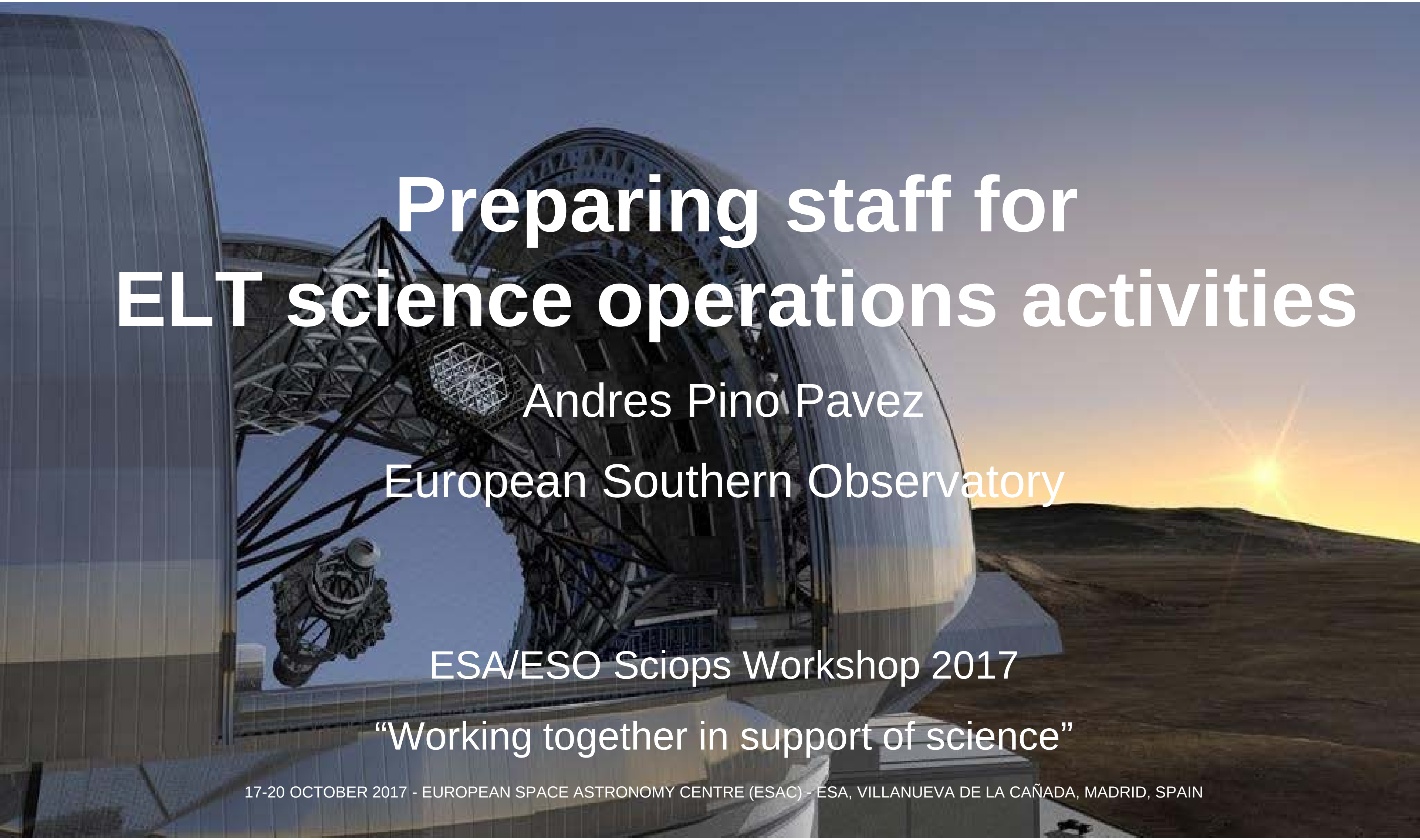


Preparing staff for ELT science operations activities

Andres Pino Pavez

European Southern Observatory

ESA/ESO Sciops Workshop 2017

“Working together in support of science”

