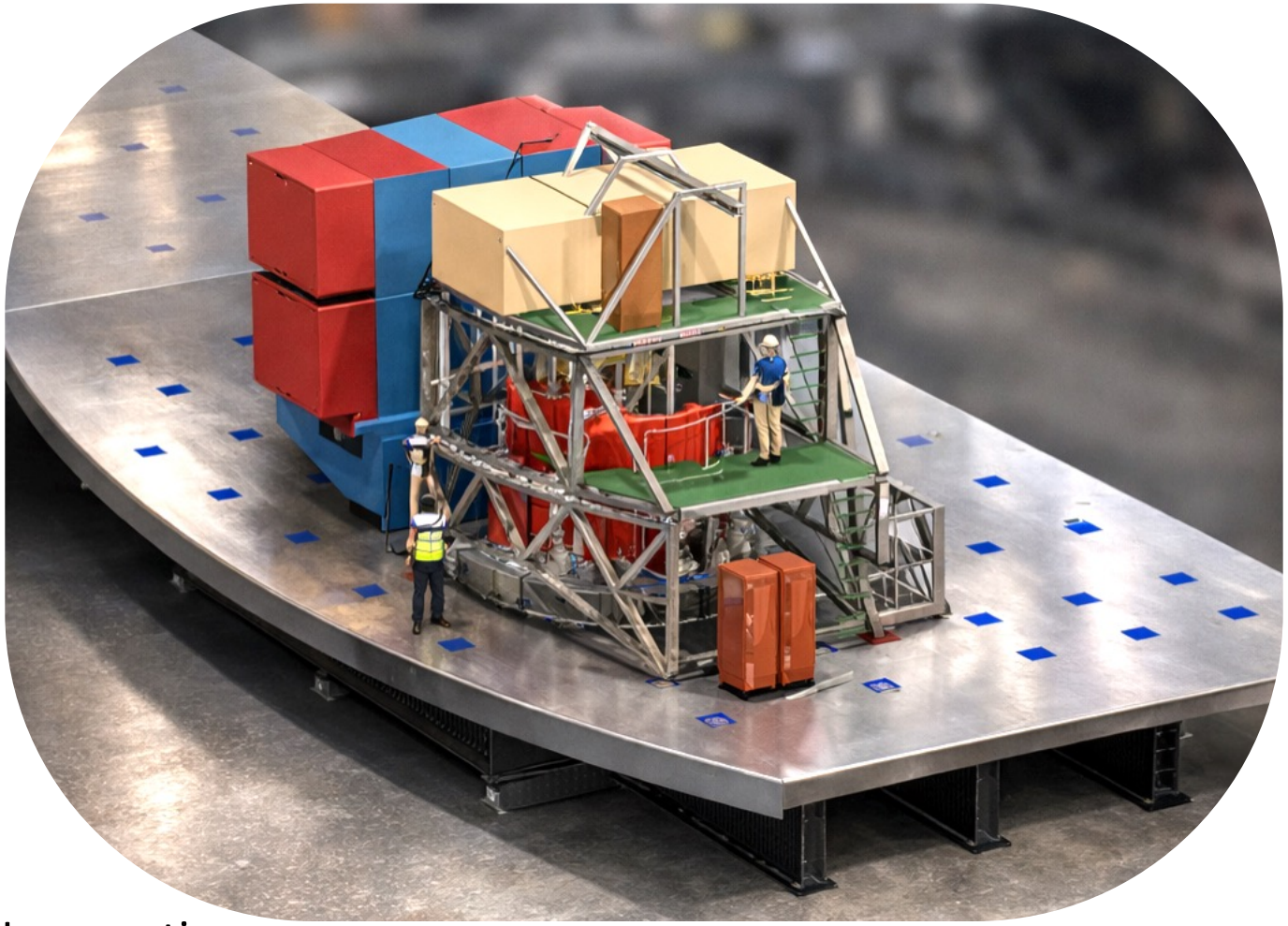
HARMONI 2.0



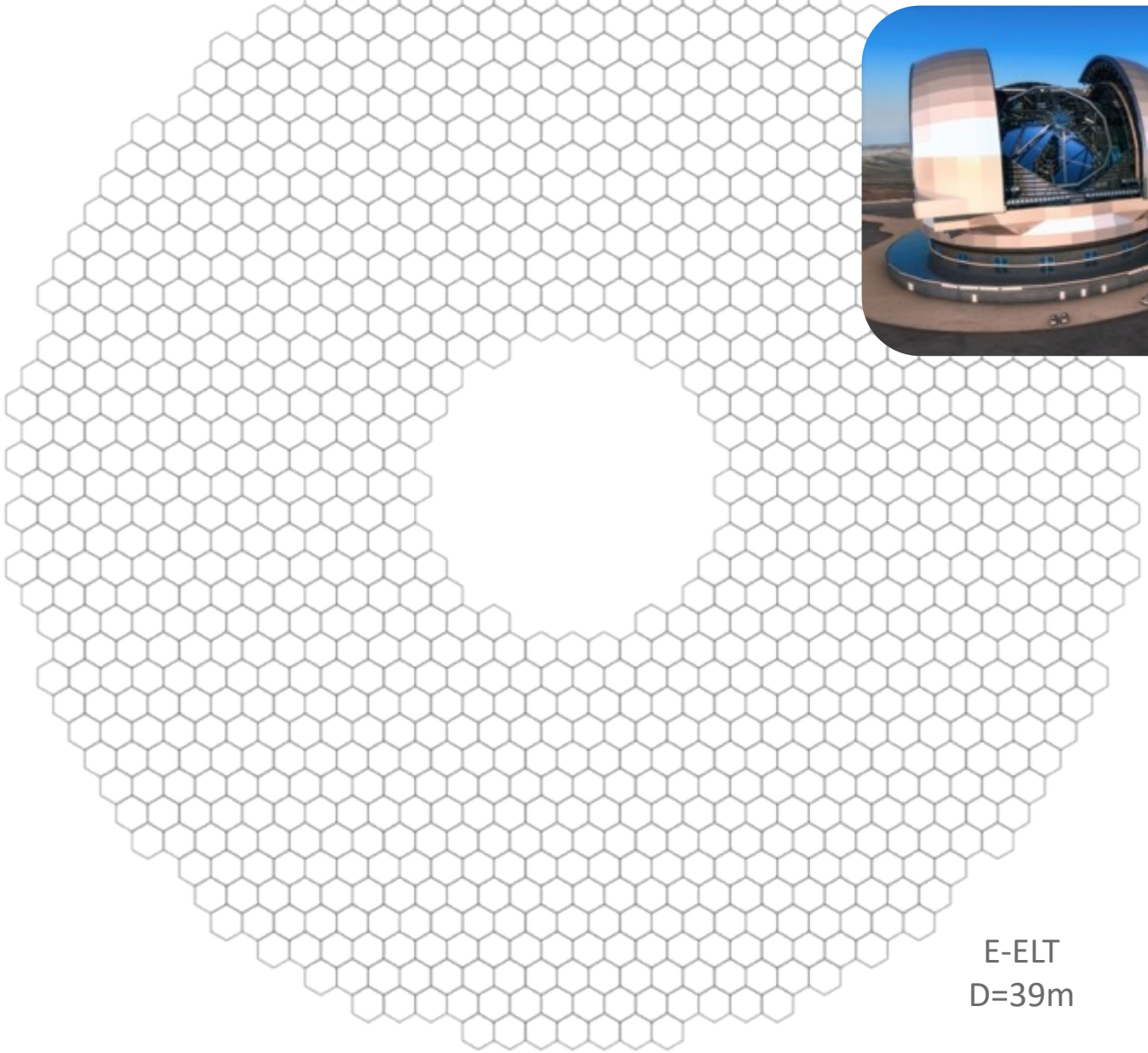
Benoit Neichel
On behalf of the HARMONI consortium

