Accompanying Optical Interferometry Worldwide: the JMMC Tools and Services

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ABSTRACT

This poster advertizes the Jean-Marie Mariotti Center* software tools, databases and services aimed at facilitating the use of optical interferometry worldwide such as preparation of observations, data reduction and data analysis. Its mission and organization are presented before listing the current software suite. Finally some facts and perspectives are mentioned.

Keywords: optical interferometry, JMMC, observation preparation, data analysis, calibrator, model fitting, image reconstruction, virtual observatory, VLTI, AMBER, CHARA

1. THE JMMC: MISSION AND STRUCTURE

The Jean-Marie Mariotti Center has been created by INSU (a division of the French Council for Research) 10 years ago to offer all the potential users of interferometric facilities the best operational environment. The mission of the JMMC is threefold: 1) develop, produce, document and maintain the software necessary for the exploitation and the follow-up of interferometric equipments, especially the VLTI, 2) contribute to the academic formation of non specialists and, 3) contribute to the prospective around new interferometric instruments. Besides training and prospective, the main activity is software oriented system analysis and software develoment.

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*http://www.jmmc.fr

The structure of the Mariotti center is dual. It is a network of 5 French laboratories supported by a software realization center and user support located at IPAG. The laboratories partners of the JMMC are:

- CRAL (Observatoire de Lyon)
- LAGRANGE (Observatoire de la Côte d'Azur)
- IPAG (Observatoire de Grenoble)
- LESIA (Observatoire de Paris)
- ONERA (Châtillon)

The Network of laboratories develops the concepts, the algorithms and the software prototypes allowing the preparation of interferometric observations, the data reduction and their analysis. It also contributes to the tests and the evolution of the software tools, the documentation and the diffusion towards to the community. The Realization Center develops and optimizes the products elaborated within the Network in order to provide them to the astrophysical community, especially via the Web. It carries on a R&D activity to provide the most modern concepts for the development and the use of applications. The detailed organization and the activities of the Jean-Marie Mariotti center are described in the following sections.

2. ORGANIZATION

JMMC being both a network of interferometry specialists and a software center, most of our thirty or so registered members participate actively in our five working groups such as:

- ASPRO: the Astronomical Software to PRepare Observations
- Catalogue of calibration sources
- AMBER data processing
- Model fitting
- Image reconstruction
- Technical staff and software development

Within each group, the Communication between astronomers, software engineers, beta testers and the user support team relies on regular meetings and dedicated mailing lists. Many collaborative tools (wiki, ticketing system, documentation system, alerts) permit to share material and help in development organization.
As a rule, the user-support (1 person) and technical team (3 engineers and 2 astronomers) are both participating to every group activity and meetings.

3. SOFTWARE SUITE AND SERVICES

Many of our tools are aimed at a general use of interferometric instruments and arrays and JMMC provides most of its expertise outside the Consortia that build these arrays or instruments. Accordingly, JMMC does not formally participate to instrument building and their first versions of Data Reduction Systems (DRS). However we gather the expertise of several ex-consortia authors of these DRS and the day-to-day continuous experience of users to maintain several DRS. To gain knowledge about instruments during their lifetime and update accordingly their DRS is a necessity for interferometric instruments. A collaboration with ESO is in place to this effect.

3.1 Observation preparation

Preparation of observations is an important issue for all who want to give access to high angular resolution techniques for the mainstream astronomer. JMMC has a long-standing experience in this domain and knows that a preparation software is mandatory, a tool that could both be educational (since we deal in our observations with such arcane observables as phase closure for example), directly useable to estimate the feasibility of an observation and sufficiently close to a particular instrument as to provide directly its "observing blocks" (OBs) to deal with observation operations.

3.1.1 Aspro2

Aspro was a complete observation preparation tool developed and maintained by the JMMC from its beginning that allowed to prepare interferometric observations with the VLTI or other interferometers. It was based on the client-server model with a lightweight java client interface and a complex server side (GILDAS / Fortran & C code / scripts). Since 2010, Aspro 2[1] is the new version of Aspro as a Java standalone program providing a new smart and dynamic graphical user interface i.e. computations are non-blocking and performed in background while the user can still interact with the interface.
Supported interferometers and instruments are listed below:

- VLTI : MIDI (2T), AMBER (3T), PIONIER (4T), GRAVITY (preliminary)
- CHARA : CLASSIC (2T), CLIMB (3T), MIRC (4T to 6T), PAVO (2T, 3T), VEGA (2T to 4T)

