MATTO: a future facility for testing Multi-conjugated Adaptive Optics techniques

Alessandro Ballone

on behalf of the whole

Instrumentation
& AdOpt Group

OAPd Days - 28/06/2024

28/06/24

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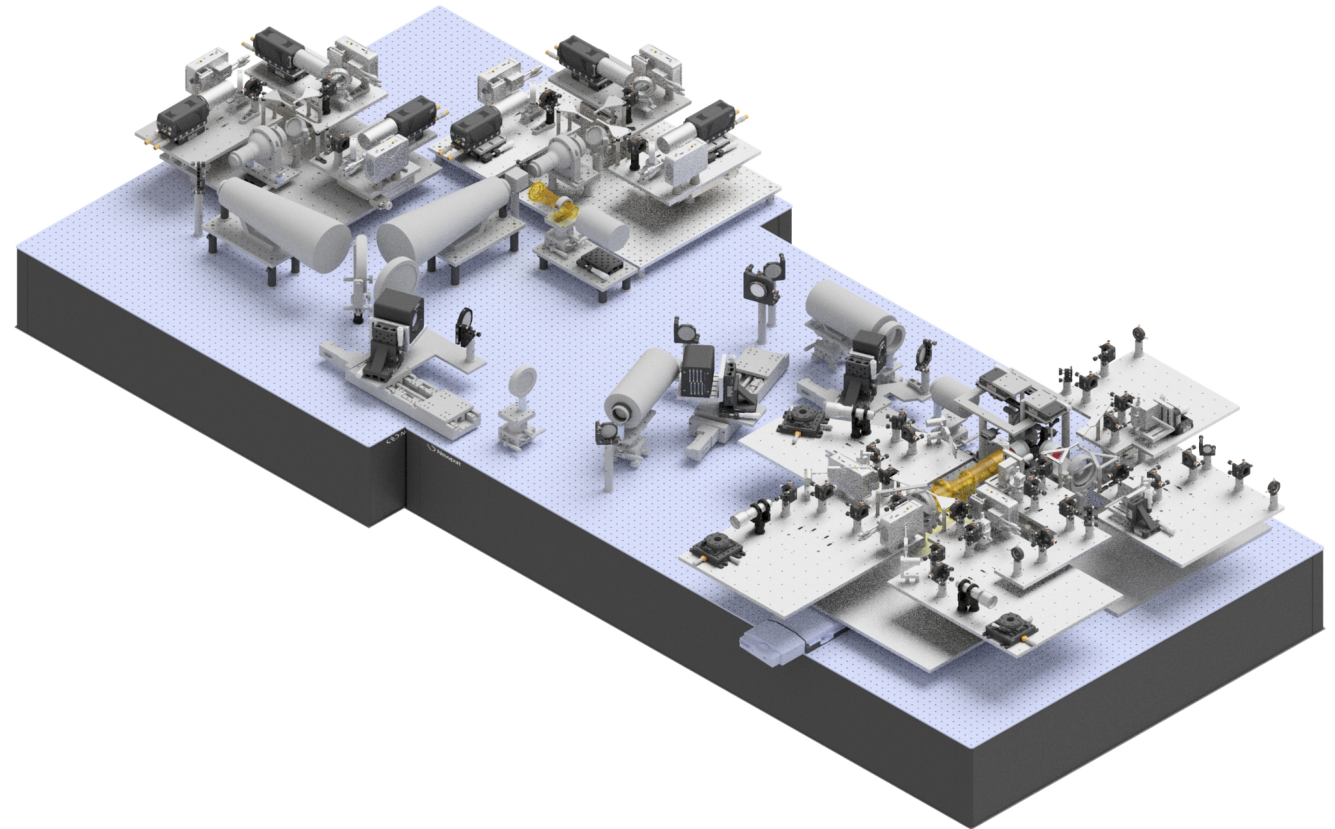
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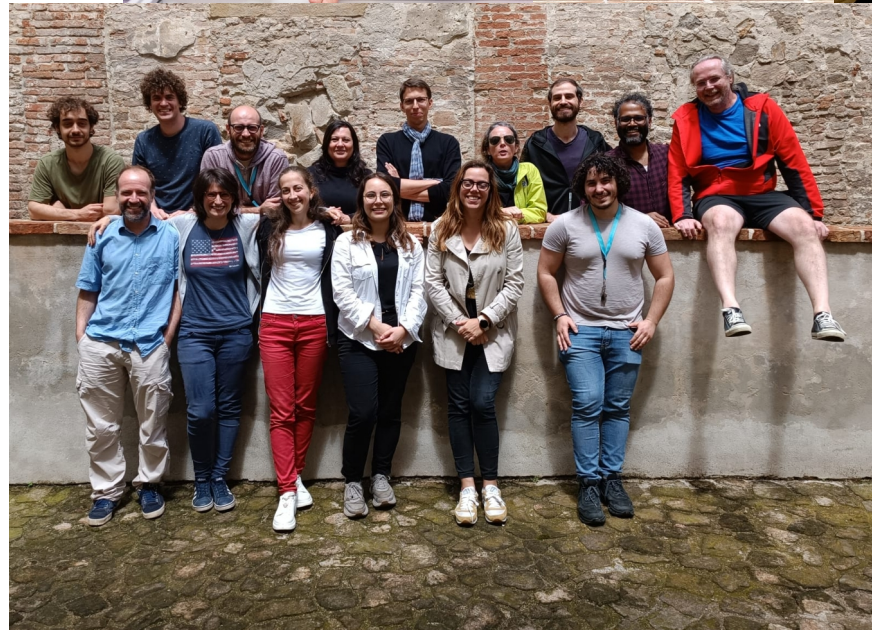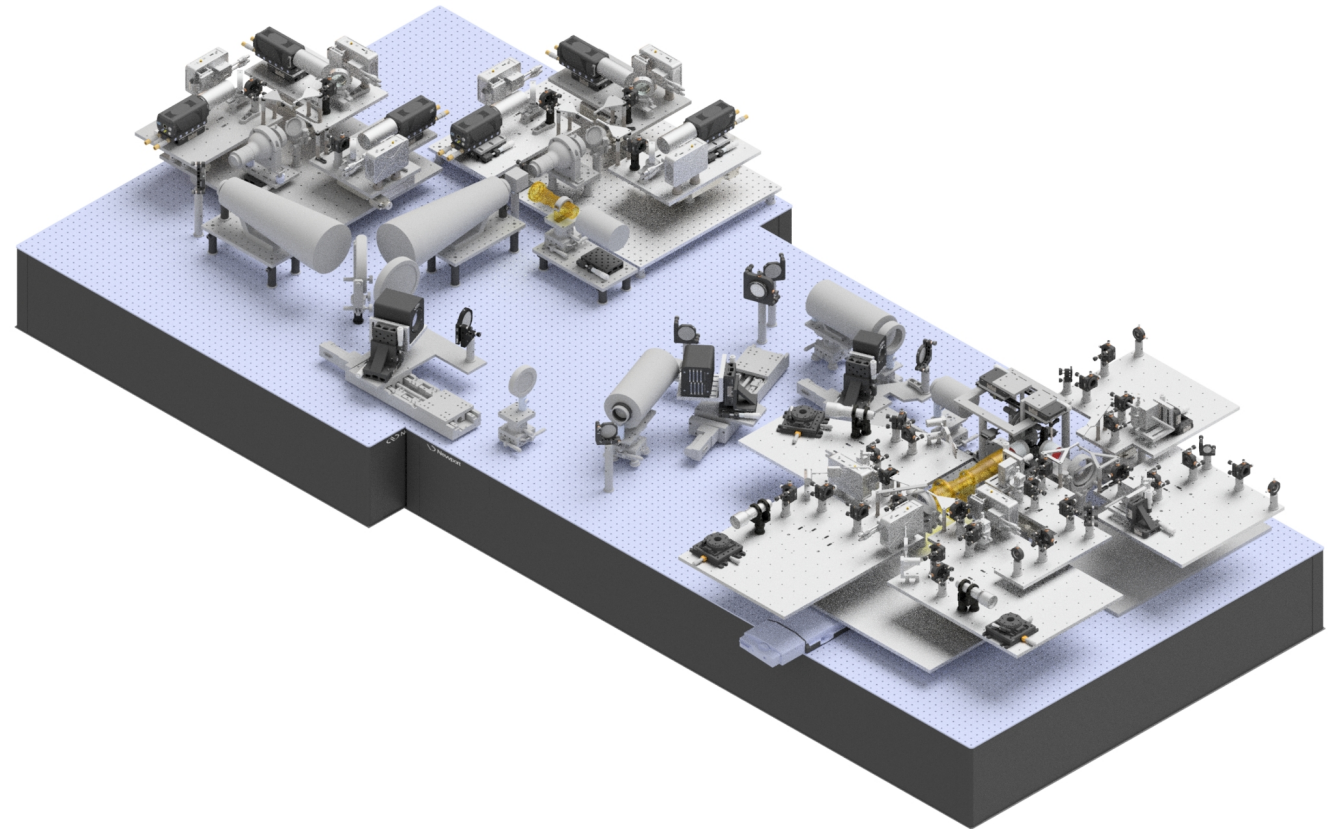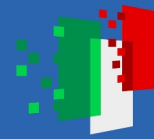
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MATTO (**M**ulti-conjugate **A**daptive **T**echniques **T**est **O**ptics) is a wide field adaptive optics bench, to be built starting from 2025.

Its ambitious goal is to serve as an international facility to test current and future MCAO techniques, mostly with <u>off-the-shelf components</u>.

It is probably the only multi-purpose bench that <u>can mimic very large and extremely large telescopes</u>!

