# Progress on Adaptive Optics for the EST

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Solarnet -S3

Overview EST
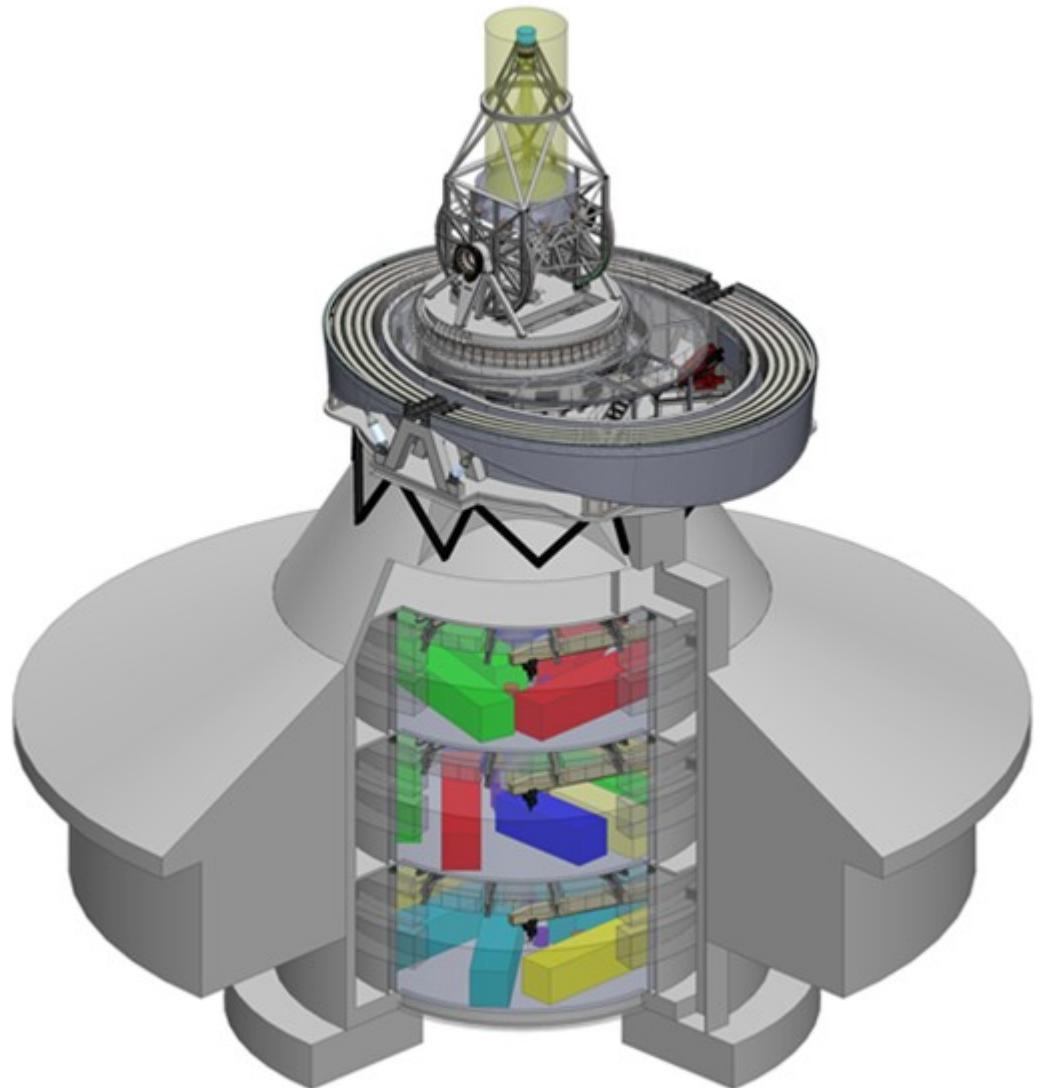
- 4-meter Solar Telescope

- On-axis Gregorian configuration

- Spectral range: 400 - 2500 nm

- Strong daytime turbulence

- High resolution in 60'' FoV

- AO/MCAO integrated in the optical path

Adaptive Optics Configurations
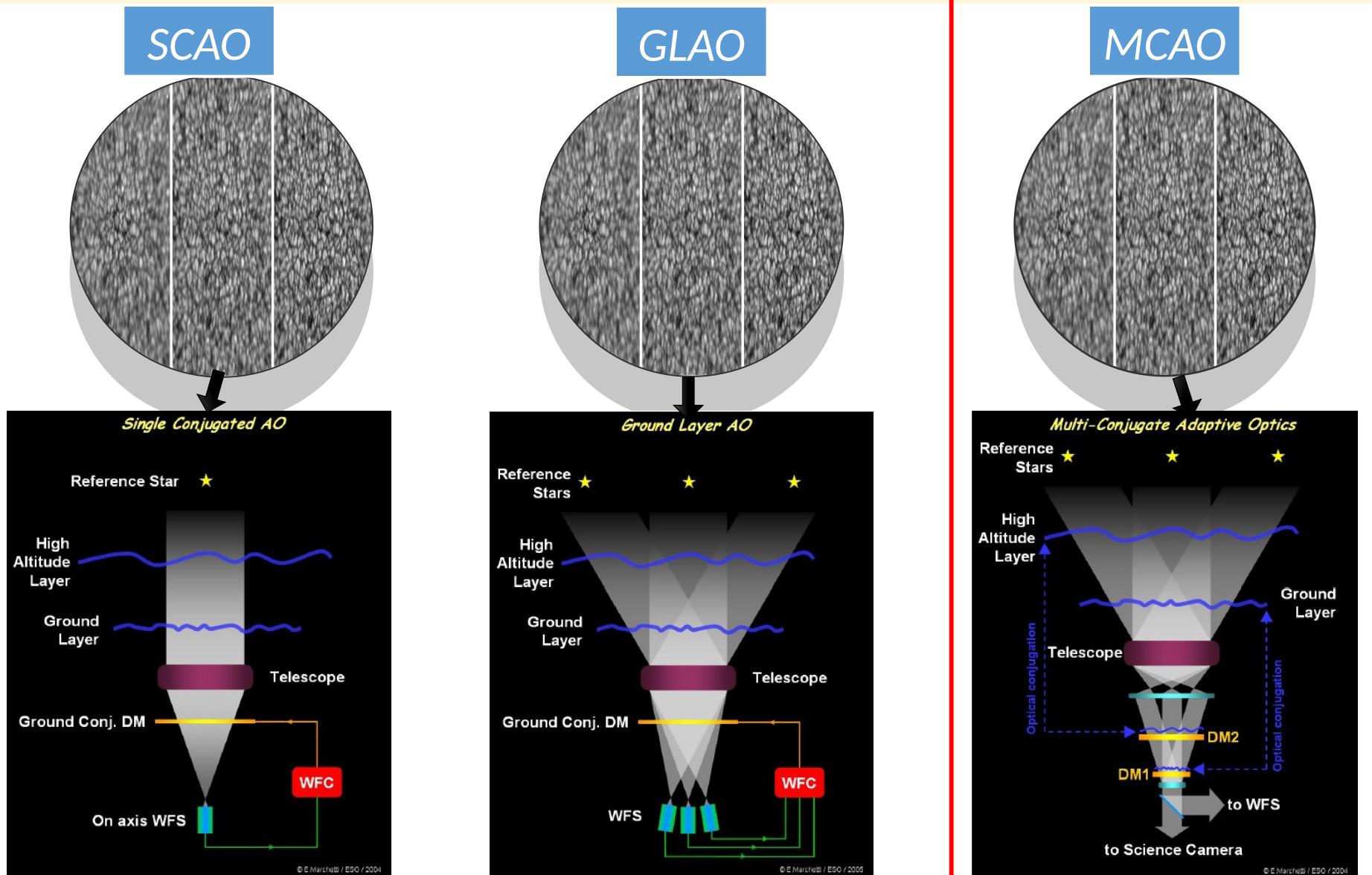
*The CLEAR multi-conjugate adaptive optics (MCAO) on the Goode Solar Telescope compared to observations with classical AO correction. / Schmidt et al. (2017)

