

## Science and Technology with the E-ELT

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This international PhD school in the F. Lucchin cycle was the first to bring together Masters and PhD students with an interest in all aspects of the science and technology of the European Extremely Large Telescope (E-ELT). It was fitting that this school was held within a year of the project formally entering the construction phase. An overview of the topics covered during the school is presented.

In total 51 students from 16 countries attended the school. As may be inferred from the title, the programme for the school was very broad. For example, experts in the adaptive optics (AO) systems with which the E-ELT will be equipped were scheduled alongside astronomers specialising in the theoretical foundations of resolved and unresolved stellar populations or the expansion of the Universe. The lecturers each gave two one-hour lectures on their subjects. They typically reviewed the state of the art in each field in the first hour and, in the second, highlighted the application of that technology to the E-ELT, or the potential of the E-ELT to further develop the field.

### E-ELT technology

Lecturers from ESO presented the background and specifics of the European Extremely Large Telescope, including the history and the final telescope design (Roberto Gilmozzi), the current status of the project (Roberto Tamai), the science drivers and the instrumentation programme (Suzanne Ramsay) and the adaptive optics (Enrico Marchetti). Bruno Leibundgut presented the Very Large Telescope (VLT) programme. Talks on specific aspects of instrumentation were also offered: in high spectral resolution spectroscopy (Livia Origlia), polarimetry

(Christoph Keller), high time resolution science and instrumentation (Andrew Shearer) and IFU spectroscopy (Sebastian Kamann). The second lecture given by Sebastian also included homework for the students: identification of individual sources from integral field spectra of the innermost cluster regions of M92.

Fundamental subjects, such as infrared astrophysics and the optimisation of telescopes and instruments for that wavelength regime, were presented by Tom Herbst, while Michel Dennefeld described spectrographs and spectroscopy. The lessons about the infrared atmosphere were further developed by Norbert Przybilla in his lecture on sky modelling.

The technologies and techniques of AO will play a very significant role for astronomers using the E-ELT, so a number of lectures covering the many flavours of AO were presented by Roberto Ragazzoni, Simone Esposito and Enrico Marchetti. Laura Schreiber described how to fit point spread functions (PSFs) to data taken with AO instruments and, along with Giuliana Fiorentino, led the students in a practical exercise of analysing images taken with different AO techniques (multi-conjugate, single conjugate and ground layer adaptive optics [MCAO, SCAO and GLAO]). The aim of the tutorial was to challenge the students to identify the technique used for the observations via the characteristics of the observed PSF across the field of view of the instrument. Giuliana further discussed how to do deep near-infrared photometry with AO instruments.

### E-ELT science

The key science cases for the E-ELT were also presented, starting with the basics of the subject and then expanding to describe the way in which the sensitivity and angular resolution of a 40-metre-class telescope would revolutionise each field. The possibilities for increasing our understanding of the Solar System were shown by Benoit Carry, with Markus Kasper detailing current and future work on exoplanets with the Spectro-Polarimetric High-contrast Exoplanet Research instrument (SPHERE) on the VLT and the Planetary Camera and Spectrograph (PCS)

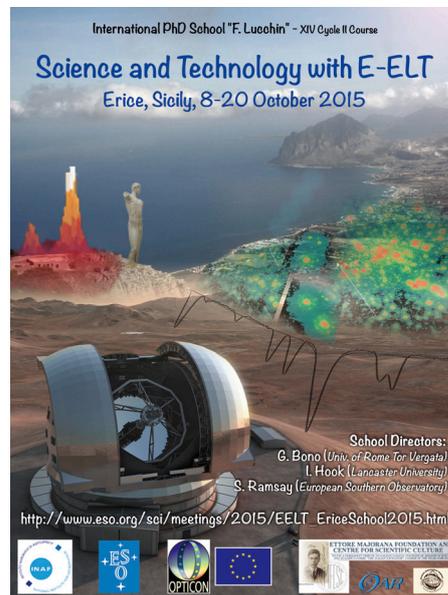


Figure 1. Poster for the International PhD School "F. Lucchin".

on the E-ELT. The role that exoplanets are going to play for the E-ELT was also covered in the lectures by Livia Origlia, together with the pros and cons of high resolution near-infrared spectroscopy. The E-ELT contribution to the understanding of protoplanetary discs was included in the lectures by Miwa Goto.

