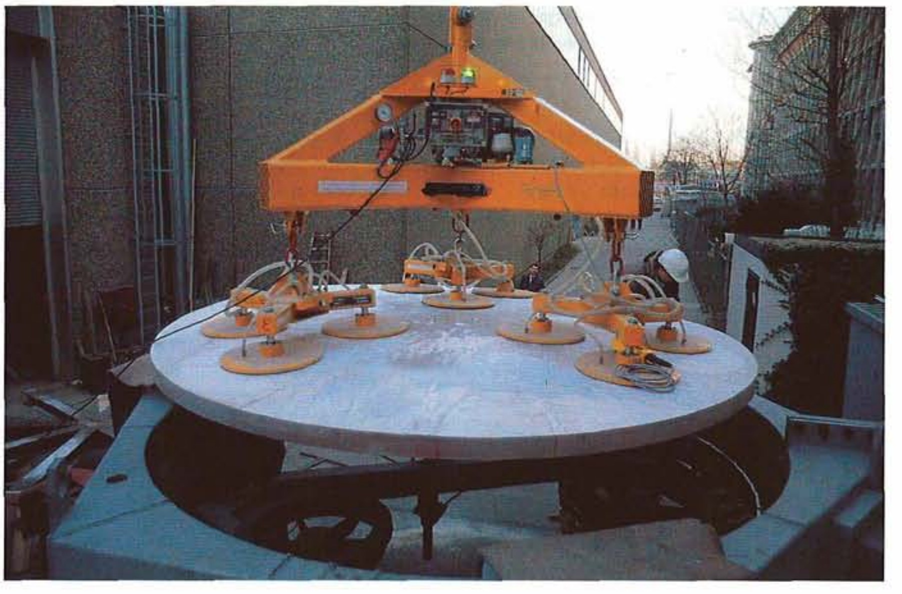
or 4 auxiliary telescopes (2 to be funded out of the VLT budget, the others by additional contributions by research groups in ESO member countries) and limited wavelength coverage (.45 to 25 μm) will start soon after the commissioning of the first large telescope on the VLT site. The full VLTI capability (including such features as the inclusion of the 8-metre telescopes, rapid reconfiguration of the auxiliary telescopes, a non-zero interferometric field-of-view, blind fringe acquisition and maintenance, extended wavelength coverage into the ultraviolet, additional auxiliary telescopes possibly at long NS baselines, additional delay lines) will evolve over a number of years after this, some of it requiring additional resources. The goal will be to provide early on at the VLT Interferometer a facility which will serve both the needs posed by the astronomical programmes of the non-experts in interferometry, as well as the needs of the experts in this rapidly developing field of astronomy. This is a tall task, but as it could be done for radio interferometry, it should also be possible to do it at optical wavelengths. The field is ready for it and the opportunity is here.

How Will the VLT Mirrors be Handled?

Schott is now putting the final touch to the building where the facility to produce the Zerodur VLT mirror blanks is to be installed. Meanwhile Schott is developing the various tools and equipment necessary for the casting, annealing, ceramization, machining and test of the mirror blanks.

Handling in particular is a major concern for Schott. The raw blanks obtained after casting are considerably heavier than the finished blanks and are also a lot more fragile because of the local defects at the surface which have a tendency to behave like perfect crack propagators. An additional difficulty is that after casting only the top surface is physically accessible.

Schott has therefore developed a special handling tool based on suction. The photograph shows a smaller-scale system developed to handle 4-m-diameter mirrors. It is being tested on an experimental thin meniscus realized in the frame of the VLT development programme. This mirror has been produced with the spin casting technology and was originally 4.1 m diameter. It has subsequently been machined down to 3.7 m diameter and to 7.5 cm thickness.



The picture shows the vacuum pumps located at the top and the large sucking cups arranged as a whiffle tree. The triangular structure is used as a vacuum buffer.