EST Adaptive Optics
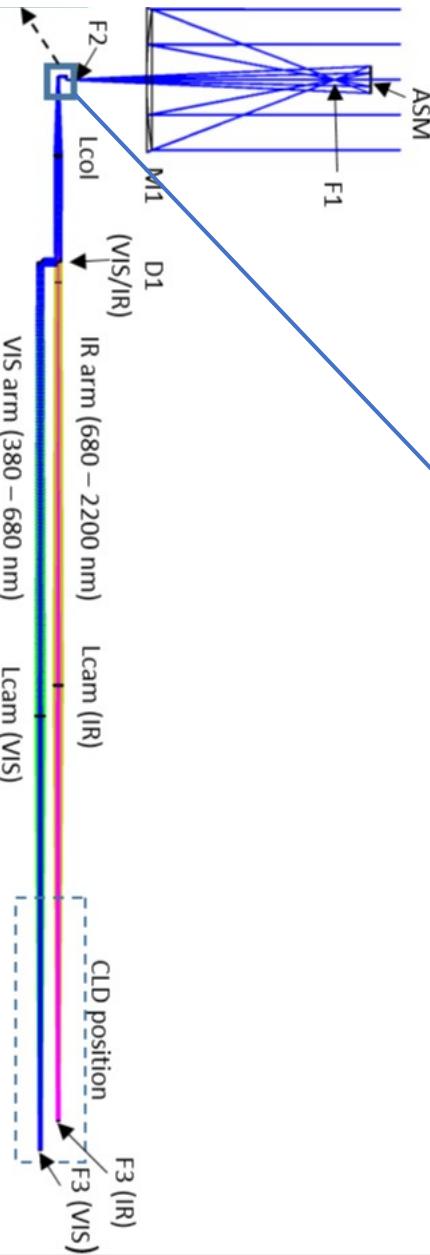
- Adaptive Secondary Mirror (ASM): AO + Tip/Tilt
- 4 Altitude DMs conjugated between 5 km and 20km
- Visible SH correlation WFS
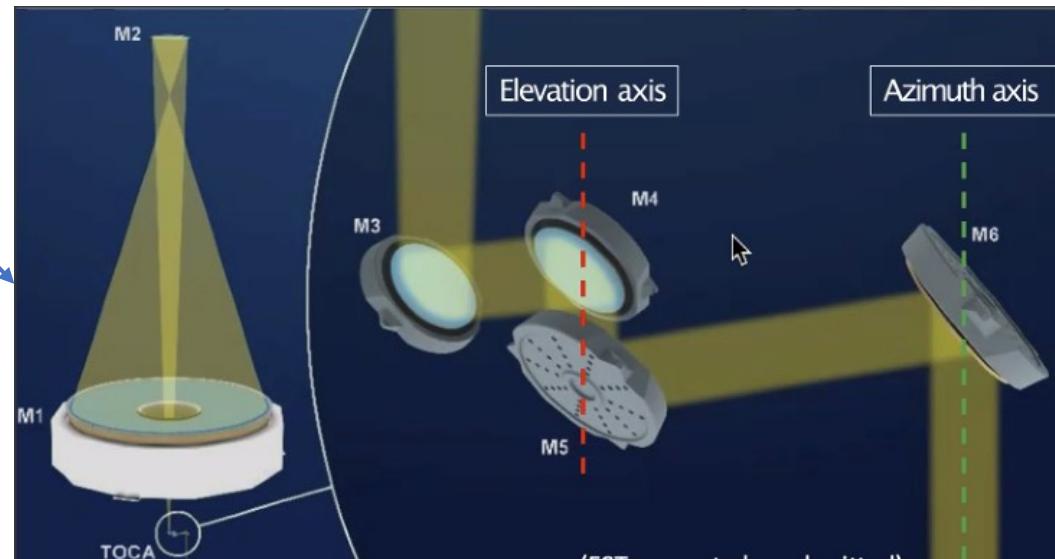
*The SR in the corrected FoV when using MCAO shall be:*
- *r0 > 10cm & FoV ≤ 30   -- >   SR ≥ 0.25*
- *r0 > 10cm & 30 ≤ FoV ≤ 60   -- >   SR ≥ 0.15*
- *r0 > 20cm & FoV ≤30   -- >   SR ≥ 0.4*
- *r0 > 20cm & 30 ≤ FoV ≤ 60   -- >   SR ≥ 0.3*
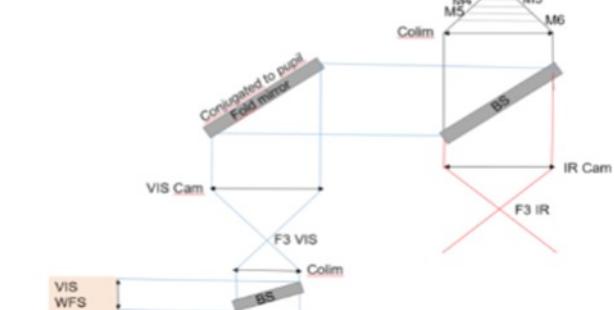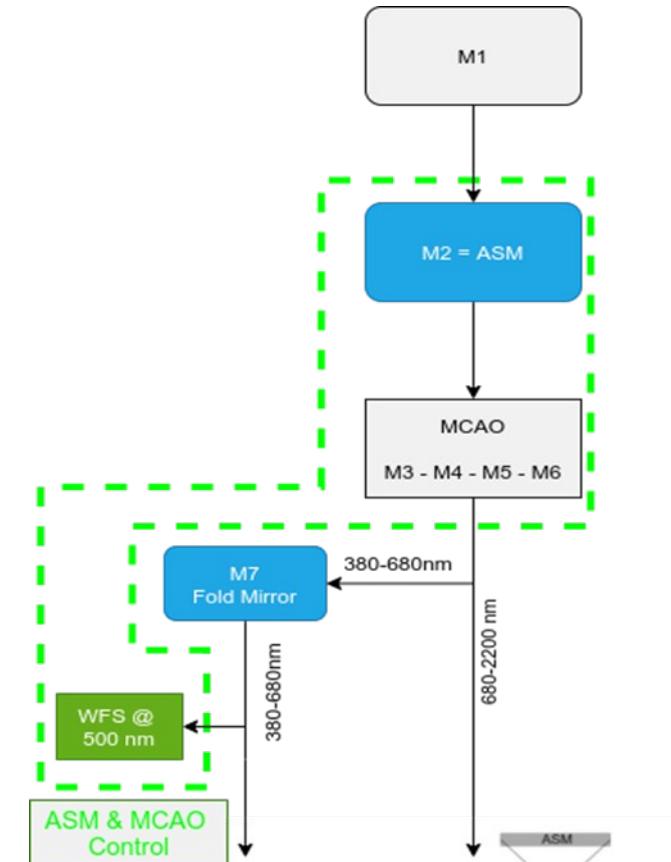
Ongoing AO Activities

- Error Budget of AO combining analytical and CFD modelling

- Definition of WFSs: configurations, number of microlenses...

- ASM: two different prototypes

- N to N simulations: DASP, FriMM, YAO, PROPER

- Laboratory test bench
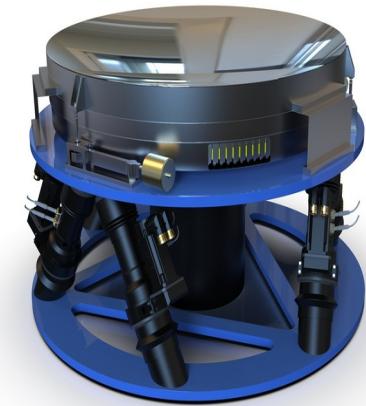
Narrow Field HO-WFS

