

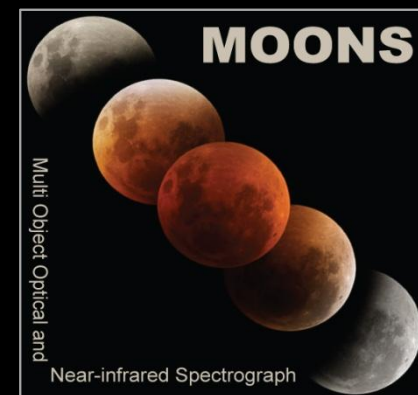
MOONS

a powerful Multi-Object Optical &
Near-infrared Spectrograph for the VLT

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Faculdade de Ciências da Universidade de Lisboa





Science & Technology Facilities Council
UK Astronomy Technology Centre



Galaxies Étoiles Physique et Instrumentation



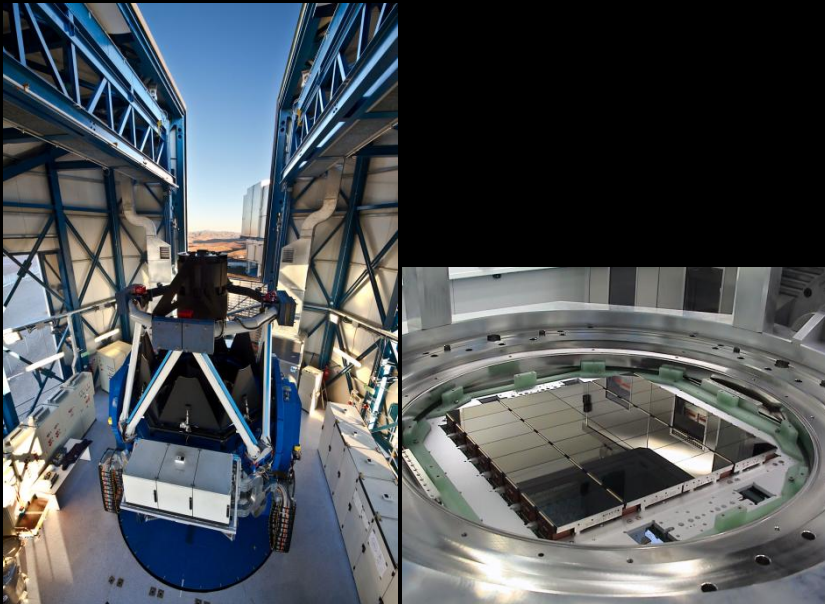
The Multi-Object Optical and Near-infrared Spectrograph, is a new instrument concept recently selected by ESO as a third generation instrument for the VLT, to be fully operational by 2018.

The grasp of the 8m VLT, combined with the large multiplex and wavelength coverage of MOONS will provide ESO community with a powerful, unique instrument able to pioneer a wide range of Galactic, Extragalactic and Cosmological studies.

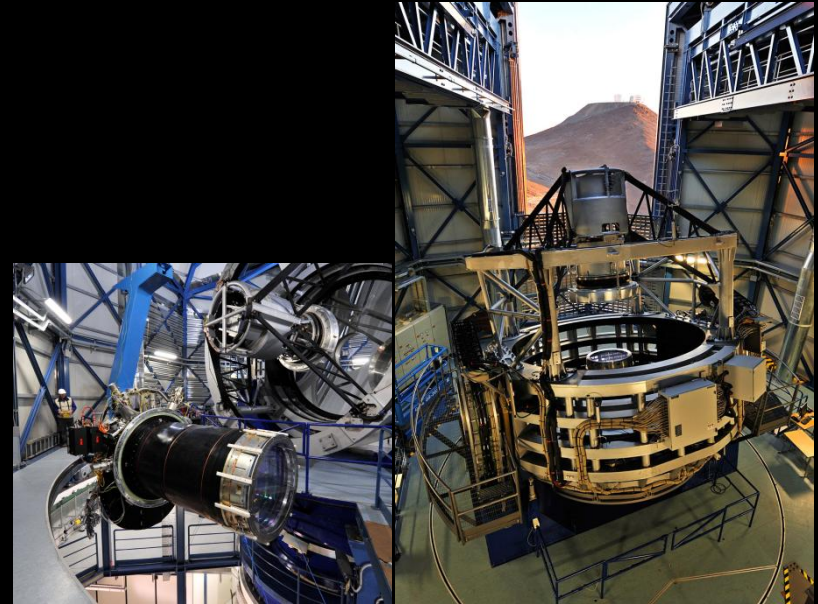
The birth of MOONS

■ Context:

ESO very well suited for large photometric surveys



VST



VISTA

The birth of MOONS



■ Context:

ESO very well suited for large photometric surveys

ESO *not* well suited for large spectroscopic surveys

FLAMES

FORS2

VIMOS

ISAAC

KMOS

SINFONI

...

Either:

- Low multiplexing
- Small fov

The birth of MOONS



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2010: ESO issues a call for a wide-field MOS

6 projects considered (opt, nir; NTT, VLT, VISTA)

The birth of MOONS



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2011: Two projects move to phase-A studies

4MOST (opt, NTT or VISTA); MOONS (opt+nir, VLT)

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The birth of MOONS



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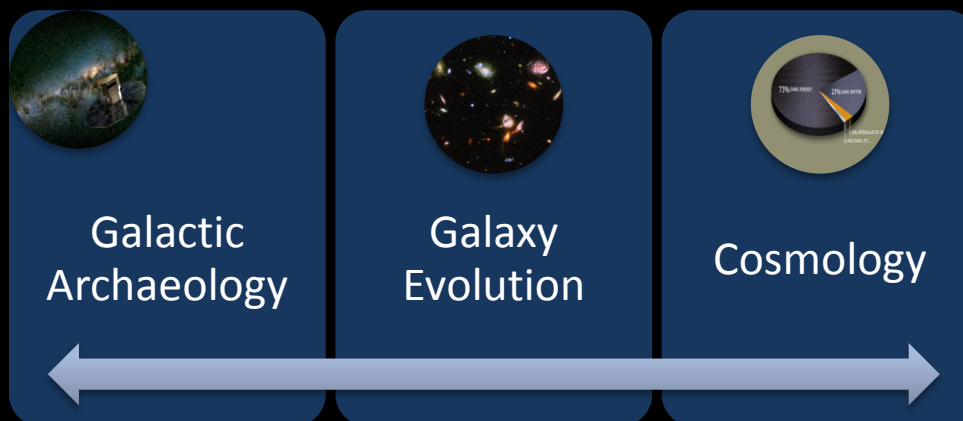
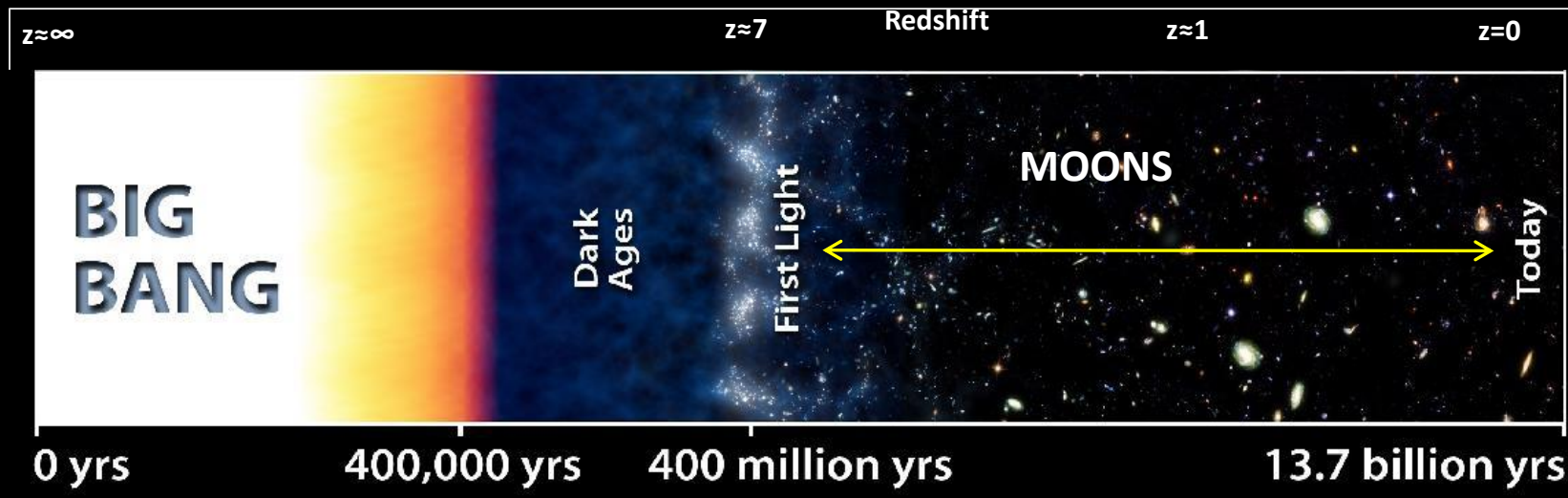
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2013: MOONS selected, proceeding to contract

2018: First light?

MOONS

Pioneer a wide range of Galactic and Extragalactic studies, filling a crucial gap in discovery space.



MOONS

Pioneer a wide range of Galactic and Extragalactic studies, filling a crucial gap in discovery space.

Field of view: 500 sq. arcmin at the 8.2m VLT

Multiplex: 1000 fibers, with the possibility to deploy them in pairs

Medium resolution:

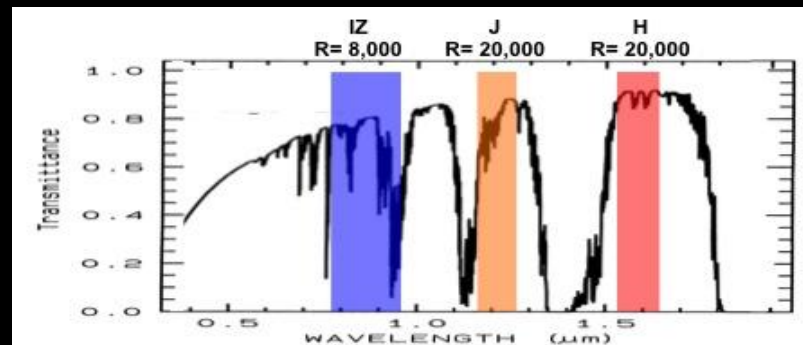
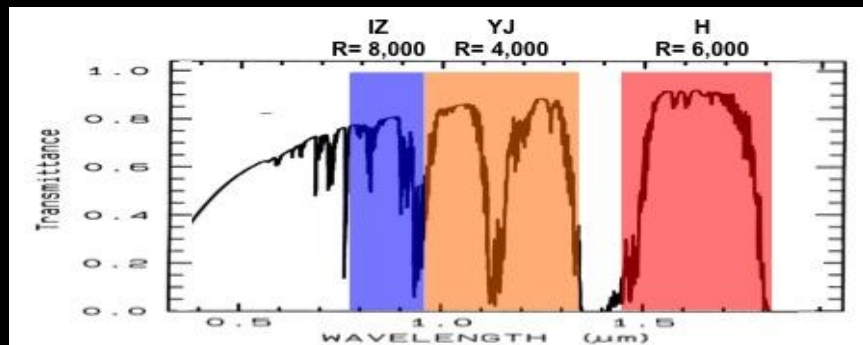
Simultaneously 0.8-1.8 μ m
at
R=4,000 – 6,000



High resolution:

Simultaneously 3 bands:

- 0.8-0.95 μ m at R = 8,000
- 1.17-1.26 μ m at R=20,000
- 1.52-1.63 μ m at R=20,000



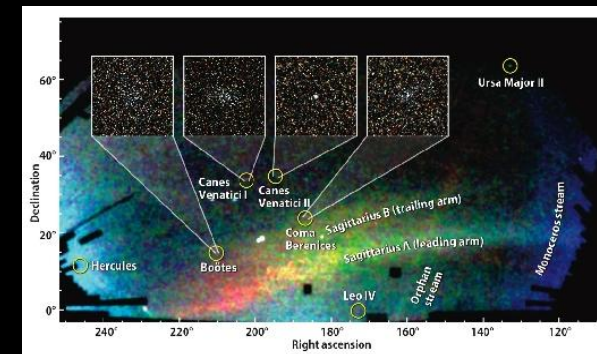
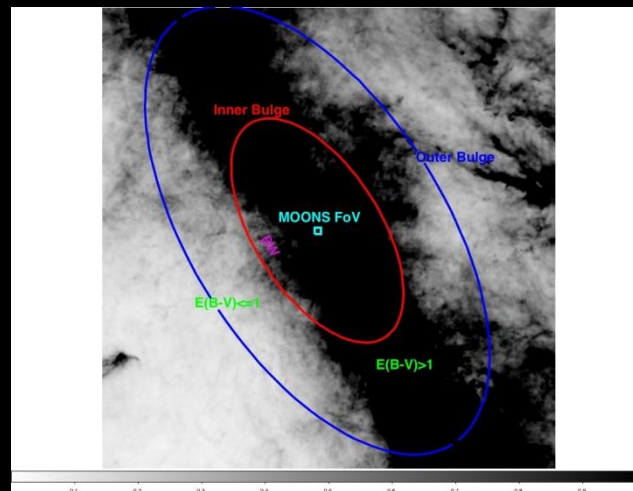
MOONS

Galactic Archaeology

Fundamental facility for necessary follow-up of ESA GAIA, VISTA surveys, Pan-STARRS, UKIDSS...

