

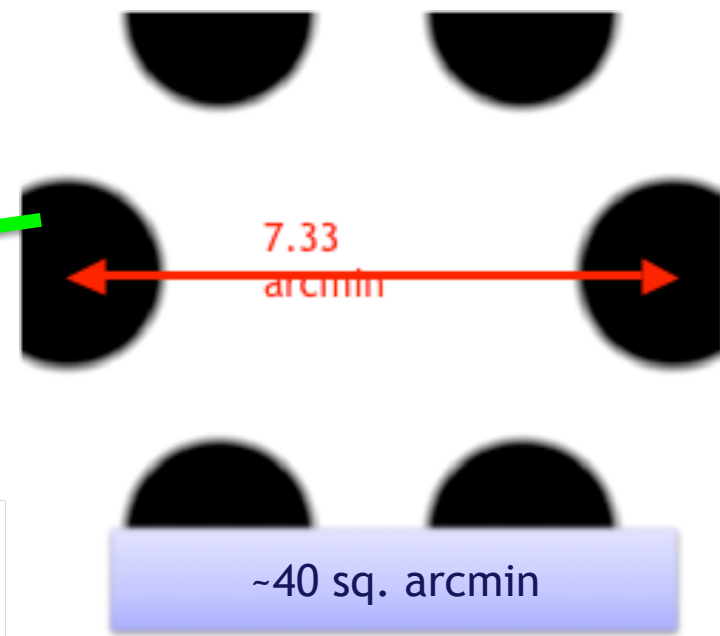
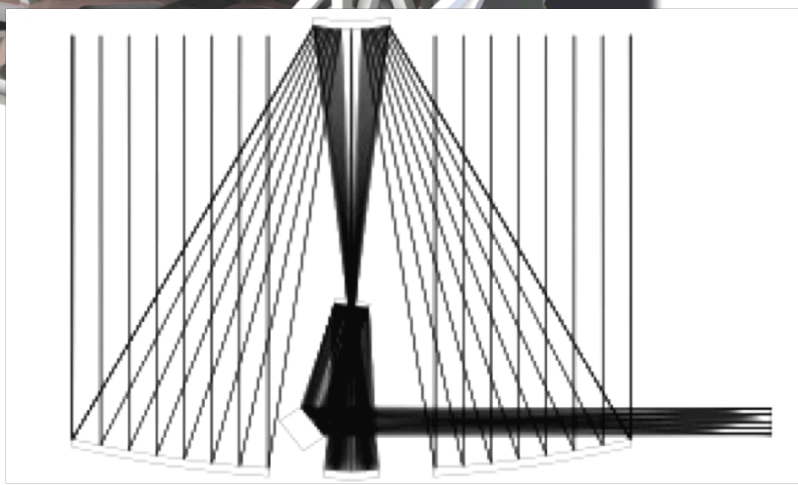
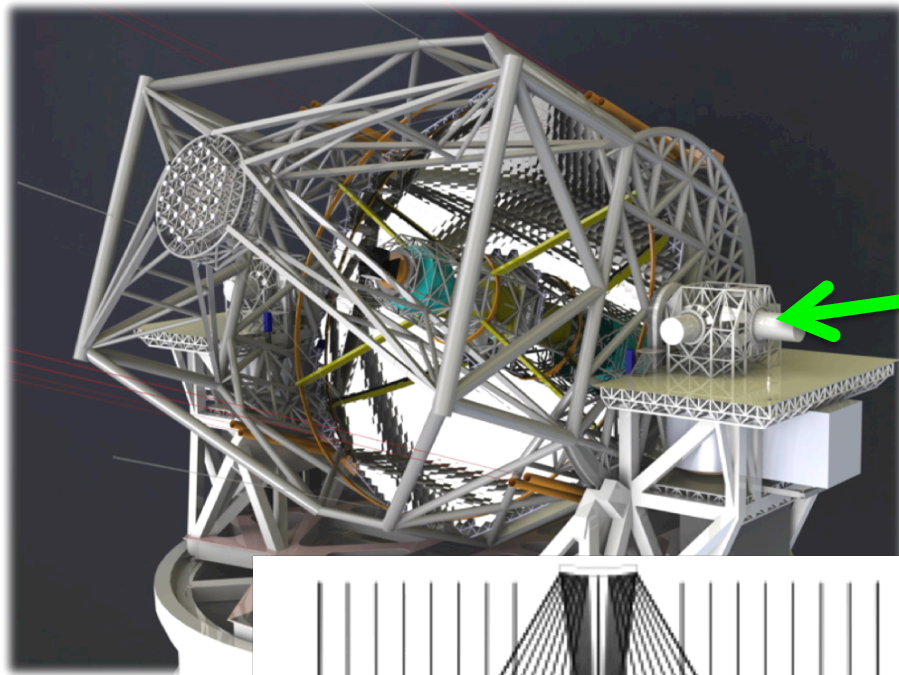
## Science requirements for an ‘ELT MOS’

