The Messenger

No. 120 – June 2005

Progress Report on X-shooter, the first second-generation VLT instrument

X-shooter is the first of the approved second-generation VLT instruments to have completed the Preliminary Design Phase. Here we give an update of developments in the project since its official launch in December 2003.

Hans Dekker and Sandro D'Odorico, ESO,
on behalf of the X-shooter Consortium team

X-shooter is a single target spectrograph for the Cassegrain focus of one of the VLT UTs, covering in a single exposure the wide spectral range from the UV- to the *K*-band. It is designed to maximize the sensitivity by directing the light to three wavelength-optimized spectrograph arms. The possibility to observe faint sources with an unknown flux distribution in a single shot inspired the name of the instrument. A first report on X-shooter was contained in the article "New VLT Instruments Underway" by A. Moorwood and S. D'Odorico at the time of project approval (2004, The Messenger 115, page 8).

After the telescope focal plane the light beam is split in three spectral ranges (UV-Blue, Visual-Red and NIR) by two dichroics and focused by auxiliary optics on three separate slits. Each spectrograph arm has optimized optics, coatings, dispersive elements and detectors and operates at intermediate resolution (R = 4 000–14 000, depending on the arm and the slit width) sufficient to address quantitatively a vast number of astrophysical applications while working in the background-limited S/N regime in the regions of the spectrum that are free from strong atmospheric emission and absorption lines.

A small Integral Field Unit (IFU) covering an area of 4 × 1.8 arcsec on the sky can be inserted in the focal plane and reformats this field as a 0.6 × 12 arcsec slit. This option can be used in time of poor seeing, for spectroscopy of slightly extended objects or for quick pointing of targets with coordinates known to 1 arcsec rms accuracy.

The small number of moving functions and instrument modes and the fixed spectral formats make the instrument simple and easy to operate and permit a fast response. With its capability to observe single objects over a wide spectral range at the sky limit, the X-shooter will be a cornerstone facility for the VLT.

The main scientific objectives of X-shooter have been elaborated during Phase A and are summarized in Table 1. The main instrument parameters are listed in Table 2.

During the Preliminary Design Phase, much time and effort has gone into optimizing the instrument mass and minimizing flexure as a function of telescope position. Two types of flexures can affect the quality of X-shooter observations: the relative motions of the three entrance slits (which has to be minimized to avoid losses in one arm with respect to the others) and those between the slits and the detector planes (which could degrade the accuracy of the wavelength and flat-field calibrations) These critical issues were already identified during the Phase A study and are due to the instrument location at Cassegrain, the weight and torque limits that apply for this focus and by the fact that from a mechanical point of view, X-shooter is an instrument cluster, rather than a single instrument. Access for adjustment and maintenance has also been a driver to this design optimization. The layout of the instrument that resulted from these optimization studies is found in Figure 1. For the flexures, while the FEA calculations are being consolidated and compared with the specifications, we do not exclude the possibility to introduce at FDR active mirror controls to compensate the slit motions.

On the optical side it was decided to change the original UVES-type white-pupil layout to a new type of white pupil layout

Table 1: Science drivers for X-shooter

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

Table 2: X-shooter characteristics

Spectral Format	Prism cross-dispersed echelle
Wavelength range	300–2 500 nm, split in 3 arms using dichroics UVB: 300–550 nm VIS: 550–1 000 nm NIR: 1000–2 500 nm
Spectral resolution	5 000 (UVB, NIR) and 7 000 (VIS) for a 1 arcsec slit
Slits	slit 12″ × 1″ (standard), 12″ × 0.6″ (high R), 12″ × 5″ (flux cal.) IFU 4″ × 1.8″ input area, 12″ × 0.6″ exit slit (3 slices)
Detectors	UVB: 2k × 4k E2V VIS: 2k × 4k MIT/LL IR: 2k × 2k Rockwell Hawaii-2RG MBE (used area 1 k × 2 k)
Auxiliary functions	Calibration Unit; A & G unit with 1′ × 1′ field and filter set; ADC for the UVB and VIS arms

dubbed 4C (for Collimator Correction of Camera Chromatism). An important advantage of 4C is the small and simple camera and the fact that prisms are used in double pass which reduces the number of prisms, hence cost and weight. The NIR optical layout and spectral format are shown in Figure 2.

The PDR was successfully passed in December 2004 (March 2005 for the Data Flow aspects of the project). Recommendations of the review board were to also cover the astrophysically very important *K*-band with the NIR instrument if this could be done without losses in the other bands and to suppress the planned closed-cycle cooler, the vibrations of which might interfere with interferometry. These modifications are now being implemented. They were facilitated by rapid technical developments in low-background IR detectors at Rockwell (as confirmed in recent laboratory tests at ESO and demonstrated by the good performance of the 2 k × 2 k Hawaii-2RG array in SINFONI). In Figure 3 we show the minimum DQE of the detectors that ESO is confident to install on the instrument. The PDR of the Data Flow addressed the expected impact of the instrument operation on the observatory, the specifications for calibration and the exposure time calculator, the requirements on the Data Reduction Software and the specification of the routines from which the pipeline data reduction will be built up.

The design and specification documents for long-lead items like optics, gratings and NIR detector are currently being prepared and will be reviewed in Q2 of this year to permit early ordering. For the IFU module a prototype has been built in Paris and is undergoing the first tests (Figure 4, next page). The instrument FDR will take place around the end of this year; the exact date depends on the outcome of the ongoing adjustments to the PDR design. First light on the telescope is expected for late 2007 with instrument release in October 2008.

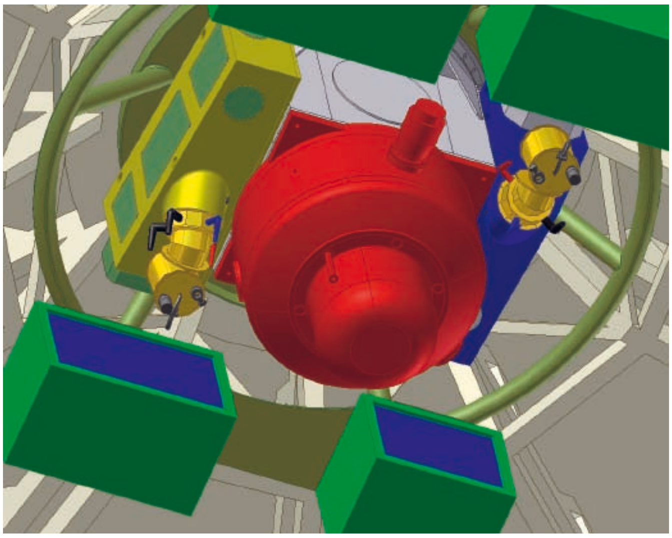
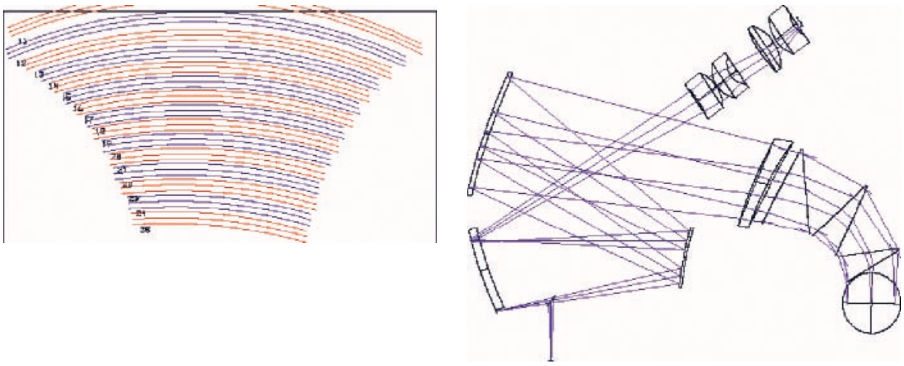


Figure 1 (above): View of X-shooter attached to the Cassegrain focus of the telescope. Compared to the Phase A design, the electronics are no longer supported by the main structure (backbone) but by a co-rotating ring. This reduces flexure and improves access. The NIR spectrograph is mounted below the backbone (3D view from Copenhagen Observatory).

Figure 2 (below): The white-pupil optical layout of the NIR spectrograph (panel on the right). The chromatism of the corrector plate (just in front of the first prism) is used to help correct the camera which consists of only four lenses. The collimated beam on the grating is 85 mm. Since the pupil mirror re-images the grating on the camera mouth at 2× demagnification, the camera is compact and inexpensive.
The left panel shows the spectral format which covers the range 1.03–2.48 μm in 15 orders over a 1k × 2k section of a Rockwell 2k × 2k array. The order separation is nearly constant due to the use of ZnSe and Fused Silica prisms, which leads to efficient use of IR detector area (optical design by ESO and the Dutch and Italian partners of the Consortium).



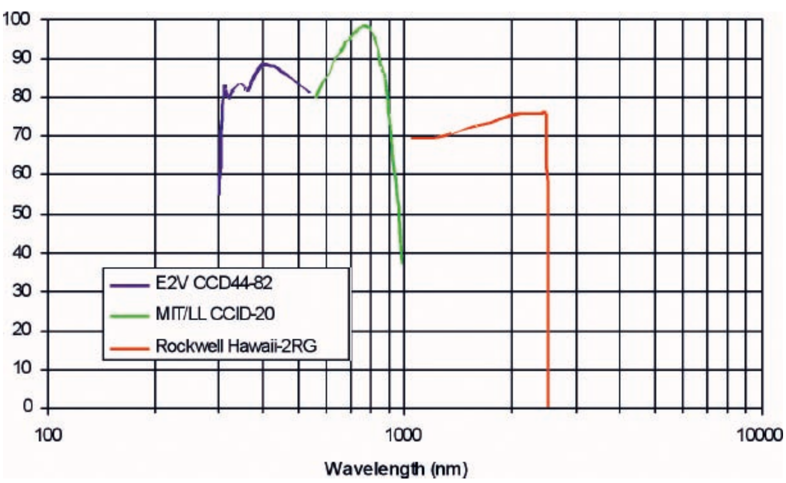


Figure 3 (left): DQE curves of the detector chips that have been selected for X-shooter. The CCDs are in-house and were measured by the ESO Optical detector team. The IR detector is on the shelf at Rockwell and is reserved for X-shooter. Dichroic crossover points are at 557 and 1019 nm. The wavelength range of X-shooter spans more than three octaves.

X-shooter is being built with – in exchange for guaranteed time – a large manpower and financial contribution from institutes in four ESO member nations. In the course of 2004 all required national funding has been secured. The total effort amounts to 67 person-years and 5.3 M€, of which ESO contributes 22 % and 28 %, respectively. The large external financial contribution is unusual in VLT instrument projects but in the case of X-shooter it allows rapid advancement of the project, decoupling it from cash flow limitations in the VLT instrumentation budget. Table 3 lists the co-PIs and collaborating institutes and their main technical contributions. The two agreements with Italy and Denmark have been signed in 2004, the one with France in April 2005 (Figure 5) and the one with the Netherlands is being signed as this issue of the Messenger goes to print.

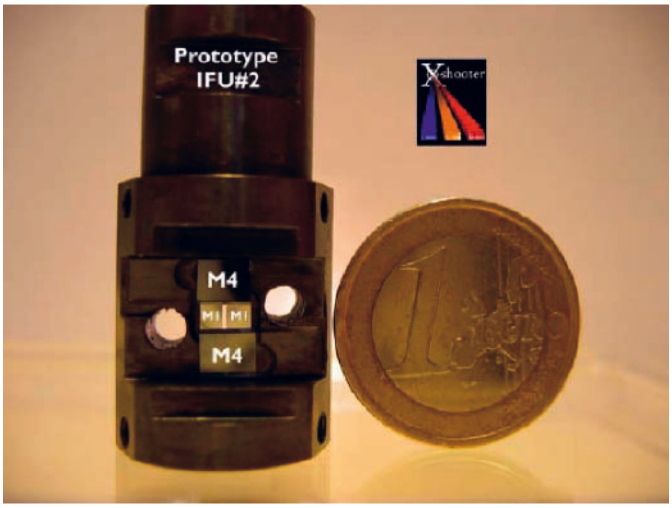


Figure 4: Part of the prototype of the IFU assembled for performance test at the laboratory of the GEPI Department of the Observatory of Paris-Meudon. View is on the input side. The IFU will reformat a field of 1.8 x 4 arcsec^2 in the sky into a slit of 0.6 x 12 arcsec^2. The central slice of 0.6 x 4 arcsec^2 can be seen between the two M1 mirrors.

Table 3: PIs, collaborating institutes and their contributions

PI and collaborating institutes	Contribution
Per Kjærgaard-Rasmussen Copenhagen University Observatory	Backbone unit, UVB spectrograph, Mechanical design and FEA, Control electronics
Sandro D'Odorico ESO	Project Management and Systems Engineering, Detector systems, optical design, various aspects of the Data Flow at the VLT, final system integration, commissioning, logistics
François Hammer Paris-Meudon Observatory, Paris VII University	Integral Field Unit, Data Reduction Software
Roberto Pallavicini Observatories of Brera, Catania, Trieste and Palermo	VIS spectrograph, Instrument Control Software, optomechanical design, integration and test of UVB and VIS spectrographs
Lex Kaper Astron, Universities of Amsterdam and Nijmegen	Opto-mechanics of cryogenic NIR spectrograph, contribution to Data Reduction Software

Figure 5: Daniel Egret, President of the Observatoire de Paris, welcomes Catherine Cesarsky, Director General of ESO, and the French participants to the project on the day of the signature of the X-shooter Agreement between ESO and the Observatoire (1 April 2005).

VLTI First Fringes with Two Auxiliary Telescopes at Paranal

The Very Large Telescope Interferometer (VLTI) at Paranal Observatory had another extension of its already impressive capabilities by combining interferometrically the light from two relocatable 1.8-m Auxiliary Telescopes in February 2005. This achievement heralds an era of new scientific discoveries. Both Auxiliary Telescopes will be offered from October 1, 2005 to the community of astronomers for routine observations, together with the MIDI instrument. By the end of 2006, Paranal will be home to four operational ATs that may be placed at 30 different positions and thus be combined in a very large number of ways (baselines). This will enable the VLTI to operate with enormous flexibility and, in particular, to obtain extremely sharp images of celestial objects.

Bertrand Koehler and the AT Assembly and Commissioning team, ESO

AT Assembly and Commissioning team

From Garching

Mechanics	Maximilian Kraus
Electronics	Jean-Michel Moresmau Martin Dimmler Arno van Kesteren
Optics	Frédéric Gonté Domenico Bonaccini
Software	Krister Wirenstrand Philippe Duhoux Robert Karban Luigi Andolfato

From Paranal

Mechanics	Volker Heinz Juan Carlos Palacio Erito Flores Luis Roa
Electronics	Gerhard Hüdepohl Juan Pablo Haddad Juan Osorio Luis Caniguante
Optics	Stéphane Guisard Stephan Del Burgo Paul Giordano
Software	Stefan Sandrock Javier Argomedo

A list of the other key persons involved in the design and development of the Auxiliary Telescope, can be found the article: The Auxiliary Telescopes for the VLTI: a status report, The Messenger 110, page 21.

The VLT was designed from the beginning with the use of interferometry as a major goal. The VLT Interferometer (VLTI) combines light captured by two 8.2-m VLT Unit Telescopes, dramatically increasing the spatial resolution and showing fine details of a large variety of celestial objects. The VLTI is arguably the world's most advanced optical device of this type. It has already demonstrated its powerful capabilities by addressing several key scientific issues, many of them summarized most recently in the last issue of The Messenger (No. 119, 2005, page 36) and presented at the workshop " The power of optical/IR interferometry" (this issue, page 48).

However, most of the time the large Unit Telescopes are used for other research purposes in a standalone way. They are therefore only available for interferometric observations during a limited number of nights every year. Thus, in order to exploit the VLTI each night and to achieve its full potential, some other (smaller), dedicated telescopes were included into the overall VLT concept. These telescopes are known as the VLTI Auxiliary Telescopes (ATs) and have 1.8 m diameter primary mirrors.

The Auxiliary Telescopes are fully autonomous, ultra-compact, and very high-precision telescopes that can be moved around and placed on any of the 30 observing stations built for them on the VLT observatory platform. From these positions, their light beams are fed into the same common VLTI focal point via a complex system of reflecting mirrors mounted in underground tunnels. The possibility to move the ATs and thus to perform observations with a large number of different configurations ensures a great degree of flexibility, unique for an optical interferometer of this size and crucial for its exceptional scientific capability. Taking also into account the four 8.2-m VLT Unit Telescopes, no less than 254 independent pairings of two telescopes (baselines), different in length and/or orientation, are available. Moreover, while the largest possible distance between two 8.2-m telescopes is about 130 metres, the maximal distance between two ATs may reach 200 metres. As the achievable image sharpness increases with telescope separation, interferometric observations with the ATs placed at the extreme positions will therefore yield sharper images than is possible by combining light from the large telescopes alone. All of this will enable the VLTI to obtain exceedingly sharp and complete images of celestial objects.

The Auxiliary Telescopes are built by the company AMOS in Liège (Belgium) as 'turnkey' telescopes meeting very stringent requirements imposed by optical interferometry. To give a few examples: i) after being relocated to a new position, the telescope is repositioned to a precision better than one tenth of a millimetre, ii) the image of the star is stabilized to better than thirty milli-arcsec, iii) the path followed by the light inside the telescope after reflections on eleven mirrors is stable to better than a few nanometers. These telescopes are technological marvels weighting 33 tons, with very compact composite enclosures, complete with all necessary electronics, an air-conditioning system and cooling liquid for thermal control, compressed air for enclosure seals, a hydraulic plant for opening the dome shells, etc. Each AT is also fitted with a 'Transporter' that lifts the telescope and relocates it from one station to another in a semi automatic way in about one hour with no more than two operators.

Auxiliary Telescope No. 1 (AT1) was installed on the observatory's platform in January 2004 (see The Messenger 115, page 15). Now, one year later, the second of the four to be delivered, has been integrated into the VLTI (see Figure 1).

After two months of re-assembly and one week of basic verification and alignment on the Auxiliary Telescope No. 2 (AT2), AT1 and AT2 were ready to be coupled around midnight during the night of February 2–3, 2005. The 'search' for fringes could start. It took in fact only five minutes to find the precise position of the Delay Line for which the "First Fringes" could successfully be captured with the VINCI test instrument (see Figure 2). Four nights later this exercise was repeated successfully with the mid-infrared science instrument MIDI.

In parallel, activities in Europe at the company AMOS were proceeding at a good pace. At the time of writing, the extensive acceptance test programme of the third telescope (AT3) has been successfully completed and the telescope is being packed. It will be shipped in mid-June and arrive on Paranal early August 2005. The fourth AT is currently in assembly phase with a delivery in Europe scheduled for early 2006.

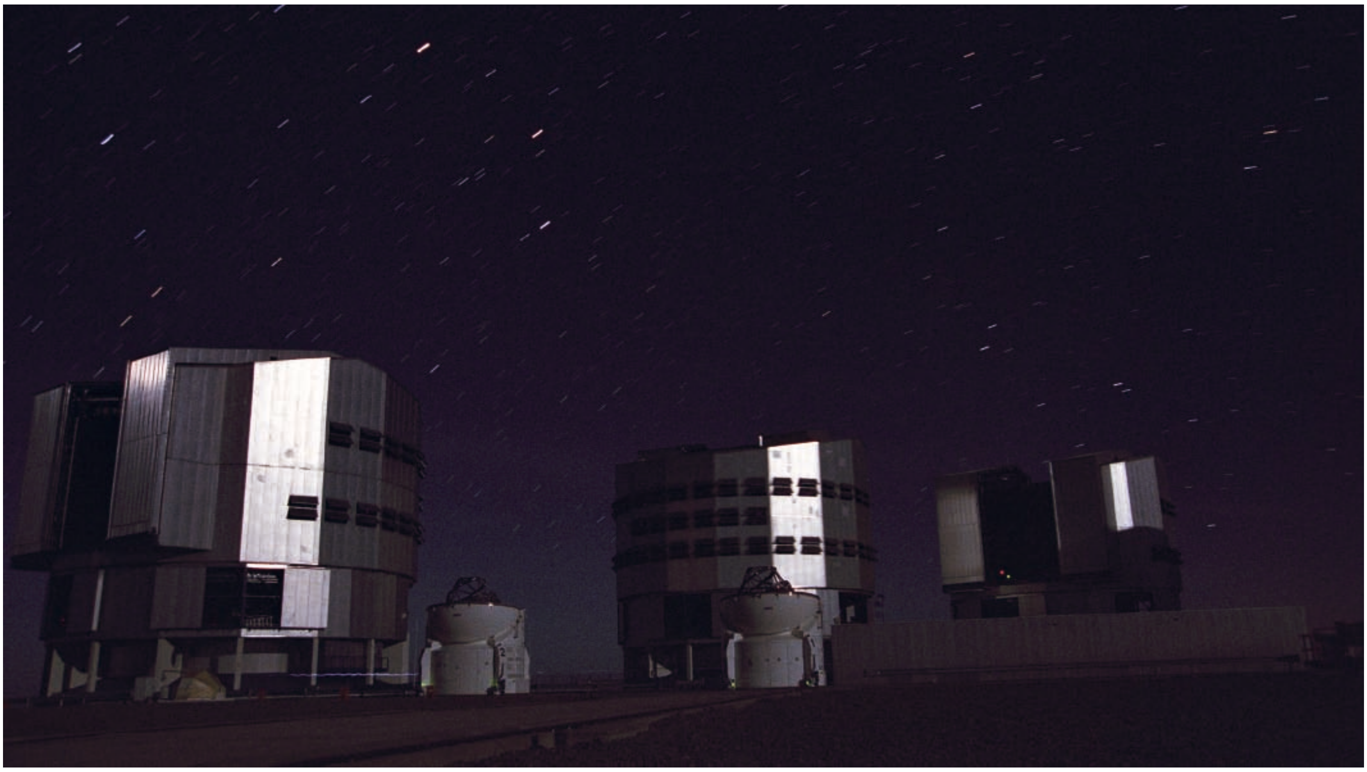


Figure 1: One year after AT1 was installed on Paranal, its brother AT2 (on the left) joins to form the first VLTI baseline with Auxiliary Telescopes. Photo by Frédéric Gonté.

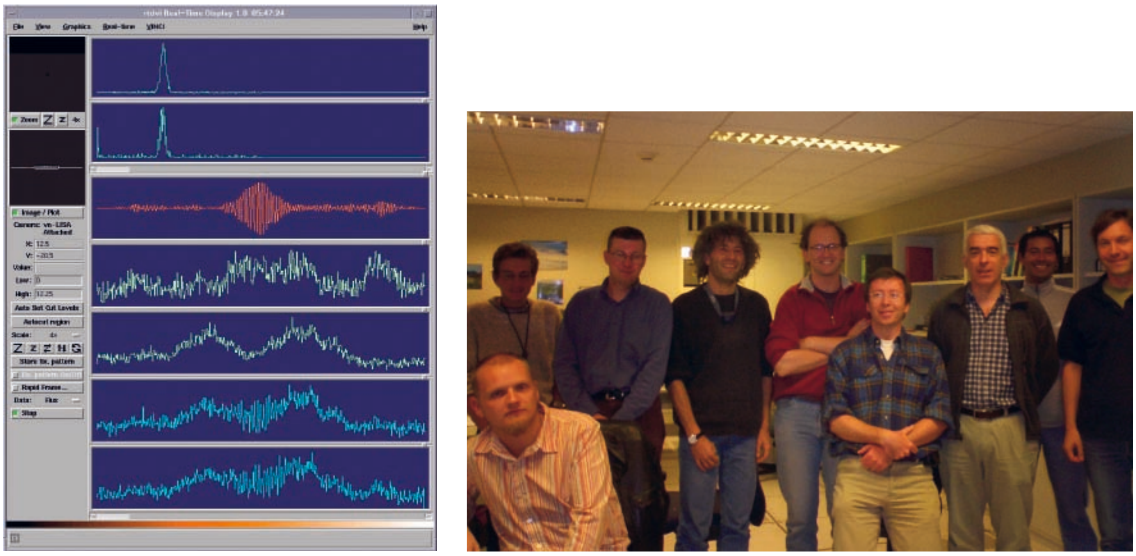


Figure 2: **Left:** The real-time display of the VINCI instrument showing the very first fringes (3rd row) obtained with AT1 and AT2 on February 2–3, 2005. **Right:** The happy team after having obtained the first fringes in the VLTI Control Room on Paranal.

The OPTICON FP6 Programme and ESO

The OPTICON FP6 programme which started at the beginning of 2004 is already playing a large role in coordinating optical and near-IR European astronomy. ESO, a full participant to this endeavour, is reaping very significant benefits for its community, in particular through the development activities aimed at validating enabling technologies for next-generation instrumentation of 8–10 m class telescopes and through a number of "structuring" network activities.

Guy Monnet, ESO

OPTICON stands for Optical Infrared COordination Network for Astronomy. It is part of the sixth Framework Programme (FP6) of the European Commission (EC) and was preceded by a smaller scale version in FP5. It was selected by the EC in the summer of 2003. The EC contribution to the 5-year programme, officially started January 1, 2004, is 19.2 M€ with matching human and financial resources coming from the 47 European groups[1] participating in this endeavour. The coordinating Institute is the University of Cambridge, with Gerry Gilmore as Project Coordinator and John Davies (UK-ATC) as Project Scientist.

The OPTICON high-level goal is the integration of (optical/IR) astronomy across Europe through three interrelated activities, Networking, Transnational Access to medium-size telescopes and critical technological developments through so-called Joint Research Activities. This paper gives an "ESO-centric" view on the programme and its present and future impact on the Organisation. Please consult the OPTICON web pages at *http://www.astro-opticon.org/* for an official view of the whole programme.

OPTICON activities started as planned at the beginning of 2004, albeit rather slowly at first until EC funds finally became available in October. Most activities are currently delayed by a few months only, with quite a number on schedule. Below is a summary of the progress made since the project start, with the emphasis put on developments that directly impact on ESO.

Joint Research Activities (JRA)

JRA1: Adaptive Optics (AO)

The goal of JRA1 is to "develop the concepts, designs and technologies required for the next generation of Adaptive Optics capabilities which will equip 8–10 m telescopes over the next decade". The activity is coordinated by ESO, with in addition INSU/CNRS, INAF-Arcetri, MPIA, NOVA, ONERA, GRANTECAN and University of Durham as participating Institutes.

The programme has fully started with four design studies delivered in 2004: a) two competing feasibility studies of VLT extreme AO systems aimed at Planet finding (LAOG, MPIA, ESO); b) conceptual design of a multi-laser ground layer AO system for MUSE & HAWK-I (ESO, NOVA); c) design of a multi-object wavefront sensor prototype for the LBT (ARCETRI, MPIA) and d) theoretical study of a high-order wavefront sensor (ONERA). A 60-actuator magnetic micro-deformable mirror prototype was also produced and tested at LAOG. Following a 2004 call for tenders, a contract with CILAS (F) was signed end of March 2005 for the delivery of a 1 370 actuators second-generation piezo-deformable mirror (INSU/CNRS, MPIA, ESO). The call for tenders for the mirror drive electronics is being finalized. This type of mirror is essential for the VLT Planet Finder and would also be required for MUSE, should the choice of a stand-alone MUSE AO system be made. A request for information for a 2 k actuators micro-deformable mirror (INSU-LAOG) has also been issued recently.

JRA2: Fast detectors for Adaptive Optics

The goal of JRA2 goal is to "bring together the best European groups and manufacturers working in the field of detectors and initiate new fast detector developments that are required for the future of European telescopes using Adaptive Optics". The activity is coordinated by INSU-CNRS (LAOG), with in addition ESO, IAC and ONERA as participating Institutes.

The programme fully started in 2004 with the detector specifications issued (ESO) and the controller conceptual design completed and reviewed (LAOG). Following a 2004 call for tenders, E2V (UK) has been selected for the development of the 240 × 240 pixels CCD detector for wavefront sensing based on L3CCD technology. The contract has been signed and development of a prototype controller has been launched by LAM for the testing of the chip.

JRA3: Fast readout High-Performance Detectors

The goal of JRA3 is to "investigate the scientific applications and technological challenges required to develop new high-speed detectors for applications in astronomical research and define, fabricate and fully characterize a high-speed low-noise detector for Adaptive Optics applications having high sensitivity". The activity is coordinated by UCAM, with in addition PPARC, ESO, MPG, NOTSA, NUIG, LSW, UFSD and Warwick as participating Institutes.

The programme fully started in 2004 with Preliminary Design Reviews of all relevant technologies (LSW), of fast controllers (UCAM) and of a camera head (PPARC). A test report on the L3-CCD has also been issued. Definition of a test sensor based on PN-chips with high 1 micron QE was completed in early 2005 and an offer was received.

JRA4: Integrating Interferometry in mainstream Astronomy

The goal of JRA4 is to "Develop tools that will enable a larger number of astronomers without specialized technical knowledge to use interferometers for their research and the growth of the interferometric community in Europe". The activity is coordinated by INSU/CNRS (LAOG), with in addition UCAM-CAV, INAF, MPIA, MPIfr, ULg, Konkoli Observatory, ONERA, CAUP,

[1] The list of participating entities, including their short names, can be found at: *http://www.astro-opticon.org/OPTICON_participants_table.pdf*

TECHNION, NCU/UMK, UNIGE, OO and UNIVIE as participating Institutes.

One major activity directly related to ESO has been the development of seven parallel concept studies (PRIMA faint object, IFSPEC, APRESMIDI, VITRUV, VIDA, Bulk Optic, DARWIN homothetic mapper) for potential second-generation VLTI instruments that were presented at the April ESO/EII Workshop. The co-phasing and fringe-tracking development and the advanced software needed to facilitate the use of modern interferometric facilities by general users have progressed well: they are directed towards both the VLTI and the LBT.

JRA5: Smart Focal Planes

The goal of JRA5 is to "develop technologies for Integral Field and Multi-Object Spectroscopy and Imaging, including technology road-mapping to establish the most promising avenues and links with industries and research organizations". The activity is coordinated by PPARC (UK-ATC), with in addition UCAM-IoA, CSEM, CRAL, LAM, IAC, INAF-Padua, ASTRON, Universität Bremen, University of Durham, Reflex, TNO/TPD and AAT Board as participating Institutes or Industries.

The programme fully started in 2004 with a first draft of the technology roadmap (UK-ATC), the beam manipulator technology (for KMOS) chosen (UK-ATC) and a review of European micro-technology capabilities for MOEM based smart slit masks completed (LAM). In the first months of 2005, the Image slicer activity is advancing rapidly, in particular with the development of slicer galvanic (Padua) and optical (Reflex sro) replication techniques. Beam Manipulators are being studied with Starbug prototypes tested at AAO and innovative field selection concepts explored at LAM. Studies of Fiber Systems (UCAM-IoA) and reconfigurable slits/masks (CSEM, IAC & ASTRON) are also progressing.

JRA6: Volume Phase Holographic Gratings

The goal of JRA6 is to "address the current difficulties with Volume Phase Holographic Gratings which prevent their full exploitation in astronomical instrumentation and promote the role of the European institutions and industries in the development of these novel devices". The activity is coordinated by INAF-Brera, with in addition ESO, IAC, ULg (ATHOL) and POLIMI as participating Institutes.

The programme fully started in 2004 with a) preparation for the fabrication and testing of cryogenic IR-VPHG prototypes; b) a high-contrast polymer selected and characterized to be used for polymer-based VPHG and c) preliminary design of new VPHG-based concepts (high-resolution spectrograph and tunable filter) and set-up of a dedicated laboratory at Brera Observatory for extensive testing of the concepts. In addition, the characteristics of a prototype UV-VPHG have been defined and its substrate procured. The objective is to test it as an upgraded UVES cross-disperser on the VLT.

OPTICON

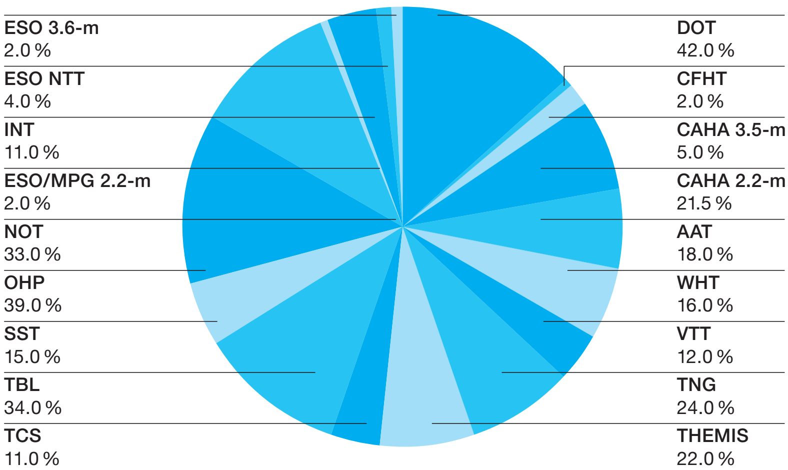
Trans-National Access Programme

This programme involves access to 18 medium-size telescopes, including the ESO 3.6-m and NTT, and the ESO/MPG 2.2-m. The Trans-National Access Office has been established at IAC-Canaries. The programme has been widely advertised by both the Office and the other participants. The total access provided in 2004 has been 313.5 days/nights or 21.7 % of the total to be given under the five-year programme. Telescope distribution is given in the pie chart. It is rather uneven, with 37 % of the total coming from only three telescopes (DOT at ORM, OHP 1.93-m and Pic du Midi 2-m TBL). ESO's part is in particular very small, with eight nights only attributed under the programme in 2004. The bar chart shows the distribution by country of the principal investigator home institution. Special efforts are being made in 2005 by the Access Office and the Telescope Director's Forum to enhance the participation of users from Central and Eastern Europe and of users from countries with no similar research infrastructures.

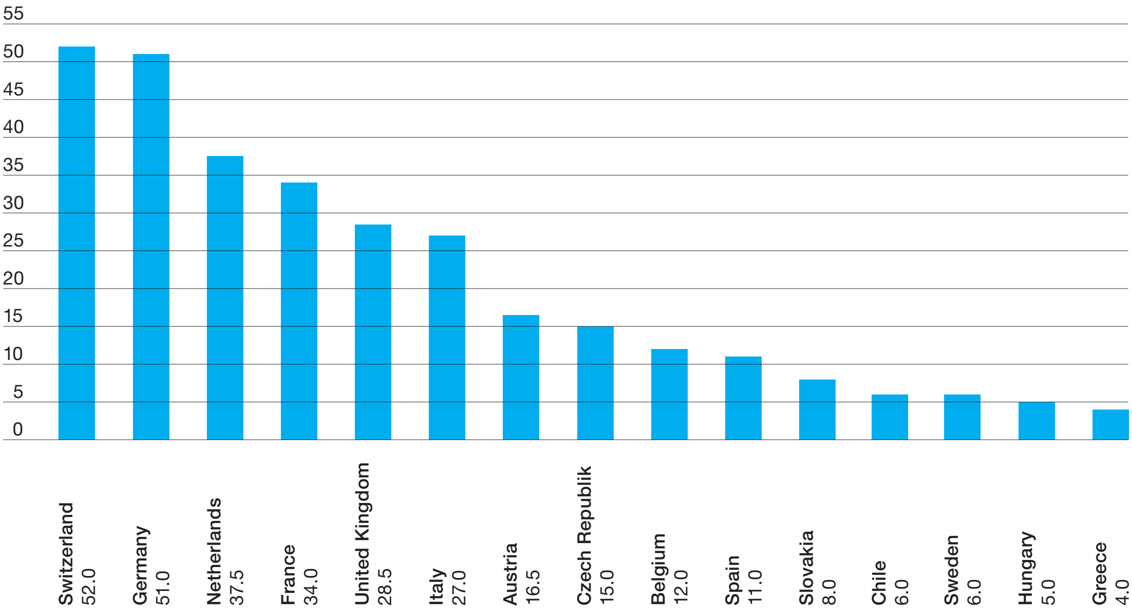
Networking Activities

Networking Activities have all started. Here are some highlights:

– NA1: OPTICON Management. OPTICON web pages have been set according to a common standard. URL is *http://www.astro-opticon.org/meetings.html.*
– NA2: Coordination and Integration of ENO facilities. Many activities related to site characterization of the Canary Islands' Observatories have been carried out with coordination of night-time seeing measurements with DIMMs, of day-time measurements at Teide Observatory and preparation for the installation of an Automatic Weather Station to obtain meteorological, dust content and extinction data.
– NA3: Structuring European Astronomy. The critically needed ELT science case has progressed considerably, with an international meeting at Berlin in May 2004 and an OPTICON meeting at Florence in November 2004. The "final" document will be available by July with a "glossy" summary already accessible from the OPTICON web site. The key technology sub-network has defined an initial technology roadmap based on three high-priority ELT instruments (high contrast imager for planet finding; multi-imaging patrol field imager for Virgo stars; multi-object integral field spectrograph for high-z galaxies).
– NA4: Mechanisms for synergy in space-ground coordination. Coordinators have been identified in all major European large astronomical infrastructures and a number of Laboratory test facilities (space or



Total amount of access per telescope from January 1, 2004 to December 31, 2004.



Amount of access per principal investigator home institution from January 1, 2004 to December 31, 2004.

ground based). Full start of the definition of synergic mechanisms is foreseen in 2005.

– NA5: Interferometry Forum. The European Interferometric Initiative (EII) has been developed (*www.strw.leidenuniv.nl/~eurinterf*). The Fizeau visitors exchange programme is very active with visitors from the Czech Republic, Israel, Poland and Hungary received in respectively French, Italian, Dutch and German laboratories. A workshop on next-generation interferometric infrastructure was held on August 23–26 in Liège.
– NA6: OPTICON Telescope Network. This includes the Telescope Directors Forum, the Operation of the Trans-National Office which administers the OPTICON Access programme on medium-size telescopes (see previous Chapter) and an activity to enhance practical research experience, particularly with respect to observing protocols. Last July, a school with 20 participants demonstrated successful use of ground and space archival data at ESO/ST-ECF.

Conclusion

The OPTICON programme is proving as an essential tool for European Astronomy. Particularly important for ESO in view of its mandate are 1) the development of key technological concepts and components (Adaptive Optics, fast detectors, Interferometric instrument concepts, smart focal plane components, high-efficiency dispersers) for second-generation VLT/VLTI instruments and as a step towards future ELT instrumentation; 2) the networks aiming at bringing together key astrophysical activities in Europe, with the Interferometric Forum and the development of the ELT science case by the community of prime importance for ESO, and 3) the OPTICON Telescope Network as a tool for better inter-observatory coordination of observing time, even if its impact on ESO is currently small. ESO is now involved in several other structuring programmes supported by the EC, like RadioNet – the OPTICON sister programme for radio astronomy, the ELT Design Study, the VO-TECH European Virtual Observatory Technical Centre, and soon ASTRONET, the strategic planning exercise for European Astronomy. Within that complex web, the European astrophysical community is being put together to define and impulse the major science goals and infrastructure developments for the next decades, including the ones that will ultimately be implemented by ESO.

