Register Number:
Date:

ST. JOSEPH'S COLLEGE (AUTONOMOUS), BANGALORE-27
M.Sc. PHYSICS - IV SEMESTER
SEMESTER EXAMINATION: APRIL 2018
PHDE 0417 - ASTROPHYSICS

Time-2 1/2 hrs. **Maximum Marks-70**

This question paper has 5 printed pages and 2 parts

PART A

Answer any FIVE full questions. **MAX. MARKS 5x10=50**

1.
   (a) What is the main function of a telescope? (**2 Marks**)
   (b) Explain Light Grasp of a telescope. (**3 Marks**)
   (c) Use the concept of light grasp to work out the limiting magnitude that a telescope can see. (**5 Marks**)

2.
   (a) Describe the evolution of a $40\,M_{\odot}$ star. Your description should include details of the evolution in the main sequence and post main sequence as well and as to what such stars will result in at the end. (**6 Marks**)
   (b) Will these stars form Horizontal branch stars? Explain. (**4 Marks**)

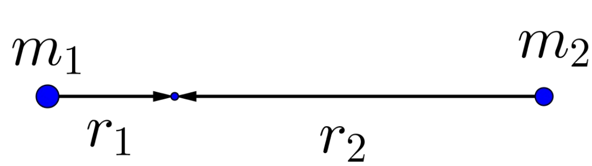

Fig.1: For question 5

3. Two masses m_1 and m_2 each revolve about their center of mass at distances r_1 and r_2 respectively in circular orbits.
   (a) Show that the system is equivalent to one smaller body revolving around another larger stationary body with a mass of $M = m_1 + m_2$. What is the mass of the smaller body? (**3 Marks**)

(b) Using this smaller mass, prove Kepler's Third law. (**7 Marks**)

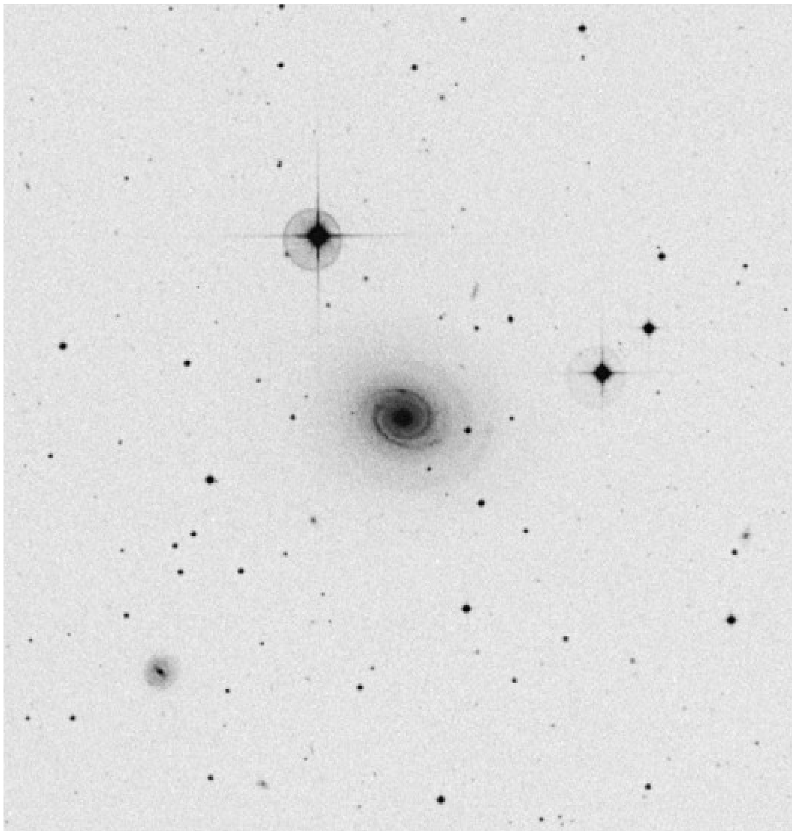

Fig. 2: NGC 1357. The field of view is 0.28 degrees (along x-axis and y-axis)

4. For a spherical object with uniform surface brightness B having a diameter D and at a distance l from a detector, show that the flux is $F=\frac{\pi}{4}B\frac{D^2}{l^2}$. The usual definitions hold ($dE=I_\nu\, dA\, dt\, d\Omega\, d\nu$ and $F_\nu=\int I_\nu \cos\theta\, d\Omega$).

5. Let u_{int} be the internal energy per unit mass of the material of a star. We will assume that $u_{\text{int}}=\varphi\frac{P}{\rho}$ where φ Is a dimensionless constant and P and ρ are the outwardly directed internal pressure and density respectively of the star. The internal structure equations (assuming a constant temperature throughout the star) are given by: $\frac{dm}{dr}=4\pi r^2\rho$ and

$$\frac{dP}{dr} = -\frac{Gm\rho}{r^2}$$ (where m is the mass of stellar material within a sphere of radius r).
Using this work out the relation between the internal energy and gravitational energy of the star (remember the total internal energy is $U_{\text{int}} = \int_V u_{\text{int}} \rho \, dV$ and the gravitational potential energy is $E_{\text{gr}} = -\int \frac{Gm}{r} dm$)

6.
(a) What are molecular clouds? (**2 Marks**)
(b) Jeans instability causes the collapse of interstellar clouds to form proto-stellar bodies. It occurs when internal pressure is not strong enough compared to gravitational potential energy. Jeans length is the critical radius of the cloud at which thermal energy (that causes the cloud to expand) is counteracted by gravity (that causes the cloud to collapse). Using energy considerations within the definition given here, estimate Jeans length in terms of the cloud temperature and density. (**8 Marks**)

