MAVIS:
EXPLOITING WIDE FIELD AO IN THE VIS RANGE

EXPECTED PERFORMANCES & CURRENT PROJECT STATUS

Valentina Viotto
on behalf of the MAVIS consortium (PI: François Rigaut)

Workshop Nazionale «Astrofisica di Frontiera con l'Ottica Adattiva Italiana» Roma 17/19 Febbraio 2020

WHAT IS MAVIS?

MCAO

ASSISTED

VISIBLE

IMAGER &

SPECTROGRAPH

Uses VLT UT4 AO Facility

- Existing deformable secondary
- Existing laser guide star facility

Instruments:
- MUSE (IFU spectrograph)
- Hawk-I
- ERIS (IR imager and spectrograph)

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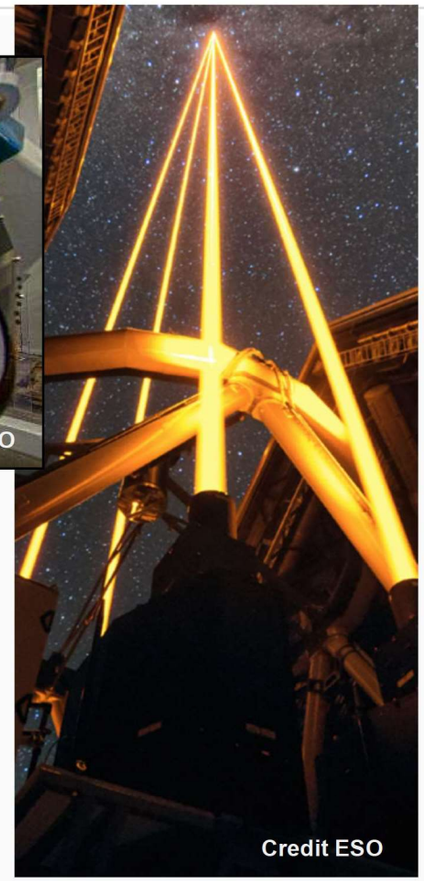


AO Module

- **Visible** (VRI, UB goal)
- **30”** Ø field of view corrected
- FWHM ≈ **20mas** (V band)
- Strehl ratio > **10%** (V band)
- Sky coverage > **50%** @ Gal. pole

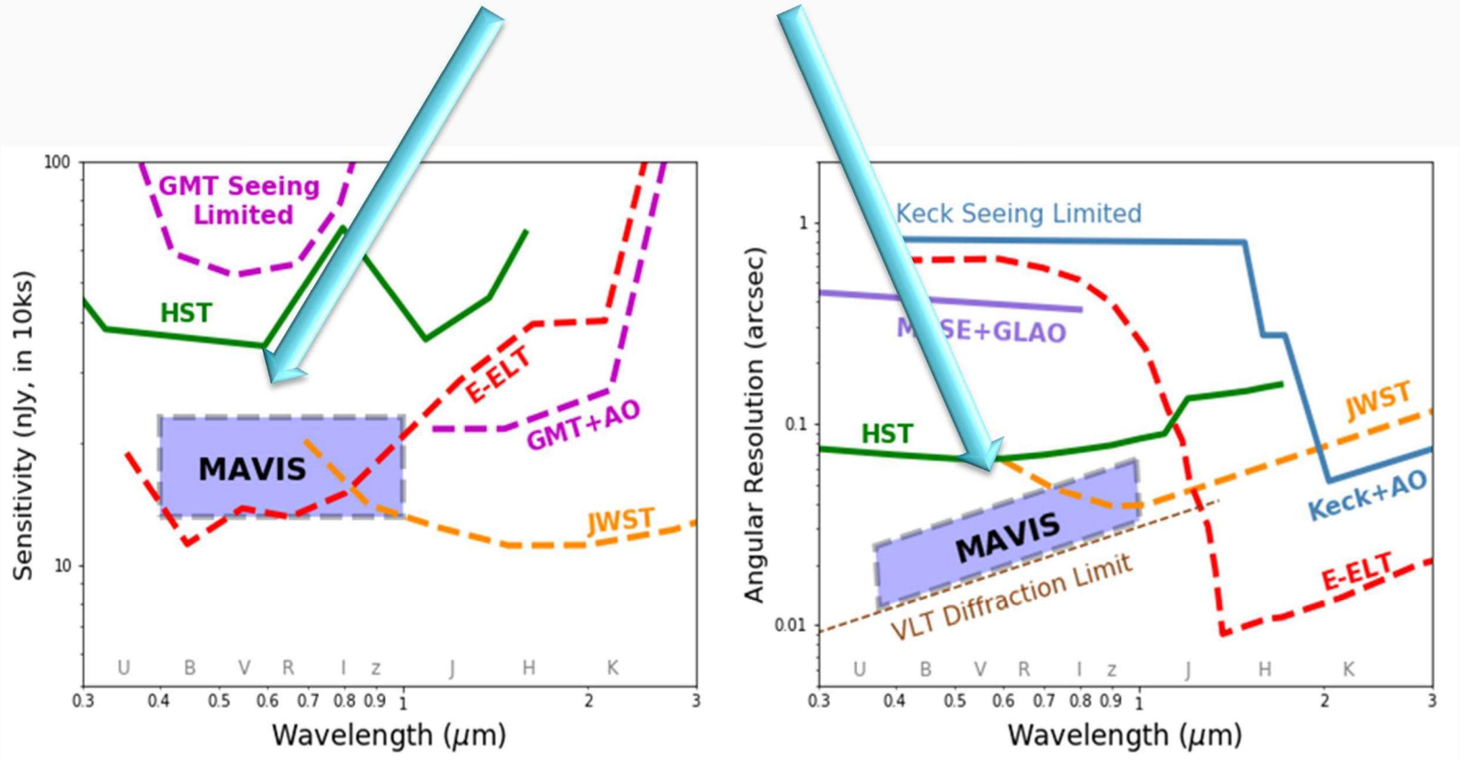
Imager

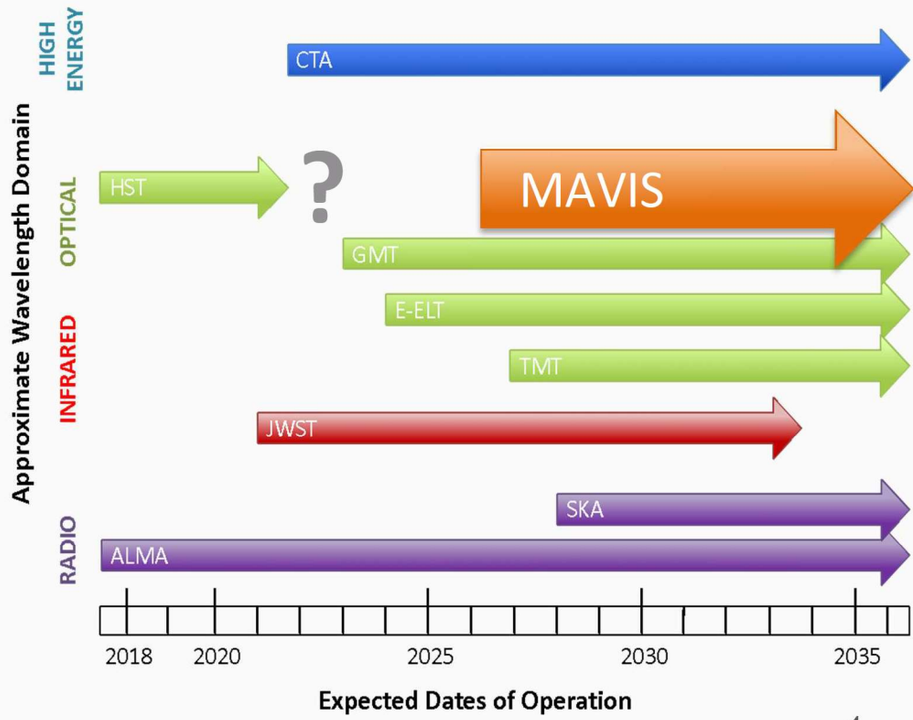
- 30”x30” FoV
- 4Kx4K pixels
- Wide + narrow band filters

IFU Spectrograph

- **25 mas and 50 mas spaxels**
  - 3.5” and 7” FoV respectively
- **~5000 and ~12000** spectral resln modes
- 4 interchangeable VPH gratings

