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An efficient facility spectrometer for the European extremely large telescope

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As a multichannel infrared instrument, EAGLE is being designed to provide 3D data for faintly received sources from the dawn of the Universe.

While our understanding of how galaxies (including ours) form and evolve has made considerable progress over the last decades, astronomers still face many outstanding questions: How did the first galaxies form? What types of sources were responsible for re-ionizing the Universe? What are the physical processes that drive galaxy formation and evolution? Answering these types of questions requires new capabilities that exceed those of the current telescopes and instruments.

For some years, the world's astronomical communities have considered constructing the European Extremely Large optical-infrared Telescope (E-ELT). The European Southern Observatory (ESO), acting on behalf of European astronomers, has come forth and settled on a nominal 42m aperture design (see Figure 1 and videos[1,2] of the E-ELT concept), which is progressing through a more advanced design and costing phase.

The combined huge collecting power (approximately 1000m^2!), gives the device its exquisite image quality capabilities (especially when using fully integrated adaptive optics). Images taken by the telescope will provide spectacular gains in sensitivity, which will in turn open new windows on the Universe. Astronomers will soon image the first observable galaxies, and study the physical processes that shaped these proto-galaxies into those one sees today found closer in space and time. It will also be possible to reconstruct the past history of nearby galaxies by observing and measuring their individual stars. Currently, this can only be applied to our own Milky Way.

Measuring the physical properties of the galaxies requires spectroscopy. This practice allows one to determine the distance, composition, and internal motions of the stars and gases shaping the galaxies. As the distance of a galaxy increases (and as we look back further in time), its spectral features normally seen at optical wavelengths are shifted to longer wavelengths (called a redshift), and at its extreme can only be observed in the infrared part of the light spectrum. Proper statistical analysis requires observations of thousands of galaxies. EAGLE is therefore built to be a 'multiobject,' 'near-infrared' spectrograph with 20 or more channels operating simultaneously at 1–2.5μm (see Figure 2).

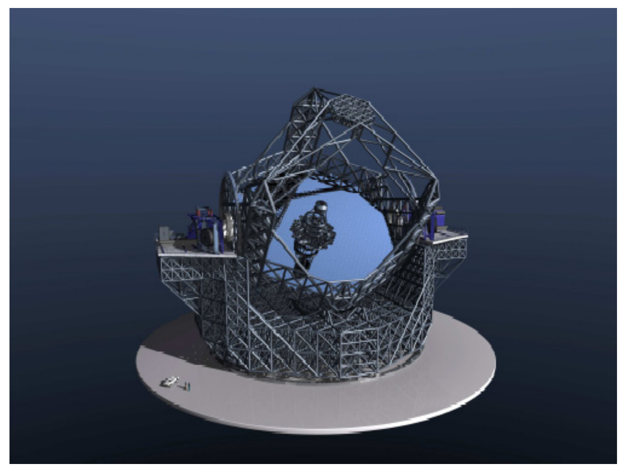

Figure 1. *The E-ELT concept. The primary mirror is 42m in diameter, featuring over 900 segments, each 1.4m wide. The total mass is of the order of 5000 tons. (Credit ESO.)*

To achieve the given objectives, we needed a target acquisition system to select the objects of interest in the telescope's focal plane. Movable 'pick-off' mirrors would enable this type of selection. The mirrors operate when the target light, diverted by the pick-offs, is then redirected to fixed spectrographs via more mirrors. The images of the galaxies are cut into slices (~40) which are then optically rearranged in a line to form pseudo-slits

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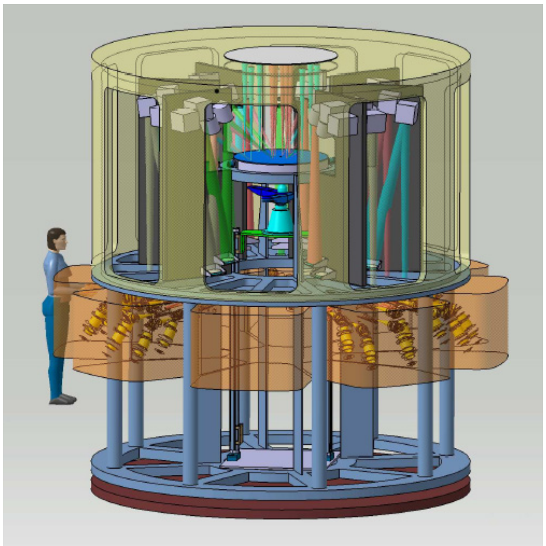

Figure 2. The EAGLE concept. The instrument is vertical at the gravity-invariant focal station of the E-ELT. The upper part is the target acquisition system in its (yellow) enclosure. The spectrographs in their cryostats are shown in the lower part (brown boxes).

at the entrance slits of the spectrographs. These 'image slicers' or 'integral field units' [3] dissect the galaxy images into more than a thousand spatial elements, each of them producing a spectrum that can then be recollated as a 3D map.

To get the best possible spatial information, adaptive optics allows for the correction of the images blurred by the atmosphere. The challenge for our telescope is to make the adaptive optic process work over a 'wide' field of view (5–10arcmin of arc in diameter).[4] Recently, ESO achieved an important milestone by demonstrating that a field of view of 2arcmin can be corrected on an 8m telescope.[5] Going beyond 2arcmin will require novel adaptive optics techniques, such as multiobject adaptive optics, which corrects the wavefront locally in the direction of each target observed by the instrument, using a deformable mirror in each channel. We are planning to test this concept at the William Herschel Telescope in a project called, appropriately enough, CANARY. Segmenting the field and fully correcting each subfield with adaptive optics is another route being explored.

Adaptive optics requires bright reference sources, which are close to the observed target, to measure in real time (a few hundred hertz) the distortion induced by the turbulent atmosphere. This wavefront sensing can be done on bright stars, but increasing the sky coverage requires the use of laser guide stars (LGSs) to accomplish this task.[4] EAGLE expects to need six to nine LGSs to perform tomographic reconstruction of the turbulent wavefront over the 5arcmin field of view of the instrument.

EAGLE is currently in a conceptual study phase (Phase A) with contributions from a consortium of French and UK institutes located in Marseille and Paris in France, and Edinburgh and Durham in the UK. The study will deliver design analyses, technology, and a detailed plan for the construction phase to ESO. The development of the instrument, possibly involving new partners, should take place from 2010 to 2017, when the E-ELT is scheduled to become operational.

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