Using UV emission-lines to derive gas-phase chemical abundances in star-forming and AGN-dominated galaxies in deep surveys

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EXCELENCIA SEVERO OCHOA

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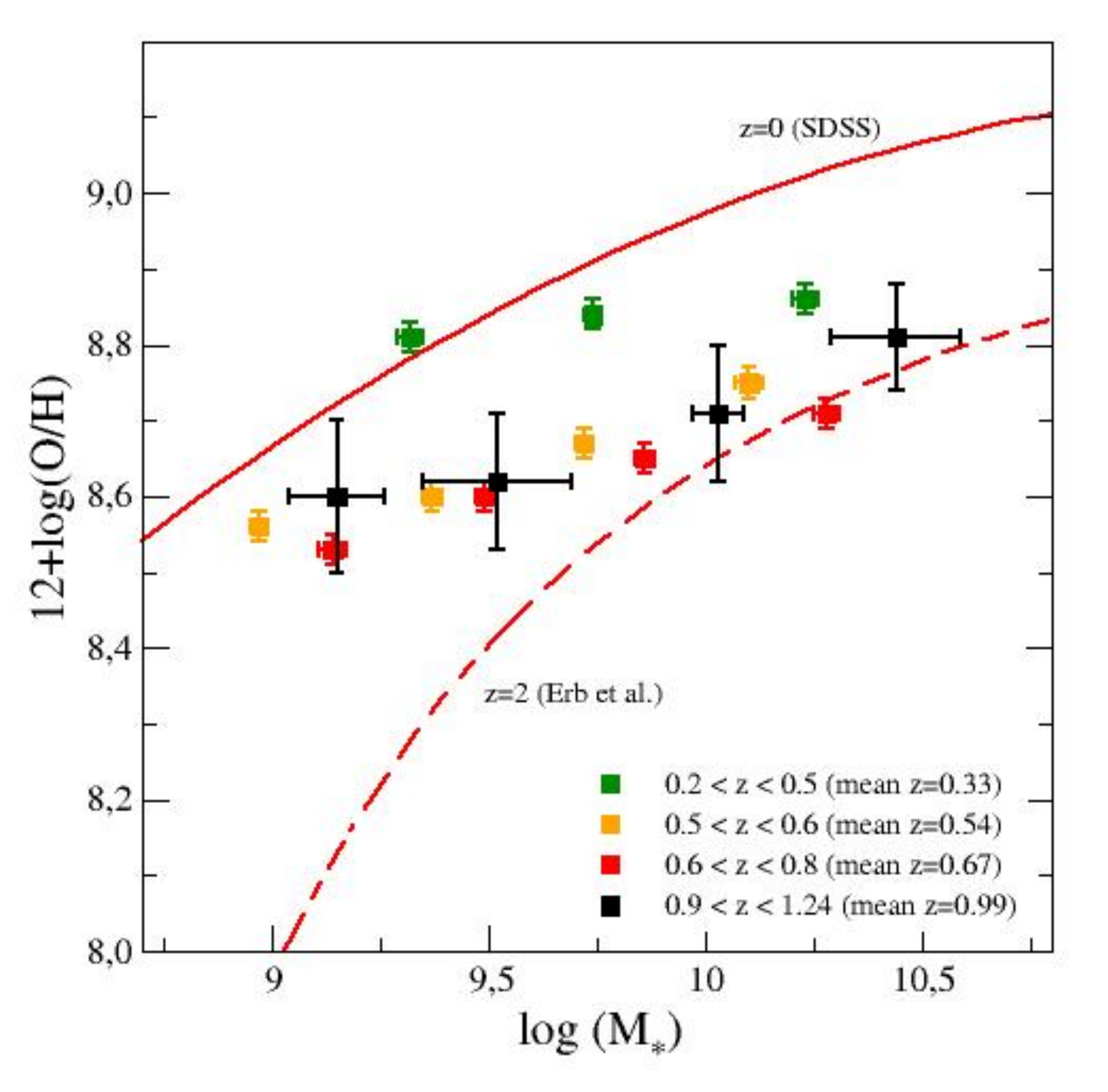
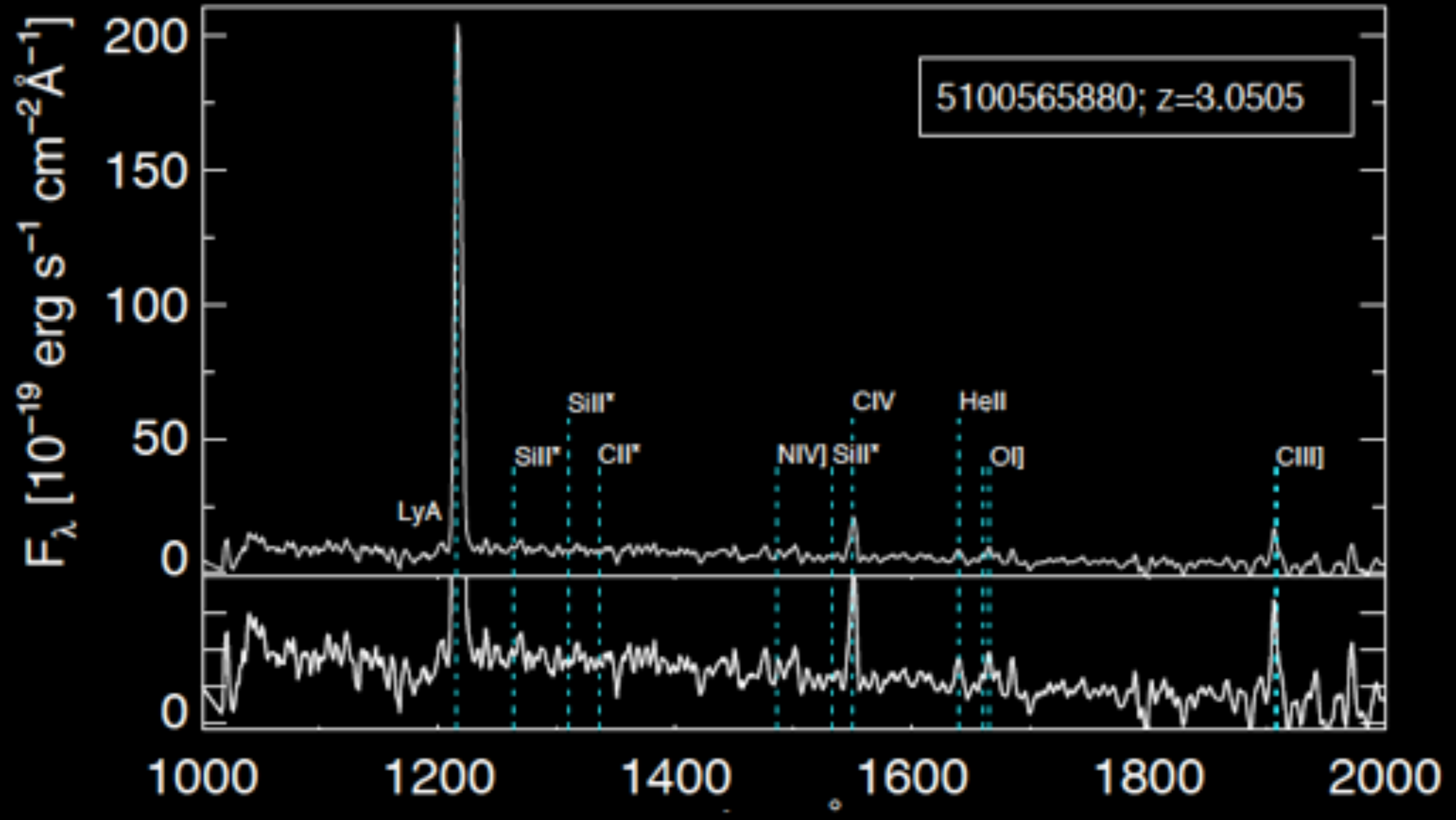
The importance of metallicity in deep surveys

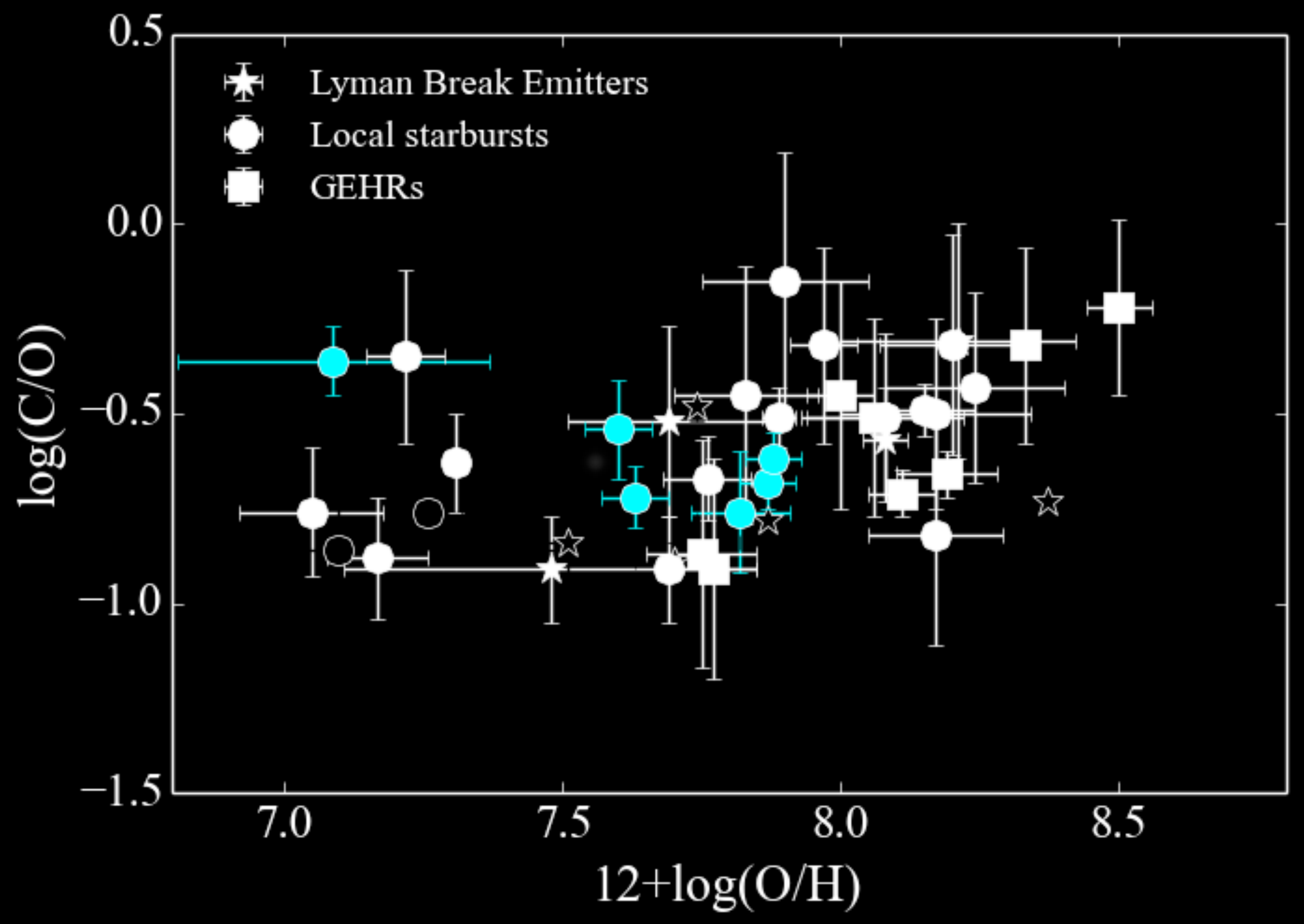


Pérez-Montero et al (2009)

The study of the relation between stellar mass and gas phase metallicity and its evolution through cosmological time is crucial to the understanding of the formation and evolution of galaxies.

Dealing with UV lines for high-z galaxies





Pérez-Montero & Amorín (2017)

The importance of secondary elements

The knowledge of the N/O ratio can complement that of O/H, since N/O gives extra information about the SFE and it is relatively independent of hydrodynamical effects

Additionally, when optical [NII] lines are used to derive O/H a previous determination of N/O is essential

