Quality Control and Instruments Monitoring for the VLTI

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ABSTRACT

The VLTI Data Flow Operations consist in monitoring the performance of the different VLTI instruments offered to the community, in verifying the quality of the calibration and scientific data and their associated products. Since the beginning of MIDI (April 2004) and AMBER (October 2005) Service Mode Operations, scientific as well as calibration data have been accumulated to monitor the instruments and the quality of the observations on different time scales and under different conditions or system configurations. In this presentation, we will describe the Quality Control procedures and give some statistics and results on the different parameters used for instrument monitoring for time scales from hours to years in the case of MIDI. We will show that this includes parameters extracted directly from the instruments (Instrumental Transfer Function, Flux stability, Image Quality, Detector stability …) and parameters extracted from some of the sub-systems associated to the instruments (Adaptive Optics, telescopes used …). We will discuss the development of the monitoring of the instruments once more instrument modes or sub-systems such as PRIMA are offered to the community.

Keywords: VLTI, Interferometry, instrument monitoring, quality control, instrument trending

THE VLTI INSTRUMENTS

The VLT Interferometer (VLTI) has been operating on Paranal since 2001 with first fringes obtained at 2µm with VINCI, the VLTI commissioning instrument. Since Period 73 (April 2004), MIDI (the MID-infrared Instrument for the VLTI), operating in the N Band between 8 to 12 µm is offered for Service Mode Observations (SM). For the past period (October 2005 to April 2006), MIDI was offered using the UT (Unit Telescopes 8.2m) or the AT (Auxiliary Telescopes: 1.8m). The second VLTI instrument AMBER (near-infrared/red focal instrument for the VLTI), operates in the bands J, H and K and has been offered for SM operations since P76 (October 2005 with either 2 telescopes or 3 telescopes. The instruments are described in ref. 4 and 5, while the operations are described in ref. 1 and ref. 3. Both instruments are part of the Data Flow and Quality Control Operations (DFO and QC) in Garching.

DATA FLOW AND QUALITY CONTROL OPERATIONS

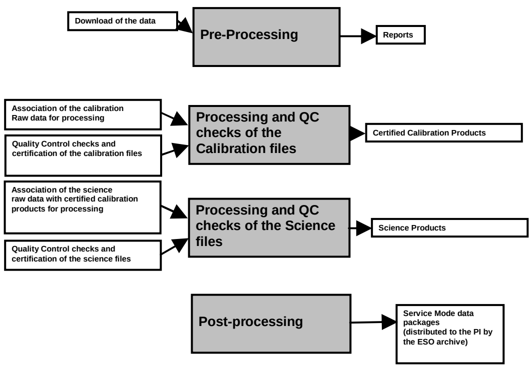

Fig 1: The observed data are archived on Paranal and are shipped to Garching several times a week. The VLTI data (typically 15GB a night for MIDI SM night and 5 GB for AMBER SM Night) are retrieved on the dedicated DFO machines for processing, quality control, instrument trending, health check and packing.

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The quality of all data measured with the VLT and VLTI during Service Mode operations are evaluated by the QC group in Garching. This is done using data flow operations and is illustrated in Fig 1.

DATA PROCESSING AND QUALITY CONTROL FOR VLTI.

1.1 Data association, pipeline processing and data products

All the raw data are processed using the ESO pipelines which are integrated in the ESO Data Flow System (DFS). These pipelines are running in Paranal and in Garching. In Paranal they are used by the Science Operations team (PSO) to assess the quality of the data after the observations and in Garching by the dedicated QC scientist to produce the calibrations and the science products. The MIDI pipeline is based on algorithms provided by the consortium; the new modes are implemented by ESO. A second MIDI Data Reduction Package, fully interactive has been developed by the consortium (ref 2). The AMBER pipeline is still under development in collaboration with the consortium.

