The future of near-IR spectroscopy: MOONS@VLT, ERIS@VLT, HIRES@E-ELT and NIRSpec@JWST

... in 8 minutes!

G. Cresci
INAF – Osservatorio di Arcetri

Meeting MacroArea 1 - Bologna 16/6/16

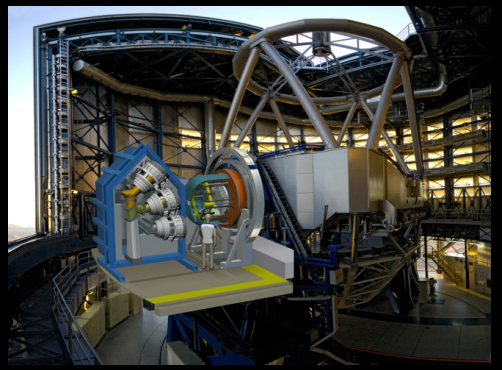
MOONS

Multi-Object Optical and Near-infrared Spectrograph for the VLT

INAF contribution: in-kind 390 k-Euros and 32 FTEs on:

- Spectrometer optics and mechanics, Arcetri (*co-PI: E. Oliva*)
- Observation preparation software, Milano
- Secondary guidance systemand End-to-end simulations, Roma

INAF return: 45 nights GTO (+ contracts to Italian companies)



First light: 2019

MOONS in a nutshell

Field of view: 500 sq. arcmin at the 8.2m VLT

Multiplex: 1000 fibers, 1" on sky each, with possibility to deploy them in pairs

Medium resolution:

Simultaneously 0.64-1.8µm

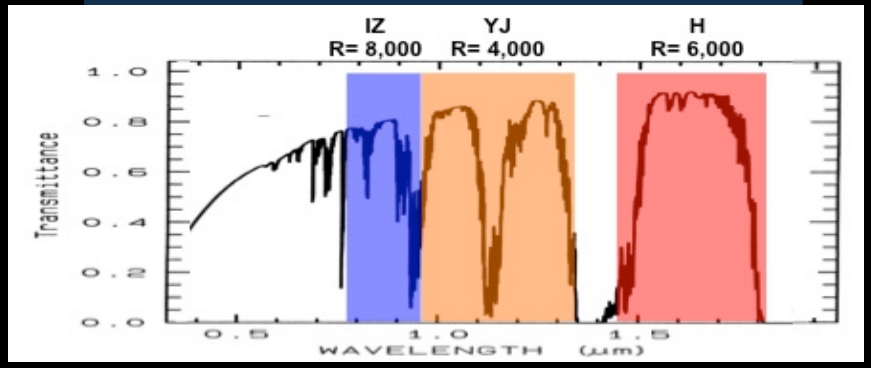
at

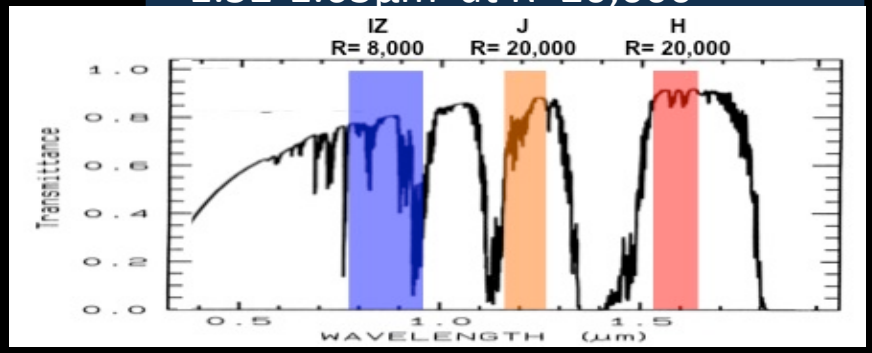
R=4,000 – 6,000

High resolution:

Simultaneously 3 bands:

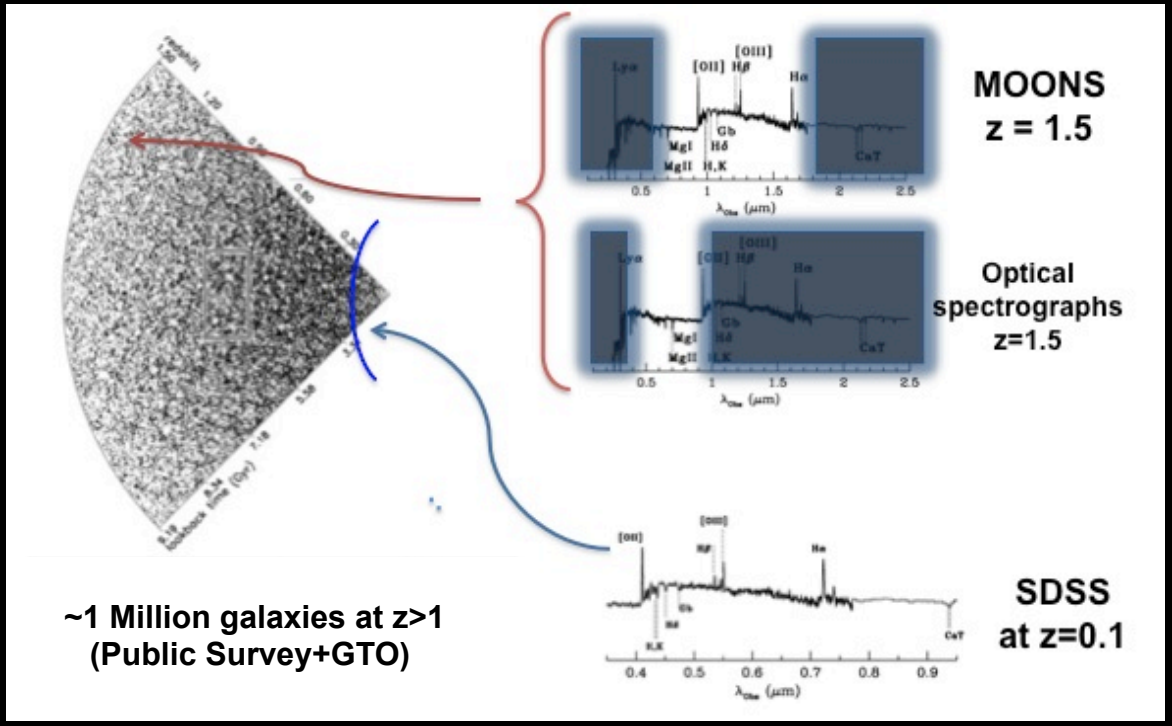
- 0.76-0.95µm at R = 9,000
- 1.17-1.26µm at R=20,000
- 1.52-1.63µm at R=20,000





Throughput ~ 30%: 1 hr -> 2 10^{-17} erg/s for emission lines at 5 σ, continuum AB=22

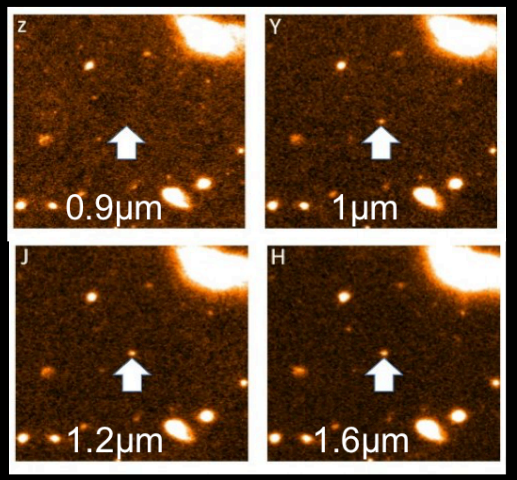
1) a SDSS-like machine at the peak of galaxy and BH formation



- ✓ Large scale structures and the role of environment
- ✓Galaxy evolution diagnostic (Metallicity, SFR, AGN, Dust, mass, BH mass, outflows and feedback etc…)
- ✓Evolution of Fundamental relations at high-z
- ✓Evolution of massive galaxies, including the passive population

2) the first galaxies and the epoch of re-ionization

- ✓ Spectroscopic confirmation of the most distant galaxies
- ✓ Establish the Lyman-α escape fraction and unveil the physics of re-ionization
- ✓ Measure star-formation and mass assembly of primeval galaxies
- ✓ Clustering of high-z galaxies and constrain the re-ionization



