Abstract Booklet

The 2007 ESO Instrument Calibration Workshop
Garching
January 23rd - 26th, 2007

Introduction

Instrument Calibration at the La Silla Paranal Observatory

G. Marconi[1]

[1] *European Southern Observatory, Casilla 19001, Santiago 19, Chile*

The philosophy and strategy adopted in calibrating the ESO Paranal and La Silla instruments will be briefly reviewed. The status of the art of the Calibration Plan and how the Observatory is handling the instrument calibration procedures will be illustrated.

The Detector Monitoring Project

Paola Amico[2], Pascal Ballester[1], Wolfgang Hummel[1], Gaspare LoCurto[2], Lars Lundin[1], Andrea Modigliani[1], Leonardo Vanzi[2]

[1] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748, Garching bei München, Germany*
[2] *European Southern Observatory, Casilla 19001, Santiago 19, Chile*

Many detectors, optical CCDs and IR arrays, are currently in operation onboard ESO instruments at the La Silla Paranal Observatory. A unified scheme for optical detector characterization has been adopted since several years in La Silla, and it is used by the Science Operation team to monitor the 18 CCDs belonging to the eight instruments operated by ESO at the Observatory. This scheme has been proven successful in insuring a high quality performance of the detectors along the years. In Paranal, detectors performance is checked by the science operation team and QC Garching using instrument-specific data reduction pipelines. In the first part of talk we review the detector characterization and monitoring plans at the two sites of the Observatory, with particular emphasis on commonalities, differences and lessons learnt.

Understanding the performance limits and the calibration requirements of an instrument is fundamental in the operational scheme followed at the observatory and crucially depends on our knowledge of the nature of the detector arrays, their key performance parameters and the way these are defined and measured. Recently two issues were addressed: 1) despite the many commonalities among detectors, different ways to check their performance are in use and 2) the characterization matrix is often incomplete, i.e. not all crucial parameters are measured for all detector systems. The detector monitoring project, arises from the desire to improve the efficiency of the data flow, simplify QC operations and promote standardization of testing procedures among detectors in use at ESO. The goals of the project are: a) designing a detector monitoring plan that covers all the detector systems in use; b) reviewing the current testing procedures and associated pipeline recipes; c) standardizing the test procedures whenever applicable; d) merging the test procedures for IR and Optical detectors when possible and describe the differences in all the other cases; e) consolidate the measurement procedures and the use of data reduction recipe and algorithms. The ultimate goal is that of providing the observatory and the instrument operation teams (IOTs) with a complete and homogeneous detector monitoring scheme. In the second part of the talk, we present the status of the project and the most recent results.

Session 1: Optical Spectro-Imagers

Optical Spectro-Imagers: IOT Overview

Nando Patat[1]

[1] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748 Garching, Germany*

I will review the Calibration Plan for optical spectro-imagers currently offered at ESO (EMMI, SUSI, EFOSC2, FORS1/2 and VIMOS), discussing various aspects related both to the scientific outcome and the instrument/site monitoring. I will also describe ongoing and future calibration projects planned by the Instrument Operations Teams, trying to give an objective view on the limitations of the Calibration Plans currently implemented at ESO for this class of instruments.

The FORS Absolute Photometry (FAP) Project

W. Freudling[1], M. Romaniello[1], F. Patat[1], P. Møller[1], E. Jehin[2], K. O'Brien[2]

[1] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748, Garching bei München, Germany*
[2] *European Southern Observatory, Casilla 19001, Santiago 19, Chile*

Photometric calibration observations are routinely carried out with all ESO imaging cameras in every clear night. The nightly zeropoints derived from these observations are accurate to about 10%. Recently, we have started the *FORS Absolute Photometry Project (FAP)* to investigate, if and how percent-level absolute photometric accuracy be achieved with FORS1, and how such photometric calibration can be offered to observers. We found that there are significant differences between the skyflats and the true photometric response of the instrument which partially dependent on the rotator angle. A second order correction to the sky flat significantly improves the relative photometry within the field. We demonstrate the feasibility of percent level photometry and describe the necessary calibrations necessary to achieve that level of accuracy.

Systematic Effects in Radial Velocity and Chemical Abundance Determination: The Case of FORS2 and FLAMES

M. Monelli[1], G. Bono[2], M. Nonino[3], P. Francois [4], F. Thévenin[5], A. Aparicio[1], R. Buonanno[6], F. Caputo[2], C.E. Corsi[2], M. Dall'Ora[7], C. Gallart[1], L. Pulone[2], V. Ripepi[7], H.A. Smith[8], P.B. Stetson[9], A.R. Walker[10]

[1] *IAC-Instituto de Astrofísica de Canarias, Spain*
[2] *INAF-Osservatorio Astronomico di Roma, Italy*
[3] *INAF-Osservatorio Astronomico di Trieste, Italy*
[4] *Observatoire de Paris, France*
[5] *Observatoire de la Côte Azur, France*
[6] *Dipartimento di Fisica, Universitá di Roma Tor Vergata, Italy*
[7] *INAF-Osservatorio Astronomico di Capodimonte, Italy*
[8] *Dept. of Physics, Michigan State University, USA*
[9] *Dominion Astrophysical Observatory, Herzberg Institute of Astrophysics, Canada*
[10] *Cerro Tololo Inter-American Observatory, Chile*

In the framework of a large program aimed at studying the old and intermediate-age stellar populations of the Carina dSph galaxy, we present two samples of spectroscopic data collected with FORS2 (≈350 stars, proprietary) and FLAMES (≈1,100 stars, archive). We discuss the approach we devised to calibrate the two multi-object spectrographs concerning the systematics affecting both radial velocities and chemical abundance estimates. Particular attention was paid in determining the effect of the mask positioning in the case of FORS2, and the sky lines subtraction in the case of FLAMES.

Session 2: Optical Multi-Object Spectrographs

ESO's Optical Multi-object Spectrographs

Linda Schmidtobreick[1]

[1] *European Southern Observatory, Casilla 19001, Santiago, Chile*

I will introduce the several instruments that ESO operates which are able to perform optical multi-object spectroscopy. Two modes are offered to perform this: In MXU-mode, the slits are physically cut into a mask which is then placed into the instrument for the observation. In MOS-mode, the slits are built by pairs of slitlets which are continuously mounted in the instrument and are individually driven.

From the point of calibration, both modes require the same treatments. I will point out the standard ways of reducing these spectra, the problems that occur, and the way we deal with them.

Furthermore, I plan to give a short introduction on how we perform the quality control, what we derive from these measurements, as well as the shortcomings of the procedures.

Quantitative Spectroscopy with FLAMES

Piercarlo Bonifacio[1,2,3]

[1] *CIFIST Marie Curie Excellence Team*
[2] *Observatoire de Paris, GEPI, F-92195 Meudon Cedex, France*
[3] *INAF - Osservatorio Astronomico di Trieste, Via Tiepolo 11, I-34131 Trieste, Italy*

Starting from the experience gained in these years with FLAMES observations I shall summarize some of the lessons learnt in preparing and conducting observations with this facility. I will also address the potentialities of some observation modes which have so-far been little explored. Finally I will talk about my approach to the analysis of of FLAMES data focusing on aspects which are peculiar to this facility with respect to other spectrographs.

Good News for MOS, MXU & Co.: A New Spectroscopic Pipeline for the FORSes

S. Moehler[1]

[1] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748, Garching bei München, Germany*

Since October 1, 2006, spectroscopic data from the two FORS instruments have been reduced with a new pipeline, which is based on a bottom-up approach. I will discuss first experiences with automatic data reduction using this software, which has signficantly increased the percentage of processed data for both instruments. I will also discuss possible new options for Quality Control.

Calibrating the VIMOS Redshift Survey Data

Marco Scodeggio[1], the VVDS and zCosmos teams

[1] *INAF - IASF Milano, Italy*

The experience obtained with the semi-automatic data reduction for some 30,000 spectra obtained with VIMOS in the MOS configuration as part of the VIMOS VLT Deep Survey (VVDS) and of the zCosmos survey is discussed. The discussion will cover different grisms, posing significantly different challenges for the calibration procedures, different calibration methods, and will be centered mainly on the experience obtained using VIPGI, the VIMOS Interactive Pipeline and Graphical Interface, to reduce the VIMOS data.

Session 3: Near-IR and mid-IR Spectro-Imagers

NIR/MIR Spectro-imagers: Calibration Plans and Monitoring Strategies

Elena Mason[1]

[1] *European Southern Observatory, Casilla 19001, Santiago, Chile*

Data reduction of NIR instruments requires quite standard calibration frames (e.g. flats, arcs, etc.). However, NIR instruments, more than optical non-cryogenic ones, might suffer of limited reproducibility of their various functions. Therefore, special operational strategies are necessary in order to guarantee both adequate calibration frames and stable performances. I will present the two extreme cases of ISAAC and VISIR comparing their calibration plan and the achieved performances.

Imaging and Spectroscopy in the MIR

E. Pantin[1]

[1] *CE Saclay DSM/DAPNIA/Sap, France*

VISIR is the mid-infrared imager and spectrometer installed in April 2004 on Melipal at Paranal. Observing in the thermal infrared from the ground is a quite challenging task since the background (atmosphere and telescope proper emission) overwhelms almost all sky sources by a typical factor of 1000. I will review the calibration processes used to observe in such conditions, how are calibrated the data, and adress the question of achieved accuracies. In particular, it will be emphasized that stability is a key issue for the differential observing techniques mandatory for ground-based observing conditions.Finally, I will propose some suggestions for VISIR amelioration of performances, and how future mid-infrared instruments shall be designed.

IR-Spectrograph Calibration Issues: CRIRES as an Example

Hans Ulrich Käufl[1] and the CRIRES Team

[1] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748 Garching bei München, Germany*

CRIRES is an adaptive optics assisted cryogenic infrared Echelle Spectrograph for ESO's VLT with a nominal resolution $\lambda/\Delta\lambda \approx 10^6$. CRIRES has a $4k \times 0.5k$ detector mosaic in the focal plane. With Nyquist sampling of the spectrum for the nominal slit width this corresponds to a Δv of $1.5km/s$. The spectrograph design will shortly be sketched. Thereafter the challenges of flux-calibration, spectral calibration and compensation of the telluric atmospheric interferences will be explained. Most of the issues for the CRIRES calibration are generic for any IR-spectrograph. Calibration principles adopted for CRIRES will be discussed and results from laboratory testing as well as from commissioning will be presented. While the performance of CRIRES in terms of resolution and stability is already quite satisfying there is also room for improvements. Some problems will be discussed and future concepts for coping with these problems will be sketched.

Calibrating IR Standard Stars

Danuta Dobrzycka[1], Leonardo Vanzi[2], Valentin D. Ivanov[2]

[1] *European Southern Observatory, Karl-Schwarzschild-Str. 2, D-85748 Garching, Germany*
[2] *European Southern Observatory, Casilla 19001, Santiago 19, Chile*

The VLT Spectrometer and Imager for the Mid–Infrared (VISIR) is a Paranal instrument dedicated to observations through the two mid-infrared (MIR) atmospheric windows: N band (8-13 μm) and Q band (16.5-24.5 μm). As part of standard operations, VISIR has been continuously observing MIR standard stars for more than a year. The derived conversion factors, sensitivities, etc. have been systematically collected in the database.

VISIR calibrators are selected from the MIR spectro-photometric standard star catalog based on the Cohen et al. (1999) catalog and supplemented with the MIR standards used by TIMMI2. Zero point fluxes (in Jy) have been calculated for the VISIR filter set by taking into account the measured transmission curve, the detector efficiency and an atmosphere model. To monitor photometric precision of VISIR observations 81 stars have been selected from the catalog. They fulfill basic criteria of non-variability (according to Hipparcos), of not being visual binaries (according to SIMBAD), and of having absolute calibration errors less than 20%. Out of these, twelve photometric standard stars were further selected for daily observations. These targets are relatively bright, have similar spectral types and are distributed uniformly in Right Ascension.

