Industry Opportunities in (E-ELT) Instrumentation

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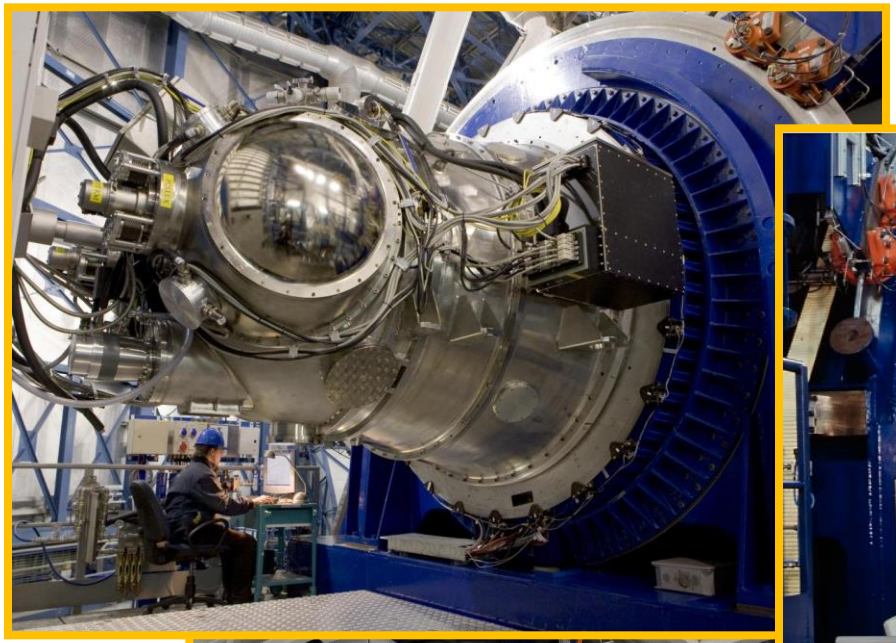
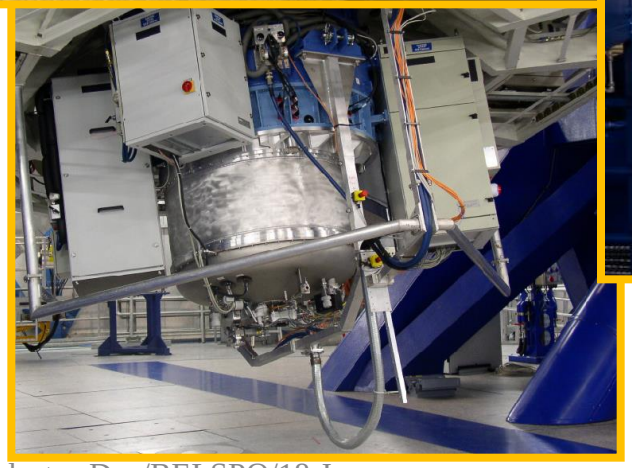
Instrumentation at ESO

- Introduction
- Instruments in Construction
- Instrument for the E-ELT
- Technologies

ESO Observatories

Introduction
Instrumentation at the VLT



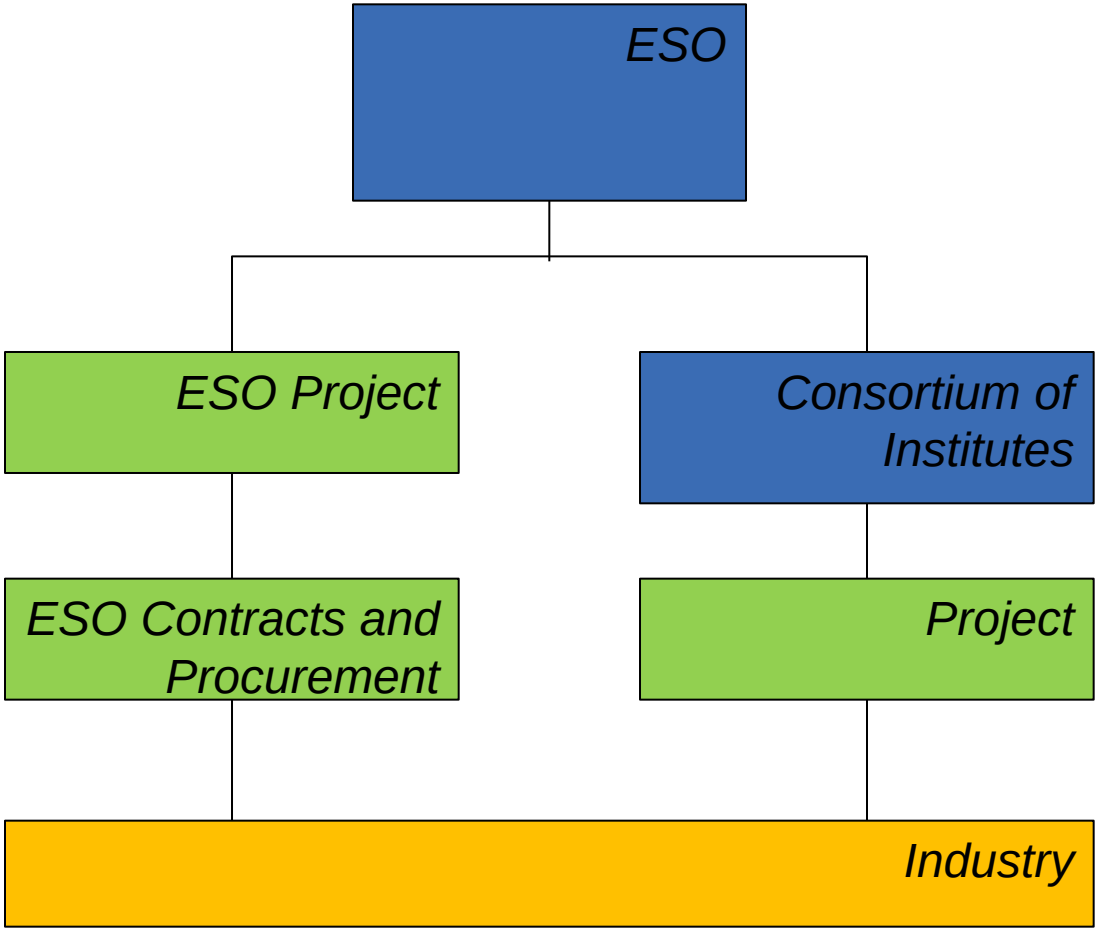


4 x 8-m VLT telescopes;
3 instruments per telescope;
VLT Interferometer

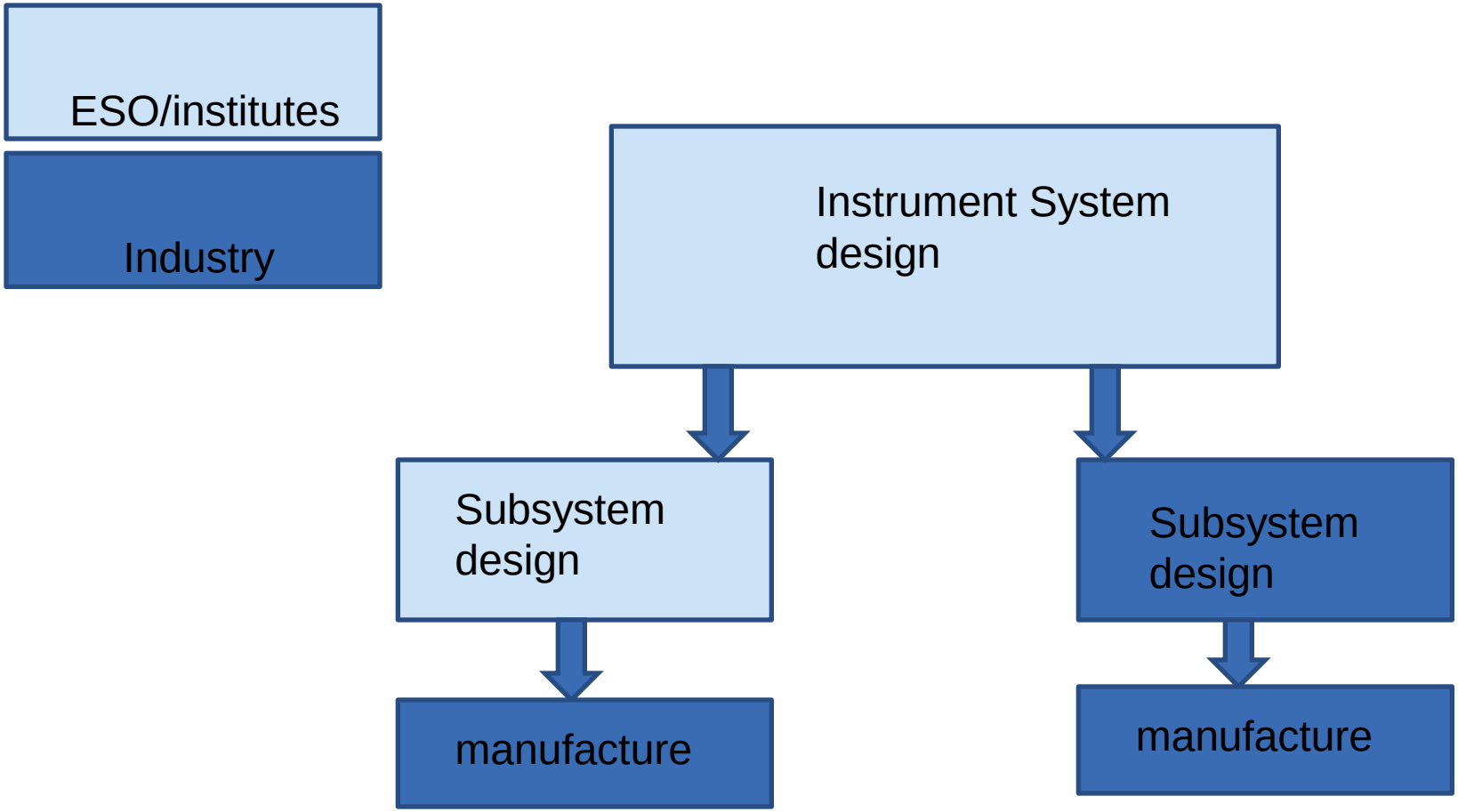
Current/Recent Instruments

- *KMOS IR 24-Integral Field Unit spectrograph*
- *MUSE 1 arcmin square optical IFU*
- *SPHERE high-order AO imager/spectrometer*
- AOF 4-laser, deformable M2, AO facility
- MATISSE LMN band 4-UT VLTI instrument
- GRAVITY K-band precision microarcsec VLTI
- ESPRESSO 10 cm/sec precision optical spectrometer
- ERIS High resolution AO imager/spectrometer

