MIDI and AMBER from the user's point of view

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Abstract

This article introduces the two instruments MIDI and AMBER of the VLTI, for which observing proposals can be submitted. The instruments are described from a user's point of view without going very deep into their technical details. Emphasis is put on practical considerations that may be useful for the preparation of observations in the various stages including the first consideration of scientific ideas, the preparation of observing proposals, and the preparation of the actual observations after observing time has been granted.

Key words: instrumentation: interferometers, techniques: interferometric, telescopes, MIDI, AMBER

1 Introduction

In this book chapter, we introduce and discuss the two instruments MIDI and AMBER, which are currently offered for observations with the VLT Interferometer. The principles of interferometry as well as the VLTI facility are described in the previous chapters of this book, and these aspects are not repeated here. The present chapter is focused on the preparation of observations, with respect to both the initial development and formulation of the scientific idea (Phase 1 proposal preparation), and the definition of the exact observational material and parameters after observing time has been obtained (Phase 2 proposal preparation). The process of reducing and modeling the data obtained with MIDI and AMBER is discussed in detail in the following chapters of this book, and these aspects are not a part of the present chapter.

The ESO Very Large Telescope Interferometer (VLTI), located on Cerro Paranal in northern Chile (La Silla Paranal Observatory), is the first optical

Preprint submitted to Elsevier *2 May 2007*

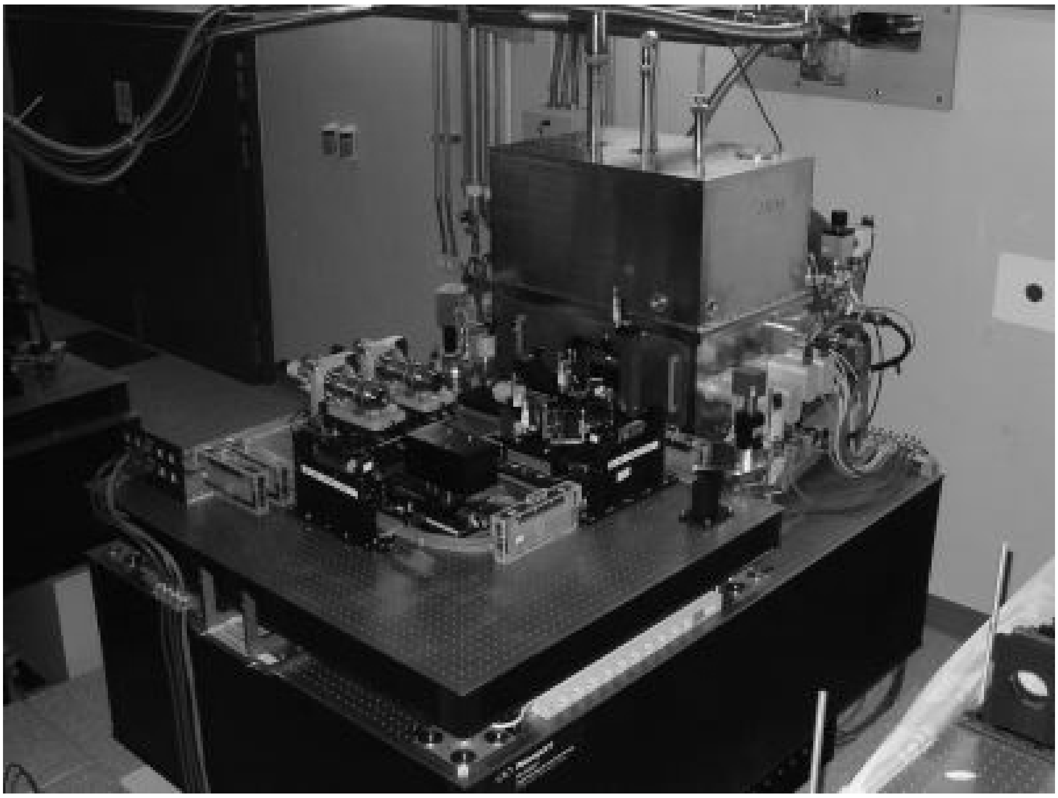


Fig. 1. The mid-infrared (8-13 μm) VLTI instrument MIDI in the beam-combining laboratory at Paranal Observatory [1].

interferometer that is operated as a general-user facility and that can be used by the whole astronomical community. The telescopes of this facility include the four fixed 8 m diameter VLT Unit Telescopes (UTs) spanning ground baselines between 47 m and 130 m, and four 1.8 m diameter Auxiliary Telescopes (ATs), which can be moved over an array of 30 stations with baselines between 8 m and 200 m. A fringe tracker (FINITO) and a dual-feed facility (PRIMA) for astrometry and phase referenced imaging will extend the capabilities of the interferometer. The details of the facility including the status of the fringe tracker FINITO and the dual-feed facility PRIMA are described by Schöller (chapter 3.1 in this book).

The VLTI includes at present two scientific instruments, the mid-infrared (8-13 μm) instrument MIDI (Leinert et al., 2003) combining two light beams at a time and the near-infrared (J, H, K bands) instrument AMBER (Petrov et al., 2003) combining three beams at a time. MIDI offers spectral resolutions of 30 and 230; AMBER of 30, 1500, and 12000. Both instruments are at present unique among interferometric facilities in their combination of spectral ranges and spectral resolutions. The science operations schemes of MIDI and AMBER are fully integrated into the well established operations scheme of all VLT instruments at Paranal Observatory from the initial preparation of observing proposals to the delivery of the data. In particular, the same kind

