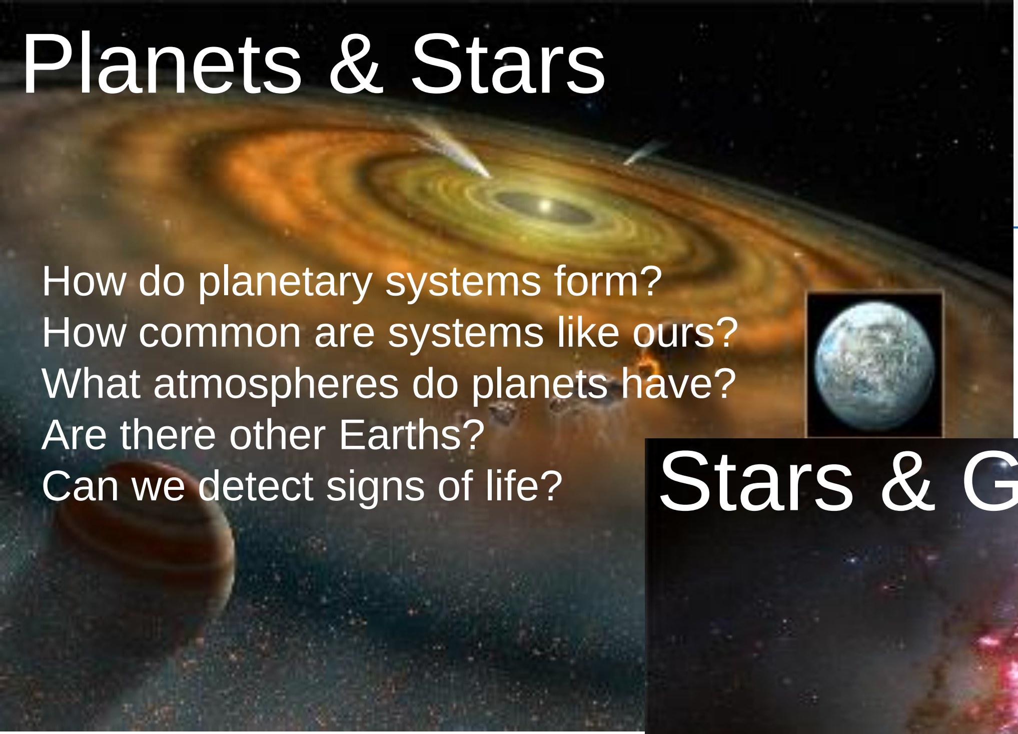
ELT Instrumentation

Suzanne Ramsay
ELT Instrumentation Manager

ELT science

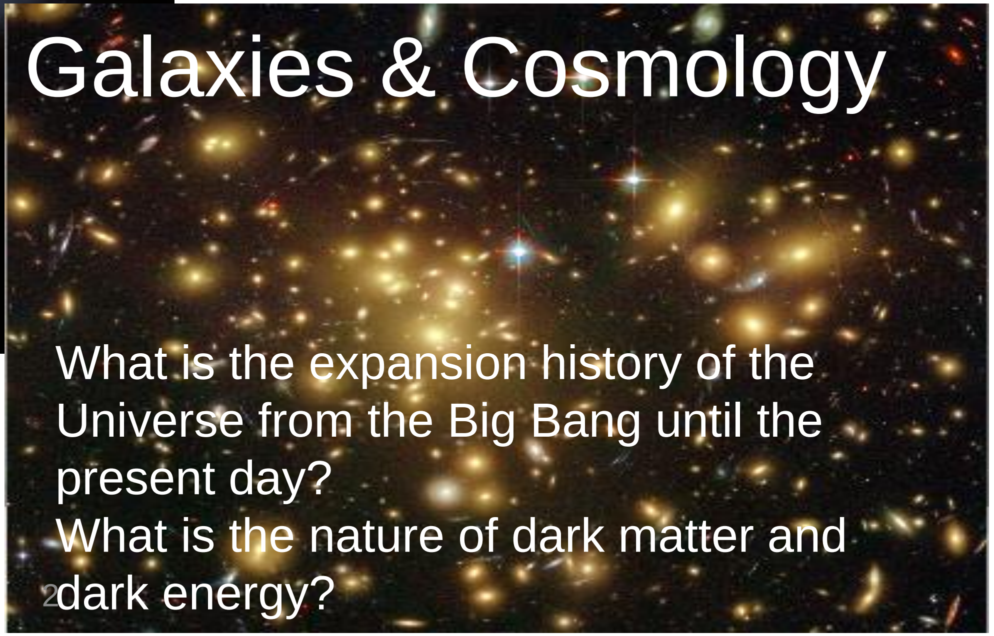


Planets & Stars

How do planetary systems form?
How common are systems like ours?
What atmospheres do planets have?
Are there other Earths?
Can we detect signs of life?

Stars & Galaxies

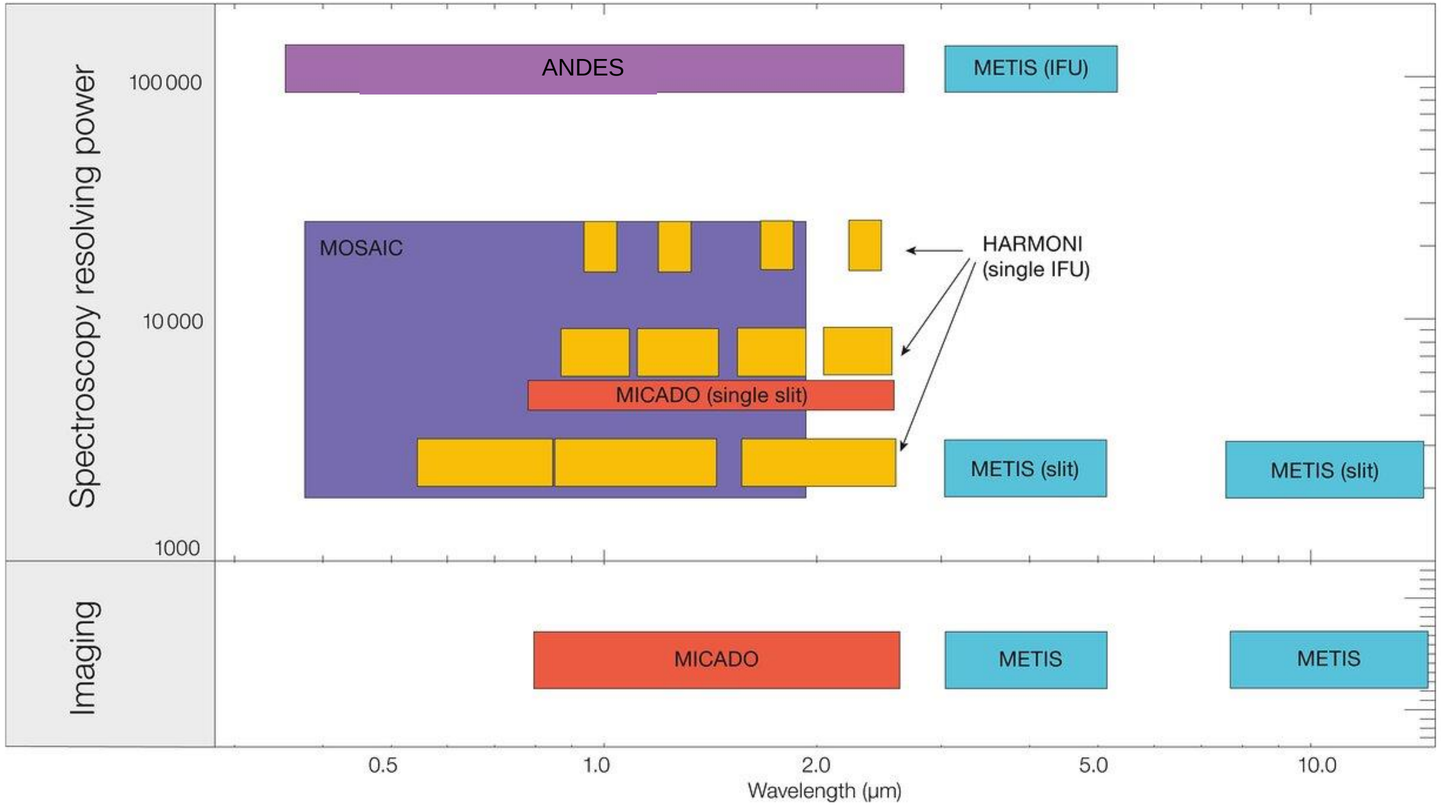
How do galaxies assemble and evolve across time?
When did the first galaxies form?
Did they re-ionise the Universe? If so, when?