ERIS: Enhanced Resolution Imager and Spectrograph

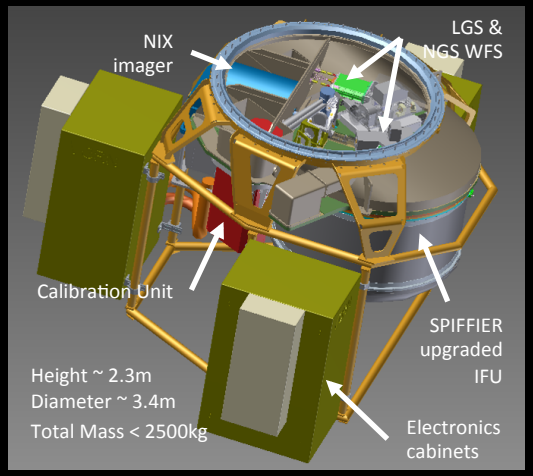
ERIS is the new generation upgrade for both NACO and SINFONI, and will be a fundamental AO capability for the VLT

MPE · INAF Istituto Nazionale di Astrofisica · Science & Technology Facilities Council UK Astronomy Technology Centre · ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich · ESO

INAF contribution 32%

- Arcetri – *Adaptive Optics, warm optics*
- Teramo – *calibration unit*
- Padova – *control SW*

INAF return: 60 nights GTO



First light: 2020

ERIS in a nutshell

AO modes
- i) NGS AO
- ii) LGS AO
- iii) seeing enhancer (LGS AO without tip-tilt)
- iv) seeing limited

Observing modes

1. SPIFFI — Integral field spectroscopy
   FoV 0.8", 3.2", 8"; R~3000 & 8000; J-K bands

2. NIX — Imaging
   J-K narrow/broad bands; 13/27 mas pix (26"/55" FoV)
   L-M broad bands; 27 mas pix (55" FoV)

3. NIX — High contrast imaging
   Pupil plane coronagraph (L-M)
   Focal plan coronagraph (L-M)*
   Sparse aperture Masking (J-M)

4. NIX — long slit spectroscopy R=500, LM band simultaneously

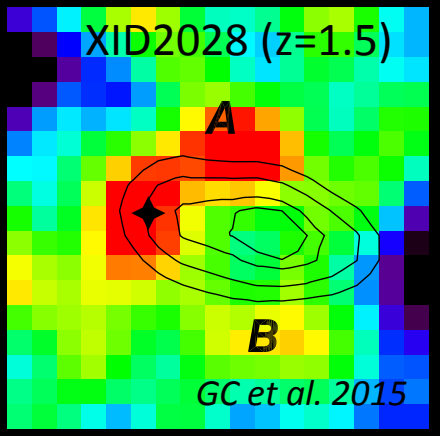
ERIS: Detailed Galaxy Evolution at High Redshift

Signatures of physical processes driving mass assembly & structural transformations

- Growth of bulges & disks
- Inflows in disks
- Imprint of clumps & (minor) mergers in kinematics
- Star formation (in clumps vs interclump)
- Feedback & quenching (outflows from star formation & AGN)

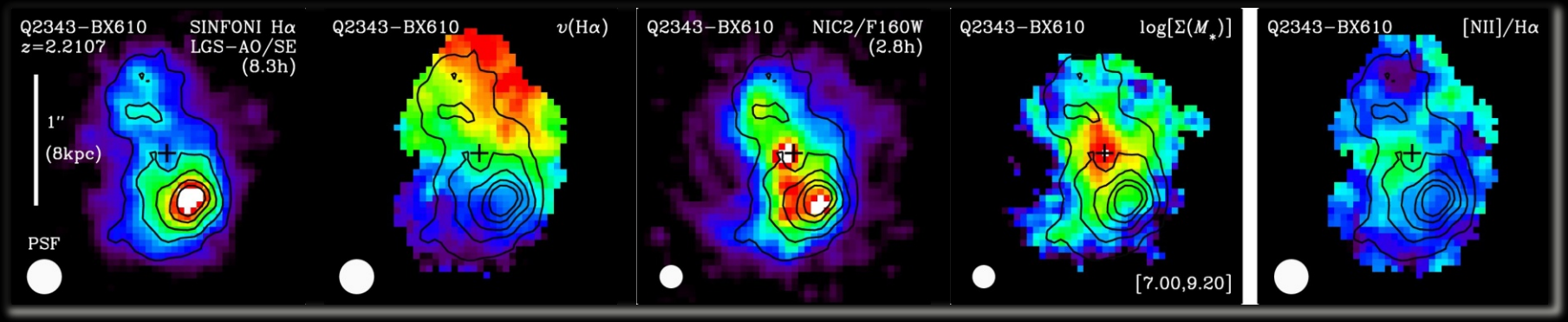
are often on scales 1 kpc and a few 10s of km/s

