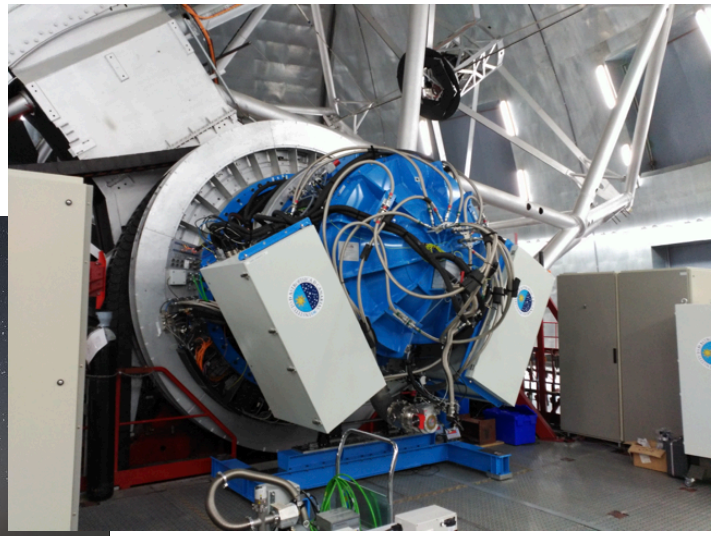
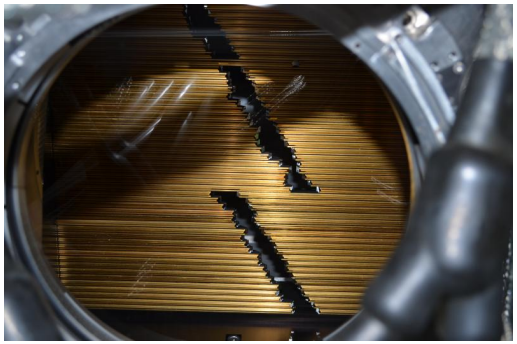
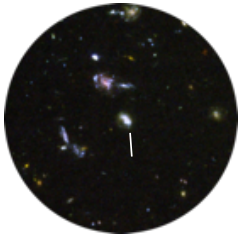
Dwarf Star-forming galaxies at different z with GTC/EMIR

J. Gallego, N. Cardiel, C. Cabello, S. Pascual, F. Garzón, M. Balcells, M. Prieto, R. Pelló, L. Domínguez-Palmero, N. Laporte, L. Patrick, A. Streblyanska, R. Guzmán, C. Krittapas







IPARCOS

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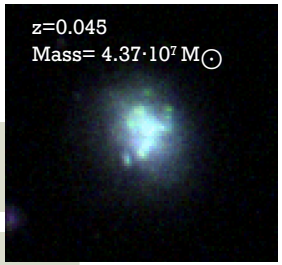
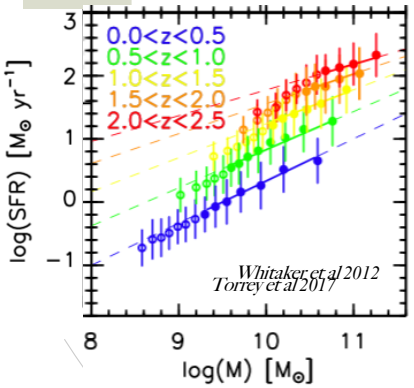
- Pilot study with VIMOS/VLT
- The GOYA survey with EMIR/GTC
- Early results with EMIR
- Dwarf galaxies: a Science Case for MOSAIC/ELT

The role of dwarf galaxies in Galaxy Evolution

Why study Low-Mass SFGs?

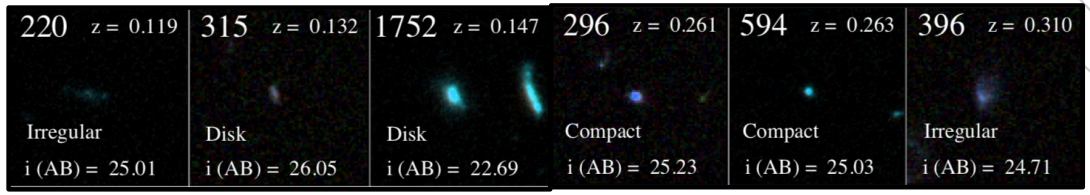




- They are the most poorly known.

  Very faint and small ⟹ difficult to observe.

- Biased to local samples and clusters

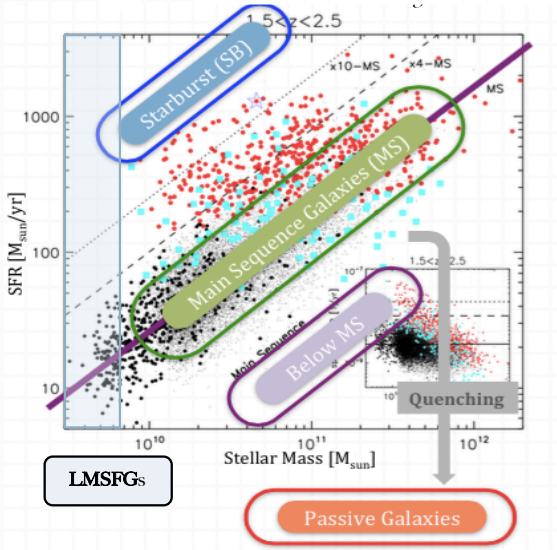


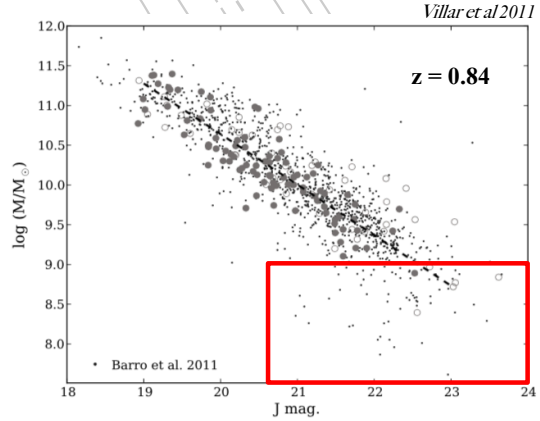
- Similar to first galaxies. Simplified scenarios ⟹ Reionization.

- Abundant systems.
  Dwarfs are the most common galaxies
  and play a significant role in galaxy evolution.

