

# Adaptive Optics @ Arcetri

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**on behalf of the AO group:**

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# Summary

## Developments and perspectives in AO:

- Instruments: from design to commissioning
- Characterization and forecast of optical atmospheric turbulence (OT)
- Expertise, facilities, instrument @ OAA
- Technological transfer: lessons learned



*proudly member  
of the ADONI community*

## The AO group

19 people: 10 staff + 9 PostDoc/TD

- + n students
- + 4 astronomers in the loop

## The OT group

2 staff + 1 student

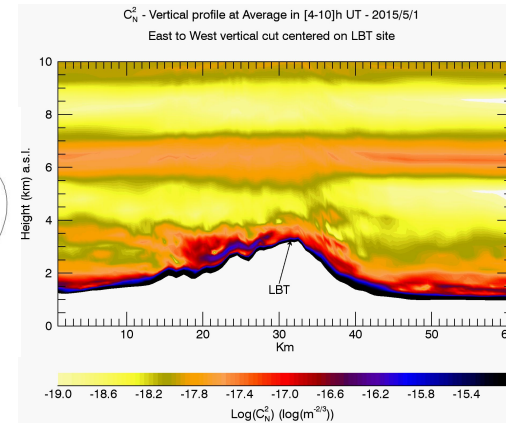
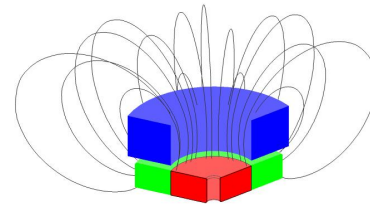
OAA has been the incubator  
for the Adaptive Secondary  
and the Pyramid WaveFront Sensor (with OAPd)

Research activity has been constant on these fields

# From 8 m-class telescopes...

Design, integration, commissioning, support of AO system for LBT & VLT:

- FLAO@LBT: 2x (Adaptive Secondaries+WFS) 2010
- Magellan: AdSec + WFS 2013
- DefSecondary @VLT 2013
- ERIS@VLT: NGS + LGS WFS (currently under commissioning)
- SOUL@LBT: FLAO upgrade (currently under commissioning)
- MAVIS@VLT
- ALTA-Center@LBT: turbulence forecast
- FATE@VLT: turbulence forecast
- SOLARNET@EST: turbulence forecast



# AO instruments: a calendar view



DM prototypes, APE,  
HOT...

MMT

Fiao #1 commissioning

FLAO #2 commissioning

ARGOS comm

Magellan commissioning



SOUL commiss.

AIV ERIS

FDR SOUL

FDR M4

PDR M4

PDR ERIS

PDR GMT



MAORY PDR

ERIS commiss.

SOUL 2 comm.

M4 OTT

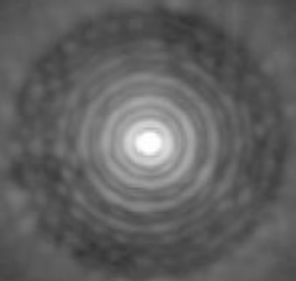
GMT-NGWFS prot.

ANDES PDR KO

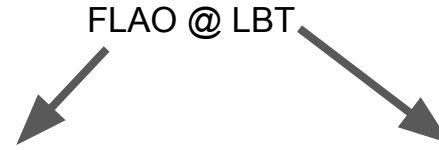
GMT-NGWFS prot.

# a few astronomical pictures....

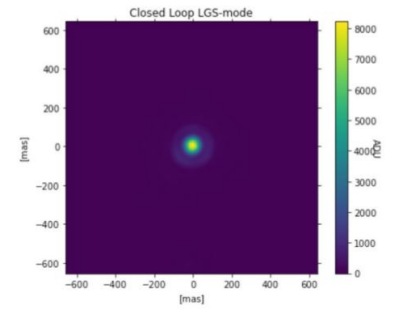
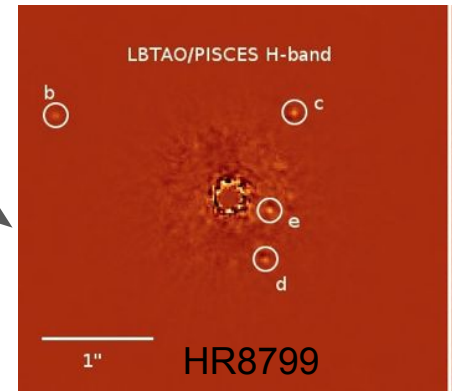
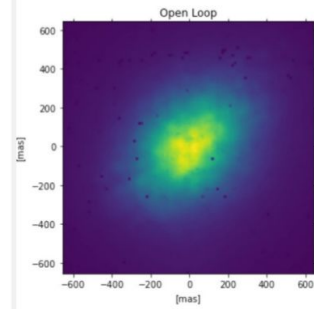
**H band SR 80%**  
**8 rings visible**