IFU+AO required to fully map physical properties

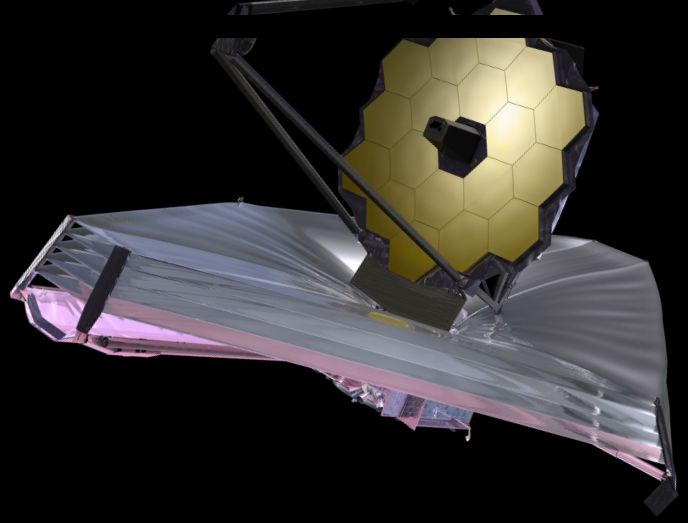


QSO outflow
(Blueshifted [OIII], contours)
on Hα map (Star Formation)

Q2343-BX610 (z=2.21, Forster-Schreiber, GC et al. 2009)



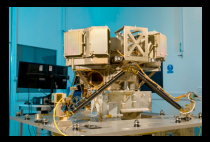
Star formation | Kinematics | Stellar light | Stellar mass | Nebular physics



James Webb Space Telescope

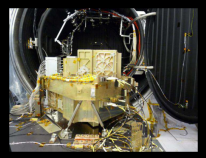
Launch: 2018

MIRI

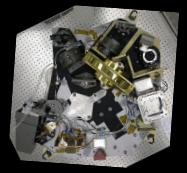


NIRSpec

FGS/NIRISS



NIRCam

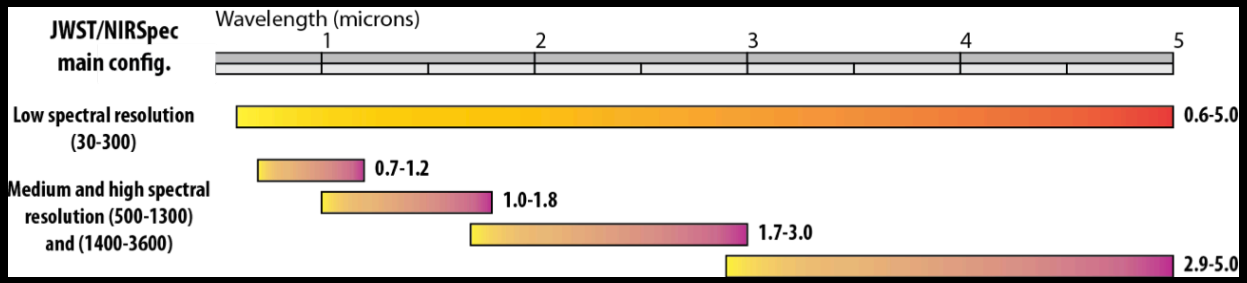


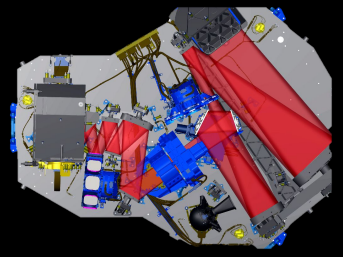
- JWST will be one of the "great observatories" of the next decade
  - joint mission between NASA, ESA and CSA
- Spectral coverage: optical to MIR (0.6-28 μm)
  - Both imaging and spectroscopic capabilities
- High sensitivity and angular resolution, low background
  - A cryogenic telescope at L2, with a 6.5 m mirror, diffraction limited at ~2 μm (0.068")
- To be launched in October 2018 for a minimum mission duration of 5 years (10-year goal). Start of science ops first half 2019
  - Over the duration of the mission, > 15% of the total JWST time to ESA member states applicants
  - Early Release science proposal deadline: August 2017, letter of intent February 2017 (!! NOW !!)

NIRSpec
NEAR-INFRARED SPECTROGRAPH

NIRSpec provides the JWST's main near-infrared spectroscopic capabilities in the 0.6-5 micron range

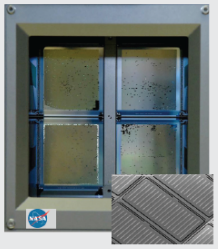
– Part of the ESA contribution to the JWST mission.