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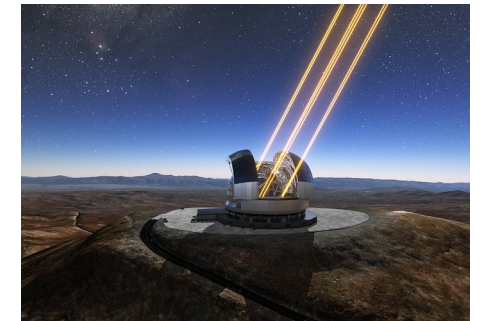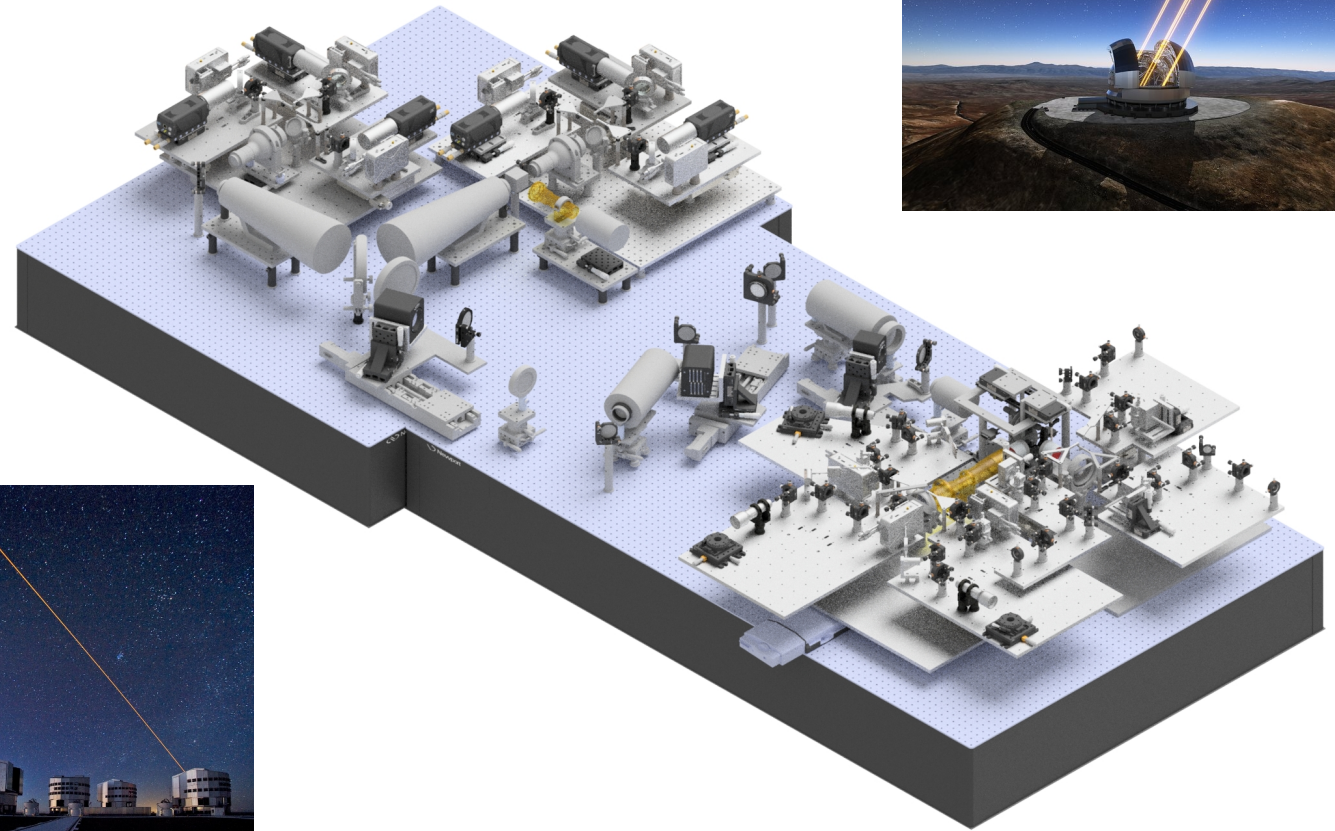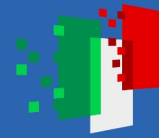
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Funded by the Programma Nazionale di Resistenza e Resilienza (PNRR), through the **STILES** Program.

STILES: Strengthening the Italian leadership in ELT and SKA.

About 70M € for many different work packages.

Coordinated by INAF, in collaboration with 7 Italian Universities and international research institutes.

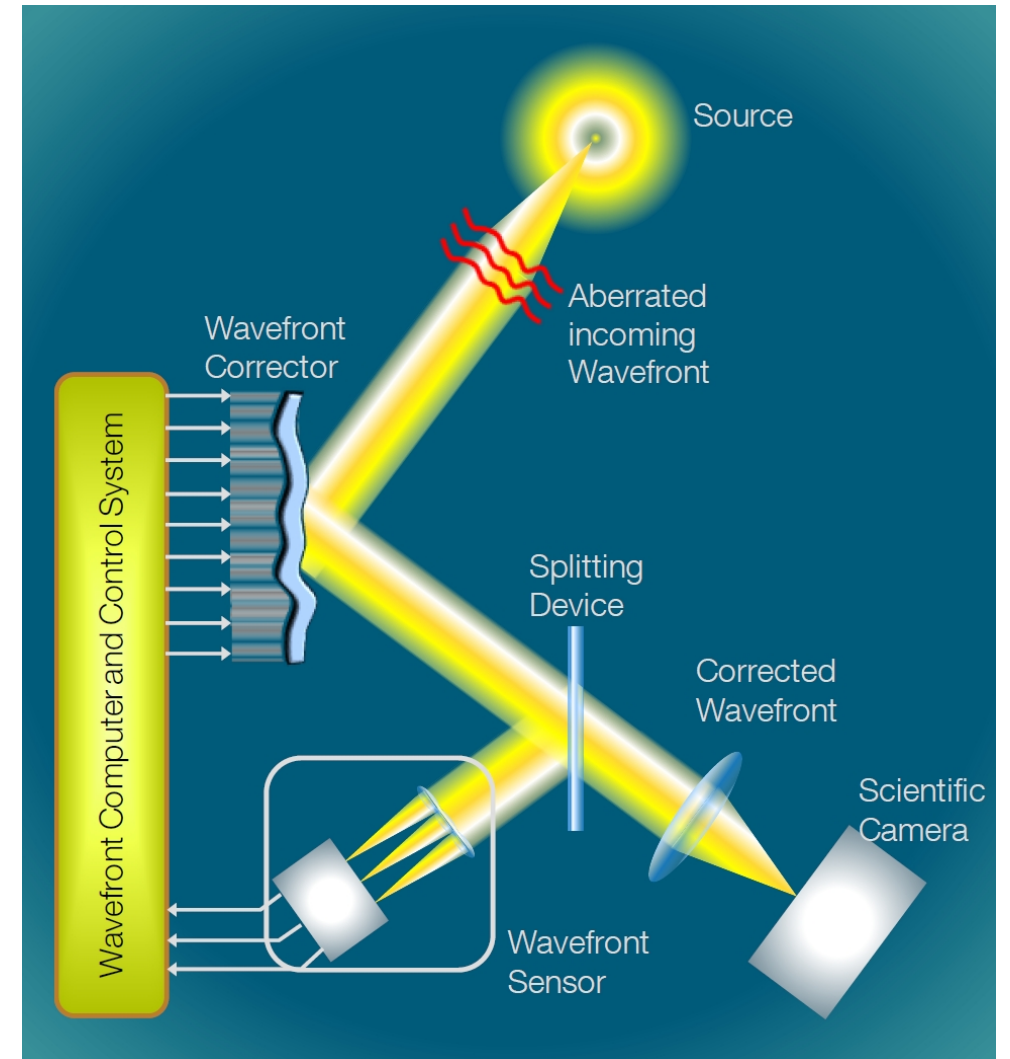STILES is funding other projects here at OAPd!

https://pnrr.inaf.it/progetto-stiles/

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How does AO work?

1) measure the distortion introduced in the incoming wavefront by the atmospheric turbulence
(through a Wavefront Sensor)

2) the measured distortion is converted in correction commands of a corrector device
(usually a Deformable Mirror)

This has to be done very fast (by a Real-Time Control System) at the typical time variation frequency of the atmospheric turbulence.
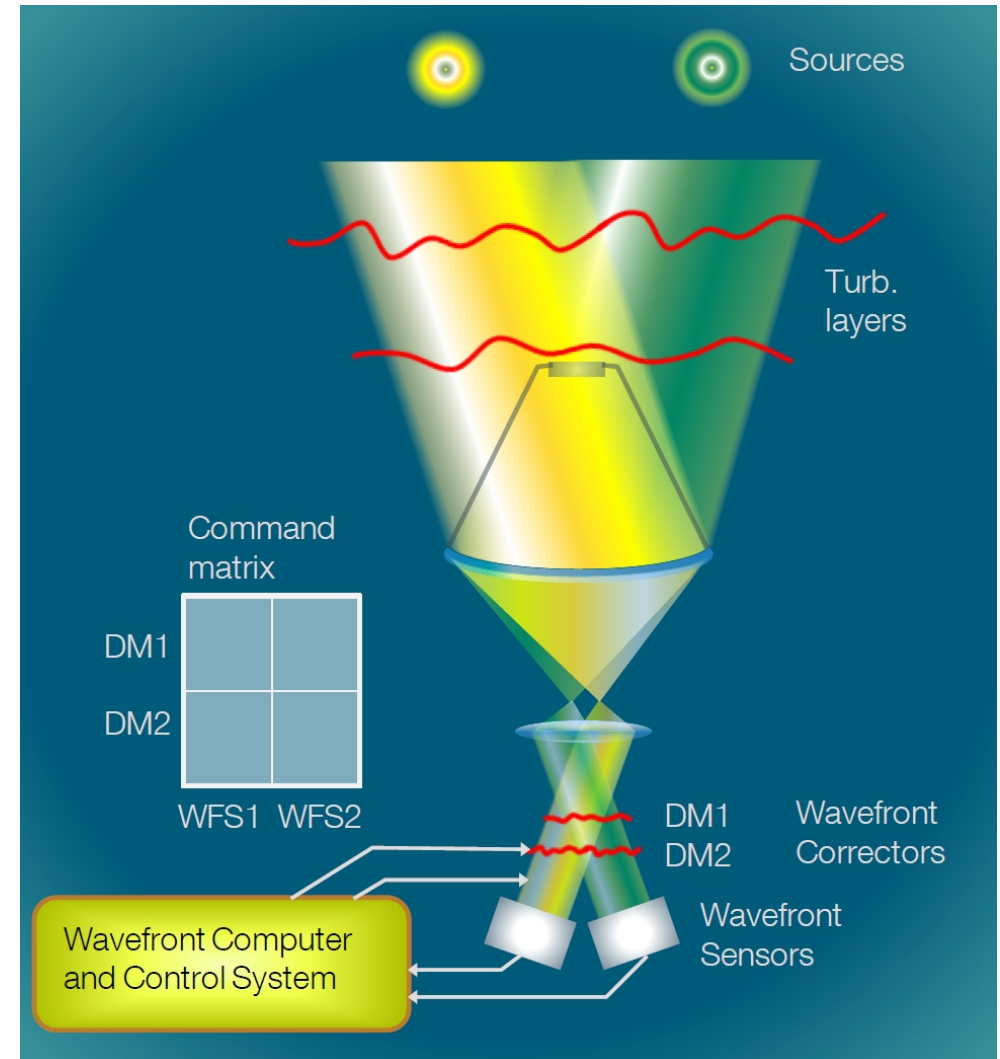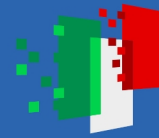
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What is MCAO? And most importantly: why MCAO?