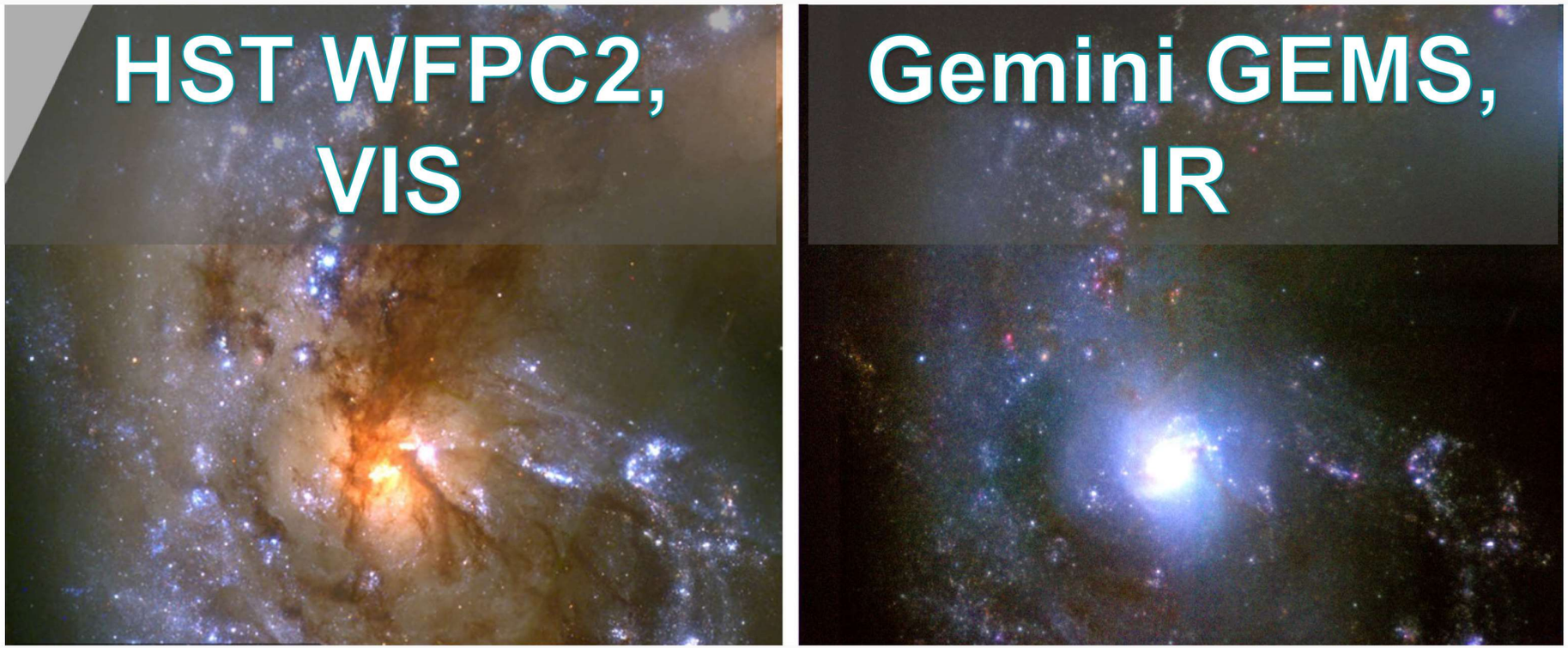
Deeper than HST, Sharper than JWST



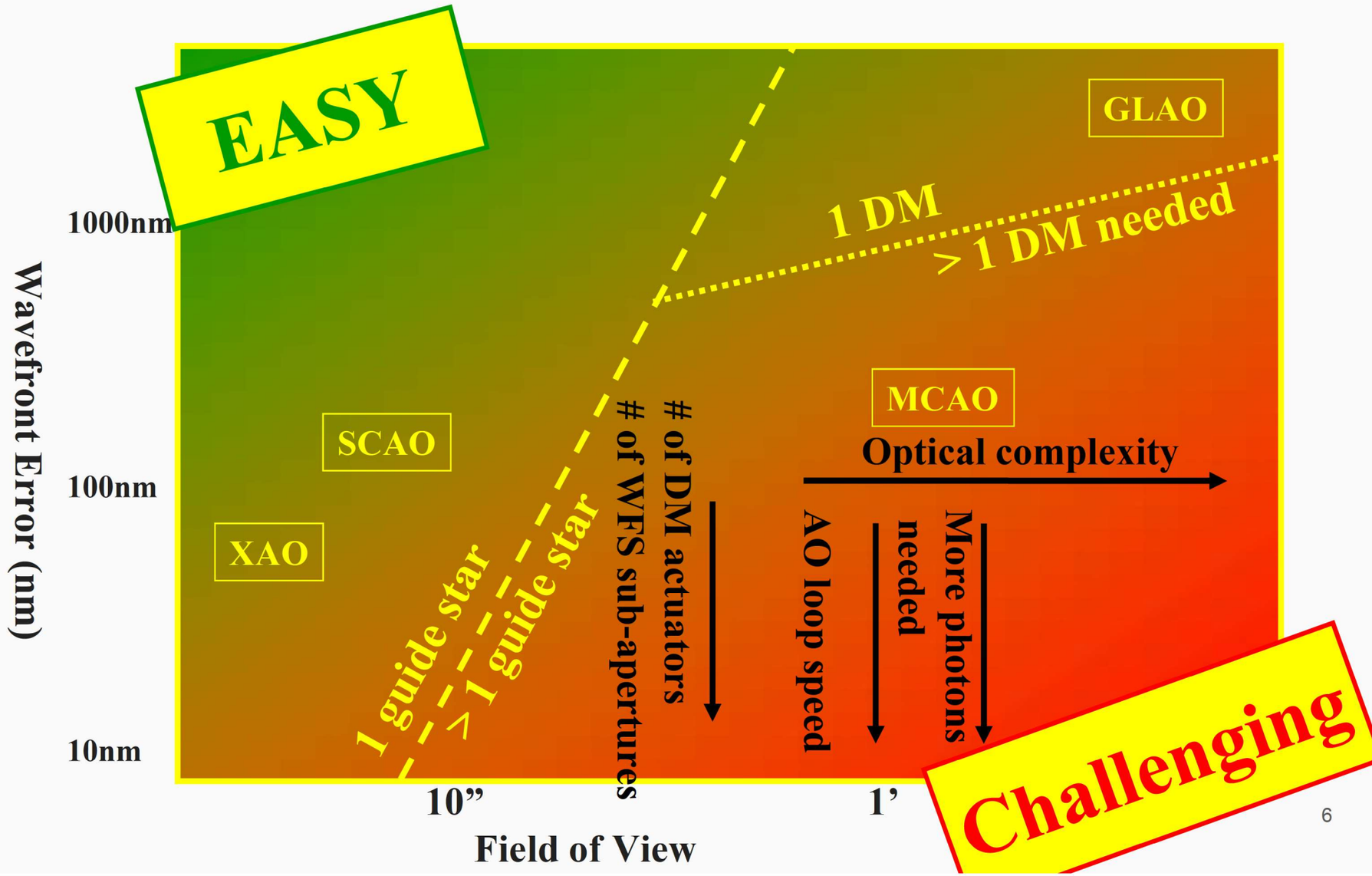


SOME REASONS TO UNLOCK THE VISIBLE WITH AO

- Optical wavelengths are **information-rich**, with many well-understood astrophysical diagnostics
- **Sky background** is x1,000-10,000 times fainter than IR - possible to **compete with space** facilities
- **Detectors** are larger, lower noise, faster frame rates, and cheaper
- **Diffraction limit is smaller!**



MCAO IN THE VIS REGIME



MCAO IN THE VIS REGIME

$$SR \approx e^{-WFE(rad)^2}$$

Atmosphere:

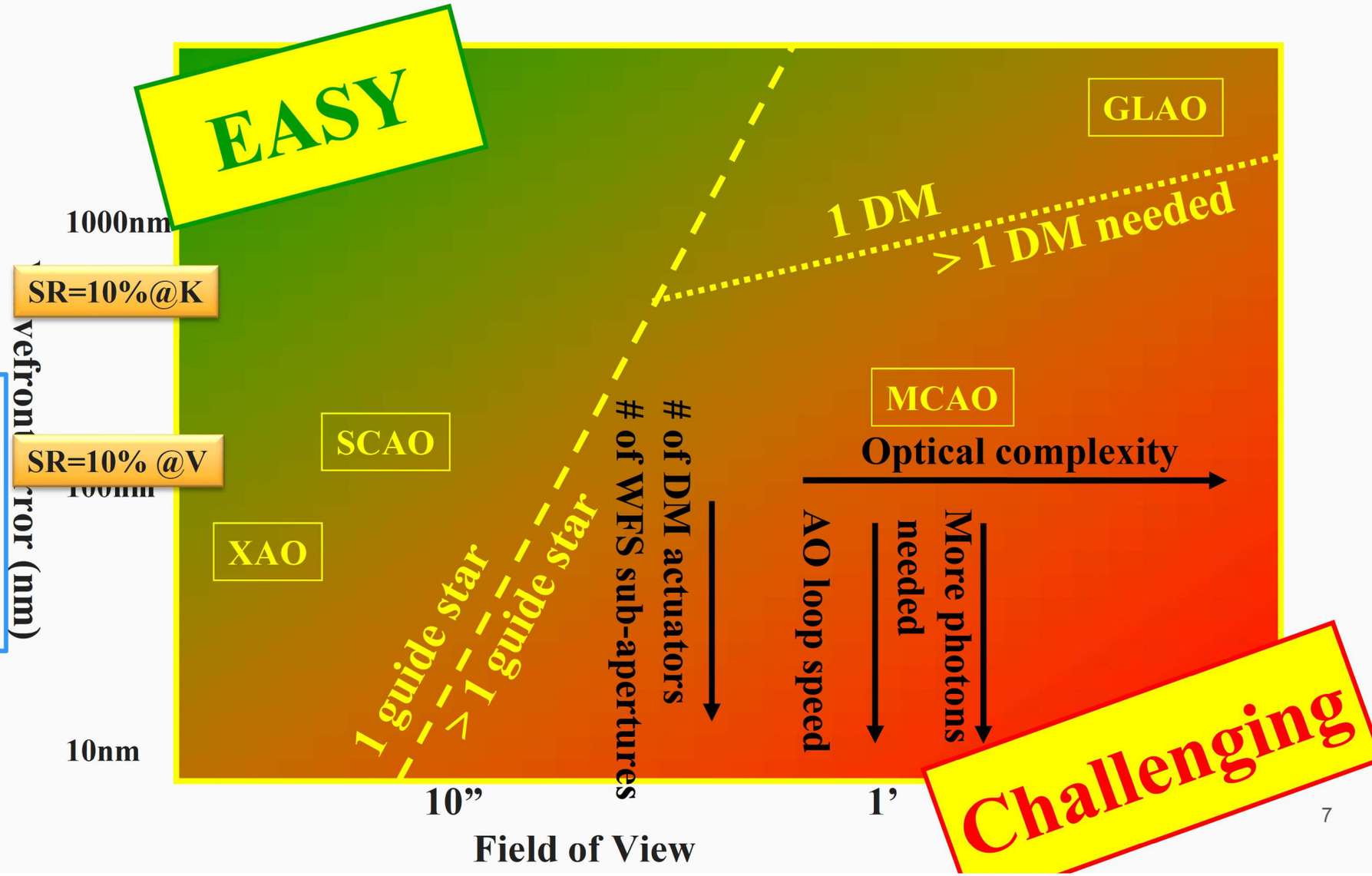
Fried parameter is shorter

(~10cm in V, ~50cm in IR)

Coherence time is shorter

(~10ms in V, ~50ms in IR)

