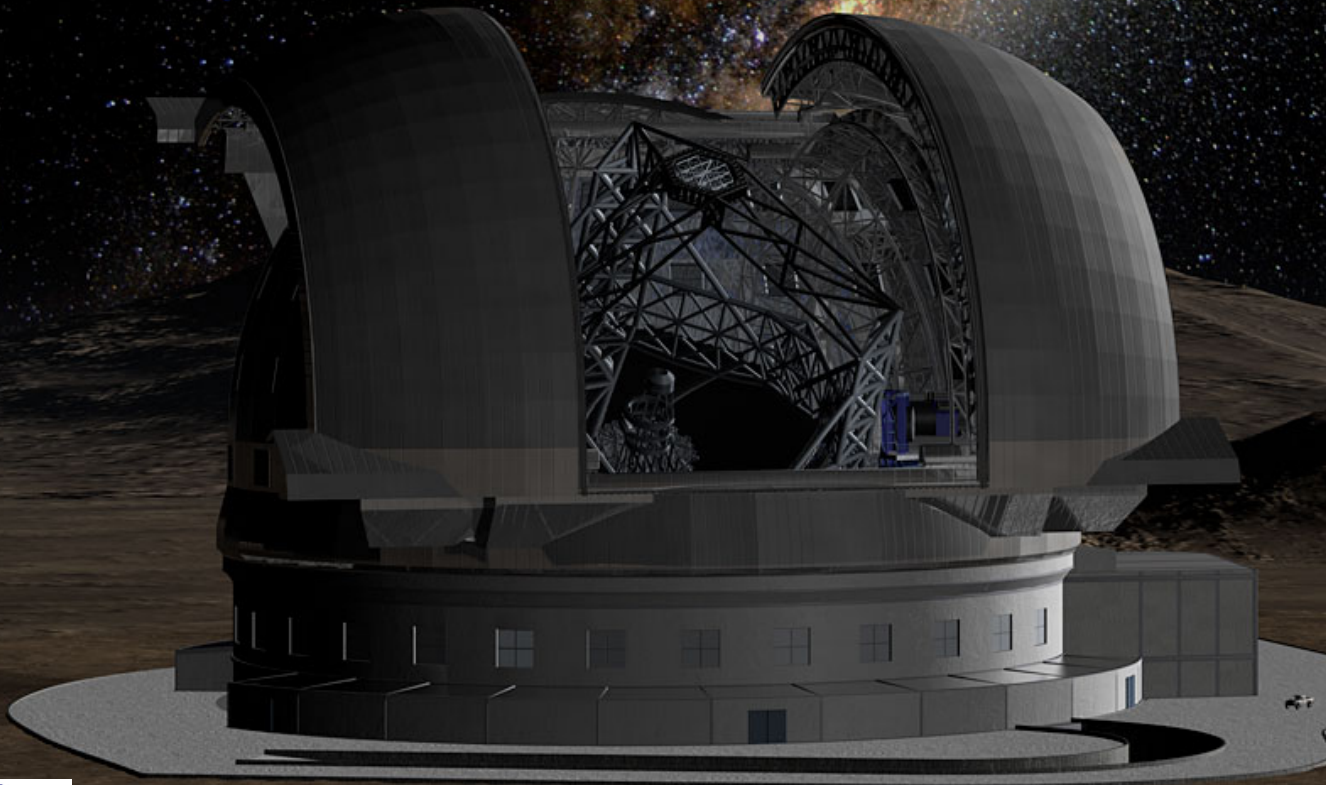


# E-ELT: the European Extremely Large Telescope

SIF, September 22<sup>nd</sup> 2015



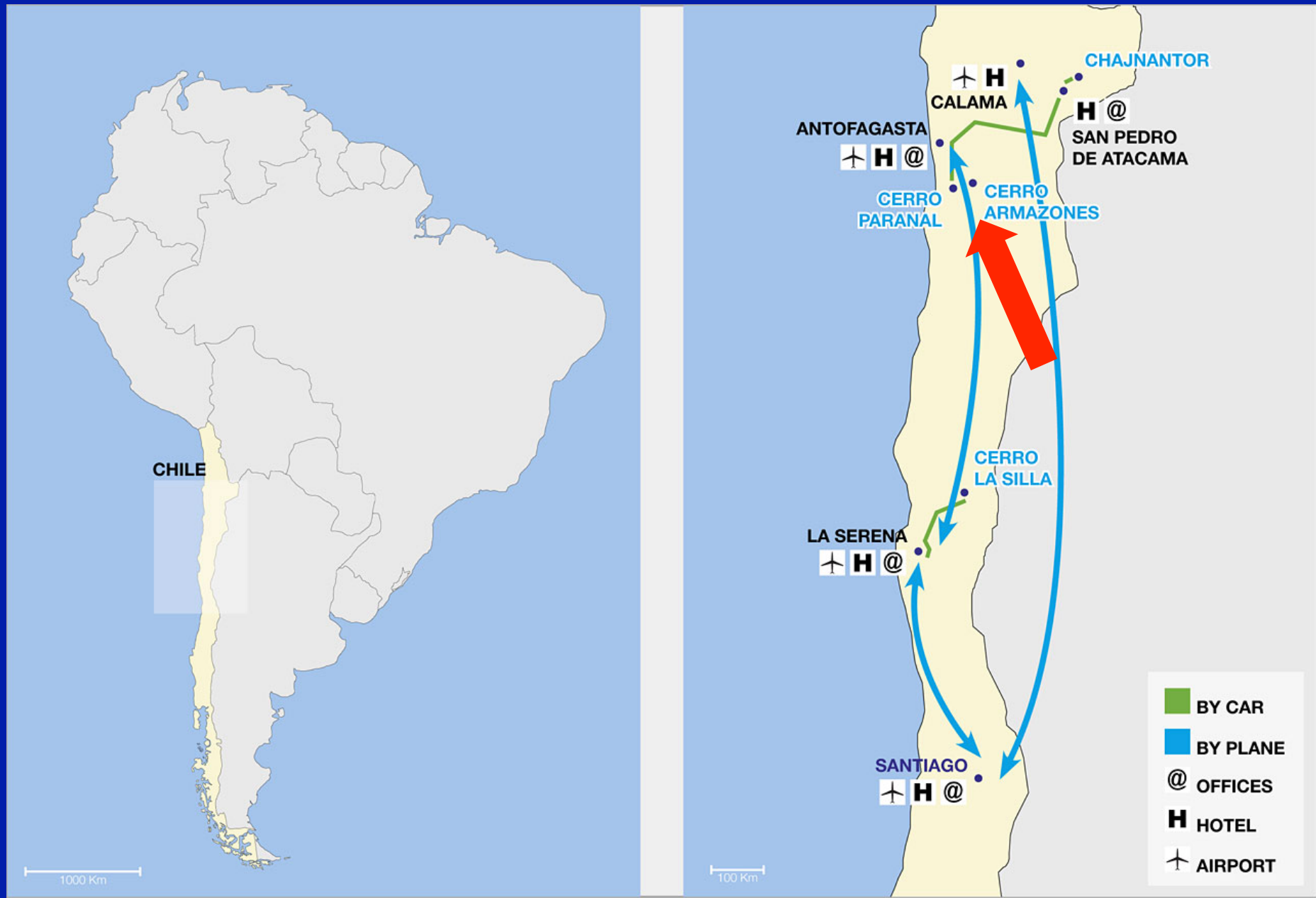
Monica Tosi  
INAF – Osservatorio Astronomico di Bologna



# E-ELT in a nutshell <sup>(1)</sup>

- **One of the 2 astronomy projects in ESFRI's (European Strategy Forum on Research Infrastructures) 2006 roadmap;**
- **To be built and managed by ESO (the European Intergovernmental Organization for Astrophysics; 15 member states);**
- **To be built on Cerro Armazones (Chile), altitude 3060 m, in the Atacama desert, 20 km from Cerro Paranal**
- **Cost: 1100 Meuros including instruments**
- **First light planned for 2024**