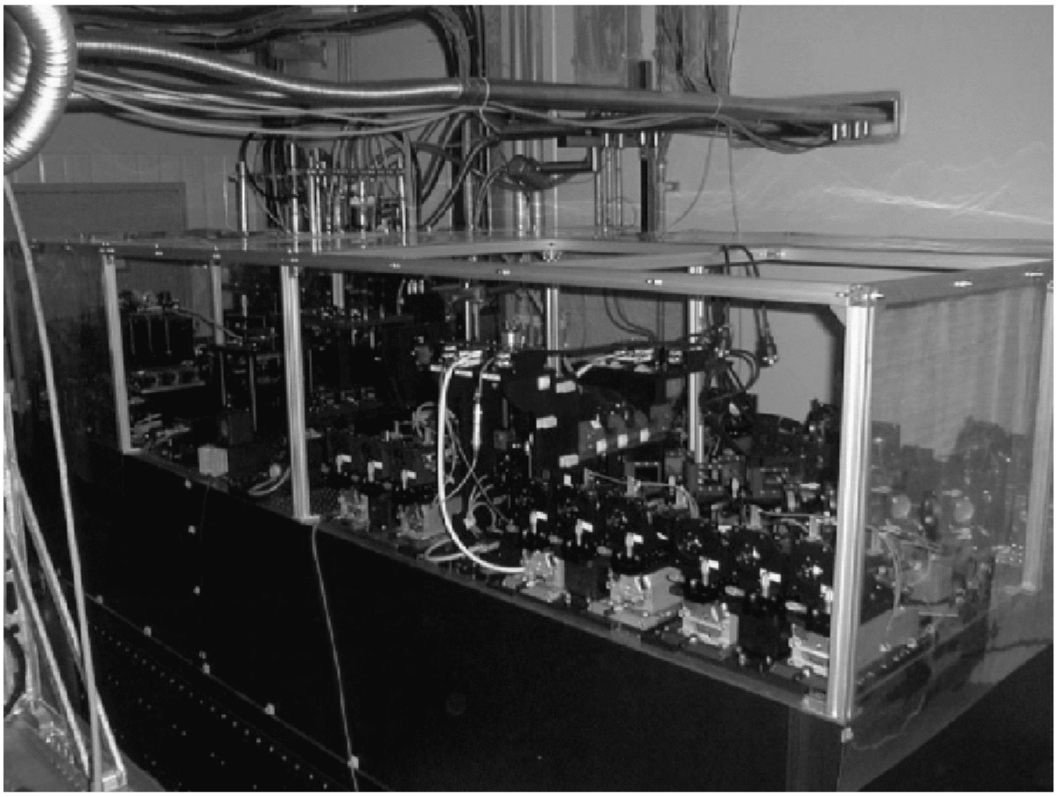


Fig. 2. The near-infrared (J, H, K bands) VLTI instrument AMBER in the beam–combining laboratory at Paranal Observatory. Photo courtesy of F. Rantakyrö.

and level of service and support is offered to users of the VLTI instruments MIDI and AMBER as to users of any instrument at the single UTs at Paranal Observatory.

The instrument MIDI has been offered for regular scientific observations since April 2004 (ESO period P73), and AMBER for observations since October 2005 (ESO period P76). Both instruments can now be used with the UTs as well as with the ATs. The regular VLTI observing periods were preceded by commissioning and shared-risk science operations using the K-band instrument VINCI (cf. Kervella, chapter 6.1 of this book), as well as by early science observations in the framework of the MIDI and AMBER science demonstration programs. The data resulting from these early observations are publicly available[2].

All information that is needed to prepare observations with MIDI and AMBER, including preparation tools, is available at the standard ESO webpages as for any other scientific instrument at Paranal[3]. These documentations are

[2] http://www.eso.org/projects/vlti/instru/vinci/vinci_data_sets.html,
http://www.eso.org/projects/vlti/instru/midi/midi_data_sets.html,
http://www.eso.org/projects/vlti/instru/amber/amber_data_sets.html

[3] http://www.eso.org/observing, http://www.eso.org/instruments

regularly updated and it is important to carefully consult the latest versions of these documents for the preparation of actual observations. The present article is by no means intended to represent an alternative to these documents, and details would inevitably be outdated for upcoming observing periods.

Earlier overviews on the technical status of the VLTI and the instruments MIDI and AMBER include, for instance, those by Glindemann et al. (2003), Morel et al. (2004), Rantakyrö et al. (2006). Earlier overviews on the operations scheme of the VLTI include, for instance, Wittkowski et al. (2004), Wittkowski et al. (2005a).

1.1 Scientific results from MIDI and AMBER

The range of astrophysical topics that can be addressed by the instruments MIDI and AMBER can be estimated by studying the results that have so far been obtained using optical/infrared interferometry in general and using MIDI and AMBER in particular.

General scientific results based on interferometry were reviewed, for instance, by Quirrenbach (2001), Baldwin & Hanniff (2002), Monnier (2003). The `OLBIN` newsletter [4] is regularly updated and provides a list of all publications related to optical interferometry.

Overviews on early results from the VLTI were presented, for instance, by Richichi & Paresce (2003) and Wittkowski et al. (2005b). More recent scientific results from MIDI and AMBER are exemplarily presented by several authors in chapter 6 of this book. The ESO telescope bibliography [5], maintained by the ESO library, contains refereed publications directly using ESO data. This database is regularly updated and provides an easy interface to search, for example, for refereed publications based on MIDI or AMBER data. At time of writing this article (Jan. 2007), it contains a number of 19 refereed publications that are based on MIDI data. Refereed publications based on AMBER data are not available as of this date, but several articles based on AMBER data are currently in press and will soon appear in this database.

Astrophysical results based on interferometric fringe data obtained with MIDI cover so far the topics of star formation & young stellar objects (Leinert et al., 2004; van Boekel et al., 2004; Preibisch et al., 2006; Quanz et al., 2006; Abraham et al., 2006), AGB & post-AGB stars (Ohnaka et al., 2005, 2006; Deroo et al., 2006; Matsuura et al., 2006), the luminous blue variable (LBV) η Car

[4] olbin.jpl.nasa.gov
[5] http://archive.eso.org/wdb/wdb/eso/publications/form

Table 1
Main characteristics of MIDI and AMBER.

	MIDI	AMBER
UT First Fringes	December 2002	March 2004
Regular observations	since April 2004	since October 2005
Simult. combined beams	2	3
Beam combination	Pupil plane	Image plane
Wavelength range	8-13 μm	1-2.5 μm (J, H,K bands)
Spectral dispersion	$R = 30$ (prism)	$R = 30$ (low res.)
	$R = 230$ (grism)	$R = 1500$ (medium res.)
		$R = 12000$ (high res.)
Lim. magnitude (UTs)	$N = 4$ (current)	$K = 7$ (current)
	$N \sim 5 - 6$ (FINITO)	$K \sim 11$ (FINITO)
		$K \sim 20$ (PRIMA)
Max. Visibility accuracy	$1 - 5\%$ ($< 20\%$ current)	1% (diff.), 3% (abs)
Airy disc FOV	$0.26''$ (UTs)	60 mas (UTs, K)
	$1.14''$ (ATs)	250 mas (ATs, K)
Spatial resolution, 200m	10 mas	1 mas (J), 2 mas (K)
Consortium	Germany/France/Netherlands	France/Germany/Italy
PI	Ch. Leinert (Heidelberg)	R. Petrov (Nice)

(Chesneau et al., 2005), and the active core of the Seyfert galaxy NGC 1068 (Jaffe et al., 2004; Poncelet et al., 2006).