Introduction
Structure of Projects



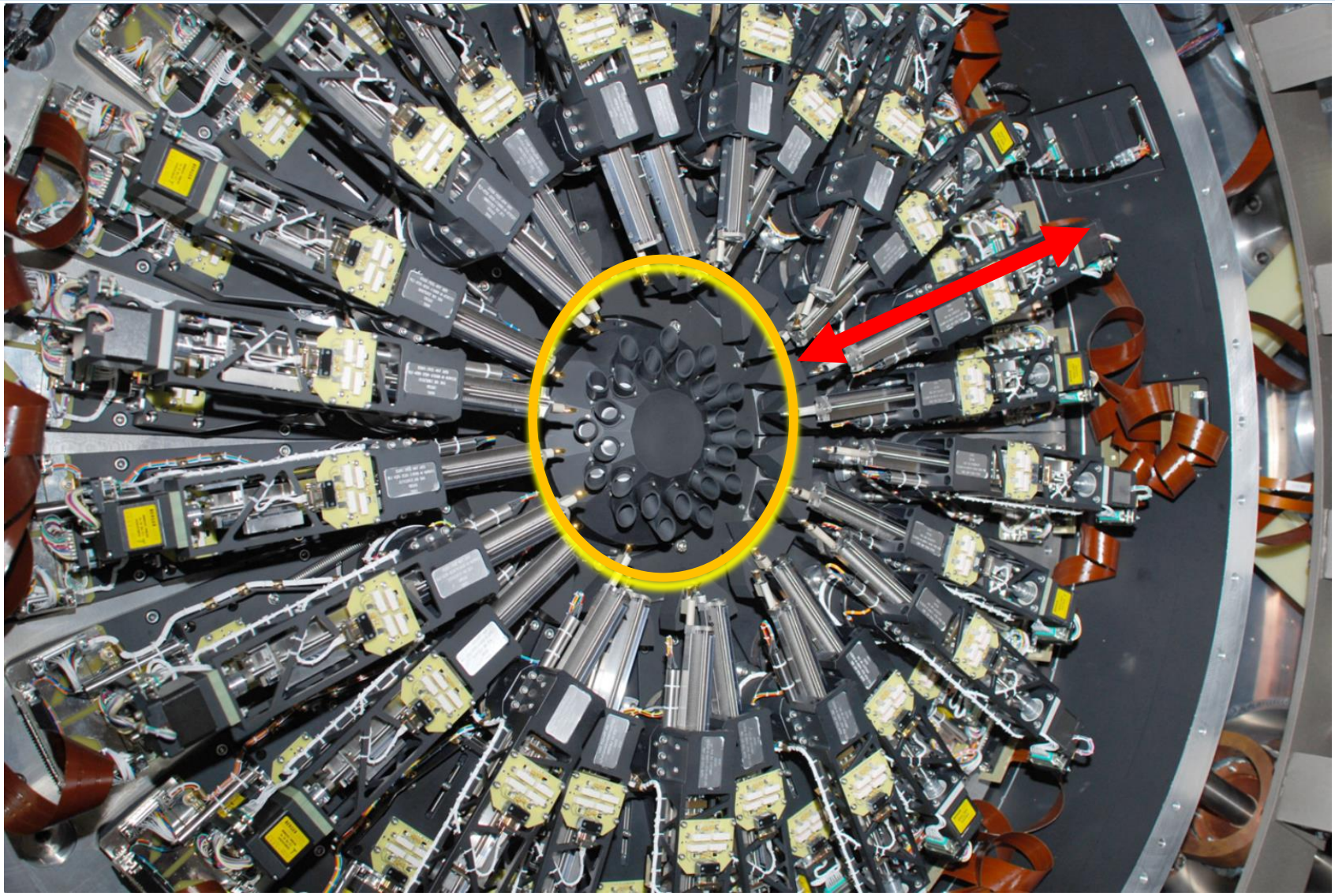
Introduction
level of procurement



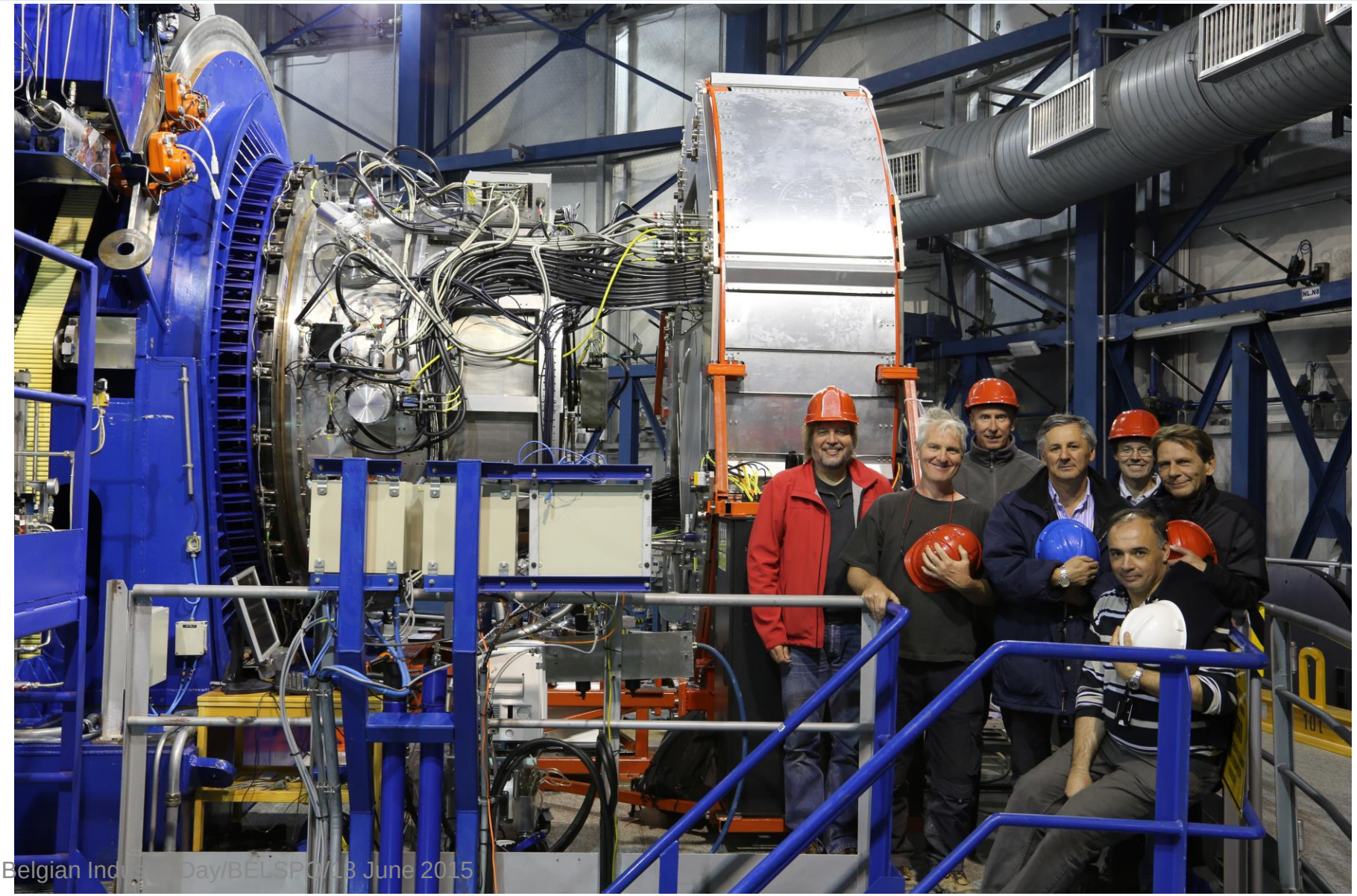
Introduction
Instrument Procurement model

- Majority of instruments obtained from consortia (teams) of member-state institutes
  - Some instruments led by ESO often with institute participation
- ESO establishes agreement for construction after a competitive phase
  - ESO pays full hardware/industrial costs
    - 2-6 M€ for VLT, 10-30 M€ for ELT
  - Institutes pay for staff to run projects
    - ESO pays this back with Guaranteed time (200+ VLT nights)

KMOS



KMOS – in operation



New Instruments for Paranal
multi-object spectrographs

- 4MOST (visible)
  - For VISTA 4m widefield telescope
  - 5 sq degrees with up to 3000 fibres
  - Spectral resolutions of 5000 and 20000
- MOONS (infrared)
  - For VLT
  - 500 sq arcminutes / 1000 fibres
  - 0.8 to 1.8 microns
  - Spectral resolutions of 5000 and 20000

E-ELT Instrument Development
Approved Roadmap

Design phase for first instruments

Delivery

Year	ELT-IFU	ELT-CAM	ELT-MIR	ELT-MOS	ELT-HIRES	ELT-6	ELT-PCS
2014	Decide science requirements, AO architecture.		VISIR start on-sky	Develop science requirements for MOS/HIRES			Start ETD
2015				Cal for Proposals Start Phase A			
2016				Consortium Selection for construction		Call for proposals	
2017							
2018							TRL check
2019						Selection	Start when ready
2020							
2021							
2022							
2023							
2024							

	Pre-studies taking the form of phase A or delta-phase A work and/or ESO-funded Enabling Technology Development (ETD)
	Decision point
	Development of Technical Specifications, Statement of Work, Agreement, Instrument Start

E-ELT Instrument Programme
First light: MICADO

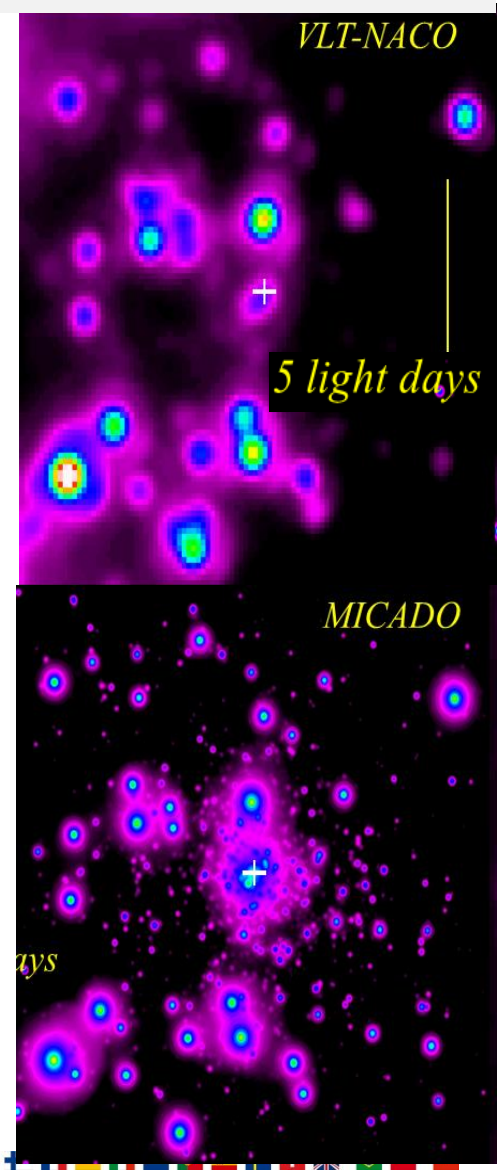
PI: Ric Davis

MPE, MPIA, USM, INAF, NOVA , LESIA

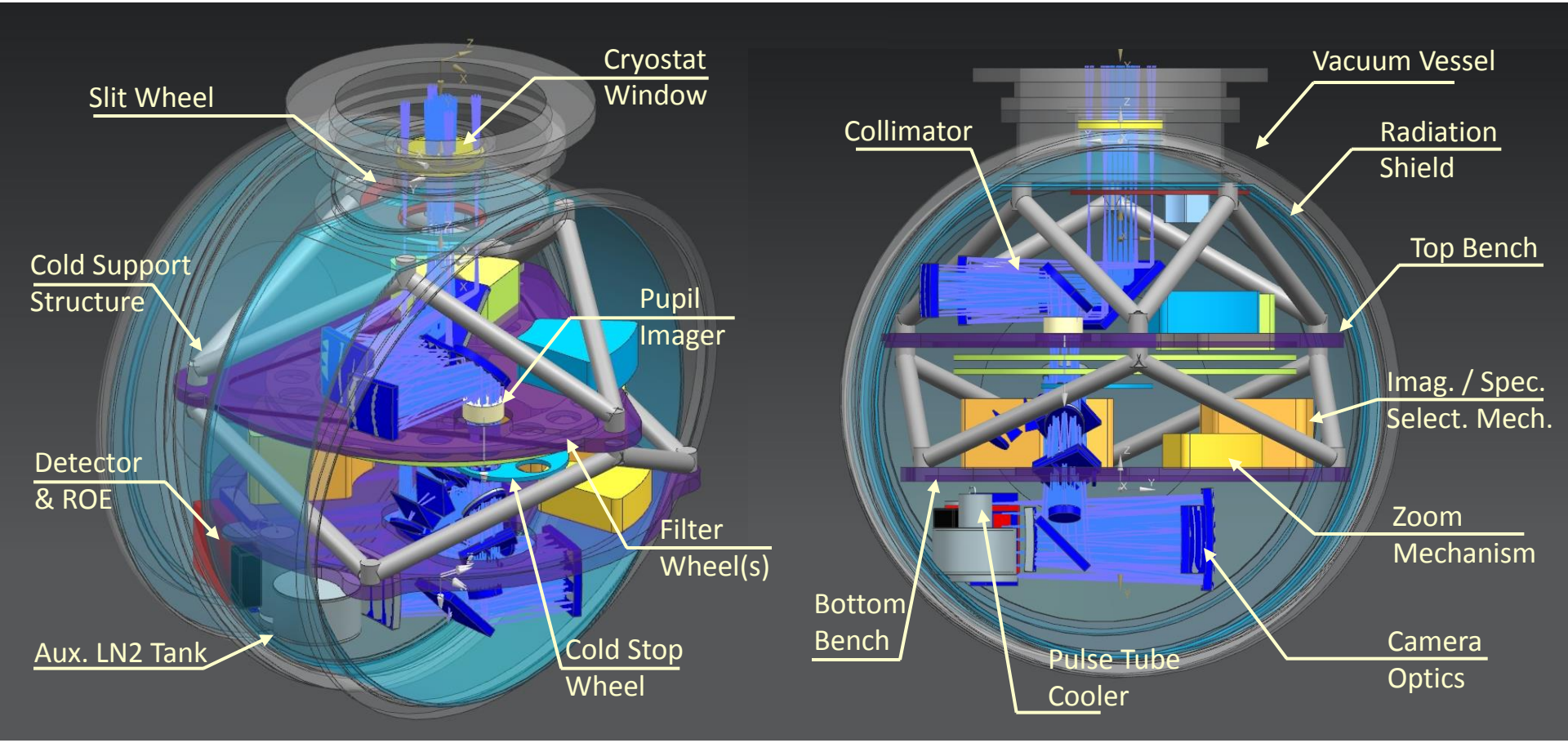
- resolution of 6-10mas over 1arcmin field
- sensitivity up to 0.5mag deeper than JWST with advanced filters
- up to 3mag deeper in crowded fields

- <40µas over full 1arcmin field
- 10µas/yr = 5km/s at 100kpc after 3-4 years
- make precision astrometry available to all

- high-throughput slit spectroscopy
- ideal for compact sources with multiple lines
- 0.8-2.5µm simultaneously at R~5000-10000



E-ELT Instrument Programme
First light: MICADO



Picture credit: MICADO, MAORY, ESO

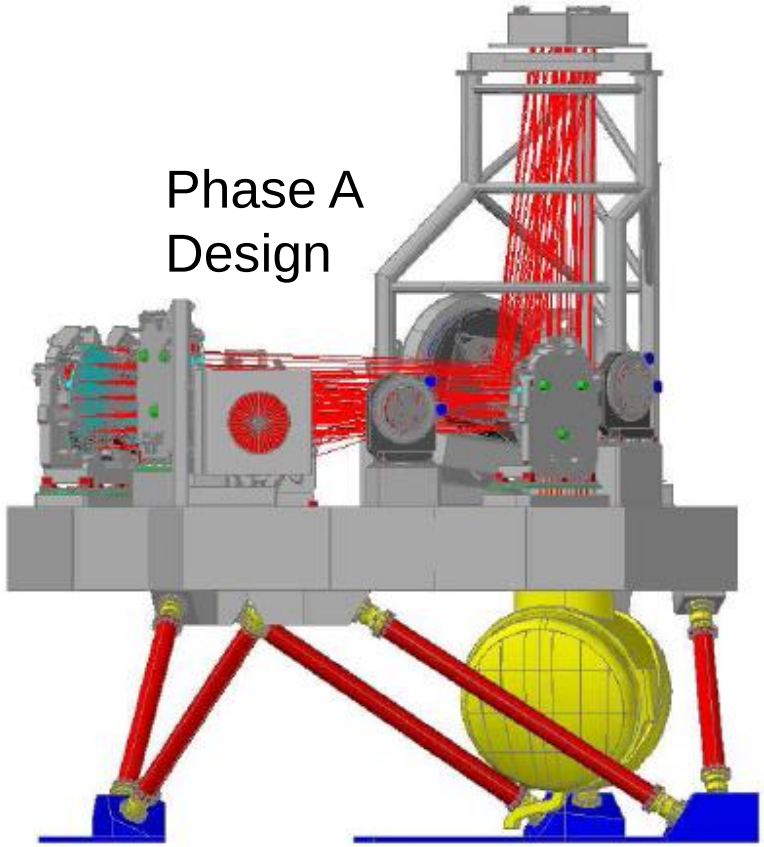
E-ELT Instrument Programme

First light: MAORY Multi-conjugate AO

PI: Emiliano Diolaiti

Consortium of INAF institutes

- Multi-conjugate AO
  - 6 laser, 3 natural guide stars
  - MAORY deformable mirrors conjugated to 4km, 12.7km
  - Two output ports
- Performance
  - 0.6 µm < λ < 2.4 µm
  - wide field - 2', 1' clear



