No. 90 – December 1997

TELESCOPES AND INSTRUMENTATION

A Deep Field with the Upgraded NTT

S. D'ODORICO, ESO

This colour deep image has been prepared from 4 deep images through the filters *B*, *V*, *r* and *i* obtained with the SUSI CCD imager at the ESO NTT. The image covers a 2.2 × 2.2 arcmin "empty" field centred about 2 arcminutes south of the z = 4.7 QSO BR 1202-0725. The four images result from the co-addition of dithered short integrations for a total of 52,800, 23,400, 23,400 and 16,200 seconds in the four bands, and the co-added images have average FWHMs of 0.84, 0.80, 0.80 and 0.68 arcsec respectively.

The data were obtained for a scientific programme approved for the ESO Period 58 and aimed at the study of the photometric redshift distribution of the faint galaxies and of gravitational lensing effects in the field. The P.I. of the proposal is Sandro D'Odorico and the Co-P.I. are J. Bergeron, H.M. Adorf, S. Charlot, D. Clements, S. Cristiani, L. da Costa, E. Egami, A. Fontana, B. Fort, L. Gautret, E. Giallongo, R. Gilmozzi, R.N. Hook, B. Leibundgut, Y. Mellier, P. Petitjean, A. Renzini, S. Savaglio, P. Shaver, S. Seitz and L. Yan. The programme was executed in service mode by the NTT team in February through April 1997 in photometric nights with seeing better than 1 arcsec. The programme, one of the first to be carried out at the NTT after the upgrading of the hardware and software to VLT standards, was a useful test case for ESO for the operation of the upgraded telescope and for the new procedures and software packages, such as Phase II proposal preparation, service observing, data-quality control and the archiving and distribution of the data. The preparation of the co-added images and the first photometric estimates have been carried out by S. Arnouts and S. Cristiani. The 3σ limiting magnitudes in the AB system computed over an aperture of 2 × FWHMs, are 27.20, 26.93, 26.61 and 26.20 in the four bands respectively. The three-colour deep image has been prepared by R.A.E. Fosbury and R.N. Hook at the Space Telescope European Co-ordinating Facility combining the *B*, *V* and (*r* + *I*) co-added frames. The fainter objects seen in this reproduction have magnitudes 26.

The image illustrates well the capability in deep imaging at good angular resolution at a 4-m-class ground-based telescope with a relatively modest investment in exposure time. It takes advantage of the combination of good seeing and fine sampling (0.12 arcsec/pixel) of the telescope point-spread function. The limiting magnitudes are already fainter than those which can be reached in spectroscopy of continuum sources at 8–10-m telescopes. The colour image shows the crowding effect at faint magnitudes and in particular the frequent close pairing of objects of very different colours, which would lead to confusion under worse seeing conditions. Of the approximately 500 galaxies detected in this field, the largest fraction are expected to be at redshifts smaller than $z = 1$ and about 20% to be distributed at higher z, up to $z = 4$ and possibly beyond.

These data will be of value for scientific investigations beside those proposed by the authors and can be used to test data-reduction and simulation packages to be applied to other larger surveys. On these grounds the calibrated images, as well as their colour combination, will be made generally available on the ESO web site by January 1998.

Sandro D'Odorico
sdodoric@eso.org

The ESO VLT – Progress Report

M. TARENGHI, ESO

The latter half of 1997 and the coming year represent certainly the most challenging time for the VLT Programme. Notwithstanding delays which occurred in some areas, the project achieved major technical progress and milestones and we are fully prepared to complete the first Unit Telescope integration on Paranal.

There has been a great deal of activity in many different areas at the ESO Paranal Observatory. Work has continued on the assembly of various components of the Telescope Structures and on the surface of the summit platform, as well as in connection with the maintenance and storage facilities near the base camp at the foot of the mountain. The Telescope Structure of the first unit is complete inside the enclosure as shown in Figure 1.

The first large unit transport to Paranal was completed successfully in July 1997. After the European Acceptance Testing, the M1 Coating Unit was shipped to Chile, see Figures 2 and 3. The installation of the unit in the Mirror Maintenance Building was finished at the end of September this year. At present the Coating Unit is being commissioned and tested. The provisional acceptance tests started at the beginning of November.

After the successful completion of the European testing by GIAT in St. Chamond, France, and a long journey from Europe to Chile, the first Very Large Telescope mirror cell (VLT M1 cell) and a concrete 8.2-m dummy mirror were unloaded in the port of Antofagasta on October 31, 1997. From here they were transported by special

Figure 1: A recent view of Unit Telescope 1 through the open slit doors in the upper rotating part of the enclosure.

Figure 2: The VLT coating plant in front of the Mirror Maintenance Building on Paranal. After removal of the upper part of the vacuum chamber, the lower part is lifted off the carriage, allowing a good view of the individual parts, including the rigid transport structure.

trucks to the Paranal Observatory, see Figures 4 and 5.

Both the mirror and the cell arrived well at Paranal and a thorough check showed that they had suffered no damage during the transport from Europe, see Figure 6. Accordingly, green light was given right away to send the first polished 8.2-metre VLT mirror of Zerodur from the REOSC factory in St. Pierre du Perray, south of Paris, to Paranal. The mirror, securely fastened in a box of the same design as the one in which the dummy mirror was moved, departed by river barge on the Seine a few days later. It was loaded on an ocean-going vessel in the port of Le Havre on November 12, see Figures 7 and 8. The expected arrival time in the port of Antofagasta is mid-December *(see Latest News on page 18)*.

GIAT started the M1 Handling Tool installation in the Mirror Maintenance Building end of July and has already completed it.

Figure 3: View from the inside of the Mirror Maintenance Building through the 10-m door. The lower part of the coating plant has been placed on the air cushion transport system which will move it along the two tracks seen in the foreground. The total moving weight with an 8.2-m mirror in the chamber is about 50 tons.

Figure 4: The convoy on the "Old Panamericana Road" in the Atacama desert, north of Paranal.

A major achievement is the completion of the polishing activity of the first M2 Beryllium Mirror by REOSC and its delivery to DORNIER in September 1997. The first Electro-Mechanical Unit tests by DORNIER have demonstrated compliance of the M2 Unit performance in the fields of focusing, centring, thermal control and sky baffle.

The system tests with the M2 Beryllium mirror started in October and the Provisional Acceptance of the M2 Unit

Figure 5: The truck with the M1 cell approaches the base camp, at the foot of the Paranal mountain. The enclosures that house the VLT unit telescopes are seen at the platform at the top.

Figure 6: The M1 cell and the dummy mirror arrive in front of the Mirror Maintenance Building (MMB). Here they are being unloaded and placed next to the 10 metre wide entrance.

no. 1 is planned for the beginning of December 1997 *(see also Latest News on page 34)*.

The first M3 Cell and Mirror were tested mid-June and will be delivered in Europe mid-November 1997.

One Cassegrain and two Nasymth adapters for Unit Telescope 1 have been accepted and have already arrived on Paranal. The adapters for the Unit Telescope 2 are also nearing completion, one Cassegrain and one Nasmyth have already been accepted and the second Nasmyth acceptance is planned for December 1997.

The Clean-Room construction has been completed successfully in Europe and is now on the ship to Antofagasta. The installation will start immediately after the completion of the Coating Unit in December 1997.

The installation of the Power Station and various subsystems has been completed. The commissioning of the diesel engines due to the adjustment of the engine to the site altitude took longer than expected because it is the first time that this type of engine has been installed at the altitude of the VLT Observatory. In October the power station was run for 200 hours showing excellent performance.

The first part of the acceptance testing of the first enclosure was performed during the second half of July 1997. The second part of acceptance testing, i.e. testing of the air-conditioning system and the operations simulations, will be performed after completion of the chilled liquid plant in parallel with ESO integration during the first quarter of 1998.

The key schedule targets, i.e. First Light and release of the first telescope for the instrumentation are planned for June 1998 and October 1998.

ESO made a considerable effort to co-ordinate the work by all contractors on the Telescope Area and Maintenance Area Buildings and succeeded in achieving excellent progress and co-operation with a minimum of disturbance between contractors performing crucial tasks side by side in the same areas.

In the reporting period the VLTI Team was reinforced and the new group head took up his duty in September. The Delay Line proposals have been received and the technical evaluations has been completed; Fokker Space was selected as a contractor. The foundations of the Auxiliary Telescopes are in an advanced phase of construction on Paranal.

Figure 7: The 8.2-m mirror being lifted from the river barge onto the M/S TARPON SANTIAGO in Le Havre.

Figure 8: The 8.2-m mirror in its final location on the ship.

A Cloudy Night Again? Blame El Niño!

A STUDY OF THE IMPACT OF EL NIÑO ON THE CLOUD COVER ABOVE ESO OBSERVATORIES IN CHILE

M. SARAZIN, ESO

Tropical ocean circulation adjusts itself permanently with respect to trade winds seasonal fluctuations. For instance in the equatorial Pacific, winds in normal regime push warm oceanic surface water towards the western edge of the basin. This generates a slope of the sea level of 40 cm per 10,000 km between Australia and South America. By the end of the year, when the trade winds weaken, the trend is reversed, the pressure is released and the ocean recovers a horizontal surface.

Should the trade winds weaken excessively, the accumulated warm water is not only released towards the east but also far southwards along the Peruvian coast as shown in Figure 1, blocking the normal upwelling of cold nutritive deep water in this area and contradicting the northward circulation of the cold Humboldt Stream along the Chilean coast. This is the so-called El Niño (named after a Peruvian Christmas festival) because it normally starts in December, near the birthday of the Christ child. This phenomenon creates tremendous sea-atmosphere thermal energy transfers, causing heavy precipitations all along the coast of South America and severe draught in Australia during the following year.

The changes in the ocean topography are nowadays monitored by dedicated satellites such as TOPEX-POSEIDON but the history of past El Niños could only be written with meteorological parameters available over long periods of time. Meteorologist have found that the difference of pressure at sea level between Tahiti and Darwin (North Australia) could be used to generate an index number fairly representative of the cyclic warming and cooling of the eastern Pacific[2]. A negative index corresponds to an El Niño while the positive periods (colder water) are named La Niña. This so-called Southern Oscillation Index (SOI), presented in Figure 2 for the past 14 years, reflects the relative strength of successive events. In particular, it is shown that the current anomaly is not yet as powerful as the devastating 1982/83 event. The object of this study is to analyse the correlation of the SOI with the cloud cover above the observatories of La Silla and Paranal so as to assess the usefulness of the SOI as a tool for the long-term planning of the observatory operation. It will be shown that not only the absolute value, but also the relative amplitude of the oscillation are to be taken into account when using the SOI as a predictor of the average clear sky statistics for the year to come.

The database of photometric quality accumulated during the 1983–1990 VLT site survey[3] is continuously maintained by the ESO site monitoring team. The statistics for La Silla[4] are extracted from the observing reports while the monitoring of the Paranal sky is performed by a dedicated staff every two hours along well established rules[5].

The average monthly percentage of photometric nights has been computed

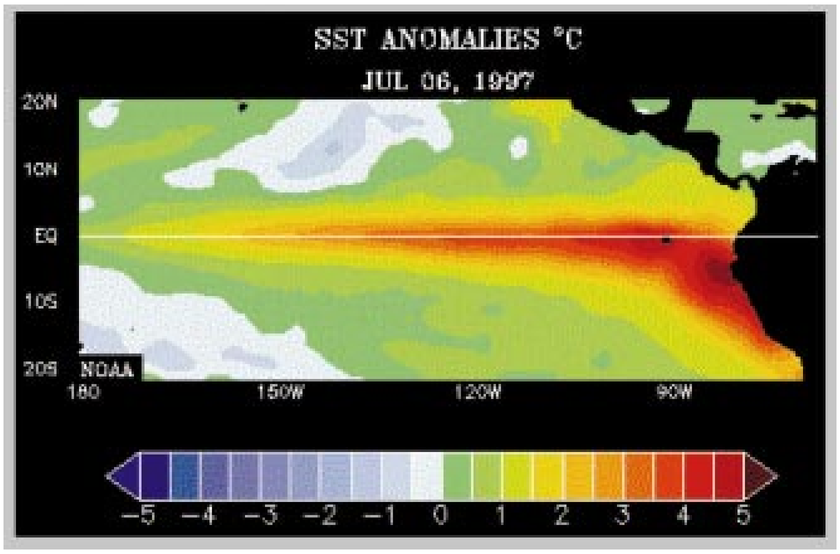


Figure 1: Map of Sea Surface Temperature Anomaly at the heart of an El Niño event. Warm surface waters spread southwards along the Peruvian coast.[1]

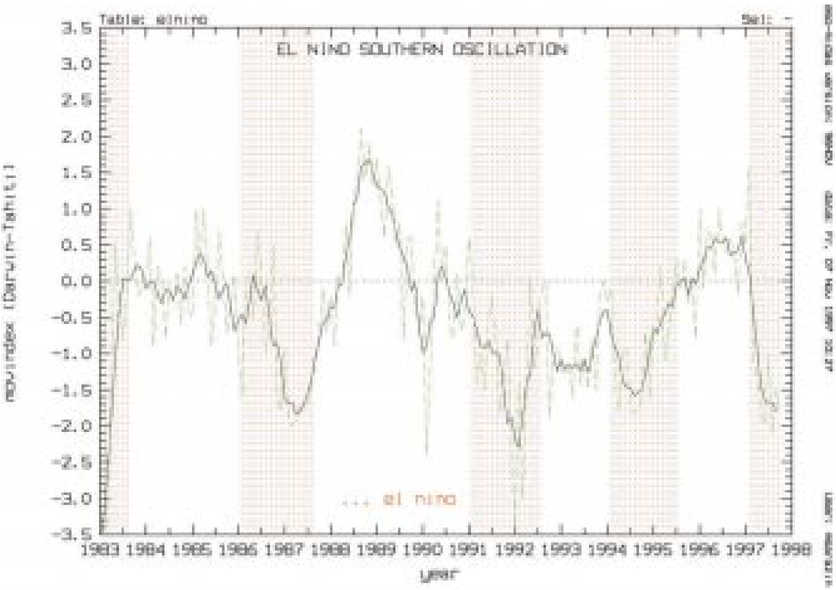


Figure 2: Southern Oscillation Index: the difference of sea level pressure between Darwin and Tahiti as monthly average (green line) and seen through a 5-month wide moving window (black line). Red shadings indicate main past El Niño events with the theoretical January occurrence and 18 months duration.

[1]Source NOAA: http://www.pmel.noaa.gov/toga-tao/el-nino/home.html

[2]See the WEB page of J. L. Daly at http://www.vision.net.au/~daly/elnino.html

[3]A. Ardeberg, H. Lindgren, I. Lundström; La Silla and Paranal: a comparison of photometric qualities, *Astron. Astrophys.*, **230**, 518, 1990.

[4]Available at http://www.ls.eso.org/lasilla/weather/weather.html

[5]VLT Site Selection Working Group; *Final Report;* November 14, 1990, VLT Report No. 62.

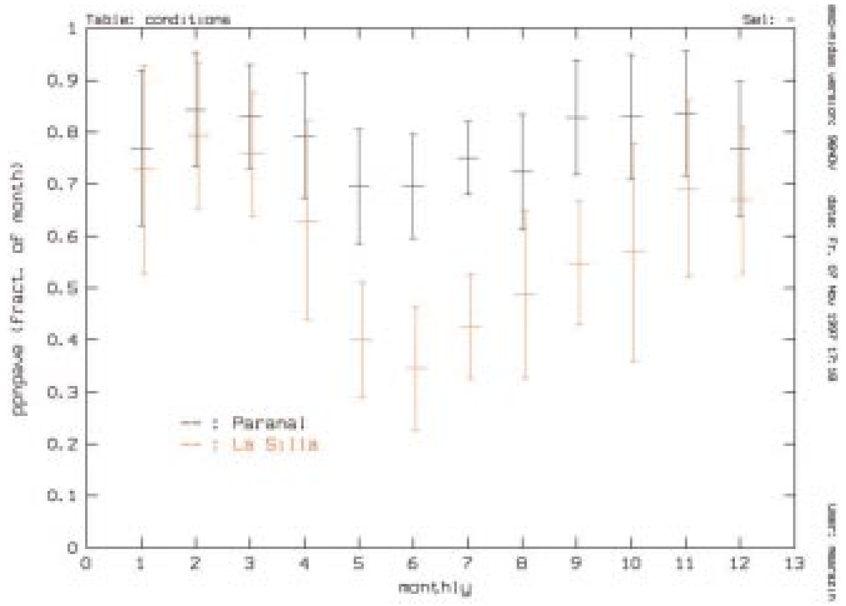


Figure 3: Cloud Cover: the average fraction of available photometric nights as a function of the month of the year at Paranal and La Silla observatories computed over the 14-year-long database. The error bars correspond to ± the rms.

for both sites over the length of the database (Fig. 3). The Cloud Cover Anomaly (CCA) is then computed for each month as the relative deviation from these average conditions. It is shown in Figures 4 and 5 that the peak-to-peak variation between surplus and deficit can reach 70% at La Silla and half that value at Paranal. However, the damage is obvious on both sites after conversion into loss of observing time: the difference in number of available photometric nights during El Niño and La Niña years can amount to 90 nights at La Silla and 50 nights at Paranal.

In spite of the fact that a fraction (50% at La Silla) of the non-photometric nights can still be used for spectroscopic observations, the efficiency of the observatory is considerably decreased as the location of the patches of sky free of clouds is not known in advance.

The observatory performance is thus directly related to the CCA, and it is easy to imagine that predicting it would allow to better plan heavy operations, such as telescope upgrade, and also to inform the astronomical community. El Niño events are supposed to start in December for a duration of one and a half year. However, a look at the SOI (Fig. 2) shows that the picture is by far not so clear. While the 1991/92 event has perfectly followed the rule, the 1986/87 had a delayed start but kept nevertheless the nominal duration so that it terminated only at the end of 1987. This phase fluctuation is particularly well reproduced for those two examples on the CCA of La Silla. Also the aborted SOI event of December 1989/January 1990 is well visible on the La Silla CCA but less obvious at Paranal. Finally, the softer El Niño of 1994/95 did not affect Paranal CCA at all, and is buried in the noise of the La Silla CCA. If the strength of an event is reflected by the amplitude of the SOI decrease during the La Niña/El Niño transition, a value larger than 1.5 would be a reason-

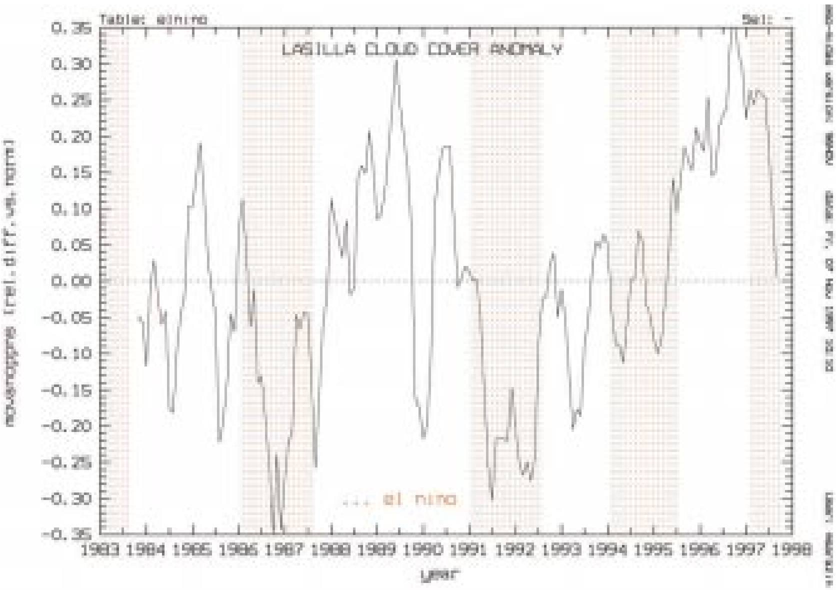


Figure 4: Cloud Cover Anomaly: the relative deviation from the monthly average number of photometric nights at La Silla observatory, seen through a 5-month-wide moving window. Red shadings indicate the strongest past El Niño events with a theoretical January occurrence and 18 month duration.

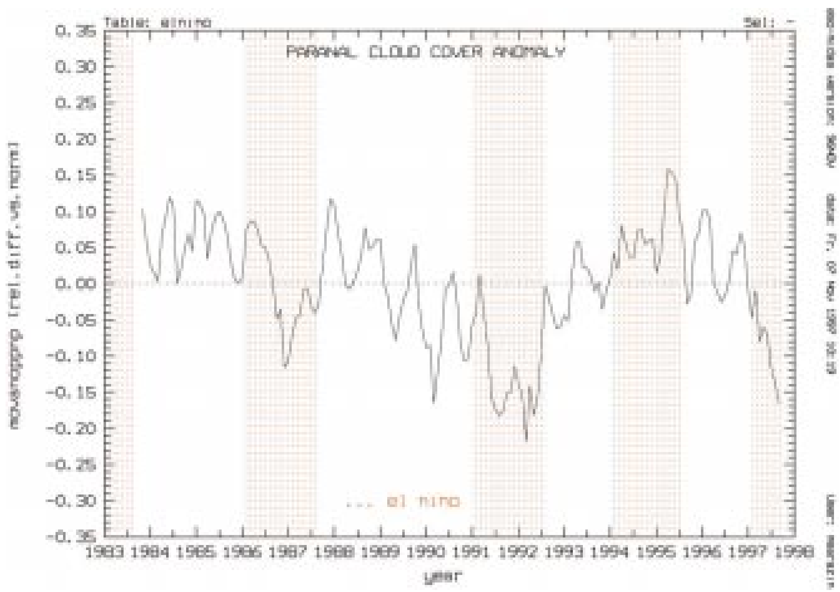


Figure 5: Cloud Cover Anomaly: the relative deviation from the monthly average number of photometric nights at Paranal observatory, seen through a 5-month-wide moving window. Red shadings indicate the strongest past El Niño events with a theoretical January occurrence and 18 month duration.

	1984	85	86	87	88	89	90	91	92	93	94	95	96	1984–1996
La Silla	57	59	53	50	66	66	56	53	51	57	58	60	75	58.5
Paranal	80	82	80	77	81	78	71	71	69	79	81	83	81	77.9

Table 1: Yearly average percentage of photometric nights at ESO sites.

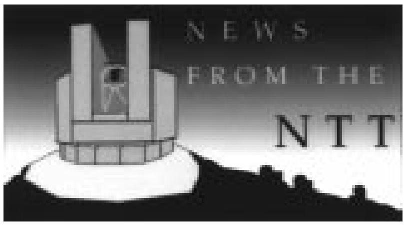
able limit for deciding of its relevance to astronomy.

In addition to the seasonal weather patterns affecting the Atacama desert[6], the analysis of the SOI-CCA dependency is further complicated by the presence of longer-term climatic fluctuations whose periods are counted in decades and which have no apparent phase relations with El Niño events. For instance La Silla, which has been following since 1992 a positive slope, is thus comparatively less affected by the current El Niño than it had been in 1991 when the effects were cumulative.