First astrophysical results based on AMBER data cover young stellar objects (Malbet et al., 2007; Tatulli et al., 2007), Be stars (Domiciano et al., 2007; Meilland et al., 2007a,b), the LBV η Car (Weigelt et al., 2007), the Nova RS Oph (Chesneau et al., 2007), and the Wolf-Rayet binary γ^2 Vel (Millour et al., 2007).

2 Description of MIDI and AMBER

The full technical descriptions of MIDI and AMBER are available in the regularly updated user manuals by Morel (2006) and Rantakyrö (2006), respectively. Here, I merely review the main characteristics. Figures 1 and 2 show images of the instruments MIDI and AMBER, respectively, in the VLTI lab-

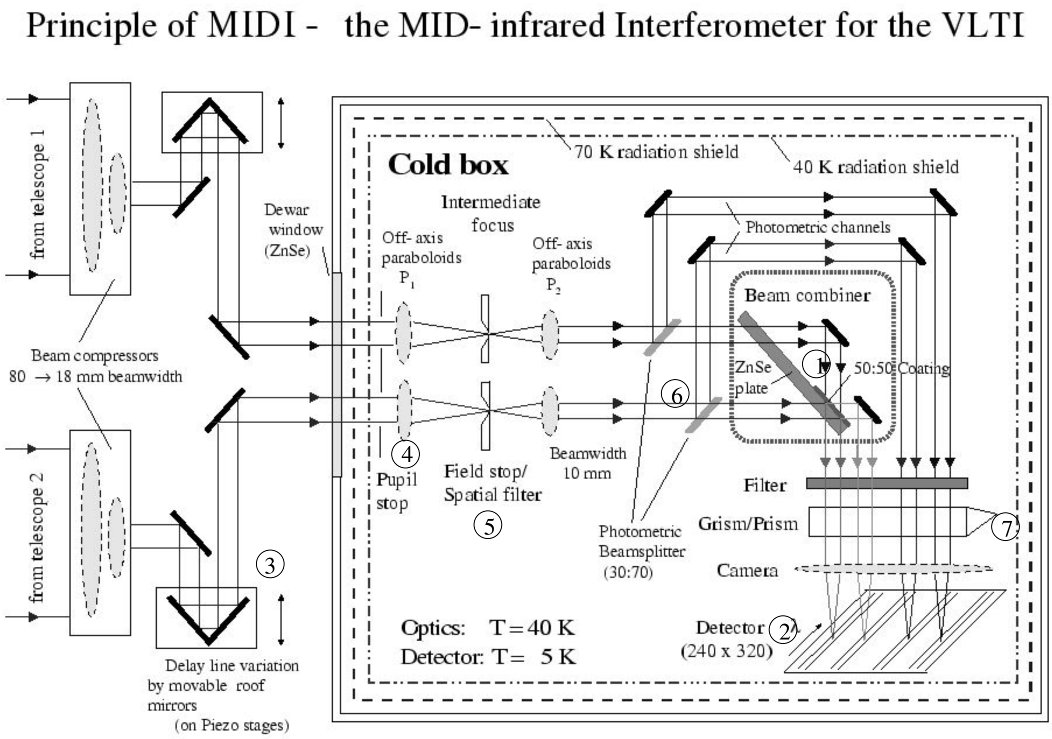


Fig. 3. Scheme of MIDI's optical setup. From Morel (2006).

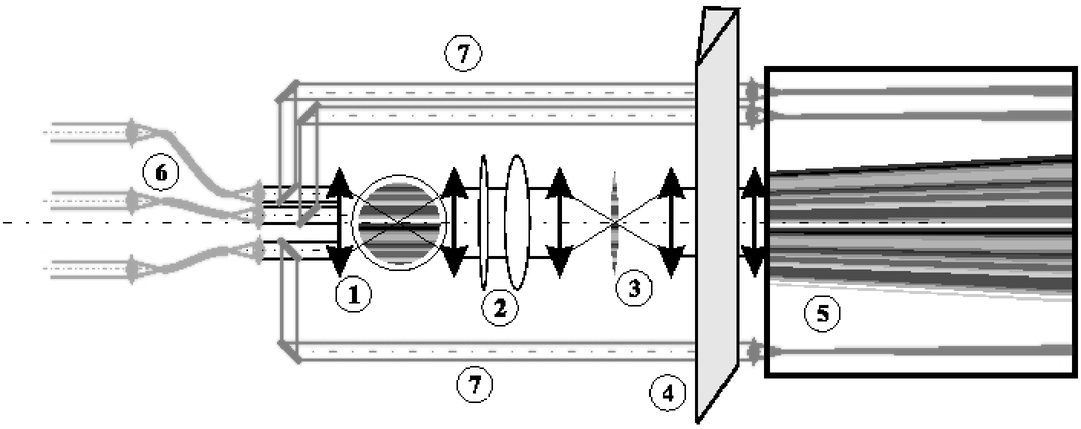


Fig. 4. Sketch of AMBER's optical setup. From Rantakyrö (2006).

oratory at Paranal Observatory. Table 1 provides an overview on the main characteristics of both instruments.

2.1 Number of beams and imaging capabilities

MIDI The beam combiner of MIDI can combine two beams from either two UTs or two ATs at a time. Astronomical targets can be probed with different baseline angles and baseline lengths projected on sky by multiple observations making use of different telescope combinations and/or making use of Earth's rotation. The primary observable of MIDI is the modulus of the visibility. Currently, a precision of up to about 5–10% can be reached. Making use of a phase-reference source employing the dual-feed facility PRIMA, phase information, and thus astrometry and imaging capabilities, can be obtained as well. To a lower precision, it may also be possible to derive some phase information from standard MIDI observations. At present, the observation of one calibrated visibility spectrum using one ground baseline takes 60 min.

AMBER The beam combiner of AMBER simultaneously combines three beams coming from a triangle of either three UTs or three ATs, and thus provides measurements of closure phases (cf. Monnier, chapter 1.5 in this book). Each instantaneous AMBER measurement provides three spectra (one value per spectral channel) of visibility amplitudes corresponding to the three baselines comprising the triangle, as well as one spectrum of triple amplitudes and closure phases. Hereby, the absolute visibility values can be measured with an accuracy of up to 3%, and relative visibilities, i.e. the visibility or closure phase in one spectral channel relative to that of a reference spectral channel, with an accuracy of up to 1%. At present, the measurement of each such instantaneous calibrated data set takes 90 min. In a way analogous to MIDI, baseline triangles with different angles and length projected on sky can be obtained by multiple observations.

