Interferometry Practice Sessions

The exercises made by the teacher :-)

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Practical session 1: Visibilities and models.

I have followed the exercises using ASPRO (and an image processing software for superposition of the graphs: GIMP) to give you an idea of what you should get with ASPRO.

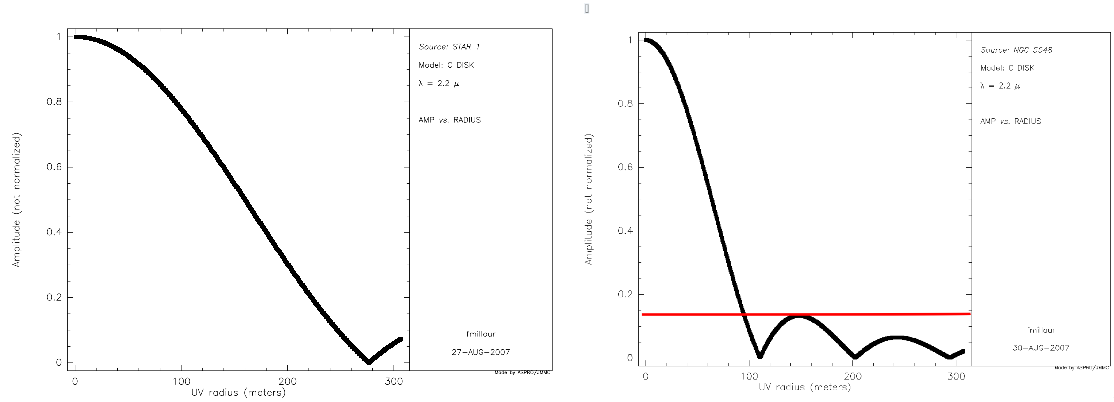
Exercise 1: Measuring a diameter.

The visibility for an uniform disk of diameter a is given by the following expression:

$$V(\rho) = \frac{\mathrm{J}_1(\pi a \rho)}{\pi a \rho} \tag{1}$$

$\rho = B/\lambda$ beeing the spatial frequency and J_1 the 1^{st} order Bessel function. Therefore the value for which the visibility becomes zero is $B = 1.22\lambda/D$ with D the uniform disk diameter.

The figure produced by ASPRO you should produce would look like that (left part):



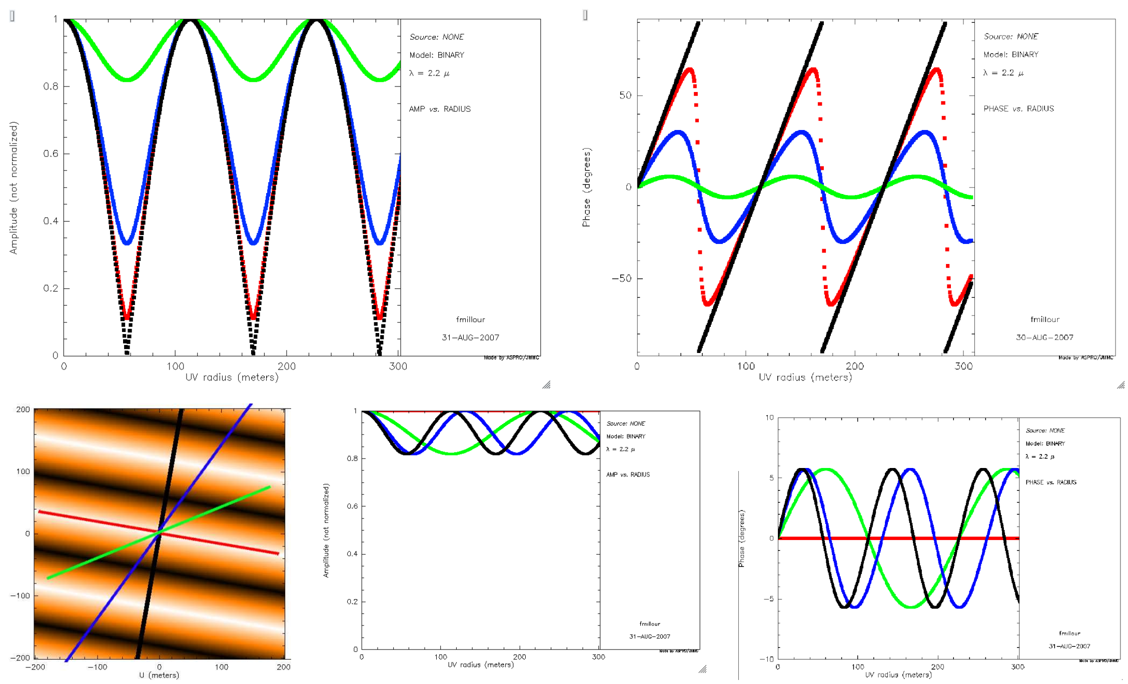
Here, the visibility zeroes around the 280 m baseline. This gives a 1.89 mas diameter for the star, close to the 2 mas input.

