Mock Exam – Astronomical Observing Techniques 2013

Name: ______________________________

Student number: _______________________

Notes:

- The total time for the exam is 3 hours.
- You can use and bring with you anything on paper such as handouts, summaries, books.
- You can write your answers in Dutch or English.
- The maximum number of points for each question is indicated in brackets.
- The maximum number of points is 50.
- The final grade is calculated as 10*(achieved exam points/50pts) + werkcollege bonus (max 1); the maximum grade cannot be more than 10

Constants:
Astronomical unit: 1 AU = 1.495×10^{6} km
Speed of light: c = 2.998×10^{8} m/s
Gravitational constant: G = 6.673×10^{-11} N m^2/kg^2
Planck constant: h = 6.626×10^{-34} m^2 kg/s
Boltzmann constant: k = 1.381×10^{-23} J/K
Parsec: 1 pc = 3.086×10^{13} km
$\sigma = 5.671\times10^{-8}$ $W/m^2/K^4$
$\tau_{Planck} = 5.4 \times10^{-44}$ s

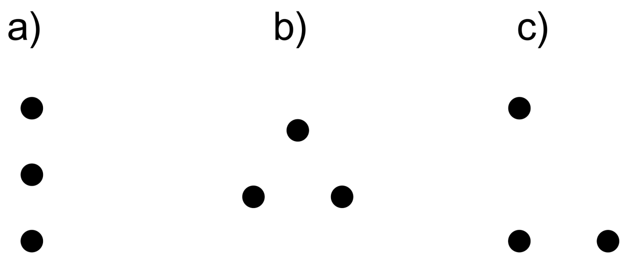
Grating Order Overlap [2pt]

The various orders *m* of a grating overlap each other in the spectrum. Show that a wavelength interval $\Delta\lambda$ that does not overlap with itself is limited by $\Delta\lambda < \lambda/m$.

Parabolic Mirror [3pt]

An amateur astronomer polished a spherical mirror with a focal length of 1200 mm and a diameter of 200 mm. Calculate the amount of glass that needs to be removed at the edge of the mirror to make it into a parabolic mirror.

Aperture Synthesis Imaging [10pt total]



The figure shows three different configurations for 3 identical radio antennae with diameters *D* in the Netherlands: a) equally spaced along a line with spacing $d=4D$ between two antennae, b) an equilateral triangle with side lengths $d=4D$, and c) an unequal triangle with distances of $2d=8D$ and $d=4D$, respectively. Geographical North is towards the top of this sheet of paper.

a) [3pts] Sketch the uv-plane coverage for these three configurations for a single measurement. Don't forget to label the axes and indicate important values on the axes.
b) [3pts] Discuss the advantages and disadvantages of the three configurations for a single measurement.
c) [4pts] Where would you place a fourth antenna? Explain your choice for all three configurations.

Stars in a box [5pts total]

Divide the sky into 40'000 equal surface elements (square degrees). 6000 stars are randomly distributed across the sky. Remember that for a Poison process the following formula holds:

$$P_i = \frac{m_i^{n_i} e^{-m_i}}{n_i!}$$

where P_i is the chance that n_i events are observed at location *i* for the expected number of events m_i.

a) [3pts] Choose one box: what is the probability that 2 or more star are in this box?
b) [2pts] What is the expected number of boxes with 2 or more stars?

CCD Imaging [10pts total]

a) [3pts] Discuss the measurement process of photons by a CCD. Include, at least, the quantum efficiency, the gain, the bias, the read noise, the dark-current and the gain (flatfield).

b) [5pts] Raw images coming out of a CCD typically need some calibration before they can be used. Explain the post-processing required for CCD imaging and indicate how you obtain each calibration parameter necessary for this post-processing.

c) [2pts] Reading out a CCD takes a finite amount of time, and some CCDs do not have physical shutters. What effect would this have on the image taken? How can you circumvent this? Mention at least two solutions.

Signal-to-Noise [10pts total]

You intend to observe a star with V magnitude 21.0 with a 3.6m telescope. The efficiency (throughput, transmission) of the atmosphere and telescope together is 70%. The V-band filter is centered at 0.55 μm and has a spectral bandpass of 1%. The quantum efficiency of the detector is 60%. When you analyze the observations, you find out that the observations are seeing limited with a FWHM of the stellar image of 0.69 arcsec.

a) [2pt] What detector pixel scale (in arcsec) should you use to properly sample the FWHM of the star?

b) [4pt] What is the flux density of the star in Jansky? (Remember that magnitude m_V=0 corresponds to a flux density of 3.92·10-8 W $m^{-2}\mu m^{-1}$)

c) [2pt] How many photo-electrons are produced every second in the detector?

d) [2pt] If there is no noise from the sky background or from the detector. How long do you have to integrate ("expose") to reach a S/N ≥ 100?

Seeing and Adaptive Optics

You are taking a long exposure image of a star in the infrared H-band (1.65μm wavelength) with the 4.2m diameter William Herschel telescope on La Palma. You measures a FWHM of the PSF of 0.8 arcseconds.

a) [2pt] What value of the atmospheric seeing [in arcseconds] would the seeing monitor at the observatory – which measures the seeing at 500 nm – show? The seeing monitor also indicates an isoplanatic angle of 2 arcsec. What isoplanatic angle would you expect in the H-band?

b) [2pt] What is the typical diameter of a turbulence cell [Fried parameter r_0, in centimeters] at the observing wavelength (H-band)?

c) [3pt] To compensate the effect of atmospheric turbulence the observatory offers you to use their new (perfect) Adaptive Optics system. What is the width of the diffraction-limited PSF (in arcseconds) that can be achieved at 1.65 μm?

d) [1pt] With the much smaller, diffraction-limited FWHM of a point source you need to adjust the image scale of the camera accordingly (keeping the same detector). Assume that we were critically sampled in the seeing limited case, and the detector would have given us a field of view (FoV) of 6.83′Å~6.83′. If we now reduce the image scale to critically sample the FWHM calculated under c), what would be the maximum FoV we can now image with this detector?

e) [2pt] You now observe an object at 1 arcmin away from the guide star that is used to sense the wavefront of the perfect AO system. What would be the wavefront error variance σ^2 for that object?