Main Aspro 2 features are listed below:

- Edit, save and load your observation settings (interferometer & instrument setup, science and calibrator targets) and share it with collaborators
- Multi configuration support to have the UV coverage overview with different configurations
- Target editor: import target information from Simbad, edit missing target magnitudes
- Model editor (see Fig. 2): each source can have its own analytical or user-defined model (FITS image)
- Observing Blocks can be generated for VLTI and CHARA instruments
- Simulate OIFITS data file with error and noise modelling
- Interoperability with SearchCal (and other VO Tools) e.g. to get calibrators for your science target
- Interactive plots (see Figures 1 and 2):
  - Observability: represents time intervals when the source can be observed with transit and elevation marks, night and twilight zones, delay line compensation for the selected base lines, (best) PoPs (CHARA), telescope shadowing (VLTI) and zenithal restriction
  - UV Coverage: shows projected baselines on the UV plane over the model image in the Fourier plane
  - Vis2: shows the square visibility vs baseline (radius) including error bars and spectral dispersion

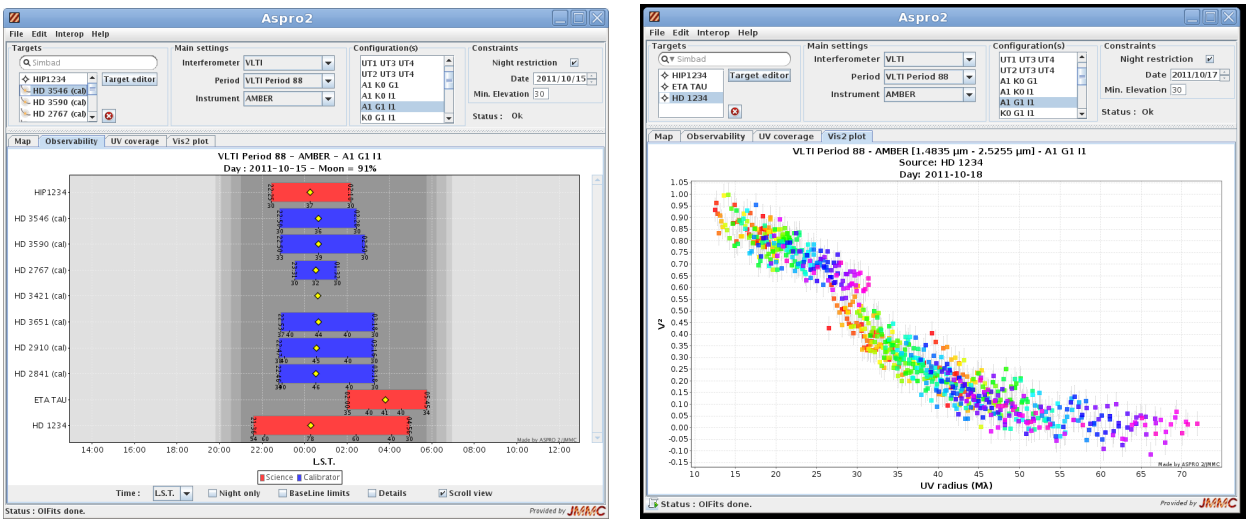

Figure 1. Aspro 2 Observability and simulated OIFITS VIS2 plots

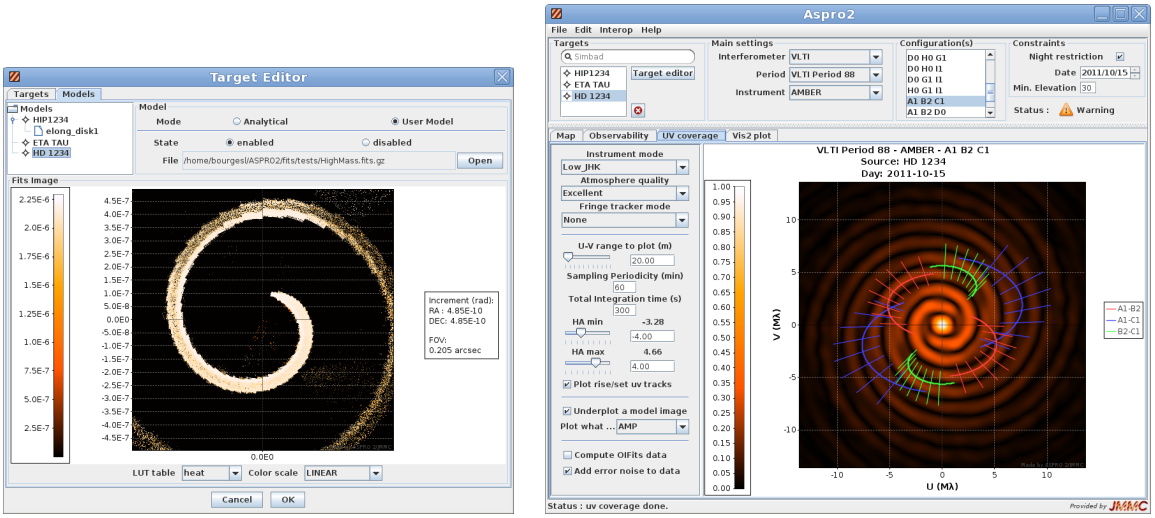

Figure 2. Aspro 2 user-defined model (FITS image) and UV Coverage plot

3.1.2 SearchCal

SearchCal is the JMMC software and service to assist the astronomers in the calibrator selection process for long baseline interferometric observations. The Java graphical user interface (see Fig. 3) let you define your science target, instrument configuration and the search area to perform queries to our SearchCal server (C / C++). It can execute the search in two cases: the Bright (V, H, K, N bands) or Faint (K band only):

- gather of a large set of information from the Vizier astronomical catalogues hosted at CDS
- filter whether each proposed star can be considered as a good calibrator
- compute angular diameter estimates of the calibrator stars mainly from retrieved photometries

Scientific and technical background of SearchCal Bright and Faint scenarios are described respectively in two papers.[2,3]
