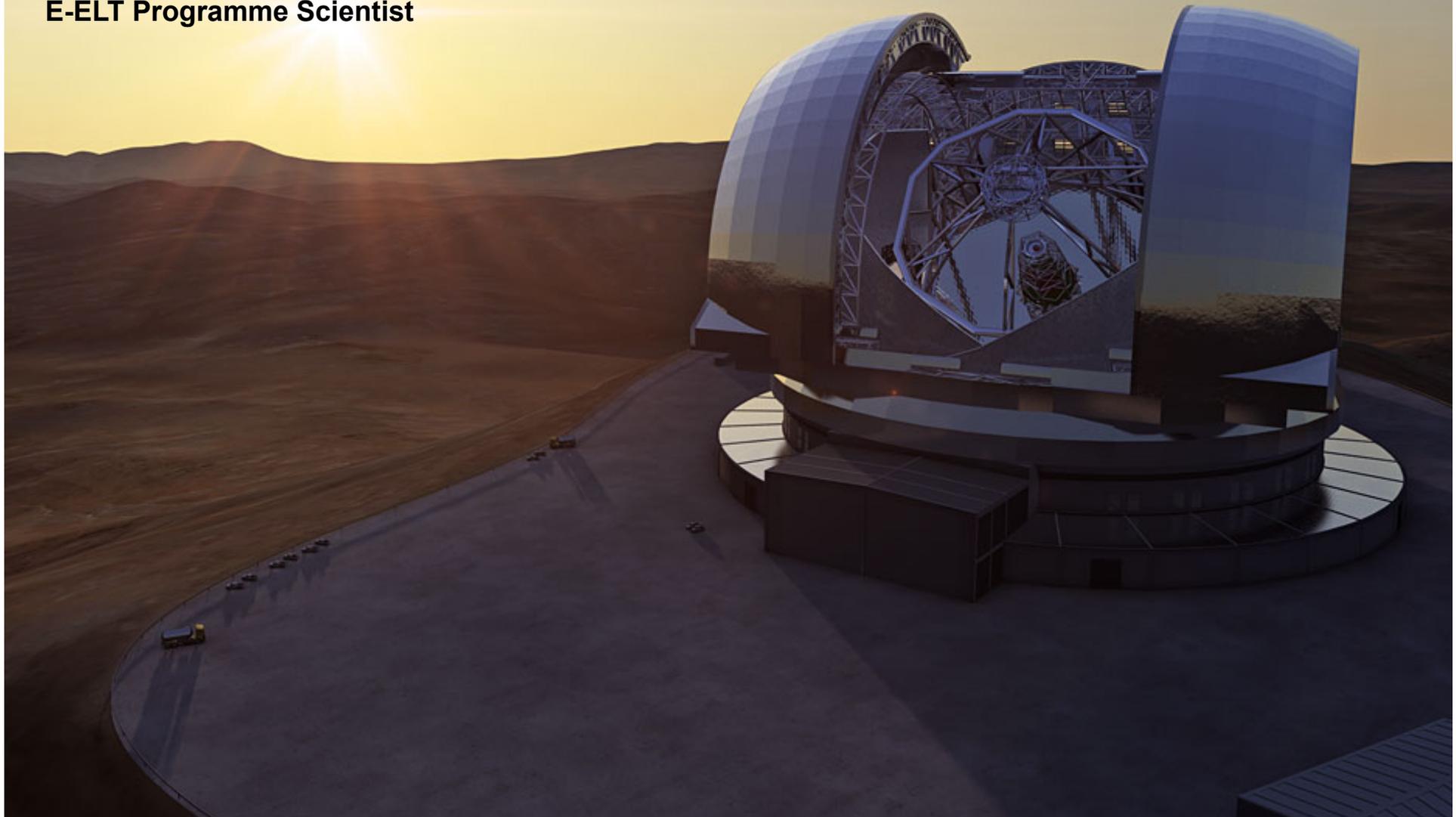




# The European Extremely Large Telescope

Michele Cirasuolo  
E-ELT Programme Scientist





# Outline

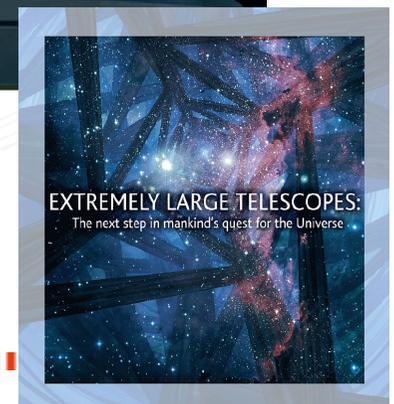
- Overview of E-ELT Programme
- Updates on the instruments
- Science



# E-ELT Science

## From the Observatory TLR:

- **Contemporary science:**
  - Exoplanets
  - Fundamental physics
  - Resolved stellar populations
  - The physics of high-redshift galaxies
  - ... and much more!
- **Synergies with other top facilities:**
  - ALMA
  - JWST
  - LSST and other survey telescopes
  - SKA
- **Discovery potential:**
  - Opening new parameter space in terms of spatial resolution and sensitivity.

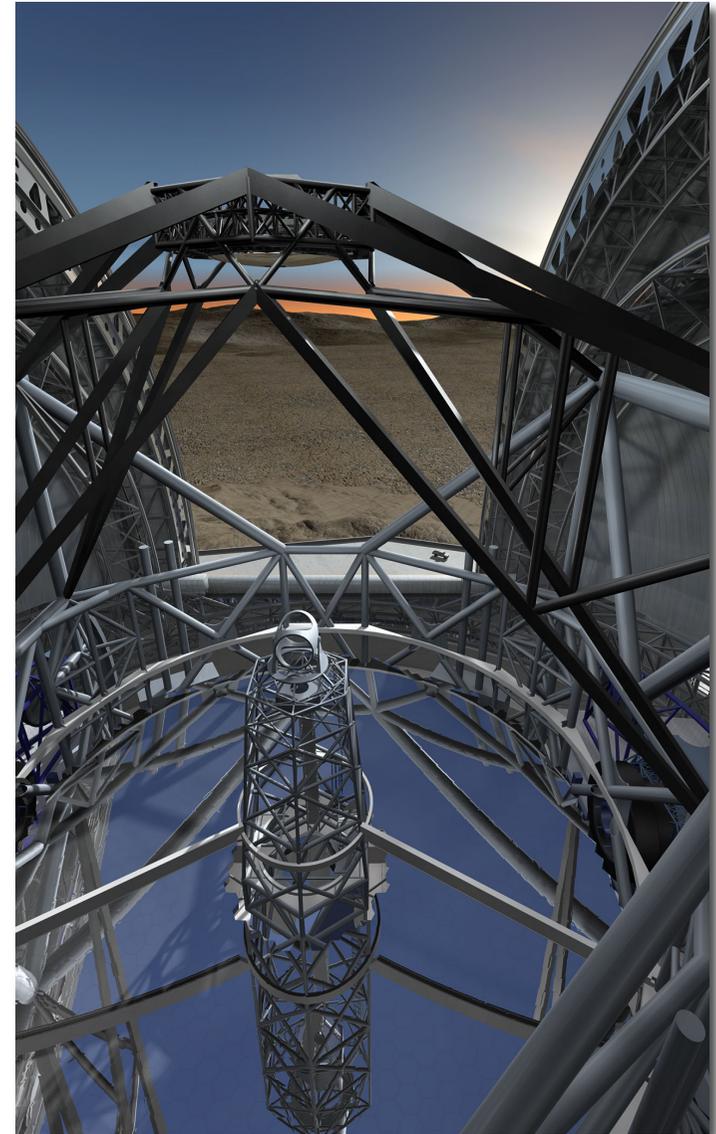




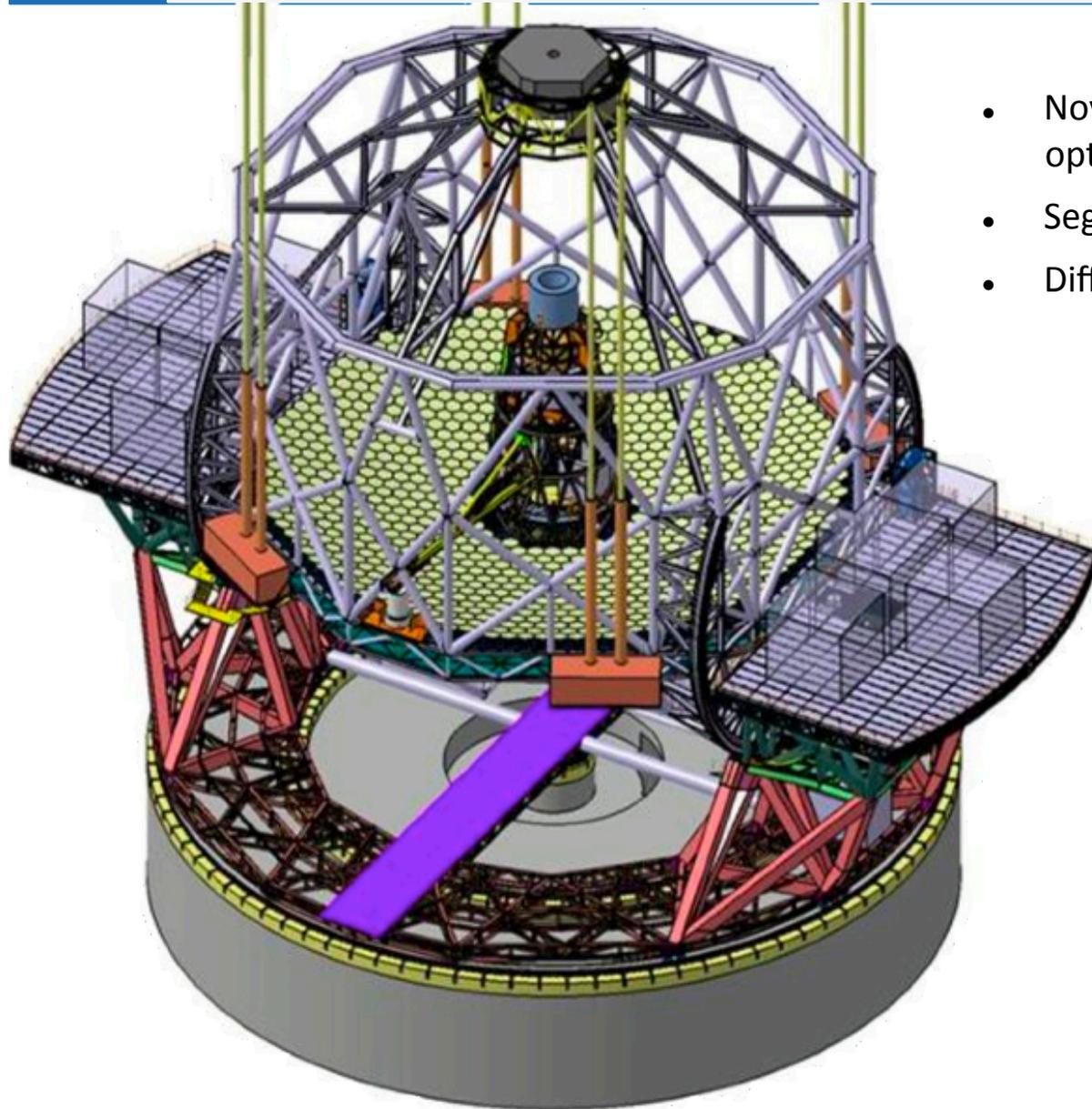
# The E-ELT

## 39-m class telescope

- Adaptive optics built in to deliver diffraction limited performance.
- Dec 2014: ESO Council gave green light for E-ELT construction in two phases
  - Funding approved for Phase I
  - Still expected that both phases will be completed.
  - Comprehensive suit of state-of-the art instrumentation
- Work well underway
- Expected first light 2024



