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Bigger Telescopes and Better Instrumentation: Report on the 1992 ESO Conference

M.-H. ULRICH, ESO

The Conference "Progress in Telescope and Instrumentation Technologies" took place in Garching on April 27–30, 1992. This meeting is one in a series of Conferences organized every other year alternately by Kitt Peak National Observatory and by ESO. The next one should take place in two years in Arizona.

The Conferences organized by ESO have a twofold purpose. First, as a meeting at the worldwide level to present and discuss recent advances in telescopes and instrumentation. Second, for the general ESO community to inform themselves of technological progress both at ESO and other observatories. This Conference was attended by 270 external participants and 69 ESO participants. There were 110 posters and 61 talks.

The first two days were devoted to large telescopes, mirror fabrication, and enclosures (51 posters, 32 talks). Adaptive optics was the subject of the third day. The fourth day saw a review of a number of optical and infrared instruments for the VLT and other telescopes. A brief outline of these topics follows.

1. Telescopes and Mirrors

At the present time thirteen individual telescopes with diameter larger than or equal to 6.5 m are under construction or are planned with various degrees of funding (see Table 1). The total collecting area of these telescopes is 675 m^2 or 70 times that of a 3.5 m telescope.

This shows the intense activity taking place now in all major observatories not only to build these telescopes but also to equip them. Among these groups building large telescopes, the most suc-

Riccardo Giacconi – ESO's Next Director General

In its 67th meeting in Garching on June 4 and 5, 1992 the Council of ESO appointed Prof. Riccardo Giacconi as Director General for the period 1993 – 1997. He succeeds Prof. Harry van der Laan whose five-year term ends this year.

Prof. Giacconi was born in Genova (Italy) in 1931 and got his education in Physics at the University of Milano, before emigrating to the United States. In his activity he has been associated with several leading institutions including Princeton University, American Science and Engineering, Harvard University and has received many honours for his achievements in science.

Prof. Giacconi is famous for his pioneering work in the development and application of X-ray technologies in astronomy, leading to the discovery of the first extra-solar X-ray source. The X-ray satellites UHURU (launched in 1970) and the Einstein Observatory (launched in 1978) are associated with his name.

Since the establishment of the Space Telescope Science Institute in Baltimore in 1981, Prof. Giacconi has been its Director, while holding a professorship at the John Hopkins University and, more recently on a part-time basis, also at the University of Milano. The ST ScI has been central to the Hubble Space Telescope's success in spite of its optical flaw and serves a world-wide community of HST users. At ESO his association with the HST will continue, because ESO Headquarters is the host of the European Coordinating Facility for the HST. The ECF is a joint venture of ESO and the European Space Agency (ESA).

The prime assignment of the new Director General will be the completion of the Very Large Telescope (VLT) Observatory which ESO is constructing with European industry in Chile's Atacama desert, while at the same time operating the world's largest infrared/optical observatory, the La Silla Observatory for the astronomy community in ESO's member states.

Table 1: *Telescopes with diameter larger than or equal to 6.5 m under construction or planned.*

Name	Primary Mirror	Telescope Location
4 telescopes making up the VLT	4 × 8.2 m thin meniscus	Cerro Paranal, Chile
Keck I Keck II	10 m segmented 10 m segmented	Mauna Kea, Hawaii Mauna Kea
Japanese Large National Telescope	8.3 m thin meniscus	Mauna Kea
Gemini	2 × 8 m. Mirror type to be decided	1 on Mauna Kea 1 in Chile (Cerro Pachon)
Columbus	2 × 8.4 m. Mirror type: Borosilicate Honeycomb	Mt. Graham, Arizona
MMT	6.5 m primary to replace the six 1.8 m mirrors. Borosilicate Honeycomb	Mt. Graham, Arizona
Magellan	6.5 m. Borosilicate Honeycomb	Las Campanas, Chile

cessful ones will be those which not only attract excellence and originality of the observing programmes but which will also make the necessary effort to achieve the highest quality and efficiency in the instrumentation and data analysis.

