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Recent progress on the E-ELT
New image catalogue of planetary nebulae
Massive star spectroscopy with X-shooter
Renewable energy plans for Paranal

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Recent Progress Towards the European Extremely Large Telescope (E-ELT)

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The European Extremely Large Telescope (E-ELT) has evolved over the last few years since the phase B review of the 42-metre design. While the design was strongly endorsed, the cost exceeded the maximum envelope and a re-baselining was implemented by the Project Office. The extent and ramifications of the new design are outlined including scientific, engineering and managerial aspects. Prototyping activities of some of the components are described and the first light instruments have been selected. The new baseline for the 39-metre E-ELT has been accepted by the ESO Council and awaits the decision on the start of construction.

The European Extremely Large Telescope (E-ELT) design has evolved significantly since the last report in *The Messenger* (Spyromilio et al., 2008) and here we aim to update the community on the activities within the E-ELT Project Office during the past few years. The construction proposal prepared for the ESO Council has been widely publicised and is available on the ESO website[1].

In the second half of 2010, the E-ELT programme underwent a series of technical and managerial reviews that provided a strong endorsement of the construction project. The activities undertaken during the phase B (2007–2010) were thoroughly reviewed by a board of external experts in September 2010 (see Kissler-Patig, 2010). The executive summary of the board report has been available for some time[2]. The short version is that "it [was] the unanimous conclusion of the review board that the technical maturity of the design of the E-ELT was sufficient to warrant the programme entering the construction phase". Moreover, the "E-ELT budget was highly cost-effective" and the "FEED methodology had been highly effective in generating reliable cost estimates" (for a definition of FEED see below p. 8).

However, the final cost estimate at the end of phase B was €200 million above the top end of the target. The project was asked to consider whether any significant cost savings could be delivered without compromising the scientific capabilities of the telescope. Unfortunately the answer to this question was no. Some reduction in scope from the 42-metre aperture would be necessary. On the other hand, following a four-year design development phase the project was also aware of areas where technical and programmatic risks existed. Realistic funding scenarios gave an earliest possible start for the project in 2012 and therefore there was time to work on mitigating those risks. The Project Office undertook to explore cost saving and risk mitigation options during 2011. These changes have been adopted by the ESO Council as the baseline for the new 39-metre E-ELT.

Science capabilities

A primary concern with respect to the new baseline for the telescope was its impact on the scientific capabilities. The E-ELT Science Office, together with the Science Working Group studied the impact on the science of the various modifications to the baseline design using the Design Reference Mission[3] and Design Reference Science Cases[4] as benchmarks for the evaluation.

The diameter of the primary mirror is the most fundamental and most important characteristic of any telescope system, but particularly for an adaptive optics assisted telescope, as it determines both its diffraction-limited spatial resolution as well as its photon-collecting power. These properties may combine differently depending on the scientific goal, as well as the observational and astrophysical circumstances. The result is that there can be many different ways in which a given science case may depend on the diameter.

At the highest level we may distinguish between the following three classes of science cases: (i) cases where science is irretrievably lost by reducing the telescope diameter; (ii) cases where the loss of telescope diameter can be compensated for by increasing the observing time or adjusting some other observational parameter; (iii) cases that are not affected by the reduction of the telescope diameter at all.

The unique spatial resolution of the E-ELT is one of its defining characteristics and hence it is not surprising that many of the science cases that have been proposed for the E-ELT aim to exploit this feature. All cases that require the E-ELT resolution to disentangle their targets from other nearby sources will be forced to adopt less demanding goals for the 39-metre E-ELT than originally envisaged for the 42-metre design. This observational scenario encompasses a vast range of science cases, and prominent examples include the direct detection of exoplanets (all high-contrast imaging applications depend particularly strongly on the diameter), the study of the resolved stellar populations of other galaxies, and studies of supermassive black holes and their environments in the centre of our own and other galaxies.

The other subcategory in this class of irretrievable loss contains cases where the observing time cannot arbitrarily be extended, even in principle. Among such cases are included observations of non-recurring transient events, such as gamma-ray bursts (GRBs) or supernovae, and short recurring events with very long periods between repetitions, such as some eclipses or transits. In all of these cases the reduction of diameter will lead to a loss of signal-to-noise (S/N) that cannot be compensated for by increasing the integration time.

The second class of science cases contains those that are limited by the S/N that is achievable on their targets, and where the S/N is not dominated by (diameter-independent) astrophysical error sources or systematic uncertainties (astrophysical, instrumental, or otherwise). To a large extent these cases principally exploit the other key characteristic of the E-ELT, namely its unique photon-collecting power. The feature that is common to all of these cases, and which sets them apart from those in the first class, is that a decrease in diameter can be compensated for by increasing the observing time in order to achieve the same result with the 39-metre as with the 42-metre E-ELT. Again, this class encompasses a vast range of science cases. Prominent examples include most studies of high-redshift galaxies, investigations of the stellar populations in the Galaxy and the search for possible variations of the fundamental physical constants.

Finally, the third class of science cases contains those cases that are limited by (diameter-independent) astrophysical error sources or systematic uncertainties, or where the reduction of diameter can be compensated for by adjusting parameters that have essentially no impact on the science. We stress that we are only referring to cases that are quasi-independent of diameter for the specific regime under consideration here, i.e. when going from the 42-metre to the 39-metre aperture. This class does not encompass many cases, but one prominent example is the detection of low-mass exoplanets using the radial velocity method.

The overall loss of scientific efficiency resulting from the reduction of the E-ELT diameter depends of course on how the observing time will be distributed among the various science cases, each following different scaling laws. This is difficult to know *a priori*, but it is reasonable to assume that the E-ELT will spend much of its time doing science that depends on the power of the diameter to the squared or fourth power, resulting in an overall loss of efficiency in the range of 20 to 35%.

In addition to assessing the overall loss of scientific efficiency, it was also evaluated whether any individual science cases are rendered completely infeasible by the reduction in the E-ELT diameter, in the sense that the diameter is now below some critical threshold value for these cases. To summarise the result of this analysis: of all the major science cases for the E-ELT, the one that is most severely affected by the reduction of the telescope diameter is the direct imaging of Earth-analogue exoplanets. Nevertheless, the overall conclusion is that none of the major science cases for the E-ELT must be completely abandoned, and that, on the whole, the E-ELT science case remains intact and does not require any major revision.

The new telescope

The costs of the E-ELT are roughly divided between: 40% for the dome and main structure; 40% for the opto-mechanics; 10% for the instrumentation; and 10% for the rest. From this breakdown it should be obvious that no individual component would deliver the significant cost saving necessary to bring the telescope within the required cost envelope.

The natural choice of reducing everything but the telescope diameter could not work. Reducing the cost of the dome required a reduction in the overall volume occupied by the telescope and reducing the cost of all other components of the programme (excluding instrumentation) also required a reduction in the dimensions of the telescope.

The 42-metre E-ELT design was based on a three-mirror anastigmat used on-axis with two folding flat mirrors extracting the beam to a suitable Nasmyth focus (Spyromilio et al., 2008). This design was driven by the requirement for a Nasmyth focus, that the telescope be adaptive and the large diameter. These three basic requirements, combined with a number of engineering risks (e.g., the maximum size of the deformable mirror that was viable within cost and schedule constraints), confined the parameter space. Our competitors have chosen more classical designs: Ritchey-Chrétien (RC) in the case of the Thirty Metre Telescope (TMT) and Gregorian in the case of the Giant Magellan Telescope (GMT). We considered whether a smaller telescope would warrant completely new thinking in the optical design, but concluded that the incorporation of adaptive optics in the telescope is a prerequisite for the dimensions that we were considering. In addition to correcting the ground layer of atmospheric turbulence, the inclusion of an adaptive element in the telescope optical train allows us to manage the aberrations of the telescope under the disturbances of wind and gravity.

The design was therefore iterated around the existing solution. Reducing the volume of the telescope could be achieved by making the primary faster (lowering the *f*-ratio). However, consideration needed to be given to the difficulty of making the segments and the secondary mirror. After some investigation it was considered that making the telescope somewhat smaller and faster would provide us with cost savings in the dome, the main structure and the primary mirror, as well as reductions in manufacturing and performance risks.

Removing the two outer rings of the primary mirror segments results in a new telescope diameter of 38.54 metres for segments that are used fully and

39.1 metres if one includes the few segments that are illuminated for 80% of their surface. The two rings accounted for approximately 200 segments from the original 984 installed in the telescope. The cost saving unfortunately is not a straight percentage of segment number as the facility costs (building the factory to produce the mirror segments and equipping it with the necessary polishing robots, etc) are relatively invariant at this scale of production. However, the risk of achieving the production goals and timescales are theoretically much reduced by the smaller number of segments.

Having lost three metres of diameter on the primary mirror of the telescope, we targeted cost savings in the other components that should be at least as dramatic. The dimensions of the dome were reduced further as we shrank the telescope Nasmyth platforms by five metres on each side, thereby reducing the dome diameter by more than 10%.

In the redesign process, the project considered which risks could be further mitigated or reduced. The large secondary mirror (a convex 6-metre in the 42-metre case) posed a series of interesting manufacturing challenges and simultaneously posed a limitation in the performance of the telescope under heavy wind loading. Specifically, the secondary mirror deflections in the wind dominated the error budget for the 42-metre design and a feed-forward control scheme for the tip-tilt M5 mirror, based on accelerometer input from the secondary, might have been necessary to meet the performance goals in the most stringent of environmental conditions. However, given the need to reduce costs and risks, reducing the size of the secondary mirror, beyond what a simple scaling would imply, provided a useful focus for the re-baselining activities.

In manufacturing large optical elements there exists a natural break-point at diameters of around 4.2 metres that arises from a series of trade-offs that involve manufacturing facilities and dimensions of machines and processes. We therefore placed a 4.2-metre diameter constraint on the secondary mirror and evolved the optical design of the 39-metre E-ELT about that solution. We have maintained, to the maximum extent possible, the linear dimensions of the quaternary adaptive mirror. Effectively this provides a somewhat denser actuator spacing in comparison to the 42-metre design, as approximately the same number of actuators now cover a smaller primary mirror.

In order to maintain the field of view of the telescope with a smaller secondary, the telescope primary mirror is now faster at *f*/0.9. However the difficulty in polishing the segments of the primary mirror is comparable between the two designs.

The aspheric coefficients of the smaller secondary mirror are different but remain within the polishing regime considered for the 42-metre baseline 6-metre mirror. The polishing solution proposed by the ESO contractors for the convex 6-metre mirror employed transmission elements, known as matrices, for the metrology. The matrices are large optical elements that more or less match the radial curvature and local aspheric departure of the mirror and cover a fraction of the surface. The mirror is then rotated under the matrix while the cavity between the matrix and the polished mirror surface creates the interferometric cavity that is used to test the accuracy of the polished surface. For the 42-metre design with 6-metre secondary mirror, two matrix units would have been necessary. The new 4.2-metre mirror radius is within the reach of a single such matrix, thereby potentially greatly simplifying the polishing metrology and the risk of mismatched references.

Speeding up the focal ratio of the primary mirror and reducing the dimensions of the secondary, also reduced the length of the telescope, which reduced the overall weight and made it easier to achieve the required stiffness. The provision of the gravity-invariant focus under the Nasmyth platform had proved to be a design driver for the mechanical structure of the telescope, requiring significant amounts of steel reinforcement to provide the necessary stiffness for the instrumentation and the pre-focal station. Moreover, it complicated the support and load transfer to the azimuth tracks. By removing the gravity-invariant focus, speeding up the primary and reducing the dimensions of the Nasmyth platforms, the telescope main structure has lost a lot of weight (several hundreds of tonnes of steel) and engineering complexity.

Design activities

It has been challenging to evaluate these ideas and to bring the E-ELT project with this new concept to a comparable level of engineering as the phase B for the 42-metre design had achieved. In particular this re-baselining was to be performed within one calendar year and with limited resources. The Project Office placed a series of delta phase B contracts to update the previous design. A revision of the dome for the new parameters and a revision of the main structure were contracted to the firms that had developed the original concepts.

The new dome is simplified relative to the phase B concept in a number of critical areas. After an evaluation by the contractors and ESO of the erection sequence for the dome and the main structure, it became apparent that the large 30 × 17-metre loading door, foreseen to allow large telescope components to enter the dome without requiring the opening of the observing doors, was not necessary, and, furthermore, it added complexity in the concrete pier of the dome. It has been removed from the plans. The dome for the 42-metre telescope design had included a requirement for a lifting platform that allowed access to the Nasmyth platforms and also to the secondary mirror. The platform was required to lift 30 tonnes to 30 metres above the floor in order to support the exchange of the secondary mirror with its cell. While engineering solutions existed and the concept was elegant, alternate cheaper solutions based on cranes can be found to enable the necessary manipulations. Removing the platform has made it possible to configure the geometry of the telescope spider that supports the secondary mirror so that it better reflects the direction of the loads generated as the telescope is inclined.

In addition to the aforementioned changes to the Nasmyth platforms, the shorter telescope made it possible to

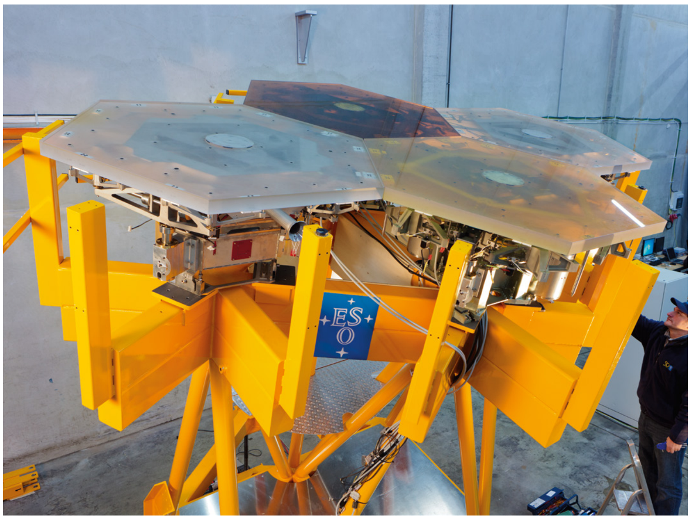


Figure 1. The segment test assembly in Garching. Four fully polished segments have been mounted on their supports. Edge sensors and actuators have been deployed on a number of the segments and control testing has started.

Figure 2. The seismic isolation test bed. Both the lateral and the vertical components of the earthquake acceleration are significantly diminished through this isolation device.

replace the carbon fibre in the spider with normal steel. This change removed one of the risks identified in the 42-metre design, and made it easier to balance the telescope.

In the area of opto-mechanics a number of activities continued throughout the delta phase B period. The secondary mirror unit contract, which was still running at the start of the delta phase B, was extended in time to cover the period of the new design. The prototyping of the polishing of the primary mirror segments is progressing on multiple fronts. One supplier has delivered to ESO segments that meet the specification for the most difficult to polish components of the primary mirror (see Figure 1). The technical feasibility of the primary mirror, we feel, is now without doubt. The project has continued to invest funds and manpower in following up different technologies for polishing with two additional suppliers: using, in one case, stress mirror techniques (as used for the Keck telescopes) and, in another case, a single, fully robotic, process. The stress mirror polishing has provided ESO with additional prototype segments and a strong interest from industrial partners to engage with the project.

Progress was also made in the area of actuators with further soft (low stiffness, high bandwidth) prototype units under construction. In the area of edge sensors the project has worked together with the suppliers to revise specifications and modify various requirements based on more detailed analysis of the results and the requirements.

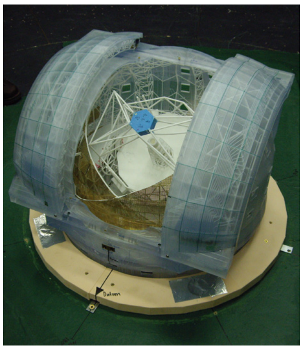
Prototype testing

During phase B and the delta phase B the project placed great emphasis on prototypes that demonstrated the practical feasibility of the designs and plans. The underlying principle was not only to test the design but also to familiarise ESO and our industrial partners with the difficulties and challenges ahead.

The E-ELT design employs seismic isolation systems to reduce the effects of ground accelerations on the dome and the main structure. Such systems are in common use in regions of high seismic risk but are usually made to isolate in the horizontal direction only. While for the dome this isolation would be sufficient, we have considered that for the telescope pier seismic isolation should include a vertical component. The challenge has been to provide the necessary isolation without reducing the stiffness of the telescope in normal operations. The necessary system was designed by the dome phase B design contractor in collaboration with providers of seismic isolation systems. During 2011 a scaled prototype system was built and tested on a large shake system (see Figure 2).

The wind tunnel testing of the dome and telescope main structure undertaken during the phase B were extended in the delta phase B to include the topography of the Cerro Armazones site. The wind tunnel results have been crucial in providing an alternate view to the computational fluid dynamics (CFD) analysis that is undertaken both in-house at ESO and by our contractors. Figure 3a shows the model used in the wind tunnel and Figure 3b a CFD simulation of the wind flow through the dome.

For the primary mirror, prototype systems have been delivered to ESO from two suppliers of primary mirror supports (including warping harnesses, extractors, packing and transporting systems, etc). Separate suppliers also delivered two sets of position actuators and a set of edge sensors. As mentioned above, a number of segments have also been manufactured. For the quaternary mirror, prototype systems have been manufactured for representative subassemblies of the mirrors, including polished deformable mirrors, electronics, actuators, etc. A complete electro-mechanical, scale one,



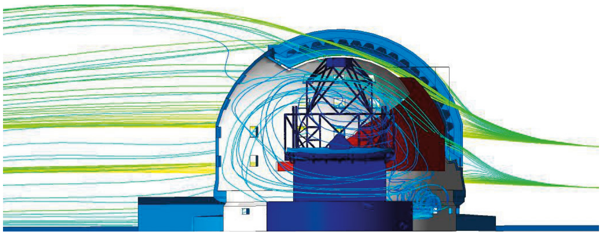


Figure 3. Figure 3a (left) shows a 1:200 scale model of the E-ELT in its dome used in the wind tunnel testing. Figure 3b (right) shows the modelled wind flow though the dome.

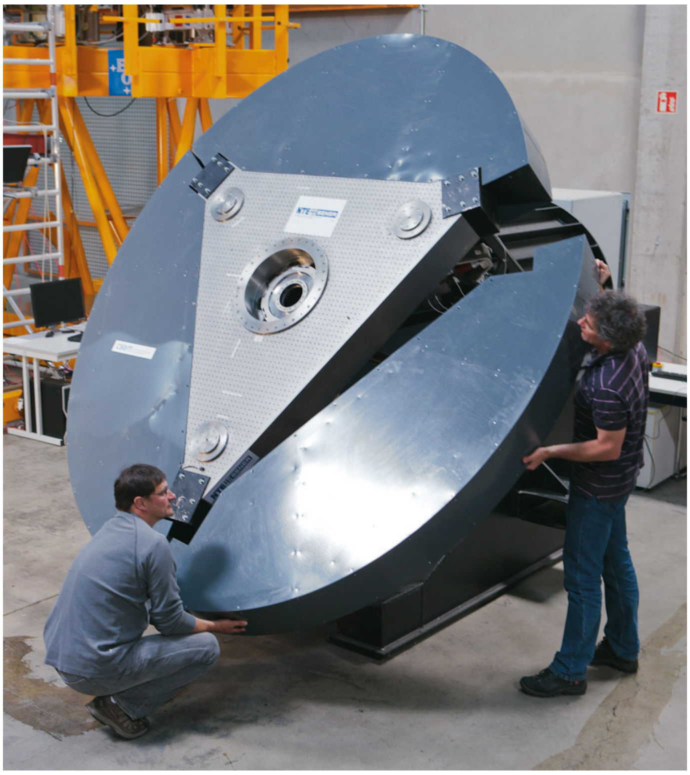


Figure 4. The electromechanical M5 prototype. In the centre is a dummy mirror that is moved in tip-tilt by three heavy-duty actuators mounted behind the system. The covers being installed by Pablo Barriga and Marin Dimmler give the full dimensions of the M5 mirror as it will be installed in the telescope.

unit has been manufactured for the tip-tilt M5 mirror (see Figure 4).

A scale one interlock system for the telescope and dome has been prototyped based on safety programmable logic circuits (PLCs). The timing system based on the IEEE 1588 standard has been demonstrated. This is a critical technology for the project as it avoids creating dedicated electronics and networks and can rely on commercial switches and networks, such as Ethernet, for the distribution of timing signals. Electronic prototype units have been constructed as demonstrators for the secondary mirror unit control and other units. During phase B industrial suppliers provided solutions for the telescope Real-Time Computer (RTC) needs. In particular a personal computer based RTC for adaptive optics was shown to be feasible and a scale one RTC for the telescope control is in construction.

The control concepts for the E-ELT move away from the monolithic integrated approach of the past, and rely on Component Off The Shelf (COTS) principles with which industry is familiar. This approach reduces the interface risk with industry. A number of these concepts have, or are being, proved in the field. In particular a prototype test of the E-ELT concepts was deployed at the Very Large Telescope (VLT) Unit Telescope 1 (UT1) dome at Paranal and is today used in operations by the observatory. The E-ELT technologies have been selected to prevent unmanageable obsolescence.

Almost all the hardware prototypes have been assembled in the E-ELT test facility located within the ESO warehouse facility in Garching Hochbrück. A stand that replicates the mirror cell structure has been built and four of the prototype segments have been mounted, complete with their support structures, actuators and edge sensors (Figure 1). The system has been tuned and the loop between the edge sensors and the actuators has been closed. The tests in Hochbrück include field tests of the control architecture and deployments of publish/subscribe components interfacing with COTS systems.

We continue to test phasing and control methodologies in technical time awarded at the 10.4-metre Gran Telescopio Canarias (GTC). This work has been extremely beneficial to our understanding of how segmented mirror telescopes are controlled and the co-operation between the GTC and the E-ELT project teams has been excellent.

New wavefront sensor detectors based on complementary metal-oxide semiconductor (CMOS) technology are under development for the E-ELT project. The prototype pixels were successful and we expect our first 600 by 600 pixel fast readout, low readout noise detector in the coming months.

The E-ELT project has contracted for the development of Vertical-External Cavity Surface-Emitting Lasers (VECSELs). These development contracts have resulted in prototype systems that are promising. In the context of the VLT Adaptive Optics Facility (AOF; see Arsenault et al., 2011), there is much ongoing work within ESO and contractors for lasers and laser launch telescopes. The E-ELT project is following this work closely as the requirements for the AOF and the E-ELT are very similar and the AOF fibre lasers form the baseline today for the telescope.

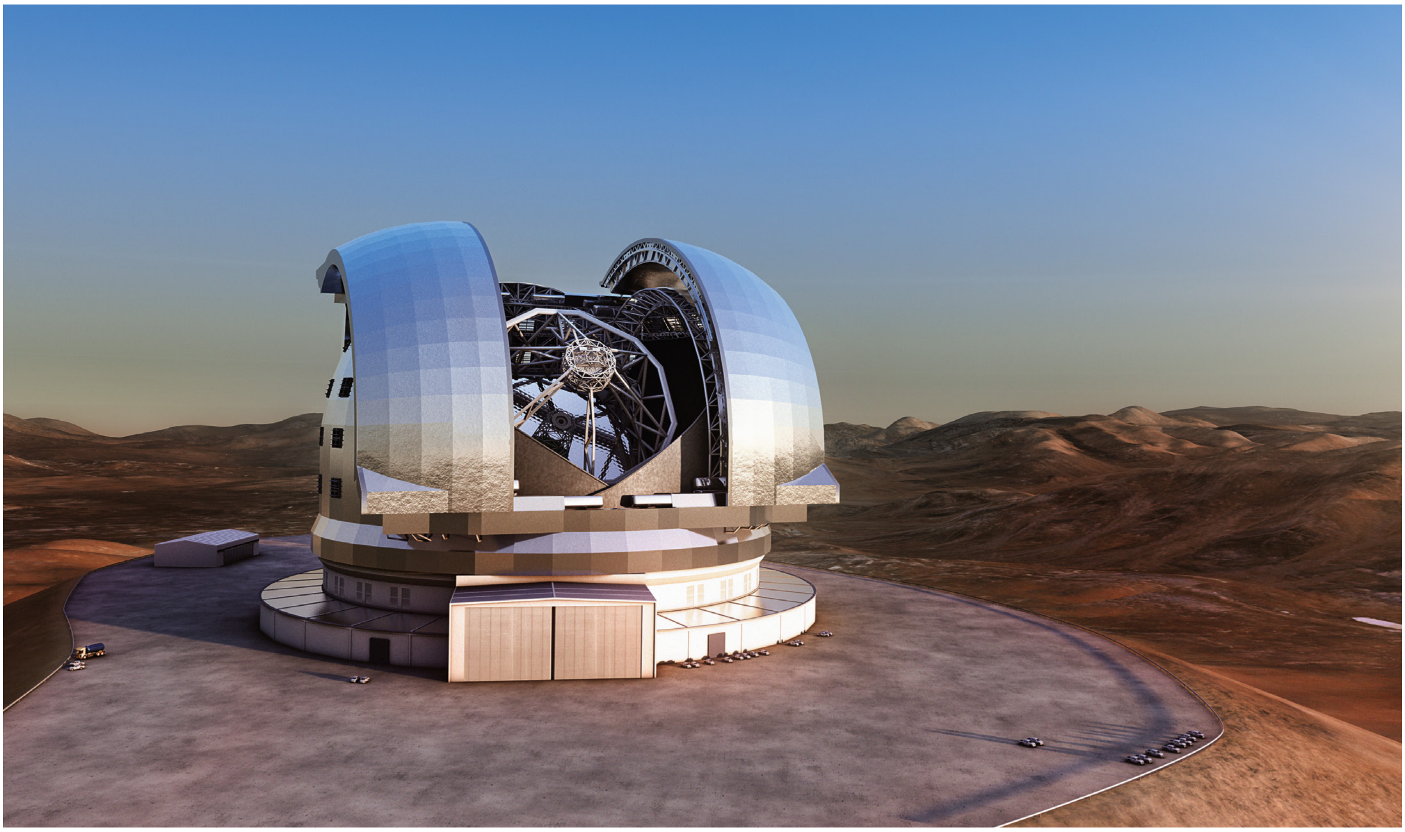


Figure 5. An impression of the E-ELT in its enclosure at Cerro Armazones.

Infrastructure

The Chilean government has agreed that ESO can incorporate the Cerro Armazones site in the Paranal Observatory[5]. This has been an important milestone for the E-ELT programme as the telescope is to be operated as an integral part of Paranal. The operational scenario presented in the construction proposal foresees that the day crew commutes from the Paranal base camp to Armazones thereby minimising the cost of additional facilities. A night crew will be resident on Cerro Armazones, but the control room is expected to be co-located with those of the UTs on Paranal.

To this purpose the design of the road linking the Armazones site with the Paranal road has had a high priority and is well underway. The more extended geotechnical survey of the Cerro Armazones peak revealed no surprises. Additional seismic testing is underway to characterise the amplification factor created by the focusing of seismic waves by the particular geometry of the peak.

Positive news is also available on the power generation front with activities undertaken by the ESO engineering directorate, the ESO representation in Chile and the Chilean authorities to support the connection of Paranal to the Chilean national grid.

Instrumentation

The instrumentation activities have resulted in conceptual designs for a number of instruments covering a broad range of capabilities (see D'Odorico & Ramsay, 2010). The instrumentation road map has been endorsed by the ESO Science and Technical Committee (STC) and presented as part of the construction proposal to the ESO Council.

The two first light instruments have been selected: a diffraction-limited imager operating in the near-infrared, fed by adaptive optics; an integral field spectrograph with a variety of plate scales ranging from the diffraction limit to seeing limited, fed by adaptive optics. The third instrument to be included in the construction project is a thermal infrared instrument. For this instrument, a technology demonstration of the detector is planned within the upgrade of the VISIR instrument at Paranal. Additional instruments are budgeted for and planned within the E-ELT programme and selections will be made in due time.

The interfaces to the observatory are under development within the ESO Instrumentation Division with support from the Directorate of Engineering.

Costing review and methodology

Analysis of costing methodologies in scientific projects, and in industry at large, showed that uncertainty in the design and lack of understanding of the risks increase the costs of projects between the cost-estimation phase and award of contract. With this in view, and with the aim of minimising this risk, the E-ELT has pioneered (at least in the field of astronomy) the concept of using competitive Front End Engineering Design (FEED) studies as the design vehicle before construction starts. These FEED contracts are awarded competitively, typically to more than one supplier, and provide not only a detailed design, but also a firm, fixed-priced offer for construction. Where feasible, the FEED contracts were combined with prototype construction at a limited scale.

By adopting this practice, the design process is not only competitive in the area of performance, but also in the area of cost. Moreover, the process provides detailed visibility of the structure and nature of the cost of design choices. It is certain that we have not retired cost risk from the project, but we consider that we better understand our cost risks. FEED offers underpin the construction proposal for the E-ELT.

Managerial

The project management structure has also evolved in preparation for construction. Council has appointed the project manager (Alistair McPherson; see profile on p. 53) to lead the construction effort and the post of project engineer has been advertised; by the time this article is in print it is expected to have been filled.

The work breakdown structure and product trees have been updated and synchronised with the budget for the construction. Technical reviews of the work undertaken by our contractors have taken place during the design process. The E-ELT has contracted expert external firms to assist the reviews of very large subsystems (e.g., the dome and main structure). Additionally the E-ELT has used external companies to verify and critique the requirements of the project, with a view to manufacturability and cost, as well as performance. As often as possible, the contracted work has been awarded to more than one supplier, providing not only a competition in cost and design, but also two independent assessments of the ESO requirements.

Three formal reviews of the project were undertaken. The first technical and managerial review of the complete phase B package took place in late 2010. A cost review took place in late 2011. Both review boards were comprised of experts drawn from the construction and management of large scientific infrastructures. A further cost, risk and management review was undertaken in late 2011 by an industrial firm specialising in such matters. All reviews gave the E-ELT project very good reports and useful feedback.

Prospects

The E-ELT project has matured from the end of phase B in 2010 and is prepared for a start of construction as soon as the ESO Council gives the go-ahead.

Acknowledgements

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Links

[1] E-ELT Construction Proposal: http://www.eso.org/public.archives/books/pdf/e-elt_constrproposal.pdf
[2] E-ELT Board report: http://www.eso.org/sci/facilities/eelt/docs/E-ELT-PhaseB-BoardReport_Exec-Summary.pdf
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[5] Agreement signed between Chilean government and ESO for Cerro Armazones site: http://www.eso.org/public/news/eso1139/

Monitoring Atmospheric Water Vapour over Paranal to Optimise VISIR Science Operations

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A water vapour radiometer has been permanently deployed on Paranal as a new tool for supporting science operations at the Very Large Telescope. The instrument allows the water vapour content of the atmosphere above the observatory to be monitored in real time with high precision and time resolution and periods of low precipitable water vapour (PWV) to be selected, providing better atmospheric transmission for observations in the infrared. The PWV measurements will be made available to VISIR users in the form of FITS header keywords. In addition, we expect that over time these data will allow a deeper insight into the atmospheric conditions on Paranal, with implications also for the operation of the European Extremely Large Telescope (E-ELT) on nearby Cerro Armazones.

