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# JMMC

## ASPRO USER'S MANUAL

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# 1 Introduction

## 1.1 Object

This document describes the usage of **ASPRO**, the JMMC general software for preparing interferometric observations. A dedicated version of this software, **ASPRO-VLTI**, allows users to simulate VLTI observations with the setups offered by ESO for the upcoming Observing Period.

## 1.2 Reference documents

- [1] JMMC-MAN-2100-0002, Revision 9.0, **ASPRO-VLTI** User's Manual

## 1.3 Abbreviations and acronyms

AMBER	Astronomical Multi Beam Recombiner
ASPRO	Astronomical Software to PrepaRe Observations
AT	Auxiliary Telescope
CDS	Centre de Données astronomiques de Strasbourg
CHARA	Center for High Angular Resolution Astronomy
COAST	Cambridge Optical Aperture Synthesis Telescope
DFT	Discrete Fourier Transform
ESO	European Southern Observatory
ETC	Exposure Time Calculator
FAQ	Frequently Asked Questions
FITS	Flexible Image Transport System
FWHM	Full Width at Half-Maximum
GI2T	Grand Interféromètre à 2 Télescopes
GILDAS	Grenoble Image and Line Data Analysis System
GUI	Graphic User Interface
IOTA	Infrared Optical Telescope Array
JMMC	Jean-Marie Mariotti Center
MIDI	MID-infrared Instrument
PDF	Portable Document Format
PS	PostScript
SIMBAD	Set of Identifications, Measurements and Bibliography for Astronomical Data
UT	Unit Telescope
VLTI	Very Large Telescope Interferometer
XML	eXtensible Markup Language

## 2 Overview

### 2.1 Brief functional description

**ASPRO** is designed to simulate/prepare observations with a variety of long baseline optical interferometers. Some prior knowledge of interferometry is preferable, though not mandatory, to take full advantage of the software. Users interested only in simulating observations with the currently supported configurations of ESO/VLTI (with the AMBER or MIDI instruments) are encouraged to use **ASPRO-VLTI**, a dedicated software based on **ASPRO** but in which many of the detailed features in **ASPRO** are transparent to the user. Note that **ASPRO** and **ASPRO-VLTI** are part of a single package (also named **ASPRO**).

**ASPRO** provides tools to check the object observability with a given interferometer, taking into account both the location of the target in the sky and the technical limitations induced by the limited extent of the delay lines of the array. After the user has selected an interferometer/instrument combination and defined the geometrical properties of his/her target, **ASPRO** allows to determine the optimal array configuration and interferometric calibrators to achieve the user's astrophysical goals. The optimization is performed through estimating synthetic interferometric observables (visibilities) as well as through fitting theoretical models on these quantities. The fitting process takes into account the measurement errors of the interferometric signal based on the instrument's ETC, when available, or a rough estimate based on past observations.

**ASPRO** is organized as a suite of five main successive modules, which are briefly presented below and described in more details later in Sect. 3. The five modules are:

- **WHEN**: to define the date and time of the simulated observation
- **WHERE**: to select the interferometer (and instrument)
- **WHAT**: to define the target properties (name, coordinates, photometry and model of its geometry);
- **OBSERVABILITY/COVERAGE**: to define the VLTI configuration to be used in the observations; this includes defining both the exact telescope array and the instrumental setup;
- **MODEL/FIT**: to calculate and plot interferometric observables and their associated uncertainties, and to fit parametric models to the synthetic interferometric signal.

The UV coverage of the object is provided by the **OBSERVABILITY/COVERAGE** module, along with an estimate of the object observability. With the **MODEL/FIT** module, the user can readily estimate if observing the target in the requested configuration will yield visibilities that are accurately measurable and that vary significantly as a function of time, for instance. In addition, this module allows the user to estimate whether the observations would yield tight constraints on the geometrical model of the source, possibly leading to the exclusion of some models, for instance. In addition to these outputs, **ASPRO** also provides a tool to search for adequate interferometric calibrators in the **WHAT** module; the user is provided with a list of possible calibrators, along with a number of relevant properties, from which the most appropriate ones can be selected.

### 2.2 System requirements

**ASPRO** is run remotely through the JMMC website. It is normally run as a Java2 applet, which means that the appropriate Java plug-in (version 1.1.2 or higher) must be installed. If it is not installed, please install the computer-specific plug-in first (see <http://java.sun.com>).

**ASPRO** can be used in *anonymous* or *authenticated* mode. Authenticated mode permits to exchange files with the server and retrieve previously stored files. When launching **ASPRO** anonymously, the user connects to one of the 16 **ASPRO visitor accounts** available. If all accounts are already being used, the application will not start and the user must try again later. All connections use one IP port in the range 50000-52500. In case of systematic failure to start the application, the user must check that he/she is not working in front of a firewall that blocks part of this port range.

An alternative method to start **ASPRO** is to launch it as a Java Webstart application, also available from the JMMC website. This only requires the installation of Java Runtime Tool Kit on the user's computer, also available from <http://java.sun.com>.

The **ASPRO** GUI has been created by JMMC based on Java and XML technologies. The use of the GUI should be totally transparent to the user; if necessary, a document describing the basic principles of the XML-based GUI is available from the JMMC website. Additional information on how to set up your computer to use Java properly can be found at [http://www.mariotti.fr/java\\_infos.htm](http://www.mariotti.fr/java_infos.htm).

### 3 Using ASPRO

This section describes how to launch the whole **ASPRO** package and to use the full **ASPRO** interface, which is only a part of this package. If problems occur while running **ASPRO**, check here for possible errors in selecting options or providing information to the software. Furthermore, right-clicking (<CTRL>-click for Macintosh users) on a variable/parameter name in any panel brings up a brief explanation of its nature and possible values. In addition, use the **Help** buttons available in each **ASPRO** panel. If no solution to a problem can be found there or in the **ASPRO** FAQ webpage on the JMMC website, please send an email to the JMMC User Support group ([user-support@mariotti.ujf-grenoble.fr](mailto:user-support@mariotti.ujf-grenoble.fr)) with a detailed description of the problem (including input parameters and error messages appearing in the LOG window, if any).

#### 3.1 Launching the ASPRO package

##### 3.1.1 The launcher applet



Figure 1: The **Application Applet** window for anonymous (*left*) and personal account (*right*) login to **ASPRO**.

To start a new **ASPRO** session, click on the **Start the Application Launcher Applet** icon/link in the **ASPRO** webpage. If the appropriate Java2 applet is installed (see Sect. 2.2), an **Application Applet** window will appear on the user's screen (see left part of Fig. 1). Select **Help** under the ? menu for a basic description of the usage of the applet. Note that, at this stage, the **ASPRO** software has not yet been started; the Java applet has only initiated a new "session", from which it is possible to start the entire suite of JMMC softwares, including **ASPRO**.

##### 3.1.2 Anonymous vs. authenticated login on the ASPRO server

The user can decide to launch **ASPRO** either anonymously (default option offered by the **Application Applet** window) or using a pre-defined username. First- or one-time **ASPRO** users can usually accommodate using the anonymous login option. For frequent **ASPRO** users and/or for repeated use of some custom input/setup files, the use of a personal account is usually more appropriate. Note that it is possible

to upload and retrieve files when using anonymous login; however, it is not possible to recover files created during previous uses of **ASPRO**.

### 3.1.3 Setting a personal account on the ASPRO server

Setting a personal account can be done simply by subscribing to the `aspro-users` mailing list. After sending an email to `sympa@mariotti.ujf-grenoble.fr` (with sub `aspro-users` in the subject line), the user will receive a confirmation email containing his/her username and password. These are the entries to provide in the **Application Applet** window after checking the *Start application using my account informations* box (see right part of Fig. 1).

### 3.1.4 Starting the ASPRO package

To start the entire **ASPRO** package, which includes the full **ASPRO** interface, either anonymously or after logging in with a valid username/password combination (do not forget to click on the `Login` button after filling the username and password fields), simply select **ASPRO** in the **Start** menu of the **Application Applet**.

When **ASPRO** is launched, one or two new tab(s) appear in the **Application Applet** window: **ASPRO** and, if the user has used an authenticated login, **File Management** (see Fig. 2). The **ASPRO** tab should indicate that **ASPRO** is now running.



Figure 2: The new tabs appearing in the **Application Applet** window after **ASPRO** has been launched.

### 3.1.5 Uploading and downloading files to/from the ASPRO server

If the user has started the application with an authenticated login, the `Open File Exchange Panel` button in the **File Management** tab allows him/her to upload/download files from his/her personal **ASPRO** account. Clicking on this button opens a **File Exchange** window (see left part of Fig. 3) that lists all files currently present on the user's account (it is empty when the account has just been created). Checking the *Enable File Management* box opens a second sub-panel in the **File Exchange** window (see right part of Fig. 3) that lists and allows to browse the files and directories present on the user's personal computer. To upload a file on the JMMC servers, highlight the file in the **Local File System** sub-panel and click on the `<` button; the file should appear in the **Remote File System** sub-panel. Reversely, to download a file from the JMMC servers, select the file and click on the `>` button after selecting the appropriate download directory. Click on the `Cancel` button in the **Remote File System** sub-panel to dismiss the **File exchange** window. This window must be dismissed to resume activity within **ASPRO**.

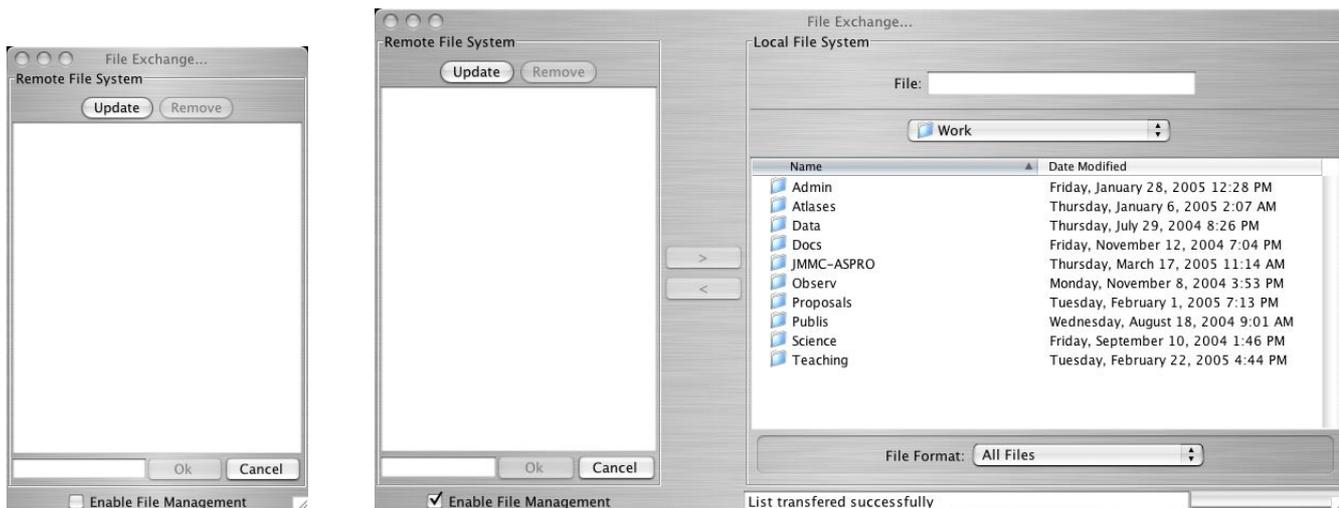


Figure 3: The **File Exchange** windows to upload and download files from a personal **ASPRO** account.

### 3.2 The ASPRO package

Once the user has launched the **ASPRO** package, he is presented with two GUI windows (see Fig. 4): the graphic window, in which plots will be presented when running **ASPRO**, and the start-up control window. At this stage, the start-up control window contains only a **Choose** menu, from which the user actually selects the JMMC software he wants to use for this session. The possible choices are:

- **AMBER, Periods 79-80**
- **MIDI, Periods 79-80**
- **Full ASPRO Interface**

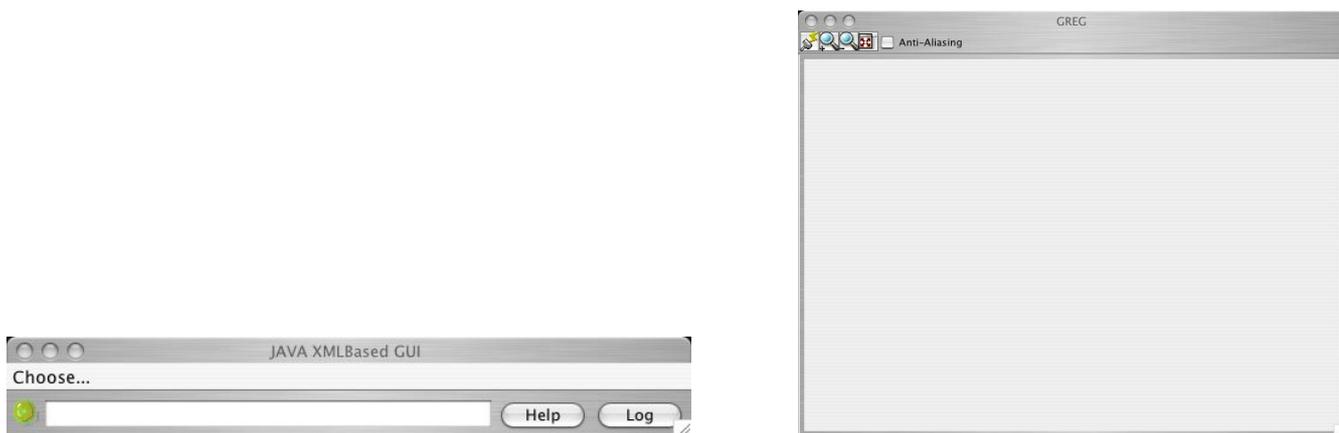


Figure 4: The two GUI windows that are automatically opened upon launching the **ASPRO** package: the start-up control window (*left*) and the graphical window (*right*).

The first two choices represent the specific versions of **ASPRO-VLTI** available for preparing observations with VLTI for Periods 79 and 80. This version of the software is not described here; a specific Users' Manual is available from JMMC.

The **Full ASPRO Interface** choices starts up the wider-scope **ASPRO** software, which allows simulations of observations with many other interferometers (CHARA, COAST, IOTA) as well as with configurations of VLTI with MIDI and AMBER that are not available for Periods 79 and 80 and with future VLTI instruments allowing observations with 4-, 6- and 8-telescope arrays. It is this generic software that is described in this document.