The SOI is not currently predictable but meteorologists are making progress in the understanding of atmosphere-ocean interaction. As far as ground-based astronomy is concerned, the assessment of atmospheric effects has also drastically improved in the past 10 years. Nevertheless, long-range forecasts will remain for some time limited to subjective analyses leading to cautious statements of the type: “Observing conditions will degrade at ESO observatories in 1998. However, if the current El Niño situation persists, conditions at La Silla will probably not reach historic lows of 1987 and 1992.”

M. Sarazin
msarazin@eso.org

[6]ESO Internal Workshop on Forecasting Observing Conditions, *The Messenger* 89, Sept. 1997, pp. 5–10.



NEWS FROM THE NTT

G. MATHYS, ESO

The NTT has, at the time when this is written, been back into operations for 4 months. Emphasis during that period has been laid on stabilising the control system and developing an operational model. Accordingly, there has been virtually no technical intervention except for fixing problems or improving the robustness, in strong contrast with the upheaval of the Big-Bang year during which most of the control system had been replaced.

The Operational Model

Two modes of operations are currently supported at the NTT: service and classical.

Service observations are performed by the NTT support astronomers according to the schedule defined by the User Support Group (USG) of the Data Management Division (DMD). The latter is established according to the OPC recommendations and is supplied to the NTT Team under the form of Observation Blocks (OBs) which reside in a database.[1] The OBs, each of which fully describes an observation, have been defined generally well before they are scheduled by the PIs of the selected programmes, using the Phase 2 Proposal Preparation (P2PP) tool. The OBs are assembled into a schedule by the Observing Tool (OT), which is the interface between the database and the High-Level Observing Software (HOS) running on the acquisition workstation.

During the second half of Period 59 (that is, for observations to be performed until the beginning of October), PIs had to travel to the ESO headquarters in Garching to run P2PP to prepare their OBs. As of its version 1.0, released by the USG in September, P2PP has started to be distributed outside ESO, and applicants who have been allocated observations in service mode with the NTT now have the possibility to install this software on their own computers and to carry out the phase 2 preparation in their home institutes. This is done with the support of the USG, which answers questions and to which possible problem reports must be addressed.

Essentially the same scheme is followed for classical observations. Visiting astronomers are invited to come to La Silla two days before the beginning of their run, to prepare the bulk of their OBs on the La Silla off-line computing system before the start of their observations. This step is carried out with the help of the NTT support astronomers. P2PP is also run at the NTT during observation to perform last-minute modifications of the OBs.

Classical observers can, of course, also get the P2PP software from ESO and use it to prepare their OBs at home. However, ESO does not have the means to provide on-line support for that case, so that questions and problems that might arise at that stage will have to be solved upon arrival of the visiting astronomer on La Silla.

A calibration plan defined jointly by the USG and the NTT Team is executed by the latter on a daily basis, so as to guarantee that all the data that are taken can later be calibrated in a standard manner. The use of P2PP and the regular execution of the calibration plan guarantee that the data coming out of the NTT are suitable for archive research. As a matter of fact, all the data taken are systematically archived.

The archiving process is still very much in the same transitional status as reported in the previous issue of *The Messenger*, as far as the automatic archiving software is concerned. However, on the operational side, significant progress has been achieved on at least two aspects. One is the implementation of a (temporary) tool to transfer in real time the data obtained during service observing to an archive machine in the ESO Garching headquarters, in order to speed up delivery to the investigators by the USG. On the other hand, on-site production of the CD ROMs on which the data are eventually archived has begun on La Silla.

System Performance

Overall, the telescope and instruments have performed very smoothly since the return into operation. There has been only a very small number of failures of the new control system, and they could in general be fixed in a minimum time. Accordingly, the overall technical downtime has been low. However two problems of more importance were

[1]The concept of OB has already been described on various occasions in previous issues of *The Messenger* (see e.g. the NTT News in the last issue).

Table 1. NTT downtime during the second half of Period 59.

Observing mode	Weather downtime (%)	Technical downtime (%)	Effective technical downtime (%)
Classical	30.5	3.8	5.5
Service	29.6	1.9	2.7
Classical & Service	30.2	3.2	4.5
Technical time	58.9	—	—
Grand total	33.7	2.8	4.2

identified, which are not intrinsic to the VLT standard control system.

As a matter of fact, the very bad weather conditions that have prevailed on La Silla throughout the Chilean winter have, by far, been the main source of loss of observing time since the NTT has resumed operations. This is clearly seen in Table 1, which summarises the NTT downtime statistics for the second half of Period 59, that is, from June 27 to October 9. The repartition of the downtime between the various operational modes is given in that table, where the successive rows correspond respectively to the nights devoted to classical observing, to those dedicated to service observing, to the total of the former two (that is, to all the nights assigned to regular observations), to the scheduled technical nights (for which the notion of technical downtime is meaningless), and finally to the grand total of all the nights of the half period. These modes are identified in the first column of the table. The other columns give, in order, the percentage of the total nighttime lost due to bad weather, the fraction of the total nighttime lost for technical reasons, and the fraction of the time when weather was suitable for observations and when it was impossible to observe because of technical problems (i.e., the ratio of the technical downtime to the difference of the total nighttime and of the weather downtime).

In terms of the performance of the NTT, the most relevant entry in Table 1 is the effective technical downtime for the nights when regular observations were scheduled, once that the total nighttime available has been corrected for the 30.2% of time during which bad weather prevented observations from being executed. The good performance of the NTT during the first months of operations is reflected by the fairly low effective technical downtime of 4.5%.

A considerable fraction of the effective technical downtime can be assigned to one of the two main problems mentioned at the beginning of this section. This problem had already been anticipated in the NTT page of the previous issue of *The Messenger*: the CAMAC motor controller has been failing repeatedly, at a rate of 2–3 times per 24 hours. Let us recall that this is one of the few parts of the control system that has not been upgraded. Similar failures were already occurring before the Big Bang, but much more seldom; they appear to be due to an intrinsic flaw in the design of the controller. The problem has been tackled energetically during the first months of operations. The huge increase of the number of failures with respect to the old control system was found to be due to a difference in the way in which the controller is accessed. A workaround was found and implemented in the second half of September, which basically restores the pre-Big-Bang level of reliability of the element. Since these failures account for a large fraction of the Period 59 technical downtime, the latter is expected to be significantly lower during Period 60.

The other major problem that was identified is a quick degradation of the telescope pointing. While pointing models are built with a root-mean-square accuracy of about 1″, pointing errors of up to 15–20″ develop in timescales of days. This situation is probably not new: pre-Big-Bang measurements were already hinting at a similar effect. The impact is actually small for most observing programmes. But the problem has been emphasised by the unusually strict requirements set by the execution at the NTT of the ESO Imaging Survey, for which mosaic images are taken, which rely on the expected excellent pointing of the NTT. It is currently under investigation, and a preliminary analysis indicates that the origin is an undue mechanical motion. However, the faulty element remains to be identified.

Technical Developments

As mentioned in the beginning of this note, emphasis in the last 4 months has been laid upon system stability. Accordingly, technical developments have been kept to a minimum, and have mainly aimed at streamlining and improving the reliability of operations. Within that framework, an area of particular relevance has been the templates (used to drive the system through the HOS), whose functionality, efficiency, and reliability have been considerably enhanced. Other areas where important consolidation work has been conducted in the background include the autoguider and the active optics. The work done may often remain almost invisible to the users, but it proves essential for the long-term robustness and usability of the system.

A rare exception to this situation has been the installation in August of a new *in-situ* cleaning unit for the primary mirror. The interest of this modification had been perceived before the Big Bang in a study of the results of the mirror cleaning. It is too early to assess the progress achieved with the new unit.

The current frozen situation of the NTT will come to an end in December, when the installation of SOFI begins. This will mark the start of a new series of major upgrades, which will be described in future issues of *The Messenger*.

Personnel Movements

There have been two departures and two arrivals in the NTT Team since the writing of the NTT page for the previous issue of *The Messenger*.

In July, Joaquín Pérez has resigned from ESO for personal reasons after many years of excellent services. Joaquín has been employed in various functions within ESO, including those of telescope operator, responsible for the preparation of the photographic plates, and member of the optics group, before joining the NTT Team as daytime operator. In all of them, he has been very appreciated for his dedication, his care, and his kindness.

In July too, Blanca Camucet has joined the NTT Team as Data Handling Operator, a new function, which falls within the framework of the support of VLT Operations by the DMD. As a matter of fact, Blanca will be assigned to the NTT only temporarily, in preparation of her passage to the VLT, as soon as the latter starts to produce data. Her current work is part of the prototyping of the VLT operational model at the NTT. Blanca's responsibilities include the archival of the data (in particular the preparation of the CD ROMs) and the maintenance of the databases.

August saw the replacement of Pierre Martin by Jean-François Gonzalez in one of the positions of postdoctoral fellow in the NTT Team, and in the function of EMMI Instrument Scientist. Pierre had joined ESO and the team in the beginning of 1996. As responsible for the commissioning of EMMI, he has been instrumental to the success of the NTT Big Bang. The difficulty of the challenge that he had to face cannot be overstated, and he takes a large credit for the fact that

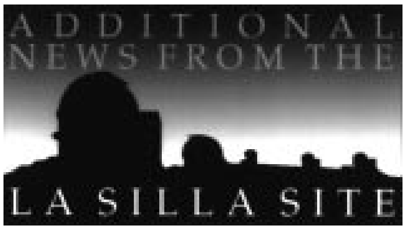
EMMI is now working smoothly and reliably. Through a well-deserved recognition of his merits, Pierre has now been hired as staff astronomer at the Canada-France-Hawaii Telescope.

I take advantage of this occasion to welcome the newcomers, and to wish success in their new activitities to those who have left us.

Erratum

In the NTT News page that has appeared in The Messenger No. 89, at the bottom of the rightmost column of page 12, reference has been made erroneously to Period 60, instead of Period 59. One should read: ". . . the already described delays . . . have prevented the NTT Team from executing many of the service observing programmes that had been approved by the OPC for the first half of Period 59 . . .".

Gautier Mathys
gmathys@eso.org



The La Silla News Page

The editors of the La Silla News Page would like to welcome readers of the eighth edition of a page devoted to reporting on technical updates and observational achievements at La Silla. We would like this page to inform the astronomical community of changes made to telescopes, instruments, operations, and of instrumental performances that cannot be reported conveniently elsewhere. Contributions and inquiries to this page from the community are most welcome.

(R. Gredel, C. Lidman)

SOFI – Current Status

C. LIDMAN

SOFI (Son of ISAAC) is the new IR imaging spectrograph on the NTT. It replaces both IRSPEC, which was decommissioned last year, and IRAC2b which will be decommissioned in 1998. SOFI recently underwent system tests in Garching. Both the spectroscopic and imaging modes were successfully tested. The efficiency of the instrument is almost double that of IRAC2b. The performance of the Rockwell HgCdTe 1024×1024 array and the IRACE controller is excellent. In non-destructive read-out, the read-out noise of the array is a few electrons. This is comparable to the read-out noise of optical CCDs. During November, the instrument will be shipped to Chile. It will be installed on the NTT during December, where it will undergo further system tests. The instrument will be commissioned during March next year and offered as an ESO common user instrument during Period 61.

Further details can be found at the NTT web page: http://www.ls.eso.org/lasilla/Telescopes/NEWNTT/NTT-MAIN.html

Image Quality of the 3.6-m Telescope (Part VI) Now Diffraction Limited at 10 Microns at the f/35 Focus

S. GUISARD, U. WEILENMANN, A. VAN DIJSSELDONK, H.U. KÄUFL, J. ROUCHER, ESO

The images at the f/35 Cassegrain focus of the 3.6-m telescope have never been excellent. As the system (c.f. [1]) was initially installed and used to do only aperture photometry, this was never an issue of major concern. In fact, it could not even be measured directly. Only with the advent of mid-infrared cameras (here TIMMI [2],[3]) the image quality could be measured easily and systematically. Several reports state that the average Image Quality (IQ) over the last years was of the order of 1.5″ FWHM with exceptionally some good images below 1.0″. These images were made with TIMMI at 10 microns, the only instrument and wavelength used presently at the f/35 focus. As a consequence of the less than perfect image quality, the Strehl ratio and hence the sensitivity for point sources was degraded, typically by a factor of two. The IQ was poor compared to the diffraction limit at 10 microns on this telescope (0.7″) and the average seeing at La Silla at the same wavelength (between 0.5″ and 0.7″). This comparison leads to the evidence that the "man-made" degradation of the image is important.

This article summarises investigations, corrective actions and the results finally obtained after several periods of technical time (Work Component

Figure 1: Hard and heavy mechanical work at the observing floor: H. Quichón and P. Alvarez are remachining the spider of the infrared f/35 secondary at the observing floor of the 3.6-m dome.

Figure 2: The team, from left to right U. Weilenmann, S. Guisard, A. van Dijsseldonk, P. Bouchet and J. Roucher "breathing down the neck" of the optical engineer waiting for the output of ANTARES, ESO's portable Shack-Hartmann camera for quantitative image quality assessments.

19 of the 3.6-m Upgrade Project) in October 1996, November 1996 and July 1997 [4].

The technical time in October 1996 was originally foreseen to remove the decentring coma by moving the secondary mirror. This defect was known for long but could never be corrected due to the lack of adjusting range of the spider of the telescope. After mechanical modification of the spider mounts the coma could be reduced from 1.0″ d80% to less than 0.3″. At the same time we discovered a large astigmatism of the order of 0.8″ coming from M2. This astigmatism was due to the (heavy) chopping counterweight of the secondary mirror which was introducing deformations in the mirror. A new counterweight was manufactured from Tungsten (density 19.3!). This allowed to achieve the same dynamical properties in the restricted design space with less than half of the mass of the old device machined from copper as now on average most of the mass of this counterweight is located farther away from the chopping rotation axis. The astigmatism produced by M2 was thereby reduced from 0.8″ to 0.4″. The actual values of coma and astigmatism due to M2 (respectively 0.3″ and 0.4″) have to be added vectorially to the same aberrations arising from M1. Thus the resulting aberrations of the complete telescope depend on the angle of rotation of M2 around its optical axis. The Optical Quality (OQ) of the whole telescope at the f/35 focus therefore varies between 0.4″ and 0.9″ depending on the position of M2, the average being smaller than 0.6″, which means below the diffraction limit at 10 microns. As a comparison, before October 1996 the OQ of the telescope at f/35 was varying between 0.9″ and 1.5″ with an average OQ of the order of 1.2″ when rotating M2.

The test images shown here were obtained during the preparation of the observing run by ESO visiting astronomers, Yan Fernandez and Hans Ulrich Käufl on July 19, 1997. Figure 3 shows the trace through an image of the double star alpha-Centaurus, (separation 1997.5: 15.8 arcsec) using the N2-filter (λ: 9.14–10.43 μm).

For these observations – unfortunately – no external seeing values were available. The image quality for 30-second averages using the standard chopping and nodding observing procedure including the telescope autoguider is 0.9 arcsec FWHM (or 2.8 pixel). Considering 3 s averages, the image quality improves to 0.74 arcsec (or 2.2 pixel). This indicates either a residual image degradation due to the atmospheric tip-tilt or resulting from the auto-guider feed-back loop. The diffraction limit (1.22 λ/D) for these observations is 0.70 arcsec.

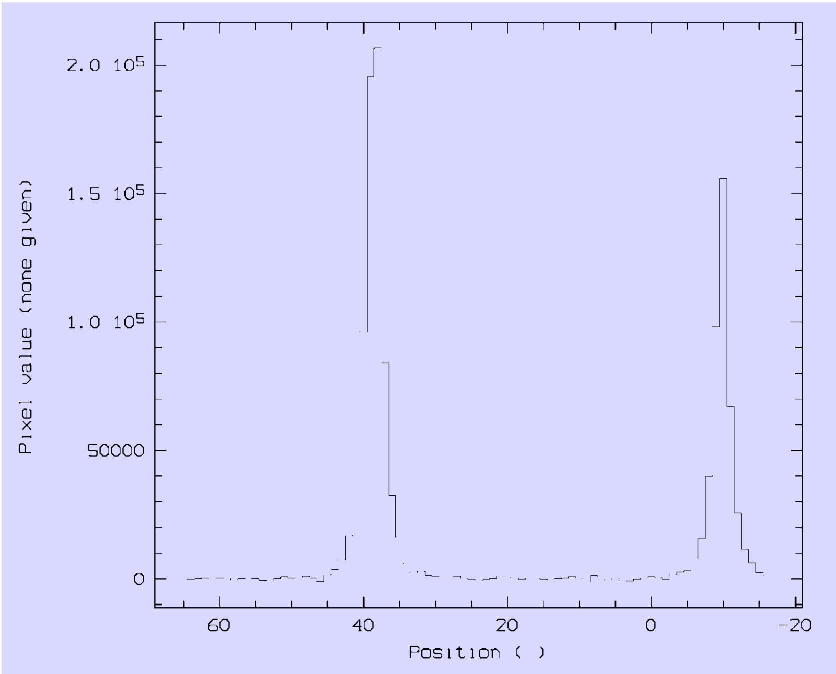


Figure 3: Trace through a 3-second exposure of the double star α Centaurus (separation 1997.5: 15.8 arcsec). For more details, see text.

The 3.6-m telescope is now well prepared for the arrival of TIMMI2, the successor of TIMMI, under construction at the Sternwarte Jena, to be installed end of 1998 (see [5] or http://www.eso.org/observing/vlt/instruments/visir/timmi2/index.html). Slight improvements (removal of the remaining astigmatism of M2, alignment of the mechanical and optical axis of M2 . . .) are still to be done and make sense for observations at shorter wavelengths.

Our thanks go to the mechanic support team who largely contributed to these improvements.

References

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[3] H.U. Käufl et al., "TIMMI ESO's new 10 µm Camera/Spectrometer", 1994, *Infrared Physics*, **35**, p. 203.

[4] S. Guisard, "Analysis and Improvement of the Optical Quality of the f/35 focus, Proposition for Further Improvements", 3.6m + CAT Upgrade 3P6-TRE-ESO-019-003, 28th July 1997.

[5] H.U. Käufl et al., 1997, *The Messenger* **88**, p. 8.

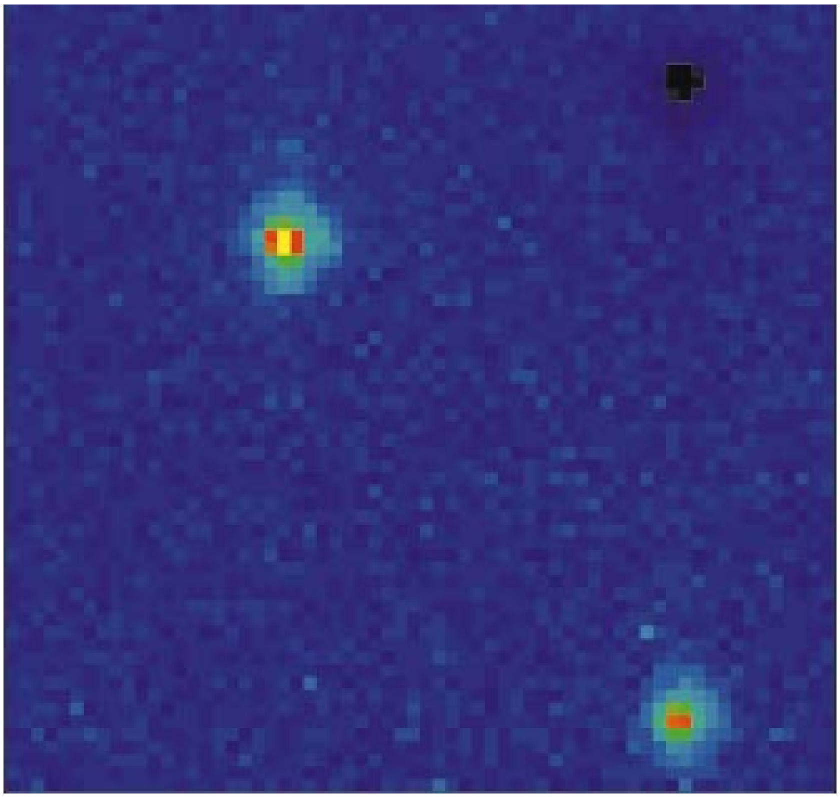


Figure 4: Colour plot of the image of α Centaurus. For more details, see text.

Image Quality of the 3.6-m Telescope (Part VII) Installation of a Spring System in the 3.6-m M1 Mirror Cell

R. GREDEL, S. GUISARD, G. IHLE

The installation of load cells in the 3.6-m M1 mirror cell in April 1997 (see June issue of *The Messenger*) allowed us for the first time in the history of the 3.6-m telescope to measure the forces exerted by the astatic levers on the main mirror. These measurements were required to optimise the force distribution among the three support rings, and to determine the characteristics of a spring system to correct for the aberrations of M1.

For the three axial support rings A, B, and C, the levers support 4385.0 kg, 4467.6 kg, and 2096.4 kg, respectively. These are fractions of 0.4005, 0.4080, and 0.1915, of the total weight of M1. The errors in the measurements are less than 0.05%. The force distribution is close to optimal fractions of 0.4080, 0.4024, and 0.1896, for rings A, B, and C, respectively, as calculated by Lothar Noethe and Franz Koch. The present load distribution results in wavefront aberrations of 9.7 nm RMS. This is significantly smaller than the errors introduced by the polishing errors of M1. Thus, it was decided not to modify the load distribution among the three rings.

The load distribution among the astatic levers in the outer ring follows a sinusoidal pattern. This is required to correct for the polishing errors of M1. As explained in detail in previous articles in *The Messenger* by Stephane Guisard, a degradation of the image quality occurs away from Zenith. This is mainly caused by the re-appearance of the intrinsic aberrations of M1, because the force exerted by the astatic levers are diminished by a factor which is proportional to cos(ZD), where ZD is the zenithal distance of the telescope. The corrective forces superimposed to the astatic support of M1 are thus not constant. In order to have a constant correction independent of ZD, it was decided to install a spring system in the M1 mirror cell. This idea was originally suggested by Rudolph le Poole, who spent two months on La Silla as an external consultant to the 3.6-m team. The springs exert a force on M1 which is independent of ZD.

The compensating force required by the springs was calculated for each lever in all three rings. It is up to 90 kg, positive for some, negative for others. With the addition of the springs, the weight of the astatic levers had to be adjusted. For most of the levers, this was achieved by moving the lever arm horizontally. For a few levers, weights up to 15 kg had to be added. The springs were installed during 10 nights of technical time in September.

Final image quality checks were performed with CCD #32 right after the spring installation. Unfortunately, the weather was very bad. Like many other observers who come to La Silla these days, we are not exempt of the effects of this year's very strong El Niño. The few measurements we have suggest that the optical quality of the 3.6-m away from Zenith has improved. The triangular term Z10 is now independent of ZD and near 0, except for one position at ZD = 60 degrees to the south, where it is 0.35 arcsec. This is most probably caused by the lateral support of the M1. Other aberrations such as astigmatism have not improved. They are believed to arise from a non-adequate lateral support as well. Because of these problems, it is planned to replace the analogue pressure regulator for the lateral support. In the coming months, we wish to install a servo control of the pneumatic pads with loop closure over the lateral load cell readings.

VLT Data Flow Operations News

D. SILVA and P. QUINN, ESO (dsilva@eso.org)

Welcome to the first article in a regular series about VLT Data Flow Operations (DFO). DFO encompasses a large range of VLT science operations related activities from proposal preparation support to service observing and archival research. Over the next several issues of The Messenger, the entire gamut of DFO activities will be discussed. Eventually, these articles will evolve into regular updates about DFO status during VLT science operations.

