

# Quality Control and Instrument Trending for MIDI: First Quality Control and Data Flow Operations Results

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## ABSTRACT

The ESO Data Flow Operations group (also called Quality Control group) is dedicated to look into the performance of the different VLT instruments, to verify the quality of the calibration and scientific data, to control and monitor them on different time scales. At ESO headquarters in Garching, Germany, one QC scientist is dedicated to these tasks for the VLTI instruments: VINCI, MIDI, AMBER, and (eventually) PRIMA.

In this paper, we focus on MIDI. In this presentation, we define the tasks of the Quality Control scientist and describe the lessons learned on quality control and instrument trending with the commissioning instrument VINCI. We then illustrate the different aspects of the MIDI Data Flow Operations supported by the QC scientist such as data management issues (data volume, distribution to the community), processing of the data, and data quality control.

## 1. THE VLTI INSTRUMENTS

The VLT Interferometer (VLTI) has been operating since the first fringes obtained with the 2 $\mu$ m VLTI commissioning instrument VINCI. The next instrument operating in the VLTI environment, MIDI, obtained the first fringes using 2 Unit Telescopes (UTs) end of 2002. MIDI (the MID-infrared Instrument for the VLT Interferometer) is a long-baseline direct interferometer in the mid-infrared (N band: 8 to 12 microns) that records spectrally-dispersed fringes. MIDI is the first instrument to allow observations with large apertures and hectometric baselines at such wavelengths. More information on the MIDI instrument and the scientific objectives are given in several papers in these proceedings [4, 5]. MIDI observations will be done in the future with the UTs as well as with the Auxiliary Telescopes (ATs). Several instruments are following MIDI: AMBER (the near infrared/red VLTI focal instrument), PRIMA (the instrument for Phase-Referenced Imaging and Microarcsecond Astrometry).

## 2. QUALITY CONTROL AND DATA FLOW OPERATIONS

### 2.1. What are the tasks of the Quality Control scientist?

Most of the tasks are common to each VLT/VLTI Quality Control (QC) scientist [7]. The main activities are to verify the quality of the data, to monitor the performances of the instrument and to distribute scientific data to the Service Mode users. The main steps of the Data Flow Operations (DFO) will be described in the following section 2.2.

During the commissioning of the different instrument modes, the QC scientist also verifies the integrity of the FITS headers keywords associated to each standard observation mode (template). This step is critical to assure accurate automatic data association and data processing.

For each VLT/VLTI instrument, ESO follows a calibration plan both for the calibration of the science data and to monitor the health of the instrument. In the case of MIDI, there are two types of calibration data: the technical calibrations for determination of the read out noise, characterization of the detector linearity, stability of the reference pixels, transmission of the dispersive optical elements, wavelength calibration and determination of the throughput of the instrument; and the astronomical calibration measurements to remove the atmospheric and the instrumental effects signature imposed on the science data.

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## 2.2. MIDI Data Flow Operations

There are two distinct data flows [1]:

- on Paranal, the data are associated on-line for display (fig. 2) and quick-look processing with the pipeline. Basic quality control is done either during the observations or on the following day,
- in Garching, the data are processed on a daily basis. Approximately 10 days separate observations and processing in Garching to allow time to ship the data on physical media from Chile to Germany. For MIDI, we retrieve full runs (several nights) at a time. The calibration data are chosen from the full set of observations. For example, when the full night of data is available, it is possible to use several calibrator measurements to obtain a better accuracy on the Instrumental Transfer Function.

### 2.2.1. Data Association

Since the data volume of a MIDI observation is of 1GB per visibility measurement, each data set is split into several smaller FITS files. To process the entire set, we need first to associate the files belonging to the same observation (see Table 1) and then associate this data set to the files (raw or processed) which will be used for calibration (fig. 1). All the different associations are based on the keywords contained in the FITS files headers.