M2 - ASM

MCAO test bench

Calibration wheel + Field Stop

Filters' wheel

F3

Motor:
Rotate about z
Precision : 1'
Manual stages:
Translate along x-y

Motor:
Rotate about z
Precision: 1 degree

Motor:
Translate along x-y-z
Precision: 0,001 mm
Manual stages:
Rotate about z

Motor:
Translate along x-y-z
Precision: 0,2 mm
Manual stages:
Rotate about z

Motor:
Translate along x-y-z. Precision: 0,2 mm

Num. Subap > 50
FoV of 10''
Frame rate ≥ 2000 fps

Adaptive Secondary Mirror

- The ASM is a challenging technology.
- Two different prototypes are under development: TNO + AdOptica
- Aperture Stop
- Fast Tip/Tilt: Assembled on a hexapod mount with 5 degrees of freedom (piston, δx, δy and slow tip-tilt)
- High order correction

TNO prototype

| Aperture	800 mm
Shape	Concave ellipsoid
Num. Actuators	2000
Act. pitch	≤ 16.2 mm

Objectives of AO tests
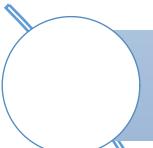
Find **optimal configuration for solar MCAO.**
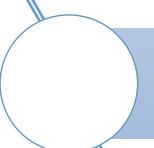
Impact of the **order of the DMs** in the MCAO performance.
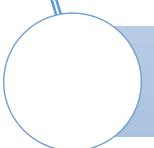
Impact of the **conjugation of DMs at certain heights**.
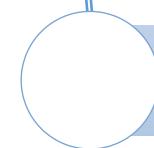
Impact of using **45º oriented DMs** on the MCAO
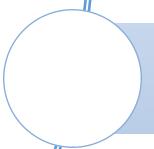
Mitigate **pupil misregistration effects** due to pupil distortion caused by altitude DMs.
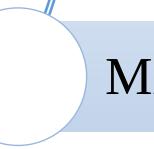
Mitigate **pupil rotation and spider footprint effects** on wavefront sensing and reconstruction.
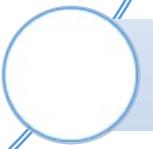
Implement **Artificial Neural Network (ANN)** in the reconstruction and control of the MCAO.

MCAO Test Bench (TB)

FoV-EST = 70 arcsec $\Rightarrow$ FoV-TB = 3°
EST Aperture: 4 m $\Rightarrow$ Apertura-TB = 26 mm