General Introduction





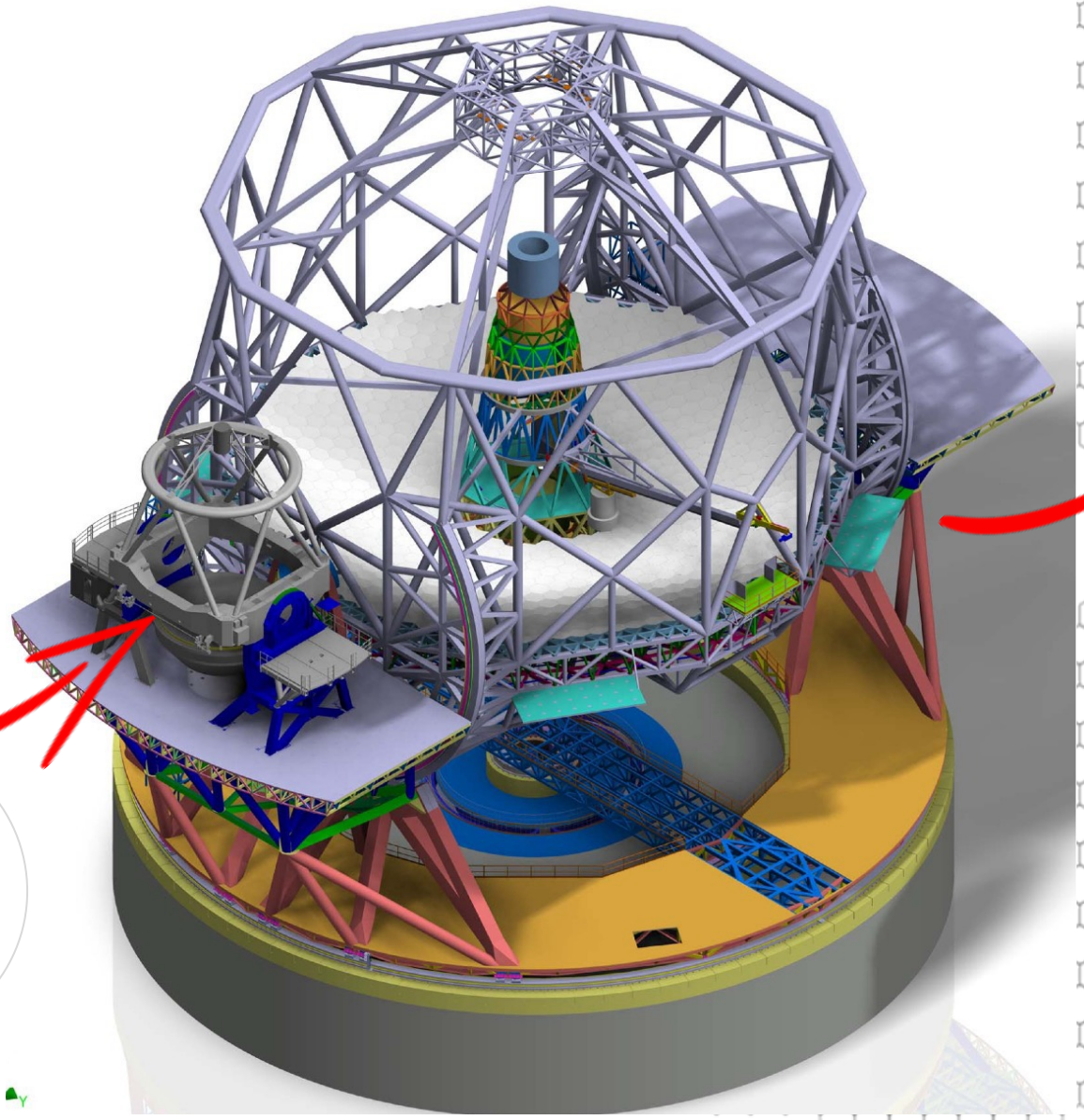
VLT - D=8m



E-ELT
D=39m

General Introduction







VLT - D=8m

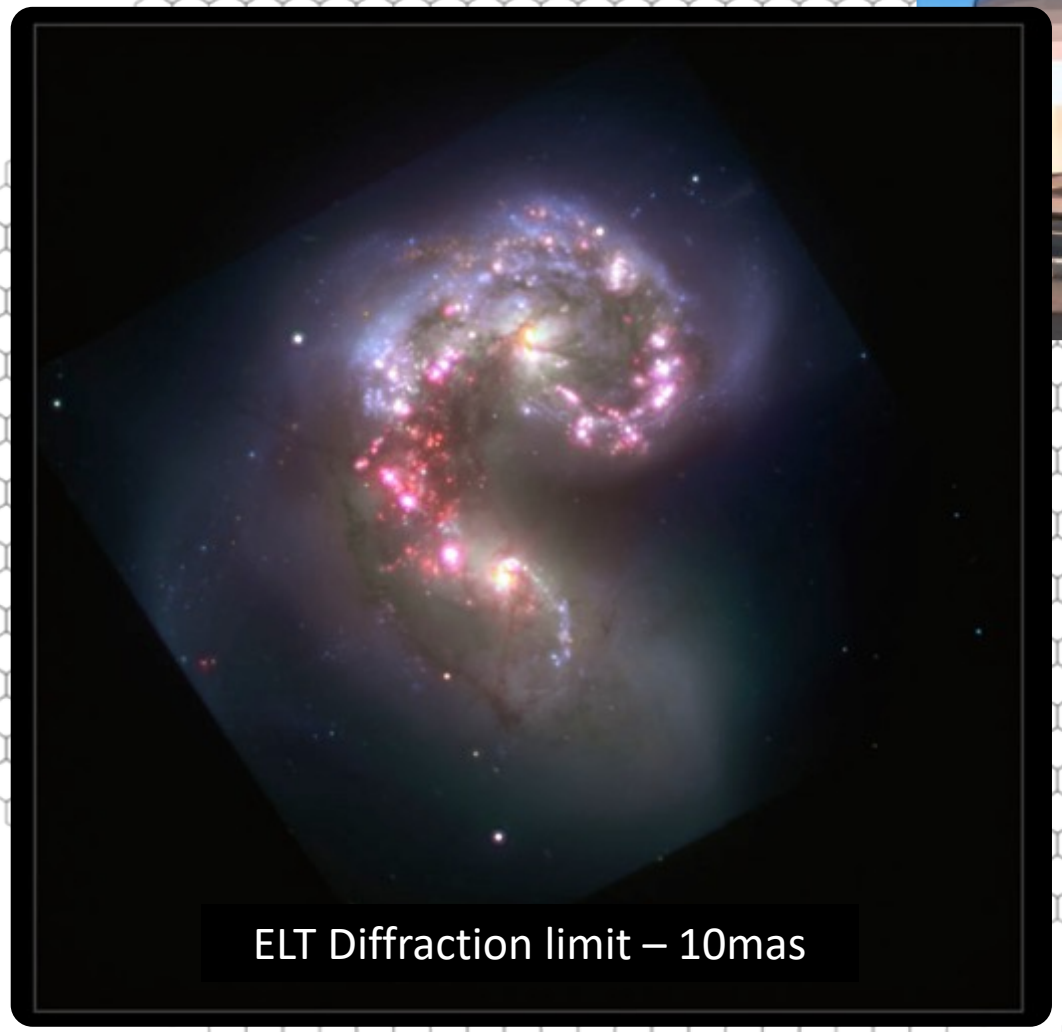
E-ELT
D=39m

General Introduction





VLT - D=8m





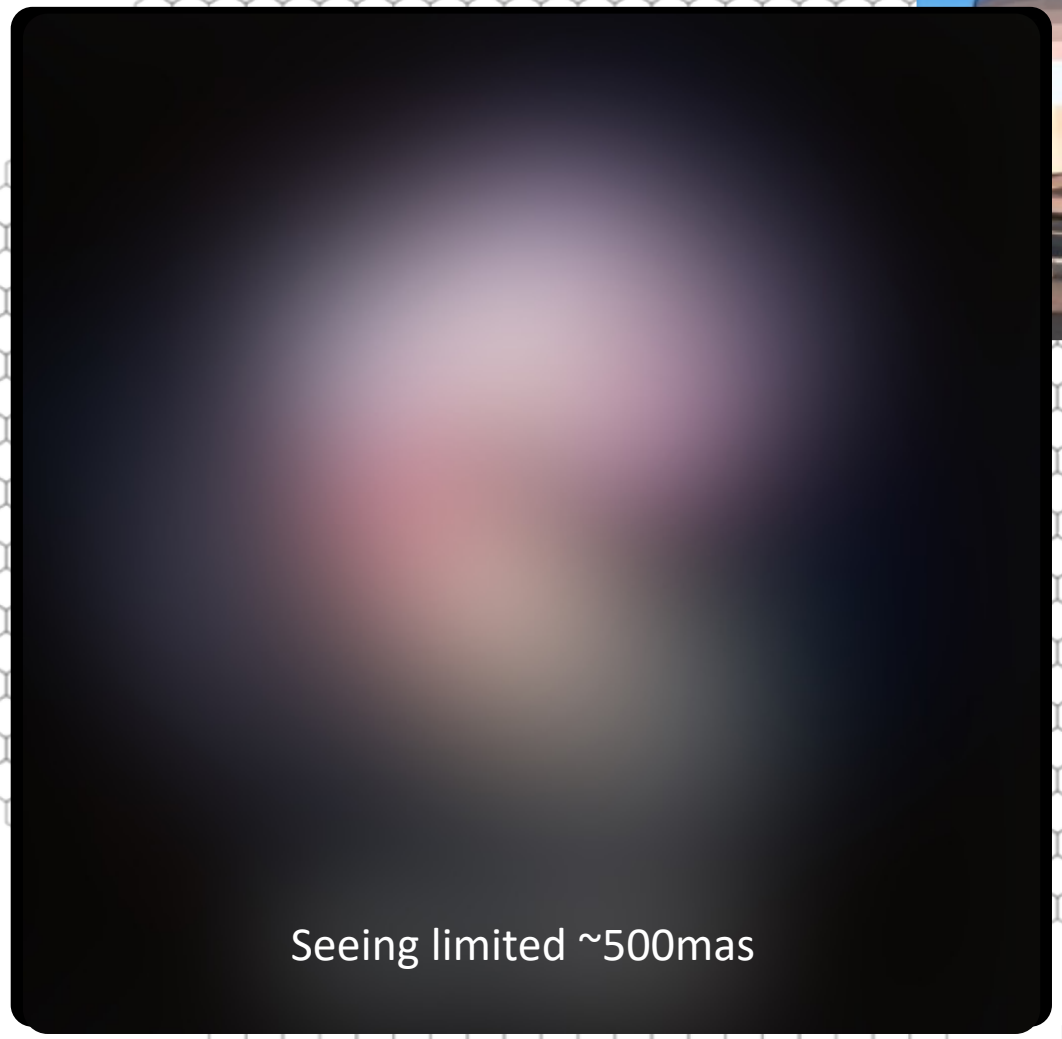
E-ELT
D=39m

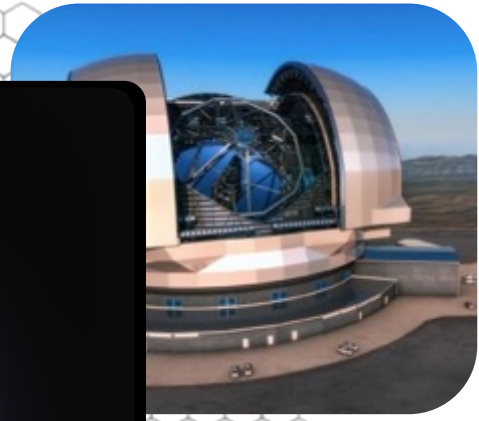
General Introduction





VLT - D=8m





E-ELT
D=39m

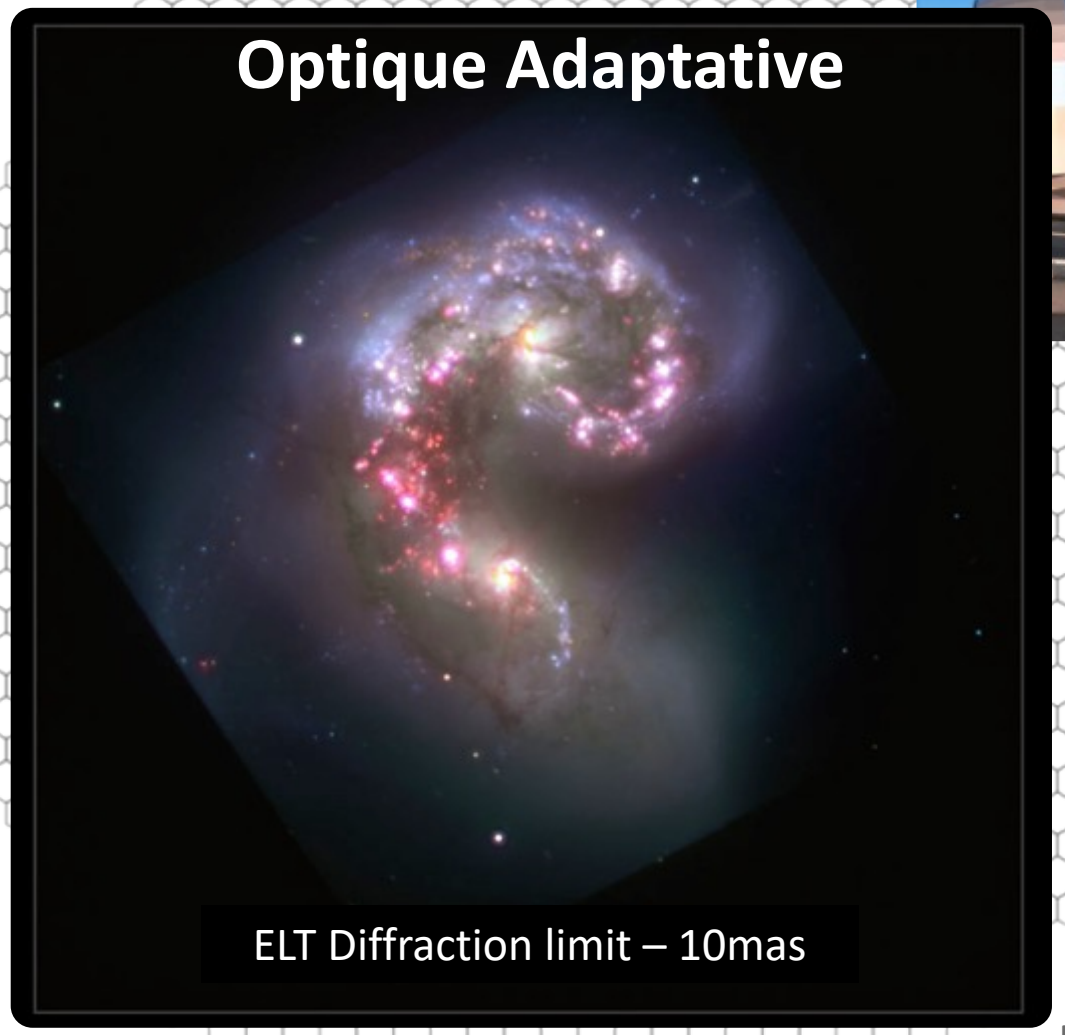
General Introduction



VLT - D=8m

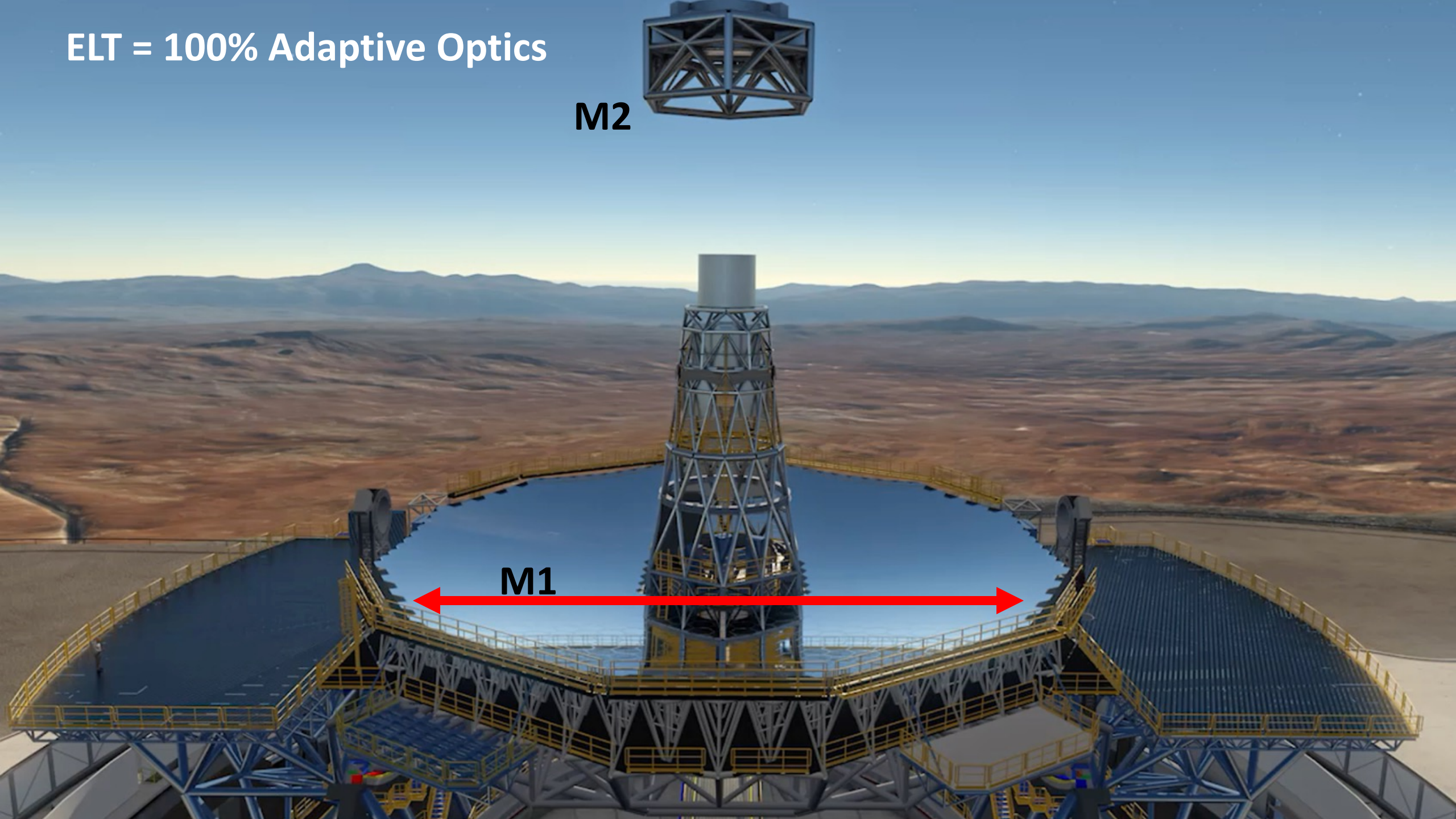


Optique Adaptative

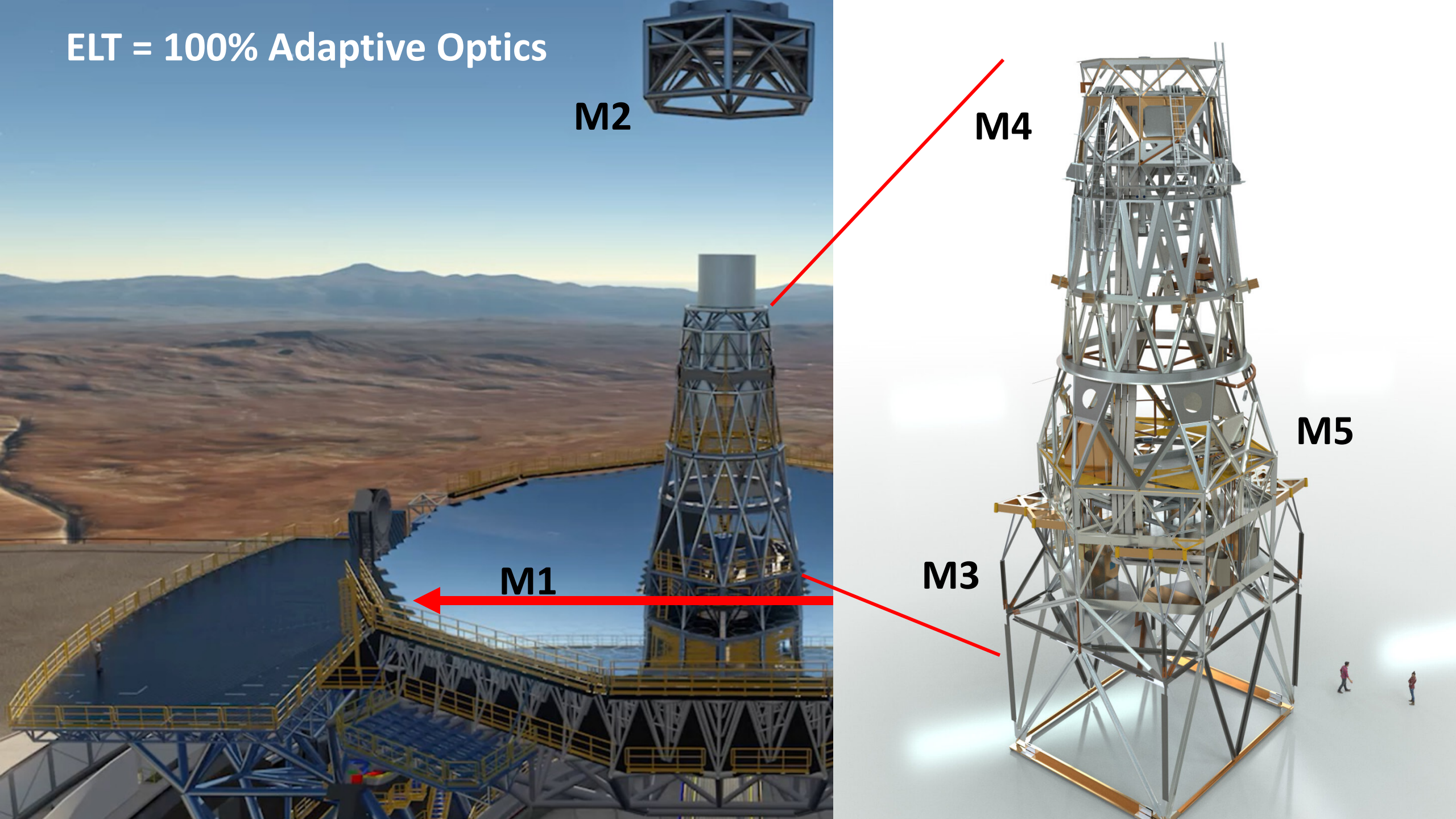




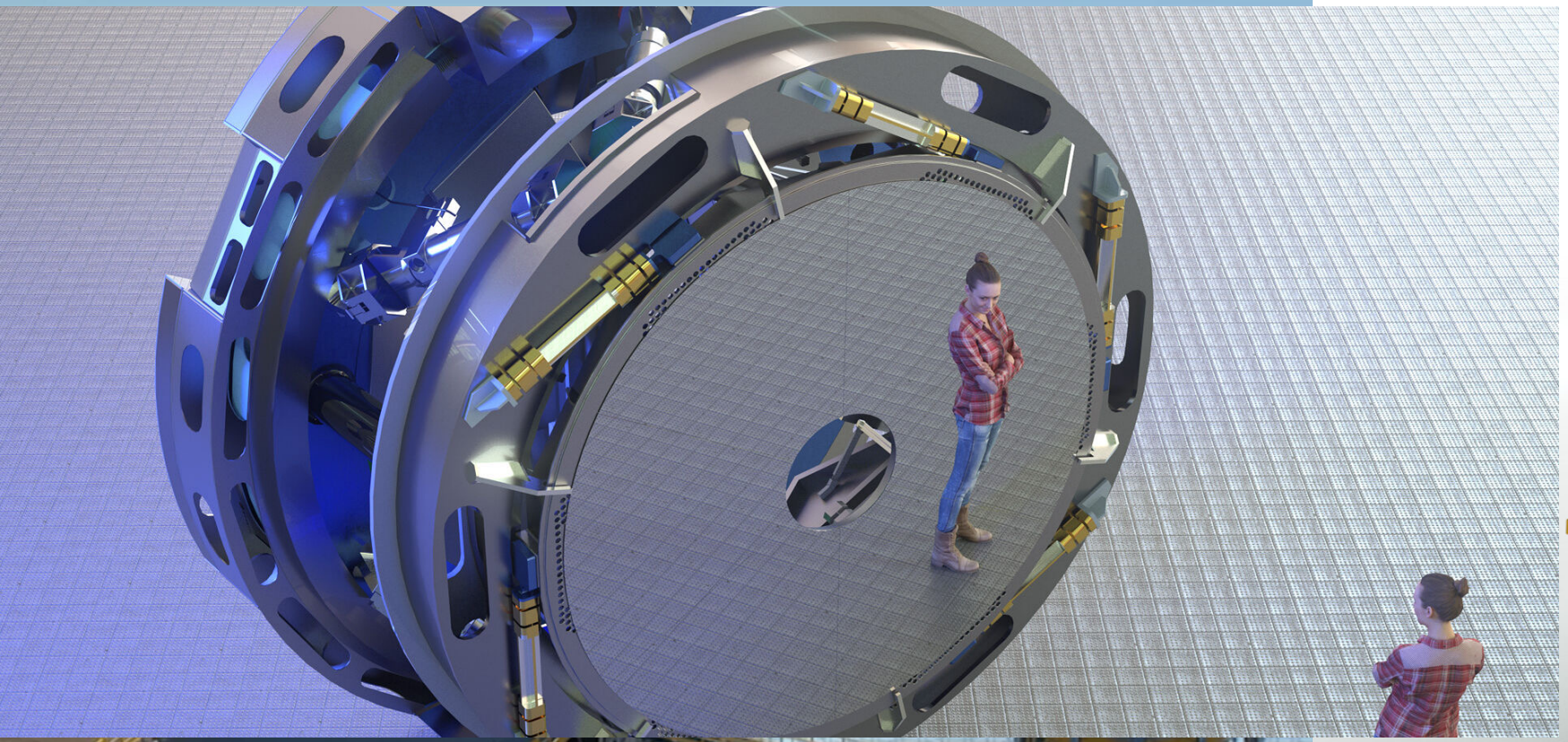
E-ELT
D=39m


ELT = 100% Adaptive Optics
M2
M1

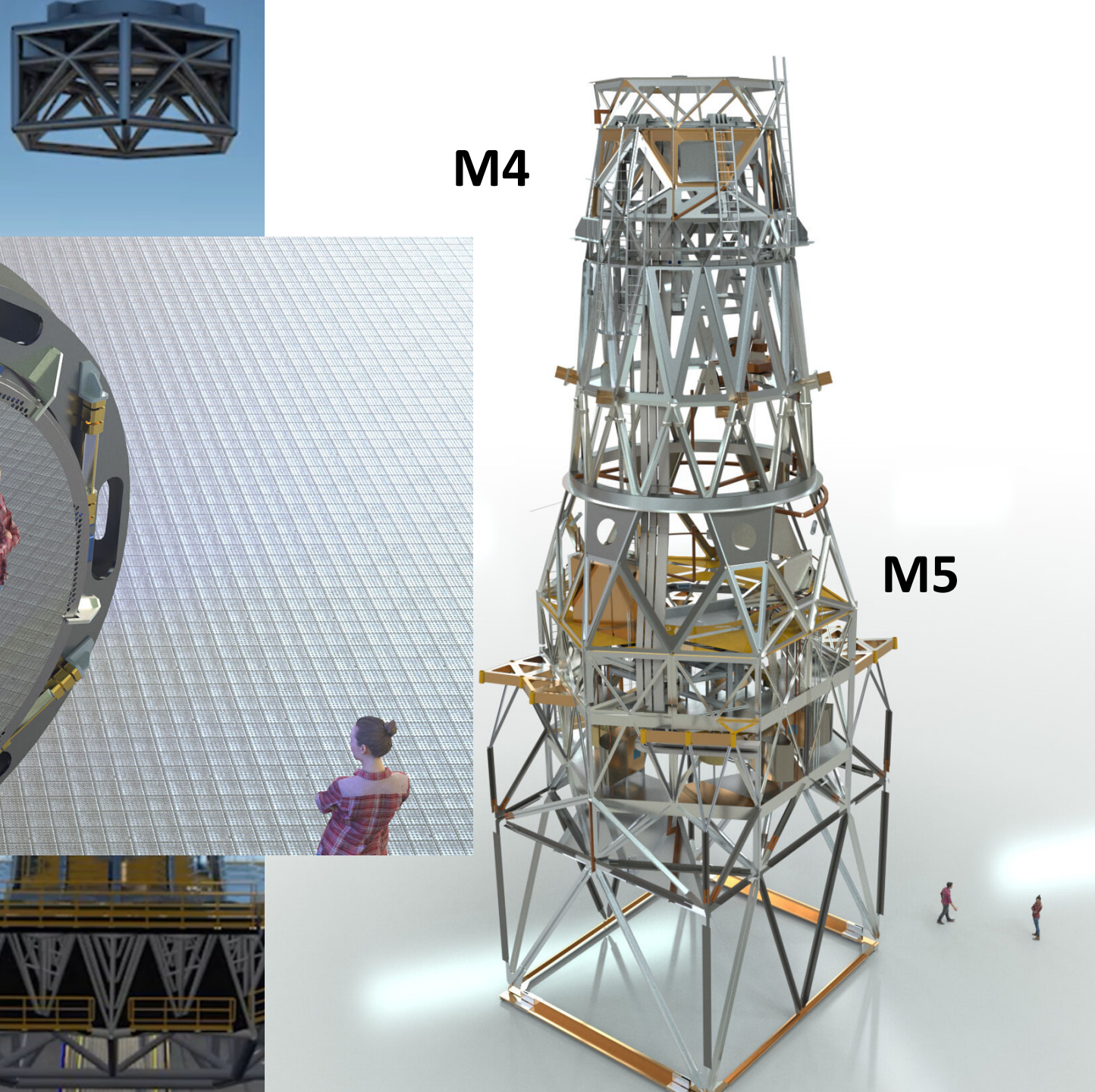
ELT = 100% Adaptive Optics