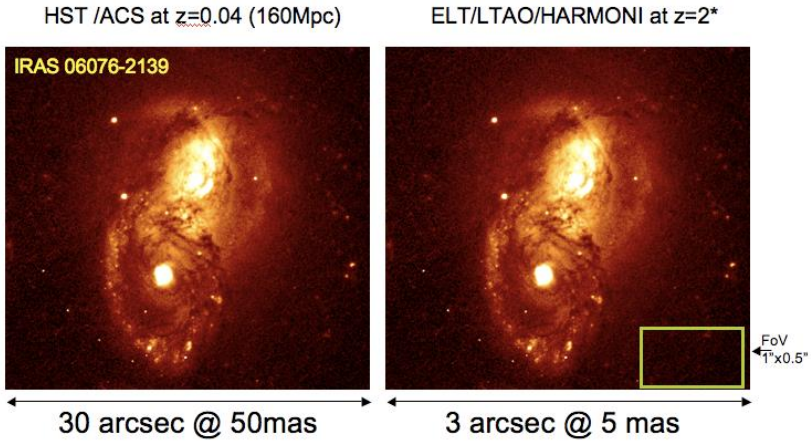
Phase A Design

E-ELT Instrument Programme
First light: HARMONI

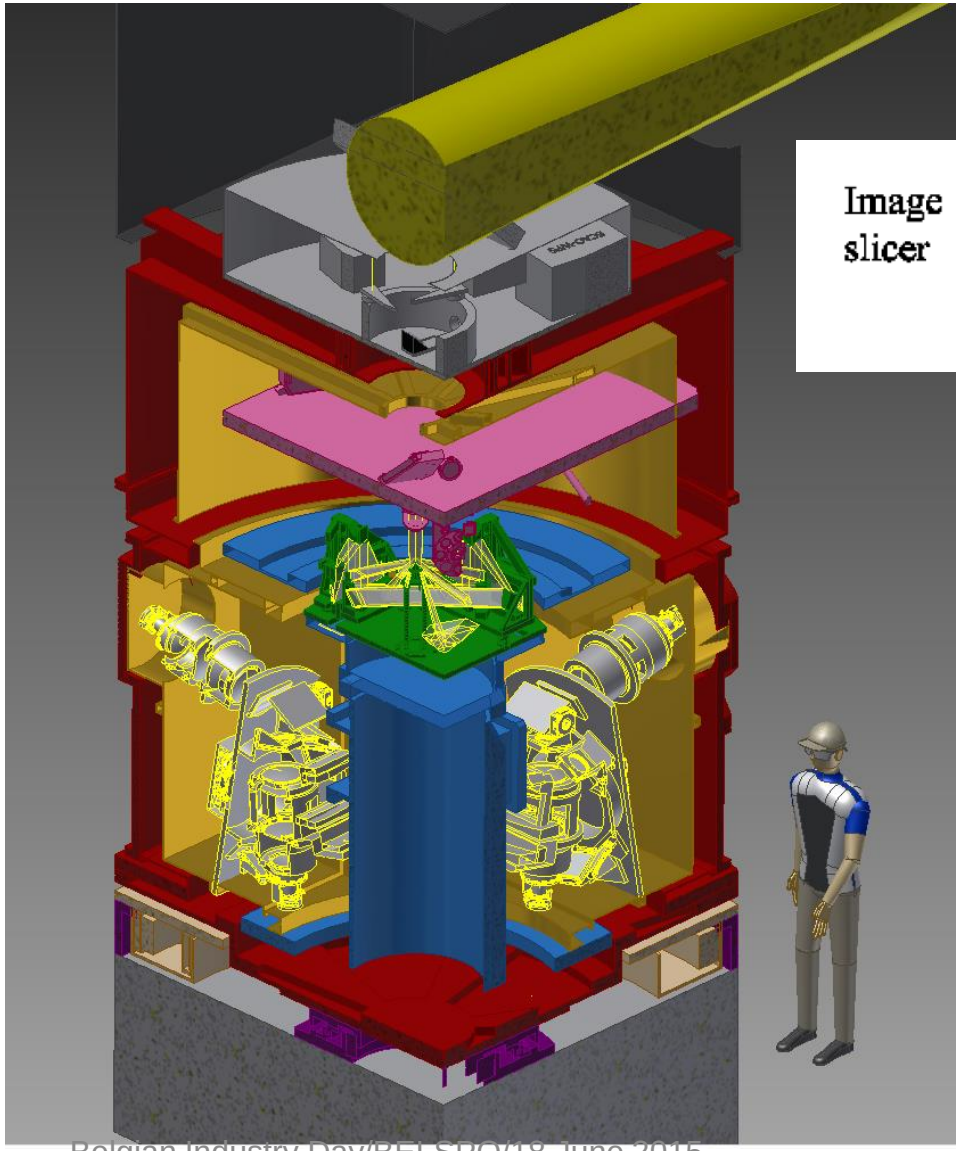
PI: Niranjan Thatte, Oxford

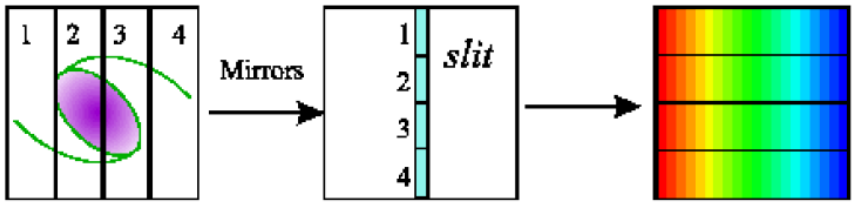
UK ATC, CRAL, CSIC, IAC

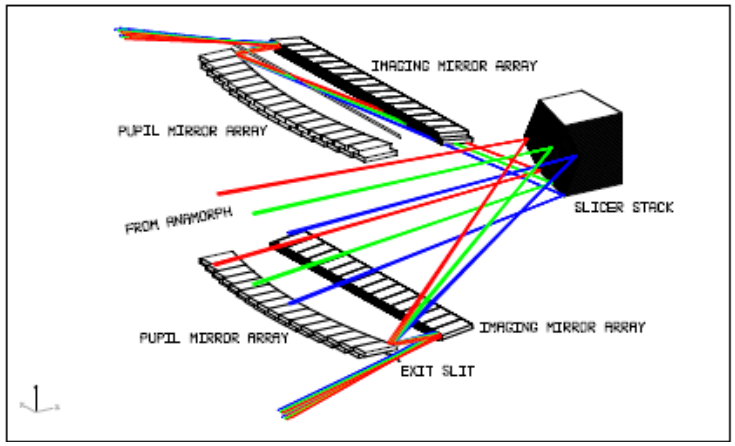
- Four spaxel scales / fields of view;
  - 60x30mas == 6.5 x 9.1” FoV (GLAO / Seeing)
  - 20x20mas == 4.3 x 3.0” (LTAO faint sources)
  - 10x10mas == 2.1 x 1.5” (LTAO bright sources)
  - 4x4mas == 0.8 x 0.6” (SCAO / diffraction limit)
- Large wavelength range
  - ~0.5 – 2.4 microns
  - (visible + near IR)
- Large (11) grating choice
  - R~500 R~3500
  - R~8000 R~20000



E-ELT Instrument Programme
First light: HARMONI

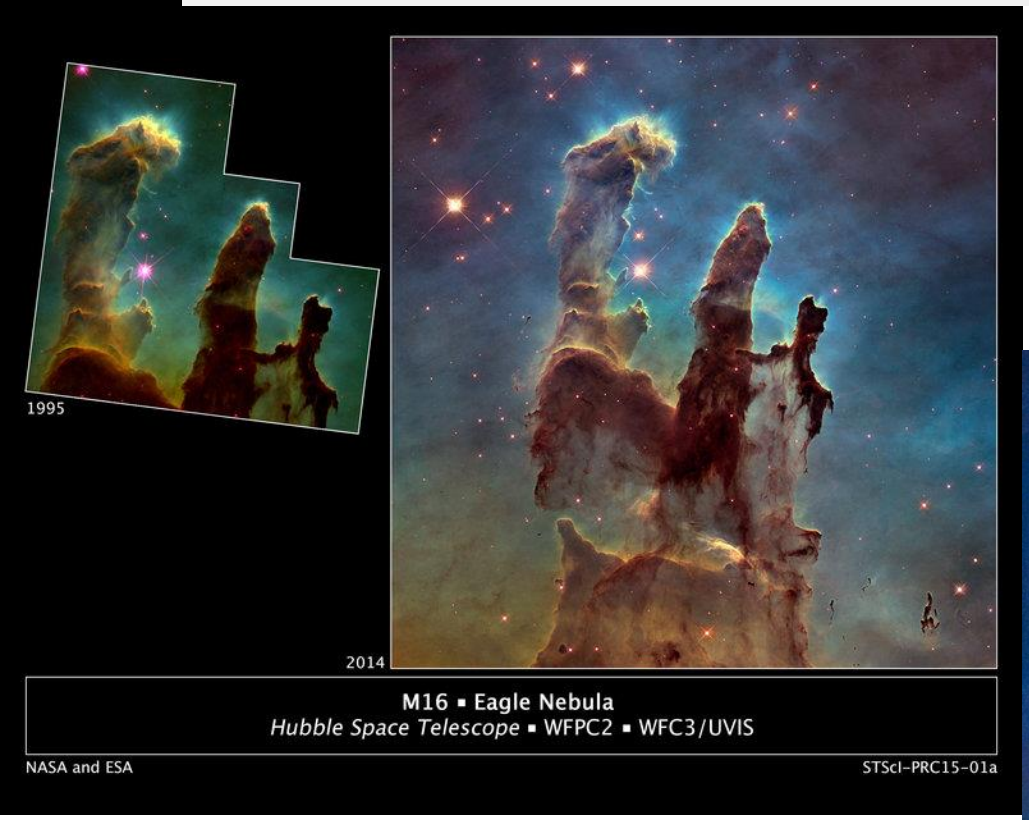




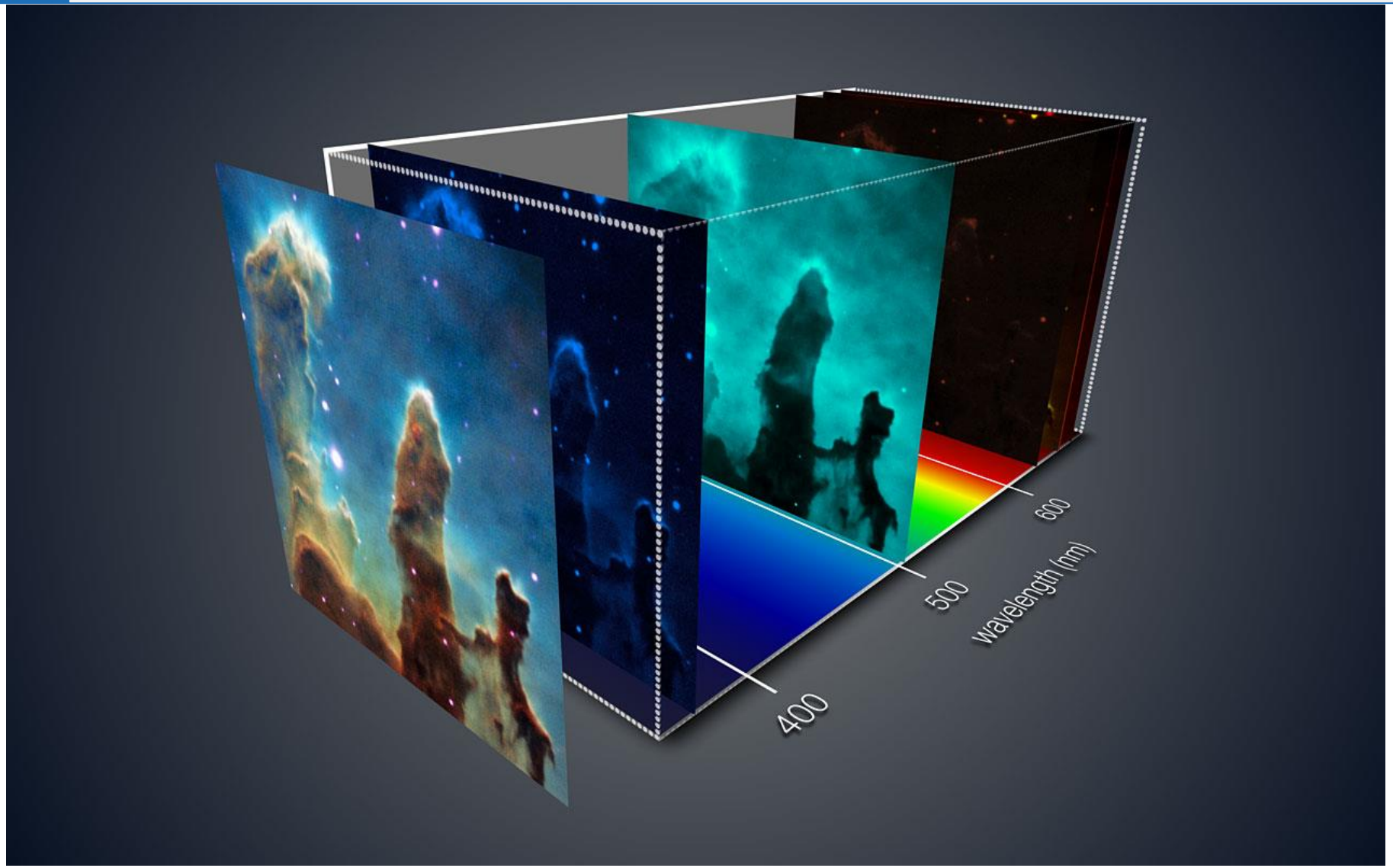


Above, the integral field unit.
The slicer stack is 64x64mm

MUSE/IFU science

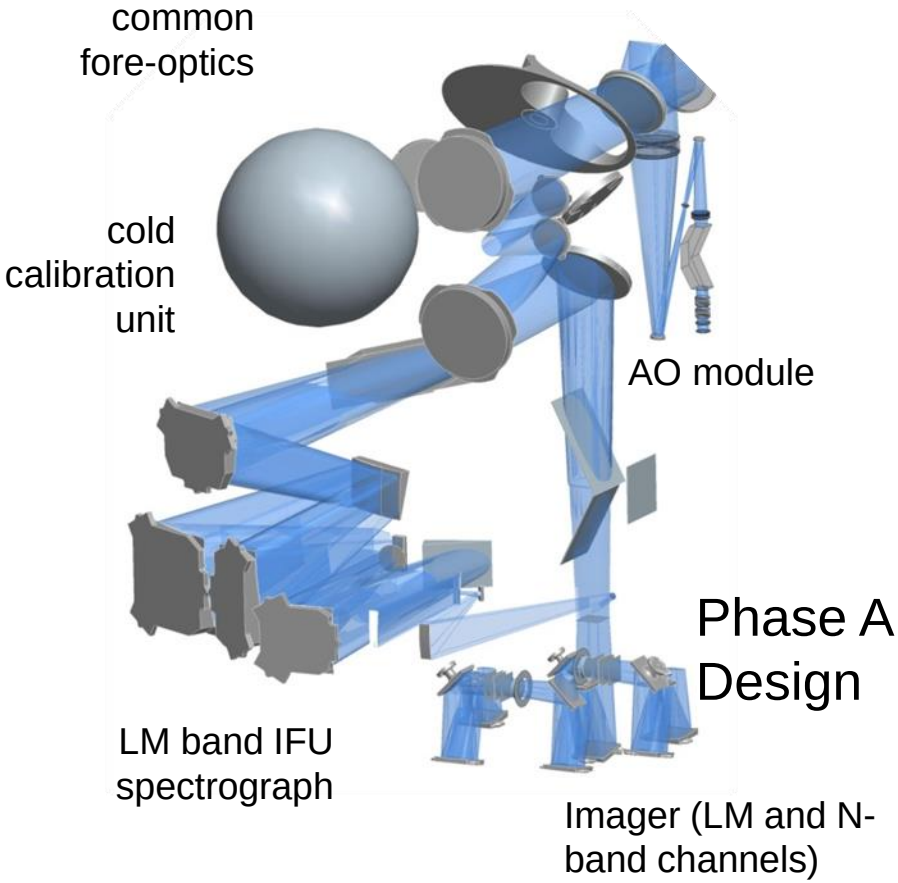


MUSE/IFU science



E-ELT Instrument Programme
METIS

- PI: Bernhard Brandl, NOVA
- MPIA, CNES, ETH Zurich, KU Lueven, Uni Wien, UK ATC