# E-ELT in a nutshell (1b)





# Armazones and Paranal



*E-ELT Status, T-Rex Project, 20 July 2015*

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Courtesy R. Tamai, ESO

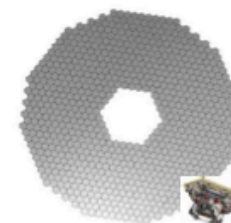
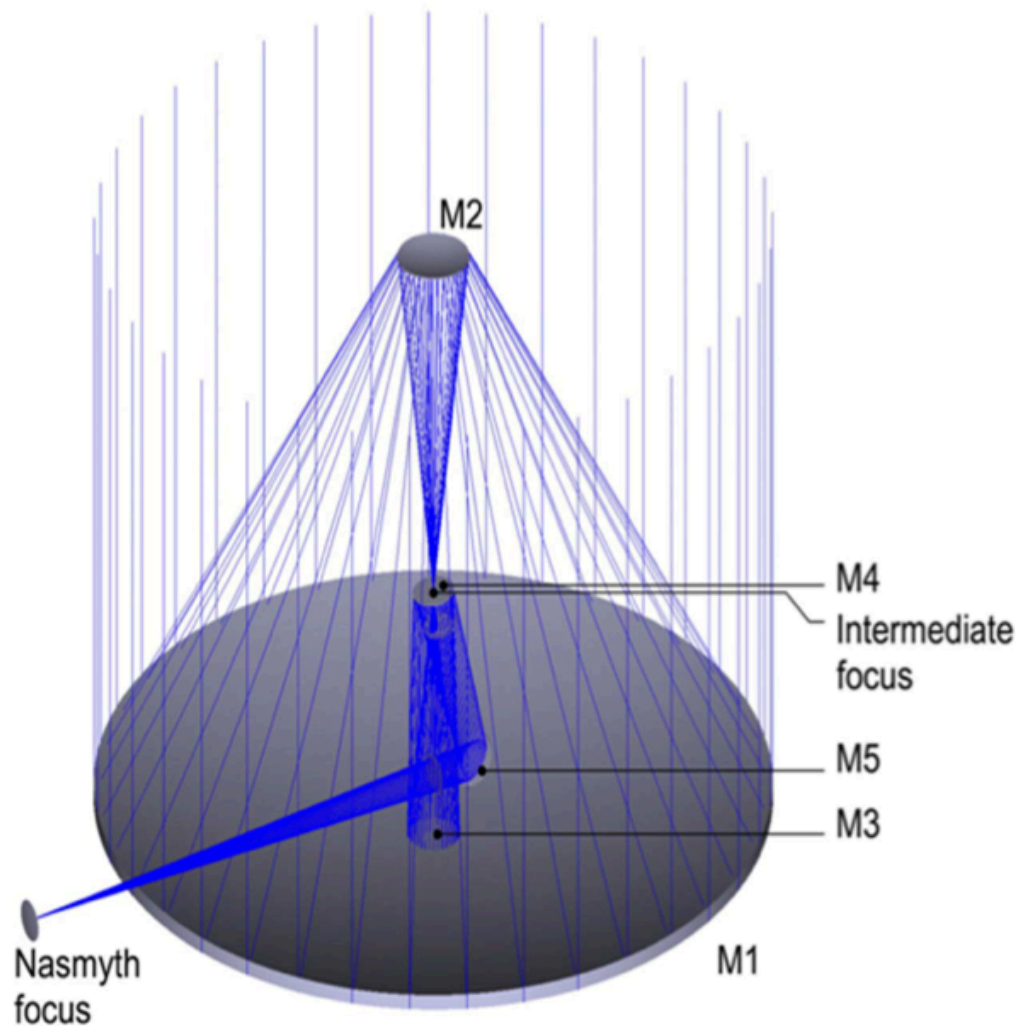
# E-ELT in a nutshell <sup>(2)</sup>

- **Optical/infrared telescope**  
(0.4 – 14  $\mu\text{m}$  depending on instruments)
- **Images 15 times sharper than with HST**
- **5 mirrors + laser guide star units**
- **Primary mirror M1: 39 m diameter, largest in the world (4-5 x current largest telescopes)**
- **M1 segmented (798 hexagonal segments, 1.4 m wide, 5 cm thick)**
- **M4: 2.6m, segmented (6 petals) and adaptive**
- **10x10 arcmin<sup>2</sup> max field of view**





# E-ELT Optomechanics



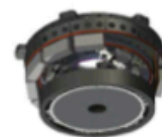
**M1 Unit**  
39-m  
Concave – Aspheric f/0.9  
Segmented (798 Segments)  
Active + Segment shape Control



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



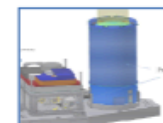
**M3 Unit**  
4-m – Concave – Aspheric f/2.6  
Active + Position Control