Among the most advanced projects, the installation of the last segmented mirror of the Keck I telescope was announced. The telescope in its present state has a FWHM of 2 arcsec. Work is now in progress to achieve the specification of a final FWHM of 0.4 arcsec. The efforts are twofold: one is to finish the figuring of each segment with an ion beam and the other is to align the 36 individual mirrors. The ion beam finishing consists in erosion of the surface with a computer operated ion beam of a few cm in diameter. This is best used to correct the last surface defects 1 to 2 μ in height. Can this process of automated measurement and computer controlled fine figuring replace the magical final touch of the experienced optician?

Regarding the VLT, it was already announced (*The Messenger* No. **67**, 1992) that the fabrication of the first mirror is well advanced: the 8.6-m blank has been annealed and is now in the process of ceramization, a process to achieve the zero expansion coefficient of Zerodur and which will take 8 months. (Ceramization is roughly speaking a way of partially crystallizing the glass mass by slow and controlled heating. The crystal has a negative coefficient of expansion which can compensate the positive expansion coefficient of a purely glassy material.) The mirror will then be shipped to the REOSC factory near Paris where it will be ground, figured and polished to its 8.2-m diameter size, then shipped to the VLT site. A second 8.6-m blank has also passed the annealing process and a third one is in the annealing oven.

The fabrication of borosilicate honeycomb mirrors is also progressing. Two mirrors, one of 1.8 m and one of 3.5 m have been completely finished. The final figure is 80% of the light within 0.3 arcsec, well within the specification. The first 6.5 m has recently been cast.

The Japanese Large National Telescope will have a thin meniscus which is being fabricated by Corning. The site of the JLNT on Mauna Kea is in a convenient location to do interferometry with this telescope and the two 10-m diameter Keck telescopes. (The Japanese project is called Subaru which means Pleiades, a poetic name which is given to quite a few projects in Japan, especially in the artistic world; for example it is the name of a poetry journal.) The large figure in dollars given for the project is the figure proposed by the astronomers to the funding agencies; it is

