Reports on the Conference

Towards the European Extremely Large Telescope

held in Marseille, France, 27 November–1 December 2006

As a prelude to the decision by the ESO Council to approve the detailed studies (Phase B) for the European Extremely Large Telescope (E-ELT) project, a meeting was held in Marseille to comprehensively present and discuss the extensive planning for this exciting project. The conference was attended by 250 astronomers and engineers (see the conference photograph in Figure 1). The strong support, together with detailed considerations and feedback from the community provided by this meeting were instrumental in the ESO Council decision a few days later. They will be further harnessed in the years to come. There were three sessions, devoted to science (1.5 days), the telescope design (1.5 days) and instrumentation (1 day). In the following articles, a summary of each session and the list of speakers and posters is presented, by the chairs of the three sessions: Isobel Hook, Guy Monnet and Jean-Gabriel Cuby.

A general discussion was held on the Thursday morning on various aspects on the project, including the need for flagship science cases, telescope design trade-offs (size, image quality), instrumentation priorities, operating modes and synergies and complementarities with other facilities. The discussion closed with the ELT Standing Review Committee (ESRC) view presented by Roger Davies and the conclusions by the ESO Director General Catherine Cesarsky. The conference web page is at *http://www.elt2006.org* where most of the presentations are accessible.

Photo: J.-P. Goudal, OAMP

Figure 1: Conference photograph taken outside the venue – Le Palais du Pharo – overlooking the Vieux Port of Marseille.

Summary of Science Sessions

Isobel Hook
(University of Oxford, United Kingdom)

The meeting began with sessions dedicated to the science drivers for the European ELT project. Many ELT science themes are already well developed through the work of the OPTICON network (see summary in Hook 2005a and the full science case in Hook 2005b), the OWL science case (see *http://www.eso.org/projects/owl*) and more recently by the ELT Science Working Group (see *http://www.eso.org/projects/e-elt/*). During the 1.5 days of science talks at this meeting these themes were developed and new ideas also emerged.

Extremely Large Questions – and how the ELT will answer

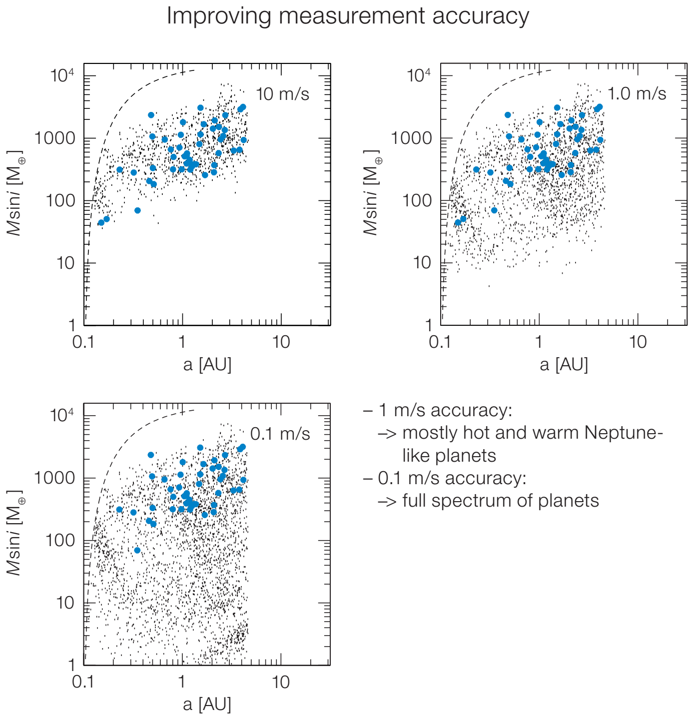
Many of the speakers discussed the current ‘big questions’ in astronomy and the ways in which an ELT will provide answers. Some showed the results of simulations or calculations made using the ELT exposure time calculator (described and demonstrated at this meeting by Markus Kissler-Patig). In the summary below the names of the speakers are given in brackets.

Exoplanets and discs

Some big questions:
- *What is the formation mechanism for planetary systems?*
- *What is the impact of feedback on star formation?*
- *What is the origin of stellar masses and the Initial Mass Function?*

The radial velocity technique – an indirect method for detecting planets via the Doppler wobble that they produce on their parent stars – was highlighted as a very powerful method for studying low-mass planets, and an ELT has the possibility to even reach down to Earth mass planets (Pepe and Chabrier). Improving the accuracy of radial velocity measurements to 0.1 m/s would reveal the entire

Figure 1: Gilles Chabrier in his presentation showed this schematic of the advances in terms of number of exo-planet detections expected from an increase in radial velocity accuracy from 10 ms^{-1} through 1 ms^{-1} to 0.1 ms^{-1}. The individual plots for the mass-distance diagram of exo-planets are from theoretical predictions by Mordasini et al. (2007) based on a theoretical formation model by Alibert et al. (2005). The black dots are the expected detections and the blue circles a comparable subset of known exoplanets. The sharp cutoff at about 5 AU is due to an assumed duration of ten years for the radial velocity survey.



underlying planet population, of which only about 10 % are accessible with current instruments (see Figure 1). This method will provide mass estimates for planets discovered by future transit searches such as COROT and KEPLER.

