The MAORY Multi-Conjugate Adaptive Optics module

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On behalf of the MAORY module Consortium
Requirements (from Phase A)

- **Multi conjugate Adaptive Optics RelaY**
  - Compensate atmospheric turbulence
  - Relay telescope focal plane to science instrument

- **Main requirements related to client instrument MICADO**
  - Wavelength range 0.8-2.4 µm
  - Field of view 53"×53"
  - Uniform adaptive optics correction with high sky coverage
  - Gravity invariant exit port with field derotation

- **Other requirements**
  - MCAO module to be placed on E-ELT Nasmyth platform
  - Lateral exit port for another possible instrument TBC
Multi-Conjugate Adaptive Optics

Strehl Ratio maps @K (2.2 μm)

SCAO

MCAO

MCAO demonstrated by MAD on VLT

Reference Stars

High Altitude Layer

Ground Layer

Ground Conj. DM

Altitude Conj. DM

Telescope

WFC

WFS

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Module architecture

E-ELT

Common Path Optics

Deformable Mirrors

Dichroic

Science Path Optics

NGS Wavefront Sensor

Exit Port

Telescope Control System

Real Time Control System

MAORY Instrumentation Software

Client Instrumentation Software

Light beam

Signal (real-time)

Signal (non real-time)
Module layout

- Pre-focal station
- Nasmyth platform
- MAORY
- Lateral port
- MICADO
  - Gravity invariant port
- Area for detached instrument

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Post-focal relay optics

Science path
Laser guide star path

Alternative optical design under discussion

Two post-focal deformable mirrors
Baseline piezo-electric actuator technology under review

Light beam from E-ELT
Gravity invariant exit port
LGS Wavefront Sensor

Why Laser Guide Stars?
- Sky coverage and performance uniformity
- Demonstrated by GeMS on Gemini Telescope in MCAO mode

LGS Wavefront Sensor description
- 6 Sodium Laser Guide Stars
- Wavefront Sensor type: Shack-Hartmann (~80x80 subapertures, 500 fps)

Sodium layer and LGS issues
- Finite distance → multiple LGS
- Tilt indetermination → Natural stars required
- Sodium density profile is structured and variable in time → Natural stars required

Sodium layer data kindly provided by Paul Hickson, University of British Columbia
NGS Wavefront Sensor

Required stars
- 3 Stars over 2.6 arcmin field of view
- Limiting magnitude $H \approx 21-22$
- Each probe split into two channels

Tip-Tilt & Focus channel
- Wavelength range 1.5-1.8 $\mu$m
- 100-500 Hz frame rate

Reference channel
- Wavelength range 0.6-0.9 $\mu$m
- Prevent propagation of spurious signals seen by LGS wavefront sensor
- Measure low-medium order modes at slow frame rate ($\sim 0.1$ Hz)
- Engineering mode:
  Full Natural Guide Star wavefront sensing at fast rate
Adaptive optics performance

Strehl Ratio
Median atmospheric conditions (seeing 0.8")

Sky coverage
Galactic Pole

Minimum field-averaged Strehl Ratio (53"x53")

<table>
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<tr>
<th></th>
<th>2.16 μm Ks band</th>
<th>1.65 μm H band</th>
<th>1.215 μm J band</th>
<th>0.9 μm I band</th>
<th>% Sky</th>
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<tr>
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<td>0.53</td>
<td>0.34</td>
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<td>0.22</td>
<td>0.06</td>
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Half-light radius

Seeing 0.8 arcsec

Seeing 0.6 arcsec

Distance from field center [arcsec]

Distance from field center [arcsec]
Ensquared Energy

Seeing 0.8 arcsec

Seeing 0.6 arcsec

Distance from field center [arcsec]

Ensquared Energy $75.75 \text{ mas}^2$
Project overview

- Phase A study Nov 2007 – Dec 2009

- MCAO module approved by ESO as part of first-light instrumentation to serve E-ELT diffraction-limited camera MICADO

- Project plan for next phases under consolidation
  - Negotiations between ESO and INAF (lead institute) are well advanced
  - INAF is supporting the project through its Directorate of Science
Project overview

- Current Consortium organisation
  - **INAF** (Lead Institute, System responsibility, sub-systems: platform, NGS WFS, deformable mirrors procurement, auxiliary equipments, science support tools)
  - **Durham University** (Real Time Control System)
  - **Observatoire de Paris LESIA** (LGS wavefront sensor)
  - **ESO** (wavefront sensor cameras, deformable mirrors development TBC)

- Preliminary project schedule

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- On-going preparatory activities with dedicated funds awarded to INAF by Italian Ministry for Research
Integration room preparation

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