ESO Science Archive has been opened to the world-wide community in April 2005. The current total archive holding is now about 50 TB.

The VLT Survey Telescope: A Status Report

The VLT Survey Telescope (VST) is now a few months from its completion. This paper briefly reviews the project, accounts for its current status, anticipates the calendar of future milestones up to first light, and lists the scientific programmes for the observing time guaranteed to the OAC by ESO for procurement of the telescope.

Massimo Capaccioli[1,2], Dario Mancini[2], Giorgio Sedmak[3]

[1]Department of Physical Sciences, University of Naples "Federico II", Naples, Italy
[2]INAF – Capodimonte Astronomical Observatory, Naples, Italy
[3]Department of Astronomy, University of Trieste, Trieste, Italy

The VLT Survey Telescope (VST; Capaccioli et al. 2003a,b) is a 2.61-m diameter imaging telescope conceived for the Paranal Observatory to support the VLT through its wide-field capabilities and to perform stand-alone survey projects. It features a f/5.5 modified Ritchey-Chretien optical layout, a two-lens wide-field corrector, with the dewar window acting as a third lens and an optional atmospheric dispersion compensator, an active primary mirror, a double-hexapod driven secondary mirror, and an alt-azimuth mounting. It will operate from the UV- to the *I*-band, preserving, within a corrected field of view of 1° × 1°, the excellent seeing conditions achievable at the Cerro Paranal site. The telescope will be equipped with just one focal plane instrument, OmegaCAM, a large-format (16 k × 16 k pixels) CCD camera built by an international consortium of the same name. Fruit of a joint venture between ESO and the Capodimonte Astronomical Observatory (OAC) of Naples, now research centre of the newly established Italian National Institute for Astrophysics (INAF), the VST (Figure 1a + 1b) is expected to become operational at Paranal in the spring of 2006.

A Bit Of History

The opportunity to undertake a major scientific and technological venture was offered to OAC by the assignment of an unexpectedly substantial grant in the framework of resources reserved by the Italian Government to promote southern regions. Such funds had been previously solicited to further develop the observing station implemented at Toppo di Castelgrande with a 1.5-m alt-azimuthal telescope (TT1). In 1996 the OAC director set a commission of experts with the task of updating the programme with ideas for a > 5 Mega-Euros observing facility, leading in science and capable of boosting the growth of the OAC community. A constraint to be duly considered was the *una tantum* nature of the grant, which strongly suggested that it would not support a regular flow of resources for operations and maintenance.

As a result, in July 1997 the Capodimonte Observatory was able to present to ESO a scientific and technical proposal envisaging the design, construction, and installation at the Cerro Paranal Observatory, of a new technology telescope with a medium aperture, specialized in, and entirely devoted to wide-field (WF) imaging at optical and infrared wavelengths. The goal was to ensure, by this instrument, its camera and the seeing qualities of the Paranal site, a more than tenfold increase in the scientific output with respect to the combination of the ESO/MPG 2.2-m reflector with WFI. Named VST for VLT Survey Telescope, the instrument was intended to complement the VLT with wide-angle imaging for the detection and pre-characterisation of sources to be further observed with the larger telescopes, but it was also meant for non-VLT related stand-alone survey programmes.

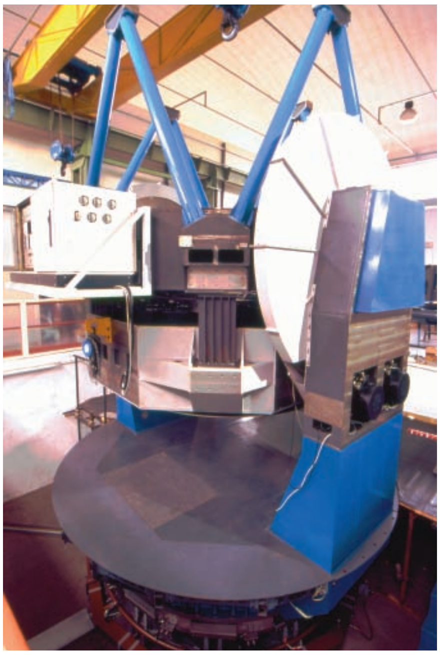


Figure 1a: The VST mounted up to the top ring, in the assembly area at Scafati (Naples).

Figure 1b: The VST top ring with the M2 cell.

The principles of the VST project were accepted by ESO a year later (Arnaboldi et al. 1998). A Memorandum of Understanding (MoU) between ESO and OAC, subscribed in June 1998, assigned to the Neapolitan observatory the procurement of the telescope, and to ESO the realization of the enclosure and the responsibility for operations and maintenance of the instrument for a minimum of 10 years. In return of its contribution, OAC was entitled to receive a share of the total VST observing time (GTO) of the order of 15–20 % (to be re-evaluated at the end of construction on the ground of the actual costs of the various components of the project), and a number of hours at one VLT UT equivalent to 50 observing nights distributed over time, with a maximum of 6 in one semester.

At its conception, the telescope was planned to support at most two instruments: a CCD camera for the optical domain (first priority), and a second camera for the non-thermal infrared domain. Technological and budget limitations, together with the appearance of another WF telescope (VISTA), led to specializing VST to the wavelength range from UV to I. The design and manufacturing of the optical camera (OmegaCAM), with a mosaic of 32 CCDs for a total of 256 Mpixels mapping the field of view of VST at a scale of 0.21 arcsec per 15 µm pixel, was contracted by a European consortium which includes the Netherlands, Germany, Italy, and ESO. The MoU was signed in January 2000.

The performance of the VST/OmegaCAM system, computed with reference to the properties of the optical components and of the CCD camera, is expected to exceed 50 % efficiency across the whole spectral range from UV- to *I*-bands. A conservative estimate of the signal-to-noise ratio of the VST system on point sources observed in 5 bands with 30 minutes exposure time gives a limiting value of ~ 26 AB mag/arcsec^2 (Figure 2).

The expected data rate for the scientific projects of the Capodimonte GTO will be nearly 5 TB/year of non-compressed data. This flow raises the need of suitable HW/SW facilities. The hardware endowment at OAC consists of two Beowulf clusters: one is made of 17 dual Opteron CPU servers, to be used for data reduction; the second is a set of 10 dual Pentium servers that will be dedicated to data analysis. Concerning the management of the VST data, software to archive fits files which uses http as transport protocol has been developed along with the *fitshdr* package, a tool for fits header manipulation. The hardware for the massive data storage will be acquired in time for the start of VST operations.

Since the beginning of the VST project, in order to adjust to the logic of surveys and to create the needed expertise, the OAC team started gathering know-how on the processing of wide-field images. This has been done through the involvement in several national and international dedicated projects which led to the following main results:

- the completion of the OAC Deep Field (OACDF), a multi-band pilot survey over 0.5 square deg conducted with the ESO/MPG 2.2-m WFI camera in cooperation with the observatories of Bologna, Padua, and Rome (Alcalà et al. 2004);
- the creation of astrometric and photometric software tools in the context of a collaboration with TERAPIX at the Institut d'Astrophysique de Paris (Radovich et al. 2004). A porting to C++ of these tools, which were initially developed in PERL, is now in progress;
- the participation within the ASTRO-WISE consortium, an EU project funded through the FP5 RTD programme. In this framework, a first version of a pipeline for the processing of wide-field images has been released. In the same context OAC is developing a tool for photometric variability, which will be mainly used for SN searches, stellar variability studies, and discovery of exoplanets.

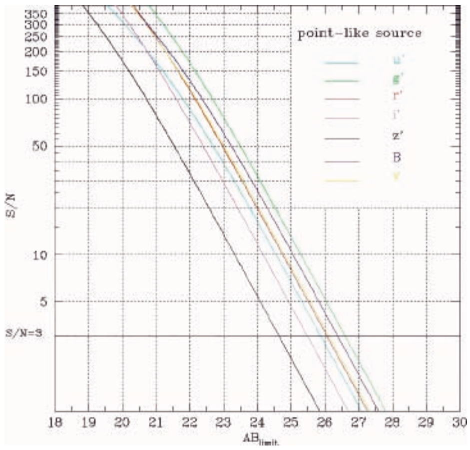


Figure 2: Example of the VST performances on stellar sources (exposure time = 30 min, seeing = 1″, airmass = 1, and no moon). The calculator is available at the address: *http://www.na.astro.it/~rifatto/vst/vocet_2.htm*.

Design

The design of the VST has been the responsibility of the Technology Working Group (TWG) of OAC in coordination with ESO for the validation of consistency to the VLT standards (Mancini et al. 2000). The project strategy was defined in order to guarantee the optimization of the whole system in terms of mechanical design and optical interfacing by the use of finite element analysis and computer modelling. The mechanical design is driven by the positioning accuracy and stability required by the optical design of each element for each optical configuration, considering the detector and its optical elements as a part of the telescope, and so improving the integrated system design. The VST basic specifications are summarized in Table 1 and the expected operational image budget is reported in Table 2 (next page). The VST enclosure at Paranal Observatory has been realized by ESO as a facility integrated into the VLT system (Figure 3, next page).

The VST optics were procured through a contract with Carl Zeiss Jena GmbH, with the Russian firm LZOS JSC as subcontractor. The primary (M1) and secondary (M2) mirrors are made from Sitall, an optical glass produced by LZOS JSC and similar to Zerodur. The lenses for the WF correctors are of fused silica produced by Schott (Figure 4, next page). The prismatic lenses for the atmospheric dispersion corrector (ADC) are made from special glasses, also by Schott. In 2002 the primary mirror was destroyed in an accident during shipment from Europe to Chile. This enforced a series of emergency actions to resolve the problem with minimum impact on the final VST schedule. The new

Table 1: VST telescope basic specifications

Telescope aperture	2 610 mm	
Image scale	0.214 arcsec/pixel	
Pixel reference size	15 µm	
Unvignetted field of view	1.47° diagonal, 1° × 1° square format	
Detector	16 k × 16 k pixels CCD mosaic	
M1+M2 EE (80 %)	< 0.3 arcsec (basic)	
M1+M2 EE (80 %)	< 0.15 arcsec (intrinsic)	
Image quality (EE)	required	80% within 2 × 2 pix at z = 0°
	two-lens corrector (worst case)	80% in 1.7 pix at z = 0°
	ADC + one-lens corrector (worst case)	80% in 1.9 pix at z = 0° 80% in 2 pix at z = 50° 80% in 3 pix at z = 70°
Ghost sky concentration	0.0004	

Table 2: VST image budget

	EE (80 %)	worst case
Two-lens wide-field corrector	$z = 0°$	$z = 50°$
no wind, no seeing	2.0 pix	n.a.
wind 6 m/s, seeing 0.4″	3.2 pix	n.a.
wind 12 m/s, seeing 0.4″	3.7 pix	n.a.
ADC + one-lens wide-field corrector	$z = 0°$	$z = 50°$
no wind, no seeing	2.1 pix	2.4 pix
wind 6 m/s, seeing 0.4″	3.3 pix	3.5 pix
wind 12 m/s, seeing 0.4″	3.8 pix	4.1 pix

contract with the LZOS JSC envisages the supply of the replica mirror at the end of August of 2005. It is expected that the new M1 shall maintain the outstanding quality figures measured on the original mirror. M2 was also slightly damaged during transportation to Chile, and has been returned to LZOS JSC for repair.

The VST is optimized for seeing-limited spatial resolution over a field of view of 1° × 1° matched to a 16 k × 16 k pixels CCD mosaic camera. It operates two different correctors: the first, consisting of two lenses, works in the range from 320 nm to 1 014 nm for observations at small zenithal distances; the second, composed of a rotating ADC coupled to one lens only, operates in the same wavelength range but to an elevation of 30° (Figure 5). A mechanical switching unit allows the appropriate corrector to be selected.

An active-optics system controls the shape of the primary mirror and the position of the secondary. M1 is supported by 84 axial actuators distributed on four rings of 12, 18, 24, and 30 elements (with a force resolution of 1 N), and by 24 radial actuators (5 N resolution) (Figure 6). The M2 position is controlled by a double-stage system, a classical hexapod and a piezo-based fine positioning device, capable of a tilt resolution of 10^{-3} arcsec and a linear resolution of ~ 1.2 nm. They allow the control system to preset and track the position of M2 in advance of and during the scientific exposure. The major aberrations corrected by the active-optics system include defocus, coma, spherical, astigmatism, quad-astigmatism, and tri-coma. The wave-front analysis is obtained by a Shack-Hartmann unit included in the probe, sensitive enough to work on guide stars of 14 mag for integration times of ~ 30s. Given the number of active systems on board of VST and the compactness of the telescope, distributed intelligence solutions have been implemented through the design and realization of embedded controllers connected to the high level control system through a CAN BUS solution.

The VST design follows the concepts used by ESO for the VLT: maximization of general reliability in terms of quality and continuity of the telescope service. It is also compliant to the VLT standards for integration at Paranal and service. The telescope azimuth and elevation axes are controlled by four pre-

Figure 3: The VST dome at Paranal, in between the VLT domes and two auxiliary telescopes.

Figure 4: One of the VST corrector lenses inspected at LZOS JSC.

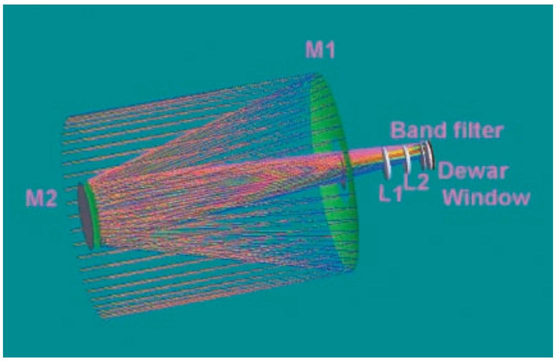


Figure 5: VST optical design.

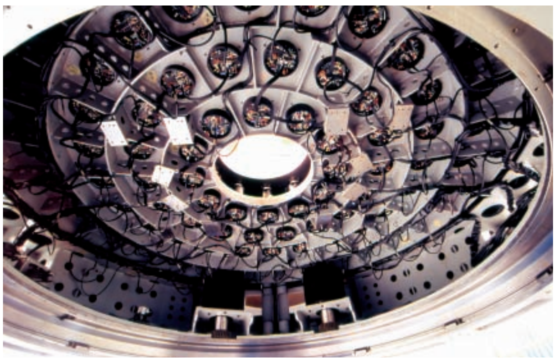


Figure 6: M1 cell seen from the back, showing the four rings of axial actuators.

loaded brushless motors per axis, driven in pairs by means of an adaptive software algorithm in order to minimize losses, consumption and improve redundancy. The azimuth axis is supported by a 12-pad hydrostatic system able to guarantee a tilt stiffness of ~ 20 GN/m. The system design allows the rapid removal of a pad for maintenance, without blocking the telescope rotation, if needed. The tracking performance of each telescope axis is expected to be better than 0.05 arcsec rms (Figures 7a and 7b).

The realization of the VST started in 1998 with the signing of the MoU with ESO. The facility was scheduled to be operational at the end of 2003, but the growing complexity of the telescope design, together with the consequences on the manufacturing activities due to the accident that occurred to M1 in 2002, have caused the date of completion of the project to shift by about two and a half years.

At the time of writing, extensive inspections and tests are being performed on all subsystems in parallel to the final improvements of some devices or functions. These will be completed in the next two months in order to be ready for a full system characterization and telescope alignment verification in the workshop following the contents of the provisional error budget table.

The telescope is expected to soon enter the preliminary acceptance procedure and hopefully move to Chile within the third trimester of 2005 in order to be assembled at Paranal by the end of the year.

The GTO Surveys

The areas of astrophysics and cosmology which may take advantage of the VST/OmegaCAM potential (Arnaboldi et al. 1999) include, just as examples: Solar System bodies, extrasolar planets, Galactic sources, nearby galaxies, extragalactic and intra-cluster PNs, faint objects surveys and micro-lensing events, medium redshift supernovae, the cosmic distance scale, cosmic structures at medium-high redshift, AGNs and quasars, degenerate objects. It goes without saying that, extrapolating from previous surveys, a major outcome is expected in form of serendipitous discoveries.

A set of survey projects (CAOS = Capodimonte Observatory Surveys) has been designed for the OAC GTO.

1. STRANO: Search for TRAns Neptunian Objects

Kuiper Belt Objects (KBOs) and Centaurs are believed to be remnant planetesimals from the formation of the Solar System and to be composed of the oldest, almost untouched materials. Their cumulative luminosity distribution reflects the size and mass distribution of the matter in the outer solar nebula, and carries information on the conditions in which this region grew and evolved. Only a

OmegaCAM: The VST Camera

Enrico Cappellaro
INAF – Capodimonte Astronomical Observatory, Naples, Italy

OmegaCAM is the large-format CCD pixels imaging camera that has been designed to exploit the square degree field of view of the VST while sampling the excellent seeing of Paranal (Kuijken et al. 2002, The Messenger 110, 15). The instrument is built by a consortium which comprises institutes in the Netherlands, Germany and Italy, and is headed by PI Konrad Kuijken (Groningen and Leiden University) with co-PI's Ralf Bender (Munich USM/MPE) and Enrico Cappellaro (INAF Naples), and project management by Bernhard Muschielok and Reinhold Häfner (USM). The Optical Detector Team at ESO has designed and built the detector system.

The CCD mosaic is the heart of OmegaCAM. It consists of a 'science array' of 32 thinned, low-noise ($5e^-$) 2 k × 4 k e2v devices, for a total count of 16 384 × 16 384 pixels. The scale is 0.21 arcsec per 15 µm pixel. Around the science array lie four 'auxiliary CCDs', of the same format. Two of these are used for guiding, and the other two for online image analysis. Readout of the full mosaic takes 45 s, and is accomplished by two FIERA controllers (a third FIERA takes care of the auxiliary CCDs).

Two magazines located on either side of the focal plane can store up to 12 filters. The primary filter set of OmegaCAM will be that of the Sloan u′, g′, r′, i′ and z′ filters. In addition, there will be Johnson B- and V-filters, a Stromgren v-filter, an Hα-filter consisting of 4 segments with redshifts of up to 10 000 km/sec, and a segmented *ugri* filter for efficient photometric monitoring of the sky.

The OmegaCAM manufacturing phase has just been completed. The CCDs have been delivered, tested and integrated into a working detector system; the mechanics has been integrated and the instrument control and data analysis software is coded. At the time of writing, extensive tests are being performed in the ESO workshop in Garching. These will be completed in early summer, and it will be soon ready for shipping to Paranal.

OmegaCAM is funded by grants from the Dutch Organization for Research in Astronomy (NOVA), the German Federal Ministry of Education, Science, Research and Technology and the Italian Istituto Nazionale di Astrofisica (INAF).

Figure 7a: The 12 pads of the VST hydrostatic support system.

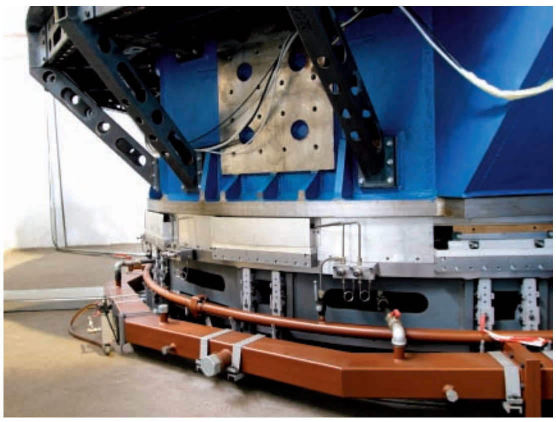


Figure 7b: Details of the hydrostatic system.

small part of the ecliptic has been explored so far. The project STRANO, carried out by INAF (Naples) with the University "Parthenope", plans a search of such "Slow Moving Objects" by a monochromatic survey of ~ 50 sq. degrees along the ecliptic. The goal is to discover ~ 200 new objects, doubling the existing samples.

2. OmegaTranS: OmegaCAM Transit Survey

This is a joint project of INAF (Naples, Padua) with MPIE (Garching) and Leiden Observatory, aimed at searching for extrasolar planet transits. Each of the three countries involved will provide one week/yr of bright GTO, possibly over several years. Targets are stars in the magnitude range 13.5 < R < 17.0, in five fields of the southern part of the Galactic disc. OmegaTranS will advance over the OGLE-III transit survey, which is arguably the most successful to date, by more than one order of magnitude. In the first year the survey will be sensitive to short-period planets, and eventually to planets with orbital periods of hundreds of days.

3. VISPO: VST Imaging Survey for Pre-main Sequence Objects, probing the low-mass end of the IMF in different environments

The goal of this collaboration between INAF (Naples, Catania, Palermo, Florence) and ESO is to investigate the IMF at very low-mass and sub-stellar regimes in outlying "cometary clouds" of Orion, where star formation may have been triggered by the strong impact of massive stars, in order to characterize the pre-Main-Sequence populations in very different environmental conditions. The sensitivity and area covered by the survey should also make it possible to single out young free-floating planetary-mass objects. The project requires 54 hours of grey-bright VST time to cover 15 sq. degrees in 3 broad bands + Hα, and ~ 30 hours of VLT for a spectroscopic follow-up of selected candidates.

4. STREGA: Structure and Evolution of the Galaxy

This multipurpose programme, coordinated with a LBT Science Verification Pilot Project, looks for the signatures of the tidal interaction with the Galactic halo of the Fornax and Sculptor galaxies, and of the globular clusters Pal 3 and Pal 12, by surveying RR Lyrae and turn-off stars in the southern part of the Fornax stream (~ 150 sq. deg. and ~ 60 VST nights). With some additional exposures, the STREGA data will be used also to: i. investigate disc and halo WDs at increasing Galactic latitudes; ii. constrain the evolution of the disc binary population; iii. clarify the nature of halo interacting binaries; iv. create a database for Galactic star counts. Follow-up observations are foreseen at the VLT (10 nights) for radial velocities and metal abundances, and at the VST itself for proper-motion measurements. The collaboration comprises INAF (Naples, Rome, Teramo), the Universities of Naples, Pisa, and Padua, ESO and CIDA.

5. STEP: The SMC in Time. Evolution of a Prototype Interacting Dwarf Galaxy

This investigation of the SMC body and of the bridge (towards the LMC) down to the turn-off of the oldest stars, carried out by INAF (Naples, Bologna, Teramo) with STScI and the Wisconsin and Basel Universities, and coordinated with complementary observing runs at the HST and VLT, consists of: 1. a deeper survey (35 sq. deg., V ~ 24.5, S/N = 10) designed to trace the star formation history of the SMC and of its stellar cluster component; 2. a shallower survey (30 sq. deg., V ~ 19.5, S/N = 100) to build homogeneous CM diagrams of the SMC wing and bridge and of most of the hosted clusters. The total request is 169 hours of VST grey-bright time, and 38 hours of VLT for spectroscopy.

6. VESUVIO: VST/OmegaCAM Exploration of Superclusters, Voids, and Intermediate Objects

This project is to understand the role of environment in galaxy evolution by the study of the detailed properties (magnitudes, colours, structure, internal distribution of stellar populations, and SFRs) of objects of all morphological types in the whole range of cosmic environment. A 100 sq. deg. region in the southern concentration of the Horologium-Reticulum supercluster, and a 10 sq. deg. spot in the Hercules supercluster, will be surveyed in 5 broad-bands to an average depth. The programme, which requires 120 VST nights + 40 nights at VLT-VIMOS, will be carried out by an international collaboration led by INAF-OAC and the Kapteyn Institute, which includes INAF (Catania,Teramo), the Universities of Naples, Athens, Innsbruck, North Carolina, and Tasmania, MPIE (Munich), and SRON (Utrecht).

7. VST-16

This deep survey of a total area of ~ 20 sq. degrees in 5 broad bands plus 11 medium bands, parallel to COMBO-17, is meant to provide photometric redshifts for over one million galaxies at $0.2 < z < 1.2$, some 10 000 galaxies at $1.2 < z < 2.5$, and ~ 10 000 quasars at $0.5 < z < 6$. Science goals include QSO evolution up to $z \sim 6$, galaxy evolution in relation to the environment, DM distribution, and large-scale structure. Part of the VST-16 survey fields will be chosen to coincide with those observed also by IR and X-ray surveys. At present, 65 nights of GTO (40 from OAC and 25 from the OmegaCAM Consortium) are planned for the VST-16 project, which is led by INAF-OAC, the Munich Observatory and MPIA (Heidelberg).

8. SUDARE @ VST: Supernova Rate Evolution at the VST

This project is to gauge the evolution of the rates of the different SN types in the range $0.3 < z < 0.8$, still poorly known despite the interest of high-z SNe for cosmology. To this aim the frequent monitoring of 1 sq. degree will be carried out for a period of 3 years, which should lead to an estimated discovery and accurate photometric characterization of a sample of 100-200 SNe. Real-time data processing and analysis is contemplated to allow for spectroscopic follow-up at the VLT. The time required for this survey is 80 h/yr, half of which comes out of the OAC GTO and the remaining out of the OmegaCAM GTO. The project is a collaboration between INAF (Naples, Padua, Teramo) and ESO.

Acknowledgements

The proposal, study, design, and realization of the VST telescope are the result of the joint efforts of a number of persons who are acknowledged here. In particular: the members of the scientific steering committee for the VST proposal, Magda Arnaboldi, Jacques Boulesteix, Kenneth C. Freeman, Loretta Gregorini, Angela Iovino, Giuseppe Longo, Tommaso Maccacaro, Yannick Mellier, Georges Meylan, Giampaolo Piotto, Roberto Scaramella, and Giampaolo Vettolani (chairman); the ESO representatives and major consultants for the project, Bernard Delabre, Philippe Dierickx, Sandro D'Odorico, Roberto Gilmozzi, Franz Koch, Richard Kurz, Lothar Noethe, Alvio Renzini, Jason Spyromilio, Roberto Tamai, and Massimo Tarenghi; for the optics, Piero Rafanelli.

Besides the authors of this paper, the VST design, assembly, and management was the responsibility of (alphabetical order): Ciro Belfiore, Massimo Brescia, Oreste Caputi, Giancarmine Castiello, Mariano Concilio, Fausto Cortecchia, Gennato Cretella, Sergio D'Orsi, Luigi Ferragina, Debora Ferruzzi, Davide Fierro, Valentina Fiume Garelli, Riccardo Leto, Guido Mancini, Gabriella Marra, Laurent Marty, Germana Mazzola, Pierluigi Mavar, Cesare Molfese, Claudio Parrella, Leopoldo Parisi, Lorenzo Pellone, Francesco Perrotta, Vincenzo Porzio, Emilio Rossi, Fabrizio Rovedi, Maria Grazia Russo, Riccardo Russo, Pietro Schipani, Giovanni Sciarretta, Gianfranco Spirito, Annalisa Terracina, and Michele Valentino.

The Italian Ministry of University and Research (MIUR), the Italian National Consortium for Astronomy and Astrophysics (CNAA), the Regione Campania, INAF, and ESO, are acknowledged for their support.

References

Arnaboldi M., Capaccioli M., Mancini D. et al. 1998, The Messenger 93, 30
Arnaboldi M., Capaccioli M., Mancini D. et al. 1999, "Wide Field Surveys in Cosmology", XIV IAP Symp., Colombi, Mellier & Raban (eds.), Edition Frontières, 343
Alcalà J. M., Pannella M., Puddu, E. et al. 2004 A&A 428, 339
Capaccioli M., Mancini D., Sedmak G. 2003a, Mem. SAIt 74, 450
Capaccioli M., Cappellaro E., Mancini D., Sedmak G., 2003b, Mem. SAIt Suppl. 3, 286
Radovich, M., Arnaboldi, M., Ripepi, V. et al. 2004, A&A 417, 51
Mancini D., Sedmak G., Brescia M. et al. 2000, SPIE-ESO Conf. on Astronomical Telescopes & Instrumentation, SPIE 4004, 79

ALMA News

Tom Wilson, ESO

Science Advisory Committee Report

The European ALMA Science Advisory Committee (ESAC) met on 23 February 2005 at ESO in Garching. On the two following days, the ALMA Science Advisory Committee (ASAC) met. In both meetings the discussions were mostly concerned with a request by the ALMA Board to consider the impact of 'rebaselining' proposals on the science that can be done with ALMA. Much of the need for rebaselining is caused by the large increases in commodity prices, such as those of steel and oil. These have led to large cost increases for ALMA. A number of possible options for savings were proposed.

The most far reaching was to reduce the number of antennas. In the bilateral ALMA project, 64 antennas are specified to achieve the primary science goals: detection in a CO or CI transition of a Milky Way galaxy at redshift $z = 3$, imaging of a protostellar disc in the nearest molecular cloud, and producing high dynamic range, high fidelity images. The effect of changing the number of antennas on these science goals was discussed thoroughly by ESAC and ASAC. The ASAC report concluded that ALMA science is driven by sensitivity and image quality. In integration time, the sensitivity varies as the square of the number of antennas. The image quality also varies as the square of the number of baselines. For a reduction to 50 operating antennas, the increase in integration time needed to reach a given sensitivity is a factor of 1.5, while a reduction to 40 operating antennas would increase the integration time by a factor of 2.3. The committee considered the effect of reducing the number of antennas on the ALMA Design Reference Science Plan (DRSP) (see *http://www.strw.leidenuniv.nl/~alma*). With 50 operating antennas, 20 % of the DRSP proposals would be difficult or impossible to achieve. With 40 operating antennas, 41 % of the DRSP proposals would be difficult or impossible to achieve, that is a substantial impact with only half of the proposals feasible. The conclusion was that an ALMA consisting of 50 antennas would still be a superb instrument while a 40-antenna ALMA would put a large fraction of anticipated programmes at risk. Thus, a 40-antenna ALMA would be qualitatively different, with longer integration times and multiple array configurations required for high-quali-

Sunrise at the Operational Support Facility (OSF) site.

ty images. See *http://www.eso.org/projects/ALMA/newsletter* for excerpts.

The ASAC report was forwarded to the Joint ALMA Office, European ALMA Board, ESO Science and Technical Committee, and ALMA Board for consideration. Presentations of the results were made at the ALMA Board, European ALMA Board and STC.

The European ALMA Regional Center

Each ALMA partner plans to establish an ALMA Regional Center (ARC). In Europe, the ARC will be structured in a distributed manner with a central node based at ESO Headquarters in Garching. This central node will provide a variety of services including user support for proposal preparation, observation preparation, and basic data analysis support.

A number of other services shall be provided by affiliated ARC nodes located at other European institutions. Chief among these services is direct face-to-face help with off-line data reduction. This structure has been approved by the ESAC, the European ALMA Board, the STC and the ESO Council.

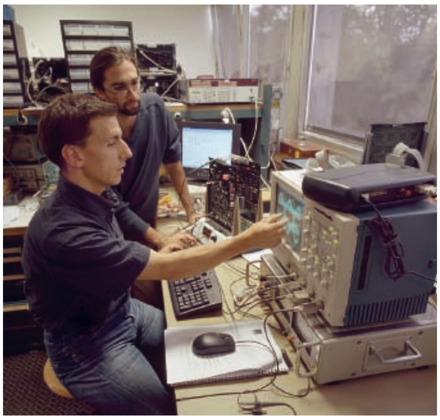
Following approval by the ESO Council, there was a 'Call for Statements of Interest', in order to solicit proposals from organizations interested in providing science support with financing provided by national funding agencies. The deadline for responses was October 2004; there were seven responses from a Bonn-Köln-Bochum consortium, IRAM Grenoble, Bologna representing Italy, Leiden representing the Netherlands, Onsala Space Observatory representing the Nordic countries, and Manchester University representing the UK. Portugal will provide postdoctoral support to another ARC node initially for training, in order to bring expertise back to Lisbon. Other countries have expressed an interest to join nearby nodes. A number of issues were discussed at a face-to-face meeting at ESO in February 2005. The most important are summarized as follows.

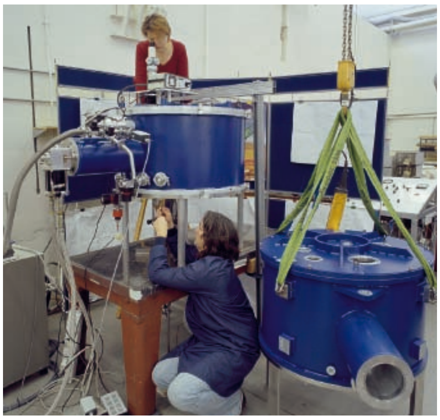
First, all nodes will be open to all European astronomers involved in ALMA data reduction. Second, the most critical short-term tasks for the ARC nodes are the training of students in radio interferometry and the development of expertise with ALMA off-line processing tools based on the AIPS++ package. As soon as ALMA becomes operational, the ARC nodes will also play a very important role in user feedback to the project. The structure of the European ARC has been a point of discussion. This will be governed by an ARC Coordinating Committee (ACC), to be chaired by the ESO ARC Manager (job advertisement on the ESO web site since mid-April). The day-to-day management responsibility remains with the individual ARC nodes, but the ACC will provide strong guidance to the nodes, with a goal of keeping the same competence level, but also encouraging specialization. There were examples of specialization at specific nodes such as imaging at the highest frequencies, polarization, or imaging with extremely high dynamic range and fidelity. In addition to duties as ACC chair, the ARC Manager will be in charge of the ARC activities within the ESO Data Management Division, coordinate ARC activities with Chile-based operations and coordinate with the North America and Japan regional centers. The next step in the European ARC development will be to work out a detailed description of tasks for the ACC, including a determination of the level of commitment from the nodes, fixing the areas of expertise among the nodes and plans for hiring within the nodes. This development shall be the responsibility of the ARC Manager. We anticipate that this person will be in place sometime around 1 October 2005.

The FP6 Proposal for 'ALMA Enhancement'

In 2002, ESAC members were informed of the possibility of additional funding in conjunction with approved construction projects from the EU within Framework Programme 6. The ESAC discussed various options for such a proposal at its June 2003 meeting. The deadline for submitting a proposal, March 5, 2004, was set by the EU in December 2003. After a discussion with the ALMA Director, Massimo Tarenghi, detailed plans were made starting in January 2004. At that time the Japanese contribution had also been clarified. The decision about the choice of receiver band, ALMA Band 5, covering 163 to 211 GHz, was made about this time. The noise temperature of the band is higher than other millimetre bands because of the atmospheric water vapour line at 183 GHz. This line is also present in astronomical sources, and there is an additional line of the 18-O line of water vapour at 203 GHz. The basic argument was that ALMA 'early science' would overlap with the ESA cornerstone mission Herschel. One of the major programmes of the Herschel instruments, HIFI, is to measure water vapour transitions. The Herschel angular resolution is 13″ at best, so the analysis of sources measured with Herschel-HIFI would be enhanced by images of the 183 GHz line measured with ALMA. The initial 'ALMA Enhancement' proposal contained a number of ALMA software projects. In the version accepted for negotiation by the EU, the budget was reduced from 12.5 million Euros to 8.5 million Euros. The software applications that were included were specific to the Band 5 receivers. These were 'phase corrections using the ALMA water vapour radiometers' and 'on-the-fly interferometric mosaicing'. The 'ALMA Enhancement' initiative has been encouraged by ESAC, European ALMA Board, STC and the ALMA Board. The negotiations are ongoing. The partners in the proposal are ESO (administration and management of the proposal), Astrophysics Group, Cambridge University (phase correction of the data), IRAM Grenoble (on-the-fly interferometric mosaicing), Onsala Space Observatory (receiver construction) and University of Chile (receiver tests). The conditions set by the Joint ALMA Observatory are that the 'ALMA Enhancement' proposal is at no cost in manpower or money to the ALMA project, and does not slow the construction of ALMA.

Work on ALMA components is going on at full speed in European laboratories. **Left:** Observatoire de Bordeaux, **Centre:** Jodrell-Bank Observatory, **Right:** Rutherford Appleton Laboratory.





The Sampo Project

As an in-kind contribution to its joining fee, the Republic of Finland is funding a three-year project to assess future data reduction and analysis software needs for the ESO community. The Sampo project, named after a mysterious artifact and source of power in the Finnish Kalevala legends, will gather requirements, assess technologies and perform detailed pilot software projects to help prepare ESO for the software challenges of data handling in the next decade.

Richard Hook[1], Palle Møller[1], Janne Ignatius[2], Kari Vasko[2], Michele Peron[1], Peter Quinn[1]

[1]ESO
[2]CSC, The Finnish IT Center for Science, Finland

The data analysis systems used by astronomers in Europe, and elsewhere, were originally developed in the 1980s, or even earlier. For analysis of optical and infrared data sets, the most popular software systems are IRAF, ESO-MIDAS and IDL whilst AIPS is still being used for interferometry. Although those systems have evolved well to cope with changing hardware and new operating systems, the fundamental underlying infrastructure is unchanged. Each of them is monolithic and provides all the components needed by both users and software developers: data access mechanisms, a scripting language, a parameter interface, graphics and display packages.

In the past few years many observatories, including ESO, have placed emphasis on the development of instrument-specific procedures (which ESO calls "recipes") to remove the instrumental signature and create calibrated data products in physical units. It must be possible to run those recipes in an automatic manner (in which case they are referred to as pipelines) as one of their primary goals is to produce the quantitative information necessary to monitor instrument performance. Whilst the first ESO instrument pipelines were developed as ESO-MIDAS applications, it rapidly became apparent that ESO-MIDAS was not well suited for automatic use. In addition, ESO-MIDAS pipelines cannot deal with the huge increase of data volumes from newer VLT instruments as they do not integrate well with frameworks providing parallel processing facilities on clusters of computers. The decision was made to move away from ESO-MIDAS and instead develop pipeline recipes as C modules which can be called from different environments. Recipes may be invoked either from an automatic pipeline running at the observatory or on the desktop through a Graphical User Interface tool (Gasgano) or a command line application (Eso-Rex), which allow users to reprocess their data offline. These tools do not, however, provide the facilities for detailed analysis of calibrated data. Data complexity is not always well addressed by standard packages either. As an example, the visualization of 3D spectroscopic data requires very specific applications that have been built outside any existing environment. As a consequence, users are currently forced to install a suite of heterogeneous tools and change between different environments several times if they wish to reprocess and analyse raw data generated by complex instruments.