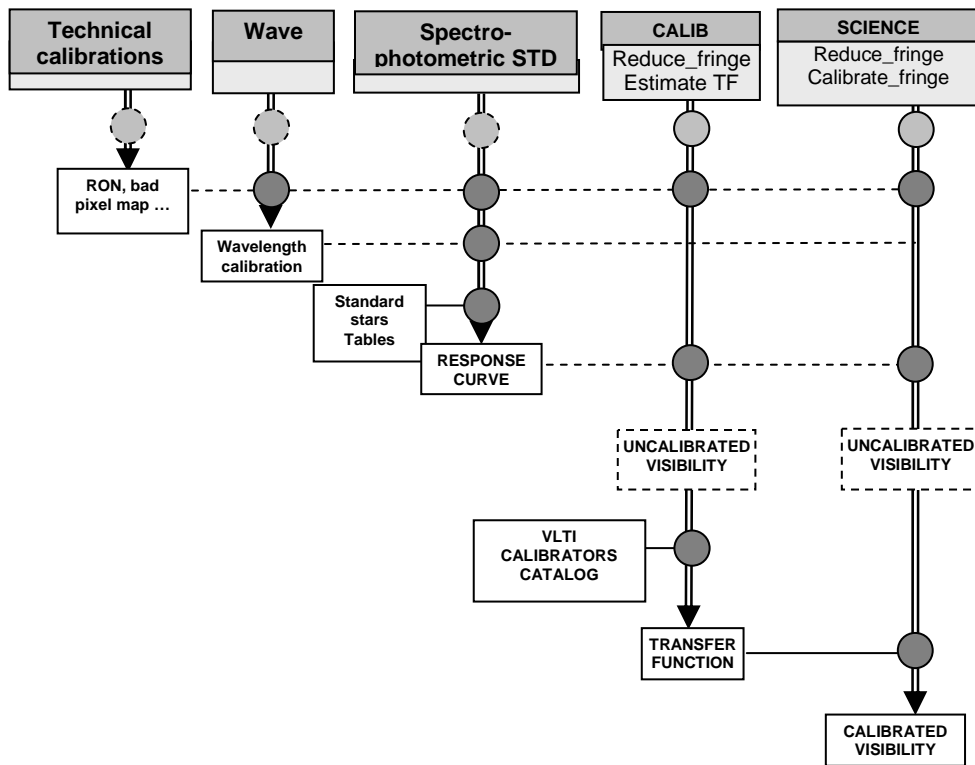


Fig. 1: Association map for the MIDI instrument. The columns (Technical calibrations, Wave, STD object) represent technical calibrations used for instrument health check, instrument trending and calibration of the raw data. For the astronomical target (SCIENCE and CALIB), an uncalibrated visibility is calculated from the raw files as an intermediate product. In the case of a CALIB object, a recipe produces an instantaneous Instrumental Transfer Function which is applied to the SCIENCE uncalibrated Visibility to remove the atmosphere and the instrument signature. The final SCIENCE product is a calibrated Visibility.

Raw file type	Comment
FRINGE	Split file #1
FRINGE	Split file #2
FRINGE	Split file #3
PHOTOMETRY	Beam A
PHOTOMETRY	Beam B

Table 1: Raw files which are associated to produce an uncalibrated raw Visibility. Each MIDI data fringe measurement is split in several smaller files (3 to 5 in average). For the first Service Mode observation, the HIGH\_SENS mode was used. In this mode, the photometric channels are not used. To calibrate the raw visibility, we need to take photometric exposures, first with beam A, then with beam B. These photometry raw FITS files need to be associated with the correct data set.

The final product for a MIDI observation is a calibrated Visibility of the science object. The science and the different calibration files are associated using rules defined for each instrument modes. For the first run of the pipeline, the association between science target and astronomical calibrator is done using either the pair science target-calibrator provided by the user or the “closest in time” rule. A full night of data is processed on these associated data sets. The QC scientist looks at the quality of the astronomical calibrators and could re-associate the science data with a more suitable calibrator if the quality of the calibrator associated to the science target is not sufficient. The data of the full night are then re-processed using these new associations.

### 2.2.2. Data Reduction

Most of the algorithms in the pipeline recipes have been described by the MIDI consortium and adapted by the DFS group in the ESO pipeline environment. The products obtained are following the recommendations of the IAU working group on Optical/Infrared Interferometry, which is leading towards a common data format and a set of tools for calibrated interferometric data (<http://olbin.jpl.nasa.gov/iau/>).

In the Paranal environment each raw file is automatically classified, associated and assigned an appropriate recipe, the data are processed using default input parameters, which have been chosen to be the most appropriate for most of the data. In the Garching environment, the data association is done with specific tools and the pipeline is run in an automatic mode after input of the best parameters. These input parameters are tuned for the main goal of the Data Reduction Software in Garching: to provide QC parameters, they are therefore not tuned to provide highly accurate results for each type of data.

