The Messenger

No. 119 – March 2005

Scientific Strategy Planning at ESO

Introduction by Ralf Bender, Chair of the Scientific Strategy Working Group

At its 100th meeting in June 2003, the ESO Council decided to install a Working Group to discuss ESO's scientific strategy until 2020. The time appeared ripe to discuss the future, as the VLT was now largely completed, ALMA had just been approved, and the ESO community had been significantly strengthened by the recent accession of the United Kingdom. Furthermore, the discussions and concept studies for the next large facilities (notably the Extremely Large Telescopes) were underway world-wide. Evidently, it was important to develop a strategy for ESO's future now.

The Scientific Strategy Working Group was composed of members of Council: Ralf Bender (Chair), Tim de Zeeuw, Claes Fransson, Gerry Gilmore and Franco Pacini; Bruno Marano and members of the STC, the VLTI Implementation Committee and the European ALMA Board: Jean-Loup Puget, Thomas Henning, and Simon Lilly. ESO was represented by Bruno Leibundgut, Guy Monnet and Peter Quinn. The Director General and the Head of Administration attended all meetings as well.

The charge to the Working Group was defined by Council as follows: "Prepare and assess the options for ESO's long term programme, taking a broad view of ESO's role in world astronomy [...]. In doing so, the Group shall consider ESO's long term scientific goals and objectives. To this end, current and future developments and the possible implications of further external collaboration and enlarged membership may also be considered."

The Working Group met three times and prepared a report accompanied by a set of recommendations. After minor revisions, the ESO Council adopted the recommendations as a formal "Council Resolution on Scientific Strategy" in its last meeting in December 2004. Both documents are printed below.

I take this opportunity to thank all Working Group members for very good and open discussions, constructive contributions and pleasant and efficient meetings.

Report from the Working Group on Scientific Strategy Planning

Introduction

1. ESO's mission was stated in the Convention as 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*". In the current world and in view of Europe's and ESO's achievements in astronomy in the last decade, ESO's mission could be stated more ambitiously: ESO should provide European astronomers world-class facilities to pursue the most fundamental astronomical questions.

2. ESO cannot do this alone. A close partnership between ESO and the astronomical institutions in its member countries is crucial to the development and preservation of the scientific and technical excellence of European Astronomy. This implies that the success of European Astronomy relies equally on a world-class ESO and on strong and active research institutions throughout Europe.

3. The granting of access to ESO facilities, participation in ESO programmes, and even membership of ESO are based primarily on scientific excellence. ESO will continue to be open to new members and collaborations, following the principles of furthering excellence and scientific cooperation.

The Astronomical Framework

4. Over the past two decades, Astronomy has entered its golden age. A few examples of what has been achieved are: We have now direct evidence for the evolution of galaxies and stars throughout 90% of the age of the universe. We have found supermassive black holes in most galaxy centres and have probed their evolution to high redshifts. We have seen the seeds of galaxies and their large-scale distribution in the cosmic microwave background. We have determined the cosmic parameters with an order of magnitude better accuracy. We have confirmed the existence of dark matter which is 5 times more abundant than ordinary matter, and we have found that the universe is filled to 70% with the so-called 'dark energy', a new state of energy of hitherto unknown nature. And last, not least, we have, for the first time, found planets around other stars.

5. It is evident that progress in astronomy is driven by both unexpected discoveries (e.g. dark matter, dark energy) as much as by particular experiments designed to test specific theories (like ongoing microwave background experiments). Astronomical discoveries are often made by pushing the limits of observation with the most powerful telescopes on the ground and the most advanced satellites in space (e.g. high redshift galaxies, black holes, gamma ray bursts etc), but smaller workhorse telescopes and instruments used in a new mode of operation can also produce very exciting discoveries (e.g. MACHOS, planets etc.).

6. Key scientific questions in astronomy and astrophysics over the next 20 years will include (i) the nature of dark matter, (ii) the nature of dark energy, (iii) the formation of the very first stars and galaxies and following their evolution from the highest redshifts until today, (iv) extreme conditions of matter and energy (e.g. black holes), (v) the formation of stars and planetary systems, and (vi) the characterization of extra-solar planets including the search for extraterrestrial life.

7. Addressing all of these questions requires a co-ordinated observational and experimental approach, spanning all wavelengths of the electromagnetic spectrum with facilities on the ground and in space but also exploring new observing windows to the universe, like underground neutrino detectors, or space interferometers for gravitational wave detection. Ground-based astronomy with large aperture telescopes plays a pivotal role in the overall concept because (a) most sources we want to study emit a large fraction of their radiation between optical and radio wavelengths, (b) this wavelength range provides crucial and detailed information about the physical nature of the sources, and (c) the sources we want to study are generally very faint. In addition, large telescopes like Keck and VLT have not only made important discoveries by themselves but also have provided crucial complementary information to discoveries made with satellites (e.g. the Hubble Space Telescope, ISO, Chandra etc.) which otherwise could often not be interpreted comprehensively and would remain inconclusive. And finally, beyond their large light collecting power, the additional strengths of ground-based telescopes are their high versatility and the possibility to explore new technologies rapidly.

8. Astronomy has from its very beginning been a technology-enabled science and is

View of La Silla from the 3.6 m telescope.

now progressing more rapidly than ever before, with its technology feedback benefiting industry. In ground-based astronomy, improving the performance of existing telescopes and the construction of the next generation of telescopes and instruments will require investment in several critical technologies. Important over the next 10+ years will be, e.g., the development of multi-conjugate adaptive optics, laser guide stars, the mastering of increasingly complex telescope/instrument systems and the handling and exploration of Petabytes of data.

ESO's Facilities

9. ESO and its collaborating institutes have a highly skilled and very motivated staff specialized in the design, construction and operation of large optical/IR telescopes and their instruments. Another major strength of ESO is the efficient management of large projects which is one reason why the VLT is the best ground-based astronomical facility today. It took decades to build this expertise and this asset must be preserved if Europe is to stay competitive in the future. ESO has also managed its facilities effectively, opening a new site for the VLT because it was scientifically advantageous to do so, and closing facilities on La Silla when no longer scientifically cost effective.

10. **La Silla** is still one of the most successful observatories world-wide. Survey and monitoring projects with dedicated instruments (e.g. HARPS for planets) have become increasingly important and produce impressing scientific results. La Silla has also been needed to provide targets for the VLT. However, with the installation of VST/OmegaCAM and VISTA, preparatory observations and target finding for the VLT will not have to rely on La Silla beyond 2006.

11. The **VLT** is the most powerful and versatile 8 m telescope system to date. It is now fully operational. Further upgrades and the development of second generation instruments should ensure European leadership in most areas of optical/IR astronomy for at least 10 more years. Once a 30 m+ telescope and the James-Webb-Space-Telescope go into operation, the role of the VLT needs to be reconsidered and more specialization may be required.

12. The **VLTI** is acknowledged to be the most advanced interferometer in the world in almost all aspects (except nulling interferometry with Keck). It will be the best system to enable faint science (e.g. structure of Active Galactic Nuclei) and ground-based astrometry, because it is the only system that can potentially combine four 8 m telescopes interferometrically. The VLTI is still being constructed, with new instruments to be added and four Auxiliary Telescopes to be completed.

13. **ALMA** will open a new window to the universe and provide unprecedented access to the gaseous medium and the star formation processes both in our Galaxy and in the most distant galaxies in the universe. ALMA will discover vast numbers of faint sources that require complementary observations at other wavelengths.

14. These facilities, and many others around the world, produce an enormous amount of archived data which is available to the astronomical community. ESO is working with European institutions in a global effort to establish an International **Virtual Observatory**. This project addresses critical requirements for handling the steadily increasing data rates from ESO telescopes and for connecting them with data sets obtained by other facilities and at other wavelengths. Data handling and processing is one of the key new challenges in astronomy.

The Extremely Large Telescope

15. The unique capabilities of an Extremely Large Telescope (30 m and larger) are (i) its 16 to 160 times larger light collecting power than a VLT UT and (ii) its potentially 10 to 40 times higher spatial resolution than the Hubble Space Telescope. The combination of these two features will enable imaging and especially spectroscopy of sources up to a factor 50 fainter than currently possible. Considering the enormous progress the Hubble Space telescope brought with its factor 10 improvement in spatial resolution, and the 8 m class telescopes with their factor 5 in light collecting power, the discovery power and impact of an ELT can hardly be overestimated. With an appropriate choice of the site an ELT should also offer unique imaging capabilities in the sub-mm range complementing ALMA.

16. The case for an ELT alone is compelling; in the context of other facilities it is overwhelming. An ELT will be an important complement to ALMA, the James Webb Space Telescope (JWST), future space missions like DARWIN and XEUS, and to other space and ground observatories. It is important to realize that, because of their intrinsically different capabilities, ELTs on the one hand and space missions like DARWIN or JWST on the other hand, will not compete but rather support each other by providing complementary information about planets, stars and galaxies. In combination, these facilities will produce the next revolution in our understanding of the universe and its constituents.

17. The scientific reach of an ELT, and its potential for making new discoveries, are so great that there is a strong case for each of the world's regions having access to an ELT. Collaborative efforts should be encouraged, but should not be allowed to compromise European access to an ELT or to its associated technological benefits. It is therefore important that European astronomy builds on its current strength and aims for a leading role in the development and construction of an ELT. This is also vital in attracting the best young scientists and keeping them in Europe. North American institutions (CalTech, UC, AURA, Canada) are undertaking a detailed design

The VLT with stations of the VLTI (foreground).

study of a 30 m telescope, the TMT. Another group of institutions (led by Carnegie Observatories) has started constructing a 21 m telescope, the GMT. Their ambition is to have first light before 2016 for both projects. Europe must keep pace with this work.

18. ESO and European Institutions are jointly pursuing technology development and concept studies towards an ELT (in part through the FP6 framework). ESO has developed what appears to be the most innovative concept to date for an Extremely Large Telescope, namely the OWL[1]. The OWL concept studies have been carried out in close collaboration with industry and indicate that a fundamentally new approach to build large telescopes should allow the construction of a 60 m telescope for a cost comparable to that of a conventional 30 m telescope. The new paradigm is based on the adoption of serialised industrial production and a fully computer-controlled optical system to reduce cost without compromising performance. Below about 60 m, the OWL concept probably loses its high cost effectiveness. A detailed design study is essential to validate the OWL approach, including instrumentation, and establish the optimal balance between science, technology, and cost.

19. The total cost for a 100 m ELT based on the OWL concept is currently estimated to be about 1200 M Euros. A 60 m ELT would cost about half this amount, or roughly the cost of VLT or ALMA.

20. Three illustrative scenarios have been developed by ESO. They are not yet optimised for cash flow or resource usage, but are sufficient to illustrate the main points in the planning. While still including some allocation for technological development in crucial areas, Scenario I corresponds to the fastest schedule technology could plausibly allow. Scenario II-100 allows more extensive design and development periods before start of construction, and a relaxed integration schedule. Scenario II-60 corresponds to a 60 m instead of a 100 m telescope.

Scenario	Telescope diameter	Phase B starts	Phase C/D starts	Start of science (partially filled)	Full completion
I	100 m	2005	2007	2012 (50 m dia.)	2016
II-100	100 m	2006	2010	2017 (60 m dia.)	2021
II-60	60 m	2006	2010	2016 (40 m dia.)	2020

Conclusions

21. Over the last decade ESO has succeeded in becoming fully competitive and indeed world leading. However, the risk of falling back is real, even in the near future, especially with respect to ELTs. To maintain its position Europe has to adopt plans which keep its scientific and technical ambitions at the highest level to remain attractive for the best scientists and engineers. This means that Europe, and specifically ESO, must participate in the most important and challenging technical and scientific developments of the future and should set priorities accordingly. This is also important for European industries.

22. In the different scenarios for ESO's future until 2015, optimal support for the VLT and ALMA and the development of an ELT are unquestionable priorities. The operation of La Silla and the enhancement of VLTI can have different priorities.

23. The success and excellence of European astronomy requires ESO to maintain the **VLT** as a world-leading facility for at least 10 more years. The VLT needs constant upgrading, including MCAO and an adaptive secondary, and a vigorous 2nd generation instrument program because ESO must:

a. keep pace with the steadily improving capabilities of other 8 m telescopes (Keck, Gemini, Subaru, LBT …),
b. continue to utilise technological advances,
c. match the evolving European science requirements, and
d. maintain developments that are critical for an ELT.

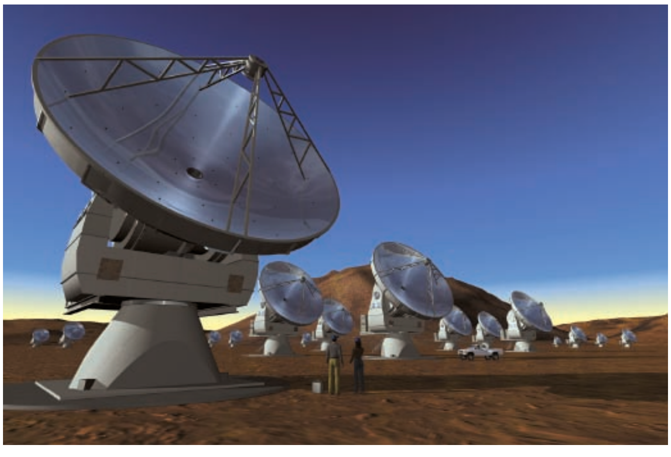
24. The unique capabilities of the **VLTI** mean that the current generation of VLTI instruments and PRIMA for two telescopes should be completed with high priority. The case for the extension of PRIMA to four beam combination using either 4 ATs or 4 UTs needs to be demonstrated with simulations of realistic observing situations. If the demonstration is convincing, four beam combination should be implemented.

25. The role of **La Silla** beyond 2006 has been cogently presented. La Silla will still be useful and competitive in many respects, but it will not be as essential for the success of ESO as the VLT, VLTI, ALMA and an ELT which consequently must have higher priority than the continued operation of La Silla.

26. The European components of **ALMA** are being constructed in collaboration with institutes within the European astronomical community. This collaboration is also critical for the development of adequate data analysis tools which will help to educate European astronomers to make best use of ALMA and perform cutting-edge science projects. ESO should build up sufficient competences in the mm and sub-mm fields to coordinate and complement the expertise and support from outside institutions.

27. ESO must ensure that Europe preserves its current world-leading position into the **ELT** era, because ESO and European astronomers cannot afford to be left behind in the most important developments in ground-based optical/IR astronomy. This can be achieved through the construction of a 60 m OWL for a cost comparable to a US 30 m telescope. Thanks to its new concept based on serialised production, an OWL-type telescope can be realized at much lower cost than a 'conventional' 30 m telescope of Keck-design. However, the advantages of serialised production only become effective beyond about 60 m and are in fact being validated for a 100 m telescope.

28. One of the advantages of the ESO conceptual design is that the telescope is designed so that it can be 'staged' in diameter, becoming available for observations with only a partially completed primary mirror. An OWL-type telescope could have first-light as a 30 m telescope on a competitive timescale and then grow to a 60 m over several additional years (the ALMA project already adopts the same philosophy), and similarly a 100 m telescope could start operations as a 50 m or 60 m. Similarly, Europe can stay competitive in timescale by adopting this 'growing a telescope' concept and so having access to a world class 30 m telescope at the same time



Artist's image of the Atacama Large Millimeter Array (ALMA).

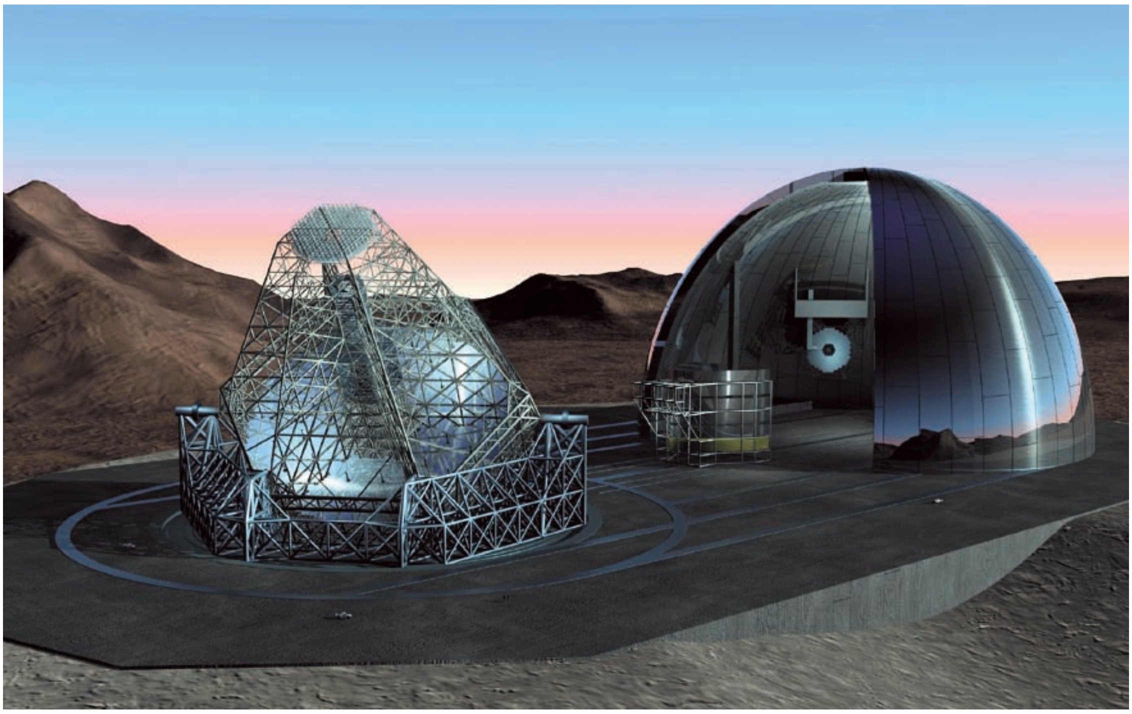
[1] In this document, the term ELT refers to all telescopes larger than 30 m, without reference to a specific design. Most technology development that has been carried out up to now (e.g. within EU-funded projects) is at the component level and is indeed design independent. The term OWL is used only when referring to the specific telescope concept that has been developed by ESO. All the statements related to OWL in this document should be revisited after the conceptual design review which is expected to take place at the end of 2005.

as the North American colleagues. Strong community involvement for system level development and provision of instrumentation will, as in the case of VLT and ALMA, be crucial for our success.

29. As with ALMA, a collaboration with North America and possibly others would enable an even more ambitious global ELT project to be undertaken.

30. ESO should continue to develop new data archiving, data access, and data mining technologies in collaboration with the European astronomical community and within the framework of the **International Virtual Observatory Alliance**. The availability of these technologies is an important factor for the future success of ESO and European Astronomy.

31. Because astronomy and astrophysics exploit leading edge technology, ESO should remain at the forefront of future mainstream and key technologies concerning telescopes, instruments, and data handling. To achieve this goal, ESO should continue its very successful partnership with European astronomical institutions and industries as in the past, also within the framework of EU funded projects.



Artist's impression of ESO's OWL concept.

ESO Council Resolution on Scientific Strategy

ESO Council, considering the report of its Working Group for Scientific Strategic Planning, ESO/Cou-990, and its recommendations in ESO/Cou-964 rev. 2, agrees that

- astronomy is in a golden age with new technologies and telescopes enabling an impressive series of fundamental discoveries in physics (e.g. dark matter, dark energy, supermassive blackholes, extrasolar planets),
- over the last decade, the continued investment of ESO and its community into the improvement of ground-based astronomical facilities has finally allowed Europe to reach international competitiveness and leadership in ground-based astronomical research,
- the prime goal of ESO is to secure this status by developing powerful facilities in order to enable important scientific discoveries in the future,
- only the continued investment in cutting edge technologies, telescopes, instruments and information technology will enable such scientific leadership and discoveries,
- ESO will continue to be open to new members and collaborations, following the principle of furthering scientific excellence,

and accordingly adopts the following principles for its scientific strategy:

- ESO's highest priority strategic goal must be the European retention of astronomical leadership and excellence into the era of Extremely Large Telescopes by carefully balancing its investment in its most important programmes and projects,
- the completion of ALMA is assured and conditions for an efficient exploitation of its superb scientific capabilities will be established,
- the VLT will continue to receive effective operational support, regular upgrading (especially to keep it at the forefront in image quality through novel adaptive optics concepts) and efficient 2nd generation instrumentation in order to maintain its world-leading position for at least ten more years,
- the unique capabilities of the VLTI will be exploited,
- the construction of an Extremely Large Telescope on a competitive time scale will be addressed by radical strategic planning, especially with respect to the development of enabling technologies and the exploration of all options, including seeking additional funds, for fast implementation,
- ESO and its community will continue their successful partnership and seek effective intercontinental collaborations in developing the most important and challenging technologies and facilities of the future.

Wide Field Infrared Imaging on the VLT with HAWK-I

HAWK-I is a new wide field infrared camera under development at ESO. With a 7.5 arcminute square field of view and 0.1 arcsecond pixels, it will be an optimum imager for the VLT, and a major enhancement to existing and future infrared capabilities at ESO.

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European Southern Observatory

The development of ever-larger format infrared detectors with excellent uniformity, quantum efficiency and noise performance has made infrared imaging a central tool in modern astronomical research. As an example, Figure 1 shows the steady increase in the amount of VLT-ISAAC near-infrared imaging time since its commissioning, to its current level of around 26 runs or 300 hours per observing period. In addition to ISAAC, NAOS-CONICA on the VLT and SOFI on the NTT also provide near infrared imaging. The reasons for the strong demand are many and varied. Fundamentally, the infrared allows the study of astronomical phenomena in otherwise inaccessible regions of time and space.

On a cosmological scale, galaxies within the redshift range $1.5 < z < 4$ have their rest-frame visible wavelengths shifted to the near IR. This then becomes the natural wavelength in which to study them, allowing a direct comparison with local galaxies. Indeed broadband IR colours allow their distances (redshifts) to be estimated photometrically. Searches in the infrared for extra high redshift ($z > 6$) young galaxies are underway at the VLT. Nearby galaxies benefit from IR imaging which reveals the older stellar population, less obscured by dust.

Closer to home, the star forming regions within our own galaxy are often hidden by dust. So in order to study important aspects of young clusters such as the initial mass function, infrared imaging is necessary to penetrate the dust, if a complete census of objects is to be compiled.

The infrared part of the spectrum also contains major emission lines. Perhaps the most important of these are due to quadrupole transitions of molecular hydrogen, the most common form of hydrogen in dense clouds. This line, usually shock excited, can reveal spectacular large-scale outflows from young stars.

Another important advantage of the near-infrared is the better image quality that is achieved compared to visible wavelengths. Since the size of the seeing disc has an inverse one-fifth power law dependance on wavelength (depending somewhat on the atmospheric turbulent outer scale), images of point sources at *K*-band can be 20% smaller than in the visible and consequently sharper.

HAWK-I: an optimum VLT imager

Infrared detectors are expensive – around 10 times the cost of comparably sized CCDs. So achieving both adequate image sampling and an ambitious field of view tends to require a large number of detectors and has historically been difficult. However, thanks to recent developments in IR detector technology which reduce the cost per pixel, the situation has greatly improved. HAWK-I, the High Acuity Wide-field *K*-band Imager, will be a near-optimum camera for the VLT. Table 1 shows the key instrumental parameters. The 7.5 arcminute square field results in outer corners of the HAWK-I field which will encroach slightly into the vignetted area of the Nasmyth field, resulting in 0.4% lower throughput in the field corners in all bands, and an approximately 25% higher background flux there in *K*-band. So this is practically the largest IR field possible at Nasmyth while keeping reasonably uniform sensitivity in all bands. By then assembling a mosaic

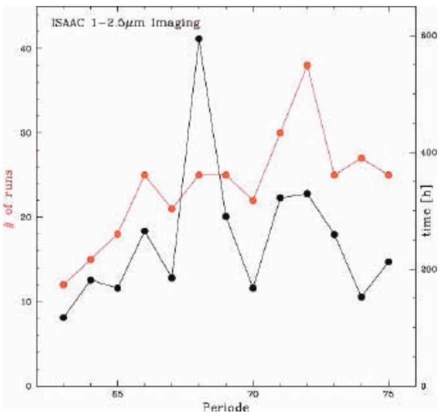

Figure 1: Statistics of near-infrared ISAAC imaging as a function of observing period. The red line shows the allocated number of runs, and the black line the number of hours, per period.

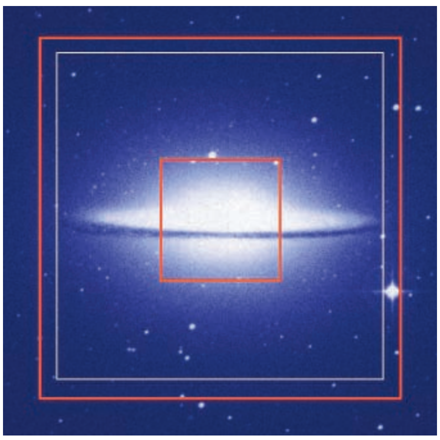

Figure 2: The galaxy M104 (Sombrero) with superimposed fields of HAWK-I (7.5′) and ISAAC (2.5′) in red, and FORS1 (6.8′) in white.

Table 1: The key HAWK-I parameters.

Detectors	4 × 2k × 2k
Pixel scale	0.106″
Field of view	7.5′ × 7.5′
Optical image quality (excluding seeing)	< 0.2 arcsec at 80 % encircled energy
Optics-only throughput	90 %
End-to-end system throughput	50 %
Number of filter positions	10
Wideband filters ordered	Y, J, H, Ks
Rest-wavelength narrow-band filters (microns)	1.58 (CH_4) 2.167 (Brγ) 2.122 (H_2)
Cosmological narrow-band filters (microns)	1.061 1.187 2.090

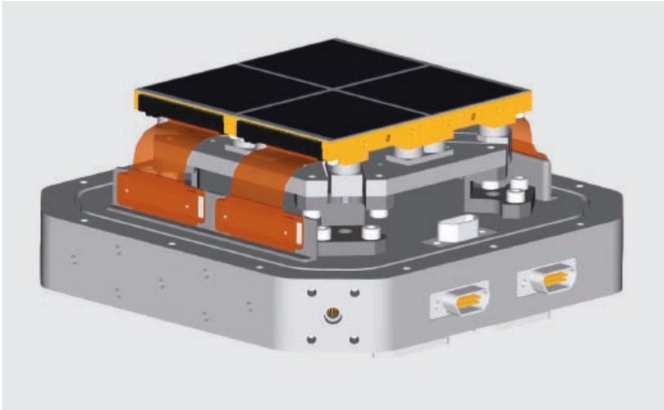

Figure 3: Drawing showing the HAWK-I focal plane, consisting of four coplanar Rockwell Hawaii-2RG detectors.

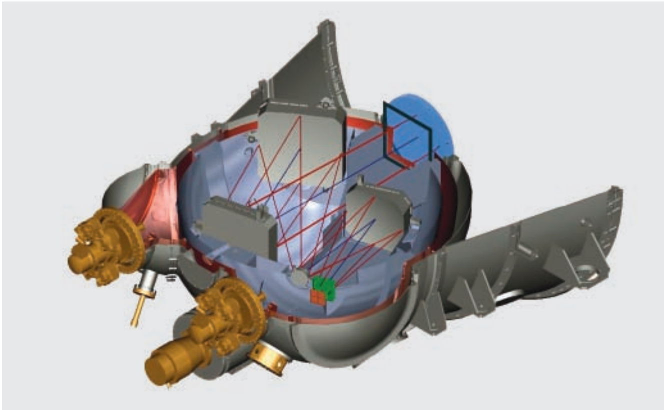

Figure 4: This cutaway drawing shows the optical components of HAWK-I and parts of the surrounding cryostat.

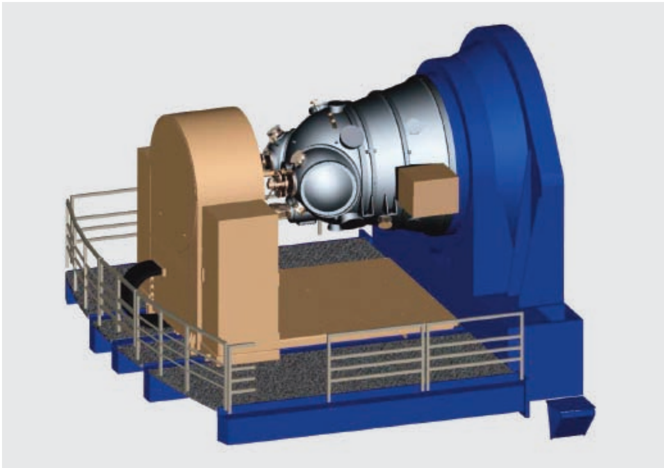

Figure 5: This drawing shows HAWK-I attached to the Nasmyth adapter (blue). The cable de-rotator (brown) is also shown.

of four 2k × 2k detectors to fill this field, a pixel scale of 0.1 arcsec/pixel results, which is sufficiently small to adequately sample the best seeing at Paranal, even with future ground layer adaptive optics correction. The end result is an imager with the best possible performance, limited predominantly by the telescope design and atmospheric seeing conditions. The enhanced field of view compared to ISAAC is shown in Figure 2.

HAWK-I, VISTA and KMOS

ESO users will also have access to imaging data from the 4 m VISTA IR camera (Emerson et al., 2004), which should be commissioned in Chile on a similar timescale (2007) giving ESO astronomers enormous infrared imaging power. With its 16 2k × 2k Raytheon detectors and 0.34 arcsec pixels, VISTA will cover 0.6 sq. degrees in a single exposure, and will be a natural pathfinder for HAWK-I and other VLT instruments. Peculiar, interesting or clustered objects discovered with VISTA will become targets for deep imaging and small mosaics at higher spatial resolution with HAWK-I/VLT. The two instruments will complement each other very well.

HAWK-I is also expected to be a major contributor of targets for infrared multi-object integral field spectroscopy with the second-generation KMOS instrument, which has a comparable field but no imaging mode.

What is special about the HAWK-I design?

Although HAWK-I is a relatively simple imager, there are ambitious and novel aspects in the design which will enhance its performance. At the heart of the instrument are its detectors. HAWK-I will use four Rockwell Hawaii 2RG arrays to make its impressive focal plane. These new-generation detectors operate from 0.8 to 2.5 microns with excellent uniformity and low dark current. They are also three-side buttable allowing a compact focal plane with a cross-shaped gap of 2.7 mm or 15 arcsec. The detectors will be assembled in a package developed by GL Scientific which allows all 32 channels per detector to be read out. A CAD drawing of the assembly is shown in Figure 3.

A unique aspect of HAWK-I will be its very high throughput. This is achieved with a powered window and all-reflective design to achieve an optics-only throughput of 90 %. The layout is shown in Figure 4. The window forms a pupil image at M3 which is the system cold stop. The high throughput alone will give HAWK-I a signal-to-noise improvement of 10–20 % over other typical imagers such as ISAAC. The window is very large, at 404 mm of clear aperture, and is made of infrared-grade fused silica. Windows this size can suffer from potential frosting as the centre cools by radiating into the cold cryostat, while conductive coupling to the warm edge is poor. Special care is being taken with baffle design and an emergency warm-air supply to ensure that condensation does not occur during operation.

HAWK-I has two six-position filter wheels for a total of 10 useable filter and two open positions. Darks will be obtained by selecting two different narrowband filters in each wheel. The filter selection has been one of the tasks of the Instrument Science Team chaired by Adriano Fontana (Monte Porzio). The final selection is shown in Table 1. Apart from the usual broad and narrow-band filters, note the methane-band filter for detection of cool brown dwarfs, and three cosmological narrow-band filters for detection of redshifted Lyman and hydrogen alpha emission lines. HAWK-I will attach to the Nasmyth adapter as shown in Figure 5.

Project progress

The HAWK-I project completed its Final Design Review on November 17th 2004, and is now entering the main manufacturing phase, although procurement of some long-lead time items, such as optics and detectors, has been underway for some time. The beginning of assembly and integration should be in September this year, leading to a Preliminary Acceptance in Europe in mid-2006, and Provisional Acceptance Chile at the end of 2006.

HAWK-I as a first-light Instrument for a VLT adaptive secondary mirror

ESO is currently studying the possibility of equipping HAWK-I with a Ground Layer Adaptive Optics (GLAO) system called GRAAL (Arsenault et al., 2004). Of course an AO correction over the 7.5 arcmin field of view will not deliver diffraction limited images. But as a minimum requirement, the Adaptive Optics must reduce the 50 % encircled energy diameter by 15 % in Y and 30 % in Ks band, when the natural seeing is 1 arcsec. The ultimate goal of the AO system is to correct the atmospheric turbulence such that the instrument resolution becomes the limiting factor. That is, the Adaptive Optics system will provide the equivalent image quality to 0.2 arcsec seeing. This would impact virtually all observing programmes with better sensitivity and spatial resolution.

The feasibility of a deformable secondary mirror and laser system for the VLT is currently being investigated. The results of this study, as well as the operational impact of such a facility, will be reviewed in the third quarter of 2005, with a decision to proceed with the development, including laser tomography, to be taken possibly at the end of 2005. Although a GLAO capability would come well after HAWK-I commissioning, the requirements for AO have been incorporated into the HAWK-I design already. These include allowing sufficient weight budget and space between the cryostat window and instrument rotator for an AO module. Tip-tilt correction must be done with natural guide stars, and options exist to use either the on-chip guide star mode of the Hawaii-2RG detectors, or to have a separate NGS pickoff ouside the instrument. A Conceptual Design Review for the HAWK-I AO was held the day after the HAWK-I instrument PDR in December 2004.

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ESO's Two Observatories Merge

On February 1, 2005, ESO merged its two observatories, La Silla and Paranal, into one. This move will help ESO to better manage its many and diverse projects by deploying available resources more efficiently where and when they are needed. The merged observatory will be known as the La Silla Paranal Observatory.

Catherine Cesarsky, ESO's Director General, commented on the new development: "*The merging, which was planned during the past year with the deep involvement of all the staff, has created unified maintenance and engineering (including software, mechanics, electronics and optics) departments across the two sites, further increasing the already very high efficiency of our telescopes. It is my great pleasure to commend the excellent work of Jorge Melnick, former director of the La Silla Observatory, and of Roberto Gilmozzi, the director of Paranal.*"

La Silla, north of the town of La Serena, has been the bastion of the organization's facilities since 1964. It is the site of two of the most productive 4 m class telescopes in the world, the New Technology Telescope (NTT) – the first major telescope equipped with active optics – and the 3.6 m, which hosts HARPS, a unique instrument capable of measuring stellar radial velocities with an unsurpassed accuracy better than 1 m/s, making it a very powerful tool for the discovery of extra-solar planets. In addition, astronomers have also access to the 2.2 m ESO/MPG telescope with its Wide Field Imager camera. Moreover, the infrastructure of La Silla is still used by many of the ESO member states for targeted projects such as the Swiss 1.2 m Euler telescope and the robotic telescope specialized in the follow-up of gamma-ray bursts detected by satellites, the Italian REM (Rapid Eye Mount). La Silla is also in charge of the APEX (Atacama Pathfinder Experiment) 12 m sub-millimetre telescope which will soon start routine observations at Chajnantor, the site of the future Atacama Large Millimeter Array (ALMA). The APEX project is a collaboration between the Max Planck Society in Germany, the Onsala Space Observatory in Sweden and ESO.

Paranal is the home of the Very Large Telescope (VLT) and the VLT Interferometer (VLTI). Antu, the first 8.2 m Unit Telescope of the VLT, saw First Light in May 1998, starting what has become a revolution in European astronomy. Since then, the three other Unit Telescopes – Kueyen, Melipal and Yepun – have been successfully put into operation with an impressive suite of the most advanced astronomical instruments. The interferometric mode of the VLT (VLTI) is also operational and fully integrated in the VLT data flow system. In the VLTI mode, one state-of-the-art instrument is already available and another will follow soon. In addition to the state-of-the-art Very Large Telescope and the four Auxiliary Telescopes of 1.8 m diameter which can move to relocate in up to 30 different locations feeding the interferometer, Paranal will also be home to the 2.6 m VLT Survey telescope (VST) and the 4.2 m VISTA IR survey telescope.

Both Paranal and La Silla have a proven record of their ability to address the current issues in observational astronomy. In 2004 alone, each observatory provided data for the publication of about 350 peer-reviewed journal articles, more than any other ground-based observatory. With the present merging of these top-ranking astronomical observatories, fostering synergies and harmonizing the many diverse activities, ESO and the entire community of European astronomers will profit even more from these highly efficient research facilities.

(based on ESO Press Release 03/05)

New observing modes of NACO

After more than two years of regular operation, a number of upgrades have recently been installed for NACO and offered to the community. The article describes the new observing modes and provides examples of astronomical applications in high-contrast imaging, spectroscopy and polarimetry.

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NAOS-CONICA (hereafter NACO) is a near-infrared imager and spectrograph fed by an Adaptive Optics (AO) system to correct for optical aberrations introduced by atmospheric turbulence. NACO saw first light on November 25, 2001, at VLT UT4 (Brandner et al. 2002, Lagrange et al. 2003, Lenzen et al. 2003) and has been offered to the astronomical community since October 2002 (period 70). Since then, the science output of NACO amounts to more than 30 refereed articles with several highlights such as the confirmation of the black hole in the Galactic Centre (Schödel et al. 2002) and discovery of its flares (Genzel et al. 2003), as well as the dynamical calibration of the mass-luminosity relation at very low stellar masses and young ages (Close et al. 2005, see Figure 1).

The AO system NAOS was built by a French consortium comprised of Office National d'Etudes et Recherches Aérospatiales (ONERA), Observatoire de Paris and Laboratoire d'Astrophysique de l'Observatoire de Grenoble (LAOG). It compensates for the effects of atmospheric turbulence (seeing) and provides diffraction-limited resolution for observing wavelengths from 1 to 5 µm, resulting in a gain in spatial resolution by a factor of 5 to 15 (diffraction limit of an 8-m-class telescope in *K*-band corresponds to 60 mas). Active optical elements of NAOS include a tip-tilt plane mirror and a deformable mirror (DM) with 185 actuators. NAOS is equipped with two Shack-Hartmann type wavefront sensors (WFS) for wavefront sensing at optical (450 to 950 nm) and near-infrared (0.8 to 2.5 µm) wavelengths.

The near-infrared imager and spectrograph CONICA was built by the German Max-Planck-Institutes für Astronomie (MPIA) and für Extraterrestrische Physik (MPE) and ESO. In its original configuration, CONICA already provided six cameras for imaging and long-slit spectroscopy in the near-infrared between 1 µm and 5 µm at various spatial and spectral resolutions on a 1 × 1 kilopixel Aladdin detector, about 40 different filters for broad- and narrow-band imaging, Wollaston prisms and wiregrids for polarimetry, various grisms and a cryogenic Fabry-Perot interferometer for spectroscopy, as well as a Lyot-type coronagraph with different mask diameters.

The great flexibility of the instrument concept triggered many ideas on how the capabilities of NACO could be extended and optimized for certain specialized astronomical applications. For example, NACO was lacking a differential imaging mode and an adequate coronagraphic mode for high-contrast observations close to bright stars with the ultimate goal of detecting extrasolar planets. Both concepts are new developments for this kind of observations and have proven in theory to enhance the achievable contrast by orders of magnitude (Marois et al. 2000, Rouan et al. 2000). Additionally, new spectroscopic and polarimetric modes have been proposed with the main goal of increasing NACO's efficiency and minimize time overheads. Table 1 lists and briefly describes the recently offered modes and upgrades, of which the major ones will be discussed in the following sections of this article.

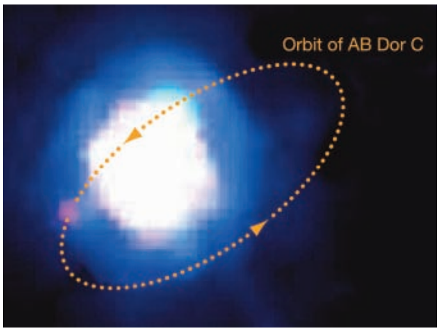

Figure 1: An enhanced false color infrared image of AB Dor A and C. The faint companion "AB Dor C" – seen as the pink dot at 8 o'clock – is 120 times fainter than its primary star. This is the faintest companion ever directly imaged within 0.156″ of its primary. Nevertheless, the new NACO SDI camera was able to distinguish it as a slightly "redder speckle" surrounded by the "bluer" speckles from AB Dor A. It takes 11.75 years for the 93 Jupiter mass companion to complete this orbit shown as a orange ellipse.

Upgrade	Date of installation	Offered since	Short description
SDI (simultaneous differential imager)	08/2003	P74	Uses a quad filter to take images simultaneously at 3 wavelengths surrounding the *H*-band methane feature at 1.62 µm. Performing a difference of images in these filters reduces speckle noise and helps to reveal faint methane companions next to bright stars.
4QPM (Four quadrant phase mask)	01/2004	P74	Subdivides the focal plane in quadrants and delays the light in two of them by half a wavelength at 2.15 µm. This coronagraphic technique helps to suppress the light of a star in order to reveal faint structures surrounding it.
Low-res prism	04/2004	P74	Allows for simultaneous spectroscopy from *J*- to *M*-band at R = 50 to 400.
Order sorting filters SL and SHK	04/2004	P74	Allows for *L*-band and *H+K*-band spectroscopy at various spectral resolutions.
Fabry-Perot interferometer	–	P74	Allows for narrow band (2 nm) observations tunable between 2 and 2.5 µm (for more information see Hartung et al. 2004).
Superachromatic retarder plate	04/2004	P75	Facilitates polarimetry by providing the possibility to rotate the position angle of polarization. Linear structure can thus be observed over the entire FoV and observation overheads are reduced.
New Aladdin III detector	05/2004	05/2004	Replaces old Aladdin II detector and has better cosmetics, linear range and read-noise.