Phase A Design

Instrument Top Level Reqs

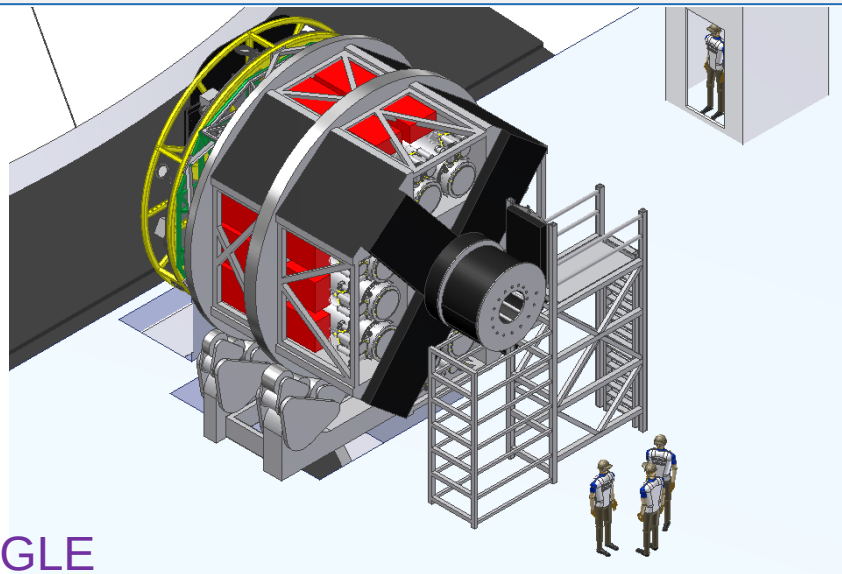
- Imaging over ~20arcsecs (LMN bands)
- R~100 000 spectroscopy (LMN)
- R~ few thousand spectroscopy (LMN, goal to extend to Q)

Development of concept and technical specification underway

ELT-MOS

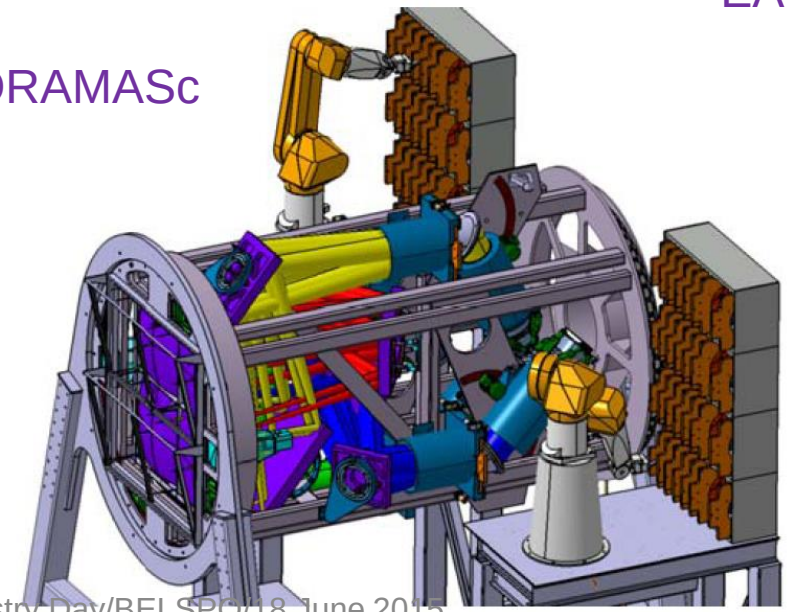
Instrument Top Level Reqs

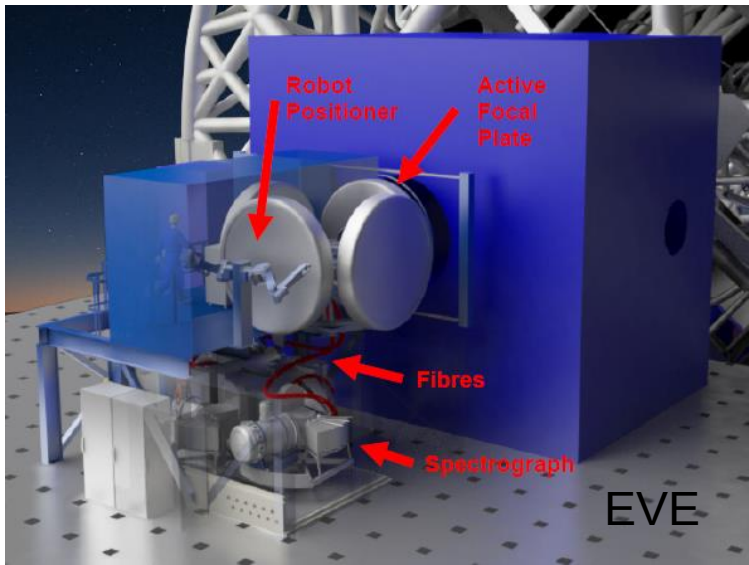
- 0.4-2.45um wavelength range
- 1 000 < R< 15 000
- Multiplex ~>400 and 2-100 (with AO)
- Seeing limited or MOAO-



EAGLE

DIORAMASc



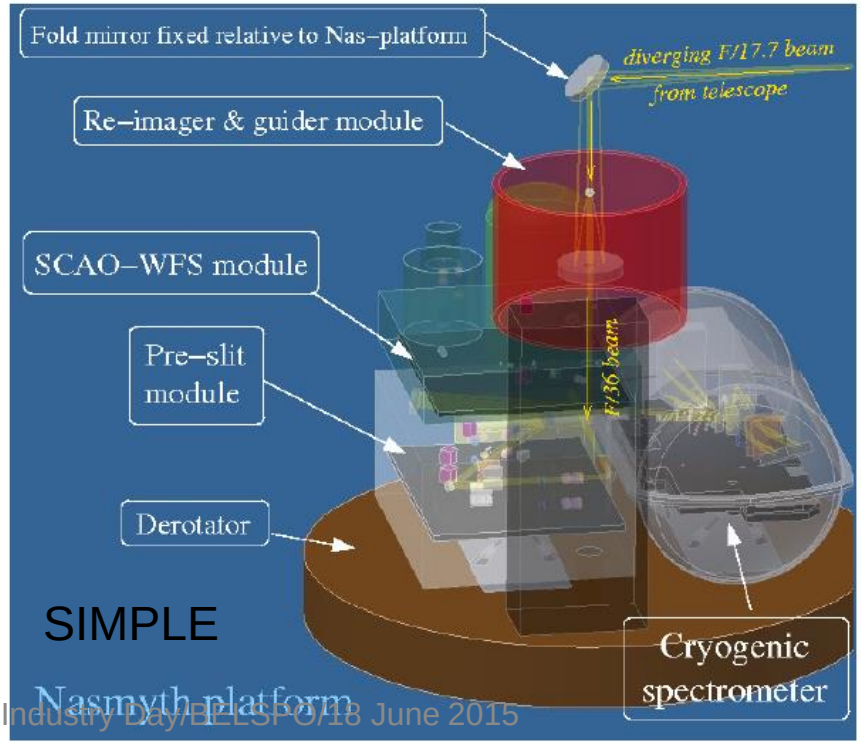


EVE

ELT-HIRES

Instrument Top Level Reqs

- 0.37-2.5um wavelength range
- 100 000 < R< 200 000
- Diffraction limited resolution >1um
- Also seeing limited performance



SIMPLE

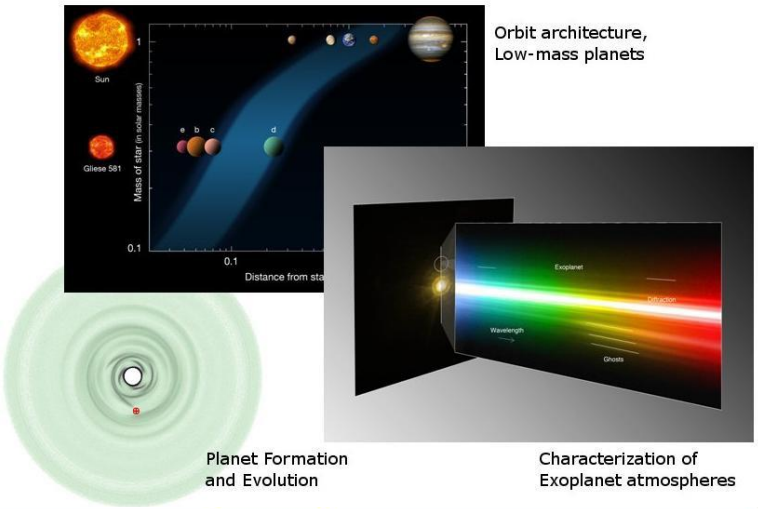
Phase A Designs

CODEX

ELT-PCS

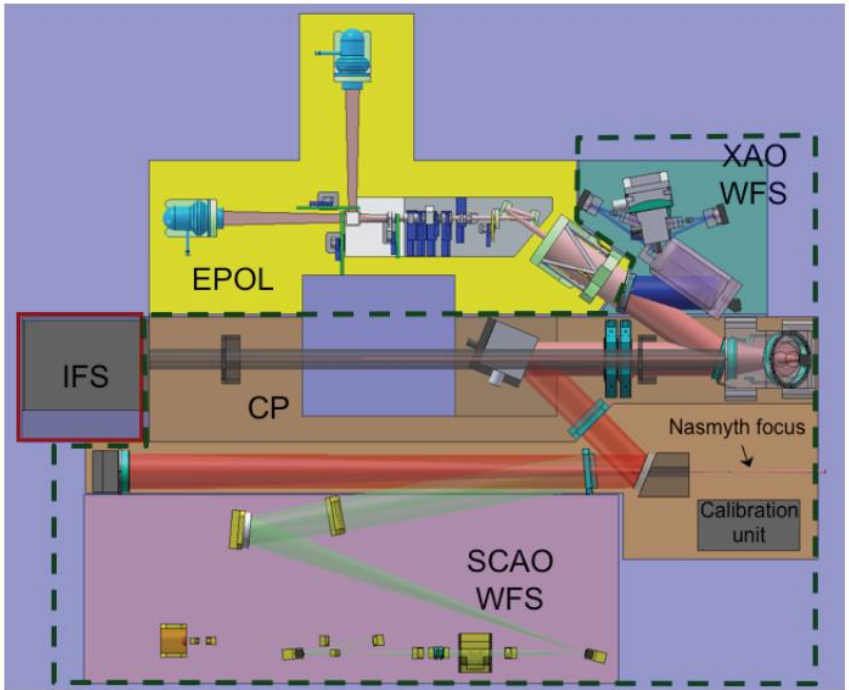
- PI: Markus Kasper, ESO
- LAOG,LESIA, Uni. Nice, LAM,ONERA, Uni.Oxford, INAF, ETH Zurich, NOVA

IFS 0.95-1.65µm
FOV: 0.8" x 0.8"/2.33mas
0.8" x 0.014" long slit
R = 125, 1400 and 20000



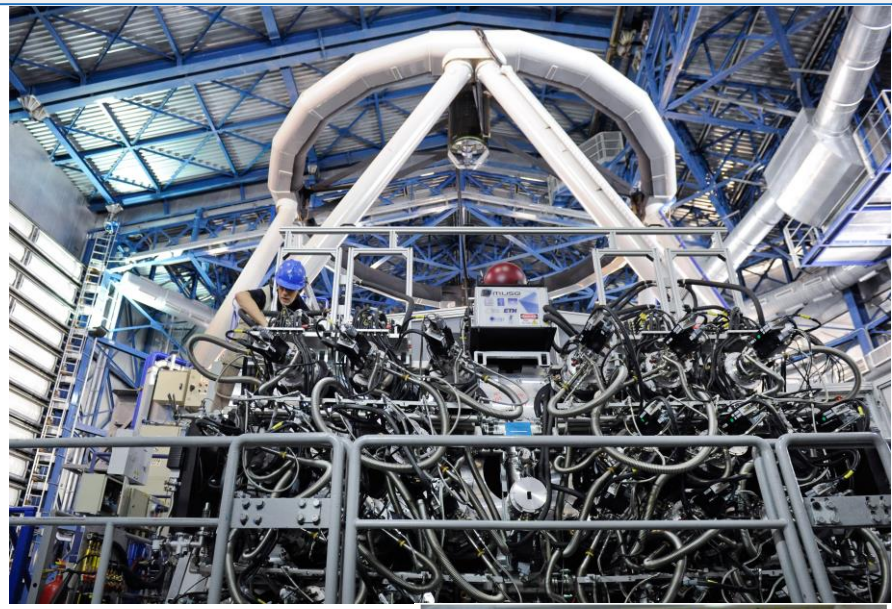
EPOL 0.6-0.9µm
Coronagraphic polarimeter
FOV: 2" x 2"/1.5mas

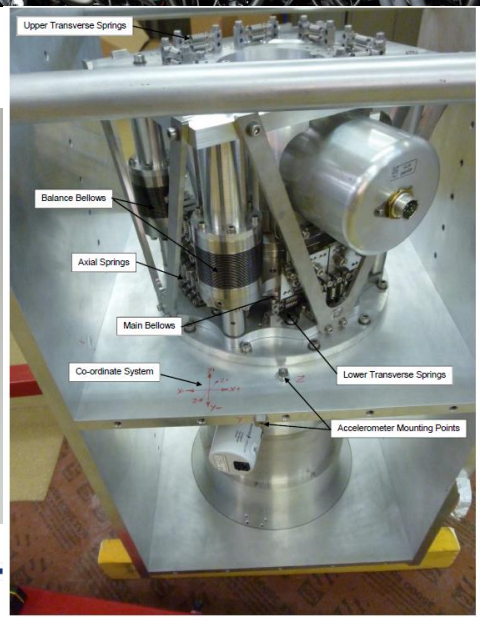
Contrast ratios – 10^{-8} – 10^{-9}
XAO – very high (90%) Strehl



