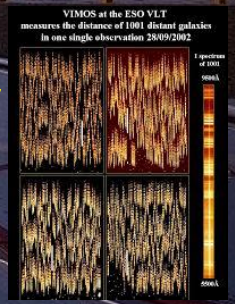
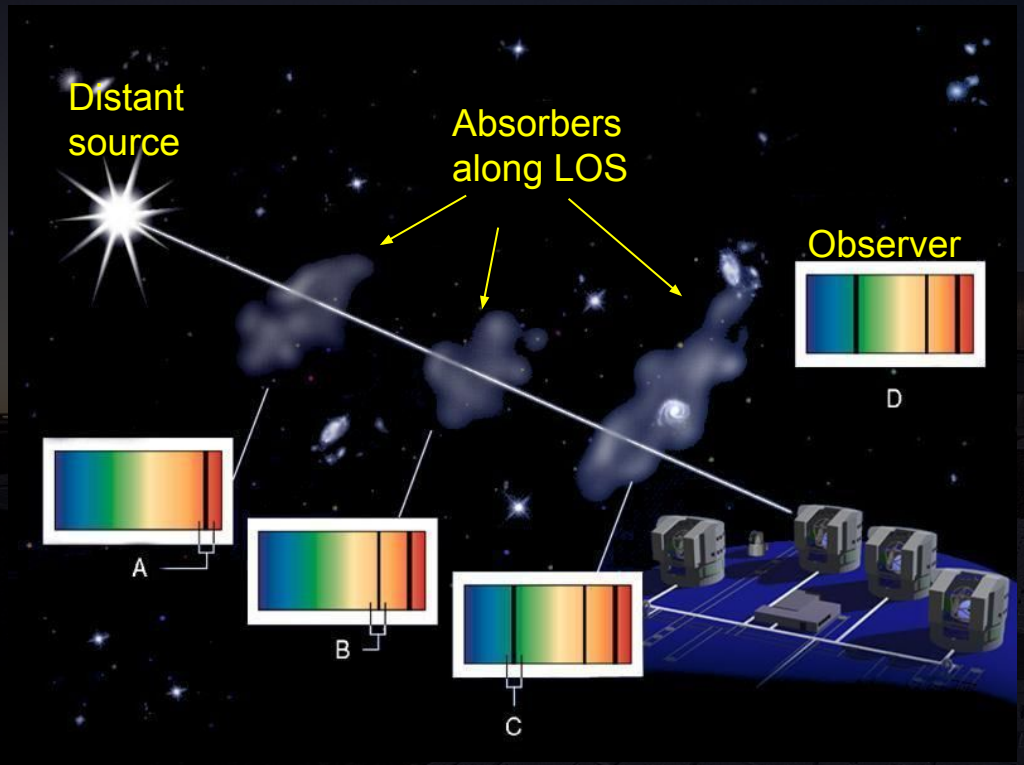
InterGalactic Medium extinction in high-z galaxies with VUDS and VANDELS

R. Thomas [ESO-Chile]
with the VANDELS and VUDS collaborations



From galaxies to cosmology with deep spectroscopic survey
A tribute to Olivier Le Fèvre. 4-8 July 2022

InterGalactic Medium extinction Principle

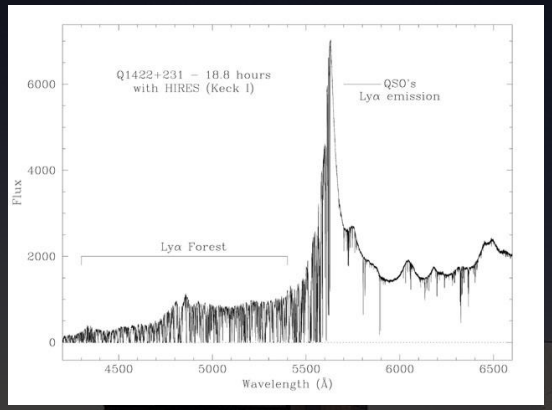


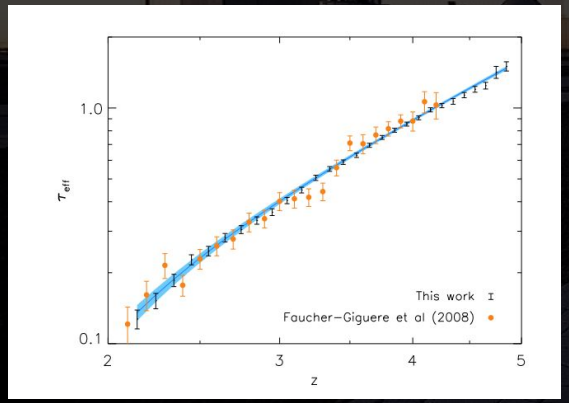
The light of distant sources is absorbed by the gaseous clouds that lie along the Line Of Sight. Photons with Lyman series wavelength are partially (or even totally) absorbed
→ Lyman alpha forest