Anisoplanatism…

We are probing only the effect of turbulence close to our reference star
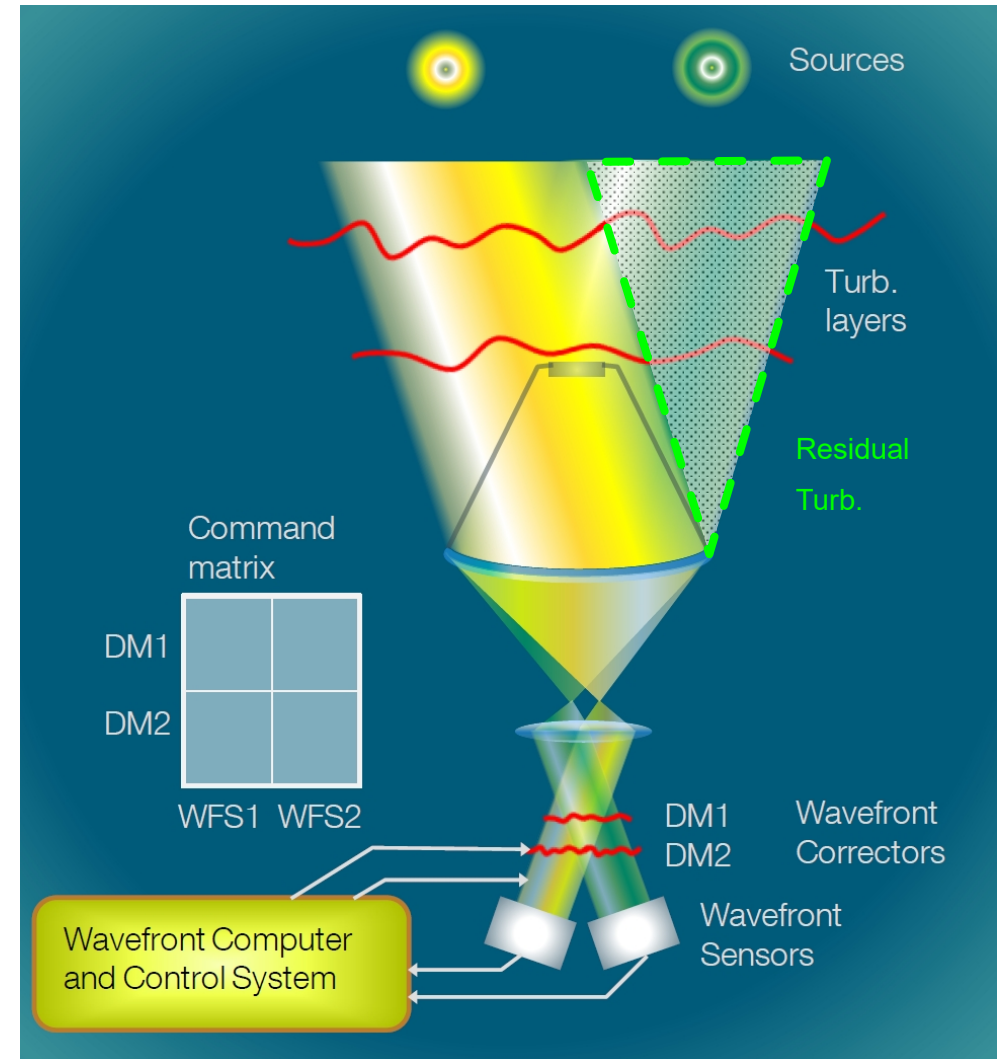(actually, within a turbulence coherence "isoplanatic" angle)

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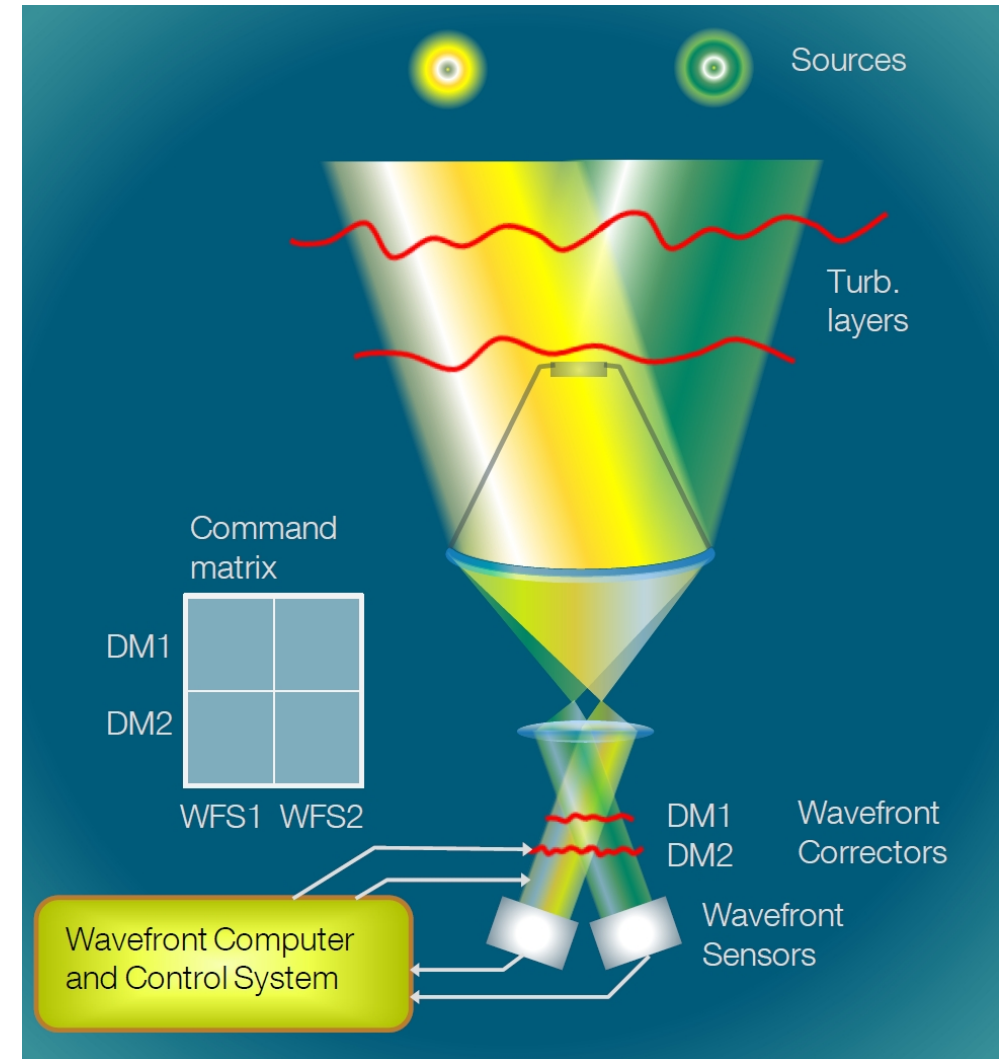
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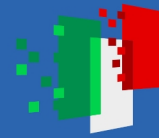What is MCAO? And most importantly: why MCAO?

Anisoplanatism…

We are probing only the effect of turbulence close to our reference star
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We want to uniformly correct **larger fields of view** and for the **effect of different atmospheric layers**!

Multi-Conjugate Adaptive Optics

And to cover the whole field of view and increase the sky coverage, Laser Guide Stars (LGS) are certainly needed!

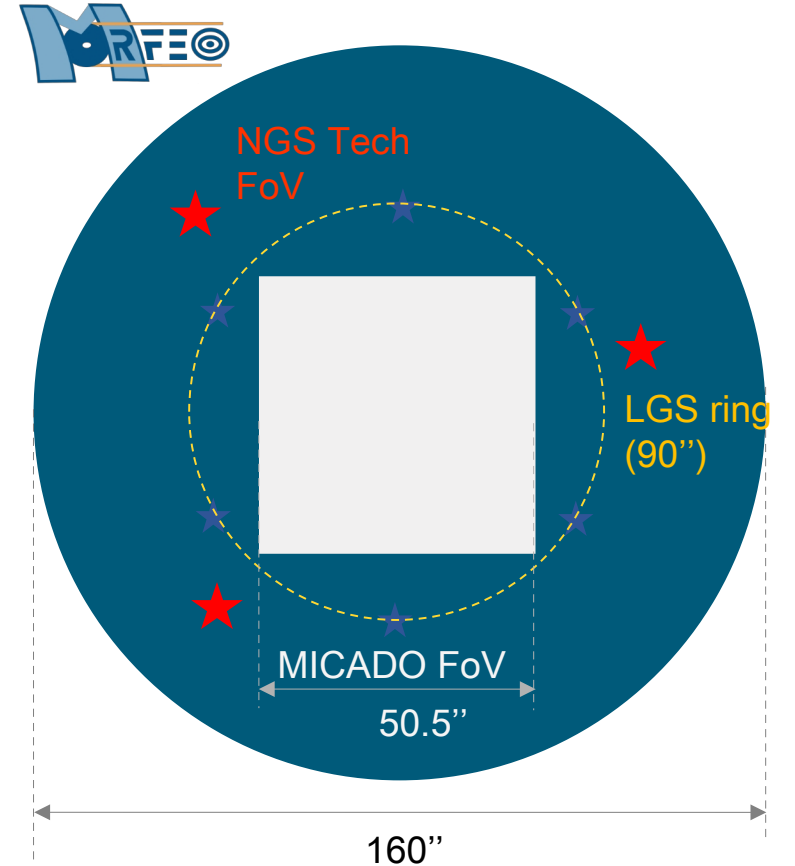# What is MCAO? And most importantly: why MCAO?