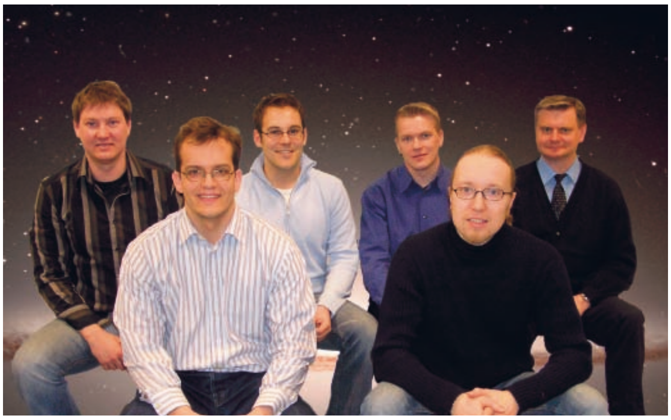
The ESO community has made it clear that better support in these areas should be a high priority. Although it is apparent that a new approach will be needed, it is still unclear what exactly will be required. Do we need a "new IRAF" or a "new ESO-MIDAS"? This is unlikely to be the correct approach, as such a system would have to become a monster if it were able to tackle data complexity and data volume and it would inevitably suffer from many of the defects of the older systems. In addition, millions of lines of code have been written as applications within the standard packages. We cannot just ignore them and start from scratch. We also generally prefer to avoid self-contained instrument packages, supporting all the steps from data reduction to data analysis, as this approach may lead to a great deal of redundancy and create major maintenance difficulties. It seems we need an environment in the broader sense of a variety of software elements (libraries, tools, standards, applications) that work together, or separately to allow efficient data handling. We need some way of ensuring access to legacy algorithms and experience. And we must be ready for the time, in the not too distant future, when data will not be necessarily located on a local disc. The rapidly evolving virtual observatory (VO) efforts are defining standards and new data access methods. A clear indication of the sorts of facilities that will be available is given by the recent Euro-VO (*www.euro-vo.org*) demonstrations. Over the next few years the VO will make the transition from numerous rapidly developing pilot projects into an operational reality. Any new software system will need to facilitate convenient access to the VO, both as a data producer and consumer. The requirements of this new world of data are a primary driver for future developments.

Background to the Sampo Project

Before the summer of 2004, when Finland joined ESO, the organization only had resources for developing VLT, VST and VISTA instrument pipelines. However, the ESO long-range plan recognized the need to address the question of a data analysis system for the future, but this project was not funded. When Finland joined ESO in 2004 it was decided that, as part of its joining fee, it would provide a contribution in kind of software effort, amounting to more than 18 person-years over three years, devoted to starting to address this outstanding problem. The project was named Sampo (*www.eso.org/sampo*) after a mysterious artifact in the Finnish Kalevala legends. Although there is strong astronomical involvement with Sampo in Finland, the skills of the new team, who joined the project at the start of 2005 and are shown in the photo on the next page, are mostly in the areas of computer science. ESO is providing the project manager (RH) and project scientist (PM) who report to the ESO Data Management and Operations Division (DMD), which retains overall control of the project. In Finland the team is coordinated by the National Coordinator (KV) and is based at two locations: CSC, the Finnish IT Center for Science, and the Observatory, University of Helsinki.

The scientific oversight comes from two bodies. The Finnish Astronomical Advisory Group (FAAG) represents the Finnish astronomical community and its interests and is chaired by one of us (JI). The ESO Faculty is represented by the Scientific Advisory Committee (SAC) that is chaired by the project scientist (PM).

In a parallel and earlier effort, an Opticon Network (3.6), with significant ESO involvement, is also looking at the question of future analysis systems and will also supply input to the project.



The current Sampo Team in Finland. From left to right: Sami Maisala, Kari Vasko, Johan Lindroos, Matti Anttila, Marko Ullgren and Tero Oittinen.

Sampo Project Goals

The project will run for three years (2005–2007). There are three main goals. Firstly the team must develop a clear idea of the science requirements for a data analysis system to satisfy the needs of the ESO community for the decade 2010–20. Among the questions to be addressed are: How should access to legacy code be provided? What should the glue needed to connect up existing software building blocks look like? What is the relative importance of the development of stand-alone Graphical User Interfaces, web applications or the provision of scripting languages with appropriate libraries and tools? At which level is interactivity needed? How does the data analysis environment provide services to the VO? Should tools for data organization be part of the system?

Secondly the project will identify risk areas and assess the technology required and test it on realistic astronomical data sets. Lastly the project will execute several pilot studies that illustrate critical steps along the road to a new system, validate the concepts and also produce significant tools of immediate value for the ESO community. This is a research and development project and can be regarded as a Phase A study.

The work will progress as a series of projects, each typically taking six months to a year, in which specific questions or problems are addressed. Initially, as the Finnish team was not familiar with astronomical software, a seminar was arranged in Helsinki and some small projects were selected to help them to learn about astronomical software. A more substantial project, PyMidas, is currently in progress and is described below.

The deliverables from these projects will be software tools that are pilot implementations addressing specific problems posed by the scientific oversight bodies listed above, complete with detailed documentation, or reports describing studies. As well as reporting to the ESO DMD, these projects will be written up and presented at the ADASS or other conferences and, where appropriate, presented as demonstrations. The model of annual cycles with demonstrations and meetings at the same times, over a period of several years, as adopted by the virtual observatory, will be followed, where appropriate.

When possible, projects will be chosen so that the resulting software tools are of direct value to the ESO community. As an example, Sampo might look at developing an architecture that would allow astronomers to use the UVES pipeline (that is based on ESO-MIDAS), newer pipelines based on CPL and other analysis tools in a convenient and uniform way. Such a development would be not only of benefit for the community but also be valuable for the operational teams who could then possibly use ESO-MIDAS pipelines not only on a local computer but also on a cluster. Another example might be addressing the questions posed by trying to connect up legacy software with data distributed through the virtual observatory in a convenient manner.

At the end of the three years a more detailed report will be presented to the ESO Head of DMD setting out conclusions from the projects and making detailed recommendations. Realistic resource estimates will be presented to allow the management to decide whether or not to proceed to a Phase B.

The First Pilot Project – PyMidas

As an initial project for the team we chose to develop an interface between the Python scripting language – which is now dominant in many areas of astronomy – and ESO-MIDAS (*www.eso.org/midas*), the main legacy data reduction and analysis system from ESO. This project is now well advanced and expected to be released in October 2005 and demonstrated at the ADASS 2005 (*www.adass.org*) conference. PyMidas allows any ESO-MIDAS command to be executed from Python using standard syntax, but also allows the developer to call on the full power of scripting in Python. ESO-MIDAS commands can be included in Python scripts – along with those from the many other Python-based systems such as PyRAF (*www.stsci.edu/resources/software_hardware/pyraf*) – and facilities from the ESO-MIDAS monitor (such as direct access to keywords, table elements and pixel values) will also be available directly from Python. This project will enhance the access to legacy code – and many valuable and trusted applications – whilst connecting the legacy with more modern technology as well as other systems.

Conclusions

A new software infrastructure will be needed to replace the ageing systems in current use if the ESO community is to be ready for the age of the virtual observatory and the new generation of instrumentation. The Sampo project, which has just started, aims to develop a detailed characterization of the requirements for future data reduction and analysis environments and to produce many useful components from pilot projects along the way. Some aspects of such a system are already apparent and we expect that a much clearer and more complete view will emerge over the three years of the project. An initial pilot project, PyMidas, is progressing well and will be made available in the autumn of 2005. More details about the Sampo project are available through the web pages at *www.eso.org/sampo* where there are links to other related documents. We very much welcome advice from the ESO community and encourage comments and questions to *sampo@eso.org*.

For many years the ESO community has asked for better tools for data analysis and data reduction. This goal has always been recognized by ESO as being very important, but a significant project could only be funded when Finland joined ESO. The Sampo project will be a major step forwards towards addressing these concerns.

Transiting extra-solar planets, follow the FLAMES ...

The past year witnessed a blossoming in the field of transiting exoplanets. Until 2003, only one transiting exoplanet was known, the famous HD 209568, first detected by radial-velocity surveys. Then in quick succession, six transiting planets were discovered among the candidates identified by photometric transit surveys. Five of these transiting exoplanets were characterized by our team with FLAMES on the VLT.

Frédéric Pont[1], François Bouchy[2], Didier Queloz[1], Claudio Melo[3], Nuno Santos[4], Stephane Udry[1], Michel Mayor[1], Claire Moutou[2]

[1]Observatoire de Genève, Switzerland;
[2]Laboratoire d'Astrophysique de Marseille, France; [3]ESO
[4]Centro de Astronomia e Astrofísica da Universidade de Lisboa, Observatório Astronómico de Lisboa, Portugal

The orbits of some extra-solar planets intersect the line of sight between the star and the observer, blocking part of the star's light and producing a detectable photometric transit. The probability to have such a geometry is about 10 % for short-period companions. After the first discoveries of planets on short orbits (often called "hot Jupiters") many ground-based surveys have been initiated to search for transit signatures from these hot planets.

Transiting planets are especially precious to study the structure and the evolution of extra-solar planets because the transit signal offers a unique way to measure directly the radius of the planet. If the transit signal can be combined with radial-velocity measurements, a direct measurement of the mass of the planet is obtained as well, the usual sin(i) uncertainty being removed by the edge-on inclination of the orbit. With both the mass and radius measured, the planet mean density becomes known. This allows us to "flesh in" exoplanets in much more detail than for the planets without transit, for which only an estimate of the minimum mass (M sin$i$) is available.

Since 2002 many transiting extra-solar planet candidates were identified as a result of the OGLE survey. To follow up on those announcements, we decided to start a systematic survey of all OGLE candidates. Using ESO facilities and in particular FLAMES on the VLT, we conducted intensive spectroscopic follow-up observations to detect the radial-velocity signatures of announced planet transit candidates, with the objective of assessing their planetary nature by measuring their mass. FLAMES is a multi-fibre link to the UVES and GIRAFFE spectrographs on the VLT.

In a previous Messenger article (June 2004) we presented the detection of the planets OGLE-TR-113b and OGLE-TR-132b that we made with FLAMES. In this article we summarize our whole campaign including the detection of two more planets (OGLE-TR-10b and OGLE-TR-111b). Complete details on this campaign may be found in a series of articles (Bouchy et al. 2004, 2005; Moutou et al. 2004; Pont et al. 2004, 2005, 2005b).

The main outcome of our FLAMES campaign is the identification and the measurement of four true planetary transits, but also the measurement of the mass of many transiting low-mass stellar companions initially tagged as possible planetary transit. Considering the stringent requirements needed to carry out this programme on both the accuracy of the radial velocity and the need for high efficiency to quickly survey a large number of faint objects, we enthusiastically report the unrivalled efficiency of FLAMES/UVES to carry out such a programme. This facility demonstrated that the apparent disadvantage of targeting faint planetary transit candidates can be compensated by their compact location on the sky that allow to benefit from the full multiplexing capability of FLAMES.

At present, seven transiting planets are known (see Table 1). If we look carefully, these measurements are puzzling in various respects. HD 209458 is almost three times less dense than Jupiter, a characteristic that is not yet understood. Three of the OGLE planets (OGLE-TR-56b, 113b and 132b) have periods around 1.5 days, much shorter than the lower limit detected by Doppler surveys of around 3 days, revealing a new class of "very hot Jupiter" (i.e. gas giants even closer to their star than the "hot Jupiters" with periods above 3 days). All three of these objects are also heavier than normal hot Jupiters. OGLE-TR-10b, OGLE-TR-111b and TrES-1 are more typical hot Jupiters, resembling those found in abundance by radial-velocity searches. They have radii ranging from Jupiter size to the anomalous HD 209458, showing that the density of hot Jupiters can vary even under similar orbital conditions.

Table 1: The seven presently known transiting exoplanets and the instrumentation used to measure their radial-velocity orbit – HIRES on the Keck telescope in Hawaii, ELODIE on the 1.93-m at Haute-Provence Observatory, and FLAMES on the VLT.

	Period [days]	Mass [M_J]	Radius [R_J]	Instrument for spectroscopy
OGLE-TR-56	1.21	1.45 ± 0.23	1.23 ± 0.16	HIRES
OGLE-TR-113	1.43	1.35 ± 0.22	1.08 ± 0.06	FLAMES
OGLE-TR-132	1.69	1.19 ± 0.13	1.13 ± 0.08	FLAMES
TrES-1	3.03	0.76 ± 0.05	1.04 ± 0.07	HIRES
OGLE-TR-10	3.10	0.57 ± 0.12	1.24 ± 0.09	FLAMES/HIRES
HD 209458	3.52	0.69 ± 0.02	1.42 ± 0.12	HIRES/ELODIE
OGLE-TR-111	4.02	0.53 ± 0.11	1.00 ± 0.09	FLAMES

The mass-radius diagram of exoplanets constitutes the main outcome of follow-up campaigns on transiting planet candidates (Figure 1). It has already spurred many studies attempting to relate the observed sizes and densities to the incoming stellar flux, the tidal effects and the presence or absence of a rocky core.

The OGLE transit survey

OGLE (Optical Gravitational Lensing Experiment) was originally conceived as a microlensing survey in the Galaxy and towards the Magellanic Clouds. Beginning in 2001, the OGLE team started a survey for transiting planets, using the wide-field camera on the 1.3-m Warsaw telescope at Las Campanas in Chile. Fields in the Galactic disc were observed every season, providing 64 transiting candidates towards the Galactic bulge from the 2001–2002 season, 73 from the 2002–2003 season in Carina, 40 from the 2003–2004 season in Centaurus and Musca (Udalski et al. 2002ab, 2005). Photometric accuracies below 1 % are obtained for up to 100 000 objects in each season, allowing the detection of transit signals of depth from a few per cent down to slightly below one per cent.

Dozens of ground-based planet transit searches are currently under way, but the OGLE survey is dominating the scene. This is probably the consequence of an adequate combination of continuous observation with a 1-m-class telescope equipped with a large detector (8 k × 8 k) and long experience of the team in stable photometric reductions. Most other surveys either rely on very small telescopes covering large fields of several square degrees, or larger telescopes available only during a very limited time.

Our FLAMES follow-up of OGLE transiting candidates

The OGLE survey provided more than one hundred planetary transit candidates, but we found that most of these transits are in fact eclipsing binaries. The measurements of the orbital motion are therefore essential to determine whether the transiting object is a star or a planet. The OGLE targets are between 15 and 18 in V magnitude, and typical planetary orbits cause velocity variations of the order of 100 m/s or lower. The observational challenge posed by the OGLE follow-up is therefore to obtain radial velocities more precise than 100 m/s for objects down to 18th magnitude in V.

In 2002, before FLAMES was available, we attempted to measure a few of the most promising OGLE candidates both with UVES in regular slit mode and with HARPS. Due to the faintness of the targets, the signal-to-noise per pixel in HARPS spectra was often rather low, causing a radial-velocity uncertainty higher than 100 m/s due to photon noise. With UVES in slit mode, enough photons can be collected to compute accurate radial velocities, but we were faced with the problem of uncertainties related to the centring of the star in the slit, that prevented us from obtaining a radial velocity with an accuracy better than 100 m/s. When FLAMES became available, the fibre scrambling effect on the incoming light from the target solved the centring problems and made our follow-up programme feasible, with the additional benefit of multiplexing (the ability to observe seven targets simultaneously with the FLAMES link on UVES).

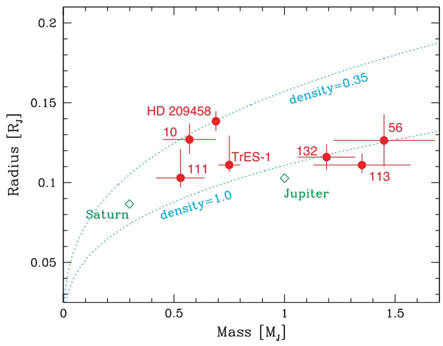


Figure 1: The mass-radius relation for the seven known transiting extra-solar planets.

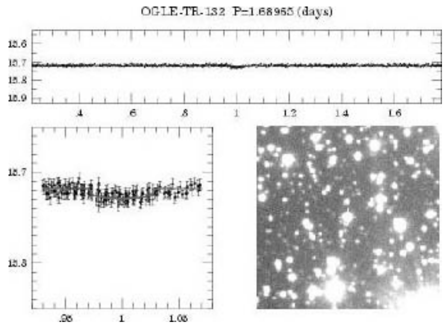


Figure 2: Complete light curve, zoom on the transit, and finding chart for one OGLE candidate, OGLE-TR-132. Planets produce shallow transits that require a high photometric accuracy and long-term stability. This can be difficult to achieve in crowded fields. OGLE-TR-132 is a candidate very near the detection threshold of ground-based surveys that was found to harbour a planet.

In 2003 and 2004, we resolved the nature of 60 OGLE transiting candidates in just eight nights with FLAMES and we found four planets. A mean rate of two nights per planet is about ten times more efficient than radial-velocity survey programmes! Regular radial-velocity survey programmes use typically one night per target through the duration of the survey, and one planet is detected out of 20 targets on average, meaning that about 20 nights are spent to get one planet. This large difference of efficiency reflects the benefit of the multiplex advantage provided by the FLAMES fibre link, and of course the benefit of the previous photometric transit survey.

To optimize telescope use, we have also opted to react in real-time during the observations. During the eight nights of the campaign we analyzed our spectra on the fly, so that we could re-allocate one of the seven FLAMES fibre links to another candidate as soon as we had enough information to identify the transiting body as a stellar companion.

Thanks to the fibre link, we could reduce the systematics in the radial-velocity measurements to less than 30 m/s. When this systematic error is combined with the photon noise error, we are reaching typical accuracies of 40–60 m/s on each individual radial-velocity measurement. Measurements with such errors would be too large to search for a planet without prior information, but in the case of transiting candidates, the orbital period and phase are known from the photometric transit signals, so that such measurements are sufficient to constrain the orbital motion of a planetary companion and measure its mass accurately.

Supporting actors in the OGLE planet follow-up: UVES and FORS

Although the main actor in our spectroscopic follow-up is doubtlessly FLAMES/UVES, there are other supporting actors in this movie. The first of them is FORS.

The shape and depth of a transit light curve are related to the size of the transiting companion, but in some cases, such as OGLE-TR-132, the transit depth is so near to the detection limit that little information can be obtained on its actual shape (see Figure 2). In such cases, FORS can be used to obtain a much better light curve, leading to improved mass and radius determination. That is what we have done for OGLE-TR-132 (see Figure 3). With the benefits of the UT aperture, the quality of the FORS camera and the good seeing of Paranal, we measured the transit shape at the milli-magnitude level, an

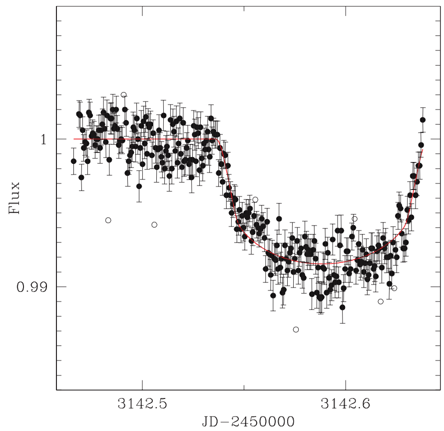


Figure 3: Light curve of the transit of OGLE-TR-132 with FORS2. To be compared with the OGLE detection light curve on Figure 2. Individual errors and systematics are near the level of 1 millimag.

achievement comparable to space performance for such a faint object.

In order to measure the mass and radius of the transiting body, one needs to have an indication of the mass and radius of the primary star. In order to do so, high signal-to-noise stellar spectra (S/N about 100) are needed. Most of our spectra collected with FLAMES/UVES have a S/N that is too low to carry out a precise spectroscopic analysis (although they are good to have precise radial velocities!). UVES in slit mode can be used to collect higher S/N spectra, refining the previous determination of masses and radii for the primary and its companion.

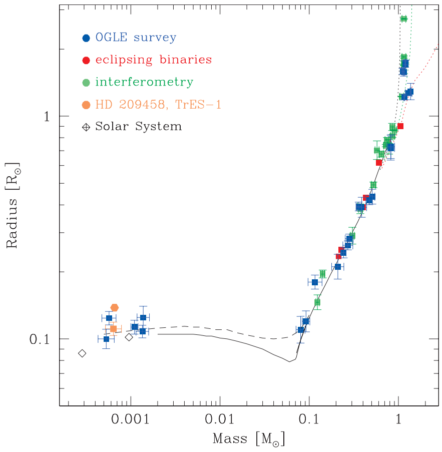
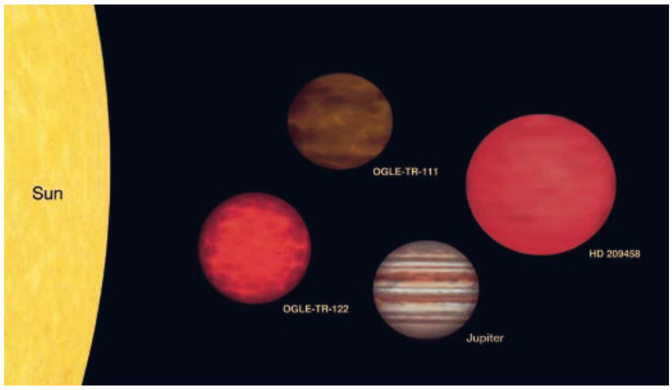


Figure 4 (left): The mass-radius diagram from stars to planets, showing the objects from our follow-up of the OGLE survey, solar-system gas giants, bright transiting planets, bright eclipsing binaries, and stars with interferometric radius determinations.

Figure 5 (below): Two stars and three planets... The transiting stellar companion OGLE-TR-122b has a size comparable to Jupiter, and is smaller than the planet HD 209458b. It produces a transit light curve indistinguishable from a planetary transit.



The mass-radius diagram from stars to planets

The main product of our spectroscopic follow-up with FLAMES is of course the characterization of the five planets described above. But another important result was the characterization of 55 candidates that were not planets. This yielded two important by-products:

- Mass and radius for several very low-mass stars, down to the Hydrogen-burning limit.
- A complete image of the range of configurations that can be confused with planetary transits.

Our follow-up of the OGLE candidates has yielded a very rich wealth of empirical information in the mass-radius plots for low-mass stars and planets (Figure 4), comparable to all other previous studies combined.

Two very small stellar objects are particularly interesting: OGLE-TR-122 and OGLE-TR-123. With masses near the Hydrogen-burning limit and radii comparable to that of the hot Jupiters, they provide an observational confirmation of the theoretical prediction that stellar radii reach down to about 0.1 $R_{\odot}$ before entering the regime of a degenerate equation-of-state. These objects also confirm that in some cases it is not possible to distinguish a hot Jupiter transit from a stellar transit from the photometry alone, and that small stellar companions occur at frequencies comparable to hot Jupiters (see Figure 5). This is a major source of concern for very deep transit surveys (such as with the HST), were spectroscopic confirmation is not possible.

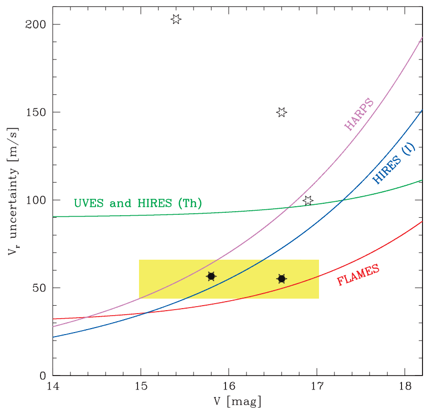


Figure 6 (left): Radial-velocity accuracy versus target magnitudes for different facilities used in the follow-up of faint transiting candidates: FLAMES/UVES on the VLT, UVES in slit mode, HARPS on the ESO 3.6-m, HIRES on the Keck Telescope in Hawaii with a Thorium calibration (Th) or an Iodine cell (I). The stars indicate the velocity dispersion due to orbital motion for detected transiting planets, normal hot Jupiters in black and "very hot Jupiters" in white. The yellow band shows the zone most relevant for the detection of normal hot Jupiters in the OGLE survey.

FLAMES ahead

The combination of 8-m-class telescope, fibre-feed, high resolution, simultaneous Thorium calibration, and multiplex capacity, puts FLAMES/UVES in a league of its own for the follow-up of deep transit surveys. No other facility in the world combines both the faint multi-object capability and the capacity to measure accurate radial-velocity.

Specialized radial-velocity spectrographs on smaller telescopes, such as HARPS on the ESO 3.6-m at La Silla, can reach a higher absolute precision, but most OGLE targets are too faint and the photon noise on the velocity exceeds the amplitude of a typical planetary orbit. Slit spectrographs on 8-m or 10-m class telescopes (UVES, HIRES) can collect the necessary S/N ratio to push the photon noise low enough, but only at the cost of large systematic uncertainties due to the centring of the object in the slit. The use of an Iodine cell can solve this problem, but only at the cost of losing transmission efficiency and most of the spectral range, so that again the photon noise becomes too large. As a result, even if it had a single fibre, FLAMES is the only facility able to derive a planetary orbit in five measurements for an object such as OGLE-TR-132. Adding to that, the 7-fiber multiplex capacity makes it the king of the jungle for transit follow-up of faint targets.

Figure 6 presents a graphic comparison of the capacity of some facilities for radial-velocity follow-up of faint planetary candidates. This diagram shows that FLAMES is the most performing facility in the relevant range – even before taking into account the multiplex facility that allows several targets to be followed at once! With FLAMES in conjunction with the results from transit surveys, ESO instrumentation has demonstrated its capability to make a major contribution to the empirical knowledge of the mass-radius relation for planets, brown dwarfs and low-mass stars.

Acknowledgements

We wish to express our gratitude to all persons that participate in the development of the UVES FLAMES link, making available to the ESO community such a unique and unrivalled facility.

References

Bouchy et al. 2004, A&A Letters 421, L13
Moutou et al. 2004, A&A Letters 424, L31
Pont et al. 2004, A&A Letters 426, L15
Bouchy et al. 2005, A&A 431, 1105
Pont et al. 2005, A&A Letters 433, 21
Pont et al. 2005, A&A, in press, astro-ph/0501615

On the track of very low-mass planets with HARPS

In only one and a half years of operation HARPS has discovered eight new extra-solar planet candidates. Many more discoveries are expected with the increase of the duration of the survey. What makes HARPS unique compared with other instruments is its unprecedented precision and its ability to discover planets with very low mass. In fact, all the planets discovered with HARPS lie in the low-mass tail of the planetary companion mass distribution. This distribution, which is known to be highly sensitive in its low mass end to the detection threshold, can be explored with HARPS in a comprehensive way. The exploration of the very low-mass end of giant planets may bring new constraints on planet formation and evolution scenarios.

Francesco Pepe[1], Michel Mayor[1], Didier Queloz[1], Willy Benz[2], Jean-Loup Bertaux[3], François Bouchy[4], Christophe Lovis[1], Christoph Mordasini[2], Nuno Santos[5], Jean-Pierre Sivan[4], Stéphane Udry[1]

[1]Observatoire de Genève, Switzerland; [2]Physikalisches Institut, Universität Bern, Switzerland;
[3]Service d'Aéronomie du CNRS, France;
[4]Laboratoire d'Astrophysique de Marseille, France;
[5]Centro de Astronomia e Astrofísica da Universidade de Lisboa, Observatório Astronómico de Lisboa, Portugal

HARPS, the High-Accuracy Radial-velocity Planet Searcher on the 3.6-m ESO telescope, became operational in October 2003. Since then, the HARPS Consortium has been carrying out a comprehensive planet-search programme on the assigned Guarantee Time Observations (GTO). The first results, which were obtained during the first GTO period and published in early 2004 (Pepe et al., 2004), announced the discovery of a Saturn-mass planet with an orbital period of seven days around the star HD 330075. Besides unveiling a new extra-solar planet, these measurements clearly demonstrated the detection efficiency and the amazing radial-velocity precision of this instrument (see The Messenger Nr. 114, 2003, page 20, for a full description): First, asteroseismology observations measured a short-time precision (during the night) of about 20 cms^{-1}. Indeed the stellar p-mode oscillations were clearly and directly identified in the time series of observations of a few stars. Second, the low residuals around the orbital solution of the discovered planet showed that the radial-velocity accuracy over several months was better than 2 ms^{-1}. This achievement is even more compelling considering that the instrument suffered several modifications during the first months of its life.

Intense sequences carried out during asteroseismology observations also made it clear that HARPS' capability for planet search was not limited by its performance but rather by the star itself. Indeed, stellar p-mode oscillations on a short-time scale and stellar jitter on a long-time scale introduce extra radial-velocity noise that cannot be neglected at the accuracy level of HARPS. For instance, even a very "quiet" G or K dwarf shows oscillation modes of several 10 cms^{-1} which might add up to radial-velocity amplitudes as large as several ms^{-1}. Moreover, any exposure with integration time shorter than the oscillation period of the star might fall arbitrarily on any phase of the pulsation cycle leading to additional radial-velocity noise. This phenomenon may seriously compromise our ability of detecting very low-mass planets around solar-type stars by radial-velocity measurements.

In June 2004 a European group of astronomers (see ESO Press Release 22/04) proved that p-mode radial velocity variability was not an issue for detecting planets. During asteroseismology measurement campaigns on the star μ Ara they measured its p-oscillation modes, but in addition, they also observed an unexpected coherent night-to-night variation of very small semi-amplitude of 4.1 ms^{-1} that was later confirmed to be the signature of a planetary companion of $m_2 \sin i$ = 14 $M_\oplus$ with an orbital period of P = 9.5 days. This discovery demonstrated that oscillation noise could be averaged out sufficiently to unveil a small radial velocity signature of a Neptune-mass planet companion.

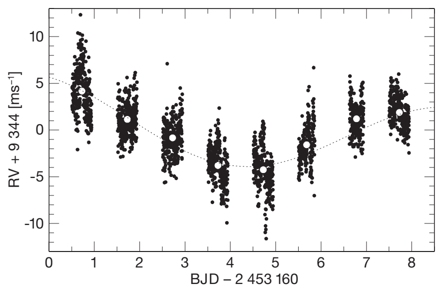


Figure 1: Asteroseismology observations of μ Ara. Although the dispersion of the radial velocity caused by stellar oscillations can be 10 ms^{-1}, one easily sees the "low-frequency" variation induced by the planetary companion on the daily radial-velocity average.

Since the discovery of the very low-mass companion of μ Ara, other very low-mass candidates have been discovered (Butler et al. 2004, McArthur et al. 2004) . These planetary companions start to populate the lower end of the secondary-mass distribution, a region so far affected by detection incompleteness (see Figure 2).

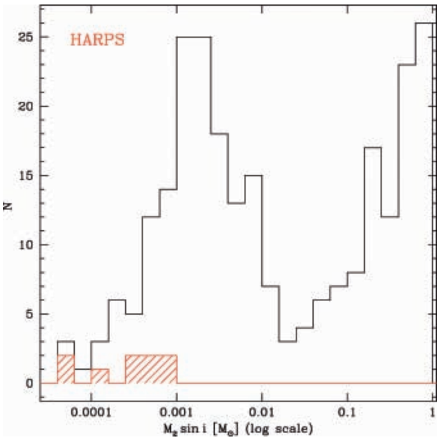


Figure 2: Mass distribution of companions to solar-type stars from 1 $M_\odot$ down to the mass of Neptune (< 5 10^{-5} $M_\odot$). The right-hand slope represents the tail of the stellar companion distribution. The left-hand peak shows the planetary companions. In between, the brown-dwarf "desert" appears clearly. The very high-precision HARPS GTO survey is devoted to explore the shape of that mass function from 1 M_{Jup} (0.001 $M_\odot$) down to the mass of Uranus and Neptune. Note that all newly detected HARPS planets clearly lie in this low-mass range. HARPS is one of the most sensitive and efficient instruments to explore this domain of the mass distribution. It will provide many new inputs for the formation and evolution theories of exoplanets.

The discovery of these very low-mass planets close to the detection threshold of radial-velocity surveys for a limited sample of stars suggests that this kind of object may be rather frequent. But already the simple existence of such planets may produce headaches for the theoretician. Indeed, statistical considerations predict that a planet with a mass between 1 and 0.1 M_{Sat} and with semi-major axis of 0.1 to 1 AU must be rare (Ida and Lin, 2004). At least for the moment, the recent discoveries contradict these predictions. In any case, the continuous detection of planets with increasingly lower mass will set new constraints to possible planetary-system formation and evolution models.

Constraining formation and evolution scenarios

Low-mass giant planets, i.e. planets with a mass in the range 10–100 $M_\oplus$ are of particular importance in order to constrain formation and evolution models. Indeed, and perhaps contrary to intuition, the presence of a large number of planets within this mass range would not be expected by any of the current theoretical formation models. However, because all the currently known low-mass planets are located close to their star, one cannot exclude that these objects were much more massive in the past and lost a significant amount of their mass through evaporation during their lifetime (see for example Baraffe et al. 2004). The situation is therefore a complex one in which formation and subsequent evolution over the system's entire lifetime has to be considered. In what follows we venture into some speculations regarding possible evolutionary scenarios leading to μ Ara type objects.

In the direct collapse scenario planets form through gravitational collapse of patches of the protoplanetary disc (Boss 2002). High-resolution simulations of this process show that planets tend to form on elliptical orbits with semi-major axis of several astronomical units and masses between 1 and 7 M_{Jup}. Even if such a planet would subsequently migrate inwards to 0.1 AU, evaporation will not be able to reduce its mass to the one inferred for μ Ara. After all, several planets of the order of a Jupiter mass are observed to exist at these distances in orbit around similar stars.

In the core accretion scenario (Pollack et al 1996; Alibert et al. 2005), forming planets in this mass range is not trivial either. The main reason is that in the standard scenario once the core mass has reached a critical value, the accretion of the gaseous envelope proceeds in a runaway fashion. Since this critical mass is of order 10–15 $M_\oplus$, planets are expected to form either less or significantly more massive than this value. Ida & Lin (2004) have argued that this mass range should be severely depleted (a planetary desert). If correct, the relatively numerous small-mass objects discovered so far start to pose a real problem. While mass loss from initially more massive objects could possibly account for the planets very close to their star (Baraffe et al. 2004), it is not clear whether μ Ara located at a distance of close to 0.1 AU could actually result from the evaporation of a more massive object.

If this were not, or only partially, the case, the existence of the planetary desert or at least its depth must be questioned. In Ida & Lin (2004), the growth rate of a planet is given by the Kelvin-Helmholtz time which becomes increasingly shorter with increasing mass. On the other hand, in Alibert et al. (2005), the gas accretion rate is actually limited by the disc once the planet has opened a gap (Veras & Armitage 2004). Monte Carlo models are being computed in order to check whether this more realistic approach changes the extent and/or the depth of the planetary desert. From an observational point of view a larger sample especially of objects for which evaporation clearly cannot play a role, i.e. far enough away from the star, would be of paramount importance to constrain these issues.

Finally, given their close location to their star, these small-mass planets are likely to have migrated to their current position from further out in the nebula. The chemical composition of these planets will depend upon the extent of their migration and the thermal history of the nebula and hence the composition of the planetesimals along the accretion path of the planet. The situation is made more complicated by the fact that the ice-line itself is moving as the nebula evolves (see for example Sasselov & Lecar 2000). Detailed models of planetary formation including these effects have yet to be developed.

More Neptune-mass planets to come

The semi-amplitude of the radial-velocity wobble of μ Ara-like objects is hardly larger than typical stellar p-mode oscillations. The discovery of Neptune-mass planets may only be feasible by applying an adequate observational strategy that includes an increase of the integration time beyond the typical period of stellar oscillations, i.e. more than 5 minutes, in order to average them out. In practice, the integration time is fixed to 15 minutes independently from the star magnitude, provided that the detector is not saturated. An example of the effect of this strategy is presented in Figure 3, which shows the low residuals of 0.9 ms^{-1} obtained on the radial-velocity curve of the planet-harbouring star HD 102117 (Lovis et al. 2005).

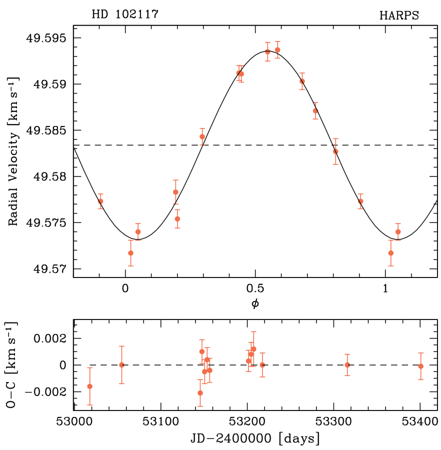


Figure 3: Measured radial velocity of HD 102117 in phase with the orbital period of the planet. The fitted orbital solution is shown as well. The residuals of the data points to this solution are only 0.9 ms^{-1} rms. This value includes photon noise and remaining "stellar noise".

We conduct this strategy on a set of 200 selected stars of the HARPS GTO survey. For this very high-precision survey an accuracy better than 1 ms^{-1} is sought for each individual measurement. So far the results obtained demonstrate that this strategy is successful. The histogram of the radial-velocity dispersion peaks at 2 ms^{-1} and decreases rapidly towards higher values. More than 80 % of these stars show dispersion smaller than 6 ms^{-1}, and more than 30 % have dispersions below 2 ms^{-1}. It must be noted that the dispersion value includes photon noise, stellar oscillations and jitter, and, in particular, it is "polluted" by known extrasolar planets (μ Ara, HD 102117, etc.) or still undetected planetary companions.

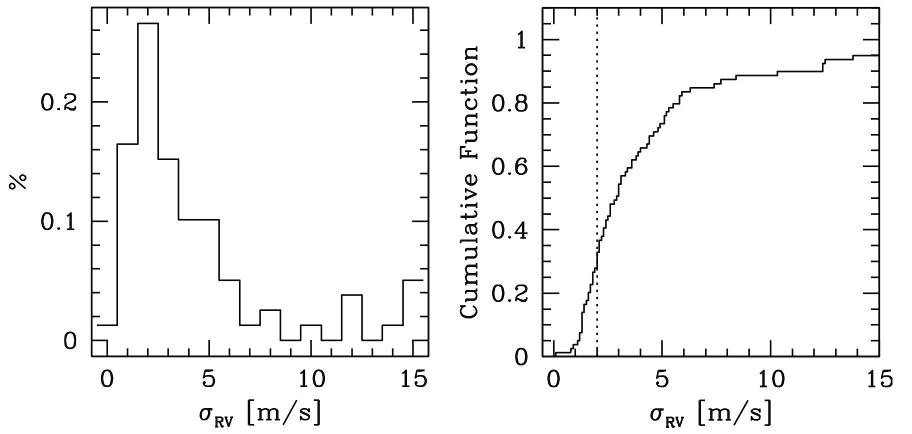


Figure 4: **Left:** Histogram of the radial-velocity scatter for all targets belonging to the very high-precision HARPS planet survey. **Right:** Cumulative distribution of the radial-velocity scatter. The distribution peaks at 2 m/s and is mainly dominated by stellar oscillations and jitter. We must point out here that μ Ara (corrected for the drift due to μ Ara b) and HD 102117, are part of this distribution, and that the orbital motions of their planets alone induce a radial-velocity scatter of 2.5 ms^{-1} and 6 ms^{-1} rms, respectively!