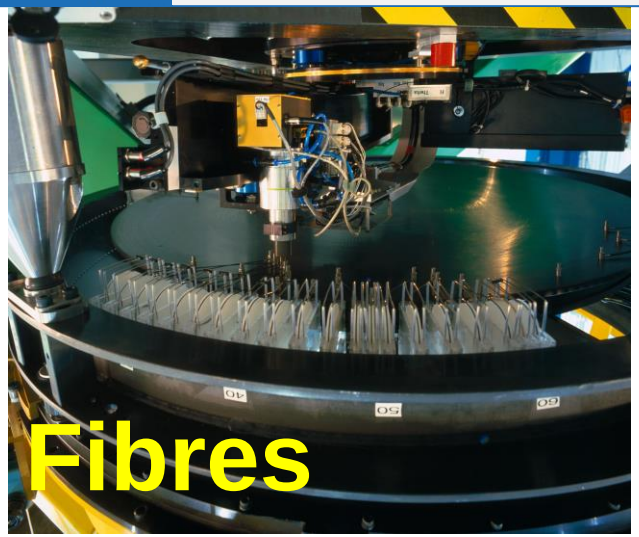
Technologies

- Cryogenics & Vacuum
  - to cool large instruments and/or detector systems
  - We care a lot about controlling vibrations
- Precision mechanics (also cryogenic)
  - encoders
  - lubrication

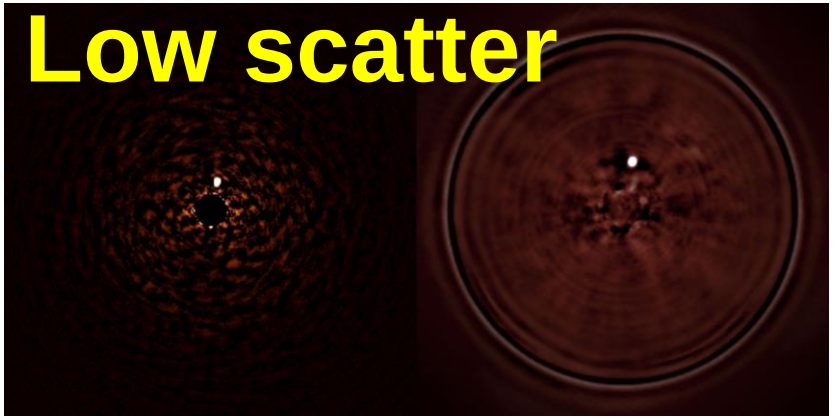


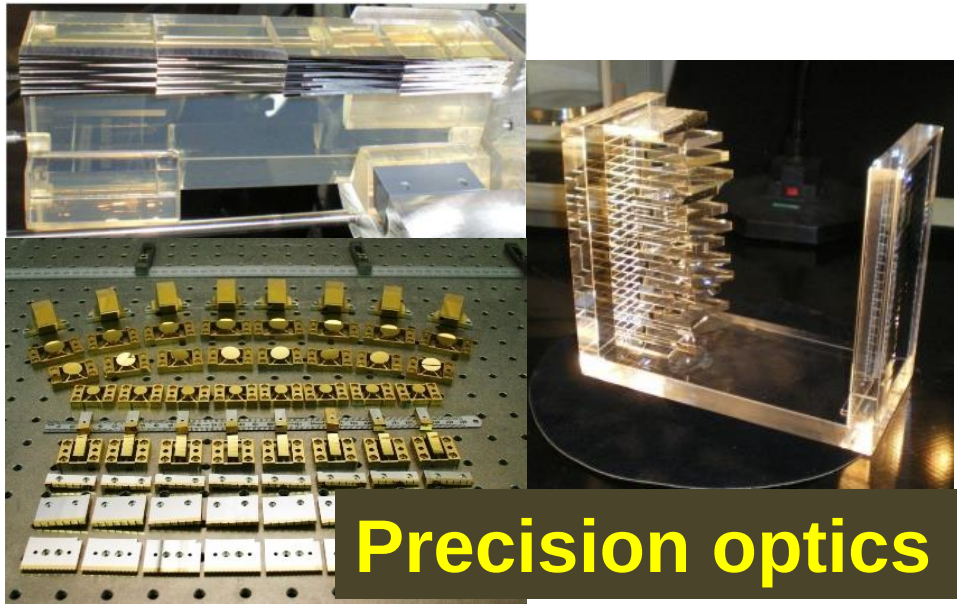


Technologies



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



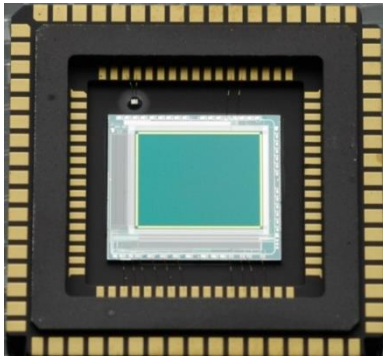


Technologies
CCD Mosaic for OmegaCAM

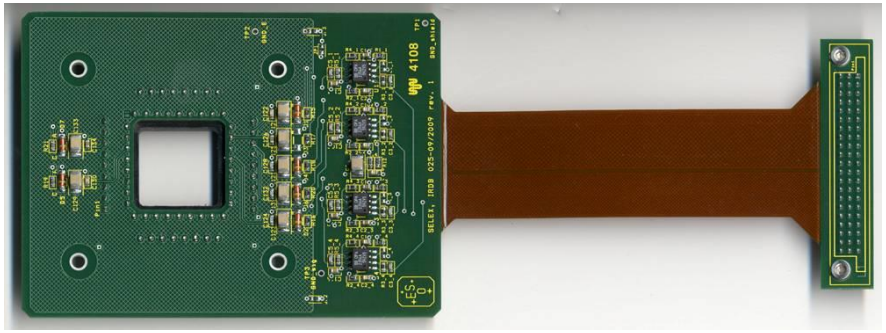
- 8 x 4 science mosaic of 2K x 4K e2v CCD44-82 devices
- 268 10^6 15µ x 15µ pixels (0.21 arcsec x 0.21 arcsec)
- + two 2K x 4K CCDs for autoguiding
- + two 2K x 4K CCDs for image analysis (AO and focus)
- commissioned in 2011 on 2.6-m VST

Technologies
λ_c=2.5 μm HgCdTe eAPD

- unlike silicon HgCdTe offers noiseless avalanche gain of up to 33
  - 3 successful predevelopment studies with 4-channel 320x256 prototype
  - new 32-channel multiplexer in development at SELEX UK



320x256 eAPD array



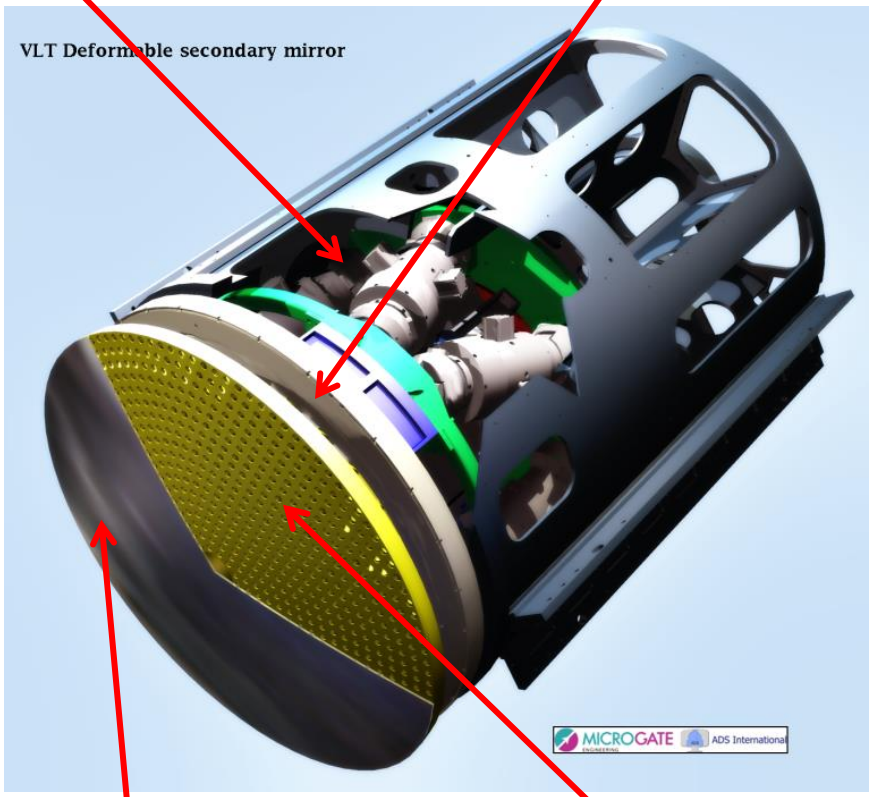
RAPID fast optical-NIR detector prototype, now on sky (LETI, ONERA, IPAG, LAM + SOFRADIR)
www.eso.org/public/announcements/ann15042/

