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# Experiences from the first AMBER open time observations

Fredrik T Rantakyö<sup>a</sup>, Pascal Ballester<sup>b</sup>, Stephane Brilliant<sup>a</sup>, Gilles Duvert<sup>c</sup>,  
Emmanuel Galliano<sup>a</sup>, Christian Hummel<sup>a</sup>, Andreas Kaufer<sup>b</sup>, Mario Kiegebush<sup>a</sup>,  
Etienne Le-Coarer<sup>c</sup>, Tom Licha<sup>b</sup>, Fabien Malbet<sup>c</sup>, Pedro Mardones<sup>a</sup>, Florentin Millour<sup>d</sup>,  
Sebastien Morel<sup>a</sup>, Isabelle Percheron<sup>b</sup>, Monika Petr-Gotzens<sup>b</sup>, Romain Petrov<sup>d</sup>,  
Andrea Richichi<sup>b</sup>, Thomas Rivinius<sup>a</sup>, Markus Schöller<sup>a</sup>, Stan Steff<sup>a</sup>, Martin Vannier<sup>a</sup>,  
Markus Wittkowski<sup>b</sup> and Gerard Zins<sup>c</sup>

<sup>a</sup>European Southern Observatory, Casilla 19001, Santiago 19, Chile

<sup>b</sup>European Southern Observatory, Karl-Schwarzschild-Str. 2, D-85748 Garching bei München, Germany

<sup>c</sup>Laboratoire d'Astrophysique de Grenoble, U.M.R. 5571 Université Joseph Fourier/C.N.R.S., BP 53, F-38041, Grenoble Cedex 9, France

<sup>d</sup>Laboratoire Universitaire d'Astrophysique de Nice, UMR 6525 Université de Nice/CNRS, Parc Valrose, F-06108 Nice Cedex 2, France

## ABSTRACT

The VLTI has been operating for about 5 years using the VINCI instrument first, and later MIDI. In October 2005 (Period 76) the first Science Operations with the AMBER instrument started, with 14 Open Time proposals in the observing queues submitted by the astronomical community. AMBER, the near-infrared/red focal instrument of the VLTI, operates in the bands J, H, and, K (i.e. 1.0 to 2.5 micrometers) with three beams, thus enabling the use of closure phase techniques. Light was fed from the 8 m Unit Telescopes (UT). The Instrument was offered with the Low Resolution Mode (JHK) and the Medium Resolution Mode in K-band on the UTs. We will present how the AMBER VLTI Science Operations currently are performed and integrated into the general Paranal Science Operations, using the extensive experience of Service Mode operations performed by the Paranal Science operations and in particular applying the know-how learned from the two years of MIDI Science Operations. We will also be presenting the operational statistics from these first ever Open Time observations with AMBER.