1. Introduction

Potential VLT users have been thinking about the science questions they want to address with the VLT for years. With the advent of VLT science operations approximately 15 months away, many potential VLT users are now beginning to think more seriously about how they will answer those questions with the VLT. As part of that planning process, users need to have a clear understanding of how the VLT will be operated.

In this article, our current perspective on user interaction with the VLT is described. Our operations plan is evolving rapidly at this time and not all of the details have been finalised. Nevertheless, our hope is that users will find a presentation of the global concepts helpful. We start with a quick overview of the VLT Data Flow System (see also P. Quinn, *The Messenger* No. 84). The majority of this article describes how users will interact with the VLT Data Flow Operations (DFO) during key data flow phases.

2. The Data Flow System (DFS): An Overview

The Very Large Telescope has the potential for being the most scientifically significant ground-based observatory in the early part of the next century. It certainly represents the largest single investment in ground-based astronomy ever made by the European community. The success of this facility will be measured by its impact on our understanding of the Universe. The VLT will only live up to its potential if it can be operated in such a way that observing programmes are executed efficiently and in a timely manner. This operational goal is complementary to the scientific goal of most astronomers. In an increasingly competitive environment, all astronomers want their observations completed as rapidly as possible to insure that they stay at the cutting edge of their fields.

The Data Flow System (DFS) was designed with these operational and scientific goals in mind. At its most fundamental level, the DFS is a set of protocols and interfaces for linking together the VLT telescopes and instruments with simple observation description tools, online data processing functionality and automated data archiving. While sitting at the telescope, an astronomer will be able to use simple software tools to create observation descriptions (called Observation Blocks or OBs)[1] which can then be executed by the DFS. As part of its normal execution process, the DFS not only produces the specified raw data but can also automatically process those data as well as archive it for later use. Simply put, the basic DFS is a system for increasing the efficiency of any astronomer using the VLT facility.

However, even the most efficient system will not prevent on-site observers, restricted to a fixed number of nights, from losing precious "time on target" to system failures and unfavourable observing conditions. At traditionally operated observatories, significant fractions of observing runs can be lost to such problems. For the vast majority of astronomers, being physically at the telescope will not mitigate the impact of these effects – they must rely on the expertise of the technical staff and the vagaries of nature to minimise their downtime. Given the choice, all astronomers would prefer to have the "perfect" observing run – completely functional instrumentation and observing conditions matched to the observational goals of their primary scientific experiment. Furthermore, most scientific communities would like the most scientifically meritorious programmes to be completed first given the well-known scarcity of resources, rather than have data randomly distributed across a set of projects, as often happens now (although all of us would like to see our programme executed first!).

Service observing is an operational way of achieving these goals. By breaking down an observing programme into a series of OBs, a programme can be executed when the observing conditions are suitable and the instrumentation is available and completely functional, not just when the observer happens to be on-site. Furthermore, the OBs of most highly ranked programmes can be given preference on any suitable night, not just when the particular PI is on-site. The DFS provides the infrastructure for service observing by providing software tools to the astronomer to create OBs and to the Data Flow Operations (DFO) staff to schedule and execute those OBs.

Will all VLT programmes be queue scheduled? Can all VLT programmes be queue scheduled? The answer to these questions is clearly and emphatically "no". It will be simply impossible to provide calibration and queue operations support of all modes of all VLT instruments, especially in the early years of VLT science operations, and ESO will not try to do so. Nevertheless, we expect that the majority of VLT users will only use a select number of instrument modes. We are trying to anticipate what those modes are and develop calibration and queue operation plans accordingly. These plans will be modified as time goes on to conform to real VLT usage patterns.

3. Interacting with the VLT DFS: A Few Critical Phases

It is important to have a sound guiding philosophy but the typical user is more interested in how they will use the VLT and what restrictions may be placed on that use. In what follows, a few critical phases of the interaction between the user and the VLT Obser-

[1]In the DFS model, Observation Blocks (OBs) describe how simple data sets are acquired and record the status of those data sets. OBs are simple – they consist of just one telescope pointing and the acquisition of a single data set. In short, OBs are the smallest items that can be scheduled and executed by the DFS.

vatory are discussed, illustrating the envisioned flexibility and efficiency of the DFS.

3.1 Proposal Creation and Review

In many ways, VLT proposal creation and review will be similar to the equivalent process at any ESO telescope. Well in advance of the proposal deadline, a Call for Proposals will be issued. This Call for Proposals will describe what VLT instruments and instrument modes will be available and when they will be available. However, in addition, information about what instrument modes will be supported by service observing and an execution and calibration plan for each of these modes will also be provided. Proposers will also be told what the anticipated fractional split between service and visitor mode observing will be for the upcoming period.

As usual, VLT proposers will have to submit a scientific and technical justification for why they should be granted VLT time. As part of the technical justification, proposers will have to justify carefully the amount of time they need to complete their programmes. To assist them in this process, ESO will supply Exposure Time Calculators. These ETCs will allow users to estimate exposure times to an ESO guaranteed accuracy. At this time, our accuracy goal is 10%, i.e. the real delivered S/N should be within 10% of the estimated S/N for a given exposure time on a given instrument/telescope combination for the specified observing conditions. These ETCs will be constantly updated using information about the real instruments obtained by the DFO staff via a programme of regular instrument performance verification.[2]

Proposers will also be asked to specify and justify whether their programme should be executed in service or visitor mode. Since most users will be able to use the standard VLT observing sequences, most VLT science programmes will probably be able to be executed in service mode. Potential justifications for visitor mode (i.e. the PI goes to the telescope and executes the programme personally) include the need for higher-precision calibration, non-DFS supported instrument modes, or highly interactive real-time decisions about data acquisition.

After submission, all VLT proposals will be reviewed for scientific and technical feasibility. The scientific feasibility review will be done by the OPC, while the technical feasibility review will be done by DFO staff. Among the issues subject to technical review and approval will be the total amount of requested time, the requested instrument configuration and operation, and the request for visitor or service mode. These technical reviews will be passed on to the OPC. As usual, programmes which are found to be scientifically meritorious may still be rejected if they are found to be technically unfeasible.

3.2 Programme Scheduling

After the review process is completed, OPC approved programmes will be assigned to service or visitor mode based on a combination of technical evaluation by the ESO staff and OPC recommendation. As with all time allocation decisions, the ESO Office of the Director General has the final responsibility for this assignment.

VLT programmes approved for visitor mode observing will be scheduled in the same manner as La Silla proposals. Visitor mode programmes will be assigned specific nights with specific instruments at specific telescopes. Users will be expected to be at the telescope to execute their programme.

VLT programmes approved for service observing, however, will be “scheduled” in a different manner. VLT queue programmes will be split into the three categories:

- **Category A: Programmes highly ranked by the OPC**. All possible effort will be made to execute all the OBs corresponding to these programmes in the requested observing period. Programmes will be placed in this group primarily because of their high OPC ranking but also to fill some undersubscribed set of observing conditions (e.g. poor seeing during bright-time).
- **Category B: Programmes well-ranked by the OPC**. Programmes in this category will only be executed if no Category A programme can be executed.
- **Category C: Programmes ranked at the cut-off line by the OPC**. These programmes will be executed only if no Category A or B programmes can be executed.

Matching requested observing conditions to expected observing conditions is a critical aspect of this grouping process. For example, it is impossible to observe only objects at a RA of 13 hours. It is also unlikely that VLT will produce 0.5″ images in the B-band every night. Thus, Category A must be populated with OBs that span all accessible target positions and all expected observing conditions more or less uniformly. Users should keep these constraints in mind when preparing their proposals. We will return to this topic in a future *Messenger* article.

3.3 Programme Preparation

The DFS is intended to be the gateway to the VLT for all VLT investigators. Although there will be low-level interfaces to all VLT systems that will in principle be available to visitor mode investigators, OBs will be the primary agents for using the VLT facility. Thus, both visitor and service mode investigators will be required to create OBs before their programmes can be executed.

Investigators allocated service-mode time will be given instructions for preparing OBs at their home institutions. These instructions will include detailed programme preparation instructions and a deadline for when their OBs need to be submitted to ESO. Most service-mode investigators will create their OBs at their home institutions but support for OB creation at ESO will be supplied if requested. As part of OB creation, users will specify what observing conditions are acceptable, what instrument configuration is required, what their targets are, and what exposure times are required. Again, the instrument ETCs will be provided to allow users to specify exposure times.

For some kinds of observing programmes (e.g. multi-object spectroscopy), some sort of preparatory observations may be required to successfully execute the main programme.

Visitor-mode investigators will be required to perform the same programme preparation. These observers could elect to create their OBs on-site minutes before they wish to execute their observations. However, they will be encouraged to create their OBs well before arriving at the telescope. Early OB creation will allow classical investigators to take advantage of the OB verification tools under development by ESO. The DFO staff will provide assistance with OB verification if requested.

3.4 Programme Execution

Visitor-mode investigators will of course be on-site to execute their own programmes. Thus, their programmes will lose time and efficiency to the usual vagaries of random observing conditions and facility downtime. Visiting astronomers will also have to absorb the not insignificant overhead of travelling to Paranal from Europe to observe. Since they will be using OBs, visiting astronomers will have the entire DFS infrastructure available to them, including on-line data processing if they wish to use it. But since the fundamental data product remains the unprocessed, raw data, visiting astronomers can choose to ignore the product of the on-line processing system. Their data will be automatically archived for later analysis and re-use after the 12 month proprietary period mandated by the ESO Council.

Service-mode investigators will have a much different experience. Service mode OBs will not normally be executed in some pre-defined order on some pre-defined date. The order in which individual OBs are executed will be determined

[2]ETCs for the NTT instruments SUSI, EMMI and SOFI are available. The current version of these ETCs are available on the ESO Web site at http://www.eso.org/dmd/data-proc/quality/simulators.html.

dynamically by a merit function whose form is still under development. High weight will be given to OPC ranking. Other parameters will include allowable zenith distance range (airmass), allowable sky background and/or lunar phase, seeing requirements, sky transparency, calibration requirements, etc.

During service observing operations, the DFO staff will endeavour to execute OBs only under the observing conditions specified by the service mode investigator. However, it may be necessary occasionally to execute some OBs under non-optimal conditions. If the data produced under these conditions clearly do not satisfy user specifications, these OBs will be repeated as time and conditions allow. In more marginal situations, ESO will work with service-mode investigators to determine whether or not the data are acceptable and whether or not these observations should be repeated.

Once a service-mode programme is initiated, achieved data quality will be monitored and compared to specified data quality. In most cases, it is expected that under nominal conditions, no PI interaction will be required. However, achieved data quality can be different from specified data quality by more than the nominal 10% accuracy for three main reasons:

• the VLT facility malfunctioned in some manner

• the given OB was executed under conditions worse than specified

• some user assumption used to compute the required exposure time was wrong

In the first two cases, OBs will usually be re-executed in a manner which is transparent to the service-mode investigator after the malfunction has been fixed or suitable conditions arise again. In the last case, an observing programme will be halted and a DFO astronomer will work with the service mode investigator to devise an alternative observing plan, if such an alternative plan is possible. During early VLT operations, ESO will be very conservative about what constitutes acceptable data and work with PIs as much as feasible.

4. A Final Note: Archive Investigators

All VLT data will eventually be accessible to the ESO community via a science archive system currently under development by the DMD Science Archive Group. The ESO Council has established a proprietary period of 12 months during which these data will only be available to the investigators associated with the original OPC approved programme. After that point, VLT data will be available for re-use. Policies for the use of the archive are still under development. Nevertheless, it is envisioned that DFO astronomers will support users of the science archive, particularly in issues of how to efficiently search for and extract data and how to reprocess it as necessary.

Next issue: a discussion of the NTT Service Observing Programme, a DFO prototype.

The VLT mechanical structure during the tests at the Ansaldo factory in Milan, Italy.

The Search for Extrasolar Planets at ESO

FINAL REPORT OF THE ESO WORKING GROUP ON THE DETECTION OF EXTRASOLAR PLANETS[1]

Prepared by F. PARESCE and A. RENZINI

1. Introduction

A dedicated Working Group on this subject was created in 1996 and has since met four times. It is composed of the following members:

A. Hatzes (Texas), M. Kurster (ESO), A. Léger (Meudon), M. Mayor (Geneva), J.-M. Mariotti (Meudon), R. Mundt (MPIA), F. Paresce (ESO, chairman), A. Penny (Rutherford Appleton), D. Queloz (Geneva), A. Quirrenbach (MPE), A. Renzini (ESO), P. Sackett (Groningen), J. Schneider (Meudon), D. Tytler (San Diego), G. Wiedemann (ESO), H. Zinnecker (Potsdam).

The assignment of the WG was to advise ESO management and ESO committees on how to help designing a competitive strategy in this field that is predicted to expand dramatically in the next years, and to become one of the leading fields of astronomy in the next century.

ESO has great potential in the search for exoplanets. With the La Silla telescopes, the VLT, the VLTI, the special characteristics of the Paranal site, and the variety of professional expertise widely spread within the European astronomical community, ESO should be able to play a leading role in the search for exoplanets. For this to happen, however, a serious effort has to be made now to develop a global strategy and to allocate adequate resources. The WG recalls, in this context, that the substantial NASA contribution to the Keck telescopes and the Keck Interferometer is driven by its interest in the search for exoplanets. Some 40% of the time of one of the Keck telescopes will be dedicated to this scientific goal. Therefore, a sporadic, uncoordinated effort by ESO could hardly be competitive. Only by allocating a major fraction of time on some of its telescopes and developing new technology – and doing it now – will ESO fully exploit its potential in this field and be truly competitive.

In this report, the WG proposes a plan to do just this. We have identified where ESO can play a critical role and that, therefore require particular attention: radial-velocity searches, narrow-angle astrometry, microlensing, direct detection, transits and timing of eclipses. In the following paragraphs, we will present a high-level executive summary of the unanimous conclusions reached by the group and its recommendations to ESO for the proper exploitation of the opportunities in each one of these areas. The appendices (not included here) contain the detailed and quantitative justifications for these conclusions and recommendations.

2. Conclusions and Summary of Recommendations

2.1. Radial-Velocity Searches

The WG recommends that a major fraction of a spectroscopic telescope (successively the CAT and the 3.6-m or some combination thereof) be devoted to radial-velocity monitoring of 1000 nearby bright stars over the next 5–10 years. The availability of a very stable spectrograph (able to reach an accuracy of 1 m/s) would be particularly helpful, but still competitive results can be obtained even with the current instrumentation, provided adequate telescope time is allocated. A dedicated spectrograph could be developed either by ESO, or by a consortium of ESO institutes, provided an adequate fraction of telescope time will be reserved. The WG notes that such a radial-velocity survey is indispensable to prepare for VLTI astrometric observations. The search for exoplanets is currently listed as one of the primary scientific goals and drivers of the VLTI. Therefore, adequate target lists should be ready by the time the VLTI will start its operations in the year 2002. Such targets will have to include objects with confirmed radial-velocity variations, so that the VLTI narrow-angle-astrometry capability will allow to complete the determination of orbital parameters and planetary mass. The detection of Jupiter-like planets with either radial velocity or astrometric techniques requires several years of consecutive monitoring. Therefore, it is crucial to start an extensive observational campaign as soon as possible.

Specifically, the WG makes the following recommendations in this area

(a) The large survey to explore the domain of brown dwarfs and giant planets with an accuracy of 5–10 m/s at La Silla with CORALIE at the Swiss 1.20-m should be complemented and extended with FEROS at the 1.52-m telescope. The first should proceed as planned and with all due support from ESO and the second should be executed as soon as possible (see *The Messenger* No. 89, p.1). Together, these two instruments are in a position to make, in a rather optimum way, a southern survey of more than 1000 stars.

(b) A large survey to explore the domain of "normal" giant planets and, maybe, the domain of short period "Uranus"-type planets with an accuracy of 1 to 2 m/s should be started at La Silla as soon as possible. This will require the following substantial commitments:

– a significant fraction (25%) of 3.6-m time over the long term (5–10 years)

– the construction of a dedicated, optimised instrument linked to the 3.6-m telescope that could be either the CES + VLC + cross-disperser together with a suitably large CCD (preferably 8K × 8K), if feasible, or a totally new spectrometer optimised to get the highest possible accuracy and fiber fed by the 3.6-m telescope. This instrument will be the most efficient one among all the possibilities offered by ESO.

(c) For this programme to be implemented quickly, therefore, in turn, also requires:

– an immediate study of the practical feasibility of a cross-disperser on the CES/VLC,

– a study and implementation of optical image slicers/scramblers and large CCD on the 3.6-m to CES link.

(d) The CAT should be kept operating at least until the time a major fraction of 3.6-m time (25%) can be devoted to a high-precision RV survey. It should be completely dedicated to the goal of reaching the required RV precisions at ESO as quickly as possible. This implies equipping it with the upgraded CES + VLC + image slicers/scramblers and, for reasons of improved efficiency and stability, with its own fibre link from its prime focus to the CES + VLC. This will provide indispensable ancillary data in the form of line profile studies at R = 220,000 and precision RV work on a smaller sample of brighter stars. The CAT will then also serve as a most useful device for experimental tests of techniques to achieve the goal of 1–2 m/s precision (cross-disperser, SW, HW, etc.).

(e) Calibrate the Iodine cell of UVES and develop the specific software to allow extreme accuracy with UVES.

[1] A number of Appendices are attached to the complete Final Report. They are not published here.

(f) Develop CRIRES to provide complementary spectral diagnostics needed to confirm the planetary rather than stellar origin of the apparent RV variations and to augment the search for planets around IR-bright K and M stars. A planetary monitoring programme conducted with CRIRES could make extended use of twilight and early-morning time, since the typical target brightness will far exceed the sky background. The use of these times should be foreseen by VLT operations and scheduling.

Supporting documentation with greater detail on the above issues can be found in Appendices A and B.

Summarising, a schedule such as the following, then, would allow ESO to become competitive in this area with the rest of the world in the required time frame:

- end 1997: start of a short-term programme with CAT+CES+VLC+image slicers/scramblers
- end 1997: CORALIE survey begins; precision expected: 5 m/s
- mid-1998: CES + VLC +3.6-m + large CCD (without cross-disperser)
- end 1998: FEROS survey begins; precision expected: 5 m/s
- early 1999: start of the long-term survey with the CES + VLC + cross-disperser + large CCD + 3.6-m (if feasible)
- late 1999: start of the long-term survey with the 3.6-m + dedicated new spectrograph (if CES cross-disperser not feasible)
- mid-1999: UVES + VLT is available to start radial velocity searches of exoplanets
- mid-2000: CRIRES + VLT should be available to start complementary IR studies of exoplanet candidates.

2.2. Narrow Angle Astrometry with the VLTI

The VLT Interferometer has the potential to perform extremely precise narrow-angle astrometry (NAA). The atmospheric limit for determining the distance vector between two stars separated by 10″ in a half-hour integration is about 10 microarcsec. The technical realisation of this potential requires monitoring of the baseline vector with 50 micron precision, and measurement of the differential delay between the two stars with 5 nm precision over a 100-m baseline.

Astrometry with 10 microarcsec precision is capable of detecting the reflex motion of solar-type stars due to Jupiters at distances up to 1 kpc; gas giant cores, i.e. planetesimals with 10 Earth masses, could be detected around nearby stars. In contrast to radial-velocity measurements, astrometry allows a full determination of the planetary orbit, and, therefore, yields the planet mass directly (without any uncertainty due to the inclination of the orbit). Moreover, astrometry can be performed for any type of star independent of its spectrum. Therefore, two types of astrometric programmes can be envisaged: first, stars with planets known from radial-velocity surveys should be observed to determine the orbital inclination; second, an astrometric survey should be performed to look for planets around stars in those regions of the HR diagram that are not accessible to radial-velocity searches. The latter programme would include, for example, pre-main-sequence objects in nearby regions of low-mass star formation and in Orion.

It is also possible to perform astrometric measurements with sub-milliarcsecond precision using a single 8-m telescope (UT). An astrometric instrument based for example on the Ronchiruler technique would have widespread applications for determining parallaxes and proper motions of extremely faint objects; it could also be used to search for Jupiter-like planets around nearby stars. It might also be possible to use a "simple" CCD camera such as the VLT test camera for astrometric measurements with a precision sufficient to detect planets.

Specifically, the WG makes the following recommendations in this area:

(a) the VLTI should be designed from the beginning to have a NAA capability with the goal of reaching 10 microarcsec precision by 2005.

(b) the main astrometric programme of the VLTI should use the 1.8-m auxiliary telescopes (AT) only; it should start as soon as these telescopes become available and no later than 2002.

(c) a substantial fraction of the AT time should be made available for NAA for 10–15 years. In this way, a few hundred stars can be included in a long-term astrometric survey.

(d) the detailed design of the metrology system and focal plane instrumentation required for astrometric measurements with the VLTI should be started now and completed before the main elements of VLTI are procured.

(e) ESO should look favourably at suggestions to implement astrometric programmes on the UT's but priority should be given to the astrometric mode of the VLTI.

2.3 Microlensing

A planet orbiting a microlens will create a distortion in the source's light curve. If the planet is located in the lensing zone of its parent star, perturbed regions of high amplification will be generated. A background source passing (in projection) behind these regions will exhibit a short-lived deviation or anomaly in its microlensing light curve. The interest of microlensing as a technique for planet detection is the information contained in the light curve about the mass ratio and the projected orbital separation in units of the primary Einstein ring radius. Roughly speaking, because of the uncertainty on the Einstein ring radius of the primary which serves as a scaling factor, the mass of the planet and its orbital separation can be determined within a factor of three.

Provided finite source effects are not important, the probability of detection is a rather weak function of planetary mass ($M_p^{-1/2}$) which makes the technique sensitive, in principle, to earth-mass planets. The reflex-motion methods discussed in Appendices B1 and B2 of this report can detect and characterise Jupiter- or Uranus-mass exoplanets but microlensing is the only one that is sensitive to earth masses and that can quickly detect Jupiters at larger orbital radii where they are actually found in our own Solar System. Due to the very low probability that a chance alignment occurs between the source and the lensing zone of a star ((3–4) $\times$ 10^{-6} toward the bulge of the Milky Way), many stars have to be simultaneously monitored to expect the detection of a few lensing events.

In practice, the source stars are in the bulge. To be observable, they must be bright and are, therefore, either red giants with $R^* = 13\ R_{SUN}$, or turn-off stars with $R^* = 3\ R_{SUN}$, the former being typically 3 magnitudes brighter than the latter. The lenses are random stars in the bulge or the disk. As microlensing is only weakly sensitive to the lens mass, the lens stars are most likely to be the most abundant ones, namely M stars of median mass of 0.2–0.3 M .

While the detection of Jupiter-mass exoplanets can be done against giants or turn-off stars, to avoid finite-source effects that dilute the signal, detection of earth-mass planets is more likely against turn-off sources. The former requires 5% accuracy photometry of giants with around-the-clock sampling at a rate of one point per 2 hours to get a correct characterisation of the event. This requires a set of longitudinally spread telescopes. The latter requires 0.5–1% accuracy photometry at a high sampling rate (e.g. one point each 20 minutes) but it can be done from a single observing site as the duration of the event is of the order of 5 hours. The unicity of the observation site decreases the probability of finding a planetary event by 1/3 but does not otherwise prevent a proper characterisation. However, an excellent-quality site is needed to obtain the accurate photometry routinely in the crowded bulge fields.