The tests have demonstrated the good functioning and the reliability of this type of handling device. Even in case of power failure the system can safely hold the mirror during several hours. A similar system is likely to be used for handling the mirror during its polishing and for its integration into the cell at the observatory. *D. ENARD (ESO)*

Adaptive Optics at the ESO 3.6-m Telescope

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From April 11 to 16, 1990, the VLT adaptive optics prototype system has been tested at the 3.6-metre telescope on La Silla. After the two preceding test periods at the Haute-Provence Observatory in October and November 1989 (see the article by F. Merkle in *The Messenger* **58,** 1989) this was the first test of the adaptive optics prototype system at the telescope for which the system was initially designed.

A description of the prototype system has been given earlier (Merkle, *The Messenger* **57,** 1989). The following table summarizes the major data:

Wavelength range:	3 to 5 micrometre partial correction at shorter wavelengths
Deformable mirror:	19 piezo-electric actuators stroke: ±7.5 micron hexagon arrangement active diameter 70 mm
Tip/tilt mirror:	gimbal mount piezo-electric actuators
Wavefront sensor:	Shack Hartmann type 5 by 5 subapertures square configuration 100 by 100 intensified Reticon detector visible limiting magnitude 9 mirror for reference source selection
Computer:	dedicated processor 68020 host processor
Infrared camera:	32 by 32 InSb array additional chopping mirror
System concept:	bandwidth 10 Hz (100 Hz sampling) modal correction mirror eigenmodes polychromatic system

Some mechanical modifications had to be made at the prototype bench at the Cassegrain f/8 focus of the 3.6-metre telescope. In addition, the limiting magnitude was improved to about magnitude 9 for a 3.6-metre aperture by using as a first stage a proximity focus intensifier and a microchannel intensifier as the second stage. Further improvements are planned in order to achieve the theoretical goal of magnitude 12 to 13. After the mechanical integration of the system at the Cassegrain focus (see Fig. 1) it took approximately three hours to align it with the telescope, to perform the calibration and initialization with a real object on the sky, and to get the first, diffraction-limited image on the control monitor of the infrared camera.

This observing run at the 3.6-metre telescope was mainly aimed at:

- verifying the gain expected from adaptive optics with a large telescope,
- measuring the effects of partial correction by adaptive optics, and
- measuring the isoplanatic angles at various wavelengths and seeing conditions.

The intention of this short summary is only to give the reader a first impression of the type and quality of the results recorded. A detailed analysis of the more than 50 high resolution images covering the J-, H-, K-, L- and M-band with integration times ranging from approximately 10 seconds to 10 minutes – there was no restriction in integration

