Observational Astronomy

Possible questions for the exam on 2024

Exam

The exam will consist of two large questions requiring a detailed answer, a few questions requiring a few sentence answers, plus a few problems similar to (or just from) the home exercises. No help from the books, lecture notes, or any other material is allowed during the exam. A standard non-programmable calculator could be used.

Questions:

1. Explain the underlying principle of the telescopes used by Galileo and Kepler. Why were telescopes from this era all very long?
2. Aberrations in reflecting telescopes.
3. How does spherical aberration affect the image produced by a telescope?
4. How does astigmatism affect image quality? Support your reasoning with a sketch.
5. How does coma affect image quality? Support your reasoning with a sketch.
6. Explain the difference between an equatorial mount and an alt-azimuth mount. Give an advantage and disadvantage of each.
7. Until the late 1970s, the largest telescopes in the world were all on equatorial mountings. Why is this, and why are the largest telescopes built since then on alt- azimuth mountings?
8. Discuss the main engineering challenges for the realization of an Extremely Large Telescope.
9. Sketch the diffraction pattern produced by a circular aperture telescope. Explain the terms Airy disk and diffraction-limited resolution.
10. Describe in detail how the Earth's atmosphere degrades the quality of astronomical images obtained from the ground.
11. If the resolution of the telescope optics used is diffraction limited, what is the relation between the observed angle subtended by a point source and the telescope's aperture diameter? Which principal effect prevents any large ground-based telescope from reaching this resolution without specialized hardware adjustments?
12. Discuss in detail the differences between Active and Adaptive Optics. What is the definition of the "Strehl ratio"?
13. What are the five principal components of an Adaptive Optics system and their function? Draw a simplified diagram of an adaptive optics system. Discuss the basic operational principles of a Shack-Hartmann wavefront sensor. What is meant by the Strehl ratio?
14. Explain the terms Fried parameter and isoplanatic angle?
15. Explain the "cone problem" for adaptive optics using laser guide stars. How can one minimize this problem? Why is it increasingly difficult to build a working adaptive-optics system at shorter wavelengths?
16. Explain why using laser guide stars does not fully correct for atmospheric turbulence. Discuss in particular the main concerns associated with the "cone problem".
17. Describe, with figures, two types of system used for focusing in X-Rays, one appropriate for low-energy photons and one for high-energy photons. Explain why different methods are needed in these two regimes.

18. Explain why it is possible to build soft X-ray telescopes using grazing incidence optics. Sketch a Wolter Type I telescope, and explain how the collecting area of such a telescope can be increased.
19. Explain the difference between QE and DQE.
20. List the main technical characteristics (parameters) of detectors used in astronomy and describe the most important of them.
21. What are the main classes of detectors? Distinguish between the photoelectric effect as it occurs in a photomultiplier tube and the creation of electron-hole pairs in a photoconductor.
22. Describe three types of detectors which are sensitive to X-rays.
23. Discuss the physical mechanism for release of electrons by X-rays in CCDs and gas proportional counters. Explain why the energy resolution of the CCDs is better. What is the Fano factor?
24. Summarize the primary detector technologies used for the detection of gamma rays.
25. Describe, using diagrams where appropriate, a three-phase surface-channel CCD and show how photo-generated charges are collected, stored, and transferred to the output.
26. What is meant by a "thinned" CCD and a "buried-channel" CCD? What are their advantages and disadvantages over a surface-channel CCD?
27. Why must CCDs be cooled to low temperatures for astronomical use?
28. Why do CCDs exhibit good response in the X-ray region and in the visible, but poor response in the ultraviolet?
29. Under what circumstances is it possible to split up long exposures into a number of shorter exposures without substantially reducing the signal-to-noise ratio of the observations? Use the signal-to-noise equations appropriate for the signal-limited and background-limited cases. Consider, in particular, the contributions of
    (i) the sky background, and
    (ii) instrumental noise.
30. Describe the major steps needed to reduce a CCD image (image processing steps).
31. What observations would be required to determine the accurate brightness (in magnitudes) of an astronomical source? Describe in detail how the observations would be analyzed.
32. Explain the two approaches of extracting magnitudes from CCD images.
33. In making differential photometry observations, explain why you should know the colors of the variable and comparison stars.
34. What is meant by the "zeropoint" of a magnitude scale?
35. Sketch a ray diagram through an astronomical spectrograph, labeling each of the major components.
36. Describe the function of each of the principal parts of a grating spectrograph.
37. Why is it preferable to use a slit in an astronomical spectrograph and in what way does the width of the entrance slit affect the resolving power obtainable in a spectrograph?
38. Describe two ways of achieving high dispersion in the design of a spectrograph.
39. Why it is important to obtain a comparison lamp spectrum? How is this done?
40. Describe the major steps needed to reduce spectroscopic data obtained with a CCD.