Where is the limit?

The threshold of the lowest-mass planet detectable by radial-velocity survey keeps decreasing. Today with the current achieved precision of about 1 ms^{-1} a Neptune mass planet can be discovered. Nobody has yet explored in detail the domain below the 1 ms^{-1} level. The measurements on μ Ara have demonstrated that it is possible to beat the stellar pulsation noise by investing sufficient observing time. One open issue however remains unsolved: the behaviour of the stars on a longer time scale, where stellar jitter and spots may impact the final achievable accuracy. In this case, an accurate pre-selection of the stars may help focusing on "good" candidates and optimizing the observation time. In addition, bisector analysis and follow-up of activity indicators such as log R'_{HK}, as well as photometric measurements would allow the identification of potential error sources.

Nevertheless, the discovery of an extra-solar planet by means of the Doppler technique requires that the radial-velocity signal induced by the planet is significantly higher than the dispersion, or requires alternatively a large number of data points. This is particularly important to rule out artefacts, given the relatively high number of free parameters in the orbital solution and more specifically for multi-planet systems. A large number of measurements could overcome this problem, but would demand an enormous investment of observing time.

The transit survey may provide another interesting route towards the characterisation of the very low-mass planets. If one considers a transit signal with known orbital period it is obvious that measuring its mass is less demanding both on the number and the accuracy of the radial-velocity measurements. For example a 2 $M_{\oplus}$-planet on a 4-day orbit would produce a radial-velocity amplitude of about 80 cms^{-1}. Given the present precision of HARPS which is estimated to about 60 cms^{-1} it may be possible to detect and measure the amplitude of the radial-velocity wobble with just a few radial-velocity measurements if we knew the period of the system.

The CNES-ESA satellite COROT to be launched in late 2006 will conduct a transit search survey in selected fields. It may detect Neptune-sized transiting planet candidates with orbits similar to μ Ara c. The radial-velocity follow-ups of the COROT planetary candidates is within reach of the capabilities of HARPS. It may deliver the precise mass of these objects. When this information is combined with the transit observation parameters one may obtain the mass-radius relation of planets in the domain of Neptune masses. This combined approach is currently carried out for OGLE planetary candidates of about the mass and the size of Jupiter and we refer the reader to the article of Pont et al. in this issue of The Messenger (page 19) for more details. In the COROT context the most exciting aspect is its capability to explore the domain of Neptune-mass planets with short period where one may expect some overlap between rocky planets and giant planets.

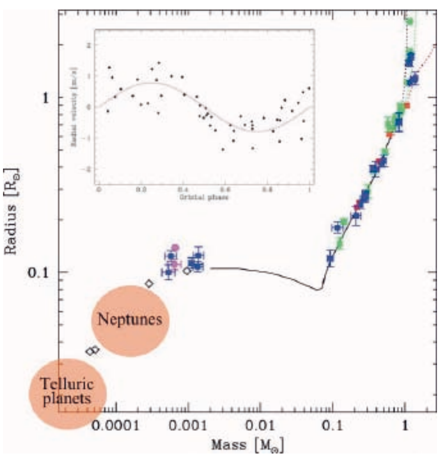


Figure 5: The mass-radius diagram from stars to planets. The low-mass end of the diagram can be investigated by the combination of precise transit search and radial-velocity measurements. With COROT and HARPS the Neptune-mass domain will already be accessible. The inserted diagram on the top left shows a simulation of the radial-velocity variation caused by a two-Earth-mass planet on a 4-day orbit around a solar-type star. With the HARPS precision of about 60 cms^{-1} only 50 measurements are needed to determine the planet mass with an accuracy of 10 %.

The future is still bright for radial velocities

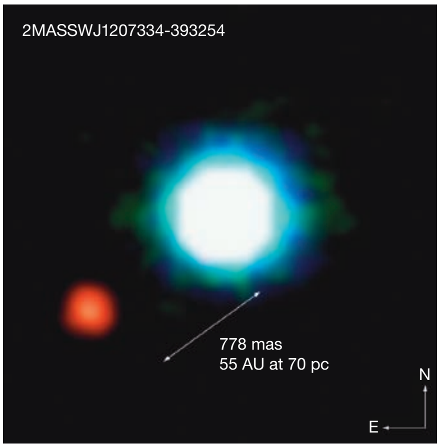
HARPS has demonstrated that radial-velocity measurements with an accuracy better than 1 ms^{-1} can be achieved. This performance makes possible an ambitious and exciting planet search programme. The HARPS GTO Planet Search Programme has led so far to the discovery of eight new low-mass planets. We can easily speculate that many more are likely to be detected in the future to further populate the very low-mass end of the giant planet mass distribution. New inputs on the theory of planetary formation are expected from these discoveries. Follow-up of COROT shallow transit candidates may allow us to push the detection limit to even lower mass.

In parallel to these developments, the possibility to increase even further the radial-velocity measurement precision is being investigated in the frame of the CODEX project (COsmic Differential EXpansion), a visible high-resolution spectrograph to be coupled with ESO's concept of an Extremely Large Telescope, the 100-m diameter OWL now under study. The main scientific driver of CODEX is the direct measurement of the universe's expansion acceleration-deceleration (Monnet G. and D'Odorico S., 2004). A project group headed by ESO and involving several European institutes is investigating the feasibility of such an instrument to reach a radial-velocity measurement precision of 1 cms^{-1} over an extended time span (> 10 years). The combination of the unique collecting power of OWL with the most accurate radial-velocity measurement techniques developed for the extra-solar planet search may make the realization of such an instrument possible. In addition to the determination of the cosmological model with a dynamical measurement at high redshift, this measurement precision will open new possibilities also in the domain of extra-solar planets. First investigations show that Earth-like planets around bright stars could be detected, provided that the total integration time is kept sufficiently long (~ hours) to average out the stellar oscillations. A number of studies have been started to investigate the instrumental aspects. HARPS may serve in this context as a test bench for attaining extremely high radial-velocity precision. Indeed, new instrumental concepts, and new calibration techniques and algorithms are being explored and could partially be verified on HARPS on the 3.6-m telescope in the near future. Nevertheless, any measurement aiming at the cms^{-1} accuracy with HARPS would be limited to very bright objects, due to the limited telescope size. A star with m_V ~ 4 would require 125 sequences of 2-minute exposures each leading to a total observing time of 5 hours to obtain a single data point with 1 cms^{-1} photon limited error. An improved version of the HARPS spectrograph at the VLT as a new-generation spectrograph seems more appropriate for this kind of science. In addition, it would represent an ideal intermediate step toward CODEX. With the refinement of HARPS and the possible future with CODEX, the Doppler technique promises us many new exciting discoveries and new knowledge in the domain of extra-solar planets.

References

Alibert, Y., Mordasini, C., Benz, W., Winisdoerffer, C., 2005, A&A 434, 343
Baraffe, I., Selsis, F., Chabrier et al. 2004, A&A 419, L13
Boss, A. 2002, ApJ 566, 472
Bouchy, F., Bazot, M., Santos, N. C. et al. 2005, A&A, submitted, astro-ph/0504043
Butler, P. et al. 2004, ApJ 617, 580
Mc Arthur, B. et al. 2004, ApJ 614,81
Ida, S., Lin, D. N. C. 2004, ApJ 604, 388
Lovis, C., Mayor, M., Bouchy, F. 2005, in press, astro-ph/0503660
Monnet, G. and D'Odorico, S. 2004, SPIE 5489
Pepe, F., Mayor, M., Queloz, D. et al. 2004, A&A 423, 385 (2004)
Pollack, J. B., Hubickyj, O., Bodenheimer, et al. 1996, Icarus 124, 62
Santos, N. C., Bouchy, F., Mayor, M. et al. 2004 A&A 426, L19
Sasselov, D. D., Lecar, M. 2000, ApJ 525, 928
Veras, D., Armitage, P. J. 2004, MNRAS 347, 613

Confirmation of the First Image of an Extra-Solar Planet



2M1207 (centre) and its Planetary Companion (red). The photo is based on three near-infrared exposures (in the H, K and L′ wavebands) with NACO. *ESO PR Photo 14a/05.*

A team of astronomers[1] has confirmed the discovery of a giant planet, approximately five times the mass of Jupiter, that is gravitationally bound to a young brown dwarf, putting an end to a year-long discussion on the nature of this object.

Last year, the team reported a faint red object in the close vicinity of a young brown dwarf (see ESO PR 23/04). The red object, now called 2M1207b, is more than 100 times fainter than the brown dwarf, 2M1207A. The spectrum of 2M1207b contains a strong signature of water molecules, confirming that it must be cold. Based on the infrared colours and the spectral data, evolutionary model calculations led to the conclusion that 2M1207b is a 5-Jupiter-mass planet. Its mass can also be estimated from a different method, which focuses on the strength of its gravitational field; this technique suggests that the mass might be even less than 5 Jupiter masses.

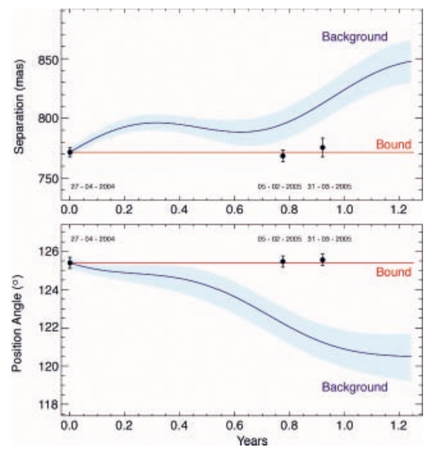
At the time of its discovery in April 2004, it was impossible to prove that the faint source is not an unrelated background object. In February and March of this year, new images were obtained of the young brown dwarf and its giant planet companion with NACO on the VLT. They show with high confidence that the two objects are moving together and hence are gravitationally bound.

The new observations therefore show that this really is a planet, the first planet that has ever been imaged outside of our solar system. The separation between the planet and the brown dwarf is 55 times the separation of the Earth and Sun.

"Given the rather unusual properties of the 2M1207 system, the giant planet most probably did not form like the planets in our solar system," says Gaël Chauvin, the leader of the team. "Instead it must have formed the same way our Sun formed, by a one-step gravitational collapse of a cloud of gas and dust."

Anne-Marie Lagrange, another member of the team from the Grenoble Observatory in France, looks towards the future: "Our discovery represents a first step towards one of the most important goals of modern astrophysics: to characterise the physical structure and chemical composition of giant and, eventually, terrestrial-like planets."

(Based on ESO Press Release 12/05)



Relative position of 2M1207b with respect to 2M1207A at three different epochs (April 2004, February and March 2005). The top panel shows the separation between the two objects in milli-arcseconds, while the lower one represents the relative angle. The blue line shows the predicted change in position if the faint red source were a background object.

[1] The team consists of Gaël Chauvin and Christophe Dumas (ESO), Anne-Marie Lagrange and Jean-Luc Beuzit (LAOG, Grenoble, France), Benjamin Zuckerman and Inseok Song (UCLA, Los Angeles, USA), David Mouillet (LAOMP, Tarbes, France) and Patrick Lowrance (IPAC, Pasadena, USA).

First Science with SINFONI

Since the beginning of 2005 another success story has gone into regular operation at the ESO facilities on Paranal. On UT4 (Yepun) an adaptive optics assisted near infrared integral field spectrometer makes an astronomer's dream come true: Obtaining a diffraction-limited image of which each pixel contains a full spectrum. In fact, such data are best thought of as a cube rather than a flat image. SINFONI is the name of the new instrument and a whole symphony of exciting science results has been obtained already.

Stefan Gillessen[1], Ric Davies[1], Markus Kissler-Patig[2], Matthew Lehnert[1], Paul van der Werf[3], Nina Nowak[1], Frank Eisenhauer[1], Roberto Abuter[1], Matthew Horrobin[1], Andrea Gilbert[1], Reinhard Genzel[1], Ralf Bender[1], Roberto Saglia[1], Marie Lemoine-Busserolle[4], Juha Reunanen[2,3], Karina Kjær[2], Maria Messineo[2], Dieter Nuernberger[2], Christophe Dumas[2]

[1]Max-Planck-Institut für Extraterrestrische Physik, Garching, Germany
[2]ESO, [3]Leiden Observatory, Leiden, the Netherlands
[4]Institute of Astronomy, University of Cambridge, United Kingdom

The new instrument SINFONI consists of two major components: The integral field spectrometer SPIFFI (Eisenhauer et al. 2003) and the adaptive optics (AO) system MACAO (Bonnet et al. 2003). At the very heart of the system is an image slicer, which cuts the image in the focal plane into slices which are then spectrally dispersed simultaneously by a grating. By means of computers the registered information can then be reassembled into the desired data cube. SPIFFI offers four different gratings, one for each of the three infrared-bands *J*, *H* and *K* and one for the combined *H*+*K*-band. The pixel scale in the spatial dimension can be chosen from 0.25 × 0.125 arcsec/pixel, 0.1 × 0.05 arcsec/pixel or 0.025 × 0.0125 arcsec/pixel (corresponding to a field of view of 8 × 8 arcsec^2, 3.2 × 3.2 arcsec^2 or 0.8 × 0.8 arcsec^2 respectively). The two smallest pixel scales are for AO assisted observations with MACAO. The latter allows one to obtain diffraction-limited spatial resolution by analyzing the wavefronts in the optical of either a natural or in near future also of a laser guide star.

SINFONI was working reliably early on, so that both science verification observations and first GTO nights (guaranteed time for the institutes that contributed to SINFONI) could be interleaved with commissioning activities in the second half of 2004. There were four GTO programmes involved: The Galactic Centre, high redshift galaxies, AGN and starburst galaxies. The science verification programme (SV) consisted of 12 programmes (see ESO web pages > Science Verification of VLT Instrument > SINFONI) for which the data were made publicly available immediately. The observations ranged from high-redshift galaxies to solar-system bodies, covering many samples of the science cases envisioned to be covered by SINFONI. Many results presented in this article are still unpublished and should not be referenced, as they are in preparation for fully refereed journal articles.

Orbits of stars in the immediate vicinity of Sgr A* (GTO, Eisenhauer et al. 2005)

One of the prime targets for SINFONI is the Galactic Centre region. Unlike in the optical bands the infrared offers a relatively unobscured view to the very centre of the Milky Way. One finds a densely populated field which has been resolved into individual stars up to 18th magnitude. Over the last 15 years, the positions of the innermost stars have been measured continuously, which has allowed one to detect actual orbits around the dynamical centre. The central mass could be measured in turn to be 4 million solar masses for an assumed distance of 8 kpc. This mass measurement and the resulting density constraint is the best evidence for the existence of a supermassive black hole in the centres of galaxies. However, in order to determine the distance and the true 3D structure of the stellar orbits, one needs also information about the radial component of the velocities. This can be obtained spectroscopically and hence brings SINFONI into play. By applying Doppler's formula the measured wavelengths of stellar lines provide absolute velocities. SINFONI now allows one to make these measurements simultaneously for all the stars. Already the first observations carried out have substantially reduced the uncertainties, leading to orbital elements with remarkably small error bars. The distance according to the new data is 7.6 ± 0.3 kpc, the mass of the central black hole is now estimated to be 3.6 ± 0.3 million solar masses (Eisenhauer et al. 2005). For six of the stars there are now determined full 3D orbits (Figure 1). The orientation of these orbits seems to be at random – e.g., they are not related with the system of two discs at radii between 0.1 and 0.5 pc (Genzel et al. 2003).

A paradox of youth in the Galactic Centre (GTO, Eisenhauer et al. 2005)

The high-quality SINFONI spectra allow determinations of the spectral types of the stars individually: 24 stars in the inner 0.7″ could be classified. By dropping stars with a total (3D) velocity lower than 500 km/s one gets a sample of stars that is free of fore- and background stars. This leaves 10 stars within the central 0.7″ – all of which surprisingly have spectral types between B0 and B9 (Figure 2). These innermost stars of our galaxy have magnitudes between 14 and 16 implying they are ordinary main-sequence stars. This is puzzling: How can we see stars so close to the central mass? The tidal forces should effectively suppress *in-situ* star formation. However, the stars are too young to have migrated from far away. Some violent formation scenarios can already be excluded: The spectra show no apparent broadening of the lines as one would expect for fast-rotating stars. Hence, SINFONI has strengthened the previ-

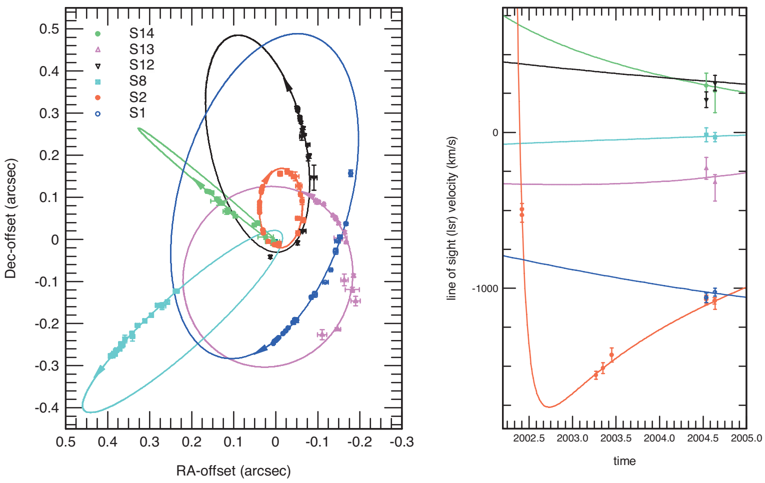


Figure 1: Position on the sky (left inset) and in radial velocity (right inset) of the 6 S-stars in the Galactic Centre included in the orbital fitting. The radial velocities are observed with SINFONI, except for S2 in 2002 which is taken from Ghez et al. (2003). The various colour curves are the result of the best global fit to the spatial and radial velocity data of S1, S2, S8, S12, S13 and S14.

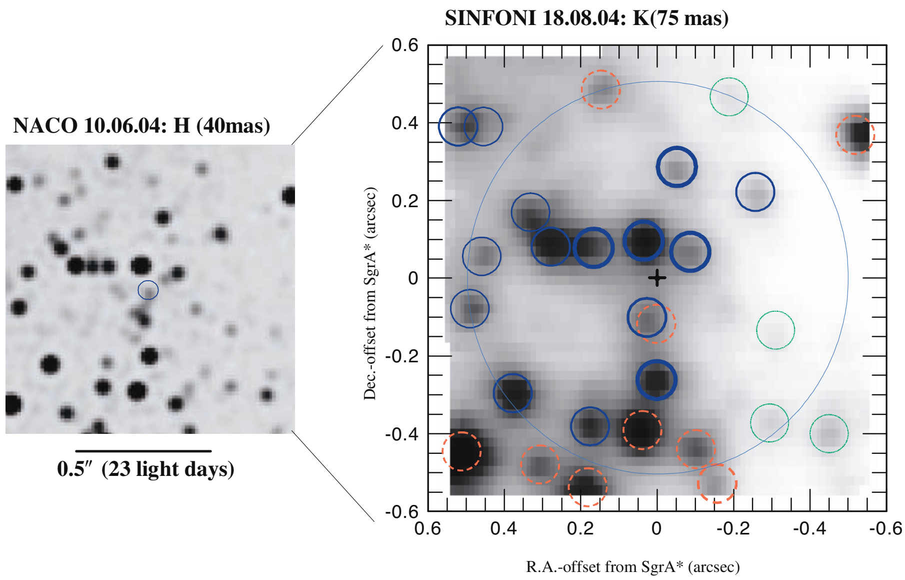


Figure 2: The central arcsecond of the Milky Way. **Left:** A processed NACO *H*-band image from June 10, 2004, showing stars from K ~ 13.3 to 17.8. SgrA* is indicated by a circle. **Right:** SINFONI *K*-band image from August 18/19, 2004, obtained by collapsing the data cube in spectral dimension. The circles around the stars encode their spectral identification: blue: early type, red: late type, thin green: uncertain but not late type; early- and late-type stars with 3D-velocities ≥ 1000 km/s are marked by thick circles, between 500 and 1000 km/s by medium thick and < 500 km/s by thin circles.

ously known paradox of youth (Ghez et al. 2003), which was before based on one star only. From the combination of the normal rotation of the stars and the random orbital orientations one can conclude that the stars were most likely brought into the central light month by strong individual scattering events.

Infrared Emission from Sgr A* (GTO, Eisenhauer et al. 2005)

During SINFONI observations two smaller flares of SgrA* were caught in their entirety. In each case excess emission over about an hour of roughly 16th *K*-magnitude was detected (Figure 3). The spectral slope of both flares was red and a synchrotron emission model with highly energetic, non-thermal electrons fits the data very well (Figure 3). In such a model during a flare, perhaps caused by a magnetic field reconnection event, a few per cent of the electrons near the event horizon are highly accelerated (up to energies larger than 1 GeV) and subsequently radiate in the near-infrared via synchrotron emission. More stringent tests should be possible in future by simultaneous observation of a stronger flare in different regimes of the electromagnetic spectrum.

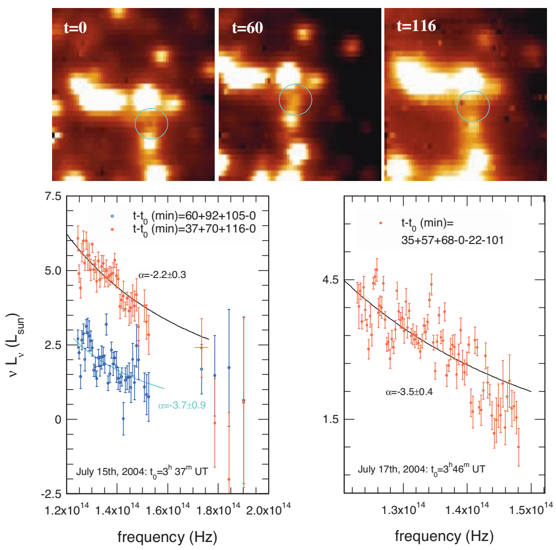


Figure 3: Observations of infrared flares from SgrA*. **Top:** Wavelength-collapsed data cubes from July 15, 2004: ‘before’ (t = 0), ‘peak’ (t = 60 min) and ‘after’ (t = 116 min) (relative to t_o = $3^h\ 37^m$ UT). **Bottom left:** dereddened spectral energy distribution (SED) of the SgrA* flare on July 15, 2003. Red circles: H/K SED averaged over three 10-minute frames near the maximum; blue circles: averaged over three frames at the rising/falling flanks; solid curves: best power law fits. **Bottom right:** The *K*-band SED for the flare on July 17, 2004, averaged over three 10-minute integrations near the peak.

SINS: Survey of high redshift galaxies (GTO, Lehnert)

Over the last decade, a new standard set of cosmological parameters has been established, including a fairly mature view of hierarchical structure formation. The basic premise of all models of large-scale structure is that fluctuations in the mass density of the early universe grow through simple gravitational aggregation/collapse. However, the evolution of the baryonic component of galaxies does not simply follow the merging of dark-matter structures. Phenomenological models have been developed to describe the formation of galaxies. These models rely heavily on simple parameterizations of the physical mechanisms that likely drive galaxy evolution. The most important ingredients are metallicity, angular momentum, stellar initial mass function, and spatial distribution of the gas, the frequency of mergers, as well as the star-formation and feedback processes such as radiation pressure and mechanical energy injection from both stars and supermassive black holes.

To begin to understand these processes, an ambitious programme is being carried out to determine the spatially resolved dynamics, ionization, and metallicity of a large sample of high-redshift galaxies with SINFONI. This survey, which was christened SINS, constitutes a major part of the MPE GTO programme. The sample is chosen to be a representative subsample of several samples such as the "BM/BX" (Shapley et al. 2004), Lyman break galaxies at $z \sim 3$, bright K-band selected, (sub)mm, infrared (ISO), and other optical/near-IR colour (e.g., R-K, J-K, etc.) selected galaxies in the redshift range of 1–3.5. Thus far, SINS have concentrated observing time on "BM/BX", K-selected, and submm-selected galaxies, having observed ~ 30 objects over ~ 10 nights. The total integration times per band range from one hour to 10 hours depending on the (not *a priori* known) surface-brightness distribution of the emission-line gas. These data demonstrate that the integral field capability and high efficiency of SINFONI are necessary to study the properties of high-redshift galaxies: the dynamics can be complicated and one does not know *a priori* the emission-line distribution or the kinematic major axis.

SINS have found that high-redshift galaxies often show spatially extended kinematics and emission-line distributions. A significant velocity shear or perhaps rotation is often observed, with a shear larger than the velocity dispersion of the gas. This is illustrated in Figure 4 for one example.

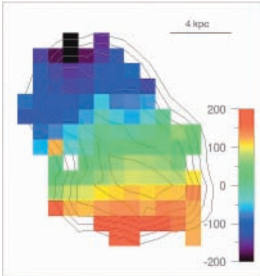


Figure 4 (left): Velocity map of SSA22a-MD41 at z = 2.1713 in H-α observed in the K-band with SINFONI: The colour bar to the right shows the relative velocities and the bar at the upper right shows the physical scale. The contours represent the H-α surface-brightness distribution. The integration time was 2.75 hours, taken as part of the SINFONI GTO SINS survey. SSA22a-MD41 shows simple rotation in relatively quiescent gas.

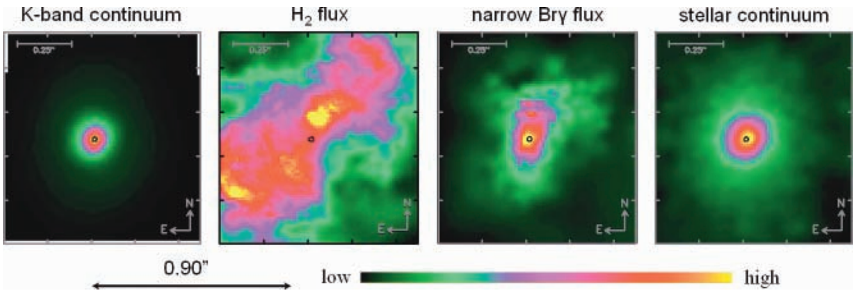


Figure 5 (above): The central arcsec of NGC 3227 with SINFONI. **Far Left:** K-band continuum; **Centre Left:** H_2 1-0S(1) line flux; **Centre Right:** Narrow Brγ line flux; **Far Right:** Stellar continuum. The continuum peak is marked by black circles. The morphologies are remarkably different. The 1-0S(1) suggests a very turbulent medium, the stellar continuum is more regular with slightly elongated isophotes.

Taking the measure of AGN – the extreme environment of NGC 3227 (GTO, Davies)

The main goals of the MPE GTO programme, on AGN are, on scales less than 100 pc, to (1) quantify the recent star formation and understand its history; (2) constrain the velocity field and dynamical mass distribution; and (3) determine the central black-hole mass via stellar dynamics. NGC 3227 is an ideal subject for AO-assisted observations since it lies at a distance of 17 Mpc, so that the 60 mas diffraction limit of the VLT at 2.3 μm corresponds to less than 5 pc. From previous estimates of its black-hole mass (30 million solar masses), the radius of influence over which it dominates the gravitational potential is 7 pc. The size scales on which models predict the canonical torus to exist are similar.

Moving inwards from the disc at large scales and the $r^{1/4}$ bulge in the central kpc, one finds a high-surface-brightness ring of gas and stellar continuum emission at radii less than 140 pc. SINFONI data (Figure 5) show that in the central 0.75 arcsec, 60 % of the stellar continuum originates from this inner disc. The timescale for star formation in this disc, determined from the ratio of supernova rate (based on the radio continuum flux) to the K-band stellar continuum yields an age upper limit of 250 Myr. This means that in the central 16 pc where the surface brightness is highest, the star-formation-rate density is 300 $M_\odot$/yr/kpc^2, comparable to the most intensely star-forming galaxies such as ultraluminous infrared galaxies.

Further evidence that stars lie in a disc is given by the isophotes, which are slightly elongated (suggestive of a weak bar), and have a position angle offset of 20° from the kinematic axis – both features of disc dynamics. But this is no thin disc: direct measurements of the stellar rotational velocity and dispersion give values more typically associated with an oblate spheroid. The gas also has a velocity dispersion of 100 km/s or more, indicative of a highly turbulent environment.

One curious result is the offset between the centroids of the continua at 2.1 μm and 2.3 μm. With respect to the centroid of the 2.1 μm continuum (dominated by stellar light), that of the 2.3 μm continuum (dominated by emission from dust heated to 500–1 500 K by the AGN) is shifted. The offset arises naturally in a torus model (Figure 6) with the same geometry as imposed by the kinematics. This is because dust at such high temperatures is located only near the inner edge of the torus, about 1 pc from the AGN; and if the clouds in the torus are optically thick at 2 μm, only one side of the inner edge is visible. In such a model the separation corresponds to the 1-pixel shift seen in the data.

While this latter result confirms the basic concept of the standard thick dusty obscuring torus, it is also clear that the concept needs to be adapted – so that it can account for the intense star formation in a disc around the AGN on scales of a few parsecs as recently observed in NGC 7469 and Mkn 231 (Davies et al 2004 a/b).

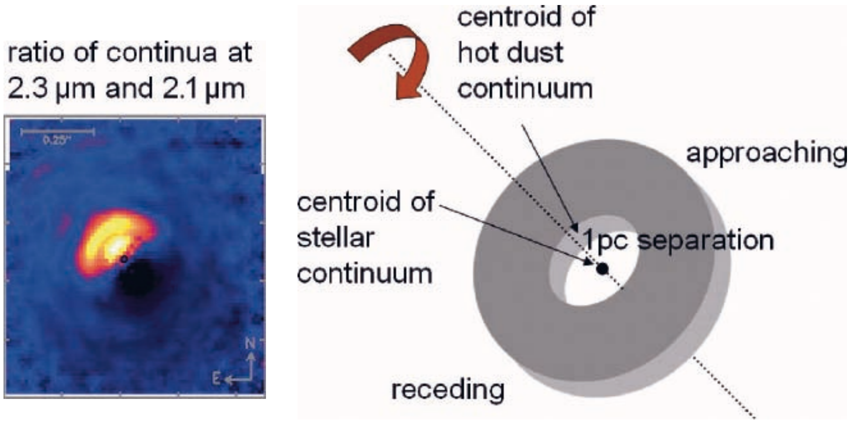


Figure 6: The ratio between the continuum at 2.3 µm and at 2.1 µm (left) indicates that there is an offset of about 1 pixel. The same is apparent between the 2.3 µm stellar and non-stellar continuum. This can be explained in terms of the idealised star-forming torus (right).

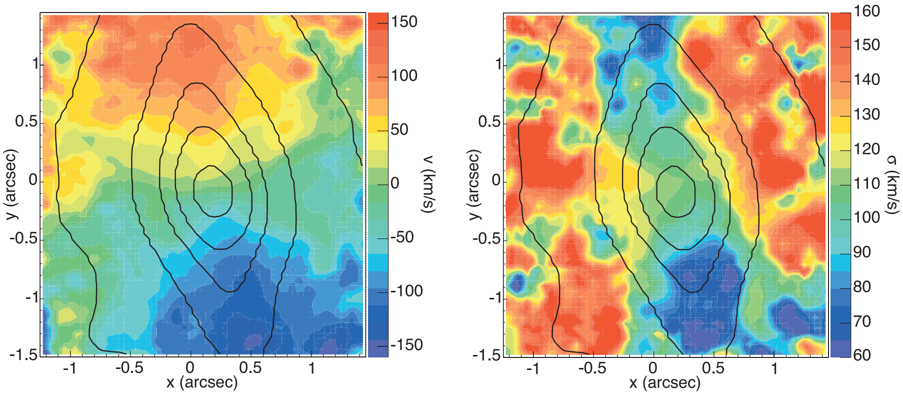
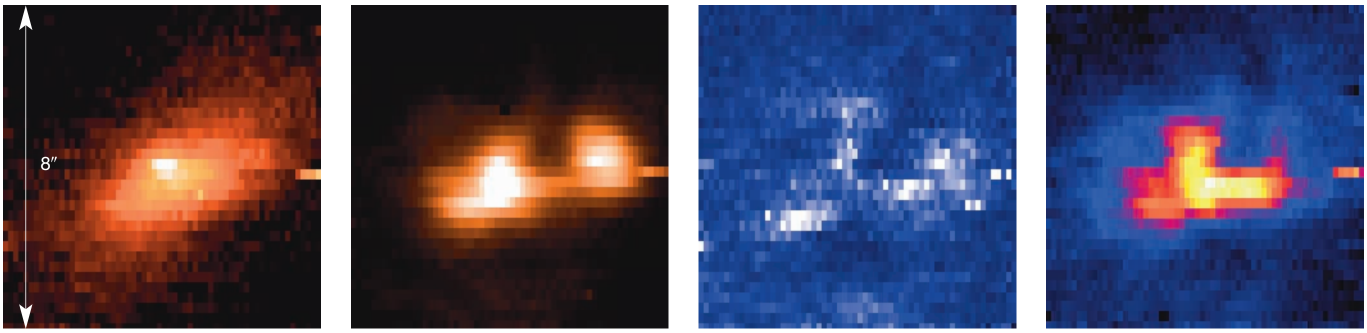


Figure 7 (left): SINFONI measurements of NGC 4486a based on a combination of fourteen 600s exposures. The stellar velocity map (left) and the velocity dispersion map (right) show a regular rotation pattern and a cold disc inside a hotter bulge component. Isophotes are overlaid for reference.

Figure 8 (below): The starburst galaxy He2-10 as seen with SINFONI. From left to right: Integrated *K*-Band image, Bracket-γ linemap (tracing the youngest stars), H_2 linemap and Fe II linemap (tracing supernova remnants).



Supermassive black holes in galaxies (GTO, Nowak)

Every galaxy with a massive bulge component probably hosts a supermassive black hole whose mass follows the mass-velocity dispersion relation and amounts to ~ 0.15 % of the bulge mass. The MPE GTO programme on supermassive black holes aims at an investigation of whether these correlations remain valid when galaxies with pseudobulges, very low-mass bulges or bulgeless galaxies are considered. SINFONI is ideally suited for this task because it allows one to resolve the innermost dust-obscured regions of disc galaxies. So far SINFONI obtained *K*-band data cubes in the 0.1″ pixel scale of the low luminosity elliptical NGC 4486a, a neighbour galaxy of M87, and the Sd galaxy NGC 3137, both at a distance of ~ 16 Mpc. Preliminary results of NGC 4486a are shown in Figure 7. HST images already revealed that this galaxy has an almost edge-on nuclear disc with a dust lane. With the SINFONI data this can now be verified kinematically. The spectra show no emission lines but strong CO absorption bands which were used to determine the stellar kinematics of the galaxy. The resulting velocity and velocity dispersion maps show a regular rotation pattern and a cold disc with a velocity dispersion of ~ 115 km/s in the centre, which decreases along the major axis. Outside the disc in the bulge the velocity dispersion is overall larger. The dust lane cannot be seen in the *K*-band image, but it can be uncovered by unsharp masking. To constrain the central black-hole mass the stellar kinematics will be modelled using a fully general axisymmetric orbit superposition code.

The starburst galaxy He2-10 (GTO, van der Werf)

SINFONI is an ideal instrument for studying starburst galaxies. These objects are generally obscured, making it necessary to go to the near-infrared, which luckily contains a number of highly diagnostic features, such as Bracket-γ (tracing the youngest stars) and [Fe II] 1.64 µm (tracing supernova remnants). SINFONI was used to obtain full JHK-band datacubes of the nearby starburst dwarf galaxy He2-10, with only 10 minutes integration time on-source per wavelength band with the 0.25″ pixel scale (see Figure 8). The *K*-band continuum reveals a fairly featureless object, dominated by a bright core which is known to host a number of bright star clusters, as shown by HST imaging. The image of Bracket-γ is strikingly different: two cores appear, one of which is close to (but not coincident with) the *K*-band core. This image is remarkably similar to the 10 µm emission as observed with VISIR, but differs strongly from the optical HST image, underlining the fact that the youngest star clusters are optically obscured. The [Fe II] image is different again, showing a slightly older starburst population which allows the progression of the starburst to be followed spatially and temporally. Finally, faint H_2 emission is seen to trace mostly the outskirts of the ionized gas as seen in Bracket-γ. Given the different morpholo-

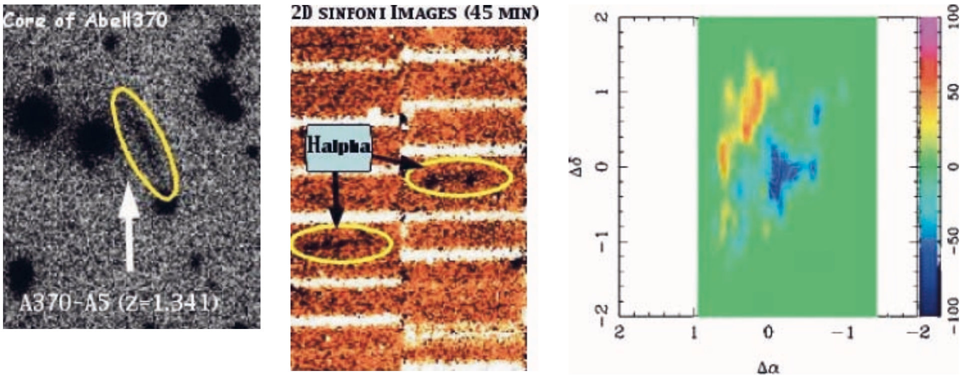


Figure 9: **Left:** A CFHT-I band image of the target: A370-A5; **Middle:** The SINFONI 2D negative image of the detection of the H-α emission line; **Right:** The H-α velocity map in km/s obtained by fitting the emission line of each spectrum to a single gaussian function after correction of the lensing effect.