### 3.3 First contact with ASPRO

Once the **Full ASPRO Interface** has been selected, the main control window offers eight menus (see Fig. 5). The **EXIT** menu allows to quit **ASPRO**. The **ASPRO** menu offers several commands associated to error handling and plotting that can be used at any time while running **ASPRO**. The **WHEN**, **WHERE**, **WHAT**, **OBSERVABILITY/COVERAGE** and **MODEL/FIT** allow the user to enter the five main modules constituting **ASPRO** (see Sect. 2.1). The **OTHER** module offers several helpful commands that can be used at any time while running **ASPRO**. All menus are described in more detail in the remainder of this document.

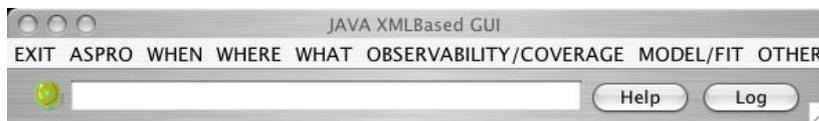


Figure 5: The appearance of the main control window GUI once the user has selected a version **ASPRO**.

In addition to these main menus, the main control window contains an **Help** button and a button to open the LOG window in which **ASPRO** prints out messages as it executes commands. The content of the LOG window can be useful while troubleshooting. To the left of these two buttons is a white-background window in which **ASPRO** provides short statements about its status while running commands; it is usually empty when the software is idle. Finally, to the left of this window is a roundish icon whose color indicates **ASPRO** status: when it is green, the software is up and running and waiting for commands from the user; when it is orange, it is executing a command; when it is red, the software has run into an error and stopped. *Commands can only be executed when this icon is green.* If it is orange, wait for the command to be completed. If it is red (or stuck on orange for at least a couple of minutes), try using (a few times if necessary) **Exit From Error Loop** under the **ASPRO** menu (see Sect. 3.5.1). If this is not enough to restore a normal running state for **ASPRO**, then there has been a severe crash; it is then recommended to quit **ASPRO** and restart if from scratch. If the same problem occurs repeatedly, checking the content of the LOG window may provide an indication of the nature of the problem.

The buttons located in the top left corner of the graphical window (see right part of Fig. 4) represent the following, from left to right:

- **Refresh Plot** redraws the last plot requested in case it did not show up automatically or if the displays contains only a red square crossed by two thin white diagonals;
- **Zoom In** increases the zoom factor and provides scrolling bars to move around in the plot;
- **Zoom Out** decreases the zoom factor;
- **Toggle Scrolling Bars On and Off** adjusts the window size to the current zoom while removing the scrolling bars;
- the *Anti-Aliasing* option can be used for improving the quality of the graphical display on your computer screen.

### 3.4 EXIT menu

The only command under the **EXIT** menu, **Exit**, quits the **ASPRO** software after confirmation in a pop-up window. After the software is shut down (the GUI windows are dismissed), the **Application Applet** window remains in the user's screen, but the **ASPRO** tab has now disappeared. The configuration of the applet window is identical to its status after the user has first started the applet (see Fig. 1); in particular, if the user had logged in with his/her personal account information, he/she has been automatically logged out. Clicking on the **EXIT** button terminates the current **ASPRO** session.

### 3.5 ASPRO menu

#### 3.5.1 Exit From Error Loop

Selecting this option forces the command interpreter to return to its default idle status (i.e., green icon in the main GUI window) without executing the remainder of an aborted command. This is to be used when **ASPRO** is stuck with a red or fixed orange icon in the main GUI window; in the latter case, check in the LOG window that the last output is indeed an error message. In some cases, it may be necessary to select this option several times consecutively to unwind the command stack.

#### 3.5.2 Ignore Error

Selecting this option forces the command interpreter to ignore (step over) the current error and to try to complete the remainder of the command. This usually does not solve problems but it may be useful in some specific cases. We strongly recommend using **Exit From Error Loop** and analyzing the error message(s) in LOG window (check for missing files, improper parameter selection, ...), instead.

#### 3.5.3 Clear Plot

Selecting this options clears the graphic window, starting a new plot from scratch.

#### 3.5.4 Refresh Plot

Selecting this option redraws the last plot requested in case it did not show up automatically or if the displays contains only a red square crossed by two thin white diagonals. This is strictly equivalent to the clicking on the first icon in the top left corner of the graphic window.

#### 3.5.5 Hardcopy

Selecting this option creates a PS file with the current content of the graphic window. The user is asked to select a name for the output file that can then be downloaded provided the user has launched **ASPRO** with his/her personal account.

#### 3.5.6 Reset Marker Size

Selecting this option forces **ASPRO** to use the default, dot-like, markers when plots are created. This overrides the selection of **Use Big Markers**.

#### 3.5.7 Use Big Markers

Selecting this option forces **ASPRO** to use larger markers when creating plots. This can be useful when plotting visibilities with their uncertainties, for instance, since the errorbar is as large as the default, dot-like, marker and it is therefore sometimes difficult to determine from the plot the actual visibilities. There is only one "big" marker size; selecting repeatedly this option will not increase the marker size every time. This can be overridden by selecting **Reset Marker Size**.

### 3.5.8 Zoom Plot

Selecting this option increases the zoom factor in the graphic window and provides scrolling bars to move around in the plot. This is strictly equivalent to the clicking on the second icon in the top left corner of the graphic window.

### 3.5.9 Zoom Off

Selecting this option decreases the zoom factor in the graphic window, i.e., it allows to zoom out. This is strictly equivalent to the clicking on the third icon in the top left corner of the graphic window.

### 3.5.10 Zoom in Same Window

Selecting this option results in the new zoomed (in or out) plots to be shown in the same graphic window.

### 3.5.11 Zoom in New Window

Selecting this option results in the new zoomed (in or out) plots to be shown in a separate graphic window.

### 3.5.12 Toggle Multi-Window Display

Selecting this option allows the user to switch between several existing graphic windows to make either one of them the currently active window.

## 3.6 WHEN menu

This menu brings the **Date & Time Setup** panel illustrated in Fig. 6. The user must provide the *Date* (format should be DD-*MMM*-YY, using decimal number for days and years and English 3-letter abbreviation for months) and *Time* (format should be HH:MM:SS in the range 00:00:00 to 23:59:59) of the observations to be simulated. Once the appropriate values have been entered, click on the **GO** button to register the values and then on the **CLOSE** button to dismiss the panel.



Figure 6: The **Date & Time Setup** panel opened by the **WHEN** menu.

## 3.7 WHERE menu

This menu allows the user to select the interferometer he/she wishes to simulate observations with. The first 8 entries represent configurations of VLTI whereas the remaining 6 represent other long-baseline interferometers. They are briefly described here.

The first 4 VLTI entries corresponds to the configurations offered by ESO for Period 76, i.e., MIDI with either the UTs or the ATs and AMBER with either 2 or 3 telescopes. Selecting one of these choices places the user in a mode of **ASPRO** very similar to that of **ASPRO-VLTI**, i.e., where a number of technical details have been set to default values so as to simplify the use of **ASPRO** for non-specialists. Users who wish to go into more details are encouraged to select the *VLT, N Telescopes* choice (see below), instead. The remaining 4 VLTI entries allow to simulate observations with 2, 3, 4 and 8 telescopes, respectively, independently of

whether the configuration is currently supported by ESO. These later choices are appropriate to simulate future observations, not yet supported by ESO but that could be conducted when they become available, for instance.

The other long baseline optical interferometers supported in **ASPRO** are IOTA (3 telescopes), CHARA (2 telescopes), PTI (2 telescopes), GI2T (2 telescopes) and COAST (4 telescopes). Finally, it is also possible to select the IRAM Plateau de Bure millimeter interferometer (6 antennas) for which the same formalism applies, though with a much longer wavelength.

In the following, we describe the use of **ASPRO** after having selected the generic *VLT, 3 Telescope* configuration. Note that most of the following applies to all interferometers, with only minor array-specific details varying from this selected choice.

### 3.8 WHAT menu

This menu represents the third main module constituting **ASPRO**, in which the user defines the target(s) he/she wishes to observe. This can be done in several ways, which are described in detail in this section:

- properties of several targets can be stored into a catalog that remains available on the user's account (see Sect. 3.8.1, 3.8.4 and 3.8.5);
- a new target can be entirely defined by hand (see Sect. 3.8.2);
- basic properties (coordinates, photometry) of a target can be recovered from a CDS request (see Sect. 3.8.3).

In addition, **ASPRO** allows to user to define a geometrical model for his/her target(s) (see Sect. 3.8.6) and provides a tool to find the most appropriate calibrators for a given scientific target, taking into account the required accuracy on the visibilities (see Sect. 3.8.7).

#### 3.8.1 Use Object Catalogue

Selecting **Use Object Catalogue** under the **WHAT** menu brings up the **New Catalog** panel illustrated in Fig. 7. This panel allows the user to load an *already existing* catalog of targets into ASPRO. If no catalog has been previously defined, the user should instead use the **Define Object Catalogue** option under the **WHAT** menu to define a new catalog that will be stored on his/her account.

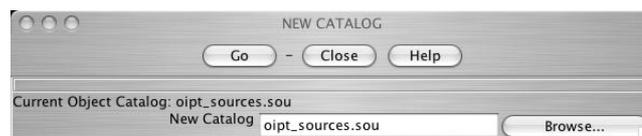


Figure 7: The **New catalog** panel opened by selecting **Use Object Catalogue** under the **WHAT** menu.

The user must either type in the name of the catalog to be used (*New catalog*) or he/she can use the **Browse** button to navigate his/her ASPRO account. Clicking on this button brings on a *File Exchange* panel essentially identical to that described in Sect 3.1.5 (refer to this section for more details). The user can highlight a catalog file already located in his/her account, possibly after having uploaded it from his/her personal computer by checking the *Enable File Management* box. Click on the **OK** button to dismiss the *File Exchange* panel, on the **GO** button to actually upload the file in **ASPRO** and on the **Cancel** button to dismiss the **New Catalog** panel. Note that it is possible to upload catalog file even for users who logged in anonymously; the file will be lost after logging out and not available for further use, however.

### 3.8.2 Single Object Entry

Selecting **Single Object Entry** under the **WHAT** menu brings up the **Source List Creation Tool** panel illustrated in Fig. 8. This panel allows the user to define a single target to be used by **ASPRO**. Users interested in simulating observations with several targets (i.e., for survey-mode programs) should use the **Define Object Catalogue** option instead.

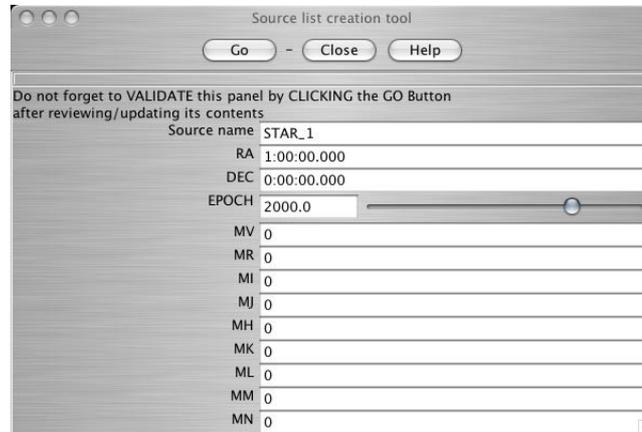


Figure 8: The **Source List Creation Tool** panel opened by the **Single Object Entry** menu.

In the upper half of the panel, the user must provide the target name (*Source Name*, with no more than 24 characters and no embedded `<space>`; use `<underscore>` instead) and its coordinates (*RA* and *DEC*; format should be `HH:MM:SS.SSS` and `DD:MM:SS.SSS`) along with the appropriate epoch (e.g., 2000.0). The epoch can be either typed in (values outside the 1850–2050 range are not accepted; the default 2000 epoch is then assumed) or adjusted with the scrolling icon to the right.

In the bottom half of the panel, the user can provide the magnitude of the target in a number of visual and infrared bands (*MV* through *MN*). If provided here, the object's magnitudes will be propagated to several other panels of **ASPRO** that need the target brightness. If no magnitude is provided at this stage, it is possible for the user to enter them later on.

Alternatively, the coordinates of the object and some of its magnitudes can also be retrieved from the CDS database by clicking on the **Query CDS By Name** button (see Sect. 3.8.3).

Once the object has been entirely defined, click on the **GO** button to validate the target and on the **CLOSE** button to dismiss the **Source Creation List Tool** panel.

### 3.8.3 Get CDS Object

Selecting **Get CDS Object** under the **WHAT** menu brings up the **Get Source Coordinates** panel (see Fig. 9). Enter a case-insensitive target name (*Enter CDS Source Name*, with no more than 24 characters and no embedded `<space>`; use `<underscore>` instead) and click on the **GO** button. If the requested object name is not resolved by SIMBAD, a pop-up window presents an error message; click on **CLOSE** to enter a new object. If the object name was resolved by SIMBAD, the panel is dismissed and an **All About My Source** panel appears with the coordinates and available photometry retrieved from CDS. The object name cannot be modified in this panel, but its coordinates and magnitudes can be. Because of possible errors in the CDS database, it is recommended to check that the coordinates are correct and, if necessary, to modify them. Also, the object can be variable and the user should provide what he/she believes is most appropriate for the simulated observations. Furthermore, it is quite frequent that some magnitudes, including the ones that are appropriate for the observations are not available through the CDS and need to be provided by the user.

