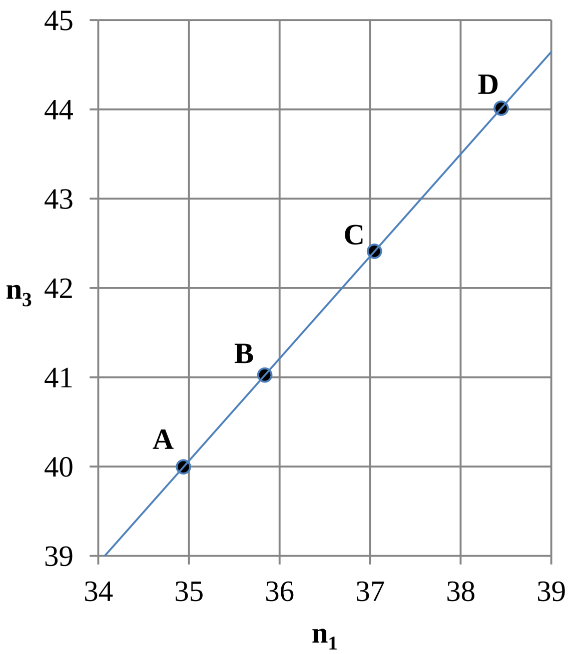
C: M31 SMBH, 1.4×10^8 solar masses

D: 10^{10} solar masses.

E: Milky Way, 0.8×10^{12} solar masses

F: M31, 1.5×10^{12} solar masses

Figure 1: The occupation of levels in Sequences 1 and 3 by the sub-Planckian mass scales related through (3) to SMBH and galactic masses.



A: ^{56}Fe nucleus

B: Atomic nucleus, A=20

C: Atomic nucleus, A=5

D: Proton

Figure 2: Particle mass scales on the levels of Sequences 1 and 3.

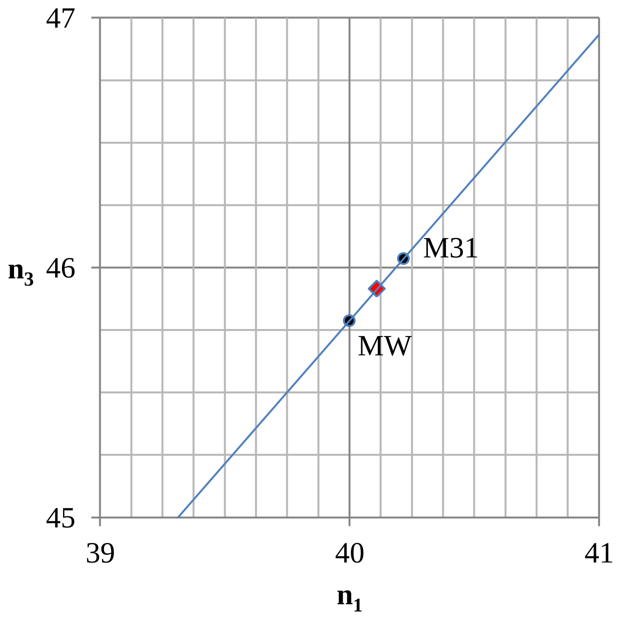


Figure 3: The sub-Planckian mass scales related through (3) to the masses of the Milky Way and M31 galaxies; shown on the levels of Sequences 1 and 3. The geometric mean (140 MeV) of the two mass scales is marked with a diamond.

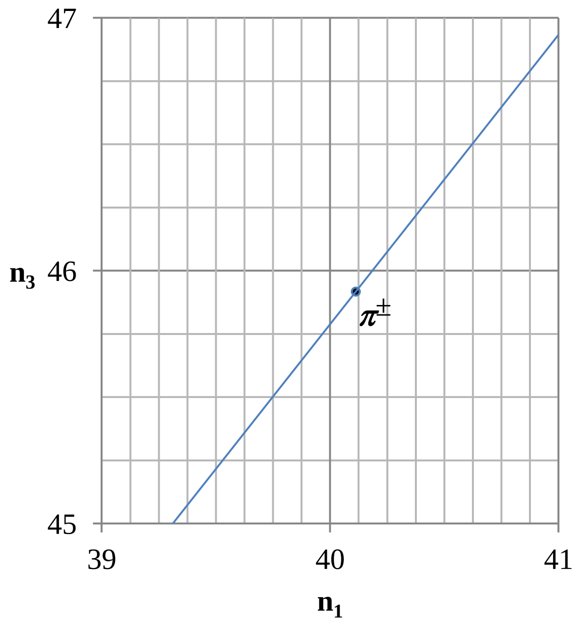


Figure 4: The charged pions on the mass levels of Sequences 1 and 3.