About the second part of the question, the right plot gives a hint of the answer: There are parts of the visibility function which is monotonical (above the red line). In these parts, one

*Based on the practice work session of D. Ségransan, J.-P. Berger and F. Malbet at the Goutelas summer school visibility gives a unique solution to the diameter of the star, where in other parts a given visibility corresponds to many different solutions. Therefore, there is a limit in visibility ($V \gtrsim 0.15$) where one can infer a unique diameter from a unique measurement.

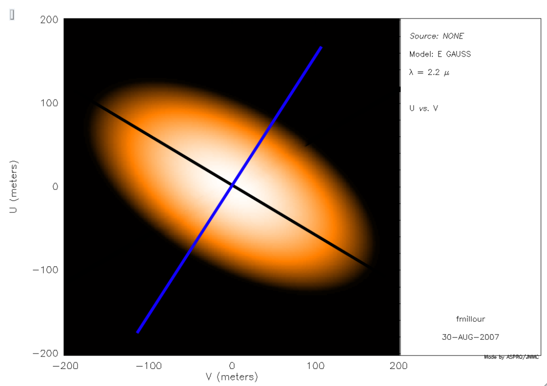
Exercise 2: Binary.

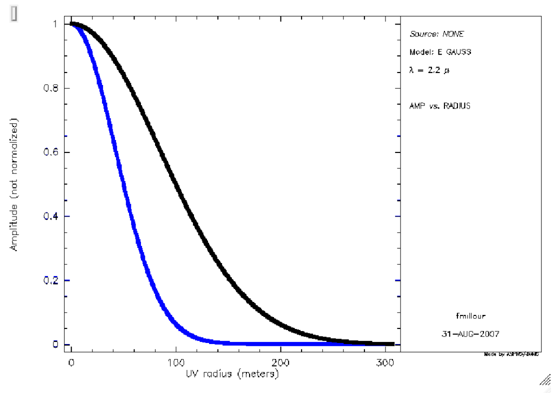
Here is what you should get from ASPRO plots: top-left is for the 4mas binary star and top-right it's the phase. 1^{st} , you see that the visibility has not a cosine shape but has sharp changes at visibility 0 for a 1 to 1 binary (black line). For other flux ratios (0.8 in red, 0.5 in blue and 0.1 in green) both the phase and visibility get smoother and the contrast of the variations gets dimmer. Please note the are Visibility plots are made with “AMP” and not “AMP$\hat{2}$” in ASPRO.



To see how visibility or phase can constrain a binary star model, one just can try to change the baselines orientation and see how visibility and phase vary: this corresponds to the figures at the bottom. You see that the phase is sensitive to the contrast of the binary (top graphs), but also to the position angle (both of the binary star and of the baseline) and of the binary separation. Therefore, the phase can be used instead of the visibility to constrain the binary parameters !

Exercise 3: Disk.



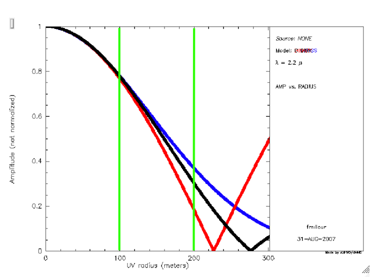


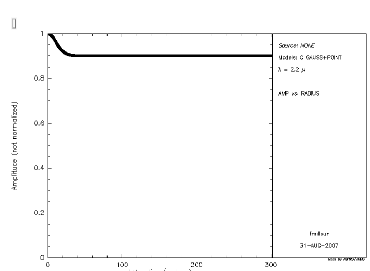
Here is an example of a disk of 2x4 mas (milli-arcseconds) and a position angle of 60 degrees. As one can see, for a given baseline and a varying position angle, the visibility goes up and down, the minimum corresponding to the major axis and the maximum corresponding to the minor axis.

