The Act of Measurement I: Astronomical Distances

B. F. Riley

The act of measurement causes astronomical distances to adopt discrete values. When measured, the distance to the object corresponds through an inverse 5/2 power law – the Quantum/Classical connection – to a sub-Planckian mass scale on a level or sub-level of one or both of two geometric sequences, of common ratio $1/\pi$ and 1/e, that descend from the Planck mass and may derive from the geometry of a higher-dimensional spacetime. The distances themselves lie on the levels and sub-levels of two sequences, of common ratio π and e, that ascend from the Planck length. Analyses have been performed of stellar distances, the semi-major axes of the planets and planetary satellites of the Solar System and the distances measured to quasars, galaxies and gamma-ray bursts.

1 Introduction

Using Planck units the Quantum/Classical connection, characterised by the equation

$$2m^{-5} = R^2 \tag{1}$$

maps astronomical distances *R* – in previous papers only the radii of astronomical bodies [1, 2] – onto sub-Planckian mass scales m on the mass levels and sub-levels[1] of two geometric sequences that descend from the Planck mass: Sequence 1 of common ratio $1/\pi$ and Sequence 3 of common ratio 1/e.[2] The sequences may derive from the geometry of a higher-dimensional spacetime [3].

First, we show that several distances associated with the Alpha Centauri system correspond through (1) to the mass scales of principal levels[3] in Sequences 1 and 3. We then show that the mass scales corresponding through (1) to the distances from both Alpha Centauri and the Sun to the other stars lie on the levels and sub-levels of Sequences 1 and 3. Then we show that the distances to the stars are also *directly* related to Planck scale: the distances lie on the levels and sub-levels of two sequences, of common ratio π and e, that ascend from the Planck length. We go on to perform an analysis of the mean orbital radii (semi-major axes) of the planets and planetary satellites of the Solar System and then analyse the distances to quasars, galaxies and gamma-ray bursts.

2 The Alpha Centauri System

The binary star Alpha Centauri AB lies in the middle of the Main Sequence. The mass scales corresponding through (1) to the two stellar radii (A: 1.2234(53) $R_\odot$; B: 0.8632(37) $R_\odot$ [4]) are symmetrically arranged about Level 35 in Sequence 1, close to Level 40 in Sequence 3, as shown in Figure 1. Nearly-coincident super-levels (levels whose level-numbers are multiples of 5) are rare, and are important locations for physics: the quarks of each generation are arranged symmetrically about mass super-levels that are adjacent to nearly-coincident super-levels [5].

The sub-Planckian mass scale (48.8 MeV) characteristic of Alpha Centauri AB, which is equal to the geometric mean of the mass scales corresponding through (1) to the radii of Alpha Centauri A and B, is plotted on the levels of Sequences 1 and 3 in Figure 2 together with the mass scales corresponding through (1) to the various orbital distances associated with the Alpha Centauri system. Alpha Centauri A and B orbit each other. Proxima Centauri orbits Alpha Centauri AB. The planets Proxima Centauri b and c orbit Proxima Centauri. The mass scales corresponding through (1) to the semi-major axis, or mean orbital radius, of each orbit are included in Figure 2. Each distance corresponds through (1) to a mass scale that is coincident with a principal level in either Sequence 1 or Sequence 3 suggesting that the classical world emerges from a quantum world.

[1] Half-levels, quarter-levels, eighth-levels etc
[2] Sequence 2 is of common ratio $2/\pi$.
[3] Levels of integer level-number

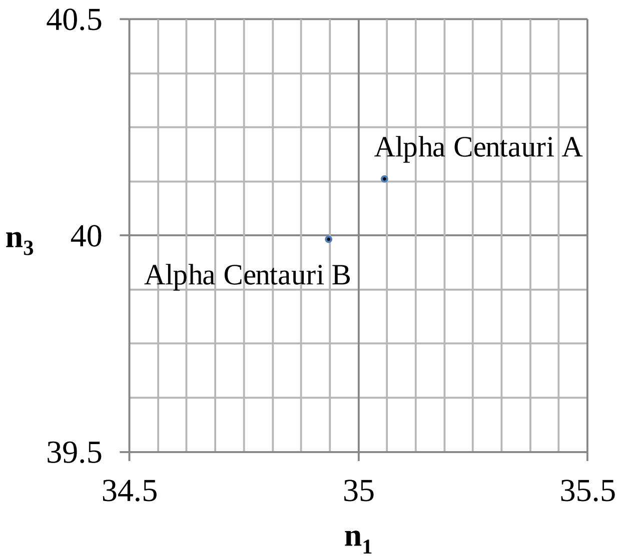


Figure 1: Sub-Planckian mass scales corresponding through (1) to the radii of Alpha Centauri A and B. Shown on the levels and sub-levels of Sequence 1 (common ratio 1/π) and Sequence 3 (common ratio 1/e).

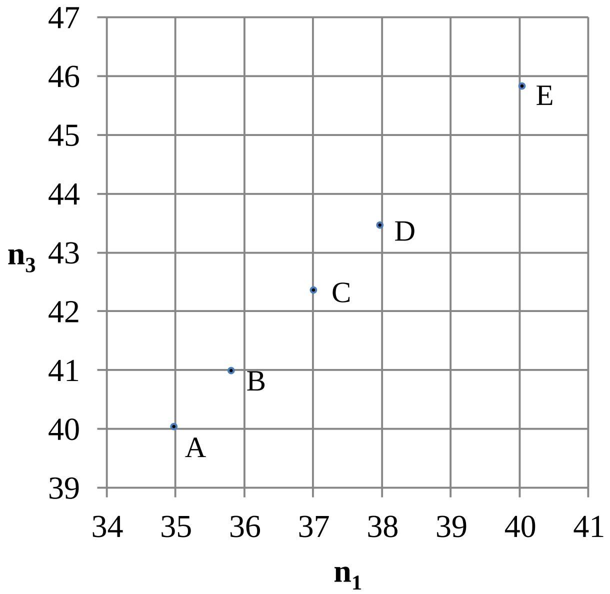


Figure 2: Sub-Planckian mass scales corresponding through (1) to:

A The geometric mean radius of Alpha Centauri A and Alpha Centauri B (1.028 $R_{\odot}$)

B The orbital radius of Proxima Centauri b (0.0485(41) AU [6])

C The orbital radius of Proxima Centauri c (1.489(49) AU [7])

D The semi-major axis of the binary Alpha Centauri AB's orbit (23.520(36) AU [8])

E The semi-major axis of Proxima Centauri's orbit around Alpha Centauri AB (8.7 +0.7/-0.4 kAU [9])

Shown on the levels of Sequences 1 and 3. The mass scales are confined to a straight line since the level-numbers in the two sequences are in constant ratio.

3 The Distances of the Nearby Stars from Alpha Centauri

On the basis of Figure 2 a first thought was to calculate the mass scales corresponding through (1) to the distances between Alpha Centauri and the nearby (to Earth) stars.[4] This has been done for six such stars, of various types: the results are shown in Figure 3. Despite the inconstancy of interstellar distances each mass scale calculated lies on a sub-level in either Sequence 1 or Sequence 3. This result immediately tells us that the act of measurement causes the distance to a star to adopt a discrete value that is codified through (1).

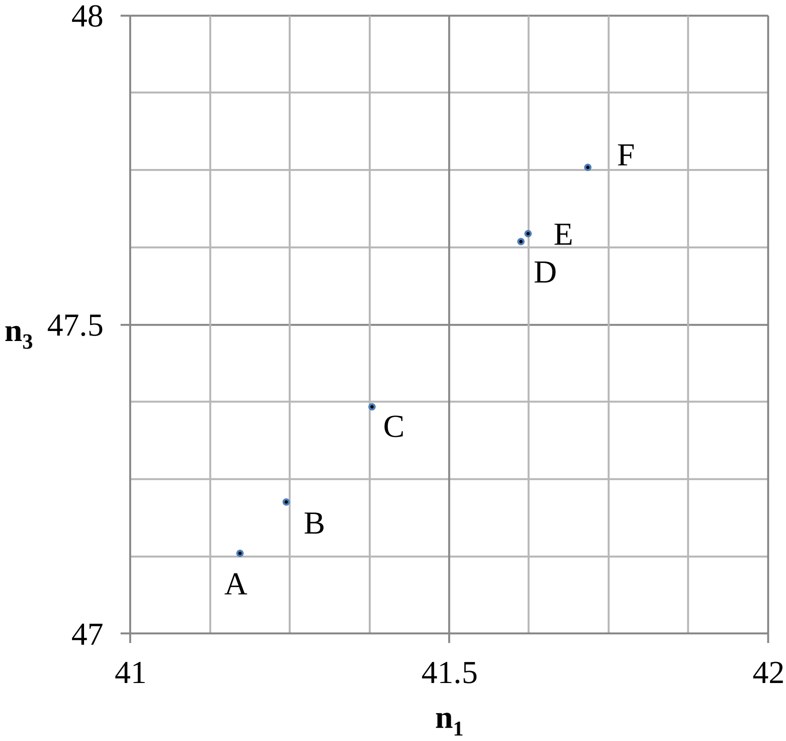


Figure 3: Sub-Planckian mass scales corresponding through (1) to the distance from Alpha Centauri of: the nearest brown dwarfs[5] to Earth; the next nearest red dwarf to Earth after Proxima Centauri; the nearest solitary white dwarf to Earth; and the nearest stars of F-type, G-type and K-type to Earth. Distances stated are from Alpha Centauri B.
A Luhman 16: a binary system of brown dwarfs; distance 1.097 pc
B Sun: G-type; distance 1.350 pc
C Barnard's Star: red dwarf; distance 1.984 pc
D Epsilon Eridani: K-type; distance 3.871 pc
E Procyon A: F-type; distance 3.997 pc
F van Maanen's Star: white dwarf; distance 5.226 pc
Shown on the sub-levels of Sequences 1 and 3.

[4] All stellar distances in this paper are taken from WolframAlpha [10].
[5] Brown dwarfs are not true stars.

4 The Distances of Nearby FGK Stars from Earth

The mass scales corresponding through (1) to the distances from Earth of nearby FGK stars lie on 'higher-order' sub-levels in Sequences 1 and 3, as shown in Figure 4. The Sun (G-type), Alpha Centauri A (G-type), Alpha Centauri B (K-type), Sirius A (A-type) and dwarf stars will be considered later.

