ASTRODEEP

PHYSICAL PROPERTIES AND METALLICITY OF STRONG EMISSION LINE GALAXIES AT z=2-4 IN VUDS (AND VANDELS)

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SEVENTH FRAMEWORK PROGRAMME

ISTITUTO NAZIONALE DI ASTROFISICA INAF

OAR

Low-mass star-forming galaxies at high redshift

Low-luminosity (sub-L*) galaxies play an important role at high redshifts
(e.g. Reddy & Steidel 2009, Alavi+14, McLure+13, Atek+14) .
(Jim's and Rebecca's talks)
They can contribute significantly to the SFRD at z>2

Low-mass galaxies with strong emission line galaxies are probably ubiquitous among UV-selected star forming galaxies at z > 4
Key role on cosmic reionization (e.g., Shim+12, Stark+13, Smit+13)

First detailed spectroscopic studies targeting z>1.5 galaxies with low assembled stellar masses (10^7- $10^{9.5}$ $M_{\odot}$) have only started in the last years (e.g. Erb+10, Christensen+12, van der Wel+11, Steidel+14, Stark+14)

LOW-MASS STAR-FORMING GALAXIES AT HIGH REDSHIFT

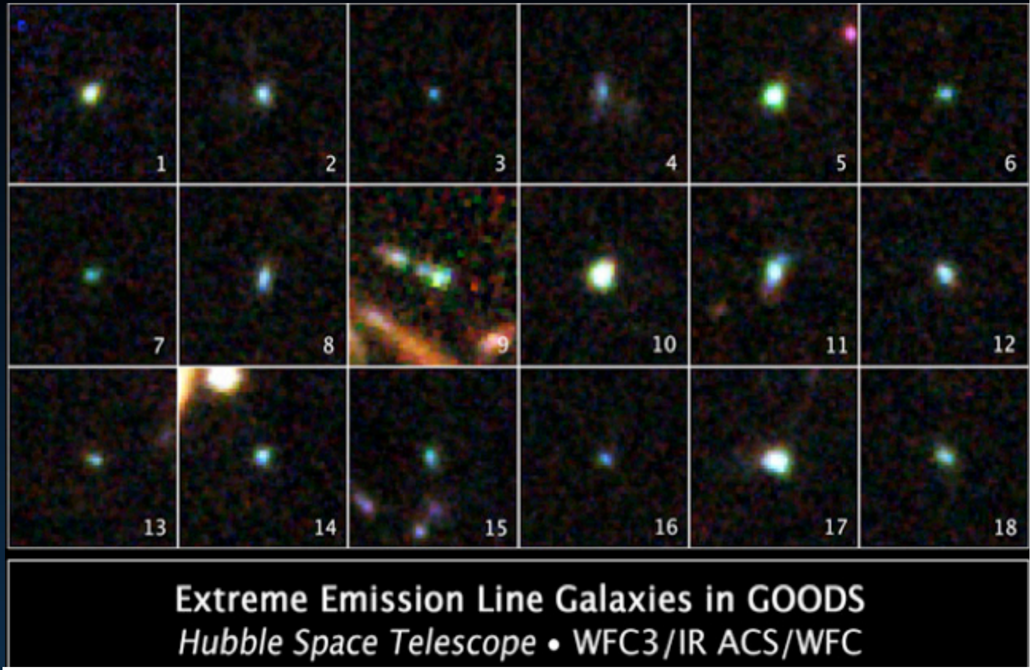
Extreme emission line galaxies (EELGs):

A substantial population of low-mass galaxies has been discovered due to their very large nebular emission (rest-frame EW(OIII)~100-1000 A; e.g., Atek +11,+14, van der Wel+11,Brammer+12,Maseda +14,Masters+14, Amorín14a,b)

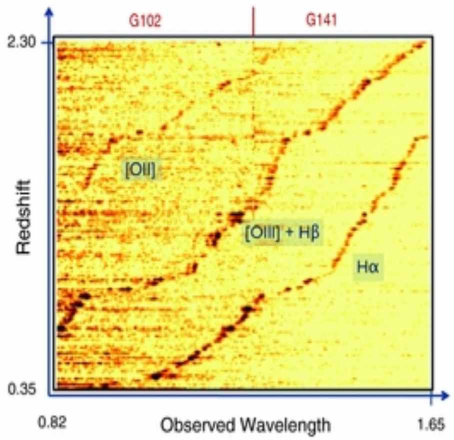
At z<1 EELGs are extremely rare. (e.g. "green peas"; Cardamone+09, Amorín+10,12,14a,b)

At z>1 EELG number densities increase rapidly (~2 dex, van der Wel+11).
They contribute up to ~35% to the total SFR of ELGs at z~1-2 (Atek+14)

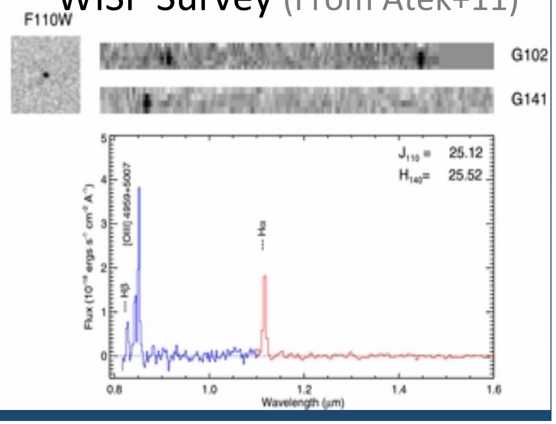
HST grism/slitless spectroscopy provide the largest samples, but it has some limitations (e.g. van der Wel+11, Xia+12,Atek+14)



Low-mass starbursts at z=1.8 in CANDELS GOODS *(van der Wel +11, Maseda+14)*



WISP Survey (From Atek+11)



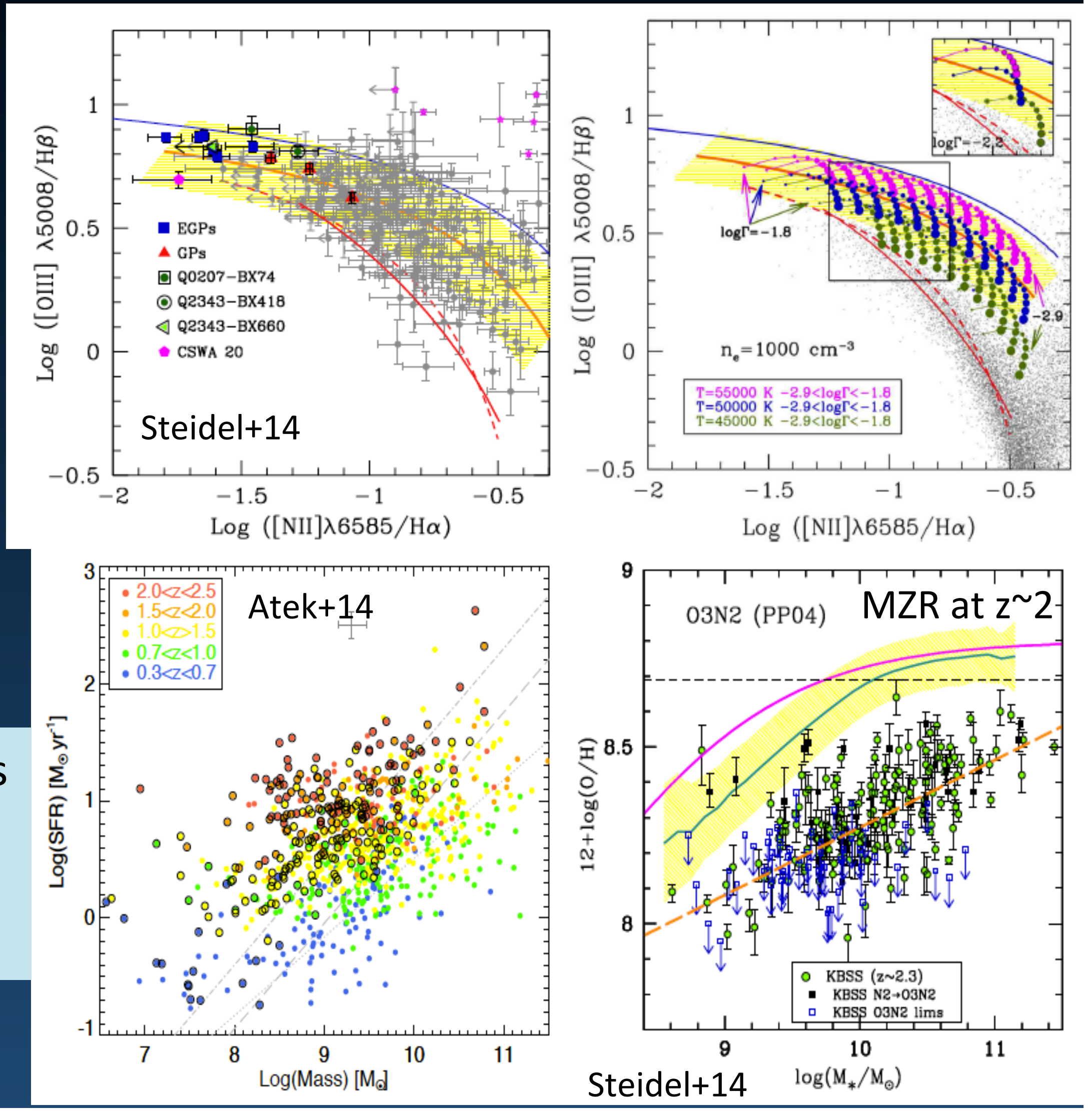
LOW-MASS STAR-FORMING GALAXIES AT HIGH REDSHIFT

Extreme emission line galaxies (EELGs):

Detailed NIR studies are limited to small samples to date (e.g. Erb+10, Maseda+14, Steidel+14)

Main properties out to z~2-2.5

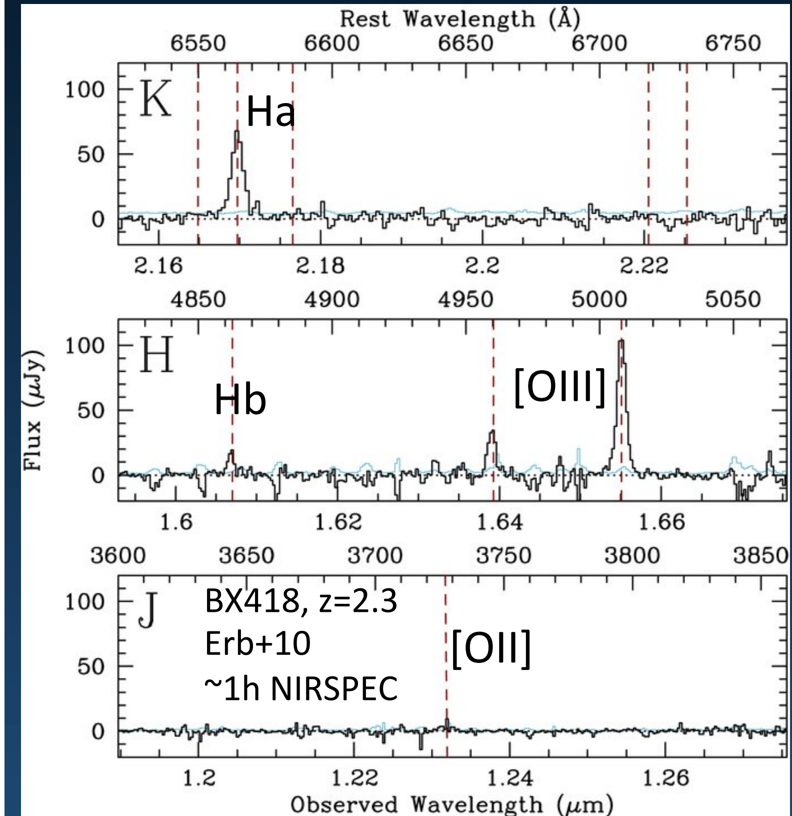
- Young starbursts (few Myr)
- Compact and irregular morphologies
- Low mass and high SFR → high sSFR
- Large nebular content and low dust
- Low metallicity and high ionization

