Shaping E-ELT Science and Instrumentation Workshop

Monday 25/02
ELT projects and first light science

Emiliano Diolaiti (INAF - Bologna)
The MAORY MCAO module for the E-ELT
MAORY is the Multi-Conjugate Adaptive Optics module for the E-ELT. It is designed to relay the telescope focal plane to the E-ELT diffraction limited near-infrared camera and to compensate the wavefront errors due to atmospheric turbulence and other effects such as windshake. In the current baseline design, the compensation of the wavefront errors is performed by the telescope's adaptive mirror M4 and tip-tilt mirror M5 and by two post-focal deformable mirrors integrated in the module. The measurement of the incoming wavefront is performed by a wavefront sensing system using both Sodium Laser Guide Stars and three faint Natural Guide Stars. The MCAO system architecture is based on a robust approach ensuring reliable peak performance as well as high sky coverage. An overview of the baseline design and expected performance is given.

George Jacoby (GMT)
The Instrumentation Plans for the Giant Magellan Telescope (GMT)
I will describe the instrumentation plans for the 25.4-m Giant Magellan Telescope (GMT), focusing on the first-generation suite and schedule, our process for selecting those instruments, and GMT's approach to develop second-generation instruments. GMT is currently developing five instruments; some, and possibly all, of these will be funded for fabrication: an optical echelle (G-CLEF), an optical MOS (GMACS), a near-IR integral field spectrograph/imager (GMTIFS), a JHKLM echelle (GMTNIRS), and a facility fiber feed (MANIFEST). I will also discuss those aspects of the program that continue to be dynamic, changing in response to factors that are inherent to projects of this scale, both internal and external to the partnership.

Luc Simard (TMT)
TMT Instrumentation: First-Light and Beyond
An overview of the current status of the Thirty Meter Telescope (TMT) instrumentation program will be presented. Science cases and operational concepts as well as their links to the first-light and future instruments are continually revisited and updated through workshops and conferences. Work on the three first-light instruments (WFOS IRIS, and IRMS) has made significant progress, and many groups in TMT partner communities are developing future instrument concepts. The main elements of our future instrumentation program will also be described.

Niranjan Thatte (University of Oxford)
HARMONI: the first light visible and near-IR spectrograph for the E-ELT
HARMONI is one of two instruments forming the E-ELT's first light suite. It provides the core spectroscopic capability at visible and near-infrared wavelengths (0.47 to 2.45 μm), over a range of resolving powers from R ($\equiv\lambda/\Delta\lambda$)$\approx$4000 to R$\approx$20000. The instrument is an integral field spectrograph, obtaining simultaneous spectra of $\approx$32000 spatial elements arranged in contiguous field. Spatial scales will range from seeing-limited to diffraction limited, assisted by SCAO (bright natural guide star AO) and LTAO (multiple LGS tomographic AO). HARMONI is conceived as a workhorse instrument that will support a broad range of science programs. HARMONI will excel at ultra-sensitive, diffraction-limited, spatially resolved, physical, chemical and kinematic studies of astrophysical sources. I will present an overview of the

instrument’s capabilities, and highlight several science cases where we expect HARMONI will make a big impact.

Ric Davies (MPE)
MICADO: the E-ELT first light imaging camera
MICADO is the adaptive optics imaging camera for the E-ELT. It has been designed and optimised to work with the LGS-MCAO system MAORY, and will provide diffraction limited imaging over a wide (1arcmin) field of view. For initial operations, and perhaps also more permanently, it can also be used with its own simpler AO module that provides very high performance on-axis using natural guide stars. The instrument will also have a simple spectrograph with a large simultaneous wavelength coverage. I will describe the instrument's key capabilities and expected performance, and outline the instrument concept, pointing out the main changes since Phase A. I will finish by discussing a few of the science drivers, highlighting the astrometric capability.

Gael Chauvin (IPAG)
Exoplanetology with the E-ELT first-light instruments
To introduce almost two decades of exoplanetary hunt, I will summarize the main observing techniques and the key results obtained so far to constrain the physics and the formation mechanisms of exoplanets. After briefly presenting the future ground and space missions in timeframe of the EELT, I will describe the perspective offered by the two first light instruments CAM and IFU, particularly using both high contrast imaging and astrometry. I will then highlight the main instrumental requirements for the success of exploiting the first EELT photons for the characterization of exoplanets.

Seppo Mattila (Finnish Centre for Astronomy with ESO)
Adaptive Optics assisted detection and study of supernovae
A substantial fraction of star formation (SF) and hence of the core-collapse supernovae (CCSNe) in the Universe are hidden behind dust. At higher-z obscured star formation in luminous and ultraluminous infrared galaxies (LIRGs and ULIRGs) actually dominates over SF seen in the UV and optical. These same objects are expected to hide in their nuclear regions large numbers of undetected CCSNe. In this talk I describe our efforts using near-IR adaptive optics (AO) imaging with VLT, Gemini-N and Gemini-S to obtain the most complete picture so far of the SN activity in the nuclear regions of local LIRGs. I will summarise what we can learn from the results already obtained.

Our results demonstrate the potential of the current 8-meter telescopes equipped with AO in discovering and studying SNe within the innermost nuclear regions of LIRGs where their detection in natural seeing limited observations is not possible. Furthermore, our AO assisted observations of SNe are also valuable for testing the feasibility and methods for the future observations of SNe at very high redshifts making use of AO corrected near-IR imaging with the E-ELT.