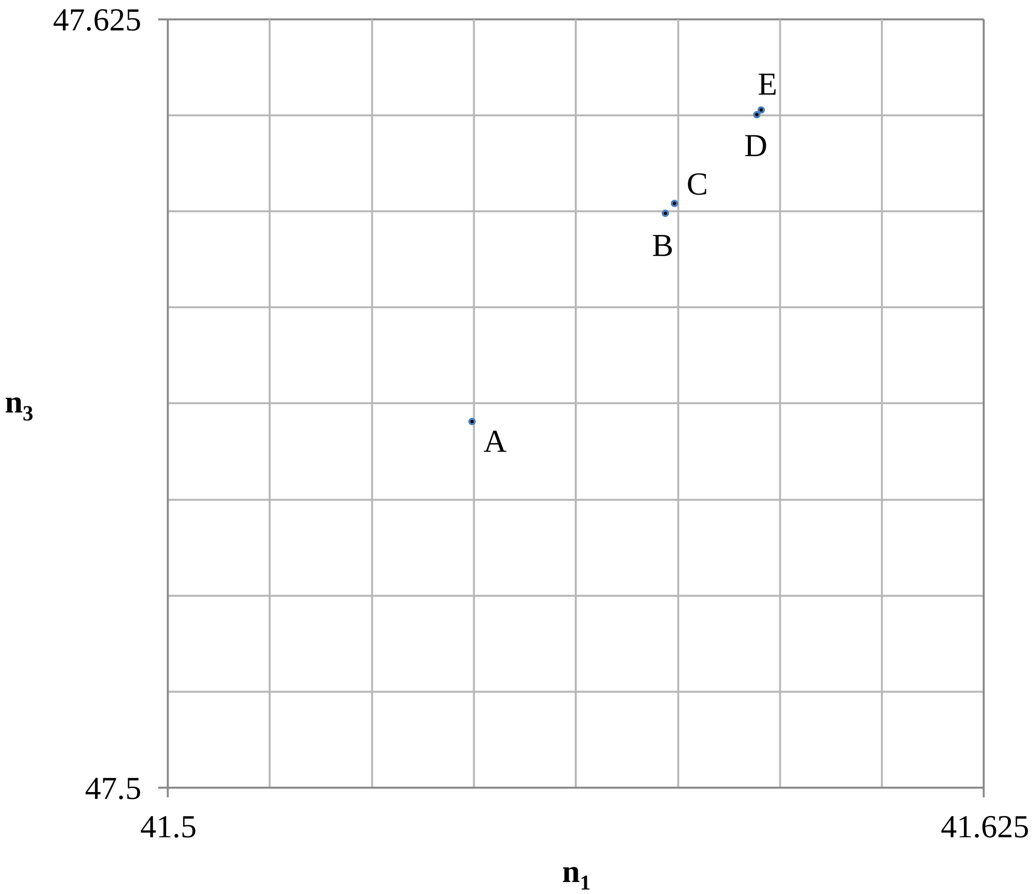


Figure 4: Sub-Planckian mass scales corresponding through (1) to the distance from Earth of all FGK stars other than the Sun and Alpha Centauri A and B within 4 pc.
A Epsilon Eridani: K-type; distance 3.212 pc
B 61 Cygni: a binary system of K-type stars; distance 3.496 pc
C Procyon A: F-type; distance 3.51 pc
D Epsilon Indi: K-type; distance 3.639 pc
E Tau Ceti: G-type; distance 3.646 pc
Shown on the sub-levels of Sequences 1 and 3.

5 The Distance of the Sun from Earth (Earth's Orbital Radius)

One might imagine that the mass scale corresponding through (1) to the semi-major axis of Earth's orbit, which is equal to the mean distance of the Sun from Earth, would lie on a principal level or low-order[6] sub-level in either Sequence 1 or Sequence 3. That it does not do so suggests that this distance corresponds through (1) to a particular sub-Planckian mass scale or sub-atomic length scale, much as the radius of the Sun, which corresponds through (1) to a mass scale closely adjacent to but not on (35, 40) in Sequences 1 and 3, corresponds to the mass of a specific nuclide (^{53}Cr) [1, 2].

[6] Low-order sub-levels are half-levels and quarter-levels.

Earth's semi-major axis[7] $A_\oplus$ = 1.496 x 10^{11} m corresponds through (1) to a mass scale $m_\oplus =$ 5.76 GeV and a length scale, $r_\oplus = 1/m_\oplus$ of 34.3 x 10^{-18} m, which may be the scale of a key parameter in the quantum theory, perhaps the effective quark radius. A quantum/classical equation connects $A_\oplus$ with the mass of the up quark:

$$\frac{A_\oplus}{a_0} \approx \frac{M_{\text{Planck}}}{2m_{\text{u}}} \tag{2}$$

where $a_0 = 0.529$ x 10^{-10} m is the Bohr radius and $m_{\text{u}} = 2.16$ MeV is the central value of the Particle Data Group's evaluation of the up quark mass [12]. From (2) with m_{u} precisely equal to 2.16 MeV, $A_\oplus = 1.495$ x 10^{11} m.

Equation (2) shows a connection between a classical parameter ($A_\oplus$) measured in units of Bohr radius and a quantum parameter (m_{u}) measured in Planck units. In [2] a connection was shown between stellar mass measured in units of inverse-Bohr radius and corresponding atomic radius measured in Planck units.

6 The Distances from Earth of Alpha Centauri and Sirius

The mass scales corresponding through (1) to the distances of the component stars of Alpha Centauri (the third brightest star in the night sky after Sirius and Canopus) and Sirius lie on high-order sub-levels in Sequences 1 and 3, as shown in Figure 5, but the distances themselves occupy lower-order sub-levels, Sirius actually occupying a principal level, in geometric sequences of distance from Earth that ascend from the Planck length with common ratio π (Sequence 1c) and common ratio e (Sequence 3c), as shown in Figure 6.

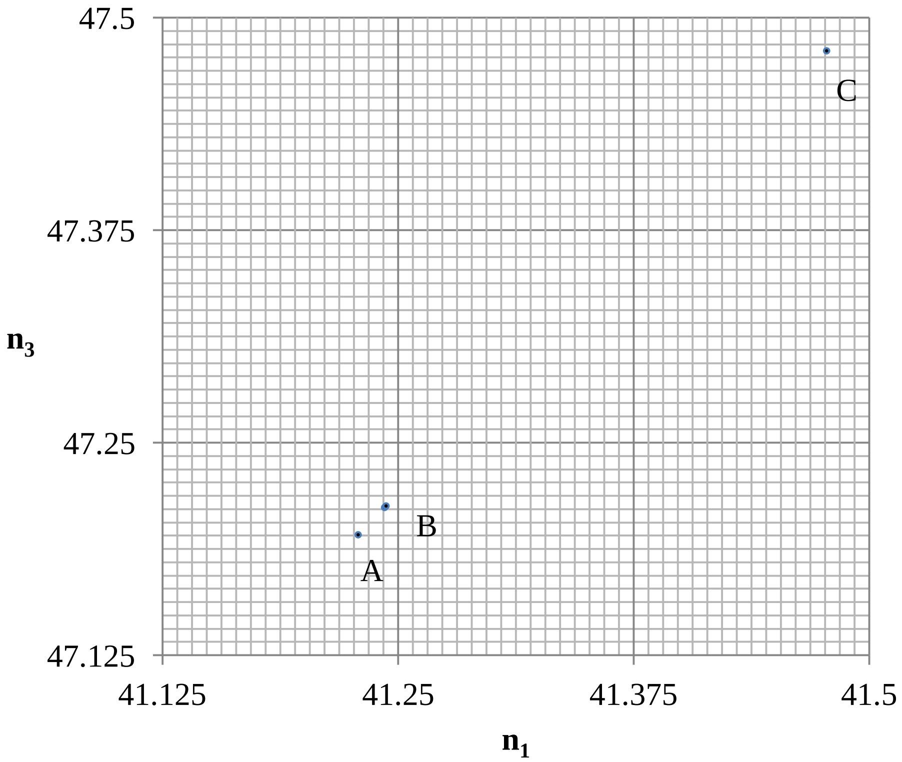


Figure 5: The distances from Earth of:
A Proxima Centauri (1.294 pc)
B Alpha Centauri A and B (1.347 pc and 1.350 pc)
C Sirius A (2.636 pc)
Shown on the sub-levels of Sequences 1 and 3.

[7] All data on the Solar System are taken from the NASA Planetary Factsheets [11].

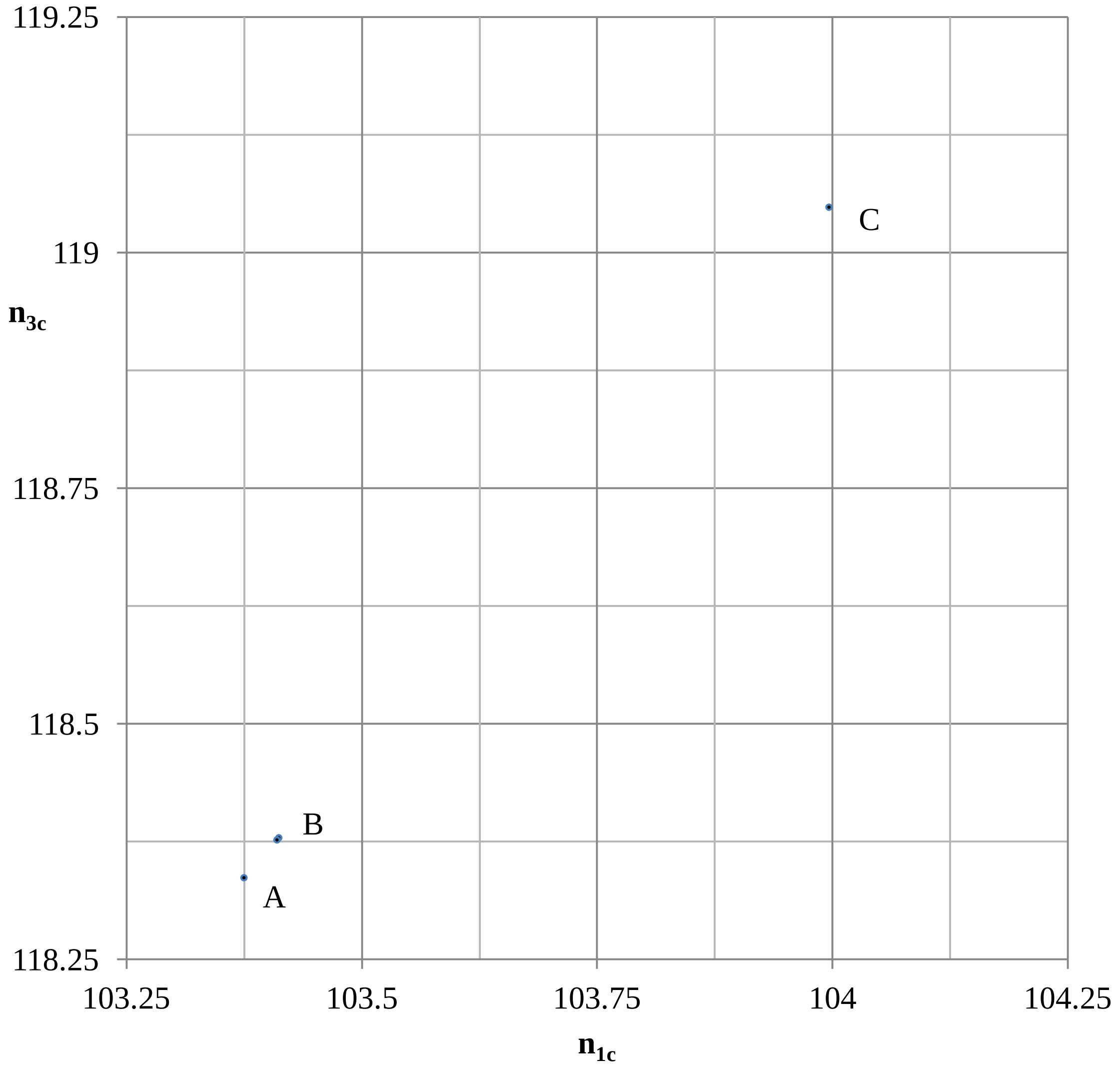


Figure 6: The distances from Earth of:
A Proxima Centauri (1.294 pc)
B Alpha Centauri A and B (1.347 pc and 1.350 pc)
C Sirius A (2.636 pc)
Shown on the levels and sub-levels of Sequences 1c and 3c.

The close association of the distances of the bright Alpha Centauri and Sirius from Earth with lower-order levels in Sequences 1c and 3c than in Sequences 1 and 3 suggests that the quantum world might sometimes emerge from the classical world.

7 The Distances from Earth of Nearby Dwarf Stars

The mass scales corresponding through (1) to the distances from Earth of the neighbouring dwarf stars, other than Proxima Centauri, cannot clearly be assigned to levels or sub-levels in Sequences 1 and 3 but lie on sub-levels in the distance sequences 1c and 3c. The distances from Earth of the nearest stars of each type (brown, red and white) are shown in Sequences 1c and 3c in Figure 7.

