The European Extremely Large Telescope
Outline

1/ Status & description
2/ Instrumentation Roadmap
3/ French Contribution
The E-ELT project

- A 40m class Telescope for the European Community
- Top priority of European ground-based astronomy (on Astronet and ESFRI lists).
- Cerro Armazones in Chile selected as the E-ELT site in April 2010.
- Detailed Design Phase completed in 2011.
- Start of operations early next decade.
- Construction cost: 1083 M€ (including first-light instrumentation).
1/ Status & description

The E-ELT project

- **Construction cost:** 1083 M€
- **Kick-off:**
  - IF 10+ members signed (DK, PT & ESP missing)
  - today 11 members :-)
  - IF 90% of the budget available
  - > 62% budget :-(
- **Politics & Brazil:**
  - New member, Brazil that **weights 300 M€**
  - Project currently discussed at Parliament in May-June 2013
- **Next ESO council**
  - June 2013; Project status re-discussed?
Following an extensive site testing campaign, involving several sites in Chile, Morocco, the Canary Islands, Argentina, Mexico, etc, ESO Council selected Cerro Armazones as the E-ELT site.

Selection criteria: impact on science, outstanding atmosphere, but also construction and operations logistics (roads, water, electricity, nearby cities, ...).
The Telescope

- 40-m class telescope: largest optical-infrared telescope in the world. (GMT = 25m; TMT = 30m)
- Segmented primary mirror.
- Active optics to maintain collimation and mirror figure.
- Adaptive optics assisted telescope.
- Diffraction limited performance. (12mas@K-band)
- Wide field of view: 10 arcmin.
- Mid-latitude site (Armazones in Chile).
- Fast instrument changes.
- VLT level of efficiency in operations.
1/ Status & description

The Telescope

• Nasmyth telescope with a segmented primary mirror.
• Novel 5 mirror design to include adaptive optics in the telescope.
• Classical 3 mirrors anastigmat + 2 flat fold mirrors (M4, M5).

M1 (seg): 39.3 m
M2: 4.2 m
M3: 3.8 m
M4 (AO): 2.4 m
M5 (TT): 2.6x2.1 m

• Two instrument platforms nearly the size of tennis courts can host 3 instruments each + Coudé lab.
• Multiple laser guide stars, launched from the side.
• Nearly 3000 tonnes of moving structure.
1/ Status & description

The Mirrors

M1: 39.3 m, 798 hexagonal segments of 1.45 m tip-to-tip: 978 m² collecting area

M4: 2.4 m, flat, adaptive 6000 to 8000 actuators

M5: 2.6 x 2.1 m, flat, provides tip-tilt correction
1/ Status & description

The Dome

- Classical design.
- Diameter = 86 m, height = 74 m.
- ~3000 tonnes of steel.
- Fully air-conditioned and wind shielded.
The Telescope
Science

• Contemporary science:
  Exoplanets: radial velocity detections, direct imaging, transit spectroscopy, proto-planetary disks
  Fundamental physics: GR in the strong field limit, variation of fundamental constants, expansion history of the Universe
  Resolved stellar populations: beyond the Local Group
  The physics of high-redshift galaxies
  ...and much more!

• Synergies with other top facilities:
  VLT, ALMA, JWST, LSST, SKA, GAIA
  PLATO, and other survey telescopes

• Discovery potential:
  Opening new parameter space in terms of spatial resolution and sensitivity
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## Selection process (2010)

### Table 1: Overview of Post Focal AO Modules and Instruments Studies

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<td>F. Hammer (GEPI); L. Kaper (Amsterdam); G. Dalton (RAL)</td>
<td>GEPI, NOVA, RAL, INAF OATs and Brera, NBI Copenhagen</td>
<td>Open Call for a new concept</td>
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<td>SIMPLE</td>
<td>L. Origlia (INAF OABo)</td>
<td>INAF OA Bologna, Arcetri &amp; Roma,Univ. Bologna, UAO, TLS, PUC (Chile)</td>
<td>Open Call for a new concept</td>
<td>U. Kaeufl</td>
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Selection process: scientific priority

- Science based prioritisation
  - All instruments candidates for selection at first light with the exception of the planet camera and spectrograph, EPICS (highest scientific priority but long technology development)

- Science Working Group Criteria for selection of first light instruments
  - Scientific impact, including certainty of scientific return
  - Complementarity with other facilities
  - Scientific Flexibility
  - Coverage of expected observing conditions
The telescope can host 7 instruments.