As shown in Table 1, the MIDI mode HIGH_SENS (high sensitivity, the full flux is used to record the fringes, then the target and the sky are measured for each beam to calibrate the fringe data), is fully supported for the UTs. With the ATs, the mode was not fully supported until end of January 2001. Since then, some hardware and software modifications were done and observations on the ATs and the UTs are now processed using the same algorithms. The second MIDI mode offered for P76 is the SCI_PHOT mode. In this mode the detector records at the same time the two interferometric channels and the two photometric channels. This mode is less sensitive than the HIGH_SENS mode (the light is split between the interferometric channels and the photometric channels) but is more accurate (the photometry is recorded at the same time than the fringes are acquired). There are 3 main steps for the processing of the data: the estimation of the Kappa Matrix, which represents the splitting ratio between the interferometric channels and the photometric channels, the estimation of the uncalibrated fringes, the calibration of the fringes with the kappa matrix and the flux. Currently only the first two steps are supported by the pipeline, the uncalibrated fringes are used to assess the quality of the observation.

Before processing, the files are associated using specific tools, the Data Organiser (DO) in Paranal and the ABbuilder in Garching (AB: Association Blocks). This association is done using specific keywords logged in the raw fits files. In Paranal and in Garching, the operations are done night by night, with use of calibrations which could be taken several nights/weeks apart. The calibrations products are first created, their quality is assessed and the products are then certified. The science data files are associated to calibrations files. The table 1 shows which data are associated before the processing.

	Mode	**category**	**Associated raw files**	**Associated products needed for processing (fits files or tables)**	**Pipeline generated products**
MIDI	HIGH_SENS	CALIB	Interferometry photometry	Calibrator database Wavelength table	Fringe visibility TransferFunction
MIDI	HIGH_SENS	SCIENCE	Interferometry photometry	Wavelength table Transfer Function	Fringe visibility
MIDI	SCI_PHOT	CALIB	Photometry files	Wavelength table	Kappa Matrix
MIDI	SCI_PHOT	CALIB	Fringe files	Wavelength table Calibrator database Kappa Matrix	Fringe visibility TransferFunction
MIDI	SCI_PHOT	SCIENCE	Fringe files	Wavelength table Transfer Function	Fringe visibility

Table 1: Each observation represents several fits raw files which are associated and classified following rules. Each set of associated raw file will produced one or several products.

When the files are associated, they are classified and sent to the pipeline for data analysis and to create the products. In the case of VLTI, the pipeline is still under development and the pipeline products are distributed to the community (PI) but cannot be used directly for high accuracy analysis. The table 2 describes the ESO pipeline products and the main Quality Control Operations for each instrument mode.

	Instrument Mode	Category	Resolution element	Instrument setup	ESO Pipeline products	Main QC parameters or plots
MIDI	HIGH_SENS (+acquisition)	CALIB	PRISM or GRISM	AT	- Acquisition product - No reduced fringe for P76 (Supported for P77)	-Size of the acquisition image, -Quality of the photometry -Dispersed visibilities -Instrumental Transfer Function
		SCIENCE				-Size of the acquisition image, -Quality of the photometry -Dispersed visibilities -Calibrated Visibilities
	HIGH_SENS (+acquisition)	CALIB	PRISM or GRISM	UT	-Acquisition product -reduced fringe product	-Size of the acquisition image, -Quality of the photometry -Dispersed visibilities -Instrumental Transfer Function
		SCIENCE				-Size of the acquisition image, -Quality of the photometry -Dispersed visibilities --Calibrated Visibilities
	SCI_PHOT (+acquisition)	CALIB	PRISM or GRISM	UT	-Acquisition product -Kappa Matrix -reduced uncalibrated fringe product	-Size of the acquisition image, -Quality of the photometry for the kappa Matrix -Kappa Matrix
		SCIENCE			-Acquisition product	-Size of the acquisition image
AMBER	Standard or differential phase	CALIB or SCIENCE	Low	JHK or HK 2 or 3 beams	-Pixel to Visibility Matrix (P2VM), -Fringe product (1 per band per baseline)	-P2VM offset, -Piston, SNR, dispersed Visibilities, Averaged Visibility, Flux, -Phase Closure for 3 beams
			Medium	JH or HK or K 2 or 3 beams		
			High	J or H or K 2 or 3 beams		

Table 2: The processing of the set of associated fits files produce one or several products (fits files or table). These files contain the results (following the OIFITS format for the fits files), and different QC parameters which are used for Quality Control, instrument trending and health check.

