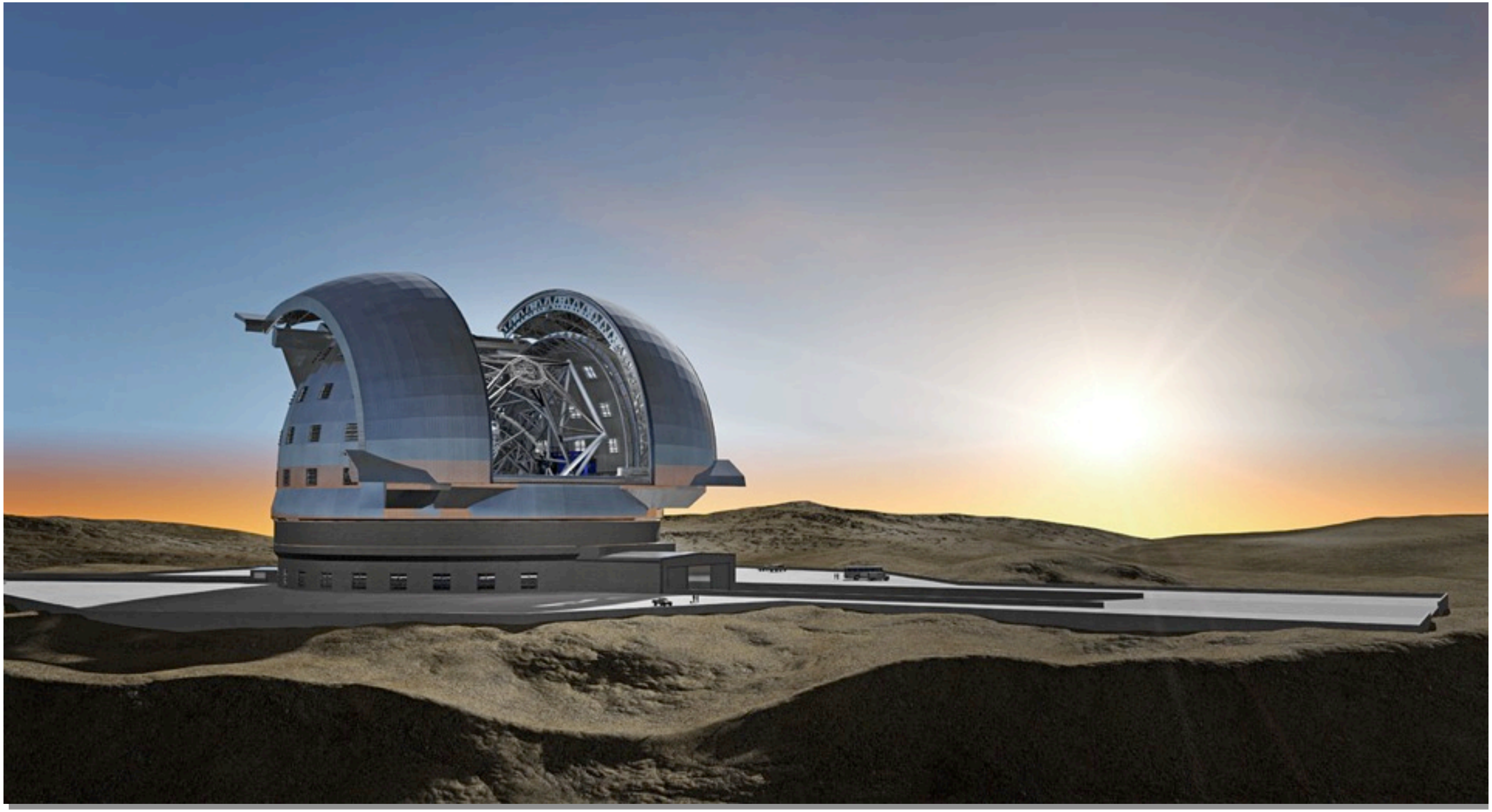
MOSAIC

MOSAIC@ELT: A Gigantic Step into the Deep Universe

presented by François Hammer

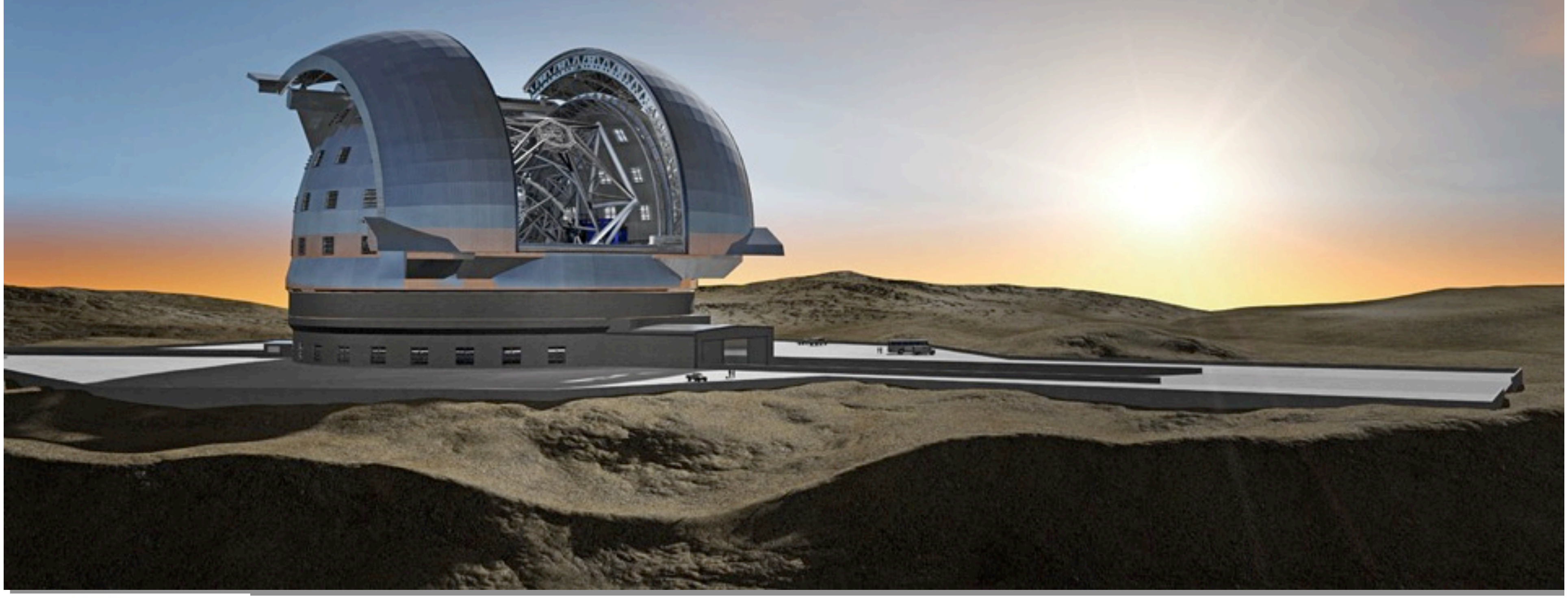
http://www.mosaic-elt.eu

ESO is now building the future largest telescope
First light: 2024



MOSAIC

MOSAIC core team has developed, then implemented:
FORS- GIRAFFE - NACO – VIMOS - X-SHOOTER – MUSE - KMOS

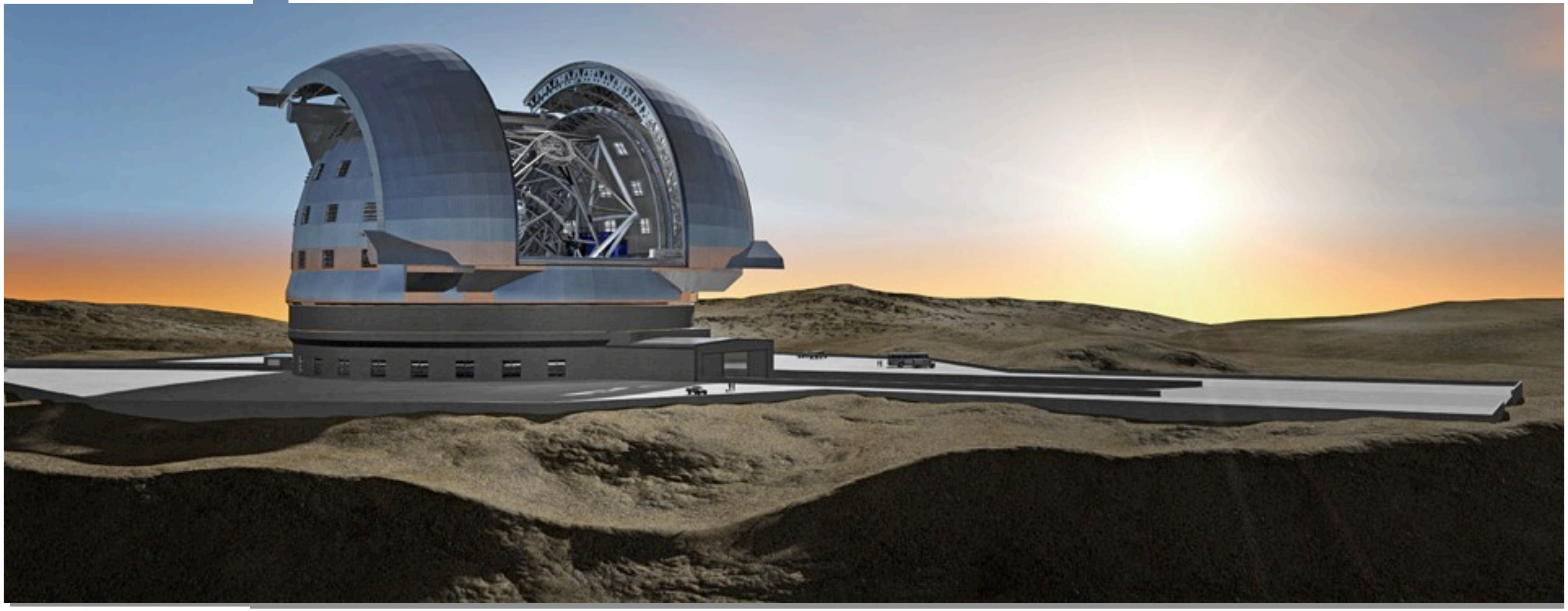


l'Observatoire de Paris | Science & Technology Facilities Council UK Astronomy Technology Centre | LAM Laboratoire d'Astrophysique de Marseille | Universiteit van Amsterdam

AIP | Durham University | NOVA | University of Oxford | irap astrophysique & planétologie

MOSAIC

Also: Heidelberg/Göttingen, Stockholm/Lund, Helsinki/Turku, Madrid/Granada/IAC, Roma/Arcetri, Vienna, Lisboa/Porto



MOSAIC

We have gathered the overall European expertise in conceiving, designing, and building:

- multi-object spectrographs,
- integral field units, and
- adaptive optics driven instruments

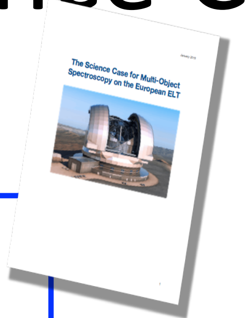
A unique worldwide expertise

Final Trade-offs for the full MOSAIC

Detailed in SPIE 2016 (Hammer et al., Evans et al., Rodrigues et al.)