DM0
NF-HO-WFS
MD - WFS
Turbulence simulator
DM1
DM2
Illumination System
Sci. cam
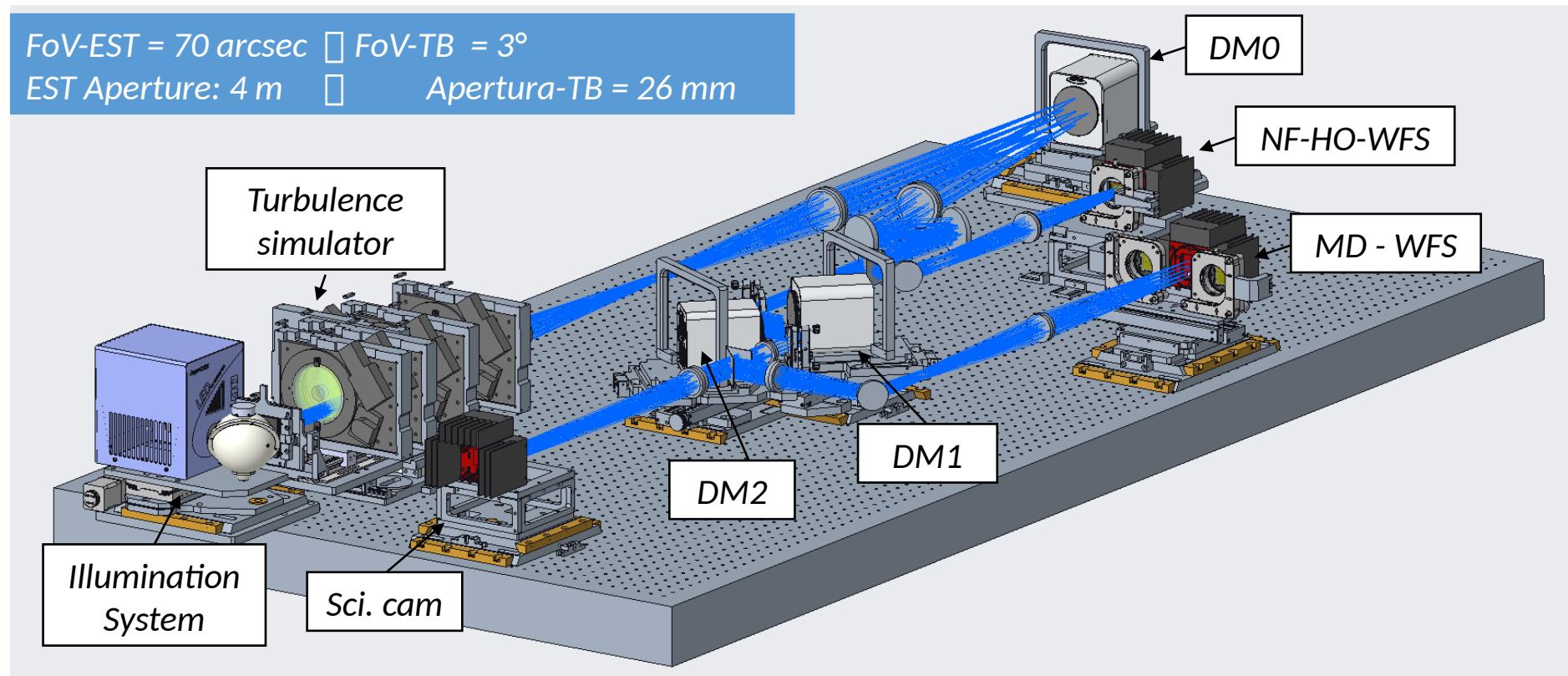
Phase Screens
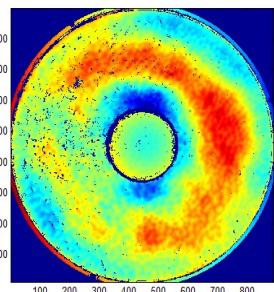
Illumination system
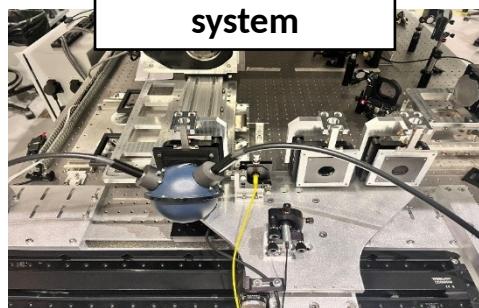
DM0@820
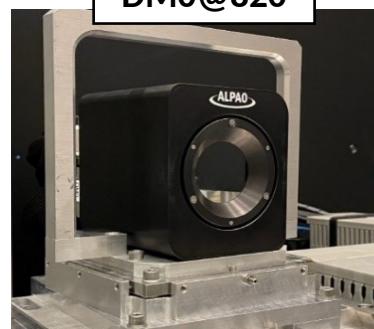