The ELT's collecting area and spatial resolution will also give it the key ability to directly detect exoplanets, as has been discussed previously (Hook 2005a, 2005b). Among the wealth of physical information provided by direct detection, Chabrier highlighted the use of direct luminosity measurements of the planet to provide key evidence for the initial conditions of the planet formation process. ELT thermal-IR spectroscopy may allow us to distinguish between brown dwarfs and exoplanets via the CO line (although the expected signatures are still not well known).

Direct imaging with an ELT (and JWST, plus astrometric observations, e.g. from GAIA) can extend the search for planets around white dwarfs 4–5 magnitudes deeper than currently possible, bringing new targets into view and allowing detection of planets with masses in the range ~1–3 M_{Jup}. This will tell us about the late evolution of planetary systems (Burleigh).

In the area of star formation the complementarity with other facilities (particularly ALMA and JWST) is very important. The superb spatial resolution of an ELT is a particular strength that will allow it to carry out a census of binary stars in clusters, which provides a probe of their formation mechanism. For example the ELT will be able to measure dynamical masses of brown dwarf binaries via astrometry (McCaughrean).

Superb spatial resolution will also allow the ELT to study dust agglomeration and processing in proto-planetary discs (via mid-IR imaging and spectroscopy, combined with ALMA). The tell-tale signs of planet formation – such as gap formation and disc warping – should be visible via near- and mid-IR imaging in dust and debris discs (McCaughrean). Indeed new simulations (Wolf) show that an ELT could detect local heating of the disc by a planet. The ELT's sensitivity to large dynamic range makes it ideal for studying the outer planet-forming region of the disc, complimentary to interferometry with VLTI for studying the inner regions (Wolf). With an ELT it would also be possible to map out the magnetic field strength in the discs of T-Tauri stars in nearby star-forming regions, as well as the field

Science Session – Talks	
Exoplanets and discs	
Gilles Chabrier	Invited review: Exoplanets
Mark McCaughrean	Invited review: Star formation
Sebastian Wolf	The formation of planets and planetary systems – science case for the ELT
João Alves	Towards pan-star formation
Matt Burleigh	Searching for ancient Solar System planets around white dwarfs
Francesco Pepe	Exoplanets by high-precision radial velocities with ELTs
Galaxy Formation	
Piercarlo Bonifacio	Invited review: Stellar populations
Livia Ogiglia	Near IR spectrosocopy: a powerful tool to trace resolved and integrated stellar populations
Renato Falomo	Probing the stellar population of galaxies with ELT
Simon White	Invited review: Physics and evolution of galaxies
Andrew Bunker	Invited review: First galaxies and reionisation
Matthew Lehnert	The physics of galaxy assembly
Mathieu Puech	Mapping the galaxy mass assembling with ELTs
Steffen Mieske	Cosmic flow studies with the ELT: how far can we reach with the SBF method
Emmanuel Rollinde	The IGM at high-*z*: the UV part of the spectrum

Frontiers of Physics	
Hans-Walter Rix	Invited review: Black holes
Peter Schneider	Invited review: Fundamental constants and cosmological parameters
Jochen Liske	The Cosmic Dynamics Experiment
Paolo Molaro	Varying fundamental constants @ ELT
Rhaana Starling	The highest redshift stars – gamma-ray bursts
Isobel Hook	Simulated observations of distant galaxies (and supernovae) with ELT AO systems
Science Session – Posters	
Philippe Amram	Rotation curves at high redshifts
Masanori Iye	Discovery of a galaxy at z=6.964 and its implication
Markus Kissler-Patig	The E-ELT Exposure Time Calculator
Simona Mei	Evolution of galaxy clusters at $z \sim 1$
Claudia Mendes de Oliveira	The low surface brightness and ultra-compact dwarf population in nearby groups
Paola Merluzzi	Pushing frontiers of galaxy evolution in clusters
Norbert Przybilla	Blue Supergiants beyond the Local Group
Hans Zinnecker	Magnetic fields in young stellar objects and star forming regions: a polarimetric ELT science case

topology over the stellar surface using polarimetry techniques such as Zeeman-Doppler imaging (poster by Zinnecker).

Galaxy formation

Some big questions:
- *What is the distribution of baryonic and dark matter in galaxies?*
- *How does the distribution evolve with redshift?*
- *When and how did galaxy halos form?*
- *What is the assembly sequence of the major components of galaxies?*
- *What is the role of internal versus external processes in building galaxies?*
- *Where did all the angular momentum come from? (observations show significantly more angular momentum than is predicted by galaxy formation simulations).*
- *How and when was the Universe reionised?*
- *How do the heavy elements cycle between galaxy components and the IGM?*

The spatial resolution of an ELT makes observations of individual stars in galaxies beyond our Local Group possible. Falomo highlighted the use of imaging to produce colour-magnitude diagrams (CMDs) – he presented a method of counting stars in regions of near-IR CMDs which, with an ELT, could be used to obtain basic star-formation histories of several galaxies as distant as the Virgo cluster.

