Science requirements for a high-definition mode for the ELT-MOS

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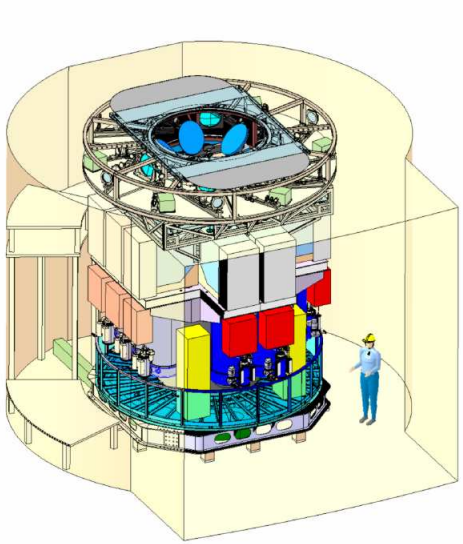
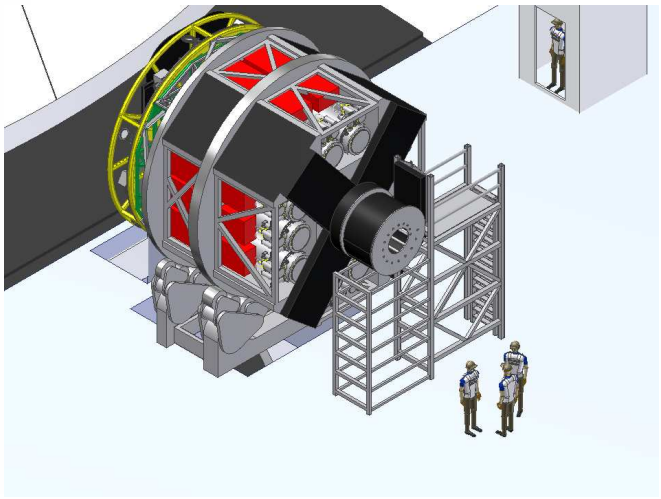
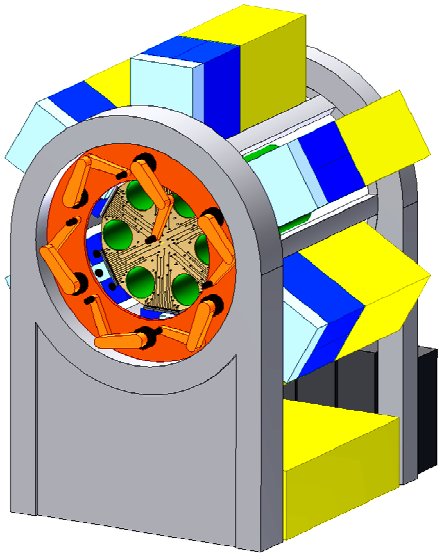
For the EAGLE & MOSAIC teams







