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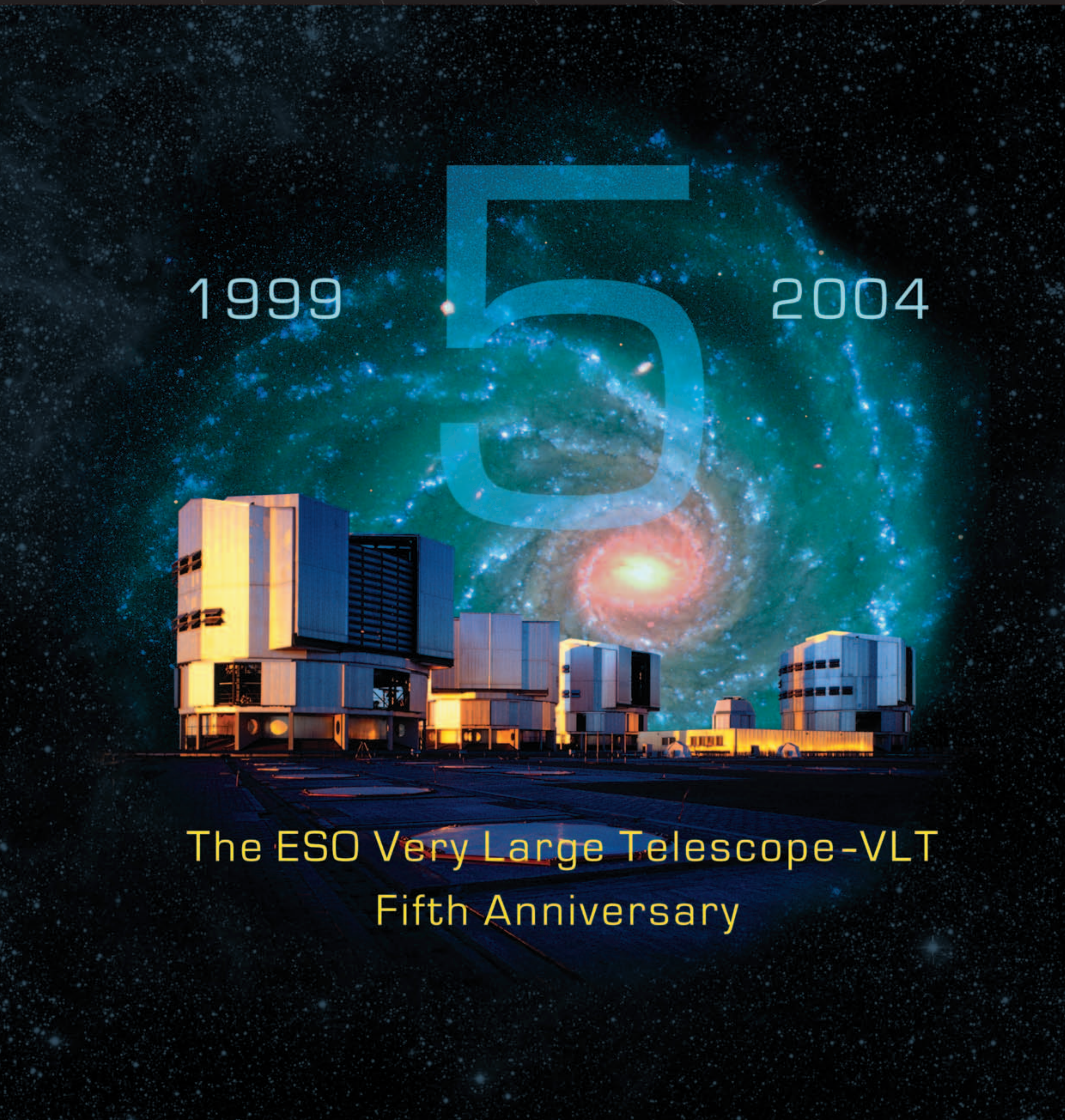


Five Years VLT

As of 1 April, 2004, ESO's Very Large Telescope has been available to the users' community for five years. Here we celebrate this anniversary.

Catherine Cesarsky, ESO Director General

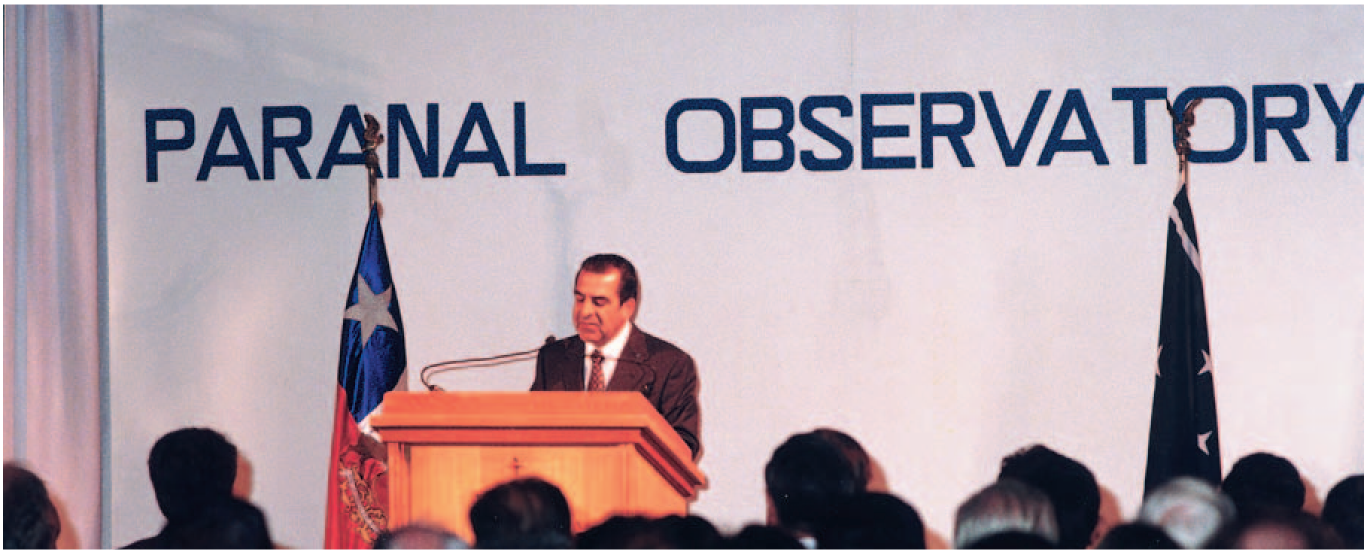
Five years of Paranal Observatory... I remember the tremendous impression this place, in construction, made on me when I visited it as a member of the Visiting Committee. It remained fixed in a corner of my brain, and filled it when the search committee seeking a successor to Riccardo Giacconi approached me. It was a challenge I could not refuse, but also the fulfillment of an unacknowledged dream.

I was only a spectator at the inauguration of the Paranal Observatory, in March 1999. I had known the Director of the VLT programme, Massimo Tarenghi, for many years, as I met him when he was in Geneva; to this day we speak to each other in French. Of course, we spectators were all excited when we were invited to see, at the same time as President Frei and his wife, the newly baptized telescope Antu in operation, but undoubtedly Massimo's more than justifiable pride and pleasure added much to the occasion. I also remember the delighted smile of Jason Spyromilio all through the night; he was operating the telescope. Many of the other people who had contributed were there, and many others could not be there other than in spirit, but all joined the celebrations. With the proverbial luck of ESO, the seeing was 0.25″, comparable to first light of NTT, as I have heard, and the spiral galaxy chosen was superb. A truly unforgettable occasion for a future DG.

Kueyen had had its first light a night or two earlier, but I have partially witnessed, as DG, the installation of FORS2 and of UVES. I was struck by the swiftness and ease with which UVES was installed: I had gone to Paranal to see a commissioning, but in fact it was front line science from the start. I had missed the first lights of Antu and Kueyen, but I was there for Yepun and Melipal. I recorded my impressions of Yepun's first light in *The Messenger* at the beginning of my second year as DG (A Midwinter Night's Dream; 2000, *The Messenger* 101, 1). Massimo and Jason were there, with Krister Wirenstrand and Rodrigo Amestica, and last but not least Roberto Gilmozzi, by then the Director of Paranal Observatory, who rushed to reduce the first couple of images as nimbly as a graduate student. I had never thought that everything could work so easily and fast, and at the back of my mind imagined that it must have been rehearsed somewhat. But for Yepun, the secondary had been late and was only just being installed when I arrived. The team was clearly a bit worried, but again everything worked instantly, the loop was closed, the guide star shrank, and they obtained the first image delivered by the smoothest mirror on earth. Roberto again reduced the data, while champagne was flowing, which we shared with the team of journalists from Discovery Channel who immortalized for us that fantastic night.

This was truly the precursor for a marvelous period. Since then it has been success upon success, with only very few setbacks. One by one, instruments have arrived, been commissioned and offered to the community. Interferometry also gave superb results from the start; just now we have had the first fringes of the second VLTI first generation instrument, AMBER. At first, the community hated things like P2PP, service observing or ESO standards. Now, most of the astronomers we serve are satisfied, as testified by the reports of both visitors and service observers and by the Users' Committee, and we have also acquired a distinguished group of collaborative laboratories.

We celebrate today the feast of the construction of the VLT, under Massimo Tarenghi, of its instruments under Guy Monnet, and its end-to-end system under Peter Quinn. Just as impressive as the construction has been the passage to smooth,



His Excellency the President of the Republic of Chile, Don Eduardo Frei Ruiz-Tagle, speaking at the Inauguration Ceremony of Paranal Observatory on March 5, 1999.

efficient and highly skilled operations. Roberto Gilmozzi, now seconded by Jason, has instilled in the observatory the high standards and enthusiasm necessary to keep it such a unique place. Of course, these are the leaders, worthy of praise. But the teams they lead are equally impressive and it is to their effective and sustained efforts, to their dedication and professionalism, that we owe the success of the VLT.

Peter Gray, followed by Roberto Tamai, has implemented preventive maintenance with such skill that these unequalled telescopes have unbelievably low downtimes. Dedicated service astronomers and TIOs, under Gauthier Mathys, have been delivering first rate data, night after night, and the quality has been checked in Garching. And the community is increasingly exploiting the ESO data archive, a rapidly growing and valuable asset. The VLT has become the internationally recognized benchmark of observatory excellence.

Finally, and most importantly, the fruits of these efforts are being reaped: the Paranal Observatory has already given rise to an impressive number of scientific results, many of which could not have been obtained elsewhere. The VLT Programme Scientist, Alvio Renzini, reviews some of the scientific highlights in an accompanying article in this issue. Overall, the VLT has been a most remarkable success, and will contribute to science at the highest level for years to come – a fantastic achievement of which we can all be justifiably proud.

Riccardo Giacconi, ESO Director General, 1993-1999

THE ACHIEVEMENT OF THE FIRST light at the VLT in 1998 represented for all of us working at ESO the achievement of a wonderful scientific, technical and sociological effort which had consumed many years of our lives.

Prof. R. Giacconi with the 17-year old Jorssy Albanez Castilla from Chuquicamata near the city of Calama, winner of the essay competition, in which schoolchildren of the Chilean II Region were invited to write about the implications of the names given to the four VLT unit telescopes.

When I joined ESO in January 1993 much preparation had already occurred. Lo Woltjer had been able to convince the European Community of the desirability of a large telescope array. The success of the NTT in the 80's gave confidence to ESO that the technology would work and that the organization could cope with the VLT. Under Harry van der Laan's directorship much effort had been expended by scientists and engineers to plan and initiate the work. It is also true that during this period the foreseen date for first light had been receding by about one year per year. An audit undertaken by Massimo Tarenghi and myself under the scrutiny of outside experts revealed that some of the cost estimates had been somewhat optimistic and that the program should be scaled back to allow for some contingency. The decision was made then by ESO Council to delay the start of the VLTI.

In my opinion, the leadership capabilities, dedication, technical and scientific competence of Massimo Tarenghi were essential in achieving success of the VLT. By carrying out the program on time and within cost, it was possible to recover the VLTI infrastructure development.

Also indispensable to this success were the profound changes which occurred at ESO as a whole. All of the staff became involved in a single coordinated effort to achieve a level of excellence and productivity rarely achieved in astronomical projects in all aspects of the Observatory activities. I was convinced that given the great lead of the Keck Group in the US in utilizing the 10-meter telescope it was important for VLT to become an even more effective machine to do science competitively.

La Silla had been operating with some very good and also some marginally productive telescopes. With the advice and support of the Science and Technology committee of ESO, half of telescopes were closed and the remainder improved to the VLT standards. By doing so we used La Silla telescopes to test software and hardware to be used on VLT.

Following a suggestion by Joe Schwarz, the command system of NTT was turned into the 5th VLT by Jason Spyromilio and his team, a fundamental contribution to VLT software development. The 3.6 meter was completely upgraded by Jorge Melnick and his team and for the first time its angular resolution was limited by seeing. Dietrich Baade provided a wide field camera for the 2.2 meter MPG/ESO telescope. Alan Moorwood built a prototype of ISAAC (called SOFI) for the NTT with great technical and scientific success. Sandro d'Odorico persuaded Jim Beletic to join ESO. Jim soon closed the sensitivity gap between US and ESO CCD detectors. These contributions are only examples of the unity and dedication of the ESO staff in supporting the VLT efforts.

The technical achievements of the VLT team under Massimo Tarenghi's leadership produced one of the most sophisticated telescopes today. The selection of beryllium for the secondary mirror, the use of parallel efforts by industry to select prototypes for the primary mirror support, the excellent and enthusiastic support by European industry were important factors in the VLT success. Site development was carried out in an exemplary fashion under the leadership of Jorg Eschwey.

The overall technical improvements in pointing, the rapidity of the active optics in coming to the best focus, the perfection of the optical surfaces have become standards for all ground-based telescopes to emulate.

Also important was the willingness of Massimo to invest considerable effort in support of end-to-end software development. This philosophy of operation came from the Hubble Telescope experience, through me, Jim Crocker, Peter Quinn and Roberto Gilmozzi. Also Piero Benvenuti as head of the European Coordinating Facility for Hubble had significantly contributed to the development of the Hubble Science operation and archiving system.

The main thrust of this effort was to present the observers with calibrated data in almost real time, the ESO staff assuming the responsibility for the data quality. Thus, for the first time, a major ground-based telescope was optimized for science productivity in the same sense that Hubble was. The robust and much expanded Educational and Outreach program received much attention during this period. The rate of science publications of ESO actually increased rather than decreased during this heavy involvement in hardware building.

So first light was for all of us the clear demonstration that we had all together succeeded. We had concluded a treaty with Chile, we were in Paranal, the first telescope worked like a charm (the first real demonstration of active optics), and we had succeeded in also preparing the infrastructure for VLTI.

It is difficult to convey the sense of gratitude I felt for all of the staff at the time, and for Massimo Tarenghi in particular, for their tremendous achievement. The ESO Council, all of its committees, and the European Astronomical Community can remember with pride their contribution to the achievement of this turning point in European Astronomy. I am confident of ESO's success in ALMA and OWL!

Roberto Gilmozzi, Paranal Director

In 1994, I joined ESO from HST to head the optical instrumentation group knowing I was to help in what was envisaged to be the premier observatory on earth. I thought that being on the supply side would be challenging enough. Little did I realize that I would end up at the receiving end of those efforts. In 1998 I was asked to shift from instrumentation and to build up the group that would initiate the science operations at the VLT in April of 1999. One of the great pleasures associated with this change was to be present at the observatory when the official first light event took place in May of 1998. Those were exciting times indeed and sufficiently fun that I stuck around during some of the commissioning to watch UT1 grow into a real operational telescope and FORS1 and ISAAC be mounted on to it. I had had many observing runs at ground based telescopes in many different observatories and like most people I was very happy with 0.6 arcsecond images and used to images above one arcsecond. In the commissioning phase we would try to take images when the conditions were good. As we saw more and more of what UT1 could do, we also recalibrated our expectations. Sub-arcsecond was 'nice', sub-half arcsecond was 'good'. Below 0.3 arcseconds was something to be pleased about (and was most frequent when the then Paranal director, Massimo Tarenghi, was on site!) The beautiful science verification image of the HDF-S was built up during the commissioning period by using those times when the conditions were good. This remains one my favorite images from the telescope.

Less than a year after the first light of UT1 we had another first light, this time UT2. Paranal only a few days before the official inauguration of the observatory and the official start of operations was indeed a hectic place. It was great to be able to have UT2 side by side with UT1 and FORS1 giving 0.25 arcsecond images the night before the assorted dignitaries and guests arrived to celebrate.

The moment of truth, for the astronomers, was of course the start of science operations in April of 1999. We had been careful to recruit as many old hands as we could so that the expertise was present to handle most situations. Gautier Mathys from the NTT, Jean-Gabriel Cuby with ISAAC and SofI experience, Chris Lidman from NTT and SofI, Herman Boehnhardt and Thomas Szeifert from FORS plus telescope operators like Norma Hurtado from the NTT and on the data flow side Jose Parra and Blanca Camucet also from the NTT to archive the data. Period 63 was going to start whether we were ready or not. I do not think we had clear performance criteria for success or failure during that first period. The motivation and excitement (maybe even a bit of panic) associated with putting the first 8.2-m into operation took up too much effort to leave time to worry about details like downtime. Whatever the downtime ended up being, we would just have to live with it. Thanks to what in retrospect were clearly heroic efforts by Peter Gray and his crew, as well as the science operations staff, we ended the first semester (P63) with 11% downtime. Not bad for a start. Secretly the commissioning crew headed by Jason Spyromilio had had a goal but did not tell us, apparently to see how we would do. We beat their goal by almost a factor of two and probably their expectations by even more. A year later this figure was down to 2% and pretty much it has hovered about this number for the past 5 years.

There are a lot of anecdotes of the first months of operations, mostly arising from misunderstandings by users of how the instruments worked and what would be sensible to request. We had the users often change manually the FIMS files that set-up FORS. Unfortunately never actually for the better but with a lot of heartache as we always thought we had made some mistake when things went wrong (and catching that spurious line feed added by the user's editor did take a lot of head scratching!). We had the observing program that demanded 0.4 arcsecond image quality but only exposed for a fraction of a second before presetting to a new position, making the use of excellent seeing time the least efficiently used time on the telescope. The observer who had the slit at a position angle of 7550 degrees and complained that the control software complained. The 0.1 arcsecond offsets between object and sky in the infrared caused some puzzled faces in the control room. The user who complained about the inefficiency of the observations but refused to use the automation built into the system. Of course it was not only the users who had to learn how to interact with the observatory. We also had to learn how to get the best out of our system. When should we start a 0.6 arcsecond program, when the seeing is at 0.5 and pray it does not get worse, or at 0.7 and hope it gets better? How do you populate the nightly queues?

Over the years we have found our path through the maze of opportunities that the VLT presents and the community has pushed us to the limits of what the telescope, instruments and astronomers can do. Together we have worked towards the same goal, to get the best science out of this beautiful machine. The astonishing results on the Galactic Centre, the metal poor stars, Uranium spectral lines, the high redshift galaxy rotation curves, micro-quasars, gamma-ray bursts, high redshift supernovae etc, all attest to the power of the VLT and its operational model. The beauty of the images from the telescope is so great that one of them was voted amongst the 10 most inspirational images of the 1990s. The European astronomical community can be proud of its achievement at Paranal.

In this issue of the Messenger you will read about the first light of another telescope on Paranal, the first of the four 1.8-m auxiliary telescopes that are to be used in the VLTI. Ever more exciting times lie ahead for Paranal with VISIR, SINFONI and the laser guide star all coming this year. Five years after the start of operations on UT1, the observatory operates its telescopes with very little time set aside for engineering (less than 10%) and very low technical downtime. Combined with excellent weather and great image quality we provide the European community with unsurpassed observing capabilities. As director of this Observatory since 1999, I have been privileged to be part of this adventure.

Excerpts from the First Five Years of VLT Science (1999-2004)

A. Renzini (ESO)

So, five years have passed since the first VLT Unit Telescope was offered to the scientific community on April first, 1999. Much indeed has occurred in the meantime on Paranal, within the ESO community, and in Astronomy worldwide. In several fields progress has been breathtaking, and the VLT has played a rapidly increasing role in pushing ahead the frontier of our knowledge in virtually every major direction, from planetary systems to cosmology.

The scope of this brief article is to highlight some representative results so far obtained with the VLT. But how to select among the 2000 projects[(1)] so far scheduled at the VLT, and the over 600 papers that have appeared in refereed journals as of February 29, 2004? Moreover, since it takes time to reduce data, analyze them, write the papers, and get them through the refereeing process, one can safely say that what has appeared so far is but a small fraction of what is already in the *pipeline*. The major impact of the VLT is indeed yet to come! Even from these first five years.

Anyway, aware of the risk of making just few friends and disappointing many, I decided to pick one representative result for each of the seven VLT instruments that have so far been offered to the community. In doing so I will follow the sequence in which these instruments were deployed.

FORS-1, the first VLT instrument, is also the only optical instrument on the VLT that allows polarimetric measurements. Exploiting this niche, two teams were first in measuring the polarization of the afterglow light of a gamma ray burst (GRB), within just 40 days of the inauguration of the Paranal Observatory (Wijers et al. 1999; Covino et al. 1999). While this early result already contributed to narrow down the choice among GRB models, this was just the first of a long series of GRB observations at Paranal, to the point that today the large majority of the known redshifts of GRB afterglows have been measured with the VLT. Yet, with the advent of the robotic telescopes now deployed on La Silla (see *The Messenger* **113**, 40 and 45), and the VLT being offered in Rapid Response Mode, there are good reasons to expect major new breakthroughs in this field from the VLT.

ISAAC, the "infrared workhorse", soon came second. Deep infrared imaging was expected to open a new window over the distant universe, and it did, while the VLT operational paradigm helped a lot. Indeed, Service Mode observing was implemented at the VLT in order to have for each observing condition the best programmes that could exploit them. In this way, almost 100 hours of Service Mode observations with better

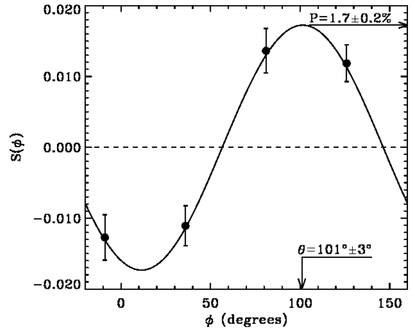


Figure 2: The polarization fraction of the afterglow of the GRB 990510 as a function of position angle (Covino et al. 1999). Data from FORS-1.

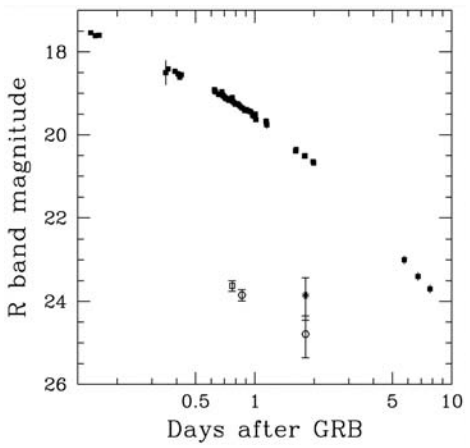


Figure 1: The *R*-band light curve of the afterglow of the GRB 990510 showing the variation of the total flux (filled symbols) while open symbols refer to the polarized flux only, given by the product of the total flux times the polarized fraction, about 1.7% (Wijers et al. 1999). Polarization data taken with FORS-1.

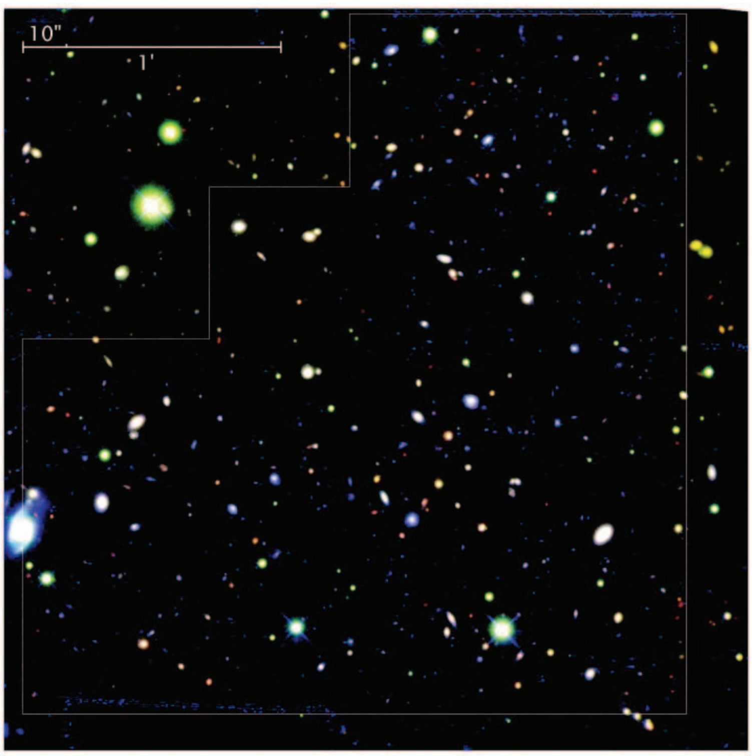


Figure 3: Three-colour composite image of the Hubble Deep Field South (HDFS) obtained combining the WFPC2 I_{814} image with the *J* and *K* band images from ISAAC (Labbé et al. 2003).

(1) This number (2000 projects) refers to the "scheduled" programmes from Period 63 up to and including Period 73. When comparing it to the number of VLT papers one should bear in mind that not all "Category C" programmes in Service Mode get carried out, and that there has barely been time for publishing papers based on data taken during the last two periods (over 500 programmes).

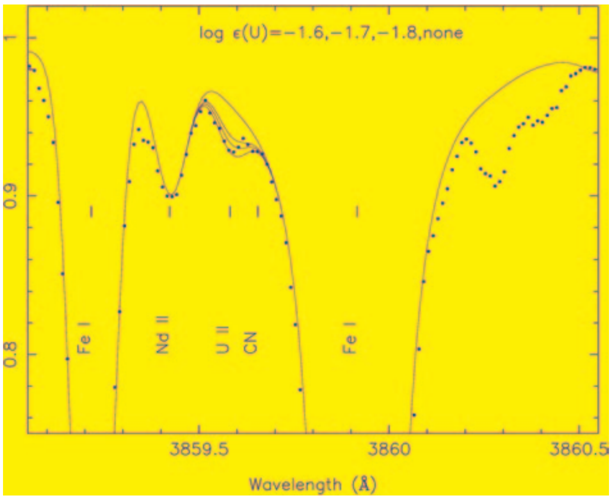


Figure 4: The UVES spectrum of the very metal poor star CS31082 including the U II line at 385.959 nm (dotted line). The solid lines show various synthetic spectra with three different uranium abundances as indicated (Cayrel et al. 2001).

than 0″.4 seeing were dedicated to the FIRES project, thus complementing HST on the HDF-South, and revealing a new population of massive galaxies at high redshift (Labbé et al. 2003) that had escaped detection by the ultraviolet-dropout technique.

UVES, the high-resolution optical spectrograph, started in the following year (2000), calling into action much of the stellar and QSO communities. Thanks to its unique response in the blue and near-ultraviolet, UVES allowed the first measurement of the Thorium/Uranium ratio in an old, very metal-poor star (Cayrel et al. 2001), thus offering a new opportunity for accurately dating the age of our Milky Way galaxy.

FORS-2, the non-identical twin of FORS-1, was deployed along with UVES on UT2/Kueyen. The main difference with respect to FORS-1 is in its higher multiplex capability. Thanks to its mask-exchange unit, over 50 spectra at a time can be obtained, more than a factor of two over FORS-1. Soon it was also upgraded with a red-optimized CCD, virtually free of fringing, making it perhaps the most powerful red-optimized optical spectrograph now in operation. Ideal for the spectroscopic study of red high-redshift galaxies, FORS-2 played the prime role in the "K20 Survey" (Cimatti et al. 2002), which has revealed a population of infrared-bright, massive galaxies beyond redshift 1.5, whose existence was unexpected by most theories of galaxy formation.

NACO, the NAOS/CONICA adaptive optics camera and spectrograph, represented quite a jump in complexity with respect to the first group of instruments. Using very early Commissioning and Science Verification data it soon led in 2002 to one of the most spectacular astronomical discoveries in recent years: tracing the 15.2 yr orbit of a star around the supermassive black hole (BH) at the centre of the Milky Way, accurately mapping its passage at the "periastron" just 17 light hours away from the BH, and allowing a most precise measurement of its mass, $(3.7 \pm 1.5) \cdot 10^6$ solar masses (Schödel et al. 2002).

FLAMES, the fibre multi-object facility feeding two spectrographs (UVES and GIRAFFE) came next. With the OzPoz positioner, FLAMES sends 130 fibres to GIRAFFE and 8 to UVES, allowing the simultaneous observation of as many targets at a time, with medium (R < 20,000) and high resolution (40,000), respectively. In this case there is little embarrassment in selecting the highlight, because so far only one team has been able to submit papers based on FLAMES data. In just a few shots during FLAMES Science Verification more medium- and high-resolution spectra of red giants in the globular cluster NGC 2808 were obtained than ever before in a single cluster. Cacciari et al. (2003) mapped the H-α emission along the red giant branch, thus starting to collect basic information on the chromospheric-like activity in these stars, that sooner or later may shed light on the still mysterious origin of red giant winds. Using

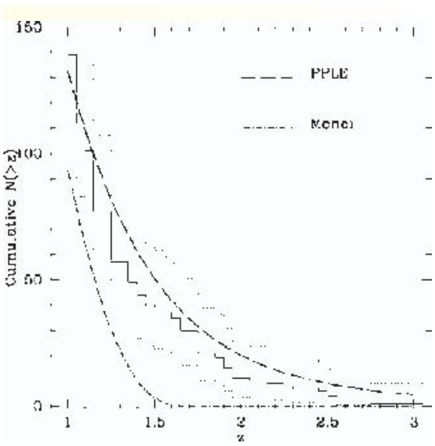


Figure 5: The redshift distribution of $K < 20$ objects at $z > 1$ from the K20 survey (Cimatti et al. 2002). The solid histogram refers to the observed distribution along with its ±3 σ confidence range (dotted lines). The theoretical predictions for a Pure Luminosity Evolution model (PLE, dashed line) and a typical CDM semi-analytical model (dot-dashed line) are also shown. Data mostly from FORS-2.

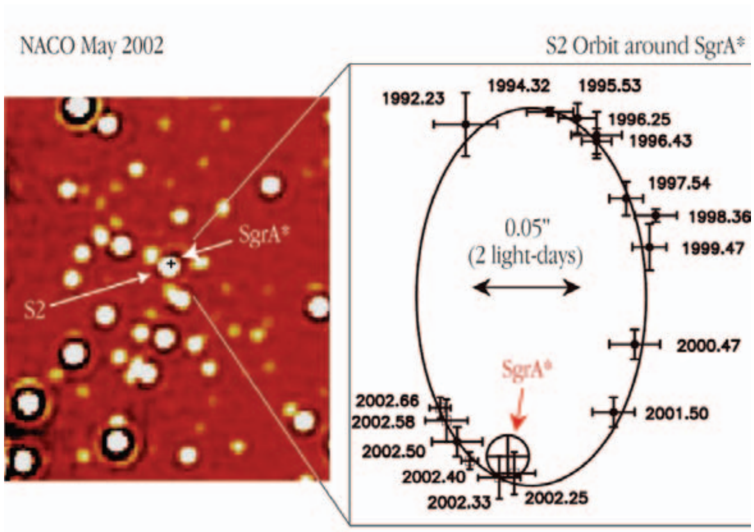


Figure 6: The orbit of the S2 star around the supermassive black hole at the Galactic centre. Data points for 2002 were all obtained from NACO observations (Shödel et al. 2002).

the same data the same team also measured the Sodium abundance in the cluster giants, finding star-to-star variations that apparently do not correlate with luminosity, implying a likely primordial origin for the variations of this p-process element (Carretta et al. 2003).

VIMOS, the last comer, is also perhaps the most complex instrument on the VLT. It is indeed made of four identical spectrographs and cameras, allowing both wide-field imaging and high multiplex multi-object spectroscopy. VIMOS has been optimized to be primarily a redshift machine, able to deliver up to 800 spectra per exposure. The VIRMOS Consortium that built the instrument had an early start with its guaranteed time in the fall of 2002. They thus begun their VIMOS VLT Deep Survey (VVDS), collected over 20,000 spectra at a rate of more than 1000 per night, and started to trace the large scale structure all the way to redshift 1.5 (Le Fevre et al. 2004). After a major intervention to eliminate some mechanical problems (August-November 2003), VIMOS is now working at full steam, delivering images and spectra at a frightening rate. Some say mapping the universe is just a matter of time.

As mentioned at the beginning, what we have seen published so far is just the tip of the iceberg. Most of the VLT data taken to date, especially with the last three instruments, is still on disks rather than papers. Most is yet to come, and probably the best too. After all, the VLT is young: it has just concluded its kindergarten years.

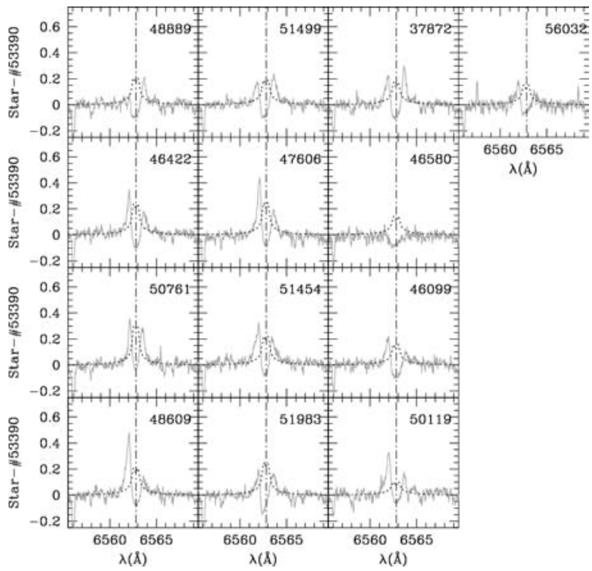


Figure 7: The Hα line profiles for a sample of red giants near the tip of the Red Giant Branch of the globular cluster NGC 2808 as observed by FLAMES/UVES (Cacciari et al. 2003). The solid line is obtained by subtracting the spectrum of a reference star from the spectrum of each of the programme stars. The dotted line shows the difference of the corresponding theoretical (model atmosphere) profiles where chromosphere/wind effects are ignored. This illustrates at once the presence of chromosphere/wind effects along with large star-to-star variations.

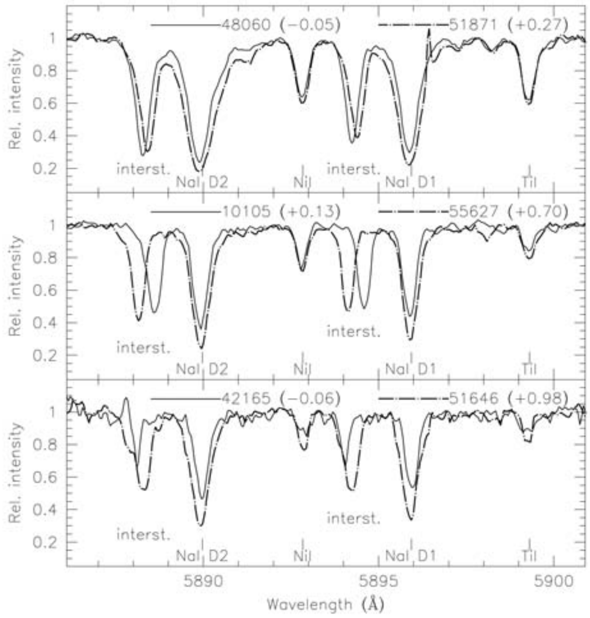


Figure 8: Three representative pairs of FLAMES/GIRAFFE spectra showing the variation of the strength of the Sodium D doublet for stars near the tip of the red giant branch (RGB) of the globular cluster NGC 2808 (top panel), about midway between the horizontal branch and RGB tip (middle panel), and (lower panel) near the horizontal branch (Carretta et al. 2003). Note the sizable star to star variations in the intensity of the Na D lines.

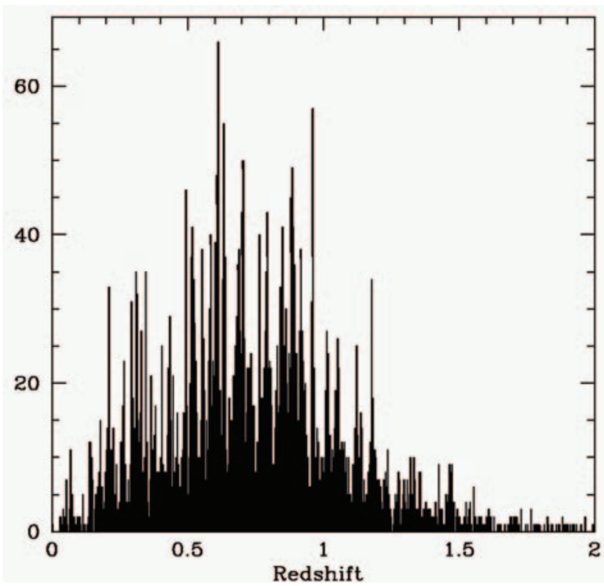


Figure 9: The redshift distribution of galaxies in the VLT VIMOS Deep Survey field VVDS-0226-04 (Le Fèvre et al. 2004). A total of 5010 I_{AB}< 24 galaxies are included in the histogram, which shows that large scale structure peaks are well traced all the way to z ~ 1.5.