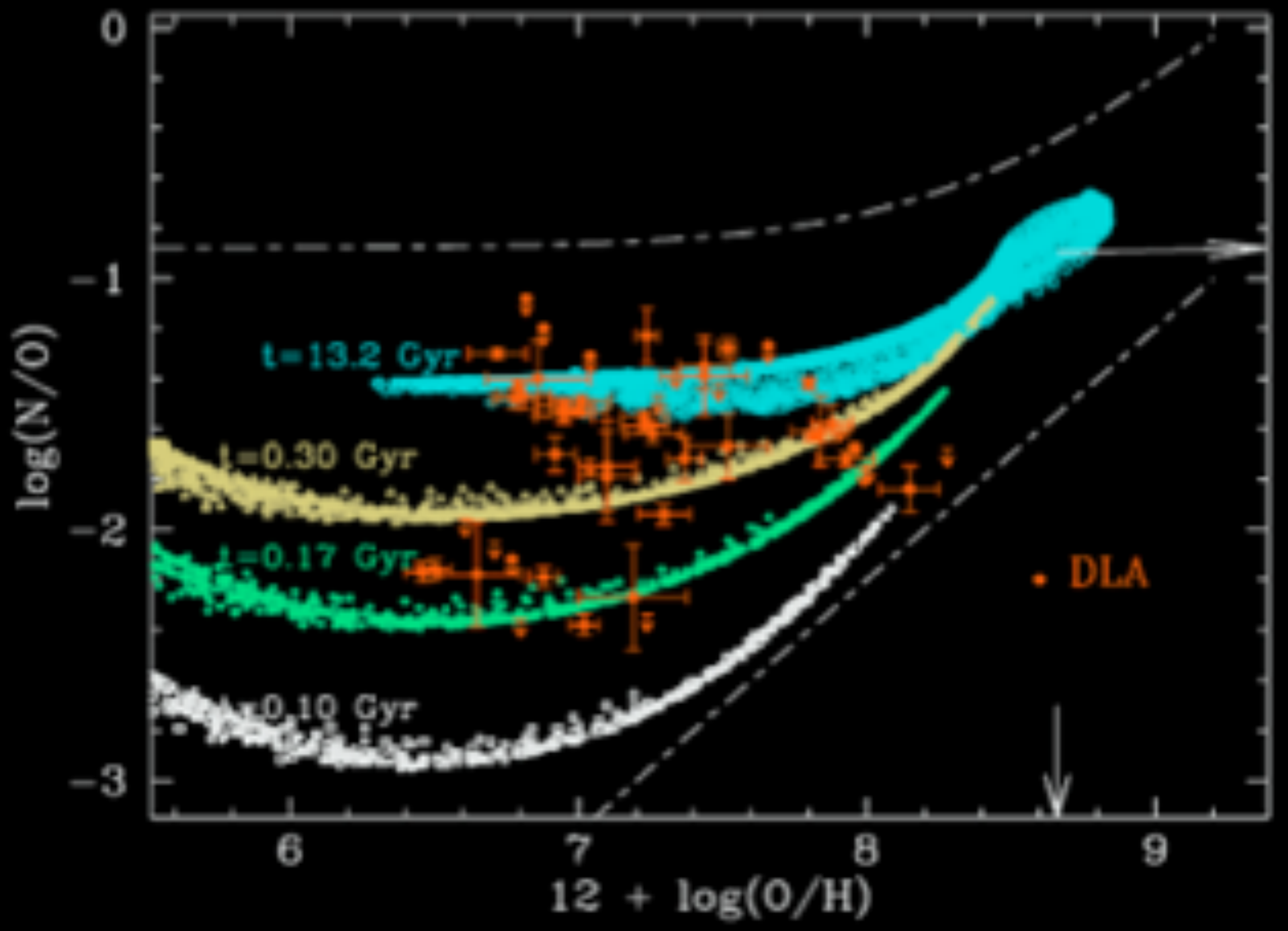
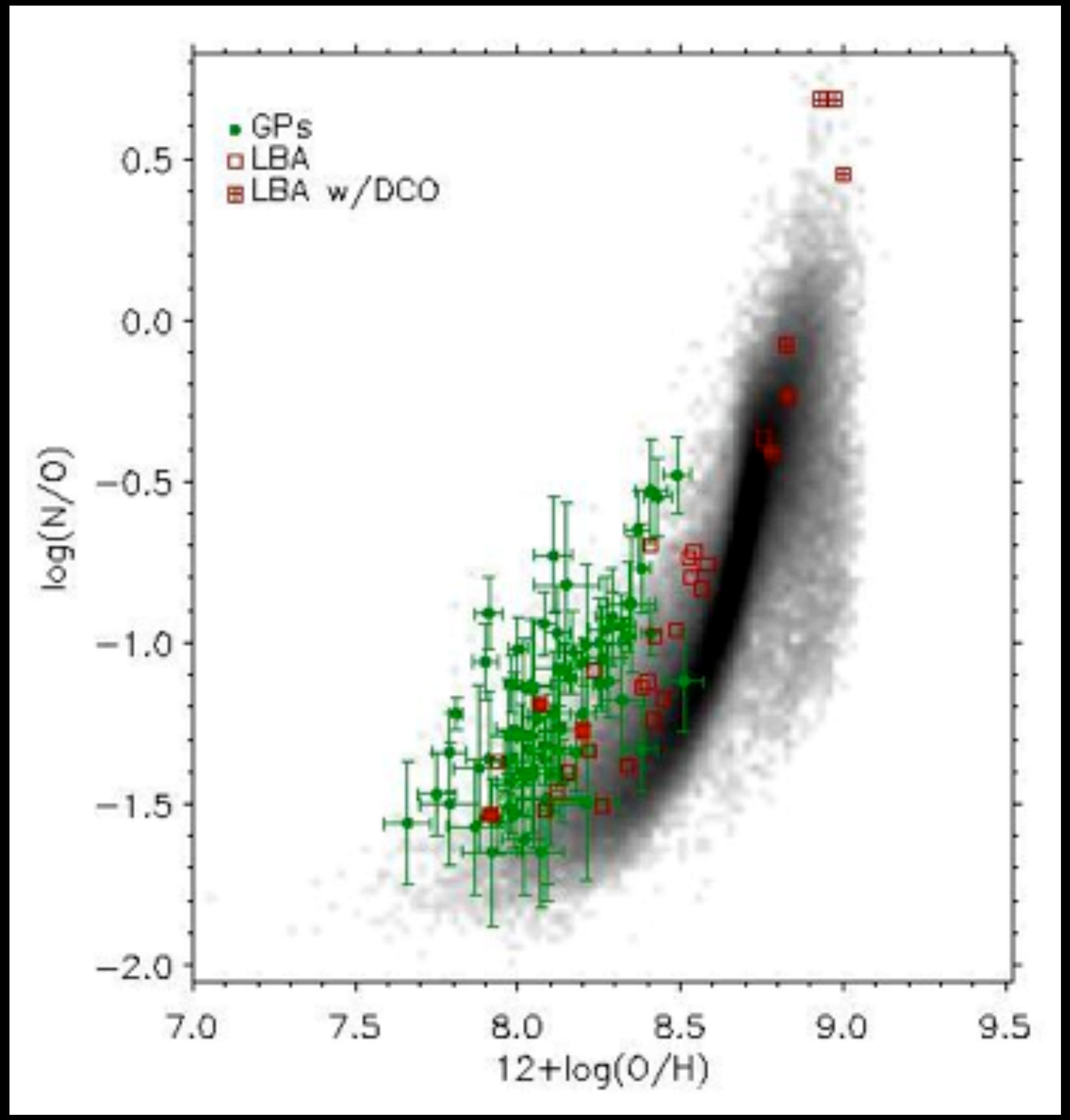


Figure 10. The relation N/O–O/H for different evolutionary times as marked in the figure. The full (cyan) dots correspond to DLA objects.

Mollá et al. (2006)

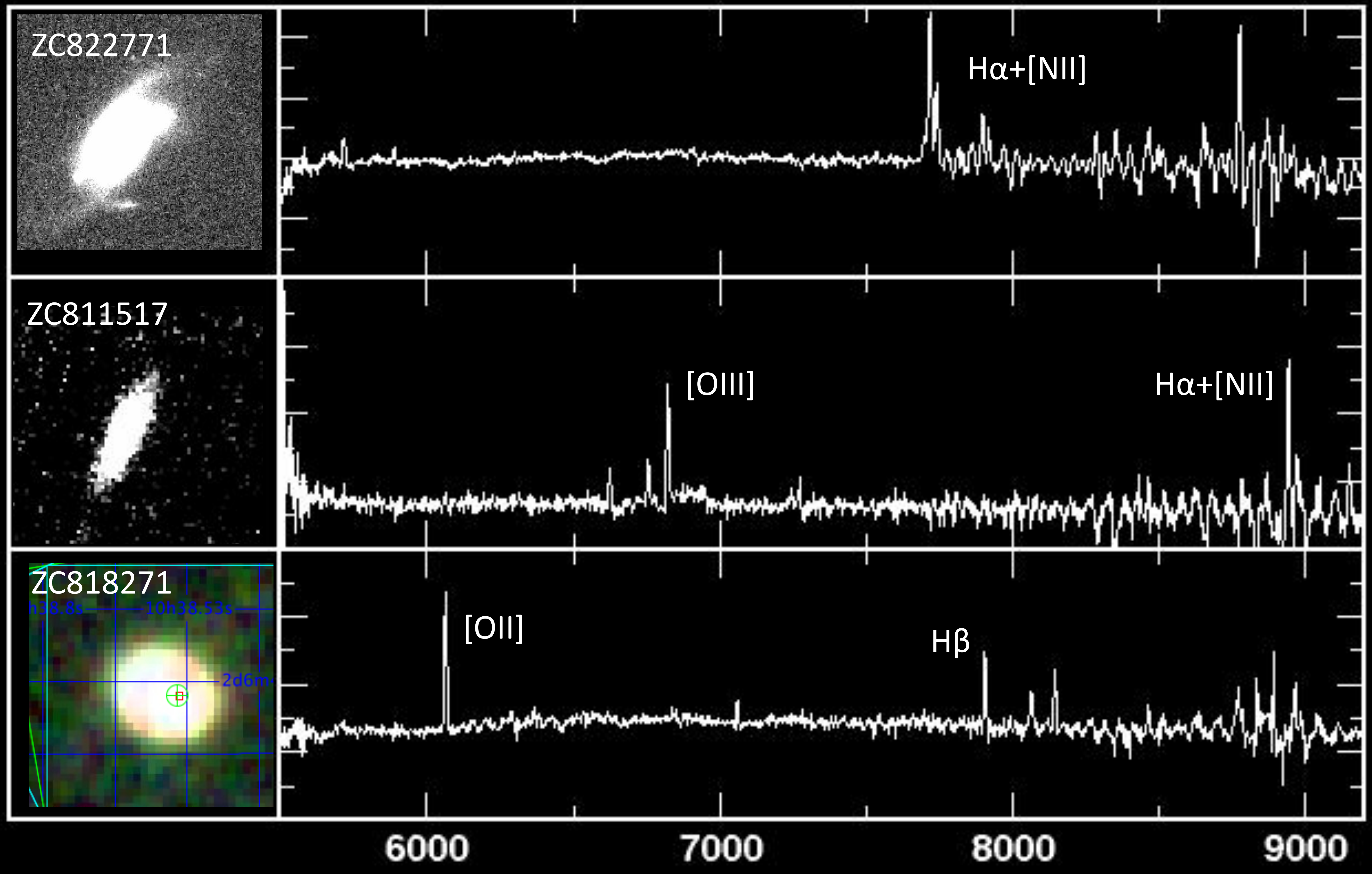


Amorín et al. (2010)

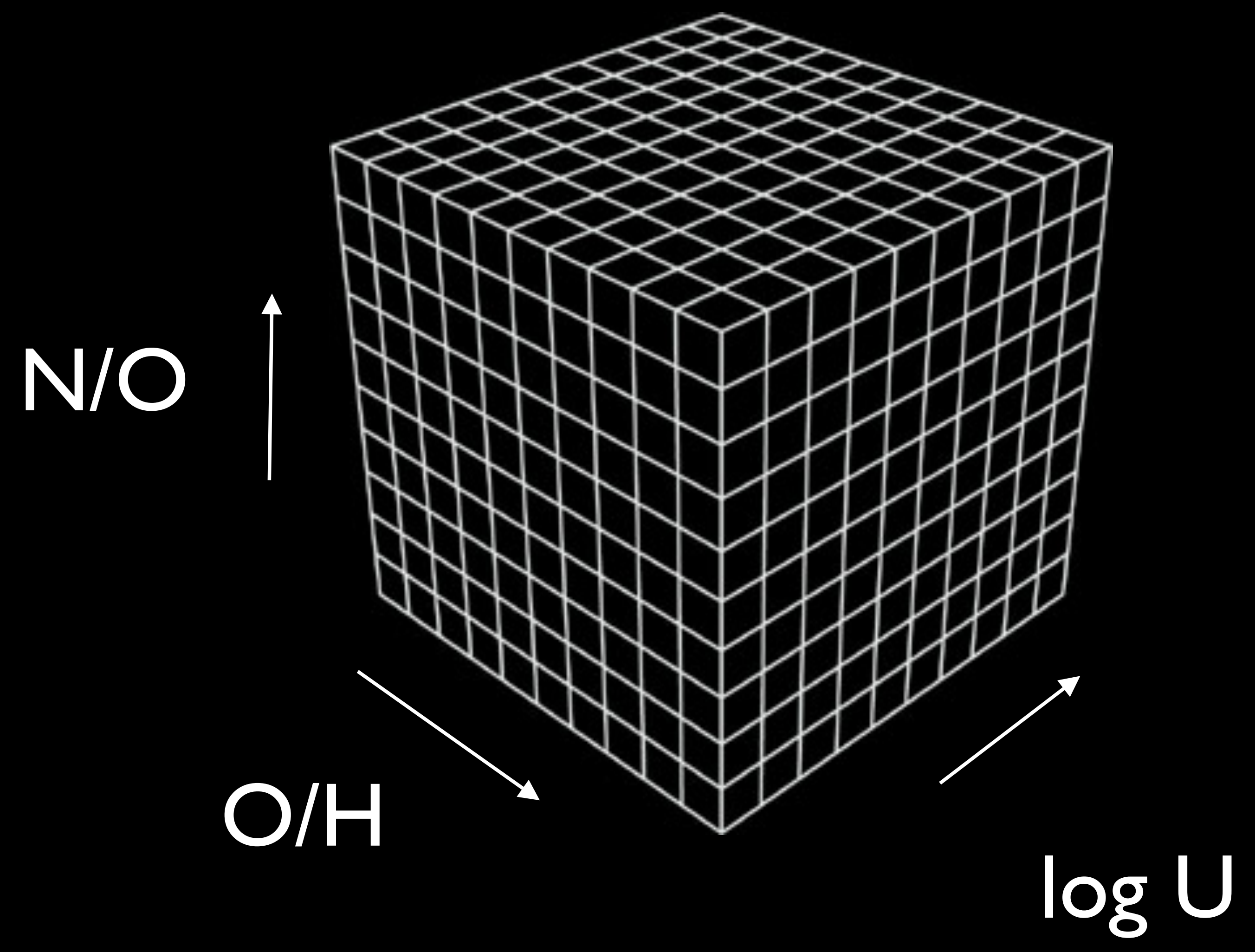
Why models are useful to derive Z?

Models complement observations in order to:

- Derive total abundances from some ionic fractions (i.e. ICF)
- Deerive all functional parameters (Z, Teff, U, dust, leaking)
- Compare objects or regions consistently with different observational coverage



Computing a grid of models



Calculation of grids of models to derive abundances from UV lines

- Cloudy v. 17.00 (Ferland et al. 2017)
- POPSTAR (Mollá et al. 2010) model stellar atmospheres (same Z as the gas, age = 1 Myr, Chabrier IMF)
- Addition of BPASS models for EELGs, and double peak power-law for NLR of AGNs
- Constant density
- Radiation-bounded geometry
- All elements scaled to O, except N and C
- Standard MW dust-to-gas ratio
- Variation of input parameter:
  - 12+log(O/H): [6.9, 9.1] 0.1bin
  - log(N/O): [-2.0,0.0] 0.125bin
  - log U: [-4.00,-1.50] 0.25bins

This gives a total of 3,927 models

Abundance derivation: HII-CHI-mistry

HII-CHI-mistry-UV (Pérez-Montero & Amorín 2017, http://www.iaa.es/~epm/HII-CHI-mistry.html)
is a code to derive O/H, N/O and log U using a χ2 weighted mean of the differences with the reddening corrected [OII], [OIII] (4363 and 5007), [NII] and [SII] optical emission lines.