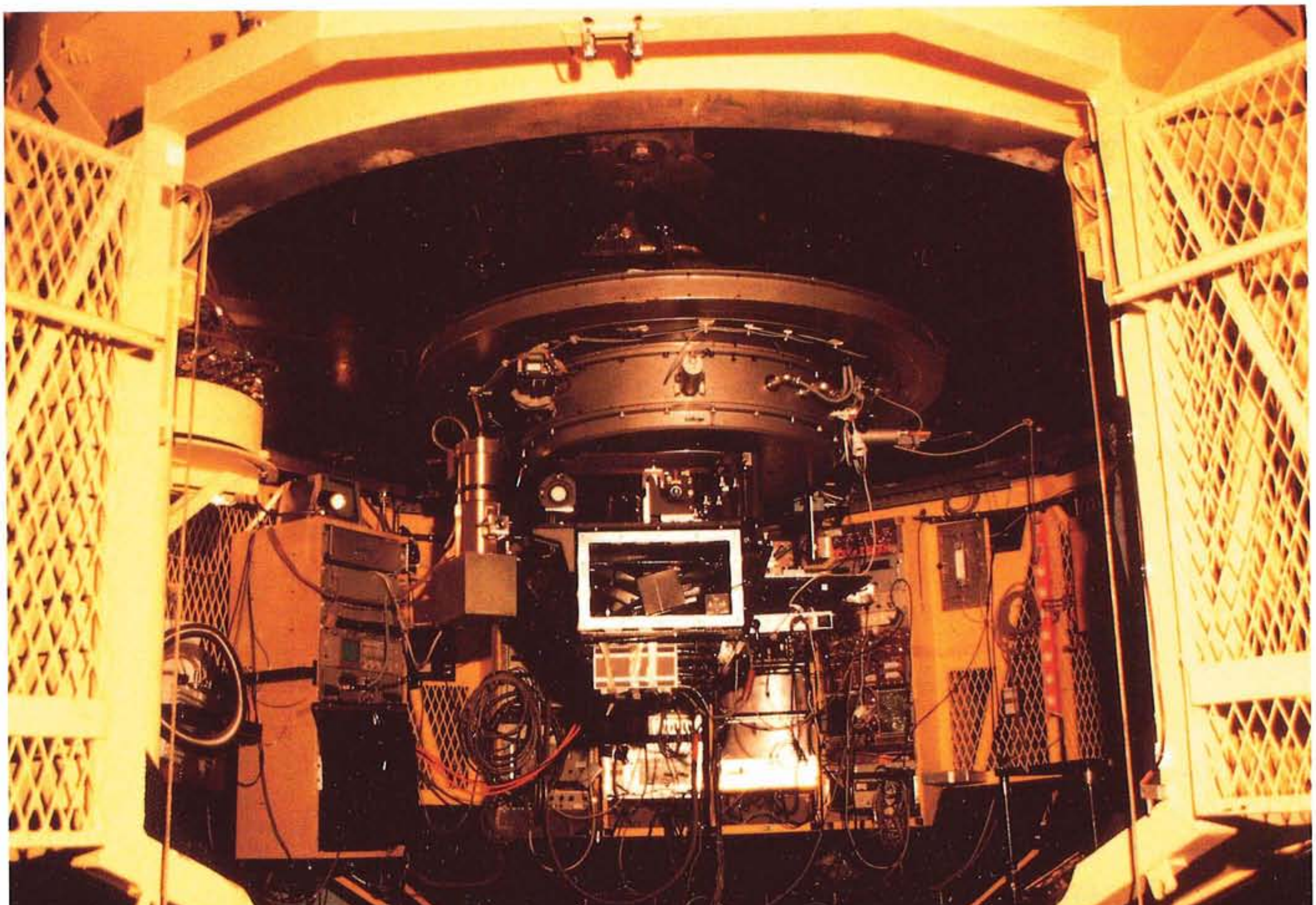

Figure 1: *The adaptive optics prototype system installed at the f/8 focus of the 3.6-m telescope. The rectangular frame is part of the optical bench that supports the system. To the left of the bench is the IR array camera and on the right side is the wavefront sensor support. The electronics rack attached to the left side wall of the Cassegrain cage houses part of the front-end electronics of the system.*

