PHY669: Astronomical Technique **End-Sem** **Apr 30th, 2025**

Maximum Mark: 40 (2 for details/logic) **Time: 180 minutes**

Name: **Roll-No:**

(i) Write your answers clearly stating all underlying assumptions (if any). Show all calculation steps.

(ii) Clearly indicate the final answer (and units if applicable). You may leave at the **final arithematic-part/expression in case you don't have a calculator**

(iii) Write your ***Answer in BLANK SPACE*** immediately after the question

1. (points) [3] Describe/list the fundamental observational differences between gravitational wave and electromagnetic radiation?

2. (points) [3] Sketch all the geometrical configurations originally proposed for X-ray telescopes (clearly mention the geometrical shapes). Which one is used mostly and why, explain briefly?

3. (points) [7 (2+4+1)]

   (a) Write the SNR (signl-to-noise ratio) of a very bright source (background is negligible) as a function of observation time t?

   (b) The 2-D image of a faint galaxy observed by a CCD covers 50 pixels. For an exposure of 5 seconds a total of 5×10^4 photo-electrons are recorded by the CCD from these pixels. An adjacent section of the CCD, covering 2500 pixels, records the background sky count. During the same exposure time a total of 5×10^5 photo-electrons are recorded from this adjacent section. Calculate the SNR and rate (with error)?

   (c) For the case above (b), estimate the length of exposure required to increase the SNR ratio to 50.

4. (points) [11 (2+ 1 + 2 + 2 + 2+ 2)]

   (a) Which primary instrument/device is used for detecting photons at Optical-UV and X-ray energies? In terms of the device characteristics, what is the primary differences between the two?

   (b) Mention the fundamental physical interaction used/exploited in the detection/observation of radio, infra-red, optical, UV, X-ray, and gamma-ray photons/radiations?

   (c) A rectangular gas detector is shielded for radiation from all directions except at the top. The top is made of a mica window of thickness l_w with an extinction coefficient/cross-section of μ_w (m^2/kg). The gas behind the window extends to a length d_g with a photoelectric absorption cross-section of σ_a and density n_g. Find the probability of absorption of the radiation by the gas (state all your assumptions clearly).

(d) Describe and explain briefly different type of mounting used for ground based telescopes (NIR/Radio/Optical).

(e) What is the expected ratio of different flavors of neutrions+anti-neutrinos in an EAS (Extensive Air Shower) and why?

(f) Describe briefly the basic working principle of Super kamiokande Japan neutrino observatory? How does it determine the direction of the observed neutrinos?

5. (points) [5 (4 +1)]

(a) How far (in light years) will a gamma ray of energy E = 1 PeV (= 10^{15} eV) travel with a 37% chance of not interacting with the CMB. Repeat it for a 1% chance. At this energy, the cross section for the interaction with a given photon of the CMB is $\sigma \approx 1 \times 10^{-29} m^2$. The number of CMB photons per unit volume is $n = 2.0 \times 10^7\ T^3\ \mathrm{m}^{-3}$ where the temperature of the CMB is T = 2.735 K. Assume the universe is static ($dI \propto e^{-\ \text{optical-depth}}$).

(b) The semi-conductor compound $H_xCd_{1-x}Te$ (x $\sim$ 0.8) leads to a band gap of 0.1 eV. What is the maximum wavelength for which this detector can be used?

6. (points) [2 (1+1)] Write the expression for the T_A in terms of the source brightness $B(\theta, \phi)$? What would be the T_A for the source of uniform brightness?

7. (points) [3] Derive the relation between directionality $D(\theta, \phi)$ and effective area A_e?

8. (points) [3 (1+2)] Photoelectric effect is one of the channels of interaction between a high energy photon (energy >= UV) and an atom. Usually the most tightly bound electron is involved in the process. The cross-section for this process is inversly proportional to the cube of photon energy. Assuming the Solar composition. which of the EM from radio to gamma-ray will be least affected and why (assume atomic gas)? If an EM of same intensity (numer of photons) from radio to gamma-ray passes through this medium, estimate the ratio of absorption for each band (relative to UV, assuming UV as 1).