JWST/NIRSpec

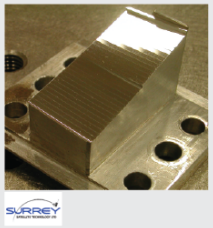
MOS



Multi-object spectroscopy with 0.2"-wide mini-slits.

- 9 square arcmin. field of view
- Low spectral resolution (30 to 300), prism-based mode covering the 0.6-5.0 micron range in one exposure.
- Medium spectral resolution (500 to 1300), grating-based mode covering the 0.7-5.0 range

IFU



IFU spectroscopy with a 0.1" sampling.

(IFU made of 30 slices for a total of 900 "spaxels")

- 3"x3" field of view
- Low spectral resolution (30 to 300), prism-based mode covering the 0.6-5.0 micron range in one exposure.
- Medium (500 to 1300) and high (1400-3600) spectral resolution modes, covering the 0.7-5.0 range in 4 exposures.
- IFU and MOS cannot be used at the same time.

SLIT

High-contrast slit spectroscopy.

(including with a 1.6"x1.6" square aperture for extra-solar planet transit observation)

- 5 slits available

All spectral resolution modes available.

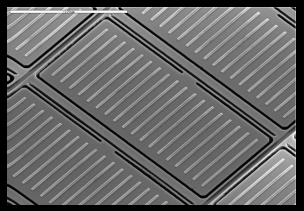
- SLIT can be used simultaneously to IFU or MOS.

NIRSpec: the challenge of MOS in space

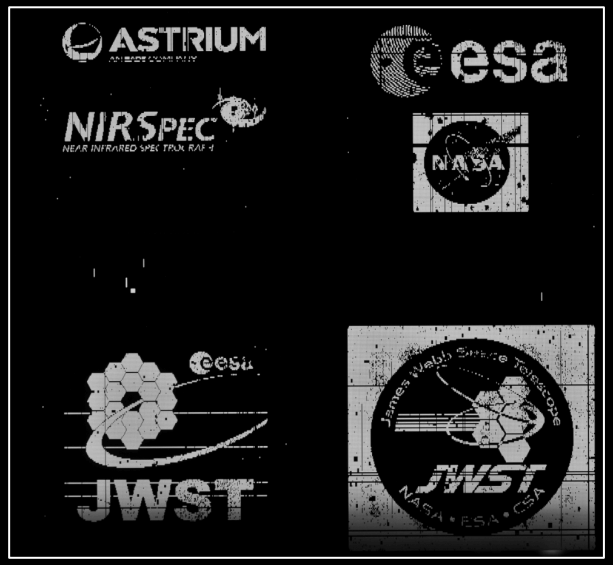
- Letting the light from selected objects (> 100) go through while blocking the light from all the other objects
- A configurable mask needed

Using 4 arrays of 365x171 micro-shutters each, provided by NASA GSFC.

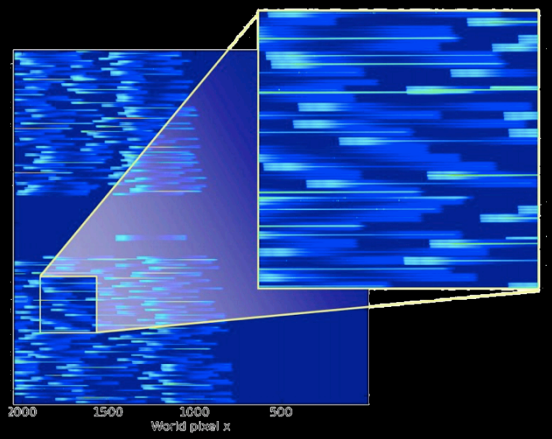
This gives us a total of almost **250 000** small apertures that can be individually opened/ closed



