# Trial Exam (Probeklausur)
# Observational Astronomy MKEP5 (SS 2011)

1. **Telescope designs**

   (a) Sketch the layout of a Cassegrain telescope and a Gregorian telescope. Discuss the advantages and disadvantages of the two solutions.

   (b) Most modern large telescopes (e.g. Keck, VLT) have Ritchey-Chrétien design. Explain in two or three sentences the idea behind this design.

2. **Turbulence and Seeing**

   (a) In many telescope domes there are side hatches (openings in the dome) through which wind can enter the dome. This wind will undoubtly create ample turbulence inside the dome. So, why did they include these side hatches?

   The Fried parameter for a good observing site under good conditions at optical wavelengths is of the order of $r_0 \simeq 10$ cm. Now let us observe a point source at this site and under these conditions.

   (b) What effect does the seeing have on our observation of the point source if we have a telescope of diameter $\underline{D = 1\text{ cm}}$? What about $\underline{D = 10\text{ cm}}$? And $\underline{D = 100\text{ cm}}$? Discuss not only the time-averaged effect of the seeing, but also what a point source looks like on the CCD if very short-time exposures are taken (times shorter than the seeing motion time scale, i.e. millisecond time scale), i.e. will one observe speckles?

3. **Photometry**
   This question concerns the topic of photometry, using a ground-based telescope. In this example, we will be observing a single star as our science target.

   (a) Describe precisely but concisely, what we mean by a "photometric measurement": what exactly is it (physically) that we measure?

   (b) What sources of noise do you know? Which are "fundamental" (i.e. we cannot eliminate them, even if we could build the "perfect" instrument)?

   (c) We observe our target star, immediately followed by a photometric standard star in the Johnson I-band filter. Both measurements are done at an airmass of 1.1. We find that we record 1,000 (one thousand) electrons from our science target in a 20 minute exposure, and 20,000 from our standard star in a 1 minute exposure[1]. The brightness of the standard star is $I = 10.0\,\mathrm{mag}$. What is the I-band magnitude of the science target?

   (d) After the calibration measurement, we observe another calibrator with a brightness of $I = 9.0\,\mathrm{mag}$ *at an airmass of 1.9* (!). In a 1 minute exposure we record 48,000 electrons from the calibrator[1]. What is the atmospheric extinction in the I-band, expressed in units of mag/airmass?

[1] These numbers have already been corrected for dark current and other instrumental effects.

(e) If we assume that our telescope+instrument system has a combined efficiency of 33%, what is the diameter of the telescope that we have used? Assume that the I-band filter has a "box-shaped" throughput curve with 100% transmission between 0.85 and 0.95 $\mu$m and 0% elsewhere, and that the photometric zero-point of the I-band is $8.3 \times 10^{-10}$ erg/s/cm$^2$/$\mu$m. Furthermore you may approximate the spectrum of the star to be iso-photonic in wavelength (i.e. it has the same number of photons per wavelength bin over the spectral range we consider) and you may assign the energy of a 0.9 $\mu$m photon to all photons in the band.

4. **Spectroscopy and spectrometers**
Consider a reflection grating with $N$ grooves with groove-spacing $d$. We let light with wavelength $\lambda$ fall *perpendicularly* onto the grating.

   (a) Show that the angular location $\theta_m$ of the $m$-th order is at:

$$\sin\theta_m = \frac{m\lambda}{d} \tag{1}$$

   In the lecture we also found that the width of one spectral resolution element is:

$$\Delta\sin\theta = \frac{\lambda}{Nd} \tag{2}$$

   independent of the order $m$.

   (b) Derive that the spectral resolving power $R = \lambda/\Delta\lambda$ is given by

$$R = Nm \tag{3}$$

   if you put your CCD camera at the $m$-th order.

5. **Radio interferometry**
Let us consider a radio interferometer array with 8 dishes, such as the current status of the ALMA observatory. Assume that they are "randomly" positioned, so that no connecting vector $\vec{r}_{ij}$ between dish $i$ and dish $j$ is identical to any other.

   (a) How many points in the $uv$-plane does such an array measure at any specific point in time? Are the $(u, v)$ and $(-u, -v)$ points independent?

   (b) If one performs an observation of a single source for 6 hours, how does this help with filling the $uv$-plane?

   ALMA is on the southern hemisphere. Suppose that we wish to observe a source that is in the northern hemisphere, though still "southern" enough to be observed by ALMA (i.e. it is still above the horizon for a significant part of the night). ALMA's dishes are arranged in a pseudo-random way such that observations toward the zenith have a relatively circular beam (beam=PSF).

   (c) The beam of ALMA for our source, which is close to the horizon, will not be circular but more or less elliptic, i.e. the angular resolution of our observation is less in one direction than in the other. In which direction is the beam elongated: Along the horizon or perpendicular to that?

   (d) If the source is at zenith distance $z$, by which factor (i.e. how much) is the elongation?