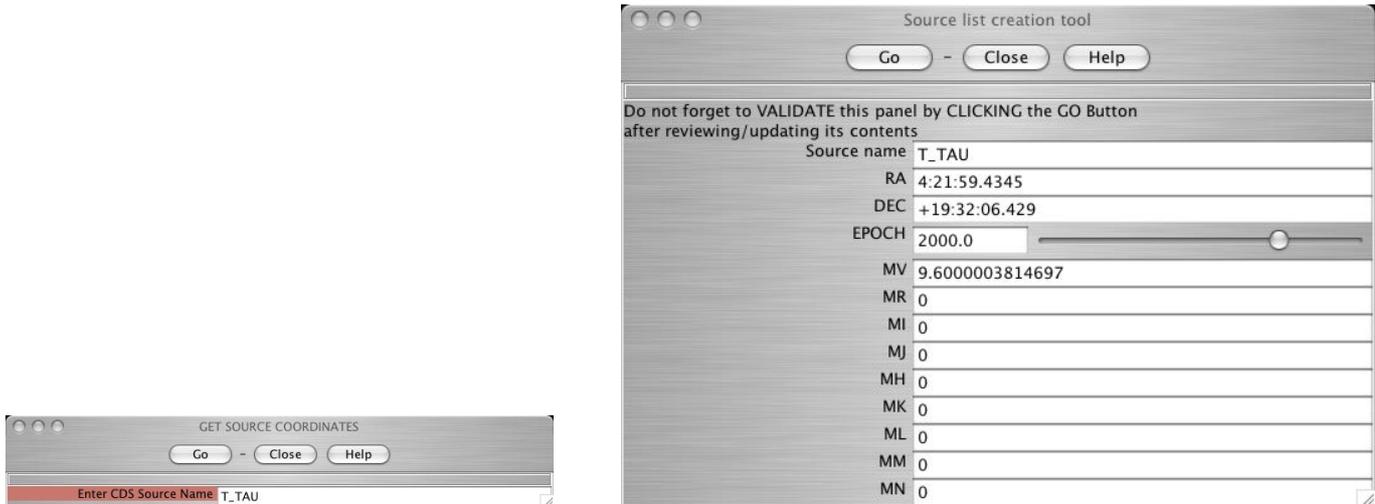


Figure 9: The **Get Source Coordinates** panel opened by the **Get CDS Object** menu (*left*) and the resulting **Source List Creation Tool** panel (*right*).

Once the object has been entirely defined, click on the **GO** button to validate the target and on the **CLOSE** button to dismiss the **Source Creation List Tool** panel.

### 3.8.4 View Object Catalogue

Selecting **View Object Catalogue** under the **WHAT** menu prints out the current source catalog in the LOG window. To view it, simply click on the **LOG** button in the main control window and scroll down to the bottom (see Fig 10). This option is useful when the user has defined multiple sources and wants to check that he/she has selected the correct catalog before proceeding further with **ASPRO**.

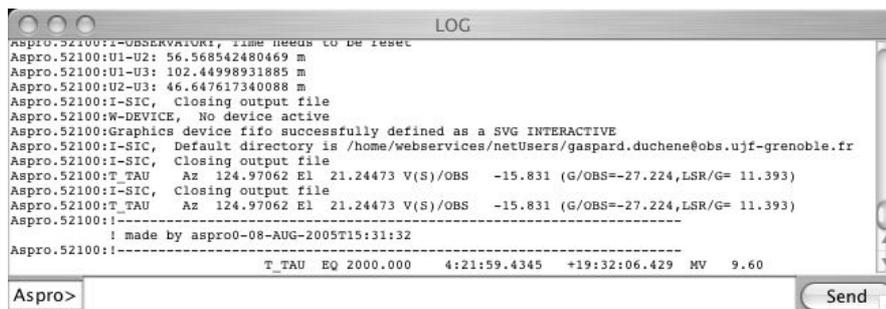


Figure 10: The latest entries in the LOG window panel after the user has selected the **View Object Catalogue** option under the **WHAT** menu.

### 3.8.5 Define Object Catalogue

Selecting **Define Object Catalogue** under the **WHAT** menu allows the user to define a new catalog of one or several targets. If the user has logged in using his/her personal account, the newly created catalog will remain available in the subsequent **ASPRO** sessions.

Selecting this option first brings up the **Basic Parameters** panel (see left part of Fig. 11), in which the user can provide the catalog name (*Catalog File To Use*, should not contain embedded `<space>`, use `<underscore>` instead; also, the sou extension should be maintained) and the number of sources of the new

catalog (*Number of Sources*). Once these two entries have been selected, click on the **GO** button and a new **Source List Creation Tool** panel will appear (see right part of Fig. 11). This is very similar to the panel illustrated in Fig. 8, except that it contains several targets if the user has created a catalog with more than one source. To open and close the sub-panel corresponding to each target, click on the arrow to the left of the **Source N** button. Note that it is not possible to make CDS queries to recover some of the properties of the targets; this option is only available for defining a single source.

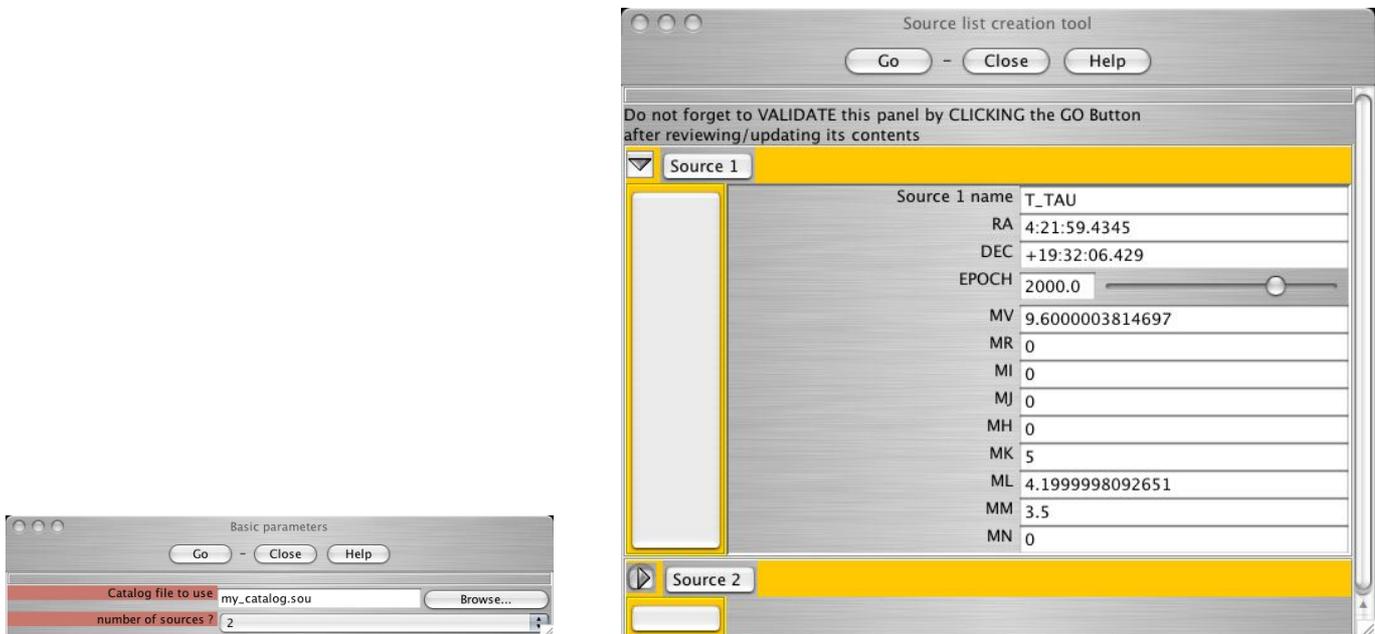


Figure 11: The **Basic Parameters** panel opened by the **Define Object Catalogue** menu (*left*) and the resulting **Source List Creation Tool** panel (*right*).

After the name, coordinates (and magnitudes) have been provided for all targets, click on each of the **Source N** and then on the **GO** button to validate the entries and on the **CLOSE** button to dismiss the panel.

### 3.8.6 Object Model

Selecting the **Object Model** option under the **WHAT** menu allows the user to define a simple analytical model to describe the geometry of his/her target(s). If a catalog of several sources has been defined and selected, the same geometrical model will apply to all targets. Note that it is not necessary to define the geometrical model of the target at this stage; it can be done later, in the **MODEL/FIT** menu (see Sect. 3.10). Also, it is not possible at this stage to use a homemade model to describe the geometry of the target(s). This is possible in the **MODEL/FIT** menu, however (see Sect. 3.10).

Selecting this option brings the **Object Simple Model** panel illustrated in Fig. 12. The method offered by **ASPRO** to do this is to select one or the weighted sum of two simple parametric models for which the Fourier Transform can be calculated analytically. This choice is provided with the *Number of Functions* scroll-down menu. The list of functions, along with the appropriate sets of parameters can be found in Table 1. Provide the name of the desired functions (*Function 1* and *Function 2*) and their associated parameters (*Parameters*). **Important:** *Be sure to provide 6 parameters for each function, even though less parameters are needed to describe some of them; fill in the list with 0s if necessary.*

The first two parameters for all models,  $\Delta\alpha$  and  $\Delta\delta$ , represent the angular offset from the coordinate center (i.e., the values entered for *RA* and *Dec*). This is useful when using a model that sums two parametric

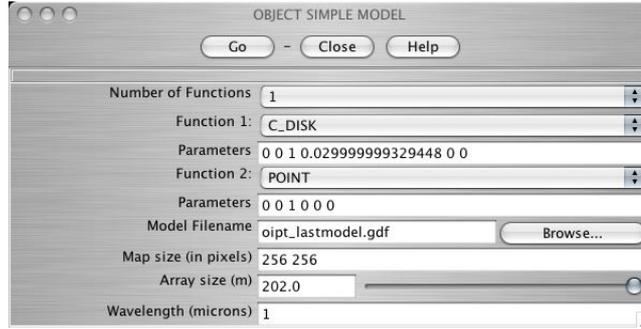


Figure 12: The **Object Simple Model** panel opened by the **Object Model** option under the **WHAT** menu.

functions that represent spatially-separated components of the object; for one-function models, these parameters should be set to 0 0.  $F_\nu$  represents the normalized flux associated to the model: when using only one analytical model, set this to 1, and when using the sum of two models, make sure that  $F_{\nu,1} + F_{\nu,2} = 1$ .  $D$  and  $D^{1/2}$  represent the diameter and FWHM of the model, respectively. The subscripts  $M$  and  $m$  indicate the major and minor axis, respectively, whereas  $i$  and  $o$  indicate the inner and outer diameters.  $\theta$  is the position angle of the major axis (models **E.Gauss** and **E.Disk**) or of the binary system (model **Binary**). Finally,  $FR$  is the flux ratio of the binary and  $C_U$  and  $C_V$  are the coefficients defining the limb-darkening profile. This profile is defined such that the Fourier Transform of the limb-darkened disk is:

$$G(u, v) = [a (J_1(x)/x) + 1.253 b (J_3(x)/x) + 2 c (J_2(x)/x^2)] / s$$

where  $x = \pi D(u^2 + v^2)$ ,  $J_1(x)$  and  $J_2(x)$  are Bessel functions,  $J_3(x) = \sqrt{0.637/x} (\sin x / x - \cos x)$ ,  $a = 1 - C_U - C_V$ ,  $b = C_U + 2C_V$ ,  $c = -C_V$  and  $s = a/2 + b/3 + c/4$ .

All angular distances must be given in arcseconds (even though milli-arcseconds is a more natural unit for optical interferometry). The position angle is expressed in degrees (following the usual astronomical convention, i.e., measured East from North).

The user must also specify the name of the file that will contain the object Fourier transform and its derivatives (*Model Filename*), either by entering the desired file name or by clicking on the **Browse** button and selecting an already existing file with **gdf** extension (in which case the previous image is replaced by the new one). This file will later be used when **ASPRO** plots visibilities and other quantities. The user must also provide the size of this file, in terms of pixels (*Map Size (in pixels)*,  $256 \times 256$  is typically a good choice) and of projected baselines (*Array Size (m)*, this should be selected to be larger than the longest projected baseline of the interferometric array). Finally, the user must indicate the *Wavelength* (in microns) at which the observations will be conducted; this is necessary to calculate the Fourier Transform of the object's geometrical model.

Once all parameters have been set, click on the **GO** button to validate the entries and on the **CLOSE** button to dismiss the panel.

### 3.8.7 Search Calibrators

Selecting **Search Calibrators** under the **WHAT** menu brings up the **Search Calibrators** panel (see Fig. 13). The basic principle of this tool is to provide the user with a list of stars that can be considered as “good” interferometric calibrators. These calibrators must fulfill a number of conditions that include: proximity to the target, similar brightness as the target and well-defined radius (hence visibility). A more detailed description of the methods used by this piece of software is provided in Appendix A.

Calibrators are search for around the last target that has been defined by the user in the **WHAT** menu. If a catalog of several targets has been defined, then all targets are available in the *Science Object Name* pull-down button and the user can choose any of them. The user must provide the desired *Observing Wavelength*

Table 1: List of available analytical models and the parameters that describe them.

Name	Description	Par. 1	Par. 2	Par. 3	Par. 4	Par. 5	Par. 6
<b>Point</b>	Point Source (Dirac function)	$\Delta\alpha$	$\Delta\delta$	$F_\nu$	–	–	–
<b>C_Gauss</b>	Circularly symmetric Gaussian distribution	$\Delta\alpha$	$\Delta\delta$	$F_\nu$	$D^{1/2}$	–	–
<b>E_Gauss</b>	Elliptical Gaussian distribution	$\Delta\alpha$	$\Delta\delta$	$F_\nu$	$D_M^{1/2}$	$D_m^{1/2}$	$\theta$
<b>C_Disk</b>	Circular disk (a.k.a. uniform disk)	$\Delta\alpha$	$\Delta\delta$	$F_\nu$	$D$	–	–
<b>E_Disk</b>	Elliptical uniform disk (i.e., inclined <b>C_Disk</b> )	$\Delta\alpha$	$\Delta\delta$	$F_\nu$	$D_M$	$D_m$	$\theta$
<b>Ring</b>	Uniform ring with finite width	$\Delta\alpha$	$\Delta\delta$	$F_\nu$	$D_i$	$D_o$	–
<b>U_Ring</b>	Unresolved (infinitely narrow) ring	$\Delta\alpha$	$\Delta\delta$	$F_\nu$	$D$	–	–
<b>Exp</b>	Exponential brightness distribution	$\Delta\alpha$	$\Delta\delta$	$F_\nu$	$D^{1/2}$	–	–
<b>Power-2</b>	$1/r^2$ brightness distribution	$\Delta\alpha$	$\Delta\delta$	$F_\nu$	$D^{1/2}$	–	–
<b>Power-3</b>	$1/r^3$ brightness distribution	$\Delta\alpha$	$\Delta\delta$	$F_\nu$	$D^{1/2}$	–	–
<b>LD_Disk</b>	Limb-darkened disk (resolved star)	$\Delta\alpha$	$\Delta\delta$	$F_\nu$	$D$	$C_U$	$C_V$
<b>Binary</b>	Binary point source	$\Delta\alpha$	$\Delta\delta$	$F_\nu$	$FR$	$\rho$	$\theta$

to calculate the calibrators' properties at the relevant wavelength. The scientific target brightness (*Science Object Magnitude in Search Band*) may have been carried over from the object definition panel or typed in by the user otherwise; it is used by the software to search for calibrators of appropriate brightness for MIDI observations. The user must then specify in which band the search should be conducted (*Search For Band*) and the range of magnitudes for the calibrators (*Magnitudes Min & Max To Search*, entered as two real numbers separated by a <space> character). Then, a first set of selection criteria must be provided by the user concerning the distance to the object (*Search Radius in R.A.*, in arcminutes, and *Search Radius in DEC.*, in arcseconds) within which calibrators should be searched for (the default values are considered a good default choice). Finally, the *Max Baseline Used* is indicated to the user; if no array configuration has been selected yet, then a default value is provided. Once the search criteria are selected, click on the **GO** button to start the search.