Technical Calibrations

Unlike the other VLT instruments, the VLTI instruments do not require the typical day time calibrations. Both MIDI and AMBER follow a calibration plan which include for MIDI data taken to measure the detector linearity, the detector Read-Out-Noise, the transmission of the dispersive elements, and the position of the reference pixels. Reference frames are also compiled and used by the Paranal operator when starting the instrument (see fig. 2). Data are also taken for wavelength calibration. More information can be found at http://www.eso.org/observing/dfo/quality/MIDI/qc/qc1.html

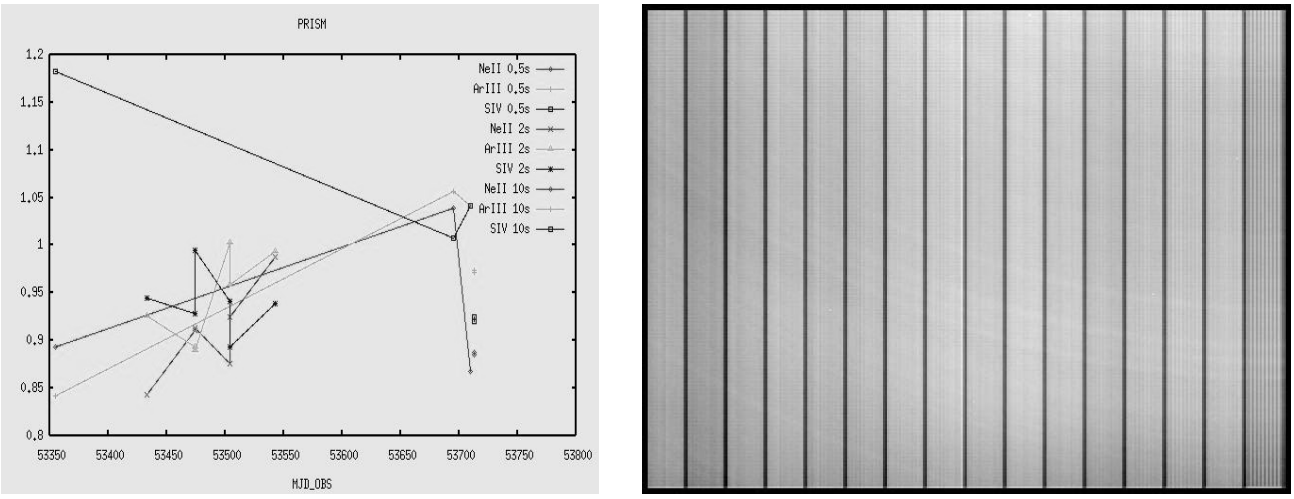

Fig. 2: Example of MIDI calibrations: transmission of the PRISM and MIDI reference frame. Note that for the transmission of the PRISM plot, the data > 1 shows that there was some saturation in the image which was not taken into account by the pipeline recipe. This is under investigation.

For AMBER, data are taken to calculate the Bad Pixels Map (BPM) and the Flat Field Map (FFM). Since the end of P76, MIDI calibration data are taken at least once a month. These data are processed with the pipeline and the analysis and the monitoring of the results are part of the health check and the monitoring of the instrument. For AMBER, the technical calibration data have been taken once and the BPM and FFM have been generated by the consortium and are distributed with the SM data packages as well as with the data analysis package developed by the consortium.