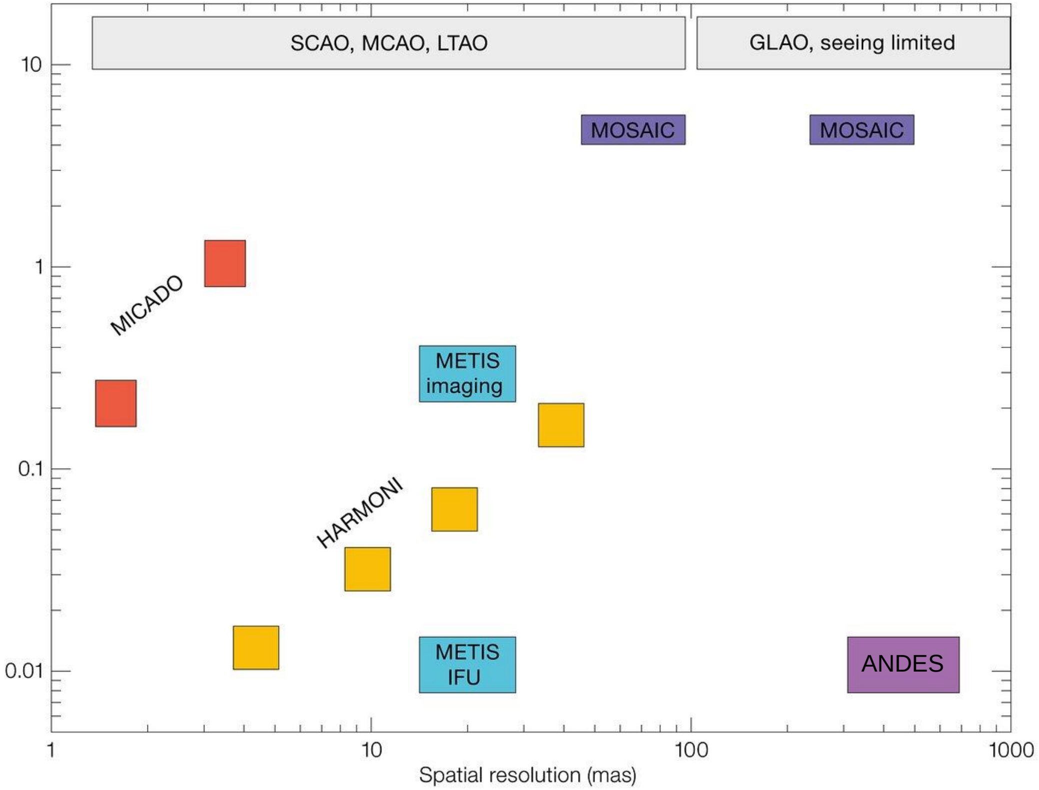


Galaxies & Cosmology

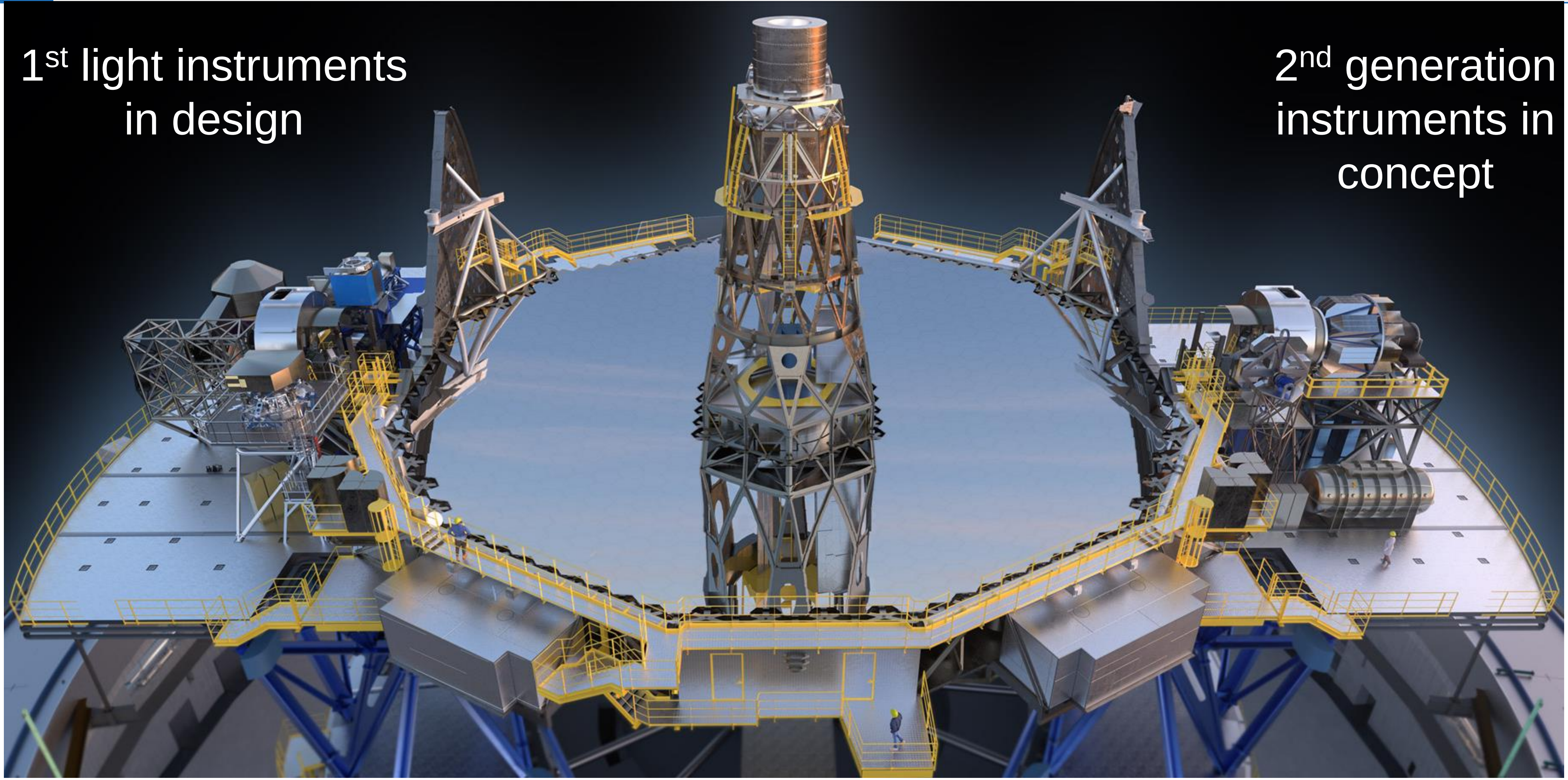
What is the expansion history of the Universe from the Big Bang until the present day?
What is the nature of dark matter and dark energy?