17-20 OCTOBER 2017 - EUROPEAN SPACE ASTRONOMY CENTRE (ESAC) - ESA, VILLANUEVA DE LA CAÑADA, MADRID, SPAIN

Paranal Observatory – the home of ELT

Why this talk

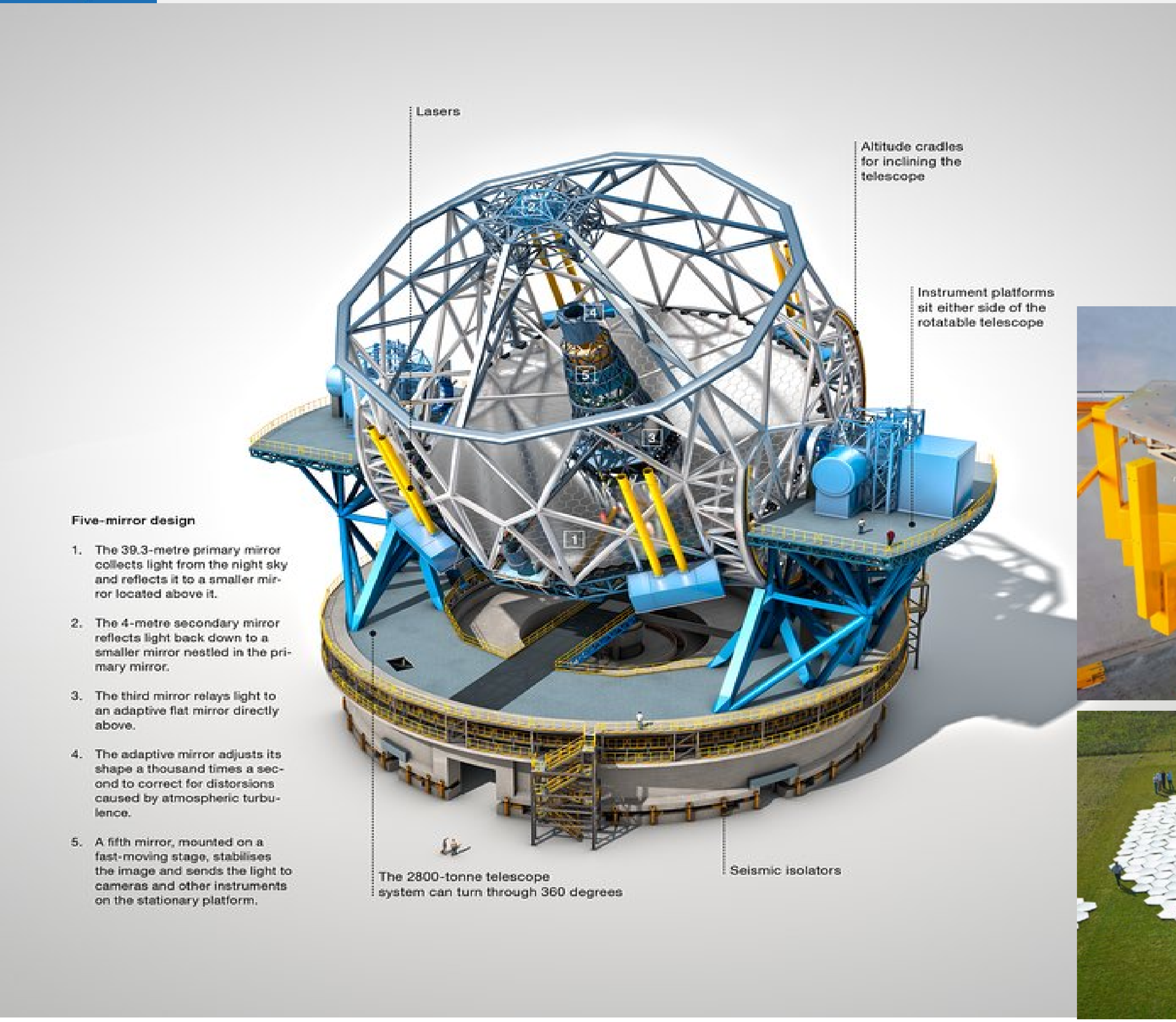
- ELT will demand various and unique areas of expertise
- Being an integral “AO Telescope” requires different awareness, new skill sets and technical background
- Additional astroclimate parameters/decisions will drive the process of prioritization of observations
- The combination of the AO Facility (DMs, Lasers) and new generation instruments, will need more and different monitoring strategies (tools and people)
  - Staff should incorporate these new techniques and parameters in a common and standard language

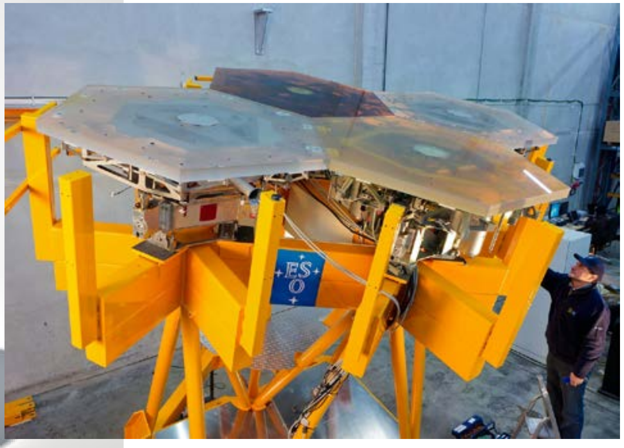
Why this talk

- A complete staff training program is the only starting point to ensure the best use of observational time and science quality
- Complexity of the system will require newer techniques and engineering knowledge