DM1 & DM2 @468
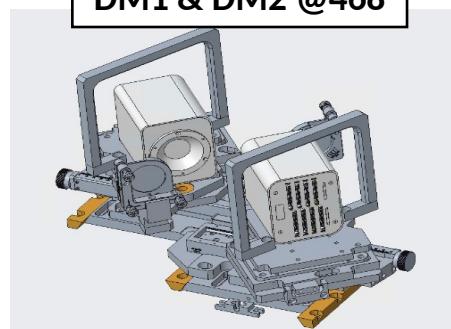
NF-HO-WFS
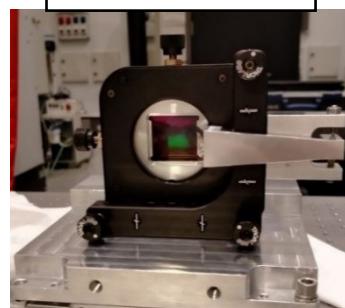
MD-WFS
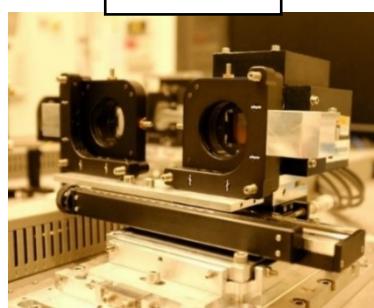
MCAO Test Bench (TB)
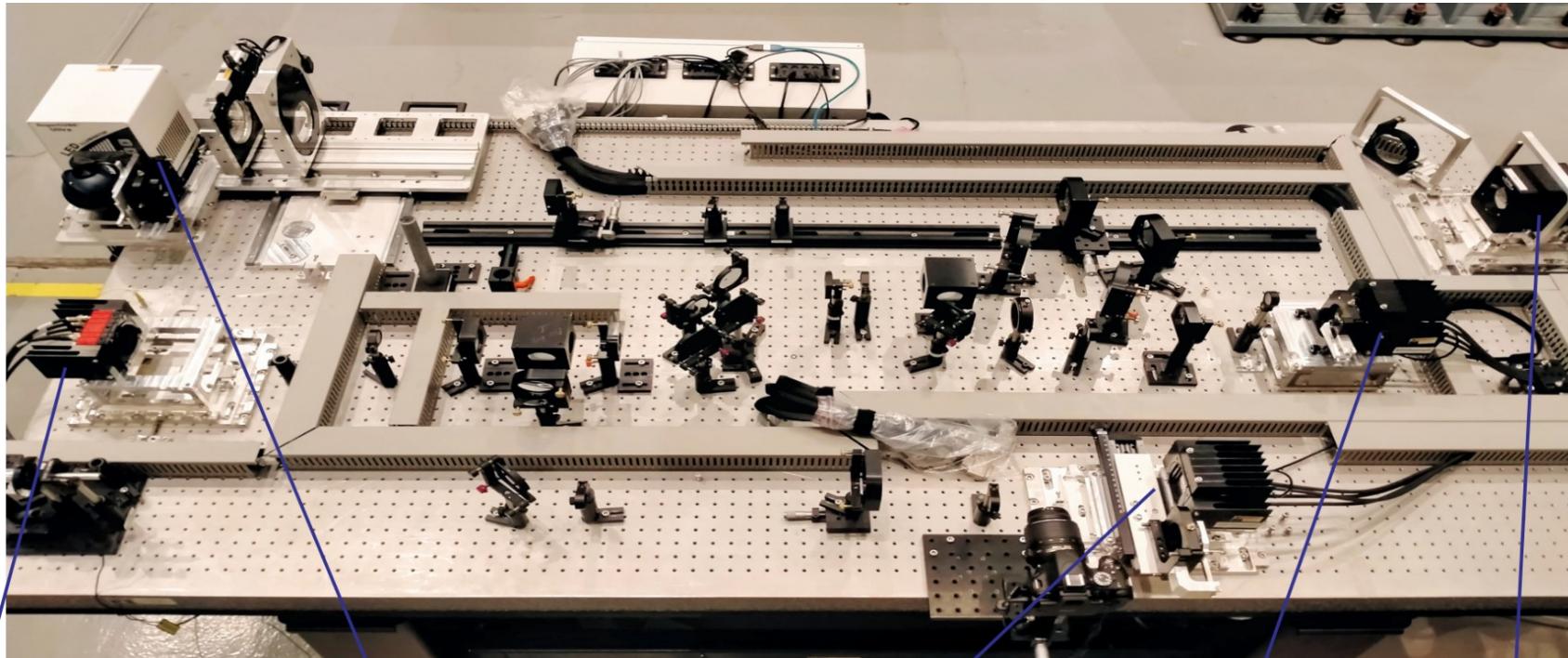
Sci - cam	Illumination System and Turbulence simulator	MD - WFS	HO - WFS	DM

