10D/4D Correspondence and the Big Bang

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The time scales of events occurring since the Big Bang, including the onset of inflation, electroweak symmetry breaking, nucleosynthesis, recombination and reionisation are related through an inverse 5/2 power law to subatomic mass scales characteristic of the events. Those mass scales derive from the geometry of 10D spacetime.

1. Introduction

From the calculation of vacuum energy density on the boundary, at the scale of the Bohr radius a_0, of an AdS spacetime [1, 2] and, separately, in the four-dimensional universe [3], we found that, with c = G = ħ = 1,

$$r_u^{\ 2} = 2a_0^{\ 5} \tag{1}$$

where r_u is the radius of the observable universe. From (1), with a_0 = 0.529 x 10^{-10} m, r_u = 14,369 Mpc. The value usually quoted is 14,300 Mpc [4].

Generalising (1), we shall relate the times t_E at which events occur after the Big Bang to a succession of specific subatomic mass scales m_Q through the equation

$$t_E^{\ 2} = 2m_Q^{\ -5} \tag{2}$$

The Big Bang timeline features widely in the literature and elsewhere. The time after the Big Bang that is attributed to an event varies somewhat but not by enough to make a significant difference to the results of the analysis. Middling values are used here. The scales m_Q resulting from (2) will be shown to be characteristic of the corresponding events.

2. The Big Bang Timeline

Processes occurring since the Big Bang include inflation, electroweak symmetry breaking, nucleosynthesis, recombination and reionisation.

Inflation commenced about 10^{-36} seconds after the Big Bang with the spontaneous symmetry breaking of the GUT force into the strong and electroweak forces. From (2), with t_E = 10^{-36} s, m_Q = 2 x 10^{16} GeV, the GUT scale.

Electroweak symmetry breaking occurred around 10^{-12} – 10^{-11} seconds after the Big Bang. From (2), with t_E = 5 x 10^{-12} s, m_Q = 2300 TeV. This, evidently, is the scale of electroweak symmetry breaking.

In the Planck Model [5], symmetry breaking is associated with mass levels that descend in geometric progression from the Planck Mass. There are three sequences of mass levels: Sequence 1, of common ratio 1/π; Sequence 2, of common ratio 2/π; and Sequence 3, of common ratio 1/e. Levels within Sequences 1, 2 and 3 are given the level-numbers n_1, n_2 and n_3, respectively. Superlevels are levels whose level-numbers are multiples of 3 (type 1) or 5 (type 2). Coincident superlevels of the same type are rare and are associated with the principal scales of particle physics [6, 7]. The mass scale (2300 TeV) associated with electroweak symmetry breaking 5 x 10^{-12} s after the Big Bang is shown at the coincidence of three type 2 superlevels in Figure 1.

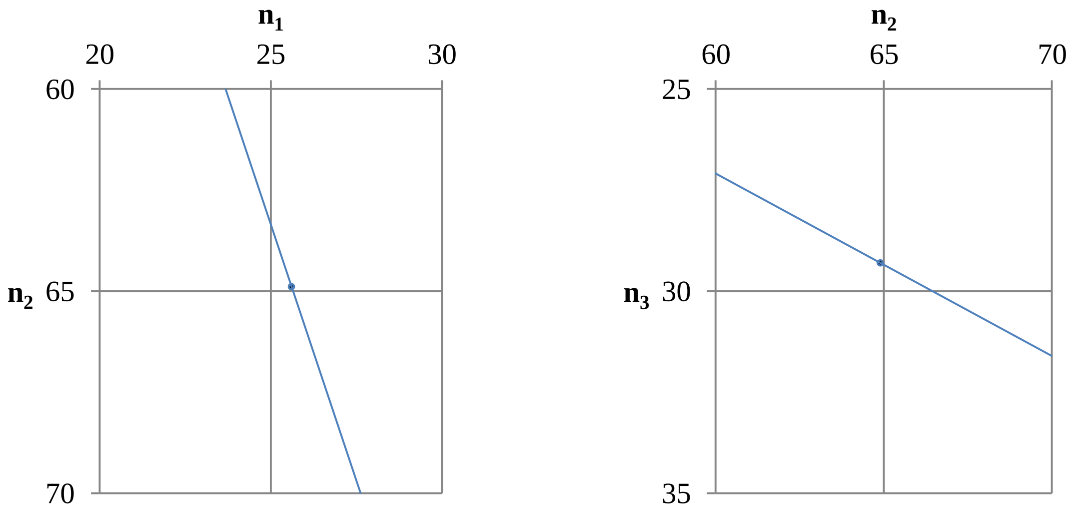

Figure 1: The electroweak symmetry breaking scale 2300 TeV in Sequences 1, 2 and 3 of the Planck Model [5]. Since level-numbers within the three sequences are in constant ratio, all mass scales will lie on a straight line, shown in blue, within each graph.