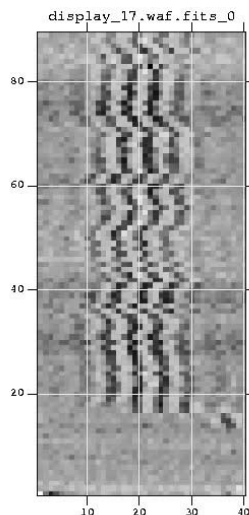


Fig. 2: MIDI waterfall display. The pre-processed data are displayed by the pipeline. The first few scans are recorded off-fringe.

The procedure for the data reduction involves different stages. For the first version of the pipeline, the algorithm creates an undispersed visibility from a dispersed interferogram (see fig. 2). For each type of object (CALIB or SCIENCE) a raw uncalibrated visibility is calculated.

At the start of the processing, the dispersed data are collapsed. The raw visibility (also called uncalibrated visibility) is calibrated for background and photometry effects. When calibration data are processed, parameters such as the estimated diameter and error are extracted from the calibrator database (see the web-based calibrator selection tool CalVin available at <http://www.eso.org/observing/etc>) to compute an Instantaneous Transfer Function. When processing science data, the calibrated visibilities are computed by using the above Transfer Function as well as the raw undispersed science visibilities.

The final product is a FITS file containing processed results and quality control data. Some of the FITS header keywords are used to store QC information. This allows the scientist to have a quick look at the quality of the data before reprocessing them with more specialized software. The pipeline produces also ASCII files to log the different steps of the pipeline processing or to summarize the most important QC parameters.

### **2.2.3. Data Distribution**

After each MIDI run, the full data set is processed. A package is created for each program which is declared completed by the ESO User Support Group (USG). The MIDI data package follows the same structure than the other VLT instruments. We distribute all the raw data associated to the program (acquisition on both telescopes, raw data on the fringe search, raw data on the fringe track and its associated calibration). Included in the package are the technical calibration data which could be used to calibrate the science data. Concerning the astronomical calibrators, we took the decision to include in each package only the data obtained on the astronomical calibrator requested by the PI. If the calibration of the science data requires more than one astronomical calibrator, the PI should request the data from the Garching archive. We also distribute product data when the data were processed successfully by the pipeline (FITS product, log and ASCII files). If several calibrators were observed during the night we provide the Instrumental Transfer Function measured on the calibrators.

## **2.3. MIDI Quality Control**

### **2.3.1. Lessons learned with VINCI**

#### **2.3.1.1. Instrument monitoring**

Since March 2001, VINCI, the VLTI commissioning instrument has been used for scientific purposes as well as a prototype for the Data Flow Operations. We have been monitoring on different time scales the Instrumental Transfer Function. In the following figure (fig. 3), the change of stations are clearly illustrated with the large jumps, while the smaller jumps are due to the atmospheric fluctuations from night to night. This kind of instrument monitoring allows also the scientists to detect instrumental problems.