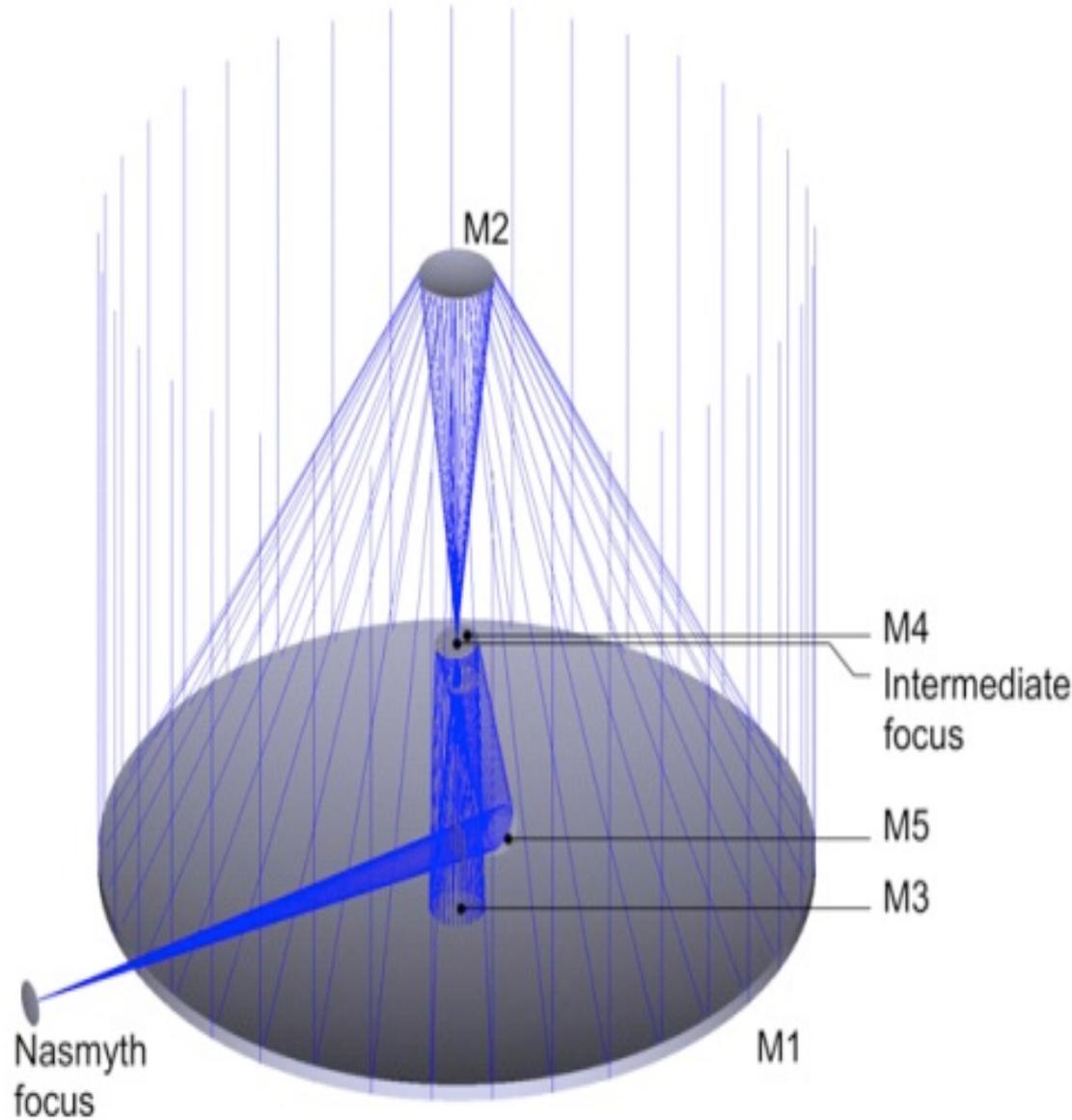
# The E-ELT: overview



- Novel 5 mirror design to include adaptive optics in the telescope.
- Segmented primary mirror (798 segments)
- Diffraction limited over full 10' FoV



# E-ELT Optomechanics



**M1 Unit**  
39-m  
Concave – Aspheric  $f/0.9$   
Segmented (798 Segments)  
Active + Segment shape Control



**M2 Unit**  
4-m  
Convex Aspheric  $f/1.1$   
Passive + Position Control



**M3 Unit**  
4-m – Concave – Aspheric  $f/2.6$   
Active + Position Control



**M4 Unit**  
2.4-m  
Flat  
Segmented (6 petals)  
Adaptive + Position Control



**M5 Unit**  
2.7x2.1-m  
Flat  
Passive + Fast Tip/Tilt



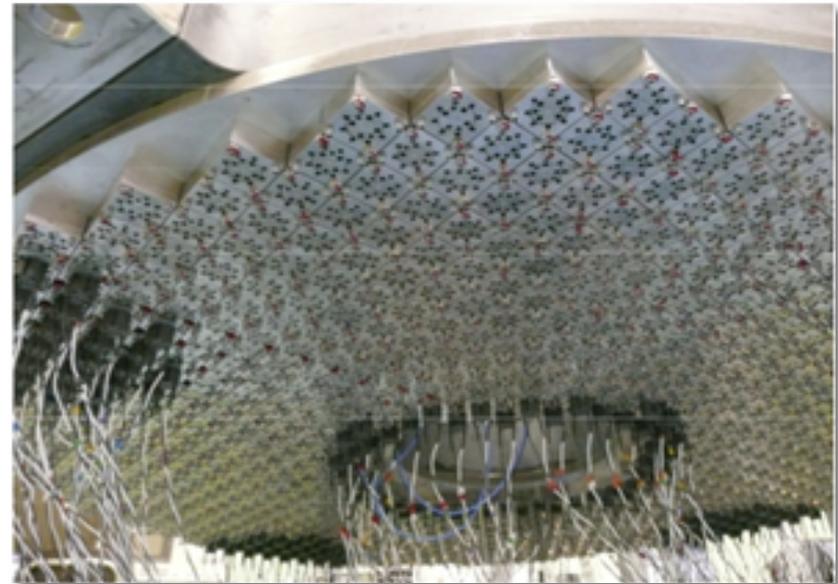
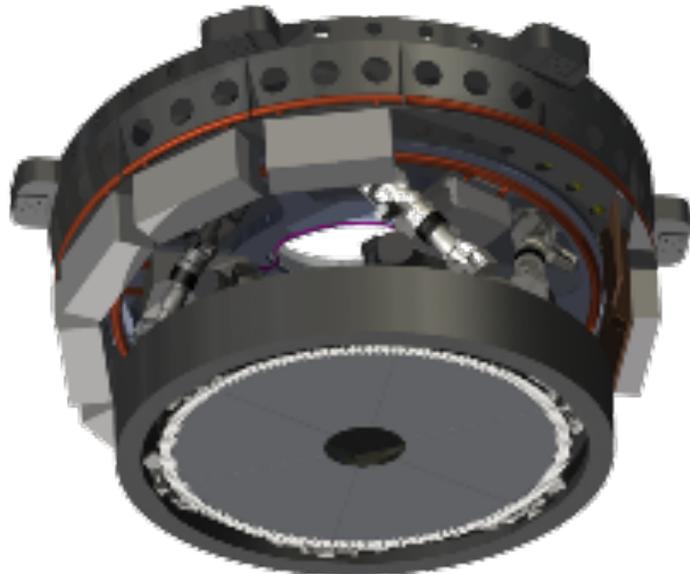
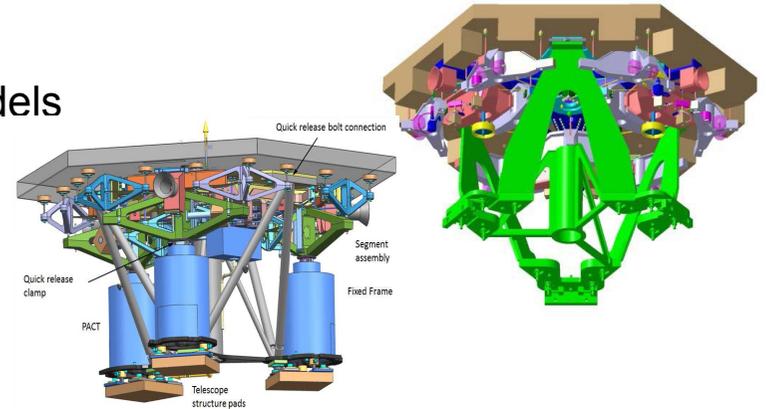
**LGSU**  
(Laser Guide Star Units)  
Laser Sources + Laser Beacons  
shaping and emitting





# Running contracts Status

- M1 Segment Support (x2, VDL and CESA):
  - Design to FDR and delivery of 4 qualification models
- M4 Cell (AdOptica)
- M4 Shell and blanks