SearchCal results are presented using different detail levels and can be filtered (visibility threshold, multiplicity

and variability, spectral types ...). Finally, the SearchCal interface can send calibrator list or sub-selection to other VO tools like Aspro2 to complete your observation or Aladin[†] to prepare finding charts.

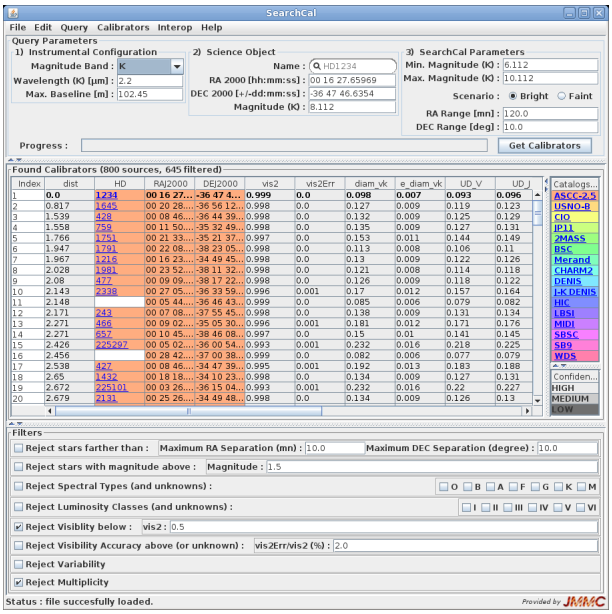

Figure 3. SearchCal calibrators list

3.1.3 Catalogues of calibrators

After a collaboration in 2008 between JMMC and ESO to provide more calibrators for VLTI observations, the JMMC has extended the SearchCal server to build in 2010 the first version of the JMMC Stellar Diameter Catalog (JSDC).[4] This new development was followed by the setup of a new dynamic catalogue referencing bad calibrators reported by the community. The BadCal catalogue is continuously growing and contains around 70 stars at the time of writing. We expect that it will be linked to the CDS database at some point to provide a complementary source of binarity status for Simbad for closed binaries detected only by optical interferometry.

Both catalogues are available online:

- JSDC is hosted on CDS Vizier and named II/300[‡]
- BadCal is hosted on the JMMC server[§]

3.2 Data Reduction

After discontinuing old data reduction pipelines for VINCI and MIDI, we maintain today the data reduction pipeline for the AMBER instrument of ESO/VLTI, named "`amdlib`". `amdlib`'s life illustrates the kind of continuous improvements a group of scientists, some of them having participating in the AMBER instrument consortia, can (and must) bring to the data reduction of an interferometric instrument that evolves with the passing of time, but also that gains from new insights from the community, outliving the consortia themselves. The signal processing algorithms used by `amdlib` are described in several papers.[5,6]

3.3 Data Analysis

As a mirror of the observation preparation tools, the data analysis tools share the need to simplify access for astronomers to the somewhat arcane "interferometric observables", the need to be educational and common to many, if not all , interferometers and instruments.

