Quiescent galaxies at cosmic noon: from individual element abundances to star formation histories

A science case for SHARP@ELT

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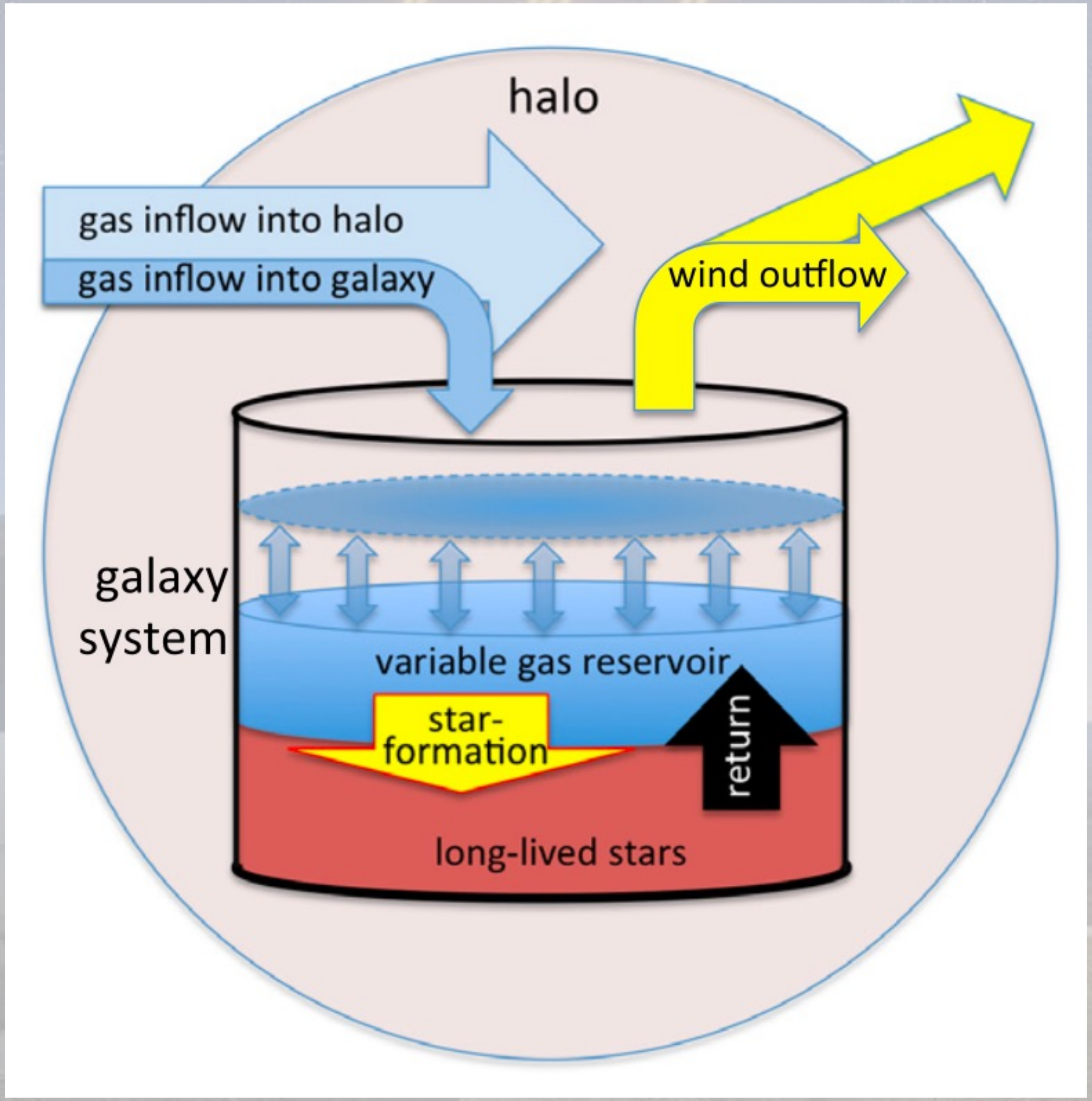
Interplay among:
- gas inflow
- gas outflow
- star formation efficiency
- IMF
- assembling/merger history

Metal content of galaxies



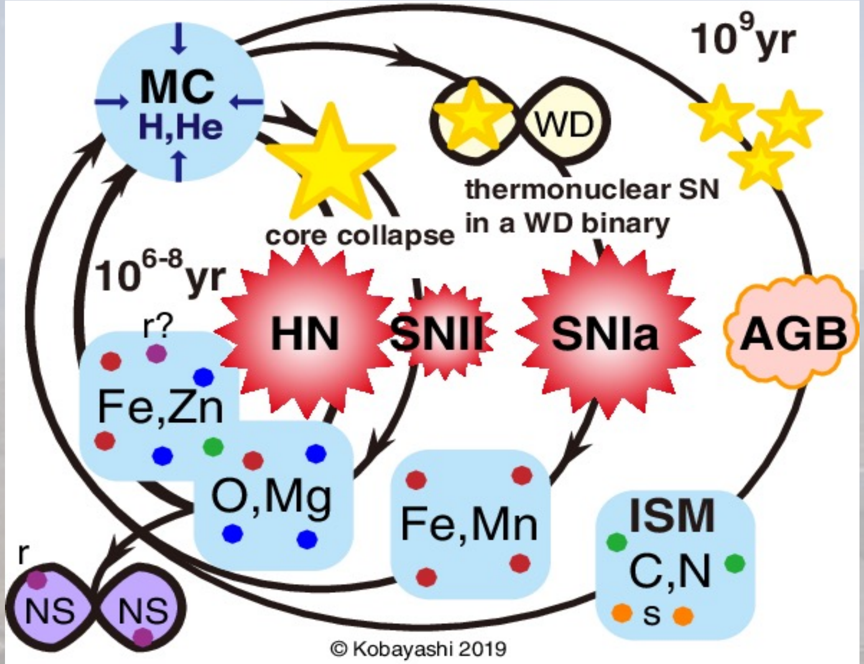
(Lilly et al. 2013)

STELLAR metal content of galaxies

Enrichment of the gas integrated over the star formation and assembly history

Galaxy mass

Environment

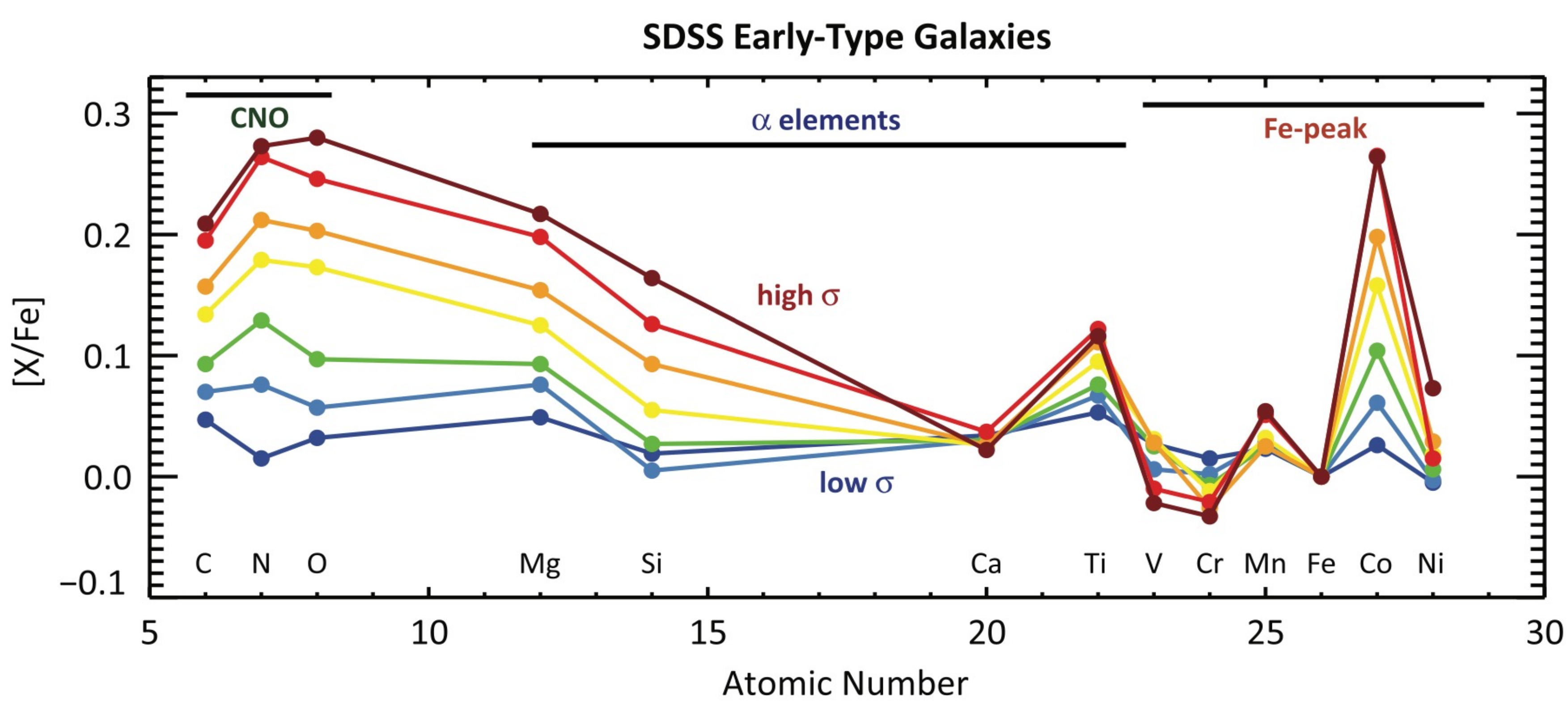


Individual element abundances (eg. [α/Fe]) provide valuable insights into the processes that shaped galaxy formation

WHAT WE KNOW

Local Universe - SDSS

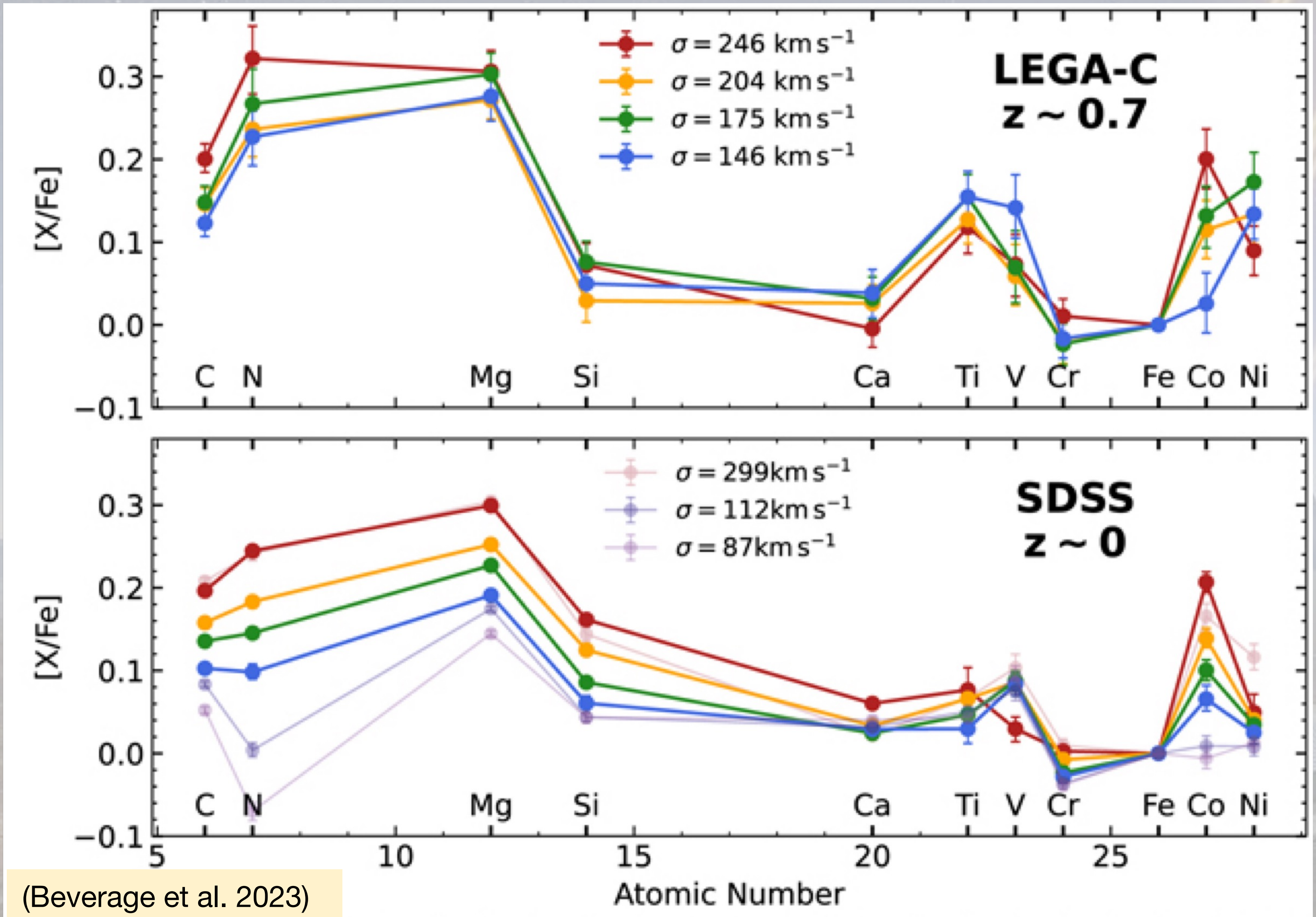
Individual element abundances VS atomic number of the elements