STEP 1

C/O is calculated using as observable adequate emission-line ratios (e.g. C3O3) insensitive to O/H and U

$$\log(\mathrm{N/O})_f = \frac{\sum_i \log(\mathrm{N/O})_i/\chi_i}{\sum_i 1/\chi_i},$$

Errors are calculated as the standard
deviation of the weighted distribution

$$(\Delta \log(\mathrm{N/O}))^2 = \frac{\sum_i \log((\mathrm{N/O})_f - \log(\mathrm{N/O})_i)^2/\chi_i}{\sum_i 1/\chi_i}.$$

STEP 2

The grid of models is constrained for the closest values of C/O and CIV] and CIII[can be used in a new iteration to derive O/H and log U in a similar way

$$12 + \log(O/H)_f = \frac{\sum_k (12 + \log(O/H))_k/\chi_k}{\sum_k 1/\chi_k}$$

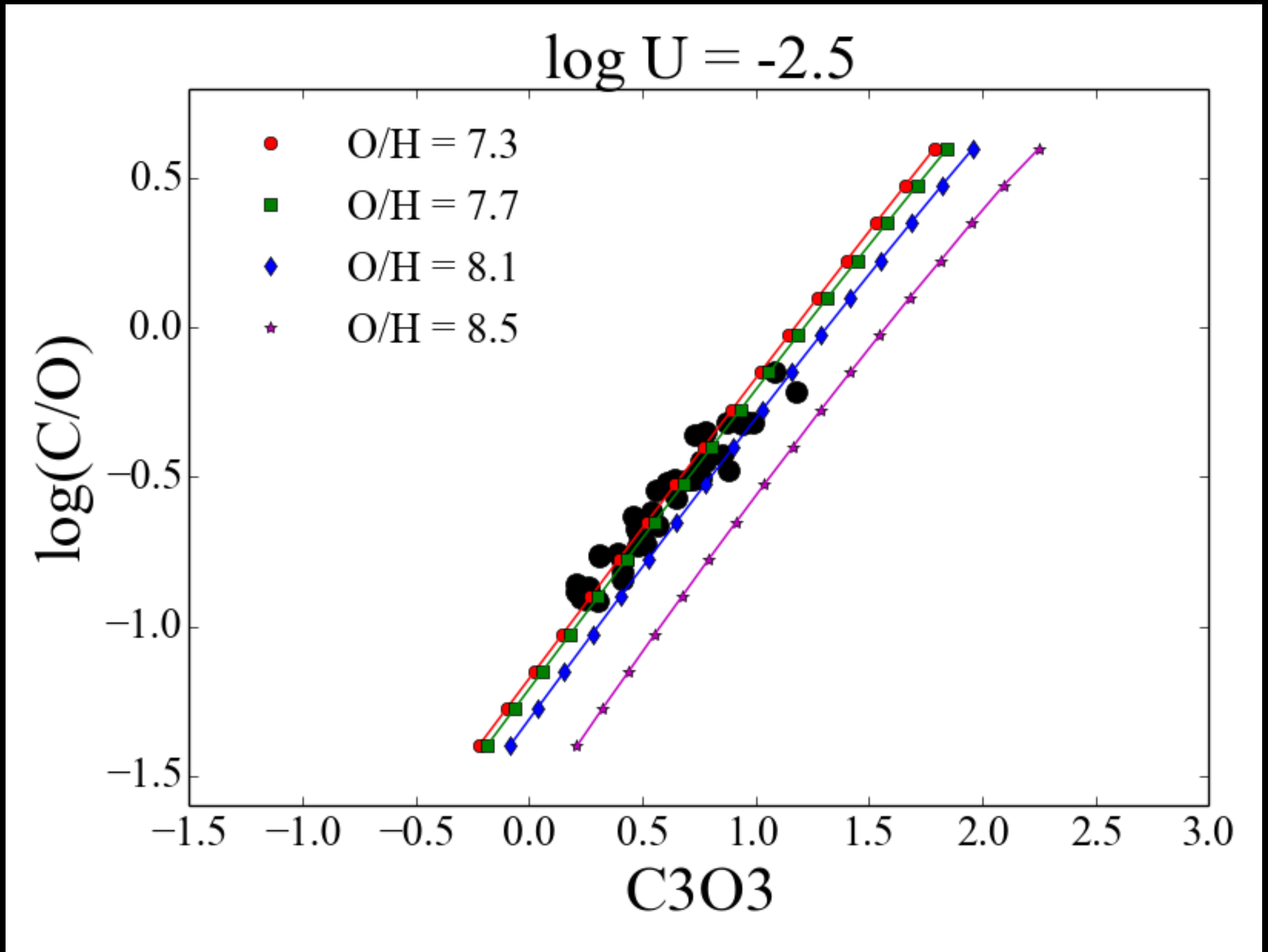
$$\log U_f = \frac{\sum_k \log U_k/\chi_k}{\sum_k 1/\chi_k}$$

$$\chi_i^2 = \sum_j \frac{(O_j - T_{ji})^2}{O_j},$$

Using C3O3 to derive C/O

$$log(C/O) = -1.069 + 0.796 \cdot C3O3$$

$$C3O3 = \log\left(\frac{I(\mathrm{C\,III]}\ 1908\ \text{Å}) + I(\mathrm{C\,IV}\,1549\ \text{Å})}{I(\mathrm{O\,III]}\ 1664\ \text{Å})}\right)$$

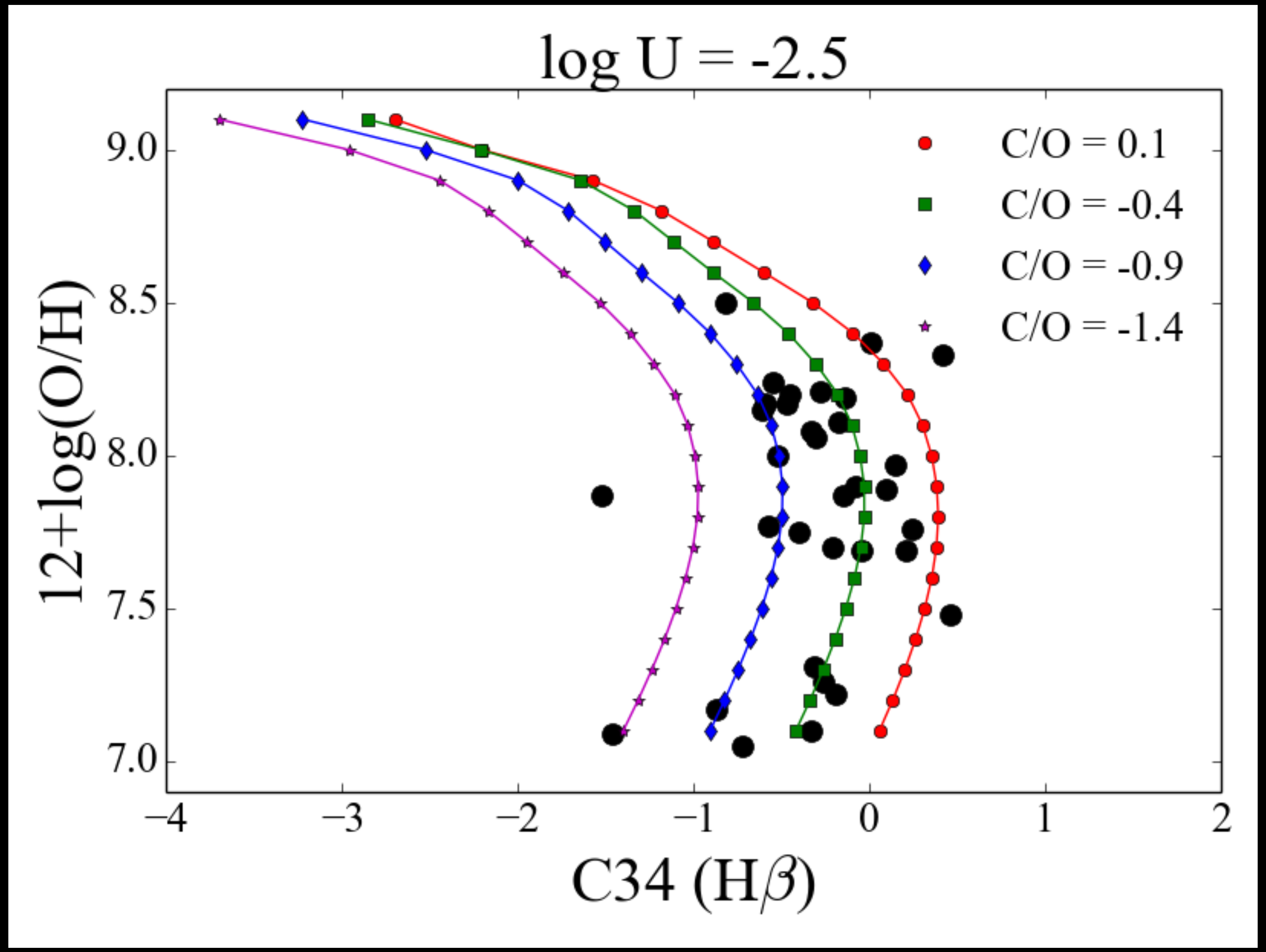


Pérez-Montero & Amorín (2017)

Derivation of O/H and log U

Once C/O is fixed, a new iteration of the remaining models is performed to make a minimization of the Chi-square values of the C34 and C3C4 parameters.

In case that the [OIII] 5007 optical line is also detected, the ratio with 1665 can be used to constrain the electron temperature and derive abundances with much lower uncertainties.

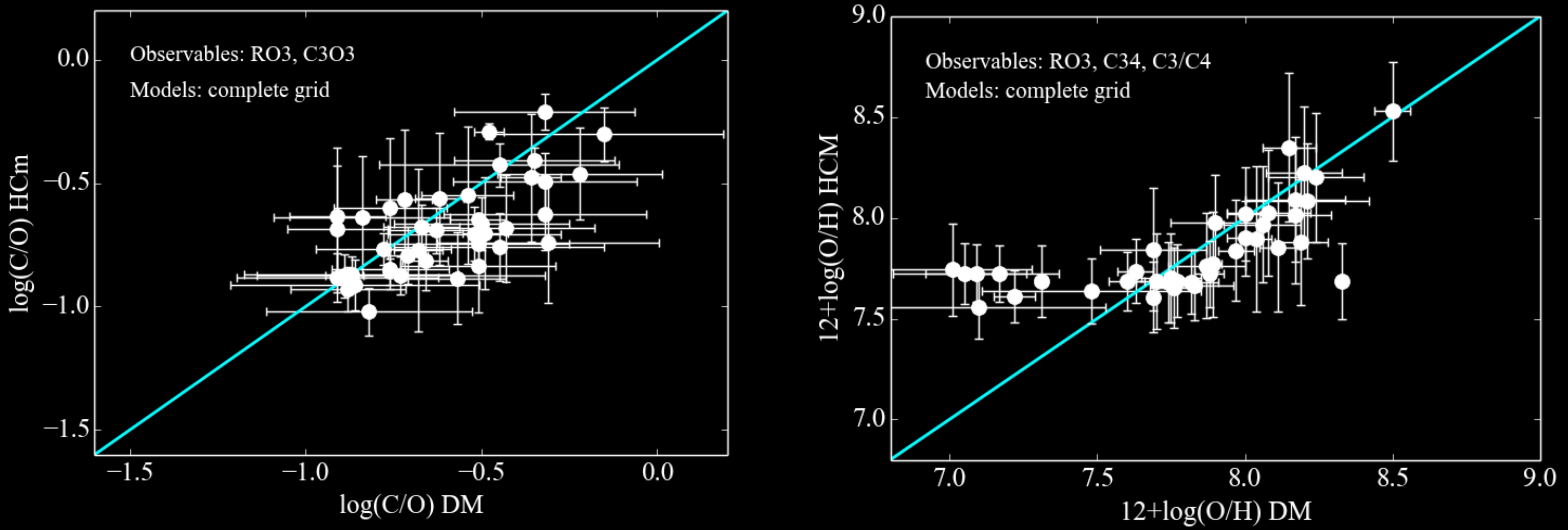


$$C34 = \log\left(\frac{I(\text{C III]}\ 1908\ \text{Å}) + I(\text{C IV}1549\ \text{Å})}{I(\text{H I})}\right)$$

$$C3C4 = \log\left(\frac{I(\text{C III]}\ 1908\ \text{Å})}{I(\text{C IV}1549\ \text{Å}}\right)$$

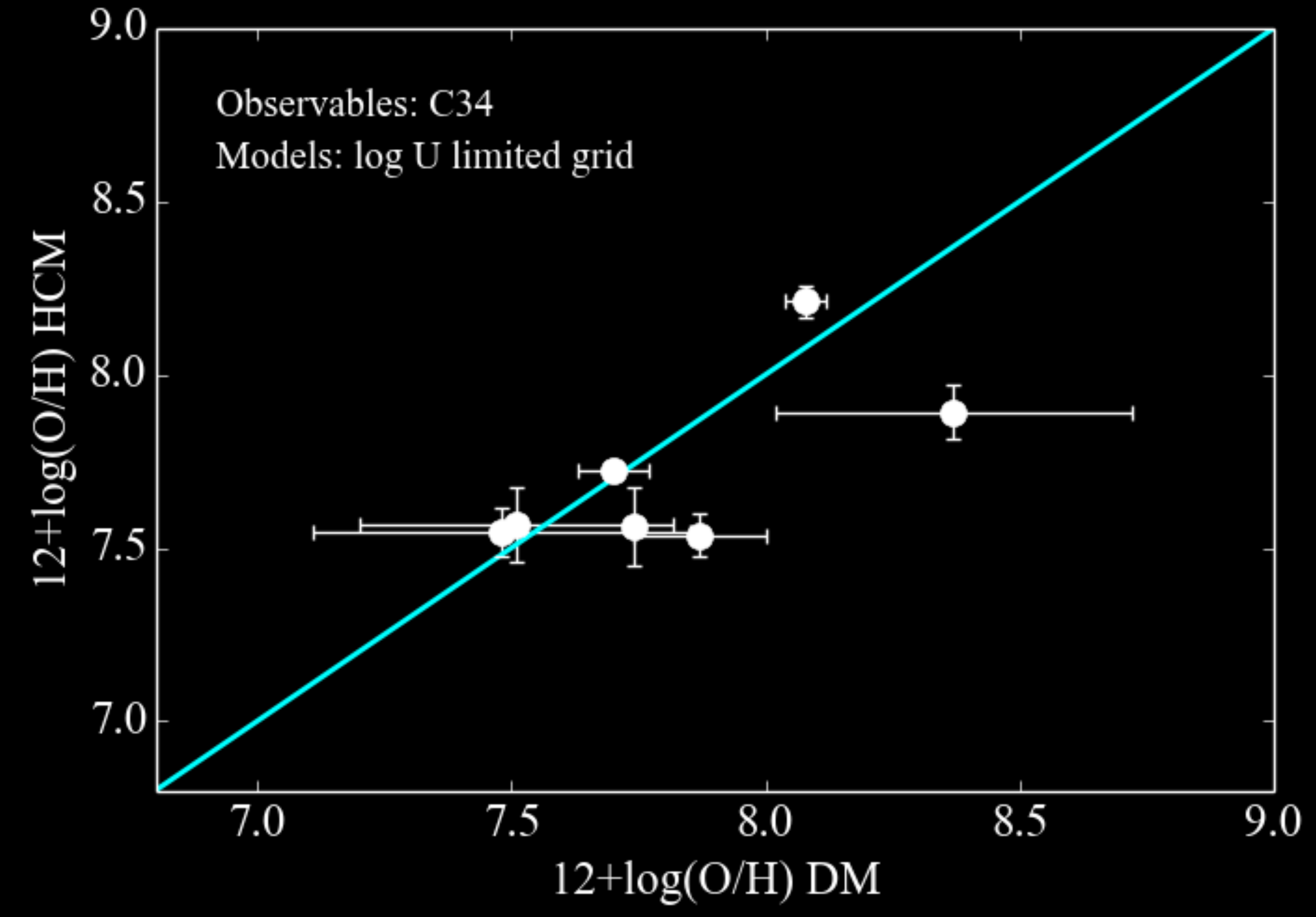
Pérez-Montero & Amorín (2017)

