MOSAIC: the E-ELT MOS

Mathieu Puech (co-PS)

On behalf of the MOSAIC consortium

& the MOSAIC ScTeam

MOSAIC

Multi-Object Spectrograph for Astrophysics, Intergalactic medium and Cosmology

Field of view: 7 x 7 arcmin at the 40m E-ELT

High Multiplex Mode

On-sky aperture : 0.6 arc sec
Multiplex : 200 (400)
R : 5000 & 15000 (5000 & 20000)
Coverage : 0.4 - 1.8 microns
(Extension to K-band)

+

High Definition Mode

- **FOV IFU**: 2.0x2.0arcsec
- **Multiplex** : 10 IFUs
- Spatial pixel scale: 80 mas
- **EE**: 25% (30) EE in 2spatial spatial pixels (H band)
- **R**:4000-5000
- **Coverage**: 0.8 - 1.8 microns

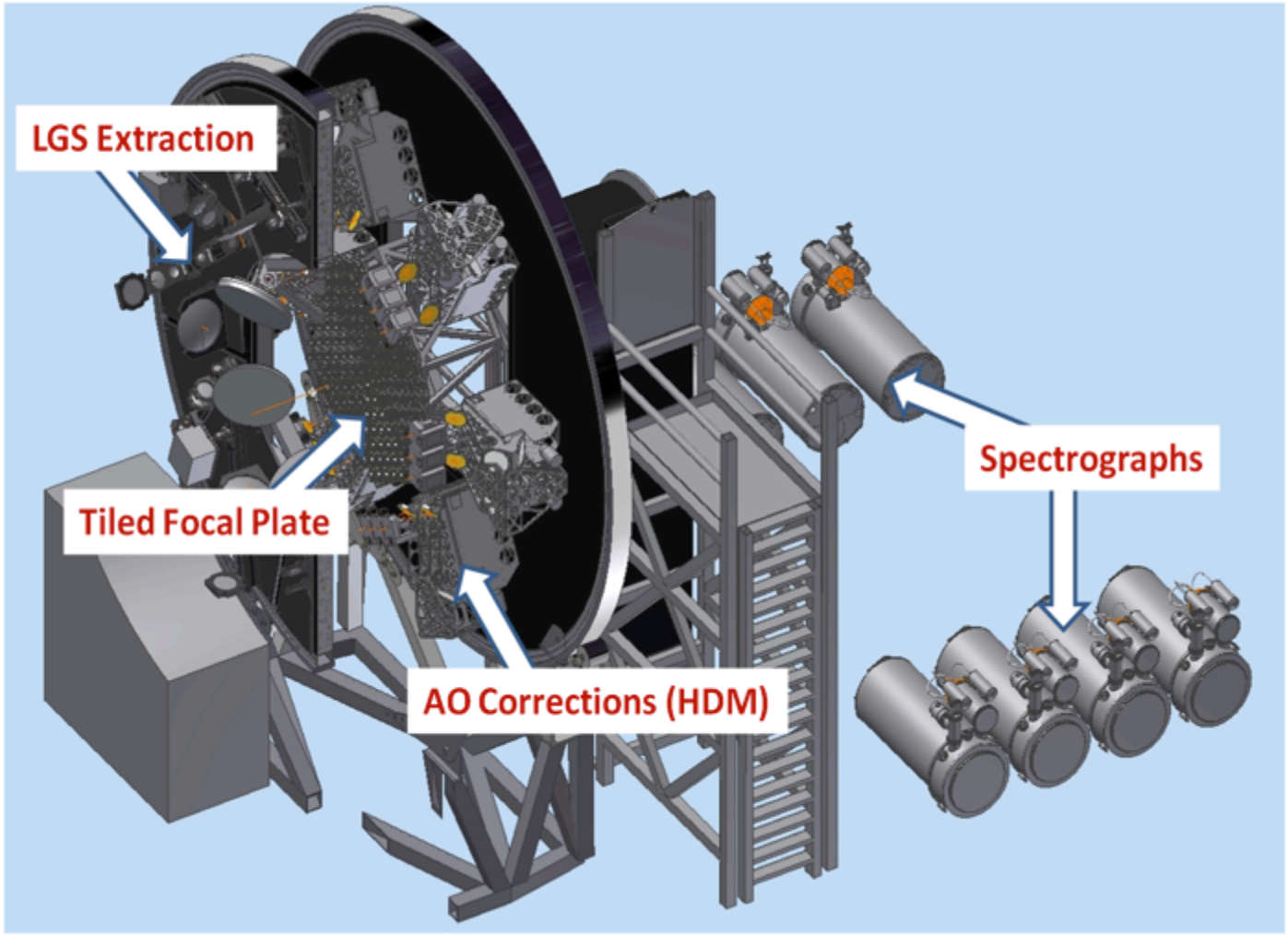
ArXiv:1501.04726

White Paper v2

A workhouse MOS for the E-ELT

MOSAIC

Pre-Phase A Design
Now integrating trade-offs: K band, blue cut, Vis-NIR split, etc.



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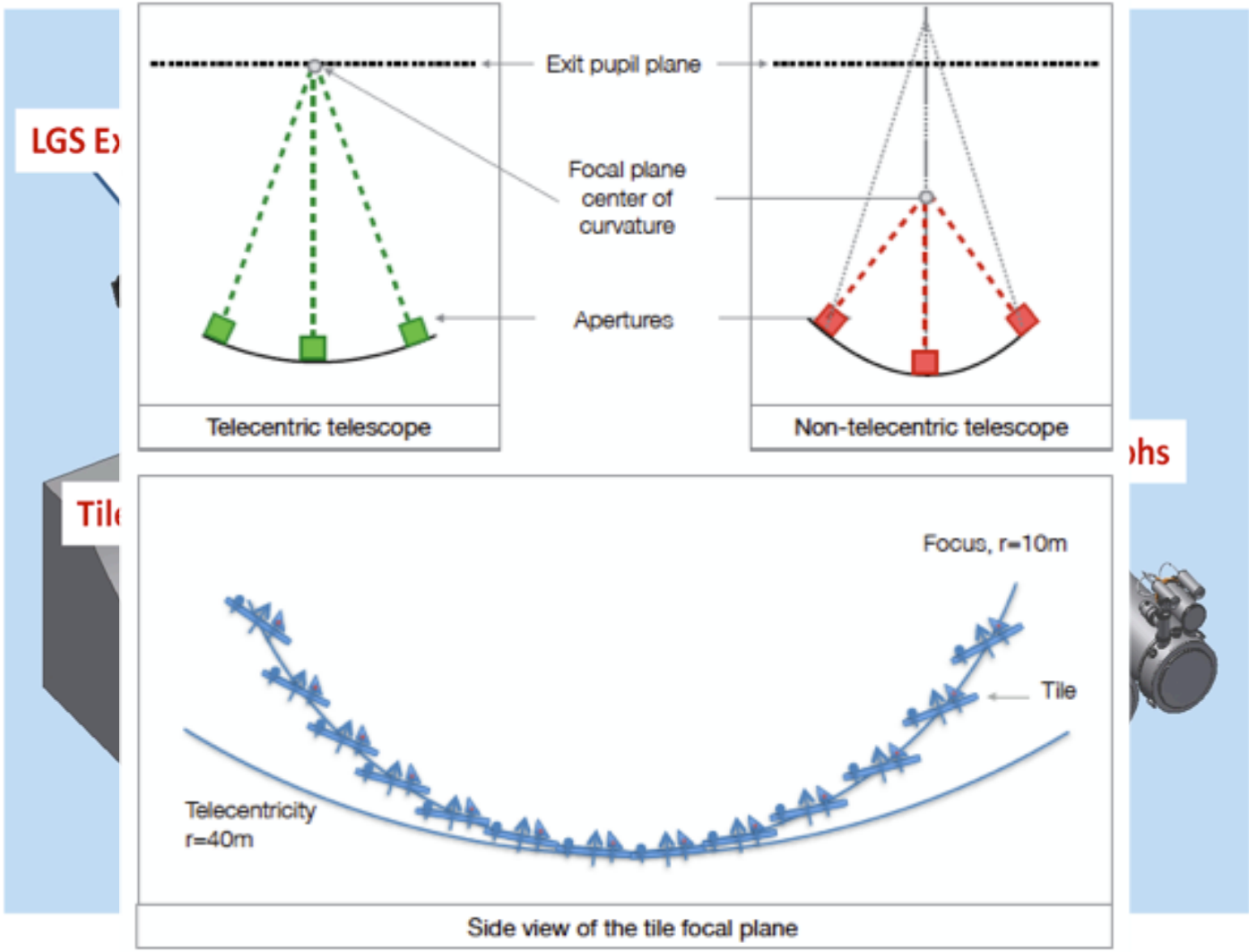