*Chris Evans (UKATC/STFC)*



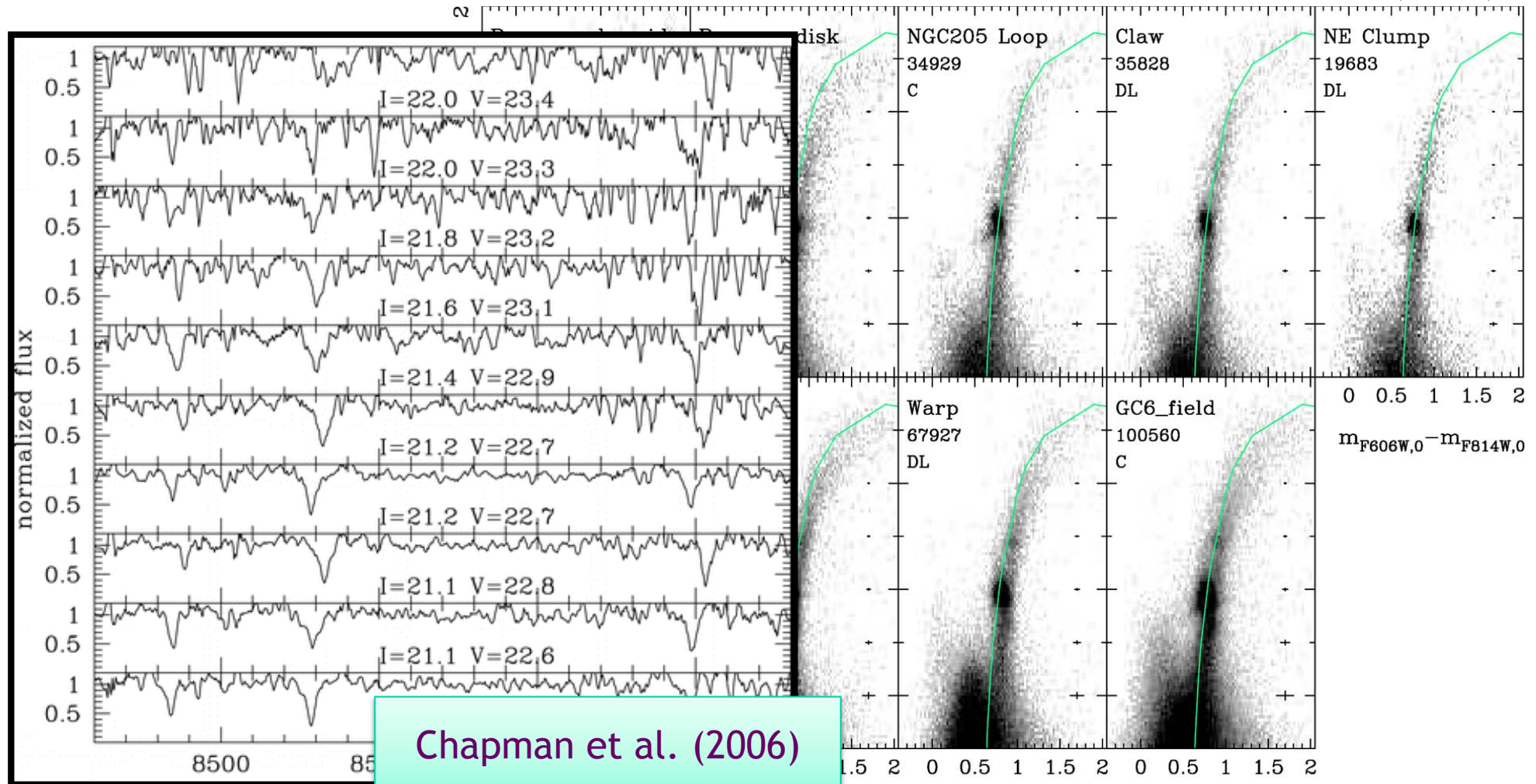
Science & Technology Facilities Council  
UK Astronomy Technology Centre