The VISIR upgrade and water vapour

The upgrade[1] of the Very Large Telescope (VLT) Imager and Spectrometer for the mid-infrared instrument (VISIR) is a project that combines improvements in hardware, software and operations. As part of the latter operations programme, a water vapour radiometer was deployed on Paranal in October 2011. The information provided by this monitor of precipitable water vapour in the atmosphere above the observatory will be used for direct support of service mode observations with the upgraded VISIR.

The requirements for the monitor were guided by the lessons learned during the work to characterise potential sites for the E-ELT in 2009 (Kerber et al., 2010a, b; Querel et al., 2010). The requirements called for a high-precision, high time-resolution stand-alone PWV monitor that provides water vapour information in (near-) real time. While several ways exist to measure PWV, it quickly became clear that a dedicated radiometer operating at 183 GHz would be the most suitable technical solution. An open call for tender resulted in the selection of the Low Humidity Atmospheric PROfiling radiometer (LHATPRO) produced by Radiometer Physics GmbH (RPG).

The instrument probes the atmosphere in two frequency ranges, focusing on two prominent emission features: an H_20 line (183 GHz) and an O_2 band (51–58 GHz). Using six and seven filters to sample the two bands, respectively, the radiometer retrieves the profile of humidity and temperature up to an altitude of about 12 kilometres (Rose et al., 2005). The radiometer is designed and built for continuous operations without human interaction and can also be fully controlled remotely. In terms of environmental conditions it is qualified for the temperature range −50 to +45 °C and an air blower and heater system protects the instrument in extreme humidity and temperature conditions.

The primary interest for VISIR is the integrated water vapour column that represents the amount of water which would result from condensing the vertical atmospheric column, expressed in millimetres. The water vapour line near 183 GHz is intrinsically very strong and still prominent at very low humidity levels, thus making it suitable for monitoring a dry site such as Paranal. Paranal has a median PWV of 2.5 mm, but with pronounced seasonal and short term variations (Kerber et al., 2010a). The PWV values encountered during any year range from nearly zero to more than 15 mm. Early results from the first few months of operations demonstrate that the radiometer starts to saturate at 20 mm — well beyond the original requirements (5 mm, with a goal of 10 mm), and hence it will be able to accurately measure all regular humidity conditions over Paranal. LHATPRO has an all-sky pointing capability and can scan the whole sky within a few minutes.

Radiometer performance validation

The radiometer underwent a qualification and acceptance test at the Umweltforschungsstation (UFS) Schneefernerhaus[2] located a little below the summit of the Zugspitze (Figures 1a, b), the highest mountain peak in Germany. During a two-week period in September 2011 the instrument's functionality and operations were rigorously tested with respect to the original requirements and technical specifications. The UFS Schneefernerhaus site was chosen for a number of reasons: low PWV values can be expected in central Europe during summer/autumn only at high elevations; the altitude of Schneefernerhaus (2650 metres) almost exactly matches the final destination of the unit, the telescope platform on Paranal (2635 metres). In addition, the UFS hosts a number of instruments measuring properties of the atmosphere, including a water vapour radiometer operating at 22 GHz and a light detection and ranging (LIDAR) instrument, allowing for parallel observations between these instruments and the new PWV monitor.

After successful completion of the provisional acceptance, the radiometer was shipped to Chile and commissioning on Paranal took place during late October/ early November 2011 (see Figure 2).

The commissioning of the RPG LHATPRO was closely modelled after the highly successful PWV campaigns conducted in 2009 as part of E-ELT site characterisation. Through technical time we had access to several VLT instruments: CRIRES, UVES, X-shooter, and of course VISIR. For these optical and infrared (IR) instruments, PWV is extracted from absorption or emission line spectra using an atmospheric model. An accuracy of about 15–20% had been demonstrated during the 2009 campaigns (Kerber et al., 2010a) with this approach and full details of the spectral fitting procedure are given in Querel et al. (2011). In addition we

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operated an infrared radiometer built by the University of Lethbridge (Canada) and provided on loan from the Giant Magellan Telescope (GMT). Finally, we had a total of 22 radiosonde launches conducted by the astrometeorology group at the Universidad de Valparaiso, Chile, again following the template of the 2009 PWV campaigns (Chacon et al., 2010).

Figure 1a. On 19 September 2011 almost half a metre of snow had to be cleared on the terrace of the UFS Schneefernerhaus before the LHATPRO radiometer could be set up for its test period in Europe.

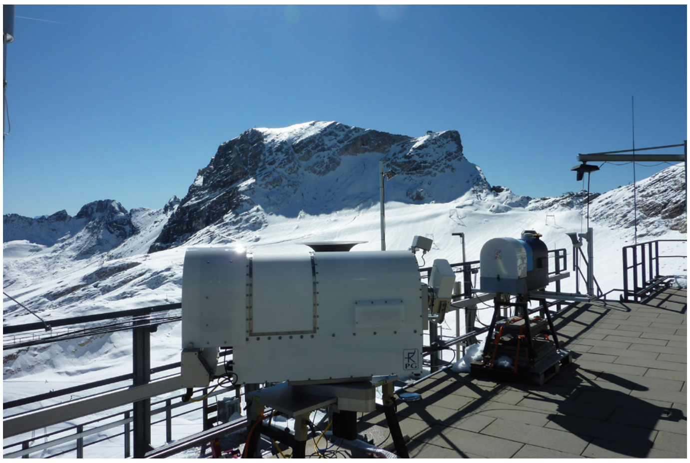

Figure 1b. Later during the test period very good conditions with low water vapour were prevalent. Note that the UFS Schneefermerhaus and Paranal are almost exactly at the same altitude of about 2650 metres above sea level.

A radiosonde consists of a very compact meteorological instrument package tethered to a helium-filled balloon. On launch it provides *in situ* measurements of the atmosphere along its ascent trajectory to an altitude of about 25 kilometres where the balloon bursts. Since the balloon is a passive device, the trajectory is the result of the lift provided by the helium and the action of the local wind. The sensors of the radiosonde provide high time-resolution profiles of temperature and dew point (humidity) over the course of about 90 minutes after launch and such a dataset is the accepted standard in atmospheric and climate research.

Observations with the VLT instruments were strategically scheduled to allow for parallel observations during the radiosonde launches while LHATPRO would operate continuously (and the Canadian IRMA operated during the night). The resulting time series is shown in Figure 3. The variation in PWV was very pronounced over the two-week commissioning period, but agreement between LHATPRO and the radiosondes is excellent (at the 1% level) across the whole PWV range. Based on an absolute calibration using liquid nitrogen and comparison with the radiosondes, an accuracy of about 0.1 mm has been demonstrated for the PWV radiometer with an internal precision of 30 μm. This ensures that reliable readings can be obtained in the driest of conditions encountered on Paranal, which of course are the most valuable periods for IR astronomy.

Figure 2. Members of the commissioning team next to the water vapour radiometer at its final location at the eastern end of the platform behind Unit Telescope 4 (from left to right: Omar Cuevas, Richard Querel, Greg Tompkins, Florian Kerber, Thomas Rose, Reinhard Hanuschik, Arlette Chacón, Julio Navarette; Mario van den Ancker is missing from this picture following a night of science support).

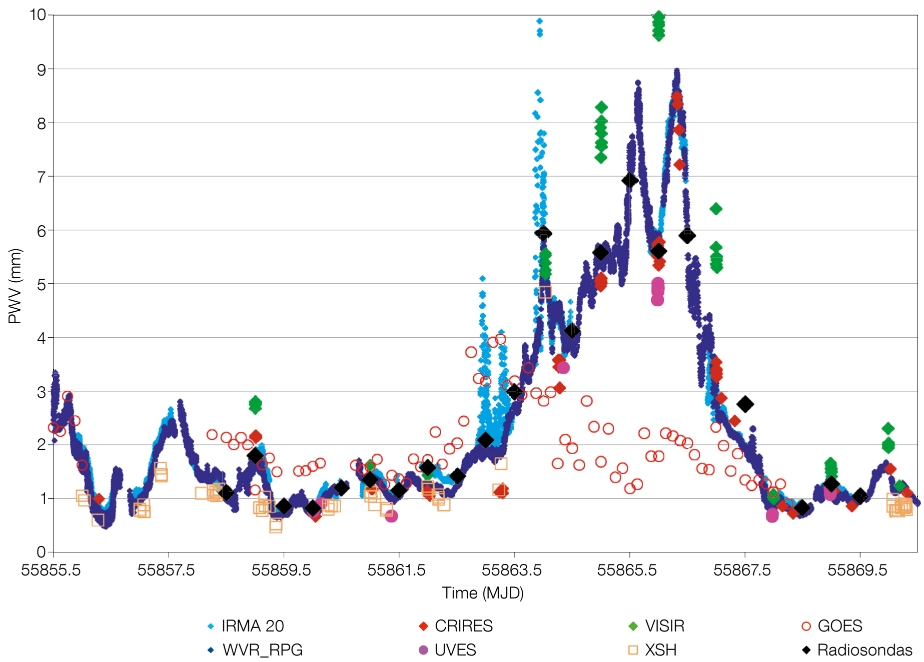

Figure 3. Time series of the water vapour measurements by various instruments during commissioning (19 October – 4 November 2011). Excellent agreement is found between the RPG radiometer (dark blue points) and the radiosondes (black diamonds). Very high PWV values were recorded during an unusual weather pattern that trapped humidity at lower elevations. Note that this water vapour is not recognised by the GOES remote sensing satellite.

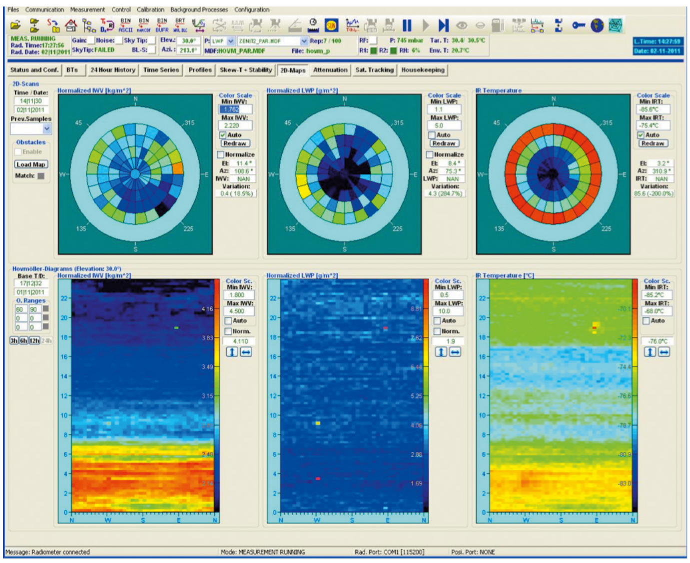

Figure 4. Operational display of the water vapour radiometer as available on Paranal. In the upper row all-sky scans of PWV, liquid water and IR sky brightness temperature taken every six hours are displayed (from left to right) which can reveal high cirrus clouds. In the bottom row Hovmoeller plots of the same parameters show a 24-hour time series of a cone scan (elevation 30 degrees) taken every 15 minutes.

Radiometer operations

As a result of the commissioning, the PWV radiometer went into trial operations, demonstrating excellent performance and high reliability under all conditions encountered. Failure of one component rendered the temperature profiling unusable for a period, while the down time for the water vapour channel is below 2 %.

Currently, the radiometer measures PWV in zenith for most of a 24-hour period interrupted by an all-sky scan (duration about 7 minutes) every 6 hours. In addition a cone scan (360 degrees in azimuth) at an elevation of 30 degrees is performed every 15 minutes. From these data a Hovmoeller diagram is created showing the conditions at any given time over the past 24 hours and serving as an early warning for incoming fronts (see Figure 4 for a view of the display from LHATPRO). An IR radiometer is also part of the LHATPRO instrument package providing measurements of the brightness temperature of the sky down to –100 °C. Thus this specific model makes it possible to detect not only water-bearing clouds, which are considerably warmer, but also cold, high altitude clouds.

Clouds are rare on Paranal, but the most common form is high altitude cirrus consisting only of ice crystals. Such clouds can be reliably detected as an increase in the sky brightness temperature of a few to a few tens of degrees with respect to a clear sky, which can be as cold as –95 °C on Paranal. This operating mode is still being tested and needs to be calibrated in terms of the extinction resulting from the clouds and hence the impact on photometry. Nevertheless, the IR channel is perfectly capable of detecting extremely thin cirrus and promises to become a useful operational tool in the future. This information is already being routinely used by the Paranal weather officer to assess the quality of a given night.

The PWV and IR sky brightness temperature are available in real time as part of the automated site monitor information in the control room. Thus periods of low PWV can be readily identified by the astronomers on duty. For service mode observations, real-time decisions can be made to select the most suitable observing programmes for the current atmospheric conditions, thereby matching the constraints provided by the Principal Investigators. All data taken by the radiometer are also archived and will be made available for more specialised use on request.

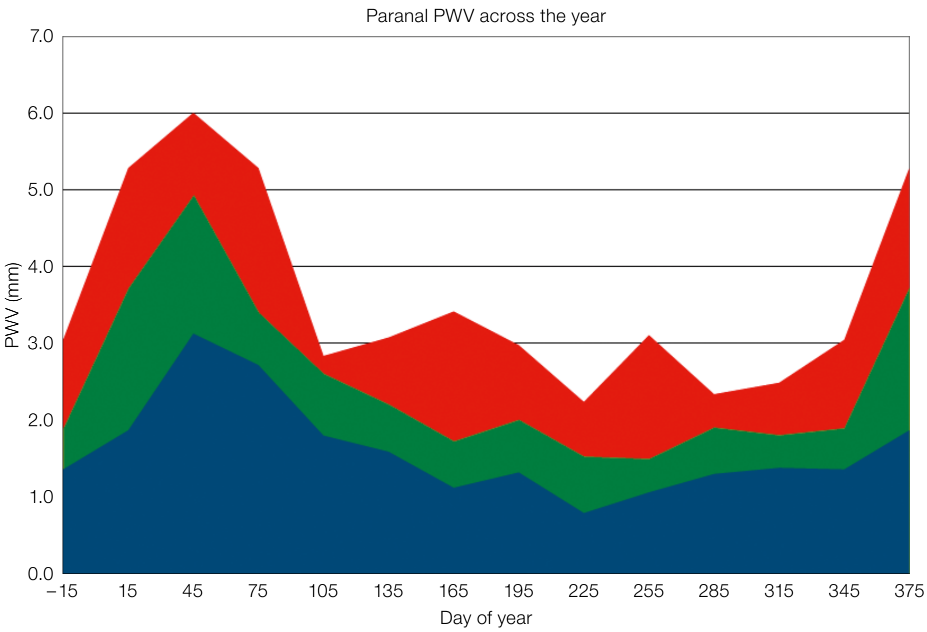

Figure 5. PWV conditions over Paranal based on the analysis of about a decade of UVES data (Kerber et al., 2010a). A pronounced seasonal variation is evident, but very low PWV (< 1.5 mm) conditions are available at the 25% level for most of the year.

■ 75% quartile
■ 50% quartile
■ 25% quartile

Support of science operations

Water vapour is one of the main sources of opacity in the Earth's atmosphere in the thermal IR, the operating range of VISIR. Moreover, the PWV content of the atmosphere above Paranal is strongly variable, both on short timescales, and with pronounced seasonal variations (see Figure 5). However, not all IR observations are equally affected by the PWV conditions: whereas imaging and spectroscopy in the *Q*-band atmospheric window from 17–21 µm will strongly benefit from being performed under conditions of relatively low water vapour, imaging in most wavelength regions of the *N*-band window (9–12 µm) would be less sensitive to PWV content.

The introduction of the new PWV monitor on Paranal offers a clear opportunity to optimise the scientific return of infrared instruments like VISIR by matching the PWV needs of each observation carried out in service mode to the actual conditions measured in real time by the PWV monitor. Hence PWV will be introduced as a formal observing constraint, analogous to seeing or sky transparency in the optical, for VISIR observations from ESO Period 90 onwards (October 2012). Apart from allowing the observatory to better match the needs of each observation to the actual atmospheric conditions at the time of observation, this new feature of the operation of VISIR will also allow the scheduling of a limited number of service mode observations under particularly dry (PWV < 1 mm) conditions, allowing the detection of fainter targets in the *Q*-band, or enabling particularly demanding observations, such as the detection of water in discs. The upgraded VISIR instrument will become available to the ESO community from October 2012. The instrument web page[3] as well as the user manuals will be updated with information concerning PWV to assist users in their proposal preparation.

Outlook

The LHATPRO radiometer has demonstrated the ability to measure the PWV above Paranal with high precision and accuracy and provide real-time information for support of science operations. For the first time, atmospheric PWV is now routinely monitored and brought into use for selecting the most suitable astronomical observations for the prevailing conditions. The PWV conditions during the time of observation will be documented for the user in the VISIR science headers. Since the PWV data are also archived, a set of temperature and humidity profiles, which provide a means of characterising the properties of the atmosphere, will be built up over time. We anticipate that this dataset will enable new insights to be derived into the atmospheric conditions over the ESO sites in northern Chile and we expect that such knowledge will prove useful for science operations of the VLT, and later the E-ELT.

Acknowledgements

The commissioning team is grateful to Paranal staff for their excellent support during the commissioning and early operations. We particularly thank Paranal Science Operations for enabling flexible scheduling of technical time which was crucial to obtain parallel observations with VLT instruments during the radiosonde launches. It is a pleasure to thank the staff at the UFS Schneefernerhaus for their assistance during the test campaign in Europe.

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Links

1 VISIR upgrade project webpage: http://www.eso.org/sci/facilities/paranal/instruments/visir/upgradeproject.html
2 Umweltforschungsstation Schneefernerhaus: http://www.schneefernerhaus.de
3 VISIR web page: http://www.eso.org/sci/facilities/paranal/instruments/visir/overview.html

PILMOS: Pre-Image-Less Multi-Object Spectroscopy for VIMOS

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The primary observing mode of the VLT visible imager and multi-object/integral field spectrometer, VIMOS, is multi-object spectroscopy, for which pre-imaging with VIMOS is currently mandatory. We report on the results of a study of the astrometric calibration of the VIMOS imaging mode and the efforts to improve it. Based on this study, we announce the introduction of an option that allows users to omit the VIMOS pre-imaging step and create masks directly from sufficiently accurate astrometric catalogues.

Introduction

The VIMOS upgrade over the last couple of years has covered hardware (including detectors and prisms), software, maintenance and operations (see Hammersley et al., 2010; Hammersley et al. in prep.). Here we concentrate on one operational issue that has now been addressed, namely the option to create multi-object spectroscopy (MOS) masks without the need to obtain pre-image exposures with VIMOS.

The original concept for VIMOS foresaw the possibility of creating MOS masks directly from astrometric catalogues, but the imaging capability was included to provide accurate astrometry in cases where no suitable catalogue was available and to aid users in placing custom slits (tilted or curved) on specific targets. In practice, when VIMOS started to be used in operations, it was decided that pre-imaging should be mandatory to ensure that uncertainties in the mapping of celestial coordinates to detector coordinates did not lead to incorrectly placed slits. This requirement had the effect of increasing the total telescope time required to obtain a typical MOS exposure by up to about 15% (Hammersley et al., 2010). Moreover, pre-images are typically obtained several weeks to a month prior to the MOS observations, but sometimes much older pre-images are used to prepare the MOS masks and the follow-up MOS observation blocks (OBs).

Ironically, the very fact that the pre-imaging procedure adopted for VIMOS worked, and the fact that pre-images as old as one or two years produced reliable MOS masks, was a good indication that the transformation from the sky to the mask plane was stable and could be calibrated in such a way to allow pre-image-less MOS observations (hereafter PILMOS). Therefore a detailed investigation of issues that can affect the reliability of PILMOS masks was undertaken to ensure that the consequent saving in pre-image exposure time would not be accompanied by large slit losses. Following the positive conclusion of this investigation, a procedure that enables users to create PILMOS masks via the use of a simple observation preparation tool was devised. This procedure has recently been tested on realistic MOS observations.

Feasibility of pre-image-less mask creation

In order to create PILMOS masks we need to be able to reliably map celestial coordinates to locations in the VIMOS mask plane. In practice we cannot calibrate this mapping directly since we do not have a detector at the location of the mask plane. However we can calibrate the sky-to-detector transformation (known as Sky2CCD) with exposures of astrometric fields and then map the mask-to-detector transformation (Mask2CCD) via calibration exposures of pinhole masks. The sky-to-mask transformation can then be derived from these two transformations. (Mask2CCD embodies the distortions resulting from the spectrograph optics, so we can effectively subtract this from Sky2CCD leaving just the sky-to-mask transformation.)

Astrometric calibration exposures were part of the original VIMOS calibration plan, but they became essentially redundant when pre-images were made mandatory and were subsequently neglected. Since the start of this project, astrometric calibration has been monitored on a monthly basis.

As part of the PILMOS project, the astrometric catalogues used by VIMOS were refined by filtering out stars with large errors in their positions and correcting for proper motions. The accuracy of the calibration of Sky2CCD is in fact limited by the form of the fit and the sparse sampling of the field of view (FoV), even for relatively dense astrometric fields, rather than by any systematic effects (such as flexure, thermal expansion, atmospheric dispersion, aging, etc; see below). Despite this limitation, the Sky2CCD calibration is still good enough to ensure that targets are not lost from the slits when performed properly.

Figure 1 is a histogram of the residuals between the predicted (using the Sky2CCD solution) and measured astrometric star positions. The measured positions are from several exposures of astrometric fields spread over several months and that differ from those used to obtain the Sky2CCD transformations being tested. It is clear that towards the edges, and especially the corners, of the detectors the fit is less reliable, but even there the vast majority of stars will be found within 2.5 pix (0.5 arcseconds) of where they are expected. Moreover, vignetting by the intregral field units (IFUs) precludes the use of the very top and bottom edges of the detectors (most of the red zone in Figure 1).

Pinhole Mask2CCD calibration exposures are essential for both the conventional pre-imaging strategy and PILMOS. They measure the distortions in the collimator and camera optics. Analysis of several months of pinhole exposures obtained at a fixed orientation (i.e., free of flexure as the field is rotated) revealed the expected thermal effects; once these were removed the Mask2CCD transformation

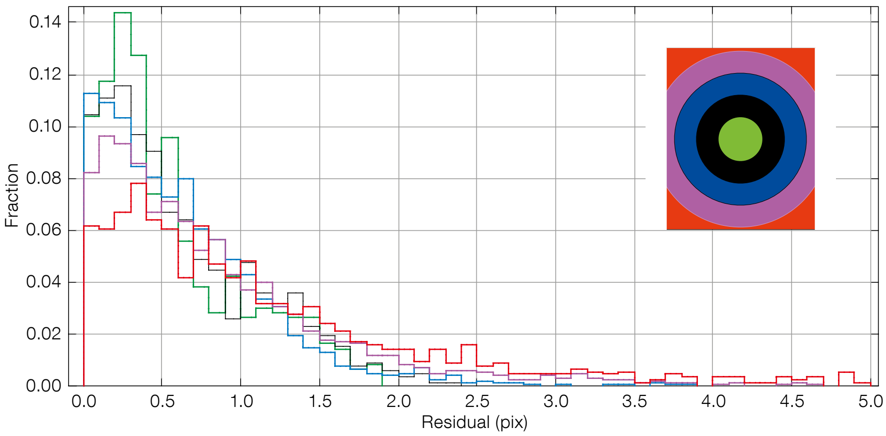

Figure 1. Histogram showing residuals between predicted and measured centroids for stars in astrometric fields. The colours indicate samples of stars at different distances (*r*, in pixels) from the centre of the detectors as follows: green *r* < 300; black 300 < *r* < 600; blue 600 < *r* < 900; pink 900 < *r* < 1200; red *r* > 1200. The inset indicates how these annuli map onto the imaging FoV of a VIMOS detector. Each histogram is normalised by the sample size.

was constant to < 0.25 pixels across the FoV. In practice some residual flexure (not seen in the pinhole exposures, which were all obtained at a fixed orientation) is to be expected even after the implementation of the automatic flexure compensation system (described in Hammersley et al., 2010). These same effects will be present in the astrometric calibrations as long as the astrometric and pinhole mask calibrations are obtained under similar conditions (epoch, temperature and orientation) and cancel out when the resulting sky-to-mask transformation is derived. The ESO quality control pages[1] provide access to diagnostics from these calibrations during VIMOS operations.

Another effect that may cause some changes in the sky-to-mask transformation for a given observation is the variation of apparent relative positions of sources with air mass and parallactic angle caused by atmospheric dispersion (see Cuby et al., 1998). The constraints applied to VIMOS observations currently in place effectively ensure that the atmospheric dispersion present in pre-images is very similar to that in MOS observations. Hence, the hour-angle constraints for MOS exposures (see below) have been retained, at least for the initial phases of PILMOS.

Several other VIMOS upgrade activities (Hammersley et al., 2010) have helped to improve the positioning of slits. For example:
– Automatic flexure compensation (AFC): Although AFC only improves the stability of VIMOS after the mask plane, it has improved the stability of the Mask2CCD transformation and thus also the derived sky-to-mask transformation;
– Mask insertion: Procedures for loading masks have been made more robust and pinholes are now added to masks to allow their proper insertion to be automatically verified.

These activities will be described in greater detail in Hammersley et al. in prep.

The PILMOS tool

PILMOS mask preparation is done with a new (extended) version of the Guidecam application, with which VIMOS users are already familiar in selecting their FoV and guide star. The new options in Guidecam are the upload of the user-contributed catalogue and a button that initiates the generation, for all four quadrants, of:
– A simulated pre-image that includes the targets in the catalogue and the area vignetted by the guide probe as well as a header containing all of the keywords and values that would have been in a real pre-image;
– A VIMOS catalogue with detector coordinates matched to celestial coordinates for each target. This intermediate catalogue enables users to prepare masks directly within VIMOS mask preparation software (VMMPS) application, thus skipping the first cross-correlation step that would have required a pre-image. A guide to the use of this tool will be available in the forthcoming release of the VIMOS User Manual (see the VIMOS support pages[2]).

Trial results

While investigating the feasibility of PILMOS, we gathered sufficient evidence to suggest that PILMOS would perform at least as well as pre-imaging in terms of minimising slit losses. Nevertheless, before offering the tool to observers we performed realistic end-to-end on-sky tests in order to rule out any unexpected problems in the PILMOS strategy.

We used the PILMOS tool to prepare masks for three stellar fields at declinations of 0, −25 and −60 degrees. Each target had a 2 arcsecond wide slit so that it was possible to accurately measure the centroids of the targets in the acquisition images. For comparison we obtained pre-images of the same fields and used these to create masks with the conventional procedure. Analysis of the acquisition images obtained with these masks revealed small but systematic differences in the mean residuals (of the order of one pixel, 0.2 arcseconds) for the PILMOS and pre-image cases that varied from quadrant to quadrant and to a lesser extent from field to field. However the scatter in the residuals was very similar and the overall performance in terms of the fraction of targets that were within about one pixel of the slit centres for each field did not differ significantly between the two methods, as summarised in Table 1.

δ (°)	Method	|Δ y| > 1.0 pix.	|Δ y| > 1.5 pix.
0	PILMOS	18(10)/58	6(5)/58
0	Pre-image	4(3)/57	1(1)/57
−25	PILMOS	22(15)/50	9(9)/50
−25	Pre-image	21(16)/50	7(11)/50
−60	PILMOS	16(9)/41	7(4)/41
−60	Pre-image	10(12)/33	10(8)/33

Table 1. Scatter in residuals for pre-image and PILMOS object centroiding. The number of targets having more than 1.0 and 1.5 pixel offsets in the three stellar test fields is listed in columns 3 and 4. The first figure in each column is the number directly measured in the data, the number in brackets is the value that would be measured if the reference stars had been optimally centred and the final number is the sample size.

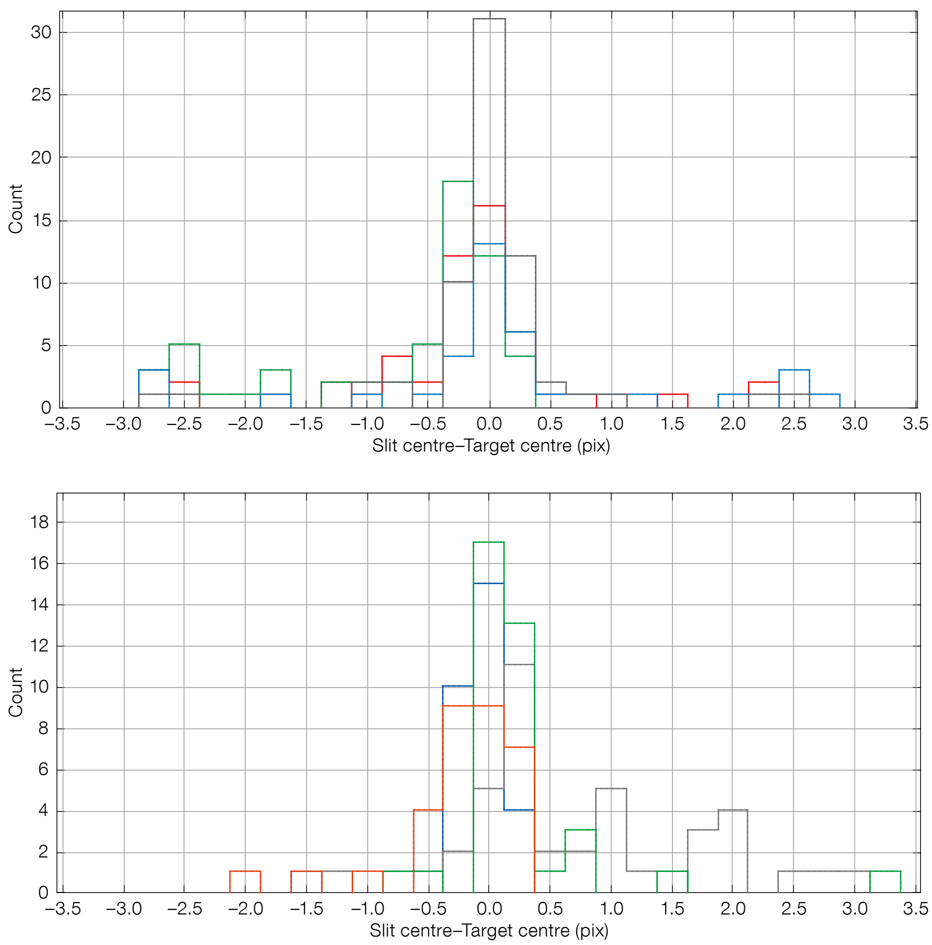

Figure 2. Centring of sources relative to the slits in the PILMOS mask acquisition image (upper) and the pre-image mask acquisition image (lower) is shown. The colours indicate the quadrants as follows: Q1 = red; Q2 = blue; Q3 = green; Q4 = grey.

As a further test, in collaboration with the Cluster Lensing and Supernova Survey with Hubble (CLASH) VIMOS Large Programme (described in Postman et al., 2012), we used the PILMOS tool to create masks based on the same input catalogue used to prepare one of the existing MOS OBs that was part of their regular programme (and thus prepared using pre-imaging). All the other details were identical. Figure 2 shows the centring of targets in all four quadrants as determined from the acquisition images of the conventional pre-image masks and the PILMOS masks. In deriving these results we corrected for slit vignetting. Note that about 40% of the targets were too faint to be identified in the short, undispersed acquisition images and do not contribute to these statistics.