The Lyα forest is thought to be the natural result of hierarchical structure formation within cold dark matter models (Cen+94)

Until VUDS: QSO

Ellison+00





Becker+15

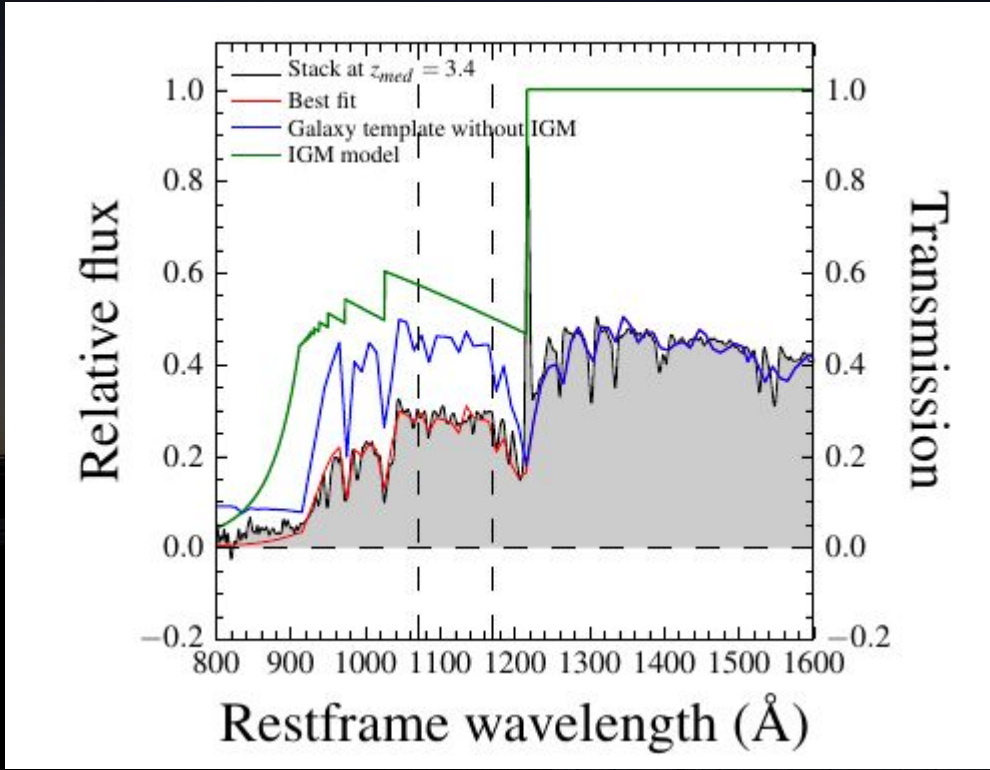
Until VUDS arrived, the IGM transmission is studied mainly from QSO data.

The use the HI optical depth related to the transmission by

$$\tau_{eff} = - \ln [Tr(Ly_{\alpha})]$$

Lot of literature and data available : Songaila+04, Dall'Aglio+08, Faucher-Guigere+08, Becker+13+15, Monzon+20, etc…

Until VUDS: galaxies?



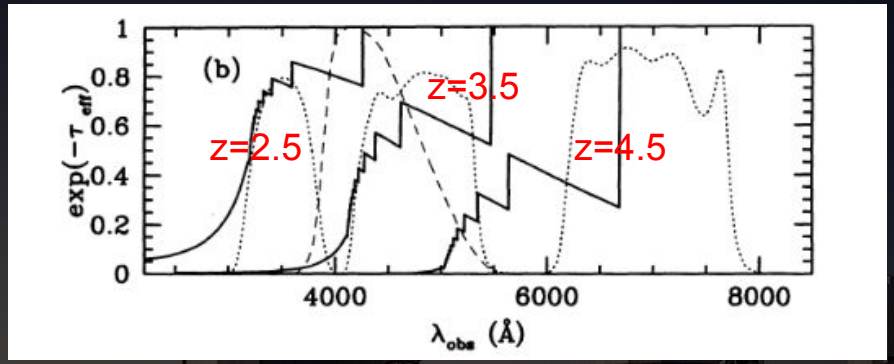
Thomas+17

The IGM transmission in galaxies was not really measured. But it was widely used in template fitting and lyman break selection techniques.