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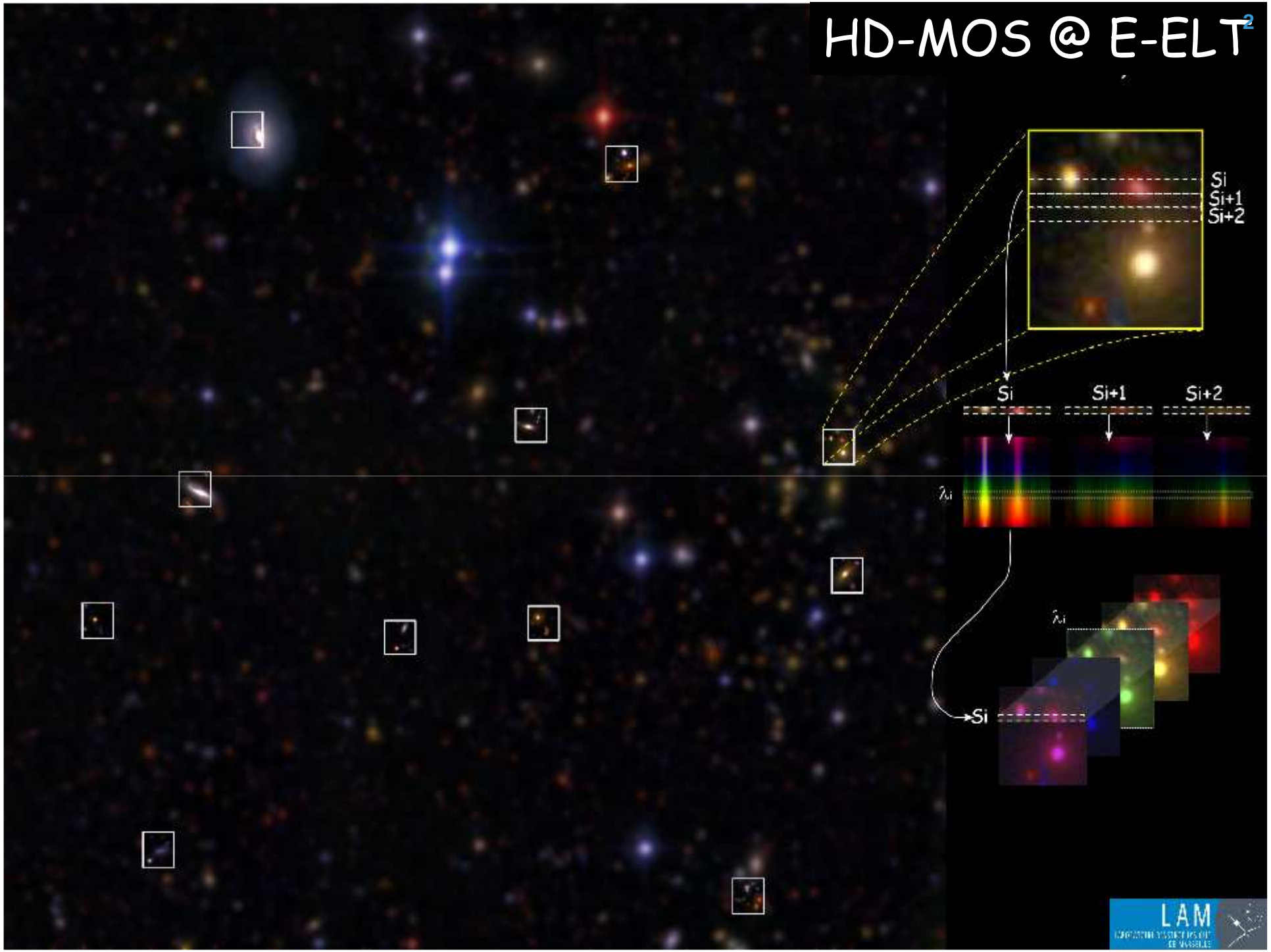
HD-MOS @ E-ELT



