New technical facilities for astronomy instrumentation

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Over the next decade, several major instrumental astronomy projects will come to fruition and will increase our understanding of the universe. One of these projects—the European Space Agency’s (ESA) Euclid mission—is due to be launched in 2020. In addition, a new set of 20–40m ground telescopes—e.g., the Giant Magellan Telescope (GMT), the Thirty Meter Telescope (TMT), and the Europe Extremely Large Telescope (E-ELT)—will reach completion by the mid-2020s. All these space and ground-based experiments require development of new concepts and technologies, as well as technical facilities for their testing and calibration campaigns.

The Euclid mission will observe 15,000 square degrees of the sky and will be the most powerful space experiment dedicated to the study of the universe. Images of more than 2 billion galaxies will be obtained, and the distance to 50 million of those galaxies will be measured. The most detailed 3D map of the universe—looking back about 10 billion years—will thus be created. Euclid will allow the distribution of galaxies during different epochs to be determined. This is a major step toward understanding the mysterious ‘dark energy’ that affects the accelerating expansion of the universe, and which is one of the main challenges of modern physics. The 39m E-ELT will be part of the European Southern Observatory (ESO). This telescope will combine a huge collecting power and fully integrated adaptive optics to achieve exquisite image quality and sensitivity. With the E-ELT it will be possible to observe rocky planets orbiting extrasolar stars, study the formation and evolution of galaxies, determine cosmological parameters, and observe the first galaxies that formed in the early universe.

At the Laboratory of Astrophysics of Marseille (LAM), we are involved with the development and support of several aspects of these experiments. We have designed and built two new technical facilities—a large cryogenic vacuum chamber (ERIOS) and the 2.5m polishing active and robotic integrated system (POLARIS)—which are dedicated to the development, assembly, and space qualification of ground and space astronomy instruments. With a budget of almost €7 million, it has taken over eight years since the concept was first conceived to realize these new facilities.

With support from the French space agency (CNES) we are responsible for the design and delivery of the Near Infrared Spectrograph and Photometer (NISP) on Euclid’s payload. NISP will be used to detect the signatures of chemical elements such as hydrogen from galaxies, so that their distance can be inferred via redshift calculations. We have designed the instrument’s mechanical structure and grisms (grating prisms). We are also responsible for the system study and instrument product assurance, as well as its assembly and final characterization in a space-like environment. This work has involved a high-quality development program for critical optical components (e.g., the grism), and the design of a silicon carbide (SiC) structure for the focal plane that hosts 16 H2GR detectors. Our ERIOS chamber

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(see Figure 1) is installed in a large integration hall, which includes a 100T seismic mass to provide high stability (<10^{-7} g at 5–100Hz). The chamber, with a volume of 45m^3, has 77K and 10^{-4} mbar cryo-vacuum capabilities. As the scientific wavelengths of NISP range from 1.0–2.3 μm, this large volume permits IR measurements and qualifications to be made without background pollution. The large volume also allows all the necessary optical qualification equipment to be housed in the chamber.

For more than 10 years we have also been heavily involved in design studies for the E-ELT. LAM is a partner on the telescope’s HARMONI first-light instrument, which is a visible and near-IR integral field spectrograph. In addition, we are preparing a bid for a multi-object spectrograph, after leading two of the three phase A studies for this instrument. In our strong E-ELT research and development program we focus in particular on adaptive optics techniques, high-contrast imaging, and optical fabrication. We have used our POLARIS technical facility (with support from ESO, and in collaboration with Thales SESO) to develop the ‘stress mirror polishing’ (SMP) technique. This methodology will allow the 1000 segments (each 1.5m in diameter) of the E-ELT’s primary mirror to be built in a cost- and time-effective manner.\(^4,5\)

Our POLARIS facility combines a full-size tool for stress polishing (up to 2.5m diameter) with robotic capabilities. We are currently (until March 2015) using POLARIS for SMP on one of the E-ELT’s mirror segments. In this process,\(^4,5\) we use a 24-actuator warping harness to generate the off-axis aspheric surface portions of the mirror segment. We first bend, and then spherically polish the segment, which is attached to the harness (see Figure 2). This allows convergence to the final form to be achieved quickly and with excellent optical quality.

We have designed and built new technical facilities at LAM for the fabrication, assembly, integration, and testing of future ground and space-based astronomy instruments. These facilities allow us to support major projects, such as the forthcoming ESA Euclid mission and the ESO E-ELT. In 2015 we will begin to use the ERIOS chamber for qualification of the NISP instrument and its associated optical ground support equipment. Our high-tech facilities are also open for use by other institutions, within the framework of an industrial or partnership policy.

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Marc Ferrari is an astronomer, and is the author or co-author of more than 160 journal and conference publications, as well as several patents. He was head of the Research in Optics and Instrumentation group for eight years. Since 2012 he has been the LAM deputy director, and is in charge of research and development, technical facilities, and partnerships.

**References**


![Figure 2](Image)