Once the search is over, the results are presented in a new window illustrated in Fig. 14. A detailed description of the window presenting the results and of the available methods to refine the search for the most appropriate calibrators is presented in Appendix A.

Once the user has retrieve a calibrator list or has confirmed that good calibrators are available for his/her target, both panels can be dismissed by clicking on the **CLOSE** buttons.

**Note** *The visibility uncertainty induced by the observation of a certain calibrator is not propagated by ASPRO. The user should remember to add this source of error to that provided by the instrument-dependent ETC, which only includes the interferometer/instrument performances.*

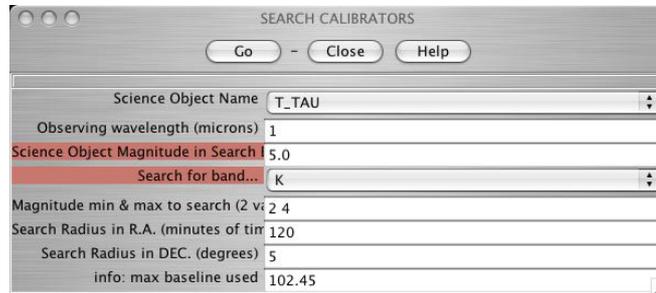


Figure 13: The Search Calibrators panel opened by the Search Calibrators menu.

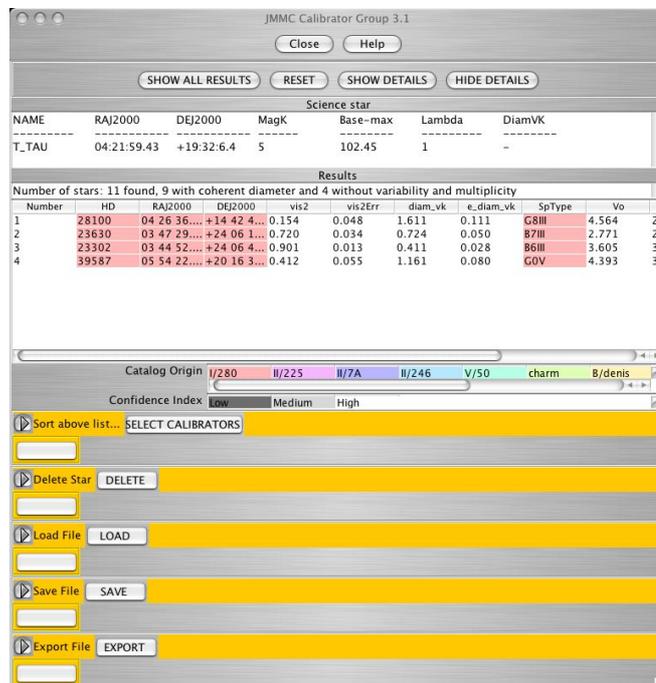


Figure 14: The window presenting the results of the Search Calibrators tool.

### 3.9 OBSERVABILITY/COVERAGE menu

The **OBSERVABILITY/COVERAGE** menu allows the user to set up the interferometric array, i.e., to choose the telescope stations, to check the general observability of the source(s) (see Sect. 3.9.1) as well as the technical limits imposed by the limited range of the variable delay lines of the interferometer (see Sect. 3.9.2) and to plot the UV coverage that can be achieved with the desired configuration (see Sect. 3.9.3).

In the following we assume that a catalog containing 2 sources has been defined in the **WHAT** module described above. The use of **ASPRO** with a single object entry rather than a several-target catalog is essentially identical and is not described here.

#### 3.9.1 Observability of Sources

Selecting **Observability of Sources** under the **OBSERVABILITY/COVERAGE** menu brings up the **Observability of Objects** panel illustrated in the left part of Fig. 15. Clicking on the **View Catalog** button is strictly equivalent to selecting **View Object Catalogue** under the **WHAT** menu (see Sect. 3.8.4). Clicking on the **Change Catalog** button brings up a **New Catalog** panel identical to that described in Sect. 3.8.1, in which the user can either type the name of an existing catalog file or browse his/her directory to select one. The *Current Source Catalog* entry in the **Observability of Objects** cannot be modified by typing a new name; the user must instead click on the **Change Catalog** button. Finally, clicking on the **Change Interferometer** button brings up a **New Observatory** panel in which the user can use the *Where* pull-down menu to define a new interferometer for his/her observations (Note that *VLT* stands for *VLT-3T*).

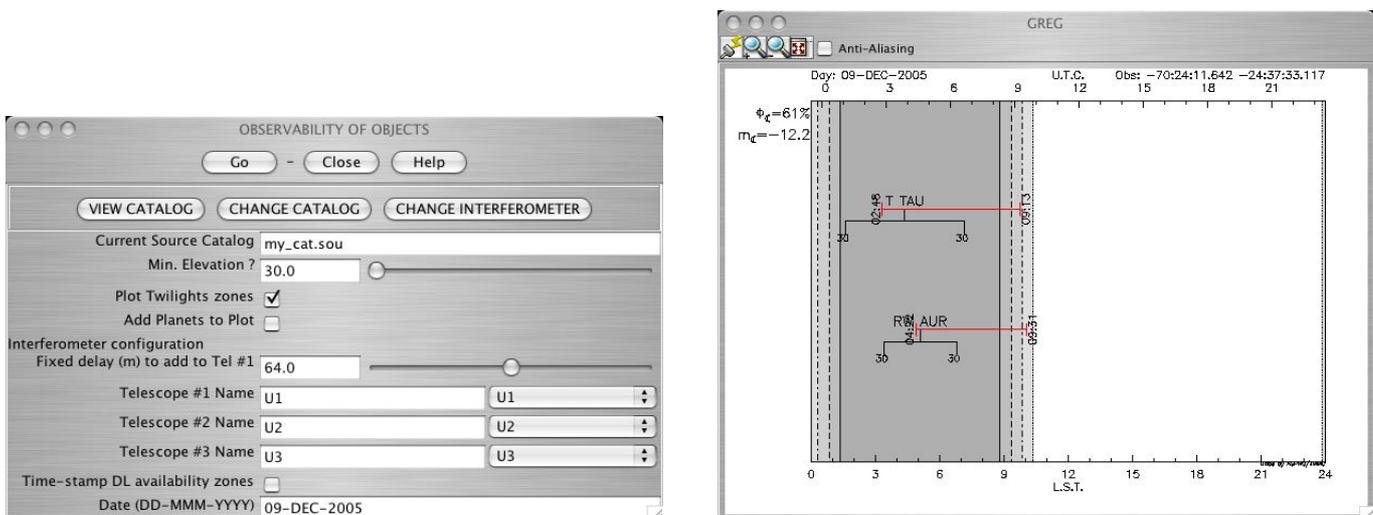


Figure 15: The **Observability of Objects** panel (*left*) and the resulting time coverage plot (*right*).

In the **Observability of Objects** panel, the user must specify the minimum elevation (*Min Elevation*) above which the target(s) should be observed with the interferometer; this can be done by either typing in an elevation (in degrees) or using the scrolling icon. If the *Plot Twilights Zone* box is checked, then the observability plot will contain a dark gray area representing night-time and light dark areas representing twilight periods. If the *Add Planets to Plot* box is checked, the observability of a number of Solar System objects (Moon, Sun, Mercury, Venus, Mars, Jupiter, Saturn, Uranus and Neptune) is indicated in addition to that of the targets in the user-defined catalog. The user must then choose a *Fixed Delay To Add To Tel #1* which will be associated to the first telescope defined below; this can be done by either typing a delay length (in meters) or using the scrolling icon. All other telescopes will use variable delay line to track the interferometric fringes of the object as it moves across the sky. Then, the user must specify the name of

the stations of the interferometric array (*Telescope #N Name*). **ASPRO** does not check that redundant stations are selected or that the requested configurations mixes ATs and UTs; the user must check that he/she does not ask such configurations. Checking the *Time-Stamp DL Availability Zones* box will result in the writing of the start and end time of the period(s) during which interferometer delay lines allow the observations of the target. Finally, the user can modify the *Date* of the observations using the same format as specified in the **WHEN** menu (see Sect. 3.6).

Once all parameters have been set to the desired values, click on the **GO** button and the target observability is plotted in the graphical window (see right part of Fig. 15). The horizontal axis of the plot represent time (local standard time and universal time are indicated on the bottom and top axes, respectively). Also indicated around the figure are the Moon phase and brightness (apparent magnitude), the date of observation and observatory coordinates. The night- and twilight-times are indicated with different shades of gray; the white area is day-time. For each target, a black horizontal line represents the period during which the object is above the minimum elevation selected above while a red line indicates the period during which the interferometer delay lines allow the observations of the target. Ideally, one would like the red line to overlap with the entire black line. If this is not the case, the user must try to change the fixed delay line of the first telescope and/or exchange the first telescope with another one, so that a variable delay line is associated to the telescope which had a fixed delay before.

Once a satisfactory configuration has been found, click on the **CLOSE** button in the **Observability of Objects** panel to dismiss it.

### 3.9.2 Observability Limites Due to Delay Lines

Selecting **Observability Limites Due to Delay Lines** under the **OBSERVABILITY/COVERAGE** menu brings up the **Delay Lines** panel illustrated in the left part of Fig. 16. Most of the entries are identical to those in the **Observability of Objects** panel described in Sect. 3.9.1. The difference between these two options is that **Observability of Sources** indicates whether the object is observable throughout its entire transit with the desired configuration, whereas **Observability Limites Due to Delay Lines** indicates, baseline per baseline, whether the delay lines can actually track the source. This later option is useful when the proposed configuration leads to a truncated observability due to delay lines limits, as the user can then visualize which baseline (and therefore telescope) is problematic. With this piece of information, the user can then decide to either change configuration or the fixed delay line.

Besides providing the same entries as in the **Observability of Objects** panel, the user must choose which target (*Plot For Object*) in his/her catalog he/she wants to study. After clicking on the **GO** button, a new plot appears in the graphic window, similar to that presented in the right part of Fig. 16. The horizontal axis of the plot represent time (local standard time and universal time are indicated at the bottom and top axes, respectively). Also indicated around the figure are the Moon phase and brightness (apparent magnitude), the date of observation, the observatory coordinates, the target name and coordinates and the fixed delay line of the array. The gray areas representing the night and twilights are shown if the *Plot Twilight Zones* box has been checked. The top black line represent the object elevation above horizon, with tickmarks every 15 degrees. The middle lines represent, for each baseline containing the telescope with fixed delay, the period during which the variable delay lines permit observation of the target. The lower line represent the total period of time during which the object is above the horizon (0 degree elevation) and within the reach of the delay lines. If the variable delay lines hit no hard limit, this line should be as wide as the top line; otherwise, the delay lines of the interferometer do not allow complete observation of the target with this specific configuration.

In the **Delay Lines** panel, clicking on the **View VLT Stations** results in a listing of all available stations of the VLT being printed in the LOG window. Along with each station name, the (U,V,W) coordinates are indicated.

When a convenient configuration has been identified and tested, click on the **CLOSE** button to dismiss the **Delay Lines** panel.

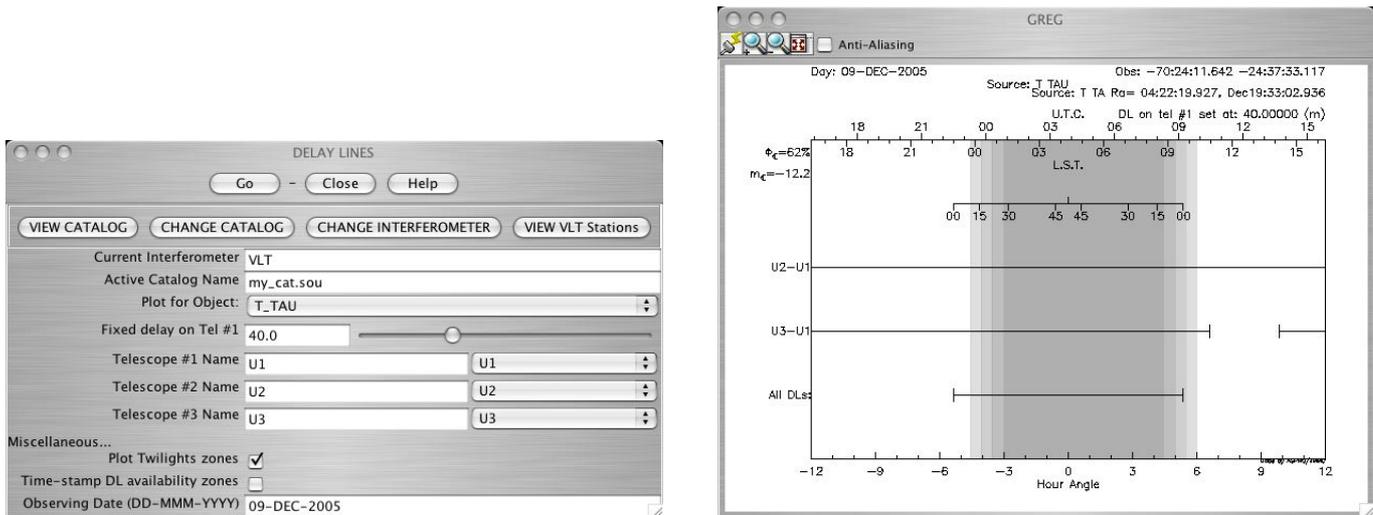


Figure 16: The **Delay Lines** panel (*left*) and the resulting time coverage plot (*right*).

### 3.9.3 UV Coverage

Selecting **UV Coverage** under the **OBSERVABILITY/COVERAGE** menu brings up the **UV Coverage** panel illustrated in the left part of Fig. 17. To access all the parameters associated with the **Plot UV Coverage** subpanel, click on the arrow to the left of this button.

