Ω_b: USING QUASARS TO CONSTRAIN PRIMORDIAL ^{2}H/H ABUNDANCE

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1. ABSTRACT

The light elements formed during big bang nucleosynthesis (BBN) include ^{2}H, ^{3}He, ^{4}He, and ^{7}Li, and were created in the first few minutes of the universe. The standard BBN theory predicts that the relative abundances of these light elements are affected by two parameters: (1) the number of massless neutrino species, and (2) the relative number density of baryons to the number density of CMB photons in the universe, η_{10} ($\propto \Omega_b$). Since the Standard Model of particle physics predicts three neutrino species (Kolb et al. 1991), the abundance of light elements is a direct link to the value of η_{10}.

One of the goals of the new "precision" cosmology in the past decade has been to use BBN theory and observations of light element abundances to get a handle on the precise baryon density of the universe. Figure 5 in Steigman (2007) shows that the primordial ^{2}H/H abundance predicted by BBN has a strong dependence on η_{10}, which makes it a very useful cosmological light element. Following Steigman (2007), we have

$$10^5(^2\mathrm{H/H}) = 2.67(1 \pm 0.03)(6/\eta_{10})^{1.6} \quad (1)$$

$$\eta_{10} = 274\Omega_{\mathrm{b,o}}h^2 \quad (2)$$

These two relations show link between ^{2}H/H abundance and Ω_b. However, a technical problem emerges when we consider the small amount of ^{2}H in the universe — it is very difficult to observe ^{2}H.

The main method of observing ^{2}H/H has come to rely on distant (z$\sim$3) quasars. If there is pristine absorbing material between us and the quasar, then ideally H and ^{2}H absorption lines can be observed and column densities can be calculated, revealing the primordial ^{2}H/H abundances. In order to be suitable for this type of analysis a quasar needs to satisfy all four criteria outlined by O'Meara et al. (2006): (1) high H column density to provide enough ^{2}H for a strong absorption feature, (2) a simple velocity structure for the intervening clumps of H absorbing material to prevent confusion of the ^{2}H and H spectral features, (3) no Lyα or metal spectral lines at the same wavelength as the ^{2}H spectral feature, (4) a bright QSO for good S/N. To date, only seven quasars have been used to determine ^{2}H/H. As of 2008, the weighted mean $\langle\log(^2\mathrm{H/H})\rangle$ = -4.55 $\pm$ 0.02, yielding $\Omega_b h^2$(BBN) = 0.0213 $\pm$ 0.0010 (Pettini et al. 2008).

Ω_b is sought by many methods, and they all acts as checks on one another. For example, the five-year WMAP results give $\Omega_b h^2$(CMB) = 0.02267 $\pm$ 0.00059 (Komatsu et al. 2009), which is within the error the quasar results. This gives support to the current BBN theory and to the value of Ω_b.

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