With the availability of one telescope at one site, the detection of terrestrial planets is possible, provided a 2.5-m-diameter-class telescope could be dedicated to the search for the duration of the bulge season (120 nights). If equipped with a state-of-the-art, ultra-large-field-of-view, high-resolution imaging detector, it could conduct a microlensing search for turn-off source events and simultaneously monitor them. A 16K × 16K detector with a 1-square-degree field of view should yield 4×10^6 suitably uncrowded turn-off stars. With a good detector (50% total efficiency), quantum noise would give $\sigma = 0.23\%$ for a V = 20, R = 19 star, in 4-minute integrations. Current state-of-the-art image-subtraction techniques indicate that realistic photometry can be achieved at levels three times that set by the photon noise.

Thus, if systematics can be controlled, one might expect a 2.5-m telescope at Paranal to perform 1% photometry of V = 20 lensing turn-off sources in 5 minutes per field (4 minutes integration plus 1 minute overhead). Since sampling every 20 minutes is required, four fields could be continuously monitored. Fields of one degree on a side are large enough that the search for microlensing events could be performed simultaneously with monitoring, with no additional observing time. About 250 stellar microlensing events (with maximum magnification above 1.13) could be expected in such a scheme over a 120-day bulge season. In principle, real-time alerting capability would not actually be required, but the auxiliary rewards of real-time detection (such as to allow follow-up spectroscopy with a very large aperture) are great. With this many events being monitored this precisely and frequently, the resulting 1.5% sensitivity to earth-mass detection could lead to about 4 earth-mass planets per season, if every lens has a terrestrial planet in its lensing zone.

Supporting documentation with greater detail on the above issues can be found in Appendix C of the complete Final Report.

Specifically, the WG makes the following recommendations in this area:

(a) Since experiments specifically designed for Jovian-mass planets are already underway and since other techniques can detect and characterise such planets, we do not recommend that ESO make a major effort with this aim using the microlensing technique. The possibility for a large single step forward lies in the detection of terrestrial-mass planets, an area in which an aggressive ESO-based campaign could result in a breakthrough.

(b) The best way to implement such a campaign is to dedicate 120 nights during the bulge season of a 2.5-m-class telescope on Paranal to a search for terrestrial planets. Since image quality is crucial in crowded southern fields, ESO will be in a unique position by having the best site in the world to study the bulge.

(c) Develop a 16K × 16K camera to allow both alerts and follow-up.

(d) With a few HST images of bulge fields, make extensive simulations of (i) planetary lensings and (ii) photometric measurements in crowded fields in typical Paranal observing conditions.

(e) Develop new data-processing techniques to control the photometric systematics resulting from crowding and seeing.

(f) Develop a data-processing system able to extract stellar lensings in a day and planetary ones in real time (15 minutes) in the monitored stellar events. This would allow the VLT to be used to obtain simultaneous spectra throughout the event.

(g) Automate the observing programme and reduction process so that eventually on-site personnel costs can be kept to a minimum.

(h) The European survey group, EROS II, operating from La Silla, is expected to provide the largest number of giant alerts. Supporting their effort appears highly desirable, the more so as it will increase the European expertise in the domain – a needed capability to prepare for the future.

(i) If the expected real-time alert capability of the follow-up teams, like PLANET and GMAN, is fully realised, flexible ESO scheduling and target-of-opportunity status on the 3.6-m would be highly desirable. This would allow spectra of the event to be taken throughout the short-lived anomaly; comparison baseline spectra could then follow at a later time. Such spectroscopy would provide detections or limits on the mass of the primary lens (i.e. the parent star of the planet) by looking for evidence of a second stellar spectrum, at a different radial velocity, superimposed on that of the source star.

2.4. Direct Detection

Direct detection of photons originating from extrasolar planets gives crucial information on these bodies that cannot be obtained with indirect methods. With direct spectroscopic and photometric observations it is, in principle, possible to determine size, temperature, chemical composition, atmospheric stratification, rotation rate, and the presence of surface features. Because of the faintness of extrasolar planets, and because of the large contrast between planet and parent star, such observations are extremely challenging. For example, it might be possible, from the ground, to observe objects like 51PegB in the near-IR, and perhaps "warm Jupiters" (i.e. planets the size of Jupiter, but with T 300 K) in the mid-IR.

Several methods have been proposed to carry out such studies, either with the VLT Unit Telescopes instrumentation, or with the VLTI:

(1) In the visible and the near-IR, the VLT UT's are able to angularly resolve a star from its planetary system up to distances of several tens of parsecs. The problem lies in the tremendous contrast between the images of the planets and their parent star. In theory, it can be overcome, but this requires a high-order AO system associated with a high efficiency coronograph and post-processing with the dark speckle method. Although future large space telescopes will be at an advantage for this kind of direct imaging, this method does not require heavy instrumental development and should be tried with the VLT, especially if photon-counting detectors become available in the near IR.

(2) Planetary spectral features predicted by recent atmospheric models should be detectable with high-resolution infrared spectroscopy using CRIRES. The planetary signal will be uniquely distinguished from the superimposed stellar spectrum because of the large Doppler shift due to the orbital motion of the planet. The infrared between 1 and 5 microns offers a vastly reduced contrast of planetary signal to stellar (noise) flux. A spectroscopic detection, in particular, of features known not to exist in stellar spectra, would be direct and unambiguous.

The spectroscopy can be supplemented by low-resolution spectro-photometry targeting the apparent infrared brightness variation (phases) of a tidally locked, isolated close planet. The instrumental requirements have been studied and incorporated in the CRIRES conceptual design. The spectro-photometry mode is available simultaneously in the low-resolution predisperser. The early realisation of this high-resolution echelle spectrograph, and its extended operation during twilight and early morning time are highly desirable. More details on this method can be found in Appendix D of the complete Final Report.

(3) If the VLT Interferometer is equipped with spatial wavefront filters such as single-mode optical fibres, the fringe amplitude can be measured with great precision. This can be used to make measurements of "double stars" with large magnitude difference, such as star-planet systems.

(4) Gaseous planets have strong molecular absorption bands. Within the bands, the planet is dark, and the photocentre of the star-planet system is centred on the star itself. Outside the bands, the photocentre is shifted slightly towards the planet. This shift of the photocentre might be detectable as a wavelength-dependent phase shift with the VLTI.

The working group therefore recommends that the instrumental requirements for direct planet detection be studied, and that appropriate instruments be included in the instrumentation plans for the VLT and VLTI. Specifically, the early realisation of a high spectral resolution IR spectrograph like CRIRES would be highly desirable.

2.5 Transits and Timing of Eclipses

Transits of extrasolar planets can be detected from the ground down to Uranus sizes. This method has, in addition, the very unique capability of detecting Saturn-like rings and, by timing of transits, habitable earth-mass moons of giant planets. The detection of transits constitutes also a first step toward the subsequent spectroscopic investigation of giant planets' atmospheres during transits. The timing of eclipses of close eclipsing binaries is a simple method for the detection of giant planets around binary stars. Possible practical implementation strategies are described in detail in Appendix E.

Specifically, the WG makes the following recommendations in this area:

(a) For the profile and timing of giant planet transits, two options are available: dedicate a 1-m telescope equipped with a CCD camera full time to the search or partially dedicate a 100 deg^2 Schmidt telescope equipped with a CCD array.

(b) For the timing of eclipsing binaries, partially dedicate a 0.8–1-m telescope coupled to a GPS clock.

3. Human and Capital Resources

The availability of adequate resources is indispensable for the successful completion of a vast and diversified effort as the one envisaged in this document. These necessarily include human as well as capital resources.

As far as human resources are concerned, it has to be realised that all the projects listed in the previous section will take many years to be completed (typically more than five years). Strong commitment by dedicated teams is therefore a prime necessary condition for any of such programmes to get started, conducted and completed. To some extent, ESO can facilitate the formation of teams with such strong commitment, but the initiative has to come directly from the community.

The search for exoplanets is a novel branch of astronomy, yet, if one looks in detail to what this search will consist of, one sees that the observational techniques will basically reduce to just a few ones. Specifically, to stellar high-resolution spectroscopy, stellar photometry in crowded fields, stellar high-accuracy photometry, and stellar narrow-angle astrometry. Expertise in these fields is widely spread within the ESO community. Therefore, recruiting the necessary human resources should not be a problem. Instead, the blooming of this new branch of astronomy clearly offers a unique opportunity to many ESO astronomers, and especially to the younger ones, to relocate themselves towards a new scientific frontier while taking full advantage of their own experience and technical know-how.

As far as capital resources are concerned, these come in two categories: telescopes and instruments. With the exception of the microlensing experiment, the other projects do not need new telescopes, but major fractions of the time of existing telescopes. In the case of the CAT, however, the dedication of this telescope to the radial velocity project requires to maintain the telescope in operation for many years, while current plans foresee its decommissioning by the end of 1998. New instruments, such as the high-resolution spectrograph capable of reaching 1 m/s accuracy and the one square degree CCD camera, are not in the current ESO planning. It is difficult to see how ESO could find the necessary resources out of its present budget, at a time when ESO is already so deeply engaged in completing the VLT/VLTI. Therefore, the allocation of fresh capital resources is likely to be critical for ESO to play the leading role in the search for exoplanets that is made possible by its vast complement of telescopes and by the scientific composition of its community.

The most promising way of proceeding appears to be one in which the scientific teams themselves provide at least part of the capital investments, or provide for the operation of a telescope. This will also make easier to the OPC to allocate them the extended periods of observing time that are necessary for each of the projects. Indeed, such an investment would represent a concrete embodiment of the long-term commitment that will have to be demonstrated before such long-term projects could be approved.

Latest News: The First VLT 8.2-m Zerodur Mirror Has Arrived at Paranal

On Tuesday, December 9, 1997, the first of the VLT M1 mirrors arrived on Paranal after a 3-day journey from Antofagasta.

Stellar Populations with Adaptive Optics: Four Test Cases

D. MINNITI[1], T.R. BEDDING[2], F. COURBIN[3,4] and B. SAMS[5,6]

[1]IGPP Lawrence Livermore National Laboratory, USA; [2]School of Physics, University of Sydney, Australia
[3]Institut d'Astrophysique, Université de Liège, Belgium
[4]URA 173 CNRS-DAEC, Observatoire de Paris-Meudon, France
[5]Max-Planck-Institut für Astrophysik, Germany;
[6]Current address: mediateam, Weidenweg 2c, 85375 Neufahrn, Germany

1. Introduction

Several beautiful photographs of galaxies greet visitors in the foyer at ESO Headquarters in Garching. Some of these photos, in particular those of NGC 5128 (Cen A) and IC 5152, contain prominent foreground stars. Some may think that these bright over-exposed stars (and their diffraction spikes) spoil the beauty and usefulness of the photographs. However, on the basis that one astronomer's noise is another one's signal, we describe a project that aims to take advantage of these fortuitously placed stars to make adaptive optics images of the galaxies behind them.

The goal of this project, first described by Minniti & Bedding (1995), is to resolve distant galaxies into their component stars. This would allow studies of the sort that are currently only possible for galaxies in the Local Group. By constructing colour-magnitude diagrams, we could measure the ages and metallicities of the stellar populations making up the galaxy. There are several advantages to performing these studies in the infrared:

• The spectral energy distributions of red giant stars peak in the infrared, increasing the contrast relative to the underlying fainter and bluer stars.

• Extinction and reddening from dust are less than in the visible ($A_K = 0.1\ A_V$).

• The degeneracy in the optical colours of the red giant branch is avoided. This degeneracy makes it difficult to determine ages or metallicities from optical photometry, especially for the more metal-rich populations that dominate bulges and ellipticals.

• The transformation between the photometric observations and theory ($M_{\rm bol}$, $T_{\rm eff}$) is easier in the infrared than in the visible: the $J-K$ colour is directly related to $T_{\rm eff}$ and the H and K magnitudes are directly related to $M_{\rm bol}$. The H filter is particularly useful for constructing deep luminosity functions because the bolometric correction is essentially independent of colour for late-type stars.

Adaptive optics (AO), which is currently only available in the infrared, gives two further benefits:

• It allows a substantial gain in sensitivity for point-source photometry by reducing the diameter of stellar images, thus increasing the signal relative to the background sky.

• The increased resolution reduces confusion in crowded regions.

One important limitation is that, until laser beacons become available, AO is restricted to fields which lie near a bright foreground star.

In this article we describe a first attempt to apply adaptive optics to the study of resolved stellar populations in galaxies (full details are given in Bedding et al., 1997). We have selected four widely different targets for this study which together provide excellent test cases and allow us to evaluate the potential of the VLT.

2. Observations

Observations were made in March and August 1995 with the ESO 3.6-m telescope using ADONIS (ADaptive Optics Near Infrared System; Rousset et al., 1994; Beuzit et al., 1994). The ADONIS instrument is the successor to COME ON+. Wavefront sensing is done at visi-

Figure 1: Image of NGC 5128, taken from the Digital Sky Survey. The image is 30′ × 30′, with north up and east to the left. All stellar images are foreground stars within our galaxy. The two brightest stars, used for wavefront sensing, are just below the centre and near the left-hand edge.

Figure 2: Photograph of IC 5152 taken at the prime focus of the ESO 3.6-m. The image is about 4″ wide. On deeper exposures, it is clear that the body of IC 5152 extends well beyond the bright (V = 7.9) foreground star.

ble wavelengths and the science detector operates in the near infrared. For the latter we used the SHARP II camera, which contains a 256 × 256 NICMOS 3 array with 0.″05 pixels, giving a field of 12.″5 × 12.″5.

An adjustable mirror in ADONIS allowed us to make offsets of a few arcseconds within a field, which we found useful in constructing a local flat field. It also allowed us to ensure that neither the bright reference star nor its diffraction spikes fell on the science detector. For each field we obtained a sequence of exposures offset by 2″ from the field centre in each of four orthogonal directions. The median of these frames was used for sky subtraction. After dark-subtraction, flatfielding and interpolation over hot pixels, the images were aligned and added to produce a single mosaic. Due to the sub-stepping process, the central 8″ × 8″ of the mosaic has the greatest effective exposure time and hence the highest signal-to-noise ratio.

3. Results

3.1 The giant elliptical galaxy NGC 5128

The S0/E pec. galaxy NGC 5128 (Cen A) is of interest both as the closest radio galaxy and because it shows evidence of having undergone a recent interaction. Fortuitously, two foreground stars are superimposed on the body of the galaxy, at distances of 4.′5 and 10.′9 from the nucleus and away from the central dust lane (see Fig. 1).

We observed fields next to both reference stars with ADONIS, but seeing conditions were poor and fast variations prevented good correction. The first star was bright (K 5) and produced too much scattered light on the science detector, preventing accurate sky subtraction. From a total integration time of 1 hour near the second star we failed to detect any individual stars in NGC 5128, down to an estimated magnitude limit of $K = 19.5$. Assuming the presence of old giant stars reaching $M_K = -5$, this allows us to place a lower limit on the distance to the galaxy of about 3 Mpc.

Since these observations, Soria et al. (1996) have published the first optical colour-magnitude diagram of the NGC 5128 halo, obtained with HST/WFPC2. They resolved this galaxy into stars and convincingly detected the tip of the old RGB at $I = 24.1$, deriving a distance of 3.6 ± 0.2 Mpc, consistent with our lower limit. These RGB stars would have K 22.5, beyond our magnitude limit. Soria et al. also detected a handful of AGB stars, extending to $I = 22.6$, equivalent to K 20.5. These stars would be at the limit of our detection and their absence is explained by the small field covered here, although we speculate that a few would have been detected with better seeing.

3.2 The halo of IC 5152

IC 5152 is a typical dwarf irregular (dIrr) galaxy on the outer fringe of the Local Group, at a distance of about 1.6 Mpc (van den Bergh, 1994). The galaxy is gas-rich and has on-going star formation, despite the fact that its isolated position appears to rule out a recent major interaction. It would be valuable to search this galaxy for an underlying old

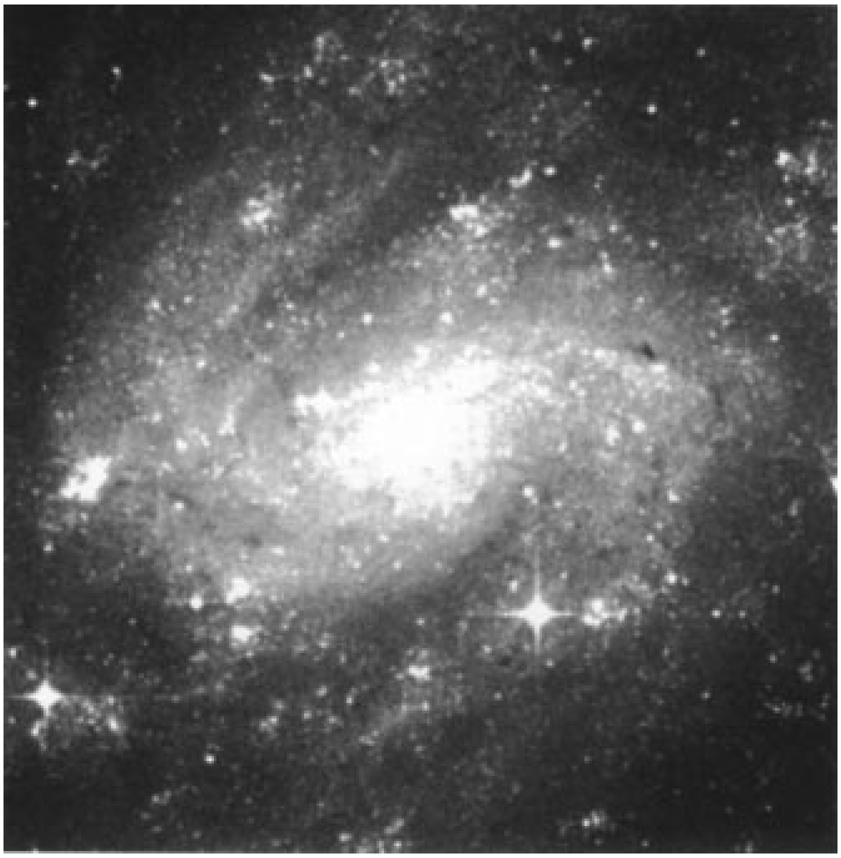
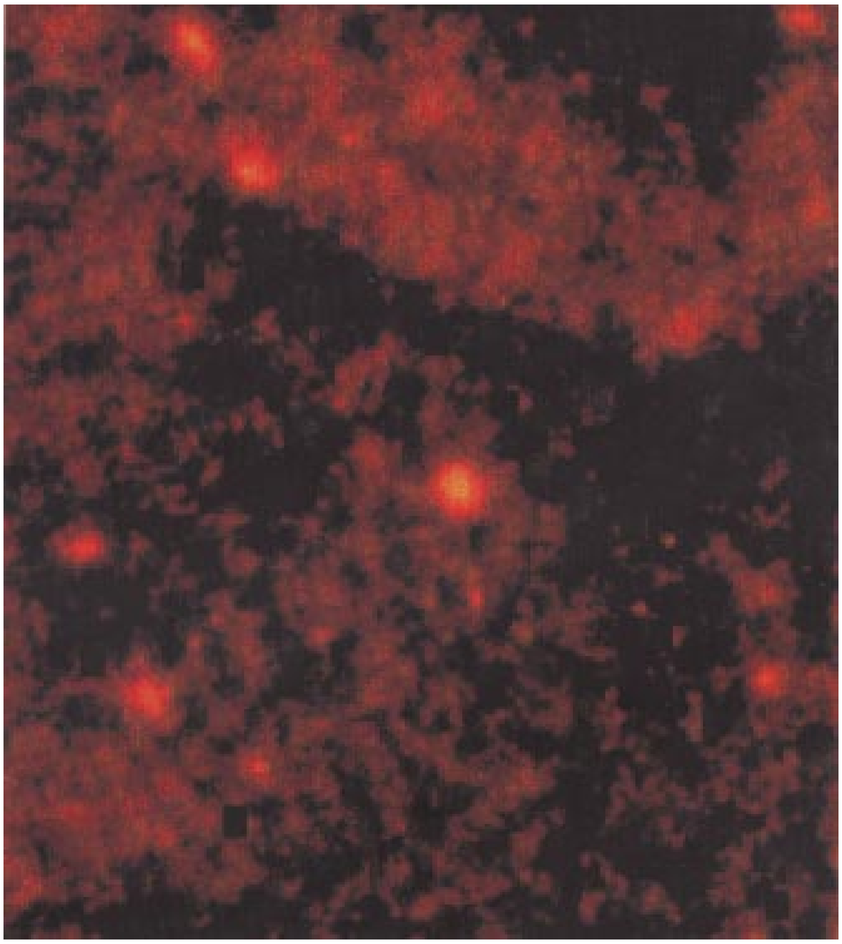


Figure 3: Image of the central 10′ × 10′ of NGC 300, taken from the Digital Sky Survey. North is up and east is to the left. The bright star 2′ SW of the nucleus was used for wavefront sensing.

Figure 4: ADONIS images of the NGC 300 disk field in K′. North is up and east is to the left. The bright elongated feature in the northern third of the image is caused by a reflection in the optical system. The image is 8″ × 8″.



population (age 15 Gyr and [Fe/H] −1) which would indicate an initial large burst of star formation. There are, however, no detailed colour-magnitude diagrams of IC 5152 at any wavelength, partly due to a very bright foreground star located next to the main body of this galaxy (Fig. 2).

We observed a field in the outer part of IC 5152 next to this bright foreground star. The seeing was 0″.6–1″.0. From a 40-minute integration at *H* we detected three very faint stellar sources but low counts prevented us from deriving accurate magnitudes.

The failure to detect more stars could indicate that IC 5152 is more distant than 1.6 Mpc, or that its halo does not extend this far from the nucleus. On the basis of these marginal detections and the results obtained on NGC 300 (discussed below), we believe that useful results would have been possible on IC 5152 under excellent seeing conditions.

3.3 The disk of NGC 300

NGC 300 is a spiral galaxy in the Sculptor Group and lies at a distance of about 2 Mpc (Freedman et al., 1992; Walker, 1995). We used a bright star superimposed on the disk, about 2′ SW of the nucleus in the prominent SW spiral arm (Fig. 3). In the future, with improved AO systems, it may be possible to use the compact nucleus of NGC 300 itself as a reference to study the central regions.

A *K′* image taken during particularly good seeing (0″.6 at the seeing monitor) revealed about twelve sources with FWHM 0″.3–0″.4. However, reliable photometry was prevented by a bright strip across the image that was probably caused by reflected or scattered light from the reference star. For comparison, a deep (30-minute) NTT frame taken in I band in 0″.6 seeing as part of a separate programme (Zijlstra et al., 1996) shows the same stars, confirming the sensitivity of adaptive optics. Note that photometry of the NTT image in this region is impossible because the reference star is saturated.