Table 1: NACO upgrades

New Aladdin III detector

The most recent upgrade of NACO performed by the ESO IR department in collaboration with MPIA was the replacement of the CONICA Aladdin II detector. At larger reverse bias voltages (high dynamic range) the cosmetic properties of the old Aladdin II array were degraded substantially by a large number of warm pixels. For this reason, it was operated close to full well applying a low reverse bias voltage (for NACO users defined as high sensitivity mode) resulting in an acceptable cosmetic appearance. However, the charge storage capacity of the detector in this mode was small, and – as a property common to all infrared detectors operating in capacitive discharge mode – the response was quite nonlinear close to the full well capacity. The new Aladdin III array promised substantial improvements of the cosmetic properties.

After installation, the new detector behaved as expected and showed greatly improved cosmetic properties. In addition, it also showed lower read-noise and flux zero points which are lower by 0.1–0.4 magnitudes, suggesting a higher quantum efficiency of the new array as summarized in Table 2.

Simultaneous Differential Imager (SDI)

Radial velocity searches provide evidence that giant extrasolar planets are common. By September 2004, 136 extrasolar planets had been discovered and about 6% of the observed stars in the solar neighborhood host extrasolar planets (see *www.exoplanets.org*). However, the radial velocity method is most sensitive to planets in close orbit up to a few AU and cannot measure parameters other than the planet's orbit and mass with an uncertainty due to the unknown inclination of the orbit. Direct detection of extrasolar planets is required if we are to learn about the objects themselves. With direct detection we can analyze photons directly from the companions allowing us to measure L_{bol}, T_{eff}, Spectral Type, and other critical physical characteristics of these poorly understood objects.

Young (100 Myr old) and massive (couple of Jupiter masses to 12 Jupiter masses) extra-solar planets are 100000 times more self-luminous than old (5 Gyr) extra-solar planets, whereas their host stars are only slightly brighter when this young. The luminosity contrast between them can thus be in the range 10^{-4} to 10^{-6} with the precise value depending on age and mass of the planet. Currently the majority of such young stars that are nearby (< 50 pc) are located in the southern star forming regions and associations (DEC < –20). To detect a faint planet near a bright star requires the high Strehl ratios delivered by NACO. However, NACO (like all AO systems) suffers from a limiting "speckle-noise" floor which prevents the detection of planets within 1″ of the primary star. Hence NACO required some method to suppress this limiting "speckle noise" floor, so planets could be imaged within 1″ of their primary star.

The SDI concept to reduce speckle noise by L. M. Close from Steward Observatory and R. Lenzen from MPIA (Lenzen et al. 2004) is based on a method presented by Marois et al. (2000). This method exploits the fact that all extra-solar giant planets cooler than about 1300 K have strong CH_4 (methane) absorption past 1.62 µm in the *H*-band NIR atmospheric window, making the planet virtually disappear at this wavelength. The difference of two images taken simultaneously on either side of the CH_4 absorption therefore efficiently removes star and speckle noise while the planet remains. A critical point of the design is the differential optical aberration after the two wavelengths have been optically separated. It has to be kept very small (< 10 nm rms) in order to match the speckle pattern at the two wavelengths and efficiently remove it by the image subtraction.

Figure 2 shows the optical concept of SDI. A double Wollaston prism, made of two identical Calcite Wollaston prisms rotated against each other by 45 deg, splits the beam into four beams of equal brightness (for unpolarized objects). The f/40 camera images the four beams onto the detector with a minimum separation of 320 pixels or 5.5″ at the pixelscale of 17.2 mas per pixel. Currently, the field of view is limited by a field mask and the usable detector area to about 3″ × 3.7″. Just in front of the detector, each of the beams passes through one of a set of narrow band filters with central wavelengths of 1.575, 1.600 and 1.625 µm and a FWHM of 25 nm.

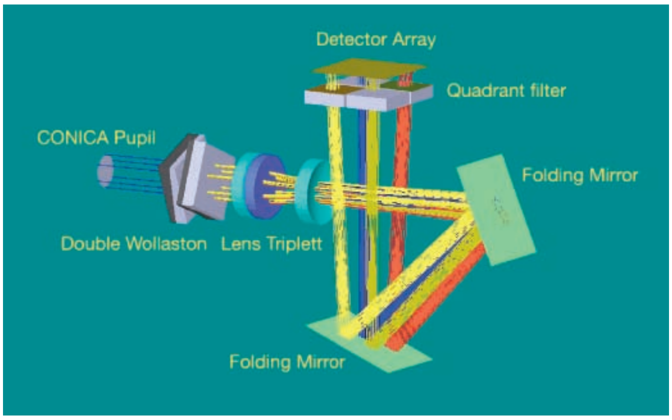

Figure 2: SDI optical concept. A double Wollaston prism splits the beam into four which are imaged through different filters located on the either side of the *H*-band methane feature at 1.62 µm.

	Pixels with variable dark current [%]			Readout noise [ADU]		Zero Points [mag]		
	High sensitivity	High dynamics	High well depth	Uncorr	Fowler	J	H	Ks
Aladdin II	0.72	7.1	56	5.6	2.1	24.01	23.87	22.99
Aladdin III	0.023	0.156	2.43	4.42	1.29	24.47	24.22	23.31

Table 2: Main properties of the old (Aladdin II) and the new (Aladdin III) Conica arrays.

The f/40 imaging optics was built such that it could just replace the existing camera L100 which had never been offered.

The contrast ratio achievable by SDI is more than two magnitudes better than that achieved by standard imaging and PSF subtraction using a subsequently observed point source. Figure 3 shows the achievable contrast for 5 sigma detection as a function of angular separation for a 32 minute exposure. The highest contrast ("double filtered") is achieved by subtracting the images taken at two different rotator angles in addition to the dual image subtraction in order to reduce the remaining instrumental speckles and by filtering out the low spatial frequencies of the images. SDI removes most of the speckle noise such that the contrast is mostly limited by stellar photon noise at intermediate angular separations and by sky background and detector read-out noise at larger angular separations. In both cases, the achievable contrast can be further improved by increasing the integration time. Figure 4 shows a reduced double filtered SDI image. Companions 9.5 magnitudes fainter than the star, are easily detected outwards of 0.5″.

Although mainly conceived for exoplanet imaging, SDI is also very useful for observations of objects with thick atmospheres in the solar system like Titan. Peering at the same time through a narrow, unobscured near-infrared spectral window in the dense methane atmosphere and an adjacent non-transparent waveband, Figure 5 shows Titan's surface regions with very different reflectivity in unprecedented detail when compared to other ground-based observations.

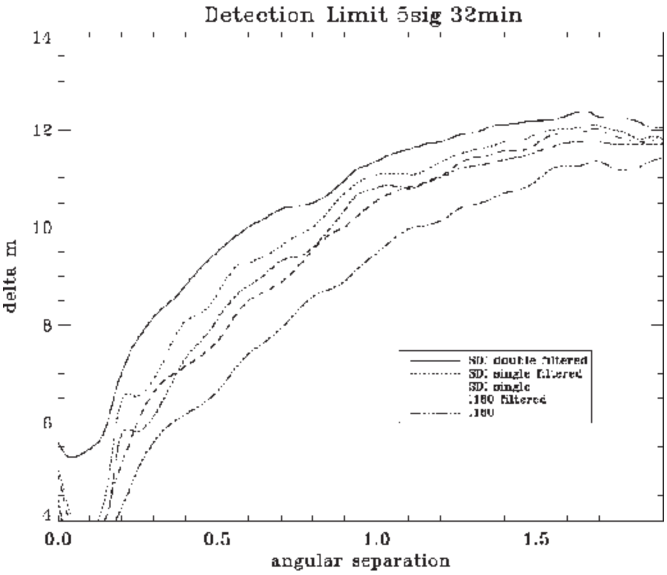

Figure 3: SDI detectivity as a function of angular separation from the star using different data reduction schemes. 'SDI double filtered' is a technique where the instrument is ro-tated half way through the observation to calibrate instrumental speckles with subsequent filtering of low spatial frequency structures. 'I160' denotes conventional imaging without speckle removal.

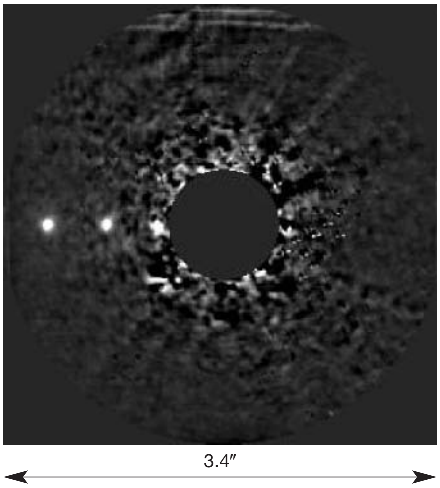

Figure 4: Final SDI image (double filtered) derived from real data which was used to derive the detection limits shown in Figure 3. The three artificial companions at 0.5″, 1″ and 1.5″ with Δmag = 9.5 (5σ detection at 0.5″) are clearly visible.

Four-quadrant phase mask (4QPM)

As for the SDI, the main scientific motivation for the 4QPM coronagraph is to increase the contrast of faint objects around bright stars. Besides the search for faint point sources as described in the previous section, the 4QPM can be used to look for hot dust around AGN (see e.g. Gratadour et al. 2005), quasar host galaxies or circumstellar emission produced by disks very close (0.1″ to 0.5″) to the central point source.

The four quadrant phase-mask coronagraph was proposed by Rouan et al. (2000). The focal plane is split into four equal areas, two of which are phase-shifted by π. As a consequence, a destructive interference occurs in the relayed pupil, and the on-axis starlight transferred outside the geometric pupil is blocked by a so-called Lyot stop. The advantage of the 4QPM over the Lyot mask is twofold: (1) no large opaque area at the centre and an inner working radius of about

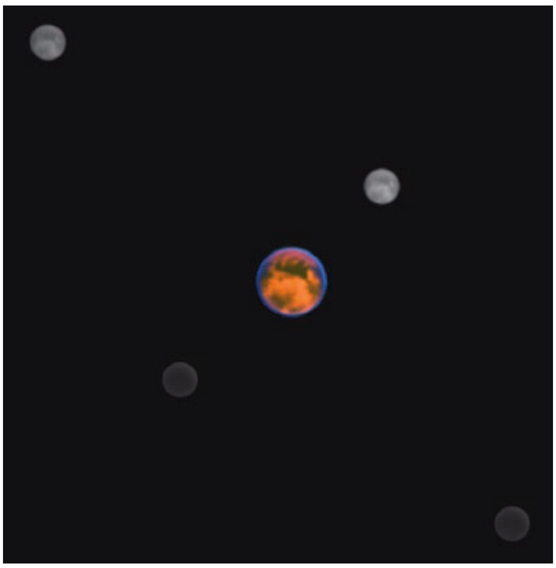

Figure 5: Titan imaged with SDI. The picture shows Titan imaged through the 4 channels of the SDI camera. Obviously, Titan appears very faint and featureless when imaged inside the methane band in the barely visible lower two images. The central color image is the difference between the out- and in-band images and has been added to the picture afterwards.

1 Airy disc, and (2) a larger achievable contrast if good optical quality is met.

The actual concept of the 4QPM in NACO as proposed by LESIA, Observatoire de Meudon, consists of a SiO_2 substrate with a 2.5 µm thick SiO_2 layer deposited on two of the quadrants. This device is placed in the CONICA mask wheel and has a working wavelength of 2.15 µm where it achieves the π phase-shift and maximum light rejection. The theoretically achievable PSF attenuation deteriorates with the square of the wavelength deviation from optimum. In practice, residual wavefront errors dominate over chromatic effects, and PSF core attenuation of about a factor 10 can be achieved all over the *K*-band while it drops to a modest factor of 4 in *H*-band (Boccaletti et al. 2004). Figure 6 displays the radial point source sensitivity achieved with NACO in a 10 minutes exposure observing a bright star. The actually achievable 4QPM performance and the contrast improvement by subtracting a subsequently observed reference PSF star strongly depend on the quality and stability of the AO correction.

Figure 7 (top) shows a beautiful example of an astronomical application of the 4QPM published by Gratadour et al.(2005). The observations show a complex environment closer to the nucleus than previously imaged at this wavelength. The identified structures are similar to what has been observed previously at longer wavelengths (3.8 and 4.8 µm), similar resolution, but without coronographic mask. Up to now they were totally hidden by the dominating emission of the nucleus at *Ks*. Shape and photometry are in very good agreement with the previous interpretation of elongated knots, shaped by the passage of a jet, and composed of very small dust grains, transiently heated by the central engine of the AGN. On the bottom of the figure, the image of a triple system HIP 1306 demonstrates the enhanced contrast for close companion detection achievable with the 4QPM.

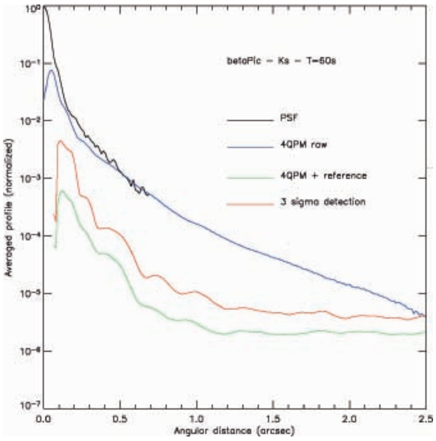

Figure 6: Radial detectivity of the 4QPM. The achievable 3σ detectivity is 10^{-4} (10 mag) at 0.5″ and 10^{-5} (12.5 mag) at 1″. Stellar residuals, i.e., the quality of the PSF reference subtraction, dominate at short angular distance, while sky and detector noise dominate at larger angular separations for this star magnitude and exposure time (courtesy Anthony Boccaletti).

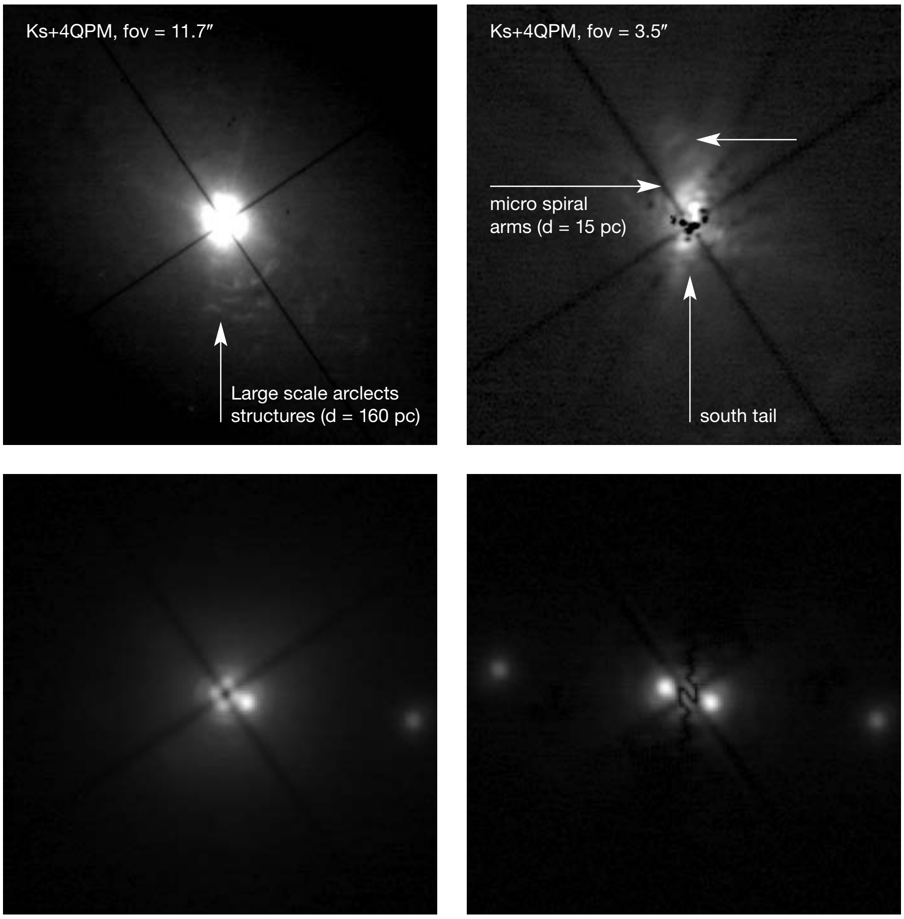

Figure 7: Top: Structures around NGC 1068 revealed at both large and close separations. The image to the right is PSF reference star subtracted. The contrast of known structures is improved with respect to previous non-coronagraphic observations (Gratadour et al. 2005). Bottom: Triple system imaged with the 4QPM. The two companions are at separations of 0.128″ and 1.075″ with brightness ratios to the main surpressed primary of Δm = 1.6 and 3.5 mag (Boccaletti et al. 2004).

Low-resolution prism

There are a number of research projects in which simultaneous, moderate resolution spectro-photometry would be useful and, in some cases, essential. Perhaps the most pressing and important case presently is the exploration of the infrared flares from the Galactic Centre black hole discovered with NACO. The flares promise to be a key tool for studying the physical processes in the strong gravity regime just outside the event horizon. For a better understanding of the emission mechanisms, it is necessary to obtain simultaneous spectral energy distributions (SED) across the *H*-through *L/M*-bands. Since the flares last typically only one hour and have time substructure of 10–20 minutes, it is not possible to obtain the data sequentially. Subtle time variability of the SED, as expected if gas falls in through the innermost accretion zone and experiences increasing gravitational redshift, also calls for simultaneous information. Other fields where the proposed new mode would be extremely useful are determination of stellar types in dense star clusters, dust features in AGN environments and spectral characterization of brown dwarfs with deep and characteristic broad atmospheric IR features.

The concept of the low spectral resolution mode of NACO has been developed by R. Lenzen from MPIA. $SrTiO_3$/CsBr turned out to be the best combination of a high dispersion and a low dispersion material, providing high transmission and a rather constant dispersion for the whole wavelength region. Figure 8 shows the spectral resolution achievable with different material combinations over the spectral range of the CONICA detector.

The low resolution prism was used by the Galactic Centre Group of the Max-Planck-Institut für Extraterrestrische Physik in July 2004 with the aim of measuring the spectral slope of the flaring source at SgrA* in the Galactic Centre. Since no flare was seen during this run, spectra of several stars in the central cluster were obtained instead, as a feasibility test and to better characterise the performance of the prism. The adaptive optics loop was closed on the infrared-bright IRS 7, using the infrared wavefront sensor. Due to the high extinction towards the Galactic Centre ($A_V = 30$ mag), there is little to be seen shortward of *H*-band; and because the *JHK* dichroic was used for the infrared wavefront sensor (in order to be able to detect the *LM*-bands) a 2.5 µm short cutoff filter was inserted. The resulting normalized *LM*-band spectra of 3 stars are shown in Figure 9 (IRS 7 with $K \sim 6.7$, IRS 16 NW with $K \sim 9.5$, and IRS 33 N with $K \sim 10.5$). Wavelength calibration was rather tricky and eventually achieved via a combination of narrow-band filter images and matching atmospheric absorption features. No correction for extinction has been applied to these spectra. Seeing limited *L*-band spectra of several other Galactic Centre stars have previously been published by Moultaka et al. (2004), and similar features can be clearly identified: H_2O ice absorption at 3.0 µm; CH_2 and CH_3 absorption at 3.4 µm; Pf γ and Brα emission at 3.74 µm and 4.05 µm respectively. The *M*-band data are the first such spectra of these Galactic Centre stars. The extraction of a spectrum for at least one of the S-sources (not shown) indicates that it should certainly be possible to obtain a 3–5.5 µm spectrum of a flare from SgrA* if one should be lucky enough to be using the prism at the right time. Actually, a *K*-band spectrum of a Galactic centre flare was obtained in July 2004 with the adaptive optics based 3D IR spectrometer SINFONI during its first commissioning run.

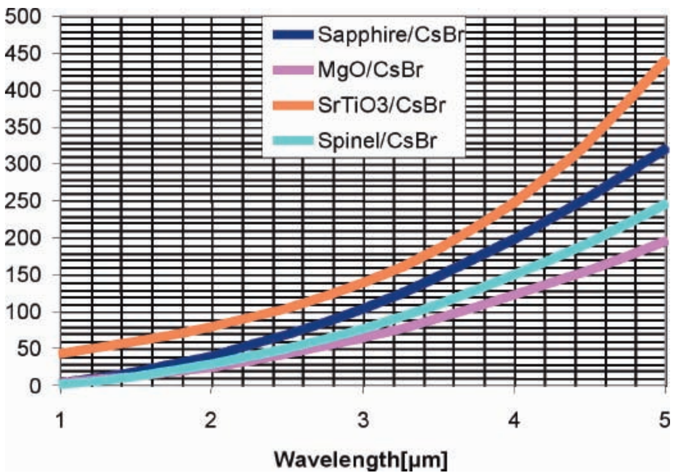

Figure 8: Spectral resolving power over the CONICA NIR range provided by prisms of different composition.

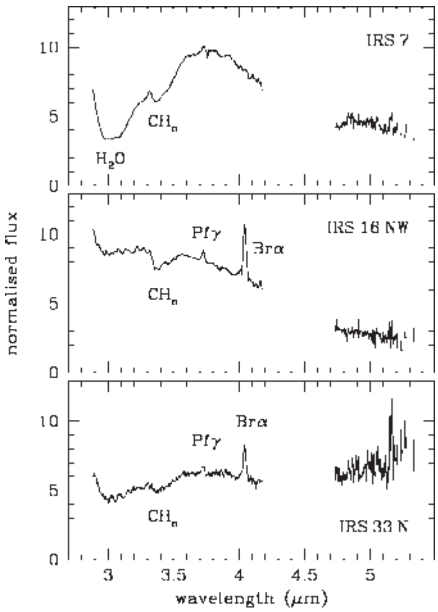

Figure 9 (left): *LM*-band spectra of IRS 7 with $K \sim 6.7$, IRS 16 NW with $K \sim 9.5$, and IRS 33 N with $K \sim 10.5$ obtained with the new low resolution prism.

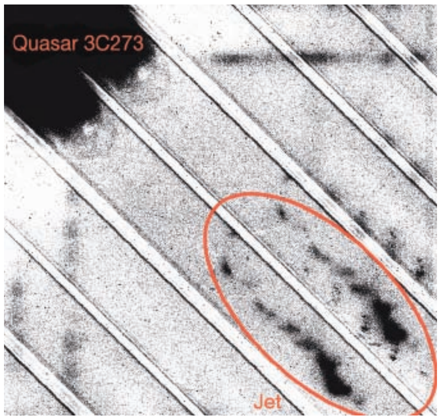

Figure 10 (below): Polarization data of the quasar 3C273 jet. NACO has been rotated to align the jet with the Wollaston stripe mask. The retarder plate can be used to turn the polarization direction in order to derive the polarization map (image prepared by Sebastian Jester).

Superachromatic retarder plate

For the detailed study of extragalactic radio jets NACO is a unique instrument. Especially in its polarization mode, information can be collected which can be combined with radio data at the same resolution in order to gain insight into the physics of these objects. Polarization studies in dusty star forming regions, circumstellar discs and envelopes, and scattering regions in AGN are other central areas where NACO is unparalleled.

Before the upgrade, polarimetry was possible using two Wollaston prisms with position angles 0° and 45° with two main limitations: (1) Linear structures (like a jet) could not be covered at once over their entire length, if these objects were longer than the angular separation of the Wollastons (3.3″). Then multiple images were necessary to cover the object completely, as by rotation to e.g. 45°, part of the object will fall out of the stripe mask. (2) With each rotation of the instrument between 0° and 45° a new alignment of the telescope pointing was necessary, leading to a substantial overhead in polarization observations.

With the new turnable retarder plate at the instrument entrance, just one Wollaston prism is used, and rotation of the plane of polarization is done by turning the plate. The retarder plate was put in place of the never offered TADC-device and is located about 12 cm pre-focal within the converging f/15 beam. The resulting focus shift due to the achromatic plate thickness of about 8 mm (3.43 mm MgF_2 thickness, 4.35 mm Quartz plate thickness) can be compensated by focus offsetting NAOS.

Figure 10 shows an example of polarimetry with NACO using one Wollaston prism and the retarder plate. The scientific goal of the observations was a polarization map of the jet of the quasar 3C273. The jet extends out to about 20″ from the quasar core located in the upper left. For this image, 94 exposures of 100 seconds each (NDIT = 1) have been added up. Only the common area of the field is shown. The jet does seem to exhibit a polarization signal (most conspicuous at inner and outer knots). Because the quasar is so bright, the image also reveals reflections due to the half wave plate and electronic ghosts within the detector.

Outlook

Although no further additional observing modes are planned so far, the work on NACO has not yet finished. The next major improvement of the system will be the installation of the Laser Guide Star Facility planned for spring/summer 2005. Additional components that NACO requires to operate with an LGS such as an additional STRAP tip tilt sensor as well as the necessary software upgrades have already been installed and tested. The first commissioning of NACO with the LGS is foreseen for fall/winter 2005. Then, a much larger fraction of astronomical objects will be accessible to the superb observing modes offered by NACO.

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Observing with the ESO VLT Interferometer

The ESO VLT Interferometer (VLTI) has been in operation since achieving First Fringes in March 2001. A broad spectrum of activities has been covered ranging from commissioning, shared-risk science observations, science demonstration and guaranteed time observations, to regular observation programmes in service and visitor mode. The VLTI operations scheme is fully integrated into the well established regular operations scheme of all VLT instruments. In particular, the same kind and level of service and support is offered to users of VLTI instruments as to users of any instrument at the single UTs on Paranal. Thereby, the VLTI has become worldwide the first general-user optical/infrared interferometric facility offered with this kind of service to the astronomical community.

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European Southern Observatory

The ESO VLT scheme allows astronomers to submit visitor mode or service mode observation programmes. In visitor mode, the astronomer is present at the telescope and can adapt the programme to specific requirements at the time of observation. In service mode, the observation details and constraints are submitted to ESO beforehand, and the observations are scheduled and carried out by ESO staff.

Service mode observing was conceived by ESO in the early days of the planning of VLT operations as a key component in optimizing the scientific return and the operational efficiency (cf. Comerón et al. 2003). The VLTI science operations scheme profits enormously from the experience gained during service mode observations at the single UTs since April 1999 and the implemented infrastructure. It follows and is fully integrated into the regular VLT operations scheme from the initial preparation of the proposal to the delivery of the data.

Table 1 shows the numbers of scheduled programmes using VLTI instruments (so far MIDI only) for the ESO observing periods P73 (observations from April to September 2004), P74 (October 2004 to March 2005), and P75 (April to September 2005). The first regular VLTI observing period (P73) has been concluded with a completion rate of 80% of the scheduled service mode observing blocks (OBs). These regular VLTI observing periods were preceded by commissioning and shared-risk science observations using the *K*-band commissioning instrument VINCI, as well as by observations within MIDI and AMBER science demonstration and guaranteed time programmes. These observations greatly helped to establish the VLTI-specific aspects of the regular operations scheme as well as to test the overall data flow system for the VLTI instruments (cf. Ballester et al. 2004).

Also shown in Table 1 are the distributions of the regular VLTI programmes scheduled so far among programme types, observing modes, as well as scientific categories (B: Galaxies and galactic nuclei; C: Interstellar medium, star and planet formation; D: Stellar evolution). Evidently, by far most of these programmes are normal programmes. A clear majority of programmes are executed in service mode, which is partly caused by the need to combine different baseline configurations (see below). There is an increasing number of scheduled programmes within the scientific category B, while the majority of the VLTI programmes are so far about equally distributed among scientific categories C and D. On the subject of this article, see also the proceedings of the 2002 Les Houches EuroWinter School "Observing with the Very Large Telescope Interferometer", edited by G. Perrin and F. Malbet. A recent description of the technical status of the VLTI can be found in Glindemann et al. (2004) and references therein. In the following, we discuss specific aspects regarding VLTI observations as currently offered to the community.

Why use the VLTI for astrophysics?

Modern astronomical observatories have succeeded in measuring the flux density across the electromagnetic spectrum for many cosmic objects, at least for the brightest objects in each important class. While one further desires to obtain the flux densities of fainter and more distant targets, another obvious goal is to map out each object's intensity structure, as a function of wavelength, in as much detail as possible (cf. Rees 2000).

For optical and infrared wavelengths, several interferometric facilities have been operated for this purpose[1]. These facilities, however, have so far often been limited to the brightest stars owing to their small collecting areas, and have often not been very easy to use for any astronomer. With the construction of the Keck and VLT Interferometers including 8–10 m class telescopes, optical/infrared interferometry is now also feasible for relatively faint sources. This, for instance, promptly enabled the first near- and mid-infrared long-baseline interferometric measurements of active galactic nuclei. In addition, the VLTI instruments provide unprecedented spectro-interferometric capabilities. Finally, as the science operations of the VLT Interferometer were integrated into the regular science operations scheme of the instruments at the single 8 m telescopes, VLTI observations can now be relatively easily performed by any astronomer.

The range of astrophysical topics that can be addressed by the VLTI can be seen by looking at the science that has already been achieved using optical/infrared interferometers. General results were reviewed by, for instance, Quirrenbach (2001), Baldwin & Hanniff (2002), and Monnier (2003). First scientific results that emerged from the VLTI

[1] See the overview provided by Peter Lawson at *http://olbin.jpl.nasa.gov*

Period	Total	Type			Mode		Category		
		Normal	GTO	DDT	s	v	B	C	D
73	23	18	4	1	15	8	1	12	10
74	19	14	4	1	13	6	2	8	9
75	24	20	4	–	18	6	3	12	9
Total	66	52	12	2	46	20	6	32	28

Table 1: Scheduled VLTI (MIDI) programmes in ESO observing periods P73–75. Listed are the total numbers of scheduled runs, as well as the distribution of programme types (normal, guaranteed time observations (GTO), director discretionary time (DDT) programmes), of programme modes (service mode 's' or visitor mode 'v'), and of scientific category ('B': Galaxies and galactic nuclei; 'C': Interstellar medium, star and planet formation; 'D': Stellar evolution).

were reviewed by Richichi & Paresce (2003), and more recent astrophysical results from the VLTI are summarized by Wittkowski et al. (this issue, page 36).

Terminology related to interferometric observations

The principle of an observation of a celestial light source with an interferometer corresponds to the classical experiment by Thomas Young in 1803 that first showed the wave nature of light. Details on the principles of optical interferometry in astronomy can be found as well in the articles mentioned above (Quirrenbach 2001; Baldwin & Haniff 2002: Monnier 2003). Also, the textbook-style proceedings "Principles of Long Baseline Stellar Interferometry" of the 1999 Michelson Summer School in Pasadena, edited by Peter R. Lawson, provide an excellent introductory overview of the technique and application of optical interferometry (available at *http://olbin.jpl.nasa.gov/iss1999/coursenote.html*).

The primary observables of an interferometer are the amplitude and phase of the observed interference pattern, also called "fringe pattern" or just "fringes". These quantities, when normalized, are also referred to as amplitude and phase of the complex "visibility". The object intensity distribution and the complex visibility are related by a Fourier transform. The spatial frequencies are often denoted u and v, and the Fourier plane is also called the "uv-plane". The total flux of the source within the field of view multiplied with the visibility amplitude for a given experiment is called the "correlated flux", corresponding to the "correlated magnitude".

The theoretical visibility amplitude of a point source is unity for any wavelength and baseline. A source is called "unresolved" (with a given instrumental setup) if its angular diameter is so small that the visibility amplitude with the given instrumental setup is consistent with unity within the precision of the measurement.

In practice, the measured visibility amplitude of a point source would be less than unity due to losses caused by atmospheric and instrumental perturbations. The real visibility amplitude of a point source as it would be obtained in an observation is called the "transfer function". To measure the transfer function, stars of known, and ideally as small as possible angular diameter are observed, and the ratio of theoretically expected and measured visibility amplitude is derived. This experimental transfer function will change due to changes of atmospheric and instrumental conditions on time scales of minutes to years.

The phase of the observed fringe pattern is disturbed by unknown atmospheric perturbations of the refractive index above each telescope on different time scales down to typically a few milliseconds at optical wavelengths, the "coherence time" of the atmosphere. This means that the observed fringe pattern constantly moves and that the integration time that is used to record the interferometric fringes can not be much longer than this time scale. To overcome this limitation, a fringe-tracking instrument, or "fringe tracker", can be used that monitors and corrects at high frequency the phase variations of the observed fringe pattern in order to stabilize it. Then, a scientific instrument can record the stabilized fringe pattern with a much longer integration time in order to improve the precision and to observe fainter targets.

Despite the use of a fringe tracker, the unknown differences of the atmospheric perturbations above each telescope cause the measured visibility phase not to correspond to the object phase of the scientific target. There are two ways to overcome this limitation. (1) The phase of the complex triple product (also called the "closure phase"), formed by multiplication of three complex visibilities corresponding to three baselines forming a triangle, is not corrupted by the phase noise caused by atmospheric turbulence, and thus gives directly the object closure phase of the scientific target. (2) If two close targets are observed through the same atmospheric pattern at the same time, and the object phase of one of the targets is known, the object phase of the unknown target can be derived relative to that of the known target. This information also includes the angular distance between the (photocentres of the) two targets, and can be used for astrometry. Also, if one target is simultaneously observed at two sufficiently close wavelength bands, the difference of the object phase at these bandpasses (of the same target) can be derived.

Overview of the VLTI

The VLTI comprises four fixed 8 m Unit Telescopes (UTs) and four movable 1.8 m Auxiliary Telescopes (ATs), two of which already arrived on Paranal. The ATs can be positioned on thirty different stations. Figures 1–3 show views of the VLTI platform. Two science instruments, a near-infrared (AMBER) and a mid-infrared (MIDI) beam-combination instrument, are in operation.

For period 75, the VLTI was offered with all four UTs, equipped with the MACAO Coudé adaptive optics systems, and the mid-infrared interferometric instrument MIDI. During the year 2005 this configuration will be extended significantly. First fringes between the first two ATs were achieved on 3 February 2005. This makes it possible to use the VLTI from now on nearly every night with competitive telescopes for further commissioning and technical tasks, as well as for science operations. It is foreseen to start the science operations with ATs using a small subset of AT configurations, and to expand the number of offered configurations as our experience is growing. For period 76, i.e. observations from October 2005, the MIDI instrument is offered with all UTs, as well as with several AT baselines. The near-infrared closure-phase instrument AMBER is being commissioned, has already obtained its first

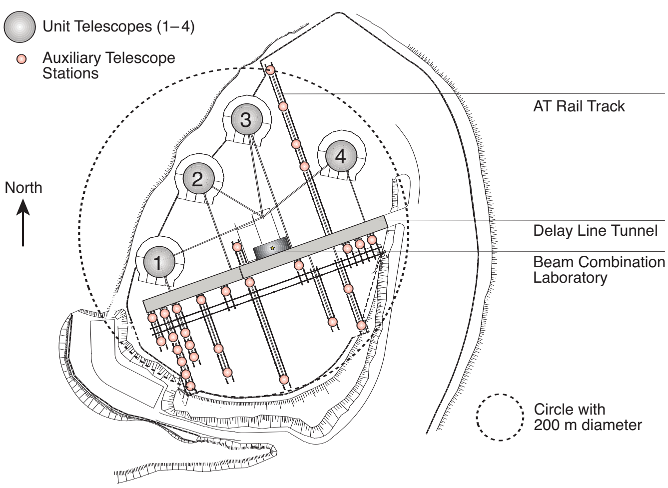

Figure 1: View of the Paranal platform with the position of the four fixed 8 m VLT Unit Telescopes (UTs) and the 30 positions for the movable 1.8 m Auxiliary Telescopes (ATs). Compare with the aerial view in Figure 2 and the recent photograph in Figure 3.

Figure 2: An aerial view of the Paranal platform as of December 1999, still in construction, with the four 8 m UTs and several foundations of the 30 stations for the 1.8 m ATs.

scientific data during the last quarter of 2004 within science demonstration and guaranteed time programmes, and is offered for regular observations with the UTs from period 76 (observations from October 2005).

Additional improvements will arise from the infrared imaging sensor (IRIS), installed in the VLTI laboratory in early January, which will stabilize the image of the observed objects in the focus of the instruments. The fringe tracker FINITO will hold the interferometric fringes in such a way that the science instruments can integrate them for much longer times than otherwise prescribed by atmospheric turbulence. Finally, the phase reference and micro arcsecond astrometry facility (PRIMA) will allow astrometric measurements with high accuracy and to directly retrieve spatial phase information of scientific targets.

The MIDI instrument

MIDI is the mid-infrared instrument of the VLTI. It combines two beams (either from two UTs or from two ATs) to provide visibility amplitudes. The light is dispersed after beam combination with a spectral resolution of either R ~ 30 (prism mode) or R ~ 230 (grism mode). The limiting magnitude for unresolved sources, i. e. the limiting correlated magnitude, is currently N = 3.25 (2 Jy) for service mode observations using the UTs and the prism mode. For visitor mode observations, when the investigator is present at the telescope and can decide whether the acquisition image and achieved beam overlap fulfills expectations, ESO accepts expected correlated magnitudes down to N = 4 (1 Jy). More technical information regarding the MIDI instrument can be found at *http://www.eso.org/instruments/midi/*.

The AMBER instrument

AMBER is the near-infrared phase-closure instrument for the VLTI. The instrument has been designed to combine simultaneously three beams, coming from a triangle of telescope stations, in order to obtain closure phases. The combined beams are spectrally dispersed with resolutions of R ~ 30 (low resolution, LR), R ~ 1500 (medium resolution, MR), or R ~ 10 000 (high resolution, HR). This means that each instantaneous AMBER measurement provides three sets (a set includes a number of spectral channels) of visibility amplitudes, for the three baselines comprising the triangle, as well as one set of triple products (including triple amplitude and closure phase). More technical information regarding the AMBER instrument is available at *http://www.eso.org/instruments/amber/*.

User support and preparation tools for the VLTI

In the same way as for other VLT instruments, all relevant information for the use of VLTI instruments is provided by ESO through different standard documents and via the standard ESO webpages, including the call for proposals, the instrument and template manuals, as well as the webpages with general and instrument-specific proposal and observation preparation instructions.

In order to assess the feasibility of a planned observation with MIDI or AMBER, it is mandatory to estimate the visibility values for the expected intensity distribution of the science target and chosen VLTI configuration. The interactive tool provided and developed by ESO to obtain such visibility estimates is *VisCalc* (Visibility Calculator). A more detailed description of this tool including examples can be found in the recent article by Ballester et al. (2004).

The second tool provided and developed by ESO to support VLTI observation preparation is *CalVin*, which may be used to select, for each science target, a calibration star (cf. Ballester et al. 2004). Based on different user-defined criteria, *CalVin* selects suitable calibrators from an underlying list of calibrators. The strategy to preferably select calibration stars from the limited underlying lists of calibration stars preserves objects which have already been studied. Hence, more and more detailed knowledge of these calibration sources will be rapidly acquired (cf. Ballester et al. 2004). For work related to diameter estimates of calibration stars, see also the last section in Wittkowski et al. (this issue) and references given there.

Proposals for observations using VLTI instruments are prepared and submitted using the standard ESO tool as for any VLT observation (see *http://www.eso.org/observing/proposals/*). For VLTI observations, the proposal includes an additional interferometric table that lists the expected angular sizes of the proposed targets and their expected visibility values and correlated magnitudes (as for instance obtained with *VisCalc*).

The actual observations are prepared with the standard phase 2 proposal preparation (*P2PP*) tool. A detailed description of observation preparation, observation tools, phase 2 and OB preparation can be obtained from the pages of the ESO User Support Department (USD) at *http://www.eso.org/org/dmd/usg/*. Just as with service mode support for any other VLT instrument, VLTI observers can obtain assistance from astronomers at the USD specialized in interferometry.

Sequences of observations

In order to obtain sufficient accuracy and precision of the object visibility values, observing sequences with alternating observations of scientific targets and interferometric calibration stars are performed. The data taken on all calibration stars are public once they arrive in the ESO archive. Hence, each investigator can make use of the information based on all measured calibration stars.

The scientific goal of an interferometric observation campaign can often only be reached if visibility measurements at a range of different points of the *uv*-plane are combined. This can be achieved by combining different ground baselines and by making use of Earth's rotation.

The sky-projected baseline length and angle, as well as the zenith distance, are uniquely defined for a given target and ground baseline configuration by the hour angle, or the local sidereal time, at which the observation is executed. The local sidereal time (LST) at which the observation shall be executed can be inserted into each observation block (OB). By this, observations at different sky-projected baseline lengths and angles can be planned, while the individual OBs are executed as stand-alone entities without the need of linked observations. However, priority is given to completing all observations on a scientific target once they have started. The preparation and planning of such observation sequences is supported by the visibility calculator *VisCalc* (see above).

The constraint sets and scheduling of VLTI observations

The required ground baseline configuration, as well as the local sidereal time at time of execution (see above) are constraints that are specific to VLTI observations and do not exist for observations with instruments at the single UTs. Moreover, the performance of VLTI-specific subsystems such as the adaptive optics systems (MACAO) for VLTI, or the fringe tracker have to be monitored in addition.

