AST383 NUCLEOSYNTHESIS

Attempt two of the four questions.

Due Tuesday, March 1

1. a) Explain why the primordial D/H ratio is often described as a cosmic baryometer.

b) This ratio is best inferred from the absorption line spectrum of QSOs at high redshift such that the Lyman lines are shifted into the optical spectrum.

Explain how the D/H measurement is made and include in your explanation remarks about why this is a difficult measurement and why so very few QSOs offer a suitable spectrum.

c) The first D/H measurement from a QSO was given in 1994 by Songalia et al. (Nature 368, 599) but today their result is ignored - why?

d) What do you consider to be the current best estimate of the primordial D/H ratio and why? Comment on the scatter in D/H measurements from QSOs and on evidence that D/H does or does not depend on metal abundance and H column density. (see Cooke et al. 2014, ApJ, 781:31 for recent D/H determinations)

2. a) There is presently a `lithium problem' in that the primordial Li abundance inferred from warm metal-poor dwarf stars is a factor of a few less than that predicted by the Big Bang.

Assess whether a new datum on the primordial lithium abundance may be obtainable from the absorption line spectrum of a QSO by answering the question:

Are neutral or ionized Li atoms likely to be detectable in the intergalactic medium along the line of sight to a QSO?

If detectable, how might you correct the measured column density for unobserved stages of ionization?

And obtain the hydrogen column density so that you can estimate the Li/H ratio?

(Assume suitable spectrographs exist on suitably large telescopes.)

3. a) Apart from the neutron's lifetime, 11 nuclear reactions control Big Bang nucleosynthesis - see Iliadis p.556 and Fig. 1 of Fields (2011, Ann. Rev. Nucl. Part. Science 61, 47). For each of these reactions compute the peak and width of the Gamow window for Big Bang nucleosynthesis (Figure 5.87 of Iliadis should be helpful) and compare this window with the range of energies over which each reaction has been measured in the laboratory.

For a summary of reaction rates see
http://www.astro.ulb.ac.be/nacreii/index.html?individualreaction.html

b) Explain why the uncertainty about the neutron's lifetime affects the yield of helium-4 from the Big Bang.

Presently, the lifetime may be uncertain by +/-3 seconds. Using Bib Bang nucleosynthesis predictions in the literature, translate this uncertainty to the uncertainty affecting the helium-4 mass fraction.

c) Explain why the number of neutrino families (presently N(nu) is considered to equal three) affects the predicted He-4 yield from the Big Bang.

Using analyses in the literature estimate the change in the He-4 mass fraction which would results from an increase in N(nu) from 3 to 5.

4. a) What is meant by the Lithium problem in Big Bang nucleosynthesis?

b) Review possible solutions to this problem within the area of stellar astrophysics. In your view, is it likely that the true solution is to be found in this area?

c) Describe one proposed solution involving a non-standard model of Big Bang nucleosynthesis. If possible, identify tests of your chosen solution.