**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

E-ELT Status, T-Rex Project, 20 July 2015

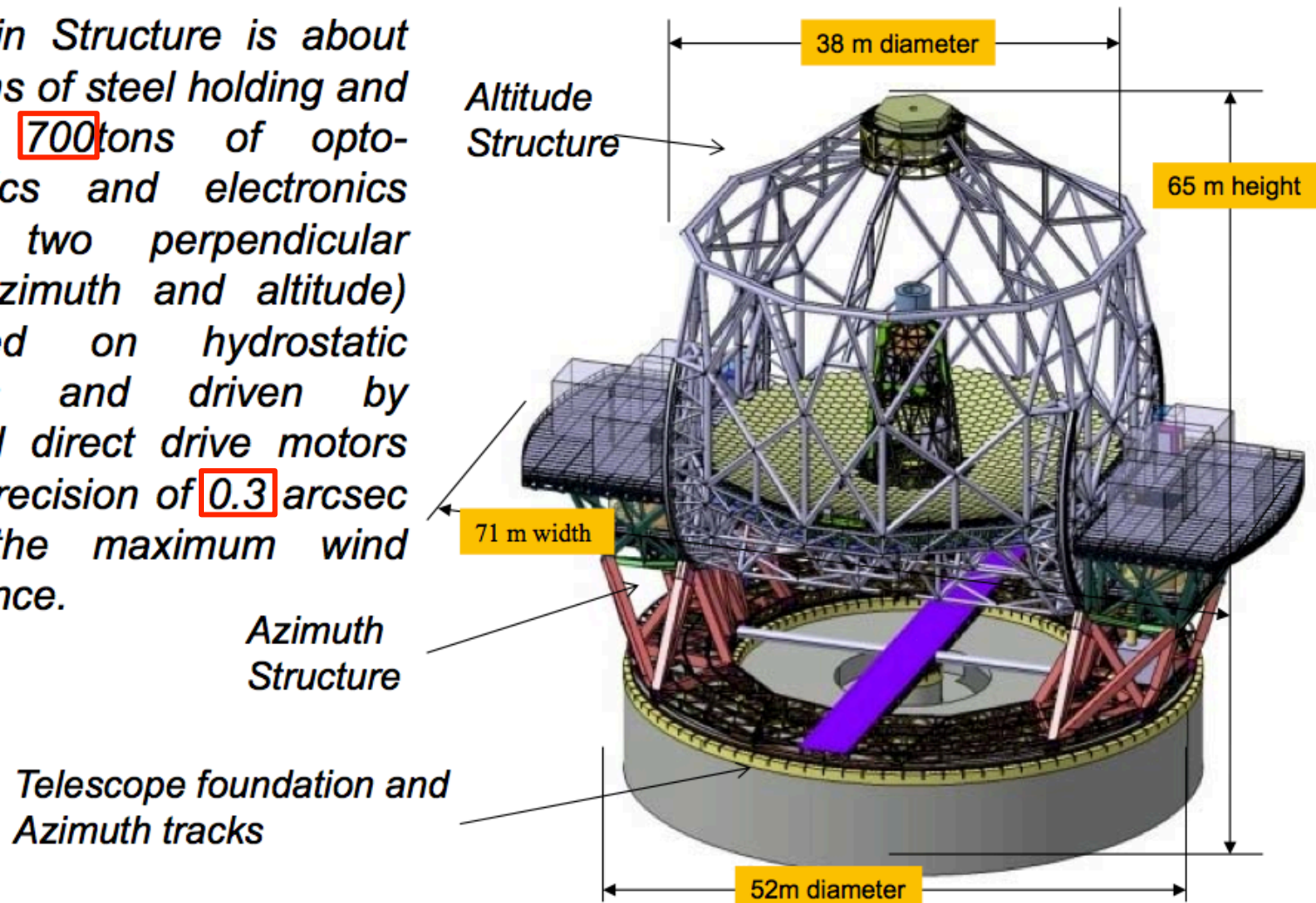


Courtesy R. Tamai, ESO



# The E-ELT: Main Structure

The Main Structure is about **2500** tons of steel holding and moving **700** tons of opto-mechanics and electronics around two perpendicular axes (azimuth and altitude) supported on hydrostatic bearings and driven by electrical direct drive motors with a precision of **0.3** arcsec under the maximum wind disturbance.