Nucleosynthesis, the process by which atomic nuclei are formed, initiated after about 300 seconds. With t_E = 300 s, m_Q = 7 GeV. In the Planck Model, 7 GeV is the scale associated with stable atomic nuclei [8]. The proton and its evident partner, the tightly bound ^{56}Fe nucleus, a scalar boson, are symmetrically opposed about the close type 1 superlevel coincidence (93, 42) in Sequences 2 and 3, of mass 7.0 GeV, as shown in Figure 2. All atomic nuclei occupy mass levels [9] and must be regarded as particles.

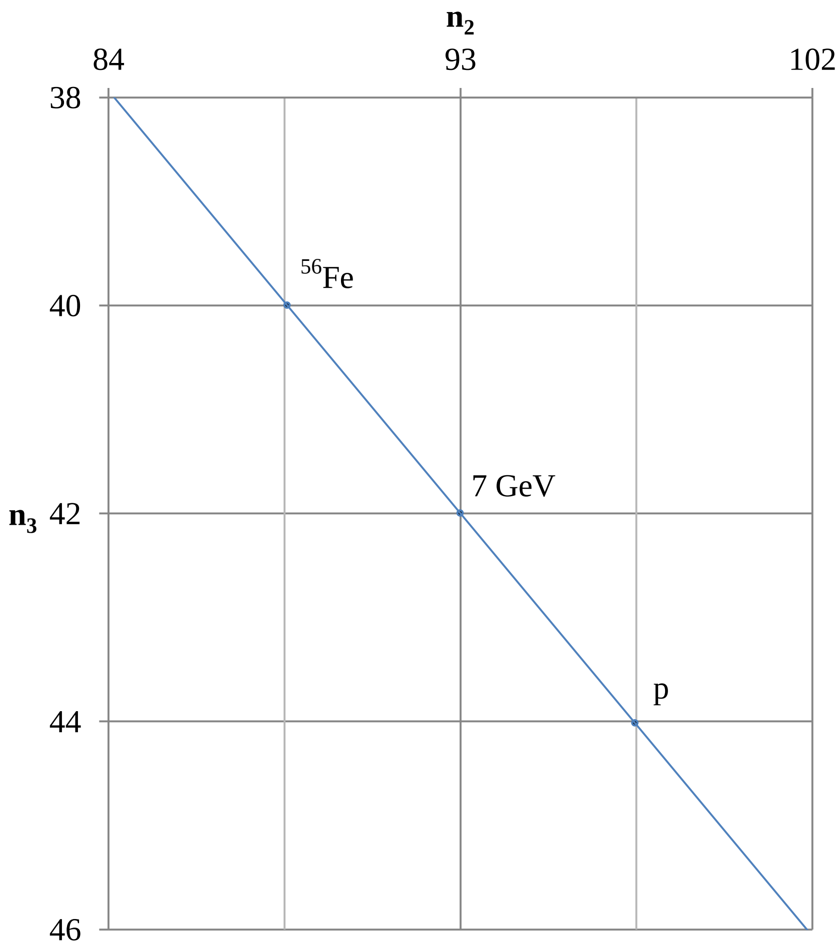

Figure 2: The mass scale of nucleosynthesis (7 GeV) in Sequences 2 and 3 of the Planck Model. Also shown are the proton and its partner the ^{56}Fe nucleus.

Recombination, or the formation of atoms, started about 240,000 years after the Big Bang. With t_E = 240,000 years, m_Q = 0.5 MeV, the electron mass, an obvious scale for this process.

Reionisation started after about 200 million years. With t_E = 200 million years, m_Q = 30 keV, the peak energy of the Cosmic X-ray Background [10]. Such hard X-rays were responsible for reionising the mainly hydrogen gas present at the start of the reionisation era.