(Conroy et al. 2014)

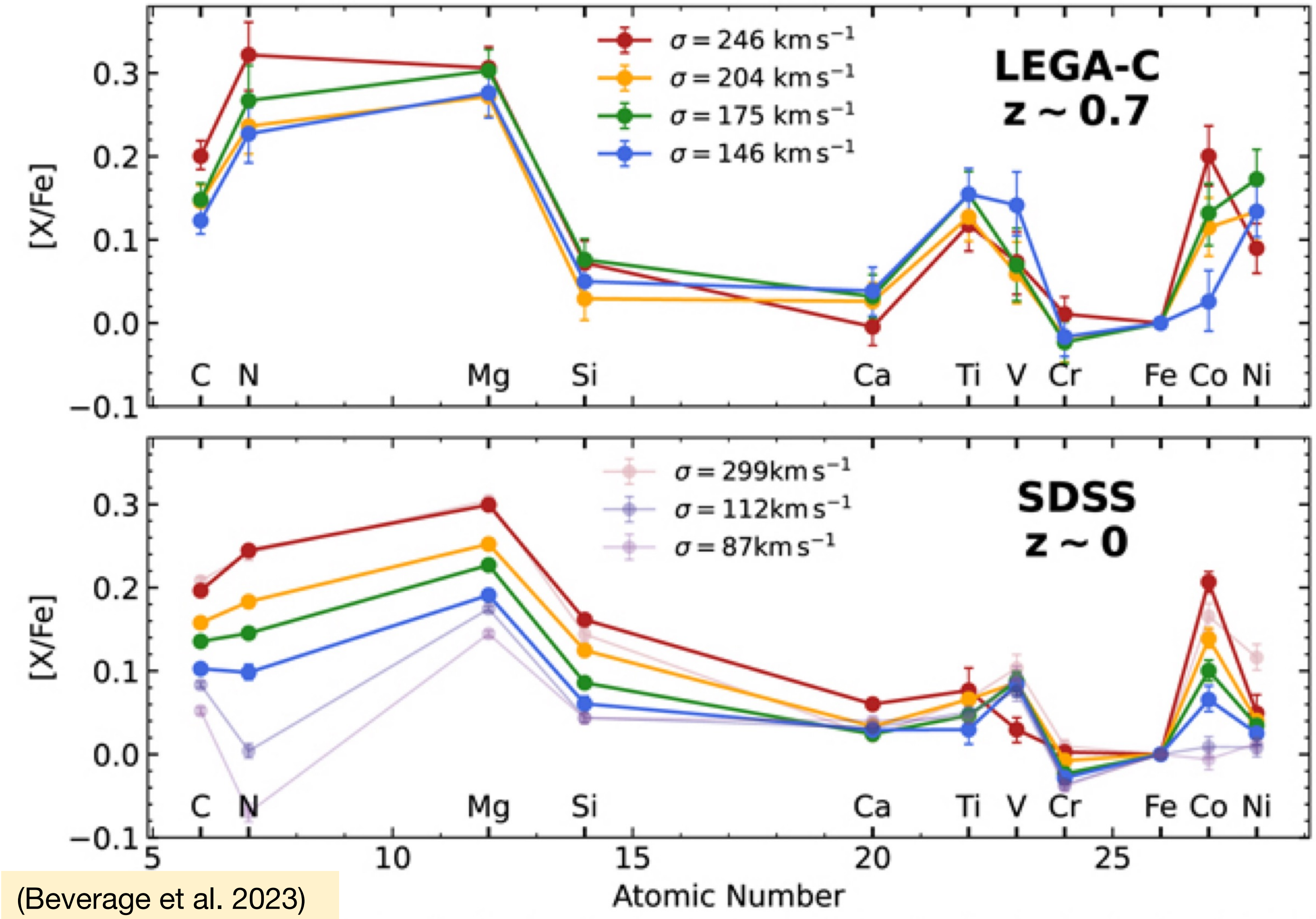
Colors refer to different galaxy velocity dispersions (i.e., total galaxy mass) from
σ = 90 km s^{-1}
to
σ = 300 km s^{-1}

Distant Universe – LEGA-C



(Beverage et al. 2023)

Distant Universe – LEGA-C



(Beverage et al. 2023)

StePS-4MOST
0.3 < z < 0.7
(PI: Iovino)

WHAT WE KNOW

From local Universe (SDSS) and z~0.7 (LEGA-C): massive galaxies are old (in terms of stellar pop ages), quite metallic and alpha enhanced

↓

massive galaxies suffer violent and fast star formation events and keep the formed metals

BUT

WHAT WE KNOW

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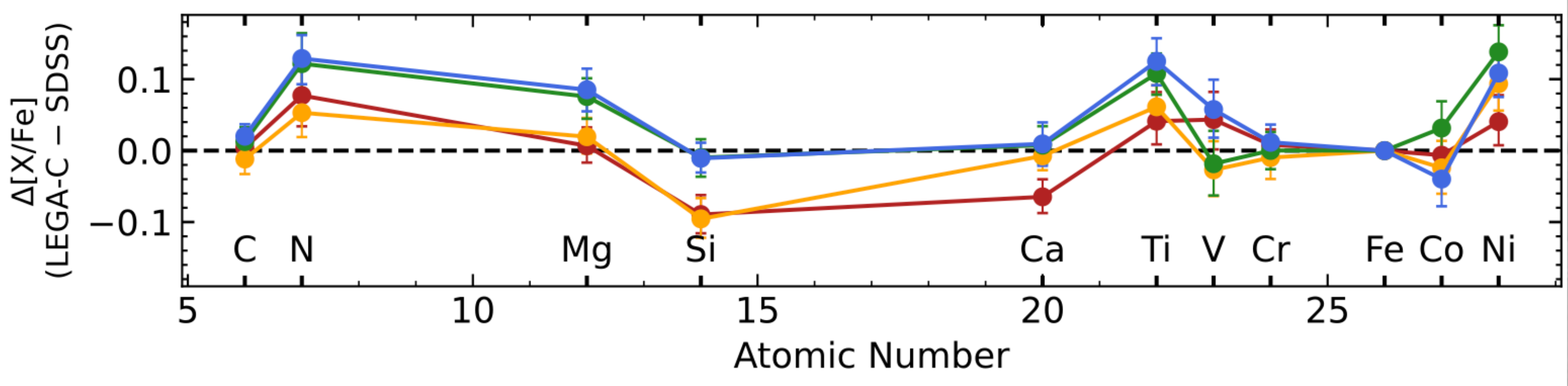
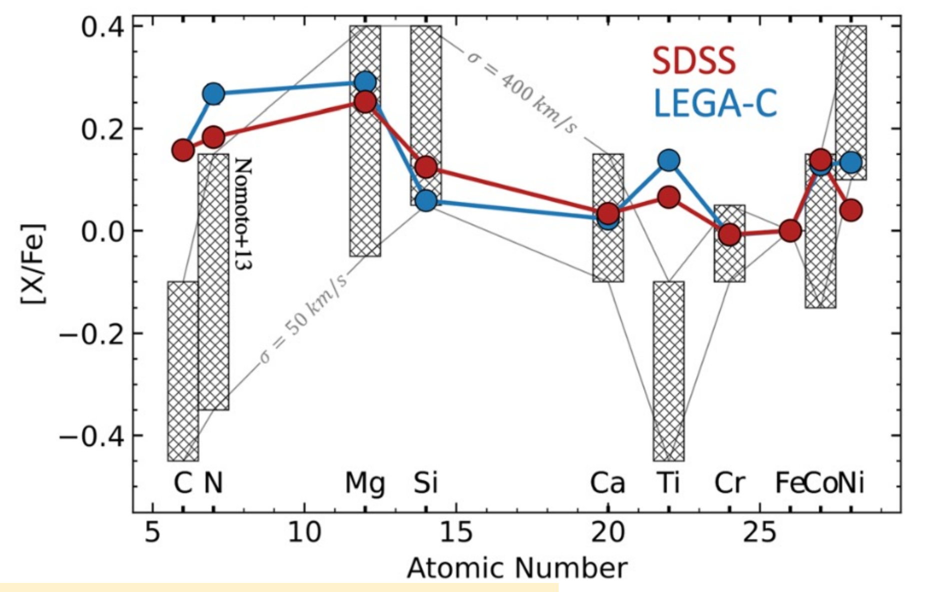




(models by Nomoto et al. 2013)

WHAT WE KNOW

From local Universe (SDSS) and z~0.7 (LEGA-C): massive galaxies are old (in terms of stellar pop ages), quite metallic and alpha enhanced

massive galaxies suffer violent and fast star formation events and keep the formed metals

BUT

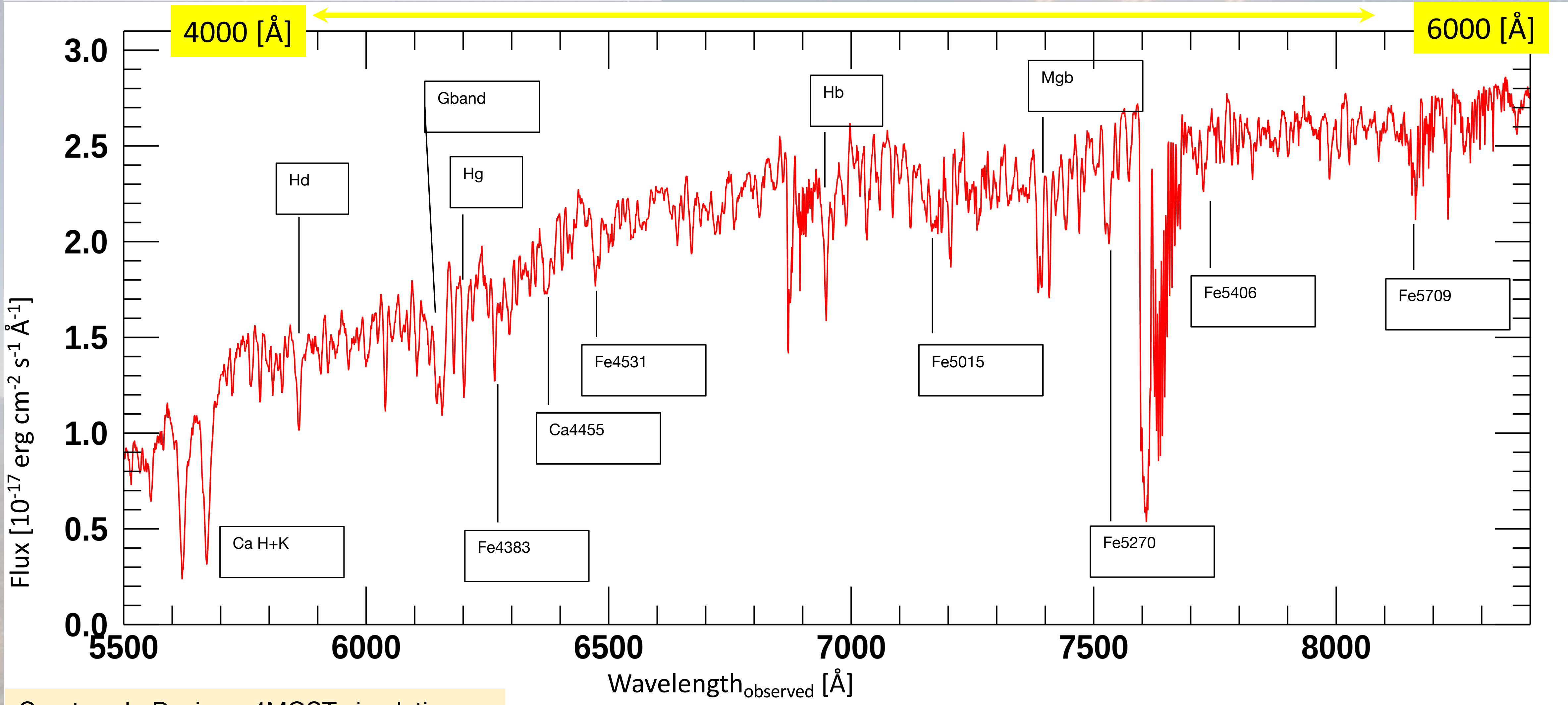
Higher redshift studies are need

At z = 2–3 (cosmic noon) closer to the initial main star forming events avoiding any diluting of the properties due to their evolution