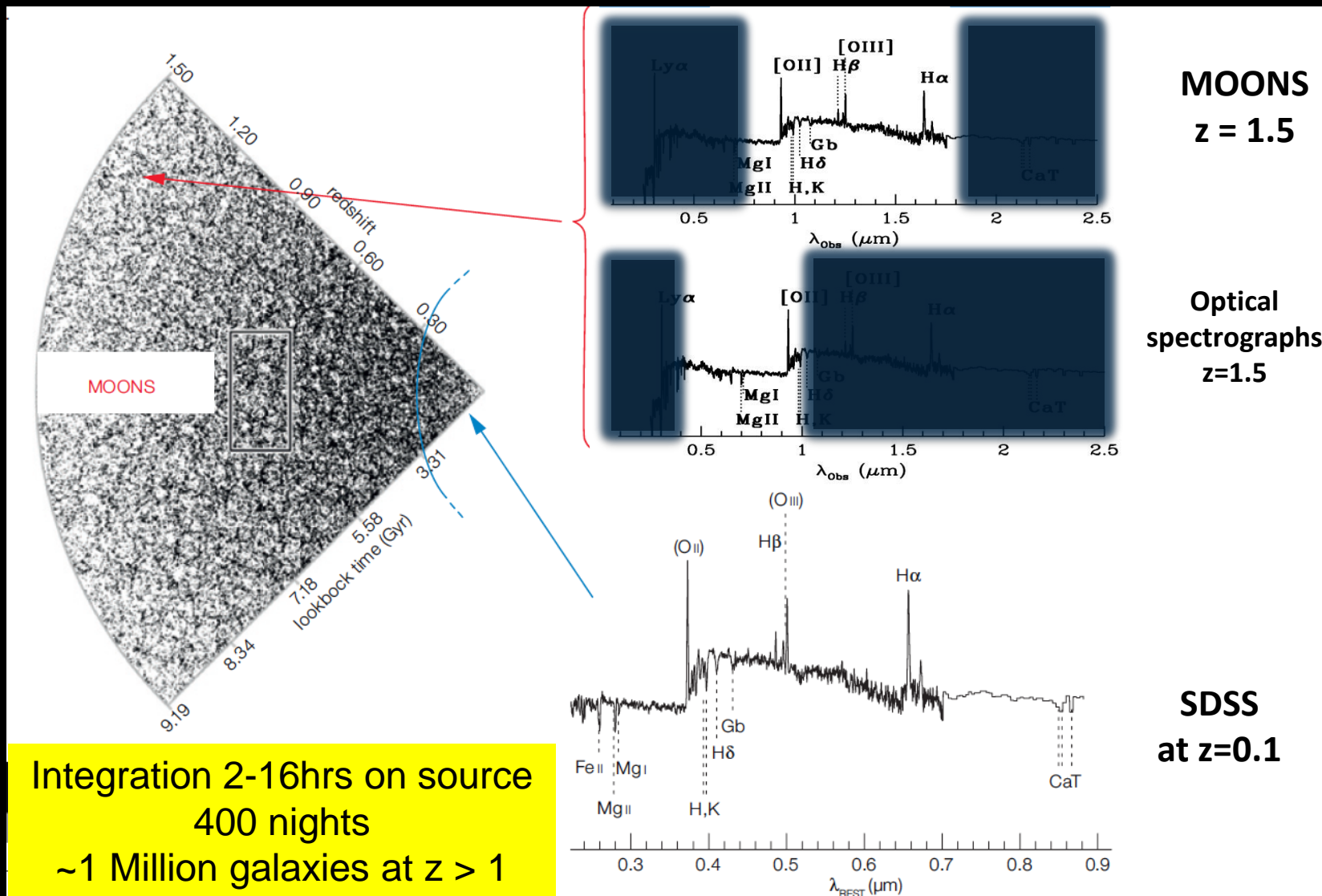
- Nature of the heavily-obscured regions of the Bulge
- Chemo-dynamical structure of the Thin and Thick Discs
- the importance of satellites and streams in the Halo.
- radial velocities and detailed chemical abundances (Fe, Se, Ca, Ti, Mg, ...) for $>10^6$ stars

The Galaxy formation history



MOONS

Galaxy Evolution

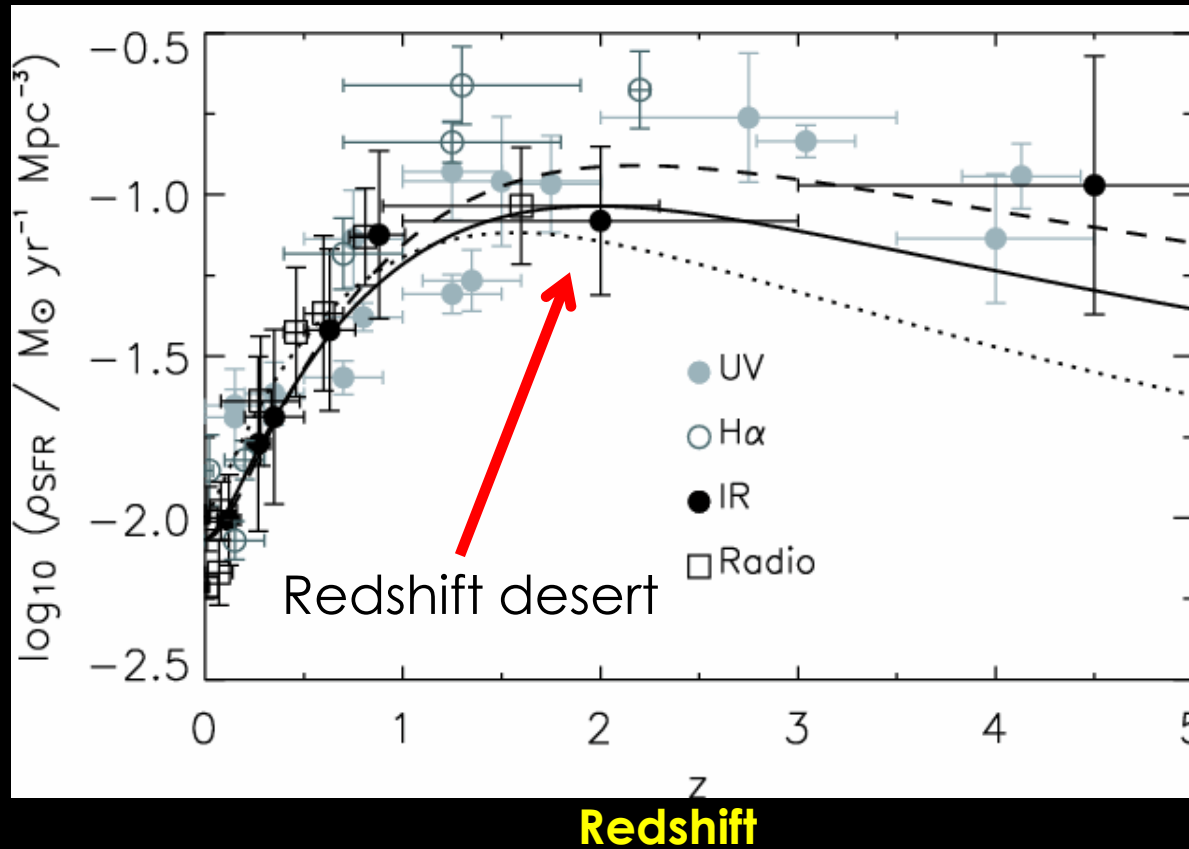


MOONS

Galaxy Evolution



Star formation rate density



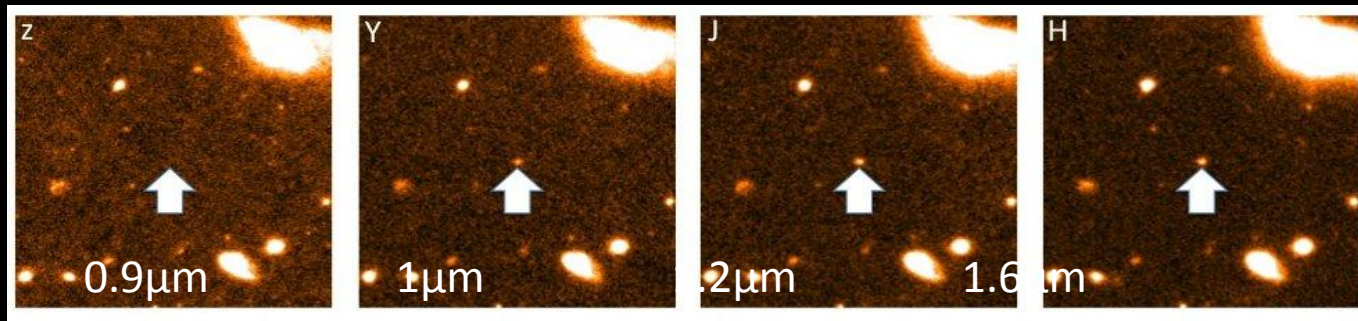
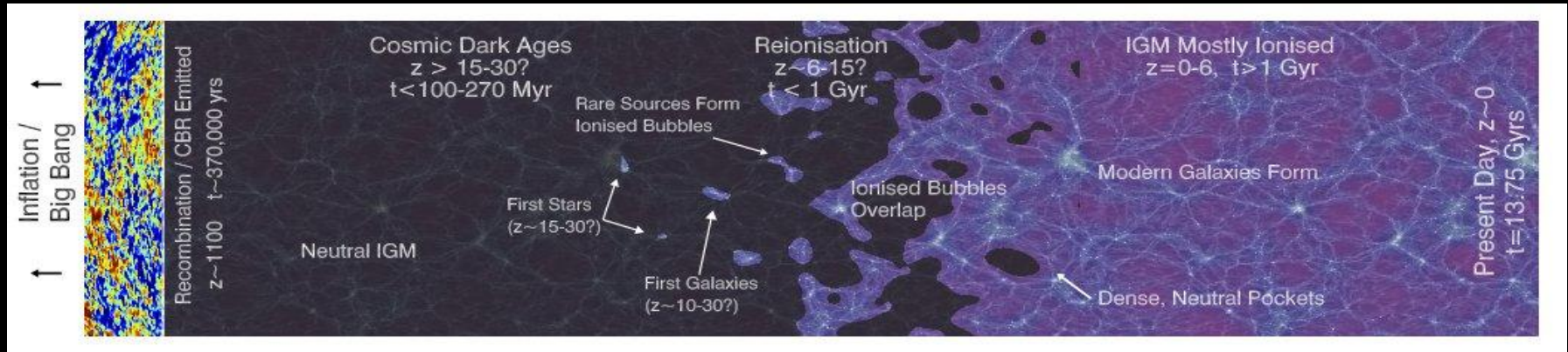
Peak of star-formation
and peak of black hole
accretion

>50% of stars produced
at $1 < z < 4$

Most massive galaxies
formed at $1 < z < 4$

MOONS

First Galaxies and Epoch of Reionisation



- ✓ Spectroscopic confirmation of the most distant galaxies.
- ✓ Establish the Lyman- α escape fraction and unveil the physics of re-ionization.
- ✓ Measure star-formation and mass assembly of primeval galaxies.
- ✓ Clustering of high- z galaxies and constrain the re-ionization.

