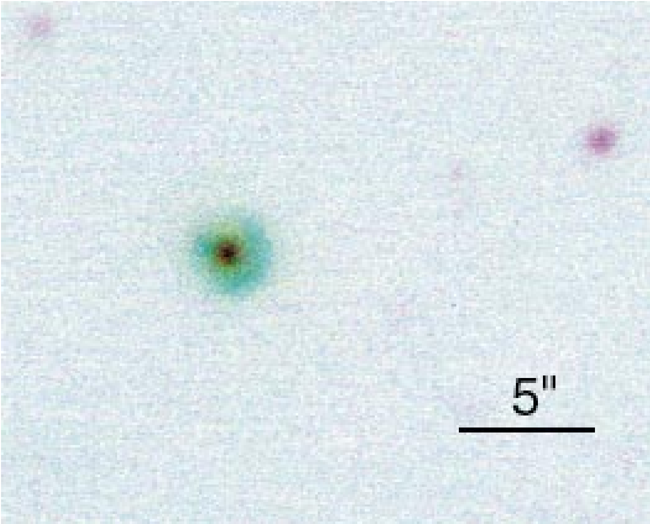

Figure 4: The colour composite image of the optical Einstein ring 0047-2808, produced by a red elliptical at z = 0.485 lensing a star-forming galaxy at z = 3.595. A 1-hour image through a narrow-band filter centred at the redshifted Lyα of the distant galaxy is coded green, while the 900-s B- and V-band images are coded blue and dark red, respectively. The lensing galaxy appears dark red at the centre of the ring.

tenance and trouble shooting support that was needed.

The rest of the SV Team, including Guido De Marchi, Francesco Paresce, Benoît Pirenne, Peter Quinn, Alvio Renzini, and Piero Rosati guaranteed quick reductions and quality control of the data in Garching and prompt feedback to the Team on Paranal. Fabio Bresolin and Rodolfo Viezzer of the Office for Science extensively contributed to the reductions and calibrations. Robert Fosbury and Richard Hook of the ST-ECF combined the coadded frames to produce the colour images presented here.

Results, problems, and strategy were discussed in daily video-conferences Garching-Paranal, that were also attended by Massimo Tarenghi, the Director of the Paranal Observatory. The video-conferences took place at about noon Garching time (6 a.m. on Paranal), with the Paranal team reporting on the observing conditions and the observations completed during the night, and the Garching Team reporting on the progress in inspecting and reducing the data of the previous nights. Then, while the Paranal people were sleeping, data from the previous night were inspected and reduced in Garching, with feedback on what was best to do during the following night being emailed to Paranal several hours in advance of the beginning of the observations. The SV Team was really active 24 hours a day.

The First Steps of UT1

M. TARENGHI, P. GRAY, J. SPYROMILIO AND R. GILMOZZI

Introduction

The Very Large Telescope is the result of 20 years' work by a large team of dedicated persons. We thank them all for their contribution. During the last few months we had the privilege to witness exciting moments. The following notes will enable the reader to share in those moments.

The Final Steps Up to First Light

During January and February 1998 the mechanical structure of the telescope underwent a series of tests and tune-ups. These activities were undertaken with the dummy cell and dummy secondary units installed. A small 8-inch Celestron telescope was attached to the telescope centrepiece, and a VLT technical CCD was put at its focus. The guide scope had first light in March. A rough pointing solution using 8 stars was derived for the telescope, which gave an rms pointing error of 8 arcseconds. The basic pre-setting and tracking of the telescope were also tested. Using a VLT TCCD for the guide scope also allowed us to test the basic functionality of the autoguiding system.

The code running on UT1 is almost identical to that running on the NTT, and very few code integration problems have arisen. The year spent on the NTT certainly has meant time saved on UT1. In Garching an additional control system, including TCCDs, routers and other peripherals, was also up and running. This allowed our colleagues at Headquarters to reproduce problems we were having on the mountain and provide quick fixes whenever possible.