On the other hand, other constraints, as for example the requirements for the regular seeing condition or for the lunar illumination may be less important for VLTI observations than for classical VLT instruments such as ISAAC or the FORSes. In general, the scheduling of VLTI observations is complicated by the additional constraints on baseline configuration and LST. As a result, one tries to avoid additional stringent constraints in order to enable a smooth and efficient science operation of the VLTI.

Quality control of VLTI data

Since P73, the MIDI data pass through the entire data flow operations systems in the same way as the data of any other VLT instrument (cf. Ballester et al. 2004). The raw files obtained during service mode observations are processed for quality control purposes using the data reduction system developed by ESO, the algorithms of which have been provided by the MIDI consortium. Each processed OB is associated with a FITS file product containing quality control parameters and results, such as the visibility value and the instrumental transfer function for data of known calibration stars, or a calibrated visibility value for a scientific target. For P73, 80% of the OBs received by the pipeline resulted in data products. For the start of the AMBER science operations, a similar data flow operations system will be available for AMBER data.

Reduction of VLTI data

The ESO pipeline data reduction as described above was developed for quality control purposes and optimized to process most of the data obtained (with a large variety of flux levels, visibility amplitudes, etc.) in an automatic way with acceptable accuracy and precision. A more detailed reduction of data from a specific programme may be necessary for scientific purposes which usually have more stringent requirements for precision and accuracy.

Two data reduction packages are currently available for the scientific reduction of MIDI data, available from MIDI consortium members of the University of Leiden and the Max-Planck-Institute for Astronomy in Heidelberg (a merged version can be found at *http://www.strw.leidenuniv.nl/~nevec/MIDI/index.html*; also see *http://www.mpia-hd.mpg.de/MIDISOFT/*). A third one from the Observatory of Meudon is about to be released to the astronomical community. These packages have some technical differences, the details of which can be found in their documentation. For a given specific purpose, one of these packages may be more suitable than another. Detailed technical information on MIDI data reduction is also being collected and compiled by Christian Hummel, and provided to the user community on an “as is” basis at *http://www.sc.eso.org/~chummel/midi/midi.html*.

So far, one package exists for the reduction of AMBER data, available from consortium member Astrophysical Lab of the Observatory of Grenoble. The AMBER package has not yet been released to the public.

MIDI data reduction will usually result in one calibrated visibility amplitude for each spectral channel and observation. For AMBER, the resulting processed and calibrated data will usually include three calibrated visibility amplitudes, corresponding to the three baselines of the triangle, and one calibrated triple product (triple amplitude and closure phase) for each spectral channel and observation.

If such interferometric data, obtained with a three station array such as the VLTI with the AMBER instrument and taken in several spectral channels and (projected) baseline configurations, are combined, it may already be possible to directly reconstruct the image of a simple object intensity distribution, for example of a binary star. The first optical images reconstructed from such sparsely sampled visibilities and closure phases, obtained with the “Cambridge Optical Aperture Synthesis Telescope (COAST)” and the “Navy Prototype Optical Interferometer (NPOI)”, were presented by Baldwin et al. (1996) and Benson et al. (1997), respectively. However, in the majority of cases so far, and probably as well in the near future, the interpretation of optical/infrared calibrated visibility values and closure phases from long-baseline interferometry is accomplished by comparison to models. A model-predicted object intensity distribution is used to compute the corresponding synthetic visibility values and closure phases for the employed baseline configurations and spectral channels, and these values are compared to the measured ones in order to find agreement or disagreement. Usually, model parameters are adjusted in order to find the best possible agreement with the measured data.

Acknowledgements

The integration of VLTI observations into the regular ESO science operations scheme has involved a lot of people inside and outside ESO, too many to name here. We warmly acknowledge this collective effort.

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Figure 3: A recent photograph taken on the VLTI platform in January 2005 by Bertrand Koehler. The first two ATs, located at station E0 and beside G0, are shown in the foreground, as well as UTs 3 and 4 (MELIPAL and YEPUN) in the background. The building that can be seen in between the ATs is located on top of the interferometric lab, where the beams coming from the UTs or ATs are combined. The beams are sent through an underground light-duct system to the interferometric lab. Courtesy B. Koehler.

Improvements at the 3.6 m Telescope

A summary of the 3.6 m image quality improvement is presented with the latest M2 upgrade and its results.

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In the early days of the 3.6 m the delivered image quality was not optimal. Image quality analysis was done almost always at the zenith using the “pupil plate”, a photographic method with defocused images. The image quality was not verified systematically at positions far from the zenith. Coma aberration was corrected by a time consuming mechanical and manual re-collimation of the M2 tilt. Other aberrations were present but found to be unstable and with unclear origins at that time. Mechanical analysis of the telescope flexure performed during the 1980s showed incorrect behavior of the top unit with hysteresis pattern (Figure 1).

Observations at the Cassegrain focus using CCD detectors have brought to light further limitations on image quality. The use of a seeing monitor confirmed large differences between the atmospheric seeing and that of the 3.6 m. On average, by the early 1990s, the 3.6 m image quality was above 1 arcsec.

Using a portable wavefront sensor (Shack-Hartmann) with a CCD detector we started a systematic campaign to investigate the image quality. The first results obtained in 1991 confirmed the degradation of the image quality as a function of Zenith distance (Gilliotte, 2001).

Several concerns were identified as: (1) Thermal effects were clearly important to the image quality stability. Defocus, spherical aberration, tilt (image stability) and also astigmatism terms contributed, to the total image quality up to 1 arcsec when the telescope dome area was warmer than outside; (2) Coma, triangular and astigmatism aberrations changed, as a function of telescope position. Values up to 0.9, 0.5 and 0.6 arcsec were seen; (3) A constant value of spherical aberration was measured (around 0.5 arcsec).

The graph in Figure 1, prepared in 1991 by a mechanical engineer (J. Cheng), illustrates the different contributions to the total measured displacement of M2 with respect to M1. It was clear that the telescope image quality needed to be improved.

The 3.6 m Upgrades

In 1995 the goal of the 3.6 m upgrade project was to obtain a sub-arcsec image quality of 0.9 arcsec over 120 deg solid angle for the average site seeing. Following detailed studies almost all telescope parts and the dome were subject to this intervention. The dome and mirror seeing were reduced by minimization of heating sources in the dome, dome air cooling, and forced ventilation in front of the mirror. The spherical aberration was corrected by lowering the focal plane by 166 mm.

Triangular aberration (up to 0.4 arcsec at 60 deg zenith distance) was found to vary with telescope elevation and a modification of the M1 cell was made. This aberration was reduced below 0.2 arcsec by means of constant force components (springs) on the M1 axial astatic levers. A new wavefront sensing method was used by means of direct CCD observations (Curvature Sensing).

During the 1990s, all efforts were oriented towards the main mirror cell and the thermal environment problems (cf. Gilliotte, 2001). By 2000 the image quality of the telescope was still limited by the coma instabilities (up to 0.6 arcsec). Close to the zenith the telescope delivered an image quality of 0.7 arcsec at best.

New instruments (HARPS) and the increasing demand for high spatial resolution observations (0.16 arcsec for EFOSC2) provided the incentive for further image quality improvement. Upon completion of the M1 cell upgrade a new project to improve the M2 unit started in 2001.

The M2 Upgrade

The following goals defined the requirements: (1) Remote collimation of M2 for coma correction; (2) Coma must be better than 0.1 arcsec after applying the collimation correction; (3) Minimization of residual telescope flexures and related hysteresis; (4) Correction of the M2 focus instabilities.

The Coudé M2 unit support and the NTT M2 collimation concept were used as starting points. A new complete top ring was built. A pantograph design was used for the M2 support allowing the M2 to tilt around the center of curvature by means of an x, y translation table.

The new unit was installed in August 2004 and immediately gave an improvement in image quality and ease of focusing operation. However hysteresis on the coma variation was still observed, preventing a precise collimation correction. The M2 cell was then the last untouched part of the 3.6 m and possibly responsible for the residual behaviour. A complete maintenance of the cell including a realuminization of M2 was performed in November 2004. Additional unexpected sources of instability in coma and astigmatism were identified and corrected.

Optical Quality Results

The results obtained after the November 2004 intervention demonstrate that the 3.6 m telescope finally delivers an excellent image quality. Figure 2 illustrates the coma variation with respect to the S-N axis of the telescope. This axis has the strongest coma aberration. The residual coma hysteresis disappeared completely.

Figure 3 shows the total aberration variation on the full sequence S-N-W-E without M2 collimation correction. The final image quality in terms of classical optical aberrations is less than 0.4 arcsec, with a very small

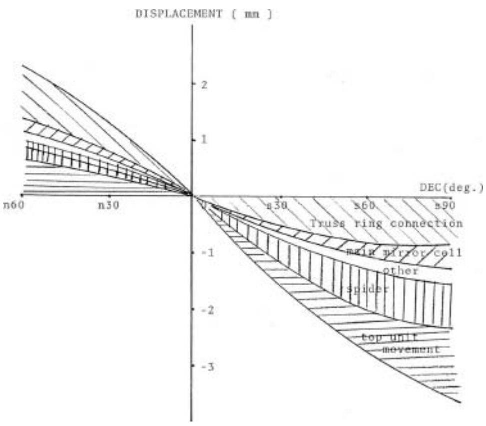

Figure 1: M1/M2 relative displacement with Declination.

amount of residual coma (< 0.2 arcsec) without collimation correction (< 0.1 arcsec with collimation correction). The main residual term is the astigmatism (as expected), contributing 0.35 arcsec when pointing far to the north.

Science Results

During the last months the improvement of the image quality of the telescope has been clearly noticed in EFOSC2, CES and HARPS observations.

The EFOSC2 seeing is measured in terms of image size and has been logged for several years. It includes telescope and instrument image quality and atmospheric seeing. In Figure 4 the evolution of the EFOSC2 seeing versus the corresponding measurements of the seeing monitor is presented. This graph covers several EFOSC2 runs. Each vertical band corresponds to one observing period. The red squares represent the seeing monitor value, while the blue squares correspond to the EFOSC2 image size in the y direction. During the most recent runs, the EFOSC2 measurements were comparable to the seeing monitor values down to 0.45 arcsec. Before the M2 upgrade the seeing as measured in EFOSC2 science images would not reach values lower than 0.7 arcsec, being limited by the telescope image quality.

HARPS observers have also noticed the improvement in image quality, gaining up to 40% more flux with respect to the pre-M2 upgrade times. In Figure 5 the gain in efficiency after the two M2 interventions (August 2004 and November 2004) is illustrated. Horizontal lines indicate average values.

The benefits of the new M2 unit are also noticed from the operational point of view: focusing operations are simpler and faster and coma aberrations can be corrected by remotely re-collimating the secondary mirror, although this option is only needed when observing to the extreme north. Since the November 2004 intervention, coma (< 0.2 arcsec) is independent of telescope pointing direction.

We look forward to many years of smooth operation and excellent image quality with the 3.6 m telescope.

Acknowledgments

We are grateful to Jaime Alonso and Ismo Kastinen for their fundamental contribution on the electronic and software part of the M2 upgrade project. The La Silla Mechanical team has been working hard all the time on the 3.6 m project and the success of the complete project is certainly in a large part due to them. Ueli Weilenman and Stephane Guisard also made major contributions through this project, leading the first M1 upgrade and in charge of the optical analysis respectively. We also thank Francesco Pepe for supplying the illustration of the HARPS efficiency.

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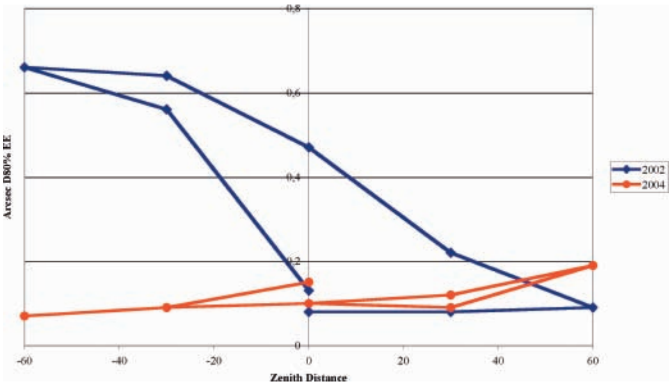

Figure 2: Coma Variation with Zenith Distance.

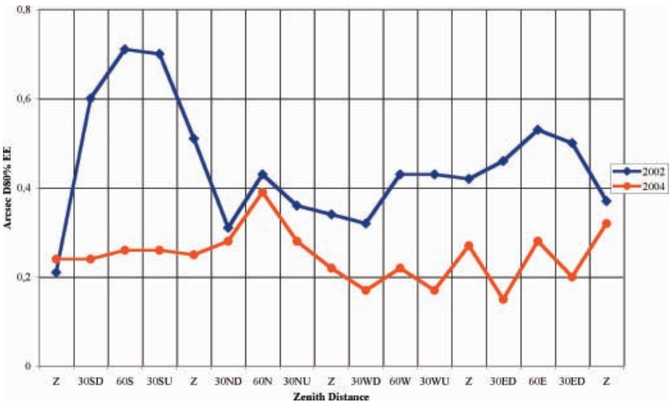

Figure 3: Image quality improvement: Optical Aberration variation with Zenith Distance.

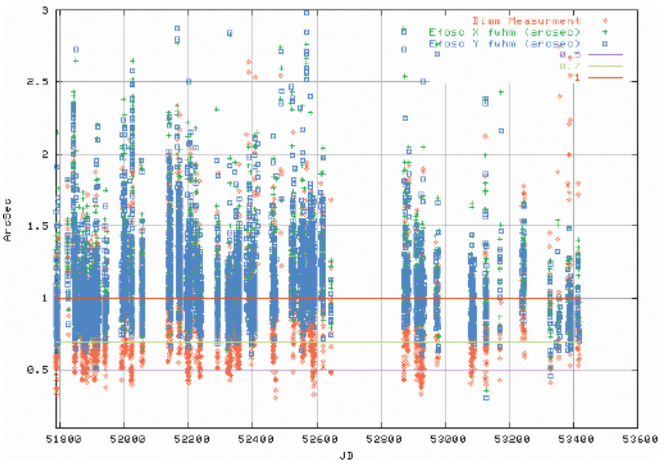

Figure 4: EFOSC2 seeing history (blue and green) compared with seeing monitor (red).

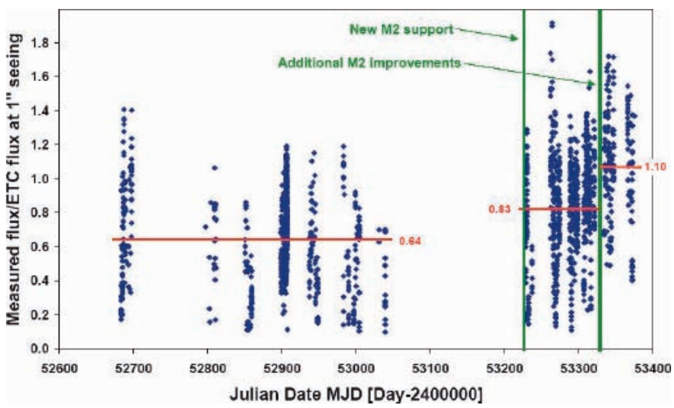

Figure 5: HARPS Efficiency variation with observing run.

Telescope Time Allocation Tool

TaToo is ESO's new Time Allocation Tool. This software scheduler is a combination of a user-friendly graphical user interface and an intelligent constraint-programming engine fine-tuned to ESO's scheduling problem. TaToo is able to produce a high quality and reliable schedule taking into consideration all constraints of the recommended programs for all telescopes in about 15 minutes. This performance allows schedulers at ESO-VISAS to simulate and evaluate different scenarios, optimize the scheduling of engineering activities at the observatories, and in the end construct the most science efficient schedule possible.

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Every six months about 900 scientific observing proposals are written to make use of ESO telescopes. Proposals are evaluated by an external Observing Programmes Committee (OPC), which recommends the allocation of telescope time via a ranked list of proposals (see Figure 1). The goal of the Time allocation Tool (*TaToo*) is to schedule the telescopes in the most optimal and reliable manner possible, taking into consideration the full set of constraints of each OPC recommended observing program. *TaToo* is not intended to be a fully automated "black-box" program, but a user friendly, interactive, semi-automated tool used by ESO's Visiting Astronomers Section (VISAS) to generate and maintain the long-term scheduling of ESO telescopes.

Today, after successfully scheduling the last two observing semesters with *TaToo*, we must take a step aside to pay tribute to the fomer Head of VISAS, Dr. Jacques Breysacher, who scheduled ESO's telescopes for almost 30 years (see Figure 2). Dr. Breysacher was the initiator and the strongest supporter of the *TaToo* project and perhaps the only one who can fully appreciate the intricacies of an automated scheduler for ESO telescopes. His experience and strong sense for practical solutions were fundamental during the development of *TaToo*.

Our approach to the scheduling technology

The challenge to develop a software tool with a high production quality has forced us to make a very careful choice of the underlying scheduling technology. The reliability of this tool and the quality of the schedule produced are of paramount importance to the observatory. A schedule solution that secures optimal observing conditions for each recommended program and maximizes the number of programs on the telescopes contributes decisively to the effective usage of ESO telescopes, boosting the scientific return of the observatory.

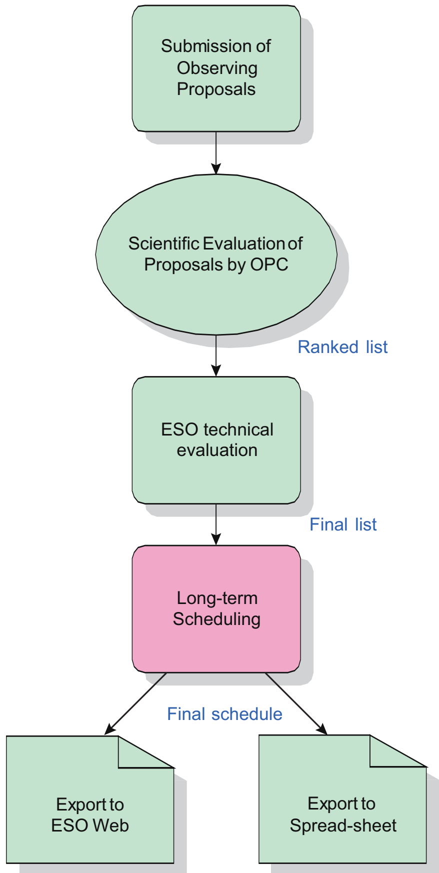
At the beginning of *TaToo*'s design, in 2003, we did an extensive evaluation of the existent telescope scheduling systems. Among the different systems were 1) Spike by Johnston and Miller (1996), 2) the system by Grim et al. (2002) based on a genetic algorithms scheduler, 3) the "Just-in case" telescope scheduling algorithm developed by Drummond et al. (1994), etc. Of all of these, only Spike was an established telescope scheduling system that due to its modular constraint satisfaction solver was flexible enough and could potentially be adapted for use at ESO. An attempt to adapt Spike at ESO is described by Giannone et al. (2000). However, the design of the Spike scheduler had been done in the early 1990s, at a time when constraint programming was still at its early stages of development. Contemporary constraint programming systems include a large number of very powerful search and constraint propagation techniques that offer more effective scheduling, see, e.g., Baptiste et al. (2001).

This conclusion, as well as a careful study of the available open-source/commercial optimization and scheduling technology, allowed us to define our approach to the development of *TaToo* as follow: "Select a modern and real-life proven scheduling technology, and focus efforts on the interface with the ESO scheduling problem". It was quite clear from the beginning of the project that developing a new scheduling technology from scratch was beyond the scope and budget of the project. Instead, most of the one year we had to complete the project would have to be spent translating the ESO scheduling problem to the language of a well-established scheduling technology.

During our search for the best scheduling technology on the market we analyzed systems based on:

- Genetic algorithms: i2 (2002).
- Linear, quadratic and integer optimization systems: Optimization Solutions Library – IBM, see COIN (2002); Xpress – Dash Optimization (2002), CPLEX – ILOG (2002).

Figure 1: The workflow of the long-term scheduling process at ESO: For each 6-month semester a large number (currently about 900) of observing proposals are submitted to ESO. The independent Observing Programmes Committee (OPC) evaluates all proposals and recommends time allocation by creating a ranked list where the proposals are ordered according to their scientific merit. The technical feasibility of the proposals is checked during the ESO's technical evaluation. The final list (OPC ranked) is then used by VISAS as input to the long-term scheduling. The final schedule is stored in an ESO database and published in web and spreadsheet forms.



– Constraint programming: CHIP V5 – COSYTEC (2002); clp(fd) – Diaz (2002) and IC-Parc (2002), open source; Solver/Scheduler – ILOG (2002); Mozart/Oz (2003) – DFKI, open source; Koalog Constraint Solver (2003).

In order to experiment with the different algorithms and modeling strategies, and to evaluate performance, we developed a prototype of *TaToo*. Finally, after comparison between a complete set of results, we selected the combination Solver/Scheduler of the French company ILOG. The Solver is a library for constraint programming while the Scheduler sets an additional abstraction layer over the Solver that simplifies and optimizes the modeling through notions like activities, resources, reservoirs, states, precedences, etc. These two libraries are being used by many organizations like Deutsche Bahn, SAP, Lufthansa, Daimler Chrysler, Deutsche Telekom, BMW, Nippon Steel, NFL, IBM, Metro de Madrid, etc. – see Connection (2003).

The software package of ILOG contains an Integrated Development Environment (IDE) with debugging functions that we used extensively during the development of scheduling models and defining optimal search strategies (Figure 3).

TaToo's architecture

The architecture *TaToo* is shown in Figure 4. The entire scheduling and control logic is hosted on the Scheduling Server. The data are stored in two databases on the Database Server(s). The clients access the system through a (fat client) graphical user interface (GUI).

Each observing program sets a range of requirements and conditions on the scheduling. The Control Logic reads them from the Observing Proposals database and transfers them to the Scheduling Engine. There, proper constraints are generated and sent to the Solver/Scheduler together with the corresponding constraint Models. The scheduling results are written back to the Operational Data database. The system operator has access to all relevant data and control over the entire scheduling process via the GUI Client (Figure 5 and Figure 6). The Models are written in Optimization Programming Language (OPL), the Control Logic and the Scheduling Engine in Perl, the GUI Client in Java. The libraries Solver/Scheduler are precompiled (written by ILOG in C++).

How does TaToo schedule?

There are two modes of scientific observations at ESO telescopes: the Visitor mode (VM) and the Service mode (SM). VM is the classical mode of observations in which the observations are executed by an astronomer from the proposing team that is physically present at the telescope. SM observations, on the other hand, are performed by the ESO observatory staff. VM observations consist of runs; a run may be additionally divided into

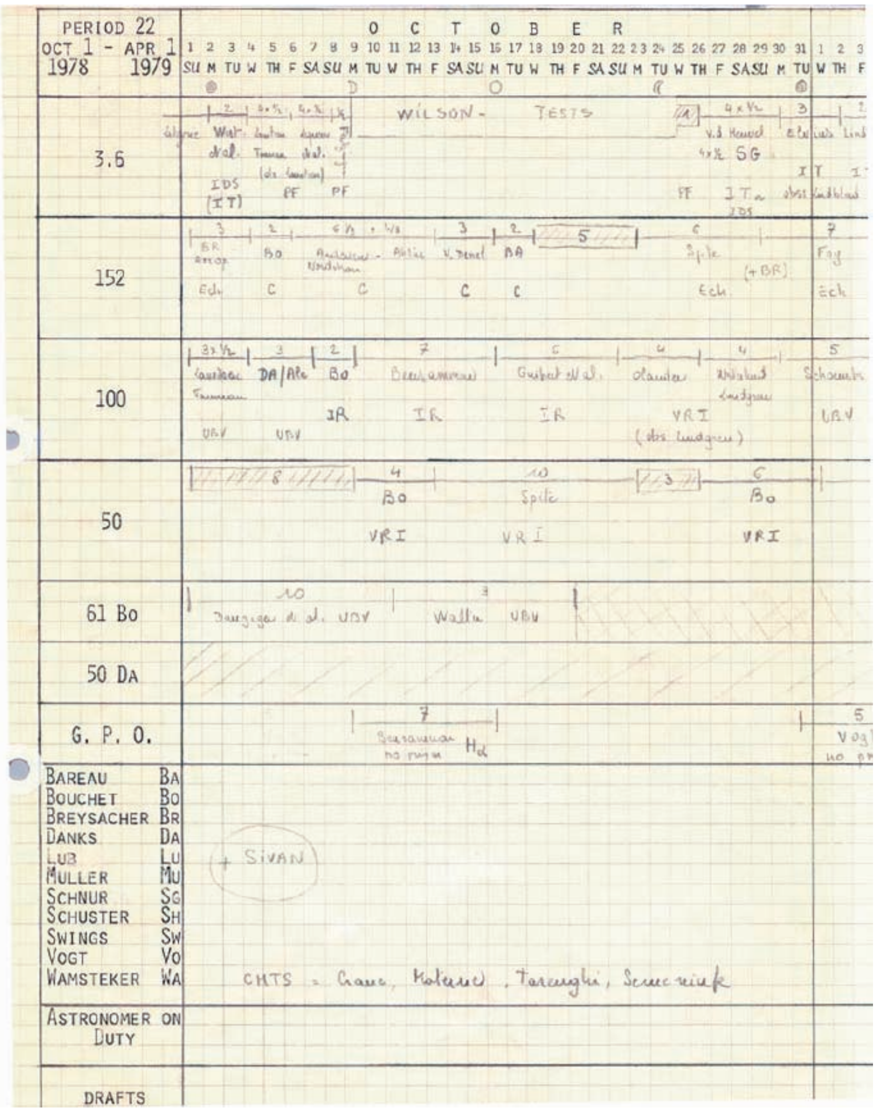


Figure 2: First ESO telescope schedule computed by Dr. Jacques Breysacher, for Period 22 (1978). The know-how accumulated during almost 30 years of scheduling ESO telescopes was fundamental in the translation of the ESO scheduling problem to scheduling technology language.

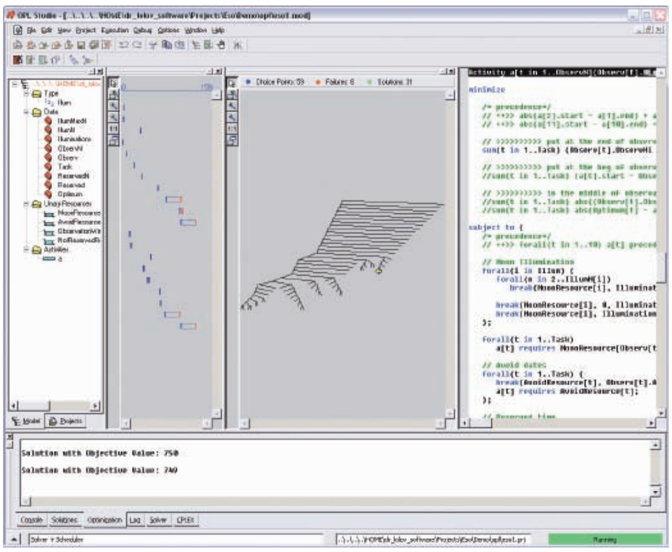


Figure 3: The OPL Studio of ILOG used for the development of the Constraint Programming models of *TaToo*. The panels show (from right to the left) the source code of the OPL (Optimization Programming Language) model; the solution search tree; the earliest/latest time spans of each variable; the data structure of the model. The lower panel shows the progress of the optimization.

sub-runs. A sub-run is the smallest schedulable entity and occupies at least half a night (Figure 7). SM observations, on the other hand, are performed in one-hour observation blocks.

From *TaToo*'s perspective, the substantial difference between VM and SM observations is the search space in which the scheduling takes place. The VM (sub)runs are scheduled on the time axis, meaning that each scheduled VM run becomes a particular, fixed time span for execution. The SM runs are scheduled in a "resources" space. A scheduled SM run is one that has been accepted in the schedule if sufficient resources for its execution are available. The observatory staff determines when a scheduled SM run will be performed after considering the meteorological conditions, the current states of the queues, and its chance of getting substantially completed by the end of the observing semester.

TaToo schedules VM runs by proper OPL models. The models take into account all parameters important for the run like OPC-ranking, object coordinates, required moon illumination, sub-runs configuration, angular distance to the moon, critical and avoid-dates, etc. (Figure 8 and Figure 9). These parameters are used to generate the corresponding constraints of the models. In some cases, e.g., to minimize the number of instrument changes, the models themselves define additional constraints at run time. The effective algorithms for constraint propagation implemented in Solver/Scheduler libraries as well as the properly selected search strategies in the models lead to very good scheduling performance. On a 2 GHz single processor computer the scheduling of all seven telescopes takes less than 15 minutes. In this time ≈ 100.000 constraints and 500–1000 sub-runs per telescope are evaluated and (some of them) scheduled.

For the scheduling of SM observations *TaToo* implements a two-step procedure:

Step 1: On this step *TaToo* generates the so-called pseudo-VM (PVM) runs. The generation works in the following way. The RA coordinate of each target of each requested SM run is used to define a visibility window where the target can potentially be observed. A new PVM run is defined for that target, including the required moon illumination as a constraint. To compensate the different time resolution of VM (0.5 nights) and SM (1 hour) a procedure fills-up the 0.5 night block in PVM by adding other relevant targets of the same SM run or of rank-neighboring SM runs.

Depending on the VM/SM time distribution and on the particular SM pressure at each telescope, a large number of interchangeable PVMs may be generated. A special procedure analyzes the configuration of the generated PVMs and removes the logical symmetries by generating sets of additional precedence constraints. This substantially prunes

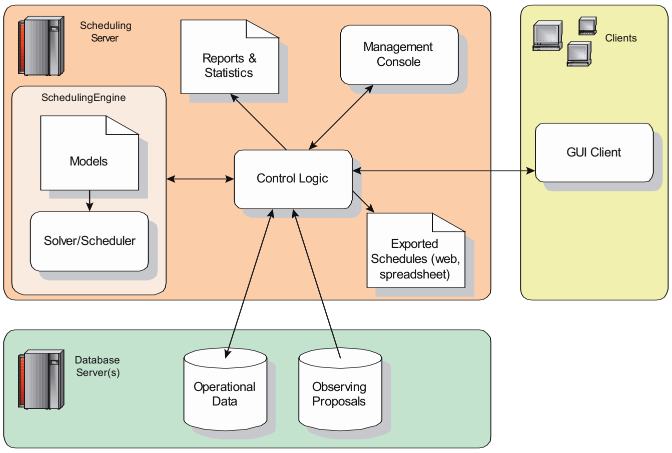


Figure 4: Architecture of *TaToo*.

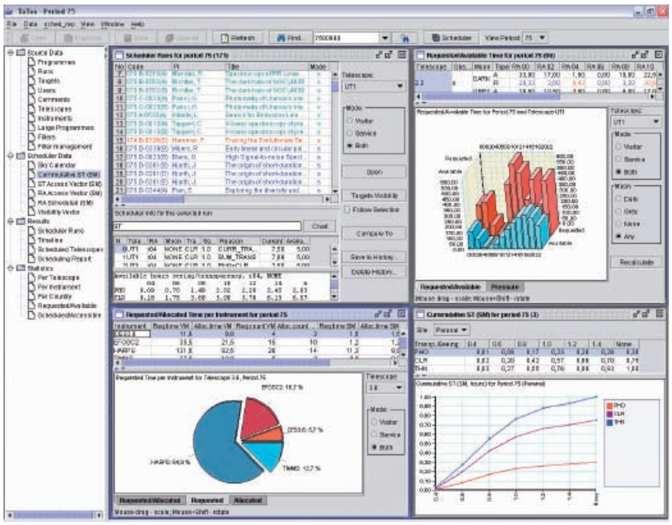


Figure 5: At any point of the scheduling process the graphical user interface of *TaToo* provides access and control of all relevant for the scheduling data.

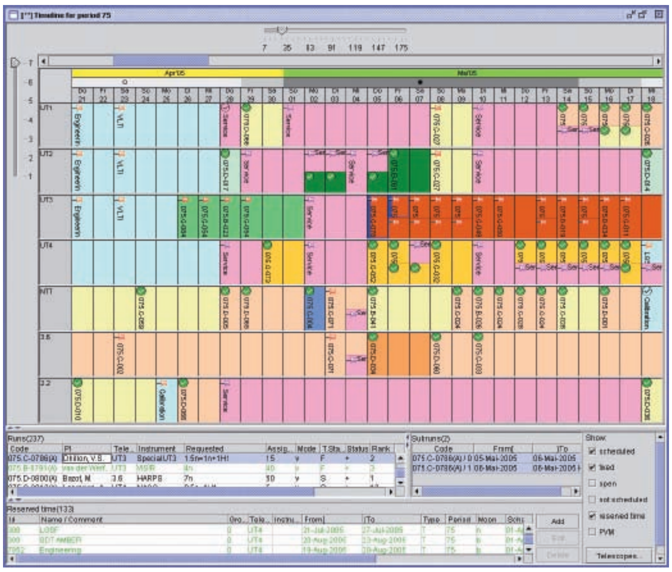


Figure 6: Graphical presentation of the final schedule in a timetable form. The instruments are color-coded. The pink color denotes time allocated for SM runs. The panes with tables below the timetable provide detailed information about each scheduled run.

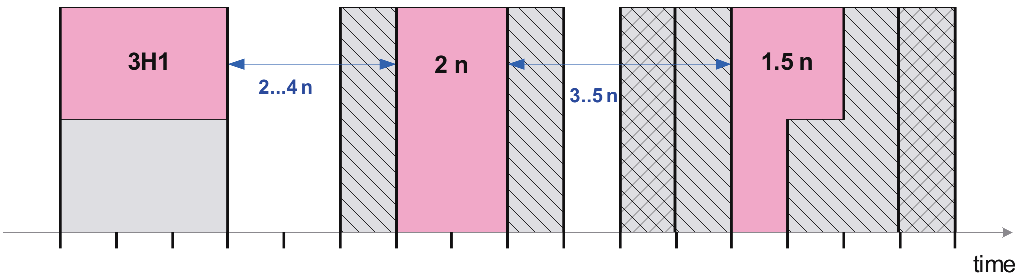


Figure 7: The VM run shown here consists of 5 sub-runs. The "3H1" are three first half-nights, followed by "2n" – two whole nights and "1.5n" – 1.5 nights starting at the beginning of a night. The required intervals the sub-runs are 3 nights ± 50% between sub-runs "3H1" and "2n" and 4 nights ± 50% between sub-runs "2n" and "1.5n". The diagonally-striped gray areas show the areas where sub-runs "2n" and "1.5n" may be scheduled, provided sub-run "3H1"is on a fixed position. Actually, *TaToo* tries to find optimal positions of all three sub-runs simultaneously by introducing from- and to-limits of the distance constraints.

the search tree and increases the overall scheduling performance.

Finally, the PVMs are competitively mixed with the VM (sub)runs by taking into account the OPC ranking list (Figure 10) and are fed to the OPL models for scheduling.

Step 2: During this step of the SM scheduling *TaToo* implements an algorithm based on the ones described in Silva (2001). The algorithm uses a RA/MOON/SEE/TRANS (RMST) model and schedules by consumption of time resources. The calculation of the available time resources is based on statistical data about the weather conditions at the observatories' sites and is performed for the time spans of the PVM runs scheduled during Step 1.

The described SM scheduling procedure provides a fair time assignment, especially in the over-subscribed RA-ranges (see Alves & Lombardi 2004) as it leverages the advantages of both the constraint programming models and the RMST model.

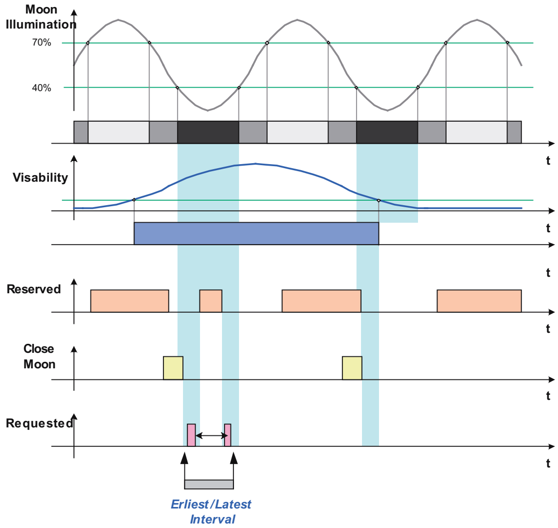


Figure 8: Illustration of the way the scheduler determines the Earliest/Latest Interval where a VM run containing two sub-runs may be scheduled. For simplicity, the figure shows only some of the constraints applied. In reality many more constraints such as critical and avoid-dates, linked runs, proper half-nights, scheduling runs of the same PI close together, minimizing of instrument setup time, etc. are applied.

Final Remarks

One of the most important characteristics of *TaToo* is its overall performance. *TaToo* is able to produce a high quality and reliable schedule taking into consideration all constraints of the recommended programs for all telescopes in about 15 minutes. This is crucial for a final optimization level where the *TaToo* operator, an astronomer, can simulate and evaluate different scenarios (e.g., further diffusing oversubscribed RA's, assessing the impact of an unpredictable instrument failure, etc.) in more or less real time. These simulations also allow for an optimal long-term scheduling of large engineering time blocks (small engineering time blocks and instrument calibrations are automatically scheduled by *TaToo*), enabling the ESO schedulers to construct the most science-efficient schedule possible.

Finally, users must keep in mind that some programs, even programs highly ranked by the OPC, might not fit the schedule due to exhaustion of a particular combination of observing conditions (Moon illumination, Seeing, etc.). Typically these cases occur when proposals request highly demanded RA's where competition with Large Programs and higher ranked programs reaches a maximum. While the number of highly ranked programs that do not fit a particular

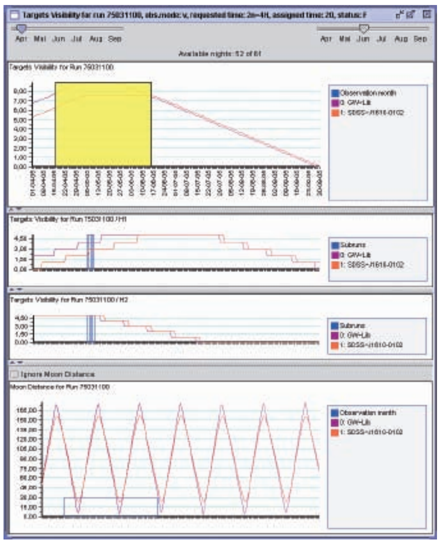


Figure 9: On the upper panel *TaToo* shows the target visibility (number of observable hours per night) for each target and the time window (the yellow box) in which the observation run may be scheduled. The second and the third panels show the visibility during the first (H1) and the second (H2) half-nights. The fourth panel illustrates the angular distance of each target to the moon. The blue rectangle drawn at 30° shows the minimal allowed angular distance.

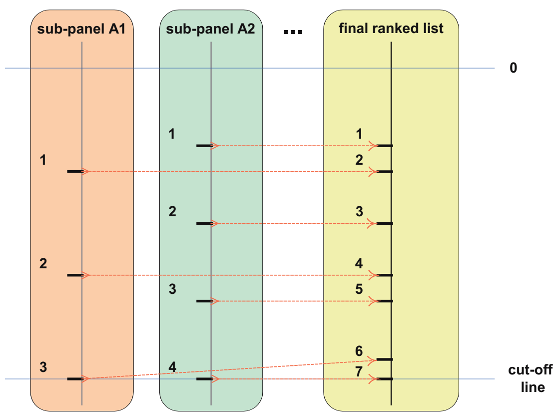


Figure 10: *TaToo* generates the final ranked list by normalizing and merging the lists of all eight OPC sub-panels: (1) For each sub-panel the list of proposals above the cut-off line is normalized between 0 and the cut-off line. (2) The normalized lists of all sub-panel are merged together. (3) In case proposals on the final ranked list overlap (like proposals A1, 3 and A2, 4 on the figure), the proposal submitted earlier is given advantage and is ranked higher. (4) Steps 1–3 are repeated for the proposals below the cut-off line.

schedule is very small (typically a few programs per semester), even these could be avoided if proposers find targets in less demanded RA's (see Alves & Lombardi 2004).

Acknowledgements

I would like to thank Dr. Vassil Lolov for the expertise, bright ideas, and motivation given to this project. Dr. Lolov worked on the TaToo project under contract with ESO. I also would like to thank the rest of the VISAS team as well as all ESO colleagues that helped with suggestions during the development of TaToo.

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ALMA News

Tom Wilson, European Southern Observatory

The Current Status of the Antenna Procurement

Presently the ALMA antenna procurement process is being delayed until further tests of the prototype antennas in Socorro NM, USA are finished. These tests involve some astronomical measurements, so winter is the most favorable time period. Once the tests are finished the results will be evaluated and a decision about the choice of ALMA antenna will be made. As all should understand, great caution is needed in reaching this decision, since the ALMA antennas will be the largest single investment in the project.

ESAC members

From Janunary 2005, José Cernicharo has become the Spanish member of the European Science Advisory Committee (ESAC). He replaces Rafael Bachiller. The names of the other national members are to be found at the web site *http://www.eso.org/projects/alma/newsletter/almanews2/ESAC*.

The Present Status of the ALMA Regional Center

The concept of the ALMA Regional Center (ARC) for Europe has been discussed by the European Science Advisory Committee (ESAC) in September 2003. This discussion is summarized in an appendix to the ESAC report. After further discussions within the European ALMA Board, the STC and ESO Council, the ESO Council approved a "Call for Expressions of Interest", with the request to submit letters of intent by 31 October 2004. Seven replies have been received. These will be discussed in a face-to-face meeting at ESO in early 2005 with the groups involved. Thus progress is being made on the organization of ARCs, and we will provide more details in future issues of *The Messenger*.

