Report on the Workshop

Ten Years of VLTI: From First Fringes to Core Science

held at ESO Headquarters, Garching, Germany, 24–27 October 2011

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The tenth anniversary of first fringes with the VLT interferometer (VLTI) was celebrated by a workshop to trace the history and progress of VLTI, review the science achievements and present the next generation instruments. Highlights of the meeting are reported and the panel discussions summarised.

To celebrate the tenth anniversary of the first fringes at the Very Large Telescope Interferometer, more than 100 astronomers from diverse scientific backgrounds came together at ESO's Headquarters. The four-day meeting featured 54 talks, of which ten were invited reviews; there were also 26 poster presentations and two panel discussions. The presentations are available for download from the conference web page[1].

The stage was set by an account of how the VLTI came into being, from the first suggestion by Antoine Labeyrie to the political birth of the VLTI in the late 1970s, to ESO Council approval in 1987 and the financial and technical challenges that had to be surmounted after the approval. A good place to read up on the genesis of the VLT and VLTI is Woltjer (2006).

Science sessions

The scientific programme consisted of three days of talks and half a day of plenary discussions. The scientific talks were divided into sessions reflecting the diversity of the research areas in which optical interferometric observations play a role: star and planet formation, stellar astrophysics, evolved stars, asteroids and active galactic nuclei (AGN). Here we summarise a number of results that underline the impact of optical interferometry, and especially of the VLTI, on these areas.

Figure 1. The conference photo in the entrance hall of ESO Headquarters.

The field of star and planet formation was introduced by three review talks. During the formation of stars, an accretion disc of gas and dust forms through which material is transported close to the young star. This "protoplanetary disc" is also thought to be the place of planet formation, as it provides the dust particles that are built up into ever larger grains and agglomerations until eventually a planet emerges. Despite its importance in star and planet formation, the detailed structure of the innermost regions of these discs (the terrestrial-planet-forming region) was unknown before the advent of infrared interferometry, due to the lack of resolution of single-dish telescopes. Studies with the VLTI and other interferometers have resolved the inner rims of these discs and confirmed that they lie close to the dust sublimation radius. They have also probed the geometry of the disc and found that these discs have a "puffed up" inner rim and that the rim is curved, as theoretically expected.

A number of talks reported on several recent attempts to reconstruct images of protoplanetary discs using VLTI data. Furthermore, the dust composition of the discs was examined and a crystallinity gradient found, in the sense that there is a larger crystallinity in the inner parts of the disc, as expected from thermal reprocessing of dust grains in the vicinity of the sublimation radius. Towards the end of the session, the first results from an interferometric survey of T Tauri stars that is currently being conducted with the VLTI visitor instrument PIONIER (see Zins et al., 2011) were presented. For the stars studied so far, the total flux was lower than expected from an extrapolation of the visibility model, indicating contributions from larger scales (possibly through scattering) around these stars.

In the field of stellar astrophysics, the review talks emphasised that the mass–radius relation is essential for stellar models and pointed out how observations with optical interferometers constrain such models by directly measuring the radii of stars. Recent observations actually found the radii to be slightly

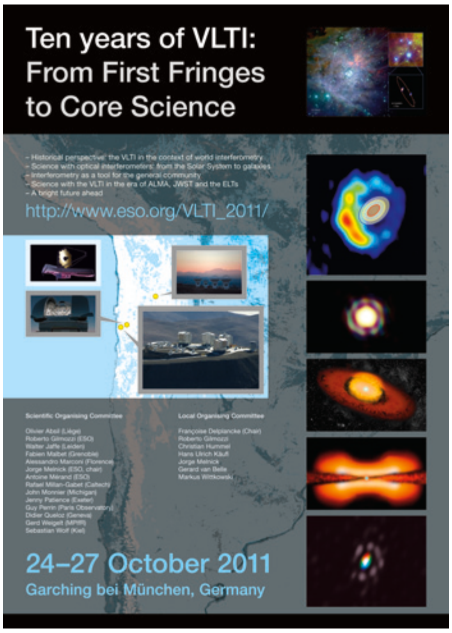

Figure 2. Conference poster depicting the VLTI among the future facilities in the next decade — ALMA, E-ELT and the James Webb Space Telescope (JWST) — and a selection of images of a variety of circumstellar discs.

