Exercises Astronomical Observing Techniques, Set 8

24 October 2012

Exercise 1

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

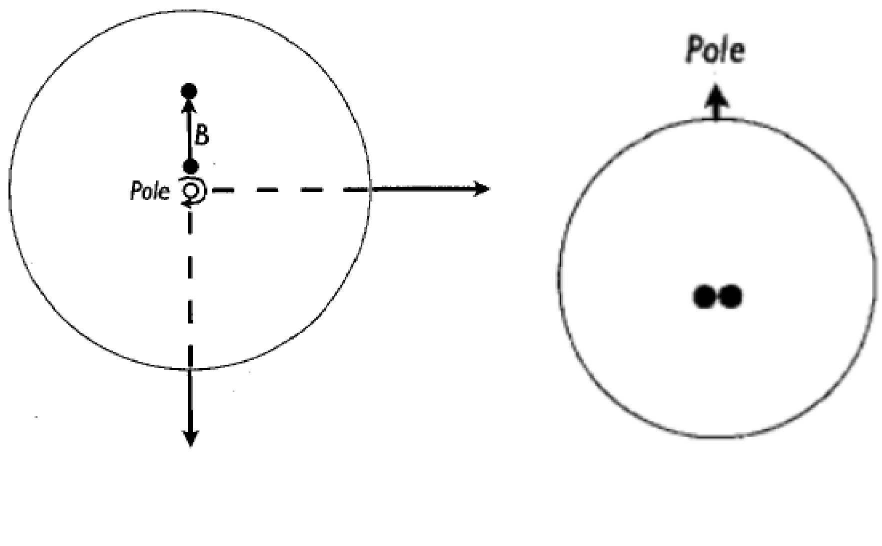
b) Give three reasons why we rather use an interferometer with a 300m baseline than a single dish of 300m diameter.

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

Exercise 2

Give at least three reasons why optical interferometry is more complicated than radio astronomy.

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) In practice, an interferometry array is placed at a certain latitude, and the picture of your u, v coverage depends on the declination of your source. Can you describe how this picture changes with declination?

e) 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 a Fourier Transform Spectrometer, the electric fields of the interfering beams arriving at the detector, are represented by:

$$\mathbf{E_1} = \mathbf{E_{01}} \cos(kx_1 - \omega t) \tag{1}$$

$$\mathbf{E_2} = \mathbf{E_{02}} \cos(kx_2 - \omega t) \tag{2}$$

where the two beams have experienced a physical path difference of $x = x_2 - x_1$. Remember that $k = 2\pi/\lambda$, k is the wavenumber. The time averaged irradiance for the k component is then

$$I_k =< (\mathbf{E_1} + \mathbf{E_2})^2 > \tag{3}$$

a) Write out the terms of the quadratic. Remember that $\mathbf{E_1}$ and $\mathbf{E_2}$ are vectors.

b) Now rewrite the interference term to a single cosine. Use $\cos(a \pm b) = \cos a \cos b \mp \sin a \sin b$ and $< \cos^2 \omega t >=< \sin^2 \omega t >= 1/2$ and $< \cos \omega t \sin \omega t >= 0$.

c) Proof that $I_k = 2I_0(1 + \cos\delta)$ for $\delta = kx$ and $\mathbf{E_{01}} = \mathbf{E_{02}}$. Use $I_0 = \frac{1}{2}E_{01}^2$.

d) The irradiance over all wavelengths I is given by $\int_0^\infty I(k)dk$, with $I(k) = I_k$. Proof that moving the mirror of the Fourier Transform Spectrometer will give you the interferogram $I(x)$, which is the Fourier Transform of the spectral distribution $I(k)$.