OPTIMOS–EVE: A Fibre-fed Optical–Near-infrared Multi-object Spectrograph for the E-ELT

François Hammer1
Lex Kaper2
Gavin Dalton3

1 GEPI, Observatoire de Paris, France
2 NOVA, University of Amsterdam, the Netherlands
3 Science and Technology Facilities Council, Rutherford Appleton Laboratory, Didcot, United Kingdom

Team members:
Michael Andersen1, Giuseppina Battaglia2, Piercarlo Bonifacio2, Bart Buijs3, Andrew Bunker5, Fanny Chemla3, Paolo di Marcantonio6, Hector Flores2, Isabelle Guinouard3, Paul Groot7,4, Elke Gänster4, Hans-Günter Ludwig3, Christophe Martayan2, Ramon Navarro2,6, Patrick Petitjean10, Matthieu Puech4, Johan Pragt1,6, Per Kjærgaard Rasmussen1, Myriam Rodrigues3, Emmanuel Rollinde3, Eric Sawyer11, Luca Sbordone3, Daniel Schaerer12, Paolo Spanò13, Ian Toth11

OPTIMOS–EVE is a fibre-fed, optical-to-near-infrared multi-object spectrograph designed to explore the largest field of view provided by the E-ELT at seeing or GLAO-limited conditions. OPTIMOS–EVE can detect planets in nearby galaxies, explore stellar populations beyond the Local Group, and probe the physical conditions of galaxies including the most distant ones accessible with the E-ELT.

One of the major challenges in spectrograph design for the E-ELT is to build an instrument that samples the largest discovery space in terms of wavelength range, spectral and spatial resolutions, and multiplex. OPTIMOS–EVE is unique in covering a very large space in the spectral domain, spectral and spatial resolution and multiplex. OPTIMOS–EVE is unique in addressing some of the key, but versatile scientific conditions of galaxies including the non-thermal infrared, has been, and will remain, a key technique to investigate virtually all types of astrophysical targets. At z = 0 most of the spectral lines, fundamental for deriving astrophysical information, are found in the UV–optical range. At higher redshifts important spectral diagnostics shift into the near-infrared (NIR), and Lyman-α becomes accessible in the optical wavelength range. Due to the unique combination of wavelength coverage, multiplex and spectral resolution, most of the science that will be explored by OPTIMOS–EVE can neither be addressed by any other instrument concept under study for the E-ELT nor by JWST instruments. OPTIMOS–EVE responds to several of the key science goals put forward by the E-ELT Science Working Group and will explore the visible to NIR wavelength region, for sources both nearby and at cosmological distances.

The OPTIMOS–EVE Phase A study Science Team explored five key science cases (see Figure 1) from which the scientific and technical requirements (see Table 1) have been derived.

Plants in the Galactic Bulge and stellar clusters, also in external dwarf galaxies. Although over 400 extrasolar planets are known, these are mostly hosted around stars in the solar vicinity. For the few distant planets, besides those around radio pulsars, the orbits and masses are unknown. On theoretical grounds, environment is expected to play a significant role in the process of planet formation. Therefore, it is important to detect and characterise planets in environments different from the solar vicinity, such as the Galactic Bulge and Local Group galaxies. With a radial velocity precision of 10 m/s for giant stars down to magnitude 20, OPTIMOS–EVE will make such a study possible and allow to be monitored up to 40 stars in each observed field.

Resolved stellar populations in nearby galaxies. With the VLT, a detailed study of the stellar populations of the Local Group galaxies has been possible. However, many galaxy types are not represented in the Local Group. In order to make further progress in our understanding of galaxy formation and evolution we need to study in detail many different types of galaxies, e.g., in the groups of Sculptor and Centaurus A. With the high efficiency, low-resolution mode of OPTIMOS–EVE and its high multiplex, the E-ELT will open up the possibility of studying the stars down to the turn-off and addressing cosmologically relevant problems, such as the lithium abundance. The medium-resolution mode, with its multiplex of 70, is well adapted for this purpose.