Figure 2 indicates that, bearing in mind the omission of the faintest targets, whilst within any quadrant the offsets vary by less than half of a 1 arcsecond slit width, not all quadrants are well aligned, both for PILMOS and pre-imaging acquisition images. Hence, in this test, performance was non-optimal in at least one quadrant for both methods, but there is no indication that the use of PILMOS significantly degrades performance relative to pre-imaging (here it is slightly better, but not at a level that is statistically significant). Global offsets are easily corrected when centring the MOS stars in their boxes during the acquisition exposures, although offsets between quadrants cannot be corrected in this way.

Figure 3 shows two typical extracted spectra, each obtained with both the PILMOS and pre-image masks, after processing by the CLASH project team using their standard data reduction. In general they found that the signal-to-noise in the pre-image and PILMOS derived spectra were very similar, confirming that the PILMOS strategy can deliver equally valid results. In this case PILMOS would have saved four minutes of pre-imaging for one hour of MOS follow-up, and once overheads are factored in, the saving is approximately 14%.

Introduction of PILMOS

From summer 2012 observers will be able to choose to omit pre-imaging and create their MOS masks directly from catalogues with the PILMOS tool. In order to do this they will need to obtain the latest version of the Guidecam tool from the ESO Phase 2 web pages[3]. In addition the following restrictions will apply to PILMOS observations:
- Slits should be at least 1 arcsecond wide (this is currently the most typically used slit width for VIMOS observations);
- Only straight slits aligned north–south are permitted (no waivers for rotator angle different from 90 degrees are allowed for PILMOS);
- Fields should be obtained within two hours of the meridian (as is currently the case for pre-image based MOS exposures);
- The contributed catalogue must have relative astrometry better than 0.2 arcseconds and absolute astrometry must be consistent with the Guide Star Catalogue to within 2 arcseconds;
- The catalogues should contain at least two suitable reference stars per quadrant that are corrected for proper motion and on the same astrometric system as the other targets.

We are continuing to monitor the stability of VIMOS distortions and the impact of issues such as atmospheric dispersion (Sanchez-Janssen et al.,in prep.) with a view to relaxing these restrictions in the future. The conventional pre-imaging strategy is available for observers who cannot meet these requirements. Pre-imaging will continue to be offered as the main option, at least during the first period that this mode is offered, for the reasons given in the introduction.

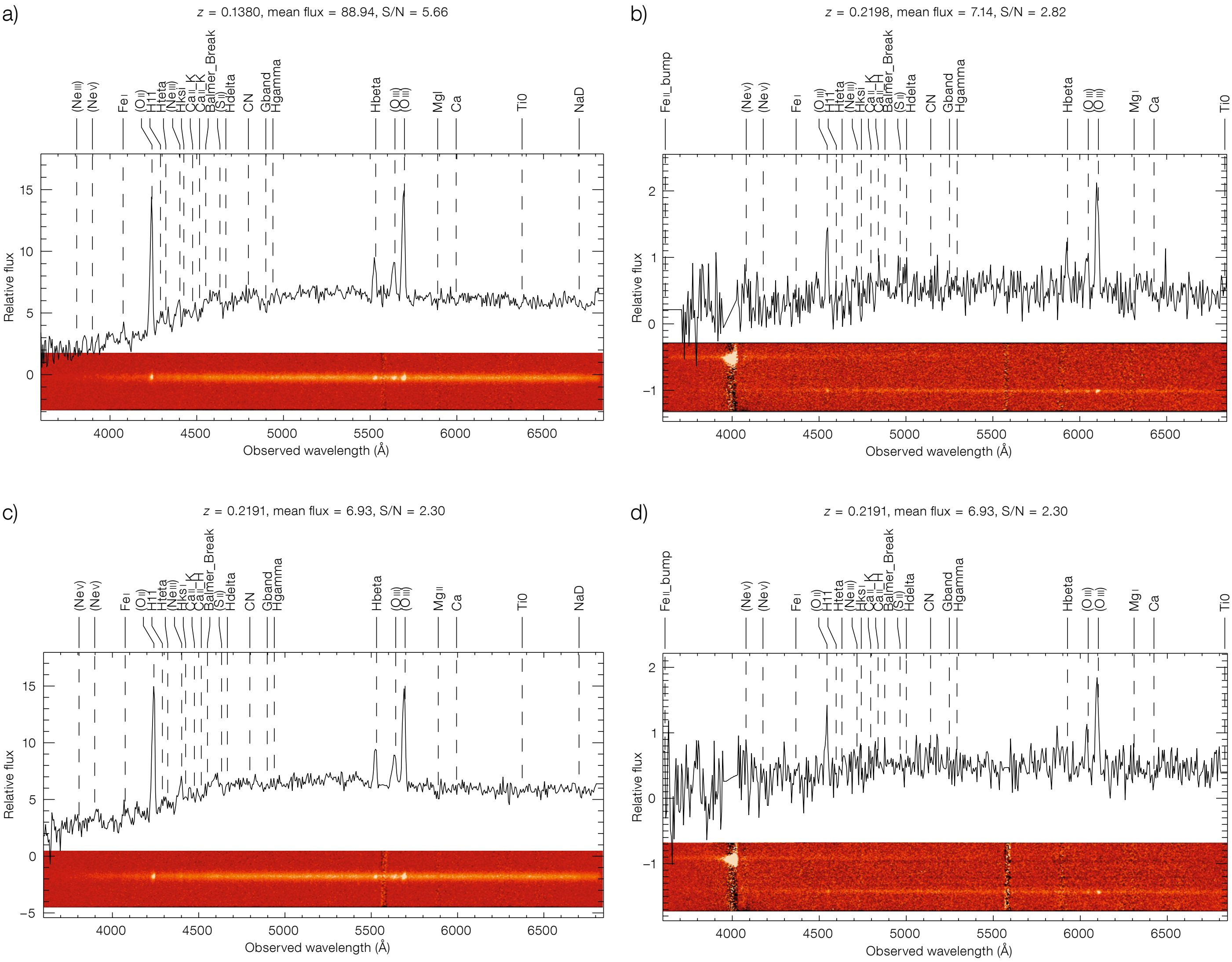

Figure 3. Example VIMOS processed spectra are shown with pre-imaging and with PILMOS: (a) and (b) were obtained with the PILMOS masks; (c) and (d) are the same sources obtained with pre-image masks. Line identifications are also shown. Note that in (b) and (d) it is the lower spectrum that is extracted.

Acknowledgements

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Links

[1] ESO quality control pages for VIMOS: http://www.eso.org/observing/dfo/quality/VIMOS/qc/mask2ccd_qc1.html
[2] VIMOS support pages: http://www.eso.org/sci/observing/phase2/SMGuidelines/VMMPS.VIMOS.html
[3] VIMOS Service Mode guidelines: http://www.eso.org/sci/observing/phase2/SMGuidelines/GuidecamVIMOS.html

A Method to Deal with the Fringe-like Pattern in VIMOS-IFU Data

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Many observers using spectrographs will be familiar with the fringes normally appearing at longer wavelengths (λ ≥ 7000 Å). In spectra obtained with the VIMOS integral field unit such a fringe-like pattern is also observed in the optical wavelength range. This fringe-like pattern affects the shape of the continuum and will, if not corrected, have consequences for derived parameters such as recession velocity, stellar velocity dispersion and line strengths. We describe an empirical method to correct for these fringe-like patterns and briefly describe the improved results.

Integrated field units (IFUs) are now common at all major observatories, where they offer an efficient means of obtaining spectra and imaging information at the same time. Due to the complex design of the IFU instruments and the large amount of information, there are often challenges for the data reduction pipelines. In the case of the VLT visible image and multi-object/integral field spectrometer (VIMOS), data from its IFU mode require additional reduction steps beyond the standard pipeline in order to handle some issues not resolved by the pipeline. The VIMOS-IFU contains 6400 microlenses coupled to fibres covering the wavelength range 4000–10150 Å with a set of six grisms (Le Fèvre et al., 2003). With the medium and high resolution grisms only a square of 40 × 40 fibres is used, yielding either a field-of-view (FoV) of 27 by 27 arcseconds at 0.67 arcseconds per fibre or a FoV of 13 by 13 arcseconds at 0.33 arcseconds per fibre. The light is fed to four different spectrographs dividing the FoV into four quadrants, which are processed separately and combined into a datacube as a final data reduction step.

For the data reduction the ESO pipeline can be used with the standard settings given in the pipeline manual. After the data reduction, the datacubes still feature some problems that need to be attended to before any scientific analysis can begin. Firstly, there are large-scale intensity differences between the four quadrants and also differences between individual spectra visible as stripes in the reconstructed image; the details of which are described in Lagerholm et al. (2012). In this article, we will focus on the more severe problem of fringe-like features visible in the spectral domain even at optical wavelengths.

The fringe-like pattern

It has been known for several years (e.g., Jullo et al. 2008; VLT VIMOS manual) that VIMOS-IFU spectra acquired with the HR-Blue and HR-Orange grisms exhibit spectral features that are visually similar to fringes. Fringes normally arise from the interference in the charge-coupled device (CCD) detection layer between the incident light and the light reflected from the interfaces of the CCD layer. Due to the typical thickness of this layer, fringes are observed at red wavelengths (> 7000 Å). The features seen in the VIMOS-IFU spectra resemble fringes but are present over the whole wavelength range (see Figure 1), suggesting that they are caused by a different mechanism. The most likely origin of the fringe-like patterns is a "pseudo-etalon" — approximately 3–10 μm thick — created by imperfect fixing of the fibre to the output prism (Hans Dekker, private communication; Lagerholm et al., 2012). The fringe-like patterns are present in the science data and in the flat field; they are also present in the raw data, and thus cannot be an artefact created by the data reduction process.

The fringe-like pattern affects more than half of the spectra in a VIMOS-IFU data cube. The amplitude and frequency of the fringe-like pattern is not randomly distributed between fibres but shows a clear connection to specific fibre modules. In quadrant 2 almost all spectra are affected, while the other quadrants exhibit regions with negligible or no fringe-like patterns (Figure 2). What is important to note is that the fringe-like pattern varies with time as indicated in Figure 1, where we plot the fringe-like pattern in the same spatial element separated in time. An explanation for this can be the change in the instrument rotator angle and associated flexure in the instrument, which changes the properties of the pseudo-etalon. In the most affected spectra, the pattern accounts for around 13% difference in intensity, peak-to-valley (PTV), while the mean value of the effect is about 6%.

The empirical correction method

We have devised an empirical method for removing the fringe-like patterns

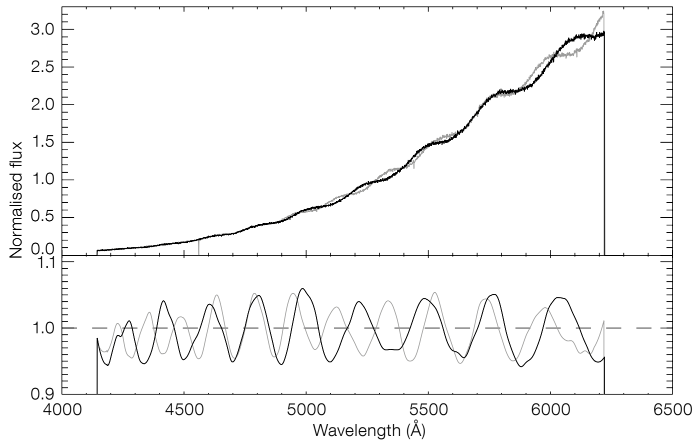

Figure 1. The fringe-like pattern in the VIMOS-IFU used with the HR Blue grism. Upper panel: Flat-field spectrum from a single spatial element (fibre) clearly showing the effects of the fringe-like pattern (black). Lower panel: the corresponding, normalised correction function for this fibre (black). In grey the flat-field spectrum and correction function are shown from the same spatial element but observed on a different night.

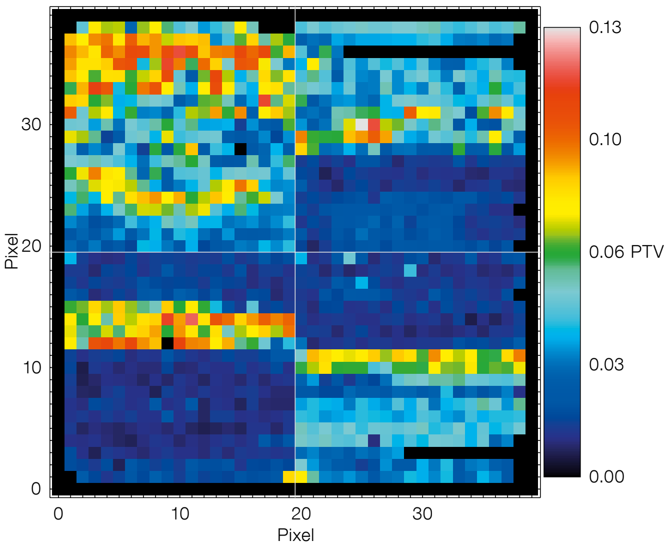

Figure 2. Spatial map of the maximum variations (PTV) in the correction spectra is shown as derived from a flat-field and the wavelength range 5188–5620 Å. Regions with a strong fringe-like pattern are clearly visible and related to distinct fibre modules. The white solid lines indicate the borders of the quadrants. Quadrant 1 is located at the top right, with quadrant numbers increasing counterclockwise.

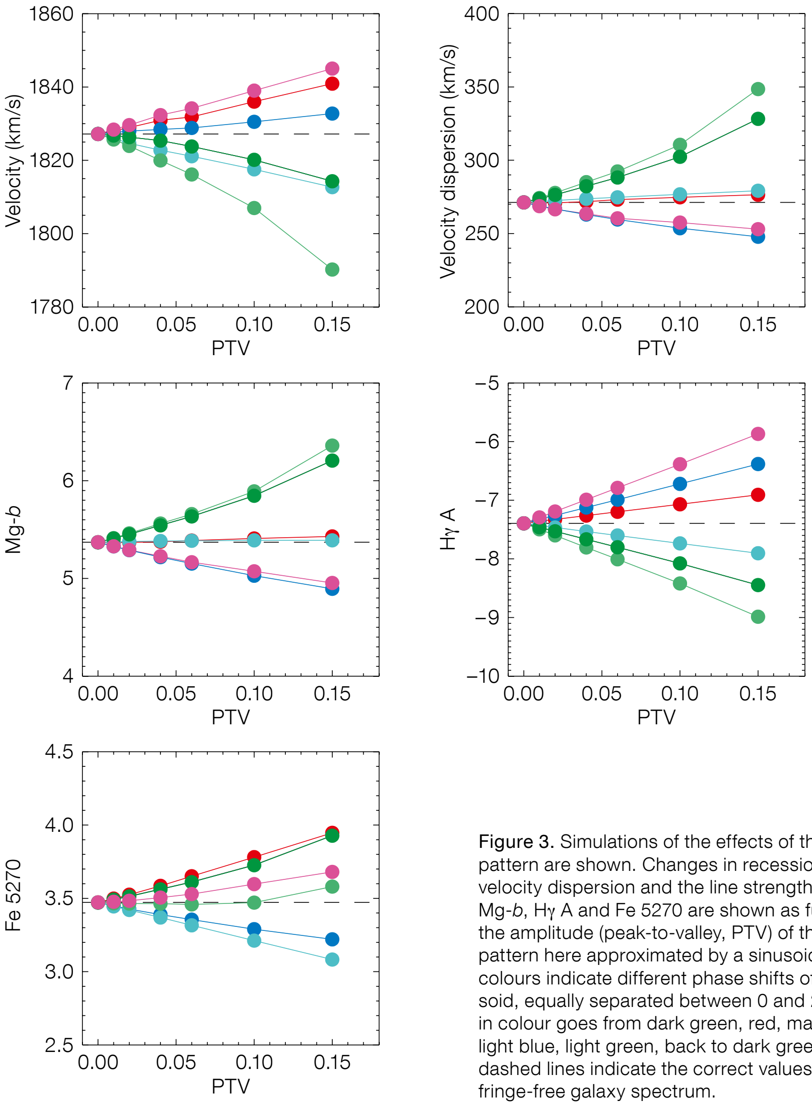

Figure 3. Simulations of the effects of the fringe-like pattern are shown. Changes in recession velocity, velocity dispersion and the line strength indices Mg-*b*, Hγ A and Fe 5270 are shown as function of the amplitude (peak-to-valley, PTV) of the fringe-like pattern here approximated by a sinusoid. Different colours indicate different phase shifts of the sinusoid, equally separated between 0 and 2 π. The shift in colour goes from dark green, red, magenta, blue, light blue, light green, back to dark green. The black dashed lines indicate the correct values given by the fringe-free galaxy spectrum.

from VIMOS-IFU data. Our method is constructed to work on data without strong intensity differences, such as early-type galaxies, which have a smooth surface brightness profile. The method was developed and tested on HR-Blue grism data (coverage 4015 –6200 Å) with the 27 by 27 arcsecond FoV.

Our method is applied on individual, fully reduced datacubes. The underlying assumption is that, to first order, the fringe-like patterns are localised, i.e. they are different between spectra that are spatially neighbouring on the sky. This is a reasonable assumption if the fringe-like pattern is caused by a pseudo-etalon associated with the fibre output prism. If all spectra have different fringe-like patterns, a median spectrum of eight spectra surrounding each spectrum (central spectrum) would be, to first order, free from the fringe-like pattern. This median spectrum can be used as an approximation of the underlying "true" spectrum, since the spectral properties of our targets vary relatively slowly as a function of spatial position and the signal in the spatially neighbouring spectra is correlated due to seeing. The ratio of the median spectrum to that of the central spectrum will provide an estimate of the fringe-like pattern, i.e. a correction spectrum that by construction has a mean of about one.

The correction spectrum is typically limited in signal-to-noise (S/N), and, since we are only interested in the overall shape of the correction spectrum, we smooth the spectrum using the *lowess* smoothing function within IDL, which is part of the IDL astronomy user's library (Landsman, 1993). Taking into account the typical frequency of the pattern, we smooth the correction spectrum using a second order polynomial for each step of 150 pixels. For each spectrum in the datacube, a smoothed correction spectrum is constructed, except in the outermost corners and spectra neighbouring more than three dead fibres. We remove the fringe-like pattern from the datacube by dividing each spectrum by the corresponding smoothed correction spectrum. The end product is a datacube corrected for the fringe-like pattern.

Science impact

If the fringe-like pattern is not corrected, it can adversely affect the science derived from the data. The fringe-like pattern changes the continuum level in the spectra and will thus affect, for example, line-strength measurements. In the Lick/IDS system (Trager et al., 1998), absorption line strengths are measured by indices, where a central feature bandpass is flanked to the blue and red sides by pseudo-continuum bandpasses. The mean level of the two pseudo-continuum regions is determined independently on each side of the feature bandpass and a straight line is drawn through the midpoint of each one. The difference in flux between this line and the observed spectrum within the feature bandpass determines the index. If the continuum level is changed due to the fringe-like pattern across the range of the blue and red bandpasses, the derived values for the indices will be wrong. Furthermore, velocity and velocity dispersion measurements can also be affected, although to a lesser extent since these measurements are typically obtained from a larger wavelength range covering several periods of the fringe-like pattern.

In order to evaluate the effects of the fringe-like pattern on typical measurements, we constructed simple simulations obtained from IFU data of nearby early-type galaxies. In these simulations we approximated the fringe-like pattern with a sinusoidal function with varying phase and amplitude to illustrate how the differences will affect derived recession velocities, velocity dispersions and line strengths. In our simulations we changed the amplitude (PTV between 0% and 15%) and phase (between 0 and 2 π). We multiplied these different simulated fringe-like patterns into a galaxy spectrum free from the fringe-like pattern and measured the corresponding velocities, velocity dispersions and line strengths. The results are summarised in Figure 3. As expected, the exact location of the fringe-like pattern determines whether a given quantity is changed in a positive or negative direction. Even for large amplitudes, a negligible change is possible when the effects of the fringe-like pattern cancel out. For a typical amplitude of 5% (PTV = 10), the velocity measurement can be affected by up to ± 20 km/s, the velocity dispersion up to ± 40 km/s, the Mg-*b* line strength index by up to ± 0.5 Å, the Hγ A index up to ± 1 Å, and the Fe 5270 index up to ± 0.3 Å. We therefore conclude that for these typical amplitudes of the fringe-like pattern, there is a significant influence on the scientific analysis. However, while these above numbers are representative for individual exposures and single fibres, the combination of several dithered exposures or fibres will significantly mitigate the problem.

As mentioned earlier, our empirical method was constructed and tested on data with slowly varying spectral properties. For other types of data, such as with strongly varying background or low intensities (the fringe-like pattern scales with the intensity), a different approach should be preferred. In these cases it may be better to rely on the combination of several exposures; we would recommend the combination of about eight exposures thus mimicking the averaging effect used in our method.

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A colour image of the grand design Sc spiral galaxy NGC 6118 taken with VIMOS. Three images in *B*-, *V*- and *R*-bands were combined and the image size is 6.5 by 5.2 arcminutes. NGC 6118 hosted a recent core collapse supernova of Type Ib, SN 2004dk. See Picture of the Week potw1022 for more details.

ESO/J. Emerson/VISTA. Acknowledgement: Cambridge Astronomical Survey Unit

A near-infrared composite of the Galactic globular cluster M55 (NGC 6809) formed from images in the *Y*- and *H*-bands taken with the VISTA telescope. M55 is a metal-poor globular cluster in the Galactic Halo at a distance of about 5.5 kpc. See Release eso1220 for more details.

The Chemistry and Magnetism of Young and Old Intermediate-mass Stars Observed with CRIRES

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In contrast to the case for the late-type stars, our knowledge of atomic transitions in intermediate-mass chemically peculiar stars and in Herbig Ae/Be stars is still quite poor. This is especially true in the infrared region of the spectrum. The recent availability of ESO's high-resolution spectrograph CRIRES now offers the opportunity to study numerous spectral features in the near-infrared spectra of these types of stars. Example observations are presented and the chemistry and magnetic field properties are discussed. During these studies a CO ring was detected around the Herbig Ae star HD 101412.

Upper main sequence stars with rich ultraviolet and optical spectra

Stars on the upper main sequence have a wide variety of chemical abundances. They are often unrelated to the processes that contributed to the bulk composition of the Sun or the population of stars with masses less than about 1.5 $M_{\odot}$. The compositions of the lower-mass stars are due to nuclear processes acting throughout the history of the Galaxy, to form chemical elements other than hydrogen and helium. Spectra of upper main sequence chemically peculiar (CP) stars reveal compositions generally thought to be confined to the surface regions, and not to the bulk of the stars. The majority of one sub-group of the CP stars, Ap/Bp stars, exhibit magnetic fields that belong to the stars as a whole and not just to star spots. Neither the origin of these magnetic fields nor the surface chemistry of this sub-group is thoroughly understood.

For the Sun or solar-type stars, there are good road maps for the near-infrared (NIR) region of the spectrum covered by the CRIRES spectrograph (c.f. Ryde et al., 2010). The same cannot however be said for A- and B-type stars, and in particular for CP stars. We know from the optical and ultraviolet (UV) spectra of CP stars that they are replete with transitions from exotic elements, as well as with high excitation transitions from overabundant elements.

Owing to the extreme richness of their UV and optical spectra, the upper main sequence CP stars have been intensively studied at the highest possible spectral resolution over the last few decades. These stars present a natural laboratory to study the element enrichment of stellar atmospheres due to the operation of various competing physical effects (such as, for example, microscopic diffusion of trace atomic species) in the presence of strong magnetic fields. Due to their generally slow rotation, it is also possible to study the isotopic and hyperfine structure of certain elements and their interaction with the magnetic field.

While many of the CP abundance patterns may be explained by separation processes in the stars themselves, there is a class of CP stars where this does not seem to be the case. These stars are named after their prototype, λ Bootis. The class represents only about 2 % of the population of A and B stars, to be compared with CP stars which may be as many as 30 % of all A and B stars. For the λ Boo stars, the chemical separation processes may have taken place outside of the stars themselves – possibly in circumstellar or even interstellar material.

The progenitors of CP stars

What might these CP stars have looked like when they were very young? Recently, considerable effort has been given to investigations of young, pre-main sequence stars known as Herbig Ae/Be stars. These stars are considered as progenitors of main sequence stars of intermediate mass. The Herbigs, as they are called, are often associated with gaseous and dusty regions of our Galaxy, where star formation is known to occur. The letter e appended to their class denotes emission. The lowest Balmer lines, Hα and Hβ, typically have emission stronger than the stellar continuum (see the example in Figure 1), while higher Balmer lines may show emission in their absorption cores.

If some fraction of Herbig Ae/Be stars are the progenitors of CP stars, we might expect them to have measurable mag-

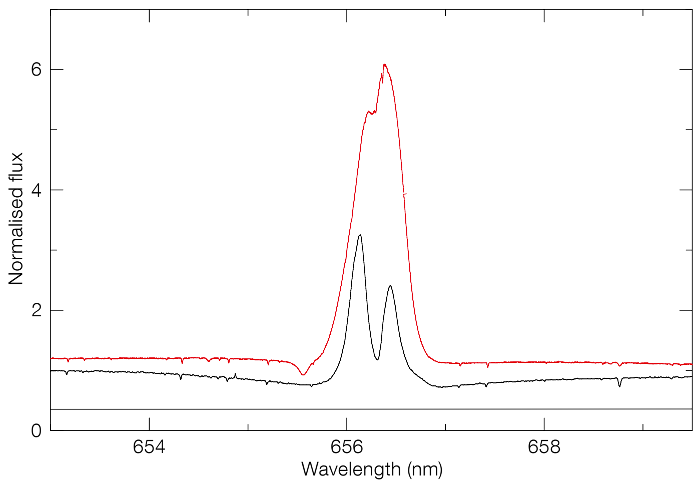

Figure 1. Example Hα emission line profiles in the two magnetic Herbig Ae stars HD 101412 (lower spectrum) and HD 190073 (upper spectrum) are shown.

netic fields and some indication of chemical peculiarities. Additionally, the progenitors of λ Boo-type peculiar stars might show some characteristic signature in their circumstellar material. Recent spectropolarimetric observations of a few Herbig Ae/Be stars have indicated that magnetic fields are important ingredients of the intermediate-mass star formation process. As an example, the sharp-lined young Herbig Ae star HD 101412 with a strong surface magnetic field of the order of a few kiloGauss (kG) has, over the past few years, become one of the most studied targets among the Herbig Ae/Be stars using optical and polarimetric spectra (Hubrig et al., 2011).

Chemistry and magnetism in the near-infrared

The recent availability of ESO's high-resolution CRyogenic Infra-Red Echelle Spectrograph (CRIRES) installed at the Antu telescope on Cerro Paranal now offers the opportunity to acquire much better knowledge of spectral features in intermediate-mass stars in the near-infrared (NIR) range (specifically 950–5200 nm). In recent months we have carried out, in a few wavelength regions, the first line identification work for the two strongly magnetic Ap stars with resolved Zeeman split lines, γ Equ and HD 154708, the magnetic Herbig Ae/Be star HD 101412, and one of the fastest rotating Herbig Be stars, 51 Oph (Hubrig et al., 2012). The CRIRES observations covered the spectral regions around the hydrogen recombination line Paγ at 1094 nm, the He I line at 1083 nm, the region of the most magnetically sensitive Fe I lines at infrared wavelengths at 1565 nm and the CO band head at 2300 nm.

The stellar lines were identified using the method of spectrum synthesis. For each star, we computed an ATLAS9 model with fundamental parameters taken from previous studies carried out by various authors. The models were used to compute synthetic spectra with the SYNTHE code (Kurucz, 1993). We adopted the atomic line lists taken from Kurucz's website[1], but we substituted the log gf values with those from the NIST database, whenever they were available. In addition, in some cases, we replaced the Kurucz log gf values for Si I by those from Meléndez & Barbuy (1999). We added a few lines of Ce III with wavelengths and log gf values computed by Biémont (private communication), and a Dy II line at 1083.594 nm taken from the VALD database (e.g., Heiter et al., 2008). The line-broadening parameters are those computed by Kurucz; they are available for most of the identified lines, except for the Sr II, Ce III, and Dy II lines, where they were computed using classical approximations.

Results of the wavelength survey of all targets, apart from the very fast rotating star 51 Oph, with *v* sin *i* = 256 km/s, may be seen on F. Castelli's web page[2]. The strongest lines are due to hydrogen and helium. Also strongly seen are C I, N I, Mg I, Si I, and Fe I. The only exotic spectral lines identified so far were due to doubly ionised cerium, Ce III (1584.8 nm and probably 1571.6 nm) in the Ap stars γ Equ and HD 154708, and singly ionised dysprosium, Dy II (1083.6 nm) in HD 154708. Apart from Ce III and Dy II, the only other lines identified from elements beyond the iron peak were due to Sr II, which were observed in all targets.

The line identification in strongly magnetic Ap stars with resolved Zeeman split lines can be strengthened by comparing the observed and expected magnetic splitting patterns. In stars with strong fields, both the central line position and the whole line profile shape, as determined by the number and relative strengths of the Zeeman π and σ components, can serve as a consistency check in the cases where line identification is doubtful. When an external magnetic field is applied, spectral lines can split into several differently polarised π and σ components of slightly different wavelengths, depending on the direction of the observer. In a longitudinal magnetic field, the π components vanish and the σ components on opposite sides of the non-magnetic line wavelength have opposite circular polarisation. Synthetic line profiles for a few magnetically sensitive lines were calculated using the software SYNTHMAG developed by Piskunov (1999). An example of our synthesis using this code assuming a surface magnetic field of 4.0 kG, *v* sin *i* = 0 km/s, and an iron abundance −4.4 dex is presented for the magnetically sensitive Fe I line at λ 15648.5 nm (Landé factor *g* = 2.97) in the spectrum of γ Equ in Figure 2.

The second observed Ap star, HD 154708, with a magnetic field modulus of 25 kG, possesses one of the strongest magnetic fields detected among the Ap stars (Hubrig et al., 2005). Stars with magnetic field strengths that exceed 20 kG are rare and only a very few such strongly magnetic stars have been detected so far. Nearly 30 % of the spectral lines remain unidentified in our study, both due to unavailability of atomic data and to the complex structure of the profiles, which sometimes are the blend of the central component of a line with the split component of a nearby line. In Figure 3 we present the magnetically-split lines belonging to Mg I 1081.11 nm, and

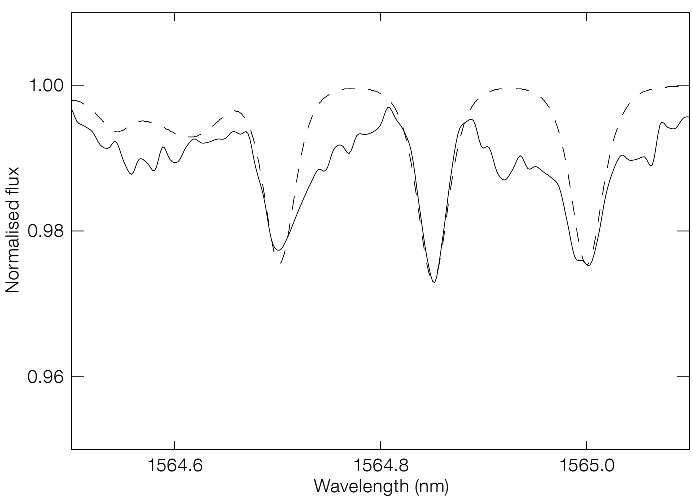

Figure 2. The synthetic line profile (dashed line) calculated for Fe I 15648.5 nm with a value of the Landé factor of *g* = 2.97 compared to the CRIRES spectrum (full line) of γ Equ.