Our *H*-band ADONIS image was not compromised by scattered light and is shown in Figure 4. It is the result of a 40-minute exposure taken in moderately good seeing (1″ at the seeing monitor). However, the slow variation of the see-

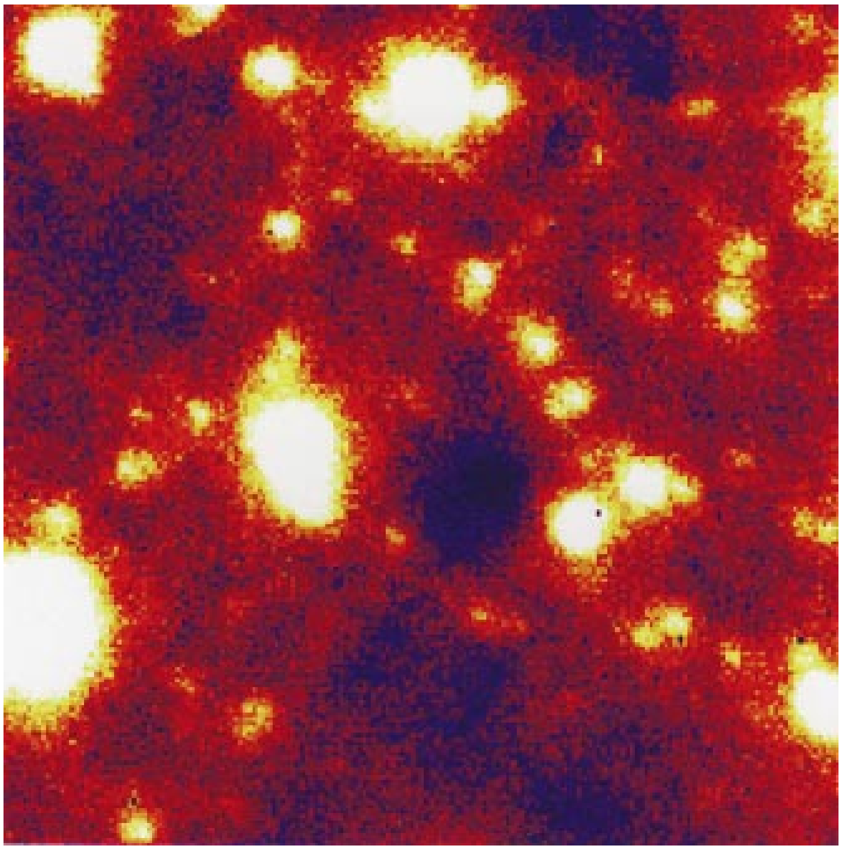


Figure 5: ADONIS K′ image of the Sgr window. The image is 8″ × 8″.

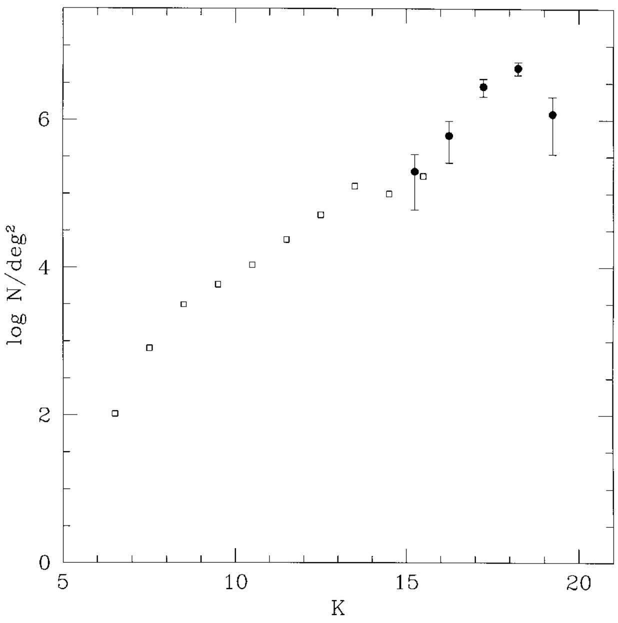


Figure 6: K luminosity function for the Sgr window. The squares are from Minniti (1995) and the filled circles are from the ADONIS observations. The lower counts in the faintest bin indicate incompleteness.

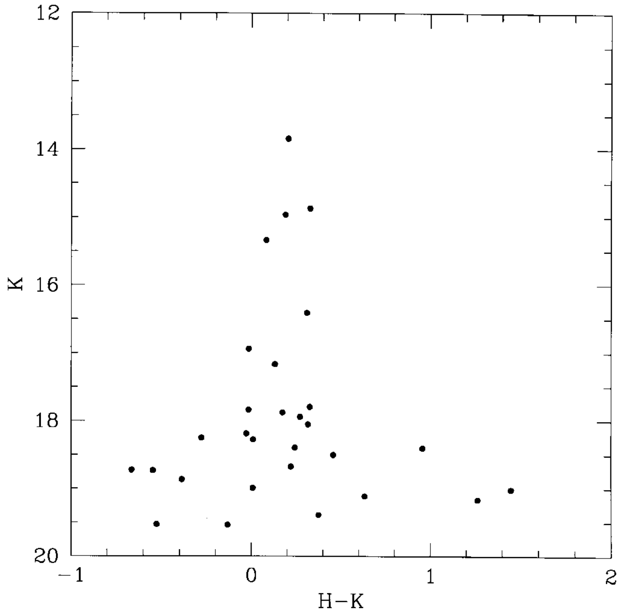


Figure 7: Infrared colour-magnitude diagram for the Sgr window. The main sequence turn-off of the bulge is at K 18, and the brightest stars in this figure lie on the sub-giant branch.

ing allowed good correction by the AO system. The stars observed here correspond to the bright supergiants with I 20.5 seen in the optical colour-magnitude diagrams of the disk of NGC 300 (Richer et al., 1985; Zijlstra et al., 1996). We did not go deep enough to detect the tip of the RGB of an old population, which would be at H = 20.5 at the distance of NGC 300.

3.4 The faintest stars in the Galactic bulge

We selected a field in the direction of the Galactic bulge, which should yield information about the structure of the inner Milky Way. We observed the Sgr field, which is located at $(l, b) = (0°, -3°)$, at a projected distance of 0.4 kpc from the Galactic centre (assuming R_0 = 8 kpc). This is a crowded field, with sources covering a wide range of magnitudes. The reference star had estimated magnitudes of K = 8 and V = 9.5.

Figure 5 shows a 40-minute exposure in K' taken on August 24, 1995 during particularly good seeing. The FWHM of stellar sources is 0″35. This image is much deeper than a combined exposure of 160 minutes taken the previous night in poorer seeing. We have found 70 stars in this image and obtained aperture photometry with DAOPHOT. Because of the variation of the PSF across the image, the aperture corrections for both the programme stars and the photometric standard are large (0.6 mag) and are therefore an important source of error in the final photometry.

Note that the accuracy of photometry and of transformation to the standard system is limited for AO observations. This is because the AO corrections differ for the programme stars, the AO reference star and the photometric standards, due to sky and seeing variations. All images were taken in a close temporal sequence to minimise these errors, but we conclude that our zero point is good to only 0.2 mag.

Figure 6 shows a K luminosity function for the Sgr window. As well as the ADONIS data, we have included the measurements of Soria et al. (1996), which cover the brighter magnitudes from K = 6 to 16. This infrared luminosity function represents the deepest measured for the Galactic bulge from the ground, reaching beyond the bulge turn-off, which is located at K 18.

Figure 7 shows a deep infrared colour-magnitude diagram from our ADONIS data. The internal errors in the K magnitudes for K 16 are small (a few hundredths of a magnitude), and for K 18 are much larger (0.5 mag). The H photometry has larger errors because of poorer seeing, and the limiting H magnitude is about one magnitude brighter than at K.

4. Conclusions

We have made a first attempt to apply adaptive optics to the study of stellar populations in our galaxy and beyond. In the cases of NGC 5128 and IC 5152, we failed to detect individual stars. We believe that these targets should be feasible with ADONIS in excellent seeing. For NGC 300 we resolved a small number of K supergiants in the disk. For the Sgr bulge window our colour-magnitude diagram and luminosity function are the deepest yet obtained, reaching the turnoff of the bulge population for the first time in the infrared. These results demonstrate the feasibility of the method. Four factors are important in determining potential results:

Seeing. The quality of adaptive correction depends critically on the temporal frequency of the seeing variations. Obtaining CMDs of distant galaxies is only feasible under excellent seeing conditions (0″8 and slow variations). Good seeing, and hence good adaptive correction, also helps to reduce the problems of field crowding.

Availability of reference stars. We require a bright star to be conveniently located for wavefront sensing. We found it best to use reference stars of V 10. Brighter stars produce stray light contamination, making it difficult to flat-field and background-subtract, and fainter stars do not allow good correction. Using a laser beacon will increase sky coverage and also eliminate the problem of scattered light from the bright reference star, an important advantage.

Field of view. Adaptive optics correction is presently restricted to a small field around the reference star. This makes it time consuming to cover large regions of sky, which is necessary to improve the statistics.

With ADONIS on the ESO 3.6-m telescope we reached a 3-sigma limiting magnitude of H = 20.0 in one hour on point sources. Based on the limiting magnitude obtained in the NGC 300 field under good seeing conditions (FWHM 0″8), we estimate that ADONIS can detect the brightest stars in bulges and ellipticals out to a distance modulus of $m - M$ 27.5 (3 Mpc). These figures are based on an absolute magnitude of $M_H = -8$ for the brightest giants in spheroidal populations of Local

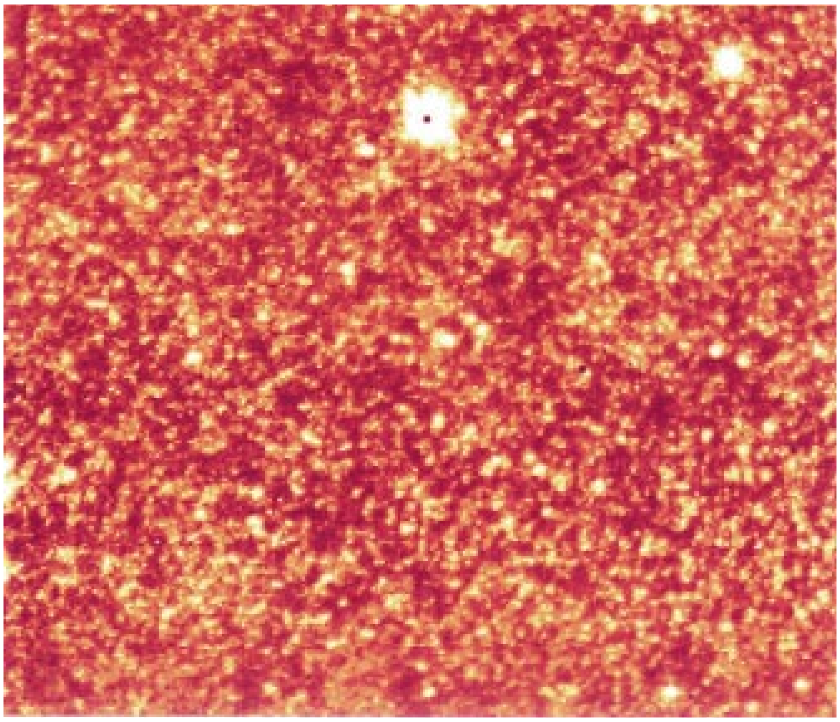


Figure 8: HST image of a halo field in NGC 5128 taken with NICMOS (Camera 3). The image is about 50″ by 45″ (the lower portion was discarded because of vignetting), centred at $\alpha_{2000} = 13^h\ 24^m\ 57^s$, $\delta_{2000} = -43°\ 02'\ 57''$. It is the mean of several 512-s integrations taken with filter F160W (H band). The two brightest objects (top) are probably foreground stars. Image courtesy of Pat McCarthy (OCIW).

Group galaxies (neglecting reddening). For comparison, the Centaurus group has $m - M = 27.8$ (Soria et al., 1996).

The results presented here should be surpassed by HST/NICMOS. Figure 8 shows an HST image of a halo field in NGC 5128 taken with NICMOS. It is one of the first images taken in the public access parallel programme. The halo of NGC 5128 is clearly resolved into thousands of red giants down to about $H = 22$.

Observations using adaptive optics on the VLT, while restricted to small fields of view, should be competitive with the HST/NICMOS image shown here because of the larger aperture and higher spatial resolution. New deconvolution and co-addition codes (e.g., Magain et al., 1997) should further improve the performance of adaptive optics. Thus, the VLT has the potential to transform extragalactic astronomy into stellar astronomy. There will be no need to rely on models and observations of the integrated light to find the physical properties of distant galaxies and their star-formation histories. Instead, we will be able to directly determine ages, metallicities and distances for the stellar populations of very distant galaxies. We might also be able to put important constraints on galaxy formation and decide on the history of mergers for a particular galaxy, just by looking at its shells and shreds.

Acknowledgements

This project was initiated when the first three authors were at ESO Garching (as Fellow, Fellow and student, respectively). We are very grateful to ESO for providing this opportunity of working in such a stimulating environment. We are happy to thank the ADONIS team and the Adaptive Optics Group at ESO for their efficiency and support, especially J.-L. Beuzit, P. Bouchet, N. Hubin, D. Le Mignant, P. Prado and E. Prieto. We also thank A. Quirrenbach, A. Zijlstra and R. Fosbury for their help and useful discussions.

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D. Minniti
dminniti@igpp.llnl.gov

The Luminosity Function of Clusters of Galaxies: A 496

NEW CLUES TO CLUSTER FORMATION AND EVOLUTION

E. MOLINARI[1], G. CHINCARINI[1, 2], A. MORETTI[1, 2], and S. DE GRANDI[3]

[1]Osservatorio Astronomico di Brera, Italy; [2]Università degli Studi di Milano, Italy; [3]MPE, Garching, Germany

1. Observations and Data

In 1993 we started, using the 1.5-m Danish telescope at La Silla, a large project aimed at a detailed investigation of the population and Luminosity Function, down to the faintest dwarf population, of the brightest clusters of the southern sample of clusters detected by ROSAT. Such sample is described in detail by Molinari et al. (1998).

All observations were carried out using Gunn *g, r* and *i* filters. In Figure 1, we display the observed mosaic for the cluster A 496. For each cluster we observed 4 fields of about 500 × 500 arcsec moving from the central region toward the outskirts up to a distance of about 20 arcmin. We were able in this way to correct for background contamination.

Assuming a King's approximation for the density distribution and a core radius of 0.25 Mpc (this corresponds, for A 496, to 531.2 arcsec for $H_0 = 0.75$) we expect in this field about 76/1000 of the galaxies which are present in the centre alone. We can therefore quite safely use this farthest frame for background correction.

The completeness of this frame was then computed in two ways. We estimated, firstly, differential counts *dN/dM* in our control field and we checked our data against the values published by Tyson (1987). The comparison gave our completeness function, but that was possible only for the *r* and *i* passbands. For the *g* band, the counts of the control field were very well fitted in the range 16 g 21 by a straight line and we extrapolated it to $g = 24$ in order to correct for completeness.

Secondly, to have more control on the faint end of the luminosity distribution, we also estimated the sample completeness via a bootstrap technique, Moretti (1997). We generated a set of images for each filter in the whole range of isophotal magnitudes and added to the observed frames. Using the distance *r* from the central cD galaxy as a free parameter, we were able to quite accurately determine the function P(*r, m*) which gives the probability of detection for a galaxy of magnitude *m* and at a distance *r* from the centre of the cluster.

Once that function is estimated for each sample of galaxies, the corrected number of counts in a given bin of magnitudes is determined by the relation:

$$N_j \ corr = \sum_i p_{j,i} = \sum_i P_{j,i}(r_i, m_i)^{-1}$$

The Luminosity Function which we discuss next was estimated using this second method, but, when applicable, the two methods agreed well within 1 sigma as to make the results rather robust.

2. The Luminosity Function

The estimate of the Luminosity Function parameters has been based on three different ways of selecting the subsample of the catalogue of galaxies which we extracted from the observations after star-galaxy separation (Moretti et al., 1998, Molinari et al., 1998). Briefly, *(i)* we considered the sample as it is without considering either the morphology of galaxies or the colour; *(ii)* we then used only a sample of red galaxies and, finally, *(iii)* we estimated the distribution of the bright E galaxies to the magnitude 19.0 which is the limit within which we are able to estimate the morphology.

The results are in excellent agreement among them and in this note we illustrate only the first more general procedure.

We chose as control field the area with co-ordinates x and y referred to the centre of the cluster such that (in arcsec): –1100 x –450 and 440 y 1030 (80.15 arcmin^2, upper left in Fig. 1). For the following analysis we referred to the area –650 x 200 and –255 y 245 as the cluster region (95.89 arcmin^2, bottom right in Fig. 1).

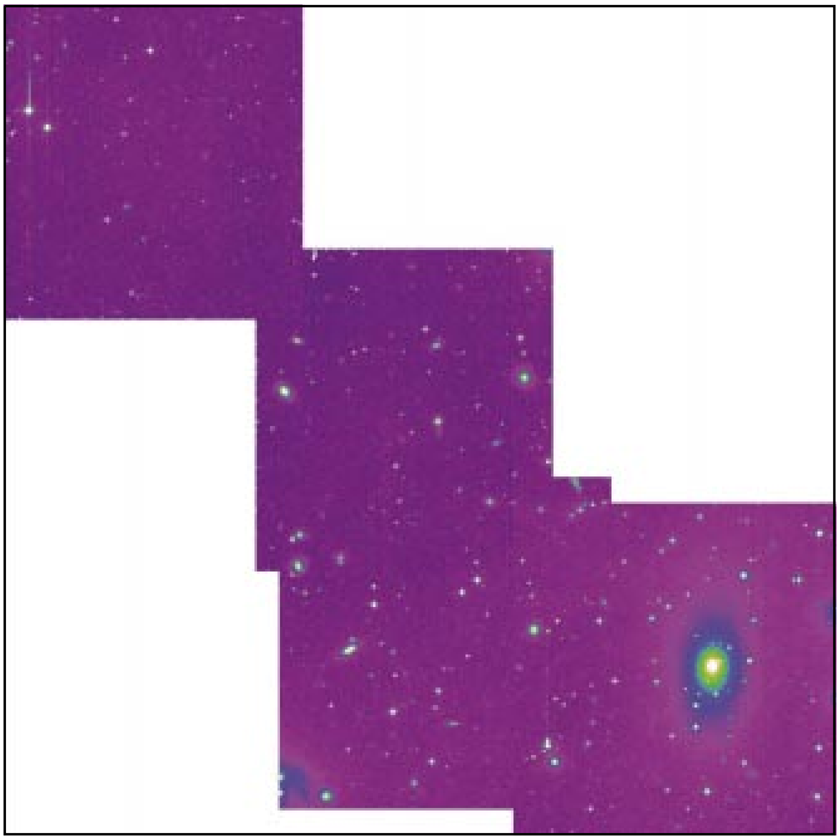

Figure 1. A composite image of Abell 496.

The cluster counts have then been derived by simply subtracting, after normalisation to the same area, the counts of the two fields for each magnitude bin. The error bars have been estimated by Poisson statistics.

In Figure 2 we reproduce the counts for the three filters and the best fitting which has been obtained by a Gaussian plus a Schechter function.

Some of the parameters are affected by a considerable error, especially the normalisation coefficients for the Gaussian and Schechter functions, with best fit given by the data taken with the Gunn *i* filter, where we have the best statistics. Anyway, there is very strong consistency and agreement among the different passbands.

3. Conclusions

We have established that in the cluster A 496 we can clearly distinguish between two populations of galaxies: the first which dominates the core of the cluster and is characterised by Elliptical and Lenticular galaxies and the second composed by fainter galaxies. This, after Virgo (Sandage et al., 1985), is the first robust result of a composite Luminosity Function.

In Coma, Bernstein et al. (1995) show, with deep exposures and excellent analysis, a sharp steepening of the Luminosity Function at very faint magnitudes in the region of Globular Clusters, in the magnitude range –12 M –10. They do not see, however, the gaussian distribution first detected by Biviano et al. (1995).

The search for such distinct populations, together with the faint tail analysis, was the motivation driving our rather large programme. Whether we can also detect differences among clusters of different morphology and with various X-ray properties will be one of the goals of the complete cluster sample.

Empirically the emerging picture is rather simple: the cluster itself is defined by the bright population of Elliptical galaxies, an old concept stressed especially by George Abell. The mass, or luminosity, distribution of such objects in a cluster clearly depends on the processes during formation and evolution. What we are able to see now is a bright population which is well mixed with the faint one in irregular, dynamically young clusters (Virgo), which is more clearly visible in more evolved clusters (Coma, Bautz-Morgan type II), and which shows as a striking feature in cD dominated clusters (Abell 496, Bautz-Morgan type I). Comparison with field luminosity functions (such as the reliable study of Zucca et al., 1996) should give hints for the understanding of the processes involved.

To some extent we rediscover, on a quantitative basis however, the old known fact that the cluster core, when compared to the field, is dominated by early-type galaxies.

The core birth scenario could have started in the epoch z 10–20 involving huge masses and helping the formation of large E/S0 galaxies. Later infall sets in and continues to the present day with galaxy-ICM interaction and subsequent ICM enrichment. Here we begin to form the dwarf spheroids, trigger starbursts in the infalling galaxies via the shocks induced by the interaction galaxy – ICM, and to shape the faint end of the cluster LF. The final shape of the faint end could also be modified by active fragmentation and become steeper than in the field, but such hypothesis needs to be investigated.

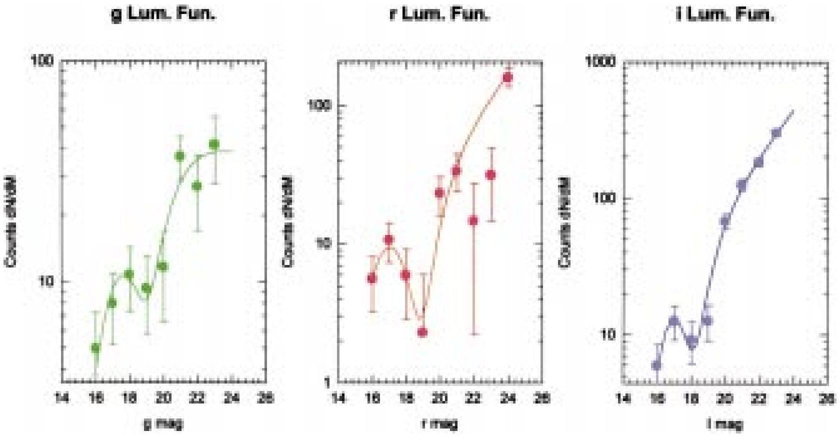

Figure 2. *The Luminosity Function of the cluster A496 (m–M = 35.53, H_0 = 75 km/s/Mpc) as observed in the g, r and i Gunn filters. The Gauss + Schechter functions have been plotted using the parameters estimated from the fit, continued line. The analysis is based on the photometry of 2355 objects of which 2076 have been classified as galaxies.*

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E. Molinari
molinari@merate.mi.astro.it

From EROS to DUO, ALADIN, GATT and Others: Wide-Field Astronomy

J. GUIBERT, Image Analysis Centre, Observatoire de Paris

The purpose of this report is to illustrate the major role of large-field imaging in all the domains of astrophysics, and to present some recent results. Most of these are based on digitisation and analysis of Schmidt images taken in the course of either sky surveys or specific programmes; however, the experience gained as well as the tools developed for the exploitation of photographic plates, have started benefiting ground-based and space CCD projects. Special emphasis will be put on the crucial importance of computer storage and processing capabilities, as well as efficient analysis and calibration software, for images up to 2 gigabytes. The resources of the Image Analysis Centre of the Observatoire de Paris, including the MAMA facility, used by a wide national and international community of astronomers, will be briefly presented.