MOONS



Possible GTO or Public Surveys

Galactic:

Survey	Mag. Limit	Spectra	Integration time (hr)	Area sq. deg	Stars	Nights
Inner disc and bulge	$H_{\text{Vega}} < 15.5$	CaT @R=8,000 (Si, Ca, Ti, Mg, Fe, Cr, Mn, CNO) @R=20,000	1-2	30	250k	50
Halo streams and clusters	$I < 21$	CaT @R=8,000 [M/H] (via Fe,Si,Ti,Mg) @R=4000-6000	0.5-1	60	500k	50
Magellanic cl. Local group	$I < 19$	CaT @R=8,000 (Si, Ca, Ti, Mg, Fe, Cr, Mn, CNO) @R=20,000	1	24	150k	20
Inner Galaxy + Gaia Legacies	$H_{\text{Vega}} < 15.5$ $I < 21$	CaT @R=8,000 [M/H] (via Fe,Si,Ti,Mg) @R=4000-6000 (Si, Ca, Ti, Mg, Fe, Cr, Mn, CNO) @R=20,000	0.5-2	~500	~3M	400

Extragalactic:

Survey	Mag. Limit	Redshift	Spectra	Integration time (hr)	Area sq. deg	Galaxies	Nights
SDSS-like	$H_{\text{AB}} < 23.5$	$0.8 < z < 1.8$	Continuum + Em. lines	0.5-4	10	200k	100
Deep	$23 < H_{\text{AB}} < 25$	$z > 1.5$	mostly Em. lines	2-16	2	30k	50
Legacy	$H_{\text{AB}} < 25$	$0.8 < z < 10$	Continuum + Em. lines	0.5-16	30	700k	400

MOONS

Comparison with other wide-field MOS

	Subaru-PSF	Other 8m near-IR MOS	4m optical MOS	MOONS		
Galactic Bulge and Disc					Multiplex	FoV
Galactic Halo					Wavel. coverage	Spectral resolution
Local Galaxies					Ideal Basic compliance Not compliant Limited sensitivity	
Galaxy evolution / redshift desert						
First galaxies						
Cosmology						

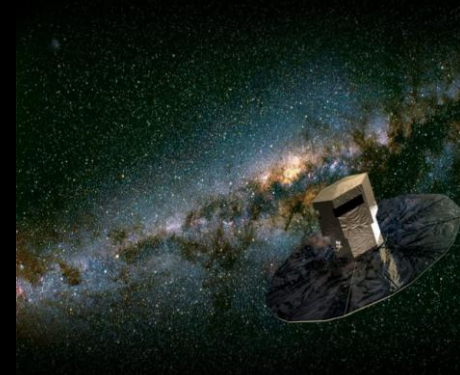
MOONS is *the* instrument of choice to tackle both Galaxy Evolution and Galactic Archaeology

MOONS

...the long-awaited near-IR MOS for the VLT

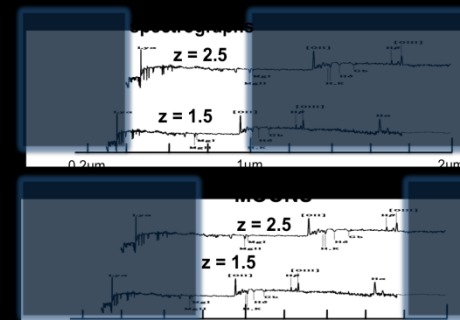
Galactic studies: essential follow-up of Gaia and VISTA

- ✓ Radial velocities and detailed chemical abundances for **several million stars** over **>1000 sq. deg.**
- ✓ Best instrument to study the inner Bulge and Disk
- ✓ Possibility to target stream, clusters in the Halo and nearby galaxies

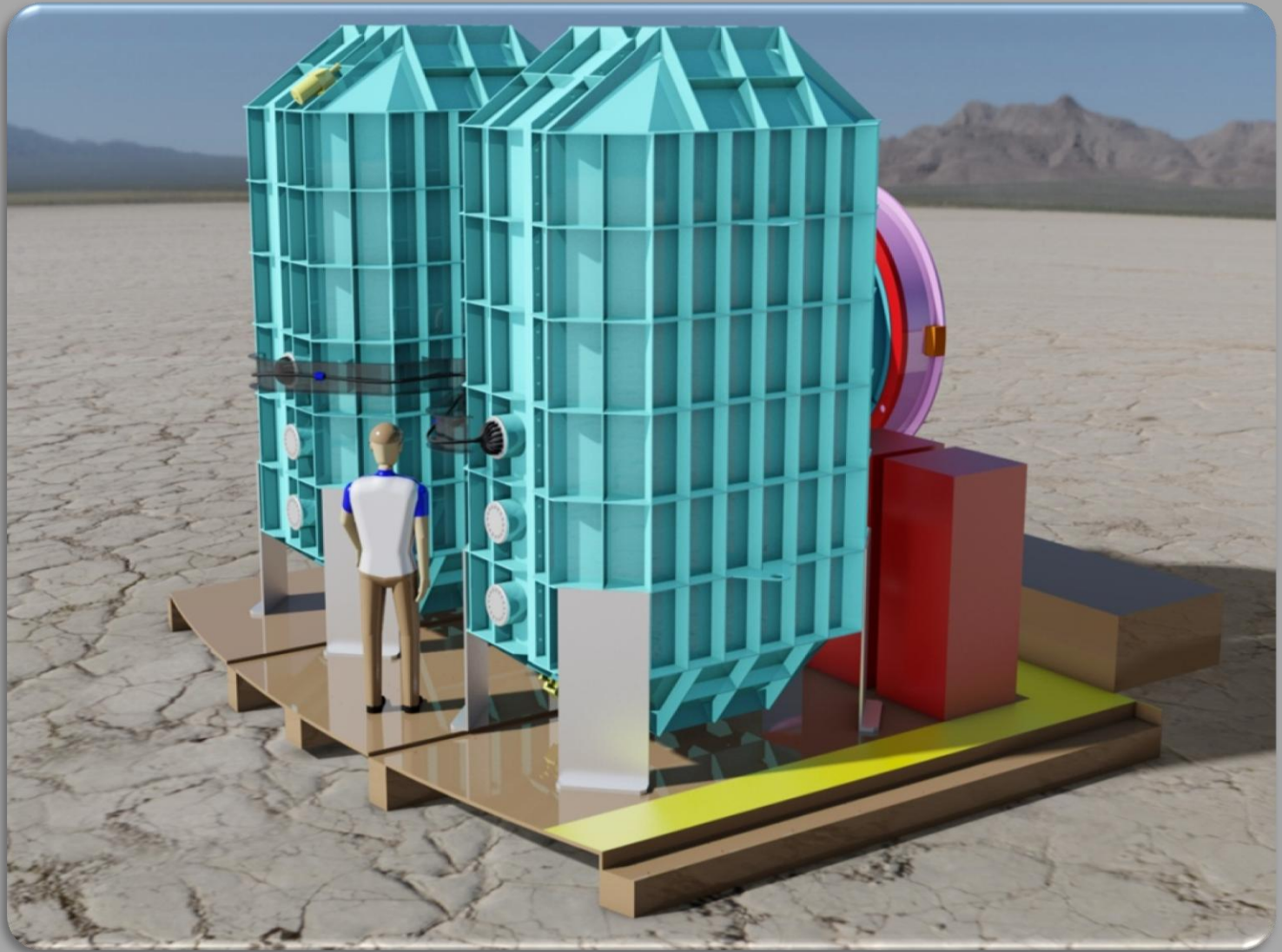


A formidable SDSS-like survey at $z > 1$

- ✓ Fundamental insights into galaxy formation and evolution over cosmic time from **~1M galaxies at $z > 1$** .
- ✓ Follow-up of the very first galaxies at $z > 7$ into the **epoch of re-ionization**.
- ✓ Follow-up of large-area imaging surveys: VISTA, Herschel, DES, UKIDSS, LOFAR, eRosita, Euclid etc.
- ✓ Pathfinder for E-ELT and ALMA.







MOONS in a nutshell



Field of view: 500 sq. arcmin
@ the 8 m VLT

Multiplex: 1000 fibers, with the
possibility to deploy
them in pairs

Medium resolution:

Simultaneously:
0.8-1.8 μm @ R=4,000 – 6,000

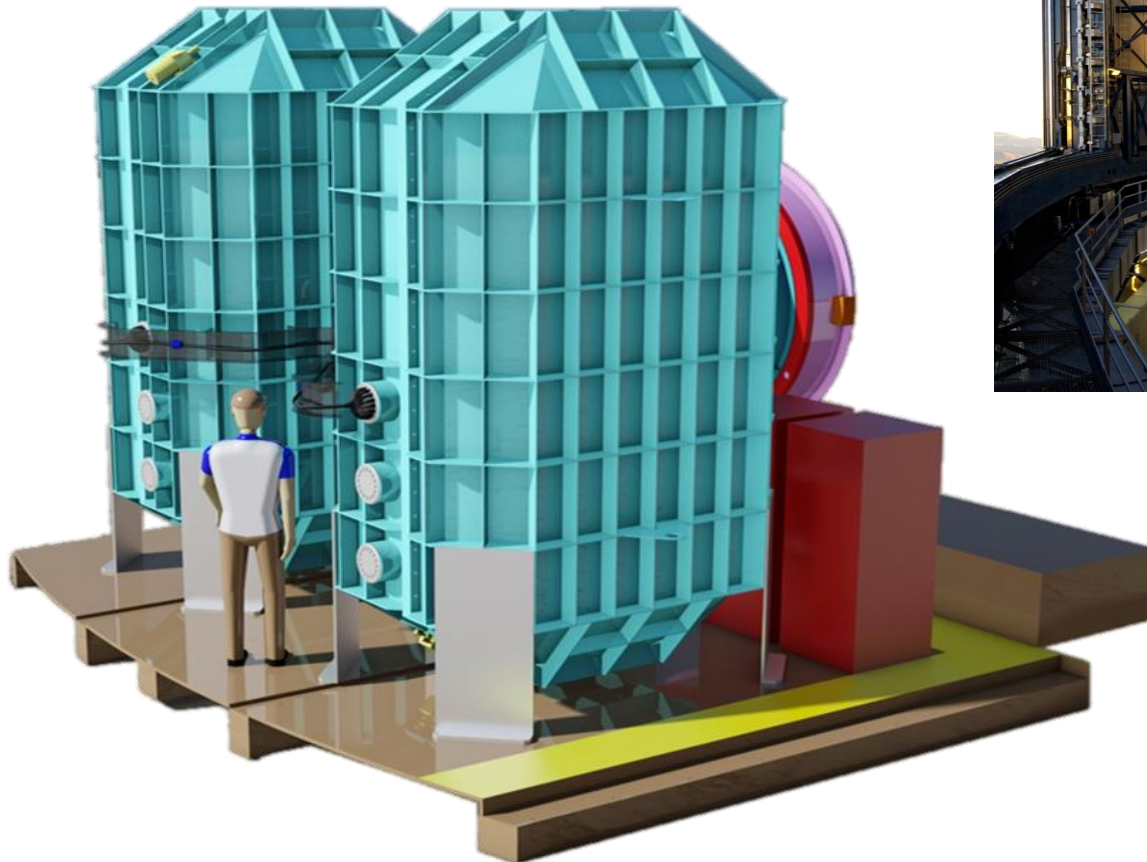
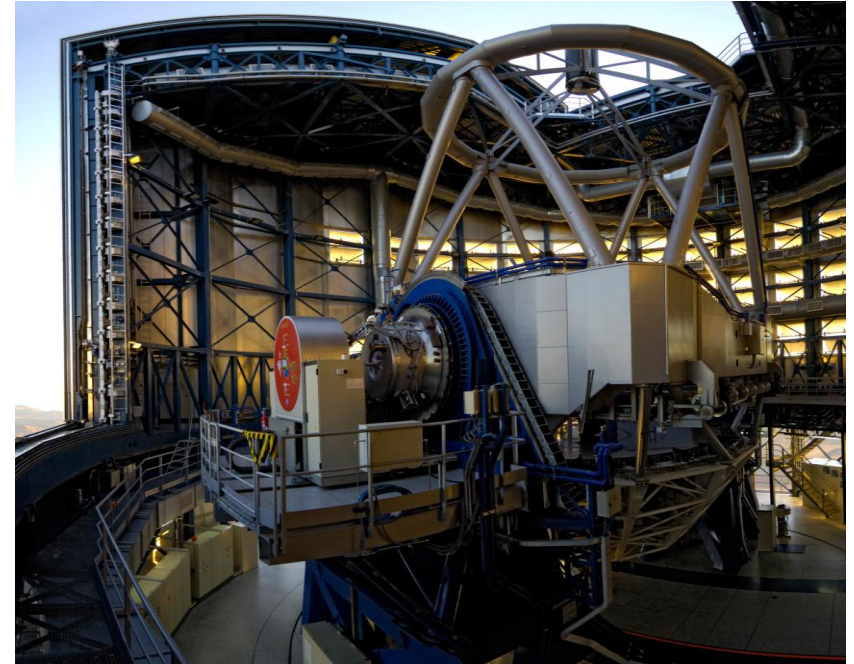