Impact on AO module design

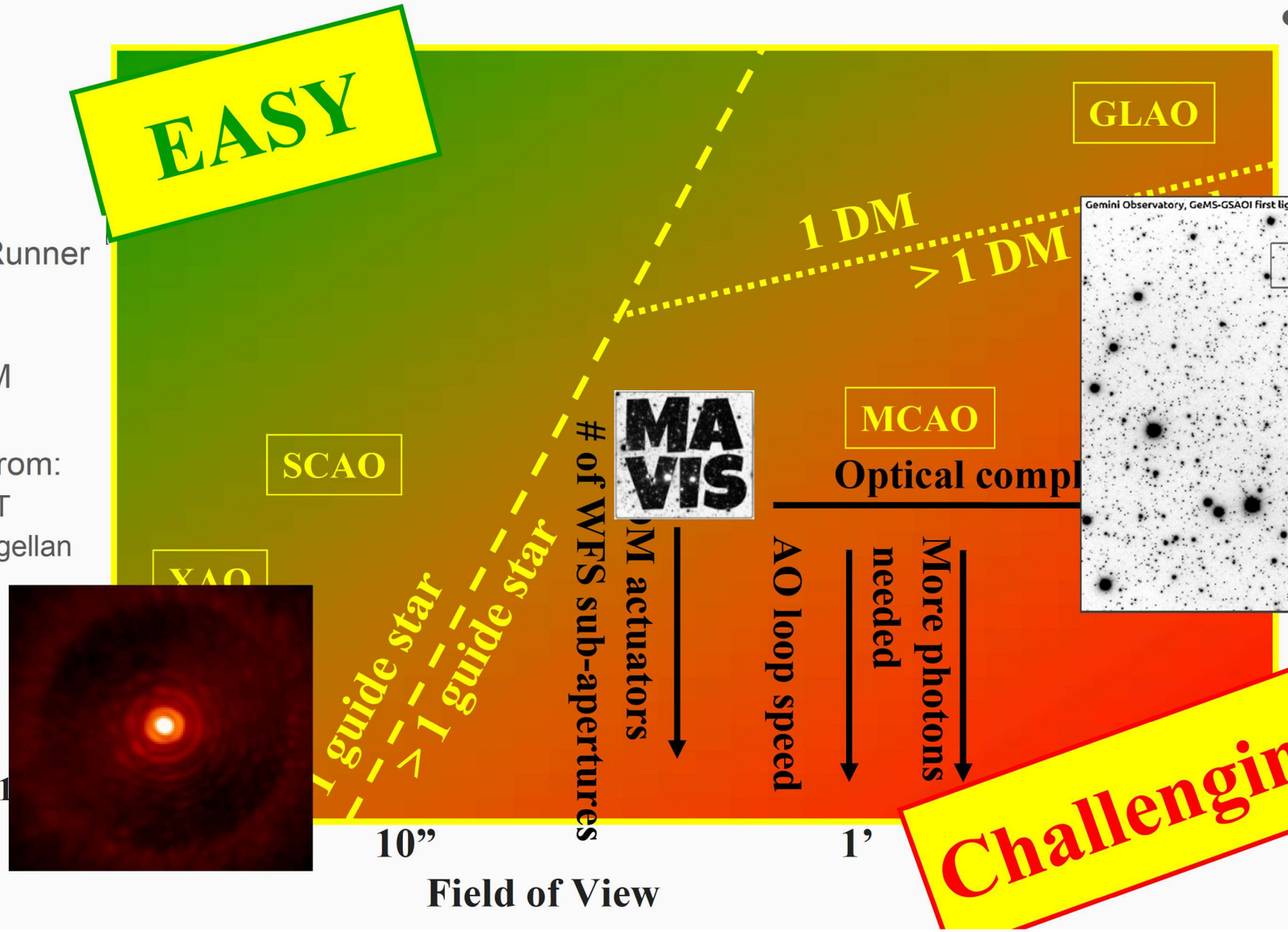


MCAO IN THE VIS REGIME

- SHARK-VIS ForeRunner
  - @650nm,
  - 50%SR,
  - 18mas FWHM

- Similar examples from:
  - SPHERE @VLT
  - MAG-AO @Magellan

- GeMS@GEMINI
  - H band
  - 87”x87”
  - 80mas FWHM



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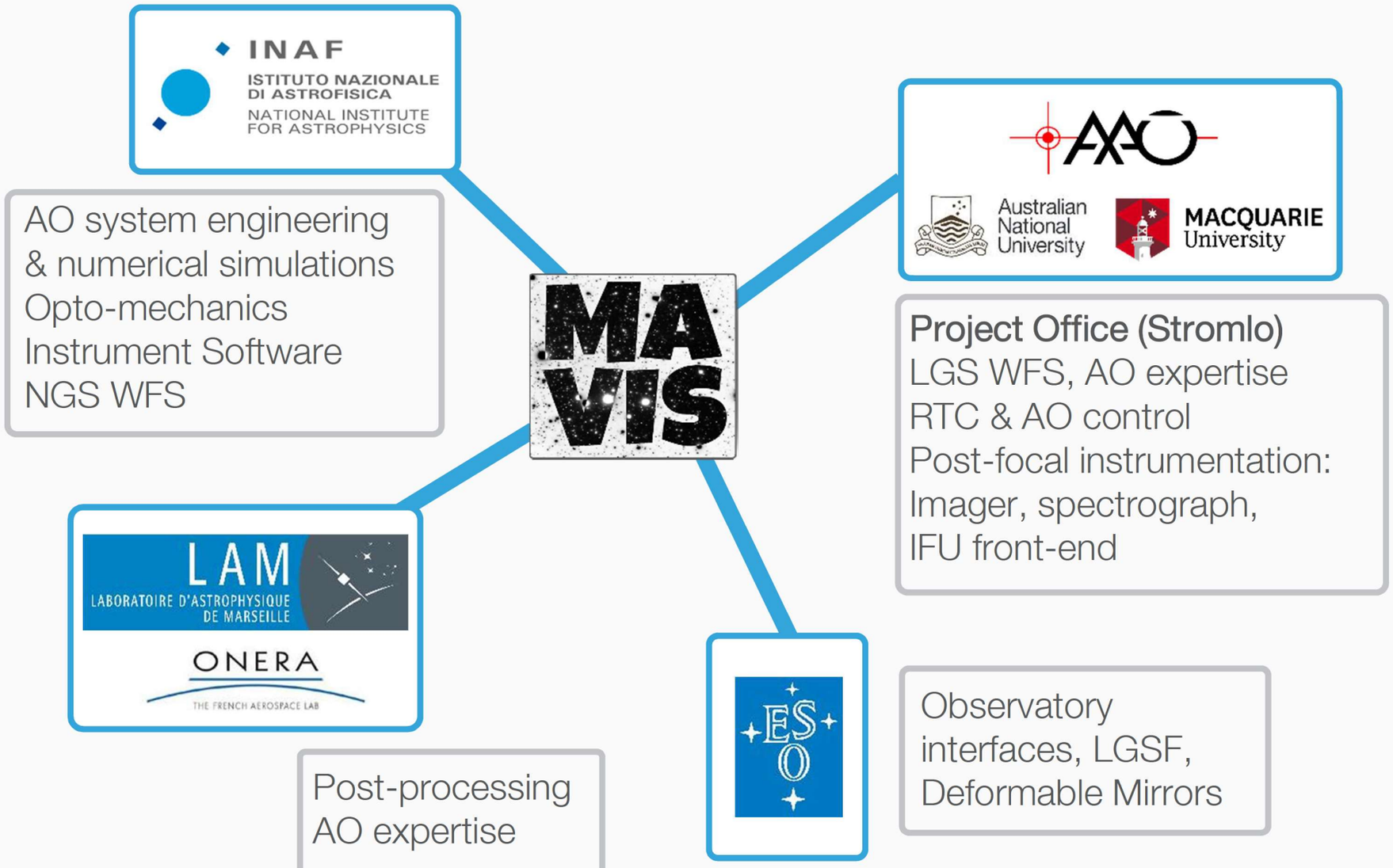
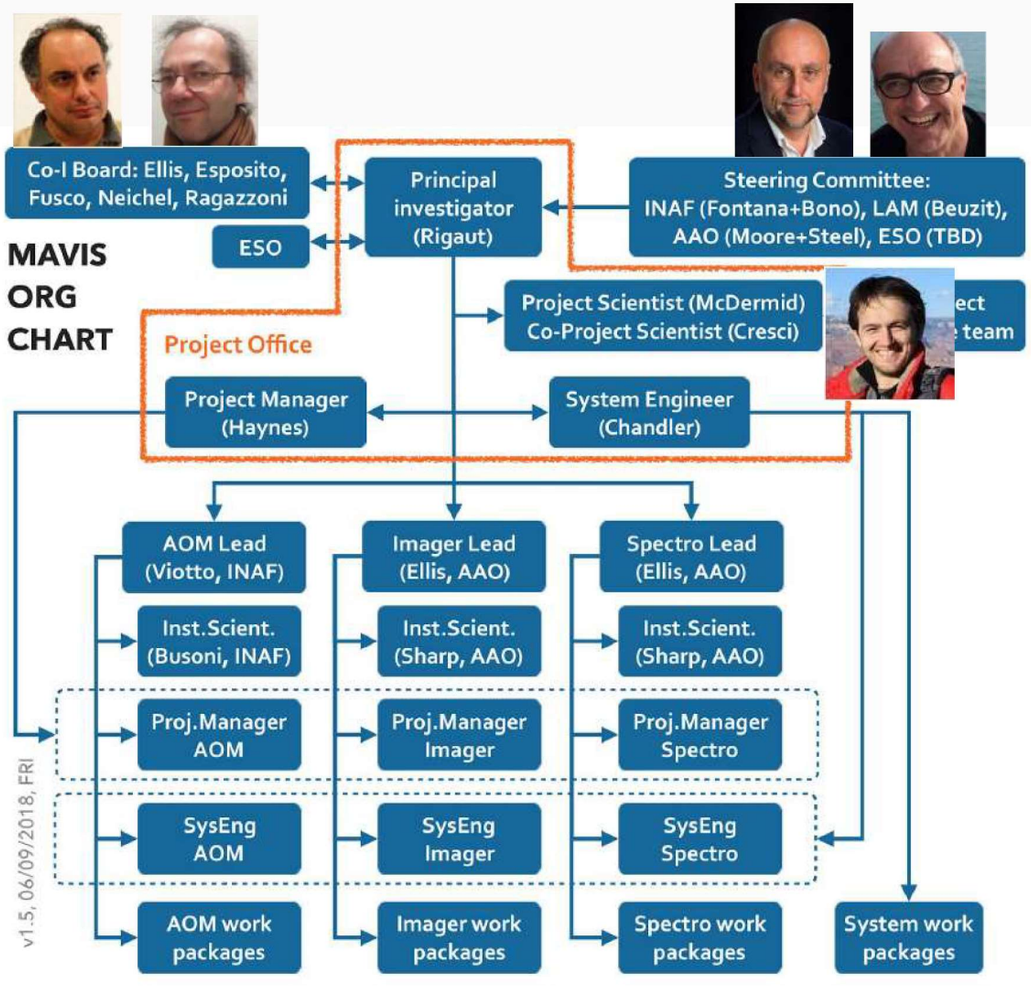
- **Diffraction limit is smaller!** V on an 8m gives same angular resolution as K on an ELT

MAVIS Consortium



INAF INVOLVEMENT IN MAVIS



AAO FTEs	8.60
INAF FTEs	5.70
LAM FTEs	2.00
Total FTEs [0]	16.30

MAVIS project — AAO (Total 2.9 FTE) AAO (2.6), INAF (0.3)

- Lead (FRI) AAO (0.6) [1]
- Management (TBA) AAO (0.7)
- Systems Engineering (DCH) AAO (0.7
- Science (RMD & GCR) AAO (INAF (
- Phase B planing & costing A

MAVIS system — AAO (Total 1.1 FTE) AAO (0.6) INAF (0.5)

- Overall mech. structure AAO (0.2)
- System electronics AAO (0.1)
- Design & concepts AAO (0.2)
- Instrument Control Software I
- Handling tools AAO (0.1)

Other instrument concepts — LAM & INAF (Total 1.25 FTE) INAF (1.0), LAM (0.25)

- BATMAN LAM (0.25)
- Fast Imager INAF (1.0)

AOM — INAF (Total 7.45 FTE) INAF (3.8), AAO (1.9), LAM (

- AO system engineering I
- Project Mngt INAF (0.3
- Optics INAF
- Mechanics
- ADCs AAO (0.15)
- LGS WFSs AAO (0.25) [2]
- NGS WFSs INAF (0.5) / LAM
- Electronics AAO (0.2)
- R Detectors AAO (0.3)
- DM procurement ESO (0)
- AO design & concepts INAF (0.3) / LAM (0.
- AO control & Perf. L (0
- Post processing LAM (0.5)
- RTCs AAO (0.4)
- AO S/W INAF (0.1)
- Tools & spares INAF
- AO MAIT INAF (0.2)
- Calibration strategy INAF (0.25

Imager — AAO (Total 1.2 FTE)

- Project Mngt AAO (0.2)
- Design & SysEng AAO (0.3)
- Optomech AAO (0.3)
- Detectors & electronics AAO
- DR pipeline AAO (0.2)

Spectrograph — AAO (Tota

- Project Mngt AAO (0.3)
- Design & SysEng AAO (0.6)
- Optomech AAO (0.6)
- Detectors & electronics A
- DR pipeline AAO (0.2)

Cal. unit — AAO (Total 0.4 FTE) AAO (0.3), INAF (0.1)

- Design AAO (0.1), INAF (0.1)
- Optomech AAO (0.15)
- Electronics AAO (0.05)

AAO | INAF | LAM

Notes:
0: FTE is here over the 15 months of the proj
1: Part of person time in other work package
2: Includes WFS holder flange
3: Starts at focal plane, includes DualAO-DM

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MAVIS: WHERE ARE WE?

2018

2019

2020

- Proposal to ESO
- Phase A:
  - Lots of interest from science community (you)
  - Project running on time and in budget
  - Successfully passed mid-term review (MTR) October 24-25

Completed activities
- Trade-off several implementation choices
- Investigate the feasibility of MAVIS' TLRs
- Converge on a baseline design
- Set up Man, SysEng and Commun. tools

On going activities
- Consolidate/Update baseline design
- Sync all disciplines to baseline
- Next step of numerical simulations to further performance estimations and inform design details.

  - Final phase A review planned 25 May 2020

2021

- Phase B to start early 2021

⋮

2026

- Current schedule calls for first light end of 2026, in line with E-ELT (...).