References

Cacciari, C., Bragaglia, A., Rossetti, E., Fusi Pecci, F., Mulas, G., Carretta, E., Gratton, R.G., Momany, Y., Pasquini, L. 2003, astro-ph/0309685

Carretta, E., Bragaglia, A., Cacciari, C., Rossetti, E. 2003, astro-ph/0309021

Cayrel, R., Hill, V., Beers, T. C., Barbuy, B., Spite, M., Spite, F., Plez, B., Andersen, J., Bonifacio, P., Francois, P., et al. 2001, Nature, 409, 691

Cimatti, A., Pozzetti, L., Mignoli, M., Daddi, E., Menci, N., Poli, F., Fontana, A., Renzini, A., Zamorani, G., Broadhurst, T., et al. 2002, A&A, 391, L1

Covino, S., Lazzati, D., Ghisellini, G., Saracco, P., Campana, S., Chincarini, G., di Serego, S., Cimatti, A., Vanzi, L., Pasquini, L. 1999, A&A, 348, L1

Labbé, I., Franx, M., Rudnick, G., Schreiber, N.M.F., Rix, H.-W., Moorwood, A., van Dokkum, P.G., van der Werf, P., Röttgering, H., van Starkenburg, L., et al. 2003, AJ, 125, 1107

Le Fevre, O., Vettolani, G., Maccagni, D., Picat, J.P., and the VVDS Team, 2004, astro-ph/0402203

Schödel, R., Ott, T., Genzel, R., Hofmann, R., Lehnert, M., Eckart, A., Mouawad, N., Alexander, T., Reid, M.J., Lenzen, R., et al. 2002, Nature, 419, 694

Wijers, R.A.M. J., Vreeswijk, P.M., Galama, T.J., Rol, E., van Paradijs, J., Kouveliotou, C., Giblin, T., Masetti, N., Palazzi, E., Pian, E., et al. 1999, ApJ, 523, L33

New VLT Instruments Underway

Alan Moorwood and Sandro D'Odorico
ESO, Instrumentation Division

Following positive recommendations from ESO's Scientific and Technical Committee in October 2003, the development of three new VLT instruments - HAWK-I, X-shooter and KMOS - has now been approved and launched. All three had been the subject of detailed PhaseA studies conducted or contracted by the Instrumentation Division and whose results were presented to the STC together with the various Review Board reports. We sketch here briefly the main science drivers and foreseen characteristics of these instruments but with the caveat that not everything is yet frozen and that complete implementation still depends on raising external funding as well as various technical issues. More detailed descriptions of these instruments and their progress will be reported in future issues.

HAWK-I is an infrared (0.85–2.5 μm), 'wide-field' (7.5×7.5 arcmin), camera with 0.1"pixels to sample the best Paranal seeing which should go slightly deeper and deliver even sharper images than ISAAC over an order of magnitude larger field. It will be built by ESO with possibly some small contributions from external institutes. HAWK-I's smaller pixels and the larger collecting area of the VLT means that it is scientifically complementary to the VISTA survey telescope. It will also replace and, for some purposes, improve upon the expected infrared imaging capabilities lost following cancellation of the NIRMOS instrument. Some of the specific science drivers identified by a team of ESO and community astronomers prior to the PhaseA study are listed in Table 1. and their full report is available on the HAWK-I Web page (http://www.eso.org/instruments/hawki).

Naturally, many of the detailed aims are to extend programmes already started with ISAAC. These include a number of surveys e.g. for high redshift galaxies and low mass stars/brown dwarfs where the next step requires at least the same limiting depth but over a larger field to increase the source statistics and chance of detecting rare objects. As some of these programmes have already involved integrations of > 100hrs/field it is clear that a larger field rather than mosaicing is now necessary! A classic example is the search for galaxies at $z > 7$ where the most promising strategy will probably be to combine infrared photometry and narrow band Lyman α imaging with HAWK-I with follow-up spectroscopy using KMOS. Some of these programmes also exploit the excellent direct imaging capabilities already demonstrated with ISAAC/VLT e.g. to find and study stellar discs. As illustrated by the results of simulations presented in the companion article by Arsenault et al. in this issue the performance, despite the large field, could also be further improved by adaptive optics correction using an adaptive secondary mirror and multiple laser guide stars.

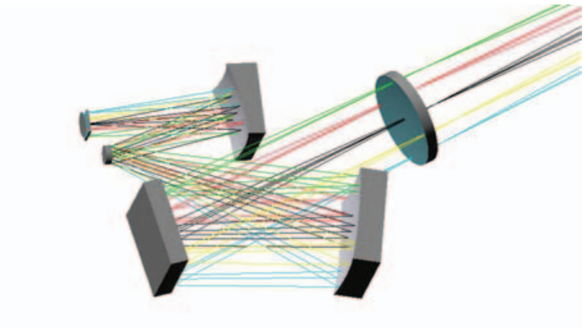


Figure 1: HAWK-I optics comprising only 4 highly reflecting mirrors and an input window/lens designed already for use with an adaptive secondary mirror and 4 laser guide stars.

The heart of HAWK-I will be an infrared detector mosaic comprising the four 2048×2048 Hawaii IIRG arrays ordered originally for NIRMOS but with cut-off wavelengths extended from 1.9 to 2.5 μm. The eyes of HAWK-I will be the optical system shown in Fig. 1 which uses only mirrors to achieve the maximum throughput (> 90%). It has also been designed with an input window/lens shaped such that it could be used to reflect light from the laser guide stars into wavefront sensors should the adaptive secondary project become a reality. Figure 2 shows how HAWK-I should look

Table 1. HAWK-I Science Drivers

- Galaxy evolution from deep multicolour surveys
- High z galaxy clusters
- Search for high z (> 7) emission line galaxies
- Stellar content of nearby galaxies
- Obscured AGN
- Structure and evolution of nearby galaxies
- Galactic star and planetary formation
- Brown dwarf surveys
- Outer solar system bodies

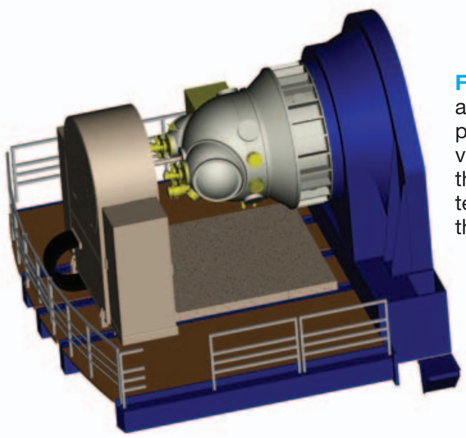


Figure 2: HAWK-I installed at a Nasmyth focus. The large port on this side of the vacuum vessel allows easy access to the detector mosaic and the filter wheels without dismounting the instrument.

Table 2: Science Drivers for X-shooter

- Spectral properties of forming stars
- Properties of cool white dwarfs
- The nature of neutron stars in close binary systems
- Physical processes in the atmospheres of brown dwarfs
- Properties of core-collapse supernovae
- Type Ia supernovae to z =1.7
- Gamma-ray bursts as high-energy laboratories and cosmological probes of the intergalactic medium
- The role of faint emission line galaxies in the redshift interval z = 1.6–2.6
- Properties of high mass star formation and massive galaxies at high z
- Metal enrichment in the early universe through the study of absorption systems
- Tomography of the Intergalactic Medium through the observations of faint background QSOs

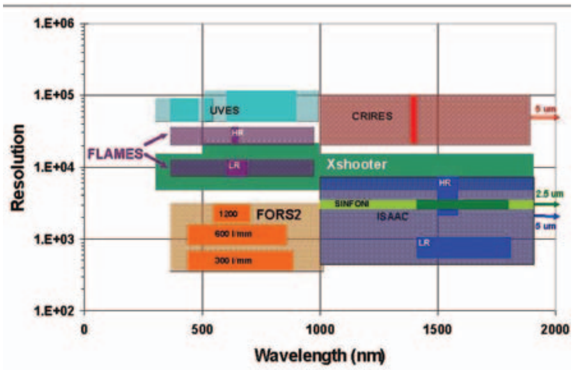


Figure 3: VLT spectrographs in the resolving power versus wavelength plane for the range of operation of X-shooter. For each instrument the light color strip identifies the spectral range of operation, the darker one the spectra coverage in a single exposure (when applicable with different gratings). VIMOS (not shown) approximately overlaps with FORS. Note that by the time X-shooter will be implemented at the telescope the FORSes and ISAAC will be beyond their guaranteed lifetime. X-shooter is unique among instrumentation under construction for 8–10m telescopes in providing full coverage from the UV to the H band in one shot.

when mounted at a Nasmyth focus of the VLT. Both the cryo/vacuum system and the cable/hose co-rotator are similar to those developed for ISAAC. In contrast, however, its only moving functions will be the two filter wheels carrying 4 broad-band and 5 narrow- band filters. The detailed specification of these filters has recently been discussed at the first meeting of the Instrument Science Team appointed to monitor the instrument development and provide advice as required.

Jeff Pirard is the Project Manager and Markus Kissler-Patig is the Instrument Scientist. As the detectors are expected to be delivered soon and the optics procurement will start immediately after the PDR in March 2004 it is hoped that HAWK-I can be built considerably faster than the more complex VLT instruments and we are aiming for an installation on the VLT around mid-2006.

X-shooter is a single target spectrograph for the Cassegrain focus of one of the VLT UTs covering in a single exposure the wide spectral range from the UV to the H band. It is designed to maximize the sensitivity by splitting the light in three arms with optimized optics, coatings, dispersive elements and detectors. It operates at intermediate resolutions (R=4,000–14,000, depending on wavelength and slit width) sufficient to address quantitatively a vast number of astrophysical applications while working in the background-limited S/N regime in the regions of the spectrum free from strong atmospheric emission and absorption lines. The layout and the small number of moving functions (and therefore instrument modes) make the instrument simple and easy to operate and permit a fast response. The possibility to observe faint sources with an unknown flux distribution in a single shot at the sky limit inspired the name of the instrument.

Four proposals for X-shooter were submitted in response to the ESO Call for Proposals for 2nd generation VLT instruments in November 2001. Following negotiations among the different groups interested in this development and ESO, a Phase A study was carried out by a Consortium of the Copenhagen University Observatory (P.I. Per Kjærgaard), INAF in Italy (P.I. Roberto Pallavicini), GEPI at the Observatory of Paris-Meudon (P.I. Francois Hammer), ASTRON and the Universities of Amsterdam and Nijmegen in The Netherlands (P. I. Lex Kaper) and ESO (P.I. Sandro D'Odorico). Hans Dekker at ESO acted as Project Manager of the study.

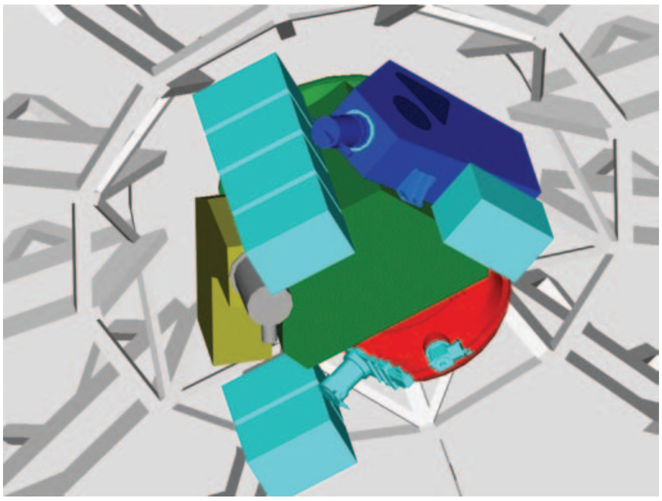


Figure 4: A CAD view of X-shooter attached to the Cassegrain focus of the telescope . While this opto-mechanical layout is likely to be substantially modified in the design of an optimized structure, it conveys the instrument concept based on the parallel operation of three arms operating in the UV, Visual-red and J-H bands.

Table 3: X-Shooter Characteristics

Spectral Format	Prism cross-dispersed echelle (order separation ≥ 12″)
Wavelength range	300–1900 nm, split in 3 arms by dichroics
Resolutions	4000–7000 for 1 arcsec slit
Slit configuration	long slit (12″) ; widths: 1″(standard), 0.6″(high R), 5″ (flux cal.); IFU 1.8×4″ input area
Detectors	2K × 4K CCDs (UV and Visual-Red arms), 1K×1K Hawaii LPE MCT(IR)
Auxiliary functions	Calibration Unit; A & G unit with 1′×1′ field and filter set; ADC for the UV and Visual-Red arms.

Table 4: KMOS Science Drivers

- The Masses (dynamical) and Growth of Galaxies
- Extremely High-Redshift (>7) Galaxies and Re-ionisation
- Connection Between Galaxy Formation and Active Galactic Nuclei
- Age-Dating of Ellipticals at $z = 2$ to 3
- Stellar Populations in Nearby Galaxies
- Galactic Astronomy (star clusters)

The main scientific objectives of the X-shooter have been elaborated during Phase A by a science team led by Jens Hjorth. With its capability to observe single objects over a wide spectral range at the sky limit, the X-shooter will be a cornerstone facility for the VLT. The scientific programs which were used to set the requirements on the capability of the instrument are listed in Table 2.

Table 3 summarizes the currently foreseen capability of the X-shooter.

With the project now approved, the Technical Specifications and the Statement of Work are being written together with the agreements between ESO and the four national groups participating in the project. Technical work is advancing toward a Preliminary Design Review in Q4 of 2004. The aim is to meet an installation at the telescope in 2007. The X-shooter is built, as other VLT instruments, with a large contribution of manpower by the national institutes in exchange for guaranteed time. Unlike others, however, the larger share of the hardware cost is also provided by the external sources. This will permit a rapid advancement of the project by decoupling it from the limitations in the cash flow of the VLT instrumentation budget.

The Web page (under construction) can be found at http://www.eso.org/instruments/.

KMOS is a near infrared, multi-object, spectrograph for which different concepts were presented at the ESO 2nd Generation Instrument Workshop in 2001 and for which

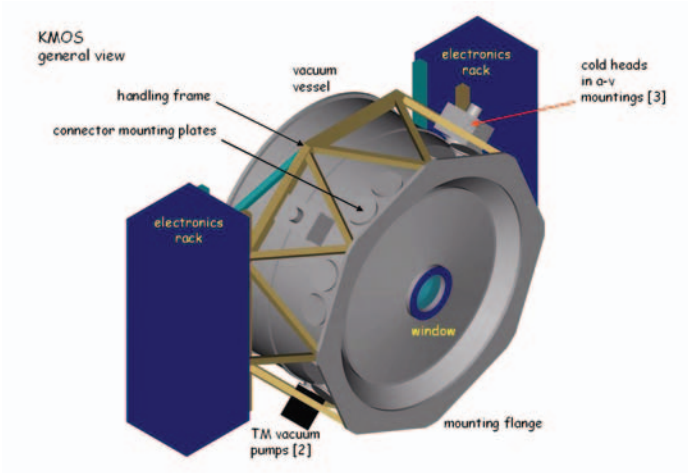


Figure 5: View of KMOS showing the vacuum vessel and instrument mounted electronic racks.

three Consortia responded to the Call for Proposals issued in Nov. 2001. In response, ESO contracted, and partially financed, competing Phase A studies to both the German/British KMOS1 consortium headed by R. Bender (USM/MPE) and R. Sharples (Durham) and the Italian/French/Swiss/British/Spanish KMOS2 consortium headed by D. Maccagni (IASF, Milan) and J.-G. Cuby (Marseille). In both cases ESO was also involved as the designated supplier of the detector systems. As judged by the review boards, both consortia delivered credible designs and performed an impressive amount of work in the relatively short space of time available to meet the Oct. 2003 STC deadline. After much discussion it was recommended by the STC that ESO continue with the KMOS1 consortium - at least up to PDR.

One of the initial prime science drivers for this type of instrument was the possibility of measuring rotation curves and/or velocity dispersions and hence of estimating dynamical masses for significantly large numbers of z ~1-3 galaxies to study their mass assembly history. As mentioned above under HAWK-I, such an instrument could also prove invaluable for follow-up Lyman α spectroscopy of z >7 galaxy candidates. These and other science drivers identified by the consortium are given in Table 4.

Table 5 summarizes the overall capabilities foreseen currently for KMOS.

Table 5: KMOS characteristics

Wavelength range	0.9-2.5 μm
Spectral Resolution	~3–4000
Field	7.2′ diameter
IFU Field	2×2″
Pixel size	0.2″
Number of IFUs	24

Figure 5 shows an external view of KMOS which does not give much away! Inside the vacuum vessel the baseline design uses cryogenic, robotic, pick-off arms to select and feed up to 24 objects to image slicers and then up to 3 spectrographs. More details can be found at http://aig-www.dur.ac.uk/fix/projects/kmos1/kmos_main.html. In parallel an alternative design using steering mirrors, which were also prototyped during the Phase A, is also continuing. In principle, the achievable gain with an adaptive secondary could also be similar to that with HAWK-I as the wavelength ranges and fields are almost the same.

In either case, KMOS will be a relatively complex instrument requiring further development and prototyping and is thus targeted for around 2010, i.e. somewhat later than HAWK-I and X-shooter. At ESO, the Instrument Responsible is Alan Moorwood, Technical Manager is Jeff Pirard and Instrument Scientist is Markus Kissler-Patig.



Three dusty beauties. Images of NGC 613, M 66 (NGC 3627) and NGC 1792 observed with FORS on the VLT. ESO Press Photos 33-03.

Towards an Adaptive Secondary for the VLT?

Robin Arsenault, Norbert Hubin,
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European Southern Observatory

Putting an Adaptive Secondary on one of the VLT Unit Telescope would offer a significant boost in the observing efficiency of the Telescope and would also constitute an important step on the roadmap towards the future ESO Extremely Large Telescope. First evaluation is that such a system, when coupled to instruments with adequate performance and equipped with proper wavefront sensors could provide either diffraction-limited performance in a small field or "enhanced seeing" images over a large field. It should be able to improve on any capability of the present M2 unit, except chopping for which one would get a smaller stroke than today. The technology is mature and a comprehensive feasibility design study will start soon, hopefully to be followed by a full design in the frame of the OPTICON FP6 program. In parallel, we will carefully evaluate in liaison with Paranal Observatory and the Instrumentation Division the cost to benefit ratio of such a system coupled to an optimized set of instruments. These will be the basis for a mid-2005 decision on whether to proceed.

Pioneering work in the development of Large Deformable Mirrors (also called Adaptive Secondaries) has been steadily pursued by the Osservatorio Astronomico di Arcetri (INAF-OAA) with DIAPM-Milano for more than 10 years. The basic concept is to correct wavefront aberrations at the Telescope final focus by the elastic deformation of a large mirror, made from a thin glass shell, through an array of voice-coil driven position actuators. Two Italian industrial partners have been associated with this development since its start, namely Microgate and ADS (see http://www.ads-int.com/MMTadopt.htm). The design and manufacturing of the thin mirror shells (Martin et al. 2000), another difficult accomplishment, has been done at the University of Arizona's Center for Astronomical Adaptive Optics (CAAO).

The first telescope using this technology is the Cassegrain 6.5m diameter MMT at Mt Hopkins AZ. The MMT Adaptive Secondary is made of a 2mm thick, 640 mm diameter zerodur plate. It "hovers" some 30 µm away from a thick reference plate and is deformed by 336 voice-coil actuators pushing on magnets glued on its back surface (Fig. 1). First light on the sky was obtained in November 2002 (Fig. 2). First science results with this system can be seen at http://mmtao.as.arizona.edu/~lclose/talks/ins/ESO_MMTAO_3.

Although this constitutes a crucial mile-

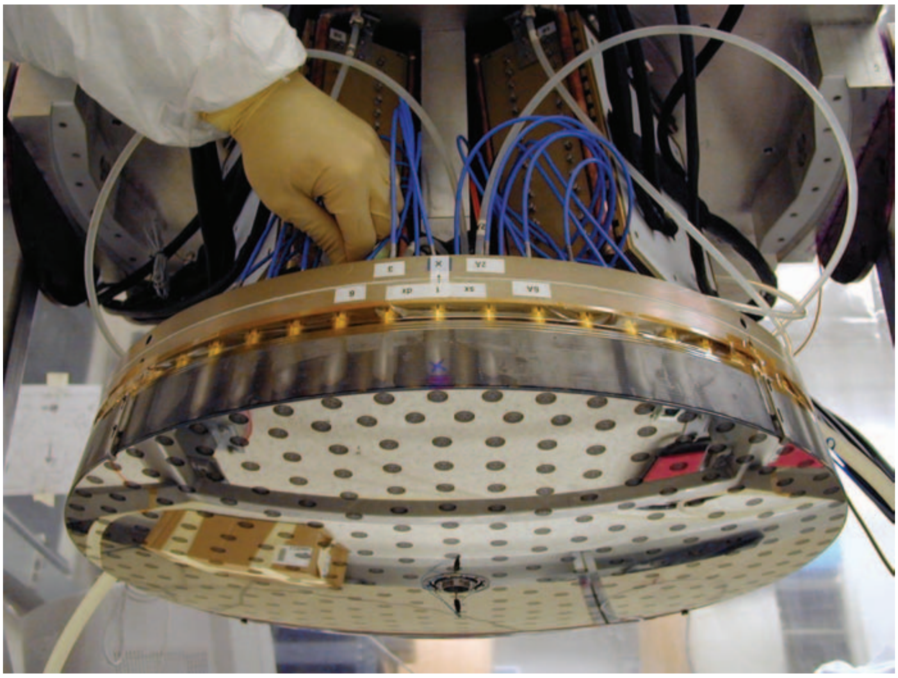


Figure 1: The MMT adaptive secondary. The black dots correspond to magnets glued on the back surface of the mirror. Photo Credit: Laird Close, CAAO, Steward Observatory.

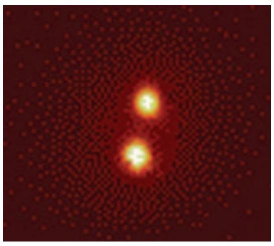


Figure 2: Twenty-three seconds integration time *H*-band image on the ARIES camera of the 0.24 arc-second separation binary star ADS8939. This image was obtained at the MMT during its November 2002 1st observing run with the Adaptive Secondary. 52 modes were corrected with an update frequency of 550 Hz, using an $m_V \sim 9$ reference star. The two stellar images have diffraction limited cores and a ~ 10% Strehl ratio. Photo Credit: Laird Close, CAAO, Steward Observatory.

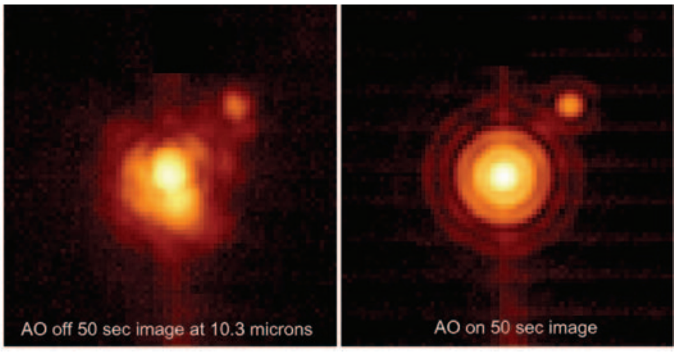


Figure 3: First mid-IR image made with the MMT Adaptive Secondary in November 2002. With AO on, the Strehl ratio is 96%, whereas with it off it is only 58%. Photo Credit: Phil Hinz (Steward Observatory).

stone, the MMT adaptive secondary was considered on the technical side as a working prototype and major re-engineering activities have been initiated by the same Consortium for the production of two Adaptive Secondary Units for the Large Binocular Telescope or LBT (D. Gallieni et al. 2002). Construction of the first 911 mm diameter LBT Adaptive Secondary, with 672 voice-coil actuators, is well advanced with final integration expected in 2004. Note that the LBT is of the Gregorian type. This makes deriving the command matrix for the adaptive mirror particularly easy by inserting a point-like calibration source at the location of the telescope prime focus.

On ESO's side, a first meeting with Microgate/ADS was held in mid-2003 to investigate the feasibility of an eventual adaptive secondary for the VLT and define the content of a conceptual design study for such a facility. The top level specifications are discussed below. From the first evaluations, it appears that such an adaptive secondary system could potentially replace the chopping unit + beryllium mirror of the VLT, therefore keeping the present general structure of the VLT M_2 unit within the available space and weight.

The motivations to implement an Adaptive secondary for the VLT can be summarized as follows:

– An adaptive secondary equipped UT would constitute a general AO facility that could feed all available foci (Nasmyth 1 & 2, Cassegrain, coudé VLTI and even a coudé instrument if there is one) of this particular UT.

–An adaptive secondary would give directly either a NACO-like diffraction-limited correction in a small field or "improved seeing" correction in a large field by acting on the ground layer turbulence only; these improvements are obtained without the light loss and increased thermal emission coming from the extra-optical components in classical AO systems.

–Instruments which could potentially benefit from such a system are: MUSE, either with a ground-layer correction (wide field mode) or by a reconfiguration of the laser guide stars allowing diffraction limited resolution in the visible over a small field of view. This configuration could still use a single deformable mirror (the adaptive secondary); a large (2′ diameter) FOV MCAO diffraction limited IR imager, ultimately replacing NACO; the Planet Finder is an attractive potential candidate with its exacting goal of observing faint companions near a very bright star. The suitability of this approach remains to be confirmed however, since calibration of the large adaptive mirror command matrix to the level required by the PF looks challenging; Hawk-I (or KMOS) for improved seeing over at least 5–6′ FOV; VISIR, as the adaptive secondary would introduce no extra instrumental background in the MIR and would provide very high Strehl ratio images (see Fig. 3), crucial for the detection of extremely low-mass companions or zodiacal disks from their thermal emission; the FALCON approach of positioning both adaptive optics and science "buttons" in a ~ 25 arc min patrol field could also benefit from an adaptive secondary which would be used as a first correction stage; this would reduce the actuator number and stroke requirements on the small AO buttons.

– Large deformable mirror technology is now reasonably matured and well-engineered solutions can be reached for the VLT.

– Large deformable mirror is a crucial technology that ESO needs to have experience with, in view of a future ELT development. Implementing this technology on the VLT will give us the necessary hands-on knowledge to develop such optimized systems, including the calibration and operational aspects.

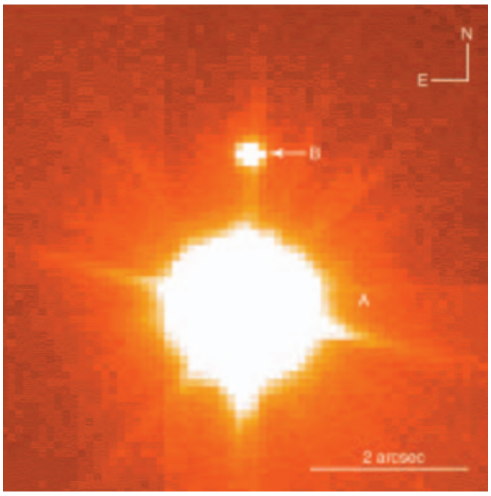


Figure 4: I-band, 1 second exposure, image of the TWA-5 double brown dwarfs system made with the FORS2 instrument on UT2 (Kueyen).
The point spread function full width at half maximum of this seeing-limited image (with fast tip/tilt correction from the secondary mirror) is a record low 0.18 arc sec.

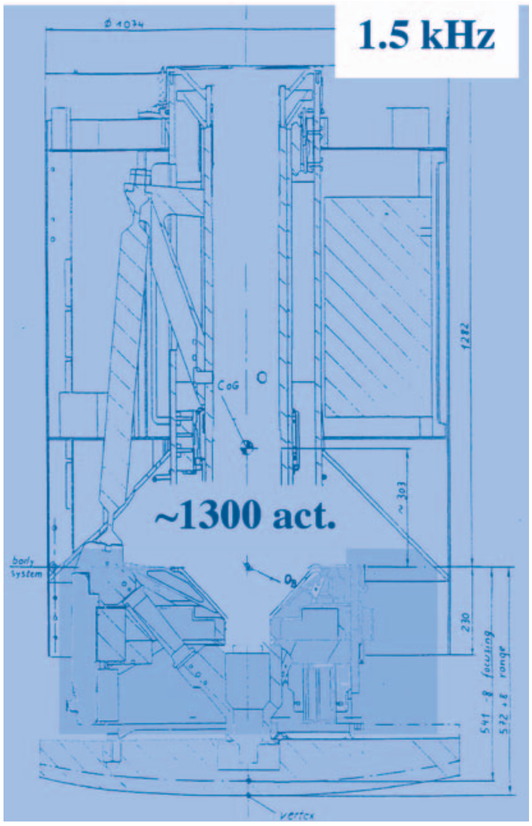
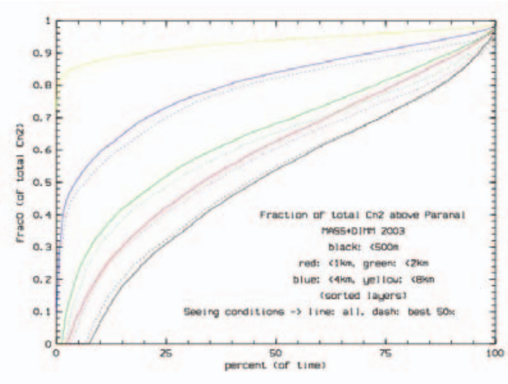


Figure 5: Schematic drawing of the M2 unit. The new adaptive secondary system would be put in lieu of the present chopping system (red) and mirror (green). The current focusing (1 d.o.f.) and centering (2 d.o.f.) systems would be kept.

Figure 6 shows the result of the combined March-September 2003 Paranal seeing campaigns with MASS + DIMM in terms of the cumulative distribution of each atmospheric layer contribution to the total refractive index structure function parameter C_n^2 as measured with DIMM. The upper layers contributions were directly measured with MASS. The ground layer contribution was obtained by subtracting these values from the total observed C_n^2. Note that for 45% of the time, half of the seeing was located in the ground layer (i.e. at altitudes < 500 m). Very similar results were obtained during the two campaigns.



Top-level specifications

The present M_2 units are true technological marvels, providing five degrees of freedom (d.o.f.) adjustments, viz. centering, focusing and tip/tilt, with a high dynamics and very high accuracies. M_2 units offer in particular a fast (up to 5 Hz) chopping capability with a large ± 17″ on-sky throw. In addition, fast tip/tilt corrections at a minimum 10 Hz bandwidth are ensured for virtually the whole accessible sky; this capability plays a large role in the proven ability of the VLT to fully take advantage of even the best seeing at Paranal, as exemplified in Figure 4. We clearly need any new such device to provide or supersede all these capabilities, a non-trivial feat indeed!

With this in mind, provisional top-level specifications for a VLT Adaptive Secondary could be set as follows:

– 1.116 mm diameter convex hyperbolic mirror

– 1,200 to 1,500 actuators (25-30 mm actuator spacing at the level of M_2)

– 40-50 µm stroke able to provide AO correction, tip-tilt and (small stroke) chopping

– a response time goal of 0.5 ms

A provisional Interface with the present M_2 unit is shown in Figure 5. In that scheme, fast tip-tilt (2 d.o.f.) corrections would be provided by the adaptive mirror, with at least equal and actually even better performance. On the other hand, this technology simply cannot provide the present large M_2 chopping capability of ± 17″ on-sky. What would be offered instead is a fast but significantly smaller on-sky chopping of ~ ± 5″. One crucial feasibility point is whether this limitation would significantly harm the scientific capabilities of the instruments using this new unit and, in particular, **any** of the VLTI instruments since they should be able to use any of the 4 UT beams. A first analysis suggests that the potential impact of this limitation on the *a priori* most demanding mid-IR instruments VISIR & MIDI would be very minor, but this point clearly needs to be investigated further.

There does not seem to be any major technical showstopper in the design and eventual production of such a system. There will be interface problems of course, e.g. coming from the rather high heat dissipation inherent in that technology. In addition, one not yet fully resolved technical issue is the need to derive good command matrixes in the presence of turbulence, since the VLT convex secondary does not permit the use of the very simple LBT approach. We are currently exploring both open-loop and closed-loop (the MMT approach) techniques to achieve that goal, using a natural reference star.

A close look at the potential gains

We have estimated the potential gains in terms of improved image quality and energy concentration with such an adaptive mirror. This has been achieved through preliminary computations using the ESO Adaptive Optics Group "simulation farm". One major uncertainty lies in the use of the present meager data on the stratification of turbulence with height over Paranal, which presently rests on only two 2-week long observing campaigns made with the MASS turbulence profiler (A. Tokovinin et al.) in March and September 2003.

We have mainly looked at the gains expected through the correction of the ground layer only. At the centre of a large field of view, 8′, the gain in "ensquared" energy (Fig. 7) is roughly a factor 2 compared to the purely seeing-limited case in all NIR wavelengths (*J, H* & *K*), with only a small degradation in the field, even at its corners (Fig. 8). For these simulations, we have chosen a relatively large 0″.9 seeing (at 0.5 µm) to realistically cover the case of ultra-deep exposures at the VLT covering tens of hours. This could be applied directly to in particular the HAWK-I NIR Imager. Note however that for all these simulations, we have only studied the limiting case where there is a bright enough reference object (a natural star or a laser guide star plus a natural one for tip/tilt correction) in the field.

A detailed look at the PSF shows that there is essentially an improved seeing effect in the whole field, with no diffraction-limited central core and very little anisoplanetism. With such a large field, fair sky coverage could be achieved in the K band with natural guide stars only; for smaller wavelengths and especially in the Visible, multiple laser guide stars would nevertheless be needed.

For smaller field of views, ~ 1′, we enter into NAOS-like corrections with now much

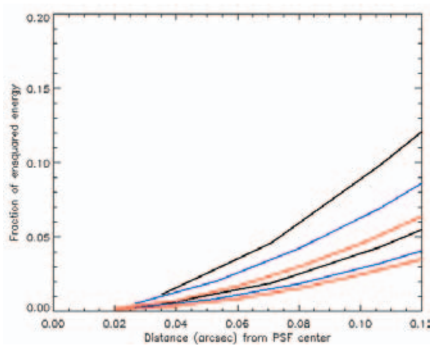


Figure 7: Fraction of "ensquared" energy at the field center with distance to the PSF center in arc sec. 3 bottom curves: without AO correction; 3 top curves: with AO correction. Black: *K*; Blue: *H*; Red: *J*. Note that typical pixel sizes on seeing-limited VLT instruments are in the 0″.12-0″.24 range corresponding to 0″.06-0″.12 on the horizontal axis of the figure.

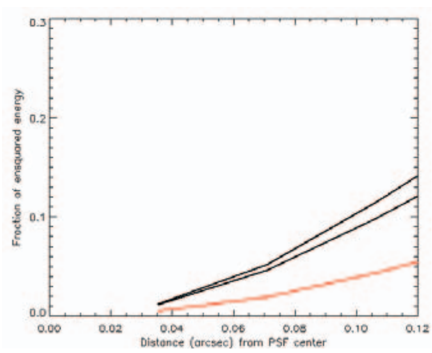


Figure 8: Fraction of "ensquared" energy in the K-band with distance to the PSF center in arc sec. Red: no AO correction; Black: AO corrected; top: in the center of the field; bottom: in the corners of the 8′×8′ field.

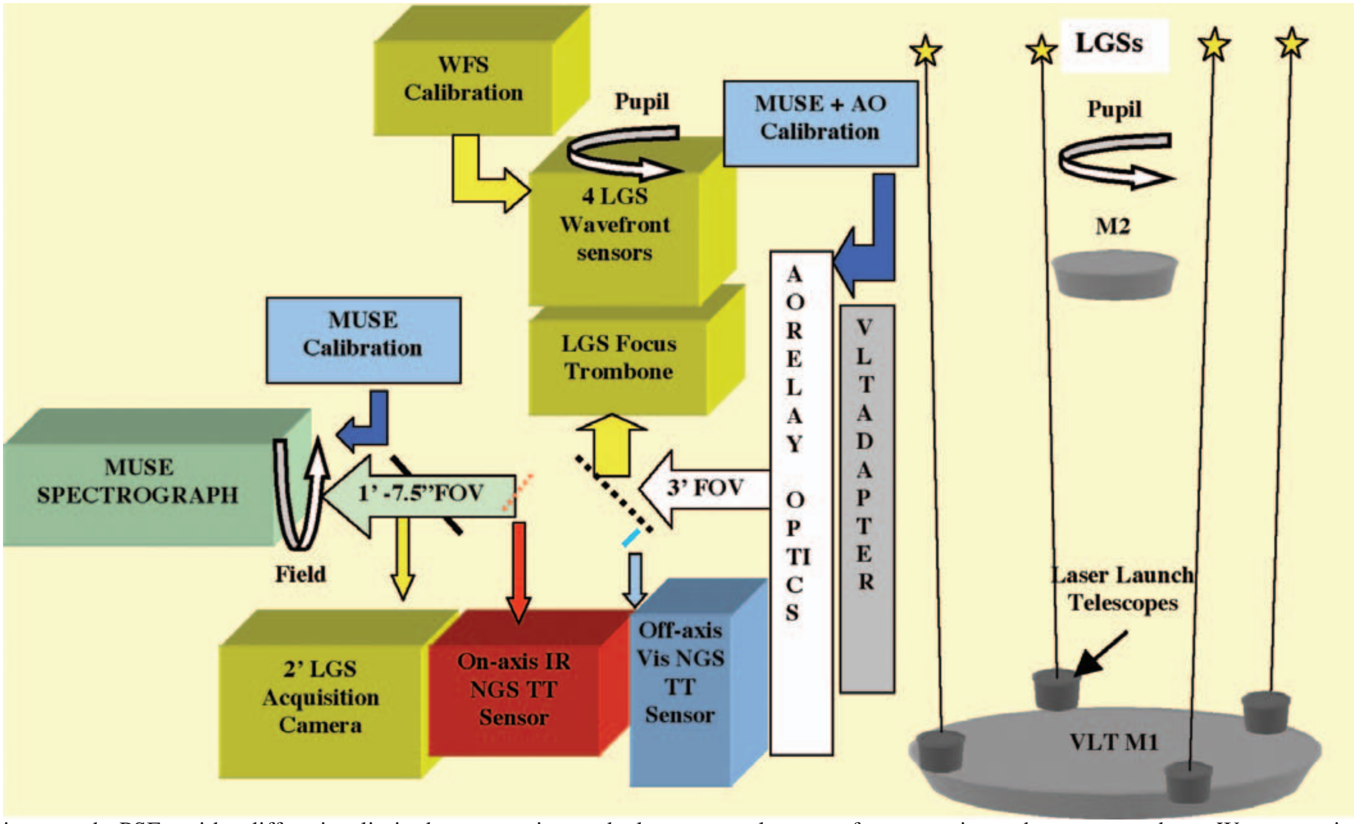


Figure 9: Conceptual design of the MUSE Ground Layer Adaptive Optics (GLAO) System. This illustrates the challenge to obtain significant Adaptive Optics corrections in the visible range. Getting a factor of 2 gain in energy concentration in the red in the 1' field of MUSE requires a high order (~ 1,200 actuators) deformable mirror, an adaptive secondary or a classical piezo-stack mirror located in a relay optical system, four ~ 12 W Na laser beams at optimum locations (60″ off-axis) and one natural guide (tip/tilt) star in a 3' field. Sky coverage would then be ~ 60% at the Galactic pole, a remarkably high value for any AO-corrected system and in particular one working in the visible range.

improved PSF with diffraction-limited cores, but also with large shape variations in the field. One also fully encounters the usual stringent sky coverage limitation which can be overcome only with a Laser Guide Star (and even multiple ones if observing in the visible range). Note that thanks to the large number of actuators on the adaptive secondary, diffraction limited imaging in the Visible (typically 20 mas FWHM at 750 nm) over a small field (~10″) seems feasible. This corresponds in particular to the MUSE narrow field mode.