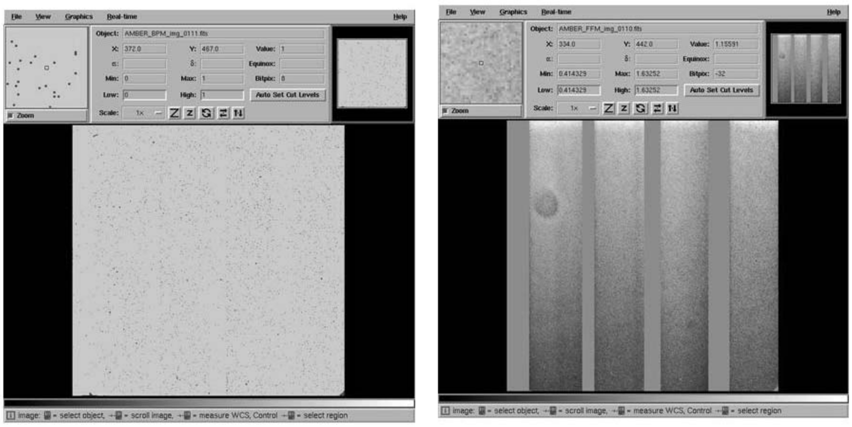

Fig. 3: BPM and FFM for the AMBER instrument.

Astronomical Calibrators data

As with the other ground based interferometers, the VLTI is affected by the atmospheric turbulence. To calibrate the science data, one is required to measure the instrumental Transfer Function using an astronomical calibrator with a well known diameter or an unresolved source (see ref 6). A VLTI observation associates always an astronomical calibrator and a science target. The selection of the calibrator can be done using several approaches. The calibrator can be chosen in catalogs using selection criteria (non variable, non multiple, no infrared excess or peculiar spectrum …), the second approach (which is chosen by the VLTI) is to compile list of potential calibrators either from existing measurements or with estimated diameters. The second option allows a monitoring of the calibrators and the fig. 4 shows the sky coverage for MIDI and AMBER as well as the sky coverage of the VINCI calibrators.

At the preparation of the SM observations, the PI can choose a calibrator from the VLTI calibrator Database (CalVin available at http://www.eso.org/observing/etc/) or select his own astronomical calibrator if none are available from CalVin. If the calibrator is chosen from the VLTI database, and if the mode is fully supported by the pipeline, the associated Transfer Function is calculated by the pipeline and is used to calibrate the Science data if any is associated and for instrument trending (see section 1.2).

