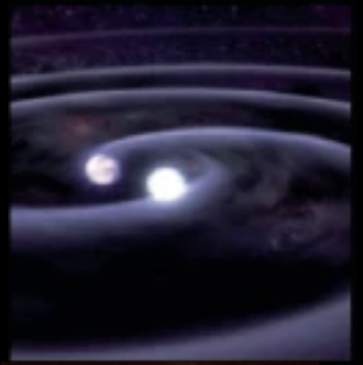
The ELT perspective on multi-messenger astronomy



Francesca Annibali (INAF-OAS)
on behalf of the MORFEO team

Multimessenger Astronomy in the Einstein Telescope era
10-12 Feb. 2026 - Padova

Extremely Large Telescope (ELT): the largest optical/IR telescope in the world

ELT in January 2025

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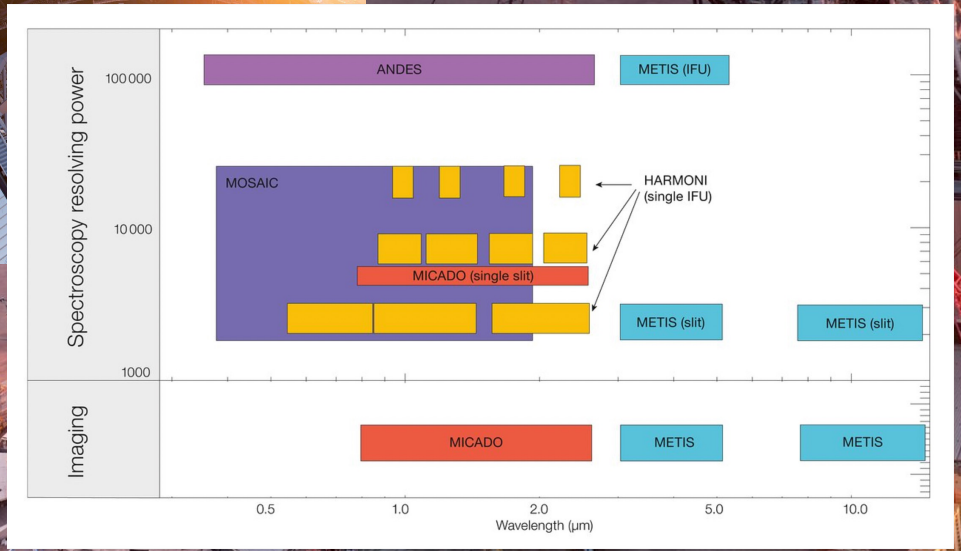

- 39 m segmented primary mirror & adaptive optics
- On Cerro Armazones, Atacama desert
- First science light in 2030
- 1st generation instruments:
  MICADO, METIS, MORFEO, HARMONI
- 2nd generation instruments:
  ANDES, MOSAIC, PCS

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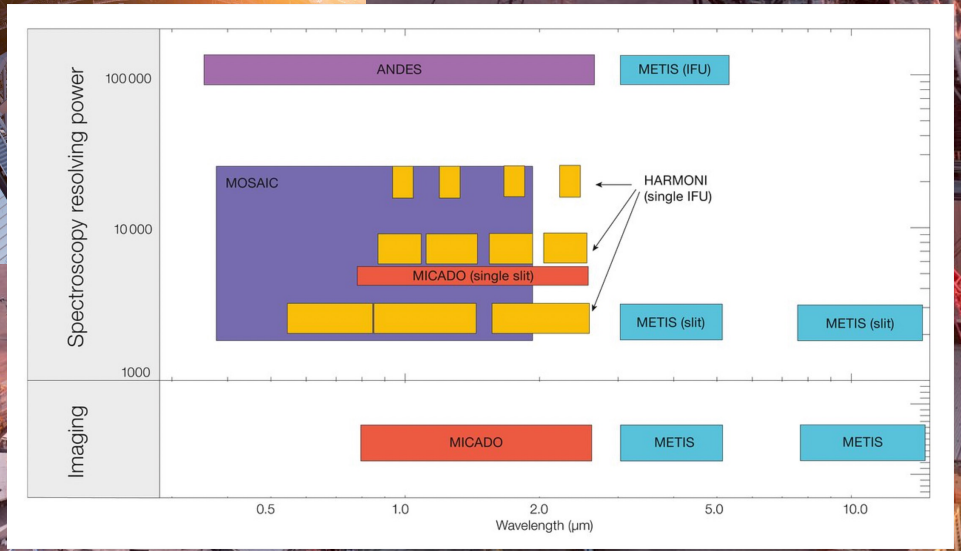