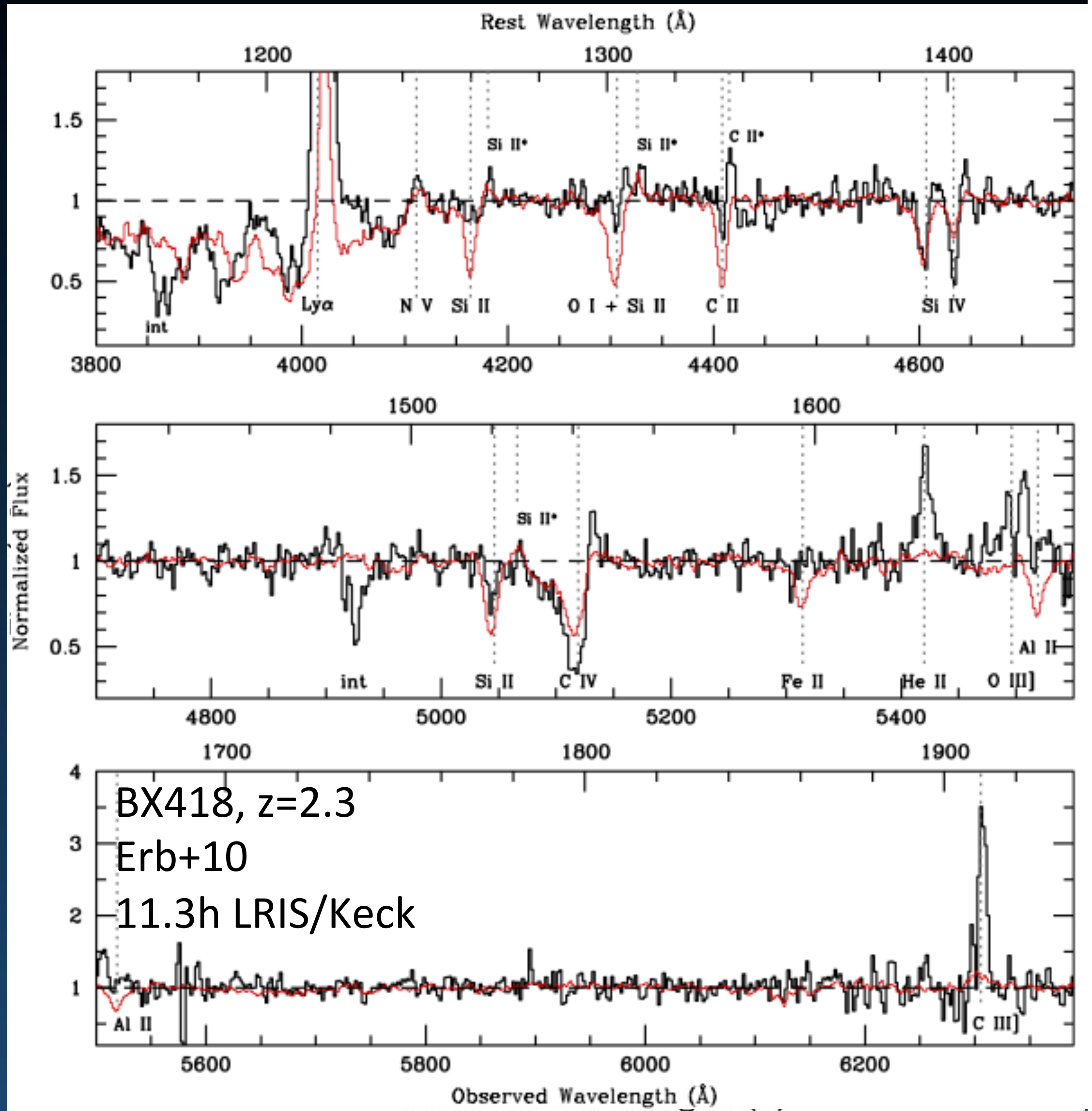


Low-mass starbursts are ideal laboratories for studying early mass assembling, chemical evolution, star formation and feedback, and cosmic reionization

The rest-frame UV spectra of EELGs at z>2

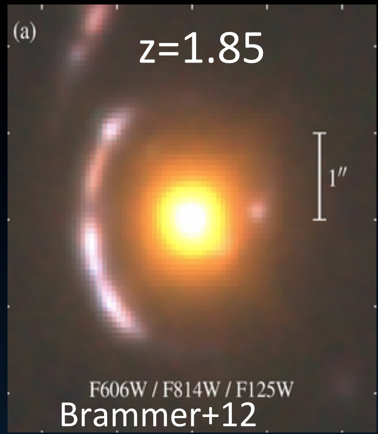
The rest-frame UV spectra show large EW nebular emission lines which are rarely seen in spectra of more massive SFGs (e.g. CIII] 1907,1909, OIII] 1661, 1666, HeII 1640 and CIV 1548,1550).

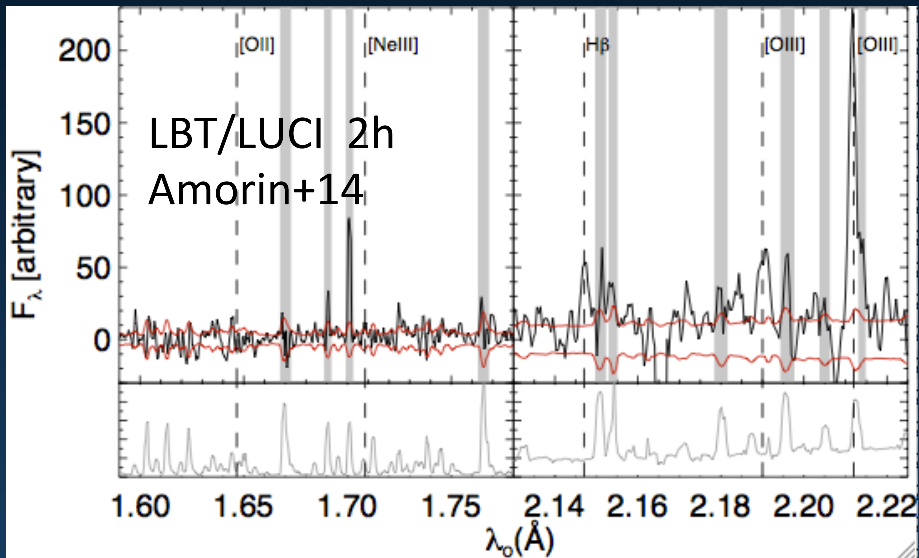


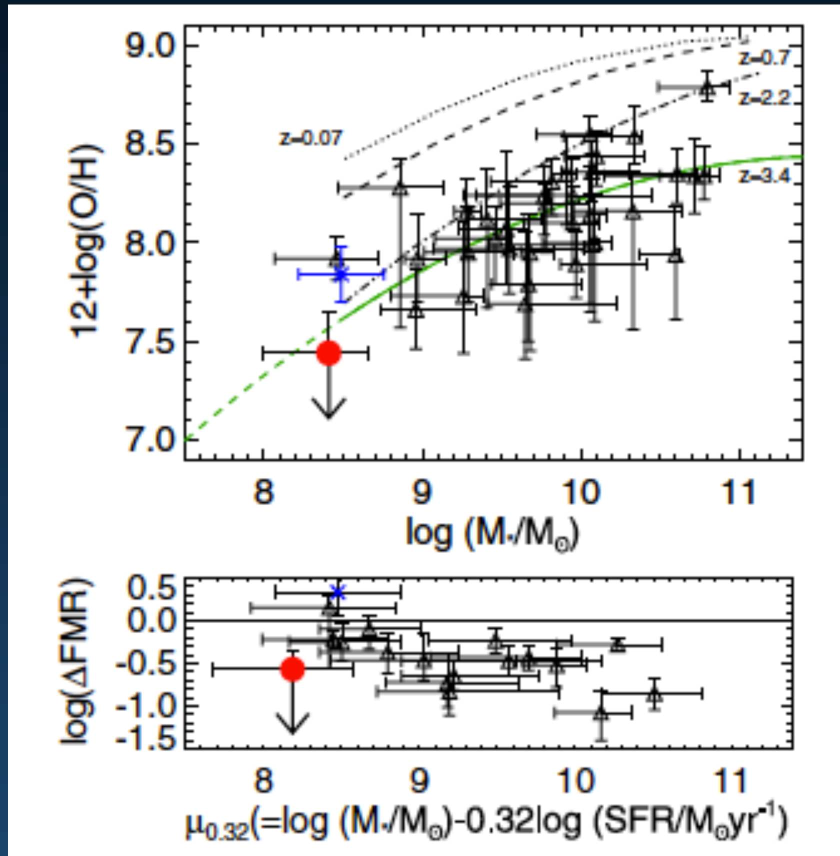


EELGs at high redshift

Strong lensing is a powerful technique
to discover and study EELGs at high redshift
(e.g. Fosbury+03, Richard+11, Christensen+12).
Samples are relatively small at the moment
But ongoing surveys (e.g. HST FF) may add lots of targets !





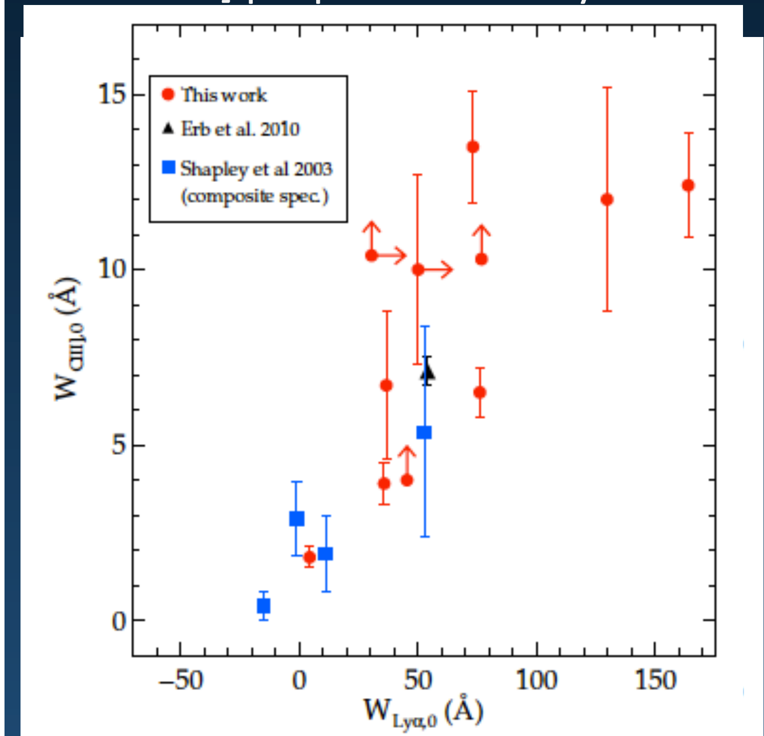


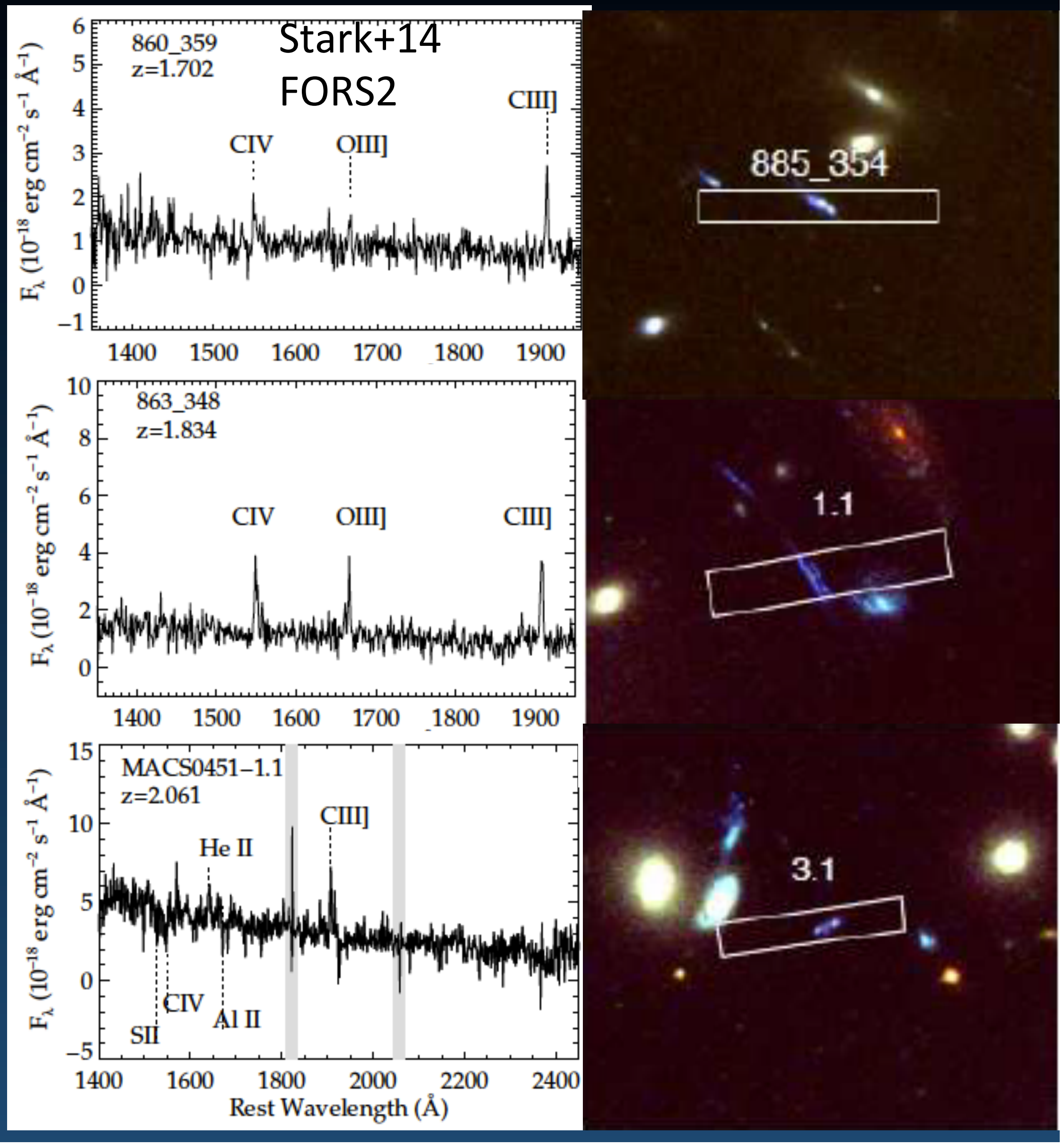
Strongly lensed EELGs are good targets to populate the low-mass end of the MZR and FMR at z>3 (Amorín+14; Bayliss+14, Belli+14)

The rest-frame UV spectra of EELGs at z>2

The rest-frame UV spectra show large EW nebular emission lines which are rarely seen in spectra of more massive SFGs (e.g. CIII] 1907,1909, OIII] 1661, 1666, HeII 1640 and CIV 1548,1550).