Meanwhile in the base camp at Paranal, a complete duplicate telescope control system was established with identical configurations to the one running the telescope. The workstations and local control units in the base camp even shared networking addresses with the machines on the mountain top. One side effect was that, given this configuration, only one set of these computers could actually be connected to the Paranal network. The base camp control system was therefore completely stand-alone. To

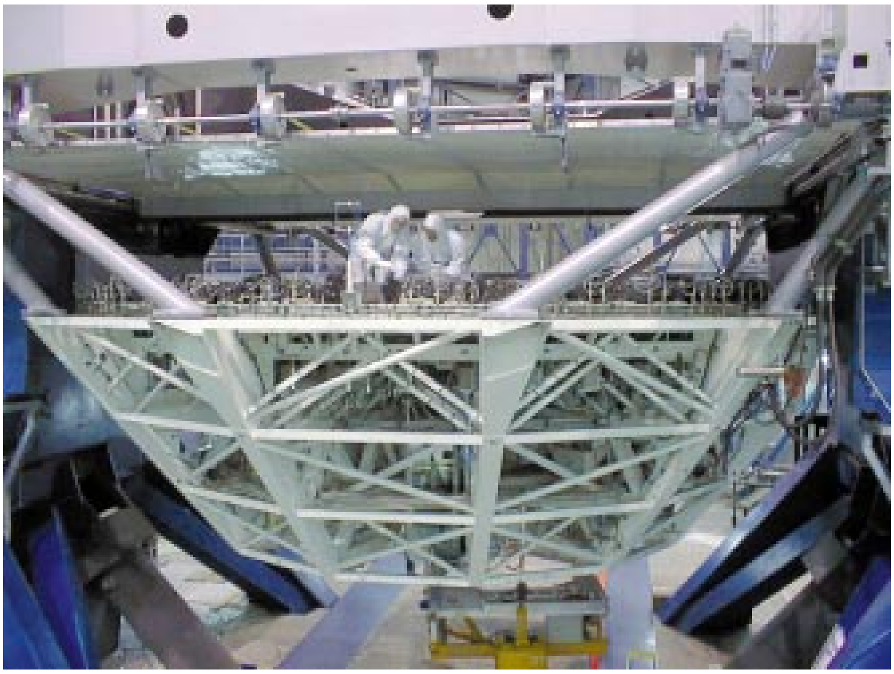

Figure 1: The start of the night.

transfer files between systems, necessary to keep the two systems aligned, a new class of network was used, known affectionately on the mountain as “footnet”.

One problem found during the tests in March was that the telescope oscillated in altitude by a few arcseconds. Extensive checks on the oil system by Juan Osorio and others did not reveal the cause. The problem was tracked down to the velocity controller that caused Martin Ravensbergen and Toomas Erm some headaches. However, they found the bug and following the fix they brought the behaviour of the telescope tracking down to excellent values. Without any windloading the telescope tracks with accuracies of 0.05 arcseconds rms for extended periods of time. However, when we pointed the telescope into the wind, the wind shake was clearly noticeable. This was expected to be the case from detailed simulations done during the design phase. The mechanism for compensating for wind shake is field stabilisation i.e. rapid motion of the secondary mirror equivalent to tip/tilt corrections. In the planning this was not foreseen to be implemented before August.

The priorities were changed. Gianlucca Chiozzi and Robert Karban went back to Garching and worked furiously on the control model to accelerate the implementation.

The secondary unit of the telescope and primary mirror cell were installed in the telescope in March. Valiant efforts by Max Kraus, who spent a good fraction of his time trying to convince everyone that an air-compressor was just like a tractor and he could fix it, which he did, together with Erich Bugueno and German Ehrenfeld along with a cast of ADS workers managed to fit the cell on to the telescope. The concrete dummy mirror was the location of many a conference on how the cell should be attached to the telescope for the first time. The behaviour of the telescope with a configuration very close to the one expected when the real glass went in could then be tested. Changes in the servo loop parameters and other such niceties, which are critical for the correct and safe behaviour of the telescope, were made.

The primary mirror cell was undergoing qualification tests now that we could move it around and tip it over. Inclination tests had been done in France prior to delivery to Paranal but now we had a real chance to move the thing around. It was hard to get Stefano Stanghellini, Gerhard Hudepohl or Marc Sbaihi out from inside the cell. We knew theoretically that pushing the emergency stop on the telescope under full speed would not activate the earthquake detector on the cell. Would it in practice? Would the airbag system inflate automatically when the cell tipped over 75 degrees? How far did the mirror move in the cell when inclined?