- Candidates to host the coalescence of black hole binary systems (BHB) generating GW150914-like events (Marassi+19)

- **High-redshift systems are much younger, so are less evolved**





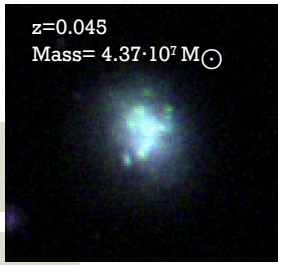
The role of Dwarf Galaxies in Galaxy Evolution

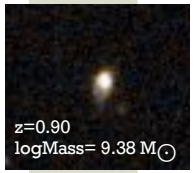
Determine physical properties of dwarf galaxies at different redshifts

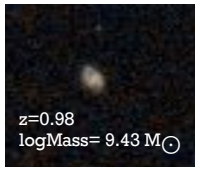
- Star Formation History
- Mass assembly
- Formation redshift
- Cosmic role

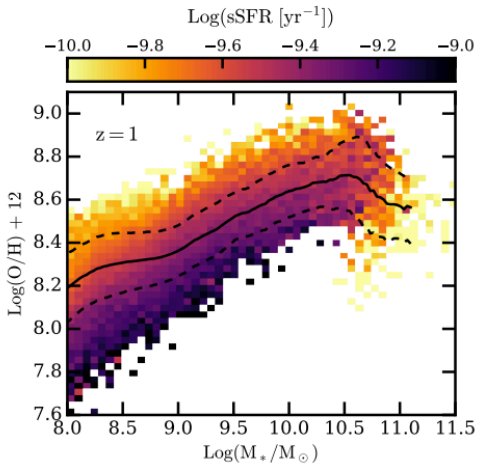
Mass assembly not well understood

- Early formation model (Dekel & Silk 1986)
- Delayed formation model (Kepner+ 1997)
- Mass dependent scheme (Mamon+ 2012)









1. To study these distant faint (J_{AB}~22-24) galaxies we need to employ infrared techniques and large ~10m telescopes.

2. The high spatial density makes them ideal for large surveys fillers!

Pilot study with VIMOS/VLT

Rodríguez-Muñoz
Ph.D. thesis
& et al. 2015

Physical properties of dwarf galaxies at different redshifts

t0 : Look-back time of the first burst
t10: Look-back time when forms 10% stellar mass
t50: Look-back time when forms 50% stellar mass

LMSFGs: Low-Mass Star-Forming Galaxies

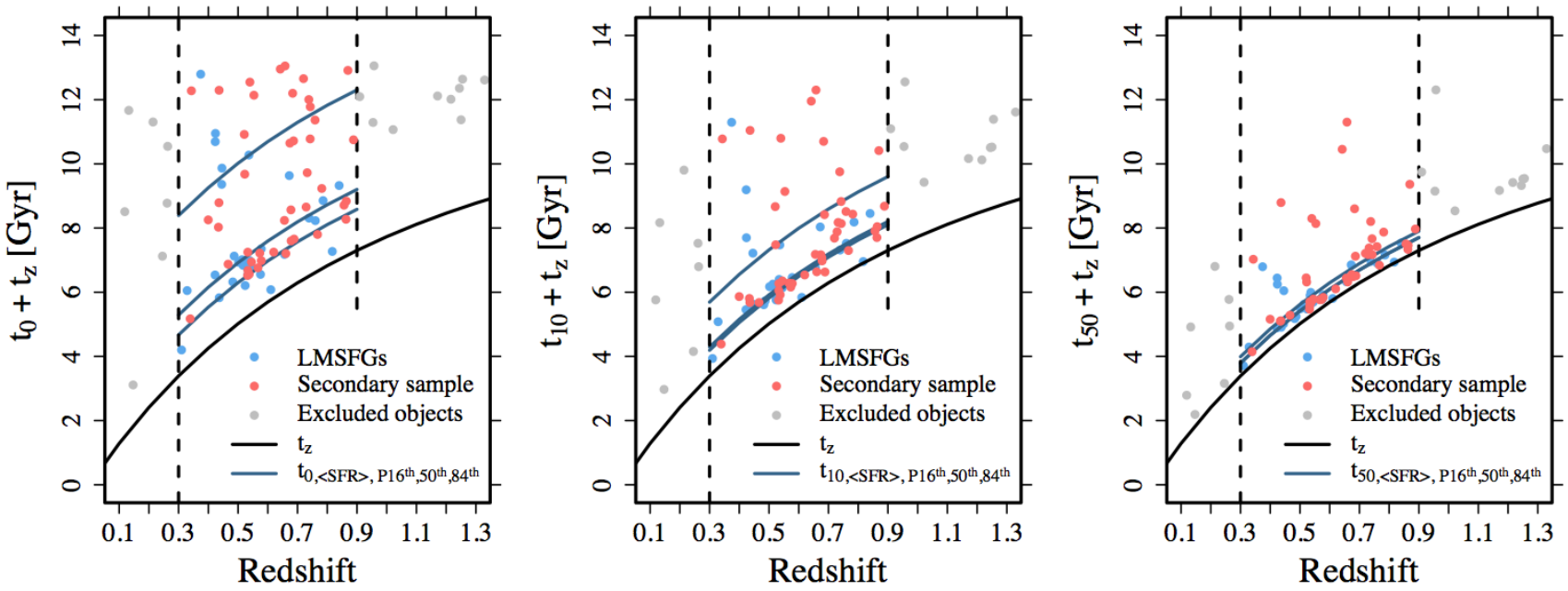
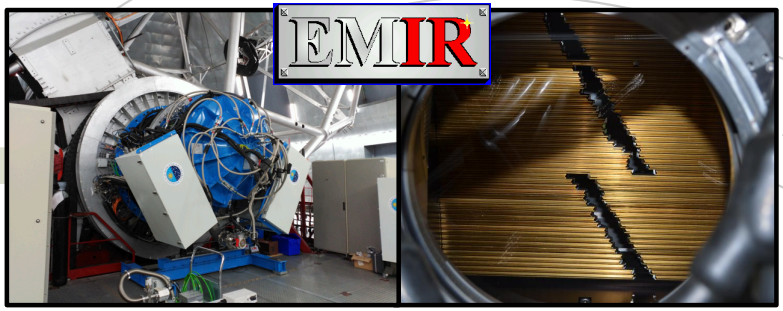


FIG. 1.— From left to right: t_0, t_{10}, and t_{50} of each individual galaxy accounting for the lookback time at the redshift of observation (t_z, black solid line). The LMSFGs and the secondary sample are represented with blue and red points respectively. Vertical black dash lines mark the limits of the final redshift range considered. Blue lines represent the values of $t_{0,\langle SFH\rangle}$, $t_{10,\langle SFH\rangle}$, $t_{50,\langle SFH\rangle}$, and associated dispersion for the LMSFGs sample.

The GOYA (*Galaxy Origins and Young Assembly*) survey with EMIR/GTC

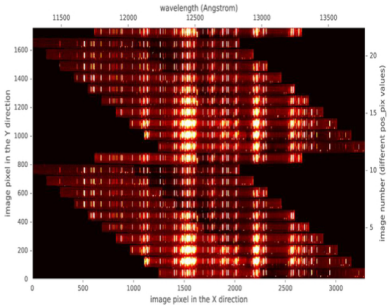
EMIR IR-MOS



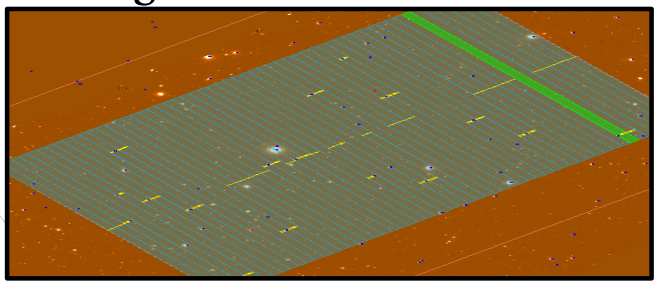
FoV: 4' x 6.67'
Spectral range: 0.9 - 2.5 μm

CSU (Configurable Slit Unit)

