

INTRODUCTION TO THE OBSERVING PREPARATION TOOL ASPRO

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Abstract. The Practice sessions of the EuroWinter School “Observing with the Very Large Telescope Interferometer” held at Les Houches in February 2002 relied on the use of ASPRO, an observing preparation tool crafted for optical interferometry, developed at the Jean-Marie Mariotti Center. This Tutorial serves as an introduction to the basic uses of this tool.

1 Introduction

ASPRO (A Software to PRepare Observations) can be thought as a virtual interferometer enforcing the golden rule of interferometry: “never make images, and since you gonna make them anyway, don’t you ever believe them”.

ASPRO provides facilities to determine the interferometer and focal instrument configurations in order to optimize the astrophysical study of the user. This optimization is done by fitting the theoretical model on synthetic squared visibilities. This fitting process takes into account the measurement errors of the interferometric signal. The best configurations will be those which minimize the errors on the estimated model parameters.

As in real life, the user of ASPRO will perform observations of a list of sources at a given time, on a given interferometer, with a given focal instrument (sect. 3). Presumably, the science objects he or she will “observe” will have some structure that can be discernible by the interferometer—an unresolved object making usually a dull science target, if a good calibrator. ASPRO thus implements various models of the objects, from simple ones to complicated, user provided ones (sect. 4). Based on the model of the object(s) and the geometrical constraints due to both the source and the interferometer, the user will obtain reduced observations (correlated fluxes, squared visibilities V^2 ...) with the kind of measurement errors one expects from the focal instrument “used” (sect. 5).

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Good observations are expected to be able to retrieve the information(s) relative to the source from the data. By fitting the model in the data and evaluating the errors, (sect. 5.1), the user is able to check if he/she has reached the best configuration (in terms of uv coverage, data accuracy...) and can also refine the observing parameters iteratively by going again through the steps described above. Sometimes ASPRO will even prove that the observations are not feasible at all...

2 Architecture and Ergonomy

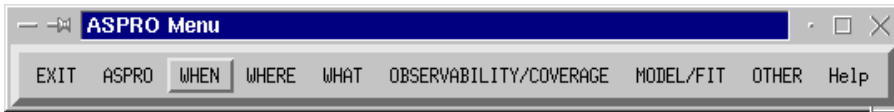


Fig. 1. The ASPRO menubar

ASPRO can be thought as made of six modules which are described hereafter. On starting aspro (typing 'aspro' at the shell prompt is usually sufficient), a menubar (fig. 1) and a graphic window appears. The three first modules **WHEN**, **WHERE** and **WHAT** correspond to the geometry setup module. The two first allow to select the date of observation and the interferometer, the latter allows to load several parameters characterizing the main properties of the observed objects. The fourth module **OBSERVABILITY/COVERAGE** allows to choose the observing configuration and to test it in terms of objects observability and UV coverage. The fifth module **MODEL/FIT** allows to load a model of the observed object, to compute the synthetic squared visibilities and the measurement errors, and to determine with which accuracy the model parameters could be constrained. Special functions are kept in the sixth module, under the menu **OTHER**.

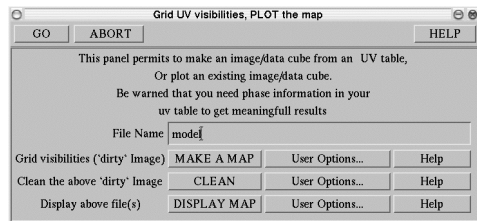


Fig. 2. A typical ASPRO panel

Ergonomy Menus in the menubar lead mainly to the opening of dedicated dialog panels. The philosophy of the panels (see example in fig. 2) is to have on the first line three buttons:



ABORT will close the panel, HELP will open an help window. GO will usually make a predefined action with the values entered by the user in the rest of the panel, in the form of a three-part entry:

Question

Where may be a Slider, a Choice List, etc... Clicking on **Question** popups a 'hint text'.

Sometimes a panel groups a number of related actions. In that case these are under the form of lines containing three buttons:

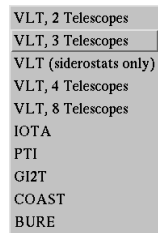
Description...

When we want to change some settings, we hit the button in the middle of the line which will pop up a subpanel with all the possible parameters and containing itself the action button located at the left of the line.

