Exercises Astronomical Observing Techniques, Set 11

Exercise 1

We want to observe a planet at a wavelength of 2μm with the help of an AO system for a 8m telescope. The AO system is proposed to use a mag_V=16 guide star. A Shack Hartmann wavefront sensor is used operating in the V-band (center = 0.55 μm, bandwidth 0.089 μm). The wavefront sensor is read out at a speed of 100 Hz. The spectral irradiance (flux density) of a source with $\text{mag}_V = 0$ is 3.92×10^{-8} W m^{-2} μm^{-1}. The seeing is 1 arcsec in the V-band.

a) Calculate the total number of photons received (per sec) from the star which can be used by the AO system. The QE for the AO wavefront sensor is 50%.

b) Calculate the number of sub-apertures needed to correct for the effects of seeing at the wavelength used for detecting the planet.

c) We assume that the star is detected by a single pixel in a sub-aperture. The CCD has a RON of 10e$^-$. Calculate the SNR per aperture per integration time used in the AO system. (you can neglect other noise sources of the detector). Is this enough to do an AO correction?

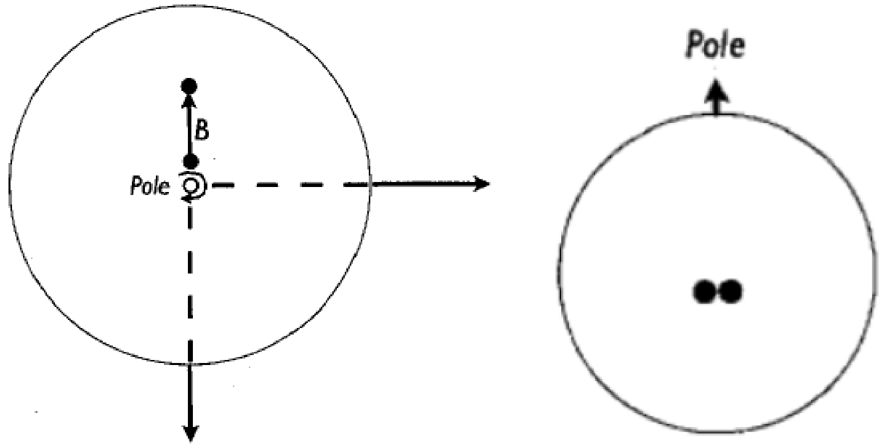
Exercise 2

a) Explain why interferometry is especially useful for radio astronomy.

b) Give three reasons why we rather use an interferometer with a 300m baseline than a single dish of 300m diameter.

c) Why would you still prefer single dish over an interferometer if 15m is enough for your resolution requirements?

Exercise 3



Astronomical interferometry works by measuring a set of u, v-points, the visibility distribution $V(u, v)$, which is the Fourier transform of the intensity distribution $I(x, y)$ of the position x, y on the sky. Each u, v-point is measured by one (projected) baseline. For a smooth reconstruction of the intensity distribution a good coverage of the u, v-points is required.

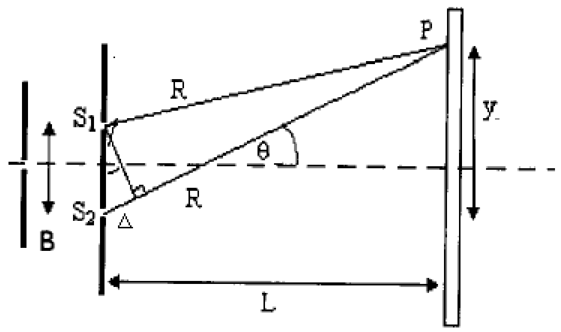
a) Consider a source located at the pole, and a simple two telescope interferometer (see Figure 2a). Imagine you are the source, looking down at the Earth. What u, v-points do you gather as the Earth rotates?

b) Add more telescopes in between the two telescopes. How is the u, v-coverage increased?

c) Now image the source at zero declination (see Figure 2b) and your telescopes at the equator. What u, v-points can you gather now as the Earth rotates?

d) Why do you rather have more telescopes than bigger telescopes in an interferometer? How should you place the telescope with respect to each other?

Exercise 4



In an optical interferometer, the beams are combined on top of each other, so that the fringes are formed similar like in a Young slit experiment (see Figure).
a) Express the optical path difference Δ in terms of the distances B, y and L. The angle θ can assumed to be small.

b) Last week we derived the intensity of two interfering beams of equal amplitude to be equal to $2I_0(1+\cos\delta)$. Rewrite this to a single quadratic term by using $\cos(a \pm b) = \cos a \cos b \mp \sin a \sin b$.

c) At which positions y_m is constructive interference? What is the minimum pixel size in order to detect fringes?