For those interested in the background, the ARC functions are divided into "User Support", which is funded within the ALMA project, and "Science Support" which is not a part of the basic ALMA funding plan. Recent accounts of the "User Support" are to be found at the web site: *http://www.eso.org/projects/alma/meetings/gar-sep04/Silva_Community_Garching.pdf*

For a description of "Science Support", see the web site *http://www.eso.org/projects/alma/meetings/gar-sep04/Wilson_Community_Garching.pdf*

For other presentations of functions given at the ALMA Community Day, see *http://www.eso.org/projects/alma/meetings/gar-sep04/*

Upcoming Events

There will be a workshop entitled "SZ Effect and ALMA" on 7–8 April 2005, at Orsay, in the Paris area. For further information and registration, email *Pierre.Cox@ias.u-psud.fr*

Planning has been started for a "Global ALMA Meeting" to be held in Madrid in 2006. This will be the first world-wide ALMA science meeting since the Washington DC meeting in 1999. The local organization of the meeting will be headed by Rafael Bachiller (OAN), while the scientific organization will be led by the Alma Scientific Advisory Committee.

View at the ALMA site on the Zona de Chajnantor. The APEX antenna is visible in front of the Cerro Chajnantor.

VISIR, A TASTE OF SCIENTIFIC POTENTIAL

VISIR, THE ESO-VLT INSTRUMENT MADE FOR OBSERVATIONS IN THE TWO MID-INFRARED ATMOSPHERIC WINDOWS (THE SO-CALLED N- AND Q-BANDS), IS NOW PRODUCING SCIENTIFIC RESULTS. SOME FIRST RESULTS ARE DISCUSSED FROM A PEDAGOGIC POINT OF VIEW, EMPHASISING THE VARIOUS MECHANISMS AT WORK THAT PRODUCE MID-INFRARED RADIATION (THERMAL DUST EMISSION, TRANSIENTLY HEATED DUST EMISSION, ION LINE EMISSION, PURE ROTATIONAL LINE EMISSION OF MOLECULAR HYDROGEN, SYNCHROTRON EMISSION). THE TWO KEY ADVANTAGES OF VISIR, I.E., ITS HIGH ANGULAR RESOLUTION AND ITS HIGH SPECTRAL RESOLUTION, ARE ILLUSTRATED RESPECTIVELY BY THE RESULTS FROM THE OBSERVATIONS OF THE BROWN DWARF BINARY SYSTEM ε INDI, AND BY KINEMATIC STUDIES OF THE GALAXY NGC 7582.

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VISIR, THE VLT MID-INFRARED Imager and Spectrometer, was installed at UT3 (Melipal) in early 2004 and was successfully commissioned between May and August 2004 (Lagage et al., 2004). After this, the time until its planned start of regular science operations in period 75 (April–September 2005) has been used to integrate the instrument into the Paranal operations and maintenance schemes and to carry out some first Guaranteed Time Observations (GTO) by the instrument consortium and Science Verification (SV) observations to demonstrate the scientific capabilities of the instrument. A complete list of GTO and SV programs can be found at *http://www.eso.org/observing/proposals/gto/visir* and *http://www.eso.org/science/vltsv/visirsv*. The data from the Commissioning and SV observations are available to the public and can be retrieved through the ESO science data archive (*http://archive.eso.org*).

Since June 2004, the sensitivities of VISIR were carefully monitored through a systematic program of observations of standard stars as often as possible. Figures 1 and 2 show a compilation of these measured sensitivities both in the imaging and the spectroscopic mode. As seen on these figures, the sensitivities are in reasonable agreement with the predicted ones. However, the last 6 months of monitoring have shown that the sensitivity of VISIR depends quite significantly on the conditions of the weather and the observations conditions (seeing, airmass, amount of Precipitable Water Vapour; the value of the latter can be found at *http://www.eso.org/gen-fac/pubs/astclim/forecast/meteo/ERASMUS/par_fore.txt*). Mid-infrared observations with VISIR will thus benefit greatly from the flexibility provided by service observing scheduling since the constraints of the observer will be much better matched to weather and observation conditions. One should also note that some spurious effects, such as detector striping, may degrade the sensitivity performance sporadically.

A sample of first scientific results from VISIR has been selected to give a first taste of the overwhelming scientific potential of this latest VLT instrument.

VARIOUS ORIGINS OF MID-INFRARED RADIATION

EMISSION OF LUKEWARM DUST GRAINS IN THERMAL EQUILIBRIUM

Dust grains (silicates, amorphous carbon, graphite ...) immersed in a radiation field reach thermal equilibrium at the temperature that corresponds to the balance between absorbed and re-radiated energy. Depending on the circumstances (orbit, central source luminosity, chemical composition) they can reach a temperature of around 100–500 K. Their re-emitted energy is mostly radiated at infrared wavelengths, such that:

$\lambda_{max} = 2898/T$ µm, T in K (Wien's law).

Hence, a warm dust grain at room temperature (i.e., around 300 K), radiates its maximum energy at around 10 µm. Mid-infrared wavelength (10 and 20 µm) windows are thus well adapted to probe dust grains in orbits around a star, typically in the planetary zone (1–50 AU). As a result, the search for footprints left by planets very close to the star in dusty discs is possible. Figure 3 illustrates this with images of the dust-disc of β-Pictoris observed without coronograph (in contrast to visible and near-infrared observations) allowing one to study structures in the innermost regions; from these observations, the mechanism of disc replenishment can be inferred (collisions of planetesimals producing small particles) (Pantin et al. 1997; Pantin et al. 2005, in preparation) and the structure of the disc gives precious indications about the presence of gravitational perturbers, such as massive planets.

Generally speaking, in the mid-IR one is approaching the Jeans limit. Thus, the contrast between the stellar photospheres and the circumstellar environment is more favorable as compared to the near-IR, where coronography is a must.

EMISSION OF VERY SMALL DUST PARTICLES AND PAH

Very small dust grains (e.g. silicates, graphite, with sizes smaller than 0.01 µm) as well as polycyclic aromatic hydrogenated grains (PAH or "big" molecules formed of benzene rings) can be heated quite far away from a source, provided that the source emits a sufficient number of visible or ultraviolet photons. These photons stochastically heat these small grains (or big molecules) temporarily to temperatures close to 1000 K. The grains then relax through vibrational modes of C-H and C-C bonds, at a few precise wavelengths mainly found in the mid-infrared range (3.3 µm, 6.2 µm, 7.7 µm, 8.6 µm, 11.3 µm ...).

The ISO infrared satellite discovered that some isolated Herbig AeBe (HAEBE) stars

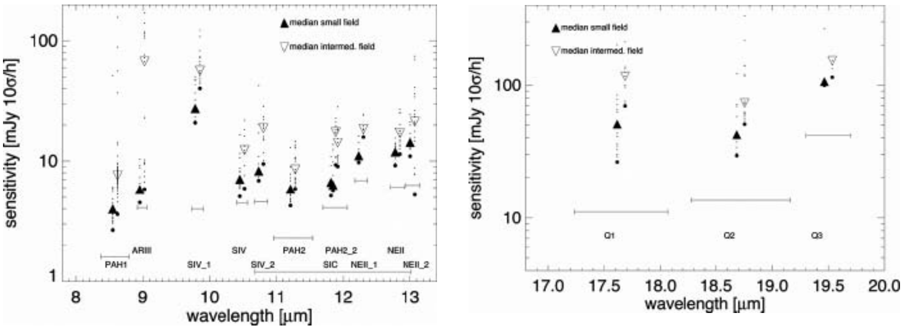

Figure1: Imager sensitivity monitored over 6 months, in *N*-band (left), and *Q*-band (right). The sensitivity is estimated for each standard star observation using the following method. One determines the radius at which the signal-to-noise is maximal. The star signal is integrated within this optimum radius and the corresponding error is computed. The sensitivity is finally deduced from the calibrated flux of the star deduced from Cohen et al. (1999) all sky network database of infrared calibrators. The horizontal bars represent the theoretical limits of VISIR sensitivity, the black dots show the "best ever" value of sensitivity reached. Note that the two pixel scales available ("small field" and "intermediate field") have differing sensitivities. Although not expected when modeling VISIR sensitivity, "small field" sensitivities are systematically better than "intermediate field" ones.

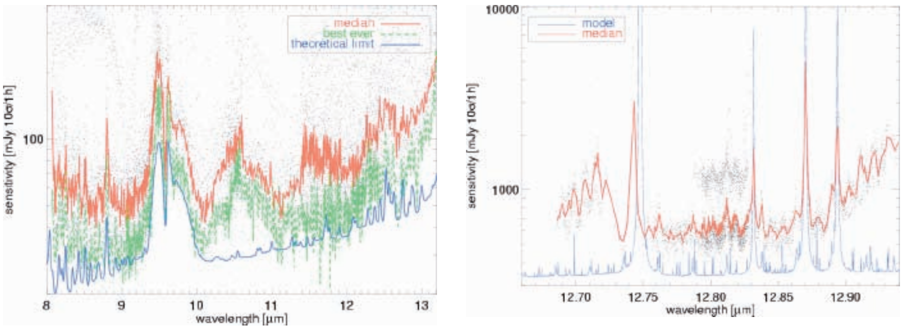

Figure 2: Spectrometer sensitivity monitored over a period of 6 months. The left panel shows the low-resolution mode in all four settings currently offered spanning the full *N*-band. The right panel displays the sensitivity measured in the long-slit [NeII] setting at 12.8 μm.

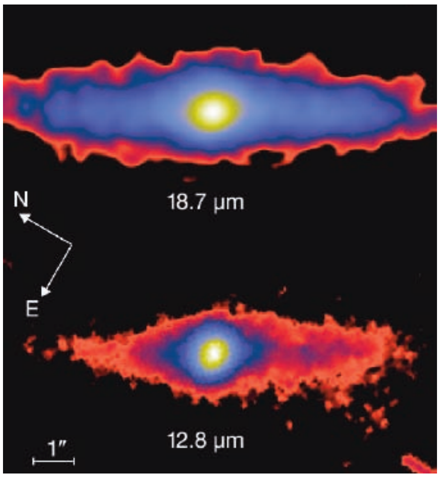

Figure 3: The dust disc of β-Pictoris seen by VISIR at 12.8 and 18.7 μm. The asymmetry (South-West side brighter than North-East side) is clearly seen. As illustrated here, the longer the observing wavelength, the colder the dust probed. However, the spatial resolution is also worse because of the diffraction limit. One key question that will be addressed with the above images is the following: is there an inner tilt in the β-Pictoris dust disc, as claimed from Keck observations (Wahhaj et al. 2003, Weinberger et al. 2003), or not, as claimed from recent Gemini observations (Telesco et al. 2005). Some more data processing (image deconvolution) is needed before having the VLT view!

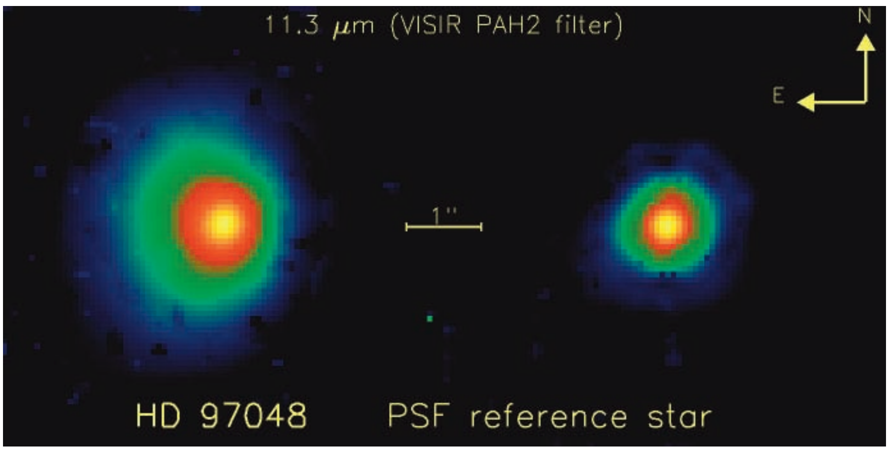

Figure 4: Image of the Herbig Ae star HD 97048. The extension seen in the "PAH" band filter centred on 11.3 μm is clearly visible. Such an extension cannot be explained just by thermal emission of dust grains at an equilibrium temperature and a population of small grains or PAH molecules transiently heated has to be invoked to explain the extension (Doucet et al. 2005). The spectroscopic observations (see Figure 5) indicate that a 11.3 μm feature attributed to PAH is indeed present. As expected the extension at 11.3 μm is larger than that observed recently at 3.3 μm with NACO (Habart et al.,2005, in preparation). A striking feature of the extension is its asymmetry. Sophisticated models including PAH, flaring disc geometry, viewing angle, inclination … are now needed to interpret these observations.

harbour dusty discs in which planetary formation is suspected to take place, and show the signature of such PAH (Waelkens et al. 1997, Waters et al. 1998).

One key programme of the VISIR guaranteed time observations is devoted to the study of a large sample of such HAEBE pre-main-sequence stars. We have observed one of these stars (HD 97048, Figures 4 and 5) using VISIR in imaging mode (PAH2 filter centred on 11.3 µm) and spectrometry mode (low-resolution 11.4 µm setting). The 11.3 µm image shows a quite large extension (2–3 arcsec) that was already suspected from previous observations (van Boekel et al. 2004). The spectrum confirms that PAH emission is indeed prominent in this disc, while the right panel of Figure 5 proves that the PAH emission is indeed spatially extended.

Line emission from ionized gas

Narrow atomic gas emission lines are also powerful probes of the astrophysical conditions. The most famous ones in the *N*-band are [NeII] at 12.8 µm, [ArIII] at 8.992 µm, and [SIV] at 10.485 µm. Narrow band (R = 50–80) filters corresponding to these lines are available in the VISIR imager and long-slit mode of the spectrometer. Concerning other lines (e.g. [HI] at 12.36 µm, forbidden lines such as [NII] at 12.79 µm, or [NaIV] at 9.04 µm), a cross-dispersed mode of the spectrometer will be offered in the future. In Figure 6, we demonstrate the possibility of studying the spatial emission of the [NeII] line in the central regions of the Seyfert 2 galaxy NGC 1068. Indeed, after subtraction the 2D continuum emission interpolated from images taken through reference filters around 12.8 µm, one obtains a map of the pure [NeII] emission (right panel of Figure 6). One can notice that the [NeII] emission is extended and follows the Narrow-Line-Regions, but, most interestingly, unveils the South-East, dust-extincted component of the ionising cone, as predicted by the unified AGN model (Galliano et al. 2005).

Emission lines from pure rotational modes of molecular gas

Although this mode has not been offered to the community yet, VISIR has the capability to obtain spectra at very high resolution (R ~ 15 000 to 30 000) of "cold" molecular Hydrogen H_2 at 12.28 and 17.03 µm. The transitions accessible to VISIR correspond to the lowest lying rotational states of the vibrational ground-state of Hydrogen. This potential is demonstrated in Figure 7 showing the emission line at 17.03 µm produced in the Orion bar (Allers et al. 2004). As shown in the same figure, the velocity structure of this cloud might be inferred from the precise central wavelength of the H_2 emission line. Additional checks are needed, however, before definitely attributing the observed wavelength changes to velocity.

This type of observation from the ground is not easy because of a strong atmospheric emission line very nearby at 17.027 µm; the high spectral resolution of VISIR makes VISIR a powerful instrument to detect the H_2 line.

Precise wavelength calibration is routinely achieved using the sky spectra recorded in the data. The observed atmospheric lines are compared with those predicted from an atmospheric model based on a HITRAN radiation transfer model. Using a cross-correlation method, an accurate wavelength calibration is derived on the fly (see Figure 8).

This observing mode offers great potential for example for the search for cold H_2 in protoplanetary discs.

Synchrotron emission from compact objects

Charged particles rotating in a strong magnetic field generate synchrotron emission. The observed spectrum is usually close to

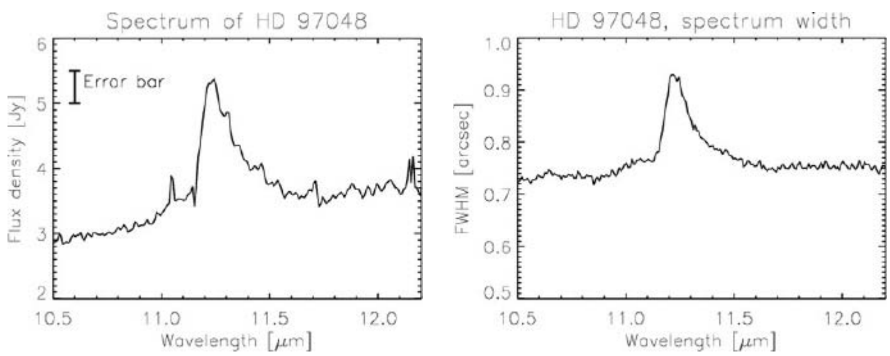

Figure 5: Left: Observed spectrum of HD 97048 around 11.4 µm in the long-slit low-resolution mode of VISIR. Right: The measured spatial full width at half maximum of the HD 97048 spectrum as a function of wavelength. The PAH emission at 11.3 µm is spatially more extended than the continuum and confirms the spatial extension of the image seen in Figure 4.

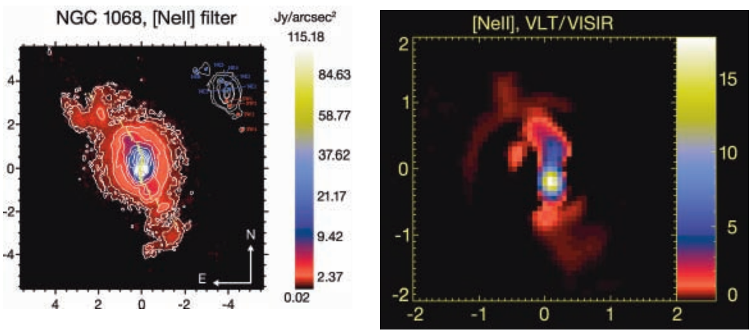

Figure 6: The Seyfert 2 galaxy NGC 1068. The left panel shows the image obtained through the NeII filter centered on 12.8 µm, and contains both the continuum and the gas emission. The yellow ticks overplotted mark the local position angle of the isophotes, showing the symmetrical twisting of the mid-infrared emission from the center to the outer parts of the AGN. Also shown is a sketch of the different knots identified in the image. The right panel shows the atomic emission line of [NeII] once the continuum component has been subtracted. Overplotted scales give the offset coordinates in arcseconds from the central engine position.

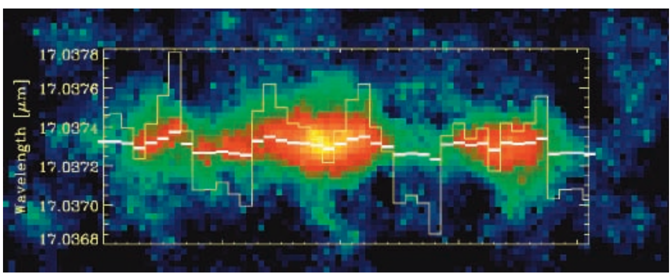

Figure 7: The Orion bar observed using VISIR in a long-slit, high-resolution setting at 17.03 µm. In the background is shown the 2D spectrum (dispersion direction is vertical, spatial direction is horizontal, North is to the left). The horizontal white bars overplotted pinpoint the local maxima of the emission line across the field. The yellow curve displays the corresponding central wavelengths as a function of the position in the field.

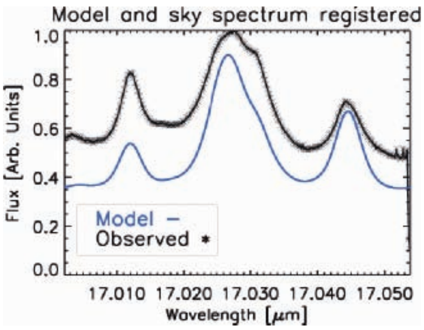

Figure 8: Wavelength calibration of the spectrometer using a cross-correlation method between the observed sky spectrum (black) and a model of atmospheric emission based on HITRAN computations (blue).

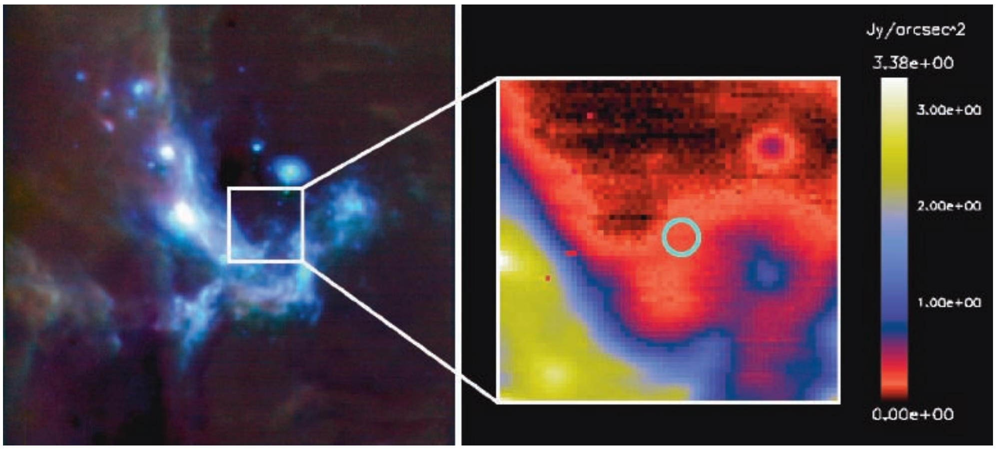

Figure 9: The Galactic Centre observed through the PAH1 (8.6 μm) filter. The goal is to detect the synchrotron emission from the black hole (position shown by the circle) and constrain its emission models.

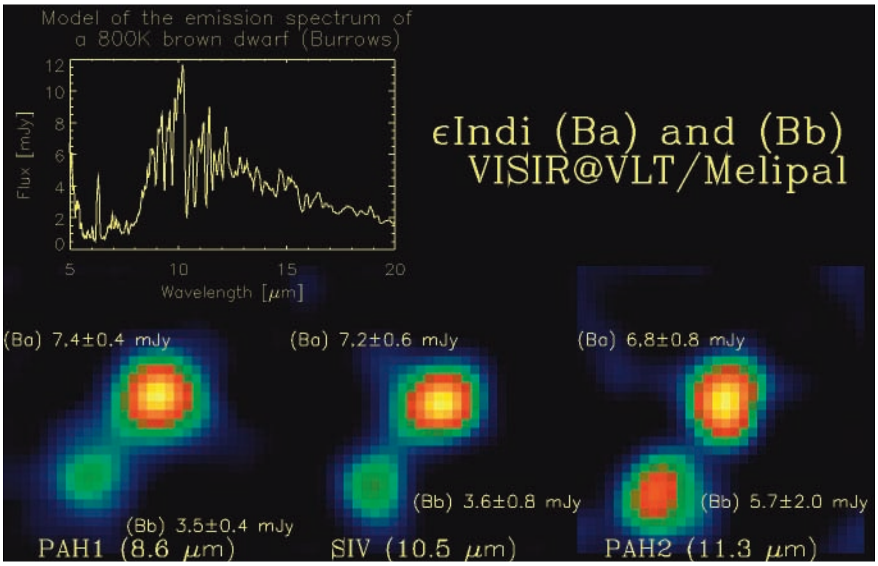

Figure 10: ε Indi, the closest binary brown dwarf, observed with VISIR in three filters (PAH1 (8.6 μm), SIV (10.4 μm), and PAH2 (11.3 μm)). We were able to spatially resolve both components, separated by ~ 0.73 arcsec, and determine accurate mid-infrared photometry for both components independently. In particular, our VISIR observations allowed us to probe the NH_3 features in both of the T1 (component Ba) and T6 (component Bb) cool brown dwarf. For the first time, we could disentangle the contributions of the two components, and find that the cold ε Indi Bb is in reasonable agreement with recent "cloud-free" atmosphere models. On the other hand, the warmer ε Indi Ba deviates significantly from any available atmosphere model calculations. It may or may not have clouds, and we might witness non-equilibrium chemical effects of NH_3 in ε Indi Bb. One should note that SPITZER could only measure a composite spectrum (Roellig et al. 2004).

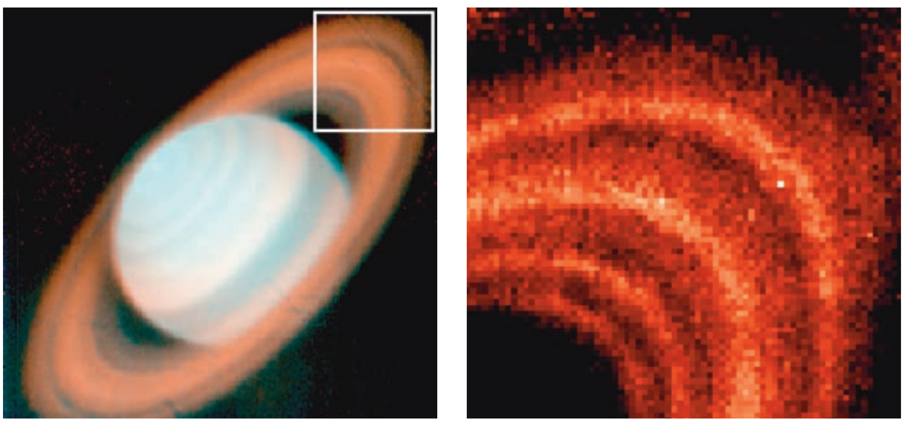

Figure 11: Left: Composite image of Saturn (blue = PAH2 filter at 11.3 μm, red = Q3 filter at 19.5 μm). The "shadow" region on the left side of the planet corresponds to ring particles with lower temperatures after cooling down in Saturn's shadow. Right: A close-up of Saturn's rings showing the D, C, B, and A rings (from left to right), Cassini's division between the B and A rings, and more interestingly, an increase of the particle temperature (hence increasing thermal emission) in the A ring just before entering the shadow of the planet.

a power-law function ($F_\nu \propto \nu^\alpha$ with α in the range 1–2) in the radio domain, peaking sometimes in the mid-infrared range as is the case for the black hole in Sgr A (Galactic Centre).

The very high extinction towards this object (A_V close to 30!) makes Sgr A impossible to detect in the visible range and quite difficult in the near-infrared range (Genzel et al. 2003).

We have monitored the Galactic Centre (see Figure 9) over four periods in order to try to detect the black hole mid-infrared emission. We could not catch it in its excited state (when it produces flares), but we could derive an upper limit of around 15 mJy for the flux in its quiescent state (Lagage et al. 2005, in preparation).

Key VISIR features: high angular resolution, high spectral resolution

High angular resolution: individual emission from a binary brown dwarf, Saturn's rings

One key advantage of VISIR over the SPITZER space observatory is the angular resolution. This is illustrated by two examples, the observations of binary brown dwarfs and Saturn's rings.

Cool stars and L and T brown dwarfs emit their energy maxima at wavelengths from the near-infrared up to 20 µm (Burrows et al., 2003), depending on their structure (dust settling, presence of "clouds", etc.) and effective temperature. We had the possibility to observe a binary brown dwarf during the science verification phase of VISIR in November 2004. As shown in Figure 10, we were able to detect the binary in the three filters with which we observed, and estimated the photometry of each of the components (SPITZER, although more suited to observe such faint objects, could only measure the spectrum of the two components and not distinguish each one separately). One can then put some constraints on the temperature, mass, and radius of each of the components (Sterzik et al. 2005, in preparation).

We observed Saturn's rings in May 2004, when the opening angle of the rings was maximal. VISIR images allow the study of the thermal emission from dust particles, and make it possible to spatially resolve the rings with a precision never reached before (see Figure 11) (Ferrari et al. 2005, in preparation). It is amazing that the resolution obtained with VISIR is equivalent to that obtained with the far-infrared focal plane FP1 of the CIRS (Composite InfraRed Spectrometer) instrument on board the Cassini spacecraft, at a distance of 20 Saturn radii during the CASSINI-HUYGENS Tour around Saturn between 2004 and 2008. CIRS will observe the rings at different wavelengths and under different viewing angles. This makes both instruments complementary. When observing such an extended object it is recommended to observe in imaging mode using jitter mode; i.e. some slight offset is applied between two nodding cycles, to avoid a significant number of bad pixels (~ 1%) affecting the final image.

High spectral resolution: Kinematics of warm gas in NGC 7582

The unique spectral resolution of VISIR in *N*- (R ~ 30 000) and *Q*-band (R ~ 15 000) allows us to resolve kinematically warm or ionized gas down to a limit of ~ 15 km/s. One example is shown in Figure 12. Here the dusty, composite starburst-Seyfert 2 galaxy NGC 7582 reveals its kinematic structure through the high spectral-resolution study of emission of ionized [NeII] gas at 12.8 µm, while the NeII filter image reveals the star-forming, circum-nuclear gas disc in the inner kiloparsec. The precision reached in velocity is around 18 km/s, and the spatial resolution of 0.4 arcsec corresponds to ~ 40 pc. From these data, one can infer an upper limit on the mass of central black hole (Wold et al. 2005, in preparation). This example shows the great potential of VISIR to study gas dynamics at high spatial resolution in the centres of galaxies.

More to come

VISIR will start science operation in visitor and service mode in P75. Only a selected number of instrument modes which could be properly characterised in the early phases of commissioning have been offered for the first proposal period. Additional modes and improved sensitivities in imaging and spectroscopy are planned to be offered for the coming observing periods. It is worth noting here that all offered instrument modes are fully supported by the newly developed VISIR (quick-look) pipeline which is available at the telescope and ESO Garching to process the data obtained in visitor and service mode. The latest information about the availability of the VISIR pipeline can be found at *http://www.eso.org/observing/dfo/quality/pipeline-status.html*. The latest information on the status of the instrument is available at *http://www.eso.org/instruments/visir/*.

Acknowledgements

We would like to thank the VISIR team at CEA, ASTRON and ESO for all their efforts to build and to bring into operation the VISIR instrument. We are further very grateful to C. Ferrari, E. Galliano and M. Wold for making some material available for this article prior to publication.

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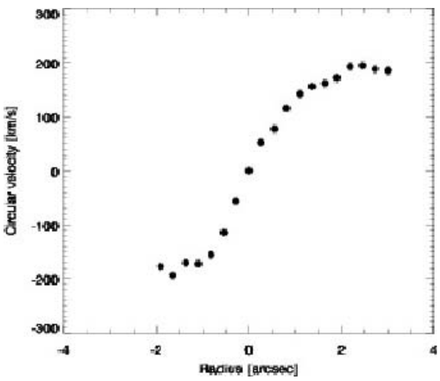
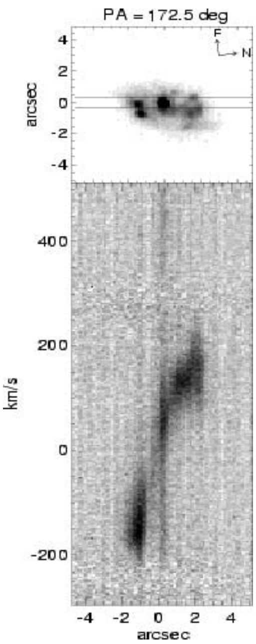
Figure 12: NGC 7582. Left panel: Rotation curve derived from the high-resolution spectrum in the 12.8 µm [NeII] mid-infrared line. Right panel: Image of NGC 7582 obtained in the [NeII] filter showing the slit position (top), and a 2D spectrum unveiling the velocity structure (bottom).





The VIMOS-VLT Deep Survey First Epoch observations: evolution of galaxies, large scale structures and AGNs over 90% of the current age of the universe

The VIMOS VLT Deep Survey (VVDS) is a major redshift survey of the distant universe, aimed at studying the evolution of galaxies, large scale structures and AGNs over more than 90% of the age of the universe. A total of 41 000 spectra have been observed so far. From the First Epoch observations conducted with VIMOS, we have assembled ~ 11 000 redshifts for galaxies with 0 ≤ z ≤ 5 selected with magnitude I_{AB} ≤ 24 in an area 3.1 times the area of the full moon. We present evidence for a strong evolution of the luminosity of galaxies and show that galaxies are already distributed in dense structures at z ~ 1.5. The high redshift population of ~ 1000 galaxies with 1.4 ≤ z ≤ 5 appears to be more numerous than previously believed. As the survey continues, we are assembling multi-wavelength data in collaboration with other teams (Galex, Spitzer-SWIRE, XMM-LSS, VLA), as well as expanding to larger scales (~ 100 Mpc) to probe the universe in an unprecedented way.

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The VVDS aims to map the distribution of galaxies at various epochs in the life of the universe, in order to trace the evolution of galaxies in connection to the large scale structures. From a well defined flux-selected sample of sources identified from deep images, we use VIMOS on the VLT to measure the distance, via the cosmological redshifts, of a large number of galaxies and AGNs back in time up to 12 billion years ago. As we aim to measure the statistical properties of galaxies as free as possible of biases, we are observing several independent fields large enough to be insensitive to large fluctuations in the distribution of galaxies in the universe. The observations of more than 100 000 galaxies are required to characterize the population of galaxies with the basic statistical measurements like the luminosity function, or correlation function.

Two main surveys make the VVDS, the VVDS-Deep and the VVDS-Wide surveys. The VVDS-Deep is a magnitude limited survey reaching down to I_{AB} = 24 in 1.3 deg^2 in two fields, while the VVDS-Wide reaches down to I_{AB} = 22.5 in 11 deg^2 in 4 fields (Table 1). The "Deep" fields are covered with a 4-passes strategy with VIMOS, leading to a spatial sampling of 1/4th to 1/3rd of the total *I*-band limited population observed in photometry, while the "Wide" fields are covered in a 2-passes strategy. A total number of 41 000 spectra have been obtained as of October 1st, 2004.

We have now completed the First Epoch catalog on the VVDS-02h field and VVDS-CDFS, corresponding to observations obtained in the fall of 2002. A total of 11 564 spectra have been measured. We are in the process of completing the redshift measurements in the VVDS-Wide fields, for which a

Field	Alpha (2000)	Delta (2000)	Survey area (deg²)	Survey mode	Observed as of 1 October 2004
VVDS-0026-04	02ʰ26ᵐ00.0ˢ	-04°30′00″	1.3 (Deep)	Deep	29 deep pointings, ~12 000 slits
VVDS-CDFS	03ʰ32ᵐ28.0ˢ	-27°48′30″	0.1 (Deep)	Deep	5 deep pointings, 1599 redshifts releases to the community *http://cencosw.oamp.fr*
VVDS-1003+01	10ʰ03ᵐ39.0ˢ	+01°54′39″	4 (Wide)	Wide now HST-COSMOS field	7 pointings, ~2 600 slits
VVDS-1400+05	14ʰ00ᵐ00.0ˢ	+05°00′00″	4 (Wide)	Wide	15 pointings, ~6 000 slits
VVDS-2217+00	22ʰ17ᵐ50.4ˢ	-00°24′27″	4 (Wide)	Wide	48 pointings, ~20 000 slits

Table 1: VVDS fields

total of ~27 000 additional spectra have been observed.

The VVDS-10h field has now become the HST-COSMOS field with 2 deg^2 being observed with an unprecedented 590 orbits of HST-ACS. Our primary choice was the VVDS-02h where more than 10 000 spectra were available at the time of the original HST proposal, which would have made the redshifts and morphology of more than 10 000 galaxies immediately available. Unfortunately, at the pressing request of ESO and HST observatories, the COSMOS field has been set on the VVDS-10h field to avoid a severe time allocation conflict, preventing the COSMOS-VVDS team to assemble redshifts in connection with the HST imaging until the acceptance of the zCOSMOS programme, now secured.

The VVDS was defined to make use of the GTO nights allocated to the VIRMOS consortium in compensation for the substantial institute investment in building VIMOS. After the large cut of the GTO from 80 to 50 nights, with only 33 nights out of these having been clear, we are now seeking Large Program status to complete the VVDS as close to originally planned.

We present here the VVDS First Epoch data, and the main science results obtained. Results discussed below are computed with $H_0 = 70$, $\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$.

Deep photometry

Excellent deep images are required for a deep redshift survey in order to select targets for spectroscopy in an unbiased way, and to constrain the spectral energy distribution of the observed objects. We have completed deep photometry over the VVDS-02, VVDS-10, VVDS-14 and VVDS-22 fields, in *BVR*- and *I*-bands using the CFHT, as well as in *U* (see Le Fèvre et al., 2004b, and references therein) and *K* (Iovino A., and the VVDS team, in prep.) for smaller areas using ESO telescopes. We present an example of our deep images in Figure 1. The photometric catalogs and images are fully public on *http://cencosw.oamp.fr/*. We are complete down to $I_{AB} = 25$, and $K_{AB} = 21.7$, which ensures that no bias is propagated from the photometry to the spectroscopy, for any galaxy type. Recently, deep *u*, *g*, *r*, *i*, and *z* photometry has been obtained on the VVDS-02h field as part of the CFHT Legacy Survey.

VIMOS multi-slit spectroscopy observations and data processing

Multi-object spectra are observed with the LRRED grism with VIMOS on the VLT and 1 arcsec slit width. The average slit number for the VVDS-Deep and VVDS-Wide is 540 and 450 slits, respectively. A pointing pattern has been defined to produce a homogeneous field coverage for the VVDS-Deep, with a grid of VIMOS pointings offset by (2,2) arcmin, with 4 pointings looking in turn at the same area in the sky. The VVDS-Wide pointing strategy allows observing each point in the sky with two VIMOS pointings producing a roughly homogeneous coverage of the large 2 × 2 deg^2 fields. In the "Deep" survey, 10 exposures of 27 minutes each are taken for a total exposure time of 4.5 h. In the "Wide" mode of the VVDS, 5 exposures of 10 minutes are taken for a total exposure time of 50 min. The galaxies observed until 1 October 2004 are shown in Figure 2.

The data processing has been progressing in two steps: extraction of the wavelength and flux calibrated one dimensional spectra with VIPGI (VIMOS Interactive Processing Graphical Interface, Scodeggio et al., 2005), and redshift measurement using KBRED, an automated tool for redshift measurement (Scaramella et al., in prep). VIPGI integrates in a very efficient environment (Scodeggio et al., 2005) the software delivered to ESO by the VIRMOS consortium for the ESO-VIMOS pipeline. It is available along with computing resources at our facilities in Marseille and Milan for anybody who obtains VIMOS data (*http://cosmos.mi.iasf.cnr.it/marcos/vipgi/vipgi.html*). The spectral resolution is R = 230, and the velocity accuracy is 275 km/s as measured from repeated observations of the same objects.

Figure 1: Composite *BVI* image from the CFHT12K survey (Le Fèvre et al., 2004a). The limiting magnitude (5σ, in 3 arcsec diameter aperture) is $I_{AB} = 25$. This image shows only 3 × 4 arcmin^2, or 1/5000th of the full 16 deg^2 imaging survey.

Measuring redshifts in a large range $0 \leq z \leq 5$

The VVDS is the first survey to assemble a complete spectroscopic sample of galaxies based on a simple *I*-band limit down to $I_{AB} = 24$, spanning the redshift range $0 \leq z \leq 5$. Magnitude limited samples have the advantage of a controlled bias in the selection of the target galaxies, which can lead to a reliable census of the galaxy population as seen at a given rest-frame wavelength.