3 Geometry constraints

The geometry constraints of the observation of a given source with a given optical interferometer are mainly due to the varying elevation of the source during the night w.r.t. the baselines chosen, the eventual varying 'horizon' seen from the telescopes used, the maximum stroke of the optical path compensation delay lines. ASPRO tries to deal with those constraints as much as possible without being too particular, so, e.g., "shadowing" of a telescope by another telescope's enclosure nearby, or speed limits on delay lines are currently ignored.

3.1 When/Where



VLT, 2 Telescopes
 VLT, 3 Telescopes
 VLT (siderostats only)
 VLT, 4 Telescopes
 VLT, 8 Telescopes
 IOTA
 PTI
 GI2T
 COAST
 BURE

In these two modules, the user can select the date of observation (defaults to today) and the interferometer (defaults to **VLT, 3 Telescopes**). The figure shows the current list of interferometers supported.

3.2 What

This module allows to load the parameters characterizing the observed objects. These parameters are used in the other modules of the software and are the following:

- the object name
- the declination
- the right ascension
- the magnitude in the $V, R, I, J, H, K, L, M, N$ bands

These parameters are best entered in a catalog, either with an editor, or using the **Define Object Catalog...** entry in the **WHAT** menu. It opens first a panel querying the number of objects to create in the catalog, then another panel with as many entries as asked for, filled with dummy values. On exit these parameters are saved in a catalog file. Loading of a particular catalog can be made with the **Use Object Catalog...** entry. The entry **Object Model** is present as a shortcut to the modeling of the source described in 4.

3.3 Observability/Coverage

This module allows the following choices:

- **Observability of Sources** to choose the interferometric configurations and check the period of time when a group of sources (a catalog) are “feasible”.
- **Observability Limits due to Delay Lines** to determine the observability of a single object as a function of the delay lines used.
- **UV Coverage & PSF** to determine the UV coverage for an object.

Observability of Sources: Once one interferometric configuration has been selected, this module will calculate the authorized observing time in terms of minimal and maximal hour angles for each object of the catalog. This calculation will be done from the object position, the delay line strokes, the telescope positions and the date of observation. The global observability of each object will be plotted in a diagram.

Then, the user could determine the UV coverage for a given object. To do that, the user has to limit the observing time within the authorized time interval, and to fix the integration time. Thanks to these informations, the module **UV Coverage & PSF** will be able to calculate the UV coverage, to save it in a UV table and to represent it graphically.

4 Source Modeling in ASPRO

Object modeling is a key point in ASPRO. Current optical interferometers, and most of the planned ones, do not have the sufficient number of simultaneous baselines, the required stability in time and a phase referencing system that could enable them to approach the capabilities of today’s radio interferometers to really make images of the object observed. In fact, most observations produced by optical arrays consist in a few, hopefully accurate (S/N of $\sim 100 - 1000$), measurements of V^2 on a *few points of the uv plane*. To get as most as possible from this sparse information, the astronomer will rely on models of the object that he/she will test against the observations.

ASPRO offers beforehand a way to make that test, to insure that the S/N ration of the planned observations will make it possible to discriminate between, e.g., two competitive models (see sect. 5).

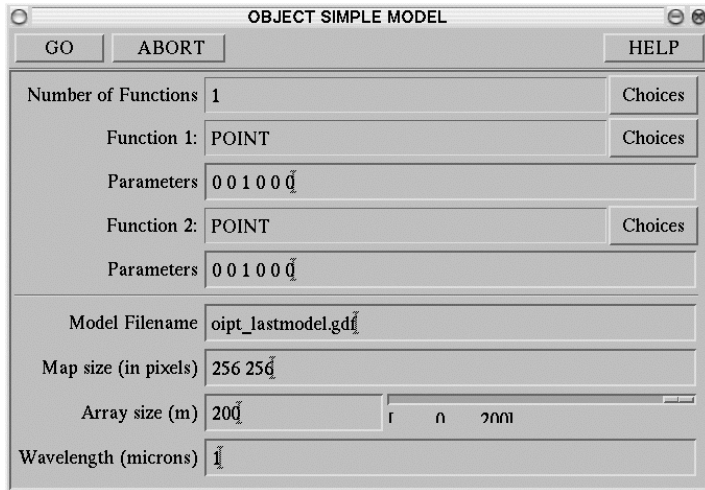


Fig. 3. The OBJECT SIMPLE MODEL Panel

ASPRO accepts two kinds of models: analytical and numerical models. These models are used to compute the synthetic interferometric signals. They are accessible from two panels, one labelled “OBJECT SIMPLE MODEL” in the WHAT module (fig. 3) and also from the “UV MODEL & EXPLORE” (fig. 4) main panel of the “MODEL/FIT” module of sect. 5