2.2 Wavelength ranges and dispersion

MIDI Each MIDI observation results in a visibility spectrum covering the wavelength range from $\sim$ 8 μm to $\sim$ 13 μm. Two spectral resolutions are available, $R \sim$ 30 using the prism to disperse the light, and $R \sim 230$ using the grism. The limiting magnitudes for the grism mode are brighter than for the prism mode, and in general higher S/N ratios can be obtained using the prism mode. The accuracy of visibility measurements is often limited by the accuracy of the photometric data that are needed to calibrate the raw fringe contrast, and can currently reach up to 5–10%.

AMBER AMBER covers the near-infrared J, H, and K bands spanning a total wavelength range from $\sim 1\,\mu$m to $\sim 2.5\,\mu$m. Three spectral resolutions are available, (low resolution, "LR") $R = 30$, (medium resolution, "MR") $R = 1500$, and (high resolution, "HR") $R = 12000$. In the case of LR mode, the full wavelength range ($\sim$1–2.5 μm) can be used during one instantaneous measurement. For MR and HR modes, the spectrum is dispersed over an area larger than the detector size, which limits the usable wavelength range during

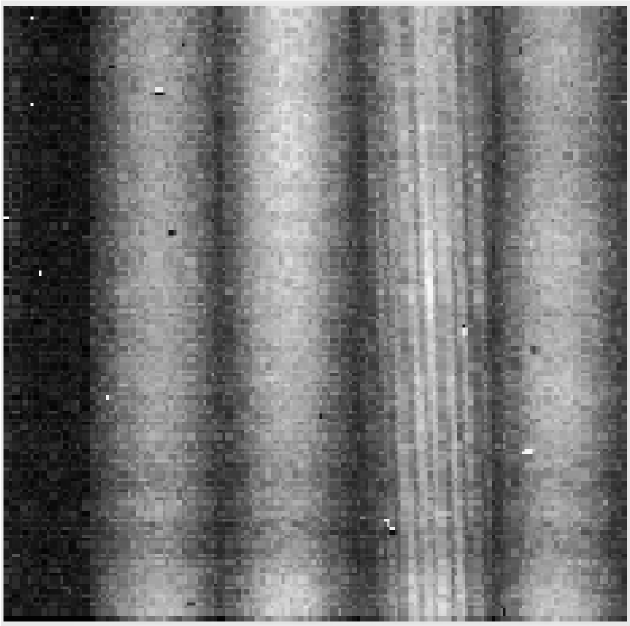


Fig. 5. Typical raw image of AMBER. Courtesy of F. Rantakyrö.

one instantaneous measurement. Here, the desired minimum and maximum wavelengths have to be specified.

2.3 Optical set-ups and method of beam combination

Figures 3 and 4 illustrate the optical setups of MIDI and AMBER.

Incoming light beams The details of the interferometer infrastructure that is used before the light beams enter the instruments are described by Schöller (chapter 3.1 in this book). In short, the light arrives as collimated beams of width 18 mm from either the UTs or the ATs (2 ATs or 2 UTs for MIDI; 3 ATs or 3 UTs for AMBER). Each incoming beam is normally corrected by the adaptive optics system MACAO in case of the UTs and by the tip-tilt system STRAP in case of the ATs at the Coudé foci of the telescopes. These systems operate at visible wavelengths. Thus, the target or a nearby natural guide star (within a distance of $\lesssim 1$ arcmin) need to be brighter than a certain limit (at present $V < 17$ for the UTs; $V < 13.5$ for the ATs). Observations at the UTs without a guide star can currently be attempted in visitor mode. There are several sources to find a natural guide star. We have often found feasible guide stars using the "2MASS All Sky Catalog of point sources" (Cutri et al., 2003) and subsequent estimate of the visual magnitude (by searching visual catalogs with the 2Mass coordinates, or by using an empirical $V - K$ color based on the spectral type of the star). A near-infrared tip-tilt system (IRIS) in the interferometric laboratory stabilizes the beam positions.

MIDI The beam-combination of MIDI takes place close to the pupil plane using half-reflecting plates (1), and the already combined beam is focused onto the detector (2). Interferograms are generated using short delay lines (3), which are part of the warm optics of MIDI, and which introduce time-modulated differences of the optical path lengths between the two beams.

Observations at mid-infrared wavelengths are strongly affected by thermal radiation from the sky and from the optics of the interferometric facility. The thermal emission of the sky shows spatial and temporal intensity fluctuations due to variable water vapor layers. In order to reduce thermal radiation from the instrument environment, most of the optics of MIDI is enclosed in a cryostat cooled at a temperature of 40 K. The array detector of MIDI is cooled at 10 K. The two incoming collimated beams enter the cryostat after passing the MIDI-internal delay lines. A pupil stop (4) inside the cryostat is used to reduce thermal radiation from background and stray-light. In addition, the chopping technique (by tilting the M2 mirrors with a frequency of the order of 1 Hz) is used as for standard mid-infrared observations to compensate the thermal background of the MIDI photometric exposures.

After the pupil stops, the light is focused onto field stops (5), which can be pinholes for spatial filtering, slits of different widths for the spectroscopic mode of MIDI, or which may provide the full field. After passing the field stop, the light beams from the two telescopes are re-collimated for the beam-combination in pupil plane. Before beam-combination, photometric beamsplitters can optionally be introduced into the beams in order to measure the photometric and interferometric signals at the same time (6). The mode using these beamsplitters is called "SCI_PHOT" mode and the mode using all the light for the interferograms is called "HIGH_SENS" mode. If the scientific target is of sufficient brightness at the wavelength of observation, the "SCI_PHOT" usually results in a more accurate photometric calibration of the raw fringe contrast. The "HIGH_SENS" mode is usually used for scientific targets with a correlated magnitude below or close to the brightness limit of the "SCI_PHOT" mode. The remaining part of the beams are combined thanks to a 50/50 ZnSe plate (1), leading to two interferometrically combined beams of opposite phase. These two collimated interferometric beams, and in case of the "SCI_PHOT" mode the two photometric beams, can be spectrally filtered, and/or spectrally dispersed by a KRS5 grism or a NaCl prism (7). The grism results in a spectral resolution of $R = 230$ and the prism in $R = 30$. The lower spectral dispersion of the prism will usually lead to a higher signal-to-noise ratio of the obtained calibrated visibility values. The grism is usually used for targets of sufficient brightness which are expected to show spectral features that could not be resolved by the prism mode. Finally, the beams are focused onto the detector (2). This detector is a Raytheon Si:As (IBC) array, and is characterized by a fast frame readout, in order to deal with the atmospheric coherence time. Since the interferograms of MIDI are generated by a temporal scan of the fringe packet using short delay lines, any single detector frame does not show interferometric fringes (in contrary to AMBER, see next paragraph).