~5300 contactless actuators driving the mirror shape at 1 kHz



# M4 Shells





# M4 Blanks

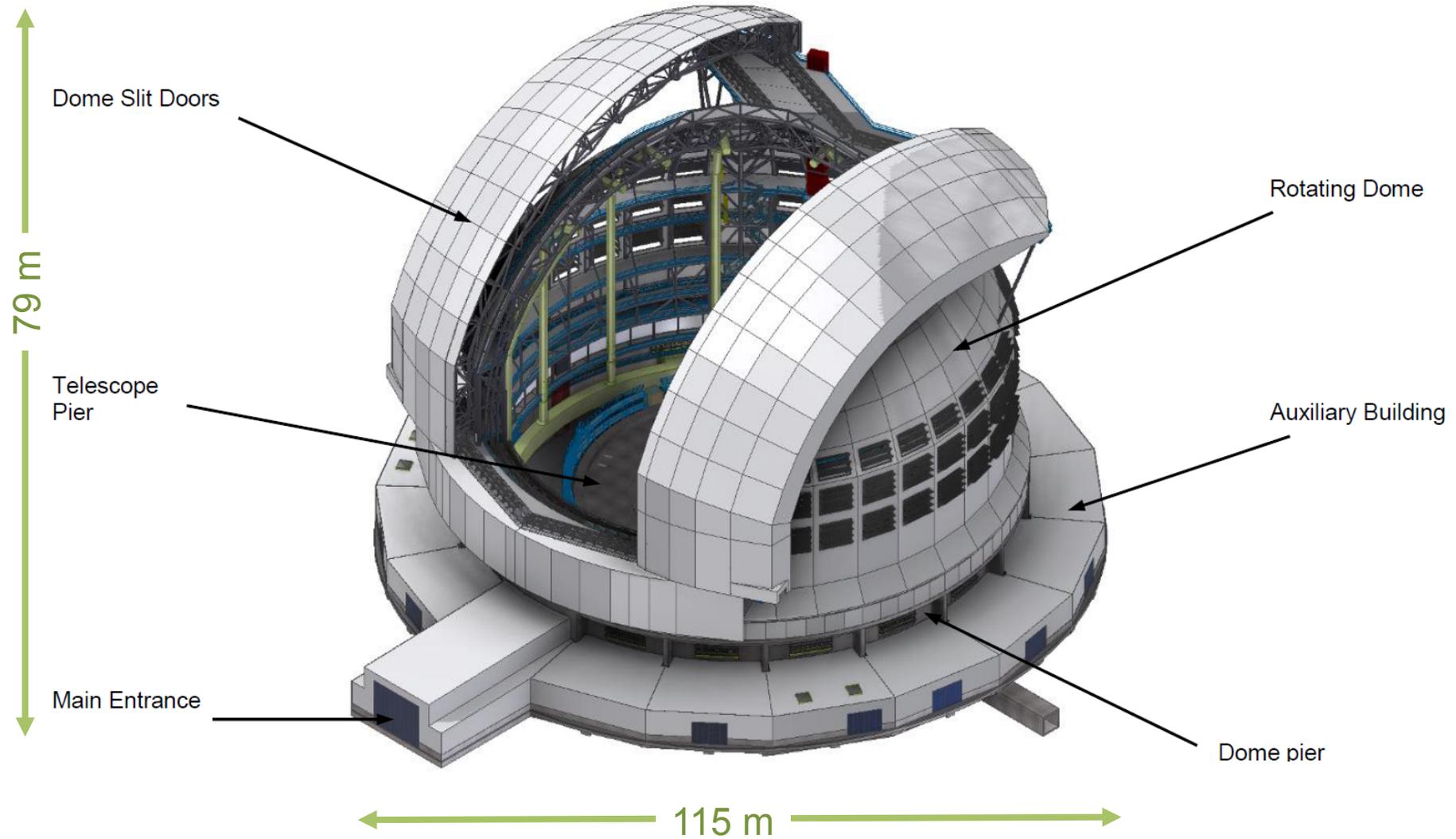




# Running contracts Status

- M1 Segment Support (x2, VDL and CESA):
  - Design to FDR and delivery of 4 qualification models
  
- M4 Cell (AdOptica)
- M4 Shell and blanks
  
- Dome and Main structure
  - Contract with ACe consortium signed 25<sup>th</sup> May 2016

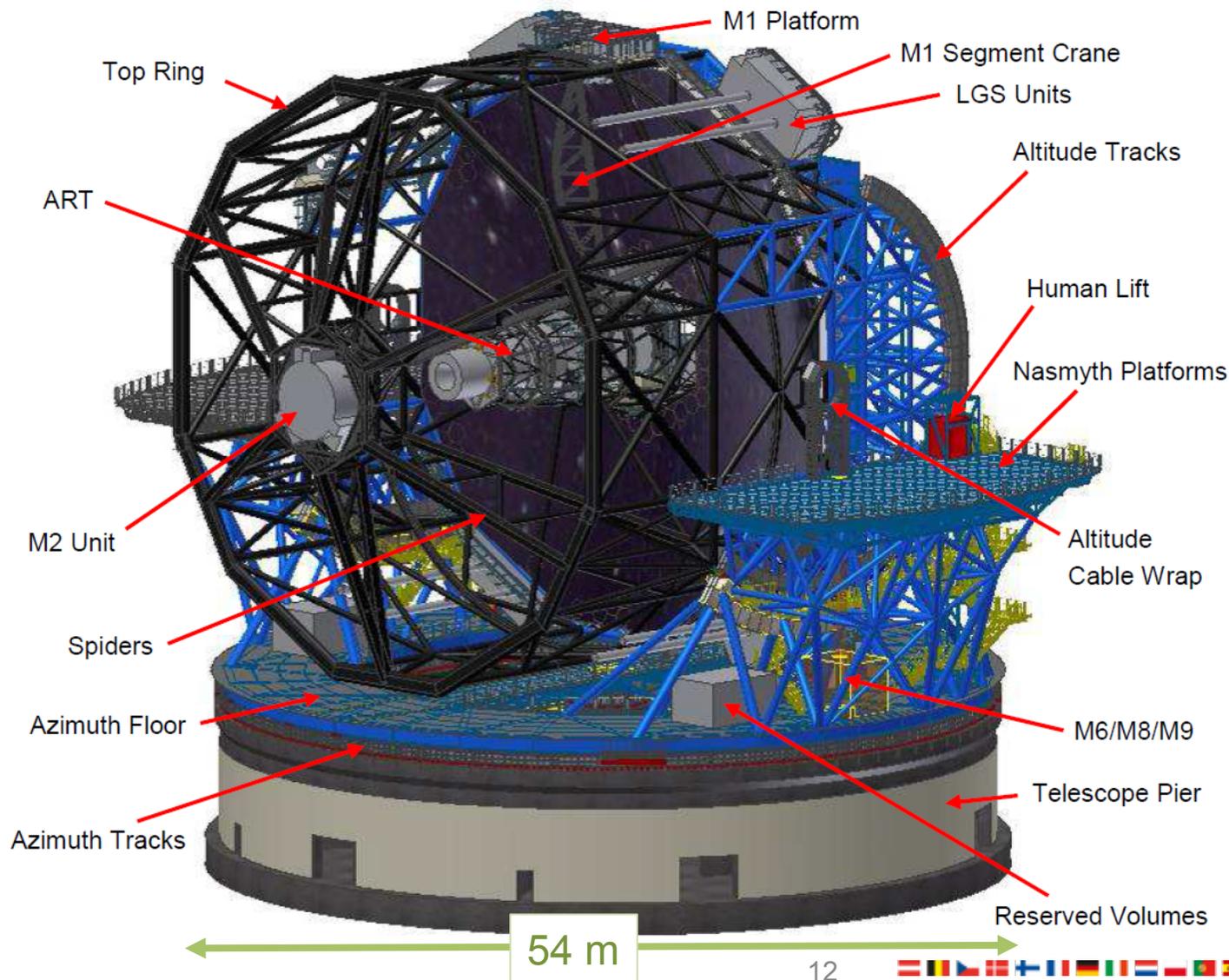
# ACe proposed Dome





# ACe proposed Main Structure

~52 m (Horizon)



