ENTROPY AND THE NUMBER OF SENTIENT BEINGS IN THE UNIVERSE

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Abstract

We postulate that the rate of entropy production of the physical universe is balanced by the rate of negentropy production of sentient beings. If correct, the number of such beings appears to be on the order of the number of baryons in the universe. Alternatives to concluding that our postulate was wrong are briefly discussed.

1. INTRODUCTION

The Second Law of Thermodynamics asserts that the entropy of the universe is increasing with time. Bekenstein and Hawking's pioneering work on the thermodynamics of black holes[1-3] has been extended to the universe as a whole[4,5], and suggests that the total increase in entropy of the universe can be calculated in principle.

O.C. de Beauregard's work[6,7] has suggested a further refinement of the Second Law of Thermodynamics. Since information contains an ordering principle, thermodynamic formulations of information theory involve a negative entropy, or *negentropy*, associated with quanta of information. The suggestion here is that as the physical entropy of the universe increases, the increase is balanced by the negentropy of sentient beings acquiring information about the universe. As M.-L. von Franz wrote, "While the regulating power of opposing entropy increasingly disappears from the universe, it circulates in a potential form in an 'elsewhere' in the shape of information, i.e. as a psychic representation."[8] In regard to this speculation it is interesting to note that Gibbons and Hawking's work in cosmological thermodynamics led them to speculate that "the derivation of these results involves abandoning the idea that particles should be defined in an observer-independent manner".[4]

Thus, if reasonable guesses are made of: (1) the rate of entropy production in our expanding universe; and (2) the rate of negentropy production by a sentient human-like creature in the universe, then if the total negentropy production by all beings balances the total entropy production we may calculate the number of human-like beings in the universe.

2. ENTROPY PRODUCTION IN AN EXPANDING UNIVERSE

The entropy of a black hole is given by the Bekenstein-Hawking relation:

$$S = (4G\hbar)^{-1} kc^3 A_H \tag{1}$$

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A_H is the area of the event horizon of the black hole. We assume that the total charge of the universe is zero, and that Mach's Principle implies that the total angular momentum is also zero. Then the radius of the universe's event horizon, which is associated with those parts of the universe we cannot see, is just the Schwarzschild radius:

$$r_o = 2GM/c^2 \tag{2}$$

and the corresponding area is:

$$A_H = 4\pi r_o^2 \tag{3}$$

If the universe is closed, the idea of a surface "envelope" becomes difficult, and one would find r_o from the volume[9]; that distinction doesn't affect our result by more than a factor of 10 or so. As the assumptions of Section 3 are much more uncertain, we ignore such subtleties here.

We combine Eqns. (1), (2) and (3) and differentiate to yield:

$$dS/dt = \frac{4\pi kcM}{\hbar} dr_o/dt \tag{4}$$

Assuming typical[10] values of M and dr_o/dt gives:

$$dS/dt \sim 10^{83} \text{ J/(sec °K)} \tag{5}$$

3. NEGENTROPY PRODUCTION IN HUMAN-LIKE BEINGS

If the calculation of Section 2 tended to gloss over a number of important questions related to the assumptions being made, it was because the neurophysiology of our memory systems remains very much a mystery[11], and the assumptions of this section are even less certain. Here we resort to two different models, one we call "linear" and the other "many-worlds".

A. Linear model

We assume an Ising-like structure for memory.[12] However, we take the number of synapses, 10^{14}, to be crucial, not the number of neurons, 10^{10}, as in reference 12. Then the number of possible binary memory states is $2^{10^{14}}$. It will be important to note that this number is much higher than von Neumann's estimate of 10^{20}, which is considered astronomical enough by many.[13] Thus we are in some sense calculating an upper-bound for negentropy production, and ignore questions of chunking and redundancy.

We further assume that evolution is efficient, and thus the available memory store is full after a lifetime of 10^2 years. Then the negentropy at death is:

$$I = k \ln (2^{10^{14}}) \tag{6}$$

and the average rate of production over 10^2 years is:

$$dI/dt \sim 10^{-19} \text{ J/(sec °K)} \tag{7}$$

B. Many-worlds model

Consistent with the many-worlds interpretation of quantum mechanics(14), which was mentioned by Gibbons and Hawking(4) in the context of the cosmological model discussed in section 2, we assume that every act of observer-participancy creates two parallel universes. After p such perceptions we have each created 2^p universes.

If we adopt a cycle time for the memory of 10^{-1} sec(15,16), then over a 10^2 year lifetime we have created:

$$2^{3 \times 10^{10}} \text{ universes} \tag{8}$$

If we assume that our knowledge of which branch of the universe we think we are in is holographically encoded throughout the entire $2^{10^{14}}$ possible firing patterns in the brain, then the total number of memory states in all universes is:

$$(2^{10^{14}})\,(2^{3 \times 10^{10}}) \tag{9}$$

The number of universes is small compared to the number of memory states, and Eqn. (9) gives a result identical to Eqn. (7) of Part A:

$$dI/dt \sim 10^{-19} \text{ J/(sec °K)} \tag{10}$$

Alternatively, we take the quantum nature of this effect seriously and take the Planck time as the cycle time of each act of observer-participancy. Then, over a 10^2 year lifetime, we have created:

$$2^{6 \times 10^{52}} \text{ universes} \tag{11}$$

and the total number of memory states in all universes is:

$$(2^{10^{14}})\,(2^{6 \times 10^{52}}) \tag{12}$$

Note that here the number of universes is large compared to the number of firing patterns in the brain, and thus the details of our neurophysiological assumptions do not affect our results.