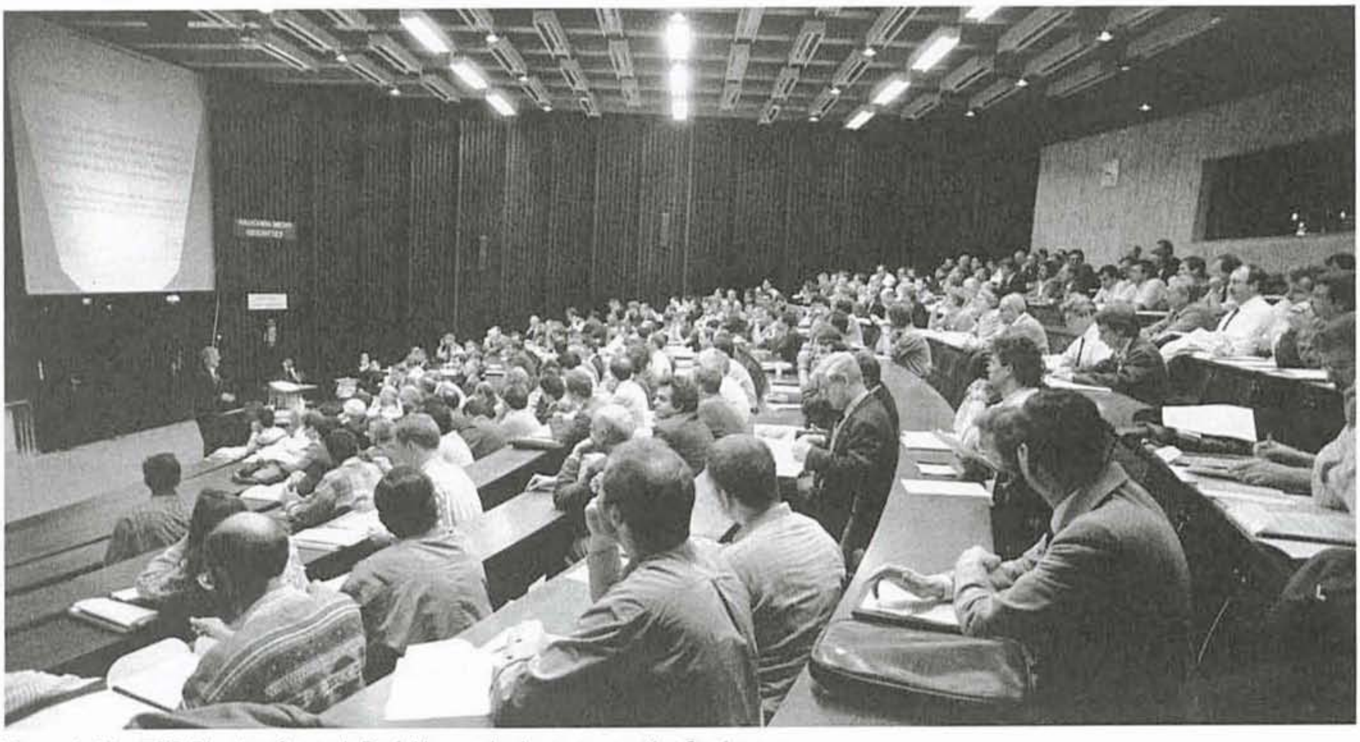

Figure 1: *The ESO Director General, Prof. H. van der Laan, opens the Conference.*

Figure 2: *From the poster gallery.*

a "pessimistic maximum". In contrast, in the Western world the tradition is to start negotiating from a small figure, an "optimistic minimum".

Several methods of producing large (convex) secondary mirrors were presented: active laps, mirror replication and also use of a profilometer to mechanically measure the shape of the surface and compare it to its ideal shape. This latter method has been successfully (specification 100% of light in $0\farcs15$) used to figure the Keck Telescope secondary which is 1.5 m in diameter and for which the maximum aspheric amplitude is 130 μ. The secondary of the VLT is presently planned to be in SiC, a compound which has a density slightly larger than Zerodur but whose Young modulus is $\sim$ 400 gigapascal instead of 70. Because of this quality the mirror can be lighter by a factor $\sim$ 4 than if it were built of glass, and thus achieve the dynamical performance necessary to accomplish the tasks of focusing, centring, image stabilization and especially chopping.

But very interesting developments were also presented for "old telescopes" built several years ago, for example the retrofitting of new technology on the CTIO 4-m telescope by transferring technology developed for the ESO NTT to this "old" 4-m telescope. Specifically, this consists in removing from the dome and building all that could be removed, improving the insulation of unmovable heat sources (pumps for example), improving the ventilation by opening 4-m-high windows in the lower part of the dome walls, refiguring the secondary, and mounting a permanent image analyzer. More ambitious is the plan to modify the primary mirror support and transform it into an active support based on air bags and inexpensive off-the-shelf controllers.

2. Adaptive Optics: Promises and Difficulties

The third day started with a summary of the Second ESO Conference on High Resolution Imaging by Interferometry (*The Messenger* No. **66**, p. 5). The rest of the day was devoted to Adaptive Optics and a poster session. This one is the first of the large European Conferences on ground-based telescopes and instrumentation in which a significant fraction of the programme was set aside for adaptive optics. This reflects firstly the increased realization of the potential importance of adaptive optics as one of the astronomer's tools in ground-based observatories. Secondly a wealth of information has become available from three well-funded US laboratories whose part of their research in adaptive optics has recently been declassified: Lawrence Livermore National Laboratory in California, Phillips Laboratory at Kirtland Air Force Base in New Mexico and Lincoln Laboratory at MIT (Massachusetts). One of the several reasons for this declassification was the rapid progress in the successful use of adaptive optics made in the astronomical context, especially the COME-ON experiment – the Meudon-ESO experiment in collaboration with three French laboratories.

