Exam – Astronomical Observing Techniques 2016

Name: ______________________

Student number: ____________________

Notes:

- **Return this form together with your solutions.**
- The total time for the exam is 3 hours.
- You can use and bring with you anything on paper.
- No electronic devices with Internet connectivity are allowed.
- The maximum number of points for each question is indicated in brackets.
- The maximum number of points is 40.
- The final grade is calculated as 10*(achieved exam points/40pts) + werkcollege bonus (max 1); the maximum grade cannot be more than 10.
- Good luck!

1. Telescopes [8pt]

a) [1pt] List the three most important reasons why most ground-based telescopes are located at high altitude sites.

b) [2pt] A colleague suggests observing the ultraviolet CIV resonance doublet at 154.8 nm and 155.0 nm in O and B-type stars with a balloon telescope. Will this work? Motivate your answer!

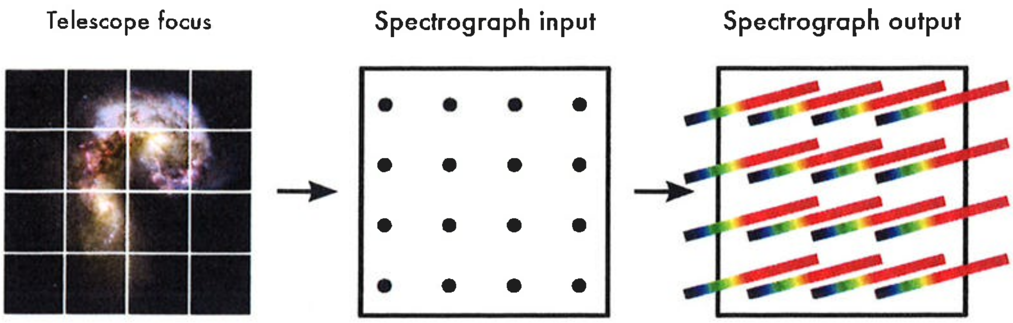
c) [2pt] You are in charge of determining the best site for a new high-resolution optical telescope. What are the two most important parameters that you would measure?

d) [1pt] Consider an X-ray telescope, a radio telescope and an optical telescope, each having the same aperture diameter. List them in order of *increasing* angular resolution.

e) [2pt] Consider two simple telescopes, each built with a single lens. Both telescopes have the same focal length, but one has twice the lens diameter of the other. How much worse is the spherical aberration in the larger-diameter telescope as compared to the smaller telescope?

2. Integral Field Unit [8pt]

Integral Field Units (IFUs) circumvent some of the problems encountered with classical spectrographs. By using a microlens array, an instrument can measure a spectrum for each individual pixel as shown below.



An IFU cuts up the image with an array of lenses (microlens array, in this example 4x4). Each of these lenses takes the light of one pixel and sends it through a spectrograph, typically a grating or a grism. The light of each pixel is dispersed, and this is then imaged onto a detector.

a) [3pt] Measuring a spectrum has long been done by using spectrographs with entrance slits and gratings. What data do you typically obtain with this method, and what are its major advantage and disadvantage?

b) [1pt] What is the advantage of tilting the spectra at the output of the IFU spectrograph?

c) [2pt] How are the spectra tilted?

d) [2pt] Assume that the microlenses are located in the prime focus of a telescope with a diameter of 8m and a focal length of 88m. If the microlenses have a focal length of 8mm, how large is the image of the telescope aperture in the focus of the microlenses?

3. Statistics [6pt]

You observe a source in to filters: Q and U. Both observations have the same intrinsic noise distributions and variances $\sigma_Q^2 = \sigma_U^2$; Q and U are uncorrelated. You calculate a new parameter $T = Q \times \sin(\varphi) + U \times \cos(\varphi)$ where φ is a constant.

a) [3pt] show that the variance of T, σ_T^2, due to noise in the measurements of Q and U is independent of φ and equal to $\sigma_Q^2 = \sigma_U^2$.

b) [1pt] If you want to have 10 times better signal-to-noise ratio, how much longer do you need to measure Q and U?

c) [2pt] The signal is distributed equally over 100 detector pixels. If a total of 100 photons are detected in each exposure, how many pixels with at least one detected photon (on average) would you expect to obtain in each exposure?

4. Angular Resolution [12pt]

An 8-m diameter telescope is operated under seeing conditions that are characterized by r_0(500nm) = 20cm.
a) [2pt] What is the expected seeing-limited angular resolution of the telescope in arcsec at 500 nm?

b) [2pt] What is the expected seeing-limited angular resolution of the telescope in arcsec at 1500 nm?

c) [2pt] You turn on an adaptive optics system that delivers diffraction-limited images. What is the expected angular resolution now at 500 and at 1500 nm?

c) [1pt] How many actuators does the deformable mirror need to have to provide diffraction-limited images at 500 nm.

d) [1pt] Up to what frequency does the deformable mirror need to correct if we assume an average wind speed of 15m/s in the turbulent layer?

e) [4pt] A clever scientist turns off the adaptive optics and completely covers the telescope aperture. She then cuts two holes in the cover at the edge of the telescope aperture on opposite sides. The holes have a diameter of 20cm. What is the angular resolution of this configuration along and across the line that connects the two apertures?

5. Solar Spectroscopy [6pt]

You are using a 60-cm solar telescope to take high-resolution spectra of the solar photosphere. You observe an area of 0.3arcsec by 0.3arcsec with an average intensity of $I = 2.8$ W cm^{-2} $nm^{-1}$$ster^{-1}$ on the solar surface is observed with a spectrograph. The exposure time is 1 ms and the bandwidth is 0.001 nm at $\lambda = 500$ nm. How many photons are detected per exposure if the efficiency of the entire instrument is 1%? Note that 1arcsec corresponds to 722 km on the solar surface, the full sphere is 4π sterad, and a photon at 500 nm has an energy of 4.0×10^{-19} J.