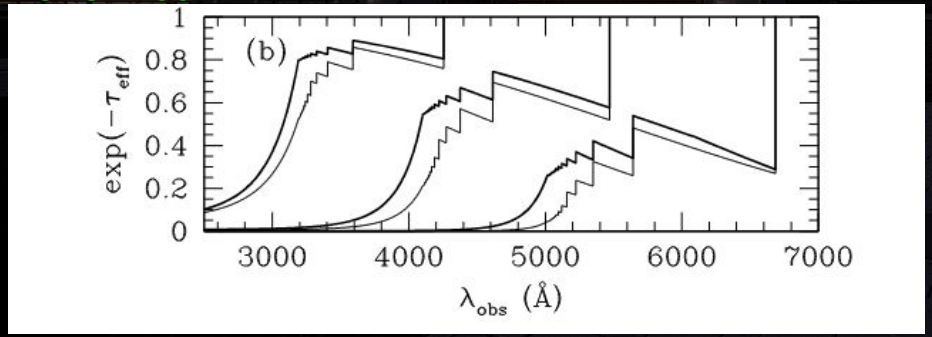
At a given redshift one would apply a template model to the galaxy template to reproduce the IGM opacity

Until VUDS: galaxies?

Madau+95



Meiksin+06



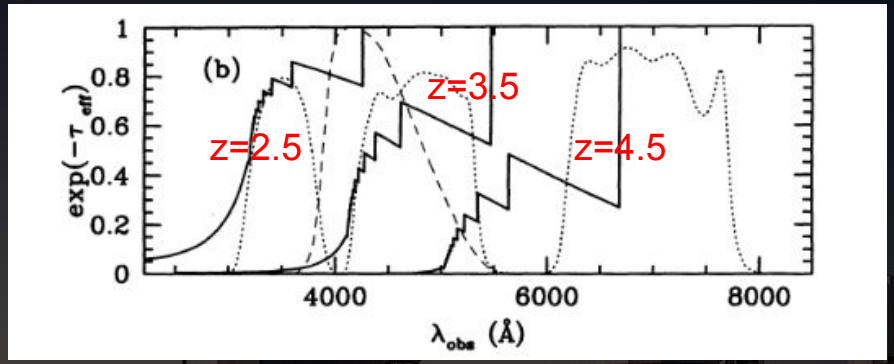
The IGM transmission in galaxies was not really measured. But was widely used in template fitting.

At a given redshift one would apply a template model to the galaxy template to reproduce the IGM opacity and then fit the galaxies.

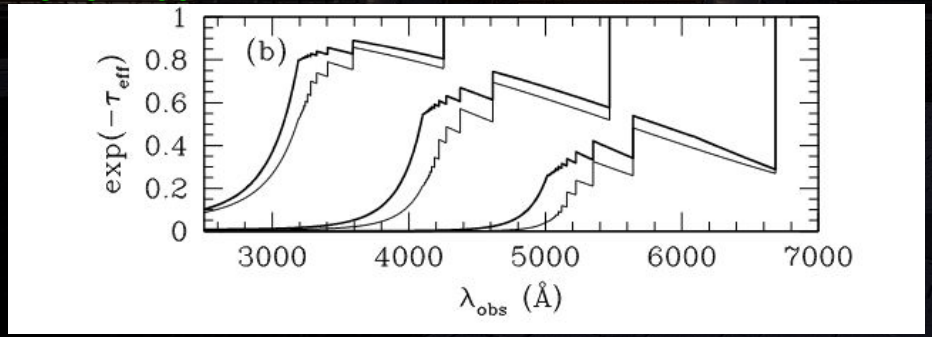
→ Two main models: Madau+95 and Meiksin +06

Until VUDS: galaxies?