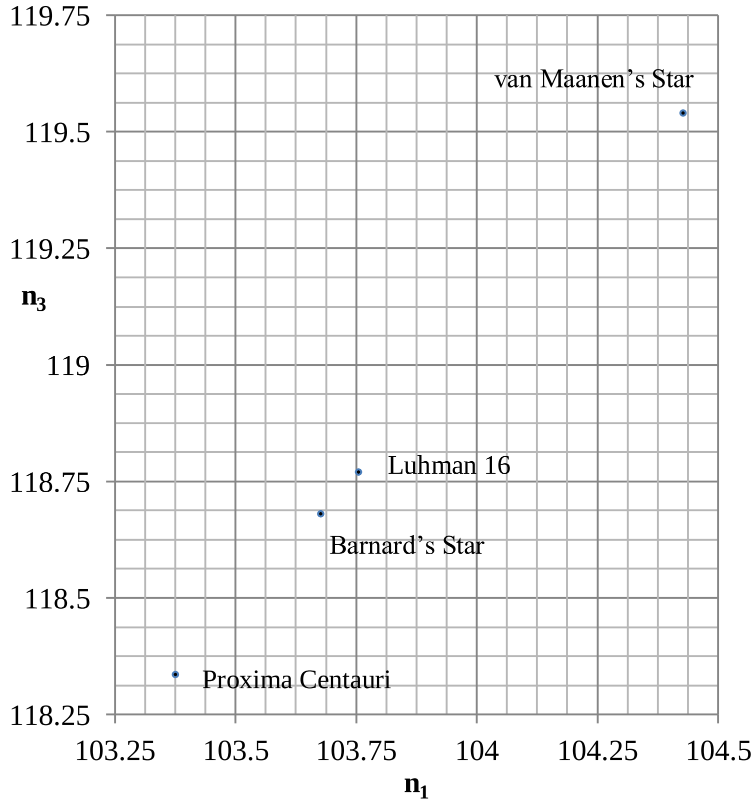


Figure 7: The distances from Earth of the nearest:
Brown dwarfs: Luhman 16, a binary system (distance 1.9980 pc)
Red dwarfs: Proxima Centauri (distance 1.294 pc); Barnard's Star (distance 1.8266 pc)
White dwarf: van Maanen's Star (distance 4.3152 pc)
Shown on the levels and sub-levels of Sequences 1c and 3c.

8 The Distances of Faraway Stars

With increasing distance from both Earth and Alpha Centauri the mass scales corresponding through (1) to the distances from the two locations to the other stars will converge onto the same levels and sub-levels within Sequences 1 and 3. The process of convergence is shown in Figure 8 for four stars at distances of up to 20 pc from Earth.

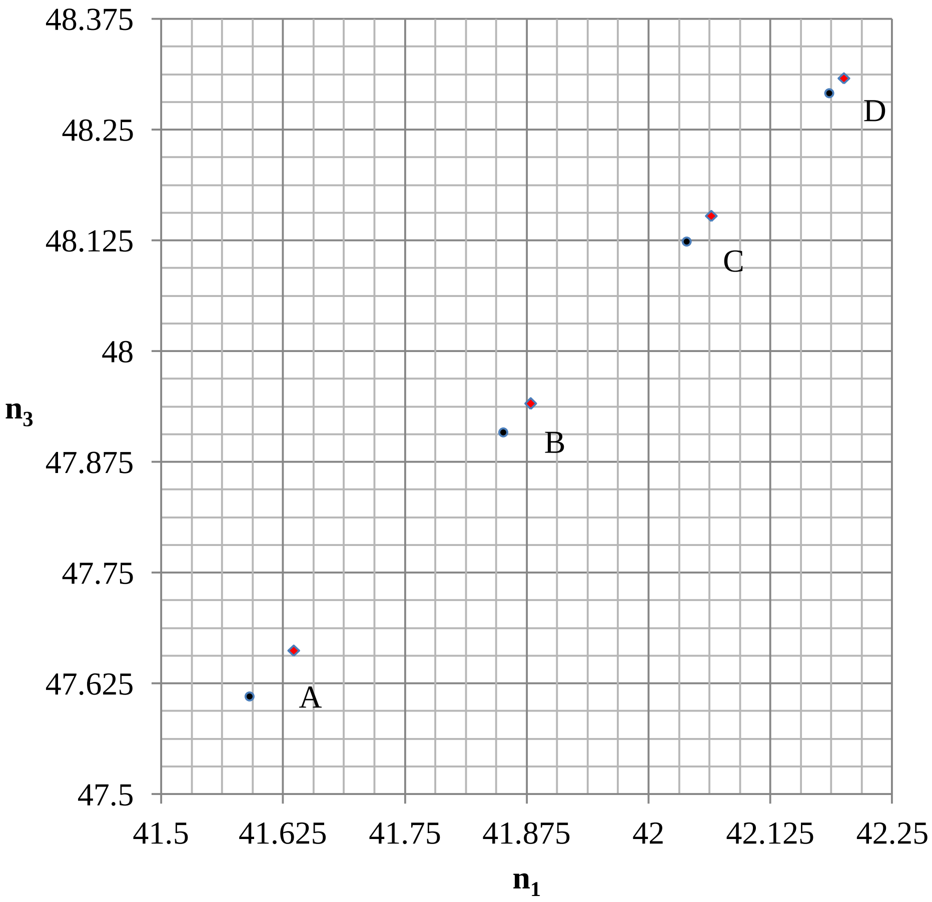


Figure 8: Sub-Planckian mass scales corresponding through (1) to the distances from Earth (black circles) and Alpha Centauri (red diamonds) of:
A Tau Ceti: a G-type star; distance from Earth 3.646 pc; distance from Alpha Centauri 4.151 pc
B Vega: the fifth brightest star as seen in the night sky; distance from Earth 7.68 pc; distance from Alpha Centauri 8.326 pc
C Capella: a system of four stars; the sixth brightest star as seen in the night sky; distance from Earth 13.159 pc; distance from Alpha Centauri 14.15 pc
D Aldebaran: a giant star; bright in the night sky; distance from Earth 20.0 pc; distance from Alpha Centauri 20.87 pc
Shown on the sub-levels of Sequences 1 and 3.

The distances from Earth and Alpha Centauri of the four stars of Figure 8 follow a similar pattern to that above on the levels of Sequences 1c and 3c, as shown in Figure 9.

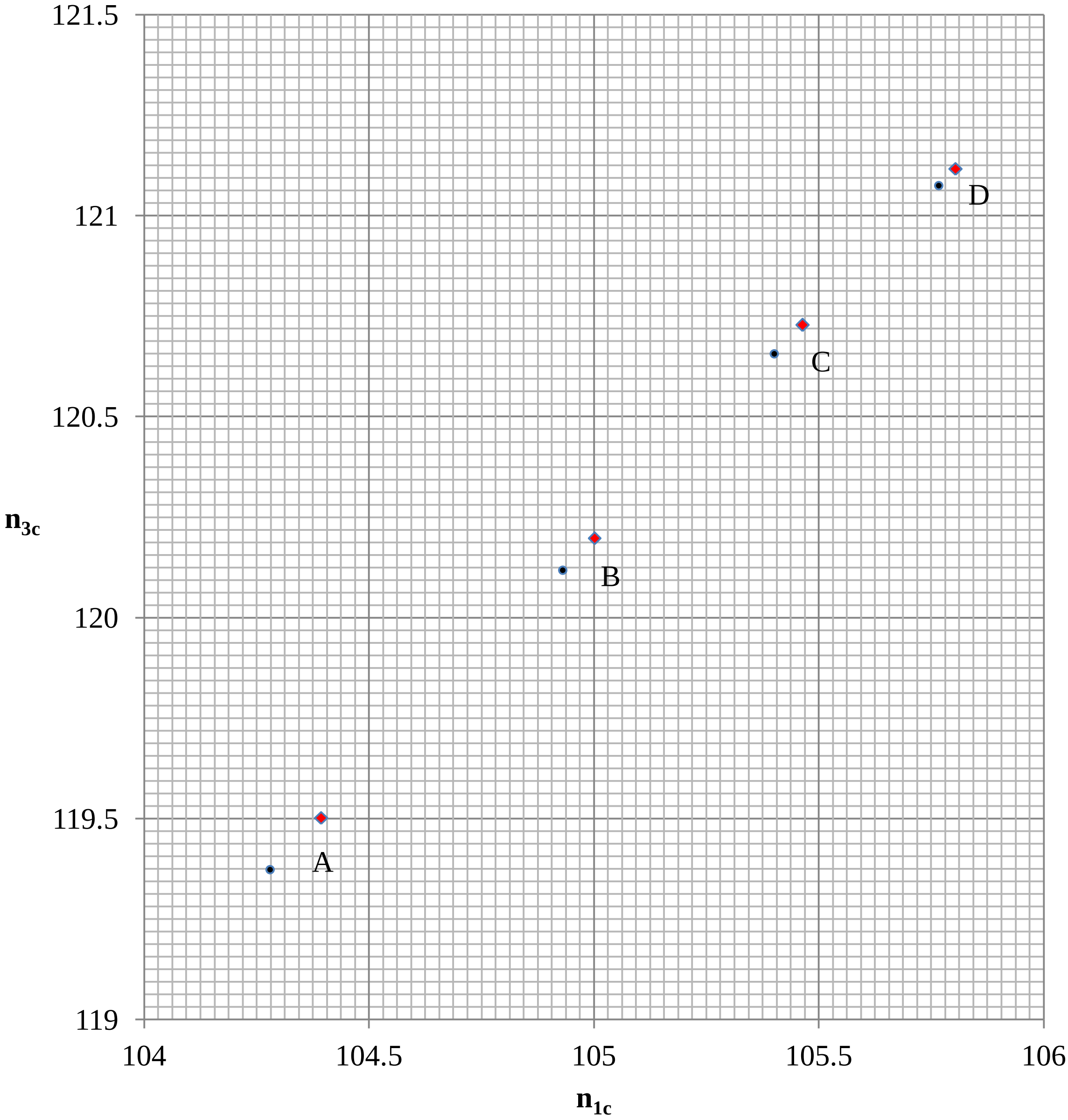


Figure 9: The distances from Earth (black circles) and Alpha Centauri (red diamonds) of:
A Tau Ceti
B Vega
C Capella
D Aldebaran
Shown on the levels and sub-levels of Sequences 1c and 3c.

Note that the distances from Alpha Centauri of the bright Vega and the nearby Tau Ceti lie on a level and a half-level, respectively, in Sequences 1c and 3c (Figure 9) but on higher-order sub-levels in Sequences 1 and 3 (Figure 8).

9 The Distances of Stars, Near and Far, from Earth

The mass scales corresponding through (1) to the distances of bright (as seen in the night sky) stars at all distances from the Earth tend to lie on or close to principal levels and low-order sub-levels in Sequences 1 and 3, as shown in Figure 10.