MEMS device – 105x206 micron shutters



> 90% of the shutters are operable

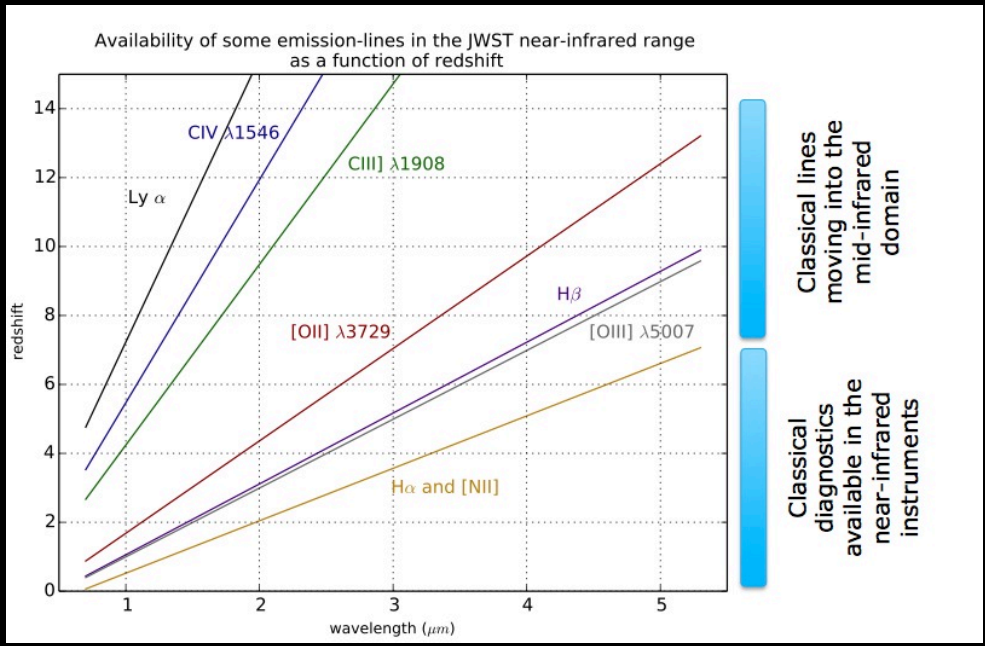


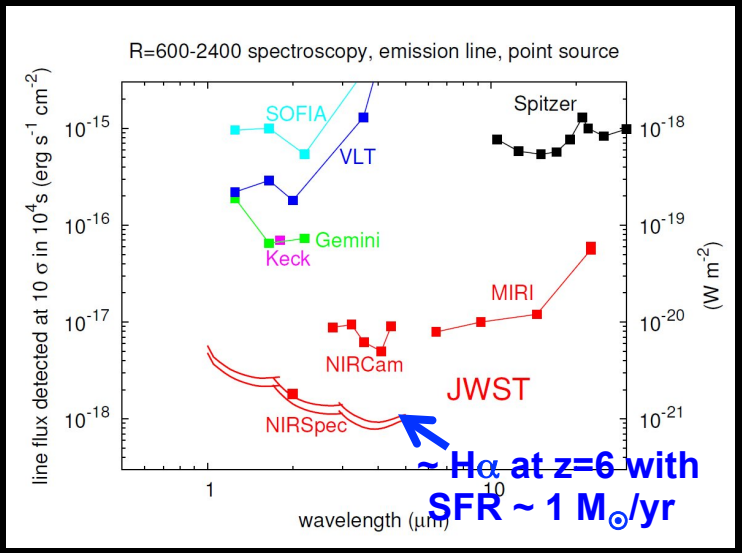
NIRSpec: a new window

While all previous studies limited to galaxies at z<3.5, due to accessible emission lines.

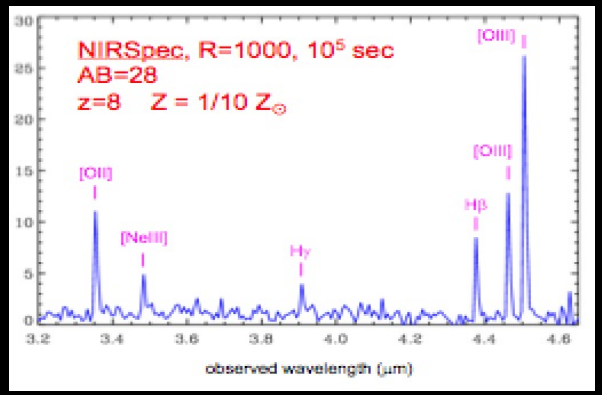
NIRSpec finally expands these studies to galaxies at z>4, up to the reionization epoch and the formation of first galaxies (z~7-10)

(see E. Vanzella talk later)





Spectroscopy: AB=29 (!!!) continuum at S/N=10 in 10^5 sec (current limit ~K_{AB}<22)



