MonkeyGod

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This document gives the equations used in my program **MonkeyGod** that can be executed from <http://spot.colorado.edu/~vstenger/Cosmo/monkey.html>. Also included is the section of Chapter 8 of my 1995 book *The Unconscious Quantum: Metaphysics in Modern Physics and Cosmology* (Amherst NY: Prometheus Books) in which MonkeyGod is described and results presented.

The four adjustable parameters of the program are:

α the fine structure constant $e^2/\hbar c$
α_s the strong interaction strength at low energy
m_e the mass of the electron
m_p the mass of the proton

The constants $\hbar$, c, G, k_B are not considered parameters. They just define the units you choose to use and can all be set to unity with no change in the physics (Planck units).

Only "low energy" physics is used. Effects of the weak interactions, for example, are not included.

The following are all textbook equations:

Bohr radius:

$$r_B = \hbar (\alpha\ m_e c)^{-1}$$

Ground state of hydrogen atom:

$$E_B = \alpha^2 m_e c^2/2$$

Radius of nucleon:

$r_N = \hbar (\alpha_s m_p c)^{-1}$

Ground state energy of a nucleon:

$E_N = \alpha_s^2 m_p c^2 / 2$

Dimensionless gravitational strength:

$\alpha_G = G m_p^2 (\hbar c)^{-1}$

The following is from E.E. Salpeter, *Astrophys, J.* **140**, 796 (1964). See also B.J. Carr and M.J. Rees, "The anthropic principle and the structure of the physical world," *Nature* **278**, 606-612 (1979):

Lifetime of a main sequence star:

$t_s = (\alpha^2 / \alpha_G) (m_p / m_e)^2 \hbar (m_p c^2)^{-1}$

The following are from W.H. Press and A.P. Lightman, "Dependence of macrophysical phenomena on the values of the fundamental constants," *Phil. Trans. R. Soc. Lond.* **A 310**, 323-336 (1983):

Maximum mass of cold, degenerate star (Chandrasekhar mass):

$M_C = \alpha_G^{-3/2} m_p$

Minimum mass and radius of planet:

$M = m_p (\alpha / \alpha_G)^{3/2} (m_e / m_p)^{3/4}$

$R = r_B (\alpha / \alpha_G)^{1/2} (m_e / m_p)^{1/4}$

Length of a "universal day":

$T_{day} = 2\pi (2)^{3/2} r_B / c (m_p / m_e)^{1/2} (\alpha \alpha_G)^{-1/2}$

Year for a habitable planet:

$T_{year} = 0.2\, r_B / c\, (m_p / m_e)^2\, \alpha^{-13/2}\, \alpha_G^{-1/8}$

In the above two cases, in the program currently on the Web but not in my book or in the results given below, I have multiplied each by a factor that gives 1 day and 1 year respectively for the parameters of our universe.

The following are from John D. Barrow and Frank J. Tipler. *The Anthropic Cosmological Principle.* Oxford: Oxford University Press (1986):

$N_1 = (\alpha / \alpha_G)\, (m_p / m_e)$

$N_2 = \alpha\, \alpha_s\, (m_p / m_e)\, N_1$

The following is the section from Chapter 8 of my book *The Unconscious Quantum: Metaphysics in Modern Physics and Cosmology* in which MonkeyGod is described:

An Infinity of Universes

One way to "sensibly" explain the anthropic coincidences within the framework of existing knowledge of physics and cosmology is to view our universe as just one of a very large number of mini-universes in an infinite super-universe.[1] Each mini-universe has a different set of constants and physical laws. Some might have life of different form than us, others might have no life at all or something even more complex that we cannot even imagine. Obviously we are in one of those universes with life.

This multi-universe picture should not be confused with the many-worlds interpretation of quantum mechanics discussed in earlier chapters. They are not at all related.

Several commentators have argued that a many-universes cosmology violates Occam's razor. I beg to differ. The entities that the law of parsimony forbids us from multiplying beyond necessity are theoretical hypotheses, not universes. Though the atomic theory multiplied the number of bodies we consider in solving a thermodynamic problem by 10^{24} or so per gram, it did not violate Occam's razor. It provided for a simpler, more powerful exposition of the rules that were obeyed by thermodynamic systems.

Similarly, if many universes cosmology provides an explanation for the origin of our universe that does not require the highly non-parsimonious introduction of a supernatural element that has heretofore not been required to explain any observations, then that explanation is the more economical.

An infinity of random universes is suggested by the modern inflationary model of the early universe described above.[2] Recall that a quantum fluctuation can produce a tiny, empty region of curved space that will exponentially expand, increasing its energy sufficiently in the process to produce energy equivalent to all the mass of the universe in a mere 10^{-42} second.

Cosmologist Andre Linde has proposed that a spacetime "foam" empty of matter and radiation will experience local quantum fluctuations in curvature, forming bubbles of "false vacuum" that individually inflate, as described above, into mini-universes with random characteristics.[3] In this view, our universe is one of those expanding bubbles, the product of a single monkey banging away at the keys of a single word processor.