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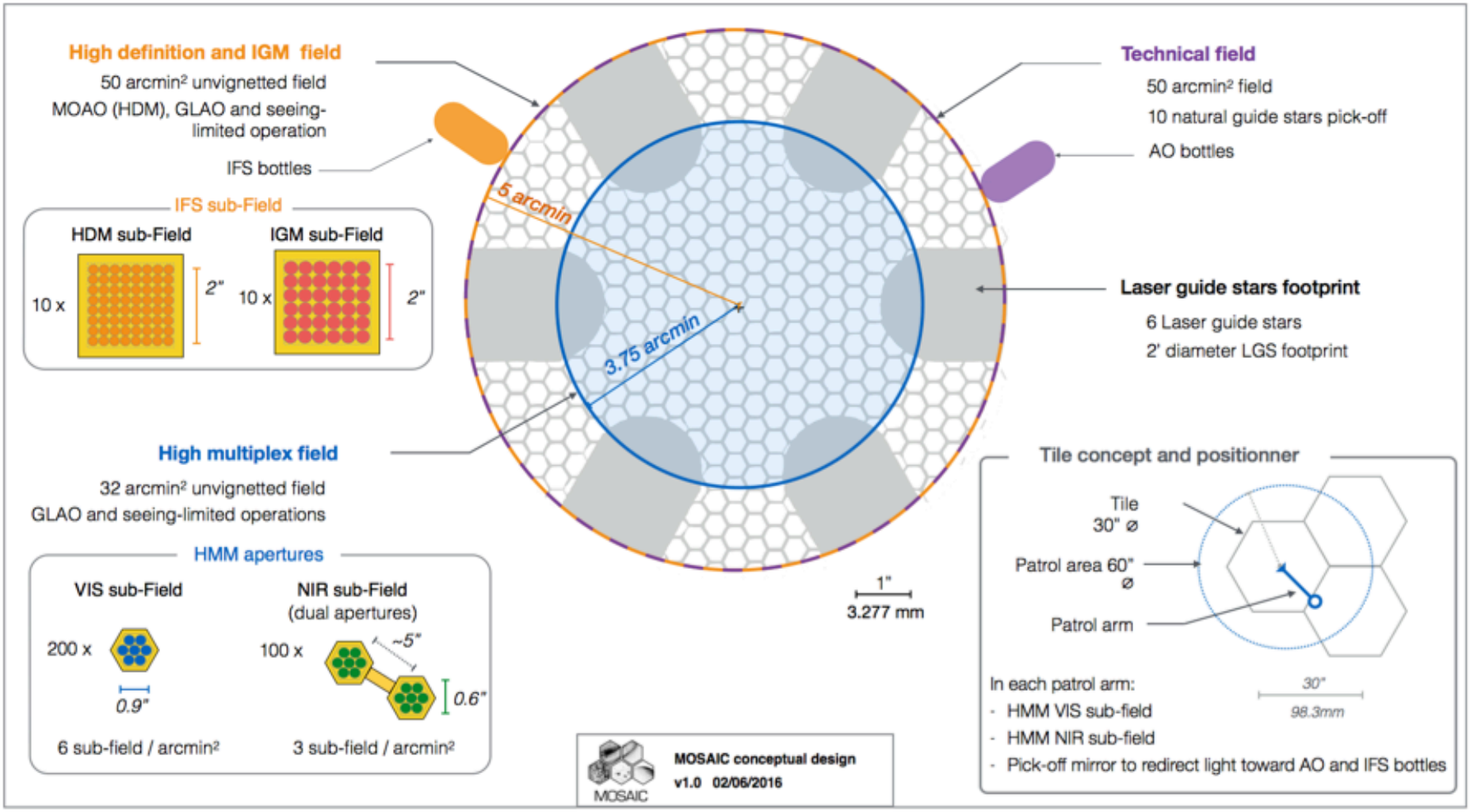
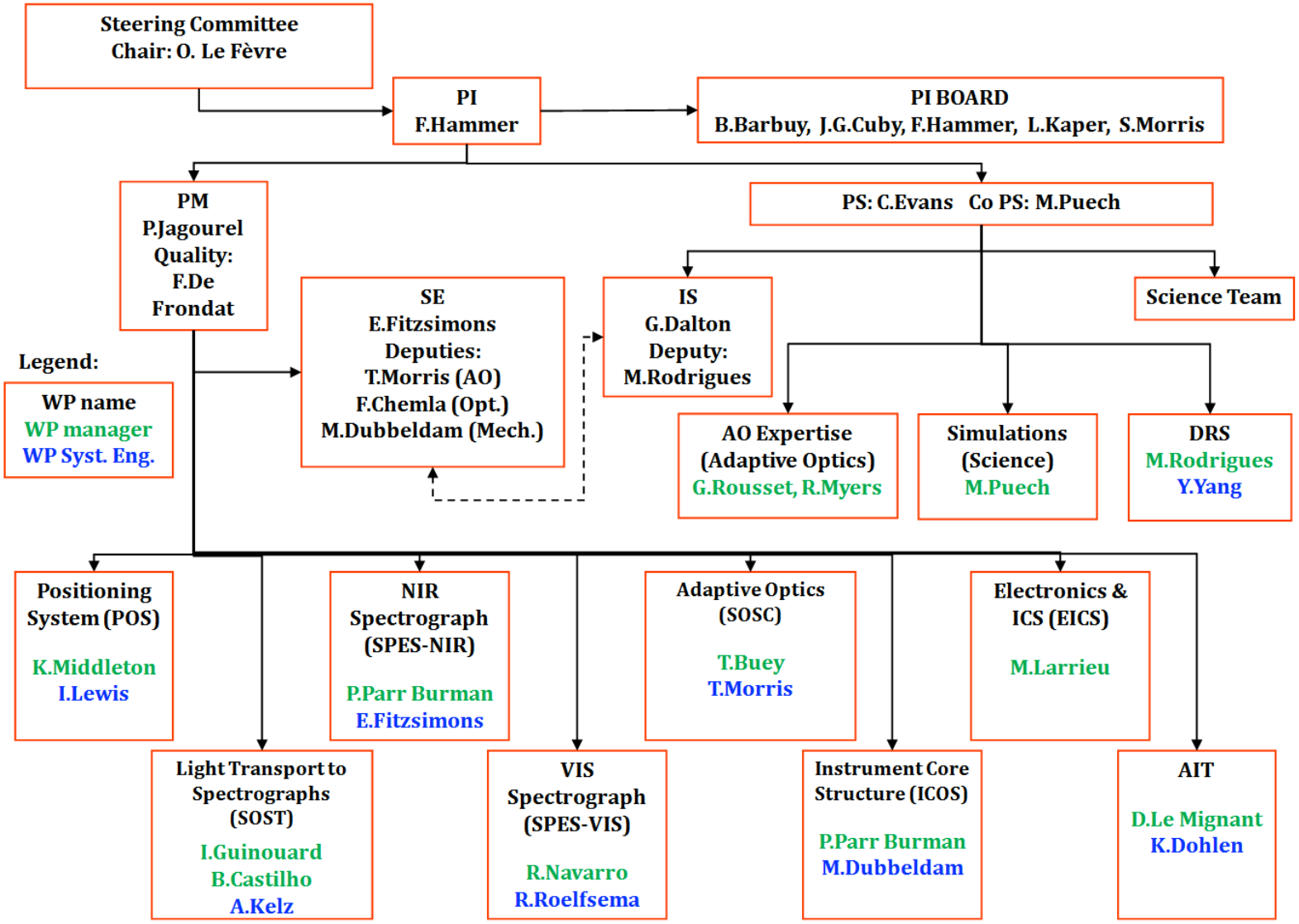
Focal plane, E-ELT non-telecentric
➔ focal plane concept: tile solution

cf Rodrigues, Dalton et al. 2016, SPIE



MOSAIC Consortium Organization chart
Phase A: March 2016 to December 2017



MOSAIC

MOSAIC core team has developed, then implemented:
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

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

SC1 : first light – spectroscopy of the most distant galaxies
Probing the epoch of reionisation

See MOSAIC White Paper, Evans, Puech et al., arXiv150104726E

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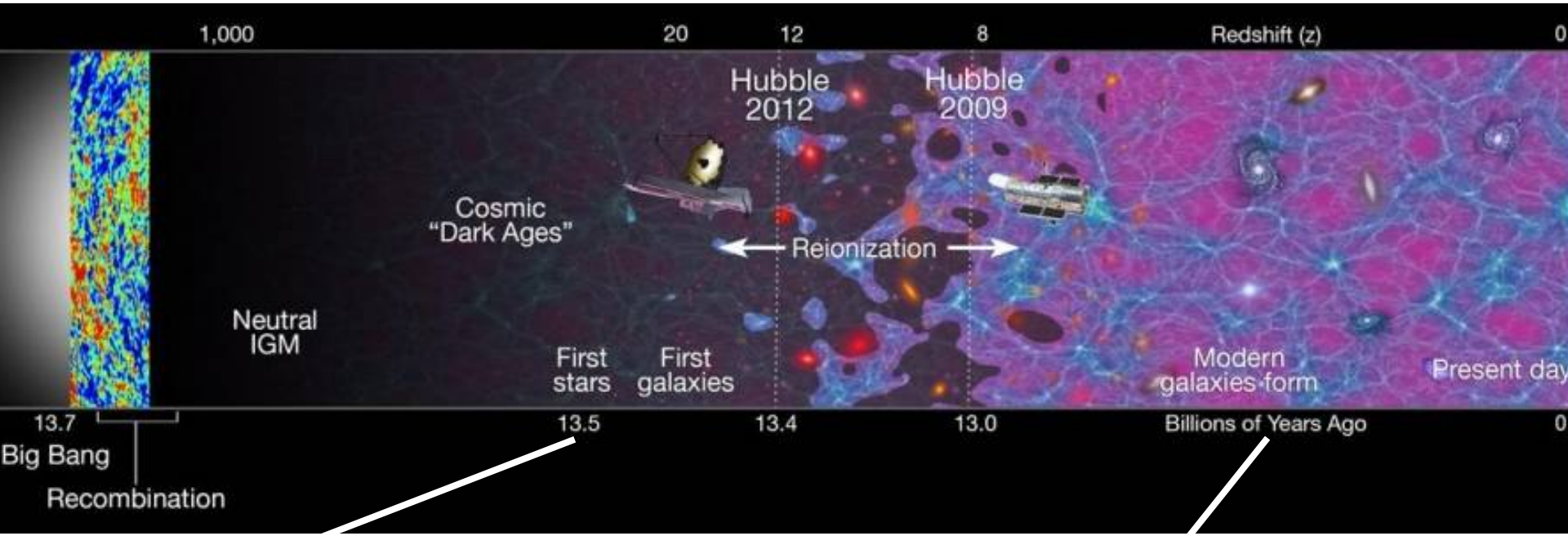

