

Exam FY3490 Observational Astrophysics

Lecturer: Prof. Manuel Linares

Examination date: June 2nd 2022.

Examination time (from-to): 9am – 12pm

Permitted examination support material: Approved calculator + formula sheet

Other information: This exam accounts for 50% of the final grade. Total score: 10 points.

Official formula sheet provided. Read carefully. Good luck!

Problem 1 [2 points]. An “interloper” in optical astronomy is a star whose angular position in the sky is very close to our science target (say $< 0.5''$). The interloper (star 1) and science target (star 2) appear very close in an optical image, even if they can be far from each other.

- In bad observing conditions (e.g. with a seeing $> 1.5''$), we cannot resolve the two stars and we measure an apparent magnitude $m_3 = 18.64$ for the resulting blend of the two sources. Calculate the true apparent magnitude of our science target, m_2 , knowing that the interloper has an apparent magnitude $m_1 = 20$. [1 p]
- Give the distance to the interloper (in kpc), if it has an absolute magnitude $M = 5$ and the extinction in this band is $A = 0.5$ mag. [0.5 p]
- If we observe from space with a 1m telescope (avoiding atmospheric turbulence), what sets the minimum/best possible angular resolution? In which wavelength range can we observe to resolve an interloper which is $0.3''$ from our target? [0.5 p]

Problem 2 [2 points]. Consider the declination (δ), maximum altitude (h) and zenith angle (z) of a star, as seen from a geographical latitude L .

- Derive the relation between h , δ and L . What is the minimum declination observable from Barcelona ($L = 41^\circ$ N) above the horizon? And at an altitude of at least 30° ? [0.5 p]
- In the common plane-parallel atmosphere approximation, calculate the dimensionless airmass (column density relative to its minimum value towards the zenith) for a zenith angle $z = 35^\circ$. [0.5 p]
- Calculate the fraction of the sky which is visible throughout a full year from Barcelona ($L = 41^\circ$ N) above the horizon. [1 p]

Problem 3 [2 points]. On a particular night, the planet Mars has an angular diameter of 15 arcsec and an energy flux of $1.0 \times 10^{-7} \text{ W m}^{-2}$. Two astronomers observe the planet, using identical CCD cameras whose pixels are 25 μm apart. Albert uses a telescope of 0.3m aperture whose focal ratio is f/8. Bertha uses a telescope of 30 m aperture whose focal ratio is f/4.

- Calculate the surface brightness (energy flux per unit area in the sky) of Mars in units of $\text{W m}^{-2} \text{ arcsec}^{-2}$. [0.5 p]
- How much energy accumulates in a single pixel of Albert's CCD image of Mars in a 100 s exposure? Give your answer in Joules. [0.75 p]
- How much energy (in J) accumulates in the same time in a single pixel of Bertha's image of Mars? [0.75 p]

Question 4 [1 point]. The bolometric peak luminosity of thermonuclear bursts is $[3.79 \pm 0.15] \times 10^{38} \text{ erg/s}$. Observing a newly discovered neutron star, we measure during a thermonuclear burst a bolometric peak flux of $[6.7 \pm 0.7] \times 10^{-8} \text{ erg/s/cm}^2$.

- Assuming that this is a standard candle, calculate the distance and its uncertainty, both in kiloparsecs (kpc). [0.5 p]
- Assuming that the measurements are normally distributed and that the quoted uncertainties represent 1-sigma confidence regions: estimate the probability that the newly discovered source is more than 7.64 kpc away. [0.5 p]

Question 5 [1 point]. In a long-slit optical spectrum:

- If the dimensionless spectral resolution is $R=1000$, what is the resolution in $\text{\AA}$ and in km/s at the Hydrogen alpha line (6563 $\text{\AA}$)? [0.25 p]
- If the spectrum covers the range 3650-7110 $\text{\AA}$ with 2035 pixels, what is the average dispersion? [0.25 p]
- From your answers above, how many pixels sample one full resolution element? [0.25 p]
- State the Nyquist criterion and, based on it, explain whether this spectrum is over, under or critically sampled. [0.25 p]

Question 6 [1 point]. A CCD pixel has 95000 e⁻. If the full-well depth of the pixel is 100000 e⁻, the gain is 1.4 e⁻/ADU and a 16-bit ADC is used, will the pixel be saturated? Explain why.

Question 7 [1 point]. Optical and X-ray telescopes.

- Draw schematically a Cassegrain reflector telescope, showing the primary and secondary mirrors and the Cassegrain focus. [0.5 p]
- Explain briefly the difficulties in focusing X-rays and the physical principle used to overcome them. [0.5 p]