Configurations

| SCAO 1	GLAO1	GLAO 2	MCAO 1	MCAO 2	MCAO 3	MCAO 4
DM0 / HO-WFS	DM0 / HO-WFS / MD-WFS	DM0 / HO- MD-WFS	DM0 / HO-WFS / DM1/ MD-WFS	DM0 / HO-WFS / DM2 / DM1 / MD-WFS	DM0 / DM1/ HO-MD-WFS	DM0 / DM2 / DM1/ HO-MD-WFS

TB: Wavefront Sensors (WFSs)

MD-WFS

HO-WFS

70'' subap.

19 dir

7 dir
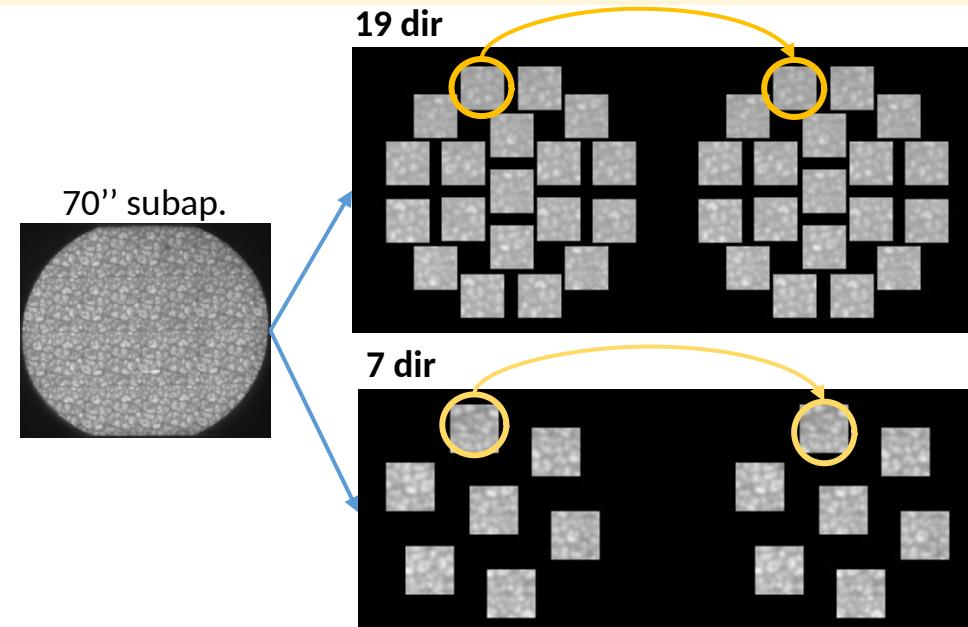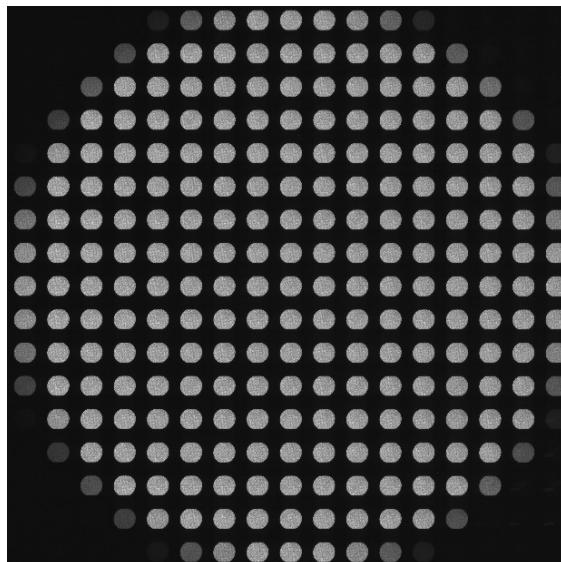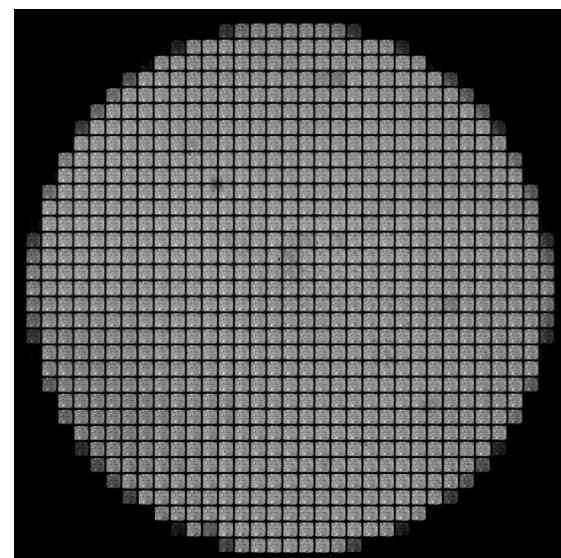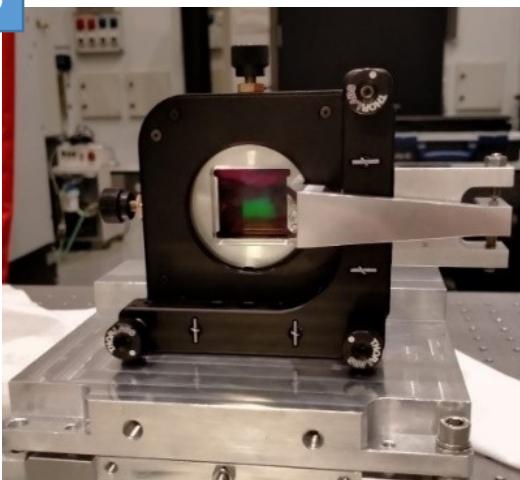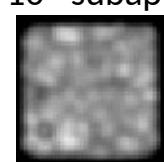
10'' subap.