And on the instrumental side as well

While an Adaptive Secondary mirror neatly suppresses the need for the bulky (and expensive) relay system, that is at the heart of any Adaptive Optics adapter (e.g. on NACO & SINFONI at the VLT), with at minimum 3 additional mirrors in the light path, it is still necessary to introduce equally expensive and always complex wavefront sensors in every instrument that must benefit from AO corrections.

Looking carefully at the cost to benefit ratio for in particular all relevant 2nd generation VLT instruments projects is thus necessary and being planned. As a first example, we are studying in close liaison with the MUSE Consortium a Ground Layer Adaptive Optics (GLAO) system coupled with the instrument and fed by the Adaptive Secondary (Fig. 9).

Conclusions

Equipping one VLT unit with an Adaptive Secondary is an exciting prospect that could in essence improve on the natural Paranal median seeing by a factor of ~ 1.4. There are however a few hurdles along the way and, in particular, the retrofitting of this technique to a working Telescope and the development of an optimized set of instruments, with adequate wavefront sensing. None of these is going to be easy, nor cheap. We are starting resolutely, but also cautiously, along this potential development, with the current feasibility study, hopefully followed by a full design study, gaining also technical know-how which is crucial on the long roadmap towards an ESO Extremely Large Telescope. Ultimately, the benefit to cost ratio of the global project will tip the scales on whether an Adaptive Secondary is implemented on the VLT or not.

References

D. Gallieni, E. Anaclerio, P. Lazzarini, A. Ripamonti, S. Spairani, C. Del vecchio, P. Salinari, A. Riccardi, P. Stefanini, and R. Biasi, *`LBT adaptive secondary units final design and construction*, Proc. SPIE **4839**, pp. 765-771, 2002.

H. M. Martin, J. H. Burge, C. Del Vecchio, L. R. Dettmann, S. M. Miller, B. Smith and F. Wildi, *Optical fabrication of the MMT adaptive secondary mirror*, Proc. SPIE **4007**, p. 502, 2000.

The First Light of the first VLTI Auxiliary Telescope

B. Koehler
and the AT1 Assembly and Commissioning team
European Southern Observatory

On January 24th, the first Auxiliary Telescope (AT1) obtained its first image of the Paranal sky. This was a long awaited event which marked the birth of a new generation of telescopes at Paranal. This article gives a brief description of the busy but exciting period of on-site re-assembly and commissioning.

On January 24th around 23h Local Time, the first Auxiliary Telescope (AT1) obtained its first image of the exceptional Paranal sky. This event happened precisely on the date that had been scheduled back in April 2003 when ESO took over the main activities on AT1 for its European tests, followed by the transport from AMOS (Belgium) to Paranal (Chile) and finally the re-assembly and commissioning at Paranal. This achievement was the result of a prompt packing by AMOS and the high dedication of the ESO ATS team both in Garching and Paranal.

This article gives a brief description of this busy but exciting phase starting from the delivery of AT1 in Liège last September.

Transport from Europe to Chile

On September 4th 2003, the AT1 was provisionally accepted in Liège. The transport from Europe to Chile, under ESO responsibility, could start. However, in mid-August when the very last details of the transport were being settled, 'Bad News #1' arrived. The sea transport company suddenly decided to refuse the AT1 cargo for unclear technical-commercial reasons linked to the breakage last year during transport (by another company) of the primary mirror of the VLT Survey Telescope (VST). After an intense search for a backup solution, a so-called 'charter vessel' was selected. These vessels take cargo on demand and at short notice (only one other cargo was taken together with AT1). This choice limited the schedule impact to a minimum, provided an even better controlled transport but resulted, of course, in a significant additional cost remaining however in the original budget estimated for transport.

The AT1 Assembly and Commissioning team

The persons listed below constituted the core team for the assembly and commissioning of AT1. They are those who made all this happened.

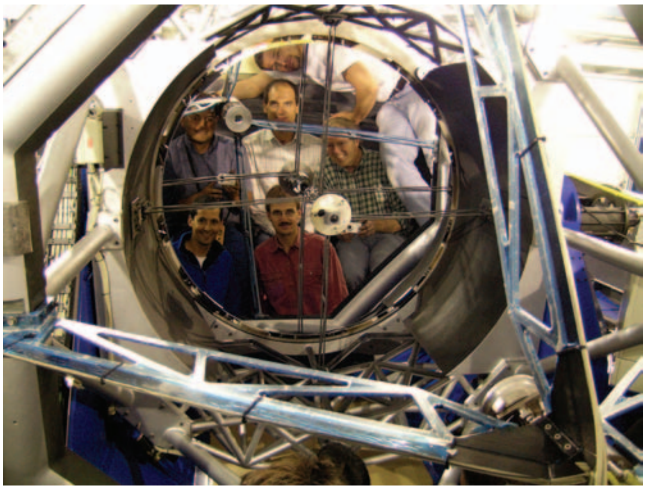
From Garching:
Mechanics, integration leader, handling: M. Kraus
Electronics: J.M. Moresmau, M. Duchateau, M. Dimmler, A. van Kesteren
Software: K. Wirenstrand, P. Duhoux, R. Karban
Optics: F. Gonte, D. Bonaccini

From Paranal:
Management: R. Tamai
Mechanics: V. Heinz, J.C. Palacio, E. Flores, L. Roa
Optics: S. Guisard, S. Del Burgo, P.Giordano
Electronics: J.Osorio, J. P. Haddad, G. Hudepohl
Software: I. Muñoz, J. Argomedo

For a list of the key persons involved in the design and development of the Auxiliary Telescope, the reader is referred to the previous article in *The Messenger* (Koehler et al. 2002).

The VLTI Auxiliary Telescope no. 1 is trucked to the top of the Paranal mountain.

The Paranal Integration Team feels relieved after the first mounting of the primary mirror (M1) inside the telescope early December 2003. All mirrors were delivered silver-coated except M1, which was coated with aluminium by ESO, using the VLT coating plant on Paranal (photo: P. Giordano).



The transport started with the pickup at AMOS on September 12th. It went very smoothly … and slowly in its last part: the truck convoy that brought AT1 from Antofagasta harbor to Paranal adapted their speed to the actual conditions of the 'old Pan Americana' dirt road and had to make an unforeseen overnight stop in the desert. On October 22th, AT1 arrived safely on Paranal.

Assembly and Integration

At the end of October came 'Bad News #2': a key member of the ESO assembly team was reassigned on short notice to an important project for two weeks. This delayed the start of the assembly and integration of AT1 to November 7th. Thanks to the hard work of the Garching and Paranal integration teams, who also had to solve various small difficulties typical of the first-time installation of such a complex system, the assembly could be finished on schedule by early December. During that time, the M1 primary mirror was aluminized for the first time using the VLT coating plant. Functional tests of each of the many sub-systems could then be carried out by the Garching Software team, who left the mountain shortly before Christmas.

During the Christmas break, 'Bad News #3' arrived: the foam inside thermal insulation panels used to protect the inner volume where the Telescope sits, had inflated, resulting in some breakage of their metallic frame! In addition, small cracks started to appear on the enclosure at the interface between the enclosure shells made of fiber glass and a non-structural piece made of plastic that holds the enclosure seals responsible for air and water tightness. Investigations at AMOS on samples in a vacuum chamber indicated that the foam expansion was due to the reduced air pressure at Paranal. The cracks on the enclosure seal supports are possibly due to the low humidity and are still under monitoring. In early January, an on-site examination by AMOS concluded that neither problems had affected the structural capacity and the functionality of AT1 and that, after quick temporary repairs, the commissioning activities could therefore proceed. A definitive repair on AT1 and solutions to avoid the problems on AT2 to AT4 are being worked out.

Move to the Observatory Top

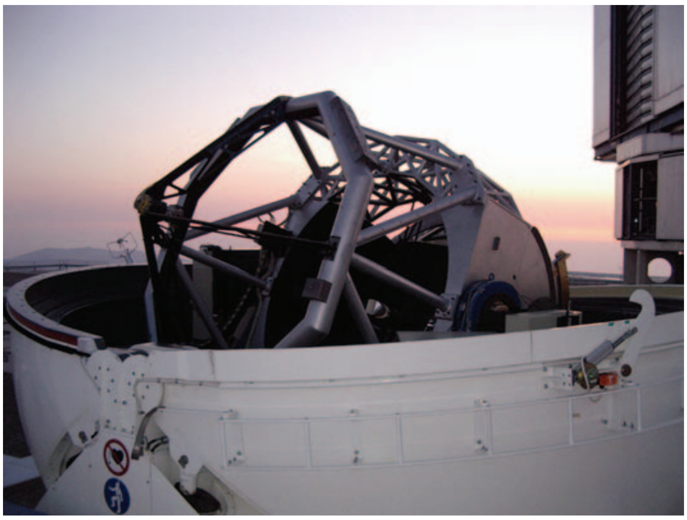
On January 12th, with only four days delay with respect to the original planning, the first move of an AT from the Mirror Maintenance Building (MMB) to the Observatory platform could start. For this move, the completely assembled AT was attached to an ESO-developed handling tool that lifts the complete AT and loads it onto a rented hydraulic trailer pulled by a truck. The day started around 7h at the MMB and was a rather intense day for the nerves of the project engineers, in particular when the 33 tons of the complete AT and what it represents in terms of cost and development effort started to be lifted for the first time by the four lifting legs. The next delicate operation was the drive to the top that required the road to be closed and that took about 2 hours. After some iteration to adjust the position of the truck over the rails, the AT was finally lowered onto its rail network between UT3 and UT4, not far from the VST. A last moment of suspense was the first crossing over the Delay Line Tunnel, whose carrying capacity is now fully exploited after the AT mass has significantly increased from the original estimates of 1991 used for the civil engineering design of the Paranal infrastructures.

Commissioning

The commissioning program started on January 13th with tests of the 'Relocation' process during which the AT is moved from one observing station to another. The excellent repeatability of the telescope position after a relocation (<0.1mm lateral and vertical and <10 arcsec angular) had already been measured in Europe as part of the acceptance tests. These values were confirmed with the AT stations in place at Paranal. This characteristic is particularly important for such a movable telescope in order to avoid lengthy optical re-alignment after a 'relocation'. Indeed, the only necessary fine alignment will be done remotely from the control room at the beginning of the observing night.

The rest of the commissioning program was then carried out up to the planned date of 18 February 2004 when the VLTI building and Paranal engineers had to be freed for the integration and commissioning activities of the VLTI instrument AMBER.

Most of the tests could be carried out successfully except a few for which the fail-



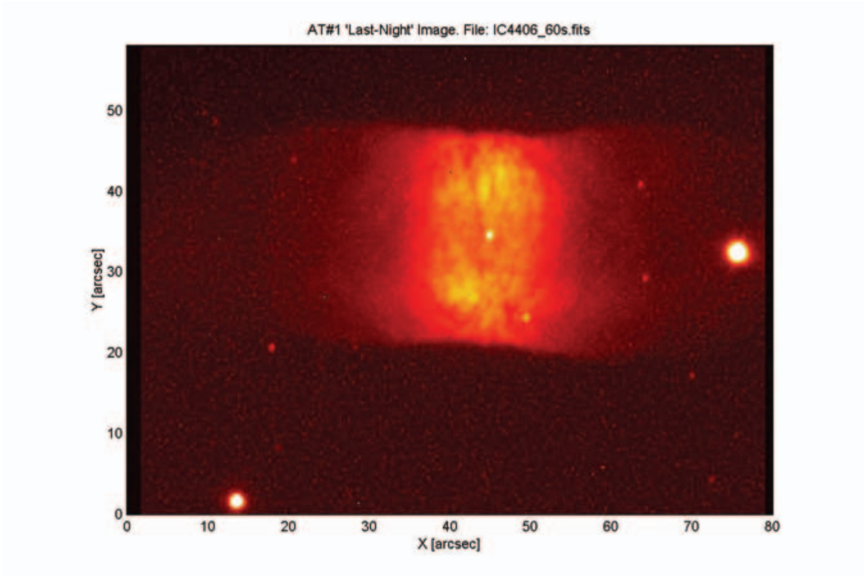
"Little" AT1 in front of UT1 ANTU (photo: F. Gonté).

ure of the measuring equipment or problems with a particular subsystem prevented reaching a definite conclusion. This was the case for the final verification of the Optical Path Length (OPL) stability and of the daytime air conditioning module. These tests, that are meant as a final verification of performance already checked in Europe, will have to be performed in a second phase of commissioning. Another open point is the final adjustment of the M1 radial support that is needed to remove a residual optical aberration (astigmatism) that varies with the telescope altitude angle from <10nm wave front error RMS at Zenith to about 200nm at 30º altitude. Even with this residual astigmatism, corresponding to lambda/10 in the K-band close to the horizon, the telescope can already be considered of good optical quality for the work in the infrared. Adjustment of the M1 support in a second phase of commissioning will however be needed to meet the stringent VLTI error budget requirements of 110nm wave front error RMS for the AT.

On the other hand, it was confirmed that the other performance aspects of the telescope such as pointing, tracking, field stabilization, are excellent. Worth noting is also the fact that only one night out of 26 was lost due to a technical problem, namely the failure of a standard ESO electronic board.

All in all, and in spite of the need for a second commissioning phase to fine tune a few elements, the commissioning of AT1 can be considered very satisfactory. It has proven that the system is healthy and has already reached a level of performance and reliability rarely reached so quickly after installation by any other telescope.

First Light celebration picture. From left to right: Ph. Duhoux, F. Gonté, R. Gilmozzi, B. Koehler, V. Heinz, S. Guisard. (Photo: S. Guisard)



First Light image: Planetary Nebula NGC 3132. Magnitude 9.2. T_{exp} = 10 sec.

The near future

The immediate next step will be the testing by ESO of AT2 in Liège during April-May 2004. This will include tests on the sky if the Belgian weather permits! AT2 will then be packed by AMOS and shipped to Chile by ESO where it will arrive in August 2004 for re-assembly and commissioning. In the meantime, a slot for a second commissioning period of AT1 at Paranal will be defined in line with the availability of engineering resources both at ESO-Garching and ESO-Paranal.

The VLTI first fringes with two Auxiliary Telescopes are currently scheduled for the (European) 2004 fall, therefore…stay tuned!

The enlarged telescope family with a VLTI Siderostat (foreground), the first VLTI Auxiliary Telescope (next to the VLTI building), three of the four Unit Telescopes and the VST enclosure (background). Photo: P. Kervella.

Reference

Koehler B. et al., 2002, The Auxiliary Telescopes for the VLTI: a status report, The Messenger, 110, 21.

ESO Press Release 01/04, First Auxiliary Telescope for the VLT Interferometer Installed at Paranal, http://www.eso.org/outreach/press-rel/pr-2004/pr-01-04.html.

Night sky brightness during sunspot maximum at Paranal

Ferdinando Patat
User Support Group - DMD, ESO

In this paper we present and discuss a large data set of UBVRI night sky brightness measurements collected at Paranal from April 2000 to September 2001. This unprecedented database allowed us to study in detail a number of effects including differential zodiacal light contamination, airmass dependency, daily solar activity and micro-auroral events.

Cerro Paranal is about 108 km S of the nearest town (Antofagasta, 225,000 inhabitants), 23 km NNW from a small mining plant (Yumbes) and 12 km inland from the Pacific Coast. This ensures that the astronomical observations to be carried out there are not disturbed by adverse human activities such as dust and light from cities and roads. Nevertheless, a systematic monitoring of the sky conditions is mandatory in order to preserve the high site quality and to take appropriate action, if the conditions are shown to deteriorate. Besides this, it also sets the stage for the study of natural sky brightness oscillations, both on short and long time scales, such as micro-auroral activity, seasonal and sunspot cycle effects. For this purpose, we have started an automatic survey of the *UBVRI* night sky brightness at Paranal with the aim of both getting, for the first time, values for this site and building a large database (Patat 2003a).

The night sky radiation has been studied by several authors, starting with the pioneering work by Lord Rayleigh in the 1920s. The interested reader can find very good reviews on this subject in the classical textbook by Roach & Gordon (1973) and the more recent work by Leinert et al. (1998).

The optical night sky radiation, as seen from the ground, is generated by several sources, some of which are of extra-terrestrial nature (e.g. unresolved stars/galaxies, galactic background, zodiacal light) and others are due to atmospheric phenomena (airglow and auroral activity). In addition to these *natural* components, human activity has added an extra source, namely the artificial light scattered by the troposphere, mostly in the form of Hg-Na emission lines. While the extra-terrestrial components vary only with position on the sky and are therefore predictable, the terrestrial ones are known to depend on a large number of parameters such as season, geographical position, solar cycle and so on.

In fact, airglow contributes a significant fraction (up to 50%) of the optical global night sky emission and hence its variations have a strong effect on the overall brightness. To illustrate the various processes which contribute to the airglow at different wavelengths, in Figure 1 we have plotted a high signal-to-noise night sky spectrum obtained at Paranal on a moonless night.

In the *B* band the spectrum is rather featureless and it is characterised by the so-called airglow pseudo-continuum, which arises in layers at a height of about 90–100 km. All visible emission features, which become particularly marked below 400 nm and largely dominate the *U* passband (not included in the plots), are due to molecular Oxygen bands.

The *V* passband is chiefly dominated by [OI]557.7 and to a lesser extent by NaID and [OI]630.0,636.4nm doublet. Besides the aforementioned pseudo-continuum, several OH Meinel bands are also present in this spectral window.

All these features are known to be strongly variable and show independent behaviour, probably due to the fact that they are generated in different atmospheric layers. In fact, [OI]557.7 nm, which is generally the brightest emission line in the optical sky spectrum, arises in layers at an altitude of 90 km, while [OI]630.0,636.4 nm is produced at 250–300 km. The OH bands are emitted by a layer at about 85 km, while the NaID is generated at about 92 km, in the so-called Sodium-layer, which is used by laser guide star adaptive optic systems.

In the *R* passband, besides the contribution of NaID and [OI]630.0, 636.4 nm, strong OH Meinel bands begin to appear, while the pseudo-continuum contribution remains constant. Finally, the I passband is dominated by Meinel bands and a broad feature at 860-870nm, due to O_2.

Several sky brightness surveys carried out in *B* and *V* passbands have demonstrated that the dark time sky shows strong variations within the same night on time scales of tens of minutes to hours, and this is commonly attributed to airglow fluctuations. Moreover, as first pointed out by Lord Rayleigh, the intensity of the [OI]557.7 nm line depends on solar activity. Later on, similar results were found for other emission lines like NaID and OH. Walker (1988) found that *B* and *V* sky brightness is well correlated with the 10.7 cm solar radio flux and reported a range of about 0.5 mag in *B* and *V* during a full sunspot cycle; analogous values were published by other authors, so that the effect of solar activity is now commonly accepted (Leinert et al. 1998).

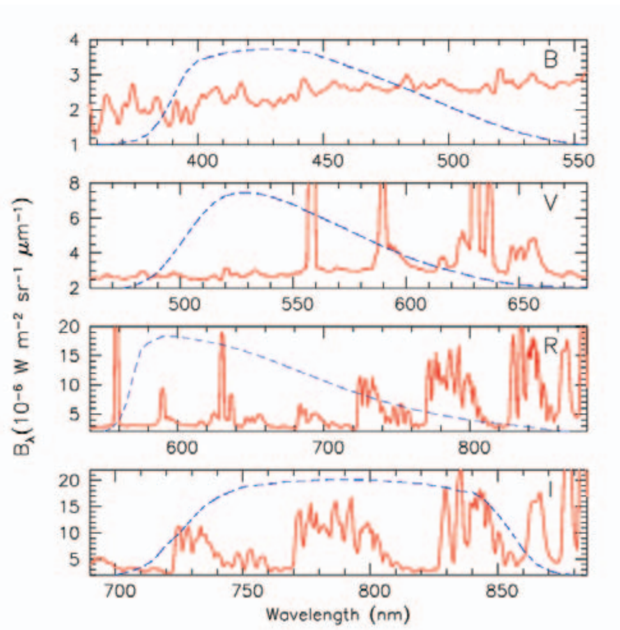


Figure 1 : Night sky spectrum obtained at Paranal in the spectral region covered by *B, V, R* and *I* passbands, whose response curves are indicated by the dashed lines.

Table 1: Zenith corrected average sky brightness during dark time at Paranal. Values are expressed in mag arcsec^{-2}. Columns 3 to 7 show the root mean square (RMS) deviation, minimum and maximum brightness, number of data points and expected average contribution from the zodiacal light, respectively.

Filter	Sky Brightness	σ	Min	Max	N	Δm_{ZL}
U	22.28	0.22	21.89	22.61	39	0.18
B	22.64	0.18	22.19	23.02	180	0.28
V	21.61	0.20	20.99	22.10	296	0.18
R	20.87	0.19	20.38	21.45	463	0.16
I	19.71	0.25	19.08	20.53	580	0.07

ESO-Paranal night sky brightness survey

The observations were carried out in Service Mode with FORS1 between April 1, 2000 and September 30, 2001 and include data obtained on 174 different nights. During these first eighteen months of activity, 4439 images taken in the *UBVRI* passbands and processed by the FORS pipeline were analysed and 3883 of them were judged to be suitable for automatic sky brightness measurements (Patat 2003b).

Due to the kind of scientific programmes which are usually carried out with FORS1, most of the observations were performed at high galactic latitude, and therefore the region close to the galactic plane is not well enough sampled to allow for a good study of the sky brightness behaviour in that area. The scenario is different if we consider the helio-ecliptic coordinate system: due to the geographical position of Paranal, the large majority of the observations have been carried out in the range $-30° \leq \beta \leq +30°$, where the zodiacal light is rather important at all helio-ecliptic longitudes. As far as the solar activity is concerned, all measurements were taken very close to the maximum of sunspot cycle no. 23, and thus we do not expect to see any clear trend. The dark time values, presented in Table 1, show quite a strong dispersion, which is typically of the order of 0.2 mag RMS. Peak to peak variations in the *V* band are as large as 0.8 mag, while this excursion reaches 1.5 mag in the I band.

As we anticipated, these estimates are certainly influenced by zodiacal light effects. To give an idea of the amplitude of this bias, in the last column of Table 1 we have reported the expected contribution Δm_{ZL} which, in the *B* passband, is as large as 0.3 mag. The sky brightness dependency on the ecliptic latitude is clearly displayed in Figure 2, where we have plotted the deviations from the average sky brightness for *B*, *V* and *R* passbands. For comparison, in the same figure we have superimposed the behaviour expected on the basis of the Levasseur-Regourd & Dumont (1980) data. As one can see, there is a rough agreement, the overall spread being quite large, probably due to the night-to-night fluctuations in the airglow contribution.

As a matter of fact, if the same sky patch is monitored for a sufficiently long time, it clearly displays smooth variations (see Figure 3). In general, the behaviour shown during single nights covers a wide variety of cases and there is no clear average trend. Of course, mild and steady time-dependent effects cannot be ruled out; they are probably masked by the much wider night-to-night fluctuations and possibly by the patchy nature of the night sky even during the same night.

The results we have obtained are compared with those of other dark astronomical sites in Table 2. The first thing one notices is that the values for Paranal are very similar to those reported for La Silla, which were also obtained during a maximum of solar activity. They are also not very different from those of Calar Alto, acquired in a similar solar cycle phase, even though Paranal and La Silla are clearly darker in *R* and definitely in *I*.

All other sites presented in Table 2 have data which were obtained during solar minima and are therefore expected to show systematically lower sky brightness values. This is indeed the case. For example, the *V* values measured at Paranal are about 0.3 mag brighter then those obtained at other sites at minimum solar activity (Kitt Peak, Cerro Tololo, La Palma and Mauna Kea).

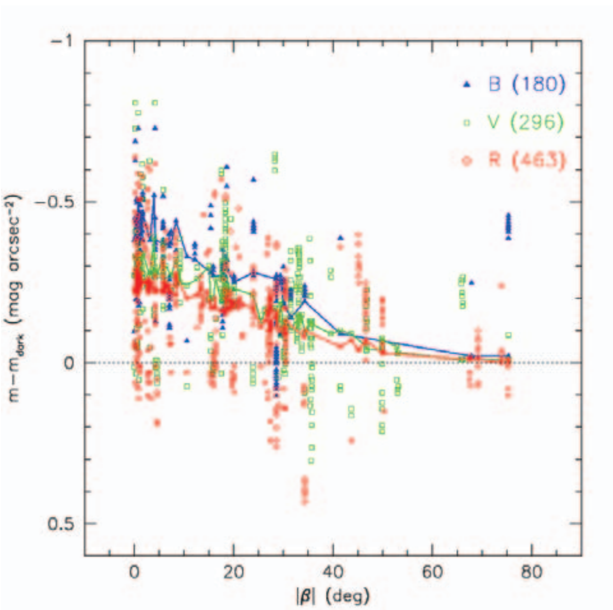


Figure 2 : *B*, *V* and *R* dark time sky brightness variations as a function of ecliptic latitude. The solid lines trace the behaviour expected from the Levasseur-Regourd & Dumont (1980) data for the different passbands.

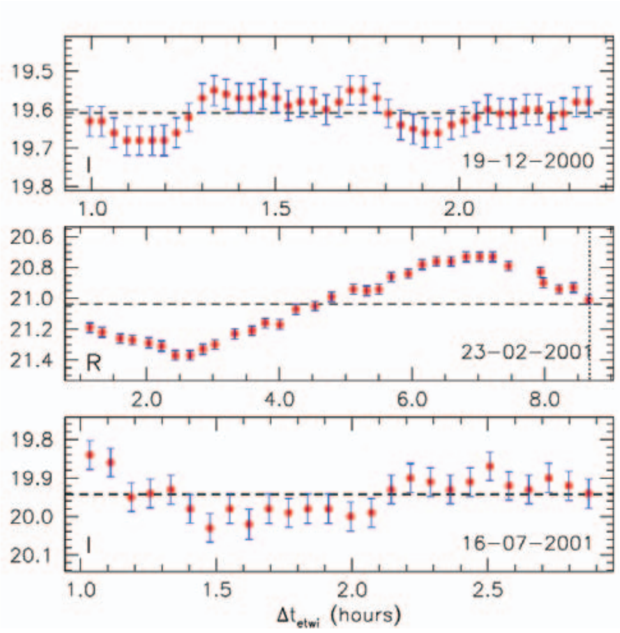


Figure 3 : Time sequences collected on 19-12-2000 (*I*), 23-02-2001 (*R*) and 16-07-2001 (*I*). The data have been corrected for airmass and differential zodiacal light contribution. The vertical dotted line is placed at the beginning of morning astronomical twilight.

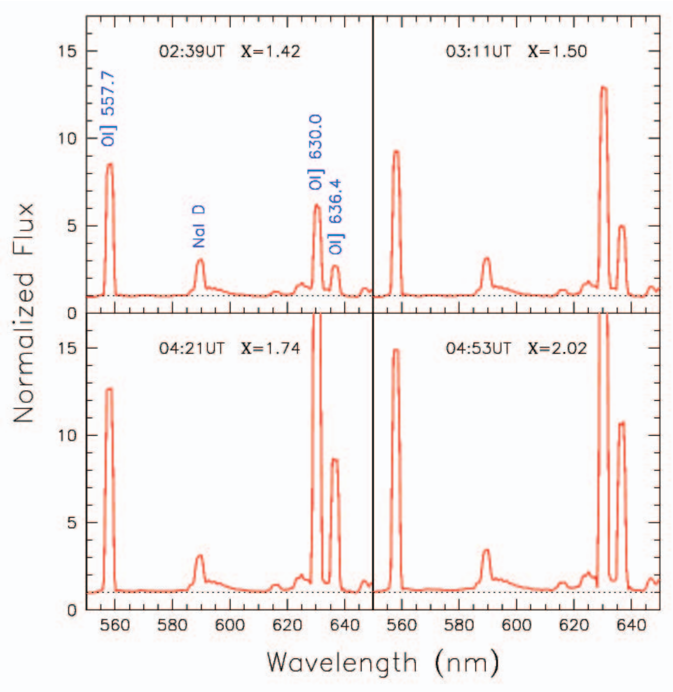


Figure 4 : Evolution of the night sky spectrum on February 25, 2001 in the wavelength range 550-650 nm. In each panel the starting UT time and airmass X are given. For presentation the four spectra have been normalised to the continuum of the first one in the region 560-580 nm.

The overall *BVRI* Paranal sky brightness will probably decrease in the next 5–6 years, to reach its natural minimum around 2007. The expected darkening is of the order of 0.4–0.5 mag arcsec^{-2} (Walker 1988) but the direct measurements which will be provided over the coming years by this survey, currently operated and maintained by the Quality Control Group, will give the exact values for this particular site.

Solar activity

As we have mentioned, during the time covered by the data here presented, the solar activity has reached its maximum. To be more precise, since the current solar cycle has shown a double peak structure, our measurements cover the descent from the first maximum and the abrupt increase to the second maximum. Mainly due to the latter transition, the solar density flux at 10.7 cm in our data set ranges from 1.2 MJy to 2.4 MJy.

Even though this is almost half of the full range expected on a typical complete 11 years solar cycle (0.8–2.5 MJy), a clear variation is seen in the same solar density flux range from similar analyses performed by other authors.

The extrapolation of our *R* nightly average sky brightness turns into an expected variation of 0.24±0.11 mag arcsec^{-2} during a full solar cycle. This value is smaller by a factor of two than that which has been reported by other authors for *B, V* and *uvgyr* for yearly averages (0.4–0.5 mag arcsec^{-2}) and it is consistent with a null variation at the 2σ level. Similar results are obtained for *B, V* and *I* passbands, thus indicating no short-term dependency from the solar activity. As a consequence, it would seem that no firm prediction on the night sky brightness can be made on the basis of the solar flux measured during the day preceeding the observations, as it was initially suggested by Walker (1988).

Sky brightness fluctuations

The night sky can vary significantly over different time scales, following physical processes that are not completely understood. The observed scatter is certainly not produced by the measurement accuracy and can be as large as 0.25 mag (RMS) in the *I* passband; this means that, in this filter, the sky brightness can range over about 1.4 mag, even after removing the effects of airmass and zodiacal light contribution.

To illustrate how complex the night sky variations can be, in Figure 4 we present a sequence of four spectra taken at Paranal during a moonless night, starting more than two hours after evening twilight. For the sake of simplicity we concentrate on the spectral region 550–650 nm, right at the intersection between *V* and *R* passbands, which contains the brightest optical emission lines. Due to the increasing airmass, the overall sky brightness is expected to grow by about a factor 1.2 in *V* and *R*, in very good agreement with what is actually measured. But something very different happens to the [OI]630.0,636.4 nm doublet: the integrated flux changes by a factor 5.2 in about two hours, causing a sensible brightening in the *R* passband. This is easily visible in Figure 4, where the [OI]630.0 nm component surpasses the [OI]557.7 nm in the transition from the first to the second spectrum and keeps growing in intensity in the subsequent two spectra.

The existence of these abrupt changes has been known since the pioneering work by D. Barbier, who showed that the [OI]630.0,636.4 nm doublet can undergo strong brightness enhancements over a couple of hours on two active regions about 20° on either side of the geomagnetic equator, which roughly corresponds to tropical sites. With Cerro Paranal included in one of these active areas, such events are therefore not unexpected.

The case of NaI D lines is slightly different, since these features follow a strong seasonal variation (more than a factor 6!) which makes them brighter in winter and fainter in summer. This fluctuation is expected to produce a seasonal variation with an amplitude of about 0.1 mag in the *R* passband, and therefore very difficult to detect due to the strong night-to-night fluctuations.

To search for possible signs of light pollution, we have examined the last spectrum presented in Figure 4 in the wavelength range 350–550 nm, where a number of Hg and Na lines produced by street lamps fall. As expected, there is no clear trace of such features; in particular, the strongest among these lines, HgI 435.8, is definitely absent. This appears clearly in Figure 5, where we have plotted the relevant spectral region and the expected positions for the brightest Hg and Na lines. In the same figure we have also marked the positions of O_2 and OH main bands: almost all features can be confidently identified with natural transitions of molecular oxygen and hydroxyl. There are probably only two exceptions, which are in any case very weak. Nevertheless, if real, they could

Table 2: Dark time zenith night sky brightness measured at various observatories (adapted from Benn & Ellison 1998). S10.7cm is the Penticton-Ottawa solar density flux at 2800 MHz [2]. Source references are given in Patat (2003a).

Site	Year	$S_{10.7cm}$ MJy	U	B	V	R	I
				mag arcsec^{-2}			
La Silla	1978	1.5	-	22.8	21.7	20.8	19.5
Kitt Peak	1987	0.9	-	22.9	21.9	-	-
Cerro Tololo	1987-8	0.9	22.0	22.7	21.8	20.9	19.9
Calar Alto	1990	2.0	22.2	22.6	21.5	20.6	18.7
La Palma	1994-6	0.8	22.0	22.7	21.9	21.0	20.0
Mauna Kea	1995-6	0.8	-	22.8	21.9	-	-
Paranal	2000-1	1.8	22.3	22.6	21.6	20.9	19.7

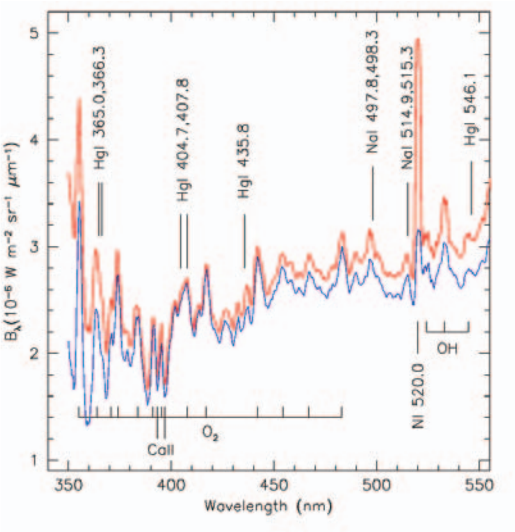


Figure 5 : Night sky spectrum obtained at Paranal on February 25, 2002 at 04:53 UT (blue line). Marked are the expected positions for the most common lines produced by artificial scattered light (upper ticks) and natural atmospheric features (lower ticks). The blue line traces part of the spectrum taken during the same night at 02:39 UT.

indicate the possible presence of some artificial NaI. If this contamination is really present, it should show up with broad NaI D features, which are a clear signature of high pressure sodium lamps. However, the inspection of a low airmass and high signal-to-noise UVES spectrum (Hanuschik 2003) has shown no traces of either such broad components or of other NaI and HgI lines.

There are finally two interesting features shown in Figure 5 which deserve a short discussion. The first is the presence of CaII H&K absorption lines, which are the probable result of sunlight scattered by interplanetary dust.

The other interesting aspect concerns the emission at about 520 nm. This unresolved feature, identified as a NI lines blend, is usually extremely weak. On the contrary, in our first spectrum (blue line in Figure 5) it is very clearly detected and steadily grows until it becomes the brightest feature in this wavelength range. This blend is commonly seen in the Aurora spectrum with intensities from 100 to 1000 times larger and it is supposed to originate in a layer at 258 km. The fact that its observed growth (by a factor 4.3) closely follows the one we have discussed for [OI]630.0,636.4 nm, suggests that the two regions probably undergo the same micro-auroral processes.

Such abrupt phenomena, which make the sky brightness variations during a given night rather unpredictable, are accompanied by more steady and well-behaved variations, the most clear of them being the inherent brightening one faces going from small to large zenith distances. In fact, the sky brightness increases at higher airmasses (see Figure 6), especially in the red passbands, where it can change by 0.4 mag going from zenith to airmass X=2. As a result of the photon shot noise increase, this turns into a degradation of the signal-to-noise ratio by a factor 1.6. Unfortunately, there are two other effects which work in the same direction, i.e. the increase of atmospheric extinction and seeing degradation. Combining the three mechanisms one can verify that the average signal-to-noise ratio decreases by about a factor of 2 passing from airmass 1.1 to airmass 1.6 (see Patat 2003a). Such a degradation is not negligible, specially when one is working with targets close to the detection limit.

The Future

The automatic sky brightness survey we have presented here continues to run. Since its start, it processes all Service Mode imaging frames obtained with FORS1 at a current average rate of more than 2600 measurements per year. This, coupled with the high accuracy one can achieve with an 8m telescope, has already given the unprecedented chance of investigating in detail a number of effects and of getting, for the first time, the optical night sky brightness for Paranal. These values are fully consistent with those of other dark sites monitored during maximum solar activity and no signs of light pollution have been detected, neither in the photometry nor in the spectroscopy we have analysed. In particular, there is no indication of a sky brightness enhancement in the critical directions of Antofagasta and Yumbes mining plant, at least not in the zenith distance range covered by the data.

In the next 2–3 years, the night sky is expected to get 0.4–0.5 mag fainter. If this is true, it will have quite a strong impact on the limiting magnitudes one will achieve, especially in the red passbands, allowing the community to push the instrumental limits a bit further. The data collected by the survey will tell us whether this is indeed the case.

As a by product, this project will also allow us to investigate a number of related issues, like the correlation with other ambient conditions, seasonal variations and moon contribution to the global background at a given position. The latter is a particularly important aspect, since it could allow the user to specify less stringent constraints, enlarging the chance that the scientific observations are executed and thus improving the observing efficiency.

In conclusion, we think that this first analysis has shown how useful and interesting these studies are, even if they could be referred to as "the art of getting rid of astronomical objects" which, admittedly, is quite an unusual activity for an astronomer.

References

Benn, C.R., & Ellison, S.L. 1998, La Palma Technical Note, 115
Hanuschik, R. H. 2003, A&A, 407, 1157
Leinert, Ch., Bowyer, S., Haikala, L. K., et al. 1998, A&AS, 127, 1
Levasseur-Regourd, A. C. & Dumont, R. 1980, A&A, 84, 277
Patat, F. 2003a, A&A, 400, 1183
Patat, F. 2003b, A&A, 401, 797
Roach, F. E., & Gordon, J. L. 1973, The light of the night sky, Dordrecht Reidel Publ. Company
Walker, M. F. 1988, PASP, 100, 496

Figure 6 : Paranal's southern horizon as seen from the platform. The original photo was taken by Leonardo Vanzi on October 6, 2002 at 08:33 UT. The Southern Cross is just rising above the Yumbes mining plant; its brightest star, α Cru, is at an elevation of 6°, while α Cru is at only 2°. The sky re-darkening can be seen very close to the horizon.