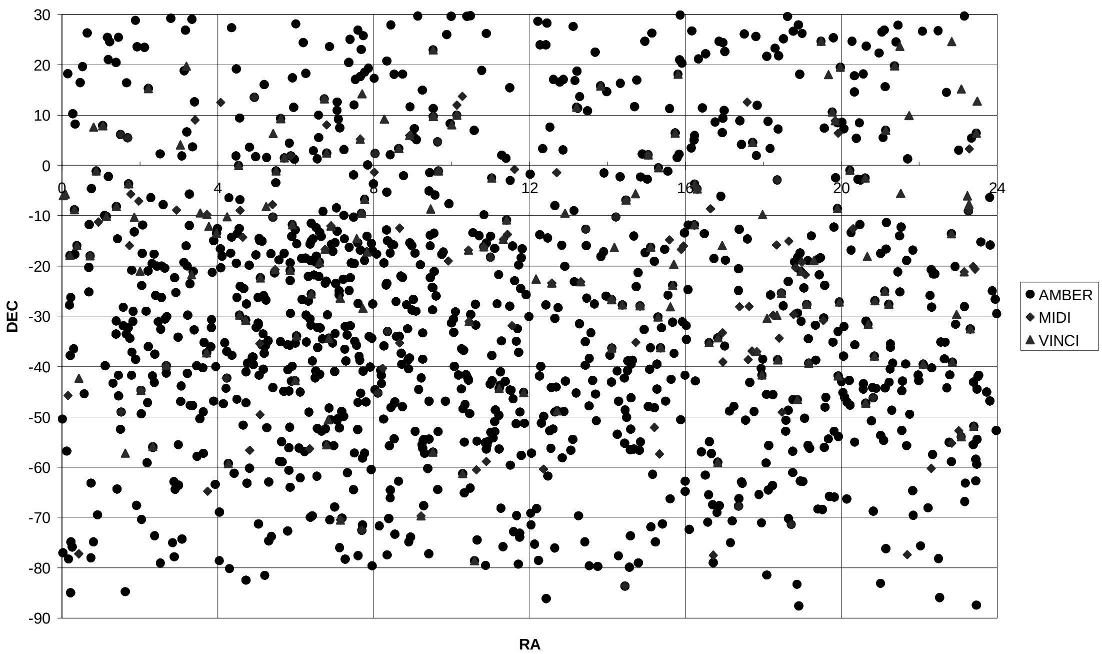

Fig 4: Sky coverage for the MIDI, AMBER and VINCI calibrators. The MIDI calibrators have been provided by the consortium while the AMBER calibrators list has been compiled from existing catalogs (see ref 8)

Science Products

Each science target is processed by the pipeline. If a transfer function (TF) is measured close (in time) to the science object, the visibility measured on the calibrator is calibrated with the TF and a calibrated visibility is also distributed with the product. If there is no calibrator from CalVin observed close in time to the scientific target, only the uncalibrated visibility is present in the product. The products are checked for quality and distributed to the PI. Because of the possible complexity of the object, the product is checked only for obvious problems.

1.2 Quality Control and Instrument trending

MIDI

For the HIGH-SENS mode, the quality of the visibility obtained is directly related to the accuracy of the measurement of the flux of the object taken after the observation of the fringe. The QC procedures check the quality of the photometric data. The figure 5 shows 2 sets of photometric data, one with some chopping problems (top), another one of good quality data (middle).

In the case of a calibrator, the flux on the target should be easily measured; the calibration product is not certified if this is not the case. In the case of a science target, the stability of the photometry is used.

The second step in the certification of the calibration product is the value of the TF (if available) or if no TF is available, the shape and the value of the calibrator visibility. Even if the diameter of the calibrator is unknown because not chosen in the CalVin database, the calibrator should be small (point source like) and without spectral feature or infrared excess. Its visibility across the spectrum should be without features and its height closed to the expected TF (fig 4, bottom). The visibility of the Science object is also studied but is not taken into account.

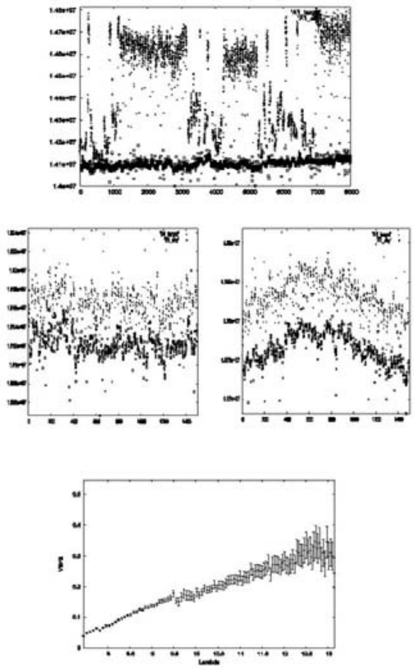

Fig 5: Quality control on the photometric data (top and middle) and on the dispersed Visibility vs. wavelength. For the top and middle images the X axis represents the frame number (1 to 8000 for the top image, 1 to 1500 for the middle), the Y axis the flux. In the top image, the flux of the target (crosses) shows variations.

The instrument monitoring consists mainly in following the variation of the TF on different time scale: during the night or for a full observing Period (6 months). An example is shown in the figure below.