An ELT would also be a very powerful spectroscopic tool for the study of stellar populations (Figure 2) – indeed a 42-m ELT would allow spectroscopic measurements about four magnitudes fainter than the JWST in the IR because it could resolve stars in significantly more crowded regions (Origlia). These measurements will tell us about the age of the stellar populations and hence the merger history of the galaxy. This in turn will allow us to understand the location and role of dark matter in the formation process. By using the ultraviolet (UV) parts of the spectrum we can study hot and metal-poor stars (Bonifacio) while in the infrared we can study cool and metal-rich stars, for example using Fe, and CNO as indicators (Origlia). A poster by Przybilla described

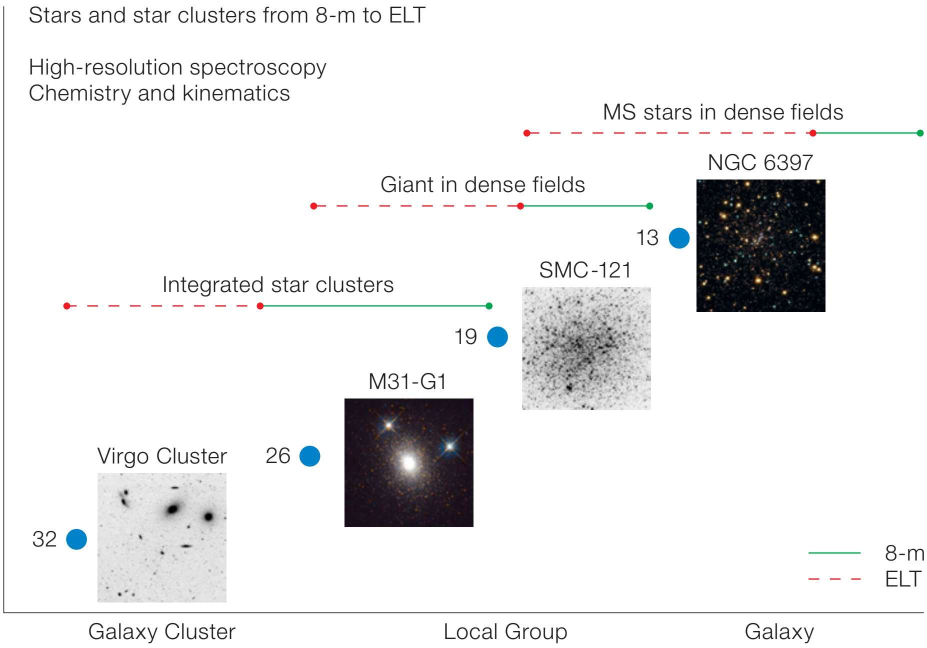


Figure 2: Schematic diagram showing the distance to which various stellar populations can be studied spectroscopically with current 8-m telescopes (green lines) and with a future 40-m ELT (dashed, red lines). The blue circles with associated number indicate the distance moduli of the representative targets (from presentation by Livia Origlia).

improvements in the theoretical interpretation of IR spectra of blue supergiants and the prospects for observing these luminous stars to large distances with an ELT.

ELTs will be capable of studying the very first galaxies, and the partnership of ELTs and JWST (which will be particularly powerful for finding the galaxies) will be crucial in this area (Bunker). Very high redshift galaxies can be found using narrow-band imaging techniques (as demonstrated by the discovery of a $z \sim 7$ galaxy – see the poster by Iye et al.) with JWST or possibly the ELT itself, and their physical properties investigated with ELT spectroscopy. The ELT will have spatial resolution matched to the size of individual H II regions at high redshift (Bunker). Another possibility for finding early galaxies is to locate the host galaxies of Gamma Ray Bursts (Starling). The ELT will also chart the evolution of metal enrichment in the intergalactic medium (Bunker) with spectroscopy of distant 'background' sources such as QSOs and GRBs (Rollinde and Starling).

With an ELT we will be able to study large samples of distant galaxies and measure motions of gas, star-formation rates and chemical abundances at many locations within each galaxy, shedding light on the physical processes at work and the role of dark matter in galaxy formation (Lehnert, Puech, posters by Merluzzi and Amram). The impressive maps of velocity fields in galaxies at $z \sim 2–3$ recently made using integral field spectrographs on the VLT (Forster-Schreiber et al., 2006; Genzel et al. 2006; Nesvadba et al. 2006), are very promising but still allow a range of interpretation because of limited spatial resolution (Lehnert). An ELT will allow higher spatial resolution observations at higher signal-to-noise – for example Puech showed simulated observations of rotation curves at $z \sim 1.6$ and dynamical classification of galaxies to $z \sim 4$ that could be made using an IFU fed by multi-object adaptive optics on an ELT.

In these ways (and combined with what we will learn about black hole formation – see the next section) an ELT will test our understanding of galaxy formation by making detailed comparisons with the predictions of galaxy formation simulations (White).

Frontiers of Physics

Peacock and Schneider (2006) provide a concise overview of this extensive field.