Tuesday 26/02
Mid Infrared astronomy with the E-ELT

Bernhard Brandl (Leiden University)
All about METIS, the E-ELT mid-infrared Imager and Spectrograph
The "Mid-infrared ELT Imager and Spectrograph" (METIS) will provide diffraction-limited imaging in the atmospheric L/M and N-band from 3 to 14 microns over an 18'x18' field of view. In addition METIS will provide high contrast coronagraphy, medium-resolution (R < 5000) long slit spectroscopy, and polarimetry, in addition to integral field spectroscopy at high spectral resolution (R ~ 100,000) at L/M band. Focusing on highest angular resolution and high spectral resolution, METIS will deliver unique science, in particular in the areas of exo-planets, proto-planetary-disks and intermediate-redshift galaxies.

In my talk I will review the instrument baseline, its expected performance, its technology readiness, and an updated science case, based on new simulations.

João Alves (Universität Wien)
Star and planet formation in the ELT era

TBD

Martin Groenewegen (Royal Observatory of Belgium)
Mid-IR astronomy with the E-ELT: the case for evolved stars

The power of a mid-infrared instrument on an ELT in the domain of evolved stars is discussed. The high spatial resolution is important to study the shaping of the wind, and the transition from the AGB to the PN phase in nearby objects. The sensitivity will allow spectroscopic and imaging studies in many Local Group galaxies.

Josef Hron (Uni Wien)
Study of Evolved Stars and their Circumstellar environment in the mid-infrared

An overview of recent results from studies on evolved stars will be presented in the light of the higher sensitivity and spatial resolution that will be offered by METIS on the E-ELT.
This will include discussion on:
- Molecular envelopes
- Dust structures
- Formation of disks

Rene Oudmaijer (University of Leeds)
Mid-infrared studies of Massive Young Stellar Objects

The formation of massive stars is still a puzzle, and part of the problem has been that the study of their formation can only be done at infrared wavelengths since the objects are deeply embedded in their native material and therefore obscured from view. In this contribution I report on our mid-infrared studies of a sample of Massive Young Stellar Objects that are drawn from a complete sample which we recently constructed from the Leeds RMS survey. Our studies are aimed at characterizing the circumstellar material, outflows and disks which probe the accretion mechanism of these objects. I will present and discuss high resolution near and mid-infrared spectroscopy, mid-infrared MIDI interferometry and diffraction limited imaging as well as near-infrared integral field spectroscopy. Based on the lessons learned, I will then discuss the opportunities offered by the ELT and the METIS instrument in particular.

Andrea Stolte (Argelander Institut für Astronomie)
Simulating E-ELT starburst cluster observations with METIS
As part of the development of the METIS young population science case, we simulate young star clusters in nearby galaxies to check the observational capabilities of a METIS-like instrument at the E-ELT. Combining METIS point-spread functions with existing data sets of Milky Way starburst clusters provides a first idea of the quality of the high-resolution images we can expect at the E-ELT. Modelling a realistic stellar/substellar mass function down to the faintest L-band magnitudes yields a first glimpse of the sensitivity at LMC and further distances that will be one of the major strengths of METIS at the E-ELT.

Ignas Snellen (Leiden Observatory)
Probing exoplanet atmospheres at high spectral resolution using METIS and HIRES
Characterization of exoplanet atmospheres through ground-based high-dispersion spectroscopy has only recently shown its enormous power. At R=100,000, the faint Doppler-shifted planet signal can be separated from the quasi-stationary telluric and stellar features, which has resulted in the first detection of an exoplanet''s orbital velocity (HD209458b - Snellen et al. Nature 2010), and has revealed the inclination and mass of the non-transiting hot Jupiter tau Bootis b (Brogi et al. Nature 2012). Since this observing method makes use of self-calibration techniques without the need of reference stars and requires very high photon-fluxes, it is particularly well suited for extremely large telescopes. I will discuss the wealth of observations that can be performed with the planned METIS and HIRES instruments - from the characterization of molecular content and atmospheric temperature structure, to planet rotation, photochemical processes and even possibly the study of isotopologue ratios. It makes exoplanet characterization a particular area of study in which the E-ELT will significantly outshine the performance of the JWST.

Wolfgang Brandner (MPIA, Heidelberg)
Direct imaging of planets with METIS
Direct imaging detection of exoplanets is challenging both because of the high contrast ratio between exoplanets and their host star, and because of the small angular separation. Direct imaging studies are particularly well suited to study orbital parameters and interactions shaping planetary orbits of multi-planet systems with relatively wide physical orbits (scales 10 to 100 AU), as, e.g., in the HR 8799 exoplanet system. Direct imaging studies, in particular in the METIS wavelength range from 3 to 12 mu, also excel in the spectral characterization of exoplanet atmospheres, whose energy budget is not dominated by the irradiation from the host star (similar, e.g., to Jupiter in the solar system). In the case of young systems, direct imaging enables us also to probe the dynamical and gravitational interaction between exoplanets and the circumstellar disk material, in which the planet originated. In addition, I will also present the requirements to directly detect and image Alpha Cen Bb, a terrestrial planet in orbit around one of our nearest neighbours.

Tuesday 26/02
Galactic astronomy with high spectral resolving power

Max Pettini (IoA, Cambridge)
Near-pristine gas at high redshifts: prospects for the E-ELT
I will describe recent work by our group and others aimed at identifying pockets of near-pristine gas at high redshifts. Analysis of the chemical composition of this gas provides clues to stellar nucleosynthesis in the metal-poor regime that complement those obtained from analogous studies of the oldest stars in the Milky Way and nearby galaxies. They also give us some of the most precise measures of the primordial abundances of the light elements created shortly after the Big Bang. A high-resolution spectrograph on the E-ELT will give us the means to greatly extend this work, which is currently in the photon-starved regime. Ultimately, such observations will clarify the nature of the First Stars and place stringent limits on hypothesised departures from the standard model of particle physics.