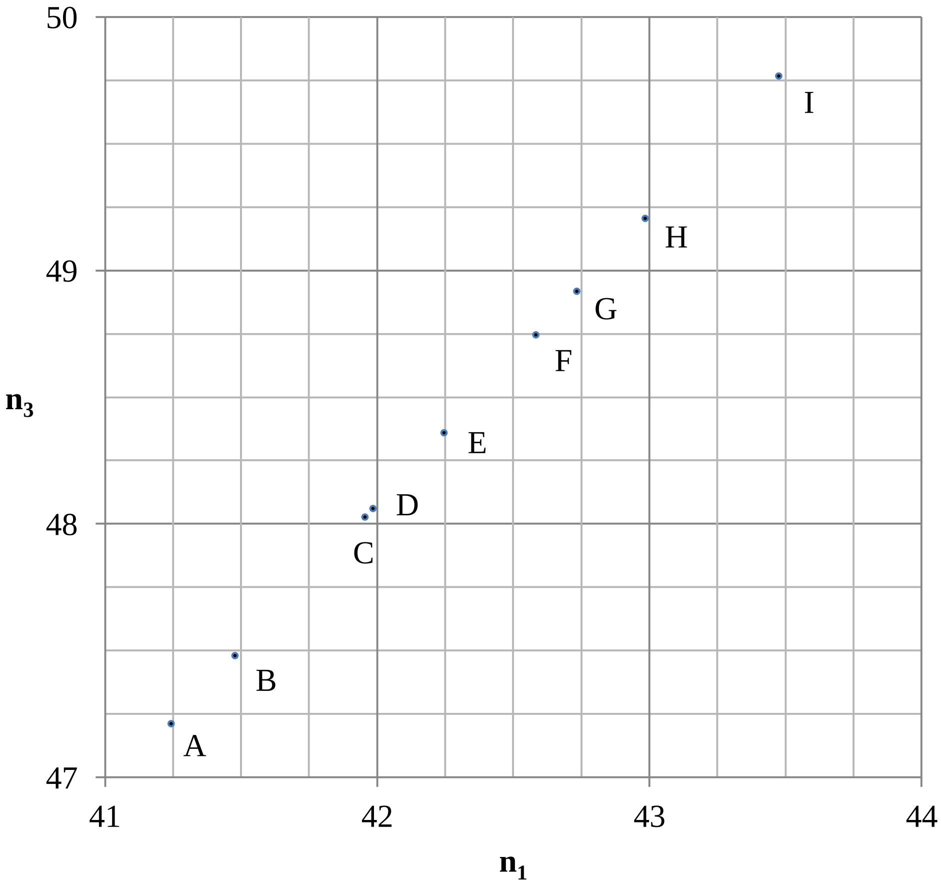


Figure 10: Sub-Planckian mass scales corresponding through (1) to the distance from Earth of:
A Alpha Centauri AB: the third brightest star as seen in the night sky; distance 1.347 pc (A), 1.350 pc (B)
B Sirius: the brightest star as seen in the night sky; distance 2.636 pc
C Pollux: the nearest giant star; bright in the night sky; distance 10.34 pc
D Arcturus: a giant star; the fourth brightest star as seen in the night sky; distance 11.25 pc
E Regulus: a bright system of four stars; distance 23.75 pc
F R Doradus: a giant star; the largest star as seen in the night sky; distance 62.39 pc
G Canopus: the second brightest star as seen in the night sky; distance 95.95 pc
H Betelgeuse: a supergiant star; the tenth brightest star as seen in the night sky; distance 196.9 pc
I Deneb: a highly luminous supergiant star; bright in the night sky; distance 802 pc
Shown on the levels and low-order sub-levels of Sequences 1 and 3.

The distance to Sirius lies on a principal level in Sequences 1c, as was shown in Figure 6, and so too does the distances to Deneb, as shown in Figure 11, while Betelgeuse is demoted from a principal level in Sequence 1 to a second-order sub-level in Sequence 1c.The distances to the other six stars of Figure 10 lie on sub-levels of first-order to fourth-order in Sequences 1c and 3c, as shown in Figures 6 and 12.

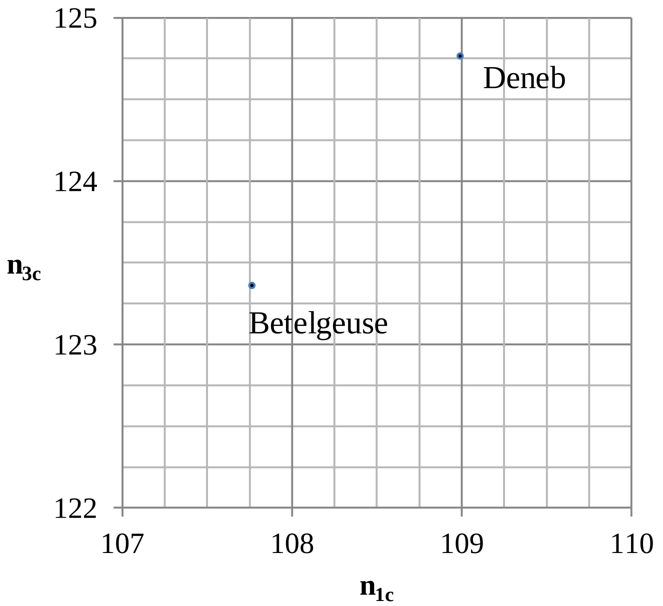


Figure 11: The distances from Earth of Betelgeuse and Deneb
Shown on the levels and sub-levels of Sequences 1c and 3c.

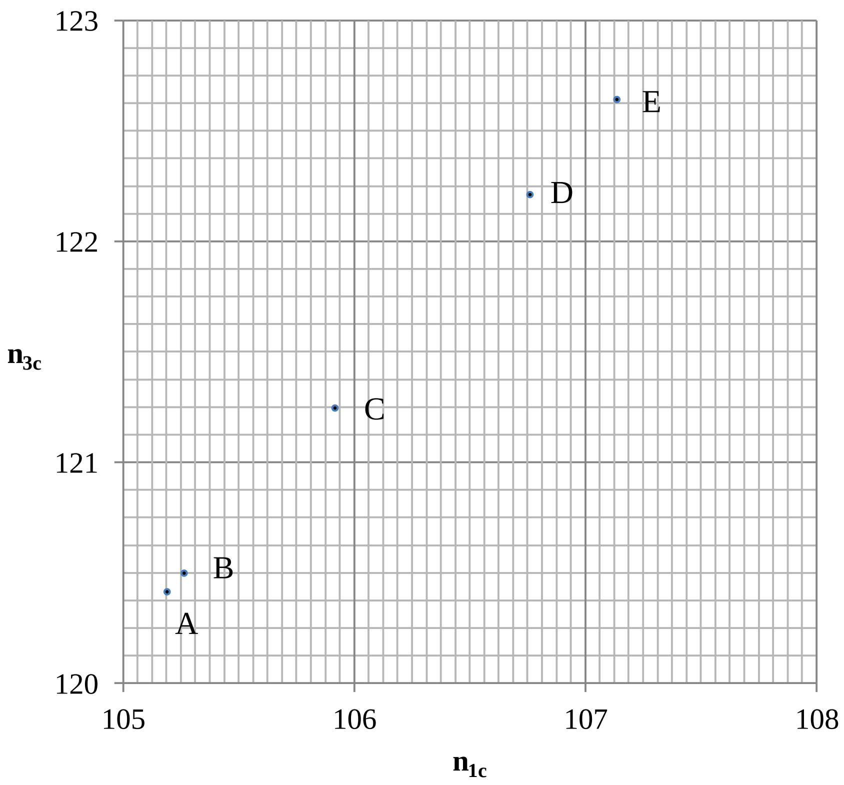


Figure 12: The distances from Earth of:
A Pollux
B Arcturus
C Regulus
D R Doradus
E Canopus
Shown on the levels and sub-levels of Sequences 1c and 3c.

10 The Mean Orbital Radii of the Planets

The mass scales corresponding through (1) to the semi-major axes of the orbits of Mercury, Venus and Mars lie close to sub-levels of the lower orders in Sequences 1 and 3, as shown in Figure 13. The semi-major axes themselves lie close to sub-levels of the lower orders in Sequences 1c and 3c, as shown in Figure 14. The Earth's semi-major axis, which might be related to the scale of a quantum parameter (Section 5), does not occupy a low-order sub-level in Sequences 1c and 3c but seems to be associated with Level 92.5 in Sequence 1c.

Figure 13: Sub-Planckian mass scales corresponding through (1) to the semi-major axes of the orbits of the rocky planets:
Mercury: 5.791×10^{10} m
Venus: 1.082×10^{11} m
Earth: 1.496×10^{11} m
Mars: 2.279×10^{11} m
Shown on the sub-levels of Sequences 1 and 3.

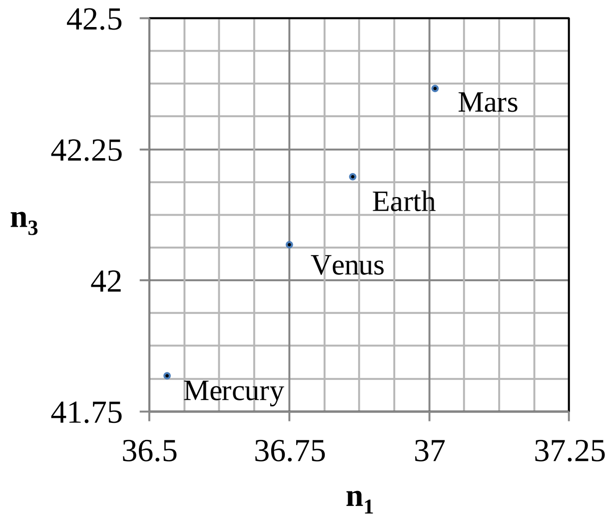
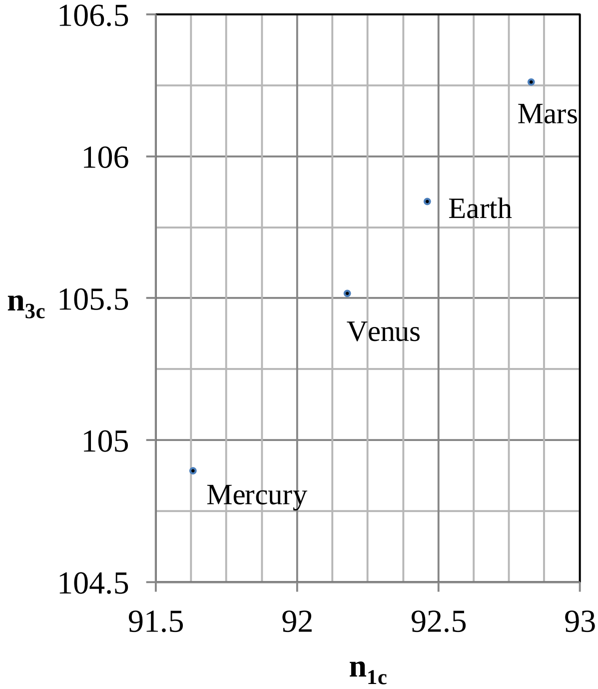


Figure 14: The semi-major axes of the orbits of the rocky planets shown on the sub-levels of Sequences 1c and 3c.



The mass scales corresponding through (1) to the semi-major axes of the orbits of the gas giant planets are shown on the sub-levels of Sequences 1 and 3 in Figure 15. The semi-major axes themselves lie close to principal levels and half-levels in Sequences 1c and 3c, as shown in Figure 16, but actually occupy higher-order sub-levels.

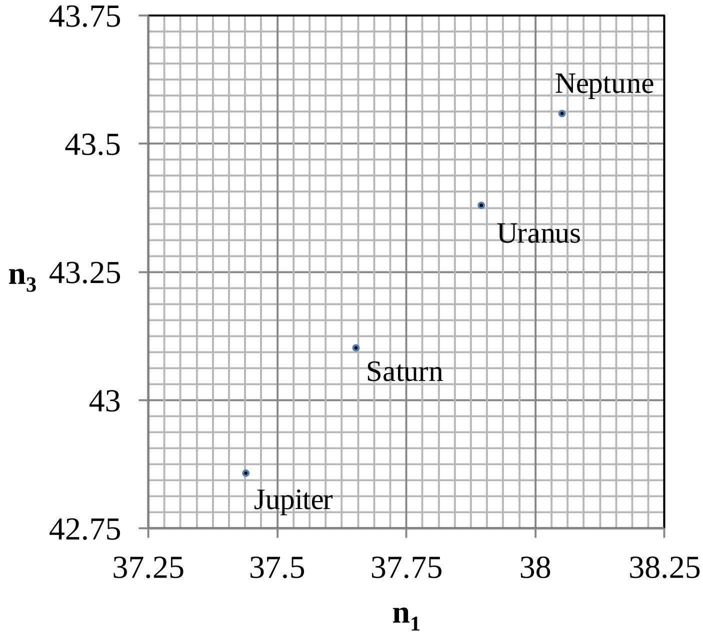


Figure 15: The semi-major axes of the orbits of the gas giant planets:
Jupiter: 7.786×10^{11} m
Saturn: 1.434×10^{12} m
Uranus: 2.873×10^{12} m
Neptune: 4.495×10^{12} m
Shown on the principal levels and half-levels of Sequences 1c and 3c.