Some big questions:
- *What is the physics of black hole growth?*

– *Can we quantitatively chart new relativistic effects near black holes?*
– *What is the dark matter?*
– *What is the dark energy?*
– *Did inflation happen?*
– *Is standard cosmology based on the correct physics? Are features such as dark energy artifacts of a different law of gravity, perhaps associated with extra dimensions? Could fundamental constants actually vary?*

The extremely high spatial resolution of an ELT will allow us to probe the "sphere of influence" of black holes at large distances from us, and hence measure the abundance of black holes and their masses. Synergy with VLTI (for high angular resolution) and JWST (for surface brightness sensitivity) were pointed out as particularly important (Rix).

Astronomy is uniquely placed to study the effects of dark energy and inflation, and can also make significant contributions to understanding dark matter and the laws of physics (in combination with laboratory experiments). The ELT's collecting area will allow it to make significant advances, for example it will be able to study Type Ia supernovae well beyond the current limits, possibly out to redshifts of around four, allowing us to measure the expansion history of the Universe and hence the effects of dark energy (Hook). With a very high resolution, high-stability spectrograph (such as the CODEX concept) – it will be possible to observe the expansion of the Universe in "real time" over a period of a decade or two (Liske). This direct, dynamical measurement of the expansion of the Universe should match geometrical measurements such as those provided by supernovae – this is a fundamental test of our model of the Universe and the framework of general relativity on which it relies.

An extremely stable, high-resolution spectrograph would also be capable of measuring changes in fundamental constants such as the fine structure constant (α) to much greater accuracy – two orders of magnitude better – than currently possible. Such a measurement is fundamentally important – variation in α would point to extra dimensions in the Universe as predicted by string theory. It would also distinguish between dynamical models for dark energy and Einstein's cosmological constant. Only astronomy can probe the value of these constants in remote regions of space-time (Molaro).

Absorption in the spectra of distant sources caused by intervening clouds of neutral hydrogen provides information about the structure of the Universe on the smallest scales (Rollinde). This can be used to test the model of inflation when combined with measurements on much larger scales (e.g. from Cosmic Microwave Background measurements).

What's New?

At this meeting we obtained a refreshing new perspective on the science case for an ELT. One area given increased emphasis compared to previous science case studies is the UV part of the spectrum. UV spectroscopy of metal-poor stars can be used to understand the discrepancy in Lithium abundances compared to the predictions of the Big Bang Nucleosynthesis model (Bonifacio). The potential use of Berylium and Uranium as age indicators was also highlighted. The UV is also beneficial for the study of QSO absorption lines enabling (for example) the measurement of the non-Euclidean geometry of the Universe which is revealed in a difference in structure evolution observed in angle versus along the line-of-sight (the Alcock Paczynski test, Rollinde).

In addition to 'new' science, some previously-studied cases were given increased emphasis – the radial velocity technique for planet detection is one such case. Improving the accuracy of radial velocity measurements to ~ 1 m/s would reveal mostly hot and warm Neptune-like planets. Improving the accuracy to 0.1 m/s would reveal the entire underlying planet population, of which only about 10 % are accessible with current instruments (Chabrier, Pepe). This requires a very high-stability spectrograph (e.g. CODEX) but also sufficient photons – the ELT will bring a larger sample of stars within reach of this technique.

Mieske introduced the subject of Surface Brightness fluctuation measurements with an ELT – this could potentially allow measurement of the distance scale to 10–15 % out to redshift ~ 0.1, which would dramatically improve the overlap with Type Ia supernovae in the measurement of the extragalactic distance ladder. However, the technique is sensitive to PSF variations across the field and this effect needs to be simulated. The case for using distant Type Ia supernovae to measure the effects of Dark Energy was also given higher prominence at this meeting (Hook).

The velocity field measurements with VLT integral-field instruments show promise for future ELT multi-IFU instruments in the study of the physics of galaxies (as described in talks by Lehnert and Peuch and poster by Amram).

Finally

Throughout this meeting the importance of complementarity with other facilities was a recurring theme. In many cases, future ELT science will be greatly enhanced with data from (for example) COROT, KEPLER, VLTI, ALMA, GAIA and JWST. In some cases contemporary observations are needed, requiring that the ELT is built rapidly so as to be operating at the same time as JWST.

And finally, after hearing about a wonderful range of science that an ELT can do, we should not forget that some of the ELT's most exciting future discoveries were not mentioned at all at this meeting – the ELT will almost certainly reveal surprises in the Universe that we cannot even imagine now!

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Summary of Extremely Large Telescope Session

Guy Monnet (ESO)

The one and a half day ELT Session started on Wednesday, 29 November with presentations of the facility high-level goals. The Basic Reference Design (BRD) of the E-ELT project had been established during the first nine months of 2006 with the help of and for the ESO community. The session mirrored the Basic Reference Design (BRD) process, starting with the final reports from the five topical community-ESO Working Groups (Science, Instrumentation, Adaptive Optics, Site Evaluation and Telescope Design) and followed by the E-ELT top-level requirements, distilled by the ELT Science & Engineering (ESE) Working Group. The BRD of the facility (Telescope, Instruments & Operation) was then presented by the ESO ELT Project Offices, with, in addition, an in-depth presentation of an alternative basic telescope design – the Gregorian option by the Euro50 team.