Adaptive optics presents substantial advantages for high-resolution direct imaging, spectroscopy, stellar coronography and long baseline optical/IR interferometry. For direct imaging, adaptive optics is more powerful than speckle interferometry for mapping relatively faint extended objects (e.g. distant galaxies). Regarding high resolution spectroscopy (say $R \sim 10^5$), adaptive optics will allow one to use a narrow entrance slit. Since for a given high spectral resolution, the linear dimension of the grating is proportional to the entrance slit width, a decrease of the slit width from 1 to 0.25 arcsecond will correspond to a spectrograph with gratings and other optical elements four times smaller. This results in a spectrograph which is less expensive, easier and faster to build, and with less thermal and

Figure 3: *Preparation for fabricating the first 6.5-m borosilicate honeycomb mirror. The 6.5-m mould under construction. At the time of the Conference, the 6.5-m mirror had already been cast.*

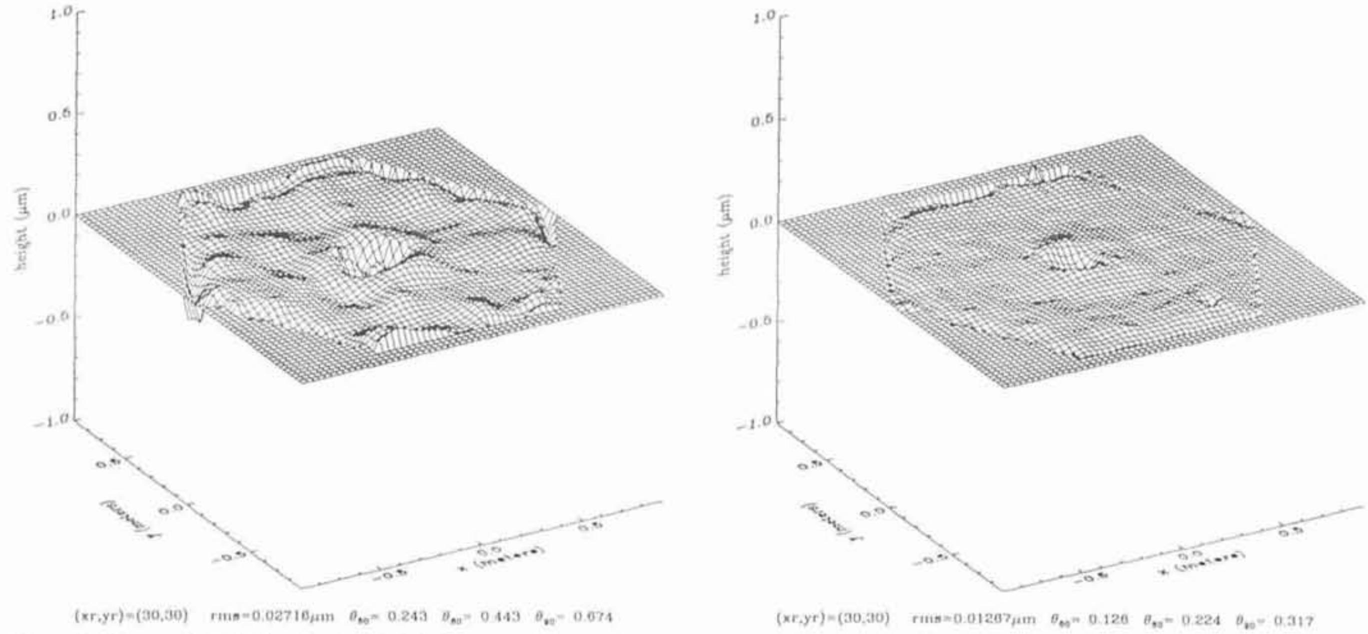

Figure 4: *Segment fabrication for the Keck Telescope 10-m diameter primary. Left: the segment surface with stress mirror polishing and warping harness but before ion beam figuring (80 % of the light in 0.″44). Right: same after ion beam figuring (80 % of the light in 0.″22 which slightly exceeds the specification) (from T. Mast and J. Nelson).*

flexure problems. As far as interferometry is concerned, it is only with a near complete wavefront correction at each telescope that one can achieve the maximum efficiency. This is an important point as the high angular resolution of the interferometer means that the photons of a given source are spread over a large number of independent picture elements. It is clear, therefore, that large collecting apertures and high efficiency must accompany the large angular resolution.