- IFU pixel size for the 10 IFUs: ≤ 80 mas, a strict limit!
- Multiplex with fibers: ~ 200 in VIS, 100 in NIR if accurate sky correction needed
- Moderate (5000) and high resolution (15000) on both VIS and NIR spectrographs
- No K-band : telescope background dominates
- Visible for λ > 450 nm : poor response of the mirror coating in the blue

From Science Cases to TLRs



The Science Case for Multi-Object Spectroscopy on the European ELT

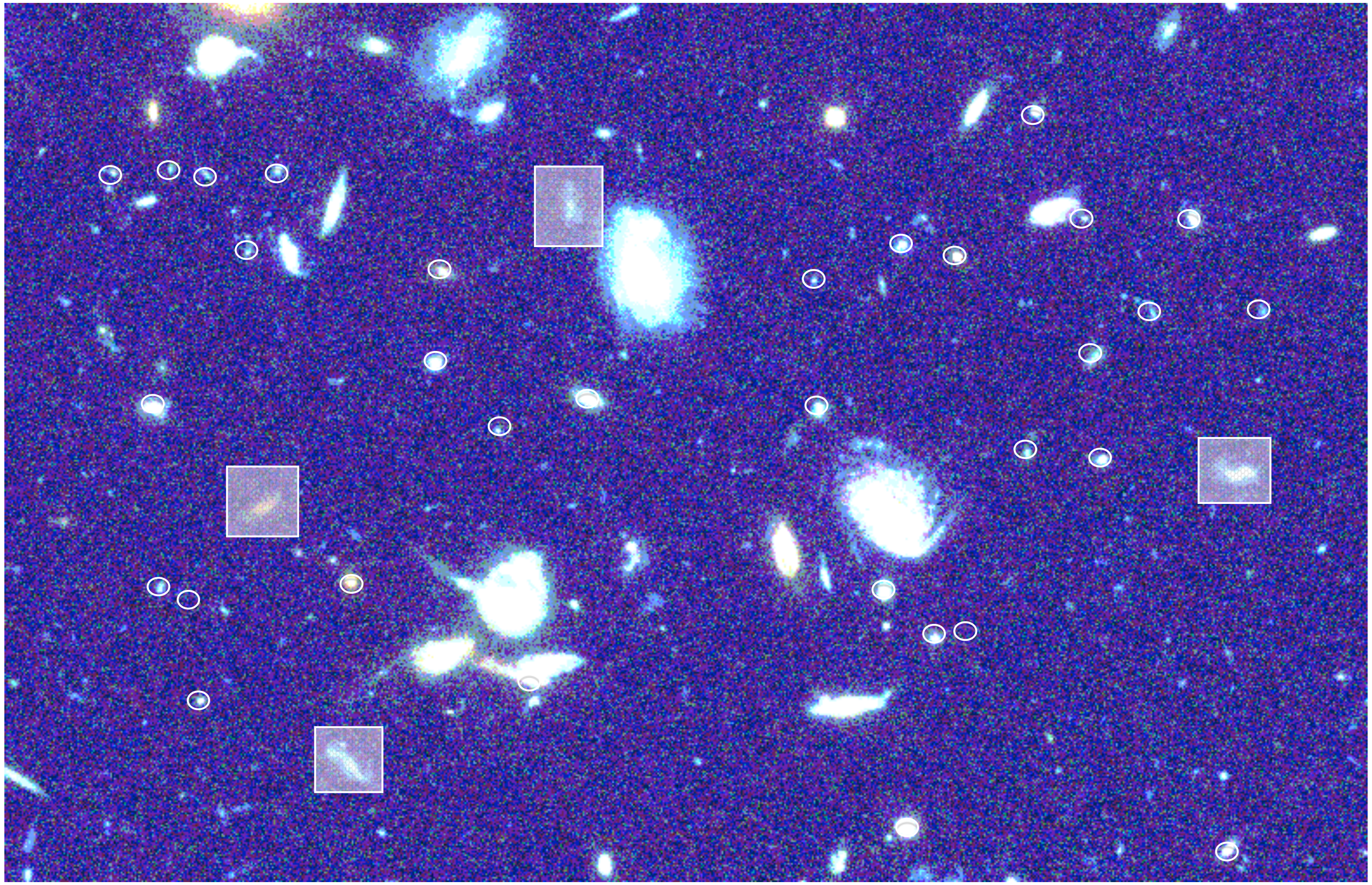
The case for high spectral resolving power in the near IR

Evans, Puech et al. 2015
arXiv150104726E

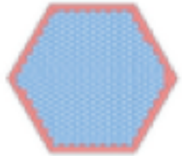
Science Case Description and Breakdown

SC-1b	First galaxies: Physical properties	
Goals	(1) To detect the Lyman break out to z ~ 17 (2) UV absorption lines to z ~ 10	
Parameter	Value	Description
Spatially resolved information	YES	MOAO
Sensitivity	(1) and (2) m=28 with S/N=5 in a few tens of hours	
Target density (arcmin^{-2})	5	10 arcmin^{-2}, but only 50% detected between OH lines
Spectral Resolution	5000	Resolve Lyα profiles w/ FWHM as low as 150 km/s
Bandwidth	1.0-1.8μm	Only a few diagnostic lines will lie beyond 1.8μm
Single obs. bandwidth	0.4μm	
Sub-field	0.6"	Diameter of early galaxies; <90mas sampling (40 optimal)
Sky subtraction	<1% of sky background	
Flux calibration & spectro-photometry	TBD	
Other calibration	TBD	
Comments		

IFUs & high multiplex modes

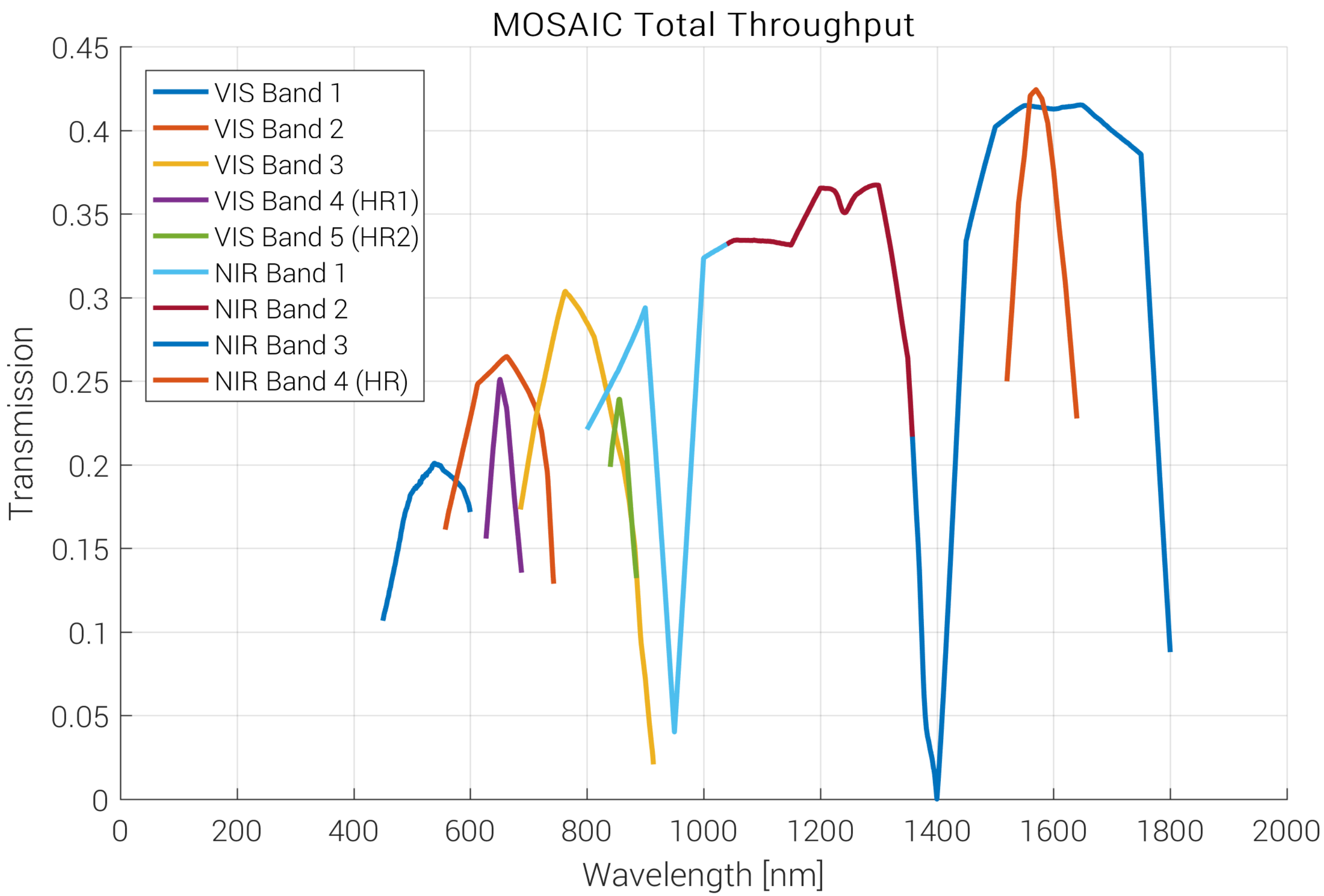


100-200 point like objects with natural seeing or GLAO
(can be used to prepare/feed low multiplex observations)
10 IFUs with MOAO in NIR, GLAO in VIS

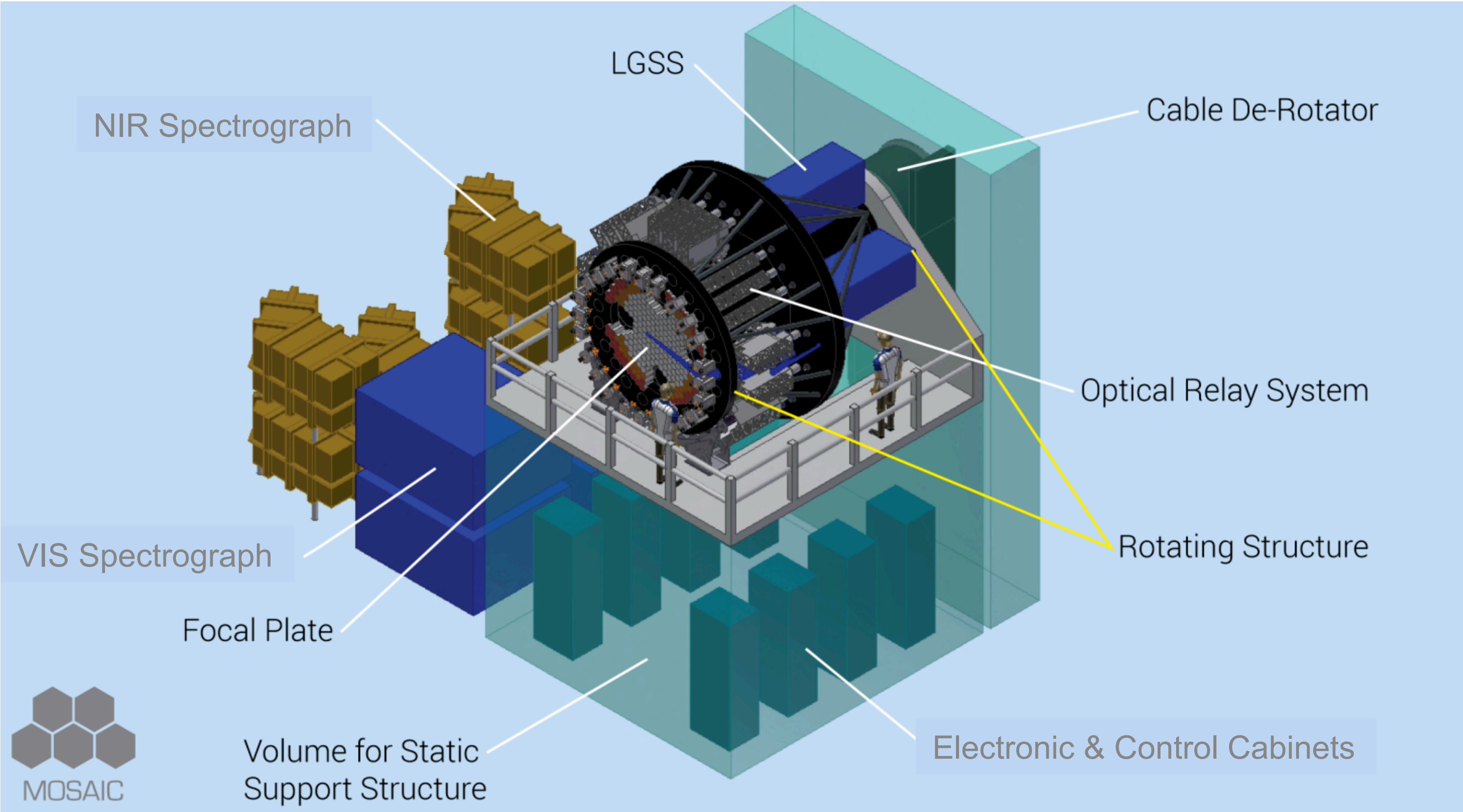
	Visible	Near IR
		
Number of apertures	10	10
Patrol area	44.2 arcmin^2	44.2 arcmin^2
Operating bandwidth	0.45 - 0.9 μm	0.8 - 1.8 μm
Outer diameter of on-sky subfield	2.31 arcsec (hexagonal)	1.9 arcsec (hexagonal)
Sampling	138 mas	80 mas
Spectral resolution	5000 & 15000	5000 & 20,000
AO performance	GLAO (~seeing limited)	MOAO: 25% EE in 150 mas