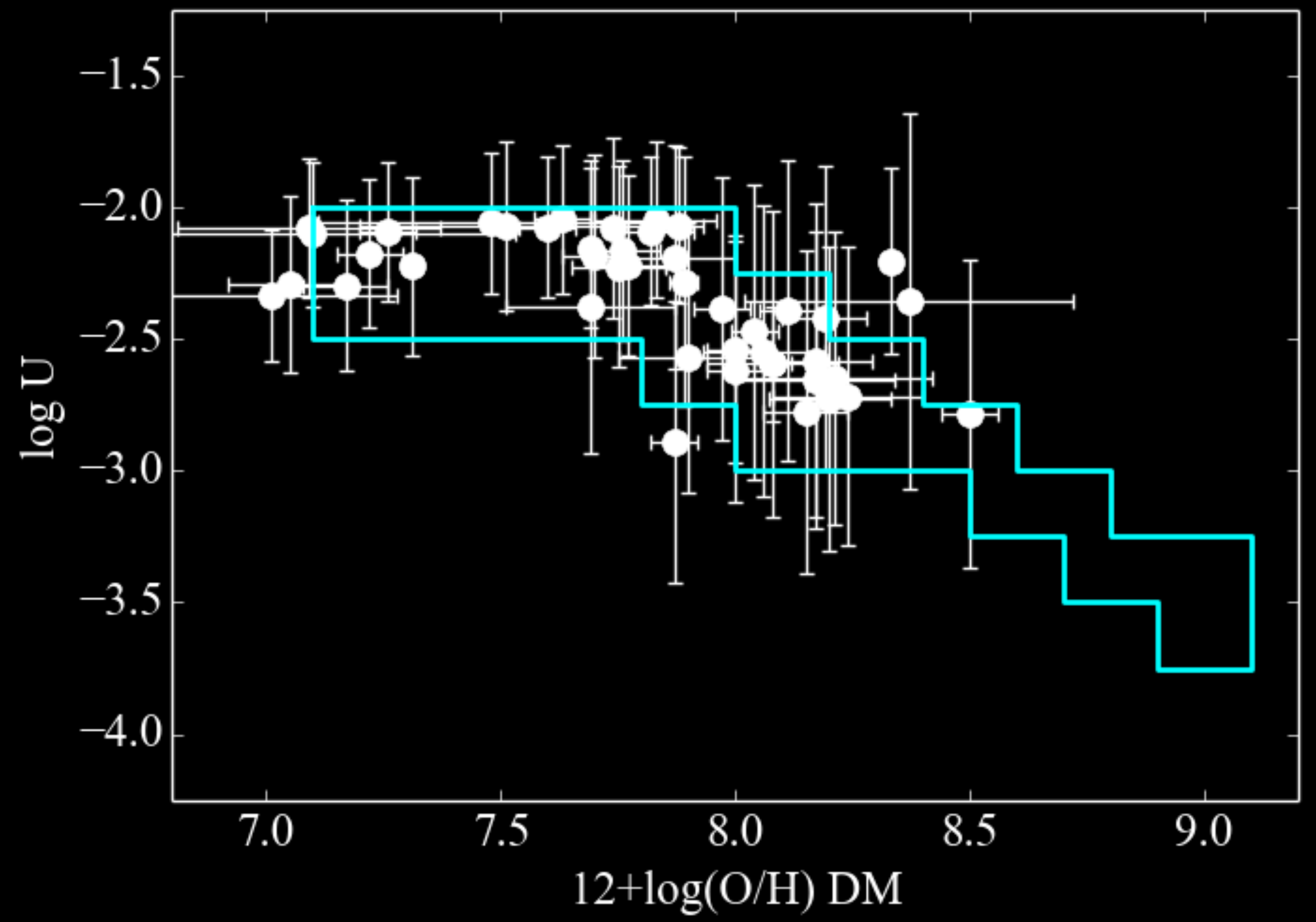
Comparison with the direct method

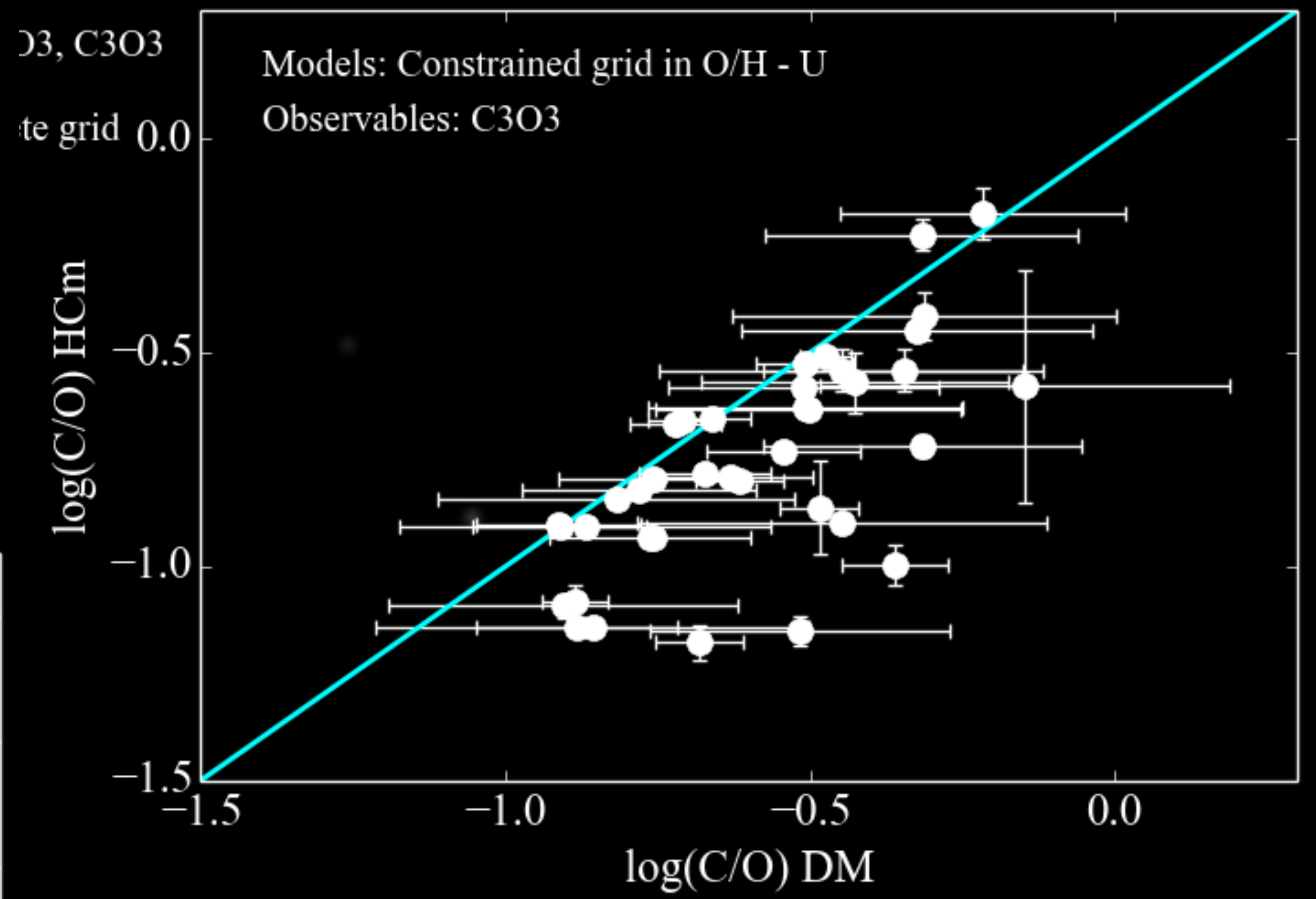


Pérez-Montero & Amorín (2017)

Comparison with the direct method





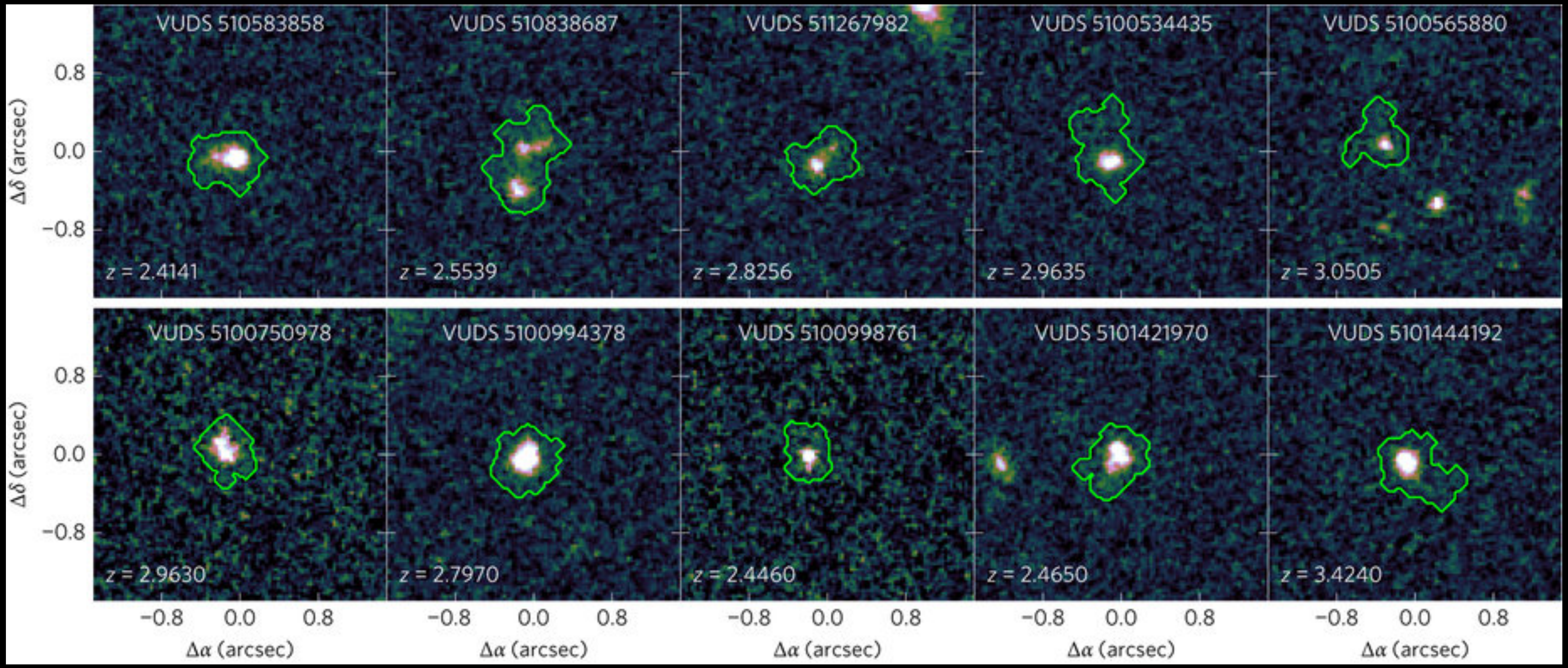


Pérez-Montero & Amorín (2017)

Searching in VUDS for analogs of primeval galaxies

We applied HCm_UV to a sample of 10 galaxies selected in VUDS on the basis of their very large [CIII] 1909 and Ly alpha equivalent widths.

These galaxies present properties quite similar to those of the primeval galaxies (e.g. low masses, high SFR, disrupted morphologies, compact sizes) but a chemical confirmation is required.

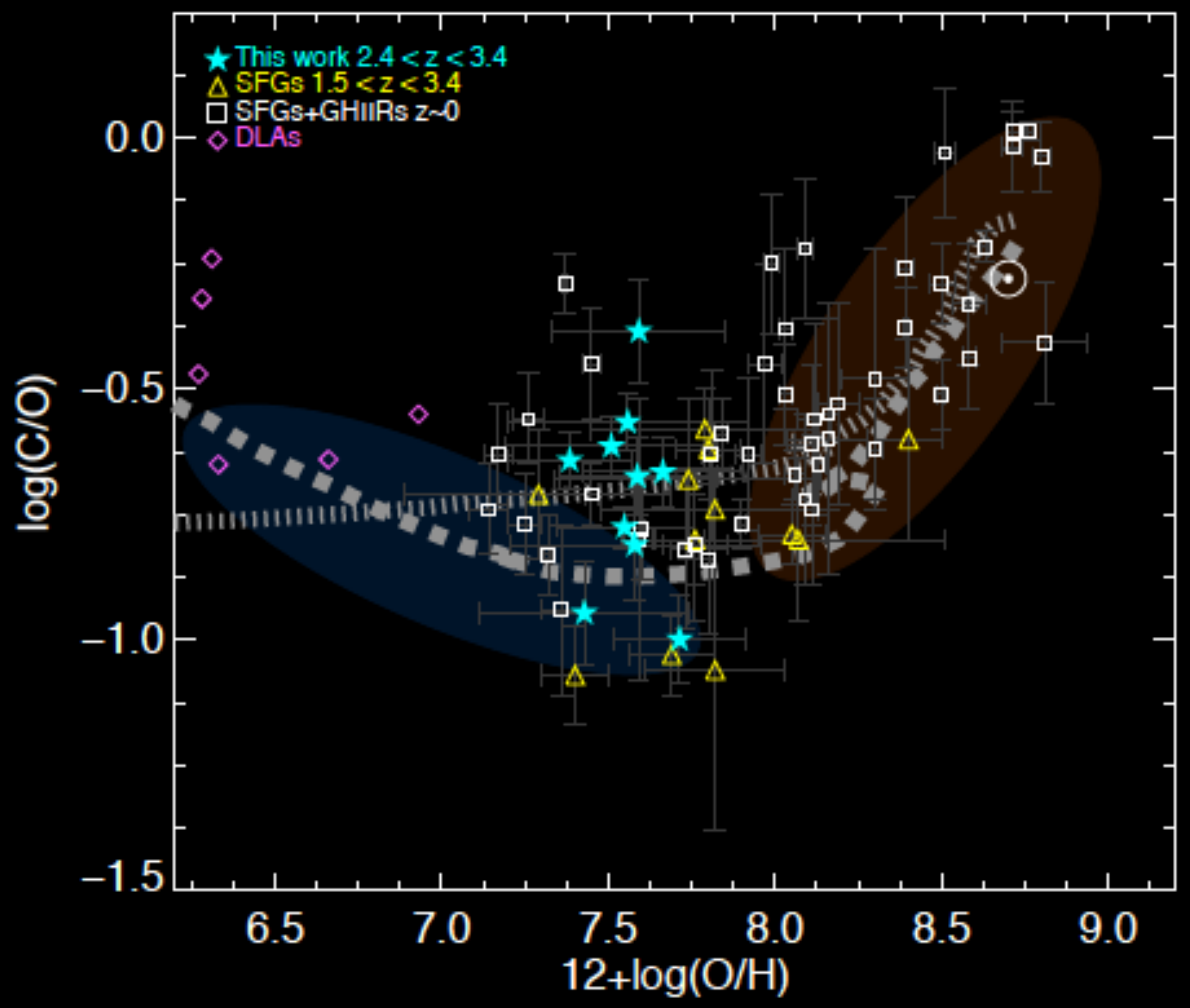


Amorín et al. (2017)

VUDs XMPs with HCm in the UV

Applying HCm_UV on the sample of galaxies at z~2.4-3.5 all of them are identified as XMPs, with sub solar values of C/O but with a large dispersion.