What are the performances of the present adaptive optics system? What are the predictable progress . . . and difficulties? From the 13 oral presenta-

Figure 5: *Synthetic interferogram calculated from the final phase map after stressed-lap polishing of the 3.5 m f/1.5 paraboloid. The measurement was made in December 1991 with a 633 nm phase-measuring interferometer through a refractive null corrector. The rms surface error is 21 nm (from Buddy Martin, Steward Observatory).* ▶

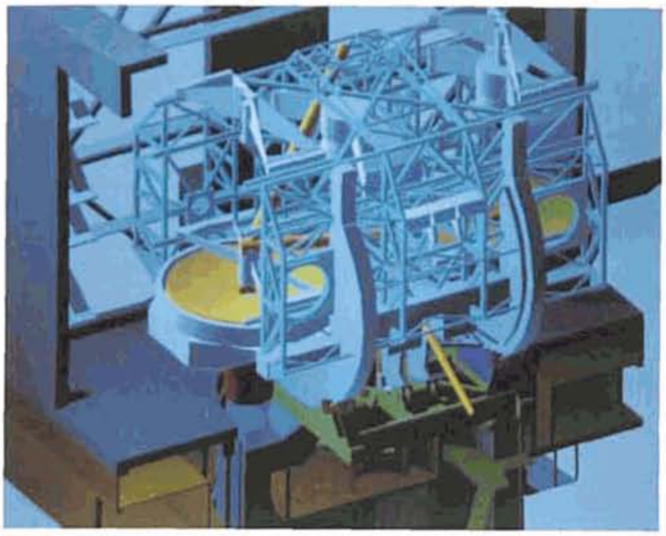

Figure 6: *Computer drawing of the Columbus Telescope (P. Salinari, Arcetri Observatory).*

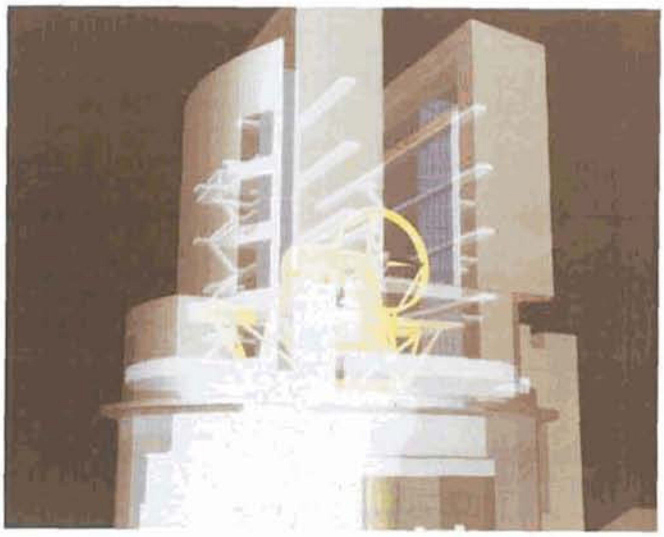

Figure 7: *The Japan National Large Telescope Project (diameter of the primary: 8.3 m). Enclosure concept: there are two large walls ("great walls"), one on either side of the telescope in order to channel and flush the air flow. Front, back, and side ventilators are provided. The enclosure will be air conditioned in the day time (from K. Kodaira, National Astronomical Observatory).*

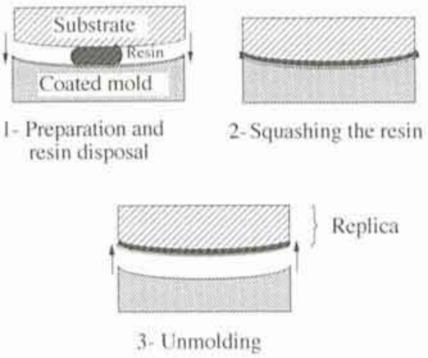

Figure 8: *Making convex surfaces by the replica technique. Prior to making the replica, the mould is coated with a reflecting substrate which at the end covers the external resin surface. The final thickness of the resin layer is 50 μ (from P. Assus, O.C.A.).*