The redshift domain above redshift 1.3 and below the redshift domain of Lyman-break galaxies $z > 2.7$ has been referred to as the "redshift desert". Crossing this "redshift desert" is critical to reduce the incompleteness of deep redshift surveys, and probe the galaxy population at an important time in the evolution. As the VVDS observed wavelength range is 5500–9500 Å, it is relatively easy to observe spectral features such as [OII]3727 Å up to $z \sim 1.4$, and then the strong UV features below 1700 Å for $z > 2.6$, but the redshift range $1.4 < z < 2.7$ is more tricky. Using high quality galaxy templates produced from VVDS galaxies to compute redshifts with KBRED we have been able to identify a large population of objects with $z > 1.4$, successfully crossing the "desert" up to $z \sim 2.2$, as other teams have also recently been doing (e.g. Steidel et al., 2004). The remaining VVDS "desert" $2.2 \leq z \leq 2.6$ is demonstrated to be the result of the selection function imposed by the combination of the faintness of the sources, the wavelength domain of the VIMOS-LRRED, and the strong OH sky emission features. A way to eliminate any possible redshift desert and follow the main population of galaxies including early-type systems would be to combine visible and near-IR multi-object spectros-

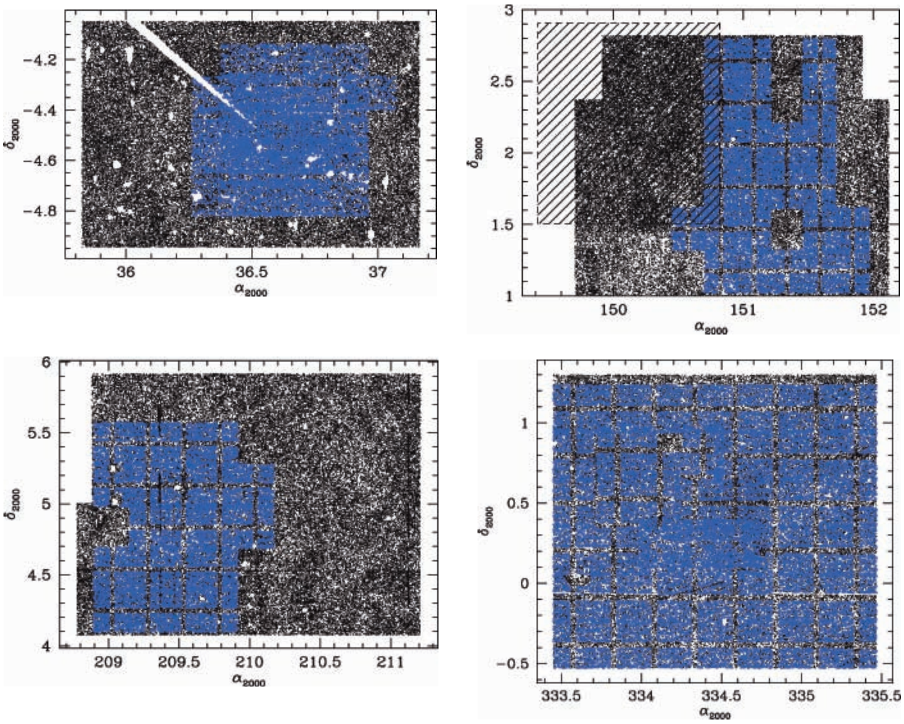

Figure 2: Field coverage of the VVDS fields as of 1st October 2004 (axis are in degrees): VVDS-02h (top-left), VVDS-10h (top-right), VVDS-14h (bottom-left), VVDS-22h (bottom-right). Galaxies with measured spectra are identified as blue dots, superimposed on the background of photometric targets with $I_{AB} \leq 24$ for the VVDS-02h field, and $I_{AB} \leq 22.5$ for the other fields. The shaded area in the VVDS-10h represents the COSMOS survey area. The VVDS-CDFS is not represented here; it contains 1599 measured VVDS redshifts (Le Févre et al., 2004b) A total of 14000 targets have been observed in the VVDS-Deep, and 27000 in the VVDS-Wide. The VVDS-22h has been covered once and awaits a second pass of VIMOS observations.

copy. Unfortunately, the cancellation of NIRMOS has postponed several critical science topics in need of statistically significant samples until KMOS comes into operation after 2010.

Our observations demonstrate that measuring redshifts at $z > 1.4$ from low resolution spectroscopy R ~ 200 can be done efficiently: a sample spectrum is shown in Figure 3, and high quality VVDS templates are shown in Figure 4 and Figure 10. Low resolution with VIMOS allows us to double or triple the number of spectra observed in one single observation compared to medium R ~ 600 resolution and up to 4–5 times more compared to R ~ 2500 observations. It is thus particularly well suited to assemble very large samples in a reasonable amount of observing time. Low resolution surveys have the capability to quantify sub-populations, identify rare populations, and establish well defined unbiased statistical samples which can then be followed up at higher spectral resolution. For programs requiring higher velocity accuracy, better sampling and S/N of narrow spectral features, medium (~ 600) or medium high (~ 2500) spectral resolution can be very useful indeed, but at a significant loss of total observed spectra.

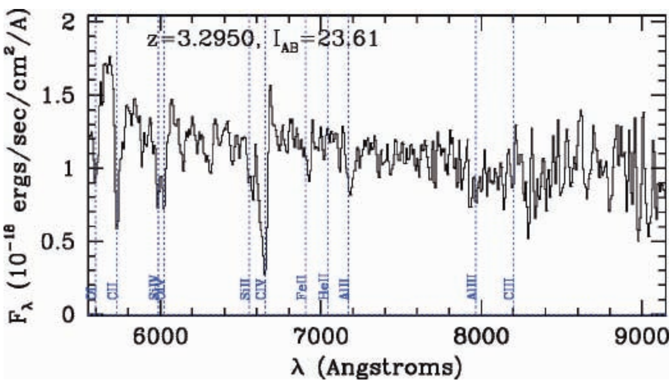

Figure 3: Spectrum of an absorption line galaxy with $I_{AB} = 23.61$, and $z = 3.2950$, demonstrating the ability of low spectral resolution (R ~ 230) to measure redshifts from absorption line galaxies down to the very faint end of the survey and at high redshift.

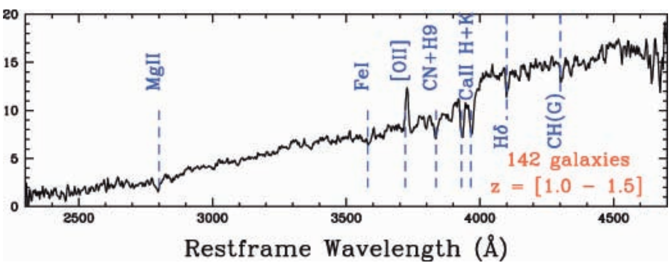

Figure 4: Example of galaxy templates constructed from the VVDS, for early type galaxies with $0.6 \leq z \leq 1.5$.

The VVDS First Epoch Sample

The First Epoch sample contains 11564 objects with spectra; 9677 are galaxies with a redshift measurement, 836 objects are stars, 90 are AGNs, and a redshift could not be measured for 961 objects (Le Fèvre et al., 2005a). There are 1065 objects (galaxies and QSOs) with a measured redshift $z \geq 1.4$. When considering only the primary spectroscopic targets, the survey reaches a redshift measurement completeness of 78 % overall (93 % including less reliable flag 1 objects), sampling ~ 25 to 30 % of the population of galaxies with $I_{AB} \leq 24$. The VVDS data on the CDFS is fully public, with 1599 redshifts available at *http://cencosw.oamp.fr/* (Le Fèvre et al., 2004b).

We have assigned to each redshift measurement a quality assessment similar to the scheme used by the CFRS (Le Fèvre et al., 1995). Comparing the redshift measurement of 426 objects observed twice and processed independently, we have been able to estimate that the probability of being correct is 53 ± 5 %, 81 ± 3 %, 94 ± 3 %, and 100 %, for galaxies with flags 1, 2, 3, 4 respectively, and that the velocity accuracy is 275 km/s. Comparison to the dataset of Vanzella et al. (2005) of 39 VVDS galaxies in the CDFS observed with VLT-FORS2, shows only 9 discrepancies, with 8 solved from the better red sensitivity of FORS2 and one with a better S/N from the VVDS spectrum. This excellent agreement is statistically fully compatible with the distribution of probabilities for the VVDS flags given the small comparison sample from FORS2 and the different observing conditions.

Redshift distribution of the $I_{AB} \leq 24$ sample

The redshift distribution of a spectroscopically selected sample of galaxies with

$17.5 \leq I_{AB} \leq 24$ has been measured for the first time from the VVDS, as shown in Figure 5. The distribution of galaxies peaks at $z = 0.8–0.9$ (median $z = 0.76$, mean $z = 0.90$), while there is a significant high redshift tail extending up to $z \sim 5$. There are 558 galaxies in our primary sample with a measured redshift $1.4 \leq z < 2.5$, 258 with $2.5 \leq z < 3.5$ and 161 with $3.5 \leq z < 5$, the largest purely magnitude selected sample at these redshifts so far.

Evolution of the luminosity function and luminosity density from $z = 2$

The evolution of the Luminosity Function (LF) has been investigated from the First Epoch VVDS sample, for $17.5 \leq I_{AB} \leq 24$ (Ilbert et al., 2005), using the ALF tool. We observe a substantial evolution with redshift of the global luminosity function in all bands from *U* to *I* rest frame, as shown in Figure 6 for the *B*-band. The LFs have been estimated within the absolute magnitude range in which any kind of galaxy is observable (dashed vertical lines in Figure 6, and Figure 7; Ilbert, O., et al., 2004). Compared to the local SDSS values, we measure a brightening ranging from 1.8–2.4 magnitudes in the *U*-band, to 0.8–1.4 magnitudes in the *I*-band, when going from $z = 0.05$ up to $z = 2$ (Ilbert et al., 2005). The stronger brightening toward bluer rest frame wavelengths suggests that most of the evolution of the global LF up to $z = 2$ is related to the star formation history, better probed with the luminosity measured at short rest frame wavelengths.

The First Epoch sample also allows the derivation of the luminosity function for each of four galaxy types out to $z \sim 1.5$ (Zucca, E., and the VVDS team, in prep.). We present in Figure 7 the LF of two extreme galaxy types (among four) that we have used to classify the galaxies. The difference is striking: galaxies with early spectral types are only mildly evolving with a 0.5 magnitudes brightening, while the late-irregular type galaxies were ~ 2 magnitudes brighter and twice more numerous at $z \sim 1.2–1.5$. At bright magnitudes $I_{AB} \leq 22.5$, our results are fully consistent with the CFRS results. Down to $I_{AB} \leq 24$, we find some significant differences compared to previous surveys based on photometric redshifts (e.g. Wolf et al., 2003), possibly due to the degeneracy in photometric redshifts computation, demonstrating the need for spectroscopic redshifts to properly assess the statistical properties of the high redshift galaxy population.

Evolution of the distribution of galaxies in large scale structures from $z = 2$

The First Epoch sample allows a direct estimate of the evolution of the spatial distribution of galaxies *from within the same survey* (Le Fèvre et al., 2005b). The main separation between galaxies is best described by the correlation length, which we have computed from the correlation functions $\xi(r_p,\pi)$ and $w_p(r_p)$ for a total of 7155 galaxies in a 0.61 deg^2 area. We find that the correlation length $r_0(z)$ increases only slightly from $z = 0.5$ to $z = 1.1$, with $r_0(z) = 2.5–2.8\ h^{-1}$ Mpc (comoving), for galaxies comparable in luminosity to the local 2dFGRS and SDSS samples. This indicates that the amplitude of the correlation function was ~ 2.5 times lower at $z \sim 1$ than observed at the present time. The correlation length is increasing to

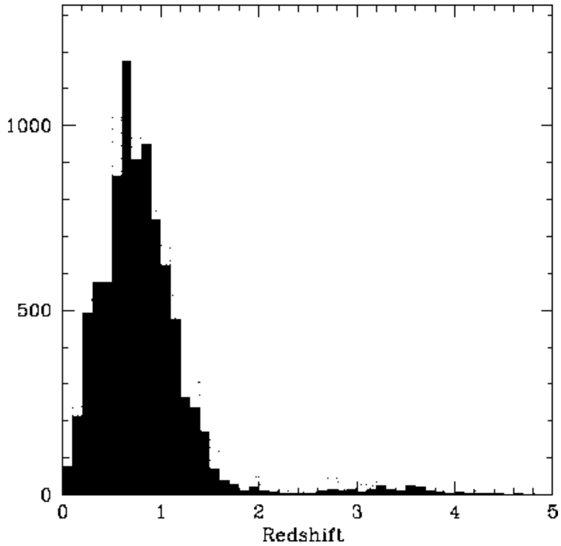

Figure 5: Spectroscopic redshift distribution of a sample of 9141 galaxies with $17.5 \leq I_{AB} \leq 24$. This sample is 78% complete. The secure redshift sample is shown as the filled histogram, and less secure redshift measurements are represented by the dashed histogram. The median redshift is $z = 0.76$, while the mean is $z = 0.90$. The dearth of objects with $2.2 < z < 2.6$ is a consequence of the observed wavelength range on the ability to measure redshifts, producing the VVDS "redshift desert" (see text).

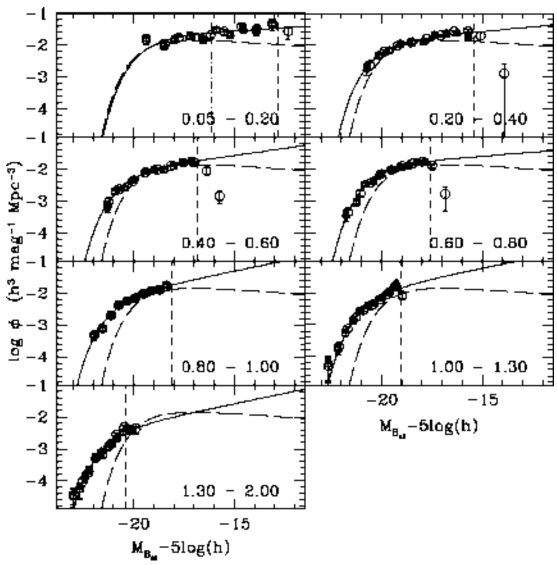

Figure 6: Evolution of the luminosity function in the rest-frame *B*-band (Ilbert et al., 2005). Each panel shows the LF computed in the redshift range identified in the lower right corner. Open circles show the VVDS values computed using the V_{max} and the continuous line is computed using the STY technique. The local LF computed by the SDSS is shown as the long dashed line in each panel as a reference.

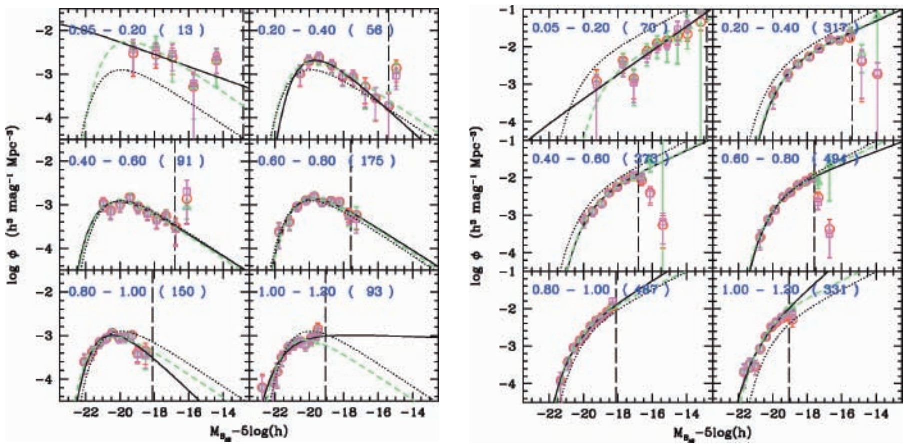

Figure 7: Evolution of the luminosity function in the rest frame *B*-band for galaxies spectrophotometrically classified as early type (left) and late/irregular type (right) (Zucca, E., and the VVDS team, in preparation). Vertical dashed lines indicate the luminosity above which no bias is expected. While the early types show a mild evolution of about 0.5 magnitudes, consistent with passive stellar evolution, the irregular galaxies exhibit a strong 2 magnitudes evolution and an increase in number density of a factor ~ 2.

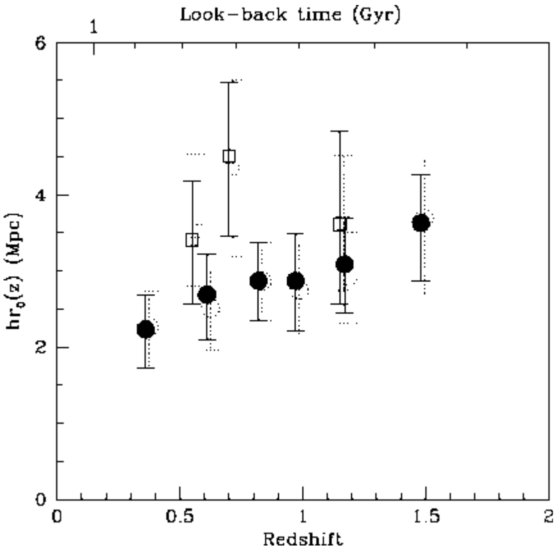

Figure 8: Evolution of the correlation length $r_0(z)$ along cosmic time (Wolf et al., 2003). The filled circles are the VVDS measurements in the VVDS-02h field, while the open squares are measured in the VVDS-CDFS field. The VVDS-CDFS point at z ~ 0.7 shows a higher correlation length because of the presence of a strong over-density at this redshift.

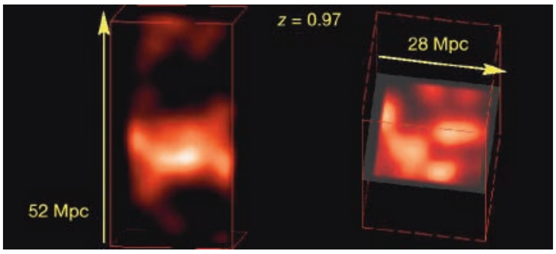

Figure 9: Galaxy density field around a large "wall" of galaxies in the VVDS-02h field. This dense structure is at a redshift z = 0.97, it is relatively thin and extends over the full transverse cone sampled so far or ~ 40 Mpc. Extending the survey up to 2 degrees size would allow us to probe such large scale structures on scales ~ 100 Mpc.

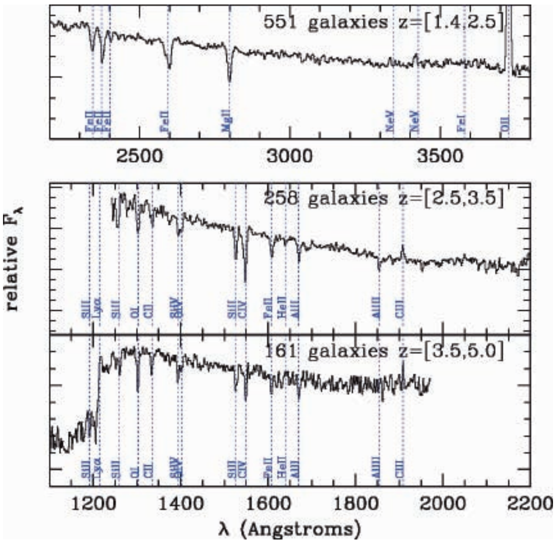

Figure 10: Composite VIMOS spectra of the high redshift VVDS First Epoch galaxy sample in each of the redshift domains z = [1.4,2.5], z = [2.5,3.5], z = [3.5,5]. UV features are clearly identified, and the blue continuum indicates actively star forming galaxies.

r_0 ~ 3.0 h^{-1} Mpc at higher redshifts z = [1.3,2.1], as we are observing increasingly brighter galaxies, comparable to the clustering length of galaxies with M_B(AB) = –20.5 locally. The slowly varying clustering of VVDS galaxies as redshift increases is markedly different from the predicted evolution of the clustering of dark matter, indicating that bright galaxies were tracing higher density peaks when the large scale structures were emerging from the dark matter distribution 9–10 billion years ago, a supporting evidence for a strong evolution of the galaxy vs. dark matter bias. This is the first time that a consistent picture of galaxy clustering is obtained over such a large time base from within the same survey as shown in Figure 8. The analysis of the clustering of sub-populations (e.g. selected by type or luminosity) is in progress (Meneux et al., Guzzo et al., Pollo et al., in preparation).

The complete spectroscopic survey samples the high redshift universe at z ~ 1 with a mean inter-galaxy separation of ~5 Mpc equivalent to the sampling of the 2dF galaxy redshift survey at a mean redshift z ~ 0.1. The galaxy density field can be computed reliably up to z ~ 1.5. It spectacularly shows strong over-densities (e. g. shown in Figure 9) alternating with low density regions, very dense walls, and filamentary distribution, which can be traced in the entire survey cone, and over transverse scales ~ 30 Mpc. The size of structures observed indicates that probing even larger scales ~ 100 Mpc is necessary, as planned in the original VVDS.

The second moment of the Probability Distribution Function (PDF) of galaxy over-densities stays roughly constant up to z ~ 1.5, with σ_8 = 0.94 ± 0.07 (in redshift space). The third moment of the PDF, the skewness, increases with cosmic time: we find that the probability of having under-dense regions is higher at z ~ 0.7 than it was at z ~ 1.5. By comparing the observed PDF of galaxy fluctuations with the theoretically predicted PDF of mass fluctuations, we find that the galactic bias is increasing by ~ 40% from z ~ 0.7 to z = 1.5. Red objects appear more clustered than blue objects at all epochs investigated. The relative bias between the density fluctuations of red and blue objects is constant as a function of redshift with a relative bias of ~ 1.4 comparable to the local z = 0 value. These results are presented in Marinoni et al. (submitted).

The high redshift 1.4 ≤ z ≤ 5 VVDS population

There are more than 970 galaxies with redshifts measured in the range z = [1.4,5] in the primary sample of the First Epoch VVDS. The composite spectra of galaxies with measured redshifts in the range z = [1.4,2.5], z = [2.5,3.5], and z = [3.5,5], are shown in Figure 10. These galaxies are bright, with absolute magnitudes M_B(AB) = –21.5 or brighter. They show a strong UV continuum indicating vigorous star formation (Figure 10). From the rest frame 1500 Å UV flux we can infer that these galaxies produce stars with a star formation rate of several tens of solar masses per year (uncorrected for extinction). The volume density of galaxies at these redshifts seems to be higher than previously reported for other galaxy populations at the same redshifts. This is under investigation and will be reported elsewhere (Le Fèvre, O., and the VVDS team, in prep.), together with the detailed properties of these galaxies (Paltani, S., and the VVDS team, in prep.).

The faint AGN population out to z ~ 5

Since the only selection criterion for the VVDS is magnitude, with no additional criteria based on morphology or colors, the VVDS is also an ideal survey for selecting a complete and unbiased sample of AGN. We have identified 133 broad line QSOs up to now, 76 identified in the VVDS-Deep survey of the VVDS-02h and VVDS-CDFS, and 57 QSOs identified so far in the VVDS-Wide survey of the VVDS-10h and VVDS-22h. The redshift distribution is shown in Figure 11. The VVDS probes ~ 2–3 magnitudes fainter than the 2dF QSO survey, extending the measurement of the LF toward the faint end, and sampling a transition regime between bright AGNs and galaxies, where standard selection for AGN samples is significantly incomplete. This is presented in Gavignaud et al. (in prep.), and Bongiorno et al. (in prep).

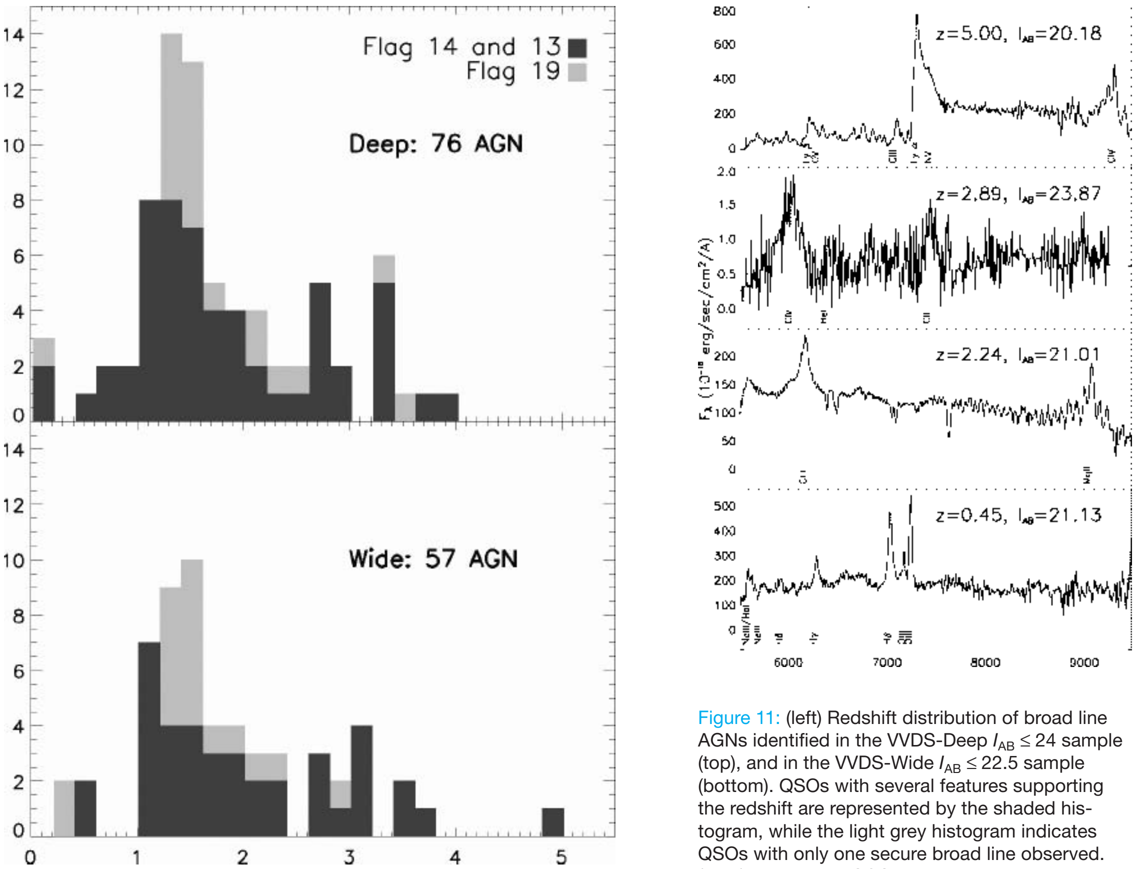

Figure 11: (left) Redshift distribution of broad line AGNs identified in the VVDS-Deep $I_{AB} \leq 24$ sample (top), and in the VVDS-Wide $I_{AB} \leq 22.5$ sample (bottom). QSOs with several features supporting the redshift are represented by the shaded histogram, while the light grey histogram indicates QSOs with only one secure broad line observed. (right) Example of QSO spectra covering our redshift and magnitude range.

Multi-wavelength observations

We have been conducting observations at wavelengths outside the optical and near-infrared window of the VVDS, and we have stimulated observations from other teams. We have observed the VVDS-02h field with the VLA at a depth 17 µJy (1σ) (Bondi et al., 2003, and Ciliegi, P., et al., in prep.). The VVDS-02h field is observed in the UV with GALEX, in the mid-IR with Spitzer by the SWIRE team, in the X-rays with XMM by the XMM-LSS team. The VVDS-22h field is observed by GALEX, and the VVDS-10h, now the COSMOS field, is observed at all wavelength from the radio to the X-ray band (*http://www.astro.caltech.edu/~cosmos/*). The immediate availability of ~1000 VVDS redshifts of UV sources detected with GALEX in the VVDS-02h has allowed publishing for the first time the luminosity function, luminosity density, and star formation rate directly measured at 1500 Å rest frame (Arnouts et al., 2004).

The SWIRE team has observed the VVDS-02h field with Spitzer, at wavelengths 3.6, 4.5, 5.8, 8 and 24 microns. The joint catalogue of SWIRE and optical data gives redshifts for more than 3200 sources at 3.6 µm, and more than 220 sources at 24 µm. The combination of deep optical, near-IR and mid-IR data will be very powerful to probe the evolution of stellar light, and dust enshrouded star formation.

A detailed dynamical study of VVDS galaxies with $1 < z < 2$ will be conducted with 3D spectroscopy and SINFONI (Lemoine-Buserolle et al.). The VVDS is a uniquely suited sample to perform an unbiased sample selection for follow-up spectroscopy, in particular to measure star formation indicators like the Hα line in emission, from near-IR spectroscopy. A UK team led by A. Bunker is proposing to use CIRPASS as a visiting instrument on the VLT to perform near-IR multi-fiber spectroscopy.

Prospects

The VVDS is now bringing into full view the distant universe of normal galaxies like our Milky Way and its progenitors over a large time of evolution. The hard but rewarding approach of a magnitude limited sample allows a statistically robust measurement of the evolution of the galaxy population using the luminosity function, correlation function, or the probability distribution function of density fluctuations. A wealth of new results will appear in the months to come from the First Epoch catalogue of ~ 10 000 redshifts and the ~ 30 000 spectra being processed. It is essential to our understanding of galaxy evolution that the VVDS be completed as originally planned with (i) an increase of the area covered in the VVDS-02h "deep" field by at least a factor 2, and (ii) a complete redshift measurement in ~ 10 deg^2 in the full VVDS-14h and VVDS-22h. This will extend the survey to ~ 100 Mpc at z ~ 1–5, unprecedented up to now, probing scales larger than the mean size of large voids and dense structures. This will undoubtedly bring new insight into the complex interplay between galaxy evolution and the underlying large scale structure distribution. The VVDS, combined with the zCOSMOS survey connecting the evolution of galaxy morphology to the large scale structures, is establishing European astronomy as a leading authority in high statistical accuracy deep redshift surveys, a central key to our understanding of galaxy evolution.

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Recent Astrophysical Results from the VLTI

We present a review of recent astrophysical results based on data obtained with the ESO Very Large Telescope Interferometer (VLTI). The very first VLTI results have already been reviewed by Richichi & Paresce (2003). Remarkably, the first scientific results from the mid-infrared instrument MIDI, which emerge from science demonstration and guaranteed time observations, already cover a very broad range of astrophysical topics. These topics include active galactic nuclei, young stellar objects and protoplanetary discs, the environments of hot stars, as well as evolved stars and their envelopes.

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Observations with the ESO VLT Interferometer started with the achievement of First Fringes in March 2001, which employed the test siderostats and the commissioning instrument VINCI. Since then, the VLTI instrumentation has been constantly expanded, and scientific observations have continuously been carried out using the instrumentation that had been available at any given time. A report on the technical status of the VLT Interferometer was for instance presented by Glindemann et al. (2004). A huge number of scientifically interesting VINCI data were secured between March 2001 and September 2004 within commissioning and early shared risk programmes, and all of these VINCI data are publicly available[1]. Early MIDI observations in the framework of science demonstration and guaranteed time programmes have been conducted since 2003. The data based on MIDI science demonstration programmes are also publicly available[2]. The MIDI instrument has been offered to the whole astronomical community for general programmes since ESO period P73 (observations starting in April 2004). First science demonstration and guaranteed time observations using the near-infrared phase closure instrument AMBER were conducted in October and December 2004.

The first refereed publications based on data obtained with the VLTI appeared in the year 2003. A review of the very first VLTI results was presented by Richichi & Paresce (December 2003). Since then many new results have been published that are based on data obtained with VLTI instruments. The ESO telescope bibliography lists for the years 2003 and 2004 a total of 21 refereed publications directly using ESO data, which were obtained with the VLTI instruments VINCI and MIDI (see Table 1). These data were taken within VINCI commissioning, VINCI shared risk, MIDI science demonstration, and MIDI guaranteed time programmes. These publications are listed in the references below. Also listed are 11 additional publications that appeared in 2005 or that are in press, and that qualify to be included in the ESO telescope bibliography. Here, we review these scientific results, concentrating on those that were published after the review of first VLTI results by Richichi & Paresce (2003). We put a particular emphasis on the results emerging from MIDI science demonstration and guaranteed time programmes (Jaffe et al. 2004; Leinert et al. 2004; van Boekel et al. 2004; Chesneau et al. 2005 a, b, c; Ohnaka et al. 2005). Recently, Richichi et al. (2005) presented an updated version of CHARM (catalogue for high angular resolution measurements), a catalogue that lists high angular resolution measurements in general, including results from the VLTI.

The VLTI results reviewed in this article illustrate that the VLT Interferometer provides excellent opportunities to address a broad range of important astrophysical topics. With the large collecting areas of the 8 m VLT Unit Telescopes, VLT Interferometry is not limited to the brightest stars, as most interferometric facilities so far, but can be used to study relatively faint sources. Results obtained so far include already, for instance, studies of the innermost cores of Active Galactic Nuclei (AGN) harbouring supermassive black holes, the origins of stars such as our sun and the formation of protoplanetary discs, fundamental parameters of stars in evolutionary stages such as our sun, the evolution and fate of stars and their mass-loss to the circumstellar environment, the environment of hot stars, and distance estimates based on measurements of Cepheid pulsations.

Remarkably, several of the publications reviewed here include results that were obtained by combing observations using different instruments and facilities. For instance, Chesneau et al. (2005a) combined observations obtained with MIDI, optical spectra taken with the HEROS instrument, and infrared spectra from the 1.6 m Brazilian telescope. Kervella et al. (2003b), Pijpers et al. (2003), and di Folco (2004) combined VINCI data with asteroseismic observations. Boboltz & Wittkowski (2005) conducted coordinated near-infrared (VINCI) and radio (VLBA) interferometry. Woodruff et al. (2004) combined VINCI observations with near-infrared speckle observations. Wittkowski et al. (2004) combined VINCI interferometry with available spectrophotometry. These examples show that interfer-

[1] *www.eso.org/projects/vlti/instru/vinci/vinci_data_sets.html*
[2] *www.eso.org/projects/vlti/instru/midi/midi_data_sets.html*

Year	VINCI	MIDI	Total
2003	6	–	6
2004	12	3	15
2005 (so far)	8	4	11
	26	7	32

Table 1: Refereed publications based on data obtained with VLTI instruments. Source: ESO Telescope Bibliography.

ometry, and in particular VLT Interferometry, is becoming a very useful complementary tool for general astrophysics among the many tools that are available to the astronomical community. It can be expected that more synergies between observations with the VLTI and external instruments and facilities will emerge, ultimately also including ALMA and OWL.

Galactic Nuclei

VLTI observations of Active Galactic Nuclei (AGN) with MIDI started soon after the instrument was ready for scientific observations with two UTs: the first interferometric spectrum of the famous Seyfert II galaxy NGC 1068 was obtained during science demonstration time in June 2003. A second set of MIDI measurements were carried out in November 2003. Also in November 2003, the first near infrared *K*-band long-baseline interferometric observations of NGC 1068 succeeded, which employed the VINCI instrument after adaptive optics wavefront correction (MACAO). The first successful MIDI observation of the second brightest galactic nucleus, that of the Circinus galaxy, became possible in February 2004. Two more measurements with baseline UT2–UT3 were obtained during guaranteed time in June.

The Circinus nucleus is over three times closer and ten times less luminous than NGC 1068. The analysis of the data shows that the central dust structure is well resolved at 10 µm even with a 43 m baseline. Nevertheless, due to the small distance, its physical size is only 1 pc diameter. The observed visibilities as a function of projected baseline orientation hint at a much flatter dust distribution than that observed in NGC 1068 (see below).

For the purpose of this overview, however, we focus on the discussion of the VLTI results of NGC 1068 since they best demonstrate the wealth of information which already has been provided by the VLTI. A first account of the MIDI observations of NGC 1068 was published by Jaffe et al. (2004). On the basis of the interferometric spectra covering the range 8 µm < λ < 13 µm taken with 78 m and 42 m baseline, respectively, the authors argue that two central components are discernible: a well resolved, warm (T = 320 K) component of 3 pc diameter which is geometrically thick ($h/r \simeq 0.6$), and a very compact hot ($T > 800$ K) component, which is marginally resolved along the source axis. The SiO absorption feature increases in depth when using higher spatial resolution, i.e. longer baseline, suggesting that the central hot component suffers strong dust extinction equivalent to $A_V > 50$. The model is visualized in Figure 1 (top).

A natural interpretation of these findings identifies the 320 K component with the AGN-heated dusty torus expected in the cores of Seyfert galaxies, while the embedded hot component represents the wall of the funnel which is heated almost to the dust sublimation temperature and confines the well studied outflows along the source axis of NGC 1068. Additional support for this picture comes from radio continuum observations with the VLBA presented by Gallimore et al. (2004): Superimposing their map of the central component S1 on the MIDI model (Figure 1 bottom) shows that the disc-like radio source coincides in size with the hot component. Presumably, in the radio continuum we observe free-free emission of the ionized gas within the funnel which is continuously released from the walls and eventually feeds the central accretion disc. It is intriguing to identify the increased height of the radio continuum source at its outer parts with the ionized gas which has just been "eaten away" from the funnel walls by the intense UV radiation from the central engine.

At the same time, Wittkowski et al. (2004) presented the first *K*-band long-baseline interferometric measurement of the nucleus of NGC 1068 (see above). A squared visibility amplitude of 16.3 ± 4.3 % was measured for NGC 1068 at a baseline length of 46 m. This value corresponds to a FWHM of the *K*-band intensity distribution of 5.0 ± 0.5 mas if it consists of a single Gaussian component. Taking into account *K*-band speckle interferometry observations up to a baseline of 6 m (Wittkowski et al. 1998), a multi-component model is suggested for the intensity distribution where a part of the flux originates from scales clearly smaller than 5 mas (< 0.4 pc), and another part of the flux from larger scales. Figure 2 shows the measured VLTI/VINCI *K*-band visibility together with possible visibility models. For illustration, two different two-component visibility curves are shown which are consistent with both, the VLTI/VINCI visibility measurement at a baseline of 46 m, and the speckle observations up to a baseline of 6 m. These models consist of a 0.1 mas or 3 mas compact core, respectively, plus a more extended component.

Taking the MIDI and VINCI results of NGC 1068 together, there remains a completely open question: How are the compact components at 2 and 10 µm related to each other? Without an accurate (relative) astrometry (to about 1 mas) available yet, we are left to speculations based on indirect arguments. From the depth of the SiO feature one infers a *K*-Band extinction toward the hot MIDI component of $A_K > 12$. One possible explanation is a very porous dust torus which occasionally leaves holes of low extinction toward its hot centre. The compact *K*-band component could then represent a direct view to the central source or the inner part of the funnel viewed through such a hole. Alternatively, the *K*-band component could be located somewhat above the torus plane: in this case it is very unlikely that dust can be heated to > 1 200 K (unless the UV radiation from the central source is extremely collimated). More probably, the *K*-band light is then scattered by dust clouds above the torus.

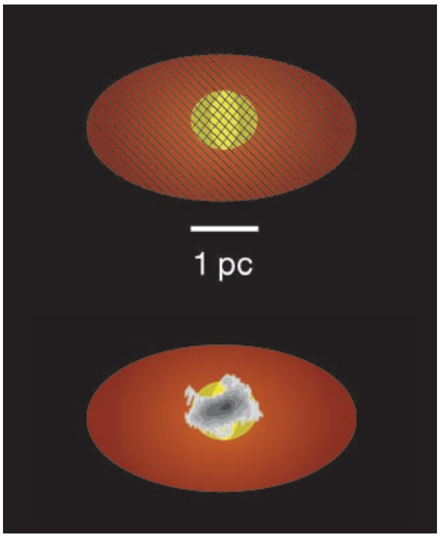

Figure 1: Top panel: Model dust distribution in the nucleus of NGC 1068 as inferred from the MIDI observations (North is at top, East to the right). A compact hot component (yellow) is embedded into the well resolved warm component (red). Hatching indicates the depth of the SiO absorption. Bottom panel: The VLBA radio continuum map at 5 GHz of the S1 component in NGC 1068 (from Gallimore et al 2004.) superimposed on the model. Note the widening of the radio component at its western edge.

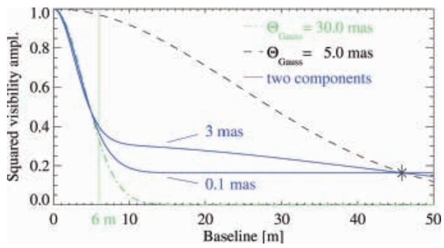

Figure 2: First *K*-band long-baseline interferometry of NGC 1068, obtained with VINCI. The VINCI visibility point at a baseline of 46 m indicates that part of the *K*-band flux originates from very small scales of less than 5 mas or 0.4 pc. Two possible two-component model visibility curves are shown which are consistent with this VINCI visibility measurement and with speckle observations up to a baseline of 6 m. These models consist of a 0.1 mas and 3 mas compact core, respectively, plus a more extended component. Based on Wittkowski et al. (2004b).

Pott et al. (this issue, page 43) describe in detail their program to study the stellar population close to our Galactic Centre. In particular, they describe the first successful MIDI observations of the dust enshrouded star IRS 3 located in the central lightyear of our Galaxy. Such studies aim at investigating the star formation history and the interaction of stars with their environment in the presence of tidal forces exerted by the gravitational potential of the central supermassive black hole.

In summary, it is obvious that already the first one and a half years of VLTI observations of galactic nuclei have provided completely new views into the cores of these still mysterious objects. New facilities like the phase-closure instrument AMBER or the external fringe tracking system FINITO will soon extend the VLTI capabilities to a level that interferometric observations of galactic nuclei will become both routine and the most important driver for our understanding of AGN physics.

Sizes and mineralogy of circumstellar discs around young Herbig Ae/Be stars

MIDI on the UTs was recently used to determine the characteristic sizes of Herbig Ae/Be star discs (Leinert et al. 2004) and their detailed dust properties (Van Boekel et al. 2004). The characteristic 10 μm sizes of the discs around seven Herbig Ae/Be stars turned out to be in the range of 1–10 AU and correlated with the slope of their SED between 10 and 25 μm (Figure 3). This correlation tends to give observational support even for such a limited sample to the hypothesis that Herbig Ae/Be star discs can be distinguished by whether they are flaring or non-flaring. In this context, one would expect, that as observed, the reddest objects should be larger since the flaring disc geometry exposes more distant material to direct illumination than the non-flaring geometry.

The detailed spectral shapes of three stars of this sample (HD 142527, HD 144432, and HD 163296) were then studied as a function of spatial scale in order to better understand the properties of circumstellar dust in these very young stars. It has been known for some time that most of the dust in discs around newborn stars is made up of silicates. In the natal cloud this dust is amorphous, i.e. the atoms and molecules that make up a dust grain are put together in a chaotic way, and the grains are fluffy and very small, typically about 10^{-4} mm in size. However, near the young star where the temperature and density are highest, the dust particles in the circumstellar disc tend to stick together so that the grains become larger. Moreover, the dust is heated by stellar radiation and this causes the molecules in the grains to re-arrange themselves in geometric (crystalline) patterns.

Accordingly, the expectation is that the dust in the disc regions that are closest to the star is soon transformed from "pristine" (small and amorphous) to "processed" (larger and crystalline) grains. Model calculations show that crystalline grains should be abundant in the inner part of the disc at the time of formation of the Earth. In fact, the meteorites in our own solar system are mainly composed of this kind of silicate. Spectral observations of silicate grains in the mid-infrared around 10 μm should tell whether they are "pristine" or "processed". Earlier observations of discs around young stars have shown a mixture of pristine and processed material to be present, but it was impossible to tell where the different grains resided in the disc.