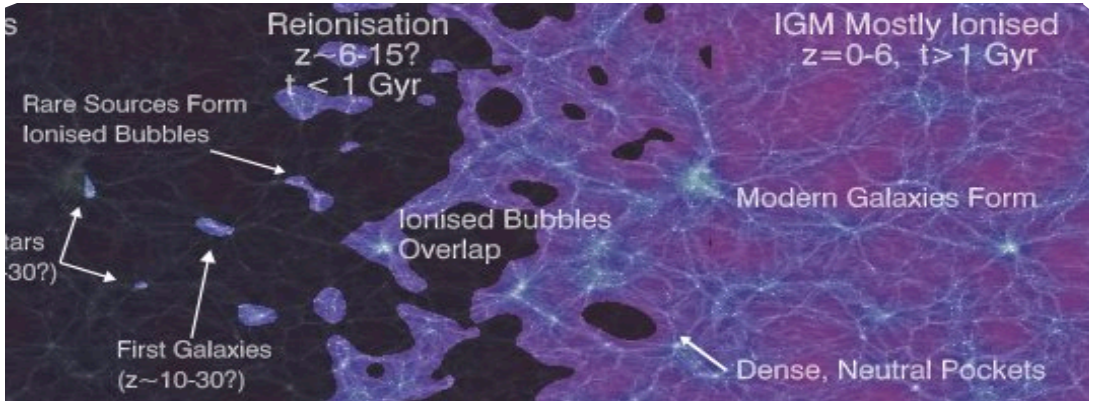

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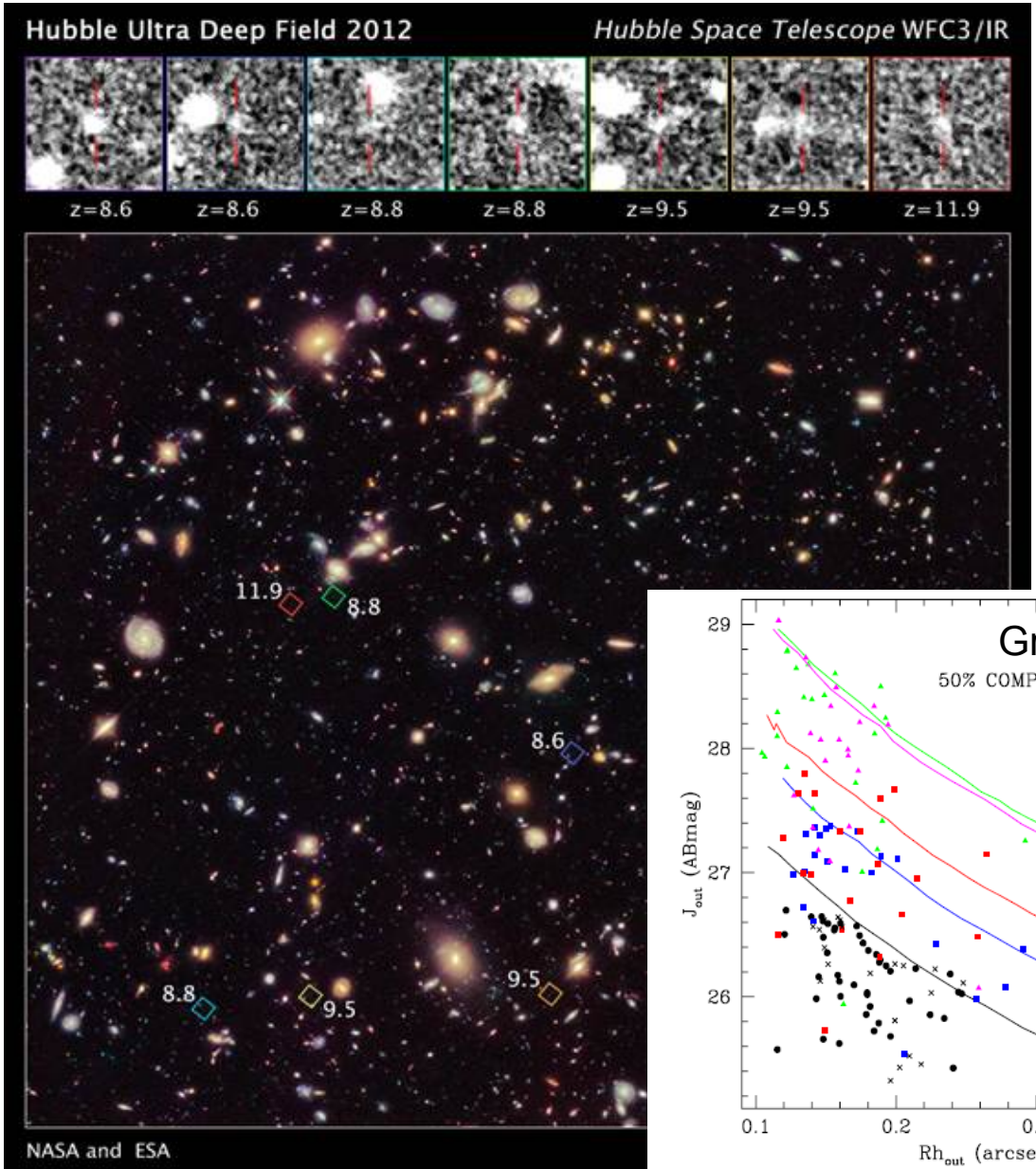
First galaxies & reionisation (SC1)

Constrain the HI fraction in the IGM using the Ly-α LF at z>7

Ultra-deep *Y* to *H* spectroscopy of a large sample of faint LBGs to detect $f_{Ly\text{-}\alpha} \sim 10^{-18/19}$ *cgs* in m_{AB}=28-30 sources



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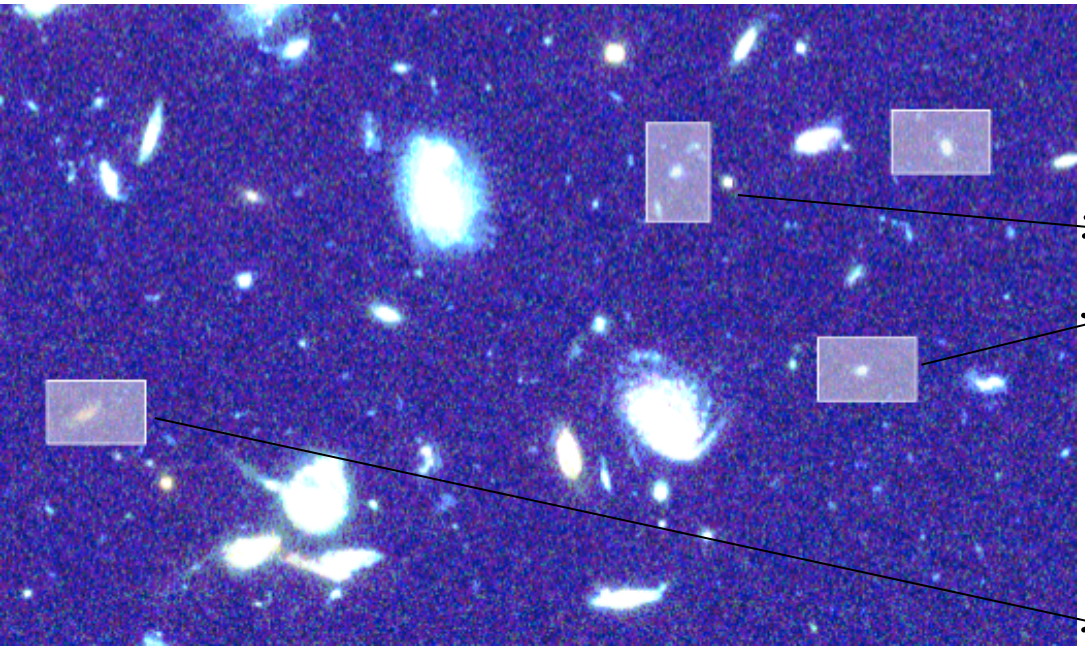
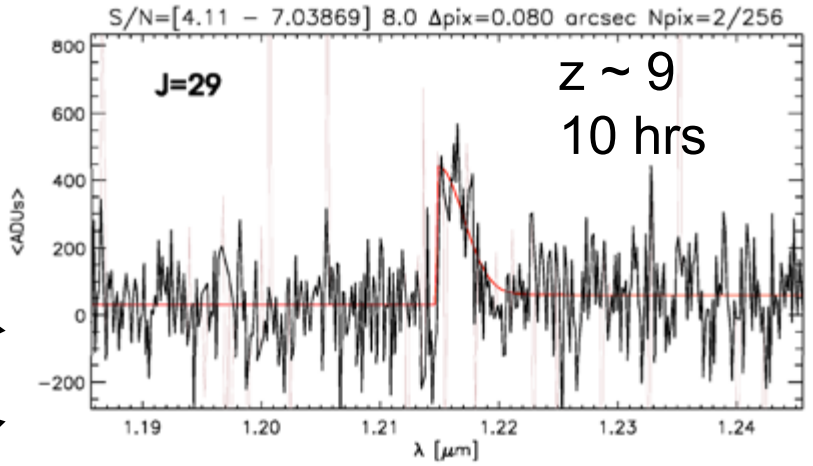
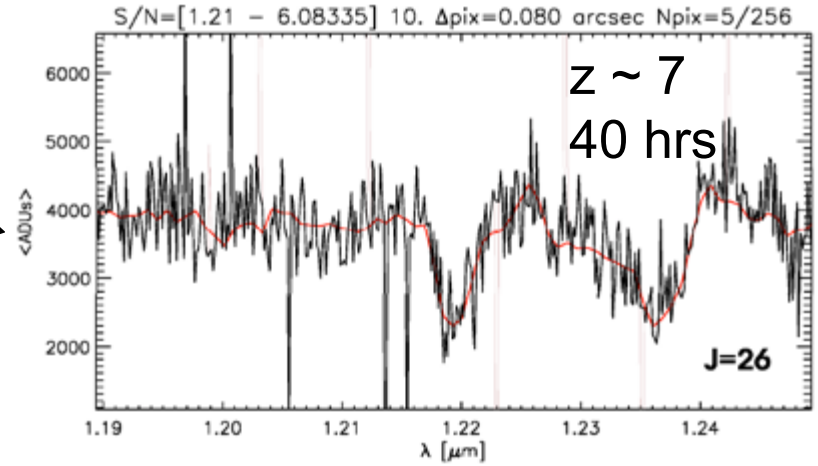
End-to-end simulations (K. Disseau)