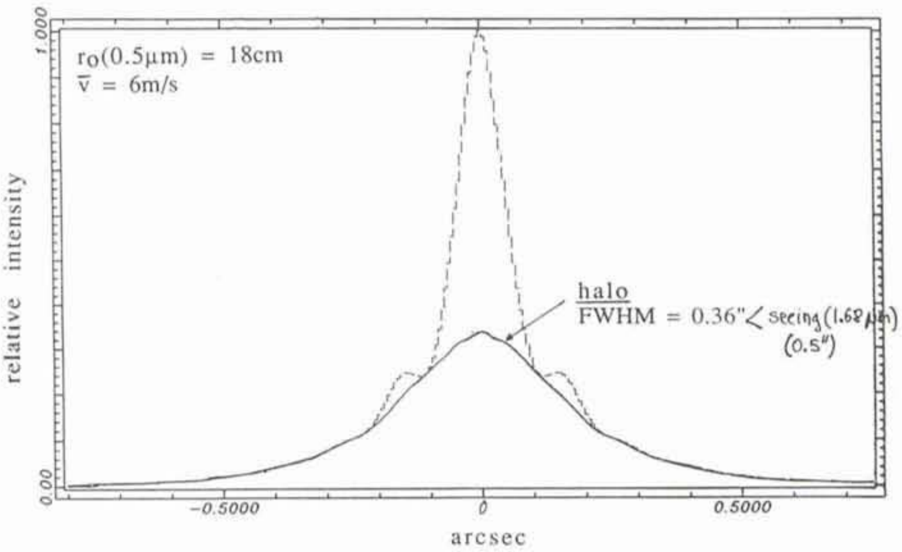

Figure 9: *Experimental PSF at 1.68 μ obtained with the COME-ON system with a seeing of 0″.5 with the ESO 3.6-m telescope. The image is composed of a halo (continuous line) of 0″.36 FWHM and a sharp core (broken line) which has the width of the Airy pattern of the telescope (F. Rigaut, G. Rousset et al. COME-ON experiment).*

tions and the 26 posters one was able to get a fair assessment of the situation.

There are two parts in an adaptive optics system: one is made up of the wavefront analyzer, the deformable mirror, the detector and the computer. The other one is the reference star.

The first part of the system is well developed: The COME-ON Plus system will have 52 actuators and a correction rate of 400 Hz. The Lincoln Laboratory experiment and the Phillips Laboratory experiment have 241 controlled actuators with wavefront sensing and analyzing performed in 0.5×10^{-3} seconds. These figures lead one to estimate that full wavefront correction is attainable in the foreseeable future at $\lambda \sim 2.2$ μ for an 8-m telescope. The VLT plans an adaptive optics system of 256 elements.

But the problems are severe regarding full correction in the visible (~ 0.55 μ). One needs a faster computer and a larger number of actuators. It is not easy but it is possible to build such a system. The real difficulty lies in the fact that one needs a reference star within the isoplanatic patch of the source to be observed, i.e. within a radius of a few arcsec. And this star must be bright to send enough photons for analyzing the wavefront in less than a few milliseconds. The only way to have such a star everywhere in the sky is to make it – with a laser beam tuned to the 0.589 μ sodium line which produces resonance scattering in the mesospheric atomic sodium layer at an altitude of ~ 90 km. The spot where the laser beam hits the sodium layer forms a point-like source. But a single artificial star is not enough for large telescopes because of focal anisoplanatism (two points diametrically located on an 8-meter diameter mirror see the point source at 90 km at angles differing by 20 arcsec, i.e. larger than the isoplanatic patch). It is proposed therefore to use several laser stars grouped within 10–20 arcseconds, plus a natural star to correct for the tilt. This is, to say the least, an expensive and cumbersome system. In addition, the laser beams produce light pollution which may be a nuisance not only for the telescope working with adaptive optics but for the other telescopes on the same site as well. Stroboscopic shutters and holographic filters could provide protection against such a nuisance but this is not well explored at present. The problem caused by the light pollution produced by the laser stars is less acute in the case of satellite surveillance from the ground than for astronomical observations. Satellites have an optical magnitude of about 15 or brighter while astronomers are interested in mapping much fainter objects as well as bright objects. Astronomers also have more limited funding. They will have to build the adaptive optics systems within the