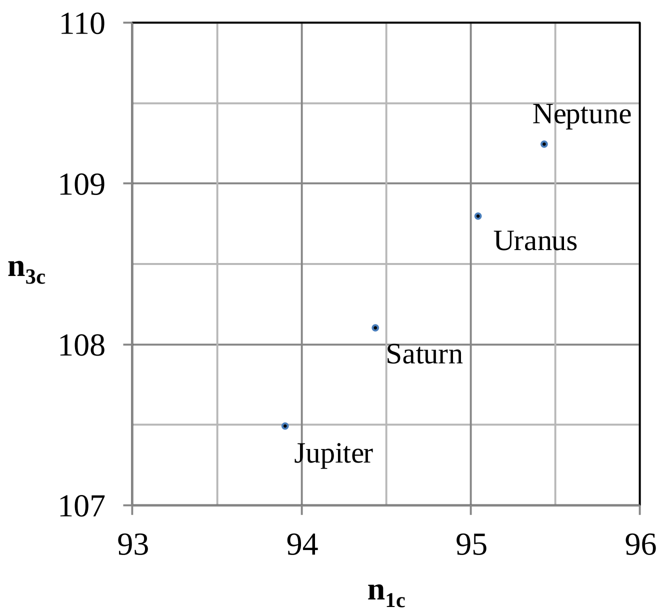


Figure 16: The semi-major axes of the orbits of the gas giant planets shown on the principal levels and half-levels of Sequences 1c and 3c.

11 The Mean Orbital Radii of Planetary Satellites

Although the Moon is receding from the Earth due to tidal forces the mass scale (62.6 GeV) corresponding through (1) to the semi-major axis of the Moon's orbit around Earth lies precisely on a sub-level in Sequence 3, as shown in Figures 17 and 18. The mass scales corresponding through (1) to the semi-major axes of the other major planetary satellites of the Solar System also occupy sub-levels in either Sequence 1 or Sequence 3, as shown in Figures 17 and 18.

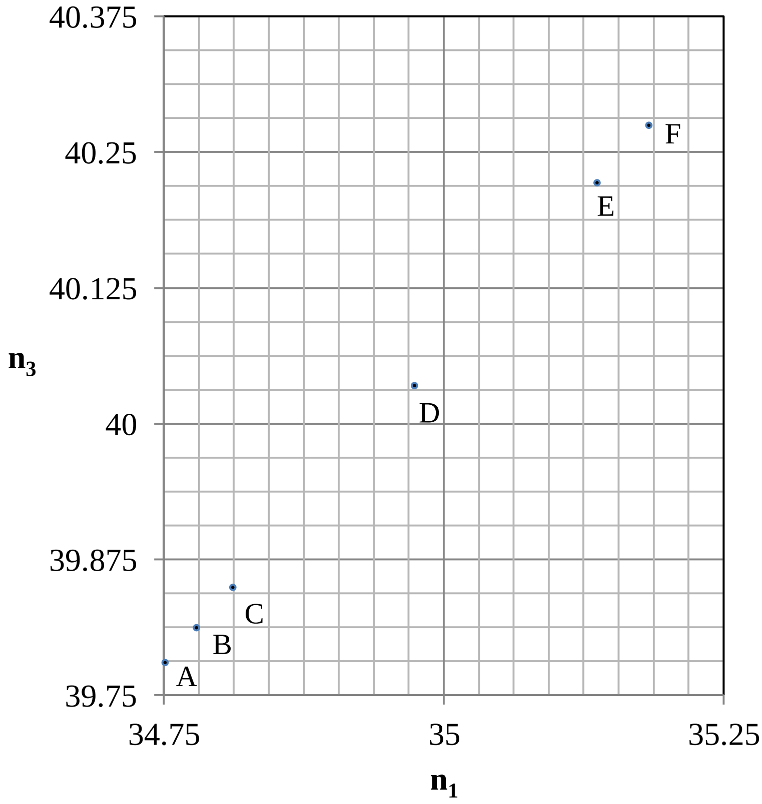


Figure 17: Sub-Planckian mass scales corresponding through (1) to the semi-major axes of the orbits of planetary satellites in the Solar System.
A Triton: the major satellite of Neptune; semi-major axis 354.76 x 10^3 km
B Moon; semi-major axis 384.4 x 10^3 km
C Io: Galilean satellite of Jupiter; JI; semi-major axis 421.8 x 10^3 km
D Europa: Galilean satellite of Jupiter; JII; semi-major axis 671.1 x 10^3 km
E Ganymede: Galilean satellite of Jupiter; JIII; the most massive planetary satellite in the Solar System; semi-major axis 1070.4 x 10^3 km
F Titan: the most massive satellite of Saturn; semi-major axis 1221.83 x 10^3 km
Shown on the sub-levels of Sequences 1 and 3.

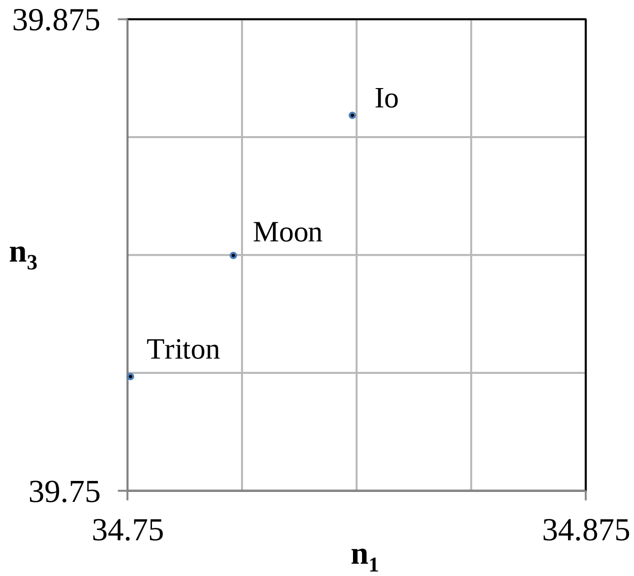


Figure 18: Sub-Planckian mass scales corresponding through (1) to the semi-major axes of the orbits of the Moon, Io and Triton (detail of Figure 17)
Shown on the sub-levels of Sequences 1 and 3.

The semi-major axes of the three planetary satellites of Figure 18 are shown on the sub-levels of Sequences 1c and 3c in Figure 19.

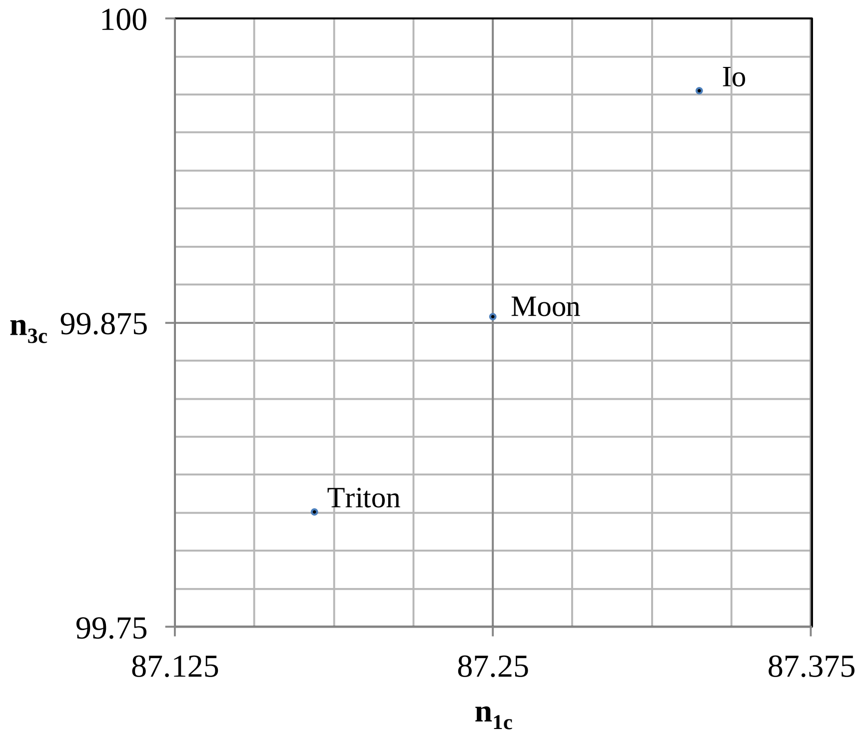


Figure 19: The semi-major axes of the orbits of the Moon, Io and Triton Shown on the sub-levels of Sequences 1c and 3c.

The semi-major axis, mean apogee and mean perigee of the Moon's orbit are shown on the sub-levels of Sequences 1c and 3c in Figure 20.

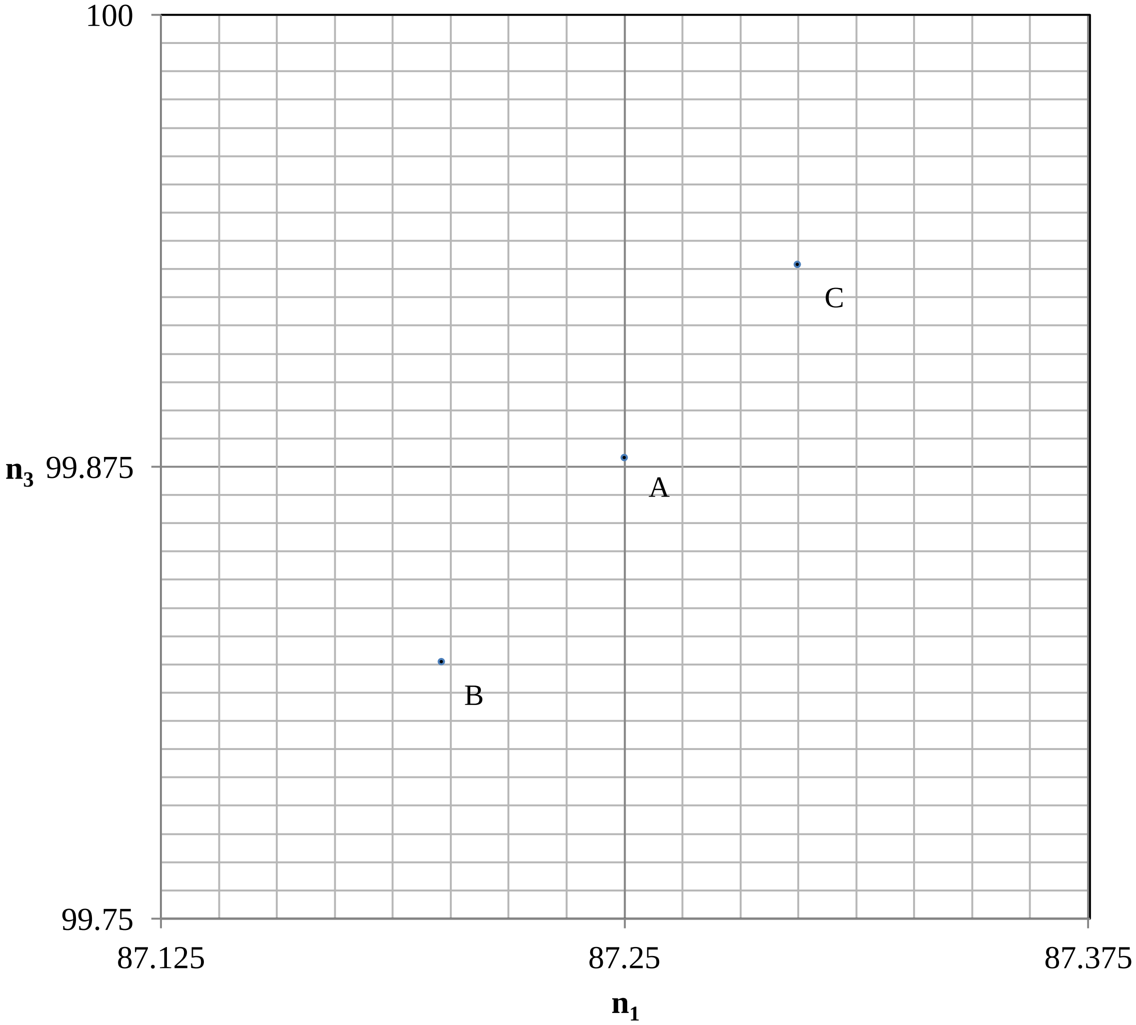


Figure 20: Orbital parameters of the Moon
A Semi-major axis: 384.4 x 10^3 km
B Mean perigee: 363.3 x 10^3 km
C Mean apogee: 405.5 x 10^3 km
Shown on the sub-levels of Sequences 1c and 3c.