We present long time coverage of the observations of selected MIR photometric standard stars and discuss possible variability of their observable properties.

We will also briefly cover two other projects on standard stars: one concerns the selection of IR telluric standards free of emission lines and the other report is on ESO's efforts to establish spectro-photometric standard stars in the near-IR for X-shooter (also see poster by Vernet et al., P 31)

Session 4: Data Flow and Data Reduction Software

The VLT End to End Data Flow

Michele Peron[1]

[1] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748 Garching, bei München, Germany*

The Data Flow System (DFS) provides the software infrastructure for supporting the end-to-end operation of the VLT. It is a distributed system composed of a collection of components for preparation and scheduling of observations, archiving of data, pipeline data reduction and quality control. The current system, its evolution since the beginning of operations in 1999 and future developments will be presented in this paper.

ESO Reflex – A Graphical Workflow System for Running Recipes

Richard Hook[1], Marko Ullgrén[2], Sami Maisala[2], Tero Oittinen[2], Otto Solin[4], Martino Romaniello[1], Michèle Péron[1], Carlo Izzo[1], Tom Licha[1], Ville Savolainen[3], Johan Lindroos[3], Pekka Järveläinen[3]

[1] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748, Garching bei München, Germany*
[2] *Observatory, University of Helsinki, Finland*
[3] *CSC, Scientific Computing Ltd, Finland*
[4] *Space Systems Finland Ltd, Finland*

Sampo is a three year project that began in January 2005. It is led by ESO and conducted by a software development team from Finland as an in-kind contribution to joining ESO. The goal of the project is to assess the needs of the ESO community in the area of data reduction and analysis environments and to create pilot software products that illustrate critical steps along the road to a new system. Those prototypes will not only be used to validate concepts and understand requirements but will also be tools of immediate value for the community.

The Sampo team has been developing new ways in which instrument pipeline recipes can be executed in a more flexible way. This has let to a prototype application called ESO Reflex that provides a new approach to astronomical data analysis. The integration of a modern graphical user interface and field-proven legacy data reduction algorithms aims to give an astronomer the best of both worlds: ease of use combined with optimal scientific results.

Much of the raw data produced by ESO instruments is reduced using CPL-based recipes. Each of these recipes performs a single task in the reduction process and they are combined to form reduction pipelines. Currently such recipes are run one at a time using a command line application EsoRex or the GUI-based application Gasgano. Using ESO Reflex, a sequence of recipes can be run as a workflow and the output of a recipe can be used as an input to another recipe. The workflow can be executed either automatically or in interactive mode, where the user can interrupt processing at intermediate stages to visualize the results and also change the processing parameters if needed.

The data classification functionality offered by ESO Reflex helps the user to select the right data for input, which also reduces the likelihood of errors. ESO Reflex also detects errors that occur during the execution of the recipes, and appropriate action can then be taken by the user.

ESO Reflex is based on a graphical workflow engine called Taverna that was originally developed for the molecular biology community in the UK. Workflows have been created so far for two intruments on the ESO VLT—the IFU mode of VIMOS and the VLTI instrument AMBER. The easy-to-use GUI allows the user to make changes to these or create their own workflows.

Scientific Data Reduction Pipelines at NASA: 30 years and Counting

Don Lindler[1]

[1] *Sigma Space Corporation, Lanham, Maryland, USA*

In the early 1970s, NASA and its international partners began development of a very successful data reduction pipeline for the International Ultraviolet Explorer (IUE). The longevity of IUE resulted in a pipeline that evolved over time giving valuable experience for development of future data reduction pipelines. However, some of the lessons learned were ignored or soon forgotten during the later stages of the IUE pipeline development and early development of the Hubble Space Telescope (HST) data reduction pipeline. The initial HST pipeline was a step backward in pipeline performance, reliability, and functionality. You might say that the young Space Telescope Science Institute (ST ScI) inherited a "lemon". The ST ScI quickly recognized the short comings of the system and began development of OPUS, a second generation pipeline. OPUS was highly successful and has been in continuous operation at the ST ScI since late 1995. It has proved to be adaptable to the increased requirements of the new HST instruments and to the requirements of many other projects including the Far Ultraviolet Spectrographic Explorer, The Chandra X-ray Observatory, the Spitzer Space Telescope, and the Gemini Observatory. As such, OPUS provides an effective infrastructure for data reduction pipelines. However, the valuable experience from individual pipeline projects is important to future pipeline development to insure the quality of the archival data in the era of on-the-fly calibration and virtual observatories. I will discuss a brief history of these NASA pipeline development efforts concentrating on the significant positive and negative lessons learned.

The End-to-End Pipeline for HST Slitless Spectra PHLAG

Martin Kümmel[1], R. Albrecht[1], R. Fosbury[1], W. Freudling[1], J. Haase[1], R.N. Hook[1], H. Kuntschner[1], A. Micol[1], M. Rosa[1], J.R. Walsh[1]

[1]*Space Telescope European Coordinating Facility, Karl-Schwarzschild-Str. 2, D-85748 Garching, Germany*

The ST-ECF has started a project to build a so called "Hubble Legacy Archive" (HLA) which will host high level data products ready to be used in the Virtual Observatory (VO). The main effort currently focuses on providing extracted spectra from data obtained in the slitless spectroscopic modes of HST.

In this contribution the **P**ipeline for **H**ubble **L**egacy **A**rchive **G**rism data (PHLAG) is presented. PHLAG is and end-to-end pipeline which performs an unsupervised reduction of slitless data taken with the Advanced Camera for Surveys (ACS) or the Near Infrared Camera and Multi Object Spectrometer (NICMOS). The input to PHLAG is data with only the basic calibration applied (bias, dark); the output is VO compatible spectra, which will be made available through an HLA-archive. The various sub-components of PHLAG – data preparation, data retrieval, image combination, object detection, spectral extraction using the aXe software, quality control – and their mutual interplay are discussed. The exquisite conditions in space and the stability of the HST instruments allow the usage of constant calibrations over relatively long time periods. In a pilot study, PHLAG is currently applied to NICMOS data taken with the low resolution grism G141, and we show a representative selection of spectra which demonstrate the high quality of the reduction achievable with PHLAG.

A Bottom-up Approach to Spectroscopic Data Reduction

Carlo Izzo[1], Yves Jung[1], Pascal Ballester[1]

[1] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748, Garching bei München, Germany*

Robustness and flexibility are key requirements for an automatic data-reduction pipeline. Robustness is the capability to manage unexpected situations due to hardware failures, supplying precise information about what went wrong, and granting in this way a thorough and safe monitoring of the instrument health. Flexibility, on the other hand, is obtained by the utilisation of algorithms which are general enough to withstand any hardware upgrade, ideally leading to instrument-independent data reduction systems.

Any bottom-up approach based both on pattern-matching techniques and on keeping to a minimum any instrument-specific assumption, goes in the direction of fulfilling such essential requisites, while simultaneously reducing the software maintenance work significantly.

The pattern-matching method extends the palette of tools available to solve calibration problems, including physical model or correlation methods. In this presentation a qualitative description of the data calibration bottom-up strategy will be given. Examples are shown of the FORS, VIMOS, EMMI, GIRAFFE and CRIRES instruments.

Model Based Calibration

Paul Bristow[1], Florian Kerber[1], Michael Rosa[2]

[1] *European Southern Observatory, Karl-Schwarzschild-Str. 2, D-85748 Garching, Germany*
[2] *ST-ECF, Karl-Schwarzschild-Str. 2, 85748 Garching, Germany*

The Calibration Support Group is a group within ESO's Instrumentation division which aims to develop and implement advanced calibration techniques for ESO instruments. Our physcial models use the engineering and design information employed to construct the instrument as a starting point, and are then optimised to describe the actual configuration of the instrument including the response to environmental effects.

We have recently delivered a wavelength calibration model for ESO's Cryogenic High–Resolution Infrared Echelle Spectrograph (CRIRES) which replaces traditional empirical fits to individual data sets with a physical model which describes the entire wavelength range simultaneously. This enables reliable wavelength calibration even in regions with a scarcity of calibration source features. We discuss the concept, the input required, the optimization algorithm and the practical application of this kind of model.

Whilst the investment of effort required to develop such a model for CRIRES has been considerable, this is already paying dividend as we reuse most of the techniques, procedures and algorithms for X-Shooter. Here the predictive power of the physical model is already employed in an early phase of the project supporting the development of both the instrument and data reduction software.

Clearly any physical model of an instrument requires high quality physical data, both to describe the instrument components and to describe calibration sources used. We present our efforts dedicated to obtaining high quality laboratory refractive index data of optical materials and spectral atlases of calibration lamps.

Based on our experiences, we provide an outlook of the possible use of advanced modeling techniques for future complex instrumentation such as that envisaged for VLT and the E-ELT.

Advanced Data Products at ESO: Calibration Challenges

Piero Rosati[1]

[1] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748 Garching, Germany*

I will report on the ESO activity of producing Advanced Data Products from archival imaging data. The main goal of this activity is to create fully processed, science ready imaging mosaics from major surveys carried out with ESO instruments, with a few percent photometric accuracy. Most of the activity to date has focused on the creation and public release of GOODS-South data obtained with ISAAC (JHK-bands) and VIMOS (U-band). Automated and accurate photometric calibration remains the major challenge of such an activity, while the creation of fully processed astrometrically calibrated imaging products from large volumes of WFI, ISAAC, SOFI, VIMOS, FORS archival data is easily achieved with the ESO-MVM data processing system. Suggestions derived from this activity on how to improve the (photometric and astrometric) calibration of ESO archival (imaging) data will be also given.

From Advanced Calibration in the VLT Era to Forward Analysis on ELT

Michael Rosa[1]

[1] *Space Telescope European Coordinating Facility, ESO, Karl-Schwarzschild-Str.2, D-85748 Garching, Germany*

The conceptual basis for advanced calibration, the predictive power of physical models, calibration standards, was developed here at ST-ECF and ESO about 10 years ago. I will review the many impressive examples of successful implementation for high resolution spectroscopy on VLT and HST. In combination with securing high precision calibration standards this methodology is becoming standard for instruments in operation and under development. Looking ahead, soon the ubiquity of pipelines containing the predictive model based kernels will allow us to address the closure of the observation calibration - data analysis information loop: Forward Analysis data analysis in the raw observational data domain.

Session 5: Adaptive Optics Instruments

Calibration of Adaptive Optics fed Instruments

Nancy Ageorges[1]

[1]*European Southern Observatory, Casilla 19001, Santiago, Chile*

ESO Paranal is currently using two different type of adaptive optics systems. The MACAO-type, based on curvature wavefront sensing and the NAOS type based on the Shack-Hartman technology. Both systems and their specific maintenance calibration will be presented and discussed. It will be explained what is monitored on a regular basis to ensure a high performance of the systems.

AO Assisted Spectroscopy with SINFONI

R.Davies[1]

[1] *Max Planck Institut für extraterrestrische Physik, Garching, Germany*

The biggest misunderstandings about adaptive optics concern the PSF: that one should know it with great detail, and that its temporal variability casts dobut on interpretation of the data. I will attempt to alleviate these concerns by discussing to what level of accuracy one needs to know the PSF, and some ways in which this might be achieved – including how, with some types of targets, one can in fact derive it from the spectral information in the science data.

I will also discuss a number of issues concerning the calibration of near infrared integral field data: fine tuning the wavelength calibration; optimising the subtraction of OH lines; aligning the slitlets. These are issues which have arisen for SINFONI and are being included in the design of the data processing software for the 2nd generation instrument KMOS.