High resolution:

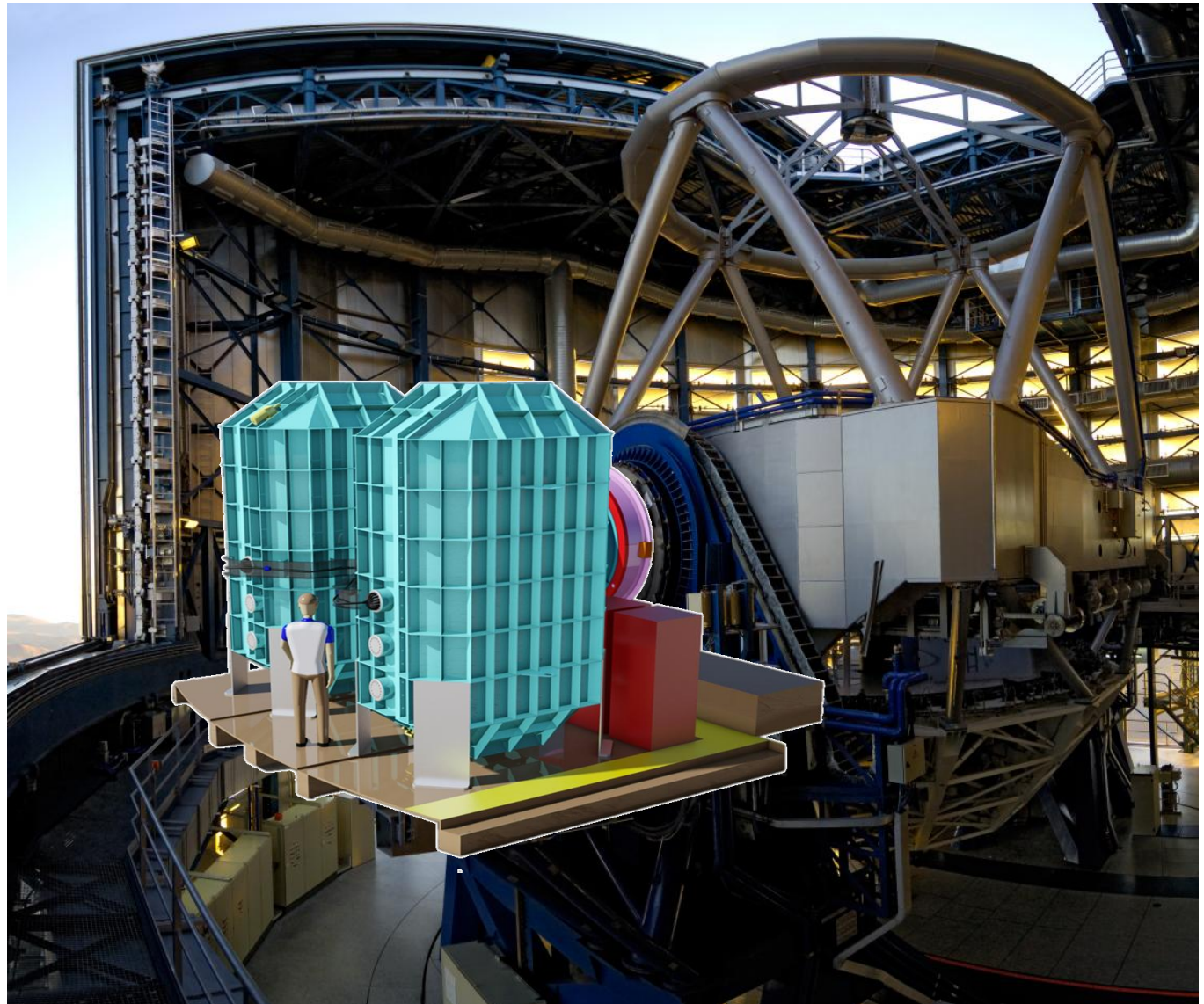
Simultaneously 3 bands:

0.8 - 0.9 μm @ R = 8,000
1.17 - 1.26 μm @ R=20,000
1.52 - 1.63 μm @ R=20,000

MOONS @ the ESO.VLT



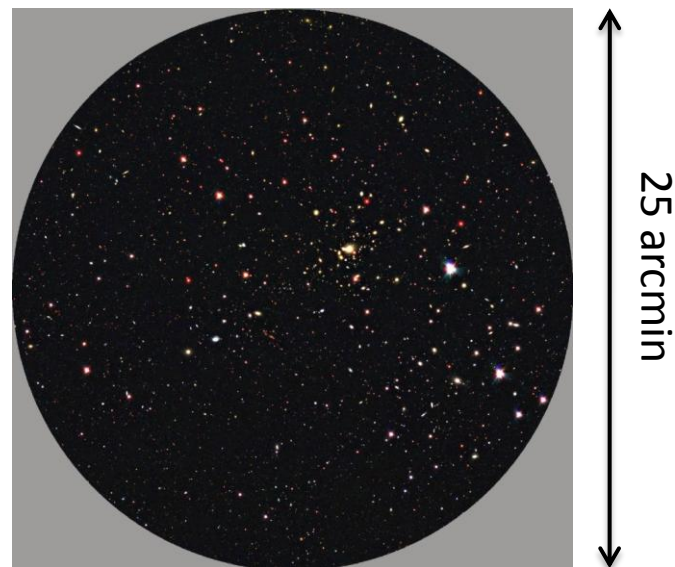
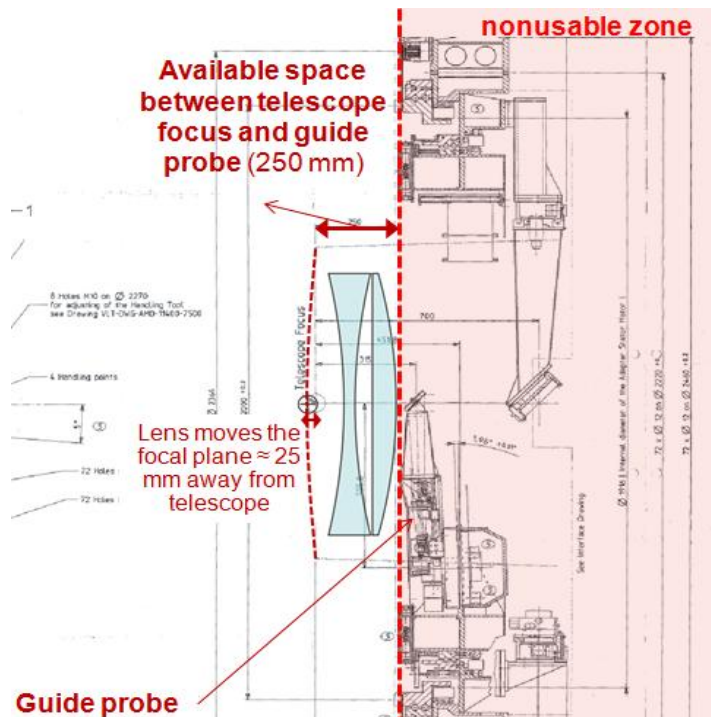
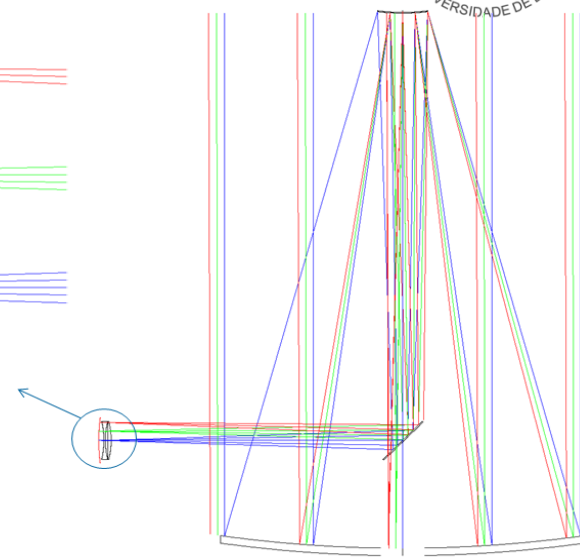
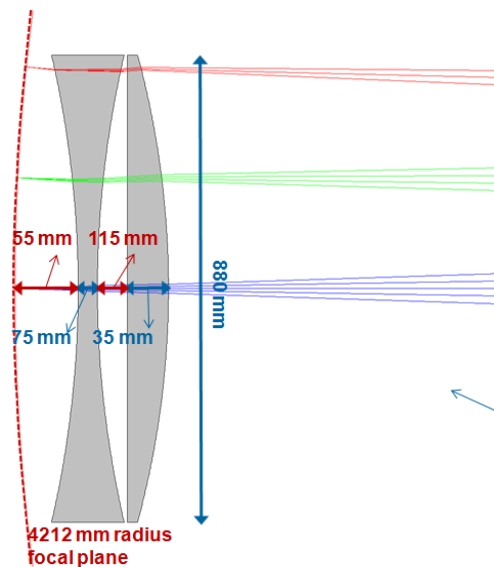
MOONS @ the ESO.VLT