Technologies

Electromagnetic deformable mirrors

Hexapod for centring & fine focusing

Cold Plate; heat evacuation & act. attachment

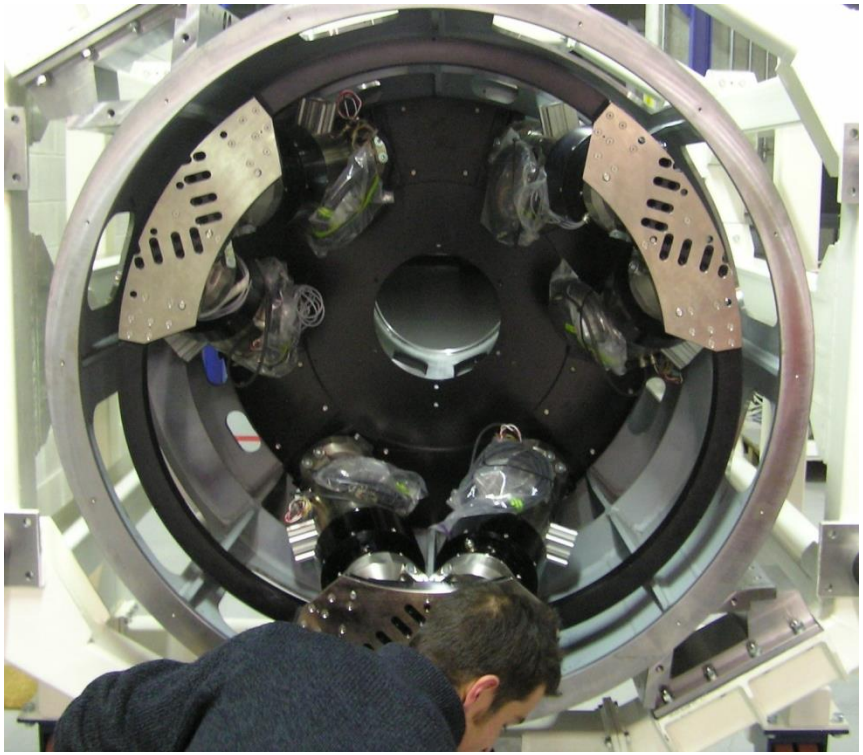


2mm Thin Shell

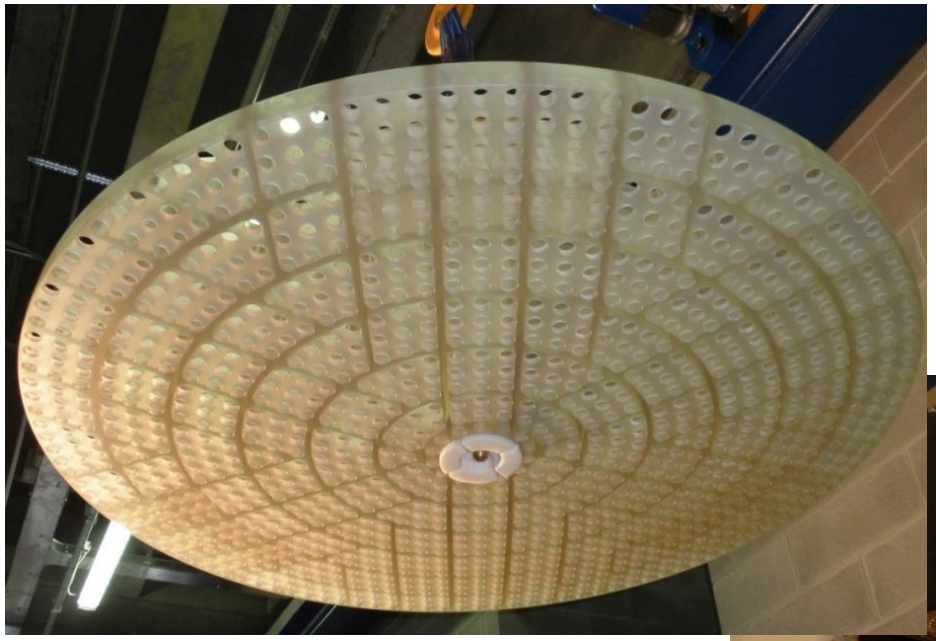
Reference body

ADS/Microgate

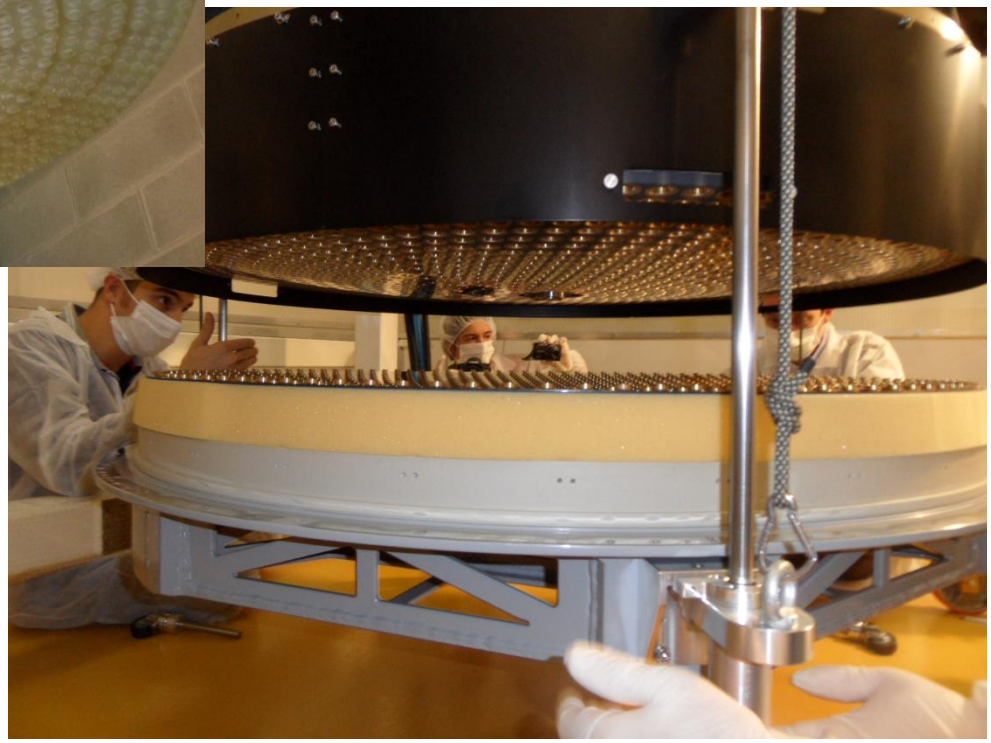
- **Ø 1.1m convex**



Technologies
Special optics for AO

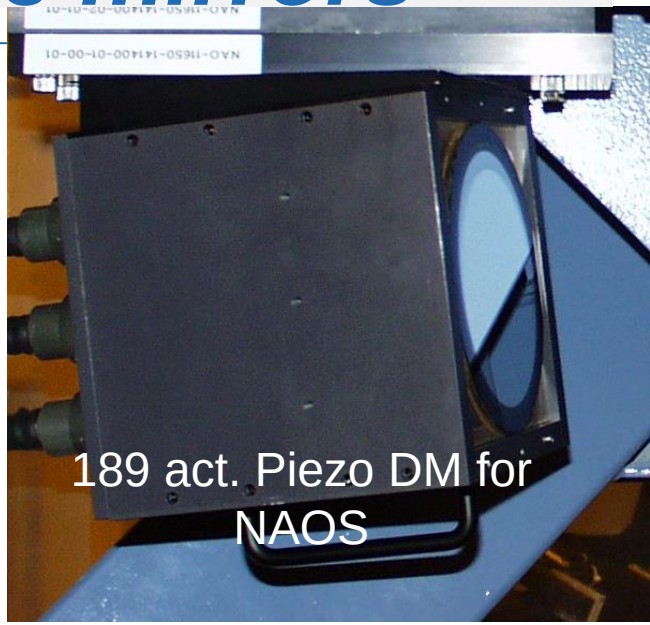


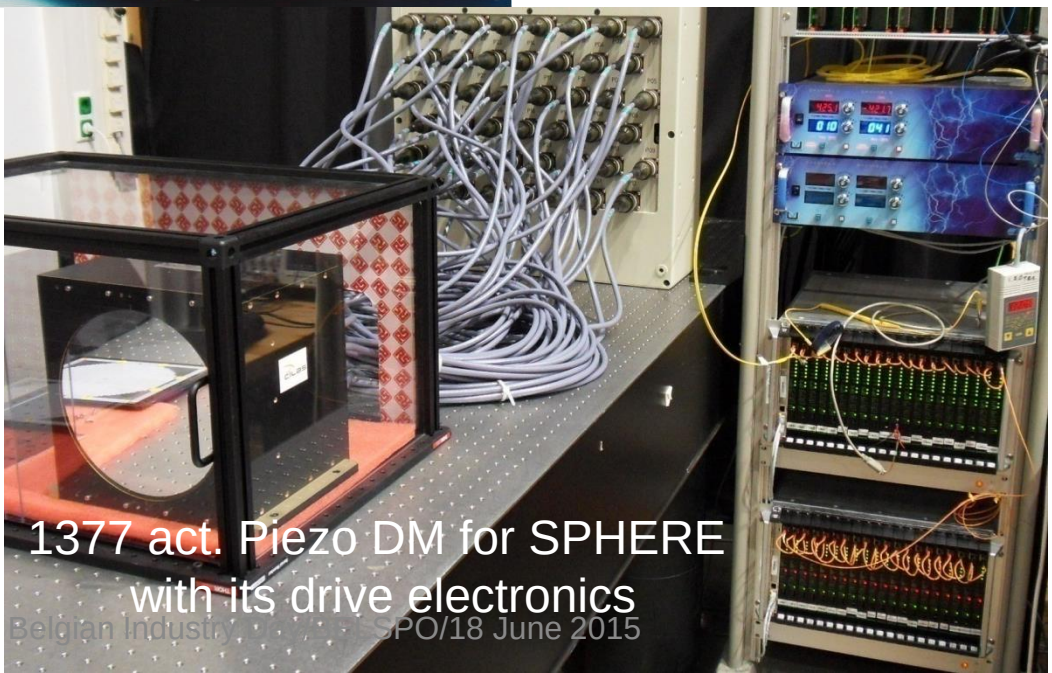
1 kHz response time

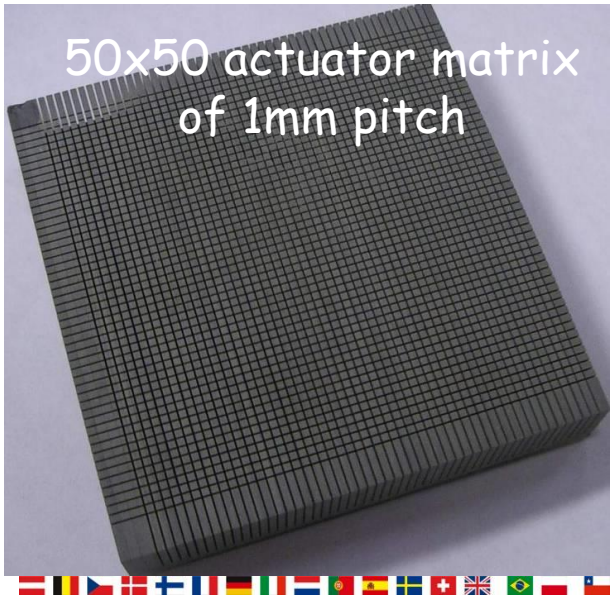


1170 electromagnetic actuators

Technologies
Piezo Deformable mirrors





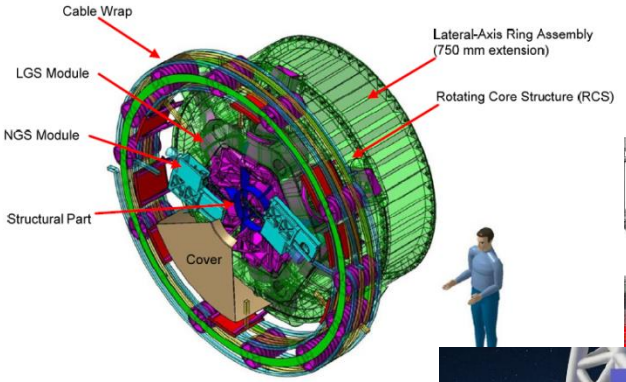


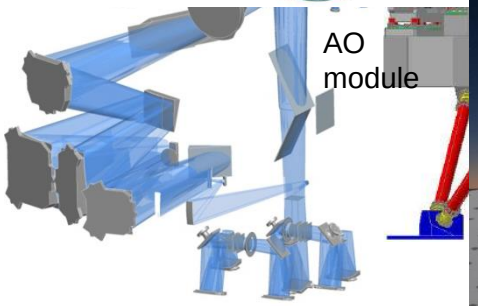
Conclusions

- ESO continues the largest ground-based astronomical instrumentation programme in the world
  - Continuing state-of-the-art developments for VLT
  - Major new instrument programme for ELT

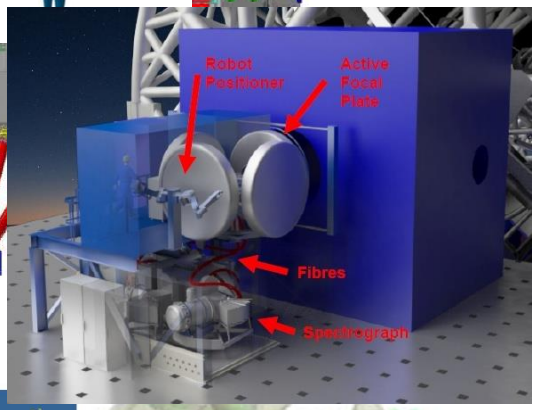
- Programme will fully utilise and challenge expertise in institutes and universities of member-states