Imaging and Treatment of the Point Spread Function in Adaptive Optics Instruments - NACO

Y. Clénet[1], C. Lidman[2], E. Gendron[1]

[1] *Observatoire de Paris, LESIA, France*
[2] *European Southern Observatory, Casilla 19001, Santiago 19, Chile*

After more than 20 years of operation with astronomical instruments, adaptive optics has now reached maturity: it is routinely used and its use is transparent for the astronomer. Though, adaptive optics assisted images have specificities compared to seeing-limited images, e.g. point spread function profile or variability. The advantage of the former, in particular for post-processing treatment of the observations, is that the PSF characteristics can be calibrated from real-time measurements of the adaptive optics system itself. I will review all these points, as well as their applications to NACO.

Probing μ-arcsecond Astrometry with NACO

Andreas Seifahrt[1,2], Ralph Neuhaeuser[1], Tristan Roell[1]

[1] *Astrophysikalisches Institut und Universitäts-Sternwarte Jena, D-07745 Jena, Germany*
[2] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748 Garching, Germany*

We present the first data to demonstrate that narrow field measurements with a relative astrometric precision of better than 100 μas (microarcsecond) are feasible with NAOS-CONICA (NACO). Such measurements would allow us e.g. to measure the astrometric wobble of extra-solar planet candidates in close stellar binaries and to determine the inclination angle of these planetary systems. This quantity can not be determined from the common radial-velocity (RV) measurements. Thus, with high-precision astrometry on NACO we can determine the true mass of extra-solar planets in such systems. We discuss here the implications on the astrometric stability of NACO and UT4 and give a roadmap for the necessary calibrations that are required to achieve this extremely high astrometric precision.

Session 6: Integral Field Spectroscopy

Integral Field Spectroscopy at the La Silla Paranal Observatory

Paola Amico[1], Stefano Bagnulo[1], Christophe Dumas[1], Carlo Izzo[2], Gianni Marconi[1], Claudio Melo[1]

[1] *European Southern Observatory, Casilla 19001, Santiago 19, Chile*
[2] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748, Garching bei München, Germany*

Integral Field Spectroscopy at the La Silla Paranal Observatory is offered in three flavours:
1) SINFONI is a near-infrared (1.1 - 2.45 μm) integral field spectrograph fed by an adaptive optics module, currently installed at the Cassegrain focus of UT4. The spectrograph operates with 4 gratings in J, H, K and $H+K$ (R 2000-4000) and three different scales (0.25", 0.1" and 0.025"), corresponding to a field-of-view of 8" $\times$ 8", 3" $\times$ 3", or 0.8" $\times$ 0.8" respectively. SINFONI can also be used in seeing limited mode (no AO).
2) VIMOS on UT3 is equipped with an integral field unit made of 6400 fibers operating in the 390-1000 nm wavelength range. Two spatial scales per fiber are available: 0.67" and 0.33"; they correspond to field of views from 13" $\times$ 13" up to 54" $\times$ 54" depending on the chosen spectral resolution (R=200-2500).
3) FLAMES-GIRAFFE on UT2 allows the observation of up to 15 targets simultaneously in the 370-940 nm wavelength range: it uses 30 small fiber bundles, each covering 2" $\times$ 3" on the sky and positioned in the 25' diameter circular field of view. Alternatively, FLAMES-ARGUS uses a fiber bundle located in the center of the FLAMES field of view, covering 6.6" $\times$ 4.2" on the sky. In both cases the spectral resolution R=11000-39000.

In this talk we review the use and science applications for these instruments, their standard calibration and maintenance operations and the principles of image reconstruction.

Integral Field Spectroscopy

E. Emsellem[1]

[1] *CRAL, Université Lyon 1, Observatoire de Lyon, France*

I will briefly review the current IFUs at ESO and their capabilities, with a special emphasis on the critical steps to extract the corresponding scientific data. In this context, I will also mention future developments and their corresponding characteristics.

Specsim: An IFU Spectrometer Simulator

Nuria P. F. Lorente[1]

[1] *UK Astronomy Technology Centre, Royal Observatory Edinburgh, UK*

As the scale and complexity of each generation of telescopes and their instruments increases, the requirement for a means of furthering our understanding of their properties and limitations, from the initial design to the point of commissioning also grows. An effective way of learning about the behaviour of a new system is to employ a software simulator to generate synthetic astronomical data, based on a given set of telescope and instrument characteristics. The Specsim tool has been developed to model, in software, the operation of Integral Field Unit (IFU) spectrometers, so as to give the science, engineering and operations teams responsible for designing, building and running such instruments a preview of the data products before the system is operational. Specsim generates synthetic data frames approximating those which will be taken by the instrument. The program models astronomical sources and generates detector frames using the predicted and measured properties of the telescope and instrument. These frames can then be used to illustrate and inform a range of activities, including refining the design, developing calibration strategies and the development and testing of data reduction pipelines. Specsim is currently used to model the Medium Resolution Spectrograph on JWST-MIRI, and KMOS on the ESO VLT. The software has been designed in a modular fashion, thus allowing the tool to expand easily to model future instruments, by incorporating new models into the existing infrastructure.

Integral Field Spectroscopy with VIMOS

Martin M. Roth[1]

[1] *Astrophysikalisches Institut Potsdam, Germany*

The VIMOS IFU is the largest of its kind at any 8m class telescope worldwide and offers interesting observational capabilities for a variety of objects from within the Galaxy out to the high redshift universe. Owing to the complexity of the instrument, as well as the resulting data, the reduction and analysis is not necessarily straight-on forward. I shall discuss instrumental effects, several relevant aspects of data reduction, and review selected scientific results obtained with the VIMOS IFU.

KMOS: A VLT Second Generation Multi-IFU Spectrometer

R.M. Sharples[1], S.K. Ramsay Howat[2], R. Davies[3], M. Lehnert[4]

[1] *Centre for Advanced Instrumentation, University of Durham, Netpark, Sedgefield, TS21 3FB, UK*
[2] *UK Astronomy Technology Centre, Royal Observatory, Edinburgh, EH9 3HJ, UK*
[3] *Max Planck Institut für extraterrestrische Physik, Garching, Germany*
[4] *GEPI, France*

We present an overview of the KMOS instrument, currently under construction by a consortium of UK and German institutes, which will provide a unique multi-object near-infrared integral-field spectroscopic capability on the VLT. We discuss the instrument architecture and the demanding requirements for calibration imposed by multi-object near-infrared integral field data. Details of the specific calibration procedures being developed for KMOS are presented in a companion paper.

Calibration of the KMOS Multi-object Integral Field Spectrometer

S.K.Ramsay Howat[1], S.Rolt[2], R.Sharples[2], R.Davies[3]

[1] *UK Astronomy Technology Centre, Royal Observatory, Edinburgh, EH9 3HJ, UK*
[2] *Centre for Advanced Instrumentation, University of Durham, Netpark, Sedgefield, TS21 3FB, UK*
[3] *Max-Planck-Institut für extraterrestrische Physik, Postfach 1312, D-85741 Garching bei München, Germany*

When it is delivered to the VLT, the K-band multi-object integral-field spectrograph (KMOS) will be the first near infrared spectrograph to use multiple integral fields units. Twenty-four pick-off arms provide the optical relay to image objects selected from a seven arcminute patrol field onto 24 image slicing integral field units (IFUs). The output from eight IFUs forms a single slit which feeds one of three identical spectrometers working over the 0.8-2.5um wavelength region. The calibration of such an instrument presents a number of challenges that have been studied during the final design phase of the instrument. In particular, flat field and wavelength calibration for KMOS will be provided by an internal calibration system of unique design. External light sources are feed via integrating spheres and high transmission light pipes to a calibration sphere with 24 output ports addressed by the 24 arms. Obtaining a high degree of field flatness is key to the sensitivity of NIR instruments. The KMOS calunit is predicted to delivery uniformities of ~0.1% over the KMOS IFU fields. In this talk, we will present the plans for end to end calibration of KMOS. This will include discussion of laboratory characterisation such as the arm position to sky co-ordinate transformation, the design and expected performance of the calibration unit and the final calibration through the data reduction pipeline. Results from modelling the instrument plus calibration system will be shown to illustrate the KMOS calibration plan.

MUSE: A Second-Generation Integral-Field Spectrograph for the VLT

McDermid R.M.[1], Bacon R.[2], Bauer S.[3], Boehm P.[3], Boudon D.[2], Brau-Nogué S.[4], Caillier P.[2], Capoani L.[2], Carollo C.M.[5], Champavert N.[2], Contini T.[4], Daguisé E.[2], Delabre B.[6], Devriendt J.[2], Dreizler S.[7], Dubois J.[2], Dupieux M.[4], Dupin J.P.[4], Emsellem E.[2], Ferruit P.[2], Franx M.[1], Gallou G.[4], Gerssen J.[3], Guiderdoni B.[2], Hahn T.[3], Hofmann D.[7], Jarno A.[2], Kelz A.[3], Koehler C.[7], Kollatschny W.[7], Kosmalski J.[2], Laurent F.[2], Lilly S.J.[5], Lizon J.L[6], Loupias M.[2], Manescau A.[6], Monstein C.[5], Nicklas H.[7], Parès L.[4], Pasquini L.[6], Pécontal-Rousset A.[2], Pécontal E.[2], Pello R.[4], Petit C.[2], Picat J-P.[4], Popow E.[3], Quirrenbach A.[1], Reiss R.[6], Renault E.[2], Roth M.[3], Schaye J.[1], Soucail G.[4], Steinmetz M.[3], Stroebele S.[6], Stuik R.[1], Weilbacher P.[3], Wisotzki, L.[3], Wozniak H.[2], de Zeeuw P.T.[1]

[1] *Leiden Observatory, Leiden, The Netherlands*
[2] *Centre de Recherche Astrophysique de Lyon, Lyon, France*
[3] *IAP, Potsdam, Germany*
[4] *LAOMP, Toulouse, France*
[5] *ETH, Zurich, Switzerland*
[6] *ESO, Garching, Germany*
[7] *IAG, Göttingen, Germany*

The Multi Unit Spectroscopic Explorer (MUSE) is a second-generation instrument in development for the Very Large Telescope (VLT) of the European Southern Observatory (ESO), due to begin operation in 2011/12. MUSE will be an extremely powerful integral-field spectrograph fed by a new multiple-laser adaptive optics system on the VLT. In its usual operating mode, MUSE will, in a single observation, produce a 3-dimensional data cube consisting of 90,000 R 3000 spectra, each covering a full spectral octave (465-930 nm), and fully sampling a contiguous 1x1 arcmin^2 field with 0.2x0.2 arcsec^2 apertures. A high-resolution mode will increase the spatial sampling to 0.025 arcsec per pixel. MUSE is built around a novel arrangement of 24 identical spectrographs (each comparable to a 1st generation VLT instrument), which are fed by a set of 24 precision image slicers. MUSE is designed for stability, with only 2 modes, and virtually no moving parts, allowing very long exposures to be accumulated. Together with high throughput, this ensures that MUSE will have extreme sensitivity for observing faint objects. This presentation will overview the technical and scientific aspects of MUSE, highlighting the key challenges for dealing with the unprecedented quantity and complexity of the data, and the integration with the VLT adaptive telescope facility - a key development on the path to extremely large telescopes (ELTs).

Session 7: High Resolution Spectroscopy

High Resolution Spectrographs - IOT Overview

Gaspare Lo Curto[1]

[1] *European Southern Observatory, Casilla 19001, Santiago 19, Chile*

ESO operates several medium and high resolution spectrographs with resolutions ranging from 10000 to 220000. They span a variety of designs, due to the main scientific goal to which they are dedicated and the wavelength at which they are operated. Nevertheless, in some cases, the maintenance and calibration tasks are alike. During this talk we will briefly discuss the calibration and characterization strategy of the spectrographs, focussing on common problematics.

Quantitative Spectroscopy with UVES

Poul Erik Nissen[1]

[1] *Department of Physics and Astronomy, University of Aarhus, DK-8000 Aarhus C, Denmark*

Since its completion in 1999, UVES has proved to be a very reliable and highly competitive high-resolution spectrograph. According to the ESO Telescope Bibliography about 500 refereed publications based on UVES data have appeared in the period 2000 - 2006 and important scientific contributions have been made in such different fields as: stellar atmospheres and abundances, stellar oscillations and pulsations, exoplanets, stellar and gas dynamics, and abundances in the high-redshift Universe.