Parameter Space covered by the instruments



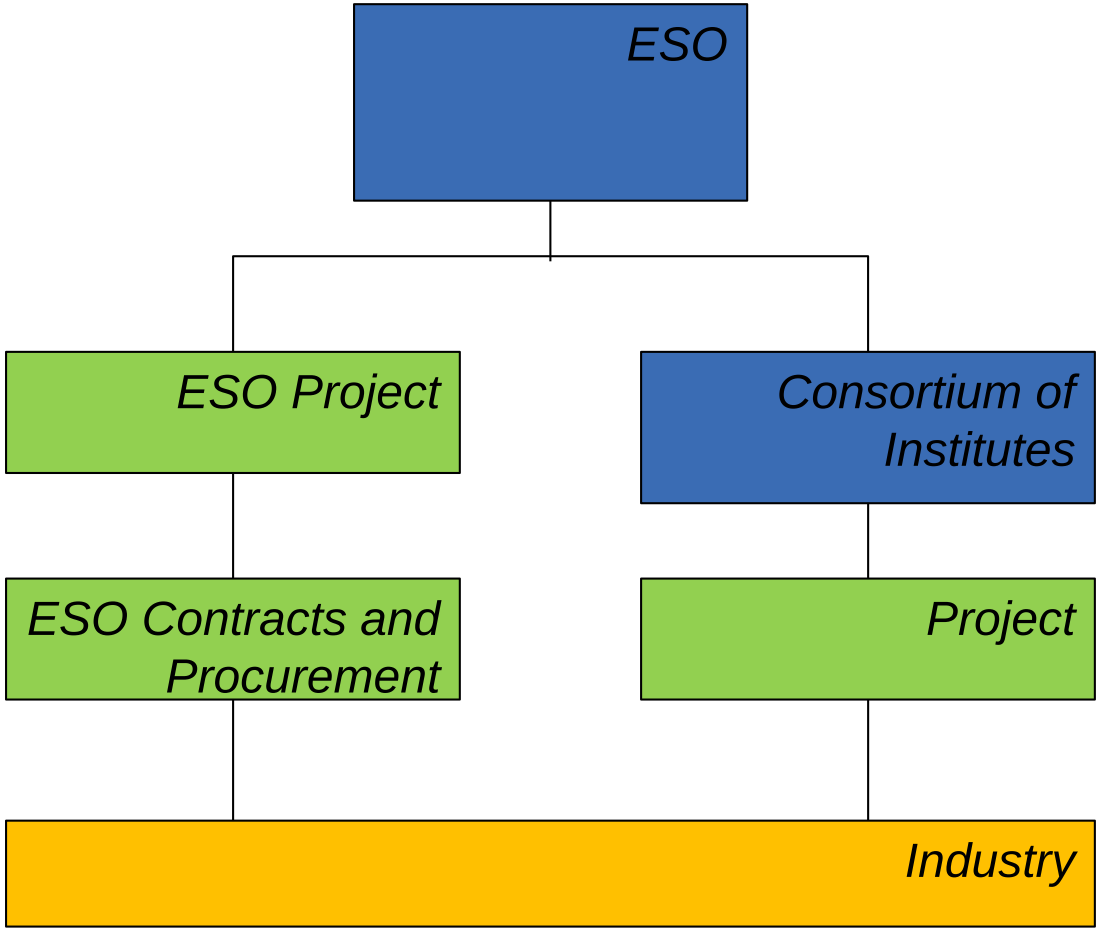


ELT M1 & Instrument platform overview



Overview

- Three instruments and two adaptive optics modules are being delivered under the ELT Construction Project by 4 external consortia
  - Total procurements >100MEuro
- MICADO, METIS and HARMONI are finishing the Final Design Phase
  - Procurements starting now and increasing in 2022/2023
- The MAORY adaptive optics module is just passed Preliminary Design Review
  - Early procurements start in 2022 (optics)
- Two new instruments, MOSAIC and ANDES, start in 2022
- In the future: ELT Planetary camera and spectrograph (see Tech Dev presentation)



Structure of ESO projects. ELT Instruments are all being built by consortia of institutes

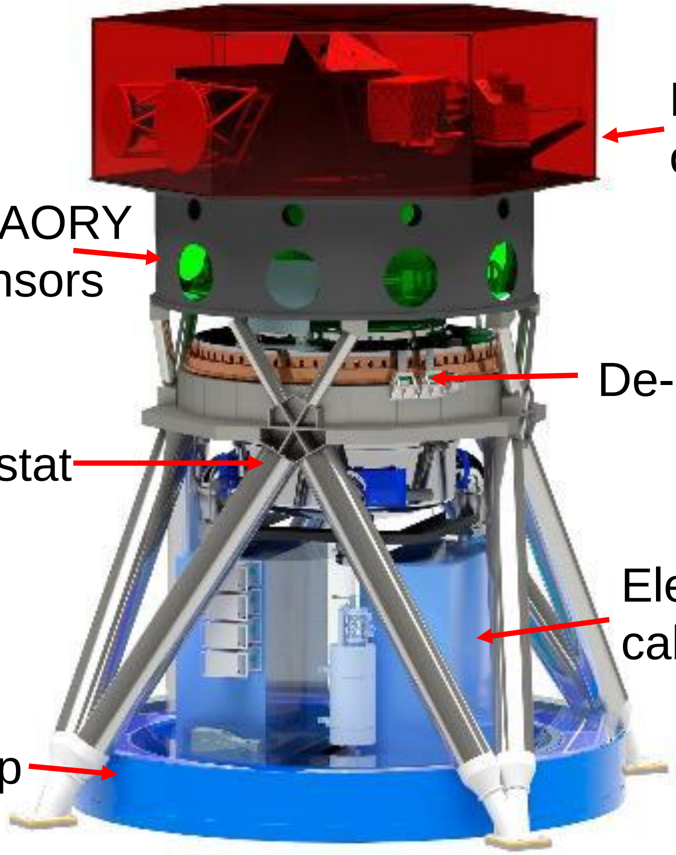
Instrument	Main specifications			Schedule				
	Field of view/slit length/ pixel scale	Spectral resolution	Wavelength coverage (μm)	Phase A	Project start	PDR	FDR	First light
MICADO	Imager (with coronagraph) 50.5″ × 50.5″ at 4 mas/pix 19″ × 19″ at 1.5 mas/pix	*I, Z, Y, J, H, K* + narrowbands	0.8–2.45	2010	2015	2019		
	Single slit	*R* ~ 20 000						
MAORY	AO Module SCAO – MCAO		0.8–2.45	2010	2015	2021		
HARMONI + LTAO	IFU 4 spaxel scales from: 0.8″ × 0.6″ at 4 mas/pix to 6.1″ × 9.1″ at 30 × 60 mas/pix (with coronagraph)	*R* ~ 3 200 *R* ~ 7 100 *R* ~ 17 000	0.47–2.45	2010	2015	2018	2023	
METIS	Imager (with coronagraph) 10.5″ × 10.5″ at 5 mas/pix in *L, M* 13.5″ × 13.5″ at 7 mas/pix in *N*	*L, M, N* + narrowbands	3–13	2010	2015	2019	2022	
	Single slit	*R* ~ 1400 in *L* *R* ~ 1900 in *M* *R* ~ 400 in *N*						
	IFU 0.6″ × 0.9″ at 8 mas/pix (with coronagraph)	*L, M* bands *R* ~ 100 000						
ANDES	Single object	*R* ~ 100 000	0.4–1.8 simultaneously	2018	2022			
	IFU (SCAO)							
	Multi object (TBC)	*R* ~ 10 000						
MOSAIC	~ 7-arcminute FoV ~ 200 objects (TBC)	*R* ~ 5 000–20 000	0.45–1.8 (TBC)	2018	2022			
	~ 8 IFUs (TBC)	*R* ~ 5 000–20 000	0.8–1.8 (TBC)					
PCS	Extreme AO camera and spectrograph	TBC	TBC					