WHAT WE NEED

- High Signal to Noise (> 20/res_element on the continuum) spectra
- Large spectral range (4000Å – 5800Å – restframe)

Optical rest-frame – quiescent galaxy at z=0.4

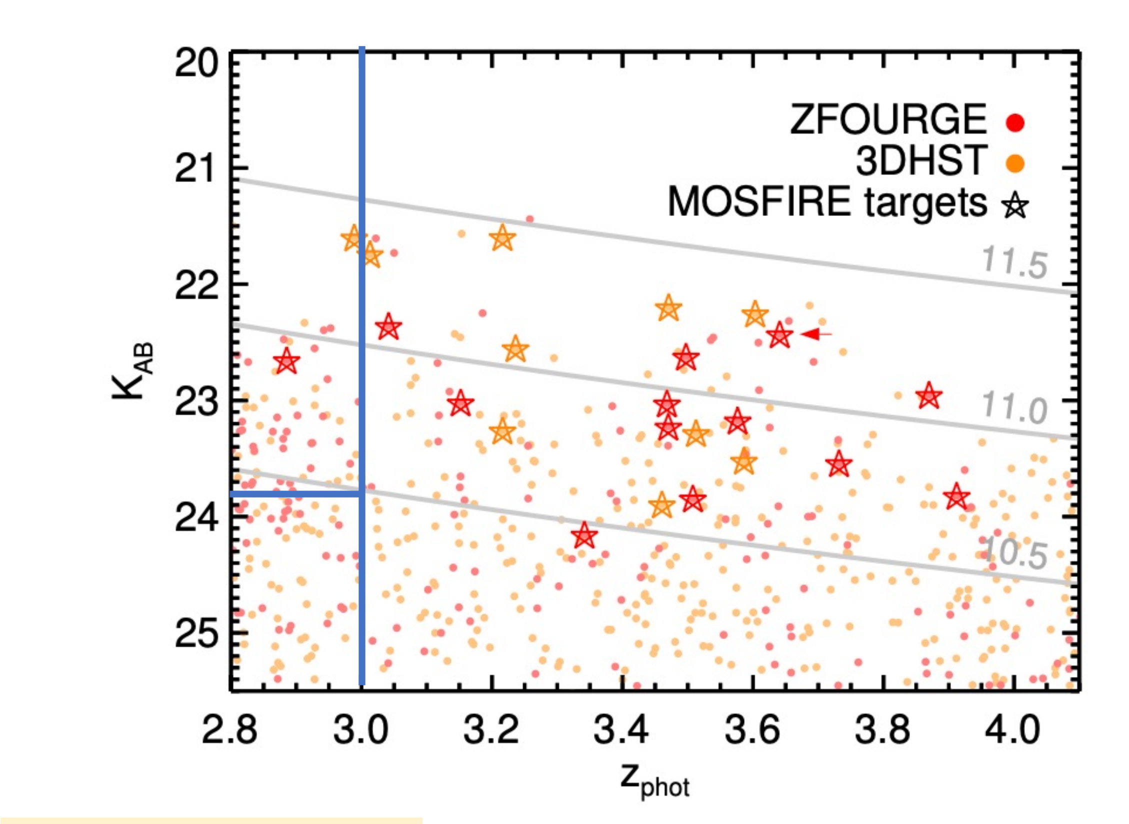


Courtesy L. Davies – 4MOST simulations

WHAT WE NEED

- High Signal to Noise (> 20/res_element on the continuum) spectra
- Large spectral range (4000Å – 5800Å – restframe)

At 2 < z < 3
- $K_{AB} < 24$ (logM > 10.5)
- 1.2 – 2.3 μm
- Re ~ 1 kpc = 0.1"



(Schreiber et al. 2018)

WHAT WE NEED

- High Signal to Noise (> 20/res_element on the continuum) spectra
- Large spectral range (4000Å – 5800Å – restframe)

At 2 < z < 3

- K_{AB} < 24 (logM > 10.5)
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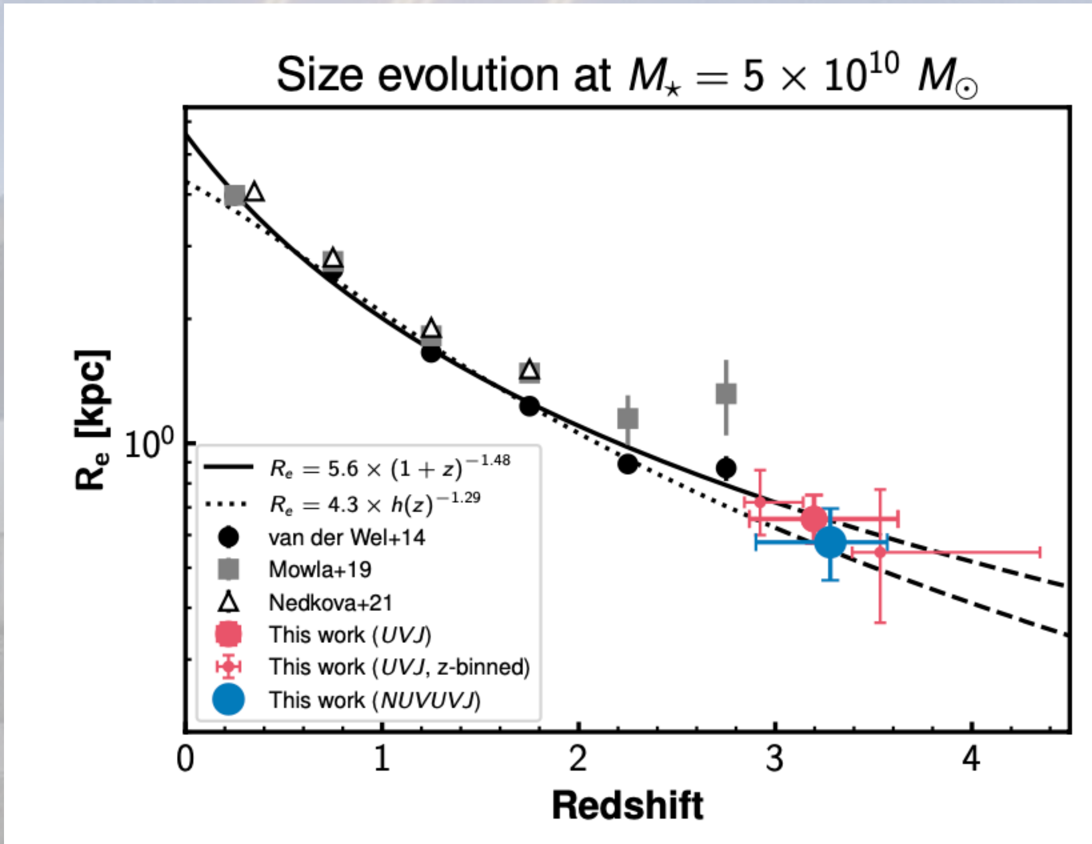
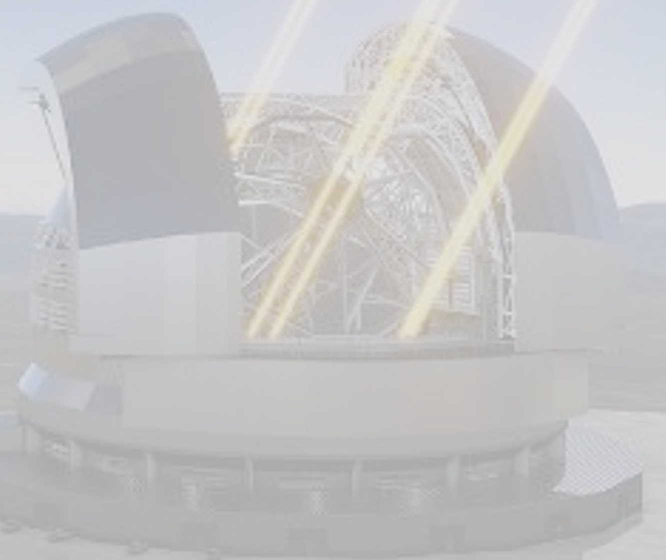


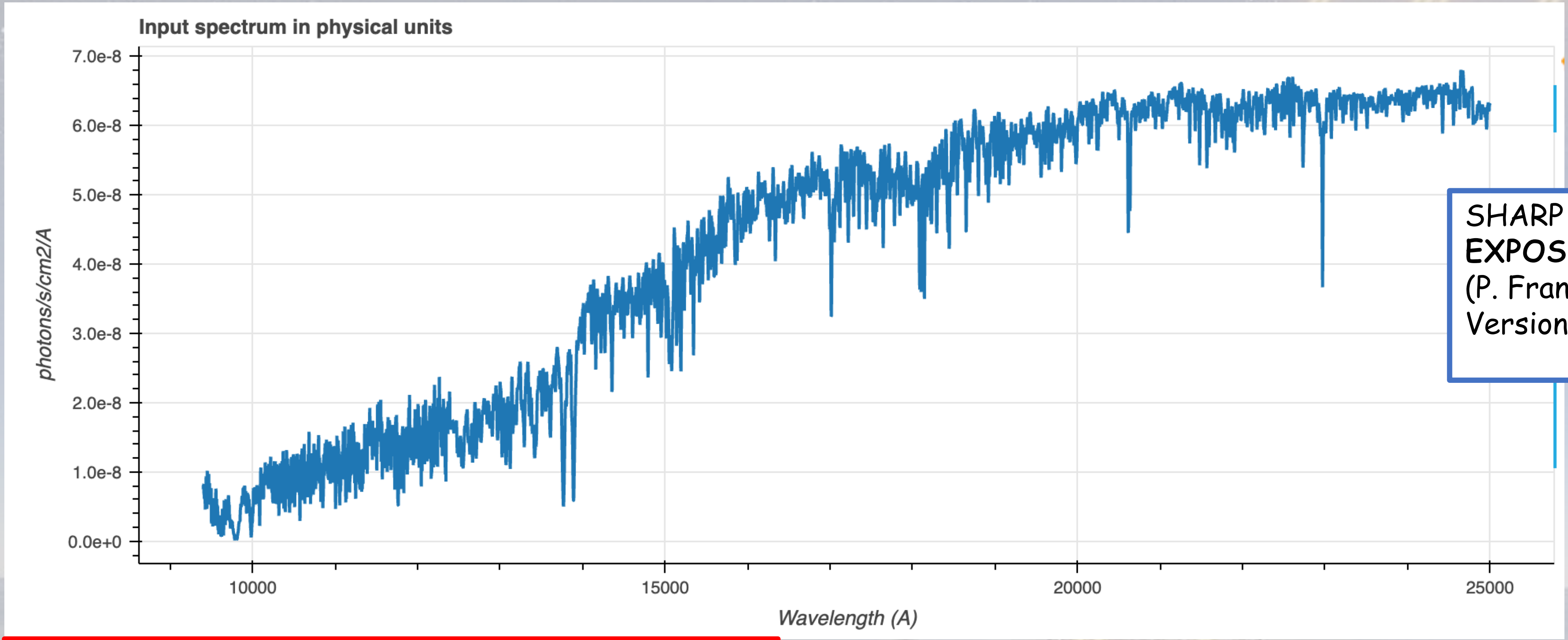
(Ito et al. 2024)