Background

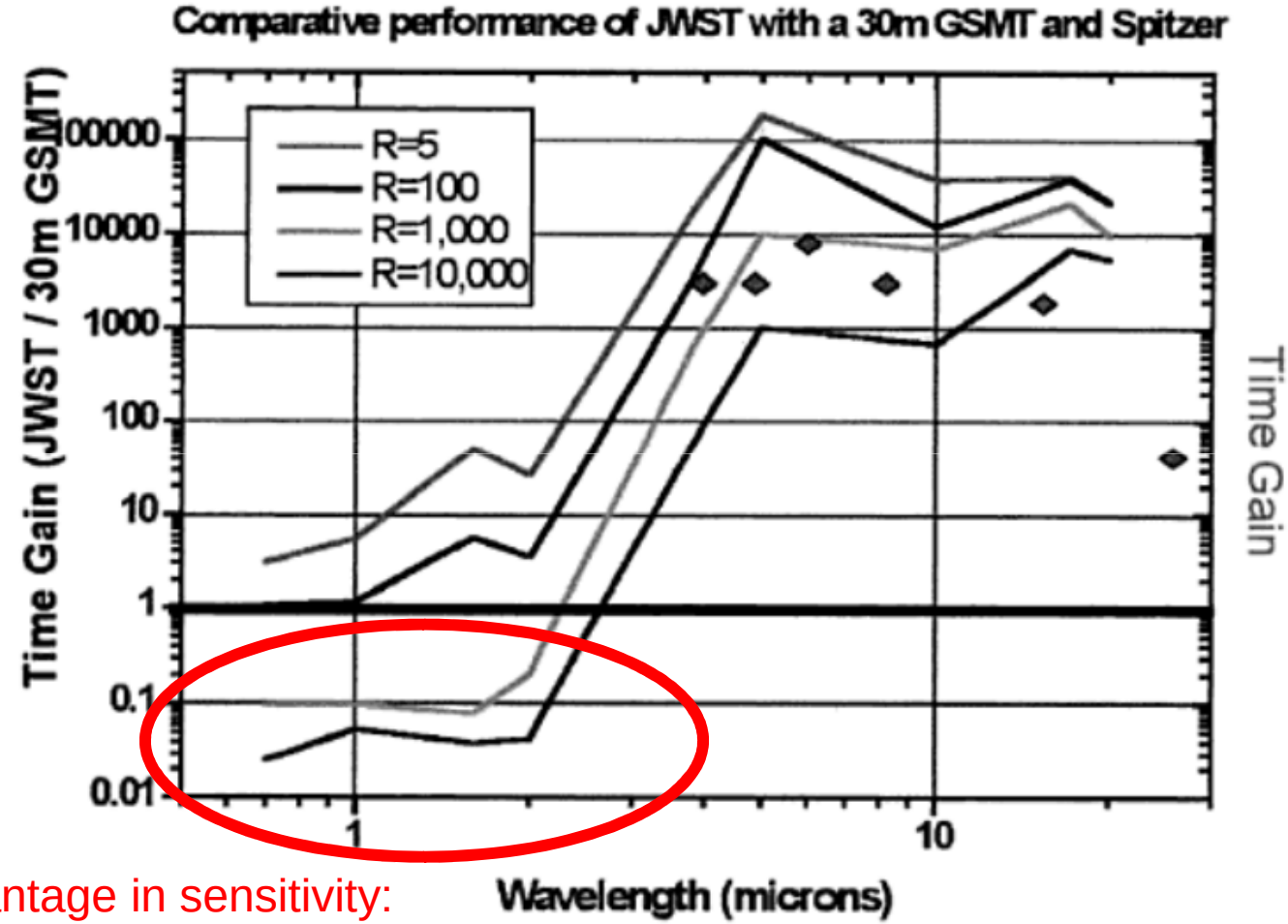
- Already 10+ yrs of science cases and instrument studies for the ELTs…
- High definition MOS modes (near IR, multi-IFU spectrographs, possibly AO assisted) have been in the ELT instrumentation plans from their inceptions.
  - OWL / MOMFIS, ELT/WFSPEC (FP6), E-ELT/EAGLE, TMT/IRMOS, GMT / MANIFEST
- For addressing highlight ELT science cases: first galaxies, mass assembly of galaxies, stellar populations beyond the Local Group, …
- Has the science perspective changed ?
- Not really. It has evolved. Much more interest now in re-ionization history than 10 yrs ago, making this top priority JWST science case stronger than ever.
- We now have now much more science data (from HST/WFC3 in particular) to reliably assess the scientific performance of ELTs, and to evaluate it in the context of JWST

Synergy with JWST

- Important to carefully address for the first yrs of E-ELT operation
- JWST will provide SEDs of exquisite quality (and homogeneity) from 0.6 to 20 μm of galaxies up to z = 10+, but will have limited spectroscopic performance on continuum sources (mostly readout noise limited in the near IR).
  - E-ELT gain over JWST: factor of 10-30 in time (depending on various assumptions)
- JWST will do *relatively* better, compared to ELTs, on emission lines than on continuum spectroscopy at R~100-1000 with NIRSpec
- Note: if JWST will bring exceptional added value, we could start today with the E-ELT: lots of targets already exist (in the 100s for the high-z targets), in most cases with HST imaging and multi-wavelength data. Many targets are too faint for follow-up by the E-ELT…