DENIS results on the Magellanic Clouds

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The large–scale IJK_s simultaneous DENIS coverage of the Magellanic Clouds has allowed us to distinguish populations of objects of different kind and age, to derive the structural parameters of the galaxies and to obtain an indication of the metallicity distribution. This photometry combined with the results from long–term monitoring programs provides important constraints on the evolution of stars. Although we have extracted a great deal of information from the dataset, the data mining benefits have yet to be exhausted.

The DENIS (DEep Near Infrared Survey of the Southern Sky) instrument was built by several European laboratories starting in 1990. It was mounted at the 1m ESO telescope in La Silla and observed the southern sky from the middle of 1994 until September 2001 simultaneously in the I, J and K_s wave bands. Technical details and scientific drivers are described in *The Messenger* No. 87 (Epchtein et al. 1997).

Though the survey was designed to observe the whole Southern Hemisphere a strong effort was devoted to complete the observations of the Magellanic Clouds (MCs). These are among the most suitable objects visible from August to March in the Chilean sky. They are our companion galaxies and because they are relatively close to us (≈ 60 kpc) we can study their stellar content in great detail. They are located in a region of low galactic extinction and this facilitates the interpretation of observations at combined wavelengths and especially in the near–infrared (near–IR) bands where the extinction does not affect the magnitudes of stars too much.

The Large Magellanic Cloud (LMC) is classified as an irregular dwarf galaxy; its most prominent feature is a central bar, similar to that of barred spiral galaxies. Its eastern side is closer than its western side. Underlying the bar is a circular disc of older stars. The appearance of the Small Magellanic Cloud (SMC) is also characterized by a bar, less pronounced, and an eastern extension called "the Wing". Lines-of-sight through the SMC appear to cover extensive depths (≈ 12 kpc); the Wing and the northeastern part of the Bar are closer to us than the southern parts.

Data in the near–IR allow us to access stages of stellar evolution that are marginally covered by optical data, such as the red giant branch (RGB) and the asymptotic giant branch (AGB) phases. These are usually referred to as late– type evolutionary phases. During the RGB phase, stars are burning Hydrogen (H) in a shell around the nucleus until they reach the tip of the RGB (TRGB), when Helium (He) combustion begins in the stellar nucleus. During the AGB phase, both H and He are burning in shells. Carbon enriches the chemical atmospheric abundance as a consequence of the third dredge–up process which brings processed matter to the surface. It may happen that the atmosphere becomes carbon dominated instead of oxygen dominated defining two different flavour of AGB stars: M–type (or O–rich) and C–type (or C–rich). AGB stars are characterized by variations in luminosity with a long period and a large amplitude and experience mass–loss at a rate that eventually concludes the AGB phase.

DENIS Catalogue of the Magellanic Clouds (DCMC)

More than one hundred thousand images in the direction of the MCs were pre–processed at the Paris Data Analysis Center and then sent to Leiden Observatory for subsequent analysis: extraction of the sources from the images, astrometry and photometry.

Using the pipeline developed by Erik Deul, which includes the SExtractor program (Bertin & Arnout 1996) for source extraction, we have compiled the DCMC, a catalogue of about 1.3 million sources and 300, 000 sources towards the LMC and SMC, respectively. These sources were detected in at least two of the three DENIS photometric wavebands. The derived standard position accuracy has an RMS of 0.001″ with a maximum excursion of 1.32″ on top of the RMS of 0.3″ of the astrometric reference catalogue (USNOA2.0). Magnitudes are estimated within a circular aperture of 7″ in diameter. The zero point of the magnitude scale was determined every night, observing about 8 standard stars and assuming a fixed extinction coefficient. The overlapping region of adjacent images was used to correct for remaining differences in zero–points. Finally we obtained a general photometric calibration specific for each Cloud on average better than 0.05 mag. All extracted objects were matched on the basis of their coordinates and geometrical parameters assuming an elliptical shape. Associated with each source are a series of flags that identify problems of different kinds in the images as well as those discovered during the source extraction process. Most cosmic rays, glitches and optical ghosts have been eliminated. Sources detected in three bands are complete to I = 15, J = 13.75 and K_s = 12.75 in the LMC and about 0.25 mag fainter in the SMC. The maximum source density is 500 sources per 0.25×0.1

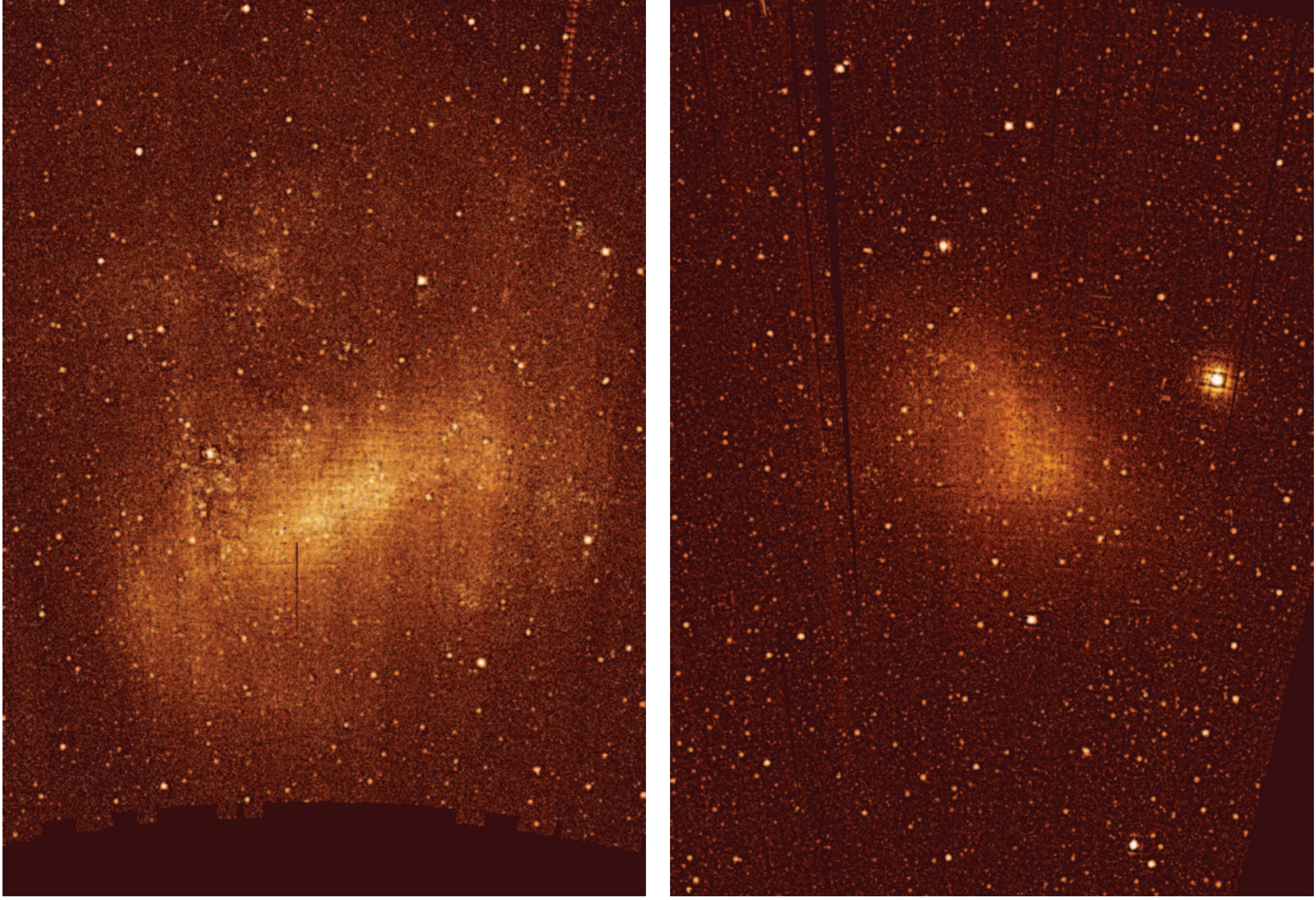

Figure 1: Combination of 21420 and 15840 *I*– band images of the LMC (left) and the SMC (right), respectively, taken with DENIS at the 1m ESO telescope on La Silla (Chile).

square degree in the centre of the LMC which corresponds to 1 source per 200 square arcsec. This is well below the IRAS confusion limit (explanatory supplement, vol. 1, VIII4) for a detected source with a typical size that does not exceed 2″.

Seventy per cent of the detected sources are true members of the MCs and consist mainly of RGB stars, AGB stars and super–giants. Galactic sources in the foreground have not been removed from the catalogue. However, they can be statistically disentangled using a combination of colours and magnitudes. They are mostly associated with ordinary dwarf stars and red giant stars. The catalogue covers an area of 19.87×16 square degrees centred on $(\alpha, \delta)=5^h27^m20^s$, $-69^d00^m00^s$ for the LMC and 14.7×10 square degrees centred on $(\alpha, \delta)= 1^h02^m40^s$, $-73^d00^m00^s$ for the SMC at the epoch J2000 (Fig. 1). The two parts of the catalogue, containing the detected sources, are ordered by increasing right ascension. A third table describes the quality of the detections on a strip by strip basis. All tables are electronically available from CDS at http://cdsweb.u-strasbg.fr/denis.html. The catalogue is presented in more detail in Cioni et al. (2000a).

At about the same time, 2MASS released simultaneous JHK_s data on the whole sky. Nikolaev & Weinberg (2000) also studied the Magellanic Clouds (i.e. distribution of stars in the colour–magnitude diagrams and surface distribution) obtaining similar results as described in this paper. Both catalogues provide highly sensitive near–IR data covering both the LMC and the SMC in their entirety and are not limited to specific objects. Note that the concentration of points in region A at $I \approx 13$ belong to the galactic globular cluster 47 Tuc.

Selection of different stars

Different types of sources are well characterized in colour–colour and colour–magnitude diagrams (Fig. 2). This figure shows sources of both MCs. Note that SMC sources have the same distribution though their location is shifted to bluer colours (because of smaller metallicity) and to fainter magnitudes (because of larger distance). The quantity of the shift is approximately 0.1 mag in colours and 0.4 mag in magnitudes.

In the $(I–J,J–K_s)$ plot we distinguish seven different regions populated statistically by different stars. At blue colours two clumps are associated with dwarfs and giants of the Milky Way Galaxy (MWG), respectively. Their numbers vary with galactic latitude and in the galactic plane, because of large extinction, they tend to merge into a single elongated structure. All other stars belong to the MCs. Those with both colours around 1.3 are RGB stars. Those brighter and redder are AGB stars: M–type at almost constant $J - K_s$ colour and increasing $I - J$ colour with increasing M subtype, and C–type having $J - K_s > 1.2$. AGB stars with $J–K_s > 2.0$ are of either chemical type and are heavily obscured by circumstellar dust, which explains their red $J - K_s$ colour.

In the $(I–J,I)$ diagram the largest concentration of sources defines the upper RGB. The TRBG, the brightest and terminal point of this distribution, is a useful distance indicator and is further discussed in Sect. 4. The plume of objects above that represents the AGB population. Two vertical sequences at bluer colours include mostly stars of the MWG, though some Cepheids and upper Main Sequence stars of the MCs are also included, but not easy to split off. The vertical extent of the foreground sources reflects the different distance at which the stars are located within the MWG. The third vertical sequence is populated by super–giant stars of the MCs.

In the $(J–K_s,K_s)$ diagram AGB stars are broken up in into M–type and C–type stars. These are all stars in region B and most of

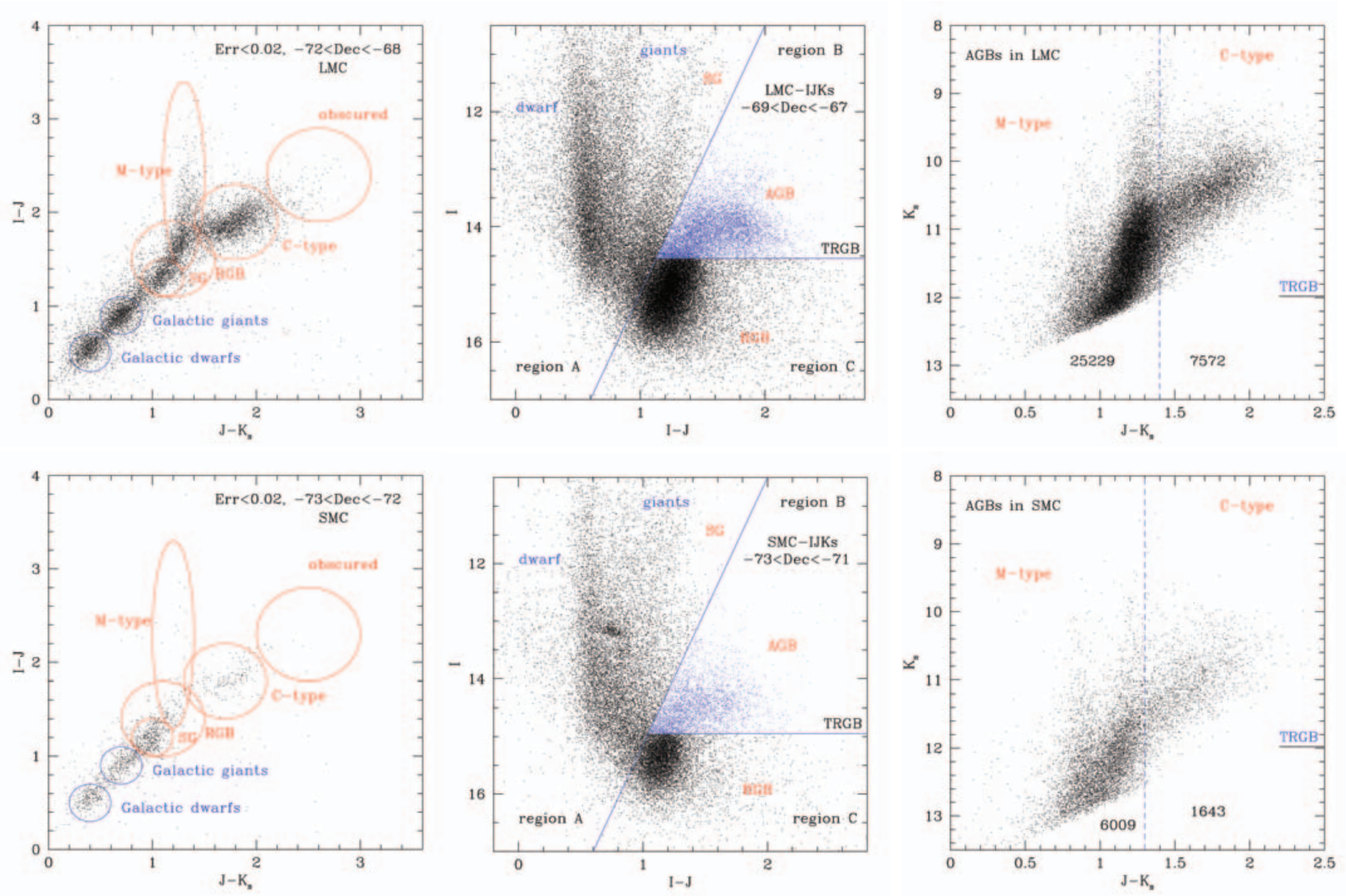

Figure 2: Colour–colour diagram ($I-J$, $J-Ks$) (left), colour–magnitude diagram ($I-J$, I) (centre) and ($J-Ks$, Ks) (right) of sources detected simultaneously in I, J and Ks in the LMC (top row) and in the SMC (bottom row). The horizontal line marks the position of the TRGB, and the slanted line at $I = -4.64(I-J) + 19.78$ defines the regions A, B and C explained in the text. The vertical dashed line discriminates M– type from C–type stars.

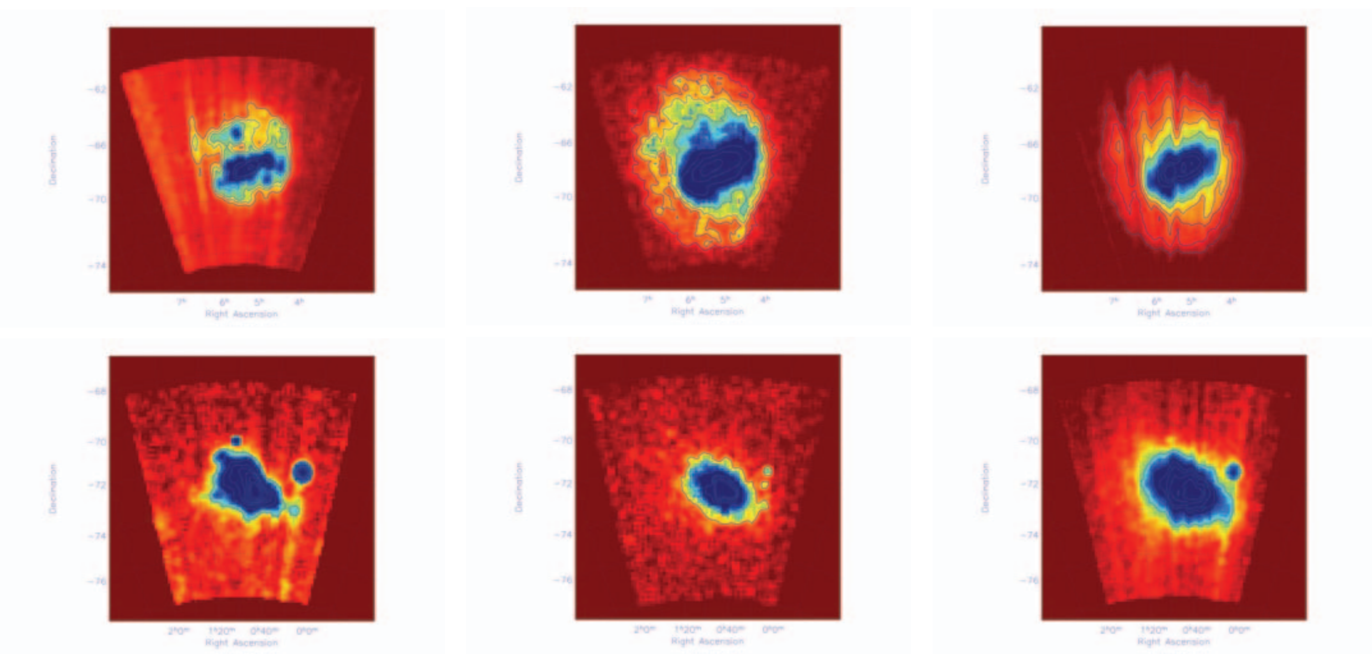

Figure 3: Star counts of the LMC (top row) and of the SMC (bottom row) – class A (left), B (centre) and C (right) objects as indicated in Fig.2 – per 0.04 deg^2. East is to the left and north on top. Coordinates are in the J2000 epoch.

the foreground sources have thus been rejected. However, the faint extension at $J–Ks$ = 0.9 does contain some foreground objects, this can be estimated from sky area far away from the MCs extension, well mixed with genuine faint MCs supergiants of spectral type K or M. Because the photometric accuracy at the AGB magnitudes is well below 0.05 mag the number of sources that have been put in the wrong side by photometric errors is negligible. For the SMC we obtain 6009 M–type and 1643 C–type AGB stars.

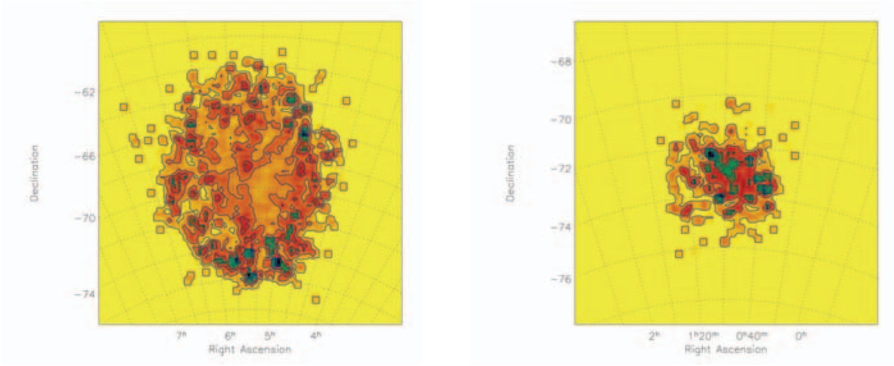

Figure 4: The C/M0+ ratio in the LMC (left) and in the SMC (right). Contours are, for both Clouds, approximately at: 0.1, 0.3, 0.4, 0.5, 0.6. Darker regions correspond to a higher ratio. Coordinates are in the J2000 epoch.

Morphology and structure

This large photometric data–set at different wavelengths and with improved sensitivity and spatial coverage allows us to investigate the large scale properties of the MCs.

In Fig. 2 we have seen a simple and straightforward tool to select three classes of objects: young, middle-aged and old stars. Sources in region (A) represent the youngest population of the MCs: the brightest main sequence stars, blue–loop stars and supergiants, excluding the foreground component, are younger than about 0.5 Gyr at the average metallicity of the MCs. Sources in region (B) are AGB stars about 1 Gyr old. Sources in region (C) are mostly RGB stars older than about 1 Gyr.

For each class of objects in each of the two Clouds, we derived their distribution in the plane of the sky by counting the sources in bins of 0.2° × 0.2°, applying a light smoothing to the resulting structure (Fig. 3). Young stars (left) show a rather clumpy and irregular distribution. The LMC is characterized by a bar and regions of star formation (i.e. Shapley III constellation at $\delta = -67°$). Two high density circular regions in the SMC coincide with galactic globular clusters 47 Tuc (west) and NGC362 (north). Note the increase in the foreground stars in the direction of the Galactic centre (upper left panel). AGB stars delineate a fairly regular structure which is even better outlined by the distribution of older RGB stars. Note that there is contamination between the extremes of the age groups (i.e. the vertical region lacking RGB stars and with an excess of young stars at $\alpha = 6^h$ in the LMC).

In summary, the morphological appearance of the MCs is quite different when stars of different age are selected. The classical irregular shape changes to that of an elliptical galaxy with increasing age. In fact sinusoidal brightness variations with a peak–to–peak amplitude of about 0.25 mag were detected as a function of position angle from the analysis of spatial variations in the apparent magnitude of the mode of the AGB distribution and the TRGB.

This is a natural distance effect, showing that one side of the LMC plane is closer to us than the other. The best fitting geometric model of an inclined plane yields an inclination angle $i = 34.7° \pm 6.2°$ and line–of–nodes position angle $\Theta = 122.5° \pm 8.3°$. Compared to the values obtained with traditional methods, van der Marel & Cioni (2001) concluded that the shape of the LMC disc is not circular, but elliptical.

Distance

The TRGB has been used successfully for several decades to estimate the distance of resolved galaxies (e.g. Lee et al. 1993). The corresponding magnitude depends weakly on age and metallicity, and yields precision comparable to that of classical distance indicators such as Cepheids and RR–Lyrae variables.

We selected from the DCMC sources detected simultaneously in three wave bands, excluding those objects with non–null (problematic) flag values. We calculated the apparent bolometric magnitude (m_{bol}) for those sources with $J–Ks > 0.4$ assuming an average extinction $E(B–V) = 0.15$. In order to identify the precise position of the TRGB in all DENIS wave bands and in m_{bol}, we used the magnitude distribution of these sources, corrected for the contribution of the foreground stars. This was estimated by comparison with magnitude distributions obtained in sky areas far away from the Cloud extension. The resulting statistics of the subtracted histogram are impressive, despite the restricted source selection (Fig. 4).

The maximum of this so-called luminosity function (LF) corresponds to giants that lie on the upper part of the RGB. Towards brighter magnitudes we encounter a strong kink in the profile, which is associated with the position of the TRGB discontinuity. Brightward of the kink follows a bump of AGB stars. At very bright magnitudes the LF has a weak tail, which is composed of stars of luminosity type I and II as well as residuals from the foreground subtraction. The algorithm constructed to quantify the position of the TRGB uses the peak of the second derivative of the LF distribution. In Cioni et al. (2000c) you will find a thorough discussion of this procedure and on the error budget.

Using an appropriate calibration (Salaris & Cassisi 1998) we derive a distance modulus of 18.55 ± 0.04 (formal) ± 0.08 (systematic) and 18.99 ± 0.03 ± 0.08 to the LMC and the SMC, respectively. The distance of the LMC is one of the main stepping stones in the cosmological distance ladder, yet has remained somewhat uncertain and controversial.

Metallicity

The ratio between M–type and C–type AGB stars is a simple and robust indicator of metallicity, that may be used to study the variation of metallicity over the face of a galaxy. Cioni & Habing (2003) have found that it varies strongly across the surface of the MCs (Fig. 5). The C/M ratio correlates with metallicity in the sense: lower metallicity, more carbon stars because in a lower metallicity environment the process that turns O–rich AGB stars into C–rich stars is more efficient, AGB stars are hotter and the number of late M–type stars is considerably reduced.

In the LMC the C/M ratio increases radially; however, the distribution is rather clumpy and that has prevented previous authors from detecting such a gradient. In the SMC the ratio is higher in some regions in the centre and lower in the wing and more generally all over the outer SMC body, but there is no clear radial trend. Using an empirical relation between the mean C/M and the mean [Fe/H] of Local Group galaxies we derive a spread of about 0.75 dex within both MCs which corresponds to the spread obtained from globular clusters.

Variability

DENIS and 2MASS magnitudes combined with the light–curves obtained from microlensing projects such as EROS, MACHO and OGLE have provided interesting constraints on the evolution of AGB stars (i.e. Cioni et al. 2001). Most AGB stars are

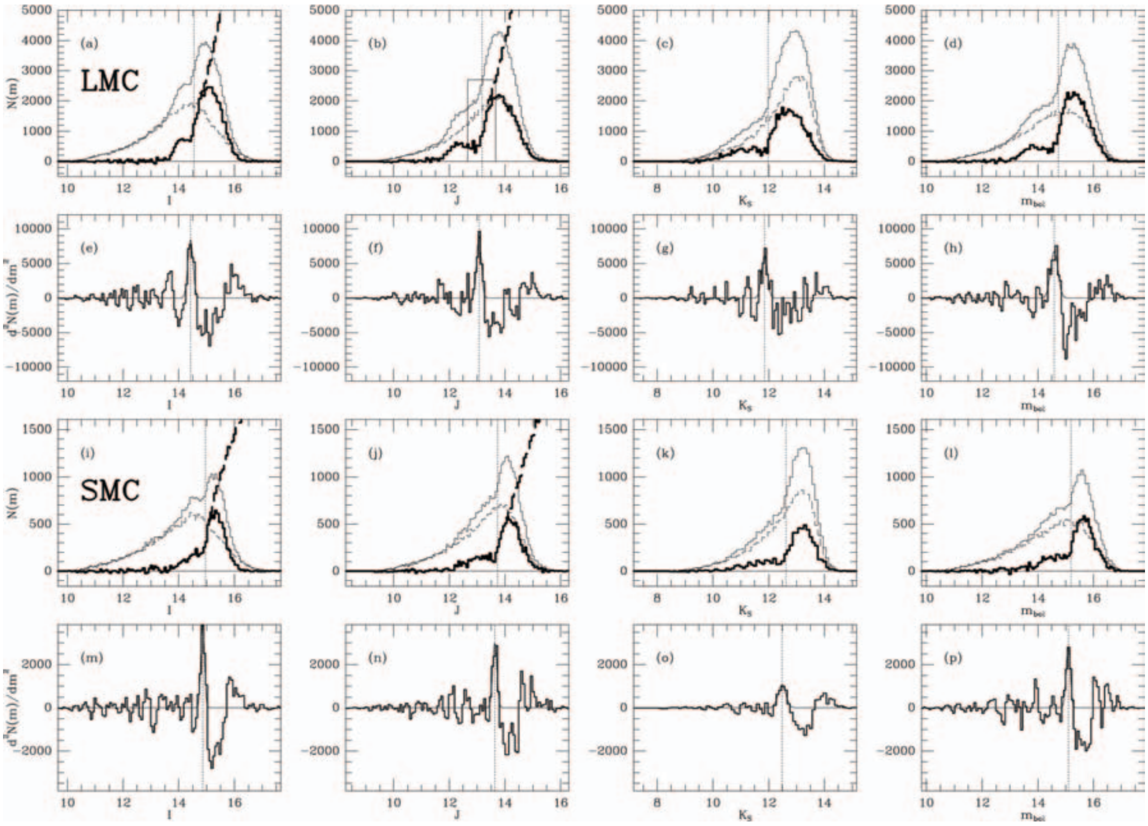

Figure 5: For each DENIS wave band and for m_{bol} the distribution of stars $N(m)$ per 0.07 mag bin and the derivative $d^2N(m)/dm^2$ are shown for the LMC (a–h) and the SMC (i–p). Upper histograms for the main field, middle histograms for the scaled o_set field and lower histograms for the foreground–subtracted field. The vertical line indicates the TRGB discontinuity.

long period variables (LPVs). They pulsate with periods between a few tens to several hundred days and amplitudes up to several magnitudes in the optical and slightly less in the near–IR wave bands. The analysis of light–curves provides amplitude and period for any given pulsation mode.

Fig. 6 shows the period–magnitude sequences as discovered by Wood (1999) for AGB stars in the MCs. Each sequence probably corresponds to a given mode of pulsation. However, pulsation–related models fail to reproduce multi–periodic stars of sequence D. Alternatively they might belong to a binary system where the long period (sequence D) is the orbital period and the pulsation period of the AGB companion lies in sequence A, B or C. A comparison with the theoretical models developed by Vassiliadis & Wood (1993) indicates that most of the AGB stars are from 0.6 to 2 Gyr old.

Stars in both galaxies obey the same relations; however, the histogram of the amplitude of pulsation of M–type and C–type AGB stars has a similar distribution but on average the C–stars have a larger amplitude in the SMC. This may indicate that either most of the C–stars in the SMC are of Mira type (ΔI > 1, period = 300^d and regular pulsation), or that the metallicity affects the amplitude in such a way that in a lower metallicity environment the amplitude of pulsation is larger. This effect cannot yet be checked in other metal–poor galaxies in the Local Group because, despite the fact that many AGB stars have been discovered, there is not enough information on their variability and type. In the LMC, C–stars occupy only the brightest part of the relations, contrary to the SMC.

The comparison between DENIS and 2MASS J and K_s magnitudes confirms that these sources are variable also in these bands.

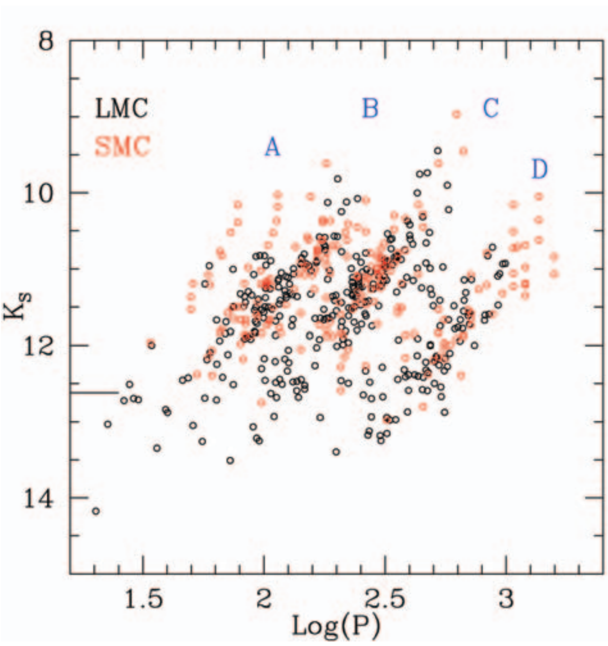

Figure 6: Period–magnitude relations for LMC (black) and SMC (red) LPVs. For comparison LMC sources have been shifted to the SMC distance. The horizontal line indicates the TRGB position. Each sequence is labelled A, B, C and D.

Acknowledgements

We thank all DENIS observers, staff and students, and in particular Pascal Fouqué, for completing the MCs observations. We are grateful to the Paris team who reduced the raw images and to Leiden Observatory for providing the necessary facilities to compile the catalogue.

References

Bertin, E., & Arnout, S. 1996, A&A 117, 393
Cioni, M.R.L., et al. 2000a, A&A 144, 235
Cioni, M.R.L., Habing H.J. & Israel F.P. 2000b, A&A 358, L9
Cioni, M.R.L., et al. 2000c, A&A 359, 601
Cioni, M.R.L., et al. 2001, A&A 377, 945
Cioni, M.R.L., & Habing, H.J. 2003, A&A 402, 133
Epchtein, N., et al. 1997, ESO Messenger 87, 27
Lee, et al. 1993, ApJ 417, 553
Nikolaev, S., & Weinberg, M.D. 2000, ApJ 542, 804
Salaris, & Cassisi 1998, MNRAS 298, 166
van der Marel, R.P,. & Cioni, M.R.L. 2001, AJ 122, 1807
Vassiliadis, E. & Wood, P.R. 1993, ApJ 413, 641
Wood, P.R. 1999, IAU 191, p. 151

High Redshift Galaxies and the Sources of Reionization

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Two of the most important issues in modern astrophysics, what reionized the hydrogen in the Universe, and how the first objects formed, have been addressed by a series of VLT observations. They indicate that the hydrogen was reionized by ultra violet photons from stars and not Active Galactic Nuclei, with most of the photons arising in relatively faint low mass galaxies.

The Universe has been expanding and cooling ever since the Big Bang. Several seconds after the Big Bang, baryons (mainly protons, hydrogen nuclei) and leptons (mainly electrons) had formed. At this point the Universe was far too hot for the electrons to become bound to the protons. Three hundred thousand years later, the temperature of the Universe had dropped to below a few thousand degrees Kelvin allowing the electrons and protons to combine, forming neutral hydrogen. For up to a billion years thereafter, the vast majority of the hydrogen, itself the dominant form of baryonic matter, remained in this neutral state.

The hydrogen that pervades intergalactic space in the current-day Universe is again completely ionized. At some point around a billion years after the Big Bang, the hydrogen in the Universe was reionized. The gas is now kept ionized by the integrated ultra-violet photon background. Ultra-violet photons with energies above 13.6 eV (wavelengths shorter than 91.2 nm) have sufficient energy to ionize the hydrogen atoms when they interact, unbinding the electrons from the protons. The majority of these photons in the current-day Universe are emitted by Active Galactic Nuclei, particularly quasars, emitted as material falls into the supermassive black holes at their centres.

The amount of UV photons emitted by known quasars has been sufficient to ionize the intergalactic hydrogen for most of the history of the Universe. However, at high redshifts (above z=4, up to when the Universe was about 10 per cent of its current age) it was not clear until recently whether quasars and other AGN produced the bulk of the ionizing photons.

The reason for this uncertainty was threefold. Firstly, it has been known for some time (e.g., Schmidt, Schneider, & Gunn 1995; Fan et al. 2001) that luminous quasars were far rarer earlier on in the history of the Universe than when it was about half its current age. Unless the relative numbers of luminous and less luminous AGN favoured the low-luminosity AGN at high redshifts, the ionizing photon density from these objects was lower earlier on in the Universe. Secondly, the Universe was smaller, and so denser, and consequently it was harder to keep the hydrogen ionized. Thirdly, it is known that there is far less star formation in the Universe today than earlier on in its history, so it is entirely possible that at some earlier time the majority of UV photons were emitted by hot young stars in star forming regions in galaxies. This possibility is particularly interesting as it links the formation of the first generations of stars and galaxies to the changing ionization state of most of the baryonic matter in the Universe.

In order to understand whether UV photons from stars or AGN initiated the reionization of the Universe, the epoch of reionization needed to be determined and then the relative impact of AGN and star-forming galaxies on the ionizing photon budget at that epoch needed to be determined.

In the late 1960s it was realised that the epoch of reionization would be revealed in the optical spectra of sufficiently distant quasars. Scheuer (1965) and Gunn and Peterson (1965) realised that a "trough" would be seen in their redshifted UV spectra, caused by the UV photons being absorbed by the neutral hydrogen at redshifts corresponding to the time before reionization. This trough would be produced even if only one per cent of the hydrogen was neutral, so strictly the edge of the trough marked the end of reionization; the process could have started considerably earlier. Identification of this trough awaited the discovery of at least one quasar seen at a redshift prior to that of reionization. Only in 2001 was the Gunn-Peterson trough finally discovered (Becker et al., 2001, Fan et al., 2001) in the spectra of SDSS quasars at z>6. These results implied that the end of reionization occurred at z=5.7–6, just under a billion years after the Big Bang. Measurements of the polarization of the Cosmic Microwave Background by the WMAP satellite (Kogut et al. 2003) seem to indicate a higher redshift for 50 per cent reionization, consistent with reionization occurring over a few hundred million years.

Finding the sources that contributed to the "End of Re-Ionization"

This result left open the question of the origin of the UV photons which reionized the hydrogen. We realised that we might be able to address this issue with VLT observations of deep fields using FORS2. The large VLT aperture combined with the excellent red sensitivity of the recently-upgraded FORS2 CCD arrays meant that it was now feasible to carry out deep ground-based imaging and spectroscopy in order to detect faint quasars and galaxies at $z > 5$ which may emit the ionizing photons.

In order to determine the feasibility of these observations, we used simulations to determine the expected colours of quasars and galaxies at high redshifts. Both quasars and star-forming galaxies have intrinsically flat rest-frame UV spectra which can be reddened by surrounding gas and dust. Dusty objects would count little towards the ambient UV photon budget, and so were ignored. Genuinely high redshift objects could be identified by sharp breaks in their spectra due to strong absorption of the UV photons

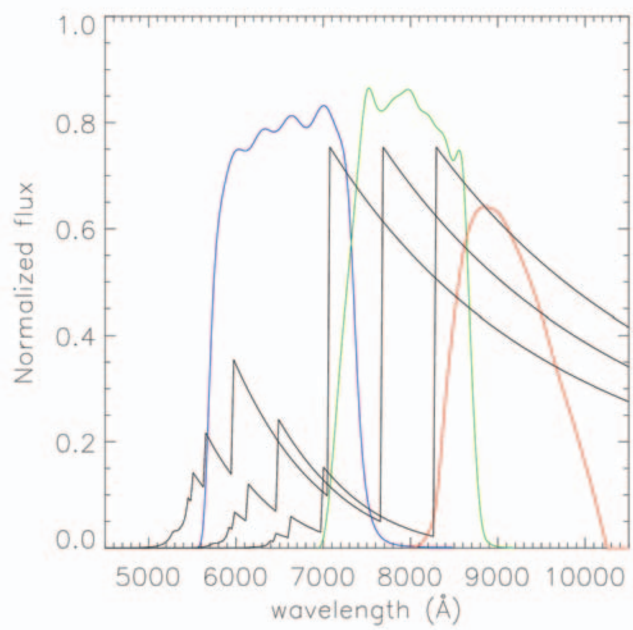

Figure 1: Power-law spectral energy distributions shown for three redshifts (4.8,5.3, and 5.8) and including absorption due to the intergalactic medium below 121.5 nm. The three colour curves represent the filter transmission of the *R* filter (in blue), the *I* filter (in green), and the *z*-band filter (in red) including the response of the CCD array.

by intervening hydrogen gas. Multi-colour imaging would identify these sources as they would "disappear" in images taken through filters sensitive to light with wavelengths shorter than that of the break (Fig. 1). This "Lyman break" technique for identifying distant galaxies has been in use for over a decade and has been championed by Steidel and collaborators to find $z = 3$ and 4 galaxies. Whereas those galaxies show sharp breaks in their spectra at wavelengths up to 500 nm, we needed to look for objects with breaks longward of about 650 nm in order to discover sources at $z > 5$.