Stark+14 studied lensed EELGs and found CIII] proportional to Lya





OUR PROJECT

Physical properties and gas-phase metallicity of strong emission line galaxies at z~2-4 in VUDS

MAIN GOALS

- Identify and characterize the best quality sample of strong line emitters at z=2-4 in VUDS
- Study SED properties using stellar + nebular models
- Use line ratios to derive ionization, and T_e-consistent C/O and O/H through photoionization models.
- Study ionization and C and O abundances as a function of mass and SFHs, in the context of chemical evolution and mass assembling

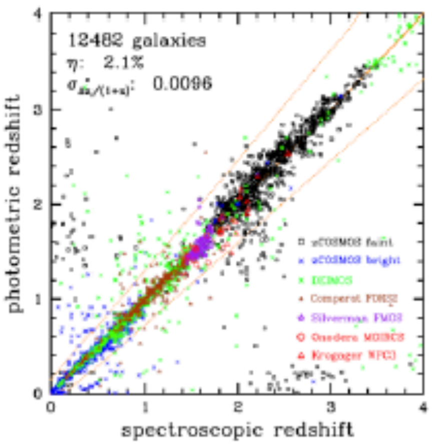
The VIMOS Ultra Deep Survey (VUDS)

OVERVIEW (see details in LeFevre +2014)

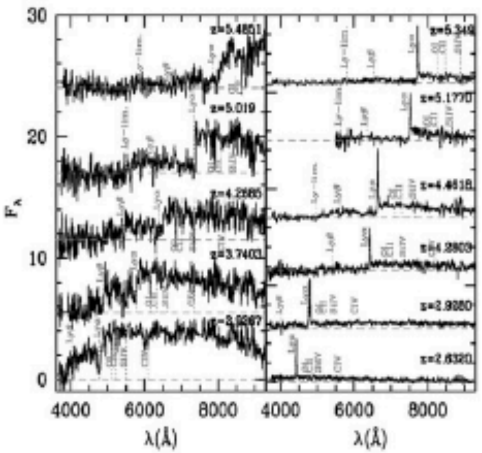
- ESO Large Program: 640h
- Focused on 2<z<6
- Wide field: 1 deg^2
- 10,000 galaxies
- 14hr integration over 3600-9300 Å
- 3 fields: mitigate cosmic variance
- Selection: photo-z + SED + colors, iAB≤25
- 8000 galaxies with z_{spec}=2-6.5

VVDS_02 COSMOS ECDFS

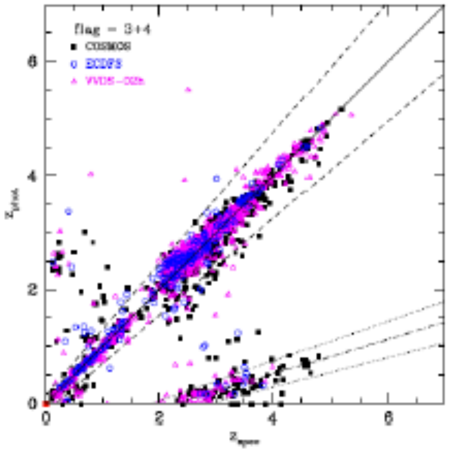
Selection



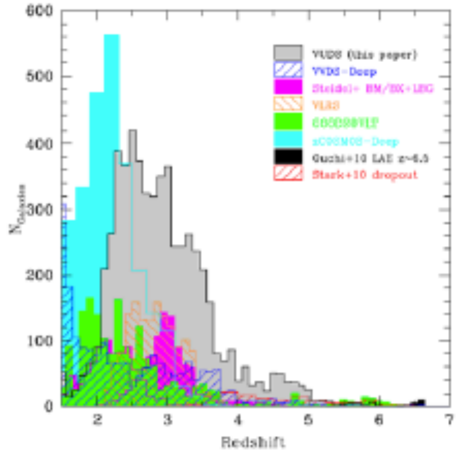
Spectra



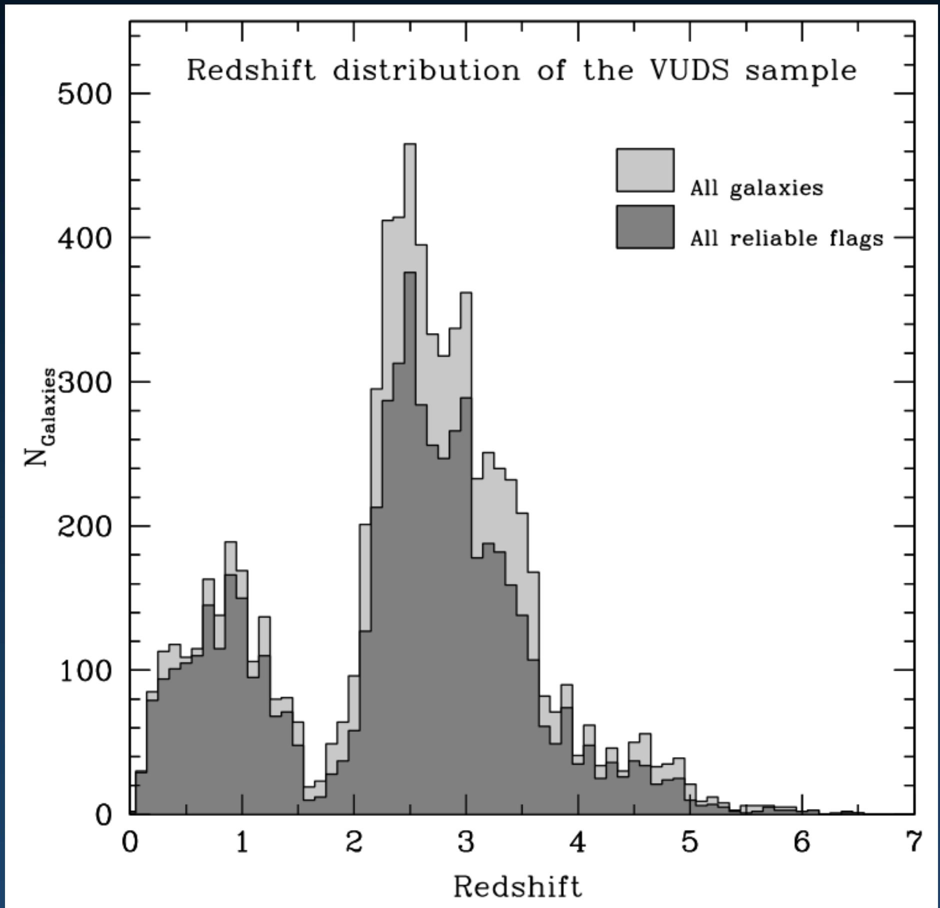
zphot – zspec

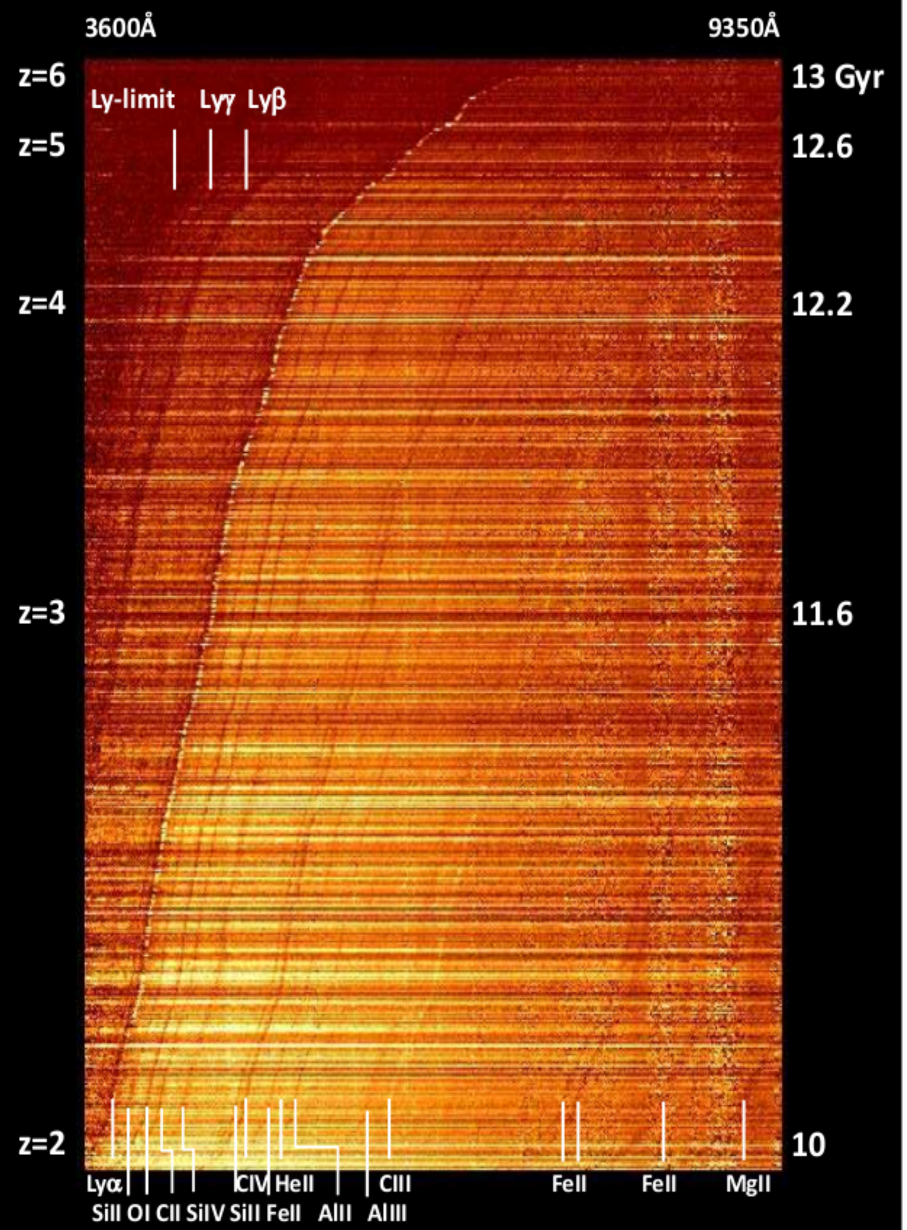


8000 zspec



The VIMOS Ultra Deep Survey (VUDS)



