UNIVERSITY OF BIRMINGHAM

DEGREE OF B.SC. & M.PHYS. WITH HONOURS

FINAL EXAMINATION

03 00716

(OBSERVATIONAL COSMOLOGY)

MAY/JUNE, 2004

Answer four parts of Question 1 and ***one*** *other question. If you answer more than two questions, only the first two answers in you answer books will be marked.*

The ***approximate*** *allocation of marks to each part of a question is shown in brackets* **[ ]**.

Total time allowed: 1.5 Hours

A table of physical constants and units that may be required will be found at the end of this question paper

(Turn Over)

Section 1

Full marks for this section may be obtained by correctly answering four questions. You may attempt as many questions as you wish, but any marks in excess of 40% will be disregarded.

1. If the measured flux in the V band of a QSO at redshift z=2 is 10^{-16} Wm^{-2} and its luminosity distance is 15500 Mpc, what is its intrinsic luminosity?

   What rest wavelength does this luminosity refer to?

   What further information would be needed to calculate the luminosity in the V band? [10]

2. Describe one piece of observational evidence for a non-zero cosmological constant. [10]

3. Sketch the variation of the scale factor of the Universe with time for
   (i) Ω_m=0.3, Ω_Λ=0
   (ii) Ω_m=0.3, Ω_Λ=0.7.
   Assume in both cases the Hubble constant has a value H_0=70 kms^{-1} Mpc^{-1}.
   Mark on your plot the current time.

   In which case of (i) or (ii) is the Universe older? [10]

4. In a Universe which is matter-dominated and has Ω_m=1 and zero cosmological constant, show that the matter density ρ_m varies with time as $\rho_m \propto t^{-2}$. [10]

5. Describe the reaction chain by which helium is produced in the early Universe. What difference would be made if the half-life of the free neutron was significantly shorter than 614 seconds? [10]

6. Estimate the redshift at the epoch of matter-radiation equality. State any assumptions you make and show how your estimate is made. [10]

   (**Note:** the radiation constant $\alpha = 7.565$x10^{-16} J m^{-3} K^{-4})

(Turn Over)

Section 2

You should attempt one question from this section. If you answer more than one question, only the first one will be marked.

7. (a) The distance to a galaxy in the nearby Virgo cluster of galaxies is measured by finding its redshift and applying Hubble's Law. Why is this an inaccurate method? (The true distance to the Virgo cluster is approximately 20 Mpc). [6]

   If instead the galaxy were in a cluster at a redshift of z=0.1, discuss whether the same method of measuring the distance would produce a higher or lower fractional accuracy in the distance. [6]

   Describe in detail a different, accurate method of measuring the distance to the galaxy in the Virgo cluster. [6]

   (b) If the mean density of the light from all galaxies is 1.5x10^8 $L_\odot$ Mpc^{-3}, what mass-to-light ratio for galaxies is required to give Ω_m=0.3 ? [6]

   What mass-to-light ratio is typically observed for the visible regions of galaxies ? [3]

   What does the difference in the above mass-to-light ratios imply? [3]

8. (a) Give estimates of the contributions to the density of the Universe (ie Ω_m) of different forms of observed baryons at the present time.

   Then estimate the contributions to Ω_m from (i) dark, unobserved baryons and (ii) dark, non-baryonic matter, explaining how you have made the estimates in each case. [18]

   (b) Show that in a radiation dominated Universe the deceleration parameter is given by $q_0 = \Omega_{rad,0}$, where $\Omega_{rad,0}$ refers to the current density of the radiation. [12]

(Turn Over)