We soon realised we had two main options. We could search for "*R*-band dropouts", objects which displayed a break between the *R* and *I* bands (allowing us to identify objects with $4.8 < z < 5.8$ with a median redshift of 5.3, according to our simulations), or "*I*-band dropouts" (objects potentially at $z > 5.5$). We chose to search for the former for several practical reasons.

Firstly, to identify a break between the *R* and *I* bands is easier and requires less telescope time than between the *I* and *Z* bands (required to identify *I*-band dropouts) because FORS2 is more sensitive in *R* and *I* than in *Z*. Secondly, contamination of our sample of candidates with lower redshift objects and stars would be far easier to identify (Fig. 2). Imaging in *R,I* and *Z* we could identify intrinsically flat spectrum sources with clear breaks between *R* and *I* fairly straightforwardly, but with only a detection in *Z* it would be unclear whether our sources were intrinsically flat spectrum with a break, or were intrinsically red sources, like low mass stars, sub-stellar objects and lower redshift reddened galaxies. Thirdly, we did not know how the luminosity function would evolve. Because of the increasing distance modulus and increased absorption by intervening hydrogen, a galaxy at $z = 6$ would be detected at far worse signal-to-noise in the *Z*-band than a similarly luminous galaxy at $z = 5.3$ in the same exposure time. Unless the luminosity function was unusually flat, our images may not have sampled enough volume to detect many I-band dropouts. Given that only 150 million years of cosmic time passes between $z = 6$ and $z = 5.3$ we took the view that the luminosity function of high redshift sources could not change dramatically over that time and so we could concentrate on the easier-to-observe *R*-band dropouts.

We identified a field of about 200 arcmin^2 with extremely low galactic extinction and infrared cirrus emission that was well-placed in RA for ease of service observing. The field was chosen to have a declination of −35°, so that it went roughly overhead at Paranal but meant that the telescope faced south, out of the prevailing wind, minimising the time the field was unobservable due to weather conditions. In 2002 we imaged 40 arcmin^2 to a depth of $R_{AB} = 27.8$, $I_{AB} = 26.5$ and $Z_{AB} = 26$. In 2003 we deepened this field in *Z* to Z = 26.5 and imaged a further 40 arcmin^2 to the same depths in the 3 filters. Two more similarly-sized regions should be imaged in 2004, leading to complete imaging of a 160 arcmin^2 region of sky.

Sources that appear to have spectral breaks can be selected from the imaging data. Starting with a flux-limited sample in the *I*-band (to $I_{AB} = 26.3$) we can identify such sources by requiring $R–I > 1.5$ (Fig. 2). To-date we have followed up spectroscopically the sources identified in the 80 arcmin^2 of imaging data we have obtained so far (see Lehnert & Bremer, 2003 for details of the first 40 arcmin^2) . All of these sources meeting the flux and colour criteria, except one, have been observed with FORS2 using the MXU mode. In this mode, a slit mask is inserted in the focal plane that had about about 40 slitlets cut into them. Each one of these slitlets is placed on an object and results in a spectrum.

Observing all these sources meeting this colour criteria, what we found is fascinating. For the objects that were either not detected, or were marginal detection in the R-band, we found that only those sources exhibited signatures suggesting they have redshifts between $4.8 < z < 5.8$ as expected from our simulations (Fig. 3). These signatures were either or both a strong emission line with an asymmetric profile and a break in continuum light. Both the asymmetric line profile, with a tail of emission to the red and a sharp blue edge, and the continuum break are caused by the strong absorption of hydrogen in the intergalactic medium or discrete absorbers (see Fig. 4 for some examples of the spectra). Sources with large breaks but bright magnitudes in R or I were found to be either very red cool stars or intermediate redshift red galaxies (spectral energy distributions and line strengths suggestive of either early type galaxies or heavily extincted star-

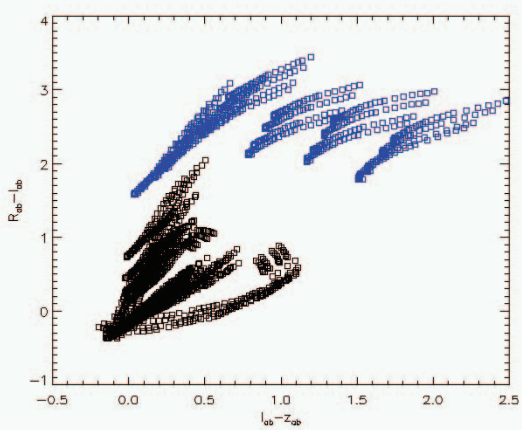

Figure 2: Colour-colour plot of model galaxies with a range of ages and total extinction. The blue squares represent galaxies with redshifts greater than 4.8 while the black squares represent lower redshift galaxies. A colour cut at $R_{ab} – I_{ab}$ is appropriate for selecting high redshift galaxies.

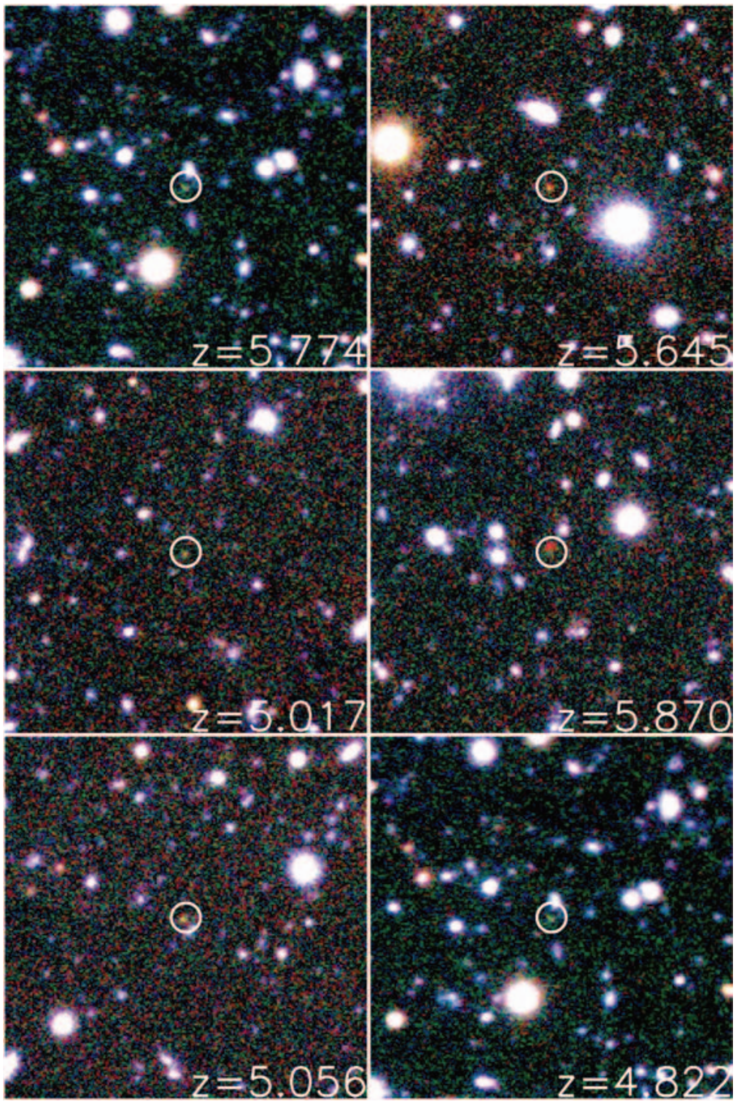

Figure 3: Three colour composites (*R,I,* and *z* are represented as blue, green, and red respectively) of sources with measured redshifts. The circles, which are 2 arc seconds in diameter, are centred on the sources with redshift indicated in the lower left corner of each box.

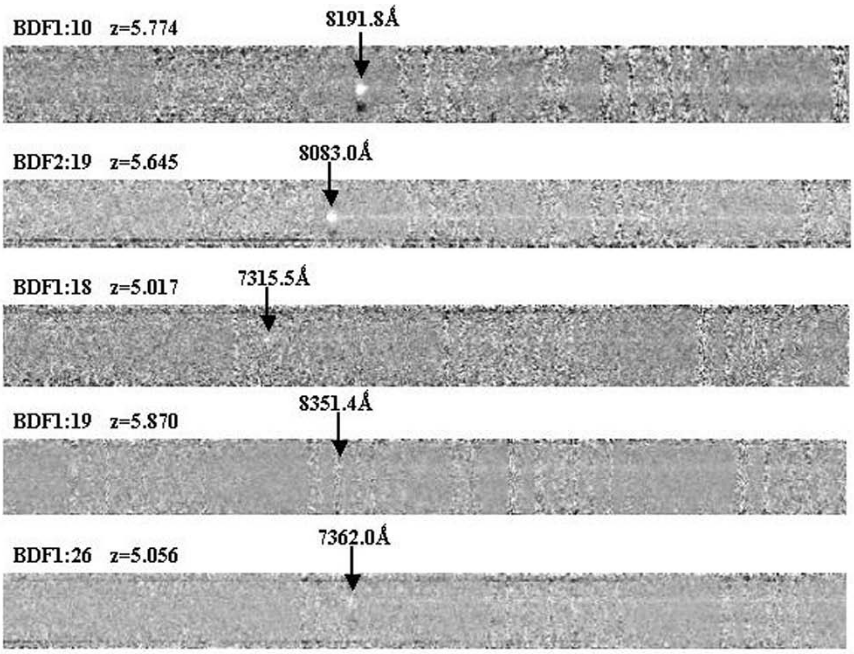

Figure 4: Two dimensional spectra of sources of break galaxies. The name and redshift are indicated above and to the left (blue) end of each spectrum and the wavelength Ly-α emission is indicated by the downward arrow. Continuum emission and then a break is visible in each.

bursts). The number of bright objects meeting the colour criteria in our fields that turned out to be stars or lower redshift galaxies was not large (~5–10). However, compared to the number of high redshift sources with confirmed redshifts, only thirteen out of a total 26 sources, implies that the "contamination rate" is about 1/3. Thus spectroscopy to confirm the nature of the colour selected sources is the key to determining important parameters such as the co-moving space density of high redshift star-forming galaxies. Without the spectroscopy, lower redshift galaxies and stars would make any such estimates very uncertain.

The Properties of High Redshift Galaxies

In our total field of about 80 arcmin^2 investigated to date, we have determined redshifts for 13 galaxies so far. The Ly-alpha emission from these galaxies (used to determine the redshifts) has fluxes of about few × 10^{-18} to few × 10^{-17} ergs s^{-1} cm^{-2} and has high equivalent widths (>30 angstroms in the rest-frame). The fluxes imply Ly-alpha luminosities of about $10^{42–43}$ ergs/s and their high emission line equivalent widths suggest very young ages (about to less than 10^8 yrs). However, it is worth noting that inferring such young ages does not rule out the existence of an older population of stars—it simply indicates that the UV continuum relative to the number of ionizing photons is relatively weak but there could be older populations of stars which do not contribute significantly to the UV continuum.

Interestingly, the widths of the Ly-α emission line are relatively modest, being at most several hundred km/s. Signatures of active galactic nuclei (AGN) are broad emission lines or strong high ionization lines of metals. Since we did not detect any broad or high ionization emission lines in any of our spectra, it appears that none of the high redshift sources were AGN. As we shall discuss later, this allows us to put constraints on the number density of relatively low power UV-selected AGN.

The colour and magnitude distribution of the sources without spectroscopic redshifts is very similar to that of the sources with redshifts. This being the case, it is a reasonable assumption that those without spectroscopic redshift are also at similar redshifts. Making this assumption doubles the sample to 26 high redshift galaxies in an area of about 80 arcmin^2. The rest-frame UV flux densities as probed by the *I* and *z*-band fluxes implies that the star-formation rate of the high redshift galaxies is about a few tenths to almost 20 solar masses per year. This is about a factor of a few to 10 higher than the values estimated using the Ly-α luminosities. This is not surprising since Ly-α suffers from both IGM absorption which may

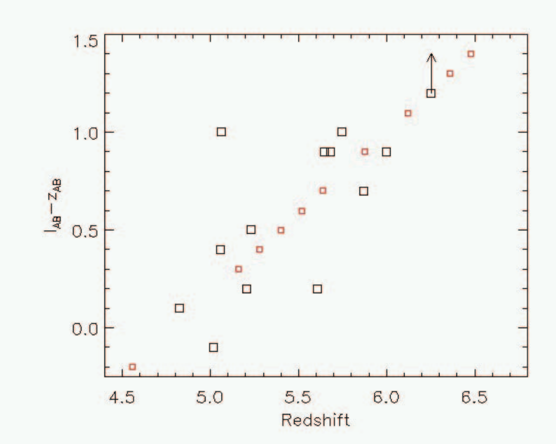

Figure 5: A plot of I-z colour versus redshift. The open black squares show the positions of galaxies with measured redshifts while the small open red squares are the colours of galaxies assuming that *I-z* = 1.2 • (*z*-4.8). The colours of the galaxies with and without redshifts over-lap well. The colours compared to galaxy models are consistent with a young population (less than 100 Myrs) and only light extinction. We note that some of the points lie beyond *z* = 5.8 and were selected as I-band drop-outs with tentative redshifts and are not discussed here.

remove a considerable amount of the intrinsic Ly-α for the high redshift galaxies and, due to high optical depth of the line, radiative transfer effects allow for the destruction of Ly-α by dust grains.

The *I-z* colours of the galaxies also reveal a very interesting trend. We find that the I-z colour correlate with redshift of the sources. Such a trend comes about due to the overwhelming influence of absorption by the IGM and the relatively small dispersion in the intrinsic colours of the sources (Fig. 5). If the colours of the galaxies were intrinsic, then there is no logical reason for such a correlation. It would require something like age or reddening to correlate with redshift which would need to be carefully tuned and thus is ad hoc. Using a model for the IGM (Madau et al. 1996) and galaxy evolutionary synthesis models we can predict the colours of galaxies for a wide range of ages and extinctions, on condition that no galaxy is older than the age of the Universe at redshifts of between 4.8 and 5.8. Doing this we find that the colours of the galaxies as a function of redshift are consistent with them being both young (less than a 100 Myrs) and relatively lightly extincted (visual extinction of a few tenths of a magnitude at most). This result is consistent with the galaxies exhibiting relatively strong Ly-α emission, which due to its fragile nature (because it is easily destroyed by dust), also suggests low extinction. In addition, the high equivalent width of Ly-α also implies relatively young ages for the burst of star formation in the galaxies.

The co-moving space density of high redshift galaxies

Using the estimated number of high redshift galaxies, the area covered in the images, an estimate of the completeness as a function of magnitude, and assumptions about the cosmological parameters, it is possible to estimate the co-moving density of sources. The completeness of the images was estimated using both model images and real images of galaxies with spectroscopically determined redshifts. These individual galaxy or model images were randomly placed in the I-band images of each field and then we tried to "recover" them using a galaxy finding algorithm that was used in originally detecting galaxies within the images. This was done as a function of *I*-band magnitude. In addition, we also checked the detection rate of the general galaxy population by investigating the surface density of sources as a function of magnitude. Only a small fraction of all galaxies are detected near the detection limit of any image. This incompleteness can be estimated by plotting surface density as a function of galaxy magnitude and determining where the number densities begin to deviate from a power-law determined from the bright galaxies in the individual images.

Generally speaking, the co-moving density of objects could now be estimated. However, as discussed earlier, the colours and magnitudes of the sample galaxies are sensitive to the source redshift due to the strong influence of the IGM absorption. Therefore, it is not a simple matter to translate all of the parameters into a co-moving density as a function of magnitude. To mitigate against these effects, we chose a more conservative approach of comparing the co-moving number density of sources at lower redshift selected using a similar technique to the one outlined here. We used the co-moving density as a function of magnitude for a sample of similarly selected galaxies at z~3 and ~4 from Steidel et al. (1999) and applied an offset to the magnitudes due to larger distance of the high redshift sources, put in the incompleteness as determined for the high redshift sample, and then used a linear relationship between *I-z* and redshift covering the range of values we determined for the high redshift sample. What we found is that the number of bright (luminous) galaxies declined significantly from $z \sim 3$ or 4 to $z \sim 5.3$ (the mid-point of our sample). The decline was roughly a factor of 2 to 3.

Although fraught with uncertainty, we can take this analysis one step further. Given that we have the luminosity function of galaxies at $z \sim 3$ or 4 we can then adjust the co-moving density and fiducial luminosity (the luminosity where the functional form of the luminosity function changes from being predominately exponential to predominately a power-law; this luminosity is represented by L* and the co-moving density by ϕ*) until we get a good representation of the data. Doing this we find that we need to decrease L* by about a factor of 3 (or about 1 magnitude) and increase ϕ* by about a factor of 3. The reason that this is uncertain is that we are only observing galaxies down to about L* and thus we are not detecting galaxies over a wide portion of the luminosity function.

This analysis indicates that the observed rate of UV photon production per unit volume of observed sources is low compared to the results for lower redshift galaxies. However, by fitting and extrapolating the luminosity function, we find rough agreement. This estimate can then be used to derive a rate of star-formation per unit volume. Making such an estimate for the best fit luminosity function, we again find rough agreement with results for $z = 3$ to 4 galaxies. However, to infer the true rate of star-formation per unit volume, one must correct for extinction. We have found evidence that the extinction in these sources is low, the optical extinction is probably less than a few tenths of a magnitude. If it is this low, then the star-formation rate per unit volume probably declined from $z = 3$ or 4 to z ~ 5.5 (Fig. 6).

Keeping their Local Volume Ionised and Re-Ionisation

From the UV luminosity function it is possible to estimate the number of ionising photons emitted per unit co-moving volume both by the sources we have directly observed and then by extrapolating to fainter sources using the best-fit luminosity function. Once we have done this we can compare the derived photon density to that required to keep the volume ionized. The UV photon density from our detected sources fell short by a factor of three relative to that produced by similar luminosity galaxies at z~3 and 4. Ferguson et al. (2002) and others had previously shown that even this higher photon density is insufficient to ionize the high redshift Universe.

The clear implication of our analysis is that the objects we have detected emit insufficient ionizing photons to keep their part of the Universe ionized, and so the bulk of ion-

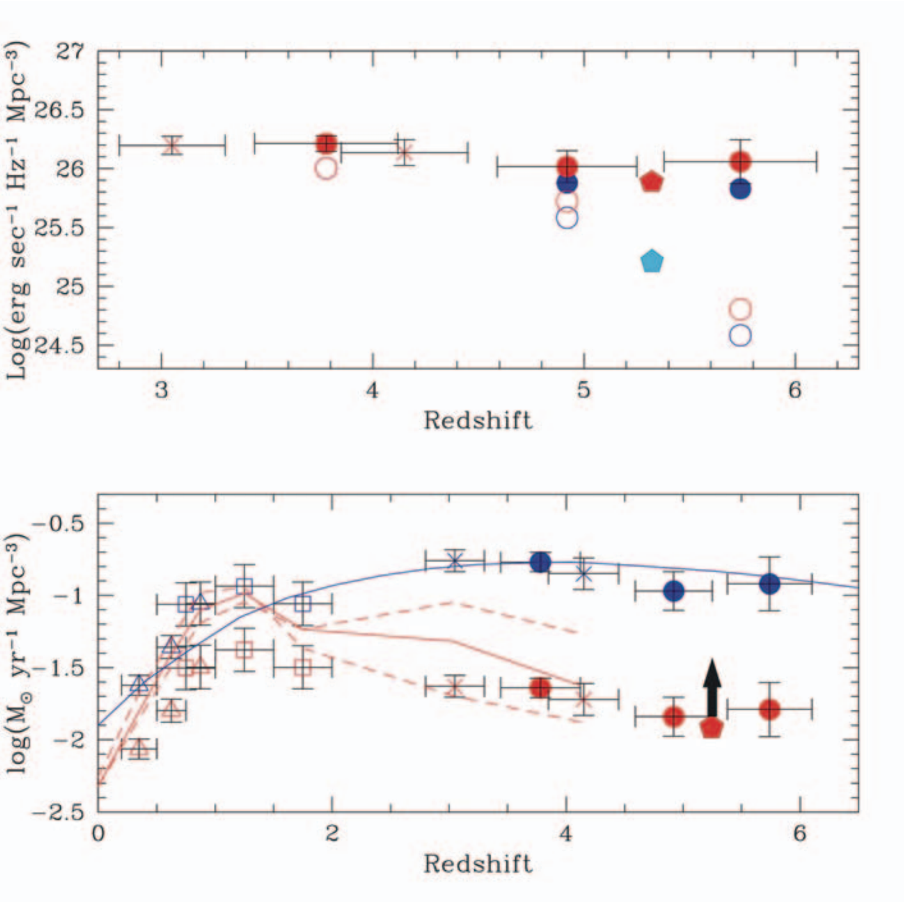

Figure 6: A reproduction of a figure from Giavalisco et al. (2004) of the UV energy density versus redshift (at the top) and the density of star-formation as a function of redshift (at the bottom). The cyan hexagon in the top panel represents the UV energy density we have observed, while the red hexagon is an extrapolation of our best fit luminosity function to low luminosities. In the bottom panel, the red hexagon represents the total star-formation rate density estimated using the extrapolated luminosity density. Giavalisco et al. (2004) applied an extinction correction of 0.8 magnitudes in the visible (blue circles show the extinction correction). Our analysis suggests that something less should be used and the arrow represents a conservative value of 0.4 magnitudes of visual extinction.

izing photons must come from less luminous objects. Given that our sources are observed within 100–200 Myr of the end of reionization, this also implies that the bulk of the photons that reionized the Universe were emitted by relatively low luminosity sources. As we detect no quasars or AGN in our volume, but many galaxies, it follows that unless the AGN luminosity function has a bizarre shape, these less luminous sources must be galaxies. Is there any way that we could have underestimated the ionizing impact of the more luminous detected sources? The photon density required to ionize a volume of IGM depends linearly on the clumping factor of the IGM. Along with many other workers in this field, we assume a clumping factor of 30. Only in the case where this factor is close to unity (in other words, the IGM is completely uniform, clearly ruled out by simulations) does the required photon density become comparable to our measured density. Given the simulations of structure formation at $z > 5$, this is extremely unlikely.

Further work and next steps

As we currently have only ground-based imaging for our field, we followed up this work by searching for similar high redshift dropout galaxies in the HST-ACS data of the GOODS CDF-S field (Bremer et al, 2004). Combining this data with FORS2 and ISAAC imaging of part of the field, we were able to photometrically select and study candidate high redshift galaxies over an area of about 150 arcmin^2. Deep CHANDRA imaging (1 Msec) was available for this field, so we could search for X-ray emission from these sources. This work showed that such sources clustered on scales comparable to that of both our field and the GOODS field, so larger areas of sky needed to be studied to avoid the effects of cosmic variance. Most sources were resolved in the ACS image, but with small effective radii (2 kpc or less at z>5), many looking like the z=5.3 source (or pair of sources) identified in the HDF-N by Spinrad et al (1998). None of the sources were detected in the CHANDRA image, either individually or stacked as an "average" source. This reinforces the result in our earlier work that the sources are star forming galaxies with no evidence of AGN emission. Even if these sources contain obscured AGN, they cannot be powerful sources.

Clearly, there is a great deal more work to be done on understanding these sources and early galaxy formation. With the completion of our 160 arcmin^2 field we will have a field similar in size to the GOODS CDF-S field in order to study clustering on the relatively large scale. With more redshifts (eventually about 25 in this field) we can start to understand the 3-dimensional clustering of the sources, comparing the distributions to detailed simulations of early structure formation. Even then we need to carry out imaging and spectroscopy of other fields over the sky to minimise the impact of cosmic variance. In order to determine the luminosity function with minimal uncertainty we need to obtain many more redshifts (100 or more) in the magnitude range we have studied thus far, and need to securely identify fainter sources. This can be done either by imaging more deeply (such as the imaging being carried out of the ACS-UDF with HST, but over a much larger area to negate cosmic variance), or exploiting the lensing amplification provided by high redshift clusters of galaxies to allow us to probe deeper down the luminosity function. With enough redshifts we may be able to identify evolution in the luminosity function over $z = 4.8$ to $z = 6$, at least crudely. In all of these studies it is clear that the VLT and its instrumentation suite will play a crucial role.

References

Becker, R. et al. 2001, AJ, 122, 2850
Bremer, M., Lehnert M., Waddington I., Hardcastle M., Boyce P., Phillipps, S., 2004, MNRAS, 347, L7
Fan et al. 2001, AJ, 122, 2833
Ferguson, H. C., Dickinson, M., Papovich, C. 2002, ApJ, 569, 65
Giavalisco, M. et al. 2004, ApJ, 600, 103
Gunn J., Peterson B., 1965, ApJ, 142, 1633
Kogut, A. et al. 2003, ApJS, 148, 161
Lehnert M., Bremer M., 2003, ApJ, 593, 630
Madau P., Ferguson H., Dickinson M., Giavalisco M., Steidel C., Fruchter A., 1996, MNRAS, 283, 1388
Scheuer P, 1965, Nature, 207, 963.
Schmidt, M., Schneider, D. P., Gunn, J. E. 1995, AJ, 110, 68
Spinrad et al., 1998, AJ, 116, 2617
Steidel C., Adelberger K., Giavalisco M., Dickinson M., Pettini M.,1999, ApJ, 519, 1

Stellar Spectroscopy of Individual Stars in Local Group Galaxies with the VLT: Kinematics and Calcium Triplet Abundances

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The large collecting area and high-throughput multi-object instruments on the VLT make it possible to carry out detailed studies of stellar properties and distributions in environments well beyond our Galaxy.

The high resolution spectrograph, UVES, has provided outstanding data for the study of stellar abundances in extragalactic environments. It is possible to observe red giant branch (RGB) stars at high resolution in galaxies as far away as Leo I (250 kpc) with UVES (Shetrone et al. 2002; Tolstoy et al. 2002), and to look at super-giants up to 1.5 Mpc away at the boundary of the Local Group (e.g., Venn et al. 2003; Kaufer et al. 2004). These studies have been, of necessity, painstakingly long integrations of individual stars down to the faint limit of the instrument (*I* ~ 19.5).

The multi-fibre instrument, FLAMES, is providing a dramatic increase in multi-plexing with a 25 arcmin diameter field of view, and 130 fibres in Medusa mode (mag. limit *I* ~ 18.5), over selectable wavelength ranges (per setting), at resolutions useful for stellar spectroscopy (R ~ 20000), and 8 fibres feeding UVES over a longer wavelength range, with a typical UVES resolution (R ~ 40000). This field of view and density of fibres is a good match to the size of the central regions of nearby dwarf spheroidal galaxies, and the number of RGB stars at magnitudes bright enough to obtain good quality high resolution spectra.

However, FLAMES is not always the best instrument for every stellar project. Due to light loss from fibre transmission, and restrictions on choice of resolution and on placing fibres close to each other, FLAMES is well suited for abundance studies of stars in uncrowded regions of our nearest neighbour galaxies (within ~220 kpc). If we want to look at more crowded regions (e.g., the bar of the LMC), or if we want to use the VLT to push beyond the galaxies in and around the halo of our Galaxy to look at a completely separate and independent environments, we have to use the slit spectrographs, FORS1 and FORS2. These instruments also have enhanced multiplexing capabilities such as slit masks, and with a blocking filter, FORS2 can match or even exceed the capabilities of FLAMES. Of course this means fewer lines from a single element at lower resolution, but the converse is that we can look at significantly fainter stars, probing a more distant and varied set of environments.

A commonly used abundance indicator at intermediate resolution is the Ca II triplet (CaT), a set of three absorption lines near 8500 Å. The equivalent widths of these lines (ie. the line flux with respect to the continuum luminosity of the star) have been shown to correlate very well with high resolution [Fe/H] abundance (see Armandroff & Da Costa 1991; Rutledge 1997). We have also made a comparison of our own, not matched on individual stars, but using preliminary results from the HR FLAMES data we are collecting for 100+ stars in the Sculptor galaxy (Hill et al., in prep.). We compare the distribution of [Fe/H] abundances found with FLAMES with those measured on the basis of the CaT from a previous FORS1 study of Sculptor (Tolstoy et al. 2001). As can be seen in Figure 1, there is good agreement between the two samples, although we note that the FLAMES results are preliminary.

The FORS2 spectrograph, combined with the red-optimised MIT/LL CCDs, is a uniquely powerful instrument for measuring the metallicities of RGB stars as faint as *I* =

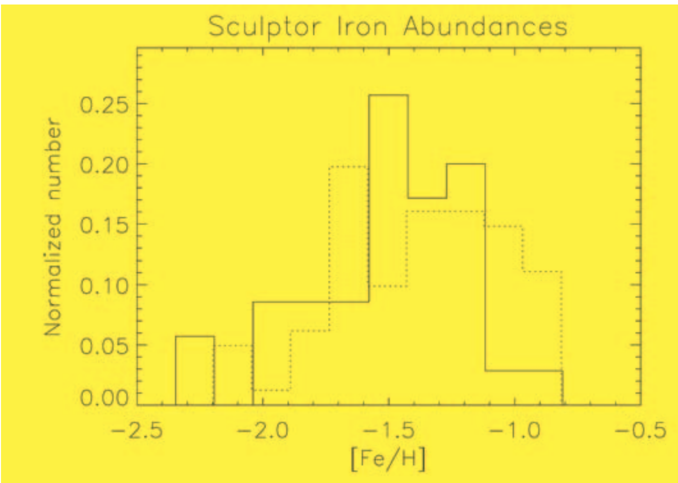

Figure 1: The solid line in the (normalised) histogram of [Fe/H] is for a sample of RGB stars observed in the Sculptor dwarf spheroidal in the CaT region (by Tolstoy et al. 2001) with FORS1. The dotted histogram comes from the preliminary results of the FLAMES LP and GTO time which are based on high resolution spectra for ~100 RGB stars in Sculptor. The samples are not overlapping, but both are randomly chosen on the RGB. The FLAMES samples are necessarily nearer the tip of the RGB. The FORS1 sample was chosen lower down the RGB, at somewhat fainter magnitudes.

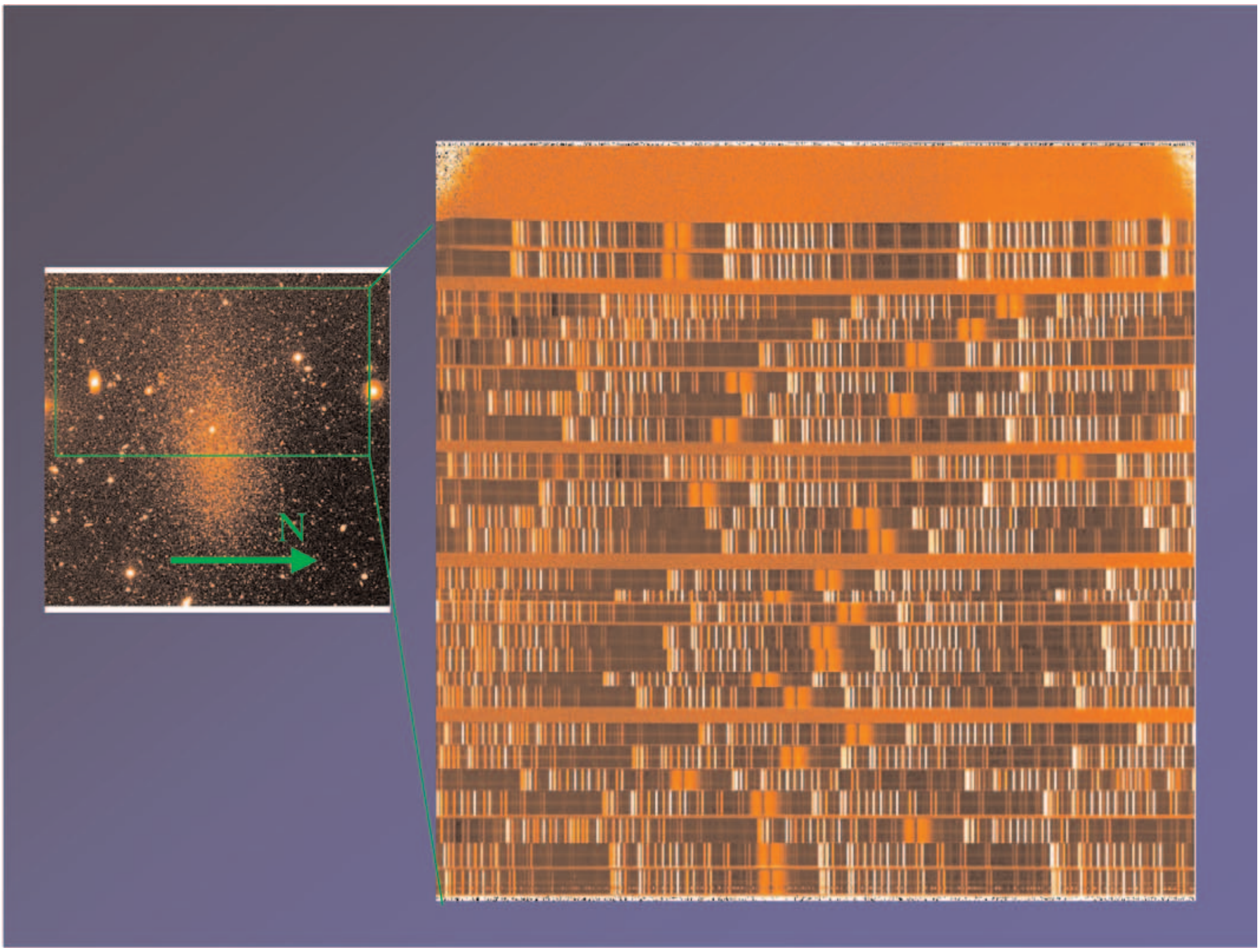

Figure 2: A FORS1 *R*-band image of Tucana taken in August 1999. The green outline shows the region covered by the MXU slit mask, and thus the region where spectra were obtained. The CCD image on the right is the raw spectra on one of the two FORS2 CCDs (the "master" CCD) for our spectra of stars in Tucana.

22. This brings every Local Group galaxy outside the Galactic zone of avoidance into range for kinematic and metallicity studies of intermediate-age and old stars. FORS1/2 can thus be used to efficiently look at samples of stars in galaxies which are too distant to allow high resolution abundances or even fibre spectroscopy (e.g., Tucana, Fraternali et al. 2004, in prep.). The field of view of the FORS1/2 spectrograph and the number of slits are a good match to the density of RGB stars in low surface brightness dwarf galaxies out to the edge of the Local Group.

In Figure 2 we can see the raw data obtained for the Tucana dwarf spheroidal galaxy, and the field of view covered by FORS2/MXU on the galaxy. Out of 47 targets placed on the slits 25 could be successfully extracted. The rest were too faint for a successful extraction. Of these successfully extracted stars 18 were considered of good enough quality to determine velocities, and of these 3 were quite distinct from the average velocity of the majority of stars. These cluster around the systemic velocity of Tucana, determined now for the first time to be 182 km/s. In Figure 3 we show the histogram of these velocities.

With this reasonably large sample of stars across the Tucana galaxy we can see if there are any obvious kinematic patterns. Figure 4 shows the velocities of the stars observed in Tucana with their positions in the galaxy. The blue crosses have velocities less than systemic, and red crosses have greater than systemic velocities. The two green crosses are at systemic velocity. There is intriguing evidence for one side of the galaxy appearing to recede and the other to be approaching. This could be interpreted as rotation, or possibly some indication of a tidal disturbance, although Tucana's isolated position in the Local Group mitigates against the latter possibility. Although the number

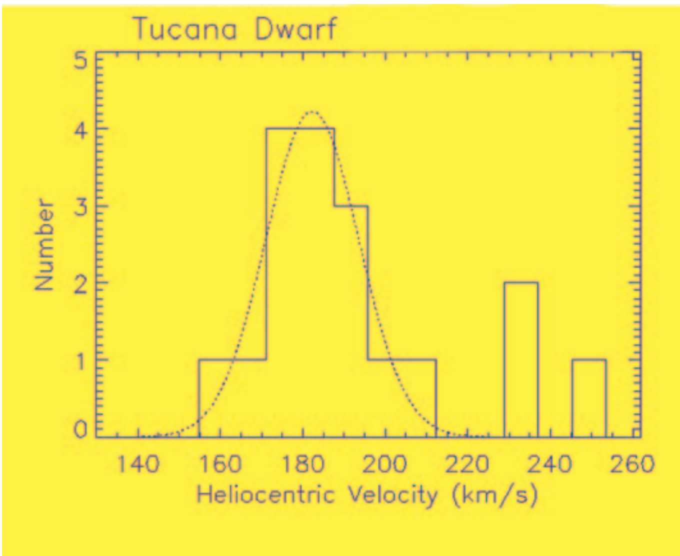

Figure 3: Histogram of the radial velocities measured from the CaT region for 18 stars in the Tucana dwaf spheroidal galaxy. The gaussian fit gives a central, systemic, optical velocity of Tucana of 182 km/s, with a dispersion on 12 km/s.