1 milliarcsecond (mas) = 0.001″


METIS
MAORY
HARMONI
MICADO

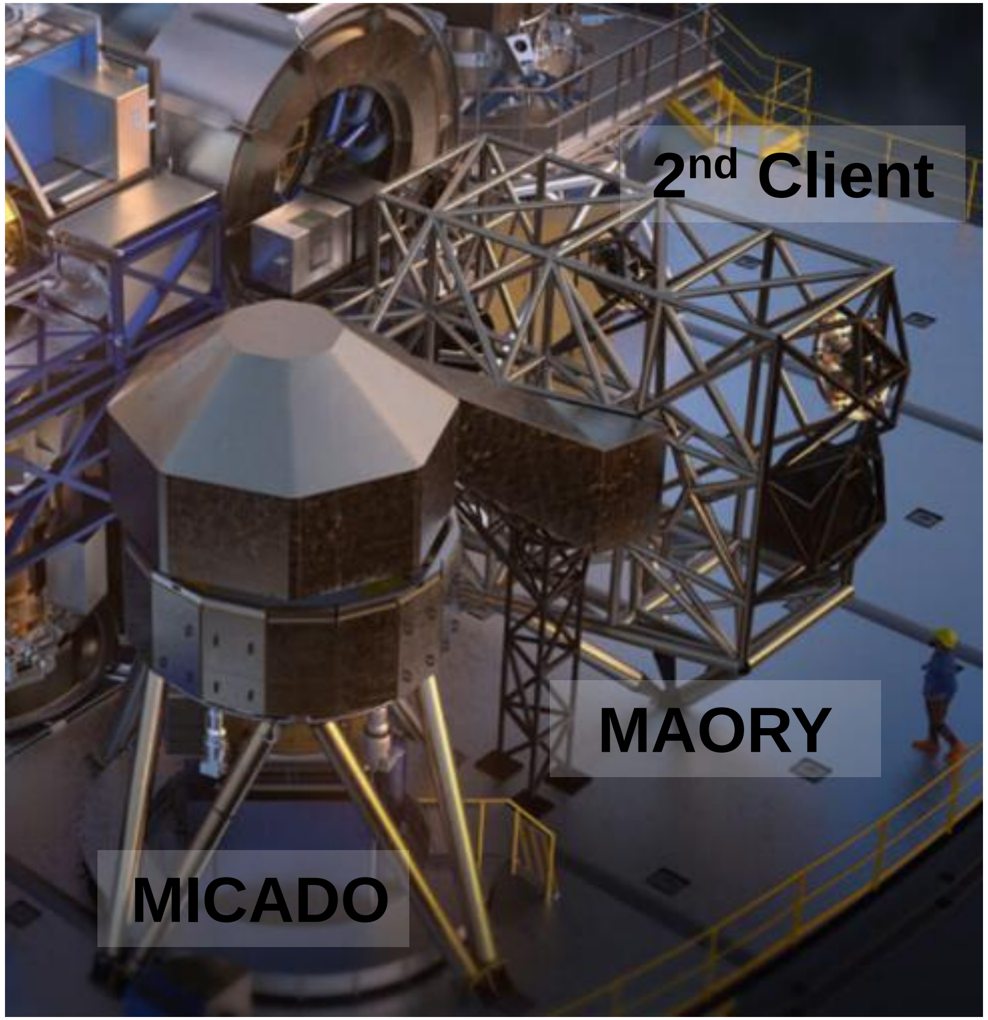
MICADO

- PI R. Davies (MPE)
- Diffraction limited **Imager and spectrograph**
- Covering the **near infrared** (0.8 - 2.45 µm)
- Spectral resolving power ~8000



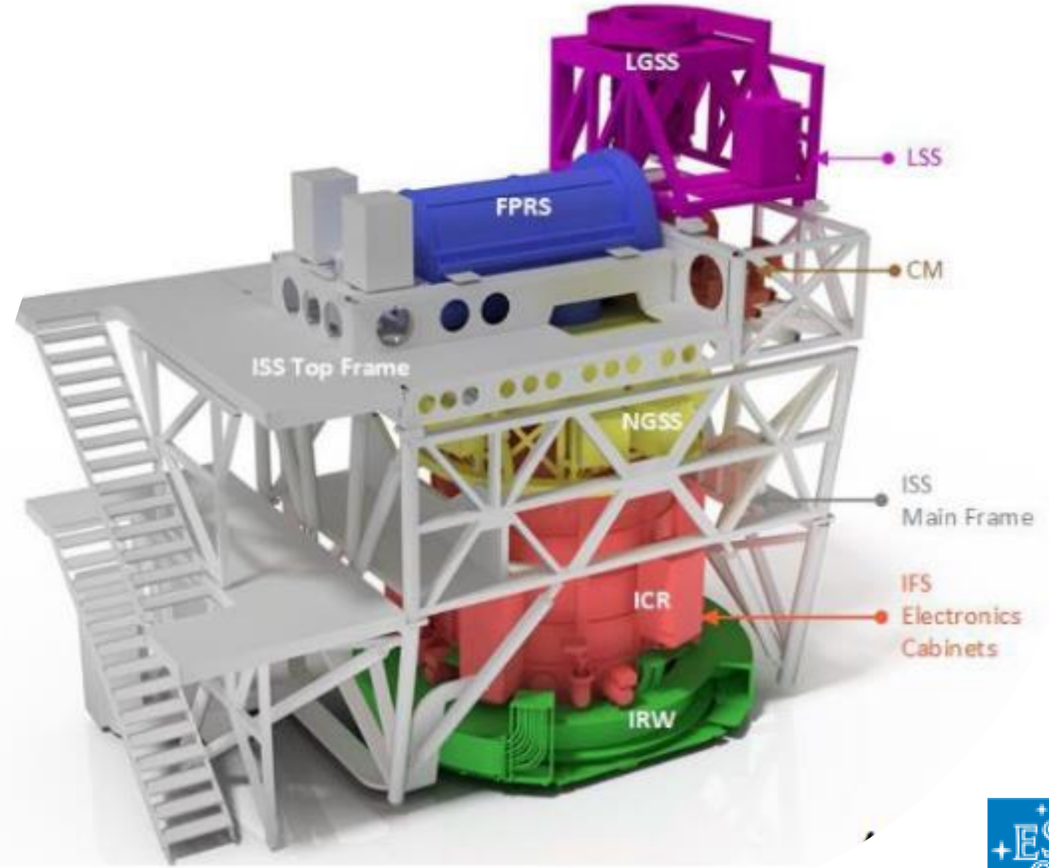
MAORY

- PI P. Ciliegi (INAF)
- Multi-conjugate adaptive optics
- Client instruments: MICADO + future MOS
- 1 (baseline) or 2 (upgrade) deformable mirrors
- Wavefront sensing with 3 natural and 6 laser guide stars



HARMONI

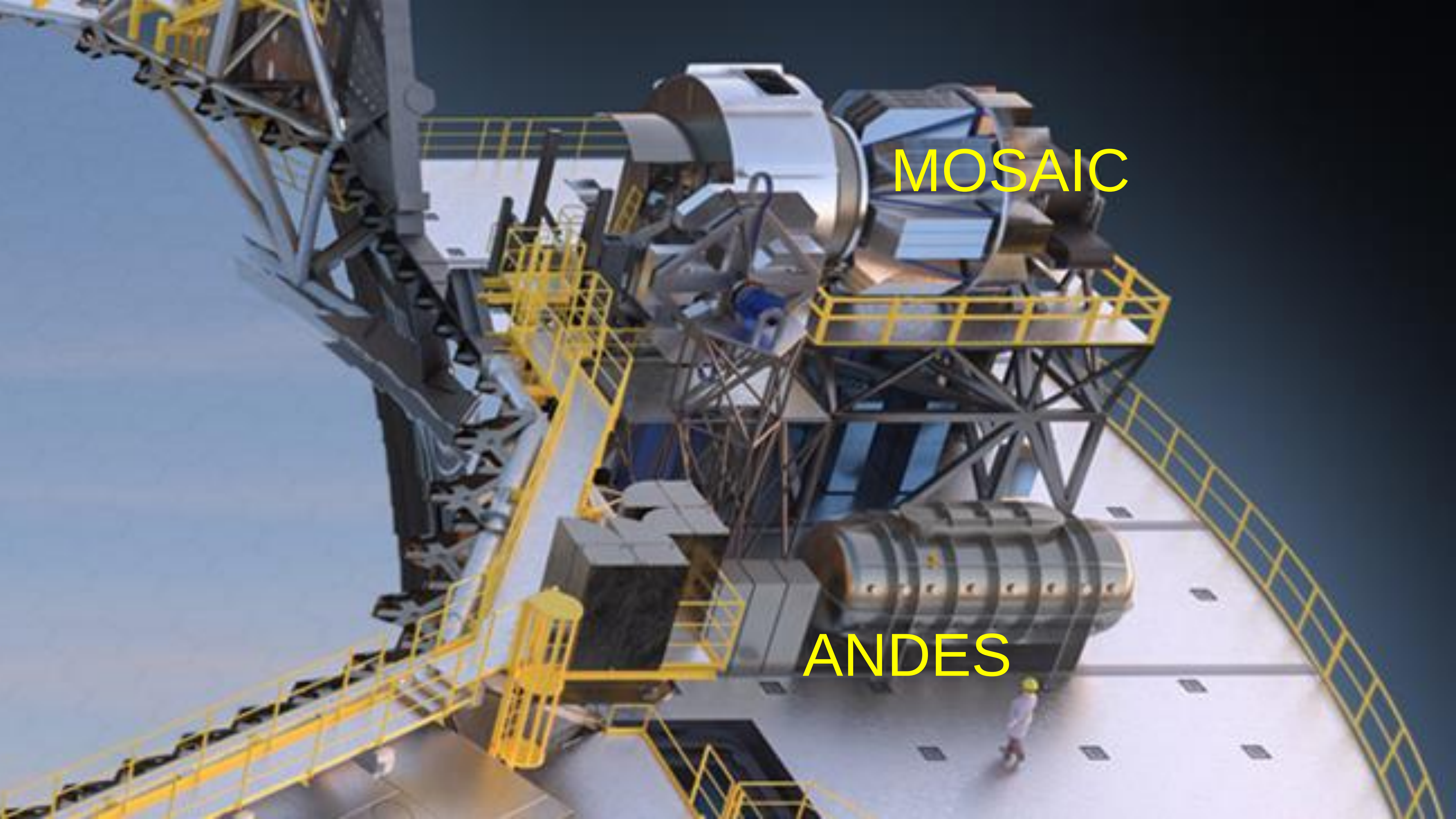
- PI N. Thatte (Univ Oxford)
- **3D spectrograph** (IFU)
- Covering **optical** (0.47 µm) to **NIR** (2.45 µm)
- **Resolving power** R=3500 - 20000
- **Image scales** 4mas to 60mas (from the diffraction limit to the seeing limit)