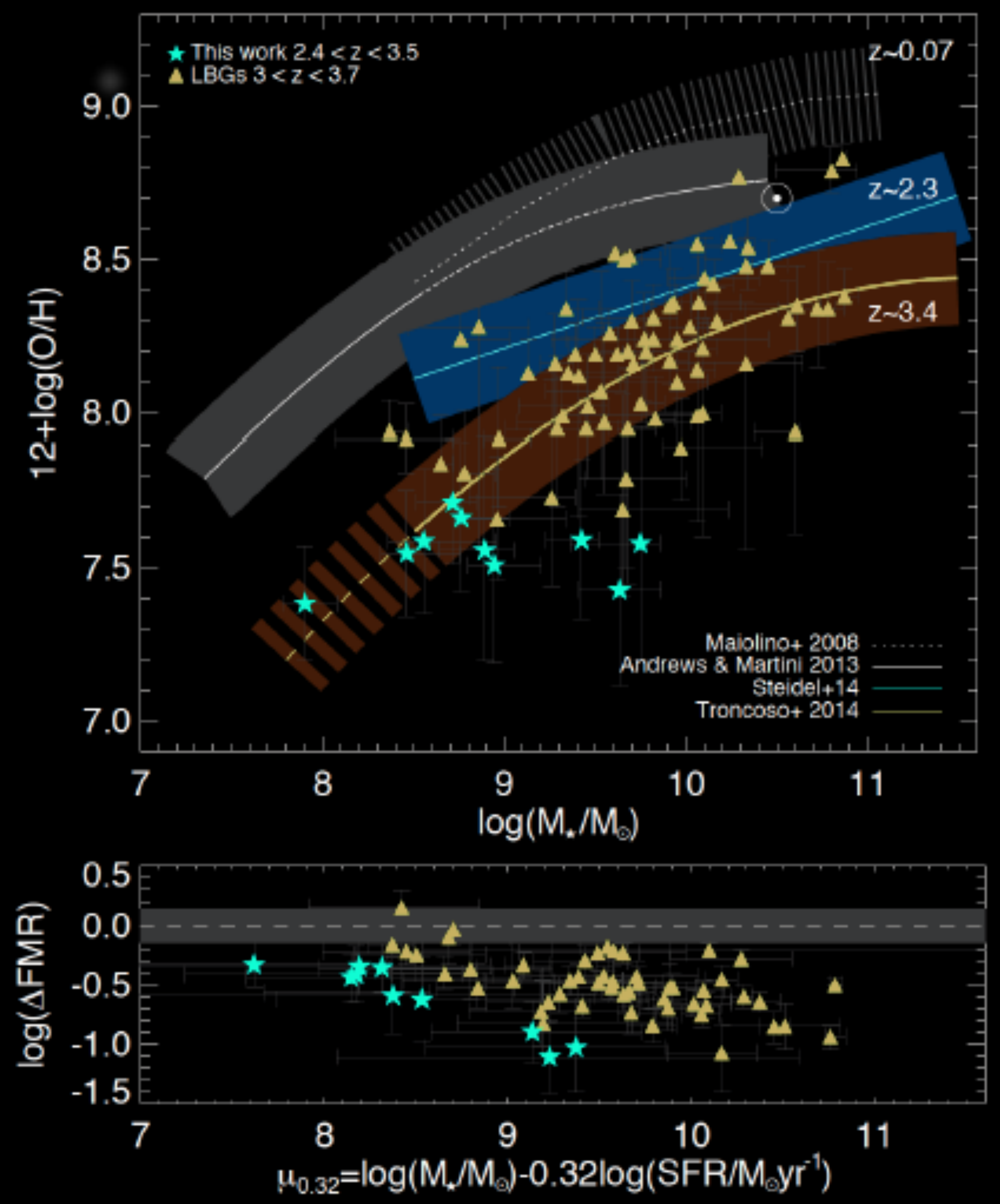
They present high values of log U, consistent with very young stellar populations, able to produce the emission of HeII in six out of them.



Amorín et al. (2017)

VUDS XMPs at high redshift with HCm_UV

Comparing with the local MZR, the galaxies present very low Z, but they are consistent with the MZR at z~3 by Troncoso+)2014).
The offset could be due to their very high SFRs, even though the FMR does not correct this effect at this redshift.

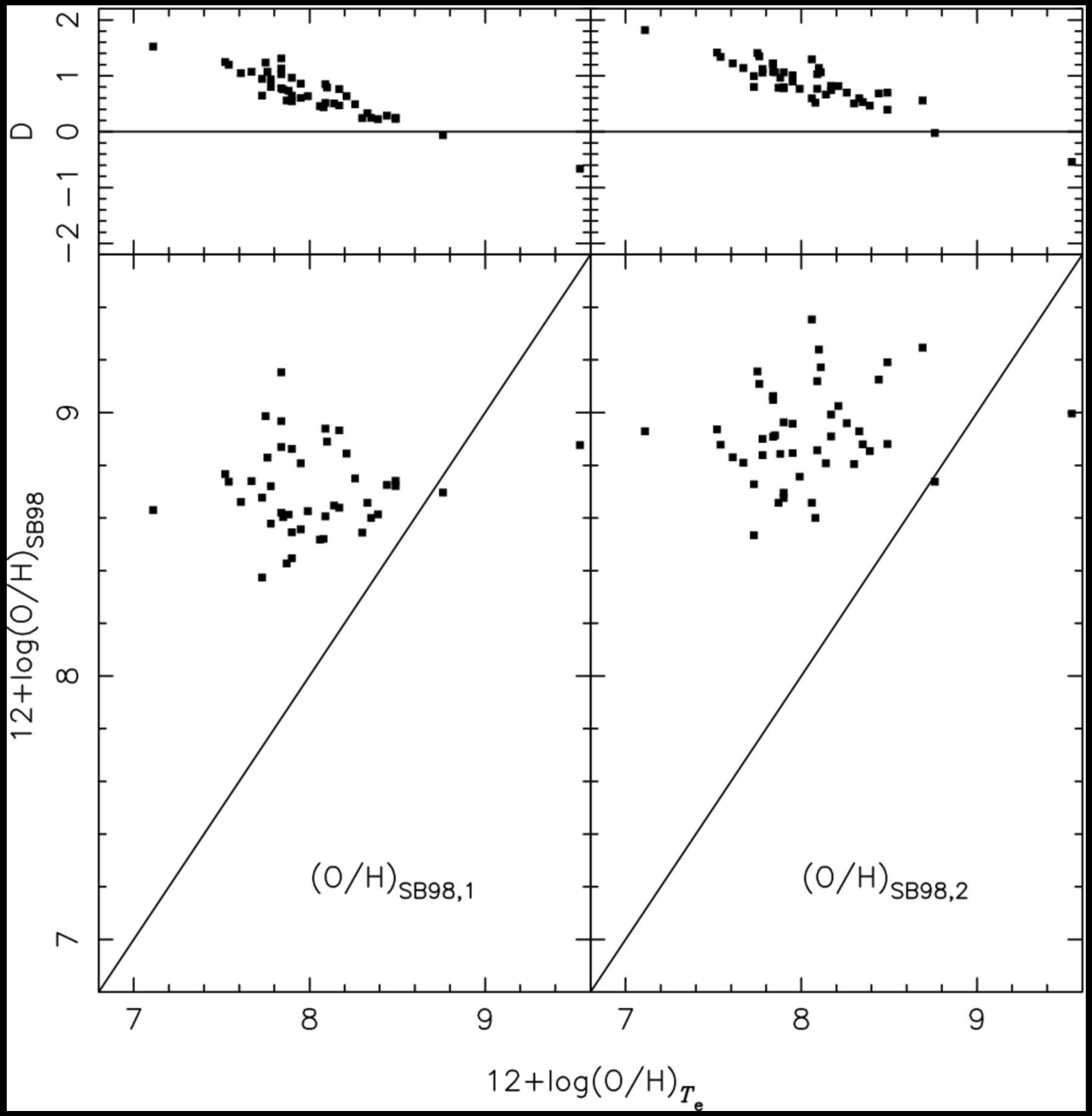


Amorín et al. (2017)

Deriving abundances in the NLR of AGN

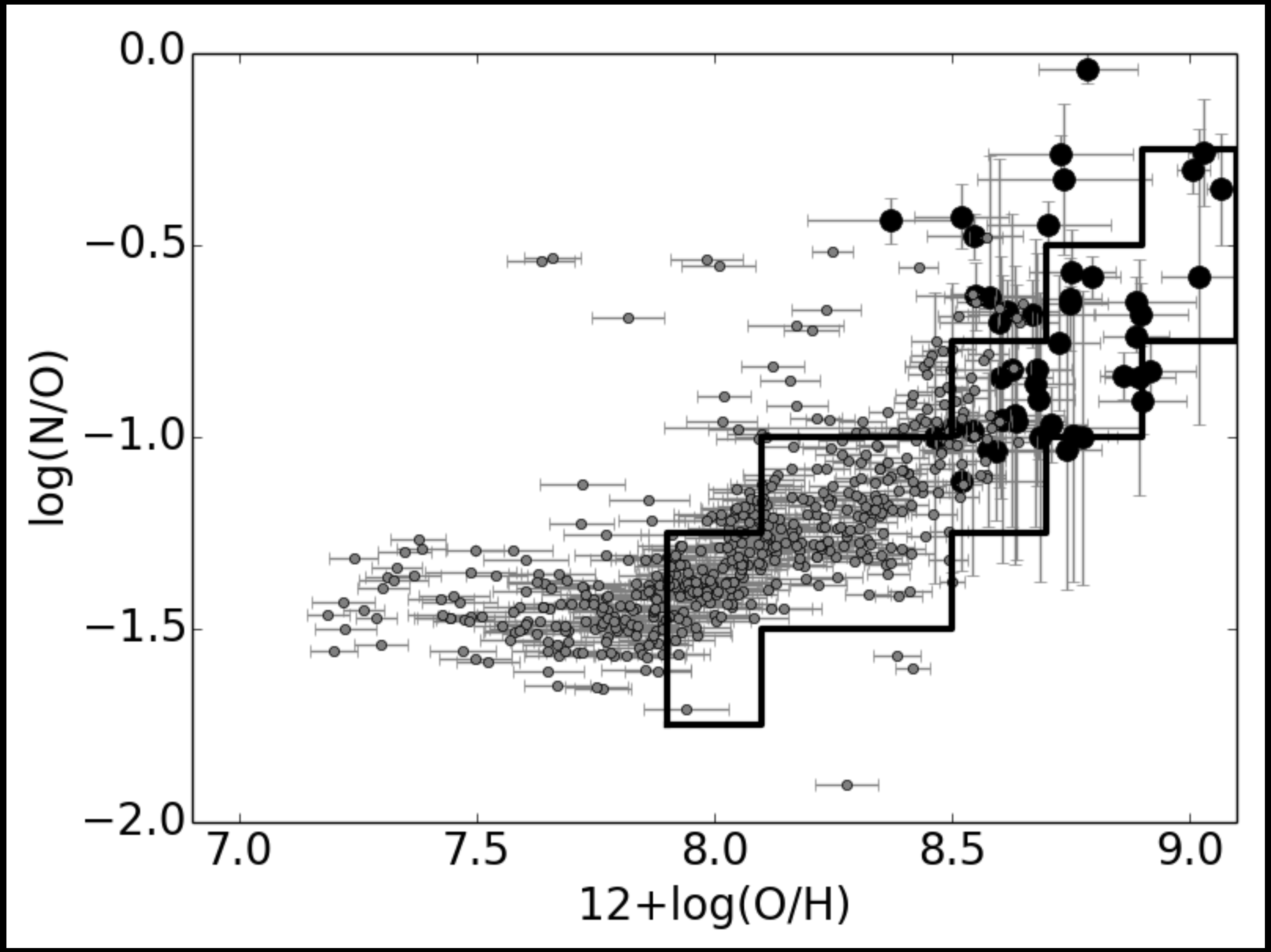
Bright optical emission-lines can also be used to derive abundances in AGN, but the direct method cannot be used (shock contribution, collisional de-excitation, temperature and abundance inhomogeneities, different ionization structure due to very energetic photons).

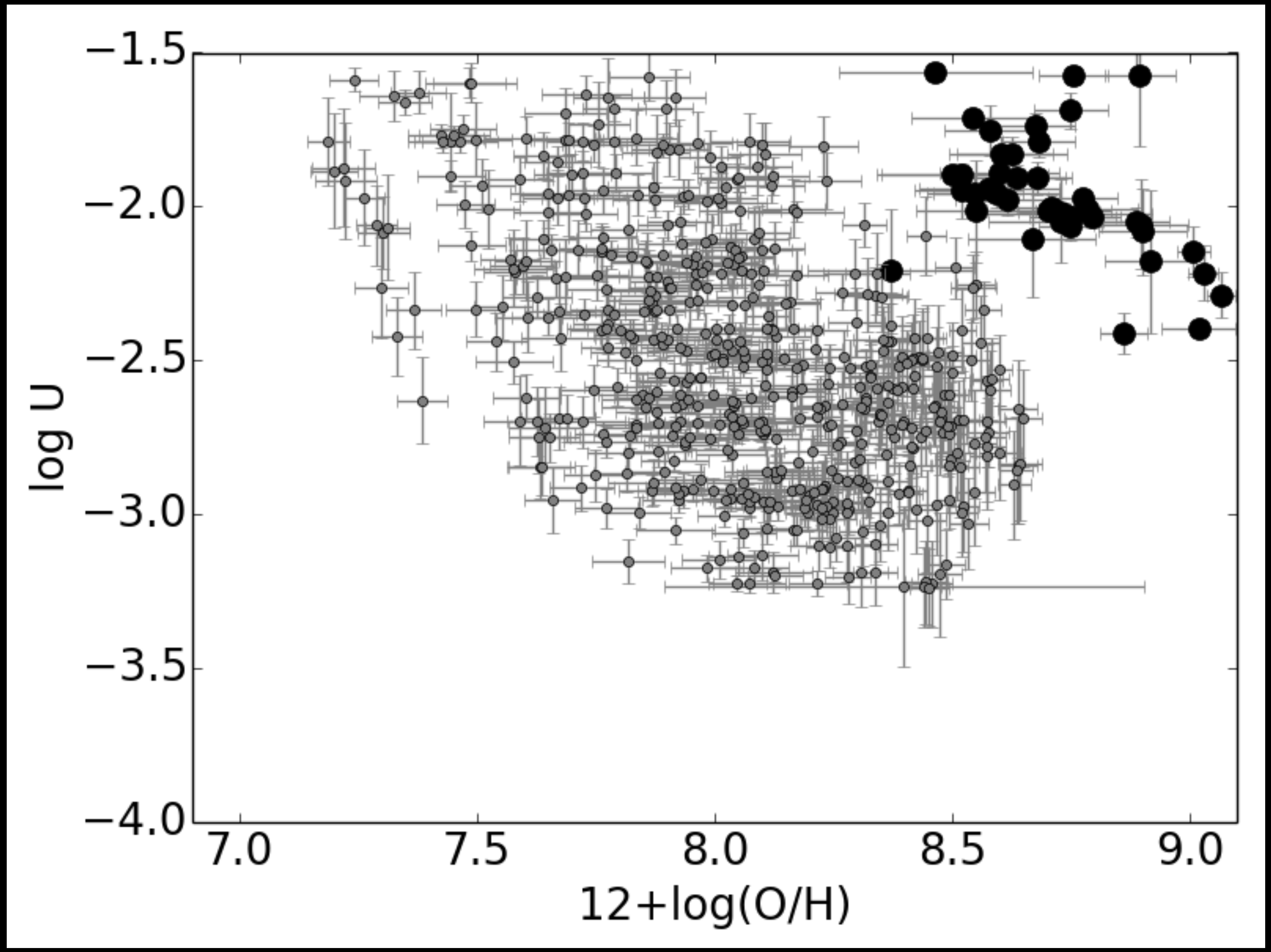
Instead models look to be the most appropriate way to derive abundances from the observational information.