Table 1. Key capabilities for OPTIMOS–EVE.

| Patro1 field of view | 7" diameter (unvignetted), 10" full field |
| Wavelength range | 370–1700 nm |
| Spectral resolving power | 60 000 18 000 30 000 |
| Number of targets | 240 70 40 |
| Apertures on sky | Single objects (0.9"), 30 medium IFUs (1.8 × 2.9"), single large IFU (7.8 × 13.5") |
| Wavelength coverage | λ=3–λ=6 (VIS); λ=10–λ=20 (NIR) |

Figure 1. Four of the five science cases of OPTIMOS–EVE with, on the right of each panel, the aperture (Φ), multiplex and the spectral resolution that will be offered to study them. The 30 medium, deployable IFUs (bottom left) can provide the best sky removal and can be used for all extragalactic cases. The fifth mode of OPTIMOS–EVE is the large IFU with 13.5 × 7.8 arc-second area for extended objects, including the 100 kpc halos of galaxies up to z = 3.5.
Tracking the first galaxies and cosmic reionisation from redshift 5 to 13. From polarisation measurements of the cosmic microwave background it appears that at \( z = 10 \) the Universe was already largely reionised, but little is known of the objects that powered this reionisation. The search for those “first sources” can be carried out with OPTIMOS–EVE to trace Lyman-\( \alpha \) up to \( z = 13 \). The ionised gas of very distant galaxies can be far more extended than the compact distribution of stellar light. With its 240 apertures, OPTIMOS–EVE will be an ideal instrument with which to catch most of the Ly-\( \alpha \) photons that can be diffused over relatively large areas (median 1.4 arcsecond at \( z \approx 3 \), see Rauch et al., 2008). Moreover the 30 medium IFUs are optimised to achieve excellent sky subtraction by sampling the sky around the target, and are thus very well suited for the first studies of the kinematics and chemistry of such primordial objects.

Mapping the ionised gas motions at large scales in distant galactic haloes. Observations of the local and distant Universe have shown that galaxies are surrounded by extended haloes of ionised gas that are the interfaces to the IGM and its enrichment with metals. The study of these haloes unravels the history of galaxy–galaxy interactions that leave recognisable signatures on the halo kinematics. OPTIMOS–EVE will be able to study galaxy haloes over the last 12 Gyr (up to \( z = 3.5 \)).

3D reconstruction of the IGM. The space between galaxies and galaxy clusters is not empty, but is filled with a very low density warm medium that is detectable as Lyman-\( \alpha \) absorption in the spectra of distant quasars. Although this provides a “cut-through” of the structure of the IGM along the line of sight, nothing is known about its transverse structure. Cosmological simulations suggest that the IGM has a filamentary structure, where filament crossings correspond to the locations of galaxy clusters. OPTIMOS–EVE will provide sufficient resolution and sensitivity to use Lyman-break galaxies of magnitude 25 as background sources. These galaxies have a sufficient spatial density to allow a real 3D reconstruction (tomography) of the IGM, which may be directly compared to cosmological simulations.

The OPTIMOS–EVE targets will be selected from imaging observations obtained with other telescopes, and many OPTIMOS–EVE studies will significantly benefit from complementary observations with JWST, ALMA and Gaia.

Instrument design concept

OPTIMOS–EVE has been designed for the E-ELT Nasmyth focus. The fibre-positioner pro-

Figure 2. Schematic overview of OPTIMOS–EVE. The three main subsystems of the instrument are clearly indicated: the focal plate carousel-positioner, containing four focal plates with various single object fibre inputs and IFUs as well as a robot positioner; the fibres, to transport the collected light to the spectrograph, guidance sensors and from the calibration source; the spectrographs, consisting of a visible fibre; the spectrographs employ VPH gratings.

Observation of multiple Ly-\( \alpha \) emitters with the FLAMES/GIRAFFE and X-shooter; it is a robust instrument, which can be developed, manufactured and integrated using existing technologies.

Performance

A few examples of instrument performance among the science drivers are presented. For diffuse Ly-\( \alpha \) sources, the use of fibres on the sky to map temporal sky variations, allows the detection with S/N = 8 for fluxes of \( 10^{-19} \) erg s\(^{-1}\) cm\(^{-2}\) in 40 hours. Galaxy halo kinematics to \( z = 3.5 \) can be studied in 10 hours per galaxy. Observation of multiple Ly-\( \alpha \) emitters with the IFUs at \( R = 6000 \) for IGM studies enables a continuum S/N from 30 to 50 to be reached in 10 hours exposure.

References


Links

http://www.OPTIMOS-EVE.eu

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