

Interferometry Practice Session 1

From models to visibilities

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Abstract

The following exercises are aimed at getting trained to the link between the object intensity distribution and the corresponding visibility curves. They are intended to be the practical application of the “Visibility modeling” Tutorial. This practical session is meant to be done with the ASPRO software and hand-made uv tables.

Practical considerations

ASPRO’s rules of thumb

ASPRO is an optical long-baseline stellar interferometry tool intended to help the observations preparation. One can find it on the website <http://www.mariotti.fr> but for this practice session we will use a local installation. Note that all exercises can also be done at home with the online version of ASPRO.

Launching ASPRO: ASPRO’s launch is made on two steps:

1. type “ASPRO” in the command line
2. in the “Choose” menu, select “Full Aspro Interface”

On the web, follow the links “ASPRO” and once the JAVA applet has launched, the steps are the same as for the local installation.

When ASPRO gets stuck: You will find quite often strange behaviours such as non-responding buttons or different response to what you expect. In any doubt case, do not hesitate to quit ASPRO by clicking the “EXIT” button. In the case this button does not work either, you still can write “exit” in the command line, which will kill the Gildas session (and the ASPRO one at the same time).

Do not worry, restarting ASPRO and entering again the different parameters is not very long !

*Based on the practice work session of D. Ségransan, J.-P. Berger and F. Malbet at the Goutelas summer school

Table 1: Parameters of the **ASPRO** model software module.

ASPRO name	Source shape	useful parameters
POINT	Unresolved (Point source)	None
C_GAUSS	Circular Gaussian	FWHM Axis
E_GAUSS	Elliptic Gaussian	FWHM Axis (Major and Minor), Pos Ang
C_DISK	Circular Disk	Diameter
E_DISK	Elliptical Disk	Axis (Major and Minor), Pos Ang
RING	Thick Ring	Inner Ring Diameter, Outer ring diam
U_RING	Thin Ring	Diameter (1 value: unresolved!)
EXPO	Exponential brightness	FWHM Axis
POWER-2	$B = 1/r^2$	FWHM Axis
POWER-3	$B = 1/r^3$	FWHM Axis
LD_DISK	Limb-Darkened Disk	Diameter, 'cu' and 'cv'
BINARY	Binary	Flux ratio, rho, theta

ASPRO name	1 st parameter	2 nd par.	3 rd	4 th	5 th	6 th
POINT	R.A.	Dec	Flux	-	-	-
C_GAUSS	R.A.	Dec	Flux	Diameter	-	-
E_GAUSS	R.A.	Dec	Flux	Maj. diam.	Min. diam.	Pos Ang
C_DISK	R.A.	Dec	Flux	Diameter	-	-
E_DISK	R.A.	Dec	Flux	Maj. diam.	Min. diam.	Pos Ang
RING	R.A.	Dec	Flux	Inner Diameter	Outer Diameter	-
U_RING	R.A.	Dec	Flux	Diameter	-	-
EXPO	R.A.	Dec	Flux	Diameter	-	-
POWER-2	R.A.	Dec	Flux	Diameter	-	-
POWER-3	R.A.	Dec	Flux	Diameter	-	-
LD_DISK	R.A.	Dec	Flux	Diameter	'cu' and 'cv'	-
BINARY	R.A.	Dec	Flux	FluxRatio	Rho	Theta

Note: for the Binary model, the flux ratio is Flux_secondary / Flux_primary and Rho & Theta are the angular separation (") and Position angle (degrees) of the binary.

Offset R.A. and **Offset Dec** are usually set to zero while **flux** is set to one.

What you will need for this particular practice session

All the exercises of this practice session will be done assuming a simple yet unrealistic (u, v) coverage. Synthetic (u, v) tables simulating such (u, v) coverages are provided for use: `strip-[J,H,K,N]-[000, . . . , 170].uvt`, where the number xxx is the projected baseline angle in degrees.

ASPRO is able to do many things but this session will focus on the *MODEL/FIT - UV plots and source modelling* part.

You will probably also need the table 1.

Exercise 1: Measuring a diameter.

The aim of this exercise is to have a first contact with uniform disks, which are very often used to perform first-order interpretations of the data.

Given a star with a 2 mas photospheric radius use the model function to plot the visibility versus the projected baseline length (baseline **radius**). Use the *MODEL/FIT.UV Plots & Source Modeling* menu. At what baseline does the visibility become equal to zero ? Use this number to evaluate the disk diameter.