In this panel, the user defines his entire configuration. First of all, at the top of the panel, the target must be selected from the current catalog (*Plot For Object*), as well as the *Wavelength* of observation.

In the **Plot UV Coverage** subpanel, the user can modify his/her choice of *Fixed Delay To Add To Tel #1* and configuration (*Telescope #N Name*). If the *Reset Frame* box is checked, a new plot presenting the UV coverage will be produced. If the box is not checked, then the plot will be superimposed on the previous UV coverage(s). This allows to visualize the result of an “observation” that include several independent sets of baselines for imaging purposes, for instance. The user must also specify the fraction of the transit during which observations will be simulated, through the *Hour Angle Start/End* and *Min/Max Elev. To Plot* entries (type in a value or use the scrolling icons). Only periods during which both the hour angle and elevation conditions are satisfied will be calculated. The user can also choose the length of the axes of the resulting UV plot (*UV Range To Plot*, in meters) and the frequency at which independent observations will be obtained (*UV Integration Time*, in minutes); note that this frequency should include the necessary time to observe a calibrator and overheads. If the *Plot Aperture Size On UV Plane* box is checked, each individual observation will be represented in the UV plane as a circle of size equal to the telescope size instead of as a point (note that those points that are outside the available range of the interferometer delay lines are shown as small points anyway, so that checking this box shows readily which part of the UV track is actually accessible). The user can also choose the *Name of the Output PSF UV Table* (either by typing it or using the **Browse** button as in Sect. 3.8.1). If the *Underplot a Model Image?* box is checked, the model of the target (more precisely, the Fourier Transform of its geometrical model, i.e., its complex visibility), as defined in Sect. 3.8.6 and input through the *Image Filename* entry, will be plotted along with the UV coverage. Doing so can help deciding right away whether the selected interferometer and configuration is appropriate for the observation of a given target. Finally, the user can decide which quantity to plot as a function of the UV coordinates (*Plot What*, where the possibilities include the complex visibility amplitude, phase and their derivatives) and which color scheme to use (*Use Image-To-Pixel Conversion*, where **Automatic** stands for **Linear**).

Once all parameters have been set, click on the **Plot UV Coverage** button to obtain a similar plot to that presented in the right part of Fig. 17. The horizontal axes represent the projected baselines along the

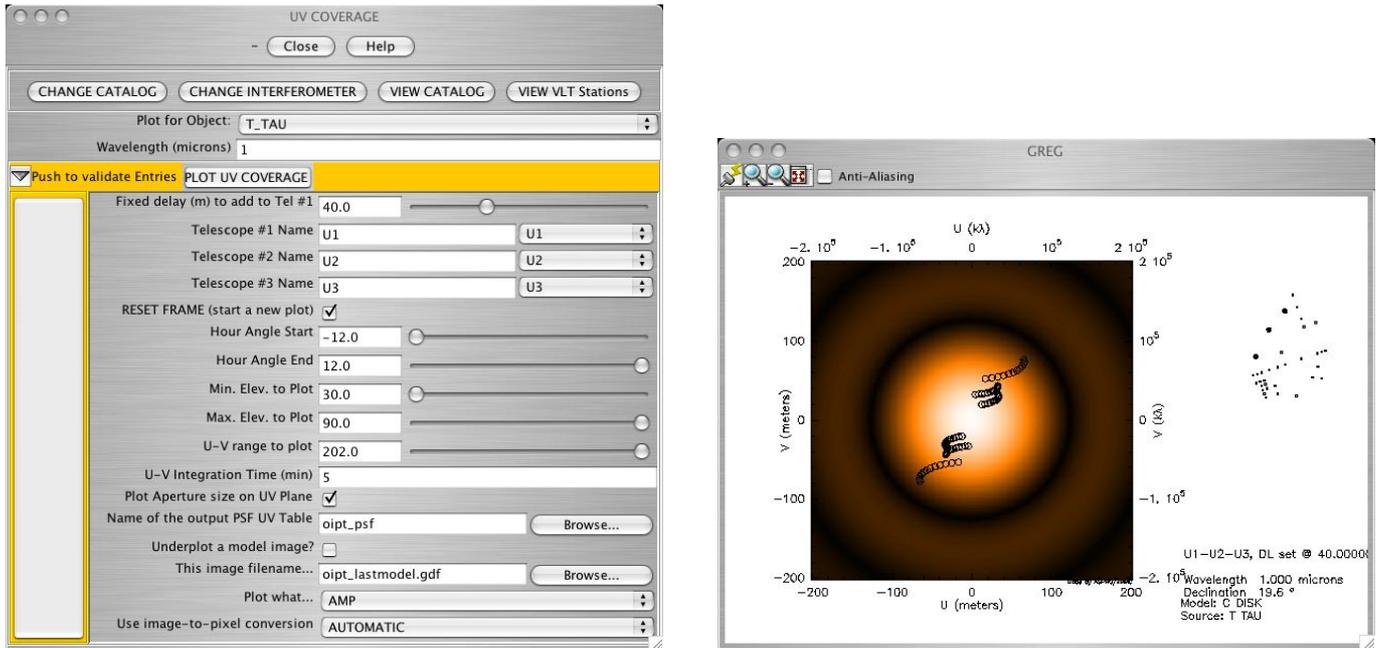


Figure 17: The **UV Coverage** panel (*left*) and the resulting UV coverage plot (*right*).

U and V axes, expressed in meters (bottom and right axes) and in unit of  $k\lambda$  (top and left axes), the latter being a useful unit for optical interferometry. The selected stations and fixed delay, wavelength, object's declination and the name of the target and its geometrical model are indicated to the right of the panel, along with a sketch of the interferometer in which the selected stations are highlighted. When overplotting a new configuration on top of another one, the UV points and telescope stations are color-coded to facilitate the use of this plot. Click on the **CLOSE** button to dismiss the **UV Coverage** panel.

### 3.10 MODEL/FIT menu

This menu represents the fifth and last main module of **ASPRO**. It is where the user can actually simulate the observations he/she has set up in the previous modules and visualize the expected results (see Sect. 3.10.1). He/she also can fit some geometrical models to the synthetic visibilities in order to decide whether the proposed observations can help constraining the model of the source (see Sect. 3.10.2 and 3.10.3). If the user plans on using the AMBER, MIDI or GI2T instrument, he/she can select the instrument with this menu, which will load an appropriate ETC into the program that calculate visibilities (see Sect. 3.10.4, 3.10.5 and 3.10.6). In the following, we assume that the AMBER instrument has been selected; selecting MIDI or GI2T changes only a few entries. If no instrument is selected, then no ETC is offered in the **UV Model & Explore** panel (see Sect. 3.10.1) and synthetic visibilities are calculated without uncertainties (or rather, each visibility is assigned  $\sigma_{|V^2|} = 1$  by default).

#### 3.10.1 UV Plots & Source Modeling

Selecting **UV Plots & Source Modeling** under the **MODEL/FIT** menu brings up the **UV Model & Explore** panel. This module consists of four subpanels (described below) that allow to define the geometrical model of the target (either as an analytical or homemade numerical model), to estimate uncertainties on the interferometric observables (for certain instrument) and to plot these observables.

After clicking on the arrow to the left of the **Source Modeling** button, the **UV Model & Source Modeling** panel looks like the left part of Fig. 18. In this subpanel, it is possible to define an analytical model that represents the geometry of the target. The user must specify the name of the file that contains

the detail of the selected UV coverage (*Template UV Table*; this should be the same as the *Name Of the Output PSF UV Table* entry in the **UV Coverage** panel described in Sect. 3.9.3) and the name of the *Output (Model) UV Table* that will contain the same updated UV table but with the calculated visibilities corresponding to the object's model. In the rest of the subpanel, the user can define the analytical model of the source in the very same way as in the **Object Simple Model** panel described in Sect. 3.8.6. If the user has already defined the model of his/her target in this previous panel, the model entries should already contain the proper values (and using this subpanel is actually not necessary). Once the model parameters are entered, click on the **Source Modeling** to calculate the interferometric observables (no plot is created at this point) and on the arrow to the left to dismiss the subpanel.

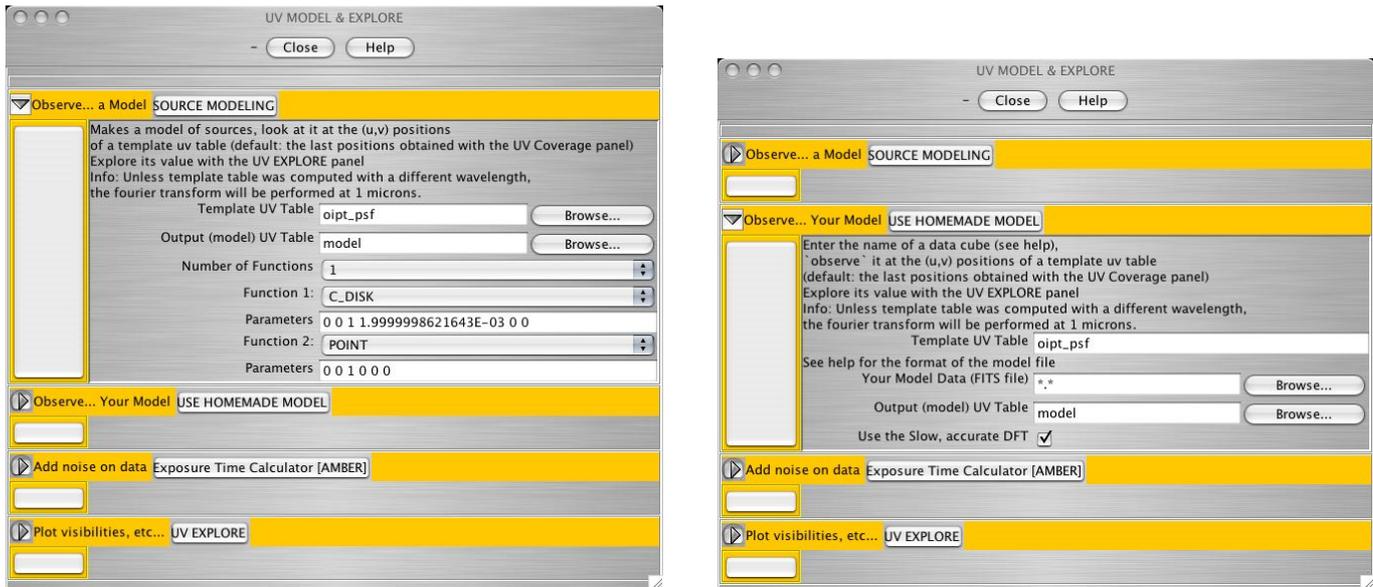


Figure 18: The **UV Model & Explore** panel to define the model of the target analytically (*left*) or through a user-provided a FITS file (*right*).

If none of the parametric models adequately describe the geometry of the target, the user can decide to use a FITS file instead, for which **ASPRO** can calculate the Fourier Transform using a DFT or a FFT. This can be done in the **Use Homemade Model** subpanel in the **UV Model & Explore** panel. To access this subpanel, click on the arrow to the left of the **Use Homemade Model** button and the panel will look like the right part of Fig. 18. As for the analytical model subpanel described above, the user must provide the *Template UV Table* and *Output (Model) UV Table* filenames. In addition, he/she must provide the name of a FITS file that contains the object's model (*Your Model Data (FITS File)*). This can be done either by typing the file name (if the file has already been uploaded in **ASPRO**) or by using the **Browse** button as in Sect. 3.8.1. The user-provided FITS file should have 2 or 3 dimensions. The third dimension, if present, represents independent spectral channel. This capability is not yet fully implemented in **ASPRO** and the software currently processes only the first slice of the input datacube. The two spatial dimensions must have the same number of pixels (i.e., square image). The FITS file header must contain a certain type of information so that **ASPRO** can deal with it properly. In particular, the pixel scale must be provided. Here is a possible beginning for a valid FITS file header:

```
NAXIS      =                2 /2 minimum!
NAXIS1     =                512 /size 1st axis
NAXIS2     =                512 /size 2nd axis
CRVAL1     = 0.0000000000000E+00 / center is at 0
CRPIX1     = 0.2560000000000E+03 / reference pixel is 256 in Alpha
```

```

CDELTA1 = -0.4848136811095E-09 / increment is 0.0001" in radians,
          / and 'astronomy oriented (negative)'
CRVAL2  = 0.0000000000000E+00 / center is at 0
CRPIX2  = 0.2560000000000E+03 / reference pixel is 256 in Delta
CDELTA2 = 0.4848136811095E-09 / increment is 0.0001" in radians.

```

In this example, the “coordinate center” (i.e., the point where the object coordinates apply) is located at the center of the 512×512 image, and each pixel is 0.1 milli-arcsecond (or  $0.48 \times 10^{-9}$  radian) on the side. Once the name of the FITS file is provided, check the *Use the Slow, Accurate DFT* box if necessary (DFT is to be preferred to FFT under most circumstances, especially as calculation time is rarely a critical aspect in **ASPRO**), click on the **Use Homemade Model** button to calculate the Fourier transform of the model and the interferometric quantities corresponding to the UV coverage, and on the arrow to the left of it to dismiss the subpanel.

At this point, the synthetic visibilities and phases corresponding to the object's model and to the UV coverage have been calculated. If one of the instruments for which an ETC is implemented in **ASPRO** has been selected (here we assume that AMBER has been selected), the user now can estimate uncertainties on these quantities. To do so, click on the arrow to the left of the **ETC [AMBER]** button, which will open that subpanel; the **UV Model & Explore** panel then looks like that illustrated in Fig. 19. In this subpanel, the user defines the expected observing conditions as well as the instrumental setup. With AMBER, the user must specify the *Observing Band* (note that **ASPRO** does not check the coherence between this selection and the wavelength used to define the UV coverage of the source), the *Spectral Resolution*, the *Seeing Conditions* (either using the *Average/Excellent* pull-down menu or providing a value for  $R_0$  in centimeters), the *Telescope Type*, the *Star Magnitude* at the observed wavelength, the *Percentage Of Time Spent On Science* (20% is typical for AMBER observations) and the name of *UV Table To Update With Computed SNR*, which should be the same as the *Output (Model) UV Table* entry described above. If the user has selected the MIDI instrument, he/she will have to specify the *Number Of Spectral Channel* to be averaged together to increase the SNR, and if it is GI2T, then the *Spectral Bandwidth* (in microns) must also be specified. Once all parameters have been set, click on the **ETC [AMBER]** button to calculate the uncertainties and on the arrow to the left of it to dismiss the subpanel.