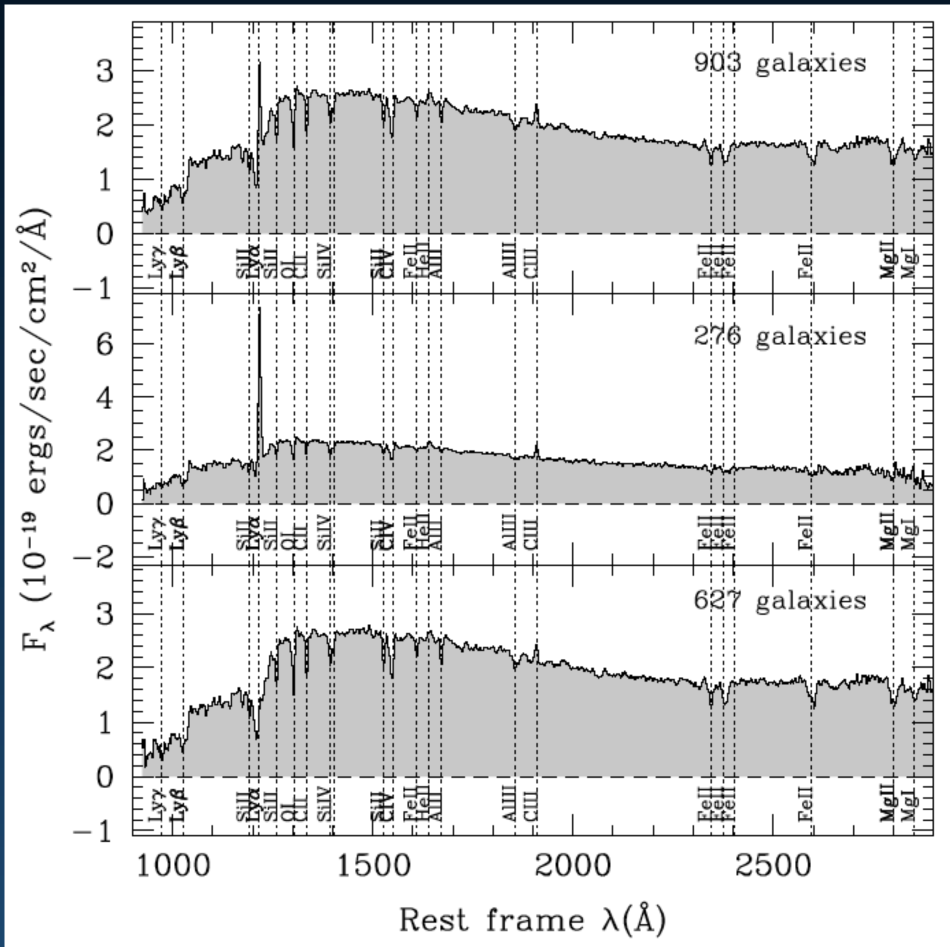


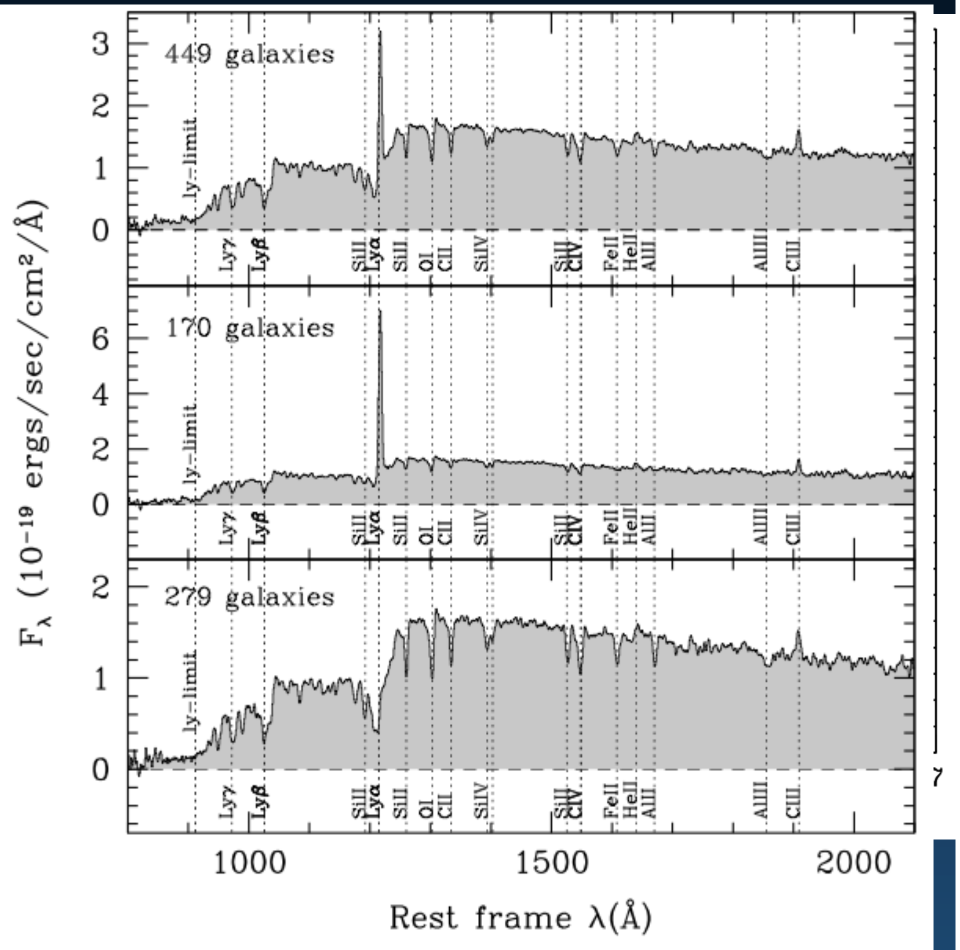
LeFevre +2014

Physical properties and gas-phase metallicity of strong emission line galaxies at z~2-4 in VUDS

SAMPLE SELECTION

STACKING: VUDS galaxies at z=2-4; LeFevre+14

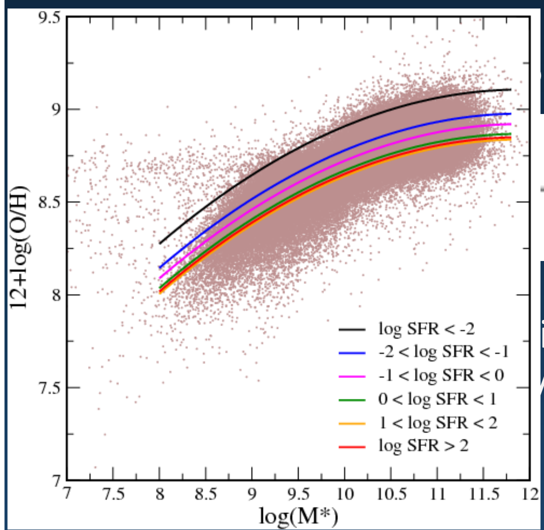


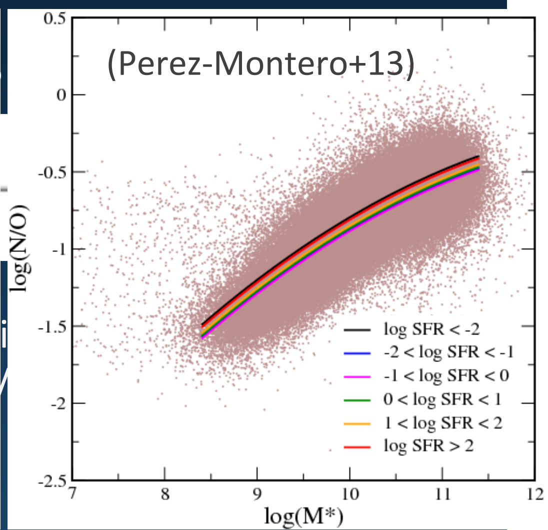


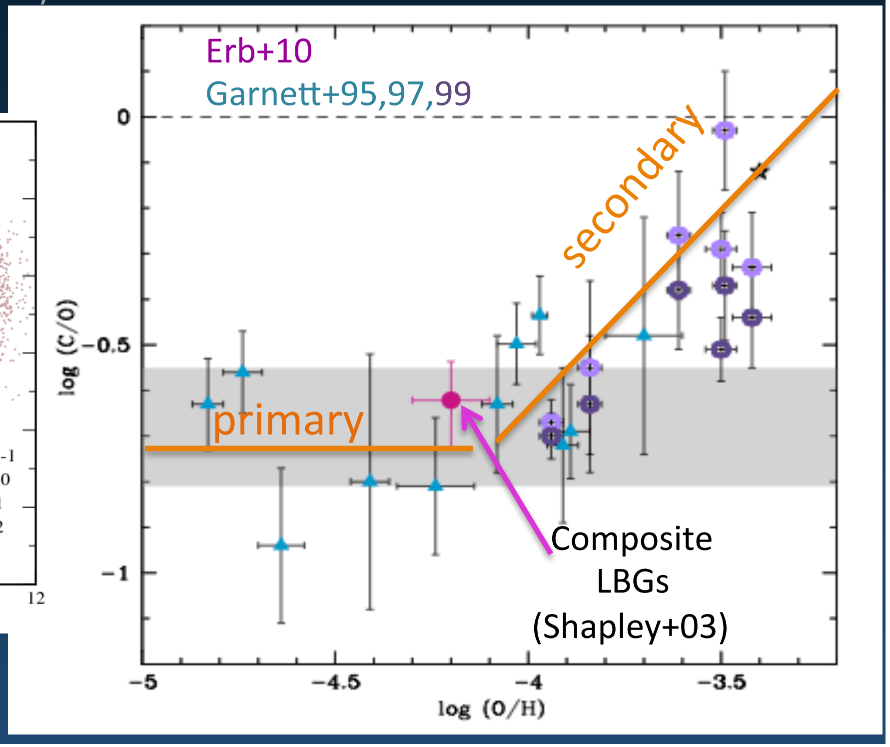
Carbon abundance in star-forming galaxies

- Carbon emission lines are better detected in the UV
- For most objects C (as N) is a secondary element and hence it scales with metallicity
- However, in earliest stages of galaxy evolution C is produced by massive stars and remains constant with Z.
- Deviations from the trend in C/O with Z can be indicative of different SFHs or pollution
- C/O should be insensitive to hydro-dynamical effects (i.e. gas flows)
- As N/O does, C/O should follow a relation with M* which do not depend on redshift nor SFR

Therefore complementary to the MZR (Perez-Montero+13)

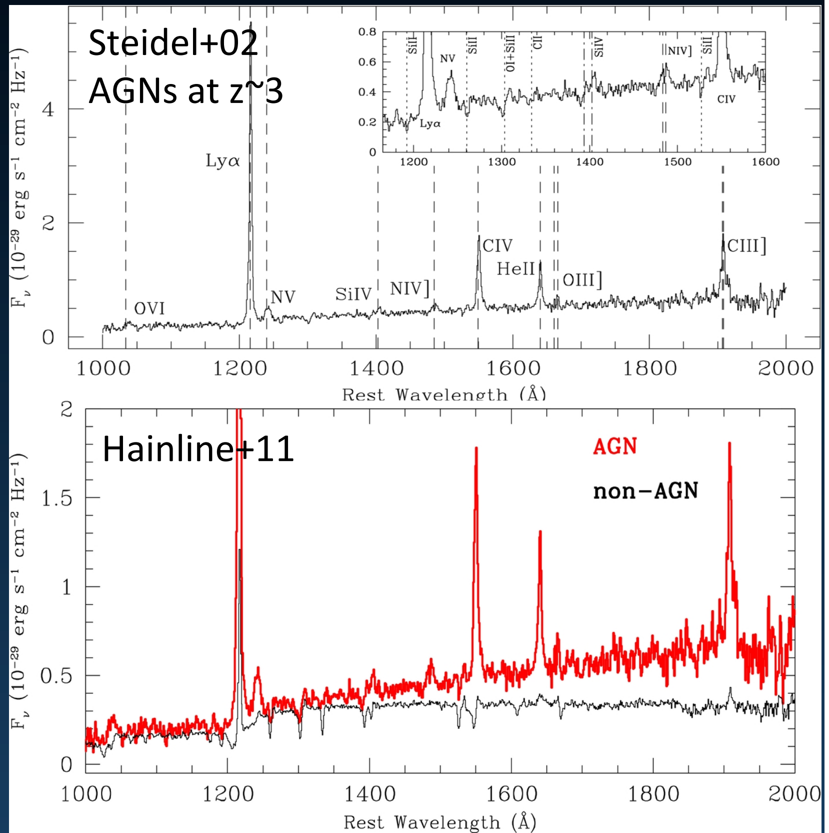






Physical properties and gas-phase metallicity of strong emission line galaxies at z~2-4 in VUDS

SAMPLE SELECTION



Parent sample

- VUDS galaxies with very reliable redshifts (>95% confidence) in the range 2 < z < 4

Sample of CIII] emitters

- Only galaxies with CIII]1908 detections (S/N>3)
- Clear AGNs are excluded

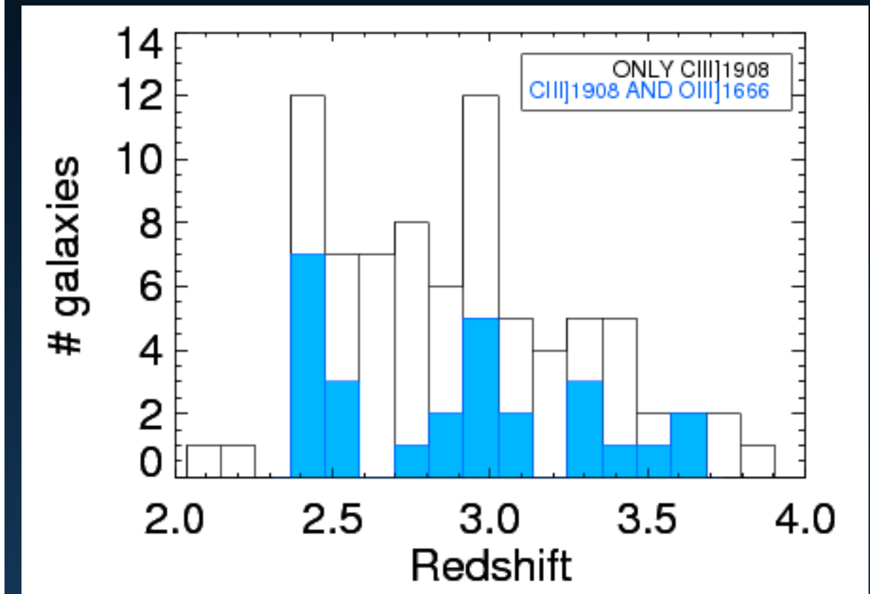
↓

Subsample of EELGs: CIII] emitters with detection in OIII]1661,1666 and EW(Lyα)>20A (LAEs)

AGN candidates: Presence of high ionization lines: NV, OVI … very high CIV/CIII] (e.g. Stark+14, Dors+14). Colors (SED fitting), X-ray detection

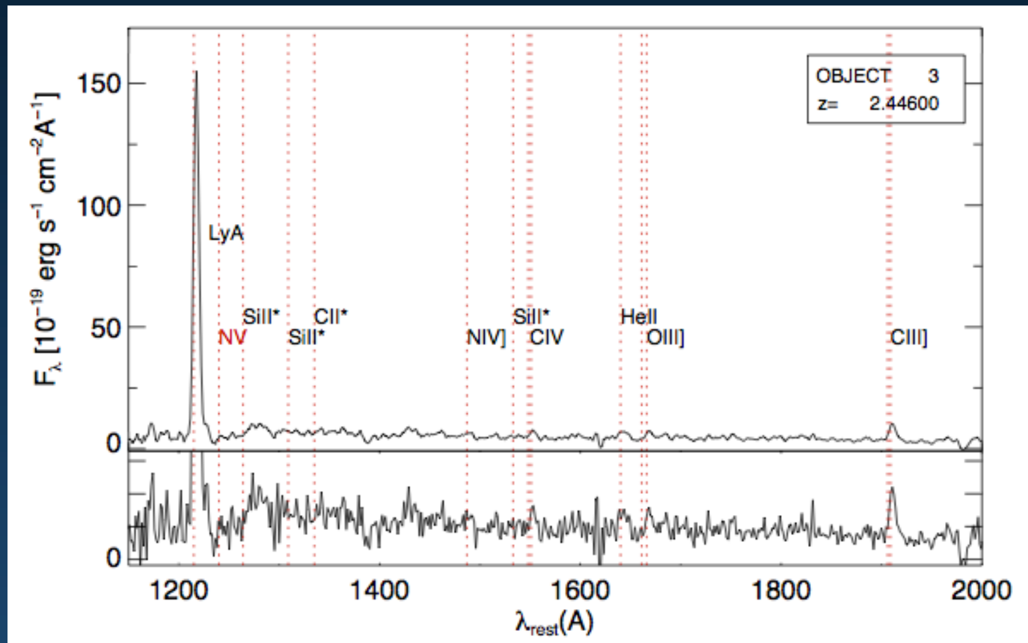
VUDS - COSMOS FIELD: FIRST RESULTS

We have found 80 CIII] emitters (SN>5) out of ~850 galaxies with reliable z_{spec}



Amorín et al. in prep.