	Visible	Near IR
	 *	
Number of apertures	200	100 (+100 on sky)
Patrol area	52.1 arcmin^2	47.3 arcmin^2
Operating bandwidth	0.45 - 0.9 μm	0.8 - 1.8 μm
Diameter of the aperture on sky	840 mas	500 mas
Spectral resolution	5000 & 15,000	5000 & 20,000
AO performance	GLAO (~seeing limited)	GLAO

Phase A study finalized, documentation in writing



Phase A study finalized, documentation in writing



MOS: exploits the mirror surface then a moderately good image quality

MOSAIC

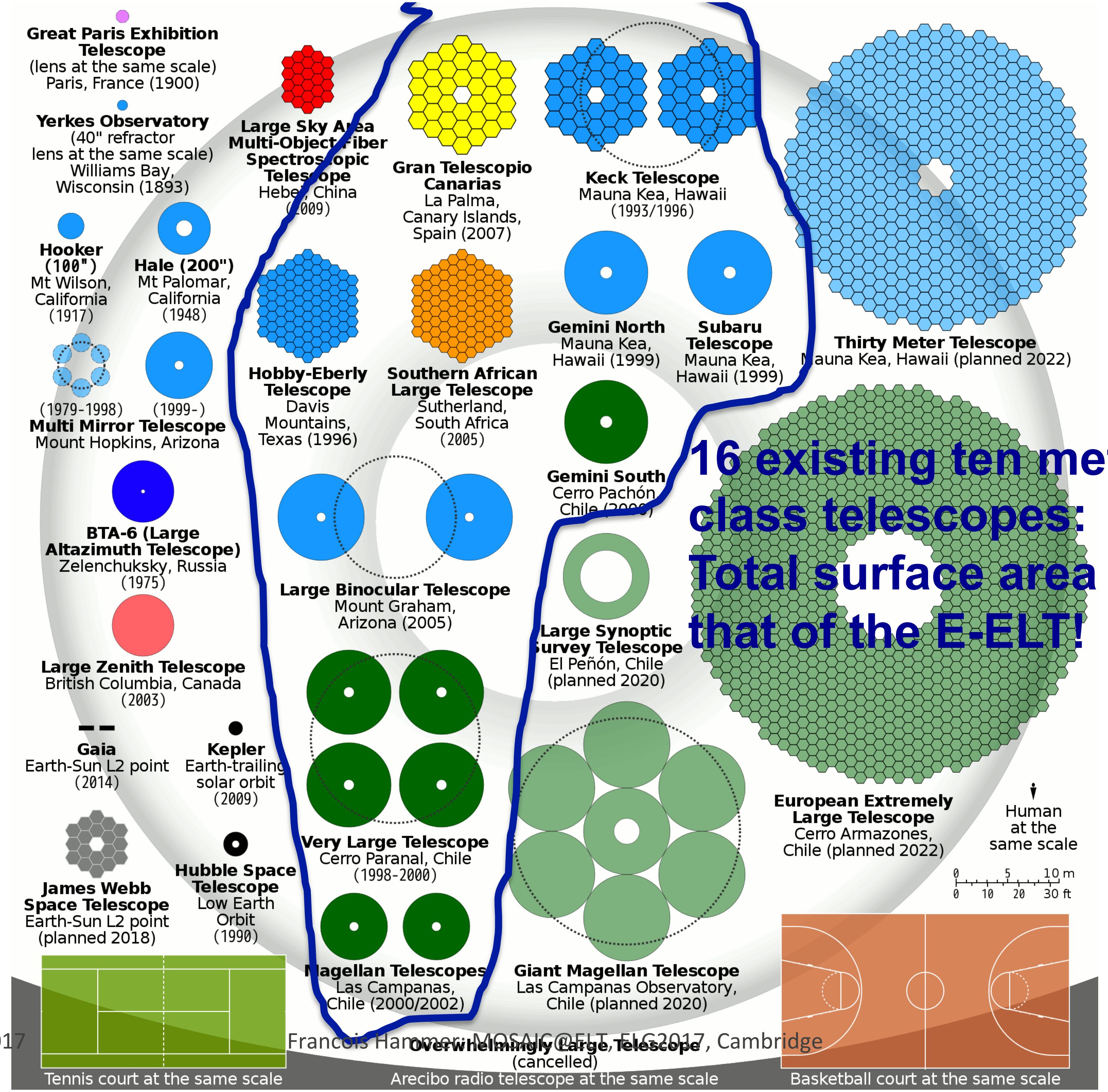
cnrs dépasser les frontières

≥130 scientists from all Europe
- -SC1: first galaxies, reionisation
- -SC2: Large scale structures
- -SC3: Galaxies mass assembly
- -SC4: AGN/Galaxy coevolution
- -SC5: Resolved stars beyond the LG
- -SC6: Galaxy archaeology
- -SC7: Galactic centre
- -SC8: Planet formation in clusters

ALL SCs tested or to be tested through an 'end-to'end' simulator at : **http://websim-compass.obspm.fr** **(see Puech et al, 2016, SPIE)**

Deployable fov: Φ=5-7 arcmin

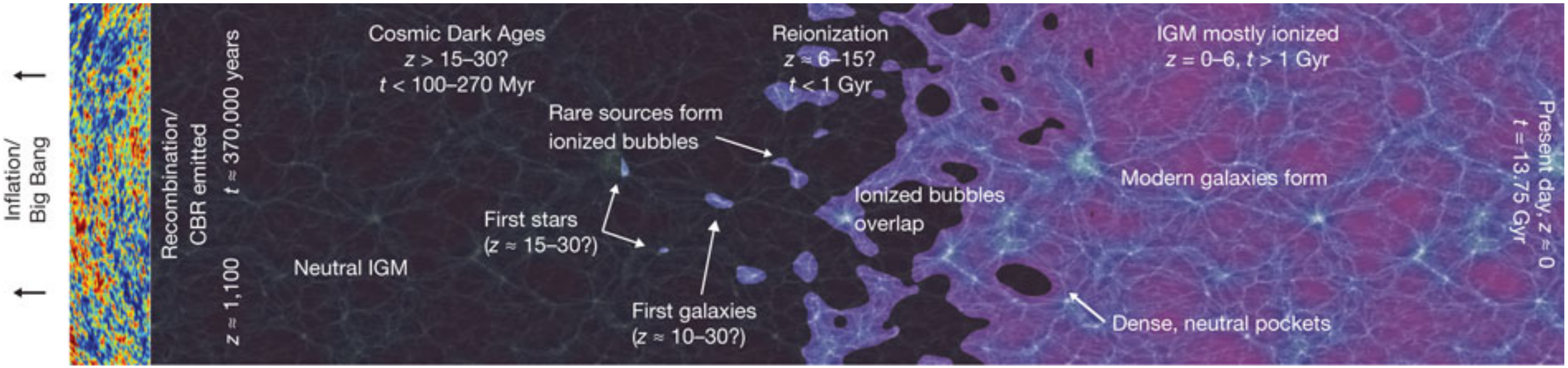
Parameter	Working assumption
High Definition Mode (HDM)	
IFU field of view	2.0 x 2.0 arcsec
Multiplex	10 IFUs
Spatial pixel size	75 mas
Ensquared Energy	≥ 25% EE
Spectral Res. Power ®	5 000
λ coverage (not simult.)	0.8 - 1.8 µm
High Multiplex Mode (HMM)	
On Sky Aperture	0.9 arcsec
Multiplex	200
Spectral Res. Power ®	5 000 & 15 000
λ coverage	0.4 - 1.8 µm
InterGalactic Medium (IGM)	
IFU field of view	2.0 x 2.0 arcsec
Multiplex	10 IFUs
Spatial pixel size	0.3 arcsec
Spectral Res. Power ®	5000
λ coverage (not simult.)	0.4 - 1.0 µm



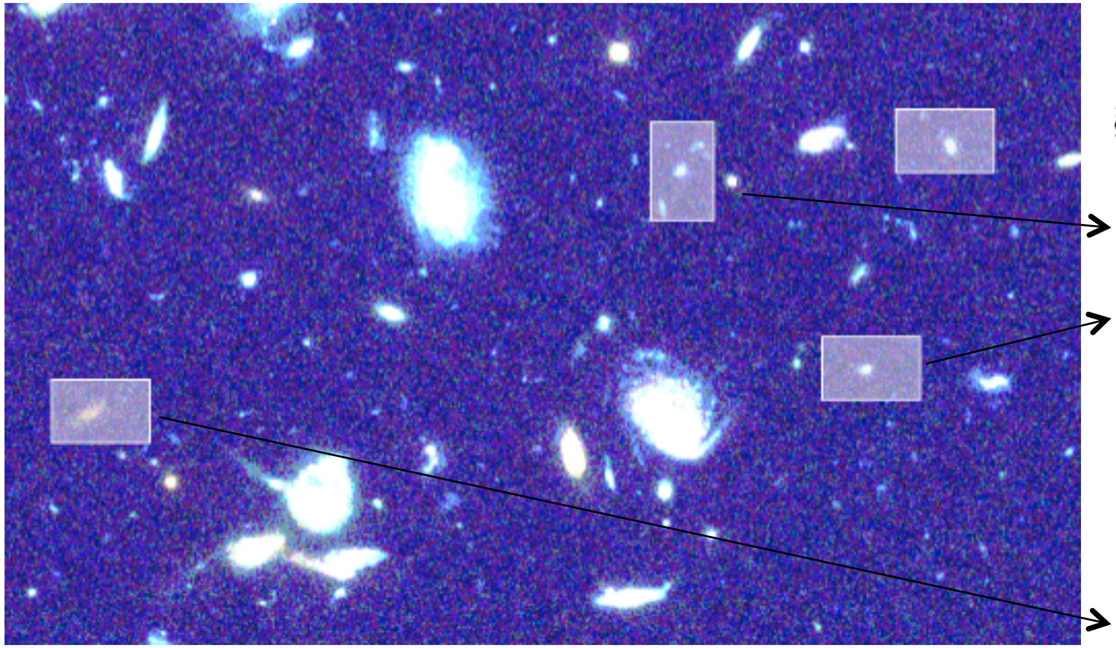
16 existing ten meter class telescopes: Total surface area = that of the E-ELT!