12 The Distances of Quasars from Earth

We have seen that the sub-Planckian mass scales corresponding through (1) to the distances measured between Earth and bright stars tend to lie on the levels and low-order sub-levels of Sequences 1 and 3; the distances tend to lie on the levels and low-order sub-levels of Sequences 1c and 3c. Six highly luminous quasars, details of which are shown in Table 1, have therefore been selected for analysis.

Quasar	**Redshift**	**Comments**
3C 454.3	0.859	Blazar; most luminous quasar
TON 618	2.219	Hyperluminous; contains most massive SMBH
APM 08279+5255	3.911	Hyperluminous; gravitationally lensed
PSO J0309+27	6.10	Farthest blazar
QSO J1427+3312	6.12	Farthest radio-loud
ULAS J1342+0928	7.54	Farthest

Table 1: The quasars selected for analysis

We use Ned Wright's cosmology calculator [13] to calculate: the light travel time; the comoving distance from Earth of the quasar; and the age of the universe at redshift z when the quasar light was emitted, in a flat ΛCDM cosmology with the Planck (2018) cosmological parameters:
H_0 = 67.4 km.s^{-1}.Mpc^{-1}, Ω_m = 0.315 and Ω_Λ = 0.685 [14]. In this cosmology the age of the universe is 13.791 Gyr. Each calculated value (times and distance) may be plotted on the levels of Sequences 1c and 3c since Planck units (c = 1) are used.

The light travel time, comoving distance from Earth and age at redshift z = 7.54 of the farthest quasar known (ULAS J1342+0928) are shown on the levels and sub-levels of Sequences 1c and 3c in Figure 21. Each value lies close to a level or low-order sub-level.

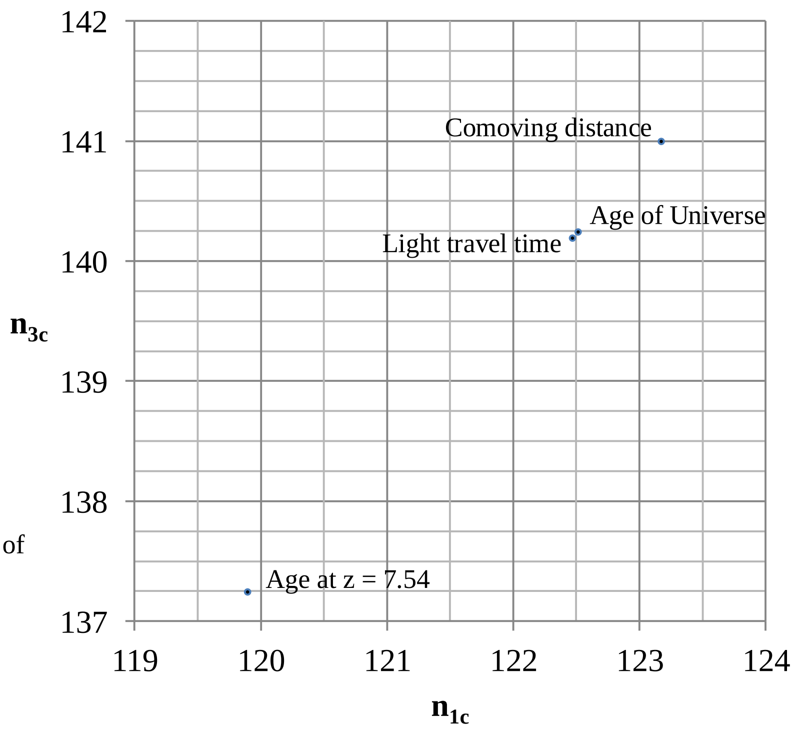


Figure 20: ULAS J1342+0928
Light travel time 13.103 Gyr
Comoving distance 29.309 Glyr
Age at z = 7.54 is 0.688 Gyr
Shown on the levels and sub-levels of Sequences 1c and 3c.

The light travel times at redshift z of the quasars in Table 1 are shown on the levels and sub-levels of Sequences 1c and 3c in Figure 22. Each light travel time lies on either a level or sub-level.

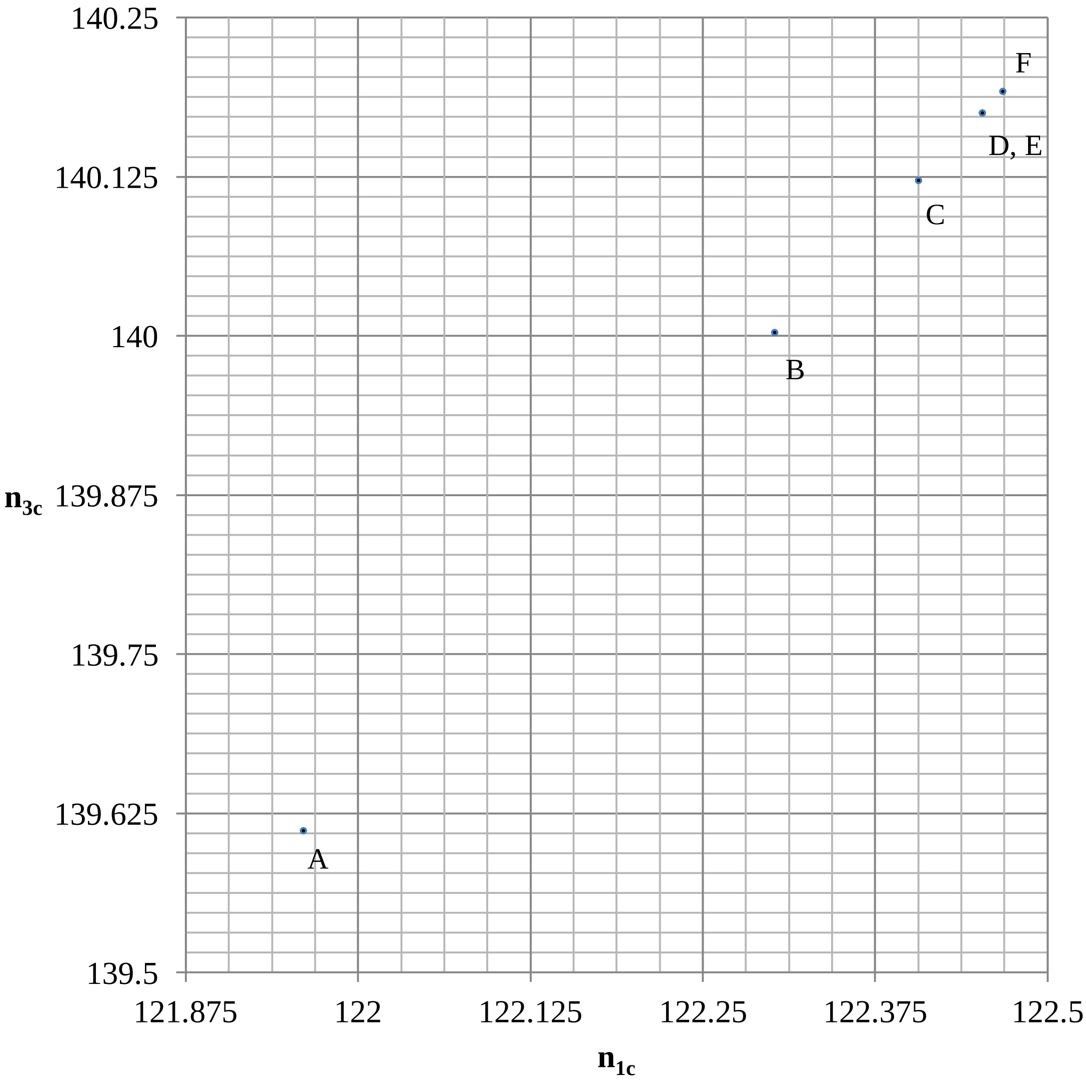


Figure 22: Light travel times of the quasars:
A 3C 454.3; z = 0.859; light travel time 7.332 Gyr
B TON 618; z = 2.219; light travel time 10.843 Gyr
C APM 08279+5277; z = 3.911; light travel time 12.215 Gyr
D PSO J0309+27; z = 6.10; light travel time 12.884 Gyr
E QSO J1427+3312; z = 6.12; light travel time 12.887 Gyr
F ULAS J1342+0928; z = 7.54; light travel time 13.103 Gyr
Shown on the levels and sub-levels of Sequences 1c and 3c.

The comoving distances from Earth at redshift z of the quasars in Table 1 are shown on the levels and sub-levels of Sequences 1c and 3c in Figure 23. Each comoving distance lies on either a level or sub-level. There is a tendency for the high-order sub-levels that are occupied to lie close to a level or low-order sub-level.