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DESIGN DRIVERS AND HIGH LEVEL PRINCIPLES

- Very ambitious TLRs and thus **tight error budget**. Based on, and kept affordable by, the **existing AOF**:
  - Constrained by **existing DSM** (e.g. set the fitting error)
  - Constrained by **existing LGSF**
- Performance TLR means:
  - Tomographic error → we need 8 (6) LGSs
  - Generalised fitting → we need 2 post-focal DMs
- Ambitious in sky coverage
  - >50% @ Galactic Pole
  - Expressed in Encircled Energy loss in the V band (less than 50%)
- Post-Focal Instrumentation not risky technically. **Cost an issue though.**

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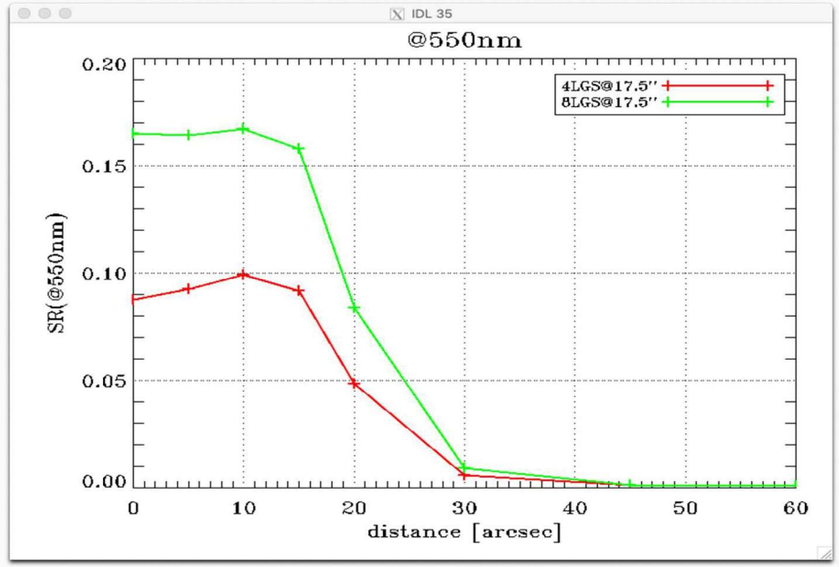
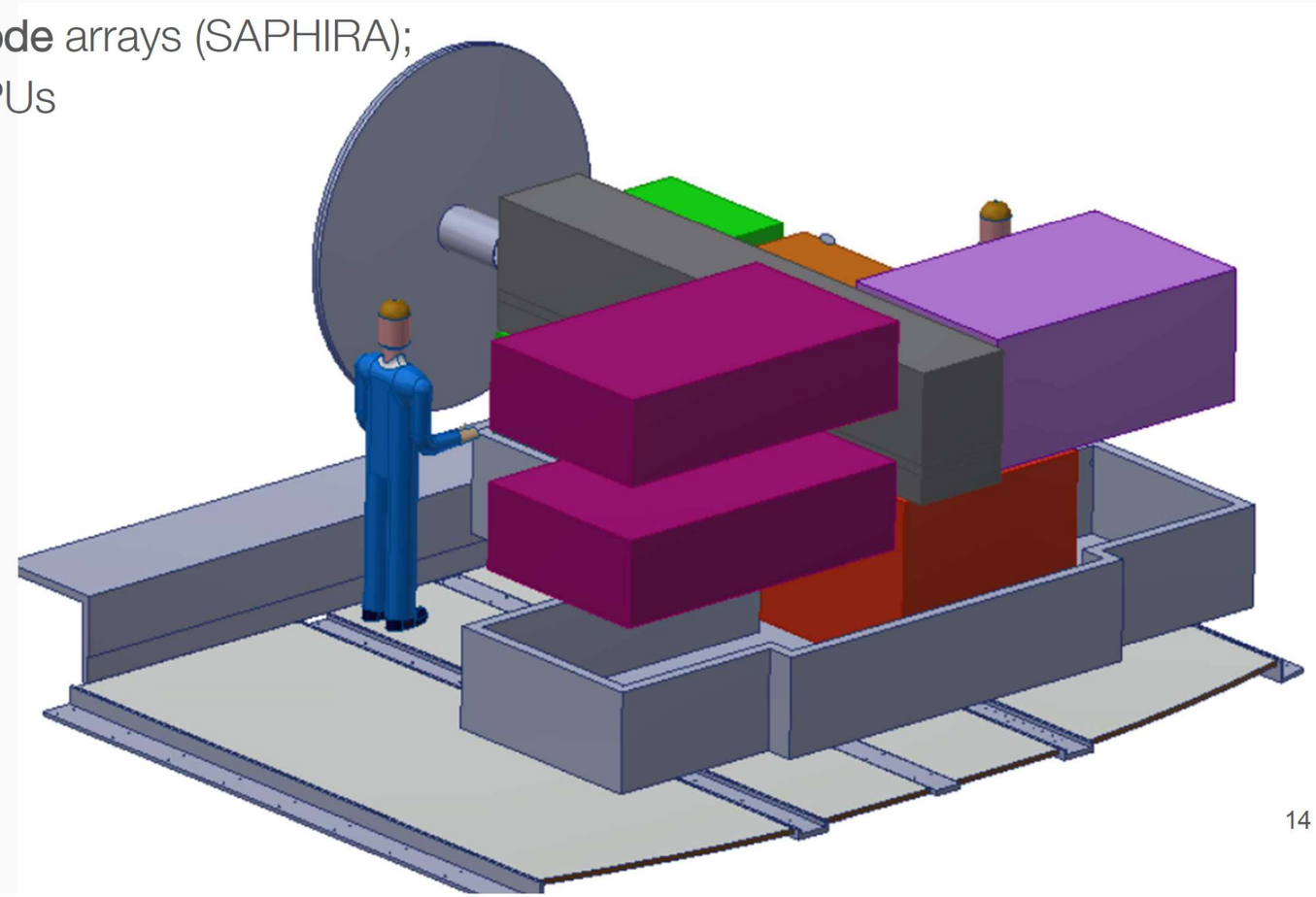


MAVIS In Numbers

- **8 Laser Guide Stars** (4 lasers, 80W of yellow light);
- **3 Deformable Mirrors** including 5000 actuators;
- **8 visible Electron-multiplied CCDs** (EMCCDs);
- **3** state-of-the-art **infrared avalanche photodiode** arrays (SAPHIRA);
- **1 Real-Time Computer** with 8 V100 nVidia GPUs
- **2 Spectrograph arms**, with 2 9kx9k CCDs
- **1 imager**, with a 4kx4k CCDs
- **~200 FTEs**
- **8 years** from Kick off to first light
- **~€12M** hardware
- **10 hours** time difference



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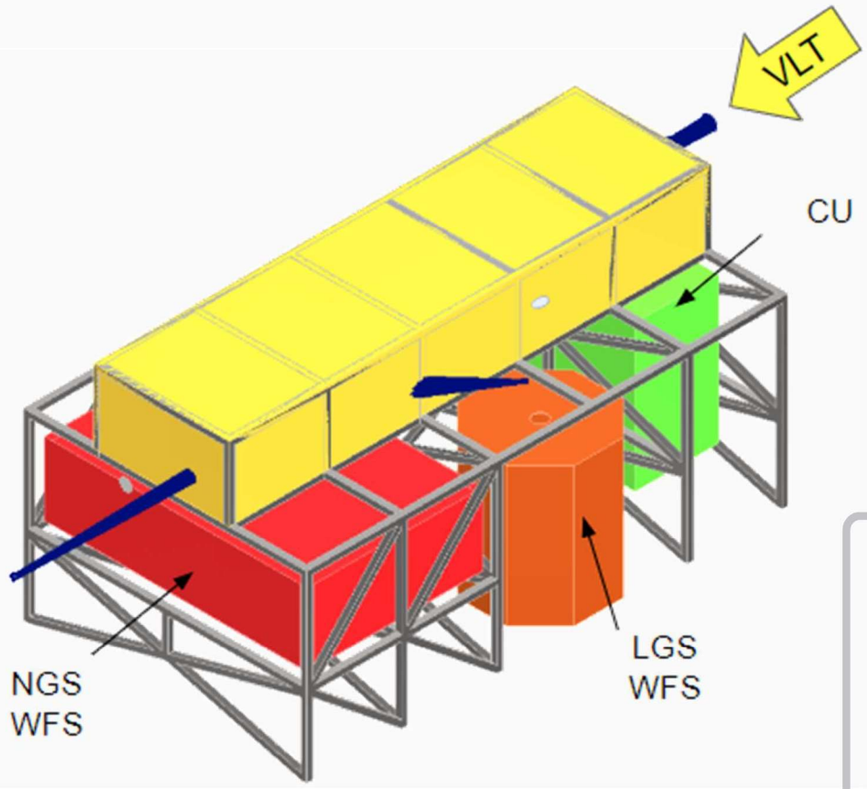
AOM Optical Design & Concept



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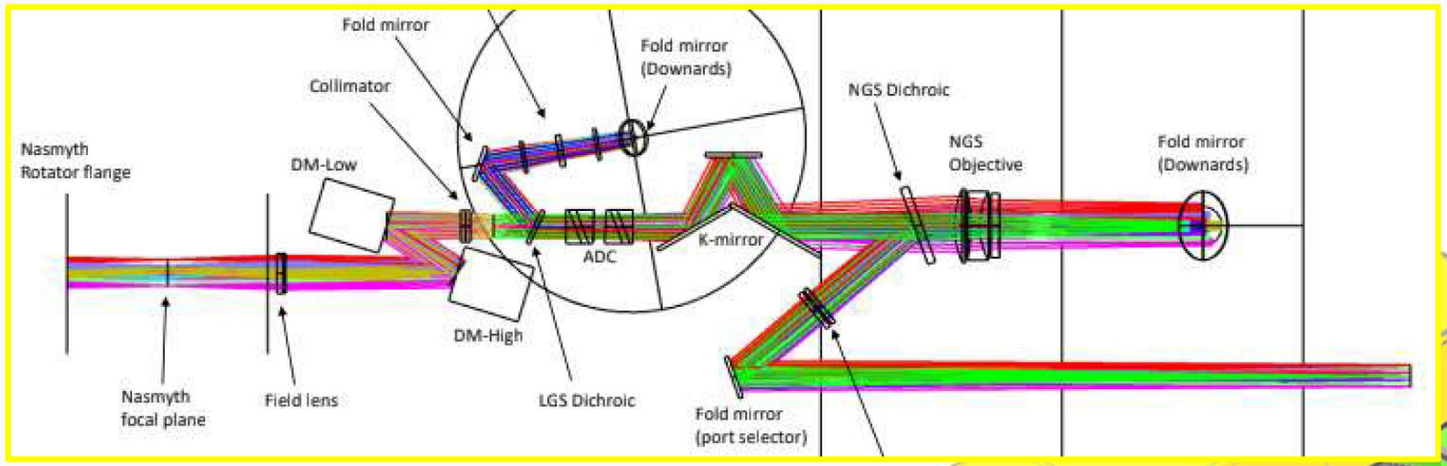