Dors et al (2015)

Using HCm in the optical to study AGNs

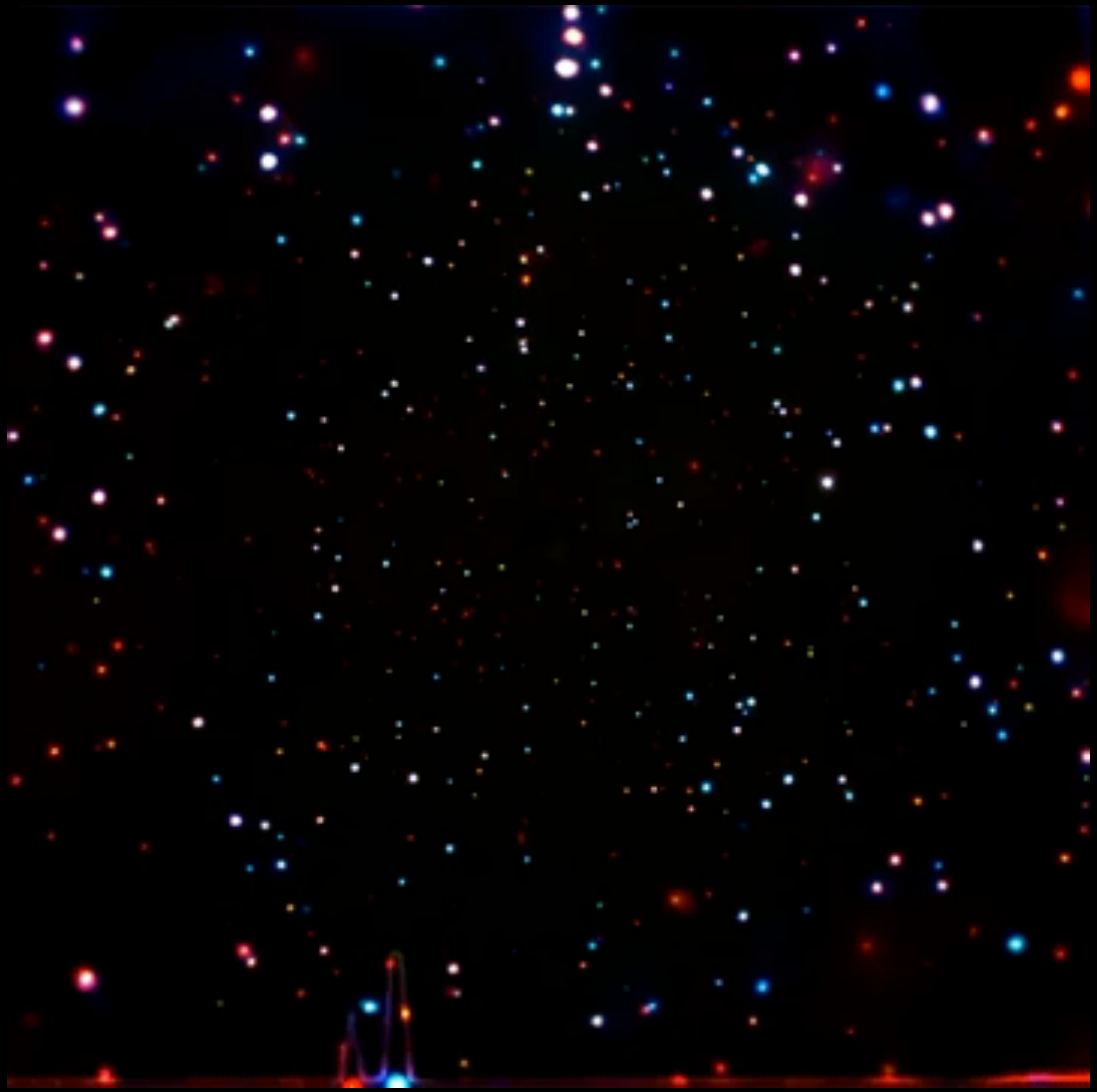




Pérez-Montero et al. (2019)

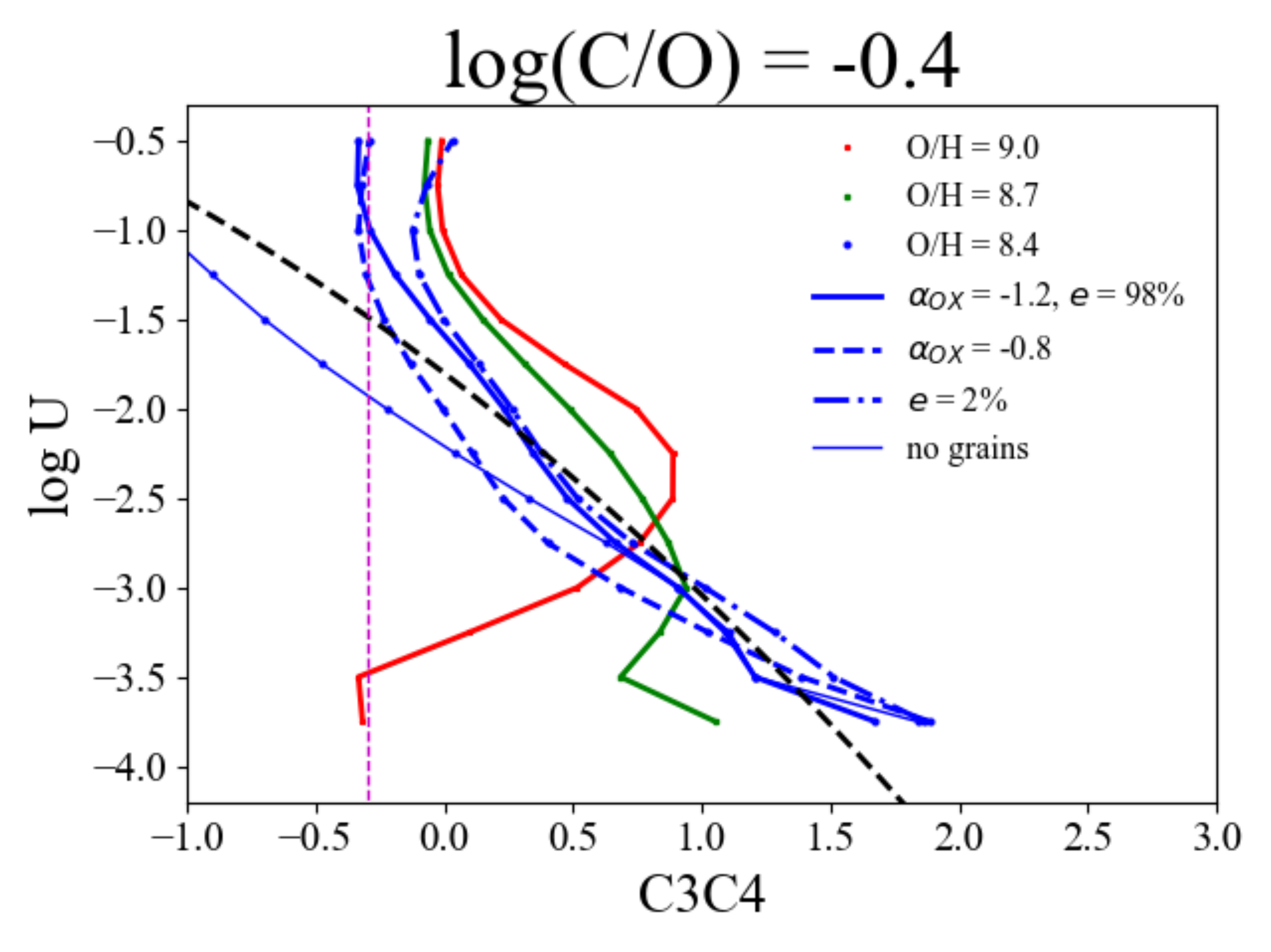
HII-CHI-mistry in the optical applied to local AGN type 2 shows a large mean U value, not depending on U, and a great dispersion for N/O.

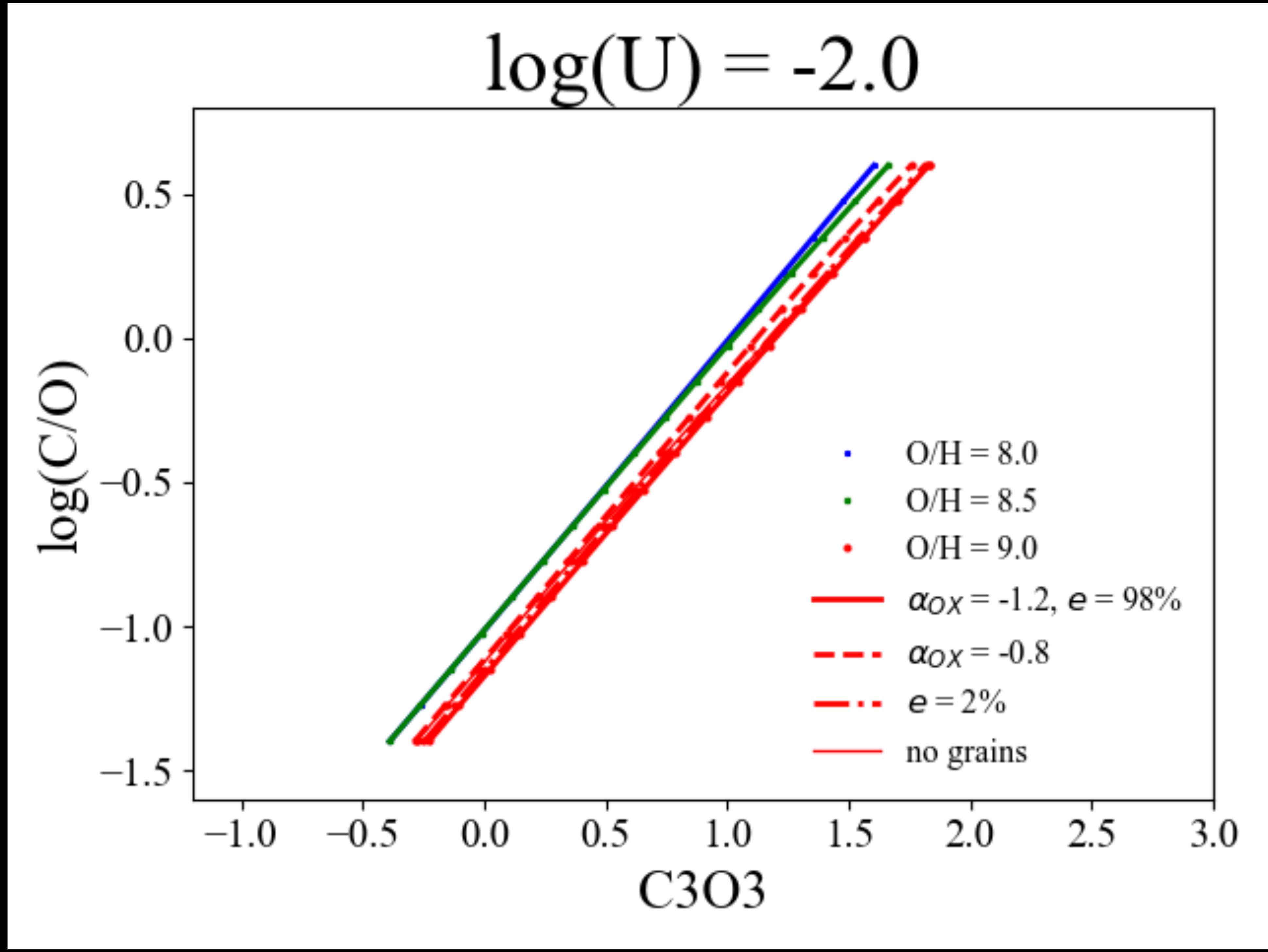
An Universe plenty of X-ray sources



Source: NASA Chandra Space Observatory. X-ray emission of a deep fielding the south hemisphere.