Valentina D'Odorico (INAF - Trieste)
Shaping the metal enrichment history *of the intergalactic medium with a high-resolution spectrograph at the E-ELT*

The abundance, distribution and ionization state of chemical elements in the intergalactic medium can be investigated through the signature they leave in the spectra of high redshift bright sources (QSOs, GRBs). These are key observables to understand fundamental processes driving the interaction between galaxies and the surrounding medium (feedback processes, outflows and inflows) and the characteristics of the re-ionization epoch, whose nature is still unclear. In this talk, I will report on the present results in this field and I will try to explain how a high-resolution spectrograph at the E-ELT would be of crucial relevance to draw a complete picture of the metal enrichment history of the intergalactic medium at high redshift.

Roberto Maiolino (University of Cambridge)
Towards the science case for HIRES

In September 2012 a workshop was organized in Cambridge to gather the community interested in the HIRES instrument for the E-ELT to discuss the science cases and the associated requirements. We are now in the process of writing a white paper that summarizes the discussions and presentations given during the workshop, as well as additional input gathered from the community during the past few months.I will summarize the broad range of science cases that have been proposed, with emphasis on the key outstanding topics. I will summarize the main science requirements and tradeoffs. There is a strong requirement for having a very broad simultaneous spectral coverage covering both optical and near-IR bands (from about 3600A to 2.5um). The main observing mode should have a spectral resolution R>100,000. However, there is also a strong demand for having the same broad simultaneous spectral coverage at intermediate resolution (R~10,000-15,000) with some multiplex capability (5-10 objects). Most science cases do not require spatially resolved information, except for a few of them that would strongly benefit from spatially resolved information, at the diffraction limit, with the high spectral resolution mode. I will also discuss the instrument stability requirements. I will mention that these requirements can be achieved through a highly modular concept, making this a low risk instrument, which can be easily upgraded or descoped, depending on budget and technical constraints and scientific priorities.

Pauline Vielzeuf (Universidade de Porto)
Probing dark energy beyond z = 2 with CODEX

Precision measurements of nature's fundamental couplings and a first measurement of the cosmological redshift drift are two of the key targets for future high-resolution ultra-stable spectrographs such as CODEX. Being able to do both gives CODEX a unique advantage, allowing it to probe dynamical dark energy models (by measuring the behavior of their equation of state) deep in the matter era and thereby testing classes of models that would otherwise be difficult to distinguish from the standard LambdaCDM paradigm. We illustrate this point with two simple case studies.

Stefano Cristiani (INAF - Trieste)
The Intergalactic Medium as a Cosmological Probe
The Lyman forest provides a powerful way to measure the baryonic and dark matter distribution at scales and redshifts not probed by other observables. Neutral hydrogen in the Intergalactic Medium (IGM) is a tracer of baryonic matter fluctuations and, at scales above the Jeans length (roughly 1 comoving Mpc at $z = 3$), of the underlying dark matter distribution. In this way, spectra of quasars allow us to measure the matter power spectrum with a unique sensitivity for a running spectral index and warm-hot dark matter. A step forward is represented by the use of multiple lines of sights at close angular separations, which make it possible to carry out cosmological tests such as the one proposed by Alcock-Paczynski in 1979, as well as to investigate in detail the astrophysics of the IGM. At present, these studies are limited by the dearth of close QSO groups bright enough to be observed with sufficiently high-resolution spectrographs at the 8-10m class telescopes. The E-ELT will open an entirely new era in this respect bringing within reach even remote dreams such as the Sandage test, with the direct observation of the cosmic acceleration/deceleration.

Sandra Savaglio (MPE)
Ultra-luminous supernovae at high redshift
Ultra luminous supernovae (ULSNe) are Ideal targets for HIRES at the E- ELT to study the interstellar medium in high-z galaxies, and explore territories difficult both with QSOs and GRBs. Unlike normal SN II or Ia, ULSN are bright in the UV ($M \sim -20$ to -23 mags) and, unlike GRBs, are bright for several months. ULSNe can be identified and followed-up in the optical for $z > 1.5$, which has the advantage that they do not need a gamma-ray or X-ray satellite, for fast identification and precise localization. GRBs can lose 3-4 magnitudes in one day. Still, high-z ULSNe need a very-large aperture because they are fainter than GRBs. In a recent investigation, it was suggested that LBG pairs are good sources of massive star formation, therefore of ULSNe (Cooke et al., 2012, Nature).

Martin Haehnelt (University of Cambridge)
IGM tomography with the E-ELT

Studying the interplay of galaxies and the surrounding Intergalactic Medium from which they form with IGM tomography is one of the key science cases for the E-ELT. I will discuss what we may learn with E-ELT Hires and E-ELT MOS in this way about how galaxies get their gas and how stellar feedback effects influence the gas supply and the physical state of the IGM.

Wednesday 27/02
Galactic astronomy with high spectral resolving power

Jay Farihi (University of Cambridge)
Archaeology of Exo-Terrestrial Planetary Systems: A Long View Science Case for UV-Red Coverage for an ELT-HIRES Instrument