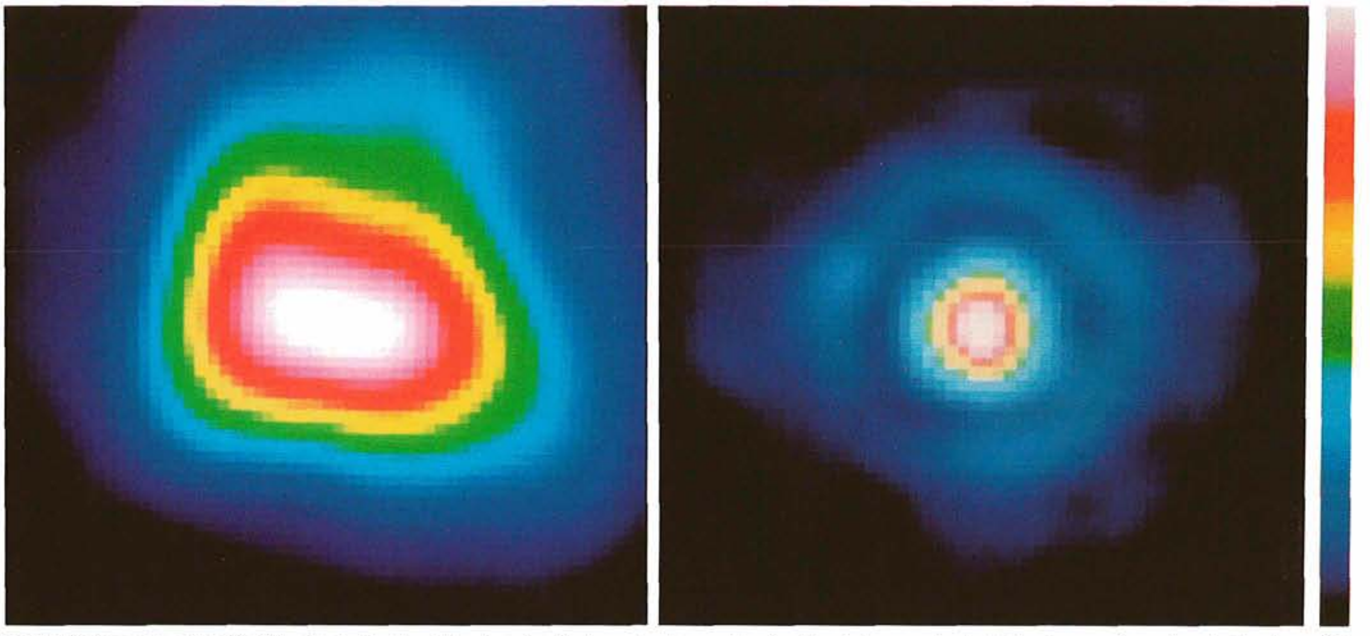

Figure 2: *Images of HR 6519 in the L-Band, without and with the adaptive optics feedback loop activated. The image diameter shrinks from 0.7 arcsec to 0.22 arcsec, which is the diffraction limit in the L-Band (3.5 μm).*

time – will take some time and will be published elsewhere.

Reference stars with magnitudes down to 9 could be used for the wavefront measurement and a spectacular gain in image quality can already now be reported.

The observed objects include bright, unresolved test objects to verify the performance of the system, independent of the object structure. In addition, a number of more complex objects of particular scientific interest were recorded, like η Carinae, some T Tauri stars, and various others.

Figure 2 shows the resolution gain when the real-time feedback of the adaptive system is activated for the object HR 6519 in the L-band. The uncorrected image (left) has a FWHM of 0.7 arcsec, the corrected (right) has 0.22 arcsec. The object served itself as reference for the measurement of the wavefront. Its visual magnitude is 4.81. The asymmetry of the uncorrected object is due to a problem with the 3.6-m autoguider which was detected during the observations. During the real-time atmospheric correction – the seeing was 0.9 arcsec in the visible range – this artefact was compensated in the same way as all other low-frequency telescope aberrations. The corrected image very clearly shows the predicted diffraction pattern. It still shows some imperfections which are due to some print-through of the actuators of the deformable mirror.

The images on page 1 show the improvement in image quality when the system is applied to the double star HR 6658 with visual magnitude 5.24 of the brighter component and 5.74 of the fainter one. The separation of the two components is only 0.38 arcsecs.

Apart from the evaluation of the performance of the system at the wavelengths for which it was designed, it was the aim of this test run to measure the effects of a partial correction by adaptive optics at shorter wavelengths. Figure 3 displays the image of the 4.7 mag star α Hydrae (HR 3748) in the J-, H-, K- and L-Band. The equivalent seeing in the visible wavelength range during the recording time was approxi-