Behaviour of the AGN models

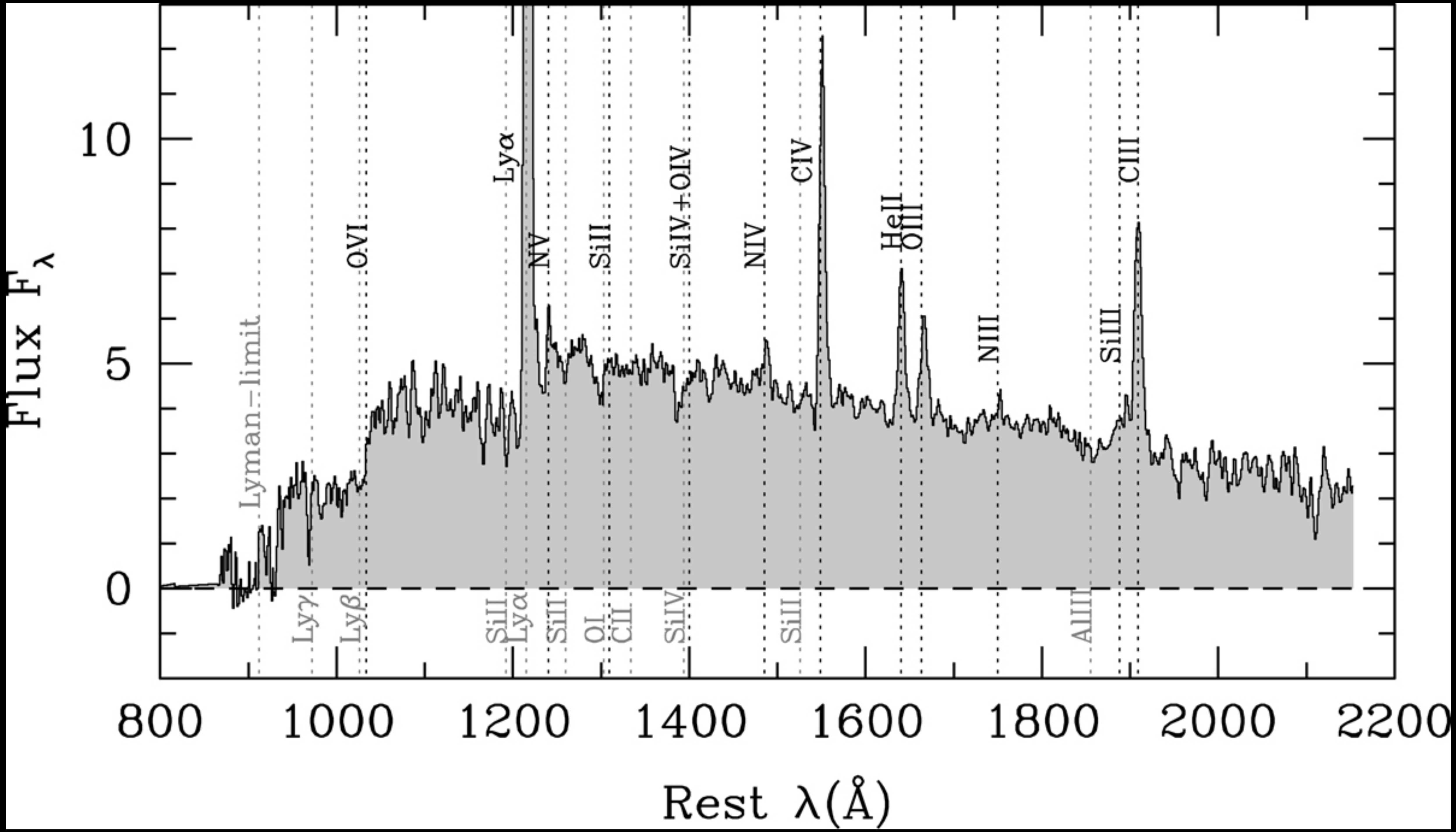




Pérez-Montero et al (in prep.)

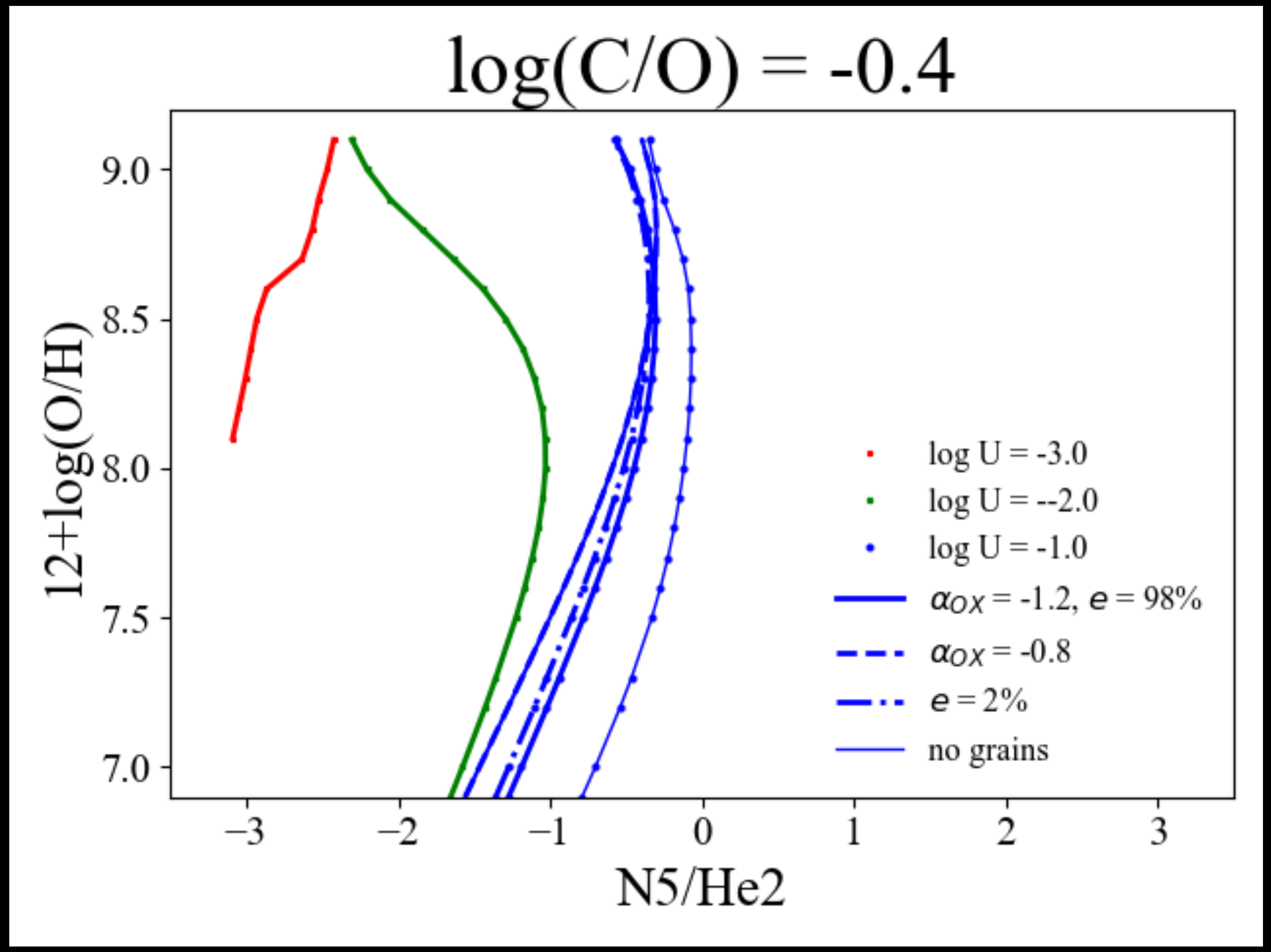
We evaluated models with different alpha_OX (-0.8 and -1.2) and different stopping criteria (fraction of free electrons of 2 and 98%).
New models without dust must be calculated in order to cover the space for C3C4 < -0.3 (e.g. Nagao et al. 2006).
The relation between C3O3 and C/O is close to that for SF, even for models without dust.

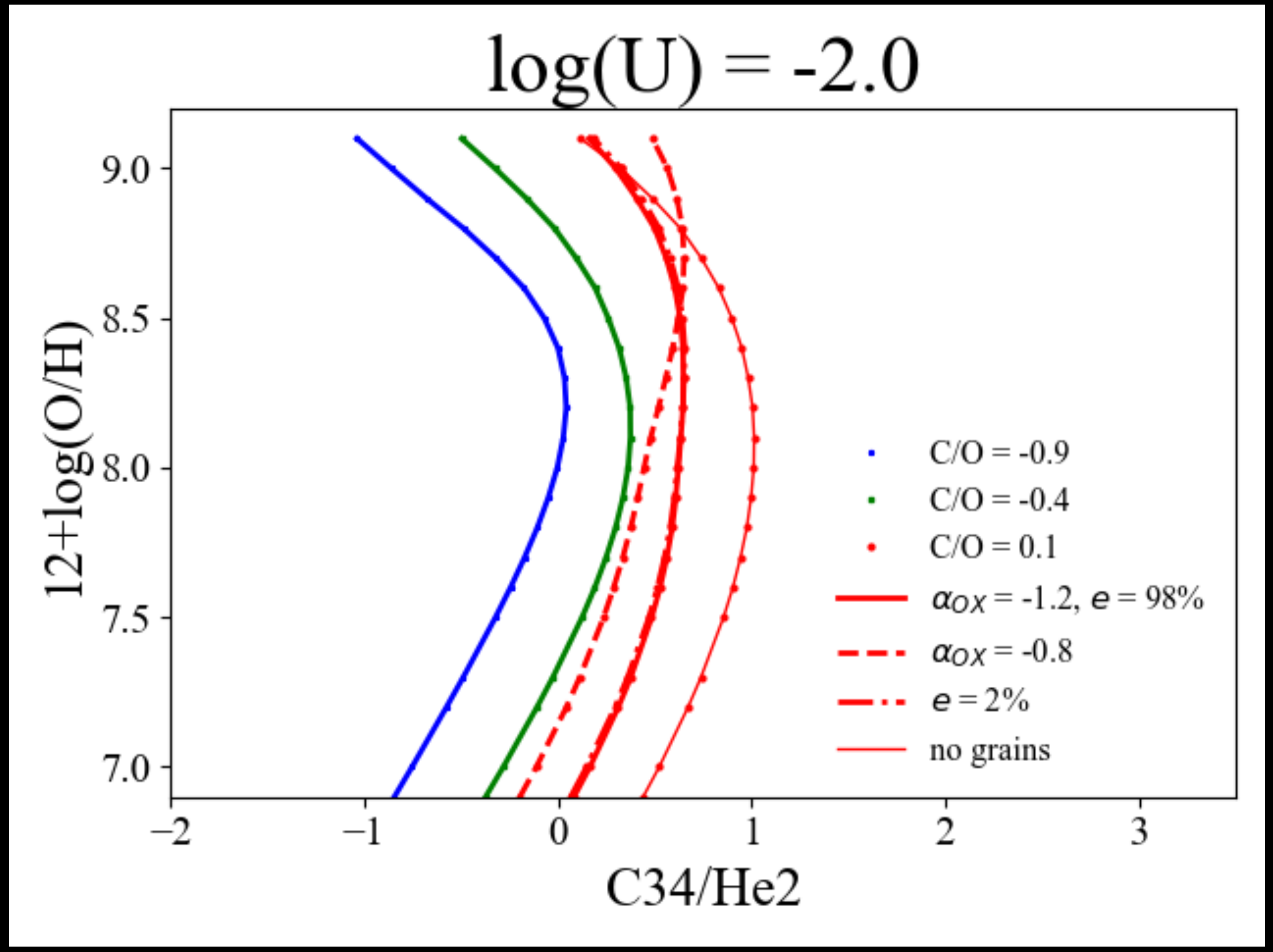
New high excitation lines



Le Fèvre et al (2019)

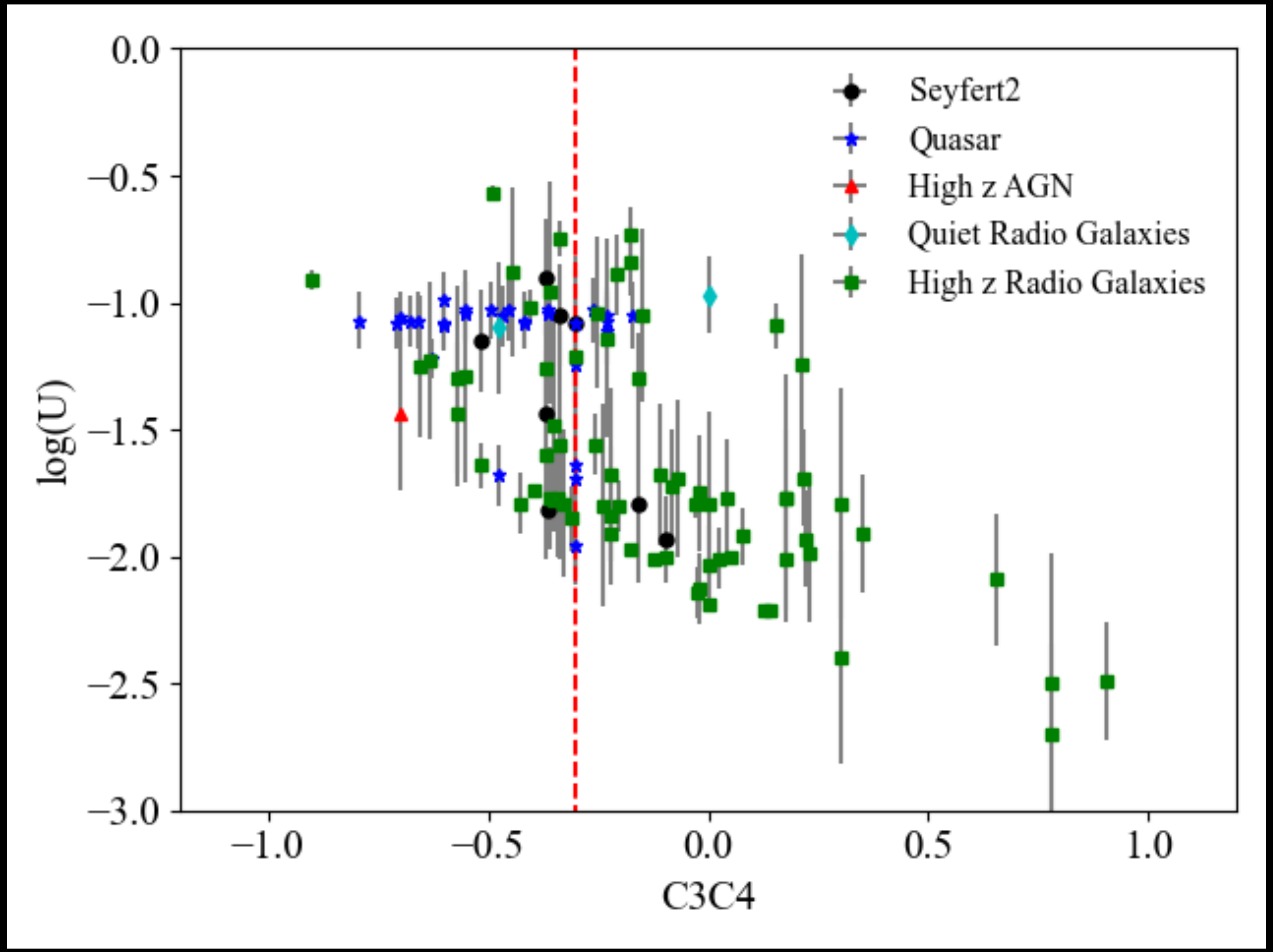
New observables based on NV] 1239å and HeII 1640å are now considered for AGNs

