2° Forum della Ricerca Sperimentale e Tecnologica

SHARP - A near-IR multi-mode spectrograph for MORFEO@ELT

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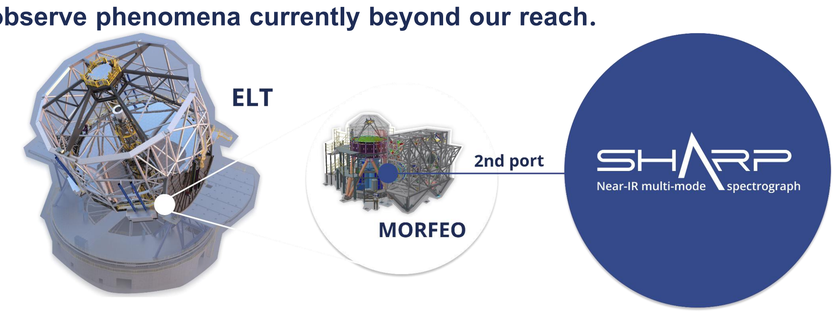
INTRODUCTION

ESO's Extremely Large Telescope (ELT) is a ground-based telescope that is expected to provide unique data thanks to the world's largest aperture and the cutting-edge Multi-Conjugate Adaptive Optics (MCAO) system MORFEO. MORFEO is able to correct a wide field for the distortion induced by atmospheric turbulence, enabling the supported instruments to explore the Universe at unprecedented depth and clarity.

The spectrograph occupying the 2nd port of MORFEO@ELT will be the most powerful instrument in the modern era, and will be able to observe phenomena currently beyond our reach.



SHARP is a near-infrared multi-mode spectrograph intended for a future ESO's call for new instrument as the device designed for the 2nd port of MORFEO@ELT.

TECHNO GRANT 2022 #1 - 98 kEUR

This grant made it possibile to finance a **PhD scholarship at Politecnico di Milano** acquiring Ing. Hossein Mahmoodzadeh.

In particular the grant financed the following activities:
- Presentation of SHARP project at SPIE and proccedings publication (Proc. of SPIE Vol. 13096 130965I-5);
- 84 **kEUR for PhD sholarship at PoliMi** (Ing. Hossein Mahmoodzdeh)
- Organization of the 3 days workshop **"Unveiling the Universe with SHARP",** 30 Sept - 02 Oct 2024, Palazzo Brera, Milano;
- paper(s) publication

SCIENTIFIC DRIVERS & MAIN REQUIREMENTS

- **What are the physical conditions that govern star formation in the early Universe?**
- **What is the dark matter content of galaxies across the cosmic time?**
- **What is the physical interplay between black holes and hosting galaxies?**
- **Where is the elusive PopIII of primordial stars?**

To answer these questions, it is needed to:

consistently track the properties of galaxies from the earliest epochs to the present. These properties are encoded in the atomic lines, whose observed wavelengths increase with increasing redshift. Therefore, to observe them in the early Universe (i.e. at high redshift) it is needed to reach the near-infrared limit (see Figure 1);

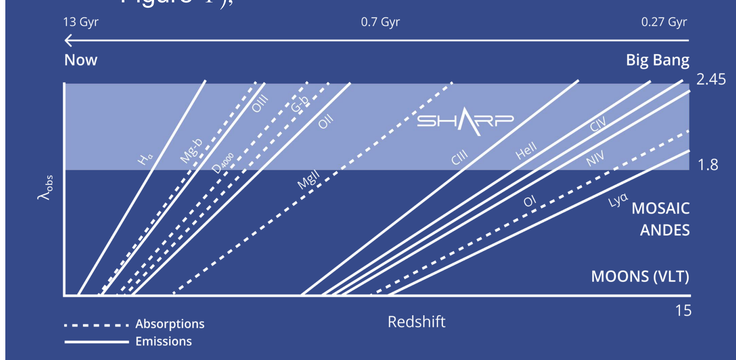


Figure 1. Observed wavelength of the main atomic emission (dashed lines) and absorption (solid lines) lines as a function of redshift. The light-blue horizontal stripe marks the wavelength limit of the next-generation spectrographs of ELT (MOSAIC and ANDES) and of the Very Large Telescope (MOONS).