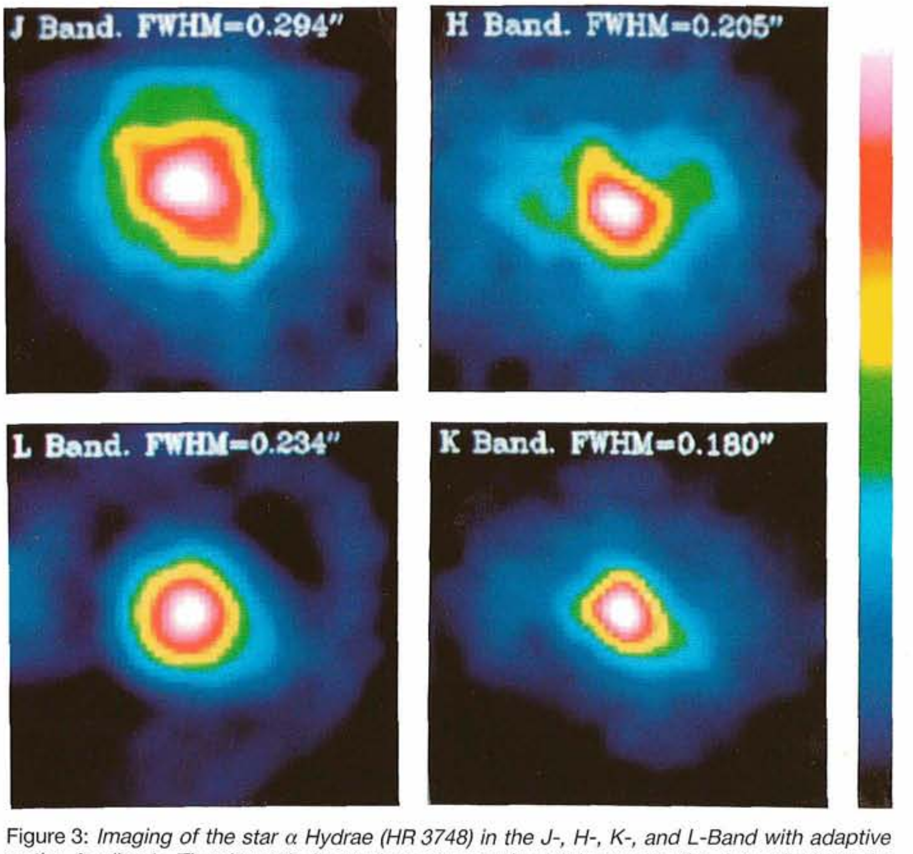

Figure 3: *Imaging of the star α Hydrae (HR 3748) in the J-, H-, K-, and L-Band with adaptive optics feedback. The dramatic image improvement is visible even in the J-Band where the system was undersampling at least by a factor of 2.5.*

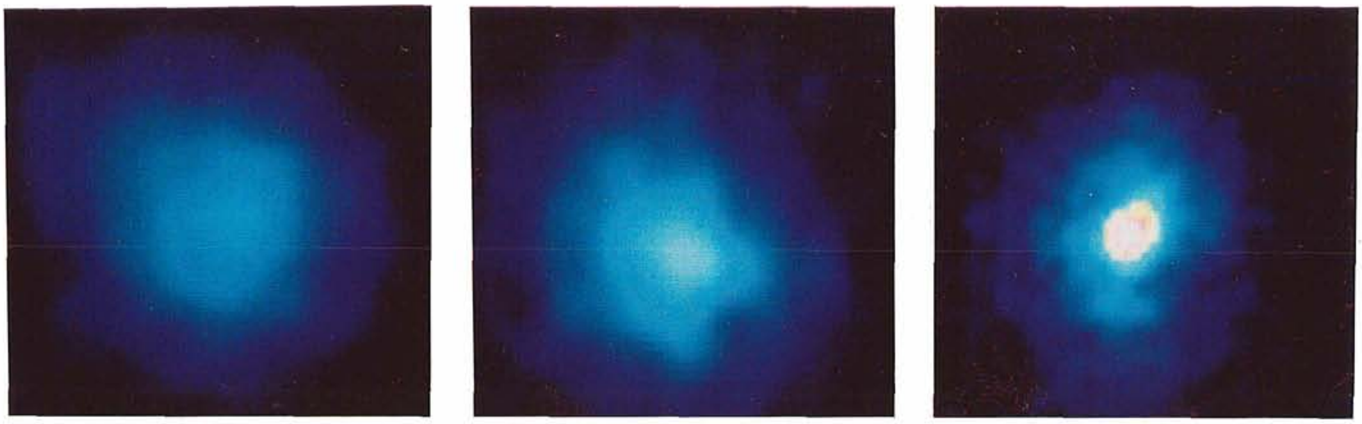

Figure 4: *This image shows an uncorrected image (left), an image corrected by the tip/tilt mirror (middle), and an image corrected by the tip/tilt and deformable mirror of the object HR 5646 (visual magnitude 3.87) in the K-Band. The object itself served as reference for the wavefront sensing. The Strehl ratio between the uncorrected and the tilt corrected image improved by a factor of 1.3, the gain to the fully corrected image is by a factor of 3.5.*