# E-ELT patrol field

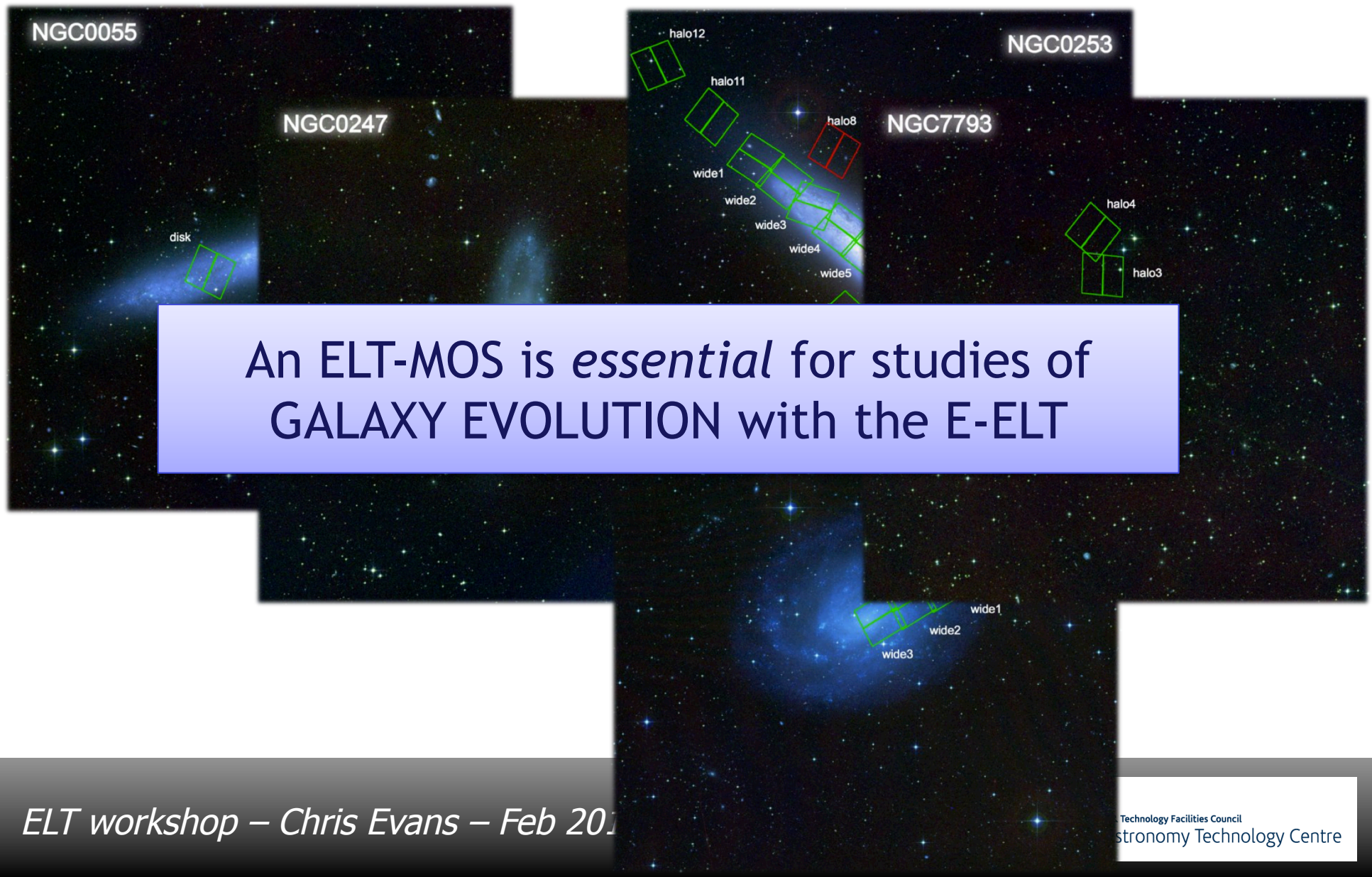


# Resolved stellar populations

Richardson et al. (2008)



# Resolved stellar populations



## **Multi-Object Spectroscopy with the European ELT: Scientific synergies between EAGLE & EVE**

C. J. Evans<sup>1</sup>, B. Barbuy<sup>2</sup>, P. Bonifacio<sup>3</sup>, F. Chemla<sup>3</sup>, J.-G. Cuby<sup>4</sup>, G. B. Dalton<sup>5,6</sup>, B. Davies<sup>7</sup>,  
K. Disseau<sup>3</sup>, K. Dohlen<sup>4</sup>, H. Flores<sup>3</sup>, E. Gendron<sup>8</sup>, I. Guinouard<sup>3</sup>, F. Hammer<sup>3</sup>, P. Hastings<sup>1</sup>,  
D. Horville<sup>3</sup>, P. Jagourel<sup>3</sup>, L. Kaper<sup>9</sup>, P. Laporte<sup>3</sup>, D. Lee<sup>1</sup>, S. L. Morris<sup>10</sup>, T. Morris<sup>10</sup>,  
R. Myers<sup>10</sup>, R. Navarro<sup>11</sup>, P. Parr-Burman<sup>1</sup>, P. Petitjean<sup>12</sup>, M. Puech<sup>3</sup>, E. Rollinde<sup>12</sup>, G. Rousset<sup>8</sup>,  
H. Schnetler<sup>1</sup>, N. Welikala<sup>13</sup>, M. Wells<sup>1</sup>, Y. Yang<sup>3,14</sup>

- ‘High definition’: Observations of tens of channels at fine spatial resolution provided by multi-object adaptive optics (MOAO).

- ‘High multiplex’: Integrated-light (coarsely resolved) observations of >100 objects corrected by ground-layer adaptive optics (GLAO).