Background. Synergy with JWST

Gardner, 2006

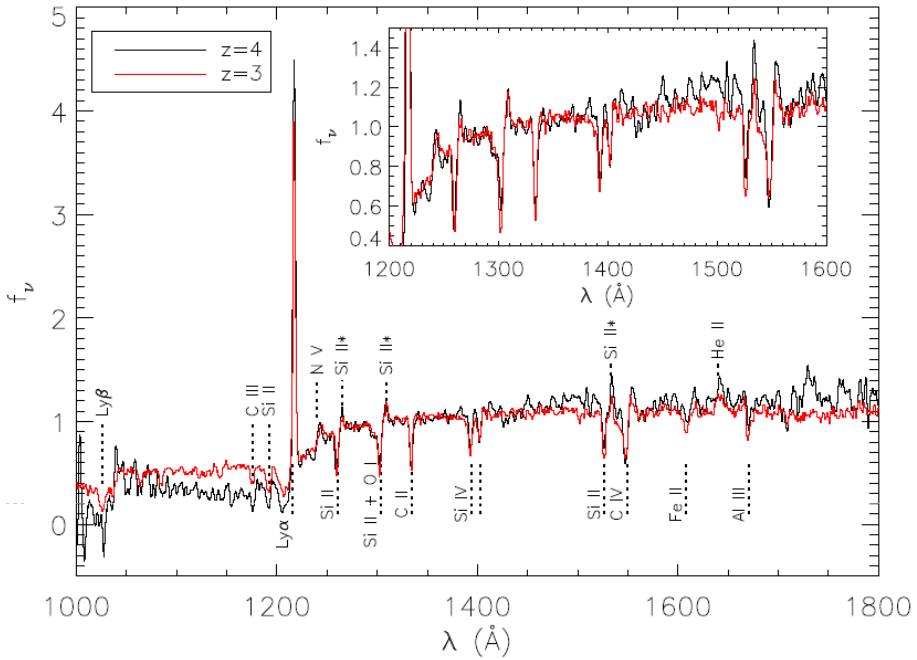


The ELT advantage in sensitivity: near IR, spectroscopy

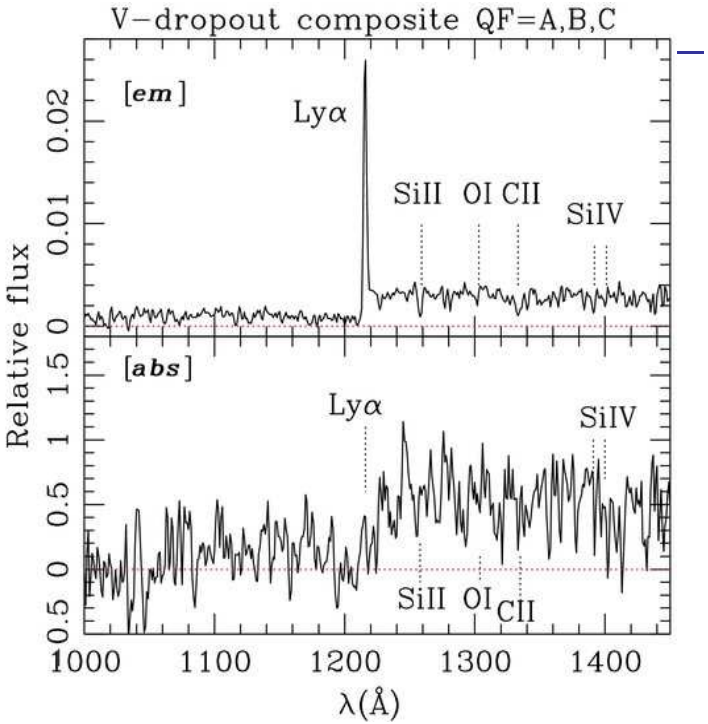
The most distant galaxies

- Re-ionization: transmission $T_{Ly\alpha}(z)$ of Lyα by the IGM as a function of z
  - Search for Lyα emission on high-z galaxies (found by WFC3/JWST). Faint objects, tens to hundreds of objects in the EELT field of view.
  - Active field of research today (see talks and posters from Dunlop, Kneib, Pentericci) with WFC3 imaging and follow-up spectroscopy with VLT, Keck etc.
  - LOFAR and SKA precursors will provide complementary data (HI). Clustering $T_{Ly\alpha}(x,y,z)$due to patchy reionization might be the next challenge (Complementarity between HI and $T_{Ly\alpha}(z)$). Lots will be done in the next 10-15 yrs. Also, JWST will do its share (emission line sensitivity).
- What will remain untouched is the UV continuum spectroscopy of these galaxies: do at z = 8 what VLT and Keck do at z = 3 to 5, enabling the study of the physical properties of the ISM, age, stellar populations, outflows, etc.

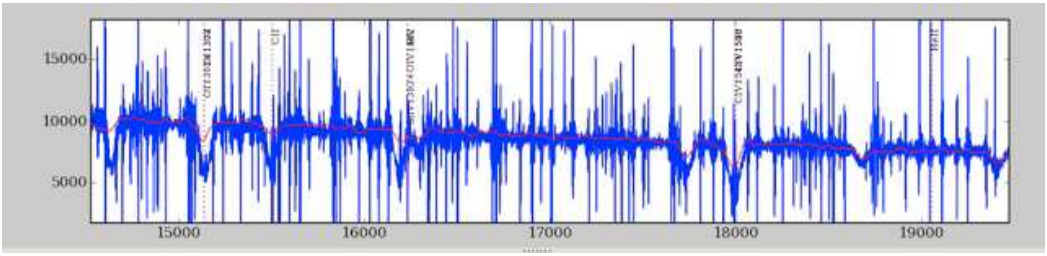
The most distant galaxies

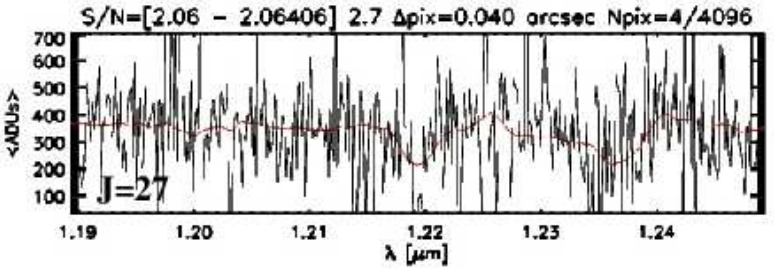


Shapley et al., 2003, Jones et al., 2011



Vanzella et al., 2009





E-ELT simulations. z ~ 8

Shaping E-ELT Scier

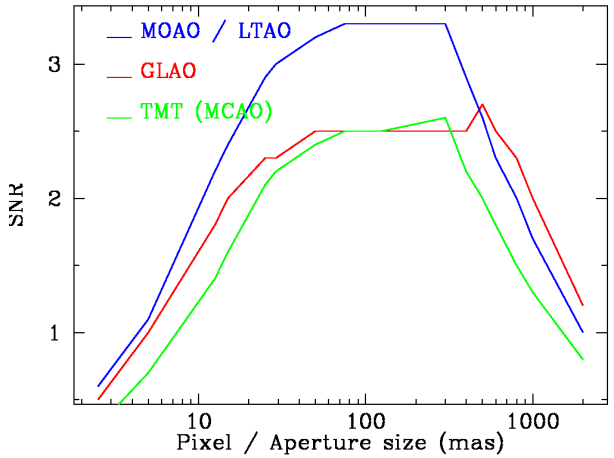
The most distant galaxies

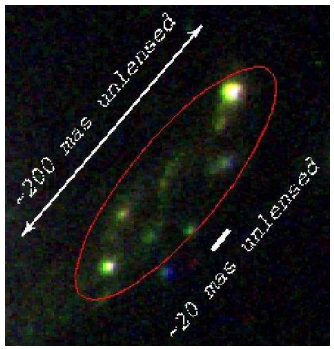
The requirements are:

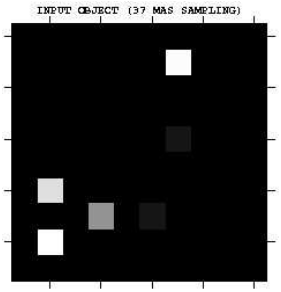
- Max patrol field
- Multiplex ~ 20 (matched to AB=27 surface density)
- Near IR (Y to Ks)
- AO assistance to improve the SNR…

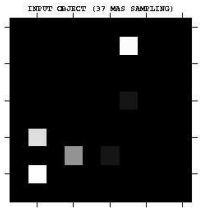
… and to enable spatially-resolved spectroscopy

Note:
50-100 mas spaxel sampling, not diffraction limited ! Similar to JWST, ALMA

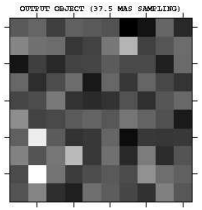




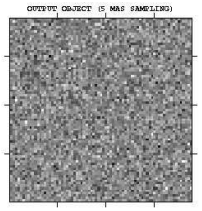




Simulated image



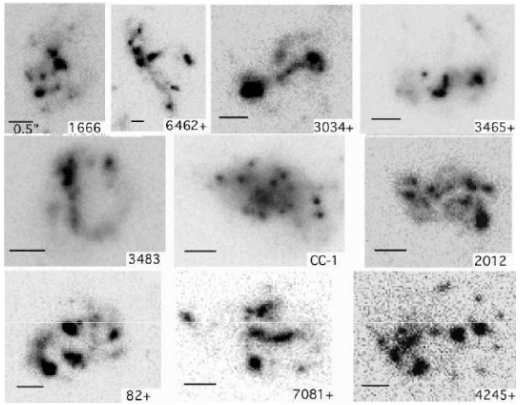
37 mas pixels

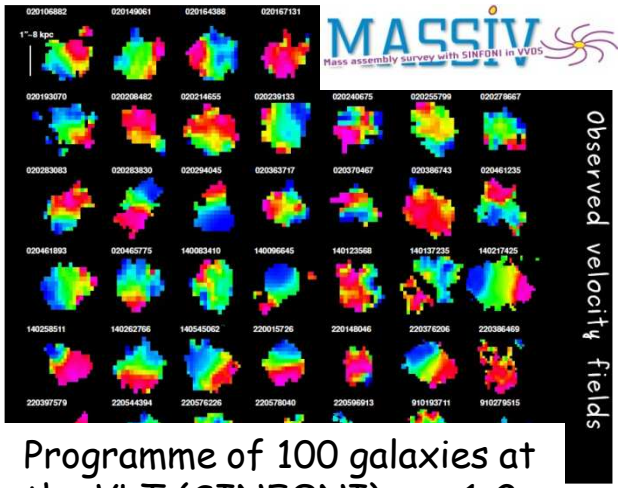


5 mas pixels

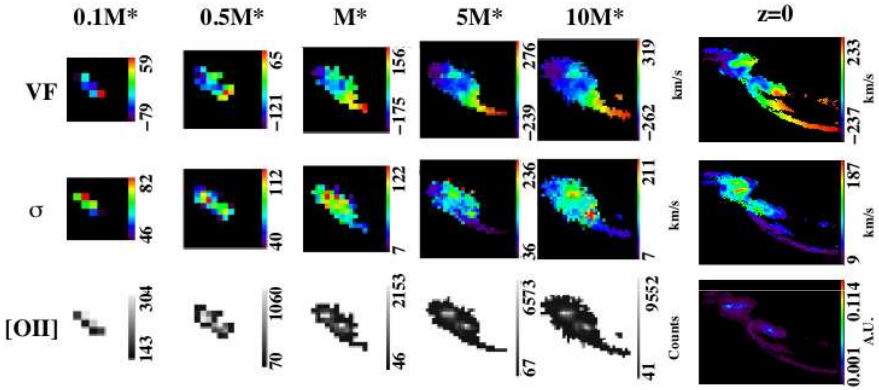
Spatially resolved properties of distant galaxies

The physics of galaxies at z = 3-6. Main processes of galaxy formation? Gas accretion? Mergers (major/minor)?