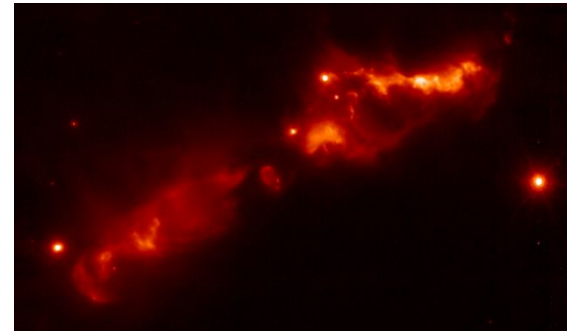
**The reference: HD175658, R =6.5, H=2.5**  
**The atmosphere: seeing 0.9 arcsec V band**  
**FLAO parameters: 1KHz, 30x30 subaps, 400 corrected modes**



ERIS @ VLT



SOUL @ LBT

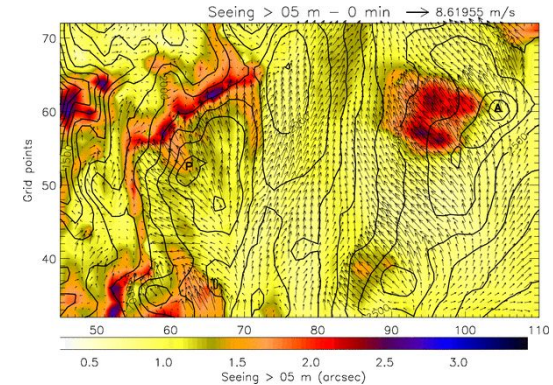


# The Optical Turbulence group



Activity: characterization and **forecast of optical turbulence**, applied to adaptive optics and **high angular resolution**

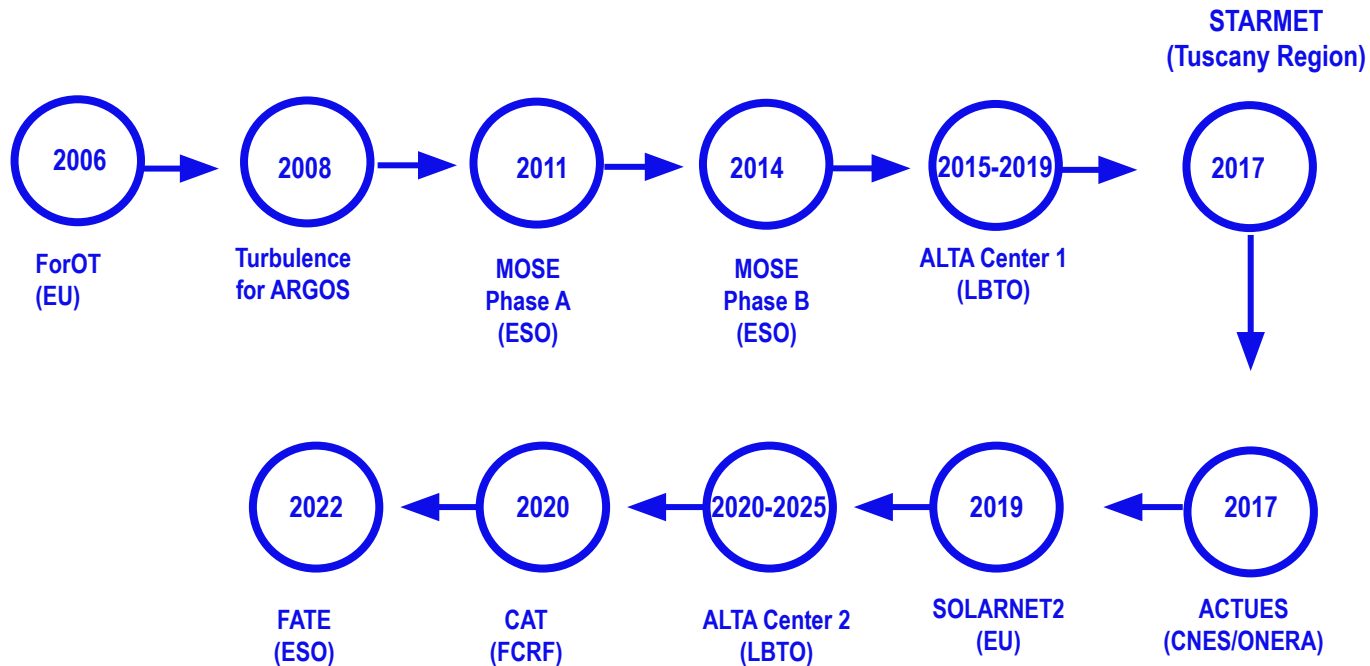
The group is born in 2006 after a **Marie Curie Excellence Grant (EU)**. Arcetri selected to work in synergy with the AO group  
→ empowerment of the high angular resolution task force in OAA