ELT = 100% Adaptive Optics



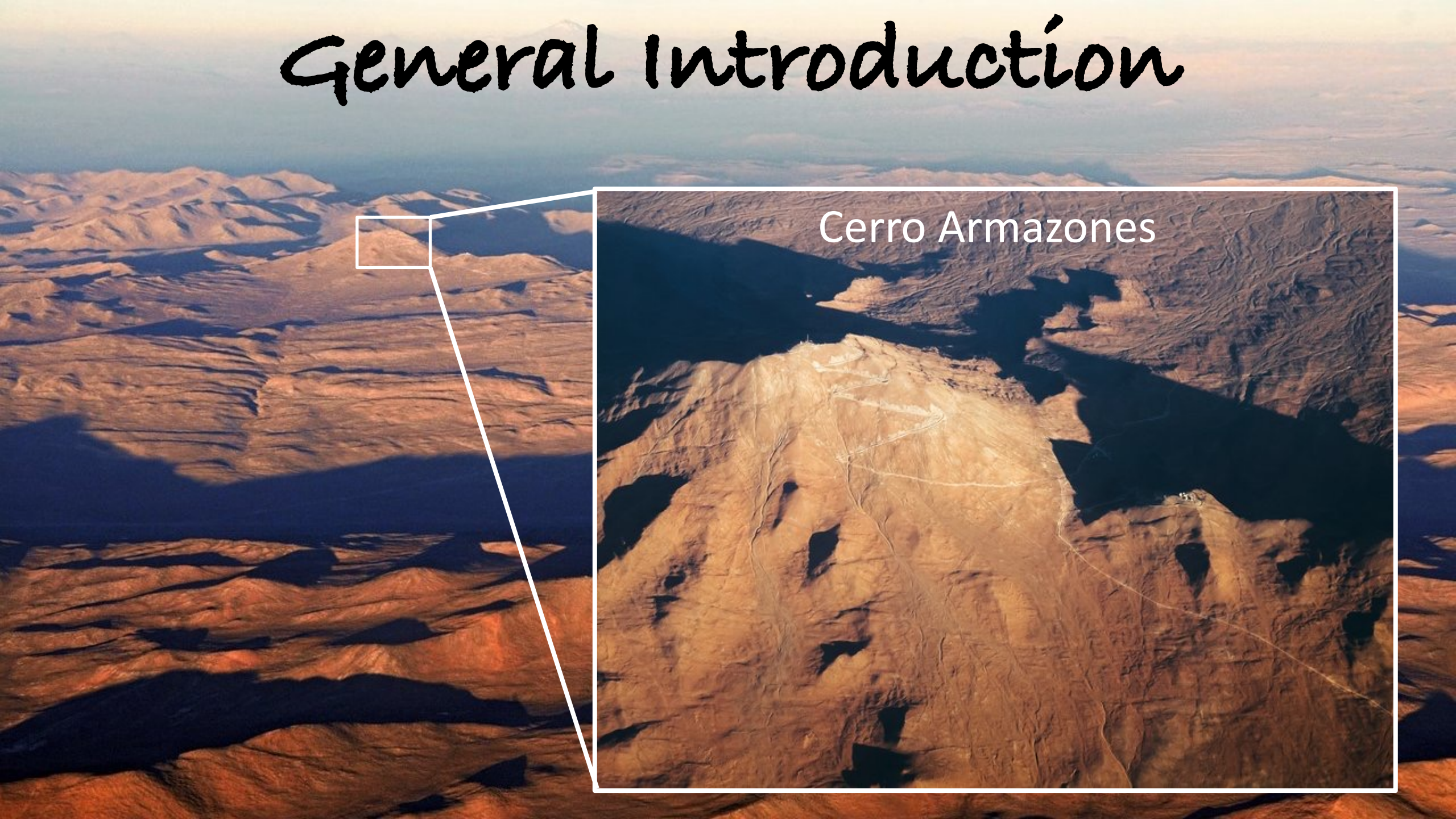




General Introduction



General Introduction



General Introduction

2014…



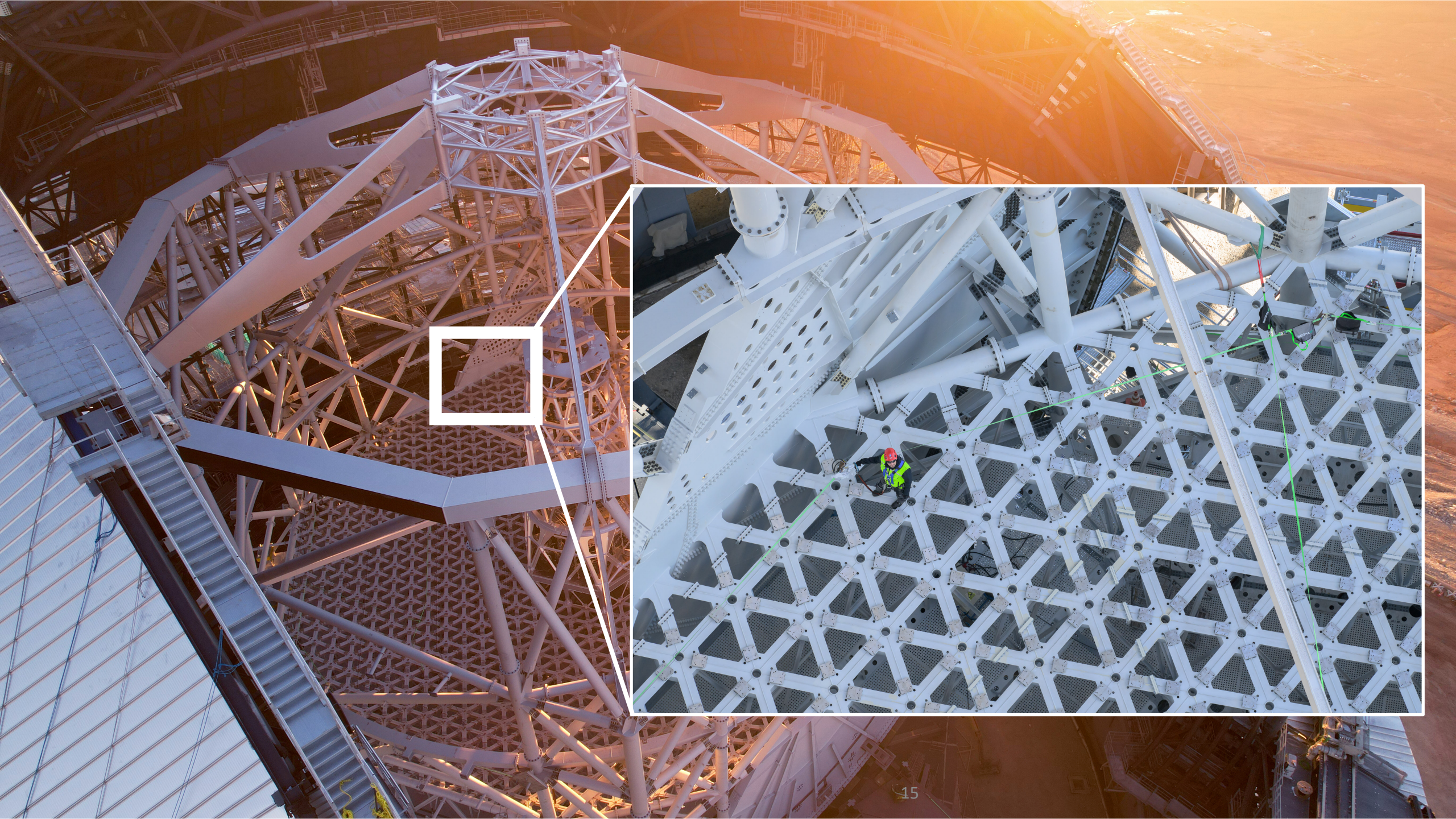




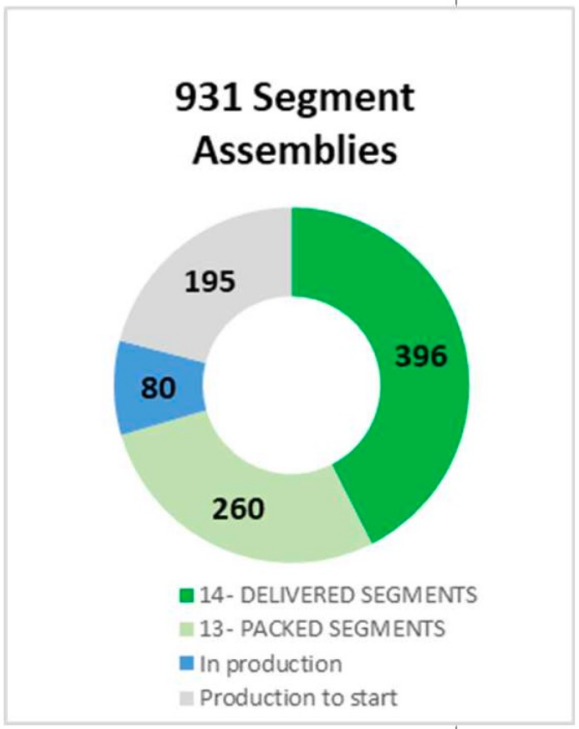
2026…

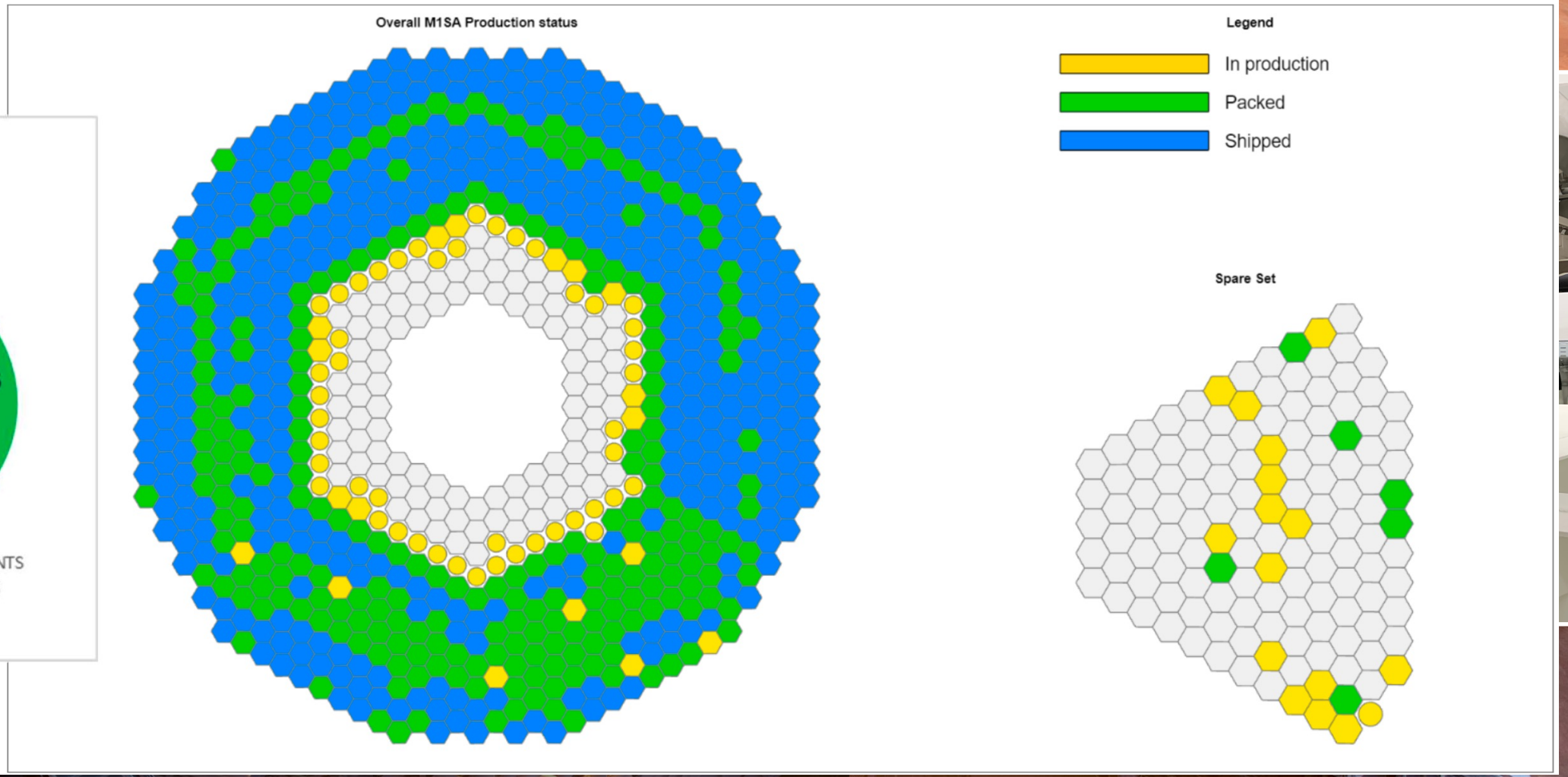






M1 segments production



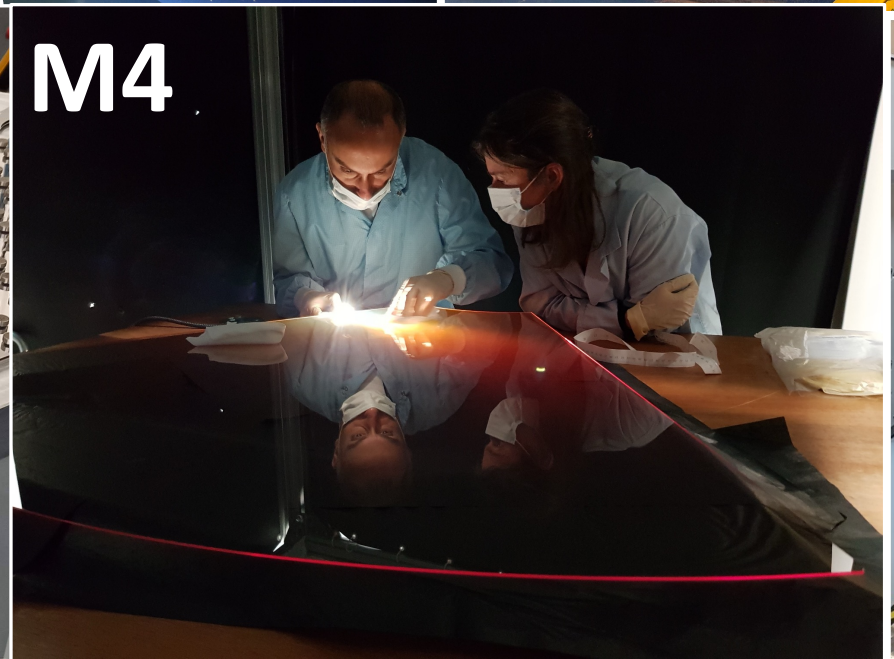


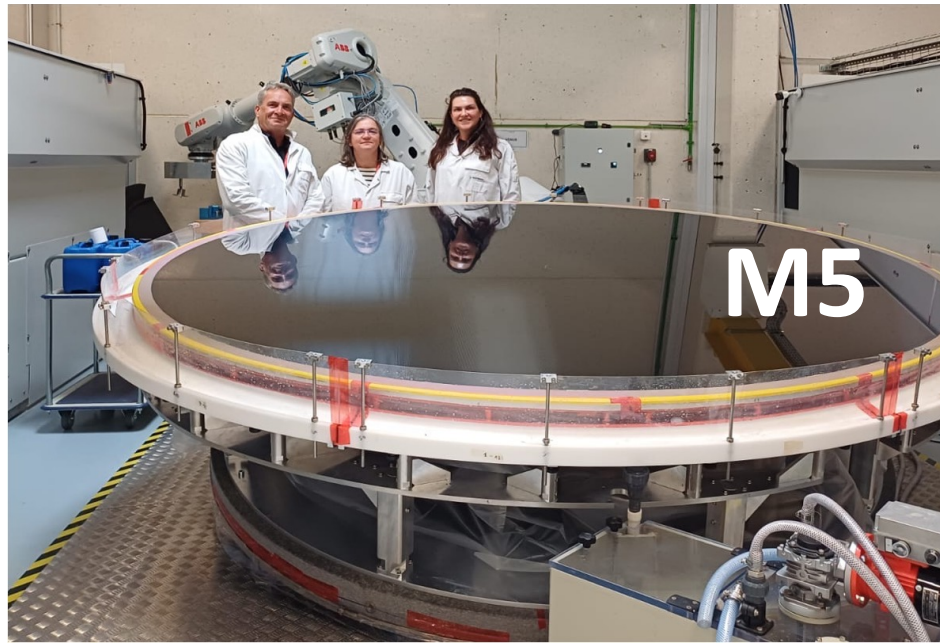

SHOCK, T°,R%, TIME Recorder Inside
VERY FRAGILE OPTICAL GLASS COMPONENT
Lift here with forks 1.8m
WG 310kg
WN 210kg
1850x1850x700mm
SHOCK, T°,R%, TIME Recorder Inside
VERY FRAGILE OPTICAL GLASS COMPONENT
Lift here with forks 1.8m
WG 316kg
WN 216kg
1850x1850x700mm
Lift here with forks 1.8m