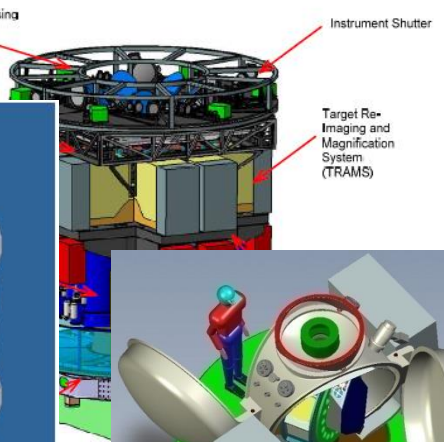
Questions

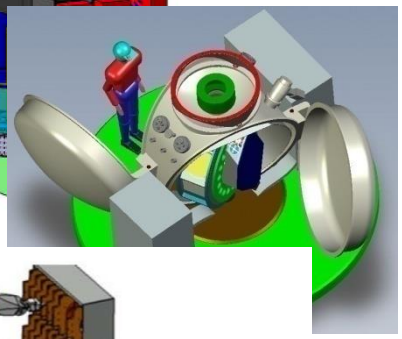


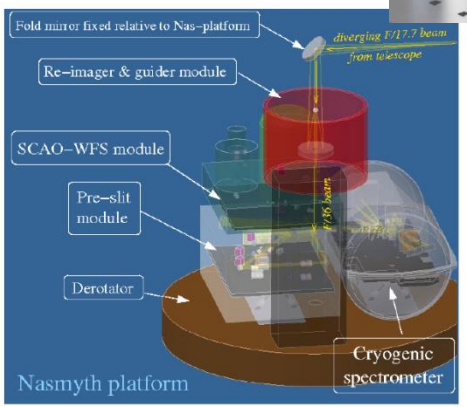


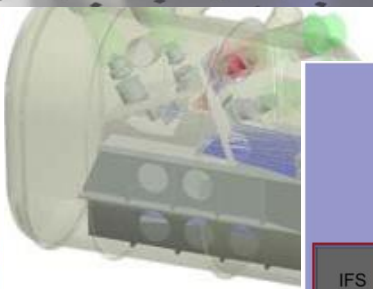
AO module

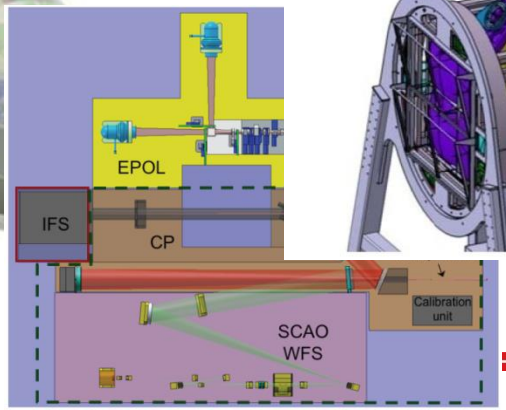


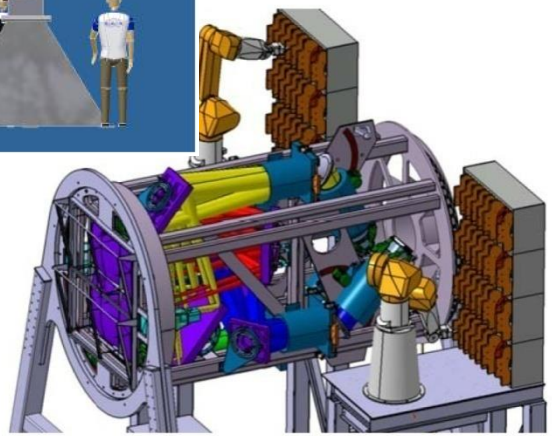








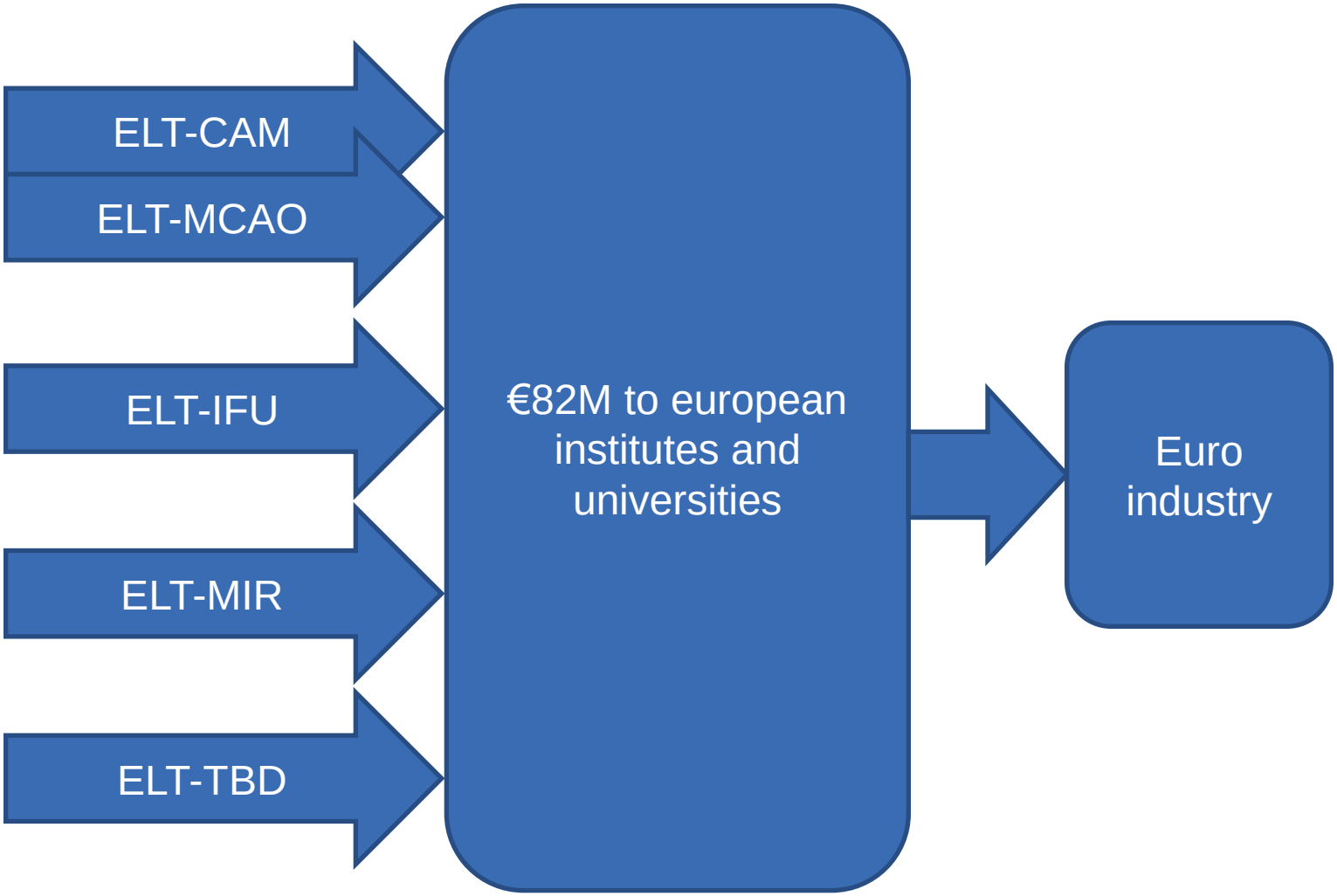




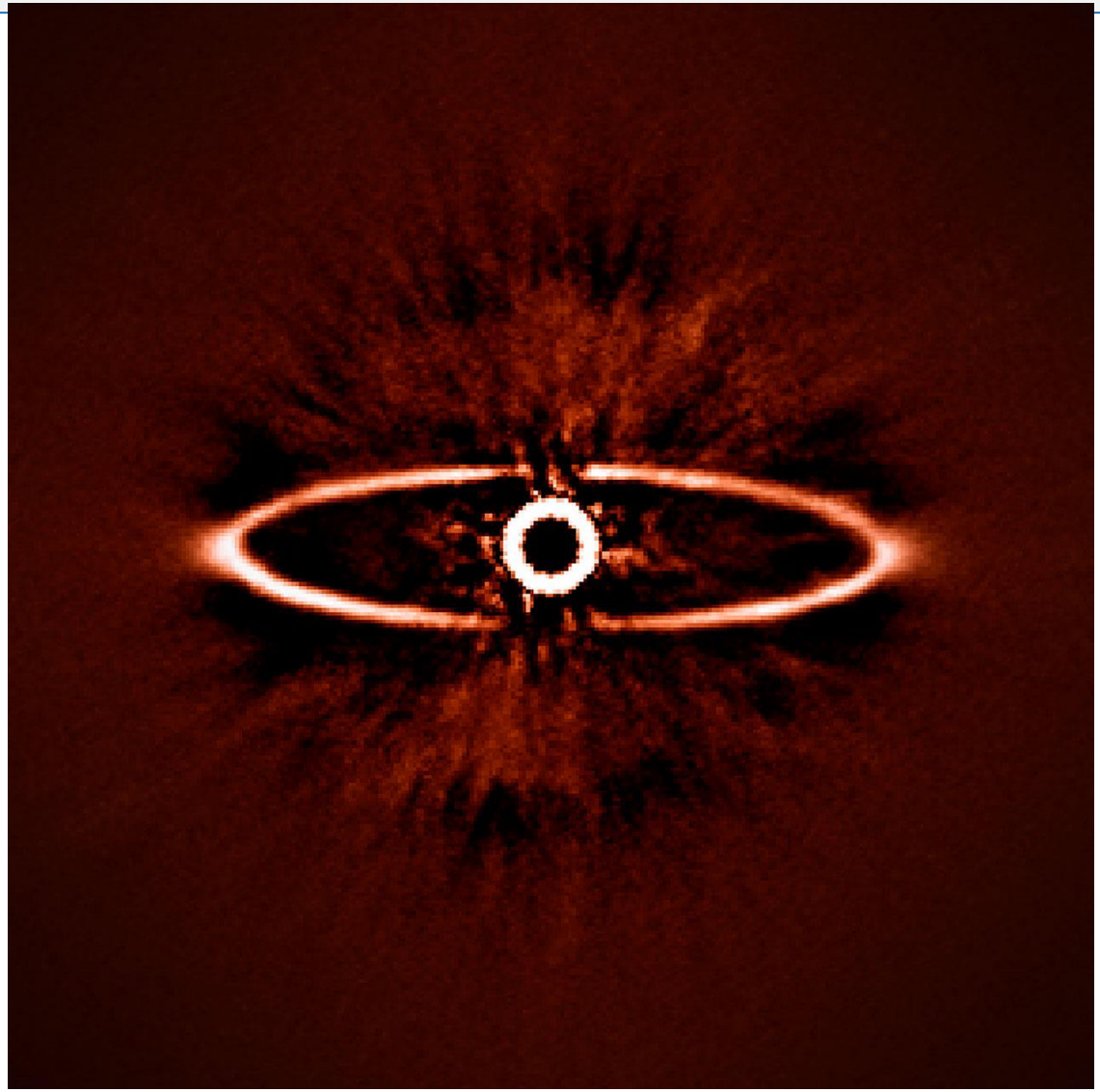
Questions

E-ELT Instrument Programme

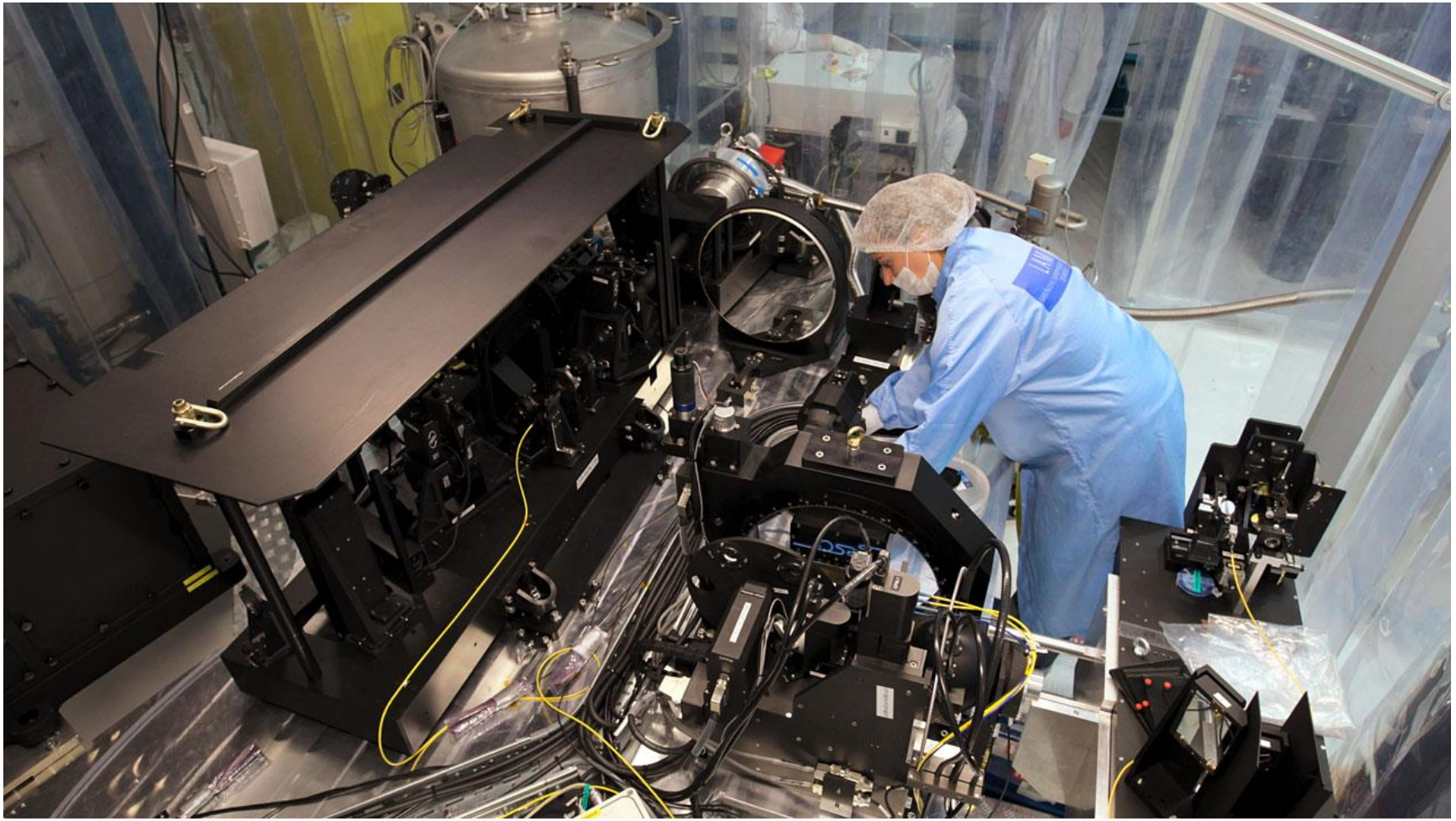
Funded by ELT construction budget



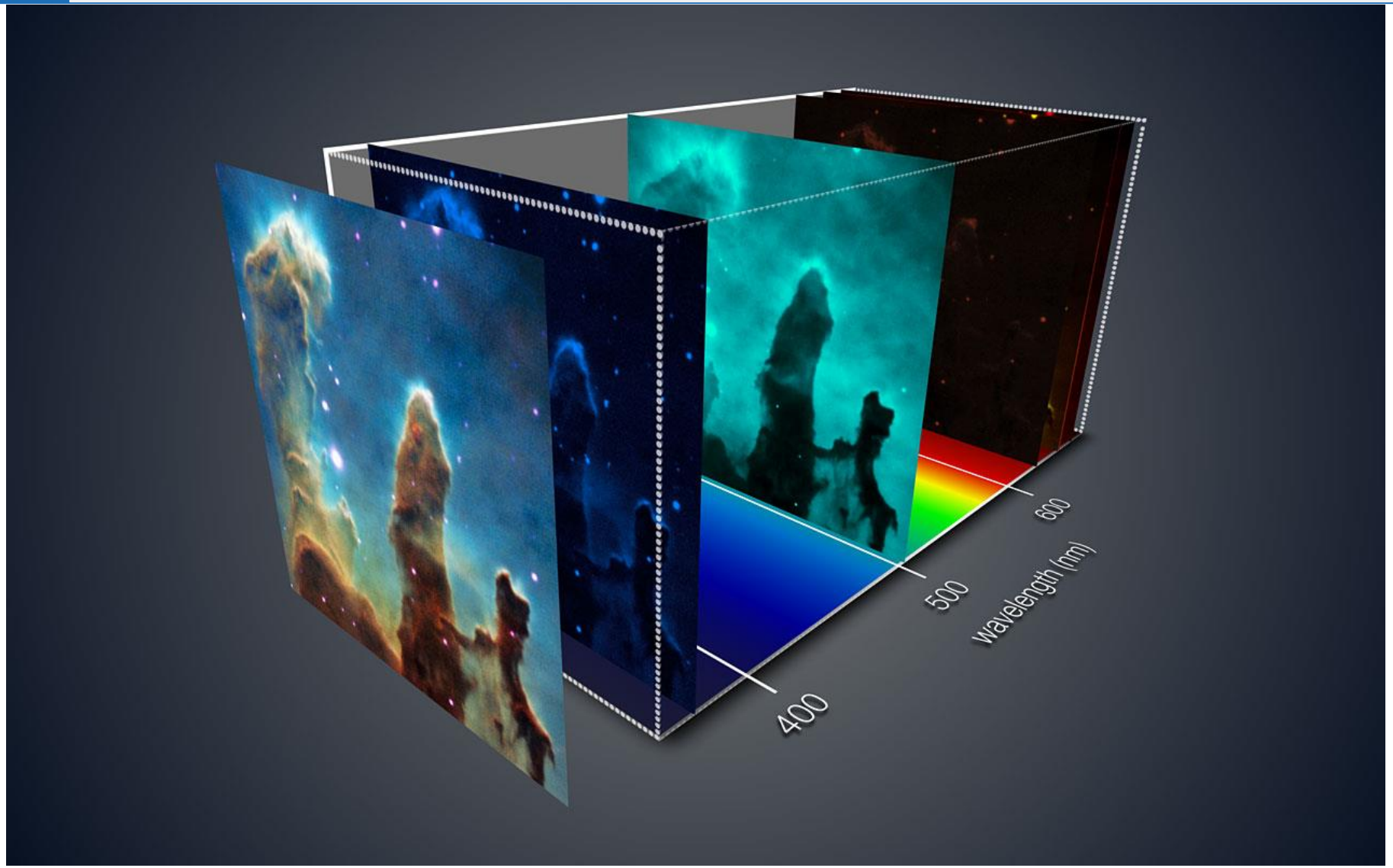
SPHERE science



SPHERE



MUSE/IFU science



IFU module

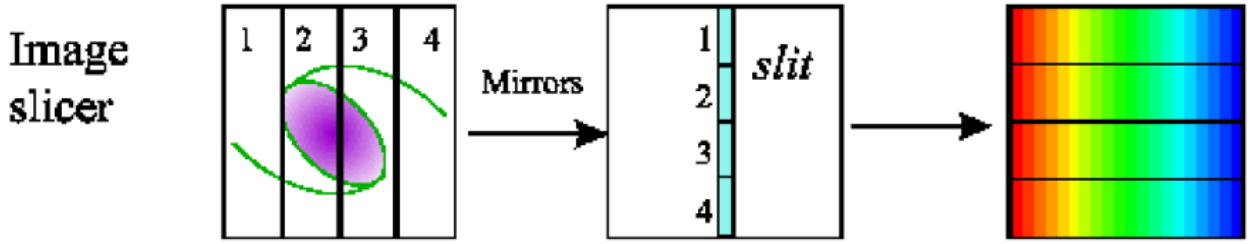
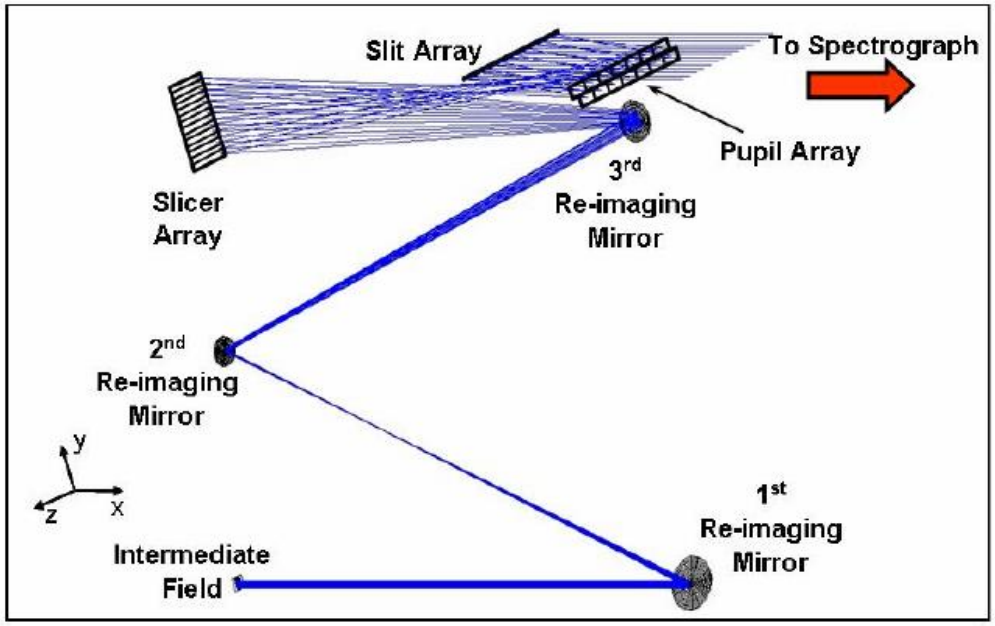