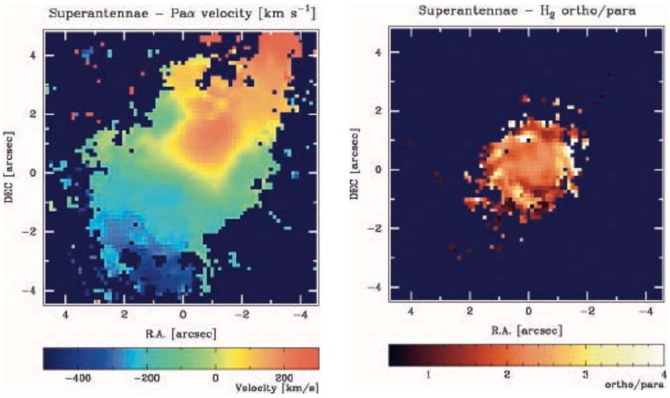


Figure 10: **Left:** Smooth velocity field of the "Superantennae" as traced by Paschen-α. **Right:** Ortho/para ratio map of the galaxy, showing an intriguing spiral structure.

gies of these tracers it is clear that simple slit spectroscopy would not have given a complete picture of the starburst; for a complete inventory an integral-field spectrograph such as SINFONI is required.

The mass and star formation of high-redshift lensed galaxies (SV, Lemoine-Busserolle)

The study of the physical properties of high-redshift galaxies has become one of the major goals of extragalactic astronomy. In particular the mass-assembly histories of galaxies have been the focus of many studies at redshifts 1 to 3 (see above). SINFONI has been used to obtain 2D velocity maps from the H-α emission line of a star-forming lensed galaxy ($z = 1.341$), behind the core of the massive galaxy cluster Abell 370. The natural magnification allows one to spatially resolve and constrain the dynamics of young star-forming galaxies 1 to 3 magnitudes fainter than those selected in blank fields. Thus, the study of lensed galaxies allows one to probe a low-mass regime of galaxies not accessible in standard observations. In this particular case (Figure 9), a rotation of 110 km/s in a disc-like geometry was measured for A370-A5.

Stellar population and kinematic properties of ULRIGS and Seyfert galaxies (SV, Ivanov)

One of SINFONI's early science cases was ultraluminous infrared Galaxies (ULIRGs) in the nearby universe. Observations were obtained for the ULIRG/Seyfert-2 galaxy IRAS 19254-7245, best known for its 350-kpc antennae, providing the galaxy a well-earned nickname "the Superantennae". Kinematics were derived from ionized and molecular gas tracers. Paschen-α was detected over much of the field of view (Figure 10, left). Surprisingly, the velocity field is relatively smooth for such a merging system. The kinematics of other emission lines, notably various H_2 lines, are similar but not identical. Furthermore, different H_2 emission lines also exhibit significant variations in their velocity fields, reflecting changes in excitation temperature and mechanism.

Both the H_2 emission-line ratios and the ortho/para ratio (Figure 10, right) rule out the UV fluorescence as the dominant excitation mechanism for the molecular hydrogen at the nucleus, despite the on-going starburst evident in Paschen-α emission. Intriguingly, there appears to be spiral structure present in the ortho/para map. Part of this structure is also visible in the Paschen-α/H_2 ratio map, so these regions are likely to be star-forming knots with higher-density molecular gas than in the surrounding areas. Based on the line ratios, the molecular hydrogen in the Superantennae appears to be dominantly shock-excited.

Supernova 1987A (SV, Spyromilio)

SN 1987A is located in the Large Magellanic Cloud and thus close enough to study its transition to a supernova remnant. Currently the pre-explosion circumstellar ring is hit by the ejecta from the supernova itself and disintegrated. With SINFONI, the ring can be spatially resolved and information about the shock processes in the different parts of the ring can be obtained. The collapsed image of the supernova ring (lower-right panel of Figure 11) reveals interesting facts of this system. The flux is very asymmetric across the ring, which is due to the inclination and light travel time. It could possibly also indicate asymmetry of the supernova explosion. Further, the data cube clearly reveals velocity dispersions of roughly 70 km/s between the two regions marked with circles on the collapsed image. Comparing the full spectra of the different bands (*J*, *H* and *K*) from spatially different regions provides a thorough account of the shock interactions taking place. As the system is changing on a timescale of ~ 0.5 yr this interaction can be followed as it evolves.

Constraining the Galactic structure with stellar clusters in obscured HII regions (SV, Messineo)

Galactic HII regions are good tracers of spiral arms. However, their distances are often poorly constrained and based only on radial velocities from gas. SINFONI can be used to improve the understanding of the spatial distribution of such HII regions by observing obscured stellar clusters in them at *H*- and *K*-band. The simultaneous classification in spectral subclasses of early-type stars and the determination of extinction correction allows one to obtain spectrophotometric distances independent from the kinematic ones. SINFONI allows one to detect the HI recombination lines from the HII region itself (gas) as well as the spectrum of the candidate ionizing star. Thus, a proper decontamination is possible. SINFONI observations of one such

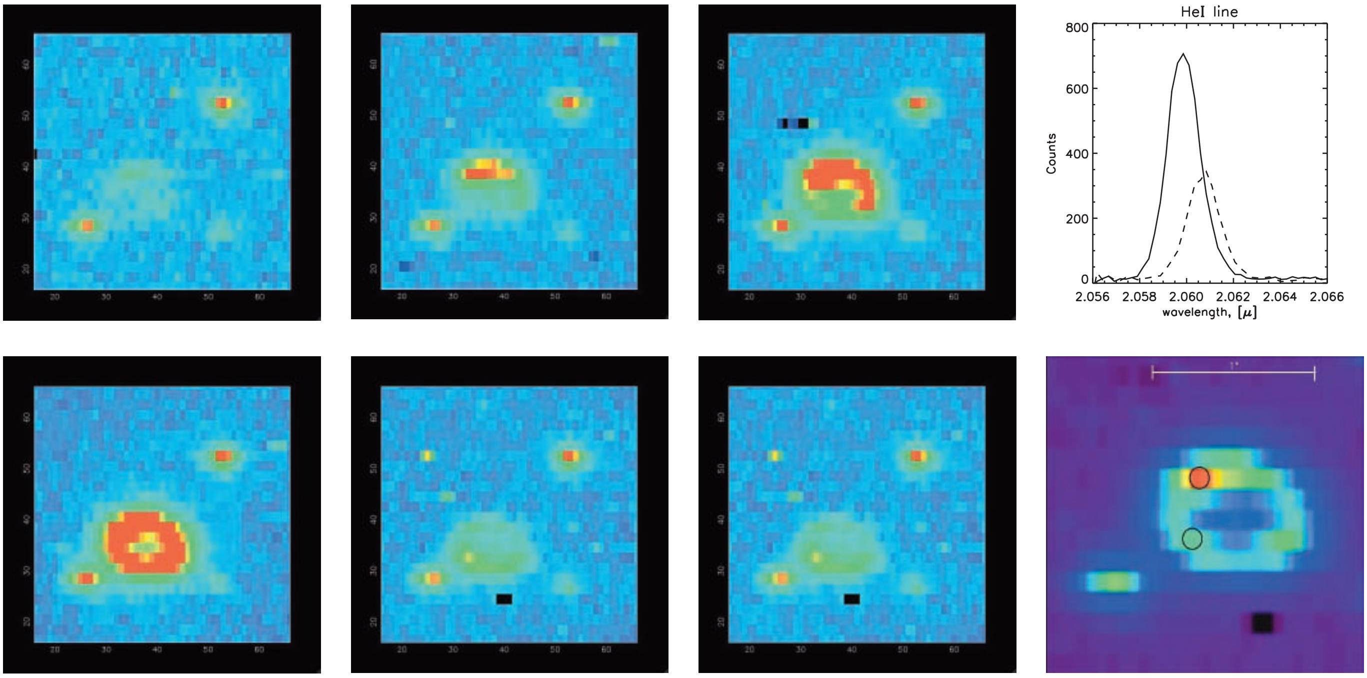


Figure 11: SN 1987A with SINFONI. **Left six frames:** different wavelengths in the data cube. The two red spots in the first frame are stars in the LMC. The green spot on the first frame is the first appearance of the HeI line (2.058 μm) when going through the cube from short to long wavelengths. Going further this line becomes visible in different places and with different strengths. The velocity difference of 70 km/s is apparent when the green spot in the first frame (full line) and the yellow spot on the last frame (dashed line) are plotted (top right). **Bottom right:** collapsed image from 2.057 to 2.063 μm.

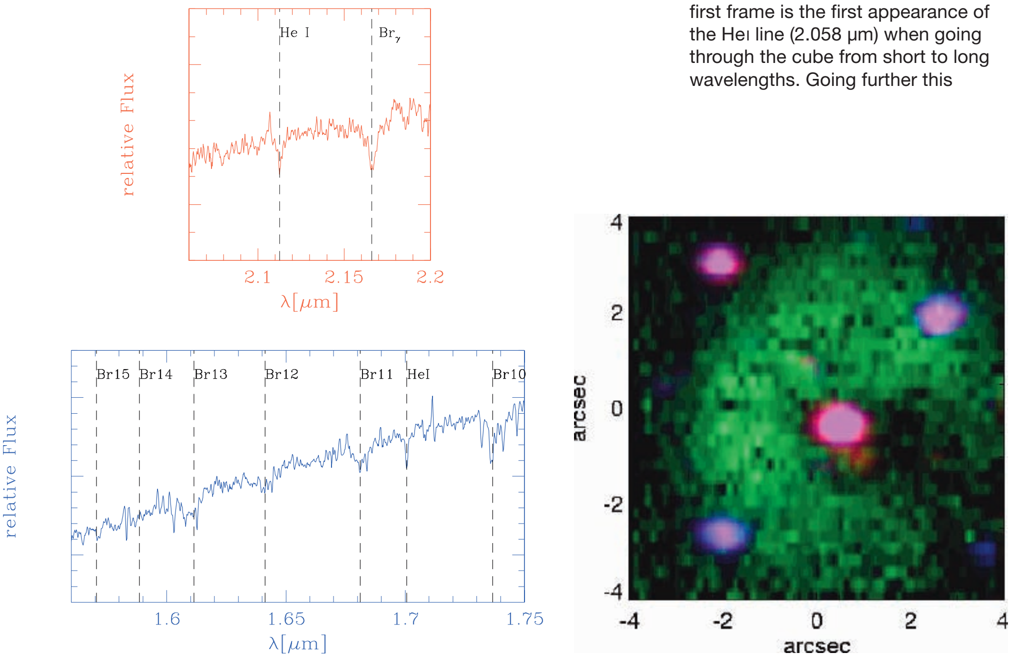


Figure 12: Right: Three-colour image of a Galactic stellar cluster at (l, b = 234.64 deg, 0.83 deg). *H*-band is in blue, Bracket gamma in green and *K*-band in red. The cluster centre is resolved and four bright stars are detected in both *H*- and *K*-band. The central star is surrounded by a nebula. **Left:** *H*- and *K*-Spectra of the central star.

cluster are shown in Figure 12. From a first comparision with a near-infrared spectroscopic atlas the spectral type of the ionizing star falls in the O9-B1 category, using the HeI and H absorption lines and the Bracket-gamma nebular emission. Apparent *H* and *K* magnitudes were also derived from the SINFONI data cube with an accuracy of 0.1 mag. Assuming a spectral type (i.e. absolute *K* magnitude and *H-K* colour) one can derive the extinction and the distance to the HII region.

Formation of a massive proto-star through disc accretion of gas: Discovery of an H_2 jet associated with the M17 silhouette (SV, Nuernberger)

The basic processes leading to the formation of high-mass stars are still a big mystery. On the one hand, they may accumulate their mass by accretion of large amounts of gas and dust through their circumstellar envelopes or discs. On the other hand, they may emanate from collisions of protostars of lower masses in the very centres of dense and massive starburst clusters. AO supported integral-field spectroscopy of the M17 silhouette disc hosting a massive protostar was performed using SINFONI (Figure 13, next page). The silhouette disc is seen almost edge-on and the diameter of its innermost densest part is more than 4 000 AU. The flared, wing-like appearance might result either from the slight inclination of the disc plane against the line-of-sight or from the external pressure which is exerted on the disc surface by ionizing photons and strong winds originating from the nearby main-sequence OB stars of the M17 cluster. The images produced from the

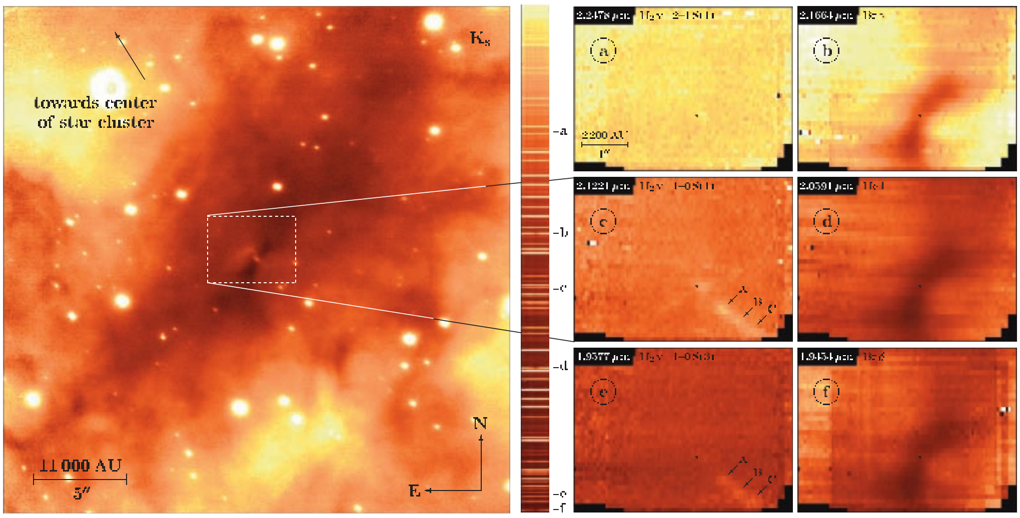


Figure 13: **Left:** NACO K_s-band image of the M17 silhouette disc, showing a field of view of roughly 60 000 AU. Dashed box: The area of the SINFONI SV study. **Centre:** *K*-band spectrum for a horizontal cut through the absorption maximum of the south-eastern part of the disc. Markers a-f denote wavelengths at which images have been extracted. **Right:** Images a-f together with the wavelengths and the most likely atomic/molecular lines. The position of the suspected protostellar source(s) at the disc centre is indicated by a cross. In panels c and e the knots of the H_2 jet are labeled with A, B and C.

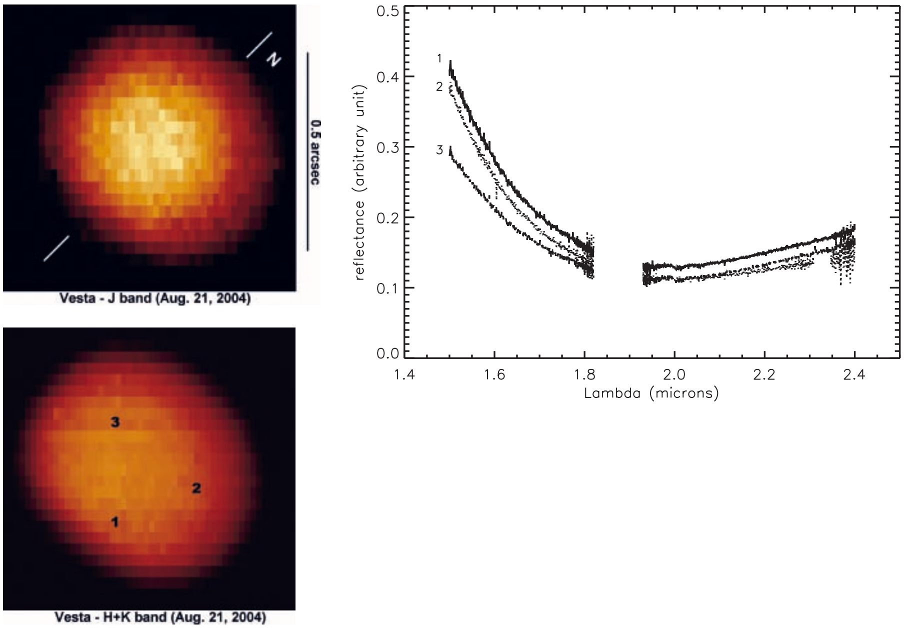


Figure 14: **Left:** Reconstructed images of Vesta obtained in bands *J* and *H+K* during the SV run of August 2004 (25 mas/pix scale). N indicates Vesta's North Pole. **Right:** Variations in the bands of pyroxenes for different locations on the surface of Vesta.

H_2 emission clearly reveal three knots of a jet. Shocks are the most likely excitation mechanism. No counter jet is seen on the other side of the disc. The SINFONI data add an important piece to the puzzle of this truly interesting source. Because ejection of material through a jet-like outflow is always linked to accretion of gas and dust either onto the circumstellar disc or onto the central protostellar source(s), the presence of the H_2 jet provides indirect evidence for ongoing accretion processes.

Near-infrared compositional mapping of small solar-system bodies (SV, Dumas)

The solar system is another domain of application for SINFONI. The instrument capability is used at its best on slightly extended objects (~ 1″), for which MACAO enables the compositional study of their fine spatial structures. The asteroid Vesta (rotation period ~ 5.3 h) displayed a 0.5″ diameter during the August and October 2004 runs (Figure 14), and its brightness (V ~ 6) provided a case for high-Strehl performances for the AO. Furthermore, with an aspect angle of ~ 90 degrees at that time, the geometry of the opposition was particularly favourable to carry out a detailed mineralogical study of both hemispheres of Vesta. Vesta displays the second largest albedo variation between opposite hemispheres (after Iapetus). Its disc integrated spectrum links the asteroid to the HED (howardites, eucrites, diogenites) meteorites and Vesta could be the main source of these types of meteorites. Vesta is the sole intact asteroid that may have undergone complete planetary-style differentiation. Eucrites and diogenites formed from magmas produced inside the asteroid and migrated toward the surface. Together with the material in between (the howardites) their spatial distribution on Vesta will help to understand what occurred at an early stage of formation of what can be considered the smallest known terrestrial planet. HST images of Vesta obtained by Thomas 1997 revealed a large impact crater in the south which has excavated the surface material to reveal the internal composition of the asteroid. This is a unique terrain to explore the composition of Vesta's mantle. The J and H+K gratings of SINFONI were used to spectroscopically map, at several rotational phases, the surface of Vesta across the 1–2.4 µm region of the spectrum. At these wavelengths, the reflectance spectrum of Vesta is modulated by the absorption bands of pyroxene, feldspar and olivine. By quantifying the spatial distribution of eucrites and diogenites at an unequalled spatial resolution, and measuring the abundance of olivine-rich regions excavated from below the crust, one expects to better understand to which degree Vesta's interior melted soon after its formation.

References

Bonnet, H. et al. 2003, Proc. SPIE 4839, 329
Davies, R., Tacconi L., Genzel, R. 2004a, ApJ 602, 148
Davies, R., Tacconi L., Genzel, R. 2004b, ApJ 613, 781
Eisenhauer, F. et al. 2003, Proc. SPIE 4814, 1548
Eisenhauer, F. et al. 2005, ApJ, in press
Genzel, R. et al. 2003, ApJ 594, 812
Ghez, A. M. et al. 2003, ApJ 586, L127
Shapley, A. E. et al. 2004, ApJ 612, 108
Thomas et al. 1997, Science 277, 1492
Wada, K., Norman, C. 2002, ApJ 566, L21

Galaxy Cluster Archaeology[1]

With the discovery of an X-ray luminous cluster of galaxies at z = 1.4 we have extended the horizon for studies of well-evolved galaxy clusters to a look-back time of 9 Gyrs. This record-breaking cluster was detected as an extended X-ray source in an archival XMM-Newton observation during the pilot study phase of a search for distant clusters. This result, combined with additional newly-identified candidates from our programme, demonstrates the potential of the XMM-Newton archive to provide a substantial sample of very distant clusters for detailed cosmic evolution studies.

Hans Böhringer[1], Christopher Mullis[2], Piero Rosati[3], Georg Lamer[4], Rene Fassbender[1], Axel Schwope[4], Peter Schuecker[1]

[1]Max-Planck-Institut für Extraterrestrische Physik, Garching, Germany
[2]Department of Astronomy, University of Michigan, Ann Arbor, USA
[3]ESO, [4]Astrophysikalisches Institut, Potsdam, Germany

It is a unique feature of astronomy among all natural sciences that it provides us with a look into the past, thanks to the long light travel times involved in covering cosmic distances. Thus our fundamental curiosity for the origin of things that make up our world today can be satisfied in the "archaeology of astronomy" by direct observations of distant objects. Galaxy clusters as the largest, well-characterized objects play a special role in this study of cosmic origins. Firstly, they form an integral part of the large-scale matter distribution in the Universe, which on cluster scales ($\geq 10\ h_{70}^{-1}$ Mpc) is determined by the dynamics and geometry of the Universe, the growth of structures by gravitational instabilities, and the seeds of density fluctuations set during an early, probably inflationary epoch. The statistics of the galaxy cluster population is therefore a sensitive measure of the cosmological parameters, the nature of the Dark Matter, and the imprint of first structures from inflation (e.g. Borgani & Guzzo 2001). That is, galaxy clusters are important probes to test cosmological models.

Secondly, they form ideal cosmological laboratories for the study of a representative part of the Universe including coeval galaxy populations and an intergalactic medium, easily studied in X-rays. Much progress has already been made with the study of the present-day and intermediate-redshift galaxy cluster population. Just to mention three of the important lessons learned: The abundance and the spatial distribution of galaxy clusters clearly show that we live in a low-density Universe with a density parameter, $\Omega_m \sim 0.3$–0.4 (e.g. Schuecker et al. 2003). Most of the early-type galaxy population of the clusters we observe today has been in place already at redshift 1 and mostly experienced passive galaxy evolution since then (e.g. Holden et al. 2005). Galaxies make up only a minor fraction of the baryonic matter in the clusters and by implication in the Universe as a whole (e.g. White et al. 1993).

Galaxy clusters are late comers to the Universe, as expected in the well-established hierarchical structure formation scenario, in which smaller objects form first and larger mass aggregates are assembled subsequently. Within our well-supported cosmological framework we expect that massive clusters already exist out at redshifts above $z \sim 2$, and poor clusters and groups of galaxies should still be around at redshifts of 3. So far we have only explored the redshift range up to $z \sim 1$ and only few clusters are known at larger distances. Thus a largely uncharted and very promising territory still lies ahead of us.

What we now need is a method to efficiently detect and clearly characterize distant galaxy clusters including information on their mass and dynamical state. X-ray observations are found to provide by far the best tool for such studies: (i) since X-ray luminosity is tightly correlated to the gravitational mass (Reiprich & Böhringer 2002), (ii) because bright X-ray emission is only observed when the cluster is well evolved showing a very deep gravitational potential well, (iii) because the X-ray emission is highly peaked and thus projection effects are minimized, and (iv) since massive clusters are still well observed at high redshifts (while the individual galaxies disappear more and more into the dense galaxy background with increasing distance, the collective X-ray light of the whole cluster still stands out). The power of X-ray observations is revealed by comparison to pure optical searches. With X-ray observations one selects preferentially well-collapsed and nearly-relaxed structures resembling the dark matter halos modeled by theoreticians, while optical searches also pick looser structures. When for example the distant $z \sim 1$ clusters found in the Red Sequence Survey conducted by Mike Gladders, Howard Yee and colleagues (Gladders & Yee 2000, 2004) are followed-up with *Chandra* X-ray observations, they find less X-ray luminous clusters than they expected for the observed optical richness (Hicks et al. 2004).

The largest success in finding distant evolved galaxy clusters has so far been achieved with the *ROSAT* Deep Cluster Survey (RDCS) led by Piero Rosati which provided four well-evolved galaxy clusters with redshifts above $z > 1$ (Rosati et al. 2002). This survey was based on the search for galaxy clusters as extended X-ray sources in archival *ROSAT* pointed observations. Now a much more powerful archive of X-ray observations collected with ESA's *XMM-Newton* observatory is at our disposal. *XMM-Newton* provides more than an order of magnitude more photon-collecting power, has a wider X-ray energy window and images the objects with three times better angular resolution than the *ROSAT* PSPC detector used for the RDCS.

With the above goals in mind we have started a pilot study to explore the prospects of an *XMM*-based survey. We now have the very first results which already provide a breakthrough discovery of the most distant, yet well-evolved X-ray-luminous cluster at $z = 1.393$ (ESO press release 04/2005; Mullis et al. 2005). Encouraged by this success and the proof of our concept, we are embarking on a comprehensive search project. Here we

[1] Based on observations with *XMM-Newton*, an ESA science mission with instruments and contributions directly funded by ESA member states and NASA, together with extensive follow-up observations with the ESO VLT.

report on our survey strategy and on the discovery of the most distant evolved galaxy cluster.

Survey Strategy

Our search for distant galaxy clusters starts with X-ray observations from the *XMM-Newton* data archive, from where we select the best fields with clean exposure times above 10 ksec, outside the band of the Milky Way and the Magellanic Clouds, and without large-scale X-ray sources which blind the field of view. Essentially all extended X-ray sources at high galactic latitudes ($|b_{II}| \geq 20$ deg) are galaxy clusters. Therefore we apply a source detection algorithm that screens the data for extended sources. With *XMM-Newton's* angular resolution (~ 8 arcsec half-power radius, ~ 64–68 h_{70}^{-1} kpc at $z = 1.0$–1.5) we are still able to well separate distant clusters from X-ray point sources given enough X-ray signal. Figure 1 shows for example the X-ray source detection for the discovered distant cluster in the field of the *XMM-Newton* observation of the Seyfert galaxy NGC 7314. Extensive tests have shown that typically 80 source photons are enough to establish a source extent which brings us to a median survey flux limit of ~ 10^{-14} erg s^{-1} cm^{-2}, about a factor of three deeper than the typical flux limit of the deepest *ROSAT*-based searches. For these flux limits we expect about 1 cluster with $z \geq 1$ and about 2.5 clusters with $z \geq 0.8$ per deg^2 (Figure 9).

The next step is a careful screening of the extended sources to look for nearby cluster counterparts in the public Digitized Sky Survey (DSS) images, data from the ESO and other public archives, and information in the literature and public data bases for previous identifications. We want to clearly focus this project on distant clusters. Figure 2 illustrates that clusters up to redshifts of 0.5 can be recognized as counterparts of X-ray sources in the second-epoch DSS images. This allows us a very efficient removal of the nearby clusters from our candidate list. More distant clusters will show blank fields in observations at these depths and they enter our candidate list for the first optical follow-up observations.

As the most efficient way to proceed, we decided to make use of the very high red-sensitivity of FORS-2 at the ESO-VLT to take snapshot images of these candidates in the R (16–19 min) and in the z (8 min) bands which not only allows us to detect distant cluster galaxies out to redshifts of at least $z = 1.4$ but also to get a photometric redshift estimate (Gladders & Yee 2000). The R&z filter combination traces the cluster distances very effectively because its brackets the 4 000 Å break in the relevant redshift regime. With the given flux limit of our survey we hardly expect to find clusters above redshifts of $z \sim 1.5$ (Figure 9). Therefore the sensitivity limit of FORS2 R and z band imaging in detecting high z cluster galaxies is well matched to our survey. Results of the red-sequence cluster detection and redshift estimate are shown in Figures 3 and 4 and will be illustrated further in the next section. With an overhead of an estimated 4–6 red sequence snapshot observations to find one $z \sim 1$ cluster candidate and a total "snap shot observing time" (including overheads) of 30 min, we arrive at an economic way of establishing good candidates of redshift $z > 0.8$ clusters, so as to be as complete as possible for our $z \geq 1$ survey.

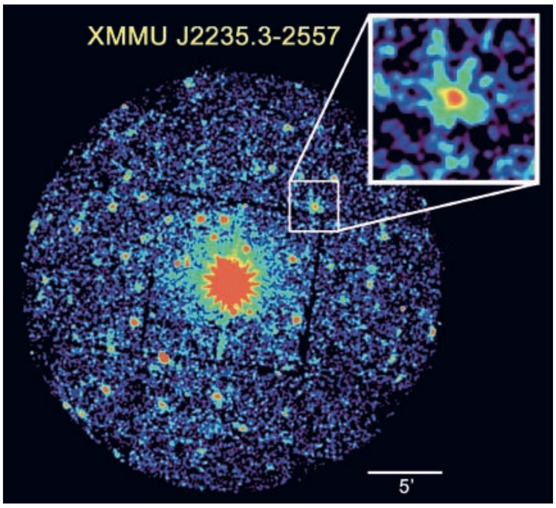


Figure 1: *XMM-Newton* image targeting NGC 7314 in which the distant cluster XMMU J2235.3-2557 (2.8′ × 2.8′ inset) was newly discovered as an extended X-ray source.

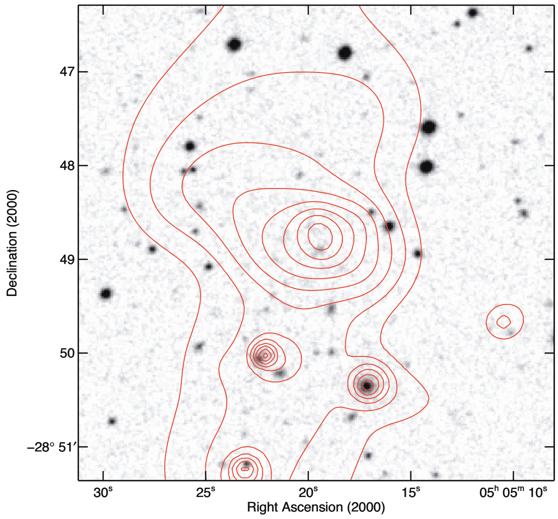


Figure 2: Example of a cluster candidate flagged by our analysis of archival *XMM-Newton* observations. X-ray contours (0.5–2 keV) are overlaid on a DSS optical image. The previously known cluster (z = 0.509) is clearly detected on this image.

The distant cluster XMMU J2235.3-2557

The detection technique with which XMMU J2235.3-2557 was selected as a distant cluster candidate is illustrated in Figure 3. The red-sequence colour, $R - z = 2.1$, gives a redshift estimate of $z \sim 1.4$. Thus far only this best distant cluster candidate from the 9 deg^2 pilot study was observed spectroscopically. It has proven to be well selected and turns out to be by far the most distant X-ray cluster observed so far with a redshift of $z = 1.393$ established by 12 concordant galaxy redshifts (Figures 5 and 6; Mullis et al. 2005)[2]. In the *XMM-Newton* observation ~ 280 source photons were recorded which allows for a good flux measurement, a rough X-ray image of the cluster (Figure 5) and a rough X-ray spectrum. The fairly compact, centrally peaked X-ray morphology, the high X-ray luminosity of $L_X = (3.0 \pm 0.2)\ 10^{44}\ h_{70}^{-2}$ erg s^{-1} in the 0.5 to 2 keV band, and the temperature estimate of $T_X \sim 6^{+2.5}_{-1.8}$ keV mark XMMU J2235.3-2557 as a well-collapsed, massive cluster of galaxies whose mass is probably around $3\ 10^{14}\ h_{70}^{-1}\ M_{\odot}$ (Mullis et al. 2005). With these properties the cluster falls close to the L_X-T_X relation established for other high redshift clusters (Rosati et al. 2002). The velocity dispersion of the cluster indicated by the 12 redshifts, $\sigma_g = 762 \pm 265$ km s^{-1}, is also consistent with other global parameters. Another sign that the cluster is a well-settled object,

2 The discovery of even more distant clusters has repeatedly been reported (e.g. Ouchi et al. 2005). These structures are not expected and have not been shown to be collapsed, nearly virialized objects as the galaxy clusters observed in X-rays to which we refer. Therefore they are most likely protoclusters, loose structures that are bound to collapse at intermediate redshifts and form the clusters that we observe today.

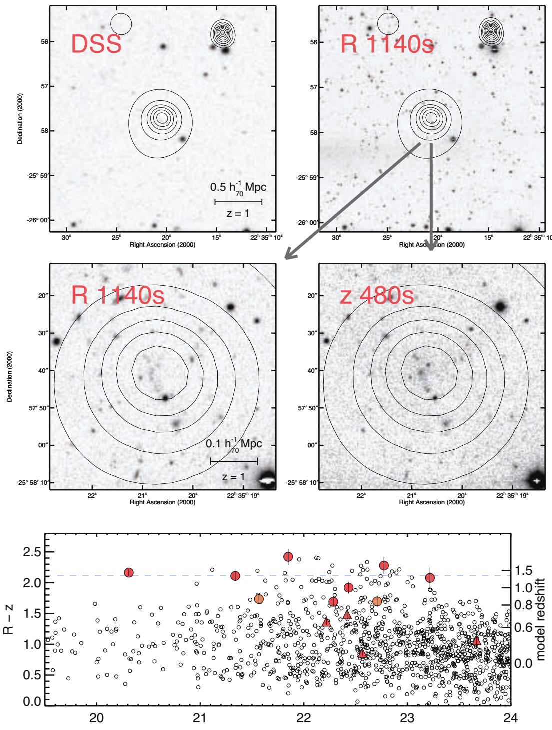


Figure 3 (left): Red-sequence detection technique applied to the cluster XMMU J2235.3-2557 at $z = 1.39$. **Top:** X-ray flux contours overlaid on the DSS and FORS2 R (1140s) and z (480s) band images. The distant cluster is clearly extended in X-rays and lacks an optical counterpart in the DSS image. **Bottom:** Colour-magnitude diagram of the 7′ × 7′ cluster centered field (AB magnitudes). Spectroscopically confirmed cluster galaxies at $1.38 < z < 1.40$ are marked in red and $1.37 < z < 1.38$ in orange. The location of the cluster red sequence calibrated by reasonable galaxy evolution models indicates a cluster redshift significantly beyond $z = 1$.

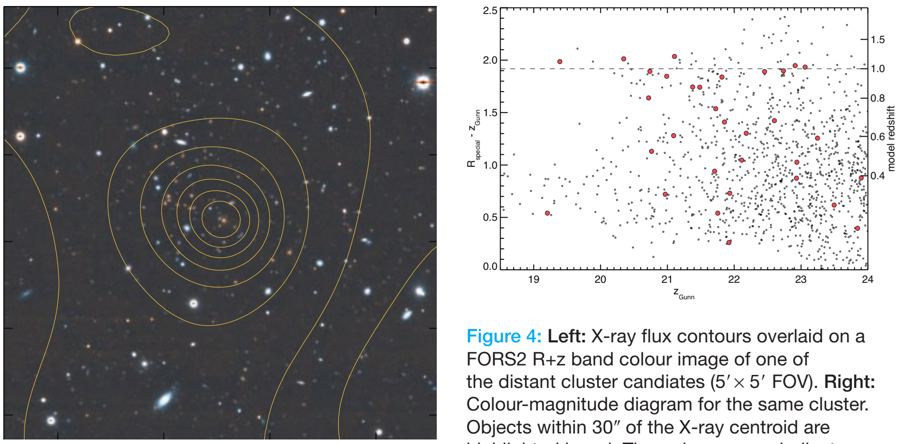


Figure 4: Left: X-ray flux contours overlaid on a FORS2 R+z band colour image of one of the distant cluster candiates (5′ × 5′ FOV). **Right:** Colour-magnitude diagram for the same cluster. Objects within 30″ of the X-ray centroid are highlighted in red. The red sequence indicates a redshift of $z \sim 1$ (horizontal line).

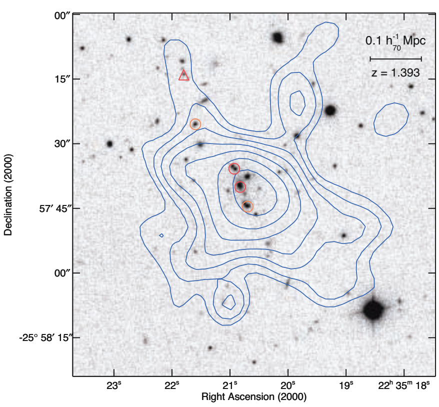


Figure 5: VLT ISAAC *K*-band image of XMMU J2235.3-2557 overlaid with X-ray contours (0.5 to 2 keV). Spectroscopically confirmed cluster members at $1.38 < z < 1.40$ are marked in red and $1.37 < z < 1.38$ in orange. Additional spectroscopically confirmed galaxy members lie outside this FOV. (Mullis et al. 2005).

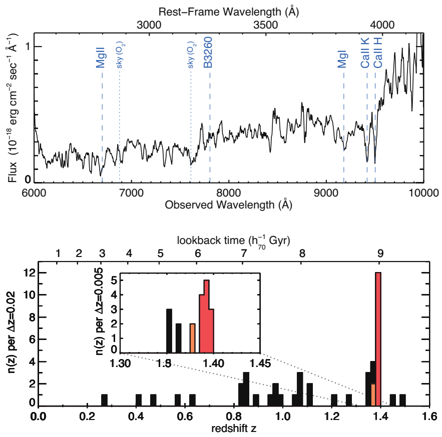


Figure 6: Top: FORS2 spectrum of the brightest cluster galaxy with $z = 1.3943 \pm 0.0003$ obtained with 4hr integration. **Bottom:** Histogram of galaxy redshifts measured in the FORS2 MXU observation in a region of 7′ × 7′ around the cluster centre of XMMU J2235.3-2557 (Mullis et al. 2005).

is a central dominant galaxy very close to the X-ray maximum (offset 3.7″, $31 h_{70}^{-1}$ kpc) which marks presumably the gravitational centre of the cluster.

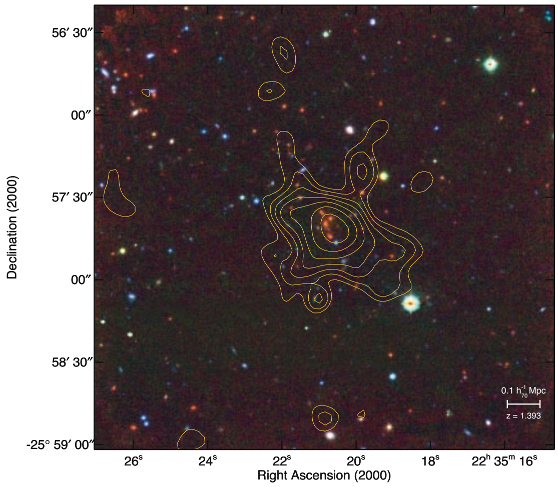
We also secured observations of this cluster with VLT-ISAAC in the K_s-band (3 600 sec) through director's discretionary observing time in December 2004. A composite colour image of the cluster is shown in Figure 7 (see next page). Overall the galaxies identified as spectroscopic cluster members show very red colours, implying that these galaxies are observed to be already old even at these large look-back times. Assuming that the cluster galaxies form at a redshift of 3 and then evolve passively to the observed redshift (e.g. Daddi et al. 2000) approximately explains the observed colour distribution (Rosati et al., in preparation).