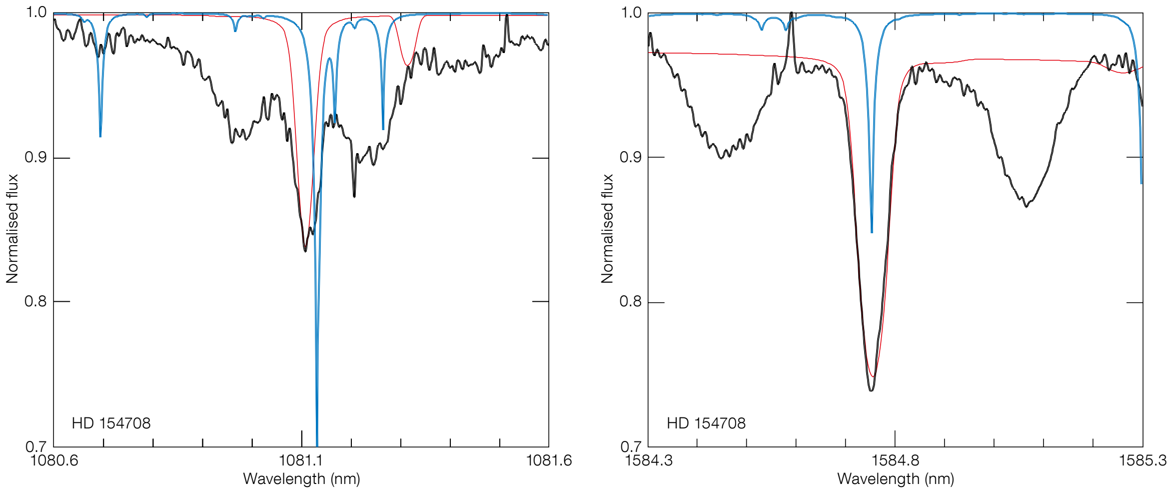

Figure 3. Magnetically split lines belonging to Mg I 1081.11 nm and Ce III 1584.76 nm in the CRIRES spectrum of the Ap star HD 154708 are shown. The blue lines indicate the contribution of the telluric absorptions. The red lines indicate the synthetic spectrum. Only the central components of the magnetically split lines have been fitted in the line identification process.

Ce III 1584.76 nm showing a rather similar split Zeeman structure.

In the absence of a magnetic field, the line at 1081.11 nm results from the superposition of five transitions of Mg I, of which the one at 1081.1053 nm is the strongest. The individual transitions correspond to different combinations of the lower and upper *J* quantum numbers. Within both the lower and the upper term, the levels of different *J* are separated from each other by less than 0.1 cm^{-1}. Thus, in the strong external magnetic field of HD 154708, which is much stronger than the atom's internal magnetic field, the electron coupling is disturbed and both terms are subject to the full Paschen–Back effect. The interesting feature of the split line profiles in the spectra of HD 154708 is that the Zeeman σ components are broad, in particular considerably broader than the π components. This indicates that the spread of the field strengths over the visible stellar hemisphere is rather large, probably significantly larger than it would be for a centred dipole.

The huge rotational line broadening of the B9 Herbig star 51 Oph with $v \sin i$ = 256 km/s prevented the reliable identification of spectral lines apart from the Mg I line at 1081.1 nm, the He I 1083.0 nm line, and the Paγ line. The spectra of the Herbig Ae star, HD 101412, have fewer lines, which accords with its abundance pattern that resembles that of the λ Boo stars. Our previous study of the abundances of the Herbig Ae star HD 101412 using UVES and HARPS spectra indicated that it may reflect a mild λ Boo, or Vega-like abundance mechanism, where the refractory elements are depleted while the most volatile elements are nearly normal (Cowley et al., 2010). The majority of the lines identified in the CRIRES spectrum belong to the elements Mg and Si, followed by a few lines belonging to N, C, Fe and Sr. Iron is underabundant, while the carbon abundance is solar; nitrogen may actually be slightly overabundant.

Detection of a narrow, inner CO ring around the magnetic Herbig Ae star HD 101412

A further surprise was found in the longest wavelength regions studied, which include the vibrational and rotational transitions of the CO molecule. The CRIRES spectra revealed a ring of gas in orbit around the magnetic Herbig Ae star HD 101412 (Cowley et al., 2012). Individual emission lines in the first overtone band of CO are presented in Figure 4. The M-shaped profiles arise because of Doppler shifts from the ring of emitting gas which is in Keplerian rotation about the star.

In HD 101412 CO-emitting gas is driven, or perhaps was evaporated, from a massive disc feeding material to the central star. Observations at high spectral resolution are capable of discerning the location and radial extent of the emitting gas. In Figure 5 we present the region of the CO band head. Because of convergence to the head, vertical sides of the profiles approach one another, coincide, and eventually cross.

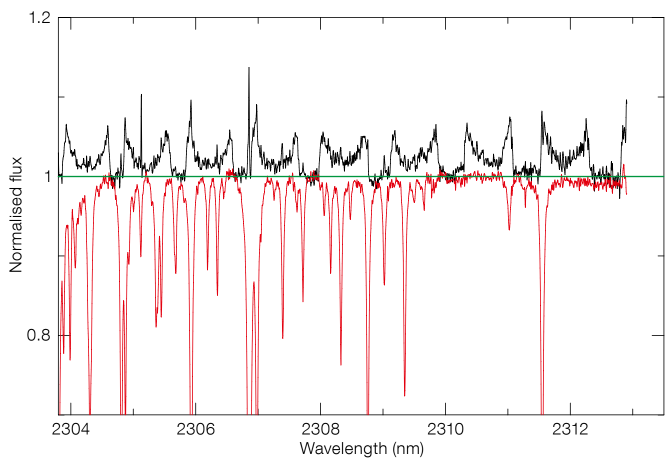

Figure 4. The black spectrum shows CO emission lines R(20) (right) to R(27) (left) in HD 101412 after removal of telluric lines using the standard (red) star HR 4537.

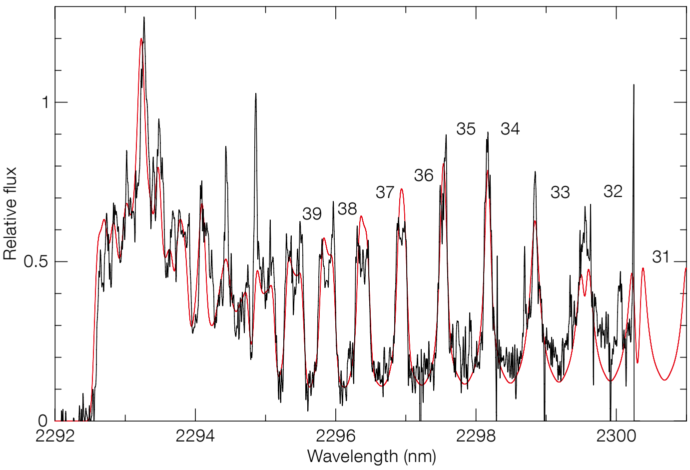

Figure 5. First overtone band head with partially cosmetic fit is shown for HD 101412. We subtracted one, and scaled the remainder vertically to fit the observations. R-branch labels are written above the M-shaped profiles. The overall distribution of intensities is somewhat better fit by assuming *T* = 2500 K rather than 2000 or 3000 K.

The CRIRES observations restrict the gas to a sharply defined ring, about one astronomical unit from the central star. The radial extent of the ring is less than a third of the distance of the ring from the star. The toroidal, or doughnut-shaped, structure poses immediate questions: How permanent is the structure? What forces might act to preserve it for times comparable to the stellar formation time itself? Is it maintained by magnetic structures? Is it held in place by orbiting planets, as with the shepherd satellites of planetary rings? Why do turbulent motions not tear the ring apart?

From a study of the relative intensities of the CO emission lines, it is possible to measure a temperature of some 2500 K (see Figure 5). This is much hotter than a planet would be at this distance. How is the gas heated, and how is the temperature maintained? The CO can be only one constituent of the gas ring. A variety of other molecules, atoms, and ions must also be present. Future observations can identify and study these species to unfold the mystery of the CO ring around HD 101412.

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Links

[1] R. Kurucz's website: http://kurucz.harvard.edu/
[2] F. Castelli's web page: http://wwwuser.oat.ts.astro.it/castelli/stars.html

This image of the Galactic field including the star cluster NGC 6604 combines 2.2-metre MPG/ESO telescope and Wide Field Imager *U*, *B*, *V*, *R* and Hα exposures. NGC 6604 is the cluster to the upper left of the image and is part of the Serpens OB2 association. The many OB stars in NGC 6604 are part of a larger star formation region powering the HII region Sharpless 54 and an outflow chimney perpendicular to the Galactic Plane. See Release eso1218 for more details.

POPIPlaN: A Deep Morphological Catalogue of Newly Discovered Southern Planetary Nebulae

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Planetary nebulae (PNe) are amongst the most complex and varied of celestial objects, displaying a wide range of shapes and colours that are difficult to explain. Using the FORS2 instrument — mostly when no other observations can be performed — we have started to build up a homogeneous morphological catalogue of deep two-colour narrow-band images of newly discovered PNe. The catalogue will be public and should soon become an invaluable tool for the community.

Planetary nebulae are a fleeting phenomenon lasting a few tens of thousands of years, thought to be the final swansong for stars of 1 to 8 $M_{\odot}$. During this dying phase, their small but hot core is unveiled, and starts to cool down to become a white dwarf. The ejected envelope is ionised and emits strongly in the lines of several elements. The misnomer "planetary" stems from the fact that some of these nearby objects resemble the discs of the giant planets in the Solar System when viewed with a small telescope. PNe are essential for the understanding of the evolution and mass loss of Sun-like stars, and because they lose much of their processed material into the interstellar medium, they contribute significantly to our Galaxy's chemical evolution. In fact, the late stages in the evolution of Sun-like stars are the main contributors of carbon enrichment in the Universe — the main reason that we are all "stardust". Moreover, planetary nebulae can be detected out to large distances from their strong emission lines and thus serve as a means whereby the motions and abundances of stars in the halo regions of distant galaxies can be investigated.

Morphology of planetary nebulae

Quite astonishingly, PNe display great variation in their shapes, ranging from spherical through to highly asymmetric, including complex substructural features like jets, filaments and rings. One estimate has it that approximately 80% of all planetary nebulae exhibit non-spherical morphologies (Parker et al., 2006). The debate as to why this is so has been raging for decades (see Balick & Frank, 2002), and despite the numerous advances in the last ten to twenty years, a convincing answer is still lacking, although the binary hypothesis is gaining more and more ground (De Marco, 2009). Stellar or even sub-stellar companions can interact with upper asymptotic giant branch (AGB) stars and shape the ejected envelope (and therefore the subsequent nebula) either by strong interactions such as common envelopes (Paczynski, 1976; Sandquist et al., 2008) or wider binary interactions such as wind accretion and gravitational focusing (Theuns et al., 1996; Nagae et al., 2004).

The binary hypothesis faces, however, an apparent paradox: the fraction of stellar companions to the progenitors of AGB stars (the precursor stage to a planetary nebula) that may interact is of the order of 30% (Duquennoy & Mayor, 1991), so how can the fraction of non-spherical PNe be as high as 80%? Several authors have noted that this discrepancy could be explained if not all the 1–8 $M_{\odot}$ stars produce a PN. Moe & De Marco (2006) argued that only ~20% of intermediate-mass stars make a PN, while the remainder transit between the giant and white dwarf phases with invisible, or underluminous nebulae (De Marco, 2011). Soker & Subag (2005) predicted the existence of a large (relative to that of non-spherical PNe), hidden population of spherical PNe that would only be found by deep searches. As noted by De Marco (2011), this prediction has been partly borne out by MASH, a deep PN survey that doubled the fraction of spherical PN from ~10% to ~20% (Parker et al., 2006; Miszalski et al., 2008) and by the Deep Sky Hunters survey, which found a similar fraction in the very faint population (Jacoby et al., 2011).

The recent publication of the Macquarie/AAO/Strasbourg Hα PNe catalogue (MASH) presented about 1200 new, spectroscopically confirmed Galactic PNe, boosting the number of Galactic PNe by nearly 80% and offering considerable scope to address problems in PN research afresh. MASH presents a most homogeneous sample of PNe over a wide evolutionary range, including evolved PNe and those interacting with the interstellar medium (ISM). The MASH PNe are typically more evolved, obscured, of larger angular extent and lower surface brightness than those in most other surveys. As such the MASH catalogue is an invaluable source for further studies requiring the use of large telescopes.

Miszalski et al. (2009), for example, revealed, by cross-correlating the MASH and OGLE-III catalogues and obtaining follow-up imaging with 8-metre-class telescopes, morphological trends induced by the presence of a close binary companion. Canonical bipolar nebulae, low ionisation structures (LIS), particularly in ring configurations, and polar outflows or jets were identified as being prevalent amongst PNe with binary central stars, and therefore associated with the influence of a binary central star. If this association were confirmed, it would help to fast track the discovery of the binaries in PNe and thereby constrain their role in the shaping (and possibly formation) of PNe.

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Morphological studies of PNe require an extensive and homogeneous database. Schwarz, Corradi, & Melnick (1992) imaged 255 PNe, through Hα+[N II] and [O III]5007 Å filters with EFOSC2 at the New Technology Telescope, during commissioning time, when the instrument rotator was not available. This catalogue proved very useful and continues to be well cited. More recently, Sahai, Morris & Villar (2011) produced a catalogue of 119 young PNe imaged by the Hubble Space Telescope, which they used to devise a new classification system.

The POPIPlaN survey

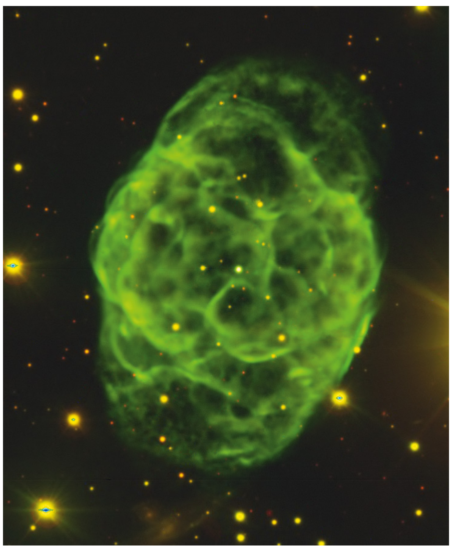
The availability of the MASH catalogue, which provides us with the necessary homogeneous sample to perform a detailed morphological classification, coupled to the great collecting power of the Very Large Telescope (VLT), prompted us to start POPIPlaN — the Paranal Observatory Project to Image Planetary Nebulae. The MASH survey generally provides only modest quality images, given that it was a photographic survey from a Schmidt telescope (spatial sampling of 1 arcsecond per pixel and limited dynamic range) at a relatively poor seeing site. High-quality images were desperately needed and this is exactly the aim of POPIPlaN: to create a homogeneous and complete morphological catalogue of the newly discovered MASH southern PNe, using deep, narrowband imaging with the FORS2 instrument at the VLT.

Figure 1. Colour-composite of the planetary nebula PN G061.4-09.5, a magnificent example of an elongated elliptical planetary nebula, with a barrel-like waist and "ansae" marking the ends of the extended ellipse. The image is based on two exposures of 240 s, taken through the Hα and [O III] filters with FORS2 on the VLT. The image covers 2.36 × 1.6 arcmin^2 on the sky. In all figures, North is up and East is to the left.

This new catalogue will by no means duplicate any existing one, but on the contrary provide much needed material required for follow-up studies. These will include, but not be limited to: derivation of statistics regarding various shapes, such as LIS, rings and jets; determination of binarity and the relationship between the presence of certain morphological traits and a central binary; studies of the interaction of PN envelopes with the ISM; analysis of the link between PNe and symbiotic stars; deeper and more detailed study with HST or adaptive optics instrumentation; kinematical studies of the newly discovered structures; and understanding the formation of the nebula and the timing of the formation of jets.

A proposal was submitted to the OPC and POPIPlaN was granted 66 hours in Observing Period 88 (P88) (Prog. 088.D-0514(A); PI: H. Boffin) and 66 hours in P89 (Prog. 089.D-0357(A); PI: H. Boffin). A proposal has also been submitted for P90 to finish the catalogue.

POPIPlaN, was specifically designed as a filler for Unit Telescope 1 (UT1) at the VLT, to be carried out in service mode by Paranal staff. The observations are done in twilight, or under thin (THN) or thick (THK) clouds. We have analysed the weather statistics for the last two years and find that there are THK conditions on at least part of 15 nights per period that could be used by our programme, as well as other occasions with THN conditions and strong wind from the north. Although the majority of our programme was done with the MIT CCD of FORS2, some of the observations were also performed when the blue E2V CCD was installed in FORS2 and nothing else could be observed. Our strategy proved extremely efficient as in P88 our programme was 95 % completed, with 230 observations done, either during bad weather or twilight. For each object, we take images, with a sampling of 0.25 arcsecond (2 × 2 pixel binning), in Hα+[N II] (with the H_Alpha+83 FORS2 filter) and [O III] (O III+50 filter), and exposure times between 240 s and 450 s, the majority being 300 s. For some objects, we have also obtained images in [O II] 3727 Å and [S II] 6723 Å as well as in the *B*- and *I*-broadband filters in order to help identify the central star. The constraints were set such that images could be taken when the seeing was below 1.2 arcseconds, or 1.4 arcseconds for a small subset, but in reality, most of the images have been taken under much better seeing conditions. Some of our images have a full width at half maximum of about 0.4 arcseconds!



POPIPlaN images

The images obtained in P88 unveil, as expected, a wide variety of intricate shapes and structures, revealing for the first time in these objects, rings, multipolar and imbricated shells and other low ionisation structures, as well as shocks. Figures 1–3 show some of the images obtained. Photometric follow-up has already been started for those PNe showing clear rings or jets, as they most likely harbour close binaries at their centre.

Since POPIPlan is aimed at creating a catalogue of great value to the community, the data have no proprietary period, thus allowing anyone to make use of them as soon as possible and prepare follow-up observations. In addition, all the images are reduced by us and made available as FITS files and as JPEG images. A colour-composite image is also produced. Sizes and important morpho-

Figure 2. Colour composite of PN G059.7-18.7, showing an intricate network of low ionisation features. Slightly to the south a pair of more distant galaxies can be seen. The image size is 2.37 by 3.1 arcminutes.

Figure 3. Collage of four images of planetary nebulae imaged in POPIPlaN. (Upper) PN G247.8+04.9 (image: 5.4 by 2.6 arcminutes) is a very extended and evolved nebula showing a clear signature of interaction with the interstellar medium; (middle left) PN G250.3-05.4 contains a slightly brighter X-shaped core (image size 2.5 by 1.4 arcminutes); (middle right) PN G224.3-03.4 is a round nebula whose southeastern edge appears greatly enhanced, most likely due to the interaction with the ISM (image size 2.5 by 1.4 arcminutes); (lower) PNG 307.3+02.0 is a canonical bipolar nebula with a bright ring-like waist (seen almost edge-on).

logical features will be indicated. In the future, all images will also be made available through the VizieR interface of the CDS in Strasbourg. The catalogue is temporally available on a web page[1].

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Links

[1] POPIPlaN images available: http://www.eso.org/~hboffin/POPIPlaN/

3D Visualisation of Integral Field Spectrometer Data

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A tool is presented for analysing integral field spectrometer three-dimensional datacubes by rendering the data in 3D with volumetric display techniques. Volume rendering can highlight features and aid the discovery of characteristics of astronomical objects that may not be easily detected with the more common two- and one-dimensional image and spectroscopy analysis tools. Examples of volume analysis are described, including Keck OSIRIS IFS data for the classical nova, V723 Cas, which exhibits a ring structure in its nova shell, and a 3D representation of observations of the supernova SN 1987a based on VLT SINFONI data.

Integral field spectrometer (IFS) instruments have been deployed at many observatories in recent years and are becoming very popular for a wide range of observational programmes. An IFS provides the ability to obtain spectra over the full extent of the instrument's field of view, removing the limitations of a slit as in conventional spectrometers. The IFS also preserves the spatial image information over the full spectral bandwidth. The resulting data product is a three-dimensional cube that contains a spectrum for every pixel in the image and an image at every element of the spectrum. The enhanced capability comes with an increase in the complexity of the data reduction and data analysis.

IFS instruments are very dependent on data reduction pipelines to support users, both in terms of real-time data assessment and offline data processing to facilitate scientific publication. Since mainstream use of IFS instrumentation is relatively recent, analysis tools are continuing to develop and astronomers are finding that working with these rich datasets can sometimes be challenging. The goal of the data processing and analysis, of course, is to extract as much science as possible. The pipeline data product of an IFS is typically a three-dimensional FITS file. These FITS files can be displayed using various tools, but it can be challenging to visualise cubes on a two-dimensional screen. A typical display tool will restrict the user to seeing either the spectra or the image in a single graphic. This article describes an approach to visualising data that employs a volume display that renders both spatial and spectral information simultaneously. The volume visualisation can reveal features that may be difficult to discover using other techniques.

Volume display tool

Two examples of IFS instrumentation for use at large telescopes include SINFONI (Eisenhauer et al., 2003; Bonnet et al., 2004) installed at the Very Large Telescope (VLT) and OSIRIS (Larkin et al., 2006) installed at the W. M. Keck telescope. Both of these instruments take advantage of the high spatial resolution of adaptive optics systems.

A volume-rendering tool was developed to analyse data for IFS instrumentation that can be used either with OSIRIS or SINFONI data. The tool[1] is coded in IDL and takes advantage of IDL's object-oriented volume-rendering routines. A set of tools for manipulating a datacube is configured in tab widget format. A screen grab of the tool is shown in Figure 1. The spectrum in Figure 1 is the longer wavelength subset of the *K*-band, using the Kn5 OSIRIS filter. The spectrum is of the classical nova, V723 Cassiopeia or Nova Cas 1995 observed in 2007. The volume display of V723 Cas data shows a continuum from the central point source and very bright coronal emission features from the nova ejecta (ring-shaped). The bright emission line is from [Ca VIII] 2.3214 μm. The emission feature is spatially resolved from the expanding nebula ejected from the nova (see Lyke and Campbell [2009] for a more detailed description of the OSIRIS study of V723 Cas).

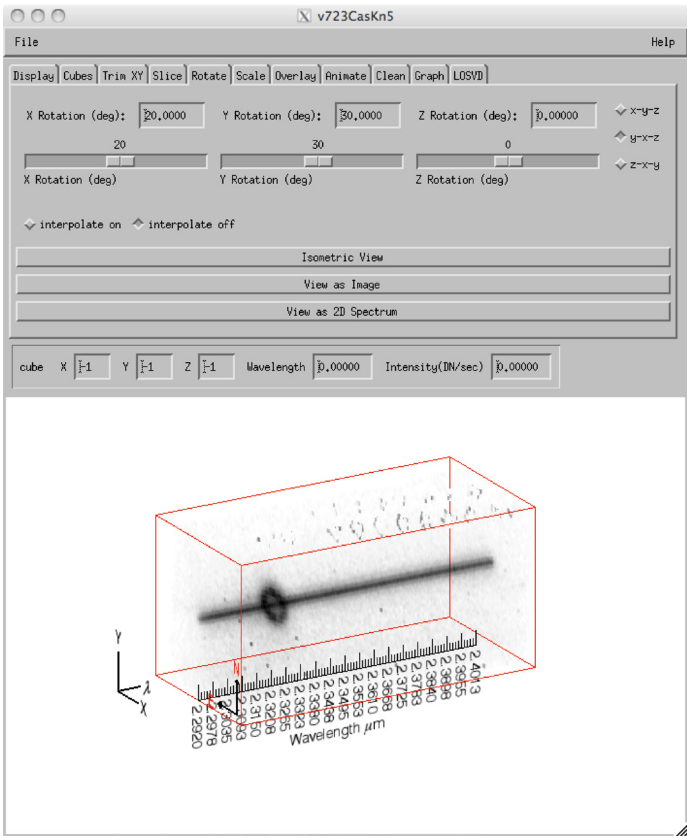
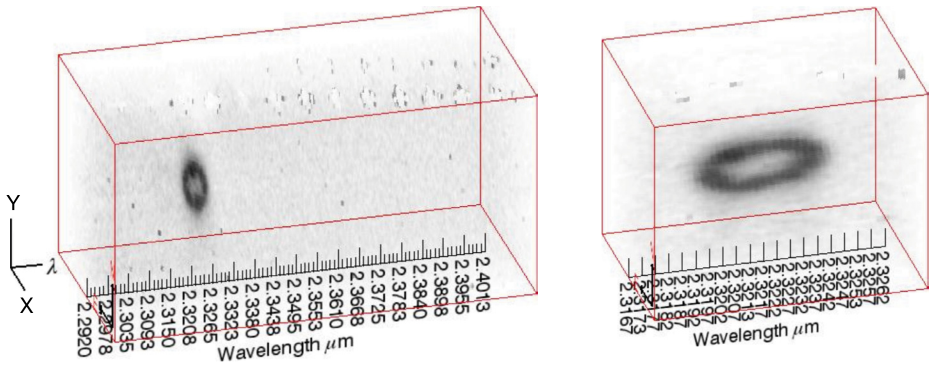


Figure 1. Screenshot of the 3D volume-rendering tool for IFS data. The display shows a continuum and a bright emission feature from the classical nova, V723 Cas. The continuum is from the central point source, but the emission feature of the [Ca VIII] fine structure transition is from the spatially resolved nova shell. The spectral coverage is of a portion of the *K*-band from 2.29 to 2.40 μm.



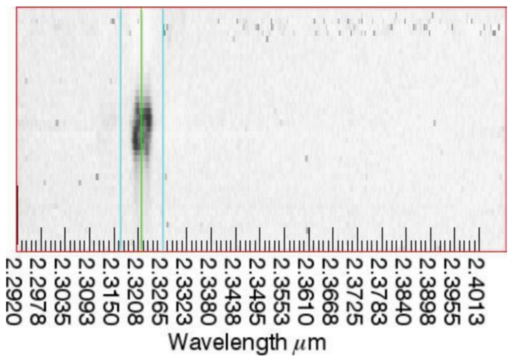


Figure 2. Manipulations of the datacube of V723 Cas are shown. The datacube is shown from an isometric perspective with the point source continuum removed (upper left) and the same cube is shown from the 2D spectrum view with lines overlaid showing the region to be trimmed (lower left). The trimmed, continuum-subtracted cube highlighting the spatially resolved [Ca VIII] 2.3214 μm emission of the nebular remnant of this classical nova is shown at upper right.

The volume tool has features that make it convenient for manipulating datacubes. The cube can be rotated to any perspective in the *xyz* viewing angle. It has options for input and output of data as well as various features for adjusting display parameters like stretch and colour. Other features include graphics overlays, axis display, zoom adjustment, aspect ratio adjustment and the ability to blink the display between multiple datasets.

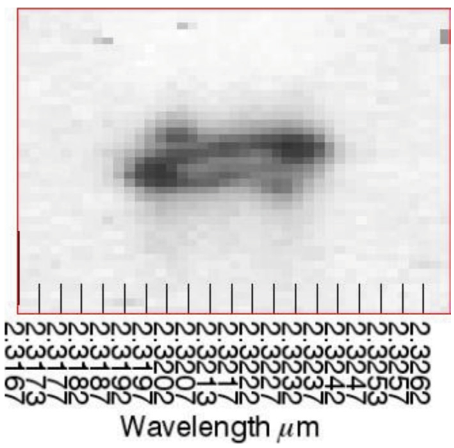
The volume tool can easily be used to trim a cube in either the spatial or the spectral dimension. Trimming the cube can help to emphasise a region of interest, since a volume display can a have a significant region of noise that tends to "muddy" the view. Slicing in the spectral dimension is essentially customising a narrowband filter to highlight only the bandpass of interest. Figure 2 demonstrates a few of the cube manipulation abilities on the [Ca VIII] 2.3214 μm feature of V723 Cas. The unresolved point source continuum of V723 Cas has been removed here, leaving only the spatially resolved emission of the nova.

With the IFS volume tool, a cube can be manipulated in many ways. The volume can be rotated in any of the three dimensions so that the cube can be viewed from any angle, including the classical views of an image or as a two-dimensional spectrum (Figure 3).

Classical nova example

Expansion parallax is a technique for determining distances to various subsets of astronomical objects. For example, when an object such as a supernova or a classical nova is observed following an outburst event and both the radial velocity and the angular expansion can be measured, the distance can be determined relatively accurately with only a few simple assumptions about the shape of the ejecta. An IFS coupled with adaptive optics (AO) affords the capability to capture both the velocity and the expansion simultaneously, thus improving the precision of the distance measurement (Lyke, 2009).

An IFS 3D datacube is a measurement of intensity as a function of spatial extent and wavelength. When the distance to an object and the start time of the expansion are known, then the three axes of the cube can be converted into units of length in order to visualise the true shape of the object. The units of the two spatial dimensions are converted from angle on the sky to length based on the conversion of arcseconds to astronomical units (AU). The extent of the nova shell in the line-of-sight dimension can be computed from its expansion velocity measured directly from the Doppler shifted lines in the spectra. Once all three dimensions have been converted to units of length, the cube size is adjusted such that each side is the same size, thus rendering



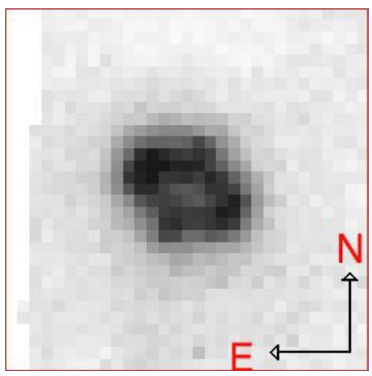
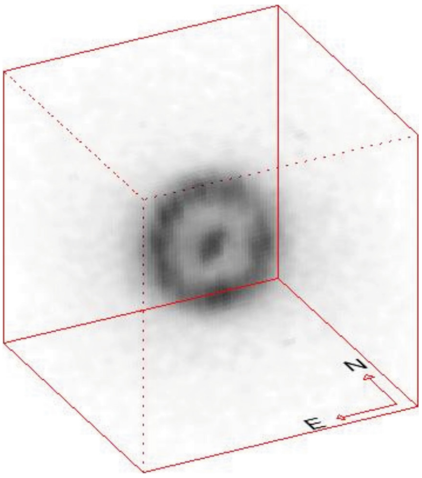


Figure 3. A 2D spectrum view (left) and an image view (right) of the [Ca VIII] emission highlighting the spatially resolved velocity structure of the V723 Cas nova shell.