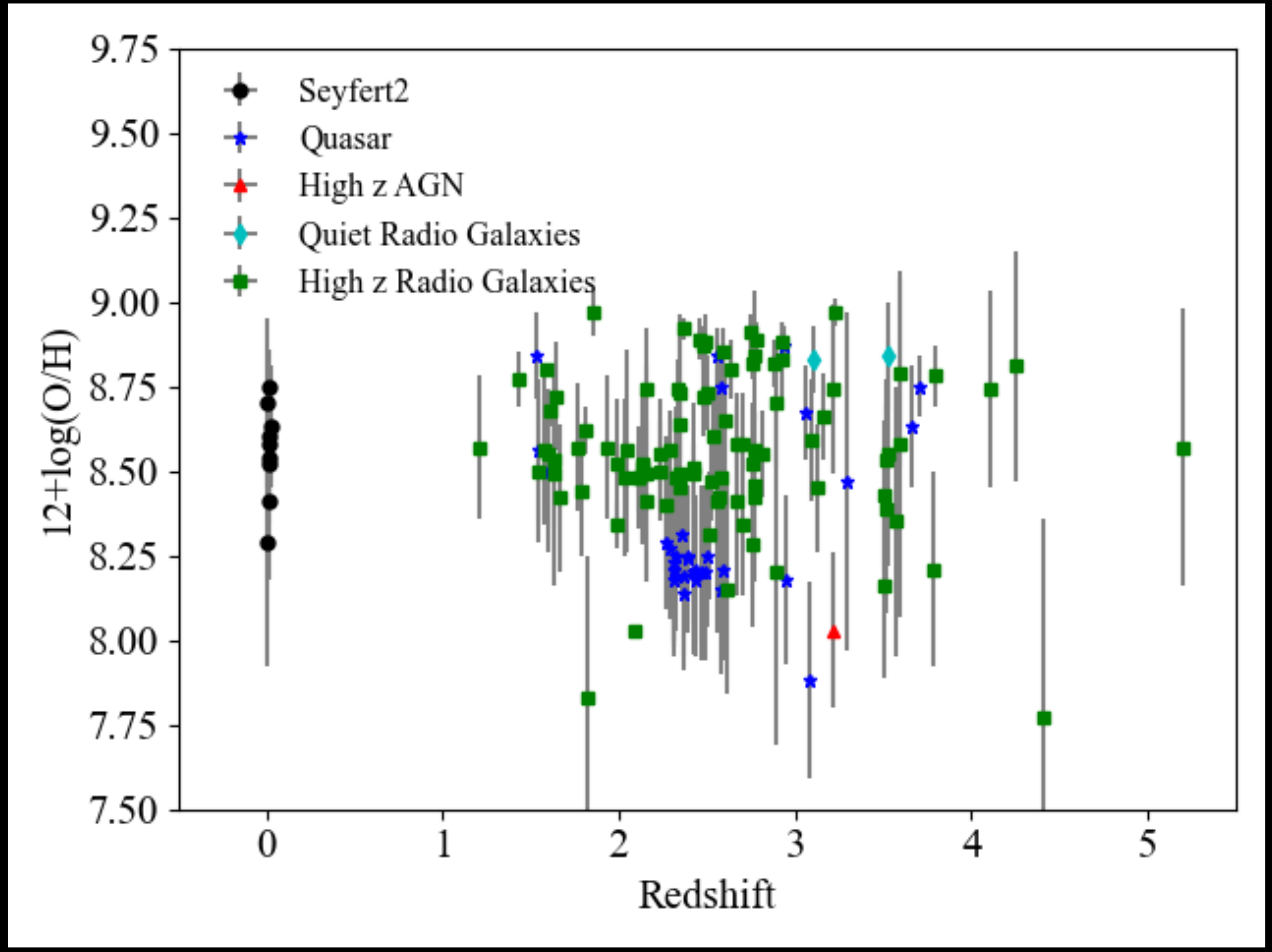




Pérez-Montero et al (in prep.)

Sample of UV emission-lines in AGN



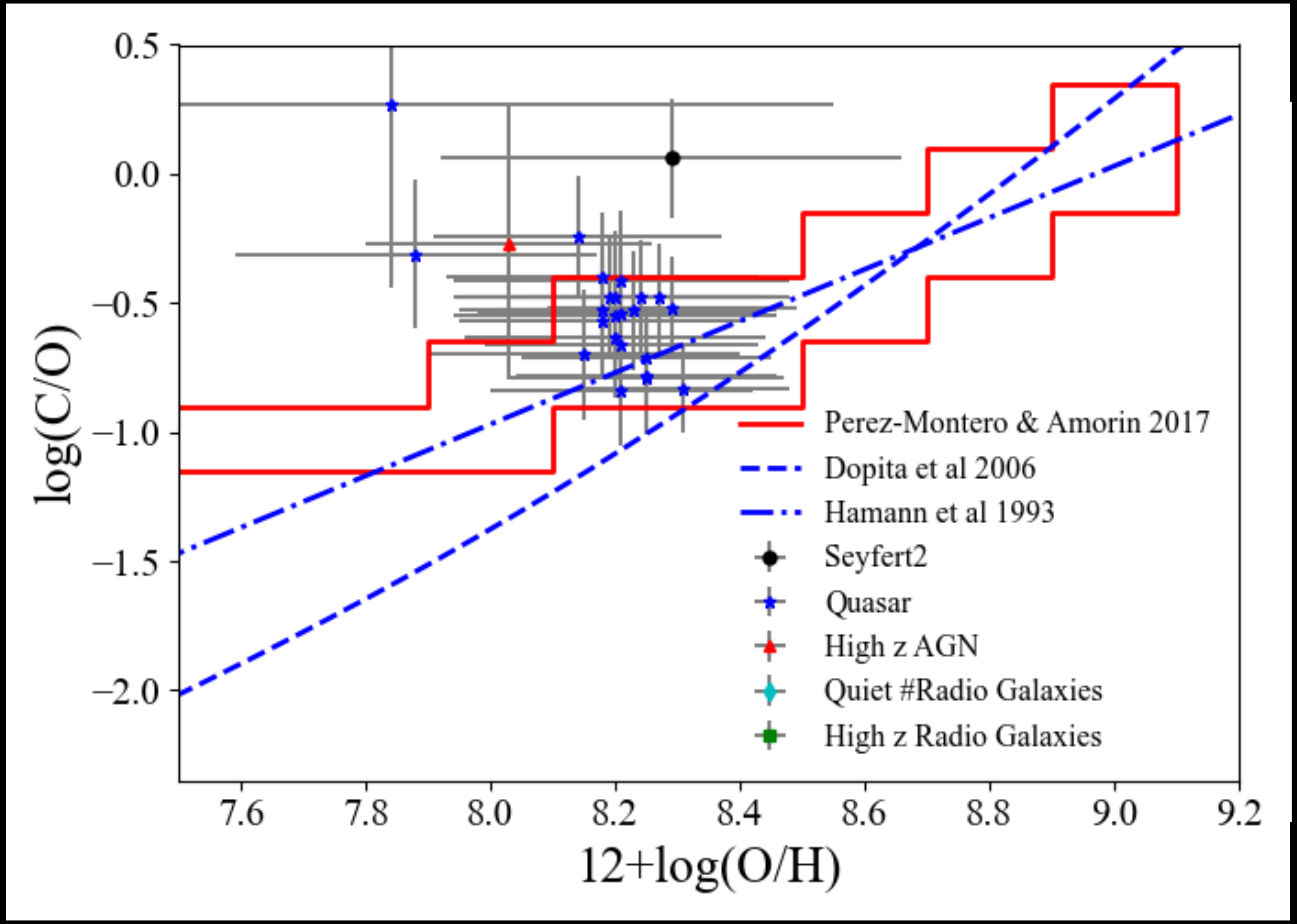


Pérez-Montero et al (in prep.)

A sample of 139 NLR in AGN with UV emission-lines has been compiled (60% without dust). There is a large dispersion with a mean sub-solar O/H value.

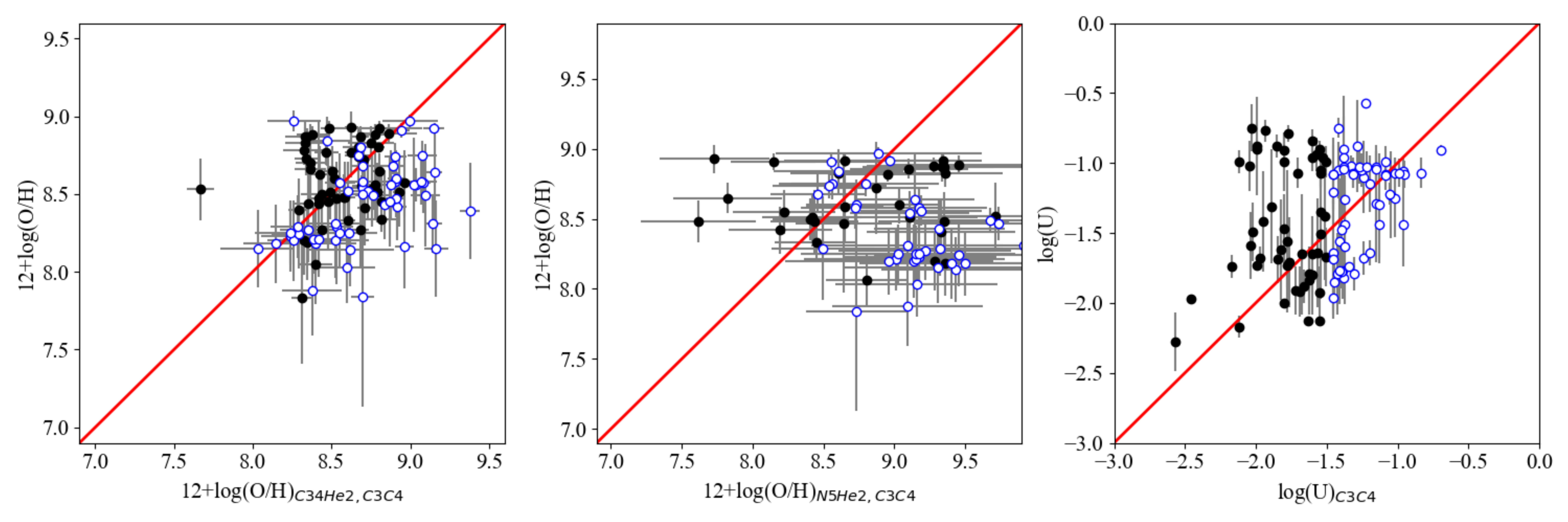
The relation between oxygen and carbon for AGNs

Only in 26 objects)mostly quasars with an upper limit for OIII] 1665 å) C(O Ould be derived. They are relatively metal-poor objects with a C/O value slightly higher than predicted.



Pérez-Montero et al (in prep.)

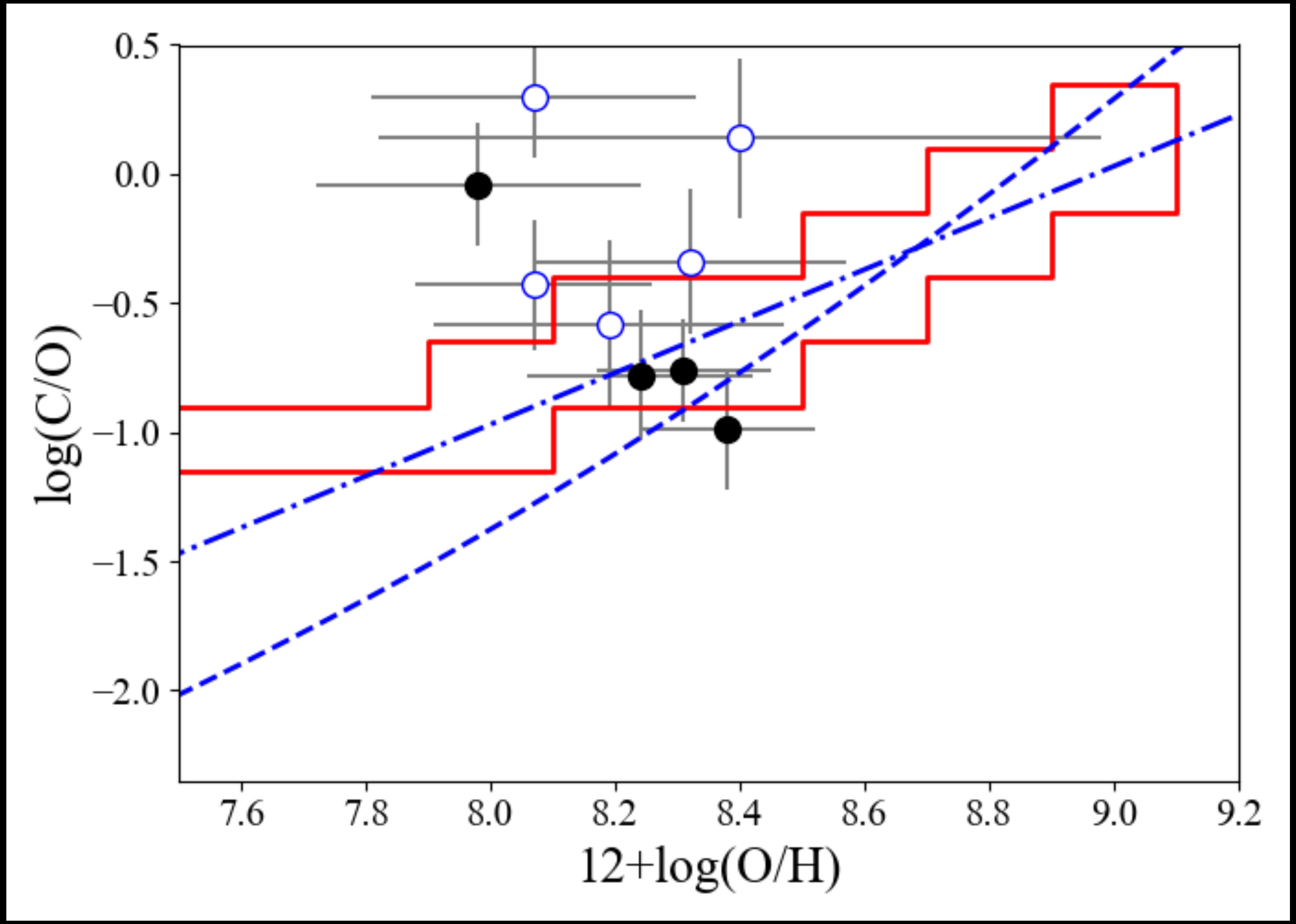
Comparison with other methods



Pérez-Montero et al (in prep.)

Preliminary application to VUDS sample

We applied the new method to a sample of 9 VUDS NLR AGNs in VUDS. The results point to very similar results to those obtained to the control sample. Most work has to be done to look for possible correlations.now considered for AGNs



Summary and conclusions

- HCm-UV provides chemical abundances both for SF and AGN using UV emission lines consistent with the direct method.
- The application to selected VUDS objects confirm their nature of analogs of primeval galaxies, given their sub-solar O/H and C/O ratios..
- More models are considered for the study of AGN, including more high excitation lines and models with or without dust, covering the observational dispersion of the C3C4 ratio.
- The compiled sample of AGN shows a great dispersion in O/H, with a sub-solar mean value and a slightly higher value for C/O.
-