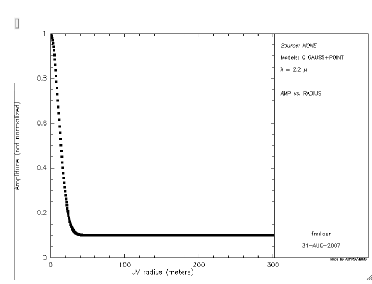
Exercice 4: Model confusion and accuracy.

Here I have superimposed the plots using the GIMP software. Uniform disk is in black, gaussian in blue and binary in red. I have added two green lines at 100m and at 200m. Here you see the importance of multi-measurements at different baselines to be able to disentangle from different object's shapes. With only one visibility measurement, you will never be able to disentangle between these different models. With the two visibility measurements, you can see that you will be able to disentangle if both you have very different long-enough baselines AND sufficient accuracy (If you have visibility error bars of 0.01 you can disentangle between the sources using 100 and 200m baselines, but not with an accuracy of 0.1).

This is illustrated by the 2 right plots. The 1st is a central point with 90% of the total flux contribution and a large (15mas) gaussian disk around with 10% of the flux. Errors bars of 10% would prevent from finding the gaussian component and you would en with a completely unresolved star. The right graph shows the same but with flux ratio inverted. So: not only the number of baselines but also the accuracy on your measurement are of high importance to disentangle between different models.





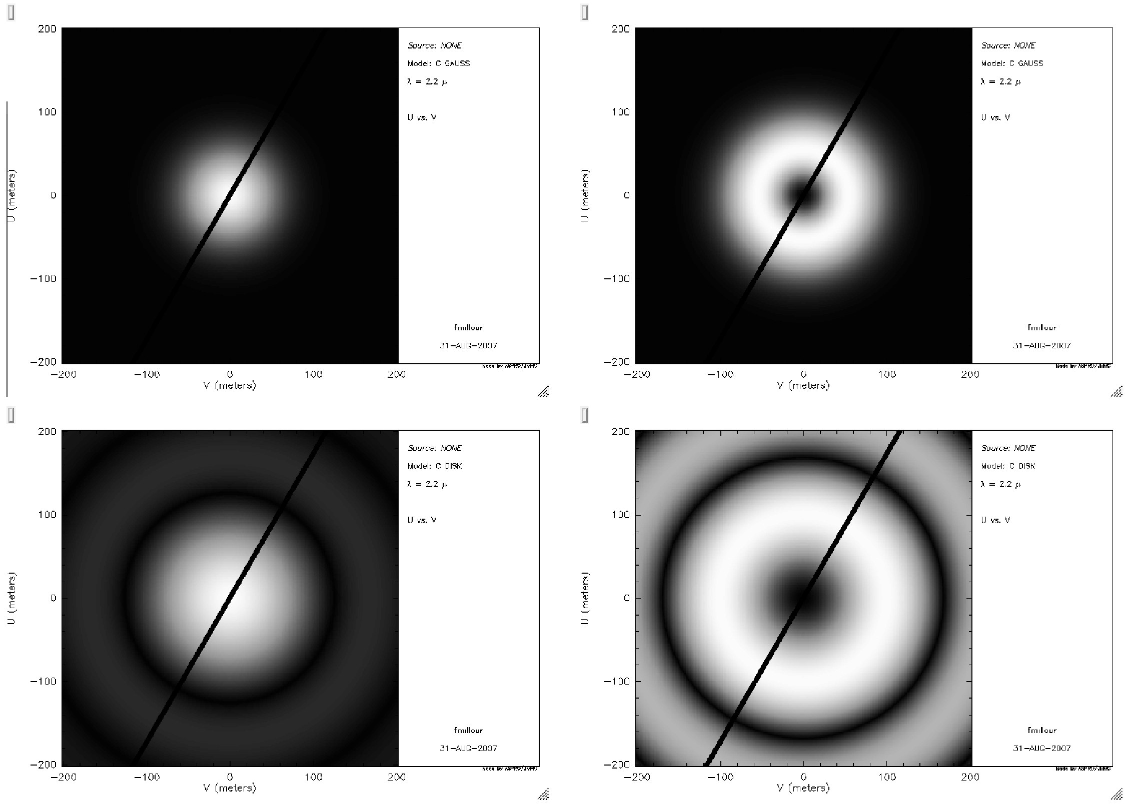


Exercise 5: Choosing the right baselines.

