JMMC-GEN-0000-0001

Revision 1.0

Date: 06/04/2001

JMMC

The Mariotti Center

Authors:
Alain Chelli <Alain.Chelli@obs.ujf-grenoble.fr> — LAOG/JMMC

Change record

Revision	Date	Authors	Sections/Pages affected
	Remarks		
1.0	06/04/2001	A. Chelli	all
	Created		

Table of contents

1 Introduction

All along the 90's the PNHRA (Programme National de Haute Résolution Angulaire) and the ASHRA (Action Spécifique Haute Résolution Angulaire), supported by the Observatoire de la Côte d'Azur (OCA) and the Observatoire des Sciences de l'Univers de Grenoble (OSUG), has promoved the creation of an interferometric center. In september 2000, the Mariotti Center (JMMC) was created by the Institut National des Sciences de l'Univers (INSU). Here comes the text explaining the scope of the document.
The JMMC aims in coordinating the french efforts in high angular resolution:

1. to fulfill the software needs generated by the new interferometric developments, especially the VLTI
2. to rationalize and to control as far as possible the processing of the interferometric signal
3. to contribute to set the users in an optimal operational position
4. to provide service and academic formation

In this context, the JMMC will be opened and will promove international collaborations, especially with VLTI partners. A non exhaustive list of the projects and instruments concerned by the center is:

- VLTI (VINCI/AMBER/MIDI/PRIMA)
- GI2T (REGAIN)
- CHARA
- DARWIN
- IOTA (FLUOR/IONIC)
- OHANA
- PTI

2 Why an Interferometric Center?

The development of interferometric instruments, especially the VLTI, is generating enormous sofware and algorithmic needs. To summarize, it is necessary to develop new and sophisticated sofware package:

- to prepare the observations
- to reduce the data
- to interpret the results in terms of simple models
- to interpret the results in terms of image reconstruction

In interferometry, there is a long way between the acquisition of raw data and the production of observables which can be interpreted by an astrophysicist. The first step is to produce calibrated visibilities and phase relations. The calibration of the object raw visibilities by a point source is a difficult task in which the french community has 30 years of experience. For a multi mode interferometer, the main problem comes from non stationnary atmospheric conditions.

This problem is highly relaxed when using single mode spatial filters but it is not completely suppressed. As a first consequence, the ultimate performances of the VLTI still have to be established. The instruments (in particular AMBER) are likely to achieve their specifications, but how close they can approach their most ambitious goals will be known only after quite some actual observations. As a second consequence, the software packages delivered to the users together with the instruments might not be perfectly optimized.

The attainment of the ultimate performances of the VLTI will require a long term follow-up and analysis of the instrument behaviour in correlation with its environment in order to identify and to quantify the long list of instrumental, atmospheric and astrophysical biases. In this context, some of the software tools allowing to modelize marginal instrument errors from environmental or technical information still have to be developed. This is unavoidable to be able to observe very faint sources and to reach the high image dynamics necessary for example for the detection of exoplanets. Besides the development of standards algorithmic tools, the fine analysis of the interferometric signal in a long term perspective to reach the ultimate performances of the instruments is one of the goals of the center.

3 Goals

The goals of the JMMC are:

- *Prospective.* The conception of new types of instruments is tightly related to the corresponding data reduction software. In other words, the way the instrument is designed depends on how we are going to process the signal and *vice versa.* The center will participate to the prospective reflexion on new interferometric instruments
- *Research and Development.* The center will
  - define optimized estimators for visibility, differential and closure phases
  - provide geometrical models to interpret experimental outputs
  - provide algorithms for image reconstruction
- *Service.* The center will
  - provide software to reduce interferometric data
  - document and maintain in the long term its productions
  - contribute to raw data archiving
  - support the users of interferometric facilities
- *Formation.* The center will organize and co-organize scientific schools in the interferometric fields for students and investigators

4 Composition of the JMMC

The JMMC is formed by two poles providing service to the community:

- JMMC-OSUG (Observatoire de Grenoble, JMMC headquarter) centered on the VLTI
- JMMC-OCA (Observatoire de la Côte d'Azur) centered on the GI2T

and by a network of 10 laboratories that have interferometric expertise:

- CRAL (Observatoire de Lyon)
- OPM (Observatoire de Meudon)
- IRCOM (Université de Limoges)
- LISE (Observatoire de Haute Provence)
- LAOG (Observatoire de Grenoble)
- OBX (Observatoire de Bordeaux)

- OCA (Observatoire de la Côte d'Azur)
- OMP (Observatoire Midi-Pyrenées)
- ONERA (Paris)
- UNSA (Université de Nice Sophia-Antipolis)

5 Organisation, Manpower and Funding

5.1 Organisation

The JMMC is headed by a scientific coordinator who manage the activities of the center and the relations with institutes abroad. He is assisted by two technical coordinators who manage the projects in each pole. The scientific actions are defined, analysed and priorized by a scientific council. The politic of development of the JMMC is managed by an executive board.

- Scientific Coordinator: A. Chelli (LAOG)
- Technical Coordinators: P. Cruzalebes (JMMC-OCA), M. Sacchettini (JMMC-OSUG)
- Scientific Council:
  - A. Chelli, G. Duvert (LAOG)
  - P. Berio, D. Mourard (OCA)
  - R. Lucas (IRAM)
  - G. Perrin (OPM)
  - E. Thiebaut (CRAL)
- Executive Board: the board is composed of the directors of the LAOG and OCA/Fresnel, members of INSU and ASHRA, the scientific and technical coordinators of the center.

5.2 Manpower and Funding

The french interferometric community gathers nearly 100 investigators and engineers, each of them being potentially active in the JMMC projects. In the last 5 years, more than 50 thesis have been defended in the interferometric field and related domains, and about 20 are under progress. At the present time, the manpower of the JMMC devoted to the current work packages amounts to:

- Investigators: 3.5 men.yr
- Engineers: 3 men.yr

The activities of the JMMC are also supported by the *Marie-Curie Training site in Astronomical Optical Interferometry and related science* (OPM, IAS, ONERA), which amounts to 96 months of PhD grants. We estimate that the manpower of the JMMC will increase by 1 to 2 men.yr during the next 5 years. At the present time, the JMMC is funded by INSU to support group meetings. Request for funds have be made to provide the JMMC-OCA and the JMMC-OSUG with new offices.

6 The Scientific Projects

The use of interferometric facilities requires software development in 4 distinct domains:

1. Preparation of observation → investigate the feasability,
2. Raw data processing → produce physical observables,
3. Models → interpret observables,
4. Image reconstruction → produce object image.

In addition, these actions would greatly benefit of advances in unified data formats and environment developments. The JMMC has formed scientific groups around priority tasks covering the 4 domains mentionned above. Each task is managed as a project with:

- Problem definition (network groups)
- Research and Development (network groups)
- User's requirements (network groups)
- Software requirements and specifications (network groups and poles)
- Sofware design (poles)
- Implementation and tests (poles and network group)

Some tasks are short *and* long term projects like ASPRO (Preparation of observations), the catalog of calibration sources, the data reduction packages of AMBER, IOTA/FLUOR → VINCI → MIDI, GI2T, and the Models. The last ones (Multi mode interferometry, Image reconstruction and Software environment) are medium and long term projects.

6.1 Astronomical Software to Prepare Observations (ASPRO)

Group composition:

- G. Duvert (LAOG), Principal Investigator
- P. Berio, D. Bonneau, B. Lopez (OCA)
- X. Delfosse, F. Malbet (LAOG)
- G. Perrin (OPM)
- F.X. Schmider (UNSA)

ASPRO is an interferometric observing preparation tool for the VLTI, but also for other instruments like GI2T, CHARA, IOTA/FLUOR, PTI. It contains 7 modules:

- *Object selection*: allow the user to load the parameters which charaterize the object through the Graphical User Interface or by quering the Simbad database
- *Calibrator search*: search in a catalog the calibrators which are the most adapted to the scientific object
- *Interferometric configuration*: allow the user to select the configuration of the interferometer and the focal instrument
- *UV Tables*: compute the UV plane coverage