1. General Context

The activities of the Image Analysis centre (hereafter: the CAI), started in 1987 with the first operational scans performed by the MAMA microdensitometer. MAMA (Machine Automatique à Mesurer pour l'Astronomie), was designed and built by the Technical Division of INSU (Institut National des Sciences de l'Univers, CNRS). Equipped with a linear RETICON array of 1,024 photodiodes, MAMA digitises a 14 × 14-inch plate in a few hours, providing a positional accuracy of 1 micron and a repeatability of 0.2 micron. In ten years, several thousands plates or films of various origins have been scanned, leading to several terabytes of pixels, and to catalogues with as many as 10 million detected objects per Schmidt field.

The MAMA facility also includes, in addition to the computer system close to the microdensitometer, a set of workstations in charge of image processing and data reduction. More than 100 gigabytes of on-line magnetic disk storage, tape recorders of different types (DAT, Exabytes, DLT), complement the CPU resources. These can be used for the exploitation of images either digitised from plates or produced by CCD devices.

Applications for scanning time, image processing, and assistance to data reduction, are examined by a Committee which meets twice a year. Collaborations with French teams are encouraged when groups from other countries are interested in extensive use of this national facility.

2. Some Scientific Results

2.1 Microlensing

• The some 300 plates taken at the ESO Schmidt in the course of the EROS (Expérience de Recherche d'Objets

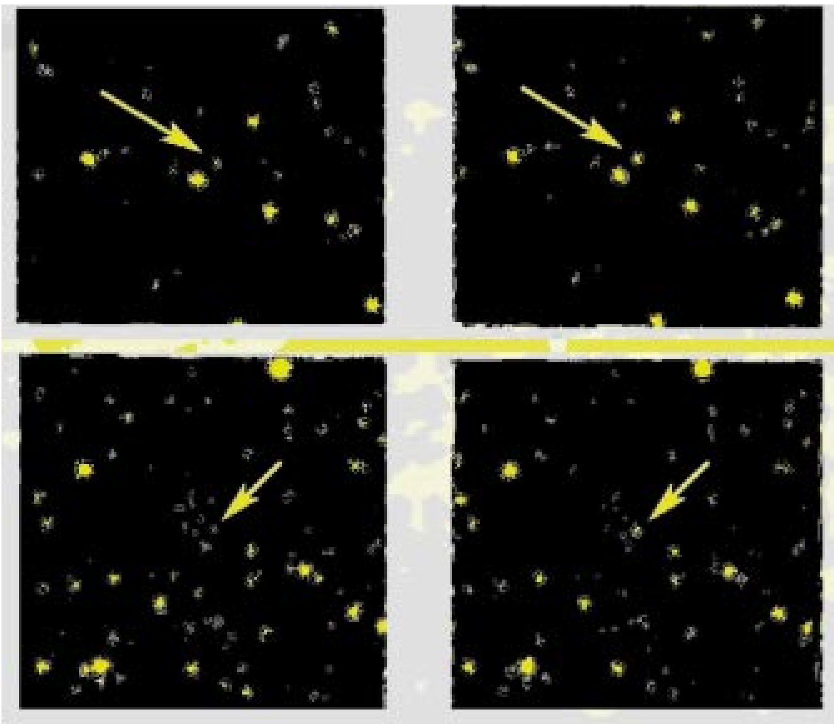

Figure 1: The two EROS microlensing candidates discovered on ESO Schmidt plates towards the LMC. Top: EROS-1, maximum light amplification on 1 February 1992; bottom: EROS-2, maximum on 29 December 1990.

Sombres) programme from 1990 to 1994, were digitised by MAMA and reduced at Centre d'Etudes Nucléaires, Saclay, and Laboratoire de l'Accélérateur Linéaire, Orsay, leading, towards the Large Magellanic Cloud, to the discovery of two microlensing events likely to have been produced in the Galactic Halo (Aubourg, E. et al., 1993, see also Fig. 1 of the present paper).

• About 300 other plates were taken at La Silla in the frame of the DUO (Disk Unseen Objects) project conducted by the Image Analysis Centre during the 1994 and 1995 seasons. Here the surveyed region was close to the Galactic Centre (Fig. 2). After digitisation, the images were reduced with a specific software developed at the CAI by Alard, C. for crowded fields. The monitoring of 13 million stars recorded during the first season lead to the detection of 13 microlensing events: 12 single lenses (Alard et al., 1995; Alard and Guibert, 1997), and a double lens, the less massive component can have the mass of a brown dwarf or a few times that of Jupiter (Alard, Mao and Guibert, 1995; see also Figure 3 of the present paper). Reduction of the 1995 season is in progress.

2.2 Galactic Structure and Dynamics

This domain is the object of many investigations at the CAI. Proper motions accurate to 2 mas/yr down to V 16–17, as well as magnitudes and colours, are obtained by several groups, either to sound the general stellar populations of the Galaxy, or to investigate specific objects: open and globular clusters, variable stars, etc.

2.2.1 Stellar Populations

• Using plates from Palomar, ESO, OCA (Observatoire de la Côte d'Azur), and Tautenburg (Germany), the Besançon team has conducted a long-term investigation of the galactic populations towards several directions (see, e.g. Robin et al., 1995; Ojha et al., 1996 and references therein. The kinematic and photometric data derived from the analysis of the plates have been widely used to constrain the Besançon Model (see, e.g., Haywood, 1994, Haywood et al., 1997).

• Similar studies have been conducted by Soubiran (1992) in the North Galactic Pole region, or are still in progress along the meridian plane of the Galaxy (MEGA project, Kharchenko and Schilbach, 1996).

2.2.2 Variable Stars

• Blink microscope detections by A. Terzan of more than 4,000 new Long Period Variables on ESO Schmidt plates covering an area of 100 square degrees including the Galactic Centre have been complemented by astrometry as well as photometry, resulting in accurate positions and, for part of them, in light curves (see, e.g. Terzan et al., 1997 and references therein; Alard et al., 1996). A comprehensive atlas of digital finding charts for these 4,400 objects is in preparation.

• The DUO search for microlensing events has also lead to the discovery of thousands of galactic variable objects (Alard et al., 1995, Alard and Guibert, 1997). Among them, contact binaries, dwarf novae, RR Lyrae… Thousands of new Long Period Variables are expected from the combination of the 1994 and 1995 campaigns.

• Reprocessing, with the DUO reduction package, of the EROS photographic images, resulted in the discovery of some 10,000 new RR Lyrae after analysis of 12 million light curves (Alard et al., in preparation).

• Mention should be made of a contribution, using the aforementioned DUO image analysis software, to the investigation of the intrinsic variability of the EROS-2 microlensing candidate (Ansari et al., 1995).

• Other investigations are in progress, e.g., studies of LPVs in the Galactic Centre region using SERC plates (Catchpole et al., in preparation)

2.2.3 Open Clusters

Among the various objects studied in this domain, we will quote here two clusters for which the juxtaposition of several Schmidt fields has allowed investigations of the kinematics and mass function over unsurpassed areas:

• The Pleiades (Schilbach et al., 1995, Meusinger et al., 1996; see also Fig. 4 of the present paper).

• Praesepe (Robichon 1997, in preparation).

Photographic plates are being complemented by HIPPARCOS and TYCHO data in the frame of an extensive investigation of several tens of clusters. A multi-colour atlas of open clusters is in preparation, in collaboration with the Institute of Astronomy, Lausanne.

2.2.4 Tidal Effects in Globular Clusters

An extensive investigation of tidal tails in 60 globular clusters has been undertaken. It is mainly based on "B" and "R" Kodak Tech Pan films exposed at the ESO Schmidt with the BG12 and RG630 filters, and on ESO, SERC and POSS survey plates, which have been digitised by MAMA. Data reduction and interpretation of the observed extensions in terms of tidal effects caused by the galactic Disk and Bulge are in progress. As an example of the most striking examples of the results obtained in the frame of this GATT (Globulars And Tidal Tails) programme, Figure 5 shows the tidal tails extending over 3 degrees displayed by NGC 288) (Léon, Meylan and Combes, in preparation).

2.3 Extragalactic Astronomy

The CAI's services are called on in different domains of extragalactic astrophysics, ranging from individual objects

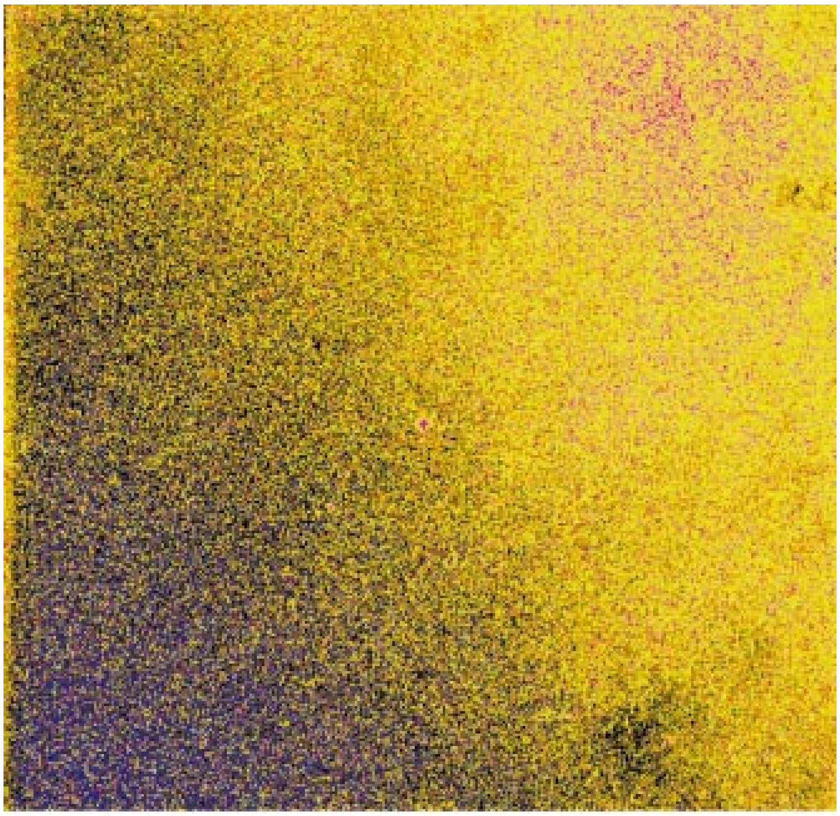

Figure 2: The field monitored in the course of the DUO programme. One of the some 200 IIIa plates taken at the ESO Schmidt at La Silla. North is to the top, east to the left. Up to 200 stars per square arcmin – i.e. per square mm of plate – are detected and deblended, resulting in 13 million stars monitored, and yielding 13 microlenses during the 1994 campaign.

to large-scale structures of the Universe and cosmological problems. Among the results obtained and programmes in progress:

2.3.1 Sagittarius Dwarf Galaxy

Unexpected extensions of this newly-known object were discovered in the course of the DUO programme (Alard, 1996). Figure 6 shows how these extensions have been unveiled by the histogram of distances to 1,500 new RR Lyrae stars towards the Galactic Bulge. Films obtained at the ESO Schmidt in 1996 will probably allow the detection of more variables of this type in additional fields, the objective being to delineate the contours of this galaxy which could be as large as the LMC.

We would like also to mention:

2.3.2 Emission-line galaxies

Automatic detection and detailed studies of emission-line galaxies from digitisation's of Calar Alto and ESO objective prism plates (Alonso, et al., 1995; Surace and Comte 1994).

2.3.3 Quasars

Surveys of ultraviolet-excess quasar candidates in large fields (Moreau and Reboul, 1995; Gosset et al., 1997).

2.3.4 Large Structures

Studies of clusters and superclusters of galaxies: morphology and segregation of galaxies in clusters (Andreon et al., 1995; Andreon, 1996); studies of X-Ray clusters (Durret et al., 1996) and of superclusters of galaxies (e.g. Quintana et al., 1995).

2.3.5 Galaxy Evolution

Luminosity function and evolution of galaxies (Bertin and Dennefeld, 1996). This study suggests that so far claimed needs for evolution of the non-dwarf galaxy population out to z = 0.2 could be due to systematic magnitude scale effects affecting previous investigations.

2.4 Identification and Astrometry of Optical Counterparts

2.4.1 Support to individual programmes

Identifying optical counterparts to determine the equatorial co-ordinates of sources detected at wavelengths ranging from the X-Ray domain to the infrared represents another important activity of the CAI, particularly in view of spectroscopic observations with large telescopes. Here, we will again select a small number of examples:

• IRAS sources (Le Sidaner and Le Bertre, 1993).

• Transient X-Ray sources (Chevalier and Ilovaisky, 1990; Kitamoto et al., 1990; Pakull et al., 1993, Feigelson et al., 1993...).

• Optical sources (eclipsing binary stars in LMC (Grison et al., 1994).

2.4.2 Contribution to the ALADIN Project

ALADIN is a new project currently under development by the CDS, Stras-

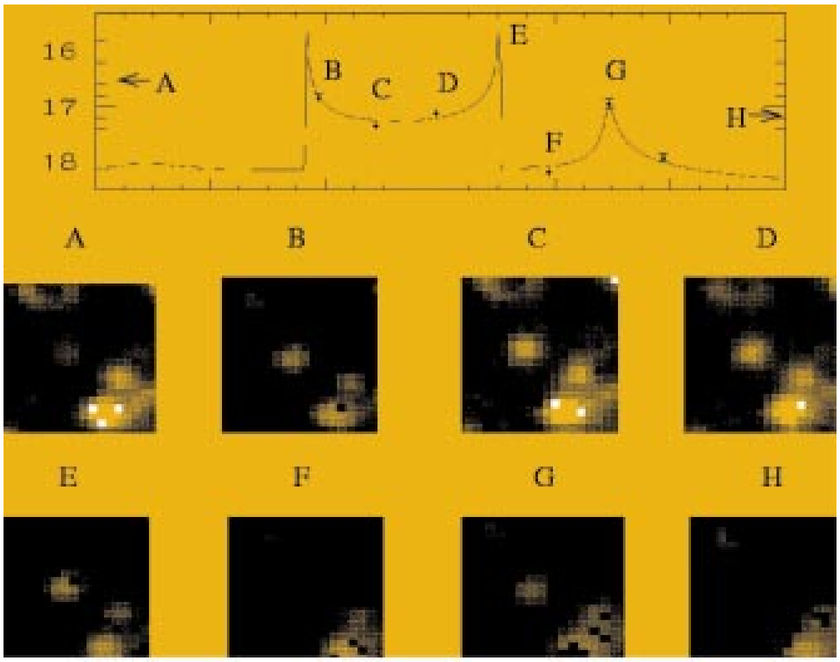

Figure 3: The double-lens DUO-02. Among the series of 8 frames displayed here (each of them extracted from a different ESO Schmidt plate), image G shows the last maximum observed during the event, which appears as an amplification by a double system (see text).

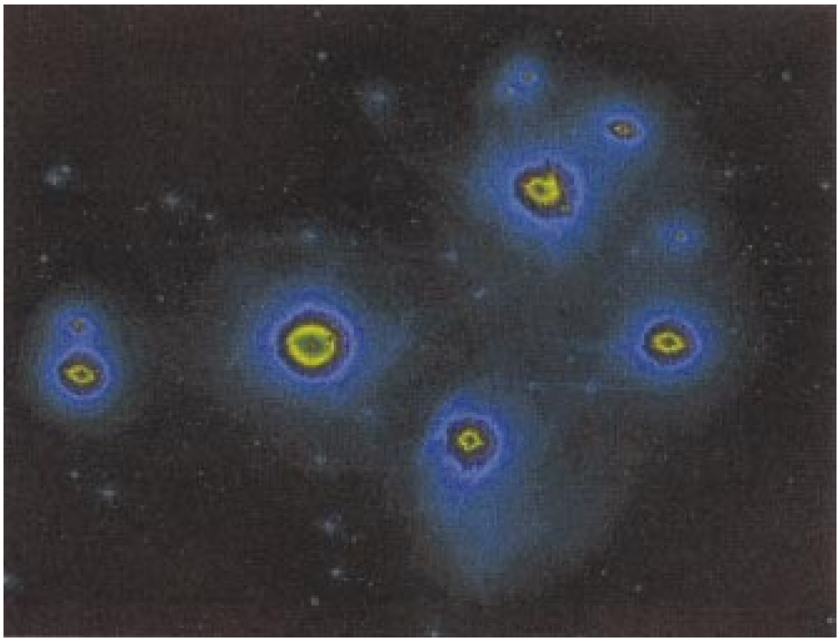

Figure 4: The central region of the Pleiades open cluster. Digitisation of a plate taken with the Tautenburg Schmidt. Proper motions accurate to 2 mas/yr in a large field have been obtained using a stack of such plates taken at different epochs.

bourg, to create an Interactive Deep Sky Mapping Facility, allowing the user to visualise on his/her own workstation digitised images of any part of the sky, to superimpose entries from astronomical catalogues or user data files, and to interactively access the related data and information from the SIMBAD database for all known objects in the field (Bonnarel et al., 1994, and CDS on the WEB). High-resolution images, obtained by digitisation of Sky Surveys, together with the corresponding astrometric calibration based on the PPM catalogue, have been provided to ALADIN by the CAI, essentially for the neighbourhood of the Galactic Plane and selected regions such as the Magellanic Clouds.

3. Image Processing and Data Reduction

Exploitation of large photographic and CCD images at CAI takes advantage of:

• efficient tools for image handling, such as mosaicing thousands of frames into images as large as 2 gigapixels.

• software like SExtractor (Bertin and Arnouts, 1996), or Extractor (developed at CAI by Alard, C.) for detection, deblending, and characterisation of sources from astronomical images in various environments

• optimised tools for astrometric and photometric calibration

• pipelines for concatenation of the aforementioned steps with object selection, pairing, etc. either on individual images or on pairs or series of exposures for colour corrections, and for studies of proper motions and magnitude variations.

Though always insufficient with respect to growing needs, increasing computer power and storage capacity are making possible the success of enterprises like the DUO programme, in which 13 million stars are detected, identified, and monitored on several hundreds of plates, implying handling of nearly 1 terabyte of data.

4. Recent Developments

The exploitation of CCD images of various origins not only is benefiting from skills and tools acquired and developed at the CAI, but motivates new efforts in several domains. This includes:

4.1 Image Processing

In the near and far infrared, the DENIS and ISOCAM images, respectively, are the objects of specific treatments designed by Alard, C. for image improvement and object detection in the cases of peculiar noise distributions or psf characteristics.

4.2 Astrometry: Complementation of Space Data and Developments of Reduction Techniques for Large Fields

This includes, among others:

• Development of astrometric reduction techniques taking advantage of the density and quality of catalogues such as TYCHO, to reach accuracies better

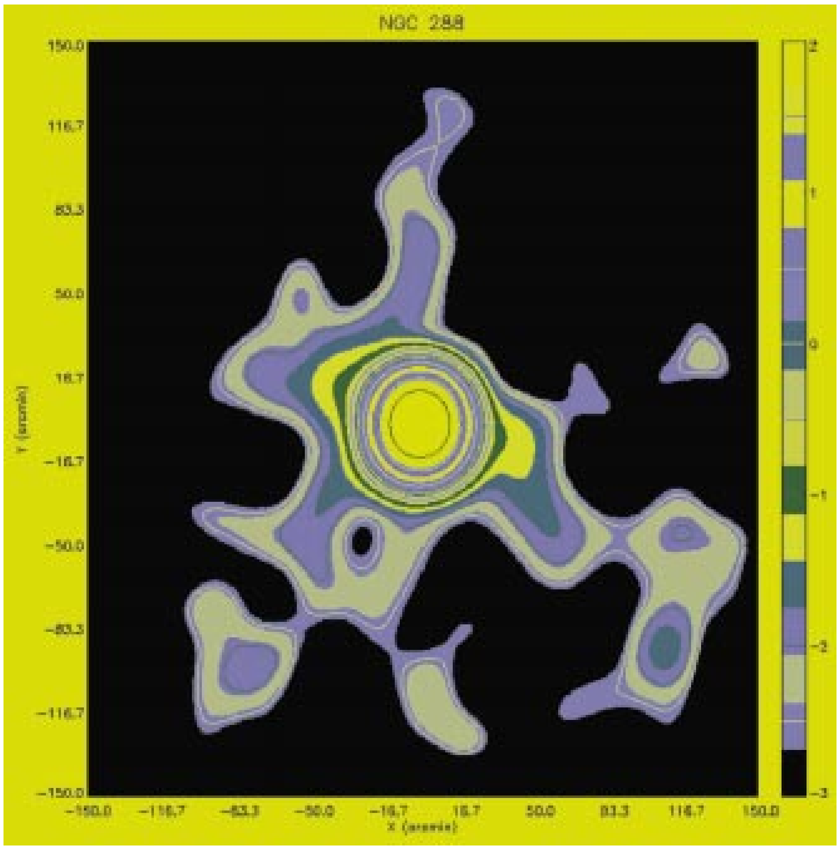

Figure 5: Tidal tails in the NGC 288 Globular Cluster. The figure displays the map of background-subtracted and wavelet-filtered surface density distribution of colour-selected stars in the field of NGC 288 from Tech Pan films taken at La Silla. This work extends the results obtained on a smaller area by Grillmair et al. (1995).

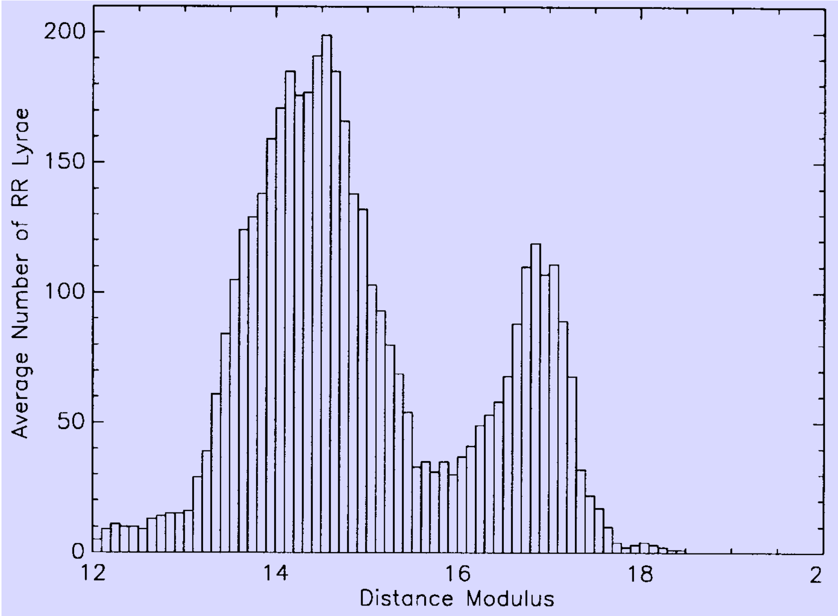

Figure 6: The extension of the Sagittarius Dwarf galaxy unveiled by the histogram of RR Lyrae stars distances.

than 0.1 arcsec in large fields (Robichon et al., 1995).