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ELT in January 2025

MICADO: Multi-AO Imaging Camera for Deep Observations

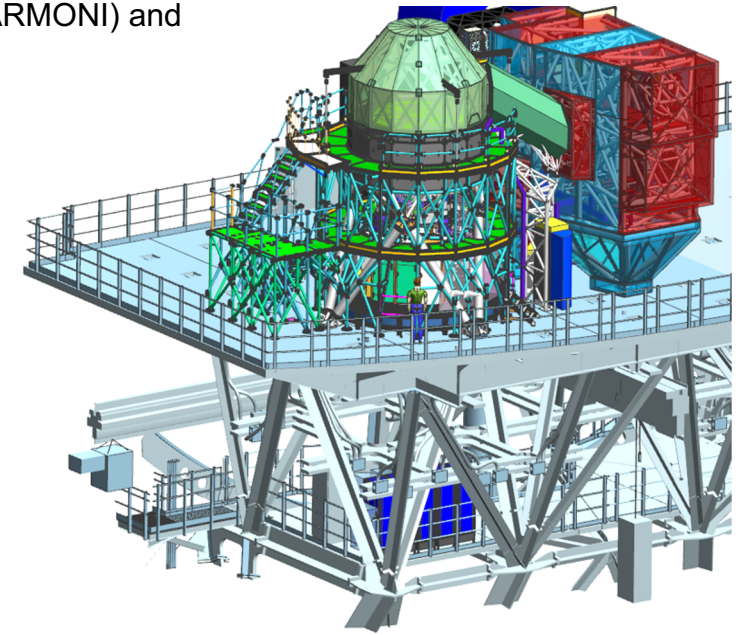
(PI R. Davies)

- First light instrument for the ELT
- Will operate in stand-alone mode (SCAO)
  until MORFEO will arrive at ELT a couple years later
- Key capabilities:

❖ 0.8-2.4µm with 27 broad/narrow filters ❖ 1.5 & 4mas pixels for 19” & 51” FoV at 6-12mas ❖ Similar sensitivity to JWST, and 6× better resolution	**IMAGING**
❖ 10-50µas precision anywhere in the field ❖ 10µas/yr = 5km/s at 100 kpc after only a few years	**ASTROMETRIC IMAGING**
❖ focal & pupil plane coronagraphs ❖ angular differential imaging ❖ small inner working angle	**HIGH CONTRAST IMAGING**
❖ for compact sources ❖ fixed configuration for 0.83-1.57µm & 1.50-2.46µm ❖ R ~20000 for point sources (R ~ 10000 across slit)	**SPECTROSCOPY**

MORFEO: Multiconjugate adaptive Optics Relay For ELT Observations (PI P. Ciliegi, INAF)

- MORFEO is the AO instrument for the ELT (serving MICADO and HARMONI) and will provide MCAO correction
- First Technical light end of 2031, commissioning in 2031-2032
- One of the largest projects with INAF leadership:
  - ❖ INAF: leader institute, 85% of FTE
  - ❖ CNRS, France : LGS WFS module
  - ❖ University of Galway, Ireland : Test Unit
  - ❖ NRC, Canada : Real Time Computer
  - ❖ Three Japanese Institutes (NAOJ, University of Kyoto, University of Osaka): two Optical elements