Can you measure a diameter if your visibility is non-zero but you know the star looks like a uniform disk ? If yes, how ?

Exercise 2: Binary.

When the amount of data you get is few visibilities the object's complexity for your interpretation cannot be too high. Therefore, binary models are often used to understand the data when asymmetries happen to be proved (by a non-zero closure phase, for example). Therefore, one has to understand the behaviour of such model.

Display the visibility and phase as a function of projected baseline (`strip-K-60`) of a binary with unresolved components with 4 mas separation, flux ratio of 1 and position angle of 30 degrees. Do the same thing with separation of 12 mas. Comment on the result.

Using the previous model now vary the flux ratio from 1 to 1e-6. Comment on how the dynamic range requirement to detect the companion translates into visibility and phase constraints ? Would the phase alone be sufficient to constraint binary parameters ?

Exercise 3: Disk.

The last model we will see in this practice session is a gaussian disk that can in a first approximation simulate a circumstellar disk. The idea here is to understand how visibilities change with the source elongation.

Display the visibility curve of a disk which is assumed to have an elliptical gaussian shape (`E_GAUSS`). Use the minor and major axes (parameters 4 & 5) to simulate an inclination. The display should be done for several PAs (`strip--(0,30,45,60,90)`). Comment on how the asphericity induced by the inclination changes the visibility function at a given projected angle.

Exercise 4: Model confusion and accuracy.

If the baseline you have chosen is too long or too small relative to your source typical size, you can get into trouble to interpret your data. We will see here why.

Use the model function to compute the visibility of a star with a uniform disk brightness distribution (2 mas radius), circular gaussian disk (1.2 mas radius) and binary (flux ratio 1, 1 mas separation, 45° PA) with `strip-K-60`. No superposition of the plot is possible, so use the "show plot in browser" option so save it as a postscript file. Compare their visibilities at 100 m in the K band. How can we distinguish between these various models ? Do the measurement accuracy play a role in such model discrimination ? What about measurements at 200 m. What do you conclude?

Construct a 2-component model in which a central unresolved star (`POINT`) is surrounded by an inclined extended structure. You can use an elliptical gaussian distribution (`E_GAUSS`) for that purpose (minor and major axes in the range 0.5 to 15 mas).

Try two scenarii:

- an extended source easily resolvable but with a flux contribution much smaller than the star;
- an extended source smaller but with a larger flux contribution.

What are the best baseline lengths to estimate the size and relative flux contributions with an interferometer?

Exercise 5: Choosing the right baselines.

Given a specific object's shape, one can determine how a baseline constrain a given model parameter. We will see this aspect here.

In order to determine the parts of the (u, v) plane which constraint the model most, one can make use of the first derivative of the visibility with respect to a given parameter. Choose a uniform disk model. What is the most constraining part in the (u, v) plane? For this exercise, in UV EXPLORE panel, use V vs U, check the `underplot model image` option, and choose the appropriate derivative in the `plot what...` line.

Exercise 6: An unknown astrophysical object.

Wavelength at which one observe an object is also important. This exercise attempts to illustrate this point.

Load the fits table `fudisk-N.fits` corresponding to the simulation of a certain type of astrophysical object (here a disk around an FU Orionis object) using *OTHER/Display a GDF or FITS image* menu. If the color scale is not appropriate, check the *Optional parameters* button and select another color scale. Notice what is the contrast of the object (NB: the angular units are in radians).

Compute the visibility of the model in the N-Band with *MODEL/ FIT.UV Plots & Source Modeling/USE HOMEMADE MODEL*. To do so, select the appropriate grid `strip-N-60` in the *Input Information* menu. Use UV EXPLORE to plot the visibility amplitude versus the spatial frequency radius.

Repeat these operations in the K band, then the H and J ones. Compare the visibility profiles. Conclude on the resolution of the object at these different wavelengths.

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

Bonus exercise: Try to guess what is in this model by just looking at the visibilities (please do not cheat !).

Using a given model of a binary star (γ^2 Vel, file `gammaVelModelForAspro.fits`), try to plot visibility and closure phases as a function of wavelength (see the "OTHER ... Export UV table as OI fits" and "OTHER ... OI fits file explorer" menus). Compare with what you would get with an ASPRO model of one gaussian and one uniform disk of diameters 0.5 mas, a separation of 3.65 mas and an angle of 75 degrees. What do you conclude ?