7.
(a) The average density of baryons in the Universe is $\bar{\rho} = (0.044 \pm 0.004)\rho_c$ where $\rho_c = \frac{3H_0^2}{8\pi G}$ is the critical density for which, the universe can be considered to be flat (H_0 is the Hubble constant $= 70 \, \text{km s}^{-1} \, \text{Mpc}$).
  i. Calculate the number density of H -atoms (protons) in SI units. (**3 Marks**)
  ii. On the other hand, if we assume that all baryons are contained in stars like our Sun (i.e. all stars have $M = 1 \, M_\odot$ and are assumed to contain only H), what would be the density of stars (assume uniform distribution of stars – i.e. ignore that there are galaxies). (**4 Marks**)
(b) If the temperature of the Cosmic Microwave Background Radiation (CMBR) is $T = 2.7 \, \text{K}$, what is the frequency of the photons making up the CMBR? (**3 Marks**)

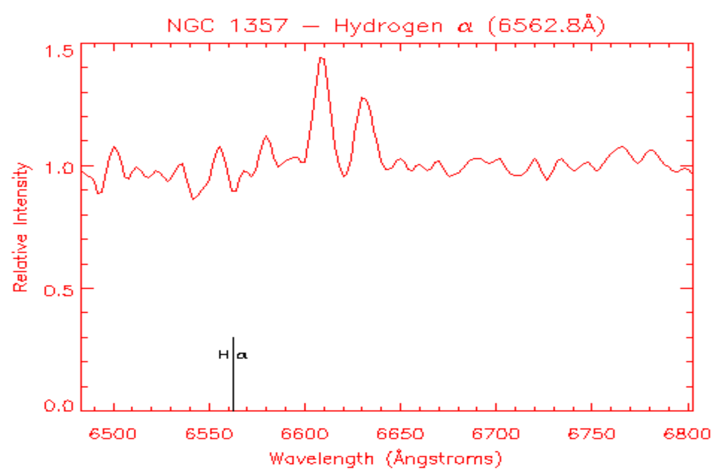

Fig. 3: NGC 1357 - H-alpha emission line(the tallest emission line in the spectrum).

PART B

Answer any <u>FOUR</u> full questions. **MAX. MARKS 4x5=20**

[Constants: h=6.6x10^{-34} J s (Planck's constant), 1eV = 1.6x10^{-19} J (electron volt to Joules), c=2.99x10^{8} m/s (speed of light), 1Å = 1x10^{-10}m (Angstrom to meters), e = 1.6x10^{-19} C (electronic charge), m_{proton}=1.673x10^{-27}kg (mass of proton), $m_{electron}$=9.109x10^{-31}kg (mass of electron), G=6.674x10^{-11}m^{3}kg^{-1}s^{-2} (Gravitational constant), $M_\odot$=1.9891x10^{30} kg (Solar mass), $R_\odot$=6.9x10^{8} m, σ = 5.67x10^{-8} W m^{-2} K^{-4} (Stefan-Boltzmann constant), M_{Earth}=5.97x10^{27}kg (Mass of Earth), $D_{earth\text{-}sun}$=1.49x10^{11}m (Earth-Sun distance), 1 inch = 2.54 cm, 1AU = 1.496x10^{11} m, 1 ly= 9.461x10^{15} m, 1 pc= 3.086x10^{16}m]

8. Use Fig. 2 and Fig. 3 to calculate the Hubble constant. Fig. 2 shows an image of the galaxy NGC 1357. The Field of View (FOV) of the image is 0.28°. The typical size of a galaxy is $20\ \text{kpc}$. With this information work out how far the galaxy is. In Fig. 3, the tallest emission line you see is that of H_α. In the lab, the H_α line occurs at 6562 Å.
   (a) Is NGC 1357 coming towards or receding from us? (**1 Mark**)
   (b) At what speed is this happening? (**1 Mark**)
   (c) What is the Hubble constant from the given data (it may not be accurate – but that's okay)? (**3 Marks**)

9. If we assume that the Sun is entirely powered by its gravitational potential energy, with its rate of energy output (Luminosity = $3.839\times10^{33}\,\text{ergs s}^{-1}$), how long would it last? Express your result in years.

10. Assuming Earth's central density to be $\rho_c = 10\ \text{g cm}^{-3}$ and that the density varies linearly from the center outward: $\rho = \rho_c\left(1 - \frac{r}{R_{\text{Earth}}}\right)$. The variation of mass is given as $\frac{dm}{dr} = 4\pi r^2 \rho$. The list of constants above gives the mass of Earth – for this mass, what would the computed R_{Earth} be? How does this compare with the actual value of $6371\,\text{km}$?

11. Proxima Centauri is a sun-like star with a radius of $7\times10^{8}\ \text{m}$ and at a distance of $4.4\ \text{ly}$. Calculate the solid-angle (in steradians) subtended by Proxima Centauri at Earth.

12. For a telescope having an aperture of 6 inches and a focal length of 1 m calculate the values for:
   (a) Limiting magnitude of an object that can be viewed from the telescope. (**1 Mark**)
   (b) Its resolving power. (**2 Marks**)
   (c) Maximum magnification (**2 Marks**)

13. If we assume that the Sun is entirely made up of Hydrogen and that all of this will fuse to Helium nuclei through $p-p$ for which the Q-value is 0.007 and that it will continue to emit energy uniformly at the rate of 3.839×10^{33} ergs s^{-1} what will by the Sun's lifetime in years?