The processes for understanding the physics of stars themselves were covered in great detail. Suzanne Ramsay discussed their formation and feedback into the interstellar medium. Observations and analysis of single stars — blue supergiants (Norbert Przybilla) and red supergiants (Miguel Urbaneja-Perez), were discussed as well as their use for distance determinations. France Allard introduced the topic of the atmospheric modelling of stars, in particular ultra-cool dwarfs. She also discussed the ongoing effort in improving the input physics of the current atmosphere models of low-mass stars. This topic was then advanced by Maria Bergemann who discussed the use of 3D atmospheric models and the challenges resulting from the new understanding of the abundances of Solar-type stars. Maurizio Salaris presented the latest results and open questions on the advanced evolutionary phases of low- and intermediate-mass stars. Variable stars and their impact on stellar astro-



Figure 2. The School group photograph looking across Bonagia Bay.

physics and cosmology were presented by Marcella Marconi, Laura Inno, Matteo Monelli and Massimo Dall’Ora. A comprehensive review of surveys for transient and variable objects was given by Michel Dennefeld together with current and future strategies for spectroscopic follow-up of transients.

Eline Tolstoy and Patricia Sanchez-Blazquez described the study of resolved and unresolved stellar populations respectively, while the physical and the chemical ingredients to build up synthetic colour–magnitude diagrams were further expanded by Santi Cassisi. The chemical enrichment of the Galactic Disc using classical Cepheids was introduced by Giuseppe Bono, together with the role that optical and near-infrared spectroscopy will play in constraining the metallicity distribution in nearby Local Group stellar systems.

Moving outside the Galaxy, Fabrizio Fiore gave two lectures on active galactic nuclei (AGN) and supernova (SN) feedback. The status of studies of the high-redshift Universe was reviewed by Richard Ellis, together with the spectroscopic and photometric synergies with the James Webb Space Telescope (JWST). Bruno Leibundgut presented the case for the accelerating Universe as revealed by studies of SNe. Joe Liske and Carlos Martins then showed how a direct measurement of this acceleration and of the funda-

mental physical constants could be achieved with great precision using the E-ELT.

All the lectures are available online at the school webpages<sup>1</sup>.

### Student participation

The students were not simply passive participants in the school. Aside from their questions to, and interactions with, the lecturers, around half of the students took the opportunity to give 10-minute presentations of their own Masters or PhD work. These presentations were of impressively high quality and the breadth of topics matched beautifully that of the school itself — from new detectors to cosmology. A novel innovation was that the final three days of the school were chaired by the students themselves. All the student chairs rose very well to this additional challenge and performed in a most professional manner.

The long duration of the school and the 9:00–19:00-hour schedule of lectures plus tutorial homework and talk preparation led to an intense two weeks for all concerned. Nevertheless it was not all work. A half-day excursion took in the Marsala museum, housing the Nave Punica and the dancing Satyr in the Mazzara museum. This was followed the next day by an expert guided tour of Selinunte and its temples. The school’s location in the small hill town of Erice afforded many opportunities for the informal interactions over lunch and dinner

that are so critical for forming strong working relationships. They were also facilitated by the beautiful terrace overlooking the Bonagia Bay that was the venue for the coffee and tea breaks (see Figure 2).

The co-directors and authors of this short report sincerely hope that this school will have informed and enthused the generation of astronomers who will be the prime users of the new facility. In closing, the students were challenged to ask what they can now do for the E-ELT. We look forward to the results!

### Acknowledgements

The school was only possible thanks to the considerable efforts of many people. The authors would like to thank in particular the lecturers for their informative and entertaining lectures. The local organising committee bore the brunt of the day-to-day work on such a school. We gratefully acknowledge all the work done by Vittorio Braga, Michele Fabrizio, Hildegard Haems, Laura Inno, Samantha Milligan and especially Giuliana Giobbi for all their help with the practicalities of the school. It is also a pleasure to thank the Director of the Majorana Centre, Dr Fiorella Ruggiu, with her administrative and technical staff for their steady and warm support in solving the many problems that turn up in the organisation of an International School. The school was supported financially by OPTICON, ESO, the Istituto Nazionale di Astrofisica, the Laboratorio Nazionale di Ottica Adattiva and by the Ettore Majorana Foundation and Centre of Scientific Culture. OPTICON is supported by the European Commission’s FP7 Capacities programme (Grant number 312430).

### Links

<sup>1</sup> School webpages: [http://www.eso.org/sci/meetings/2015/EELT\\_EriceSchool2015.html](http://www.eso.org/sci/meetings/2015/EELT_EriceSchool2015.html)