GTO (105 NIGHTS IN TOTAL)	
INAF	80.3
CNRS	9.2
UoG	2.5
NRC	6.0
JPI	7.0

AO with MORFEO at ELT

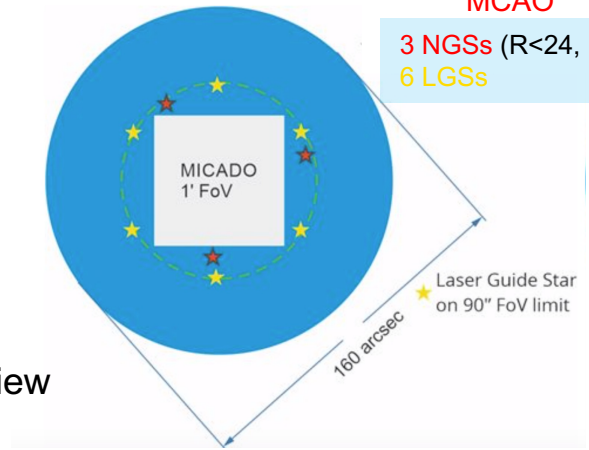
- ✓ MORFEO will provide spatially uniform multi-conjugate adaptive optics (MCAO) correction to MICADO over a large field of view (~1 arcmin^2)
- ✓ MORFEO will also support SCAO over a smaller ~10” field of view

SCAO

1 NGS (R<16)

MCAO

3 NGSs (R<24, H<21)
6 LGSs



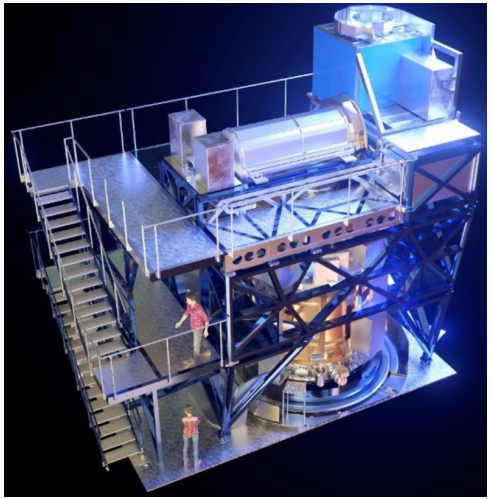
- ✓ Uniform Strehl Ratio and FWHM over a large field of view
- ✓ Large sky coverage

Possibility to adress a large variery of science cases based on astrophysical relevance rather than on feasibility criteria

HARMONI: High Angular Resolution Monolithic Optical and NIR Integral field spectrograph (PI J. Dunlop, Univ of Edinburgh, UK)

- HARMONI recently rescoped (MORFEO will provide AO correction)

Simplified HARMONI		
Spatial pixel scale	6x6 mas	25x25 mas
FoV	1.2”x 0.9”	3.8” x 5.1”
Wavelength range	0.8 – 2.4 μm	
Spectral resolution	R=7000 (Iz, J, H, K) R=3000 (Iz+J, H+K)	
SCAO	4x4 mas sampling	
MCAO		



- Courtesy Mark Swinbank (HARMONI PS)

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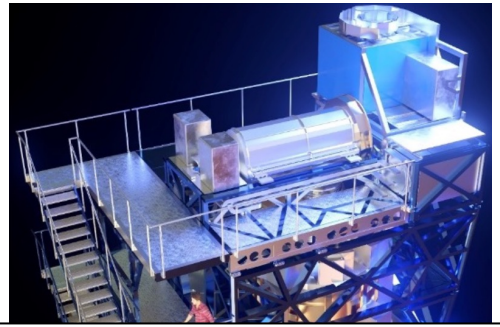

