The participants at the E-ELT Design Reference Mission and Science Plan workshop assembled in the grounds of ESO Headquarters.

and to encourage the community to provide input to this wide-ranging survey of the scientific aspirations for the E-ELT. The workshop was timed to take place shortly before the deadline for DRSP submissions.

This was the second DRM workshop funded by the FP7 programme, E-ELT Preparatory Phase. The first took place in May 2008 and focused on simulation tools and methods, rather than results. This year's workshop attracted 83 registered participants (up from 34 last year), which we are happy to interpret as a reflection of the community's rising interest in the E-ELT.

The introductory session covered the E-ELT project status, a summary of the science case and the DRM, and a summary of the methods and aims of the DRSP, including a live demo on how to complete the online submission form.

This introduction was followed by presentations grouped into sessions based on four broad science themes: Stars and Planets, Galactic Centre and Black Holes, Resolved Stellar Populations and High Redshift Universe, each being closed by an open discussion. On the second day there was also a session on instrumentation and observing techniques. All presentations are available from the workshop web page[1].

In addition to covering the key, well-established E-ELT science cases and instrument studies, the presentations and discussion sessions included themes that had not been covered in depth previously, such as opportunities for high-impact science from high-precision astrometry, polarimetry and high-time-resolution observations.

Overall, the workshop was perceived as being very lively and interesting. It provided very valuable input to the E-ELT project on its way to completing the detailed design phase by the end of 2010.

Acknowledgements

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Links

[1] http://www.eso.org/sci/facilities/eelt/science/drm/workshop09/

Report on the ESO Workshop

Imaging at the E-ELT

held at ESO Garching, Germany, 29 May 2009

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The aim of this one-day workshop, part of the FP7-funded programme to prepare for the European Extremely Large Telescope, was to bring together members of the community working on wide-field imagers on 4–8-metre-class telescopes and on instruments and science cases related to imaging at the E-ELT, exploring complementarities and synergies between the two communities.

The workshop was organised as part of the FP7 programme "Preparing for the construction of the European Extremely Large Telescope (E-ELT)", within the Work

SEVENTH FRAMEWORK PROGRAMME

Package 6000 "Networks of Nodes of Expertise". The goal of the network "Wide Field Imaging at the E-ELT; from GLAO to diffraction limit" is to identify the parameter space of the upgrade path in the area of wide-field imaging (WFI) at the E-ELT, within the framework set by the scientific requirements and the E-ELT instrument studies already in place. Using WFI at the E-ELT we intend to go beyond those applications that require very high Strehl ratios on single sources over a very small field, such as those required, for example, by the imaging of planets. The workshop followed the three-day workshop on the E-ELT Design Reference Mission and Design Reference Science Plan (Hook et al., p. 51). The programme and presentations are available at the workshop web page[1].

The workshop covered four main topics: the current WFI projects on 4–8-metre-class telescopes; the performance and limitations for E-ELT imaging; the current plans for wide-field imaging at future large telescopes, including the expected performance in imaging of the US Thirty Metre Telescope (TMT) and the James Webb Space Telescope (JWST); and a dedicated session on future prospects with imaging at the E-ELT.

WFI projects on 4–8-metre-class telescopes

The first session covered the overview of the current status of the existing wide-field imagers, up to 8-metre-class facilities, the requirements for current instrumentation and the scientific goals. Gavin Dalton presented a brief overview of the Visible and Infrared Survey Telescope for Astronomy (VISTA) system, information on the commissioning process, and an outline of the public surveys that form the major part of the first phase of VISTA science operations (see also Arnaboldi et al., 2007, for a presentation of the ESO public survey projects). VISTA is a 4-metre wide-field telescope with a 1.7-degree field of view 64 Mpix infrared camera (see Emerson et al., 2006, for a more extensive overview).

A stimulating overview of the Hyper-Suprime Cam (HSC) project was given by Satoshi Miyazaki from the National Astronomical Observatory of Japan. HSC is the Subaru next generation wide-field camera. This project represents the upgrade of the 10-year-old (and very successful imager) Suprime-Cam (SC) on the Subaru 8.2-metre telescope. The goal is to expand the field of view (FoV) to 1.5 degrees in diameter, while maintaining the same image quality as for SC in *r*-, *i*-, *z*-, *Y*-bands. It implies that the instrumental point spread function (PSF) is less than 0.4 arcsecond full width at half maximum (FWHM) and could reach even higher quantum efficiencies for the CCD detectors in the red. These constraints are set by the weak-lensing survey requirements, which aim at taking full advantage of the excellent image quality and the wide FoV.