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MRFEO

NGS Tech FoV

LGS ring (90'')

MICADO FoV

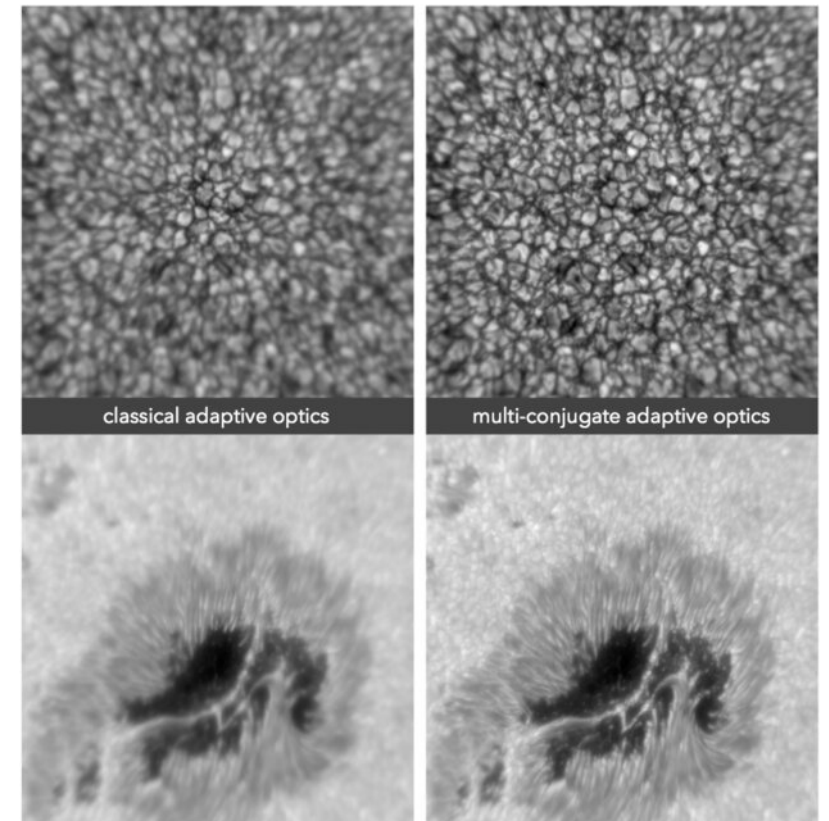50.5''

160''

What is MCAO? And most importantly: why MCAO?

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Multi-Conjugate Adaptive Optics

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Credit: Schmidt et al. (2017), Inouye Solar Telescope

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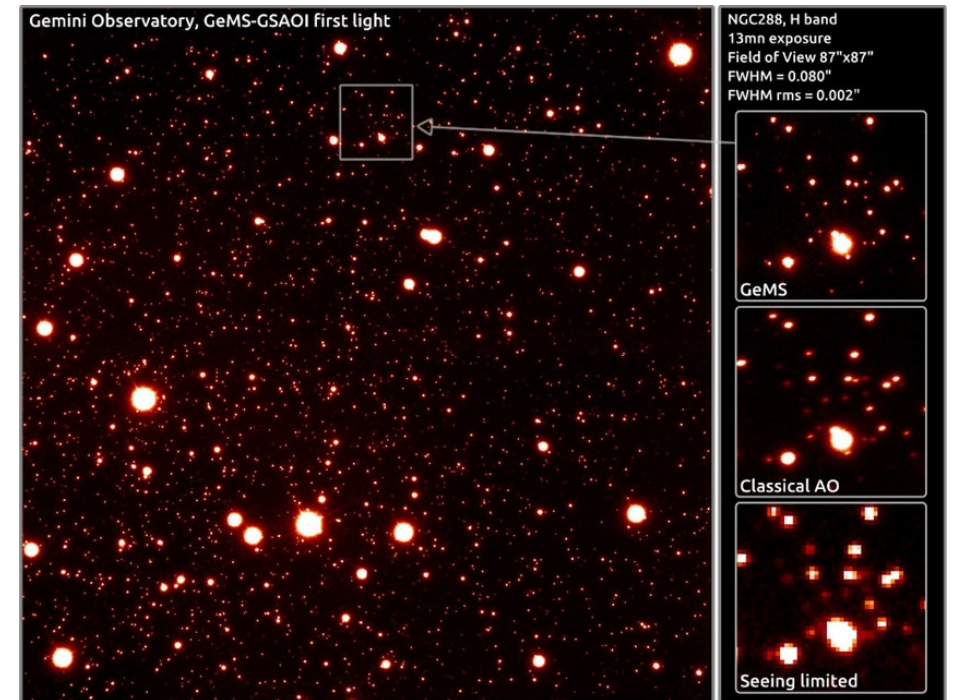DI ASTROFISICA

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Credit: Neichel & Rigaut (2012), Gemini Observatory

What is MCAO? And most importantly: why MCAO?

See Oleksandra & Paolo's talk!

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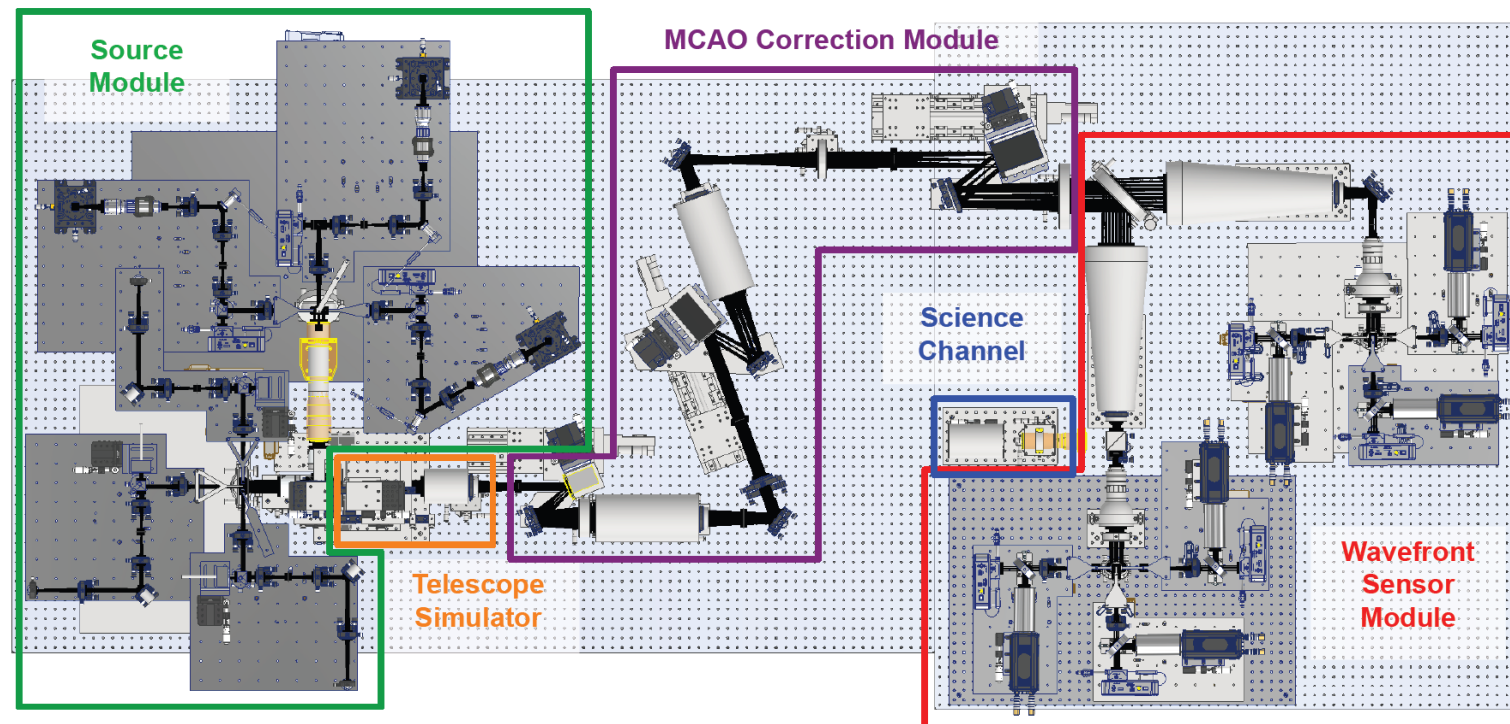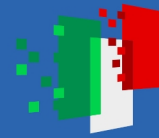
MATTO needs to adapt to:

  - source types, numbers, positions

- (new!) wavefront sensing techniques

  - telescope sizes (the whole system
      has to be "rescalable")

- new technologies or future upgrades

- different atmospheric characteristics

      The magic word is...
      MODULARITY!