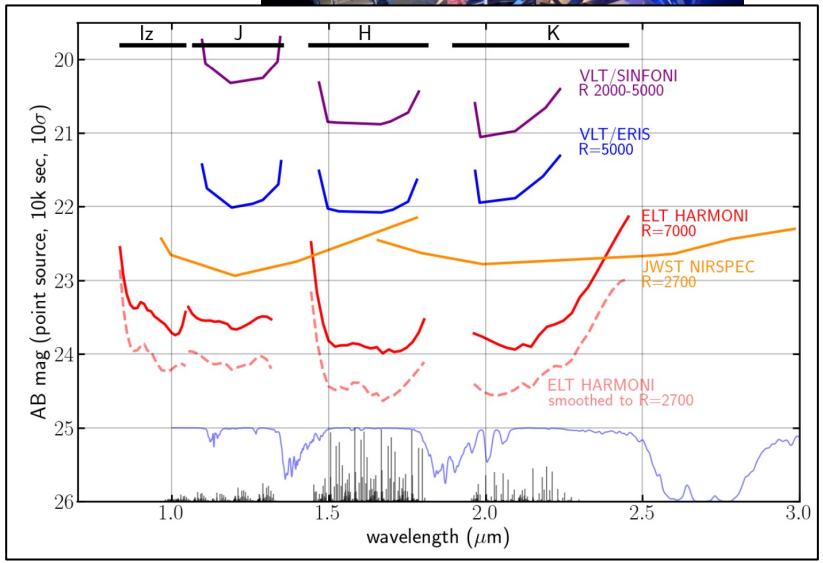

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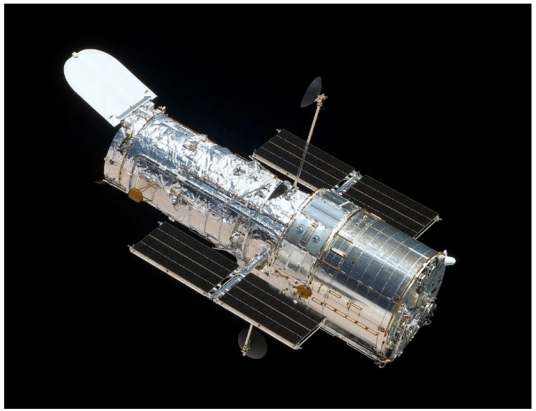
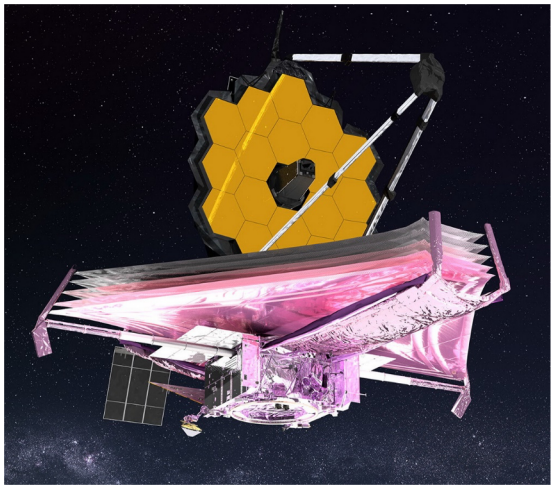
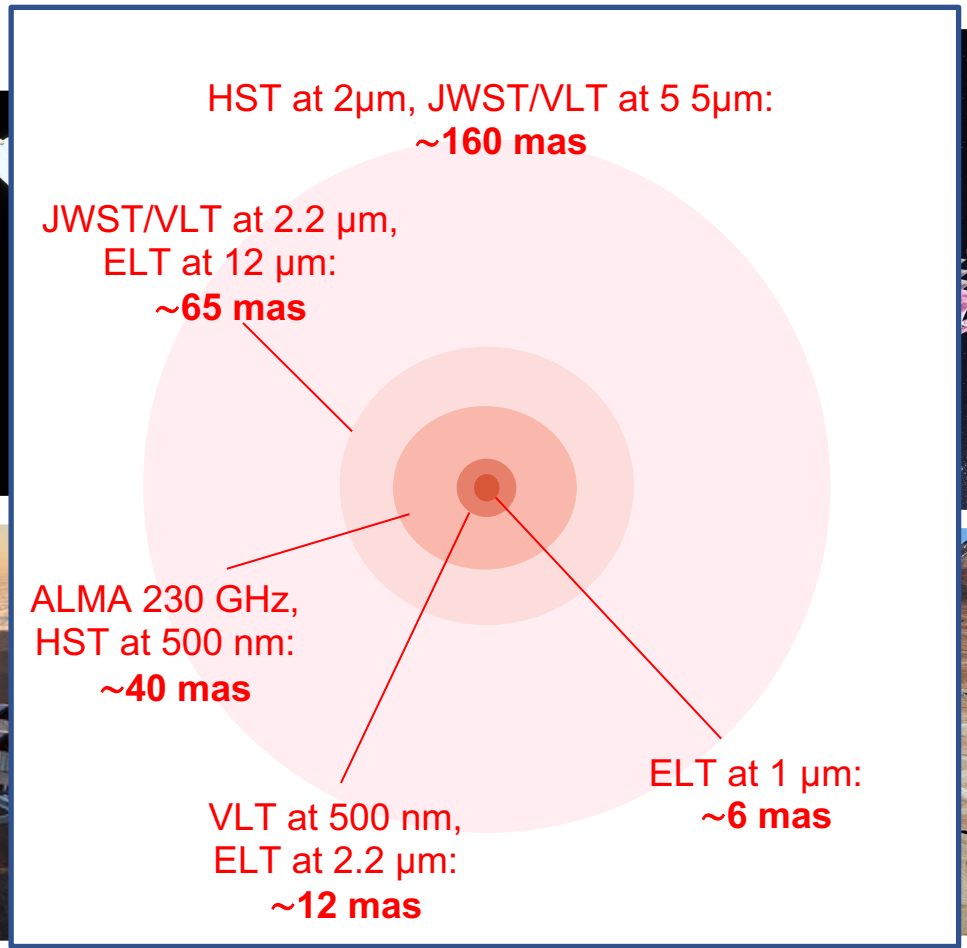
MORFEO+MICADO: resolution in context

