Discipline of Astronomy, Astrophysics and Space Engineering

INDIAN INSTITUTE OF TECHNOLOGY INDORE

Spring Semester	**Academic Year 2020-21**
Mid Semester Exam	**Course Code : AA 472N/672N**
Date: **25 January 2021** Max. Time Duration : **2 Hr (from 10:00 am)**	Max Marks : **40**
Number of Questions : 4	Number of pages in the Question Paper: 2

Instructions:

- The **exam starts at 10:00 am and will be of 2 hrs. Additional 30 minutes will be given to upload the answer sheet**.
- Write your **Roll number and name on each page of the answer sheet** that you will scan and upload as a PDF file.
- All Questions are compulsory and should be answered in the same order. Further **insert page numbers on all pages**. The sub-questions within each question should also be answered in order.
- All questions are clear and in case if you feel that there is something missing and need to assume then go ahead and state the assumption and justification.
- *Undertaking :* Every student is requested to copy this undertaking and fill up with their name, roll-number, signature and date on the first page of their answer-sheet.
  Without this undertaking, answer sheet will not be considered as a valid one:
  *I, ———(write your name and roll number) ————————- hereby declare that during the course of this exam, have **NOT USED** any means of communication through phone, chat or any messaging, VoIP or social media app to discuss regarding this exam with any human or any bot. (your signature and date)*

1. *Distances and Magnitudes* – **Total : 10 marks**
   Consider a star within our Milky Way galaxy that has an effective temperature of 3500 K and a diameter of 0.045″. The trigonometric parallax is observed to be 0.007″.
   - Find the distance of this star (in parsec), radius (in units of solar radius $R_\odot$), luminosity (in terms of $L_\odot$) [3 marks]
   - Define sensitivity and resolution of an optical telescope. If the above star has an apparent magnitude of 8.0, will it be visible to an unaided eye whose limiting magnitude is 6.0. [2 marks]
   - Consider this star to be part of a quadruple system with three other identical stars at the same distance. Find the apparent and absolute magnitude of this quadruple system and comment if the system is brighter or fainter with respect to an individual star [3 marks]
   - If one of the star has galactic co-ordinates as (l,b) = (45°, 0°), find the approximate distance to this quadruple system from the Galactic centre. [2 marks]

2. *Milky-way Kinematics* – **Total : 10 marks**
   The following information relating to the properties of Milky Way galaxy is available with you : a) Distance from the Galactic Center is $R_0 = 8.122$ kpc, b) the proper motion of Sgr A* (Galactic Center) is $\Omega = 6.38$ milliarcseconds/year, c) the solar motion is 12 km/s ahead of the Local Standard of Rest, and d) the measured radial and tangential velocity dispersions of local stars are related by $\sigma_r^2 = 2.2\sigma_\phi^2$. Using the above information obtain the following quantities :
   - Our reflex speed with respect to the Sgr A* [2 marks]
   - The Orbital velocity of the Local Standard of Rest around the centre of the Milky Way? [2 marks]
   - The Oorts' constant A and B ? [4 marks]
   - What interpretation about the rotation curve can be made based on values of Oorts constant ? [2 marks]

3. *Spiral Galaxies* – **Total : 10 marks**
For a typical spiral galaxy, the azimuthally averaged radial light profile can be fitted using *exponential disks*.

$$I(r) = I_0 \exp\left(-\frac{r}{R_d}\right)$$

where I_0 is the value of central surface brightness in solar luminosities per square parsec and R_d is the scale length in kpc.

- Estimate the total Luminosity (L) that is enclosed with $x = r/R_d$ scale lengths. What is the total luminosity in the limit $x \to \infty$? How many scale lengths contain half the total light ? Plot the cumulative enclosed luminosity $L(< x)$ and mark the half light radius. [6 marks]
- Assuming a "spherical disk" obtain the expression of rotation velocity $V_d(r)$ from $L(x)$ assuming M/L to be constant along the radius and plot $V_d(r)$. Argue why choosing M/L as a constant throughout the disk is justified for spiral galaxies? [4 marks]

4. *Relevant Timescales* – **Total : 10 marks**

(a) Derive the expression for relaxation time scale considering only weak encounters of stars and show

$$t_{\rm relax} = \frac{t_{\rm s}}{2\ln\Lambda}$$

where $\Lambda = b_{\rm max}/b_{\rm min}$ with b being the distance of impact and t_s is the strong encounter time scale. [6 marks]

(b) Consider a star in the two cases mentioned below. Obtain the value in years for a) Crossing time scale, b) Relaxation timescale and c) Strong encounter time scale for such a typical star with following information : (Assume $\ln\Lambda = 20$).

- Globular cluster : Size = 5 parsec , Velocity = 10 km/s and number density = 10^4 pc^{-3} [2 marks]
- S0 galaxy : Size = 60000 light years, Velocity = 30 km/s and number density = 0.1 pc^{-3} [2 marks]