1° REQUIREMENT

- High Signal to Noise (> 20/res_element on the continuum) spectra
- Large spectral range (4000Å – 5800Å – restframe)

At $2 < z < 3$
- $K_{AB} < 24$ (logM > 10.5)
- 1.2 – 2.3 μm
- Re ~ 1 kpc = 0.1″



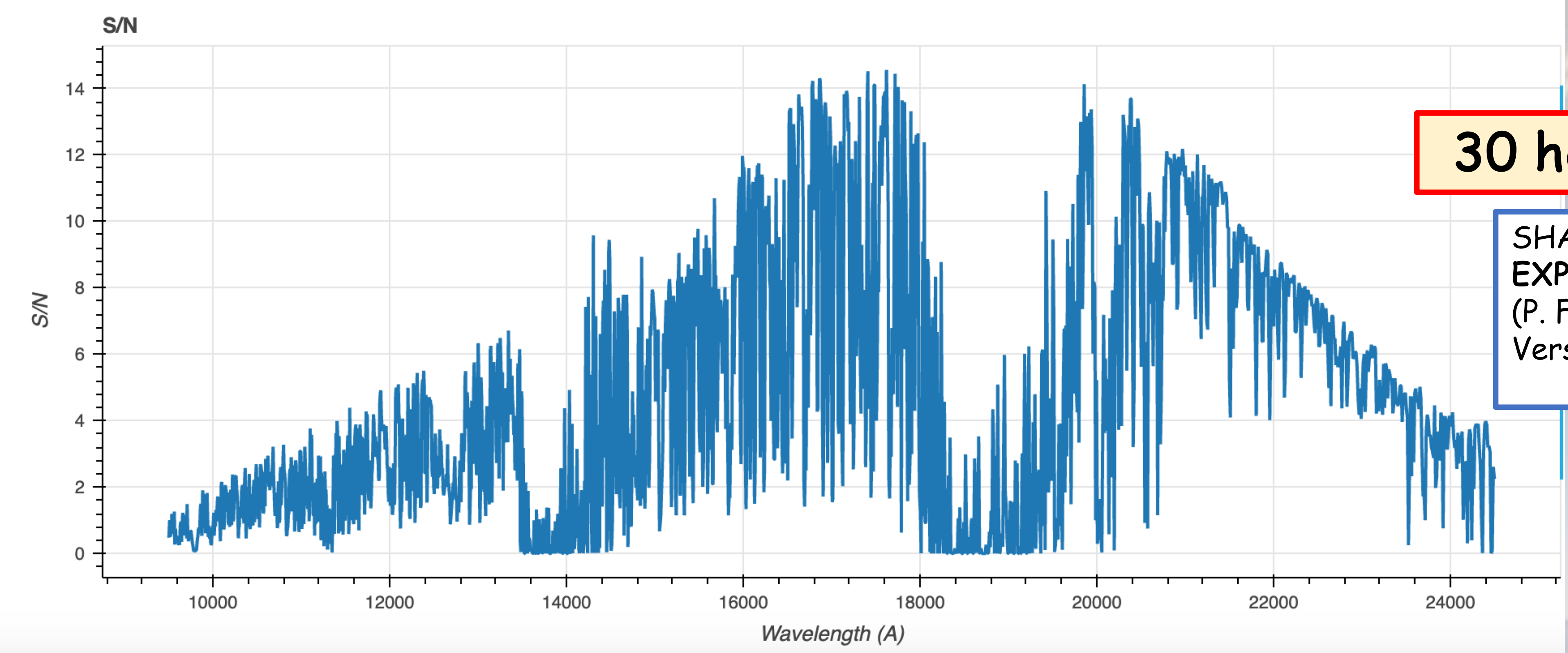


SHARP
EXPOSURE TIME CALCULATOR
(P. Franzetti)
Version 0.2

TARGET = galaxy K_{AB}=24 @z=2.5

TEMPLATE : SSP_BC016_Chab_Zsun_2Gyr

EXTENDED SOURCE
Effective radius : 100 mas
Sersic index : 4.0



30 hours (3600 x 30s)

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TARGET = galaxy K_{AB}=24 @z=2.5

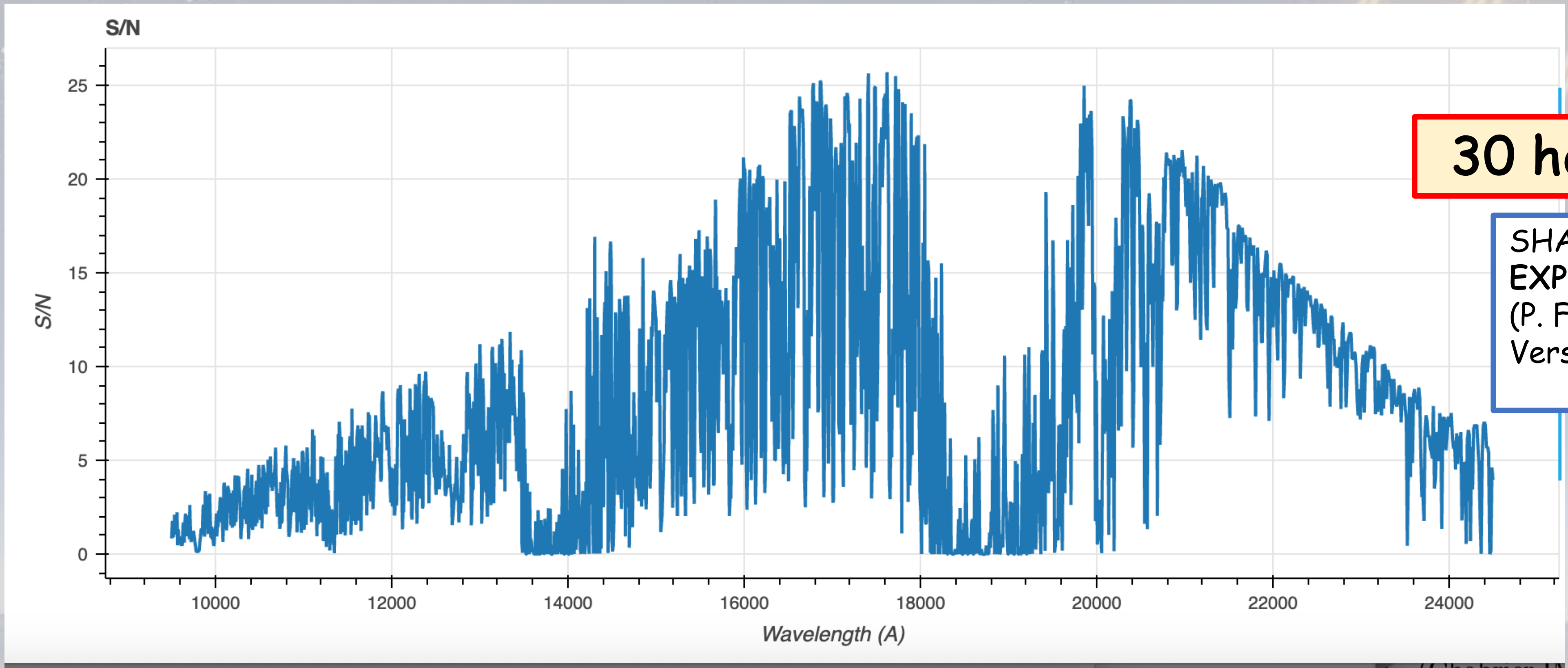
TEMPLATE : SSP_BC016_Chab_Zsun_2Gyr

EXTENDED SOURCE
Effective radius : 100 mas
Sersic index : 4.0

GLAO

Slit = 200 mas
Integrated over 12 spatial pixels
(1 pixel > 1σ sky noise)

S/N ~ 12-13 / resolution element



30 hours (3600 x 30s)

SHARP
EXPOSURE TIME CALCULATOR
(P. Franzetti)
Version 0.2

TARGET = galaxy K_{AB}=24 @z=2.5

TEMPLATE : SSP_BC016_Chab_Zsun_2Gyr

EXTENDED SOURCE
Effective radius : 100 mas
Sersic index : 4.0

MCAO

Slit = 200 mas
Integrated over 6 spatial pixels
(3 pixels > 1σ sky noise)

S/N ~ 20-25 / resolution element

1° REQUIREMENT

- High Signal to Noise (> 20/res_element on the continuum) spectra
- Large spectral range (4000Å – 5800Å – restframe)

At 2 < z < 3
- $K_{AB} < 24$ (logM > 10.5)
- 1.2 – 2.3 μm
- Re ~ 1 kpc = 0.1″

→ Need of MORFEO MCAO on ELT

2° REQUIREMENT

- High Signal to Noise (> 20/res_element on the continuum) spectra
- Large spectral range (4000Å – 5800Å – restframe)

