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Infrared Interferometry at the ESO VLTI

A. Richichi, A. Glindemann, P. Kervella, F. Paresce, M. Schöller, M. Tarenghi, and M. Wittkowski

ESO, Karl-Schwarzschildstr. 2, D-85748 Garching b.M. - Germany

Abstract. We describe the ESO Very Large Telescope Interferometer (VLTI). This new facility is one of the largest interferometers in the world, and the most powerful one in the southern emisphere. We illustrate the main features and characteristics of the VLTI, which is currently undergoing an intensive phased development plan with several subsystems becoming progressively available. We summarize the main scientific drivers of the VLTI and mention a few among the scientific results obtained during the early operation of this facility.

Key words. Techniques: interferometric – Infrared: general

1. The VLTI facility

The ESO Very Large Telescope Interferometer (VLTI) is located on top of Cerro Paranal in Chile, and is based on the same infrastructure as the widely known ESO VLT observatory. In addition to the four 8.2 m VLT Unit Telescopes (UT), the VLTI can combine the light of a number of 1.8 m Auxiliary Telescopes (AT), which are relocatable over a grid of 30 stations (see Figure 1). Currently, 3 ATs are in advanced stage of construction, and the possibility exists to acquire more. Also, two small test telescopes of siderostat design with an aperture of about 0.4 m are also available. These are relocatable over the same grid of the ATs, and are used mainly for commissioning purposes.

While the VLTI access to the UTs is subject to competition with the many important observational programs that are carried out using specific single-mirror instrumentation, the ATs are totally dedicated to (and specifically designed for) interferometry. Therefore, the VLTI constitutes in fact a separate observatory on Cerro Paranal, which can operate independently every night of the year.

The light from each telescope is propagated through a system of underground ducts, which feed it into the so-called delay-line tunnel. This is the heart of the interferometer, consisting of an underground, 120 m-long tunnel with high-precision tracks for eight delay lines, three of which are in place and three more are about to be installed. The delay-line tunnel is filled with air, but its conditions are carefully kept stable by design and by eliminating almost completely human access.

From the delay-line tunnel, the light beams are brought into the interferometric laboratory, where they are finally fed into one or more of the available instruments

Send offprint requests to: arichich@eso.org

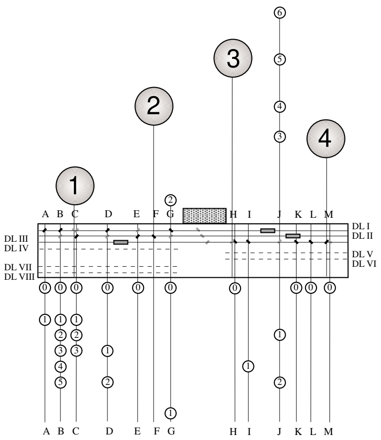

Fig. 1. General layout of the VLTI. Marked are the positions of the 4 UTs, the 30 AT stations, the systems of light ducts (vertical lines in the figure), the delay line tunnel, and the interferometric laboratory.

described later. The interferometric laboratory (see Figure 2) is also located underground and is also subject to strict procedures for access and for environment control. This guarantees that the locally generated turbulence and vibrations are kept at a minimum.

2. VLTI subsystems and instrumentation

The VLTI is a complex machine, which relies on a number of subsystems in order to ensure an efficient and reliable process of interference. Among these, it is important to mention the delay lines, the fringe tracker, the adaptive optics (AO) systems. The delay lines Derie (2000) consist of cat's-eye retroreflectors mounted on carriages which travel in a very accurate mode along 60 m tracks on each side of the tunnel. They are controlled by a sophisticated metrology system, in order to achieve accuracies of a few microns in their positioning. The fringe tracker, dubbed FINITO and developed jointly by ESO and the Observatory of Torino Gai (2002) is a development of a protoype initially built by the Observatoire de la Côte d' Azur. It is planned to be installed and commissioned in early 2003. The AO system for the VLTI is based on the MACAO system developed by ESO, and will equip each of the UTs in a phased schedule. The first two systems will be made available for interferometry in July 2003, and will benefit especially near-infrared observations. Another crucial subsystem is PRIMA, the so-called dual-feed facility that will feed the light from two different directions in the sky into the VLTI Delplancke et al. (2000). One beam will be used to sense and track the fringes on a relatively bright source, while the other beam will be directed independently to a (faint) source in its vicinity. In this way, the VLTI will reach its ultimate sensitivity, which will be close to K=20. Another fundamental application of PRIMA will be narrow-angle astrometry, in which the phase difference between two nearby objects will permit to measure angular distances at the level of 10^{-5} arcseconds.