We now stand firmly in the era of solid exoplanet detection via Kepler and other state of the art facilities. Yet the empirical characterization of these most intriguing planets is extremely challenging. Transit plus radial velocity information can yield planet mass and radius, and hence planet density, but the bulk composition remains degenerate and completely model−dependent. The abundances of a handful of exoplanet atmospheres can be estimated from transit spectroscopy, but probing only the most tenuous outer layers of those planets. Fortunately, as demonstrated by Spitzer and complementary ground−based observations, debris−polluted white dwarfs can yield highly accurate information on the chemical structure of rocky minor planets (i.e. exo−asteroids), the building blocks of solid exoplanets. The white dwarf distills the planetary fragments, and provides powerful insight into the mass and chemical structure of the parent body. By studying these planetary system remnants, we gain empirical insight into the assembly and chemistry of terrestrial exoplanets that is unavailable for any exoplanet orbiting a main−sequence star. In the Solar System, the asteroids (or minor planets) are leftover building blocks of the terrestrial planets, and we obtain their compositions -- and hence that of the terrestrial planets -- by studying meteorites. Similarly, one can infer the composition of terrestrial exoplanets by studying the chemistry of their tidally destroyed and accreted asteroids at polluted white dwarfs. Critically for the E-ELT, this science case will remain relevant in 12 years (and well beyond) as there is no other available method to obtain the bulk elemental abundances of solid exoplanets. By 2024 we may have more than 100 known Earth analogs, but only the "archaeological" method will provide empirical information on their surfaces and interiors, and only if we can observe a suitably high number of asteroid-polluted white dwarfs to gain a robust statistical picture of exoplanet chemical structure and formation. To achieve this critical science goal, observers need full optical wavelength coverage (ultraviolet through red, similar to the UVB + VIS arms in X-Shooter) in a high-resolution spectrograph on the E-ELT. I will review this young and innovative field, present state of the art results, current limitations, and synergies with current and future facilities, especially ALMA.

Didier Queloz (University of Cambridge/ University of Geneva)
Setting the stage for exoplanet atmosphere studies with NGTS and CHEOPS
Setting the stage for exoplanet atmosphere studies with NGTS and CHEOPS
Abstract: Detection and measurement of exoplanet atmosphere using transiting planet have open new horizon to understand planet structure and origins. With the E-ELT using HIRES unprecedented programs open up detection of molecules in planet atmosphere will be possible.
I will present two experiments that will change the sceneri. NGTS is a ground base transit detection experiment that will detect and caracterize hot Neptune on bright stars accessible to E-ELT. Cheops mission selected by ESA will detect transiting Earth size planet on the brightest stars of the sky, making possible further caracterization with the E-ELT

Miwa Goto (University Observatory Munich)
Spatially resolved infrared spectroscopy for the study of protoplanetary disks - lesson learned from CRIRES and SINFONI
Spatially resolved infrared spectroscopy for the study of protoplanetary disks - lesson learned from CRIRES and SINFONI
Abstract: We will present the molecular line spectroscopy of protoplanetary disks by CRIRES performed by the highest possible spatial resolution and the highest possible spectral resolution currently affordable to the community. We discuss what we could understand with the VLT and how the ELT opens a new horizon. We will contrast the CRIRES results with the 2D spectroastrometry by SINFONI to show how a high spectral resolution spectrograph would be coupled with an IFU, and why it is necessary.

Leonardo Testi (ESO)
Disk-star interaction and evolution at the time of planet formation
Disk-star interaction and evolution at the time of planet formation
Abstract: In the early phases of pre-main sequence evolution, the evolution of the star and the inner regions of the disk are closely connected. In this phase of evolution, the inner regions of the disk are supposed to host the formation of terrestrial planets. I will discuss high-resolution spectroscopy with the EELT as a unique probe of this region of the disk-star system. I will also briefly mention the synergies and complementarity of EELT and ALMA studies in this area.

Markus Kasper (ESO)
Roadmap for PCS
Presently, dedicated instruments at large telescopes (SPHERE for the VLT, GPI for Gemini) are about to discover and explore self-luminous giant planets by direct imaging and spectroscopy. The next generation of 30m-40m ground-based telescopes, the Extremely Large Telescopes, have the potential to dramatically enlarge the discovery space towards older giant planets seen in reflected light and ultimately even a small number of rocky planets. The E-ELT Planetary Camera and Spectrograph (PCS) serves this purpose. Building on the heritage of the EPICS phase-A study, this contribution presents revised requirements, a possible instrument concept, performance analysis as well as the R&D necessary to realize the instrument.

Eike Guenther (Thueringer Landessternwarte Tautenburg)
Planets in the galactic bulge and in nearby dwarf galaxies
Up to now most surveys for extrasolar planets have focused on stars in the solar neighborhood. We thus know almost nothing about planets in the Galactic Bulge, or in dwarf galaxies. However, theory predicts that the environment plays a crucial role for the process of planet formation. It is therefore expected that the properties of planets depend on whether they have formed in the solar neighborhood, in the Galactic Bulge, or in a dwarf galaxy. In order to understand the formation of planets it is thus highly important find out what impact of the environment on the formation of planets is. A high-resolution echelle spectrograph on the E-ELT would in principle allow to detect planets in the Galactic Bulge and in nearby dwarf galaxies. In this talk the prospects, difficulties, and instrumental requirements to carry out such a survey are discussed.

Nuno Santos (Universidade de Porto)
Towards the detection of optical reflected light from other worlds
We present and discuss on the prospects of detecting the reflected light from a short period extra-solar planet using high-resolution spectroscopy. In particular, we explore the use of the cross-correlation technique to derive the spectral S/N needed to detect the reflected light spectrum of an Earth-like planet orbiting another sun. We show that its detection is possible with a high-resolution spectrograph mounted on the E-ELT. Such a detection will allow to derive the planetary geometric albedo and its orbital velocity, allowing thus to estimate the real mass of the planet even in cases where a transit has not been detected.

Paolo Molaro (INAF - Trieste)
Detection of the Rossiter-McLaughlin effect in the 6th June 2012 Venus Transit: a test bench for the study of other Earths with HIRES@ E-ELT
Eclipsing bodies on stars produce radial velocity variations on the photospheric stellar lines known as the Rossiter-McLaughlin (RM) effect. The effect originally observed in eclipsing binaries was also shown to be produced by extrasolar planets transits. We report the detection of the RM effect in the Sun due to the Venus Transit of 6th June 2012 by means of HARPS recorded integrated sunlight as reflected by the Moon. The observations show that the partial Venus eclipse of the solar disk produced a modulation in the radial velocity with an amplitude of ~ 0.8 m/s in agreement with the theoretical model. The radial velocity change is comparable to the solar jitter and more than a factor 2 smaller than previously detected in extra-solar Hot Neptunes. This detection can be seen as a test bench of the kind of studies of transits of Earth-size bodies in solar type stars by means of an HIRES at the E-ELT.