MOONS from telescope to detector

Field Corrector

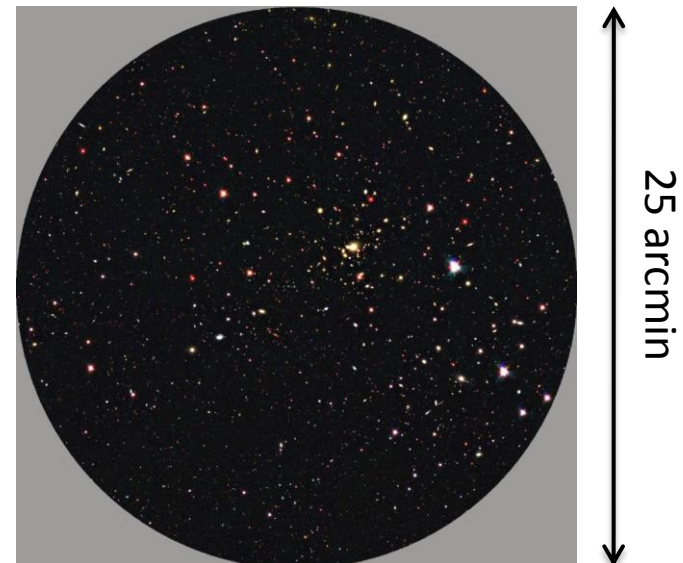
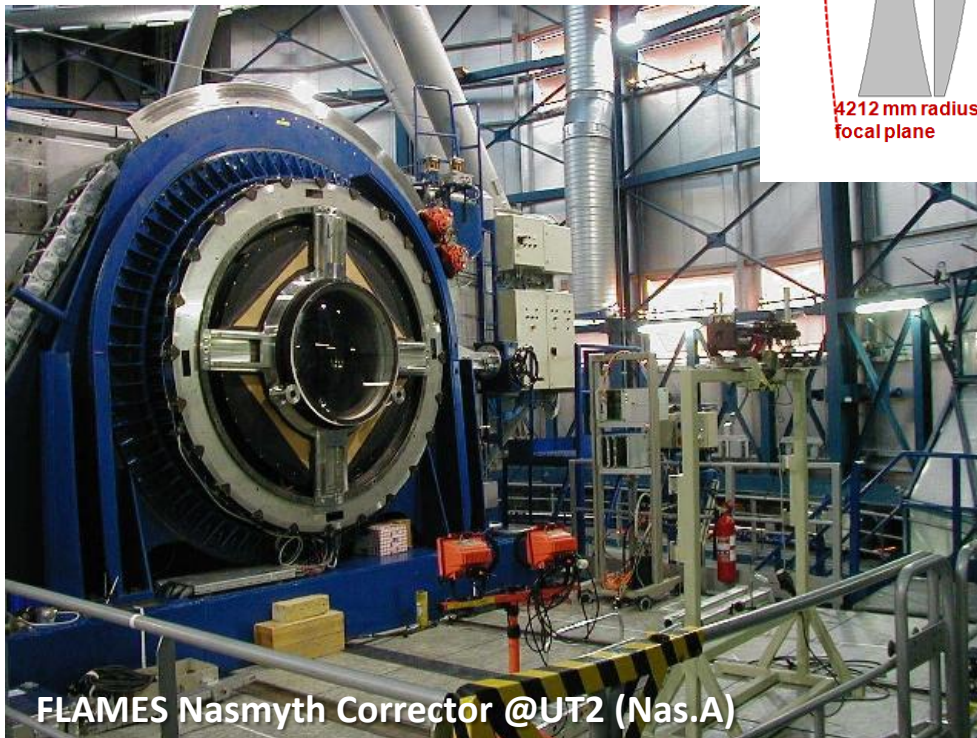
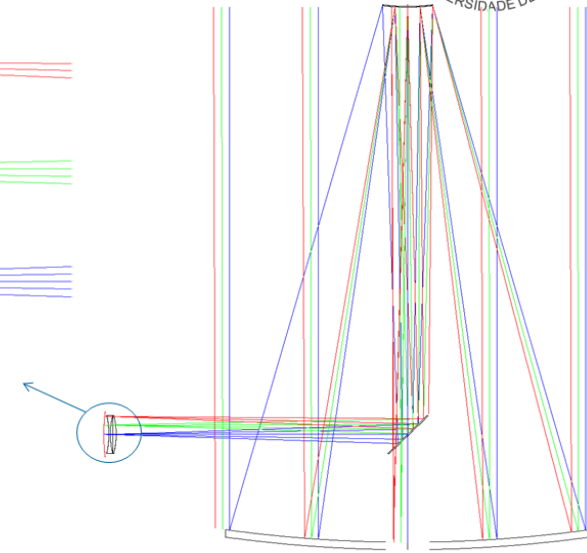
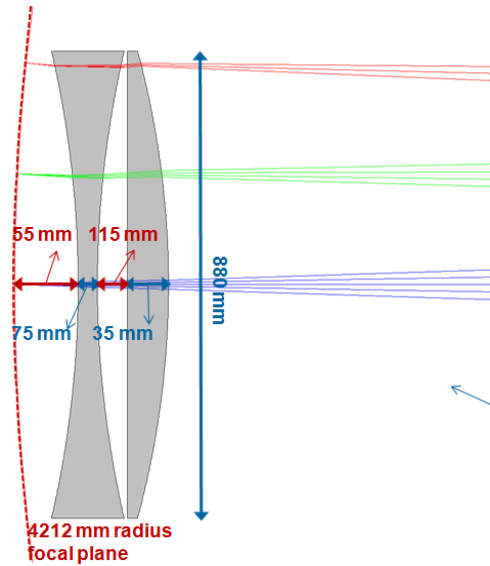
1. Improve image quality
2. Provide a concentric exit pupil to the field curvature
3. Reduce the field curvature



MOONS from telescope to detector

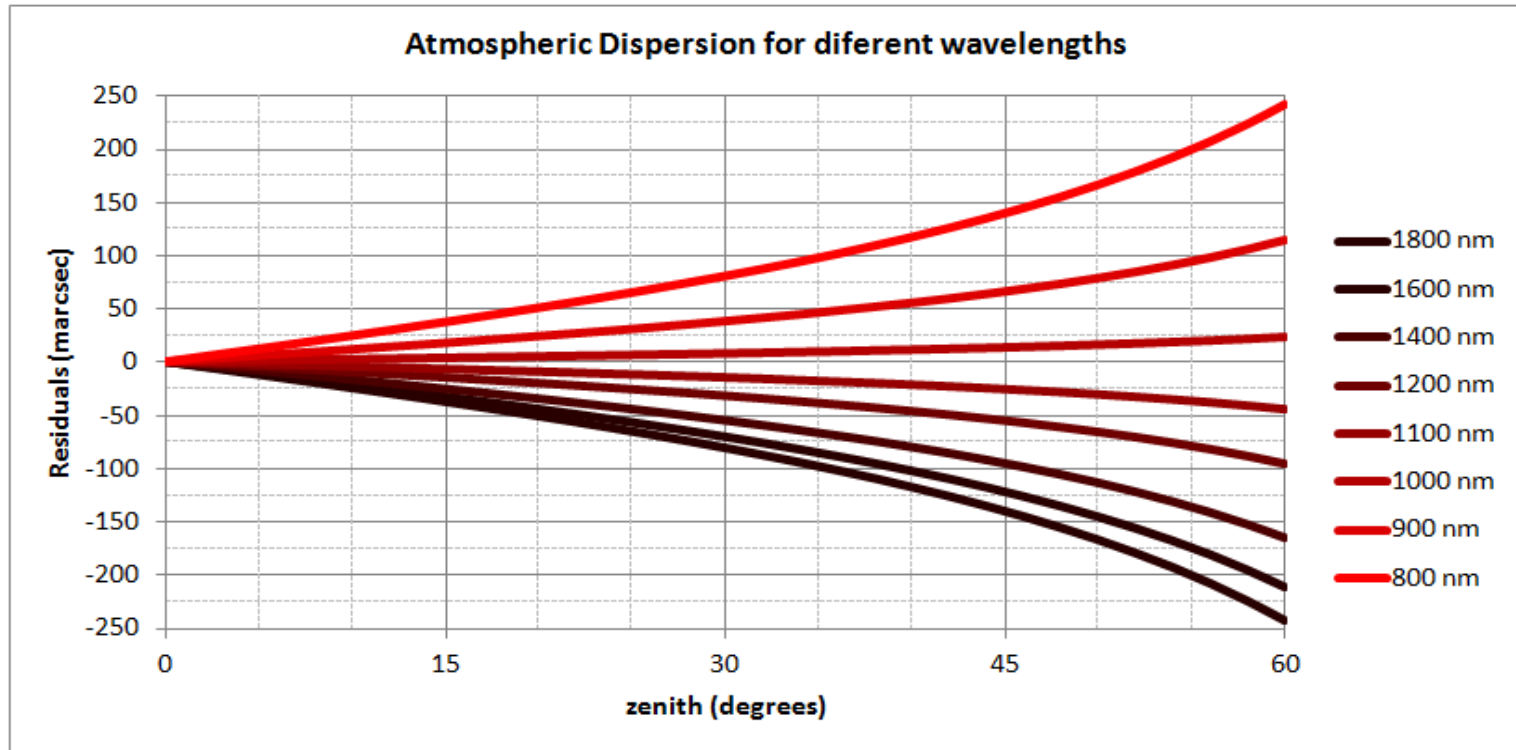
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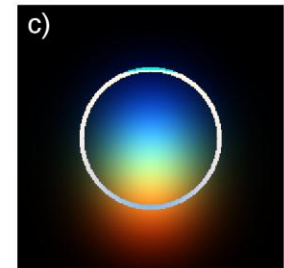
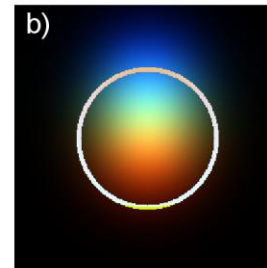
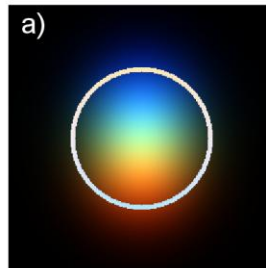


MOONS from telescope to detector

“No ADC” (Atmospheric Dispersion Compensator)

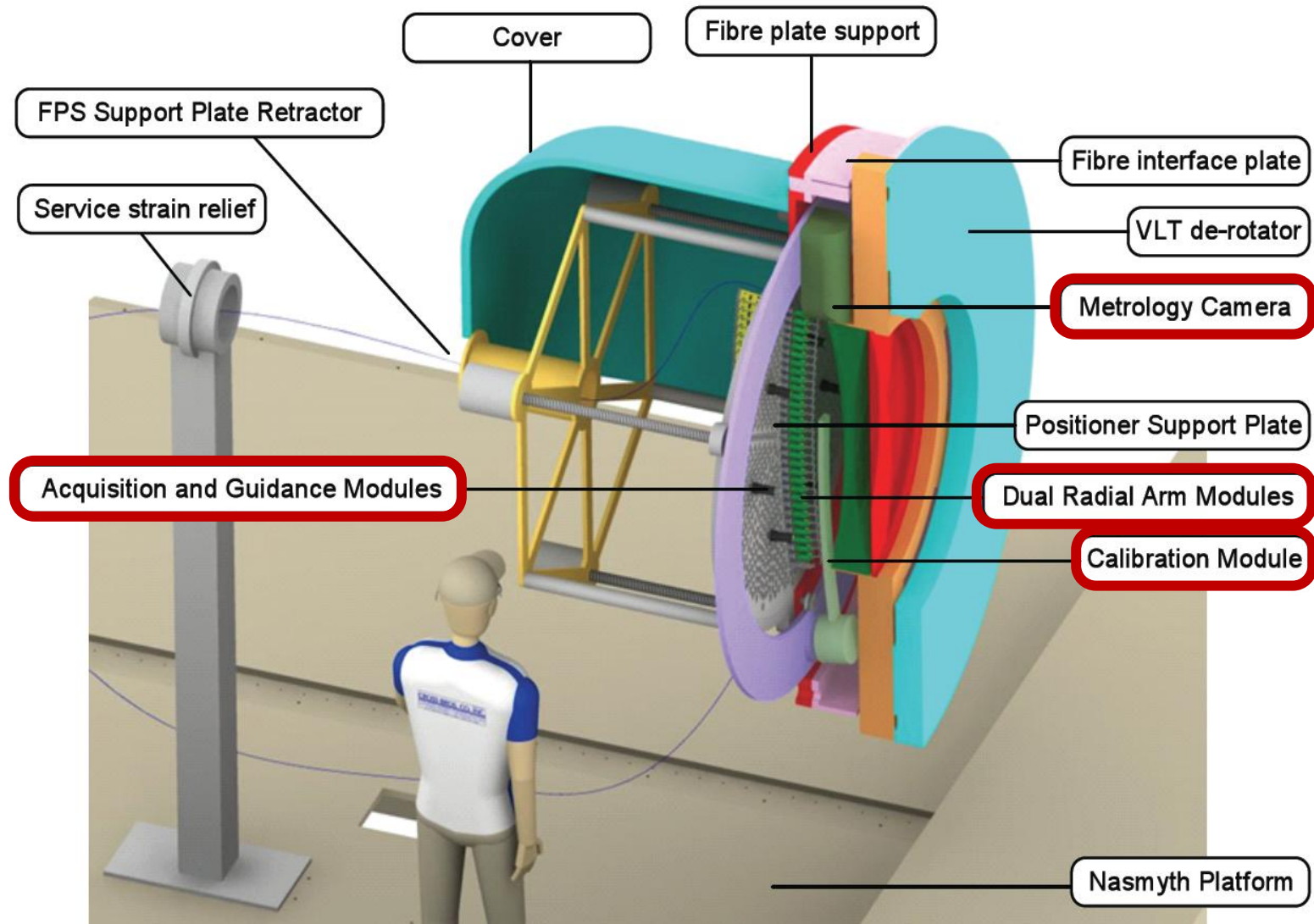


The uncertainty in the fibre position will cause an uncertainty in the spectral “transmission efficiency”