- *Modelling*: fill the UV plane with model data
- *Exposure Time Calculator*: compute the expected signal to noise ratio on the visibility, the differential and the closure phases
- *Model Parameter Errors Calculator (MPEC)*: calculate the error on the parameters of an analytical model of the object (spatial spectrum) from a gaussian fit of the measurements (visibility and closure phase, differential phase)

Time scheduling. The development of ASPRO is divided in 3 phases:

- Phase 1: contain all the previous modules (except for the calibrators, MPEC only with predefined models). Deliverable in October 2001
- Phase 2: version with calibrators and a WEB interface. Deliverable in march 2002
- Phase 3: allow to query the Simbad database, differential and user models with associated MPEC. Deliverable in December 2002

6.2 Catalog of calibration sources

Group composition:

- P. Berio (OCA), Principal Investigators
- D. Bonneau, P. Cruzalèbes (OCA)
- P. Borde, G. Perrin (OPM)
- X. Delfosse (LAOG)

The selection of suitable calibration stars is crucial to obtain the ultimate precision of the interferometric instruments. In interferometry the calibrators must have physical properties (magnitude, colors, etc...) close to those of the scientific target. The calibrators for faint objects will be unresolved or only very partially resolved at all baselines. On the other hand, the calibrators for bright objects will be resolved. The smaller the calibrators the lesser their intrinsic visibility is sensitive to the exact angular diameter and to sources of instabilities. As a consequence, bright calibrators must satisfy stronger constraints than faint ones.

So, we propose to build an evolutive catalog of stars giving all the useful informations for the selection of calibrators with respect to the requirements of the astrophysical program. The catalog will be constituted of faint unresolved calibrators and brighter resolved calibrators:

- **Catalog of unresolved calibrators**. The catalog of unresolved (or very partially resolved) calibrators will be based on the Hipparcos and TychoII catalogs and complemented with the infrared photometry (J, H, K, L, M and N) from the JP11, DENIS and 2MASS catalogs. The angular diameter will be estimated from the surface brightness technique based on the colour indices, or/and on the spectro-photometric technique used for the FLUOR instrument.
- **Catalog of resolved calibrators**. This catalog will contain bright and resolved calibrators with stable radial velocity estimated from high accuracy radial velocity monitoring program. Such calibrators are known to have stable photosphere. They will be observed and followed routinely with the VLTI to determine accurate visibility curves and to check the visibility curves stability.

6.3 AMBER+

Group composition:

- A. Chelli (LAOG), Principal Investigator
- G. Duvert, F. Malbet, D. Mouillet (LAOG)
- R. Petrov (UNSA)
- Associate students: P. Mège, E. Tatulli (LAOG)

The members of this group are already involved in the development of the software which will be delivered by the AMBER consortium. The center intends to prolongate this work beyond the hand over of AMBER to ESO. The aim is to provide a second generation software for the AMBER instrument, based on a long term follow up of the instrument and an analysis of its biases, drifts and instabilities. This second generation software will certainly be necessary to reach the ultimate instrument performances and to approach and even overtake its more ambitious present goals. The center can also be involved in the developpement of additional software for potential extensions of AMBER, such as its multi mode module, if such extensions are eventually implemented.

6.4 VINCI and MIDI+

Group composition:

- G. Perrin (OPM), Principal Investigator
- V. Coudé du Foresto (OPM)
- Associated students: P. Borde (OPM)

The JMMC is providing a complete data reduction software for the VINCI experiment. It is based on the IOTA/FLUOR reduction package, adapted to read VINCI data format.
The VINCI software can naturally be extended to the MIDI sofware. The center is interested in the long term follow-up of the MIDI instrument in order to provide a second generation of the MIDI sofware (MIDI+).

6.5 The GI2T Instrument

GI2T Group composition:

- D. Mourard (OCA), Principal Investigator
- P. Berio, M. Pierron, F. Vakili (OCA)
- Associated students: S. Hamdani (OCA), C. Vérinaud (postdoc, Arcetri)

This group is currently working to optimize the data reduction software of the GI2T/REGAIN instrument. Different topics are considered:

- high accuracy calibration of visibility by modelling and monitoring of instrumental and atmospheric effects such as: variation of seeing, influence of outer scale of the atmosphere, residuals of differential polarization, tracking errors.
- preparation of algorithms for visibility estimate in case of partial correction of seeing by adaptive optics.
- dedicated tools for spectrally resolved interferometry, in the field of observation preparation tools and data reduction software.