At 2 < z < 3
- K_{AB} < 24 (logM > 10.5)
- 1.2 – 2.3 μm
- Re ~ 1 kpc = 0.1″

COMBINED WITH MCAO

MOSAIC

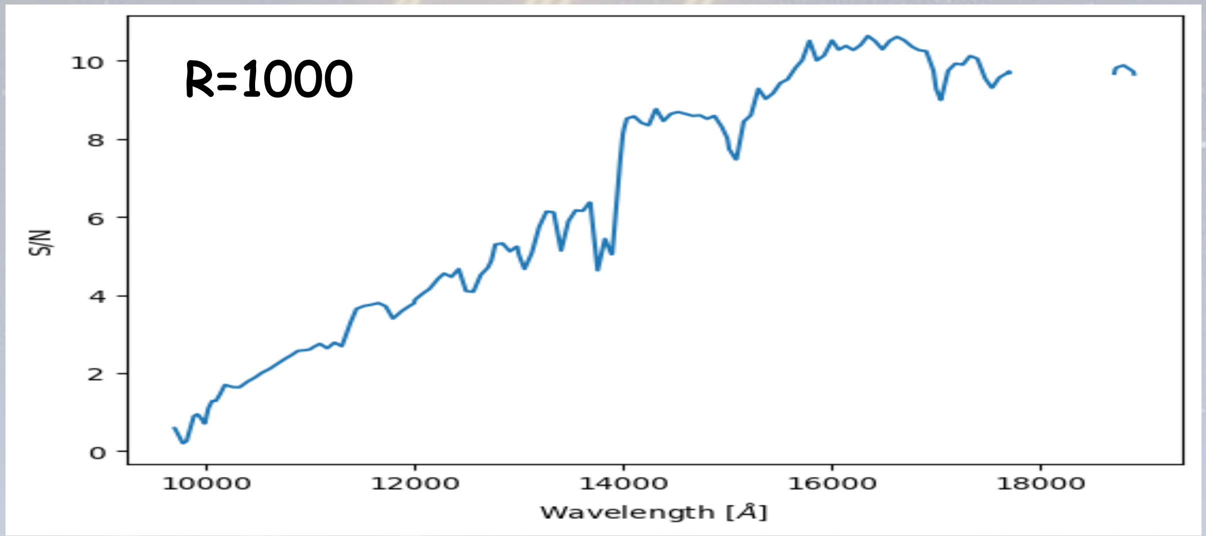
MOSAIC - GLAO

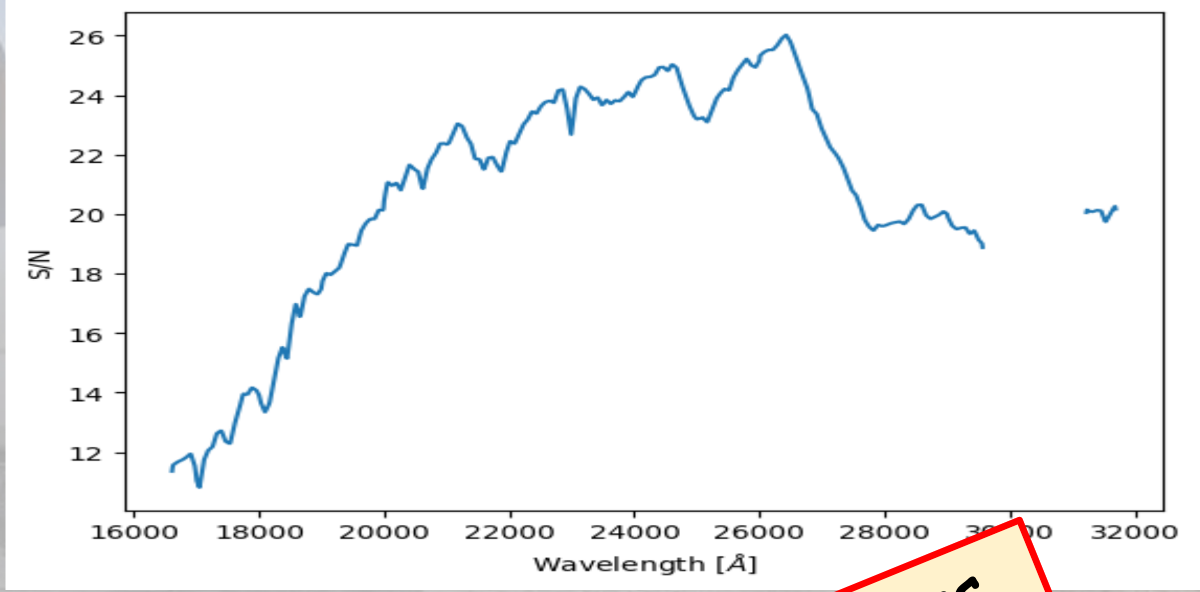
Instrument configuration name	Mode	Operating wavelength (μm)	Multiplex	Aperture on sky (arcsec)	Spectral resolution (λ/Δλ)
MOS-VIS-LR	MOS	0.45 – 0.7	200	0.7	R ~ 4,000
MOS-VIS-HR	MOS	0.45 – 0.877	100	0.7	R ~ 18,000
MOS-NIR-LR	MOS	0.77 – 1.80	200	0.6	R ~ 4,000
MOS-NIR-HR	MOS	0.77 – 1.80	200	0.6	R ~ 18,000
mIFU-LR	mIFU	0.77 – 1.80	8	2.5	R ~ 4,000
mIFU-HR	mIFU	0.77 – 1.80	8	2.5	R ~ 18,000

WEBB SPACE TELESCOPE

Table 1. Spectral configurations available in NIRSpec MOS mode

Disperser-filter combination	Nominal resolving power	Wavelength range † (μm)
G140M/F070LP	~1,000	0.70–1.27
G140M/F100LP		0.97–1.84
G235M/F170LP		1.66–3.07
G395M/F290LP		2.87–5.10
G140H/F070LP	~2,700	0.81–1.27
G140H/F100LP		0.97–1.82
G235H/F170LP		1.66–3.05
G395H/F290LP		2.87–5.14
PRISM/CLEAR	~100	0.60-5.30



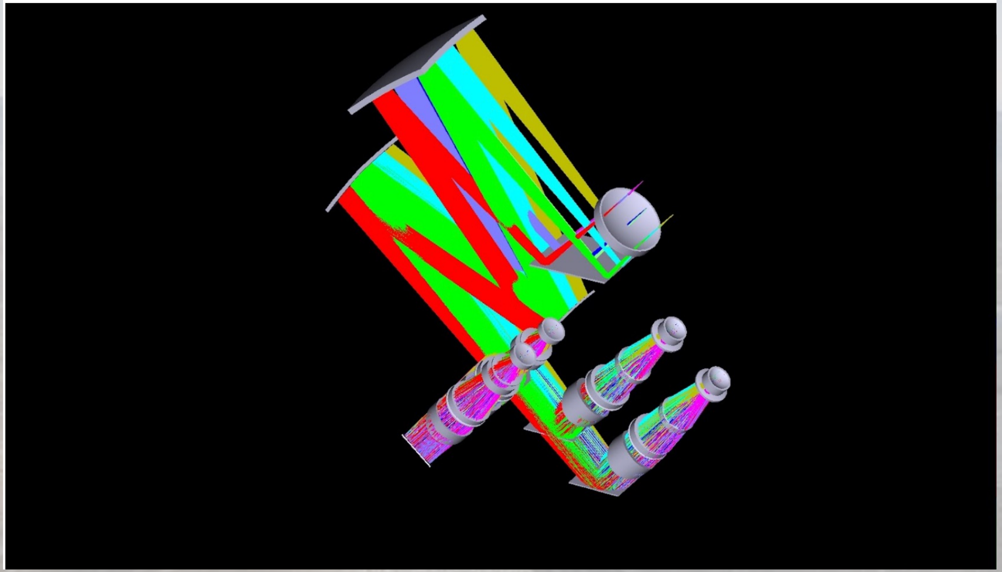


30 hours

SHARP

SHARP - MCAO!

A near-IR multi-mode spectrograph conceived for the Multi-Conjugate Adaptive Optics module MORFEO@ELT



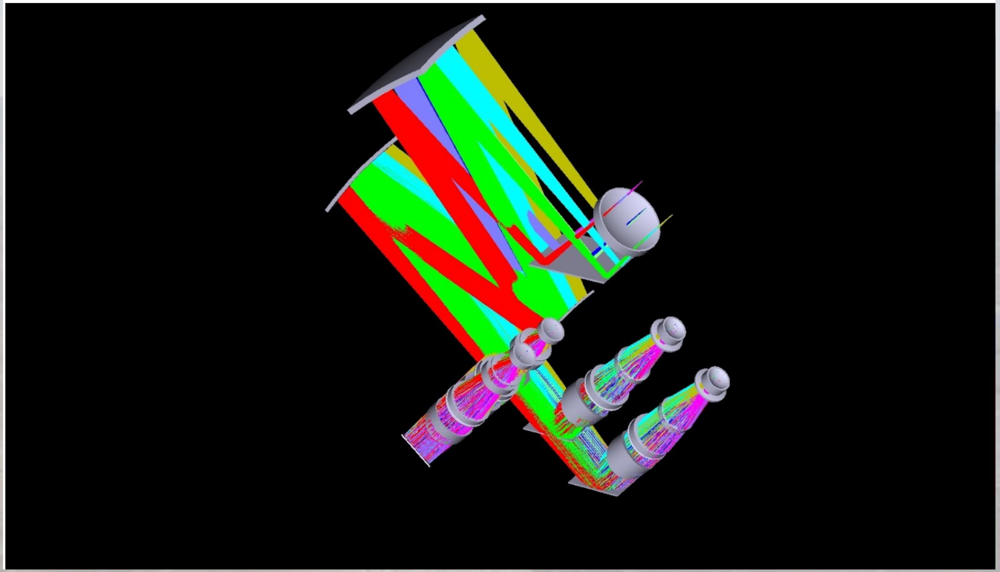
NEXUS

- Slitlet MOS
- Multiplexing 30
- Resolution R ~ 6000, ~ 2000 and ~ 300

The 0.95-2.45 μm wavelength range will be simultaneously obtained in one shot

SHARP - MCAO!

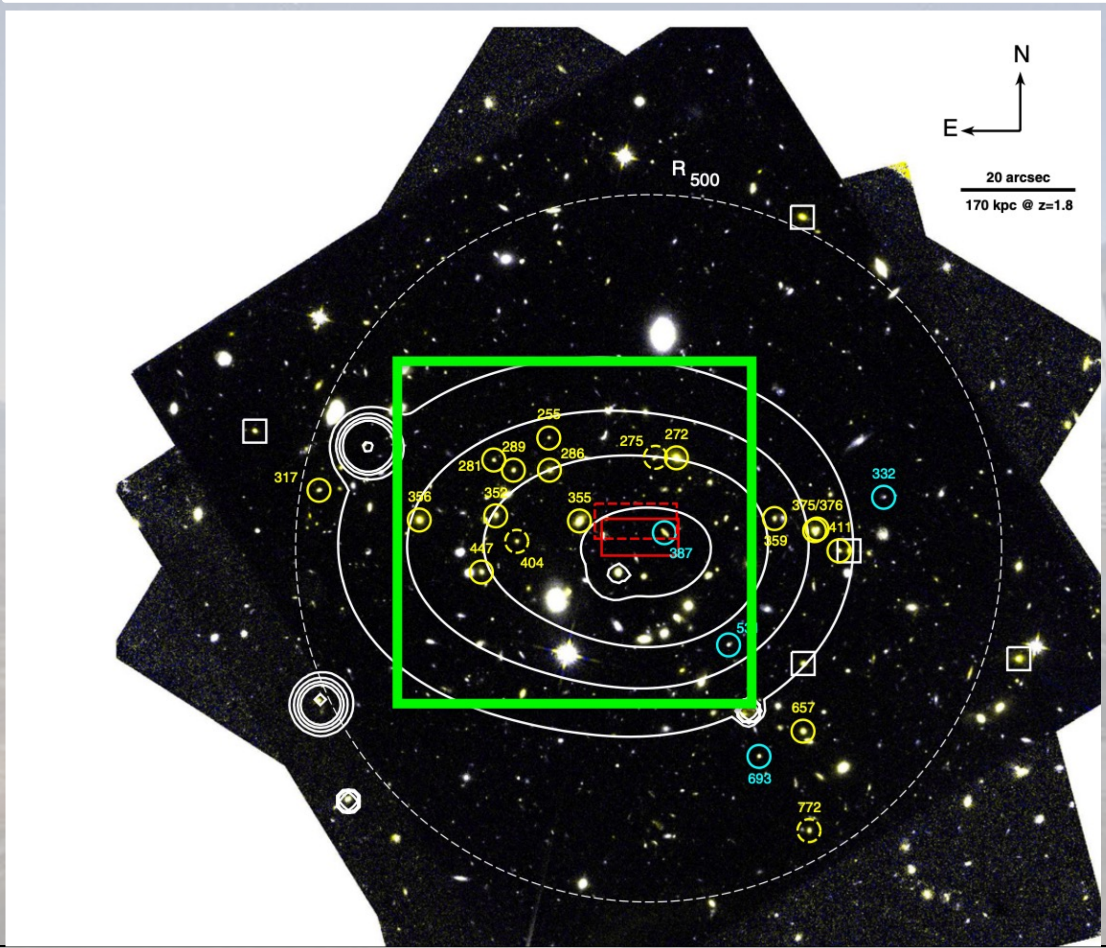
A near-IR multi-mode spectrograph conceived for the Multi-Conjugate Adaptive Optics module MORFEO@ELT