METIS

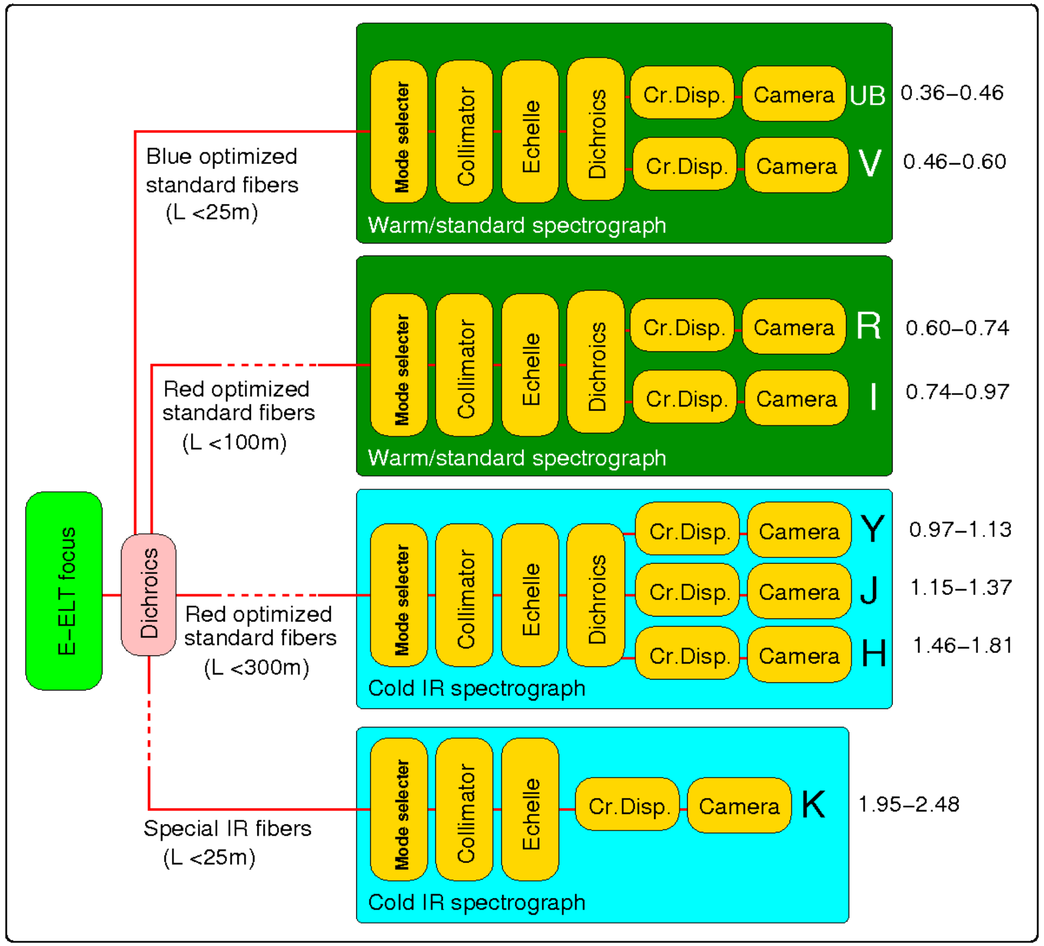
- PI B. Brandl (Univ. Leiden)
- **Imager and (IFU) spectrograph**
- Covering the **MIR** (3 - 14 µm)
- Spectral resolving power up to 100 000

UK Astronomy Technology Centre


MOSAIC
ANDES

ANDES: ArmazoNes high Dispersion Echelle Spectrograph

- PI: A. Marconi (INAF)
- Wavelength range ~0.55-1.8 µm
  - Goal: 0.33-2.4 µm
- **Spectral resolution R=100,000-150,000**
- Fibre-fed echelle spectrograph
- **Accuracy < 10cm/s**



MOSAIC: Multi-object spectrograph

- PI: L. Tasca (LAM)
- **Multi-object spectrograph**
- Wavelength range: 0.4 – 1.8 μm
- 8 IFUs deployable over **40 arcmin^2 patrol field**
- Simultaneous fibers on ~80 objects

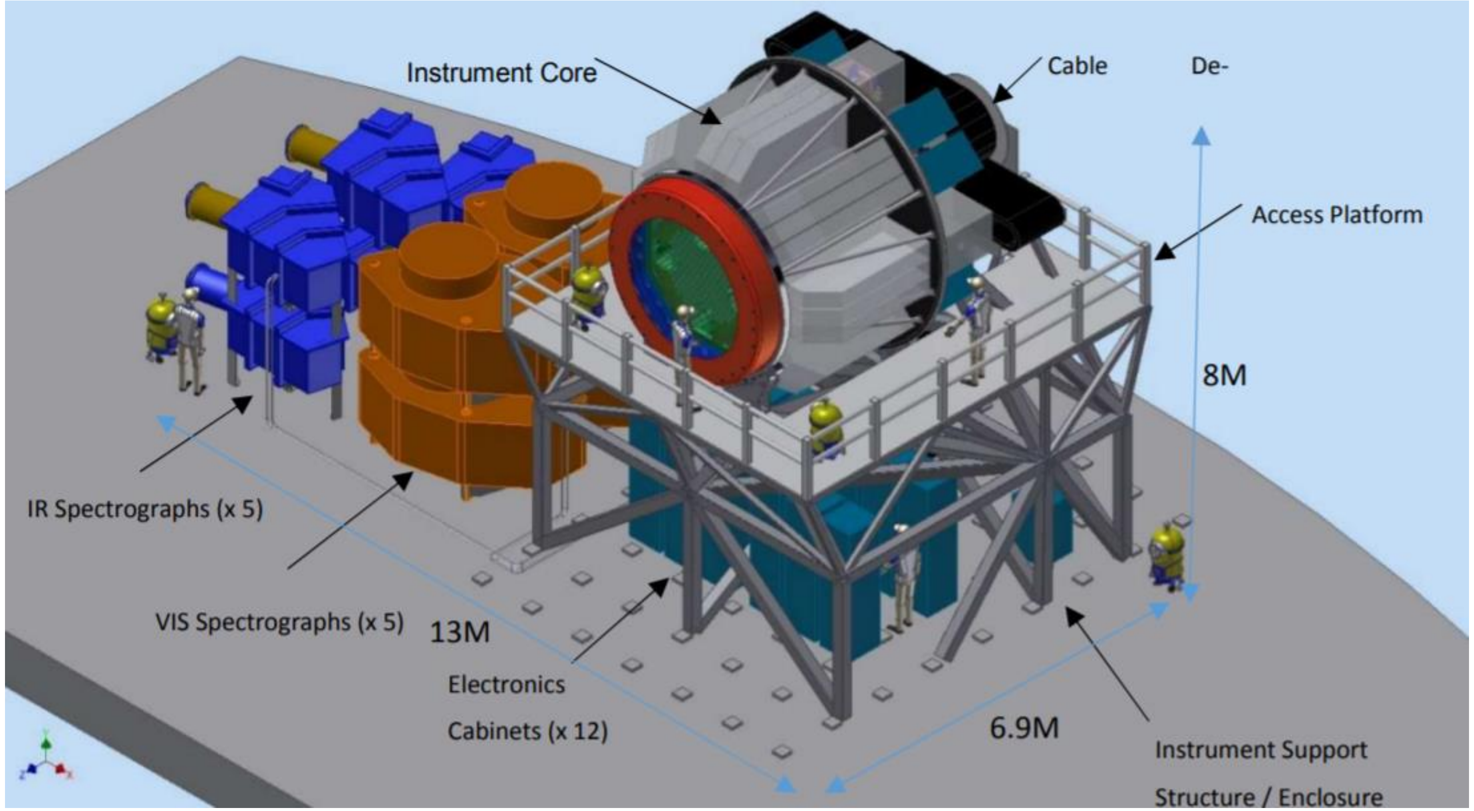
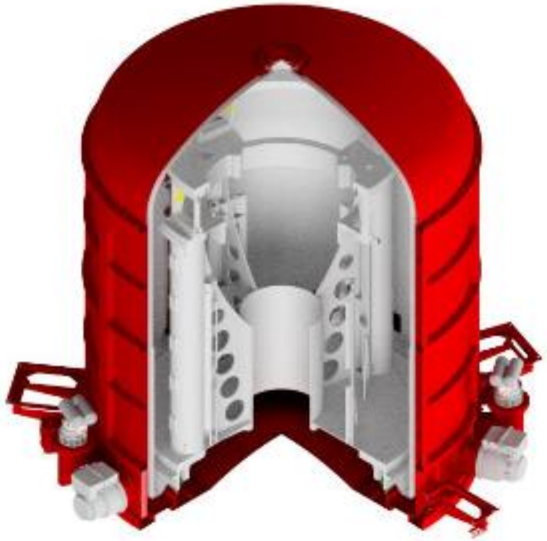