- dedicated tools for Spectro-Polarimetry-INterferometry (SPIN)
- definition and use of special visibility measurements using the dense sampling of regions of the UV plane allowed by multi mode operation.

6.6 Multi mode (large field) interferometry

Group under constitution:

- Transversal group from CRAL, LAOG, UNSA and OCA
- Associated students: P. Mège, E. Tatulli (LAOG)

The use of monomode fibers like in the AMBER experiment allows to stabilize the interferometric signal which is, to the first order, no longer sensitive to the variations of atmospheric conditions. However, the drawback is a drastic reduction of the field of view to the lobe size of the instrument (the equivalent Airy disk). This makes problematic the observation of objects partially resolved by one telescope.

To overcome this problem, it is necessary to work without fibers. It is the case of the GI2T instrument which is a multi mode interferometer. This means that the field of view is much larger than the instrument lobe size and is only limited by geometrical constraints. In this case, the interferometric signal is very sensitive to the variations of atmospheric conditions. This sensitivity, however, decreases as the phasing of the entrance pupils increases with the help of adaptive systems. The GI2T group is working, in collaboration with investigators of CRAL, LAOG, UNSA and OCA, on the definition and the qualification of stable estimators for large field interferometry with partially phased entrance pupils. A direct application could be the use of the AMBER experiment in a large field configuration (without fibers).

6.7 Models

Group under constitution:

- Principal investigator: F.X. Schmider (UNSA)
- A. Chelli, G. Duvert, F. Malbet (LAOG)
- Associated students: E. Tatulli (LAOG)

For a 2 or 3 telescopes interferometer, the sparse UV plane coverage will generally not allow to reconstruct images. This group aims in developping a general formalism to interpret the outputs (visibility, closure and differential phases) in terms of geometrical models.

6.8 Image reconstruction

Group under constitution: E. Thiebaut (CRAL), Principal Investigator

In the future, the VLTI could be working with at least 7 telescopes (4 UT and 3 AT). It is commonly admitted that image reconstruction is possible from the output of at least 4 to 5 telescopes. The classical radio and millimetric techniques are not directly applicable to the outputs of optical interferometers because the absolute phases will generally not be accessible to the latter. The aim of this group is to investigate and to propose solutions for image reconstruction from VLTI measurements (visibility and closure phase).

6.9 UNified Interferometric DEvelopment Environment (UNIDEE)

Group under constitution: P. Valiron (LAOG), Principal Investigator

The group is a common initiative of both JMMC and IRAM in order to share the expertise and developments between the radio and optical communities in the perspective of the future interferometers (ALMA, VLTI, etc...).

In the short term UNIDEE will provide guidelines and practical solutions to interoperate existing software, thus permitting to develop hybrid data reduction pipelines and databases taking the best of most popular or promising softwares (IDL, Yorick, GILDAS, AIPS++, etc).

In a longer term challenge, UNIDEE will impulse an interdisciplinary reflexion open to computer science communities, in order to develop innovative development strategies and tools. [UNIDEE's preliminary objectives are: a fast attractive learning curve, networking and database capabilities, an efficient and portable design, an excellent upward compatibility, the ability to grant remote access to experts.]

More generally, the unified environment will facilitate the sharing of experience between the user scientists, and the Center specialists, and will ease the implementation of original observing or data reduction strategies on the new generation instruments.

7 Formation

It appears necessary to organize actions of formation to prepare the scientific community to the use of interferometric facilities. The JMMC is organizing or co-organizing various schools in the interferometric field:

- *Astrophysique et Interféromètre du Very Large Telescope: préparation des premières observations du VLTI*, Nice (France) 22-24 octobre 2001, responsable: B. Lopez (OCA).
- *Observing with the Very Large Telescope interferometer*, Les Houches (France) 3-8 février 2002, responsables: F. Malbet (LAOG) & G. Perrin (DESPA).