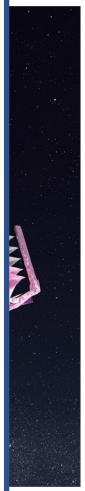




MORFEO+MICADO: resolution in context

10 mas at:		
Galactic Center	8 kpc	0.4 mpc
Cen A	4 Mpc	0.2 pc
Virgo Cluster	18 Mpc	1 pc
Cosmic Noon	z~ 2	80 pc





Exploring the Early Universe with Gamma-Ray Bursts

From Fiorentino +17 white book, a science case proposed by E. Maiorano, A. Rossi, E. Palazzi, G. Stratta, et al. + CIBO collaboration

- Long GRBs associated with the death of massive stars
- At z>6, they may be signatures of PoP III stars

With MORFEO/MICADO/HARMONI@ELT:

1) Absorption spectroscopy of fading afterglow

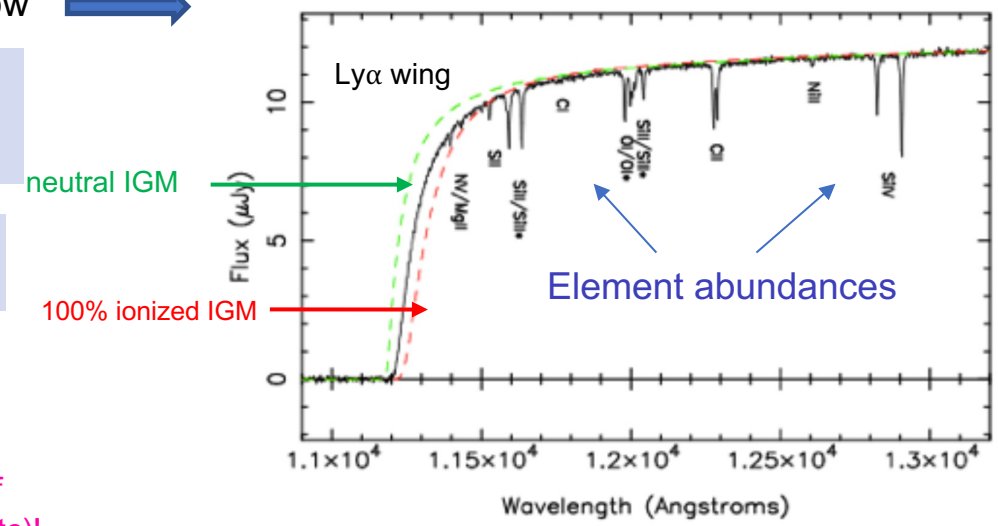
Cosmic chemical evolution: AGs provide high-S/N spectra enabling study of abundances in host and intervening absorbers.