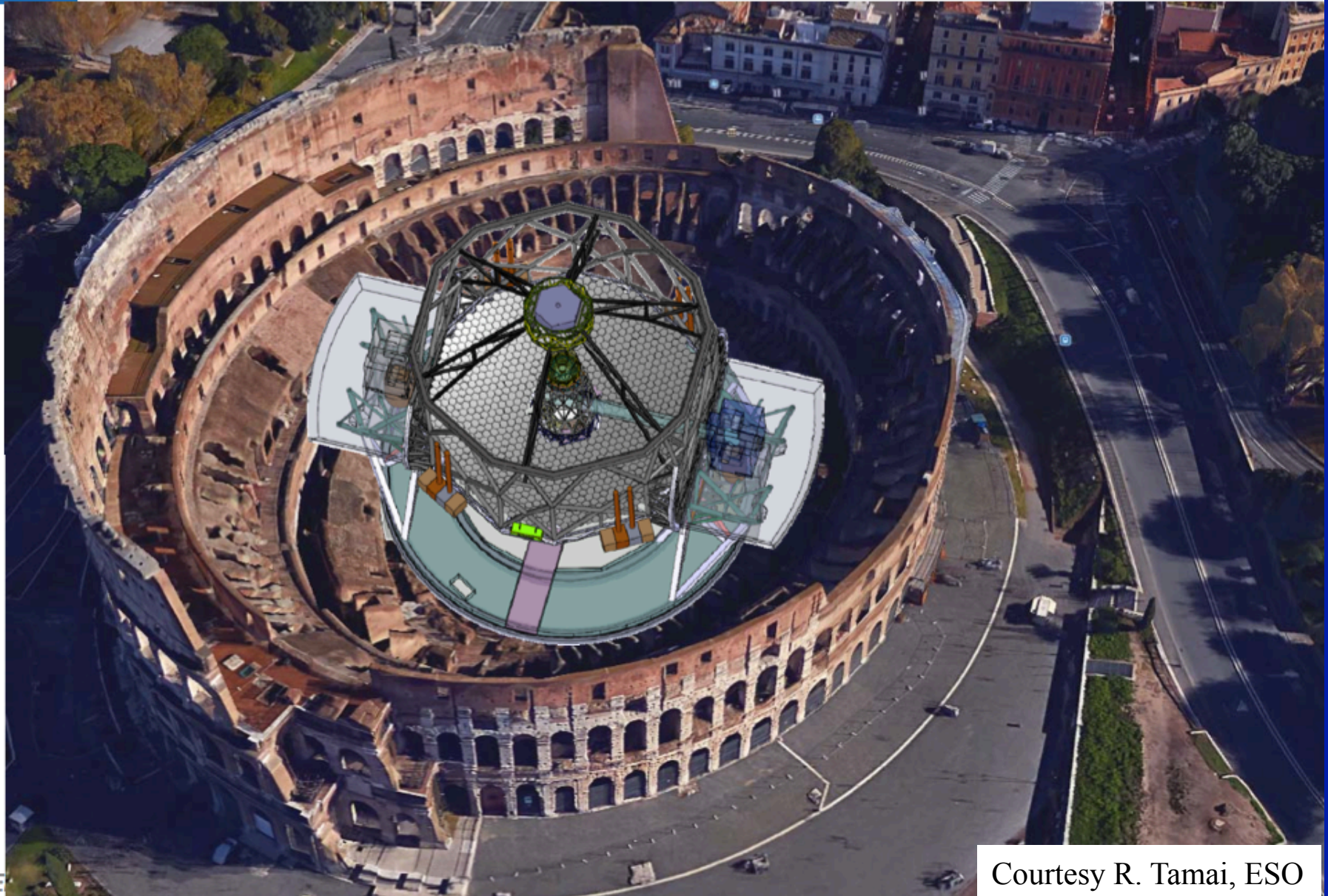




**E-ELT** compared with  
current ESO 8m telescopes (VLTs)  
and with a familiar monument



# To put it in perspective



# E-ELT in a nutshell <sup>(3)</sup>

## Planned instruments

### First light (2024):

- **MICADO** (imager) + MCAO module **MAORY**
- **HARMONI** (IFU spectrograph) (+ **LTAO**)

### Next (Possibly at same time):

- **METIS** (mid-IR imager and spectrometer)

### Later (when budget available and selection made):

- **HIRES** (high resolution spectrograph)
- **MOS** (multi-object spectrograph)