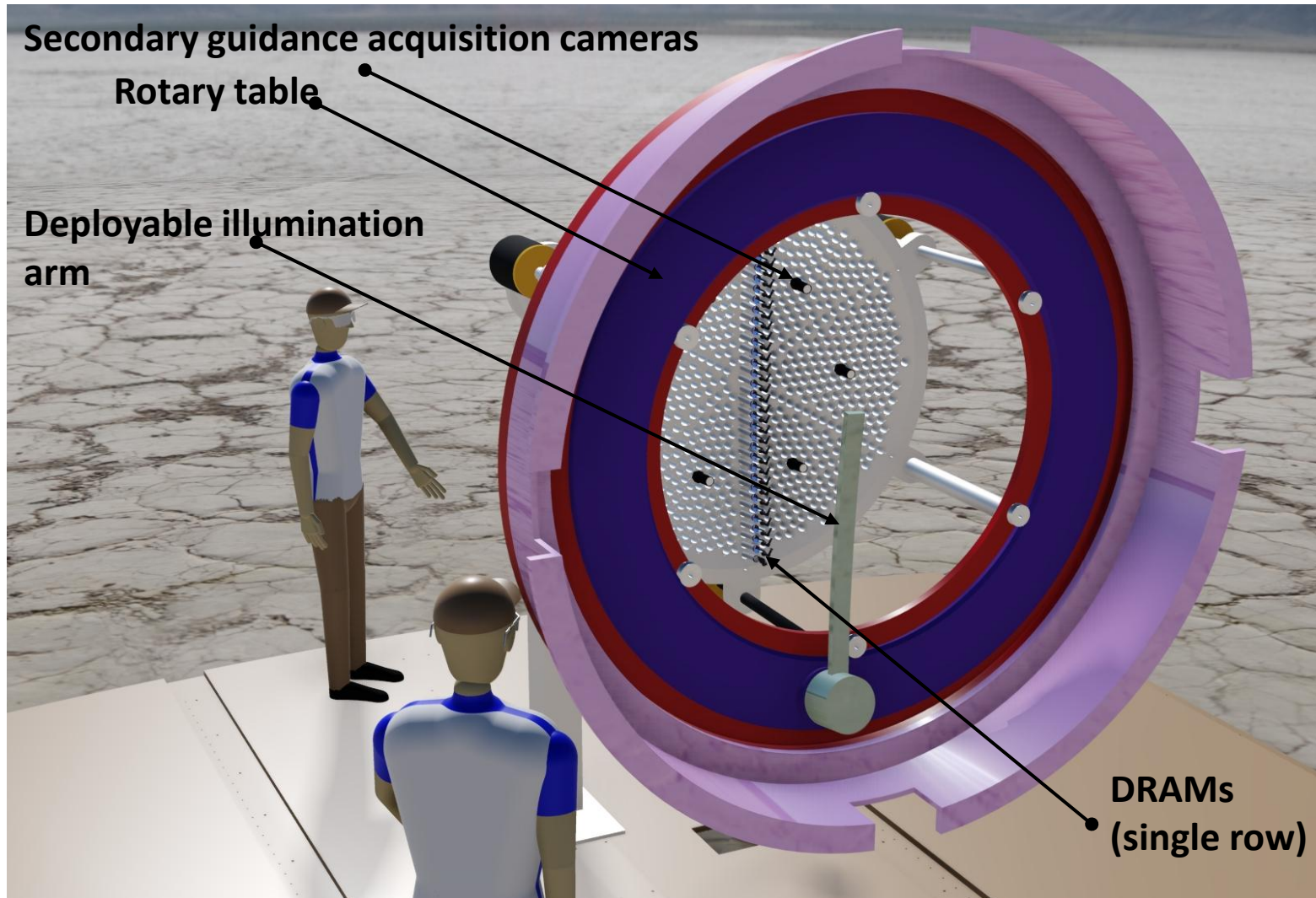
MOONS from telescope to detector

Front End (attached at the Nasmyth rotator)



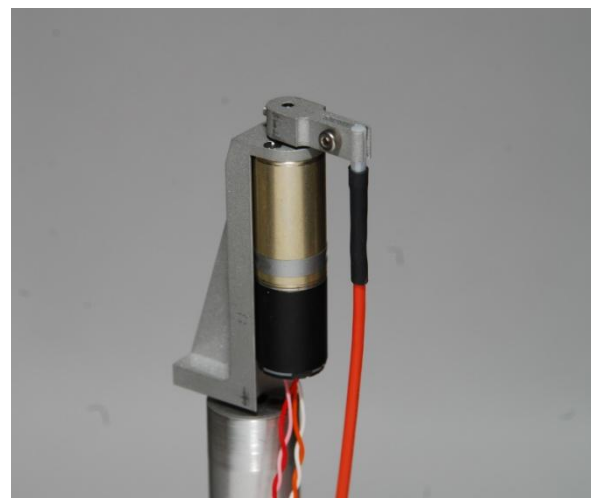
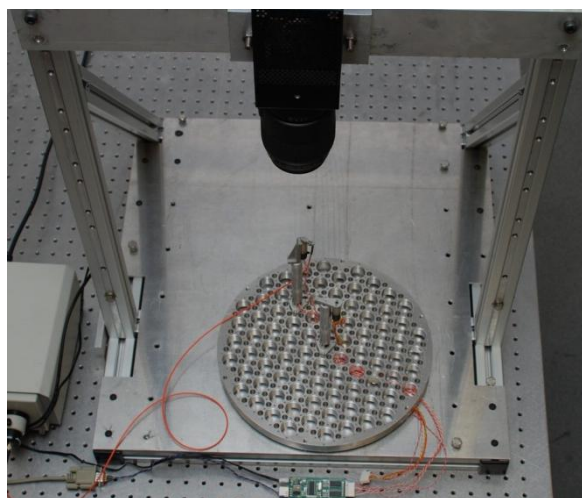
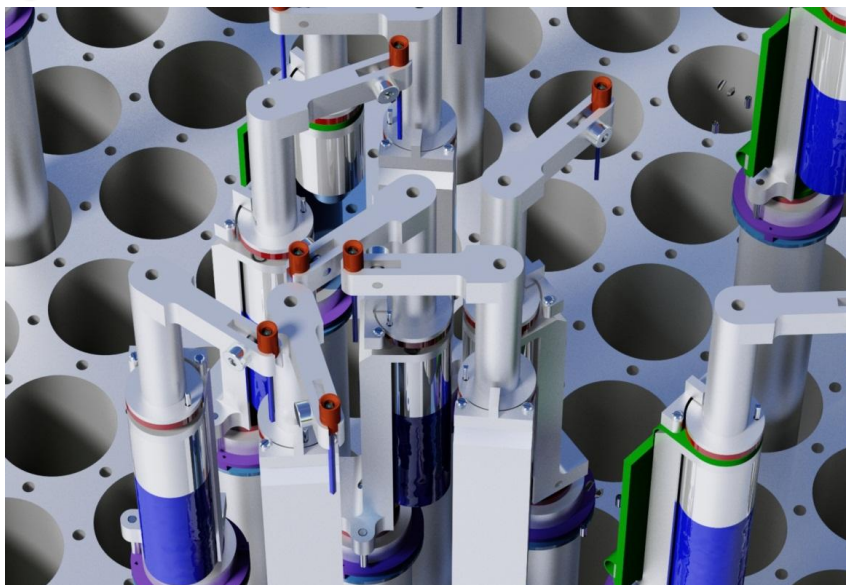
MOONS from telescope to detector