Challenge

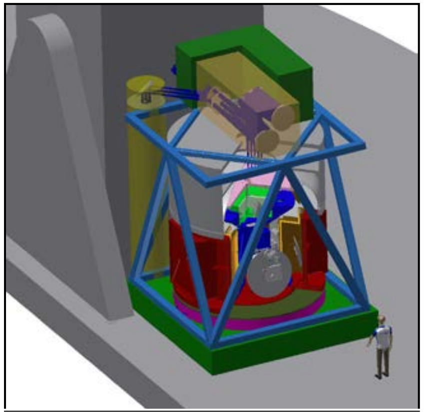
ELT Design


Lasers
Altitude cradles for inclining the telescope
Instrument platforms sit either side of the rotatable telescope
Five-mirror design
1. The 39.3-metre primary mirror collects light from the night sky and reflects it to a smaller mirror located above it.
2. The 4-metre secondary mirror reflects light back down to a smaller mirror nestled in the primary mirror.
3. The third mirror relays light to an adaptive flat mirror directly above.
4. The adaptive mirror adjusts its shape a thousand times a second to correct for distorsions caused by atmospheric turbulence.
5. A fifth mirror, mounted on a fast-moving stage, stabilises the image and sends the light to cameras and other instruments on the stationary platform.
The 2800-tonne telescope system can turn through 360 degrees
Seismic isolators
1
2
3
4
5

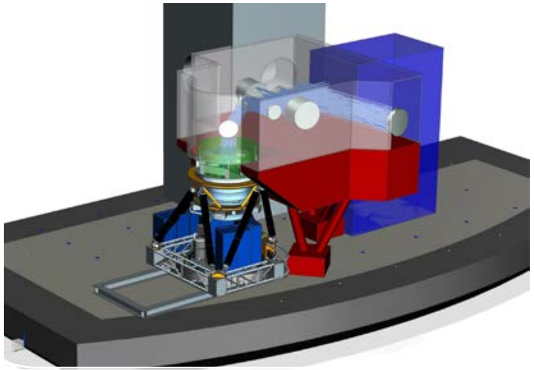


ELT Instrumentation Programme

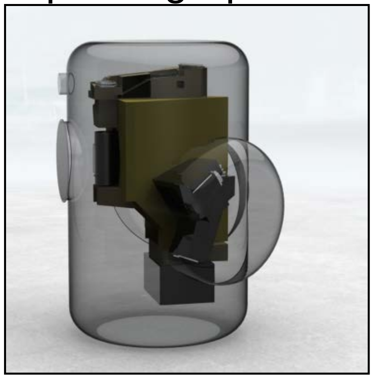
HARMONI
Integral Field Spectrograph



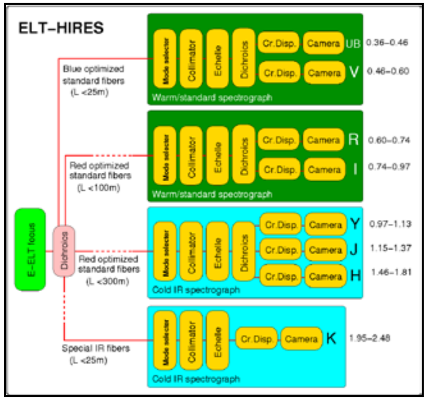
MICADO+MAORY
Imager and single slit spectrograph



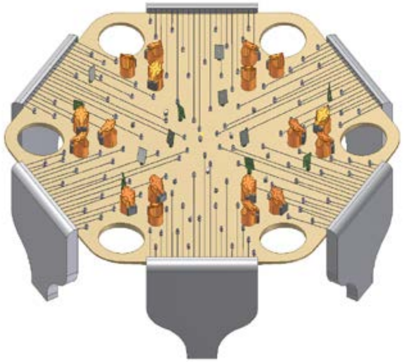
METIS
Mid-IR imager and spectrograph



HIRES
High resolution spectrograph



MOSAIC
Multi-object spectrograph



PCS
Extreme AO imager and spectrograph

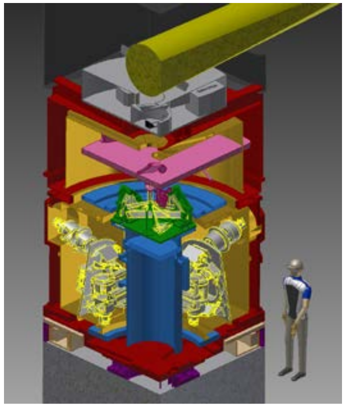
ELT 1st Gen Instrumentation

HARMONI

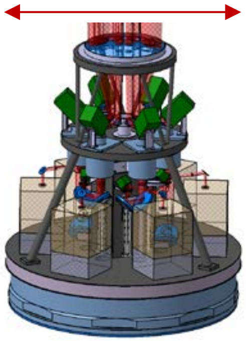
High Angular Resolution Monolithic Optical and Near-Infrared spectrograph

- **“3D” Integral Field Unit spectrograph**
  >> Think “MUSE+KMOS”
- Covering **optical** (0.47μm) to **near-IR** (2.45μm)
- Resolving power from R=3500 to 20000
- **Range of spatial scales** with field of views from 9”x6” to 0.8”x0.6” and 32000 spatial pixels
- From **seeing limited observations** down to the **diffraction limit**
- with SCAO and LTAO
  - A factor of ~>100 in size scales