• Contribution to the link of the HIPPARCOS Catalogue to an extragalactic reference frame (Kovalevsky et al., 1997).

• New tools are under development for exploitation of Carte du Ciel plates. Combined with recent positions provided for instance by the TYCHO mission, such accurate first-epoch data can be used to improve the proper motions of reference catalogues.

• Use of efficient tools built for the retrieval of thousands of reference stars in large images and astrometric reduction algorithms to calibrate CCD images (collaborations with the Côte d'Azur Observatory and the EROS project).

4.3 Spectral Classification

A request, supported by several groups of various origins, has been submitted to the CAI for the realisation of a digital atlas of spectra containing several hundreds of MK standards.

Contact

Jean Guibert, Centre d'Analyse des Images, Observatoire de Paris, 77 avenue Denfert-Rochereau, F-75014 Paris.

Fax: (33) 1-40-51-20-90; E-mail: Jean.Guibert@obspm.fr; www: http://dsmama.obspm.fr

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Real-Time Spectroscopy of Gravitational Microlensing Events – Probing the Evolution of the Galactic Bulge

D.J. LENNON[1], S. MAO[2], J. REETZ[1], T. GEHREN[1], L. YAN[3], A. RENZINI[3]

[1] Universitäts-Sternwarte München; [2] Max-Planck-Institut für Astrophysik; [3] ESO

1. Introduction

Gravitational microlensing refers to the apparent brightening of a background source by a lensing object located sufficiently close to the line of sight. This gravitational focusing effect does not require the intervening object to be luminous, and hence has been suggested as a way to detect astrophysical dark matter candidates in the Galactic halo [1]. The challenges in detecting this effect are two-fold: Firstly, the probability of a star in nearby galaxies (including our own) to be microlensed is tiny, only one in a million. This means that millions of stars have to be monitored, and automatic data-processing is essential. Secondly, one has to tell microlensing events apart from many other intrinsic variations exhibited by stars. Fortunately, the symmetric, achromatic and non-repeating nature of a microlensing event distinguishes itself. Indeed, both obstacles have been overcome and the detection of microlensing has become a full enterprise [2]. Many groups are currently monitoring the Galactic bulge and the Large and Small Magellanic Clouds for microlensing events*. At the time of writing, more than two hundred microlensing candidates have been discovered by the DUO, EROS, MACHO, and OGLE collaborations; of these, about fifteen are towards the LMC, one towards the SMC, while the rest are towards the Galactic bulge [3, 4, 5, 6, 7]. An exciting observational advance is that most microlensing events can be identified in real-time while they are still being lensed. This allows detailed follow-up observations with much denser sampling, both photometrically and spectroscopically. Two groups, the PLANET and GMAN are conducting detailed photometric follow-ups [8, 9]. Our group is engaged in spectroscopic observations of selected microlensing targets (see section 2).

ESO has played a leading role in the spectroscopic studies of microlensing events. The first spectroscopic confirmation of microlensing was performed at ESO by Benetti, Pasquini and West [10], while the first spectral observations of a binary lens event were carried out by Lennon *et al.* [11]. Such spectroscopic studies are not only the strongest discriminator between variable stars and genuine microlensing candidates but also of importance for many other reasons. The spectra obtained allow detailed analysis of source properties, such as atmospheric parameters, stellar radius and radial velocity. Accurate stellar radii are essential to derive relative transverse velocities, a quantity much needed in order to derive the lens masses. Spectroscopic studies also yield essential information for a small fraction of more peculiar events. For the exotic binary caustic events [12], spectroscopic studies can resolve the stellar surface with very high accuracy and provide new opportunities to study limb-darkening profiles, well known only for the Sun. Spectral analysis can also provide important clues to some puzzles in microlensing. For example, there appears to be an over-abundance of long duration events. Currently, it is not even known whether these lensed sources belong to the disk or bulge populations. As these populations are thought to be kinematically and chemically distinct, a spectroscopic survey is needed to disentangle the disk and bulge contributions.

While these aspects are of importance for understanding the observed microlensing rate towards the Bulge, Lennon *et al.* [11] demonstrated for the

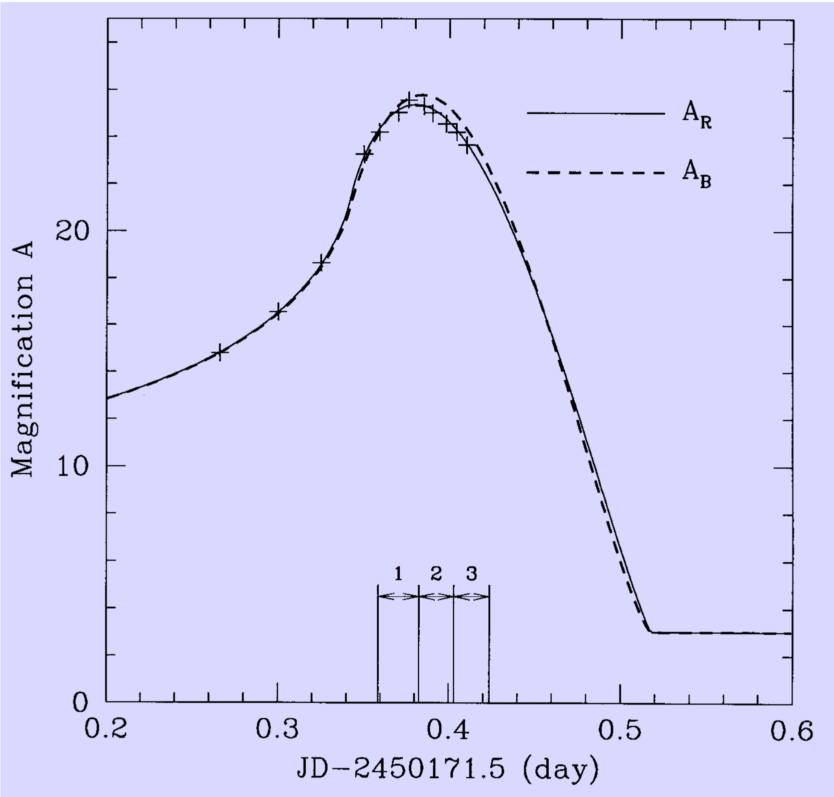

Figure 1: Simulation of the R-band light curve for the microlensing event 96-BLG-3 near the caustic crossing (solid line) and approximate data points (crosses). The thick dashed line shows the prediction for the B-band. The difference between the magnifications in B and R is due to the variation of limb-darkening profiles with wavelength (here assumed to be like the Sun). The vertical lines at bottom indicate the three-minute time intervals during which our spectra were taken. The binary nature of the lens was announced on March 28 (JD=2450171) by the MACHO collaboration [13], approximately one day from the peak. An earlier caustic crossing on March 25 was also identified, as well as previous complex behaviour.

*More information can be found at http://wwwmacho.anu.edu.au/ for the MACHO collaboration. Links to other collaborations can also be found there.

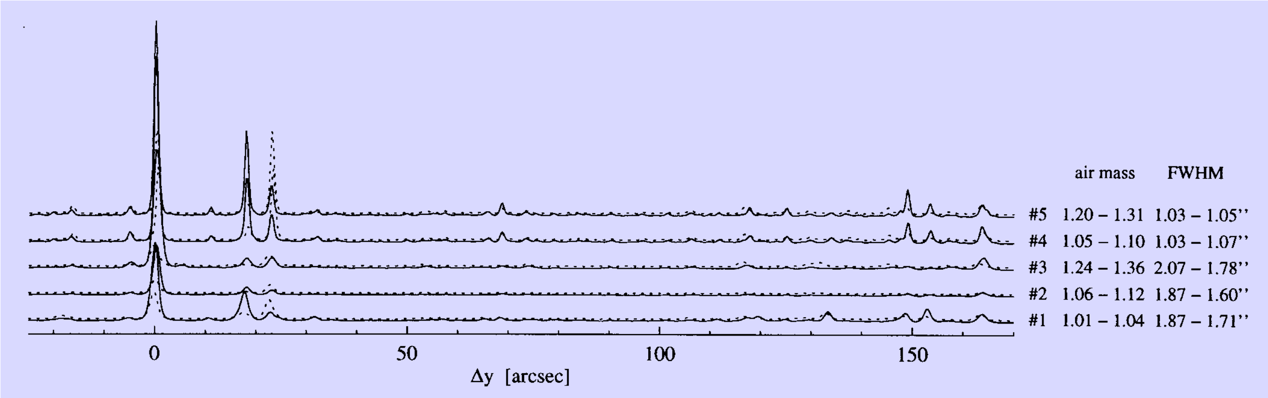

Figure 2: A section of the spatial profiles of five different 97-BLG-56 exposures, those averaged from 4380–4480 Å are dotted, while those averaged from 6350–6450 Å are solid lines. The microlensed target is situated at 0 arcsec but one can see a faint neighbouring star just to the its left, well resolved in exposures #4 and #5. On the right we give the air mass and also the FWHM of the spatial profiles. Since the seeing for exposure #3 was best, it appears that movement of the target along the slit may have caused additional broadening of the spatial profile.

first time that these events presented an exciting opportunity to investigate the formation and evolution of the Galactic Bulge itself. The reasoning goes as follows: Arguably, the most reliable picture that we have for the evolution of the galaxy is based upon very detailed abundance and kinematical studies of nearby disk and halo cool main-sequence stars, similar to the Sun. Unfortunately, such stars in the Bulge are intrinsically too faint for a 3–4-m-class telescope to get even a moderate resolution spectrum with good S/N. However, for the event we studied in 1996 using the NTT, the source was a G-type dwarf undergoing a magnification by a factor of 25 at the time of observation (cf. Fig. 1). The NTT was briefly the largest optical telescope in the world! Even with an 8–10-m-class telescope, such as the VLT or Keck I/II, high resolution and high S/N spectroscopy is out of the question for such intrinsically faint targets. Why not make most efficient use of telescope time and carry out such observations with the assistance of a gravitational lens? Over several observing seasons, and with the help of gravitational microlensing surveys, our aim is therefore to perform a systematic spectroscopic investigation of bulge sources. We expect that the results from this campaign will provide a fundamental insight into the formation and evolution of the bulge of our Galaxy. In the rest of this article we describe our first steps on this road, and summarise the current status of the project.

2. Programme

The feasibility of carrying out a systematic programme of spectroscopic observations of on-going microlensing events was first discussed by the two lead authors early in 1996 while DJL was a visitor to the MPIA. These early discussions received an unexpected boost when DJL, while carrying out another programme at the NTT telescope on La Silla, received a telephone call from Dave Bennett of the MACHO collaboration with the information that a binary microlensing event was *predicted* to undergo a caustic crossing during that observing run! That event, 96-BLG-3, was duly observed by us as a target-of-opportunity and a preliminary analysis has already been published [11]. Note that for an event such as 96-BLG-3, in which the *lens* is a binary system, the light curve may differ dramatically from the standard single lens curve, with the appearance of spectacular spikes as the source crosses caustics or near cusps. Extremely high amplifications may be reached during such occurrences. In Figure 1 we show schematically the timing of our observations compared to a light curve which approximates the behaviour of 96-BLG-3 during the relevant caustic crossing. The MACHO team's prediction of such an exotic event was an impressive feat, further strengthening our belief that on-going microlensing events could and should be spectroscopically monitored. Given this impetus, we therefore submitted a proposal to ESO requesting time on the NTT for a more systematic spectroscopic investigation of microlensing events towards the Galactic Bulge.

We opted for the NTT for a number of important reasons. Chief among these was the expectation that after the 'big bang', some observing on the NTT would be offered in service mode with observations being carried out in queue scheduled mode. Note that ours was not the usual kind of target-of-opportunity proposal, in the sense that we could estimate the expected rate of discovery of new events, as well as their probable range of magnitudes. Our observing programme could therefore be well defined except that we would only have an advance warning of weeks or days, depending on the event duration. Our hope was that we could get the relevant information into the system early enough to allow the NTT team to carry out the observations we required. One additional very important aspect of the NTT is that EMMI is permanently mounted on the telescope, unlike EFOSC1 on the 3.6-m telescope for example. Our only remaining minor concern was that the relevant grism or grating would be mounted in the instrument.

While ESO clearly regard the NTT as an important test of various operational and technical aspects for the VLT, we also saw this programme as a way of gaining valuable experience (for us and for ESO) since we also hope to pursue this work with the VLT. We were therefore extremely gratified that the OPC awarded us 30 hours of NTT time for this project during the period July – September 1997. We were further impressed by the professional assistance of the NTT team on La Silla and the Data Management Division in Garching in implementing and carrying out our programme in what has been a very successful beginning.

3. Current Status

At the time of writing we have data for a total of five events, two were observed previously as targets-of-opportunity, while three events have so far been observed using the NTT and EMMI under our spectroscopic monitoring programme. The events are described below. (We follow the MACHO naming scheme such that 96-BLG-3 refers to event number 3 towards the Galactic Bulge in observing season 1996.)

• 96-BLG-3. A binary microlensing event (the lens is a binary system), the first to be observed spectroscopically. It was observed as the source star traversed a caustic, leading to a very high amplification by a factor of 25 (cf. Fig. 1).

• 97-BLG-10. Another anomalous event with evidence for caustic cross-

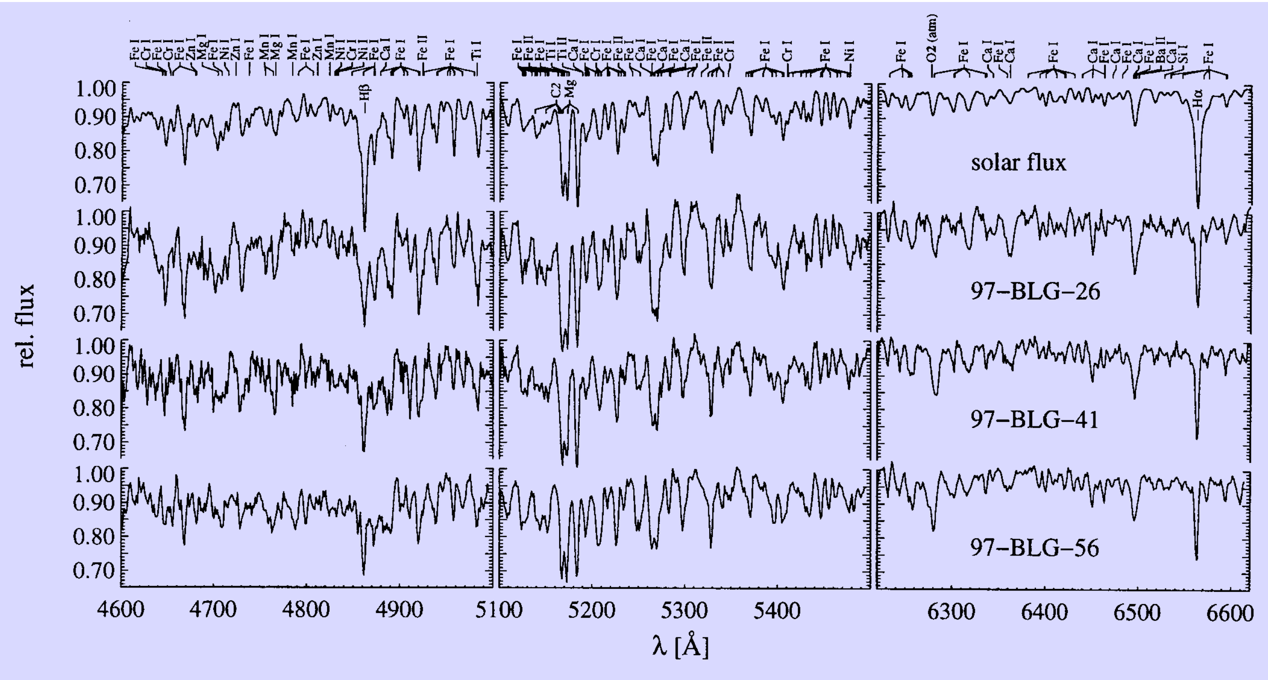

Figure 3: This montage compares the convolved solar flux spectrum (120 km/s Gaussian) with spectrograms of three recently observed microlensing events obtained with the NTT. For all of the observations we used EMMI in RILD mode with grism #5 giving a nominal spectral resolution of 1100 for a 1-arcsec slit and wavelength coverage of 3985–6665 Å. The actual seeing limited resolution is 15% higher. The signal-to-noise ratio of the normalised spectra is 90 (97-BLG-26), 85 (97-BLG-41) and 200 (97-BLG-56). Strong spectral lines are denoted. Telluric absorption lines, particularly O_2 and H_2O at Hα, have not been eliminated, though monitored with white-dwarf exposures.

ings, however the data-reduction process is complicated due to the presence of another nearby star in the aperture of the spectrograph. (Unlike the other events, this was observed at the ESO 3.6-m telescope using EFOSC1 in echelle mode.) Maximum amplification has been estimated as 13.3.

• 97-BLG-26. This was a long-duration, high-amplification event, with a maximum amplification of 8.0, in which the source star is probably a late type sub-giant.

• 97-BLG-41. Another case of an anomalous event indicating that the lens is a multiple system. Again this was observed during a caustic crossing when the source was amplified by a large factor.

• 97-BLG-56. The maximum amplification for this event was also reasonably high (5.5), although the source is intrinsically bright and it is most likely a giant. The expectation here is that one may be able to detect finite source effects such as discussed in [14].

Due to the crowded nature of the fields used for microlensing surveys, plus the requirement that sometimes one is seeking to identify line-profile or continuum-slope variations, the reduction of data is a complicated business which must be performed carefully. This is carried out using a suite of IDL routines developed and maintained at the Universitäts-Sternwarte München. The analysis of these data will be carried out using improved techniques compared to those used by us in earlier work [11].

4. The Challenges

We set ourselves the goal of deriving stellar parameters with typical accuracies of $\Delta T_{\rm eff}$ 200 dex, $\Delta \log g$ 0.3 dex and Δ[Fe/H] 0.2. The difficulty in achieving this objective using low-resolution spectroscopy of cool stars is illustrated in Figure 4 which shows that the theoretical low-resolution spectra (R 1300) are only responding at a level of 3% to variations in gravity and metallicity of 0.5 and 0.3 dex respectively. This means that non-intrinsic features must be either eliminated or excluded from the fit estimation to an accuracy of better than 97%. This makes great demands on the processes of data acquisition, calibration, reduction and spectroscopic analysis. In particular we need to understand the behaviour and properties of the telescope (NTT) and spectrograph (EMMI) used to obtain the data. On the analysis side we have had to develop reliable methods for the interpretation of low-resolution spectra of cool dwarfs and subgiants. In the following we briefly discuss our techniques and some of the problems encountered.

4.1 Data Reduction

The Bulge fields are all very crowded, therefore high *spatial* resolution is important to separate the target spectrum from that of close neighbours. Figure 2 shows spatial profiles (note that we use a long slit) of 5 sequential exposures of 97-BLG-56; it demonstrates that in this case a seeing FWHM smaller than one arcsec is required. Although photometric conditions are not required because we analyse normalised spectra, we need one or more additional stars on the slit to serve as *differential* photometric calibrators to separate intrinsic variations of the continuum slope from those caused by varying transparency, seeing FWHM, airmass, or misaligned parallactic angle. Ideally the calibrator should sit exactly on the slit, providing equal sensitivity to inaccuracies in telescope pointing for both stars; of course the angular distance between both should be sufficiently small to minimise sensitivity to rotator inaccuracies. Figure 2 demonstrates that this has not always been achieved! Nevertheless, we extract all spectra on the slit with a S/N 10, using an optimal extraction technique. We are currently testing a method which allows one to include more than a single profile in the extraction window in order to disentangle spatially blended spectra.

4.2 Spectrum Analysis

We use *line-blanked,* plane-parallel, homogeneous model atmospheres (cf. [17], and references therein). These models (temperature and pressure structures) are similar to those generated with ATLAS9 of R.L. Kurucz, in particular both codes use the standard mixing-length theory to calculate the convective flux. However, we use a

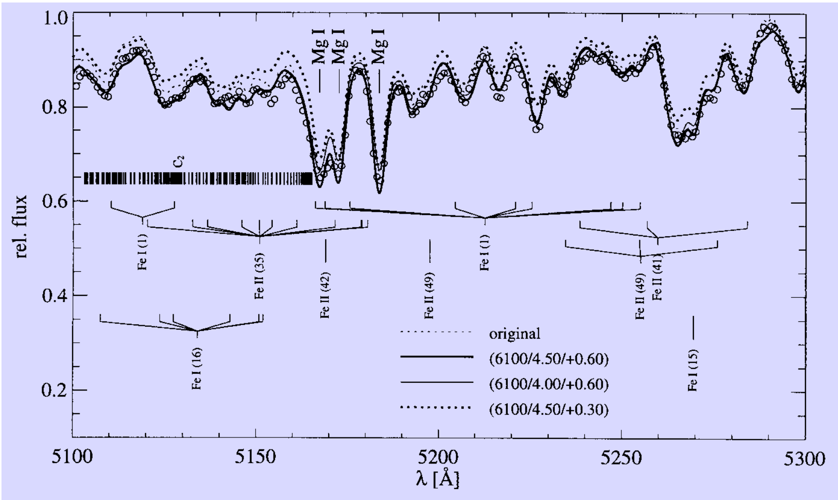

Figure 4: Comparison of synthetic spectra with the previously observed spectrum of 96-BLG-3 (open circles). One improvement over our original work (thin dotted line) [11] is the inclusion of C_2 opacity resulting in a much improved fit bluewards of the Mg I 5167.3 Å component. One can see that the model (T_{eff}/log g/[M/H] = 6100/4.50/ + 0.60) now fits all the data points quite well in this spectral range. Strong iron multiplets are also indicated.

mixing-length parameter that is spectroscopically determined [17], which has some effect on the derived effective temperature. Line opacities are taken into account using opacity distribution functions from Kurucz 1992 [16], scaled to account for the fact that Kurucz' adopted solar iron abundance was overestimated. Atomic and molecular line data originate from Kurucz, except that most of the f-values and broadening parameters have been adjusted such that the line profiles fit the high-resolution solar flux atlas ([15]) in the spectral regions around Hα, Hβ and the Mg b lines (Figure 4).

We determine the *best fit* parameters T_{eff}, log g, [Fe/H], as well as the width of the instrumental profile, presently assumed to be a Gaussian. Synthetic spectra corresponding to randomly selected sets of parameters are interpolated from a pre-calculated grid. A merit function for each set of parameters is then derived which is basically estimated as a χ^2-function, with additional goodness-of-fit criteria used to control the weights assigned to various pixels. Our *Monte Carlo* calculation contains typically a few hundred fit evaluations. The merits are sorted starting with the lowest value which corresponds to the model parameters of the *best* fit, while the fit merits may be used to estimate the uncertainty. As an example, the quality of the fit to the spectrum of 96-BLG-3 is shown in Figure 4. The improvement of the merit function is an important matter of concern in the nearest future, we will also define a physically based strategy to determine error boundaries. A further refinement currently being tested is that of deriving [Mg/Fe] and [C/Fe] abundance ratios.