mately 0.75 arcseconds FWHM. The image improvement is dramatically evident even down to the J-Band where the system was undersampling, at least by a factor of 2.5. This corresponds to an improvement from 0.56 to 0.23 arcseconds (theoretically smallest possible value, i.e. the diffraction limit: 0.22 arcseconds) in the L-Band, from 0.58 to 0.18 arcseconds (limit: 0.13 arcseconds) in the K-Band, from 0.6 to 0.21 arcseconds (limit: 0.10 arcseconds) in the H-Band, and from 0.66 to 0.29 arcseconds (limit: 0.07 arcseconds) in the J-Band. This improvement at shorter wavelengths will be an important feature for interferometry with the VLT. The evaluation of the partially corrected images will help to build an analytical model for partial correction by adaptive optics.

Another important part of this test run was to measure the contribution of the image motion stabilization with the tip/tilt mirror in comparison to a full correction. Figure 4 shows an uncorrected image (left), an image corrected by the tip/tilt mirror (middle), and an image corrected by the tip/tilt and deformable mirror of the object HR 5646 (visual magnitude 3.87) in the K-Band. The object itself served as reference for the wavefront sensing. The seeing in the visual region varied between 0.7 and 0.85 arcseconds at the time of these measurements. The maximum intensity (Strehl ratio) between the uncorrected and the tilt corrected image improved by a factor of 1.3, the gain to the fully corrected image is by a factor of 3.5. This gain is limited due to the partial correction, since these measurements are taken in the K-Band at 2.2 micrometre.

Another important aim was the measurement of the isoplanatic angle as a function of wavelength, seeing, and order of correction. The system allowed offset angles between the object and reference source of up to 35 arcseconds.

As mentioned above, a detailed analysis of all results is now underway. This preliminary presentation of some of the most important results is only a brief introduction to the spectacular improvements which can be expected from adaptive optics at a large telescope.

Acknowledgements

The authors' thanks are due to many colleagues at ESO, Observatoire de Meudon, ONERA, and LASERDOT who have contributed to the design and construction of this prototype system. In particular, we are thankful to Claude Marlot of Observatoire de Meudon and the Mechanical Workshop at La Silla for "adapting" the adaptive system to the 3.6-metre telescope.

What's Next in Adaptive Optics?

During the past half year it has been demonstrated that adaptive optics is a proven technique for high-resolution imaging in the near-infrared domain. The results obtained with the VLT adaptive optics prototype system give only a first impression of what will be possible in the future with systems with deformable mirrors with several tens or even hundreds of subapertures, compared to the 19 actuators the ESO system has today.

Adaptive optics devices are highly complex systems. The multichannel feedback loop requires very fast and powerful processors. Due to this complexity, adaptive optics systems are often considered as devices which are far from becoming a general user instrument of an observatory. It has frequently been assumed that only specially trained operators or the persons involved in the construction of the system can operate it and that it will therefore necessarily have quite a restricted use.

However, the observations with the VLT adaptive optics prototype system at the 3.6-m telescope have now made it quite clear that adaptive optics can become a tool which can be offered to any observer without special expertise. Although the current prototype is operated from three keybords, not including the infrared camera acquisition system (see the article by Merkle in the *Messenger* **58,** Fig. 4), the operation follows a clear procedure which could be taken over by an additional host computer. All functions can be automated without a major increase of the system's complexity. Also the optomechanical part, which at the moment still requires occasional human interaction, is now close to be completely remote controlled.

With the information and experience gained during the first test run at the 3.6-metre telescope, we are a big step closer to an "Adaptive Optics User Instrument for Infrared Wavelengths" which could be offered to any visiting astronomer. With the current plans to upgrade the prototype to approximately 50 subapertures, an adaptive system for full correction of a 4-metre-class telescope for the wavelength region above about 2 μm will become available. In the beginning it will be a bench-type instrument, but in less than three years it could be converted to a fully integrated system – as the "active optics" is already for the NTT.

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