Calibration System



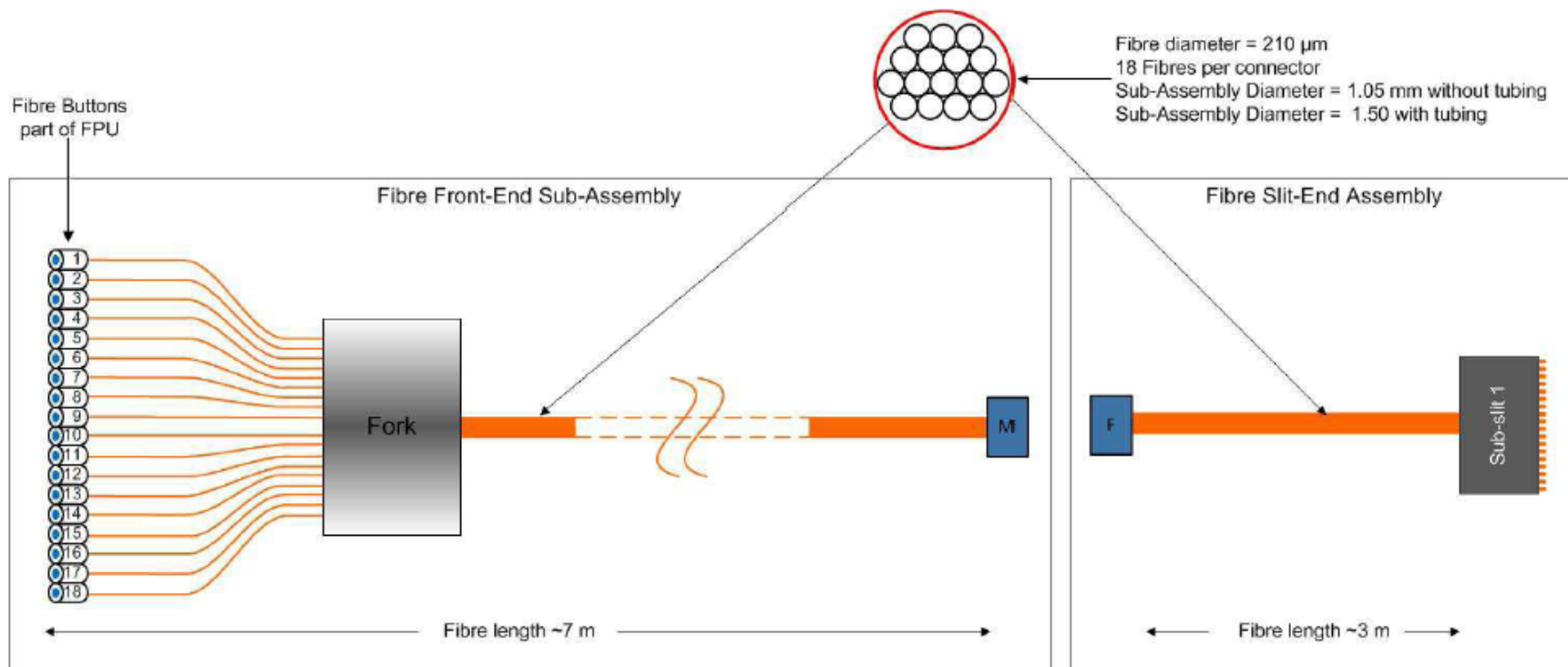
MOONS from telescope to detector

DRAM Fibre positioners



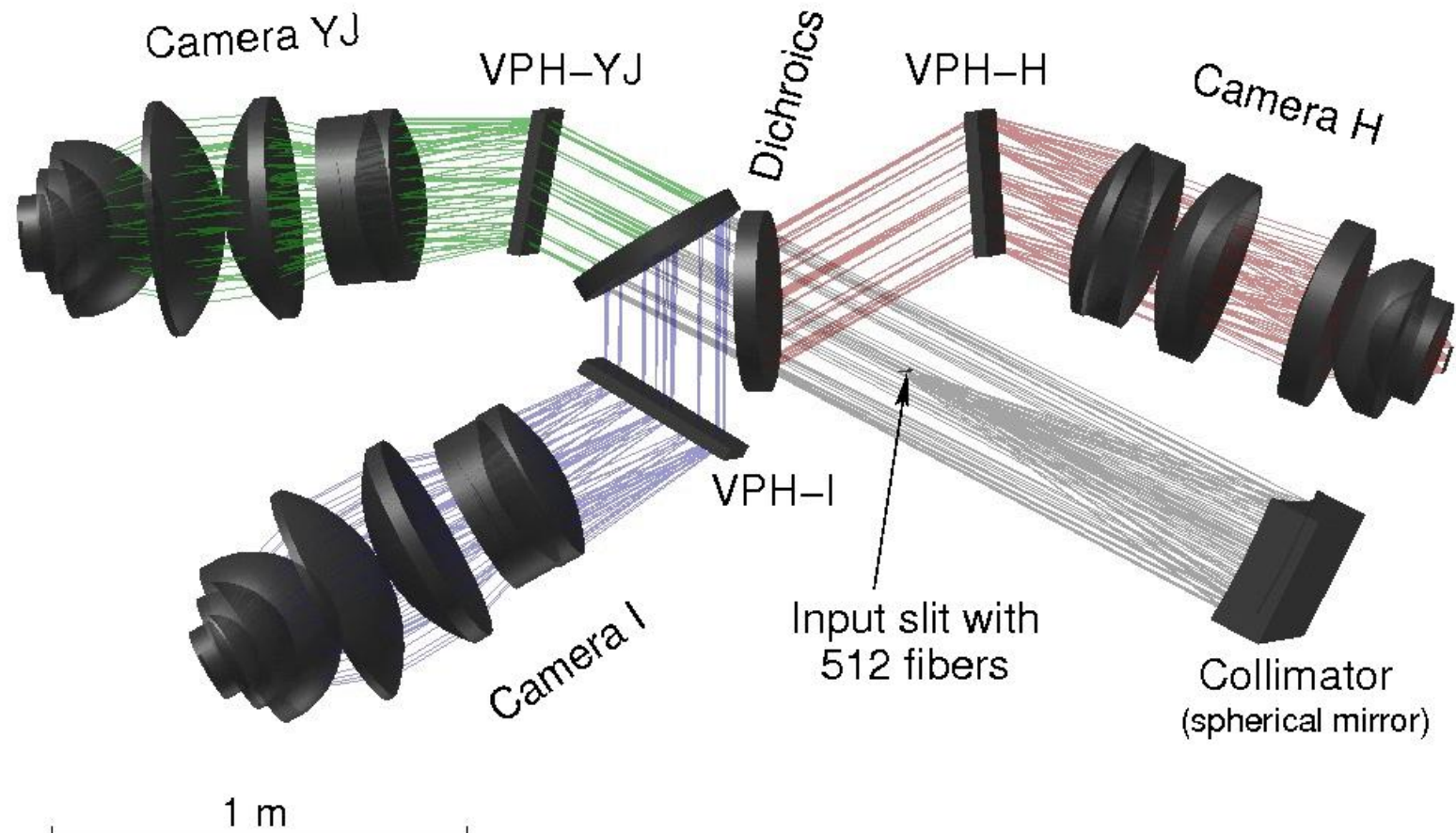
MOONS from telescope to detector

More than 1000 fibres ...



MOONS from telescope to detector

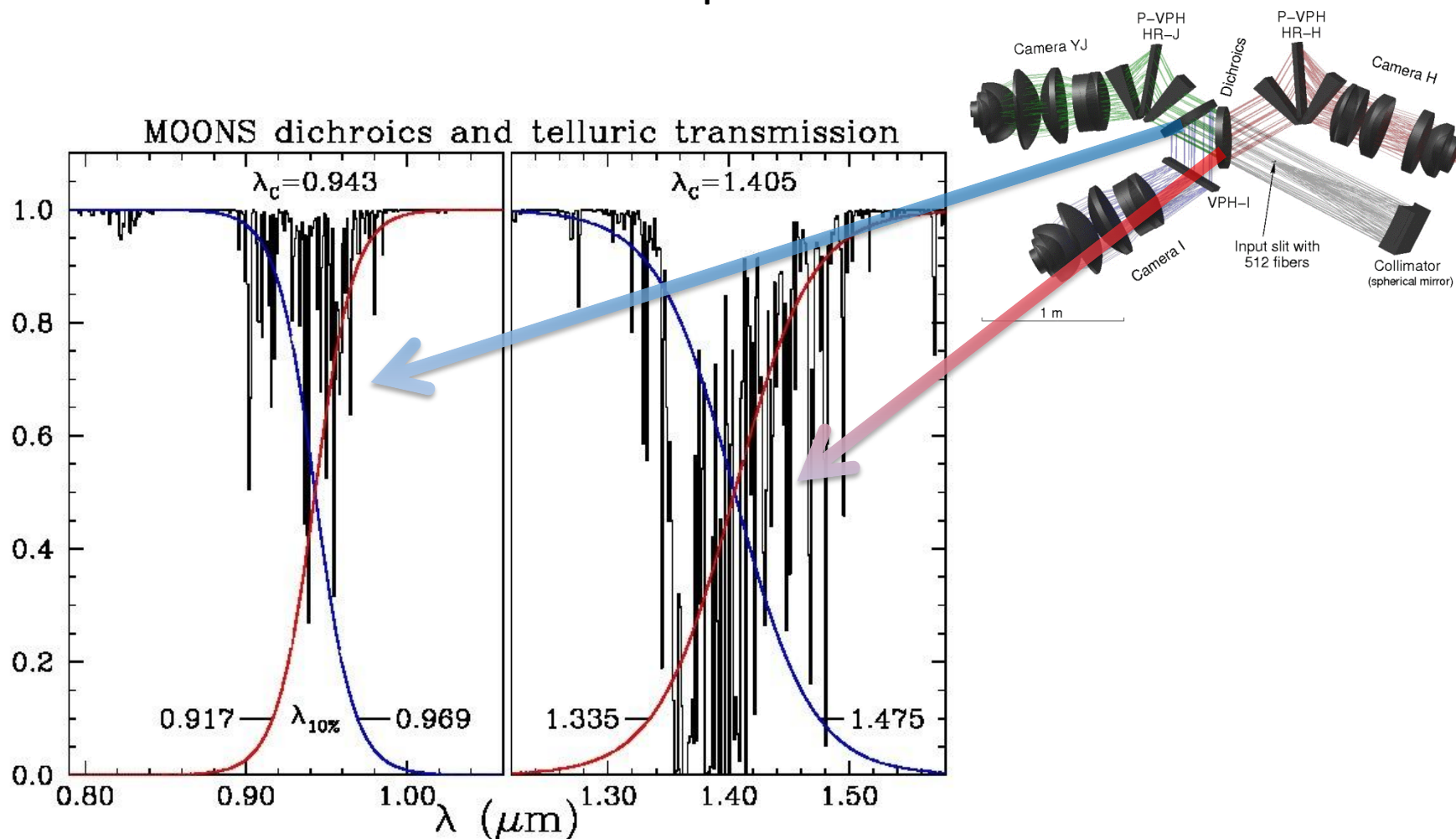
Triple Arm Spectrograph



MOONS from telescope to detector

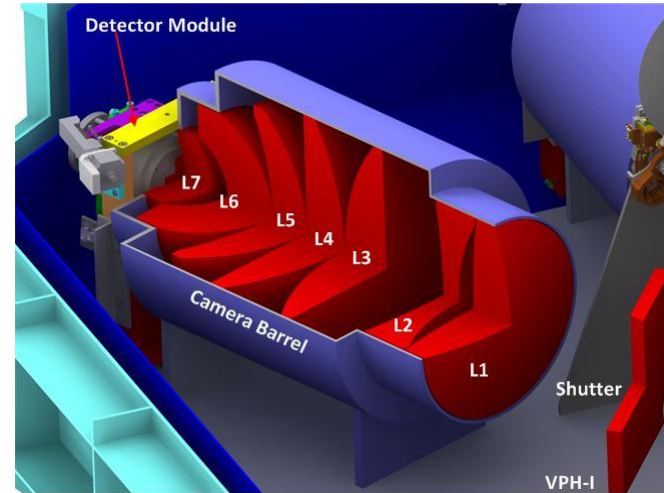
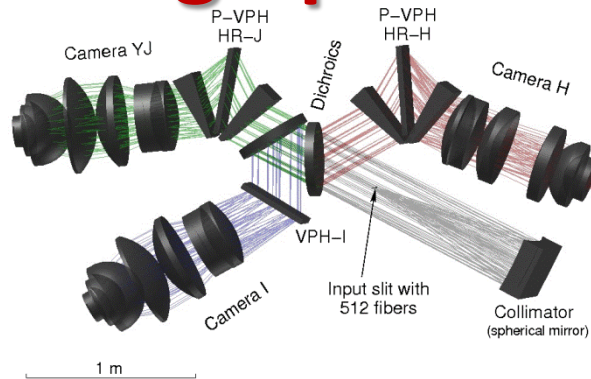
Triple Arm Spectrograph

