The Handbook of Mathematics, Physics and Astronomy Data is provided

KEELE UNIVERSITY

EXAMINATIONS, 2012/13

Level III

Monday, 14th January 2013, 16:00–18:00

PHYSICS/ASTROPHYSICS

PHY-30001

COSMOLOGY

Candidates should attempt to answer THREE questions.

NOT TO BE REMOVED FROM THE EXAMINATION HALL

1. What is the best method of estimating the total mass of a l galaxy? Explain briefly how the method works. [20]

   Within a spherical volume with a radius estimated at 100 Mpc we observe 1.8 million galaxies with an average measured mass of 10^{11} $M_\odot$ each. What is the average density within this volume? [10]

   Assuming that this density equals the critical density, what must be the recession velocity of a galaxy on the edge of the 100 Mpc sphere, as seen from its centre? Use this to predict the value of H_0. [30]

   Suppose you observe the velocity of one galaxy 100 Mpc away. There are at least five reasons why the observed velocity might differ from your prediction, and why your predicted H_0 may not be accurate. List these reasons. [25]

   If you made the same estimates using volumes with radii much smaller or larger than 100 Mpc, would you expect to get the same answer? [15]

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2. Consider a flat universe consisting only of radiation and dark ene such that it obeys the Friedman equation:

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho_{\text{rad}} + \frac{\Lambda}{3}$$

for a positive cosmological constant Λ.

Stating your assumptions and justifying your arguments, find expressions for the expansion rate of this universe at different times. Sketch a as a function of t. [30]

Now consider the same universe but for a negative Λ. Again, justifying your answers, outline the behaviour of this universe over time and again sketch a against t. [30]

Give a physical interpretion of a negative Λ. [20]

Outline a type of observation that could tell you whether Λ was positive or negative. [20]

3. State the equivalence principle of General Relativity. [10]

Starting from the equivalence principle, produce an argument for why gravity must bend the path of light. [20]

Explain the principle of gravitational lensing; give an example of where gravitational lensing has been observed, sketching what is seen. [20]

Explain, in outline, how gravitational lensing might be used to trace the distribution of dark matter. [20]

Discuss the nature of dark matter and the observational constraints on its nature and distribution. [30]

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4. Explain what is meant by the "observable horizon" of the universe. Explaining your answer, discuss one easily made observation that demonstrates that there must be an observable horizon to our universe. [25]

   Is this observable horizon compatible with the Cosmological Principle? Justify your answer. [15]

   Consider a spatially infinite and homogenous but *static* universe. Assuming galaxies of uniform luminosity, show that the number of sources, N, brighter than some apparent brightness S has a slope of $-\frac{3}{2}$ on a plot of $\log(N)$ versus $\log(S)$. [25]

   If that (spatially infinite, homogenous, static) universe had a finite age, how would an observable horizon be revealed in your $\log(N)$–$\log(S)$ plot? Sketch this situation. [15]

   Discuss ways in which you expect our universe to differ from that universe. State possible differences you might expect to see in a $\log(N)$–$\log(S)$ plot. [20]

5. Three major pieces of evidence for our current Big Bang model are: (i) The Hubble flow; (ii) the existence of the Cosmic Microwave Background, and (iii) Big Bang nucleosynthesis. Taking each of these in turn, describe what is observed and explain why it supports the Big Bang model. [3 × 20]

   List and discuss the various observational evidences that point to a period of inflation early in the Big Bang. If our universe had not undergone inflation, how would it be different? [40]