**Keywords:** AMBER, VLTI, VLT, Science Operations, Paranal, ESO

## 1. INTRODUCTION

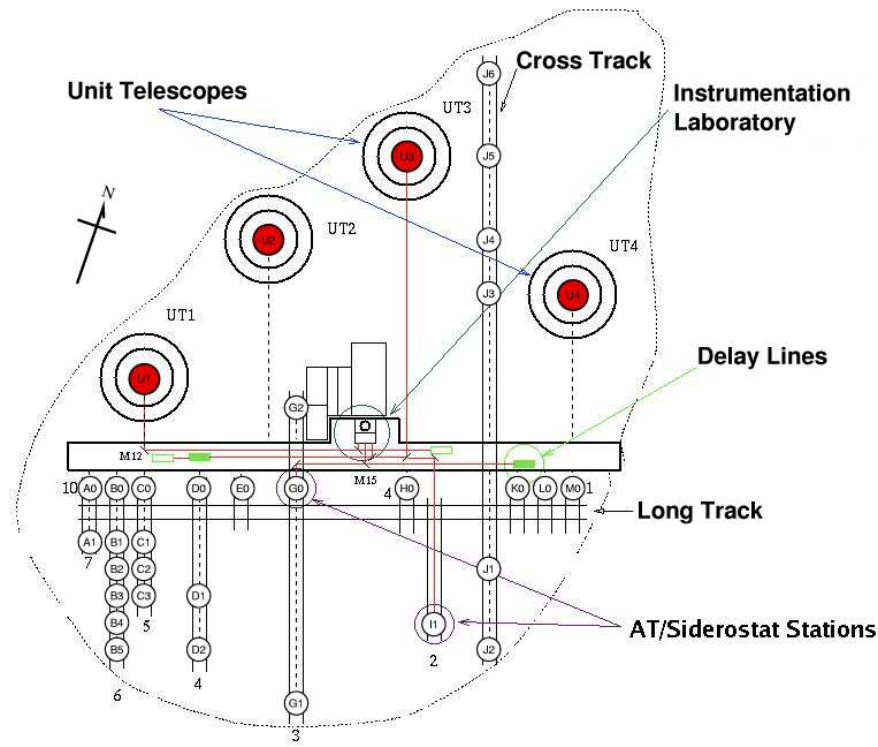
The ESO *Very Large Telescope Interferometer* (VLTI) located at Cerro Paranal in northern Chile is a part of the ESO *Paranal Observatory*. The VLTI is a general purpose interferometric facility that offers various instruments to the general astronomical community: VINCI<sup>1</sup> (no longer in use in science observations), MIDI<sup>2</sup> (a two beam mid infrared instrument, with spectroscopic capabilities from R=30 to 230), and AMBER<sup>3</sup> (a three beam JHK band instrument with spectroscopic capabilities from R=30 to R=12000).

This paper focuses on the experiences from the Science Operations with AMBER in observing Period 76 (P76) covering October 2005 to March 2006. In Section 2 we present the VLTI and in Section 3 we give a brief introduction to the AMBER instrument. In Section 4 a brief presentation of the general Science Operations is given, in Section 5 details the specifics of Science Operations with AMBER, Section 6 is dedicated to the operation and statistics for the P76 and finally Section 7 presents the conclusions.

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Further author information: (Send correspondence to F.T.R.)

