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Primordial Nucleosynthesis

(J. Audouze)

Primordial nucleosynthesis which is responsible for the formation of the lightest elements (D, ^{3}He, ^{4}HE and ^{7}Li) might be as important as the overall expansion of the Universe and the cosmic background radiation to prove the occurrence of a dense and hot phase for the Unvierse about 15 billion years ago. As recalled in many reviews (e.g. refs. 1, 2) the standard Big Bang nucleosynthesis leads to two important conclusions regarding (i) a limitation of the baryonic density such that the corresponding cosmological parameter $\Omega_B \leq 0.1$; (ii) a limitation of the number of neutrino flavours to 3-4 consistent with the results concerning the widths of the Z_0 and $W^{\pm}$ particles[3].

The most recent progresses concerning this important problem deal with (i) some recent abundance determinations of the light elements; (ii) the discussion of the validity of the standard Big Bang model; (iii) the chemical evolution of the D and ^{3}He abundances; (iv) the elaboration of models taking into account either the decay of non baryonic particles or the inhomogeneities resulting from the quark-hadron phase transition.

RECENT ABUNDANCE DETERMINATIONS OF THE LIGHTEST ELEMENTS

An excellent review of the D abundances can be found in ref. 4. There is a tentative determination[5] of the D/H ratio in (z ~ 3) absorption line QSOs. Concerning ^{3}He a recent reconsideration of the interstellar $^3He^+$/H ratio from radio lines has reduced somewhat but not eliminated the large abundance range reported in previous analyses[6,7].

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The primordial ^4He abundance (Y_p) has been thoroughly discussed in a recent conference[8]. There seems to be a slight tendency towards lower values of Y_p (e.g. refs. 9 and 10). Finally, regarding ^7Li the discovery of $^7Li/H \sim 10^{-10}$ in Pop II stars[11] is confirmed by two different groups [12,13].

THE VALIDITY OF THE STANDARD BIG BANG NUCLEOSYNTHESIS

The so-called Chicago-Bartol group is still strongly arguing about the striking validity of the simple (canonical) Big Bang model. This group has also studied the implications on their models of new nuclear reaction rates which could affect the ^7Li abundance[14] (see also ref. 15) and found no reason to abandon their views regarding the success of such models[16]. These views are challenged in part by the Paris group since there seems to be a growing discrepancy between the baryonic density deduced from low Y_p values on the one hand and low $\left(\frac{D+{}^3He}{H}\right)_p$ values on the other hand (e.g. ref. 2).

SPECIFIC MODELS OF GALACTIC EVOLUTION

In order to overcome this difficulty the Paris group[17] have considered models implying for instance varying rates of star formation where D can be destroyed thoroughly during the galactic history and where a low Y_p value would correspond to a high $\left(\frac{D+{}^3He}{H}\right)_p$ value. There is an observational test which could discriminate between the Chicago-Bartol and the Paris views depending on the non-variability or the variability of the D/H ratio observed in different regions of our Galaxy.[18]

PRIMORDIAL NUCLEOSYNTHESIS AND PARTICLE PHYSICS

Since standard Big Bang models put very strong constraints on the baryonic density of the Universe, many attempts have been made to alleviate such an important constraint. Among them one can quote (i) the partial photo-disintegration of ^4He and ^7Li induced by photons coming from the decay of massive non-baryonic particles such as massive neutrinos and gravitinos[19], photinos[20], and WIMPS of any kind[21]; (ii) the consideration of an anisotropic universe[22] although the ^7Li abundance puts severe constraints on this specific model[23,24]. (iii) the possible effect of the quark-hadron phase transition on the primordial nucleosynthesis, a most exciting proposal made first by Applegate et al.[25], followed by Alcock et al.[23]. This phase transition might induce the formation of neutron and proton rich zones, the existence of which could affect the outcome of the primordial nucleosynthesis. In that frame it has been argued[25] that this model could allow the possibility of having $\Omega_B = 1$ consistent with the results of the primordial nucleosynthesis, while other investigations show that the primordial abundance of ^7Li rules out this most exciting idea.[23,26]

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Background Radiation in the Universe

(G. De Zotti)

MICROWAVE BACKGROUND

a) Spectrum. A collaboration between US and Italian groups performed accurate observations at five wavelengths[1]. The experiment was particularly conceived to achieve the highest possible relative accuracy, allowing an effective search for spectral distortions. The Berkeley and the Milano groups further improved the spectral coverage[2].

Johnson and Wilkinson[3] avoided the main problems of ground-based experiments (primarily the atmospheric emission) by flying a special radiometer operating at λ = 1.2 cm on a balloon. Thus they arrived at the most precise measurement reported to date: $T_o = 2.783 \pm 0.025$ K.

Accurate determinations of T_o at 2.64 mm and estimates at 1.32 mm were also obtained through high-resolution observations of the CN absorption lines[4].

The good agreement between all results listed above, involving very different systematic effects, is encouraging. The brightness temperature in the Rayleigh-Jeans region is now known to better than 1%; Bose-Einstein distortions with a chemical potential larger than a few times 10^{-3} are ruled out. The ensuing constraints on processes of cosmological interest have been recently reviewed[5].

The information on the Wien tail of the spectrum has also been growing fast in the last few years. The balloon-borne photometer flown by Peterson and co-workers[6] has made measurements at five wavelengths, ranging from 3.5 to 1 mm. The new results do not confirm the strong excess around the peak[7]. Most recently, a rocket-borne radiometer, designed to measure the background radiation in six passbands between $\simeq$ 1 mm and $\simeq$ 100 μm, was launched by a