A number of first-generation instruments have been, or are being built for the VLTI. The first one is VINCI, a K-band, 2-beam combiner which has been developed by the Observatoire de Paris in collaboraton with ESO. Strictly speaking VINCI was designed to be used as a test instrument only. It achieved first fringe detection

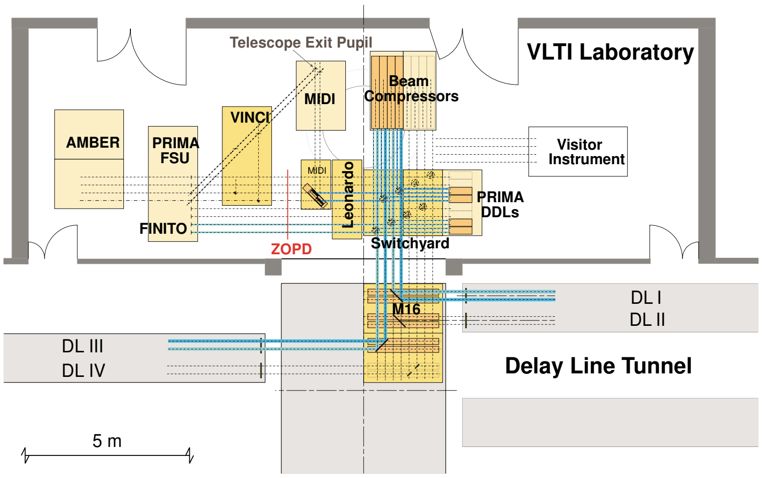

Fig. 2. Layout of the underground focal laboratory.

in March 2001 with the siderostats, and in October 2001 with the UTs (see ESO PR 06/01 and 23/01, 2001). VINCI is currently being used to characterize the AT stations, as well as the optical, mechanical and software subsystems of the interferometer. It will also be used to commission new subsystems as they come on-line, such as for instance the fringe tracker and the adaptive optics system.

MIDI is the VLTI instrument designed to operate in the mid-IR. It is being developed jointly by a consortium of German, Dutch and French partners led by the Max-Planck-Institut für Astronomie in Heidelberg Leinert et al. (2000). It will work at 10 and 20μm, with some spectroscopic capabilities. It is expected that the instrument will achieve first fringes in December 2002. One of the challenges imposed by MIDI is the very high data rate, given that individual exposures will have to be limited to a few tens of milliseconds by the background brightness. Continuous rates of about 2Mb/s are expected, and will require special care to be dealt with by the pipeline and archive facilities of ESO.

For the near-IR range, the facility instrument which will be offered by the VLTI is AMBER, which is being built by a consortium of French, German and Italian institutes based mainly, but not only, in Nice, Grenoble, Bonn and Florence Petrov et al. (2000). AMBER will cover the 1 to 2.4μm range, with a range of medium and relatively high spectroscopic dispersions, up to $R = 10^4$. It is noteworthy that this instrument is designed to combine either 2 or 3 telescopes. In this latter case, closure phases can be measured, which are fundamental if one wishes to attempt actual imaging (as opposed to the measurement of visibilities only, which is the classical product of standard interferometers). First fringes are expected in the beginning of spring 2003.

Limiting magnitudes in long (cumulative) integrations for MIDI are close to N=8 (with fringe tracker on the UTs), and close to K=13 for AMBER (AO on the UTs). These limits are for self-tracking on the scientific source. The dual feed facility PRIMA would allow to push these limits significantly.

To maintain the best conditions in the VLTI laboratory, all instruments are designed to be operated remotely from the control room, and will not need human intervention during the night. The same applies of course to the delay line tunnel. It should be noted that space has been reserved (to the right of the laboratory in

Fig. 2) for the possibility of visitor instruments. One first such instrument could be the GENIE nulling instrument, which is currently being studied by the European Space Agency and that should serve as a technology demonstration for the Darwin space interferometer Fridlund et al. (2000).

3. Early results

The bulk of the observing time with the VLTI in 2001 and 2002 has been and will be devoted to commissioning tasks, in order to test and characterize the performance of the various subsystems and of the infrastructure. Nevertheless, a few observations have brought results of high scientific interest. Commissioning data obtained on sky sources have been released in two batches, one in January and one in April 2002. Details on how to access the data can be found on the ESO VLTI WEB page. It is intended to continue the release of commissioning data of public interest also in the course of 2002.

A summary of key scientific drivers for the VLTI, as well as of a few recent results obtained during commissioning observations, has been recently presented Paresce et al. (2002). The scientific potential of the VLTI is of course dependent on the degree of completeness and on the implementation of the various subsystems. In this initial phase without fringe tracker and AO, the limiting (correlated) magnitude is $\approx$K=8 on the UTs: ideal targets are constituted mainly by bright stellar sources. In this respect, it is worth mentioning that results -in some cases for the first time- have been obtained in the following areas: measurement of the angular diameters of main sequence cool stars; diameters and pulsation of Mira stars, including asymmetries of the circumstellar material in a few objects; the diameters of few Cepheid stars, which are the key to a revised and improved distance scale; the characteristics of the central sources of a few peculiar objects, such as η Car; the environment of some young massive objects, such as HAeBe stars.

Following the implementation of FINITO and MACAO, and with the MIDI and AMBER instruments online, by mid-2003 the VLTI will be able to push the limits of interferometry and break new ground in terms of sensitivity. This will open the door to advanced studies in stellar astronomy. Around K=13-14, the VLTI performance will be just sufficient to tackle a few extragalactic objects as well. However, it will be only with the availability of PRIMA that the full potential for extragalactic science will be reached. It should also not be forgotten that PRIMA will enable also very accurate astrometry, in particular suited for the direct detection of exoplanets.

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