[†]http://aladin.u-strasbg.fr/aladin.gml
[‡]http://cdsarc.u-strasbg.fr/cgi-bin/VizieR?-source=II/300
[§]http://apps.jmmc.fr/badcal

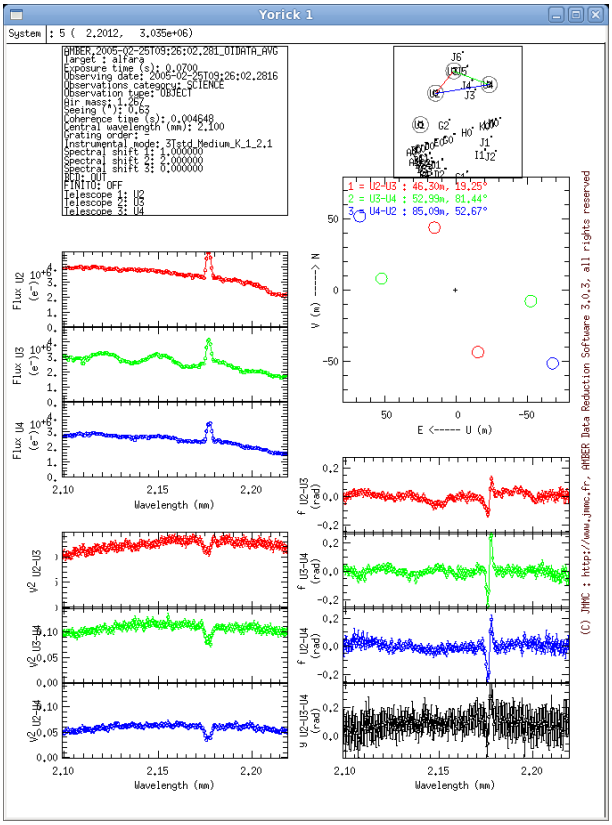

Figure 4. AmberDRS yorick interface plotting correlated fluxes, square visibilities, differential phases per baseline and closure phases per baseline triplet

3.3.1 LITpro

The LITpro software is developed for the model fitting of data obtained from various stellar optical interferometers and written in the OI Exchange Format (OIFITS). This software has been described[7] and is leaded by Isabelle Tallon-Bosc. It comes from CRAL develpments and get main contributions from Michel Tallon.

It provides a evolving set of elementary geometrical model building functions, all combinable together, which allow to fit (with a modified Levenberg-Marquardt algorithm) broad band Visibilities, Square Visibilities or Closure Phases, or any combination of previous observables. It allows to visualize by various plots the data as well as the models and the results of the fits. Tools also have been developed to help users to find the global minima.

LITpro is based on the client server model. The scientific group leverages its expertise in the field by working on the fitting-engine side (yorick code easily updatable on the server), while the technical group is in charge of the Java graphical interface developments.

User's feedback helps the group to regularly add new features. Nowadays the work of our Model Fitting Group members is focussed on how to bring support for polychromatic data (including polychromatic models) in LITpro.

3.3.2 Wisard

Wisard stands for "Weak-phase Interferometric Sample Alternating Reconstruction Device". It is a software for the reconstruction of images from interferometric data.

It is based on the PhD thesis work of S. Meimon and in references.[8–11] Ref.[8] is the first presentation of the method, Ref.[9] describes the noise model, and Ref.[10,11] are an overview of Wisard with reconstructions from

