Big Bang Nucleosynthesis and Modern Cosmology

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Big bang nucleosynthesis (BBN) is the testing ground upon which many cosmological models must ultimately rest [1]. A key quantity for BBN is the baryon-to-photon number ratio η which is constrained from observations of cosmic microwave background (CMB) radiation.

A popular explanation for the flat universe and the near isotropy of CMB comes from an epoch of rapid inflation in the early universe. In some special kind of inflationary model which involves non-minimal coupling between matter and gravity, the universe makes a transition from an inflation driving potential to a dark energy producing quintessence. BBN study can put a significant constraint on this model as the nonminimal couplings lead to an excess energy density in gravity waves which alter the predicted light element abundances [2].

In addition, a large extra-dimension affects the dynamics of the universe and BBN. In a Randall-Sundrum II braneworld cosmology, the cosmic expansion rate for a 3-space embedded in a higher dimensional space can be written with a simple equation including additional terms to that of the 3-space dimensional case. The modified term includes the dark radiation term that scales as a^{-4} with a the scale factor of the universe. Because of this scaling almost similar to that of normal radiation, it can significantly alter the fit to BBN abundances and the CMB, and hence, can be constrained [3].

Figure 1 shows the latest constraint on the dark radiation in the $\rho_{\rm DR}/\rho$ vs. η plane [3]. Here, $\rho_{\rm DR}$ is the energy density of the dark radiation, and ρ is the total energy density of relativistic particles. Dark and light shaded region are the allowed region from observations of the primordial D and He abundances, respectively. Contour lines show the 1, 2 and 3σ confidence limits from fits to the CMB power spectrum. Some papers refer to invisible relativistic particles including neutrinos as dark radiation. However, they are completely different from extra-dimensional dark radiation. The former clumps in the universe while the later does not. Their effects on the CMB temperature fluctuation are then different [3].

Many papers have considered the possibility that BBN could constrain a first-order quantum chromodynamics transition. However, a large effect on BBN from the transition is probably not possible since results from lattice gauge theory seems to rule out a first-order transition at low baryon density. Nevertheless, the possibility of baryon inhomogeneities during BBN arising from other mechanisms remains a viable possibility [4].

A time dependence of fundamental constants in an expanding universe appears in theories that attempt to unify gravity and other interactions. BBN is sensitive to variations in the the average light quark mass. A re-evaluation of the effects on BBN from the quark mass variation was performed taking into account an independent evaluation of the resonant ^{3}He(d,p)^{4}He reaction rate based upon the forward and reverse reaction dependence on the quark mass. The newer abundance constraints narrow the range of possible variations in the quark mass, and the deduced range is consistent with less than a 0.7 % variation in the averaged quark mass [5].

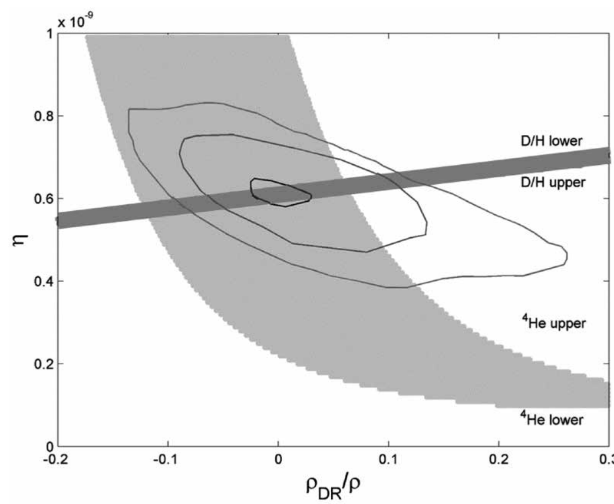

Figure 1: The calculated constraint on the dark radiation in the parameter plane of $\rho_{\rm DR}/\rho$ and η [3], where $\rho_{\rm DR}$ is the energy density of the dark radiation, and ρ is the total energy density of relativistic particles. Dark and light shaded region are the allowed regions from observations of the primordial D and He abundances, respectively. Contour lines delineate the 1, 2 and 3σ confidence limits from fits to the CMB power spectrum.

References

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