# MOS requirements

Workshop in Amsterdam

Assembled a science team

Meetings in UK, Italy, Brazil, NL

New science simulations

## Multi-object spectroscopy on the European Extremely Large Telescope

25-26th October 2012 - University of Amsterdam

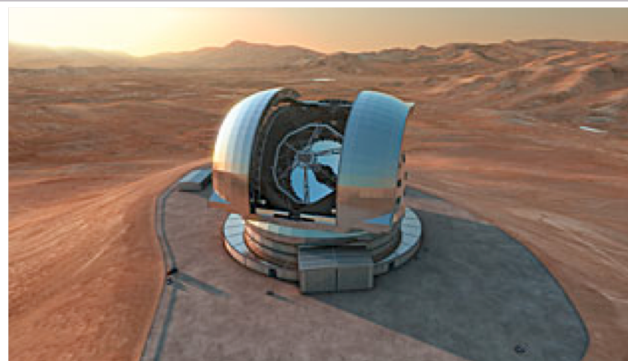
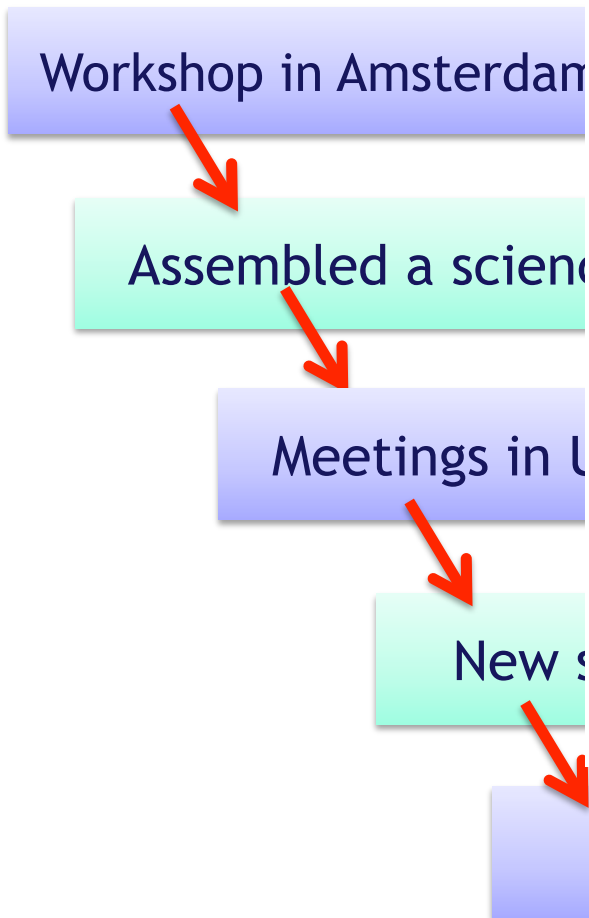
[Venue](#) | [Accommodation](#) | [Programme](#) | [Participants](#) | [Registration](#)  
| [Contact](#) | [links](#)

Turingzaal, NIKHEF, Science Park 105, 1098 XG Amsterdam, The Netherlands

The workhorse instruments of the 8-10m class observatories are their multi-object spectrographs (MOS), providing ground-based and space-borne imaging surveys from, e.g., there will be a plethora of we believe there is a strong and compelling case for a MOS as one of the first E-ELT instruments. By exploiting the excellent image quality across the full focal plane of the telescope combined with its we will be able to obtain the one of the key scientific from studies of stellar galaxies.



# MOS requirements



Document Title	ELT-MOS White Paper: Science Overview & Requirements
Issue	1.0
Date	22 February 2013
Editors	Chris Evans (UK ATC) & Mathieu Puech (GEPI)

Contributors:

Beatriz Barbuy, Nate Bastian, Piercarlo Bonifacio, Elisabetta Caffau, Jean-Gabriel Cuby, Gavin Dalton, Ben Davies, Jim Dunlop, Chris Evans, Hector Flores, Francois Hammer, Lex Kaper, Bertrand Lemasle, Simon Morris, Laura Pentericci, Patrick Petitjean, Mathieu Puech, Daniel Schaefer, Eduardo Telles, Niraj Welikala, Bodo Ziegler



# *ELT-MOS White Paper*

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- SC1: First light - spectroscopy of the most distant galaxies
- SC2: Spatially-resolved spectroscopy of high-z galaxies
- SC3: Role of high-z dwarf galaxies in galaxy evolution
- SC4: Tomography of the IGM
- SC5: Resolved stellar populations beyond the Local Group
- SC6: Galaxy archaeology with metal-poor stars

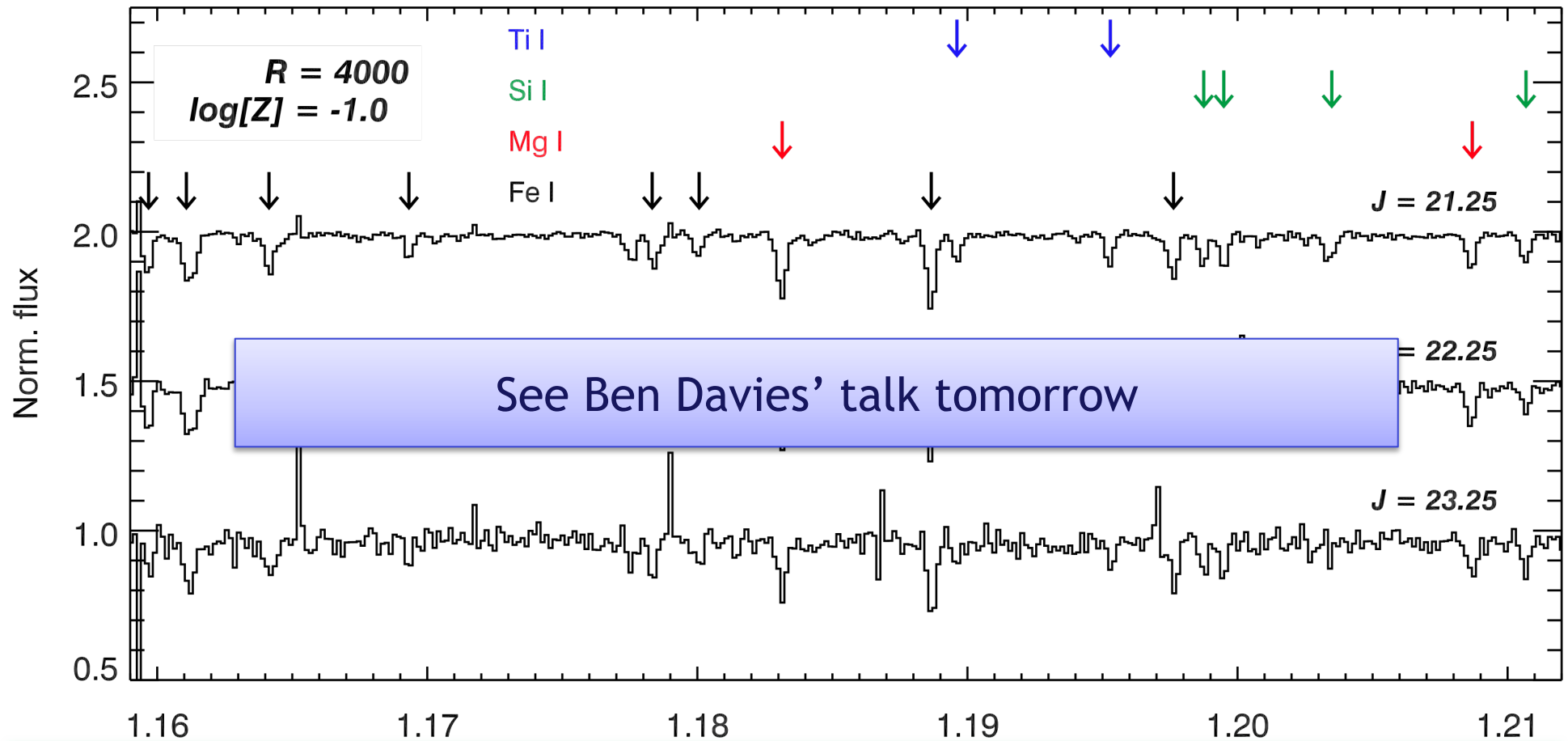
& more...





