AA 405/605

Assignment IV

Date: 28.10.2021 **Deadline: 12.11.2021**

1. The latitude and longitude of Indore is 22.7196° N and 75.8577° E. The LST at Indore on 01 November, 2021 at 9PM (IST, local time) is 23.25 Hrs. The star Betelgeuse is a bright supergiant star which will explode following a supernova in the (near?) future. Recently it generated a lot of interest as it has been consistently dimming since December 2019 indicating significant implication about its fate. This dimming in intensity of the star is more deeper, faster and longer than any previous behaviour observed from this variable star. Calculate the altitude and azimuth of Betelgeuse (RA = 05 h 55 m 10.3 s, Dec = $+07°24'25''$) as measured from Indore at that time.

2. An observer is located at latitude ϕ and longitude λ. Calculate the altitude of the celestial pole and the altitude of the celestial equator for this observer.

3. The most northerly star of the Southern Cross, γ Crucis, has declination $-57°$. At what latitude will it just be visible? At what latitude will it pass directly overhead? At what latitudes will it never set?

4. (a) What is the difference of magnitudes for two stars if one is a million times "brighter" than the other? (b) The original Palomar Observatory Sky Survey photographic plates reach to a magnitude of about $m = 21$. Compared to the brightest stars, $m \approx 0$, how "faint" are the 21st magnitude stars, i.e., what is the ratio of fluxes? Repeat for the Hubble Space Telescope (HST) which can reach to $m_V \approx 28$. (c) The bright star Sirius has $m_V = -1.44$ and is at distance 8.8 LY. Would Sirius be visible to the HST if it were in our sister galaxy Andromeda at distance 2.5 MLY? (d) Would a star identical to the sun (absolute magnitude $M_V = 4.82$) in Andromeda be visible to the HST?

5. (a) Prove that specific intensity in distance-independent.

   (b) The surface brightness of a galaxy at a distance d is I_0 mag arcsec^{-2}. I_0 corresponds to the total galaxy flux per arcsec^{-2}. Assume that the galaxy is made up of stars of absolute magnitude M. Show that the number of stars contained within 1 arc second square patch of the image of this Galaxy is given by

$$N = \left(\frac{d}{10 \text{ pc}}\right)^2 10^{0.4(M-I_0)}$$

6. (a) Compute the specific flux F_ν (in erg/cm^2/s/Hz) and F_λ in erg cm^{-2} s^{-1} $\AA^{-1}$ from a $V = 22$ magnitude galaxy. What is the rate at which V-band photons from this object in the V band strike the mirror of the Hale 200-inch-diamter telescope from this object? [For Vega in V band, $F\lambda = 3.63 \times 10^{-9}$ erg cm^{-2} s^{-1} $\AA^{-1}$, and $F_\nu = 3.636 \times 10^{-20}$ erg/cm^2/s/Hz]

   (b) A spectrum of this galaxy is taken. The effective entrance aperture of the spectrograph is 2×2 arcsec^2 . The surface brightness of the night sky at Palomar in the V band on a dark night is 20.4 mag/arcsec^2 (i.e., 1 arcsec^2 emits a flux equivalent to that of a V = 20.4 mag object). What is the effective V magnitude of the foreground sky patch as seen by the spectrograph in its aperture?

(c) Now assume that the overall efficiency of the telescope + spectrograph + detector is 10%. A resolution element in the spectrum is 10 $\AA$ wide, and we are interested in the region around $\lambda = 5500\AA$. How many counts per resolution element are detected from the galaxy spectrum alone in a 1-hour exposure? From the foreground sky?

(d) If a blank piece of sky is measured at the same time in order to subtract the sky spectrum from the total, what is the signal-to-noise ratio per resolution element in the final, sky-subtracted galaxy spectrum? (Neglect the detector noise, and assume Poisson photon statistics.)

7. Calculate the distance of a Cepheid whose apparent magnitude is +13 magnnitude on average, and whose absolute magnitude is -4 m on average, assuming that it is affected by interstellar absorption at a rate of 1.5×10^{-3} mag pc^{-1}.

8. For a spectrometer, if x is the linear distance along the spectrum from some reference point, then we have for an achromatic imaging element of focal length f_2, the *linear dispersion* is given as

$$\frac{dx}{d\lambda} = f_2 \frac{d\theta}{d\lambda}$$

where θ angular distance along the image. A grating is used in first order, with the spectrum observed at an angle of 15° with respect to the grating face. If the spectrograph has a camera of focal length 300 mm, how many lines per mm are required to give a reciprocal linear dispersion of 20 $\AA$/mm?