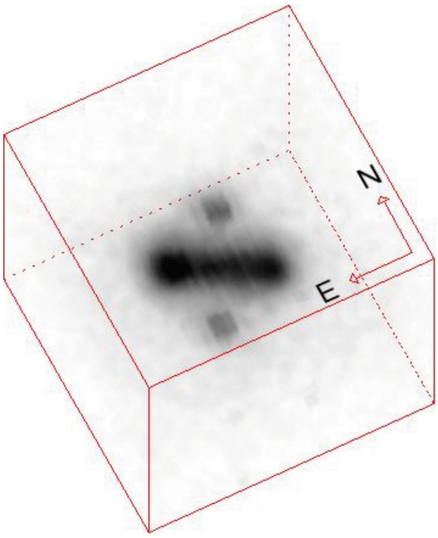


Figure 4. The true 3D morphology of the V723 Cas nebular remnant is shown. From the distance and time since eruption, the angular and velocity dimensions can be converted to create a cube with sides of equal units of length, in this case 3300 AU (5.0 × 10^{11} km). The 3D analysis clearly reveals the very distinct equatorial ring and polar "blobs" that are viewed both face-on (upper) and edge-on (lower) in the two different views.

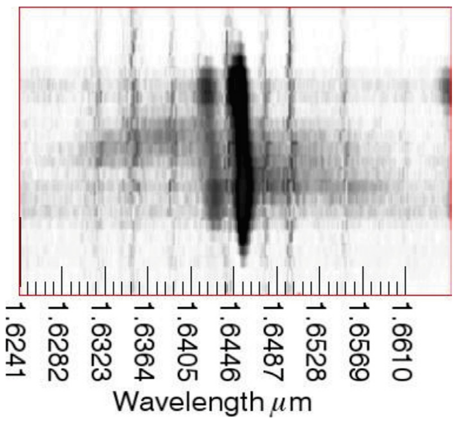
the object in its true 3D morphology. Figure 4 shows the V723 Cas nova shell in [Ca VIII] emission from two viewing angles, one perpendicular to an equatorial ring that has formed in the nebular shell, and one viewing the ring edge-on where polar knots become more evident. These features are much more evident in the 3D display and demonstrate the usefulness of this type of analysis.

Supernova example

Although the tool was originally developed at Keck for use on OSIRIS data, it was subsequently adapted for use on SINFONI data with some relatively minor modifications. The work associated with adopting the tool for SINFONI was done during the summer of 2011 while the lead author participated in the ESO visitor programme in Garching. Supernova SN 1987a is one of the objects to which we are interested in applying the 3D analysis. This supernova is well suited for this purpose since the distance to the object is fairly well constrained due to its location in the Large Magellanic Cloud and the time of the eruption is very well known. Having good values for these parameters potentially allows the morphology of the ejecta to be rendered in 3D since the cube dimensions can be converted to units of length.

However, 3D analysis of SN 1987a is proving to be challenging for several reasons. The primary difficulty is the great distance to the object (50 kpc), which of course makes detecting and resolving the shell much more difficult. The observations must be taken long enough after the explosion to allow the shell time to expand to the point where it is large enough resolve from Earth, even with a large telescope equipped with AO. However this delay gives the nebular material time to cool, become more rarefied, and diminish in brightness. Yet another challenge is the fact that the emission spectrum of SN 1987a has multiple components, due to the rings that existed prior to the explosion in 1987. The rings emit in some of the same wavelengths as the supernova ejecta, but have a very different velocity structure and different relative line strengths. The multiple sources of emission are difficult to disentangle in the integral field spectra.

SINFONI data acquired in 2005, and subsequently reduced using the instrument pipeline, were input to the IFS volume tool. The data in this example are over a narrow region of the *H*-band centred on a [Si I]+[Fe II] emission line blend at 1.644 μm. Figure 5 shows the image view and 2D spectrum, displaying the spatially resolved supernova ejecta in the central portion as well as the inner ring surrounding it. A detailed analysis of the SINFONI study of SN 1987a is presented in Kjær et al. (2010). The 2D spectrum reveals the brighter and narrower emission lines that are from the inner ring, whereas the broader, Doppler-shifted features are from the high velocity ejecta. There are also several telluric features complicating this part of the spectrum.



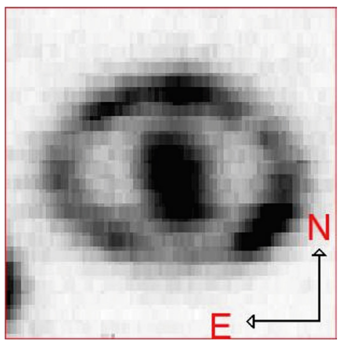


Figure 5. The 2D spectrum view (left) and the image view (right) of SN 1987 is shown in the blended [Fe II]+[Si I] emission lines. Two sources of emission are distinguishable in the 2D spectrum and image view: the inner ring, visible as two relatively narrow lines in the spectrum; the much broader feature, Doppler-shifted by the high velocity ejecta, in the central regions.

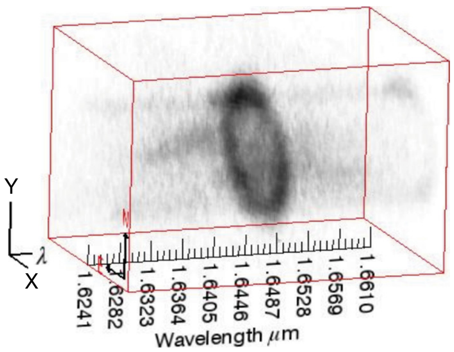
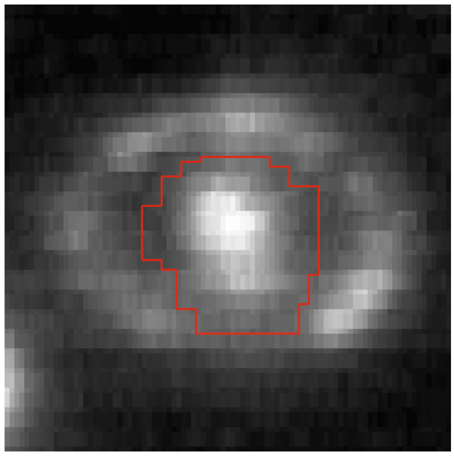


Figure 6. 3D volumetric display is shown of [Si I]+[Fe II] blended line emission at 1.644 µm from SN 1987a.



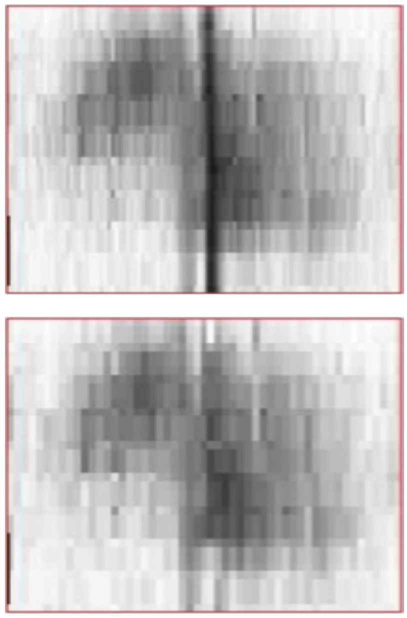


Figure 7. Isolating the emission of SN 1987a ejecta from the inner ring emission. On the left, the spatial selection by cutting out the cube around a polygon, outlined in red, is shown. At right, the 2D spectrum of the polygon-selected cube region before (upper) and after (lower) subtraction of the peak emission from the inner cube is shown.

Figure 6 shows the volume display of the same datacube as Figure 5, but tilted such that the entire volume can be seen. This allows both the spatial and spectral dimensions to be shown in one graphic, the intent of which is to help reveal subtle features that may not be apparent in the 2D views of the data. However, SN 1987a does not give up its characteristics easily and any new features that were not already discussed in Kjær et al. (2010) are not obvious in the volume rendering. It is presented here as an example to demonstrate the potential capability of analysing SINFONI data in this manner.

Nevertheless, additional processing was attempted to separate the ring emission from the ejecta such that the true 3D shape of the supernova shell could be visualised. Figure 7 shows a region spatially cut from the original cube outlined by a polygon. Additional processing included a Gaussian fit to the peak narrow line of each spectrum of the cube that was then subsequently subtracted to help reduce the flux contribution from the inner ring. Figure 7 shows a comparison of the two 2D spectra with and without the removal of the bright line. The processing helps to isolate the ejecta from the other sources within the original datacube.

Figure 8 shows a rotated volume display of the fully processed cube. The dimensions of the cube are approximately 3.0 × 10^{12} km on a side. Unfortunately, it is hard to derive a definitive shape of the ejecta from the volume display due to its complex and diffuse nature. The 3D graphic only gives a hint of the morphology, one that is consistent with the conclusion in Kjaer et al. (2010) of the SN ejecta with its asymmetric lobes expanding at different angles. The 3D analysis of SN 1987a has proved to be significantly more challenging than that of the classical nova V723 Cas. The V723 Cas data has much brighter coronal lines in the *K*-band where telluric features are less of an issue. The SN 1987a data are much more complex with blended lines of very high velocities within a forest of telluric OH lines. Nevertheless, SN 1987a is one of the most compelling objects in the nearby Universe and thus any attempt to understand its true nature is worthwhile.

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Links

[1] A beta version of the IDL tool can be obtained by email to: randyc@keck.hawaii.edu

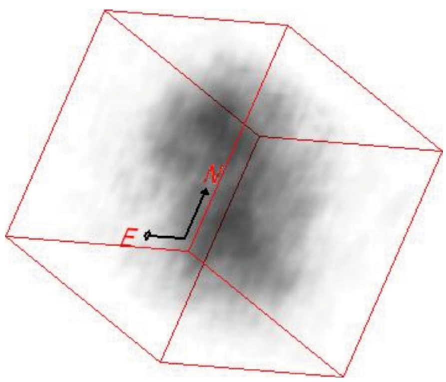

Figure 8. 3D spatial representation of SN 1987a, isolating the blended [Si I]+[Fe II] emission lines of the shell from the inner ring, is shown. This visualisation highlights the asymmetric nature of the shell as determined in Kjær et al. (2010). The cube dimensions are approximately 3.0 × 10^{12} km on each side.

First published ALMA Early Science Cycle 0 Result — Mapping of the Fomalhaut Debris Disc

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The Atacama Large Millimeter/submillimeter Array (ALMA) Early Science Cycle 0 observations have been proceeding with up to 24 antennas since 30 September 2011. The first result of Cycle 0 observations has recently been published (Boley et al., 2012): ALMA 850 μm continuum mapping of the dust in the debris disc around the nearby A3V star Fomalhaut (the naked eye star alpha Piscis Austrini, V mag. 1.16). These observations were observed with only 13 and 15 antennas, but amply demonstrate the quality of science that ALMA can achieve and provide a foretaste of what can be expected in the coming years.

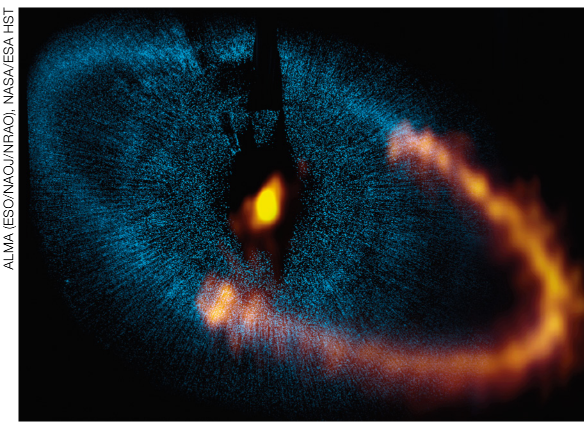
The presence of a dusty disc around the young main sequence star Fomalhaut had been known since the detection of an infrared excess (Aumann, 1985) with the Infrared Astronomical Satellite (IRAS). The filigree structure of the disc was revealed by Hubble Space Telescope (HST) imaging with the Advanced Camera for Surveys (ACS) with a coronagraph (Kalas et al., 2005). The disc is slightly elliptical in appearance with a major axis length of about 140 Astronomical Units (AU) and eccentric with respect to the stellar position. The puzzle about discs/rings around main sequence stars is that they cannot be the original proto-stellar disc, which would have long since dissipated, but must be actively replenished or trapped to be detected at all. From a second epoch of HST ACS imaging, Kalas et al. (2008) detected the proper motion of a bright spot in the outer disc around Fomalhaut and proposed this as a planet candidate (Fomalhaut b) with a mass of up to three Jupiter masses. The interactions between this candidate planet and the debris disc could explain the eccentricity of the dust ring, well measured with HST (Chiang et al., 2008).

However subsequent near-infrared (NIR) imaging with the Spitzer Space Telescope at 3.6 and 4.5 μm (Marengo et al., 2009), did not detect this planet when it was expected to be brighter than in the HST optical imaging. This implied either an unusual atmospheric composition or that it was not a true planet but a dust feature, perhaps enshrouding a lower mass planet. Janson et al. (2012) obtained deeper Spitzer 4.5 μm observations and concluded that the optical and NIR data pointed to a transient, optically thin dust cloud. However, what is not disputed is that there must be one or more planets in the Fomalhaut system to preserve a dust disc.

The longest wavelength observations of emission from large dust grains around Fomalhaut were made by the Australia Telescope Compact Array at 7 mm (Ricci et al., 2012) at a spatial resolution of about 12 arcseconds. The higher resolution ALMA observations were performed in the continuum at 850 μm which is mostly sensitive to emission from millimetre-sized dust grains. ALMA was used in its compact configuration with baselines from 14 to 175 metres and with Band 7 (275–373 GHz). The spatial resolution (synthesised beam) was 1.5 by 1.2 arcseconds, but the dusty ring was too large to be encompassed by a single ALMA primary beam, so ALMA was pointed at the northern half of the disc (where Fomalhaut b lies).

Figure 1 shows the ALMA map (corrected for the response of the primary beam) from Boley et al. (2012) superimposed on the HST ACS image from Kalas et al. (2005; 2008). This reveals a very narrow distribution of millimetre-sized grains with a radial width of only 16 AU; moreover the inner and outer radii of the disc are much sharper than indicated by the sub-micron sized particle distribution from the HST map. The millimetre-sized grains in the ring are much less affected by radiation pressure than the smaller (sub-micron) grains which have a broad tail of emission to large radii. Boley et al. suggest several explanations for the existence of the ring and its form; the favoured interpretation was that it is shaped by two shepherding planets, similar to the shepherding moons of the ε ring of Uranus — Cordelia and Ophelia. The required planet masses would be around several Earth masses, concordant with their non-detection by HST or Spitzer. A further intriguing result from the data is a possible flux excess on the star itself, suggesting an additional dusty region much closer to the star.

ESO astronomer Bill Dent (ALMA, Chile), one of the observing team, concluded in the press release: "ALMA may be still under construction, but it is already the most powerful telescope of its kind. This is just the beginning of an exciting new era in the study of discs and planet formation around other stars"[1].



ALMA (ESO/NAOJ/NRAO), NASA/ESA HST

Figure 1. Superposition of part of the NASA/ESA Hubble Space Telescope ACS image of the scattered optical light of the Fomalhaut debris disc (from Kalas et al., 2005, 2008) and the ALMA 850 μm continuum image (from Boley et al., 2012) of the northern section of the disc.

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Links

[1] ESO press release: http://www.eso.org/public/news/eso1216/

X-shooter Spectroscopy of Massive Stars in the Local Group and Beyond

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Combined with the collecting power of the Very Large Telescope, X-shooter is the most sensitive medium-resolution spectrograph currently in operation, allowing us to perform quantitative spectroscopy of objects that, up to now, were deemed too faint. In addition, with its unique wavelength coverage, X-shooter provides access to an unprecedentedly large number of diagnostic lines. We review our recent work on massive stars in Local Group dwarf galaxies and in NGC 55, an irregular galaxy in the foreground of the Sculptor Group. The observations were obtained as part of the ESO Science Verification Programme and the NOVA–Dutch Guaranteed Time Observation Programme. The aim is to investigate the evolutionary status of high-mass stars in various environments and to test the theory of radiation-driven stellar winds at metallicities below that of the Small Magellanic Cloud.

Massive stars are linked to a wide variety of astrophysical processes and phenomena. Their intense radiation fields, strong stellar winds and violent supernova explosions stir the ambient interstellar medium, which is typically a site of star formation. Their explosions produce the neutron stars and black holes that are used to test extreme physics and general relativity. Massive stars affect the dynamical evolution of the star clusters in which they reside and are thought to play a crucial role in the formation and evolution of galaxies. They are also the candidate first stars, anticipated to have reionised the Universe some few hundred million years after the Big Bang. Given their importance for various fields of astrophysics, a clear understanding of the formation and evolution of massive stars is essential.

At optical and near-infrared wavelengths massive stars emerge from their natal clouds typically within the first million years after formation, such that a census of their masses, rotation rates and multiplicity characteristics may provide important insight into the end product of the star formation process. A detailed understanding of their evolution further requires the identification and analysis of stars in various evolutionary phases up to the pre-supernova stage, thus deriving evolutionary connections between these phases. Comparisons between observations and stellar evolution models must be done for stars in different chemical environments as the ratios of stars in different phases (e.g., that of O to Wolf–Rayet stars), as well as the ratio of Type Ib/c to Type II supernovae, are found to be metallicity dependent. With most long-duration gamma-ray bursts occurring at low metallicity and the anticipated role played by massive stars in the early Universe, including its re-ionisation and galaxy formation, it is particularly interesting to study massive stars in low metallicity environments.

These considerations have motivated the study of massive stars in the Large and Small Magellanic Clouds (LMC and SMC respectively). Massive OB, Luminous Blue Variable (LBV) and Wolf–Rayet (WR) stars in the Magellanic Clouds have been studied intensively in the past decade (e.g., Mokiem et al., 2007; Evans et al., 2008). One important result that has emerged from these studies is that the rate of gas outflow driven by radiation pressure on spectral lines is both predicted and found to be metallicity, Z, dependent in a range from $Z_{\odot}$ to 0.2 $Z_{\odot}$. This mass-loss rate *versus* metallicity dependence is expected to play an important role in explaining the observed frequencies of different evolutionary phases and of supernova types.

With the latest generation of 8–10-metre-class telescopes, massive stars in more distant galaxies can now be individually resolved, allowing us to probe a wider span in environmental properties, albeit so far mostly at low spectral resolution ($R \sim 2000$) and within the Local Group (e.g., Bresolin et al., 2007). Although quite a number of exciting objects have been identified, detailed quantitative spectroscopic analyses of the most massive stars have remained cumbersome for obvious reasons: low signal-to-noise ratio and/or modest spectral resolution complicate (or prevent) the removal of nebular emission, among other corrections. Besides enabling a better nebular subtraction, the higher spectral resolution offered by X-shooter allows a more accurate surface temperature, gravity and mass-loss determination. It also allows for the analysis of weak metallic lines, crucial to derive abundances and accurate projected rotational velocities. These quantities are the key to establish and characterise the evolutionary stages of massive stars and their feedback. Here we report on the first analyses of massive star mass loss at sub-SMC metallicity, which appears to contradict our expectations.

Mass loss at low metallicity

The gas outflow of hot massive stars is driven by radiation pressure on metallic ions in the star's atmosphere, and consequently its strength is predicted to scale with metallicity ($\dot{M} \propto Z^{0.69 \pm 0.10}$; Vink et al., 2001). This prediction has been verified for massive stars in the Galaxy and in the Magellanic Clouds observed in the VLT–Flames Survey of Massive Stars (Evans et al., 2008), where the empirical relation $\dot{M} \propto Z^{0.78 \pm 0.17}$ was found (Mokiem et al., 2007). The theory has, however, never been tested at sub-SMC metallicity. Because the evolution of massive stars is greatly influenced by the amount of mass and angular momentum lost through their strong stellar winds, determining the wind strength was one of the main goals of our quantitative spectroscopic analysis.

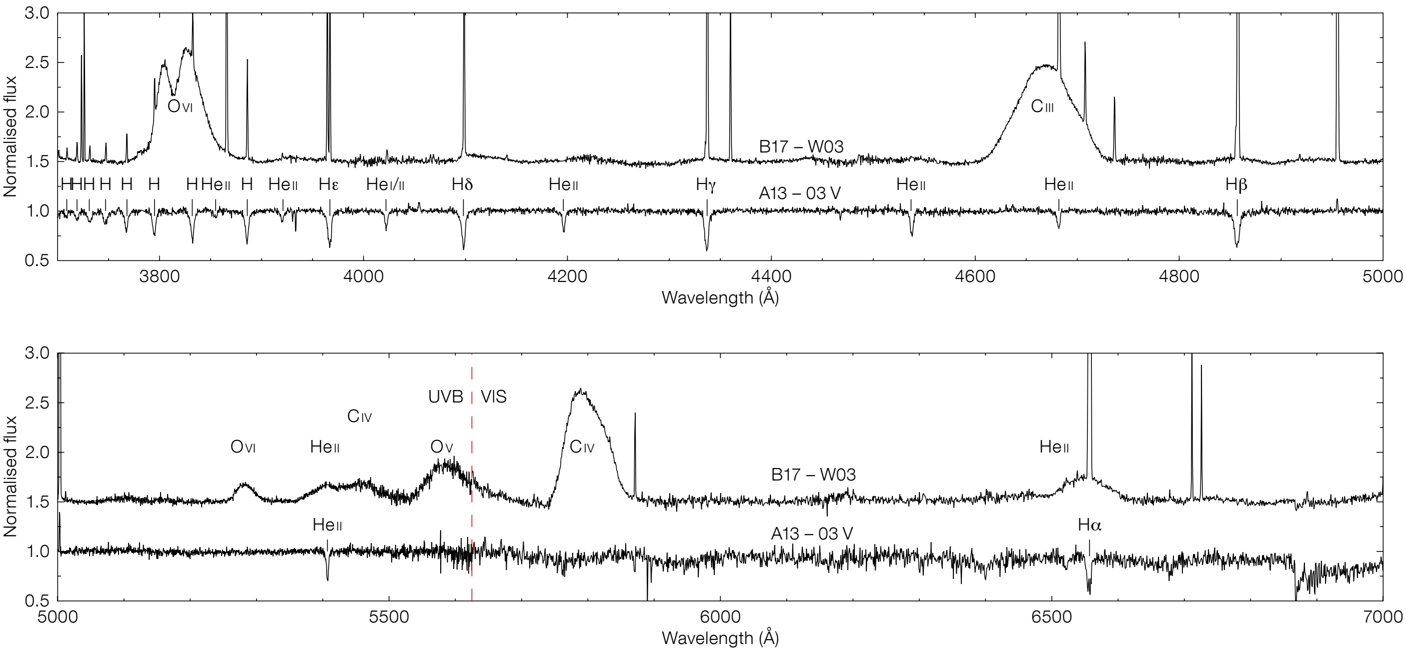
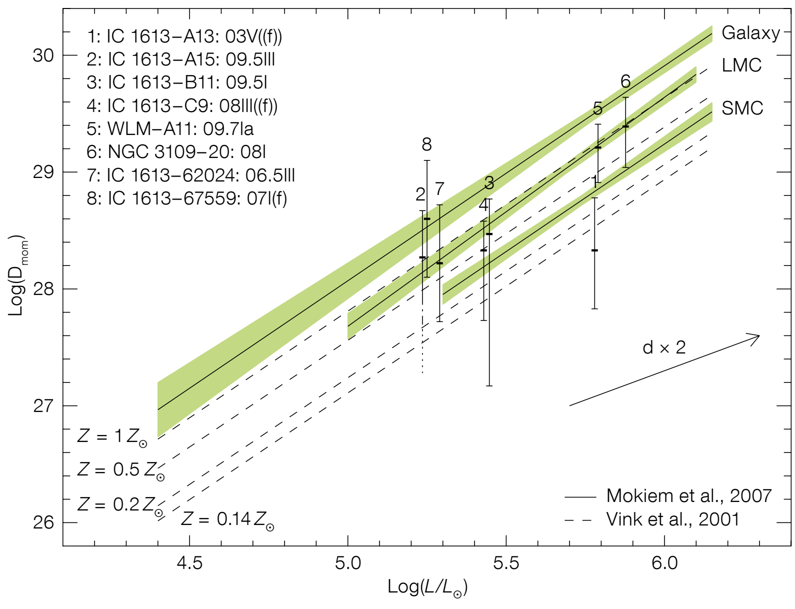


Figure 1 (above). Part of the X-shooter normalised spectra of two sources in IC 1613 are shown: A13 (O3V, lower spectrum in the two panels) and B17 (WO3, upper spectrum in the two panels). The WO spectrum has been reduced in flux by a factor of five and shifted to fit the panel. The main spectral lines are labelled. The vertical dashed line marks the transition between the UVB and VIS arms of X-shooter.

The Local Group dwarf galaxies IC 1613, the Wolf–Lundmark–Melotte (WLM) galaxy and NGC 3109 are ideally suited to probe the properties of massive stars in low-metallicity environments. These galaxies all have a metallicity of approximately $Z_{\odot}/7$ (i.e. lower than that of the SMC), a very low foreground reddening, and a young stellar population. Their distances are such that one can still resolve and individually study the brightest objects. We have thus obtained X-shooter spectra of several massive stars in these galaxies (four in IC 1613, and one each in WLM and NGC 3109). The targets were chosen to probe the whole range of O-type stars, with spectral types ranging from O3 V to O9.5 I. An example spectrum is displayed in Figure 1.

We find that the stars in our sample appear to exhibit surprisingly strong winds, with a mass-loss rate expected for LMC metallicity (objects 2–6 in Figure 2; Tramper et al., 2011). In a similar study, Herrero et al. (2011) also report stronger than predicted mass-loss rates for another two massive stars in IC 1613 (objects 7 and 8 in Figure 2). Although more stars need to be observed and analysed to draw firm conclusions, these unexpected results may have interesting implications. For example, the single-star channel to produce long-duration gamma-ray bursts depends on a star retaining a rapidly spinning core at the end of its life, and the star therefore cannot lose too much angular momentum through its wind. This result would thus

Figure 2 (below). The wind momentum–luminosity diagram is shown. Dashed lines indicate theoretical predictions from Vink et al. (2001) for different metallicities. Solid lines and shaded areas indicate the observed wind momentum–luminosity relations for the Galaxy, LMC and SMC samples (Mokiem et al., 2007). The shift between the predictions and the empirical measurements can be explained by wind inhomogeneities, which are not included in the analysis. Our observations in metal-poor galaxies are overplotted, objects 1–6 are from Tramper et al. (2011). Objects 7 and 8 are from Herrero et al. (2012) and Herrero et al. (2011), respectively. Although the error bars are large, the positions of objects 5, 6 and 8 are incompatible with theoretical predictions. Figure adapted from Tramper et al. (2011).



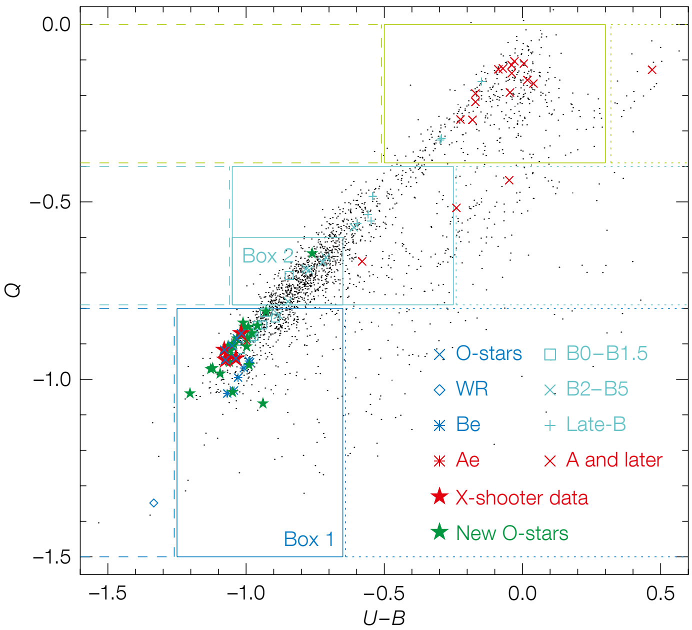


Figure 3. The *Q vs. U–B* diagram of IC 1613 is shown with the locus of O and B stars. Black dots represent good quality photometric data for IC 1613 stars. For each *Q*-horizontal band, the central box corresponds to unreddened or moderately reddened objects. Large symbols mark the position of stars with known spectral type (from Bresolin et al., 2007). X-shooter observations from Tramper et al. (2011) are marked with red stars. Green stars mark the position of newly confirmed O-type stars from low-resolution VLT-VIMOS or GTC-OSIRIS spectroscopy and illustrate that O-type stars concentrate in Box 1. Figure adapted from Garcia et al. (2009).

imply that fewer progenitors are produced through this channel. Also the single-star population at low metallicity would produce more Wolf–Rayet stars than currently thought, as a consequence of the higher mass-loss rate. This would lead to an increase of the number of Ib and, potentially, Ic supernovae.

Herrero et al. (2012) recently re-analysed object 7 in Figure 2 and concluded that the object position in the wind momentum-luminosity diagram can be reconciled with a sub-SMC line-driven wind model, assuming that the object is a fast rotator seen pole-on with an unusually rapid acceleration law for its stellar wind; it is this solution that is presented in Figure 2. Whether such a scenario can explain the other three problematic objects in Figure 2 remains to be investigated. From a purely statistical point of view, it seems unlikely that four high-inclination fast rotators have been picked out in a sample of only eight objects. Clearly, a larger observational sample is needed to understand the origin of this apparent discrepancy between the observations and the line-driven wind theory at sub-SMC metallicity.

Searching for new massive stars in IC 1613

As currently only a small number of massive stars are known in galaxies beyond the Magellanic Clouds, a large effort to identify new O-type stars has been initiated at the Instituto de Astrofísica de Canarias (IAC) in Tenerife. This identification proceeds in two steps: a photometric pre-selection of the most promising massive star candidates, followed by a spectroscopic confirmation using low-resolution multi-object spectroscopy.

The photometric pre-selection is based on the reddening-free parameter *Q*. Calculated from broadband Johnson photometric colours, $Q = (U–B) – 0.72(B–V)$ increases monotonically from spectral type O to A. Because of its definition the Q-parameter depends on the adopted reddening law and is subject to larger photometric errors than for individual filters. OB stars occupy a well-defined locus in the *U–B vs. Q* diagram (see Figure 3). While *Q* is an indicator of spectral type, *U–B* holds the information about whether the star is reddened or not. Known O stars and B supergiants in nearby resolved galaxies are mostly found in a progressing sequence in the *U–B vs. Q* diagram (marked with boxes 1 and 2 in Figure 3), and usually have $Q \leq -0.4$.

The target selection method thus proceeds as follows. Starting from a catalogue with small photometric errors (< 0.05 mag) to minimise the uncertainty on *Q*, "blue-*Q*" stars with $Q < -0.8$ are first selected; this provides a list of OB star candidates. In order to separate the O- and B-type stars, additional information is needed (see Garcia et al., 2009). The final list of O-star candidates is made of "blue-*Q*" objects with evolutionary masses over 30 $M_{\odot}$ as derived from colour–magnitude diagrams (Garcia et al., 2010) and a detection in far ultraviolet images from the GALEX satellite (GALEX-FUV).