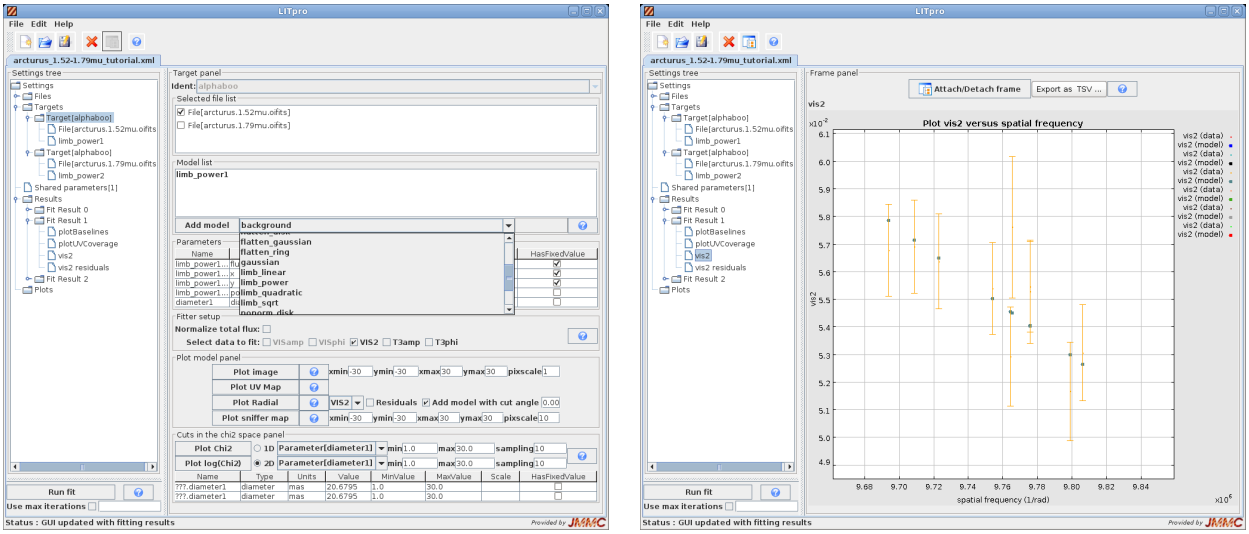

Figure 5. LITpro snapshots showing from left to right, the interface to compose a model and the result plots

both simulated and experimental data. S. Meimon and L. Mugnier have rewritten the software from scratch to be delivered in the European FP6 in 2007. M. Vannier has pushed some effort until 2012 mainly to support the OIFITS format and allow better handling of data inside. A. Domiciano also helped to optimize performances which now are in the range of the other image reconstruction tools.

Wisard will be beta tested before the end of 2012 to be released and packaged for the community. The software is written in the commercial language IDL, but may run in the future using the free Gnu Data Language (GDL). Mac, Linux and Windows delivered packages will be bundled with associated documentation and sample data (from the various IAU's Imaging Beauty Contests[12]).

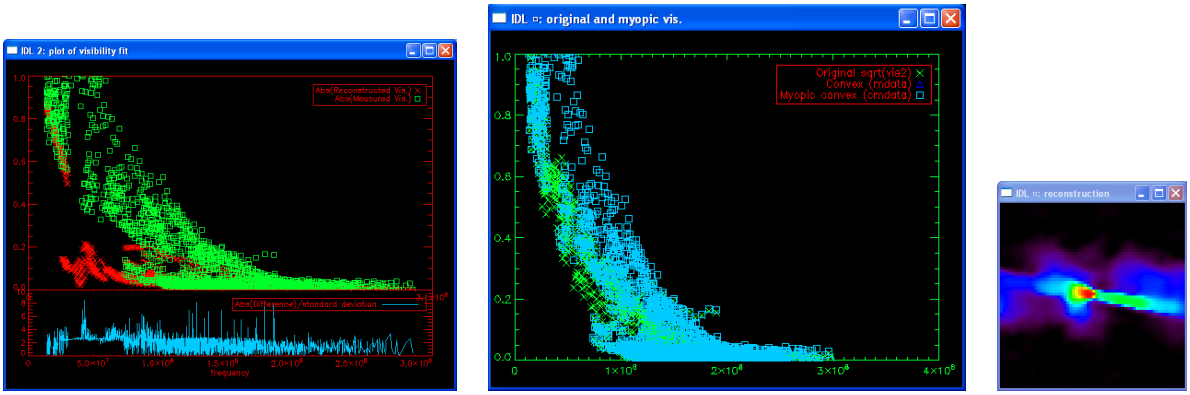

Figure 6. Wisard plot represent from the left to right, 1) visibility / residual data, 2) blind and convex visibilities and 3) the reconstructed image.