3. Mass Scales of the Big Bang

For each event in the Big Bang timeline, the square of the time after the Big Bang (ABB) when the event occurred (${t_E}^2$) is plotted against $2{m_Q}^{-5}$, where m_Q is the mass scale of the responsible process. The relationship is shown in Figure 3. The data points lie on a straight line of gradient 1, as required by (2).

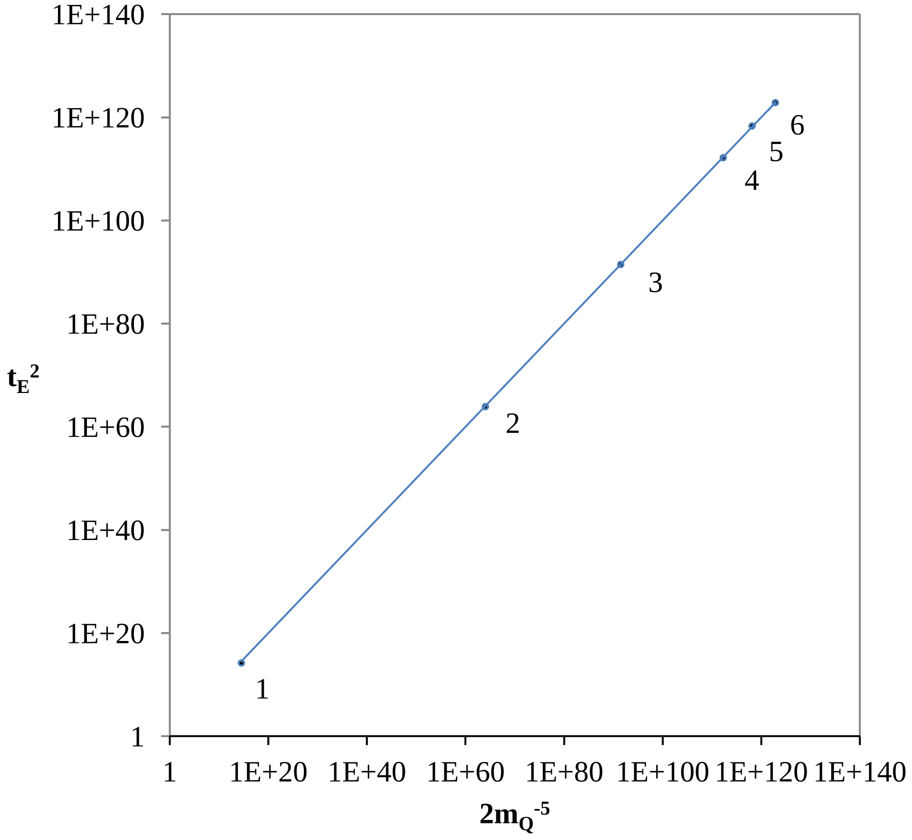

Figure 3: An inverse 5/2 power law relationship between the time scales of events occurring after the Big Bang (ABB) and the mass scales characteristic of the events. The values of t_E and m_Q used are shown below.

1 *Inflation initiates*. 10^{-36} s ABB; GUT scale, 2 x 10^{16} GeV.
2 *Electroweak symmetry breaking*. 5 x 10^{-12} s ABB; 2200 TeV (n_2 = 65).
3 *Nucleosynthesis initiates*. 300 s ABB; 7.0 GeV scale (n_2 = 93).
4 *Recombination initiates*. 240,000 years ABB; electron mass scale, 0.511 MeV.
5 *Reionisation initiates*. 200 million years ABB; CXB scale, 30 keV.
6 *The observable universe*. Light takes 47 billion years to traverse the radius of the observable universe; scale of the inverse Bohr radius, 3.7 keV.

The low mass scales associated with recombination, reionisation and the radius of the observable universe are shown within Sequences 1 and 2 of the Planck Model in Figure 4.