# Example trade-off: Opt. vs. nIR?

Davies et al. (2010)  
Evans et al. (2011)



AO correction better in J-band, and stars are intrinsically red  $(I-J) = 0.5-1.0$

# ELT-MOS White Paper

Table 3: Summary of top-level requirements from each Science Case

Case	Target densities	FoV/target	Spatial resolution	$\lambda$ -coverage ( $\mu\text{m}$ )	$R$
SC1	1-2 arcmin <sup>-2</sup>	2" × 2" <sup>3</sup>	40-90 mas	1.0-1.8 1.0-2.45	5,000
	10s arcmin <sup>-2</sup>	–	(GLAO)	1.0-1.8 1.0-2.45	>3,000
SC2	1-2 arcmin <sup>-2</sup>	2" × 2"	50-80 mas	1.0-1.8 1.0-2.45	5,000
	10s arcmin <sup>-2</sup>	–	(GLAO)	1.0-1.8 1.0-2.45	> 3,000
SC3	≥ ~20 arcmin <sup>-2</sup>	–	(GLAO)	0.8-1.7	≥5,000 ~10,000
SC4	0.5-1 arcmin <sup>-2</sup>	2" × 2"	(GLAO)	0.4-1.0 0.37-1.0	5,000 10,000
SC5	Dense	1" × 1" 1.5" × 1.5"	≤75 mas 20-40 mas	1.0-1.8 0.8-1.8	5,000
	10s arcmin <sup>-2</sup>	–	(GLAO)	0.4-1.0	≥5,000 ≥10,000
SC6	10s arcmin <sup>-2</sup>	–	(GLAO)	0.41-0.46 & 0.60-0.68 0.38-0.46 & 0.60-0.68	≥15,000 ≥20,000