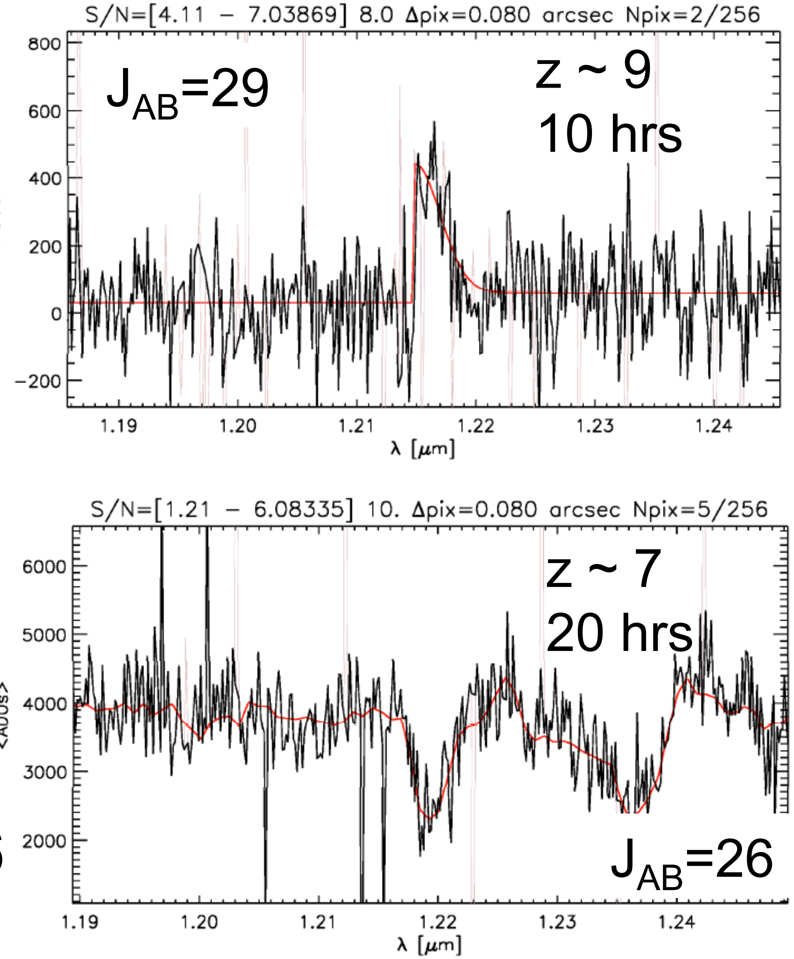
The reionisation of the Universe: first objects

E-ELT & JWST VLT & HST



Most distant galaxies: MOSAIC, follow-up of JWST imagery: Higher spectral resolution, search for popIII?

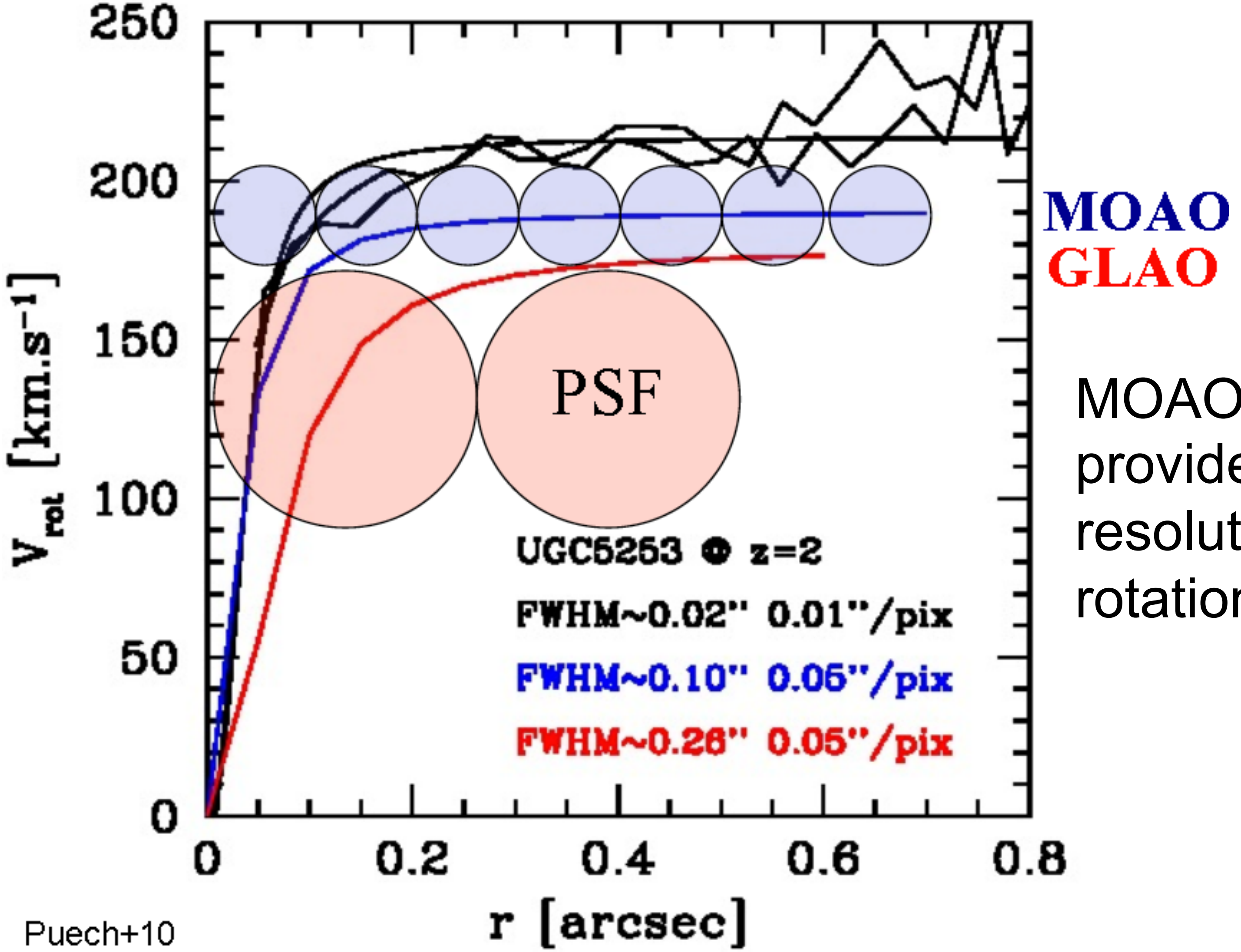




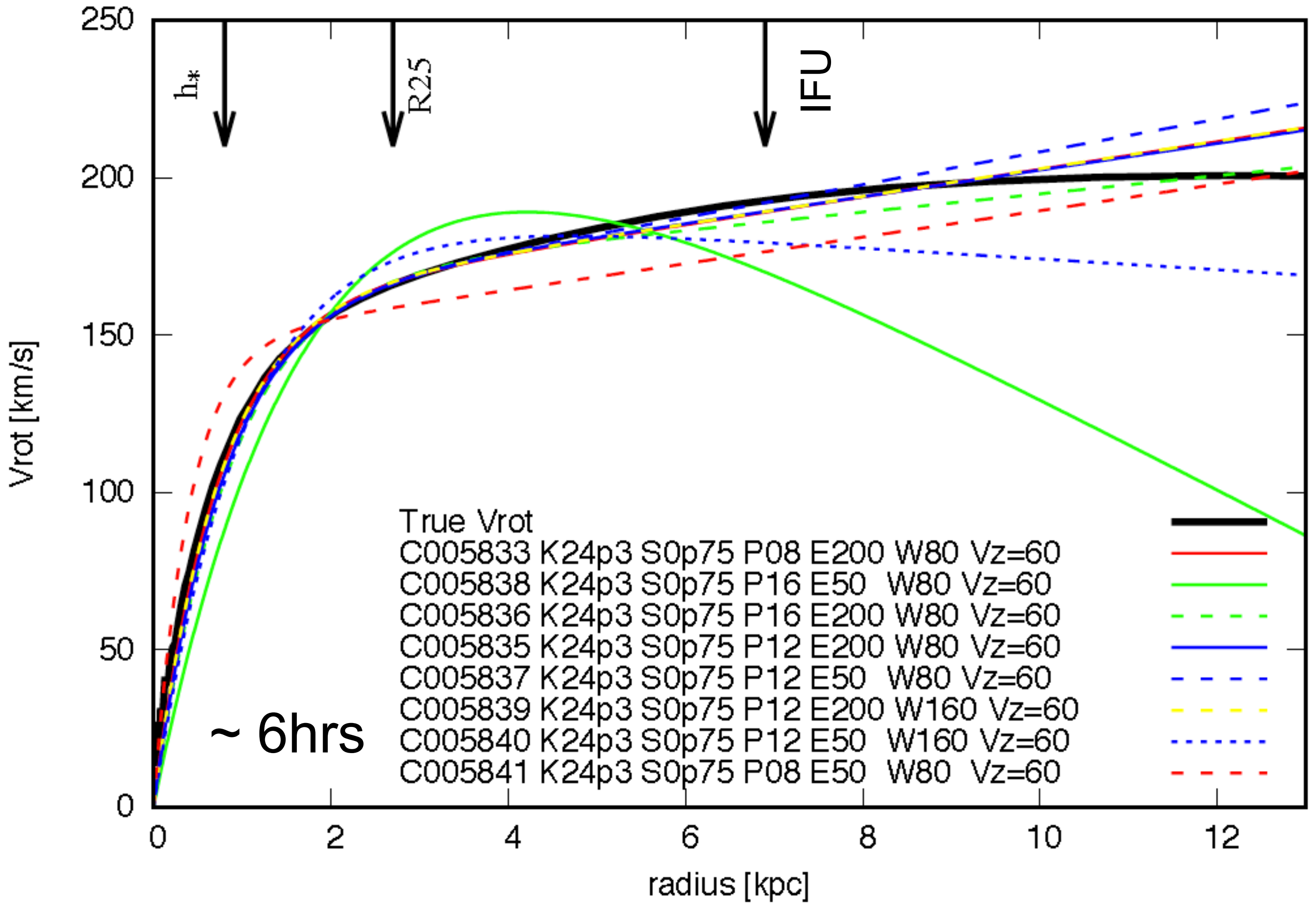
Simulations: Disseau et al. SPIE, 2016

IFUs: unbeatable for the best sky subtraction

High definition mode: dark matter evolution from well-sampled rotation curves up to z=4



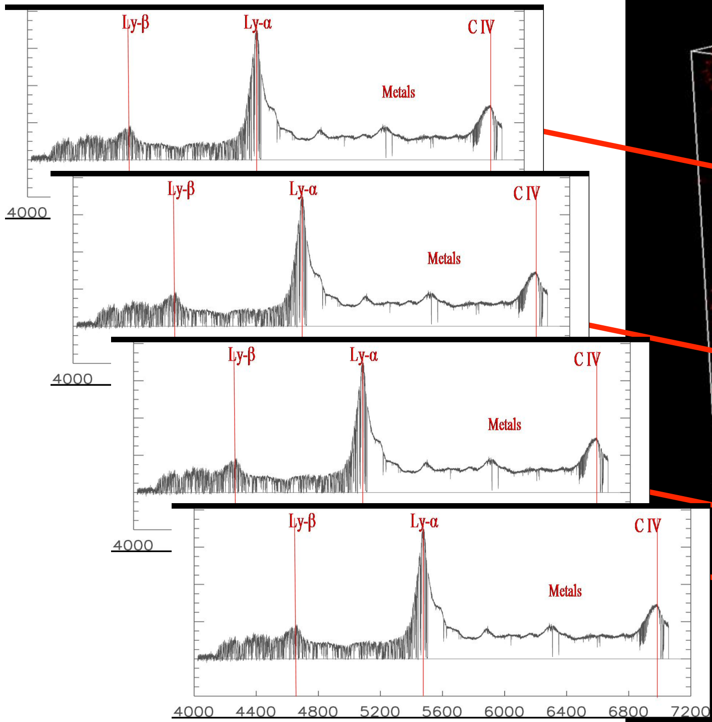
MOAO is required to provide at least 5 to 7 resolution elements per rotation curve side