Image credits: MOSAIC consortium

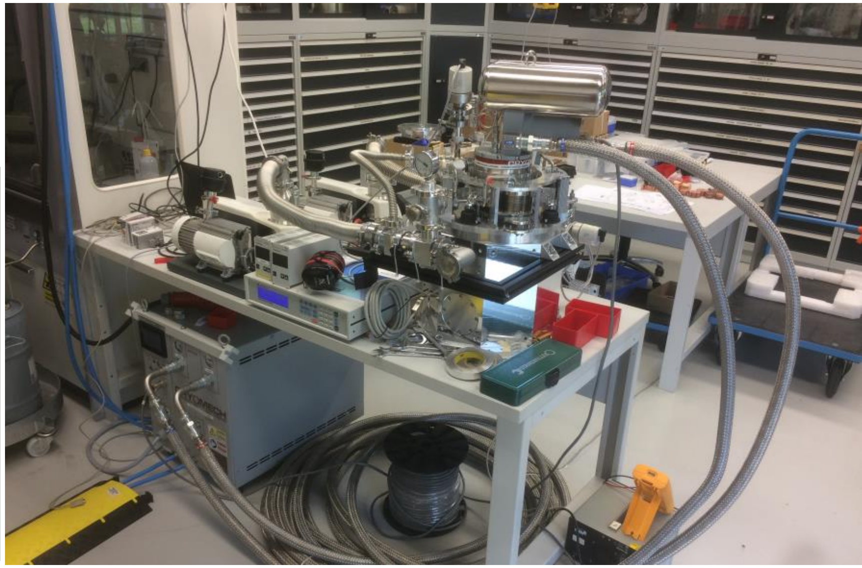
Technologies

- Our infrared instruments operate at temperatures in the range 40K to ~120K
- Cryogenics & Vacuum
  - to cool large instruments and/or detector systems
  - We care a lot about controlling vibrations
- Precision mechanics (also cryogenic)
  - encoders
  - lubrication



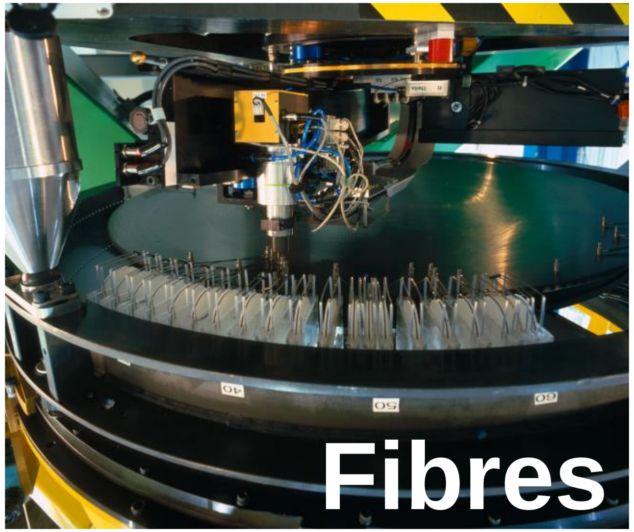
HARMONI Cryostat cut-through (4m high, 3.5m diameter)

Pulse tube cooler tests at ESO

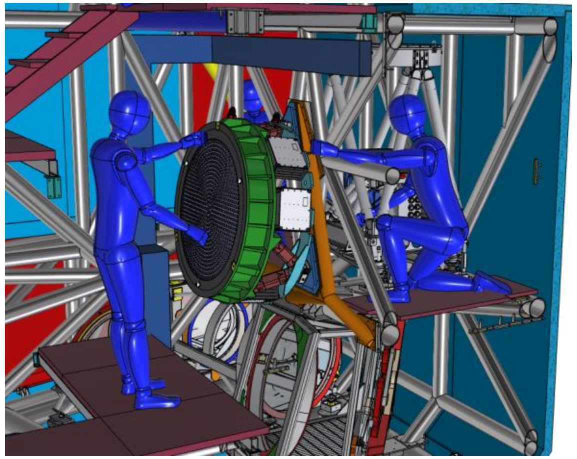


Cryogenic pick-off arm, positioning accuracy 120µm

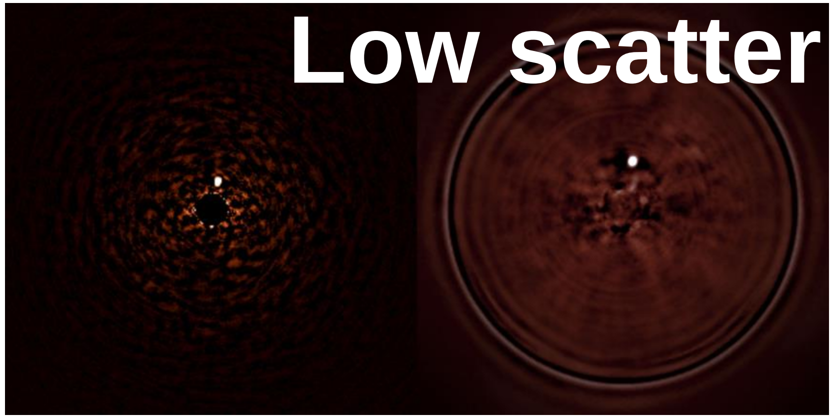
Technologies

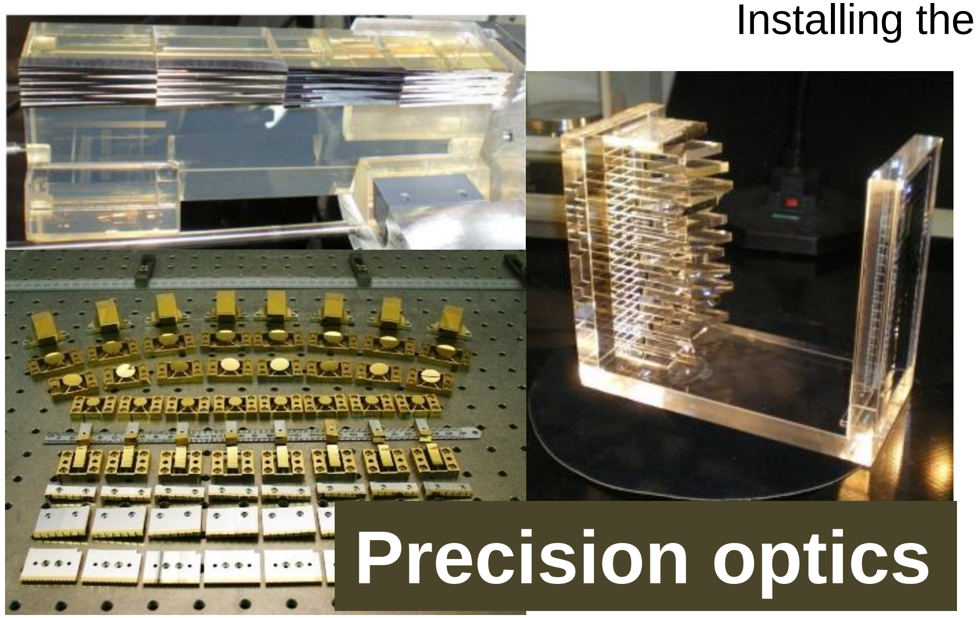


- Optics
  - Broadband coatings, high tranmission
  - High throughput fibres (positioners!)
  - Fine polishing/low scattering
  - Size scales from metres to millimetres
  - Dispersion gratings