2007 – 2010: 9 instruments and two adaptive optics module concept studies were conducted by the community.

Instrument Roadmap (2011):

- Following recommendations by the E-ELT SWG and ESO's Scientific Technical Committee: 2 first-light instruments identified: a diffraction-limited near-infrared imager (CAM) and a single-field near-infrared wide-band integral field spectrograph (IFU). ELT-1 & 2.
- The next group (ELT-3, 4 and 5) has been broadly identified as covering the mid-infrared (MIR), as well as multi-object (MOS) and high-resolution spectroscopy (HIRES). Equal priority
- Planet camera spectrograph (PCS), separate track, high-scientific priority.
- Flexibility is maintained by including an as yet unspecified instrument.
- All concept studies remain in the pool of possible instruments.
## The instruments

<table>
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<tr>
<th>Instruments - First Light</th>
<th>AO</th>
<th>Mode</th>
<th>λ (µm)</th>
<th>Resolution</th>
<th>FoV &amp; Sampling</th>
<th>Add. mode</th>
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<tr>
<td>ELT-1: CAM (MICADO) - 2023</td>
<td>SCAO, MCAO</td>
<td>IMG</td>
<td>0.8 – 2.4</td>
<td>3000</td>
<td>53.0” / 3 mas</td>
<td>Coronography</td>
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<td></td>
<td>MRS</td>
<td>0.8 – 2.4</td>
<td></td>
<td></td>
<td>Astrometry (40µas)</td>
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<tr>
<td>ELT-2 IFU (HARMONI) - 2023</td>
<td>SCAO, LTAO</td>
<td>IFU</td>
<td>0.5 – 2.4</td>
<td>4000</td>
<td>1.0”-10.0”</td>
<td>Coronography</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10 000</td>
<td>/ 4 – 40 mas</td>
<td></td>
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<tr>
<td>ELT-3: MIR (METIS) - 2023/2027</td>
<td>SCAO, LTAO</td>
<td>IMG</td>
<td>3 – 13</td>
<td>5000</td>
<td>18”/ 12 mas</td>
<td>Coronography</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MRS</td>
<td>3 – 13</td>
<td>100 000</td>
<td></td>
<td>Polarimetry</td>
</tr>
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<td></td>
<td></td>
<td>IFU</td>
<td>3 – 5</td>
<td></td>
<td>0.4*1.5 / 4 mas</td>
<td></td>
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<tr>
<td>ELT-4/5: HIRES (CODEX/SIMPLE) - 2023/2027</td>
<td>SCAO, LTAO</td>
<td>HRS</td>
<td>0.37 – 0.71</td>
<td>130 000</td>
<td>0.82”</td>
<td>Polarimetry?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.84 – 2.50</td>
<td>130 000</td>
<td>0.027”*0.5”</td>
<td></td>
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<tr>
<td>ELT-4/5: MOS (EAGLE/EVE/ DIORAMA) - 2023/2027</td>
<td>MOAO</td>
<td>Slits</td>
<td>0.37 – 1.4</td>
<td>3000 – 2500</td>
<td>6.8” / 0.1”</td>
<td>Multiplex ~ 400</td>
</tr>
<tr>
<td></td>
<td>IFUs</td>
<td></td>
<td>0.37 – 1.4</td>
<td>5000 – 30 000</td>
<td>420’/ 0.3”</td>
<td>Multiplex ~ 100</td>
</tr>
<tr>
<td></td>
<td>IFUs</td>
<td></td>
<td>0.8 – 2.45</td>
<td>4000 – 10 000</td>
<td>2” / 0.04”</td>
<td>Multiplex ~ 10</td>
</tr>
<tr>
<td>ELT-X: PCS (EPICS) - 2027/2030</td>
<td>XAO</td>
<td>EPOL</td>
<td>0.6 – 0.9</td>
<td>125 – 20 000</td>
<td>2.0” / 2.3 mas</td>
<td>Coronography</td>
</tr>
<tr>
<td></td>
<td>IFS</td>
<td></td>
<td>0.95 – 1.65</td>
<td>0.8”/ 1.5 mas</td>
<td></td>
<td>Polarimetry</td>
</tr>
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</table>
Multi flavors for AO

SCAO:
- low techn. Risks
- reduced sky coverage
- anisoplanetism
- Strehl ~ 70%
- CAM, IFU, MIR

LTAO:
- 6 LGS & 2 NGS
- < 30" FoV
- excellent sky coverage
- Strehl ~ 50%
- IFU, MIR