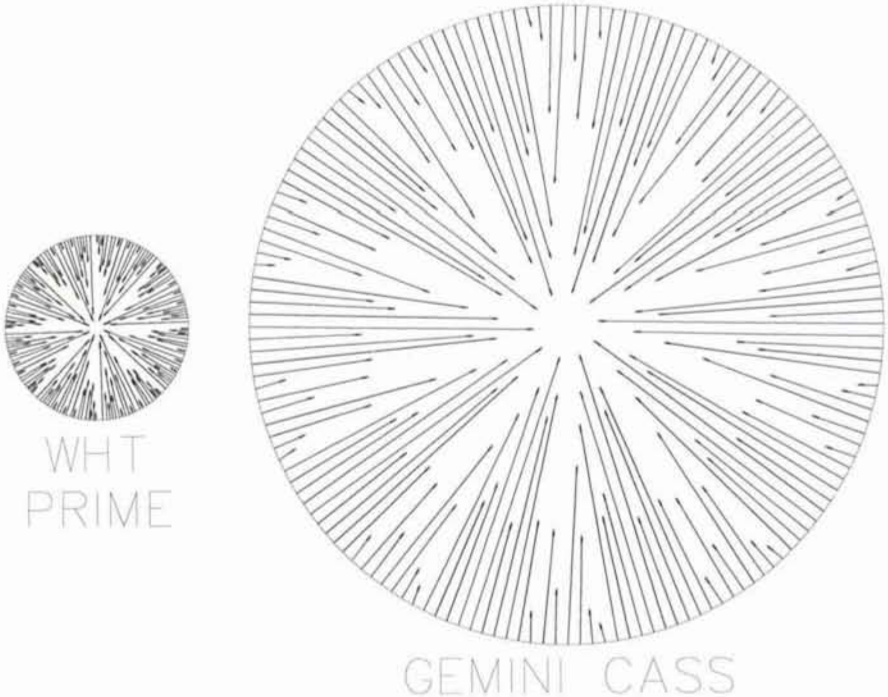

Figure 10: *Multiaperture spectroscopy with optical fibres. The arms positioning the entrance of the optical fibre at the prime focus of the William Herschel Telescope on La Palma (diameter 4 m) and at the Cassegrain focus of one of the planned 8-m telescopes of the Gemini project (drawn to scale) (from I. Parry, Univ. of Durham).*