F.T.R.: E-mail: frantaky@eso.org, Telephone: +56 2 463 3000, FAX: +56 2 463 3001

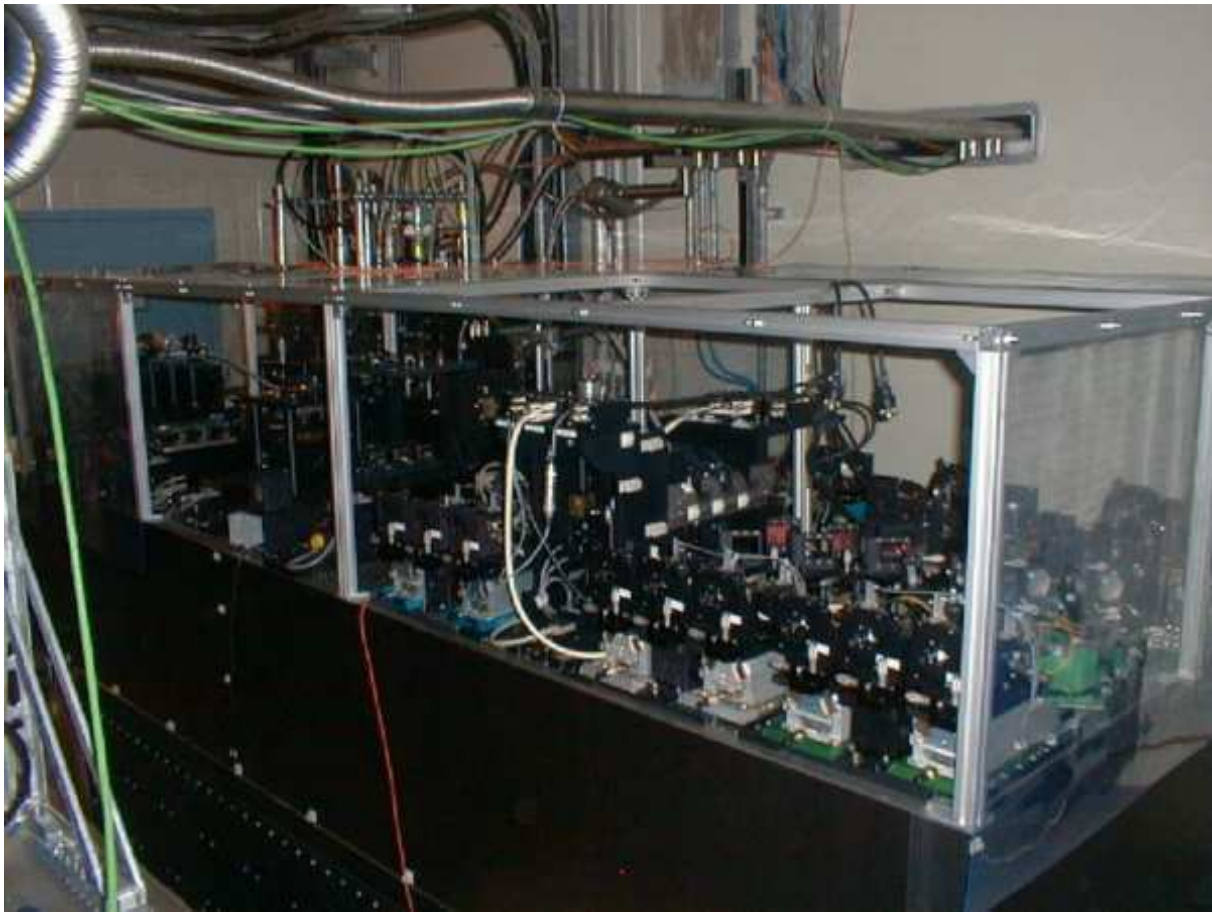


**Figure 1.** A schematic view of the VLTI where the telescope pads for Auxiliary Telescopes (ATs) and siderostats are visible, as well as the four UTs. In the center are also shown the delay line tunnels, VLTI control building and the interferometric lab. The AMBER observations are currently carried out with three UTs simultaneously. Two ATs are in regular science operations with MIDI and one is currently being commissioned at Paranal and the remaining fourth AT will be installed in 2006.

## 2. THE VLTI

The general concept of the VLTI is to provide an interferometric focus to the instruments, like modern telescopes provide almost diffraction-limited beams to their instruments. Therefore the VLTI infrastructure works like a general facility which provides the following functions:

- Sampling of the  $(u, v)$  plane with four fixed Unit Telescopes (UTs) and four transportable Auxiliary Telescopes (ATs) with baselines ranging from 8m to 200m.
- Collection of light with four 8 m Unit Telescopes (UTs) and three 1.8 m Auxiliary Telescopes (ATs). See Figure 1 for an aerial view of the telescope positions.
- Wavefront correction at the telescopes: in the first phase adaptive optics for the UTs (MACAO) and tip-tilt correction for the ATs (STRAP).
- Transportation of the primary and secondary beams from the telescopes to the focal lab.
- Compensation by the delay lines (DLs) of the optical path difference due to the sidereal motion.
- Correction of the slow ( $<1$  Hz) tip/tilt motion of the beams (caused by seeing effects in the tunnel) by means of a fast detector sensing the beam motions and sending corrections to the X-Y table so that the beams are kept centered on the optical axis (IRIS). IRIS uses the H-band for the guiding so if IRIS is used no H-band light goes to AMBER.



**Figure 2.** The AMBER instrument on its optical table in the VLTI lab.

All these subsystems need to work perfectly to allow successful AMBER observations, thus engineers are performing a rigorous maintenance plan of all these systems before any VLTI observations are executed with either AMBER or MIDI.

### 3. THE AMBER INSTRUMENT

The AMBER Instrument was built under ESO agreement by the AMBER Consortium. Members of the Consortium are: Département Fresnel de l'Observatoire de la Côte d'Azur, Nice (OCA, France); Département d'Astrophysique de l'Université de Nice - Sophia Antipolis Nice (UNSA, France); Laboratoire d'Astrophysique de l'Observatoire de Grenoble, Grenoble (LAOG, France); Max-Planck Institut für Radioastronomie, Bonn (MPIfR, Germany) and Osservatorio Astrofisico di Arcetri, Firenze (OAA, Italy). The Principal Investigator is Romain Petrov (Nice, France), and Project Scientist Fabien Malbet (LAOG, Grenoble, France). AMBER was installed in the VLTI lab at PARANAL in March 2004, subsequently it has been through three commissioning runs for various modes. The Instrument Scientist for AMBER in Garching is Andrea Richichi and in Paranal Fredrik Rantakyö. Software support at Paranal was given by Mario Kiekebusch, and hardware/engineering support at Paranal by Pedro Mardones.