larger than predicted by models — a result which modellers will have to address. Talks on the cosmological distance scale highlighted the importance of well-understood errors in Cepheid distance measurements to calibrate the first rung of the cosmic distance ladder. A programme to reach beyond the current uncertainty of the present-day Hubble parameter H_0 (3 %) by studying Galactic Cepheid stars with the interferometric Baade–Wesselink method was presented. In this method the diameter and pulsation velocity of the stars are measured interferometrically and spectroscopically to achieve a distance measurement independent of the period–luminosity relation. Using the FLUOR instrument at the US-based Center for High Angular Resolution Astronomy (CHARA) interferometer, it was found that the assumptions about the pulsation of the stars break down when a precision of better than 1.5 % is reached. In order to increase the precision, more refined stellar models are therefore needed.

For the evolved stars, the review talk stressed the many aspects in which interferometric observations contribute. For example, by following the time evolution of the outburst of the recurrent nova T Pyxis earlier in 2011 with both the VLTI and the CHARA Array, it was shown that simple spherical models for the outflowing material are incorrect, and that the morphology is best described as a bipolar flow — this was later confirmed by NACO observations.

The asteroid observations with the VLTI finally convinced us that interferometry might contribute to saving the planet! With MIDI observations it is possible to measure the size, shape and thermal inertia of the main belt asteroids — quantities that are otherwise hard to quantify. The thermal inertia determines the strength of the Yarkovsky effect that can modify the orbits of the asteroids so that they may become potentially dangerous near-Earth objects.

For the area of AGN research, the review talks concentrated on the progress brought about by current interferometers and outlined the expectations for future interferometers. Apart from confirming the unified model of AGN, which invokes a dusty "torus" to explain the two different spectral types, observations with the VLTI also showed that the tori of edge-on (type 2) objects differ from galaxy to galaxy, both in geometry and in temperature structure. On the other hand, face-on (type 1) objects seem to show a uniform radial brightness distribution, as shown in a mini-survey using both near-infrared observation at the Keck Interferometer and MIDI at the VLTI. A debate is still open as to whether or not the sizes of the tori scale uniformly with AGN luminosity (i.e., are independent of spectroscopic type) and whether or not this relation holds also for high luminosities. The first VLTI Large Programme is addressing that question. The first AMBER observations of an AGN in "no track mode" using the AMBER instrument (see Malbet et al., 2007) were also presented. In order to spectro-interferometrically resolve an emission line in the broad line region using the differential phase signal, a factor of about five in sensitivity improvement is still needed.

Next generation instrumentation

The science talks were followed by a session presenting the next generation instruments of the VLTI. A report on the first science results from PIONIER demonstrated how efficient interferometric observations are, once four telescopes are combined at the same time. The latest results of the astrometric commissioning of the PRIMA instrument (see van Belle et al., 2008) were presented.

The near-infrared second generation VLTI instrument GRAVITY was presented, with particular emphasis on the technological challenges (see Eisenhauer et al., 2011). In order to achieve the necessary resolution to observe orbits and flare events at less than six Schwarzschild radii from the supermassive black hole in the Galactic Centre — this corresponds to an angle of 10 microarcseconds — the GRAVITY team will improve the infrastructure of the VLTI (including infrared adaptive optics for all telescopes, the metrology system from the instrument to the VLT primary mirror, and a sophisticated fringe tracker using a Kalman controller) as well as provide a very sensitive instrument by harvesting as many photons as possible.

The thermal infrared second generation VLTI instrument MATISSE was also presented. Compared to the current mid-infrared instrument, MIDI (Leinert et al., 2003), MATISSE will widen the spectral coverage to include the *L*-band, which contains several interesting spectral features of water ice and polycyclic aromatic hydrocarbons (PAHs). Like GRAVITY, it will also combine the light of four telescopes, providing six baselines and three independent closure phases at a time and thereby allow the reconstruction of real images for the first time in the *L*- and *N*-bands at angular resolutions of about 3–10 milliarcseconds.

Synergies

The two largest ESO projects of the decade, the Atacama Large Millimeter/submillimeter Array (ALMA) and the European Extremely Large Telescope (E-ELT), were presented, and in particular how they are expected to work together with the

VLTI. Crucially, ALMA is offered as a high-fidelity imager — and not as an interferometer — to open it up to the whole science community and not only to those who are interferometrically inclined. At the end of the session views were presented on the high-resolution astronomy infrastructure a few years into the future. In contrast to ALMA's approach, the audience was asked to change its mental picture of optical interferometers: these are not high-resolution facilities for all kinds of science, but very specialised observatories that contribute crucially to a few selected science cases.