Survey ~50 Ultra-Luminous infrared galaxies discovered by the *SPITZER* space telescope
mass, velocities of gas and stars, details of star formation



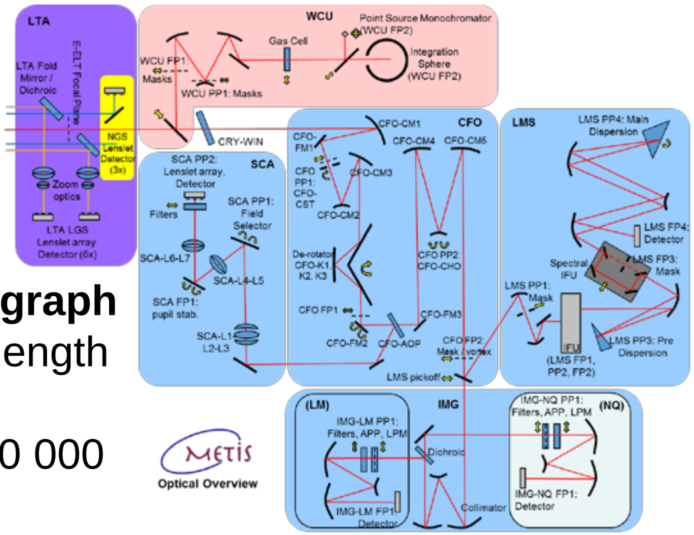
Quarter view of the HARMONI spectrometer cryostat. More than 4m in diameter, cooled to ~ -150˚C.



HARMONI-LTAO concept

ELT 1st Gen Instrumentation

HARMONI
METIS

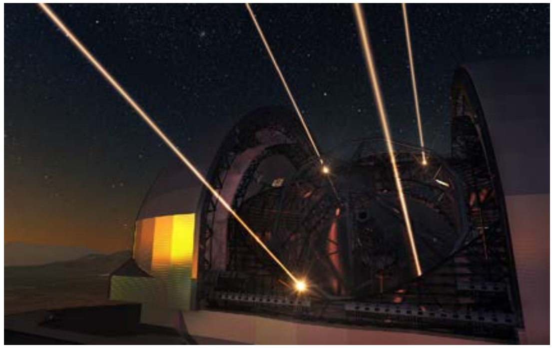


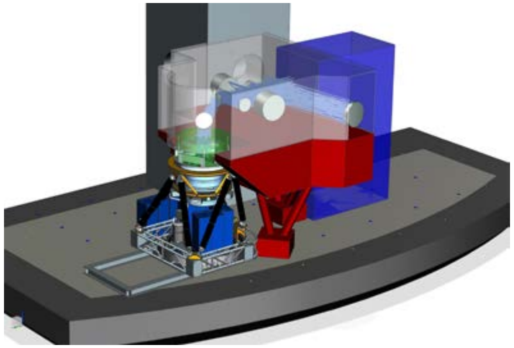
- **Single conjugated adaptive optics fed imager** (10”x10” FOV) **and (3D) spectrograph**
- Covers the **thermal / mid infrared** wavelength range from 3µm to 19µm
- Spectral Resolving power from ~100s-100 000 (with IFU)
- **Coronography** for observations of exoplanets, disks

ELT 1st Gen Instrumentation

HARMONI
METIS
MAORY and MICADO

- **Multi-conjugate AO system** using **6 laser guide stars and 3 natural guide stars**
- **1 or 2 deformable mirrors in addition to ELT M4** to correct atmospheric turbulence
- **Single-conjugate AO** as Joint development between MAORY and MICADO, managed by MICADO
- Optical beam can feed MICADO or second instrument port

