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Constraints from big bang nucleosynthesis on a time-varying cosmological constant

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Abstract. The limits from big bang nucleosynthesis on a class of models with time-varying Λ-term are reexamined. In particular, it is discussed how the stringent bounds previously derived may be relaxed.

Recently, many authors have proposed cosmological models where the Λ-term decays continously during the evolution of the Universe (Overduin & Cooperstock 1998 and references therein). In this approach, the Λ-term depends on the variables dynamically relevant and also on some phenomenological parameters, which should be constrained from observations.

Here, we rediscuss the bounds inferred from primordial nucleosynthesis on the parameter β arising in the phenomenological law (Lima & Maia 1994, Lima & Trodden 1996)

$$\Lambda = 3\beta H^2 + 3(1-\beta)\frac{H^3}{H_I},$$

where H is the Hubble parameter and H_I^{-1} is an arbitrary time scale related to an initial inflationary stage. This model presents a smooth transition between the inflationary epoch and the FRW-like radiation era. In particular, if $H_I \sim M_{\rm pl}^2$, it explains the discrepancy between the expected and the effectively observed values of the cosmological term. At the time of nucleosynthesis, the second term in the r.h.s. of the above equation is negligible, resulting in a Universe with an effective age of $t_0 = 2H_0^{-1}/3(1-\beta)$. Using the estimates of H_0 and t_{gc} (the age of globular clusters) available at that time, it was found that $\beta \geq 0.21$. Later on, by analysing the constraints from nucleosynthesis, Birkel and Sarkar (1997, hereafter BS) derived that $\beta \leq 0.13$, thereby concluding that the model was ruled out by these combined data. Here we argue that both results are not so definitive and that the limits on β still deserve a closer escrutiny.

Recent measurements of the Hubble parameter yields $H_0 = 70 \pm 10 km/s/Mpc$ (Freedman 2000) and $t_{gc} = 13 \pm 1$Gyr, thus decreasing the age lower bound on β to 0.06, if the minimal values of H_0 and t_{gc} are considered. This lower bound is much smaller than the one of our previous analysis, and also well below the upper limit of BS. In addition, using updated values of element abundances in an adapted version of Kawano's nucleosynthesis code (Kawano, 1992), we have found a slightly greater upper bound, $\beta \leq 0.16$), which relax even further the age problem. Our main results are summarized in Fig. 1 below.

Finally, we stress that the most attractive feature of the model is its nonsingular and deflationary evolution. Since both aspects are independent of β, the scenario is by no means ruled out from observational constraints based on

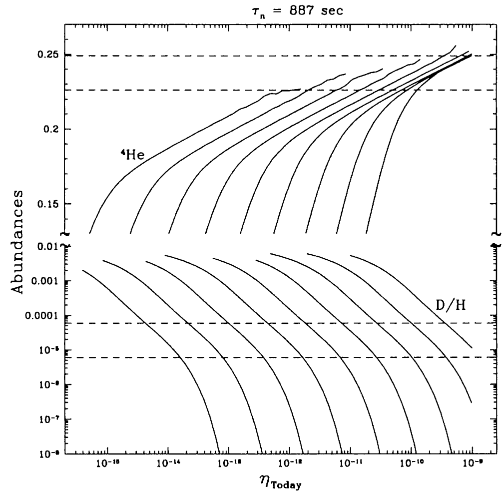

Figure 1. Abundances of primordial ^4He and D/H as functions of η_{today}. Dashed lines correspond to observational values (Molaro 1997). From right to left, β ranges from 0 to 0.16 (step 0.02). We assumed 3 light neutrino species and the neutron lifetime $\tau_n = 887 \pm 2s$.

this parameter. These analyses are also rested on the assumption that Λ decays only into the dominant component of the cosmic fluid. However, after the end of the radiation era, a decay into matter driven by an effective parameter (β_m) is not forbidden from first principles. In this case, bounds for this free parameter derived in the radiation epoch are not valid to the matter dominated phase. Still following this reasoning, one may ask why to neglect the decay into neutrinos after their decoupling from radiation, as have been done here and in BS. In the same vien, without a more careful study, the chemical potential associated with the products of the decaying vacuum cannot be neglected, as usually done in the standard nucleosynthesis treatment. In principle, all these potentially important issues should be addressed before a more definitive conclusion.

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