Source Module

MCAO Correction Module

Science Channel

Telescope Simulator

Wavefront Sensor Module

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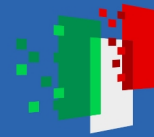STILES – IR0000034
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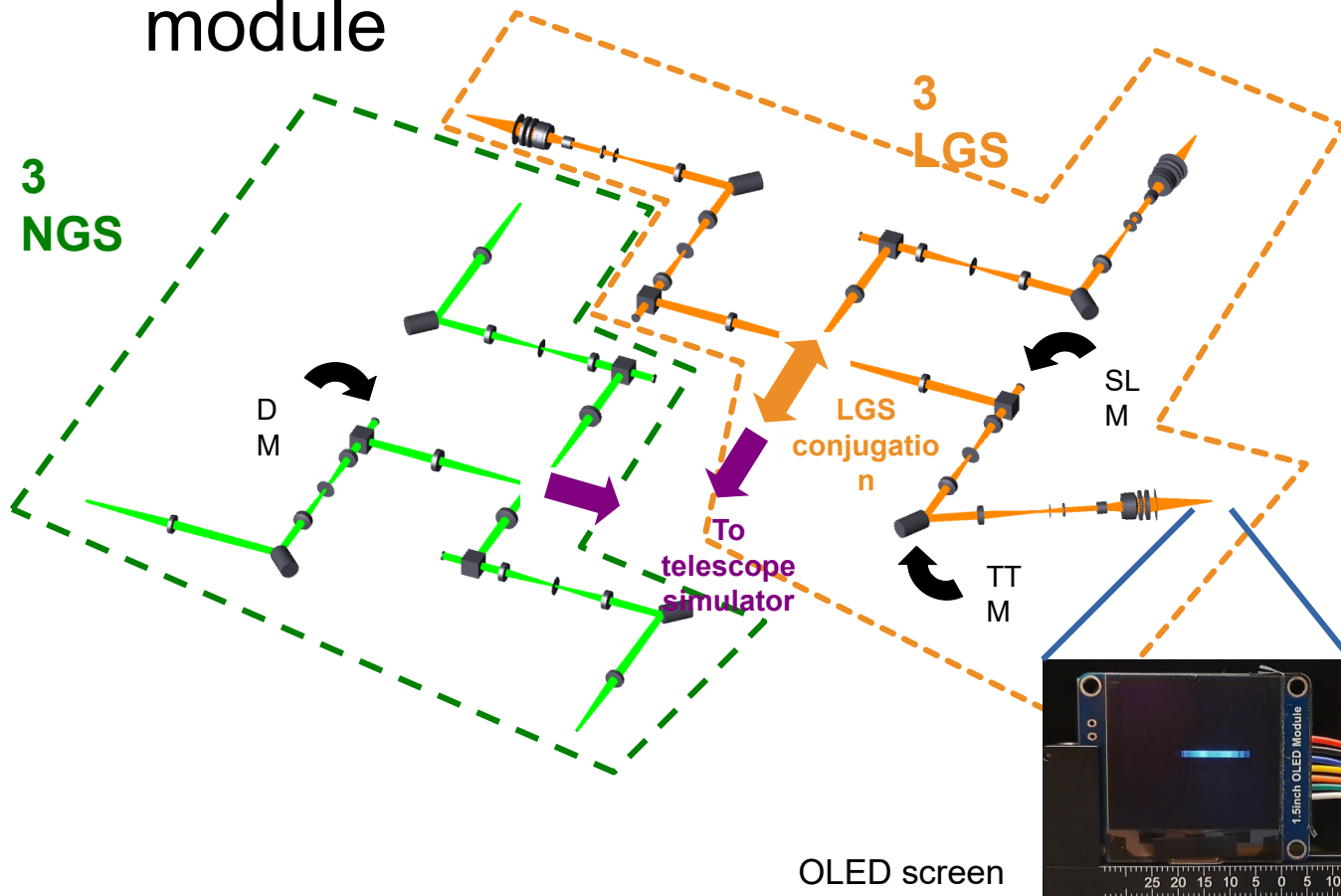
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Source module

3 NGS

3 LGS

LGS conjugation

To telescope simulator

DM

SLM

TTM
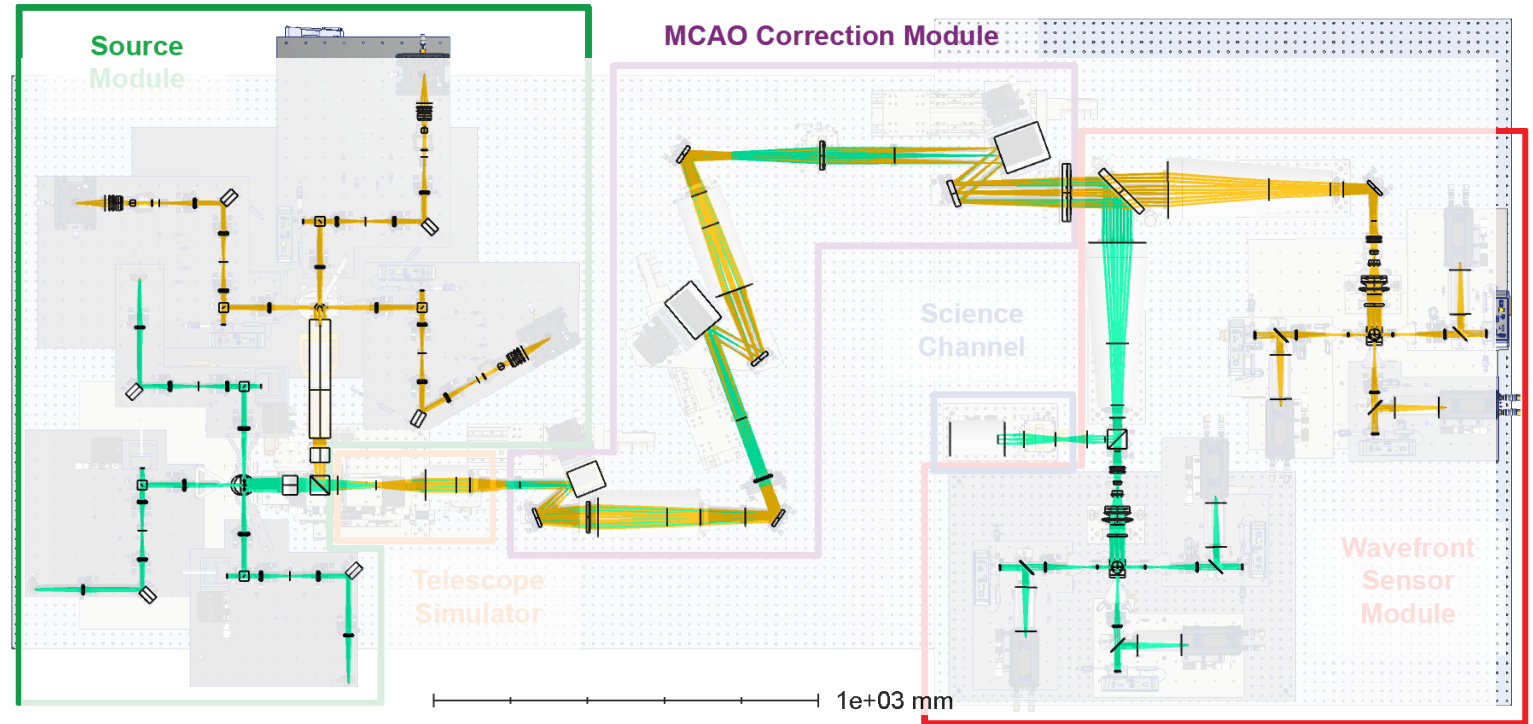
OLED screen

3 NGSs and **3 LGSs** (the latter simulated with OLED screens to reproduce the source elongation)

Controlled simulated turbulence via:

- **3 Deformable Mirrors** (~100 actuators each) for the NGSs

- **3 Tip-Tilt Mirrors** + **3 fast Spatial Light Modulators** for the LGSs

The LGSs channel can be conjugated at different altitudes via a linear stage

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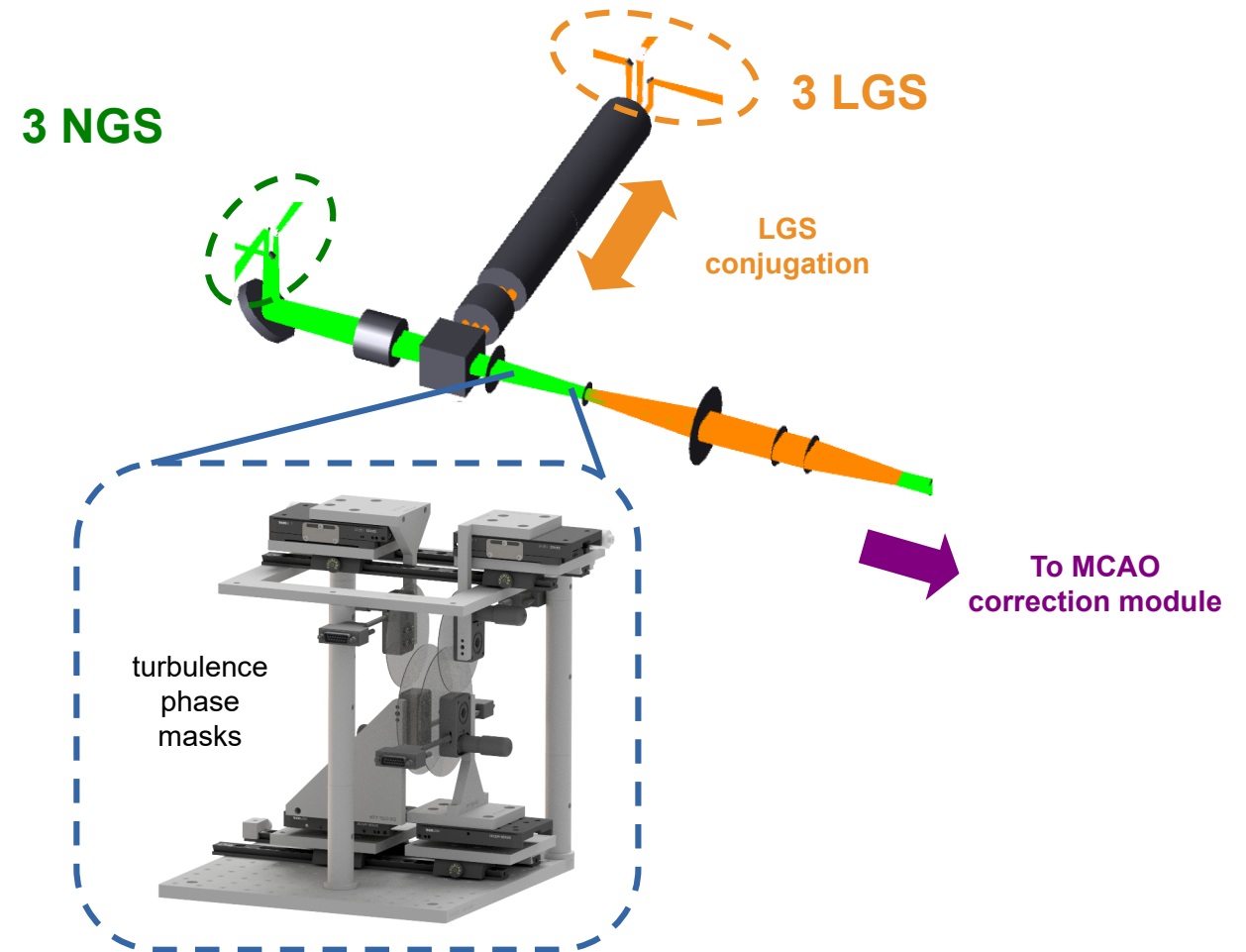
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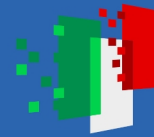DI ASTROFISICA