Reionization: AGs provide info on column density of HI → constrain on f_{esc}

2) Imaging/emission line spectroscopy of host galaxy

Detection of z>6 GRB is ≲1/yr, but increased rate of discovery with future facilities (SVOM, THESEUS, etc)!

z=8.2 simulated ELT afterglow (~1 day after)



Characterization of electromagnetic counterpart candidates of multi-messenger compact binary coalescence systems

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- Electromagnetic counterpart of NS-NS and NS-BH mergers
- Studying host galaxy + klilonova

By resolving in detail the host's stellar population, we could get insights on the age of the progenitor

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MORFEO/MICADO Simulations by Letizia Scaloni, PhD student at INAF-OAS/Unibo

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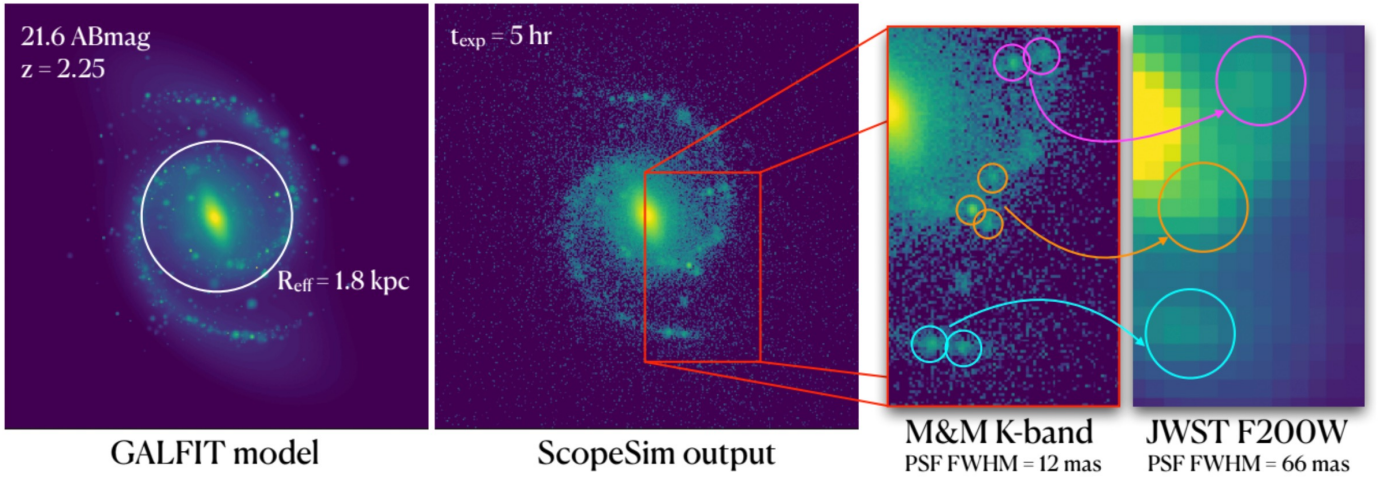

Revision of White Book from Fiorentino+17

- Need to revise science cases at the light of recent discoveries (e.g, JWST revolution)
- Re-evaluate science feasibility due to updated MORFEO performances. Also new tools for simulations now available.
- First draft of WB foreseen for the end of May
- Input from multi-messenger community very welcome!

Thank you!

1st and 2nd generation instruments