With its high redshift, this cluster provides a look-back time of 9 Gyrs, 0.5 Gyrs more than with the previously most distant cluster RDCS 1252-29 ($z = 1.24$). Figure 8 (see next page) illustrates the increasing horizon in our X-ray galaxy cluster studies. It is remarkable that at these redshifts we still observe a cluster galaxy population that is well aged and shows a pronounced red sequence in the colour-magnitude diagram. It allows us to characterize galaxy populations for the first time in high-density environments at the largest look-back times accessible to date. There are more, urgent questions we want to address with a laboratory at this large look-back time, such as: do we still find a lot of Fe in the intracluster medium as observed in X-rays in more nearby clusters? Are clusters more compact with increasing redshifts as predicted by structure-formation models? We are confident, that deep observations with *VLT ISAAC*, *SPITZER*, *HST*, *Chandra*, and *XMM-Newton*, that we have proposed, will bring us much closer to answering these questions.

Prospects for a Comprehensive Survey

Any general conclusions on cosmic evolution from observations of distant clusters cannot be based on a single cluster, but have to be drawn from a statistical analysis of the evolution of the whole galaxy cluster population. Therefore it is important to obtain a sizable, statistically defined sample of objects in the high-redshift range. Because clusters are rare objects in the Universe, large search volumes are required. To conduct a large enough dedicated survey with expensive, medium-field-of-view X-ray space observatories like *XMM-Newton* (FoV = 26′ × 27′) becomes almost prohibitive. Therefore the search for distant clusters becomes a typical application of the data accumulating in the *XMM-Newton* archive, which provides a total survey area unrivaled by any dedicated project.[3]

3 The XMM-LSS collaboration led by M. Pierre is conducting a medium-sized XMM-Newton survey for galaxy clusters (e.g. Pierre et al. 2004).



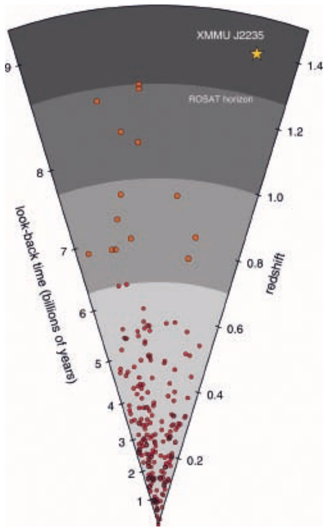
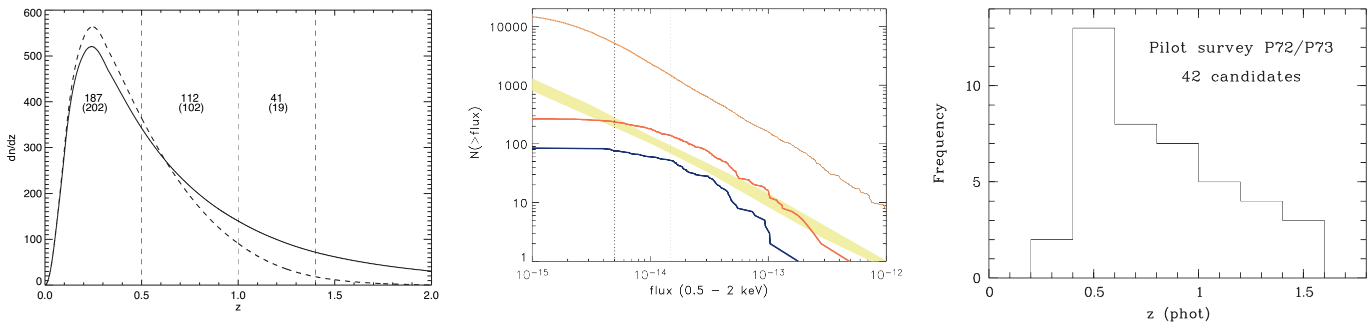


Figure 8 (left): Cone diagram illustrating the reach of ROSAT in the search for distant clusters in comparison to the new window opened by *XMM-Newton*. Redshift is marked on the right and the corresponding cosmic look-back time on the left axis. The ROSAT clusters shown are those from the RDCS and the 160 deg^2 surveys (Rosati et al. 2002, Vikhlinin et al. 1998). The newly discovered cluster at z = 1.4 illuminates a remote regime well beyond the ROSAT horizon.

Figure 7 (above): Composite colour image of XMMU J2335.3-2557 overlaid with X-ray contours. The red channel is an ISAAC K_s-band image (3 600s), the green channel a FORS2 z-band image (480s) and the blue channel a FORS2 R-band image (1 140s) (Mullis et al. 2005).

Figure 9 (below): **Left:** Expectations for the cluster detections as a function of redshift for a 14 deg^2 survey as calculated on the basis of the RDCS and 160 deg^2 surveys (Rosati et al. 2002, Mullis et al. 2004). The solid line gives the expectations for no evolution and the dashed line the more realistic predictions including the estimated evolutionary effects. **Middle:** Number counts as a function of detected flux in the best screened 12 deg^2 survey region: all detected X-ray sources (upper, orange line), all clearly extended sources (middle, red line), distant cluster candidates (lower, blue line). The yellow band indicates the logNlogS curve derived by Rosati et al. (2002) from the RDCS. **Right:** Distribution of the estimated photometric redshifts of the candidates from our pilot study.



Our goal in the present approach is to find at least 50 galaxy clusters at $z \geq 1$. A sample of at least this size is necessary to construct well-defined distribution functions, like the X-ray luminosity function, for comparison with lower redshift samples, to cover a range of X-ray luminosities and morphologies to look for trends in the relation of the galaxy population with cluster mass and dynamical state, and to have a good enough statistical basis to constrain cosmological models (e.g. Haiman et al. 2001). With the statistics shown in Figure 9 this requires a search in a sky area of at least 50 deg^2 and comprises the search in about 500–600 deep *XMM-Newton* exposures (see also Romer et al. 2001). This amount of data already exists in the archive and has been screened by us (Schwope et al. 2004).[4] Figure 9 shows the results from a very careful screening of ~ 25 % of this survey area in the form of a logNlogS number counts diagram. The results show that we have slightly more candidates in the flux regime above 10^{-14} erg s^{-1} cm^{-2} than predicted promising a high completeness of the sample with some room for an unavoidable contamination fraction.

In summary the prospects for this survey look very promising. Even though the project is very ambitious, the expenses are still moderate. We have demonstrated that the VLT-FORS2 instrument can very efficiently be used to detect galaxy clusters out to redshifts of $z \sim 1.4$ and to obtain a first redshift estimate with short imaging exposures. With this rapid way to select the high z candidates we can clearly focus our project on the most distant clusters. We only include candidates with photometric redshifts of $z \geq 0.8$ to be complete at $z \geq 1$ and thus limit the more expensive spectroscopic observations to a minimum. To achieve the final goal of this project of finding at least 50 $z \geq 1$ clusters we will also make use of observations in the northern sky at other observatories. However, the very efficient detection method described here which builds on the special properties of the VLT-FORS2 instrument, will be unrivaled and the project conducted at the ESO VLT will remain the important core of this project.

4 In the coming three years there should even be enough observations for a survey covering more than 100 deg^2. A similar survey is also possible with *Chandra* but the larger field of view and larger photon collecting power of *XMM-Newton* makes this observatory the prime choice.

References

Borgani, S. & Guzzo, L. 2001, Nature 409, 309
Daddi, E., Cimmati, A., Renzini, A. 2000, A&A 362, L45
Gladders, M. & Yee, H. 2000, AJ 120, 2148;
Gladders, M. & Yee, H. 2005, ApJS 157, 1
Haiman, Z., Mohr, J. J., Holder, G. P. 2001, ApJ 553, 545
Hicks, A., Ellingson, E., Bautz, M., Yee, H., Gladders, M., Garmire, G. 2004, astro-ph/0410167
Holden, B. P., van der Wel, A., Franx, M., Illingworth, G. D., Blakeslee, J. P., van Dokkum, P., Ford, H., Magee, D., Postman, M., Rix, H.-W., Rosati, P. 2005, ApJ 620, 83
Mullis, C. R., Vikhlinin, A., Henry, J. P., Forman, W., Gioia, I. M., Hornstrup, A., Jones, C., McNamara, B. R., Quintana, H. 2004, ApJ 607, 175
Mullis, C. R., Rosati, P., Lamer, G., Böhringer, H., Schwope, A., Schuecker, P., Fassbender, R. 2005, ApJ 623, L85
Ouchi, M., Shimasaku, K., Akiyama, M., Sekiguchi, K., et al. 2005, ApJ 620, L1
Pierre, M., et al. 2004, J. Cosmol. Astropart. Phys. 2004, Sept. No. 11, 594
Reiprich, T. H., Böhringer, H. 2002, ApJ 567, 716
Romer, A. K., Viana, P. T. P., Liddle, A. R., Mann, R. G. 2001, ApJ 547, 594
Rosati, P., Borgani, S., Colin, N. 2002, ARA&A 40, 539
Schuecker, P., Caldwell, R. R., Böhringer, H., Collins, C. A., Guzzo, L., Weinberg, N. N., 2003, A&A 402, 53
Schwope, A., et al. 2004, Adv. Space Res 34, 2604
Vikhlinin, A., McNamara, B. R., Forman, W., Jones, C., Quintana, H., Hornstrup, A. 1998, ApJ 502, 558
White, S. D. M., Navarro, J. F., Evrard, A. E., Frenk, C. S. 1993, Nature 366, 429

The Horsehead nebula: a beautiful case

The Horsehead nebula has been a great source of speculation and inspiration for the last century. We give a brief discussion of why that is as well as summarizing our recent observations using SOFI on the NTT.

Emilie Habart[1,2], Malcolm Walmsley[2], Alain Abergel[1]

[1]Institut d'Astrophysique Spatiale, Orsay, France;
[2]Osservatorio Astrofisico di Arcetri, Firenze, Italy

A thing of beauty is a joy for ever it has been said and the Horsehead Nebula is a case in point. Poems have been written about it (see one of them by Lisa Odland, Figure 1) and its mysterious shape has clearly been an attraction for many. It has also been a puzzle for many astronomers ever since Herschel and those who followed him turned their attention to the nature of the nebulae. The characteristics of these objects became much clearer after it was possible to take photographs and in fact the discovery of the Horsehead can be said to go back to the 1880s when the photographic programmes in Harvard and elsewhere got started. It was based on this information that E. E. Barnard, J. C. Duncan and others exploited the new telescopes of the 20th century (mainly Mt. Wilson and Yerkes) and started really to understand the nature of the mysterious dark nebulae.

This was of fundamental importance for a number of reasons. Above all, the nature of the obscuring particles was critical for understanding the distance scale and the nature of our Milky Way. That was presumably one reason why Hubble was interested in the nature of the particles causing reflection nebulae. But another reason was to understand the nature of these clouds. Where did they come from and where were they going? And why were they partially in emission and partially dark? And were the dark areas due to holes or rifts in the nebulosity?

Barnard was already convinced in 1913 that the Horsehead (not then known as such) was due to a dark object projected against bright nebulosity (see Figure 1). He also noted that the west side is very well defined and sharp! We know now that this sharpness is due to the fact that the Horsehead is being irradiated by the UV radiation of the O9 star σ Ori half a degree (3.5 parsec) away to the west. Figure 2 shows a modern map of the CO emission which illustrates the situation. The Horsehead is clearly visible as part of the L 1630 molecular cloud. The UV radiation at wavelengths below 912 Å (the hydrogen ionization edge) ionizes and ablates the western edge gas and is thus slowly destroying the cloud. However, in the meantime, the edge lights up both due to the hot ionized gas streaming away and due to the dense neutral gas on the eastern side of the ionization front. This latter layer is compressed due to the effect of the ionization front and heated by UV radiation at wavelengths longward of 912 Å. This has the consequence that the neutral dense layers also emit strongly and thus the Horsehead, in addition to all its other properties, is a fascinating laboratory with which to study the physics of ionization fronts. In fact the edge of the Horsehead is an example of what has come to be known as a PDR or Photon Dominated Region where incident UV radiation from a hot star heats a dense neutral gas layer. Several teams around the world including the Meudon group led by Jacques Le Bourlot and Evelyne Roueff have developed sophisticated models of the structure of such dense neutral layers and part of our interest in the Horsehead has been to test such models. The edge of the Horsehead – a PDR viewed almost edge-on – allows us to follow *directly* the penetration of the far-UV radiation into the cloud.

Ah, to softly slip behind the scene,
One clear and snow-draped, silent winter night,
To pierce the density which seems to screen,
Obstruct the splendour of that cosmic light,
To pass beyond that dark and mystic cloud,
Which looms like portal in a garden wall,
The ancient loveliness within to shroud,
How it ones fancy does inspire, enthrall,
In that great starlit garden of the sky,
Where light eternal dwells in calm repose,
Who knows what beauty there might greet the eye,
What undreamed truth a brief glimpse there disclose,
As strange as thought, to thought there is no space,
At will, ones thoughts the universe may embrace.

Figure 1: The Horsehead is clearly visible in the plate from Barnard's 1913 article shown on the left. This or something like it was the inspiration for Lisa Odland's poem.

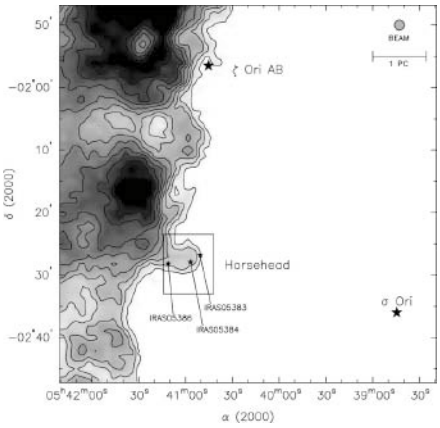


Figure 2: The exciting σ Ori O9 star is shown here on a large CO (1-0) integrated intensity of part of the L 1630 molecular cloud made with the Bell Labs 7-m telescope. The Horsehead is seen as an emission region extended out to the west. Note the presence of a young protostar IRAS 05383 embedded in the Horses crest.

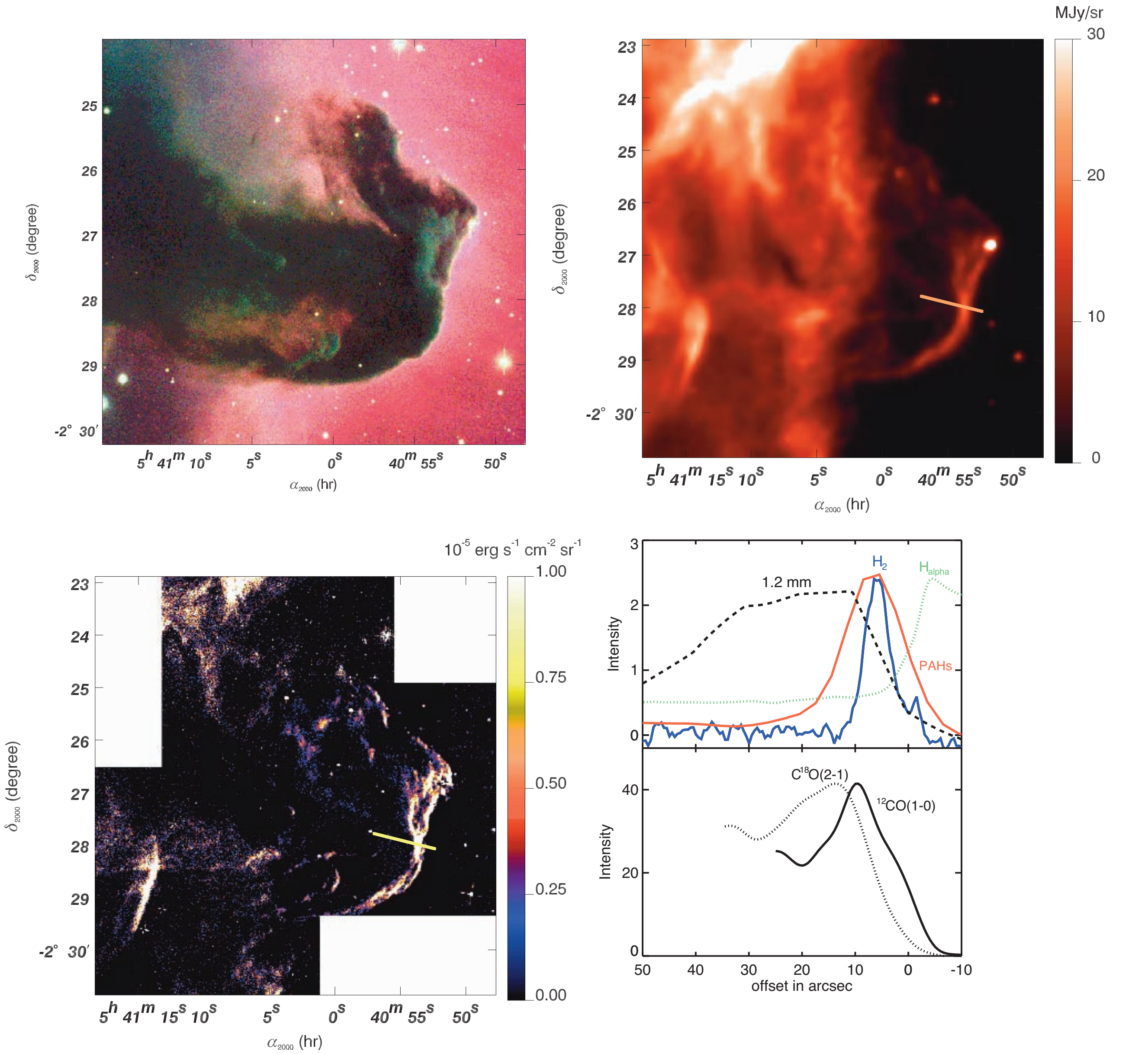


Figure 3: **Top left:** VLT composite (B,V and R bands) image. **Top right:** ISOCAM (6″) image (5–8.5 µm). **Bottom left:** SOFI/NTT (1″) image in the H_2 2.12 µm line. **Bottom right:** Emission profiles throughout the edge of the Horsehead nebula along the cut shown in the maps.

Why you may ask does this matter apart from the intellectual satisfaction of understanding ionization fronts and PDRs? One reason is the evidence for star formation associated with such compressed layers. In particular, there appear to be young protostars associated with the Horsehead. In the early 1980s, Reipurth and Bouchet used the ESO 3.6-m and the Danish 1.5-m to get deep images of the Horsehead in a number of filters as well as infrared photometry for a number of interesting objects. One of these (B33-1) was later detected by the IRAS satellite (IRAS05383, see Figure 2) at wavelengths beyond 10 microns and seems likely to be very young and associated with an outflow. It is situated interestingly right on the crest of the Horsehead!

High angular resolution images of the H_2 emission

Our involvement in this began when, in order to study the physical structure of the Horsehead nebula PDR, we obtained high angular resolution imaging observations of the H_2 1-0 S(1) line emission at 2.12 µm using SOFI on the ESO NTT telescope. This line emission is very sensitive to both the FUV radiation field and the gas density and the angular resolution (~ 1″) is ~ 5–10 times better than previous observations at infrared and mm wavelengths. We were also motivated by the image obtained with ISOCAM on the ISO satellite showing emission in the so-called UIR or Unidentified Infrared Bands at 6.2 and 7.7 µm (see Figure 3) usually associated with PAH molecules or Polycyclic Aromatic Hydrocarbons. The edge of the Horsehead nebula represents one of the sharpest mid-IR filaments (width: 10″ or 0.02 pc) detected in our Galaxy by ISOCAM (Abergel et al. 2003).

Sharp gas density gradient

The H_2 fluorescent emission presents striking filaments which coincide with those seen with ISOCAM. What does this mean? In addition to the front where hydrogen gets ionized (see the H_α line emission shown in red in the VLT composite image, Figure 3), the models predict a front somewhat further into the cloud where H_2 gets dissociated and our observations appear to delineate this layer.

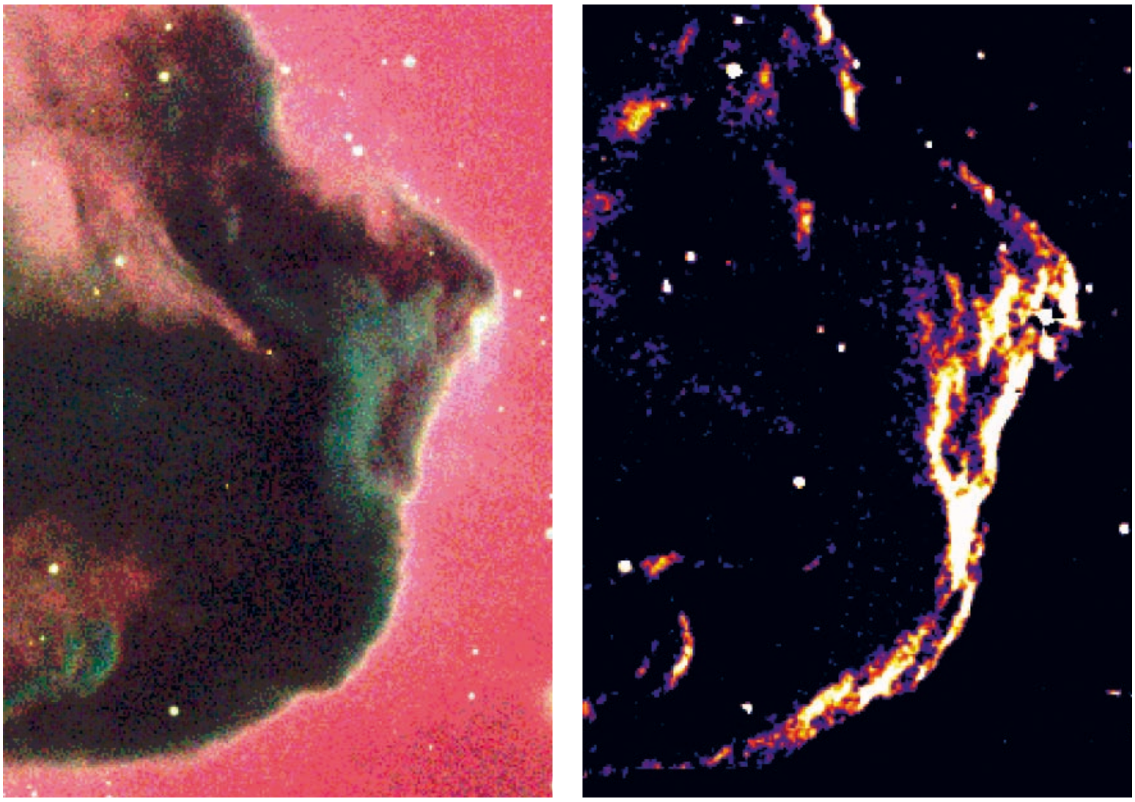


Figure 4: Zoom on the illuminated edge of the Horsehead. **Left:** VLT composite image. **Right:** SOFI image in the H_2 2.12 μm line.

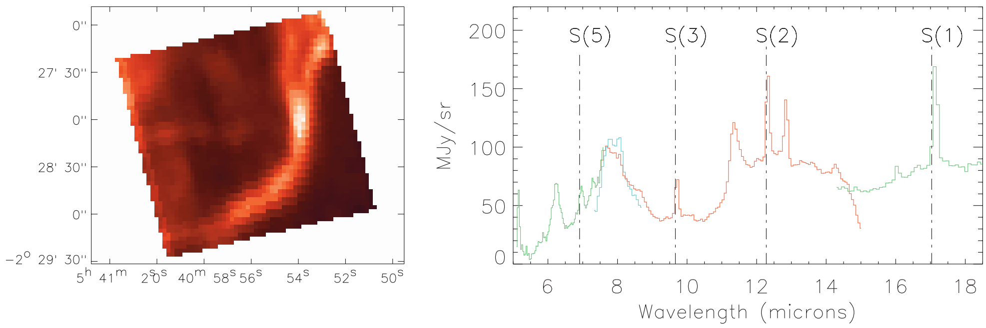


Figure 5: Horsehead nebula observed with Spitzer in the IRS spectroscopic mode. **Left panel:** Map in the continuum emission at 15 μm. **Right panel:** IRS spectrum at the position of the bright filament. Aromatic bands (6.2, 7.7 and 11.3 μm), H_2 (0-0 S(1), S(2), S(3), S(5)) and atomic lines (NeII at 12.81 μm) are easily detected.

From our models also, we conclude that there must be a sharp gradient in density between the H_2 emitting and inner cold molecular layers and Figure 3 also shows our attempt at modelling our SOFI observations together with the ISOCAM data and recent CO and millimetre continuum results (Teyssier et al. 2004, Pety et al. 2004). We conclude that the density rises by an order of magnitude in a layer of thickness 0.02 parsec. The thermal pressure which we infer is a factor of more than one hundred larger than the mean ISM pressure. Whether this is enough to cause gravitational instability is controversial but certainly it is sufficient to compress any pre-existing cores in the molecular cloud. If these are initially close to being unstable, the extra push from the Horsehead PDR may be enough to initiate collapse.

Sub-structures at the edge of the nebula

In the SOFI data, we also discover sub-structures unresolved by ISOCAM. At the edge of the Horsehead, we can in particular clearly distinguish narrow filaments well separated at several places along the interface (see Figure 4). These infrared filaments may represent the PDR edge at different positions along the line of sight. Some of these filamentary structures are also seen in the visible image (see Figure 4), but not everywhere because of the combined effects of extinction and projection.

Future

It is evident that to get further understanding of these regions, one needs additional information on the physical and dynamical conditions from the ionization front to the neutral molecular layer. One step forward in this regard will be supplied by the instruments on the Spitzer telescope and we show in Figure 5 some of the first results from the IRS spectrometer. The H_2 rotational lines will give us a good estimate of the temperature of the neutral warm gas ($T \geq 80$ K), while atomic lines such as NeII at 12.81 μm trace the ionized gas. Sorting out the implications of this will take some time but it is already clear that both higher spectral and spatial resolution are needed in order to understand the role of the Horsehead in triggering star formation. In this regard, the combination of CRIRES in the 1–5 μm range and VISIR at longer wavelengths will be very powerful. CRIRES will have a spectral resolution of up to 3 km s^{-1} and VISIR a spatial resolution of ~ 0.3″ (roughly 120 AU at 10 μm) opening new windows on PDR structure and kinematics. The last word on the Horsehead is far from having been said.

References

Abergel, A., Teyssier, D., Bernard, J. P., Boulanger, F., Coulais, A. et al. 2003, A&A 410, 577
Barnard, E. E. 1913, ApJ 38, 496
Habart, E., Abergel, A., Walmsley, C., Teyssier, D., & Pety, J. 2005, A&A, in press
Odland, L. 1946, Popular Astronomy 48, 570
Pety, J., Teyssier, D., Fossé, D., Gerin, M., Roueff, E., Abergel, A., Habart, E. 2005, A&A, in press
Pound, M. W., Reipurth, B. & Bally, J. 2003, AJ 125, 2108
Reipurth, B. & Bouchet, P. 1984, A&A 137, L1
Teyssier, D., Fossé, D., Gerin, M., Pety, J., Abergel, A. & Roueff, E. 2004, A&A 417, 135

Resolving the Host Galaxies of Quasars at $z = 2.5$ with VLT + NACO

Based on the most widely accepted model for structure formation in the universe, the massive galaxies we see today are the result of the merging of smaller structures. Looking far enough, and therefore far back in time, one should then be able to see galaxies getting smaller and smaller. To explore this issue we focus on quasars host galaxies and trace their properties up to redshift $z = 2.5$ (about 8 billion years in the past). Observations indicate that up to $z \sim 2.5$ quasar hosts are massive galaxies that are fully formed even at these early epochs. This is in partial disagreement with the hierarchical merging scenario, for the formation of massive spheroids.

Riccardo Scarpa[1], Renato Falomo[2], J. K. Kotilainen[3], Aldo Treves[4]

[1]ESO; [2]INAF, Osservatorio Astronomico di Padova, Italy;
[3]Tuorla Observatory, University of Turku, Finland;
[4]Università dell'Insubria, Como, Italy

Ground-based imaging together with higher-resolution Hubble Space Telescope data show that in the local universe ($z < 0.5$) powerful quasars (QSO) are found in massive elliptical galaxies. At higher redshift (up to $z \sim 2$) the available data confirm this scenario (Falomo et al. 2004, and reference therein), in particular indicating that the luminosity of QSO host galaxies is consistent with that of massive spheroids undergoing passive evolution.

For $z > 2$ the properties of the hosts are very poorly known because of the severe difficulties of getting direct information on these galaxies. There are, however, some indirect arguments supporting the above scenario. The Sloan Digital Sky Survey has observed hundreds of high-redshift QSO sufficient to constraint their space density up to $z \sim 6$ (e.g., Fan et al. 2003). These objects trace the existence of ~ 109 solar masses super-massive BHs (Willott et al. 2003). If the proportionality observed in the local universe between the BH mass and the hosting spheroid holds also at these epochs, then one could argue that massive host galaxies are already formed at these redshifts. Furthermore, even in the highest-redshift objects known, evidence has been found for the existence of molecular gas (Walter et al. 2004), dust (Bertoldi et al. 2003), and metals (Freudling et al. 2003), indicating that even at these early epochs QSO are associated with galaxies that have experienced significant star formation.

These observations appear at odds with the widely accepted Λ cold dark matter cosmologies, which predict a significant drop in mass of high z galaxies as a consequence of the processes of hierarchical merging (e.g., Kauffmann et al. 2000).

In this context, it is important to push as far as possible in redshift the direct detection and characterization of QSO host galaxies. In particular, a key point is to probe the properties of the host at epochs close to (and possibly beyond) the peak of quasar activity ($z \sim 2.5$), to verify whether the properties observed at lower redshift, like the central black hole – bulge mass relation, hold even at these early epochs. This is not attainable either with HST or 4-m-class telescopes equipped with adaptive optics (AO) systems because of the modest aperture that translates into a limited capability to detect faint extended nebulosity. One thus has to resort to 10-m-class telescopes equipped with AO systems to reach the required spatial resolution and depth. For instance, in a recent study by Croom et al. (2004) of nine $z \sim 2$ quasars imaged with AO at Gemini North telescope, one source at $z = 1.93$ was resolved. No quasars at $z > 2$ have been till now clearly resolved using AO imaging systems, though some claim in this sense has been made (Kuhlbrodt et al. 2005).

Here we present the first results of a pilot programme aimed to secure near-IR (K-band) images of quasars in the redshift range $2 < z < 3$, using the AO system at VLT. As we shall show, observations allow us to pin down the host galaxy-luminosity at very early cosmic epochs. The comparison with the results obtained at lower redshift then puts some constraints on the models for galaxy evolution and for the joint formation of galaxies and their central supermassive black hole. The results presented here (a full account of which is given in Falomo et al. 2005) refer to the first run of observations, during which images of three QSO were obtained.

We focus here on the radio-loud quasar PKS 0113-283 located at $z = 2.555$ (Hook et al. 2003). Observations were obtained using NAOS-CONICA, the first Adaptive Optics System on the VLT. We used the S54 camera that provides a field of view of 56 x 56 arcsec with a sampling of 54 mas/pixel. A jitter procedure was followed, with individual exposures of 2 minutes per frame and total integration time of 38 minutes. In the final image a spatial resolution of 0.22 arcsec was achieved (Figure 1). Photometric calibration, performed using standard stars observed during the same night, yields an internal accuracy of ~ 0.1 mag. A star at approximately the same angular distance (16.3 arcsec) from the AO guide star as the target (which is at 15 arcsec from the GS) was used to reliably model the Point Spread Function (PSF) of the system, since the shape of the PSF mainly depends on the distance from the AO guide star. Possible 2D asymmetries of the PSF due to differences in the relative positions of the target and the PSF star with respect to the AO guide star have negligible effect when one considers the azimuthally averaged radial profile. The comparison between the radial surface brightness profile of this star with that of the QSO indicates that the target is resolved (Figure 2). The radial profile was then fitted with a combination of a point source and an elliptical galaxy convolved with the proper PSF.

The result of the fit indicates that the host galaxy is a luminous giant elliptical with apparent magnitude K = 19.1 ± 0.3, corresponding to an absolute magnitude $M_K = -27.6$ (including K-correction, $H_0 = 70$ km s^{-1} Mpc^{-1}, $\Omega_m = 0.3$, and $\Omega_\Lambda = 0.7$), and an effective radius $R_e = 7.5 \pm 3$ kpc.

Assuming 1 mag of evolutionary effects this correspond to a present epoch magnitude of $M_K = -26.6$, fully consistent with the properties of local giant elliptical galaxies (e.g., Pahre 1998).

Our observations demonstrate that when a PSF characterization is possible, it is feasible to directly detect the host galaxy of quasars at redshift $z > 2$. In the case of PKS 0113-283, at $z = 2.555$, it was found that the quasar is hosted by a massive and fully-formed galaxy, with the size and luminosity expected from the trend observed for lower-redshift quasars (see Figure 3). A similar trend is also observed for radio galaxies (Willott 2003). Therefore, up to $z = 2.5$ there is no evidence of the decrease in mass (luminosity) expected in the hierarchical merging scenario for the formation and evolution of spheroidal galaxies. This result is also difficult to reconcile with models for the joint formation and evolution of massive galaxies and their supermassive black holes (e.g., Kauffmann et al. 2000), which predict quasars should be found in progressively less massive galaxies.

More VLT + NACO data have been secured during period 74 to put this result on solid statistical grounds, and possibly push even further in redshift the direct detection of quasars host galaxies, allowing for more and more stringent tests of the current cosmological models for structure formation.

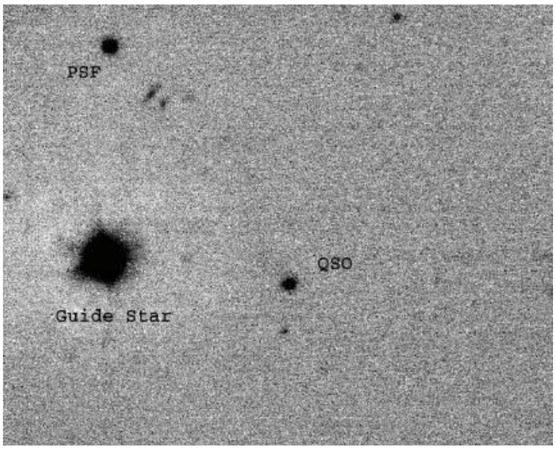


Figure 1: The full NAOS-CONICA field of view of the image of PKS 0113-283 (North is up and East to the left). The guide star used for the adaptive optics and the star used to model the PSF of the system are labeled. The image was obtained in the *K*-band, which at the redshift of the object corresponds to rest *V*-band.

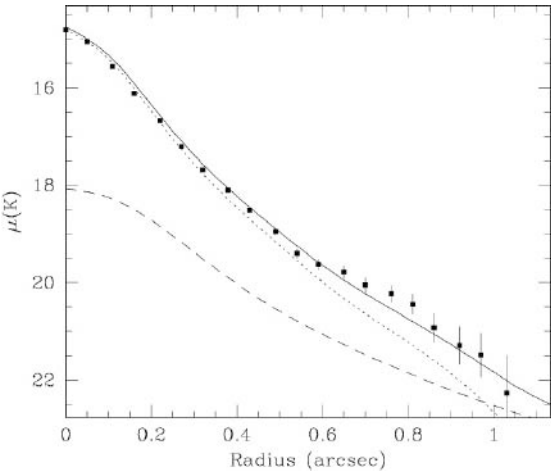


Figure 2: The observed radial surface brightness profiles of PKS 0113-283 (filled squares), superimposed on the fitted model (solid line) consisting of the PSF (dotted line) and an elliptical galaxy convolved with its PSF (dashed line). The associated errors are a combination of the statistical photometry in each bin and of the uncertainty on the background level (that is dominant at the faintest fluxes).

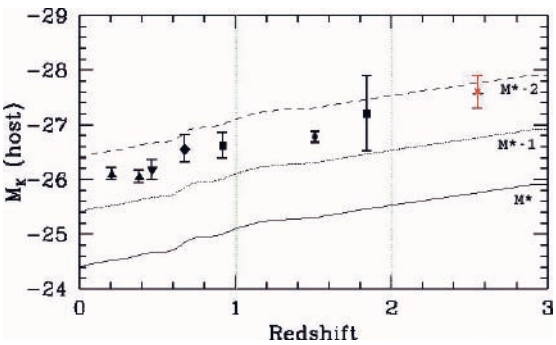


Figure 3: The evolution of radio loud quasar host luminosity compared with that expected for massive elliptical galaxies with magnitude M*, M*-1, and M*-2 (solid, dotted, and dashed line, respectively) undergoing passive stellar evolution. That is, these lines represent the loci of objects with constant mass (constant number of stars), in which stars are getting younger and therefore more luminous as *z* increases. The new detected host galaxy at *z* ~ 2.5 (in red) is compared with the data for samples of lower-redshift radio-loud quasars (Falomo et al. 2004).

References

Bertoldi, F., Carilli, C. L., Cox, P., et al. 2003a, A&A406, L55
Croom, S. M., Schade, D., Boyle, B. J., Shanks, T., Miller, L., and Smith, R. J. 2004, ApJ 606, 126
Falomo, R., Kotilainen, J. K., Pagani, C., Scarpa, R.,and Treves, A. 2004, ApJ 604, 495
Falomo, R., Kotilainen, J. K., Scarpa, R., and Treves A. 2005, A&A 434, 469
Fan, X., Strauss, M. A., Schneider, D. P., et al. 2003, AJ 125, 1649
Freudling, W., Corbin, M. R., and Korista K. T. 2003 ApJ 587, 67
Hook, M., Shaver, P. A., Jackson, C. A., Wall, J. V., and Kellermann, K. I. 2003, A&A 399, 469
Kauffmann, G. and Haehnelt, M. 2000, MNRAS 311, 576
Kuhlbrodt B., Örndahl E., Wisotzki L., and Jahnke K. 2005, A&A, in press (astro-ph 0503284)
Pahre, M. A., Djorgovski, S .G., and de Carvalho, R. R. 1998, ApJ 116, 1591
Walter, F. et al. 2004, ApJL 615, 17
Willott, C. J., McLure, R. J., and Jarvis, M. J. 2003 ApJ 587, L15

A New Isotopic Abundance Anomaly in Chemically Peculiar Stars

The discovery of a new isotopic anomaly in young, chemically-peculiar stars draws attention to extraordinary chemical separation processes that must take place in the atmospheres of these stars. No other natural processes are known that can do this so efficiently.

Charles R. Cowley[1], Fiorella Castelli[2], Swetlana Hubrig[3]

[1]University of Michigan, Ann Arbor, USA;
[2]Osservatorio Astronomico di Trieste, Italy; [3]ESO

Stellar astronomers recently found a rare calcium isotope. They discovered ^{48}Ca on ESO spectra taken with the UVES echelle spectrograph. The dominant isotope of calcium is usually ^{40}Ca, with 20 protons and 20 neutrons. The relatively large neutron excess in ^{48}Ca (28 neutrons) makes it difficult to explain this isotope within the standard schemes of the origin of the elements. Almost any process that would make ^{48}Ca would overproduce other neutron-rich isotopes.