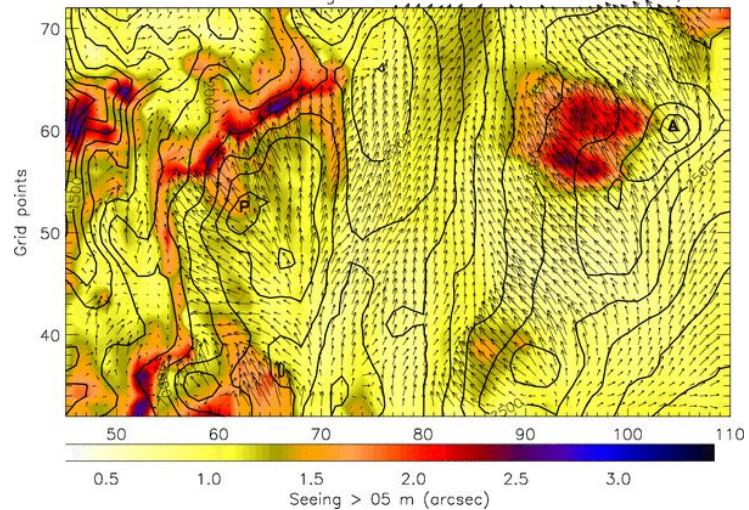
**The team has a solid leadership in turbulence forecast, acknowledged by:**

- High number of publications/citations in the field
- PI of the OT automatic forecast system @ LBT (**ALTA Center**) and @ VLT (**FATE**)
- ESA expressed interest for our activity for the free space optical communication
- ALTA Center is the unique astronomical site providing forecasts at different time scales

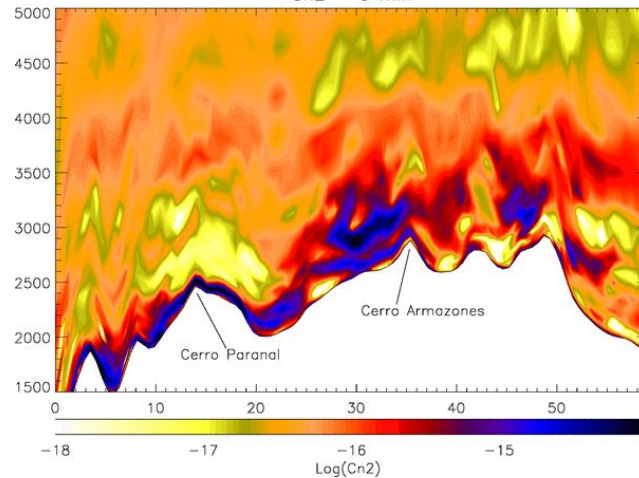
# Optical Turbulence Group Projects: calendar view



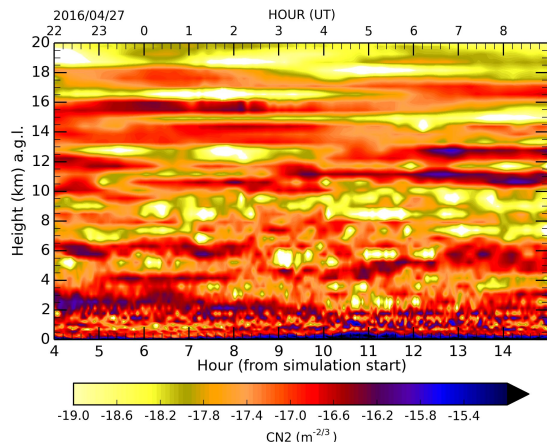
Seeing > 05 m - 0 min → 8.61955 m/s



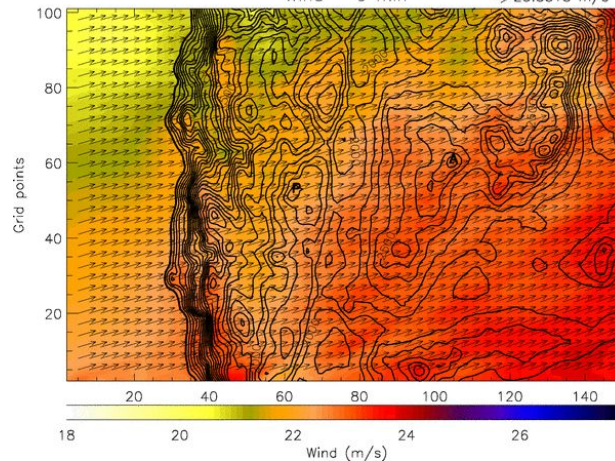
Cn2 - 0 min



$C_N^2$  - Vertical profile temporal evolution



Wind - 0 min → 23.8818 m/s



Wind speed @12 km  
(jet stream)  
Paranal+Armazones



# Laboratories, facilities

- 2x small + 1x large optical laboratories
- clean room
- large integration hall with crane, chiller, humidity control, heat exchangers, IT
- mechanical workshop
- electronic workshop
- simulation servers (GPU)

Interferometers, Def Mirrors, Cameras, Spatial Light Modulators, Motion Control, Actuators&Sensors,...