Thanks to a hundred-fold increase in angular resolution with the VLTI and the highly sensitive MIDI instrument, detailed infrared spectra of the various regions of the protoplanetary discs around the three young Herbig Ae stars, only a few million years old, now show that the dust close to the star is much more processed than the dust in the outer disc regions. In one star (HD 142527) the dust is processed in the entire disc (Figure 4). In the central region of this disc, it is extremely processed, consistent with completely crystalline dust. In the other two stars (HD 144432 and HD 163296) the dust in the inner disc is fairly processed whereas the dust in the outer disc is nearly pristine (Figure 5).

An important conclusion from the VLTI observations is, therefore, that the building blocks for Earth-like planets are present in circumstellar discs from the very start. This is of great importance as it indicates that planets of the terrestrial type like the Earth are most probably quite common in planetary systems, also outside the solar system.

The present observations also have implications for the study of comets. Some – perhaps all – comets in the solar system do contain both amorphous and crystalline dust. Comets were definitely formed at large distances from the Sun, in the outer regions of the solar system where it has always been very cold. It is therefore not clear how processed dust grains may end up in comets. In one theory, processed dust is transported outward from the young Sun by turbulence in the rather dense circumsolar disc. Other theories claim that the processed dust in comets was produced locally in the cold regions over a much longer time, perhaps by shock waves or lightning bolts in the disc, or by frequent collisions between bigger fragments.

The MIDI observations now imply that the first theory is the most likely explanation for the presence of processed dust in comets. This also implies that the long-period comets that sometimes visit us from the outer reaches of our solar system are truly pristine bodies, dating back to an era when the Earth and the other planets had not yet been formed. Studies of such comets, especially when performed in-situ, will therefore provide direct access to the original material from which the solar system was formed.

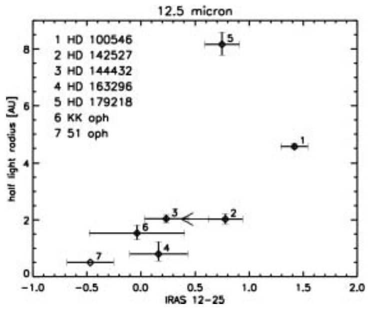

Figure 3: Correlation between the mid-IR spectral slope and the half light radius corresponding to the observed visibilities at 12.5 μm. The largest sources are those with the reddest mid IR SED. From Leinert et al. (2004).

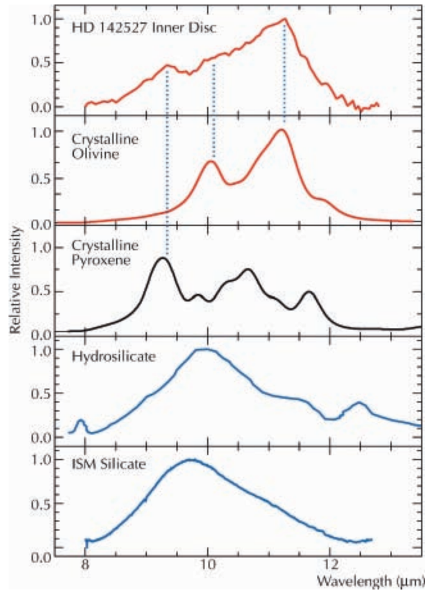

Figure 4: The mid-IR spectrum of the inner region of the protoplanetary disc around the young star HD 142527, as observed with MIDI (upper panel). Below it are shown laboratory spectra of two crystalline minerals as well as of an Interplanetary Dust Particle (IDP; captured in the Earth's upper atmosphere) with hydrated silicates and, at the bottom, a typical telescopic spectrum of dust grains in the interstellar space. The spectral "signatures" of crystalline pyroxene and olivine, i.e. peaks at wavelength 9.2 and 11.3 μm, respectively, are clearly visible in the spectrum of the inner stellar disc, demonstrating the presence of these species in that region of the disc. From Van Boekel et al. (2004).

Hot stars and their environment

Be stars are hot stars that exhibit Balmer lines in emission and free-free infrared excess, interpreted as due to a compact equatorial gaseous disc around these objects. Be stars are relatively frequent among the B-type objects. α Ara (HD 158427, B3Ve), which is one of the closest Be stars with an estimated distance of 74 pc (Hipparcos parallax) and an infrared excess among the highest of its class, has been chosen for the first MIDI observations of a Be star (Chesneau et al. 2005a). Surprisingly, α Ara could not be resolved with the 102 m projected baseline of the UT1 and UT3 telescopes, putting an upper limit to

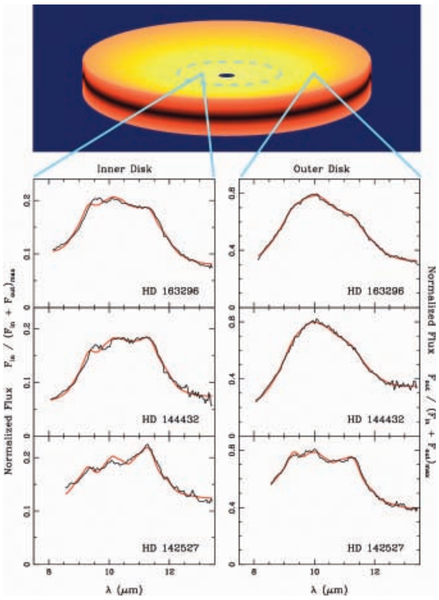

Figure 5: Schematic view of a circumstellar disc and the observed MIDI-spectra of the inner and outer regions of the discs around three young Herbig Ae stars, HD 163296, HD 144432 and HD 142527 (black lines). In all of them, there are clear spectral differences between the inner and outer regions, indicating a difference in mineralogy. The general broadening of the spectral "mountain" in the inner discs is a sign of larger grains and the spectral peak at wavelength 11.3 µm indicates the presence of crystalline silicates (cf Figure 4). Also shown are best-fit model spectra (red lines), based on mixtures of the mentioned mineral species. From Van Boekel et al. (2004).

the disc size in the *N*-band of the order of ϕ_{max} = 4 mas ± 1.5, i.e. 14 R_* at 74 pc and assuming R_* = 4.8$R_\odot$, based on the spectral type.

On the other hand, a high density of the disc is mandatory in order to reproduce the strong Balmer emission lines and the infrared excess. Optical spectra from the HEROS instrument, and infrared ones from the 1.6 m Brazilian telescope have been used together with the MIDI visibilities to constrain the system parameters. Using the circumstellar parameters from the SIMECA code, a good agreement was found with spectroscopic and interferometric data only if the disc is somehow truncated at about 25 R_*. The authors found variations of the hydrogen recombination line profiles and of the radial velocities of α Ara, and they argue that this may be an indication for a possible low-mass companion that could cause the truncation of the disc.

Using the stellar parameters from the model, i.e. a mass of 10 $M_\odot$, a 70 day period would give a radius of about 32 stellar radii, a value in agreement with the estimate based on the MIDI data for a disc truncated at 25 R_*, i.e. somewhat smaller than the companion orbit. Figure 6 shows a schematic view of the proposed model for the Be star α Ara and its circumstellar environment, including the possible unseen companion.

Previously, Domiciano de Souza et al. (2003) reported on VINCI observations of the rapidly rotating Be star Achernar. They found an oblateness of Achernar which exceeds theoretical predictions and, hence, puts new perspectives on our understanding of the Be phenomenon. α Ara presents a rotational velocity *v* sin *i* which is even larger than that of Achernar, and is, hence, likely to be very distorted, as well. The oblateness of the surface of α Ara can be studied with AMBER, and this will likely provide additional implications on the wind model.

The famous Luminous Blue Variable (LBV) η Car was recently studied by Chesneau et al. (2005b) by combining MIDI observations and adaptive optics measurements using NACO at the VLT. They reached a spatial resolution of 60–80 mas with deconvolved NACO images in the *L*-band. MIDI in interferometric mode provided a mean resolution of about 20 mas. Using this combination of MIDI and NACO observations, the authors were able to study the clumpiness of the nebula as well as to isolate the flux of the central star. The latter enabled them to constrain the spectral energy distribution (SED) of the central source by itself for the wavelength range from 2.2–13.5 µm.

Stars on the Asymptotic Giant Branch (AGB)

Interferometry is known to be a valuable tool for studying fundamental stellar parameters, the atmospheric structure, and the circumstellar environment of AGB and post-AGB stars. The spectro-interferometric capabilities of the VLTI instruments at near (AMBER) and mid-infrared (MIDI) wavelengths are expected to lead to new important insights into this stage of stellar evolution, and in particular into the atmospheric structure, the mass loss process, the formation of circumstellar envelopes, and the evolution of AGB stars toward planetary nebulae. Figure 7 shows a schematic diagram of a typical Mira variable and its surrounding environment. The various regions shown in this diagram can be probed by combining observations from various interferometric instruments and facilities in a multiwavelength study. In particular, mid-infrared interferometric observations are adequate for probing the outer atmosphere, i.e. the region between the top of the photosphere and the dust envelope where mass outflows are expected to be initiated, and the expanding dust shell.

Ohnaka et al. (2005) presented the results of the first mid-infrared interferometric observations of the Mira variable RR Sco with MIDI, coordinated with *K*-band observations using VINCI. The MIDI instrument has made it possible to measure the wavelength dependence of the visibility between 8 and 13 µm with a spectral resolution of ~ 30 (Figure 8, panel a). In this spectral region, a huge number of molecular lines due to H_2O and SiO are located, which allows one to directly study the parameters of the molecular gas in the outer atmosphere. Figure 8 (panel b) shows the obtained wavelength dependence of the angular diameter of

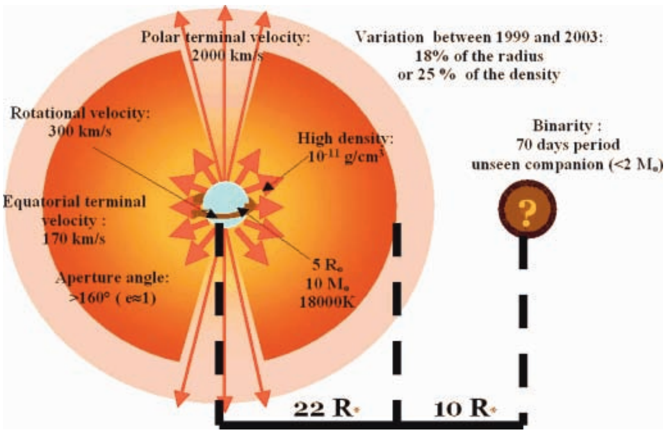

Figure 6: Schematic view of the proposed model for the Be star α Ara and its circumstellar environment. From Chesneau et al. (2005).

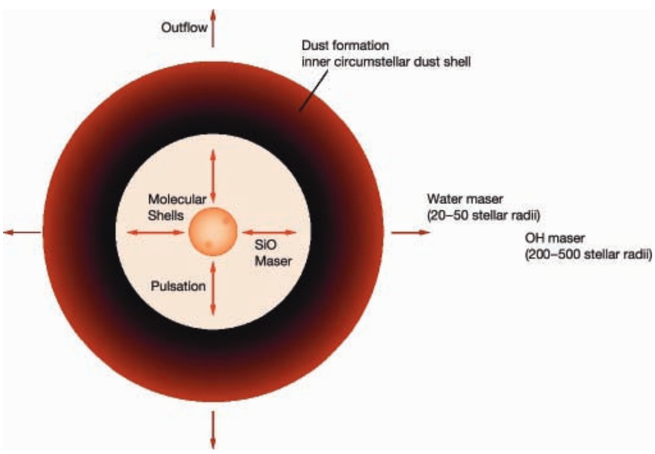

Figure 7: Schematic view of a Mira variable star.

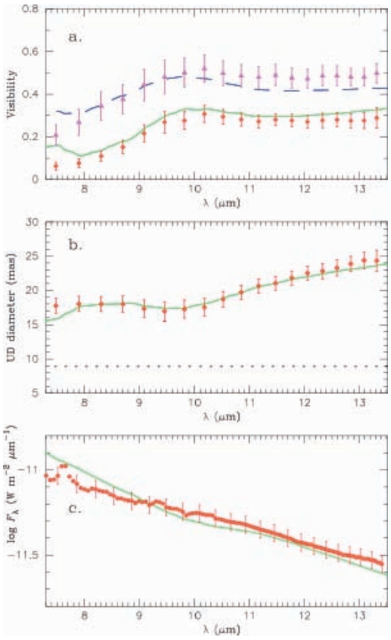

Figure 8: MIDI observations of the Mira variable RR Sco. Comparison between the visibility observed with MIDI (a), uniform-disc diameter (b), and spectrum (c) and those predicted by the best-fit model for RR Sco consisting of a warm H_2O + SiO envelope and an optically thin dust shell.
a: The diamonds and triangles represent the visibilities observed with projected baseline lengths of 99.9 m and 73.7 m, respectively, while the corresponding predicted visibilities are represented with the solid and dashed lines, respectively.
b: The filled diamonds represent the observed uniform-disc diameters, while the solid line represents the model prediction. The dotted line represents the continuum angular diameter estimated from the VINCI observation.
c: The filled circles represent the calibrated spectrum of RR Sco obtained from the MIDI observations. The solid line represents the spectrum predicted from the best-fit model. From Ohnaka et al. (2005).

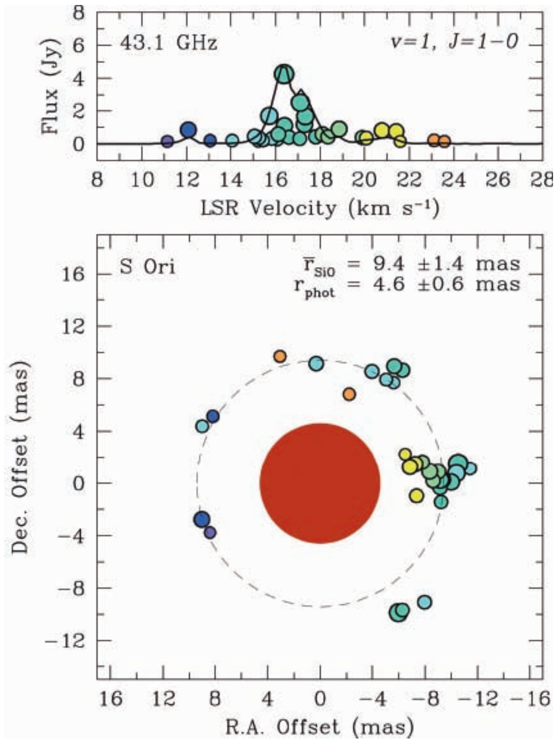

Figure 9: First-ever coordinated observations between ESO's VLTI and NRAO's VLBA: SiO maser emissions toward the Mira variable S Ori measured with the VLBA, together with the near-infrared diameter measured quasi simultaneously with the VLTI (red stellar disc). From Boboltz & Wittkowski (2005).

RR Sco. The angular diameter of 15–24 mas between 8 and 13 µm is significantly larger than the *K*-band diameter of 10.2 mas measured using VINCI, only three weeks after the MIDI observations. This wavelength dependence of the observed angular diameter of RR Sco can be interpreted in terms of the presence of a warm molecular envelope and an expanding dust shell. Ohnaka et al. (2005) derived physical parameters of these components using the *N*-band visibilities and the spectrum obtained with MIDI together with the *K*-band visibility measured with VINCI as observational constraints. Their model calculations show that optically thick emission from the H_2O + SiO envelope extending to ~ 2.3 stellar radii with a temperature of 1 400 K makes the apparent mid-infrared diameter much larger than the near-infrared angular diameter. The increase of the angular diameter longward of 10 µm can be explained by the presence of an optically thin dust shell consisting of corundum and silicate with an inner radius at 7–8 stellar radii.

Additional insights into the conditions of the molecular gas in the outer atmospheres and circumstellar environment of AGB stars can be achieved by measuring and mapping the maser radiation that some of these molecules emit. Boboltz & Wittkowski (2005) conducted concurrent observations of the Mira variable S Ori as part of a program intended to exploit the power of long baseline interferometry at infrared and radio wavelengths to study the photospheres and nearby circumstellar envelopes of evolved stars. Figure 9 shows the results of the first-ever coordinated observations between NRAO's VLBA (Very Long Baseline Array) and ESO's VLTI. The VLBA was used to observe the 43 GHz SiO maser emission (represented by the circles color-coded in bins of radial velocity) concurrent with near-infrared *K*-band VINCI observations of the stellar photosphere (represented by the red disc in the centre of the distribution). The SiO masers were found to lie at a distance of about 1.7 stellar radii or 1.5 AU. With concurrent observations such as these, parameters of the circumstellar gas, as traced by the SiO masers, can be related to the star itself at a particular phase in its pulsation cycle. Such measurements can be used to constrain models of stellar pulsation, envelope chemistry, maser generation, and stellar evolution.

Fundamental parameters, most importantly radii and effective temperatures, of the photospheres of the central cool giant stars themselves have been frequently obtained with interferometric and other high angular resolution techniques, thanks to the favorable brightness and size of these stars. Richichi and Roccatagliata (2005) recently conducted new accurate measurements of the angular diameter of the cool giant Aldebaran using near-infrared interferometric and lunar occultation techniques. They discuss explanations for the elusiveness of a common angular diameter value which includes temporal variations as well as a dependence of the stellar diameter on wavelength.

Through the direct measurement of the centre-to-limb intensity variation (CLV) across stellar discs and their close environments, interferometry also probes the vertical temperature profile, the chemical composition, and horizontal inhomogeneities. Limb-darkening studies have already been accomplished for a relatively small number of star using different interferometric facilities. Wittkowski et al. (2004) presented the first limb-darkening observation that was obtained with the VLTI. Using the VINCI instrument, they measured *K*-band visibilities of the M4 giant *ψ* Phe in the first and second lobe of the visibility function. These observations were found to be consistent with predictions by PHOENIX and ATLAS model atmospheres, the parameters for which were constrained by comparison to available spectrophotometry and theoretical stellar evolutionary tracks.

For cool pulsating Mira stars, the CLVs are expected to be more complex than for non-pulsating M giants due to the effects of molecular layers close to the continuum-forming layers. Broad-band CLVs may appear as Gaussian-shaped or multi-component functions. Woodruff et al. (2004) and Fedele et al.

(2005) presented *K*-band VINCI observations of the prototype Mira stars *o* Cet and R Leo, respectively. These measurements at post-maximum stellar phases indicate *K*-band CLVs which are clearly different from a uniform disc profile already in the first lobe of the visibility function. The measured visibility values were found to be consistent with predictions by recent self-excited dynamic Mira model atmospheres (Ireland et al. 2004 and references therein; Scholz & Wood 2004, private communication) that include molecular shells close to continuum-forming layers. Figure 10 shows as an example the comparison of the VINCI observation of the Mira stars R Leo (Fedele et al. 2005) with the predictions by the dynamic model atmospheres mentioned above.

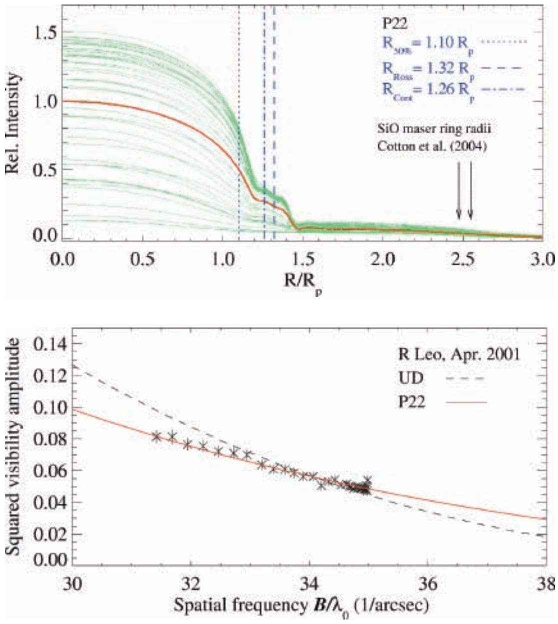

Figure 10: VINCI observations of the *K*-band intensity profile of the Mira variable R Leo and comparison to dynamic model atmosphere predictions (Ireland et al. 2004 and references therein; Scholz & Wood, private communication). The top panel shows the CLV prediction by model P22 (green lines: monochromatic CLVs; red line: filter-averaged CLV), and the bottom panel shows the corresponding visibility curve (red line) compared to the measured R Leo visibility values. Also indicated in the top panel are the mean positions of the SiO maser shells observed by Cotton et al. (2004). Based on Fedele et al. (2005).

Post-AGB stars

Further steps towards our better understanding of the stellar mass loss process are interferometric measurements of post-AGB stars. One of the basic unknowns in the study of late-type stars is the mechanism by which spherically symmetric AGB stars evolve to form axisymmetric planetary nebulae (PNe). Antoniucci et al. (2005) presented the first detection of the envelope which surrounds the post-AGB binary source HR 4049 by *K*-band VINCI observations. They report on a physical size of the envelope in the near-infrared *K*-band of about 15 AU (Gaussian FWHM). These measurements provide information on the geometry of the emitting region and cover a range of position angles of about 60 deg. They show that there is only a slight variation of the size with position angle covered within this range. These observations are, thus, consistent with a spherical envelope at this distance from the stellar source, while an asymmetric envelope cannot be completely ruled out due to the limitation in azimuth range, spatial frequency, and wavelength range. Further investigations using the near-infrared instrument AMBER can reveal the geometry of this near-infrared component in more detail, and MIDI observations can add information on cooler dust at larger distances from the stellar surface.

Chesneau et al. (2005c) very recently presented MIDI observations of the circumstellar environment of the massive OH/IR star OH26.5+0.6. This source is assumed to be at the tip of the AGB phase, and to have entered the superwind stage only about 200 years ago. The emission of the dusty envelope, appeared to be resolved by a single UT. The MIDI acquisition image taken at 8.7 µm exhibited clearly an asymmetry of the envelope of this star. In interferometric mode, no fringes were detected. The authors argue that this failure to detect fringes, caused by an over-resolved size of the source at this wavelengh range, gives additional constraints on the opacities of the inner regions of the dust shell or close vicinity of the star.

Cepheid pulsations and distance estimates

For almost a century, Cepheid variable stars have occupied a central role in distance determinations. This is thanks to the existence of the Period-Luminosity ($P-L$) relation $M = a \log P + b$ which relates the logarithm of the variability period P of a Cepheid to its absolute mean magnitude M. This relation is the basis of the extragalactic distance scale, but its calibration is still uncertain at a $\Delta M = \pm 0.10$ mag level. This uncertainty can be overcome by an independent estimate of the distance to a sufficient number of nearby Cepheids. Trigonometric parallaxes are generally too uncertain to provide strong enough constraints, and an alternative is provided by the Baade-Wesselink (BW) method. Its basic principle is to compare the linear and angular size variation of a pulsating star, in order to derive its distance through a simple division. Interferometry allows one to measure directly the angular diameter variation during the pulsation cycle, while the linear size variation can be obtained by high resolution spectroscopy (through the integration of the radial velocity curve). As described and reviewed in detail by Kervella et al. (ESO Messenger, 2004), the VINCI observations of 7 southern Cepheids (Kervella et al. 2004c) allowed the calibration of the zero point of the $P-L$ relation using interferometric BW distance measurements. The resulting zero point value is identical to the one obtained using a large number of Hipparcos parallaxes by Lanoix et al. (1999). This encouraging result strengthens confidence that no large bias is present on the $P-L$ calibration (Kervella et al. 2004b). Additionally, the VINCI measurements provided new calibrations of the Cepheid Period-Radius and Surface brightness-Color relations (Kervella et al. 2004a), two important relations to constrain theoretical models of Cepheids.

Very low mass stars and stellar evolution near the main sequence

The VLTI was used to precisely measure fundamental parameters of very low mass dwarf stars and of stars close to the main sequence (MS). During evolution after the main sequence, up to the subgiant and red giant stages, the stellar diameter increases enormously, up to several hundred times that of the present Sun. Even while the star is still close the the original MS, it inflates slowly. This means that the size of a given MS star is linked to its age. When combined with a theoretical stellar evolution model, a direct measurement of the size of a star therefore provides an estimate of its age.

Until recently, the mass-radius relation for very low mass stars was poorly constrained. The VINCI observations of four nearby M dwarfs using the 8 m telescopes UT1 and UT3 allowed the measurement of accurate angular sizes, and improved our knowledge of these faint stars (Ségransan et al. 2003). In particular, our nearest neighbour Proxima (M5.5V) was measured for the first time, with a very small radius of 0.145 $R_\odot$, only slightly bigger than Jupiter (0.103 $R_\odot$).

The angular diameters of a number of nearby dwarf stars were measured with high precision using VINCI, with the goal to establish their age based on numerical models of their evolution. The addition of the diameter as a constraint reduces dramatically the uncertainty of the evolutionary state of the star. For instance, the two components of our nearest neighbor, the binary star α Centauri, were resolved for the first time using VINCI (Kervella et al. 2003b). The 0.2 % accuracy of the angular diameter measurement of α Cen A is among the highest precisions ever achieved by interferometry. The numerical modeling of α Cen A and B and constraints from observed asteroseismic frequencies available in the literature reproduces the di-

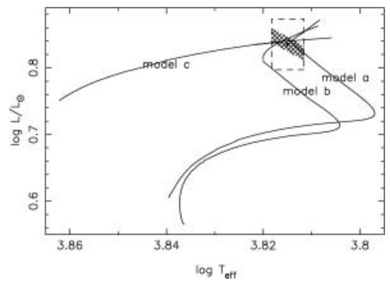

Figure 11: Evolutionary tracks in the Hertzsprung-Russel diagram of three models of Procyon A. The dashed rectangle delimits the classical uncertainty domain for luminosity and effective temperature, while the hatched area delimits the much reduced uncertainty when considering the interferometric radius. Model a is the most probable and indicates an age of 2.3 Gyr. From Kervella et al. (2004f).

ameters obtained by VLTI within their very small error bars.

The VINCI measurements of the bright stars Sirius A (Kervella et al. 2003a) and Procyon A (Kervella et al. 2004f) allowed the estimate of a very young age of 200–250 Myr for the dwarf Sirius, and an older age of 2.3 Gyr for the subgiant Procyon. Figure 11 shows as an example three evolutionary track models of Procyon. The interferometric constraint reduces considerably the uncertainty domain in the HR diagram, especially when coupled with asteroseismic observations. The age estimates based on the modeling of the interferometric data are confirmed by the cooling ages of the two white dwarfs that orbit Sirius A and Procyon A.

Similar modeling studies were also conducted for the debris disc stars α PsA, β Pic, ε Eri and τ Cet (Di Folco et al. 2004). These stars are MS or pre-main sequence stars with spectral type A to K presenting a far infrared excess, which has been commonly identified with circumstellar dust in optically thin discs. These discs are in turn often associated with planetary systems presumably already formed. The determination of the stellar ages is an essential information to study the evolution of the discs.

Diameter estimates of interferometric calibration stars

Interferometric measurements require the monitoring of the interferometric transfer function, which in turn is derived from observations of interferometric calibration stars. Usually those stars are selected as calibration stars that do not show any peculiar characteristics, and that have a well-known angular diameter and are as little resolved as possible. The need for well-known interferometric calibration stars has stimulated work aiming at measuring angular diameters of such candidates as well as establishing surface brightness-colour relations that allow the estimate of angular diameters based on known brightness and colour.

Richichi & Percheron (2005) recently described a massive ongoing effort, that was started in 2001, to accumulate observations on calibration stars with the aim of developing a VLTI-based system of high accuracy calibration stars. Observations of 191 calibration star candidates have been conducted with the VLTI and the near-infrared *K*-band commissioning instrument VINCI since March 2001, using six different siderostat and five different UT baselines. Based on angular diameters of these stars that have previously been available in the literature, the authors also discuss the evolution of the measured VLTI transfer function for the period 2001 to mid 2004. Work in progress aims at calculating a global VLTI-based solution that will determine uniquely new diameters of a subset of about 50 chosen calibration stars by minimizing the scatter of the residuals for each VLTI night under consideration.

Also, over the past two years, 16 new angular diameter measurements of nearby MS dwarfs and subgiants were obtained with the VINCI instrument, with the goal to calibrate the specific surface brightness-colour (SB) relations of these stars with high accuracy (Kervella et al. 2004e). The smallest dispersions are obtained for the visible-infrared based relations, in particular those based on the *B* and *K* magnitudes. These relations allow the prediction of very accurate (within 1%) angular diameters of candidate calibration stars for long baseline interferometry.

The MIDI consortium has established a list of calibration stars for the MIDI instrument based on spectro-photometric observations of candidate stars and fitting of the data to atmosphere models (B. Stecklum, ESO calibrator workshop 2003; van Boekel et al., submitted).

Acknowledgements

The figures that appeared earlier in other journals were reproduced by kind permission of their authors and the journals in which they originally appeared. We are grateful for valuable discussions on the topics of this review with several colleagues.

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VLTI Observations of IRS 3: The brightest compact MIR source at the Galactic Centre

The dust enshrouded star IRS 3 in the central light year of our galaxy was partially resolved in a recent VLTI experiment. This observation is the first step in investigating both IRS 3 in particular and the stellar population of the Galactic Centre in general with the VLTI at the highest angular resolution. We outline what scientific issues can be addressed by a complete MIDI dataset on IRS 3 in the mid-infrared.

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The nature of star formation and evolution close to a super-massive black hole is of broad astrophysical interest. Due to its proximity (~ 8 kpc), the centre of our galaxy (GC) offers a unique variety of experiments and observations, which grows together with the technical progress and the commissioning of new instruments. At present, the angular resolution of the VLTI already allows us to resolve the dust envelopes of some stars in the GC. A structural analysis on the scale of tens to hundreds of AUs opens the way for a detailed study of stellar properties, as well as of the interaction between a star and the GC environment.

The unusually large number of massive, young stars in the stellar cluster at the GC (e.g. Genzel et al. 2003, Eckart et al. 2004, Moultaka et al. 2004) is indicative of an active star formation history despite the tidal forces exerted by the gravitational potential of the central black hole. The presence of numerous stars in short-lived phases of their development, such as dust producing Wolf-Rayet (WR) stars, indicates that the most recent star formation episode took place not more than a few million years ago. IRS 3 with its 1–2 arcsec extended mid infrared (MIR) excess is one of the most prominent of these sources (Viehmann et al. 2005; Moultaka et al. 2004).

Why is this source a good starting point for VLTI observations of the GC region with MIDI, the MID-infrared Instrument for the VLT Interferometer? Pott et al. (2004) reviewed the technical aspects of VLTI-GC observations, which are ideally suited to study the capabilities of the new instruments close to the system limits under normal observing conditions. Here we focus mainly on astrophysical aspects.

The nature of IRS 3 is not yet identified unambiguously. In the late 1970s, it was argued that IRS 3 is a dust-enshrouded supergiant with a compact circumstellar dust shell. IRS 3 was found to be the most compact and (together with IRS 7) hottest MIR source (T ~ 400 K) in the central cluster, with total integrated flux densities of about 30 Jy at 8 µm to 12 µm.

Given its high luminosity of ~ $5 \cdot 10^4\ L_\odot$ IRS 3 may in fact be a star at the very tip of the Asymptotic Giant Branch (AGB). These most luminous dust-enshrouded AGB stars will stay at a high luminosity during their entire mass loss phase. Their mass-loss rates, derived from observations, span a range from about 10^{-7} to $10^{-3}\ M_\odot yr^{-1}$ (van Loon et al. 1999) with wind velocities of the order of 10–20 km/s. In general the more luminous and cooler stars are found to reach higher mass-loss rates. This is in agreement with model calculations. For a synthetic sample of more than 5 000 brighter tip-AGB stars a collective mass-loss rate of $5.0 \times 10^{-4} M_\odot yr^{-1}$ was found. Of these, 20 are carbon-rich super-giants with a large IR excess and a mass-loss rate well in excess of $10^{-6} M_\odot yr^{-1}$, including 10 dust-enshrouded, extreme tip-AGB stars seen in their short-lived (~ 30 000 yrs) super-wind phase with a mass loss of $>10^{-5} M_\odot yr^{-1}$. They produce about 50 % of the collective mass-loss of the whole sample.

A recent identification of a carbon-rich WR star of type WC5/6 as a near infrared counterpart of IRS 3, based on the detection of a 2.11 µm He I/C III line (Horrobin et al. 2004), is probably applicable to a K ~ 15 faint star ~ 120 mas east of the bright source. However, given the fact that most other dust enshrouded sources in the central stellar cluster have been associated with hot and luminous young stars, an identification of IRS 3 with a massive WR star in its dust forming phase cannot be fully excluded either. Extensive mass loss associated with bright continuum emission takes place in the WC stage. Products of helium burning are dredged up to the surface, enhancing the carbon and further depleting the hydrogen abundance.

As shown by Viehmann et al. (2005), the dust shell of IRS 3 is interacting with the GC ISM. They find the photocentre of IRS 3 in the ISAAC M-band image shifted by ~ 160 mas to the NW with respect to the L-band image. About 1″ to the southeast of IRS 3 high-pass filtered L- and M-band NAOS/CONICA images show a sharp interaction zone of the outer part of the dust shell with the wind arising from the IRS 16 cluster of hot, massive Helium stars.

We designed a VLTI experiment with MIDI (N-band, 8–12 µm) to investigate the dust shell of IRS 3. The lower spectroscopic resolution used (R = 30) offers dispersed visibility data over the entire *N*-band, as well as a spectrum of the uncorrelated flux density. The first VLTI detection of a star in the GC was achieved in June 2004: We partially resolved IRS 3 with the VLTI using MIDI on the 47 m UT2-UT3 baseline (see Figures 1 and 2).

It was found that ~ 25 % of the flux density of IRS 3 is concentrated in a compact (i.e. unresolved) component with a size of ≤ 40 mas (i.e. ≤ 300 AU). This agrees with the interpretation that IRS 3 is a luminous compact object in an intensive dust forming phase. In general, the visibility amplitude was found to increase with wavelength by ~ 0.05. Although the uncertainty of a single visibility value (5–10 %) seems to be too large to unambiguously identify such a trend, the error on the slope (i.e. wavelength dependent variation) of a visibility dataset over the entire *N*-band is of the order of 1 % only. This trend indicates that the compact portion of the IRS 3 dust shell is extended and only partially resolved on the UT2-UT3 baseline. We also find indications for a narrower width of the 9.3 µm silicate line towards the centre, indicating the presence of fresh unprocessed small grains closer to the central star in IRS 3 (van Boekel et al., 2003).

In addition, the remaining six of the seven brightest (*N*-band) MIR excess sources in the GC were observed (IRS 1W, 2, 8, 9, 10, 13) with the same instrumental setup. Most of them are located in the Northern Arm of the ISM or associated with the mini-spiral of ionised gas and warm dust (Figure 1). They appear to be hot stars with strong, fast winds that create bow shocks as they plough through the gas and dust of the mini-spiral. The MIR emission associated with theses sources arises most probably from these bow shocks that can be resolved at 2 µm.

All of these six sources are fully resolved at a 2 Jy flux level, i.e. only upper limits on the visibility limits could be estimated with the baseline used. Therefore, IRS 3 is not only the hottest but also the most compact bright source of MIR emission within the central stellar cluster.

We will conduct further VLTI/MIDI observations of IRS 3 to enlarge the *uv*-plane coverage (Figure 3). The foreseen baselines UT3-UT4 (62 m) and UT1-UT4 (130 m) are complementary to UT2-UT3 in terms of length and orientation. The final dataset will cover an angular resolution of about 13 mas at the longest baseline up to 100 mas. These observations will be ideally suited to provide information about the radial structure and symmetry of the correlated flux, about the inner edge of the dust shell, as well as about a possible binary character of IRS 3. Collisions of winds in binary systems may support dust formation through density increase and rapid cooling of the material.

A bright compact source like IRS 3 is also technically essential for future VLTI phase-reference experiments at 10 µm in order to investigate other nearby sources, e.g. the Sgr A* black hole. For this purpose it is important to know the strength and compactness of IRS 3 on the longest baselines.

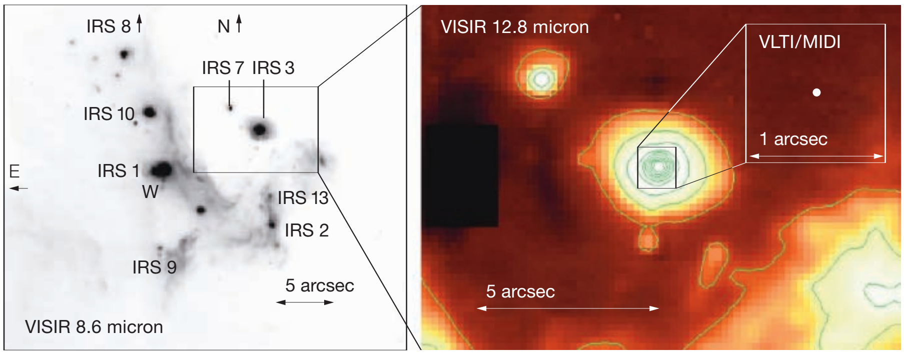

Figure 1: VISIR MIR images with the observed targets indicated and an inset demonstrating the scale on which the current UT2-UT3 VLTI/MIDI data detected a compact source with a visibility of about 25%.

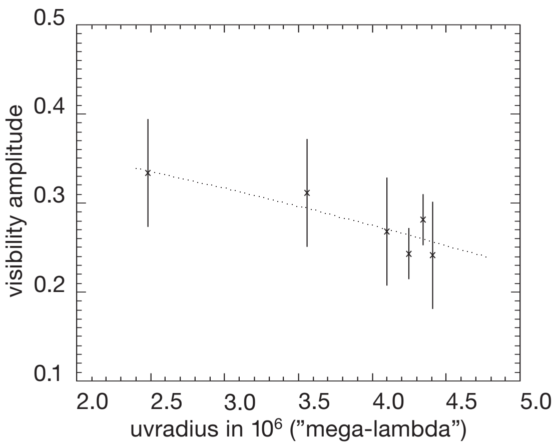

Figure 2: Median 8–12 µm visibility of IRS 3 as a function of projected baseline length. Currently the uncertainty of the visibilities is above all affected by the instrument calibration. Therefore the errors are given by the standard deviation of the instrument calibration over the entire night.

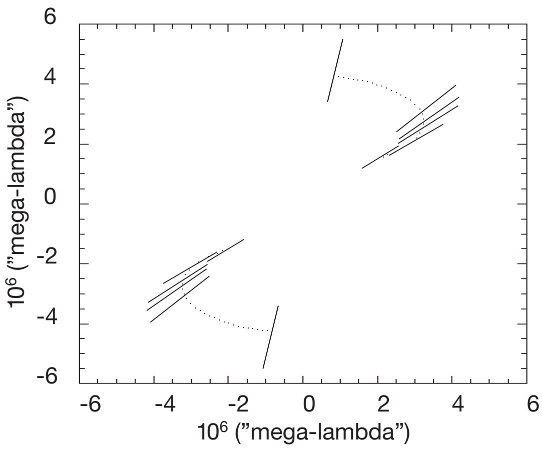

Figure 3: The *uv*-coverage of the observations in P73 is shown. The dotted line indicates the change of projected baseline length due to earth rotation. Whereas the earth rotation curve is calculated at a central wavelength of 10.34 µm the solid lines are showing the *uv*-coverage of each dispersed, calibrated visibility dataset.

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Comparison of Science Metrics among Observatories

A comparison of various scientific metrics is presented. In particular, we examine the impact of the HST and VLT observatories through publication rates, citation rates and the number of highly cited publications. Both observatories are major contributors to today's astrophysics research endeavour and currently rank among the most successful astronomical facilities as measured by the above categories.

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The European Southern Observatory (ESO) and the Space Telescope Science Institute (STScI) have developed science metrics tools to measure and monitor the scientific success of their telescopes. Two recent papers outline the methodology used to produce the metrics and evaluate the results: "Metrics to Measure ESO's Scientific Success," by Leibundgut, Grothkopf & Treumann (2003) and "Hubble Space Telescope Science Metrics", by Meylan, Madrid & Macchetto (2004).

In an attempt to put the results into a broader context, we present here a comparison between the individual science metrics of HST (*Hubble Space Telescope*) and VLT (*Very Large Telescope*). The two facilities have rather different, yet often complementary, capabilities. They also serve a similar community of optical and near-IR astronomers. It is generally acknowledged that they have leading roles in astronomical research. Here we try to assess the relative roles and the scientific impact of the two observatories.

The Hubble Space Telescope, launched in April 1990, is the product of collaboration between NASA and the European Space Agency. During its lifetime HST has had nine extremely successful instruments, six of which are by now decommissioned. Unique capabilities of HST include the access to UV wavelengths, the unmatched large-field, high spatial resolution and the low background at near-infrared wavelengths.

The Very Large Telescope is one of the major ground-based observatories, with four 8 m unit telescopes and the capability of combining them (and smaller auxiliary telescopes) for interferometry. In operation since 1999, the VLT has grown to include all four unit telescopes and ten instruments are currently offered to the community. The instrument suite covers most wavelengths accessible from the ground, adaptive optics instruments for small-field high spatial-resolution imaging, high-resolution spectroscopy and multi-object spectroscopy.