I thought it might be fun (and instructive) to see what some of these universes might look like. From the values of just four fundamental constants, the physical properties of matter from the dimensions of atoms to the length of the day and year can be estimated. Two of these constants are the strengths of the electromagnetic and strong nuclear interactions. The other two are the masses of the electron and proton.

This is not, of course the whole story. Many more constants are needed to fill in the details of our universe. And other universes might have different physical laws. I have no idea what those laws might be; all I know is this universe and its laws. Varying the constants that go into our familiar equations still will give many universes that do not look a bit like ours. The gross properties of our universe are determined by these four constants, and we can vary them to see what a universe might grossly look like with different values of these constants.

I have written a program, *MonkeyGod,* listed in the Appendix to this chapter, which the reader is welcome to use. Try your own hand at generating universes. Just choose different values of the four constants and see what happens. While these are really only "toy" universes, the exercise illustrates that there could be many ways to produce a universe old enough to have some form of life.

To illustrate this important point, Fig. 8.1 shows a scatter plot of N_2 vs. N_1 for 100 universes in which the values of the four parameters were generated randomly from a range five orders of magnitude above and five orders of magnitude below their values in our universe, that is, over a total range of ten orders of magnitude. We see that, over this range of parameter variation, N_1 is at least 10^{33} and N_2 at least 10^{20} in all cases. That is, both are still very large numbers. Although many pairs do not lie exactly on the diagonal $N_1 = N_2$, the coincidence between these two quantities is not so rare.

The distribution of stellar lifetimes for these same 100 universes is shown in Fig. 8.2. While a few are low, most are clearly high enough to allow time for stellar evolution and heavy element nucleosynthesis. I think it is safe to conclude that the conditions for the appearance of a universe with life are not so improbable as the those authors, enamored by the anthropic principle, would have you think.

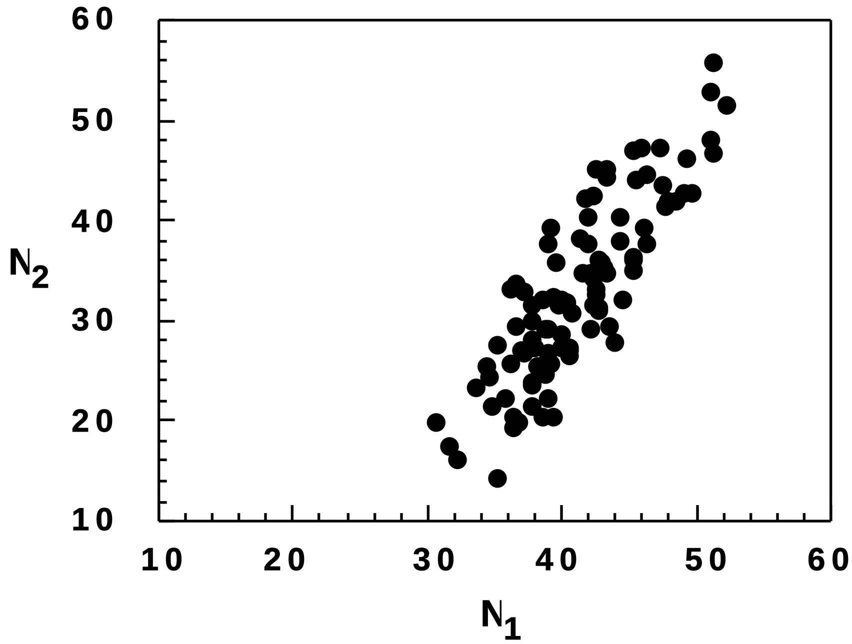

Fig. 8.1. Scatter plot of N_2 vs. N_1 for 100 universes in which the values of the four parameters were generated randomly from a range five orders of magnitude above and five orders of magnitude below their values in our universe. We see that, over this range of parameter variation, N_1 is at least 10^{33} and N_2 at least 10^{20} in all cases.