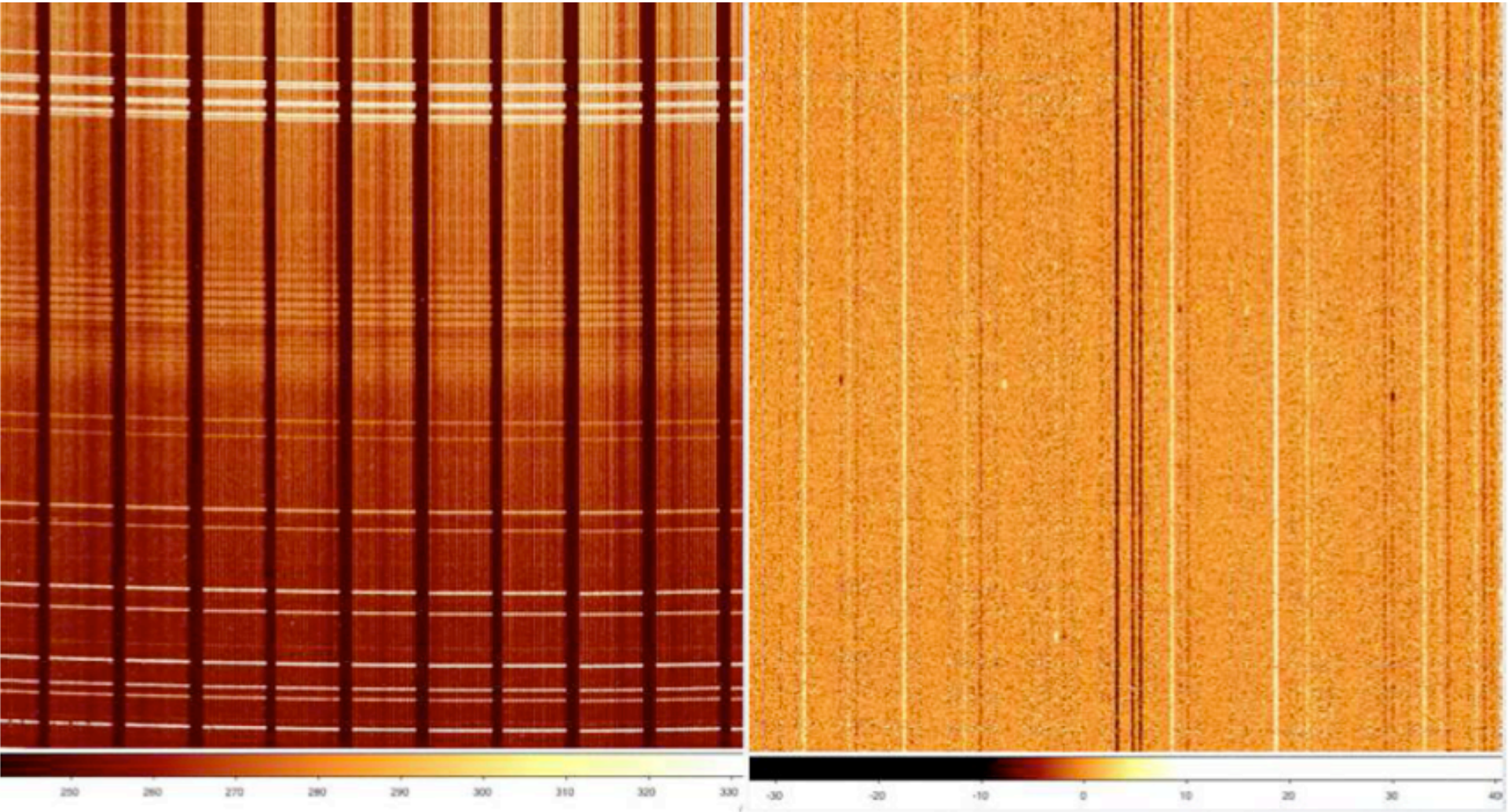






IFUs: unbeatable for the best sky subtraction

Sky subtraction with fibers demonstrated with FLAMES (I-band) on sky



Expected in J-band: 0.6% of the sky-continuum & at the theoretical limit (~ 0.2-0.3%) with IFUs (Yang et al., Messenger, 2013; Rodrigues et al. 2012)

SC1 : first light – spectroscopy of the most distant galaxies

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SC2 : Evolution of large-scale structures

Tomography of the IGM & missing baryons

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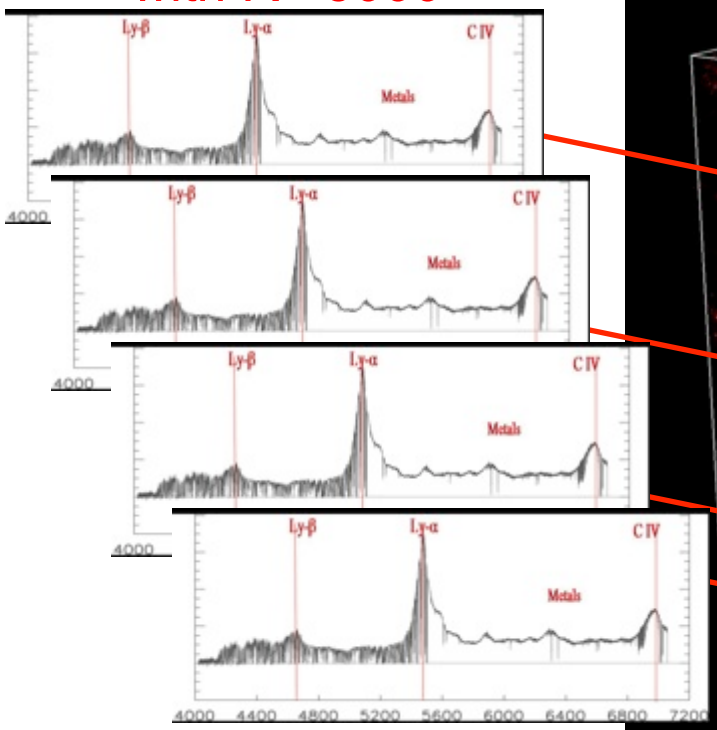
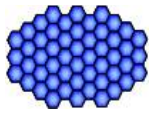
Direct 3D reconstruction of the IGM
(from P. Petitjean)