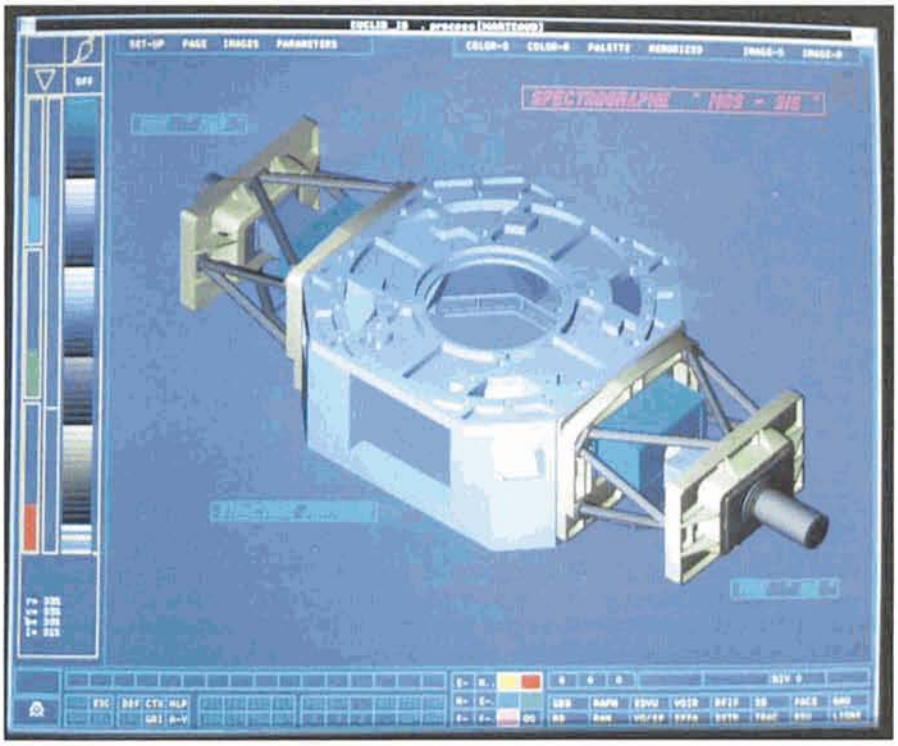

Figure 11: *The Second-Generation CFHT Cassegrain Spectrograph is in reality a double spectrograph. One arm (here at top left) is MOS, a multi-object spectrograph with a 10 arcmin field. The other arm (bottom right) is SIS, a sub-arcsecond imaging spectrograph with a 3 arcmin field.*

resources at their disposal. They will therefore be faced with choices and compromises. These compromises will translate into imperfections of the point spread function (PSF). Among these less than perfect PSF, which ones will be most useful, or best adapted to a particular type of observations? The one with the faintest halo? The narrowest central peak? The maximum strehl ratio? Simulations of observations of different objects with a variety of PSF are a prerequisite to answering these questions. The answer will depend both on the scientific application of adaptive optics and on technical limitations.

3. Instruments and Components

The fourth day of the Conference was devoted to the description of instruments under construction for 4-m class or 8-m class telescopes with a large fraction of the time given to the instrumentation for the VLT. (Six VLT instruments are now in the final design stage – see *The Messenger* **65**, 67.) Present and predicted performances of three types of components were also discussed: optical fibres, CCD and NICMOS detectors.

The two largest groups of instruments represented in the 33 posters and the 16 talks were the faint object spectrographs and the infrared instruments. In the first case, the impetus is given by the current emphasis on cosmological observational programmes and the increasing reliability and sophistication of optical fibres and multislit systems. In the case of the infrared instruments, the impetus comes from the rapid improvement of the performances of infrared detectors, in particular the number of pixels, and the perspective of using the large telescopes at or near their diffraction limit.

While almost all of the telescopes and instrument designs were for multipurpose observations, one project stood out: The Sloan Digital Sky Survey is a 2.5-m telescope (with a 3-degree field of view) whose scientific purpose is to obtain a new sky survey, and to measure optical spectra of 1 million galaxies and quasars selected from this survey with the aim of getting an empirical description of their 3-D distribution (large-scale structure) and their cosmic evolution.

The telescope is devoted to the above astrophysical project and does not have to justify its existence beyond the accomplishment of this project. In that sense, it bears some similarities with the large experiment built around particle accelerators or the older generation of radio telescopes.

A distant cousin and complement of this project is the DEEP, the Deep Extragalactic Evolutionary Probe. This is a spectrograph planned for the Keck Telescope and which will be dedicated to one task: obtaining the redshift and velocity dispersion of 10^4 to 1.5×10^4 faint galaxies of magnitude up to 23 to 24. The spectrograph is in fact made up of 4 identical spectrographs at the Cassegrain focus of the Keck telescope. The spectrographs probe 4 fields disposed symmetrically around the optical axis, the central field being used for TV acquisition and guiding.

Mirror Container and VLT 8.2-m Dummy Mirror Arrive at REOSC Plant

P. DIERICKX and W. ANSORGE, ESO

Within the framework of the VLT primary mirror polishing contract, an 8.2-metre reinforced concrete dummy mirror was manufactured in Dunkirk by SOCOFRAM, REOSC subcontractor for the manufacturing of the dummy mirror, mirror handling tool and transport container.

Although no "first light" is scheduled for this unfortunate brother of the Zerodur mirrors, it is already experiencing the first steps in the life of a real mirror. Indeed, the dummy mirror will serve many purposes:

- test of the mirror handling tool;
- test of the mirror container upon road and river transport and upon handling;
- test of the grinding and polishing machines at REOSC plant;
- tests with the primary mirror cell and structure;
- integration tests in Chile.

The two first steps are now com-