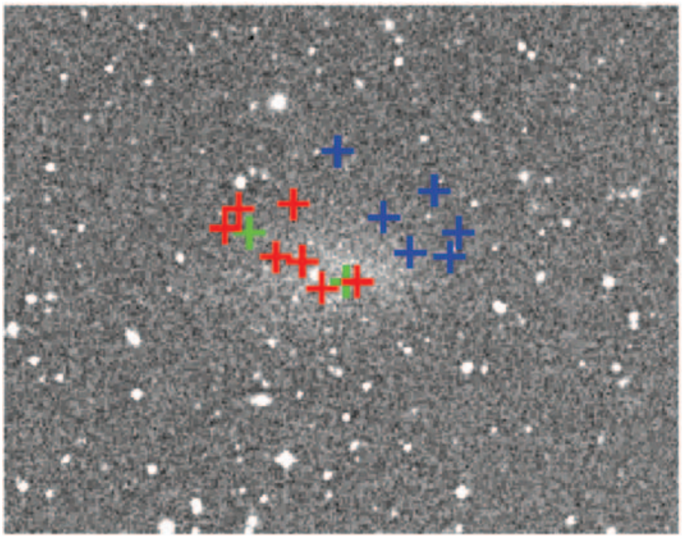

Figure 4: A 20′ by 14′ field of view centred on Tucana, taken from DSS plates. The blue crosses represent those stars with velocities less than v_{sys} (182 km/s) and the red crosses greater than systemic. The green crosses are those stars at systemic velocity. North is up and East to the left.

statistics are still very small, interestingly, if this is rotation it would be, as expected, rotation about the minor axis.

In Figure 5 we show preliminary results from the CaT metallicities of these stars in Tucana. The spread in abundances looks quite similar to Sculptor (from Tolstoy et al. 2001). From this plot, and taking into account the velocity and position of Tucana in the Local Group it is clear that the properties of Tucana are consistent with those of nearer Galactic satellite dwarf spheroidal galaxies, such as Sculptor.

The efficient use of FORS1/2 is not restricted to the faintest stars; the same techniques can be successfully applied to much nearer galaxies. Here, the efficiency with which it is possible to change the slit configuration, the ease of target acquisition based on pre-images and slit configurations created with the FIMS software, together with seeing of 0.7 arc-seconds have allowed major new studies of crowded regions like the center of the LMC bar (e.g., Cole et al. 2004, in prep.). With a surface brightness of 20.6 mag/arcsec^2, RGB stars in the bar were beyond the capabilities of spectrographs on 4-meter class telescopes. Crowding problems can be minimized by target selection from pre-images taken in good seeing, and the difficulties of sky fiber placement can be completely avoided by using slits that span many arc-seconds around each target. These capabilities ensure a valuable place for FORS even after the advent of large fibre systems such as FLAMES.

In nearby galaxies, where targets are bright, the speed with which high signal-to-noise spectra can be acquired becomes a tremendous advantage of FORS1/2. Comparing CaT spectra of RGB stars in the LMC obtained in a large survey of field stars, UT4/FORS2 yields higher signal-to-noise in 1200 second exposures (Cole et al. 2004) than CTIO-Hydra in exposures 10 times as long (Smecker-Hane et al. 2004, in prep). Because the metallicity distribution functions of galaxies are not well constrained, sample size is a crucial aspect of any chemical evolution study. Sparse samples, measuring only a few stars, can all too easily miss minority populations which may be critical for understanding the chemical (and dynamical) evolution of the host galaxy.

There are several galaxies in the Local Group for which we do not have even the most basic information, such as the optical radial velocity. This is especially important for dwarf spheroidal type galaxies which have no (observable) gas. Once the stellar velocity of the system is known it is possible to look more carefully for associated gas and to analyse possible orbital trajectories to its current location.

We have used the FORS spectrographs to determine the optical velocities, previously unknown, of Antlia (Tolstoy & Irwin 2000), and Tucana (Fraternali et al. 2004) and a reassessment of the optical velocity of Phoenix (Irwin & Tolstoy 2002). In the case of the Tucana dwarf spheroidal, it has always been held to be an unusual object because of its extreme distance from the Galaxy and M31, unlike all other Local Group dwarf spheroidals (at least prior to the discovery of Cetus).

In the case of the Phoenix and Antlia dwarf galaxies it is possible for the first time to make clear the association of the optical galaxy with the HI gas seen near these objects. Without a reliable optical velocity this association remained uncertain. These kinematic studies therefore have far reaching implications for our understanding of evolutionary processes in nearby dwarf galaxies.

There are currently two large programmes at ESO to use FLAMES to increase the number of stars with velocity and abundance measurements to improve detailed modelling in several nearby galaxies (e.g., 171.B-0588, PI Tolstoy), for which the first results will be available soon. This ability to look at individual stars in different galaxies with such accuracy over such a large range in distance means we can probe the properties of stars in many different environments - metal poor, metal rich, dense, sparse etc. This is an exciting era for understanding the detailed properties of resolved stellar populations across the Local Group, which naturally will have implications for studies of the most distant galaxies.

References

Armandroff & Da Costa 1991, AJ, 101, 1329
Irwin & Tolstoy 2002, MNRAS, 336, 643
Kaufer et al. 2004, AJ, in press
Rutledge et al. 1997, PASP, 109, 907
Shetrone et al. 2003, AJ, 125, 684
Tolstoy & Irwin 2000, MNRAS, 318, 1241
Tolstoy et al. 2001, MNRAS, 327, 918
Tolstoy et al. 2003, AJ, 125, 707
Venn et al. 2003, AJ, 126, 1326

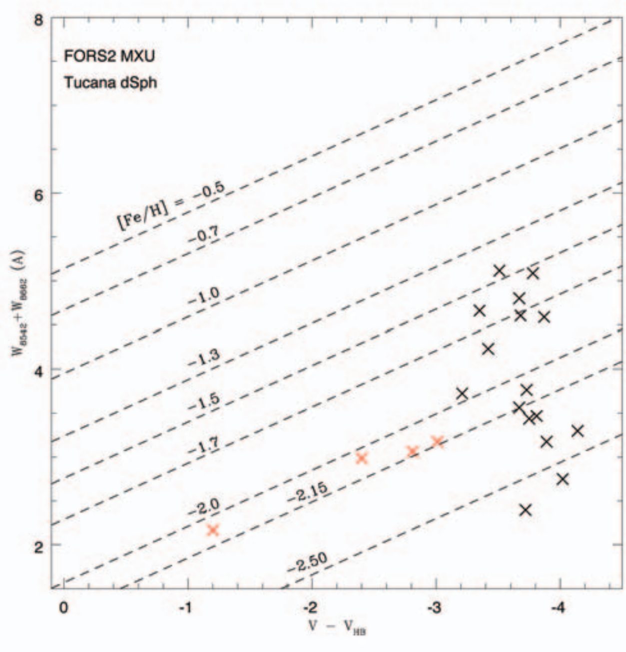

Figure 5: The black crosses are the measurements of the CaT widths of the two strongest lines in our FORS2/MXU spectra of stars in Tucana plotted against the difference in their magnitude with that of the horizontal branch in Tucana (V_H). The dashed lines are the relations calibrated by Tolstoy et al. 2001 corresponding to where stars of different metallicity should lie. The red crosses are the CaT measurements taken with the same instrumental set up and processed in the same way for stars of known metallicty in Galactic globular cluster, M15.

FIRST DETECTION OF CARBON MONOXIDE IN THE ATMOSPHERE OF URANUS

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CARBON MONOXIDE HAS BEEN DETECTED FOR THE FIRST TIME IN THE ATMOSPHERE OF URANUS, FROM INFRARED SPECTROSCOPY USING ISAAC AT THE VLT. THIS RESULT PROVIDES NEW CONSTRAINTS ON THE PLANET'S INTERIOR, AND ILLUSTRATES SIGNIFICANT DIFFERENCES BETWEEN THE TWO "ICY GIANTS", URANUS AND NEPTUNE.

WHY ARE URANUS AND Neptune so different? Among the four giant planets, both share the common status of "icy giants", which refers to their global composition, mostly made of an icy core. This icy core accreted only a small fraction of protosolar gas. In contrast, in the case of the "gaseous giants" Jupiter and Saturn, this protosolar component, mostly made of hydrogen and helium, was predominant.

We could thus expect that Uranus and Neptune, with their similar sizes and comparable densities, would be sister planets. However, the planets exhibit remarkable differences in many ways. First, Neptune has a strong internal energy source while Uranus shows no evidence for it. In addition, Neptune's atmosphere exhibits an intense dynamical activity (shown, in particular, by strong temporal morphological variations), while Uranus is much more sluggish. Last but not least, both carbon monoxide CO and hydrogen cyanide HCN were found in large abundances in Neptune's stratosphere, while these species could not be detected so far in Uranus (Rosenqvist et al., 1992, Marten et al., 1993). CO, in particular, is about a thousand times more abundant in Neptune's stratosphere (with a mixing ratio of 10^{-6} with respect to hydrogen) than in Jupiter's atmosphere (Bézard et al., 1992), while its stratospheric abundance in Uranus is at least 30 times lower than the Neptune value. Marten et al. (1993) suggested that convection might be inhibited in Uranus' interior, preventing CO (as well as other species like HCN and phosphine PH_3) to come from the interior.

The detection (or non-detection) of CO and PH_3 in the tropospheres of both Uranus and Neptune would be a good test of this hypothesis. Phosphine, in particular has been detected in large abundances (larger than expected by out-of-equilibrium thermochemical models) in both Jupiter and Saturn; these large amounts are attributed to convective motions which bring up PH_3 from the deep interior up to observable atmospheric levels of a few bars or less. Searching for PH_3 in Uranus and Neptune, however, is more difficult, because phosphine is expected to condense at a level of about one bar.

OBSERVATIONS AT THE VLT

The 5-μm spectral window offers a good opportunity for probing the deep atmosphere of giant planets, because this range is free of methane absorption. In the case of Uranus and Neptune, the 5-μm radiation is expected to come from above a cloud deck located at about 3 bars, presumably made of H_2S ice (Baines et al., 1995).

Observations were performed in October-November 2002 with the ISAAC (Infrared Spectrometer And Array Camera) instrument mounted at the VLT-UT1 (Antu). We used the long-slit mode of the instrument (Cuby et al., 2000) in the long-wavelength mode, with a slit height of 120 arcsec and a slit width of 2 arcsec, corresponding to a resolving power of 1500. Using two different grating positions, we covered the 4.60–5.00 μm range. Data were reduced using the Eclipse software (Devillard, 1997) and the IRAF standard package. The star HR 8293 was used for calibration.

Figure 1 shows the calibrated spectrum of Uranus, obtained from dividing the raw spectrum of Uranus by the stellar spectrum (Encrenaz et al. 2004). Data have been replaced by zeros in the spectral regions of strong telluric absorption. In order to recover the information contained in these spectral ranges, we multiplied, in the modelling phase, the synthetic spectrum of Uranus by a model spectrum of the Earth atmospheric absorption, and the result was convolved to the atmospheric function. The telluric absorption spectrum was validated by comparison with the star spectrum.

Figures 1 and 2 show that the observed spectrum of Uranus is the sum of three components. The first one consists of a few strong emission lines due to the H_3^+ ion (especially at 4.684 and 4.875 μm), already detected previously in Uranus's upper atmosphere (Trafton et al., 1993, 1999; Encrenaz et al., 2003). We attribute the second, unexpected component to a set of CO emission lines which can all be attributed to the J-components of the CO(1-0) band, from R7 to P8 (4.60-4.73 μm). Two mechanisms can be considered a priori to explain the emission: fluorescence or thermal emission in the stratosphere. Modelling the thermal CO(1-0) emission shows that the fit with the data is not satisfactory, for any value of the rotational temperature. Even for a low temperature (T= 150 K), the fit with the data is very poor as shown in Fig. 1, and this fit would be even worse for higher temperatures. The thermal emission mechanism has thus to be excluded, and fluorescence has to be favoured. Finally, the third component appears as a weak continuum between 4.75 and 5.00 μm. We attribute this continuum to solar reflection above the the cloud level at 3 bars, presumably due to H_2S ice.

MODELLING AND INTERPRETATION

The fluorescence emission of CO in Uranus was calculated using a code derived from the fluorescence of CH_4 in Jupiter and Saturn which successfully reproduces the observed methane emission at 3.3 μm (Drossart et al., 1999). Calculations show that, because the CO-H_2 collision rate is very low, non-LTE effects start to play a role at relatively low altitudes, around the tropopause at 100 mbar, and become predominant above the 10 mbar level. This situation is very different from the case of the methane fluorescence in the giant planets, because the CO-H_2 collision

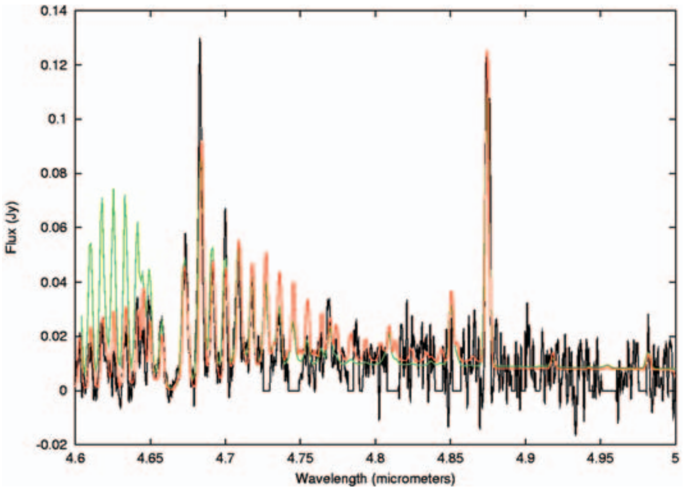

Figure 1: The calibrated spectrum of Uranus (black line). Red line: best-fit model, including CO fluorescence, H_3^+ emission and tropospheric emission. Green line: three-component model with CO fluorescence replaced by CO thermal emission at 150 K, normalised at 4.71 µm.

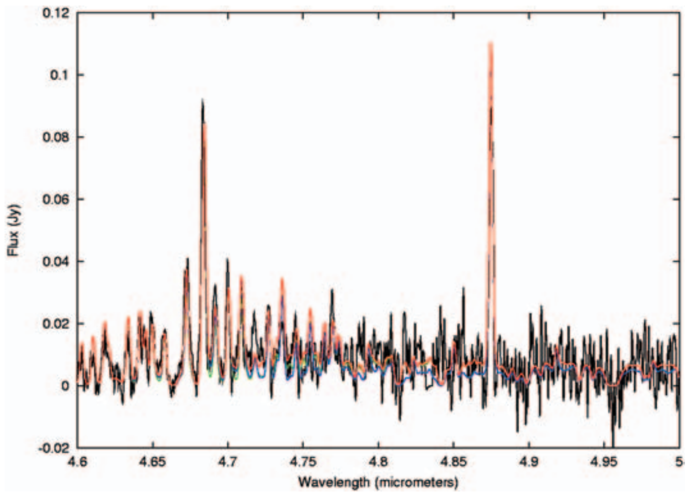

Figure 2: The raw (undivided) spectrum of Uranus (black line) compared to different synthetic models multiplied by the atmospheric transmission function. Red line: best-fit model (CO = PH_3 = 0). Green line: CO = 2 10^{-8}, PH_3 = 0. Blue line: PH_3 = 1 10^{-6}, CO = 0.

rate is about 100 times smaller than the CH_4-H_2 rate (which is predominant in Jupiter and Saturn's stratosphere, because CH_4 condensation does not take place in these planets, whereas it does in Uranus and Neptune). As shown in Fig. 2, a good fit of the fluorescence emission of CO in Uranus is obtained for a mean constant CO mixing ratio of 3 10^{-8}. We note that the CO fluorescence probably takes place predominantly in the region 0.1–1 bar.

Figure 2 also shows a comparison of the data with various models of the reflected tropospheric component, assuming different mixing ratios of CO and PH_3 in the deep troposphere of Uranus. It can be seen that the best fit is obtained where no CO or PH_3 are present; upper limits are inferred, corresponding respectively to 2 10^{-8} for CO and 10^{-6} for PH_3. For comparison, we note that, in the case of Jupiter and Saturn, the CO mixing ratios inferred from the data are about 1–2 10^{-9}; the measured PH_3 mixing ratios are 6 10^{-7} and 2-6 10^{-6} respectively.

We now have three different constraints to reconcile: (1) The upper limit inferred from the millimeter data implies that the CO mixing ratio is less than 3 10^{-8} in the stratosphere, i.e. above the 100 mbar pressure level; (2) the fluorescence emission of CO analysed in the present study is consistent with a CO mixing ratio of 3 10^{-8} in the 0.1–1 bar pressure range, i.e. in the upper troposphere; (3) from the fit of the tropospheric continuum in our data, we infer that the CO mixing ratio is less than 2 10^{-8} in the lower tropopause, above the 3 bar level.

It should be noted first that there is a large uncertainty (by a factor of about 2) in the CO abundance derived from our fluorescence model, which prevents us from deriving firm conclusions about the CO vertical distribution. However, if the numbers given above were to be confirmed, the only interpretation would be that the CO mixing ratio is not constant throughout the atmosphere of Uranus. This would probably imply that CO is, at least in a large fraction, of external origin. Indeed, if CO were of internal origin, we would expect its mixing ratio to be constant up to the upper stratosphere. As in the case of H_2O, detected in the stratospheres of all giant planets with the ISO satellite (Feuchtgruber et al., 1997), the CO external source could come either from icy satellites or from interplanetary meteorites.

Let us note finally that the upper limits of CO and PH_3 inferred in the deep troposphere of Uranus suggest that, as proposed by Marten et al. (1993), convection might be locally inhibited in the interior of Uranus, leading to the absence of vertical transport and dynamical activity. The origin of this inhibition, probably connected to the absence of internal heat in Uranus, remains to be understood.

References

Baines, K. H. et al., Icarus 114, 328, 1995
Bézard, B. et al., Icarus 159, 95, 2002
Cuby, J.-G. et al., The Messenger 101, 2, 2000
Devillard, C., The Messenger, 87, 1997
Drossart, P. et al., ESA SP-427, 169, 1999
Encrenaz, Th. et al., Plan. Space Sci., 51, 1013, 2003
Encrenaz, Th. et al., Astron. Astrophys. 413, L5, 2004
Feuchtgruber, H. et al., Nature 389, 159, 1997
Marten, A. et al., Astrophys. J. 406, 285, 1993
Rosenqvist, J. et al., Astrophys. J. 392, L99, 1992
Trafton, L. M. et al., Astrophys. J. 405, 761, 1993
Trafton, L. M. et al., Astrophys. J. 524, 59, 1999

Correcting spatial gradients: The case of Wide Field Imager photometry

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We present a method to significantly reduce large-scale photometric variations seriously affecting imaging data from the Wide Field Imager (WFI). The primary source for these gradients is non-uniform illumination, which cannot be corrected by standard flatfielding techniques. Comparison of our observations with well-calibrated multi-colour photometry from the SDSS enabled us to characterize and quantify these variations and finally to model them using a second-order polynomial. Application of the model to our observations and an independent dataset consistently reduced the large-scale gradients and thus provides a generally valid and simple tool for improving WFI photometry.

Any astronomical imaging system is affected by intrinsic and external effects, which limit the quality of the resulting data. In this vein, modern CCDs exhibit, e.g., small-scale variations in quantum efficiency. However, such intrinsic shortcomings are generally corrected during the flatfielding process. Yet several large-scale effects may vary with time and pointing and are more difficult to treat. For instance, stray light can hardly be avoided in complex optical instruments, leading to a non-uniform illumination of both flatfield and science exposures.

ESO's Wide Field Imager (WFI) has repeatedly been reported to exhibit significant large-scale spatial gradients in photometry across each of its eight individual CCD chips and particularly over the entire mosaic's field of view (e.g., Manfroid et al. 2001).

An assessment of presence and magnitude of such variations requires the comparison of a well-sampled observational dataset against a photometrically calibrated standard sample. Since the general method of taking exposures of a small number of standard stars (e.g., Landolt fields) on each of the single CCDs is rather time consuming, it is much more efficient to calibrate observational data against well-defined datasets with comparable or even larger spatial coverage.

For the purpose of the present work, we benefited from the fact that all of our observed fields coincide with the area surveyed by the Sloan Digital Sky Survey (SDSS, Stoughton et al. 2002, Abazajian et al. 2003). The high accuracy and homogeneity of the multi-colour photometry from the SDSS and its general availability enabled us for the first time to directly calibrate WFI photometry against a dense grid of local quasi-standard stars and thus to thoroughly correct the emerging large-scale gradients on the science frames. For a detailed technical description of our method the reader is referred to Koch et al. (2004).

Primary data

In an imaging run in May 2001 we used the WFI to target three different fields in and around the globular cluster Palomar 5. These data aim at analyzing the luminosity function in the cluster and its tidal tails (Odenkirchen et al. 2001, 2003) and are subject to a subsequent paper (Koch et al. in prep., Koch 2003). For the purpose of this instrumental note, the exact location of the fields is irrelevant, as long as there is an overlap with the SDSS and the regions are not exceedingly highly crowded.

Observations were carried out both in the V and R filter, where each field was exposed five times (900s for the V-, 600s in the case of the R-band). Single exposures were dithered against each other to cover the gaps between adjacent CCD chips. The observations were performed under good conditions, with the seeing ranging from 0.7″ to 1.1″, and an average airmass of 1.2.

For a description of the standard reduction steps we refer the reader to Koch et al. (2004); for the time being it should suffice to say that all steps were carried out for each of the CCD chips separately. For our case of twilight flatfield corrections this means that a mean value for each chip was determined to normalize the flatfield to unity, hence preserving the gain differences between individual CCDs. Finally, aperture photometry was carried out using DoPHOT.

Photometric gradients

Since the observed fields in Palomar 5 coincide with the equatorial stripe of the SDSS, we matched the stars on each single WFI exposure by position against the SDSS database. Constraining the magnitude range to 16.3 mag $< r <$ 21.7 mag[1] in order to avoid saturated objects and larger photometric errors, this procedure yielded approximately 200 common objects per CCD chip, filter and field.

In the next step, linear transformations of the kind $R = R(r,g,i)$ and $V = V(g,r)$ were used to compare our instrumental WFI magnitudes V and R to the quasi-standard photometric *ugriz*-system of the SDSS.

The residuals e of the transformation for the case of the R-filter are shown in Figure 1 (top left) versus vertical position on the CCD. In this plot the distribution of residuals is not flat across the camera or on the CCDs, but instead the gaps and parabolic gradients appear distinctly. The overall

[1]Lowercase letters denote SDSS magnitudes (Smith et al. 2002)

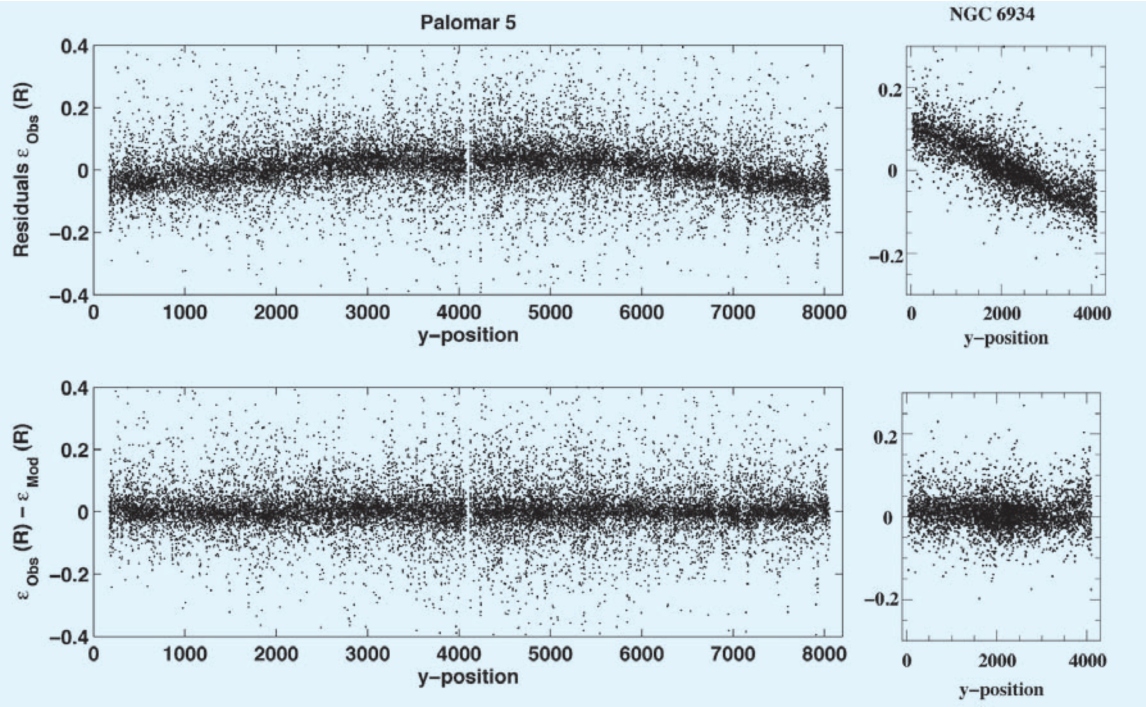


Figure 1: Top left panel: Residuals ε (in mag) of the transformation between WFI and SDSS magnitudes for the case of the *R*-filter. The coordinate system is such that the origin is at the bottom left corner of the camera, the axes (in pixels) increasing from bottom to top (y) and left to right (x). The bottom right panel shows the residuals after the calibration model (eq. 1) was subtracted. The right panels display similar results for independent data for the globular cluster NGC 6934.

observational scatter of these residuals is approximately 0.08 mag on each chip and the zeropoint differences reach values of 0.19 mag. Likewise there is a similarly strong variation with x-position and also for the *V*-filter.

A model for the gradients

The output data from all exposures on each chip were now combined to build an extensive dataset with excellent spatial sampling. Thus the number of stars to be used in the subsequent analysis amounts to ca. 2200 per CCD, or 17754 for the whole camera mosaic.

Judging from the shape of the curves in Fig. 1, a low-order polynomial appears to be suited to model the variation of residuals with position (x,y) on each CCD. Hence we performed a weighted least squares fit of a function

$$\varepsilon(x,y) = Ax^2 + By^2 + Cxy + Dx + Ey + F \quad (1)$$

to the observed residuals.

The actual values for the model coefficients *A*-*F* can be found at http://www.astro.unibas.ch/~koch/#WFI and also in Koch et al. (2004).

To estimate the pure global properties of the overall variations, we then removed the intensity level offsets that were introduced by the individual flatfielding of each chip. This was achieved by calculating a mean value of the residuals and adjusting it to fit each adjacent CCD. These additive additional zeropoints are of the same order of magnitude as the fit constants *F* in eq. (1).

Figure 2 displays contour maps of the final offset-corrected model map according to eq. (1). The resulting photometric variations reach peak-to-valley amplitudes of 0.19 mag both in *V* and *R*.

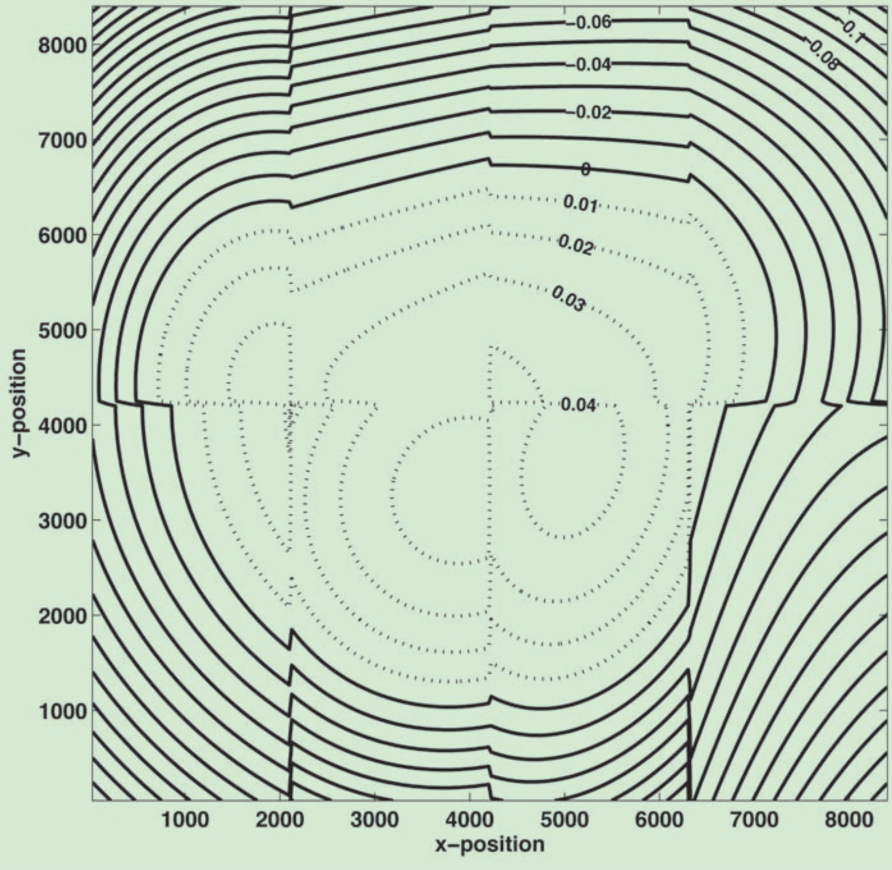
Apart from the overall similar appearance of the maps for the *V* and *R* filters, we point out that the *V*-band residuals show a more central concentration than those on the *R* map. An additional difference is the salient feature on the two leftmost CCDs in the case of the *V* map: there is a band of higher brightness along the vertical axis. This well-known problem arises from stray light due to bright stars that are reflected from the tracker CCD (located left of the camera) onto the science mosaic.

In the final step, the model correction terms were subtracted from the observed residuals. The resulting post-fit residuals are plotted in the bottom left panel of Fig. 1. As an essential outcome, there is a considerable flattening of the large-scale structure, suggesting that our correction method is a successful tool for significantly reducing gradients. Moreover, after the subtraction, the overall scatter was reduced to 0.06 mag. One should note that the *V*-correction, though not shown here, shows similarly good results in terms of reduced scatter and gradients (cf. Koch et al. 2004). Yet there are still some slight variations remaining, in particular at the very edges, where our model was extrapolated instead of being determined in the fit.

Independent test by complementary data

In order to ensure that our correction coefficients are not limited to correcting only our own data, from which they were calculated, but also are suited to calibrate datasets from different runs, we applied it to photometric data of the globular cluster NGC 6934. These observations were obtained at La Silla in September 2000, also both in *V* and *R*. Contrary to the processing of our Pal 5 data, the flatfielding here was performed on the entire camera simultaneously, thus normalizing all CCDs of the entire mosaic to a common gain. This way, initial zeropoint offsets between single chips are removed when dividing by the flatfield.

The photometric gradients from this analysis are shown in the right panel of Fig. 2: The upper right plot displays the difference of stars measured on the lower CCD panel (chips #54 to #57) and those of the same stars located on the upper CCD panel (#50 to #53) of an exposure dithered by one chip size in y-direction (~16′). Also in this case there is a strong spatial dependence of the photometry to be seen. After subtraction of our calibration terms both the overall scatter and gradients were visibly reduced (bottom right panel of Fig. 2). Here, the r.m.s.



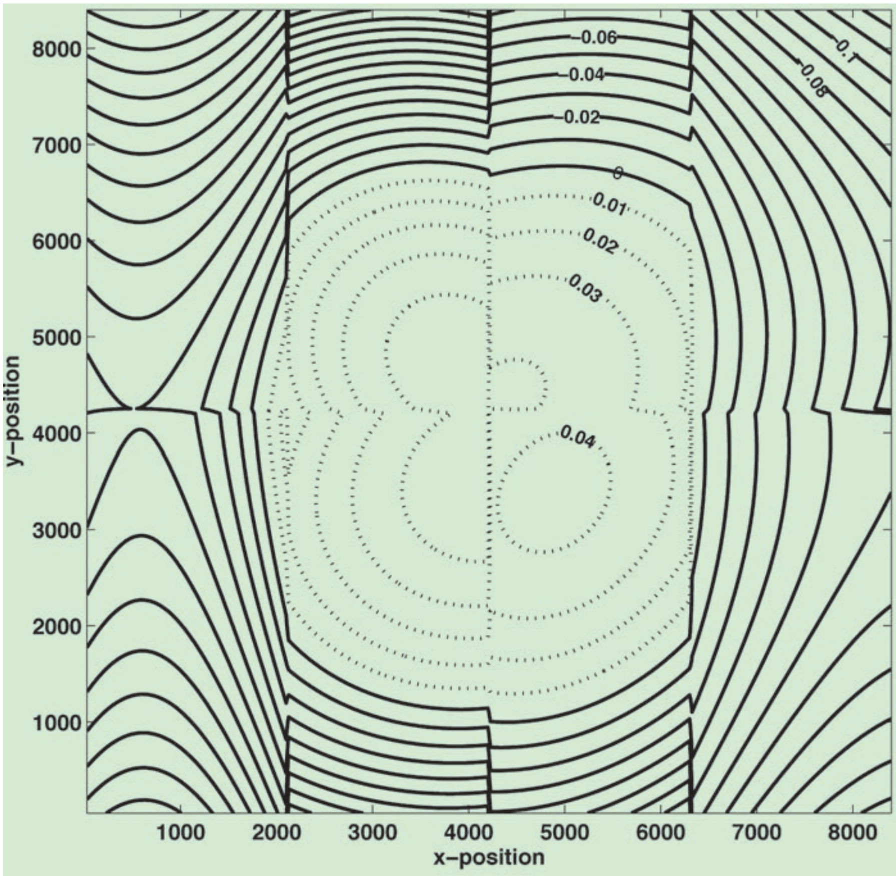


Figure 2: Best-fit second-order calibration map after removal of the mean offsets that arose from different flatfield scale factors. The map for the R-band is on the left, the right panel shows the correction map for the V filter. Contours are separated by 0.01 mag. Near the centre of the camera, stars are measured fainter than near the edge.

scatter diminished from 0.07 mag to 0.04 mag.

Benefits and caveats of the model

Previous attempts have been made to calibrate WFI photometry, each pursuing different methods. Among these are the use of superflats, the construction of calibration maps via exposures that are shifted with respect to each other, or determining the calibration by means of "standard" stars (Landolt, Stetson or others) observed on each of the CCD chips. All these methods have their individual advantages and disadvantages. The most common drawbacks are, however, that the number of standard stars is generally small and/or the required number of exposures is large, making these calibration methods rather time consuming.

Considering the entirely separate observations and reductions of the NGC 6934 dataset, it is encouraging that our devised method yields such a good result in terms of strongly reduced gradients. This is a reliable indication that it can be generally applied to other WFI datasets to correct for these common large-scale variations. One should note, however, that it can only be considered as generally valid if there is no significant change in the optical setup of the telescope. In this vein, the coefficients cannot, e.g., correct data from the last quarter of 2002, where a major baffle re-engineering was performed at the 2.2 m telescope.

Yet, we encourage WFI users to apply our coefficients to their respective datasets, or, in turn, benefit from excellent databases provided by the publicly available multicolour driftscan surveys like the SDSS to pursue similar calibrations to correct large-scale illumination effects.

References

Abazajian, K., et al. 2003, AJ, 126, 2081
Koch, A. 2003, Diploma Thesis, University of Heidelberg
Koch, A., Grebel, E.K., Odenkirchen, M., & Caldwell, J.A.R. 2004, AN, 325, DOI 10.1002/asna.200310176, astro-ph/0310301
Manfroid, J., Selman, F., & Jones, H. 2001, The Messenger, 104,16
Odenkirchen, M. et al. 2001, ApJ, 548, L165
Odenkirchen, M. et al. 2003, AJ, 126, 2385
Smith, J.A., et al. 2002, AJ, 123, 2121
Stoughton, C., et al. 2002, AJ, 123, 485

The Users' Committee

Hans Van Winckel, Chairperson of the UC

Unlike other committees of ESO, the Users' Committee (UC) acts as a direct link between the 'general users at large' and the ESO officials and focuses on the broad range of interactions of the current users with the ESO observatories. The aim of the committee is to streamline the requests from the users and advise the Director General and the ESO staff, with the goal of making the whole process from Phase I proposal writing up to reduction of the data as efficient and transparent as possible. Clearly, input from as many users as possible (read: all users) is needed to get a census on the legitimate needs of the community and in this article several ways to do so are restressed.

The UC and the general user.

In recent years, the ESO observatories and user interaction with ESO has changed considerably. The most dramatic change for the general user is no doubt the success of the service observing possibilities. The original goal to reach an even share between visitor and service mode observations turned out to be untenable and today more than 70 percent of the requested time is in service mode. With the global standardisation and the full paranalisation and lasillalisation of the instruments, the streamlined rigid data gathering procedures work and offer the user, even in service, very efficient tools for their observing strategies. The Users' Support Group (USG) and the Data Management Division (DMD) are now the main interaction channels for many of the users, more than the staff of the observatories. Overall, both observatories, Paranal and La Silla, receive good to excellent satisfaction rates by the users, while individual instruments may score less well. The role of the UC as an interplay between the users and the ESO staff to further improve the ESO services was outlined by Lutz Wisotzki in the Messenger nr. 106, 2001, p46 and will not be repeated here.

The evaluation of ESO's telescope and instrument performances by the user is monitored on a daily basis by night reports (for visitors); on a run-basis by end-of-mission reports (visitors) and finally yearly by the UC meeting. It is in this UC meeting that a series of action items (AI) and recommendations are formulated which are filtered from the general users' requests. Most of these AI and recommendations materialise in concrete results by the next UC meeting, illustrating that the users' requests have significant weight to trigger reaction.

UC spring meeting

During this yearly spring meeting, the UC handles a full agenda : short briefings on the instrument-telescope performances and the proposal handling process; presenting problem reports from the users ; discussing new reports on the future of ESO that became available (like the report of the LaSilla 2006+ working group) and a half-a-day focus on a special topic, related to the use of ESO's facilities, and which is covered in much more detail. To increase communication with the user we post the minutes, with the list of AI's and recommendations, on the web a few weeks after the meeting on the page http://www.hq.eso.org/gen-fac/commit/. Also the national delegates will personally contact the user to give feedback on any specific item she/he raised. One can see that quite a few of last years' meetings have resulted in concrete actions already. To name but a few: simpler proposal phase I submission; test account to check the Phase I proposals through the ESO system; release of part of the EIS pipeline; and certainly: no late communication of the proposal OPC results. Other AI or recommendations take longer and are repeated (for example, the decision on the implementation of the recommendations of the LaSilla2006+ report or the updates of all web-pages and cleaning of redundant old links). Although the yearly spring meeting is the most prominent UC business, this does not need to be exclusively so. You can contact your national delegate the whole year round and a good moment may even be just after your run (if in visitor mode), or during the reduction process, when the real quality of your data becomes clear. The latter is certainly the case for service mode observers. At the request of the UC, ESO organised also a poll of visitor mode observers which was presented by Fernando Commeron et al., 2003, *The Messenger* 113, p. 32. The questionnaire is still available to service mode observers and should be submitted by them (http://www.hq.eso.org/dmd/usg/survey/sm_questionnaire.html).