AMBER, the near-infrared focal instrument of the VLTI is located in the VLTI lab. It is capable of operating in the bands J, H, and, K i.e. 1.0 to 2.5 $\mu$ m. AMBER can combine the light from three telescopes simultaneously,

thus enabling also the use of closure phase techniques. It works with spectrally dispersed single mode fringes and thus gives spectral resolutions  $R = 35$ , **LR** (Low Resolution Mode using a prism - with simultaneous observation of the full J, H and K bands),  $R = 1500$ , **MR** (Medium Resolution Mode using a grism - observing in the J, H or K band) and  $R = 12000$ , **HR** (High Resolution Mode using another grism - observing in the J, H, or K bands).

In Period 76 AMBER was offered in the **LR** and with the **MR** Mode in K band only. The magnitude limits of AMBER in P76 were  $K=7$  with **LR** on UTs and  $K=4$  with **MR-K** on the UTs. As AMBER is an instrument still under commissioning several new modes are expected to be offered to the astronomical community (e.g. in P78 the High Resolution K-band mode was opened for Open Time Science Operations), similarly the current magnitude limits are conservative estimates and expected to be increased with further developments in data reduction and improvements in VLTI subsystems.

#### 4. GENERAL SCIENCE OPERATIONS

The aim of the VLTI Science Operations is that it should be working seamlessly within the standard Science Operations frame in use for the non-VLTI VLT UT instruments. The VLTI Science Operations (SciOps) at PSO<sup>4</sup> is quite complex and here we highlight only the issues relevant to the AMBER Science Operations in P76. The objectives for AMBER Science Operations are the same as any instrument at the PSO. These basic objectives<sup>5</sup> for the Service Mode operations are:

- The scientific objectives of an observing run are not achieved unless all observations are completed.
- A run should not be scheduled unless it has a high probability of completion.
- It is better that a smaller number of runs are totally completed than that many runs are incomplete.
- If the observing conditions permit, the runs with higher scientific priority as defined by the OPC should be completed preferentially over lower-priority runs.

These objectives guides the planning and execution of the desired observations for all VLT and VLTI instruments. Apart from these objectives there is another cornerstone of the VLT/VLTI Science Operations which for the VLTI can be phrased as:

**The VLTI with its selected instrument (MIDI or AMBER) should be completely transparent to the user whether in Service Mode or as a Visitor. He/she can stop worrying about the functioning of either the telescopes or the instrument, and instead just concentrate on achieving the scientific goals of his/her project.**

The *Science Operations* with MIDI have shown that this goal has been achieved.

#### 5. AMBER SCIENCE OPERATIONS SPECIFICS

In addition to the standard VLT Science Operations constraints and requirements, operating with AMBER has a few additional ones:

- AMBER was offered in P76 with all possible combinations of three UTs, yielding four possible baseline configurations. Thus not only the observation has to be performed with the normal observing constraints but also using the desired baseline configuration requested by the user.
- By giving a LST constraint for the observation the user can select the projection angle of the three baselines on the sky when his/her target is observed. As many scientific targets in P76 are asymmetrical (stars with winds, disc around stars etc) the LST constraints were frequently used and were of fundamental importance to achieve the requirement of the user.
- For each science target there was a calibrator associated with it. This calibrator had to be observed either directly before or after the target of scientific interest. Without this calibrator the observation of the science target has no scientific validity. As each observation, either science or calibrator, takes one hour the minimum time slot for a successful AMBER observation is two hours.

How these constraints affected the AMBER Science Operations is discussed in the following section.

## 6. P76 OPERATIONS

The VLTI runs with the MIDI and AMBER instruments were typically scheduled on the UTs as a block of three to five nights every month. These blocks were shared between MIDI and AMBER and involved different telescope configurations, and mixed Visitor Mode and Service Mode operations. To assure that the VLTI setup including the telescopes, active optics and delay lines (see Section 2) were ready for the operation there was a scheduled countdown of checks of each of the subsystems before each observing block. These checks were finalized with technical tests of the instrument on the sky with all subsystems running to ensure that all were ready before the start of the observing run.

