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JMMC

ASPRO/SC AT ESO

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1 Background:

Assessing the feasibility of an observation is necessary nowadays to gain access to large international facilities such as ESO's VLT. This is all the more necessary for interferometric facilities like VLTI, because interferometry is intrinsically complex and the evaluation of the feasibility of a particular observation needs dealing with a number of geometrical or instrumental constraints that can severely affect the outcome of the observation. For example, because interferometric observations only sample a few points in the (u, v) plane, it is not sufficient to run a back-of-the-envelope calculation to show that a baseline of a certain length will resolve an object's structure. While this may indeed be true, it also quite possible that such observations do not provide any useful constraint on the object geometry, which is what the observer wanted in the first place.

To answer such a need, facilities owners such as ESO, or dedicated expertise centers such as the JMMC provide tools to evaluate this feasibility. By nature, these tools are able to be used for proposal preparation but can sometimes be used also for observation preparation and planning.

ESO supports the preparation of observations at the VLTI through tools available from its ETC web page http://www.eso.org/observing/etc/. In particular, it offers VISCALC and CALVIN. VISCALC allows the user to compute visibilities and other observation-related quantities for a number of model sources or free-input images, while CALVIN allows the selection of suitable calibrators. The ESO tools, although general in their intrinsic design, are in fact normally offered at each period with specifically selected features adapted to the actual current observational settings.

Among several other SW tools, JMMC has developed and actively supports ASPRO (“Astronomical Software to PRepare Observations, http://jmmc.fr/aspro_page.htm). ASPRO is a generic software configurable for various kinds of optical and radio interferometers. It is declined in different versions, one of them being dedicated to preparing and simulating observations at the VLTI.

The present document is a proposal for proactive collaboration between the ESO institute and JMMC to govern the evolution of several JMMC software tools for an adapated use by the whole ESO-VLTI user community.

2 CURRENT TOOLS AND CAPABILITIES

2.1 ESO TOOLS:

The tools are dedicated to the observation planning with MIDI and AMBER.

2.1.1 Current status

Two interactive tools are provided by ESO for these purposes, the visibility calculator **VisCalc** and the calibrator selection tool **CalVin**. **VisCalc** provides calculations of synthetic dispersed visibilities based on software models of the VLTI instruments. The declination and spectral energy distribution, as well as the source geometry, are parameters used to specify the scientific target. Visibilities are calculated analytically for uniform discs, Gaussian discs, and binaries, and numerically for a user-provided brightness distribution, which is uploaded as a FITS file. The user-specified observation parameters include the starting hour angle and the duration of the observation, as well as the instrument and array configuration. Different results can be displayed including observability as a function of local sidereal time, shadowing effects on the VLTI platform, limitations by the stroke of the delay lines, the uv-tracks, the input image and its Fourier transform, and plots of visibility versus time.

CalVin suggests suitable calibrators from an underlying list of stars based on different user-definedcriteria such as magnitude, spectral type, and distance on sky. The strategy to preferably select calibration stars from the limited underlying lists of calibration stars preserves objects, which have already been studied. Hence, more and more detailed knowledge of these calibration sources will be rapidly acquired. Currently, the underlying CalVin list of calibration stars for MIDI is based on the catalogue of calibration stars that has been developed by the MIDI instrument consortium by spectro-photometric observations of candidate stars fitting the data to atmosphere models (B. Stecklum, ESO calibrator workshop 2003). The underlying list of CalVin calibration stars for AMBER is currently based on the catalogues of Bordé et al. (2002) and Mérand et al. (2006).

The most recent versions of both tools released in December 2006 include in addition calculations of the visibility at the wavelength of FINITO in order to assess the feasibility of a MIDI or AMBER target/calibrator to be used as guide star for FINITO. Both tools can be accessed from the VLT Exposure Time Calculators page on http://www.eso.org/observing/etc. The standard version shows only the configurations that are offered for the current Call for Proposals. It is updated for each new Call for Proposals in order to reflect the offered VLTI baseline configurations and instrument modes. An "expert" version, accessible from the ETC preview page (http://www.eso.org/observing/etc/preview.html) offers an extended interface with many more choices. It supports the modes and configurations that are currently not offered.