Telescope simulator

Light from NGSs and LGSs is collected, combined and sent to MCAO correction module

Another type of controlled simulated turbulence via:

- **4 thin glass phase screens**, with a photo-lithographicallly etched "turbulence history"

Mounted on rotating stages (simulating very high wind speed) and can translate to inject turbulence at different atmospheric altitudes

3 NGS

3 LGS

LGS conjugation

To MCAO correction module

turbulence phase masks

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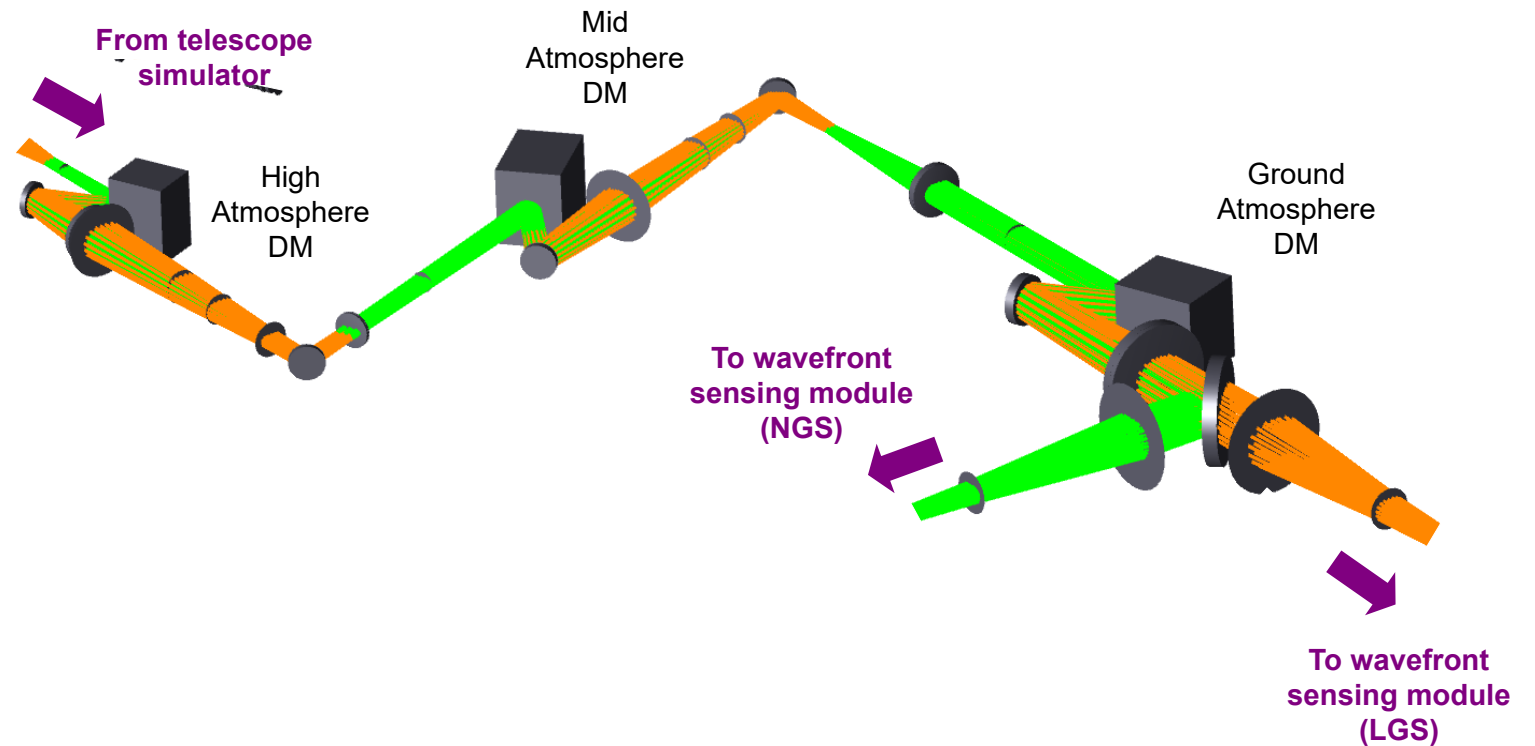Investimento 3.1

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MCAO correction module

3 large Deformable Mirrors for the correction of different atmospheric layers, with adjustable conjugation distance:

- <u>High</u> Atmosphere (~200 actuators)
- <u>Mid</u> Atmosphere (~450 actuators)
- <u>Ground</u> Atmosphere (~800 actuators)

Turbulence can also be injected via DM commands!

From telescope simulator

Mid Atmosphere DM

High Atmosphere DM

Ground Atmosphere DM

To wavefront sensing module (NGS)

To wavefront sensing module (LGS)

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Wavefront sensing module & Science channel

3 + 3 Spatial Light Modulators:
acting as phase masks to mimic any Wavefront Sensor (Shack Hartmann, curvature, Pyramid… or any new idea! E.g., see <u>our poster on the Ingot WFS</u>)

3 + 3 GigE technical cameras
1 High-Resolution GigE scientific camera

Motorized stages to adapt the conjugation of the LGS channel and to span the Field of View
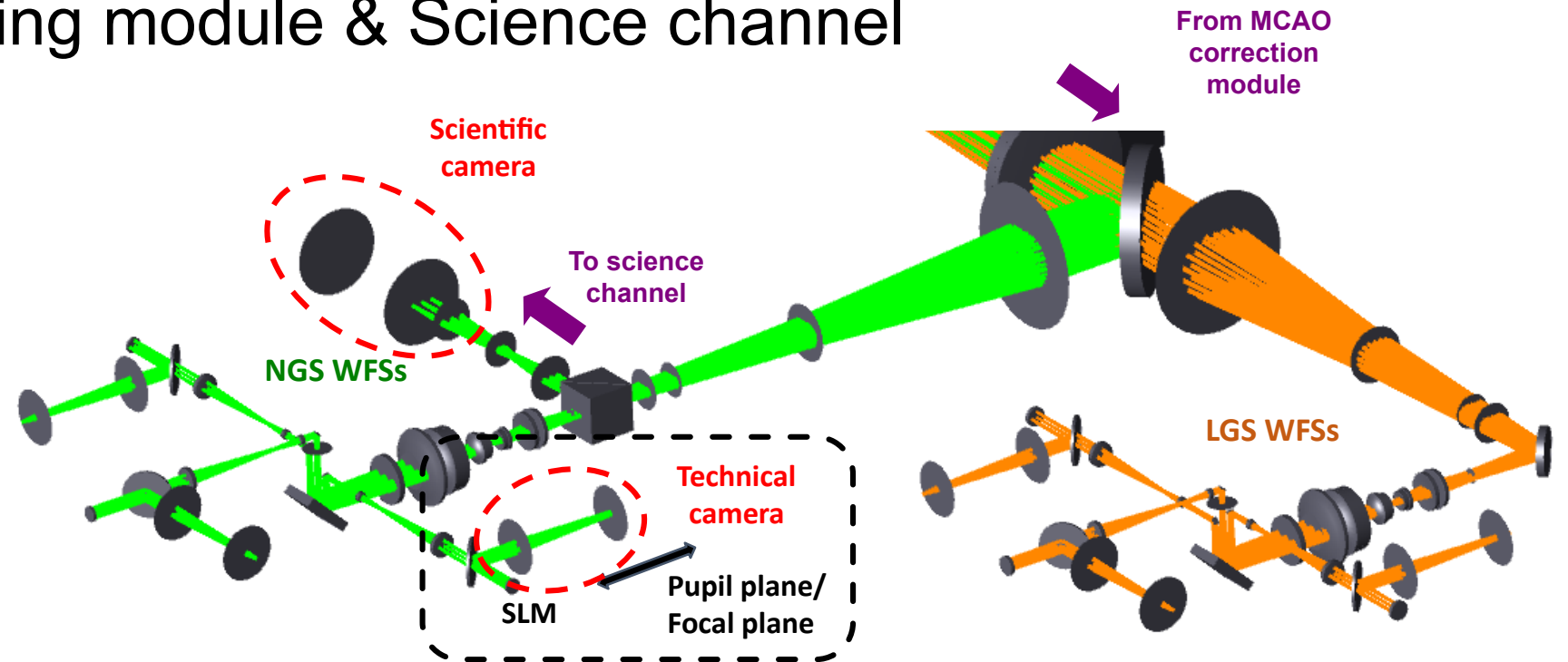
Real-Time Control

