Open note examination

UNIVERSITY OF BIRMINGHAM

DEGREE OF BSc & MSci WITH HONOURS

FINAL EXAMINATION

03 00716

(OBSERVATIONAL COSMOLOGY)

MAY/JUNE, 2005

Total time allowed: $1\frac{1}{2}$ Hours

Answer Section 1 and any one question from Section 2.

Section 1 counts for 40% of the total marks for the course. 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.

Section 2 consists of two questions, each carrying 30% of the course mark. Answer only one of these two. If you answer more than one question from Section 2, only the first will be marked.

A further 30% of the course credit derives from coursework assignments already submitted.

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

Calculators may be used in this examination but must not be used to store text. Calculators with the ability to store text should have their memories delected prior to the start of the examination.

Students may use their course notes in the examination, but textbooks are not permitted.

Tables 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. Give two reasons why it is more helpful to think of the cosmological redshift as arising from the expansion of the Universe, rather than from Doppler shifts due to the recession of galaxies. [10]

2. Which isotope provides the best constraints on cosmic nucleosynthesis, and why? [10]

3. Einstein introduced the cosmological constant, Λ, in order to achieve a static universe. Show that such a universe must have positive curvature. Argue, from the Friedmann equation, that this static state would be unstable. [10]

4. What is the K-correction for galaxy fluxes, and on what does it depend?
   A standard ΛCDM cosmology has $\Omega_\Lambda = 0.7$ and $\Omega_m = 0.3$. Explain whether, in such a universe, the K-correction at $z = 1$ is
   (a) larger than,
   (b) smaller than, or
   (c) identical to
   that for a similar galaxy in a flat universe with $\Omega_m = 1$. [10]

5. Which of the following remain constant as the Universe evolves: the Hubble parameter H, the density parameter Ω, the critical density ρ_c, the curvature constant k?
   Justify your answer for each. [10]

6. Explain why galaxies 1 Mpc across are not found in the Universe. [10]

(turn over)

<u>Section 2</u>

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

7. Consider the hypothesis that we live in a universe with a matter density of 9×10^{-27} kg m^{-3}, a cosmological constant corresponding to $\Omega_\Lambda = 0.6$, a Hubble constant $H_0 = 70$ km s^{-1} Mpc^{-1}, and dynamically negligible radiation density.

   (a) Explain whether space is positively or negatively curved, and find the radius of curvature. [9]

   (b) Explain whether the expansion of the Universe is accelerating or decelerating, and find the value of the deceleration parameter, q_0. [5]

   (c) Make a qualitative sketch of the evolution of the scale factor with time, justifying the form of your plot and marking the position of the current epoch on it. [9]

   (d) Give two examples of observations which are inconsistent with this cosmology. [7]

8. (a) Discuss what you see as the strongest and weakest points of the current ΛCDM 'consensus cosmology'. [10]

   (b) Calculate the temperature of the Universe 1 s after the Big Bang, assuming that the evolution of the scale factor to the present day has followed the relation, $a(t) \propto t^{1/2}$, for a flat, radiation-dominated universe. Explain why this model is invalid, and say whether your derived temperature will be too high or too low. [12]

   (c) Given that the mean free path for electron scattering is

$$\lambda = \frac{1}{n_e \sigma_T},$$

   where n_e is the electron density, and the Thompson cross-section is $\sigma_T = 6.65 \times 10^{-29}$ m^2, show that the Universe will be very opaque at this $t = 1$ s epoch. [8]

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