The method has been tested in IC 1613 using low-resolution ($R \sim 2000$) spectra taken with the VLT-VIMOS and GTC-OSIRIS instruments. The success rate of this pre-selection method is impressive. For VIMOS, the pre-selection was based only on the *Q*-parameter. Fourteen O stars were newly identified out of a sample of 24 candidates, thus a success rate of 60 %. The success rate of the GTC-OSIRIS list, that also uses evolutionary masses and GALEX detection, reaches 70 %: 9 out of 13 candidates are O stars, while the other objects are early-B stars.

To summarise, the VLT-VIMOS and GTC-OSIRIS observations have provided us with a list of 23 newly identified O stars (see Figure 4) to be followed up with X-shooter. This multiplies the sample of known O stars in IC 1613 by a factor of four and will allow for a much larger-scale study of the winds of early-type stars at very low metallicity.

Beyond the Local Group

To test even further the capabilities of X-shooter in this field of research, we set out to perform quantitative spectroscopy of some of the most massive early-type stars beyond the Local Group. The NGC 55 galaxy lies in front of the Sculptor group, at a distance of about 2 Mpc and is similar in shape and metallicity to the LMC. The population of massive blue stars in this galaxy has been identified in the context of the Araucaria project (Gieren et al., 2005). Classified as an early-O supergiant from published low-resolution FORS2 spectra (Castro et al., 2008), we selected source C1_31 as a candidate very massive star in this galaxy

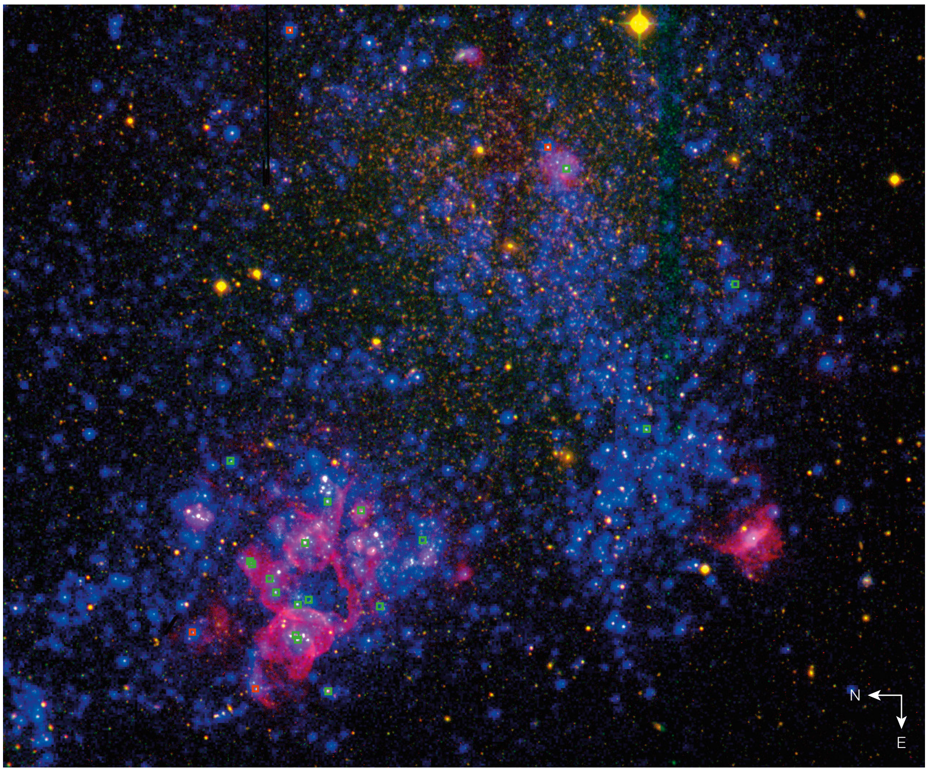


Figure 4. IC 1613 three-colour composite image made with INT-WFC images taken with the Hα- (red) and *V*-band (green) filters plus GALEX's FUV-channel (blue). Red squares mark the objects with X-shooter spectra (see Figure 3 and Tramper et al., 2011) while green squares show the location of newly identified O-type stars from low-resolution VLT-VIMOS or OSIRIS-GTC spectroscopy.

(Figure 5), and observed it with X-shooter during Science Verification.

The spectrum that we obtained has been a riddle (Hartoog et al., 2012). Most of the Balmer lines and the He I lines were strongly affected by nebular contamination, in stark contrast with previous low-resolution data. Yet, the resolving power of X-shooter was sufficient to separate the wings of the stellar photospheric lines from the nebular emission affecting the line cores (see Figure 5). The absence of the He II 4200,4541 Å lines in the spectrum was, given our signal-to-noise ratio, setting a firm upper limit to the effective temperature of about 35 000 K, in contradiction with the proposed early-O supergiant classification. The properties of the superposed nebular spectrum, however, suggested a very hot ionising source, with a temperature of about 50 000 K.

We compared the observed spectrum with synthetic spectra from a grid of FASTWIND stellar atmosphere models, which allowed us to investigate the nature of the source and its stellar parameters. A model resembling a late O star could reproduce all the hydrogen and helium line profiles, except for He II 4686 Å and Hα. These lines, present in emission in our X-shooter spectrum, have a full width at half maximum of about ~3000 km/s, and are reminiscent of the lines found in WR star spectra. However, peaking at about 20 % of the continuum level, these lines are not very strong, and definitely too weak for typical WR stars.

The large spectral coverage of X-shooter allowed us to estimate the extinction directly from our data by a comparison of the (relative) flux-calibrated spectrum with the spectral energy distribution of a standard hot star model. Given its extinction-corrected flux, we estimated the source to be about a factor ten more luminous than typical early-O supergiants.

In order to synthesise these different elements into a consistent picture, we considered C1_31 to be a small stellar cluster rather than a single source. Indeed the projected size of our entrance slit corresponds to a physical distance of just below 10 pc, i.e. large enough to contain a small open cluster such as Trumpler 14 or NGC 6231. Pursuing this solution, we can reproduce all observed spectral features, the properties of the surrounding ionised region and the visual brightness of the target by combining about ten late-O/early-B (bright) giants, and one or two WN stars, a class of WR stars that can be very hot, but do not show very strong carbon lines (which would have been prominent in the target spectrum).

This work illustrates an inherent difficulty in extragalactic stellar spectroscopy, i.e., the risk of observing a cluster (or an unresolved multiple object) instead of a single star. Thanks to the unique combination of high resolution and large wavelength coverage, allowing many different diagnostic lines to be observed, X-shooter can play a critical role in unveiling the composite character of such objects. Obviously the cluster composition that we proposed for NGC 55 C1_31 may not be the unique solution, but the conclusion that NGC 55 C1_31 is not a single star but a cluster that contains at least one very hot WR star, is robust. Higher angular resolution is a must to further disentangle such a group of stars and to study the evolutionary stage of the identified population.

Future prospects

With the advent of the European Extremely Large Telescope (E-ELT) it will become possible to resolve stellar populations in a representative sample of galaxies of different morphologies in and beyond the Local Group, such as the spiral-dominated Sculptor and M83 groups and starburst galaxies such as M82. The high contrast and sensitivity of wide-field (up to 10 arcminutes) adaptive optics, routinely providing a spatial resolution a factor of ten better than seeing-limited observations at the VLT, will provide the opportunity to simultaneously obtain spectra of several hundreds of individual (massive) stars within a targeted galaxy. Several concepts of the required E-ELT multi-object spectrograph (OPTIMOS and EAGLE) have been explored (Hammer et al., 2010; Le Fèvre et al., 2010; Morris et al., 2010). For the study of massive stars, wavelength coverage as far to the blue as possible would be required, but also the near-infrared provides valuable spectral diagnostics. For the first time we will be able to explore the properties of massive stars over the full range of environments, from the lowest metallicities up to the sites of violent star formation in starburst galaxies.

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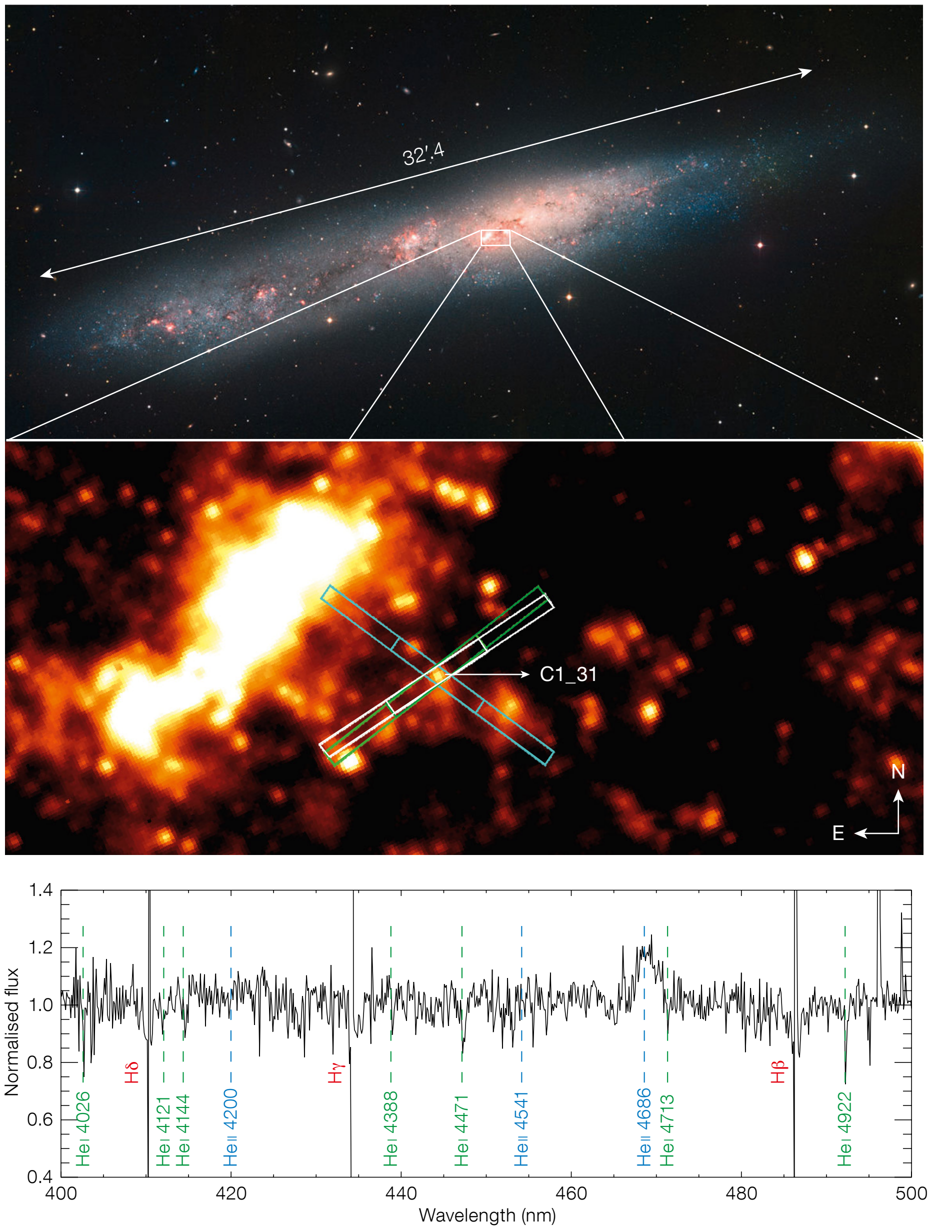
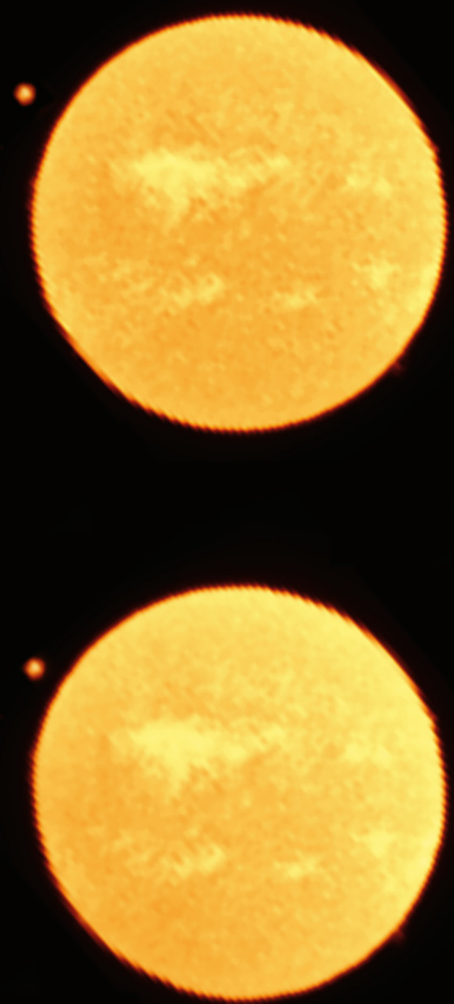


Figure 5. Top panel: MPG/ESO 2.2-metre WFI colour-coded image (*B*, *V*, Hα) of NGC 55 is shown. Middle panel: zoomed-in FORS2 Hα image around the position of C1_31; the rectangles indicate the projections of the X-shooter entrance slit during our three different observations. Bottom panel: Co-added C1_31 spectrum with the main spectral features identified. Figure adapted from Hartoog et al. (2012).

ESO/IDA/1.5-metre Danish/R. Gendler and C. Thöne

NGC 4945, shown here, is an SB barred spiral galaxy in the nearby Centaurus A group of galaxies. The colour image was formed from exposures taken with the 1.5-metre Danish telescope at the La Silla Observatory in *B*-, *V*- and *R*-bands. NGC 4945 has a heavily obscured Seyfert 2 active galactic nucleus which has been extensively studied. See Picture of the Week 1007 for more details.

Florian Gourgeot, an ESO student in Chile, exciting Chilean schoolchildren about the wonders of astronomy as part of the outreach programme *Viaje a las Estrellas*. See p. 48 for details.



ALMA

One of the ALMA antennas was used to produce an image of Venus and the Sun just before the transit on 6 June 2012. The two images, obtained at a wavelength of 3 millimetres and taken 16 minutes apart, show the approach of Venus towards the disc of the Sun; Venus set at Chajnantor shortly after the images were taken. See http://www.almaobservatory.org/en/announcements-events/429-venus-as-seen-by-one-of-the-alma-antennas-before-the-transit for details.

Renewable Energy for the Paranal Observatory

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[1] ESO

The operation of observatories at remote sites presents significant demands for electrical energy. The use of renewable energy may become the solution to cope with the ever-rising prices for electrical energy produced from fossil fuels. There is not only a purely commercial aspect, but also the carbon footprint of observatory activities has to be considered. As a first step on the way to a "greener" Paranal Observatory, we propose the installation of a solar cooling system for the cooling of the telescope enclosures, using the abundant insolation that is freely available in the north of Chile. Further into the future, feasible options for photovoltaic and wind energy could supply the needs of the Paranal Observatory in a sustainable manner.

The location of the Paranal Observatory in the Atacama Desert has, apart from its remoteness, two other important advantages: the clear night-time sky in northern Chile provides astronomers with more than 320 clear nights per year; the clear day-time sky also provides abundant sunshine. But 20 years ago, when oil was still cheap, little thought was given to the fact that the situation for economic provision of energy to the observatory could one day change. It is increasingly difficult for the Paranal operations budget to accommodate the growing financial demand for electrical energy production. The increasing energy costs cannot be predicted in an easy way for the near future and depend heavily on exchange rates, oil prices and the global economy.

Between 2003 and 2010, electricity prices in Chile rose on average by 6.8 % per year, according to statistics from the Organization for Economic Co-operation and Development (OECD[1]). The renewable energy share in Chile was 49 % in 2009[2] with, however, a downward trend anticipated in the coming years as coal-fired power plant projects, presently under discussion, begin to be realised. Confronted with these facts, the Observatory started to look into possible solutions to control its energy costs. One obvious option is the production and use of renewable energies.

There are however some caveats and boundary conditions that have to be taken into account:
- Paranal is operating in "island mode" and has no connection to the Chilean power grid.
- Solar energy cannot easily be stored, either as electrical or thermal energy.
- Wind energy is highly intermittent and requires a full back-up by conventional energy generators.
- Any solution adopted for Paranal should be compatible with the European Extremely Large Telescope (E-ELT) project which is planned to be built on the nearby Cerro Armazones peak, and not pose any precedents or dependencies for this new project.
- The proposed investment should be reasonable and the time for return on investment should be as short as possible.

Paranal power consumption has remained stable over the past few years, despite the addition of the VISTA survey telescope and the VLT Survey Telescope (VST). In the telescope area, the four unit telescopes (UTs), the VLT Interferometer (VLTI) and the VST consume 67 % of the total power of approximately 1200 kW. A breakdown of the power use across the Observatory is shown in Figure 1.

Beyond purely economic considerations, the long-term impact of observatory operations on global climate and environmental sustainability should also be addressed. The carbon footprint of the Observatory is, at 22 000 metric tonnes of CO_2 per year (see Figure 2), at a level that is hardly sustainable. (The cost to offset the entire CO_2 emission of the Paranal Observatory would be in the range of € 500 000 per year [at € 23 per tonne of CO_2]). The CO_2 emission of the Observatory translates into approximately 46 tonnes of CO_2 per peer-reviewed VLT science paper per year, which itself is equivalent to the yearly CO_2 footprint of ten people at the current world average. The main contributor to the CO_2 footprint is the electricity generation by liquefied petroleum gas (LPG, consisting of butane/propane). A reduction in the number of international and domestic flights, i.e. by eliminating visitor mode observations, would only reduce the footprint by some 10 %, but would have an undesired

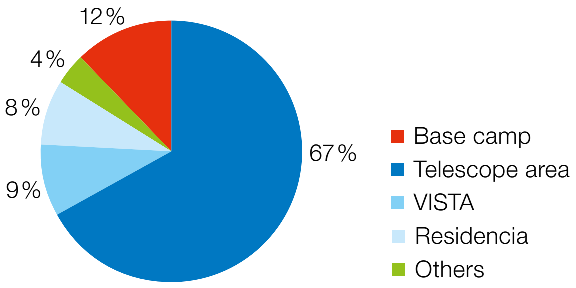

Figure 1. The breakdown of average electrical power distribution between the various elements of the Paranal Observatory (100 % = 1200 kW).

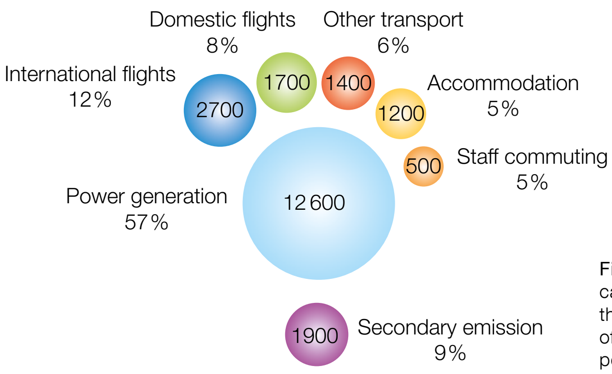

Figure 2. The breakdown of the carbon footprint for the operation of the Paranal Observatory in terms of tonnes of CO_2 equivalent and by percent.

impact on the operational model of Paranal. Connection to the Chilean grid would also not improve the carbon footprint much, once coal dominates the energy mix in Chile. This demonstrates that a real reduction of the CO_2 emission can only be achieved if electricity is generated from *renewable* sources.

Alternatives

Looking at all the known technical options and discarding those that are not suitable for the Observatory — either due to its mountain location, or for other reasons — there remain basically only three alternatives for energy generation from renewable sources:
- solar thermal energy, harvested either by concentrating or flat collectors;
- solar electricity, by means of photovoltaic panels in staring or tracking mode;
- wind energy, with windmills on a nearby mountain ridge, avoiding increased turbulence at the observing site.

Solar thermal energy is the easiest option of all, as it uses known, simple and cheap technology that has been available for many decades. Using concentrating collectors, processing of heat up to 600 °C can be achieved to drive Stirling engines or Rankine cycle turbines, while flat collectors can deliver hot media just below the boiling point of water- or glycol-based coolants.

Photovoltaic (PV) energy is a modern technology, but ripe for industrial use, and it has been proved that it can be competitive in terms of reliability and cost and is almost maintenance free. Crystalline solar cells now reach efficiencies in the range of 20%, while thin-film cells are just about crossing the 15% level. The costs for PV have now almost reached the magic barrier of 1 €/W, which is considered to be the price where PV becomes economically feasible. Manufacturers of PV technology now guarantee a service life of more than 20 years.

Wind energy on the other hand is attractive from the point of view of simplicity, but has some drawbacks, such as intermittency, that could have a more serious effect at Paranal compared to PV, for example. Wind turbines cannot be installed in the immediate vicinity of the Observatory due to the long turbulence tail they cause. Siting them further away would result in higher installation costs. Estimates show that two wind turbines of the 800 kW class would cover ~40% of the Observatory's energy demand.

With the possibility of getting a connection to the Chilean power grid sometime in the near future, both PV *and* wind are highly attractive solutions for the future and should be kept on the alternative energy agenda of Paranal. Under conservative assumptions, up to 50% of the energy demand could be covered using these three technologies.

Expanding on these ideas, business models like BOO (Build-Own-Operate) or DFBO (Design-Finance-Build-Operate) could be considered as well, also in the context of the E-ELT. Due to their intrinsic modularity, PV fields and wind turbines can be added with little effort and at will to an existing system and cope with growing demand and increasing energy costs. The higher energy costs rise, the sooner alternative solutions become economically interesting and the shorter the return time on investment is. This fact should not be left out of the discussion. During 2010 and 2011, we looked into possible solutions to, at least partially, provide the Observatory with renewable energy and explored one idea that would in fact be in line with the considerations listed above: a solar cooling system for the VLT telescope enclosures.

The cooling of the VLT enclosures

Paranal uses three chillers that produce cooled media for the cooling of all the electronic equipment, the scientific instruments, the buildings and the enclosures of the VLT. These chillers operate almost continuously, as the demand for cooling during the night at 660 kWth (thermal) is only about 30% lower than during the day. This extra demand of around 300 kWth during the day is only used for air conditioning the VLT enclosures.

During the day, there is an almost perfect correlation between cooling demand and availability of solar energy. With an adsorption or absorption system, this thermal energy can be transformed into cooling energy and supply the air-conditioning systems in the telescope enclosures. The load of at least one chiller could be taken over and approximately 150 kW of electrical power could be saved. This would correspond to 15% of the generated power and about 5% of the energy, translating into savings of the order of €150 000 per year at *present* energy prices. This solution is simple and does not imply very sophisticated technology. Several solar cooling plants are already operating in southern Europe and the Middle East and compare in terms of reliability to conventional

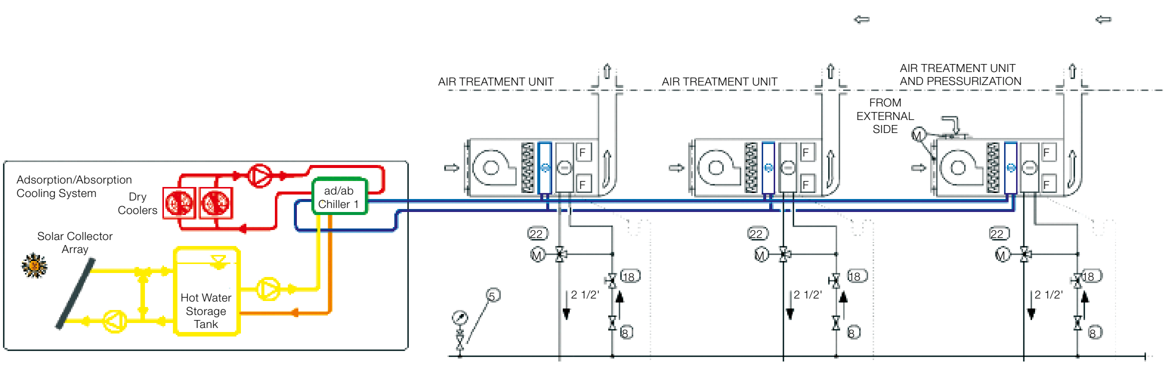

Figure 3. A solar-powered cooling circuit for one Unit Telescope is shown. See text for explanation of the various elements. The solar circuit is shown in yellow; ab(d)sorption cooler in green; dry cooler (red); cooled media delivery (blue) for three air-handling units at the telescopes (only one shown).

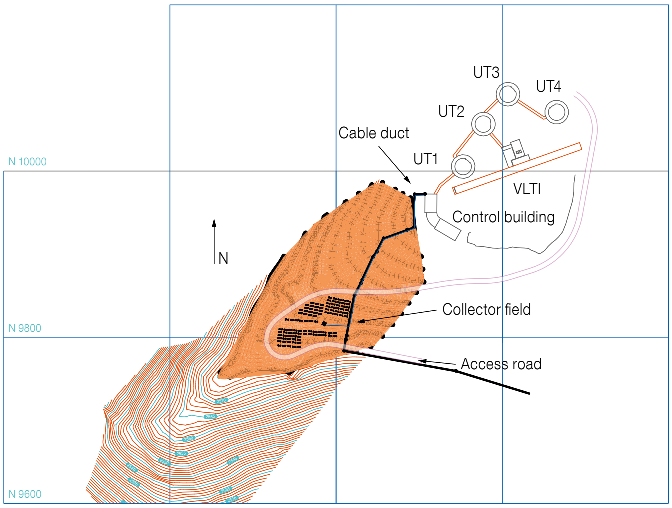

Figure 4. Proposed location of the solar array collector field at the Paranal Observatory; the connection to the telescope enclosures is shown.

plants with electrical compressor chillers. The temperature that an absorption cooler can deliver does not however reach the low levels that are required by the technical equipment in the telescopes (3–5 °C). There are two possible ways to implement this system on Paranal.

One solution would supply the cooled media directly to the air-handling units located on the outside of the VLT enclosures. Figure 3 shows the diagram of the system: hot water from the solar panels (yellow) acts as a thermal compressor in the absorption chiller[3] (green) and evaporates the water from a water / lithium bromide solution. The water is then condensed by means of the dry cooler loop (red) and absorbed back again into the lithium bromide. The cold water (blue), produced in the absorption process, then feeds the air-handling units (black) of the telescope enclosures. The other possible solution would be to use the solar energy circuit to pre-cool the return flow from the cooling system and feed this pre-cooled water to the electrical chillers to further lower its temperature to the desired level. It has not yet been decided which of the two solutions will finally be chosen. A detailed engineering study is required to explore these options.

A collecting area of approximately 1500 square metres is required for the solar collectors, which would require an area of 2000 square metres of land. A suitable place has been identified in the vicinity of the present satellite antenna (see Figure 4).

The absorption machine would be placed in a container nearby and the piping would be routed through existing ducts to the control building and the telescopes.

Other energy savings

Beyond the large-scale projects for the implementation of renewable energies, energy saving also has to be addressed. The awareness of the Observatory staff with respect to energy saving is growing and together with technical solutions, can reduce the waste of energy. Many proposals have been made, but they are sometimes difficult to put into practice.

On the larger scale, pumps may be switched off if they are not in use or idling, recirculation pumps and fans could be upgraded with variable speed control. Capacitor banks for the compensation of reactive power are currently being installed on the low voltage grid and will save of the order of €100 000 in LPG per year. The hot water for the Paranal Residencia is already heated with the exhaust gas from the gas turbine, but this system could be expanded also to the container camp and later be upgraded to a solar heating system. Waste water treatment and recycling is another example where costs and resources could be saved.

On the smaller scale there are all the desktop computers, screens and printers that could either be switched off or put into hibernation, lights in corridors and telescope tunnels could be motion controlled and office equipment could either be switched off completely or put into hibernation, etc. There are many opportunities to tackle the energy issue also from the side of savings and we will continue to address them over the coming years.

Outlook

Unfortunately, when the VLT project was conceived in the early nineties, renewable energy concepts were not on the agenda. To refurbish the Paranal Observatory now with renewables would be expensive and only partially lead to an ideal solution. Compromises have to be made and the heritage from sustainability not designed-in right from the beginning will always remain. Nevertheless rising energy prices will force us to go this route and the solar cooling project is just at the beginning of the green path that the Paranal Observatory is willing to take! Astronomy is one of the oldest sciences and perhaps could be considered as one of the purest. We should try to avoid contributing to the pollution of the atmosphere of our planet, and make use of the abundant energy that the nuclear fusion reactor at the centre of our Solar System is producing for free.…

Acknowledgements

I would like to thank P. Vanderheyden and C. Ramirez for their valuable input and discussions towards helping this idea fly. Many other Paranal staff members contributed with their ideas and kept the spirit high to contribute to energy savings/renewable energy and promoting a greener Observatory. Special thanks go also to R. Tamai and A. McPherson for sharing their plans for E-ELT power generation.

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[1] OECD: http://www.oecd-ilibrary.org/economics/country-statistical-profile-chile_20752288-table-chl
[2] International Energy Agency: http://www.iea.org/stats/electricitydata.asp?COUNTRY_CODE=CL
[3] Absorption Chillers: http://www.solair-project.eu/143.0.html

Report on the ESO/IAG/USP Workshop

Circumstellar Dynamics at High Resolution

held at Foz do Iguaçu, Paraná State, Brazil, 27 February–2 March 2012

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The workshop was jointly sponsored by ESO, the Brazilian National and São Paulo state agencies CAPES and FAPESP, and the University of São Paulo. Nearly 70 participants gathered to discuss the immediate surroundings of stars, mostly those more massive and hotter than the Sun. The venue, near the spectacular Iguaçu waterfalls, and topic proved to be well chosen to attract a balanced crowd: about one third of the participants came from each of Brazil, other ESO member states and Chile, and ESO non-member states.

The dynamics of circumstellar envelopes is an active research frontier that has benefited greatly from the advent of high-resolution observational techniques in the spectral and spatial domains. The diverse and complex circumstellar environments revealed by these observational techniques are particularly evident near hot, high-mass, stars, where stellar radiation plays a large, if not crucial, role in continuously shaping the immediate environment.

Circumstellar structures have not only been resolved spatially, but also have been followed over characteristic timescales of their variation. This dynamical evolution has been modelled for discs and winds: we are now directly observing and measuring the consequence of the physical mechanisms operating within the circumstellar environments. As a result, current observing facilities, not least the ones operated by ESO, have allowed the field to progress from a static picture of the circumstellar environment towards understanding its dynamics and the physical processes dominating the dynamics.

Figure 1. The conference group photo taken against the splendid backdrop of the Iguaçu Falls.

Circumstellar discs and outflows

The meeting started with two oral sessions on circumstellar discs and their outflows. The first, focused on observations, was opened by reviews on discs and their properties during various evolutionary phases by R. Oudmaijer and by introductions to, and results from, various observing techniques, such as polarimetry (presentation by A.M. Magalhães) and both amplitude and intensity interferometry (by P. Nuñez and F. Millour). A. Kaufer showed the late B supergiant Rigel to be a particularly interesting case, exhibiting a cyclically recurring large-scale circumstellar structure. In two contributions exploring the fate of circumstellar ejecta of less massive stars over longer timescales, R. de la Reza wondered why no ejection shells had yet been discovered around lithium-rich giants, and T. Ueta introduced the Herschel Planetary Nebula Survey.