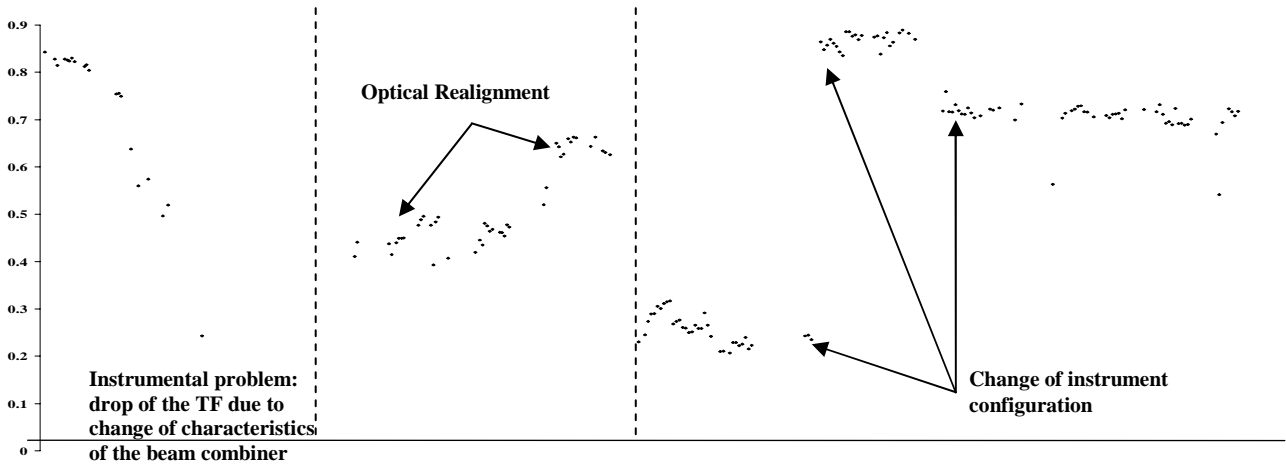


Fig. 3: This plot of the VINCI Transfer Function illustrates the modifications in the instrument due to unexpected problems, to realignment or to stations changes. The smaller jumps are due to the atmospheric fluctuations which vary from night to night.

### 2.3.1.2. Astronomical Calibrators

An important issue in interferometry is the removal of the instrumental and atmospheric effects to calibrate the visibility. This is done by observing astronomical calibrators with known characteristics. For VINCI/VLTI, we choose to select a number of objects to be observed as potential calibrators [2]. Several of these objects have been studied with VINCI at  $2\mu\text{m}$  to provide more accurate measurements (fig. 4). For MIDI a selection of potential MIDI calibrators have been provided by the MIDI consortium. Photometry was performed for these stars and the limb-darkened diameter was obtained by fitting atmospheric models [3]. Some of these calibrators were common for the two instruments VINCI and MIDI. When possible, we study them with VINCI, to understand their behaviour at  $2\mu\text{m}$ .

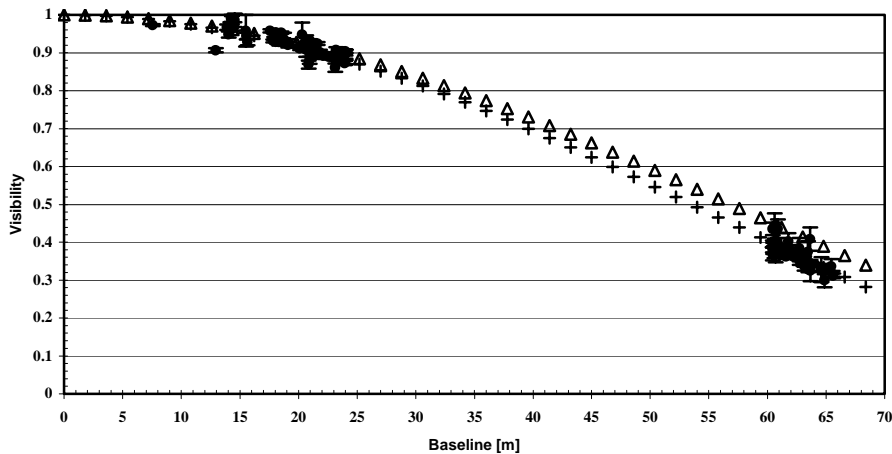


Fig. 4: Data obtained on a potential MIDI calibrator using the VINCI instrument. The projected baselines range from 7 metres to more than 60 metres. The previously assumed diameter (triangles) could be refined using VINCI data (dots) and a new diameter in the K band (crosses) could be fitted to the measurements.

### 2.3.2. Quality Control and instrument trending

Service Mode observations started in April 2004 with the MIDI instrument. These data went through the whole Data Flow Operations procedure: from the retrieval of the data, to their distribution. The set was used to assess both the quality of the raw data and of the pipeline products, detect any problems or instability in the data and start instrument trending. More information on Quality Control and Data Flow Operations is available at [www.eso.org/observing/dfo/quality/](http://www.eso.org/observing/dfo/quality/)

For this first MIDI Service Mode run, 90% of the Observation Blocks (OB) has been successfully processed by the pipeline. We are still in the process of defining the limitation of the instrument mode associated with the pipeline recipes as well as the list of QC parameters which best describe the status of the instrument and the quality of the observations. By processing large data sets, we evaluate the limitations set by the observing procedures, the instrument mode and the pipeline algorithms. For example, we detected some instability in the measurement of photometry data on faint objects. A more detailed analysis shows that for object brighter than 15Jy, the photometry data used to calibrate the raw visibility are accurate to about 15%. This sets a limitation in the accuracy obtained on calibrated visibility for these data processed with the first version of the pipeline.