resolve the properties of galaxies on scales of 150-200 pc, which correspond to the dimensions of giant molecular gas clouds that track the galaxies' dynamics and the regions where star formation occurs. To sample sizes of 150-200 pc over the entire cosmic time, it is needed an angular resolution of ~0.03 arcsec (see Figure 2);

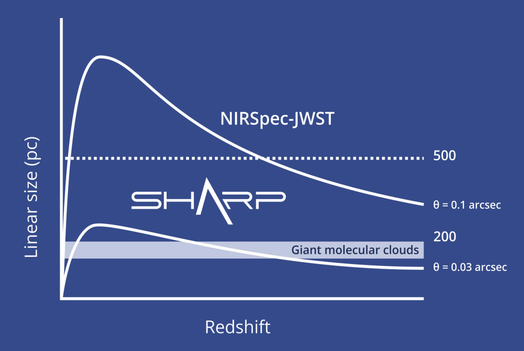


Figure 2. The linear size subtended by an angle θ ~0.031‘ equal to the pixel scale of SHARP (lower curve), and that subtended by an angle θ=0.1‘ corresponding to the NIRSpec@JWST (upper curve) as a function of redshift. The grey stripe represents the size of giant molecular gas clouds. The angular resolution reached by MORFEO+SHARP resolves this size over the entire cosmic time.

SHARP in detail

SHARP consists of two main units: a slitlets Multi-Object Spectrograph (MOS) called NEXUS and a multi-Integral Field Unit (mIFU) called VESPER. The instrument is fed by an Atmospheric Dispersion Corrector and a Natural Guide Star Unit.

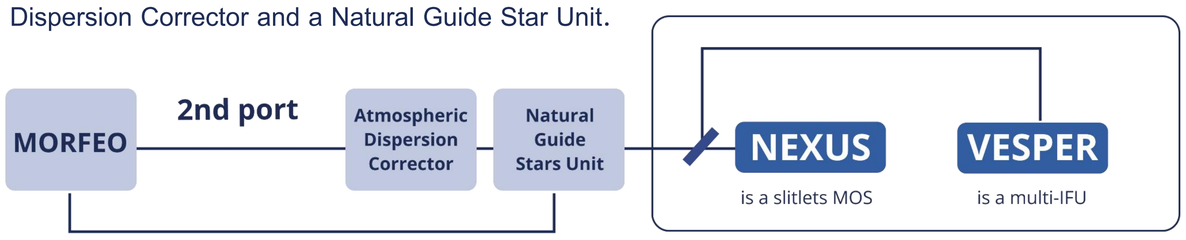


Figure 3. Components and optical path from the 2nd port of MORFEO to SHARP.

NEXUS		VESPER	
[0.95-2.45] μm (simultaneous)		[1.2-2.4] μm (simultaneous)	
Field of view	~1.2'x1.2' AO corrected	**Area probed**	~24"x70" AO corrected
Multiplexing	~30 slits	**Number of IFSs**	12
Pixel scale	35 mas/pixel	**Field of view (single IFS)**	1.7"x1.5" (spaxel 31 mas)
Spectral resolution	6000/2000/300 (ext) ~17000 (point source)	**Spectral resolution**	3000/4000 (extended/point source)

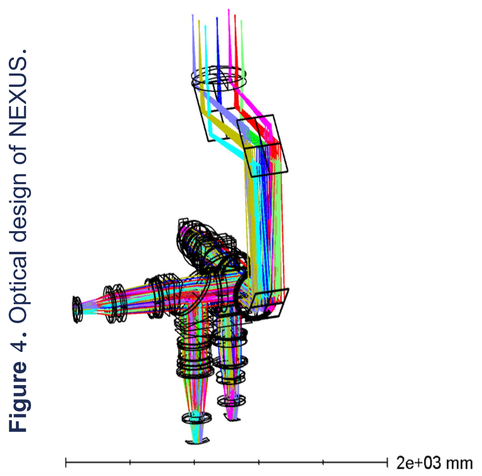


Figure 4. Optical design of NEXUS.