MCAO:
- 6 LGS & 3 NGS
- 1' FoV AO corrected
- several DMs
- Strehl ~ 50%
- CAM

MOAO:
- X NGS
- Small IFU FoV
- several DMs/IFU
- Strehl ??
- MOS
# Instrument Roadmap

## Roadmap

<table>
<thead>
<tr>
<th>Year</th>
<th>ELT-IFU</th>
<th>ELT-CAM</th>
<th>ELT-MIR</th>
<th>ELT-4 (MOS or HIRES)</th>
<th>ELT-5 (MOS or HIRES)</th>
<th>ELT-6</th>
<th>ELT-PCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>Decide science requirements, AO architecture</td>
<td>VISIR start on-sky</td>
<td>Develop science requirements for MOS/HIRES</td>
<td></td>
<td></td>
<td>Call for proposals for ETD</td>
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<tr>
<td>2013</td>
<td></td>
<td>TRL Review</td>
<td>Call for proposals for MOS/HIRES</td>
<td></td>
<td></td>
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<tr>
<td>2014</td>
<td></td>
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<tr>
<td>2015</td>
<td></td>
<td></td>
<td>Selection ELT-MOS/HIRES</td>
<td></td>
<td></td>
<td>Call for proposals</td>
<td></td>
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<tr>
<td>2016</td>
<td></td>
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<td>2017</td>
<td></td>
<td></td>
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<td>TRL check</td>
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<tr>
<td>2018</td>
<td></td>
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<td>TRL check</td>
<td></td>
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<tr>
<td>2019</td>
<td></td>
<td></td>
<td></td>
<td>Selection</td>
<td>TRL check</td>
<td></td>
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<tr>
<td>2020</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TRL check</td>
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<tr>
<td>2021</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TRL check</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2022 Tel. technical first light</td>
<td>Pre-studies taking the form of phase A or delta-phase A work and/or ESO-funded Enabling Technology Development (ETD)</td>
<td></td>
<td></td>
<td>Decision point</td>
<td>Development of Technical Specifications, Statement of Work Agreement, Instrument Start</td>
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First Light in 2027!
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3/ French Contribution
3/ French contribution

Telescope

- Pilotage : ESO
- Contributions FR = LAM
  - Co-phasage segments M1 (senseur ZEUS)
  - Refocalisation LGS dans plan WFS (miroirs VCM)
  - Prototype segment asphérique M1 (polissage sous contrainte) -> transfert de savoir-faire vers Thales-SES0
  - Attente décisions ESO
  - Calendrier et ressources restent à préciser

ELT-CAM

- Pilotage : MPE (R. Davies)
- Consortium: MPE, MPIA, USM, NOVA, OAPD, LESIA
- First Lights: 2023
- Participation FR
  - LESIA: Co-I ?, responsabilité module SCAO (étude système, optique, mécanique, électronique, logiciel contrôle, WFS, RTC), coronographie, masquage pupille, traitement données OA (reconstruction PSF)
  - GEPI/Pôle OSPM: soutien au LESIA
  - **IPAG**: contributions possibles à définir (optique, mécanique, électronique??)
3/ French contribution

**ELT-IFU**
- Pilotage : Oxford (P.I. N. Thatte)
- Consortium: Oxford, UK-ATC, CSIC, IAC, CRAL, ONERA
- First Lights: 2023
- Participation FR (25 à 30%)
  - CRAL: Co-I (R. Bacon), IFU (image slicer et découpeur champ), caract. VPHG, logiciel contrôle, pipeline réduction données
  - ONERA: Co-I (T. Fusco), responsabilité module SCAO (étude système, simulations, etc.) & LTAO?
  - **IPAG**: contribution logiciel contrôle, autres?
  - LAM: contribution module SCAO (conception opto-mécanique, MAIT), possibilité zoom fore-optics

**ELT-MIR**
- Pilotage : U. Leiden (P.I. B. Branble)
- First Lights: 2024 – 2027?
- Participation FR
  - IRFU: Co-I (E. Pantin), cryo-mécanismes, unités calibration, tests détecteurs et coronographes, bande N
3/ French contribution

**ELT-MOS**

Pilotage: LAM ou GEPI?
Consortium: X partenaires (FR, UK, NL, BR...)
First Lights: 2024 – 2027?
Participation FR
  ✓ LAM: PI ou co-PI, management, optique, mécanique, spectro MOS, MAIT, réduction données
  ✓ GEPI: PI ou co-PI, systèmes à fibres et réduction de données
  ✓ LESIA: OA grand champ, simulations
  ✓ ONERA: MOAO dans suite EAGLE
  ✓ Lagrange: contribution réduction données MOS
  ✓ **IPAG**: soutien sur aspects particuliers?