Roberto Ragazzoni reported on the Large Binocular Telescope (LBT) wide-field imager project, the commissioning of the cameras and early science results. These 23 × 23 arcminute cameras can image simultaneously in ultraviolet and in optical wavelengths with peak performance of 0.4 arcsecond FWHM in the *U*-band and 0.5 arcsecond FWHM in the *V*-band. The high throughput enables a limiting magnitude of 25.6 AB mag in the *Z*-band in 3 hours exposure. There are now more than 20 papers either submitted or accepted coming from the early science with LBT imaging.

The transition to discussing imaging with the next generation telescopes was laid by the scientific overview of Jarle Brinchmann on the deep extragalactic imaging surveys and the expectations of the new facilities. In his comprehensive overview, Brinchmann outlined the dramatic advances in extragalactic research in the last couple of decades, and how deep imaging has been essential to this evolution. A comprehensive overview of deep fields is available[2]. The strong evolution in extragalactic research is expected to continue in the coming decades with the development of very wide-field imagers on 8-metre-class telescopes as well as wide-field imagers on the next generation of 30–40-metre-class telescopes. It is clear that a major advance for these large telescopes is in their improved spatial resolution over limited field of view (FoV), which will be of major interest for a wide range of extragalactic research fields. With current-day adaptive optics (AO) technology it is unlikely that this kind of instrument will reach a large enough FoV to become a true survey instrument. Brinchmann argued that a camera with a lower order AO correction, but much larger FoV than those currently foreseen would be of significant scientific interest for deep extragalactic surveys and as a fast imager of faint transient phenomena, as high-*z* supernovae and gamma-ray bursts. The current evaluation that emerges from a comparison in mapping speed with HSC on Subaru at optical wavelengths and NIRSPEC on JWST indicates that an imager with a FoV of 15 arcminutes on the side, sensitive from 0.35–1.5 μm and designed to take advantage of higher order AO correction with 50 % ensquared energy in 0.1 arcseconds at ~ 1 μm would be an ideal match; see Figure 1 for an illustration of such effective synergies.

The performance and limitations of E-ELT imaging

This session included an overview of AO simulations at the E-ELT by Miska Le Louarn and a presentation by Gavin Dalton on the detectors for imaging — optical and near-infrared (NIR), with a forward-look towards technology developments that may have significant impact on the feasibility of wide-field imaging with ELTs. Le Louarn presented in particular the results of simulations for Ground Layer Adaptive Optics (GLAO). The goals of GLAO are to improve the seeing on a "wide" FoV, rather than reaching the diffraction limit, by correcting for the atmospheric turbulence averaged on many natural stars and/or laser guide stars. "Wide" field in this case means fields from 5 to 7 arcminutes. Simulations in the *K*-band show that there can be up to 50 % gain in image quality with respect to the natural seeing with three natural guide stars (NGS). The need for three NGSs and constraints on their magnitudes restrict the sky coverage to about 50 %; this may improve with higher efficiencies and fainter stars. The sky coverage can increase by using three laser guide stars, but this imposes more load on the operational aspects of GLAO.