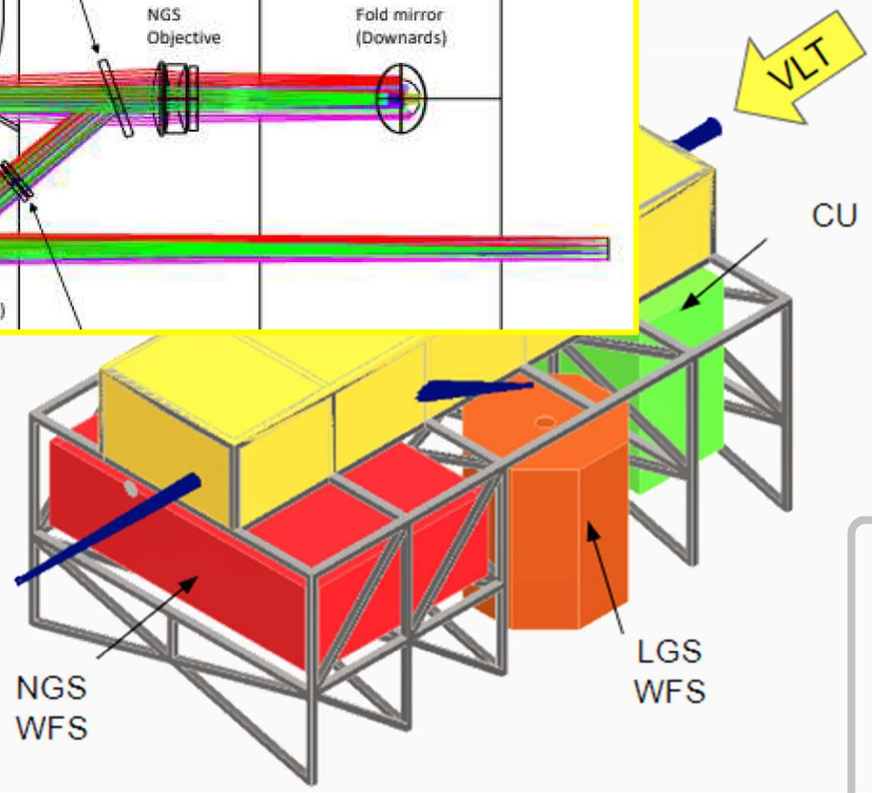

Post Focal Relays

- provides input for CU
- corrects for atmospheric dispersion
- provides field de-rotation (NGS+SCI)
- re-images meta-pupils onto DMs
- feeds the NGS WFS (2 arcmin NIR FoV)
- feeds the LGS WFS with focused FoV
- delivers a 30” diameter FoV to the instruments (VIS band)
- provides at least 2 output ports and includes means to switch

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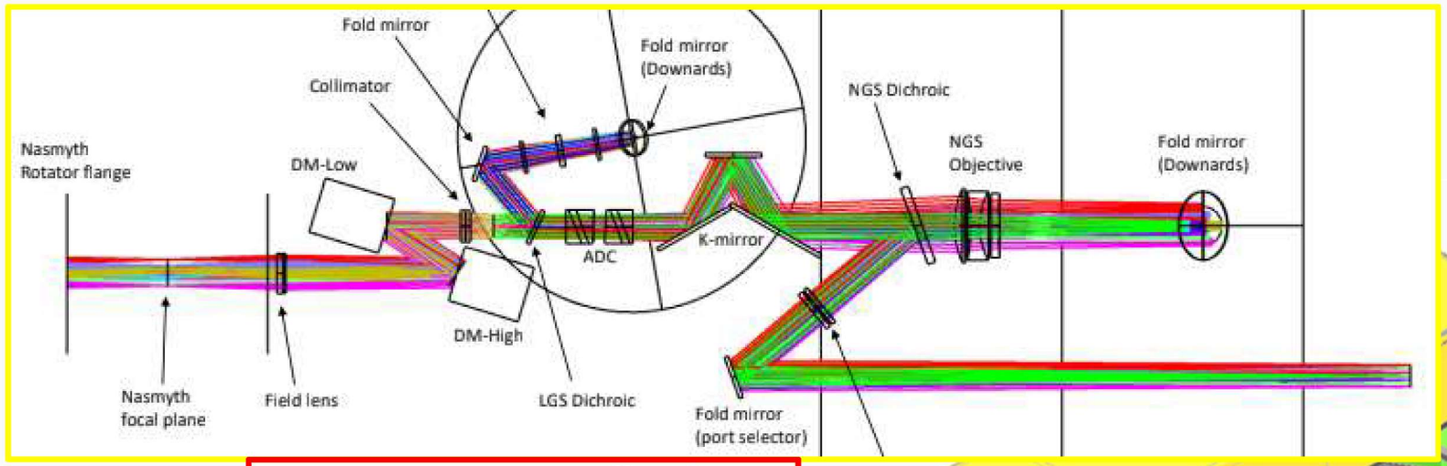
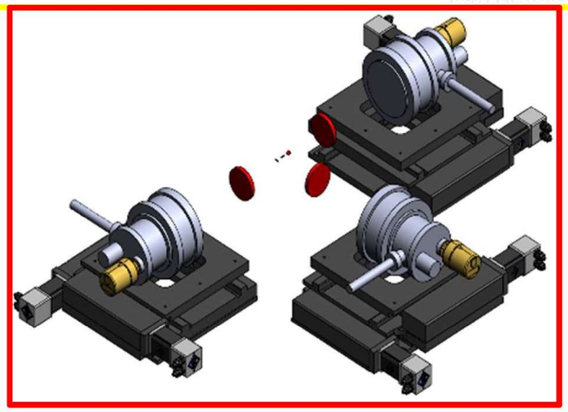
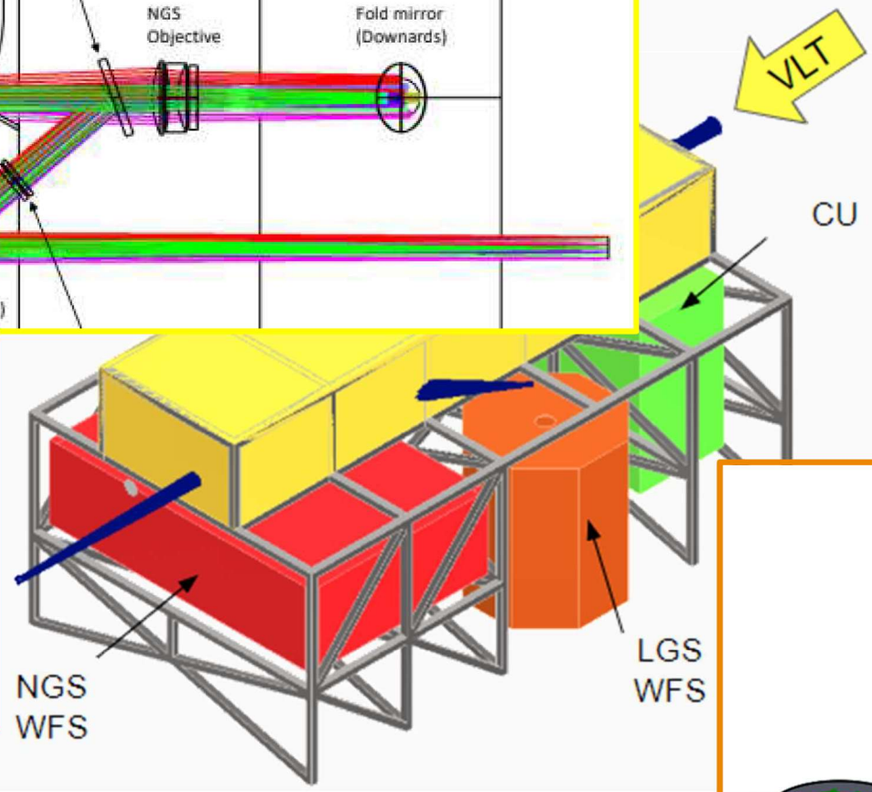
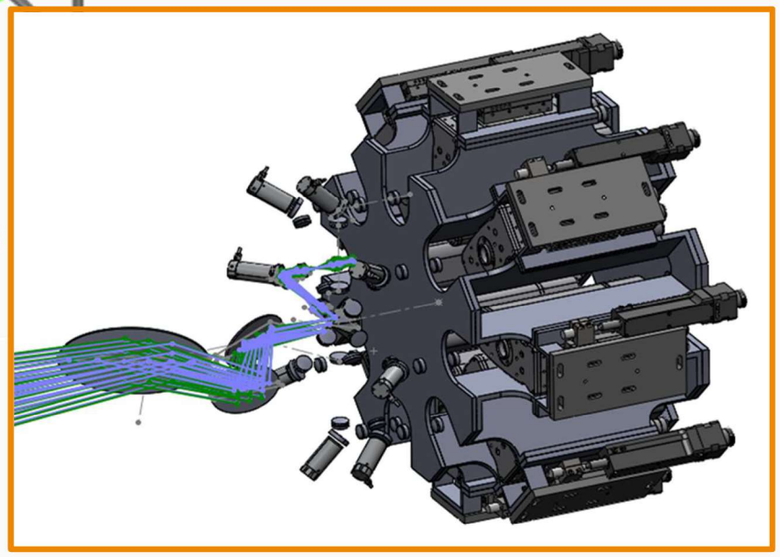






LGS WFS

- 8 LGSs (@17.5” radius)
- Type: S-H WFS
  - 40x40 sub-ap pupil sampling
  - #pix/subap 6x6
- includes FP steering mirrors
- includes means for FoV derotation



NGS WFS

- Up to 3 NGSs can be sensed (J+H bands)
- 2 arcmin diameter unrestricted patrolling FoV
- 5 arcsec Pick-off FoV for single NGS
- Tomographic truth sensing included

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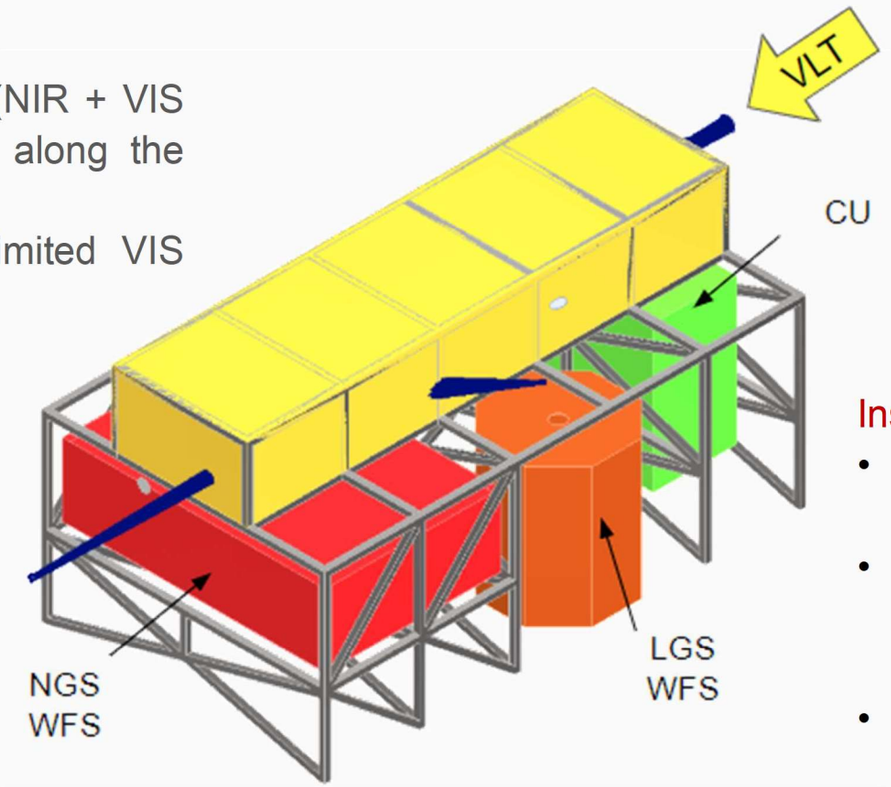
AOM Optical Design & Concept

Calibration Unit

AOM Calibration

- NGS and LGS WFS calibration sources (NIR + VIS point-like sources). Sources shall move along the optical axis to change conjugation
- Alignment sources (on-axis, diffraction-limited VIS and IR sources)
- NCPA mask (gridded-pinhole mask)



Instruments calibration

- Distortion mask for astrometric calibration
- Spectral and spatial flat fielding - Continuum source across full wavelength range
- Wavelength calibration - emission lines covering the full spectral range (regularly spaced)
- Alignment source for spatial alignment of IFU slices (e.g. Ronchi mask)