Allow to configure and observe in real time up to **55 slits!**



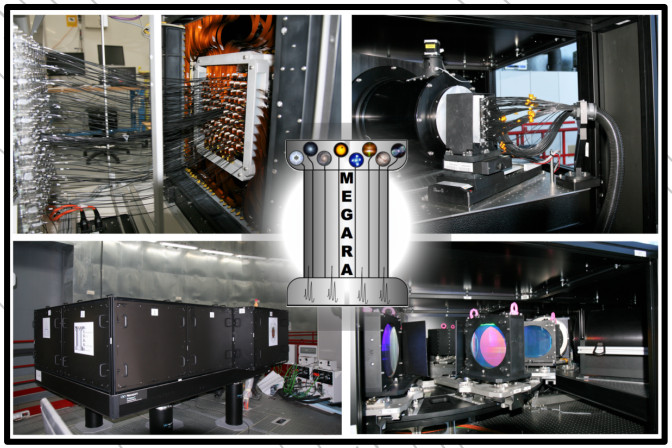
Searching for Hα emission of LMSFGs at z~1



GOYA survey

- **300h EMIR GT @ GTC 10.4m**
- **4h Exp Time, R=3500**
- **High-redshift universe at z~1 (t = 6 Gyr)**
  - ❑ Low Stellar Mass galaxies
  - ❑ Massive galaxies
  - ❑ Primordial galaxies

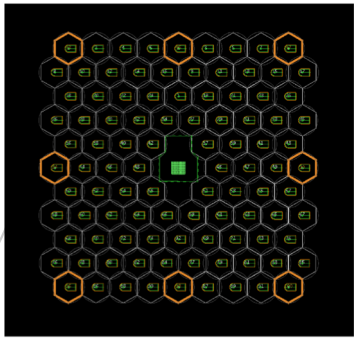
MEGARA VIS-MOS



Searching for [OII]3727, Hβ 4861 and [OIII]5007 emission

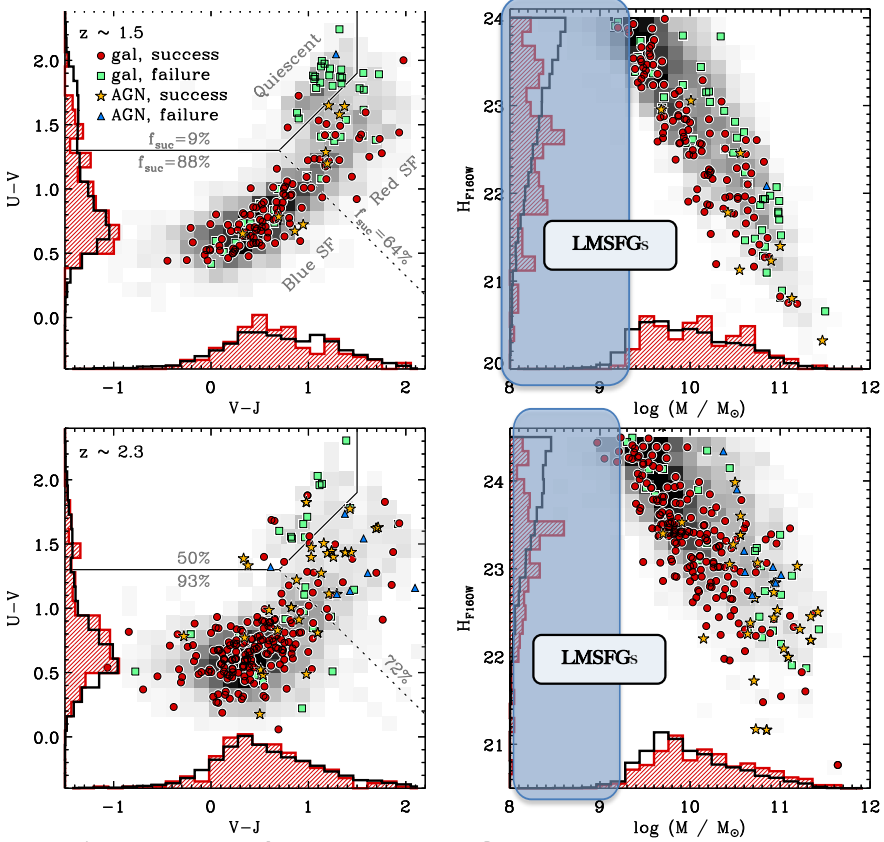
FoV: 3.5' x 3.5'
Spectral range: 3600 - 9600 Å

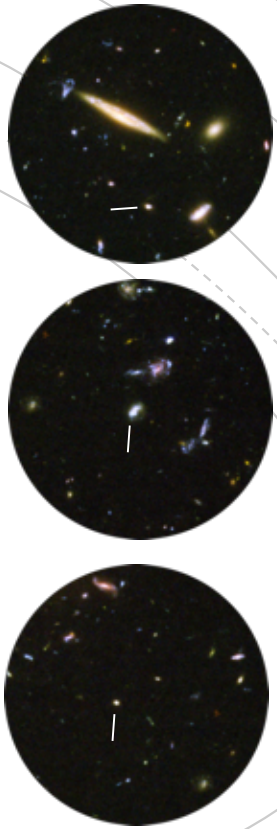
92 robotic positioners holding 7 fibres each of them

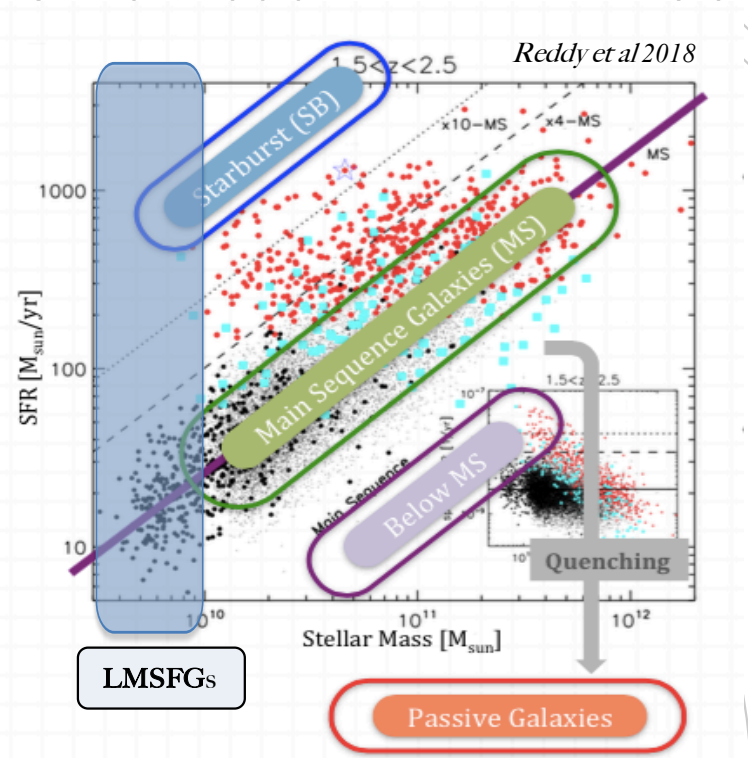


EMIR/GOYA survey: Low-Mass Star-Forming Galaxies (LMSFGs) 0.7 < z < 1.7

MOSDEF survey (Krieck et al 2014)