### Later (call in 2016):

- **ELT-6** (could be anything)

### Later (when technology ready):

- **PCS** (planetary camera and spectrograph)



# The Baseline Roadmap

Instrument	Status	
MICADO	For recommendation/approval by Committees	} Constr. budget
MAORY	For recommendation/approval by Committees	
HARMONI/LTAO	For recommendation/approval by Committees	
METIS	For recommendation/approval by Committees	
ELT-MOS	Call for Proposals to be issued July 2015	} Ops budget
ELT-HIRES	Call for Proposals to be issued July 2015	
ELT-6	Call for proposals in 2016	
ELT-PCS	To proceed when technology is ready (2019)	



## HARMONI & LTAO

- IFU spectrograph from 0.5 to 2.4  $\mu\text{m}$
- 3 spatial pixel scales
  - From diffraction limited to coarse "seeing limited" scale
- Low (3000) medium (7000) high (20000) spectral resolution
- Includes
  - Non-sidereal tracking
  - Single Conjugate AO mode
- Statement of Work includes LTAO study to PDR. Led by LAM & ONERA. Draft technical specifications are part of deliverables
  - Will go to construction when Phase II funding is confirmed



## MICADO

Precision Imager with 2 pixel scales and >30 filters

- 1-2 mas & 3-4mas

Includes fixed-format spectroscopy mode

Includes

SCAO module (shared with MAORY)

Non-sidereal tracking



## MAORY

- Multi-Conjugate 6-laser AO system for MICADO + 1 auxiliary port
  - Corrected field of 70" for MICADO and 2.5' at Aux port
- Designed for 2 internal DMs + M4 (3-layer correction)
- Includes
  - non-sidereal tracking
  - SCAO module (shared with MICADO)

**PI E. Diolaiti (INAF)**



# METIS

## L,M,N,Q<sub>short</sub> Imager and spectrometer

### Imaging

Minimum of 10 filters. 10x10" [20x20] field

Coronagraphy

### L,M Spectroscopy

Low, medium, IFU/x-dispersed high resolution

### N Spectroscopy

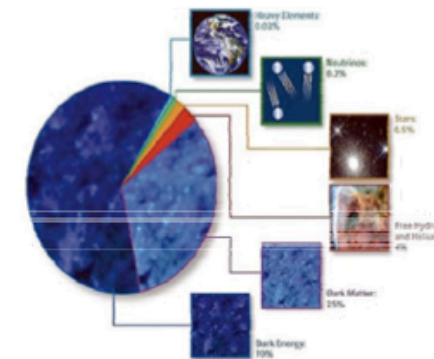
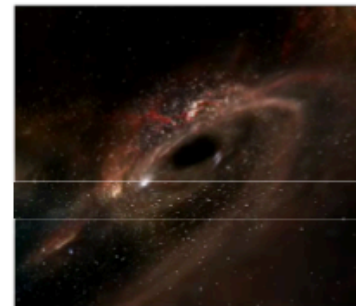
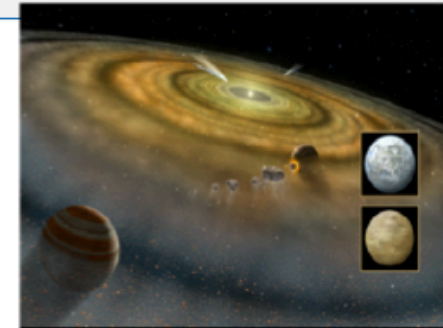
Low and medium resolution

### Includes

SCAO and non-sidereal tracking

# Science drivers

- Planets in other stellar systems
  - Imaging *and* spectroscopy
  - *The quest for Earth-like exo-planets*
- Stellar populations
  - In galaxies inaccessible today (e.g. ellipticals in Virgo cluster)
  - Across the whole history (i.e. extent) of the Universe
- Cosmology
  - The first stars/galaxies, closer to Big Bang
  - Direct measure of deceleration
  - Evolution of cosmic parameters
  - Dark matter, dark energy
  - Tests of GR around black holes
- The unknown
  - Open new parameter space