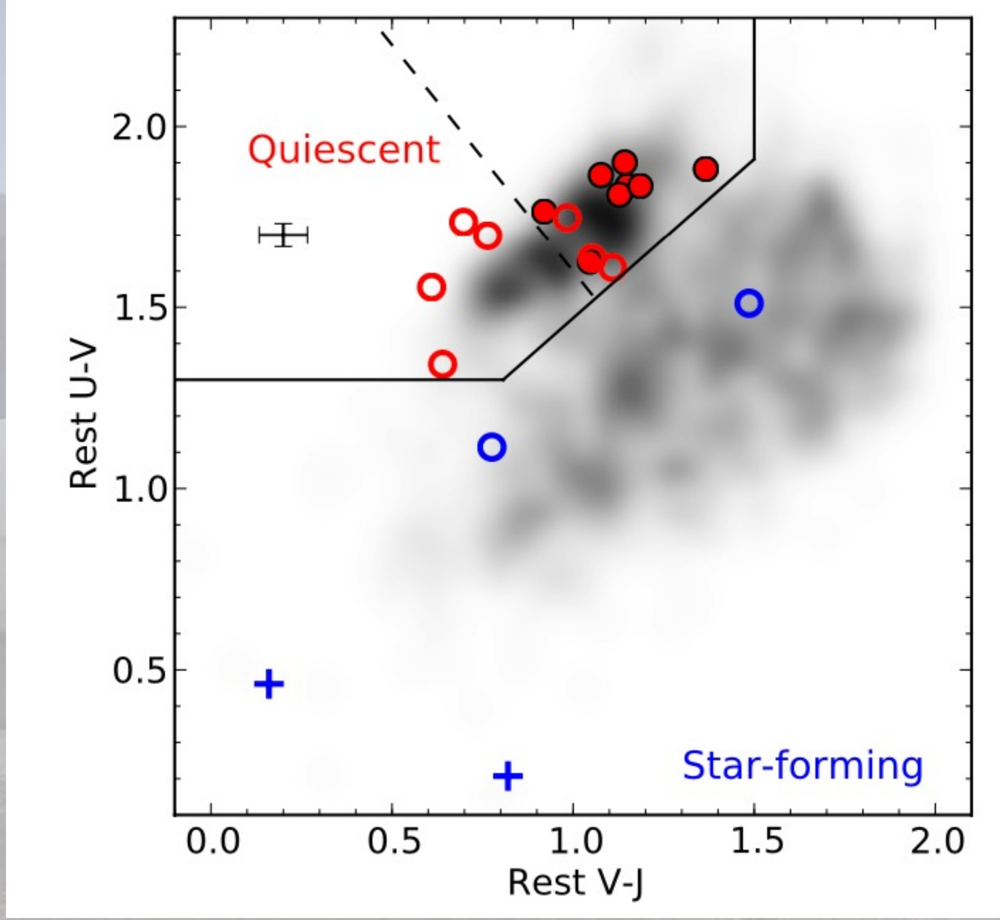


NEXUS
- Slitlet MOS
- Multiplexing 30
- Resolution R ~ 6000, ~ 2000 and ~ 300

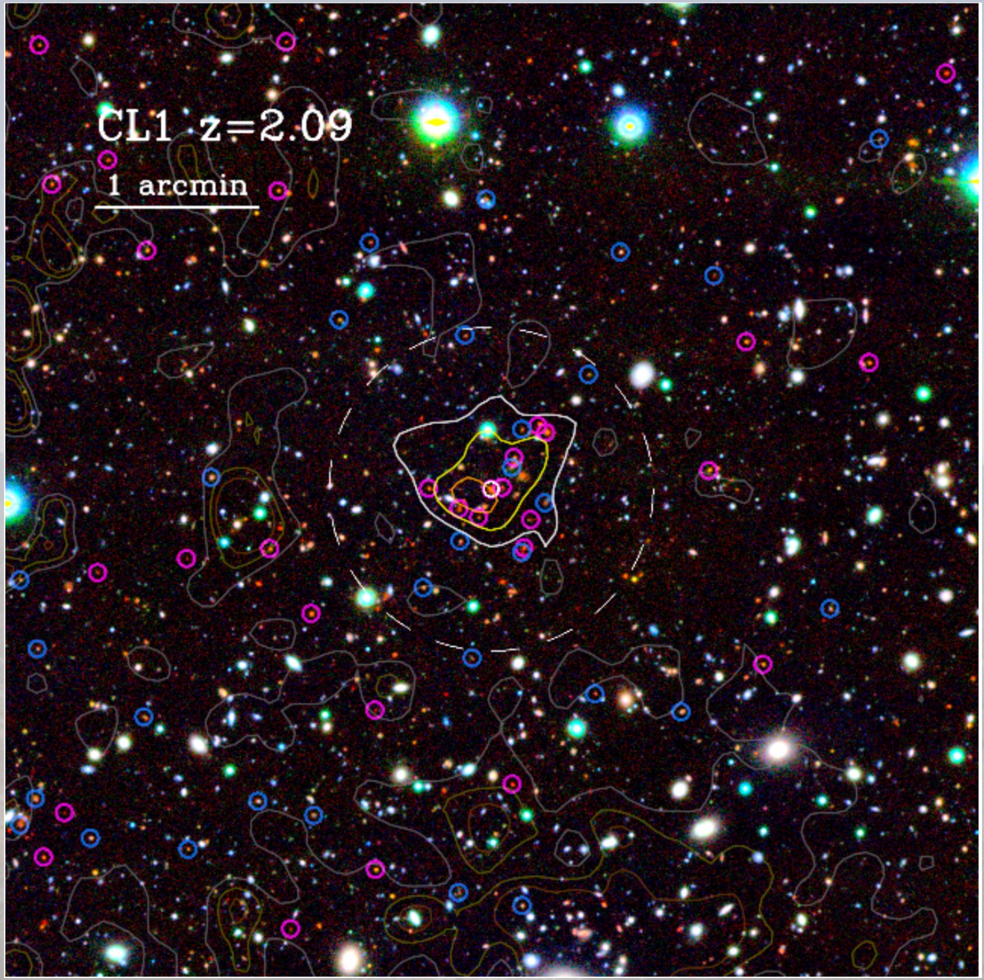
The 0.95-2.45 μm wavelength range will be simultaneously obtained in one shot

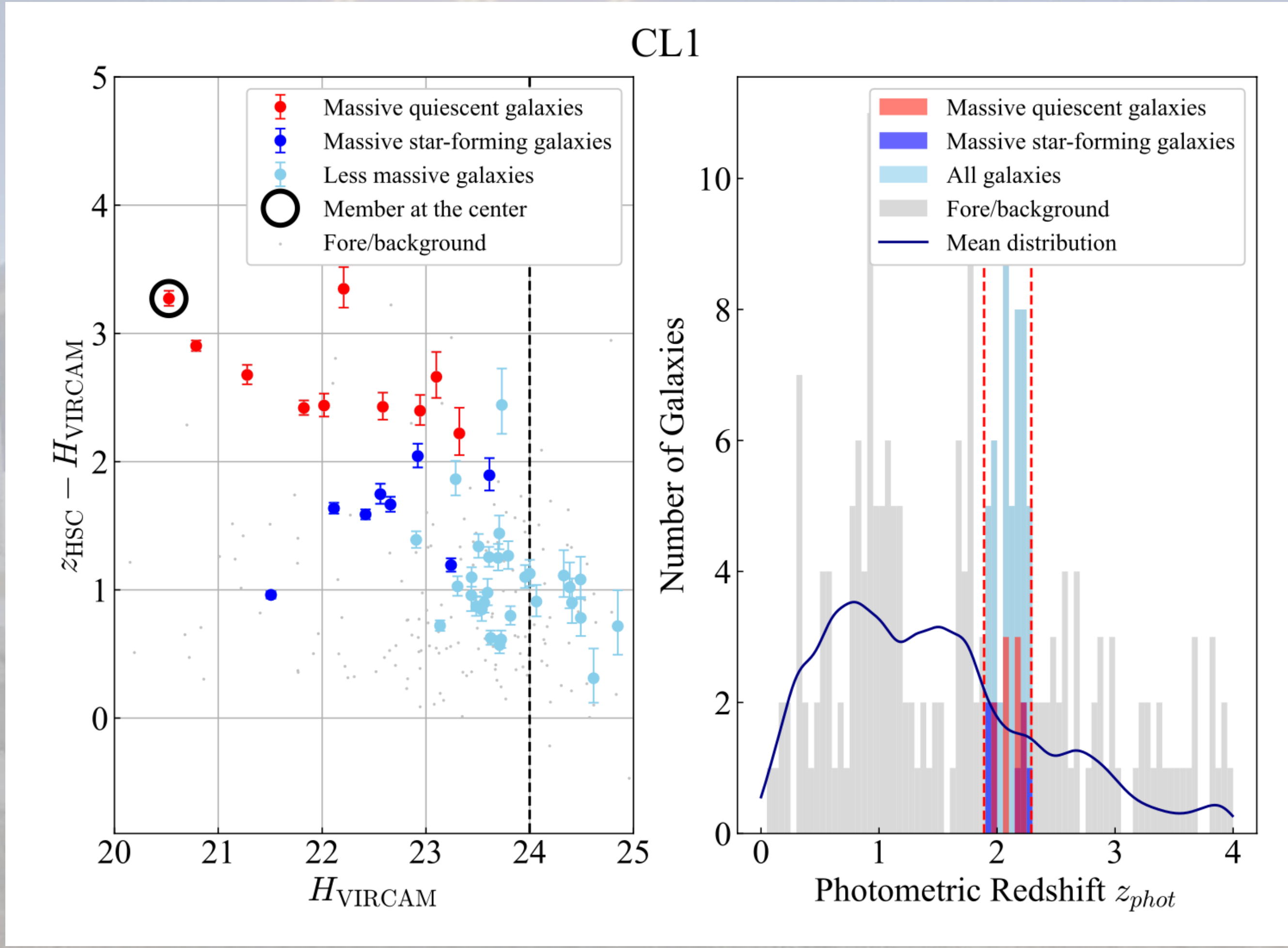
JKCS 041
z=1.8
WFC3@HST - G141 grism
- 11 quiescent members (+ 3 quiescent galaxies at z > 2) in the fov of SHARP-NEXUS
(Newman et al. 2014 – Andreon et al. 2014)