In most cases, standard UVES observations and pipe-line reduction of the data are fully adequate for obtaining good high-resolution spectra. For programmes requiring very high quality spectra, one should, however, give special consideration to flatfielding and removal of CCD fringing and telluric lines. Examples of such programmes will be discussed, e.g. detection of uranium in very metal-poor stars, the lithium isotope ratio in turnoff stars, sulphur abundances in halo stars, and the determination of precise effective temperatures of stars from the wings of hydrogen lines.

High-Resolution and High-Precision Spectroscopy with HARPS

C. Lovis[1], F. Pepe[1] (presenter), et al.

[1] *Observatoire de Genève, Switzerland*

Extra-solar planet search at a level of precision below 1m/s sets strong requirements to the quality and stability of the wavelength solution. It also forces us to understand the effects of instrumental stability, on the one hand, and the quality of the wavelength reference, on the other hand, since both will have an impact, although in a different way, on the short- and long-term precision of the instrument. I will shortly present the calibration principles of HARPS, which lead to its extra-ordinary wavelength solution and, as a direct consequence, to its unique radial-velocity precision. In particular I will present the improvements of the thorium-lamp calibrations we made during the past three years, but I will also discuss the present limitations. Finally, I will give an outlook on further possible improvements which can be made in view of the extreme precision required by instruments like CODEX@ELT.

Laser Comb: A Novel Calibration System for High Resolution Spectrographs

C. Araujo-Hauck[1], L. Pasquini[1], A. Manescau[1], Th. Udem[2], T.W. Hänsch[2], R. Holzwarth[2,3], A. Sizmann[3], H. Dekker[1], S. D'Odorico[1], M.T. Murphy[4]

[1] *European Southern Observatory, Karl-Schwarzschild-Str. 2, D-85748 Garching, Germany*
[2] *Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany*
[3] *Menlo Systems GmbH, Am Klopferspitz 19, D-82152 Martinsried, Germany*
[4] *Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK*

With HARPS, the ESO community has established a new standard in the wavelength accuracy and stability of spectroscopic measurements of astrophysical sources. The next generation of high resolution spectrographs at VLT and the ELT will push these performances further. One crucial subsystem is the wavelength calibration source, currently a Th-Ar lamp, which shows a number of drawbacks and limitations. ESO and the Max-Planck-Institut für Quantenoptik have studied the feasibility, and are now starting the development of a laboratory demonstrator for a wavelength calibration system based on laser frequency comb techniques. Such a calibration system will give higher wavelength accuracy and stability by providing a series of perfectly equidistant emission lines, covering a large wavelength range in the visible and perfectly stabilized to the 10^{-11} to 10^{-15} level. The absolute reference is provided by an atomic clock, which guarantees long term stability over the years required for some of the measurements.

Session 8: Atmospheric Effects

Calibration of Photometric Data

David L. Burke[1]

[1] *Kavli Institute for Particle Astrophysics and Cosmology, Stanford Linear Accelerator Center, Stanford University, USA*

Science studies made by the Large Synoptic Survey Telescope (LSST) will reach systematic limits in nearly all cases. Requirements for photometric measurements accurate to 1% are particularly challenging. Advantage will be taken of the rapid cadence and pace of the LSST survey to use main sequence stars to calibrate stability and uniformity of astrometric and photometric data. A new technique using a tunable laser is being developed to calibrate the wavelength dependence of the total telescope and camera system throughput and response. Spectroscopic measurements of atmospheric extinction and emission will be made continuously to allow the broad-band optical flux observed in the instrument to be corrected to flux at the top of the atmosphere. Calibrations with standard stars will be combined with instrumental and atmospheric calibrations.

The GTC Photometric Calibration Programme

J.M. Rodriguez Espinosa[1], A. Di Cesare[1], P.L. Hammersley[1]

[1] *Instituto de astrofisica de Canarias, Tenerife, Spain*

The GTC is a 10.4m segmented telescope that is about to have first light. Science operation will begin in about one year time. In order to ensure that the data coming from the GTC have the required quality and homogeneity and to foster the re-utilization of the data archive, a strategy for an adequate calibration of the data is being implemented. As part of this strategy, a catalogue a standard stars suitable for the photometric calibration of the GTC facility instruments is being put together. The GTC facility instruments are quite versatile and include both broad and narrowband filters plus some tuneable filters, and span the range from the near UV to the mid IR. The GTC Catalogue of Standard Stars that we are producing, consists of a number of stellar calibrated stellar fields, which include stars, which are suitable for a 10m. telescope, and are not variable, non - binary and not having infrared excesses if they are to be used in the infrared. The catalogue consists of 30 star fields evenly distributed across the sky. The fields contain sources over the range 12 to 22 magnitude, spanning a wide range of spectral types (A to M) for the visible and near infrared.The stars are being spectro-photometrically calibrated, through the use of spectral templates. This allows selecting the band-passes and thus the calibration magnitudes appropriate for the variety of filters in the GTC facility instruments.

Precipitable Waver Vapour Measurements with VISIR

Alain Smette[1], Hannes Horst[1], Julio Navarrete[1]

[1] *European Southern Observatory, Casilla 19001, Santiago 19, Chile*

One of the main cause of the variations of the mid–IR sensitivities for ground–based telescope observations is the variable amount of precipitable water vapour (PWV) in the atmosphere. Time–consuming observations of standard stars are therefore needed to assess the sensitivities that a science observations can reach.

In this talk, we show that a 10s integration, 19.5 μ medium–resolution VLT/VISIR sky spectrum can be used to determine the PWV within a few percents. We compare the VISIR PWV measurements with satellite–based ones and found large discrepancies in a number of cases. The correlation between mid-IR sensitivities and VISIR PWV measurements shows a much reduced scatter compared to a similar correlation based on satellite–based PWV measurements. Such spectra can therefore be used to assess the instantaneous quality of the sky.

Session 9: Interferometric Instrumentation

Calibrations of the VLTI Instruments (MIDI and AMBER)

S. Morel[1], F. Rantakyrö[1], Th. Rivinius[1], S. Stefl[1], Ch. Hummel[1], S. Brillant[1], M. Schöller[1], I. Percheron[2], M. Wittkowski[2], A. Richichi[2]

[1] *European Southern Observatory, Casilla 19001, Santiago 19, Chile*

[2] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748, Garching bei München, Germany*

We present here a short review of the calibration processes that are currently applied to the instruments AMBER and MIDI of the VLTI (Very Large Telescope Interferometer) at Paranal. We first introduce the general principles to calibrate the raw data (the "visibilities") that have been measured by long-baseline interferometry. Then, we focus on the specific case of the scientific operation of the VLTI instruments. We explain the criteria that have been used to select calibrator stars for the observations with the VLTI instruments, as well as the routine internal calibration techniques. Among these techniques, the "P2VM" (Pixel-to-Visibility Matrix) in the case of AMBER is detailed. Also, the daily monitoring of AMBER and MIDI, that has recently been implemented, is introduced.

VLTI with AMBER

F. Millour[1,2,3] & the AMBER consortium

[1] *Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany*
[2] *LAOG, 414 rue de la piscine, 38400 Saint Martin d'hères, France*
[3] *LUAN, Université de Nice, Parc Valrose, 6000 Nice, France*

I present here the tips and tricks of the AMBER/VLTI data reduction and calibration process, including how to check the quality of the result. The Astronomical Multi-BEam Recombiner (AMBER) instrument is the multiaxial spectrally dispersed near infrared interferometric recombiner of the Very Large Telescope Interferometer (VLTI), allowing to combine simultaneously up to three telecopes in the J, H and K bands. The resulting data products are the spectrally dispersed visibilities, closure phases and differential phases that can be easily used for an astrophysical purpose. We will see that the calibration process of AMBER is currently mainly limited by the vibrations of the Unit Telescopes (UT) and the absence of a working fringe tracker, but that with careful data selection and some assumptions on the origins of the vibrations, we can already achieve performances very close to the original specifications for bright objets. We will see also that with the Auxilliary Telescopes (AT), the problems are almost removed. Moreover, a potentially strong improvement of the data reduction algorithms is also foreseen allowing a step forward in limiting magnitude and quality of the data products.

MIDI Calibration

W. Jaffe[1]

[1] *Leiden Observatory, Leiden University, The Netherlands*

I review the current procedures for calibration of measurements of both correlated fluxes and visibilities with the MIDIfrared interferometer (MIDI). I will describe our efforts to increase the precision of the results with the so-called SCI_PHOT observing mode.

Session 11: Polarimetry

IOT Overview of Polarimetry Calibration

Nancy Ageorges[1]

[1] *European Southern Observatory, Casilla 19001, Santiago, Chile*

ESO instruments permit to perform polarimetric observation in the visible as well as in the near-infrared, in imaging and/or spectroscopic mode. An overview of the existing facilities as well as of their calibration plan related to polarimetry will be given, pointing out the pro and cons. An emphasis will be put on the FORS1 instrument.

Calibration of Polarimetric Data

H.M. Schmid[1]

[1] *Institute of Astronomy, ETH Zurich, Zürich, Switzerland*

ABSTRACT. The calibrations for spectropolarimetric data and polarimetric imaging are discussed. There are various aspects which play an important role for the calibration of polarimetric data. First of all, there are the polarimetric precision requirements defined by the scientific goal of the observations. All polarimetric data require a characterization of the telescope and instrument polarization which is usually based on (and verified with) standard star observations. Using standard procedures it is possible to reach typically a polarimetric precision of $\Delta p \approx \pm 0.2$ % for the degree of polarization and $\Delta\theta \approx \pm 2^\circ$ for the polarization positions angle for the Cassegrain instruments FORS1 and EFOSC2. If a higher precision is required, then one has to investigate carefully telescope and instrument hardware effects as well as limitations in the data reduction procedures, and even the selection of suitable standard stars needs to be considered. Some of these issues are discussed in more detail based on polarimetric data from ESO telescopes.

Finally, also an outlook is given on some general calibration issues related to the polarimetric mode foreseen for SPHERE, the future VLT planet finder instrument.

Session 12: Wide Field Imagers

Six Years of WFI Operations: Lessons Learned

F. Selman[1], B. Conn[1], O. Schuetz[1]

[1] *European Southern Observatory, Casilla 19001, Santiago 19, Chile*

The Wide-Field Imager at the 2.2-m telescope at La Silla saw first light Dec 13, 1998, and was offered to the ESO and MPI-A communities starting Jan 18, 1999, that is, over 8 years ago! During this time it has been used to discover high redshift galaxies; to study the clustering properties of galaxies over large scales; to map the mass distribution in clusters of galaxies using weak lensing; to trace the intracluster medium using narrow-band filter imaging of planetary nebulae; to observe the resolved stellar population of Local Group galaxies; to study the rotation rates of young stars; to search for extra-solar planets using the transit method; to discover NEOs and new satellites of the giant planets; etc. In this presentation we will highlight the many lessons learned during these years of operations, that is, what we did right, what we did wrong, and what we would do differently in the future. We will place special emphasis on the characterization of the photometric properties of this instrument, and what we did to ensure that *wide-field photometry* is not an oxymoron.

The Ins and Outs of Wide Field Imaging

Mike Irwin[1]

[1] *Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge, CB3 0HA, UK*

Optical and near-infrared wide field cameras on 2- to 4m-class telescopes are increasingly being used to conduct large scale imaging surveys. With total data-rates approaching 1 Tbyte/night automated pipeline processing and data management facilities are crucial. Although processing near-infrared data is in some ways technically more challenging than the optical, the majority of the processing requirements and the adopted solutions are common to both.

In this presentation I will describe the general princples required for an end-to-end system capable of delivering science-grade, quality-controlled calibrated images and catalogues. This will be illustrated with some practical examples from current optical and near-infrared surveys.