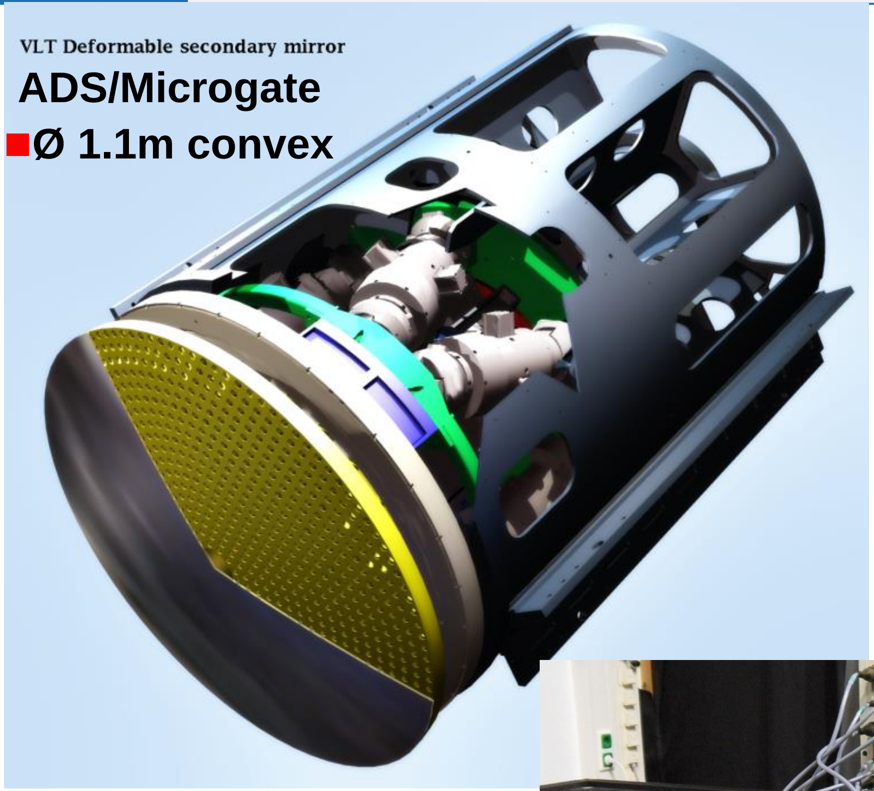


Installing the MAORY mirrors



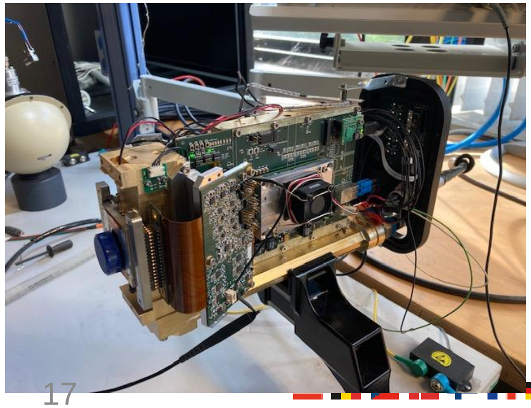


Technologies for Adaptive Optics



- Deformable mirrors on many size scales and with different technologies
- Wavefront sensing cameras (ESO)
- Real Time Computing

1377 act. Piezo DM for SPHERE with its drive electronics



ALICE and LISA camera prototypes in the ESO lab

Conclusions

- ESO continues the largest ground-based astronomical instrumentation programme in the world
  - Continuing state-of-the-art developments for VLT
  - Major instrument programme for ELT reaching the procurement stage
- READ MORE AT ELT.ESO.ORG
- This programme fully utilises and challenges expertise in institutes and universities of member-states
- Innovation and quality are critical to the success of ELT

Thank you

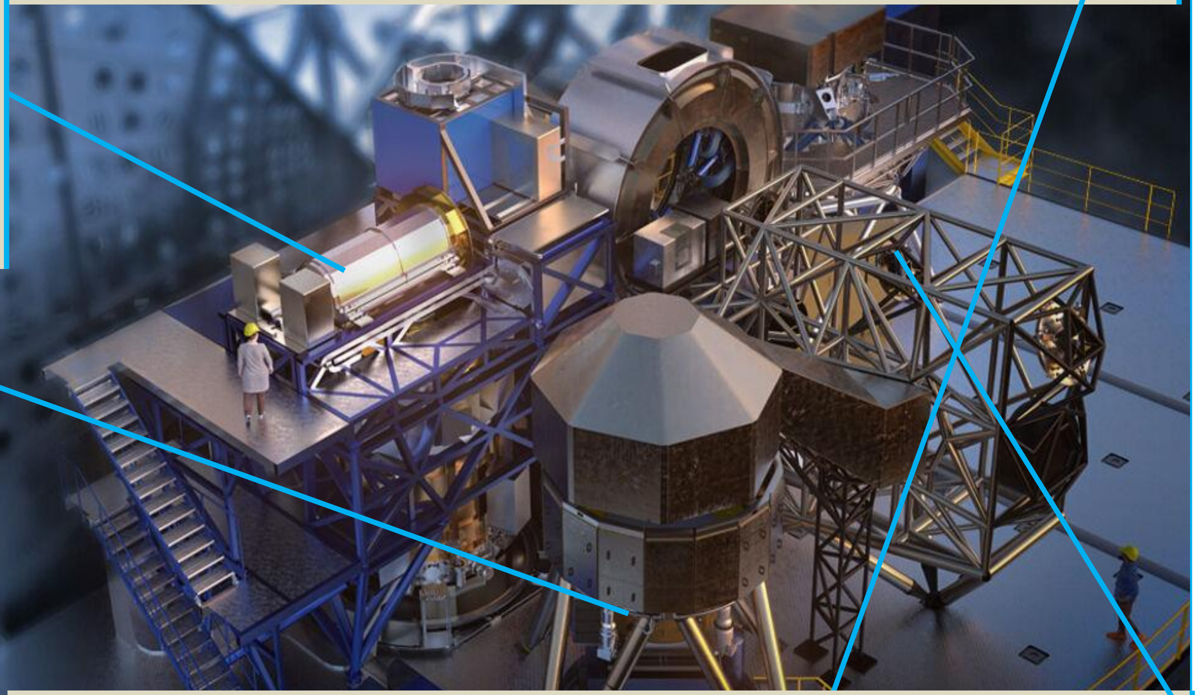
ELT First set of Instruments & Technologies

METIS: Mid infrared instrument:

- *Geosnap IR detector with digital interface*
- *400-500 mm free form cryogenic optics (40-70K)*
- *Reliable low dissipation cryogenic mechanisms (400mm)*
- *Low vibration cooling systems*

HARMONI: Near IR AO assisted 3D spectrograph

- *Reliable low dissipation cryogenic mechanisms (400mm)*
- *Low noise fast readout wavefront sensors*
- *IR and visible gratings*



MICADO: Near IR Adaptive Optics assisted instrument:

- *3-4 m accurate rotating platform*
- *Low vibration cooling systems*
- *High accuracy free form cryogenic optics 500 mm*
- *IR/Visible 500 mm dichroic*