AMBER The beam-combination of AMBER takes place in image plane by focusing the separate beams from the three telescopes into a common Airy pattern that contains the interferometric fringes. AMBER uses single-mode optical fibers for spatial filtering in order to obtain high-precision visibility measurements.

The rather complex optical setup of AMBER can be separated into three subsystems, (1) the warm optics including spectral filters, the spatial filter module, and the beam combination, (2) the spectrograph, and (3) the detector.

The incoming collimated beams enter the spatial filter module (no. 6 of Fig. 4). Each beam is separated into the near-infrared J, H, and K fractions of the light, and these separated light beams are inserted into J, H, and K single-mode optical fibers for the spatial filtering, and recombined so that the airy discs of each band have the same size. The light leaves the spatial filter module again as one collimated beam per telescope. These three beams are arranged so that they form a fixed non-redundant setup of the pupil. This means that the beams are arranged in a way, such that the three pairs of beams (A-B, B-C, A-C) each form a fixed and unique distance, i.e. the distance between beams A & B is different from that between B & C, and again different from that between A & C. These distances between the beams are fixed by the re-arrangement, and are thus independent of the pointing on sky. This technique ensures that the fringe spacings corresponding to the three baselines of the triangle are always the same and different from each other. Photometric beams (no. 7 of Fig. 4) are separated using beamsplitters. The remaining light beams are focused into a common Airy pattern that contains the interferometric fringes (no. 1). The now interferometrically combined beam passes a cylindrical optics that concentrates the light of each spectral channel into one single column of pixels that contain the interferogram in order to reduce noise at the detector.

These interferometrically combined beams enter a standard long-slit spectrograph that disperses the light in a direction perpendicular to the column of the interferogram produced before. This spectrograph includes an image plane cold stop and cold pupil masks to reduce background and stray light. The spectrograph offers three choose-able spectral resolutions of $R = 30$, $R = 1500$, and $R = 12000$.

Finally, the signal is detected by one quadrant of a 1024×1024 pixel Hawaii detector. A typical final raw image is shown in Fig. 5. It contains the three photometric beams and the interferometric beam (second from right) which are spectrally dispersed in vertical direction. The horizontal axis of the interferometric beam contains a variation of optical path difference. Each horizontal line of the interferometric beam thus contains for the respective wavelength a set of three interferograms corresponding to the three baselines. As the pupil was re-arranged to a fixed non-redundant set-up, these three interferograms have different fixed fringe spacings and can thereby be separated (only one interferogram can easily be seen in the example of Fig. 5).

3 Preparation tools for MIDI and AMBER

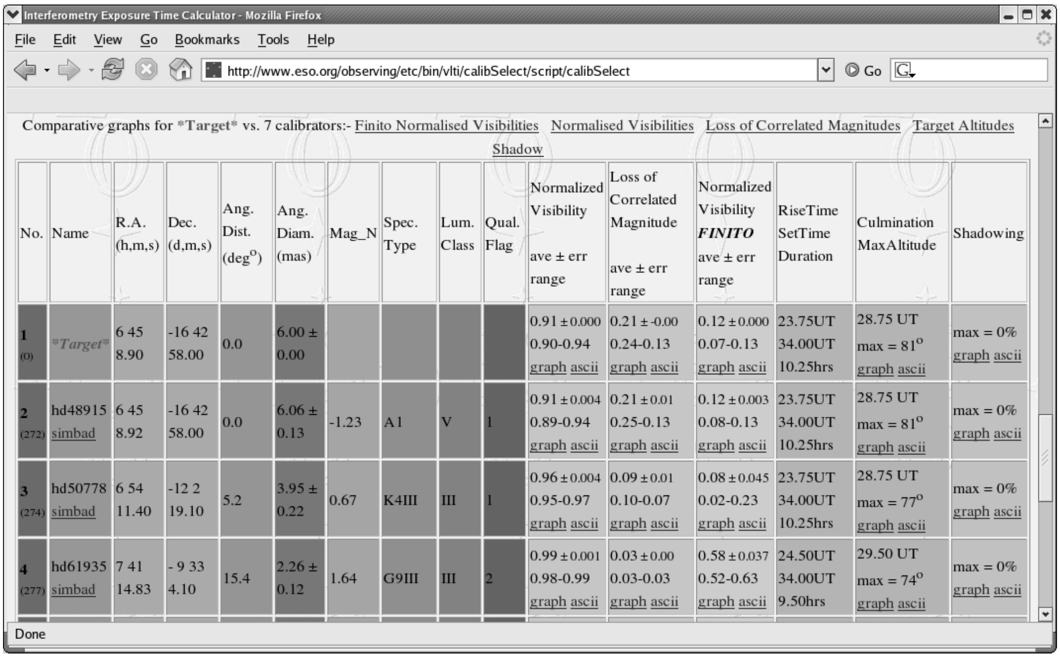
In order to plan an interferometric observation with MIDI and AMBER and to assess its feasibility, it is necessary to estimate the visibility values for the expected intensity distribution of the science target and the chosen VLTI configuration (cf. Berger, chapter 1.2 in this book). In addition, appropriate calibration stars to derive the interferometric transfer must be selected (cf. chapters 2.2 & 2.3 by Boden and Bonneau in this book). Two interactive tools are provided by ESO for these purposes, the visibility calculator VisCalc and the calibrator selection tool CalVin. A detailed description of these tools including examples can be found in Ballester et al. (2004). Both tools can be accessed from ESO web [8] . Figs. 6 & 7 show for illustration screenshots of the preparation tools VisCalc and CalVin. These tools are offered and supported by ESO. Their use is not mandatory, and any other tools can be employed as well.

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. Visibilities may also be calculated numerically for a user-provided brightness distribution which is uploaded as a FITS file. The user-specified observation conditions 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 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 (cf. Ségransan, chapter 1.4 in this book).

CalVin suggests suitable calibrators from an underlying list of calibrators based on different user-defined criteria 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 calibra-

[8] http://www.eso.org/observing/etc

Fig. 6. Example of the visibility calculator VisCalc [6]. (Top) Part of the input parameter definition. (Middle) Example of the result page, here showing the uv tracks overlaid onto the 2-d visibility plot. (Bottom) Example of the result page, here showing the visibility values for three selected baselines as a function of time.