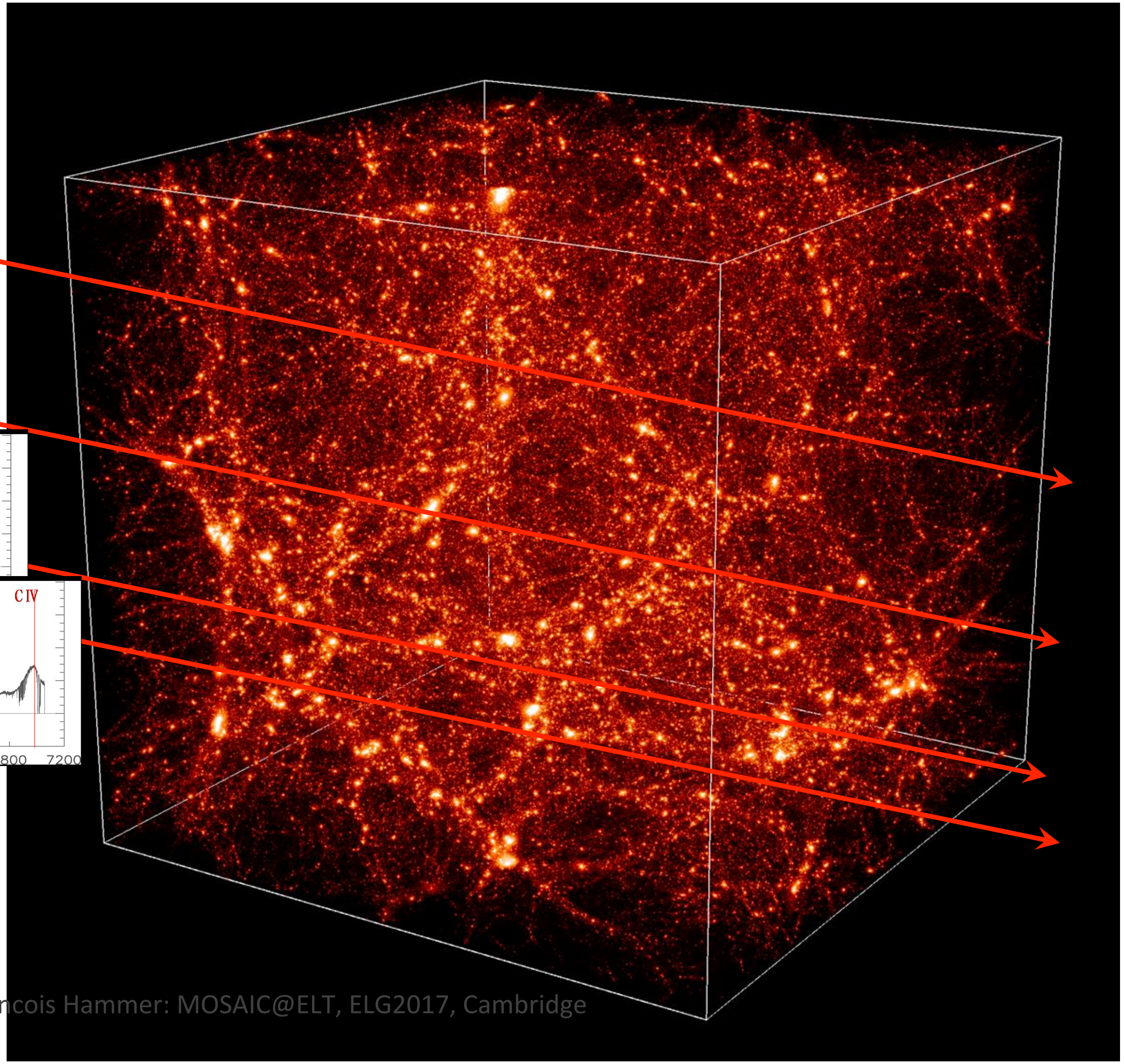


Simulations of a z=3.6 L* galaxy with EW=50, 200A,
pixel scale =80 to 160 microns
Study still preliminar, from Jianling Wang (with Mathieu Puech)

Direct 3D reconstruction of the IGM
(excerpt from P. Petitjean)

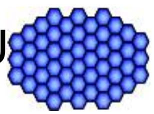
No QSOs but Lyman break galaxies observed with R≥ 5000



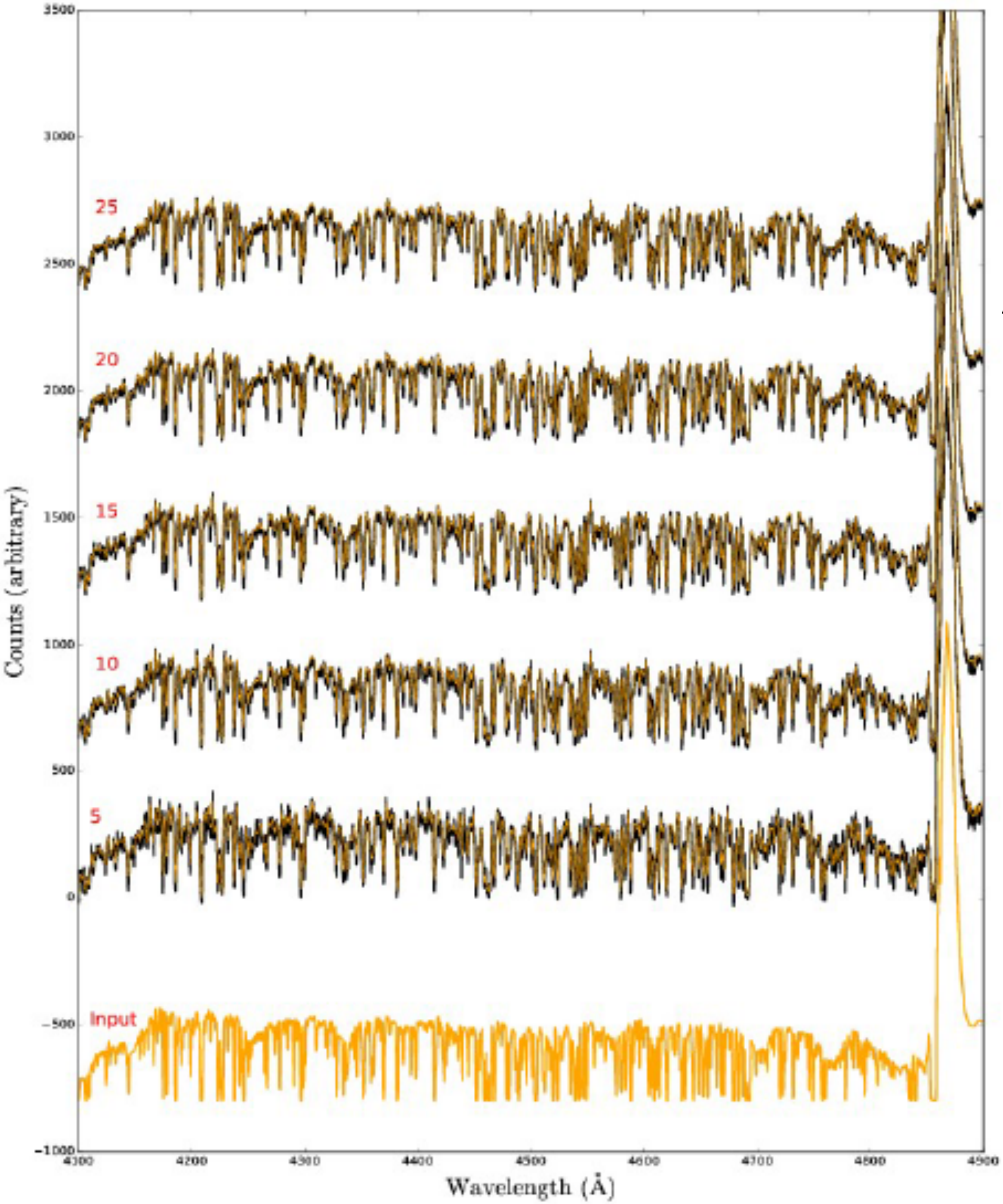


1.8''x2.9''

≥10 x IFU



R=6000



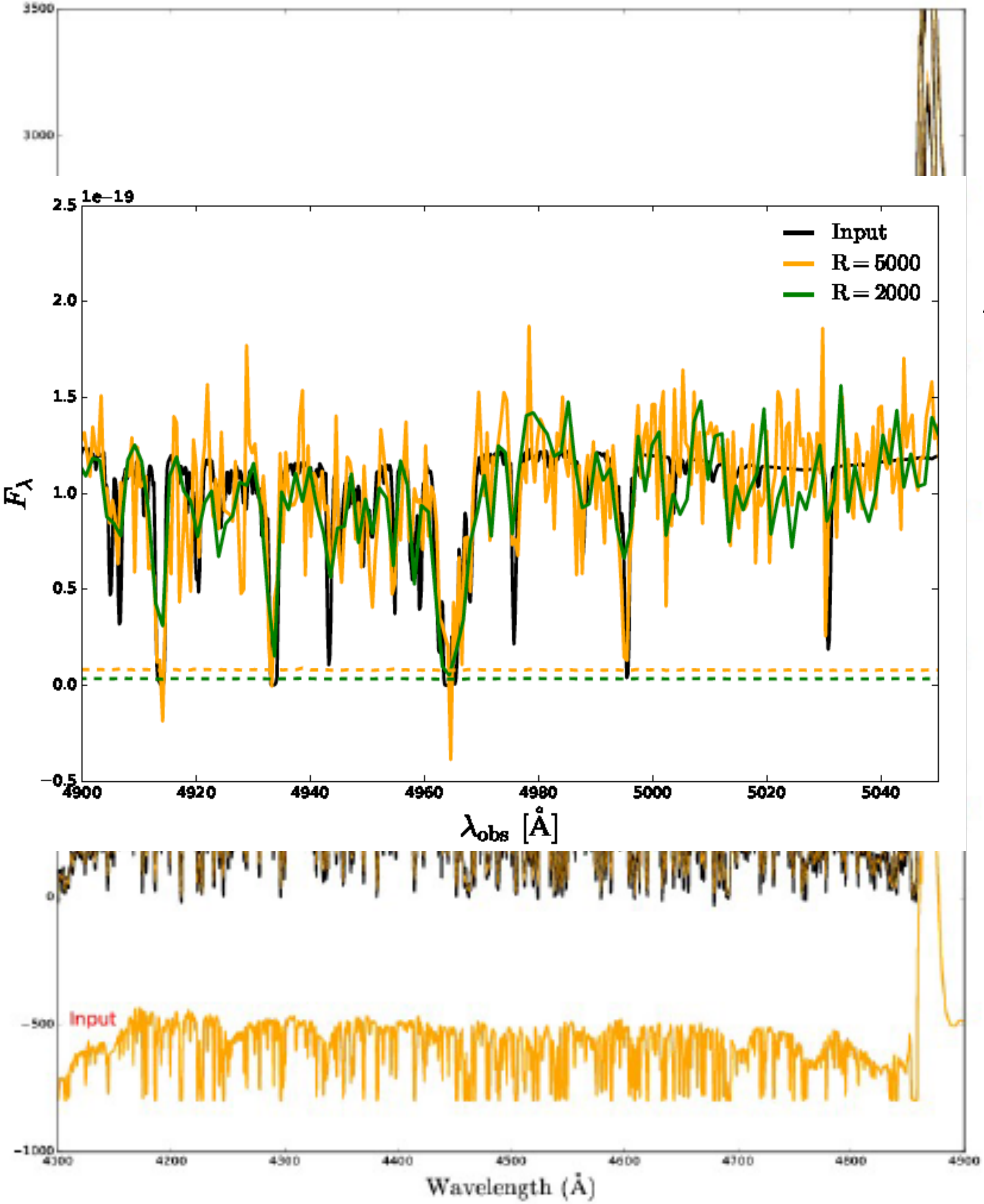
Lyman forest:
targets at z=3.5,
AB=24.5-25.5 (2-10 hrs)