Lift here with forks 1.8m
Lift here with forks 1.8m
Lift here with forks 1.8m
M05015
PROCESSED SATCs


M2
SAFRAN

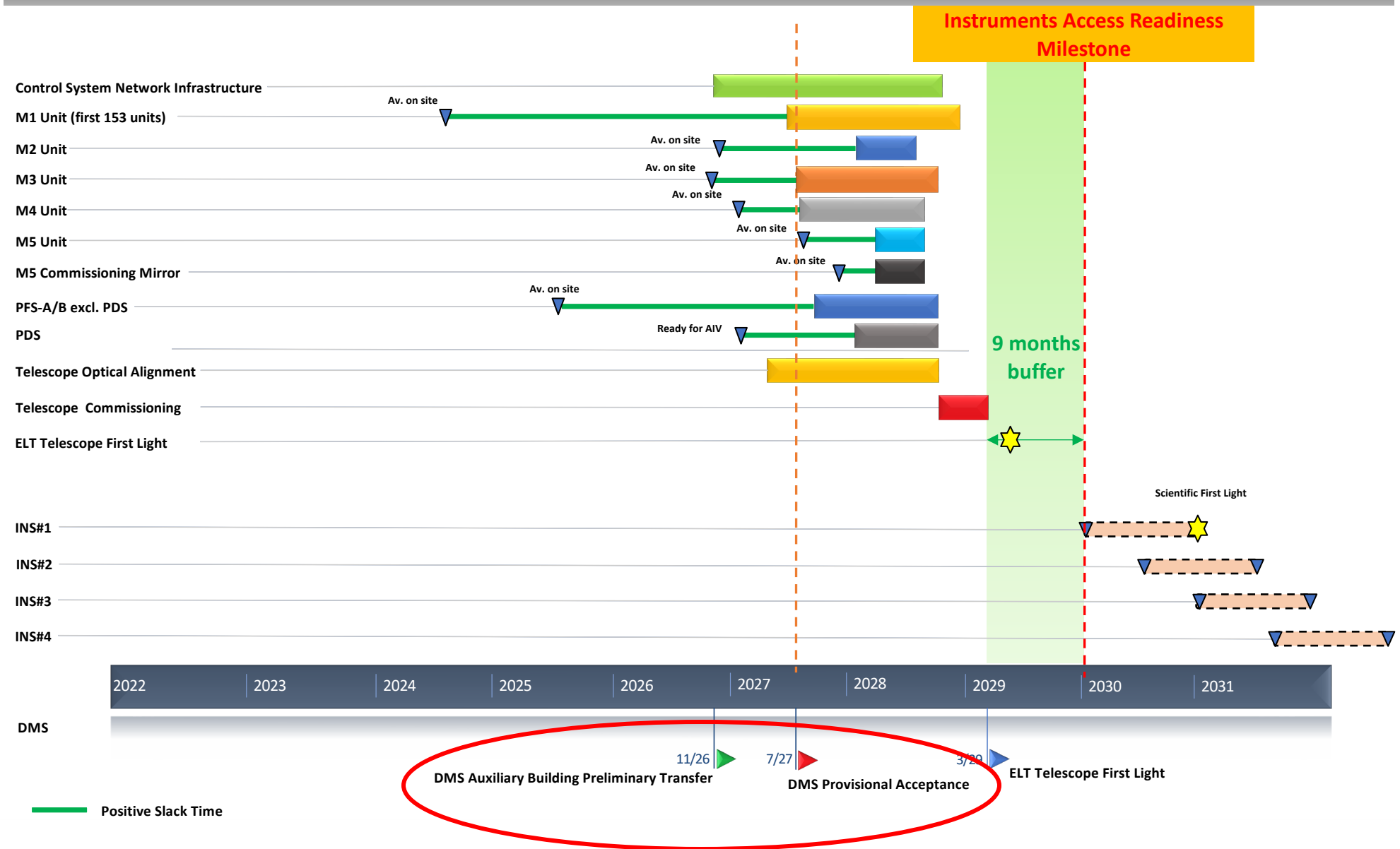

M3




M4


M5

Schedule


Instruments Access Readiness Milestone
Control System Network Infrastructure
M1 Unit (first 153 units)
M2 Unit
M3 Unit
M4 Unit
M5 Unit
M5 Commissioning Mirror
PFS-A/B excl. PDS
PDS
Telescope Optical Alignment
Telescope Commissioning
ELT Telescope First Light
Av. on site
Ready for AIV
9 months buffer
Scientific First Light
INS#1
INS#2
INS#3
INS#4
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
DMS
11/26
DMS Auxiliary Building Preliminary Transfer
7/27
DMS Provisional Acceptance
3/29
ELT Telescope First Light
Positive Slack Time