The Garching-Bonn Deep Survey (GaBoDS) Wide-Field-Imaging Reduction Pipeline

Hendrik Hildebrandt[1]

[1] *Argelander-Institut für Astronomie, Universität Bonn, Auf dem Hügel 71, D-53121 Bonn, Germany*

In this talk, our publicly available Wide-Field-Imaging reduction pipeline is introduced. The procedures applied for the efficient pre-reduction, astrometric and photometric calibration, as well as coaddition are presented with data from the ESO Wide-Field-Imager (WFI) as an example. Special emphasis is given to science projects that have been completed or are still ongoing using our pipeline. In particular, the reduction of optical data from the ESO Deep Public Survey including the WFI-GOODS data is described. The end-products of this project are now available via the ESO archive. In addition, I discuss WFI observing strategies and their influence on data processing.

Calibrating VISTA Data

Jim Emerson[1], Simon Hodgkin[2], Peter Bunclark[2], Mike Irwin[2], Jim Lewis[2]

[1] *Astronomy Unit, Queen Mary University of London, Mile End Road, London, E1 4NS, UK*
[2] *Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge, CB3 0HA, UK*

ESO's VISTA (the Visible and Infrared Survey Telescope for Astronomy) will start observing for six Public Surveys from the latter part of 2007, and will be used for a wide range of programs. Plans for calibrating VISTA data will be described, with emphasis on how the photometric calibration can benefit from the many 2MASS objects that will appear in each VISTA pawprint and tile.

The VISTA Data Flow System Pipeline

Jim Lewis[1], Mike Irwin[1], Peter Bunclark[1], Simon Hodgkin[1]

[1] *Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge, CB3 0HA, UK*

The Visible and Infrared Survey Telescope for Astronomy (VISTA) is a new ESO telescope that will be commissioned in mid 2007. The telescope and camera have both been specifically designed for survey work in the visible and near infrared (although it will only have an infrared camera to start with). The focal plane will consist of 16 2k by 2k non-buttable chips with a pawprint of 0.6 square degrees. With an expected nightly data rate of 200-400 Gb, automated pipeline processing and data management requirements are paramount.

Pipeline processing of IR data is far more technically challenging than for optical data. IR detectors are inheriently more unstable, while the sky emission is over 100 times brighter than most objects of interest and varies in a complex spatial and temporal manner. In this presentation we describe the pipeline architecture developed to deal with the IR imaging data from VISTA. We discuss the issues involving robustly removing instrumental signatures, sky correction, astrometric and photometric calibration. We also describe some of the checks that have been put in place to monitor data quality and system integrity.

SkyMapper and the Southern Sky Survey: A Photometric and Astrometric Complement to VST

Stefan C. Keller[1], Brian P. Schmidt[1], Michael S. Bessell[1]

[1] *Research School of Astronomy and Astrophysics, Australian National University, Australia*

ABSTRACT The SkyMapper telescope will perform the Southern Sky Survey; a multi-colour and multi-epoch survey of the southerly 2pi steradian of the sky starting in mid-2007. The Southern Sky Survey aims to provide all-sky photometry to g=23 with global accuracy of better than 0.03 magnitudes and astrometry to better than 50 milliarcsecs. The resulting catalogue has potential applications for the calibration of data obtained with numerous ESO facilities, in particular VST.

Quality Control Monitoring for WFCAM

Marco Riello[1]

[1] *Institute of Astronomy, Cambridge, UK*

Over 30 Tb ($\sim 600,000$ fits files) of raw WFCAM data from 3 semesters of observations have been pipeline-processed by the Cambridge Astronomical Survey Unit (CASU) producing ~ 60 Tb of processed images ($\sim 3.5 \cdot 10^{13}$ pixels) and source catalogues ($\sim 10^9$ detections). We present the data Quality Control (QC) infrastructure that has been put in place to effectively deal with such a large data volume. Moreover, the current system was developed as a prototype for the Vista Data Flow System (VDFS): CASU will indeed process most of the data produced by the Vista public surveys starting in the last quarter of 2007. QC measures are produced during pipeline processing and saved in the image/catalogue FITS headers. Only after a night has been fully processed, the information is extracted from the FITS headers and stored into a relational database that, eventually, serves a number of report-generating tools. QC measures includes: sky brightness and noise, average stellar ellipticity, average seeing, astrometric calibration errors, per-image and nightly averaged photometric zero-points and errors, number of detected sources per chip. The QC system has been used also to investigate the near-infrared sky brightness at Mauna Kea Observatory.

Workshop Summary

Dietrich Baade[1]

[1] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748, Garching bei München, Germany*

Posters

P 1

Instrumental Line Shapes for Molecular Line Parameter Retrieval from High Resolution Fourier Transform Spectra for Terrestrial or Planetary Atmospheric Remote Sensing

Mohammed Badaoui[1], Franz Schreier[2], Georg Wagner[2], Manfred Birk[2]

[1] *Institut Agronomique et Vétérinaire Hassan II, APESA, Unité de Physique, B.P. 6240, Rabat Al Irfane, 10101, Morocco*
[2] *DLR — German Aerospace Center, Remote Sensing Technology Institute, Oberpfaffenhofen, D-82234 Wessling, Germany*

Remote sensing from space by means of spectroscopic techniques is a powerful tool in terrestrial and planetary atmospheric sciences. However, the availability of improved Fourier Transform Spectrometers, FTS, and the advance in computational capabilities are not sufficient to retrieve the atmospheric characteristics as temperature and molecular species concentrations. One also needs complete and precise knowledge of molecular spectroscopic line parameters for radiative transfer modeling and solution of the inverse problem. Consequently several spectroscopic databases have been compiled in the last decades, most notably the HITRAN database [1], GEISA databank [2], and JPL catalogue [3].

This communication presents nonlinear least-squares-fitting procedures that adjust a modeled transmittance to match the observed spectrum taking into account a comprehensive modeling of the FTS instrumental apparatus function or Instrumental Line Shape (ILS). Consequently, one retrieves molecular spectral lines parameters (position, intensity, pressure broadening, and pressure shifting) in a considered spectral window. Two codes developed independently have been intercompared recently: A "Does'nt Use Derivatives" (DuD) version of nonlinear least squares[4] and the FitMAS code utilizing analytical Jacobians.[5]

Nonlinear least squares fit techniques require an initial guess of parameters to be fitted in the iterative process: initial line parameters can be read from databases or from simple peak lists given by experimentalists. For new molecules, the peak finder program "Derpt"[6] has been used successfully with the DuD–code.

Only Voigt profile is considered in the DuD–code, whereas FitMAS also considers line–narrowing effects modelled by Rautian line profiles. For modeling the ILS, our methods take into account the influence of the throughput and optionally the phase error and the non-multiplying channelling (DuD only) [7].

An example will be given about line parameters measurements of Ozone (O_3) pure rotational spectra[5] measured at DLR's molecular spectroscopy laboratory. Emphasize will be made on the retrieval of line strengths.

[1]L. Rothman et al., The HITRAN 2004 molecular spectroscopic database. *J. Quant. Spectr. & Rad. Trans.*, 96: 139-204, 2005

[2]N. Jacquinet-Husson et al., The 1997 spectroscopic GEISA databank. *J. Quant. Spectr. & Rad. Trans.*, 62: 205-254, 1999

[3]Submillimeter, millimeter, and microwave spectral line catalog. *J. Quant. Spectr. & Rad. Trans.*, 60: 883-890, 1998

[4]M. Badaoui and M. Alaoui Elbelghiti. A method of determination of line parameters from Fourier Transform Spectroscopy (FTS) data. *Phys. Chem. News*, 21: 94-100, January 2005

[5]G. Wagner, M. Birk, F. Schreier, and J.-M. Flaud. Spectroscopic database for ozone in the fundamental spectral regions. *J. Geophys. Res.*, 107(D22): 4626, doi: 10.1029/2001JD000818 (ACH 10-1 - 10-18), 2002

[6]H. Delouis, "Thèse d'Etat", Orsay-France, 1973

[7]M. Badaoui, "Thèse de Doctorat", Université de Paris VI (07 December 1993)

P 2

Faint NIR Polarimetric Standards

R. Barrena[1], J. A. Acosta-Pulido[1], A. Manchado[1]

[1] *Instituto de Astrofísica de Canarias, Víia Láctea s/n, 38205 La Laguna, Spain*

We supply a catalogue of low polarized standards in J, H and Ks near infrared bands. The catalogue only contains faint targets (J mag∼14) in order to construct a list of reference stars appropriate to be observed in 10m class telescopes. The observations were performed using LIRIS (mounted at WHT telescope) polarization mode, capable to obtain the four light beams, corresponding to the 0, 45, 90 and 135 deg orientations, thanks to a double Wollaston prism. We present a list of ∼50 targets contained in 5 fields distributed in a wide right ascension range.

P 3

Stellar Sources for the In-orbit Spectrophotometric Calibration of the Medium Resolution Spectrometer of the Mid Infra-Red Instrument on board the JWST

Eva Bauwens[1], Joris Blommaert[1], Leen Decin[1,2]

[1] *Instituut voor Sterrenkunde KUL, Celestijnenlaan 200D, B-3001 Leuven, Belgium*
[2] *Sterrenkundig Instituut Anton Pannekoek, University of Amsterdam, Kruislaan 403, NL-1098 Amsterdam, The Netherlands*

For the spectrophotometric calibration of space based instruments, like the Medium Resolution Spectrometer (MRS) of the Mid InfraRed Instrument (MIRI), the accuracy is limited to our knowledge of the spectra of the sources used as calibrators. As the sensitivity of this instrument is much higher than previous ones, there is a need for stars with a high accuracy spectra which can be used as calibrators. These high accuracy spectra combined with a range of different spectral types and a good coverage of the flux range of the instrument by the set of calibration sources, will result in the most accurate spectrophotometric calibration possible.
In this contribution we will describe the method used to obtain these spectra and a first list of candidate sources for this purpose, as well as the preparatory observations needed to further increase the accuracy of the spectra.

P 4

Relative and Absolute Calibration of 1.54m@Danish and WFI@2.2m Telescope Images

A. Calamida[1,2], G. Bono[2], C.E. Corsi[2], L.M.Freyhammer[3], P.B. Stetson[4], R. Buonanno[1]

[1] *Universita' di Roma Tor Vergata, Via della Ricerca Scientifica 1, 00133 Rome, Italy*
[2] *INAF-Osservatorio Astronomico di Roma, Via Frascati 33, 00040, Monte Porzio Catone,Italy*
[3] *Centre for Astrophysics, University of Central Lancashire, Preston PR1 2HE, UK*
[4] *Dominion Astrophysical Observatory, Herzberg Institute of Astrophysics, National Research Council, 5071 West Saanich Road, Victoria, BC V9E 2E7, Canada*

We describe the strategies adopted in the relative and absolute calibration of two different data sets: images collected with the 1.54m Danish Telescope (ESO, La Silla) in the u, v, b, y Strömgren filters and U, B, V, I-band images acquired with the Wide Field Imager (WFI) mounted on the 2.2m Telescope (ESO, La Silla). In the first case, comparing analytical with aperture photometry for each frame, we find a trend in both the X and Y directions of the chip. The corrections result in a set of first and second order polynomials that correct the instrumental magnitudes of each individual frame as a function of X and Y-coordinates. In the case of the WFI camera, instead, we apply two methods, one for images collected before 2002, with the ESO filters $U/38_{ESO841}$ and $B/99_{ESO842}$, and a different one for data secured starting from 2002, with the filters $U/50_{ESO877}$ and $B/123_{ESO878}$. The positional and color effetcs affecting images collected with the old filters, in fact, are larger than those affecting images acquired with the new ones. In the first case we treat the eight WFI chips separately, while in the latter one, we directly corret the WFI pointings.