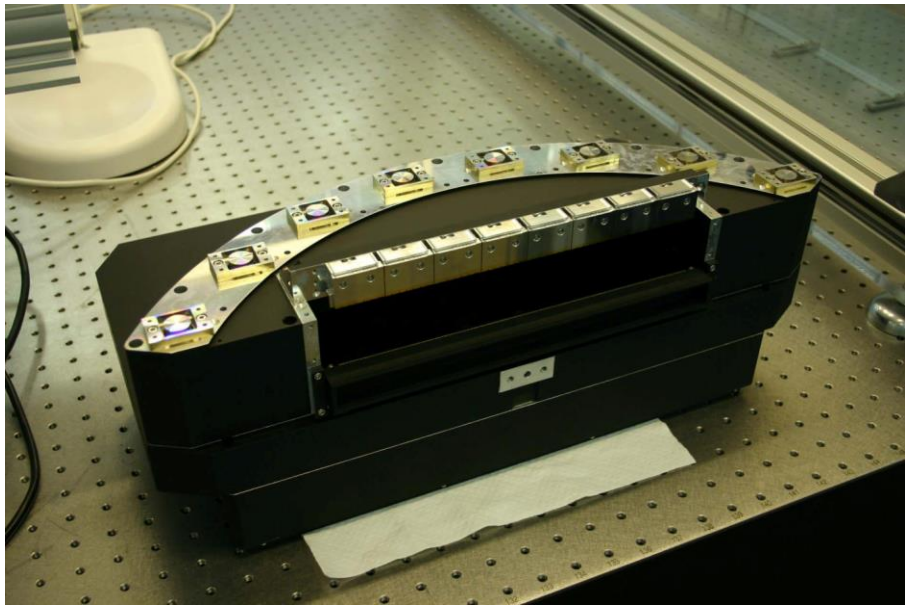
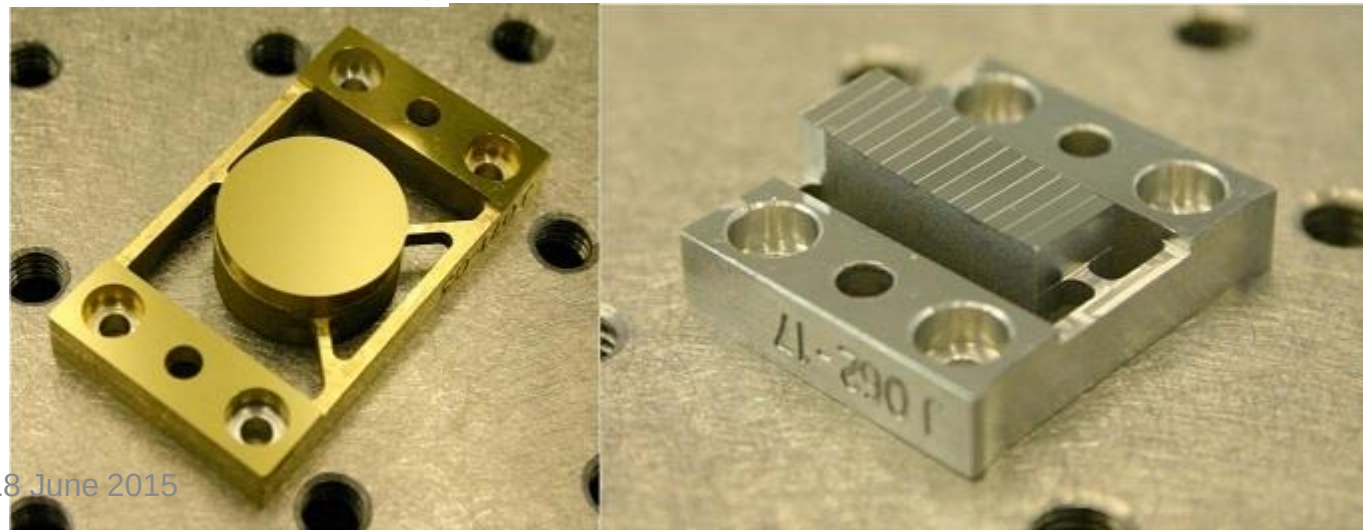


Image slicer
1
2
3
4
Mirrors
1
2
3
4
slit

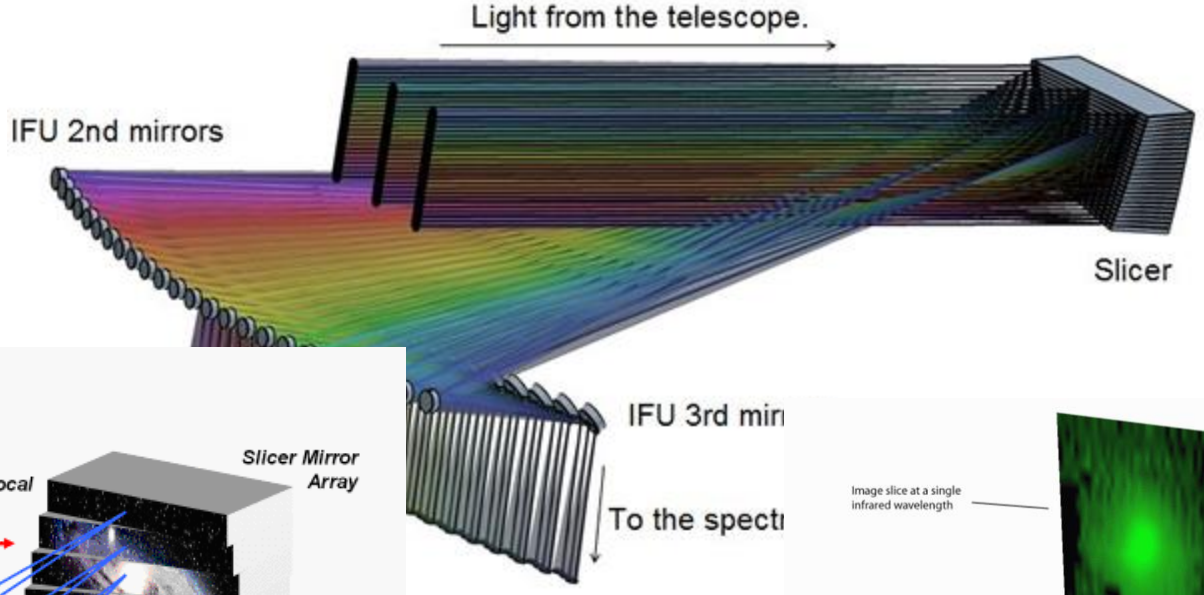

Slit Array
To Spectrograph
Pupil Array
3rd Re-imaging Mirror
Slicer Array
2nd Re-imaging Mirror
y
z
x
1st Re-imaging Mirror
Intermediate Field

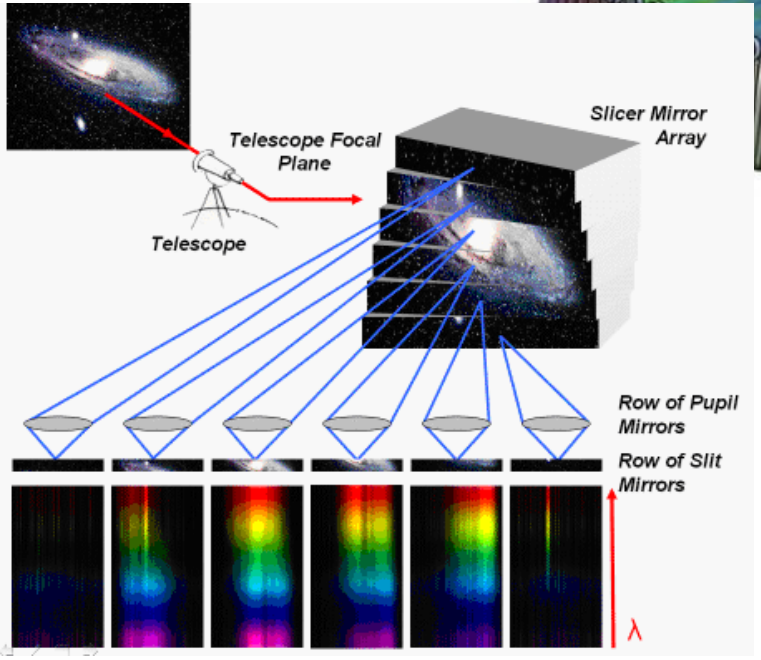


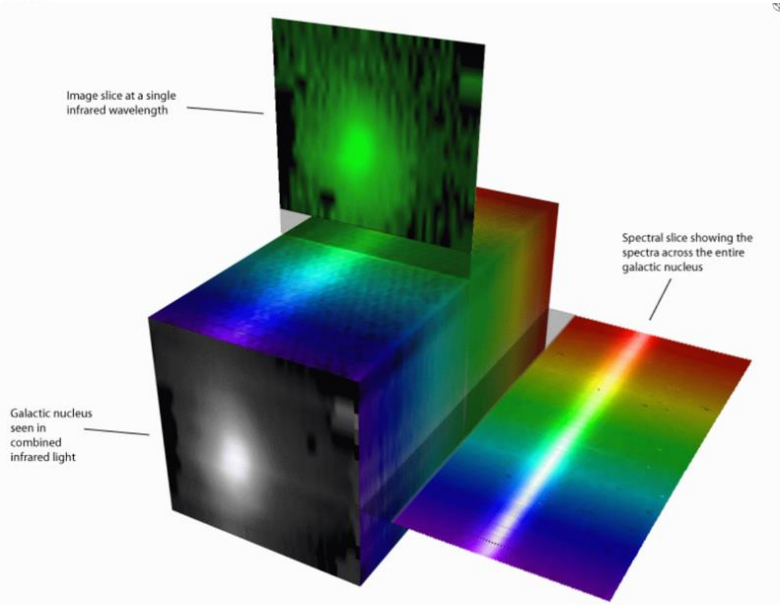


http://atc.mtk.nao.ac.jp/E/Projects/TMT/development_of_IFU.html

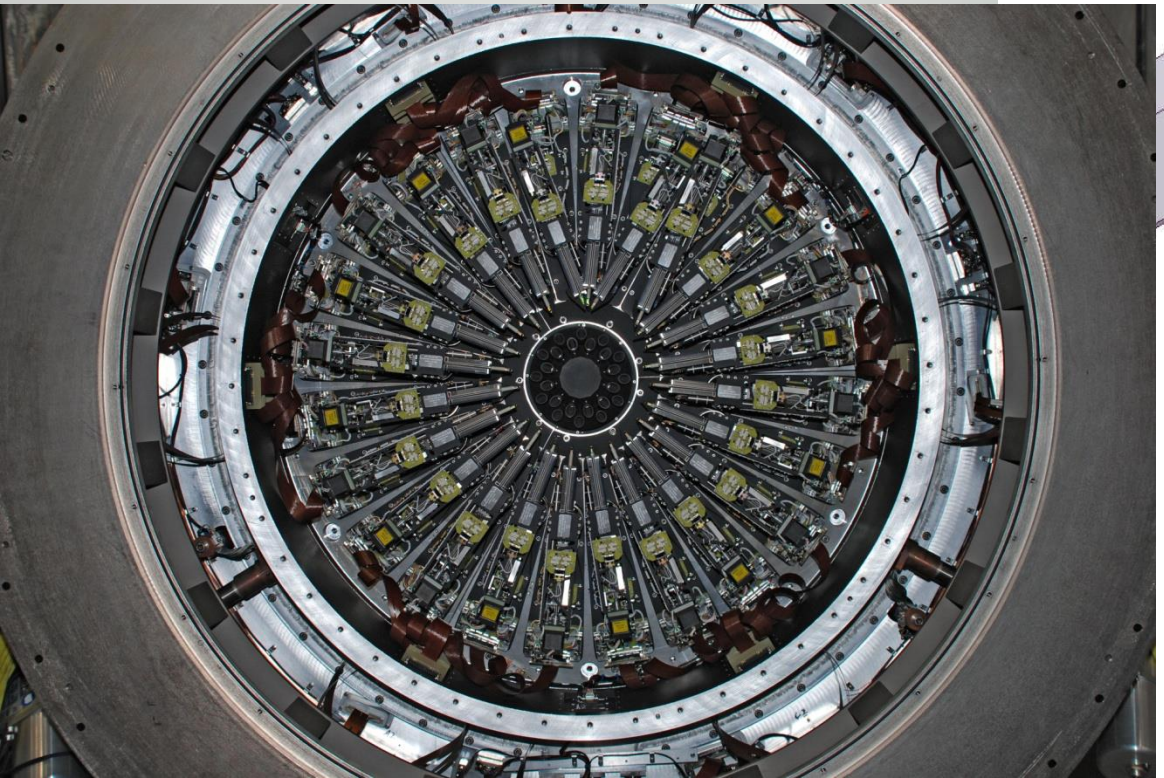
- http://atc.mtk.nao.ac.jp/E/Projects/TMT/development_of_IFU.html

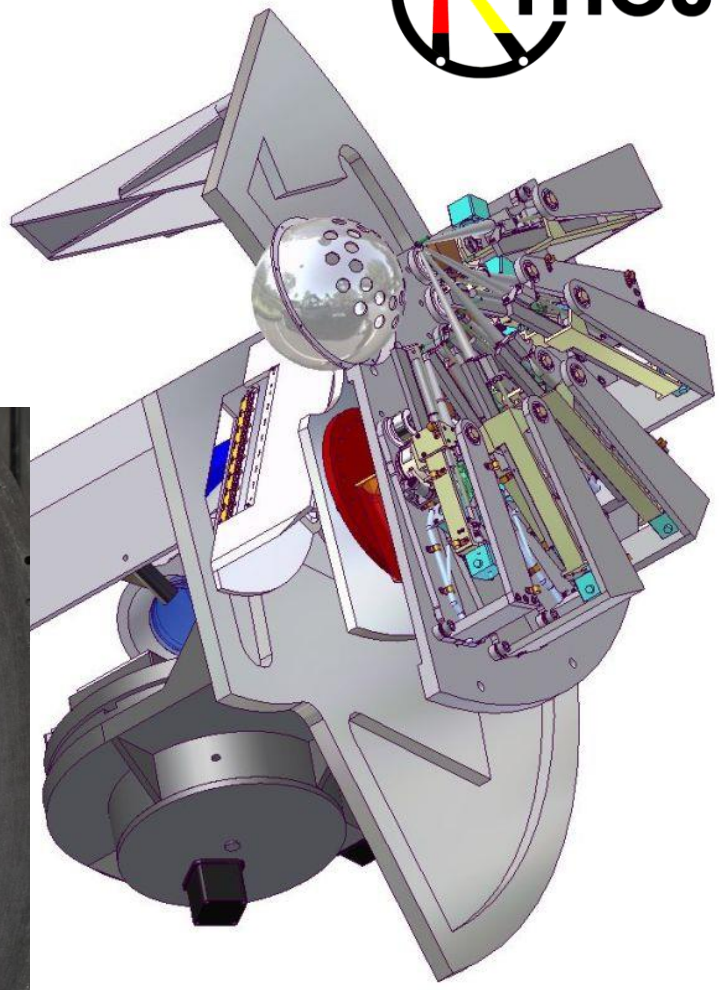






Pick-off arms





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