The idea here is to use the nice feature of ASPRO that is able to plot the derivatives of visibility versus the different parameters of the input model. Left is the model visibility and right is its derivative relative to the model size, up is a gaussian disk and low is an uniform disk.

Here the size used is the same in the two cases: 2 mas and you see that optimal baseline is about 50m for the gaussian disk and 100m for the uniform disk. Therefore, using different baselines you will be able to both disentangle the model shape (Sharp - UD - or smooth - gauss - edges ?) but also constrain it's typical size.

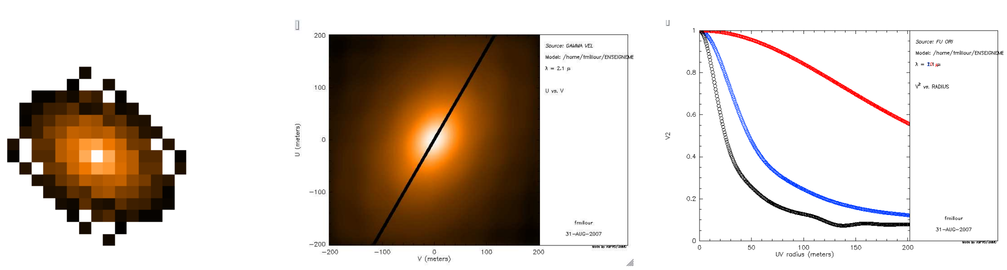
You must also notice that the optimal baseline to constrain a given model corresponds to a visibility of about 50%. This is a very important thing to know: too long or too short baselines will not tell you too much about your source size or shape !



Exercise 6: An unknown astrophysical object.

This object's model is a young stellar disk made by F. Malbet. Note, as for the previous disk model, that the large visibilities correspond to the minor axis of the model whereas the low visibilities correspond to the minor axis.

The right panel shows the visibility for the minor axis with different wavelength: J (black), K (blue) and N (red). This shows you which wavelength to use to observe your object: K-band allow to both have high visibilities for the extended component and low visibilities for the detailed structure of the disk.



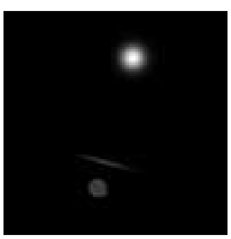
Exercise 7: Play with spectral variations, closure phases, etc.

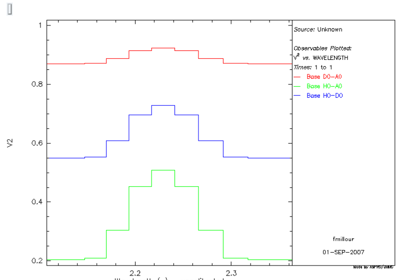
Since this is a bonus exercise, you are not obliged to have reached this point. Here you can see the intensity map of the model, the visibilities for a given observational setup (A0-D0-H0) and the closure phase. Here I have used in purpose an aligned baseline array to illustrate this exercise:

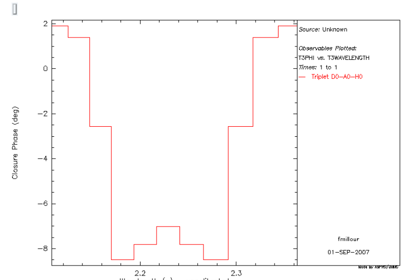
- The different visibilities are decreasing with baseline. Therefore the object is barely resolved by the interferometer. You cannot distinguish qualitatively between a uniform disk, a gaussian disk or a binary star, but you can say the object is resoloved at the largest baseline ($\approx$130m) and is therefore of size about 2mas.
- The non-zero closure phase gives you information about the asymmetry of the object. Here we have a non-zero but very small closure phase. The only simple model you know which gives you a non-zero closure phase is a binary. The fact that the closure phase is not 180 degrees gives you the information that the flux ratio is not 1/1.

Therefore, only looking qualitatively at your data you can say:

- I have likely observed a binary star
- the separation is about 2mas
- the flux ratio is not 1/1
- so far I cannot say if each component has been resolved or if there is a third component.







Practical session 2: UV coverage and source observability.

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