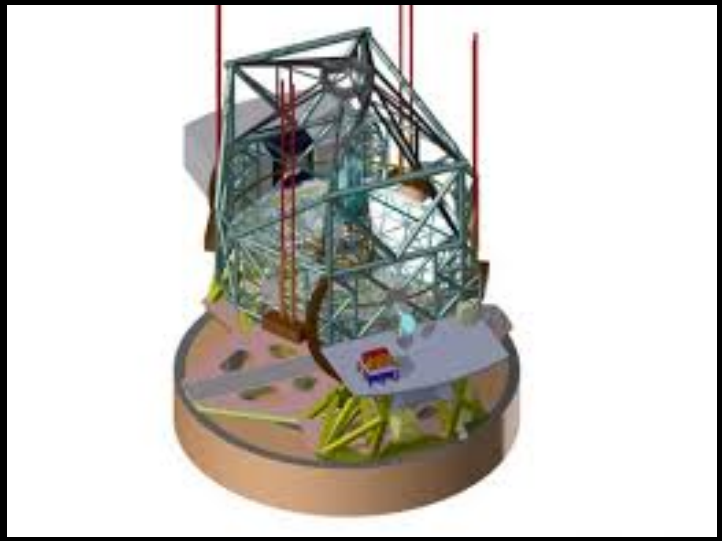
E-ELT HIRES

High Spectral resolution R~100,000 over 0.4-2.5 μm

Merging of instruments in early E-ELT phases: CODEX (optical) and SIMPLE (near IR)

International Consortium:

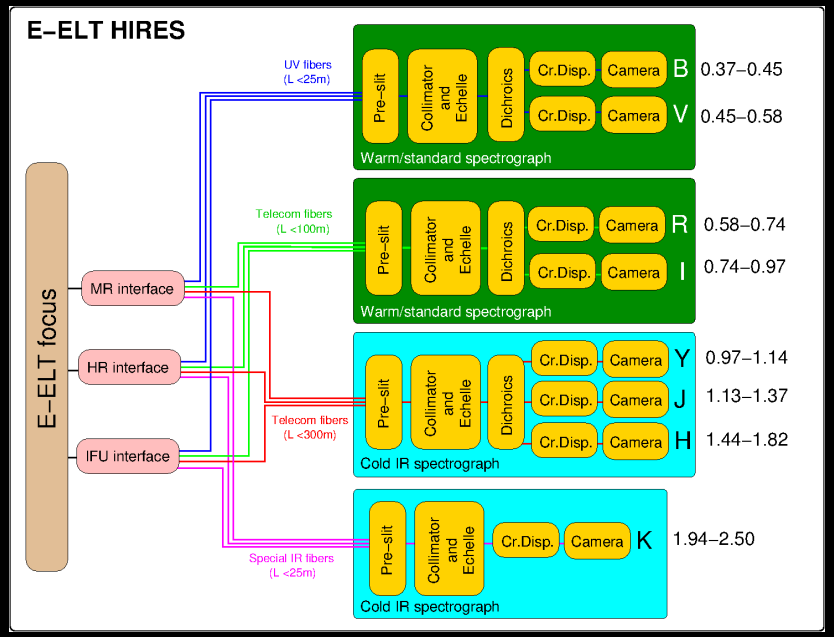
- Italy INAF lead technical institution, A. Marconi PI
- Brazil (Theoretical and Experimental Physics of the Natal University), Chile (Pontificia Universidad Catolica+), Denmark (Niels Bohr Institute Copenhagen +), France (Laboratoire d'Astrophysique de Marseille+), Germany (Leibniz-Institute for Astrophysics Potsdam+), Poland (Nicolaus Copernicus University Toruń +) Portugal (Institute of Astrophysics and Space Sciences), Spain (Instituto de Astrofisica de Canarias+), Sweden (Uppsala University+), Switzerland (Observatoire de Genève+), United Kingdom (University of Cambridge+)