	HO-WFS	HO-MD-WFS	LO-MD-WFS
ML array (MLA)	33 x 33	33 x 33	17 x 17
Pix/subap	40 pix (binning mode 2x2)	175 pix	233 pix
FoV	10''/subap	70''/subap	70''/subap
Plate Scale	0.25 arcsec/pix	0.4 arcsec/pix	0.3 arcsec/pix

***Control RTC: DARC. (Durham University)***
Frequency: 30 Hz (WFS limited)

TB Results

SCAO point source

r0 = 10.5cm, AO = OFF

r0 = 10.5cm, AO = ON

$$r_0\left(\lambda@525\,nm\right)10\,cm$$

r0 = 22cm, AO = OFF

r0 = 22cm, AO = ON

$$r_0\left(\lambda@525\,nm\right)22\,cm$$
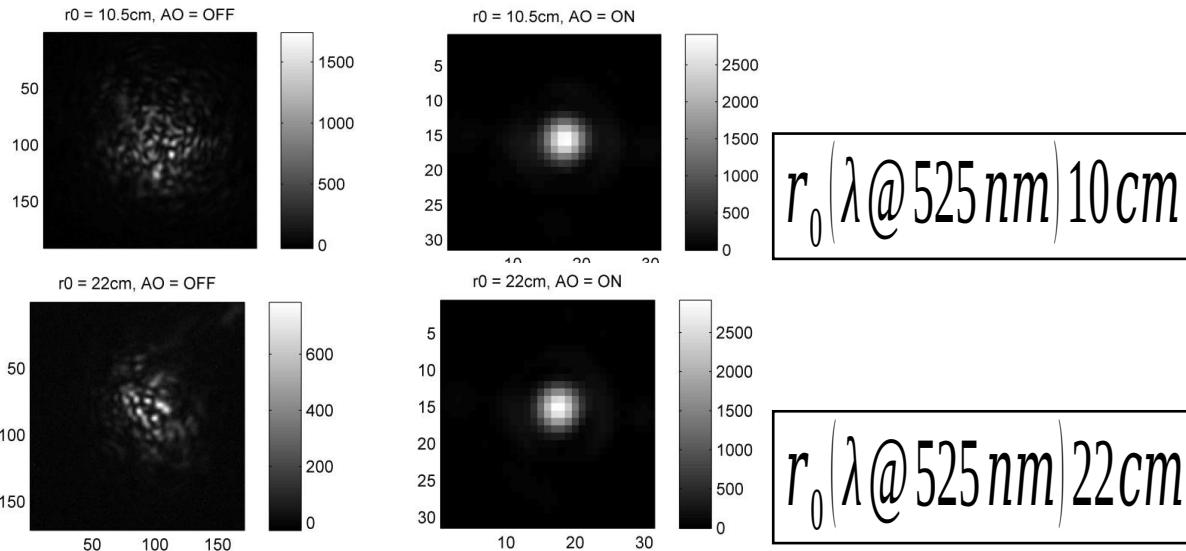
SCAO extended object

$$r_0\left(\lambda@525\,nm\right)10\,cm\,CL$$
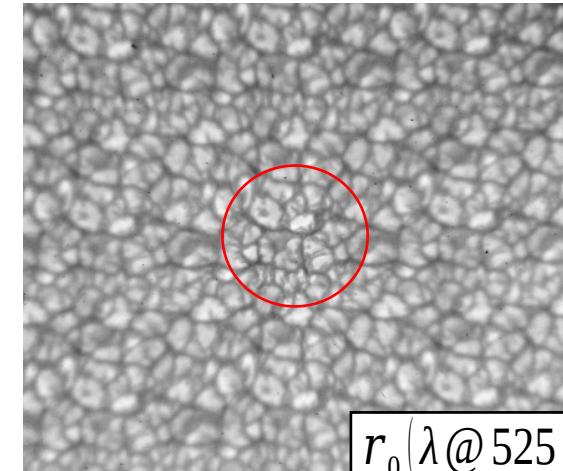
GLAO extended object