EXAMPLE SPECTRA

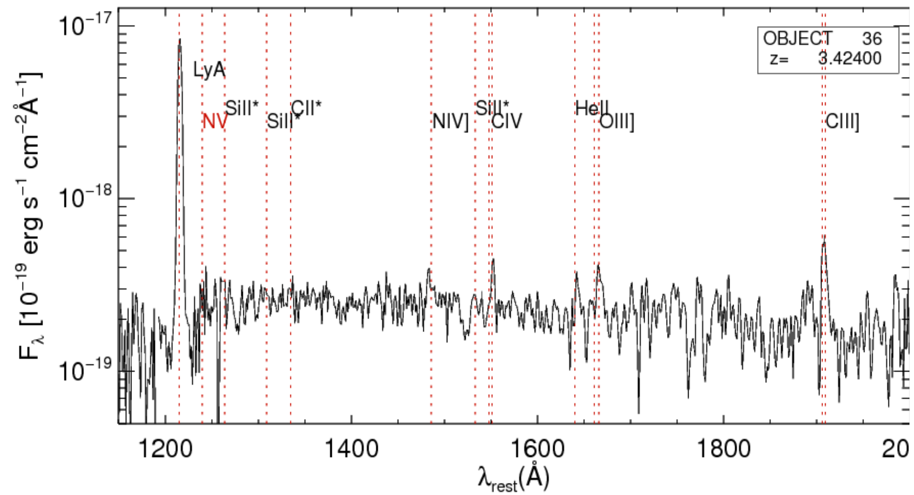


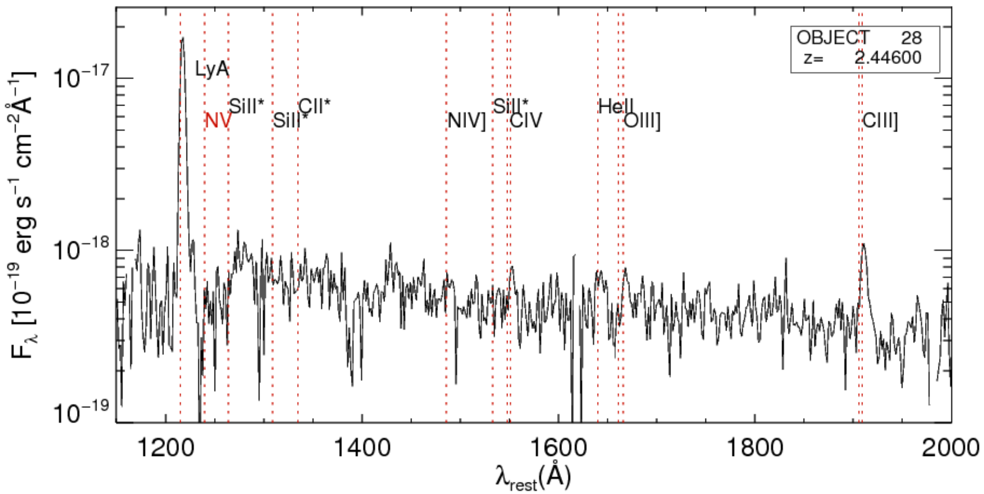
30% of them show OIII] detection (SN≥3) and high Lyα EWs (>20 Å)

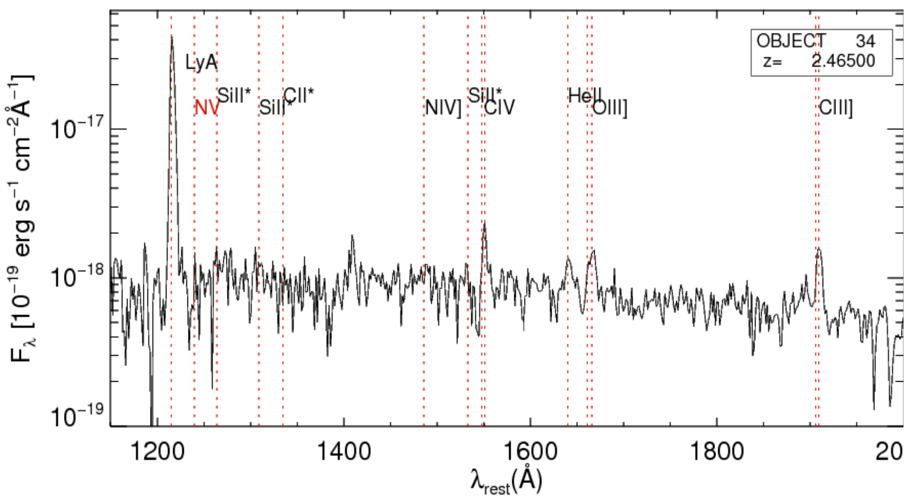
VUDS - COSMOS FIELD: FIRST RESULTS

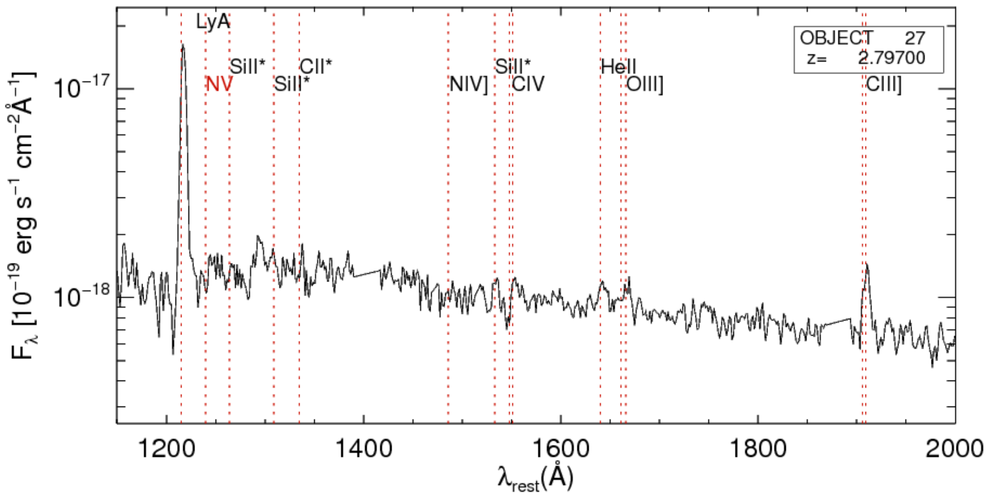
Amorín et al. in prep.

EXAMPLE SPECTRA



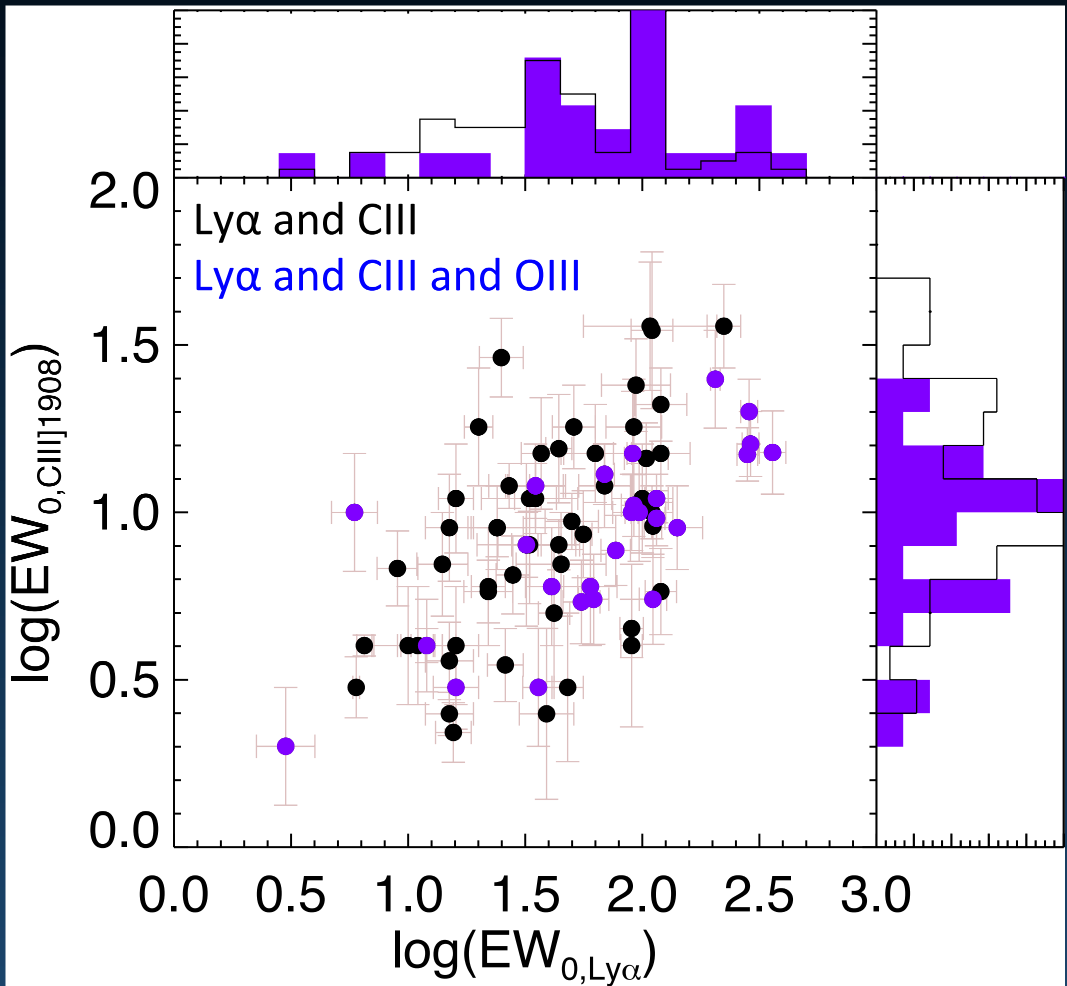






VUDS - COSMOS FIELD: FIRST RESULTS

Amorín et al. in prep.



We find a positive correlation between CIII] and Lyα equivalent widths

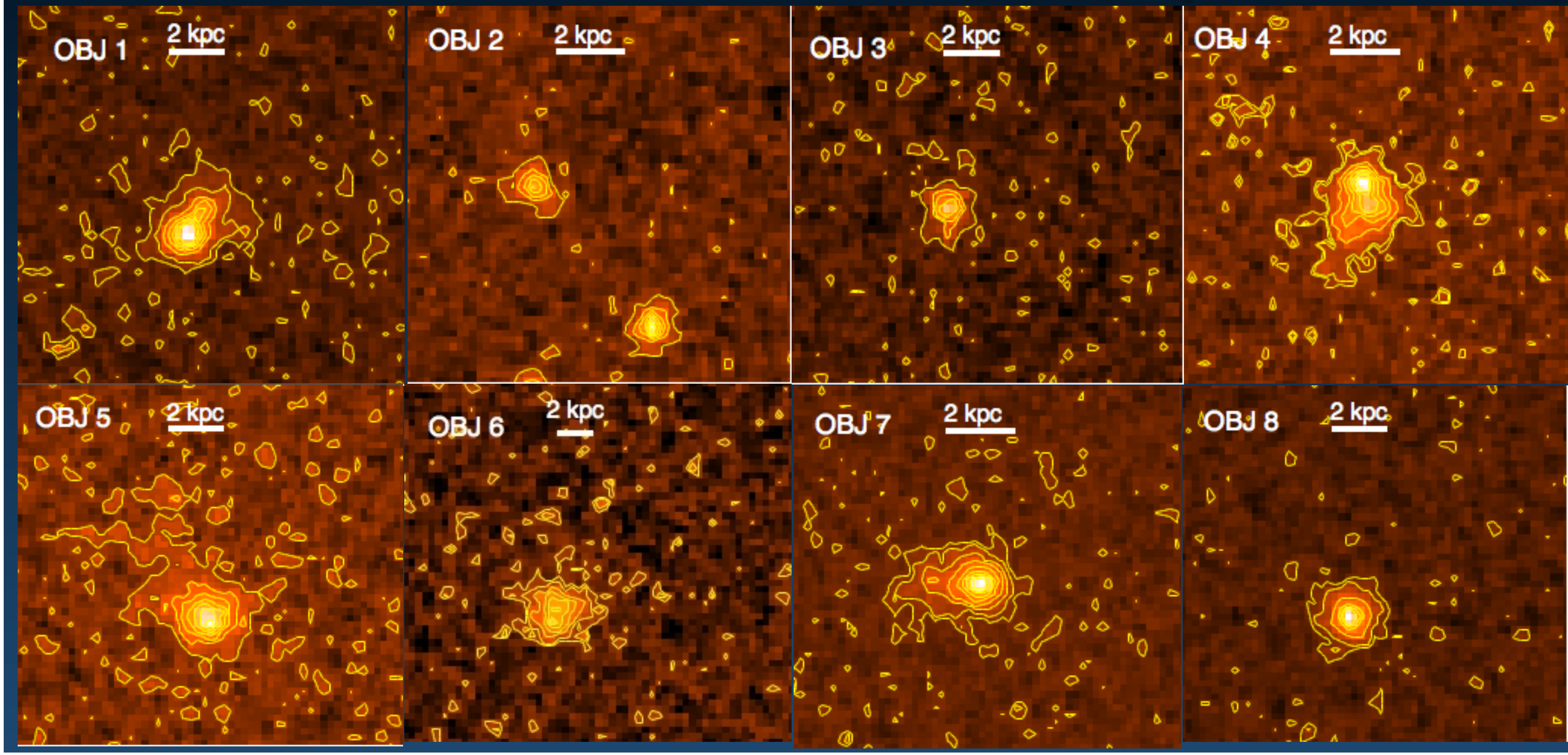
Our results provide statistical significance to previous results based on few objects (Stark+2014)