E-ELT (ESO) Session: The E-ELT Programme	
Catherine Cesarsky	ESO, Europe and the World Scene
Roberto Gilmozzi	Overview of the Programme including ELT-DS
Establishing the basic E-ELT Concepts	
Marijn Franx	Science WG Conclusions
Colin Cunningham	Instrumentation WG Conclusions
Gérad Rousset	Adaptive Optics WG Conclusions
Roland Gredel	Site Evaluation WG Conclusions
Daniel Enard	Telescope Design WG Conclusions
Daniel Enard	E-ELT Top-level Requirements
Towards the E-ELT Basic Reference Design	
Jason Spyromilio	Telescope Design Overview
Arne Ardeberg	Aspects of Combined Gregorian/Nasmyth Design
Sandro D'Odorico	Instrumentation Aspects
Fernando Comerón	Operational Aspects
Jason Spyromilio	BRD Close-out and Discussion
General Discussion on the E-ELT Programme	

E-ELT high-level goals

The ESO goal is to provide an ELT for and to the community, with continuous feedback during the process and full involvement of research institutes and high-tech industries. The decision time was immediately after the meeting, with the objective to start operation of the facility no later than 2018.

E-ELT top-level requirements

The full ELT 'toolbox', created in the first four months of 2006 by the five topical ESE Working Groups is accessible from *http://www.eso.org/projects/e-elt/publications.html* and the five chairs presented a comprehensive summary of their respective Working Group conclusions during the conference. The top-level requirements distilled by ESE call for an instrumentation-friendly visible to mid-infrared collector with a superb image quality, a built-in adaptive optics corrector and a working field of up to 10 arcmin diameter. Special emphasis is put on getting a general-use facility with fast all-sky access and a fully flexible scheduling capability. Attention should be given to synergies with ALMA, VLT and JWST.

E-ELT Basic Reference Design (BRD)

The BRD has been developed by the then (1 June 2006) newly created ESO E-ELT Project Office, still in close connection with the ESO community. It is in charge of the project and is getting advice from the ESE subcommittee established by the ESO STC. Furthermore, the ESO Council has established the ELT Standing Review Committee (ESRC) to oversee the whole project.

Two basic optical designs have been carefully explored. Each holds a 42-m f/1 aspheric primary mirror, covers a 10 arcmin diameter field and offers multiple foci for instrumentation. One, analogous to Euro50, features a three-mirror combination with a concave (Gregorian) secondary mirror. The other is a five-mirror combination with a convex (Cassegrain) secondary mirror. The two designs are shown in Figure 1 of Roberto Gilmozzi and Jason Spyromilio's article on the E-ELT in this issue (page 11).

Detailed mechanical models for both approaches were developed and iteratively optimised. Their pointing performances were established under closed-loop operation. Detailed feasibility, costing and schedule for all critical components – especially the large internal deformable mirror – were obtained. Choosing between these two alternatives provoked lively debates within the Working Groups, especially the Telescope Design one, with ESE and ESRC, and finally during the conference. The final consensus was to take the five-mirror design as the baseline choice henceforth, with the three-mirror option as a backup to be further explored in the next years. Overall feasibility of the project has now been well established, with excellent performance, a global facility preliminary cost around 850 M€ (for a 42-m primary) and a ~ 10 year design and construction schedule.

General Discussion and Conclusions

Following the conference discussions, and given the ESO Council decision, to start immediately the full design phase (Phase B) of the European ELT project, a very large consensus was reached on the following actions:
- develop in parallel with community help an in-depth scientific Design Reference Mission (DRM), identifying in particular flagship science cases (extra-solar planets, physics of galaxies at all redshifts, foundations of physics);
- establish from the DRM the expected scientific performance versus telescope diameter to permit an early decision (June 2007) on that crucial design and cost/timeline parameter;
- put forward, together with the community, a long-term instrumentation plan, scientifically optimised through the DRM, but also featuring a simple instrument ready from Day 1;
- keep the VLT dual operation model (service and classical) with a mix of individual, large and legacy programmes and, when the facility enters into operation, let it evolve with the market;
- establish a high level of collaboration with the other ELT projects, in particular on enabling technology programmes, site selection and cooperation, e.g. plan for complementary instruments with reciprocal access.

Summary of Instrument Sessions

Jean-Gabriel Cuby
(Laboratoire d'Astrophysique de Marseille)

The conference week ended with the instrumentation session on Thursday afternoon and Friday morning (see tables for lists of talks and posters). Instrumentation aspects had been introduced earlier in the week by D'Odorico who presented preliminary designs of the telescope instrument interface and future plans for instrument studies and development. The first part of the instrumentation session on Thursday afternoon was dedicated to presentations of instrument conceptual studies performed in the context of the ELT Design Study (DS), a technology development programme supported by the Sixth Framework Programme (FP6) of the European Commission and coordinated by ESO. Some of these instrument studies were initiated in 2005 in the context of the ESO 100-m OWL telescope and were further elaborated in the framework of the ELT Design Study. Cunningham gave an overview of the eight instruments that would be described later, stressing the main outcomes of these studies and the future plans, and providing a comprehensive overview of the technology developments that will be required. Some of these developments are already being carried out as part of the FP6 OPTICON and ELT DS programmes.