Methodologies for assessment of scientific impact have been developed by several authors for individual observatories (Meylan, Madrid & Macchetto 2003, 2004; Leibundgut, Grothkopf & Treumann 2003, Crabtree & Bryson, 2001), comparisons between observatories (Trimble 1995, Benn & Sanchez 2001, Trimble, Zaich & Bosler 2005) or generally the impact of journals or astronomical subfields (Abt papers, Schwarz & Kennicutt 2004). Almost all investigations converge on the basic data input for the metrics: numbers of papers published, citations to these papers, and impact measured through highly cited papers. Differences in the analyses mostly stem from different input databases and weighting of stated goals of the investigation, e.g. which audience is addressed. For observatories, the prime interest is, of course, to evaluate how the data collected with their facilities contribute to scientific progress.

In the following we use the number of refereed publications as one measure of the productivity of the VLT, HST and other observatories, which provided us with the appropriate input data. We then proceed to investigate the number of citations these papers generate, which measures their impact within the scientific astronomical community. Further investigations try to find the high-impact papers based on observatory data.

As of the end of 2004, 120 refereed papers combined data from HST and VLT. The complementarity of these two observatories is reflected in these papers. We performed an analysis to investigate what projects make use of both observatories.

Our study is based on databases that are *complete* in the sense that they collect all papers that use data from the respective observatory. The databases are maintained at ESO and STScI separately and we made an effort to homogenize them for the comparison.

Number of papers based on HST and VLT data

In order to compare publication statistics among different observatories, it is essential to assess the selection criteria applied by each observatory and to relate the different criteria to each other in a meaningful way. The first ingredient is a complete list of papers based on observatory data. One might think that it would be easiest to rely on the mentioning of facility usage by the authors, for instance through acknowledgements in footnotes or through the use of data set and facilities identifiers[1]. However, these linking initiatives are voluntary for the authors. They will only help facilities to derive metrics when they are applied widely and reliably.

Automated searches in the NASA Astrophysics Data System (ADS) do not lead to complete lists of papers. A 2002 study at ESO showed that retrieval of papers through ADS alone missed approx. 20 % of relevant papers, while at the same time an equal number of papers was erroneously included (Grothkopf & Treumann 2003). Similar findings have been confirmed in various further trials. The main reason for the unreliability of automated searches is not so much the unavailability of full texts (ADS currently covers only title, abstract and keywords of recent papers), but rather the fact that retrieval tools are not capable of interpreting the context in which search terms appear. Thus, we still need human as-

[1] Identifiers for data sets and facilities are currently being introduced by AAS journals. They are meant to improve navigation between scientific papers and online data, see for instance Eichhorn et al. (2003).

sessment in order to distinguish between papers that meet our selection criteria and those that mention search terms in contexts that are irrelevant for our purpose.

At most large observatories, librarians or dedicated personnel screen the literature and identify all articles based on data from the respective facilities. These databases are used for multiple purposes including, for example, the Annual Report's section on scientific articles published by the observatory. At ESO and STScI, we have achieved a high reliability through manual screening of print journals in combination with searches using ADS, and created comprehensive databases.

The HST publication database contains papers since the special HST *Letters* issue of the *Astrophysical Journal* in March 1991; the ESO telescope bibliography contains publications from 1996 onwards for La Silla papers and from 1999 onwards for VLT papers.

Our databases list refereed papers that use HST or VLT data pertaining to at least one of the following data categories: (i) PI/CoI (Principal Investigator/Co-Investigator) data, i.e. publications in which at least one of the authors was a participant of the original proposal; (ii) archival data, i.e. papers using data where none of the authors was a member of the original proposal group; and (iii) papers using public data sets. We do not include papers that merely cite results published in previous articles. ESO excludes conference proceedings, even if published in refereed journals. STScI, in contrast, includes conference proceedings in refereed journals.

One would expect that the HST numbers of publications are somewhat enhanced compared to those of ESO due to this slight difference. At the same time the citation rates are possibly decreased as citations to conference papers, even if refereed, are typically lower than in the refereed literature (e.g. Schwarz & Kennicutt 2004). Despite these differences, the statistics derived from the two databases are comparable, bearing in mind that the overall aim is to compare them in a broader context rather than on the basis of cross-checks among individual papers. We believe that the metrics we derived are objective and reproducible.

At ESO, papers are categorized by telescopes, instruments and observing modes (visitor or service). It is also noted whether these are original observations or archival data. For all papers using VLT data, the programme IDs that generated the data are obtained either from the publication, from the observing schedule or from the authors.

The ESO and STScI databases are publicly available. The ESO bibliography can be searched using the web interface described by Delmotte et al. on page 50 of this Messenger issue. In addition, but without search options for specific telescopes or instruments, both databases are available through the ADS Abstract Service by activating the filters ESO/Telescopes and HST, respectively. Active links to the corresponding archives are provided for all papers using HST and VLT.

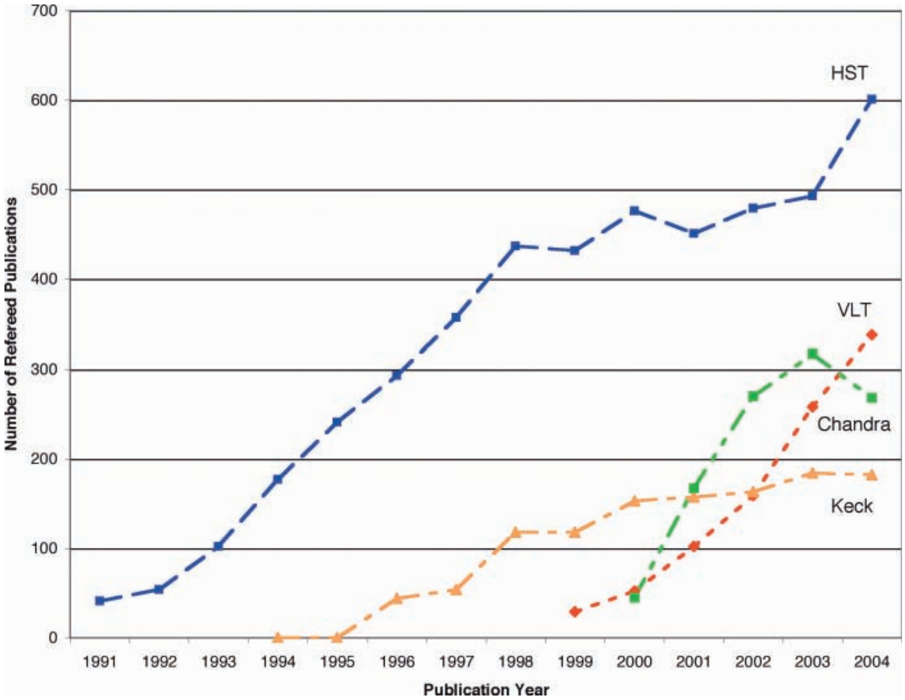


Figure 1: Number of refereed papers using VLT, HST, Keck, and Chandra data (as of January 2005).

Figure 1 gives the total numbers of papers per year for the VLT and the HST. For comparison, we also include publication numbers for the Keck Observatory and the Chandra X-ray Observatory. We obtained these values from the Keck Science Bibliography (*http://www2.keck.hawaii.edu/library/keckpub00.html*) and from the Chandra Data Archive (*http://cxc.harvard.edu/cgi-gen/cda/bibliography*; see also the article by Green and Yukita 2004).

The VLT and the HST are both very productive telescopes: as of January 2005, HST has provided data for a total of 4634 refereed papers (over 14 years), VLT for a total of 938 (over six years). Both observatories, as well as Chandra, profit from a large user community. The start-up years of the VLT are nearly identical in numbers of papers published compared to the early years of HST operations showing a strong and regular increase per year. In the case of the VLT, part of this increase is due to the continuous expansion of the facility and the addition of new telescopes and instruments. The instrument complement increased from two instruments in the first year to four for the second, third and fourth year of operations, with a further increase to today's complement of ten instruments.

The HST reached a publication rate of about 500 refereed papers per year, eight years after launch. The impressive contribution of the HST reflects the fact that it provides unmatched spatial resolution imaging at ultraviolet through near-infrared wavelengths as well as spectroscopic observations at wavelengths that ground-based telescopes cannot access. Furthermore, the HST has been regularly refurbished with new generations of instruments through successive servicing missions, maintaining state-of-the-art technology.

The publication rate for the VLT is still increasing at the rate HST was displaying during its first eight years. As an aside we note here that up to 2004 there are still more papers published per year based on data obtained with telescopes at La Silla than from the VLT (337 vs. 344 in 2004).

	HST (1991–2004)		VLT (1996–2004)	
	# of papers	%	# of papers	%
ApJ/ApJS	2269	48.9	235	25.1
AJ	851	18.4	52	5.5
A&A	586	12.6	527	56.2
MNRAS	369	8.0	74	7.9
PASP	106	2.3	1	0.1
Nature	47	1.0	18	1.9
Others	406	8.8	31	3.3
Total	4634	100.0	938	100.0

Table 1: Distribution (absolute numbers and percentages) of refereed HST and VLT papers published in the five core astronomy journals as well as *Nature* (as of January 2005). Note that these are the total numbers of papers published over the current lifetime of the observatories, i.e. 14 years for HST and six years for the VLT.

A direct comparison is difficult at this stage. The HST is a mature observatory with a large user community and has operated over more than a decade. The VLT is still in its ramp-up phase. Neither the total numbers of papers nor the numbers of papers per year provide a good indication how the two observatories compare to each other. Figure 1 needs to be interpreted rather carefully in this respect. It will have to be seen what level the VLT will reach after several years.

About 90 % of the HST papers and 95 % of the VLT papers that were published until the end of 2004 appeared in the five major astronomical journals, i.e. *Astrophysical Journal* and its *Supplements (ApJ/ApJS)*, *Astronomical Journal (AJ)*, *Astronomy & Astrophysics (A&A)*, *Monthly Notices of the Royal Astronomical Society (MNRAS)* and *Publications of the Astronomical Society of the Pacific (PASP)*. Table 1 shows the absolute numbers and percentages of HST and VLT publications in these journals. For comparison, the corresponding numbers for publications in *Nature* are also included. The table reflects the partly different affiliations of the user communities of the two observatories. *ApJ* continues to be the preferred journal for most authors of HST-based papers. On the other hand, the ESO user community prefers to publish in *A&A* in which it is exempt from page charges.

Citations

In order to assess the scientific impact of refereed papers based on HST and VLT data, we obtained the number of citations for each paper in our databases from ADS. We are aware that the set of citations provided by ADS is not complete, mainly because some citing journals are not within the ADS database. However, with regard to the major *refereed* astronomical journals ADS is a very reliable source of citations. For many major astrophysics journals, the coverage is even complete back to volume 1.

Recently, Trimble, Zaich & Bosler (2005) argued that the contribution to papers based on several observatories should be apportioned and split according to the contributions from each observatory. This is a reasonable approach for investigations which aim to deduce general trends in astronomy publishing. For observatories such an approach is not really suitable as the weighting process (like the one in Trimble et al.) would require resources that are not available at the moment. The critical information for observatories is how often their data have made a contribution to the scientific literature. Hence we chose to count every paper as a full contribution in our databases and analysis, even if several telescopes provided data. This of course means that papers making use of VLT and HST data will show up in both databases (see section "Papers based on VLT and HST data at the same time"). For the high-impact papers (see below) we actually do weight the contribution by each observatory.

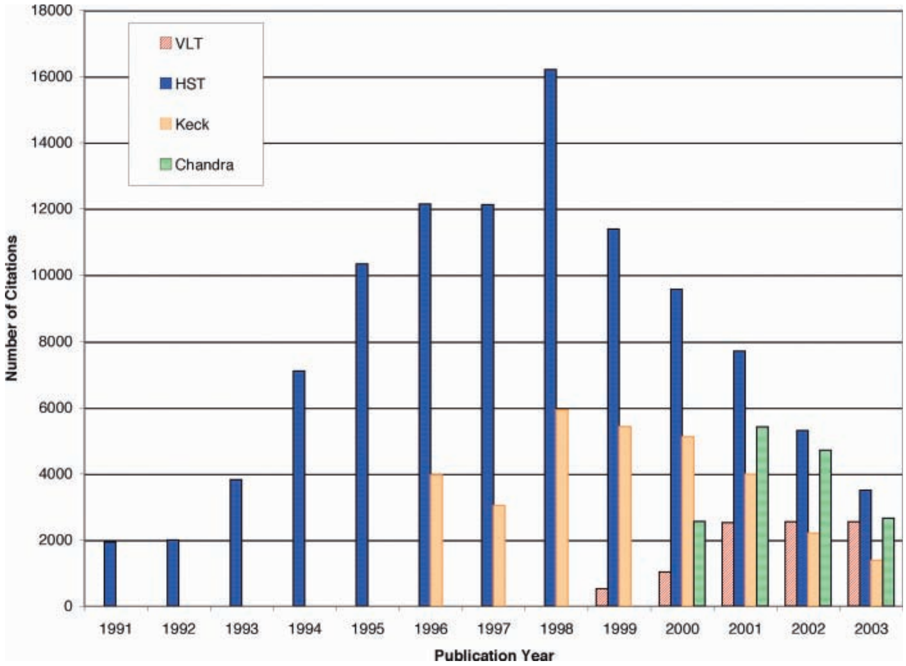


Figure 2 (above): Total number of citations to VLT, HST, Keck and Chandra publications by year (as of December 2004).

Figure 3 (below): Number of citations per paper relative to HST citations (as of December 2004).

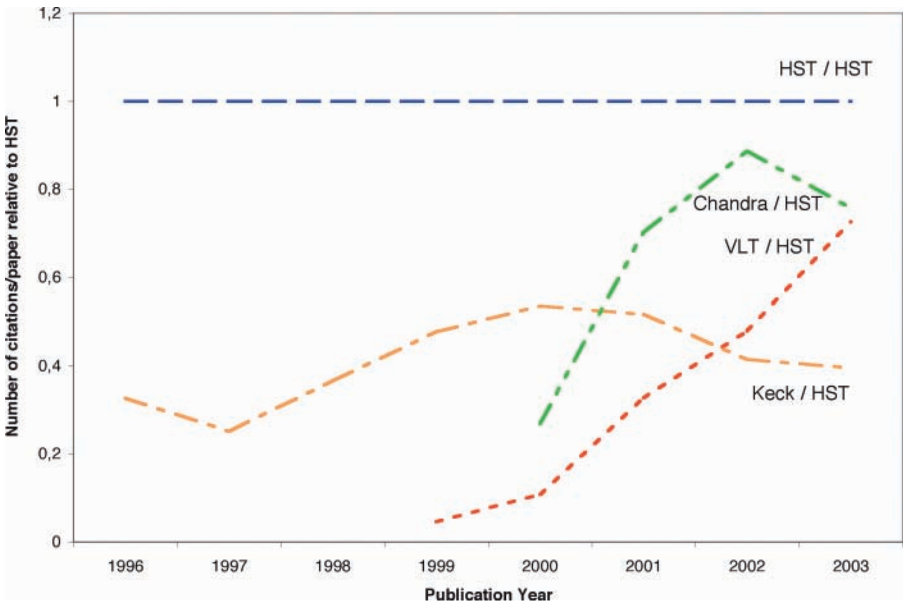


Figure 2 shows the total number of citations for HST and VLT papers by year. Both observatories are contributing significantly to astrophysics research and the publications based on their data form an integral part of the astrophysical literature. The HST still leads in the total citations (as it does in the number of papers published, cf. Figure 1). However, there have been significant changes over the past few years. The VLT has a steadily increasing citation rate compared to other observatories, while Chandra has made a substantial impact right from the start. The Keck citation rates remain constant at a high level. This is illustrated in Figure 3 which shows the evolution of the numbers of citations relative to HST. This figure removes the 'history' effect inherent in citation statistics and allows a direct comparison of the observatory statistics.

Average citation rates are a highly simplified means of assessing the success of publications. The distribution of citations per paper is highly non-uniform and hence averages and standard deviations are only crude, if at all appropriate, means for such an analysis. One should also keep in mind that there are severe differences in the way papers are cited per astronomical subfield and other secondary effects. A very good analysis of such additional parameters is given by Schwarz & Kennicutt (2004). To offset these statistical distortions we decided to use the median, which is in general a much more robust statistical indicator. Hence, Figure 4 shows the median number of citations per paper. The steady increase of the VLT citations is an indication of the non-static situation of these statistics. At the moment, the VLT and the HST are nearly identical considering the mean citations of papers. The differences might be a signature of the different age of the two observatories, although a more detailed analysis might be warranted here.

We further analyzed the 100 most frequently cited papers based on VLT and HST data, respectively. Interesting trends are shown in Figure 5. Almost half of the most cited papers based on VLT data (1999–2004) were published in *A&A* (43 % of the top 100 VLT papers, citations from ADS), reflecting the preference of publishing VLT data in *A&A* (cf. Table 1). Many of the most-cited publications appeared in *ApJ* (39 %). The share of highly cited papers published in *Nature* (9 %) is large compared to the overall percentage of VLT papers published in this journal (approx. 2.0 %, cf. Table 1). In fact, half of the VLT papers published in *Nature* made it into the top 100.

A clear majority of the top 100 HST papers (1991–2004) were published in *ApJ/ApJS* (67 %); this fraction is even larger than the already high percentage of all papers published in these journals as given in Table 1 (approx. 50 %). As with VLT, articles published in *Nature* are highly represented among the most cited papers: 1 % of all HST articles are published in this journal vs. 5 % among the top 100.

High-Impact Papers

The term High-Impact Papers (HIP) was coined by the Institute for Scientific Information (ISI) (see *http://www.isinet.com/rsg/hip/*). It defines the 200 most cited papers for a given year. The numbers presented here were obtained from the ADS by querying the database for 200 papers, sorted by descending citation count. The method we used is described in greater detail in Meylan, Madrid & Macchetto (2004). These 200 most cited publications could be refereed or unrefereed, observational or theoretical papers. For each of them we read the full text, selected those that present observations, and attributed the citations to the facility or facilities that contributed the data. In the case of usage of data from multiple observatories, citations are distributed according to a weight corresponding to the amount of data provided by each facility. As a result, each observatory received a normalized percentage of its contribution to high impact papers.

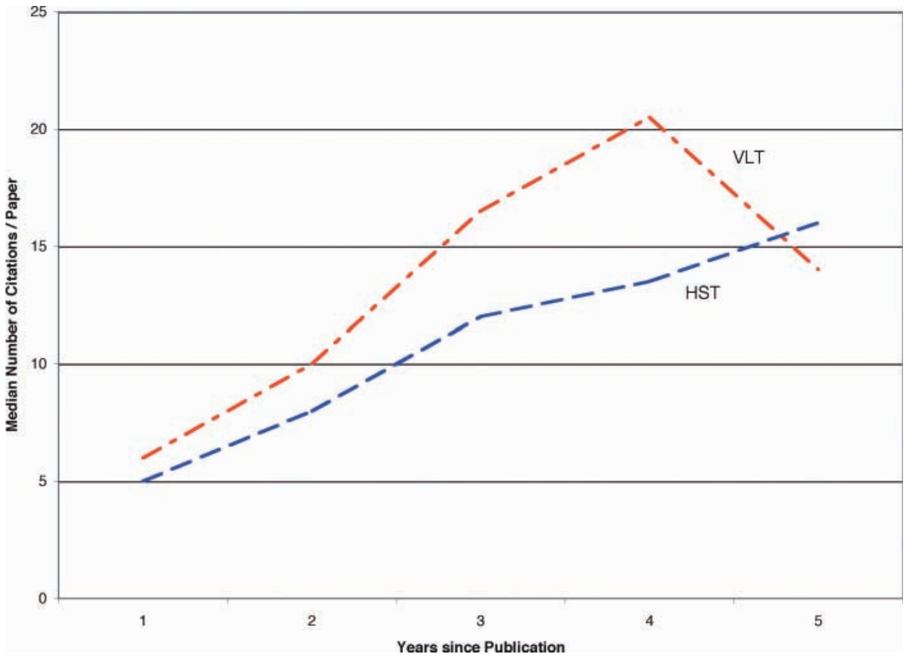
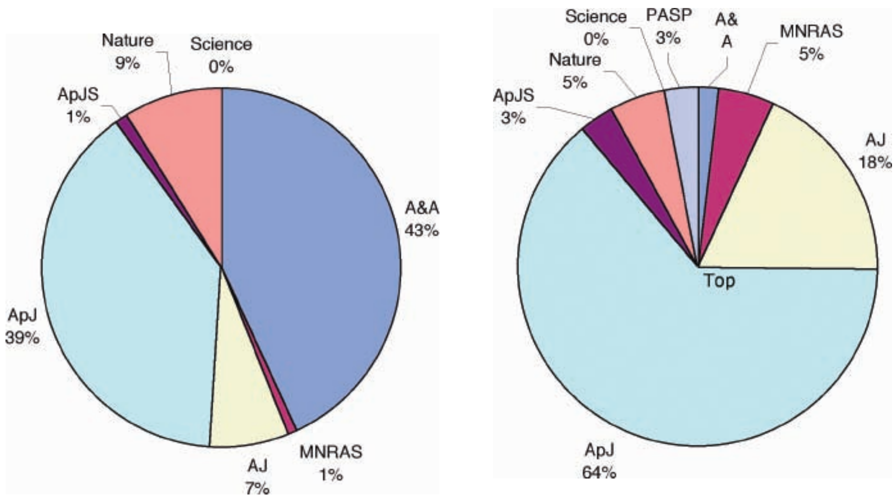


Figure 4 (above): Median number of citations for VLT and HST papers as a function of years since publication (publication years 2003–1999, as of January 2005).

Figure 5 (below): Fraction of most cited VLT (left) and HST papers (right) published in various journals.



The citations for each year were obtained 16 months after the year ended, i.e., citations for the year 2001 were retrieved in April 2003, for the year 2002 in April 2004 etc. At this time, the citations had not yet reached their peak (typically after two years, see Meylan, Madrid & Macchetto 2004). To make sure that the relative impact per facility remains the same also over a longer time, we cross-checked the high impact papers published in 1999 and 2001 in December 2004 (five and three years respectively after publication) and found that only 3 % of the 100 most cited 1999 papers and 7 % of the 100 most cited 2001 papers had changed.

In Figure 6 we present the evolution of the contribution of selected facilities to these HIP. The number of available facilities, both ground- based and in space, is increasing and many of them contribute to high impact papers. For instance Chandra and the VLT contributed to HIPs for the first time in 2000. Accordingly, the share of already existing facilities becomes smaller.

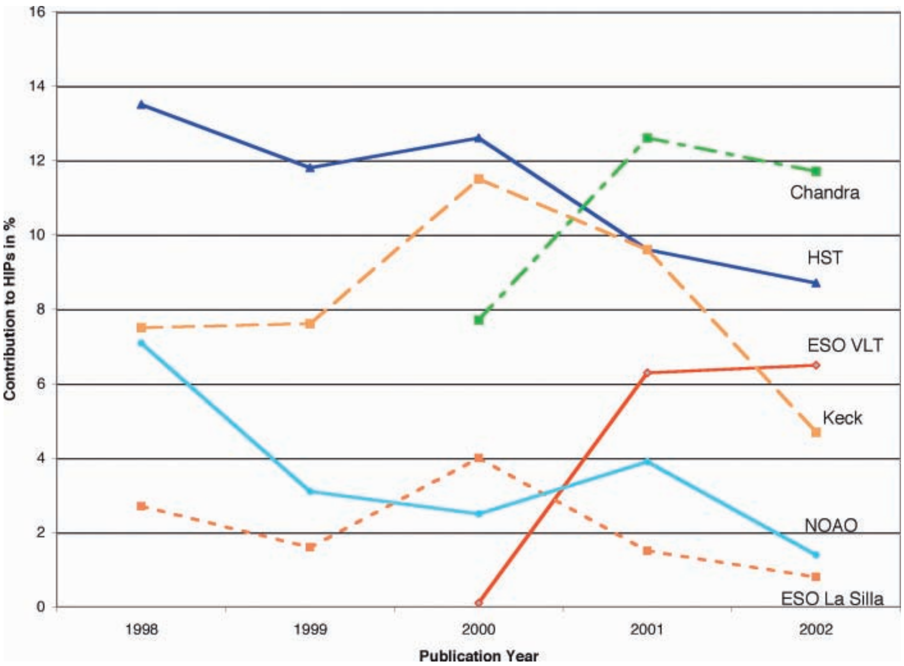


Figure 6: Contribution of selected space and ground-based facilities to the total citations of the 200 most cited papers per year. NOAO includes papers based on Kitt Peak Observatory and CTIO.

Papers based on VLT and HST data at the same time

HST and VLT data are increasingly combined in the same paper. The collation of multi-wavelength datasets and the comparison of complementary observations across the electromagnetic spectrum have significantly improved the physical picture that astronomers obtain from celestial objects. This leads to publications based on observations coming from several sources. The interdependence between ground- and space-based observations is steadily increasing. This trend was confirmed by Trimble, Zaich & Bosler (2005) and reflects a change in the way astrophysical research is being conducted. This can further be seen in the science cases for future facilities, which typically explore the expected synergies with other projects. Up through the end of 2004, 120 refereed papers used data from both observatories. Many authors combine the unique capabilities of the two facilities to obtain new astronomical knowledge. The most common cases we encountered were papers where high-resolution VLT spectra are combined with HST archival images; several papers presented follow-up VLT spectroscopy of objects previously observed with HST. This pattern had previously also been observed between HST and Keck. The deep fields are prime examples. In particular ISAAC and the FORS instruments are used in parallel with data obtained with WFPC2, ACS and NICMOS. These papers show clearly that ground-based telescopes and space missions do not compete, but support and complement each other and lead to higher scientific productivity through effective use of collaborations.

Conclusion

HST and VLT are amongst the most prolific observatories and are fully competitive with other large facilities like Chandra and Keck. They also have taken the leadership role from older observatories, although the rate of publication of data for example from La Silla telescopes still remains high.

After slightly more than five years of operations, the VLT shows a similar development observed in other successful observatories. Soon after First Light, publication statistics started to rise steeply and are rapidly approaching 1000 refereed publications by the end of 2004. These first five years are nearly identical to the development of HST during its early years.

An equally positive trend can be noticed for citations made to publications based on ESO data. The mean number of citations per refereed paper tends to be at the level of established observatories. The citation rate is still rapidly increasing and is approaching the HST citation rate.

A study of the contributions to high impact papers from some of the major telescopes available at present shows that the VLT contributes to a considerable fraction of them and thus occupied a place among the most important facilities only a few years after the start of its operations. Interesting differences can be seen regarding where papers from the VLT and HST are published. While for the European community, the prime user of the VLT, *Astronomy & Astrophysics* remains the journal of choice, the majority of HST data are published in the *Astrophysical Journal*. Most other journals are used with a comparable frequency.

HST continues to dominate the number count of published papers per year and shows no sign of contributing less than in past years to the overall impact that these papers have on astronomical research.

Acknowledgements

This article has made use of NASA's Astrophysics Data System. We are grateful to Angelika Treumann, who maintains the ESO telescope bibliography and gave essential comments on the manuscript. Our thanks also go to the STScI librarian Sarah Stevens-Rayburn, who has made invaluable contributions to the HST bibliography; Sarah also kindly removed the non-native English speakers' flavour from the manuscript. We thank Karen Levay from MAST for her help in handling the database of the HST bibliography. Arnold Rots from Harvard/Smithsonian Center for Astrophysics, as well as Peggi Kamisato from W. M. Keck Observatory kindly provided information on Chandra and Keck publication and citation statistics.

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The ESO Telescope Bibliography Web Interface – Linking Publications and Observations

The ESO telescope bibliography links scientific papers based on VLT observations with underlying observing proposals and archival data. It can be queried through a web interface at ESO as well as through a filter at the NASA Astrophysics Data System (ADS) from which active links lead to the ESO Archive. These services are prerequisites of the Virtual Observatory as they allow users to keep track of the entire lifetime of scientific proposals, from scheduling to observations and publications.

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The ESO telescope bibliography started out in the late seventies as a compilation of papers authored by ESO staff and visiting astronomers at the ESO telescopes in Chile. These lists, published in the ESO Annual Report, provide today the only record of papers based on ESO observations arising from those early years.

In the early nineties, ESO began to store bibliographic information of relevant papers in a database which is now maintained by the library. Later, the focus shifted from bibliographic details to observing facilities. In 1996, we started to associate telescope information to all papers based on data from ESO La Silla. Instrument information has been added to La Silla papers since 2002, and to papers using VLT data from First Light onwards.

Furthermore, all VLT-based papers reference the programmes from which the data originated through programme identification codes (programme IDs), the unique identifiers of ESO observing proposals. Programme IDs are the vital link between archive and pre-observing (proposal and phase II) information and will become a key component in joining the various ESO databases in preparation for the Virtual Observatory.

Harvesting Data

Today, the ESO telescope bibliography is a relational database that contains refereed papers based on new or archived ESO data. Papers that merely cite results published in previous papers are not included. We also exclude conference proceedings, even if published in refereed journals. The compilation process was described in detail in a recent Messenger article (Leibundgut, Grothkopf & Treumann 2003) as well as in Grothkopf et al. (this issue, page 45).

The Web Interface

As of July 2004, public access to the database became available through a web interface, located at *http://www.eso.org/libraries/telbib.html* (see Figure 1). This is the result of a collaboration between the ESO library staff and the DMD/DFO Database Content Management team within the ESO Archive. New entries in the database as well as potential updates of already present records are made available to the community via an automatic process that runs every night.

The general layout of the web interface is a query form that offers search options by bibliographic and observational criteria. Like most ESO/ST-ECF Science Archive Facility query forms, it is based on WDB, a software dedicated to building interfaces between the World Wide Web and SQL databases (Rasmussen 1995). One of the main advantages of WDB is the possibility to convert data from and to the database. Data retrieved can be converted for instance into hypertext links, which provide an easy mechanism for joining databases. Thus, the telescope bibliography is now linked to the ESO observing programme and scheduling interface of the ESO/ST-ECF Science Archive Facility.

Query Parameters

The query form is divided into three areas: *Bibliographic Information*, *Observation Information* and *Display Options*. The *Bibliographic Information* section offers searches based on authors, title, journal and volume as well as by uniform bibliographic code (BibCode[1]). In the *Observation Information* section, queries can be limited by specific observing facilities on three hierarchical levels: site/archive, telescopes and instruments. The *Program ID(s)* field allows one to retrieve papers based on ESO programme identification codes.

For each area, various query parameters are available, either as text fields, checkboxes or pull-down menus. A checkbox in front of each parameter defines whether or not it will be displayed on the result page. By default, all bibliographic information as well as the instruments and programme IDs will be shown, while the observing sites and telescopes will not. These settings can be changed according to the users' preferences. Detailed search instructions are located at *http://archive.eso.org/eso/publications.html* and can be accessed by following the hyperlinked search option labels. Further online help on how to specify queries and use operators is available through the "query Help" button on the main search screen.

Result lists can be arranged in a number of ways by using the *Display Options*. The output format is either HTML or plain text. If more than one record is retrieved, information will be displayed in tabular format, one paper per line (Figure 2).

The *Paper ID* takes users to the full record display. By following that hyperlink, all available information will be displayed in a single HTML frame (Figure 3), regardless of the parameters selected on the query page.

[1] For information on BibCodes see *http://cdsweb.u-strasbg.fr/simbad/refcode/section3_2.html*

Figure 1 (above): ESO telescope bibliography web interface at *http://www.eso.org/libraries/telbib.html.*

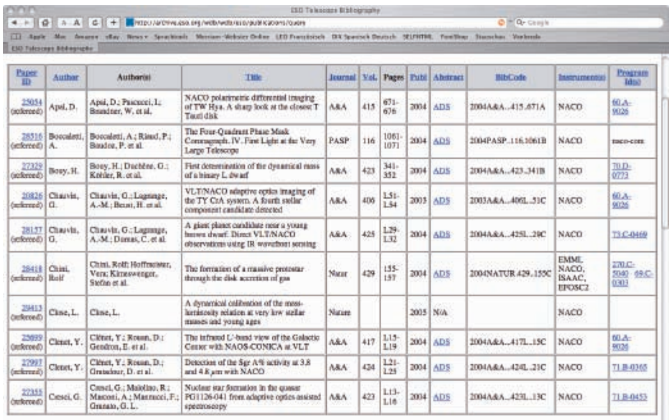
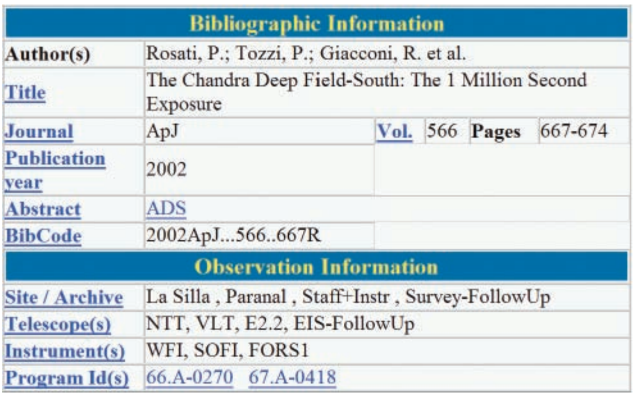


Figure 2: Sample results page.



Bibliographic Information					
Author(s)	Rosati, P.; Tozzi, P.; Giacconi, R. et al.				
Title	The Chandra Deep Field-South: The 1 Million Second Exposure				
Journal	ApJ	Vol.	566	Pages	667-674
Publication year	2002				
Abstract	ADS				
BibCode	2002ApJ...566..667R				
Observation Information					
Site / Archive	La Silla , Paranal , Staff+Instr , Survey-FollowUp				
Telescope(s)	NTT, VLT, E2.2, EIS-FollowUp				
Instrument(s)	WFI, SOFI, FORS1				
Program Id(s)	66.A-0270 67.A-0418				

Figure 3: Full record display (excerpt).

Digital Weaving

Unless the default display settings were changed, the query results page will provide further hyperlinks that point towards external databases:

ADS links to the abstract at the ADS Abstract Service (mirror located at ESO, *http://esoads.eso.org/abstract_service.html*). From there, the full refereed article can be retrieved (provided the library subscribes to the journal), typically either in HTML or in PDF format. BibCodes (see above) play a major role here in joining the data repositories of ESO and ADS. Linking scattered information among multiple databases and systems is part of information integration and will ultimately enable data discovery among heterogeneous datasets. This is possible thanks to the development of interoperability standards and tools for which the BibCode usage is a first example.

Program IDs provide access to observing programme information and to the underlying observations (Figure 4). As of October 2004, abstracts of proposals are made available once the proprietary period of the associated data has expired. In addition, links to raw and possibly reduced data as well as to other publications related to the same programme are provided.

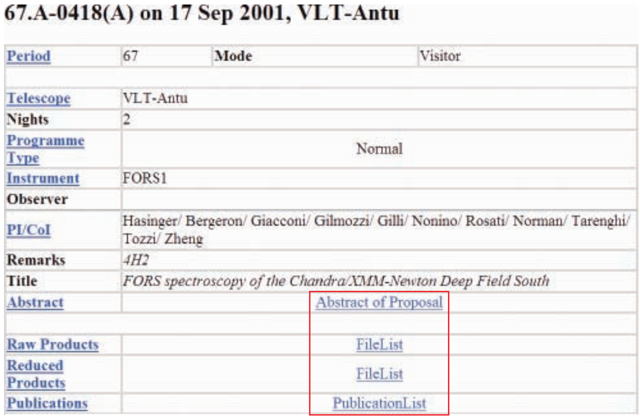
The reverse link has also been implemented. Starting at the ESO observation schedule query form at *http://archive.eso.org/wdb/wdb/eso/sched_rep_arc/form*, observing programme information can be retrieved by various qualifiers. From the results pages, users can reach the list of publications associated with a given VLT programme ID.

Access Through ADS

Another way of retrieving papers using ESO telescope data is via the ADS Abstract Service. On the main ADS search screen, users can scroll down to the Filters section and choose *Select References In / All of the following groups: ESO/Telescopes*. In addition, at least one other search criterion must be entered, for instance a publication year or an author's name.

ADS harvests new entries in our database at least once per week from an ESO web page. Unlike the ESO interface, however, ADS does not cater for queries limited to specific telescopes and instruments; only the entire database can be searched.

Linking datasets and publications is currently a much discussed issue and procedures are being designed for future papers to refer back to the datasets related to them (Accomazzi & Eichhorn 2004). In this context, ADS has already implemented an option to access accompanying online data stored in data centers. This option can be activated by following the letter D hyperlink ("On-line Data") provided on ADS query result pages. For instance, if ESO data are associated with a paper, the D link takes users into the ESO



67.A-0418(A) on 17 Sep 2001, VLT-Antu

Period	67	Mode	Visitor
Telescope	VLT-Antu		
Nights	2		
Programme Type	Normal		
Instrument	FORS1		
Observer			
PI/CoI	Hasinger/ Bergeron/ Giacconi/ Gilmozzi/ Gilli/ Nonino/ Rosati/ Norman/ Tarenghi/ Tozzi/ Zheng		
Remarks	*4H2*		
Title	*FORS spectroscopy of the Chandra/XMM-Newton Deep Field South*		
Abstract	Abstract of Proposal		
Raw Products	FileList		
Reduced Products	FileList		
Publications	PublicationList		

Figure 4: Observing Programme query result page (excerpt). Entries provide access to the proposal abstract, raw and possibly reduced products as well as further publications resulting from the same proposal.

telescope bibliography from which proposal and observation information can be accessed as described above.

New Challenge for the Virtual Observatory

Online data in astronomy are increasing dramatically. The major astronomical journals are available in electronic format. New methodologies for information retrieval have to be applied in order to exploit these data repositories in the context of the Virtual Observatory. Implementing interoperable archives and communication protocols is a major task in order to enable knowledge discovery. Web-based technologies and new user interfaces are part of this approach for which the ESO telescope bibliography is one example.
It serves several purposes:
– Bibliometrics and measuring scientific success by deriving statistics on the number of papers published per hierarchical level, e.g. observatory, telescope, instrument or programme ID.
– Access to proposal information, scheduling and archived raw data based on bibliographical references.
– Setting the pace towards the ongoing Virtual Observatory through the development of inter-connected databases.

The ESO telescope bibliography also endows maximum return of science benefits from observing proposals as it fulfils the basic requirement of providing access to each point of their life cycle.

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ESO Exhibitions in Granada and Naples

Ed Janssen, European Southern Observatory

From September 13–17 2004, the annual JENAM (Joint European and National Astronomical Meeting) conference was held at the Palacio de Congresos in Granada, Spain under the title 'The many scales of the Universe'. At the conference, ESO maintained a 65 sqm exhibition stand showing the most recent scientific and technical achievements at the organisation. The conference was attended by over 450 participants, but also media and local politicians visited the event. The ESO stand drew great attention both from the conference participants and the media, resulting in several articles and television broadcasts in Spain.

Given Spain's participation in the ALMA project and its interest in joining ESO, it is hardly surprising that among Spanish visitors and conference participants there was a strong interest in the presentation of ALMA and the OWL project, as well as in ESO in general. Many questions were asked and the attending ESO staff was busy with providing additional information material about our organization.

Jorge Melnick giving one of many interviews at the JENAM conference in Granada.

From November 10, 2004 to January 30, 2005, ESO took part in the 'Futuro Remoto' exhibition, held at the Città della Scienza in Naples, Italy. Città della Scienza is the first Italian science centre, an innovative museum where visitors can learn about science in an interactive way. Every year more than 150 000 guests, especially school pupils, visit the museum.

'Futuro Remoto' is a yearly multimedia event for the advancement of scientific and technological culture. In the past 17 years it has strongly contributed to bring the students and the citizens closer to scientific research and technological innovations. This is testified by an ever increasing flux of public, richness of programmes and media coverage.

ESO at the 'Futuro Remoto' exhibition.

The event consisted of exhibitions covering about 3 000 sqm as well as a series of public lectures by well-known scientists from Italy and abroad, including Seth Shostak, Margherita Hack, Paolo Nespoli and Massimo Capaccioli. Shows, workshops, interactive demonstrations, etc. completed this successful event. With about 31 000 visitors in the short period between 10th and 28th November, the organisers decided to extend the period of opening by a week. The success of 'Futuro Remoto' clearly demonstrated the strong interest in science by the Italian public and ESO was pleased to play a role in this public outreach activity.

EAAE Meeting at ESO Headquarters

Richard West, European Southern Observatory

The 'Catch a star' (CAS 2004) competition is enjoying ever increasing popularity in schools across Europe. The announcement of the prize winners for CAS 2004 took place during the EAAE meeting – in an animated atmosphere as can be seen in these pictures.

The European Association for Astronomy Education (EAAE) held its triennial General Assembly at ESO Headquarters on March 4–6, 2005. The formal sessions were embedded in a meeting on "New Teaching Opportunities in Astronomy" which exposed more than 70 participants from all over Europe to the latest didactic trends in this area. The EAAE was created in 1995 and has been closely associated with ESO ever since in a very fruitful collaboration with the ESO EPR Department and its Educational Office.

The meeting was opened by EAAE President, Fernand Wagner (Luxemburg), who gave an overview of current EAAE activities, together with other officials of the Association. This being the International Year of Physics and the centenary of Einstein's trailblazing research papers, much attention was given to the question of how to incorporate the related physics topics into current school curricula. This is clearly not an easy task – relativity is an elusive subject for young people (and the public). Fortunately, there are several applications in daily life, e.g. GPS navigation. There is no lack of connections with astronomical objects either and this science is thus a very useful medium (gravitational lenses, black holes) for discussing this subject. Other sessions dealt with exoplanets, one of the hottest topics in present astrophysics and always of great interest to school students for obvious reasons.