General Introduction



MORFEO
MICADO
METIS
HARMONI

ANDES
MOSAIC

General Introduction



MORFEO
MICADO
METIS
HARMONI



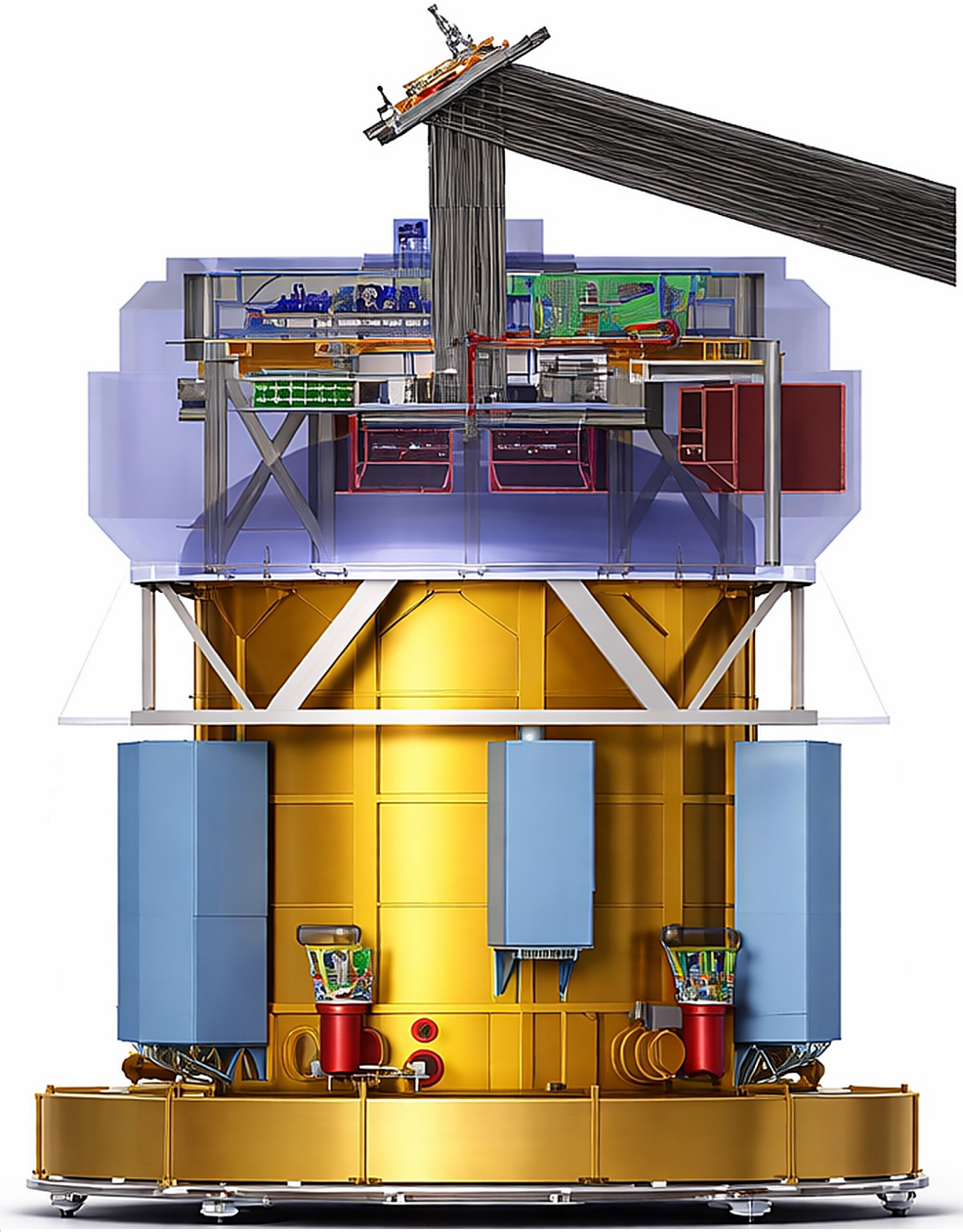
Groupe ELT-France

Journées ELT-France 26-28 Janvier 2027

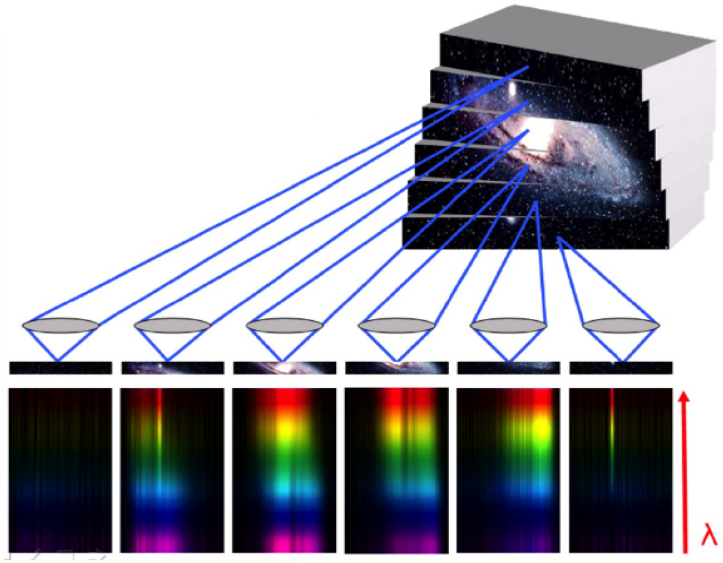
CPJ CNRS ELT

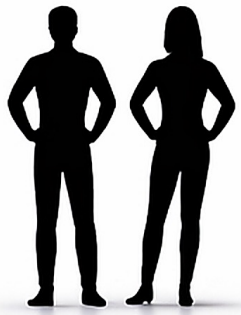


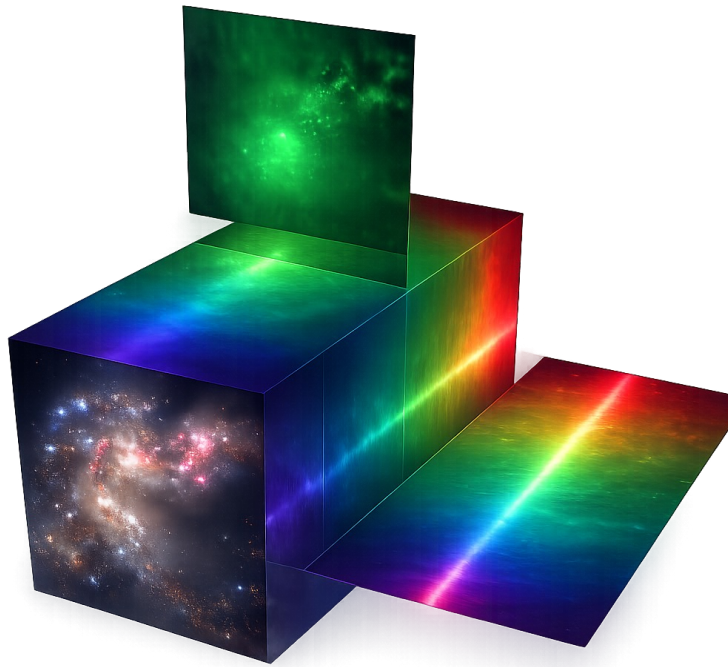
ANDES
MOSAIC



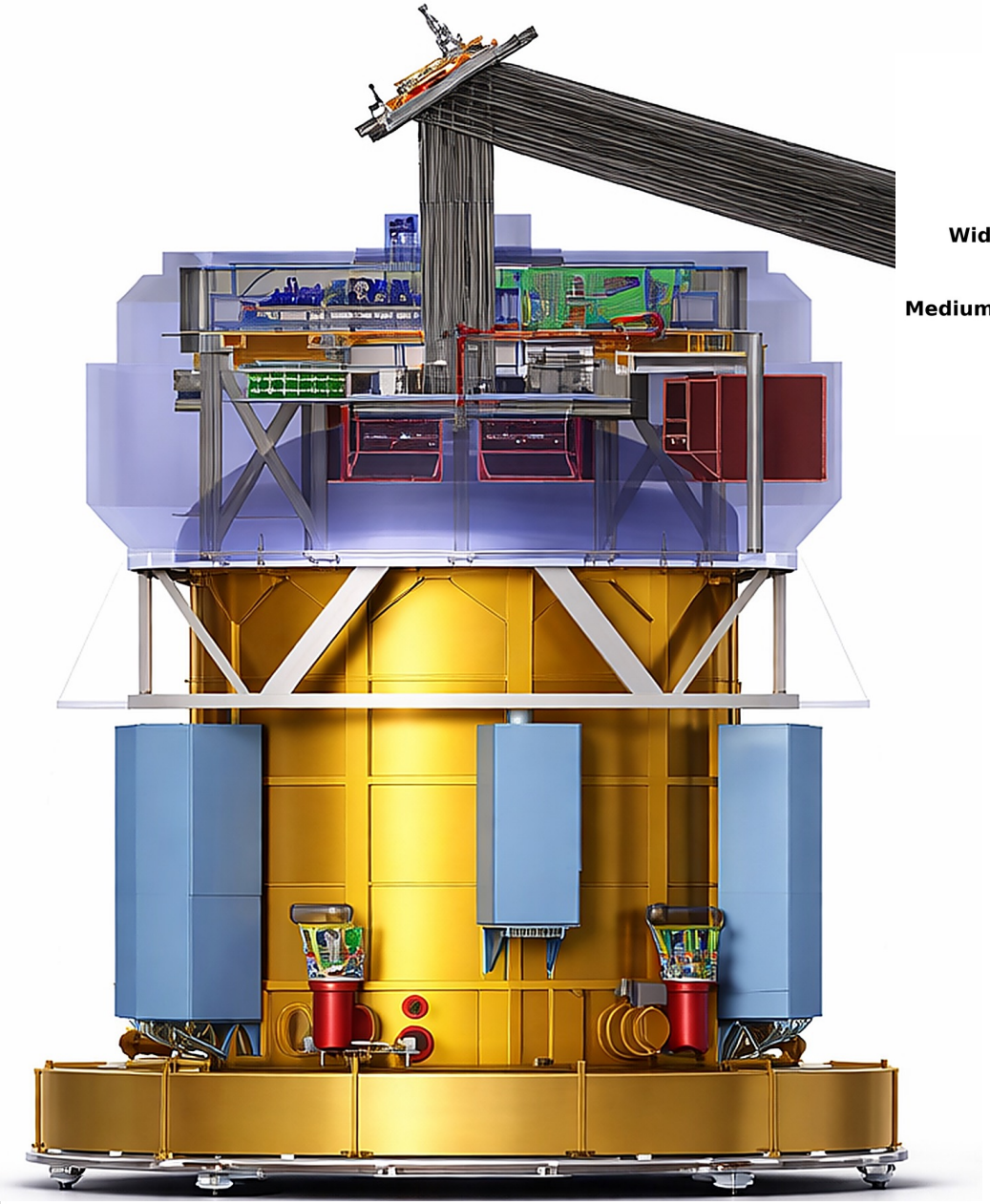
HARMONI

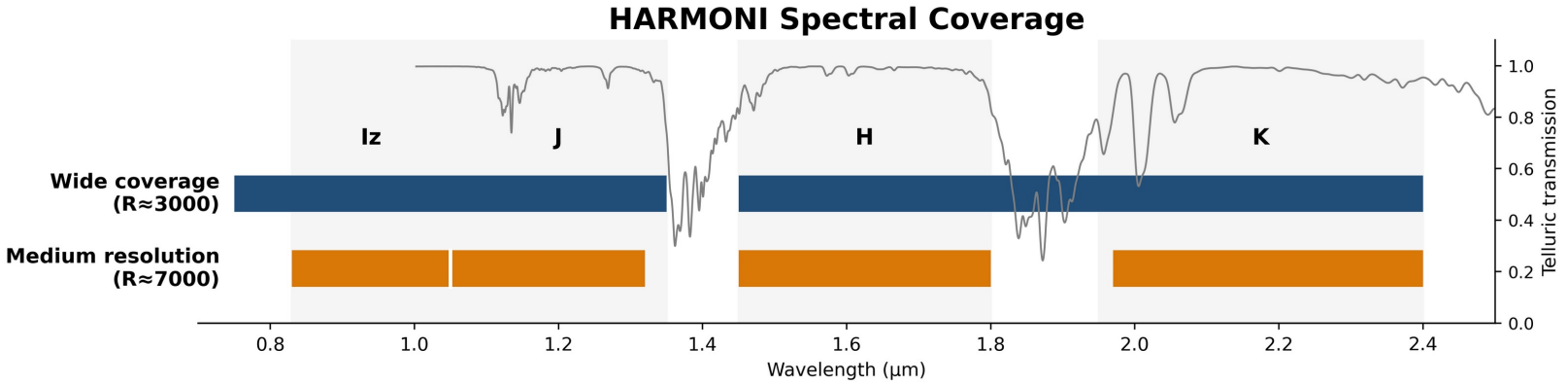






THE UNIVERSITY OF EDINBURGH
UKRI Science and Technology Facilities Council
UK Astronomy Technology Centre
UNIVERSITY OF OXFORD
LAM LABORATOIRE D'ASTROPHYSIQUE DE MARSEILLE
Durham University
INSTITUTO DE ASTROFISICA DE CANARIAS IAC
CRAL CENTRE DE RECHERCHE ASTROPHYSIQUE DE LYON
CENTRO DE ASTROBIOLOGIA CSIC - INTA
UNIVERSITY OF MICHIGAN
IPAG Institut de Planétologie et d'Astrophysique de Grenoble
irap astrophysique & planétologie
ONERA THE FRENCH AEROSPACE LAB
ESO





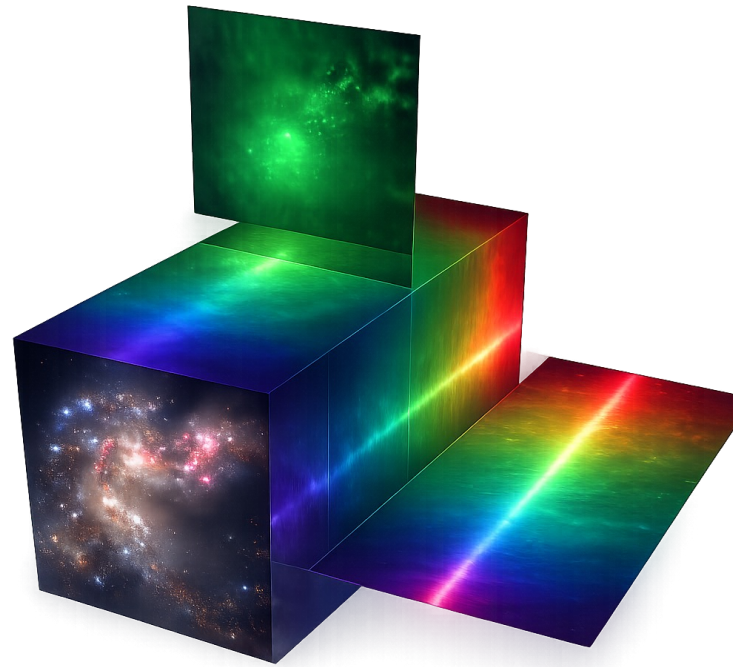
FoV: 5.3″ × 3.8″

25 mas spaxels

FoV: 1.3″ × 0.9″

6 mas spaxels

214 × 152 spatial elements



THE UNIVERSITY OF EDINBURGH

UKRI Science and Technology Facilities Council
UK Astronomy Technology Centre

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Institut de Planétologie et d'Astrophysique de Grenoble

irap
astrophysique & planétologie

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PDR 2017 **FDR 2022**

In 2022, HARMONI started its Final Review Process, however the project faced significant managerial and technical difficulties – too many modes / too many risks

In 2024, and after 2 years of audits / RedFlag, the HARMONI Executive Board decided to press the reset button, and commanded the project to work on:

- **New Management team / organization**
- **Propose a rescoped instrumental solution that would preserve the main science goals, while simplifying the instrumental development**
- **New development plan based on the new instrument proposition**

New Management team



Benoit Neichel



Anne Costille





David Le Mignant







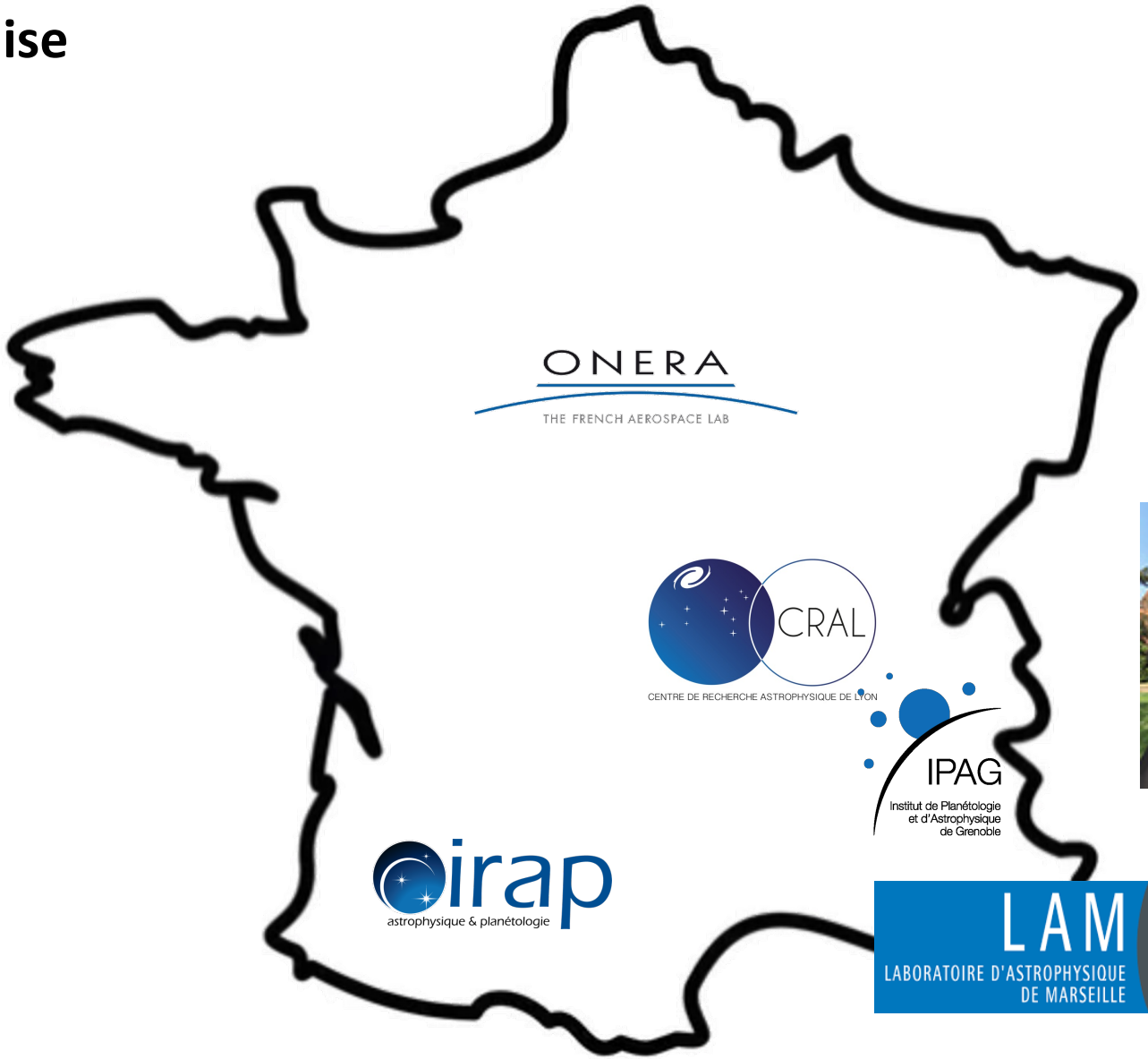






Matthias Tecza

Implication Française



3 Co-Is

Nicolas Bouché





Alexis Carlotti

Audrey Delsanti



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irap astrophysique & planétologie
ONERA THE FRENCH AEROSPACE LAB
ESO

Instrument Rescope -> Back to Science

WG1 - Stellar Populations
Mario Mateo / Miriam Garcia

WG2 - Nearby Galaxies
Eric Bell / Dieu Nguyen

WG3 - High Redshift Universe
Nicolas Bouche, Adelaide Claeyssens

WG4 - Solar System
Olivier Groussin / Audrey Delsanti

WG5 - Exoplanets
Arthur Vigan / Mickael Bonnefoy

WG6 - Transient Astrophysics
Kieran O'Brien

The science working groups and instrument team evaluated key science cases **to identify the essential capabilities HARMONI must retain**. Each science WG were asked to review the spatial and spectral capabilities, the absolute pointing requirement and the AO performance.

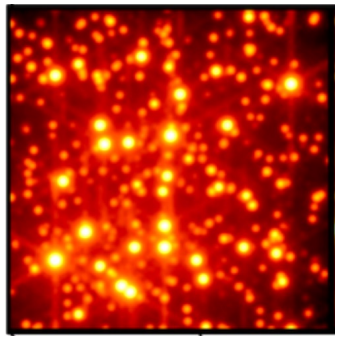
Solar System



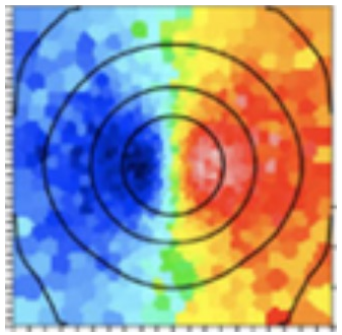
Exoplanet



Resolved Stellar Populations



Nearby galaxies and BH



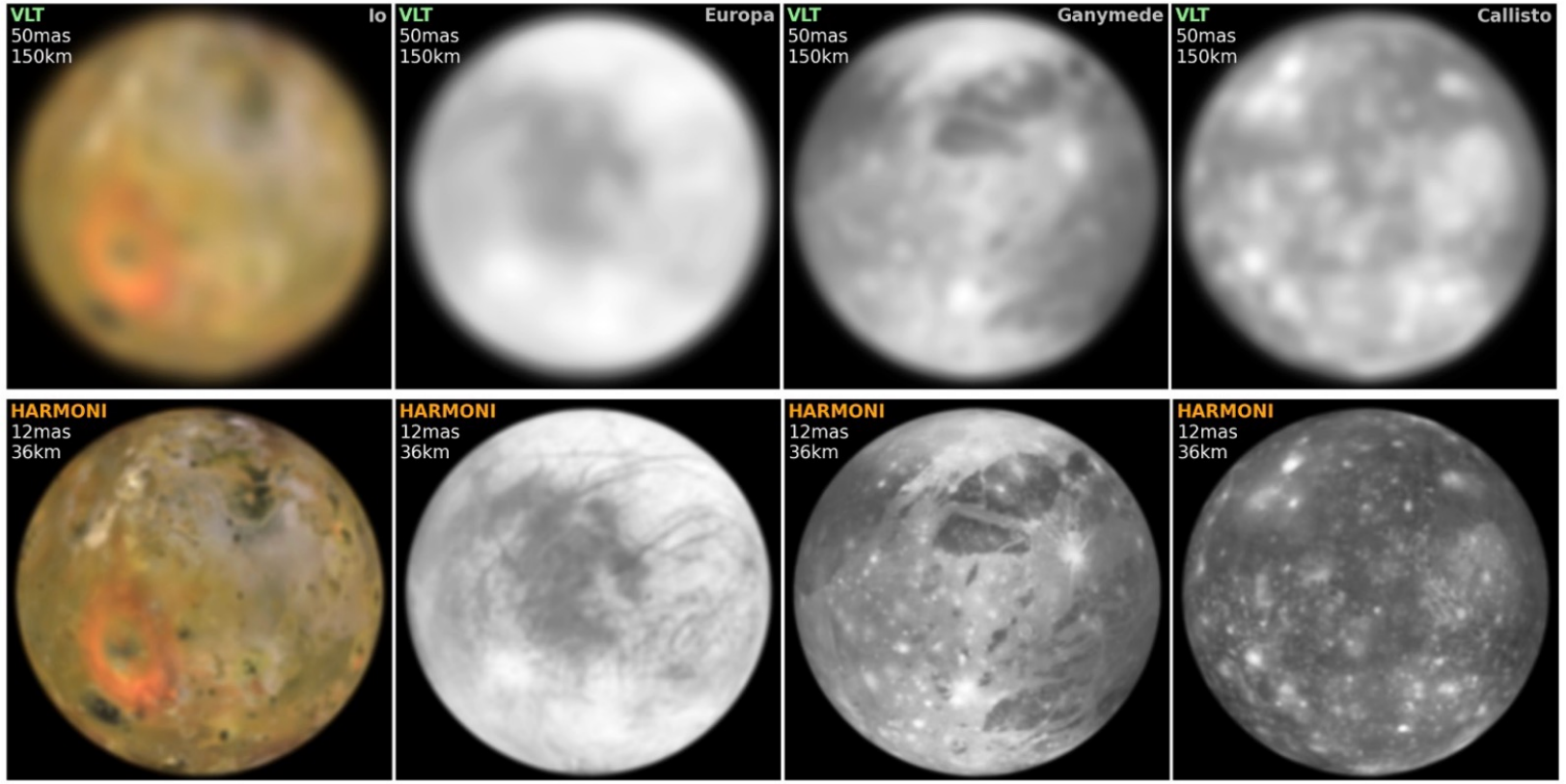
High Redshift universe



Re-visiting the Science Cases – Solar System

WG4 - Solar System
Olivier Groussin / Audrey Delsanti

- Characterizing the giant planet atmospheres
- Characterizing the surfaces of giant planet satellites
- Surface characterization of spatially resolved icy dwarf planets and binary systems beyond Neptune.



Instrument requirements:

2 plate scales: **6 mas**, close to the sample diffraction limit, for spatially resolving dwarf planets and small features on extended objects, and a larger scale of **25 mas**, which offers the best sensitivity for studying faint objects (spatially unresolved) and mapping very large, extended objects such as planets.

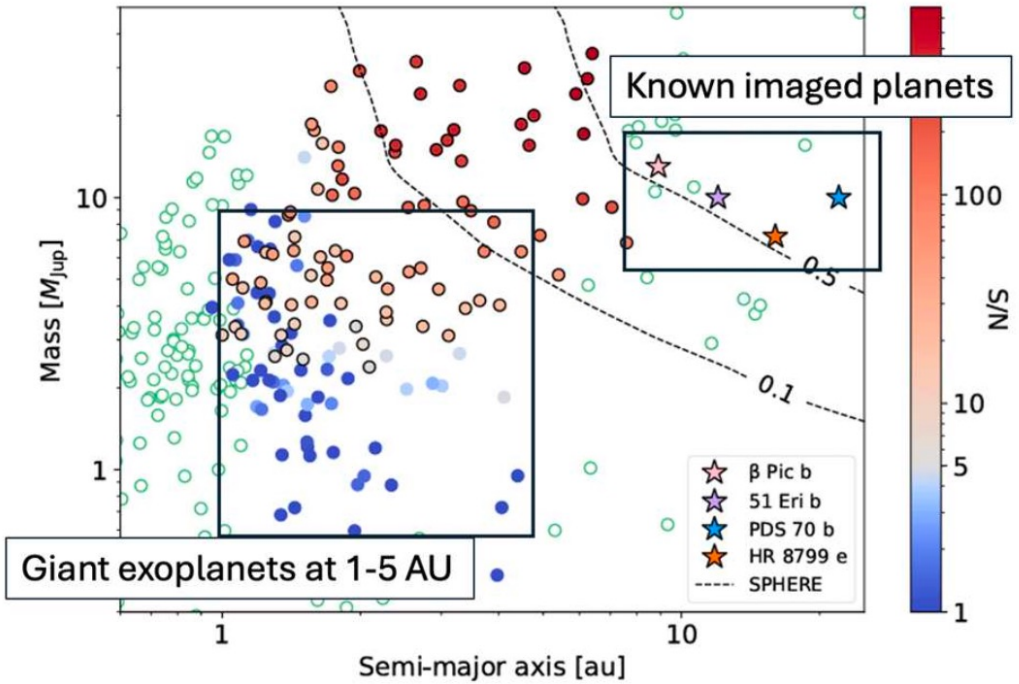
2 gratings: the Low Resolution (LR) grating with simultaneous H+K and the Medium Resolution (MR) grating.