P 5

Spectro-Interferometric Calibrations: Differential Mode with AMBER-VLTI

Merieme Chadid[1]

[1] *Observatoire de la Cote d'Azur - LUAN, France*

Here, we report new algorithms in the differential mode to calibrate the high resolution spectro-interferometric observations for a non resolved source, using AMBER (Astronomical Multiple BEam Recombiner for the VLTI) and the displacement of the photocenter with wavelenght, independently from the atmospheric turbulence.

P 6

Calibration of AMBER Visibilities

P. Cruzalèbes[1], A. Spang[1], S. Sacuto[1]

[1] *Observatoire de la Côte d'Azur, Laboratoire Gemini, UMR-CNRS 6203, av. Copernic, F-06130 Grasse, France*

VLTI-AMBER interferometric data are usually reduced with a software package resting on the AMDLIB library, available for the community. Rather than using provided standard routines based on various frame selection options, we have developped an alternative processing chain for low resolution H- and K-band data leading to robust estimates of visibilities and their associated errors, mainly based on the spectral analysis of the interferometric measurements. Application to the observation of a bright giant star and its calibrator during a paranalization run is presented.

P 7

SPHERE-IFS: A Tool for Direct Detection of Giant Planets

S. Desidera[1], A. Berton[2], R.U. Claudi[1], R. Gratton[1], J. Antichi[1], M. Turatto[1], M. Feldt[2], K. Dohlen[3], J.L. Beuzit[4], P. Puget[5]

[1] *INAF - Osservatorio Astronomico di Padova, Italy*
[2] *Max Plank Institut für Astronomie, Heidelberg, Germany*
[3] *Lab. d'Astrophysique de Marseille, France*
[4] *Lab. d'Astrophysique de l'Observatoire de Grenoble, France*
[5] *Observatoire de Paris, France*

The 2nd generation VLT instrument SPHERE will include an integral field spectrograph to enhance the capabilities of detection of planetary companions close to bright stars. SPHERE-IFS is foreseen to work in near IR ($0.95 - 1.35\ \mu m$) at very low resolution. We present the concept of the instrument and the plans to achieve extreme luminosity contrast using it.

P 8

The VLT-FLAMES Survey of Massive Stars: Instrumental Stability and Detection of Massive Binaries

C. J. Evans[1], D. J. Lennon[2], I. Hunter[2,3], T. Augusteijn[4], S. J. Smartt[3]

[1] *UK ATC, Royal Observatory Edinburgh, Blackford Hill, Edinburgh, EH9 3HJ, UK*
[2] *Isaac Newton Group, Apart. de Correos 321, E-38700, S/Cruz de La Palma, Canary Islands, Spain*
[3] *Dept. of Physics & Astronomy, Queen's University Belfast, Belfast BT7 1NN, Northern Ireland, UK*
[4] *Nordic Optical Telescope, Apart. de Correos 474, E-38700, S/Cruz de La Palma, Canary Islands, Spain*

We introduce our VLT-FLAMES Large Programme that has observed ∼800 early-type stars in the Galaxy and the Magellanic Clouds. The service-mode data sample a wide range of observational epochs, revealing a large number of massive binaries. In the course of disentangling the kinematics of these systems, cross-correlation techniques reveal the excellent wavelength-stability of the FLAMES spectra – this stability enables well-constrained orbital parameters to be found.

P 9

Developmental Aspects of a Multi-Slit Spectro-Polarimeter

Koshy George[1], K. Sankarasubramanian[1], Raja Bayanna[2], Haosheng Lin[3], P. Venkatakrishnan[2]

[1] *Space Astronomy and Instrumentation Division, ISRO Satellite Centre, India*
[2] *Udaipur Solar Observatory, Physical Research Laboratory, India*
[3] *Institute for Astronomy, University of Hawaii, USA*

We report the development aspects of an integral field unit, multi-slit spectro-polarimeter (MSSP) operating in optical to near infrared regime, which can be used to derive simultaneous spectral and vector magnetic field information at high spatial, spectral and temporal resolution of any extended astronomical object like the Sun, with limited spectral coverage. The instrument will be first developed and tested in laboratory which in a later stage will be used as a focal plane instrument for the Multi application solar telescope (MAST). The major technological challenges inolved in setting up and calibration of the instrument will be discussed. The scientific motivation for the system will be highlighted, with special emphasis on science limitations imposed by similar existing instruments elsewhere.

P 10

Efits, A New Efficient and Flexible FITS Library

A. Grado[1], M. Pavlov[2,3], M. Capaccioli[2], L. Limatola[2]

[1] *INAF-Osservatorio Astronomico di Capodimonte, Naples, Italy*
[2] *INAF-VSTceN, Naples, Italy*
[3] *Sternberg Astronomical Institute, Moscow, Russia*

The era of petabyte data-flow regime and precision astronomy calls for an overall efficiency of the software used to process the data and a careful control on the errors introduced by the processing. We present a new fits library called Efficient fits (Efits) developed to satisfy basically two requirements. The first related to the efficiency and flexibility and the second one related to the accuracy. To achieve the first goal the library contains special mechanism/layer, which supports different I/O methods (disk and shared memory, currently), and allows easily to extend the set of supported methods in the future. The usage of the shared memory allows to efficiently exchange data among independent processes in a modular pipeline, also the library can work on single extension of FITS file extracted directly from Multiple Extensions FITS (MEF) files without previously splitting them. For the second goal a true noise map, mandatory in some science application, is created implementing a noise map propagation mechanism which create (or modify) a noise map each time a mathematical operation is performed on an image. Structure, mechanisms adopted and preliminary results are presented.

P 11

Error Propagation in the X-Shooter Pipeline

M. Horrobin[1], P. Goldoni[2], F. Royer[3], P. François[3], G. Blanc[2], J. Vernet[4], A. Modigliani[4], J. Larsen[4]

[1] *University of Amsterdam, the Netherlands*
[2] *APC/UMR 7164, France*
[3] *GEPI, Observatoire de Paris-Meudon, France*
[4] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748, Garching bei München, Germany*

The pipeline for the 2nd generation VLT instrument X-Shooter, which is currently in production, will be the first ESO pipeline to fully propagate errors from raw data through to fully reduced science products. This poster gives an overview of the motivations, complications and solutions of found during its development.

P 12

Present and Future Instruments Involving Spectropolarimetry

Swetlana Hubrig[1]

[1] *European Southern Observatory, Casilla 19001, Santiago 19, Chile*

We present the potentials and advances of existing and planned facilities which have a spectropolarimetric mode. Emphasis will be put on the methods of measurement and their accuracy.

P 13

QC and Analysis of MIDI Data Using *mymidigui* and OYSTER

C. A. Hummel[1]

[1]*European Southern Observatory, Casilla 19001, Santiago 19, Chile*

In April of 2004, the MIDI mid-infrared beam combiner on the VLTI of the European Southern Obervatory on Cerro Paranal became the first interferometric instrument world-wide offered to the astronomical community in service mode. That operational model, geared towards users who are not necessarily experts in interferometry, deserves special attention in the areas of successful use and reliability of the results.

A tool has been written by the author for Paranal Science Operations to support quick-look data quality control, in parallel with the MIDI pipeline. MyMidiGui is based on the MIA+EWS data reduction software developed by MIDI consortium members University of Leiden and Max Planck Institute for Astronomy in Heidelberg. MyMidiGui offers additional capabilities to examine the acquisition images and photometry exposures. All calibrator data taken by ESO telescopes are in the public archive, and can therefore be used to study real-life instrument performance and evolution. We report on these results including the new SCI_PHOT mode.

P 14

Origin and Processing of Fringing in the VIMOS IFU

E. Jullo[1], L. Christensen[1], A. Smette[1], S. Bagnolo[1], C. Izzo[2], G. Marconi[1]

[1] *European Southern Observatory, Casilla 19001, Santiago 19, Chile*
[2] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748, Garching bei München, Germany*

In addition to the detector fringing, the VIMOS IFU suffers from additional fringing that may produce flux variations of 10% even in the V band. Their origin has not been clearly determined.

In this report, we present the analysis of calibration data obtained in October 2006. We show that fringing originates at the level of the pseudo-slits, likely at the interface between the output lenses of the fibers and the prisms used to fold the beams towards the spectrograph. Data seem to indicate that the glue used to fix the lenses to the prism has become loose in a number of pseudo-slits. The instability of the fringes are likely caused by the imperfect fixation of the prisms.

P 15

The CRIRES Data Reduction Challenges

Yves Jung[1], Paul Bristow[1]

[1] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748, Garching bei München, Germany*

CRIRES is a cryogenic high-resolution pre-dispersed infrared echelle spectrograph, developed by ESO. It provides a resolving power of up to 100,000 between 1 and 5 micrometers.

Science operations with CRIRES will start from P79 on, and the data reduction pipeline is in a rather advanced state. It has been used during commissionning and Science Verification runs to evaluate the sensitivities and the stability of the instrument in the different modes.

Beside the usual infrared specific calibration difficulties, the high resolution capabilities of the instrument were particularly challenging when it came to the development of a precise, robust and automatic wavelength calibration.

This poster gives an overview of the different tasks achieved by the CRIRES pipeline, and concentrates on the whole wavelength calibration strategy including the physical model development, a new correlation method, and the problems linked to the instrument high resolution.

P 16

Circular Polarization Observations in ESO by Using UT2 and FORS1

Seppo Katajainen[1], Vilppu Piirola[1], Harry Lehto[1], Andrei Berdyugin[1]

[1] *Tuorla Observatory, Univ. of Turku, Finland*

We present results from circular polarimetry made by using UT2 and FORS1. In our ESO Programs 076.D-0608A, 076.D-0608B and 077.D-0499A between Dec 12 2005 and Apr 20 2006, we observed a sample of Intermediate Polars (IPs, magnetic cataclysmic variables) by circular polarimetry. The aim of our studies were to detect possible weak polarization effects in Intermediate Polars (IPs) and to find out how many of IPs in our sample are polarized and to calculate also their magnetic field stregths via polarimetry.

The measured polarization found in a sample of Intermediate Polars varied from nearly zero per cent up to few per cent, and thus we needed high S/N. As the polarization in these objects is due to cyclotron cooling effects near the surface of the WD, and the WD has typically a spin period between 10 and 20 minutes (in some systems only few minutes) we also needed high time resolution to cover enouh well fast circular polarization variations. These requirements all together underlineds the importance of large telescopes and their light collecting power, such as found in VLT. In some cases even VLT and FORS1 combination was found to be slightly limited in search for very weak polarization effects combined with high time resolution. The FORS1 circular polarization data reduction and calibration methods are discussed.

P 17

CRIRES: Establishing Wavelength Standards in the Near Infrared

F. Kerber[1], A. Seifahrt[1], P. Bristow[1], G. Nave[2], H.U. Käufl[1], M.R. Rosa[3], C.J. Sansonetti[2], R. Siebenmorgen[1,4], A. Smette[4]

[1] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748 Garching, Germany*
[2] *National Institute of Standards and Technology, Gaithersburg, MD, USA*
[3] *Space Telescope European Co-ordinating Facility, Karl-Schwarzschild-Str.2, D-85748 Garching, Germany*
[4] *European Southern Observatory, Casilla 19001, Santiago 19, Chile*

We report on our efforts to provide high accuracy wavelength calibration to the scientific observations with the Cryogenic High-Resolution IR Echelle Spectrograph (CRIRES), ESO's new high resolution (R∼100,000) infrared (IR) spectrograph at the VLT. Traditionally, astronomical spectroscopy in the near IR has relied on atmospheric features of the night sky for wavelength calibration. In particular the lines from rotation-vibration levels of the hydroxyl radical OH (Meinel bands), which account for the night time OH airglow emission, are routinely used for this purpose.