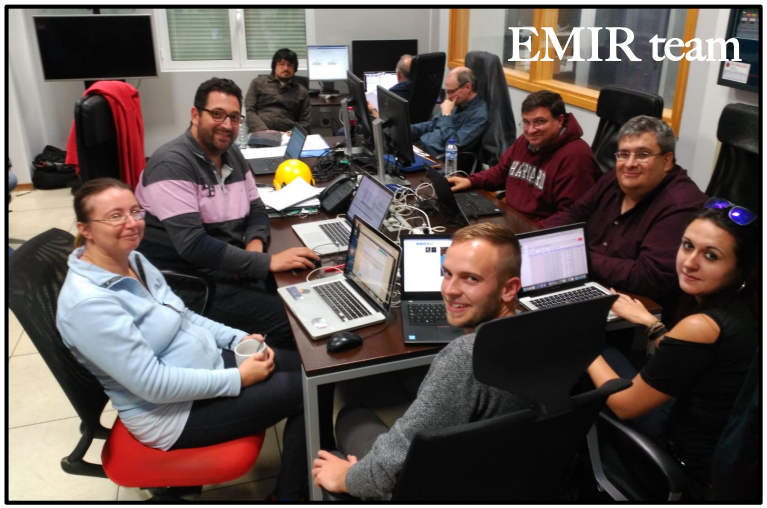






GOYA survey: EMIR/MOS commissioning

May 2018
July 2018
January 2019
March 2019

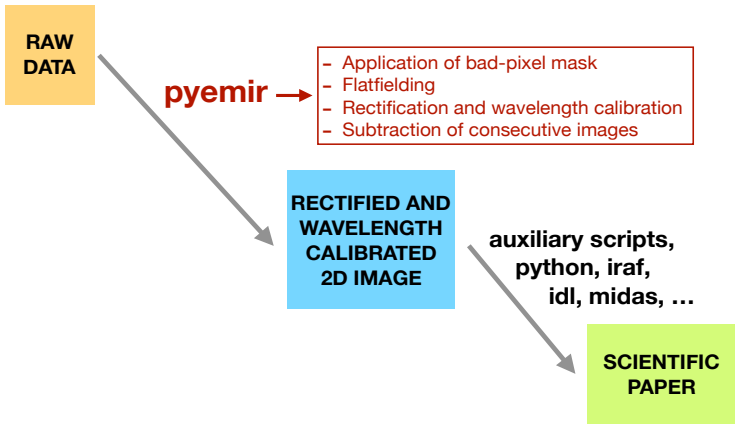


Main aims:

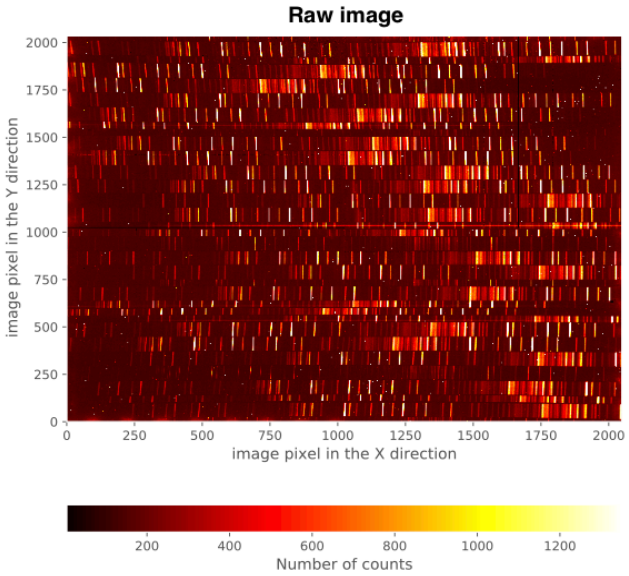
- Install the new Control Branch and associated functions.
- Calibrate the drift of the A&G box.
- Verify the changes introduced in the EMIR control system
- Scientifically validate:
  - the MOS mode
  - the mask preparation tolos
  - acquisition procedure
- Integrate new functionalities of the DRP.

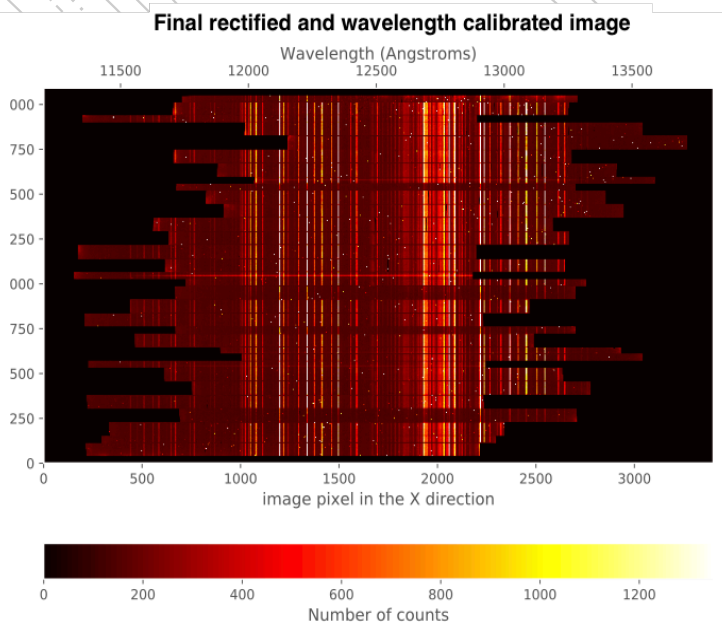
EMIR/GOYA survey: Working with EMIR MOS mode

Reducing EMIR spectroscopic data with pyemir



A data reduction pipeline, **pyemir**, based on Python, has been developed in order to facilitate the automatic reduction of EMIR data
(Cardiel, Pascual, Gallego et al)

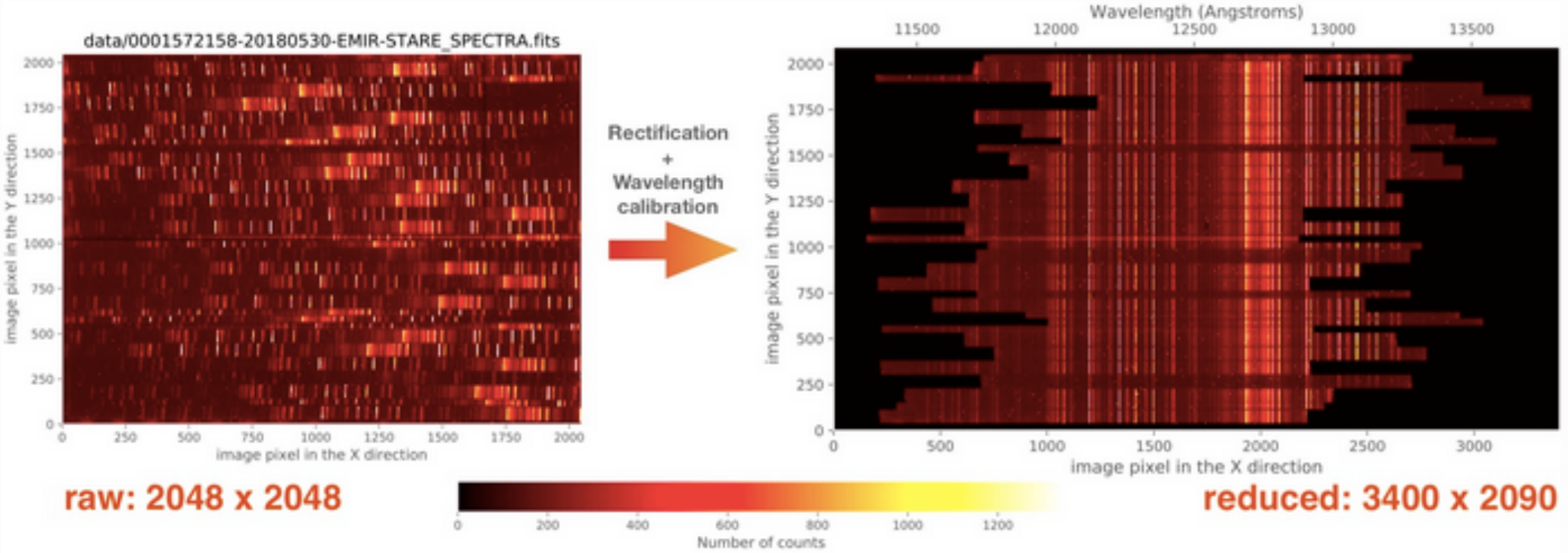




PyEMIR is public

EMIR/GOYA survey: Working with EMIR MOS mode

Optimized Pipelines are crucial !