Brandl began the series of instrument talks presenting MIDIR, a mid-IR imager and spectrograph concept for the E-ELT. This is a high visibility, multi-purpose instrument to study in particular planet formation, the Galactic Centre, the environment of black holes, etc. A poster by Lenzen described a VLT instrument concept that could serve as a prototype of MIDIR on the E-ELT, and a poster by Venema detailed some of the technical solutions to be implemented on MIDIR. Dent then presented HISPEC, a high spectral resolution (R ~ 150 000) near-IR spectrograph concept covering a wide range of scientific applications, from the radial velocity detection of low mass exoplanets, the characterisation of exoplanet atmospheres, to the study of the IGM at high redshift.

Two instruments, MOMSI and WFSPEC, looking somewhat similar at first sight, were presented by Evans and Moretto respectively. However, the instruments are aimed at rather different – but both highlight – science cases. MOMSI is a near-IR multi-IFU instrument designed for resolving stars in nearby galaxies – out to Virgo for the brightest populations. WFSPEC is designed for the study of the first objects in the Universe and the study of the physical processes at work in galaxy

Instrumentation Session – Talks

Small Studies	
Colin Cunningham	Overview of the FP6 ELT Instrumentation Programme and Technology Challenges for ELT Instruments
Bernhard Brandl	MIDIR, the Thermal/Mid-IR Instrument for the E-ELT
Bill Dent	HISPEC, the Case for High-resolution Near-IR Spectroscopy on the ELT
Chris Evans	MOMSI: A Multi-object, Multi-field Spectrometer and Imager for the European ELT
Gil Moretto	Wide-field Spectrograph Concepts for the European Extremely Large Telescope
Christophe Verinaud	Imaging and Characterising Exoplanets with the E-ELT: the Challenges of EPICS
Luca Pasquini	CODEX: an High-resolution Visual Spectrograph for the E-ELT
Michael Redfern	HITRI, the High-time Resolution Instrument for the E-ELT
Other concepts and detectors	
Mark Casali	Near-IR Imager for the ELT
Gavin Dalton	IR Detectors
Francisco Garzón	SMART-MOS: a NIR Imager-MOS for the ELT
Eric Prieto	A Target Selection System for ELT Multi-object Instruments: System and Trade-off Analysis
High-contrast imaging	
Anthony Boccaletti	Comparison of Coronagraphs for Exoplanet Imaging with ELTs
Niranjan Thatte	High-contrast Imaging Spectroscopy of Extrasolar-planets with an Integral-field Spectrograph
Wide-field Imaging and Spectroscopy	
Benoît Epinat	Wide-field Spectro-imaging and High-*z* Galaxies: Merit Factor for Several Concepts
Eric Gendron	Multi-object AO System for the E-ELT – Strategy and first results
Roberto Ragazzoni	Wide and Very Wide Field Imaging as a New Challenge for E-ELT Adaptive Optics
Hans Ulrich Käufl	Quantitative Analysis of Infrared Sensitivities for High Altitude Sites

Instrumentation, Adaptive Optics and Site Testing Posters

Bill Dent	SCELT – a wide-field submillimetre camera for the ELT
Denis Fappani	Deformable MS-VLT THIN Shell manufacturing
Marco Ferrari	New active optics techniques for large off-axis segments manufacturing
Olivier Hernandez	Improved 3D spectrograph for ELTs: applications of new technologies
Olivier Hernandez	3DSiS: 3D spectrograph improved simulator for ELTs
Florian Kerber	Calibration of ELT instruments
Rainer Lenzen	An AO-supported Mid-IR facility as a second-generation instrument for the VLT, prototyping the E-ELT
Noria Lorente	SPECSIM: the IFU Spectrometer Simulator
Fabrice Madec	Active beam steering mirror concept for multi-IFU
Patrice Martinez	Optimisation of Apodized Lyot Coronographs for ELTs
Vincent Minier	ArTeMiS: Wide-field submillimetre imager for next-generation telescopes
Iciar Montilla	Monolithic Integral Field Unit Spectrograph for the E-ELT
Hernán Muriel	Site Testing in the North-West of Argentina
Mamadou N'Diaye	Coronagraph feasibility studies on FRIDA
Guy Perrin	Diffraction-limited high dynamic range imaging with the E-ELT from the visible to the infrared
Didier Rabaud	New concept of Real Time Computer based on bi-Xeon cluster ATCA Infiniband for next-generation OA (1000–10000 actuators)
Didier Rabaud	Electronics drive for new generation OA (1000–10000 actuators)
Raymond Sharples	Novel Technologies for Imaging and Spectroscopy
El Arbi Siher	Aerosol index map over North Africa ELT sites
Christian Surace	Towards a new kind of processing software, a FASE prototype
Samantha Thompson	Developments in large adaptive carbon-fibre composite mirrors for ELTs
Lars Venema	MIDIR – technical solutions for the thermal/mid-IR Instrument for the E-ELT
Jean Vernin	Present status of Dome C site testing – Implication for an ELT
Arthur Vigan	ZEUS, a cophasing sensor for the future ELTs
Sébastien Vivès	Innovative Global Approach for High-performance Low-cost Integral-field Unit (IFU)
Frederic Zamkotsian	MOEMS devices for ELT instrumentation