AND

Metallic lines (missing baryons):
targets at z= 3.5,
AB=24.5-25.5

Simulations from Jure Japelj

ambridge



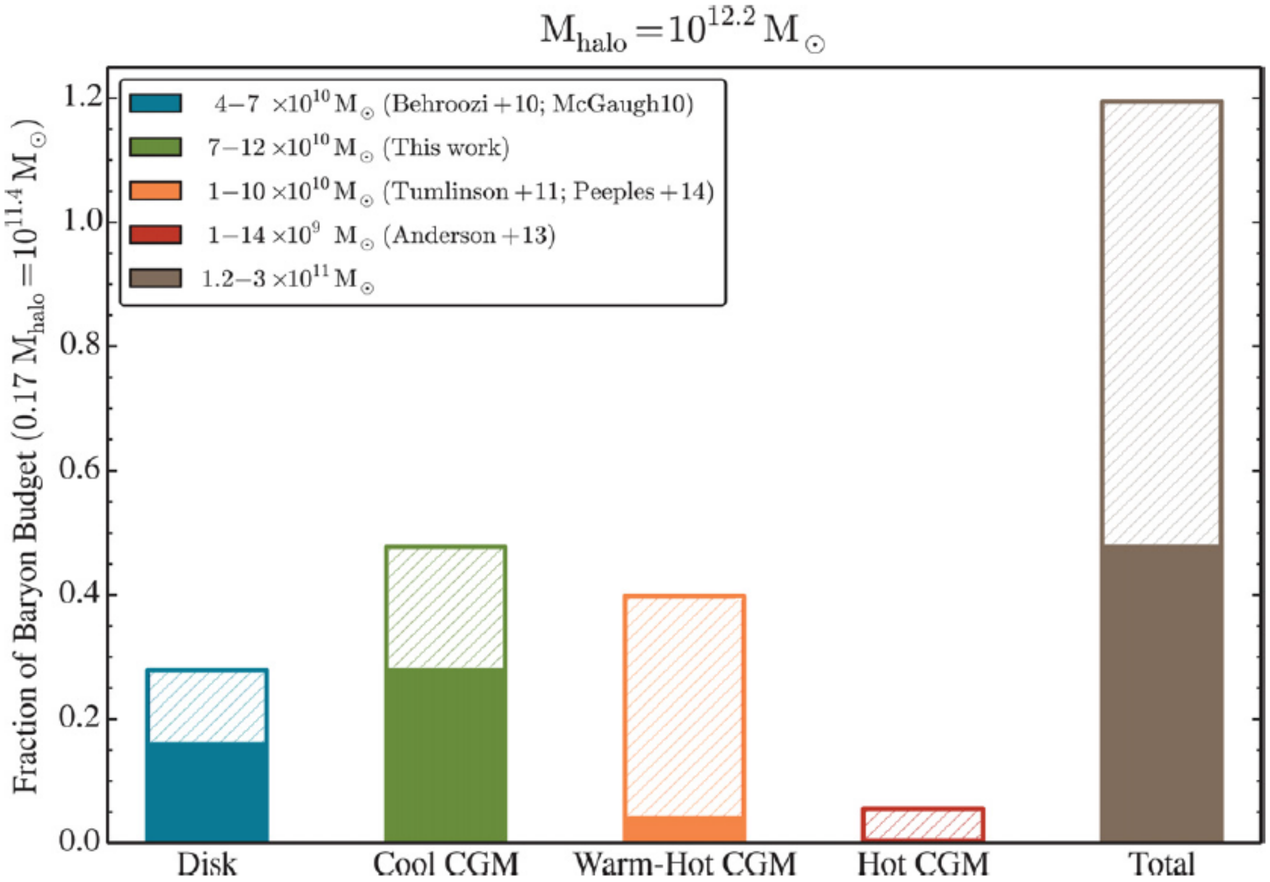
Lyman forest:
targets at z=3.5,
AB=24.5-25.5 (2-10 hrs)

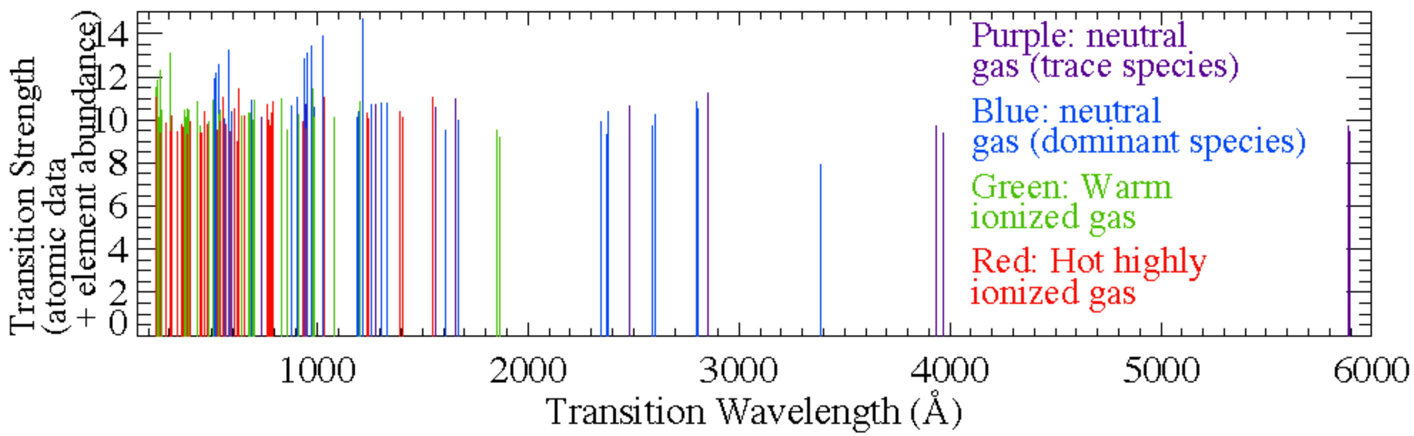
AND

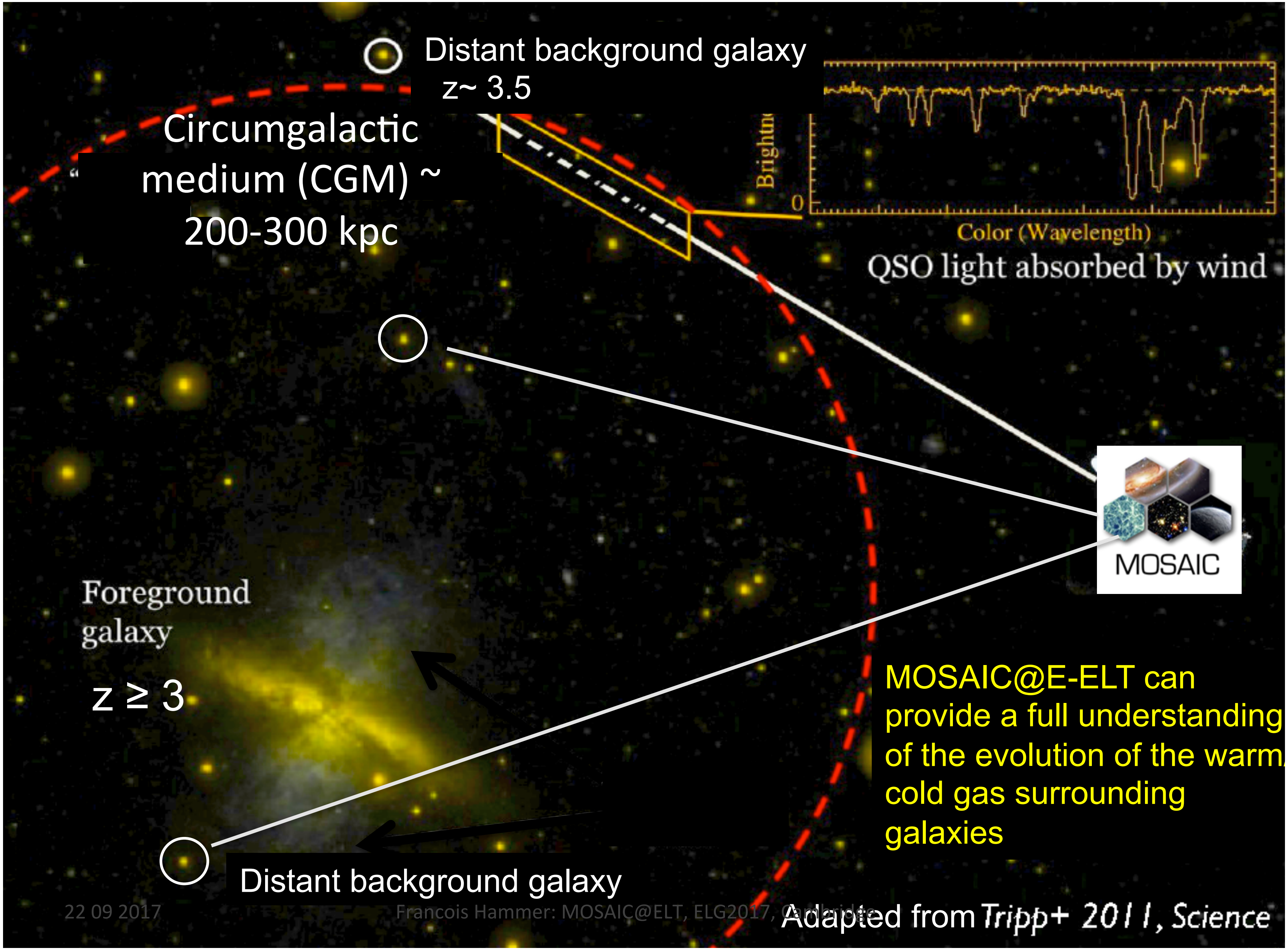
Metallic lines (missing baryons):
targets at z= 3.5,
AB=24.5-25.5