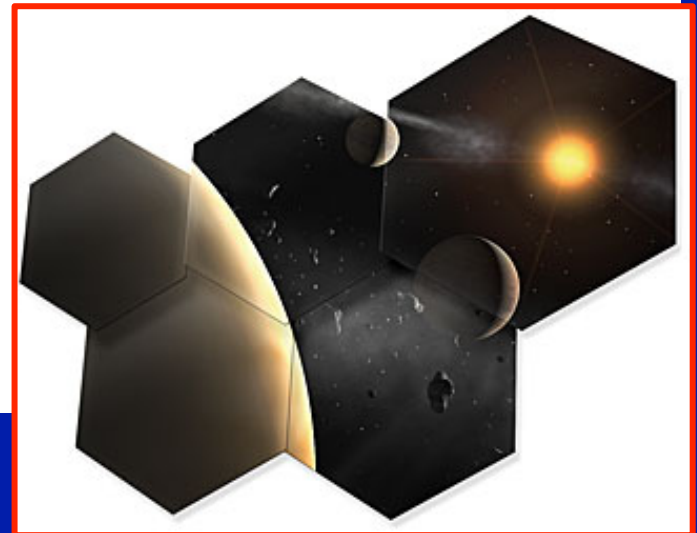


# E-ELT science<sub>(1)</sub>

[http://www.eso.org/sci/facilities/eelt/science/doc/eelt\\_sciencecase.pdf](http://www.eso.org/sci/facilities/eelt/science/doc/eelt_sciencecase.pdf)

## Are we alone ?

- **Direct imaging of exoplanets around stars < 150 pc away, discovery of exoplanets with astrometry (MICADO)**
- **Exoplanets atmosphere, rocky planets, habitable zones, detection of life signatures (HIRES,  $R=10^5$ )**
- **Formation history of solar system (METIS)**
- **Discovery of earth-like exoplanets from RVs (HARMONY, HIRES)**



# E-ELT science<sub>(2)</sub>

[http://www.eso.org/sci/facilities/eelt/science/doc/eelt\\_sciencecase.pdf](http://www.eso.org/sci/facilities/eelt/science/doc/eelt_sciencecase.pdf)

## **Resolved stellar populations (a few examples)**

- **MBH in GC, 10 Gyr old TO stars resolved in nuclear star clusters at 3 Mpc, RGB in central regions of ellipticals in Virgo (MICADO)**
- **IMBHs, chemo-dynamics of stars in GC (HARMONY)**
- **chemo-dynamics of stars LG (HARMONY and MOS)**
- **formation of stars and proto-planetary disks; detailed chemistry of old and young stars out to nearby galaxies (HIRES)**
- **Protoplanetary disks (METIS)**



# E-ELT science<sub>(3)</sub>

[http://www.eso.org/sci/facilities/eelt/science/doc/eelt\\_sciencecase.pdf](http://www.eso.org/sci/facilities/eelt/science/doc/eelt_sciencecase.pdf)

## **Distant galaxies and the first objects in the universe**

- **Physical properties of high- $z$  ( $z \approx 10$ ) galaxies, of GRBs and host galaxies, from 1<sup>st</sup> light to 1<sup>st</sup> galaxies (HARMONY and MOS)**
- **structural properties and color gradients of  $z=3$  galaxies, extragalactic transients (MICADO)**
- **3D IGM reconstruction, chemistry of first objects (HIRES and MOS)**
- **Nuclei of AGN and ULIRGs => growth of SMBH (METIS)**



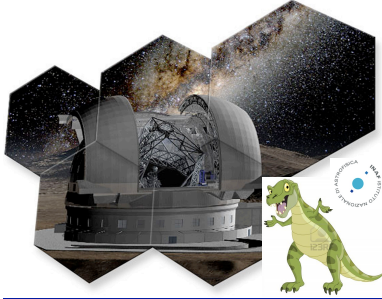
# E-ELT science<sub>(4)</sub>

[http://www.eso.org/sci/facilities/eelt/science/doc/eelt\\_sciencecase.pdf](http://www.eso.org/sci/facilities/eelt/science/doc/eelt_sciencecase.pdf)

## **Cosmology and fundamental physics**

- **primordial D, properties at cosmic re-ionization epoch, fundamental constants (fine-structure  $\alpha$ , proton/electron mass ratio  $\mu$ ) (HIRES)**

**INAF contributes  
to the E-ELT with  $\sim 4$  M€/yr**



INAF contributes  
to the E-ELT with  $\sim 4$  M€/yr

and with the *Progetto premiale*  
T-REX-1 and T-REX-2 (PI: M. Tosi)