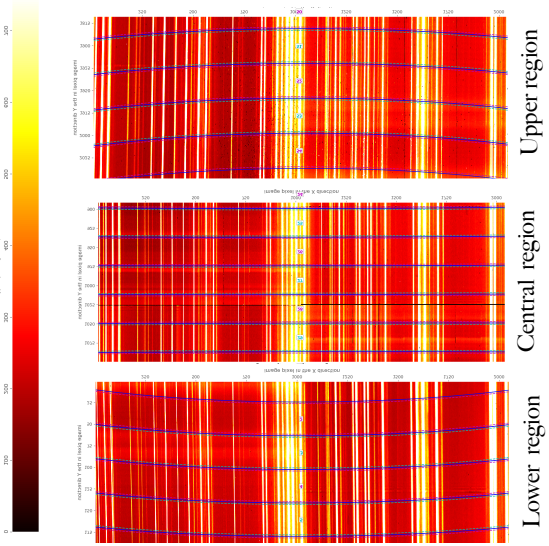


EMIR/GOYA survey: Working with EMIR MOS mode

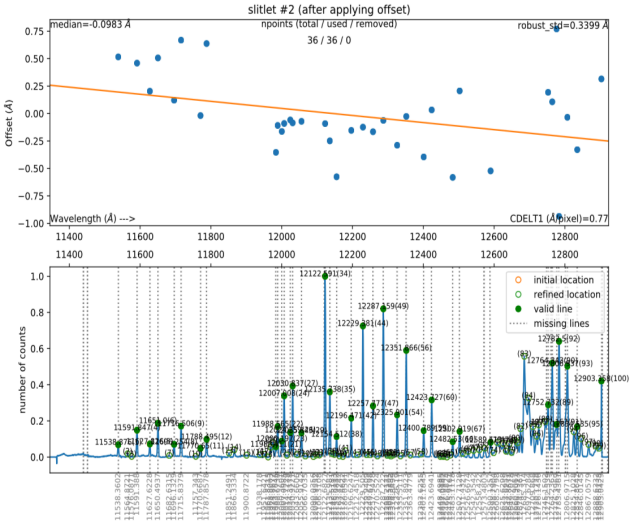
pyemir

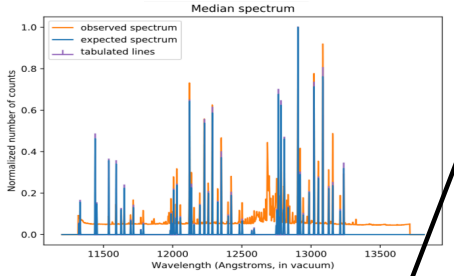
- Application of bad-pixel mask
- Flatfielding
- Rectification and wavelength calibration
- Subtraction of consecutive images

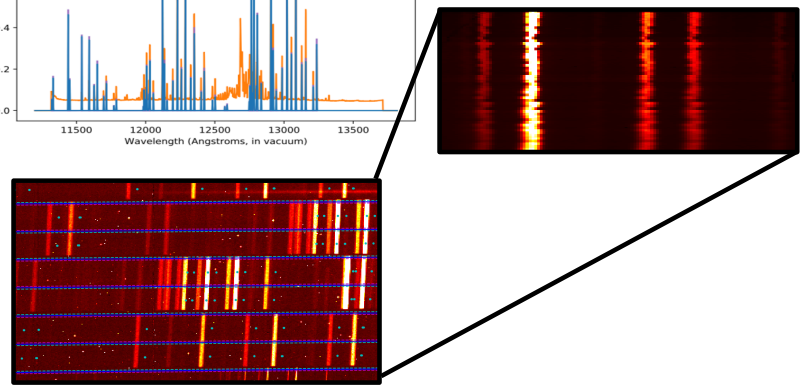
Rectification



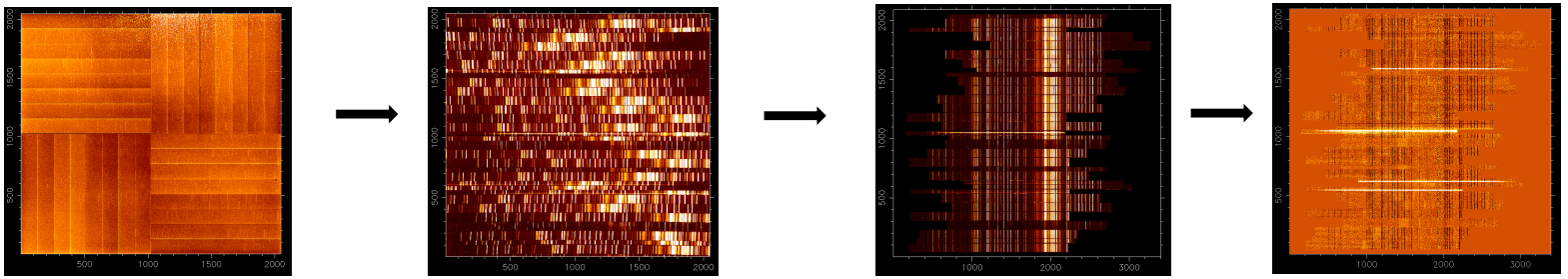
Wavelength calibration





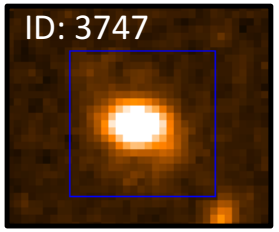


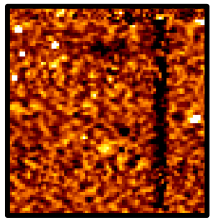
Raw frame → Raw spectra → Reduced spectra → Final image



EMIR/GOYA survey: Working with EMIR MOS mode

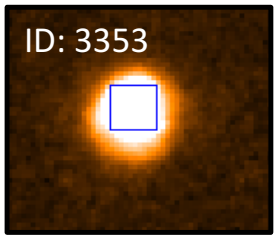
7 ABBA blocks
J band
Slit width: 0.8”
Exp.Time: 2.8h