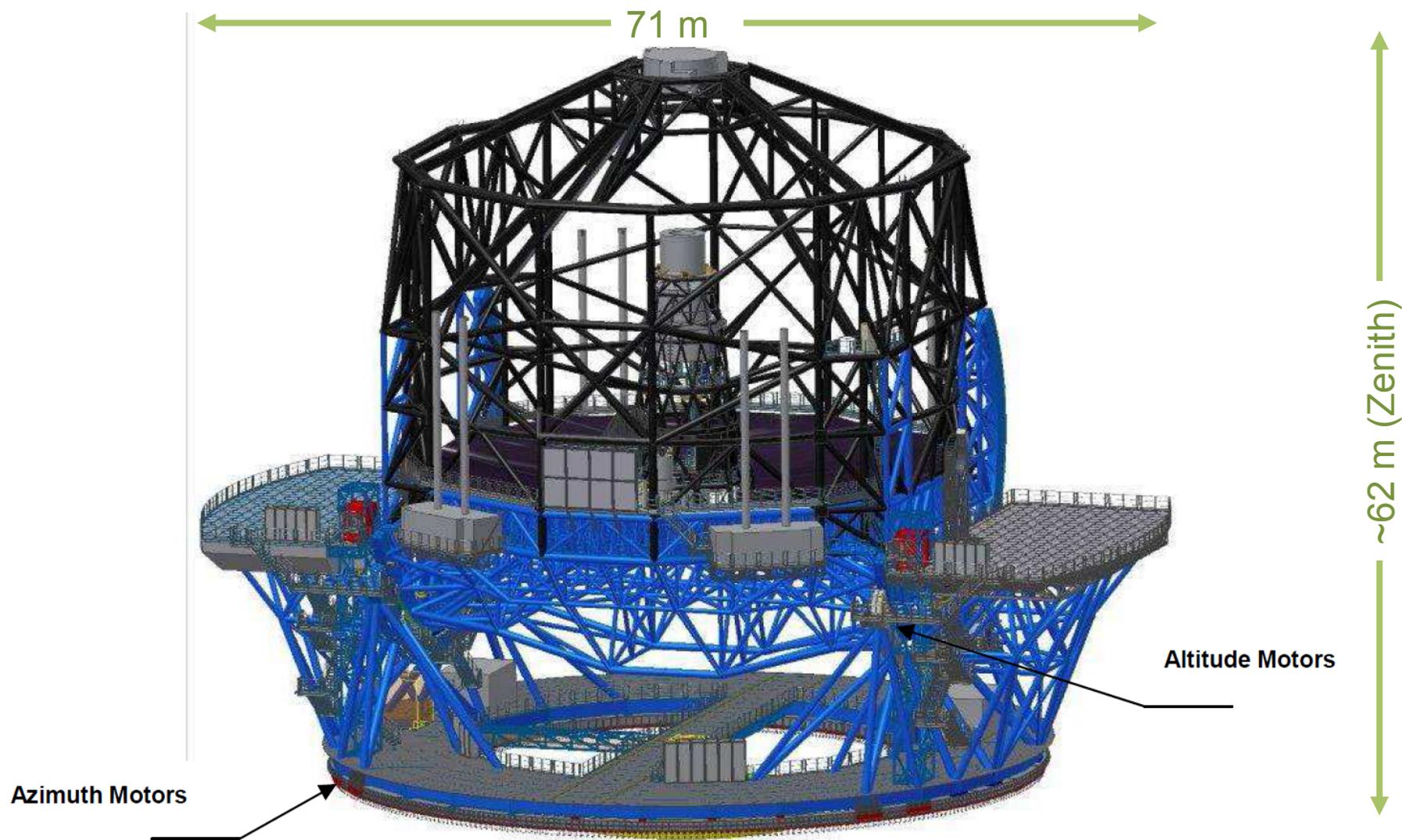
54 m

12



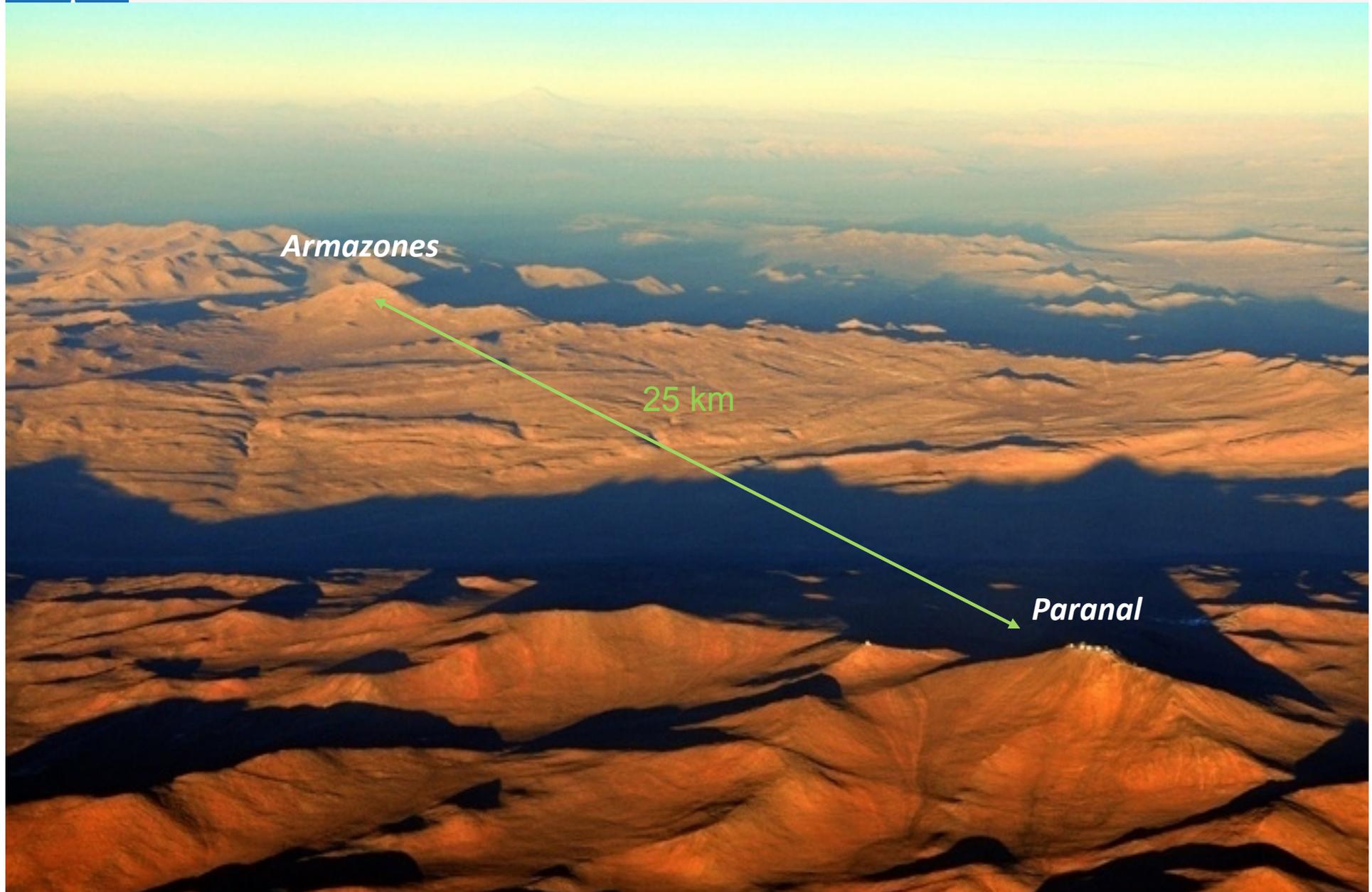


# ACe proposed Main Structure





# The site





# The site





# E-ELT Instrumentation Programme

## Instrumentation Roadmap

- ELT-CAM (MICADO+MAORY)
- ELT-IFU (HARMONI+LTAO)
- ELT-MIDIR (METIS)

Preliminary design started in  
September 2015

- High resolution spectrograph (HIRES)
- Multi-object spectrograph (MOS)

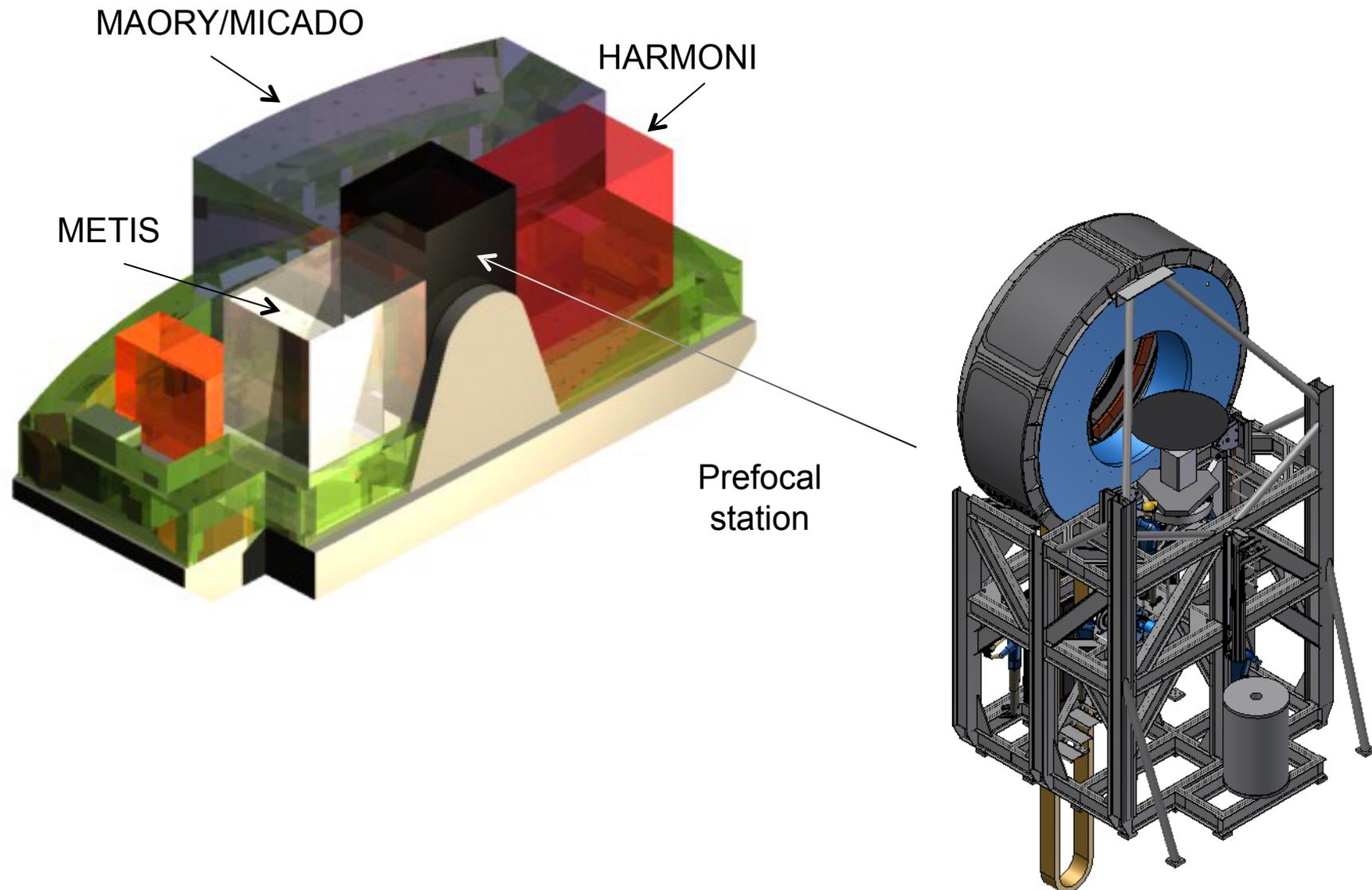
Phase A started in  
April 2016

- Open slot 6
- XAO PCS instrument





# Instruments update

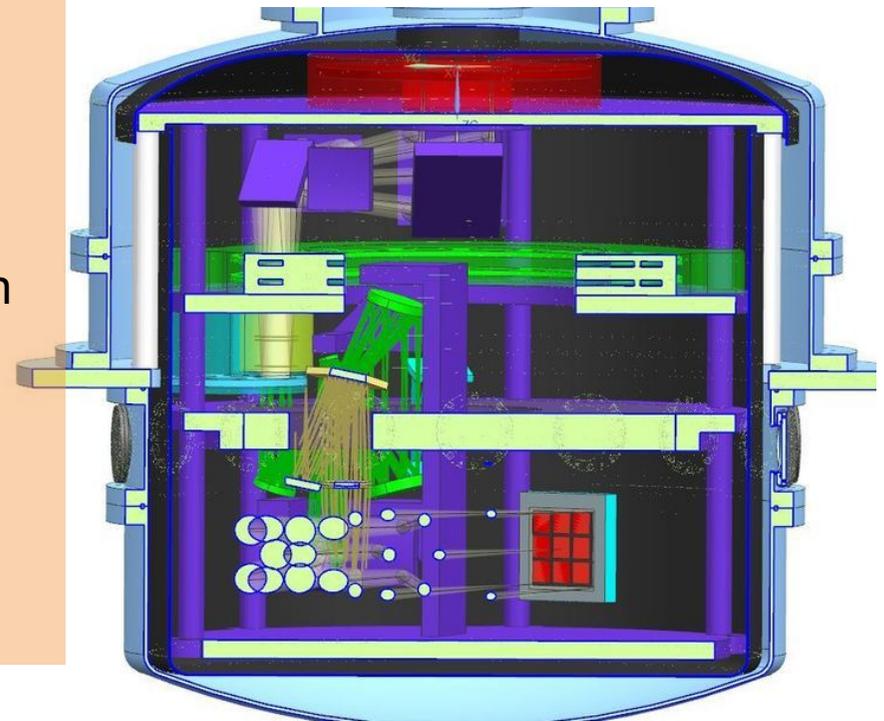


# MICADO+MAORY

## MICADO

PI: R. Davies MPE, Germany

- **Imaging** 0.8-2.4 $\mu$ m, pixel scales of
  - 4mas (FoV  $\sim$ 53")
  - 1.5mas (FoV  $\sim$ 20")
- **Astrometric imaging** with 50 $\mu$ as precision
- **Spectroscopy for single slit** R $\sim$ 8000.
- **Coronagraphic imaging**
- Time Resolved Astronomy (goal)