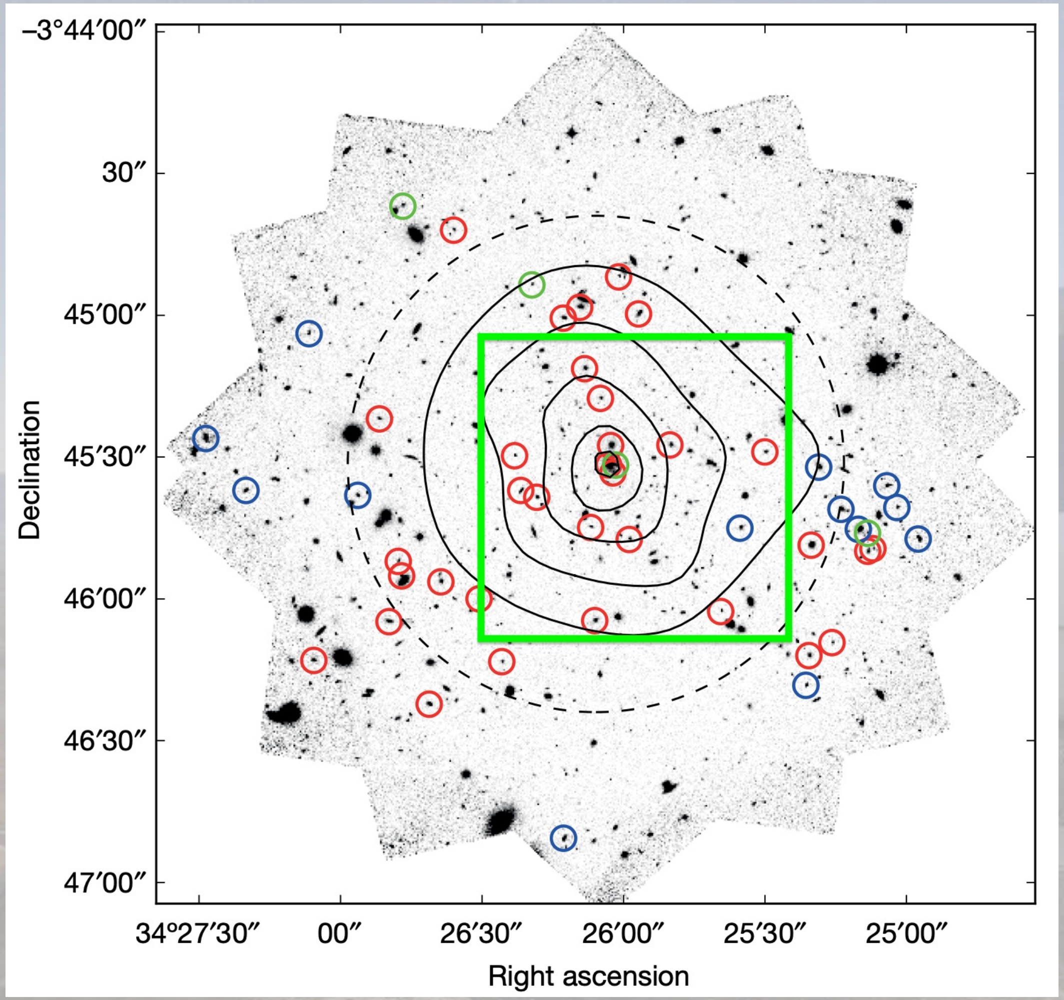


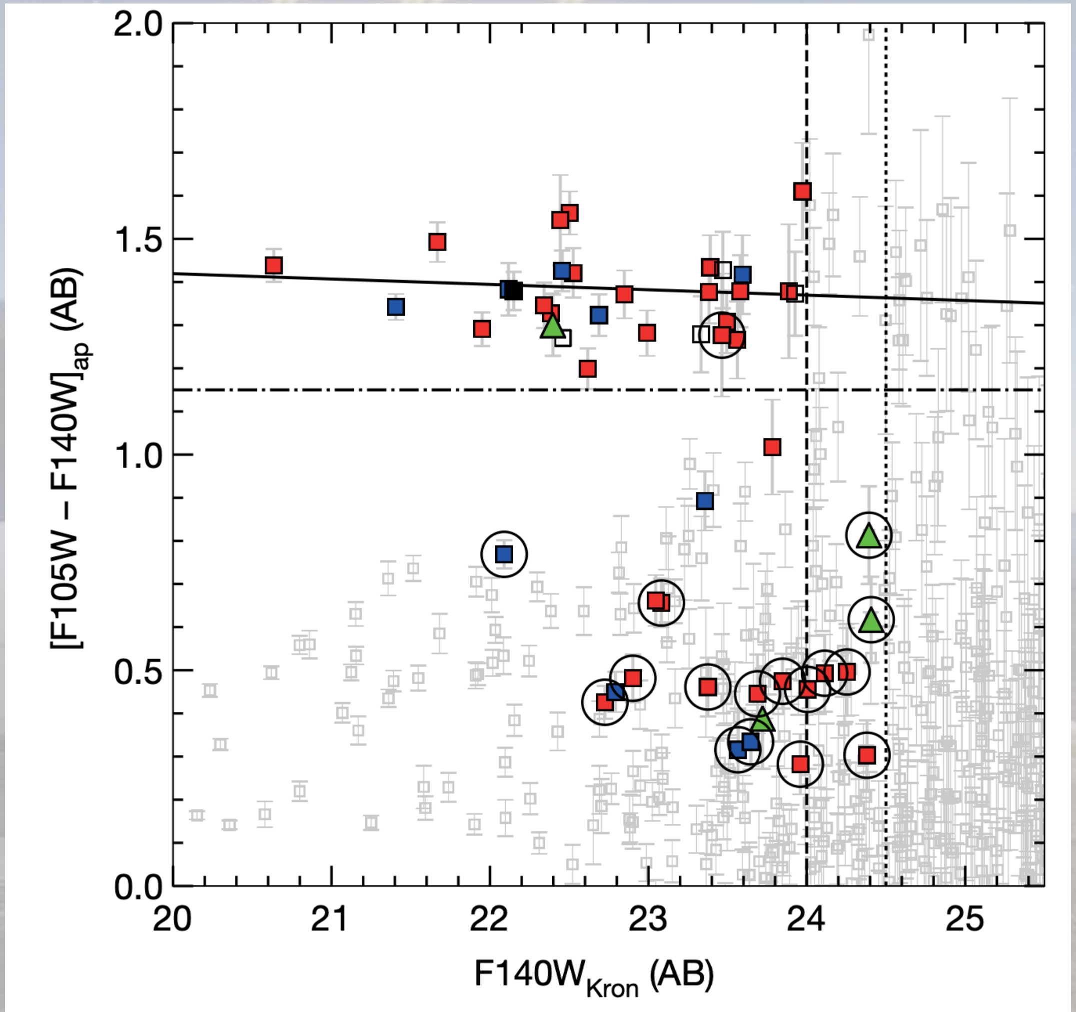
CL1 in the XMM-LSS field (Hyper Suprime-Cam photometry)
z=2.09
10 quiescent galaxies in the fov of SHARP-NEXUS
(Kyiota et al. 2024)





XLSSC122(F105, F140+G141 WFC3@HST)
z=1.98
~ 15 red sequence galaxies in the fov of SHARP-NEXUS
(Willis et al. 2020)





CrossM

Spectroscopic Confirmation of a Protocluster at $z = 3.37$ with a High Fraction of Quiescent Galaxies

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Abstract

We report the discovery of MAGAZ3NE J095924+022537, a spectroscopically confirmed protocluster at $z = 3.3665^{+0.0009}_{-0.0012}$ around a spectroscopically confirmed *UVJ*-quiescent ultramassive galaxy (UMG; $M_{\star} = 2.34^{+0.23}_{-0.34} \times 10^{11} M_{\odot}$) in the COSMOS UltraVISTA field. We present a total of 38 protocluster members (14 spectroscopic and 24 photometric), including the UMG. Notably, and in marked contrast to protoclusters previously reported at this epoch that have been found to contain predominantly star-forming members, we measure an elevated fraction of quiescent galaxies relative to the coeval field ($73.3^{+26.7}_{-16.9}\%$ versus $11.6^{+7.1}_{-4.9}\%$ for galaxies with stellar mass $M_{\star} \geqslant 10^{11} M_{\odot}$). This high quenched fraction provides a striking and important counterexample to the seeming ubiquitousness of star-forming galaxies in protoclusters at $z > 2$ and suggests, rather, that protoclusters exist in a

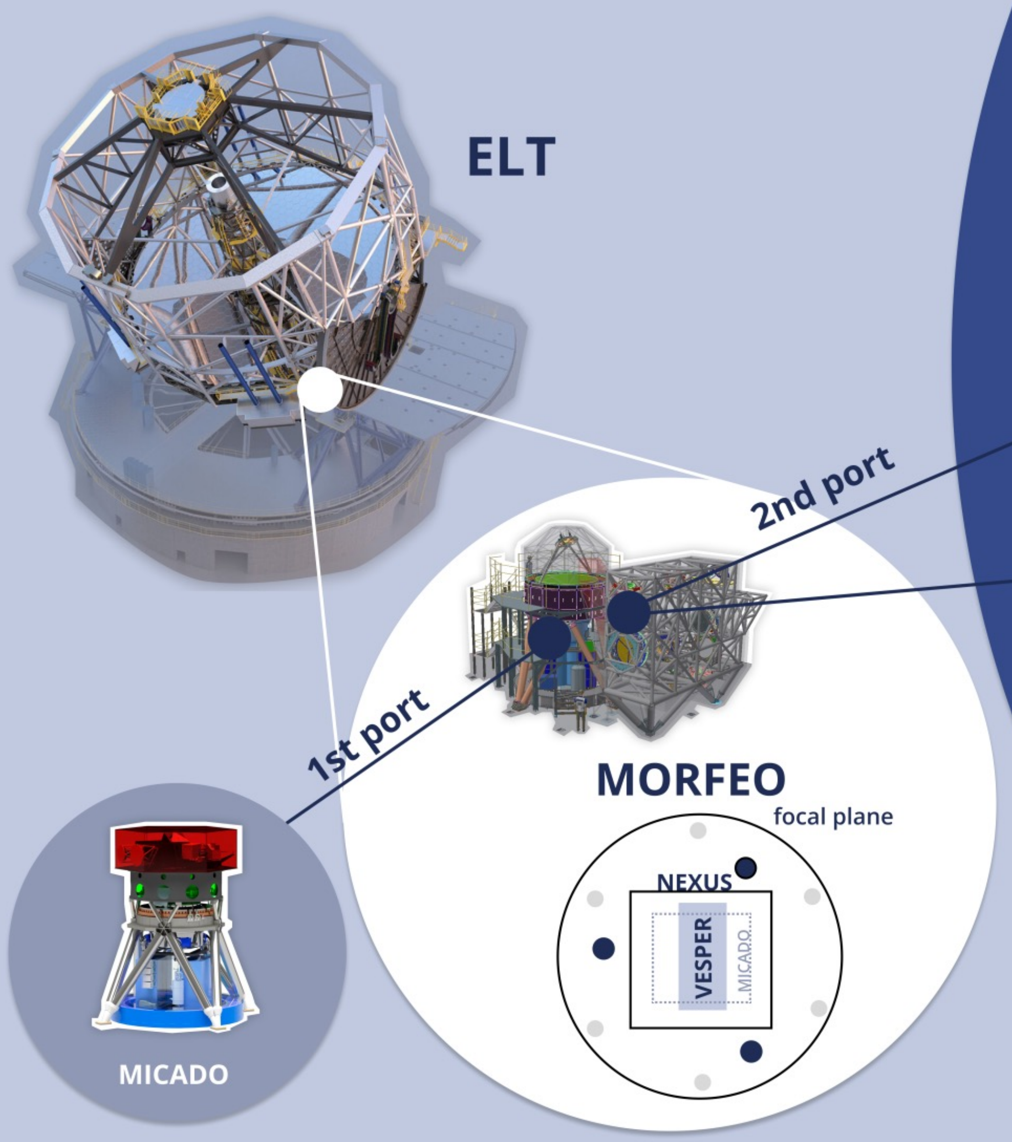
SUMMARY

- Individual element abundances (eg. [α/Fe]) give insights into the mechanisms that shaped the formation and evolution of galaxies (e.g., quenching mechanisms)

- High redshift studies are necessary to constrain the initial formation mechanisms avoiding a diluting of the properties due to their evolution (e..g, merging)

- Need of high SNR (> 20/res_element) + wide wavelength range spectra (4000Å – 5800Å – restframe)

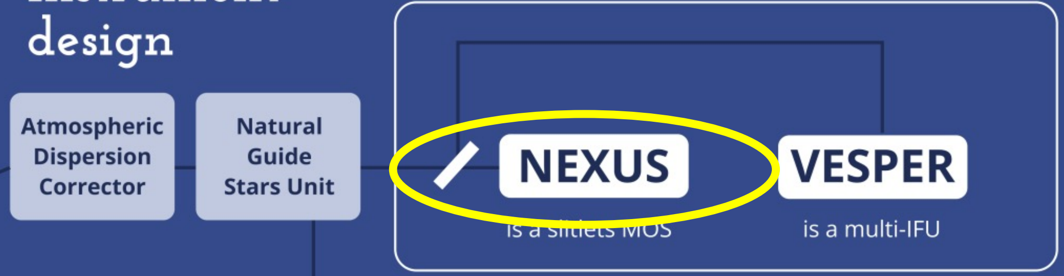
- MCAO allows to limit the required exposure time