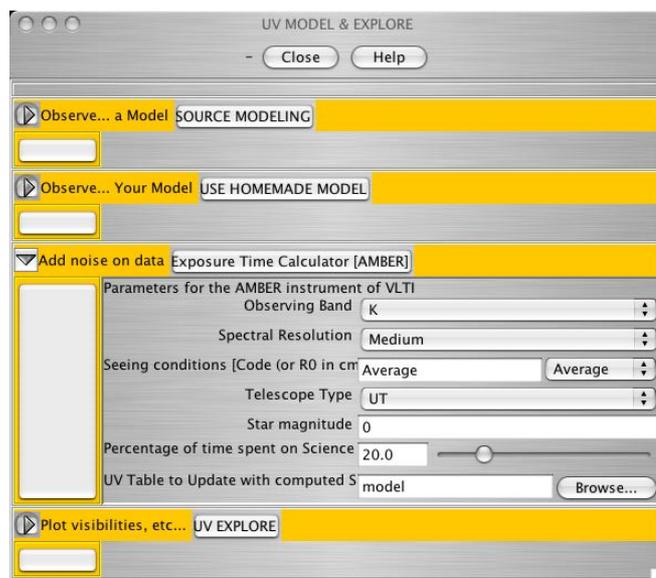


Figure 19: The **UV Model & Explore** panel with the **ETC[AMBER]** subpanel opened.

It is now possible to plot the simulated interferometric observations. To do so, click on the arrow to the left of the **UV Explore** button to open this subpanel (see left part of Fig. 20). The user must first indicate

the *UV Table Name To Explore* (this should be the same as the *Output (Model) UV Table* and *UV Table To Update With Computed SNR* entries described above) and can also decide which quantities to plot (*X data* and *Y data* for the horizontal and vertical axes, respectively); the possible choices are listed in Table 2 along with a brief description. Selecting **V** for *Y data* and **U** for *X data* will produce a plot very much similar to the one shown in Fig 17. Checking the *Add Errorbars to Plot* box enables uncertainties to be plotted. The limits of the plot along both axes (*Plot limits*;  $X_{min}$   $X_{max}$   $Y_{min}$   $Y_{max}$  in that order) can either be chosen by the user or automatically computed (which is achieved with the default 0 0 0 0 selection). The user can also choose to check the *Plot Model Curve* box, which superimpose on the calculated visibilities, the theoretical visibilities as a (set of) continuous red curve(s). If the model is axisymmetric, only one curve appears when plotting **AMP<sup>2</sup>** as a function of **RADIUS**; if the model is non-axisymmetric or when plotting quantities as a function of **ANGLE**, numerous curves appear, corresponding to different position angles or radii in the Fourier domain. Checking the *Underplot Model Image* box will result in plotting the Fourier transform of the object's model if the choice of *X data* and *Y data* permits it (i.e., if U and V are selected). The user can also select the name of the file that will contain the created plot in GILDAS format (*This Image Filename*, provided either by typing it or using the **Browse** button; a **gdf** filename extension is assumed), the quantity to plot as a function of the UV coordinates (*Plot What*, where the possibilities include the complex visibility amplitude, phase and their derivatives) and which color scheme to use (*Use Image-To-Pixel Conversion*, where **Automatic** stands for **Linear**). These latter two options are relevant when the *Underplot Model Image* box has been checked.

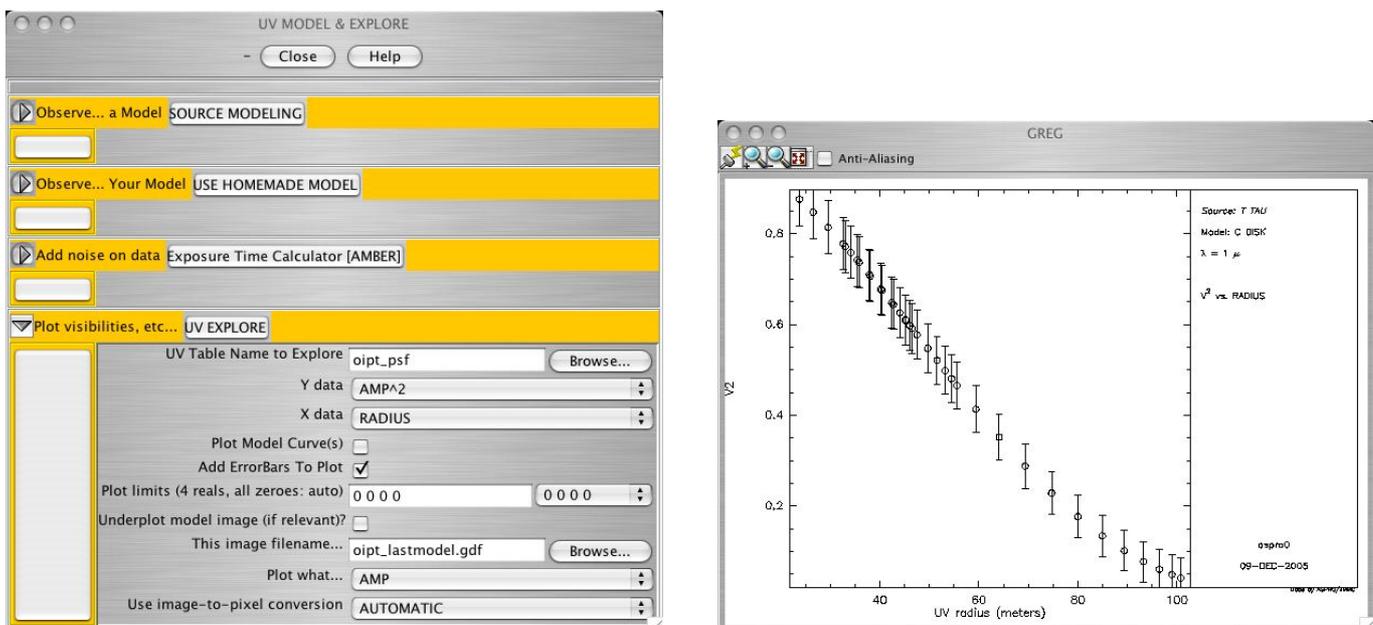


Figure 20: The **UV Model & Explore** panel to plot synthetic interferometric observables (*left*) and the resulting visibility plot (*right*).

If the plotted visibilities (or other quantities) appear unsatisfactory to the user, for instance because they do not change enough with time or because they are too small to be confidently measured, the user should try to change his/her instrumental setup and array configuration. Otherwise, simply click on the arrow to the left of the **UV Explore** button to dismiss the subpanel and on the **CLOSE** button to dismiss the whole **UV Model & Explore**.

Table 2: Quantities that can be selected to plot the results of the simulated observations.

Variable	Description
<b>U</b>	Fourier coordinate corresponding to the East-West axis
<b>V</b>	Fourier coordinate corresponding to the North-South axis
<b>ANGLE</b>	Position angle in the Fourier plane
<b>RADIUS</b>	Radius in the Fourier plane
<b>AMP</b>	Amplitude (visibility $ V $ ) of the Fourier Transform of the model
<b>AMP^2</b>	Squared amplitude ( $ V^2 $ ) of the Fourier Transform of the model
<b>PHASE</b>	Phase ( $\Phi(V)$ ) of the Fourier Transform of the model
<b>REAL</b>	Real part ( $Re(V)$ ) of the Fourier Transform of the model
<b>IMAG</b>	Imaginary part ( $Im(V)$ ) of the Fourier Transform of the model
<b>SIG_V2</b>	Uncertainty on the squared visibility ( $\sigma( V^2 )$ )
<b>TIME</b>	Time of observation
<b>DATE</b>	Date of observation
<b>SCAN</b>	Sequential number of scan
<b>NUMBER</b>	Sequential number of observation

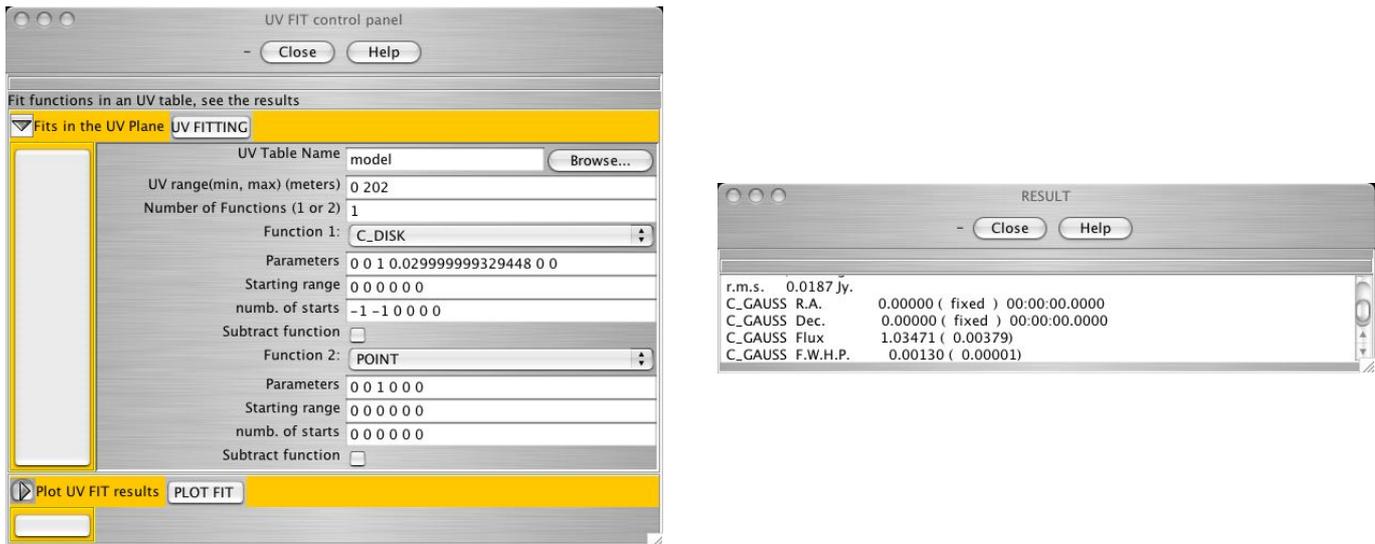


Figure 21: **UV Fit Control Panel** (left) and result window (right) for the **Fits In the UV Plane** menu.

### 3.10.2 Fits In the UV Plane

This menu allows the user to fit an analytical model to the synthetic visibilities and uncertainties (when available) created in the **UV Plots & Source Modeling** menu. Along with a best fit model, uncertainties on the parameters are provided, giving an indication as to whether the proposed observations can help constraining the geometry of the target.

Selecting the **Fits In the UV Plane** menu opens the **UV Fit Control Panel** panel illustrated in the left part of Fig. 21. Clicking on the arrow to the left of the **UV Fitting** button opens this subpanel, which allows to fit an analytical model to an existing model-populated UV table. The user must provide the input *UV Table Name* (typing the filename or using the **Browse** button), the range of UV coordinates over which to perform the fit (*UV Range*, representing by the minimum and maximum projected baselines to be fit, separated by a <space>) and the parametric model to be fit. This can be one or the weighted sum of two simple parametric models. Use *Number of Functions*, *Function 1*, *Function 2* and *Parameters* in the same way as in defining the object model (see Sect. 3.8.6). In addition, the user can provide a range of possible values for the model parameters (*Starting Range*) and a number of (evenly-spaced) values to test throughout that range (*Numb. of Starts*; -1 means that the parameter is fixed to its prescribed value and 0 provides an automatic fit). If a variable is not fixed, then the value listed in *Parameters* is a first guess from which the iterative fitting process starts.

Clicking on the **UV Fitting** button, the fit is performed and a pop-up **Results** window appears. This window presents the results of the fit (see right part of Fig. 21). At the bottom of that window, the result of the fit is summarized as follows, with a first line providing the r.m.s of the fit (presented in flux units), a qualitative indicator of the goodness-of-fit. The rest of the results are presented with one line per model parameter following the format:

Model\_Name Variable\_Name Best\_Fit ( Uncertainty )

If the parameter was held fixed, the **Uncertainty** entry reads **fixed** instead of a numerical value. In the example presented in Fig. 21, a **C\_GAUSS** model was fit to visibilities created using a **C\_DISK** model. Note that fitting the same model as the one used when creating the UV table results in the original parameters being exactly (infinite accuracy) recovered since no extra noise is added to the simulated visibilities (the r.m.s. value is then 0.0). Also, this fitting can be performed even though no visibility uncertainties have been estimated, providing only an indicative fit.

The **Plot Fit** subpanel of the **UV Fit Control Panel** panel is still under construction and is not described here. Once done with fitting the simulated observations, click on the **CLOSE** button to dismiss this panel.

### 3.10.3 Model Parameter Errors Calculator

This menu allows the user to fit an analytical model to the synthetic visibilities created in the **UV Plots & Source Modeling** menu. Along with a best fit model, uncertainties on the parameters are provided, giving an indication as to whether the proposed observations can help constraining the geometry of the target. This is an alternative, though not as realistic (visibility uncertainties are not taken into account here) to the algorithm used in the **Fits In the UV Plane** menu. However, the **Model Parameter Errors Calculator** fitting procedure does not provide a quantitative estimate of the goodness-of-fit and it is usually not possible to decide whether a certain model fits better the data than another one. We strongly recommend the use of the **Fits In the UV Plane** menu instead.

This menu is still under construction and is based on a module developed for **ASPRO-VLTI**. The **Model Parameters Errors Calculator** panel is illustrated in the left part of Fig. 22. Consequently, the user should not use the **Back To Source Def**, **Back To Obs Setup** and **Back To Visibility Panel** buttons. The user only needs to define the parametric model to be fit, which can be one or the weighted sum of two simple parametric models. Use *Number of Functions*, *Function 1*, *Function 2* and *Parameters* in the same way as in defining the object model (see Sect. 3.8.2). For each function, the user can decide whether or not to fix the parameter value to his/her initial guess rather than letting it vary; this is done using the *Masked Parameters* entry. This can only take values of 0 (free parameter) or 1 (fixed parameter). The fit is performed iteratively from the initial guess (*Parameters* entries) in a way that does not take into account the visibility uncertainties. It is therefore not representative of an actual observation/analysis procedure and should not be considered as a strong result by the user.