Figure 2: The team on the night of April 25.

The test camera had now been installed on the telescope. Martin Cullum and Ricardo Schmutzer were testing the software to make sure that when we needed to open the shutter, the instrument would actually take a good image. Flat fields and bias frames were taken constantly.

It was time to coat the mirrors before putting them into the telescope. Both the primary and the secondary mirrors had been on the mountain for a while sitting in their boxes waiting for their turn. So the coating chamber was fired up for a final check and ... we had a failure in the system which damaged the aluminium target used for the sputtering. Our colleagues in Linde, the prime contractor for the coating unit, were despondent. Not only had the unit failed at a critical time but they would also have to come all the way back to Paranal to repair it. A quick recovery plan was needed. Michael Schneermann went off to find another target (a non-trivial task since these are custom-made out of the purest aluminium) and Linde tried to find out what had gone wrong.

We now had to find a way to proceed without endangering the timeline for the telescope nor of course any of the optics. The secondary mirror went to La Silla, under the watchful eyes of Paul Giordano. Paul travelled with it along the 70 km of dirt road linking Paranal to the Pan-Americana highway at the excruciatingly slow speed of 5 km/h and then the other 700 km down to La Silla. Paul coated the secondary mirror at the 1.5-m tank and returned to Paranal. The quality of the coating and the mirror were excellent with reflectivities above 90 per cent and micro-roughness around 10 Angstroms. The mirror was then put into the unit, which, as mentioned above, was already installed in the telescope.

The primary was not so simple. We decided that we should install the uncoated mirror in the telescope and go ahead with the final preparations towards first light. Our integration plan, released back in 1996, for the first-light specification, allowed us to have an uncoated mirror at first light. In order not to delay the availability of the VLT to the community in April 1999, we decided (in agreement with the Director General) to proceed with first light as planned. So, in the third week of April, the cell went on its way down to the base camp, had the dummy mirror removed and the 8.2-m zerodur thin meniscus installed. On the night of the 21st of April, the telescope was almost all in place. Both the primary and the secondary mirrors were in place. We had already planned for a small celebration when these events had taken place. In the base camp, ESO and SOIMI had a party. For some of us it had to be cut short. We decided that on the same night we would try the telescope optics out. Before doing so, the protective plastic over the primary, which was placed on the mirror to protect it during transport from Europe to Paranal, had to be removed. Francis Franza and Paul Giordano put on their clean-room clothing, climbed on the mirror and started peeling the plastic off. We had thought the operation would take an hour or so but ended up taking three hours. Now we had a real telescope. The primary mirror looked truly beautiful. A couple of tests with the enclosure closed to ensure everything was O.K. and the big moment arrived. The enclosure doors were opened, the mirror cover retracted, and we pointed the telescope at a globular cluster. Zero forces were set on the primary and then the telescope was refocused manually. In a moment of great relief, the “first star” appeared on the guide probe. In retrospect, looking at that image, it is obvious that we had left the reference light arm (without the light on) in the beam, which explains the shadow one can see on that image. The star was about 2 arcseconds in size. Lothar Noethe quickly let us all know that this was exactly according to the specification for the zero forces configuration of the primary. Some of us had expected the star to just drift away, others that it would look nothing like a star. In fact, the telescope did us proud. Immediately the Director General was informed.

Now the task of running the telescope at night passed to the commissioning team although officially we had not had first light. Active optics tuning was the main task. Lothar Noethe, Stephane Guisard and Roberto Abuter started mapping the aberrations of the telescope, their orientation and their dependence on zenith distance. After a couple of nights of looking at 2 arcsecond stars and from time to time at stars that looked like pieces of string or propellers (when Lothar induced aberrations to check the behaviour of the cell), the time came to close the loop. The DIMM was not running that night, so we do not know what was the outside seeing. When the loop closed, the star became really small. We started taking short exposures with the guide probe and measuring the FWHM. The active optics was working away continuously correcting the mirror shape and the position of the secondary mirror. The first images were 0.8 arcseconds in size. Great jubilation in the little wooden hut inside the enclosure where all of the control was taking place. Stephane Guisard was placing bets as to whether we would beat the 3.6-m record. A few minutes later as the active optics worked, the images went down to 0.4 arcseconds. Only 3 nights after the optics had gone in, the telescope was already matching our highest expectations.