3.4 Virtual Observatory (VO)

The IVOA[¶] defines VO standards to build one worldwide infrastructure and tools. We have used some tools and libraries to provide web services (BadCal) and manage interoperability between our own tools but also with other vo tools. This framework helps the astronomy community to drive developments in a shared and collaborative way. Our policy is to use the VO standards and the VO tools and their interoperability when

[¶]http://www.ivoa.net

they can fill our requirements and conversely, to complement the VO set of tools when our developments (e.g., Applauncher, below) could benefit a larger audience than the small interferometric community.

3.4.1 AppLauncher

The JMMC technical group has developed the application launcher to enhance the interoperability environment provided by IVOA. A meta-data registry has been setup to provide a collection of VO applications (including ours) with their VO capabilities. Using the AppLauncher, the user does not have to start the applications before exchanging interpoerability messages (SAMP protocol).

AppLauncher also provides a graphical dock that can be considered as a VO application portal.

This kind of technical development is done in the framework of the biannual technical meetings organized by IVOA. These "Interop" meetings aim to:

- conclude standardization process done through collaborative tools
- drive future developments
- decide the best way to enhance the VO development based coming from many members contributions.

4. FACTS AND PERSPECTIVES

4.1 Facts

To estimate the impact of JMMC products onto the community, we gather since 2009 statistics on web access logs and publication citations.

4.1.1 Software usage statistics

JMMC software packages are distributed using two different methods: binary or source packages requiring user registration (AmberDRS, WISARD ...) or Java applications (anonymous usage) using Java Web Start. This deployment mechanism provides an auto update feature that helps us to get finer activity statistics:

- Since 2000, more than 400 accounts have been created to download data reduction software or use the initial Aspro software working in client / server mode.
- Since 1st January 2012, 680 distinct IP addresses made 5700 application start up and 110 AmberDRS downloads. The usage maps in Fig. 7 show the international community of JMMC users: 50% FR, 20% DE, 10% USA, 20% others.
- high availability on web (software download) and services (database, SearchCal and LITpro servers)

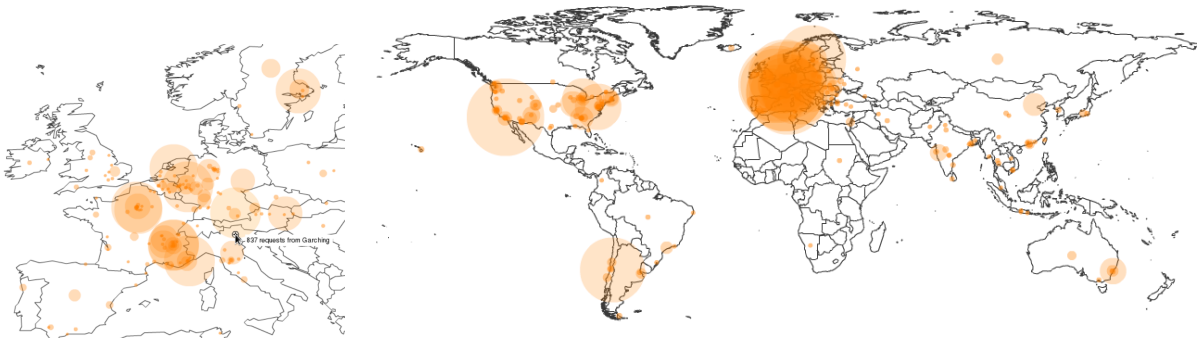

Figure 7. The left map show requests coming from Europe next to the worldwide sites

4.1.2 Publication Citations

Thanks to the olbin publication database[13] hosted on JMMC server, we can track articles that acknowledge JMMC products. The histogram presented on Fig. 8 presents the currently 69 refereed articles [‖]. We will try our best to keep the very good citation level like in 2011 where 25% of the referenced articles were citing the JMMC.

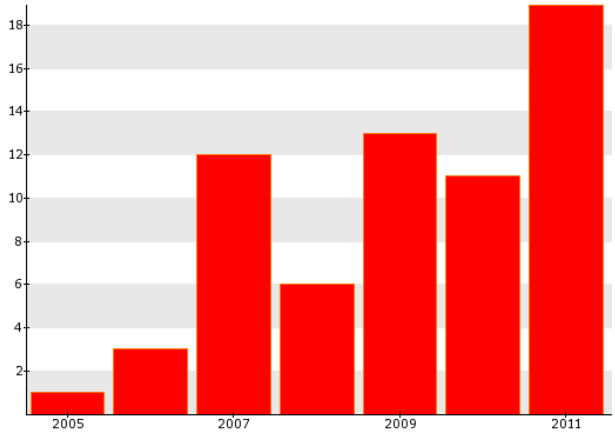

Figure 8. Publications stored into the olbin publication database which acknowledges the JMMC

4.2 New projects

4.2.1 Aspro2 extensions

To support instrument-specific process, Aspro2 will support plug-ins extensions. Some first developments has been done for the VEGA instrument of CHARA, where the PIVOT proposal and observation management tool uses Aspro2 for scheduling requirements and observation strategy.

