Queen Mary
University of London

M.Sc. EXAMINATION

ASTMO52 Extragalactic Astrophysics (Sample paper)

xxxxx, xx May 2008 xx:xx-xx:xx
Duration: 1.5 hours

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1. (a) [8 marks]

Use a simple argument to show that H_0^{-1} is a measure of the age of the universe and use current values of H_0 to estimate this age.

[Solution]

(b) [8 marks]

Sketch the Hubble tuning-fork diagram and describe the different types of galaxies it includes.

[Solution]

(c) [9 marks]

Explain briefly how the rotation curves of spiral galaxies can be determined by combining observations made at optical and radio wavelengths. How does the galaxy's orientation to the line-of-sight affects these measurements?

[Solution]

2. (a) [13 marks]

In the solar neighbourhood, the stellar mass-function $\varphi(M)$ is given by

$$\varphi(M) = \varphi_* \left(\frac{M}{M_*}\right)^{-\alpha},$$

where M is the mass of a star and φ_* and M_* are constants. Show that the total mass density M_{total} of stars per unit volume is given by

$$M_{total} = \frac{\varphi_* M_*^2}{(\alpha - 2)} \left(\frac{M_{low}}{M_*}\right)^{2-\alpha},$$

where M_{low} is the lower cut-off of the mass spectrum.

[Solution]

(b) [12 marks]

The luminosity L of a main sequence star is very roughly proportional to its mass to the power 3.3

$$L(M) = L_* \left(\frac{M}{M_*}\right)^{3.3},$$

where L_* is the luminosity of a star of mass M_*. Show that the total luminosity-density L_{total} of stars in the solar neighborhood is given by

$$L_{total} = \frac{\varphi_* M_* L_*}{(4.3 - \alpha)} \left(\frac{M_{high}}{M_*}\right)^{4.3-\alpha},$$

[This question continues overleaf . . .]

where M_{high} is the upper cut-off of the mass spectrum.

[Solution]

3. (a) [7 marks]

Outline briefly why many astronomers believe that the ultimate power source in the active galactic nuclei (AGN) is the accretion of matter through a disk around a supermassive black hole.

[Solution]

(b) [8 marks]

The Eddington luminosity $L_{Eddington}$ of an object of mass M is given by

$$L_{Eddington} = 4\pi \frac{GMm_p c}{\sigma_T},$$

where m_p is the mass of the proton and σ_T is the Thomson scattering cross section. Show that this relationship can be obtained from equality of two forces: the first force is the pressure of radiation acting on electrons, while the second force is the gravitational force acting on protons. Why should these two forces acting on different objects be equal?

[Solution]

(c) [10 marks]

The luminosity $l(r)$ per unit area of an accretion disc around a black hole of mass M, at a distance r from the centre of the disc, is given by

$$l(r) = \frac{3}{8\pi} \frac{GM\dot{m}}{r^3} \left[1 - \left(\frac{r_{lso}}{r}\right)^{1/2}\right],$$

where r_{lso} is the radius of the last stable orbit. Give a physical reason for the luminositys vanishing at r_{lso} itself. Assuming that the accretion disc radiates as a black body, estimate the maximum temperature occurring in a disc, around a black hole of mass $10^8 M_\odot$, accreting material at the rate of one solar mass a year, and calculate the typical energy of the corresponding emitted photons.

[Solution]

4. You can assume that a black hole binary emits gravitational wave with frequency

$$\nu = \frac{2}{T}$$

and amplitude

$$h \approx \frac{m}{M}\frac{r_g^2}{rR},$$

where T is the orbital period, r is the separation distance between the two black holes, R is the distance to the binary and r_g is the gravitational radius of a more massive black hole ($M > m$).

(a) [7 marks]

From what distance will it be possible to detect gravitational radiation from the binary system containing supermassive black holes of mass M and αM if the orbital period, T, is given?

[Solution]

(b) [7 marks]

How small should the separation between the black holes in the binary be in order to detect gravitational waves from the binary if the distance and the masses are given?

[Solution]

(c) [11 marks]

How many sources of gravitational radiation can be detected if the distribution of the binaries over masses, frequencies and distances is known?

[Solution]

[End of examination paper.]