No QSOs but Lyman break galaxies observed with R≥ 5000

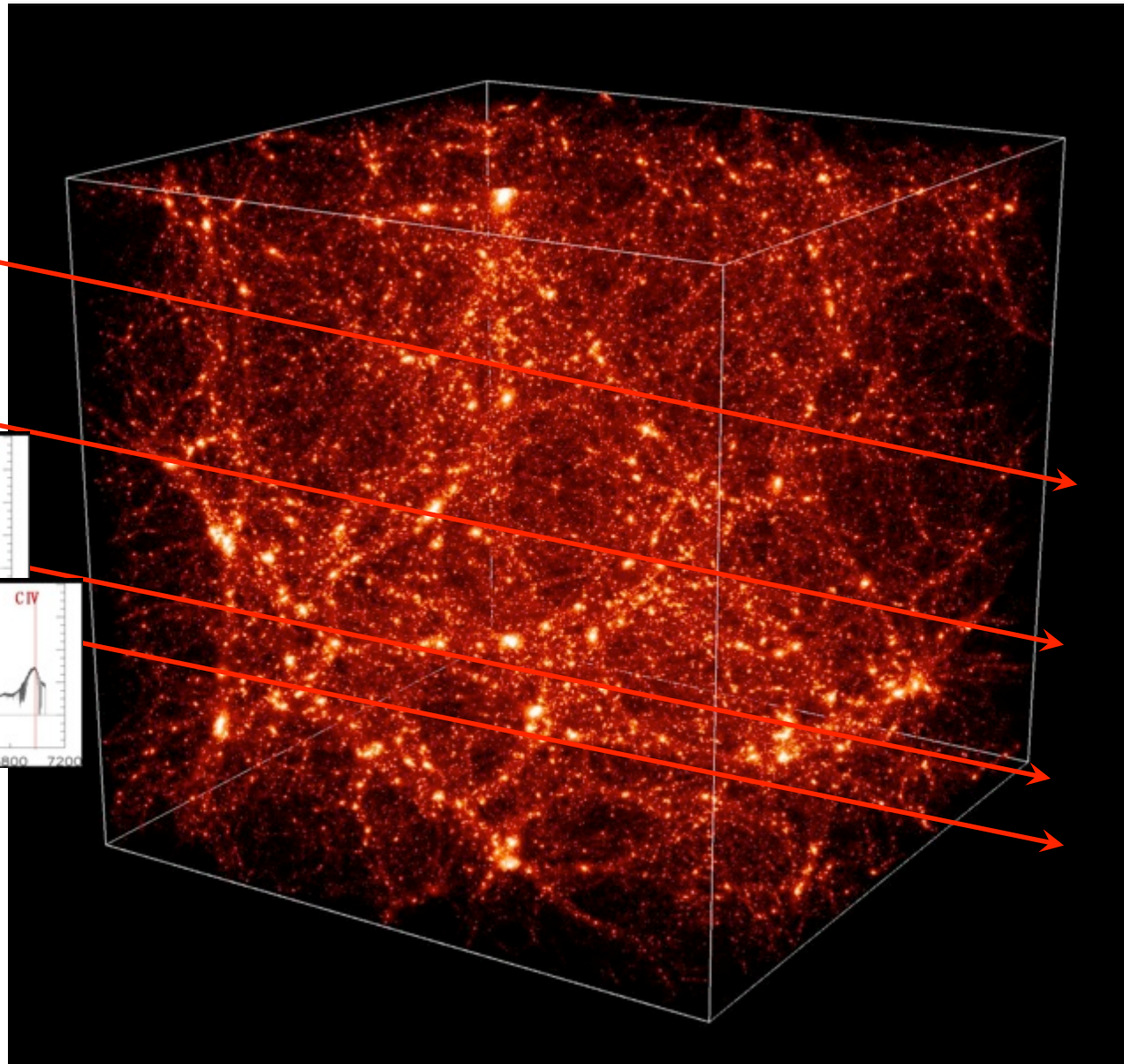


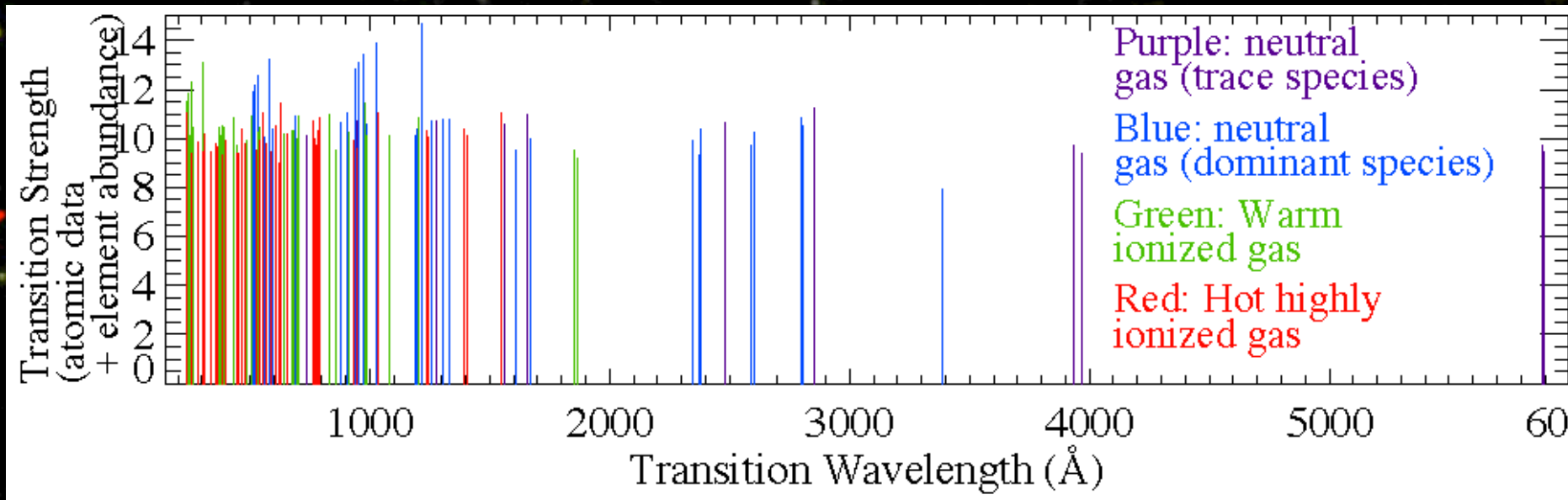
1.8''x2.9''

≥10 x optical IFU



R=6000





Foreground galaxy

z ~ 2.5

Distant background galaxy

MOSAIC

MOSAIC@E-ELT can provide a full understanding of the evolution of the warm/ cold gas surrounding galaxies

Adapted from *Tripp+ 2011, Science*

SC1 : first light – spectroscopy of the most distant galaxies

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SC3 : Mass assembly of galaxies through cosmic times

Spatially-resolved spectr. of high-z emission line galaxies – inventory of dark matter

The puzzling role of high-z dwarf galaxies in gal. Evol.

Stellar populations – integrated abs. Line spectr.

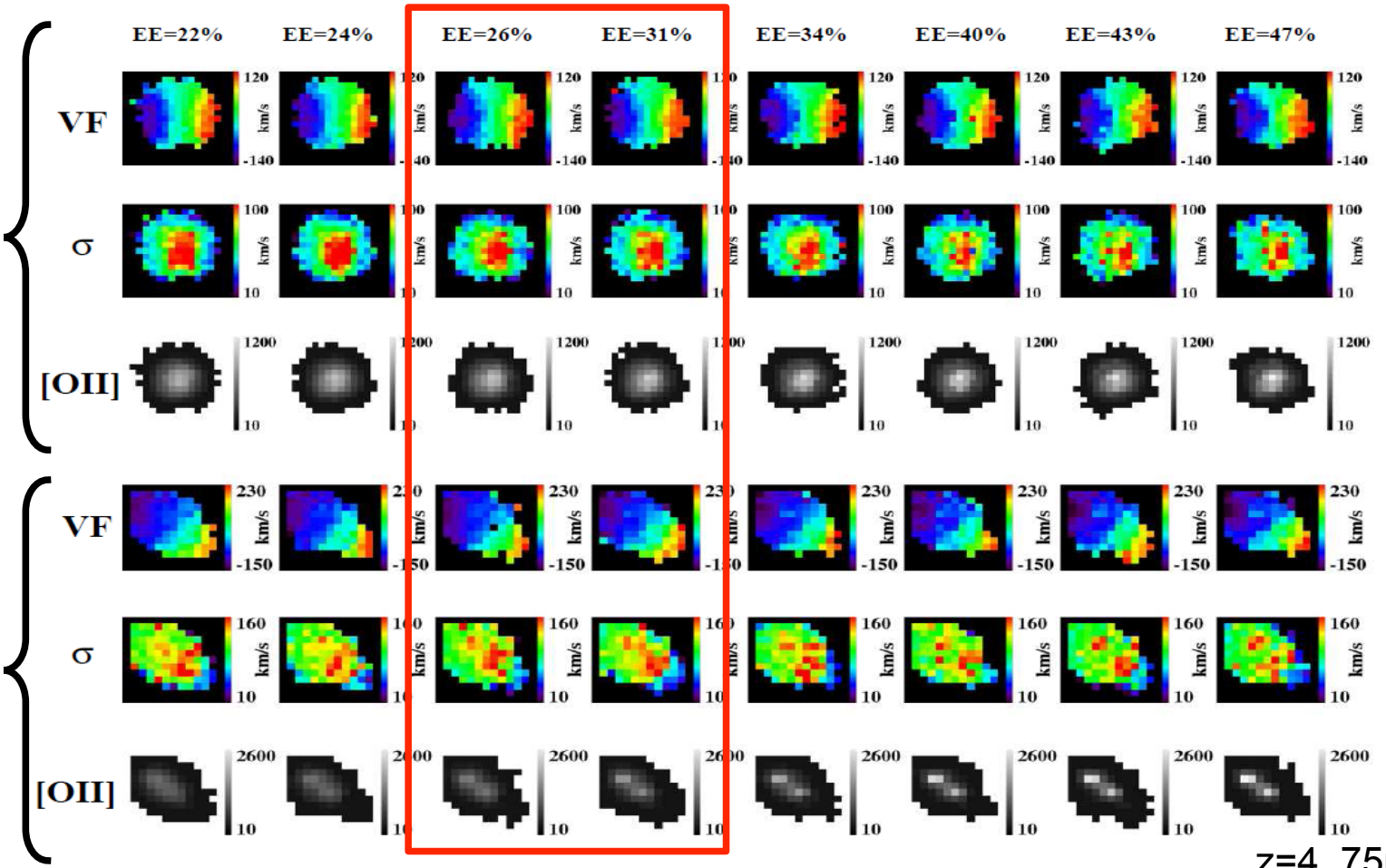
See MOSAIC White Paper, Evans, Puech et al., arXiv150104726E

MOSAIC

The mass assembly of galaxies

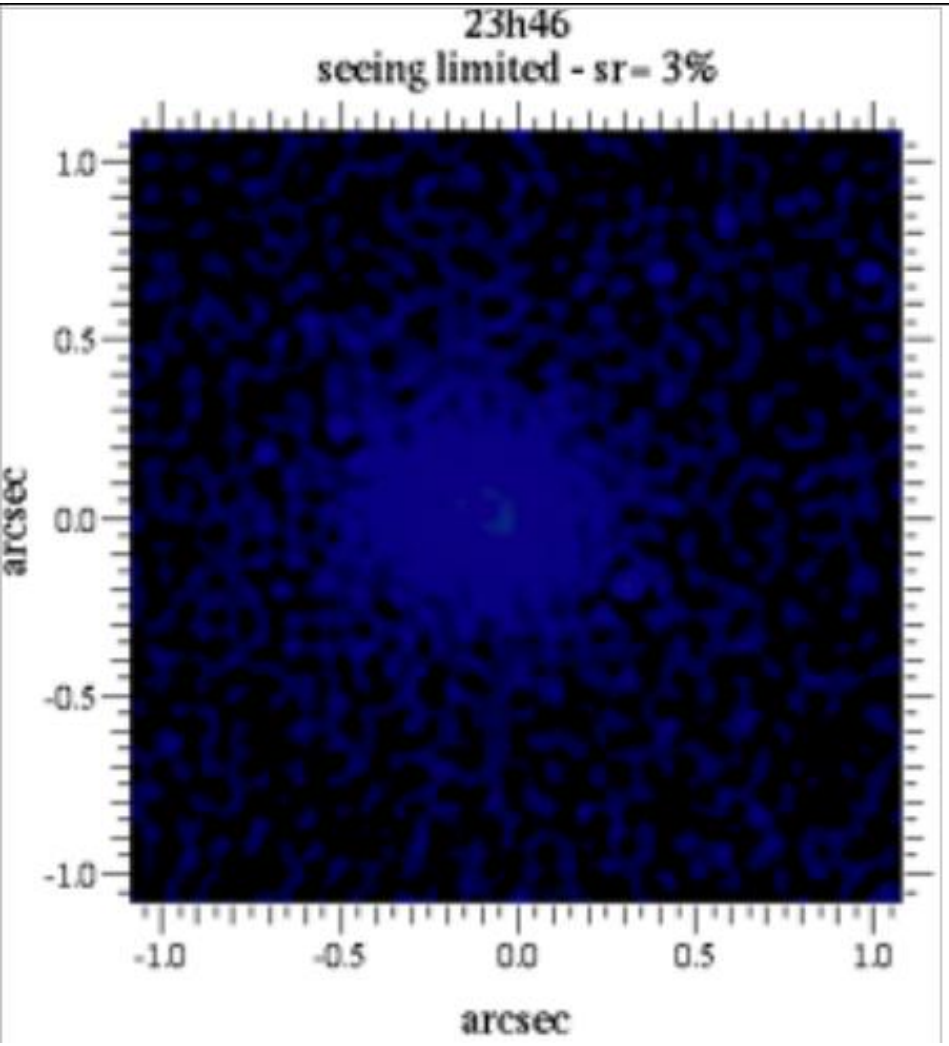
Optimal spatial sampling : ~50-75mas/pixel (~ 10 D.L.)
MOAO mandatory for recovering the 2D kinematics