Programme of 100 galaxies at the VLT (SINFONI). z = 1-2



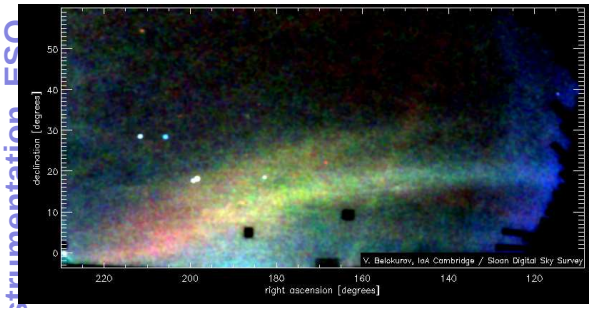
EAGLE simulations of a z = 4 merger (Puech et al.)

Requirements:

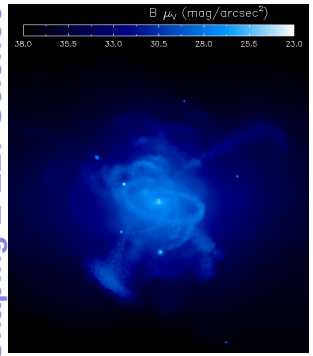
- Max field of view
- Multiplex > 20
- 3D capabilities (IFU, fov ~ 2")
- Near IR J to K bands
- Image quality – AO assisted

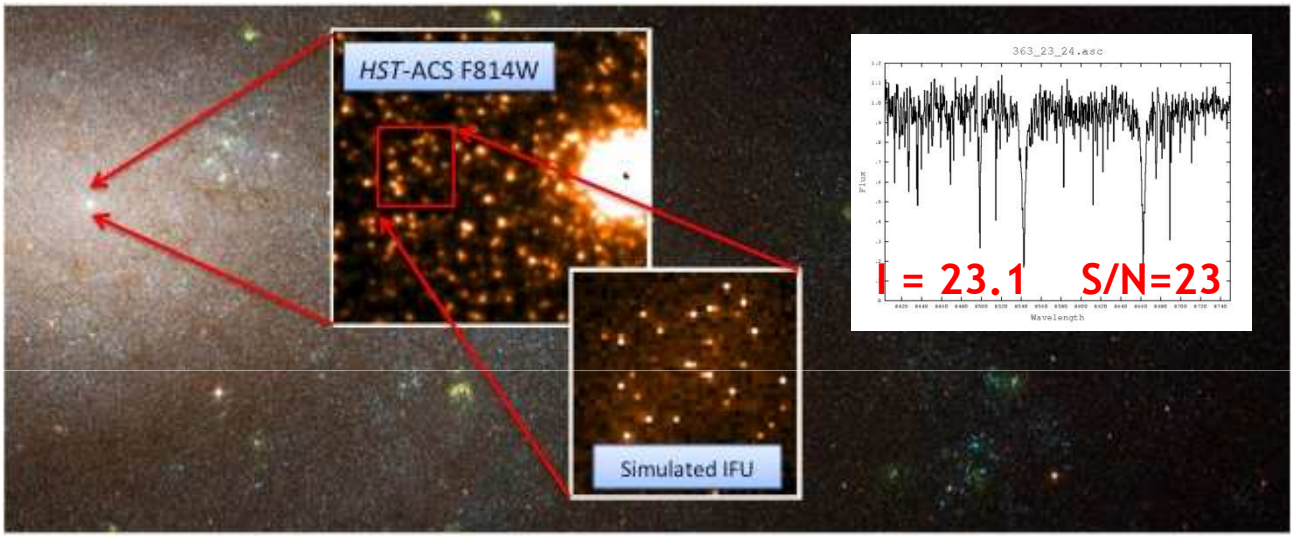
Resolved stellar populations beyond the Local Group

Stellar archaeology from resolved stellar populations and kinematics.



Studies in MW, MCs, nearby dwarph speroidal galaxies, etc.