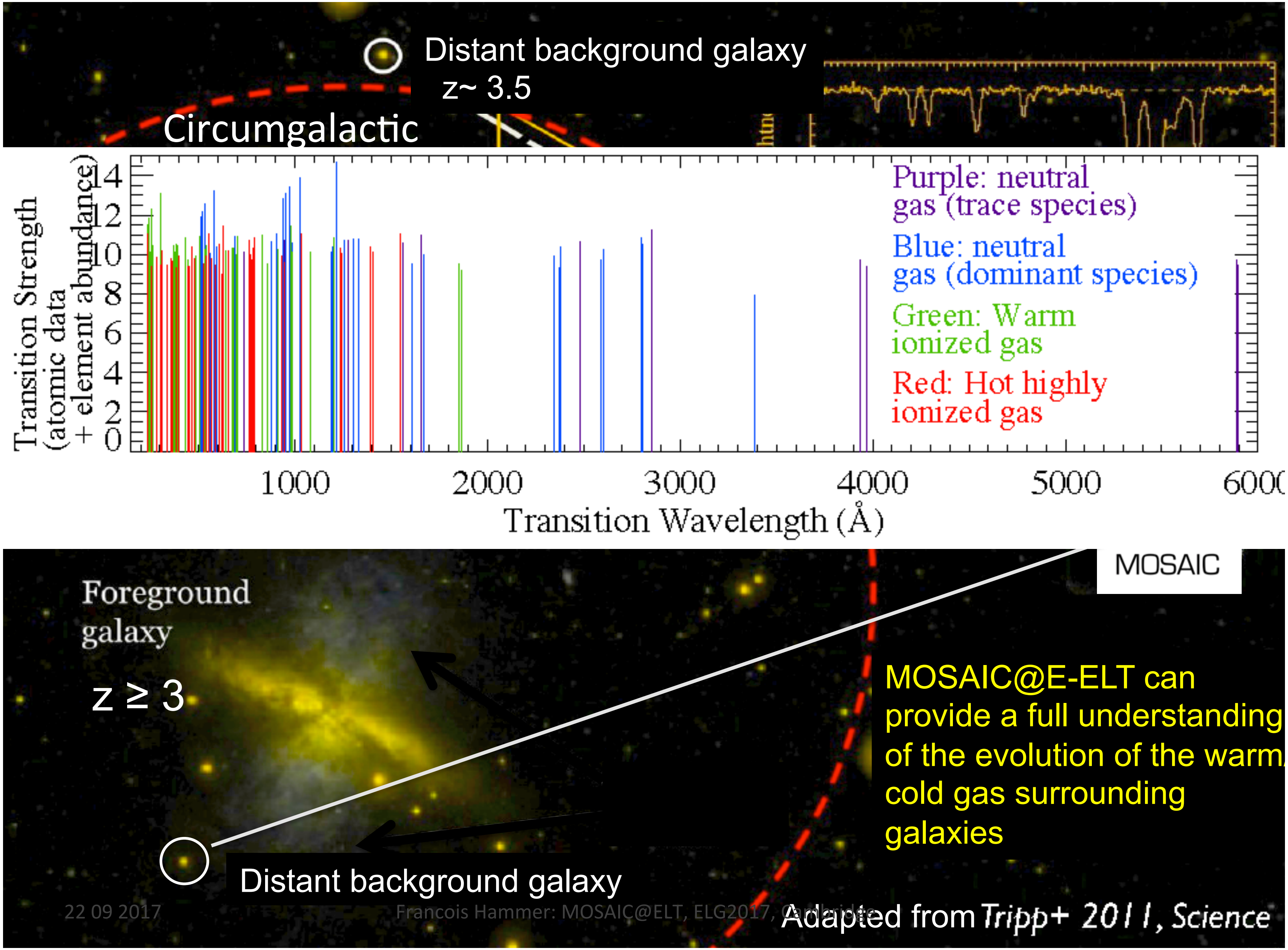
Simulations from
Jure Japelj

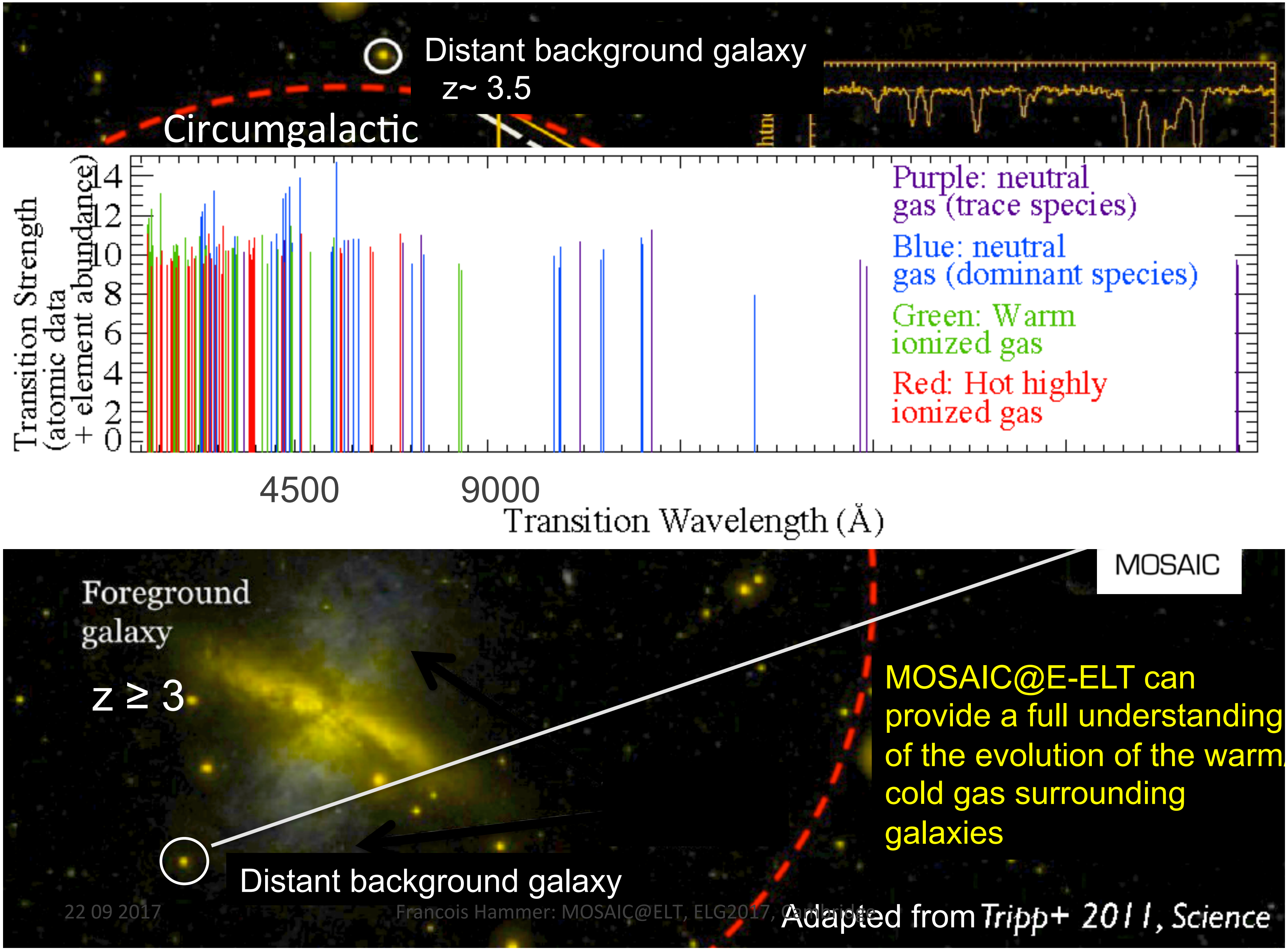
z ~ 0.1 Werk et al. 2014






Distant background galaxy
z~ 3.5
Circumgalactic medium (CGM) ~ 200-300 kpc
Brightn
0
Color (Wavelength)
QSO light absorbed by wind
MOSAIC
Foreground galaxy
z ≥ 3
MOSAIC@E-ELT can provide a full understanding of the evolution of the warm/ cold gas surrounding galaxies
Distant background galaxy
Adapted from Tripp+ 2011, Science


Distant background galaxy
z~ 3.5
Circumgalactic
Transition Strength
(atomic data
+ element abundance)
0
2
4
6
8
10
12
14
1000
2000
3000
4000
5000
6000
Transition Wavelength (Å)
Purple: neutral
gas (trace species)
Blue: neutral
gas (dominant species)
Green: Warm
ionized gas
Red: Hot highly
ionized gas
MOSAIC
Foreground
galaxy
z ≥ 3
MOSAIC@E-ELT can
provide a full understanding
of the evolution of the warm/
cold gas surrounding
galaxies
Distant background galaxy
Adapted from Tripp+ 2011, Science

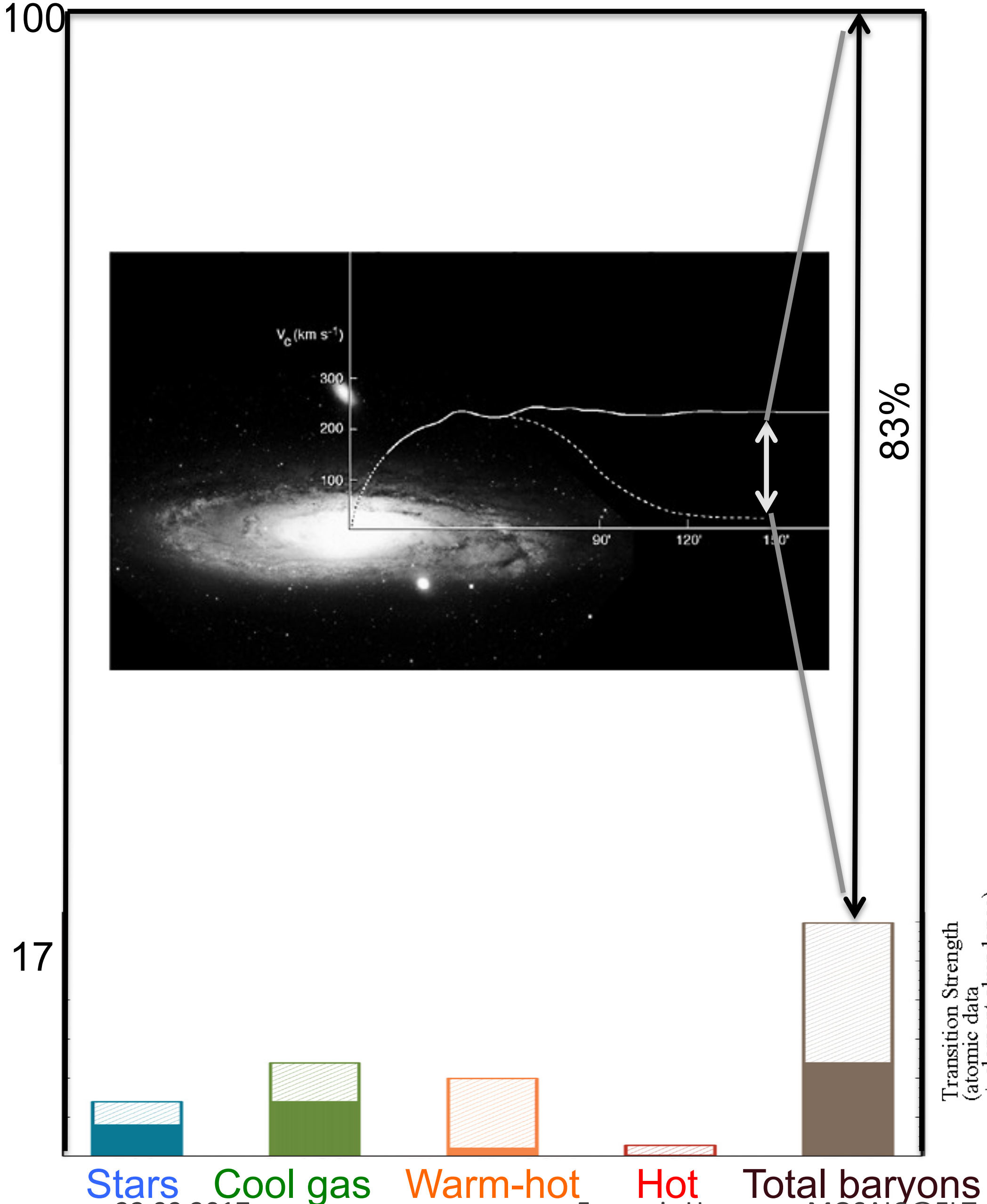


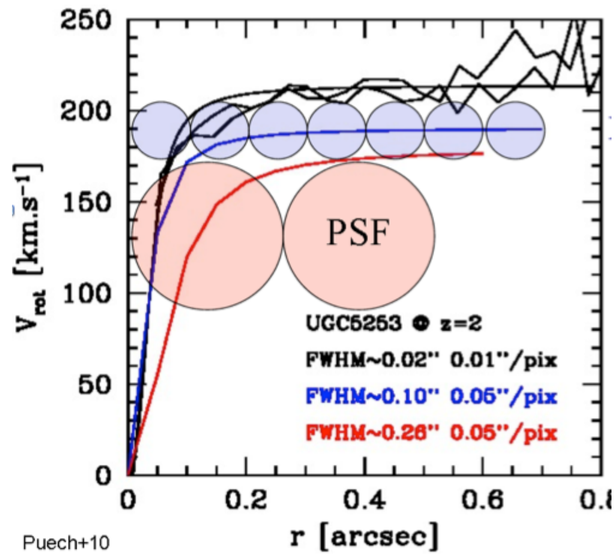
Distant background galaxy
z~ 3.5
Circumgalactic
Transition Strength
(atomic data
+ element abundance)
0
2
4
6
8
10
12
14
4500
9000
Transition Wavelength (Å)
Purple: neutral gas (trace species)
Blue: neutral gas (dominant species)
Green: Warm ionized gas
Red: Hot highly ionized gas
MOSAIC
Foreground galaxy
z ≥ 3
MOSAIC@E-ELT can provide a full understanding of the evolution of the warm/cold gas surrounding galaxies
Distant background galaxy
Adapted from Tripp+ 2011, Science