# ELT-MOS White Paper

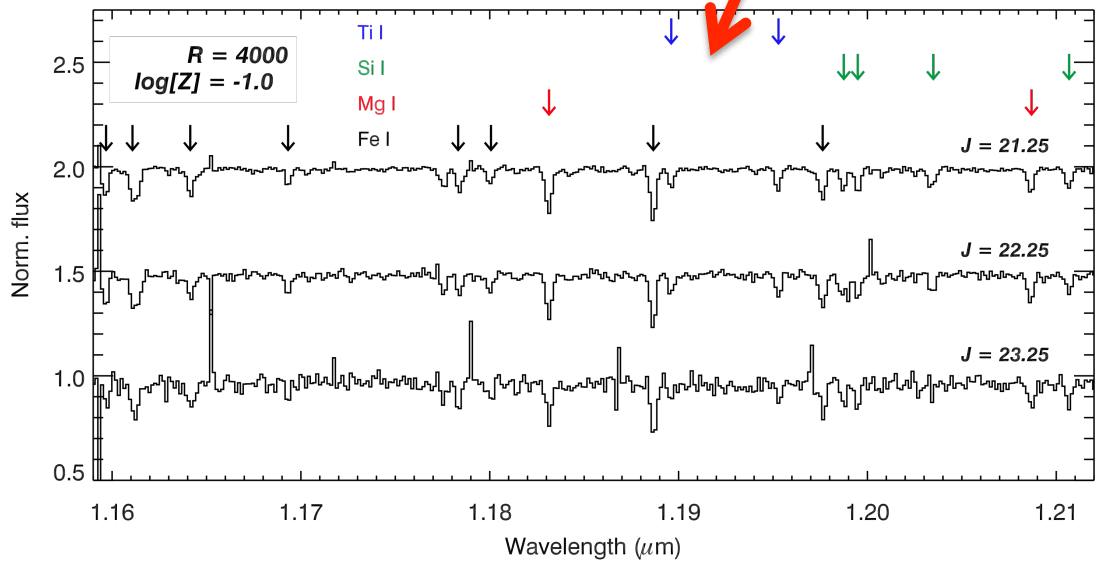
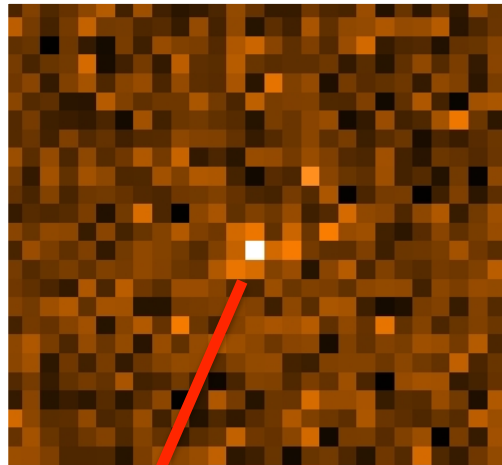
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Case	Target densities	FoV/target	Spatial resolution	$\lambda$ -coverage ( $\mu\text{m}$ )	$R$
SC1	1-2 arcmin <sup>-2</sup>	2" × 2" <sup>3</sup>	40-90 mas	1.0-1.8 1.0-2.45	5,000
	10s arcmin <sup>-2</sup>	–	(GLAO)	1.0-1.8 1.0-2.45	>3,000
SC2	1-2 arcmin <sup>-2</sup>	2" × 2"	50-80 mas	1.0-1.8 1.0-2.45	5,000
<p>Next stage: prioritise requirements from the different cases via trade-offs, taking into account technical &amp; operational feasibility</p>					
SC4	0.5-1 arcmin <sup>-2</sup>	2" × 2"	(GLAO)	0.4-1.0 0.37-1.0	5,000 10,000
SC5	Dense	1" × 1" 1.5" × 1.5"	≤75 mas 20-40 mas	1.0-1.8 0.8-1.8	5,000
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# Example trade-off: Spatial sampling?

See poster by  
Puech et al.

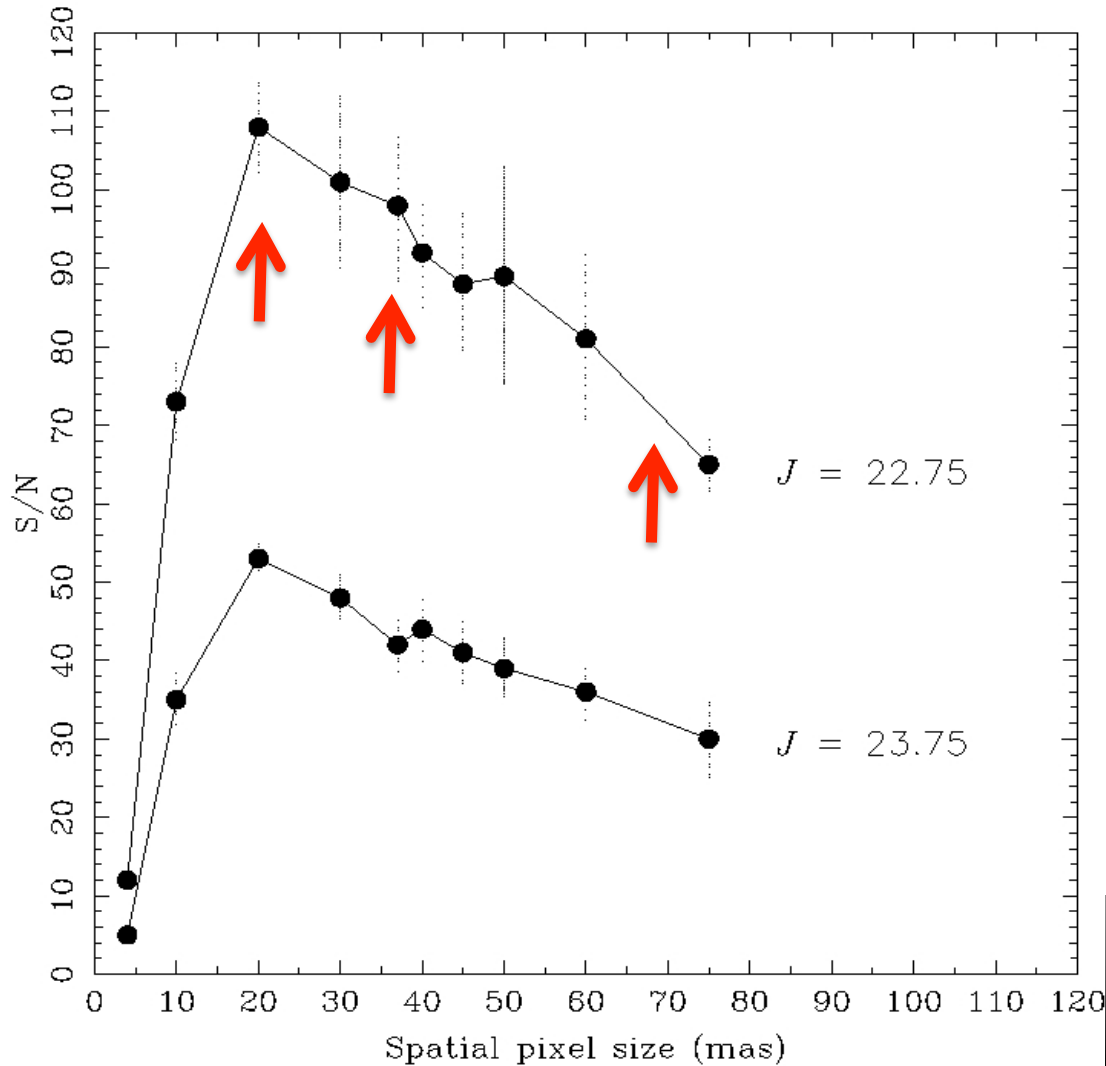
- Spectral simulations using ‘WEBSIM’ from Puech et al. (2008)
- MOAO PSFs
- $t_{\text{int}} = 10\text{hrs}$
- J-band
- $R \sim 4000$