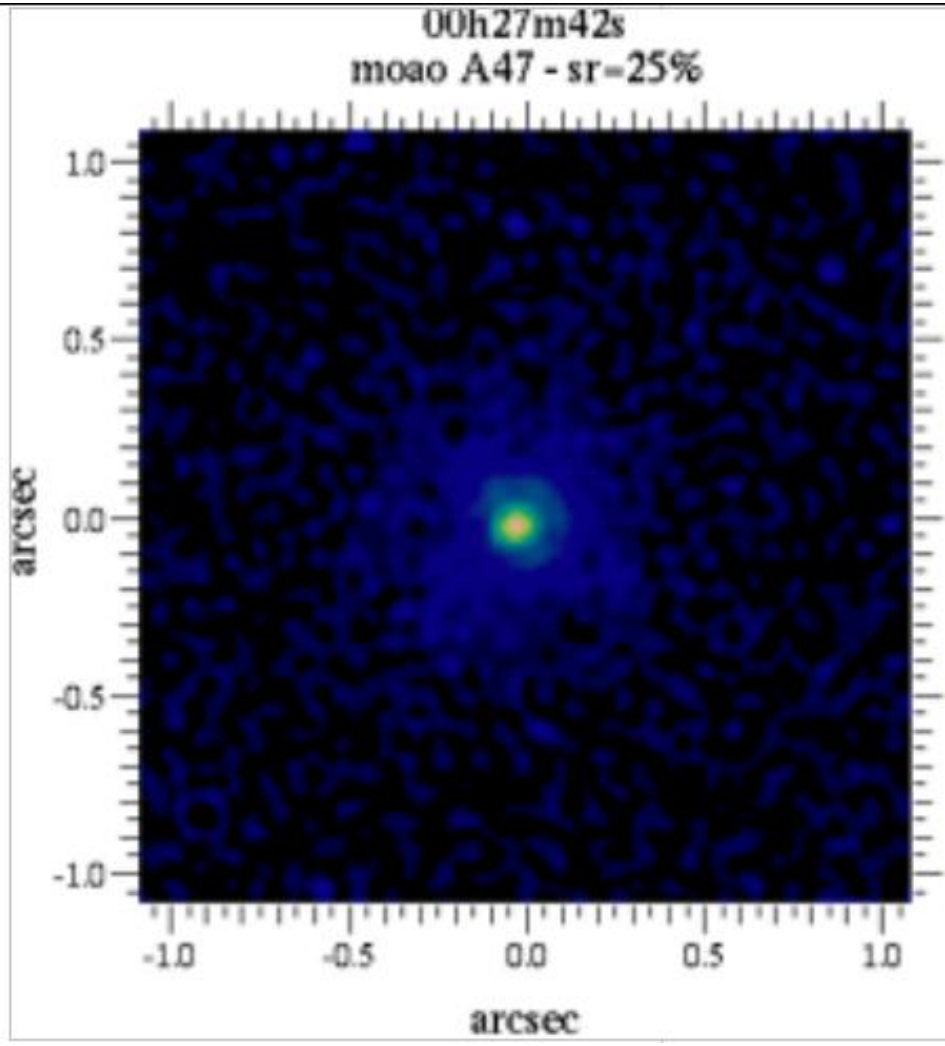
Puech+08



z=4, 75mas/spaxel

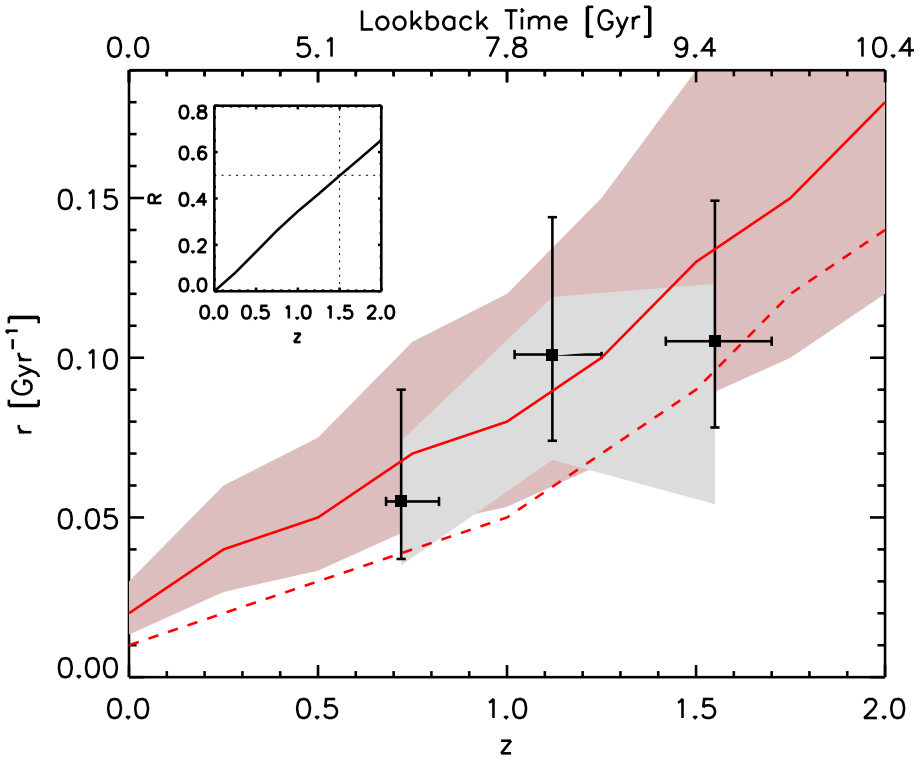
MOAO demonstrated on sky with Canary (2010-16)





Evolution of the fraction of mergers/disks

Test of the formation of structures in Λ-CDM

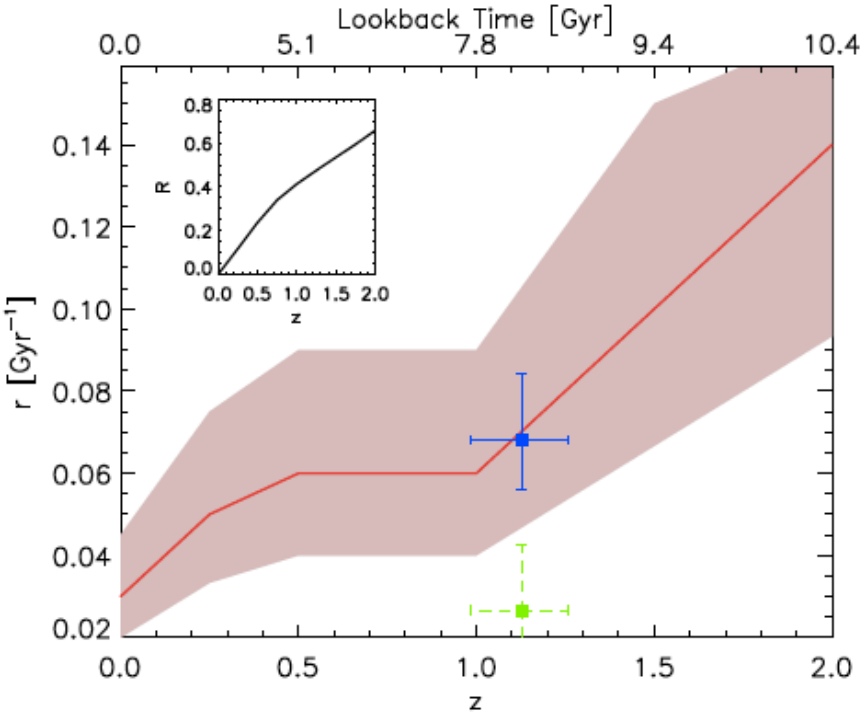


KMOS-3D re-analysis

Rodrigues et al., in rev.