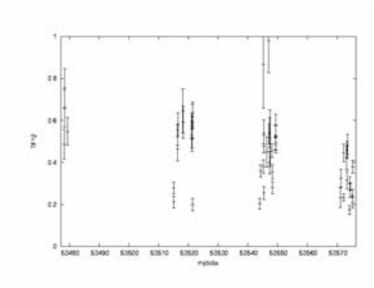

Fig 6: Transfer Function for the MIDI instrument

AMBER

The AMBER instrument is described during this conference (ref 3). AMBER quality control consists mainly in monitoring the offset between the different photometric and interferometric channels (fig. 7). This offset is calculated during the calibration of the Pixel to Visibility Map (P2VM).

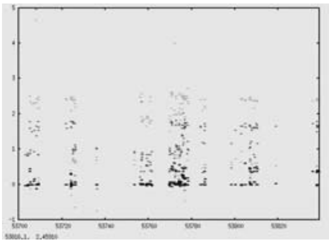

Fig 7: offsets for the photometric channels as calculated by the pipeline. For good quality data, this offset should not be larger than 3. The scale represented here is -1, +5.

Different plots are also produced using the data products; a final plot containing them is generated and included in the PI packages (fig. 8).

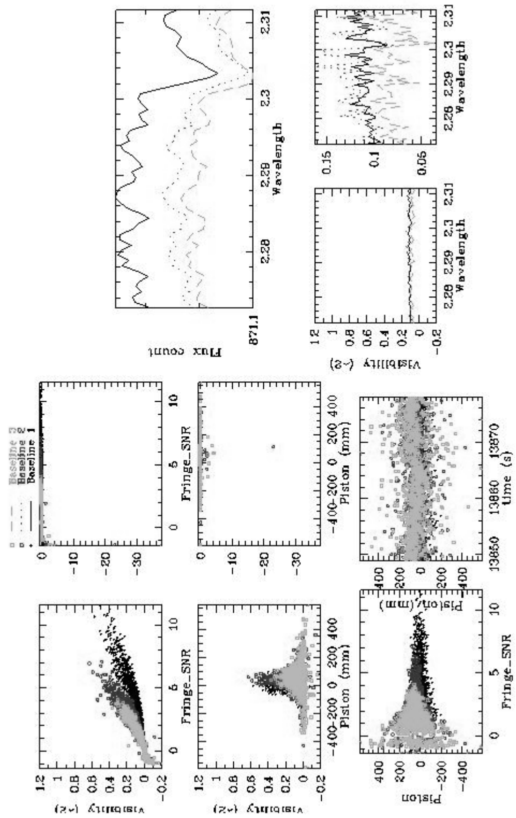

Fig 8: Quality Control plot produced for AMBER using 3 telescopes (3 baselines). The data on the left show respectively (top to bottom) the Visibility vs the fringe SNR, the Visibility vs the fringe piston and the piston vs the fringe SNR. The Visibility plots are scaled between -0.2 and 1.2. The middle top plots show also the Visibility vs SNR and vs Piston but with the real scale and show the outliers. The middle plot shows the piston vs time.

VLTI

The VLTI is not limited only to the interferometric instruments MIDI and AMBER but includes also a variety of subsystems such as MACAO (the adaptive optics system for the VLTI at the UTs), the delay lines, the variable curvature mirrors (VCM). Some of them need to be controlled and monitored. During this conference, a poster (ref 9) is presented on the influence of the MACAO performances on the interferometric measurements. During the campaign of observation with MIDI on the AT, the importance of the VCMs was also shown.

QC AND THE INTERFEROMETRIC COMMUNITY

The main interaction between the QC group in Garching and the astronomical community is the compilation of the PI data packages. During P76, more than 80 packages were sent to the different AMBER and MIDI PIs.

The study of the potential VLTI calibrators is also an important part of the Quality Control tasks done in collaboration with the interferometric community. A calibrator program was started at ESO at the beginning of the VINCI observations (ref 7). The same program is also under way with MIDI and AMBER. The observations on the calibrators are analyzed and the results are used to update the list of potential calibrators used in CalVin (for example variable objects or calibrators with infrared excess are removed).

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