matters arising

Weak interactions in the big bang

THE apparent arbitrariness of the numerical values assumed by the various constants of physical theory has from time to time led to the conjecture that these quantities may not be fixed numbers at all, but vary from epoch to epoch as the Universe evolves. Such a suggestion was advanced, on the basis of some discussion about gauge theories and spontaneous symmetry breaking, by Domokos, Janson and Kövesi-Domokos[1] in connection with the weak interaction coupling strength. They propose that this coupling strength was comparable with electromagnetism during the primordial fireball phase of the big bang (specifically, before $T \simeq 10^5$ K). This is some 10^{10} times greater than at present, and its consequences are being investigated by the authors.

One consequence which they will discover is that, on general grounds, the lifetime of the neutron against β decay, $n \rightarrow p + e^+ + \bar{\nu}$, would presumbly be reduced by the same factor of $\sim 10^{10}$, making the half life of neutrons in the fireball phase a mere 10^{-7} s or so. The implications of this are profound. According to current models of the hot big bang, protons and neutrons are maintained in thermodynamic equilibrium by electron–positron processes until the end of the lepton era at $\sim$ 1 s (10^{10} K). After this, the electron–positron pairs annihilate, and the neutron/proton abundance ratio is thereafter 'frozen in' until the temperature drops sufficiently low (about 10^9 K) for helium synthesis to occur. Essentially all the remaining neutrons are incorporated into helium (where they remain stable) after a few hundred seconds, which is well within the currently measured lifetime of the neutron.

Accepting the model of Domokos *et al.* would lead to the conclusion that the neutron abundance would not remain frozen at all during the intermediate cooling phase, but would decay to virtually zero long before nucleosynthesis could begin. The consequences of that would be an absence of neutrons in the universe—indeed, a universe composed entirely of hydrogen.

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[1] Domokos, G., Janson, M.M., and Kövesi-Domokos, S., *Nature*, 257, 203–204 (1975).

DOMOKOS ET AL. REPLY—DAVIES' remark[1] concerning our recent letter[2] raises a relevant issue; in fact, we have been studying this problem for some time. If intepreted literally, our result may lead to the paradox pointed out by Davies. The careful reader will, however, have noticed that in order to illustrate the basic idea expressed in our letter (generation of a distinction between weak and e.m. interactions through a cosmological background) we took an extremely crude idealisation of an expanding universe. In fact, our input scalar curvature is: $R/(3p-\rho) = 0$ $(x < x_0)$ and $R \sim x^{-3}$ $(x > x_0)$. In such a universe the temperature drops abruptly from infinity to essentially 'zero' at x_0. Hence, for $x < x_0$ there is no nucleus formation and no neutron decay either (due to an infinite time dilatation factor). All this can take place only for $x > x_0$. Then $\varphi(x)$ rises very rapidly and gets close to its present value quite soon. Thus, even in this highly idealised model, there seems to be no qualitative contradiction with usual ideas of He formation. On the basis of computer experiments performed with more realistic models, we are now under the impression that the general shape of the curve $\varphi(x)$ is correctly given by our model[2]. Davies' observation imposes a consistency condition on more realistic model calculations: φ must come out to be substantially different from zero during the epoch of primordial He formation.

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[1] Davies, P. C. W., *Nature*, 259, 157 (1976).
[2] Domokos, G., Janson, M. M., and Kövesi-Domokos, S., *Nature*, 257, 203–204 (1975).

Methylation of organolead and lead(II) compounds to $(CH_3)_4Pb$ by microorganisms

RECENTLY evidence[1] showed that microorganisms can transform certain lead compounds into Me_4Pb; addition of Me_3PbOAc to sediment samples apparently always increased the production of Me_4Pb. The addition, of lead(II) compounds did not, however, lead to definite effects, and with pure bacterial isolates no transformation of Pb^{2+} to Me_4Pb could be observed[1]. Doubt has since been cast[2] on the significance of a microbiological conversion of Me_3PbOAc to Me_4Pb, preferring a chemical mechanism; also alkylation of $Pb(NO_3)_2$ could not be detected (ref. 2).

Our studies of the behaviour of lead compounds in the presence of microorganisms show that Pb^{2+} can be biologically alkylated to Me_4Pb, and this helps to explain the formation of Me_4Pb from Me_3PbOAc in anaerobic systems.

In aqueous solution, alkyl lead compounds R_2PbX_2 and R_3PbX (X = anion) redistribute according to

$$4Me_3PbX \rightleftarrows 2Me_2PbX_2 + 2Me_4Pb \quad (1)$$

$$2Me_2PbX_2 \rightarrow Me_3PbX + MeX + PbX_2 \quad (2)$$

$$3Me_3PbX \rightarrow 2Me_4Pb + MeX + PbX_2 \quad (3)$$

reaction (2) is much faster than (1)[3,4] and therefore Me_3PbX seems to be relatively stable at room temperature. The stoichiometry of its decomposition can be described practically by reaction (3).

In water samples (dilution water[5,6]) seeded with microorganisms from an aerated aquarium, we observed, apart from the inhibition of biodegradation, that di-alkyl and tri-alkyl lead concentrations decreased considerably faster in both aerobic and anaerobic conditions than in sterile samples, and that the proportions of products no longer agrees with predictions from the above system of equations. After addition of Me_3PbCl to an anaerobic sample, less Pb^{2+}, but more Me_4Pb was formed than is required by reaction (3). Furthermore, the amount of Me_4Pb produced in a given time was considerably higher than from a sterile sample (by a factor of 5–10 in a week). Therefore the possibility that Me_4Pb was produced only by redistribution (reaction (1)), could be excluded, and it was an obvious assumption that Me_3PbCl and/or Pb_2^{+}, formed according to reaction (3), had been alkylated by microorganisms to Me_4Pb.

We then investigated whether Pb^{2+} could be alkylated by microorganisms in the same anaerobic conditions. We inoculated water samples containing $Pb(OAc)_2$ in different low concentrations (Table 1) and sealed the flasks after flushing with N_2. The analysis for Me_4Pb (the only volatile lead compound in the system) was carried out by slowly sweeping the gas phase above the solution with N_2 through an 0.2 N methanolic iodine scrubber solution[7]; the lead content was determined colorimetrically with 4-(2-pyridylazo)-resorcinol[8]. The experiments were reproducible, provided that the seed was not more than 6–7 weeks old.

We therefore conclude, that besides the formation of Me_4Pb by redistribution according to reaction (1), biological alkylation of Pb^{2+} must be considered as