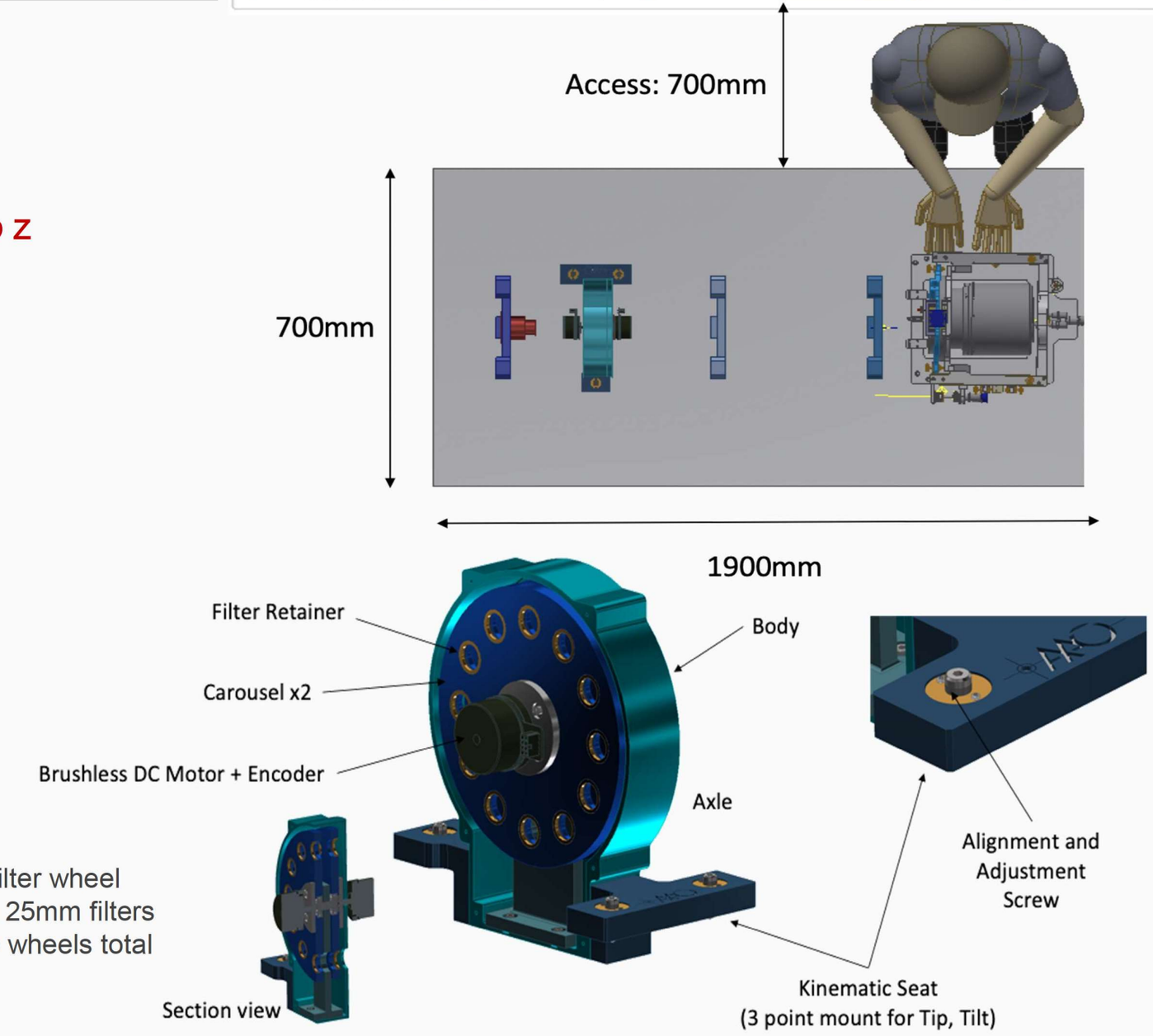
Goal is to maximize calibrations which can be done during the day with the dome lights on.

IMAGER OVERVIEW

Fundamental requirements

- Diffraction limited imaging from V to z
- Imaging from U to z

Parameter	Requirement
FOV	30.1 x 30.1 arcsec
Angular Resolution	16.3 mas
Pixel Size	7.3 mas
Detector format	4k x 4k
Distortions	0.7 mas

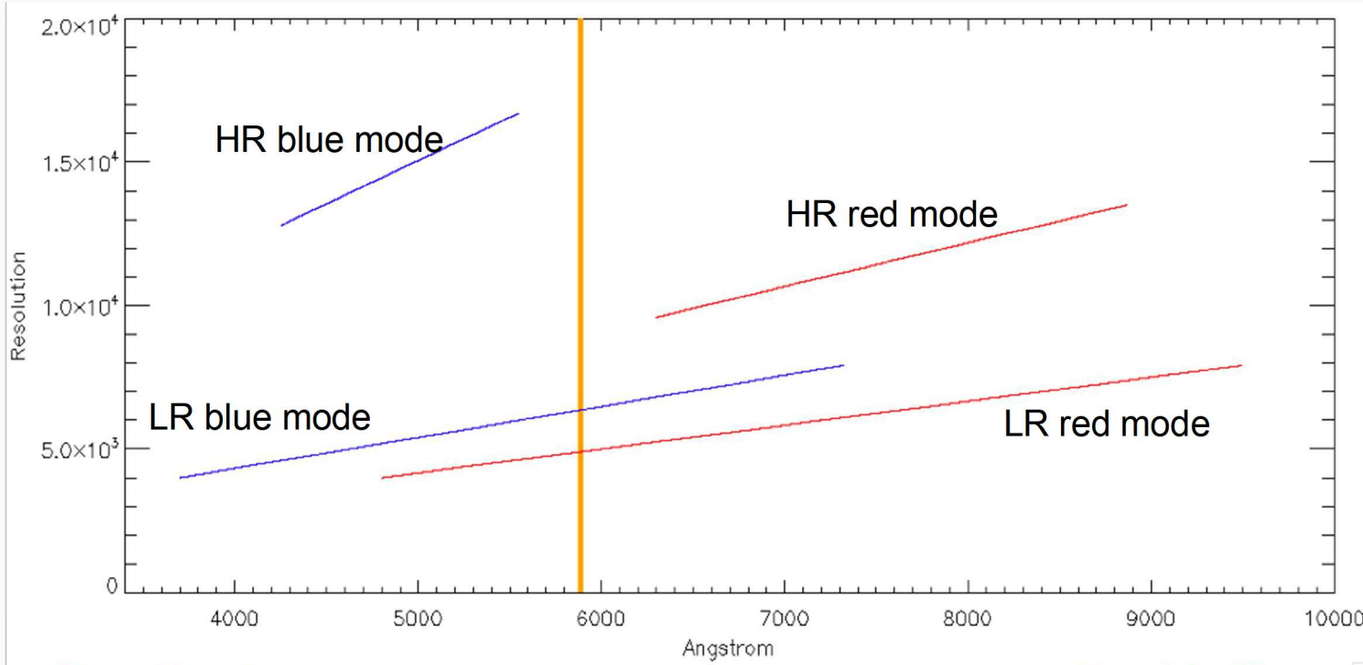


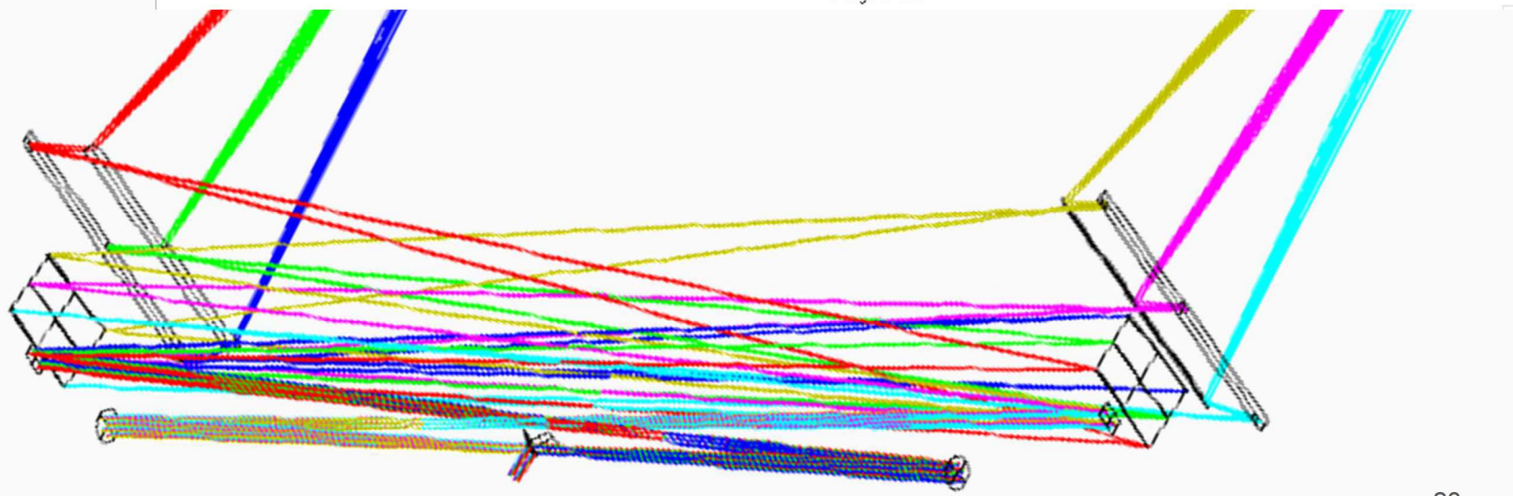
SPECTROGRAPH DESIGN CONCEPT

Baseline design choices:

- IFU Spectrograph
- 2x resolution modes
- 2x channels (blue-red)
- Full wavelength range: 370-1000nm

Parameter	Requirement
FOV	3.5” and 7”
Spaxels size	25 mas and 50 mas
Spectral resolution	5000 and 12000
Dispersive element	4 VPH gratings





AoB

- Data reduction and flow:
  - data flow system and a data reduction pipeline will provide science-grade data products (including signal, error and data quality as a minimum)
  - a reconstructed PSF for a given observation will be provided. The AO module will record all data needed (telemetry).

- AO performance infos:
  - Keeps loop closed (for “object” exposures) over a 1 hour observing block.
  - Strehl ratio > 10% (in V band)
  - Strehl ratio uniformity over the science FoV < 10% of the average (for wavelengths > 500nm)

- Operations:
  - will be compatible with visitor and service mode operations.
  - will minimize the downtime
  - will allow to observe non-sidereal science targets (up to 100 arcsec/hour) including the use of natural guide stars (NGS) with one of them having a different non-sidereal motion.