In order to provide reliable and accurate wavelength standards for CRIRES the European Southern Observatory (ESO), in collaboration with the the Space Telescope European Co-ordinating Facility (ST-ECF) and the National Institute of Standards and Technology (NIST), embarked on a project to establish Th-Ar wavelength standards in the 900 nm–5000 nm operating range of CRIRES. Based on current findings we conclude that Th-Ar hollow cathode lamps hold the promise of becoming a standard source for wavelength calibration for near IR astronomy, providing a high density of sharp well-characterized emission lines with the ease and efficiency of operation of a commercial discharge lamp. In addition, and for use at wavelengths larger than 2500 nm, we have used existing data from NIST on the spectrum of the N_2O to establish a gas cell filled with N_2O as a calibration source.

Both sources were extensively tested during CRIRES commissioning runs and both will be used for routine operations of the instrument. We will give an account of the results achieved so far with an emphasis on comparison of laboratory data and observations obtained during CRIRES commissioning.

P 18

A User's View of VIMOS-IFU Calibrations

Harald Kuntschner[1]

[1] *Space Telescope European Co-ordinating Facility, ESO, Karl-Schwarzschild-Str.2, D-85748, Garching bei München, Germany*

The ESO VIMOS-IFU pipeline produces wavelength calibrated spectra for all working fibres and each quadrant separately. Using a recently carried out science program with VIMOS-IFU (HR-blue, 13" $\times$ 13") I analyse the quality of the basic calibrations.

Furthermore, I study the instrumental resolving power as function of wavelength and position within the field-of-view (FOV). A rather large variation between 1.8 – 3.0 Å(FWHM) is found. There are clear trends with wavelength, but most importantly, significant differences between Fibre Modules are visible. The differences between Modules translate into sharp steps within the FOV and can jeopardize the scientific exploitation if not corrected for.

P 19

Recent Developments in the Optimal Extraction of UVES Spectra

Jonas Møller Larsen[1], Pascal Ballester[2], Valentina D'Odorico[3], Cédric Ledoux[4], Andrea Modigliani[2], John Pritchard[2], Hugues Sana[4], Alain Smette[4]

[1] *Rovsing A/S, Dyregaardsvej 2, DK-2740 Skovlunde, Denmark*
[2] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748, Garching bei München, Germany*
[3] *INAF - Osservatorio Astronomico di Trieste, via G.B. Tiepolo 11, Trieste I-34131, Italy*
[4] *European Southern Observatory, Casilla 19001, Santiago 19, Chile*

The UVES data reduction pipeline has been supporting UVES operations since April 1st, 2000 and is available to the science community for the reprocessing of data with personalized reduction strategies.

It uses the technique of optimal extraction to achieve higher signal-to-noise (S/N) of faint objects, corresponding to an increase in effective exposure time up to 70% compared with a simple extraction.

Initial releases of the pipeline had limitations in the extraction quality at certain S/N ranges. We describe the challenges specific to extracting high and low S/N echelle data, a new implementation to overcome these challenges and present results showing significant improvements with respect to earlier versions.

P 20

ALBUM, a Tool to Analyse Slitless Spectra from the ESO Wide Field Imager

C. Martayan[1,2], D. Baade[1], J. Fabregat[3], M. Floquet[2], A.-M. Hubert[2], E. Bertin[4], C. Neiner[2]

[1] *European Southern Observatory, Karl-Schwarzschild-Str. 2, D-85748 Garching bei München, Germany*
[2] *GEPI-Observatoire de Paris, 5 place Jules Janssen, 92195 Meudon cedex, France*
[3] *Observatori Astronmic de la Universitat de Valncia Edifici Instituts d'Investigaci Polgon La Coma 46980 Paterna Valncia, Spain*
[4] *Institut d'Astrophysique de Paris, , 98bis boulevard Arago, 75014 Paris, France*

We report on a new software tool - ALBUM - to reduce and analyse spectra obtained with the unique slitless spectroscopic mode of the ESO Wide Field Imager at the 2.2-m MPG telescope on La Silla.

The task is illustrated with some sample observations performed in a survey for emission line stars in the Magellanic Clouds. In order to reduce the effects of overlapping spectra, the spectral coverage was limited by a narrow Halpha filter. The challenges associated with this particular mode of the WFI in general - and a very poor focusing in particular - are identified, and we explain the methods adopted for the reduction of the CCD images, the extraction of the spectra, the astrometric calibration, the cross correlation with other catalogs, etc. Next, our code ALBUM is described, which is used to analyse the $\simeq$8 million spectra obtained and to detect the signature of line emission in Halpha. First estimates of the proportions of emission-line stars, especially of Be stars in SMC clusters, are discussed and compared with the Milky Way. Finally, we also present results on a statistical study of the variability of WFI-selected Be stars in the SMC in the OGLE database.

P 21

Paranal NIR Extinction Coefficients

E. Mason[1], G. Lombardi[1], C. Lidman[1], A.O. Jaunsen[1]

[1]*European Southern Observatory, Casilla 19001, Santiago, Chile*

ISAAC at Antu is a NIR imager and spectrograph which is in operation since 1999. Its calibration plan foresees the observation of a photometric standard star during the evening twilight, when the instrument is in use. The ESO archive (http://archive.eso.org) contains a large amount of photometric standard stars observations which can be used to characterize the NIR extinction of the Paranal site. This has been done by us retrieving and analyzing all the Persson standards (Persson et al. 1998) that have been observed with ISAAC/SWI in the JJsHKs filters during PHO or CLR nights. Results are presented together with the color term correction applicable to ISAAC SW filters.

P 22

VIMOS Total Transmission Profiles for Broad-Band Filters

S. Mieske[1], M. Rejkuba[1], S. Bagnulo[2], C. Izzo[1], G. Marconi[2]

[1] *European Southern Observatory, Karl-Schwarzschild-Str. 2, D-85748 Garching bei München, Germany*
[2] *European Southern Observatory, Casilla 19001, Santiago, Chile*

For each of the four VIMOS quadrants, we present total transmission profiles in the broad band filters (U, B, V, R, I, z). Those are obtained from recent observations of spectrophotometric standard stars, using the low resolution grisms LR blue (U,B,V) and LR red (R,I,z). What has been available to ESO up to now are the "average" efficiency curves for all four quadrants (available through the ETC), whereas some of our customers asked for the characteristics of the individual quadrants. We investigate complementary ways of deriving filter transmission estimates, and compare the derived curves with the values used by the ESO ETC.

P 23

Improvements in the Residual OH Emission Removal in SINFONI Pipeline Spectra

Andrea Modigliani[1], Richard Davies[2], Christophe Dumas[3], Mark Neeser[1]

[1] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748, Garching bei München, Germany*
[2] *Max Planck Institut für extraterrestrische Physik, Postfach 1312, D-85741 Garching, Germany*
[3] *European Southern Observatory, Casilla 19001, Santiago 19, Chile*

The strong and variable OH air-glow emission lines in the 1-2.5 micron spectra impose severe restrictions on the observing strategy. This is particularly true for instruments which use Integral Field Spectroscopy techniques to sample the sky, as they are characterized by a narrow field of view.

SINFONI is an integral field spectrograph which combines Near Infrared spectroscopy and adaptive optics and whose field of view is image sliced. It is mounted at Yepun, the fourth Unit Telescope (UT4) of the ESO-VLT and has been operational since April 1st, 2005.

SINFONI operations are supported by a pipeline, as part of the Data Flow Operations.

The standard SINFONI observational strategy is to do a sequence of object-sky observations to sample the object and the sky at regular intervals. This observing technique is limited temporally by changes in the flux of the OH lines on time scales of 2-3 minutes, spectrally by variations in flux among individual OH lines, and by instrument flexures which may result in spectral format shifts, which can lead to P-Cygni type residuals.

These effects are indeed present in some spectra generated by early pipeline releases and triggered the search for an improved algorithm that can correct them. As part of a collaboration between ESO and MPE, we have implemented in the SINFONI pipeline an algorithm originally developed by MPE to solve these problems. In this paper we present the first results of the new algorithm.

P 24

Calibration of the Relationship between Precipitable Water Vapor and 225 GHz Atmospheric Opacity via Optical Echelle Spectroscopy at Las Campanas Observatory

Joanna Thomas-Osip[1], Andrew McWilliam[2], Mark Phillips[1], David Osip[1]

[1] *The Observatories of the Carnegie Institute of Washington, Las Campanas Observatory, Chile*
[2] *The Observatories of the Carnegie Institute of Washington, USA*

We report on the calibration of the relationship between precipitable water vapor and opacity at 225 GHz at Las Campanas Observatory as measured by a Tipping Radiometer. This relationship is a function of altitude and temperature and thus is highly dependent on location. We determine the relationship applicable at Las Campanas Observatory by using high-resolution Magellan Echelle spectra to measure the precipitable water vapor independently and absolutely. Temperature insenstive (between 220-300K) lines allow the use of a single temperature atmospheric model as long as the lines are unsaturated. Absolute calibration was achieved by measuring the humidity in the path length of the McMath Solar telescope with a psycrometer[1]. We have expanded the method presented by Brault et *al.* (1975) with improved partition functions and additional lines. Based on this calibration, we present Southern hemisphere winter-time precipitable water vapor statistics for Las Campanas Observatory as measured during a two month campaign. We find that the median winter value of 2.4 mm is consistent with that measured at the nearby La Silla Observatory during the VLT site survey [2] and inconsistent (lower by a factor of approximately two) with estimates, also for La Silla, derived from GOES-8 satellite imagery and the European Centre for Medium-Range Weather Forecasting (ECMWF) meteorological numerical model [3]. Furthermore, in the Southern hemisphere winter months, we can expcect good conditions for infrared observing $\leq$1.5 mm) at the tenth percentile level.

References

[1] Brault, J.W., Fender, J.S., & Hall, D.N.B. 1975, *JQRST*, 15, 549.

[2] Morse, D. & Gillett, F. 1982, AURA Eng. Report 73.

[3] http://www.eso.org/gen-fac/pubs/astclim/lasilla/h2o/

P 25

The Use of Telluric Lines for Wavelength Calibration in L and M Band

Christina Papadaki[1], Linda Schmidtobreick[1]

[1]*European Southern Observatory, Casilla 19001, Santiago, Chile*

With ISAAC's long wavelength medium resolution spectroscopic mode, we observed telluric standard stars covering the whole possible wavelength range (2.6μm - 5.1μm). We measured the position and strength of the telluric lines present in the spectrum. Arc lamps taken directly after each spectrum provide a precise wavelength calibration for these sky-lines. We compare the spectrum and the telluric lines with synthetic sky spectra, and find a good correlation. The synthetic spectra also allow the identification of the observed telluric lines.

We provide a catalogue and an atlas of these lines to use for later wavelength calibration. This will go into the ISAAC pipeline.

P 26

VLTI Instruments: From J to N Band Instrumental Calibrations, from Short to Long Baseline Astronomical Calibrations

Isabelle Percheron[1]

[1] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748, Garching bei München, Germany*

There are two VLTI instruments offered to the community: AMBER, the Astronomical Multi-BEam combineR operating in the JHK bands and MIDI, the Mid-Infrared Interferometric Instrument operating in the N Band.

For these two instruments, normal detector and instrument calibrations (such as the determination of the Read-Out-Noise, of the Bad Pixel Map, or of the transmission of the optical elements) must be measured following a specific calibration plan. In addition, data to determine the calibration of the full system have to be taken continuously during the scientific observations to remove the instrumental effects and the distortion due to the turbulent atmosphere.

We will show here some of the detector and the instrumental calibration, and we will emphasize on the calibration of the full system (atmosphere, VLTI instruments and VLTI sub-systems such as MACAO, the AO system for the VLTI). We will describe the procedures to select and observe an astronomical calibrator suitable for the calibration of the science target. To choose the best calibrator, one has to take into account the length of the baseline, the spectral type and the position in the sky of the scientific object, the size of the telescopes as well as the atmospheric parameters at the time of the observation. We will present some of the results of the analysis of these calibration data. We will show how these results are monitored over different periods of time to insure an accurate calibration of the scientific data observed with the VLTI instruments.