# MICADO+MAORY

## MAORY

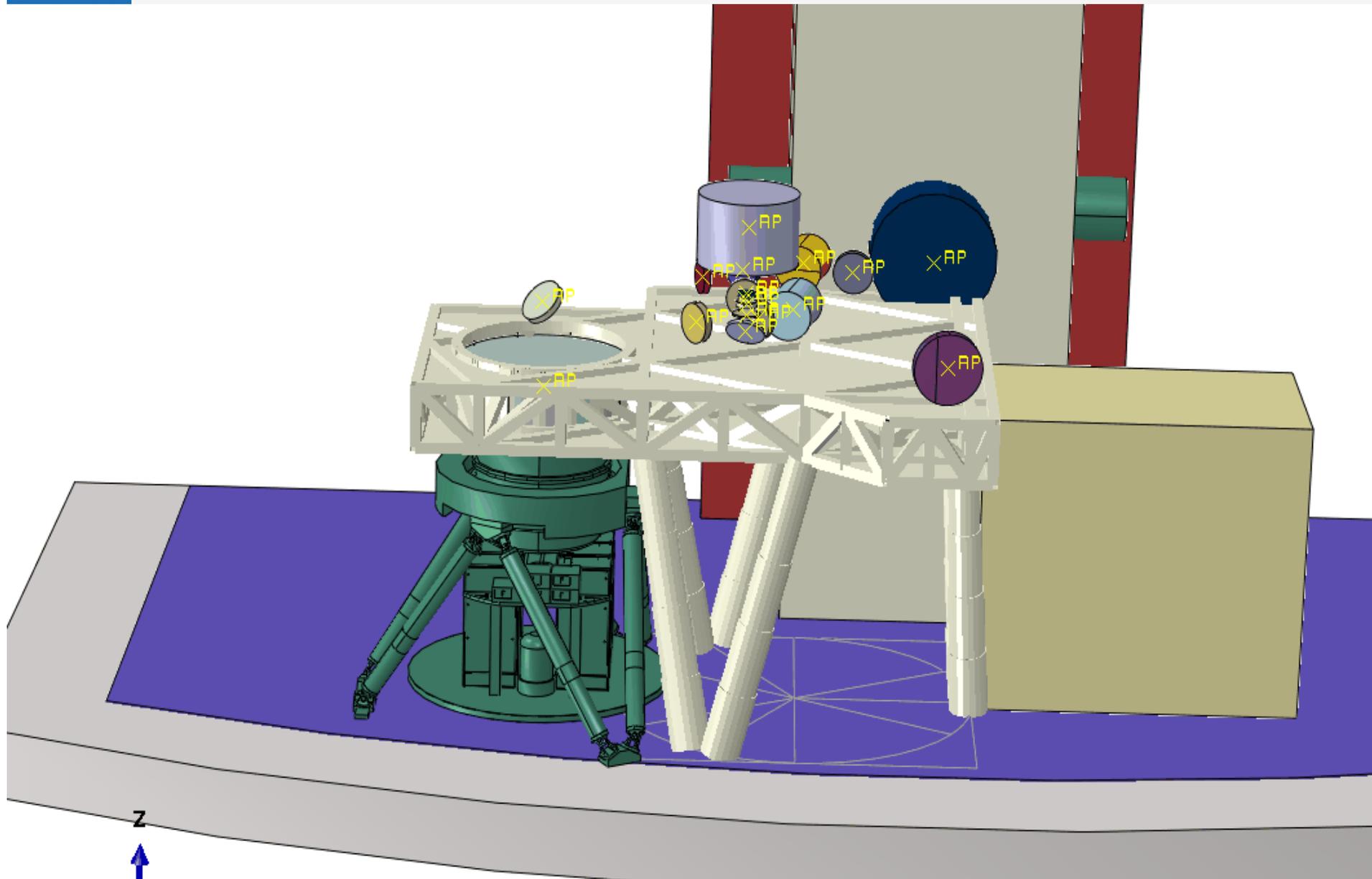
PI: E. Diolaiti INAF, Italy

- **SCAO and Multi-conjugate AO**
- 6 laser, 3 natural guide stars
- **2 deformable mirrors** conjugated to 4km, 12.7km + M4
  - (Single DM initial, upgrade path to 2 DMs)
- **2 output ports** (MICADO + future instrument)
- $0.6 \mu\text{m} < \lambda < 2.4 \mu\text{m}$
- **Field of view** 2 arcmin, 1 arcmin clear





# MICADO+MAORY





# HARMONI

## HARMONI

PI: N. Thatte University of Oxford, UK

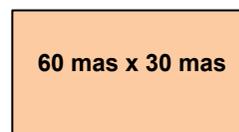
- **3D spectrograph** (IFU)
- Covering **optical** (0.47  $\mu\text{m}$ ) to **near-IR** (2.45  $\mu\text{m}$ )
- From **seeing limited** down to the **diffraction limit** with SCAO and LTAO
- Range of **resolving powers** from  $R=3500$  to 20000
- Range of **spatial scales** with field of views from 9"x6" to 0.8"x0.6"



# HARMONI + LTAO

## Diffraction-limited, single field NIR IFU

- Four spaxel scales / fields of view;
  - 60x30mas/6.5 x 9.1" FoV (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)



For non-AO & visible observations

20mas



For optimal sensitivity (faint targets)

10mas

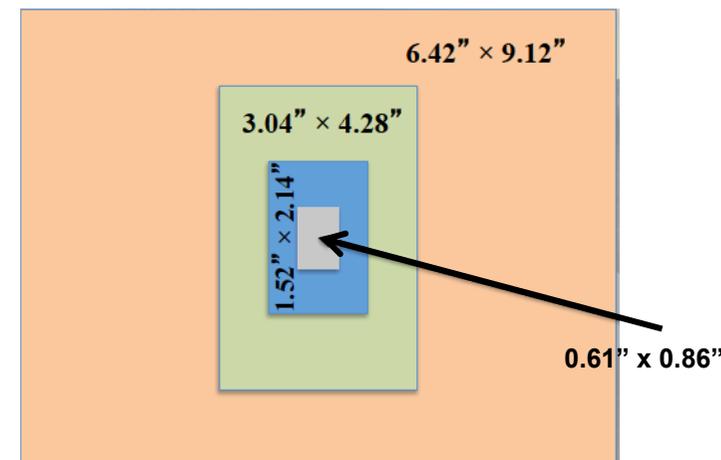


Best combination sensitivity and spatial resolution

4mas



Highest spatial resolution



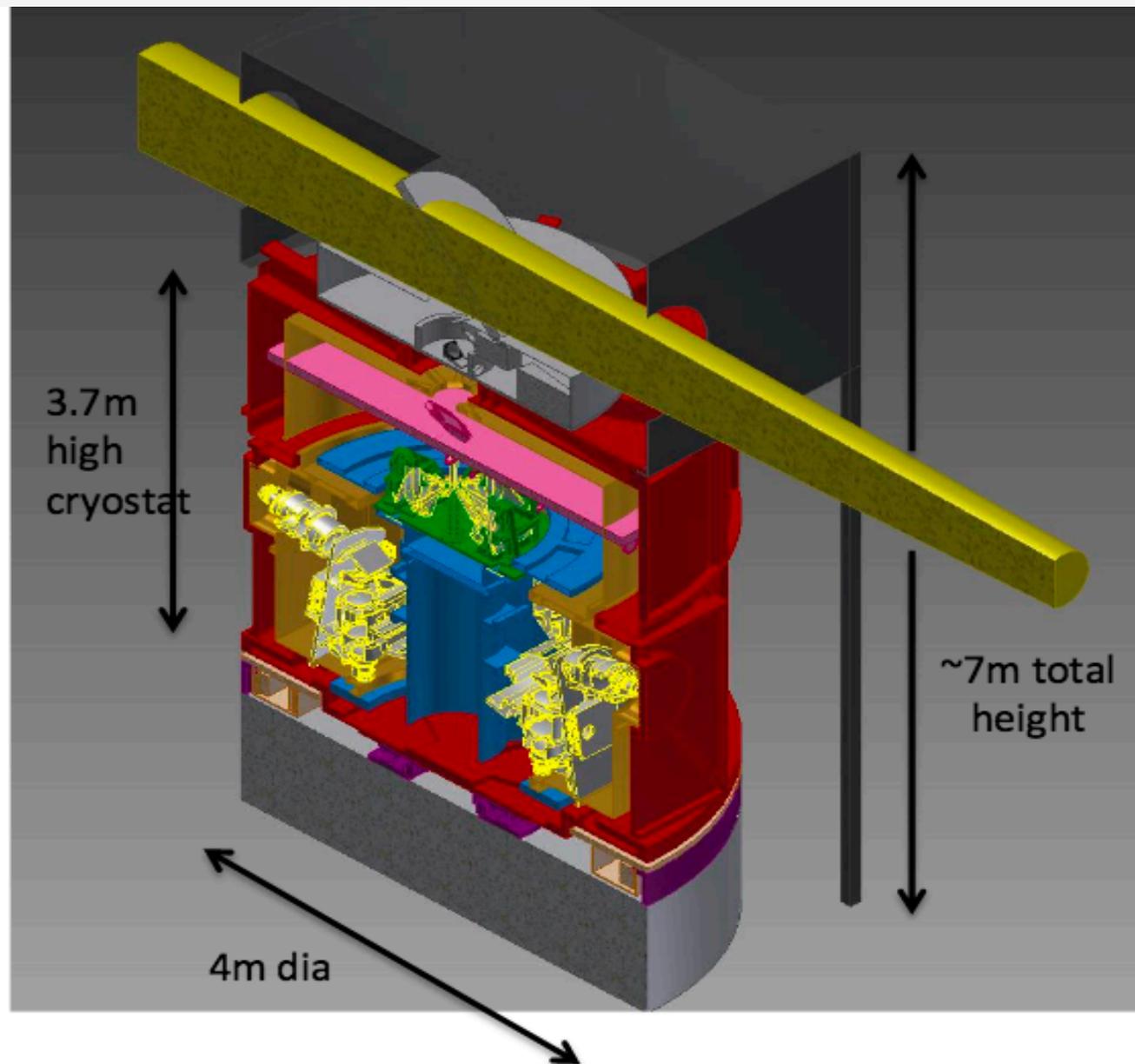
Large wavelength range & resolution combinations:

Bands	Wavelengths (μm)	R
"V+R" or "I+z+J" or "H+K"	0.45-0.8, 0.8-1.35, 1.45-2.45	~3000
"I+z" or "J" or "H" or "K"	0.8-1.0, 1.1-1.35, 1.45-1.85, 1.95-2.45	~7500
"Z" or "J_high" or "H_high" or "K_high"	0.9, 1.2, 1.65, 2.2 (TBD)	~20000





# HARMONI + LTAO





# METIS

## METIS

PI: B. Brandl NOVA, Leiden , The Netherlands

- **Imaging at L, M, N, Q-bands;**
- **Coronagraphy for high contrast imaging** at L, M and N-band (goal: coronagraphy for IFU spectroscopy);
- Low/medium resolution **slit spectroscopy** at L, M, and N-band;
- **High resolution  $R \sim 100,000$  IFU spectroscopy** at L and M band (goal: high resolution IFU spectroscopy at N band);



ETH zürich



Science & Technology Facilities Council  
UK Astronomy Technology Centre

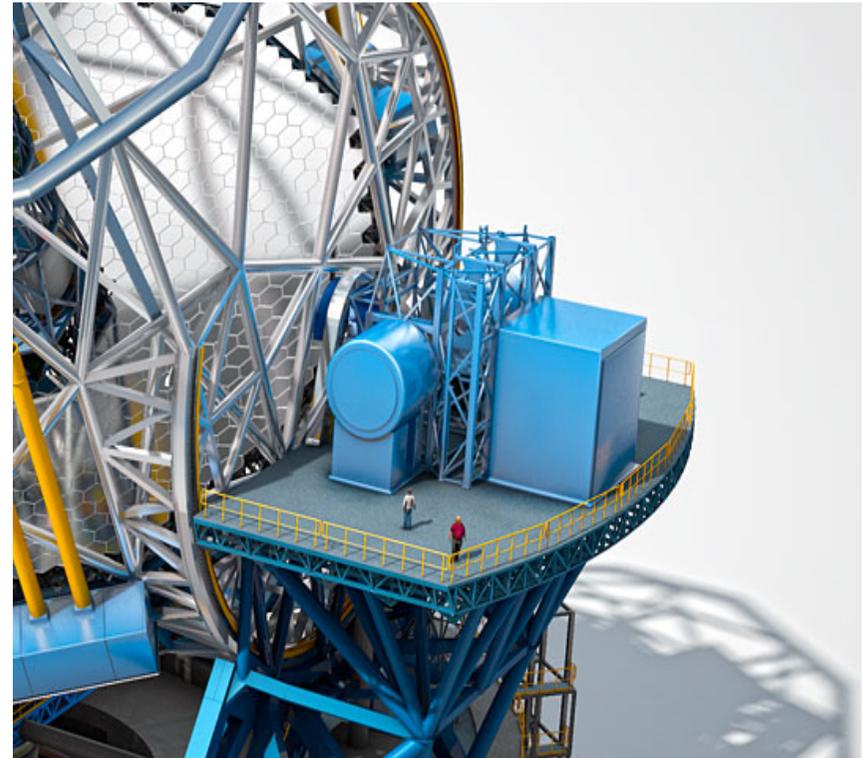
KATHOLIEKE UNIVERSITEIT  
LEUVEN





# Second generation instruments

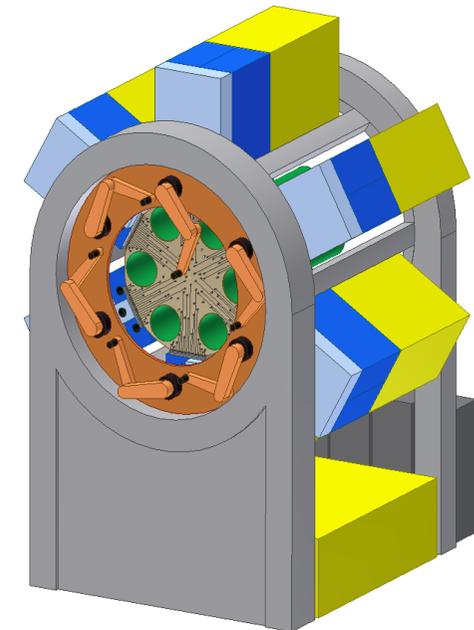
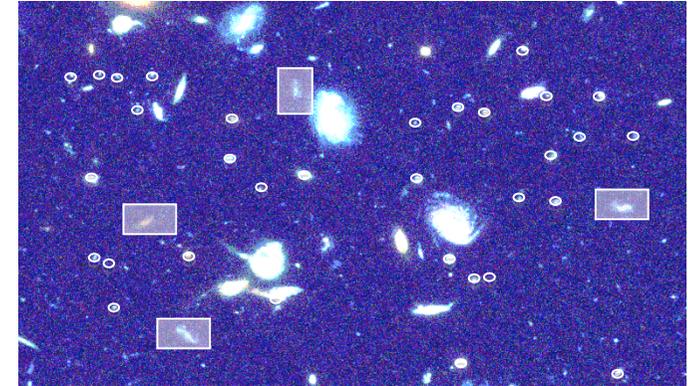
Selected in 2015  
and  
Phase A started in March 2016



## Multi-object spectrograph (MOSAIC)

PI: Francois Hammer (GEPI, France)

- Wavelength range: 0.4 – 2.45  $\mu\text{m}$
- High definition (HDM, 80 mas/pix) with  $\geq 10$  MOAO IFUs
- High multiplex (HMM, 100-250), GLAO/seeing resolution
- $R=5000-20,000$



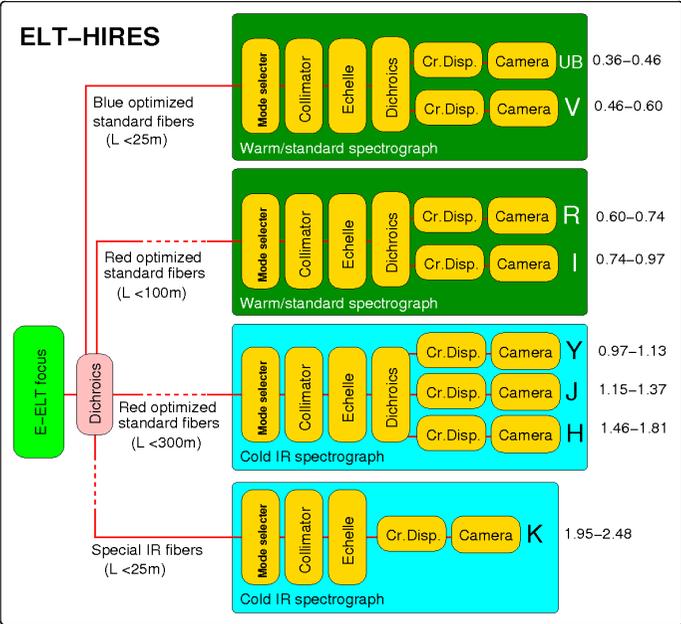
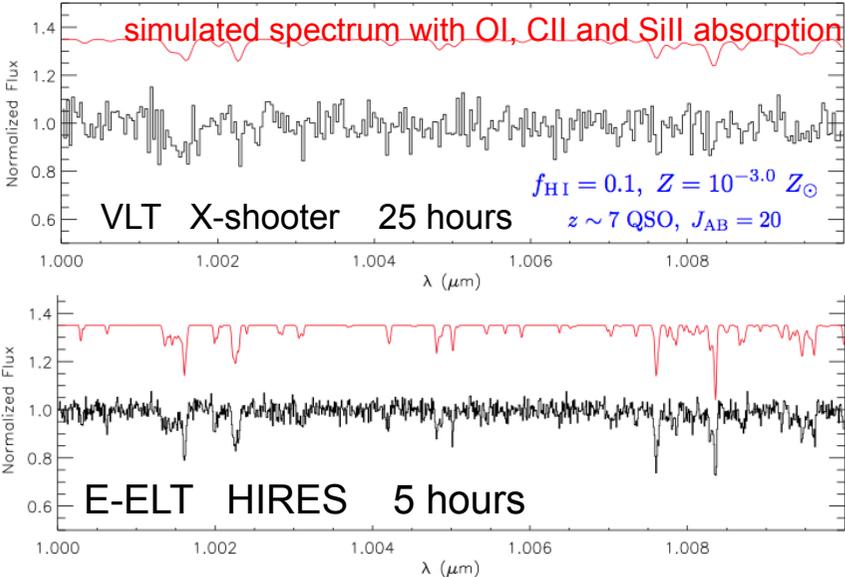


