Open note examination

UNIVERSITY OF BIRMINGHAM

DEGREE OF BSc & MSci WITH HONOURS

FINAL EXAMINATION

03 00716

(OBSERVATIONAL COSMOLOGY)

MAY/JUNE, 2006

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. Use a sketch to explain why the presence of a non-zero value for the cosmological constant (Λ) leads to an increase in the inferred age of the Universe. Argue from the Friedmann equation that a Universe whose evolution is dominated by Λ will expand exponentially. [10]

2. Show that Hubble's Law is consistent with the Cosmological Principle. [10]

3. Why is it reasonable to take the pressure of matter in the Universe to be zero at the present time, as in the "dust" model? Would this approximation still be valid at the epoch of recombination? [10]

4. Given that the overdensity of density perturbations grows linearly with the scale factor in an expanding Universe, explain why there is a problem reconciling the small amplitude of the fluctuations observed in the Cosmic Microwave Background, with the presence of virialised structures at the present epoch. How does the existence of dark matter enable this problem to be resolved? [10]

5. Explain why the Universe was radiation-dominated during its early evolution, and derive the time-dependence of the energy density, $\rho(t)$, during this phase. [10]

6. According to the currently popular hierarchical merging model, what is the evolutionary relationship between elliptical and spiral galaxies? [10]

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) Describe how the mass-to-light ratio of an elliptical galaxy could be estimated observationally. How would this estimate depend upon the value of H_0? [10]

   (b) If the bright elliptical galaxies at the centres of clusters are assumed to have a fixed physical diameter, show that in an Einstein-de Sitter universe (Ω_m=1, Λ=0) their observed angular sizes would be a minimum at $z \sim 1$, and would *increase* at higher redshifts. [15]

   (c) What difficulties can you see in using this method to constrain cosmological parameters? [5]

8. (a) With reference to the Robertson-Walker metric, explain the difference between the *comoving coordinate* and the *proper distance* of a distant galaxy. [5]

   (b) Adopting the time evolution of the scale factor, $a(t)$, appropriate for an Einstein-de Sitter universe, use the Robertson-Walker metric to calculate the comoving distance to our particle horizon. Why is this significantly larger than the distance ct_0 travelled by a photon over the age, t_0, of the Universe? [15]

   (c) Using this horizon distance, and assuming a typical galaxy luminosity of $10^{10} L_\odot$, estimate the total number of galaxies within the observable Universe. Explain the assumptions you make, and comment on the deficiencies in your estimate. [10]