Most CIII emitters are LAEs (EW>20A)

→ Support to the use of CIII as a tool for finding young galaxies at higher redshift

HST-ACS (F814W) Morphology

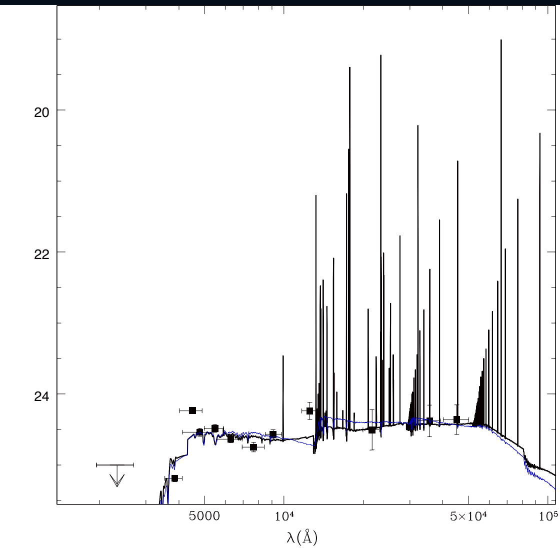
- Visual inspection: small and irregular galaxies dominate the sample
- Significant number of tadpoles…
- Morphological analysis is underway (Ribeiro + VUDS, in prep.)

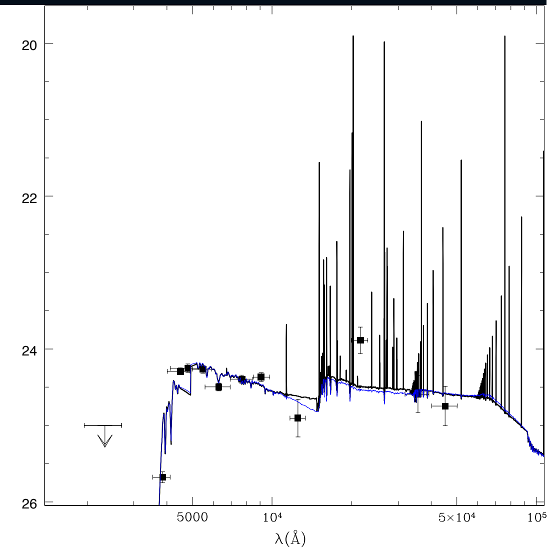


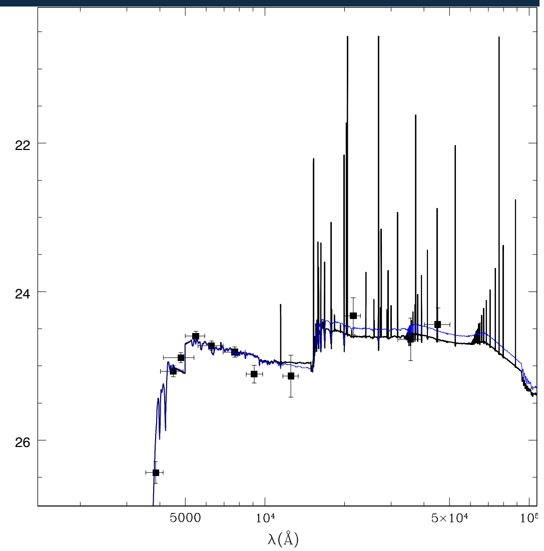
VUDS - COSMOS FIELD: SED Fitting

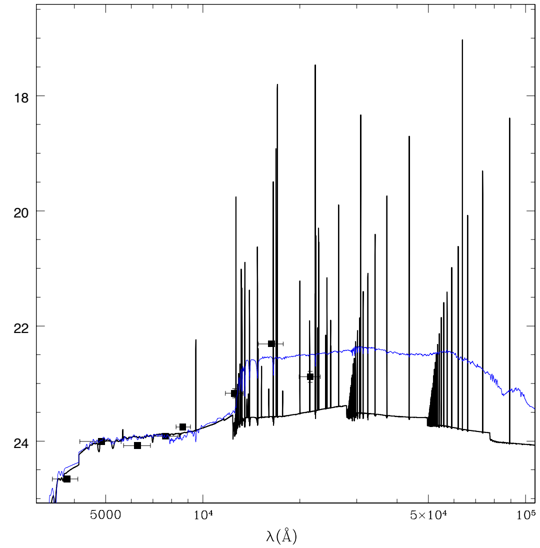
We use two similar approaches
Le Phare (Ilbert+2010) and
photoz (Fontana+2006)

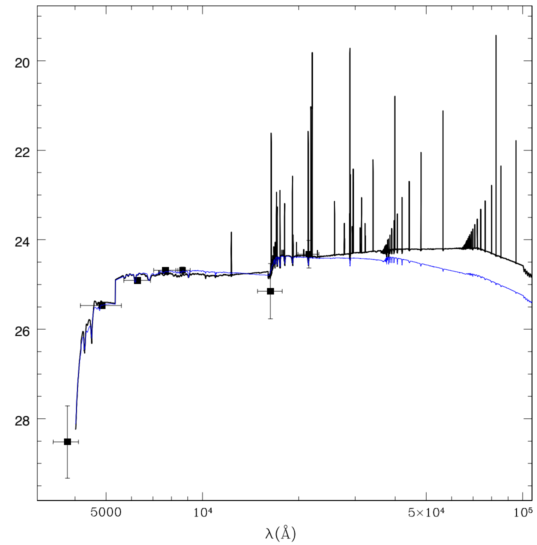
Stellar and Nebular models
(Bruzual & Charlot 2003 + Schaerer & de Barros 2009) including different recipes SFHs, Z, ages…
(details,e.g. Castellano+14, Santini+14)





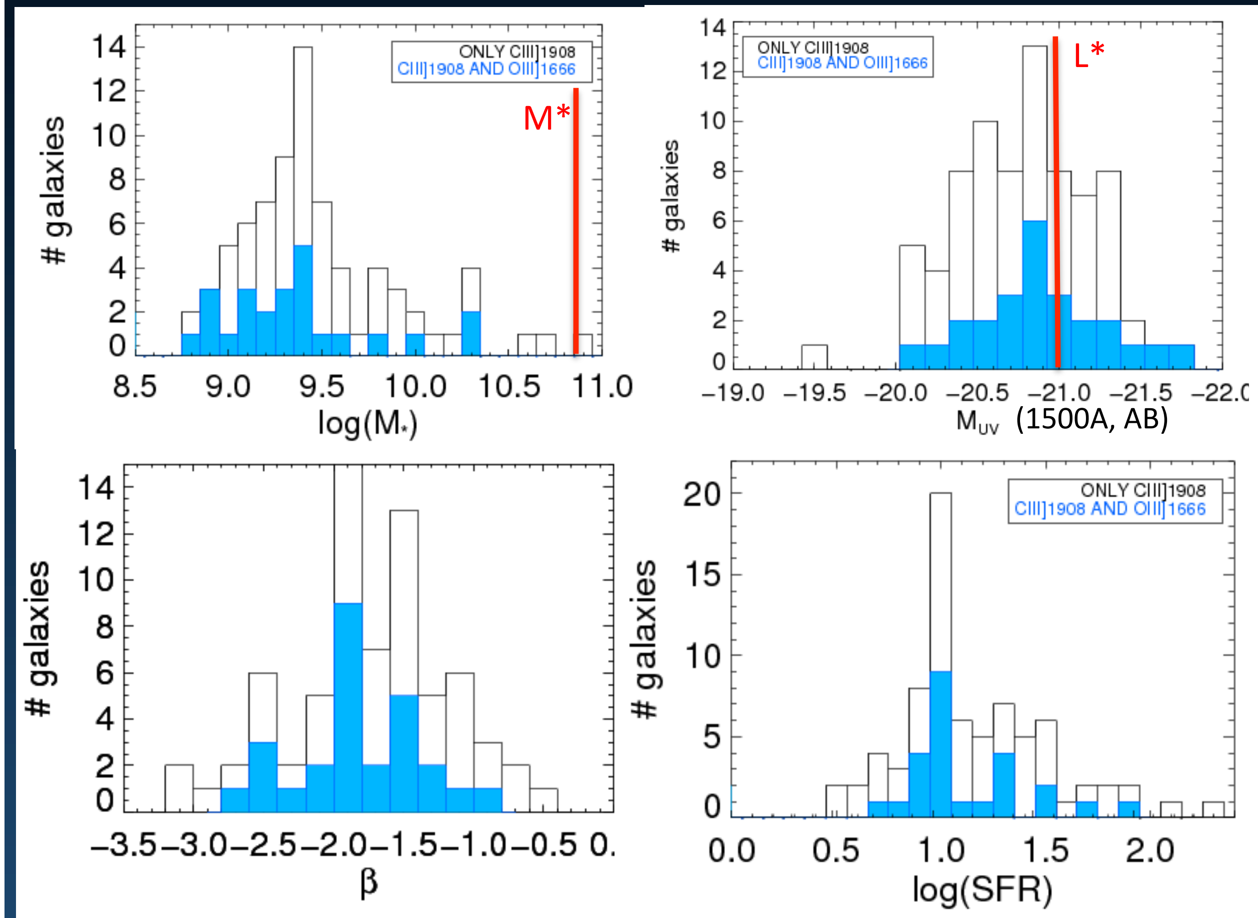


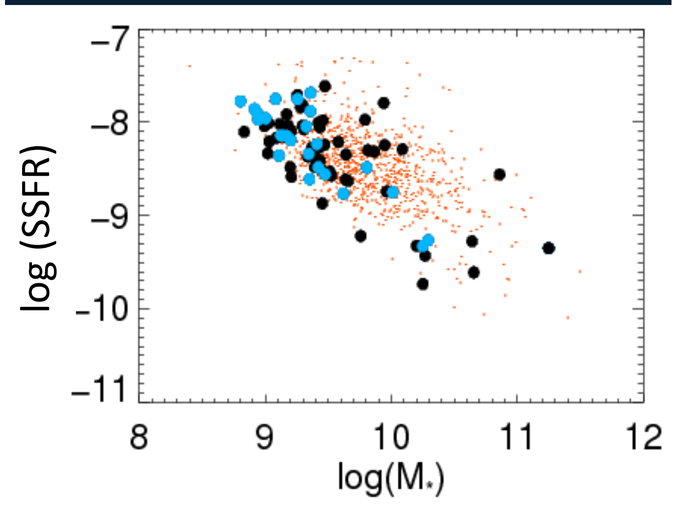




VUDS - COSMOS FIELD: SED Fitting

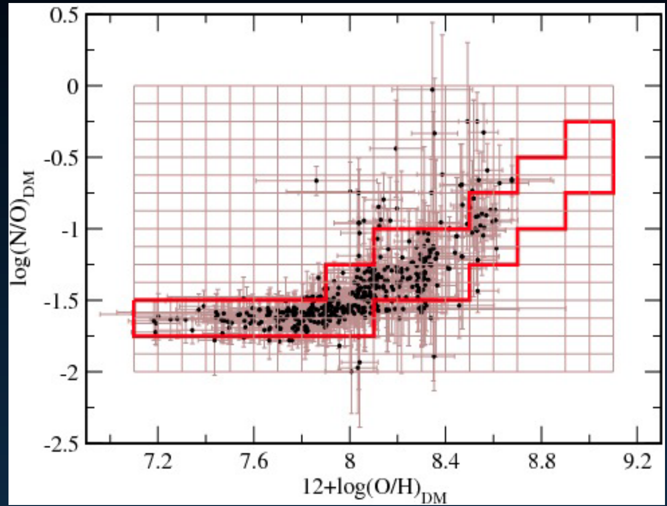
First results (based on LePhare's method) show CIII emitters as low-luminosity, low-mass galaxies. Young ages, high SSFR, low Z, low dust….