2.1.2 FURTHER DEVELOPMENTS

Further planned developments for VisCalc and CalVin (implementation presumably in 2007) include support for 3-telescope observations with AMBER by calculation of synthetic triple amplitudes, closure phases, and differential phases; improved support for the different instrument modes (synthetic visibility and phase calculations for medium and high resolution modes); and extended target definitions. The latter consist of elliptical uniform and Gaussian discs, as well as definitions of target geometry as a function of wavelength by uploading user-provided stacks of target geometry at different wavelengths in one fits file.

The main addition to the VLTI in the short-term (2007-2009) will be the PRIMA facility. ESO observers will have the possibility to use PRIMA as a stand-alone differential delay instrument (for astrometry programs), or as a front-end to the MIDI or AMBER instruments. The PRIMA astrometry observation preparation tool is being prepared by the PRIMA consortium as part of the PAOS software development program. The support for PRIMA when used with MIDI or AMBER will need to be provided. The latter includes calculations of visibility values at wavelength and fringe detection mode of PRIMA in order to assess whether a target is feasible as PRIMA guide star, as well as a selection option in CalVin to return calibrators that can be used as phase references.

On a longer time-scale, one or more VLTI 2nd generation instruments may be selected and developed (current proposal include VSI, MATISSE, GRAVITY). The initial studies indicate that these instruments will involve a 4-telescope beam combination, and possibly up to 6-beams. The tools developed under the terms of the present document should allow supporting these coming instruments as well.

The support for calibrators needs to be extended: Phase calibrators for PRIMA (see above),

choice of selecting a calibrator from a well known underlying list (fixed approach), or by selecting any suitable calibrator from an analysis of large databases and from estimates of the physical properties (dynamic approach). Future versions of these tools shall have the option to create OBs based on the selected target, instrument mode, and array configuration.

In summary, with regard to the current capabilities of VisCalc, CalVin, the following additional features are required:

Spatial-Spectral Distribution of the source (the geometry of the source can vary with the wavelength).

Support for 3-4-6 beam operations including calculations of triple amplitudes, closure phases, and differential phases.

Dynamic selection of calibrators up to magnitude H or K=12

Separate visibility modelling for the on-axis and the off-axis sources (PRIMA)

Separate visibility modelling at different wavelengths (FINITO, FSU)

Output of OBs for the selected target and instrument mode, and array configuration.

2.2 JMMC TOOLS

2.2.1 ASPRO

ASPRO is a general-purpose interferometer simulator. It supports up to 64 “telescopes” and stations. It is easily configurable for new facilities or upgrade of existing facilities due to its modularity: the geometrical constraints are kept in description files; the specifics for instruments (such as noise models) are left to external plugins; the user interface is programmable through a command interpreter and its JAVA widgets are easily reconfigurable.

A dedicated version of ASPRO using specialized widgets is maintained at JMMC for the VLTI users; this version evolves with the configurations, capabilities and observing modes described in the successive calls for Proposal of AMBER and MIDI.

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 he defines 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.

In summary Aspro provides:

- Intuitive interface

- Client-server mode or standalone
- Publication-quality graphics
- Target coordinates look-up using target name (Simbad)
- Upload of user-defined source images (FITS), or
- Geometrical Models (Point source, Elliptical Gaussian source, Circular Gaussian source, Circular Disk, Elliptical Disk (inclined), Annulus (Resolved Ring), Unresolved Ring, Exponential brightness, $B = 1/r^2$, $B = 1/r^3$, Limb-Darkened Disk, Binary.
- Telescope’s horizons (optical) or shadowing (radio) taken into account (Array specific)
- Sun avoidance periods
- Delay line stroke/speed limits taken into account
- Displays UV plane object visibility map (amplitude, phase and derivatives) overlaid with UV track
- Delay line information is available
- Information plotted (with errorbars): any vs. any for Amplitudes, Phases, U, V, Baseline Length, Baseline Angle, V^2, time, date, hour angle, phase closures.
- Measurement errors simulated for several focal instruments (MIDI, AMBER…)
- Fit of models in the synthesized visibilities, or
- Parametric error estimate on measurements
- Results can be viewed through a java applet viewer, written in PS or PDF format, exported in OI-FITS format, etc.
- ASPRO serves also as a front-end to the separate JMMC program SearchCal (see below).