IMAGES survey

Puech et al. 2012

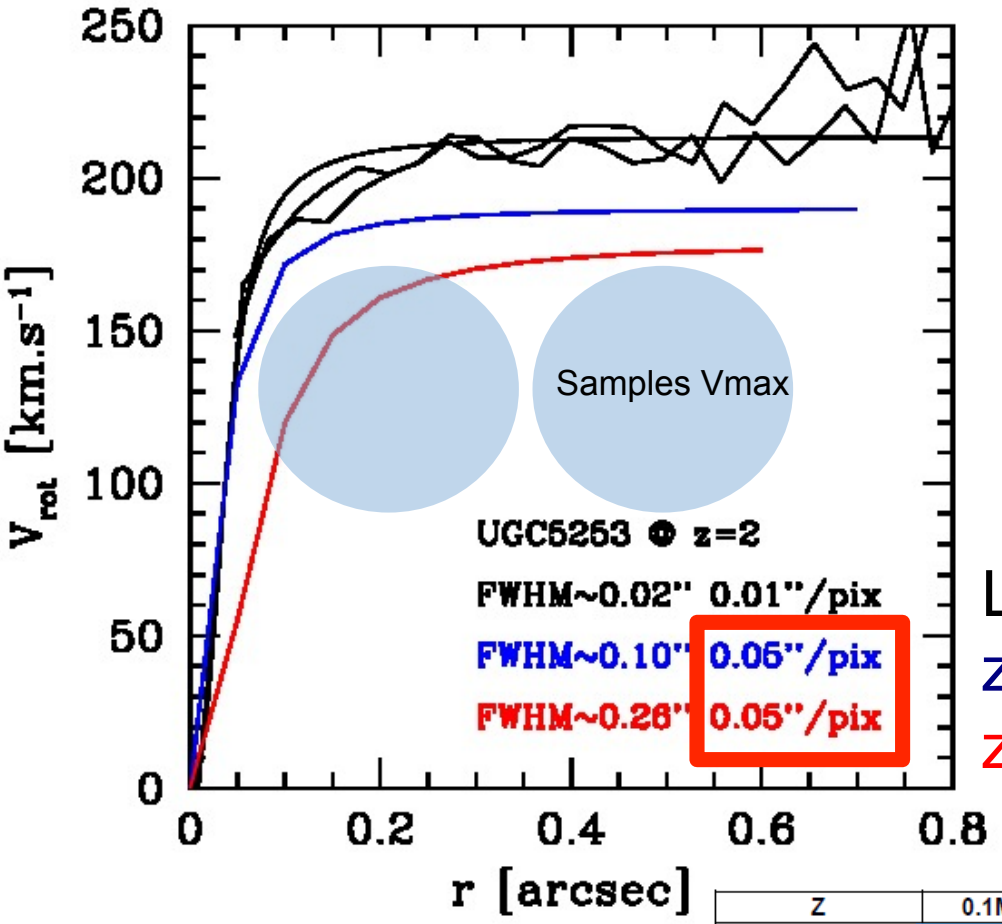


Requires large & representative samples

Agreement w/ semi-empirical models (Hopkins+09)

RCs at high-z

Bosma criterion $B=R_{gal}/FWHM > 7\text{-}10$ to study the shape of the RC (Bosma78)



B=40
B=7
B=2.3

V_{rot} can be recovered using maximum likelihood methods provided 7>B>2 but NOT the shape of the RC !

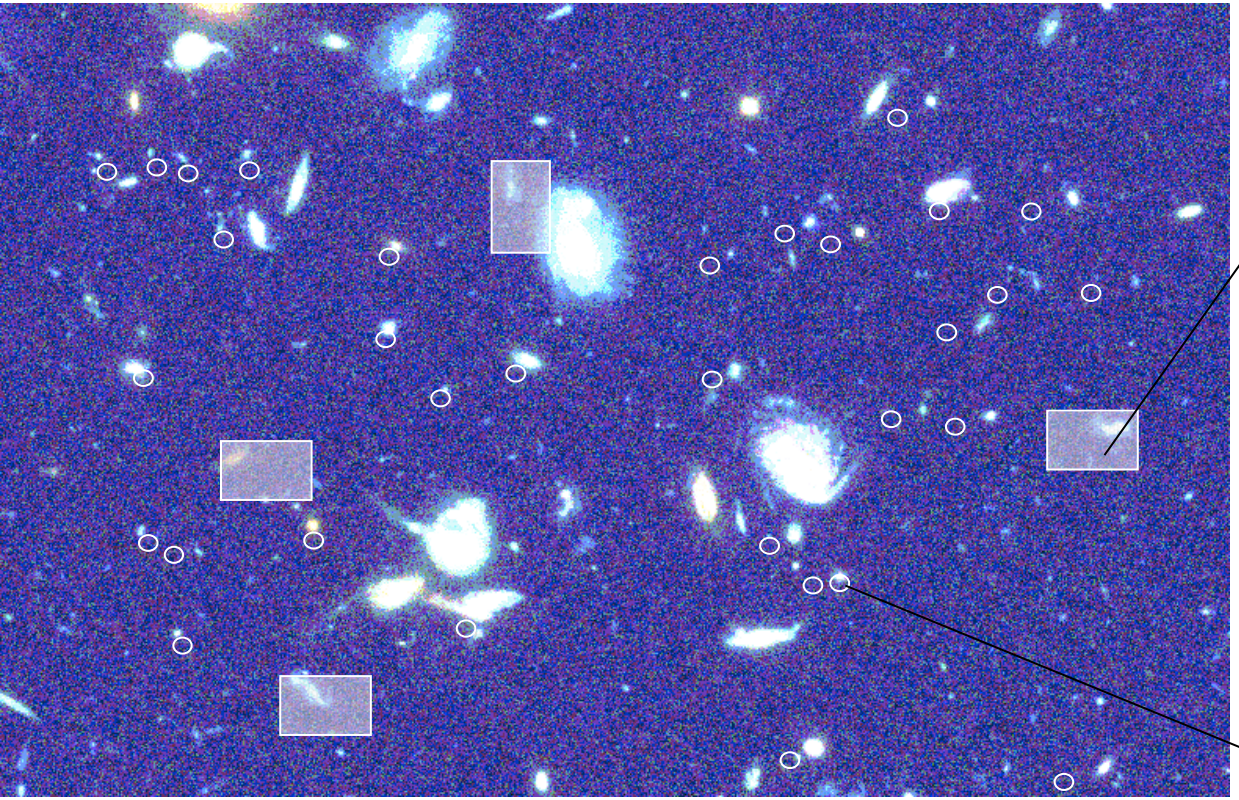
Local
z=2 MOAO
z=2 GLAO

E-ELT with MOAO required : this is MOSAIC

Puech+10

Z	0.1M*(z)	0.5M*(z)	M*(z)	5M*(z)	10M*(z)
2	170	300	380	670	850
4	80	150	190	330	430
5.6	70	130	160	280	350

SC3: High definition + high multiplex modes



Mergers/disks fraction, RC & evolution of dark matter content

Chemistry & kinematics of z > 2 LMC/SMC mass galaxies: R=6000 & 15000, far better resolved than by JWST!

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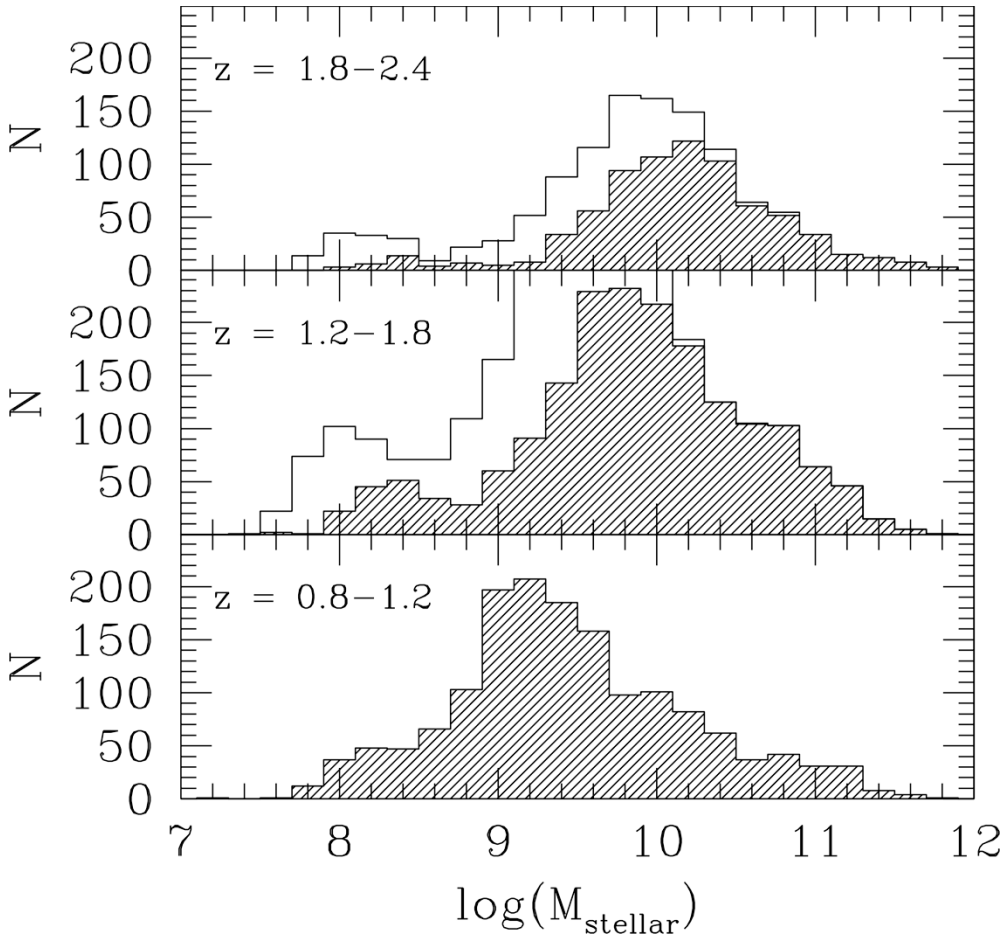
SC3: Study the numerous distant galaxy population

1600 galaxies at z> 1.5 in an E-ELT FoV (mostly dwarfs)

- Origin of dwarves: primordial galaxies or tidal dwarfs?
- Low surface brightness galaxies in the gaseous-rich Universe
- Test of curvature (Λ using HII galaxies)



m_J(AB)<26

Based on CANDEL counts & Dahlen photo'z

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SC4 : AGN/Galaxy coevolution

See MOSAIC White Paper, Evans, Puech et al., arXiv150104726E

Second half of White Paper

arXiv150104726E

SC5: Resolved stellar populations beyond the Local Group (Evans et al.)