## Optical lab (small)



## Integration HALL



## Optical lab. (large)



## electr. lab

# ... & expertise

Control strategy for Pyr-WFS

Optical metrology - optical calibrations

Machine learning/deep learning

Control strategy for adaptive mirrors

PSF fitting&simulations

Multiphysics, FE simulations

hydrodynamic modelling

Forecast of optical turbulence  
parameters, applied to astron.  
observations

Simulations codes, GPU

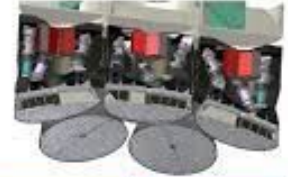
# ...toward the ELTs

Development, analysis, testing, of AO systems for ELT and GMT:

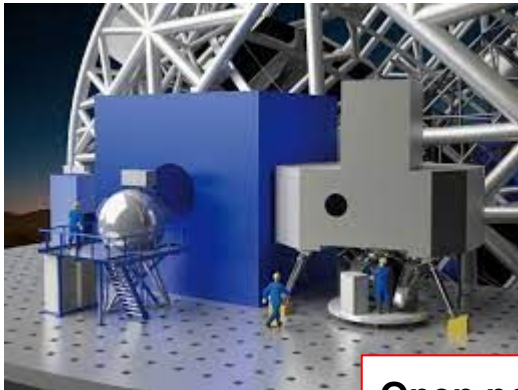
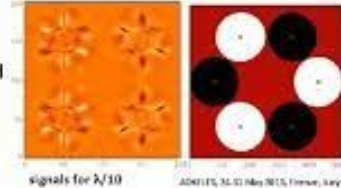
- MAORY
- ANDES
- M4 (sub-contract for optical testing)
- GMT-Pyr WFS: NGWS

Key elements of NGS AO of GMT

(1) Adaptive secondary mirror of 7 units with 672 actuators. Each.



(2) A pyramid WFS measuring over 4600 continuous modes and segments differential piston.



**Open points:**  
Phasing segments  
MCAO, tomography  
AO & control strategy

# The complex organization of ELT projects

Time scale, team organization, multi-institute - multi-national structure, competences diversity, facilities and logistics:

these aspects tend to “explode” for an ELT project.

***How are groups&INAF addressing these issues?***

e.g. **MAORY**: start date conceptual design <2010, conceptual design 2012, start date PDR 2015, PDR 2021...

the “small team organization structure” is not longer working. REQ:

- new management approach
- different view on contracts (AdR/TD) and **formation/tenuring**
- new approach to “extreme” competences (from **optics to QA**)
- bureaucracy vs science
- facilities and logistics: think big!

what if 2, 3 projects together?



- constant R&D activity, also triggered by telescope runs, but
- **R&D largely linked to project results and schedule**



little room for game-changer R&D

# Technological transfer: lessons learned

The development of the adaptive secondaries is a showcase of tech. transfer:  
partners: OAA, AdOptica (Microgate + ADS)

	INAF		AdOptica	
	Activity	Leadership	Activity	Leadership
Stage1: Protot., LBT AdSec (2x) + Magellan	Development, simulation, operations, testing	System	<b>manufacturing</b>	engineering
Stage 2: VLT- DSM, M4 Phase A	Simulations, optical design, optical testing	AO expertise, optical metrology shared lead	Manufacturing, Simulations, engineering	system shared lead
Stage 3: M4	Optical testing	advanced optical metrology	Manufacturing, Simulations, engineering	system full lead

# Technological transfer: lessons learned

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partners: OAA, AdOptica (Microgate + ADS)

	INAF	AdOptica
	INAF narrowed its commitment to Deformable Mirrors projects, now limited to advanced optical metrology (M4) or AO-system-wide supervision (GMT)	
Stag Prot AdS Mag	Comments: <ul style="list-style-type: none"><li>● leadership and contracts yielded to industry:<ul style="list-style-type: none"><li>○ would INAF be able to build M4? or: difference between M4 and MAORY</li></ul></li><li>● lower contracts and no GTO</li></ul>	
Stag DSM	but	
Stag	<ul style="list-style-type: none"><li>● paid for R&amp;D and serendipity research</li><li>● paid to be involved in project (beneficial to ERIS/MAORY/ANDES...)</li></ul>	