Livia Origlia (INAF - Bologna)
High resolution IR spectroscopy over the full 0.95-2.45 micron spectral range: first results from GIANO
GIANO is the high resolution near IR spectrograph recently commissioned at the Telescopio Nazionale Galileo. The instrument includes a few innovative features like a fiber-fed system transmitting out to the K band and an U Ne lamp for wavelength calibration. First results from science spectra of cool stars are presented.

Wednesday 27/02
Multi-object spectroscopy on the E-ELT

James Dunlop (IfA Edinburgh)
E-ELT & Galaxies in the first billion years
I will briefly review what the latest deep near-infrared imaging and the reddest optical spectroscopy has revealed about the evolution of galaxies at z = 6 - 10, and the ability of the emerging galaxy population to reionize the Universe. I will then discuss the prospects for improving our knowledge of this crucial epoch with the E-ELT.
In particular I will focus on the design requirements for a MOS spectrograph as motivated by the number density, sizes and likely spectroscopic features observable from galaxies in the reionization era.

Danny Lennon (ESA)
Massive Stars, Big Questions, and the E-ELT
I will discuss some pressing open questions concerning massive stars; covering their formation, evolution and their deaths. I will explain how these problems may be addressed by multi-object spectroscopy of massive star populations in nearby galaxies, and will illustrate this with some examples of ongoing work in our closest neighbors with the Local Group.

Jean-Paul Kneib (EPFL)
Unveiling the first galaxies at the epoch of re-ionisation through E-ELT and cosmic lenses
With its large collecting power and the high spatial resolution it can achieve through AO techniques, the E-ELT will be a prime telescope to observe at the limits of the Universe. Nevertheless, the E-ELT will still be limited in focussing on the very first galaxies. With the help of massive galaxy clusters acting as cosmic lenses, one can push the E-ELT to its very limit and unravel the physics of the first objects. To achieve this, however, new high throughput, wide-integral-field spectrograph will be required.

Olivier Le Fèvre (Laboratoire d'Astrophysique de Marseille)
Galaxy formation and assembly with an imaging multi-object spectrograph
Studying the first phases of galaxy formation and assembly will require probing very deep (magnitude up to AB~30) reaching redshifts beyond z=7, and assembling large representative samples for a robust statistical analysis comparable to what is done today at z~2-3. Imaging multi-object spectrographs offer the high versatility needed to find these objects in large numbers and make detailed spectroscopic studies. I''ll discuss the DIORAMAS instrument concept that we propose for the EELT in this context.

François Hammer (GEPI - Observatoire de Paris)
Galaxy mass assembly with the ELT-MOS: lessons from the VLT & HST IMAGES survey
Using the deepest and most complete observations of distant galaxies (IMAGES), we have investigated the progenitors of present-day large spirals. Observations include spatially resolved kinematics from VLT, detailed morphologies from HST, and photometry from UV to mid-IR. Six billions years ago, half of the present-day spirals were starbursts experiencing major mergers, evidenced by their anomalous kinematics and morphologies. They are consequently modelled using hydrodynamics models. This provides a new channel of disk formation, e.g. disks reformed after gas-rich mergers, in agreement with the predictions of state of the art LCDM models. To investigate how galaxies have assembled their mass during the last twelve billion

years requires an ELT-MOS and this is leading to precise science requirements for its spatial, spectral resolution, wavelength coverage and multiplex.

Jean-Gabriel Cuby (Laboratoire d'Astrophysique de Marseille)
Science requirements and instrument concepts for a high definition mode for the ELT-MOS
A wide field multi Integral Field Unit (IFU) spectroscopic capability instrument, fed by Adaptive Optics (AO) and operating at near infrared (IR) wavelengths, has been a common aspiration of all ELT projects from the outset. Such a capability is required to answer many of the most exciting questions in contemporary astrophysics related to galaxy formation and evolution ranging from the nearby universe to the epoch of re-ionization. Such a capability shall form integral part of any ELT-MOS as a "High Definition" Mode. We briefly review the main science cases requiring this high definition mode and how they flow down into science requirements. Overall instrument concepts using Multi-Object Adaptive Optics (MOAO) are described. Associated performance estimates and technology development plans are also described.

Chris Evans (UKATC/ STFC)
Science requirements for a multi-object spectrograph on the E-ELT
The cases advanced for multi-object spectroscopy with the E-ELT span a wide range of science areas, from studies of resolved stellar populations in the local Universe, out to the most distant galaxies. The requirements for these cases can largely be split into two types of observations: coarsely resolved observations of >100 objects across the patrol field of the E-ELT ("high multiplex"), and spatially-resolved observations of tens of objects which exploit high-performance adaptive optics ("high definition"). I will summarise the requirements on an ELT MOS which flow down from these cases, with reference to simulations of spectroscopy of high-z galaxies and resolved stellar populations, used to constrain the spatial sampling, wavelength coverage, and spectral resolving power.

Hector Flores (Obs. Paris, Meudon)
Spatially resolved kinematics and star formation in distant galaxies
Spatially resolved kinematics and star formation in distant galaxies
Abstract: Today, we are limited in our measurements of velocity fields and star formation regions (among other characteristics) of distant galaxies not only due to sensitivity but also spatial resolution. The main drawback is that we need to integrate over kpc-large areas of a galaxy that averages out detailed information except for a few "study cases" (like with Sinfoni AO). With an ELT/MOS, we will be able to perform resolved measurements of a large number of normal (not peculiar) galaxies with which we can study e.g. the onset of the Tully-Fischer relation, Fundamental plane, Schmidt-Kennicutt relation.