The **analytical models** provided by ASPRO are the following:

- point source
- elliptical gaussian source
- circular gaussian source
- circular disk
- elliptical disk (inclined)
- annulus (resolved ring)
- unresolved ring
- exponential brightness
- power laws
- limb-darkened disk
- binary

These models depend on one or several parameters and allow to calculate the squared visibility with respect to the coordinates in the UV plane (U, V) and the wavelength (λ). These models also give the partial derivatives of the complex visibility with respect to each model parameters. Once the model is selected, the GUI allows the user to load the initial value of the model parameters. When computing the model, a data cube of the complex visibility of the model as a function of u and v , and its partial derivatives, is saved in a file and can then be plotted in the background whenever ASPRO displays a function of u and v (uv coverage for example).

The **numerical models** are provided by the users. They consist in images of the scientific object. These images should be presented in FITS format, with suffi-

cient header information to define the angular size (in radians) of the object. When using a numerical model, **ASPRO** will extract the visibility information requested (e.g., V^2) from a Fourier Transform of the image or data cube.

5 The Model/Fit module

The module **MODEL/FIT** contains tools that will fill the observations obtained with the previously defined uv coverage with, e.g., the squared visibilities of the source model, add the proper measurement errors based on the user’s choice of the focal instrument, and perform accuracy fits.

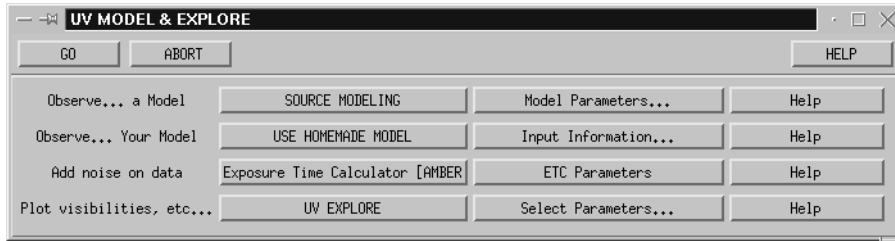


Fig. 4. The UV MODEL & EXPLORE Panel

As stated above (sect 4), preparing useful observations demands that the S/N expected from the focal instrument are taken into account. The first step is thus to select the appropriate focal instrument in the droplist of **MODEL/FIT**, then oneig. 4

This GUI allows the user to choose between both models, “**SOURCE MODELING**” for the parametric models, “**USE HOMEMADE MODEL**” for the numerical model.

Once the model selection is done, this module calculates the synthetic interferometric signal at each point of the UV plane. In the case of analytical models, the synthetic squared visibilities are calculated by the analytical function of the model. In the case of numerical models, the synthetic squared visibilities are calculated by Fourier transforming the images provided by the user.

Then, the module calculates the errors for each measurement through the specific ETC of the focal instrument (ETC stands for “Exposure Time Calculator” in (bad) conformance with an ESO naming). The parameters of these ETCs are: the values of the squared visibilities, the magnitude of the scientific object, the wavelength, the spectral bandwidth, the operating mode of the focal instrument, the seeing value and the integration time.

Tools of graphical representation of the “observations” thus obtained are available with the “**Plot visibilities, etc...**” submenu.

5.1 Fit

Finally, the user can use the second part of this module (“**Model Parameter Errors Calculator**”) in order to estimate with which accuracy the model parameters (usually the same analytical models as before) could be constrained.

This processing will be done by classical fitting routines based on non-linear least squares method. This can be done even on visibilities tables derived from a numerical model, or even real observations. At the time of writing, fitting a user-provided model is not implemented but scheduled.

6 Other menus

The **OTHER** menu groups a variety of useful tools, to import, export, grid, clean and plot uv tables and images.

References

- “ASPRO”, Powerpoint Presentation available at <http://www-laog.obs.ujf-grenoble.fr/~jmmc/diaporama-aspro.ppt>
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