UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualifications:-

B.Sc. *M.Sci.*

Astronomy 3C36: Cosmology and Extragalactic Astronomy

COURSE CODE	:	**ASTR3C36**
UNIT VALUE	:	**0.50**
DATE	:	**08-MAY-03**
TIME	:	**14.30**
TIME ALLOWED	:	**2 Hours 30 Minutes**

03-C0087-3-70

TURN OVER

Answer THREE questions.

The numbers in square brackets in the right-hand margin indicate the provisional allocation of maximum possible marks for different parts of a question.

The following may be assumed if necessary:

Energy density of black-body radiation, $U = aT^4$,
where the radiation constant is $a = 7.6 \times 10^{-16}$ J m^{-3} K^{-4}
Mean photon energy for black-body radiation at temperature T: $2.7kT$
Acceleration equation, $\frac{\ddot{R}(t)}{R(t)} = \frac{-4\pi G}{3}\left[\rho(t) + \frac{3p}{c^2}\right] + \frac{\Lambda}{3}$
Stellar Initial Mass Function, $\frac{dN}{dM} = K\left(\frac{M}{M_\odot}\right)^{-(1+\gamma)}$
Speed of light, $c = 2.998 \times 10^8$ m s^{-1}
Mass of hydrogen atom $m_H = 1.673 \times 10^{-27}$ kg
Boltzmann's constant $k = 1.381 \times 10^{-23}$ J K^{-1}
1 kpc $= 3.086 \times 10^{16}$ km

1. List, without going into detail, observed properties of the Universe that are successfully accounted for in the context of the Big Bang model. [3]

   Summarize the major difficulties the Big Bang model encounters. [6]

   Outline the main features of inflation, and show how it addresses difficulties with the Big Bang model. [9]

   If $\Omega_M = 0.3$ at $t_0(\sim 4.5 \times 10^{17}$s) and [2]

$$|\Omega(t) - 1| = \frac{|k|c^2}{R^2H^2},$$

   calculate by how much Ω_M differs from unity at the epoch of nucleosynthesis ($T \simeq 10^2$s), assuming that the Universe was radiation dominated ($R \propto t^{2/3}$) .

2. Discuss any two (but *only* two) of the following:

   - The evidence for a matter-based universe, and the Sakharov conditions for baryogenesis [10]
   - Small-scale structure in the cosmic microwave background. [8]
     What is the number density of 2.7K Cosmic Microwave Background photons? If such photons outnumber baryons by a factor 10^9, what is the ratio of matter:radiation energy density in the present-day universe? [2]
   - The 'winding problem', and the nature of spiral structure. [8]
     Provide a numerical illustration of the winding problem by calculating the pitch angle and interarm separation if the rotational velocity of a galaxy is 200 km s^{-1} at a galactocentric distance of 8 kpc. [2]

3. Briefly summarize the principal arguments for the existence of 'dark matter', noting in each case the possible nature of that matter. [6]

Describe in detail three methods for determining masses of clusters of galaxies. [14]

4. Discuss the narrow-line absorption systems observed in the spectra of quasars. [10]

Describe the Gunn-Peterson test [7]

The number of quasar absorption lines between redshifts z and $z + dz$ due to intervening bodies is given by [3]

$$\frac{dN}{dz} = \frac{n_0 \sigma(z) c}{H_0} \frac{1+z}{\sqrt{1+\Omega_0 z}}$$

where n_0 is the present-day number density of absorbing bodies, each having cross-sectional area $\sigma(z)$ at redshift z. If damped Ly-α systems are due to intervening galaxies or their progenitors, estimate $\sigma(z=3)$ if there are $n_0 \simeq 0.05$ galaxies Mpc^{-3}, $dN/dz = 0.15$ at $z = 3$, and the universe has a flat geometry. Express your answer in terms of h, in units of kpc^2.

5. Without recourse to mathematical detail, briefly describe the 'G-dwarf problem', and possible solutions thereto. [4]

If $t_{\rm MS}$, the main-sequence lifetime of a solar-type star, can be approximated by [7]

$$\left(\frac{t_{\rm MS}}{10\ \rm Gyr}\right) \simeq \left(\frac{M}{M_\odot}\right)^{-2.5}$$

show that the late-time dependence of the luminosity of an isolated, coeval stellar population can be described by

$$L(t) = K E_{\rm RG} \left(\frac{M_{\rm RG}}{M_\odot}\right)^{2.5-\gamma} \left(\frac{M_\odot}{25\ \rm Gyr}\right), \qquad (5.1)$$

explaining the meaning of all symbols, and all assumptions made.

Show further that the mass of metals injected by such a population into the interstellar medium (ISM) is [7]

$$M_Z = \frac{\alpha K M_\odot^2}{\gamma - 1} \left(\frac{M_\odot}{M_{\rm min}}\right)^{\gamma-1} \qquad (5.2)$$

where α is the fraction of the initial mass of a star returned to the ISM in a supernova explosion.

By using equations 5.1 and 5.2, compute $M_Z/L(t_0)$, the mass of metals per unit present-day luminosity for this population, if [2]

$\alpha = 0.1 \quad \gamma = 1.4 \quad M_{\rm RG} = 0.85 M_\odot \quad E_{\rm RG} = 3 \times 10^{10} L_\odot\ {\rm yr} \quad M_{\rm min} = 10 M_\odot$

State the units in which you give your result.

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