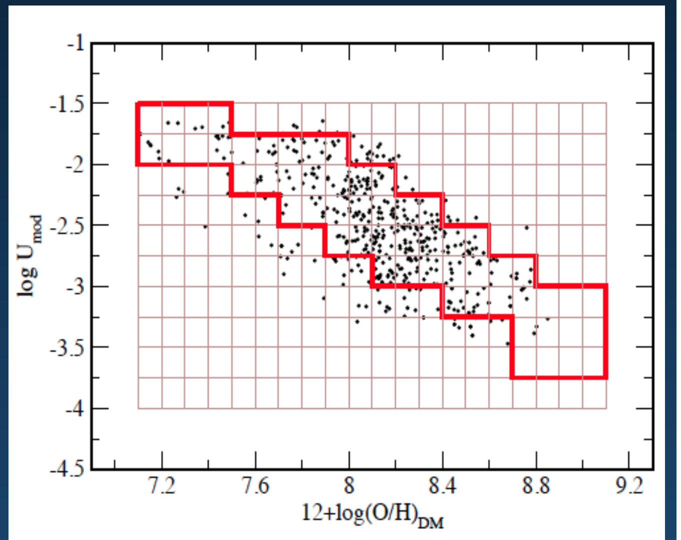


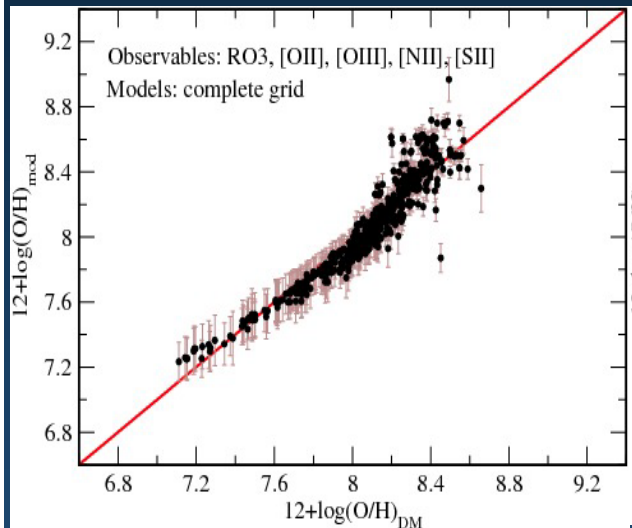


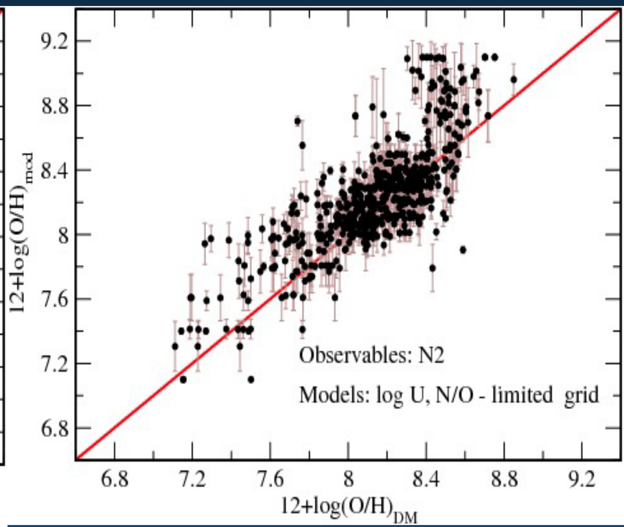
Derivation of T_e-consistent model-based abundances

- We use a Python script called HII-CHI-MISTRY (Perez-Montero 2014) http://www.iaa.es/~epm/HII--CHI-mistry.html
- HII-CHI-MISTRY is a model-based algorithm that leads to a derivation of O/H and N/O consistent with the direct method over all ranges of Z even in absence of an estimate of the electron temperature. This is done by constraining the space parameter in Z, N/O, and U, empirically.
- We are using a new version of HII-CHI-MISTRY adapted to include emission lines in the UV range (e.g. using C/O instead of N/O and defining new metallicity-sensitive indexes based on UV lines)



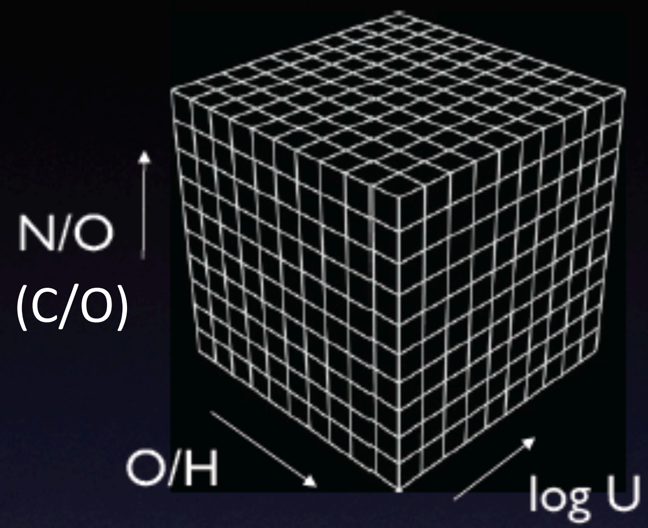






(Perez-Montero 2014)

Photoionization Models



All models can be got from the Million Model Mexican DataBase (3MdB, Morisset 2013)

A large grid of photo-ionization models was calculated to obtain emission-lines under different input assumptions.

<u>Model properties</u>:
- Code: Cloudy v. 13.03
- Ionizing SED: POPSTAR (Mollá+ 2010), instantaneous burst of 1Myr at the metallicity of gas
- Geometry: Plane-parallel
- Gas density: 50 cm-3
- Dust-to-gas ratio: Default MW ratio
- Abundances: Scaled to oxygen
- 12+log(O/H) = [7.1 – 9.1] in bins of 0.1dex
- log)(N/O) = [-2.0, 0.0] in bins of 0.125 dex
- Log U = [-4.0, -1.50] in bins of 0.25 dex

This gives a total of 3927.

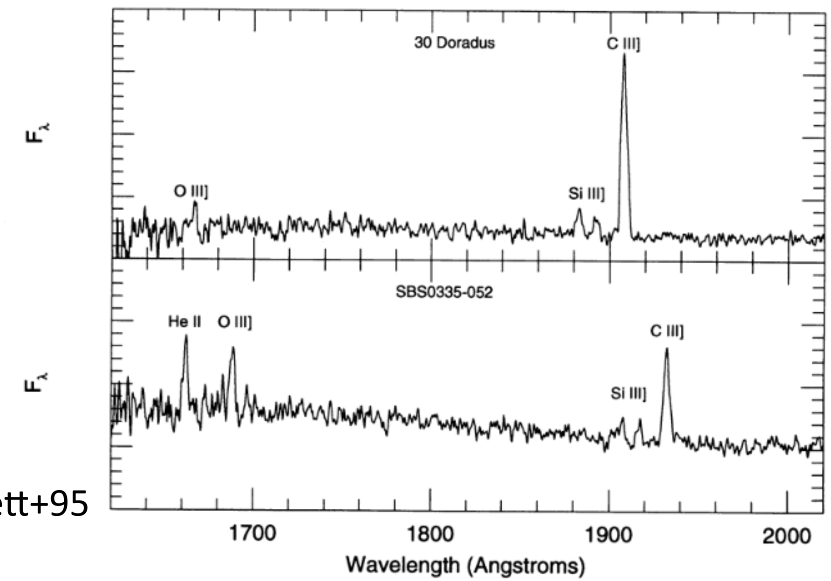
Control samples

In order to compare the results from the HCM method with the abundances derived from the direct method, we will use a control sample of objects with a direct estimate of the T_e, U, and C/O

All local GHII regions and HII galaxies observed in the UV (from Garnett+95,97,99; Kobulnicky & Skillman+97, 99, etc)

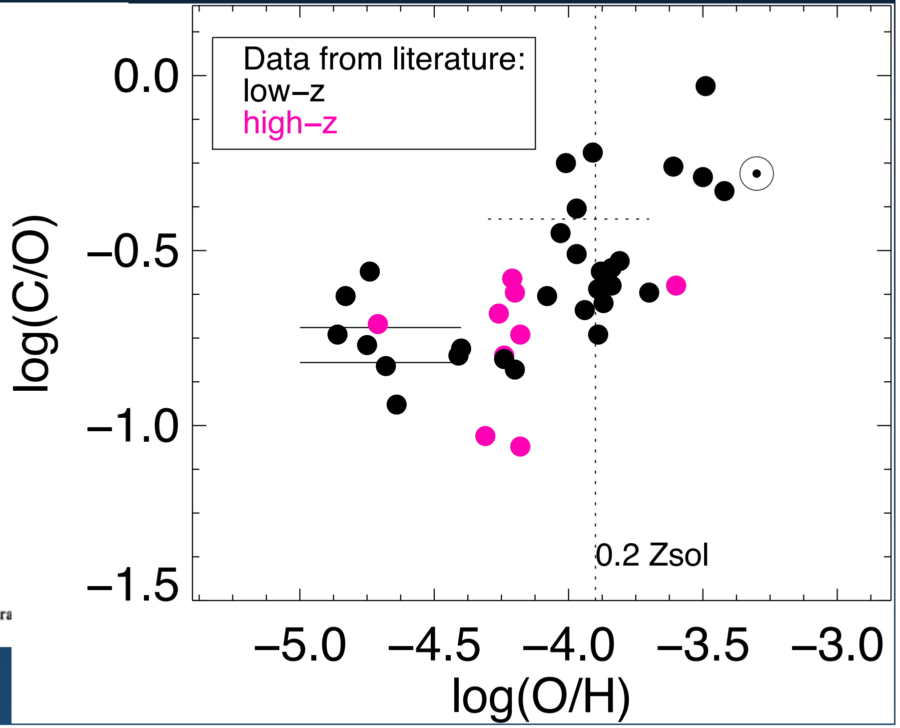
The few high-z galaxies observed so far (From Fosbury+03; Erb+10; Christensen+12; Bayliss+14, etc)

Most of them are strongly lensed systems



Garnett+95

FIG. 1.—FOS spectra of two giant extragalactic H II regions, showing the O III] 1666 Å, Si III] 1883, 1892 Å, and C III] 1908 Å features. *Top*: 30 Dora SBS 0335−052. Both spectra have been smoothed with a three-point Gaussian filter.



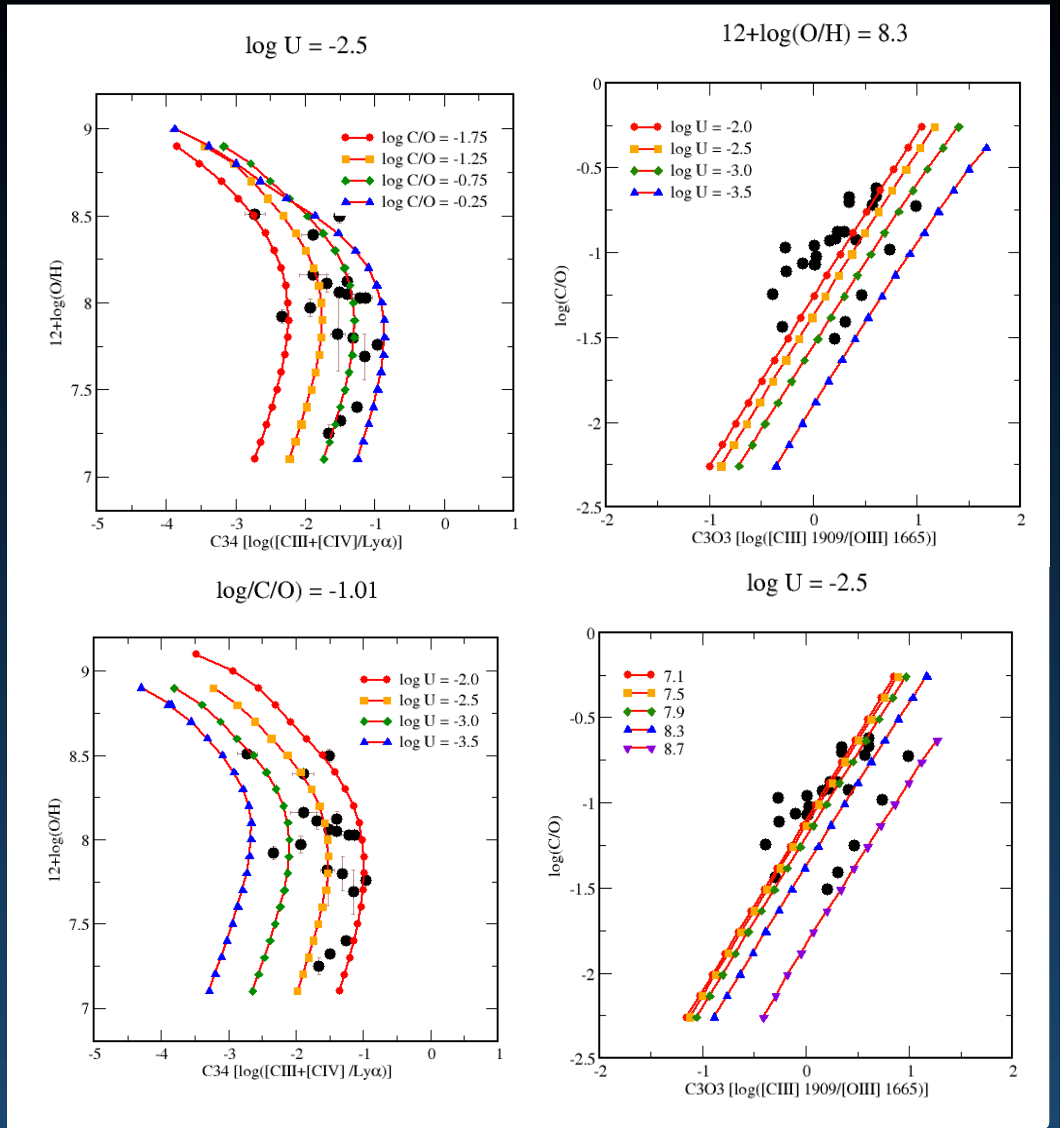
Derivation of model-based abundances using *HII-CHI-MISTRY*

