Final Examination

Physics 3151 Winter 2003–2004

16 April 2004

Instructions

Answer *four* out of the following *nine* questions. All questions have equal value. The examination is intended to be of two hours' duration.

1. Describe the formation of a main–sequence star from a cloud of gas and dust, making reference to the virial theorem and to angular momentum considerations. What impediment would star formation encounter in the early universe, where there is no dust and the gas has zero metallicity (excepting a little $^7_3\mathrm{Li}$)?

2. Describe in detail the structure and functioning of a typical H II region.

3. State the "Cosmological Principle". To what extent is it supported by what is known of the distribution of galaxies? To what extent is it supported by the existence and distribution of the CMBR? What are some alternatives to the Cosmological Principle?

   (a) What is meant by "dark matter"? How is it detected.

4. Derive the Friedmann equation

$$\left[\left(\frac{1}{R(t)}\frac{dR(t)}{dt}\right)^2 - \frac{8}{3}\pi G\rho(t)\right] R(t)^2 = -kc^2$$

   in Newtonian cosmology for a "dust"–filled universe.

   (a) What is meant by "dust" in cosmology? Is the very early universe "dusty" (say at $t = 100\,\mathrm{s}$)?

   (b) Solve the Friedmann equation for $k = 0$, and express the solution in terms of the Hubble time $t_H = 1/H_0$.

5. What is meant by the "Strong Principle of Equivalence"? How does it lead to the prediction that a gravitational field deflects light, and to gravitational time dilatation or redshift? Outline the principal assumptions of general relativity.

   (a) Describe the structure of an AGN, and describe which parts are responsible for radio emission (as in radio galaxies and radio–loud quasars), emission in the visible (quasars, Type I and Type II Seyfert galaxies), and X ray and γ ray emission. Describe the optical spectra of quasars and of the two types of Seyfert galaxy.

6. Describe the X − ray and γ−ray sources known as "X − ray binaries", with reference to their luminosities and variability. What is the difference between accretion in LMXBs and in MXRBs thought to be? What types of compact objects are found in X − ray binaries? Describe either Her X − 1/HZ Her or Cyg X−1/HDE 226868 in detail.

7. From studying the light curves and optical spectrum of Algol (β Per) it is known to comprise an old, evolved star and a younger, *more massive*, companion, in a system which is nearly eclipsing. Why is this paradoxical? Give a resolution for this apparent making detailed reference to the Roche model and the movement of the Lagrangian point L_1 in the course of the evolution of the system.

8. Describe a procedure by which the separation and masses of a double–lined eclipsing spectroscopic binary can be determined. You may assume that the eclipses are total.

   (a) U Cep is an Algol system with an orbital period of 2.49 da that has increased by about 20 s in the past 100 years. The masses of the two stars are $m_1 = 2.9M_\odot$ and $m_2 = 1.4M_\odot$. Assuming that this change is due to the transfer of mass between the two stars in this system, estimate the mass transfer rate.

9. Write an essay of two pages or so on a topic in astrophysics of your own choosing.

$G = 6.7 \times 10^{-11}\,\mathrm{N \cdot kg^{-2} \cdot m^2}$
$c = 3.0 \times 10^8\,\mathrm{m \cdot s^{-1}}$
The sesquialterate law: $P^2 = \frac{4\pi^2}{G(m_1+m_2)}a^3$.
$M_\odot = 2.0 \times 10^{30}\,\mathrm{kg}$
$R_\odot = 7.0 \times 10^8\,\mathrm{m}$