Interferometry Exposure Time Calculator - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://www.eso.org/observing/etc/bin/vlti/calibSelect/script/calibSelect

Comparative graphs for *Target* vs. 7 calibrators:- Finito Normalised Visibilities Normalised Visibilities Loss of Correlated Magnitudes Target Altitudes Shadow

No.	Name	R.A. (h,m,s)	Dec. (d,m,s)	Ang. Dist. (deg°)	Ang. Diam. (mas)	Mag_N	Spec. Type	Lum. Class	Qual. Flag	Normalized Visibility ave ± err range	Loss of Correlated Magnitude ave ± err range	Normalized Visibility *FINITO* ave ± err range	RiseTime SetTime Duration	Culmination MaxAltitude	Shadowing
1 (0)	*Target*	6 45 8.90	-16 42 58.00	0.0	6.00 ± 0.00					0.91 ±0.000 0.90-0.94 graph ascii	0.21 ± -0.00 0.24-0.13 graph ascii	0.12 ±0.000 0.07-0.13 graph ascii	23.75UT 34.00UT 10.25hrs	28.75 UT max = 81° graph ascii	max = 0% graph ascii
2 (272)	hd48915 simbad	6 45 8.92	-16 42 58.00	0.0	6.06 ± 0.13	-1.23	A1	V	1	0.91 ±0.004 0.89-0.94 graph ascii	0.21 ±0.01 0.25-0.13 graph ascii	0.12 ±0.003 0.08-0.13 graph ascii	23.75UT 34.00UT 10.25hrs	28.75 UT max = 81° graph ascii	max = 0% graph ascii
3 (274)	hd50778 simbad	6 54 11.40	-12 2 19.10	5.2	3.95 ± 0.22	0.67	K4III	III	1	0.96 ±0.004 0.95-0.97 graph ascii	0.09 ±0.01 0.10-0.07 graph ascii	0.08 ±0.045 0.02-0.23 graph ascii	23.75UT 34.00UT 10.25hrs	28.75 UT max = 77° graph ascii	max = 0% graph ascii
4 (277)	hd61935 simbad	7 41 14.83	- 9 33 4.10	15.4	2.26 ± 0.12	1.64	G9III	III	2	0.99 ±0.001 0.98-0.99 graph ascii	0.03 ±0.00 0.03-0.03 graph ascii	0.58 ±0.037 0.52-0.63 graph ascii	24.50UT 34.00UT 9.50hrs	29.50 UT max = 74° graph ascii	max = 0% graph ascii

Done

Fig. 7. Example of the calibrator selection tool CalVin [7], here showing an example of a result page.

tion sources will be rapidly acquired. Currently, the underlying CalVin list of calibration stars for MIDI is based on the catalog of calibration stars that has been developed by the MIDI instrument consortium by spectro-photometric observations of candidate stars and fitting of 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 catalogs by Bordé et al. (2002) and Merand et al. (2006). The use of CalVin and its underlying catalogs is not mandatory, any other calibration target that appears more suitable to the observer can be used as well.

The tools to prepare the proposal and to prepare the actual observations after time has been granted are the same as for any other instrument at Paranal, and their VLTI-specific features are discussed in the next section.

4 Observing with the VLTI

The ESO VLT scheme allows astronomers to submit visitor mode or service mode observation programs. In visitor mode, the astronomer is present at the telescope and can adapt the program to specific requirements at the time of observation. Visitor mode is the best choice for more complex and challenging programs that might require decisions at the time of observing and can not fully be planned beforehand. In service mode, the observation details and constraints are submitted to ESO beforehand, and the observations are scheduled

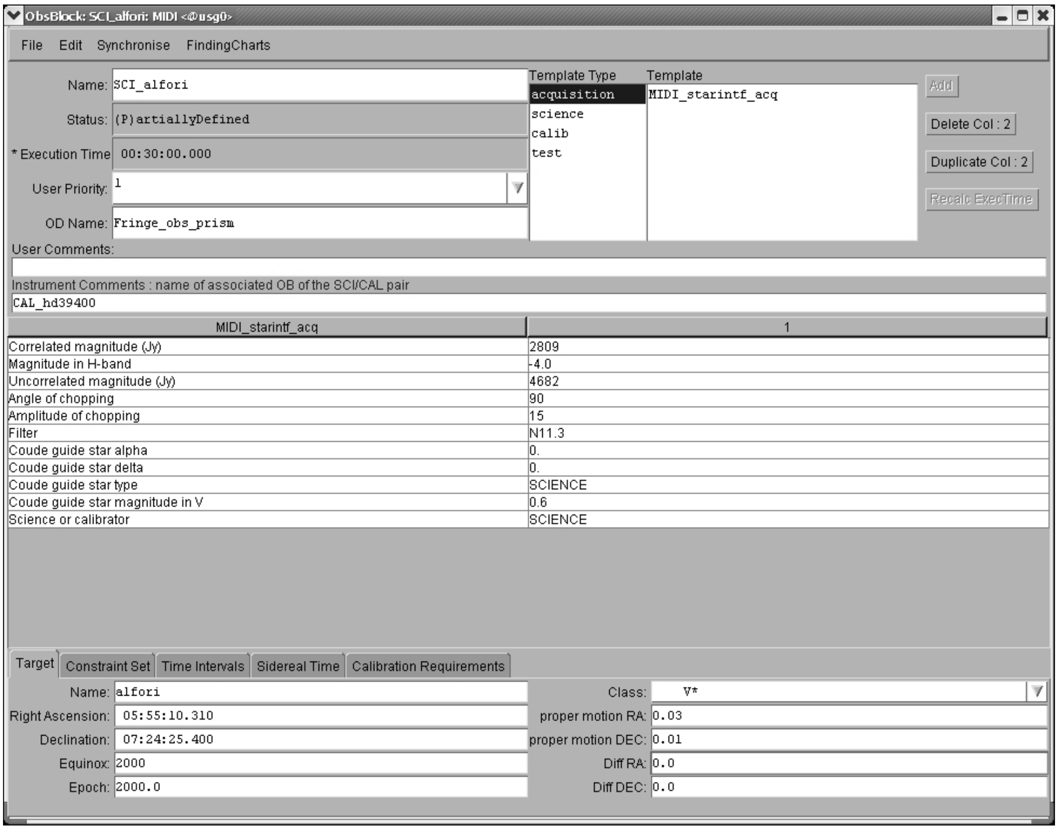


Fig. 8. Screen shot of the current (as of P78) p2pp tool to define the actual observations with MIDI. From the MIDI p2pp tutorial, which is regularly updated, available from the pages of the User Support Department [9]; cf. Morel (2006).