Ao

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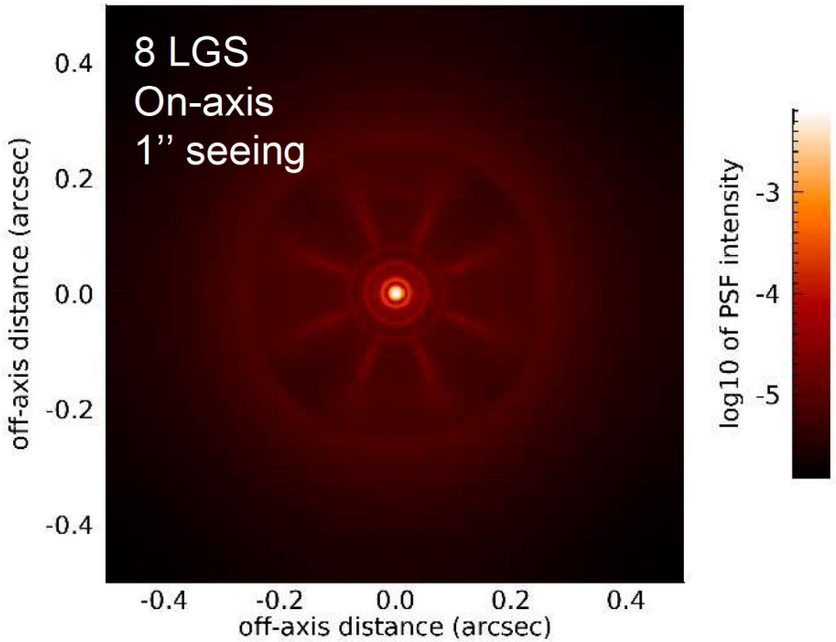

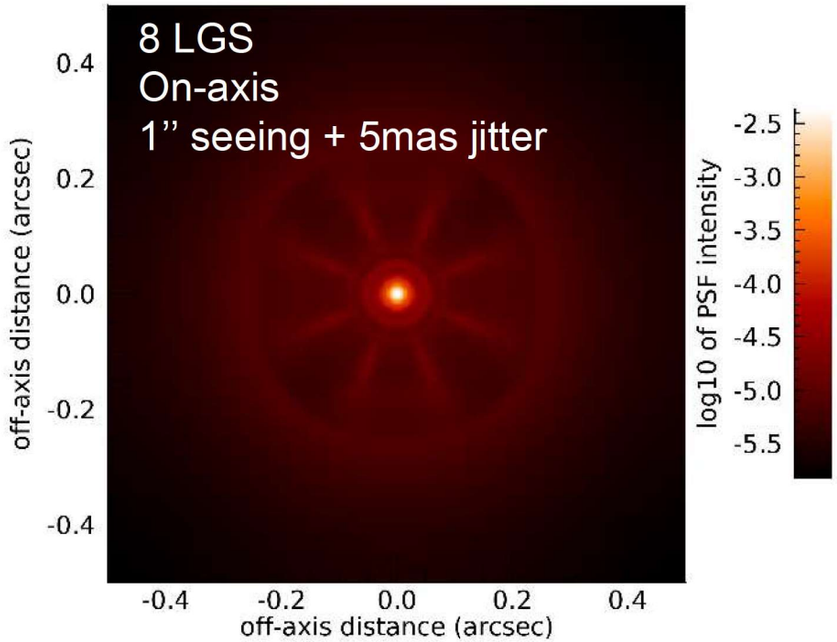

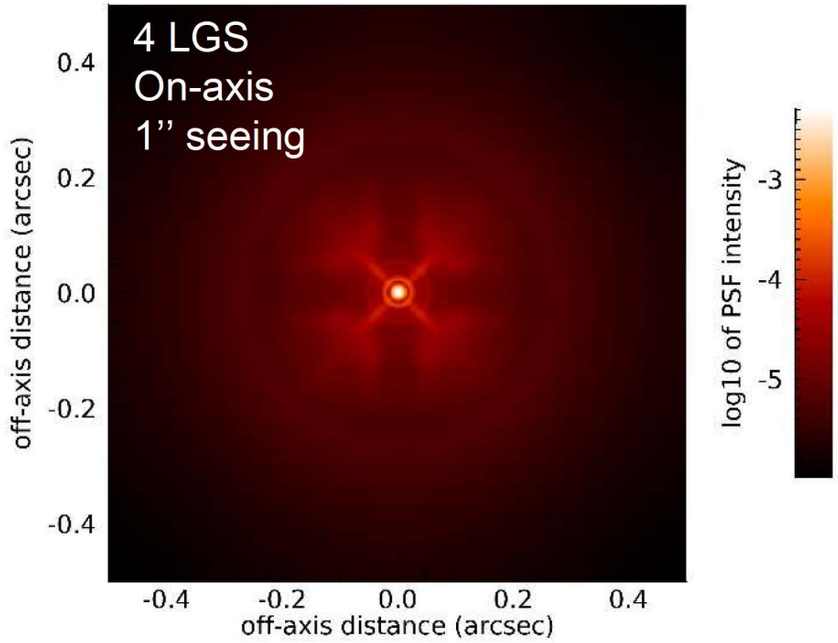

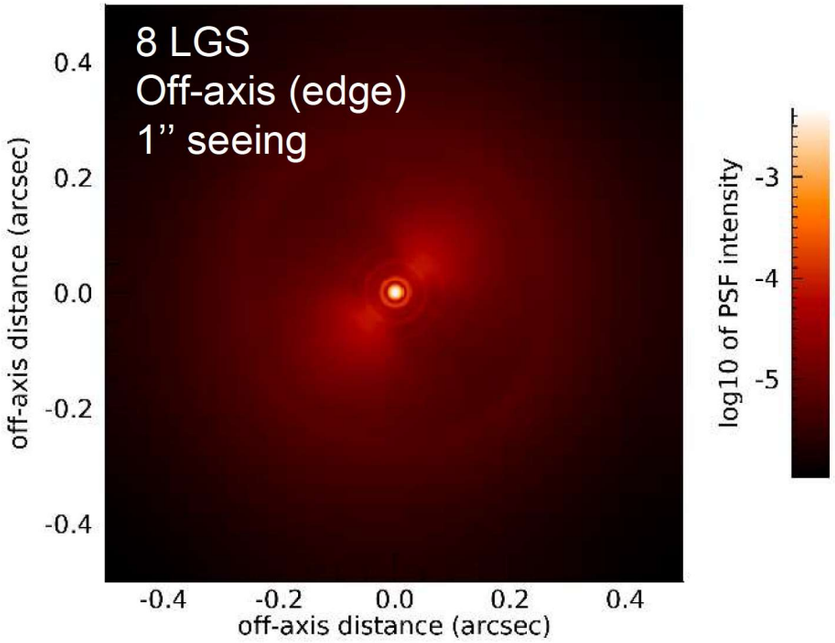

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MAVIS SCIENCE TEAM

Project Scientist: Richard McDermid

Co-Project Scientist: Giovanni Cresci

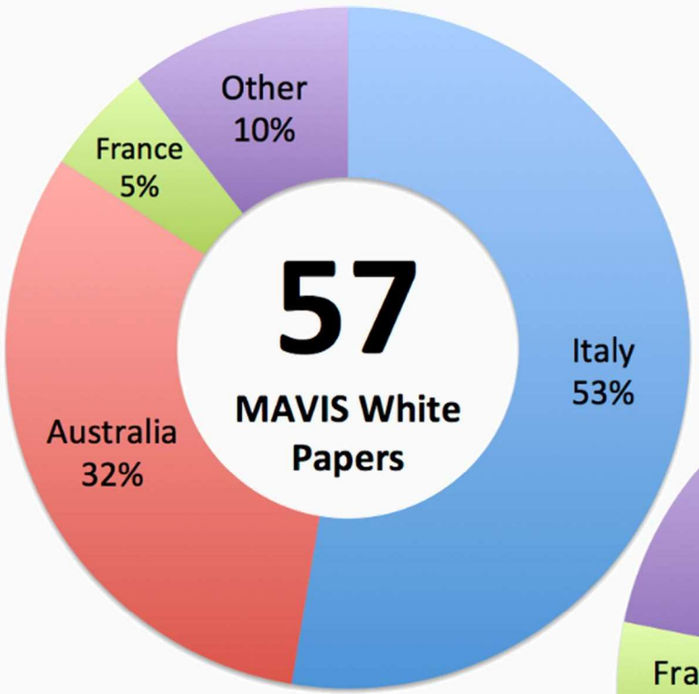
Local Reference points:

- Marco Gullieuszik (Padova)
- Laura Magrini (Arcetri)
- Giuseppe Bono (Roma)

4-8 November 2019
Villa il Gioiello
Europe/Rome timezone

MAVIS WHITE PAPERS

Lead Author Affiliations by Country



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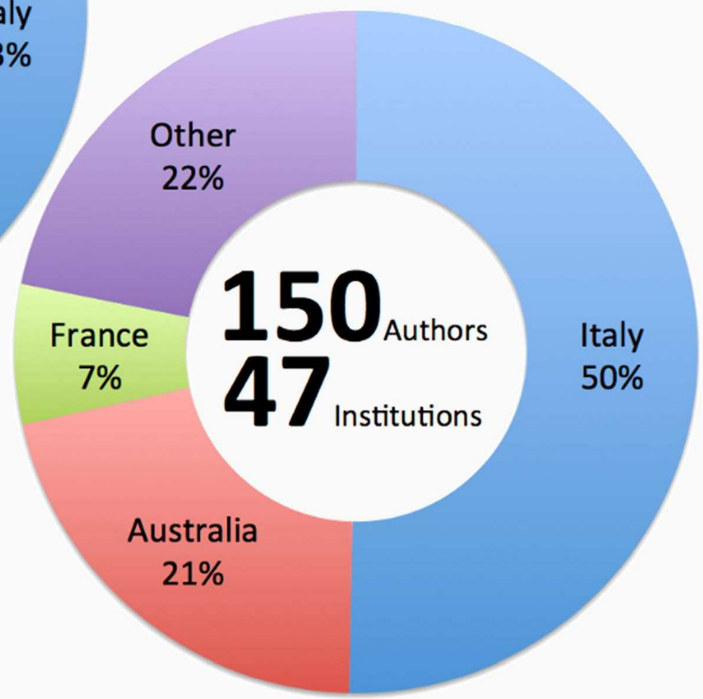
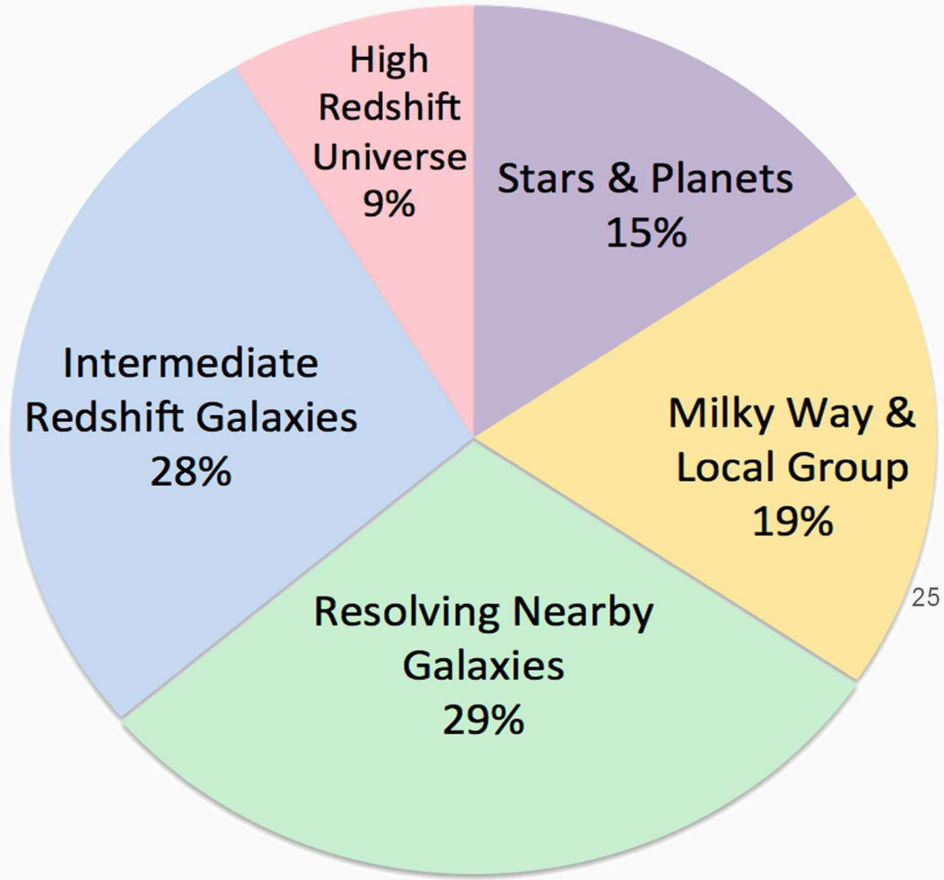
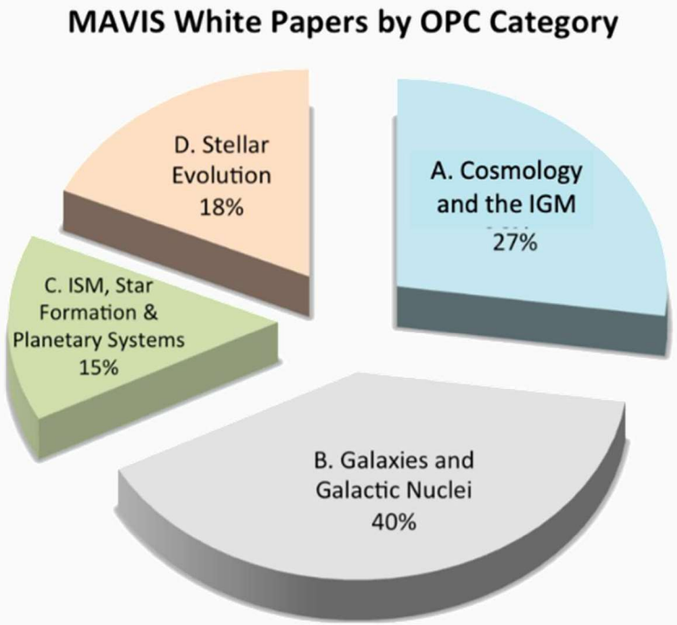
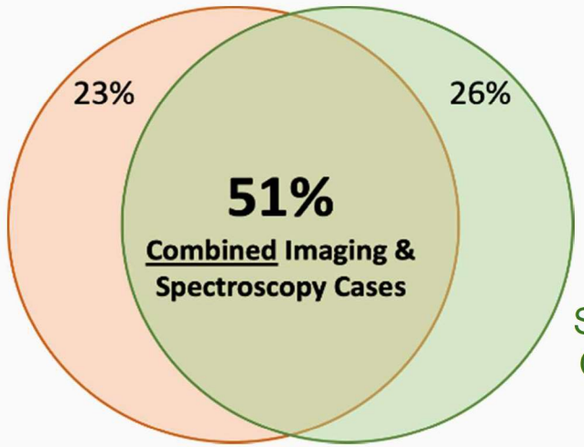