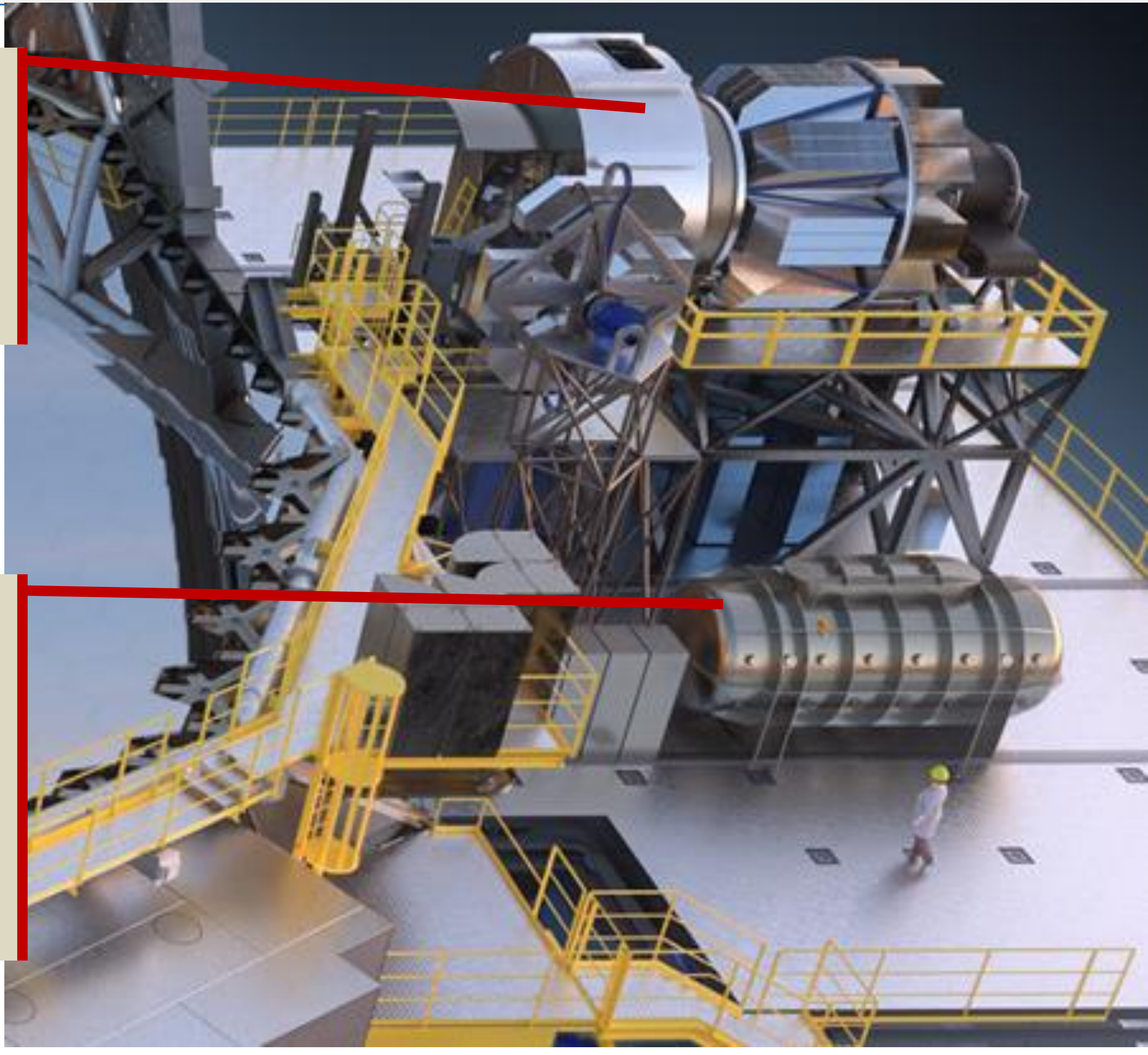
MAORY: Multi-Conjugate AO system

- *1 m class deformable mirrors*
- *600-800 mm class dichroic (600nm cutoff)*
- *Low noise fast readout wavefront sensors*

2nd generation ELT instruments and technologies

MOSAIC: Multi Object AO assisted spectrograph
Technologies to be developed

- *Large format VPHs (~300mm) for medium resolution spectroscopy (5,000-20,000) in optical and near-IR*
- *Curved detectors (CCD) 4Kx4K*
- *Coating with high performance from 0.35 to~2microns*



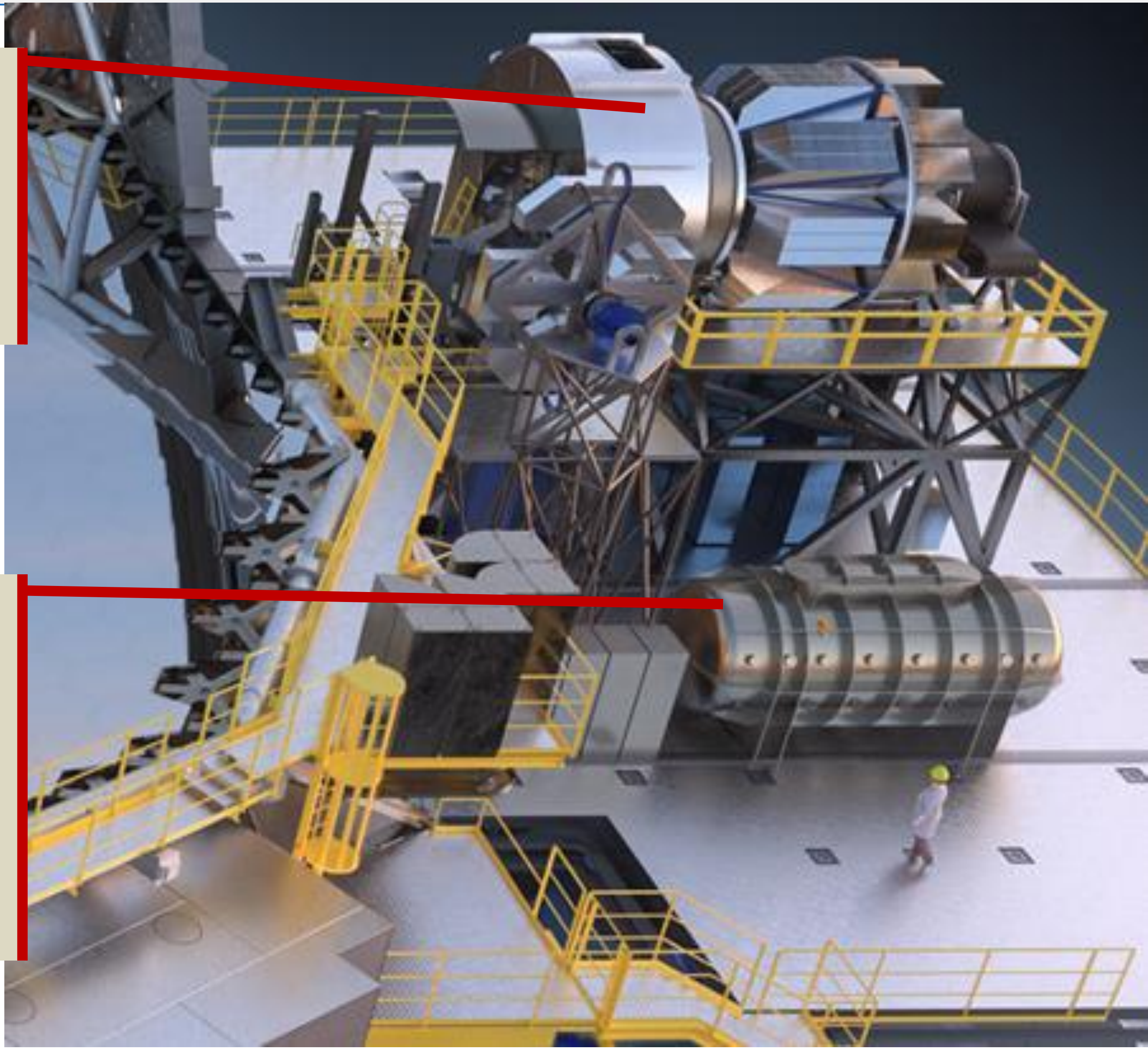
ANDES: high resolution spectrograph:
Technologies to be developed

- *High-efficiency gratings for high resolution spectroscopy R > 100,000*
- *Robust & high-efficiency fibres for K-band (2.0 < λ < 2.4 microns)*
- *Coating with high performance from 0.35 to ~2microns*
- *Ultra stable calibration source: Laser Frequency Comb*

2nd generation ELT instruments and technologies

MOSAIC: Multi Object AO assisted spectrograph
Technologies to be developed

- *Large format VPHs (~300mm) for medium resolution spectroscopy (5,000-20,000) in optical and near-IR*
- *Curved detectors (CCD) 4Kx4K*
- *Coating with high performance from 0.35 to~2microns*



ANDES: high resolution spectrograph:
Technologies to be developed

- *High-efficiency gratings for high resolution spectroscopy R > 100,000*
- *Robust & high-efficiency fibres for K-band (2.0 < λ < 2.4 microns)*
- *Coating with high performance from 0.35 to ~2microns*
- *Ultra stable calibration source: Laser Frequency Comb*