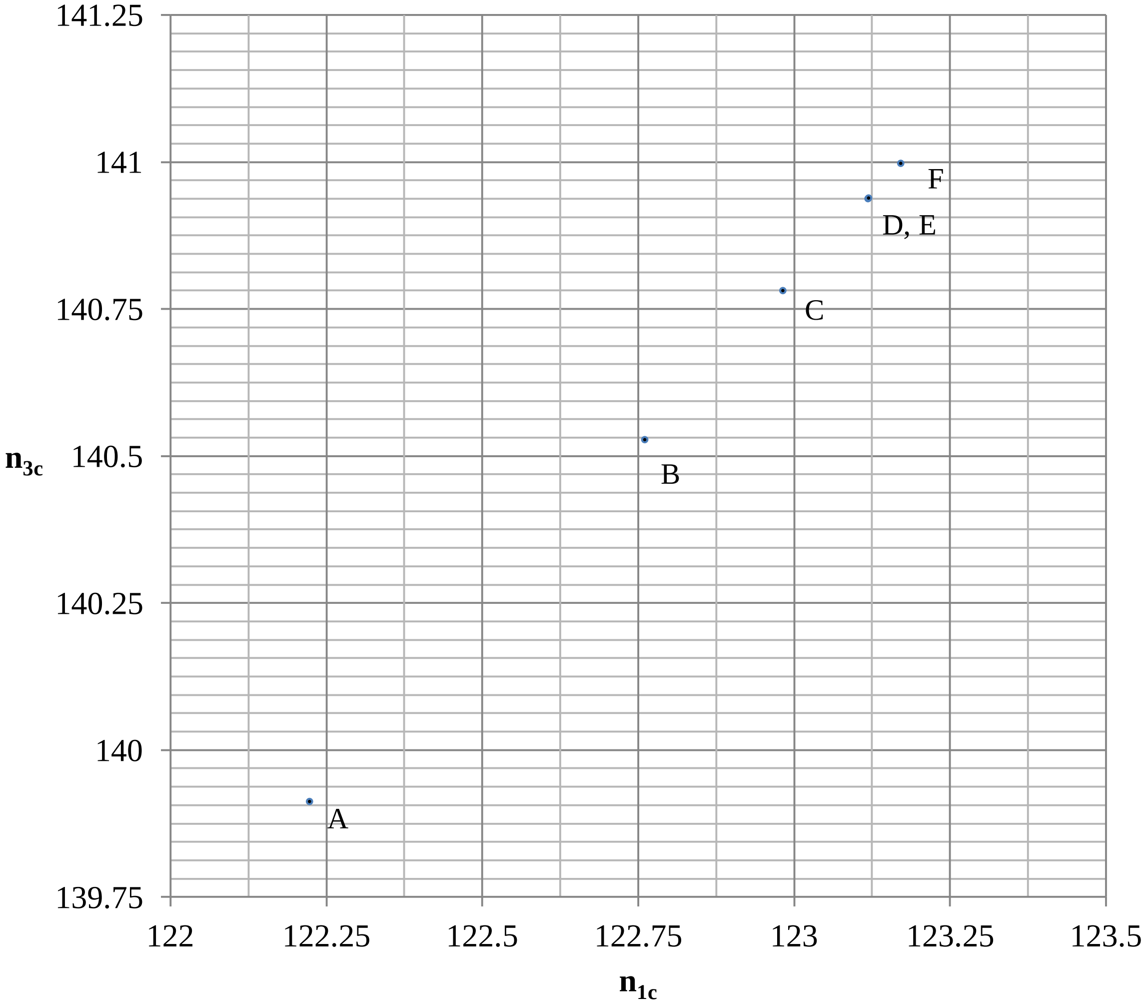


Figure 23: Comoving distances from Earth of the quasars:
A 3C 454.3; z = 0.859; comoving distance 9.901 Glyr
B TON 618; z = 2.219; comoving distance 18.320 Glyr
C APM 08279+5277; z = 3.911; comoving distance 23.703 Glyr
D PSO J0309+27; z = 6.10; comoving distance 27.604 Glyr
E QSO J1427+3312; z = 6.12; comoving distance 27.631 Glyr
F ULAS J1342+0928; z = 7.54; comoving distance 29.309 Glyr
Shown on the levels and sub-levels of Sequences 1c and 3c.

Measurements of the light travel times and comoving distances to the quasars have produced discrete values within Sequences 1c and 3c, with levels and low-order sub-levels preferred locations, which is in line with the findings for stars. Even the age of the universe when the quasar light was emitted tends to lie close to a low-order sub-level, as shown in Figure 24.

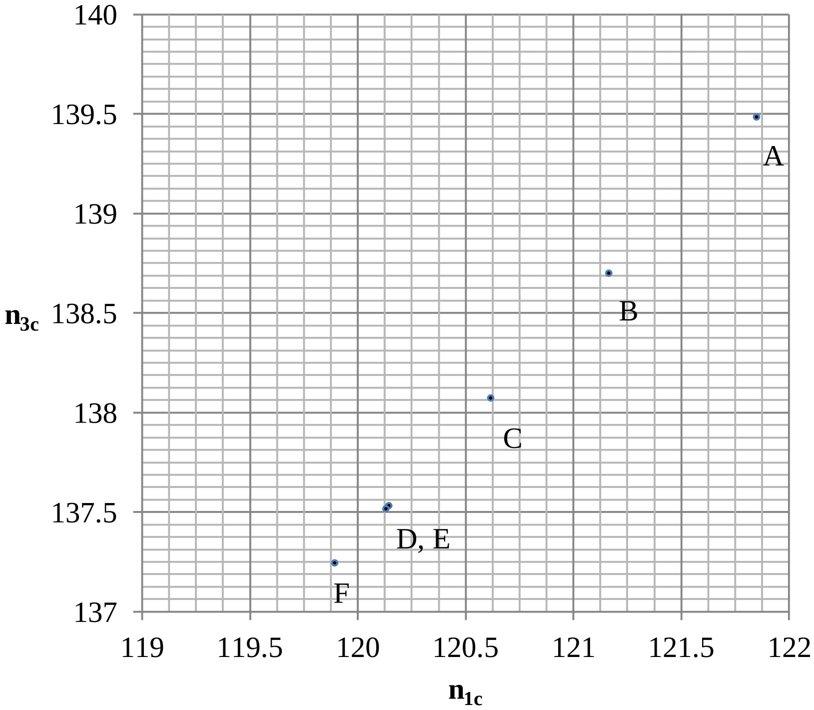


Figure 24: Age of universe when the quasar's light was emitted:
A 3C 454.3; z = 0.859; age 6.459 Gyr
B TON 618; z = 2.219; age 2.948 Gyr
C APM 08279+5277; z = 3.911; age 1.575 Gyr
D PSO J0309+27; z = 6.10; age 0.907 Gyr
E QSO J1427+3312; z = 6.12; age 0.903 Gyr
F ULAS J1342+0928; z = 7.54; age 0.688 Gyr
Shown on the levels and sub-levels of Sequences 1c and 3c.

13 Scale Factors

Consider a quasar at redshift z. In the FLRW metric the (classical) scale factor a when the light from the quasar was emitted is given by $a = 1/(1+z)$. At present $a = 1$. Equation (1) relates 'classical' length and 'quantum' mass scales through an inverse 5/2 power law. We therefore write the quantum scale factor as

$$a_Q = (1+z)^{2/5} \tag{3}$$

and find that at the redshift of each of the six quasars we have considered a_Q takes values that are fractional powers of either π or e as shown on the sub-levels of Figure 25. Low-order sub-levels are evidently preferred: those occupied are of second-order ($\frac{1}{4}$ - levels) to fifth-order ($\frac{1}{32}$ - levels).

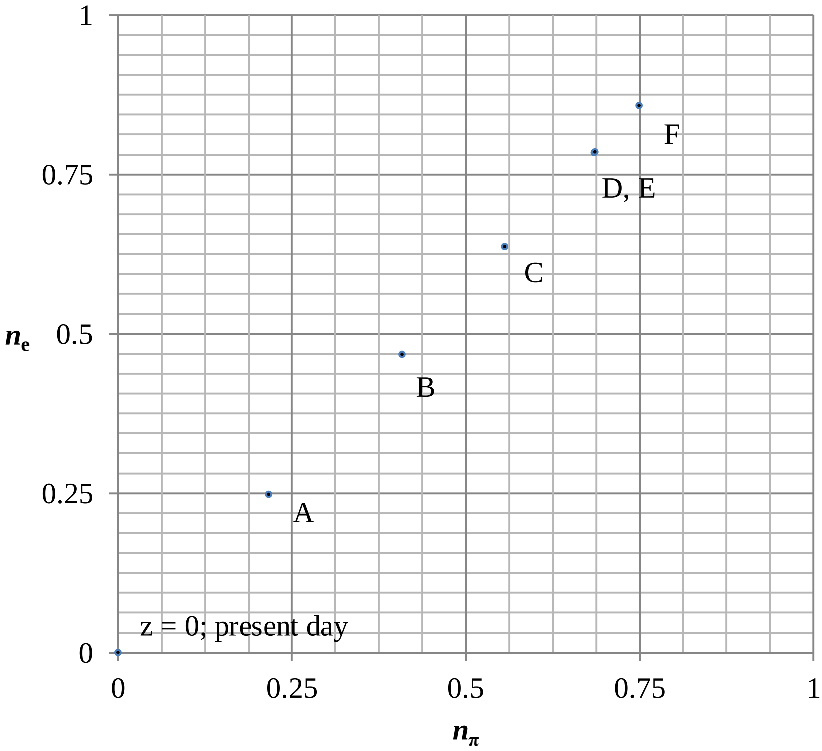


Figure 25: Quantum scale factors a_Q at the redshifts of the quasars:
A 3C 454.3; z = 0.859; a_Q = 1.281
B TON 618; z = 2.219; a_Q = 1.596
C APM 08279+5277; z = 3.911; a_Q = 1.890
D PSO J0309+27; z = 6.10; a_Q = 2.190
E QSO J1427+3312; z = 6.12; a_Q = 2.193
F ULAS J1342+0928; z = 7.54; a_Q = 2.358
Shown as powers, n_π and n_e, of π and e, respectively.

The classical scale factors also lie on the sub-levels: those occupied are of third-order ($\frac{1}{8}$ - levels) to sixth-order ($\frac{1}{64}$ - levels).

The quantum scale factor a_Q at the redshift of each of the three farthest observed galaxies and three farthest observed quasars is shown as powers n_π and n_e of π and e, respectively, in Figure 26: each scale factor lies on a sub-level.

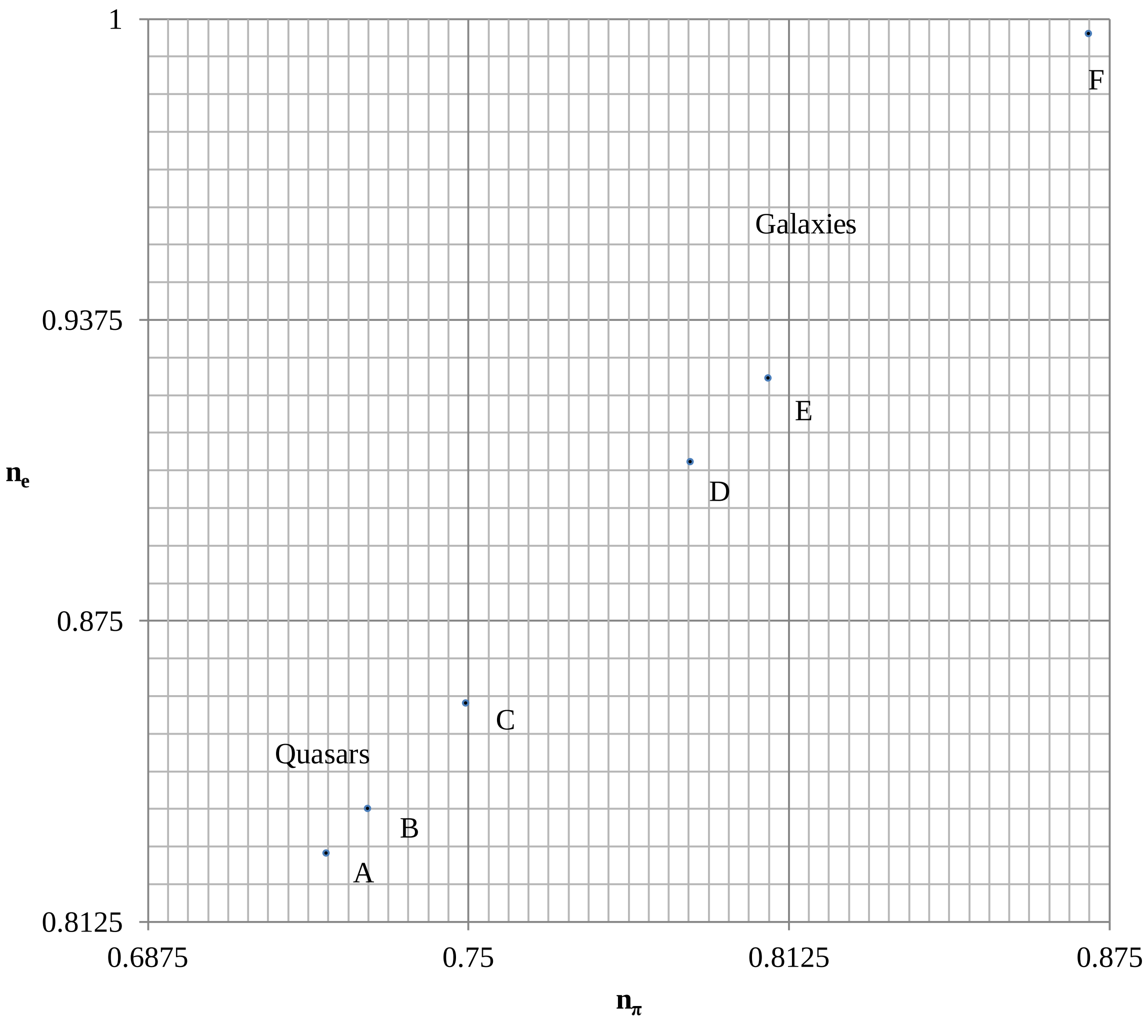


Figure 26: Quantum scale factors a_Q at the redshifts of the farthest observed
quasars:
A CFHQS J2348-3054: z = 6.90; a_Q = 2.286
B ULAS J1120+0641: z = 7.08; a_Q = 2.307
C ULAS J1342+0928: z = 7.54; a_Q = 2.358
galaxies:
D EGSY8p7: z = 8.68; a_Q = 2.479
E MACS1149-JD1: z = 9.11; a_Q = 2.523
F GN-z11: z = 11.09; a_Q = 2.710
Shown as powers, n_π and n_e, of π and e, respectively.