P 27

Laboratory Measurements of Calibration Sources for X-shooter

F. Saitta[1], F.Kerber[1], P. Bristow[1], H. Dekker[1], S. D'Odorico[1], C. Dupuy[1], J.-L. Lizon[1], A. Norup Sorensen[2], J. Vernet[1]

[1] *European Southern Observatory, ESO, Karl-Schwarzschild-Str.2, D-85748 Garching, Germany*
[2] *Copenhagen University Observatory, Juliane Maries Vej 30, DK-2100 Copenhagen OE , Denmark*

We report on simulations and laboratory measurements to characterize the spectral output and operational properties of a selection of pen-ray lamps containing the noble gases Ne, Ar, Kr, and Xe as well as a Th-Ar hollow cathode lamp. The tests are being done at ESO with a commercial Fourier Transform Spectrometer. Based on the results of the laboratory work one will select which combination of these lamps will be used as calibration sources for the near-IR arm (1000–2500 nm) of the X-shooter spectrograph.

P 28

THELI - Automatic Reduction of UV to mid-IR Imaging Data

Mischa Schirmer[1], Thomas Erben[2]

[1] *Isaac Newton Group of Telescopes, Santa Cruz de La Palma, Spain*
[2] *Argelander Institut für Astronomie, Universität Bonn, Germany*

THELI is a stand-alone package for the automatic reduction of imaging data, mostly based on C/C++ programmes, and can be run on the command line or by means of a GUI. The entire reduction process is fully transparent to the user and essentially instrument-independent. Data from optical multi-chip cameras is handled as well as the intricacies of near-IR and mid-IR imagers.

P 29

A New Generation of Spectrometer Calibration Techniques with Optical Frequency Combs

Piet O. Schmidt[1], Stefan Kimeswenger[2], Hans-Ulrich Käufl[3]

[1] *Institute of Experimental Physics, Technikerstr. 25, A-6020 Innsbruck, Austria*
[2] *Institute of Astro- and Particle Physics, Technikerstr. 25, A-6020 Innsbruck, Austria*
[3] *European Southern Observatory, Karl-Schwarzschild-Str. 2, D-85748 Garching, Germany*

Astronomical spectrographs have a resolution ($\Delta\lambda/\lambda$) ranging between a few hundred to 80 000 (Appenzeller et al. 1998, Käufl et al. 2004). They are usually calibrated using HeAr and ThAr lamps for low and high resolution spectroscopy, respectively. These lamps emit lines according to the atomic or molecular species that is excited in the gas discharge. Unfortunately, the position of the emitted lines from a single lamp typically covers only a small fraction of the spectrometer's spectral range. Furthermore, the exact position of the lines depends strongly on environmental conditions. Another problem is the strong intensity variation between different lines. For example, the HeAr lamp overexposes the 5 876 Å line while nearly no other line is visible between 4 000 and 6 900 Å (line intensity ratios > 300). High order fitting of the instrument's dispersion relation, although needed, isn't possible. Future instruments will have an improved resolution limit, possibly reaching up to 1 000 000. Laboratory precision laser spectroscopy has experienced a major advance with the development of optical frequency combs generated by pulsed femto-second lasers. These lasers emit a broad spectrum (several hundred nanometers in the visible and near infra-red) of equally-spaced "comb" lines. Self-referencing of the laser establishes a precise ruler in frequency space that can be stabilized and calibrated to the 10^{-18} uncertainty level (Stenger et al., 2002, Zimmermann et al. 2004). The invention of these lasers has revolutionized precision optical spectroscopy.

We propose the exploration of the merits of this new technology for the calibration of astronomic spectrometers. Optical frequency combs provide equally spaced lines of well defined frequency and intensity ratios typically < 10. The absolute frequency of these lines can be stabilized via the Global Positioning System's (GPS) time signal to an absolute precision of better than 10^{-12} per day. The typical separation of 100 MHz would require a resolution of 20 000 000 or more. Astronomical spectrographs will see these devices as white light sources. We propose here two complementary solutions to this issue, depending on the resolving power of the spectrometer to be calibrated. Further investigations and laboratory are planed.

For medium and high resolution spectroscopy we propose to filter the output of a frequency comb generator with an external cavity. Interference inside the cavity leads to a frequency dependent transmission of the incident light. The length of the cavity defines the spacing of the transmission maxima, whereas the mirror reflectivities determine their width. We can choose these parameters in such a way that a whole set of neighboring comb lines will be transmitted e.g. every 500 GHz ($\Delta\lambda$=6 Å @ 6 000Å). These numbers can be easily varied by several orders of magnitude in either direction.

Calibration of spectrometers with a resolving power below 1 000 may not need the accuracy and associated technical effort. We propose to use a spectrograph grating to split and recombine the output of a white light source into its components. In between, a mask containing selectable transparent slits is used to block or transmit selected components. This can be either a fixed lithographically produced mask or a more versatile spatial light modulator. A spatial light modulator consists of an array of liquid crystal elements that can be individually switched electronically to transmit or block light. That way, the pattern can be dynamically adjusted to fit the different resolutions required for different spectrograph modes.

References:

Appenzeller, I., Fricke, K., Furtig, W., et al., 1998, Messenger, 94, 1

Käufl H.-U., Ballester, P., Biereichel, P., et al., 2004, SPIE, 5492, 1218

Stenger, J., Schnatz, H., Tamm, C. & Telle, H.R., 2002, PRL, 88, 073601-1-4

Zimmermann, M., Gohle, C., Holzwarth, R., Udem, T., & Hänsch, T.W., 2003, Opt. Lett., 29, 310

P 30

Near-Infrared Photometric Standards for GTC/EMIR

Marc Vallbé Mumbrú[1], L. López[1], A. Di Cesare[1], P. Hammersley[1], F. Garzón[1], J. M. R. Espinosa[1]

[1] *Instituto de Astrofísica de Canarias, Spain*

We present a poster about the NIR photometric calibration of standards for EMIR, which affects all the NIR imagers and spectrographs of the GTC. We are building our own database of photometrically stable stars compatible with models of atmospheric emission which are: (1) faint enough so that they don't saturate the detectors (EMIR will saturate on a 14^{th} magnitude star in ~ 1 second when doing broad-band imaging); (2) which are homogeneously spaced along the declinations available to GTC; and (3) which are useful for all the narrow- and broad-band filters (accomplished by accurately determining the spectral energy distribution of a number of the calibration sources to use as spectral flux calibrators). This is part of a large on-going project to set up suitable calibration standards from 0.35 to 2.5 microns.

P 31

Building Up a Database of Spectro-photometric Standard Stars from the UV to the near-IR

J. Vernet[1], F. Kerber[1], S. D'Odorico[1], R. Bohlin[2], V. Ivanov[1], C. Lidman[1], E. Mason[1], T. Rauch[3], F. Saitta[1], A. Smette[1], J. Walsh[4], R. Fosbury[4], P. Goldoni[5], P. Groot[6], F. Hammer[7], M. Horrobin[8], L. Kaper[8], P. Kjaergaard-Rasmussen[9], R. Pallavicini[10], F. Royer[7]

[1] *European Southern Observatory, Karl-Schwarzschild-Str.2, D-85748, Garching bei München, Germany*
[2] *STScI, 3700 San Martin Drive, Baltimore, MD 21218, USA*
[3] *Institut für Astronomie und Astrophysik Tübingen, Sand 1, D-72076 Tübingen, Germany*
[4] *ST-ECF, Karl-Schwarzschild-Str. 2, D-85748 Garching bei München*
[5] *Service d'Astrophysique, Centre d'Etudes de Saclay, F-91190 Gif-sur-Yvette Cedex, France*
[6] *Radboud Univ. Nijmegen, Postbus 9010, 6500 GL Nijmegen, The Netherlands*
[7] *Obs. de Paris, 5, place Jules Janssen, F-92195 Meudon, France*
[8] *Univ. Amsterdam,Postbus 19268, 1000 GG Amsterdam, The Netherlands*
[9] *Niels Bohr Institute for Astronomy, Blegdamsvej 17, DK-2100 Copenhagen, Danemark*
[10] *INAF - Osservatorio astronomico di Palermo Giuseppe S. Vaiana, Piazza del Parlamento 1, I-90134 Palermo, Italy*

We present a project aimed at establishing a set of 13 spectro-photometric standards suitable to support one of the crucial science operation modes of X-shooter: spectro-photometry over a very wide wavelength range from 320 to 2500 nm. Currently no set of standard stars covering this wavelength range is available. We are extending the useful range of existing optical flux standards into the near infrared (NIR) by means of integral field spectroscopy observations with SINFONI combined with sophisticated white dwarf stellar atmospheric models. Using two primary HST white dwarfs as a reference we aim to achieve $\sim 10\%$ accuracy including telluric effects. While this project is tailored to the needs of X-shooter it will also benefit any other NIR spectrographs, providing a huge improvement over existing flux calibration methods. Moreover, the new set of standard stars will also serve as a stepping stone for ELT operations.

P 32

Modelling the Fringing of the FORS2 CCD

J. R. Walsh[1], H. Kuntschner[1], E. Jehin[2], A. Kaufer[2], K. O'Brien[2], M. Riquelme[2], A. Smette[2]

[1] *Space Telescope European Co-ordinating Facility, ESO, Karl-Schwarzschild-Str.2, D-85748, Garching bei München, Germany*
[2] *European Southern Observatory, Casilla 19001, Santiago 19, Chile*

Thinned CCD detectors display fringing which arises from the interference of multiply reflected light in the layers of the CCD. If the layer construction - the thicknesses and refractive indexes of the layers - is known, then the observed fringing can be accurately modelled and used to correct imaging and spectroscopic data for its effects. In practice the specifications on the actual deposited layer thicknesses may not be known to sufficient accuracy to predict the fringe behaviour. Thus calibration data, in the form of monochromatic flat fields, is required and can be modelled using the technique outlined by Malamuth et al. 2003, which has been applied to ACS CCD's.

Initial tests to model the observed fringing of the FORS2 MIT CCD are described. A set of six monochromatic flat fields was generated by shining light from a tunable monochromator into the FORS2 instrument calibration unit. Peak-to-peak fringe amplitude of 7-8% was measured at a wavelength of 970nm. In order to model the CCD structure, a series of monochromatic flats at closely spaced wavelengths is required, which would have been very time-consuming to acquire with the monochromator. An alternative strategy is outlined. The method is quite general and the fringing characteristics of CCDs could be systematically calibrated while still in the test laboratory.

P 33

The MUSE Data Reduction Pipeline - Plans and Status

Peter M. Weilbacher[1], Joris Gerssen[1], Martin M. Roth[1], Petra Böhm[1]

[1] *Astrophysikalisches Institut Potsdam, Germany*

On our poster we will present a short overview of the instrumental properties of the 2nd generation VLT instrument MUSE. We will show which steps are foreseen for data reduction and post processing, and discuss the current design for the overall pipeline and how it is embedded in the VLT Data Flow System. Some details of the first draft implementation will be given as well as the schedule for the data reduction software within the MUSE project.

P 34

Master Response Curves for Flux Calibration of VIMOS Spectroscopy

Burkhard Wolff[1]

[1] *European Southern Observatory, Karl-Schwarzschild-Str. 2, D-85748 Garching, Germany*

The VIMOS instrument offers two spectroscopic modes: multi-object spectroscopy (MOS) using masks with up to 200 slits and an integral field unit (IFU) consisting of 6400 fibres. Spectro-photometric standard stars are observed on a regular basis for both modes. They are intended for measuring the overall instrument efficiency and for providing response curves for flux calibration of scientific observations. The latter goal can, however, not always be achieved with a single standard star exposure because of changing weather conditions during the night and because of operational and instrumental limitations. This problem can be solved by investigating standard star observation from several nights, selecting a good set of response curves from these observations, and finally averaging them. This procedure has been executed for the two spectroscopic modes and all grisms of VIMOS. In this poster, we describe the creation of averaged response curves and demonstrate their usage for relative flux calibration.