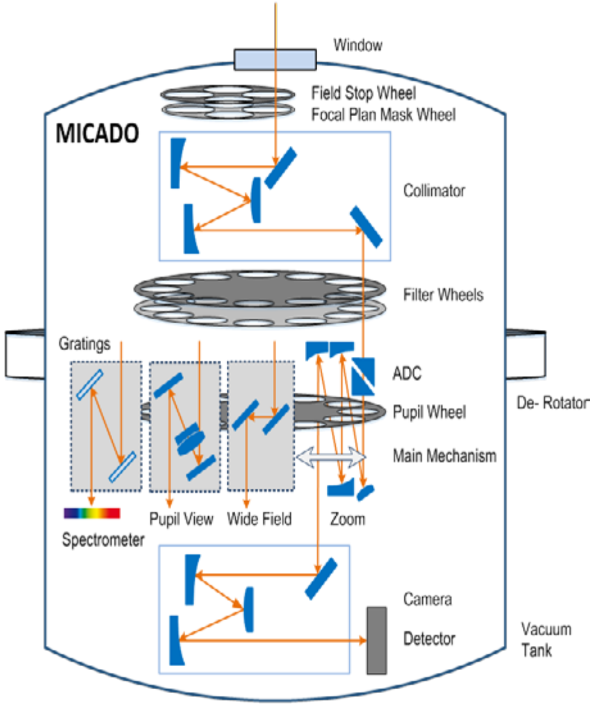




ELT 1st Gen Instrumentation

HARMONI
METIS
MAORY and MICADO

- **Imaging** from 0.8-2.4µm, > 30 filters, an array of 3x3 detectors with 4096x4096 pixels each. Pixel scales of 4mas (FoV ~53”) and 1.5mas (FoV ~20”)
- **Astrometric imaging** to 50µarcsec precision across whole imageSpectroscopy for single compact objects, two settings (0.8-1.4µm and 1.5-2.4µm) at spectral resolving power ~8000.
- **Coronagraph plus single conjugate AO**
- **Time Resolved Astronomy** as fast as 4ms



AO Experience on-site

- After more than 15 years performing operations with AO/Laser systems, staff has good knowledge of current techniques and awareness of meteorological conditions for operations
- Most of this background is born from the operations itself
- Specificities are so broad, that dedicated training has to be provided
- Existing know-how (TIOs):
  - 8 operators are usually working in UT4 (MUSE, HAWKI, SINFONI,LGSF)
    - 4 of them are the main supporters for AOF installation and commissioning (4LGSF, GRAAL, GALACSI)
  - One specialist in meteorological data analysis

Experience on-site

- AO and UT-VLTI Instruments require skills about AO techniques and meteo constrains (8 out of 17 Instruments)
  - Not all operators have internalized those requirements
  - For other instruments, Seeing and Transparency are the main drivers for selecting the observations

GOAL: All operations staff should be available for AO/ELT Operations by 2022

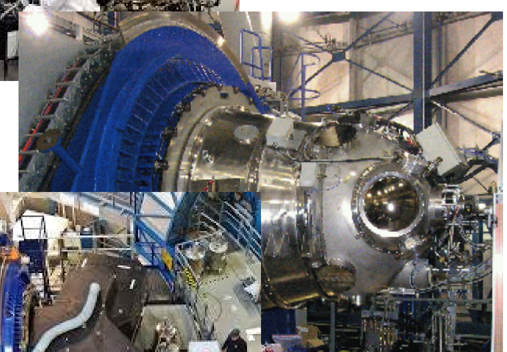
Current UT4 operators to be fully certified by 2018

Certification Campaign for rest of TIOs (2019-2022)

AO systems at VLT

INSTRUMENTS



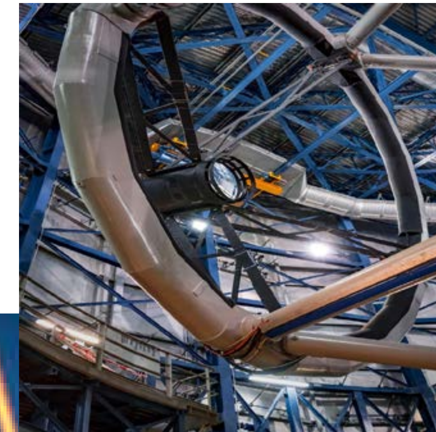



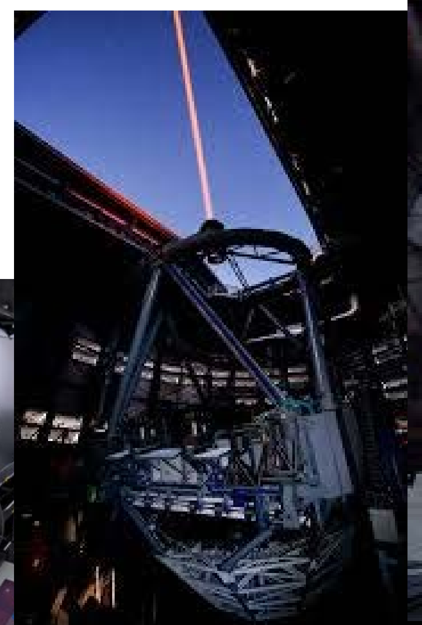

- NAOS VIS+IR WFS (SCAO)
  - NACO (Nasmyth Adaptive Optics System (NAOS) Near-Infrared Imager and Spectrograph (CONICA)
  - SINFONI (Spectrograph for INtegral Field Observations in the Near Infrared)
- MUSE (Multi Unit Spectroscopic Explorer)
  - GALACSI
- HAWK-I (High Acuity Wide field K-band Imager)
  - GRAAL (GLAO)
- SPHERE (SCAO & XAO) (Spectro-Polarimetric High-contrast Exoplanet Research)
- VLTI Instruments
  - AMBER, PIONIER, GRAVITY