Many devices to be controlled at high rates

Turbulence typical coherence time frequency ~ **1 kHz**!!!
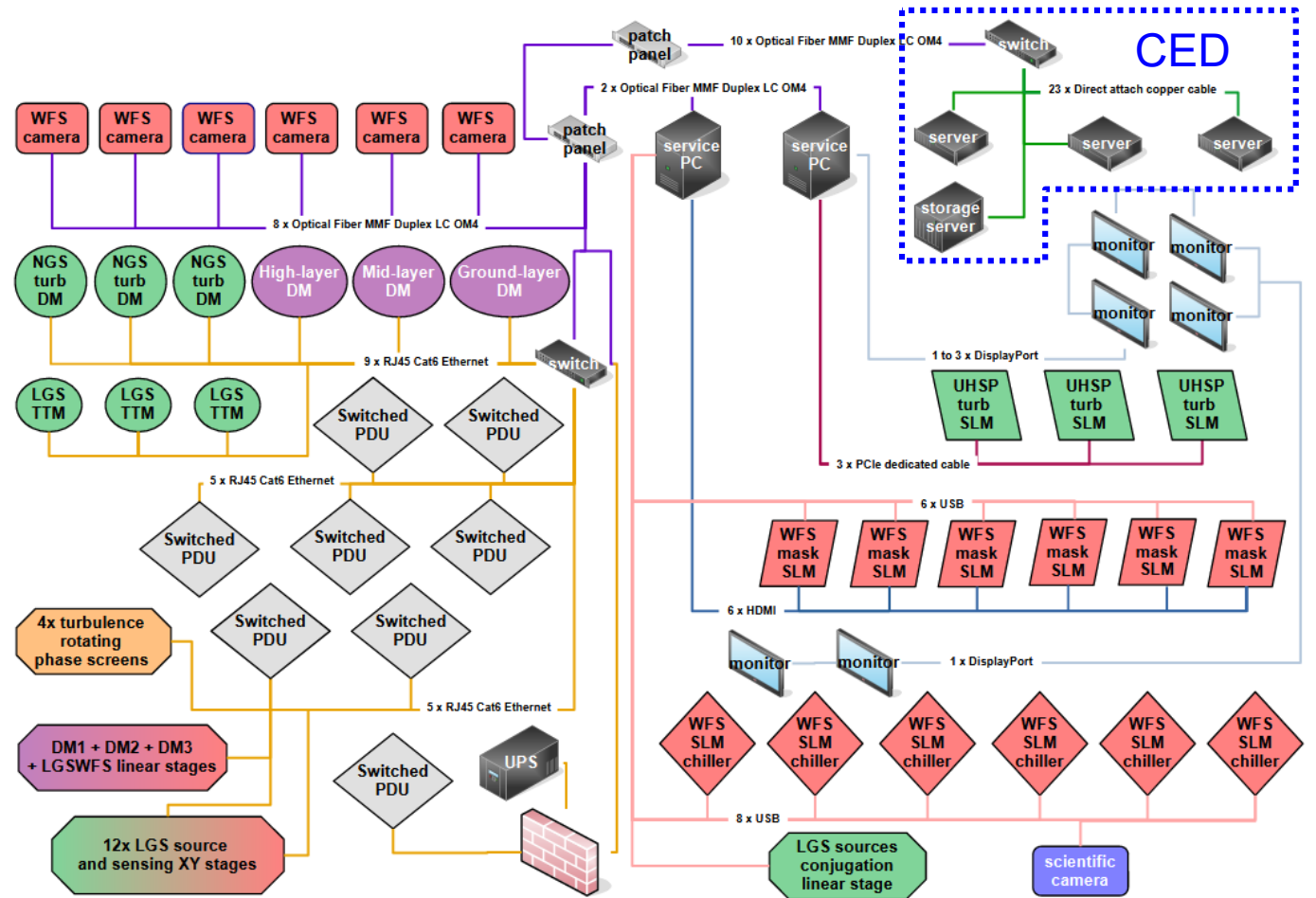
3 x servers (OS: Linux) with 6 cutting-edge AMD EPYC 9648X CPUs
+
1 x storage server
+

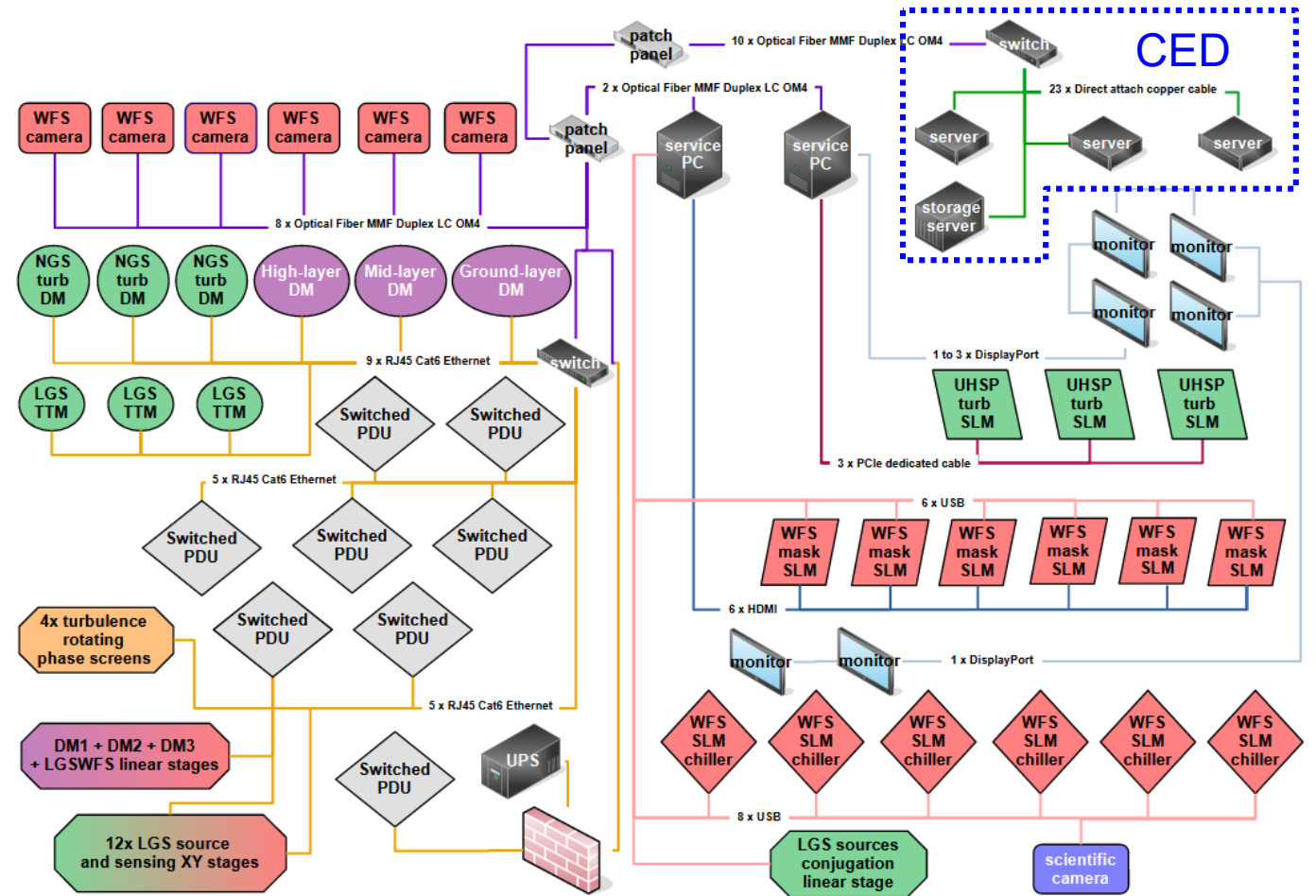2 x AMD/Intel workstations (OS: Windows) for additional interface

Real-Time Control

MATTO is multi-purpose → needs to adapt to different experiments

MATTO is a facility → long lived, can/will be upgraded with new devices

Again, the magic word is… MODULARITY!

We will develop our own RTC SW, based on the **DAO** (Durham Adaptive Optics) RTC package (in collaboration with CfAI