More details are found in the ASPRO user manual.

2.2.2 SearchCal

This utility is used to find the best calibrator at hand during the planned observations, based on a series of constraints, especially the sky distance, the closeness in magnitude or spectral type, etc… It 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. SearchCal uses "*Virtual Observatory*" techniques to extract the required astronomical information from a set of stellar catalogs available at the CDS. Compared to the static or closed-list approach, the merit of this strategy is first to take into account any enrichment of the catalogs by new observational data and secondly to evolve naturally with the increase of limiting magnitudes and baseline lengths of the interferometric facilities.

SearchCal uses the on-line interface with the VizieR data base at the CDS to extract astrometric and spectro-photometric parameters of the objects around the science object, creating an initial list of stars This list is enriched by the stars present in the *Catalogue of calibrators for long baseline stellar interferometry* (Bordé et al. 2002) and the *Catalog of bright calibrator stars for 200-m baseline near-infrared stellar interferometry* (Mérand et al. 2005). If available, the measured angular diameter is obtained through the data of the *Catalog of High Angular Resolution Measurements* (Richichi et al. 2005).

Then, for each star on the initial list, calculations are made to correct the interstellar absorption and to compute missing magnitudes. The photometric angular diameter and its associated accuracy are estimated using a surface brightness method based on the (*B*-*V*), (*V*-*R*) and (*V*-*K*) color index. Then, the expected visibility and its error are computed.

The list of possible calibrators is finally proposed to the user via a JAVA interface and the final choice can be made by changing the selection criteria: accuracy on the calibrator visibility, size of the field, magnitude range, spectral type and luminosity class, variability and multiplicity flags.

2.2.3 Current Software Design Description of JMMC tools

2.2.3.1 SearchCal

SC is a client/server application. The server is written in C++, the GUI client in JAVA. The server handle requests using a message passing system, providing command-line, VO query and GUI interaction. The software design description of SC is available in the document JMMC-TRE-2600-0001.

2.2.3.2 ASPRO

ASPRO, as distributed by JMMC, is a thinClient/server version of a standalone application based on the IRAM/LAOG **gildas** software suite (distributed by ESO with SCISOFT).

The standalone ASPRO, as most of the **gildas** software, is written in Fortran and C. It uses X11 for its graphic interface, the Motif or Xforms widgets library for GUI , and uses the SIC command interpretor for keyboard interaction and procedures.

ASPRO itself is 12000 lines of Fortran code. With the rest of the gildas library used, the total amount of lines is 150000.

The web version of ASPRO is simply an instance of ASPRO running on a server, with GUI deported to the client using an XML message passing gateway on the server and a JAVA GUI interface substituting JAVA widgets and SVG graphic display to the X11 and Motif interfaces used in the standalone application. In the web version, user interaction with the instance of ASPRO running on the server is mostly limited to the GUI widgets interaction. Non-graphic outputs of ASPRO are reported in a log window.

The ASPRO interface is very flexible, since the GUI is created dynamically by SIC procedures, and can be easily adapted to VLTI evolutions. The standalone version can be used to test new interfaces or evolutions, wich can benefit to the web version without added work. Switching between the standalone and server version is a matter of changing an environment variable. Java GUI evolutions (windows multiplicity, themes, etc…) can be set up easily since the GUI is independent with the main application.

3 Proposal

Following the general agreement MOU between ESO and JMMC (2006), and in view of the requirements described in sect. 2.1.2 already covered by the current status of the SC and ASPRO utilities, it is proposed to further the collaboration between ESO and the JMMC by concluding one or two specific agreements on 1) SearchCal and 2) ASPRO:

3.1 Concerning the two applications:

They shall be maintained by JMMC at JMMC headquarters, with a mirroring of the applications on a TBD number of hosts maintained by ESO on ESO sites. The mirroring requirements and implementation details will be agreed upon by both parties and are subject to change on request by each party.