SHARP

Near-IR multi-mode spectrograph

Instrument design



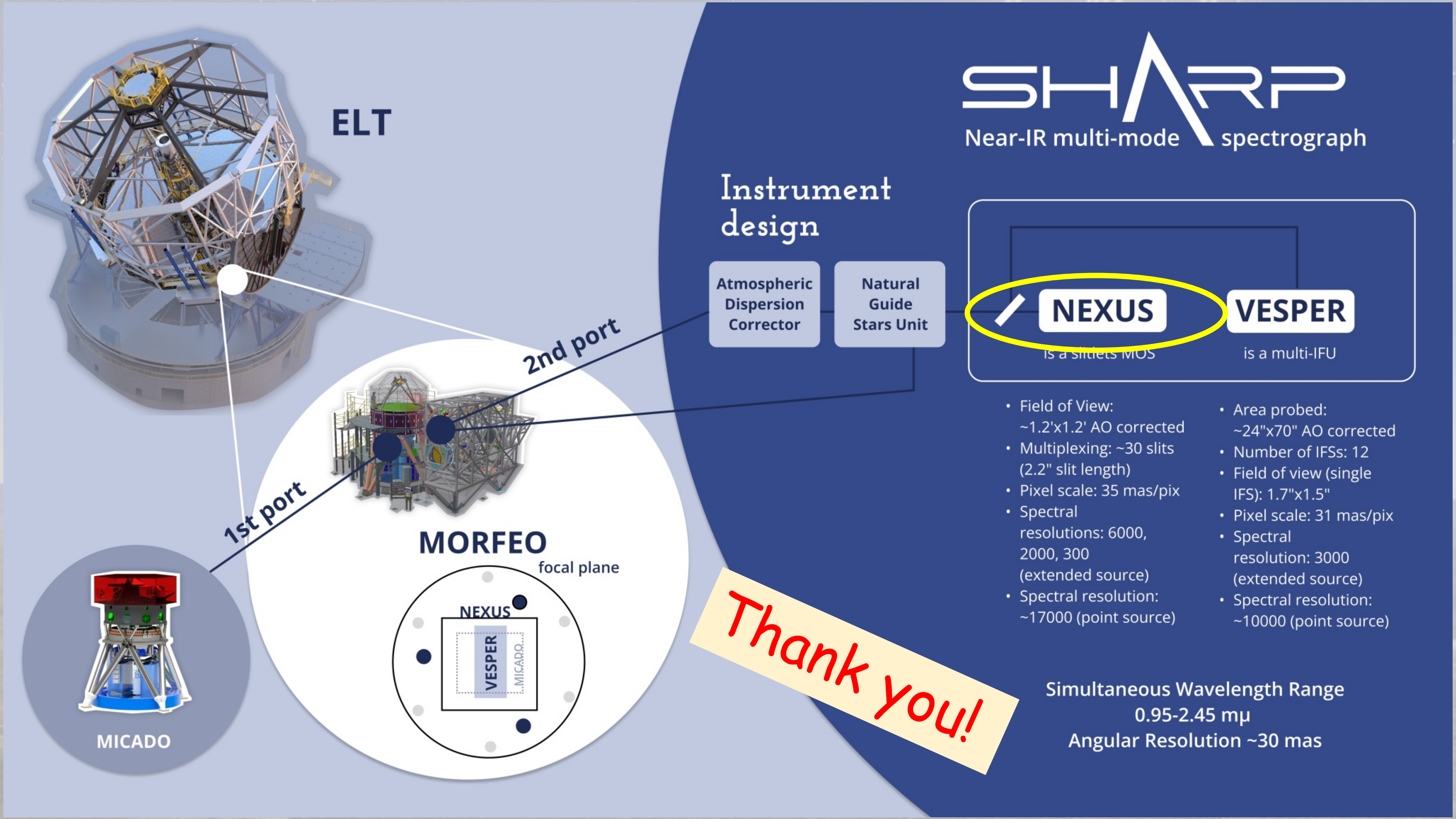
NEXUS

- Field of View: ~1.2'x1.2' AO corrected
- Multiplexing: ~30 slits (2.2" slit length)
- Pixel scale: 35 mas/pix
- Spectral resolutions: 6000, 2000, 300 (extended source)
- Spectral resolution: ~17000 (point source)

VESPER

- Area probed: ~24"x70" AO corrected
- Number of IFSs: 12
- Field of view (single IFS): 1.7"x1.5"
- Pixel scale: 31 mas/pix
- Spectral resolution: 3000 (extended source)
- Spectral resolution: ~10000 (point source)

Simultaneous Wavelength Range
0.95-2.45 mμ
Angular Resolution ~30 mas



ELT
SHARP
Near-IR multi-mode spectrograph
Instrument design
Atmospheric Dispersion Corrector
Natural Guide Stars Unit
NEXUS
is a slitlets MOS
VESPER
is a multi-IFU
2nd port
1st port
MORFEO
focal plane
NEXUS
VESPER
MICADO
MICADO
• Field of View: ~1.2'x1.2' AO corrected
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Angular Resolution ~30 mas
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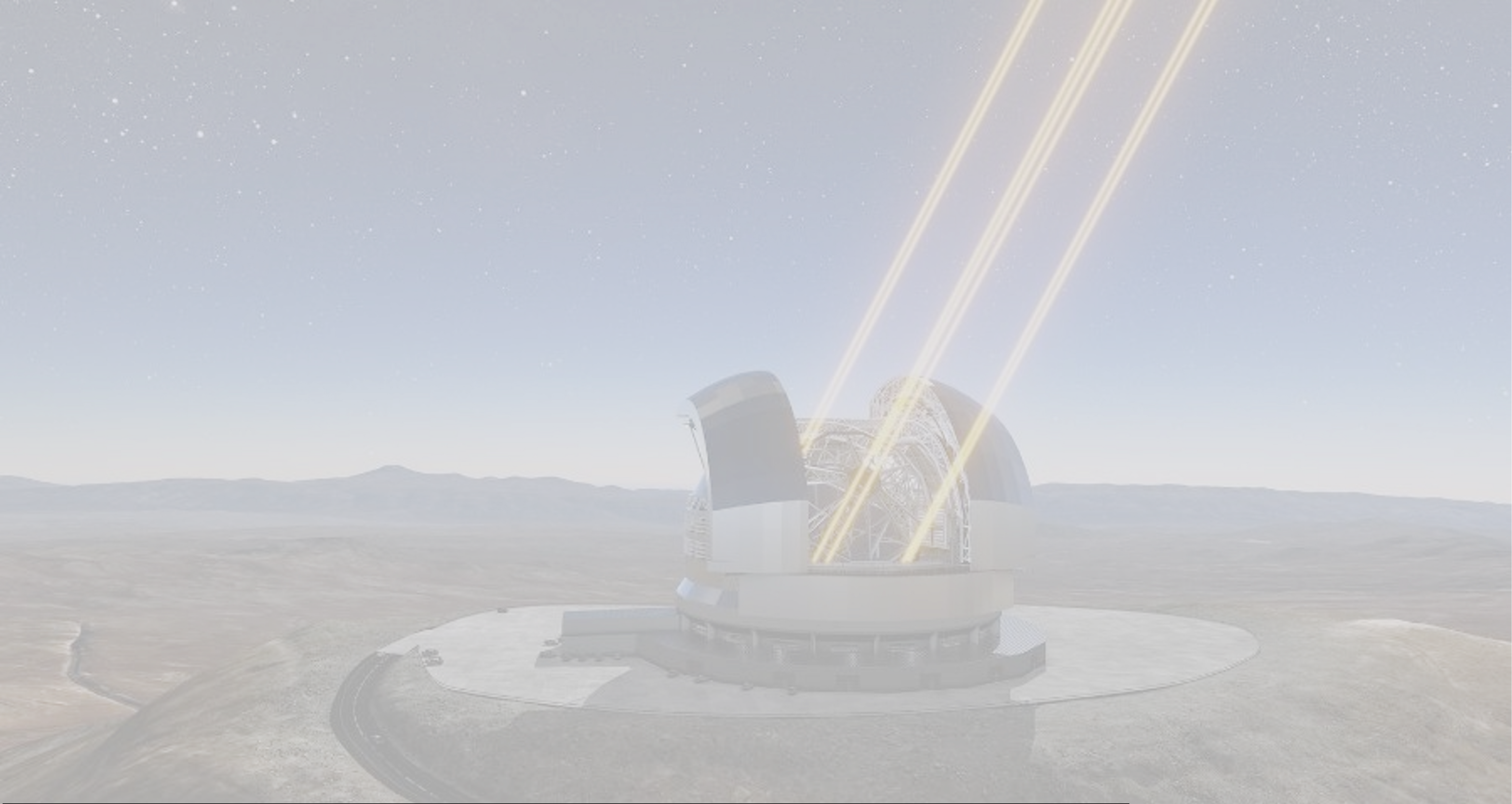

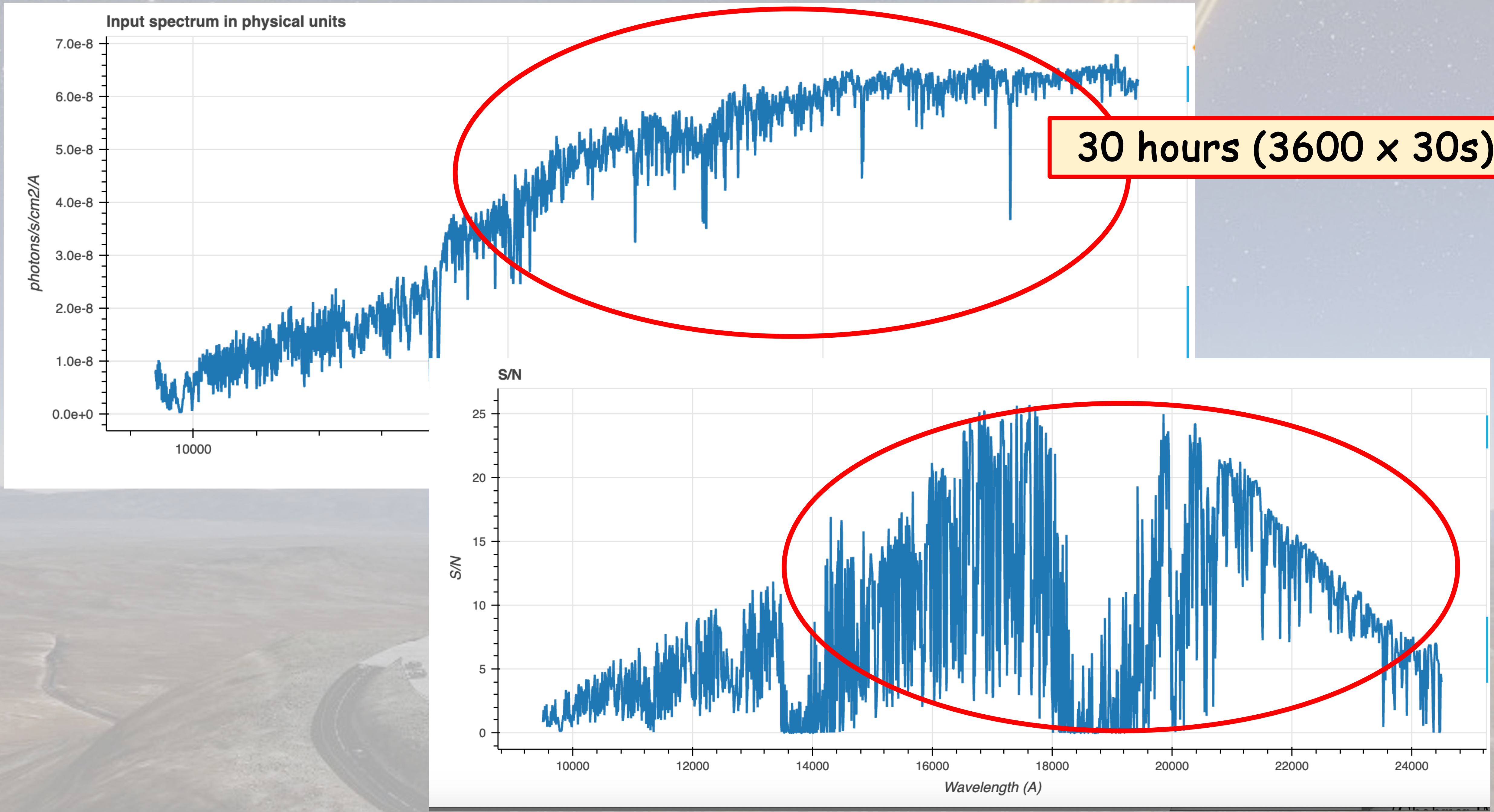

30 hours (3600 x 30s)

ANDES

ANDES – seeing limited

Instrument design

The ANDES baseline concept is that of a modular fiber-fed cross dispersed echelle spectrograph composed by four ultra-stable modules (called in our Project terminology, *subsystems*), namely UBV, RIZ, YJH and K, capable of providing a simultaneous spectral coverage (goals included) of 0.35 -2.4 μm at a resolution of 100,000 with several, interchangeable, observing modes ensuring maximization of either accuracy or throughput.