The negentropy produced is:

$$I = k \ln (2^{6 \times 10^{52}}) \tag{13}$$

and the rate of production over 10^2 years is:

$$dI/dt \sim 10^{20} \text{ J/(sec °K)} \tag{14}$$

4. RESULTS & DISCUSSION

Dividing Eqn. (5) by Eqn. (7), (10) or (14) gives estimates of the number of sentient beings ranging from 10^{102} (linear model and many-worlds with a 10^{-1} sec cycle time) down to 10^{63} (many-worlds with a Planck time). The linear model was an upper-bound calculation; reducing the number of memory states in that model would raise the number of beings still higher. To put these numbers into context, the number of baryons in the universe is thought[10] to be on the order of 10^{80}.

Admitting to some hope for a more reasonable result to these calculations[17], we close with some alternatives:

1. The assumption that entropy and negentropy production are equal was wrong to being with.
2. Baryons, electrons, neutrinos, etc., are sentient with a large number of internal degrees of freedom. There is current speculation that hadrons have large numbers of degrees of freedom.[18]
3. Implicit is the assumption that equilibrium thermodynamics is appropriate. If this is not correct, a self-organising universe with negentropy production through dissipative structures makes the calculation of Section 2 incorrect.
4. The human memory system contains a great deal more potential than we have allowed for.
5. We have not included the negentropy production due to the communication that occurs between sentient beings.

We fear that alternative (1) is probably the most reasonable, although the other alternatives are personally more attractive. Thus, we leave it to the reader to decide if this note describes a speculation that failed.

References

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2. Bekenstein, J., *Phys. Rev.*, D9, 3292 (1974).
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5. A fairly non-mathematical review is by R. Penrose, in S.W. Hawking and W. Israel, eds., *General Relativity*, Cambridge University Press, New York, pp.581-639 (1979).
6. de Beauregard, O.C., *Found. Phys.*, 6, 539 (1976).
7. de Beauregard, O.C., *Le Seconde Principe de la Science du Temps*, Paris (1963).
8. von Franz, M.-L., *Number and Time*, Rider, London, p.209 (1974).
9. See, for example, Bekenstein, J.D., *Phys. Rev.*, D23, 287 (1981). When Mach's Principle was invoked earlier, this was almost equivalent to asserting that the universe is closed.
10. Misner, C.W., Thorne, K.W. and Wheeler, J.A., *Gravitation*, Freeman, San Francisco, p.738 (1973).
11. For a recent overview, see Mark, R.F., in R. Porter, ed., *Studies in Neurophysiology*, Cambridge University Press, New York, pp.301-309 (1978).
12. Little, W.A. and Shaw, G.L., *Behav. Psych.*, 14, 115 (1975).
13. See, for example, Wooldridge, D.E., *The Machinery of the Brain*, McGraw-Hill, Toronto, p.189 (1963).
14. See, for example, DeWitt, B.S. and Graham, N., eds., *The Many-Worlds Interpretation of Quantum Mechanics*, Princeton University Press, Princeton (1973).
15. Reference 13, p. 190.

16. Edelman, G.M., in G.M. Edelman and V.B. Mountcastle, *The Mindful Brain*, M.I.T., Cambridge, p.81 (1978).
17. Actually, I was hoping for a number close to unity!
18. Yukawa, H., *Suppl. Prog. Theor. Phys.*, 67, i (1979).

Author's Reply to Previous Reviewer Remarks

Thank you for your letter of September 16, indicating that my paper "Number of Sentient Beings in the Universe" is suitable for publication in SST. You indicate in your letter that there is some problem with my numerical result, Eqn. (5). The remainder of this letter details my calculation. I am not willing to bet my life on its correctness, but I am unable to find the flaw.

First, I derive in detail Eqn. (4). The Bekenstein-Hawking relation is:

$$S = (4G\hbar)^{-1}\, kc^3\, A_h \tag{1}$$

where

$$A_h = 4\pi r_o^2 \tag{2}$$

and

$$r_o = 2GM/c^2 \tag{3}$$

Combining Eqns. (1), (2) and (3) above gives:

$$dS/dt = \frac{4\pi kcM}{\hbar}\, dr_o/dt \tag{4}$$

which is also Eqn. (4) in my manuscript.

The values of the constants I use are:

$$k = 1.38 \times 10^{-23}\ \text{J/K}$$

$$c = 3 \times 10^8\ \text{m/s}$$

$$\hbar = 6.63\,(10^{-34})/2\pi\ \text{J–s}$$

$$M = 5.68 \times 10^{56}\ \text{gm} = 5.68 \times 10^{53}\ \text{kg}$$

$$dr_o/dt = 0.66\ \text{lyr/yr}$$

where the last two numbers are from page 738 of *Gravitation*. Using the conversion factors that

$$1\ \text{light-year} = .946 \times 10^{18}\ \text{cm} = .946 \times 10^{16}\ \text{m}$$

$$1\ \text{year} = 3.15 \times 10^7\ \text{secs}$$

and substituting in Eqn. (4), I continue to get:

$$dS/dt = 5.54 \times 10^{82} \quad (5)$$

expressed in SI units.

Thus, I believe my calculation in my paper is correct. If I am making one of those trivial errors over and over again, I am unable to find it.

Reviewer Comment

This is a very good paper for SST. It is based on a clearly far-fetched hypothesis, but one worthwhile trying to test. The author goes on exploring it clearly and simply, reaching rather disappointing conclusions which he very honestly reports. Of course, one could discuss the interpretation given of negentropy as information, as well as the so-called (erroneously, to my mind!) "many-world interpretation" of quantum mechanics. Nevertheless, since the author's standpoint is made explicit, the paper is exempt of the delusions and evasions which characterise so many speculations.

Therefore I strongly recommend publication in SST. I would only suggest that the title contain some explicit reference to the nature of the argument, such as "entropy and the number of, etc.".