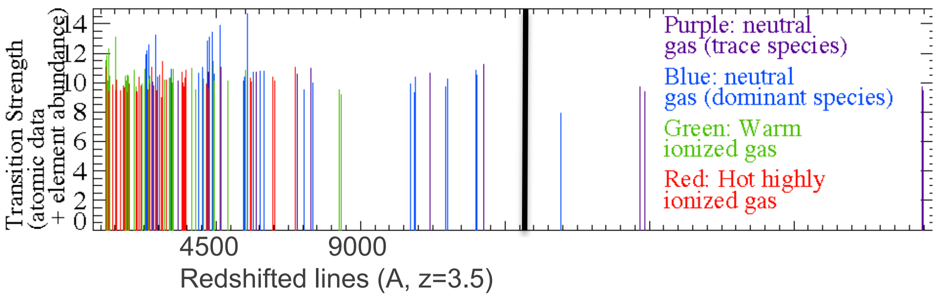
% Fraction of matter in the local Universe

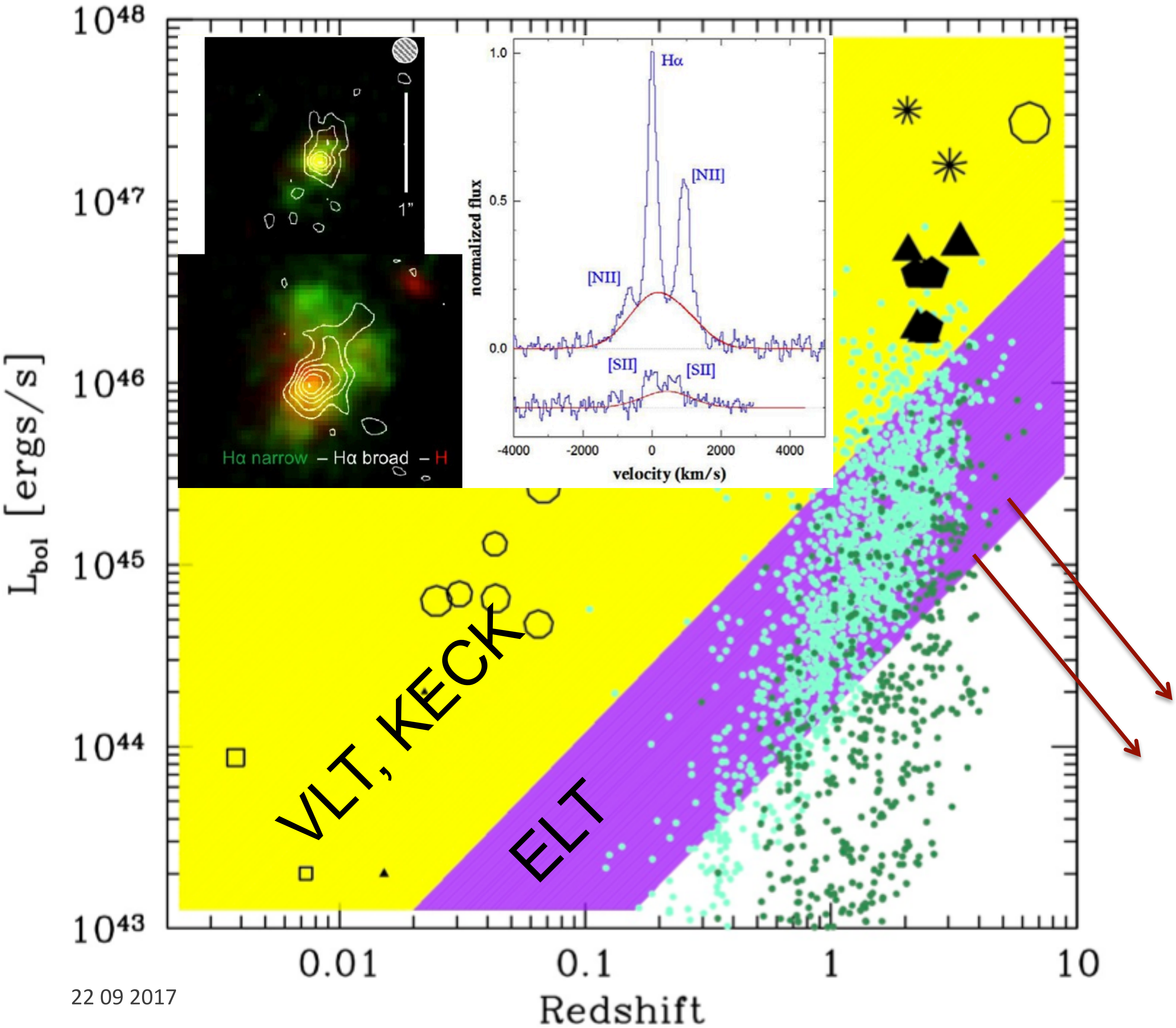
in the distant Universe (%) z=3-3.5

MOSAIC



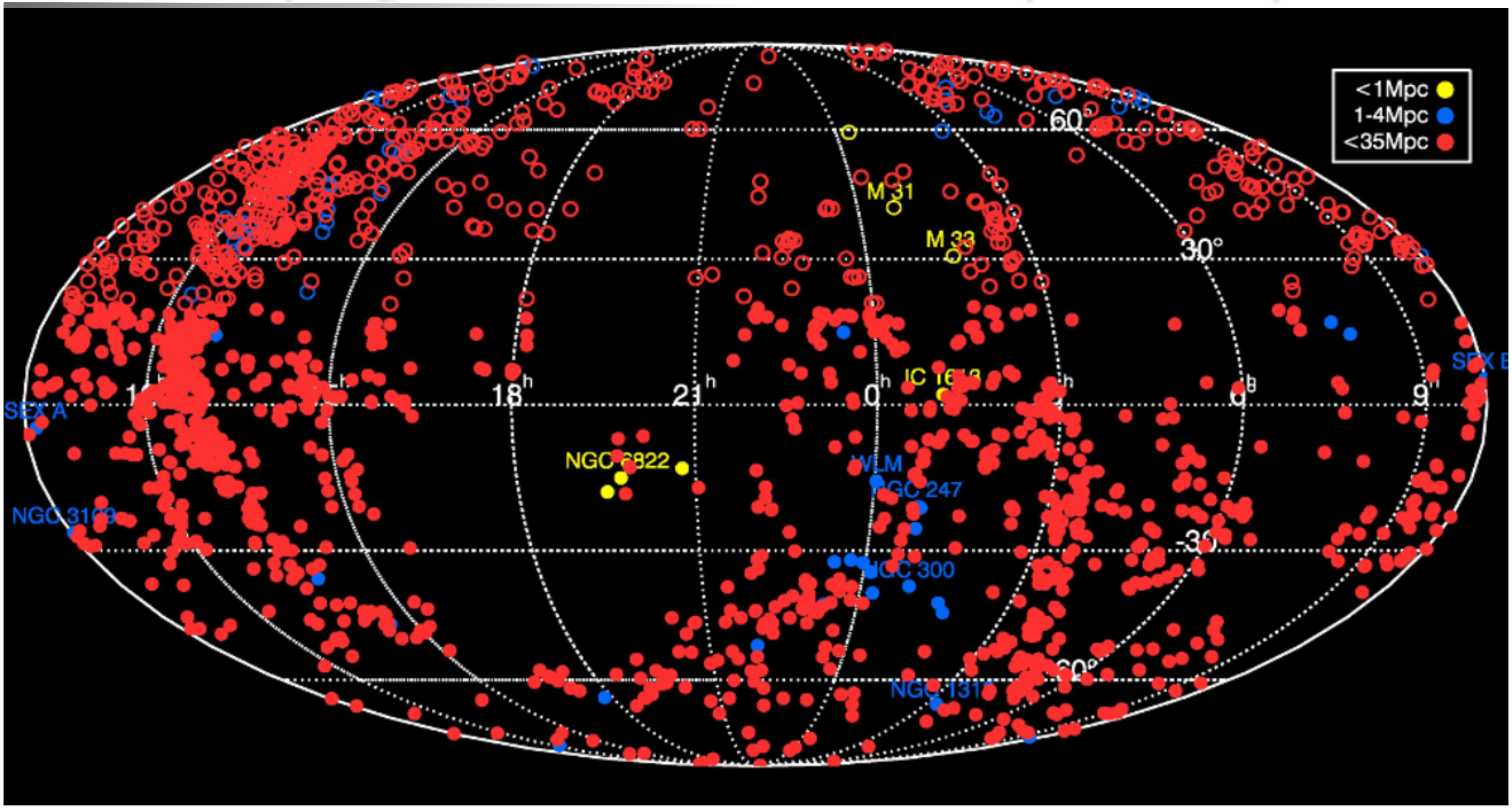






At z > 6: witnessing the elaboration of the first super massive black holes

Red supergiants can be observed up to 35 Mpc



MOAO for accurate metal abundances (CaT) in such a large volume that all galaxy types can be investigated!

Numerous science cases with MOSAIC Here a list of "only the MOS can do it @ELT"

- The first distant galaxies: the only E-ELT instrument to follow-up JWST
- Dark matter inventory & galaxy formation: sufficient number of galaxies
- Hierarchical model (formation of dwarfs): with R≥ 10000 (>> JWST)
- Baryon inventory (ISM & IGM): B band, reasonable scale (multi FoVs)
- AGN feedback & formation: formation of the super massive black holes
- Galaxy archaeology incl. halo & LG galaxies: sufficient number of stars
- Bulge, disk of the MW: follow up large surveys
- And much more

No competitors: an inventory of baryonic (star & gas phases) & dark matter at high z

- The first distant galaxies: the only E-ELT instrument to follow-up JWST
- **Dark matter inventory & galaxy formation: sufficient number of galaxies**
- Hierarchical model (formation of dwarfs): with R≥ 10000 (>> JWST)
- **Baryon inventory (ISM & IGM): B band, reasonable scale (multi FoVs)**
- AGN feedback & formation: formation of the super massive black holes
- Galaxy archaeology incl. halo & LG galaxies: sufficient number of stars
- Bulge, disk of the MW: follow up large surveys
- And much more

MOSAIC

Conclusion

- The ELT is in building process: 2024
- Multi-IFUs in NIR (MOAO, rotation curves) and in VIS (redshifted ionised absorptions) are unique for an inventory of all phases (DM, multi-phase gas) of the matter
- they are very competitive for sky-subtraction, light concentration & no aperture losses;
- the most efficient E-ELT instrument to follow JWST and to uncover reionisation responsible;
- MOS exploits at first the gain in telescope size and can be implemented without difficulties at the telescope, not being too demanding for AO interfaces;
- Phase B: 2018, still 2-3 years from now for welcoming new partners

Spectroscopic Surveys with the ELT: A Gigantic Step into the Deep Universe

17 – 20 October 2017

In Toledo, Spain