Allocated budget:

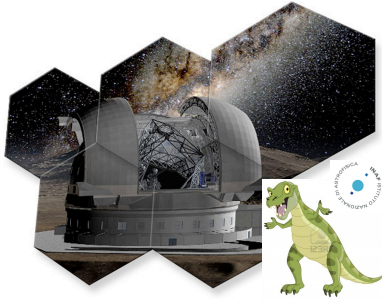
3.9 M€ (1<sup>st</sup> year) + 2.7 M€ (2<sup>nd</sup> year)

Kickoff meeting T-REX-1: 28/9/2012

Kickoff meeting T-REX-2: 28/5/2014

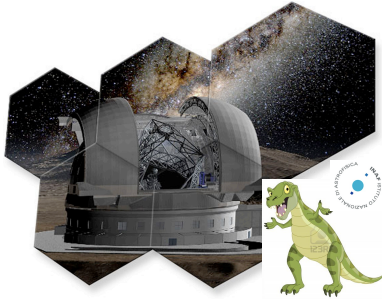
**T-REX participants:**

more than 100 researchers, distributed over most of the  
INAF institutes and 6 universities.



# T-REX: Main Objectives

- **Strengthen the position and role of INAF and Italian Universities in the international consortia**, currently under development, for the realization of the E-ELT instruments.
- **Support the executive design phase of the E-ELT instrumentation**, strengthening facilities and laboratories.
- **Promote the formation of young researchers to be employed in the design and construction of instrumentation for the E-ELT** via training by highly qualified personnel.
- **Develop new technologies to ensure the feasibility of the E-ELT instruments.**  
Ensure the maintenance/enhancement of scientific and industrial know-how.
- **Promote integration processes between research institutes, universities and industry.**
- **Promote the transfer of technology from the field of astronomical instrumentation to other fields such as renewable energy, medical technologies, information technology and communication and to technologies aimed at nano-electronics using lithographic techniques.**

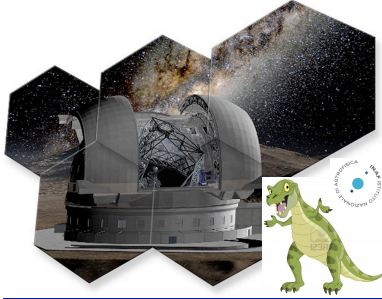


# T-REX: Main Objectives

- Strengthen the position and role of E-ELT in the international consortia, currently under development of the E-ELT instruments.
- Support the execution of the scientific program, ensuring the continuity of the E-ELT instruments.
- Promote the development of scientific and industrial know-how and qualified personnel in the field of astronomical instrumentation, design and construction of large-scale instruments.
- Develop the scientific and industrial know-how of the E-ELT instruments. Ensure the continuity of the scientific and industrial know-how.
- Promote the transfer of technology from the field of astronomical instrumentation to other fields such as renewable energy, medical technologies, information technology and communication and to technologies aimed at nano-electronics using lithographic techniques.
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**Maximize Italian contribution to E-ELT technology and corresponding return**

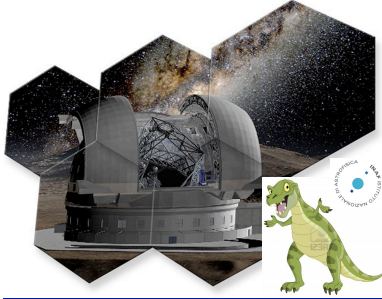




# T-REX

## Operating Units (and coordinators)

- OU-1 ELT-INAF COORDINATION (M. Tosi)
- OU-2 ELT-MIRRORS (G. Pareschi)
- OU-3 ELT-CAM (E. Diolaiti)
- OU-4 ELT-HIRES (E. Oliva)
- OU-5 ELT-MOS (B. Garilli)
- OU-6 ELT-PCS (R. Gratton)



# Italian Achievements

I'm proud to acknowledge that:

- The ESO – ADS-Microgate contract for M4 is in place
- The ESO – INAF contract for Maory has been approved
- The HIRES consortium has a solid configuration and A. Marconi (UNIFI) as PI

Cerro Armazones before



Blasting the top



Cerro Armazones now





# On-site work



*E-ELT Status, T-Rex Project, 20 July 2015*

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Courtesy R. Tamai, ESO



Thank you