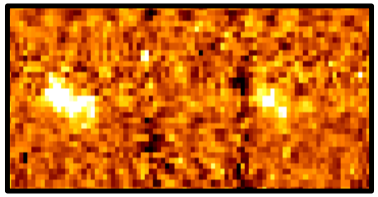


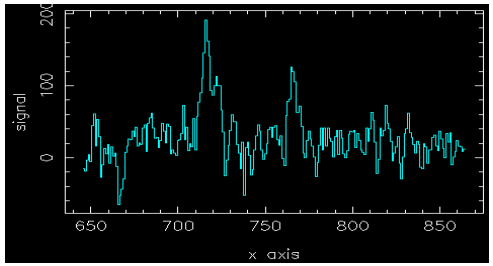


[OIII]5007 emitter

z_{spec} = 1.473, J_{AB} = 22.33, lmass = 9.77 M_o

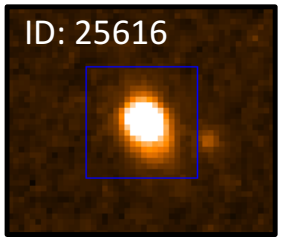


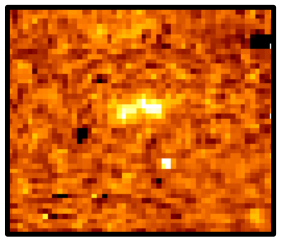


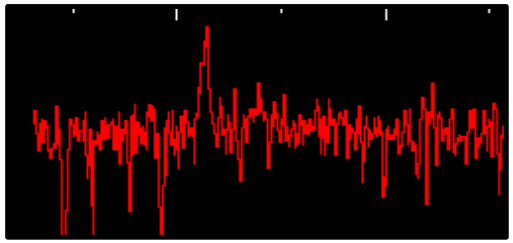


Hα + NII emitter

z_{spec} = 0.7909, J_{AB} = 20.31, lmass = 10.3 M_o

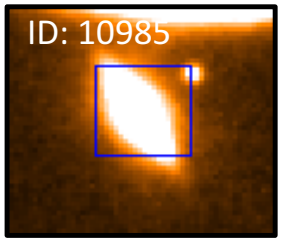




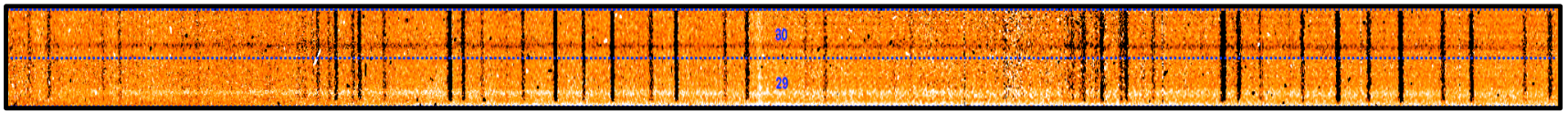


Hα emitter

z_{spec} = 0.8970, J_{AB} = 21.78, lmass = 9.38 M_o

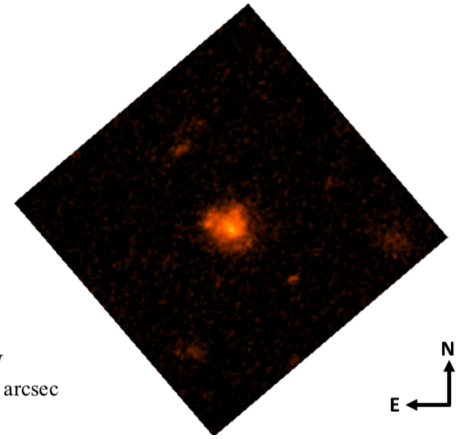


Continuum z_{spec} = 0.4539, J_{AB} = 19.5, lmass = 10.6 M_o



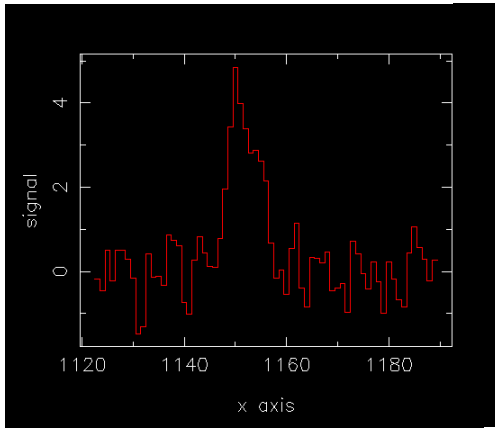
EMIR/GOYA survey: Working with EMIR MOS mode

H-α emitters → J band

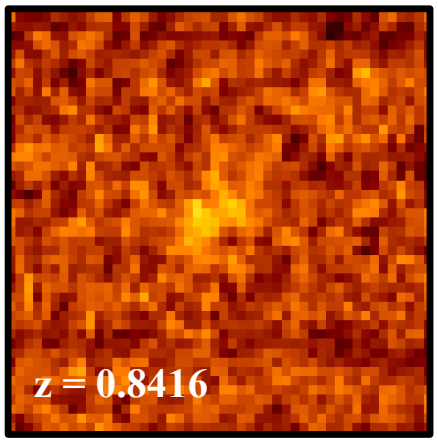


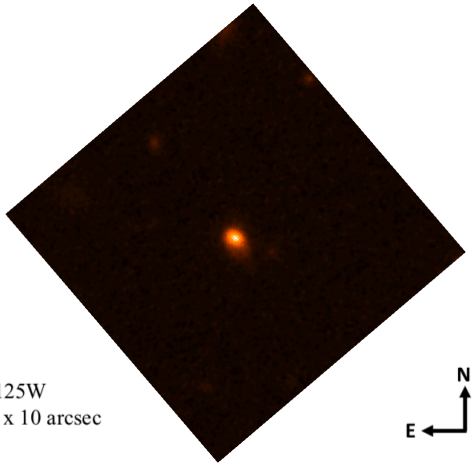
Filter: F125W
FOV: 10 x 10 arcsec

Slit 49 (mask3a_J)
ID: 32688
z_{spec} = 0.8412
J(AB) = 22.34
Log(Mass/$M_\odot$) = 9.83



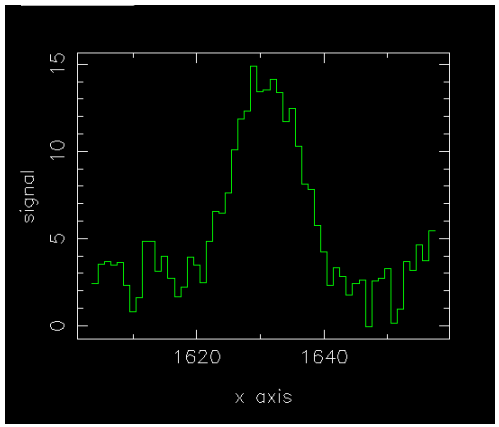
Exp.Time: 3.6h



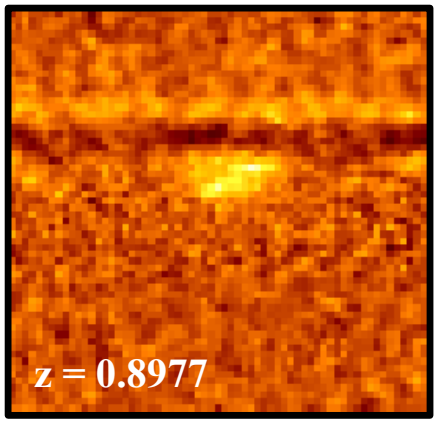


Filter: F125W
FOV: 10 x 10 arcsec

Slit 50 (mask3a_J)
ID: 33209
z_{spec} = 0.897
J(AB) = 21.87
Log(Mass/$M_\odot$) = 9.76