To allow flexibility in baseline configurations there were at least of three UTs scheduled in each block and occasionally there were 4 UTs available for use with the VLTI instruments, allowing the use of different baseline configurations with AMBER and six with MIDI. The night astronomer that performed the operations could select the proper baseline for each part of the night and the UTs not in use were used for non-VLTI Service Mode operation. Thus in a particular night, half the night could be spent on MIDI operations switching twice between two different baseline configurations and the end of the night dedicated to AMBER observations with a particular telescope triangle. As each change between instruments and/or baseline configuration required approximately 30 minutes the astronomer had to evaluate the final scientific output based on using different baseline configurations, instruments and fulfilling the LST constraints versus the time lost between configurations.

### 6.1. AMBER Observations in P76

In period 76 there were 49 programs with 77 observing runs submitted as proposals for AMBER. In the end 21 programs with 24 observing runs were finally accepted, of which 12 were Service Mode programs. This meant that 71 observing blocks (OBs) were to be executed in Service Mode for AMBER in period 76. For this approximately 14 nights in total were allocated for AMBER observations split between Visitor Mode programs and Service Mode programs, assuming an average of 10 hours per night this corresponds to a total of 140 hours of observations. Of these 14 nights nine were dedicated to service mode observations and five nights to Visitor mode observations.

**Table 1.** Observing time statistics for AMBER in observing P76 covering October 1st, 2005 to March 31st, 2006. Time, the total actual time used in this mode, OBs, the number of OBs executed in this mode, Successful, is the number of OBs that are classified as successfully executed (i.e. this considers that both the Science and Calibrator OBs in a pair has both to be executed successfully to be considered a success), Failed, is the number of OBs that failed, Not Executed, the number of OBs scheduled but not executed in this period and Reclassified, the number of OBs that originally were successfully executed but failed as the corresponding Science or Calibrator OB failed. Note that in the case of Visitor Mode programs no classifications were done on the quality of the observation, and thus columns Successful, Failed, Not Executed and Reclassified have no entries.

Observing Mode	Time	OBs	Successful	Failed	Not executed	Reclassified
Service	63h 39m	71	30	28	13	8
Visitor	45h 42m	54	n/a	n/a	n/a	n/a

The difference between allocated times and the used times are that telescopes were handed back to non-VLTI SciOps as there were no programs in the queues for that particular time and/or the weather conditions did not allow AMBER operations. Instead of causing weather time losses, the individual telescopes were handed back to non-VLTI Science Operations that had programs that could be executed under those conditions and still be classified as successful. Even though telescopes were handed back to standard VLT operation it still meant that due to the rapid change in weather that programs were partially executed and had to be aborted and thus causing a loss.

In Table 2 we give the amount of time due to losses, classified as Technical, Weather and Operational. Operational losses were only due to accuracy of the used Optical Path Difference (OPD) models (the OPD models are used to move the delay line carriages to positions that compensate for the different lengths that

the light has to travel from each telescope to reach AMBER). Weather losses do not necessarily mean clouds, but most commonly that the atmospheric conditions were such that the Adaptive Optics (MACAO) could not perform adequately due to the fast atmospheric turbulence (i.e. low  $\tau_0$ ) and/or poor seeing. Technical losses were a mixture of hardware and software problems, ranging from problems with technical CCDs, delay line metrology to software issues with computer control problems.

**Table 2.** Time accounting of losses due to different reasons during AMBER Science Operations in P76. Weather losses are when weather conditions were such that it interfered with the ongoing execution of an AMBER program. Technical losses are split up between Hardware (HW) and Software (SW) caused losses, Operational losses represent problems with OPD models and Total the total time lost in period 76.