Thursday 28/02
Multi-object spectroscopy on the E-ELT

Norbert Przybilla (Universität Erlangen)
Supergiant studies out to Virgo and Fornax: instrumental requirements for a multiobject-spectrograph on the E-ELT
Massive supergiant stars throughout the upper reaches of the Hertzsprung-Russell diagram are primary targets for the study of young stellar populations over large distances. While crowding poses a serious challenge for the present instrumentation, AO-assisted observations with the next generation of extremely large telescopes will provide the necessary spatial resolution. Future observations with an intermediate-resolution multi-object spectrograph on the E-ELT will allow samples of individual stars out to the Virgo and Fornax clusters of galaxies to be studied in great detail. This will facilitate massive star evolution for a wide range of metallicities to be studied and systematic investigations of the chemical evolution of all kinds of actively star-forming galaxies of the Hubble sequence to be undertaken.

Beatriz Barbuy (Universidade de São Paulo)
The Galactic Bulge and its globular clusters
Scenarios of bulge formation will be presented, together with clues on the more likely scenarios, as studied with large sets of spectroscopic data. In particular we will discuss the chemical abundances in galactic bulge stars, that are key to have clues on the early enrichment by the first massive supernovae in the central parts of the Galaxy. This information, together with their kinematics, can inform if the galactic bulge has the characteristics of a pseudobulge or a true bulge. He-enrichment is also an issue since there is some evidence for a high He abundance. Globular clusters in the central parts of the Galaxy are also a source of evidence on the same issues. In particular the metal-poor globular clusters concentrated in the inner parts might be the oldest objects in the Galaxy, and therefore inform on the earliest phases of galaxy formation. The need for multi-object spectroscopy in these crowded fields will be discussed.

Thierry Lanz (Observatoire de la Côte d'Azur)
Spectroscopy of resolved stellar populations in the Local Group
Medium to high resolution spectroscopy of individual stars in galaxies allows to probe the evolution of a system, through the imprints that past events have left on the chemical composition and dynamics of stellar populations. In this contribution we wish to make a case for studying resolved stellar populations in galaxies of the local group with the ELT equiped with a MOS, concentrating on a few major open questions:
- Dwarf galaxies are building blocks of larger systems in cosmological scenarios. However, the spheroidal dwarf galaxies nearest to the Milky-Way (see e.g. Tolstoy, Hill, Tosi 2009 for a review largely based on VLT/FLAMES results on these systems) have most probably suffered interactions with the MW that have influenced their evolution. Dwarf galaxies far away from the two large spirals of the LG have on the other hand evolved in a rather isolated manner, still contain metal-poor gas, and are fascinating probes of galactic evolution on the smallest scales. Reaching full chemical and dynamical information in these systems for stellar populations of all ages (ie. not only the youngest and brightest populations such as supergiants) is only possible with a MOS on the ELT.
- The oldest and most metal-poor stars in the Milky-Way have opened up a new window to understand the nature and properties of first stars in the universe (e.g. Cayrel et al. Large program "First stars", Caffau et al. 2011). Extremely metal poor stars in systems outside the Milky-Way are still restricted to very small samples in the

most nearby dwarf galaxies (e.g. Tafelmeyer et al. 2010, Frebel et al. 2010, Starkenburg et al. 2012, Kirby et al. 2012), and the full benefit of observing the signatures of first stars in diverse environment (in galaxies of different masses for example) will have to await spectrographs on the ELT.
- Unsolved problems in nucleosynthesis will also be presented (e.g. *primordial* Li, s-process production, origin of C...), where observations with a high résolultion spectrograph on the ELT would provide decisive steps forward.

Piercarlo Bonifacio (Observatoire de Paris)
The extremely metal-poor stars in external galaxies
In the standard cosmological model the Universe that emerged from the hot and dense phase, called the big bang, was made only of hydrogen and helium (and traces of lithium). As soon as the first massive stars were formed they exploded as supernovae and began to pollute the gas with the metals they produced. In the Galaxy we observe extremely metal poor stars, down to a metallicity (Z) of about 4.5e-5 the solar metallicity. Some theories of star formation in metal-free gas predict that below a "critical metallicity" it is not possible to form low-mass stars, while others predict that even in metal-free gas, low-mass stars can be formed. The study of the metal-weak tail of the metallicity distribution function can give us information on this critical metallicity and on the mass distribution of the first generation of stars.
This information may allow us to understand the role of the first stars in the re-ionization of the Universe. We know very little about these extremely metal-poor stars in other galaxies. Did star formation in metal-free gas proceed in the same way in all the Universe, or was it affected by the local environment? We now stars down to a metallicity of 1.e-3 the solar metallicity exist in Local Group galaxies. However the numbers are too small to have an idea of the metal-weak tail of the metallicity distribution function. The giant branches of the dwarf galaxies in the Local Group are too scarcely populated to provide sizeable samples of these rare populations. To observe such samples it is necessary to go to the turn-off of these galaxies, this requires to obtain intermediate resolution spectra down to V=25, in order to reach at least a few galaxies. A Multi-Object-Spectrograph on the E-ELT will be able to provide us this unique information and afford a major break-through in the field.