AO systems at VLT

SYSTEMS / SUBSYSTEMS

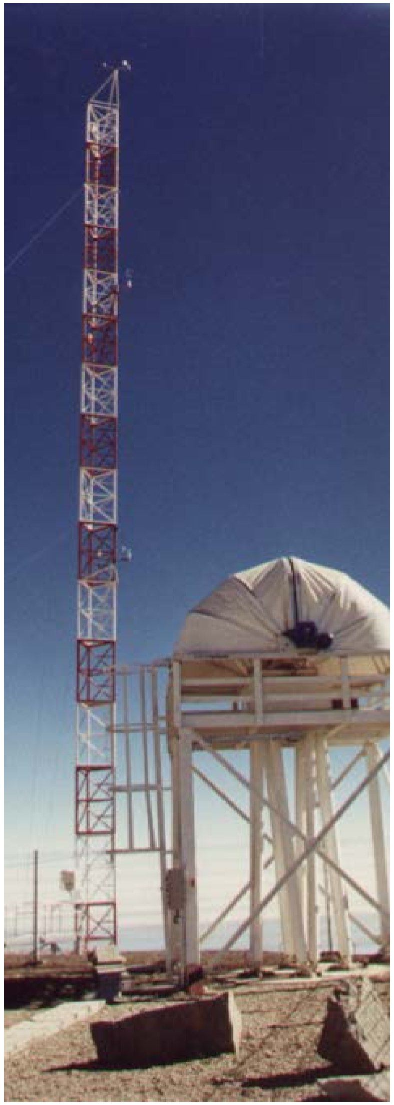
- MACAO VLTI (VIS WF)
- CIAO VLTI (IR WFS)
- LGSF / 4LGSF   (Laser Guide Star Facility)
- DSM (Deformable secondary Mirror – UT4)





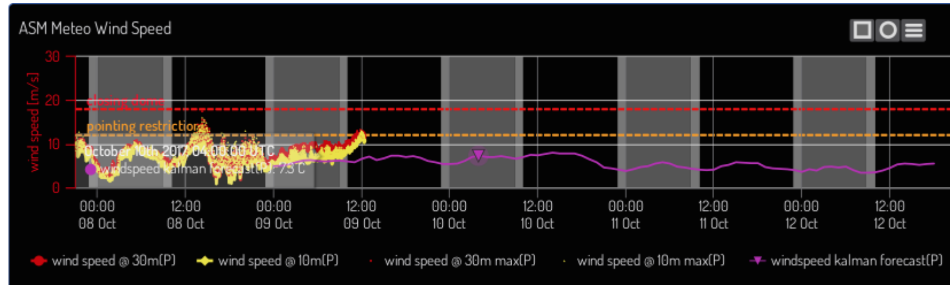
Meteorological data at VLT

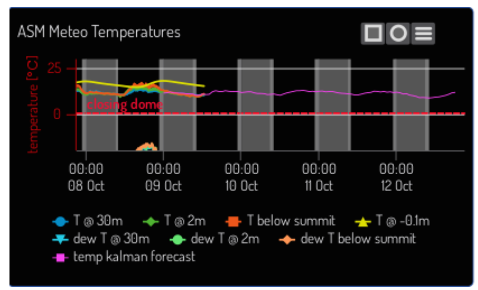
- MASS - DIMM
  - Turbulence velocity/altitude (7 layers), Seeing, Coherence Time, Isoplanatic Angle, relative flux variation
- SLODAR
  - Turbulence in Surface Layer (10 level up to 500m), Seeing, GL fraction (300/500 mts)
- LATHROP (Radiometer)
  - WV and sky background temp
- STEREO - SCIDAR (ELT project)
  - HR turbulence Profiler (300 Layers – 32Km
- METEO Tower
  - Ambient and Dew Temperatures, HR, atm pressure, Wind speed and direction, particle counter

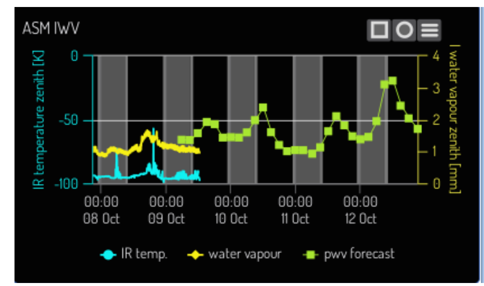


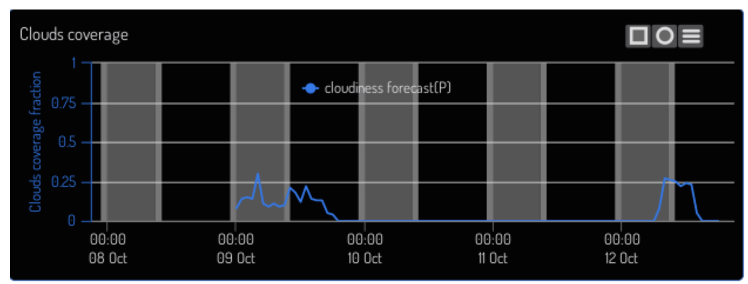
Meteorological data at VLT

- Meteo Forecast
  - Wind Speed
    - Direction and m/s
  - Temperature
  - Water Vapour
  - Clouds Coverage
- Future (?)
  - Coherence Time
  - Seeing
  - Turbulence layers