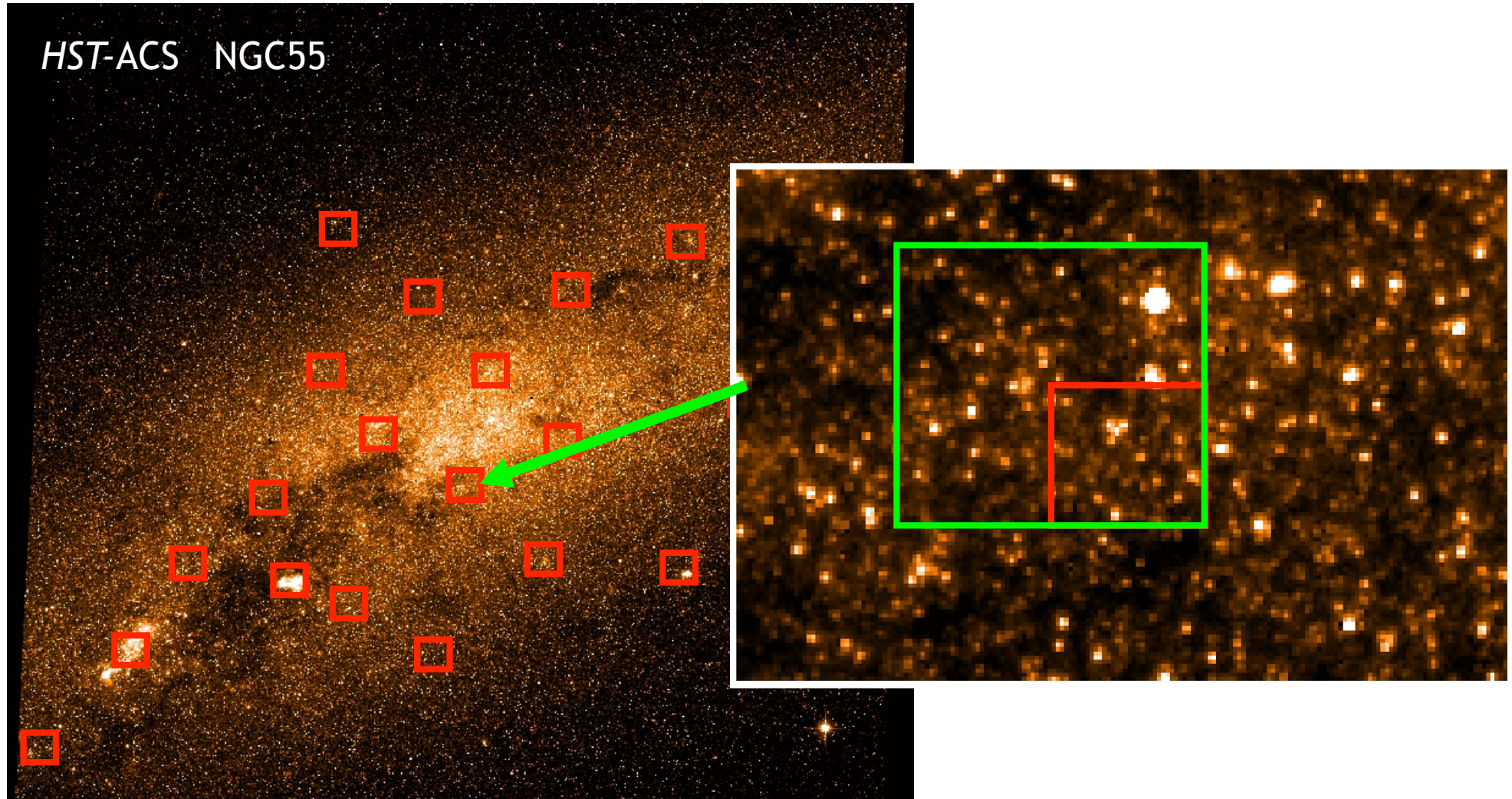
# Example trade-off: Spatial sampling?

See poster by  
Puech et al.