Lex Kaper (University of Amsterdam)
A high-multiplex fibre-fed MOS for the E-ELT
Spectroscopic observations of astronomical objects are, in their broadest definition, the foundation on which we build or discard astrophysical models of the Universe and its content. Multi-object spectrographs have been, and will remain key to provide the spectroscopic samples to address the important scientific questions related to the origin and evolution of stars and galaxies, motivating the construction of the E-ELT. The current challenge is to make sure that the E-ELT will be equiped with such a facility, as early as possible, to efficiently explore its large field of view, to collect the relevant samples, and to face the competition with TMT and GMT. A MOS is expected to be a workhorse instrument for the E-ELT. It should also remain flexible enough to be used in twenty years time to address problems that are beyond our imagination. The solution is to design an instrument that samples the largest discovery space in terms of wavelength range, spectral and spatial resolution, and multiplex. A fibre-fed MOS, such as OPTIMOS-EVE, is unique in covering a large domain in the spectral resolution (R=5000-30000) versus multiplex (40-240) plane, and this for a large wavelength range (370-1600nm). It also offers a unique range of apertures, including multiple IFUs, which can be adapted to a large variety of science cases. We will highlight a number of key science cases, and the corresponding scientific requirements, and demonstrate that they can be met with a fibre-fed MOS.

Ben Davies (Liverpool John Moores University)
Stellar Spectroscopy Beyond the Local Group with the EELT
Precision stellar spectroscopy, to determine e.g. chemical composition, has traditionally required very high spectral resolution. This has limited the distance at which such studies can be performed on even the brightest stars to the Milky Way and its satellites. We are pioneering techniques to adapt these studies to much lower resolution spectra (R~3000), which are therefore compatible with MOSs and IFUs. This means that for the first time quantitative spectroscopy is now possible for large samples of stars at Mpc distances. We will show that with the EELT it will be possible to use a galaxy''s brightest stars to obtain (a) distances more reliable than Cepheids, and (b) metallicities more reliable than HII regions and CMD-fitting, out to the distance of the Coma Cluster, a substantial volume of the local universe containing entire groups of galaxies.

Stefano Zibetti (INAF - Arcetri)
Stellar populations in intermediate-/high-redshift galaxies with E-ELT-MOS
Studies of stellar populations in galaxies require high SNR spectra in order to detect absorption features that are sensitive to their age and metal content. Already at z~0.7 these studies become extremely challenging even with 6-8m class telescopes, so that exposures >>10 hrs are requested, both because galaxies are faint and the relevant features move to the red and NIR spectral regions. A medium resolution (R~3-4000) optical-NIR MOS on an ELT is therefore a (the) unique opportunity to make progress in this field and trace the formation and chemical evolution of stellar populations in galaxies back to z~3.

Dimitri Gadotti (ESO)
Strengthening the case for deployable IFUs at the E-ELT
High multiplex capabilities at the E-ELT are crucial to maximize its scientific output. I will show that this is the case not only in studies of a large number of objects (e.g. a field with many galaxies at high redshifts), but also in studies of resolved stellar populations in individual nearby galaxies. A full picture of the current chemo-dynamical structure of galaxies depends on our ability to thoroughly probe the variety of existing structural components, such as bulges, disks, bars, spiral arms, rings, stellar haloes and kinematically decoupled cores, some of such components occuring multiple times in the same galaxy. A high multiplex optical/near-infrared spectrometer with deployable integral field units is arguably the most efficient way to achieve these goals, which constitute one of the main science cases for the E-ELT.

Jose Afonso (University of Lisbon)
Dissecting the first radio galaxies with the E-ELT
Over the coming decade, deep and wide radio surveys will reveal millions of radio galaxies all throughout the Universe History. Surveys like EMU, WODAN, or LOFAR will cover the sky at unprecedented depths over the largest possible areas, helping to reveal fundamental aspects of galaxy formation and evolution. In particular, large samples of candidates to be the first radio galaxies in the Universe will be assembled, and it will take the full power of the E-ELT to understand their nature. In this talk, I will defend the case for a NIR MOS on the E-ELT, as an essential tool to reveal the earliest black hole growth and the dynamics of the earliest galaxy and structure formation in the Universe.

Thursday 28/02
Future instrument concepts and science cases

Roland Bacon (CRAL)
Is a MUSE-like instrument feasible for the E-ELT?
An integral field spectrograph with a wide field of view, large spectral range, high throughput and able to work efficiently with the adaptive optics is quite attractive for the E-ELT. This is just what MUSE is for the VLT. In this talk I would like to review the science impact and the feasibility of a MUSE like instrument for the E-ELT.

Dainis Dravins (Lund Observatory)
Diffraction-limited E-ELT imaging in the blue with intensity interferometry
Intensity interferometry, pioneered by Hanbury Brown et al. long ago, determines spatial properties of a source by measuring the second-order coherence of light. This software method connects optical apertures only electronically, making the method practically insensitive to atmospheric turbulence and optical imperfections; permitting observations over long baselines, through large airmasses, and at short optical wavelengths. Plans are to apply it on Cherenkov telescope arrays for diffraction-limited imaging over kilometer-scale baselines. The method fundamentally differs from other imaging techniques currently used in astronomy although it has analogies to image synthesis with the LOFAR radio interferometer.

Intensity interferometry can be applied also to E-ELT with a hardware-wise extremely small and simple instrument, a two-dimensional high-speed photon-counting detector with each pixel viewing one subaperture of the E-ELT entrance pupil. Cross correlating fluctuations in the photon streams from all pairs of subapertures provides optical visibilities for very many baselines, enabling aperture synthesis and diffraction-limited imaging also at short optical wavelengths. A different choice of software would instead provide a photometric signal of very high time resolution.

Such a small technical instrument could produce two-dimensional imagery already during the E-ELT construction phase, when its main mirror still is only sparsely and incompletely filled, and at wavelengths much shorter than those for later AO operation, even under poor seeing

Limiting magnitudes have been evaluated for Cherenkov telescopes to be around m(v)=8. The E-ELT error budget is more favorable thanks to improved image quality and better background sky avoidance; feasible use of small and efficient solid-state photon-counting detectors; good optical collimation permitting the use of narrow-band interference filters to isolate spectral features; isochronous optical paths that do not limit how fast electronics that can be used and – since all pixels are in one location – no issues in long-distance signal transmission. Very likely, the limiting magnitude could be rather fainter than for Cherenkov telescopes, probably even reaching extragalactic sources. Besides imaging astronomical sources using nanosecond timescale photometry, the signals of intensity correlations on slower timescales would provide sensitive diagnostics of telescopic mechanical vibrations.