Isotopic anomalies have been found for other elements, notably in helium, mercury, and platinum. It appears there is a class of star capable of separating isotopes with astonishing efficiency!

The Chemically Peculiar Stars

The stars with isotopic anomalies are members of a diverse group with unusual and sometimes bizarre surface compositions. They are now called CP stars, where the "CP" stands for chemically peculiar. This notation was introduced to describe chemically peculiar *main-sequence* stars – stars still converting hydrogen to helium in their interiors. These CP stars lie on the *upper*, hotter part of the main sequence. Their spectral types range roughly from early B to middle F. The group defined here does not include objects where the surface compositions have been altered by internal nuclear reactions.

Quantitative analyses of CP stars show that the abundances of certain elements can vary by many orders of magnitude from those in the sun. An element can be overabundant by as much as a factor of a million (10^6). Most abundance anomalies in CP stars are not so extreme, ranging typically from being marginally detectable to perhaps a factor of a thousand.

Isotopic Anomalies

Isotopic anomalies in the elements helium and mercury were discovered in the 1960's. For some time, these were the only cases of isotopic anomalies known in CP stars. Other isotopic abundance anomalies are now known, in platinum and thallium – both quite heavy elements. It is interesting that in all these cases, the heavy isotopes are increased in abundance.

The Discovery of ^{48}Ca in Stellar Spectra

In the summer of 2004, Fiorella Castelli and Swetlana Hubrig announced the discovery of ^{48}Ca. This was the first indication of an isotopic abundance variation of a light element since the discovery in the 1960's of the ^{3}He stars. They studied lines of singly ionized calcium (Ca II) belonging to the *infrared triplet*. Figure 1 shows the relevant energy levels, and the strongest lines of Ca II. Wavelengths in the infrared triplet have significant shifts, for ^{48}Ca vs. the common isotope, ^{40}Ca. These shifts owe their existence to the subtle interactions of the 3d electrons with the atomic nuclei.

Stellar Observations of ^{48}Ca

Figure 2 shows regions of a stellar spectrum studied in great detail by Castelli and Hubrig (2004). The upper part of the figure shows typical fits of the observed (black) and computed (red) spectra. The wavelength shifts here are of the order of 0.001 nm. Contrast the fits in the upper part of Figure 2 with those in lower two panels, showing the Ca II lines. The calculated features are some 0.02 nm to the violet of the observed lines. Shifts of this magnitude cannot possibly be due to a measurement error. Using laboratory measurements by Nörterhäuser et al. (1998), Castelli and Hubrig found that excellent fits to the stellar profiles can be obtained if calcium is assumed to be 97 % ^{48}Ca.

Cowley and Hubrig have been working on UVES spectra of a different variety of CP stars. Wavelengths of the infrared triplet were available for several of them. Interestingly, the Ca II lines in the most peculiar of their stars, the notorious Przybylski's star, appeared to show the ^{48}Ca shifts. When another spectrum of the same star, obtained with a different spectrograph also indicated ^{48}Ca, they decided to measure additional spectra, concentrating on magnetic CP stars, but including a few other exotic types. Eventually, they assembled the 22 wavelength measurements for CP stars displayed in Figure 3.

Figure 3 shows that the two wavelengths are correlated – both are shifted by roughly the same amount. This is just what would be expected if the stars had differing admixtures of ^{48}Ca, with points for nearly pure ^{48}Ca at the upper right. The cluster of points at the lower-left corner indicates a normal (solar) isotopic mix. If the discordant measurements were caused by blending or instrumental effects, such a correlation is much less likely.

The third line of the Ca II triplet has been unavailable for most stars, because of the settings of the UVES spectrograph. Fortunately, beginning in April 2005, new settings make it possible to observe all three lines simultaneously.

What Does It Mean?

Since the pioneering work of Georges Michaud in 1970, abundance anomalies in CP stars have come to be recognized as due primarily to chemical separation. Atoms in the atmospheres of stars are subject to gravitational settling and an opposing outward force due to radiation. The theory of chemical separation has been highly successful in explaining the overall chemical anomalies of the CP stars.

Isotopic anomalies are difficult to explain. A most notorious anomaly occurs for stars where the heaviest stable isotope of mercury, ^{204}Hg, is the most abundant. Here, a scheme is required to push out the lighter isotopes from the star's photosphere, while preventing replenishment from below.

The ^{48}Ca anomaly is the first of its kind to be established in the magnetic sequence of CP stars. It is significant that we find the ^{48}Ca anomaly over a wide range of effective temperatures and atmospheric conditions.

While details of the isotopic fraction processes discussed here are uncertain, one fact is clear. These CP stars have by far the most unusual natural fractionation mechanism known.

References

Castelli, F. & Hubrig, S. 2004, A&A 421, L1

Cowley, C. R. & Hubrig, S. 2005, A&A 432, L21

Nörterhäuser, W., Blaum, K., Icker, P., et al. 1998, Eur. Phys. J. D2, 33

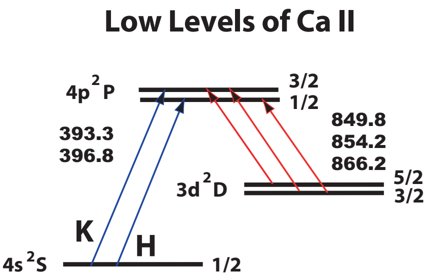


Figure 1: Partial energy-level diagram for the one-electron spectrum Ca II. Fraunhofer's H and K lines connect the ground 4s^{2}S-term to the first term to which an allowed transition is possible. These lines are known as resonance lines. Transitions from the ground term to the 3d^{2}D-term are forbidden, but transitions from the 3d^{2}D- to the 4p^{2}P-term are allowed, and form the infrared triplet.

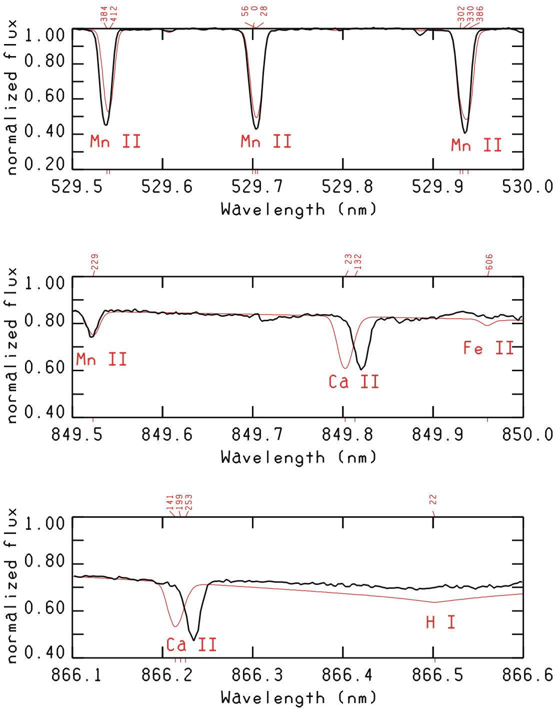


Figure 2: Discovery observations of ^{48}Ca. Most spectral features in HR 7143 (HD 175640, shown in black) could be well matched by calculations shown in red. The upper panel is typical. The central and bottom panels show the region of two lines of the infrared triplet, where it is seen that the stellar feature is shifted to longer wavelengths by 0.2 Å (0.02 nm). These shifts are just what would be expected if the calcium were mostly present as the isotope ^{48}Ca.

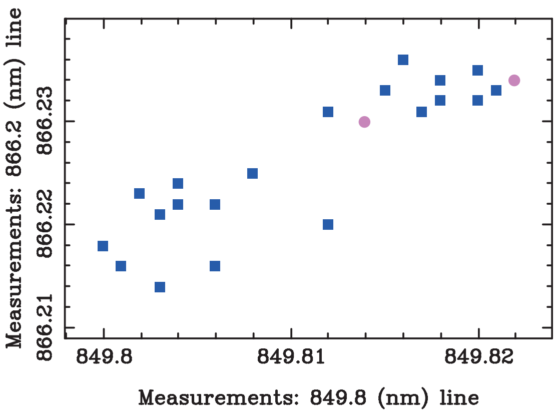


Figure 3: Stellar wavelengths for Ca II 866.2 nm vs. 849.8 nm. The points are wavelength measurements for two lines of the infrared triplet. The laboratory wavelengths are 849.802 nm and 866.214 nm. Two points in purple are from the original discovery by Castelli and Hubrig, made for non-magnetic CP stars. The blue points are measurements for the same transitions but in magnetic CP stars.

The photo zooms-in on the LMC H II region N214C. The field size is 193″ × 201″ corresponding to roughly 160 × 170 light-years. The brightest object, situated toward the middle of the nebula, is the Sk-71 51 cluster. A striking compact H II blob lies ~ 60″ (~ 50 light-years) north of Sk-71 51. *ESO PR Photo 12b/05.*

ESO Studentships: PhD opportunities in Garching and Santiago

Markus Kissler-Patig, Andreas Kaufer, Bruno Leibundgut, Felix Mirabel; ESO

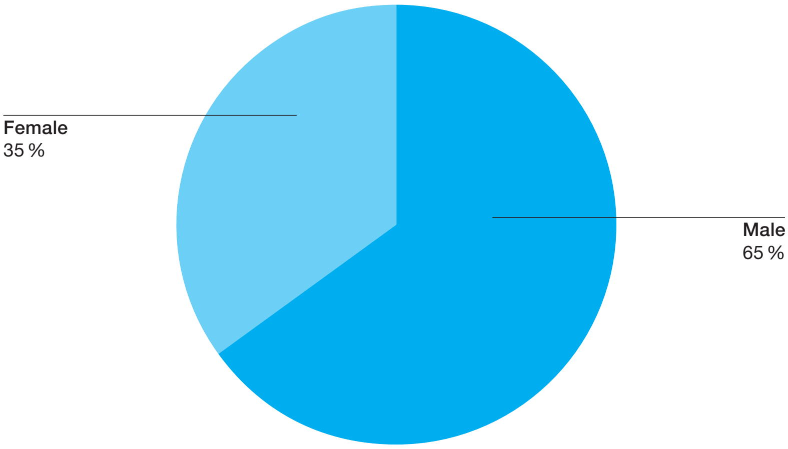
ESO offers a number of opportunities for graduate students to spend part of their research studies in the observatory environment. The primary aim is to give young researcher the opportunity to discover ESO during their PhD studies and participate in an exciting research environment. Further, this represents one of many opportunities for students to be immerged in an international environment and to work at one of the centres of European and worldwide astronomy. Last but not least, it allows researchers/supervisors of ESO's community to foster stronger links with their ESO colleagues.

Historical Background

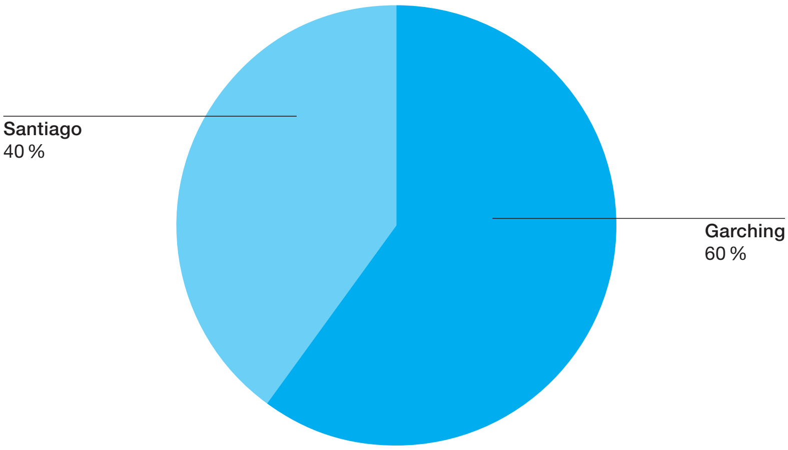
In the early days there was no formal studentship programme, and there were few students at ESO. One avenue was provided by the French, later the Belgians, who allowed some of their students to do the 'cooperant' service with ESO in Chile. Some of these students later became ESO staff astronomers and have served the organisation for many years.

The formal studentship programme was introduced to ESO under the directorship of Harry van der Laan (see The Messenger 55, 12, 1989). He launched, to supplement the already existing fellowship programme, a studentship programme with eight studentships split between Garching and Santiago, later 16 students at ESO at anytime.

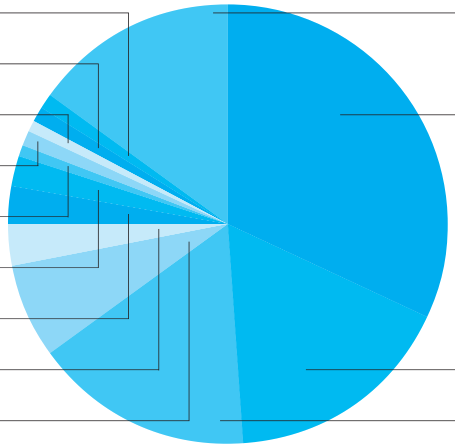
Many students who spent some time of their formative years at ESO have come back to take up a staff position or supported ESO in the community. Reading through the list of former students at ESO one encounters many of the leading astronomers in Europe today. We consider this programme to be very effective in binding ESO into its community. Together with the fellowship programme the studentships are a major link of community astronomers with their colleagues at ESO. Into the VLT era, the studentships offer rather unique opportunities, such as gaining hands-on experience with modern instrumentation, reduction and analysis techniques, or interferometry. In this respect, ESO provides distinctive complements to the education of young astronomers that may not be offered at every university. Of course, spending a couple of years of study in a country like Chile holds appeals for some as well. A comprehensive report on studentships in Vitacura is given in Danielle Alloin's recent article (The Messenger 117, 61, 2004).



Students' gender
Distributions of genders of ESO students, averaged since 1992. The 1/3–2/3 female/male distribution corresponds closely to the distribution of applications from both genders. The distribution is similar for Santiago and Garching.



Students' duty station
Distribution of students per duty station since 1992 – While the distribution was close to 50/50 until the end of the '90s, the IMPRS has tipped the balanced in favour of Garching in recent years.



Students' nationality
Breakdown of ESO students' nationality since 1992. French students seem to have made the most out of ESO studentships, followed equally by Germans and Italians. About 1/6 of the studentships were taken by non-ESO member state applicants.

The 'regular' ESO studentships: a visit during your PhD studies

The regular ESO studentships comprise the core of the studentship programme. These provide PhD students with funding for 12 to 24 months to pursue their research at ESO. The studentships can be taken up either at the ESO headquarters in Garching, Germany, or at the ESO science office in Santiago, Chile.

In order to be eligible for this programme, students must be enrolled in a PhD programme at their home university. Ideally, they would come after their first year to visit ESO for 1–2 years, before returning to their home institutions to finish their PhD. This implies that the student's supervisor gets into contact with an ESO scientist who could act as local supervisor during the student's stay. The home supervisors are usually encouraged to profit from ESO's visitor programme and could spend extended periods of time at ESO themselves.

We have about 10 such studentships available at a given time at each site. We can typically offer five new positions per year both in Garching and in Vitacura. Indeed most students choose to stay for the maximum of two years at ESO.

The deadline for applications is June 15 every year, with an evaluation and notification in July for starting dates anytime after September, typically within the next year. The application form and list of material to provide can be found on the ESO web pages under 'Vacancy Announcement > ESO Studentship Programme'. The studentship web pages also include a link to the faculty pages on which the research interests of the ESO faculty members are listed.

Funding schemes for students in Europe still vary from country to country. We try to provide flexibility as much as possible within the two-year studentships. With the application we request a guarantee from the home institution that the financing for the student is secured for the whole PhD.

We also receive requests from students who would like to spend some time at ESO with their own funding. We try to accommodate these students at ESO within the available resources.

The students are selected by ESO astronomers according to their proposed research programme, the expected support by the ESO supervisor and the home PhD supervisor, and the promise they show for future research. We have had rather good success in the past and ESO students have fared rather well in their research careers.

The IMPRS studentships in Garching: full PhD studies at ESO

ESO participates in the 'International Max-Planck Research School for Astrophysics' in Garching (see also *www.imprs-astro.mpg.de*). This graduate school is funded through the Max-Planck Society and involves the astronomical institutes around the Garching Campus: the Max-Planck Institute for Astrophysics (MPA), Max-Planck Institute for Extraterrestrial Physics (MPE), ESO, and the astronomy departments of the Ludwig-Maximilian University and Technical University of Munich.

The graduate school hosts over 50 students at any given time, of which ESO provides two positions per year, i.e. six students total at any given time.

The difference to the regular studentships is that these IMPRS studentships are only offered in Garching, and more importantly, allow students to spend their full PhD period at ESO and obtain a PhD from the IMPRS graduate school (formally, the PhD certificate is issued by one of the universities in Munich).

Thus, students can apply directly to this scheme without enrolling at any other university or having already a supervisor or defined subject. The application deadline for an IMPRS studentship is December 15, to start the studies in the following September – it is therefore wise to plan a bit ahead of time and already think about applying early during the masters/diploma/DEA/etc. period.

The application procedure is described on the IMPRS web page (see above), and it is recommended to contact ESO faculty members in Garching to learn about the proposed topics (also listed on the ESO faculty web pages).

ESO IMPRS students get a grant similar to that of the regular students, but lasting for the full 3 years of their PhD. The competition is fierce: usually over 140 students apply for the ~ 15 offered positions, of which only two are typically available at ESO (the others in the other institutes of the graduate school).

Studentship conditions – grant, benefits, no duties

The studentship employment conditions are comprehensively described on the ESO web pages under 'Personnel Dept > Employment Conditions for Students'. In summary, the grant includes travel expenses and some removal expenses when joining/leaving ESO, a competitive monthly salary, as well as some extra allowance for married students. Students and their families are covered through ESO's health insurance. In addition, ESO will pay for the students to visit their home institution once per year, support their scientific travels (observing runs and conferences) within some generous limits, and offer to their supervisors to plan a stay at ESO within the frame of ESO's visitor programme.

A student does not need a visa or work permit when employed by ESO (given the international status of the organization), nor does her/his family need a residence permit. Note, however, that spouses that wish to work will need a regular German/Chilean work permit (and that this might be complicated in Chile without the spouse renouncing the privileged ESO status).

Students in Chile have the opportunity to volunteer for a small amount (up to 40 days/nights per year) of functional work at the La Silla Paranal Observatory, if they wish to gain some experience in observatory operations.

Vitacura and Garching – Great scientific surroundings

Both Vitacura and Garching offer exciting scientific environments to students. Vitacura hosts about 10 students, 15 postdocs and 35 faculty members; Garching hosts about 15 students, 15 postdocs, 45 faculty members. Both sites have state-of-the-art computer and networks facilities to which students have full access. Further, the Santiago office has tight connections to the astronomy departments for the Universidad de Chile and the Pontifica Universidad Católica (including regular joint activities and colloquia) and an analogous programme in Chile to the IMPRS is being discussed between the Office of Science in Vitacura and the Universities of Chile. ESO Garching is within a short walking distance of the Max-Planck Institutes for Astrophysics and Extraterrestrial Physics with which colloquia and conferences are shared on a regular basis.

Both sites host several workshops and conferences per year to which the students have free access. Garching also offers, through the IMPRS, a three-week block of lectures (in English) at graduate level each semester.

In summary, the alternatives to conduct research as a student ESO are manifold and the scientific environment very rich. The ESO studentship represents unique opportunities to immerge in an international observatory environment during one's PhD studies.

The only complaint lately received from students was about the weather, and this only in Garching. But surely the many other advantages more than make up for it.

Current ESO students in Chile: in the back from the left – Nicole Nesvacil, Pascale Hibon, Sylvain Baumont, Christophe Couronne, Hannes Horst; in the front row: Pasquier Notredame, Alessandro Ederoclite, Alberto Scatarzi (missing on the picture: Carla Gil, Celine Delle Luche, Frank Coppolani).

Current students in Garching – in the back from the left: Michaela Döllinger, Marta Mottini, Alessandro Rettura, Karina Kjær, Andres Carmora Gonzalez, Stephane Blondin, Andreas Seifahrt; in the front from the left: Veronica Strazzullo, Bettina Gerken, Kim Nilsson, Isabelle Gavignaud, Nate Bastian, Yuri Bialetski, Stefan Uttenthaler, Jarek Rzepecki, Marcelo Mora, Morag Hastie (missing: Aglae Kellerer, Jörg-Uwe Pott, Silvia Vicente).

'Towards a Europe of Knowledge and Innovation' – EIROforum presents a major science policy paper

Claus Madsen, ESO

The European societies are undergoing fast changes these years. The need to manage the European integration process as well as to develop adequate solutions in the face of globalization and the pressure on the 'European way of life' led the Heads of states and governments of the EU to set for themselves the goal of developing the most dynamic knowledge-based economy in the world within a 10-year period. Both the goals and the policies to reach them are known as the *Lisbon Agenda* and the *Lisbon Process*, respectively, reminding us that it was in the city of Lisbon – in the year 2000 – that this development was started. Now, at half-time, the process has been reviewed and the governments have acknowledged the need to focus on the most essential policy areas that must be developed to achieve success. Central to the revised Lisbon agenda is the notion of 'knowledge' – 'creation' of knowledge through science, its dissemination through education and its exploitation by society through technological development.

As part of its contribution to the ongoing debate about *Lisbon*, the seven EIROforum partner organizations have presented a joint science policy paper laying out their ideas and proposals in order to further the Lisbon Process. With the title 'Towards a Europe of Knowledge and Innovation', the paper analyses the challenges to science raised by the Lisbon Agenda and the contribution that science can make in this context. It suggests directions that political actions should take to strengthen science and thus enable it to support the attainment of the goals set at the Lisbon Summit. These suggestions include proposals for concrete actions involving the EIROforum organizations, both in terms of activities that reach out to society at large (e.g. in education, public awareness of science, etc.) and actions that aim to improve the conditions for researchers and thus to achieve EIROforum's overall vision of 'creating a climate in Europe in which relevant, competitive scientific research (basic and applied) can be undertaken in an efficient, cost effective and successful way'. The document discusses the need for fundamental research

Presenting the EIROforum Science Policy Paper: (left-to-right) Colin Carlile (DG, ILL), Bill Stirling (ESRF), Robert Aymar (CERN), François Biltgen (EU Competitiveness Council), David Southwood (ESA), Janez Potocnik (EU Commissioner), Catherine Cesarsky (ESO), Ian Mattaj (EMBL), Jérôme Paméla (EFDA Associate Leader), and Katya Adler, moderator and BBC correspondent.

(‘science-driven frontier research’), the central role of research infrastructures, both as a means to carry out competitive research and as catalysts for structuring the scientific communities and developing new research projects. In this context the paper also provides a brief overview of the current trends within the scientific disciplines covered by the EIROforum organizations and presents some of the future large research facilities that European scientists will need to remain competitive. Last but not least, the document addresses the difficult issues of how to strengthen the European Research Area (ERA), seen as an essential part of the Lisbon Process, and the role that the EIROforum organizations can – and should – play within the ERA.

The paper was formally presented to the public on April 20 in Brussels at an event at the Berlaymont Building, the seat of the European Commission. In the presence of Janez Potocnik, European Commissioner for Research and François Biltgen, who as Luxembourg Minister for Culture, Higher Education, Employment and Research represented the EU Competitiveness Council, the seven Directors General presented their ideas to an invited audience of Commission officials, representatives from the European Council and the member states as well as the press.

Said Commissioner Potocnik: “I welcome the EIROforum Science Policy Paper and I support the development of further partnerships between the European Commission and EIROforum towards our common objectives of consolidating the European Research Area and progressing in the Lisbon agenda. [...] Your organizations, CERN, EFDA, EMBL, ESA, ESO, ESRF, ILL play an essential role in the European Research Area. They contribute to structuring the ERA by gathering around them strong scientific communities in their respective scientific fields. They enable European scientists to engage in cutting-edge research by providing them with top-class facilities and services. They improve the visibility and the attractiveness of European science all over the world. In addition, your *Forum* provides now a platform for coordination and collaboration, which pools together the expertise of these organizations in their respective fields. It also facilitates high-level interactions with external European institutions.”

Speaking on behalf of the EU Presidency, Mr Biltgen added: “The European Research Area will only become a reality if it can rely on joint and well-coordinated efforts, at both European and national level, in combination with activities of the relevant intergovernmental organizations. Europe and its political leaders have fully understood the importance of ‘the knowledge triangle’ which underpins all components of the Lisbon strategy. Today’s economy and the well-being of citizens rely more than ever on the progress of knowledge and its transformation in new products, processes and services [...] Joint efforts of all stakeholders at Union and at national level should contribute to create that positive climate your vision paper is referring to, a climate in which relevant, competitive scientific research can be undertaken in an efficient, cost-effective and successful way, and let me add, ensure in the long term the competitiveness of our economy as well as deliver wealth and prosperity for the European citizen.”

ESO Director General Catherine Cesarsky and Janez Potocnik, EU Commissioner for research.

Report on the workshop on

The power of optical/IR interferometry: recent scientific results and second-generation VLTI instrumentation

Andrea Richichi, Andreas Glindemann, ESO

This Workshop was held in Garching from April 4 through April 8, 2005, with 2.5 days dedicated to science from interferometers, and 2.5 days dedicated to concepts of second-generation instrumentation for the VLTI. With about 170 registered participants from a large number of countries and institutions, it can be safely stated that the workshop was a huge success. This massive participation forced the organizers to abandon the idea of holding the workshop inside the ESO headquarters, and accept the generous offer of a vast meeting room at the MPE, made by Prof. R. Genzel. Similarly overwhelming was the number of contributions. The number of requests for just the scientific part of the workshop could have easily filled a full week-long schedule with interesting oral presentations, and difficult selections were necessary.

Naturally, the VLTI was in the spotlight, and with good justification. More than half of the total of the world's interferometric refereed publications in 2004 originated from VLTI results, and at the Workshop about two thirds of the 39 oral presentations were similarly centred on recent VLTI results. Next to the well-known VINCI and MIDI, the newly arrived AMBER instrument could also be showcased. AMBER is in fact still under commissioning, and will start its open time observations in October 2005. In spite of the venue and of the implicit focus on the VLTI, a large number of speakers were not directly associated with the ESO interferometric community, and many of the presentations also gave results obtained at other facilities.

At the beginning and midway through the Workshop, the audience was fascinated by historical perspectives, spanning about two decades, on the initial ideas, development and implementation of the VLTI, as presented by two major players in the project, P. Léna and J. Beckers. Also fascinating was the outlook on the future of VLTI (and beyond) provided at the closing of the science part by A. Quirrenbach and T. Henning. The final format of the scientific part of the Workshop consisted of six sessions on four main topics. Some selected highlights are summarized below.

A. Richichi reviewed the statistics on measurements of angular diameters. About 650 sources have at least one direct measurement, but in fact only half of them have repeated measures and only about one third are of sufficient accuracy to constrain theoretical models significantly. Breakthroughs are quietly occurring in this field, such as very accurate measurements of second-order quantities (flattening, limb-darkening), and angular diameters of important, but not well-studied, objects such as main-sequence and pre-main-sequence stars. G. Perrin reviewed the subject of interferometric measurements of late-type stars, concentrating in particular on narrow spectral-band measurements of Mira stars, on the subject of fundamental or overtone pulsation, and on the circumstellar components.

Perhaps one of the most exciting subjects was that of Cepheid stars, with interferometers now able to directly measure the angular variations of the diameters and thus to calibrate precisely the Period-Luminosity relationship. Speakers on this topic included P. Kervella, A. Mérand and J. Davis, with results from the VLTI, CHARA and SUSI interferometers. Impressive illustrations of the progress in this field are provided in Figures 1 and 2.

An outstanding target was Eta Car. Both O. Chesneau and T. Gull devoted their presentations to this exotic object, reporting on observations with MIDI, as well as with HST and VLT. Also R. Petrov reported, among his survey of AMBER results, some brand new observations of Eta Car which, although of very preliminary nature, are sure to fuel much interpretative work (see Figure 3).

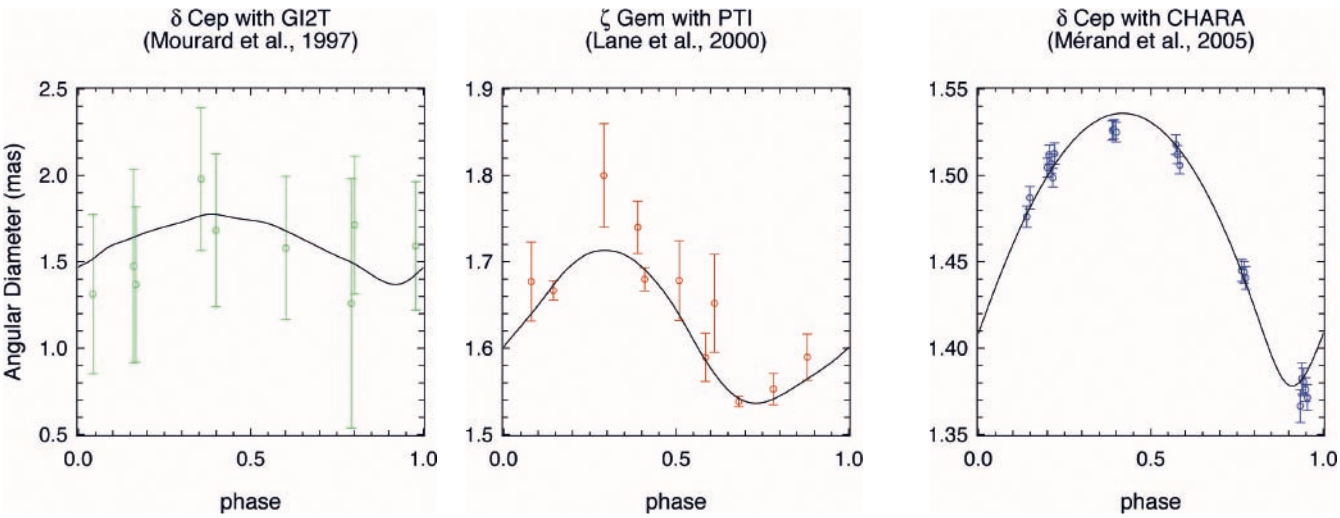


Figure 1: Progress in detecting angular-diameter variations in Cepheids by interferometry (presented by Mérand). **Left:** first attempt (Mourard et al. 1997, Science with the VLT Interferometer, Proceedings of the ESO workshop, p. 334). **Centre:** first detection (Lane et al. 2000, Nature 407, 485). **Right:** recent results by Merand et al. (submitted).

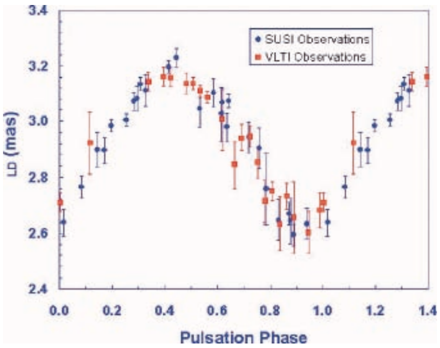


Figure 2: Comparison of SUSI and VLTI measurements (optical and near-IR, respectively) on the Cepheid star l Car (presented by J. Davis, VLTI measurements by Kervella et al. 2003, Semaine de l'Astrophysique Française, Conference Series, p. 531).

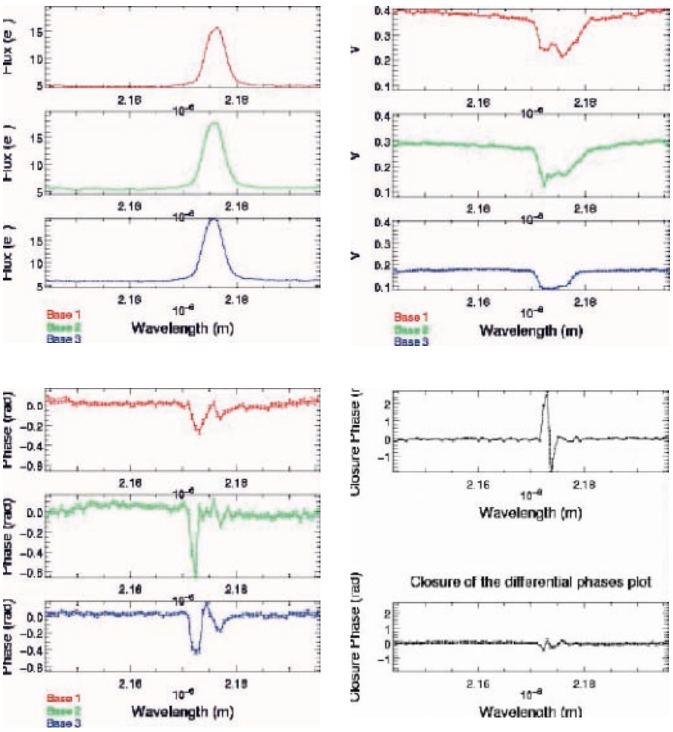


Figure 3: AMBER observations of Eta Car on a 3-UT combination. **Left:** the spectrally dispersed visibilities on the 3 baselines. **Right:** same, for the differential phases (presented by R. Petrov).

Next to the single giant stars and their circumstellar environments, a staple food of interferometry is represented by binary and multiple stars on one side, and by young stellar objects on the other: it was certainly interesting to note that the amount of results, some of which very recent and yet unpublished, was comparable across these areas. C. Hummel reviewed the subject of interferometric measurements of binary and multiple stars, highlighting the precision which is now obtained in the orbital results also for systems with just a few milliarcsecond separation (see Figure 3).

A. Boden reported a preliminary physical orbit for the pre-main-sequence star HD 98800 B. He obtains masses for the two components of ~ 0.5 and ~ 0.4 solar mass, with an accuracy of 5 % which is unprecedented among the very rare determinations of this kind for pre-main-sequence stars (see Figure 3).

The last part of the workshop took the audience from the familiar subjects of stellar astrophysics to more exotic areas. K. Meisenheimer reviewed the subject of interferometric measurements on AGNs, a field which did not exist until two years ago and that now already has several observations, mostly obtained at the VLTI. He detailed in particular the ground-breaking observations obtained by MIDI on NGC 1068 first (Figure 6, see next page), and then on Circinus A. A. Poncelet further illustrated the diversity of theoretical models available and how the data can constrain them.

The subject of the Galactic Centre also took a share of the spotlight, with recent MIDI/VLTI observations of IRS3 presented by A. Eckart, representing the first observation by interferometry of a mid-IR source in this region. A. Eckart concluded that the observations, when analyzed in combination with other photometric and spectroscopic data, will permit one to assess the size, geometry and grain composition of this source. Modelling is currently in progress. Even more intriguing were the prospects for future

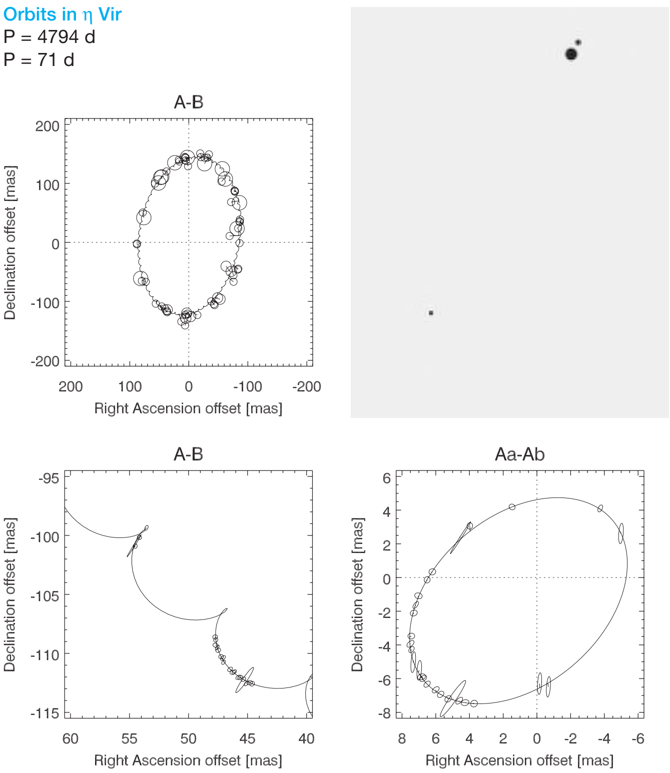


Figure 4: Orbits in the triple system Eta Vir (presented by C. Hummel). The image shows the constellation of the three stars with A, accompanied by Ab, in the upper right and B in the lower left. The other curves show: the A-B orbit, a zoom-in on the orbit of B displaying loops due to the motion of the photocentre around the centre of mass of component A, and (note the scale) the Aa-Ab orbit.

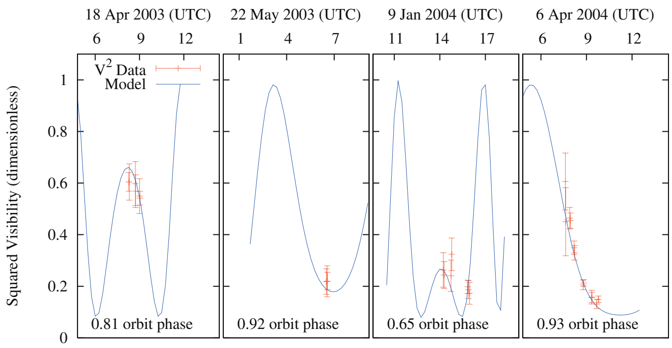


Figure 5: Orbital measurements of HD 98800B, obtained with the Keck Interferometer (presented by A. Boden).

studies of the inner parts of the Galactic Centre presented by T. Paumard. The speaker showed that the mass and mass distribution in the GC can be studied by following the orbits of stars in a region smaller by about one order of magnitude of what is currently possible. Such orbits would have periods of about one year, and with their high ellipticity and precession would permit one to infer the relativistic effects of the strong gravity connected with the black hole at the centre of our own Galaxy.

Interferometric studies of exoplanets are another subject which will keep us waiting for 1–2 more years, but equally rich in exciting perspectives. The issue was reviewed by D. Queloz, who compared the RV, transit and interferometric methods for the study of exoplanets. He argued that the VLTI will provide invaluable information on these systems starting with the first results from PRIMA, and suggested a strategy of massive surveys with this facility. He also advocated that stability and accuracy should be the first requisites of second-generation VLTI instruments.