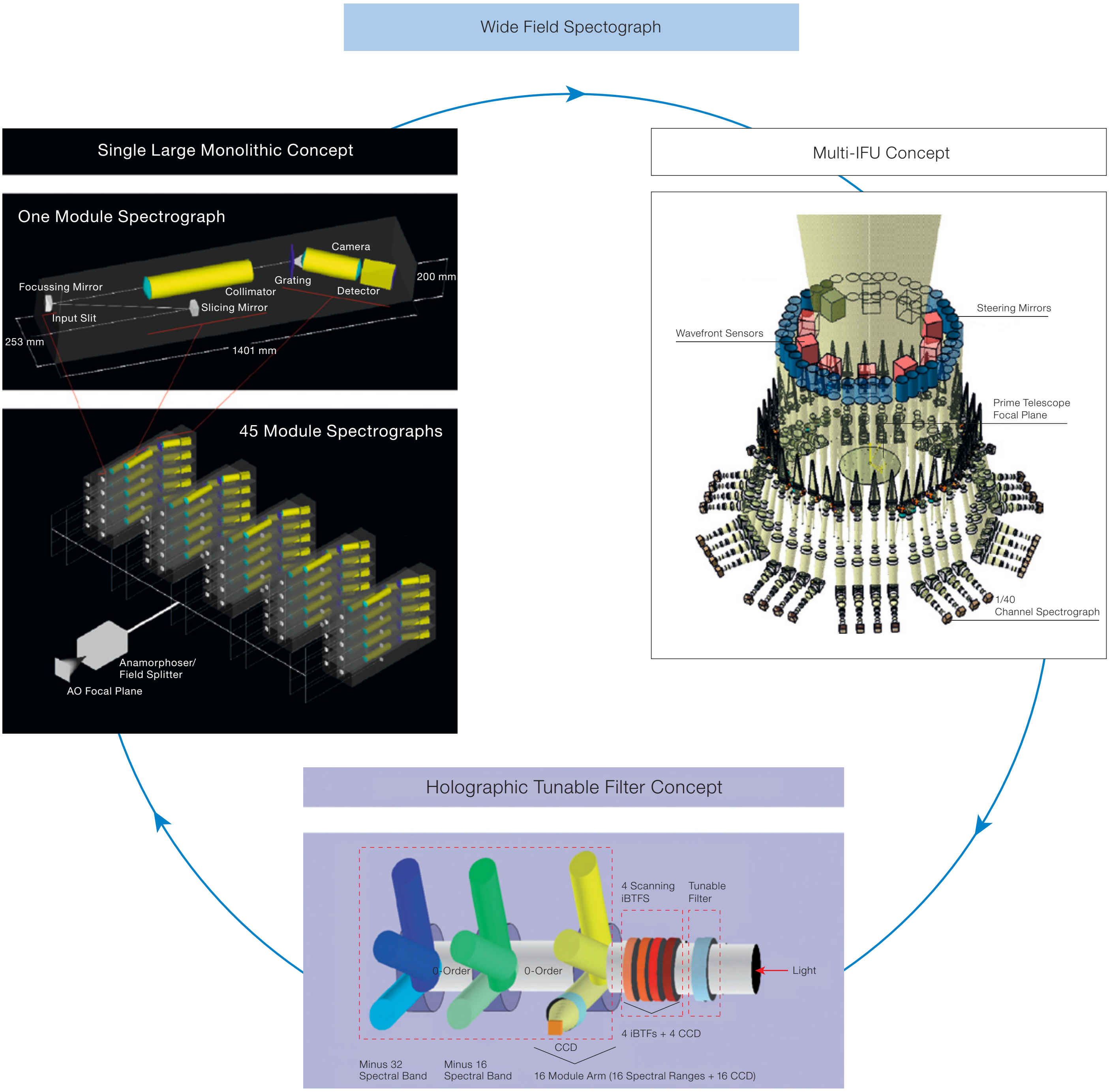

Figure 1: Instrument concept studies were performed as part of the FP6 ELT Design Study. Their aim was to define the global concepts, identify the requirements on telescope and site, and to elaborate roadmaps, but not to perform detailed designs (the interface to the telescope was not available since the E-ELT Basic Reference Design was proceeding in parallel). Here is illustrated the case of a wide-field spectrograph, for which three different concepts were investigated.

formation and evolution across cosmic times. The differences between MOMSI and WFSPEC lie in spatial and spectral resolution requirements. A series of posters described alternative concepts to WFSPEC (Montilla, Hernandez) and detailed aspects of WFSPEC subsystems (Madec, Vives).