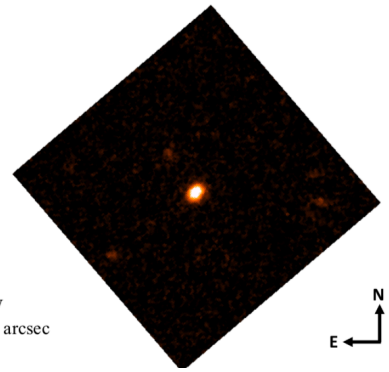
Exp.Time: 1.8h



EMIR/GOYA survey: Working with EMIR MOS mode

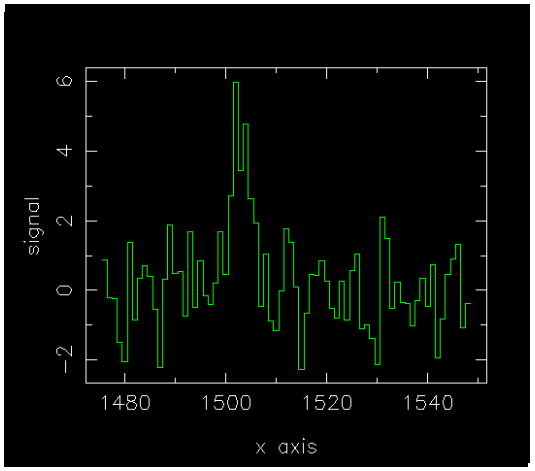
Lots of hard work!

H-α emitters → J band

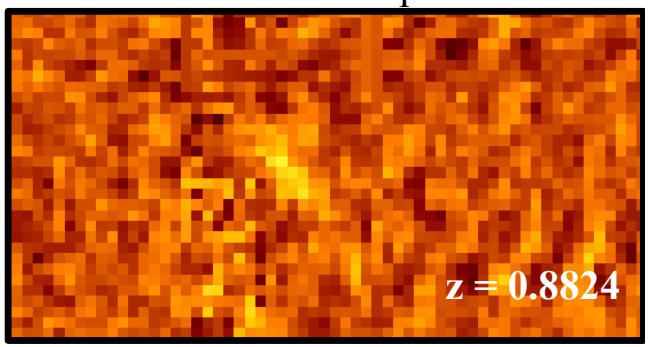


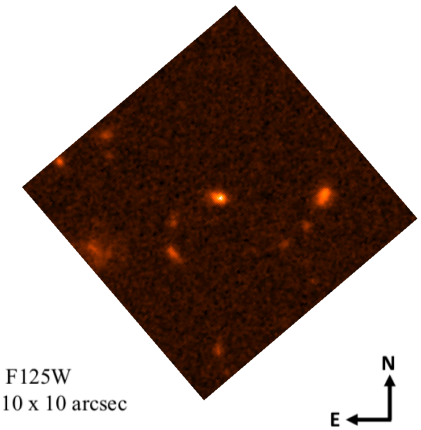
Filter: F125W
FOV: 10 x 10 arcsec

Slit 17 (mask3a_J)
ID: 16370
z_{spec} = 0.8821
J(AB) = 22.77
Log(Mass/$M_\odot$) = 9.43



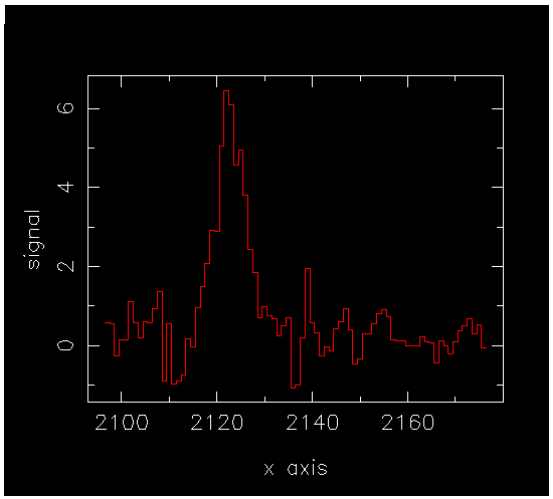
Exp.Time: 3.6h



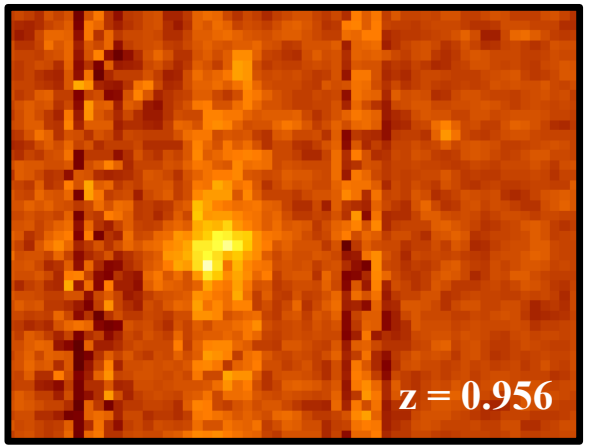


Filter: F125W
FOV: 10 x 10 arcsec

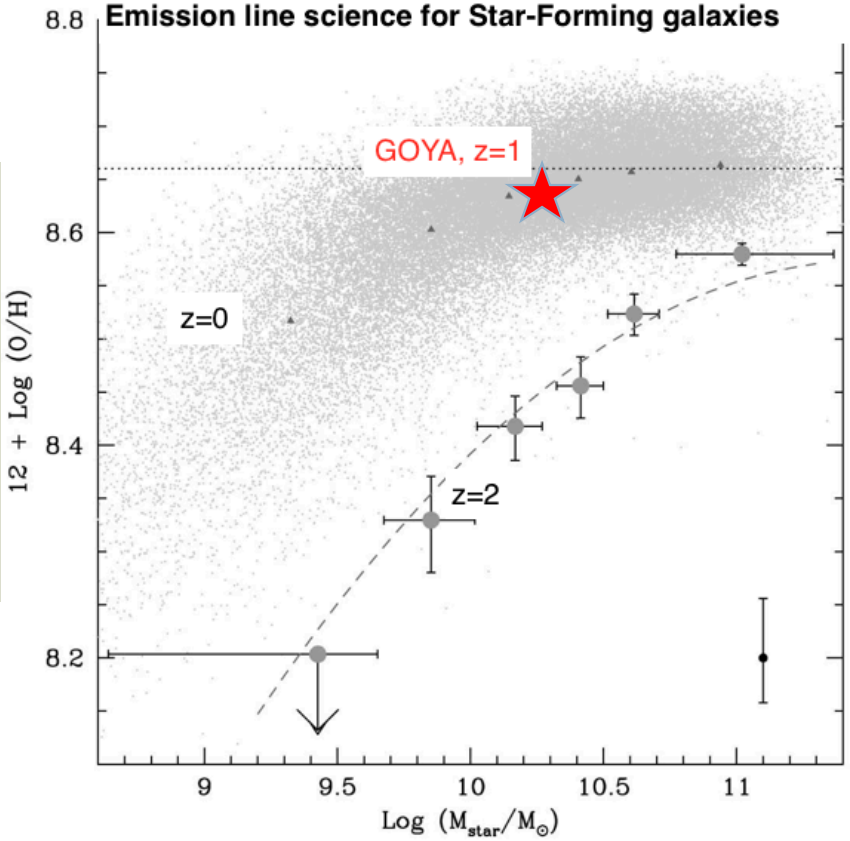
Slit 46 (mask1a_J)
ID: 23583
z_{phot} = 0.922
J(AB) = 23.39
Log(Mass/$M_\odot$) = 8.41



Exp.Time: 5.2h

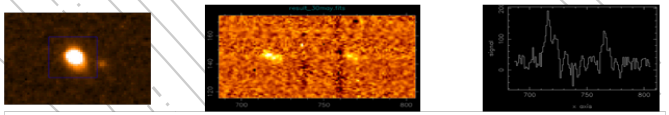


GOYA survey: Early results with EMIR

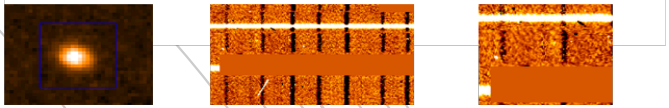


- Hα6563 and [NII]6584 emission-line fluxes were used to estimate the metallicity of star-forming galaxies at z=1.
- The dotted horizontal line is solar metallicity.
- GOYA galaxies show high metallicities (red star), in good agreement with evolved disks (Sanders et al. 2018).