14 Gamma-Ray Bursts

Gamma-ray bursts are very luminous events and as such their distances from Earth are of interest to us here. Four gamma-ray bursts, details of which are shown in Table 2, have been selected for analysis.

Gamma-Ray Burst	Redshift	Comments
GRB 080916C	4.35	Most energetic
GRB 080319B	0.937	Most optically luminous
GRB 030329	0.168	Very bright radio afterglow
GRB 170817A	0.009727	Nearest; gravitational wave event

Table 2: The gamma-ray bursts selected for analysis

The comoving distances from Earth of the gamma-ray bursts lie on the levels and half-levels of Sequences 1c and 3c, as shown in Figure 27. The quantum scale factor a_Q at each value of redshift is shown as powers n_π and n_e of π and e, respectively, in Figures 28 and 29; each scale factor lies on a sub-level.

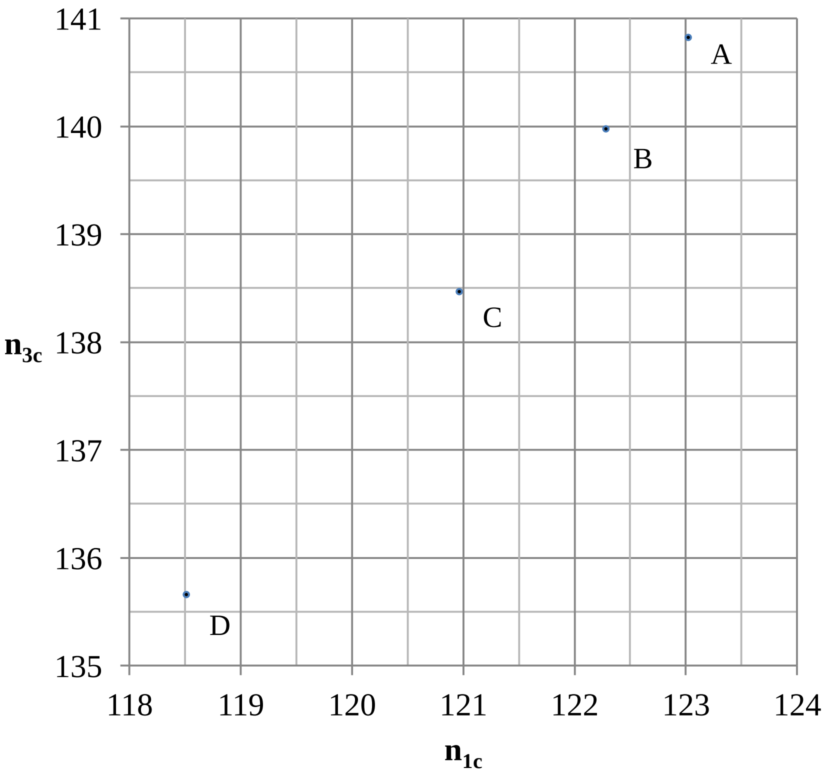


Figure 27: Comoving distances from Earth of the gamma-ray bursts:
A GRB 080916C; z = 4.35; comoving distance 24.672 Glyr
B GRB 080319B; z = 0.937; comoving distance 10.572 Glyr
C GRB 030329; z = 0.168; comoving distance 2.338 Glyr
D GRB 170817A; z = 0.009727; comoving distance 0.141 Glyr
Shown on the levels and sub-levels of Sequences 1c and 3c.

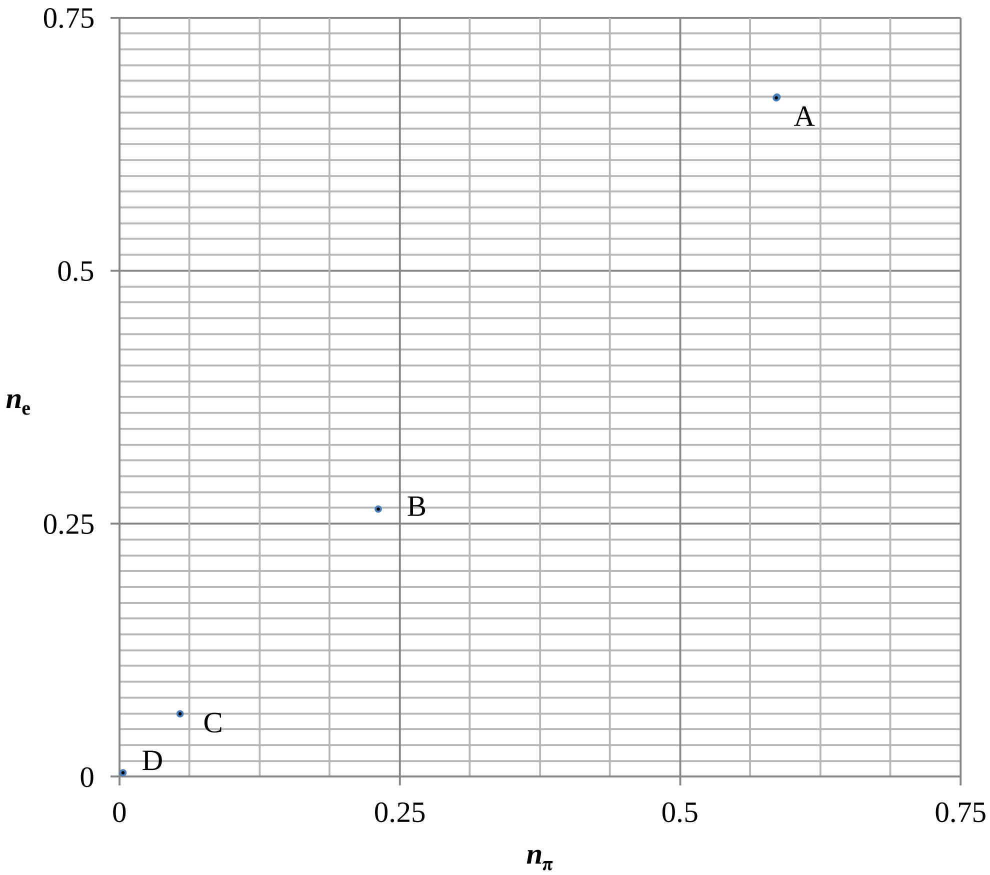


Figure 28: Quantum scale factors a_Q at the redshifts of the gamma-ray bursts:
A GRB 080916C; z = 4.35; a_Q = 1.956
B GRB 080319B; z = 0.937; a_Q = 1.303
C GRB 030329; z = 0.168; a_Q = 1.064
D GRB 170817A; z = 0.009727; a_Q = 1.004
Shown as powers, n_π and n_e, of π and e, respectively.

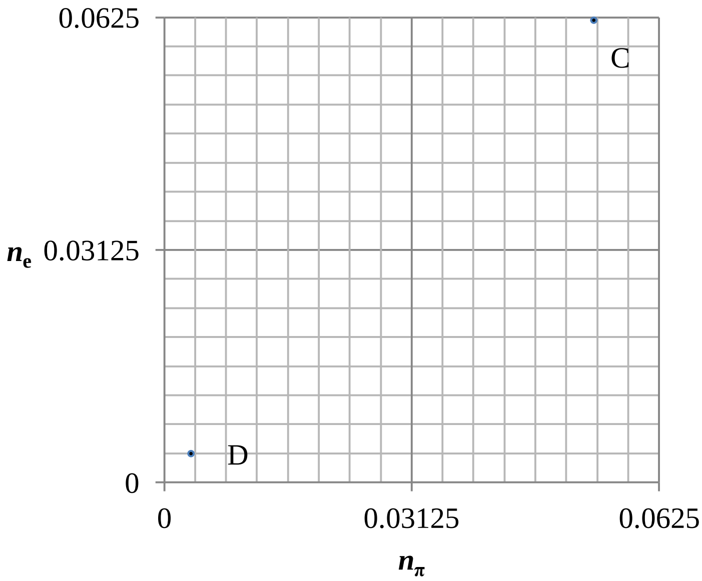


Figure 29: Quantum scale factors a_Q at the redshifts of the gamma-ray bursts:
C GRB 030329
D GRB 170817A
(detail of Figure 28)
Shown as powers, n_π and n_e, of π and e, respectively.

15 Discussion

The distances measured between Earth and all astronomical bodies and objects correspond through the Quantum/Classical connection to mass scales on the levels and sub-levels of Sequences 1 and 3. The distances themselves lie on the levels and sub-levels of Sequences 1c and 3c. Space is discrete in that our measurements of distance, and time, take discrete values. When a distance measurement is made the value is taken from a large number of possible values on a probabilistic basis. For bright stars, principal levels and low-order sub-levels in Sequences 1 and 3 are the most probable locations for the mass scales corresponding through the Quantum/Classical connection to the adopted distance values; principal levels and low-order sub-levels in Sequences 1c and 3c are the most probable locations for the distance values themselves. Exact level occupation in both types of sequence is not possible.

The measurement of distance, and of anything else, perturbs the system constituting the observer and the observed. The greatest degree of perturbation seems to occur when the parameters of *bright* objects are measured. Greater perturbation then means that the values most probably adopted as a result of the measurements are those that occupy the lower order levels of the sequences. Coincident low-order levels are the preferred locations for the brightest of objects. We can now see a reason why the parameters of the supremely apparently-bright Sun take such particular values: for example, its radius $R_{\odot} \approx \mathrm{e}^{100}\, l_{\mathrm{Planck}}$, its rotation period $P_{\odot} \approx \pi^{100}\, t_{\mathrm{Planck}}$, its central temperature $T_{\odot} \approx \pi^{-50}\, T_{\mathrm{Planck}}$ and its spin angular momentum $S_{\odot} \approx 2^{250}\, \hbar$ [16].

In time, measurements of distance will produce new values in response to the measurement process. The mass scales corresponding through the Quantum/Classical connection to the distances of the nearby stars will move off the sub-levels they currently occupy onto, probably, higher-order sub-levels.

During the preparation of this paper several experiments were carried out to ascertain what effect the act of measurement has on the values taken by parameters closer to home. The findings of those experiments are described in The Act of Measurement II: Closer to Home [17].

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