# ELT-HIRES

## High-resolution spectrograph

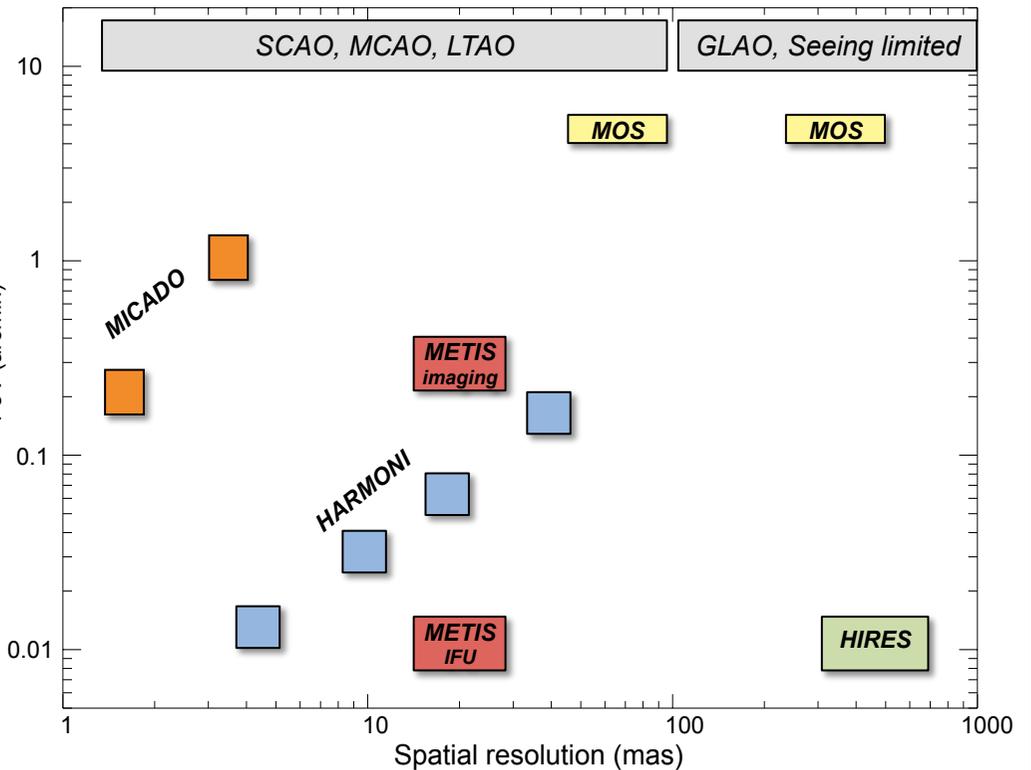
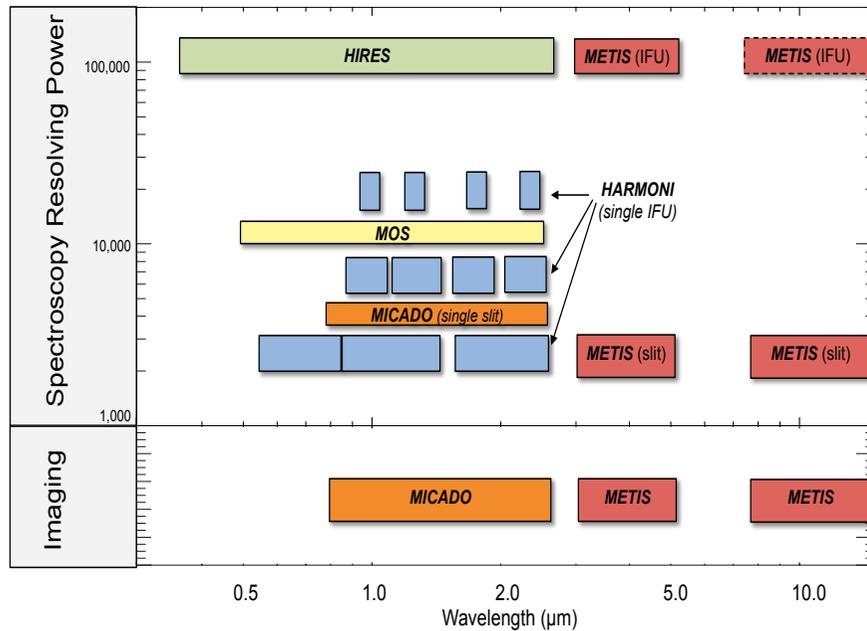
PI: Alessandro Marconi (INAF, Italy)

- Spectral resolution:  $R > 100,000$
- Wavelength range:  $0.37 - 2.4 \mu\text{m}$
- Accuracy:  $< 10 \text{cm/s}$





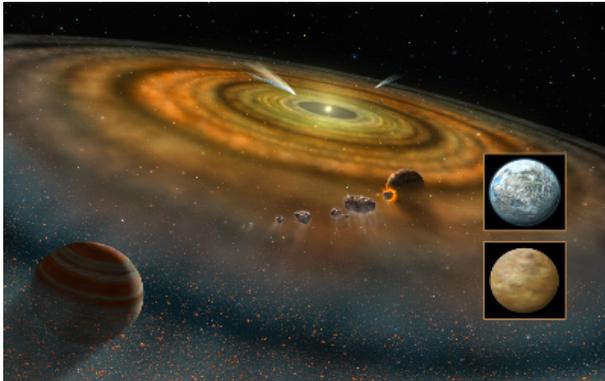
# E-ELT capabilities



- Near-diffraction limit performance
- Multiple plate scales
- 50μas precision astrometry (MICADO)
- High-contrast / Coronagraph
- Non-siderial tracking



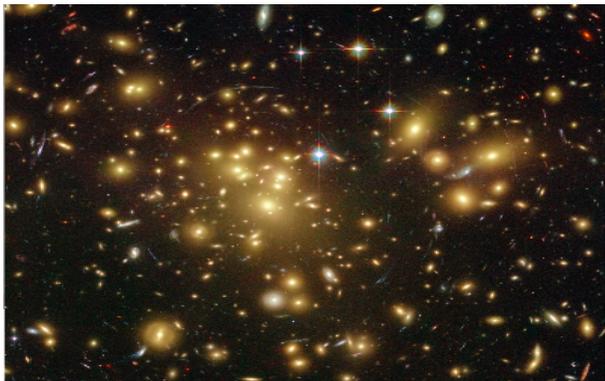
# Pioneering science



Planets & Stars



Stars & Galaxies



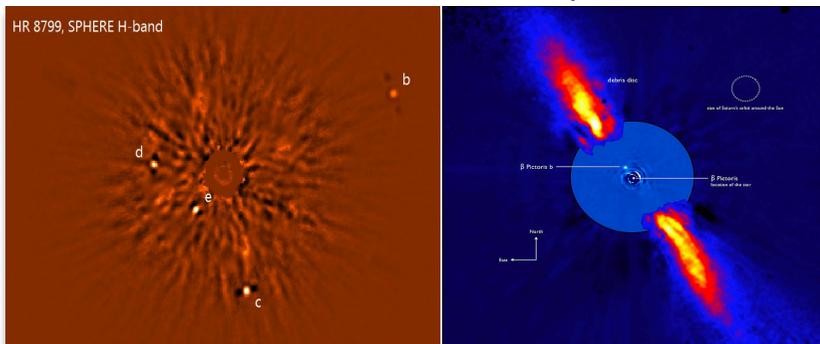
Galaxies & Cosmology



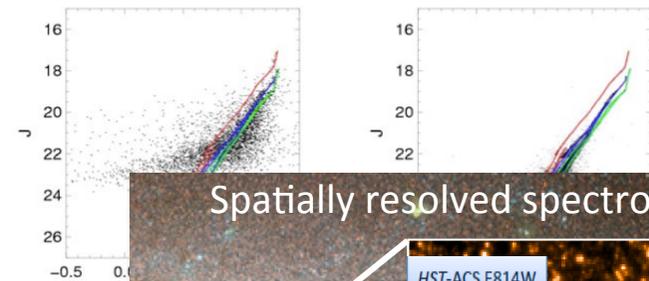
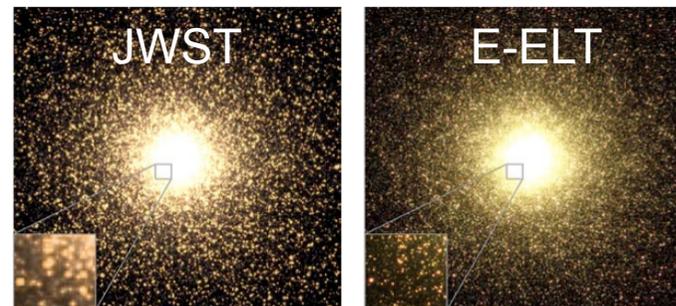