The concepts build upon the earlier design study of the QuantEYE instrument carried out for ESO for the then OWL telescope concept (Barbieri et al., 2007; Dravins et al., 2005, 2006) and the subsequent development of the AquEYE and IquEYE instruments, operated at Asiago and on La Silla (Naletto et al., 2007, 2009, 2010). Recent overviews of intensity interferometry are by Dravins et al. (2012ab).

Martin Roth (Leibniz Institut für Astrophysik Potsdam)
Extreme Multiplex Spectroscopy at the E-ELT
The last decade has seen rapid evolution of integral field spectroscopy at 4-8m telescopes, with high impact on the study of galaxies, e.g. the SAURON, ALTAS3D, CALIFA surveys. Next to the 2-dimensional mapping of extended objects, we have begun to explore the potential of IFUs for PSF-fitting 3D spectrophotometry in crowded fields [arXiv:1211.0445], an area harboring one of the most competitive edges of the E-ELT. I shall demonstrate the technique with results from pilot studies at 4m/8m telescopes as well as from numerical simulations, and argue that for E-ELT instrumentation beyond ELT-IFU, it seems to be inevitable to employ IFUs, including MOS.

Klaus Strassmeier (Leibniz Institut für Astrophysik Potsdam)
A polarimetric focal station for a fibre-fed high-resolution spectrograph on the E-ELT
We present science highlights and a conceptual design for a spectropolarimetric focal station for ESO's European Extremely Large Telescope (E-ELT). It uses the intermediate f/4.4 focus, the only symmetric focus of the telescope. A dual channel, full Stokes-vector polarimeter provides on-axis light for the wavelength range 380-1600nm to up to two spectrographs arms simultaneously via two pairs of fibers. With such spectropolarimetric capability and a proper spectrograph for the optical and – optionally – for the near infrared wavelengths, the E-ELT would be able to provide the full parameter space of an incoming wavefront. Because of the on-axis entrance location of the polarimeter collimator and an entrance aperture of just 1.3 arcsec, the expected poor image quality of the intermediate telescope focus is not directly relevant.

Roberto Ragazzoni (INAF - Osservatorio Astronomico di Padova)
NGSs only on AO for the E-ELT
In this contribution the current status of the study to assess the performances of a Global Multi Conjugated Adaptive Optics System onboard of the E-ELT will be presented. The aim is to establish the achievable performances in terms of image quality with respect to sky coverage using the GMCAO concept employing a larger (from 5 to 10 arcminute) technical Field of View to assess the informations needed to compensate in real time the central one to two arcminute scientifically exploitable area. Technological readiness with respect to other techniques like Multi Object and Laser Guide Stars AO are outlined along with the options to demonstrate such a technique on the sky.

The study is performed under ESO contract, currently by R. Ragazzoni, M. Bergomi, M. Dima, J. Farinato, D. Greggio, D. Magrin, L. Marafatto, V. Viotto

Annalisa Calamida (STScI)

Galactic globular cluster absolute ages by observing white dwarfs with the E-ELT

We present the results of near-infrared (NIR) imaging simulations of Galactic globular clusters (GGCs) to be observed with the European Extremely Large Telescope (E-ELT). The simulated images show that with E-ELT we will be able to estimate the absolute ages of these GGCs with an accuracy better than 5%, by using two different diagnostics. The first one is based on the difference in magnitude between the main-sequence turn-off (MSTO) and a well-defined knee located along the lower main sequence (Calamida et al. 2009, Bono et al. 2010), and it is independent from distance and reddening. This feature is caused by the collisionally induced absorption (CIA) of molecular hydrogen, and it is easily identified in the NIR color magnitude diagrams (CMDs) of the simulated clusters. The second diagnostic is based only on white dwarf (WD) cooling sequence features and specifically on the difference in magnitude between the WD blue TO (WDBTO) caused by CIA along the cooling sequence and the WD red TO (Bono et al. 2012). Both features are clearly defined in the NIR CMDs of the simulated GGCs. This age diagnostic is minimally affected by metallicity, it is indipendent from distance and reddening, and it is based on different physics compared to the MS knee method. The first diagnostic can be currently used to estimate GGC absolute ages from data observed with the Hubble Space Telescope and the 8-10m class telescopes (Sarajedini et al. 2009; Brown et al. 2010: Bono et al. 2010), while we will need MICADO on the E-ELT to fully exploit the potential of the second diagnostic based on the WD cooling sequence features.

Giuliana Fiorentino (INAF-Bologna)

Blue Compact dwarf galaxies as seen by E-ELT

We will present the science case of Blue Compact dwarf (BCD) galaxies as they will be observed by an Extremely Large Telescope (ELT). Due to the high surface brightness of these starburst galaxies (e.g. 17-22 mag/arcsec^2
for NGC1705), even using the best instruments on board of HST we can not reach stars fainter than about 3-4 magnitudes below the Tip of the Red Giant Branch, i.e. older than 1 Gyr. Thus, our view of these objects is far from complete. The next generation of giant telescopes are expected to shed light on the Star Formation Histories of these galaxies reaching the Horizontal Branch, i.e. resolving stars as old as 10 Gyr.

We will present simulations of starburst dwarfs and BCDs as they should be seen by a multi--conjugate adaptive optics assisted imager working at the diffraction limit (e.g. a MAORY+MICADO like system) on a 39.3m diameter ELT. We will perform our analysis in IJHKs filters making use of the new PSFs available on the MAORY website.