Non-sidereal tracking up to 40"/hour during a 900-second DIT.

Re-visiting the Science Cases – Exoplanets

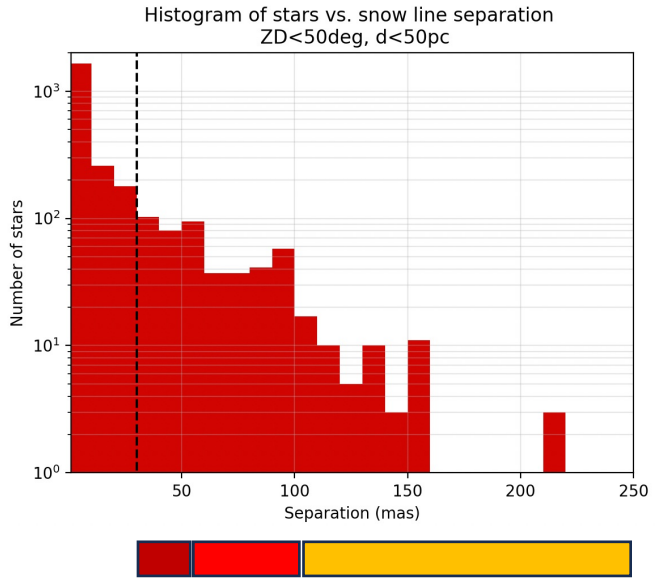
WG5 - Exoplanets
Arthur Vigan / Mickael Bonnefoy

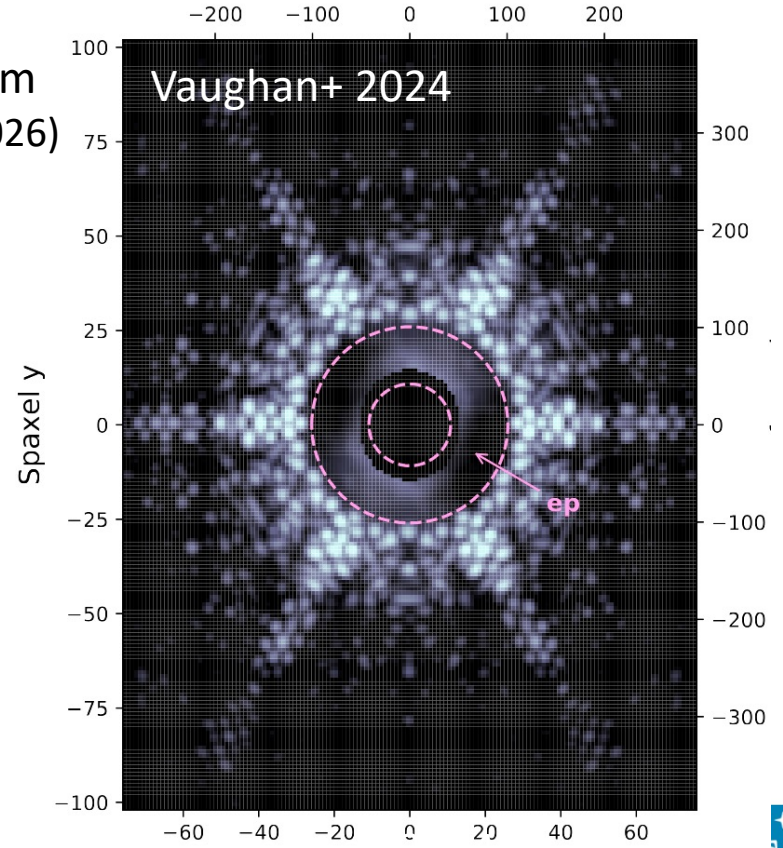
- Peering into the planet population at the snow line, where young giant planets form
- **Opportunity to add a new apodizer** -> Proxima b (37mas, <1e-7 contrast) and more young giants: down to 2AU at 50pc, and 5AU in the ScoCen & Taurus regions



Houllé et al. 2021

Young systems snowline histogram
(using the MOCA database, Gagné+ 2026)

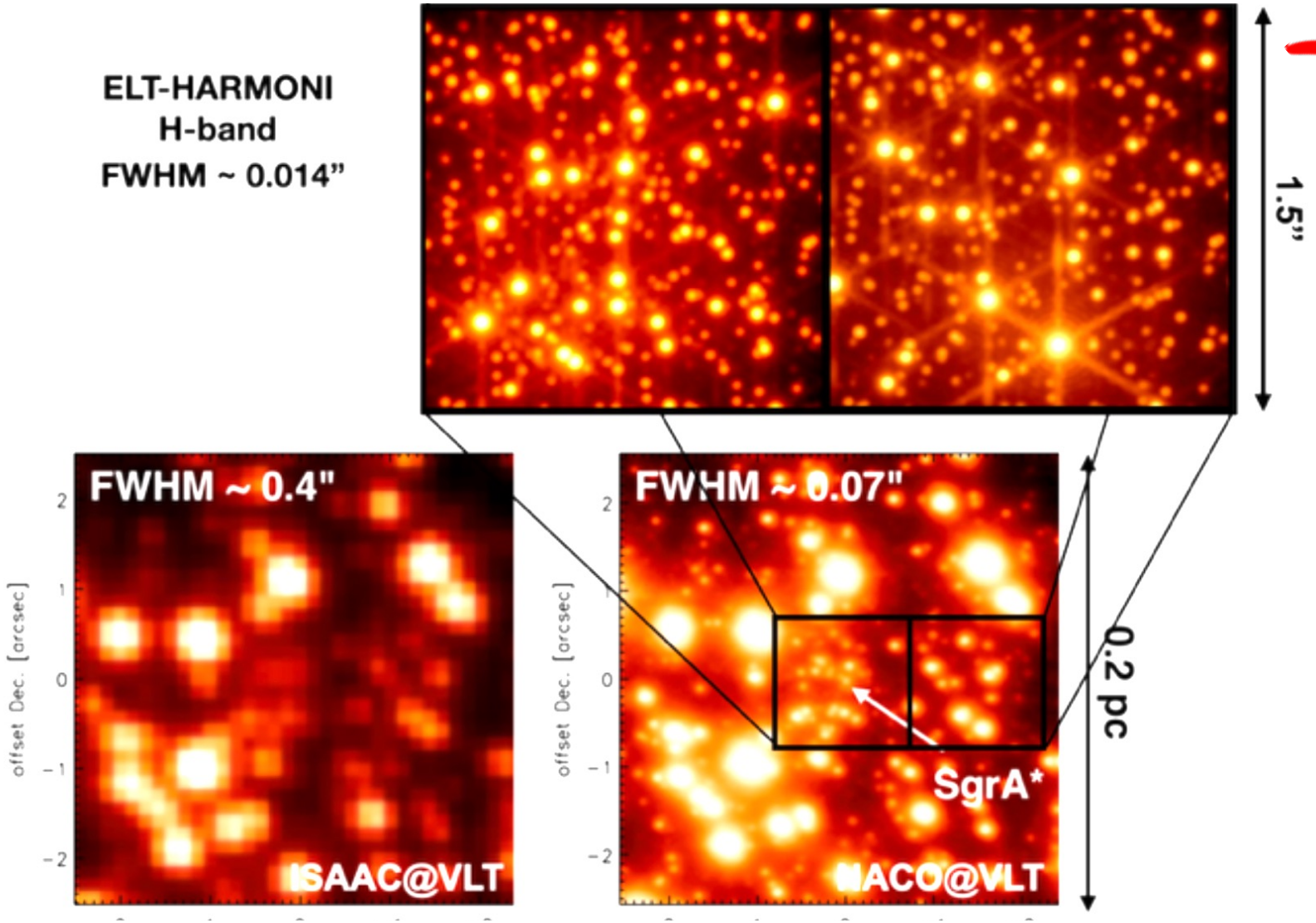




Check also Bidot+ 2024, Martos+ (in prep)

Re-visiting the Science Cases – Resolved Stellar Populations

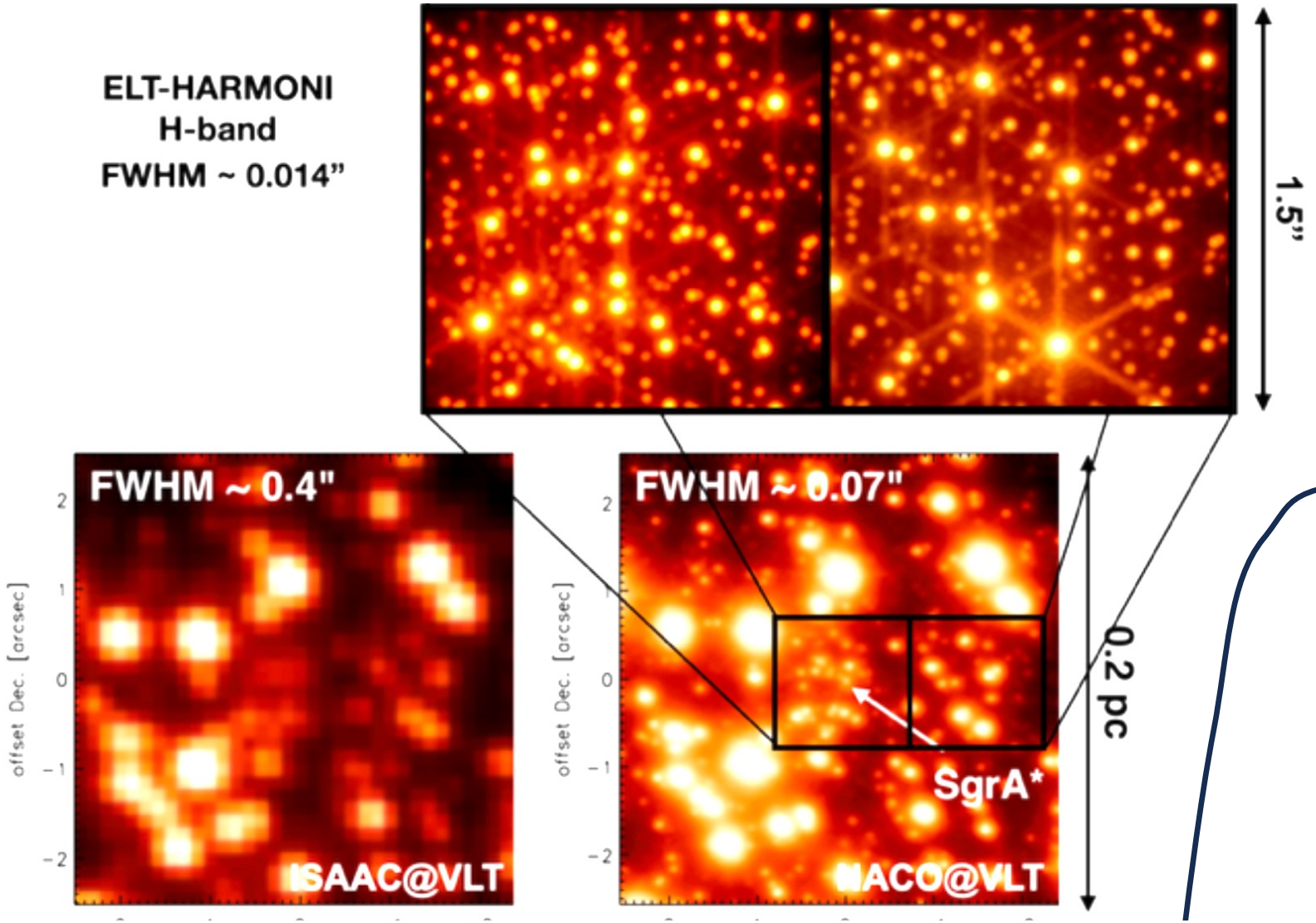
WG1 - Stellar Populations
Mario Mateo / Miriam Garcia

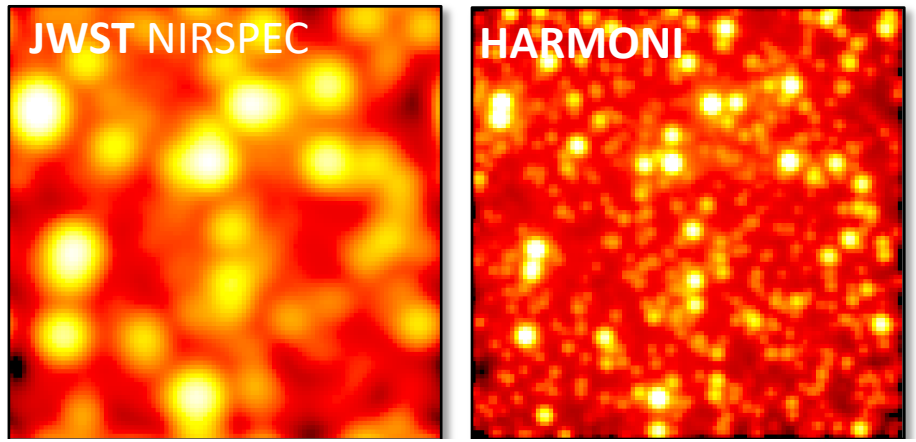


Retain a minimum of **two spaxel-scales, one which well samples the PSF (6-7mas), AND a largest scale (25 mas)**

Re-visiting the Science Cases – Resolved Stellar Populations

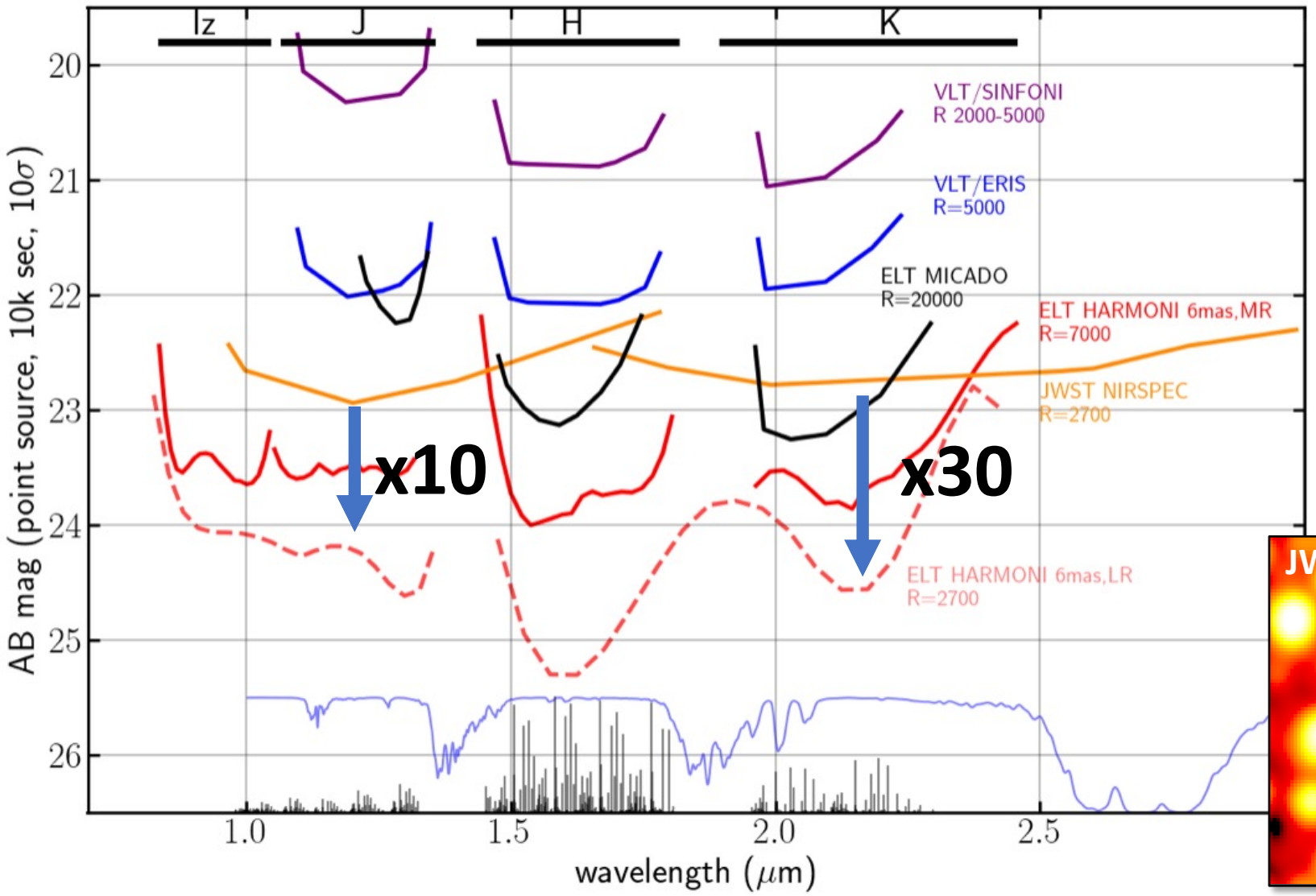
WG1 - Stellar Populations
Mario Mateo / Miriam Garcia