The following talks presented what are probably the two most challenging instruments for some of the most fascinating 'extreme' E-ELT science cases. The instrument for detection and characterisation of planets in outer planetary systems (EPICS) was presented by Verinaud. Studies at the frontiers of physics, such as the direct measurement of the differential expansion of the Universe and the universality of the physical constants (the CODEX instrument) was presented by Pasquini. EPICS is one of the most demanding instruments in terms of telescope and Adaptive Optics performance, while CODEX requires innovative instrumental concepts to achieve the required instrument stability.

The day concluded with Redfern stressing the importance of designing E-ELT instruments with detectors providing high-time resolution capabilities that could open up a variety of science cases dealing with rapid phenomena in stars, close binaries, pulsars and AGNs. The last instrument presented which formed part of the ELT Design Study, SCELT, is a submillimetre instrument and a nice complement to ALMA, if the E-ELT was to be located on a very high altitude site (poster by Dent).

Starting the last day of the conference, Casali presented two near-IR imager concepts for the E-ELT, a Narrow-Field MCAO imager and a Wide-Field (~ 7 arcmin) Imager for which various AO options can be contemplated. Some flavour of this instrument is likely to be the first science instrument on the E-ELT. The instrument presented by Garzón relies on MOEMS (MicroOptoElectroMechanical Systems) for a 2 arcmin field of view near IR Multi-Object Spectrograph, using a micro-mirror array. A poster by Zamkotsian provided further details on MOEMS micro-slit and micro-deformable mirror technology and characterisation.

The second part of the instrumentation session concentrated on specific aspects of the instruments or on adaptive optics. Dalton defended the case for an innovative approach to IR detector development and procurement. Indeed, procurement of the many (> 100) 2 k × 2 k IR detectors, ideally required for the complete E-ELT instrumentation plan, would represent one of the highest single cost items of the whole project, not mentioning the risks associated with reliance on a single source procurement. Prieto presented a system and trade-off analysis of a target selection system based on pick-off and beam steering mirrors, including parameters related to the telescope interface. This target selection system can be used to feed a multi-channel instrument, or a multi-purpose instrument facility.

Two talks dealt with methods under consideration for the direct detection of exoplanets. Boccaletti presented a system analysis of various types of coronographs, concluding that the Apodized Lyot coronograph, detailed in a poster by Martinez, was the most promising candidate. Thatte gave a fairly convincing talk on the promise of integral-field spectroscopy illustrated by real data obtained at the VLT with SINFONI on AB Dor.

The relative merits of various instrument concepts (multi-IFU, single-IFU and a scanning system) were illustrated by Epinat for two types of high-redshift galaxy observation: when the position of the sources are known; and for blind searches of line-emitting objects. Gendron presented the challenges of Multi-Object Adaptive Optics (MOAO) with preliminary results from simulations and laboratory measurements, and a roadmap to MOAO, including technology developments and demonstration experiments. Ragazzoni gave as usual a very lively talk, presenting his latest thoughts on the merits of natural and laser guide stars and their impact on the performance of wide (and even very wide!) imaging on an ELT. No doubt this discussion will go on for some time yet. The final talk was by Käufl who presented an interesting model for simulating the atmospheric radiance and transmission in the near-IR, up to five microns, allowing quantification of the gains to be achieved in this thermal IR regime by going to high altitude (and cold) sites. The meeting was brought to a conclusion by Gilmozzi who summarised the many paths that led to the E-ELT design that were presented during the conference in Marseille.

The conference was a timely opportunity to revisit all the instruments that had been in the air, either for OWL or as part of the ELT Design Study effort, and to enter into the details of some of them. It is however clear that the initial suite of the E-ELT instruments will have significantly fewer instruments in total, and/or will require some combinations of those proposed. The process by which these instruments will be selected, studied and procured will be elaborated in the next months, as the whole project proceeds to Phase B. The E-ELT Marseille Conference will be remembered as the place and time where and when the first part of the road to the E-ELT was paved.

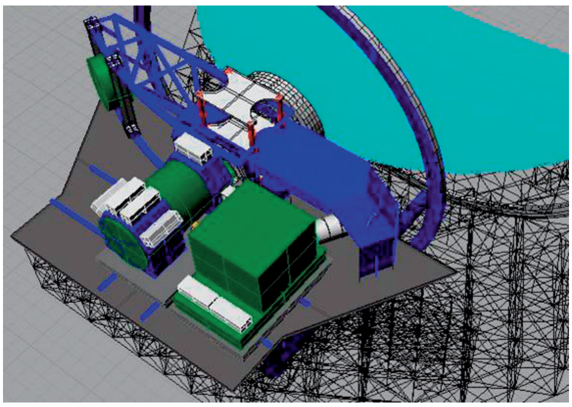

Figure 2: A schematic view of a planned E-ELT Nasmyth platform is shown, with two science instruments in place on the platform and a test camera (green box to upper left).