Dichroics tuned to telluric absorption features



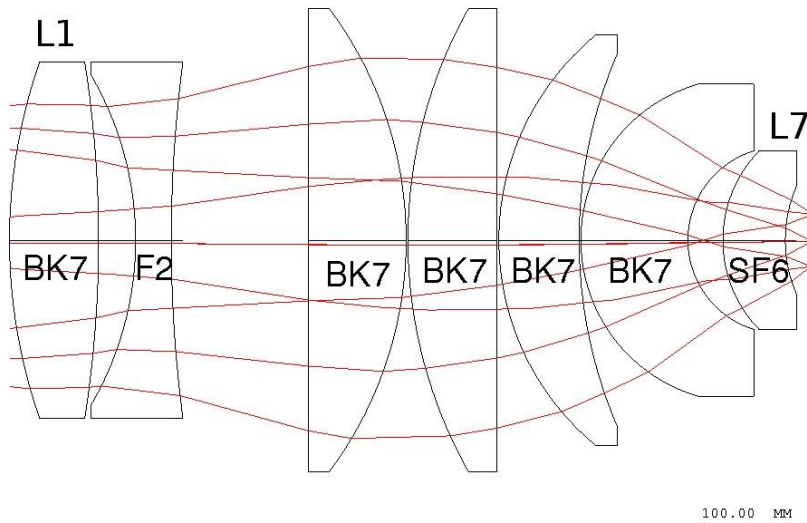
MOONS from telescope to detector

Spectrograph Camera

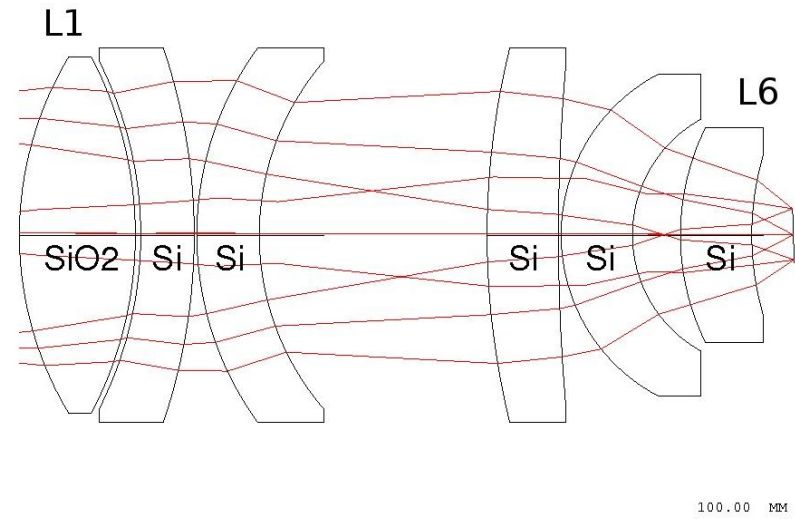


“Linearly chromatic” spherical F/1 cameras

Camera YJ & I



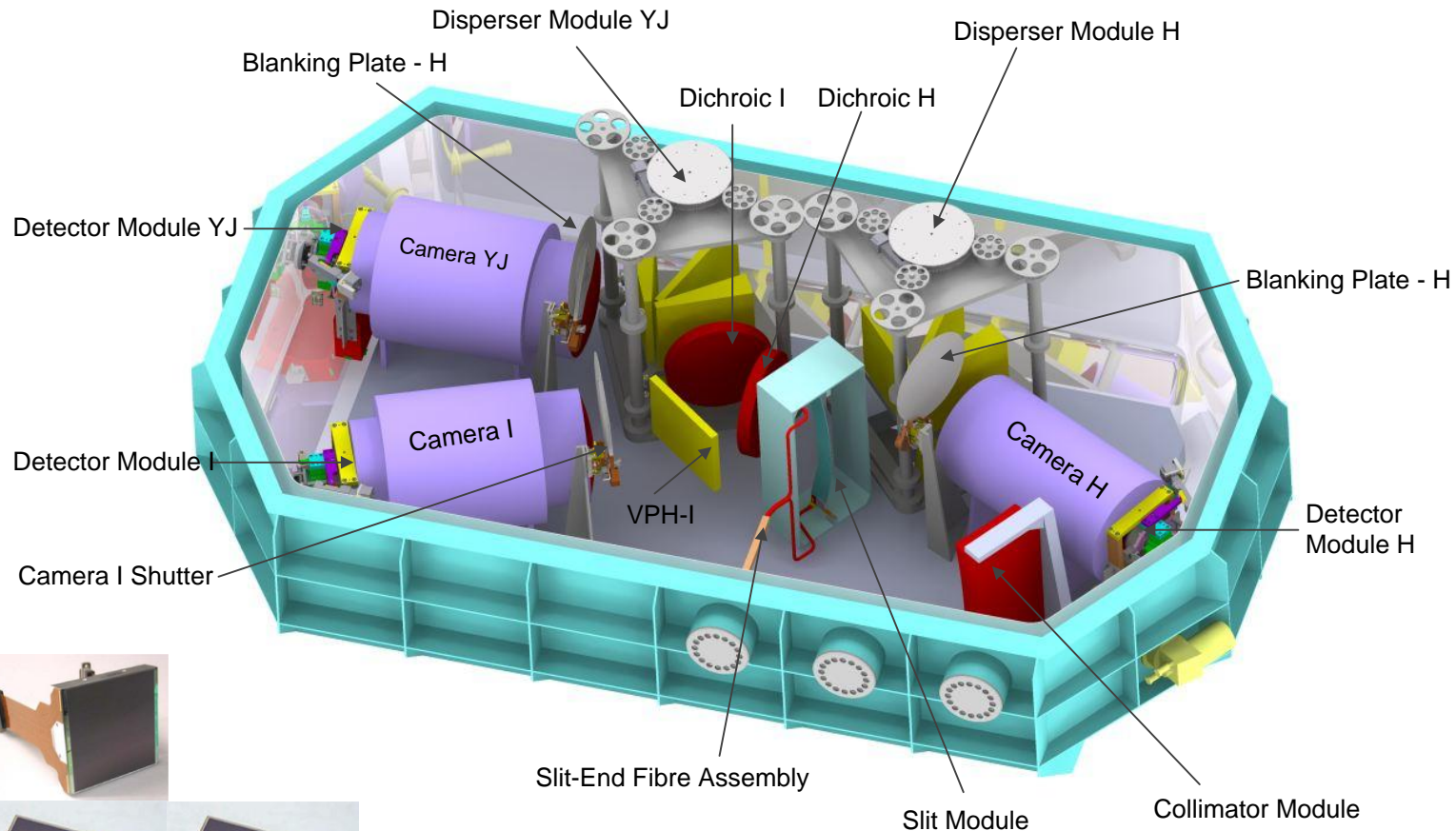
Camera H



MOONS from telescope to detector

Spectrograph Opto mechanical layout

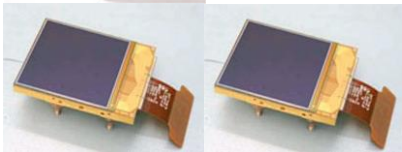
Two identical spectrograph instruments



1x e2v CCD 283
4k x 4k



2x Teledyne H4RG
4k x 4k



MOONS from telescope to detector

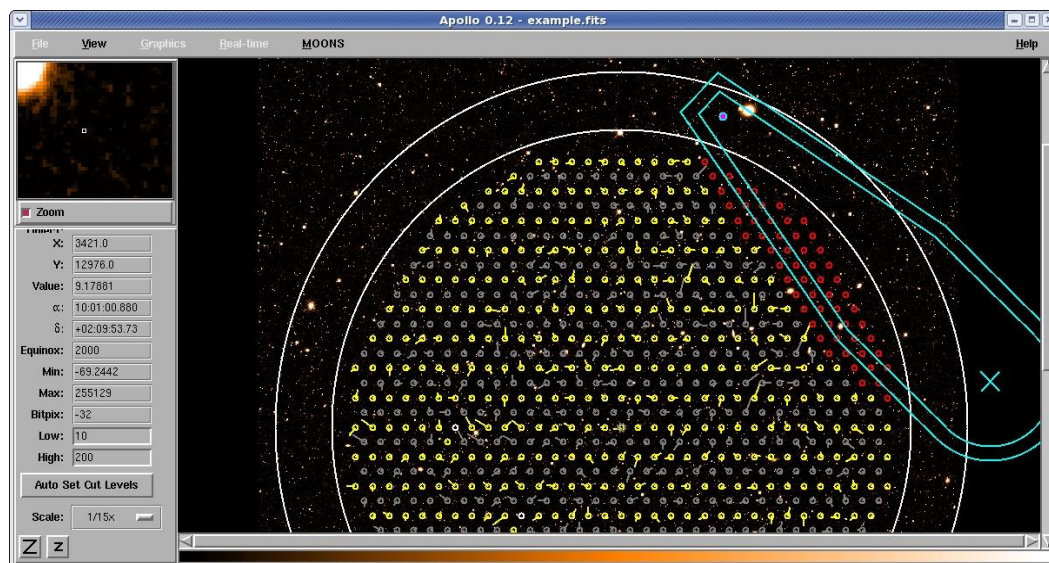
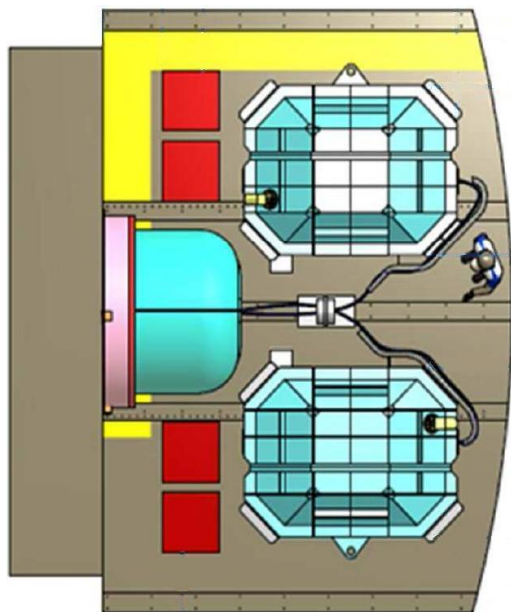
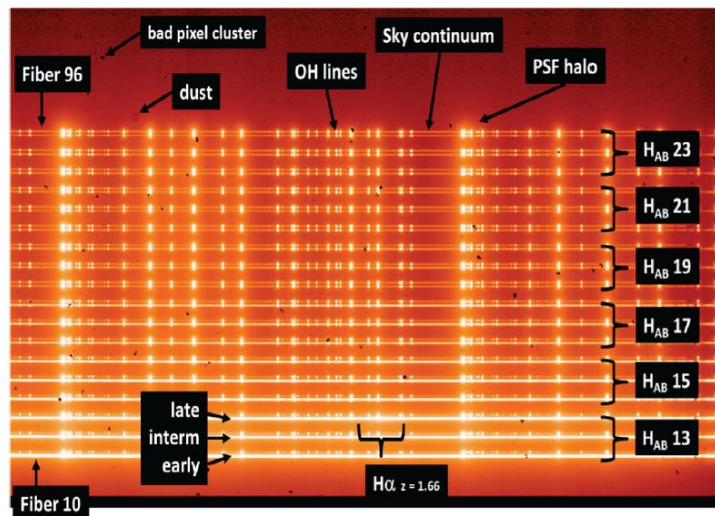
Instrument Control Electronics

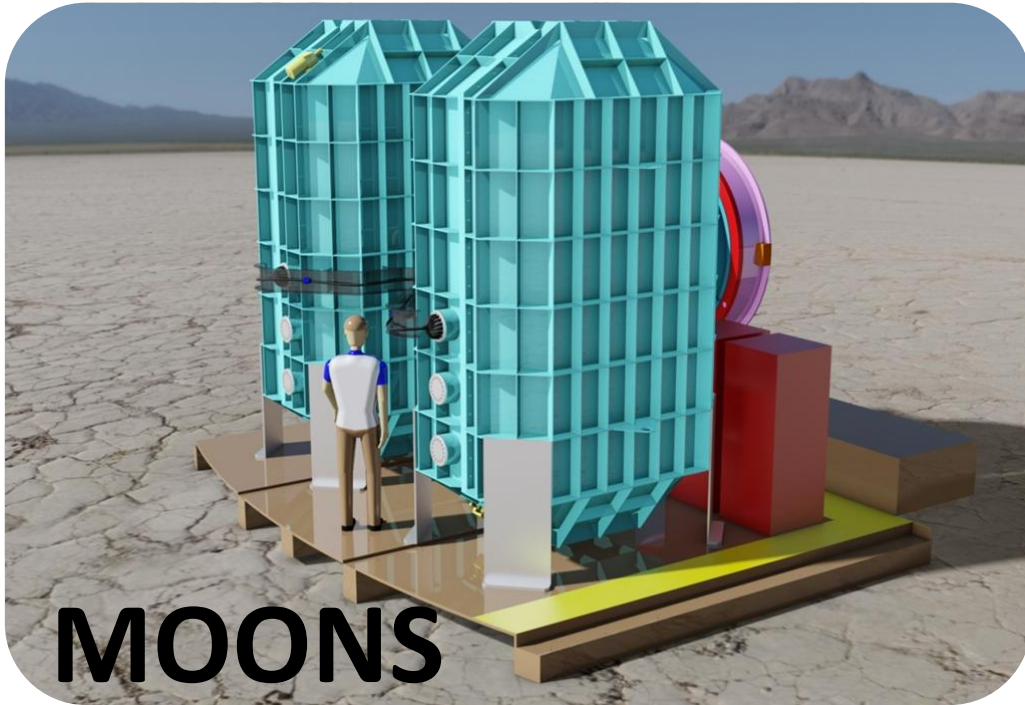
Instrument Software

Preparation Software

...

End-to-end simulation
of a raw *H*-band
MOONS frame





MOONS

a powerful Multi-Object Optical & Near-infrared Spectrograph for the VLT



Thank you for your attention!...

Questions?