Department of Physics

Examination paper for FY3215 – Observational Astrophysics

Examination date: May 15th 2023

Examination time (from-to): 15:00-19:00

Permitted examination support material: Approved calculator + formula sheet

Academic contact during examination: M. Linares
Phone: 95754811

Academic contact present at the exam location: YES (17:00-18:00)

OTHER INFORMATION
This exam accounts for 50% of the final grade. Total score: 10 points. Official formula sheet provided. Read carefully. Good luck!

Get an overview of the question set before you start answering the questions.

Read the questions carefully and make your own assumptions. If a question is unclear/vague, make your own assumptions and specify them in your answer. Only contact academic contact in case of errors or insufficiencies in the question set. Address an invigilator if you wish to contact the academic contact. Write down the question in advance.

InsperaScan: For all problems and questions you are meant to answer on handwritten sheets.

Problem 1 [2 points]. A CCD observes two sources in the same band, 400-600 nm. Source A has a spectrum such that the distribution of photons (or "spectral photon flux density") in the 400-600 nm band is given by $p_A(\lambda)=A\lambda^3$. Source B has a distribution of photons given by $p_B(\lambda)=B\lambda^{-2}$ in the same band. The two sources generate photoelectrons at exactly the same rate.

a. Find the relation between the normalization constants A and B, if the wavelength λ is expressed in microns. [1 p]
b. Compute their brightness ratio F_B/F_A, i.e., the ratio between their energy fluxes (in erg/s/cm^2) in this band. [1 p]

Assume that the detector's quantum efficiency is "flat as a pancake" (not a function of wavelength).

Problem 2 [2 points]. Let us compare the James Webb Space Telescope (JWST, launched in 2021) and the Extremely Large Telescope (ELT, under construction in Chile). The detection threshold of the JWST (aperture 6.5 m) for a certain application is m=28.0 mag.

a. What is the magnitude threshold for the same application of the ELT with a 24 m aperture? Assume that the background for the ELT is 2 magnitudes per square arcsec brighter than that of the JWST. Assume also a transparent but turbulent atmosphere, so that the point spread function (PSF, full width) for the ELT is 4 times as wide.

Problem 3 [2 points]. To quantify the light received from extended or diffuse sources, we often use their "surface brightness". A uniform gaseous nebula has an average surface brightness of 17.77 magnitudes per square arcsec. This means that we receive as many photons in one square arcsecond as we would get from a 17.77 mag star.

a. If the nebula has an angular diameter of 13.5 arcsec, what is its total apparent magnitude? [0.5 p]

If the nebula were moved to twice its original distance, keeping the same physical size and luminosity, what would happen to its:

b. angular area, [0.5 p]
c. total apparent magnitude, [0.5 p]
d. and surface brightness? [0.5 p]

Question 4 [1 point]. Construction of a monolithic 8192x8192 pixel CCD array is technologically possible. How long would it take to read this array through a single amplifier at a pixel readout speed of 25 kHz?

Question 5 [1 point]. Proportional counters have been used as large collecting area and high time resolution X-ray detectors for decades.

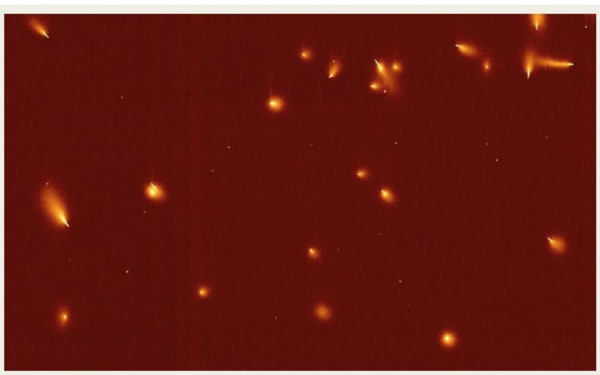
a. Explain briefly how they are made and how they operate. [0.5 p]

In a Fourier analysis of an X-ray light curve collected with a proportional counter, we first set a constant time bin of t=1 ms and then obtain the Fourier transform of a data segment with a total length or duration T=1024 s.

b. Define, calculate and interpret the corresponding Nyquist frequency. [0.25 p]
c. What will be the frequency resolution in the resulting power spectrum? [0.25 p]

Question 6 [1 point]. A student owns a 15 cm telescope with a focal ratio of f/10. What is the diffraction-limited resolution of this telescope (as per Rayleigh's criterion) when observing light of wavelength 650nm? Quote your answer both in arcseconds on the sky and mm in the focal plane.

Question 7 [1 point]. Why do cosmic rays in ground-based CCD images generally produce single pixel events (right Figure) while those in space-based CCD images (left Figure) can produce longer streaks and wiggles?


Blobs/streaks - charged particles. Small dots - X-ray events.