Using VINCI experience and the data from the MIDI observations, we are gaining knowledge about instrument monitoring. Using the CalVin list (the VLTI calibrator selector available at <http://www.eso.org/observing/etc/>), we selected some potential calibrators to be observed each night and which will allow us to detect any trends in the instrument and therefore identify any changes or systematic effects. Fig. 5 shows the Instrumental Transfer Function measured on MIDI over three nights. Because the first SM run duration was only of 4 nights, the time scale available for this type of monitoring is rather short.

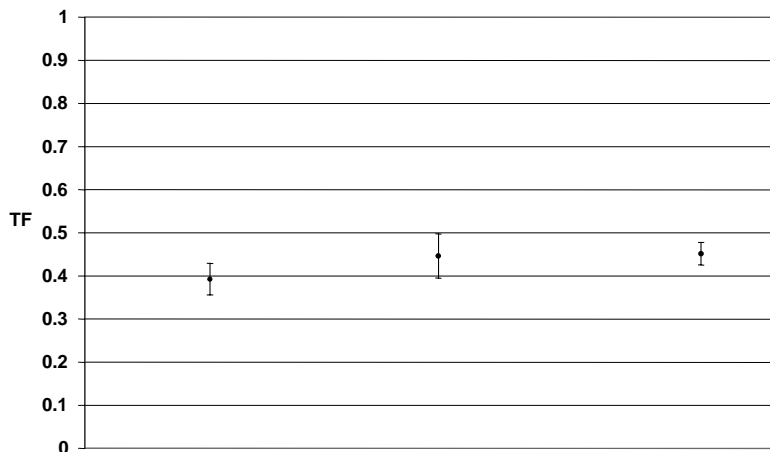


Fig. 5: The same bright calibrator was observed each night during the first MIDI Service Mode (SM) run to provide initial trending data. As with VINCI, some of the variations of the Transfer Function (TF) are due to atmospheric fluctuations.

## 3. CONCLUSION

During this first Service Mode run we could test the full Data Flow Operations scheme. We also provided the users with some results on the quality of their data within certain limitations set by the observing procedures, the instrument and the pipeline algorithms. Over the following months, as more Service Mode runs will take place, we will be able to monitor the instrument over different time scales.

For interferometric data, it is also important to understand the importance of astronomical calibrators (equivalent of standard stars for photometry or spectroscopy). One of the roles of the QC scientist, together with the VLTI team is to study the potential interferometric calibrators with the different instruments. This is also one of the topics often discussed

within the interferometric community and in particular within the IAU working group on Optical/IR Interferometry ([olbin.jpl.nasa.gov/iau/](http://olbin.jpl.nasa.gov/iau/)).

## REFERENCES

1. P. Ballester, T. Licha, D.J.McKay, S.Morel, I.Percheron, M.Petr-Gotzens, A.Richichi, C.Sabet, M. van den Ancker, M.Wittkowski, *The MIDI Data Flow: First Observing period*, The ESO messenger 116, in press, 2004.
2. A. Richichi, I. Percheron, *CHARM: A Catalog of High Angular Resolution Measurements*, Astron. Astrophys., 386, 492-503, 2002.
3. ESO mini-workshop on VLTI Calibrators ([www.eso.org/~arichich/download/vlticalibs-ws/](http://www.eso.org/~arichich/download/vlticalibs-ws/)), 2003.
4. S. Morel, P. Ballester, B. Bauvir, P. Biereichel, J-G. Cuby, E. Galliano, N. Haddad, N. Housen, C. Hummel, A. Kaufer, P. Kervella, I. Percheron, F. Puech, F. Rantakyro, A. Richichi, C. Sabet, M. Schöller, J. Spyromilio, M. Vannier, A. Wallander, M. Wittkowski, C. Leinert, U. Graser, U. Neumann, W. Jaffe, J. deJong, *Preparing MIDI science operation at VLTI*, these proceedings, 2004.
5. M. Wittkowski, P. Ballester, F. Comeron, C. Hummel, A. Kaufer, S. Marteau, S. Morel, P. Nass, I. Percheron, M. Peron, M. Petr-Gotzens, F. Rantakyro, A. Richichi, M. Schöller, D. Silva, M. Van den Ancker, A. Wallander, *Observing with the VLTI Interferometer*, these proceedings, 2004.
6. P. Ballester et al, *VLTI Interferometry in the Data Flow System*, Proc. SPIE Vol. 5493, in press, 2004.
7. W. Hummel et al, *Quality Control and Data Flow Operations of NACO*, ESO proceedings "Science with AO", 2003.