Pointing solutions and field stabilisation tests were started in order to improve the performance of the telescope. Pointing quickly came down to around the 3-arcsecond rms level. Field stabilisation baffled us all for a while. The nature of various time delays and the synchronisation of the TCCD with the secondary unit kept people busy for a while. Antonio Longinotti, our CCD software expert, made a couple of configuration changes and now we could move the M2 unit at frequencies up to 20 Hz.

Although first light was specified for the night of the 25th of May, the internal planning target date was the 15th of May. By this time we had moved out of the hut in the enclosure and were operating the telescope from the relative comfort of the control room. On the night of the 15th of May we decided that we should meet all specifications laid out in the integration plan for the telescope. The target was to be ω Cen. Conditions were excellent: low wind and good seeing. We started a 10-minute exposure on target with the test camera. We had never tried anything as long as this. Krister Wirenstrand anxiously waited for the test camera CCD to read out. This was to be the first true image taken with the telescope on a scientific CCD. When the image was transferred to the Real Time Display, we quickly measured the image quality. Great jubilation again as the stars appeared at 0.48 arcseconds. A series of other measurements on tracking stability and image quality verified the telescope had met all the performance criteria for first light.

By now, the new aluminium target had arrived on the mountain and had been integrated into the coating unit. Performance verification of the coating unit by Linde was under way. On the 18th of May the coating unit was ready. At 4 a.m. the telescope was stopped and parked in the mirror removal configuration. Martin Cullum and Francis Franza started taking the test camera off and by midday the mirror cell was off the telescope.

That night the cell and mirror were in the base camp. The mirror was detached from the cell overnight and the following day lifted out of the cell and into the coating unit. Our washing unit is not yet on the mountain. However, visual inspection of the mirror showed only light dust had settled during the 4 weeks the mirror had been in the telescope. Paul Giordano and Francis Franza started the long and laborious cleaning of the mirror using carbon dioxide snow. This worked very well, especially at the edge of the mirror. The mirror was now as clean as we could get it. The coating unit was sealed, evacuated and then the mirror was coated. The time had come to see what it would look like. We were concerned that since some dust had been left on the mirror, the coating might fail. We were glad to be proven wrong. Although better coatings will come, the first was already good. The reflectivity was above 90 per cent around the edges of the mirror and dropped to 89 per cent in areas where the CO_2 cleaning had not worked so well.

The mirror was put back into the cell and driven up to the telescope the following morning. Two nights and three days after it was removed, the completed operation returned the telescope back for further tests before first light. Would the

Figure 3: The first star.

Figure 4: Informing the DG.

Portuguese Minister of Science at Paranal

On Sunday, July 19, 1998, ESO was honoured to receive a visit by the Portuguese Minister of Science and Technology, Professor Mariano Gago, to the Paranal Observatory. The Minister was accompanied by the Ambassador of Portugal to the Republic of Chile, Mr. Rui Félix-Alves and a delegation.

The Minister visited the various VLT installations and, a scientist himself, expressed great interest in this new facility, now being constructed by the European Southern Observatory on behalf of the ESO member states. As foreseen in the 1990 Agreement that associates Portugal and ESO, discussions about future Portuguese membership in ESO have started.

The Portuguese Minister of Science and Technology, Professor J.M. Gago, with the VLT Project Manager and Director of the Paranal Observatory, Professor Massimo Tarenghi (right), ESO astronomer Dr. Jason Spyromilio (left) and members of the delegation in the VLT Control Room.

pointing solution have changed? Would the alignment and active optics calibration need to be repeated? The pointing indeed had changed. The stars appeared a full 2 arcseconds away from where they were before the entire operation took place. Such a small change encouraged us that the active optics would not need re-calibration. Indeed there seemed to be no need. The telescope was delivering 0.4 arcsecond images yet again.