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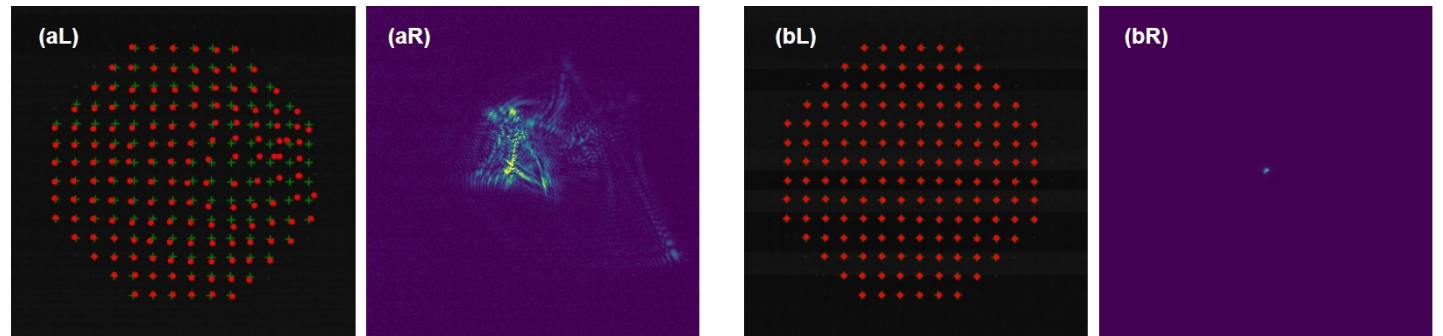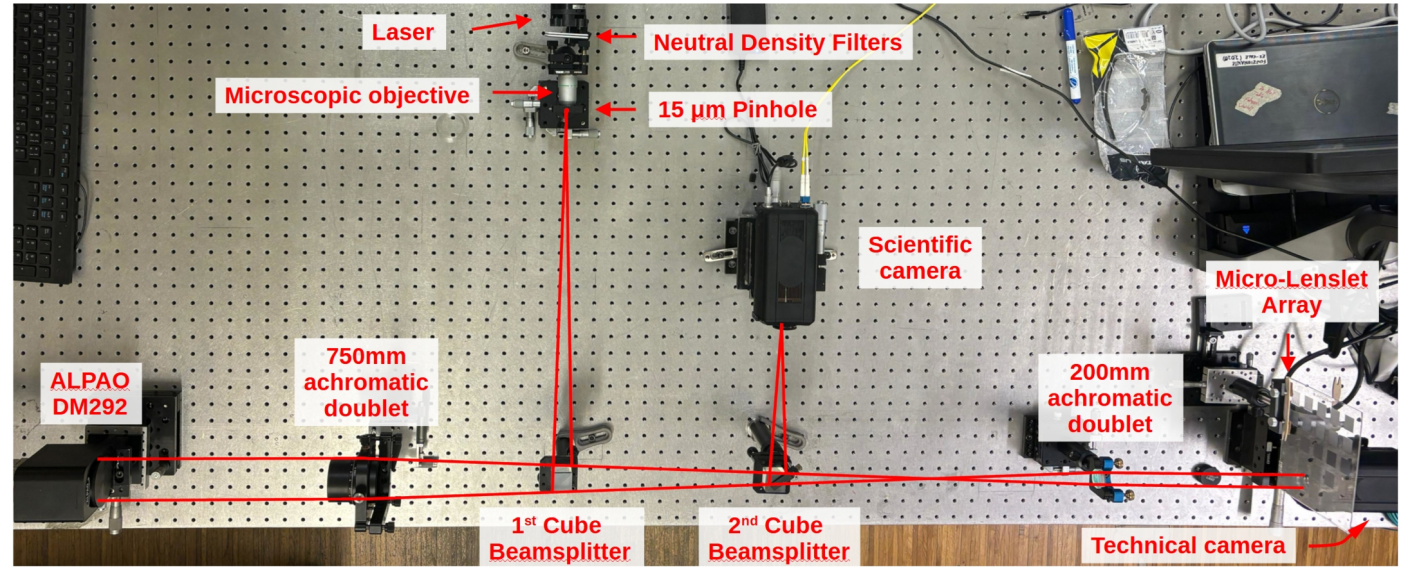STILES – IR0000034
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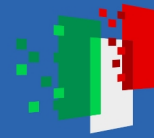
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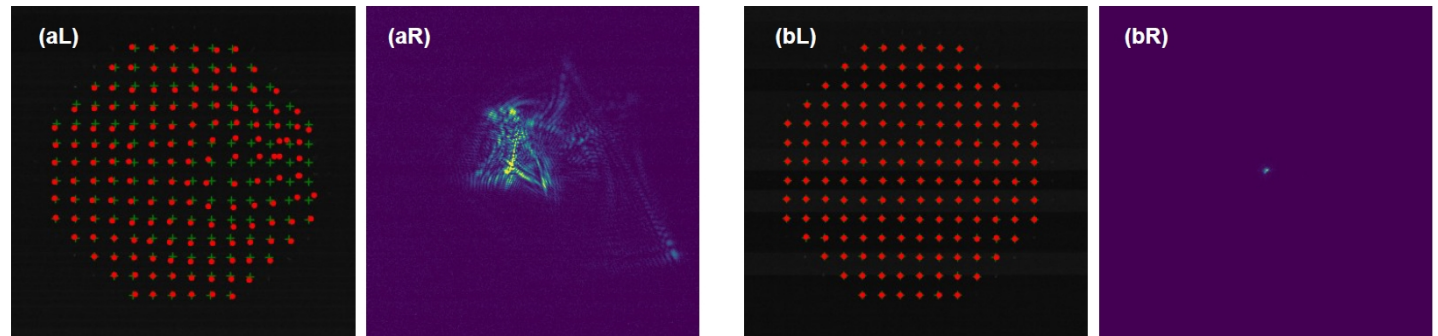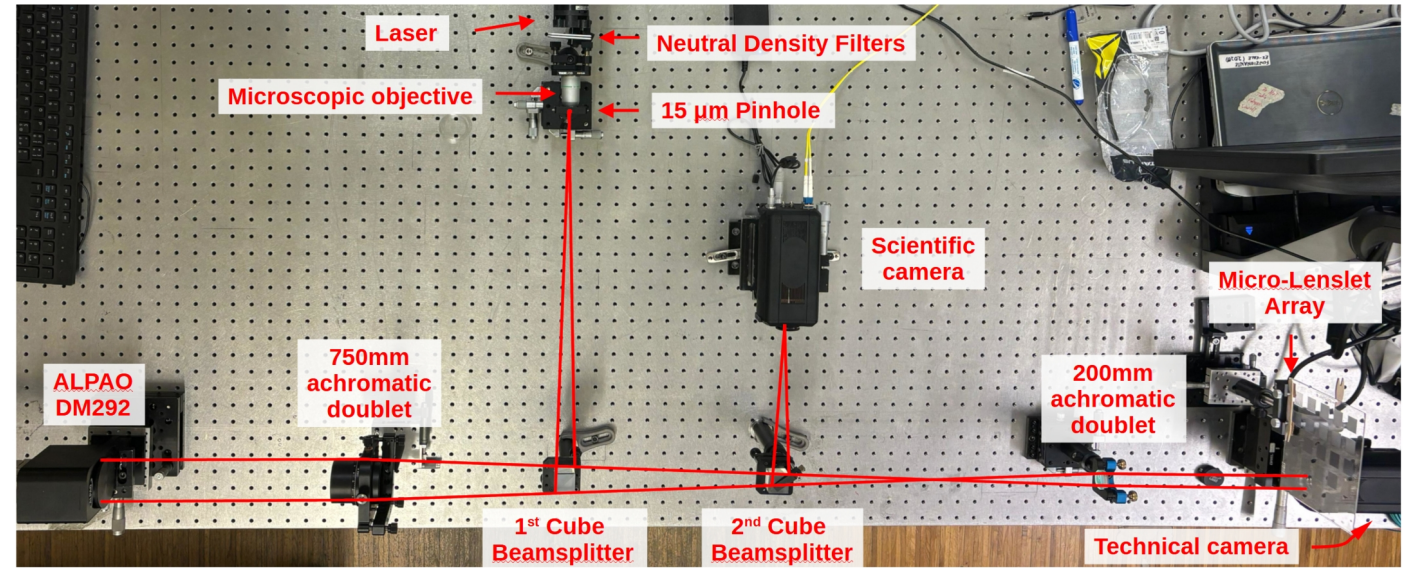STILES – IR0000034
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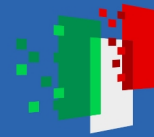
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Where?

In the ex-CED!
(see also OAPd Days poster about labs!)
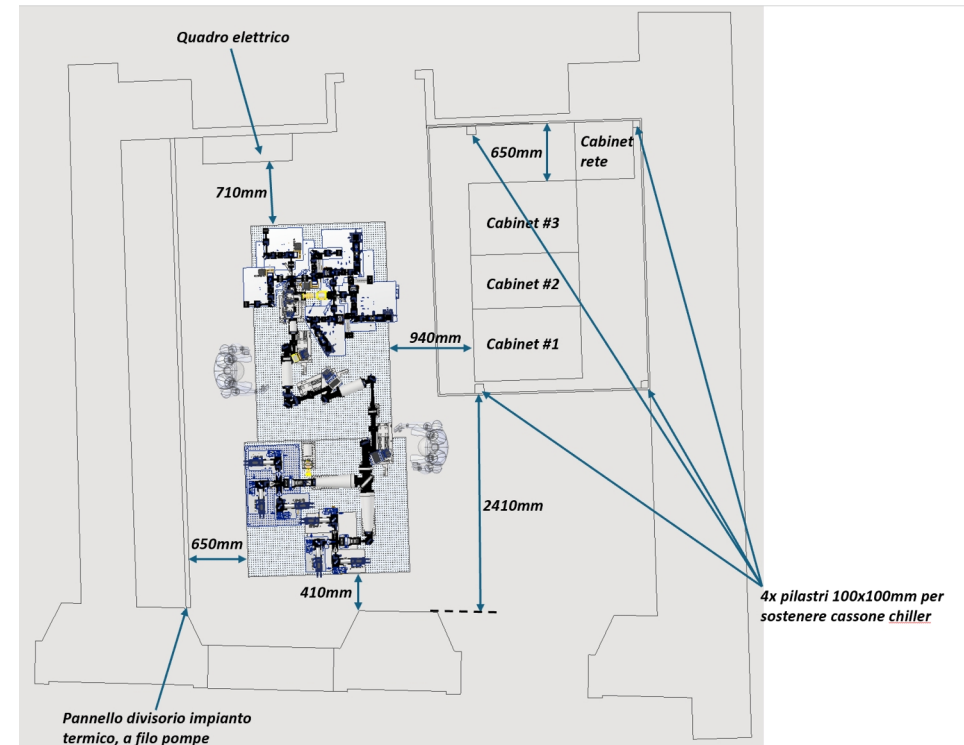
Thanks, in advance, to Danilo Selvestrel, Amedeo Petrella, Gigi Lessio, Nicola Di Cicco for helping setting up the room...

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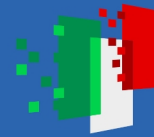ISTITUTO NAZIONALE DI ASTROFISICA

When?

Starting very soon…

Ready by the end of 2026
(hopefully…)

Intensive procurement...
Many thanks to all the
administrative staff helping with it!!!!!

Already started,
some material is already here!

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Summary:

- In OAPd, a new facility for testing Multi-Conjugated Adaptive Optics. For the whole INAF, but even for any international institute wishing to use it!

- Working to test all the Very and Extremely Large Telescopes.

- Very ambitious and multi-purpose → Very complex and demanding…

- A first complete version ready by the end of 2026.

MATTO is coming to town!

(and I hope you are all still awake...)

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