The second session then concentrated on the theory addressing the observational phenomena. Magnetohydrodynamic wind models were presented in detail by A. ud-Doula, a topic picked up frequently in later contributions. One of the most interesting aspects of the current state-of-the-art disc modelling is that the Be star models have begun to converge to a common physical basis, namely that of a geometrically thin disc in Keplerian rotation that is driven by viscosity (talks by J. Bjorkman and C. Jones). This provided a most valuable common baseline for further exploration, as was shown by D. M. Faes for an interferometric phase effect so far not considered, and by R. Halonen concerning the role of polarimetry in revealing the disc structure. X. Haubois extended the theoretical understanding of Be star discs into the temporal domain, while A. Granada approached the issue from a different direction by investigating how Be stars fit into the current understanding of stellar evolution.

δ Sco and Be stars as laboratories for circumstellar disc physics

In July 2011, the highly eccentric binary δ Sco went through periastron passage, more than ten years after the previous one. The previous periastron event and the evolution since, summarised by A. Miroshnichenko, sparked significant interest in the object, as δ Sco seems to have started to build up a circumstellar Be star disc around that time. Therefore, the 2011 periastron passage was anticipated to clarify if and how the periastron has any connection to mass ejection and disc formation. On this occasion the disc around the primary was fully developed, so monitoring its response to the passage of the secondary was another

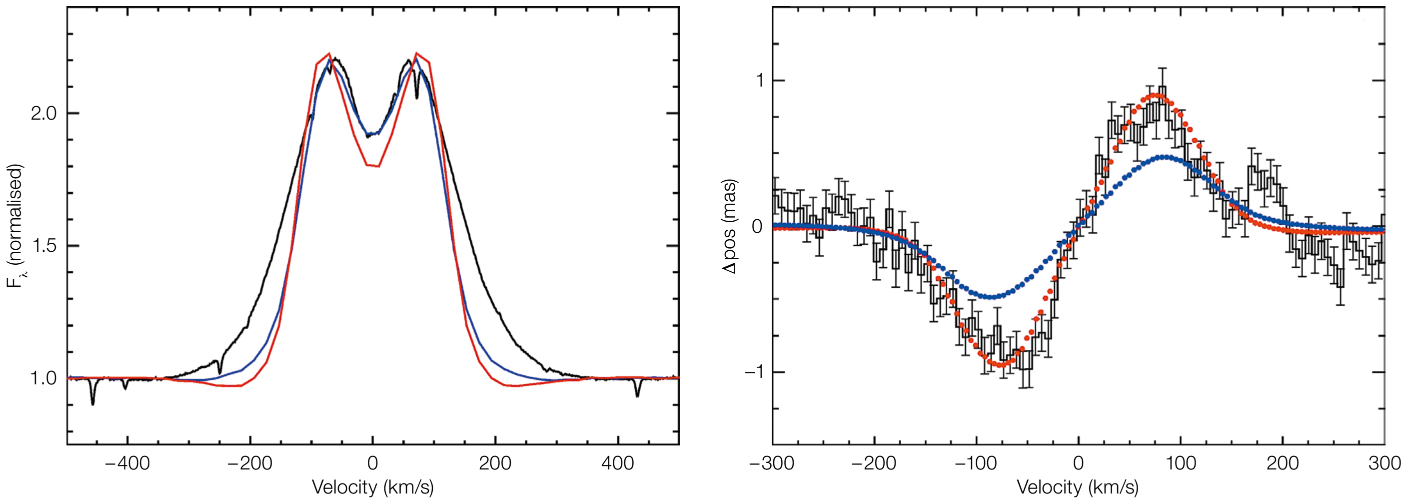

Figure 2. Spectroastrometric observations of β CMi. The data are compared to HDUST models featuring angular momentum and Keplerian rotation (blue and red respectively). The combination of high spectral resolution and sub-milliarcsecond spatial precision constrain the disc kinematics. Only the Keplerian model can simultaneously recreate the observed line profile (left) and the spectroastrometric signature (right). From Wheelwright et al. 2012, MNRAS 423, L11.

attractive opportunity in 2011. Observations of the 2011 periastron and their preliminary interpretations were presented by S. Štefl in the oral session and by some posters.

High angular observations of Be stars, at the Very Large Telescope Interferometer (VLTI) as well as other interferometric facilities, and their implications were reviewed by Ph. Stee, while the dynamical theory of Be discs in binaries was presented by A. Okazaki. Observations of the latter were shown by R. Mennickent, pointing out the existence of hundreds of peculiar double periodic binaries, in which the non-orbital photometric period, originating from a circumstellar disc, is typically longer than the orbital one by a factor of about twenty.

The presentation by H. Wheelwright, comparing observations of the disc of β CMi to kinematic models of the circumstellar velocity field, reinforced the understanding presented already in the previous sessions and by Stee: Be star discs are in Keplerian rotation. Consensus on this controversial result, growing since a meeting in Sapporo, Japan, in 2005, is probably among the most significant achievements of this workshop, given that this issue has been debated for decades, sometimes quite controversially.

Dynamics of circumstellar material and tidal interactions in hot binaries

The δ Sco periastron found significant attention within the Be star community. But the fact that η Carina is an eccentric binary, interacting in many ways, has certainly impacted the community still more deeply. Consequently, this star and other Luminous Blue Variables (LBVs) featured prominently in this section, beginning with a review given by J. Groh on interferometric data and a contribution by Z. Abraham on radio observations. The question whether possibly all LBVs with giant eruptions might be binaries was raised by C. Martayan.

Moving away from these most extreme cases, D. Cohen, S.P. Owocki, and J. Sundqvist presented the recent developments of the theory of radiatively driven stellar winds on a broader scale, ranging from X-rays as shock diagnostics, via structural questions in general, to temporal variability. The remainder of the session was devoted to more individual topics, in particular the interferometric study of a B[e] star by M. Borges Fernandes, the circumstellar structure of a Be X-ray binary during a giant outburst by Y. Moritani and the modelling of [WCE] stars by G. Keller.

Massive star formation out of a dynamic environment

The session on star formation began with an unusual setup. Since M. Krumholz could not be present in Iguaçu, he agreed to give his talk on the theory of massive star formation via Skype on one screen, while the slides were shown on the other. This *ad hoc* teleconferencing solution worked flawlessly, and the audience was rewarded with a very interesting contribution on collapsing molecular clouds. L. Ellerbroek provided insights into an alternative scenario of the accretion history of an intermediate-mass young stellar object.

Interferometry is a major driver in this field, with baselines ranging from typical single-dish diameters (aperture masking, talk by S. Lacour) via long optical baseline interferometry like the VLTI (presentation by W.J. de Wit) to the kilometre-scale baselines in the submillimetre range that will be offered by ALMA (presentation by N. Evans).

Magnetospheres of hot stars

The observational facts about magnetically-governed environments of hot stars were introduced by E. Alecian, and complemented by R. Townsend, providing an overview of theoretical insights into the interplay between rotation, magnetic field and stellar wind. Detailed examples were presented by V. Petit and A. Carciofi; T. Rivinius argued that a sufficient number of such objects are currently known to permit statistical analysis, and possibly to postulate these objects as constituting a class of magnetic hot stars. Many of these newly found magnetic stars were provided by the MiMeS survey, summarised by G. Wade, which finds a magnetic field incidence of typically 10% in massive stars, very similar to lower-mass (but still non-convective) stars. The only striking exception are the Be stars, a class for which not a single magnetic member has been found. This result has the potential to settle another longstanding debate, namely what role, if any, magnetic fields play in the formation of discs around Be stars.

Closing talks

The final talk of the meeting was given by D. Baade, summarising the contributions, reminding the participants of the progress made and presented at the meeting, but putting emphasis as well on the work left to be done.

A public talk by D. Baade, translated simultaneously from English into Portuguese, on ESO's Extremely Large Telescope and the quest for extraterrestrial life was attended by members of the Pólo Astronômico, a large and active group of amateur astronomers, as well as the conference participants. A Star Party, prepared by the Pólo Astronômico for after that talk unfortunately could not be held due to bad weather. The excursions to the Brazilian and Argentinean sides of the Iguaçu waterfalls were as spectacular as expected for a visit to one of the new seven wonders of nature[1].

The generous sponsorship not only by ESO but also by Brazilian agencies enables us to publish printed proceedings in full colour, which will appear in the conference series of the Astronomical Society of the Pacific, edited by A. Carciofi and T. Rivinius.

Acknowledgements

We are very grateful for the enthusiastic work of both the scientific and local organising committees. The meeting benefitted greatly from the organising support of Maria Eugenia Gomez and Marketka Šteflova. We thank the Pólo Astronômico for their enthusiasm and the staff of the Rafain Palace Hotel for their assistance.

Links

[1] New seven wonders of nature: http://www.n7w.com

Report on the Workshop

Observing Planetary Systems II

held at ESO, Vitacura, Chile, 5–8 March 2012

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Claudio Melo[1]
Ralf Siebenmorgen[1]
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This second edition of the Observing Planetary Systems workshop was aimed at bringing together the two communities of Solar System and exoplanetary system scientists to review the recent progress made in our understanding of the formation of the Solar System and its early chemistry, and how this picture fits with our current knowledge of the formation and evolution of planetary systems in general.

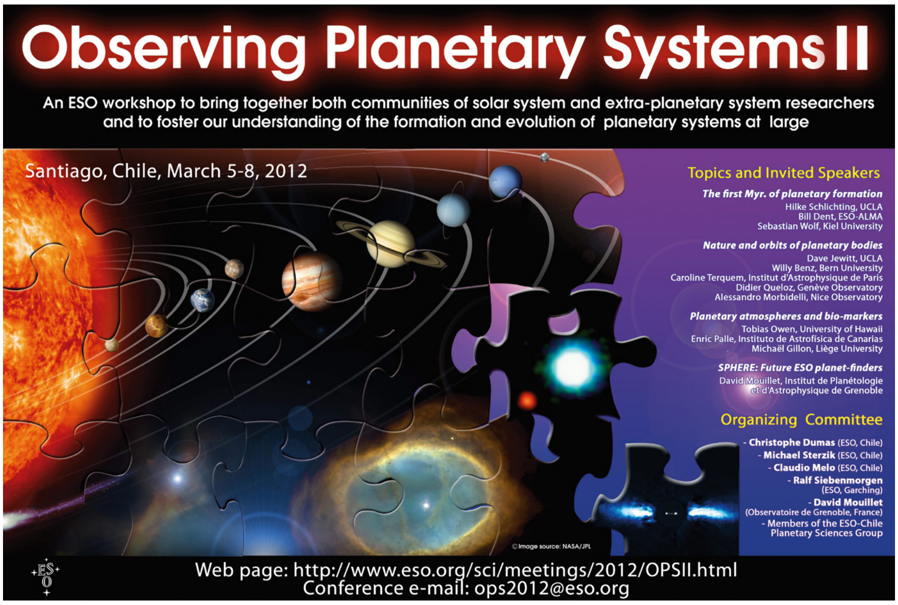

Figure 1. The workshop poster.

Motivation

Exactly five years after our successful Observing Planetary Systems workshop held in March 2007 (see Sterzik & Dumas, 2007), we again brought the two communities of Solar System and extraplanetary system scientists together at the ESO/Vitacura headquarters in Santiago de Chile for the second edition of this conference (OPS II). The focus was similar to five years ago, i.e. to review, from an observational standpoint, our progress in understanding the processes involved in planetary formation and the application of the knowledge of the Solar System to help constrain our picture of extrasolar systems in general (see the meeting poster in Figure 1).

The conference was very well attended, with more than 100 registered participants, and the limited capacity of our meeting room unfortunately forced us to decline some interesting contributions. Participants to this workshop represented 15 countries: Brazil, Argentina and Chile in South America, Canada and USA in North America, and the rest of the participants coming from ten different European countries, with a significant representation from Spain, United Kingdom, France and Germany. Out of 107 participants, 27 were graduate students, which provided a great opportunity to update our young researchers on the latest developments in this highly dynamic field. The meeting was held over four full days, covering the main aspects of planetary formation and characterisation within four distinct sessions: "Planetary discs and the first Myrs of planetary formation", "Nature and orbits of planetary bodies: Models and Observations", "Planetary atmospheres and bio-markers", and "Future planet-finders and novel technologies". Contributions were made by a combination of invited talks (11 different invited speakers), contributed presentations (44) and posters (38 in total).

We opted again for a prompt release of the presentation material rather than having printed proceedings at a later stage. The oral contributions were also filmed with the consent of each author and all this material (PDF and videos) is available on the conference website[1]. One of the innovations made during this second edition was to provide a real-time video link of the presentations in a separate location, adjacent to the main conference room. People (registered and non-registered participants) could thus follow the discussions while working in groups, in the nice and comfortable environment of the ESO-Chile library. This service was highly appreciated by the meeting participants.

In order to take advantage of the presence and interest of many international experts, the conference was immediately followed by a single-day workshop focused on high-contrast imaging and spectroscopy of planetary systems, to review the latest progress made in observing techniques, technology and data-reduction. More information about this workshop can be found on its website[2] and it is briefly described at the end of this report.

Scientific highlights

The linear progression offered over the four days of this workshop, from the study of the early stages of planetary accretion to the formation of planetary bodies, their dynamical interaction and physical composition, paved the way for the final sessions. Here observing programmes aimed at characterising the atmospheres of exoplanets, demonstrating techniques to search for biomarkers and describing the potential breakthroughs expected from the latest/future ground- and space-based planet-finding machines were all discussed.

The morning of the first day was dedicated to far-infrared and submillimetre observations of stars surrounded by discs in their various stages of formation, from directly after collapse to photoevaporating and debris discs. The early results of Herschel programmes to study disc properties, and the distribution and evolution of the dust/gas ratio were described (by W. Dent and G. Meeus), emphasising the need for improved evolutionary models and access to high-resolution images (as presented by L. Testi). Some objects like TCha (talks by N. Evans and N. Huelamo) are exciting targets to further constrain planet formation models as they are a clear example of how massive planets create gaps within the disc, impacting the evolution of the disc/gas material as well as the formation of other planetary embryos within the same system. The signature of forsterite at 69 μm turns out to be another powerful tracer of gaps in discs, and hence a tracer of planet formation history.

Competing processes of accretion were described (talk by H. Schlichting) throughout their evolution from small-scale bodies to planetesimals and planets. Runaway growth explains well the current mass and distribution within the Kuiper Belt of the Solar System, as well as the measured mass ratio for Kuiper-Belt binaries. The rest of the first afternoon was used to discuss: the crucial role of multi-wavelength observations of discs; and the need for higher spatial resolution to improve the current models of disc evolution and planetary formation (presentation by S. Wolf).

The second and third days were dedicated to models and observations of exoplanetary systems. It contained an interesting series of presentations on how early planetary dynamics (e.g., through planet resonances and inclined orbits) is able to shape the final distribution (in distance, and mass) of exoplanets seen today in mature systems (talks by C. Terquem, Y. Alibert, and A. Morbidelli). Interestingly, planets accessible to direct imaging are still hard to find. This is a consistent result of all ongoing major adaptive optics (AO) surveys, even after the tremendous progress made over the past few years in lowering the detection limits via improved observing techniques (as exemplified by presentations by B. Biller, R. Galicher, E. Nielsen, M. Bonavita and J. Rameau).

Precision radial velocity surveys in combination with transit observing campaigns remain the main sources for harvesting the population of inner planets efficiently, allowing derivation of robust physical and statistical properties (talks by D. Queloz and M. Gillon). The β Pic system is a showcase of how ESO's top-class instrumentation has led to the characterisation of disc morphology and the first image of the giant planet embedded within it (presentation by

A.-M. Lagrange). Early (and already abundant) results of the TRAPPIST experiment were provided (by E. Jehin), both on the study of comets (the most primordial objects in the Solar System) and in the search and characterisation, via transits, of exoplanets. The role of water in planetary formation was also presented (talk by D. Jewitt), not only regarding its ability to develop life, but also from the perspective of what we can learn from the study of comets, and other pristine objects like Trans-Neptunian Objects, on the early thermo-chemical processes undergone since the formation of the Solar System.

The last day of the meeting was first dedicated to astrobiology, and how the study of Earthshine can provide a benchmark when searching for signatures of life elsewhere in the Universe (presentation by E. Palle and M. Sterzik). The scientific promise of future planet-finding instruments soon to be installed on large ground-based telescopes is considerable, but the technological challenges still significant (as presented by D. Mouillet). The ground-based effort will be complemented by space missions like EchO and Plato to push even further the limits of our understanding on how planets form, why they are so diverse in size, orbit and composition, and ultimately what fraction of planets harbouring life could be detected from their atmospheric signatures.

Prospects

The five-year period observed between the two first editions of this meeting appears to be an adequate frequency to keep the community up to date on the latest developments made in the discovery of exoplanetary systems and our understanding of their extraordinary diversity (with respect to their dynamical aspects, the nature of their bodies and the mechanisms involved in their formation).

In the same way that this second edition saw a surge in results presented from transit observations and very encouraging prospects from a future astrobiological characterisation of exoplanets, we can expect the next and third edition to contain an increased number of contributions coming from ALMA and the first extreme-AO planet finders (e.g., SPHERE). These future facilities, added to the continuous improvements made by radial velocity and other techniques, will no doubt dramatically shake up our vision and understanding of the formation of exoplanetary systems, their diversity and suitability to develop extraterrestrial life, while contributing to a deeper understanding of the particular place held by the Solar System.

High Contrast Imaging and Spectroscopy Workshop (HConIS)

Immediately following the Observing Planetary Systems II conference, this one-day workshop focused on high contrast imaging and spectroscopy techniques. ESO experts Julien Girard and Dimitri Mawet moderated no less than 15 talks, which covered many aspects of this exciting field. The morning session started with a science-oriented talk about the spectral properties of β Pictoris b (by M. Bonnefoy), followed by back-to-back presentations on the development status and schedule of planet-finders: the ESO SPHERE instrument (by D. Mouillet) and the Gemini Planet Imager (GPI), by M. Hartung. Additional contributions followed on novel data-processing concepts making extensive use of focal plane wavefront sensing in order to suppress quasi-static aberrations (talks by R. Galicher and M. Kenworthy). Coronagraphic techniques for ground and space missions were also reviewed extensively (by D. Mawet, F.-Y. Bourget and A. Boccaletti), as well as new spectroscopic follow-up applications (in talks by A. Vigan and J. Girard). Finally, several presentations were given on interferometric techniques based on diluted facilities (by J.-P. Berge and D. Rouan) or Fizeau-like (from P. Tuthill and F. Patru).

The very friendly and informal atmosphere of this workshop favoured constructive discussions among the 70 attendees (most of whom were also OPSII participants). We thank the ESO Office for Science, who provided the lunch in the park and all the coffee and cheese breaks! This first edition of HConIS, extended further the last session of the OPSII meeting and was in a way complementary to the "In the Spirit of Lyot" conferences held in 2007 and 2010, bringing together high-contrast observers and instrumentation specialists. All presentations and video streaming of the presentations can be found online[2].

Acknowledgements

We would like to thank ESO for allocating the financial support for this workshop, and all the people who made this venue so pleasant, in particular Maria-Eugenia Gomez, our librarian who acted as workshop secretary, Paulina Jiron from the Office for Science, and the ESO-Chile administration for the excellent logistic support received.

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Links

[1] OPSII conference web site: http://www.eso.org/sci/meetings/2012/OPSII.html
[2] HConIS workshop webpage: http://www.sc.eso.org/~jgirard/hconis

The ALMA Regional Centre in the Czech Republic and the ALMA Winter School in Prague

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The scope of the work of the Atacama Large Millimeter/submillimeter Array (ALMA) Regional Centre in the Czech Republic is briefly outlined and a short report is presented on the recent Winter School held in Prague.

The Atacama Large Millimeter/submillimeter Array (ALMA) is under construction on the Chajnantor plateau in Chile and will consist of up to 66 antennas to observe in the frequency range from 30 GHz to 950 GHz, with very high sensitivity and angular resolution. ALMA is an international collaboration between Europe, East Asia, North America and Chile. Astronomers from the different participating countries will interact with ALMA via ALMA Regional Centres (ARCs). In Europe, the main Regional Centre is located at ESO Garching and seven ARC nodes are spread over the continent.

The Czech ARC node should provide regional support to applicants from countries of the Central and Eastern European region, e.g., from Poland, Slovakia, Hungary, etc., that are not yet ESO members, and to Czech ALMA users. In particular it will provide the following services:
1) scientific and technical support to ALMA users in the fields that are not yet covered, or are covered only partially, by other existing European ARC nodes, and especially: (i) solar and (extra)galactic astrophysics, (ii) laboratory measurements of molecular spectral lines;
2) observation planning and data quality checking;
3) data storage and processing and data reduction using CASA (Common Astronomy Software Applications package, which is used to process both interferometric and single-dish data from ALMA).

P. Suchan

Figure 1. The participants of the ALMA Winter School in Prague in front of the entrance of the Astronomical Institute.

Our node is to be formed as a consortium of the Astronomical Institute, Academy of Sciences of the Czech Republic (ASCR) and the Institute of Chemical Technology in Prague, with further cooperation with the Charles University in Prague and the Masaryk University in Brno.

ALMA and solar research

In Europe the Czech ARC node is the only one devoted to solar physics. For solar research it is important to know the limitations of ALMA and the requirements for solar observations:
1. The field of view (FoV) of ALMA is rather small (21 arcseconds × λ_{mm}). For a detailed study of the "quiet" chromosphere for example, this FoV is sufficient. However, for phenomena in which global effects are important (e.g., in solar flares), it would be desirable to increase the FoV, e.g., by an observing technique called "on-the-fly" (OTF).
2. Compared with other astrophysical radio sources (e.g., molecular clouds, galaxies) the solar radio flux is very strong and the ALMA detectors are very sensitive. Therefore, for solar observations an appropriate attenuation of the signal is necessary.
3. To reduce the solar electromagnetic flux reflected to the antenna focus, it will be very useful to scatter the visible/infrared part of the spectrum by milling the surface of the antennas.
4. ALMA can directly measure temperature maps in the chromosphere. For this purpose a precise calibration technique is necessary.
5. For transient phenomena such as solar flares, a flexible communication protocol between scientists and observing staff regarding observing targets is necessary. In proposals for flare observations, it would be very difficult to specify the observing targets in advance.

Since the observing capabilities of ALMA are so advanced, involvement of the solar community is highly desirable. To encourage potential observers, the new Czech ARC node is being built under the supervision of ESO. Although we are fully aware of the problems that are specific to solar observations (small field of view, strong radio flux, calibration and so on), we hope that advanced OTF mapping and calibration techniques will overcome these difficulties. ALMA has the potential for new insights and new discoveries, especially in a mostly unexplored wavelength range, making it highly desirable for solar research. More information about solar research with ALMA can be found in Karlický et al. (2011).

ALMA Winter School in Prague

The purpose of this two-day Winter School, which took place at the Astronomical Institute of the Academy of Sciences in Prague, was to prepare the European astronomical community for ALMA Early Science operations in Cycle 1, which is expected to start in January 2013.

The first day was devoted to theoretical issues related to ALMA. At the beginning the ALMA project was presented with particular focus on the role of the Czech ARC node. During the day we had lectures about radio interferometry, molecular spectroscopy, CASA and the AOT (ALMA Observing Tool). The AOT is the tool used for the preparation and submission of proposals for ALMA. We finished the day with practical exercises using the AOT.

The second day was mainly devoted to practical exercises with the CASA package. To learn the CASA package we used science verification data for the M100 spiral galaxy. Also examples of proposals were presented and the submission process was explained. In addition a lecture on solar research with ALMA was given.

Around 20 people from Croatia, the Czech Republic, the Netherlands, Poland and the United Kingdom participated in our ALMA Winter School. Invited speakers at the School were Dirk Petry and Andy Biggs, both from ESO.

Acknowledgements

We would like to express many thanks to Paola Andreani, Dirk Petry and Andy Biggs (from the ALMA Regional Centre in Garching) for their help with our ALMA Winter School.

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Volunteer Outreach Activities at ESO Chile

The ESO-Chile Outreach Volunteer Team[1 *]

[1] ESO

ESO staff in Chile are often asked to disseminate astronomical knowledge to schools and to the general public. A significant number of volunteers are now involved in these activities and the most recent projects in low-income schools and neighbourhoods are described and possible perspectives discussed.

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Introduction

The Chilean public has been aware of Chile's extraordinary dark-sky treasures for a long time. Discoveries and upcoming new telescope projects are often reported in the press and interest in the achievements of astronomers and engineers is steadily growing. But astronomy is more than scientific publications and their accompanying press releases: it is a wonderful educational tool at each stage in life. It can often offer uncharted paths to the discovery of essential concepts in physics and mathematics, but also more generally to the development of scientific reasoning based on observation and experimentation.

ESO staff in Chile are often approached to spread astronomical knowledge to schools and the general public. In recent years some of these initiatives have grown and have involved a significant number of volunteers. We report on the most recent developments in low-income schools and neighbourhoods in order to "democratise the sky", and also discuss various aspects of these activities.

Estrellas en las Escuelas

The study of astronomy and the Universe is part of any school programme and appears at different stages in a pupil's career. Several national and local initiatives in Chile have been set up to support both pupils and teachers in the development of teaching activities in science. One of the most renowned programmes, called *Enseñanza de las Ciencias Basada en la Indagación* (ECBI), is the result of the joint efforts of the Chilean Academy of Science, the Department of Medicine of the Universidad de Chile and the Ministry of Education (with financial support from the European Union). Its primary goal is to reinforce children's capability to establish scientific reasoning based on experiments. The ECBI programme, when funding permits, already helps active elementary school teachers in the teaching of science. Since astronomy is not always a priority, volunteers from ESO have been approached to develop pedagogical activities with teachers and pupils, under the supervision of the ECBI executive director (P. Reyes) and with the collaboration of the

Figure 1. Photographs of schoolchildren and parents participating in the *Viaje a las Estrellas* activities: queuing to look through the telescope (upper left); learning about the planets (upper right); making models of the planets (lower left); telescope viewing of the night sky (lower right).

Municipalidad de Lo Prado (represented by S. Huiaquiñir and A. Herrera).

The *Estrellas en las Escuelas* activities all began with a series of lectures for 12 teachers from different schools. The lectures were designed to include practical activities in the classroom and concluded with a visit to the Universidad Metropolitana de Ciencias de la Educatión (UMCE) telescope, thanks to the help of Prof. L. Barrera. Following some excellent contacts with some school directors, two *Noche de las Estrellas* (observing nights) were organised in two schools — Escuela Poeta Pablo Neruda and Escuela Poeta Vicente Huidobro. The ESO team, with the support of the Office for Science and ePOD, presented several stands, including a magic performance, rocket and satellite building, an inflatable planetarium, Solar System paintings, Moon–Earth exploration and telescope observations (see Figure 1). Students from the Pontificia Universidad de Chile and representatives of the amateur group *Telescoperos* joined us and brought telescopes and a planetarium. These events attracted not only pupils and their parents from the two schools, but also from neighbouring schools which was one of the main goals of the directors. It was particularly moving to see people of all ages lining up in front of the telescopes to discover the Moon, Jupiter and Venus. All parties concluded that these events should be expanded to more schools and the representatives of the municipal council assured us they would provide financial support to develop them as a pedagogical tool.

Viaje a las Estrellas

A group of enthusiastic Vitacura fellows, students, and staff have been bringing the world of astronomy to social housing communities in Renca in a programme named *Viaje a las Estrellas* (literally, an effort to democratise the sky). These activities have been coordinated by Fundación Gestión Vivienda, a private non-profit corporation dedicated to social housing project development. Their projects include not only the building of housing, neighborhood clubs and libraries, but also provide community coordination to promote responsibility for the improvement of the social and cultural life. Our group of volunteers has performed several demonstrations using the stars and the Universe as the main subjects (see the upper image on the Astronomical News section page, p. 38). These activities range from telescope viewing of the planets and the Moon to magic shows, ALMA antenna model building, pavement art, rocket launching, etc. The volunteers for this project were basically the same as for the *Estrellas en las Escuelas* project, and this allowed us to get a better feeling for which activities are appropriate for which age groups. In particular, the age range of the children targeted in this programme is quite large, from approximately 4 to 15 years, together with many interested parents. This activity was supported by one of the community organisations, Biblioteca Mujer de Esfuerzo.

The programmes are complementary: *Estrellas en las Escuelas* targets the pupils and teachers (with the teachers providing a huge capacity to pass on information to others) in an academic environment, while *Viaje a las Estrellas* focuses on the families, bringing science to the communities as another route to the education of children.

Challenges and perspectives

The different activities have been a tremendous success and the ESO-Chile volunteers will no doubt be called upon once again in 2012. Preparations for these activities have also been a very nice way to get to know our colleagues in a different context. The focus will now be to develop our palette of activities and to adapt them to the different audiences we encounter. ESO has already agreed to fund the purchase of one telescope, which will be more than welcome. Working together with higher authorities, whether local (schools, associations) or national (the education ministry) has proved to be a powerful way to make sure we meet the needs of the different communities. The challenge is now to keep up the momentum while continuing with our own research and operational tasks and to encourage new volunteers to get involved in order to assure the longevity of the effort.

The team

The ESO-Chile outreach volunteer team consists of all those listed above and is growing fast. In addition, we have been accompanied during these activities by colleagues from other institutes in Chile and abroad: D. Carrasco, C. Infante, C. Sifón at Pontificia Universidad Católica de Chile; C. Tappert at Universidad de Valparaiso; R. Zepeda, a member of the *Telescoperos* group that provided the telescopes; Prof. L. Barrera at Universidad Metropolitana de Ciencias de la Educación; N. Huelamo (Centro de Astrobiologica [CAB], Madrid); and A. Galenne (Observatoire de Meudon, Paris).

Acknowledgements

We warmly thank the ESO-Chile Office for Science (in particular the great support from Michael West, Paulina Jiron and Veronica Hormazabal), ePOD-Chile (particularly Valentina Rodriguez), Gonzalo Argandoña, Philippe Gitton, the ECBI team led by P. Reyes, the Municipalidad de Lo Prado and Fundación Gestión Vivienda.

Inspiring Young Brazilian Astronomers at the La Silla Observatory

Jorge Meléndez[1]

[1] Astronomy Department, Instituto de Astronomia, Geofísica e Ciências Atmosféricas, Universidade de São Paulo, Brazil

Eight astronomy students from the University of São Paulo in Brazil had the invaluable experience of visiting the La Silla Observatory from 27–30 April 2012. This visit proved an excellent opportunity to develop stronger links between the new generation of Brazilian astronomers and ESO.

The group of astronomy graduate students was led by the author as part of the activities for the graduate course in Observational Astrophysics at the Universidade de São Paulo (USP). I started teaching this course in March 2012 at the Astronomy Department of the Institute of Astronomy, Geophysics and Atmospheric Sciences (IAG) at USP, and thought it would be important for the students to visit a world-class facility such as La Silla. Since I had been allocated time in late April 2012 for my ESO Large Programme for a search for planets around solar twin stars, I asked the Director of the Paranal and La Silla Observatories, Andreas Kaufer, if the IAG/USP students could join my observing run and get to know the telescopes at La Silla. I was delighted when this exceptional visit was approved.