Now all we had to do was wait for the 25th of May and keep our rendezvous with the press. Of course we could not resist and took images on the nights leading up to the first-light night. Julio Navarrete was on hand in the ASM hut running the DIMM and the meteorological station and answering the constant call on the radio: “Julio, can we have seeing please?” The night of the 24th was beautiful. Things had been going too well. At the beginning of the night the earthquake detector on the mirror cell went off. Stefano Stanghellini and Marc Sbaihi worked to release the mirror from the safety clamps and a few hours later the telescope was available again. Then at the end of the night when closing the telescope down, a major problem occurred. The mirror cover jammed half way across the mirror. Could it be repaired in time for the night of the 25th? Marc Sbaihi and the ADS crew came to the rescue. Working just above the mirror from early in the morning until after sunset, they managed carefully to open the cover and provide the beam to the telescope. The final hurdle had been overcome. The telescope was operational again. All this effort – and then the weather worked against us. The first half of the night things went well and some images were taken. Krister Wirenstrand operated the telescope while Anders Wallander made sure the test camera took the images. However, in the second half following our little internal celebration, the weather was poor and we shut the telescope down.

Commissioning of UT1

The commissioning of UT1 officially started immediately after first light. Most activities in commissioning involve tuning of telescope parameters and understanding how UT1 should be used. A number of software modifications are being made based on this better understanding that we have developed.

It took us far too long but eventually we realised that we had been focusing the telescope in the wrong way. We worked it out and on the 1st of June a new procedure was used. Since then the telescope has been in autofocus mode. We have made the guide probe parfocal with the instrument and have let active optics handle the telescope focus. In this mode the telescope focus is maintained continuously throughout an exposure as the active optics runs.

Improvements in the field stabilisation have been taking place. Birger Gustafsson has been reducing the delays in the M2 and Philippe Duhoux improved the centroiding algorithm in the CCD software. These changes improve the performance of the telescope under heavy wind load.

A lot of small changes here and there improved the reliability of the system and the operability of the telescope. Marco Chiesa worked on the control algorithm for the enclosure rotation and parking which has made the operation much smoother and faster. Thanh Phan Duc improved the guide-star acquisition procedure significantly.

Marc Sarazin, Stefan Sandrock and Rodrigo Amestica have brought the ASM to fully automatic status. Commissioning UT1 includes working with a cm-class telescope and understanding its problems as well. We are learning what it is to have a fully automatic telescope running.

Paranal is truly a beautiful site. The winter has given us quite a number of nights with poor conditions, sometimes it is cloudy and occasionally the seeing does go above 1 arcsecond. However, the beautiful nights are truly spectacular. On the night of the 26th of June, Anders Wallander and Ivan Muñoz took a series of 30-second exposures with an image quality below 0.35 arcseconds including one at 0.27 arcseconds.

The control and quality of the optics is excellent. Long exposures (900 and 1800 seconds) are taken as a matter of course to check the performance of the telescope under realistic observing conditions. The telescope routinely matches the outside. The active optics is run in continuous closed loop.

FORS, the first instrument to go on to the telescope in September, is already being re-integrated on the mountain, and ISAAC, which goes onto the telescope in November, is already integrated in the Control building.

A first commissioning/installation of the data-flow software was undertaken by Peter Quinn, Michèle Péron and Miguel Albrecht in June. All data from UT1 are now being archived immediately after they are taken. This includes the extensive operations logs that record all actions of the system. For example, all aberrations calculated in every active optics calculation are logged. All temperatures of the telescope, and there are many, are also logged. Every preset, offset, change in guide star and many other actions are logged. All telescope errors or unforeseen events are also logged. We use this information to better understand the telescope and how it can be optimised.

A lot of work remains to be done. The tertiary mirror will go into the telescope in August and the Nasmyth foci can then see light for the first time. The Linear Atmospheric Dispersion Compensator for the Cassegrain focus also goes into the telescope in August. Commissioning of the Nasmyth foci will take place between instrument installations. A better understanding of the dome louvers and how they affect the telescope performance is high on our priority list.

Science verification of the telescope is scheduled for the dark run in August, and we fully expect some beautiful data to result from these two weeks.