EAAE and ESO are currently involved in several joint educational projects. For one of these, "Catch a Star! 2004", the winners were announced via a Webcam; the five top prizes are trips to various observatories and went to teams from Spain, Bulgaria, France, Germany and Belarus.

The ALMA Interdisciplinary Teaching Project (ALMA ITP, see Messenger 117, pp 63–65) met with much interest, and the possibility to link many different teaching topics within one specific research project is considered as one of the most promising paths towards better and more exciting science teaching in the schools.

Plans are now being drawn up for a European Astronomy Day in 2006 (most probably on Friday, October 20), with associated opportunities for active participation of school students and their teachers. During the ensuing discussion many useful suggestions were made for international projects on this occasion.

It has become increasingly clear that in order to raise and maintain the interest of young people in science, it is necessary to begin as early as possible, addressing the age group of 5–9 year-olds. This implies science teaching already in the primary school. A full session therefore dealt with this topic and the participants received positive reports from several pilot projects. During three long sessions on new teaching methods, several teaching projects at the foremost frontline were presented and thoroughly discussed, some involving semi-professional equipment like large CCD's and image processing, robotic telescopes, etc. There is no doubt that doing science " (almost) like the scientists" is a great stimulus to the students.

The participants came away from the meeting with a good feeling that many new developments are now taking place and that there is much new material and experience which may advantageously be introduced into the classes. The EAAE members look forward to further intensifying their efforts to improve astronomy education in Europe's schools and ESO, through its Educational Office, will continue to support the EAAE in the best possible way. Indeed, this direct "link" between the world's top telescopes and Europe's schools has already proved its worth in numerous ways, stimulating science teaching in many places.

Public Affairs Highlights in Chile: Achievements of 2004

Valentina Rodríguez and Felix Mirabel,
European Southern Observatory

One of the priorities of ESO is to contribute to the academic, educational and cultural development in Chile, fostering excellent relationships with its people and government at all levels. Here we present three 2004 highlights of our extensive outreach programs in Chile.

President Ricardo Lagos, ESO Director General, Dr. Catherine Cesarsky, and Dr. Jason Spyromilio, future Director of La Silla-Paranal observatories.

President Lagos visits Paranal

The ESO Paranal Observatory was honored with a very special overnight visit on December 9th to 10th, 2004. The President of Chile, Ricardo Lagos Escobar and his wife Luisa Durán, arrived to the VLT for the first time and were hosted by the ESO Director General, Dr. Catherine Cesarsky; ESO's Representative in Chile, Mr. Daniel Hofstadt; Prof. Maria Teresa Ruiz, Head of the Astronomy Department at the Universidad de Chile, and ESO staff members. The distinguished visitors were shown the various high-tech installations at the observatory, including the Interferometric Tunnel with the VLTI delay lines and the first Auxiliary Telescope. Explanations were given by ESO astronomers and engineers and the President, a keen amateur astronomer, gained a good impression of the wide range of exciting research programs that are carried out with the VLT. President Lagos participated in the imaging of the barred spiral galaxy NGC 1097, located at a distance of about 45 million light-years (see cover).

Interactive Astronomy

One of the most popular stands at the Interactive Museum in Santiago (MIM) is the new Astronomy Exhibition developed by ESO in collaboration with MIM. Since the opening on November 12th 2004, this astronomical journey has captured the attention of children and adults with four dynamic videos and a unique space walk through galaxies, nebulae and planets. In 20 minutes, visitors not only learn basic concepts of astronomy such as gravitation, spectroscopy and space-time, but also enjoy some of the most stunning astronomical images collected by ESO telescopes in Chile.

ESO's Representative in Chile, Daniel Hofstadt, and MIM Director, Haydée Domic, join Mrs. Luisa Durán de Lagos (in the centre) during the opening of the Astronomy Exhibition.

Planetary Ecology Success

Since 1997 ESO has sponsored in Chile the PROED programs of Planetary Ecology, Helios and Universum, making astronomy more accessible for students and teachers of public schools from the II, III and IV Regions in Chile.

ESO support has made it possible to train teachers, develop kits of didactic materials, provide access to amateur telescopes, astronomy exhibitions, regional and national Workshops on Astronomy for schools and the establishment of science-teachers networks.

The success of these programs is based on innovative and participative methods, including experiments in the classroom with the students.

An example of this is the Planetary Ecology program, almost completely financed by ESO for children between 8 and 12 years. There are already 268 trained teachers in 153 schools using this program to teach students about space, earth, water, air and the ecosystem in an imaginative way.

Chilean students of the Planetary Ecology program supported by ESO.

Fellows at ESO

Nicolas Bouché

I arrived at ESO Garching in September 2003 as a postdoc under a joint MPA/ESO contract funded by the European Community Research Training Network ("The physics of the intergalactic medium") just after graduating from the University of Massachusetts. Since I was little – when Halley's comet last came around to be precise – I wanted to become an astronomer. Given that I grew up in Belgium I knew about ESO and its state of the art facilities. It was thus a great privilege to start my career at ESO headquarters. Of course my interests as a professional astronomer took me as far as you can from comets. I now study galaxy formation and distant galaxies at redshifts of two to three. More specifically, my thesis was centered on using cross-correlation techniques to measure (and put constraints on) the mass of a class of high-redshift gas clouds, the so-called Damped Lyman-alpha Absorbers.

I was very fortunate that during my stay at ESO, many fellows worked in my field, namely, the field of quasar absorption line systems. This vibrant environment led to new collaborations, many, many helpful discussions and new friendships. I also benefited greatly from the institutions around ESO, the Max-Planck Institut für Astrophysik and the Max-Planck Institut für extraterrestrische Physik where I just started a three year contract. These three institutions are at the forefront of European astronomy, are leading many cutting edge experiments and it's a great pleasure to be part of it.

Even though, when the fog rolls in for two months at a time, it's like living in a submarine, Bavaria is a beautiful region with many possibilities centred on the Alps or just in Munich.

Eric Depagne

I am at the moment right in the middle of my four years contract as a fellow in Chile. I have my duties at Paranal where, as a night astronomer, I do the observations on UT2 (FLAMES, UVES and FORS1).

Paranal is an incredible place to see. After a two hour drive from Antofagasta, in the middle of the desert, you can see the four telescopes on top of the beheaded mountain. Then, you enter the residencia. And you feel like being in the jungle! So much humidity, compared to outside!

My scientific work is the understanding of our Galaxy's childhood. There are mainly two ways to do so. Either you look at very distant extragalactic objects, or you look at very old galactic ones. That's what I do.

Some low mass stars have atmospheres that are not evolving with time. Thus, by studying the chemical composition of these atmospheres, we have a quite direct access to the material from which these stars were formed. As we suppose that these stars were formed very early after the Big Bang, the chemical composition of these atmospheres puts strong constraints on the Big Bang and the supernovae models. And a striking thing concerning these atmospheres is that at that time, we have been able to detect half of the elements of the periodic table – elements from Hydrogen to Uranium!

Markus Hartung

It's fascinating to sit in the control room, piloting a world-class cutting-edge telescope! A single mouse click and 400 tonnes are moved to point to the new target. Between the active optics giving the 8-m-primary-dish its optimum shape and a deformable mirror countersteering 500 times per second to correct atmospheric turbulence in real time we finally recover space-like resolution. And the more you look into the details, the more you are amazed that all these systems work reliably together to comprise one of the sharpest eyes with which to explore the universe.

This is about the thrill of being a fellow at the VLT. You probably won't believe that being a fellow is all fun and games. Well, I admit that the work can be very demanding and stressful, and after a long shift there can be friction. Paranal science operations seems ultra-organized – rules and regulations everywhere. One might forget that they are not there to bother but to help people work together successfully – no doubt about their positive pay back! When I take care of visiting astronomers as part of my fellow's duties, it is a pleasure to see most of them leaving happy and impressed by the observatory. The team spirit is great, and I really enjoy the privilege of working with such ambitious people from all over the world.

I started as an ESO Paranal fellow with my duty station in Santiago in June 2003. Before, I had been working on my PhD at the MPIA in Heidelberg and had strongly contributed to the CONICA project. The marriage of this versatile infrared camera with the NAOS adaptive optics system took place in Paris. I spent one year there integrating the instruments before they were shipped to Paranal and commissioned at the fourth VLT telescope. When I joined ESO, I had already worked for several months at Paranal. Then, I did not get a chance to explore Chile, but I hoped in my heart that I would return to catch up with it. And here I am now – with my wife and my (Chilean) son, born last December in Santiago – it's been a truly exciting experience!

Jochen Liske

For my PhD I decided to be adventurous and exchanged the homely shores of the river Rhine (Bonn) with the sandy beaches of the South Pacific. At the University of New South Wales in Sydney, Australia, I worked on my beach volleyball skills as well as the intergalactic gaseous structures called "quasar absorbers", which provide a wealth of information on the physical conditions in the early Universe, studying large-scale structure, the radiative environment of powerful quasars and weighing the "normal" matter content of the Universe.

At the end of my PhD in 2001 I moved to the misty shores of the Firth of Forth (Edinburgh) to explore a different area of research and to begin work on the Millennium Galaxy Catalogue, a large-scale survey of local galaxies. When trying to understand how galaxies evolve with time we need to compare today's galaxies with those in the early Universe. It is particularly important to be able to distinguish the various constituents of galaxies as they are believed to be the result of different formation processes. The Millennium survey provides a detailed picture of (cosmologically speaking) nearby galaxies and hence forms the "today" part of the above comparison.

Last year I moved to the banks of the Mühlbach (ESO) where I am continuing my work both on quasar absorbers and galaxy evolution. I am also supporting SINFONI, a new VLT instrument currently being commissioned. Recently, I got involved with a working group who are considering the use of OWL for an experiment designed to literally watch the Universe change its expansion speed over the timescale of a decade or so! Crazy? Possibly, but great fun! This is the sort of thing that makes ESO a fascinating place. Here you get to see the wheels of astronomy turn and watch the future take shape.

The UKIRT Infrared Deep Sky Survey (UKIDSS): data access

Andy Lawrence, University of Edinburgh
Steve Warren, Imperial College London

As part of the UK accession to ESO, it was agreed that all astronomers in ESO member states would have access to the data from the UKIRT Infrared Deep Sky Survey (UKIDSS – *http://www.ukidss.org*). This exciting survey is 3 magnitudes deeper than 2MASS over 7 500 square degrees, as well as having small deep areas, all the way down to a one square degree Ultra Deep Survey to $K = 23$. UKIDSS is therefore the real equivalent to optical sky surveys such as those from the Palomar, UK and ESO Schmidt telescopes, and the SDSS (see *The Messenger*, 108, 31). A substantial fraction of the survey is in the southern sky. The survey is being carried out by the new UKIRT Wide Field Camera (WFCAM), which has just been commissioned – see the press release at *http://outreach.jach.hawaii.edu/pressroom/2004-wfcam/*). The survey starts in March and will take seven years. There will be a sequence of releases, each of which is available only to ESO astronomers (and a small additional list of individuals in Japan) for eighteen months, following which the data become public worldwide.

Access to reduced data and survey products will be through a queryable science archive known as the WFCAM Science Archive (WSA: *http://surveys.roe.ac.uk/wsa*). The WSA link is not live until the first release, but you can try out the interface by using the SuperCOSMOS Science Archive (SSA: *http://surveys.roe.ac.uk/ssa*). During the ESO-proprietary period, you will need to register for a username and password to obtain access. However the WSA team do not expect to vet and authorise every astronomer in Europe who potentially might want access to UKIDSS, and furthermore this list will change from month to month. Rather, we will be agreeing a list of "community contacts" to whom we will delegate the task of producing a list of authorised local usernames. Ingesting these into the WSA database will be automated, so that updating these lists as people leave and join should be easy to do at fairly regular intervals. "Community" will normally mean one particular university or observatory, but could potentially mean any well defined group of astronomers.

We have set up a preliminary list of community contacts which can be found on the UKIDSS web site at *http://www.ukidss.org/archive.html*. If you think your organisation or department needs to be added, please talk amongst yourselves to choose a contact, and send an email to the UKIDSS registration team below. Note that this can be done at any time from now on – the list can grow slowly. As soon as we have an agreed initial list, we will send out instructions for registering your members.

UKIDSS Registration Team:
Andy Lawrence, Edinburgh, *al@roe.ac.uk* (UKIDSS Consortium PI)
Steve Warren, Imperial College London, *s.j.warren@imperial.ac.uk* (UKIDS Consortium Survey Scientist)
Nigel Hambly, *nch@roe.ac.uk* (WSA Scientist)
Andy Adamson, *a.adamson@jach.hawaii.edu* (Head of UKIRT)

A central region of the Orion Nebula captured in the infrared by UKIRT's Wide Field Camera (WFCAM), courtesy of the Joint Astronomy Centre. (Data processing was by Chris Davis and Watson Varricatt). In a single exposure WFCAM can image a region the same area as the Full Moon.

SYMPOSIUM ON RELATIVITY, MATTER AND COSMOLOGY

11–14 July 2005, Bern, Switzerland

The EPS-ESA-ESO-CERN Symposium on 'Relativity, Matter and Cosmology', will take place from July 11 to 14, 2005 at the University of Bern. The Symposium will be part of the centenary celebrations of Albert Einstein's *annus mirabilis* and take place in the framework of the 13th General Conference of the European Physical Society, EPS13, under the general title 'Beyond Einstein – Physics for the 21st Century'. The EPS-ESA-ESO-CERN Symposium 2005 is expected to become one of the highlights of the 'World Year of Physics 2005', also declared the 'International Year of Physics' by the United Nations.

Plenary speakers will introduce the topics, and ample time and space will be provided for contributed papers and posters describing original work, preferably by young scientists.

Plenary Speakers in the EPS-ESA-ESO-CERN Symposium on 'Relativity, Matter and Cosmology' will include K. Danzmann, G. Drexlin, G. Efstathiou, J. Engelen, C. W. F. Everitt, E. Fiorini, W. Gelletley, F. Iachello, V. M. Kaspi, G. Ross, B. F. Schutz, J. Silk, D. Spergel, J. Stachel, and F. Wagner.

The following Sessions for contributed papers and posters are foreseen:

- The Fundamental Laws of Physics and the Constancy of Fundamental Constants
- Tests of Gravitational Theory and General Relativity
- Quantum Gravity
- Dark Energy
- Gravitational Waves
- String Theory and Extra Dimensions
- The Standard Model and Beyond
- LHC Physics and the Origin of Mass
- Neutrino Oscillations and Masses
- Matter in Extreme Conditions
- Dark Matter
- The Early Universe
- Cosmological Parameters
- Matter in the Universe
- Supernovae in Cosmology

EPS13 comprises two other co-located Conferences, one on 'Photons, Lasers and Quantum Statistics' and another one on 'Brownian Motion, Complex Systems and Physics in Biology'. It is anticipated that each one of these Conferences will attract about 300 physicists and astronomers, not only from Europe, but also from other continents. Registration for EPS13 will give access to all three conferences, which will be run in parallel and in close proximity to each other.

Further information can be found at *http://www.eps13.org*

ESO Workshop on

MULTIPLE STARS ACROSS THE H-R DIAGRAM

12–15 July 2005, ESO Headquarters, Garching, Germany

Multiple (i.e. triple, and higher order) stellar systems comprise a significant fraction of stellar populations. Their role in stellar physics has not yet been fully recognized. Stars of some specific types can originate only in multiple systems. An interplay between tides, nuclear evolution and dynamics is a rich field of contemporary research. The growing observational data on multiple systems with a variety of characteristics is used to critically examine the assumptions underlying stellar evolutionary models.

The main aim of the workshop is to bring together observers using different techniques (e.g. spectroscopy, high angular resolution imaging), from X-rays to far-IR, on ground-based single telescopes or interferometers, and on space observatories. The combination of techniques is vital for comprehensive studies of multiple stars that span a wide range of angular separations and stellar types.

The current state of observational and theoretical knowledge will be reviewed. Priorities for future studies will be identified, so as to provide the necessary input for further progress in the understanding of the genesis of multiple stars, their structure and their role for the study of stellar evolution.

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

SOC members: J. Bouvier, L. M. Close, P. P. Eggleton, R. F. Griffin, W. I. Hartkopf, S. Hubrig (co-chair), Ch. Leinert, M. Petr-Gotzens, M. Sterzik, A. Tokovinin (co-chair), S. Udry

LOC members: Ch. Stoffer, P. Bristow, A. Kellerer, M. Petr-Gotzens

Full details and registration information can be retrieved from *http://www.eso.org/gen-fac/meetings/ms2005/* or by e-mail to *ms2005@eso.org*

Deadline for registration: 30 April 2005

MPA/ESO/MPE/USM Joint Astronomy Conference on

Open Questions in Cosmology: the First Billion Years

22–26 August 2005, Garching, Germany

The accepted lore about the state of modern cosmology is that existing data constrain models well enough that few important questions remain to be either asked or solved. In the last year, a wealth of new data about the cosmological background radiation, early star and galaxy formation as well as cosmological evolution in general has been generated. The theoretical prejudice is that the current concordance cosmological model provides a description of our universe consistent with most of these observations. But does it provide the definitive framework against which these new observations can be tested? This meeting will present the latest data, confront them with conventional and alternative models, and review emerging technologies and expected data for their potential to challenge our current understanding of the universe.

Invited Speakers: K. Adelberger (OCIW), J. Bergeron (IAP), V. Bromm (U. Texas, Austin), P. Cox (IAS), L. Cowie (U. Hawaii), R. Ellis (Caltech), X. Fan (U. Arizona), A. Ferrara (SISSA), K. Gorski (JPL), Z. Haiman (Columbia), P. Jakobsen (ESA), K. Jedamzik (U. Montpellier), C. Lawrence (JPL), P. Madau (UCSC), S. Malhotra (STScI), K. Olive (U. Minnesota), J.-L. Puget (IAS), S. Ryan (Open University, UK), A. Songaila (U. Hawaii), J. Schaye (IAS), R. Schneider (OAA), C. Steidel (Caltech), F. Walter (MPIA), S. D. M. White (MPA)

Scientific Advisory Committee: X. Fan (U. Arizona), A. Ferrara (SISSA), K. Gorski (JPL), P. Jakobsen (ESA), B. Leibundgut (ESO), A. Loeb (Harvard), J. Silk (Oxford), A. Songaila (U. Hawaii), M. Umemura (U. Tsukuba), S. D. M. White (MPA)

Local Organising Committee: A. J. Banday, B. Ciardi, S. D. M. White (MPA); W. Freudling, B. Leibundgut, P. Shaver (ESO); M. Lehnert (MPE); E. D'Onghia (USM)

Further information can be found at: *http://www.mpa-garching.mpg.de/~cosmo/2005/*

Deadline for registration and abstract submission: 20 May 2005

ESO Conference on

Science Perspectives For 3D Spectroscopy

10–14 October 2005, ESO Headquarters, Garching

The expansion in 3D instrumentation – obtaining spatially resolved spectra over an area of the sky – on large telescopes has been phenomenal over the past few years. Examples at ESO on the VLT are SINFONI, the Integral Field Unit (IFU) of VIMOS, the Argus mode of FLAMES; at Gemini the GMOS instrument has an IFU mode; OSIRIS is soon to reach Keck. There are also powerful consortium instruments such as SAURON and CIRPASS which were designed for rather specific problems. Several new tunable filters will see first light this year and sterling work continues to be carried out by facility IFU instruments on 4 m class telescopes such as at La Palma (INTEGRAL) and Calar Alto (PMAS). Accompanying this leap in instrumental capabilities, the volume of data delivered is set to increase as larger or multiple IFU's are planned, such as the MUSE or KMOS instruments for the VLT.

It is over five years since the last conference on 3D spectroscopy and time to assess where the technique is going and what are the current and future perspectives for science from 3D spectrographs. This conference will focus on the current science and the plans for the near future. All areas of astrophysics will be covered for which 3D spectroscopy brings special benefits – from the Solar System out to high redshift galaxies. There will be brief presentations of new instruments and techniques but the primary emphasis will be on the science from 3D spectroscopy.

The conference is co-sponsored by Euro3D, which is a European Union funded Research Training Network. Euro3D currently employs 10 post-docs at centres throughout Europe to work on integral field spectroscopy (*http://www.aip.de/Euro3D/*).

The meeting will consist of longer invited reviews with shorter contributed talks and posters. The proceedings will be published in the Springer ESO Astrophysics Symposia series.

SOC members: J. Allington-Smith (Durham), S. Arribas (IAC, STScI), A. Bunker (Exeter), R. Bacon (Lyon), G. Cecil (North Carolina), R. Davies (Oxford), C. Dumas (ESO), P. Ferruit (Lyon), R. Genzel (MPE), J. Bland-Hawthorn (AAO), A. Quirrenbach (Leiden), G. Wright (Edinburgh)

LOC members: J. Walsh (ESO), M. M. Roth (AIP), M. Kissler-Patig and C. Stoffer (ESO)

Further details are available at *http://www.eso.org/3Dspec05* or by e-mail to *3Dspec05@eso.org*

Deadline for pre-registration: 15 May 2005
Deadline for final registration: 01 September 2005

Felix Mirabel becomes ESO Representative in Chile

Starting on April 1, Felix Mirabel will take up a double role as ESO Representative in Chile and Head of ESO's Office for Science in Chile.

Felix Mirabel was born in 1944 in Uruguay. After finishing secondary school, he went to Argentina where he obtained a PhD in Astrophysics at the University of La Plata, and a Master degree in Philosophy from the University of Buenos Aires. He pursued postdoctoral studies at Jodrell Bank in the UK, at the University of Maryland, and then in Puerto Rico using the Arecibo radiotelescope. In 1990, after having worked at Caltech as a Guggenheim fellow, he moved to France working as director of research at the CEA (Saclay), where he stayed until joining ESO.

His scientific career has spanned the electromagnetic spectrum, from his early work in the radio domain to the optical, then infrared, millimetre and X- and gamma-ray astronomy. He has made use of a wide variety of the world's observational facilities, including all of ESO's major telescopes, from the 3.6 m to the SEST, from the NTT to the VLT.

His research has covered topics such as star formation, galactic structure, compact binaries, gamma-ray bursts and interacting galaxies. He is particularly well-known for the identification of ultra-luminous infrared galaxies as a new class of objects and for his discoveries of microquasars in our galaxy, for which he has been awarded prizes in the US and in Europe, and last year a Doctorate Honoris Causa from the University of Barcelona.

On April 1, Felix Mirabel will take up a double role: he will be ESO's Representative in Chile as well as the Head of ESO's Office for Science in Chile. As ESO Representative, his main wish is to continue to improve the present very good relationship between ESO and Chile, both with its people and authorities. He feels that "this is a very good time to take up this post, following the excellent work done by Daniel Hofstadt." He sees continued strengthening of the relations with Chile not only through an enhancement of scientific capabilities of Chilean universities but also through cultural and educational programmes at large. In his post, Felix Mirabel will also strive to work in harmony with the US and Japan for the construction of ALMA.

In his other role as Head of ESO's Office for Science in Chile, his aim is to foster science across all ESO centres in cooperation with Chilean research groups. "When I arrived, I was impressed by the work of Danielle Alloin. Together with Daniel Hofstadt, she has shaped Vitacura and made it an attractive astronomical centre in Chile. I also appreciate very much the fact that all ESO staff members, fellows and students are eager to enhance science in Chile, organizing by own initiative thematic groups of discussion and helping in a great variety of activities. Certainly, my new tasks won't leave me much time to continue my own research in the same way as before. But through this new role in the organization I aim to work for excellent conditions of astronomical research in Chile, and I am convinced that I will greatly enjoy the discoveries to be made at ESO by the young generation of astronomers."

ESO Studentship Programme

The European Southern Observatory research student programme aims at providing opportunities 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 ESO offices in Santiago (Chile). These positions are open to students enrolled in a Ph.D. programme at a university in an ESO member state or, exceptionally, at an institution outside 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 interests 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 as many as 40 days/night work per year at the La Silla-Paranal 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, 2005.

Please apply by: filling the form available at *http://www.eso.org/gen-fac/adm/pers/forms/student05-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 2005. 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.

For further information contact Christina Stoffer (*cstoffer@eso.org*).

Applications are invited for the position of

Head of Administration

Career Path: VII

Purpose and scope of the position: The main task is to provide efficient administrative services and advice to the Director General, Division Leaders and to staff members in the scientific and technical areas in the fields of financial planning and accounting, personnel management, purchasing, legal and contractual matters, information systems and building and site maintenance. As a member of the ESO Management the Head of Administration contributes essentially to the development of the overall policy, strategic planning, relations to the members of the personnel and maintains professional contacts at highest level outside the Organisation. ESO employs in total approximately 650 staff members and the Administration Division comprises the Administration at the Headquarters in Garching near Munich and the Administration in Santiago (Chile). The successful candidate will be supported by some 50 qualified staff members.
Professional requirements/qualifications: An appropriate professional qualification as well as substantial management and leadership experience within a scientific organisation, preferably international, and knowledge of administrative, legal, financial and personnel procedures are required. Excellent communication skills and a very good knowledge of English are essential. Good knowledge of the German language would be an important asset. Additional knowledge of other European languages, in particular Spanish, would be an advantage.
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 support 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. Either the title or the grade may be subject to change according to qualifications and the number of years of experience.
Staff category: International Staff Member.
Duty station/Place of residence: Garching near Munich, Germany, with regular duty travels to Chile.
Starting date: 1 September 2005.
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 (to be obtained from the ESO Home Page at *http://www.eso.org/gen-fac/adm/pers/forms/*) by

30 April 2005.

For further information please contact Mr. Roland Block at *rblock@eso.org*.
You are also strongly encouraged to consult the ESO Home Page (*http://www.eso.org*) for additional information.

Although preference will be given to nationals of the Member States of ESO: Belgium, Denmark, Finland, 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.

Applications are invited for an Operations Staff Astronomer position in 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

Career Path: V

Assignment: The successful candidate will support observing operations in both visitor and service mode at the VLT Unit Telescopes (UT) on Paranal. 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. Paranal Operations Staff Astronomers contribute to the challenge of operating a world leading astronomical facility so as to optimize its scientific output, have the opportunity to acquire expert knowledge of novel instrumentation, and may be given the overall responsibility for an instrument. Flexibility exists so as to tailor duties and responsibilities as a function of personal expertise and interests.
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 in 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 135 nights 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 Paranal Operations Astronomers.
Education: Ph.D. in Astronomy, Physics or equivalent.
Experience and knowledge: The Observatory is seeking a staff astronomer with substantial observing experience (at least three years). The ideal candidate will be active researcher and have excellent observation oriented research records, will be familiar with a broad range of instrumental, data analysis, archiving and observational techniques, and 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. 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 pension scheme, medical, educational and other social benefits as well as professional training opportunities and financial support in relocating your family. 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), the ESO Application Form (*http://www.eso.org/gen-fac/adm/pers/forms/*) and four letters of reference should be submitted by

30 April 2005.

For further information, please consult the ESO Home Page (*http://www.eso.org*) or contact Mrs Nathalie Kastelyn, Personnel Department, Tel. +49-89-3200-6217.

Although preference will be given to nationals of the Member States of ESO: Belgium, Denmark, Finland, France, Germany, Italy, The Netherlands, Portugal, Sweden, Switzerland, and United Kingdom, no nationality is à priori excluded.

Applications are invited for the position of an

ALMA Back-end Integration and Data Communication Engineer

Career Path: V

Purpose and scope of the position: Within the European ALMA team, the selected candidate will take up responsibilities in the monitoring of production contracts and in the integration, commissioning and acceptance of the Back-end sub-system and related data communication infrastructures (fibre optic based system) of the ALMA radio telescope. As such, the selected candidate will be part of the ALMA Back-end Integrated Product Team (BE IPT). The position will involve duties in ALMA partner regions, Europe, North America and Chile in the form of frequent and occasionally extended missions.

Duties and responsibilities: The position will include several of the following tasks:

- Elaboration of BE integration & test plans and support for the development of an operations and maintenance plan in close collaboration with the System Engineering & Integration IPT.
- Definition of applicable Quality Management processes, mainly in the areas of production, integration and validation in the ALMA project.
- Participation in and organisation of product reviews.
- Monitoring of the installation, commissioning and acceptance of the BE sub-systems and fibre optic distribution infrastructures on site.
- Support for developing and maintaining the BE sub-system specifications and interfaces and for assuring that the sub-system designs comply with defined specifications.
- Monitoring of detailed sub-system performance of the BE sub-system technical budgets.
- Contribution to the ALMA configuration and change-control processes.
- Direct reporting to the ESO ALMA Back-end manager. Support the IPT manager in monitoring schedules and the technical performance of all back-end subsystems.

Professional requirements/qualifications: University degree (or equivalent) in Electrical Engineering or Physical Sciences. Further qualifications and experience in a scientific domain would be advantageous, e.g. a post-graduate experience in radio-astronomy research and/or in high speed fiber optic networks and advanced electronics industrial environment. At least three years of working experience in an engineering position on multidisciplinary, high technology, advanced electronics and fibre-optic data communication project(s).

Experience and knowledge: The ideal candidates will have experience in:

- Design, development, production installation and commissioning of advanced electronic systems, high speed optical data communication systems, optical components and related infrastructures.
- Establishing Assembly, Integration and Verification Plans communication and electronic systems.
- Configuration and Quality management.
- Excellent communication skills, a good command of the English language and a strong sense of team spirit are essential.

Duty station: Garching near Munich, Germany.
Starting date: As soon as possible.
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. The title or 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 (*http://www.eso.org/gen-fac/adm/pers/forms/*) by

15 April 2005.

For further information please contact Mrs Nathalie Kastelyn, Personnel Department, Tel. +49-89-3200-6217. You are also strongly encouraged to consult the ESO Home Page (*http://www.eso.org/*) for additional information about ESO.

Although preference will be given to nationals of the Member States of ESO: Belgium, Denmark, Finland, France, Germany, Italy, The Netherlands, Portugal, Sweden, Switzerland, and United Kingdom, no nationality is à priori excluded.

Applications are invited for the position of a

Senior Engineer – Head of Paranal Engineering Department

Career Path: V

Purpose and scope of the position: The role of the Paranal Engineering Department is to carry out the assembly, integration and troubleshooting of the VLT (Very Large Telescope), the instrumentation of the VLT and of the VLTI (VLT Interferometry), of the VST (VLT Survey Telescope), VISTA (Visible and Infrared Survey Telescope), of all the facilities required on the Observatory (Power Station, Air Compressors, Chillers, etc), and to provide general engineering support of maintenance, troubleshooting and fault repair to nightly operations.
The Engineering Department of the Paranal Observatory comprises 5 engineering groups (Mechanical, Electronic, Software, Optics, and Instrumentation), with a total workforce presently consisting of 45 engineers and 15 technicians.
The telescopes and instruments are large, complex systems that involve many advanced technologies and that require a high level of engineering support.

Duties and responsibilities: Reporting to the Head of Engineering of the La Silla-Paranal Observatory, the successful candidate shall have the responsibility of:

- The four telescopes with their instruments making them available for Science operations 365 nights per year;
- The integration activity of new instruments and telescopes ensuring they are properly performed on time;
- The engineering support to the commissioning of the interferometric complex;
- Additional technical responsibilities including that of the Power Station and of the auxiliary systems (compressed air, chillers, etc.);
- The definition of operational procedures and long-term planning;
- The personnel management (in particular training and performance evaluation) and supervision of the five engineering groups;
- The preparation of the annual budgets and the scheduling of support staff.

Professional requirements/qualifications:

- University Degree in mechanical, optomechanical or aeronautical engineering.
- At least ten years of relevant on field engineering experience in large multi-discipline scientific/of high technology projects;
- Technical experience in optomechanic systems will be a plus.

see next page

Managerial Competence Criteria

- Ability to identify key strategic issues, opportunities and risks;
- Capability to communicate links between the Organization's strategy and the work unit's goals; establish/identify and communicate broad and compelling organizational directions;
- Strong managerial/leadership skills; with demonstrated experience to perform and/or oversee the analysis of complex human resources, financial, logistical or administrative management policy and program issues;
- Ability to effectively lead, supervise, mentor, develop and evaluate staff and design training/skills enhancement initiatives to ensure effective staff development;
- Excellent oral/written communication skills in English. Working knowledge of Spanish or the willingness to learn it;
- Proficiency with the Microsoft Office package.

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 support in relocating your family. The initial contract is for a period of three years with the possibility of a fixed-term extension or permanence.

Staff Category: International Staff Member. The grade may be subject to change according to qualifications and the number of years of experience.

Duty Station/Working Schedule/Place of residence: The ESO Paranal Observatory, at Cerro Paranal (120 km south of Antofagasta), is located at an altitude of 2600 m. The working system is typically 5/2 (Monday to Friday) or 8/6 with accommodation provided on site. After a first period of 5/2 the final turno will be agreed upon with the supervisor according to the operational requirements. The place of residence will be Antofagasta or Santiago.

Starting date: As soon as possible.

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 (to be obtained from the ESO Home Page at *http://www.eso.org/gen-fac/adm/pers/forms/*) by

30 April 2005.

For further information please contact Mr. Walter Demartis at *wdemarti@eso.org*.
You are also strongly encouraged to consult the ESO Home Page (*http://www.eso.org*) for additional information.

Although preference will be given to nationals of the Member States of ESO: Belgium, Denmark, Finland, 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.

Applications are invited for the position of an

ALMA Project Planner/Scheduler

Career Path: V

The Atacama Large Millimeter Array (ALMA) is an international astronomy facility. ALMA is an equal partnership between Europe and North America, in cooperation with the Republic of Chile, and is funded in North America by the U.S. National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC), and in Europe by the European Southern Observatory (ESO) and Spain. ALMA construction and operations are led on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI), and on behalf of Europe by ESO.

The ALMA construction project has adopted a management structure based on the Integrated Product Team (IPT) concept. The IPT concept provides a method of managing tasks carried out across multiple organizations and locations. Each Level One WBS element is managed by an IPT responsible for delivering the required sub-systems on time, within the specified cost and meeting the project requirements.The ALMA Project Control Managenent System (PMCS) is centralized under the leadership of the ALMA Project Controller located in the ALMA offices in Santiago, Chile with staff located in Chile, Europe and North America.

Purpose and scope of the position: The successful candidate is part of the ALMA PMCS team and reports to the European Project Controller. Responsibilities include: maintaining integrated project schedules for activities conducted in Europe; coordinating work activities with IPT's; progressing schedules and assisting in identifying and resolving schedule conflicts; providing Earned Value Management (EVM) reporting and variance analysis in conjunction with the Project Controller; developing and controlling associated project documentation; providing change and problem management.

The position involves duty travels to ALMA partner regions, Chile, Europe and North America.

Duties and responsibilities:

- Using Project Planning & Control (PP&C) tools, document and maintain master and sub-project plans including schedule, tasks, milestones, resource assignments and time/expense tracking for large, geographically dispersed, IPT activities and subcontracted work.
- Configure and customize PP&C software programs including determining user requirements; establishing and maintaining multiple remote user accounts; establishing data interfaces; and developing internal and executive reports.
- Assist the Project Controller with analyzing and reporting on the required master and sub-project plans to plan, track and display IPT efforts and performance.
- Assist with the integration of cost accounting and other plans into the master project schedule to facilitate EVM; collect periodic updates and reconcile differences; develop, analyze and report on EVM metrics as directed by the Management IPT.
- Assist with development and maintenance of additional project management tools and processes to assist the Project Controller in overseeing the IPT efforts and activities.

Professional requirements/qualifications:

- University degree in Engineering or technology related fields.
- Significant experience using medium to high-end Project Planning & Control tools (e.g. Open Plan, COBRA, Primavera, MS Project Server, MS Project Professional, etc.).
- Experience of working in large collaborative multi-cultural project environments.
- Ability to coach technical and financial personnel in Earned Value Management (EVM) and project scheduling methods (e.g., critical path method).
- Project Management Professional (PMP) certification is a plus.
- Proficiency in MS Office applications (Outlook, Word, PowerPoint, Excel and Access).
- Multi-tasking competencies to manage multiple efforts or projects.
- Excellent communication skills, a good command of the English language and a strong sense of team spirit are essential.

Duty station: Garching near Munich, Germany.

Starting date: As soon as possible.

see next page

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 support in relocating your family. The initial contract is for a period of three years with the possibility of a fixed-term extension or permanence. The title, grade and level of responsibility may be subject to change according to qualification and the number of years of experience. Serious consideration will be given to outstanding candidates willing to be seconded to ESO on extended leaves from their home institutions.
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 (*http://www.eso.org/gen-fac/adm/pers/forms/*) together with the names of four individuals willing to provide professional reference letters. Applications should be submitted by

15 April 2005.

For further information please contact Mr. Roland Block, Head of Personnel Department, Tel.: +49-89-3200-6589. You are also strongly encouraged to consult the ESO Home Page (*http://www.eso.org/*) for additional information about ESO.

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Personnel Movements

1 December 2004 – 28 February 2005

Arrivals

Europe

Araujo Hauck, Constanza (RCH)	Paid Associate
Boxheimer, Jutta (D)	Graphics Designer
Delmotte, Nausicaa (F)	Paid Associate
Demartis, Walter (I)	Personnel Officer
Fechner, Matthias (D)	Student
Harrison, Paul (UK)	Paid Associate
Hastie, Morag Ann (UK)	Student
Kiupel, Katarina (D)	ERP System Specialist
Nilsson, Kim (S)	Student
Rahoui, Farid (F)	Student
Robinson, Mark (UK)	Programme Controller
Strazzullo, Veronica (I)	Student
Surdej, Isabelle (B)	Paid Associate

Chile

Amado Gonzalez, Pedro Jose (E)	Operations Astronomer
Arenas, Eduardo (PE)	Procurement Officer
Camuri, Massimiliano (I)	Electronics Engineer
Carstens, Johan (S)	Electronics Engineer
de Brito Leal, Luis Filipe (P)	Student
Gonzalez, Victor (RCH)	Software Engineer
Horst, Hannes (D)	Student
Markar, Kiriako (RCH)	Logistics Supervisor
Nicoud, Jean-Luc (CH)	Mechanical Engineer
Reveco, Johnny (RCH)	Software Engineer

Departures

Europe

Beckers, Jean-Louis (B)	Project Controller
Cioni, Maria-Rosa (I)	Fellow
Mackowiak, Bernhard (D)	Paid Associate
Huxley, Alexis (UK)	Software Engineer
Pignata, Giuliano (I)	Student

Chile

Alloin, Danielle (F)	Head of Science Vitacura
Arredondo, Diego (RCH)	System Administrator
Billeres, Malvina (F)	Fellow
Johansson, Lars Erik (S)	Paid Associate
Pantin, Eric (F)	Paid Associate
Ragaini, Silvia (I)	Student
Nakos, Theodoros (GR)	Student
Casquilho Faria, Daniel (S)	Student
Sbordone, Luca (I)	Student
Suc, Vincent (F)	Student

Recent Proceedings from the ESO Astrophysics Symposia

Volume	Title	Editors
16/2003	Astronomy, Cosmology and Fundamental Physics	Peter A. Shaver, Luigi DiLella, Alvaro Giménez
15/2004	Toward an International Virtual Observatory	Peter J. Quinn, Krzysztof M. Górski
14/2003	Extragalactic Globular Cluster Systems	Markus Kissler-Patig
13/2003	From Twilight to Highlight: The Physics of Supernovae	Wolfgang Hillebrandt, Bruno Leibundgut
12/2003	The Mass of Galaxies at Low and High Redshift	Ralf Bender, Alvio Renzini
11/2003	Lighthouses of the Universe: The Most Luminous Celestial Objects and Their Use for Cosmology	Marat Gilfanov, Rashid Sunyeav, Eugene Churazov
10/2003	Scientific Drivers for ESO Future VLT/VLTI Instrumentation	Jaqueline Bergeron, Guy Monnet
9/2003	The Origin of Stars and Planets: The VLT View	João F. Alves, Mark J. McCaughrean
8/2003	Gamma-Ray Bursts in the Afterglow Era	Enrico Costa, Filippo Frontera, Jens Hjorth
7/2003	Deep Fields	Stefano Cristiani, Alvio Renzini, Robert E. Williams
6/2003	Mining the Sky	Anthony J. Banday, Saleem Zaroubi, Matthias Bartelmann
5/2003	Quasars, AGNs and Related Research Across 2000	Giancarlo Setti, Jean-Pierre Swings

For further information look at *http://www.springerlink.com/openurl.asp?genre=journal&issn=1431-2433*

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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 eleven countries: Belgium, Denmark, Finland, 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 2600 m high mountain approximately 130 km south of Antofagasta. The VLT consists of four 8.2 m 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 2400 m altitude, ESO operates several optical telescopes with diameters up to 3.6 m. The third site is the 5000 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 1600 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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The ESO Messenger:
Editor: Peter Shaver
Technical editor: Jutta Boxheimer
http://www.eso.org/messenger/

Printed by
Peschke Druck
Schatzbogen 35
D-81805 München
Germany

ISSN 0722-6691

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Front Cover Picture: *Galaxy NGC 1097*

This is an almost-true colour composite based on three images made with the multi-mode VIMOS instrument on the 8.2 m Melipal Unit Telescope of the VLT. The observations were made on the night of December 9–10, 2004, in the presence of the President of the Republic of Chile, Ricardo Lagos. The exposures were taken and pre-processed by ESO Paranal Science Operation astronomers, with additional image processing by Hans Hermann Heyer (ESO). More details are available in ESO Press Release 28/04.