# Planets and stars

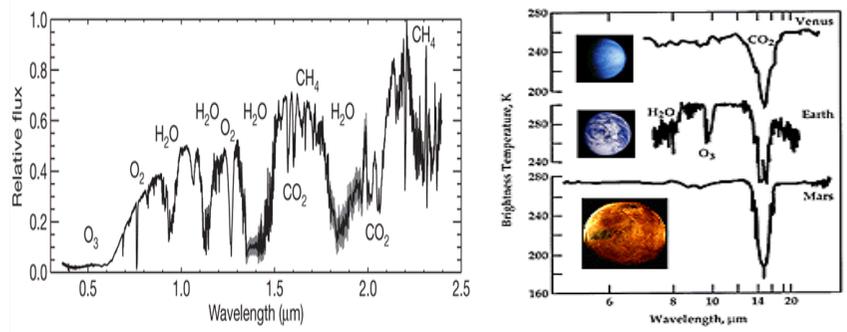
## Direct detection of exo-planets



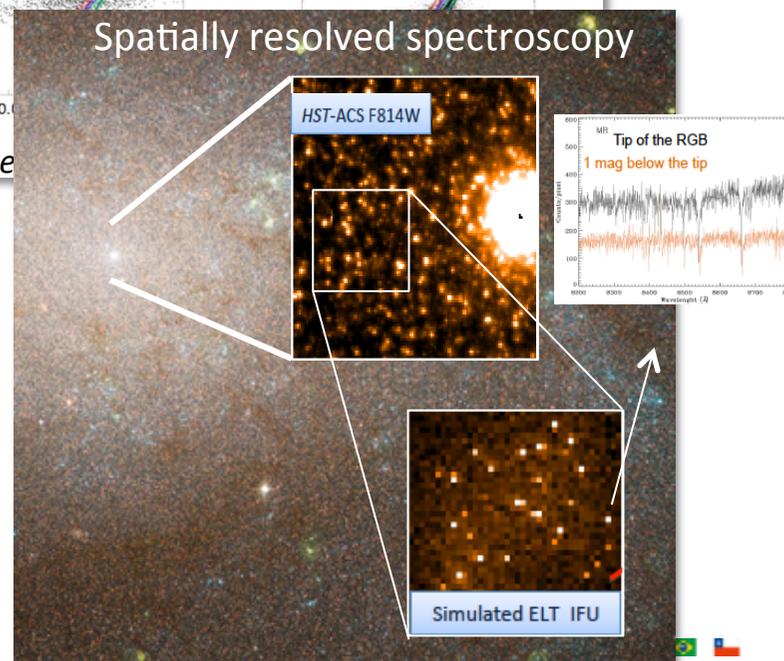
## Colour-magnitude diagrams



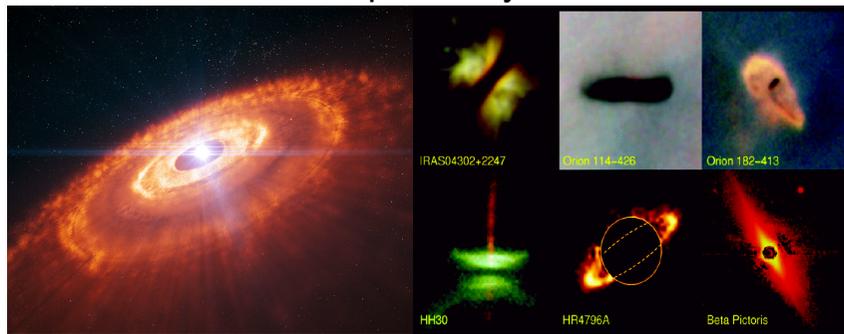
## Exo-planets atmosphere



## Spatially resolved spectroscopy



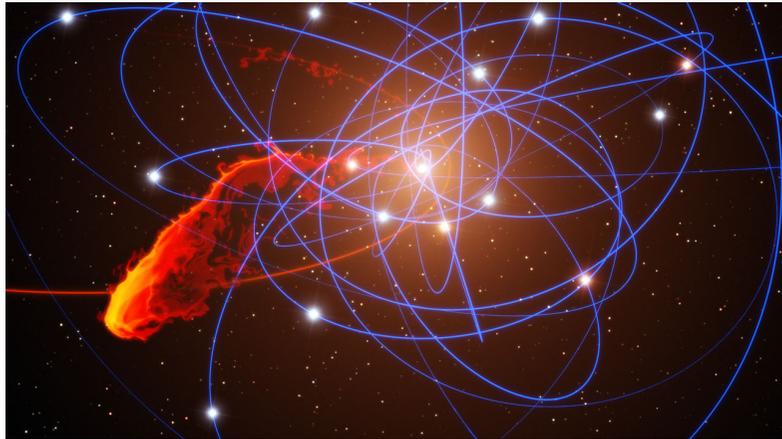
## Proto-planetary disks



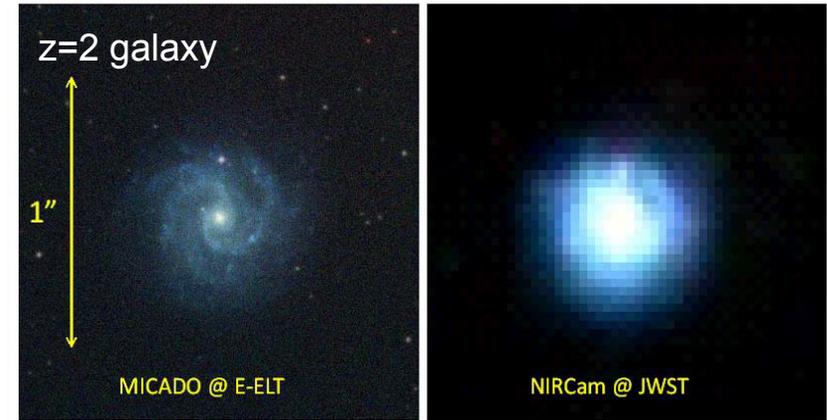


# Stars and Galaxies

Galactic center and test of GR



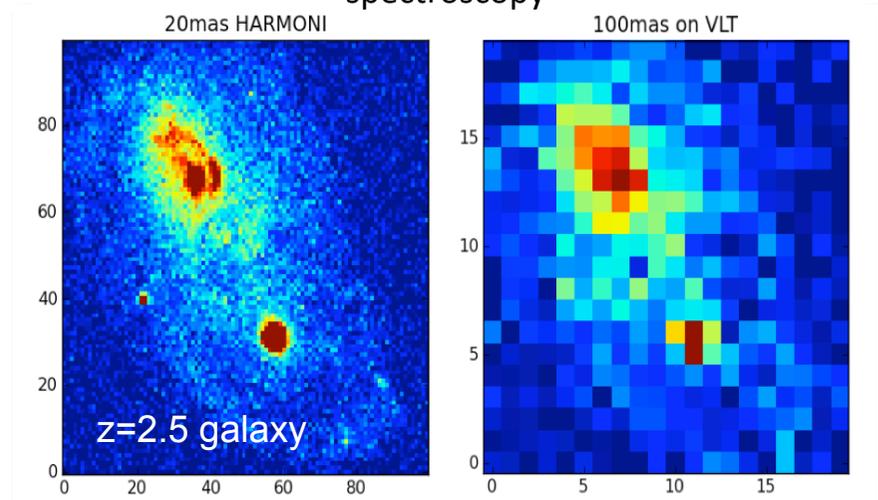
Structure and morphology of galaxies



Galactic archaeology up to Local Group



Dynamics and physics from spatially resolved spectroscopy

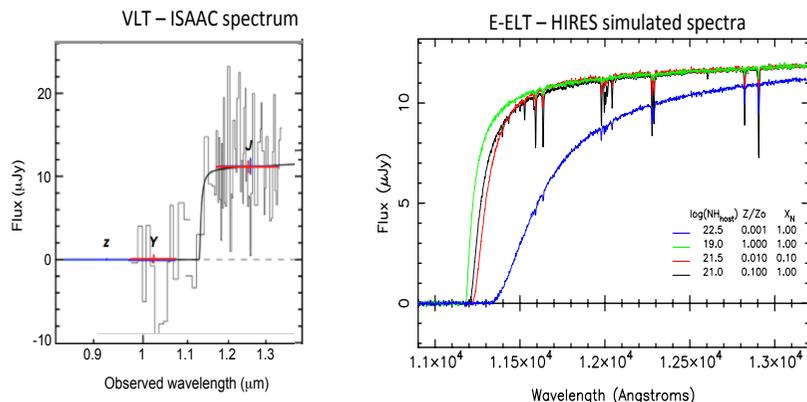




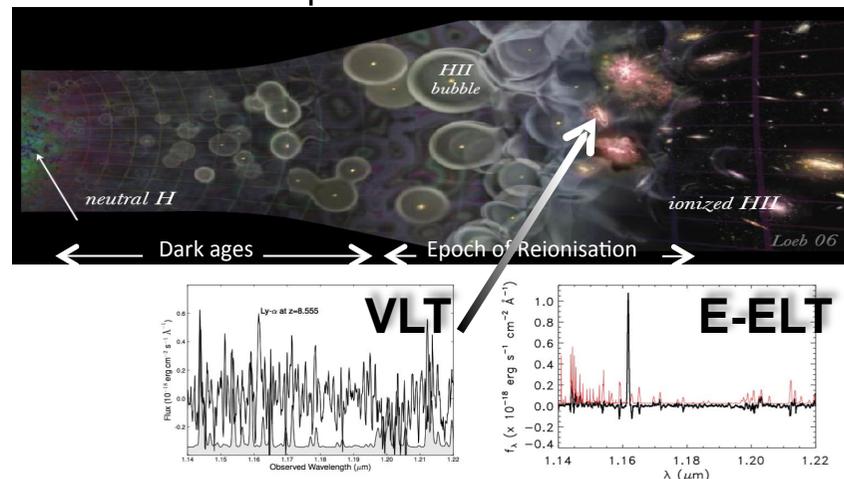
# Galaxies and Cosmology

## Transient Universe

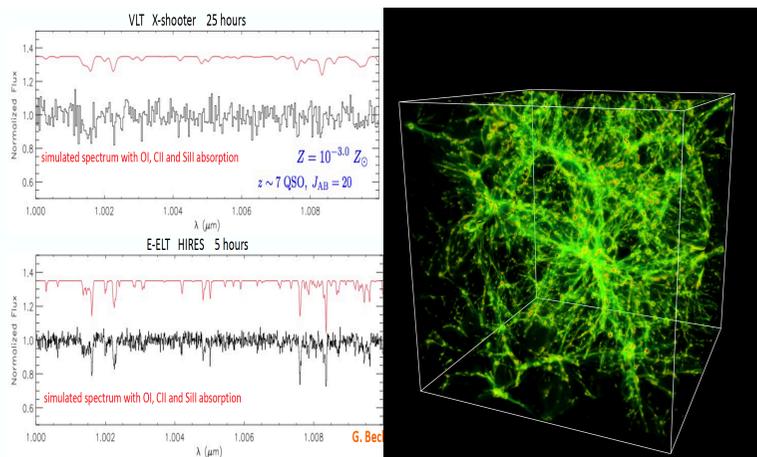
GRB 090423 at  $z=8.2$



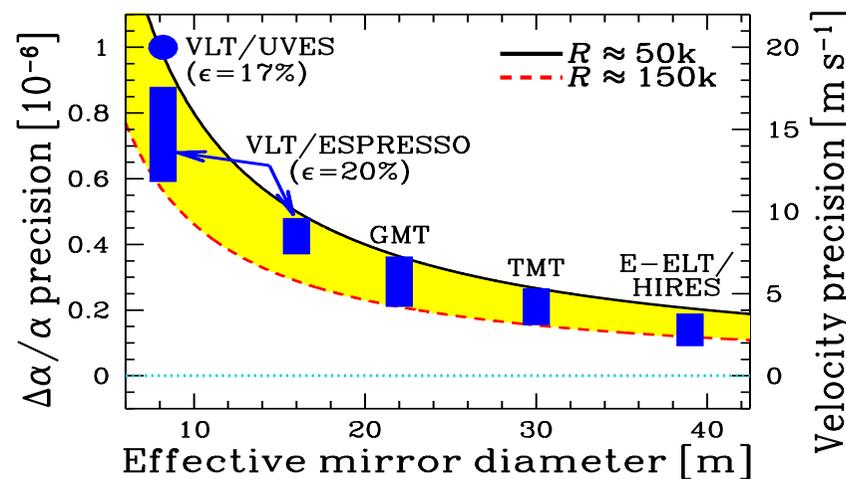
## Epoch of reionisation



## Chemical enrichment of the IGM



## Fundamental Physics





# Summary

- Good momentum across the E-ELT Programme
- Most of the contracts ongoing
- Preliminary Designs of instruments progressing well
- Exciting scientific capabilities
- Planned first light in 2024