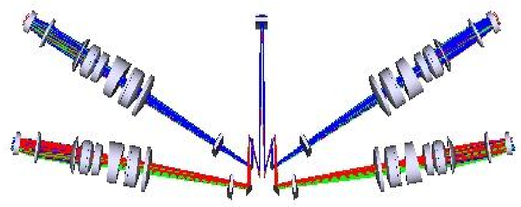


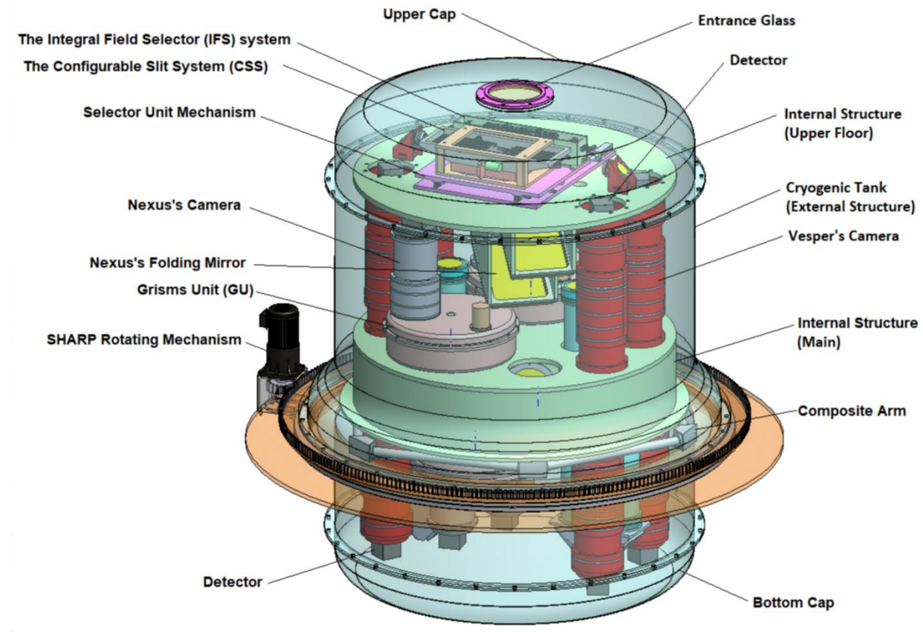
Figure 5. Optical design of VESPER.

NEXUS is fed by a Configurable Slit System (CSS) deploying 30 slits of length 2.4" over a field of 1.2'x1.2'. Each slit is fed by an inversion prism allowing to rotate the field subtended by the slit by an arbitrary angle. The light coming from MORFEO and coming out from the CSS is splitted into four wavelength ranges, which are fed to a dedicated camera (see Figure 4).

VESPER is an image slicer consisting of 12 probes called Integral Field Selectors (IFSs), which are disposed in a cartesian xy grid contiguous along the x direction and deployable along ~60" in the y direction (see Figure 5).

Optical design by Paolo Conconi.

OPTO-MECHANICAL CONCEPTUAL DESIGN



Preliminary design of the system (by Hossein Mahmoodzedeh). The cryogenic cylindrical tank has dimensions of 2000 mm in diameter and 3000 mm in height.The design involves the two main systems: NEXUS, comprising four-wheel mechanism systems and four independent cameras, and VESPER, composed of two main channels, two slicing systems, and eight independent cameras. At the entrance of both NEXUS and VESPER, there are two critical subsystems: the Configurable Slit System (CSS) for precise mechanical alignment of the slits, and the Integral Field Selector system for collecting spatially resolved spectra from specific positions.

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