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CONSISTENCY OF THE STANDARD MODEL OF PRIMORDIAL NUCLEOSYNTHESIS: RESPONSE TO THE COMMENT OF OLIVE AND TURNER

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Stecker Responds: In my previous paper, I made two points: (A) That arguments constraining the mean density of the universe and the number of neutrino flavors appear unjustified in view of the astrophysical data, and (B) that "the simplest big-bang model for helium production may be untenable." I argued that *prima facie* inconsistencies appear to exist in the present data when related to the orthodox baryon dominated (BD) model, and possibly even in the neutrino dominated (ND) model, which I discussed[1] as an approach to relieving the inconsistencies in the BD case. I believe this point of view to be valid, and that it has been strengthened by recent measurements of low helium abundances in other galaxies which have undergone less stellar nucleosynthesis.[2-4]

For this discussion, I use the notation of Olive and Turner with the exception of defining Y_0 as the observationally derived value of Y_p and Y_c as the value calculated with the standard model. The corresponding deuterium abundances will be denoted by X_0^D and X_c^D. Olive and Turner argue that $Y_0 \lesssim 0.25$. The new observations, however, give $Y_0 = 0.216 \pm 0.015$ (ref.2), $Y_0 = 0.216 \pm 0.013$ (ref.3) and 0.216 ± 0.02 (ref.4). Together with the references given previously[1], these analyses support the stronger limit $Y_0 \lesssim 0.23$ used previously. One might argue that scatter in the data would allow a larger value for Y_0, however, the existence of considerably lower Y_0 value measurements for individual galaxies would suggest the opposite conclusion, since He, once produced, is not readily destroyed. Individual measurements[2,3] in the range 0.17-0.18 may be evidence for $Y_0 < 0.2$ rather than 0.23.

The calculated value Y_c is a function of several empirical parameters, $Y_c = Y_c(\Omega_N, h, T, \tau_{1/2}, N_\nu)$. Olive and Turner take $N_\nu \gtrsim 2$. However, since $m_{\nu_\tau} \lesssim 250$ MeV, by the well known cosmological arguments[5], conservatively, $m_{\nu_\tau} \lesssim 100$ eV, unless the τ neutrinos have decayed. However, Cowsik[6] has determined that the lifetime of ν_τ is greater than the age of the universe. Thus, ν_τ should be included in the model, giving $N_\nu \gtrsim 3$. Then, with $\tau_{1/2} = 10.68 \pm 0.07$ min.[7] and $T = 2.8 \pm 0.1$ K[8], one requires $\Omega_N \lesssim 4.1 \times 10^{-3}h^{-2}$ for $Y_c \lesssim 0.23$ and $\Omega_N \lesssim 1.9 \times 10^{-3}h^{-2}$ for $Y_c \lesssim 0.2$. This is clearly inconsistent with the BD case ($\Omega=\Omega_N$) for $\Omega \gtrsim 0.2$.and $h \gtrsim \frac{1}{2}$ (ref.9). furthermore, $\Omega_N \lesssim 4.1 \times 10^{-3}$ gives a deuterium abundance $X_c^D \gtrsim 6.8 \times 10^{-4}$ for $N_\nu \gtrsim 3$ (ref.10). Thus, if we invoke such a low value for Ω_N as to account for Y_0, we must give up using the standard model to calculate X^D, since $X_0^D = 3.6 \times 10^{-5} << X_c^D$ (ref.11). Using Olive and Turner's lowest value $\eta = 3 \times 10^{-11}$ gives $X_c^D = 2 \times 10^{-3}$, almost two orders of magnitude too large. Of course, we may invoke stellar destruction of D to lower X^D, but this in turn implies more stellar nucleosynthesis, *ergo* more stellar He and a lower Y_p. We must, at any rate, abandon the use of X_0^D to place theoretical limits on Ω_N.

For the ND case ($\Omega_N << \Omega$) one must determine an observational lower limit for Ω_N. From the X-ray observations of hot gas in galaxy clusters[12], one finds $\Omega_N \gtrsim 0.02$, even in the ND case. Such gas should be associated with galaxies in general[13]. Recent evidence of cooler gas associated with the outer parts of galaxy clusters[14] imply an even higher value $\Omega_N \gtrsim 0.06$. Thus, we may have a problem with the standard model even in the ND case, since $Y_0 \lesssim 0.23$ implies $\Omega_N \lesssim 0.004h^{-2}$. This problem is aggravated for $h \sim 1$ (Aaronson, *et al.* and Davis *et al.*, ref.9) and, in any case, is in conflict with the deuterium abundances. Further discussion and data regarding all of the relevant parameters of this complex problem will be of utmost importance.

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