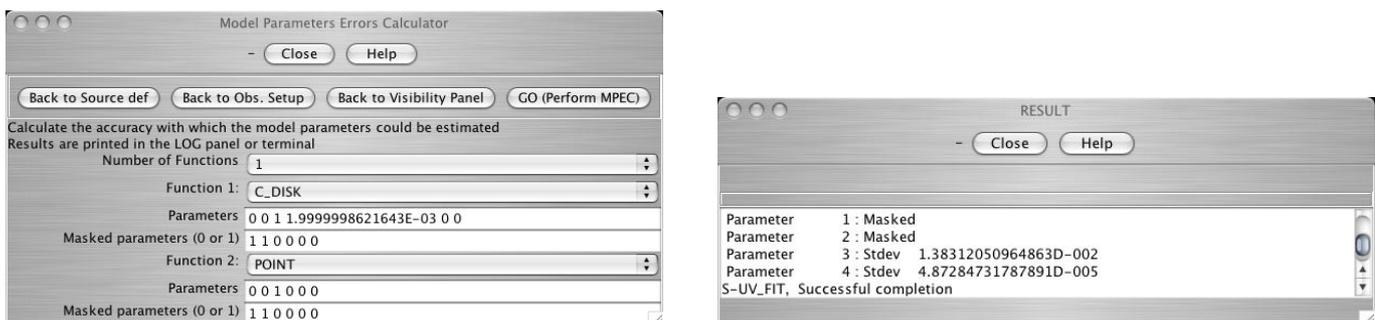


Figure 22: The **Model Parameters Errors Calculator** panel (*left*) and the resulting **Result** panel (*right*).

Clicking on the **GO (Perform MPEC)** button starts the fitting process and the results are presented in a new **Result** panel. Scrolling down this window, the user can find a series of lines corresponding to each model parameter (see right part of Fig. 22). For those parameters that were held fixed, the entry reads **Fixed**; for those which vary, a **Stdev** entry is followed by a number, which is the estimated uncertainty on the parameter. In the example illustrated in Fig. 22, a uniform disk function is fitted, which can be represented with 4 parameters (two for the location, the total flux and the radius). Here, the flux is recovered with an accuracy of 1.4% and the radius with an accuracy of 3.7%. Note that if the flux had been held fixed, the accuracy on the radius would have been significantly lower, on order 2.2%.

When the fit is performed, click on the **CLOSE** button to dismiss the panel.

### 3.10.4 Select Instrument AMBER

Selecting **Select Instrument AMBER** under the **MODEL/FIT** menu loads the AMBER-specific ETC into the module that calculates the synthetic visibilities (see Sect. 3.10.1).

### 3.10.5 Select Instrument MIDI

Selecting **Select Instrument MIDI** under the **MODEL/FIT** menu loads the MIDI-specific ETC into the module that calculates the synthetic visibilities (see Sect. 3.10.1).

### 3.10.6 Select Instrument GI2T

Selecting **Select Instrument GI2T** under the **MODEL/FIT** menu loads the GI2T-specific ETC into the module that calculates the synthetic visibilities (see Sect. 3.10.1).

## 3.11 OTHER menu

### 3.11.1 Show Current Setup

This menu opens a **Status** window in which the basic properties of the observation being simulated are summarized (see left part of Fig. 23). The information provided includes the interferometer, instrument, array configuration, current object, wavelength and name of a few key files for **ASPRO**. No modifications to the setup can be performed from this panel; it is exclusively informative but provides an overview of what has been selected by the user so far. Note that many variables have default values, so that no parameter presents an empty field even at the time **ASPRO** is launched (the only exception being *Model File*, which represent the name of the user-provided FITS model of the object). Click on **CLOSE** after reviewing the parameters (the panel will be automatically dismissed once another module is opened).

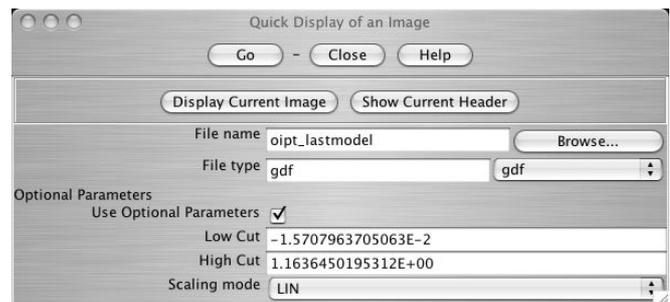
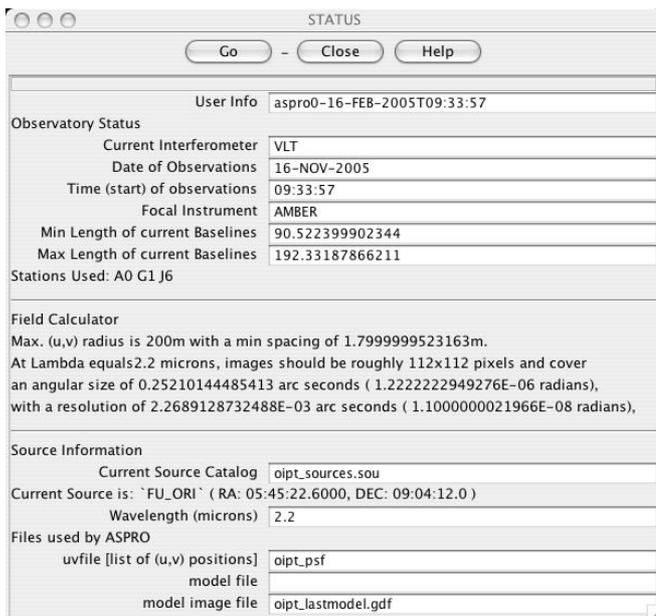


Figure 23: Current setup panel (*left*) and image display panel (*right*) obtained from the **OTHER** menu.

### 3.11.2 Plot Current Interferometer Setup

Selecting this options results in a new plot that represents a sketch of the selected interferometer along with the name of the offered stations. Each telescope of the array is represented with its actual size.

### 3.11.3 Show Plot In Browser (PS file)

Selecting **Show Plot in Browser (PS File)** under the **OTHER** menu creates a PS file containing the current content of the **ASPRO** graphic window. The file is automatically displayed by the user's browser and, simultaneously, stored in the user's **ASPRO** account where it can later be retrieved.

### 3.11.4 Show Plot In Browser (PDF file)

Selecting **Show Plot in Browser (PDF File)** under the **OTHER** menu creates a PDF file containing the current content of the **ASPRO** graphic window. The file is automatically displayed by the user's browser and, simultaneously, stored in the user's **ASPRO** account where it can later be retrieved.

### 3.11.5 Display a GILDAS or FITS Image

Selecting **Display a GILDAS or FITS Image** under the **OTHER** menu brings up the panel illustrated in the right part of Fig. 23. The user must specify the *File Name* of the image to plot (the extension, e.g., *gdf* for a GILDAS format image, should be removed from the filename) as well as the *File Type*; the latter will be assumed to be the extension of the filename. Clicking on the **Display Current Image** creates the plot in the graphic window, using a default linear scale from two automatic values. If the user wants to change the limits of the color scale, or its nature (**linear**, **logarithmic** or **histogram equalization**), he/she should check the *Use Optional Parameters* and specify the *Low Cut* and *High Cut* values, as well as the *Scaling Mode*. Clicking on the **Show Current Header** results in the file's header being printed in the LOG window. Click on the **CLOSE** button to dismiss the panel when done.

### 3.11.6 List UV Table Content

Selecting this option brings the **List a Table Content** panel illustrated in the left part of Fig. 24. The user must specify the name of the UV table he/she wants to list (*Input Table*, must be file with a *uvt* extension), as well as the name of a text file (*Output List File*) in which the UV table will be saved for future usage. Both entries can either be typed in or the filenames can be indicated using the **Browse** buttons as in Sect. 3.8.1. Once the filenames are provided, click on the **GO** button, and the UV table is presented in a new pop-up window (see right part of Fig. 24). The file contains one line per measurement and per individual baseline. Each line contains the UVW projected baseline coordinates, a dummy observation date, the time since the beginning of observations (in seconds), the code for the two telescope stations, the real and imaginary part of the complex visibility and its weight (i.e., its uncertainty).

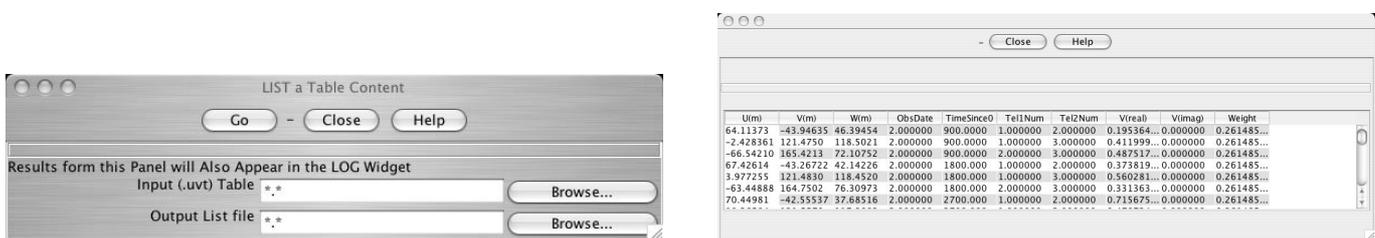


Figure 24: The **List a Table Content** panel (*left*) and the resulting UV table listing (*right*).

### 3.11.7 Export File

Selecting **Export File** under the **OTHER** menu brings up the **Export a File** panel illustrated in the left part of Fig. 25, which allows to transform a GILDAS-format image into a FITS file. The user must indicate the name of the *Input GILDAS File* and of the *Output FITS file*, either by typing them or by using the

**Browse** button as in Sect. 3.8.1. The *FITS Flavour*, i.e., the type of FITS file, must be indicated. When all parameters are set, click on the **GO** button to export the file, and on the **CLOSE** button to dismiss the panel.

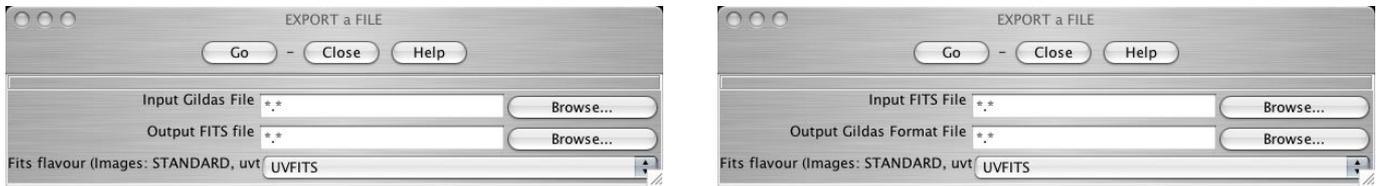


Figure 25: The **Export a File** (*left*) and **Import a File** (*right*) panels.

### 3.11.8 Import File

Selecting **Import File** under the **OTHER** menu brings up the **Import a File** panel illustrated in the right part of Fig. 25, which allows to transform a FITS file into a GILDAS-format image. The user must indicate the name of the *Input FITS File* and of the *Output GILDAS format file*, either by typing them or by using the **Browse** button as in Sect. 3.8.1. The *FITS Flavour*, i.e., the type of FITS file, must be indicated. When all parameters are set, click on the **GO** button to export the file, and on the **CLOSE** button to dismiss the panel.

### 3.11.9 Export UV Table as OLFITS

Selecting **Export UV Table as OLFITS** under the **OTHER** menu brings up the **Export an UV Table as OI FITS** panel, in which the user can provide the name of a UV table (.uvt extension) and export it in a standardized OLFITS file, which can be downloaded from the JMMC server for further use. Click on the **GO** button to perform the conversion and on the **CLOSE** button to dismiss this panel.

## A SearchCalibrators Tool

### A.1 Goals

SEARCH CALIBRATOR builds a dynamical catalogue of stars with all useful information for the selection of the calibrators most adapted to the requirement of the astrophysical program.

### A.2 Method

Two methods are used, one specific for the N band (e.g., the MIDI instrument of ESO), one used for the VJHK bands (suitable for the AMBER instrument in J,H and K).

#### A.2.1 N-Band case

**Definition of calibrator field** The maximum angular distance (in RA and DEC) of calibrators from the object is given by the user.

**Flux constraints** Three cases are considered for the range of magnitude of the calibrators following the object brightness (see Table 3).

$F_{obj}$ (Jy)	$[F_{min} - F_{max}]$	$[\text{mag } N_{min} - \text{mag } N_{max}]$
<10	[5 - 20]	[2.2 - 0.7]
[10 - 100]	[5 - 50]	[2.2 - -0.3]
>100	[5 - 100]	[2.2 - -1.0]

Table 3: Magnitude Search Range vs. Flux of Object.

**List of possible calibrators** The program finds the possible calibrators in the list of mid infrared interferometric calibration sources established by van Boekel et al. (2005). The result is a list of stars with known parameters in astrometry (equatorial and galactic positions, proper motion, parallax), spectral classification, photometry as well as indication of variability and multiplicity and computed value of the measured angular diameter. For each calibrator, the squared visibility ( $V_{cal}^2$ ,  $\Delta V_{cal}^2$ ) is computed as function of the angular diameter, wavelength and maximum baseline.

#### A.2.2 Other Bands

**Definition of calibrator field** The search is based upon user-specified criteria of angular distance and magnitude around the Scientific Object.

**List of possible calibrators** The program sends a request to the CDS database using “scenarios” based upon the selected photometric band (K). The result is a list of stars with known parameters in astrometry (equatorial and galactic positions, proper motion, parallax), spectral classification, photometry (Johnson magnitudes) as well as indication of variability and multiplicity and known value of the measured angular diameter. For each star, the angular diameter is computed using a surface brightness method and color index calibration using V magnitude and (B-V), (V-R) and (V-K) color index. For each star, the squared visibility ( $V_{cal}^2$ ,  $\Delta V_{cal}^2$ ) is computed as function of the angular diameter, wavelength and maximum baseline.

**Post processing of the calibrators** A coherence test of the photometry is done by comparison of the computed diameters from the different color index. The star is rejected if one of the computed diameter differs more than  $2\sigma$  from the mean value.

### A.3 Further selection of the calibrators

It is possible, once the list of calibrators has been constructed, to refine the choice of the calibrators using several selection criteria:

- field size around the science object
- object–calibrator magnitude difference
- spectral type and luminosity class
- accuracy on the calibrator visibility
- information regarding the calibrator variability and multiplicity

### A.4 Results of the SearchCalibrators tool

Once the CDS request is answered, a Result Panel pops up (fig. 26).