Finally, we also need to estimate the effect of the lens itself on the perceived flux spectrum of the source since the normal limb darkening law is to some degree distorted by the amplification (cf. the B and R band light curves in Figure 1). (For the present we ignore the possibility that the lens itself contributes significantly to the observed flux.) For example, we know that for the sun the Hα line profile, which is our primary effective temperature diagnostic, is significantly different in centre and limb spectrograms. For 96-BLG-3 we have already computed the effect of the lens on Hα and confirmed that for this object, at the time of observation, the perturbation of the profile is small compared to the uncertainties in the analysis. However, this is of course something which must be considered in general, and is particularly relevant when the source is a giant.

4.3 Preliminary Results

In Figure 3 we show a montage of spectra for the 3 targets observed so far under the auspices of our NTT target-of-opportunity programme. We have derived preliminary stellar parameters for only two of these targets, which are subgiants, since we do not yet have atmospheric models suitable for the analysis of giants. The Balmer line wings presented in Figure 3 indicate effective temperatures of 5200 ± 200 K for 97-BLG-26 and 5000 ± 200 K for 97-BLG-41. Gravities are log g 3.9 ± 0.3 and 3.2 ± 0.3, respectively, whereas 97-BLG-26 appears to be metal-rich ([Fe/H] 0.3 dex) and 97-BLG-41 to be slightly metal-deficient ([Fe/H] –0.2 dex). Due to the high S/N we expect that the uncertainty of the derived metallicities does not exceed 0.3 dex. We have also obtained preliminary radial velocities for other objects falling on the long slit (cf. Fig. 2). The accuracy of the stellar parameters, and therefore the derived radii and stellar masses, are expected to be significantly improved in a more complete analysis.

5. Future Plans

We plan to continue spectroscopic surveys of microlensing events, it is clear that with a sizeable spectroscopic sample one can learn much about the formation and evolution of the Galactic bulge through dynamical and stellar atmosphere studies. The up-to-date status of this project is available at http://www.mpa-garching.mpg.de/ smao/survey.html. It will be very exciting to use the larger telescopes such as the VLT in this work, in fact, the KECK I has already been used to observe the finite source size event 95-BLG-30 [14], and indeed, a more systematic spectroscopic survey was carried out this year (Minniti, private communication). The implications of moving to a larger aperture are obvious; it will be possible to resolve peculiar events with much better time (and therefore spatial) resolution. More subtle events such as blending of light by the lens may become observable with the VLT due to the difference between the lens and source radial velocities. A series of centre to limb spectra could then be used to constrain stellar models of the poorly understood atmospheres of cool giants/supergiants. Microlensing candidates in the LMC and SMC, which are typically fainter by about three magnitudes, come within reach of spectroscopy. In particular, using the VLT and UVES, high S/N and high-resolution spectra will be quite easily obtainable for the more strongly amplified sources such as are discussed above. This will permit the analysis of Bulge dwarfs with an accuracy comparable to that of their nearby field and halo counterparts, and allow us to investigate their chemical compositions in detail, looking at relative abundances of light, α-process, Fe-group, *r*-process and *s*-process elements. The VLT, given its expected flexibility when it comes to scheduling and the wide range of optical and IR instrumentation *permanently* available at its many foci, is ideally suited to this kind of multi-faceted project.

6. Acknowledgements

Carrying out service-mode observing for a project such as ours is not easy, but we at least want to make sure that it is not a thankless task! Special thanks are due to the staff at La Silla including Gauthier Mathys, Chris Lidman, G. van de Steene and the rest of the NTT team. We also thank ESO staff at Garching, particularly Dave Silva and Albert Zijlstra in the Data Management Division for their profes-

sional assistance. Of course, this work would not be possible without the real-time alert system of the MACHO collaboration and the photometric follow-up networks of the PLANET and GMAN collaborations. We have also benefited from discussions with the EROS and OGLE collaborations. We are indebted to Dave Bennett, Chris Stubbs and Charles Alcock (MACHO), Penny Sackett (PLANET), and Jim Rich (EROS) for discussions and encouragement.

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LATEST NEWS:

The First M2 Unit and Beryllium Mirror Delivered to ESO

S. STANGHELLINI, ESO

At the time this edition of the *Messenger* went to press, the first M2 Unit and the first M2 Beryllium mirror of the VLT have successfully passed the final and most critical phase of their acceptance testing in the integration hall of Dornier Satellitensysteme in Friedrichshafen, Germany. This closes a period of more than seven months of severe tests performed to guarantee that the Secondary Unit and its mirror meet the stringent requirements necessary to ensure the full optical quality of the VLT. This period was characterised by a close interaction between the Dornier and the ESO team following the project[1] to establish the complex test procedures and to review the results.

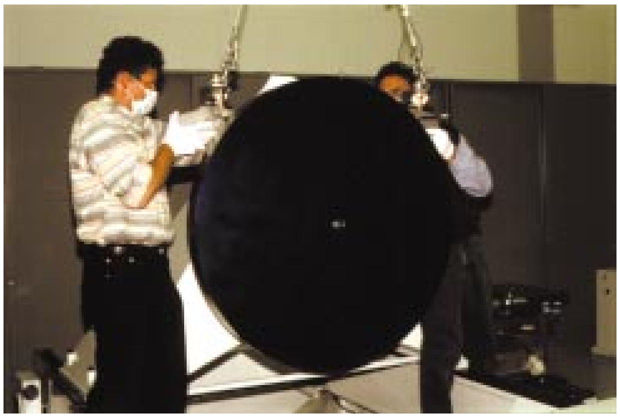
The test programme started in May 1997 with the tests of the software, closely followed by the tests of the electromechanical unit, done with the help of a lightweighted dummy mirror. The test results, although successful, led to a number of improvements and optimisations, performed by Dornier during the following months.

During the same period, REOSC Optique in Paris was completing the final polishing of the first Beryllium mirror, which after integration of its titanium support system, and following optical tests, was delivered to Dornier in September 1997.

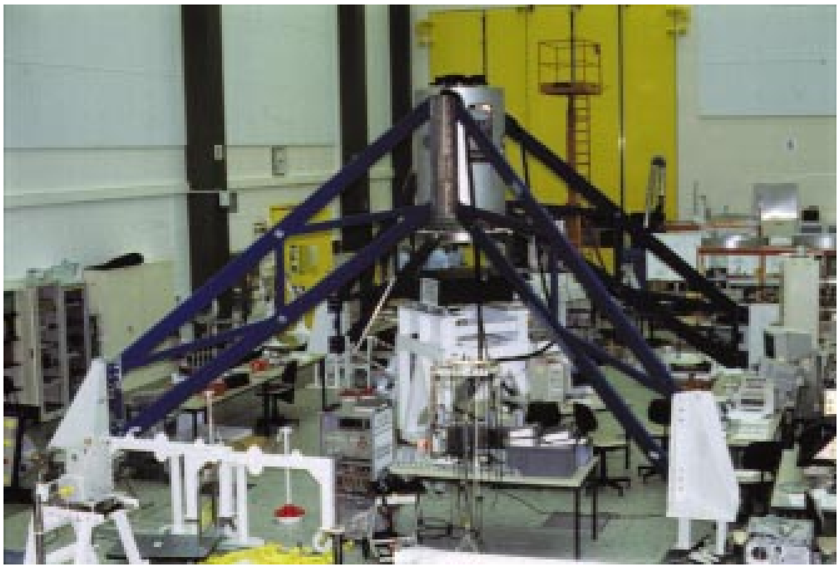
Here, the M2 mirror was dynamically tested to determine its inertia and the position of its centre of gravity, crucial elements for the proper balancing of the chopping mechanism. In October, the M2 mirror was inserted for the first time in the M2 Support Unit to check the differences between the dummy and the real mirror. In November, finally, a test set-up with real telescope spiders that carry the M2 and its support was prepared and assembled in the integration hall of Dornier. Due to the flexible mounting, it was possible to detect any unbalance in the M2 Unit that might possibly affect the telescope pointing.

These final tests were successful and have now led to provisional acceptance of the M2 Unit. They have not only shown full compliance with the ESO chopping and tip-tilt (*field stabilisation*) requirements, but have also demonstrated the feasibility to tune the system for active rejection of unwanted mechanical resonances.

It is therefore expected that the M2 Unit will be successfully integrated in the first VLT Unit Telescope. At the time this note is being written, the M2 Unit is being packed and will soon be shipped to Paranal in its special container.



The M2 Beryllium mirror in the test laboratory of DASA, Ottobrunn, Germany, during the determination of its inertia and centre of gravity. The mirror is protected by a peelable protective layer.



The M2 Unit with the Beryllium mirror at Dornier during the spider tests. The mirror is in front of the granite block used for the testing. The spider structure is anchored to the floor by means of dedicated interfaces, simulating the attachment to the top ring of the telescope.

[1] The ESO team involved in the acceptance of the M2 Unit is composed by the author and by G. Jander, A. Michel, M. Duchateau, B. Gustafsson, P. Giordano, W. Ansorge.

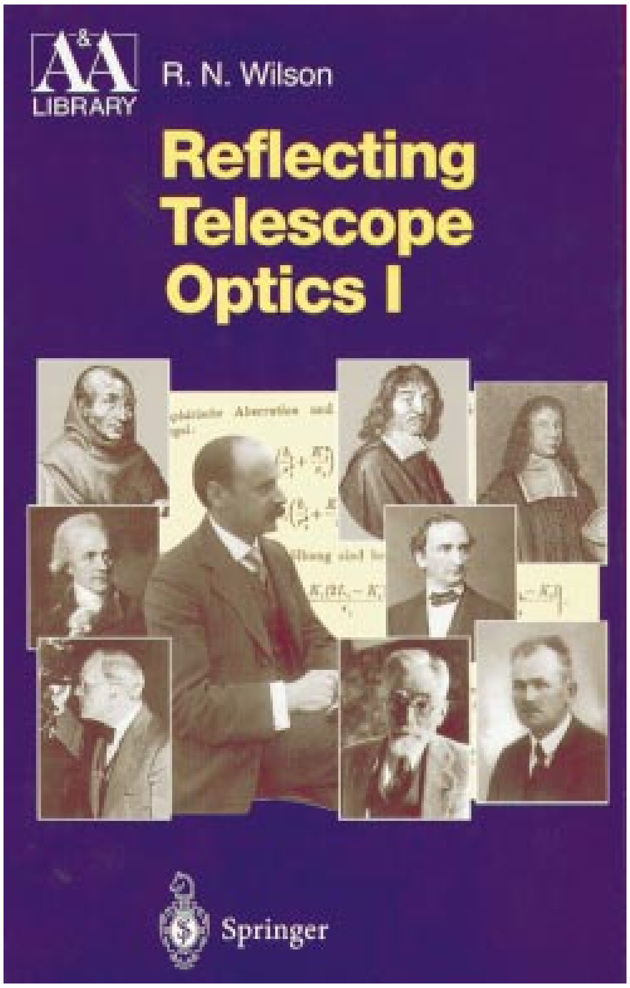
OTHER ASTRONOMICAL NEWS

BOOK REVIEW

Reflecting Telescope Optics I*

R. N. Wilson
Hardcover, A&A Library
ISBN 3-540-58964-3 Springer Verlag
Price DM 128.—

Since the mid-19th century and the application by Foucault of chemical silvering to glass mirrors, reflecting telescopes have gradually taken over from refracting ones, to eventually become the dominant telescope concept over the entire 20th century. Reflecting Telescope Optics I (RTO I) is an unequalled reference for those who have interest in the field, be they students, telescope designers, professional or amateur astronomers.



In Chapter 1 the author takes us on a short, fascinating and at times surprising, journey through the history of telescope design. A delightful story of men, ideas and fascinating machines. It stems from the account by the author that optics is one of those sciences whose progress is inescapably tied to the progress of experimentation and technology. Chapter I tells about great ideas which, sometimes, had to wait for centuries before being understood and recognised.

The second and third chapters deal with Gaussian optics and aberration theory, respectively. Fundamental aspects of Gaussian optics are reviewed in a concise manner, albeit to a level of detail sufficient to make the book a valuable reference for an advanced course on geometrical optics. The same comment applies to the third chapter, which deals with aberration theory of telescopes – in the broadest sense. All relations necessary to set up a design, understand and evaluate its first-order (paraxial) properties and third-order aberrations are clearly demonstrated and their implications thoroughly analysed. Section 2.2.5.2, in particular, will be invaluable to set up the basis for a two-mirror telescope design, while section 3.2.4 provides all necessary information to evaluate its aberrations. Tables and practical examples provide most useful illustrations to the theory, and serve as well for quick reference when reviewing properties of existing designs.

A thorough review of one- and two-mirror design solutions is provided in sections 3.2.6 and 3.2.7, together with detailed illustrations and numerical examples. Section 3.3 provides much detailed and useful information on third order aberrations.

A unique and most complete review of wide-field telescope designs, from Schmidt and Maksutov solutions to less known three- and four-mirror designs, is proposed in section 3.6; off-axis designs are addressed in section 3.7, together with a detailed analysis of the effects of decentring of 2-mirror telescopes. Even if this is certainly not its main purpose, there is little doubt that these sections will retain the attention of amateur telescope makers as well.

Elaborating on a generalisation of the Schwarzschild Theorem, the author demonstrates the relation between the number of optical surfaces and the achievable compensation of third-order aberrations. The four-mirror designs with spherical primary and secondary mirrors derived in section 3.6.5.3 pave the way for giant telescopes beyond the 10-m range.

Despace effects are reviewed in much detail (section 3.8), unfortunately in the restricted case of two-mirror designs only. As such effects can be of utmost importance with regard to preservation of optical quality and may come to play a role in a trade-off between otherwise equivalent designs, it seems to me that a broader – and, in view of its tremendous complexity, simplified – account would have usefully complemented the review of three- and four-mirror designs of section 3.6.

A brief but quite complete account of diffraction theory and its relation to aberrations is provided in section 3.10. This section is essential to the completeness of RTO I; it provides the key to understanding image formation and properties, and appeals to the broadest range of readers.

Chapter 4 covers field correctors and focal extenders/reducers in great detail, and provides a brief account of atmospheric dispersion correctors, thereby adding to the completeness of RTO I.

Finally, theory meets reality in chapter 5, which provides a delectable and most instructive account of major telescope projects – and ideas related to them – from the early 19th century until the mid-1980's.

It should be pointed out that, although RTO I deals with telescope optics in a largely theoretical manner, realistic constraints and limitations are given due regard, a consequence of the author's impressive experience in telescope design and fabrication.

This review would be incomplete if no acknowledgement were made to the rigorous and consistent formalism of the author, as well as to the useful indices, list of symbols, tables and figures, the most complete bibliography, and the unique portrait gallery of major figures in the field.

Indeed, a unique reference in a superb presentation.

* Reflecting Telescope Optics I is the first in a series of two volumes by Raymond N. Wilson, formerly Senior Optical Engineer at ESO. Amongst other major achievements, Ray Wilson developed at ESO the concept of Active Optics, applied to the 3.5-m NTT and 8-m VLT telescopes.

ANNOUNCEMENTS

CNRS – Observatoire de Haute-Provence and European Southern Observatory

6th ESO/OHP Summer School in Astrophysical Observations

OBSERVATOIRE DE HAUTE-PROVENCE, FRANCE

15–25 July 1998

The ESO/OHP Summer School offers young astronomers the opportunity to gain practical observing experience under realistic conditions. Participants will work in groups of three and will be guided by an experienced observer in the use of the instrumentation of OHP. Each group will carry out a small observing programme on the telescopes of 0.8–1.9 m aperture, all equipped with a CCD detector (direct imaging and spectroscopy), and reduce the data with MIDAS or IRAF. The results will be related to relevant additional information from the astronomical literature, and presented in a brief summary to the other participants at the end of the school.

The preparation of the practical work will be supplemented by a series of 90-minute lectures which will be given by invited specialists. Foreseen subjects include: (a) Spectrographs and spectroscopy, (b) Principles of photometry, (c) Detectors, and (d) Data-reduction techniques.

The working language at the summer school will be English. Applications are invited from graduate students working on a Ph.D. thesis in astronomy at an institute in one of the ESO member countries. Application forms are available from the organisers and are to be returned by March 31, 1998. Additionally, a letter of recommendation by a senior scientist familiar with the applicant's work is required. Up to eighteen participants will be selected and will have their travel and living expenses fully covered by the school.

THE ORGANISERS

M.-P. Véron
Observatoire de Haute-Provence
F-04870 Saint Michel l'Observatoire
France
mira@obs-hp.fr

G. Meylan
European Southern Observatory
Karl-Schwarzschild-Strasse 2
D-85748 Garching
gmeylan@eso.org

PERSONNEL MOVEMENTS

International Staff

(1 November – 31 December 1997)

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MEI, Simona (F), Student
VIEZZER, Rodolfo (I)

Chile

PATAT, Ferdinando (I)
ENDL, Michael (A), Student
WIRENSTRAND, Krister (S), Senior Software Engineer
(Transfer from Garching to Paranal)

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ZIJLSTRA, Albert (NL), User Support Astronomer
GRÖSSL, Martin (A), VLT Project Engineer
ERBEN, Thomas (D), EIS Programme

Chile

BENETTI, Stefano (I), Fellow
SHETRONE, Matthew (USA), Fellow

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(1 November – 31 December 1997)

ARRIVALS

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PARRA, Jose (RCH), Data Handling Administrator

DEPARTURES

CLAVIJO, Patricia (RCH), Bilingual Secretary Personnel
PILLEUX, Mauricio (RCH), Mechanical Engineer AIV
GARCIA, Enrique (RCH), Electronic Technician
LEON, Washington (RCH), Cleaner

List of Scientific Preprints

(October–November 1997)

1250. R.A. Méndez and W.F. van Altena: A New Optical Reddening Model for the Solar Neighborhood. Galactic Structure Through Low-Latitude Starcounts from the Guide Star Catalogue. *A&A.*
1251. D. Baade: Pulsations of OB-Stars: New Observations. Invited review, to appear in F.-L. Deubner et al. (eds.): Proc. IAU Symp. No. 185. *New eyes to see inside the sun and stars. Pushing the limits of helio- and asteroseismology with new observations from the ground and from space.*
1252. M. Le Louarn, R. Foy, N. Hubin, M. Tallon: Laser Guide Star for 3.6m and 8m Telescopes: Performances and Astrophysical Implications. *M.N.R.A.S.*
1253. P. Rosati, R. Della Ceca, C. Norman, R. Giacconi: The ROSAT Deep Cluster Survey: The X-ray Luminosity Function out to z = 0.8. *Ap.J. Letters.*
1254. L. Pulone, G. De Marchi, F. Paresce, F. Allard: The Lower Main Sequence of ω Cen from Deep HST NICMOS Near IR Observations. Submitted as a *Letter* to the *Astrophysical Journal.*

ESO Director General Receives Honoris Causa Degree

On October 24, 1997, in Rome, the ESO Director General, Riccardo Giacconi, was awarded an Honoris Causa Degree by the University of Rome "La Sapienza".

VACANCY NOTICE

The EUROPEAN SOUTHERN OBSERVATORY (ESO), an international organisation for research in astronomy, is presently constructing the world's most powerful facility for optical astronomy. Located at Cerro Paranal in the Chilean Atacama desert – a unique astronomical site – the Very Large Telescope (VLT) and VLT Interferometer Array will lead ground-based astronomy in the 21st Century. When completed in 2003, the VLT will consist of four 8-m optical telescopes and a number of movable auxiliary telescopes allowing independent observations with each of the telescopes or combined observations with the entire array. With "First Light" for the first 8-m telescope in 1998 and the beginning of science operations in early 1999, ESO is offering a selection of demanding job opportunities in the development, commissioning and operation of the VLT.

20 Positions for Scientists and Engineers

• Data-Flow Operations Astronomers in Garching

Operations staff astronomers at the ESO Headquarters in Garching near Munich will be responsible for user support of visiting and service-mode astronomers, quality control of VLT data, long-term monitoring of VLT instruments, data distribution and support of archival research using the VLT Science Archive facility.

• Engineers in Garching and on Paranal

The positions available will be dedicated to the VLT telescopes, the associated instruments and observatory installations in the field of optics, detectors, infrared, mechanics and electronics. Software engineering positions are available to develop the VLT Data-Flow System for data analysis and programme management.

• VLT Astronomers on Paranal

Staff astronomers have specific responsibilities for the scientific operations at the observatory and are expected to devote up to 50 % of their time to dynamic and independent research programmes. Their responsibilities include the co-ordination of service-mode observations, introduction and support for visiting astronomers, night operations and data-flow operations in co-ordination with colleagues at the ESO Headquarters in Garching near Munich.

• Science Deputy in Chile

The Deputy of the Associate Director for Science is expected to devote up to 50 % of his/her time to science and will be responsible for the administration of the scientific activities of the ESO-Chile astronomers, the organisation of seminars and workshops, the selection of students and fellows in collaboration with the Directors of the Paranal and La Silla Observatories.

A most important task is to foster collaborative scientific projects with the Chilean astronomy community.

For all positions it is envisaged to offer initially a 3-year contract with the possibility of fixed-term extensions or indefinite contracts. Astronomers are appointed at the Assistant, Associate or Full Astronomer level. Associate and Full Astronomer positions will be considered for tenure after 5 years of service. Promotions will be based on scientific as well as functional achievements.

ESO offers attractive working conditions including relocation, and the remuneration will be commensurate with background, experience and family status. The organisation encourages both men and women with relevant qualifications to apply.

For full details of all vacancies and the application form, see http://www.eso.org/gen-fac/adm/ – or contact

ESO, Personnel Services,
Karl-Schwarzschild-Str. 2,
D-85748 Garching, Germany.

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ESO, the European Southern Observatory, was created in 1962 to . . . establish and operate an astronomical observatory in the southern hemisphere, equipped with powerful instruments, with the aim of furthering and organising collaboration in astronomy . . . It is supported by eight countries: Belgium, Denmark, France, Germany, Italy, the Netherlands, Sweden and Switzerland. It operates the La Silla observatory in the Atacama desert, 600 km north of Santiago de Chile, at 2,400 m altitude, where fourteen optical telescopes with diameters up to 3.6 m and a 15-m submillimetre radio telescope (SEST) are now in operation. The 3.5-m New Technology Telescope (NTT) became operational in 1990, and a giant telescope (VLT = Very Large Telescope), consisting of four 8-m telescopes (equivalent aperture = 16 m) is under construction. It is being erected on Paranal, a 2,600 m high mountain in northern Chile, approximately 130 km south of Antofagasta. Eight hundred scientists make proposals each year for the use of the telescopes at La Silla. The ESO Headquarters are located in Garching, near Munich, Germany. It is the scientific, technical and administrative centre of ESO where technical development programmes are carried out to provide the La Silla observatory with the most advanced instruments. There are also extensive facilities which enable the scientists to analyse their data. In Europe ESO employs about 200 international Staff members, Fellows and Associates; at La Silla about 50 and, in addition, 150 local Staff members.

The ESO MESSENGER is published four times a year: normally in March, June, September and December. ESO also publishes Conference Proceedings, Preprints, Technical Notes and other material connected to its activities. Press Releases inform the media about particular events. For further information, contact the ESO Information Service at the following address:

EUROPEAN
SOUTHERN OBSERVATORY
Karl-Schwarzschild-Str. 2
D-85748 Garching bei München
Germany
Tel. (089) 320 06-0
Telex 5-28282-0 eo d
Telefax (089) 3202362
ips@eso.org (internet)
ESO::IPS (decnet)

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