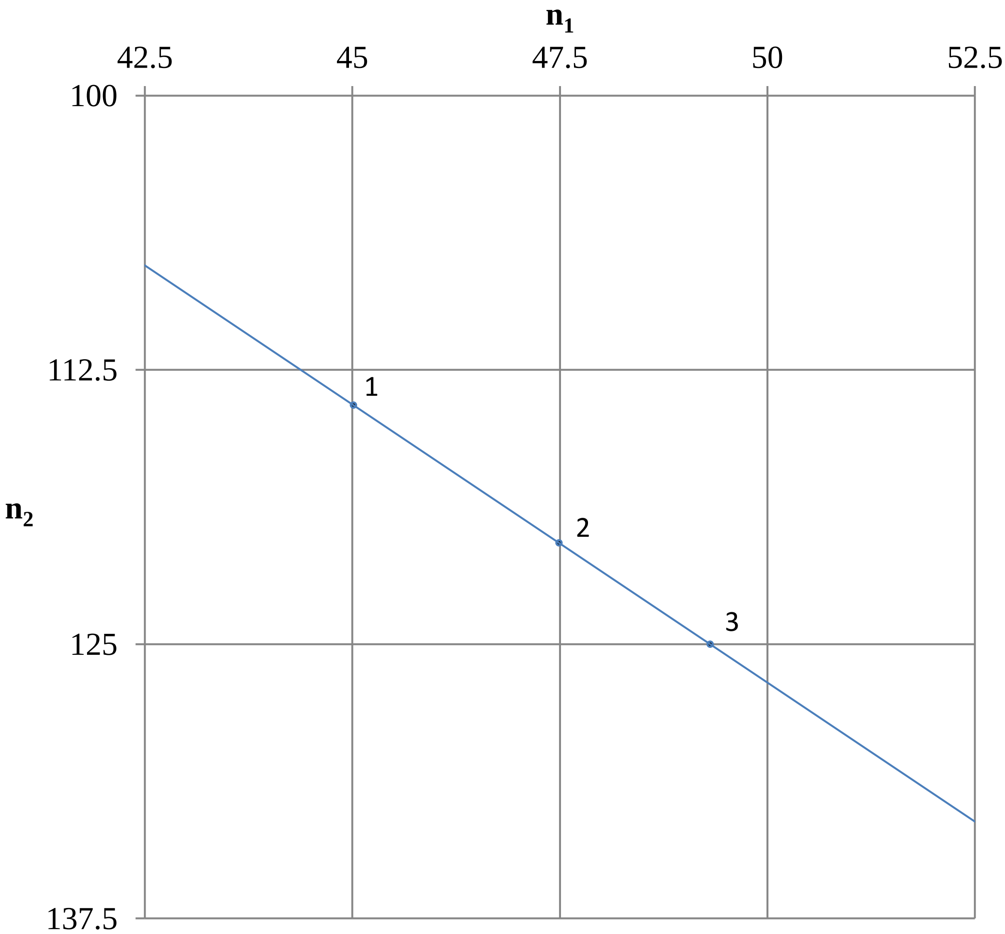

Figure 4: Low mass scales associated with Sequences 1 and 2 of the Planck Model.

1 *Recombination*; electron mass, 0.511 MeV.
2 *Reionisation*; CXB, 30 keV.
3 *Observable universe*; ${r_u}^{-1}$ = 3.7 keV.

4. Discussion

Equation (1), which relates the radius of the observable universe to the Bohr radius, arose from considerations of vacuum energy. The vacuum energy density calculated from a fit to the base ΛCDM model using WMAP9 data [11] is equal to that calculated on the boundary of an AdS spacetime [1, 2], at the scale of the Bohr radius a_0, and is given by (with c = G = ħ = 1)

$$\rho_\Lambda = \frac{1}{2}{a_0}^{-5} \tag{3}$$

During the first moments following the Big Bang, though, spacetime was characterised by a succession of much shorter length scales and immense vacuum energy density. In the model developed [1, 2, 3], the vacuum energy is confined within an n-sphere whose characteristic length scale (its radius) is equal to the characteristic length scale of the AdS spacetime. As the n-sphere inflated, it was characterised in turn by a series of scales, the values of which are defined by the geometry of an $AdS_6 \times S^4$ spacetime [12]. The processes in the Big Bang timeline were triggered as specific scales were reached. Eventually, the radius of the n-sphere will have grown to be equal to the Bohr radius, which may be a limiting value. The corresponding radius of the four-dimensional universe is as observable today. It is given by (1).

5. References

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