The screenshot shows a software interface for displaying search results. At the top, there are buttons for 'Close' and 'Help'. Below that are 'RESET', 'SHOW ALL RESULTS', 'SHOW DETAILS', and 'HIDE DETAILS'. The main content area is titled 'Science star' and contains a table with columns: NAME, RAJ2000, DEJ2000, MagK, Base-max, and Lambda. The first row shows 'ETA\_TAU' with coordinates 03:47:29.80 and +24:06:18.5, magnitude 0.000, base-max 102.45, and lambda 2.10. Below this is a 'Results' section with a summary: 'Number of stars: 13 found, 8 with coherent diameter and 4 without variability and multiplicity'. This is followed by a table with columns: Number, dist, HD, RAJ2000, DEJ2000, vis2, vis2Err, diam\_vk, e\_diam\_vk, and SpType. The first four rows are numbered 1 to 4. Below the table are several interactive elements: 'Catalog Origin' with a dropdown menu showing options like II/280, II/225, II/7A, II/246, V/50, Borde, Merand; 'Confidence Index' with a dropdown menu showing Low, Medium, High; and a series of buttons: 'Sort above list...' (with a 'SELECT CALIBRATORS' button), 'Delete Star' (with a 'DELETE' button), 'Load File' (with a 'LOAD' button), 'Save File' (with a 'SAVE' button), 'Export CSV File' (with an 'EXPORT CSV' button), and 'Export VOT File' (with an 'EXPORT VOT' button).

Figure 26: Result Panel

#### A.4.1 Initial selection

The panel consists in three sections, the Science Star window, the Results window and a set of subpanels allowing a refinement of the selection of the calibrators based on various selection parameters.

The **Science Star window** shows the parameters of the Science object: name, position (RA, DEC), N magnitude and maximum baseline, computed angular diameter (K Band).

The **Results window** shows the list of the calibrators without any indication of variability or multiplicity. Only some selected parameters are given (see table 5 for JHK results, 4 for N-Band results), unless the **SHOW DETAILS** button has been activated. By clicking on the name of the column and dragging the column, it is possible to personalize their order.

The top border of the panel presents 4 buttons:

**RESET** : button to show the full list of the potential calibrators.

**SHOW ALL RESULTS** button to display the full list of the potential calibrators, including those which are variable, multiple of that have inconsistent diameters (which are excluded from the default list).

**SHOW DETAILS** button to display the full list of measurements returned by the program. All available parameters are given in Tables 6 and 7 for N and JHK band search respectively).

**HIDE DETAILS** button to display only the principal measurements returned by the program. Only some selected parameters are given (Tables 5 and 4 ).

The lower part of the panel is a set of selection tools used to refine the list of calibrators and load/save results.

**SELECT CALIBRATORS** is described below in sect.A.4.2.

**DELETE** to delete a star of the list. Click the arrow, enter the number of the line to be suppressed, click the **DELETE** button.

**LOAD** to load a result saved as a file. Click the arrow, enter the name of the File (name.scl), click the **LOAD** button.

**SAVE** to save in a file all the information of the list of calibrators. Click the arrow, enter the name of the File (name.scl), click the **SAVE** button. Retrieving this file is possible within the File Exchange Panel (see sect. ??)

**EXPORT CSV** to save in a file the list of calibrators as displayed in the results window. Click the arrow, enter the name of the File (name.csv), click the **EXPORT** button. Retrieving this file is possible within the File Exchange Panel (see sect. ??)

**EXPORT VOT** to save in a file the list of calibrators as displayed in the results window in the VOTable format<sup>1</sup>. Click the arrow, enter the name of the File (name.vot), click the **EXPORT** button. Retrieving this file is possible within the File Exchange Panel (see sect. ??)

### A.4.2 Refining the selection

To refine the selection, do:

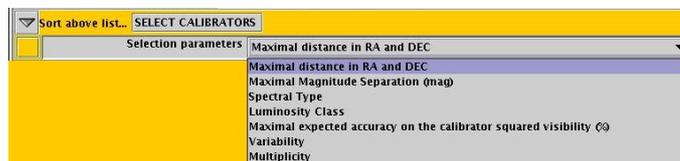


Figure 27: Refining the selection

Click on the arrow left of **SELECT CALIBRATORS** to open the list of selection parameters (fig. 27)  
Select the parameter

<sup>1</sup>See <http://www.ivoa.net/Documents/latest/VOT.html> for more information about this format

Click on **SELECT CALIBRATORS** button to open a specific choice panel...

Enter the value of the selection parameter

Click on **OK** button to start the selection

The new result is displayed in the “Result” window.

Click the **RESET** button to return the previous result.

#### 1. Field around the Science Object

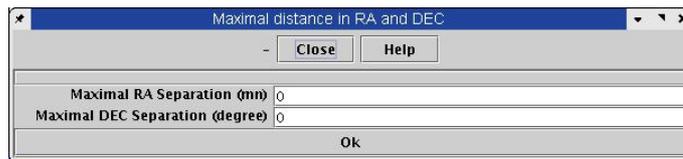


Figure 28: Field Selection Tool

#### 2. Maximum magnitude difference (Science Object - Calibrator)



Figure 29: Maximum magnitude difference Selection Tool

#### 3. Spectral Types (Temperature class) of the Calibrators

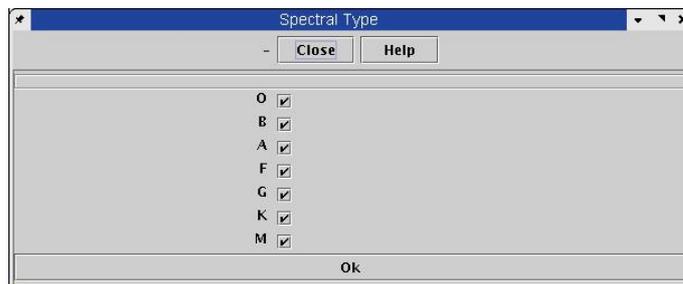


Figure 30: Spectral Types Selection Tool

#### 4. Luminosity class of the calibrators

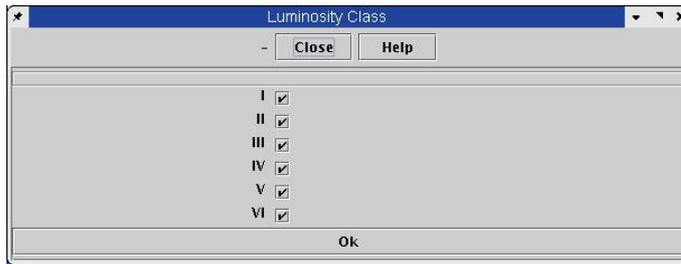


Figure 31: Luminosity class Selection Tool

5. Maximal expected accuracy on the calibrator visibility ( $\Delta V_{cal}^2/V_{cal}^2$  in %)

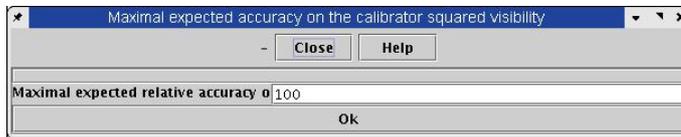


Figure 32: Maximal expected accuracy Selection Tool

6. Variability

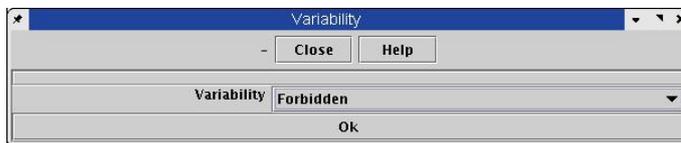


Figure 33: Variability Selection Tool

7. Multiplicity



Figure 34: Multiplicity Selection Tool

## A.5 Description of columns in the Search Calibrator result panel

### A.5.1 Short list column description, N-Band case

Table 4: Short list column description, N-Band case

Col. Num.	Identifier	Explanation
1	Number	entry index
2	dist	calibrator–object angular distance in degrees
3	HD	HD number
4	RAJ2000	right ascension J2000
5	DEJ2000	declination J2000
6	vis2	squared visibility $V_{cal}^2$
7	vis2Err	estimated error on $V_{cal}^2$
8	Dia12	computed angular diameter in band.
9	e.Dia12	error on the angular diameter.
10	F12	mid-infrared flux (Jy) at $12\mu\text{m}$ .
11	SpType	MK spectral type
12	N	N magnitude computed from F12 using the relation $Nmag = 4.1 - 2.5 \log(F_{12\mu}/0.89)$ .
13 to 16	vis2 ( $\lambda$ ) and vis2Err( $\lambda$ )	computed visibility and estimates error for the limits of the N band ( $\lambda 8\mu\text{m}$ and $\lambda 13\mu\text{m}$ ).

### A.5.2 Short list column description, JHK-Band case

Table 5: Short list column description, JHK Bands case

Col. Num.	Identifier	Explanation
1	Number	entry index
2	dist	calibrator–object angular distance in degrees
3	HD	HD number
4	RAJ2000	right ascension J2000
5	DEJ2000	declination J2000
6	vis2	squared visibility $V_{cal}^2$
7	ErrVis2	estimated error on $V_{cal}^2$
8	diam_vk	estimated $\phi_{VK}$ from the (V,(V-K)) calibration
9	e.diam_vk	estimated error on $\phi_{VK}$
10	SpType	MK spectral type
11	V	mag V
12	J	mag J
13	H	mag H
14	K	mag K

### A.5.3 Full table description, N-Band case

Table 6: Column description, N-Band case

Col. Num.	Identifier	Explanation
1	Number	index
2	dist	calibrator-object angular distance in degrees
3	HD	identification by HD number
4	RAJ2000	right ascension J2000
5	DEJ2000	declinaison J2000
6	vis2	computed squared visibility $V_{cal}^2$
7	vis2Err	estimated error on $V_{cal}^2$
8	Dia12	computed angular diameter at $12\mu\text{m}$ .
9	e.Dia12	error on the angular diameter.
10	orig	source of the IR flux IRAS or MSX.
11	F12	mid-infrared flux (Jy) at $12\mu\text{m}$ .
12	e.F12	relative error on F12 (%)
13	SpType	MK spectral type
14	N	N magnitude computed from F12 using the relation $Nmag = 4.1 - 2.5 \log(F_{12\mu}/0.89)$ .
15 to 18	vis2 ( $\lambda$ ) and vis2Err( $\lambda$ )	computed visibility and estimates error for the limits of the N band ( $\lambda 8\mu\text{m}$ and $\lambda 13\mu\text{m}$ ).
19	Calib	c for stars selected as spectro-photometric calibrators.
20	Mflag	indication of binarity (angular separation $\geq 2''$ ) from Hipparcos catalog.
21	Vflag	indication of variability from SIMBAD (SB or eclipsing B);
22	V	V magnitude.
23	H	H magnitude.
24	plx	trigonometric parallaxes
25	e.plx	error on plx
26	pmRA	proper motion in RA.
27	pmDE	proper motion in DE.
28	A_V	visible interstellar absorption.
29	Chi2	Chi2 value for the model fitting of spectro-photometric data.
230	SpTyp_Teff	spectral type from adopted modelling effective temperature.

### A.5.4 Full table description, JHK-Band case

Table 7: Column description JHK bands case

Col. Num.	Identifier	Explanation
1	Number	index
2	dist	calibrator-object angular distance in degrees
<b>Computed squared visibility from measured angular diameter or computed <math>\phi_{vk}</math> diameter</b>		
3	vis2	computed squared visibility $V_{cal}^2$
4	vis2Err	estimated error on $V_{cal}^2$
<b>Estimated photometric angular diameters</b>		
5	diam_bv	diameter $\phi_{bv}$ from (V,(B-V)) calibration
6	diam_vf	diameter $\phi_{vf}$ from (V,(V-R)) calibration
7	diam_vk	diameter $\phi_{vk}$ from (V,(V-K)) calibration
8	e_diam_vk	estimated error on $\phi_{vk}$
<b>Identifiers</b>		
9	HIP	HIP number
10	HD	HD number
11	DM	DM number
<b>Astrometric data</b>		
12	RAJ2000	right ascension J2000
13	DEJ2000	declination J2000
14	pmDec	proper motion in declination
15	pmRA	proper motion in right ascension
16	plx	trigonometric parallax
<b>Spectral Class</b>		
17	SpType	MK spectral type
<b>Variability - Multiplicity</b>		
18	VarFlag1	Known variability from GCVS/NSV <ul style="list-style-type: none"> <li>• G : variable known in the General Catalog of Variable Stars</li> <li>• N : variable known in the New Suspected Variable catalog</li> </ul>
19	VarFlag2	Variability in Tycho-1: <ul style="list-style-type: none"> <li>• U : apparent variability in the Tycho data, may be due to duplicity</li> <li>• V : strong evidence of intrinsic variability</li> <li>• W : suspected intrinsic variability</li> </ul>
20	VarFlag3	Variability type : <ul style="list-style-type: none"> <li>• C : no variability detected ("constant")</li> <li>• D : duplicity-induced variability</li> <li>• M : possibly micro-variable (amplitude <math>\leq</math> 0.03 mag)</li> <li>• P : periodic variable</li> <li>• R : V-I color index was revised due to variability analysis</li> <li>• U : unsolved variable which does not fall in the other categories</li> </ul>
21	MFlag	Multiplicity Flag
<b>Galactic coordinates</b>		
22	GLAT	galactic latitude
23	GLON	galactic longitude

Col. Num.	Identifier	Explanation
<b>Radial velocity</b> _____		
24	RadVel	radial velocity (km/s)
25	RotVel	rotation velocity $v \sin i$ (km/s)
<b>Measured angular diameter from CHARM (Richichi and Percheron, 2002)</b> _____		
26	LD	limb darkened disc diameter (mas)
27	e.LD	error on limb darkened disc diameter (mas)
28	UD	uniform disc diameter (mas)
29	e.UD	error on uniform disc diameter (mas)
30	Meth	method of measurement
31	lambda	wavelength
<b>Computed angular diameter from Catalogue of calibrators stars for LBSI (Bord et al., 2002)</b> _____		
32	UDDK	uniform disc diameter in K band (mas)
33	e.UDDK	error on uniform disc diameter (mas)
<b>Photometry</b> _____		
34-43	B, V, ..., N	Johnson's magnitudes U, B,V, R, I, J, H, K, L, M, N
<b>Photometry corrected for interstellar absorption</b> _____		
44	$A_V$	visual interstellar absorption