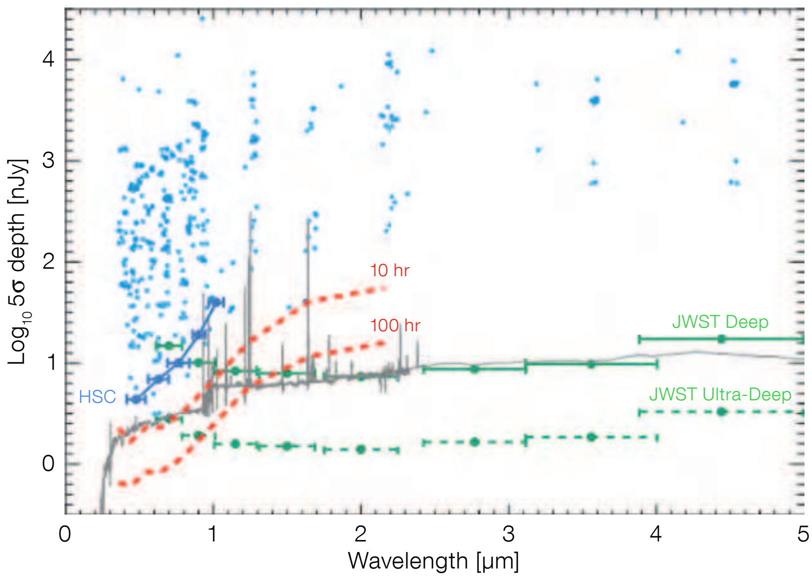

Figure 1. The depth of extragalactic fields as a function of the wavelength of observation. This is contrasted with the nominal goals of the JWST Deep and Ultra-Deep surveys (in green, from Gardner et al., 2006), as well as the depth one might be able to reach with an 8-metre-class telescope in 50 hrs, here represented by HSC (blue). This is compared with a typical spectral energy distribution of a star-forming galaxy at $z = 1.5$ (in grey), normalised to the JWST Deep target depth at 2 μm. Note that while such a star-forming galaxy will be easily detected in the near-infrared by JWST, it will be fainter in the optical than an 8-metre-class telescope is expected to reach in 50 hrs. However in 10 hours with the E-ELT it will be possible to detect it in the optical (upper red dashed line) and a 100-hour exposure with the E-ELT will complement the depth of the JWST Ultra-Deep field in the optical (lower red dashed line). From J. Brinchmann's contribution to the FP7 report of the Network "Wide Field Imaging at the E-ELT; from GLAO to diffraction limit".

Plans for imaging with the next generation telescopes

Luc Simard presented an overview of the instrument suite being developed for the TMT and Simon Lilly gave a presentation on the status of the James Webb Space Telescope and the NIRCAM camera. In the case of TMT, there are two instruments that work in the visible and are seeing-limited, the Wide Field Optical Spectrometer (WFOS) and the High resolution Optical Spectrometer (HROS). The FoV of the former is 40.5 arcminute^2. The gain in this case is a factor 14 with respect to 8-metre-class telescopes, while it becomes 200 for high-contrast AO observations of unresolved sources, but still allows the scientific cases such as intergalactic medium tomography and the stellar archeology in the local Universe to be pursued. The AO-driven imagers, like IRIS and the Planet Formation Instrument (PFI), are targeting 15 × 15 arcsecond FoV and 2-arcsecond radius, respectively.

Imaging at the E-ELT

MICADO, described by Renato Falomo, is the imaging camera for the multi-conjugate adaptive optics system for the E-ELT. The goal of the consortium building MICADO (PI Reinhard Genzel) is to design a simple and robust instrument that can address as much of the primary NIR science as possible, in time for first light at the E-ELT. MICADO will work from 0.8 to 2.5 μm, and cover a FoV of 53 × 53 arcseconds. The pixel scale is 3 milliarcseconds (mas), with a PSF FWHM of 6 mas (*J*-Band) and 10 mas (*Ks*-band). Main scientific drivers for the instrument design are the Galactic Centre, the study of the resolved stellar population beyond the Local Group and the study of galaxy morphology in the high redshift Universe. The multi-conjugate adaptive optics (MCAO) module for the E-ELT is MAORY, and Paolo Ciliegi discussed the results of PSF simulations. The FoV of MAORY is 150 arcseconds in diameter, and it can support the diffraction limit (DL) requirement of MICADO very well. Ciliegi commented that if the target area for a wide-field imager on the E-ELT is 5 × 5 arcminutes, then the technology required is GLAO, and one moves away from the diffraction-limited MCAO space. Olivier Le Fevre showed the wide-field imaging possibilities with OPTIMOS, which envisages a 7 × 7 arcminute FoV, with wavelength coverage from 0.37 to 1.4 μm, and 0.05-arcsecond pixels. This instrument is primarily a multi-object spectrometer using up to 500 multi-slits in the optical and 170 in the NIR. Operation of such an instrument is foreseen in natural seeing or GLAO.

In addition to the technical presentations, two short contributions on science cases with the E-ELT were also included: one on the resolved stellar populations in the Virgo cluster by Magda Arnaboldi and the other on resolved starburst clusters near and far, by Andrea Stolte.

Prospects

The scientific programme of the one-day workshop ended with a lively discussion on the prospects for imaging with the E-ELT and the role of an imager covering the full scientific field of the telescope. While it became clear that the instrument suite at first light would aim to exploit the largest advantage in terms of sensitivity with respect to an 8-metre-class telescope and JWST, i.e. operation at the diffraction limit over fields less than 1 arcminute, the outcome of this one-day workshop indicates that GLAO is a promising technique. If successfully implemented over a FoV of several square arcminutes, it would naturally complement the first light instrument suite of the E-ELT and the capabilities of JWST, even if the latter retains a performance advantage because of the reduced sky background.

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[1] http://www.eso.org/sci/facilities/eelt/fp7-elt-pub/wfi_workshop/index.html
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