and carried out by ESO staff. Service mode observing was conceived by ESO since the early days of the planning of VLT operations as a key component in optimizing the scientific return and the operational efficiency (cf. Comerón et al., 2003). The VLTI science operations scheme profits enormously from the experience gained during visitor mode and service mode observations at the single UTs since April 1999 and the implemented infrastructure. It follows and is fully integrated into the regular VLT operations scheme from the initial preparation of the proposal until the delivery of the data. A detailed description of observation preparation, observation tools, phase 2 and observing block preparation can be obtained from the pages of the ESO User Support Department (USD) [13]. An observing block defines all the instrumental and observing parameters that are needed for the execution of a certain observation. Just as with service mode support for any other VLT instrument, VLTI observers can obtain assistance from astronomers at the USD specialized in interferometry. The actual observations are prepared with the standard phase 2 proposal preparation (P2PP) tool. Figs. 8 & 10 and 9 & 11 show examples of the current versions of the p2pp tool for MIDI and AMBER, respectively.

[13] http://www.eso.org/org/dmd/usg

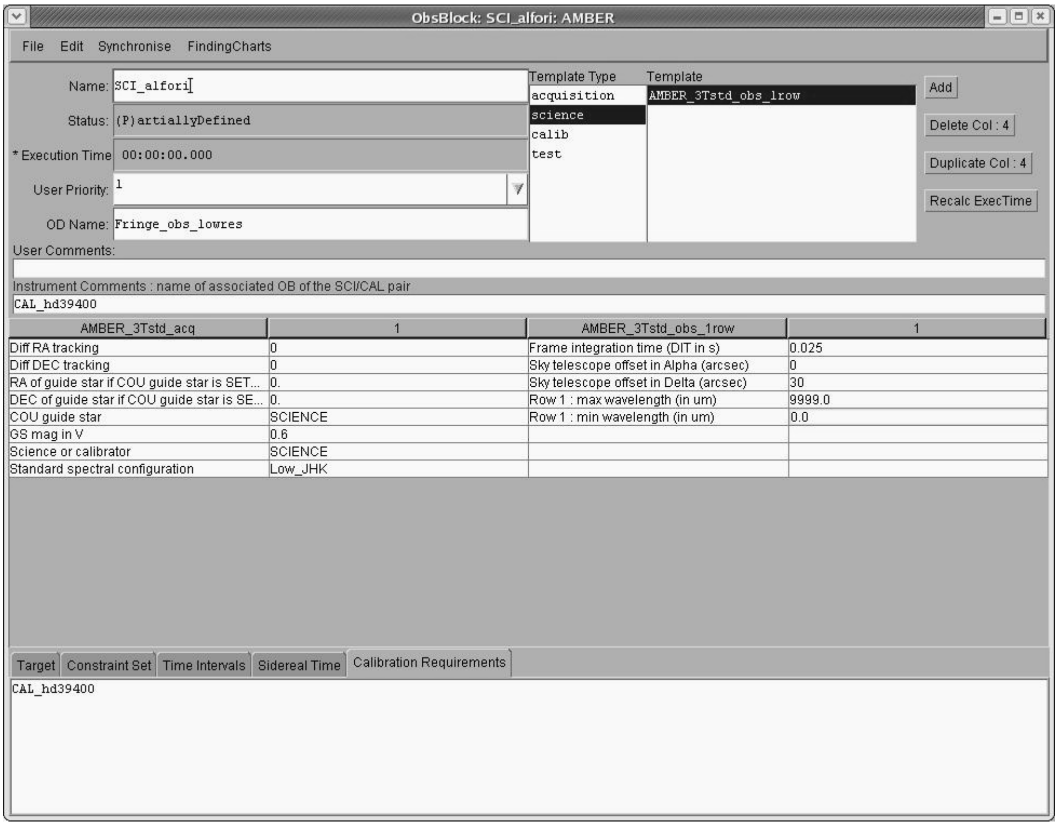


Fig. 9. Screen shot of the current (as of P78) p2pp tool to define the actual observations with AMBER. From the AMBER p2pp tutorial, which is regularly updated, available from the pages of the User Support Department [10] ; cf. Rantakyrö (2006).

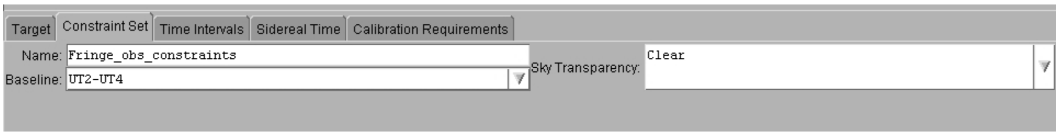


Fig. 10. Screen shot of the current (as of P78) MIDI-specific constraint set including the baseline configuration chosen (here UT2-UT4) and the sky transparency. From the MIDI p2pp tutorial, which is regularly updated, available from the pages of the User Support Department [11] ; cf. Morel (2006).

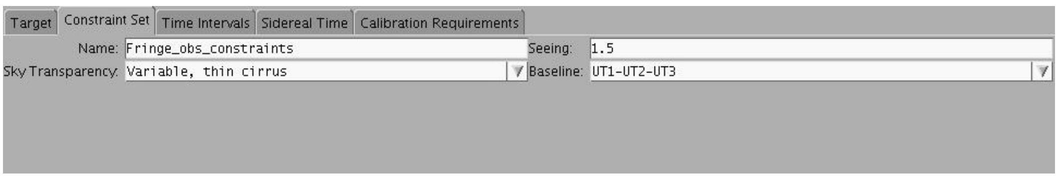


Fig. 11. Screen shot of the current (as of P78) AMBER-specific constraint set including the baseline configuration (here UT1-UT2-UT3), the seeing, and the sky transparency. From the AMBER p2pp tutorial, which is regularly updated, available from the pages of the User Support Department [12] ; cf. Rantakyrö (2006).

Regularly updated MIDI and AMBER p2pp tutorials including such examples are available from the pages of USD. In the following, I briefly discuss a few specific requirements of interferometric observations and how they are integrated into the general ESO VLT scheme.

4.1 Calibration of the interferometric transfer function

In order to obtain a sufficient accuracy and precision of the object visibility values, observing sequences with alternating observations of scientific targets and interferometric calibration stars are performed. Each investigator using service mode observations is requested to submit a calibration star observing block (OB) for each science star OB. This pair of OBs is executed sequentially. The two OBs of the pair are only considered completed if both OBs of the pair were successfully executed. For visitor mode observations, also more complex sequences of scientific targets and calibration stars can be chosen by the visiting astronomer. The data taken on all calibration stars are public once they arrive in the ESO archive. Hence, each investigator can make use of the information based on all measured calibration stars.