JMMC will be in charge of the maintenance and development of the applications, with a welcomed aid of ESO staff. ESO will maintain the network access and facilities needed for the mirroring.

JMMC will have remote access to the ESO mirrors with the necessary privileges for testing the behavior of the mirror copy of the application(s).

ESO shall provide system support, if necessary, to enable the use of the software solutions (external libraries, java machine updates, etc…) needed by the applications when running on the ESO mirrors.

Access to the applications on the ESO hosts will be public without registration[1].

ESO will provide support for the users of its mirror copies in the manner ESO feels convenient. Bug or feature reports reported to ESO through its user support mechanism will be made available immediately to JMMC for correction or comment through the ESO bug report mechanism.

The evolution of ASPRO and SC will follow the evolution of the VLTI instruments and instrumental modes, on a basis synchronous with the Call For Proposals, CfP). This evolution will be defined 6 month in advance for major changes (support of a new instrument such as PRIMA), and no less than 2 month in advance for CfP changes limited to configuration files..

For the version changes synchroneous with the CfP, the new version will be present at ESO and tested at least one week prior to the CfP.

During the validity of the CfP, (one month), a dedicated support will be provided by the ESO / JMMC associates either in the form of a trained person based in Garching or through a rapid response line. Problems arising during the time of the Call for Proposals, will be dealt with immediately with the highest priority by JMMC.

At least two meetings of the “ESO/JMMC Advisory Committee” installed by the ESO/JMMC MOU will be held per year. The scope of these meetings will be: 1) to inform mutually on the evolution (management, methods, infrastructure, projects…) of each party, and 2) monitor the progress of the software development, to demonstrate what is already available, and to discuss problems and management issues. Additional meetings can be called for by ESO or JMMC if deemed necessary.

[1] JMMC encourages ESO to implement methods to identify the users of theses programs in order to be able to inform them of updates, performance or security issues.

3.2 Concerning SearchCal:

JMMC will improve SC to import object lists, or query databases, and use new scenarios, not already present in the application (TBC). This may involve an ESO adaptation of these additional databases to e.g., VO queries. (TBD case by case)

Critical databases should be defined, and SC tailored to use them, to enable local work without network to CDS.

User Interface: JMMC will continue to improve the new SC Java interface readability based on evaluation by of ESO users.

3.3 Concerning ASPRO

3.3.1 internal (library and plugins) capabilities

The following capabilities shall be added to ASPRO:

- Moon avoidance periods
- Spatio-spectral Distribution of the source (the geometry of the source can vary with the wavelength): geometrical models, user Data Cubes.
- Related model improvements: take into account spectral resolution, beam shape and speckle noise, uv smearing.
- Differential phase and its associated representations.
- Fit or parametric error estimate on differential phases.
- Separate visibility modeling of the object in one or more alternate observing band (FINITO at the time of writing, PRIMA FSU later)
- Output of OBs for the selected target and instrument mode, and array configuration (additional plugins that need to be further defined).

3.3.2 user interface

The ASPRO user interface shall be modified to regroup all information, user inputs, plots, etc, in one single window, in a way permitting to apply external presentation layouts without any need of recompiling.

3.4 Deployment at ESO

It is proposed to deploy the JMMC software in 3 phases:

Phase 1: as a mirroring of the JMMC version active at the time of agreement, starting a period of parallel use of JMMC software and ESO software by the community; This period comprises a training period for ESO staff members and evaluation by the community.

Phase 2: implementation of a modified user interface such as in 3.3.2, and all necessary changes to adapt aspro (server) for extended uses as in 3.3.1, and SC as in 3.2.

Phase 3: rewriting of critical pieces of code, if deemed useful and affordable, for, e.g., portability of efficiency issues.

4 Balance of efforts:

The intent is to share efforts on the additional costs involved in servicing ASPRO and SC at ESO. Details are TBD.