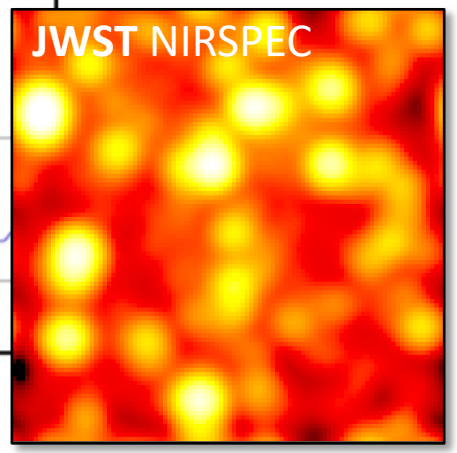


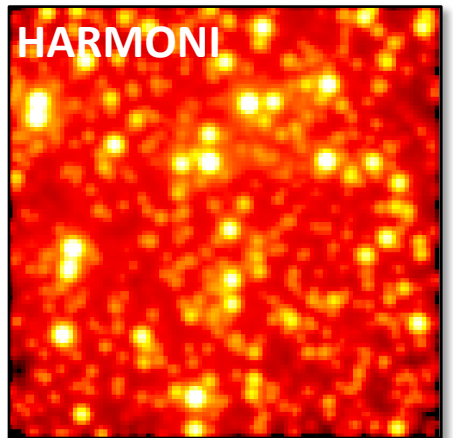
Re-visiting the Science Cases – Resolved Stellar Populations

WG1 - Stellar Populations
Mario Mateo / Miriam Garcia



Sentivity + High angular Resolution

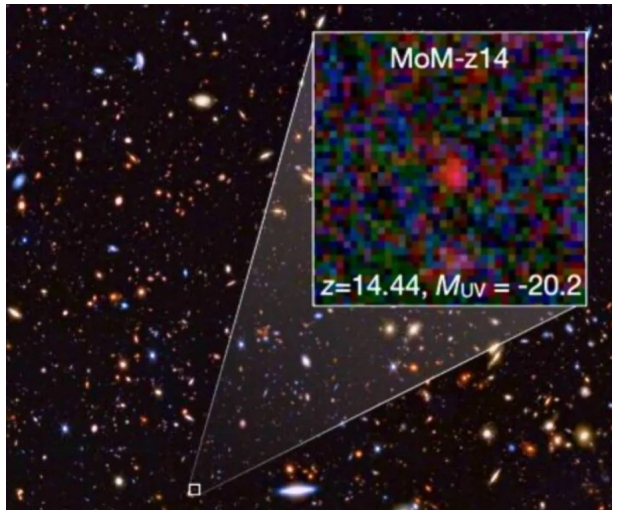


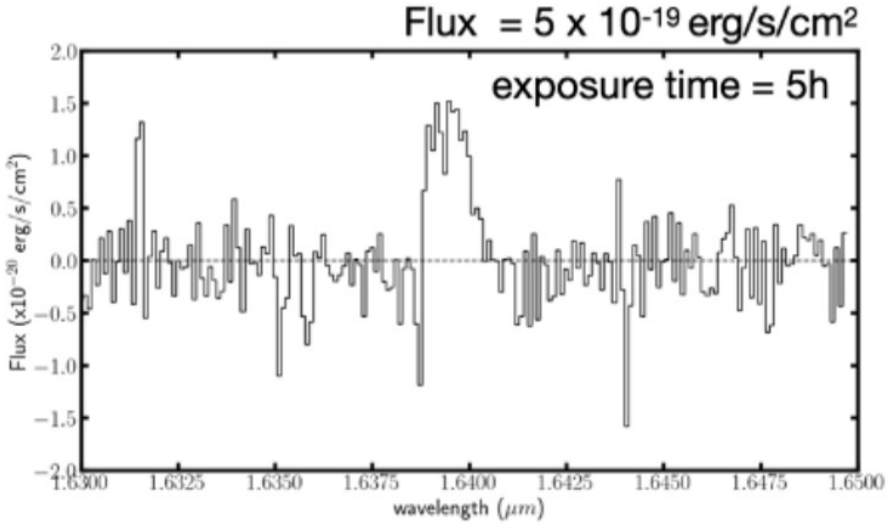


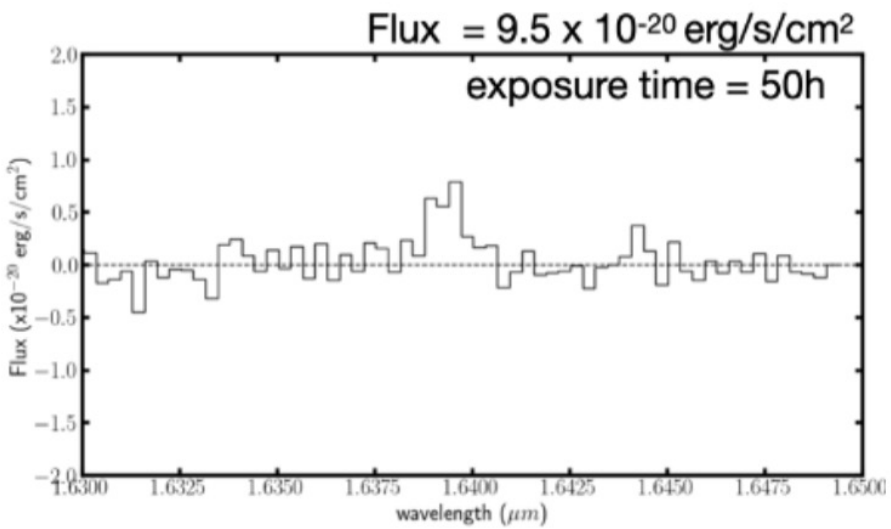
Re-visiting the Science Cases – High-z Universe

WG3 - High Redshift Universe
Nicolas Bouche, Adelaide Claeyssens

Epoch of Reionization & Population III stars: Searching for the signatures of Population III star clusters from galaxies within the Epoch of reionization.





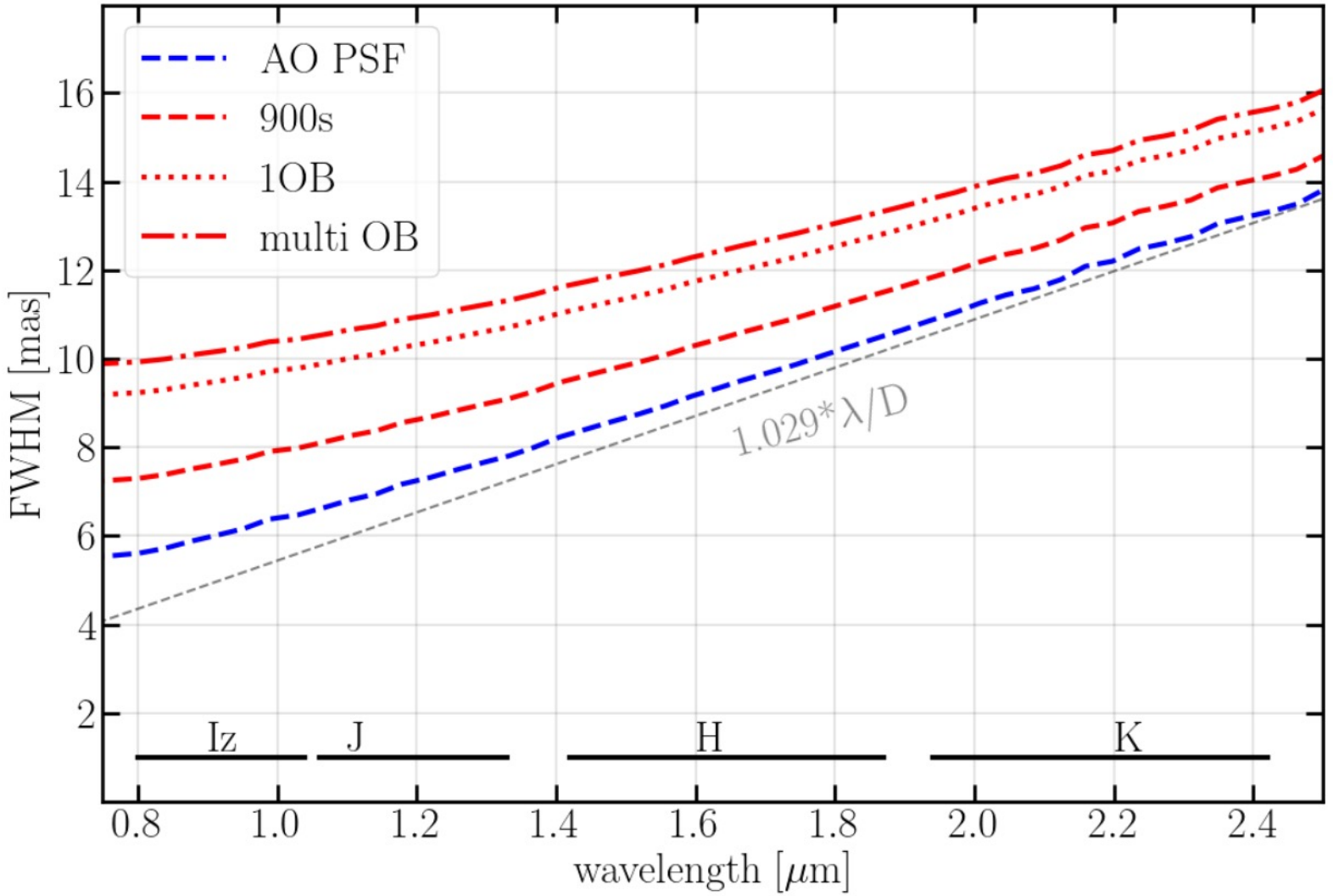


Blind stacking to better than 1 spaxel is mandatory to ensure the S/N and image quality is not degraded.

Emission lines will be only detected at ~1σ in a 1-hr exposure -- 50-100hr exposures are envisaged to detect Pop III star clusters at z~10, possibly only detecting the emission at 10σ in the final cube.

To align the cubes with those from other facilities (JWST, ALMA), absolute WCS calibration to at least 30mas is also mandatory

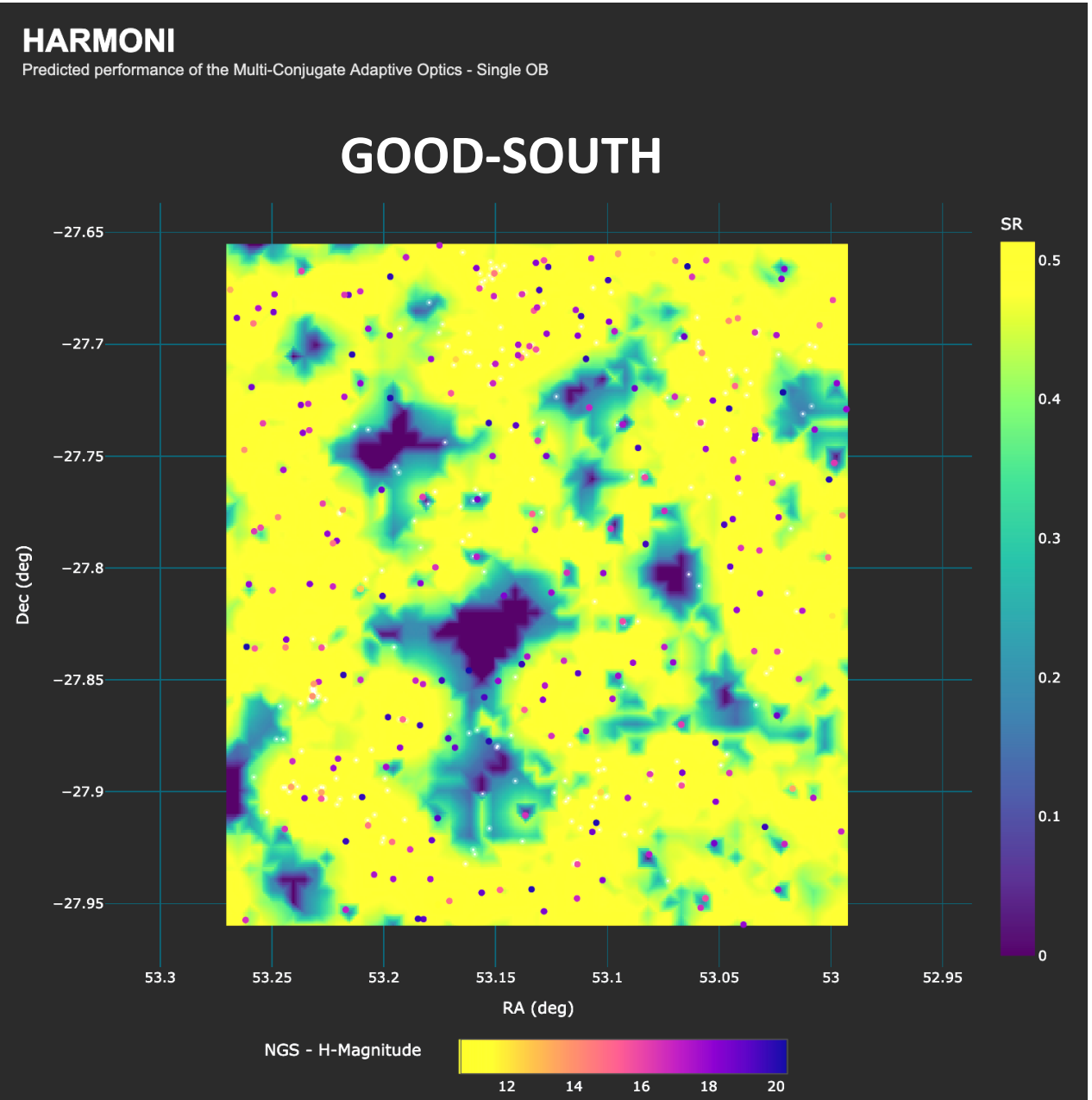
MORFEO + HARMONI PERFORMANCE

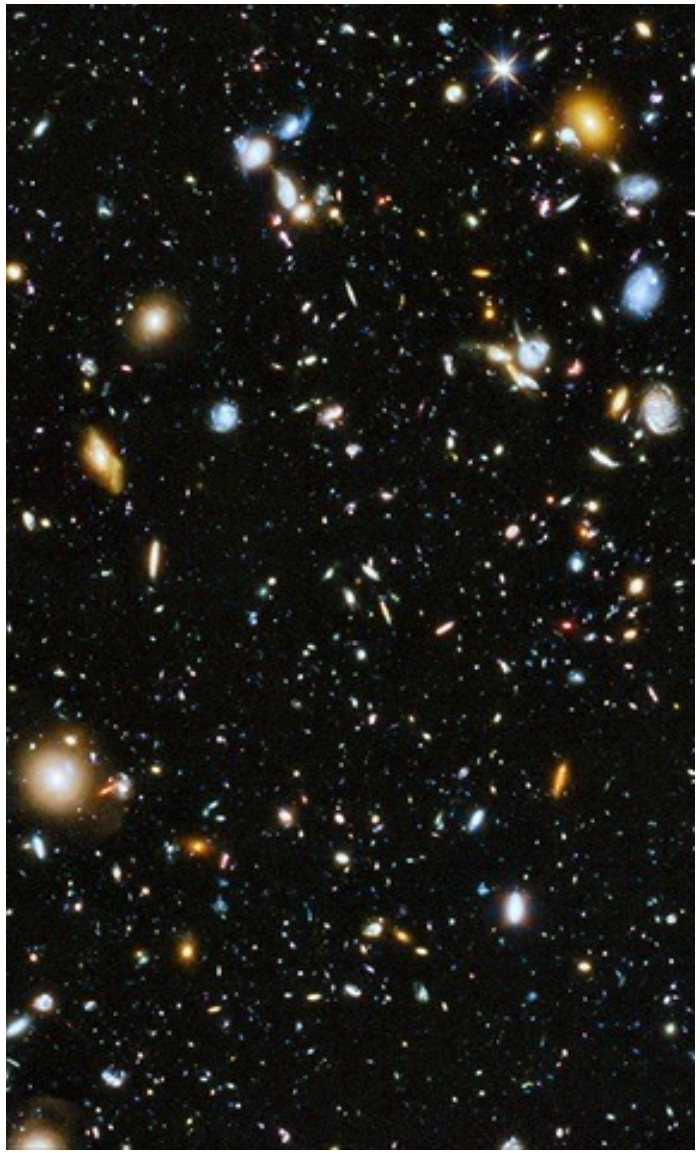


Close to diffraction limit, even for multiple exposures (blind stacking) and over most of the sky

THE UNIVERSITY OF EDINBURGH
UKRI Science and Technology Facilities Council
UK Astronomy Technology Centre
UNIVERSITY OF OXFORD
LAM LABORATOIRE D'ASTROPHYSIQUE DE MARSEILLE
Durham University
INSTITUTO DE ASTROFISICA DE CANARIAS IAC
CRAL CENTRE DE RECHERCHE ASTROPHYSIQUE DE LYON
CENTRO DE ASTROBIOLOGIA CSIC - INTA
UNIVERSITY OF MICHIGAN
IPAG Institut de Planétologie et d'Astrophysique de Grenoble
irap astrophysique & planétologie
ONERA THE FRENCH AEROSPACE LAB
ESO

TipTop / HSIM -> https://astro-tiptop-services.github.io/astro-tiptop-services/gui_SkyCov



