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DO NEUTRON STARS DISPROVE MULTIPLICATIVE CREATION IN DIRAC'S LARGE NUMBER HYPOTHESIS? *

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ABSTRACT

Dirac's cosmology, based on his large number hypothesis, took the gravitational coupling to be decreasing with time and matter to be created as the square of time. Since the effects predicted by Dirac's theory are very small, it is difficult to find a "clean" test for it. Here we show that the observed radiation from pulsars is inconsistent with Dirac's multiplicative creation model, in which the matter created is proportional to the density of matter already present. Of course, this discussion makes no comment on the "additive creation" model, or on the revised version of Dirac's theory.

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Dirac's cosmology is based on his large number hypothesis [1),2)] (L.N.H.) which is the assumption that if two large numbers are comparable there is some deep underlying physical reason and not a mere accident. It turns out that the ratio of the estimated age of the Universe, t_p, to e^2/mc^3 (m,e being the mass and charge of the electron, and c the speed of light) is 7×10^{39}. Also, the ratio of the electric to gravitational force between an electron and a proton, $e^2/G\,Mm$ (M being the proton mass and G the gravitational "constant") is 2×10^{39}. Further, the estimated number of nucleons in the Universe, N, is of order 10^{78}. On the basis of his L.N.H. Dirac takes G to vary inversely with time and N to vary as the square of time. For total conservation of energy he invokes a "negative energy sea" which is not observable. (Incidentally, this problem of matter creation does not arise in Dirac's revised theory [3)].) Dirac then constructs two models depending on whether matter is created uniformly through all space (additive creation) or more where more matter is present (multiplicative creation). In the one case astronomical distances scale up while in the other case they scale down, with time [1),2)]. This fact provides a test of the theory in principle by observing solar system distances over sufficient periods of time. Unfortunately, the test is not very "clean" as there could be many other factors responsible for such effects at the type of accuracy required of 10^{-10} every two years.

Before going on to consider a "clean" test of multiplicative creation in L.N.H. let us consider the conclusions of the hypothesis. It can be argued that $e^2/G\,Mm$ is fundamental as matter is composed of atoms whose structure depends on the forces between protons and electrons. However, there seems to be no reason to prefer $t_p(mc^3/e^2)^{-1}$ to $t_p(Mc^3/e^2)^{-1}$ which is 4×10^{42} or the ratio of t_p to the Planck time $\sim 10^{61}$, or $(mc^3/e^2)^{-1}$ to Planck time $\sim 10^{21}$, etc. Considering the number of dimensionless quantities that can be constructed in this way it is inevitable that two or three of them are comparable to an order of magnitude. Whereas an exact agreement of two forty digit numbers is unlikely, an order of magnitude agreement has a probability of one in forty only. If more than forty such dimensionless constants can be found then there is a certainty that at least two will agree to an order of magnitude! For this reason one may have difficulties in accepting the L.N.H. as such, but this does not in any way disprove Dirac's cosmology with varying G and creation of matter.

To obtain a "clean" test of the theory we need some phenomenon in a critical state where very small effects would make a very big difference. For multiplicative creation such a critical situation is provided by neutron stars. They radiate away a small fraction of their mass, and the effect of this mass loss can be observed. If they were also "accreting" matter due to multiplicative creation, the mass loss would be drastically altered. Relying on the observed data we can see what limits would be imposed on the neutron star mass. Let us consider this point in more quantitative detail.

Since multiplicative creation requires an increase of mass proportional to the mass and the square of the time, we must have

$$m_{t_1}/t_1^2 = m_{t_2}/t_2^2 \quad . \tag{1}$$

Thus the mass at time t can be expressed in terms of the mass at the present time by

$$m_t = m_{t_p}(t^2/t_p^2) \quad . \tag{2}$$

Thus the ratio of change of the mass of a neutron star due to multiplicative creation at the present time is

$$(dm_t/dt)_{t=t_p} = (2m_{t_p}/t_p)_{t=t_p} \quad . \tag{3}$$

According to the "traditional" neutron star model of pulsars [4),5)] their energy loss was due to dipole radiation. It is well known now [6)] that there are also other mechanisms responsible for energy loss

$$dE_{rad}/dt = dE_{rot}/dt + \Delta E/dt \quad , \tag{4}$$

where dE_{rad}/dt is the total energy radiated, dE_{rot}/dt is the rotational energy loss given by

$$dE_{rot}/dt = I\omega\dot{\omega} \tag{5}$$

(I being the moment of inertia of the neutron star, ω its frequency and $\dot{\omega}$ the rate of decrease of frequency) and $\Delta E/dt$ is the non-rotational energy that could be radiated.

Putting multiplicative creation into the picture we get the total energy loss dE_T/dt being given by

$$dE_T/dt = -dE_{rad}/dt + 2mc^2/t_p \quad . \tag{6}$$

Now, for the observed slowing down of pulsars to be consistent with Eq.(6), i.e. the left-hand side to be negative we must have

$$|dE_{rad}/dt| \geqslant 2mc^2/t_p \quad . \tag{7}$$

This equation gives a limit of the mass of the pulsars

$$M = t_p(dE_{rad}/dt)/2c^2 \tag{8}$$

for a given amount of radiated energy.

Using the standard method of deducing the radiated energy from the observed energy flux [5)] on the data for 20 neutron stars [5),7)] we find that 18 of them are entirely incompatable with multiplicative creation, as we would require them to have masses less than $10^{-5}\ M_\odot$, and even down to $2 \times 10^{-8}\ M_\odot$! Of the other two one has a mass less than $0.06\ M_\odot$, while the other is only limited by the Ruffini limit [4)]. We conclude that apart from other considerations multiplicative creation of matter is ruled out by the existence of neutron stars.

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Table I

Serial No.	Pulsar P S R	Distance $\times 10^{21}$ cms.	Observed energy flux $\times 10^{31}$ egrs./sec.	M $\times 10^{27}$ gms.	M/M $\times 10^{-6}$
1	0328	3.1	2.0	3.3	1.6
2	0527	5.0	0.3	0.5	0.25
3	0532*	6.1	5×10^6	8.3×10^6	4.1×10^6
4	0628	0.6	0.5	0.83	0.4
5	0808	0.4	0.03	0.05	0.02
6	0823	2.8	0.3	0.5	0.2
7	0833*	1.5	7×10^4	1.2×10^5	0.6×10^5
8	0834	1.2	1.0	1.7	0.8
9	0950	0.2	10.0	17.0	0.08
10	1133	0.4	1.0	1.7	0.8
11	1237	1.5	0.2	0.33	0.16
12	1506	1.2	5.0	8.3	4.1
13	1642	0.5	3.0	5.0	2.5
14	1749	3.3	1.0	1.6	0.8
15	1919	0.8	0.2	0.33	0.16
16	1929	0.5	3.0	5.0	2.5
17	1933	6.1	4.0	6.7	3.8
18	2015	3.0	0.02	0.03	0.016
19	2045	1.2	0.05	0.08	0.041
20	2218	4.3	4.0	6.6	3.3

The distance and the observed energy flux of 20 pulsars is given. On the basis of Eq.(8) and this data, the calculated upper mass limit, M, is given in grams and solar masses. The pulsars marked with a * are not inconsistent with multiplicative creation, but the others are—even if we allow neutron stars with mass as little as $10^{-5}\ M_\odot$!

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