4.2.2 GetStar and new catalogues

The work-flow developed in the frame of the JMMC Calibrator group for SearchCal has started to be generalized for another requested feature. GetStar will try its best to retrieve and compute information for any star on the same way it is done for calibrators. All results will be returned to the user even if no diameter can be computed.

The JSDC computation code is now 24 times more faster than the first version and returns the full sky bright calibrators in about one hour. A public release of the second version of the JSDC will be available after implementation of some improvements (refined cross matches handling proper motion, spectral types, and multiplicity).

4.2.3 OIFITS Explorer

JMMC started to develop a new software to browse and plot OIFITS data files. Some other features will be studied (filter, convert, post process). To be integrated in the existing software suite, it will be developed as a standalone app and also embedded in Aspro 2 / LITpro software.

This tool will get VO interfaces to retrieve OIFITS files coming from archives (using SAMP web profile) and may also interact with other VO applications.

[‖]the complete list of articles can be retrieved online http://www.jmmc.fr/database_olbin_publications.htm

4.2.4 OIFITS Archive

More and more data coming from optical interferometer are now distributed across many computers. Many of them are used for publications or are quietly sleeping on a disk without being reachable easily. One way to share and make retrieval easier would be to setup a data portal. This portal could be queried from various ways to get target related information with data responding to some constraints. For each entry the portal would give meta data of interest, tool links and access urls.

This effort requires a lot of aspect to provide a long term infrastructure. IVOA and already running data centers will certainly help setting up such tools for optical interferometry. Our community members must work together to achieve such development. JMMC has installed some collaborative tools and a data archive prototype** have been setup to facilitate exchanges in the new Virtual Observatory For Optical Interferometry group (namely VO4OI)

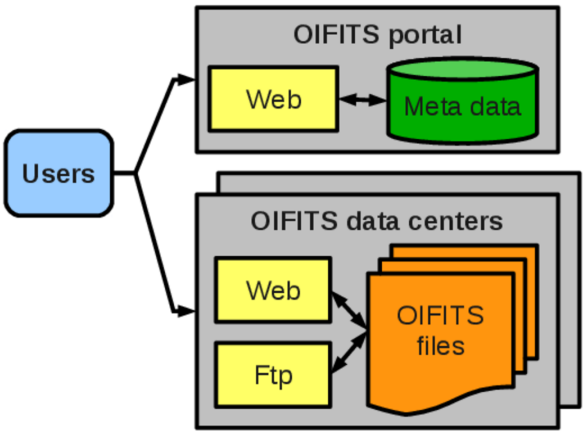

Figure 9. Architecture of a distributed OIFITS archive

One VO data model for optical interferometry IVOA already defines common data models and access protocols properly (images, spectrum, catalogues), but more specific concepts applied in interferometry are not yet well handled. It is now necessary to have one data model properly handling scientific and physical aspects of interferometry.

Optical interferometry facilities in general and JMMC in particular obey the OIFITS[14] data interchange standard for their products. This standard has been put to the test by many interferometric facilities since its publication and has fulfilled the expectations. In view of our "customer's" returns (e.g., needs for model fitting), it is however time for a refurbishing which would address new requirements. We started an exchange wiki†† on the subject of a revision of the OIFITS standard, whose efforts should be continued. We believe that several existing VO standards are relevant and should be analyzed because some of them could probably fill several requirements. This effort is not easy but would facilitate the necessary integration of optical interferometry in the VO.

5. IN LIEU OF CONCLUSION

The software suite is driven by JMMC members who are also observers. Because our tools are offered to the community, we are happy to get its feedback and suggestions to enhance current tools or implement new ones.

**http://apps.jmmc.fr/oidb

††http://www.jmmc.fr/twiki/bin/view/Jmmc/OIFITSTwoProject

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