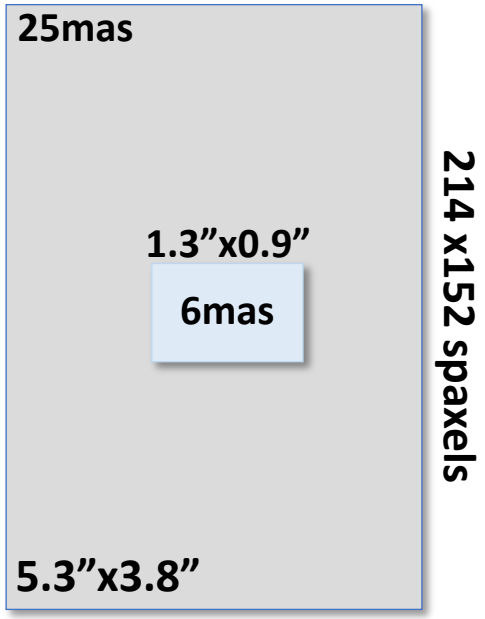


Re-visiting the Science Cases

Top Priority
Suitable with some impact
Desirable
Low importance / not applicable
o: SWG minimal acceptance

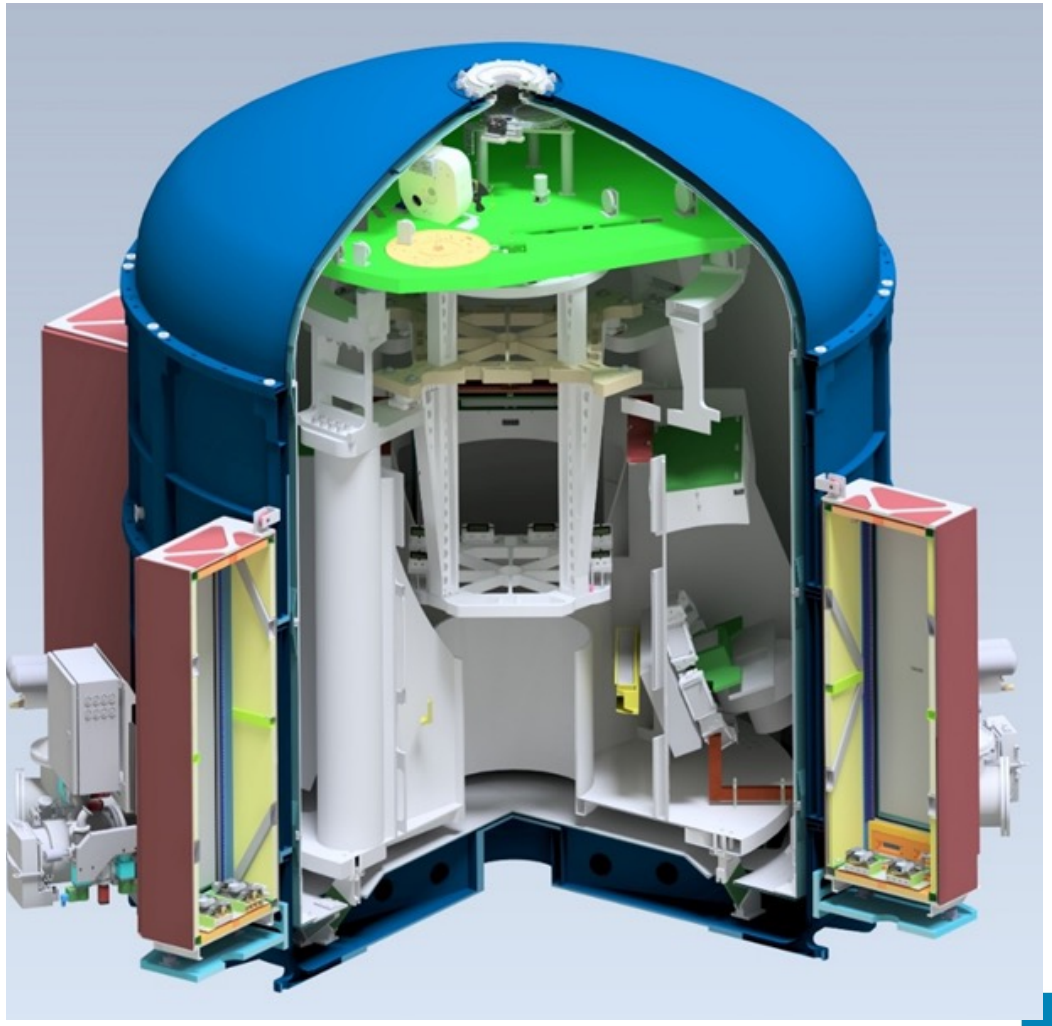
		AO				Spaxel Scale					Gratings											
											VIS	LR		MR				HR				
	Reference Science Case	HCAO	MCAO	SCAO	NoAO	4mas	6-7mas	10mas	20-25mas	30x60	V+R+I	Iz+J	H+K	Iz	J	H	K	z	H_high	K_short	K_long	
SWG1	1.1: Resolved stellar pops in crowded fields						o		o					o	o	o	o					
	1.2: Resolved stellar pops at the faint limit						o		o					o	o	o	o					Severe impact without LR
SWG2	2.1: Supermassive black holes at z<1						o		o					o	o	o	o					
	2.2 :IMBHs in nuclear clusters						o		o					o	o	o	o					Scale>=6mas mandatory
SWG3	3.1: Galaxy Dynamics at z~1--3						o		o					o	o	o	o					
	3.2: Star forming regions and clumps in high-z galaxies						o		o					o	o	o	o					Scale >=6mas mandatory
	3.3 :Population III stars at z>10						o		o					o	o	o	o					
SWG4	4.1: Dwarf planets beyond Neptune					o	o		o			o	o									Complete loss without H+K
	4.2 Surface of giant planet satellites					o	o		o			o	o									
	4.3: Giant planet atmospheres					o	o		o			o	o									
SWG5	5.1: Detection of exoplanets					o	o								o	o	o					
	5.2 Characterisation of exoplanets					o	o								o	o	o					MR acceptable
	5.3: Protoplanetary and debris disks					o	o								o	o	o					
SWG6	6.1: Transient and Time Domain Astronomy						o		o			o	o									Iz+J LR mandatory
	# Top priority:	3	8	3	0	6	8	1	6	0	0	6(1)	7(1)	5(3)	5(5)	5(5)	5(5)	0	1	1	1	No of mandatory (suitable)

Instrumental simplifications : 2 spatial scale, 2 spectral families



From 181 configurations to 26
From 26 cryogenic motors to 14

Simplified Spectrograph



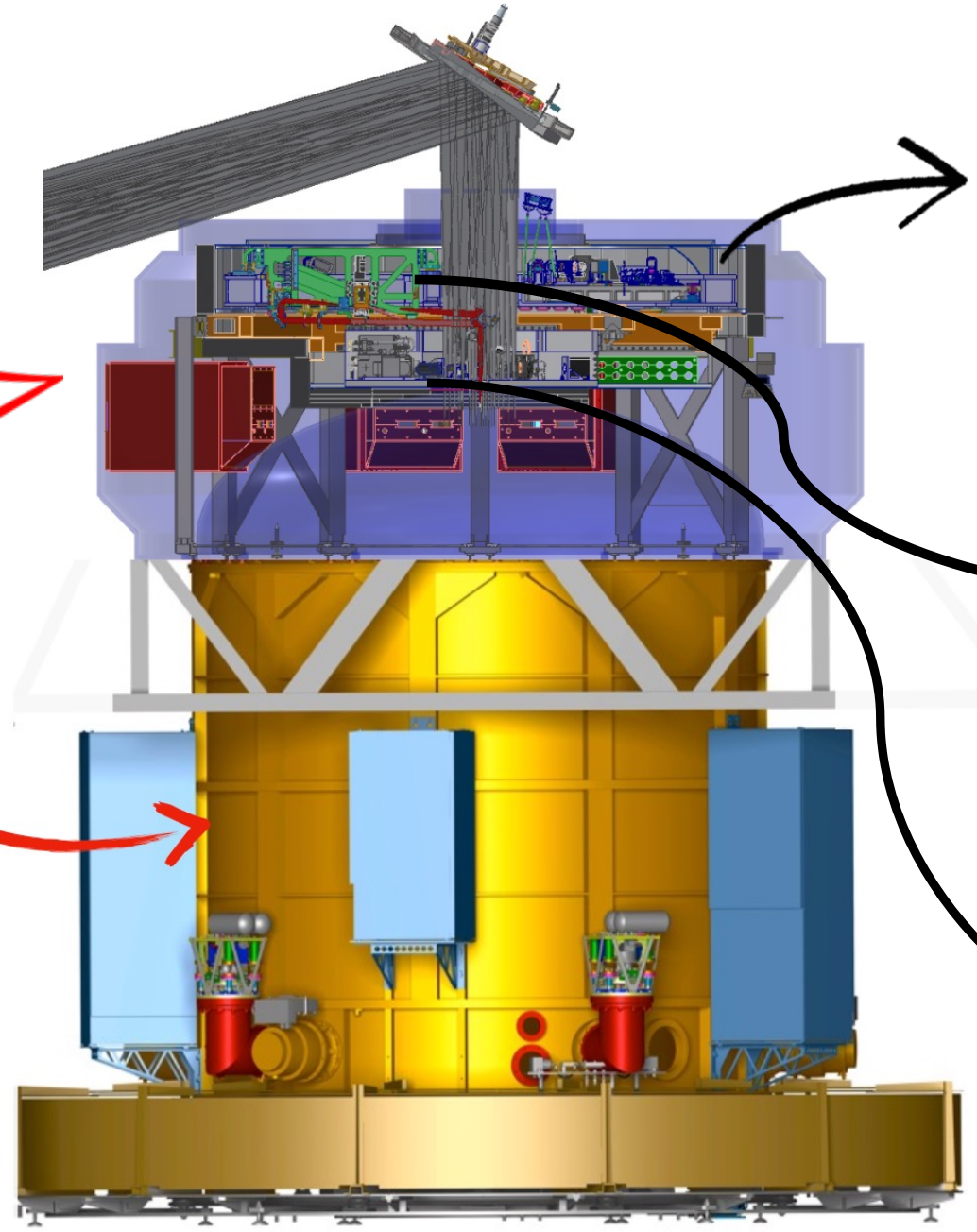
Grating	λref (µm)	Rref	λmin (µm)	λmax (µm)
LR1 (Iz+J)	1.05	3000	0.75	1.35
LR2 (H+K)	1.93	2750	1.45	2.40
MR1 (Iz)	0.94	7000	0.83	1.05
MR2 (J)	1.19	7000	1.05	1.32
MR3 (H)	1.63	7000	1.45	1.80
MR4 (K)	2.19	7000	1.97	2.40

HARMONI AO MODES: SCAO, HC, MCAO

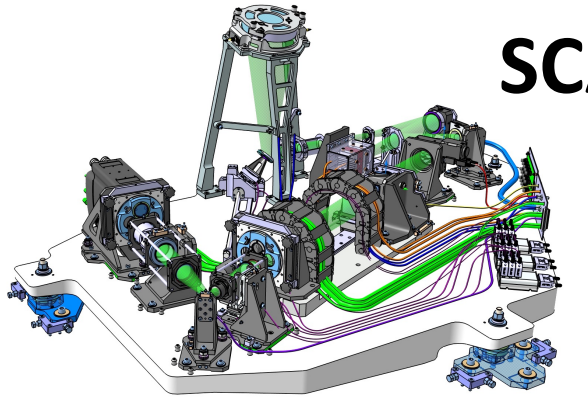
MORFEO

AO

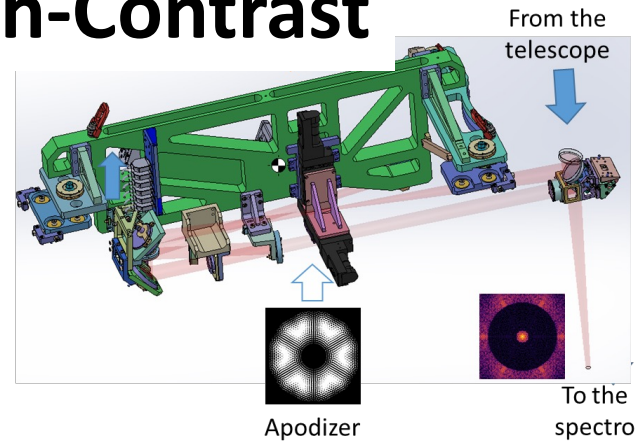
IFS



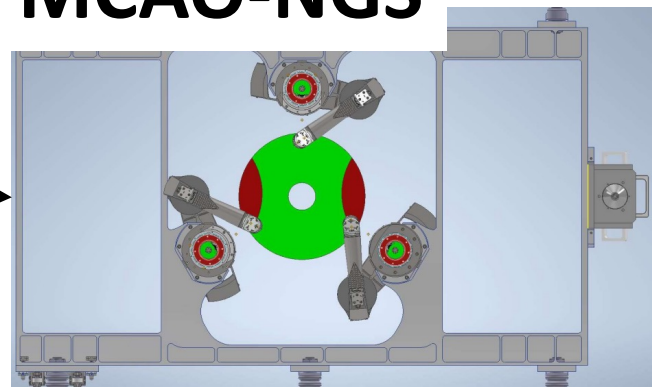
SCAO

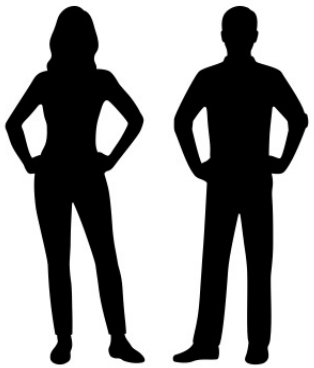


High-Contrast

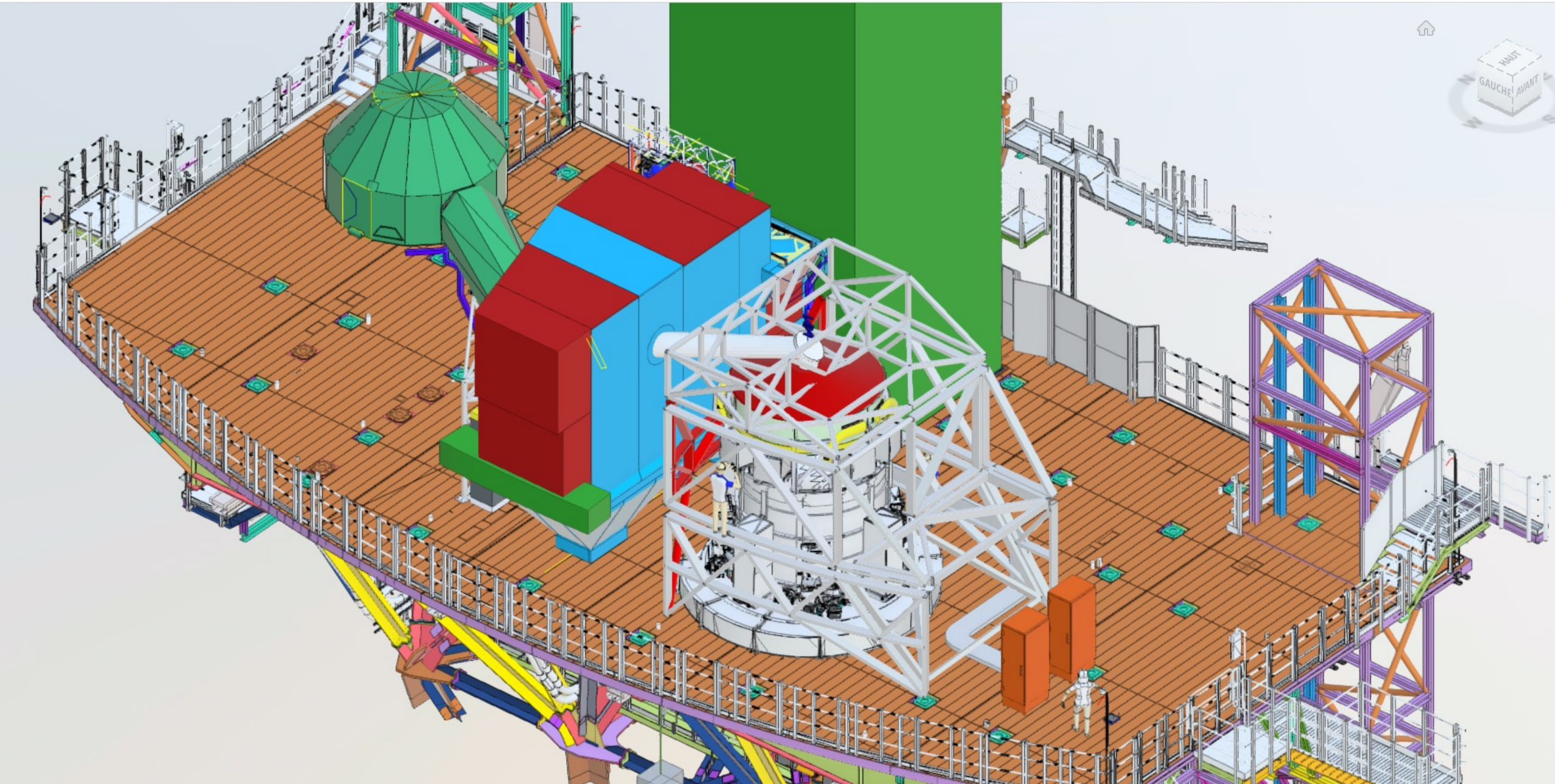


MCAO-NGS





Instrumental simplifications: mutualization of the LGSWFS of MORFEO





End of the Rescope Phase

STC Approval for the re-scoped HARMONI

Following the recent (9-10 June) ESO Council meeting, the full report from the April 2026 ESO Science Technical Committee meeting has now been released.

- The STC congratulates the Consortium and ESO for their productive collaborative work on the Rescope.
- Following ESC, the STC fully endorses the new Technical Specifications as presented in the document received.



Groupe ELT-France

Journées ELT-France 26-28 Janvier 2027

CPJ CNRS ELT