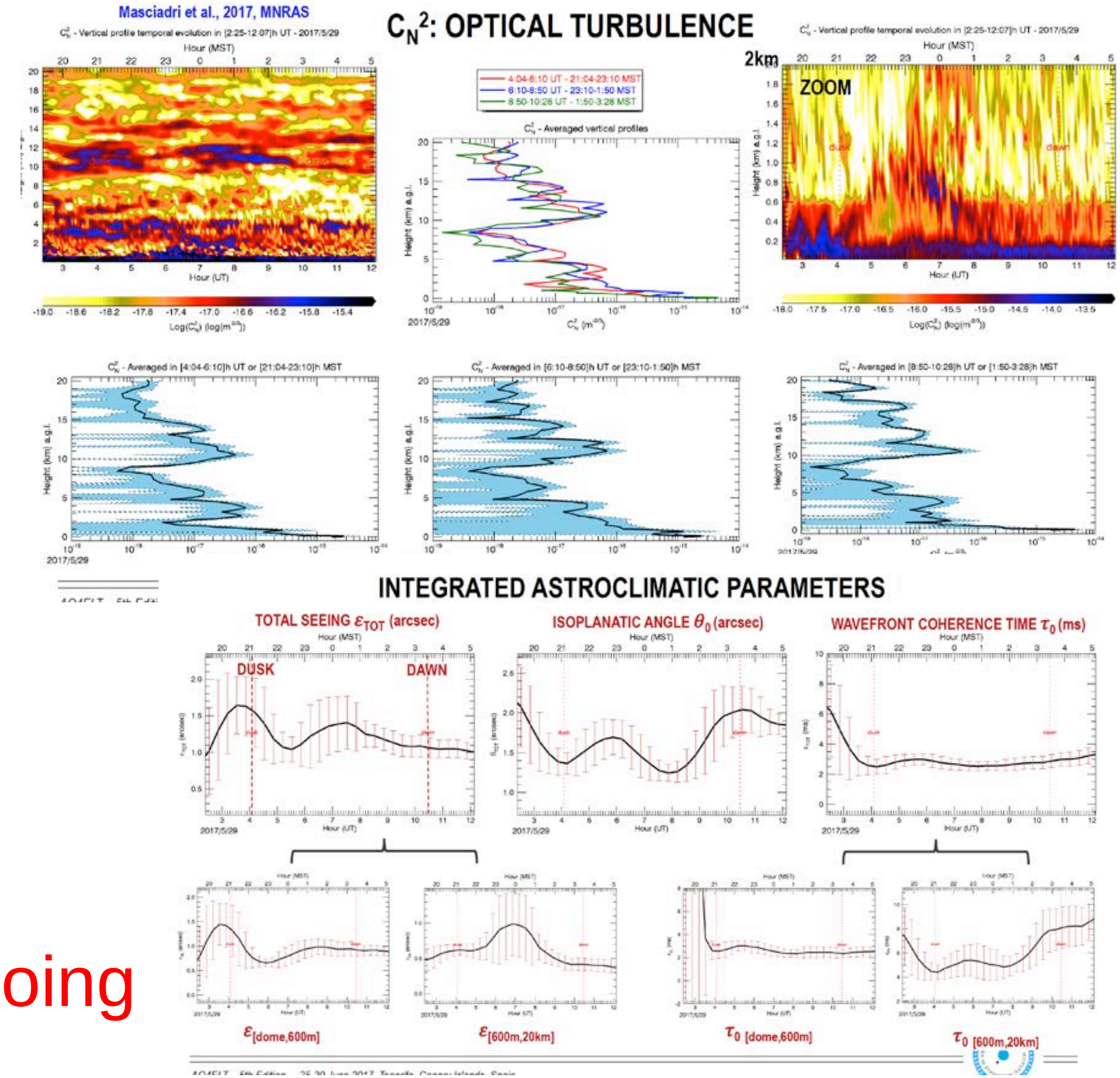




Meteorological data at VLT

- Meteo Forecast
  - ➢ Wind Speed
    - Direction and m/s
  - ➢ Temperature
  - ➢ Water Vapour
  - ➢ Clouds Coverage
- Future (?)
  - ➢ Coherence Time
  - ➢ Seeing
  - ➢ Turbulence layers