**ELT-HIRES**

• Pilotage : U. Bologna ou Obs Geneve?
• First Lights: 2024 – 2027?
• Consortium: Obs. Geneva, Univ. Bologna, Porto...
• Participation FR
  ✓ LAM: Intérêt potentiel expertise SOPHIE et SPIROU
3/ French contribution

**ELT-PCS**

- Pilotage : ESO (M. Kasper), **IPAG** (J.-L. Beuzit)
- Consortium: 9 partenaires (ESO, IPAG, LESIA, LAM, Lagrange, OAPD, Oxford, ETH-Z, NOVA)
- First Lights: 2027 – 2028?
- Participation FR
  - **IPAG**: PI ou co-PI, management, système, valorisation R&D et expérience SPHERE, MAIT, réduction données
  - LAM: Co-I, valorisation R&D engagée (WFS, coronographie)
  - Lagrange: valorisation R&D engagée (stabilité, coronographie, traitement signal, etc.)
  - ONERA: valorisation expertise SPHERE
  - LESIA: valorisation R&D
  - GEPI: valorisation R&D masques coronographiques si filière adaptée
More information

The science users web pages:
www.eso.org/sci/facilities/eelt

The E-ELT Construction Proposal:
www.eso.org/sci/facilities/eelt/docs/eelt_constrproposal.pdf

The E-ELT Science Case:

The E-ELT Design Reference Mission:

The public web pages:
www.eso.org/public/telesinstr/eelt.html

Brochures, Posters, etc:
www.eso.org/public/products/brochures/

Gallery:
www.eso.org/public/images/archive/category/eelt/
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<td><strong>OPTIMOS-EVE</strong></td>
<td>F. Hammer (GEPI); L. Kaper (Amsterdam), G. Dalton (RAL)</td>
<td>GEPI, NOVA, RAL, INAF OATs and Brera, NBI Copenhagen</td>
<td>Open Call for a new concept</td>
<td>S. Ramsay</td>
<td>7/10/08</td>
<td>30/03/10</td>
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<tr>
<td><strong>SIMPLE</strong></td>
<td>L. Origlia (INAF OABo)</td>
<td>INAF OA Bologna, Arcetri &amp; Roma, Univ. Bologna, UAO, TLS, PUC (Chile)</td>
<td>Open Call for a new concept</td>
<td>U. Kaeufl</td>
<td>30/10/08</td>
<td>4/03/10</td>
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2/ Instrument roadmap

Instrument studies

- The goal of the study programme was to carry-out a suitable number of instrument studies
  - to work with the ESO community towards construction
  - to verify that instruments can be built at an affordable cost and that they properly address the highest priority scientific goals,
  - to work with telescope and operation groups to identify and define interfaces with the other subsystems and the observatory infrastructure.

- 9 instrument and 2 post-focal AO studies carried out by >300 scientists and engineers in 40 institutes throughout the ESO community
## Selection process

**ESO/COU 1275, December 2009**

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<th>Nr.</th>
<th>Evaluation Criteria for E-ELT instrument selection</th>
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</table>
| 1   | **Scientific Merit:**  
     (a) the instrument addresses science goals identified as of highest priority for the E-ELT  
     (b) the instrument can be conceived as an E-ELT workhorse to be used for a variety of programmes, leading to a broad spectrum of potential discoveries  
     (c) the instrument will benefit and complement observations of other major facilities in astrophysics like ALMA and the JWST, which will be already in operation at the time of first light |
| 2   | **Proven Technical Feasibility and Simulated Performance:** the instrument feasibility and its expected performance have been properly demonstrated in the study |
| 3   | **Affordability:**  
     (a) the instrument cost is well estimated and justified  
     (b) the cost to ESO falls within or close to the preliminary budget envelope. |
| 4   | **Timely Match to the telescope + PFAO performance:** the instrument schedule of implementation is well matched to the path of the telescope + AO to full performance. The instrument includes the possibility to do prime science even during the time when the telescope cannot operate with AO. |
Selection process

- First light instruments
  - ELT-CAM: NIR diffraction-limited camera with moderate field size
  - ELT-IFU: NIR IFU spectrograph with optical-IR coverage and seeing limited to diffraction limited capabilities
  - Adaptive optics systems as required to meet the science cases of each instrument