Panel discussions

On the last day of the workshop there were two panel discussions: the future of the VLTI; and the challenges of (optical) interferometers as a common user facility. The former was considered as an initial discussion forum to assemble the thoughts of the community and provide ideas for the further development of the VLTI after the second generation instruments. This discussion provides invaluable input to help ESO shape its plans for the future of the VLT/I in the E-ELT era.

The panel moderator gave an overview of recent developments that appear interesting for the future of the VLTI. One of the most promising developments is the "hybrid mode", i.e. the combination of one (or more) of the large Unit Telescopes (UTs) with one (or more) of the smaller Auxiliary Telecopes (ATs). This mode was first demonstrated in 2011 and will offer more baselines and better sensitivity (compared to AT-only operations), answering two of the biggest wishes of VLTI users. Another important development is the introduction of the infrared avalanche photodiode detectors that are on the verge of entering astronomy. It is believed that these photon-counting detectors will change interferometric observation and bring about a breakthrough in terms of sensitivity and the way interferometers can be operated.

Regarding the further development of the VLTI, several participants suggested exploring the possibility of expanding the spectral coverage to the visual. This would require a re-coating of all mirrors in the VLTI optical path, but since the maximum VLTI baseline length is limited by the size of the Paranal platform, this is the only way to increase the resolution, which is seen as the necessary step forward for stellar interferometry. While the visual waveband would also be interesting for AGN, more sensitivity and reliability for observations of weak targets are of greater interest to AGN interferometrists. Hybrid UT–AT combinations would add new baselines to the array and thereby improve image fidelity and they would also increase the sensitivity compared to AT-only baselines. The prevailing outlook at the panel discussion on the VLTI as a common user facility was that the ability to reconstruct real images will bring a huge step forward and attract new users to the VLTI.

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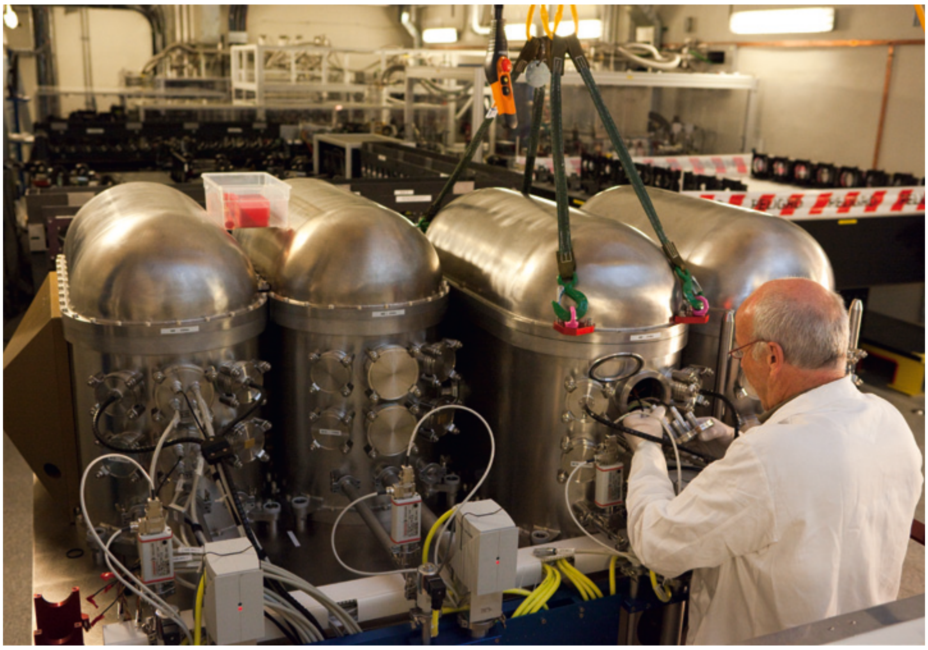
Links

[1] Workshop webpage: http://www.eso.org/sci/meetings/2011/VLTI_2011.html



A photograph from 2009 showing the Very Large Telescope Interferometer (VLTI) laboratory at the Paranal Observatory. In the foreground, undergoing maintenance, the differential delay lines of the PRIMA (Phase Referenced Imaging and Microarcsecond Astrometry) instrument are seen.