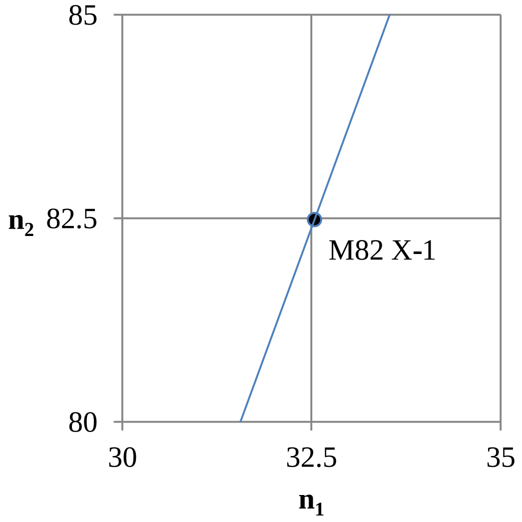


Figure 5: The sub-Planckian mass scale (0.81 TeV) related through (3) to the mass (428 solar masses) of the ultraluminous X-ray source M82 X-1; shown on the levels of Sequences 1 and 2.

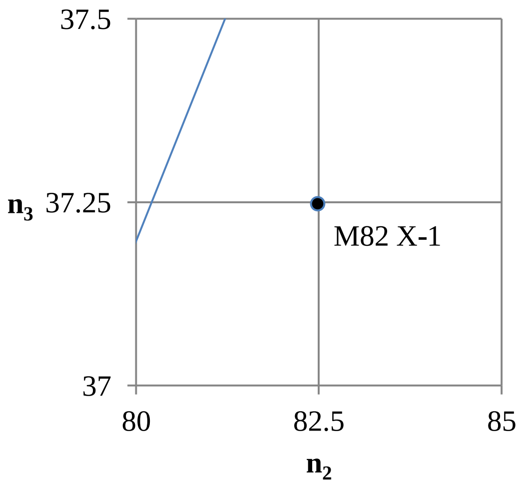


Figure 6: The sub-Planckian mass scale (0.81 TeV) related through (3) to the mass (428 solar masses) of the ultraluminous X-ray source M82 X-1; shown on the levels of Sequences 2 and 3.

5. Neutron Stars

The gravitational collapse of a massive star may result in the formation of a neutron star. Calculations based on realistic equations of state incorporating the effects of general relativity suggest lower and upper limits of ~1.5 and ~2.7 solar masses on the masses of neutron stars [10]. These two limits correspond to the values of two sub-Planckian principal mass levels, as shown in Figure 7.

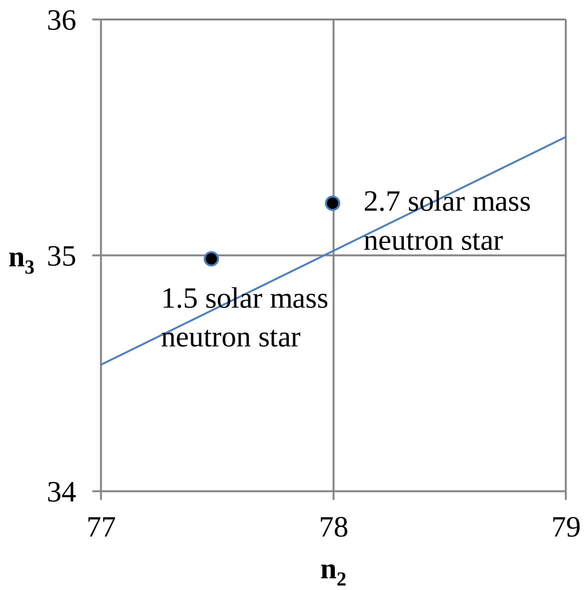


Figure 7: The sub-Planckian mass scales related through (3) to the masses of neutron stars; shown on the levels of Sequences 2 and 3. Level 78 in Sequence 2 is of value 6.2 TeV. Level 35 in Sequence 3 is of value 7.7 TeV.

6. Stellar Mass Black Holes

Stellar mass black holes have masses in the range 5-15 solar masses. The corresponding sub-Planckian mass scales coincide with half-levels either side of Level 79 (8.4 solar masses; 3.9 TeV) in Sequence 2, as shown in Figure 8. Stellar mass black holes in the Milky Way have been shown to be well described by a narrow mass distribution at 7.8±1.2 solar masses [11].