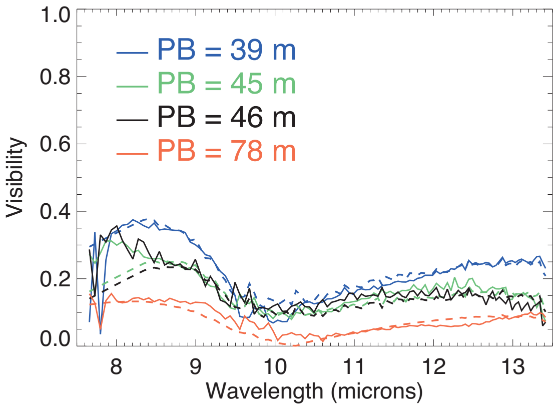


Figure 6: MIDI/VLTI observations of NGC 1068 (various baselines) and the comparison with theoretical models (presented by A. Poncelet).

Second-Generation Instrumentation for the VLTI

The second part of the workshop continued with the same enthusiasm as the first part. M. Schöller, R. Petrov and Ch. Leinert discussed the lessons learned during the implementation of the VLTI and its instruments. The stage was then given to the instrument proposals, which we summarize briefly below. Most of the proposals required the so-called VLTI '4 × 4' box, with four UTs and four ATs equipped with PRIMA star separators, a 4-beam Fringe Sensor Unit, four Differential Delay Line Units (two more than currently foreseen) and improved Metrology. In addition, there were presentations of general concepts for multi beam fringe tracking (M. Gai and F. Cassaing), for multiple anamorphic beam combination (E. Ribak), for the combination of VISTA with the VLTI (G. Perrin) and for the use of heterodyne detection in the *N*-band (R. Schieder). A large number of posters covered an even wider area of instrumental and technical topics.

The **Après-MIDI** concept was proposed by the former MIDI Consortium presented by B. Lopez (OCA, Nice) and S. Wolf (MPIA, Heidelberg). Their approach is to upgrade MIDI by adding a 4-beam imaging mode with filters to complement its current spectroscopic mode with two beams only. Prime science targets are the study of the complex circumstellar environment of (young or evolved, single or multiple) stars and of the detailed structure of AGN tori. The upgrade involves adding an opto-mechanical subsystem in front of MIDI and exchanging a few optical pieces inside the Dewar.

Two competing concepts – **VITRUV** and **CavCam** – that could lead to a successor to AMBER were introduced. They permit multi-beam (four, six or even eight) combination instead of the current 3-beam only with AMBER. Prime science targets are stellar surfaces, circumstellar environments, microquasars, and the central part of AGNs. Both instruments have roughly the same footprint as AMBER in the VLTI Laboratory.

VITRUV, a four- to eight-beam near-IR instrument, was proposed by a Consortium presented by F. Malbet (LAOG, Grenoble) and P. Garcia (CAUP, Porto). In their technical concept integrated optics is used to provide a compact maintenance-free beam recombiner. Extensions to the *I*- and *L*-bands, plus the addition of a medium spectral resolution mode (for e.g. stellar jets/winds and stellar dynamics around super-massive black holes) were also discussed.

A technically different approach was advocated by D. Buscher from Cavendish Laboratory (hence the provisory instrument name '**CavCam**') at University of Cambridge. He proposed a four- to six-beam beam combiner with an Envelope Sensor Unit, i.e. not tracking the individual fringe like an FSU but instead the fringe package envelope given by the group delay. The use of bulk optics ensures optimal efficiency (~ 25 % improved transparency compared to integrated optics) but less accurate visibility measurements since the fringes are not calibrated in flux. The use of group delay tracking also is less accurate compared to fringe tracking, but observations would be more sensitive and could be obtained on many science objects lacking a bright enough reference source required for fringe tracking.

VIDA, a potential additional mode to VITRUV, was presented by O. Lardière (Collège de France) and J. Schneider (Observatoire de Paris). Here, a densified pupil is used providing high sensitivity and high dynamic range at the cost of an extremely small field of view. Prime science targets are exoplanets (Hot Jupiters may be detectable), stellar surface imaging, gravitational lenses and AGNs. A VIDA test bench is currently under development at OCA.

R. Neuhaeuser (University of Jena) introduced the **NIFI** instrument aiming – on the technical side – at investigating integrated optics based subsystems (beam recombination and Delay Lines) in the *J*-, *H*- and perhaps *K*-band. The scientific impetus is to detect close companions to young stars and directly image stellar convection.

VEGA was proposed by D. Mourard (OCA, Calern). This would be essentially a remake of the REGAIN instrument that is installed at the GI2T (Calern). Operating in the 0.5–0.9 μm region, with a spectral resolution ~ 5 000, it would combine up to four telescopes. Photon-counting detectors with 30 % Q. E. are used to obtain a good sensitivity. Two modes are foreseen, x-λ spectroscopy with polarimetric information and multi-band pass imaging. Prime science targets are spots on magnetic stars, AGN, Cepheids and astroseismology.

A. Quirrenbach (University of Leiden) discussed **I-UVES**, linking the existing UVES instrument with a beam combiner in the VLTI Laboratory via 150-m long incoherent fibers. This provides high-resolution (R ~ 60 000) single-baseline interferometric data in the visible, λ = 0.6–0.9 μm. Without adaptive optics on the Auxiliary Telescopes they would have to be stopped down to about 50 cm. This instrument would essentially be dedicated to the precise testing of stellar models via diameter versus wavelength, oscillation mapping and direct measurement of star differential rotation.

With all the instruments discussed so far serving more general science cases, F. Eisenhauer (MPE, Garching) presented a dedicated single-topic science facility for the VLTI. The approach is to develop a low spectral resolution (~ 30) large efficiency (fully optimized for the *K*-band), high accuracy (dedicated AO system with an IR wave-front sensor, internal differential delay lines, cryogenic enclosure) system combining up to six beams. Preliminarily dubbed **GRAVITY**, it was essentially conceived to probe strong General Relativity effects by observations of close stellar orbits and differential astrometry of flashes in the Galactic Centre, plus possibly photometric detection of hot Jupiters.

GENIE, the Darwin ground demonstrator was presented by P. Gondoin (ESA). It is based on 2-beam interferometry in the *L*-band

and would offer both a nulling and a constructive mode. The science case covers in particular the survey and detection of possible exo-solar zodiacal dust discs, as well as Peg-asides. Other applications include stellar formation, circumstellar environments, and AGNs. The Genie Science Team (co-sponsored by ESA and ESO) has produced a comprehensive report on the scientific prospects of this concept. After two ESA-funded Phase A studies were performed in 2004 by ALCATEL and ASTRIUM, the decision has to be taken which concept to choose.

Conclusions: towards Second-Generation Instrumentation and Infrastructure

The quality of the presented instrument concepts was remarkably high. While in the mid-infrared Après-MIDI was basically without competition except for the fact that one could ask for a more powerful spectroscopic mode, the near-infrared had a dense field of competitors. Here the choices to be made are between bulk optics vs. integrated optics and envelope tracking vs. fringe tracking on the technical side, and wide vs. narrow scope on the scientific side. But with such an enthusiastic and knowledgeable community, there should be no doubt that whatever choice is taken we will have a second generation of VLTI instruments that will ensure further workshops like this one.

Dutch Minister of Science Visits ESO Facilities in Chile

Mrs. Maria van der Hoeven, the Dutch Minister of Education, Culture and Science, who travelled to the Republic of Chile, arrived at the ESO Paranal Observatory on Friday afternoon, May 13, 2005.

The Minister was accompanied, among others, by the Dutch Ambassador to Chile, Mr. Hinkinus Nijenhuis, and Mr. Cornelis van Bochove, the Dutch Director of Science.

The distinguished visitors were able to acquaint themselves with one of the foremost European research facilities, the ESO Very Large Telescope (VLT), during an overnight stay at this remote site, and later, with the next major world facility in sub-millimetre and millimetre astronomy, the Atacama Large Millimeter Array (ALMA).

The Delegation in front of Kueyen (UT2). From left to right: Prof. T. de Zeeuw, Dr. C. Cesarsky, Dr. C. van Bochove, Minister M. van der Hoeven, Ambassador H. Nijenhuis, Prof. P. van der Kruit, Prof. E. van Dishoeck, Mr. H. van der Vlies, Mrs. van der Kruit, Mr. H. van den Broek, Dr. L. Le Duc, and Prof. F. Mirabel.

At Paranal, the guests were welcomed by the ESO Director General, Dr. Catherine Cesarsky; the ESO Council President, Prof. Piet van der Kruit; the ESO representative in Chile, Prof. Felix Mirabel; the Director of the La Silla Paranal Observatory, Dr. Jason Spyromilio; by one of the Dutch members of the ESO Council, Prof. Tim de Zeeuw; by the renowned astrophysicist from Leiden, Prof. Ewine van Dishoek, as well as by ESO staff members.

The visitors were shown the various high-tech installations at the observatory, including many of the large, front-line VLT astronomical instruments that have been built in collaboration between ESO and European research institutes. Explanations were given by ESO astronomers and engineers and the Minister gained a good impression of the wide range of exciting research programmes that are carried out with the VLT.

Having enjoyed the spectacular sunset over the Pacific Ocean from the Paranal deck, the Minister visited the VLT Control Room from where the four 8.2-m Unit Telescopes and the VLT Interferometer (VLTI) are operated. Here, the Minister was invited to follow an observing sequence at the console of the Kueyen (UT2) and Melipal (UT3) telescopes.

"*I was very impressed, not just by the technology and the science, but most of all by all the people involved,*" expressed Mrs. Maria van der Hoeven during her visit. "*An almost unique level of international cooperation is achieved at ESO, and everything is done by those who can do it best, irrespective of their country or institution. This spirit of excellence is an example for all Europe, notably for the new European Research Council.*"

Catherine Cesarsky, ESO Director General, remarked that Dutch astronomers have been part of ESO from the beginning: "*The Dutch astronomy community and industry play a major role in various aspects of the Very Large Telescope, and more particularly in its interferometric mode. With their long-based expertise in radio astronomy, Dutch astronomers greatly contribute in this field, and are now also playing a major role in the construction of ALMA. It is thus a particularly great pleasure to receive Her Excellency, Mrs. Maria van der Hoeven.*"

The delegation spent the night at the Observatory before heading further North in the Chilean Andes to San Pedro de Atacama and from there to the Operation Support Facility of the future ALMA Observatory.

On Sunday, May 15, the delegation went to the 5 000-m Llano de Chajnantor, the future site of the large array of 12-m antennas that is being built there and should be completed by 2013. The Minister visited the 12-m APEX (Atacama Pathfinder Experiment) telescope and saw the technical infrastructure.

"*I am fully confident that the worldwide cooperation in ALMA will be equally successful as the VLT, and I am convinced that the discoveries to be made here are meaningful for the Earth we live in*", said Mrs. van der Hoeven. "*History and future are coming together in the north of Chile, in a very special way,*" she added. "*In the region of the ancient Atacamenos, scientists from all over the world are discovering more and more about the universe and the birth and death of stars. They even find new planets. They do that on Paranal with the VLT and soon will be doing that on the ALMA site.*"

(from ESO Press Release 14/05)

ESO Receives Computerworld Honors Program 21st Century Achievement Award in Science Category

In a ceremony held in Washington, D.C. (USA) on June 6, 2005, ESO, the European Organisation for Astronomical Research in the Southern Hemisphere, received the coveted 21st Century Achievement Award from the Computerworld Honors Program for its visionary use of information technology in the Science category. Sybase, a main database server vendor and member of the Chairmen's Committee, nominated ESO's Data Flow System in recognition of its contributions to the global information technology revolution and its positive impact on society.

The citations reads: "*ESO has revolutionized the operations of ground-based astronomical observatories with a new end-to-end data flow system, designed to improve the transmission and management of astronomical observations and data over transcontinental distances.*"

This year's awards, in 10 categories, were presented at a gala event at the National Building Museum, attended by over 250 guests, including leaders of the information technology industry, former award recipients, judges, scholars, and diplomats representing many of the 54 countries from which the 17-year-old program's laureates have come.

"*The Computerworld Honors Program 21st Century Achievement Awards are presented to companies from around the world whose visionary use of information technology promotes positive social, economic and educational change,*" said Bob Carrigan, president and CEO of Computerworld and chairman of the Chairmen's Committee of the Computerworld Honors Program. "*The recipients of these awards are the true heroes of the information age and have been appropriately recognized by the leading IT industry chairmen as true revolutionaries in their fields.*"

The ESO Data Flow System (DFS) allows both traditional on-site observing as well as service observing, where data is collected by observatory staff on behalf of the ESO user community based on user-submitted descriptions and requirements. In either case, the data is captured by DFS and saved in the ESO science archive. After a one-year proprietary period during which the original investigators have private access to their data, researchers can access the data for their own use. ESO was the first ground-based observatory to implement these operational concepts and tools within a complete system. It was also the first ground-based observatory to build and maintain such an extensive science archive that does not only contain observational data, but also auxiliary information describing the operation process. In both areas, ESO remains the world-leader in end-to-end observatory operations on the ground.

"*The result of our strategy has been a significant increase in the scientific productivity of the ESO user community*", said Peter Quinn, Head of ESO's Data Management and Operations Division, responsible for DFS. "As measured by the number of papers in peer-reviewed journals, ESO is now one of the leading astronomical facilities in the world. Coupled with cutting-edge optical telescopes and astronomical instruments at the Chile sites, the DFS has contributed to this success by providing the fundamental IT infrastructure for observation and data management."

The case study about ESO, together with the case studies from the other winners and laureates of the 2005 Collection, is available on the Computerworld Honors Program Archives On-Line, *www.cwheroes.org*. The Computerworld Honors Program is governed by the Computerworld Information Technology Awards Foundation, a Massachusetts not-for-profit corporation founded by International Data Group (IDG) in 1988. The Computerworld Honors Program searches for and recognizes individuals and organizations who have demonstrated vision and leadership as they strive to use information technology in innovative ways.

The ESO Data Management and Operations Division web page can be found at *http://www.eso.org/org/dmd/*.

(from ESO Press Release 16/05)

Receiving the Computerworld 21st Century Achievement Award for Science on behalf of ESO: Preben Grosbøl, Michele Péron, Peter Quinn (Head of the ESO Data Management Division) and David Silva.

ESO at the European Research and Innovation Salon in Paris

Ed Janssen, ESO

From June 3–5, 2005, ESO took part in the European Research and Innovation Salon, which was held at Paris Expo (France). The event, organized under the auspices of the French Government and the European Commission, was the first of its kind in Europe and was mostly aimed at the general public. This first event had over 24 000 visitors, including high-ranking officials, a great success given the numerous events that took place in Paris the same weekend.

The standard ESO Exhibition (65 sqm), showcasing the observatories as well as ALMA and the plans for the OWL telescope, also included scale models and was further extended with a giant projection screen, presenting a selection of the best pictures of ESO installations and astronomical objects.

A videoconference with Paranal also took place each day, and many people took the opportunity to ask numerous questions to staff astronomer Christophe Dumas, who kindly helped us make this event a great success.

ESO Director General, Catherine Cesarsky, gave a talk with the title 'The ESO Very Large Telescope: How to explore Space while keeping your feet on the ground', which was attended and appreciated by many visitors.

Christoph Dumas answering visitors' questions during a videoconference with Paranal.

Visit of former French Minister of Science, Education and Technology, Prof. Claude Allègre (centre), and Prof. Jean Audouze (right), chairman of the Scientific Committee of the event, at ESO's stand.

Fellows at ESO

Martin Vannier

I joined ESO in June 2003, as a fellow with duty on the VLTI in Paranal. Before this, I had had a first feeling of ESO/Chile during a six-month traineeship in 1997. I remember that I enjoyed as much being in the action of a big observatory as having a taste of Chile. I then worked for a year at the European Space Agency on the future GAIA satellite. After this experience, I chose a scientific PhD, with still a large part of innovative technology, rather than an engineering career.

I did my PhD in Nice on colour-differential interferometry, a technique combining high-angular resolution and spectroscopy, which allows one to measure small displacements of the photocentre with wavelength. This mode is becoming operational at the VLTI, first with MIDI (10 microns), and now with the near-IR instrument AMBER. Among many possible applications, the most ambitious is the spectroscopy of hot extrasolar planets. This requires extremely good instrumental stability and precise monitoring of atmospheric effects. Part of my PhD was to translate these requirements into specifications for the AMBER instrument. Therefore, it was as much a logical step as an exciting possibility to come and follow the progress of the VLTI for my post-doc. Since the arrival of AMBER last year, I have worked on data processing methods to reach the challenging goal of measuring a few 10 000th of a fringe, the required precision for detecting a "hot Jupiter" exoplanet. I am also interested in other scientific applications of interferometry: stellar binarity, symbiotic stars, velocity fields of emission-line stars, ...

I see ESO as a unique and exciting place to work. Certainly, the international diversity of its participants and the ambition of its current projects contribute to making my fellowship a very positive experience.

Martin Zwaan

Born a few metres below sea level, I initially felt more comfortable with low-altitude radio telescopes than optical telescopes on high mountain tops. Consequently, my PhD work in Groningen was based primarily on radio surveys of the neutral hydrogen 21-cm line. After finishing up the thesis, I moved to Melbourne, Australia, where I worked on HIPASS, a 'blind' extragalactic 21-cm survey covering more than half the sky. These kinds of surveys provide interesting anchor points for observations of neutral hydrogen via absorption lines from a time when the universe was much younger. One of my main scientific interests is therefore to deduce a consistent picture from these two sets of information and understand the evolution of gas in galaxies.

Late 2003 I came to Garching. One of my reasons to apply for the ESO fellowship was to venture more into spectral ranges corresponding to wavelengths shorter than the width of the page you read this on. The first step is to millimetre wavelengths. For my functional work I am involved in ALMA and I am looking forward to using this instrument to study galaxy gas components that are chemically more complicated than neutral hydrogen. Secondly, using optical wavelengths, I am trying to learn more about faraway galaxies that hold the gas that gives rise to absorption lines.

Working at ESO means being at the astronomical barycentre of Europe. It really feels that way when you have to decide if you want to attend the seventh interesting science talk in a week's time. But not only scientifically, also personally the move to Garching has been a very positive experience, especially because I became a father only two months after arriving here.

ESO/MPA Workshop on

Carbon-Rich Ultra Metal-Poor Stars in the Galactic Halo

28 November – 2 December 2005, Schloss Ringberg, Tegernsee, Germany

The main goal of the workshop is to thoroughly discuss, review and understand in depth all aspects related to the many carbon-rich stars found in the last decade among the oldest and most metal-poor objects of the Galactic Halo, i.e. their origin, nature, main characteristics, and implications for the chemical evolution of the (early) Galaxy.

Keen interest in this class of objects has arisen from the extensive HK survey of metal-deficient stars conducted by Beers, Preston, & Shecman. Among the several exciting results, this survey has revealed for the first time an unexpectedly large number of very metal-poor stars with anomalously strong CH and CN bands (up to 25–30 % in the metallicity range [Fe/H] < –2.5 compared to a few per cent among stars of higher metal abundances). This significant increase in the frequency of carbon-enhanced stars at the lowest metallicities has been further confirmed by the more recent Hamburg/ESO stellar survey and it may have an impact on chemical evolution issues and abundance trends in the early Galaxy. Their presence in the very early phases of the Galaxy formation has recently been discussed in connection with the early metal pollution of the intergalactic medium.

In recent years, several high-resolution spectroscopic analyses of carbon-rich ultra metal-poor stars, making use of the largest ground-based telescope facilities, have become available and/or are presently under way. Similar efforts have been devoted to the theoretical aspects (nucleosynthetic origin of the observed carbon and influence on the early Galactic chemical evolution), in order to properly compare observations and theoretical predictions and to understand the nature and history of these stars.

Because of all these new efforts and developments, we think this is a very exciting time to get together and discuss certainties and uncertainties, the many open issues, and the future needs to significantly advance our understanding of these objects.

For more details please check: *http://www.mpa-garching.mpg.de/~crumps05/*

Please note that because of space reasons, the number of participants is limited to 40 and that the deadline for *early* registrations was on April 30. But there are still some places available!

Contacts: Francesca Primas (*fprimas@eso.org*) and Achim Weiss (*aweiss@mpa-garching.mpg.de*)

ESO Conference on

Groups of galaxies in the nearby Universe

5–9 December 2005, Santiago, Chile

Comparative studies of galaxy groups and group members, and detailed studies of individual groups, promise an understanding of the evolution of the groups themselves as well as their stellar systems. Historically, the former approach was pursued for nearby groups, while the latter was restricted to the Local Group. The recent advance of technology allows both approaches to be combined. The next generation of extremely large telescopes and space missions will make it possible to study nearby groups at the same level of detail as is currently achievable for the Local Group. We will hold a conference aiming to summarize the considerable progress that has been made since the last meetings dedicated to galaxy groups, and to formulate the new problems that can be tackled both with the new instrumentation available to the community, and with the ever advancing theoretical work.

The participants will discuss the following topics: (1) Search, definition, classification, and statistics of groups; comparison with clusters and field; surveys (imaging, spectroscopy) at all wavelengths: X-rays, optical, IR, etc.; (2) Evolution of galaxies in groups: DM, gas, dust; Stellar and galaxy populations in groups; mergers, starbursts, nuclear activity; galactic chemical evolution; (3) Evolution of groups as a whole: Dynamical evolution, chemical evolution of the intra-group medium; galactic luminosity function; Role of environment (density); (4) Groups in the context of cosmological structures: Comparison with clusters of galaxies and field population; Group environment; Distances to groups; Theoretical/numerical simulations of groups and the intra-cluster/intra-group medium; Sunyaev-Zel'dovich effect; (5) Extreme groups: densest, largest, closest, with most peculiar galaxy population, etc.; (6) The fate of nearby groups; and the future avenues of research, both theoretical and observational.

Invited Speakers: Local Group(s) – Eva Grebel, Group searches/surveys – Vince Eke, Evolution of Galaxies (in Groups) – observational – Chris Conselice, Evolution of Galaxies (in Groups) – theoretical – Ray Carlberg (tbc), Evolution of Groups (as a system) – Ann Zabludoff, Intragroup Medium/Gas processes – Trevor Ponman (tbc), Groups in a Cosmological context – Stefano Borgani, Overview/Summary/Future – Ken Freeman
Scientific Organizing Committee: Stefano Borgani (Trieste, Italy), Gary Mamon (IAP), France Warrick Couch (NSW, Australia), Claudia Mendes de Oliveira (Sao Paulo, Brazil), Gary Da Costa (ANU, Australia), John Mulchaey (Carnegie, USA), Duncan Forbes (Swinburne, Australia; Chair), Bianca Poggianti (OAPD, Italy), Roberto Gilmozzi (ESO), Trevor Ponman (Birmingham, UK), Deidre A. Hunter (Lowell, USA), Evan Skillman (Minnesota, USA), Leopoldo Infante (PUC, Chile), Ann Zabludoff (Steward, USA)
Local Organizing Committee: Ivo Saviane, Valentin Ivanov, Jordanka Borissova (ESO)
Further information is available at: *http://www.sc.eso.org/santiago/science/NGG/* or by e-mail to *groups2005@eso.org*
Deadline for pre-registration: 31 July 2005

High Honour for Daniel Hofstadt

Gonzalo Argandoña and Felix Mirabel, ESO

Daniel Hofstadt, former ESO representative in Chile, was honoured last May 12 by the Chilean government, in a ceremony held at the Chilean Ministry of Foreign Affairs, with the presence of ESO Director General, Dr. Catherine Cesarsky.

Mr. Hofstadt received from the Minister of Foreign Affairs Ignacio Walker the Medal "Bernardo O'Higgins". This award is given by the Chilean government to selected foreign citizens in recognition of their outstanding services and contributions to the country, particularly in the fields of science, technology and culture.

Daniel Hofstadt receives the award "Bernardo O'Higgins" from the Chilean Minister of Foreign Affairs Ignacio Walker (at the right).

Ignacio Walker expressed the gratitude of the Chilean government for ESO contributions to the education in the country, including the establishment of scholarship programmes for undergraduate students in region II, training courses in science and astronomy for teachers, the donation of a permanent astronomy exhibition at the popular Interactive Museum in Santiago (MIM) and the implementation of an itinerant planetarium, among recent projects supported and financed by ESO in Chile.

"*It is evident that the astronomy in Chile is in a growing stage, in which the investments of ESO and the work of outstanding individuals like Mr. Hofstadt have played a significant role,*" said Walker.

This homage from the Ministry of Foreign Affairs is the culmination of a long and fruitful career of Daniel Hofstadt within ESO, since 1972 when he first joined the organization as electronic engineer at La Silla Observatory to work on the advancement of instrumentation of the telescopes. From the early 80's, he assumed new duties, becoming responsible for technical research service. He was also involved in the installation of all telescopes arriving those years to LSO, including the 3.6-m telescope and the NTT.

A few years later, he became chairman of the management team at LSO, coordinating the different services managed by that time from La Silla, including administration, technical services and personnel.

In 1995, he moved to the Vitacura office in Santiago to assume further responsibilities, as the ESO representative in Chile.

He took up this new role while the VLT was under construction at Paranal, in northern Chile. By that time, Mr. Hofstadt faced the challenge of expanding the cooperation and dialogue between ESO and Chile, establishing strong relationships with the government and its authorities, which allowed to successfully overcome the initial difficulties that affected VLT construction.

Later on, Daniel Hofstadt supervised the development and construction of the Paranal residence until its full completion. He also participated in the negotiations with the Chilean government that successfully ended in a new agreement that authorized ESO to establish a new centre for astronomical observation in the country, the Atacama Large Milimeter Array (ALMA).

On April 1 this year, Daniel Hofstadt retired from ESO, and Felix Mirabel became the new representative of the organization in Chile. Mirabel also assumed the role of Head of ESO's Office for Science in Chile.

The Chilean Minister of the Interior, José Miguel Insulza; former ESO representative in Chile, Daniel Hofstadt; his wife Sonia Hofstadt; and Dr. Catherine Cesarsky.

Richard West retires

Claus Madsen, ESO

It is hard to believe, but after 35 years of service, Richard West has retired from ESO.

Born 1941 in Copenhagen, Richard did his baccalaureate in 1959. In 1964, he obtained his degree (Mag. scient. et cand. mag.) in astronomy and astrophysics at Copenhagen University, followed by a period as Assistant Professor (Amanuensis) at Copenhagen University Observatory. In 1970, he joined ESO as Assistant Astronomer to the ESO Director General, Adriaan Blaauw.

In 1972, Richard was charged with setting up the ESO Sky Atlas Laboratory (then at the CERN premises in Geneva), and thus – together with Hans-Emil Schuster – with leading one of the first and largest scientific programmes of ESO: the systematic mapping of the southern skies by means of the 1-m ESO Schmidt Telescope at La Silla and later also involving the 1.2-m UK Schmidt Telescope at Siding Springs.

Facing the press – Richard West during the Shoemaker-Levy 9 event.

Working with the Schmidt plates gave him ample opportunity to pursue his great scientific interest, the study of minor bodies in the Solar System. Over the years, he has published 150 scientific papers, discovered numerous minor planets and four comets. The most spectacular comet, C/1975 V1 (West), was found by Richard on 5 November 1975 on a Schmidt plate. During March 1976 it became one of the brightest comets of the twentieth century, at least partly because the nucleus had broken into four or more fragments, three of which persisted for some months with distinct comae and tails. Another scientific high point for him was the 1986 passage of Comet P/Halley, which he observed from La Silla. He carried out some of the earliest observations as the comet reappeared after passing the Sun; observations that were very important for the precise determination of the orbit – and thus for the successful encounter between the comet and ESA's Giotto space probe.

Serving the scientific community

Besides running the Atlas project and pursuing his own scientific interests, he also found time and energy to spend on organizational matters. He served as Assistant General Secretary of the IAU in 1979–1982, followed by a term as General Secretary (1982–1985). He also presided over various IAU Commissions and was a member of the Executive Committee of ICSU.

In the wake of the political changes in eastern Europe in the early 1990'ies, he led the ESO support programme for central and eastern European scientists, lending a helping hand to many a scientist in need. In this activity, ESO benefited from Richard's intimate knowledge of the scientific communities of these countries, but it was also a task, which he undertook with strong conviction and, at times, great personal courage.

Science Communication

Richard is a gifted communicator, and already during his time in Denmark, he became known in that country as a commentator of the US Space Programme, for which he was awarded the Rosenkjær prize.

At ESO, he quickly involved himself in the ESO Messenger and became its editor in 1976–1980. In 1986 he resumed the editorship until 1993.

In 1986, ESO's Director General Lodewijk Woltjer asked him to establish an Information Service at ESO. In the time to come it would spearhead the development of professional public communication by science institutes in Europe. Richard remained head of the department until his retirement. Outreach activities are about highlights and Richard experienced many – such as the NTT first light and inauguration and the VLT first light media campaign. Yet, the moment, which stands out for those of us who had the privilege to be around was the Shoemaker-Levy 9 collision with Jupiter in 1994. At the ESO Headquarters, it began on July 16 with a densely packed ESO auditorium full of media people, including numerous camera crews. For a full week, Richard led the effort to keep journalists informed and entertained through daily press briefings, a daily in-depth news report and uncounted live interviews. In the September 1994 issue of the Messenger (pages 47–48), Rudi Albrecht offers a vivid account of those exciting days.

Richard also oversaw ESO's engagement in education. He became the father of the great pan-European science teachers' meetings, which led to the formation of the European Association for Astronomy Education (EAAE) and have now developed into the well-known Science on Stage events. Indeed Science on Stage is EIROforum's flagship activity in the field of education, strongly supported by the European Commission and, increasingly, by the education authorities of the member states. With his own scientific interests in mind it is only fittingly, though, that the last educational activity he organized for ESO was in connection with the Transit of Venus on 8 June 2004. This activity developed into a truly global science outreach programme and provided clear evidence for the public attraction that astronomy exerts.

In spite of so many years in 'the limelight', in TV, on the radio, or in lecture theatres across the world, Richard has stayed true to himself and his values: Extreme personal modesty, tolerance and openness, rich in ideas and with an ability to think in unconventional ways.

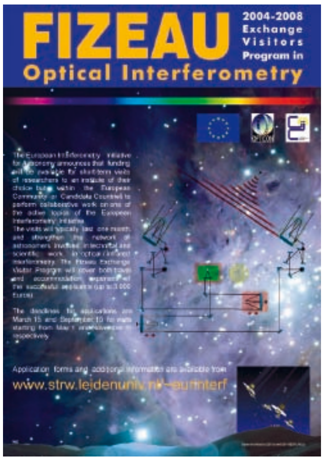
From studying old bodies in the Solar System, he now spends his time with young buddies, his six wonderful grand children, in close orbit around him and his wife, Tamara. We wish him joy and happiness and, perhaps, with his pedagogical influence, astronomy may one day see another member of the West family observing with, who knows, the OWL telescope.

Fizeau Exchange Visitors Programme

Optical Interferometry in Europe

Deadline 15 March & 15 September (up to 2008)

ESO is a partner in the European Interferometry Initiative (EII) that is linked to the OPTICON project of the European Commission's FP6 programme. The EII is funding a visitor programme for researchers (Ph.D, postdoc, and tenured staff) to institutes of his/her choice within the European Community. The goal is to perform collaborative work on one of the active topics related to Optical Interferometry (R&D, science, etc.). A visit to one of the institutes will typically last one month, and strengthen the network of astronomers engaged in technical and scientific work on optical/infrared interferometry.



Biannual deadlines are **March 15** and **September 15**.

Further details and application information can be found at: *http://www.strw.leidenuniv.nl/~eurinterf*

Personnel Movements

1 March 2005 – 30 June 2005

Arrivals

Europe

Bronnert, Iris (D)	Secretary/Assistant
de Jong, Jeroen (NL)	Astrometry and Operations Software Developer
Donino, Gabriele (I)	Software Engineer
Galea, Caterina (I)	Head of Finance Department
Holzlöhner, Ronald (D)	Physicist/Engineer
Junker, Georg (D)	Programme Controller
Kreutle, Isolde (D)	Secretary/Assistant
Muradore, Riccardo (I)	System and Control Engineer
Pierfederici, Francesco (I)	Senior Scientific Software Engineer
Rejkuba, Marina (HR)	User Support Astronomer
Rino, Bruno (P)	Software Engineer
Turolla, Stefano (I)	Software Engineer

Chile

Araya, Alejandra (RCH)	Personal Assistant
Argandoña, Gonzalo (RCH)	Public Relations Officer
Bergman, Per Mikael (S)	Operations Staff Astronomer
Davila, Rodrigo (RCH)	Mechanical Technician
Kubas, Daniel (D)	Associate
Lombardi, Gianluca (I)	Student
Monaco, Lorenzo (I)	Fellow
Moya, Maria Angelica (RCH)	Head of Administrative Services Vitacura
Naef, Dominique (CH)	Fellow
Rivinius, Thomas (D)	Operations Staff Astronomer
Sababa Nadja, (RCH)	Secretary
Scharwächter, Julia (D)	Fellow
Torres, Soraya (RCH)	Secretary

Departures

Europe

Fiorentino, Mauro (I)	Software Engineer
Fischer, Peter (D)	Head of Finance Department
Gavignaud, Isabelle (F)	Student
Ivanescu, Liviu (CDN)	AIT Engineer
Kraft, Gabriele (D)	Accounting Clerk
Lampersberger, Brigitte (A)	Administrative Clerk
Ounnas, Barbara (DK)	Personnel Officer
Ounnas, Charlie (FR)	Software Engineer
Paresce, Francesco (I)	VLTI Project Scientist
Seichter, Nicole (D)	Secretary/Assistant
West, Richard-Martin (DK)	Head of Education and Public Relations

Chile

Carrasco, Oscar (RCH)	Safety Engineer
de Brito Leal, Luis Filipe (P)	Student
Giordano, Paul (F)	Head of Optical Group Paranal
Herrera, Gabriel (RCH)	Mechanical Technician
Hofstadt, Daniel (F)	Representative of ESO in Chile
Smoker, Jonathan (UK)	Operations Staff Astronomer

ESO Fellowship Programme 2005/2006

The European Organisation for Astronomical Research in the Southern Hemisphere awards each year several postdoctoral fellowships to provide young scientists with opportunities and facilities to enhance their research programmes. The goal is to bring young astronomers 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/*.

For the first time this year, four **dedicated ALMA fellowships** will be offered (two in Garching and two in Santiago) in addition to the several regular fellowships offered at both places. Also, dedicated VLTI fellowships are again available in Chile.

All fellows have ample opportunities for scientific collaborations within ESO both in Garching and Santiago. A list of current ESO staff and fellows and their research interests can be found at *http://www.eso.org/science/sci-pers.html* and *http://www.sc.eso.org/santiago/science/person.html*. Additionally, the ESO Headquarters in Munich, Germany host the Space Telescope European Coordinating Facility and are situated in the immediate neighbourhood of the Max-Planck Institutes for Astrophysics and for Extraterrestrial Physics and are only a few kilometres away from the Observatory of the Ludwig-Maximilian University. In Chile, fellows have the opportunity to collaborate with the rapidly expanding Chilean astronomical community in a growing partnership between ESO and the host country's academic community.

In **Garching**, fellows spend up to 25 % of their time on support or development activities in the area of e.g. instrumentation, operations support, archive/virtual observatory, VLTI, ALMA, public relations or science operations at the Observatory in Chile. Fellowships in Garching start with an initial contract of one year followed by a two-year extension.

In **Chile**, the fellowships are granted for one year initially with an extension of three additional years. During the first three years, the fellows are assigned to one of the operations groups on Paranal, La Silla or ALMA. Together with the astronomer in charge, they contribute to the operations at a level of 80 nights per year at the Observatory and 35 days per year at the Santiago Office. During the fourth year there is no functional work and several options are provided. The fellow may be hosted by a Chilean institution and will thus be eligible to apply for Chilean observing time on all telescopes in Chile. The other options are to spend the fourth year either at ESO's Astronomy Centre in Santiago, Chile, or the ESO Headquarters in Garching, or any institute of astronomy/astrophysics in an ESO member state.

We offer an attractive remuneration package including a competitive salary (tax-free), comprehensive social benefits, and provide financial support in relocating families. Furthermore, an expatriation allowance as well as some other allowances may be added. The Outline of the Terms of Service for Fellows provides some more details on employment conditions/benefits.

Candidates will be notified of the results of the selection process between December 2005 and February 2006. Fellowships begin between April and October of the year in which they are awarded. Selected fellows can join ESO only after having completed their doctorate.

The closing date for applications is October 15, 2005.

Please apply by filling the form available at *http://www.eso.org/gen-fac/adm/pers/vacant/fellowship05_form.pdf* attaching to your application:
- a Curriculum Vitae including a publication list (the latter split into refereed and non-refereed articles, please)
- an outline of your current and past research, as well as of your research plans if you came to ESO (max. 2 pages)
- a brief outline of your technical/observational experience (max. 1 page)
- arranging for three letters of reference from persons familiar with your scientific work to be sent to ESO before the application deadline.

All documents should be typed and in English.

The application material has to be addressed to:

European Organisation for Astronomical Research in the Southern Hemisphere
Fellowship Programme
Karl-Schwarzschild-Straße 2
85748 Garching bei München
Germany
vacancy@eso.org

Contact person: Markus Kissler-Patig, Tel. +49 89 320 06-244, Fax +49 89 320 06-497, e-mail: *mkissler@eso.org*

All material must reach ESO by the deadline (October 15); the same applies to recommendation letters which should be sent directly by the reference person; applications arriving after the deadline or incomplete applications will not be considered!

Applications are invited for the position of

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 Organisation for Astronomical Research in the Southern Hemisphere (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 Management Control 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.
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, grade or 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

31 Juli 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.

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 the United Kingdom, no nationality is a priori excluded.

ESO, the European Organisation for Astronomical Research in the Southern Hemisphere, 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 2 600 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 2 400 m altitude, ESO operates several optical telescopes with diameters up to 3.6 m. The third site is the 5 000 m high Llano de Chajnantor, near San Pedro de Atacama. Here a new submillimetre telescope (APEX) is being completed, and a giant array of 12-m submillimetre quality antennas (ALMA) is under development. Over 1 600 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 has about 600 employees.

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 Public Affairs Department at the following address:

ESO Headquarters
Karl-Schwarzschild-Str. 2
85748 Garching bei München
Germany
Phone +49 89 320 06-0
Fax +49 89 320 23 62
ips@eso.org
www.eso.org

The ESO Messenger:
Editor: Peter Shaver
Technical editor: Jutta Boxheimer
www.eso.org/messenger/

Printed by
Peschke Druck
Schatzbogen 35
81805 München
Germany

ISSN 0722-6691

Contents

Telescopes and Instrumentation

Reports from Observers

Other Astronomical News

Announcements

Front Cover Picture: *First image of an extra-solar planet*

See the press release reprinted on page 25 for details. Two major articles on extra-solar planets are also published in this issue: Pont et al. (page 19) and Pepe et al. (page 22).