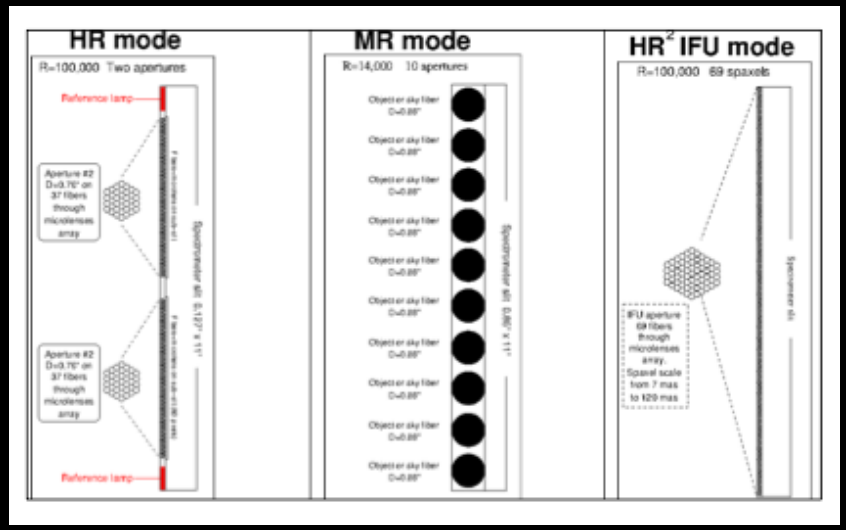


HIRES Consortium has been awarded the Phase A study for a high resolution spectrograph at E-ELT → Kick Off date: March 22, 2016, Max Duration: 2 years

E-ELT HIRES: Instrument Concept

- 4 independent fiber-fed spectrometers optimized over 4 spectral ranges (UBV, RI, YJH, K): simultaneous coverage 0.37-2.5 µm
- Different observing modes are obtained using different and independent groups of fibers feeding each spectrometer: from bundle of fibers to pseudo-slits
- "Seeing" or diffraction limited
- Possible main observing modes
  - UHR R=150,000
  - HR R=100,000
  - MR R=15,000 x10 MOS capability
  - HR2 R=100,000 IFU with 69 spaxels





E-ELT HIRES: Science Teams

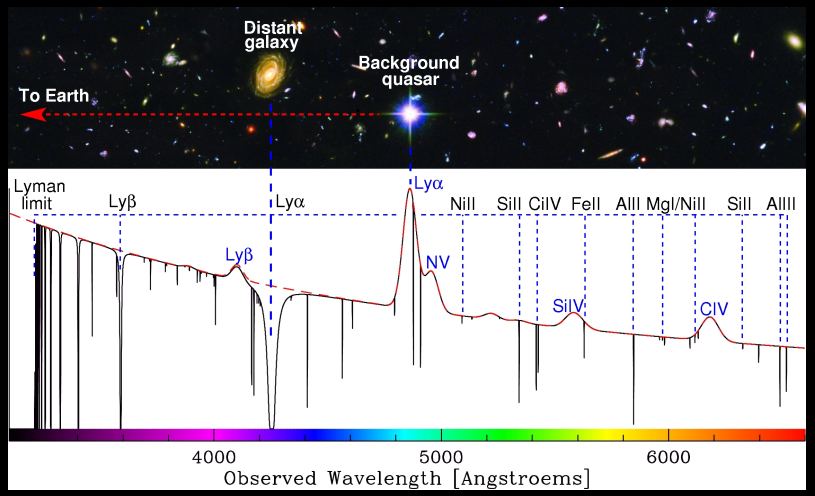
MA 1 related HIRES Science Team WG:

- ✓ **Formation and evolution of Galaxies and Intergalactic Medium**

Coordinator D'Odorico, V., Deputy Zackrisson E.,
…, GC, Stefano Covino, …

- ✓ **Cosmology and Fundamental Physics**

Coordinator Liske, J., Deputy Martins, C.
…, Stefano Cristiani, Paolo Molaro, …



Italian Science Team that follows HIRES development and provides support to HIRES Science Team and forum on high-res spectroscopy in general

Coordinator: Stefano Cristiani

If interested send email to:
Stefano Cristiani (cristiani@oats.inaf.it)
Alessandro Marconi (marconi@arcetri.inaf.it)

http://www.hires-eelt.org/

E-ELT HIRES: Science Cases

- ✓ Exoplanets (characterisation of Exoplanets Atmospheres: detection of signatures of life)
- ✓ Stellar Astrophysics (abundances of solar type and cooler dwarfs in galactic disk bulge, halo and nearby dwarfs: tracing chemical enrichment of Pop III stars in nearby universe)
- ✓ Intergalactic Medium (Signatures of reionization and early enrichment of ISM & IGM observed in high-z quasar spectra, Metals from first stars)
- ✓ Fundamental Physics (variation of fundamental constants - α, mp/me Sandage Test)
- ✓ Protoplanetary Disks (dynamics, chemistry and physical conditions of the inner regions)
- ✓ Stellar Populations (metal enrichment and dynamics of extragalactic star clusters and resolved stellar populations)
- ✓ Galaxy Evolution (massive early type galaxies during epochs of formation and assembly, gas flows in/out galaxies)
- ✓ Supermassive Black Holes (the low mass end)

Community White Paper: Maiolino et al. 2013, ArXiV:1310.3163