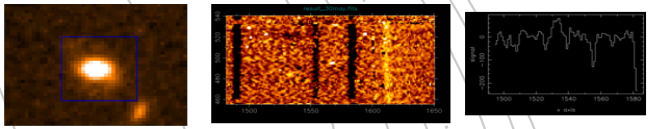
Examples of emission lines for Star-Forming galaxies



Hα6563 and [NII]6584 emission-lines Slit4_mask30may2018. Texp=2.8h. CANDELS-3353. J_{AB}=20.31, z=0.748, logM*=10.3 Rotation?



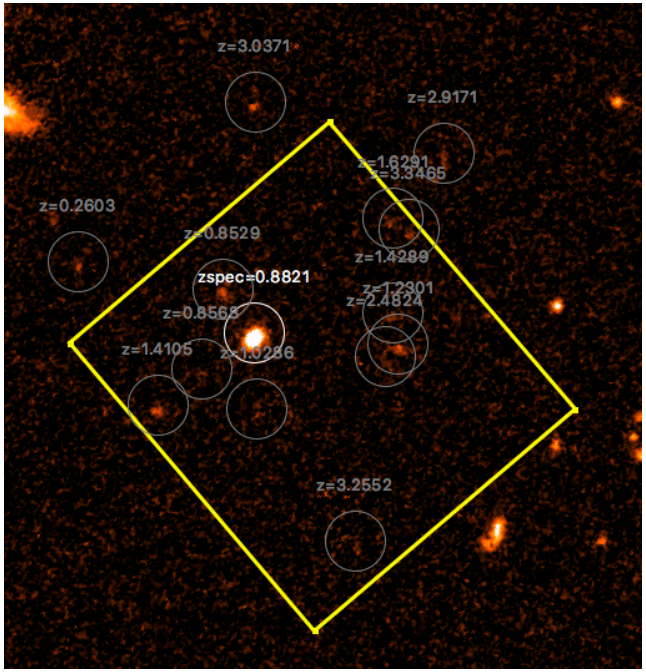
Hα6563 emission-line Slit16_mask30may2018. Texp=2.8h CANDELS-1436. J_{AB}=22.94, z=0.98, logM*=9.43.

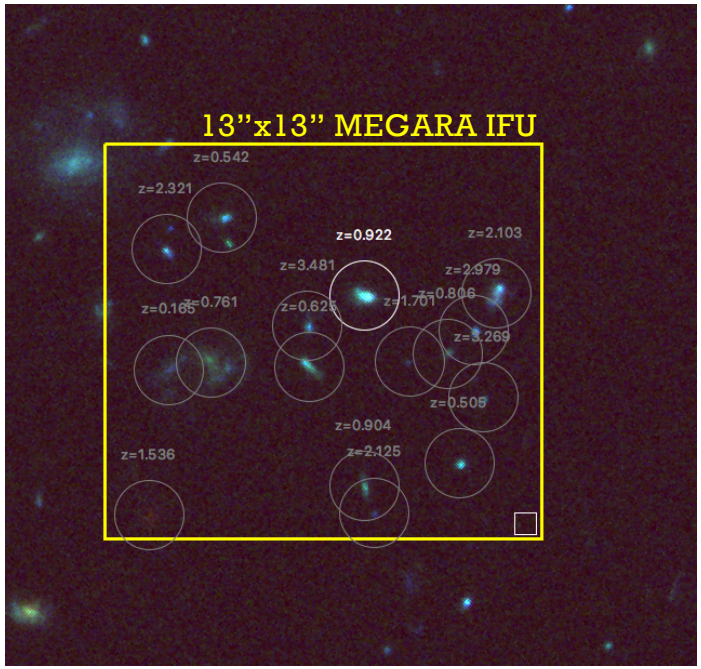


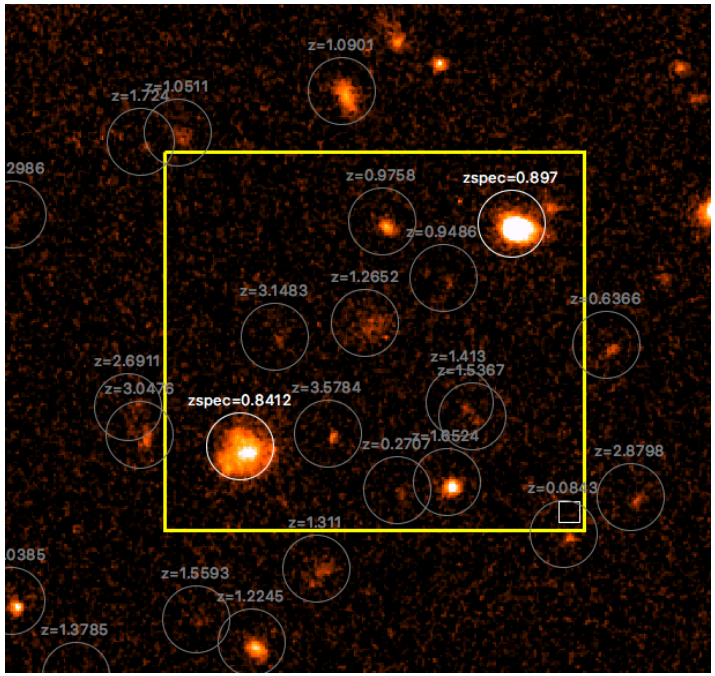
[OIII]5007 emission-line Slit13-14_mask30may2018. Texp=2.8h CANDELS-3747. J_{AB}=22.33, z=1.473, logM*=9.77. OIII-emitter

GOYA survey: Early results with EMIR

- Environment studies and Large Scale Structure
- Star Formation Histories







HST CANDELS ACS/WF3 color images
CANDELS spec-z's and phot-z's

Dwarf galaxies: A Science Case for MOSAIC/ELT

MOSAIC @ ELT can provide spectroscopy deep enough

Prioritized Science Case: Evolution of Dwarf Galaxies

MOSAIC

Source densities: GOODS-S cosmological field (150 arcmin2, 3D-HST catalog, (Skelton et al. 2014) contains about 20,900 galaxies with

$7 < \log M^* < 3*10^9$ J < 29 (AB mag) Phot-z < 2.4

Targets per E-ELT patrol field (40 arcmin2) of about 5,000.

Dwarfs can play the fillers role