Obs Mode	Weather	Tech(HW):Telescopes	Tech(HW):VLTI	Tech:SW	Operational	Total
Service	5h 33m	6h 25m	1h 37m	0h 30m	5h 10m	19h 15m
Visitor	0h 0m	4h 55m	0h 30m	1h 30m	8h 13m	15h 08m

We define the effective time used by AMBER as the time actually used by the instrument and subtracting the time lost due to Technical, Weather, and Operational losses. The “Success Time” is defined as the time needed to execute successfully one OB, either Science or Calibrator. This number only reflects the time needed for the execution of an individual OB and do not reflect the Calibrator-Science pair success rate. As eight OBs were completed within constraints, passing the pipeline quality control criteria, but “Reclassified” (see “Reclassified” in Table 1), these were counted as successes for purposes of calculating the “Success Time”. We have also counted two OBs that were formally executed within constraints, but failed as they were more extended than expected by the user and thus had too big contrast loss to fulfill the pipeline quality criteria. The total number of successfully observed OBs were thus 40. In Table 3 we present these numbers with numbers of percentage completed of programs and runs (each program consists of one or several runs).

**Table 3.** AMBER statistics for Period 76. Success Time, the total time (corrected for losses) divided by the number of successful OBs (counting Calibrator and Science OBs separately) and represents the average time needed to obtain a successfully executed OB. Execution Time, is the total corrected time divided by the total number of executed OBs, Runs, is the percentage of runs completed and Programs, the percentage of programs completed, where the last two are only relevant for Service Mode operations.

Observing Mode	Success Time	Execution Time	Runs	Programs
Service	1h 6m	0h 46m	29%	25%
Visitor	N/A	0h 34m	n/a	n/a

## 7. CONCLUSIONS AND THE FUTURE

Five main conclusions have been drawn from our experience with Science Operations in P76:

1. Despite being the first Open Time Science Observations with AMBER the actual time needed to obtain a successful observations was close to the estimated execution time of 1 hour. Including the failed observations the actual execution time was much shorter than predicted.
2. Although we successfully executed 30 out of 71 observations (43%), actual run completion was only 29%.
3. The quality of the OPD models (that are good enough for MIDI and AMBER in Medium Resolution) were not accurate enough to allow precise and successful AMBER Low Resolution (LR) observations, thus causing a 12% effective downtime.

4. The two hours needed to obtain a calibrated uv-point make AMBER very sensitive to abrupt changes in weather conditions. The system also has to be working without technical interruption for this time a technical problem however minor can jeopardize a successful observation.
5. A total Technical downtime of 10% sounds much but as AMBER is sensitive to any problem on any of the three telescopes this translates to a 3.5% downtime for each telescope, a very good number.

Of these conclusions items 2, 3, 4 represent problems that need to be solved. Below we present the solutions to the three major problems above:

1. The issue of the quality of the OPD models was addressed when this became apparent as a significant cause of downtime. Historically these models were created from the offsets determined during normal science observations with MIDI and thus the sky coverage was poor and sources with high proper motions were included in the fit, and increase significantly the RMS of the fitted model. The new procedure to determine an OPD model is to allow the dedicated use of the UTs in pairs with MIDI with the sole purpose of collecting OPD model data. The sources were selected to have no or very small proper motions and observed all over sky and thus allowing an even sky coverage.
2. By improving the way that the objects are acquired and light is centered on the AMBER fibers we have managed to decrease the time needed to perform one observation by 15 minutes in P77. The total time for the execution of one OB is 45 minutes in P77 and work is in progress to parallelize the fringe acquisition so that we can in the end reach the one hour for each science and calibrator pair. By reaching a total execution time of one hour we should be much less sensitive to any abrupt changes in the external weather conditions and/or technical problems.
3. Even with the best model the fringes may drift slowly with time and this decreases the sensitivity of the instrument. As a typical full set of exposures takes 15 minutes this slow drift could then affect the data quality. Thus in the end of Period 76 it was implemented a coherencing routine that recenters the fringes on all baselines after each single exposure. The results in the last runs of P76 and in the beginning of P77 have been excellent. The fringes are frequently stabilized and thus the last exposure has the same quality as the first one taken just after the fringe acquisition.
4. Even using effectively all the allocated time it is difficult to complete runs/programs that includes different baseline configurations and setups as it cannot be guaranteed that all baseline configurations are available at all times, thus we recommend the users when submitting new programs so that any scientific program is designed so that scientifically meaningful results can be achieved in a single night. With the ongoing improvement in execution times we will be able to observe more targets in a given time allocated to a given baseline configuration, and with even further improvements in baseline configuration flexibility this suggestion can be removed,

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