Also incl: Extragalactic star clusters (Larsen)

Tests of the extragalactic IMF (Bastian)

Cephieds & the extragalactic distance scale (Lemasle)

Structural components in external galaxies (Gadotti)

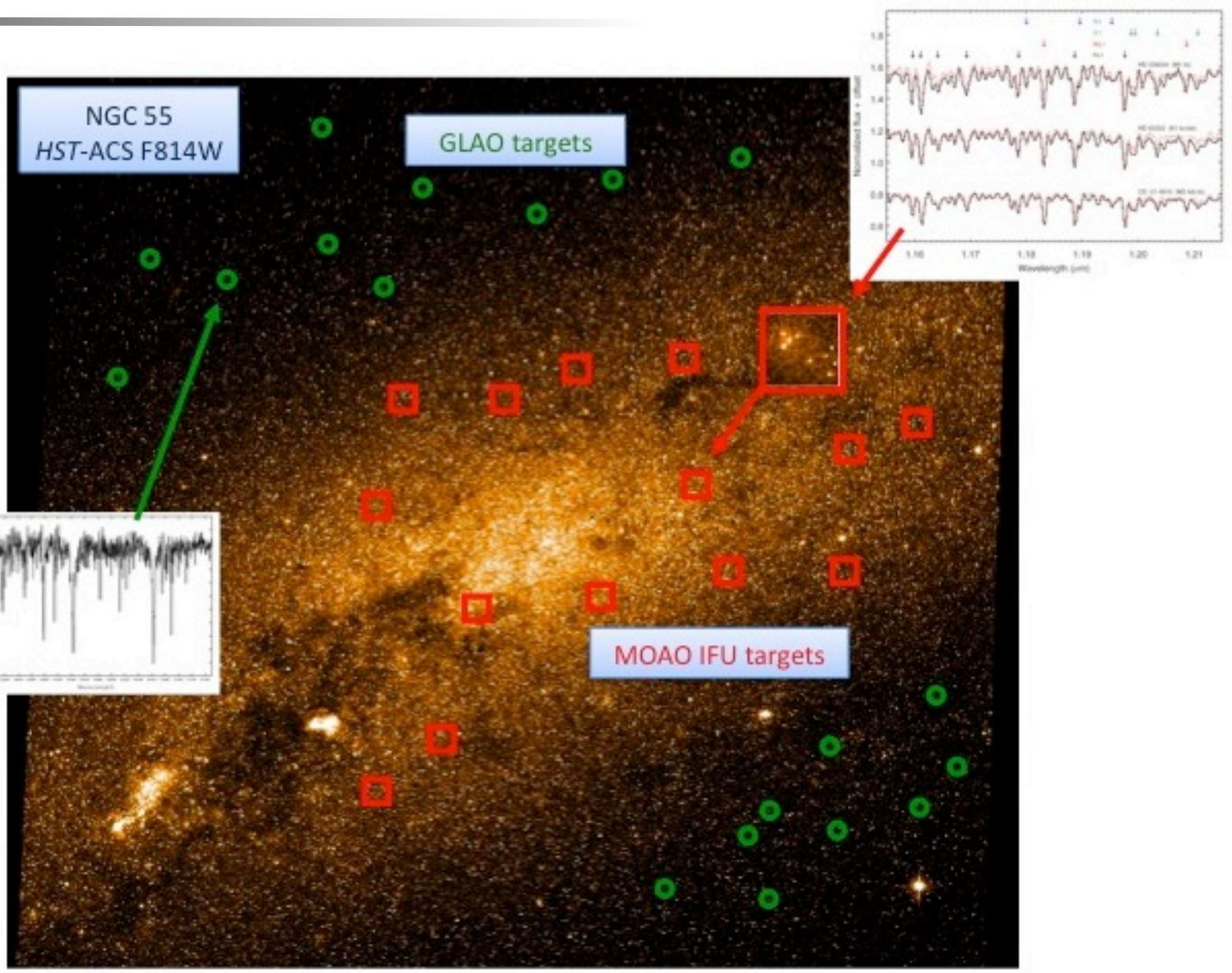
SC6: Galaxy Archaeology (Barbuy, Lesmasle, Caffau, Battaglia et al.)

SC7: Galactic Centre science (Paumard)

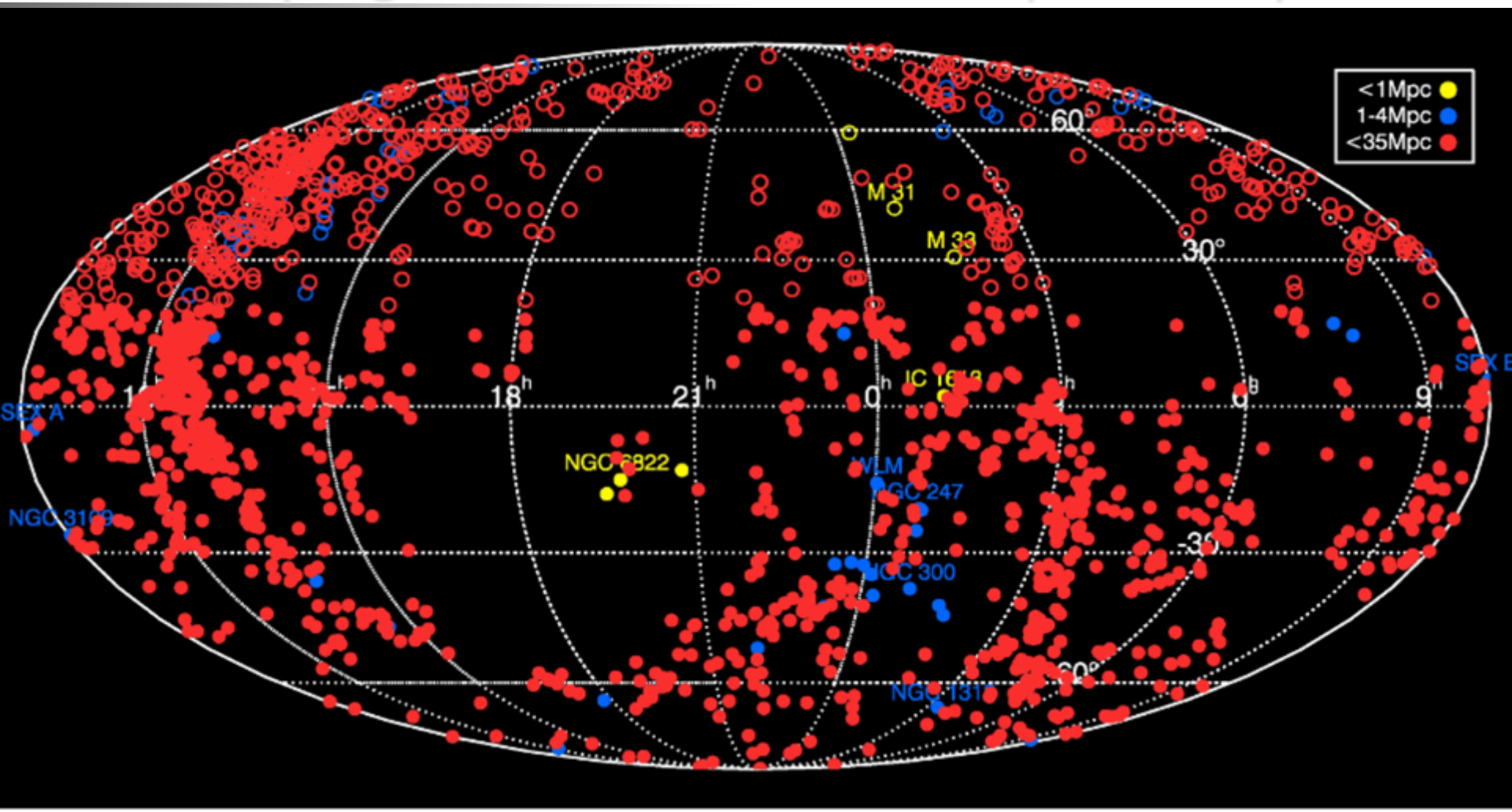
SC8: Planet formation in diff. environments (Guenther, Bonifacio et al.)

Example case: NGC 55

Evans et al. Proc. SPIE
arXiv:1207.0768



Red supergiants can be observed up to 35 Mpc



MOAO for accurate metal abundances (CaT) of all galaxy types!

Survey plan - simulations

From Science with MOS: towards the ELT area (Cefalu, Sept 15) & MOSAIC Science meeting (Paris, March 16)

* MW populations: bulge, disk, bar
* MW populations: halo / first stars
* Extragalactic stellar populations
* Spectroscopy of first-light galaxies
* Dynamical formation of galaxies
* Extended gas in primeval galaxies
* Baryon inventory & evolution in galaxy haloes/IGM
* Dark matter inventory & evolution in rotating discs
* Spectroscopy of high-z dwarf galaxies

Identifying the most "outbreaking science"

MOSAIC

Synergies w/ MOONS

E-ELT & MOONS: MOONS will be an ideal science path-finder for the MOSAIC@E-ELT instrument ➔ risk mitigation

Spectrograph: Cooling of fibers and design of the shutter (vacuum, vibrations, etc)

Fibers: Cooling the fibers between the front-end and the spectrograph; control of fiber responses for faint targets

DRS: Test all the algorithms and observational strategy (operations) for accurate sky-subtracting

Science: The two surveys (stellar and extragalactic) can be used to generate samples to be observed with E-ELT/MOSAIC

Conclusions

- MOSAIC will the ‘survey machine’ of the E-ELT : ‘outbreaking science’ from cosmology to planets, while studies of individual sources will be limited
- Multi-IFUs + MOAO are very competitive vs. TMT for sky-subtraction, light concentration & no aperture losses
- MOS: the only E-ELT instrument to follow-up JWST sources
- MOSAIC is relatively low risk (fibres, AO etc.)
- Phase A (March 2016- Dec. 2017) to prepare the ELT-MOS & Public Surveys
- Strong synergies with MOONS: technical risk mitigation, feeding MOSAIC with sources