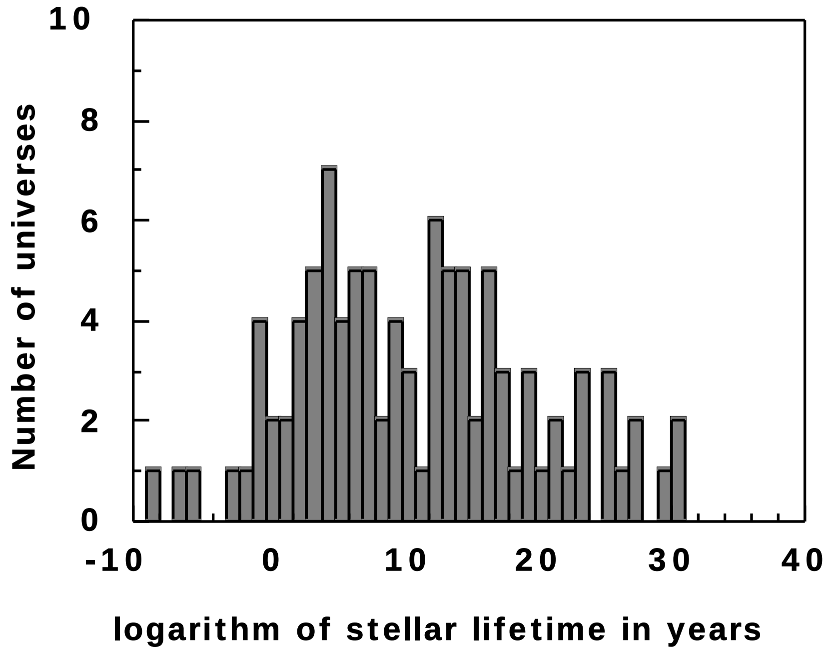

Fig. 8.2. Distribution of stellar lifetimes for the 100 random universes described in the text.

Appendix:

The program computes the following quantities: the (Bohr) radius and binding energy of the hydrogen atom, the radius of a nucleon (proton or neutron) and its binding energy in a nucleus, the lifetime and mass of a typical star, and the radius, length of day, and length of year for a typical planet.[4] It also computes the numbers N_1 and N_2 mentioned in the main chapter text.

The lifetime and mass of a typical main sequence star sets the scale for the age of a universe populated, in the vicinity of at least once such star, by complex material systems assembled from chemical elements produced in the stars themselves. Thus we can easily determine what a universe will look like if it possesses values of the basic parameters that differ from our own.

The following shows some typical outputs. The strength of the electromagnetic force is given by **alpha** (for greater familiarity, 1/alpha is printed out). The strength of the strong nuclear force is **alpha_s**. Both of these quantities are dimensionless (that is, they have no units). The electron mass is indicated by **me**, the proton mass by **mp**. Both are in kilograms. In the tables below, I have rounded off most of the results since only orders of magnitude are really significant in a calculation of this type. The abbreviation for the units in the answers are standard in any physics text.

First we have the universe we know and love:

1/alpha	alpha_s	mp (kg)	me (kg)
137	.2	1.67e-27	9.11e-31

Bohr radius	=	5.29e-9	cm
Hydrogen binding energy	=	13.6	eV
Nucleon radius	=	1.05e-13	cm
Nucleon binding energy	=	18.76	MeV
Minimum stellar lifetime	=	6.77e+8	yr
Mass of star	=	3.69e+30	kg
Radius of planet	=	5700.	km
Mass of planet	=	5.e+23	kg
Length of day	=	6	hr
Length of year	=	6	days
N1	=	2.2e+39	
N2	=	6.0e+39	

The fact that the day is shown as 6 hours and the year as 6 days should not worry the reader. Only orders of magnitude should be considered. Thus a day on a typical planet is of the order of 10 hours and a year is of the order of 10 days. Our planet earth is a bit atypical, with a year of the order of 100 days, but that’s only an order of magnitude higher, which is pretty good for these calculations.

The next example has all the constants the same except I have set the proton mass equal to the Planck mass:

1/alpha	alpha_s	mp (kg)	me (kg)
137	.2	2.e-8	9.11e-31

Bohr radius	=	5.29e-9	cm
Hydrogen binding energy	=	13.6	eV
Nucleon radius	=	8.79e-33	cm
Nucleon binding energy	=	2.2e+20	MeV
Minimum stellar lifetime	=	6e-1	yr
Mass of star	=	2.6e-8	kg
Radius of planet	=	8.e-21	km
Mass of planet	=	1.7e-29	kg
Length of day	=	1.6e-9	hr
Length of year	=	1.5e+34	days
N1	=	1.8e+20	
N2	=	6.0e+39	

Note how the age of a main sequence star is a fraction of a second, obviously far to small to allow time for the cooking of the heavy elements needed for life. This illustrates that a huge difference between the proton mass and the Planck mass is needed for a long-lived universe.

The final example has all the parameters differing greatly from their values in our universe. Yet a viable, though strange, universe results:

1/alpha	alpha_s	mp (kg)	me (kg)
1000000	.001	1.e-30	1.e-35

Bohr radius	=	3.5	cm
Hydrogen binding energy	=	2.8e-12	eV
Nucleon radius	=	3.5e-8	cm
Nucleon binding energy	=	2.8e-7	MeV
Minimum stellar lifetime	=	2e+14	yr
Mass of star	=	1e+37	kg
Radius of planet	=	3e+13	km
Mass of planet	=	1e+23	kg
Length of day	=	4e+15	hr
Length of year	=	1e+39	days
N1	=	5e+43	
N2	=	5e+39	

This universe has atoms that have a diameter of 7 cm, days 10^{15} hours long, and years of 10^{39} of our days. Yet stars live for 10^{14} of our years, which should be long enough to produce the materials of life.

Notes

1. For a recent discussion of this idea, see Linde 1994.

2. I use the word “infinity” to mean a number much larger than any of the other numbers being used in the discussion.

3. Linde 1982, 1987, 1990, 1994. See also, Atkatz 1994.

4. The astronomical quantities were calculated using the formulas of W.H. Press and A.P. Lightman in Press 1983.