LINE RATIOS

C34 = (CIV+CIII)/Lya
An index similar to R23 …
C3O3 = CIII]1908/OIII]1666
C3C4 = CIII]1908/CIV1551
RO3 = [OIII]5007/[OIII]1666

Using *PyNeb* (Luridiana+15) the code derives the physical conditions, ionic abundances etc..
e.g. C2+, O2+ and C3+
and obtains C/O = (C2+ + C3+)/O2+

If O5007 is available then we have Te[OIII]



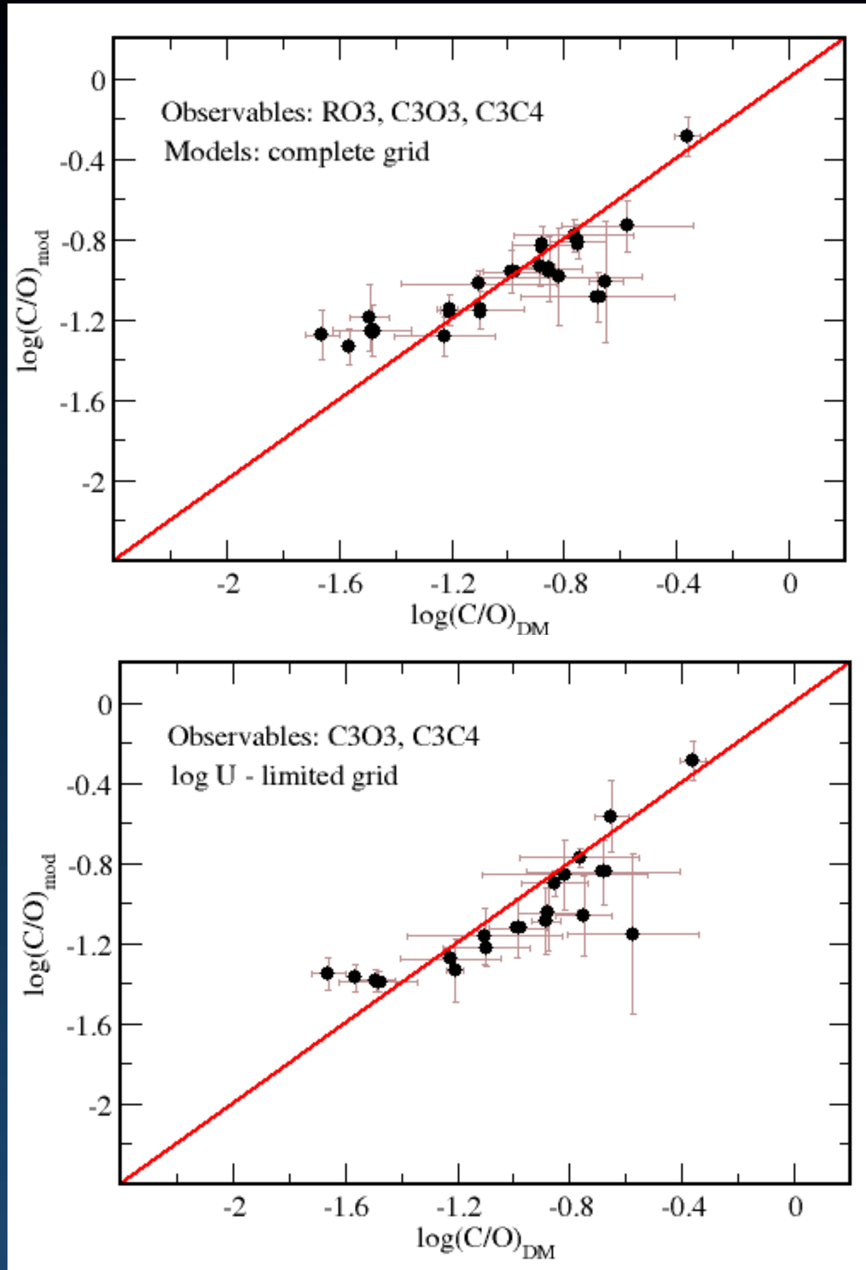
Derivation of model-based abundances using *HII-CHI-MISTRY*

LINE RATIOS

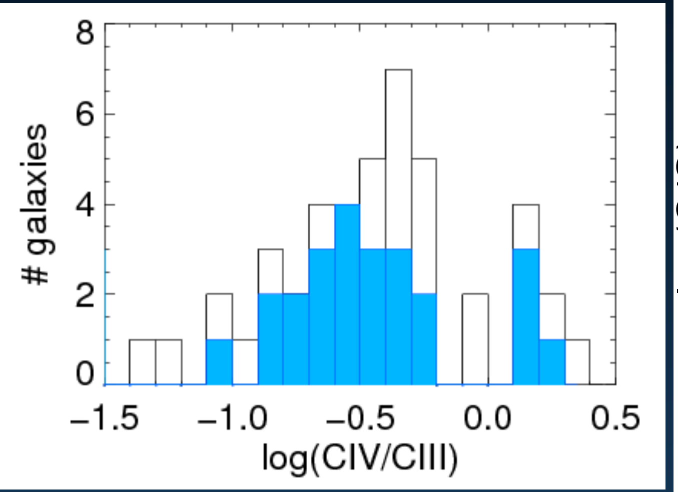
C34 = (CIV+CIII)/Lya
An index similar to R23 …
C3O3 = CIII]1908/OIII]1666
C3C4 = CIII]1908/CIV1551
RO3 = [OIII]5007/[OIII]1666

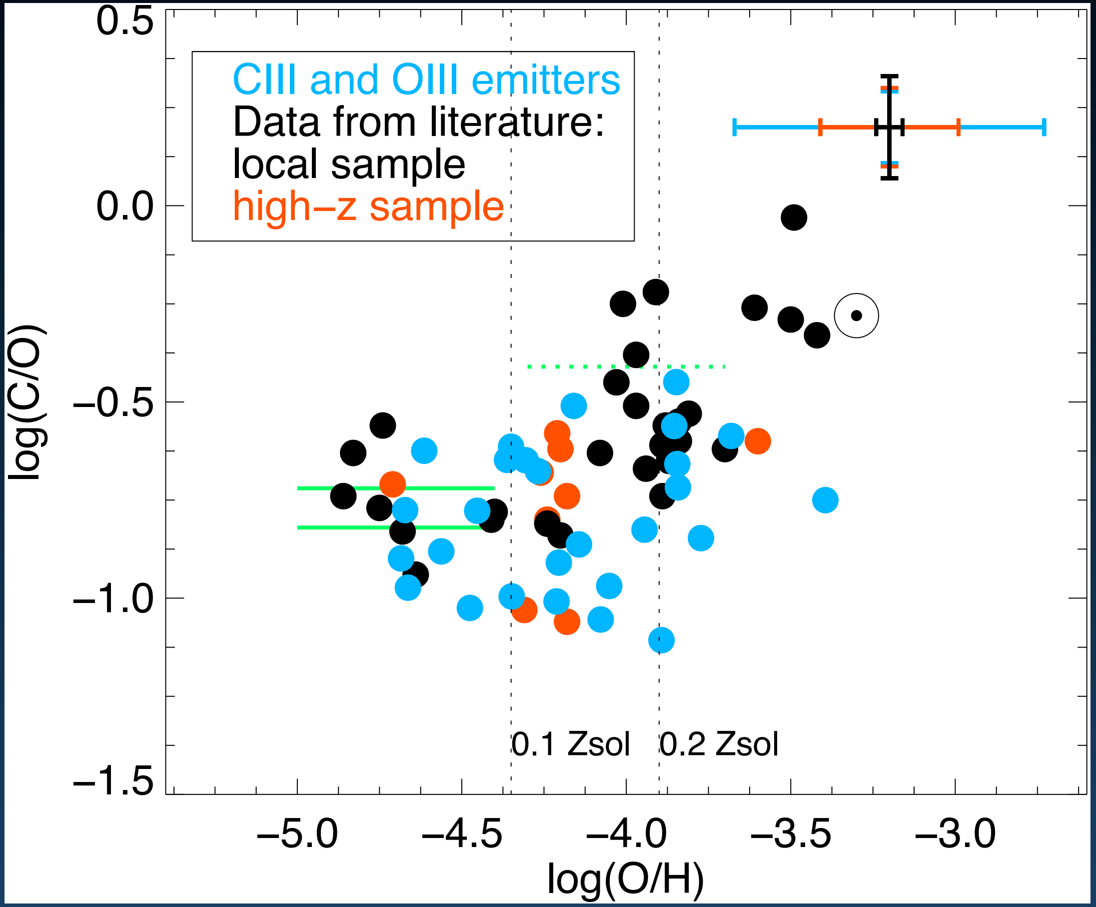
Using *PyNeb* (Luridiana+15) the code derives the physical conditions, ionic abundances etc..
e.g. C2+, O2+ and C3+
and obtains C/O = (C2+ + C3+)/O2+

If O5007 is available then we have Te[OIII]



First (preliminary) results





Most EELGs in VUDS seems to be young metal-poor systems

Summary

VUDS provides high quality spectra for an unprecedentedly large sample of emission line galaxies at z>2. Its unique sensitivity allow us to detect a large sample of 80 CIII emitters at z=2-4 in the COSMOS field. Most of them are LAEs.

Based on preliminary SED fitting and morphological inspection, our data strongly suggest that CIII emitters tend to be compact, low-mass, high SSFR galaxies. Best models also suggest young ages and low-dust attenuation as a dominant property.

Preliminary spectroscopic analysis over 80 galaxies suggest that CIII and Lyα equivalent widths are correlated, giving statistical support to previous findings.

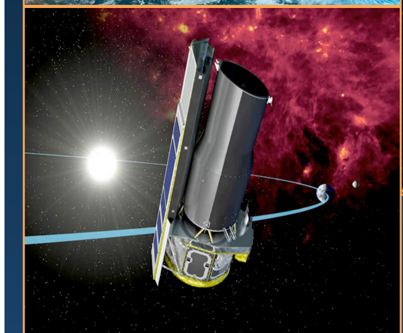
We find that ~30% of the CIII emitters are EELGs. They show additional high ionization nebular lines (e.g. CIV, HeII and OIII]).

Based on a robust method that combines simultaneously observed line ratios and photoionization models we find that these EELGs show strongly subsolar C/O abundances, consistent with galaxies in early phases of their evolution, high ionization and low metallicity.

More detailed analysis and results coming soon....NIR follow-up spectroscopy in the short-term plans

VANDELS

A VIMOS spectroscopic public survey Co-PIs: R. McLure (Edinburgh) & L. Pentericci (Rome)

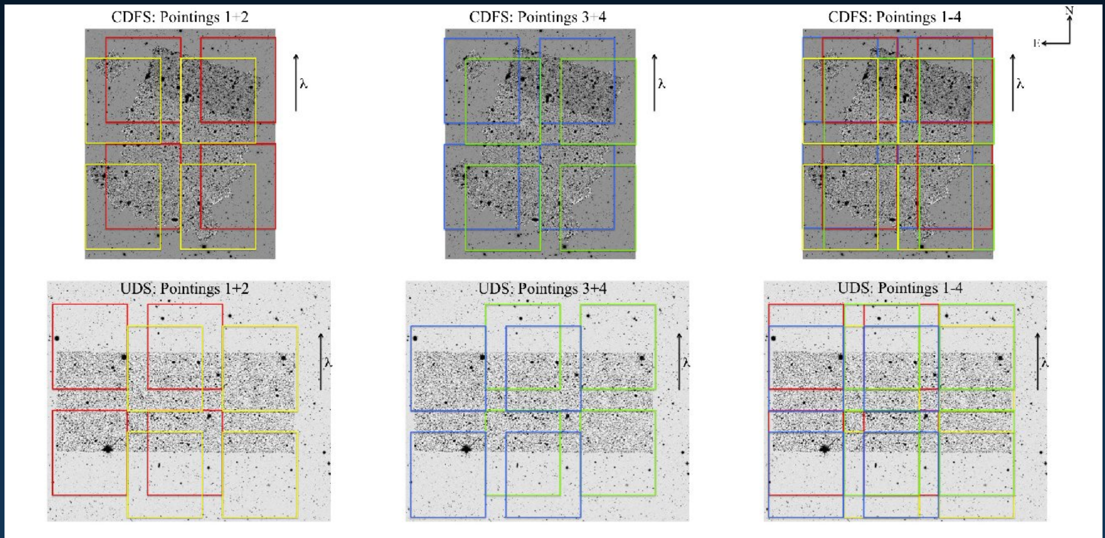


A deep VIMOS survey of the CANDELS UDS and CDFS fields

Unveiling the astrophysics of high-redshift galaxy evolution

MAIN SCIENCE CASES

1. Constraining metallicity, dust and star formation rates in galaxies at 2.5< z< 5.5
2. Massive galaxy assembly at 1.5 < z < 2.5
3. A spectroscopic derivation of the stellar mass function and star formation histories at z> 2.5
4. Measuring galactic outflows at 1.5 < z < 4.5
5. The progenitors of compact passive galaxies



TECHNICAL DETAILS

** VIMOS medium resolution spectroscopy in the range 4800-10000 A
** up to 80 hours *on source integration*
** more than 2600 galaxies observed
** total area 0.2 square degrees around the HST CANDELS areas (UDS&CDFS)
** to be conducted over ≈260 nights in the next 4 years

THANK YOU !