Neutron Diffusion and Nucleosynthesis in an Inhomogeneous Big Bang Model

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Motivation

- Certain baryogenesis models lead to inhomogeneous baryon distributions.
- The neutrino heating effect in an inhomogenous model might be measurable and different from its standard model value.
- Diffusion and nucleosynthesis in the inhomogeneous model needed to be understood and explained before neutrino heating was implemented.

Spherically symmetric model - high baryon density for shells with radius $[0, \frac{1}{2}r_i]$. Low baryon density for shells with radius $[\frac{1}{2}r_i, r_i]$ ($r_i =$ distance scale).

The number density $n(i,s)$ for isotope i in shells s obeys this equation.

$$\begin{aligned}\frac{dn(i,s)}{dt} &= \frac{1}{n_b(s)} \sum_{j,k,l} N_i \left(-\frac{n^{N_i}(i,s) n^{N_j}(j,s)}{N_i! N_j!}[ij] + \right. \\ &\quad \left. \frac{n^{N_k}(k,s) n^{N_l}(l,s)}{N_k! N_l!}[kl] \right) \\ &\quad -3\dot{\alpha} n(i,s) + \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 D_n \frac{\partial n(i,s)}{\partial r} \right) \qquad (1)\end{aligned}$$

The first term controls nuclear reactions within a shell s. The second term accounts for the expansion of the universe. The third term controls the diffusion of neutrons between shells.

Future Research

- Publish diffusion and nucleosynthesis results in a journal article
- Discuss neutrino heating results in talk at COSMO-02, journal article.
- Apply inhomogeneous model to constraints from CMB observations.
- Apply to variation of fine structure constant.

Sources

Kainulainen, K., Kurki-Suonio, H., Sihvola, E. Physical Review D. **59**, 083505 (1999).

Kurki-Suonio, H., Sihvola, E. Physical Review D. **63**, 083508 (2001).

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Figure (1): Number densities for $r_i = 25000$ cm.

$\frac{r_i}{r_o}$

$\frac{n_i}{n_o}$

Figure (4): $X_{^4\mathrm{He}}$ in the IBBN Program

r_i in cm

η

Figure (5): $Y(\mathrm{d})/Y(\mathrm{p})$ in the IBBN Code

r_i in cm

η

Figure (6): Constraints: $X_{^4\mathrm{He}} = 0.228 - 0.248$, $Y(\mathrm{d})/Y(\mathrm{p}) = 2.9 - 4.0 \times 10^{-5}$, $\log[Y(^7\mathrm{Li})/Y(\mathrm{p})] = -9.45 \pm 0.02$

r_i in cm

η

$X_{^4\mathrm{He}} = 0.228$ $X_{^4\mathrm{He}} = 0.248$ $\frac{Y(\mathrm{d})}{Y(\mathrm{p})} = 2.9 \times 10^{-5}$

$\frac{Y(\mathrm{d})}{Y(\mathrm{p})} = 4.0 \times 10^{-5}$ $\log\left[\frac{Y(^7\mathrm{Li})}{Y(\mathrm{p})}\right]$ =-9.65 $\log\left[\frac{Y(^7\mathrm{Li})}{Y(\mathrm{p})}\right]$ =-9.25