

# Observational Astrophysics and Data Analysis

Questions for the exam on 10.00, Thursday, May 12, 2011 in TÄ219

## Exam

The exams will consist of two questions from the list below plus two 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 calculator maybe needed.

## 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. Describe in detail how the Earth's atmosphere degrades the quality of astronomical images obtained from the ground.
10. Sketch the diffraction pattern produced by a circular aperture telescope. Explain the terms Airy disk and diffraction-limited resolution. 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?
11. Discuss in detail the differences between Active and Adaptive Optics. What is the definition of the "Strehl ratio"?
12. 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?
13. Explain the terms Fried parameter and isoplanatic angle? What is the order of magnitude of the Fried parameter for an 8 m telescope with seeing of 0.75" at
  - (a) visible wavelengths (5,000Å) and
  - (b) near-infrared wavelengths (2.2 $\mu$ m)?
14. 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?
15. Explain why using laser guide stars does not fully correct for atmospheric turbulence. Discuss in particular the main concerns associated with the 'cone problem'.
16. How do professional astronomers choose where on the Earth's surface to site new telescopes?
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. 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.
21. Describe three types of detectors which are sensitive to X-rays.
22. 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?
23. Summarize the primary detector technologies used for the detection of gamma rays.
24. Describe three types of detectors which are sensitive to Gamma rays. Explain how Laue diffraction can be used to construct a low resolution Gamma ray telescope.
25. Describe two types of Infrared detectors.
26. Describe the principles of operation of a bolometer, illustrating your answer with a sketch of a block diagram showing the components of a bolometer.
27. Describe the principles of operation of transition edge sensors and explain their advantages compared with semiconductor bolometers at far infrared wavelengths.
28. Explain the principle of operation of a quantum calorimeter, and describe an application of transition edge sensors as quantum calorimeters discussing the factors which affect the design of the calorimeter.
29. 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.
30. What is meant by a "thinned" CCD and a "buried-channel" CCD? What are their advantages and disadvantages over a surface-channel CCD?
31. Why must CCDs be cooled to low temperatures for astronomical use?
32. Why do CCDs exhibit good response in the X-ray region and in the visible, but poor response in the ultraviolet?
33. What is meant by an "image photon-counting system"? Why are they advantageous for very low light levels? What is their primary disadvantage?
34. Discuss in which aspects the operation of infrared arrays is different from that of CCDs.
35. 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.
36. Describe the major steps needed to reduce a CCD image (image processing steps).
37. 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.
38. Explain the two approaches of extracting magnitudes from CCD images.
39. In making differential photometry observations, explain why you should know the colors of the variable and comparison stars.
40. What is meant by the "zeropoint" of a magnitude scale?
41. Sketch a ray diagram through an astronomical spectrograph, labeling each of the major components.
42. Describe the function of each of the principal parts of a grating spectrograph.
43. What is the purpose of the collimator in an astronomical spectrograph?
44. Why is it preferable to use a slit in an astronomical spectrograph?
45. What are the advantages of the grating over the prism as the dispersing element in a spectrograph?
46. What is meant by the term "blaze" when used in reference to a grating?
47. In what way does the width of the entrance slit affect the resolving power obtainable in a spectrograph?
48. Sketch the diffraction pattern produced by a grating in a spectrograph illuminated by a white-light source.
49. Describe two ways of achieving high dispersion in the design of a spectrograph.
50. Why it is important to obtain a comparison lamp spectrum? How is this done?
51. Describe the major steps needed to calibrate a high-resolution spectrograph with a CCD.