EAGLE simulations of stellar spectra in a nearby galaxy at 2 Mpc

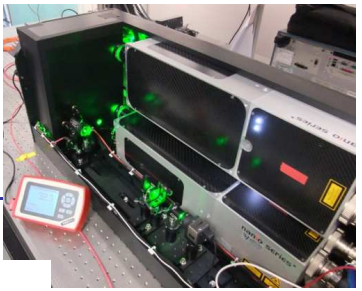
Requirements:

- High multiplex / distributed geometry
- I band (Ca Triplet) → Can be done in the J band
- Image quality – AO assisted (SNR, confusion)
- Spectral resolution (R > 8,000)

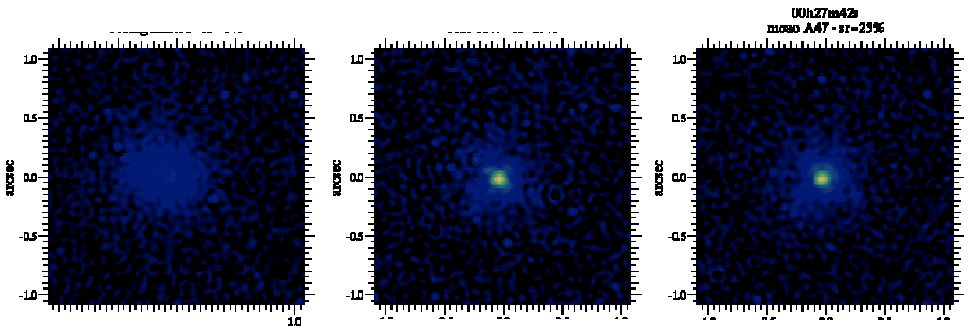
Technology Readiness

- The EAGLE Instrument Phase A Study has demonstrated that the Technology Readiness Level (TRL) of all sub-systems had TRL > 6-7, but for:
  - Real Time Controller and Wavefront Sensors that need be developed for the E-ELT
  - MOAO as a system. Currently TRL = 5 after Canary NGS and LGS demonstration phase. Multi-LGS demonstration phase in progress
  - 84x84 Deformable Mirrors, but backup solutions exist with commercially available DMs (e.g. 64x64 Boston DMs for GPI/Gemini)

CANARY: the MOAO pathfinder

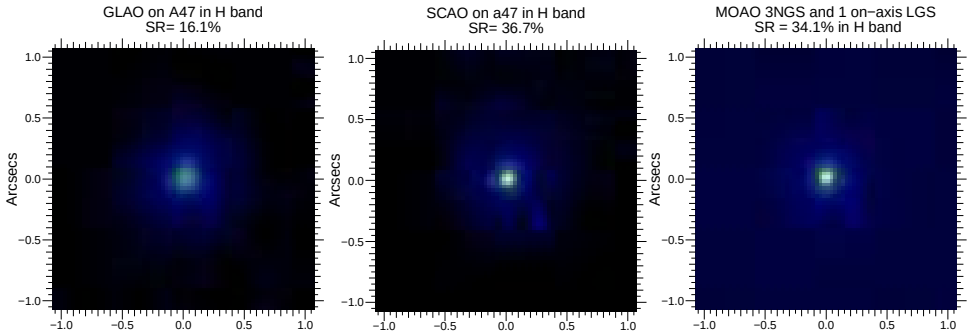


From NGS mode (2010)



Seeing 3% SCAO 27% MOAO 25%

To LGS/NGS mode (2012)



GLAO 16% SCAO 37% MOAO 34%

Conclusions

- A high definition MOS mode is as much required for the E-ELT as it was 10 yrs ago. It will ideally complement JWST, ALMA etc. in a 'spectroscopic follow-up' mode enabling to tackle key scientific questions otherwise impossible to address.

- The TRL is high enough that no further R&D is required. Development programs should be started instead, essentially for the Deformable Mirrors (several vendors in Europe and US)

- Clearly, this is one flavor of MOS among others. Some combination of MOS instruments or modes is required to address the huge variety of science cases that the E-ELT will address, a la MANIFEST for GMT.

MOSAIC (see poster by P. Jagourel