- Spectral simulations using ‘WEBSIM’ from Puech et al. (2008)



# Spatial sampling vs. survey speed

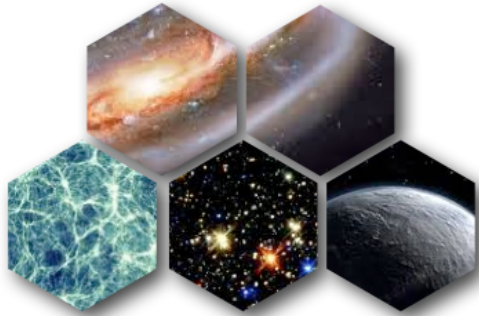


# Summary

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- Compelling & well-defined cases for an ELT-MOS
- ELT-MOS White Paper presenting top-level cases
- Two modes: ‘high multiplex’ & ‘high definition’
- MOS instruments have become the workhorses of the 8-10m
- MOS instruments early-on in GMT and TMT plans
- An E-ELT MOS will be an essential part of its instrument suite

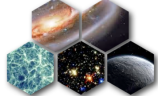




# MOSAIC







Poster by Jagourel et al.

Synergies with HIRES?



## MOSAIC : The E-ELT MOS

Pascal Jagourel, Alistair Basden, Beatriz Barbay, Fanny Chemla, Jean-Gabriel Cuby, Gavin Dalton, Chris Evans, Hector Flores, Eric Gondron, François Hammer, Peter Hastings, Zoltan Hubert, Lex Kaper, David Lee, Richard Myers, Simon Morris, Tim Morris, Phil Parr, Burman, David Pearson, Mathieu Puech, Phil Rees, Gérard Rousset, Hermine Schnettler

### MOSAIC

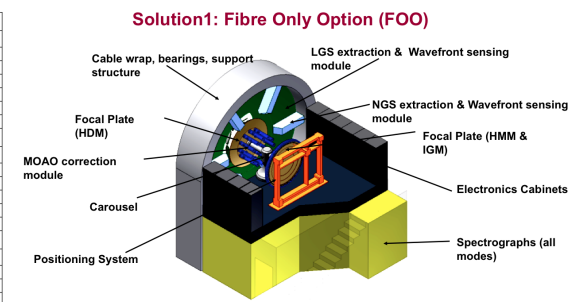
Multi-Object Spectrograph for Astrophysics, IGM studies and Cosmology

There is a strong and compelling case for MOSAIC as one of the first E-ELT instruments offering both **high multiplex** and **high definition** capabilities. By exploiting the excellent image quality across the full focal plane of the telescope, combined with its tremendous light-gathering power, we will be able to obtain the large samples necessary to tackle some of the key scientific drivers of the E-ELT project, ranging from studies of **stellar populations** out to the **highest-redshift galaxies**.

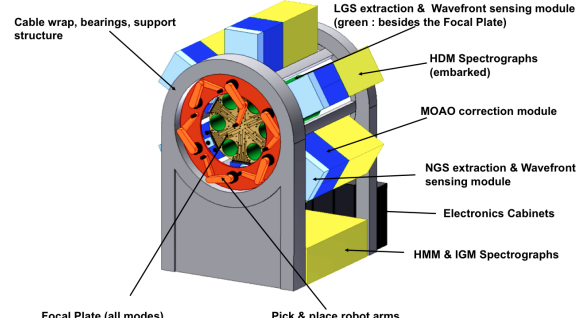
#### Instrument modes & Specifications

High Definition Mode (HDM)	
Parameter	Range
IFU field of view	1.5 x 1.5 arcsec - 2.0 x 2.0 arcsec
Multiplex	≥ 10 IFUs
Spatial pixel size	40 - 80 mas
Ensquared Energy	30% - 40% EE
Spectral Res. Power	≥ 4000
λ coverage (not simult.)	1.0 - 1.8 μm up to 0.8 - 2.45 μm
High Multiplex Mode (HMM)	
Parameter	Range
On Sky Aperture	0.9 arcsec
Multiplex	100 - 200
Spatial pixel size	≤ 0.9 arcsec
Spectral Res. Power	≥ 5000 & 20000
λ coverage (simultaneous)	0.4-1.0 μm up to 0.37-1.8 μm @ R ≥ 5000
InterGalactic Medium (IGM)	
Parameter	Range
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 up to 0.37 - 1.0 μm

#### Solution1: Fibre Only Option (FOO)



#### Solution 2: Mixed Architecture Design (MAD)



*What is next ?*

*Perform all trade offs and come out with a unique solution while considering :*

*The expected Science*

*The costs*

*The operability*

*The complexity*

*The risks*

*The schedule*

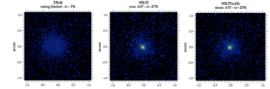
### CANARY : The MOAO pathfinder !

Rayleigh LGS

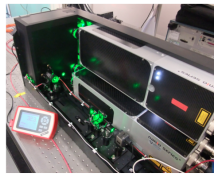
- Range 10 to 20 km, gate up to a few km

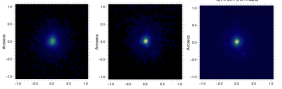
To LGS/NGS mode (2012)

On-sky results with 3 off-axis NGS + 1 on-axis LGS for tomography



Seeing: 3%    SCAO: 27%    MOAO: 25%





GLAO: 16%    SCAO: 37%    MOAO: 34%

**MOSAIC will benefit from an on sky fully proven MOAO Mode !**