Feedback request

The way to express needs and/or remarks are certainly not fully exploited by the users and only about 50% of the visitors fill in their end-of-mission reports, while the service questionnaire triggered a 1/6 reply rate. Clearly this should increase. By the time this *Messenger* is published, the preparation of the yearly UC spring meeting will be in full swing. The national representative of the UC (see Table 1) will come to you soon with a plea to answer, not only a list of specific questions on your experience with ESO's observatories, but also with a request to express yourself in whatever you feel is necessary to streamline the process from proposal to publication. It is obvious that the delegates can only call themselves 'representative' on any subject if a fair response in generated. Only then can the UC play its full role.

Table 1: The national members of the Users' committee

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The national mandate is 4 years, updates can be found on
http://www.hq.eso.org/gen-fac/commit/uc/

Report on the ESO Workshop on

Large Programmes and Surveys

Stefan Wagner (Landessternwarte Heidelberg)
and Bruno Leibundgut (ESO)

During the 1980s ESO introduced "Key Programmes" to make best use of the observational resources. A first assessment of the success of the Key Programmes was done in 1993 and came to the result that the concept had severe shortcomings (cf. *Messenger* article by Cesarsky and Kudritzki 1994, Messenger 75, 45). In particular, a large fraction of the available observing time was committed to these Key Programmes and they were severely limiting the access to ESO telescopes for general users. In addition, the scientific impact of these Key Programmes was not very high. To avoid this mistake for the VLT a working group of community astronomers was formed in 1996 to discuss ways of achieving the best possible scientific return of the VLT. The report suggested introducing "Large Programmes" for projects which would require substantial observing time (more than either 100 hours or 10 nights) for a well-focused scientific goal. The duration of these Large Programmes was limited to no more than two years (four semesters). Up to 30% of the total time available for the community could be committed to Large Programmes. Subsequently it was requested that progress reports be presented to the OPC in each semester. The working group also suggested that "at about the time of the start of operations of UT3 the definition of the Large Programmes and its implementation should be reconsidered." With one telescope entering into operation per year it turned out that this review would be based on more experience by extending the timeline foreseen initially. In 2002 sufficiently many Large Programmes had ended and it was time to assess the impact the Large Programmes have had.

Between the start of VLT operations in 1999 (P63) and 2003 (P71) 47 Large Programmes were approved by the OPC for Paranal and La Silla telescopes. They cover almost all current astronomical topics from the Solar System to the exploration of the cosmological parameters. A list of all approved programmes is given in Table 1. ESO and the OPC thought that a workshop with the Principal Investigators (PIs) of the Large Programmes would be the best way to assess their impact.

Workshop

During three days, May 19 to 21, 2003, about 70 astronomers gathered in Garching for an assessment of the scientific impact of Large Programmes and to discuss planning for future surveys at ESO. Several members of the OPC and STC actively participated in the workshop.

Every PI of a Large Programme (LP) approved up to ESO Period 69 was invited to present the results of their project. All LPs but one were presented in half-hour talks. A two-hour discussion session was held to assess whether the current scheme of LPs is adequate or should be adjusted.

We experienced very good presentations with a range of very interesting results. After all, these Large Programmes were supposed to be amongst the most exciting current projects. Not all programmes had finished taking data at the time of the workshop, but it was possible nevertheless to get a good overview. The first day of the workshop was devoted to extragalactic topics. The progress on faint, distant galaxies has been truly remarkable. We heard reports about the enhanced clustering of EROs, indications of a new population of distant galaxies that may contain nearly half of the mass at these redshift, the evolution of the interstellar medium and the characterizations of galaxy clusters. The latter are important laboratories for the comparison of observations with theory. Although there was only one presentation on distant supernovae, it can be seen from Table 1 that there are at least three Large Programmes dealing with this topic. The day ended with objects closer to home: a study of dwarf elliptical galaxies and the mapping of gas in the Magellanic Clouds.

The second day was dominated by Large Programmes dealing with stellar astrophysics and solar system objects. Two programmes to study the distribution and nature of Trans-Neptunian Objects have been carried out at ESO. The companions of stars, be they planets, brown dwarfs or other stars have been the focus of a few Large Programmes. While planets have not been found yet, the projects provide important constraints on the formation scenarios of stars and their companions. Stars do not form in isolation and in the formation process change their environment as well. Astrochemistry is a powerful tool to assess the conditions around stars and infer how they formed and what is happening in the process. Two Large Programmes concentrated on the chemical abundances of stars. In one case, stars in globular clusters were investigated to improve their placement in the HR diagram and hence provide better distances, which then constrain the cluster ages and give lower limits to the dynamical age of the universe. The first stars formed are still around and can be observed as metal-poor inhabitants of the Milky Way. While Gamma-Ray Bursts and Supernovae have not been observed in our Galaxy (at least during the existence of ESO), they have stellar progenitors. One Large Programme has been devoted to each problem. The characterisation of the GRBs themselves and their host galaxies is providing more and more clues to the nature of these explosions. A search for progenitor systems of Type Ia Supernovae among the known white dwarfs has been conducted at the VLT and yielded some tentative results. Before the discussion session Jacques Breysacher gave an assessment of the scheduling impact Large Programmes have had.

The general impression was that most LPs have produced excellent results and unique science, which would have been unachievable through regular programmes. They allowed European astronomers to compete directly with the best groups worldwide, some of whom profit from significant access to large telescopes operated by private institutions. A small number of LPs clearly suffered from insufficient manpower to reduce and analyse the data quickly. LPs operated by well-organised teams with a mix of project leaders and young students and postdocs fared very well. In several cases, European expert teams have formed for LP proposals. The LPs have had the effect of unifying the community in certain astronomical fields. In a few cases LPs have been the inspiration or motivation for successful European research networks, several of which have been funded through EU programmes.

The effectiveness of the restriction of LPs to two years duration was recognised as a useful incentive to produce important results quickly, one major reason to originally introduce the LPs. Some discussion about the number of approved LPs took place but no case was made for either decreasing or increasing the 30% limit. It was re-confirmed that LPs should only be approved when they represent excellent projects. To make sure that LPs are compared to the regular programmes, it was suggested that the OPC should consider comments from both subpanels of their respective proposal category.

It was also suggested that ESO should capture the return of the LPs in the form of

Large Programmes at ESO

Prog ID	PI	Title
163.O-0333	Arnaboldi	A deep and shallow U imaging survey: preparation to the VIRMOS Deep Redshift Survey
163.H-0285	Maza	Optical and Infrared Observations of Supernovae
164.O-0089	Arnaboldi	A deep and shallow U imaging survey: preparation to the VIRMOS Deep Redshift Survey
164.H-0376	Maza	Optical and Infrared Observations of Supernovae
164.O-0560	Cimatti	A stringent test on the formation of early type and massive galaxies
164.L-0310	Forveille	Companions to nearby M dwarfs: Planets, Brown Dwarfs and Stars
164.O-0612	Franx	Formation and Evolution of Galaxies from Ultra-Deep ISAAC Imaging: A Public Survey
164.O-0561	Krautter	Public Imaging Survey
164.I-0605	van Dishoeck	Origin and Evolution of Ices in Star-Forming Regions
165.H-0464	van den Heuvel	The Physics of Gamma-Ray Bursts (GRBs) and the Nature of their Hosts
165.L-0263	Gratton	Distances, Ages and Metal Abundances in Globular Cluster Dwarfs
165.N-0115	Dejonghe	The internal dynamics of Fornax and NGC 5044-group dwarf ellipticals (dEs)
165.N-0276	Cayrel	Galaxy Formation, Early Nucleosynthesis and the First Stars
165.S-0187	Hainaut	Very distant TNOs: the Missing Mass of the Solar System
165.I-0402	Rubio	Deep CO(2-1) observations of molecular regions in the Magellanic Clouds
165.H-0588	Napiwotzki	Are White Dwarf Binaries the Progenitors of Type Ia Supernovae
166.A-0106	Bergeron	The Cosmic Evolution of the Intergalactic Medium
166.A-0162	White	The ESO Distant Cluster Survey: Evolution in Clusters since z~1
166.A-0701	Rosati	The Galaxy Population of the most distant Massive Clusters and their Internal Dynamics
167.D-0173	Gratton	Distances, Ages and Metal Abundances in Globular Cluster Dwarfs
167.C-0340	Boehnhardt	Physical Properties of the Most Pristine Solar System Bodies: Transneptunian Objects and Centaurs
167.D-0407	Napiwotzki	Are White Dwarf Binaries the Progenitors of Type Ia Supernovae
167.A-0409	Miley	Tracing the Formation and Evolution of Clusters and their Central Massive Galaxies to z>4
167.A-0492	Fransson	Supernovae at high redshift
168.A-0322	Franceschini	An ESO-SIRTF Wide-Area Imaging Survey (ESIS), Targeting the History of Cosmic Transformation of Baryons in Stars and Active Nuclei
168.A-0485	Cesarsky	The Great Obseratories Origins Deep Survey: ESO Public Observations of the SIRTF Legacy/Chandra Deep Field South
169.A-0382	Lidman	Distant Type Ia SNe and Cosmology: Constraining the Nature of the Dark Energy and Assessing the Importance of Dust and Evolution
169.A-0458	Franx	Galaxy Mass-to-Light Ratios at z>1 from the Fundamental Plane: Measuring the Star Formation Epoch and Mass Evolution of Galaxies
169.D-0473	Gratton	Distances, Ages and Metal Abundances in Globular Cluster Dwarfs
169.C-0510	Beaulieu	PLANET II: A Simultaneous Search for Microlensing and Transiting Planets using a Worldwide Network
169.A-0595	Boehringer	In-depth XMM-VLT Study of Cosmic Structure and Evolution with Massive Clusters and Groups of Galaxies
169.A-0725	Krautter	Public Imaging Survey
170.A-0143	Cimatti	The nature and evolution of infrared galaxies: bridging optical and SIRTF-SWIRE data with
170.A-0519	Leibundgut	The Ω project: measuring the equation of state of the universe
170.A-0788	Cesarsky	The great observatories origins deep survey: ESO public observations of the SIRTF Legacy/HST
170.A-0789	Krautter	Public Imaging Survey: WFI follow-up of XMM-Newton Serendipituous fields
170.A-0790	Krautter	Public Imaging Survey - GALEX and SIRTF coverage and completion of the Deep Survey
170.D-0010	Christlieb	Nucleo-chronometric age dating of the oldest stars in the galaxy and the nature of the r-process
171.A-0486	Pain	Measuring the Cosmic Equation of State and the Star Formation Rate: spectroscopic identification of supernovae in the CFHT Legacy Survey
171.A-3045	Cesarsky	The great observatories origins deep survey: ESO public observations of the SIRTF Legacy / HST Treasury / Chandra Deep Field South
171.A-3054	Giallongo	An ultra deep IFU sepctroscopic coverage of the Hubble Deep Field South
171.B-0442	Tacconi	The dynamics and evolution of galaxy mergers: properties of the 1 Jy ULIRG sample
171.B-0520	Gilmore	Towards the temperature of cold dark matter: quantitative stellar kinematics in dSph galaxies
171.B-0588	Tolstoy	Dwarf galaxies: remnants of galaxy formation and corner stones for understanding galaxy evolution
171.D-0004	Gieren	The Araucaria Project: improving the distance scale with stellar distance indicators in nearby galaxies
171.D-0237	Smartt	The FLAMES survey of massive stars in the Magellanic clouds

reduced data and other data products. ESO should explore the capabilities of its archive to maintain the legacy data produced by LPs. When submitting, the proposer should indicate what data products they expect to deliver within which time frame. It was also suggested that a stronger PR effort should accompany successful Large Programmes.

Currently, LPs have to report to the OPC about their progress at each call for proposals. Effectively, a LP can be judged no sooner than about one year after approval. A final report listing the achievements, including publication list, should be implemented.

Overall the LPs are considered a success and should be continued. They provide European astronomers with a chance to achieve important results in a competitive and timely fashion.

Public Surveys

On the last day the Workshop focused on Public Surveys. The subject was introduced by a series of presentations on survey-related Large Programmes, past and current public surveys, EIS survey infrastructure, other major surveys worldwide, plans for the UKIDSS surveys, VST/OmegaCam and VISTA.

Surveys provide large, homogeneous data sets covering a variety of combinations in the parameter space of multiband, depth and area. Often surveys span longer times and a broader scope than LPs. Out of their database, large uniformly treated products can be generated, which can be used for a variety of scientific purposes.

At ESO, surveys have been handled as LPs in the past years. Some of them have been conceived as Public Surveys, such as the various EIS surveys (e.g. Pre-FLAMES, Deep Public Survey, and the GALEX and XMM follow-up surveys), FIRES and GOODS. Others have been handled as proprietary (or private) surveys, such as the U-band VIRMOS survey and the SWIRE optical follow-up. Many of these surveys are also connected to legacy-type programmes at satellites and other observatories.

Over the past several years the EIS team has developed a Survey System that is now virtually complete and will offer the possibility of processing imaging survey data from a variety of instruments, both optical and infrared.

With VST and VISTA ESO is about to start operation of two survey telescopes in the coming years. Proper planning for the optimal use of these facilities is an urgent need. The UKIDSS surveys will take 1000 nights at the UKIRT telescope over the next seven years and all its products will be public to the ESO community. VISTA will devote 75% of its time to surveys. Both UKIDSS and VISTA will generate a strong demand for complementary data in the optical.

At the end of the workshop a two-hour discussion session focused on the future implementation of surveys at ESO. By and large general agreement emerged on the following issues:

- Surveys will be an important and necessary tool to optimize the science returns of the VLT
- Besides public surveys, there may well be Guaranteed Time Observations and private surveys
- Scientific and scheduling coordination of surveys is essential for a rational and effective use of survey telescopes
- To ensure coordination, surveys should be evaluated as a distinct category with respect to LPs. ESO should establish a proper procedure to ensure such coordination.
- One of the lessons learned from the EIS experience is that stronger involvement of the community in survey production is necessary to ensure the scientific quality of the products and their timely delivery.
- For optimal results to be achieved, effective forms of cooperation between ESO and its community will have to be established.
- For each survey a dedicated team should take the responsibility for survey design and products, while ESO will support the team effort by making available the EIS Survey System through the Visitor Programme.
- Surveys and Virtual Observatory activities should be properly interfaced for mutual benefit.

Surveys will be an important contribution to the science produced with ESO facilities in the forthcoming era of dedicated survey telescopes. New procedures should be followed to ensure timely delivery of high quality survey products for the entire ESO community.

A Report on a Workshop on

Future Large-Scale Projects and Programmes in Astronomy and Astrophysics

Organisation for Economic Co-operation and Development (OECD) - Global Science Forum

Ian Corbett (ESO)

This workshop was proposed by Germany, which invited ESO to act as host, and took place on December 1-3, at the Deutsches Museum (December 1) and at the Ludwig-Maximilians-Universität (December 2, 3). It was attended by government-appointed delegates from fifteen Global Science Forum Member countries and Observers, three non-OECD countries, representatives of ESO, the President of the International Astronomical Union, invited speakers, and the OECD secretariat, and was chaired by Ian Corbett of ESO.

The Munich workshop is the first of two meetings that are being convened under the aegis of the Global Science Forum. The goal of these workshops is to produce a concise policy-level report, intended primarily for agency officials, programme managers and facility managers, containing consensus findings and conclusions. It is intended to give them a long-term overview of the field and of the issues that governments and community may wish to consider. It will not be prescriptive regarding any particular project or programme. The two principal components of the report will be:

1) A strategic perspective on potential future large facilities or projects during the next 10–15 years, based on important scientific goals, and connections to other fields.
2) An enumeration and analysis of trends, issues, and concerns relevant for long-term planning and priority-setting by government officials and scientific organisations, with an emphasis on prospects for international co-ordination and co-operation.

The report may well recommend follow-on activities. A report on the first meeting was presented to the Global Science Forum in February, which enthusiastically welcomed the progress made.

Scientific Presentations

Two public keynote presentations, given by Malcolm Longair and Martin Harwit, took place on the evening of December 1. During the following two days, workshop participants heard eight presentations in two general categories: (1) a broad review of the main scientific challenges in the field of astronomy, focussing on the key unanswered questions and the type of information that is sought by researchers, and (2) a survey of the principal observational and technological advances that are needed, with an emphasis on those areas that offer opportunities for strengthened international co-operation. The presentation materials are available on the Global Science Forum internet site: www.oecd.org/sti/gsf.

The talks were excellent and, following each presentation and during a longer discussion period at the end of the workshop, participants debated a wide range of issues. A consensus emerged on the broad scientific perspectives and generic issues of relevance to governments. Delegates very much regretted that the major space agencies, in particular ESA and NASA, were unable to present their perspectives, although the Workshop was very clear in stating the complementarities of ground and space and the value of co-operation and consultation between the agencies.

1) The general subject areas enumerated below will now be discussed further at the second and final workshop that will be held on April 5 and 6, 2004 in Washington, DC.
2) A Global Strategic Vision for Astronomy and Astrophysics.
3) Key Areas for Investment (including education and training).
4) Generic policy issues for large collaborative projects.
5) Management and sharing of astronomical data.
6) Evaluation and protection of sites for present and future large facilities.

Small working groups are now preparing draft material for Washington in each of these areas (ESO people are involved in several of them) so that there can be a more focussed discussion which leads to consensus agreement on the framework and contents of the report. This will be written after Washington and presented to the Global Science Forum at their meeting in late June. It will be a public document, available on the OECD GSF web site and widely distributed to governments and agencies.

Finland to Join ESO

Finland will become the eleventh member state of the European Southern Observatory. In a ceremony at the ESO Headquarters in Garching on 9 February 2004, an Agreement to this effect was signed by the Finnish Minister of Education and Science, Ms. Tuula Haatainen and the ESO Director General, Dr. Catherine Cesarsky, in the presence of other high officials from Finland and the ESO member states.

Signing of the Finland-ESO Agreement on February 9, 2004, at ESO Headquarters in Garching. At the table, the ESO Director General, Dr. Catherine Cesarsky (left), and the Finnish Minister of Education and Science, Ms. Tuula Haatainen (right).

Following subsequent ratification by the Finnish Parliament of the ESO Convention and the associated protocols, it is foreseen that Finland will formally join ESO on July 1, 2004.

The Finnish Minister of Education and Science, Ms. Tuula Haatainen, began her speech with these words: “On behalf of Finland, I am happy and proud that we are now joining the European Southern Observatory, one of the most successful megaprojects of European science. ESO is an excellent example of the potential of European cooperation in science, and along with the ALMA project, more and more of global cooperation as well.”

She also mentioned that besides science ESO offers many technological challenges and opportunities. And she added: “In Finland we will try to promote also technological and industrial cooperation with ESO, and we hope that the ESO side will help us to create good working relations. I am confident that Finland’s membership in ESO will be beneficial to both sides.”

Dr. Catherine Cesarsky, ESO Director General, warmly welcomed the Finnish intention to join ESO. “With the accession of their country to ESO, Finnish astronomers, renowned for their expertise in many frontline areas, will have new, exciting opportunities for working on research programmes at the frontiers of modern astrophysics.”

“This is indeed the right time to join ESO”, she added. “The four 8.2-m VLT Unit Telescopes with their many first-class instruments are working with unsurpassed efficiency at Paranal, probing the near and distant Universe and providing European astronomers with a goldmine of unique astronomical data. The implementation of the VLT Interferometer is progressing well and last year we entered into the construction phase of the intercontinental millimetre- and submillimetre-band Atacama Large Millimeter Array. And the continued design studies for gigantic optical/infrared telescopes like OWL are progressing fast. Wonderful horizons are indeed opening for the coming generations of European astronomers!”

She was seconded by the President of the ESO Council, Professor Piet van der Kruit, “This is a most important step in the continuing evolution of ESO. By having Finland become a member of ESO, we welcome a country that has put in place a highly efficient and competitive innovation system with one of the fastest growths of research investment in the EU area. I have no doubt that the Finnish astronomers will not only make the best scientific use of ESO facilities but that they will also greatly contribute through their high quality R&D to technological developments which will benefit the whole ESO community. “

(ESO Press Release 02/04)

Report on the first Advanced Chilean School on Astrophysics

"Extrasolar Planets and Brown Dwarfs"

Danielle Alloin (ESO) and Dante Minniti (PUC)

Organized by D.Minniti (PUC), D.Alloin (ESO), MT.Ruiz (UChile), G.Pietrzynski (UConcepcion), and sponsored by the FONDAP Center for Astrophysics, European Southern Observatory, Princeton/ Catolica Universities, Fundacion Andes, SOCHIAS, and NRAO, the goal of this series of Schools (http://www.astro.puc.cl/ ~school/) is to train the young generation of astronomers on different topics. The School format has been chosen in order to allow a deep approach of the selected themes, as well as to maximize exchanges between the invited lecturers and the attendees.

For this School on Extrasolar Planets and Brown Dwarfs, held in Santiago on 15-19 December 2003, the four main lecturers were (see photo): Jill Knapp (UPrinceton), Michel Mayor (UGenève), France Allard (ENS Lyon), and Scott Tremaine (UPrinceton).

Since the mid-90s, the field of brown dwarfs and extrasolar planets has bloomed in a spectacular fashion, both on the observational side and on the modeling side. Rather than report on all the advances beautifully presented at the School, let us examine some of the points which remain in the to-do lists shown by the different lecturers.

First of all, we shall stick, for the time being, to the definition adopted by the IAU:

- "star": mass above 80 M_{Jup}, H-burning core
- "brown dwarf": mass between 80 and 13 M_{Jup}, D burning core, large variation of the surface temperature from an M dwarf (3,000 K), to a T dwarf(< 1,300 K)
- "planet": mass less than 13 M_{Jup}

One notices that this definition is not linked to the object formation scenario.

The number of objects known so far are: about 120 planets (at distances up to 30 pc) and about 400 brown dwarfs (at distances up to 200 pc).

On the front of observing:

- Brown dwarfs: Jill Knapp and other contributors at the School reported that it is a "tough job" to find them (intrinsic luminosity less than $2{\cdot}10^{-6}$ solar luminosity and (*V-K*) ~ 10). Exploiting the all-sky surveys available today, more than one million objects have been searched for: only 60 L dwarfs have been found... Good progress has been made in the M/L/T brown dwarf classification (on the basis of their spectra).

To-do list: increase the sample of brown dwarfs, to test models, make a proper motion survey in the NIR, formation scenario: ascertain the low mass end of the stellar IMF, the relation planets = brown dwarfs?

- Extrasolar planets: Michel Mayor and other contributors reported that it is as well a "tough job" to find planets (light contrast star/planet around 10^{10}, request for 1 m/s velocity precision). Radial velocity searches have so far provided all known planets (~120), except for one. About 2000 stars in the solar vicinity are currently monitored (at distances less than 30 pc). Among the 120 known planets, 10 are multiple planet systems.

The use of other methods for planet discovery, such as transit, reflected light, microlensing, etc... is in progress.

To-do list: understand the amazing dependence on the metallicity of the parent star, investigate the brown dwarf desert and investigate its implications on the formation scenarii, increase the sample of known planets up to 10^4, so that statistical properties can be derived with some confidence: at the current rate of planet discovery (about 10/year), this will take 10^3 years!! Can we wait that long?

It was also extremely interesting to hear about intrinsic limitations in planet searches: accoustic modes of the parent stars, spots of the parent stars, and in the case of multiple planet systems, the difficulty in finding a unique solution in the decomposition of the radial velocity curve.

- Of course, a wealth of groundbased and space tools for discovering planets and brown dwarfs were discussed (incomplete list!): HARPS (1m/s precision), optical and NIR interferometry, adaptive optics -in the future multi-conjugate adaptive optics, COROT, KEPLER, ALMA for protoplanetary discs, SIM, GAIA, GEST, OWL and ELTs in general.

On the front of modeling:

- The atmospheres of brown dwarfs were extensively discussed by France Allard. They are rather well understood and modeled (thanks, among other factors, to the tremendous increase in computational power).

To-do list: improve the opacities, consider more realistic dust grains (composition, shape)

- Dynamics, kinematics, formation scenarii: a large panel of fascinating problems were discussed by Scott Tremaine and other contributors at the School..

To-do list (a subset...): elucidate the "mystery" of the planetesimal growth from cm size to km size, understand the physics hidden in the term "viscosity" in protoplanetary discs, understand the "peculiarities" of the Solar system: its ellipticity, the location of Jupiter, the origin of chondrules, formation scenarii: collapse versus coagulation of planetesimals.

- Some other interesting questions concerning the modeling of planetary systems were raised: are closed-box models valid? Given that half the mass of the Solar system is in small bodies, taking into account only massive planets to study the dynamics of planetary systems might be misleading; how to disentangle evolution (such as planet migration) from intrinsic properties?; what is the role of star multiplicity in the formation of planetary systems?; which is the fraction of lost planets?

In conclusion, an enlightening School, which took place in the grounds of the Observatory of Cerro Calan in the heights of Santiago. About 80 attendees (more than half of them from South America) enjoyed the lectures, the discussions in the shadow of the trees, and contributed to the friendly atmosphere. Finally, the School dinner at Casa Piedra allowed everyone to admire a beautiful sunset on the rio Mapocho.

REPORT ON THE INTERNATIONAL WORKSHOP

PHYSICS OF ACTIVE GALACTIC NUCLEI AT ALL SCALES

DANIELLE ALLOIN (ESO),
ON BEHALF OF THE ORGANIZERS

THIS WORKSHOP was held at ESO/Vitacura on December 3-6, 2003, and organised by Danielle Alloin, Poshak Gandhi, Rachel Johnson, Paulina Lira, Sebastian Lopez, Jose Maza, with support from the European Southern Observatory, FONDAP/Conycit, and the Universidad Chile.

The study of the physical processes at work in Active Galactic Nuclei has kept a large number of astronomers busy since the discovery of the first radio galaxies in the sixties... There is now a clear consensus about the source of energy in AGN, namely gravitational energy released through matter accretion onto a massive black-hole. Moreover, tremendous progress has been made in unveiling, analyzing and modeling the different components in AGN: the accretion disc, the jets of relativistic particules, the X-ray absorber very close to the central engine, the so-called "torus" which funnels the ionizing radiation, the surrounding clouds of dense material (in the broad-line region and in the narrow-line region), the jet-induced effects on larger scales, etc...

One of the goals of the Workshop being to train young researchers in the field, we started with a tutorial. As an introduction to the topic, Dr. Hagai Netzer gave a very comprehensive and overall picture of AGN physics. He pointed out that, in spite of today's remarkable insights into the AGN phenomenon, some key questions remain open. One of them is the "energy budget problem", that is the large discrepancy between the energy output required from the observed line emission (under dominant photoionization processes) and that extrapolated from the observed continuum energy distribution. Another key point is related to the detailed understanding of the physical processes hidden in the "alpha" parameter used to parametrize the viscosity of the accretion disc.

Following the tutorial, reviews and discussion about most of the AGN sub-systems were given by specialists in the field. Physical processes in jets were discussed through a multi-wavelength approach by Dr. Diana Worrall. The status of dense material in the form of clouds from the broad-line region and the narrow-line region, was successively reviewed by Dr. Bradley Peterson and Dr. Bob Fosbury. They presented our current knowledge about the structure, size and kinematics of these regions, as well as their links and relationship with other AGN sub-structures. The use of the variability of the central engine to probe material at distance from it (reverberation mapping) was reviewed in an exhaustive manner.

The mere survival and the physical conditions of cold material in the harsh -in terms of radiation- environment of an AGN were discussed by Dr. Jack Gallimore and Dr. Moshe Elitzur, including the dust component, the neutral and the molecular gas. Excitation of the molecular gas and heating of the dust particles are topics which were particularly discussed at the Workshop. The origin and the physical parameters of winds, in the context of AGN, were presented by Dr. Martin Elvis.

Another key question in AGN is that of their fueling mechanism: how is accreted matter carried inwards? Dr. Sharda Jogee discussed the interplay between an AGN and its environment, as well as various mechanisms to transport gas from tens of kiloparsecs to tens of parsecs. The role played by non-axisymmetries and transient nuclear bars was highlighted. The discussion on triggering of AGN at early epochs (redshifts 1 to 3) took us to a very new aspect in AGN studies: their role as cosmological probes.

Indeed, the formation epoch and formation mechanisms of massive black-holes is one of the most interesting problems in today's astrophysics. At which stage in the evolution of the cosmic web did massive black-holes form? The problem can be addressed through the study of AGN populations at different redshifts, their location with respect to large scale structures and the connections between galaxies and massive black-holes. Such new developments in AGN physics were presented in a complementary fashion by two reviewers, Dr. Omar Almaini and Dr. Niel Brandt.

Although it was generally felt that AGN studies had developed so well over the last three decades that a "plateau" in their understanding had been reached, they are again on the stage thanks to two factors: firstly, there is a wealth of new observational constraints (especially in the X-rays and in the IR/mm) to rejuvenate their physical modeling, and secondly, their role as cosmological probes make them of prime interest in the study of the early ages of the Universe.

Finally, two reviews were presented about the outstanding facilities available at observatories based in Chile for studying the physics of AGN, one by Dr. Chris Lidman and the other by Dr. Malcolm Smith.

The Workshop was attended by around 70 researchers, with a strong participation from South America, 53% including Chile. In addition to the reviews, a set of oral contributions and a large number of posters provided some recent and exciting results. The Workshop turned out to have a perfect format and size for boosting discussions and exchanges. The pleasant environment of the ESO grounds in Vitacura/Santiago also played its role in the success of the Workshop. And of course, we shall all remember the closing Chilean "asado" which took place on a sunny afternoon in the peaceful garden of Cerro Calan Observatory.

Pictures taken during the Workshop as well as the presentations made available so far (to be updated as more of them are received), can be found at: http://www.sc.eso.org/santiago/science/sympcl2003.html

A volume in the Springer series Lecture Notes in Physics is in preparation: it will contain the tutorial and the main reviews given at the Workshop.

Report on a Micro-Workshop held at ESO/Vitacura on January 28, 2004

Optical Interferometry Brings New Frontiers in Astrophysics

Christian Hummel and Danielle Alloin

ESO's VLTI is the first interferometer offered to the community of astronomers world-wide in service mode. Taking advantage of the presence of distinguished visiting interferometrists and members of the VLTI team at ESO Vitacura, a one-day micro-workshop was organized to introduce more ESO and Chilean astronomers and students to this observing mode and to make them consider the role the VLTI could play in their research. After introductory talks on interferometry, data reduction, and calibration, some outstanding recent results from VLTI/VINCI and other interferometers were presented, demonstrating impressively how optical interferometry has already contributed to advances in some fields of astrophysics, e.g. in testing stellar evolution theory.

Research possible now or in the near future with existing or soon to be installed instruments on VLTI was highlighted in the field of stellar physics, where the possibilities are numerous, and in the field of AGN research.

The instruments and observation planning tools were described from the point of view of the user, conveying the feeling that those astronomers not specialized in optical interferometry are indeed encouraged to apply for observations with the VLTI.

Finally, the second generation of VLTI instruments was also presented, as well as some new concepts which will make interferometry in the optical and IR even more powerful.

The attendees, between 40 and 50, were astronomers and students from ESO, PUC, UChile, UTarapaca, as well as engineers, technicians, and telescope operators from Paranal.

It was a great pleasure to share the enthusiasm, inspiration, and lively discussion which were present throughout the micro-workshop. We hope this will bring more and more users to the interferometric observing mode and its immense promises.

Many thanks to the speakers, V. Coudé du Foresto, E. Galliano, C. Hummel, P. Kervella, S. Morel, A. Quirrenbach, M. Schoeller, and M. Vannier.

Fellows at ESO

Nicolas Cretton

I came to ESO Garching at the end of 2001, after a first post-doc at the Max-Planck Institute in Heidelberg. I got my physics diploma from Geneva University (Switzerland) before I moved to Leiden (The Netherlands) to work on a PhD project, under the supervision of Profs. Tim de Zeeuw and H.-W. Rix.

My research focuses on the dynamics of galaxies and their dark matter content: central supermassive black holes and large-scale dark halos. Studying unseen components of galaxies is intimately linked to the (dynamical) modelling one applies to the (kinematical) observations. Indeed, an over-simplified model could give the wrong answer regarding the presence of, say, black holes: it would only reveal its own limitations. In that spirit, I have implemented and extended the "orbit" method to model galaxies, originally invented by Martin Schwarzschild. This method makes no *a priori* assumptions about the dynamical structure of the galaxies and is therefore well adapted to the question of dark matter.

Before coming to ESO, my work was almost purely theoretical, although I was modelling real galaxies and not just studying "academic" questions. The pertinence of my models also depends on the quality of the data (spatial and spectral resolution, S/N, extension, etc) so it was natural for me to try to get more expertise in the observational field. In this way, I was hoping to 1) better understand the observations and what they really mean (e.g., can we trust this error bar?) and 2) write better observing time proposals and 3) improve my general astronomy experience to increase my chances of getting a permanent position. Therefore I applied to ESO and fortunately got the job! At ESO, I got involved in the FLAMES group, led by Luca Pasquini. FLAMES is a multi-fibre spectrograph for the VLT which is revolutionizing the measurement of discrete stellar velocities, thanks to its multiplex capabilities, its spectral resolution and the collecting power of the VLT. In addition, it has two integral-field modes, where integrated spectra can be obtained over all the field of view simultaneously. I really enjoyed the atmosphere in Luca's group, mostly due to the personalities of its members and the success of the instrument!

I am now in my last (third) year as an ESO fellow and I can say that I have really enjoyed my time here: ESO is a great place to do and discuss science, not only because of all the in-house expertise, but also because it is located right next to two Max Planck Institutes where astronomy research is also done. At ESO, one really has the feeling of being at the right place, where important things happen, where the latest news is discussed and where tons of talks are given each week and plenty of visitors pass by. Furthermore, Munich is a very nice city, with plenty of nature nearby (lakes, forests, hiking and skiing in the Alps).

Emanuele Daddi

Astronomy entered my life literally by accident. At the age of 15 I broke a leg playing football, and never-ending queues waiting in an Italian public hospital forced me to do plenty of reading. With great excitment I realized from a magazine of popular astronomy that a wealth of incredible wonders are out there in the sky, within the grasp of cheap instrumentation that even my own few savings of grandmothers' tips would suffice to buy. One month later the leg was OK, the grandmothers' tips had gone, and I had started exploring the Universe, with stars (uhm...), galaxies (ehi !), nebulae, planets, comets, etc, with a 14 cm telescope (0.03% of each of the 4 VLTs' collecting area!).

After 15 more years the passion for the Universe has even increased. In fact, I may say that research in astronomy is my favorite hobby, and I find myself very fortunate that it has also become my job. Since December 2001 I have been an ESO fellow in Garching, thus now in the third and final year of the fellowship. Before that I had done university and PhD studies in my home town, Firenze, working at the observatory on the Arcetri hill, where Galileo had been observing at the dawn of modern astronomy.

It was hard to leave the nice Tuscany weather for breezy Garching, but after two years I can say it was worth it. ESO is the best place to be in Europe for those like me who are interested in astronomical observations, as most of the cutting edge European instrumentation and telescopes are planned, built and operated here. It is a great advantage for research competitiveness to be in daily contact with the most experienced people in the field.

As a change from my early beginnings, my main research field is distant, faint galaxies: those that even after hours of VLT integration sometimes show just a barely significant detection. My duties at ESO are well matched to my own research interests as I am working for the GOODS survey which is releasing deep public data to the community. The final goal of these efforts is to understand how galaxies formed through the ages and thus in some sense to go past searching for our cosmic origins. There are so many big open questions and technical and practical challenges (the speed of light is finite and the Universe perhaps is not), that it sounds like we will never finish making new discoveries in these fields, and space for jobs will hopefully always be there for astronomers to enjoy!

Poshak Gandhi

After my very first job interview in 2001 (for the Fellowship), I found it difficult to believe that ESO would want to employ me; or that I would agree to come to Chile, very far from my native India. I'm glad that I was wrong on both counts!

The friendly and stimulating environment of ESO-Chile helped to make the transition from student to post-doctoral fellow easy. The large international staff at the Santiago premises, constant stream of visitors and world-class instrumentation expertise sets the scene for collaborative scientific exchange, always helped along with a glass of excellent Chilean wine.

ESO operations at Cerro Paranal are a good lesson in team-work. Like a restless bees' nest, the united effort of all individuals assures a constant hatching of incredible scientific results. I am a night-astronomer for ISAAC and the FORSs, as well as the web-manager for Science Operations. It is sometimes a challenge to work under the demanding conditions and deliver quality support. But the beautiful vista of the Southern sky on a dark night is deeply refreshing.

I am studying obscured active galactic nuclei – supermassive black holes at the centres of distant galaxies that emit huge amounts of energy (typically rivaling 10 billion Suns), yet do not show obvious signs of this activity because they are surrounded by a thick veil of gas and dust. X-ray telescopes can penetrate this veil, but follow-up work in the optical and near-infrared regimes, with telescopes such as those at ESO, is vital to truly understand these black holes.

I love the Chilean people's friendliness, but often complain about the food. Meanwhile, we're giving good business to the only Indian restaurant here. Perhaps in the distant future, Chile Chicken Korma con Choclo will be a 'traditional' dish on the menu...

Dieter Nürnberger

Originally, I come from Franconia in the northern part of Bavaria, Germany. In my younger days I was often found star gazing there. Later on, for my studies of Physics and Astronomy, I enrolled at the nearby University of Würzburg which is well known due to Röntgen's discovery of X-rays more than one century ago. In fact, when I was searching for a suitable topic for my Diploma thesis, work related to data taken with the X-ray satellite ROSAT would have been very timely. Instead, I ended up studying the gas and dust emission of circumstellar disks and envelopes around low mass pre-main sequence stars.

Although I was officially still affiliated to my home university over the next few years, I left Germany in October 1997 to work on my PhD thesis. I joined the Institut de Radio-Astronomie Millimétrique (IRAM) in Grenoble, France, to learn about radio astronomy in general and millimeter interferometry in particular. During that time I had the pleasure of spending several weeks per year as Astronomer-on-Duty at IRAM's Plateau de Bure interferometer (PdBI). At this remote observatory, located at an altitude of about 2550m in the midst of the French Alps, I had some of the most memorable experiences of my life.

Since the time of my PhD thesis, my own scientific work has been focused on the identification and characterization of intermediate and high mass protostars. For that purpose I am using two independent approaches. The first one deals with high angular resolution studies of protostellar candidates, which I had selected from the IRAS point source catalogue. The planned follow-up PdBI observations of the most promising sources would have been crucial for my thesis but were unfortunately severely affected by two tragic accidents on Plateau de Bure during 1999.