4.2 Sequences of observations

The scientific goal of an interferometric observation campaign can often only be reached if visibility measurements at a range of different points of the uv-plane are combined. This can be achieved by combining different ground baselines and by making use of Earth's rotation. For VLTI observations, each instantaneous visibility measurement requires the preparation and submission of one OB. Multiple observations of the same source at different times and/or or with different baseline configurations require the submission of multiple OBs. For observations in service mode, these multiple OBs are executed independently. The sky-projected baseline length and angle, as well as the zenith distance, are uniquely defined for a given target and ground baseline configuration by the hour angle, or the local sidereal time, at which the observation is executed (cf. Ségransan, chapter 1.4 in this book). The local sidereal time (LST) at which the observation shall be executed can be inserted into each observation block (OB). By this, observations at different sky-projected baseline lengths and angles can be planned, while the individual OBs are executed as stand-alone entities without the need of linked observations. However, priority is given to completing all observations on a scientific target once they have started. The preparation and planning of such observation sequences is supported by the visibility calculator VisCalc. Constraints on the date of observations can be given as well, as for other VLT instruments.

4.3 Scheduling of VLTI observations

The required ground baseline configuration, as well as the local sidereal time at time of execution are constraints that are specific to VLTI observations and do not exist for observations with instruments at the single UTs. Moreover, the performance of VLTI-specific subsystems such as the adaptive optics systems (MACAO) for VLTI, or the fringe tracker have to be monitored in addition. In general, the scheduling of VLTI observations is complicated by the additional constraints on baseline configuration and LST. In particular for UT observations, certain UT baselines may not be available at any given date of observation due to constraints of the single telescopes such as technical downtime due to re-coating or commissioning activities. The LST constraint does not only constrain the time during a given night, but also the number of nights during the period at which the LST constraint can be fulfilled. As a result, it is advisable to avoid constraints more stringent than absolutely necessary for the scientific goal of the observation in order to enable a smooth and efficient science operation of the VLTI.

4.4 Precision of coordinates and sky accessibility

The precision of the provided target coordinates is very important for observations with the VLTI in order to quickly find the interferometric fringes. Also proper motions are an issue with VLTI and need to be inserted into the p2pp tool since many sources we observe are bright, thus usually close and have proper motions which can not be neglected. For instance, a coordinate error of 0.7 arcsec using the longest UT baseline of 130m translates into an optical path difference of 450 μm, which is more than five times the coherence length in AMBER low resolution mode.

For VLTI observations with certain baseline configurations, there may be regions on sky that are not accessible. This is due to two effects, shadowing of AT stations by nearby UTs, and the limited stroke by the delay lines (max 105 m). The preparation tool VisCalc as well as the VLTI-specific p2pp instructions available from the pages of USD give the details of these limitations, which have to be taken into account for the planning of observations with the VLTI.

Table 2
Overview on the numbers of scheduled observing programs and their assigned times using MIDI for ESO period P73 to P78. So far, AT observations have been scheduled in service mode only.

	# of programs	in service mode (SM)	in visitor mode (VM)	Ass. hours SM	Ass. nights VM
P73, UTs	21	17	4	77h	3.5n
P74, UTs	19	13	6	86h	2.7n
P75, UTs	27	21	6	152h	7.2n
P76, UTs	25	21	5	77h	6.5n
P76, ATs				231h	
P77, UTs	29	19	10	85h	3.7n
P77, ATs				324h	
P78, UTs	24	17	8	76h	3.3
P78, ATs				268h	

Table 3
Overview on the numbers of scheduled observing programs and their assigned times using AMBER for ESO periods P76 to P78.

	# of programs	in service mode (SM)	in visitor mode (VM)	Ass. hours SM	Ass. nights VM
P76, UTs	21	19	2	71h	4.0n
P77, UTs	15	12	3	51h	4.4n
P78, UTs	22	18	4	85h	4.0n

5 An overview on past and present VLTI observing periods

Tables 2 and 3 show the numbers of scheduled observing programs and the assigned observing times using the VLTI instruments MIDI and AMBER since the start of regular MIDI observation in period P73 (observations from April to September 2004). In total, a number of 146 MIDI observing programs by 59 different PI have been scheduled during ESO periods P73 to P78; as well as a number of 58 AMBER observing programs by 36 different PIs during ESO periods P76 to P78. A clear majority of the VLTI programs are executed in service mode, which is partly caused by the need to combine different baseline configurations that can not be realized during successive nights. Most programs fall into the categories of stellar evolution (ESO category "D": 71 MIDI and 31 AMBER), closely followed by star and planet formation (ESO category “C”: 63 MIDI and 24 AMBER).

The VLTI facility is at present constantly evolving as discussed in detail by Schöller in chapter 3.1 of this book. In the immediate future, AMBER and MIDI observations will continue making use of UTs and ATs, with improvements outlined by Schöller. Phase A studies for three potential second generation VLTI instruments are ongoing, which might replace AMBER and MIDI after 2011 (cf. again chapter 3.1 by Schöller).

6 Summary

The VLTI with the mid-infrared instrument MIDI and the near-infrared instrument AMBER is routinely offered and operated for service mode and visitor mode observations. The same kind and level of support is offered to users of the VLTI instruments as to users of any VLT instrument. The complexity of interferometry and the VLTI infrastructure is mostly hidden to a regular user, since only the main instrument modes and parameters need to be chosen by the PI of the program. However, awareness of the complexity and caveats of the overall interferometer and its instruments is helpful for the correct understanding, analysis and interpretation of the data.

In the present chapter, we have introduced the instruments MIDI and AMBER as they are currently offered for observations. The VLTI with its instruments is constantly evolving, so that the latest ESO documents (call for proposals, instrument manuals, template manuals) have to be consulted in detail for the actual proposal preparation. An introduction into interferometry is provided in chapters 1 & 2 of this book; a description of the VLTI facility and planned upgrades can be found in chapter 3.1; an introduction into data reduction of data obtained with MIDI and AMBER follows in chapter 4.

Acknowledgments

I acknowledge with thanks material provided by the instrument scientists Sebastien Morel and Fredrik Rantakyrö, as well as their comments on the manuscript. The integration of VLTI observations into the regular ESO VLT operations scheme is a collective effort that has been involving a lot of people inside and outside of ESO.

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