MAVIS White Papers by Theme



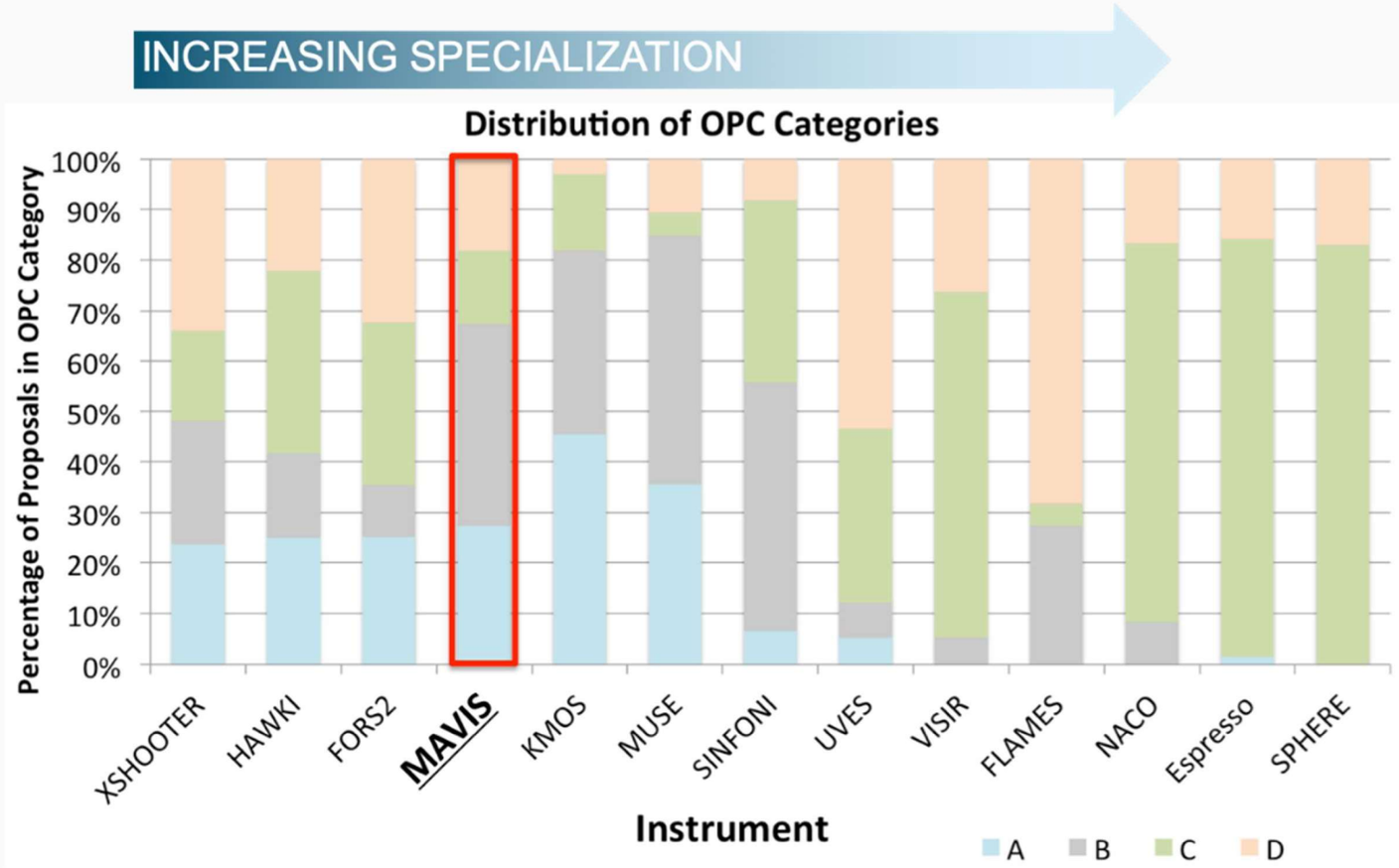
MAVIS: A GENERAL-PURPOSE INSTRUMENT



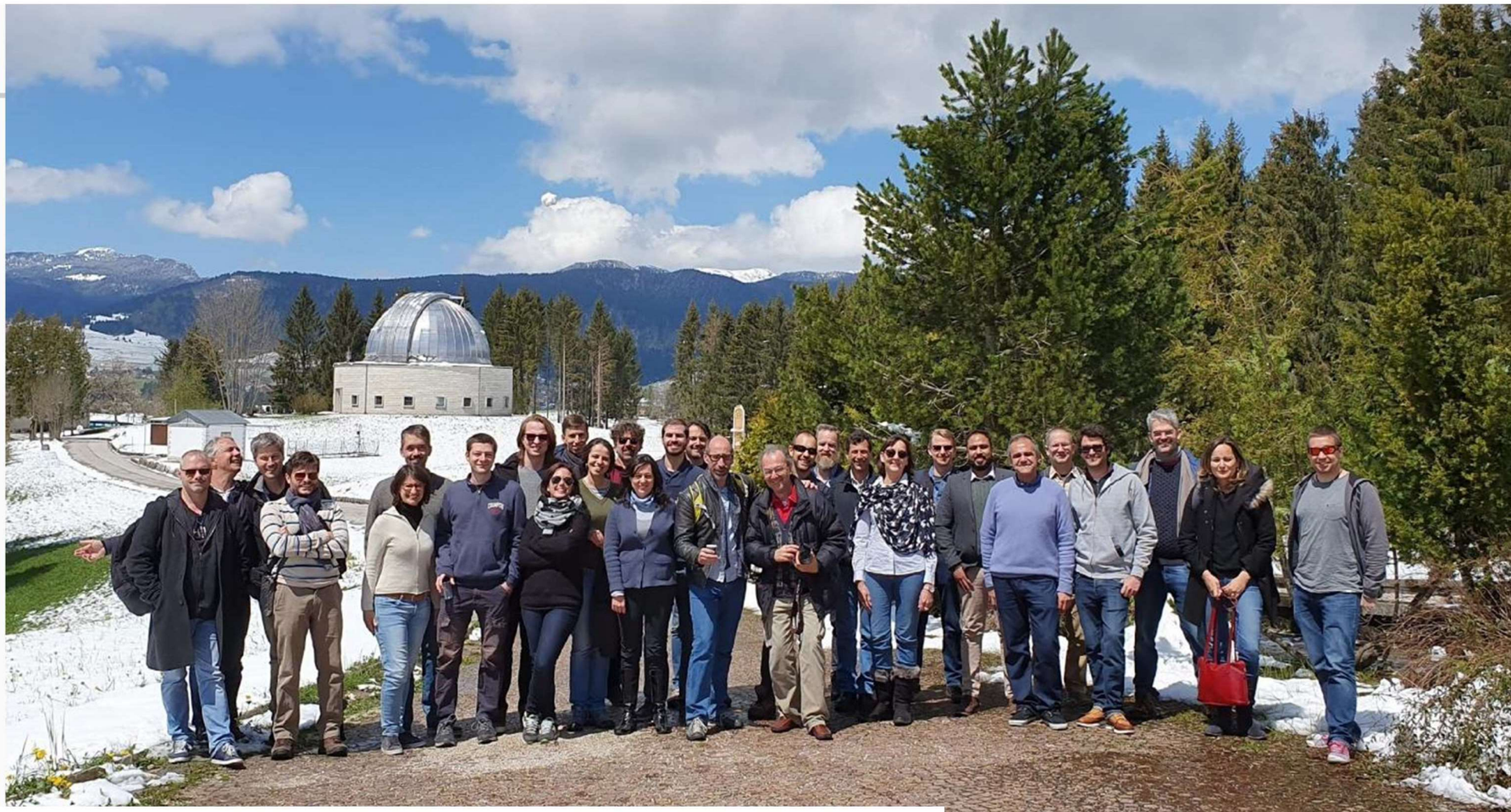


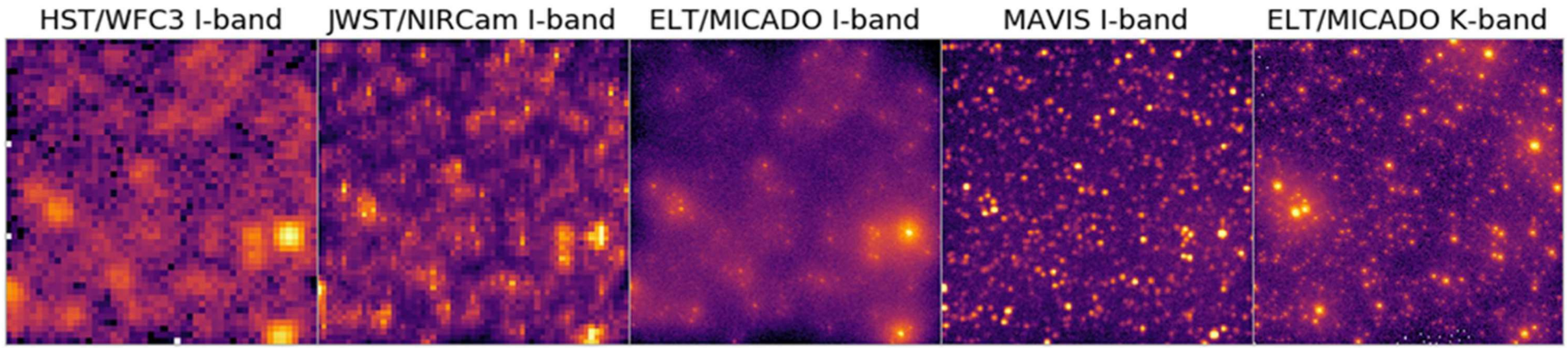
Imaging Only Science Cases

Spectroscopy Only Science Cases



THANK YOU




HST/WFC3 I-band
JWST/NIRCam I-band
ELT/MICADO I-band
MAVIS I-band
ELT/MICADO K-band

end of presentation.