We were warmly welcomed at La Silla. All the staff and most of the astronomers observing there were very helpful with all aspects of our trip. We visited the ESO 3.6-metre, the 3.58-metre New Technology Telescope (NTT) and MPG/ESO 2.2-metre telescopes and were given detailed explanations of the telescopes and their related instrumentation. Getting close to the HARPS spectrograph, the very precise instrument for planet hunting that was being employed for the Large Programme, was one of the highlights of the trip. The observations for my Large Programme were being undertaken by Luca Casagrande, a team member of the collaboration. He explained to the students how the observations are performed. Thanks to the HARPS pipeline that reduces the spectra in a few seconds, the students could discover for themselves the most promising candidates for hosting planets around our sample of solar twins.

The students enjoyed all aspects of our visit, experiencing for themselves the life of observational astronomers. During the first half of the visit the weather was not very friendly, but during the second half the skies cleared. Although it was a privilege to observe with large telescopes, it was also wonderful to see, with the naked eye, the beauty of the night sky, the magnificent Milky Way and its dark clouds, our neighbouring galaxy, the Large Magellanic Cloud, and some stellar clusters with the help of binoculars. During the day it was a magical experience to witness the vivid colours of the sky and their contrast with the white domes and the desert mountains, especially at sunset. The contact with other astronomers and students working at La Silla has surely widened the astronomical vision of the student visitors. The visit to La Silla ended with two other memorable experiences. We hiked around the La Silla site in search of petroglyphs. This proved to be a challenging but exciting experience, and we successfully found the ancient petroglyphs. Finally, during our last night at La Silla, the students were awakened by a 5.5 magnitude earthquake with an epicentre close to the city of La Serena.

Taking advantage of this rare opportunity to visit La Silla, the group also made a one-day trip to other nearby observatories while they were based in La Serena. The visit to La Silla was a fantastic and unforgettable experience for the students. They have learned a lot, not only about telescopes and instruments, but also about themselves, and that dreams can come true. This trip will surely inspire them for many years to come.

Acknowledgements

We would like to thank: Peter Sinclaire, who showed us around the different telescopes and their instrumentation; Luis Wendegass for his detailed explanations about the petroglyph trail; Luca Casagrande, who was observing with HARPS at the 3.6-metre; as well as the other astronomers and ESO staff for their kind help. We warmly thank Andreas Kaufer for promptly authorising the visit to La Silla and for providing free local transportation and accommodation. Finally, we are most grateful for the prompt financial support provided by the Vice Dean of Graduate studies at USP (Prof. Dr. Vahan Agopyan) and the Director of IAG/USP (Prof. Dr. Tércio Ambrizzi).

Fernando de Sousa Mello

Figure 1. The visiting students in front of the 3.58-metre NTT telescope. From left to right: student Ana Molina, Prof. Jorge Meléndez, students Patricia Martins de Novais, Miguel Paez, Nathália Cibirka, Fernando de Sousa Mello, Viviane Salvador Alves, Marcelo Tucci Maia and Andressa Silva Ferreira.

Ana Molina

Figure 2. The Brazilian graduate students pose in front of the, now de-commissioned, 15-metre SEST submillimetre telescope, with Prof. Jorge Meléndez on the left.

Retirement of Klaus Banse

Pascal Ballester[1]
Michèle Péron[1]

[1] ESO

On 30 April 2012, after 34 years of service, Klaus Banse left ESO to enjoy a well-deserved retirement. Klaus joined ESO in Geneva in December 1977, when ESO had only about 80 employees. He was initially recruited to develop "algorithms for the astronomers", but really started his career at ESO by developing control software for the ESO measuring machines (Crane, 1979).

In 1979, ESO began the planning and development of a new image processing system to fulfill increasing data analysis and image processing needs, and Klaus became the main architect of ESO-MIDAS (originally the Munich Image Display Analysis System), first released in 1982 (Banse et al., 1983). The MIDAS Memo column in *The Messenger* documented progress during the first decade of development, during which time Klaus and the MIDAS team adapted the system from Fortran 77 to the C programming language, and from VAX/VMS to a variety of Unix platforms, and later to Linux-based operating systems. By the end of 1992, MIDAS had been distributed to 160 astronomical institutes in 37 countries, and Klaus was in permanent contact with its many users, while consolidating the system standard interfaces and the core display functionalities. The system remained the foundation of data reduction processes for the VLT first light in 1998 and for the first instruments of the VLT. A new architecture for the VLT pipelines was developed in 2000, relying fully on C-based data reduction chains, and in 2004, Klaus became the team leader of the ESO Common Pipeline Library remaining in this position until his retirement. Over his 34-year career at ESO, Klaus was a key resource in the field of astronomical data analysis, as techniques in astronomy evolved from scanning photographic plates to handling hundreds of gigabytes of data on multithreaded architectures.

A very well attended leaving party was held at ESO Headquarters on 3 May 2012 attended by the ESO Director General Tim de Zeeuw (see Figure 1), many colleagues and members of the ESO swimming club, of which Klaus was a founding member. We were honoured to present Klaus with a book on the historical vistas of information handling in astronomy, signed by colleagues from Europe, the USA and Canada, in recognition of his contributions to the international development of astronomical data reduction systems (see Figure 2). We will not only miss Klaus's technical skills but also his congenial personality and his dedication. We wish Klaus all the best for his retirement.

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Figure 1. The ESO Director General Tim de Zeeuw offering Klaus Banse his hand in appreciation of Klaus's many years of service to ESO.

Figure 2. Klaus Banse enjoying the good wishes of colleagues in the book presented to him at his retirement party.

Staff at ESO

Alistair McPherson

As one of four boys brought up in Scotland, I was always the one with a screwdriver in my hand looking to "fix" something. It seemed inevitable that my love of things mechanical would lead me into engineering and I did this by joining the army, attending Sandhurst and completing a degree in aeromechanical engineering. I then commanded a number of units in the UK, Hong Kong and Germany — both helicopter support units and mechanical workshops — leading my soldiers on operations in Northern Ireland, the Gulf War and Bosnia.

As my career progressed I became more involved in procurement programmes, initially as a member of a French, German and UK project based in Paris and my last job in the army was as the programme manager for the Lynx helicopter fleet. In this job, I was responsible for all engineering, maintenance and airworthiness issues, as well as the procurement of a replacement fleet of some 100 helicopters.

After my job with Lynx, which I really enjoyed for the variety of engineering, leadership and politics, I made the decision to leave the army and seek a complete change of direction. Whilst looking for another career opportunity, I saw an advertisement for the job of VLT Infrared Survey Telescope (VISTA) project manager at the observatory in Edinburgh. As I read the advert I realised that I had the qualities and experience that they were looking for and applied. The rest is history.

I thoroughly enjoyed this appointment and I learned a great deal about telescopes and how the astronomy community worked. This also gave me an introduction into ESO and, of course, Paranal. So, when I was no longer required on VISTA and there was an opportunity on the European Extremely Large Telescope (E-ELT), I was pleased to come to Garching and join the team at the latter part of phase B.

I have had a varied, interesting and challenging career both in the army and in the world of observatories. Although I still barely scratch the surface of the astronomy side of the work, I am fascinated and motivated by being at the frontline of some pioneering engineering within the E-ELT project. I continue to enjoy the challenges that we face and, according to my wife, I apparently enjoy working with younger intelligent people. Maybe that keeps me young?

Many challenges lie ahead of us as we move towards E-ELT construction, but as an organisation we can work together to achieve the completion of this vision. I look forward to leading the team which will deliver the reality of the E-ELT.

Fellows at ESO

Maja Vučković

I have been living in Santiago de Chile and working as an ESO Fellow for two years. Of that time I have spent about six months in the Atacama Desert at the Paranal Observatory as a VLT support astronomer. While on Paranal, I am also a Fellow responsible for X-shooter on Unit Telescope 2 (UT2), the unique echelle spectrograph that can obtain a simultaneous spectrum from ultraviolet to near-infrared wavelengths (0.3–2.5 μm). This simultaneous wavelength coverage is a major advantage for photometrically and spectroscopically variable objects as it allows the various contributors to a spectrum to be disentangled, which is one of the hottest topics of my research at present. While in Santiago, apart from enjoying a "normal life", I am trying to understand what the hot subdwarf stars do.

I was one of those children who dreamed of becoming an astronomer when they were growing up. My grandma frequently took me from the roof of our vacation house in the mountains as I would often fall asleep there while watching the stars. I was mesmerised by the night sky, while all her other grandchildren would safely be sleeping in their beds surrounded by their favourite toys. Even though it seems that I have known what I wanted to do since my childhood, the road to where I am now was anything but straightforward, and it took many years.

Thirsty for knowledge during my undergraduate studies of astronomy at the University of Belgrade, my home town, I was totally taken by the observational astronomy course. The undergraduate studies at my university at the time were based mostly on following courses, passing written and oral exams and at the time I didn't have a clue what research was all about. After the oral exam I went to my professor, Istvan Vince, and told him (more like complained) that I was bored of just studying, solving problems and taking exams, and that I would like to *do* something! He gave me some stellar spectra to reduce. Soon after I found myself at an international conference eagerly presenting a poster with my work and discussing the temperature sensitivity of Mn lines over dinner ... Now I know — that is what research is about.

However, my undergraduate studies were interrupted by the difficult situation in my country (Serbia). Torn by civil wars, decimated by sanctions, hyper-inflation and finally NATO bombing, life took a "parallel path" and I felt the need to contribute to humanity while living through a humanitarian catastrophe. I fully engaged in activism and spent several years as a volunteer in a non-governmental organisation (NGO) taking care of and helping refugees, mainly adolescent girls who had been traumatised by the war and the bombing. In fact my first proposal was not in astronomy at all! It was for a European Union grant to foster the livelihood of girls who had suffered violence, by founding centres in several towns of Serbia which would work to raise awareness, educate society, and improve integration, while also serving as shelters. When the situation in the country stabilised somewhat, I decided it was time for me to continue with my life. I asked myself yet again what it was that I wanted to do, and my mind took me back to the very same roof of my grandma's house ... it was clear that I wanted to continue studying astrophysics!

Asteroseismology, the relatively young branch of astronomy devoted to the study of internal stellar structure on the basis of stellar vibrations, caught my attention. While reading more I found out about the Whole Earth Telescope (WET), a worldwide network of cooperating astronomical observatories linked together to obtain uninterrupted time-series measurements of variable stars. The idea sounded profound to me: that a group of

Maja Vučković

scientists would use the Earth's rotation — the biggest enemy of any asteroseismologist — as a tool to obtain continuous 24-hour light curves in order to derive the fundamental parameters of stars. The headquarters were at Iowa State University (ISU) and I contacted Steve Kawaler, the professor at the Department of Physics and Astronomy and director at the time. He told me what I should do in order to enroll for graduate studies at ISU. Several months later I had my farewell party.

I arrived in Ames, Iowa in August 2001 with my life packed in two suitcases, ready to start my graduate studies in astrophysics. During my first day at the ISU campus I met Steve, who opened the door of science for me. He is one of those professors who can transmit his thrill for science, and stamina for research, to the student, while letting you struggle, but never fall. After a few months I was already observing at the 2.1-metre telescope at the Kitt Peak National Observatory as one of the observing sites for my first WET run. The more I learned about asteroseismology the more I was enchanted by it — the fact that we can "look" into the interiors of stars by studying their pulsations is still what keeps me going.

My strong observing interest resulted in my adopting the small University Observatory, equipped with a Fick 0.6-metre telescope, for high-speed photometric monitoring of rapidly pulsating subdwarf B (sdB) stars. As soon as the skies had cleared, even if only very late in the night, I'd head off to the Fick Telescope; my friends still joke about the strong correlation between the clear skies and my disappearance from every party!

The research in asteroseismology of sdB stars, during my Masters studies at Iowa, mainly consisted of gathering, analysing and interpreting photometric data in white light. Through this study it became clear to me that the ultimate goal of any asteroseismological study can only be achieved with accurate pulsation frequencies and an unambiguous identification of the oscillation modes. While I was writing up my thesis on PG0014+067, an intriguing pulsating sdB star, Conny Aerts, the professor at the Institute of Astronomy at the University of Leuven, and the world's leading expert on mode identification, came to our department to work with Steve. We discussed my research over a few lunches, she saw my devotion to observing and, in between the lines, gauged my nostalgia for the cobbled streets of European towns. Soon after she returned to Belgium, I received an offer to continue my research on sdB stars with her in Leuven. The University of Leuven had so much to offer: it is one of the oldest universities, is in the middle of Europe, they make one of the best dark chocolates in the world, not to mention all the varieties of beer, AND I could continue studying pulsating sdB stars!!!

I arrived in Leuven in August 2005, with my life packed in two suitcases ready to start my PhD. The Institute of Astronomy (IvS) is a great place to work, the friendliness and the enthusiasm of all the people there quickly made it into my new home. I still have that nostalgic look when I talk about it. Apart from offering me a comfortable research nest, it allowed me to fulfill my thirst for observing. The IvS has a 1.2-metre Mercator Telescope at one of the most beautiful European observing sites on La Palma in the Canary Islands and I spent at least two months per year observing there. Also, observing time is shared with the twin 1.2-metre Euler Telescope at La Silla. I will never forget my first observing run at the Euler Telescope — it was my first encounter with the southern skies and with the desert. I can't really tell which of the two made the stronger impact on me; but the feeling of peacefulness and fulfillment I felt while observing there is the one I come back to whenever the inevitable question of a (somewhat lost) nomadic, modern-day astronomer "is this all worth it?" comes to my mind.

While studying the origin and evolution of hot sdB stars during my PhD, my research interest naturally expanded into studying close binary stellar evolution, in particular post common envelope ejection systems. Once the PhD was defended, it was time to find a "real" job; I guess for everyone this is a scary moment as all of a sudden you have to get out of your PhD "bubble" and begin your way through life. In the heat of my PhD party a good friend, an ESO Fellow in Chile at the time, started to convince me to apply for the very same job. One of his strongest arguments was "you would love it". He was right!

In April 2010 I arrived in Santiago, this time with my life packed into somewhat more than two suitcases. Again, starting another four-year life cycle, I moved to a different continent, ready for my ESO Fellowship and the new challenges of life.

During my last *turno* at Paranal, I was sitting at the back of UT1 watching the sunset, something I usually do every day while observing there. It is also the point where the day and the night crew meet. But that day I was alone and my thoughts took me far far away, back to one of my high school days. The surprised face of my high school professor appeared in my mind when I had told him that I would study astronomy. He wanted to challenge my choice and simply asked "But why?", as he was sure I would study philosophy. "Because philosophy I know I can do, but astronomy — I am not sure if I am able to?!" I answered.

The sun has set into the Pacific without a green flash yet again, and I hurry to start the observing night. In some ways it felt as if I had just woken up after almost 20 years, in the middle of the desert, behind one of the biggest telescopes, with a clear answer to my childhood question.

Beware of your dreams, they may come true!

Giacomo Beccari

The oldest memory I have of the stars is of Ursa Major. When I was a child, during the summer holidays, I used to sit on the strong shoulders of my father and spend time with him wandering along the beach at night watching the stars. The constellation of Ursa Major was the only one that my father ever knew, but he used to show it to me every night, telling me fantastic stories.… That constellation appeared to my eyes as the most beautiful thing in the sky … and still does.

I was born in Verona some years ago. I like to see myself moving around with a funny Veronese flavour permeating my personality: that strange mixture of romanticism (Romeo and Juliet as it were), passion and fanaticism (go to a soccer stadium in Verona on Sunday and you will understand), and South Tirolean rationalism. I studied astronomy at the University of Bologna followed by a PhD in astronomy and informatics at the Astronomical Observatory of Teramo. I am proud of seeing myself as a disciple of the glorious Italian school of stellar astrophysics. Even if I do not know much about the constellations, astronomy is for me, as for all the astronomers I have met so far, a passion. To do a colour–magnitude diagram (affectionately called a CMD) can be therapeutic. As an example, I remember in 2010, when the Italian team was badly eliminated from the Football World Cup, I was so depressed that I went to my office and downloaded some images of 47Tuc from the Hubble Space Telescope (HST) archive. I analysed the data and it was only after I saw the beautiful cluster's main sequence in the CMD that I started to breathe again!

After a one year post-doc, I left Italy for a fellowship at ESA/ESTEC, in the Netherlands. It was my first experience of living abroad. I left Italy with a suitcase full of pizza, spaghetti, mamma, Valpolicella, *"cornetto e cappuccino, grazie"*, globular clusters and blue stragglers. Two years later I left ESTEC with a suitcase containing much less spaghetti, but lots of great experiences, memories of nice people,

Giacomo Beccari

new scientific projects, new ideas, a few kroketten, and knowing that science is much more than sitting at the desk in the office analysing data.

I came to ESO as a fellow with the desire to discover how a big astronomical observatory works, what's behind it. In Garching I found a community of excellent scientists and an enthusiastic environment that triggered new collaborations and ideas. I asked to be assigned for my functional duty as support astronomer at the Very Large Telescope (VLT) in Paranal. This experience has been even more exciting than I thought. I will always remember the first time I walked into the Control Room … UT1, UT2, UT3, UT4… there is no cause for alarm … VST, VISTA, VLTI … *mamma mia!* Then walking back … interferometry, wide-field multi-band surveys, high resolution adaptive optics imaging, multifibre and single object spectroscopy at almost all wavelengths … on top of hundreds of "there is no cause for alarm". How much science is done in this place in one night? It's magic! But then you walk to the platform and there is the secret.

I am sure that every single person who has had the chance to see this place has been impressed. You are there, the Sun is going down, the sky turns red, and you see these machines, as if from a Kubrick movie or a book by Philip K. Dick, opening their big eyes to a beautiful sky. This is the secret. Years ago a group of astronomers had a dream … a desire that, maybe, looked much bigger than themselves. Many people gave a piece of their life for that … many of them were enthusiastic … maybe some were not … many of them were nice and funny … maybe some were not … many of them were devoted … and others maybe were not. But the desire became a reality. This is being human … fulfilling a desire that is so big that it flies way above the individual capabilities of those who realise it. Let's be honest: the astronomical community is a funny one … people looking at galaxies at redshift 10 000, waiting for that photon coming every ten days, with the aim of discovering the origin of life … and we do not have any idea of how the Solar System was born. But you are there, the Sun goes down, the stars are coming: there's silence … there is no cause for alarm … it's time to do science.

External Fellows at ESO

In addition to the ESO fellowships, a number of external fellows are hosted at ESO and a profile of one of these fellows is presented.

Yiannis Tsamis

It is customary for these profiles to begin with personal recollections. In honour of this tradition, I submit that my links to ESO can be traced back to the early 1980s when, seated on my grandma's lap at home in Greece, I was watching Carl Sagan on our new colour TV set cruising through the Cosmos on a makeshift starship. "E-ELT's home is only a few microparsecs beyond that yellow dwarf star, some billion ewros into the future", I clearly heard him pronounce. Well, there is an element of truth in it though, as then there were no health warnings, conveniently, about the corruptive power of TV on a child's tender soul. An "E-ELT" was perhaps E.T. misspelled and the "ewro", well that's actually "euro" in Maltese according to Wikipedia. Perhaps the euro (or rather the Greek rendering, ευρώ) will become a standard unit in economochaotics theory come the 22nd century.

My more tangible links with ESO can be traced back to winter 2006 when I came to stay as a visitor for two freezing months to work with Jeremy Walsh on VLT FLAMES data of planetary nebulae. I was at the time a postdoc at University College London and I knew Jeremy from his visit to Meudon during my Gruber Fellowship there in 2004. ESO seemed to me to be definitely different from other academic environments. There was an unlimited supply of free cappuccino to give any high street café a run for its money, an endless list of quality seminars each week, and a formidable array of experts and visitors willing to debate the latest developments in astronomical instrumentation and data analysis. The fact that the place is situated right next to the beer capital of Europe is of course an added bonus: because sometimes astronomy is thirsty work, as was demonstrated in the lively 10 pm discussion sessions at the conference "Mapping Oxygen in the Universe" in Tenerife this May!

At ESO everybody also speaks the language that the papers are written in, which makes it all the easier to blend in no matter where you come from. I had my sights set on Garching since then and applied for an ESO Fellowship, but failed. But failing doesn't matter one bit as long as you succeed in the end, and so we asked Bruno Leibundgut in the spring of 2008 whether ESO would consider me as a candidate for a Marie Curie intra-European (IEF) fellowship. ESO was involved in other FP7 projects, but had not hosted an IEF before. My proposal was some twenty pages long (as these things usually are), and was evaluated and ranked by independent experts along with many others throughout Europe.

Yiannis Tsamis

When the positive results came out (thank you FP7!), I had only just moved to a position at the Instituto de Astrofísica de Andalucía (IAA) in Granada on a Gran Telescopio Canarias (GTC) Consolider grant to work with Pepe Vílchez, and then parenthood followed soon after. Our young family's time in Granada was great and I would have stayed at the IAA, if the chance to move to ESO on a personal grant had not arisen. It was a difficult moment because the IAA is a wonderful place and the Spanish colleagues are truly excellent and had been very welcoming. I delayed the start of the IEF as much as I could and this gave me time to establish lasting links, and to become involved in Spanish-led projects such as the MEGARA integral field spectrograph to be installed on the 10-metre GTC.

For my research I have been making good use of ESO's VLT to study protoplanetary discs (the theme of my Marie Curie fellowship), planetary nebulae and blue compact galaxies in the nearby Universe. I investigate the chemical composition of these sources through their emission lines, observed by integral field spectrographs such as FLAMES or VIMOS. It all seems so far removed from the reach of the 4.5-inch telescope I still keep back home and with which I used to split ε Lyrae or observe the scars of Shoemaker-Levy 9 on Jupiter in 1994 from downtown Thessaloniki. Munich is really an excellent place to live in and work. Holding my fellowship at ESO has given me leave to spend considerable time away, suiting the needs of our family (thanks to the flexible IEF rules), a generous travel allowance (NASA Ames near San Francisco and Morelia in Mexico are next in line), all the while benefiting from the remarkably stimulating environment. The people who work here are lucky and I guess they know it; they should cherish it in these testing times. Becoming involved with ESO has been a truly positive experience. Χίλια ευχαριστώ/*mille grazie* to Alessandro and Silvia for putting up with their personal astronomer. Thanks and all the best, to all ESO staff too.

Announcement of the Conference

The First Year of ALMA Science

12–15 December 2012, Hotel Cumbres Patagónicas, Puerto Varas, Chile

The Atacama Large Millimeter/submillimeter Array (ALMA) Early Science operations started at the end of September 2011. Over one hundred high profile science projects have been identified as high priority for execution. The first exciting scientific results from Science Verification datasets and Cycle 0 observations have begun to appear in refereed journals since the beginning of 2012. By the end of this year, the ALMA users community will be in a position to review the first science results produced by this new and unique facility.

The conference will include all the ALMA science topics covered by Early Science observations, from Solar System bodies to objects in our own Galaxy, from the local to the high redshift Universe. While the conference will obviously be focused on ALMA observational results, presentations and discussions on related theoretical implications and predictions will be included, as well as relevant complementary data from other major facilities. The conference will also be an ideal venue to discuss the scientific priorities for the upgrades to the ALMA development plan in the context of the first results from Early Science.

To allow more ALMA users to propose contributions based on results from their Cycle 0 projects, we have selected a late deadline for abstract contributions of 27 October 2012.

Important deadlines:
- Registration opens: 1 June 2012
- Abstract deadline: 27 October 2012
- Contributed talk selection: 16 November 2012

The conference website is:
http://www.almasc.org/2012

More details are also available by email:
asc2012@alma.cl

The conference is co-sponsored by the Joint ALMA Observatory and the ALMA partners (ESO, NAOJ and NRAO), with additional support provided by the EC-FP7 Radionet3 project.


ESO/S. Guisard (www.eso.org/~sguisard)

ESO

European Organisation for Astronomical Research in the Southern Hemisphere

ESO Fellowship Programme 2012/2013

The European Organisation for Astronomical Research in the Southern Hemisphere awards several postdoctoral fellowships each year. The goal of these fellowships is to offer outstanding young scientists the opportunity to further develop their independent research programmes in the exciting scientific environment of one of the world's foremost observatories.

ESO is the foremost intergovernmental astronomy organisation in Europe. Its approximately 110 staff astronomers, 40 Fellows and 50 PhD students conduct frontline research in fields ranging from exoplanets to cosmology, offering one of the most vibrant and stimulating scientific settings anywhere in the world.

Fellowships are available both at ESO's Headquarters in Garching near Munich, Germany, and at ESO's astronomy centre in Santiago, Chile. The ESO Headquarters is situated in one of the most active research centres in Europe, boasting one of the highest concentrations of astronomers. ESO's offices are adjacent to the Max Planck Institutes for Astrophysics and for Extraterrestrial Physics and only a few kilometres away from the Observatory of Munich's Ludwig-Maximilian University. Additionally, ESO participates in the recently formed 'Universe' Excellence Cluster at the Garching Campus, which brings together nearly 200 scientists to explore the origin and structure of the Universe. Consequently, ESO Fellows in Garching have many opportunities to interact and collaborate with astronomers at neighbouring institutes.

In Chile, Fellows have the opportunity to collaborate with the rapidly growing Chilean astronomical community as well as with astronomers at other international observatories located in Chile. The advent of the new ALMA building next to ESO's Santiago offices and the arrival of many astronomers and fellows working on the ALMA project have further enhanced the stimulating scientific environment available to ESO Chile Fellows.

The fellowships in Garching start with an initial contract of one year followed by a two-year extension (3 years total). In addition to developing their independent research programmes, ESO Garching Fellows will be expected to engage in some functional work, for up to 25% of their time, related to e.g. instrumentation, VLTI, ALMA, E-ELT, science operations support either in Garching or at one of ESO's observatories in Chile, or public outreach. This provides the Fellows with the opportunity to get involved with ESO projects or operations, and to gather valuable insights and experience not available in any other setting.

The fellowships in Chile are granted for one year initially, with annual extensions for three additional years (4 years total). During the first three years, the Fellows are assigned to one of the science operations groups of Paranal, ALMA or APEX, where they will contribute to the operations at a level of 80 nights per year.

During the fourth year there is no functional work and several options are provided. The Fellow may be hosted by a Chilean institution where she/he will be eligible to apply for time on all telescopes in Chile via the Chilean observing time competition. Alternatively, the Fellow may choose to spend the fourth year either at ESO's astronomy centre in Santiago, or at the ESO Headquarters in Garching, or at any institute of astronomy/astrophysics in an ESO member state.

The programme is open to applicants who will have achieved their PhD in astronomy, physics or a related discipline before 1 November 2013. Early-career scientists from all astrophysical fields are welcome to apply. Scientific excellence is the prime selection criterion for all fellowships.

We offer an attractive remuneration package including a competitive salary and allowances (tax-free), comprehensive social benefits, and we provide financial support for relocating families.

If you are interested in enhancing your early career through an ESO Fellowship, then please apply by completing the web application form available at http://jobs.eso.org. Reference letters to support your application should be sent to vacancy@eso.org for Garching and vacchile@eso.org for Chile.

Please include the following documents in your application:
- a Curriculum Vitae with a list of publications (ONLY published papers, NOT papers in preparation);
- a proposed research plan (maximum two pages);
- a brief outline of your technical/observational experience (maximum one page);
- three letters of reference from persons familiar with your scientific work.

The closing date for applications is 15 October 2012, and review of the application documents — including the recommendation letters — will begin immediately. Incomplete applications will not be considered.

Candidates will be notified of the results of the selection process between December 2012 and February 2013. Fellowships shall begin in the year in which they are awarded.

For more information about the fellowship programme and ESO's astronomical research activities, please see: http://www.eso.org/sci/activities/FeSt-overview/ESOfellowship.html. For a list of current ESO staff and fellows, and their research interests please see: http://www.eso.org/sci/activities/personnel.html. Details of the Terms of Service for fellows including details of remuneration are available at: http://www.eso.org/public/employment/fellows.html.

For further general information about fellowship applications, please see our Frequently Asked Questions (FAQ): http://www.eso.org/sci/activities/FeSt-overview/ESOfellowship-faq.html. Questions not answered by the above FAQ page can be sent to: Eric Emsellem, Tel. +49 89 320 06-914, e-mail: eemselle@eso.org (for Garching) and Michael West, Tel. +56 2 463 3254, email: mwest@eso.org (for Chile).

Although recruitment preference will be given to nationals of ESO Member States (members are: Austria, Belgium, Brazil, the Czech Republic, Denmark, Finland, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden, Switzerland and United Kingdom) no nationality is in principle excluded.

The post is equally open to suitably qualified female and male applicants.

The ALMA Newsletter

The ALMA Newsletter provides updates on recent developments at the Joint ALMA Observatory, progress at the ALMA site, in-depth articles on instruments and observing techniques together with calibration, profiles of ALMA staff, reports on workshops and special events, a list of future meetings related to ALMA across the globe, and lots more.

The ALMA Newsletter is available for download at http://www.almaobservatory.org/en/outreach/newsletter. It currently appears twice to three times per year and is edited by Lewis Ball (ALMA Deputy Director), Rainer Mauersberger (ALMA Commissioning Scientist) and William Garnier (ALMA Education and Public Outreach Officer).

An email alert of new editions can be obtained by email to: almanewsletter@alma.cl with "subscribe ALMA newsletter" in the body.

More information on ALMA can be found on the ALMA homepage: www.almaobservatory.org

Personnel Movements

Arrivals (1 April–30 June 2012)

Europe	
Andre, Mathias (A)	Web and Advanced Projects Coordinator
Grudzien, Thomas (F)	Software Engineer
Rakich, Andrew (AUS)	Optical Engineer

Chile	
Daire, Amal (RCH)	Administrative Assistant
Mužić, Koraljka (HR)	Fellow
Pauwels, Evert (NL)	Product and Quality Assurance Programme Manager

Departures (1 April–30 June 2012)

Europe	
Banse, Klaus (D)	System Analyst Programmer
Lablanche, Pierre-Yves (F)	Student
Longinotti, Antonio (I)	Senior Software Engineer
Moresmau, Jean-Michel (F)	Electronics Engineer
Panić, Olja (BIH)	Fellow

Chile	
Argandoña, Gonzalo (RCH)	Public Relations Officer
Cortes, Angela (RCH)	Telescope Instruments Operator
Yegorova, Iryna (UA)	Fellow

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Contents

Front cover: An 870 μm image from the Atacama Pathfinder Experiment (APEX) telescope taken with the LArge BOlometer CAmera (LABOCA) superimposed on a visible light image (from the Digitized Sky Survey 2) of the M78 region (Orion B molecular cloud). The APEX image in orange highlights emission from cold dust at around 20 K heated by dense cores of forming stars. M78 (NGC 2068) is the visible reflection nebula at the centre of the image but it has a more heavily embedded star formation region to the south with a chain of dense cores (orientation is north up, east left). At the top of the image is another dusty low to intermediate mass star formation region, NGC 2071. See Release eso1219 for more details. Credit: ESO/APEX (MPIfR/ESO/OSO)/T. Stanke et al./Igor Chekalin/Digitized Sky Survey 2