$$r_0\left(\lambda@525\,nm\right)$$

$$r_0\left(\lambda@525\,nm\right)$$
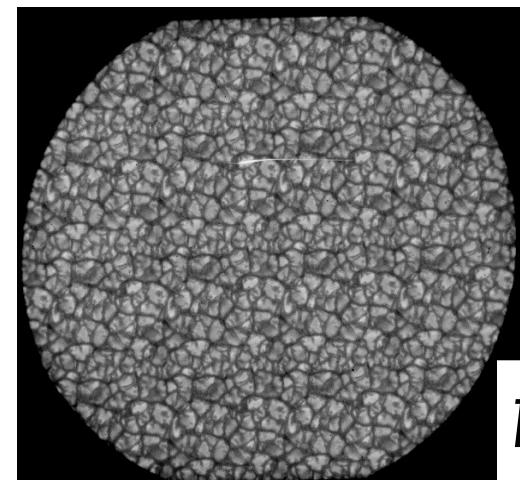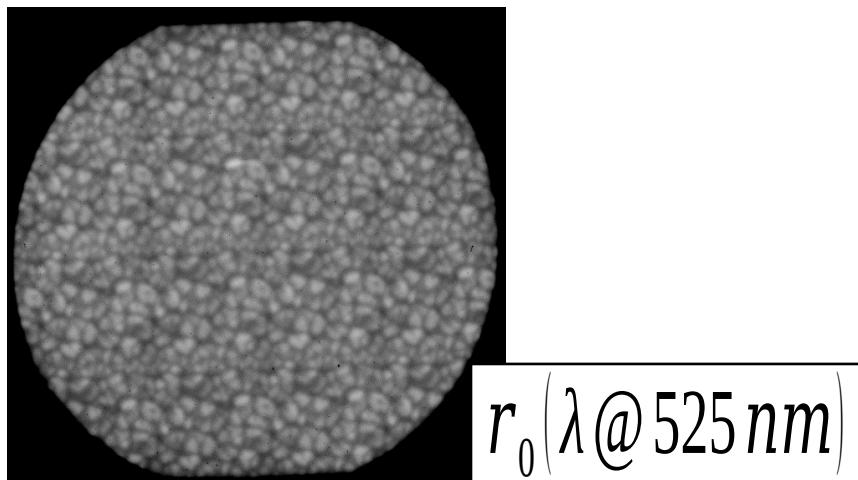
Perspective

- Improve bench alignment to increase image quality

- Improve correlation algorithms.

- Complete GLAO configurations

- Implement MCAO with altitude DMs.

- Verify simulation results

- Future AO projects

THANK YOU SO MUCH!

QUESTIONS?
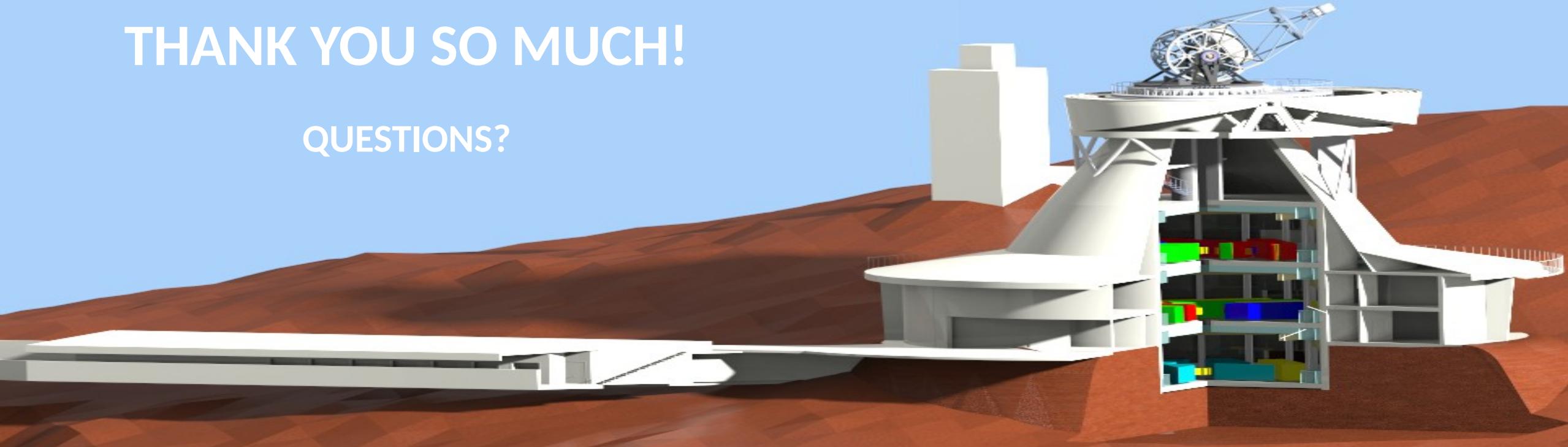
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