The second approach and my PhD thesis itself deal with a comprehensive multi-wavelength study of the galactic starburst region NGC 3603. The basic idea is to find evidence for ongoing star formation processes which are triggered and/or revealed by energetic photons and strong stellar winds originating from the OB stars of the central star cluster. As this region is only accessible from the southern hemisphere I was visiting Chile once or twice per year to observe with several ESO facilities, like the SEST, the 3.6m and the VLT Antu.

Currently, my curiosity about the formation of high mass stars pushes me towards the feasibility limits of today's telescopes and antennae, including the Australia Telescope Compact Array (ATCA) in Narrabri, Australia, and, of course, ESO's VLT(I) on Paranal, Chile. Thus, in order to keep track of the most recent generation of instruments as well as due to all the positive experiences which I gained at IRAM's PdBI, it was my greatest desire to continue working at one of the state-of-the-art observatories. In August 2002, when I started my ESO fellowship in Santiago with functional work on Paranal my wildest dream became true: here I'm able to live my profession with all my heart, enthusiasm and dedication.

The Venus Transit 2004 (VT-2004) Programme

Richard West and Henri M.J. Boffin (ESO)

Why did Captain Cook travel to Tahiti? How big is the Solar System? How is it possible to detect Earth-sized planets in orbit around other stars? And how is it possible to participate actively, together with many other people on other continents, in an extremely rare celestial event - one that has never been seen before by any person now alive?

These and others are questions that the ambitious "VT-2004" programme tries to answer.

On June 8, 2004, Venus - the Earth's sister planet - will pass in front of the Sun. This event, a 'transit', is extremely rare - the last one occurred in 1882, 122 years ago. Easily observable in Europe, Asia, Africa and Australia, it is likely to attract the attention of millions of people on these continents and, indeed, all over the world.

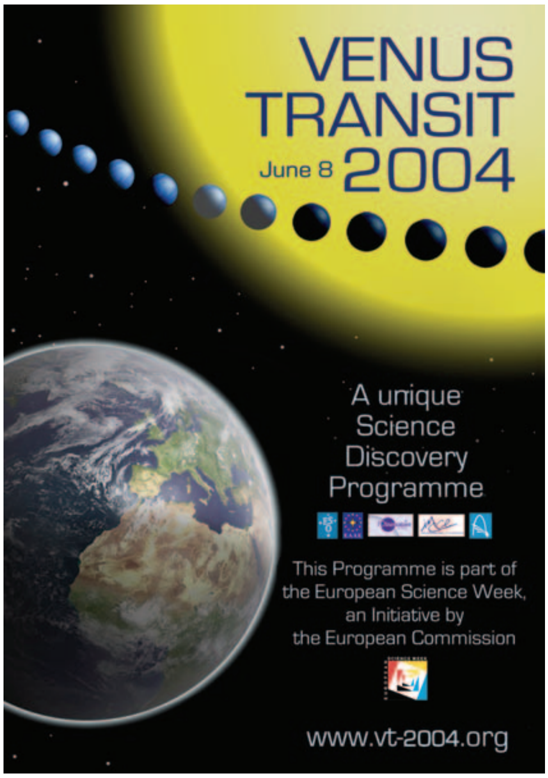
The European Southern Observatory (ESO), in collaboration with the European Association for Astronomy Education (EAAE), the Institut de Mécanique Céleste et de Calcul des Éphémérides (IMCCE) and the Observatoire de Paris in France, as well as the Astronomical Institute of the Academy of Sciences of the Czech Republic has therefore set-up the Venus Transit 2004 (VT-2004) programme with support of the European Commission, within the framework of the European Science and Technology Week.

VT-2004 takes advantage of this extraordinary celestial event to expose the public - in a well-considered, interactive and exciting way - to a number of fundamental issues at the crucial interface between society and basic science.

Main objectives of the VT-2004 programme

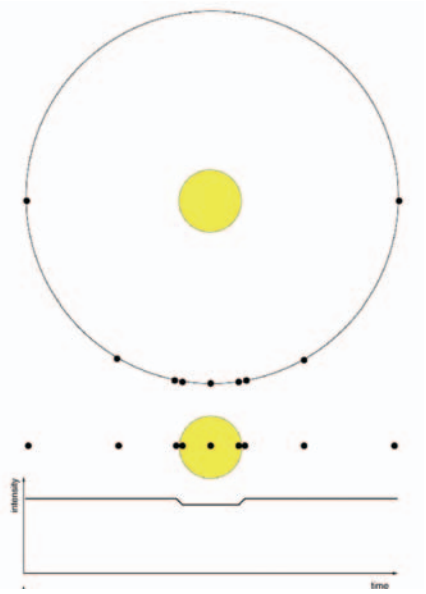
A key intention is to introduce (and "sensitise") the public to various issues of general interest, with the Venus Transit and related issues as a natural starting point:

- **The basis of the measurement of the Universe:** For centuries, it was not possible for humankind to know the distance of the planets, the Sun and the stars from the Earth: all celestial bodies appeared to be located on the same "celestial sphere". The ignorance of these distances or their large uncertainty, led to a wrong appraisal of the distances in the Universe and hence to wrong models for our world. After the modelling of the Solar System by Copernicus, Tycho Brahe, Galileo and Kepler, it was possible to deduce the distances in the Solar System from the knowledge of the distance from the Earth to only one planet. Rare transits of Venus in front of the Sun provided unique opportunities to measure the Earth-Venus distance by observing the event from several different sites in the world. From this, all other distances in the Solar System could then be deduced and, from that, the distances to stars by trigonometry. These measurements were made mainly during the 18th century, often under very dramatic conditions but, also as the forerunners of European scientific collaboration, as fundamental scientific projects. It is the stated goal of the VT-2004 programme to have such measurements remade by today's students, pupils of high schools, amateur astronomers, and interested laypeople, for educational purposes, helping them, through thorough and didactic, yet exciting, preparations of the event, to understand how the Universe was first measured.



- **The uncertainty of scientific measurements:** From the knowledge of the historical aspects of Venus transit observations, the public may appreciate the uncertainties of the different measurements performed at different epochs. Furthermore, the individual action of each participant in the VT-2004 Observing Campaign will allow considerations about the uncertainty of his/her own measurement. Thanks to the individual timing of the different phases of the Venus transit, and the connection to a powerful resource centre, each participant will be able to compare their values with those of other contributors and with the theoretical ones, and thus obtain an appreciation of the personal accuracy achieved and the associated consequences.

- **Extra-solar planet research:** Nowadays, the simple observation of the transit of a planet in front of the Sun will not entail novel and useful scientific observations since radars have replaced such distance measurements, achieving much higher precision (now at the level of one metre!). However, transits of exo-planets in front of stars other than the Sun constitute similar events, difficult to observe, but one of the best current opportunities to detect the presence of small exoplanets around other stars. In fact, the transit method is probably - for the next decade at least - the only method to



Variations in stellar brightness and velocity, caused by an orbiting exoplanet that transits the disk of its central star. Consecutive positions of the planet in its (circular) orbit are marked by black dots, with the motion from left to right.

detect Earth-sized planets around stars other than the Sun. And as such, the transit method may ultimately lead to the discovery of other habitable worlds. The VT-2004 programme introduces this highly exciting topic.

- **Scientific methods and international collaboration:** Simultaneous observations of the same transit event by observers from different locations are required to measure the solar "parallax" (the angle under which one Earth radius is seen from the Sun). It is inversely proportional to the Earth-Sun distance and therefore allows the true value of this fundamental cosmic distance, known as the "Astronomical Unit" to be deduced. In the same manner that the ancient scientific campaigns for the observation of this event enabled the first measures of this distance to be obtained (which, however, were not all equally accurate), the present, wide VT-2004 Observing Campaign is being co-ordinated with new tools, demonstrating how coordination and international collaboration may be a powerful lever in science. A modern approach is proposed, e.g., by using GPS devices for the localisation of the observation sites and by network communications, thereby illustrating the progress from numerous local observations via data pooling towards the determination of a fundamental value.

- **The stellar nature of the Sun**: Participants will need to rehearse their observations before the Venus transit and they will obviously observe the Sun in detail (VT-2004 will ensure that safety issues will figure prominently!). They will discover the very active nature of our central star, with sunspots, flares and prominences appearing and disappearing. This will generate interest in the physical nature of the Sun, to be supported by comprehensive educational material. Another aspect is the way the solar activity affects our daily lives, with natural phenomena such as auroras and the associated impact on satellites and communications. This will also be a fine opportunity to introduce and further develop the theme that the Sun is our nearest star and as such allows us to understand other stars in the Universe.

- **Invite the public to approach the history of sciences:** In spite of the fact that the Venus Transit event is rare, and in the context of our scientific and technological capabilities today is absolutely unique, the historical background is extremely rich. Only a few such events have been observed since the 17th century when the knowledge of the planetary motions became sufficiently good enough to permit the prediction of such events. Johannes Kepler first predicted planetary transits in front of the Sun in the 1620's, and Pierre Gassendi was the first to observe a transit from Paris in 1631. During the 18th and 19th centuries, Venus transits in front of the Sun were a welcome opportunity for European scientists from several countries to join efforts in order to obtain an improved estimate of the fundamental Astronomical Unit. This objective was very important since that one measurement would then allow the astronomers to deduce the size of the entire Solar System (from the observed planetary motions and Kepler's Laws). Halley, Delisle and la Hire, in particular, tried to establish the best methods to predict and observe the first and last contacts of Mercury or Venus with the Solar limb and to get the most accurate value of the Astronomical Unit. The history of Solar System science and therefore the astronomical progress are thus closely related to these historical collaborations, organised to obtain basic data from the observations of these events.

- **Dissemination of information about the structure and movements in the Solar System:** Venus transits are very rare - only four events can be observed every 243 years. The first Venus transit was observed in 1639, the most recent one in 1882. The next will occur in 2012, but it will not be visible from Europe. The Moon and the planet Mercury also present transit events in front of the Sun. The Moon transits cause the well-known solar eclipses. Mercury transits are more frequent than Venus transits; during the 20th century, fourteen Mercury transits occurred. But their observation is very difficult since the apparent diameter of Mercury is only about 1/200th of that of the Sun. The Venus transits are very rare but are easily observable since the apparent diameter of Venus' disk is about 1/30th of that of the Sun. The

The 1882 Transit of Venus as Seen from Chile

This year, on June 8, Venus will pass in front of the solar disc. The complete transit can be seen from Europe. Only 8 years later, on June 5, 2012, another Venus transit will be visible from Chile.

In the past, such transits were of crucial importance in measuring the size of the solar system and led to many expeditions to very remote places. These expeditions have been reported extensively and are even part of modern literature. References to expeditions to observe the 19th century transits are less frequently found in present-day literature than the more crucial and sometimes more tragic 18th century ones, since the results did not actually lead to a major improvement in the value of the astronomical unit.

What is noteworthy however is that the 19th century Venus transits were not only monitored by expeditions from the established astronomical "superpowers" France and England, as was the case in the 18th century, but by a bunch of "newcomers", like Austria, Belgium, Brazil, Denmark, Germany, Italy, Mexico, the Netherlands, Portugal, Russia, and the United States. And when it came to observing the 1882 transit from a good site in the southern hemisphere, Chile turned out to be an excellent choice. Word on this was also spread during an international conference on Venus transits held in Paris in early October, 1881. Among its participants was the former director of the Chilean National Observatory, Carlos Moesta. Astronomers from Belgium, Brazil, France, Germany and the United States spent a few weeks in or near Santiago and in Punta Arenas to observe the transit.

To know more about the various expeditions to Chile to observe the 1882 Venus Transit, read the article by Dr. Hilmar Duerbeck on the vt-2004 web site: http://www.vt-2004.org/Background/Infol2/EIS-F7.html understanding of these events implies detailed and accurate knowledge of orbital dynamics, as these celestial events only occur in particular configurations: when the orbital nodes of the Venus orbit are located near the Sun-Earth axis.

Public participation

The VT-2004 programme is establishing wide international networks of individuals (including school teachers and their students, amateur astronomers, interested laypeople, etc.) and educational institutions (astronomical observatories, planetaria, science centres, etc.). It encourages real-time measurements of one of the most fundamental astronomical parameters, the distance from the Earth to the Sun.

VT-2004 also explains the relation of the Venus transit to a highly visible front-line research area, the search for extra-solar planets. The transit method is the only one, which, in the near future, has the potential to discover Earth-size planets in orbit around other stars and thus, possibly, alien habitable worlds. It promotes web-encounters and international collaboration throughout Europe as well as in Africa and Asia, stimulating observations of this rare celestial event, with debates via the Internet and the opportunity to add local observational contributions to a large, common database.

The VT-2004 programme is centred on the delivery of detailed explanations in most European languages of all aspects (scientific, technical, historical, etc.) of the transit event itself as well as its implications for the search for life. It is based on the active involvement of the media, students and teachers and amateur astronomers in order to spread this information as widely as possible and to ensure the highest return and common benefit.

A video contest with interesting prizes is also being launched in the framework of the VT-2004 programme. Everybody with a video camera and who participates in observations of the transit is invited to produce a short film (not exceeding 8 min) that documents their preparations for the transit and the actual observations, conveying the personal impressions of the event itself and those of being part of the programme. The winners will be selected by a professional jury - and they will be invited to present their videos at the VT-2004 "Final Event", a 2-day meeting in November 2004 in a European capital, with the possibility of winning one of the top prizes. As explained below, this meeting will also host expert dicussions about the many aspects of the unique VT-2004 public educational programme.

The Internet is the main vector of interaction, with a central website now being developed at: www.vt-2004.org. It comprises extensive background information, recommendations for active participation by individuals and groups, and also offers profound insight into the many interesting facets of this celestial phenomenon. There is also a VT-2004 Web Forum, as well as numerous links to organisations (observatories, planetaria, science centres, amateur clubs and associations, etc.) which are members of the wide VT-2004 Network. Educationally oriented organisations that plan activities in connection with the Venus Transit are welcome to join this network - registration details will be found at the corresponding webpages.

The Venus Transit observed in 1874. On this series of rare historical photos, the black disk of Venus is seen at the bottom, near the solar limb (credit: IMCCE).

In order to promote the Venus transit and provide information about the opportunities for participation in the various countries and geographical regions, a number of VT-2004 National Nodes have been established. They collaborate closely with the organisers of the programme and constitute the main contact points for the media in the corresponding countries.

The VT-2004 website also contains an art gallery with drawings made by children.

Observations of the transit

On Tuesday, June 8, 2004, via the central VT-2004 display, all interested parties may follow in real-time the majestic progress of Venus' black disc across the solar surface, covering the distance from limb to limb in a little less than 6 hours. Live images (and possibly, videos) from leading (solar) observatories will be made available with very high throughput, involving a large number of mirror sites all over the world. In Europe, this transit happens during the morning of that day.

Moreover, observational data from a large number of observers in Europe and on other continents will be collected within the framework of the VT-2004 Observing Campaign in near-real time. This is the modern reenactment of a famous historical observation which was used by observers in the 17th, 18th and 19th centuries to measure the distance between the Earth and the Sun. A running estimate of the resulting value of this distance will be provided, illustrating this most fundamental step towards the cosmological distance scale and the determination of the size of the Universe.

The observations by the public required for this project will naturally lead to observations of the Sun itself and the discovery that our central star is far from being a quiet and boring lamp in the sky but rather a complex and highly interesting celestial body.

Evaluation of the implications

In addition to activities around the Venus Transit itself, the organisers also aim at evaluating in gross terms the sociological impact of such a very rare astronomical event and the way it is perceived in the different countries. Because the programme provides a field test for the execution of large-scale public activities relating to a particular scientific event with strong operational constraints (including the requirement to act in real-time as the scientific event progresses), the organisers expect to gather valuable experience for future continent-wide activities involving the same mechanisms and carried out under similar conditions.

The VT-2004 Final Event will bring together the main participants in this project from many different European countries. It will serve to discuss the project and its impact, identifying possible differences from country to country and showing how it is possible to share good practices in the future. The outcome of this rare celestial event and the overall experience from this unique public education project will clearly be of very wide interest, not just in the field of astronomy.

More information is available at the VT-2004 website (www.vt-2004.org). The organisers of the VT-2004 programme may be contacted via *vt-2004@eso.org*.

Upcoming Change in the Supported Archive Output Media

Benoît Pirenne
ESO DMD and ST-ECF

In 13 years of data distribution at the ESO/ST-ECF archive, numerous different sorts of media have been offered to our users: 9-track tape reels, DAT-DDS 1 & 2, Exabyte. Still available today are the DAT-DSS 3 and the DLT 4000 and DLT 7000, as well as CD-R and DVD-R. The reasons for the changes have always been adaptation to the available technology, costs, request size as well as the popularity of the media with our user community. For this reason, every few years, the available choice is reviewed: the older, less popular media are removed and replaced by newer, more appropriate technologies.

We think the time has again come to review the available choice and to reconsider what we offer. If the best technology in terms of costs, convenience and compatibility for exchanging data today is the network, studies carried out recently indicate that with many of our archive "customer" sites in Europe, data requests of only up to a few GB could be served using FTP transfer. As the time of VST, VISTA and ALMA is approaching, the need for a hard medium to transport and deliver hundreds to thousands of GB of data is still there. Already today, requests for WFI data regularly go beyond 100GB and in this case the transfer using say, tapes, is more appropriate.

However, the tape formats we are using are outdated and suffer from a lack of user-friendliness. Moreover, the newer high capacity models usually impose both the archive site and the recipient of the data to procure expensive drives that do not always guarantee readability. Disks, however, do not impose any specific reading equipment on the user. In recent years, magnetic disks have become very affordable and their individual capacity has increased to a point where they can easily compete with the largest tape units, and without having the tape disadvantages: they allow direct file access, preservation of file names, etc. The advent of the USB disk has brought to life an opportunity to solve our data transport problems. However, if the price of disk drives has gone down significantly in recent years, they have not yet reached the point where they could simply be given away to users. Recipients of the disks will therefore be required to return them to ESO within a working week.

To make the disks readable on as many computer platforms as possible, we choose to create a file system on the disk so as to make it look like a (very) large CD. In this way, three of the main operating systems used by astronomers could be supported with the same setup: all of Linux, Solaris 8 and MacOS X can easily read the disks that we so produce.

Starting in April 2004, the archive will no longer support tapes as archive data distribution media. The remaining methods to obtain data from the ESO/ST-ECF archive will be -besides FTP- DVD-R and USB/FW disks. More technical details regarding the new system will be published shortly on the archive home page (http://archive.eso.org/). A somewhat more detailed account of this policy change was published in the *ST-ECF newsletter*, 35, January 2004.

ESO - Arcetri Conference on

Chemical Abundances and Mixing in Stars in the Milky Way and its Satellites

Castiglione della Pescaia (Grosseto, Italy)
September 13-17 2004

The Fibre Large Array Multi-Element Spectrograph (FLAMES) will produce a large amount of spectroscopic abundances for stars in different environments, from Galactic open clusters to dwarf galaxies in the Local Group, allowing a quantum leap in different astrophysical areas.
At the same time, in recent years significant advances have been achieved in the modelisation and interpretation of observed abundances, in particular as far as stellar mixing is concerned. Mixing phenomena that occur in stars are responsible for the variations of surface chemical abundances throughout the stellar lifetime. Thus, understanding mixing in stars is necessary for a safe use of the observed abundances as tracers of the evolution of galaxies.
The main aim of the workshop is to interpret observed abundances in the framework of the most recent theoretical predictions from the models. The implications for primordial (BBN) abundances, for stellar yields, and for the chemical evolution of our Galaxy and its satellites will also be addressed.

The format of the meeting will consist of invited reviews and talks, contributed talks, and posters.

SOC members: J. Andersen, G. Gilmore, G. Meynet, P. Molaro, L. Pasquini (Co-Chair), N. Prantzos, S. Randich (Co-Chair), R. Rood, C. Sneden, M. Spite, M. Tosi, A. Weiss

Full details and registration information can be retrieved from http://www.arcetri.astro.it/~cast04/ or by email to *cast04@arcetri.astro.it*

Deadline for pre-registration: 15 February 2004
Deadline for final registration: 15 May 2004

PERSONNEL MOVEMENTS

International Staff

(1 January 2004 - 31 March 2004)

ARRIVALS

EUROPE

ALONSO, Maria Victoria (ARG)	Associate EIS
ANTONIUCCI, Simone (I)	Student
CREDLAND, John (GB)	Head of ALMA Division
LOMBARDI, Marco (I)	Astronomer
LOPS, Roberto (I)	Associate EIS
MACKOWIAK, Bernhard (D)	Education Officer
MAZZOLENI, Ruben (I)	Paid Associate
VUCHOT, Luc (F)	Student

CHILE

BLANCO-LOPEZ, Leonardo (F)	Student
COPPOLANI, Franck (F)	Student
DUMAS, Christophe (F)	Operations Staff Astronomer
GUEGUEN, Alain (F)	Student
NAEF, Dominique (CH)	Associate
SMETTE, Alain (B)	Operations Staff Astronomer

DEPARTURES

EUROPE

BREYSACHER, Jacques (F)	Head of Visiting Astronomer's Section
DELMOTTE, Nausicaa (F)	Student
KASTEN, Helga (D)	Technical Draughtswoman
MIGNANO, Arturo (I)	Associate
RAIMONDO, Gabriella (I)	Student
STRIGL, Gisela (D)	Science Archive Operations Specialist
VAN HEST, Frank (NL)	Student
WILHELM, Rainer (D)	Engineer/Physicist

CHILE

ERM, Toomas (S)	Electrical Engineer
KERVELLA, Pierre (F)	Fellow
MENDEZ-BUSSARD, René (RCH)	Astronomer
MORELLI, Lorenzo (I)	Student

Local Staff

(1 December 2003 – 31 March 2004)

ARRIVALS

AGURTO RUIZ, Claudio	Opto-Mechanical Technician
BOLADOS AROSTICA, Carlos	Opto-Mechanical Technician
DURAN URRUTIA, Carlos	Telescope Instrument Operator
HUERTA CORTES, Rodrigo	Electronics Engineer
INZUNZA PERALTA, Lorena	Telescope Instrument Operator
MARTINEZ PARADA, Mauricio	Telescope Instrument Operator
TORRES CASTILLO, Danilo	Electronics Engineer

DEPARTURES

ARANDA CONTRERAS, Ivan	Archival Technician
GODOY MUNOZ, Eugenia	Bilingual Secretary
LAGARINI MIRET, Andrea	Executive Bilingual Secretary
NAVEA VILLARROEL, Francisco	Shop Assistant
RIVERA MAITA, Roberto	Temporary Site Testing

ESO Studentship Programme

The European Southern Observatory research student programme aims at providing opportunities and facilities to enhance the Ph.D. programmes of ESO member-state universities. Its goal is to bring young scientists into close contact with the instruments, activities, and people at one of the world's foremost observatories. For more information about ESO's astronomical research activities please consult http://www.eso.org/science/

The ESO studentship programme is shared between the ESO Headquarters in Garching (Germany) and the Vitacura offices in Santiago (Chile). These positions are open to students enrolled in a Ph.D. programme in the ESO member states and, exceptionally, at a university outside the ESO member states. Students in the programme work on their doctoral project under the formal supervision of their home university. They come to either Garching or Santiago for a stay of normally one or two years to conduct part of their studies under the co-supervision of an ESO staff astronomer. Candidates and their home-institute supervisors should agree on a research project together with the ESO local supervisor. A list of potential ESO supervisors and their research interest can be found at http://www.eso.org/science/sci-pers.html#faculty and http://www.sc.eso.org/santiago/science/person.html. A list of current PhD projects offered by ESO staff is available at http://www.eso.org/science/thesis-topics/.

It is highly recommended that the applicants start their Ph.D. studies at their home institute before continuing their Ph.D. work and developing observational expertise at ESO. In addition, the students in Chile have the opportunity to volunteer for a small amount of duties (~ 40 nights per year) at the La Silla Observatory. These duties are decided on a trimester by trimester basis, aiming at giving the student insight into the observatory operations and shall not interfere with the research project of the student in Santiago.

The closing date for applications is June 15, 2004.

Please apply by: filling the form available at http://www.eso.org/gen-fac/adm/pers/forms/student04-form.pdf and attaching to your application:

- a Curriculum Vitae (incl. a list of publications, if any), with a copy of the transcript of university certificate(s)/diploma(s)
- a summary of the master thesis project (if applicable) and ongoing projects indicating the title and the supervisor (maximum half a page), as well as an outline of the Ph.D. project highlighting the advantages of coming to ESO (recommended 1 page, max. 2).
- two letters of reference, one from the home-institute supervisor/advisor and
- one from the ESO local supervisor, and a letter from the home institution that i) guarantees the financial support for the remaining Ph.D. period after the termination of the ESO studentship, ii) indicates whether the requirements to obtain the Ph.D. degree at the home institute are already fulfilled.

All documents should be typed and in English (but no translation is required for the certificates and diplomas).

The application material has to be addressed to:

European Southern Observatory
Studentship Programme
Karl-Schwarzschild-Str.2
85748 Garching bei München (Germany)

All material, including the recommendation letters, must reach ESO by the deadline (June 15); **applications arriving after the deadline or incomplete applications will not be considered!**

Candidates will be notified of the results of the selection process in July 2004. Studentships typically begin between August and December of the year in which they are awarded. In well justified cases starting dates in the year following the application can be negotiated.

Applications are invited for the position of an

ESO Representative in Chile
-Head of the Office for Science Santiago-

Career Path: VI / VII

Assignment: The ESO representative reports directly to the Director General for the ESO representation duties in Chile and regarding the science activities to the Head of Office for Science in Garching . The main task will be:

- The representation of ESO, continuation and further development of the positive working relationships with the Chilean governmental, regional and local authorities where ESO projects are located.
- The representation of ESO's political and legal interests in Chile regarding e.g property, mining rights etc. in close coordination with the Head of Administration.
- Public relations, media support, exhibitions, educational programmes in close cooperation with the Directors of Observatories and the Education and Public Relation Department.
- The implementation of ESO science policies in Chile, to foster science across all ESO sites in Chile and to support efforts of ESO staff to conduct science at a high level.
- The pursuit and active support of the Fellowship, Studenship, Visitor programmes and the carrying out of scientific exchanges with the Chilean and European community through a strong and attractive Workshop Programme.

As a Senior Astronomer and member of the ESO Science Faculty the postholder is expected and encouraged to actively conduct astronomical research.

Qualification and Experience: Basic requirements for the position include:

- a university degree at PhD or equivalent level in physics or astronomy,
- substantial experience in management and leadership,
- an excellent record of achievements in one or more areas of modern astrophysics,
- excellent communication skills and a strong sense of team spirit as well as
- very good knowledge of written and spoken English and Spanish.

Experience in dealing, at a high level, with government departments and agencies, would be an advantage.

Duty station: Santiago, Chile.

Starting date: 1 January 2005

Remuneration and Contract: We offer an attractive remuneration package including a competitive salary (tax free), comprehensive pension scheme and medical, educational and other social benefits as well as financial help in relocating your family. The initial contract is for a period of three years with the possibility of a fixed-term extension or permanence. Serious consideration will be given to outstanding candidates willing to be seconded to ESO on extended leaves from their home institutions. The title or the grade may be subject to change according to qualification and the number of years of experience.

Applications : If you are interested in working in a stimulating international research environment and in areas of frontline science and technology, please send us your CV (in English) and the ESO Application Form **by 30 June 2004.**

All applications should include the names of four individuals willing to give professional references.

For further information, please contact Mr. Roland Block, Head of Personnel Department, Tel +49 89 320 06 589, e-mail: rblock@eso.org. You are also strongly encouraged to consult the ESO Home Page (http://www.eso.org/)

Applications are invited for an Operations Staff Astronomer-Deputy Head of the Science Operations Department at the Very Large Telescope on Cerro Paranal near Antofagasta, Chile. This post is open to suitably qualified men and women:

Operations Staff Astronomer

Deputy Head of the Paranal Science Operations Department

Career Path: V

Assignment: The Science Operations Department at ESO's Paranal Observatory (PSO) is responsible for all aspects of the direct support of observing operations of the VLT, the VLTI, and in the future, of the VST and VISTA, so as to optimize the scientific output of this world leading astronomical facility. The department currently comprises 26 operations staff astronomers, 14 telescope instrument operators, and 5 data handling administrators, as well as, for the functional part of their assignment, 15 postdoctoral fellows of ESO's Office for Science. Further recruitment is planned once all auxiliary telescopes of the VLTI, VST and VISTA become operational.

The successful candidate will provide direct support to observing operations in both visitor and service mode: short-term (flexible) scheduling of queue observations, calibration and monitoring of the instruments, and assessment of the scientific quality of the astronomical data. As deputy he/she will assist the Head of PSO in the execution of his tasks in particular in the definition and implementation of the operations procedures and policies, organization of the support work, staff management and performance evaluation, interface with other groups across ESO involved in VLT operations support, and reporting activities.

As a members of the ESO Science Faculty, with an appointment at the level of Assistant or Associate Astronomer, he/she will be expected and encouraged to actively conduct astronomical research up to 50% of the time. 105 nights per year are spent at the observatory carrying out functional duties, usually in a shift of 8 days on Paranal, 6 days off. The rest of the time is spent in the Santiago office. Financial support for scientific trips and stays at other institutions, including in Europe, is foreseen.

Education: Ph.D. in Astronomy, Physics or equivalent; at least 5 years of postdoctoral experience.

Experience and knowledge: The ideal candidate has substantial observing experience (at least 8 years), excellent observation oriented research records, is familiar with a broad range of instrumental, data analysis, archiving and observational techniques, and is conversant with at least one major data reduction package such as MIDAS, iraf or IDL. Of special value would be experience in telescope and instrument operations and a record of instrumental experience, such as the participation in the design, construction or calibration of existing instruments. Experience in the management of projects and leadership as well as excellent command of the English language, a working knowledge of Spanish or a willingness to learn, and a strong sense of team spirit are essential.

Duty station: Paranal and Santiago, Chile

Starting date: As soon as possible

Contract: The initial contract is for a period of three years with the possibility of a fixed-term extension or permanence. Promotions will be based on scientific as well as functional achievements.

Remuneration: We offer an attractive remuneration package including a competitive salary (tax-free), comprehensive social benefits, and provide financial support in relocating families. Furthermore, an expatriation allowance as well as some other allowances may be added. Either the title or the grade may be subject to change according to education and the number of years of experience.

Applications consisting of your CV (in English language) and the ESO Application Form (to be obtained from the ESO Home Page at http://www.eso.org/) and four letters of reference.

should be submitted by 7 May 2004.

For further information, please consult the ESO Home Page or contact Mrs. Nathalie Kastelyn.

Applications are invited for a Staff Astronomer position at APEX (the Atacama Pathfinder EXperiment) located on Chajnantor near San Pedro de Atacama, Chile.

Staff Astronomer

Career Path: V

Assignment: APEX is a sub-mm telescope presently being erected at the ALMA site of Chajnantor in Chile through a collaboration between the MPIfR, ESO and Sweden. The site is excellent for sub-mm observations, and the telescope will be equipped with bolometer arrays and heterodyne receivers for observations at sub-mm wavelengths as well as in the THz band. We seek one staff astronomer for APEX. He/she will join a team of scientists, engineers, and technicians, in total 20 people, responsible for the operation and maintenance of the antenna and its instrumentation. Astronomers will be part of the science operations group responsible to support observations, both in visitor mode and service mode, to develop calibration and quality control procedures for the instruments, to control the configuration of the system, and to develop operational procedures for the telescope including pointing models. The Science Operations team will consist of staff astronomers, fellows and telescope operators.
As an astronomer and member of the ESO Science Faculty, the successful candidate will be expected and encouraged to actively conduct astronomical research up to 50% of the time using APEX and other facilities. The APEX astronomers spend 105 nights per year carrying out functional duties in the APEX base in Sequitor and at the telescope, which is located on Chajnantor at an altitude of 5000 m, usually in a shift of 8 days in Sequitor with trips to Chajnantor, followed by 6 days off. The rest of their time is spent in the Santiago office. Scientific trips and stays at other institutions, also in Europe are foreseen.
Education: Ph.D. in Astronomy, Physics or equivalent
Experience and knowledge: APEX is seeking active a staff astronomer with a solid publication record in observational astronomy. Observational experience with (sub)mm telescopes will be an asset. At least three years of post-doctoral experience as well as excellent communication skills and a good command of the English language (spoken and written) will be required.
Duty station: Sequitor, Chajnantor and Santiago, Chile
Starting date: As soon as possible
Contract: The initial contract is for a period of three years with the possibility of a fixed-term extension. Promotions will be based on scientific as well as functional achievements. It is necessary to take a high altitude medical examination before taking up the post.
Remuneration: We offer an attractive remuneration package including a competitive salary (tax-free) and comprehensive social benefits. Furthermore, an expatriation allowance as well as some other allowances may be added. Either the title or the grade may be subject to change according to education and the number of years of experience.
Applications consisting of your CV (in English language) and the ESO Application Form (to be obtained from the ESO Home Page at http://www.eso.org/) and four letters of reference

should be submitted by 7 May 2004.

For further information, please consult the ESO Home Page or contact Mrs. Nathalie Kastelyn.

Applications are invited for a Staff Astronomer position in the Science Operations Department at the VLT Observatory on Cerro Paranal near Antofagasta, Chile.

Operations Staff Astronomer (VLTI)

Career Path: V

Assignment: The first components of the VLT Interferometric Array (VLTI), including the science instruments MIDI and AMBER, are currently being commissioned. Scientific operations of the VLTI are expected to start in the first half of 2004. The successful candidate will support observing operations in both visitor and service mode at the VLTI. The tasks to be performed include the short-term (flexible) scheduling of queue observations, the calibration and monitoring of the instruments, and the assessment of the scientific quality of the astronomical data. The VLTI astronomer will contribute to the challenge of operating a world leading astronomical facility so as to optimize its scientific output, will acquire expert knowledge of novel instrumentation and techniques, and may be given the overall responsibility for an instrument.
Operations astronomers may be members of the ESO Science Faculty, with an appointment at the level of Assistant or Associate Astronomer. They will be expected and encouraged to actively conduct astronomical research up to 50% of the time. 105 nights per year are spent at the observatory carrying out functional duties, usually in a shift of 8 days on Paranal, 6 days off. The rest of the time is spent at the Santiago office. Depending on qualification, expertise, and personal interest, Operations Astronomers may alternatively be offered an appointment with up to 20% of the time for personal research and 150 days per year to be spent on the observatory. Financial support for scientific trips and stays at other institutions, including in Europe, is foreseen for all VLT Operations Astronomers.
Education: PhD in Astronomy, Physics or equivalent.
Experience and knowledge: The successful candidate combines substantial observing experience (at least 3 years) with active research and has observation oriented research records. Familiarity with a broad range of instrumental, data analysis, archiving, and observational techniques is required. He/She must be conversant with at least one major data reduction package such as MIDAS, iraf or IDL. Of special value would be a record of instrumental experience, such as the participation in the design, construction or calibration of existing instruments, as well as experience in telescope and instrument operations. Experience in any area of observational interferometry would also be an asset. Excellent communication skills, a good command of the English language, a working knowledge of Spanish or a willingness to learn and a strong sense of team spirit are essential.
Duty station: Paranal and Santiago, Chile.
Starting date: As soon as possible.
Contract: The initial contract is for a period of three years with the possibility of a fixed-term extension or permanence. Promotions will be based on scientific as well as functional achievements.
Remuneration: We offer an attractive remuneration package including a competitive salary (tax-free), comprehensive social benefits, and provide financial support in relocating families. Furthermore, an expatriation allowance as well as some other allowances may be added. Either the title or the grade may be subject to change according to education and the number of years of experience.
Applications consisting of your CV (in English language) and the ESO Application Form (to be obtained from the ESO Home Page at http://www.eso.org/) and four letters of reference

should be submitted by 7 May 2004.

For further information, please consult the ESO Home Page or contact Mrs. Nathalie Kastelyn.

Although preference will be given to nationals of the Member States of ESO: Belgium, Denmark, France, Germany, Italy, The Netherlands, Portugal, Sweden, Switzerland, and United Kingdom, no nationality is à priori excluded. The post is equally open to suitably qualified male and female applicants.

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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 ten countries: Belgium, Denmark, France, Germany, Italy, the Netherlands, Portugal, Sweden, Switzerland and the United Kingdom. ESO operates at three sites in the Atacama desert region of Chile. The Very Large Telescope (VLT), is located on Paranal, a 2,600 m high mountain approximately 130 km south of Antofagasta. The VLT consists of four 8.2 metre diameter telescopes. These telescopes can be used separately, or in combination as a giant interferometer (VLTI). At La Silla, 600 km north of Santiago de Chile at 2,400 m altitude, ESO operates several optical telescopes with diameters up to 3.6 m. The third site is the 5,000 m high Llano de Chajnantor, near San Pedro de Atacama. Here a new submillimetre telescope (APEX) is being completed, and a large submillimetre-wave array of 64 antennas (ALMA) is under development. Over 1300 proposals are made each year for the use of the ESO telescopes. The ESO headquarters are located in Garching, near Munich, Germany. This is the scientific, technical and administrative centre of ESO where technical development programmes are carried out to provide the Paranal and La Silla observatories with the most advanced instruments. ESO employs about 320 international staff members, Fellows and Associates in Europe and Chile, and about 160 local staff members in Chile.

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 Education and Public Relations Department at the following address:

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Interested in ALMA Science?

Over the last year, ALMA scientists have developed a Design Reference Science Plan (DRSP) with the goal to provide a prototype suite of ALMA projects that could be carried out in ~3 years of ALMA operations. This plan provides a quantitative reference for developing the ALMA science operations plan, for software design, and for other appplications within the project. Check out your favorite observing program by clicking on "ALMA DRSP" through the ESO ALMA Web site, or go directly to: http://www.strw.leidenuniv.nl/~alma/

Ewine van Dishoeck
(Chair, ALMA European Science
Advisory Committee)

ALMA Community Meeting

The second 'ALMA Community Meeting' will be held on September 24, 2004 at ESO, Garching. Topics will include an update of the project, the European ALMA Regional Center, and the science that can be done in the early science phase and later with the full array. The local organization committee will consist of T.L. Wilson (chair), R. Laing, C. De Breuck and M. Zwaan. The scientific organizing committee is formed by the European ALMA Science Advisory Committee. Check the ESO-ALMA Web page this summer at http://www.eso.org/projects/alma/ for registration, logistical information and updates on the programme.

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