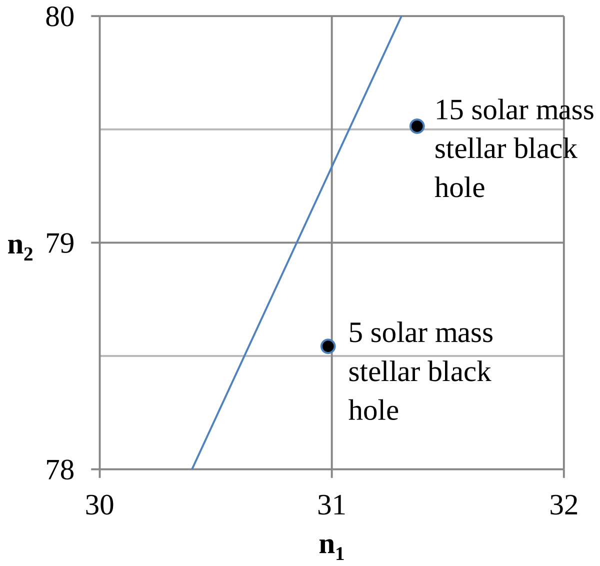


Figure 8: The sub-Planckian mass scales related through (3) to the masses of stellar mass black holes. Level 31 in Sequence 1 is of value 4.7 TeV. Level 79.5 in Sequence 2 is of value 3.1 TeV.

7. The Black Hole Information Paradox

The 10D/4D correspondence may have some bearing on the black hole information paradox. Consider a black hole of Schwarzschild Radius $r_S = 2m_{BH}$. In Planck units, the entropy of the black hole is given by

$$S_{BH} = A/4 = 4\pi {m_{BH}}^2 \tag{4}$$

where $A = 4\pi {r_S}^2$ is the area of the event horizon. From (2), as the black hole evaporates and ${m_{BH}}^2$ decreases, ${l_{10}}^5$ increases. As in [12], we identify l_{10} with the characteristic length scale of an $AdS_5 \times S^5$ spacetime. So, as the entropy of the black hole apparently decreases, the volume of the corresponding 5-sphere in ten-dimensional spacetime increases, ultimately to Planck scale. Does the information that is seemingly lost from the evaporating black hole transfer to a 5-sphere in ten-dimensional spacetime?

8. Conclusions

We have shown that cosmological mass scales correspond, through the 10D/4D correspondence, to sub-Planckian mass scales derived from a ten-dimensional model. The mass scales of supermassive black holes, neutron stars and stellar mass black holes all correspond to sub-Planckian mass scales that lie within bounds imposed by the geometry of the ten-dimensional spacetime. Specific particle analogues, e.g. atomic nuclei of particular mass number, have been shown to occupy conspicuous locations within the level structure of the

Planck Model. We will present the results of an investigation into the analogy between TeV-scale particles and stellar mass black holes in another paper.

The 10D/4D correspondence on super-Planckian mass scales may be central to the resolution of the black hole information paradox.

9. References

1. B. F. Riley, *10D/4D correspondence and the Big Bang*, viXra:1503.0104
2. B. F. Riley, *The Planck Model*, viXra:1311.0053
3. B. F. Riley, *The black hole as a trans-Planckian particle*, viXra:1505.0084
4. B. F. Riley, *Standard Model scales from warped extra dimensions*, arXiv:0809.0111
5. B. F. Riley, *Particle mass levels*, viXra:0909.0006
6. R. Genzel, F. Eisenhauer and S. Gillessen, *The galactic center massive black hole and nuclear star cluster*, Rev. Mod. Phys. 82 3121 (2010), arXiv:1006.0064
7. R. Bender et al, *HST STIS spectroscopy of the triple nucleus of M31: two nested disks in Keplerian rotation around a supermassive black hole*, Astrophysical Journal 631 280 (2005), arXiv:astro-ph/0509839
8. J. Peñarrubia et al, *A dynamical model of the local cosmic expansion*, MNRAS 443 3 2204-2222 (2014), arXiv:1405.0306
9. D. R. Pasham, T. E. Strohmayer and R. F. Mushotzky, *A 400 solar mass black hole in the ultraluminous X-ray source M82 X-1 accreting close to its Eddington limit*, Nature 513 7516 74-76 (2014), arXiv:1501.03180
10. H. Bradt, *Astrophysics processes: the physics of astronomical phenomena*, Cambridge University Press (2008)
11. F. Özel et al, *The black hole mass distribution in the galaxy*, Astrophysical Journal 725 2 1918 (2010), arXiv:1006.2834
12. B. F. Riley, *The cosmological constant from* $AdS_5 \times S^5$, viXra:1307.0107