Studies on-going



The plan

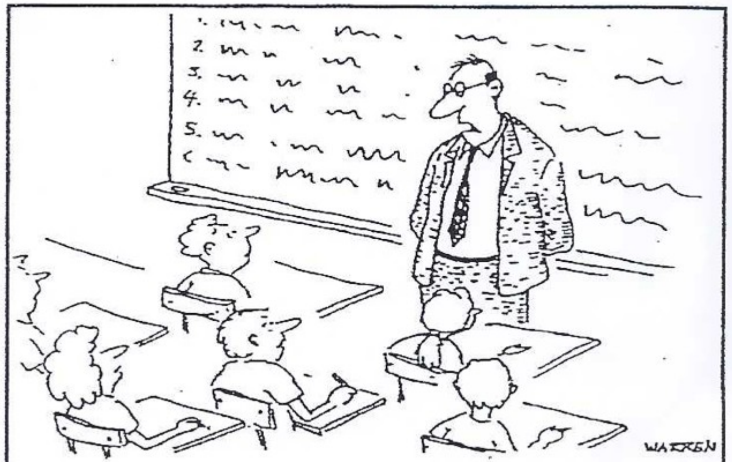
- Identify areas of development
  - Adaptive Optics basics and techniques
  - Astro-meteo
- Identify needs for astronomical observations decision-making process
- Identify an interdisciplinary group for AO facility maintenance and support on-site
  - System and Optics, Laser Specialists, Instrumentation, Electronics, Astronomers and Operators

UT4/AOF Operations Team

ASTROMETEO-IOT

The plan

- Equalize high level support
  - Design and implementation of a HL training process (i.e. ESO-PUC)
- Generates a general training process for all other actors
  - By UT4/AOF Operations Team (ideally)
- Foster synergies and hands-on activities during commissioning
- Stablish AOF as a living area that needs constant follow-up and procedures update



'I expect you all to be independent, innovative, critical thinkers who will do exactly as I say'

The plan

- Adaptive Optics Training *(now happening)*
  - High Level Training (w PUC Chile)
    - 2 days of “Basics lectures”, preparing for the laboratory activities
    - 4 days of “Advanced lectures”

Basics in Adaptive Optics
Basics in AO
Basics of AO reconstruction
Basic of optics and atmosphere
Basics of wave-front (WF) correction
Distributed AO (Tip-tilt/High order mirrors)
Basics of Natural Guide Star (NGS) WF sensing
Introduction to AO simulations + written exam #1

The plan

- Adaptive Optics
  - High Level Training (w PUC Chile)
    - 2 days of “Basics lectures”, preparing for the laboratory activities
    - 4 days of “Advanced lectures”

Advanced lessons
AO history and challenges
Advanced lesson on WF correction
Tomographic AO principles
Written exam #2 (30 min) & Exams correction
Layered turbulence model
Advanced lecture on NGS WF sensing
Extreme AO specificities Vibrations mitigation

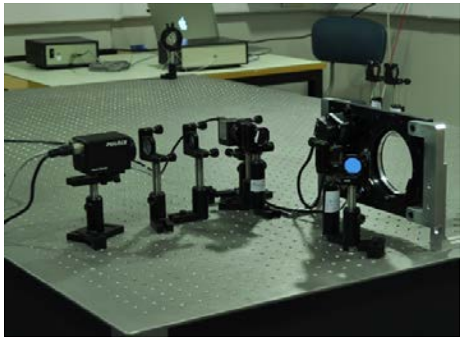
The plan

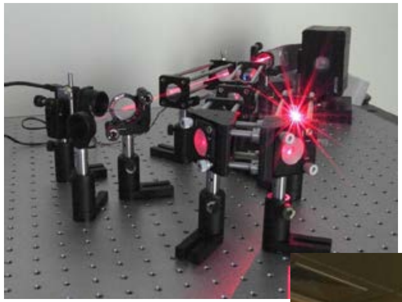
- Adaptive Optics
  - High Level Training (w PUC Chile)
    - 2 days of “Basics lectures”, preparing for the laboratory activities
    - 4 days of “Advanced lectures”

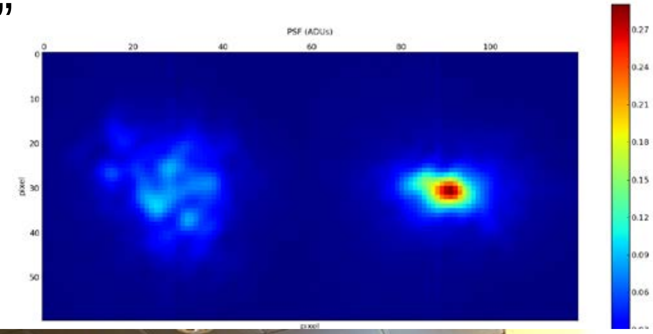
Advanced lessons (cont)
From Kolmogorov to von Kármán
Laser Guide Star WF sensing
Advanced reconstruction & control
Understanding an AO system diagram
Turbulence monitoring
Overview on WF sensing methods
AO calibration AO Simulation tools

The plan

- Adaptive Optics
  - High Level Training (w PUC Chile)
    - 2 days of “Basics lectures”, preparing for the laboratory activities
    - 4 days of “Advanced lectures”







The future plan

more training to come during the next years…

- IOT activities
- ELT Software
- ELT Hardware
- Astrometeo
- PLCs & Control
- Instruments
- Operations

ELT will enable exciting scientific capabilities and strong synergies with JWST, GMT, TMT, SKA, LSST, ALMA and others

Special thanks to:
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