The cast of people working towards a successful VLT is too great to mention explicitly in such an article. The administrative support both in Garching, Santiago and Paranal that somehow managed to get all the pieces onto the mountain in time are thanked. Isabel Osorio was ever present and helping with pretty much everything. We also thank La Silla for providing us with coating facilities. Special thanks are due to Armin Silber, Enzo Brunetto, Mario Kiekebusch, Olaf Iwert and Claudio Cumani who all worked to get the test camera going; Marco Quattri who spent most of the northern winter on the mountain monitoring the erection of the telescope; Mathias Hess who worked tirelessly on the M1 cell and the transport of the mirror and then missed first light by a few weeks; Jean-Michel Moresmau who managed to fit the Cassegrain adapter into the cell and hook up all those little cables and wires; Manfred Ziebell who never stopped worrying about everything and anything and Michel Duchateau who worried about all the little details like emergency stop buttons; Jörg Eschwey and the facilities department on Paranal who built most of the things around us and who also switched all the lights off in the base camp; Canio Dichirico who made sure we had power when we needed it; Bruno Gilli, Gianni Raffi, Giorgio Filippi and others in the software group who kept us on the true path. Of course, we thank the entire VLT division in Garching for designing and building such an excellent telescope; our system and network administrators on the mountain, Chris Morrison, Nick Lock, Marcelo Carrasco, Sebastian Lillo, Graeme Ross, Mark Tadross and the ever present Harry Reay who made sure all systems were ready. We apologise to all that we have missed in our thanks.

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The Cost of the VLT

Text of a Report of the ESO Director General to Council at its (extraordinary) meeting of September 15, 1998

The purpose of this document is to provide an overview of the VLT cost evolution since 1987, and an estimate as of to-date of the total cost of this project at ESO until the completion of the VLT/VLTI in 2003. The total cost we quote includes the external contractual costs, the internal labour and other costs directly VLT-related, the development of the Paranal Observatory and its operations until 2003. This is the date that will see the completion of all 8-metre telescopes, the auxiliary telescopes and all approved instrumentation. It does not include the manpower costs at member state institutes contributing to the instrumentation programme.

The information compiled here is extracted from documents already submitted to Council. However it appears useful after the successful completion of first light, which removes any major technical uncertainties, to present a summary giving Council a global perspective on the project.

1. The VLT Contractual Cost

The VLT Programme was approved in 1987 on the basis of a proposal known as the “Blue Book”, which gave a cost estimate of 524 MDM (1998 prices) for the external contracts, including 34.8 MDM (1998 prices) for VLTI.

Since then the scope of the VLT Programme has evolved considerably to include some major new features and more complex solutions. These include the introduction of a Cassegrain focus and adapters with their subsequent impact on the M1 Cell and Main Structure, sophisticated test cameras, a time reference system, astronomical site monitors, etc.

In 1993 a complete Cost to Completion analysis was performed (Cou-483 and Add.) and subject to an external audit in 1994. Council subsequently approved a VLT Programme for 592 MDM (1998 prices) in which the Interferometry part had been postponed and its funding reduced to 7 MDM (Cou-516 conf.).

ESO worked out a recovery plan for the VLTI, which was presented to Council in 1996. The cost of this new plan (32 MDM in 1998 prices) was financed by reprogramming within the VLT and Instrumentation programme, by an additional contribution of 10 MDM by MPI and CNRS and through release of contingency funds.

Thus in the period 1994 to 1998 we have not changed the VLT programme cost to member states while fully restoring the VLTI programme.

The current VLT cost ceiling of 602 MDM for external contracts appears quite firm since we are at a point in the programme where we have committed 87% of the contractual cost. The increase of 15% with respect to the Blue Book Value of 1987 is fully justified by the substantial changes in scope of the project mentioned above.

2. Total Cost of the VLT Programme

The Blue Book did not provide an estimate of the total cost (including ESO staff and other internal costs). An evaluation of the VLT-related internal costs, i.e. engineering costs in Garching and site costs at Paranal, was performed in 1993 and also subject to the 1994 external audit.

In 1996 ESO submitted to Council a long-range plan to bring the Organisation to the steady state of operations of the full VLT/VLTI (1996–2003) while implementing strict cost containment measures to meet a reduction in the projected mem-