Madau+95



Meiksin+06



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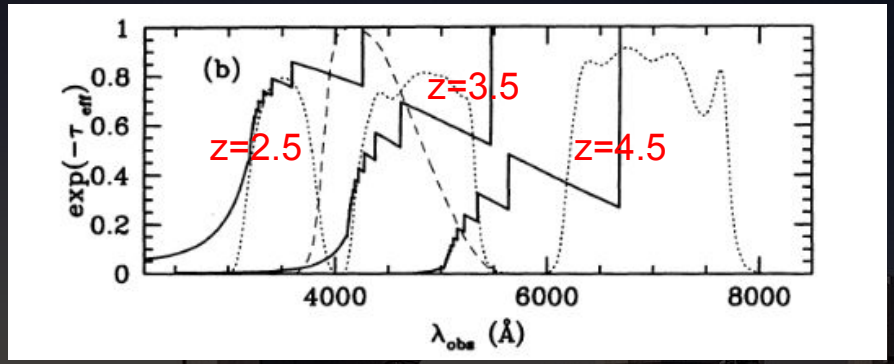
At a given redshift one would apply a template model to the galaxy template to reproduce the IGM opacity and then fit the galaxies.

→ Two main models: Madau+95 and Meiksin +06

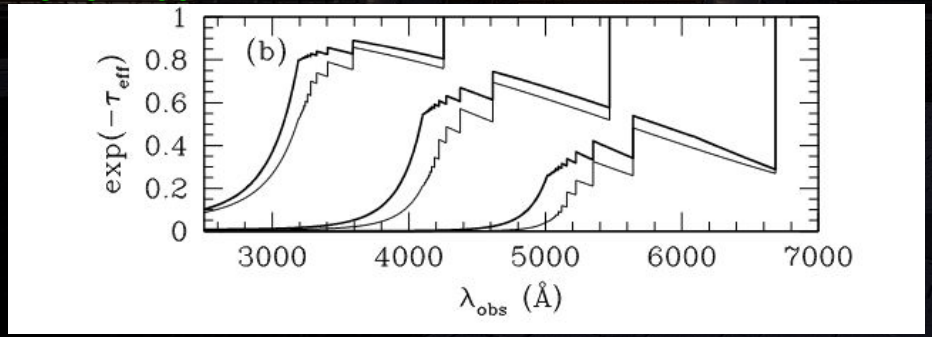
One redshift ↔ One curve

Until VUDS: galaxies?

Madau+95



Meiksin+06

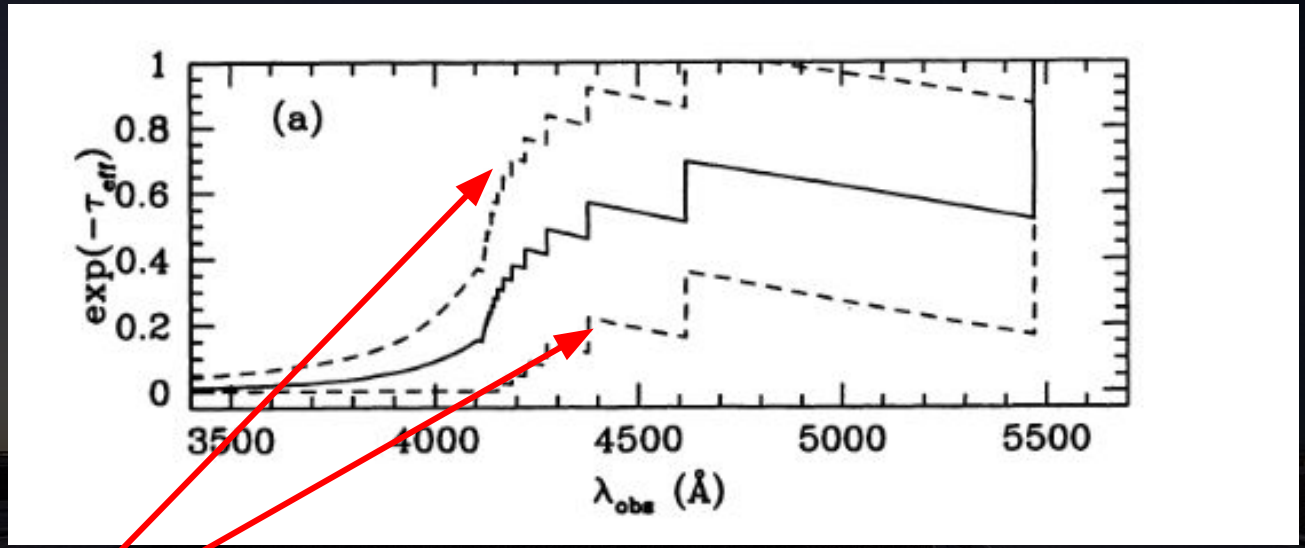


Equivalent to saying that at a given redshift all LOS towards distant objects are populated by the same number of gaseous clouds with similar properties, producing the same transmission independently of the position of the observed galaxy or QSO in the sky.

→ Need to extend the parameter space

Toward a free IGM

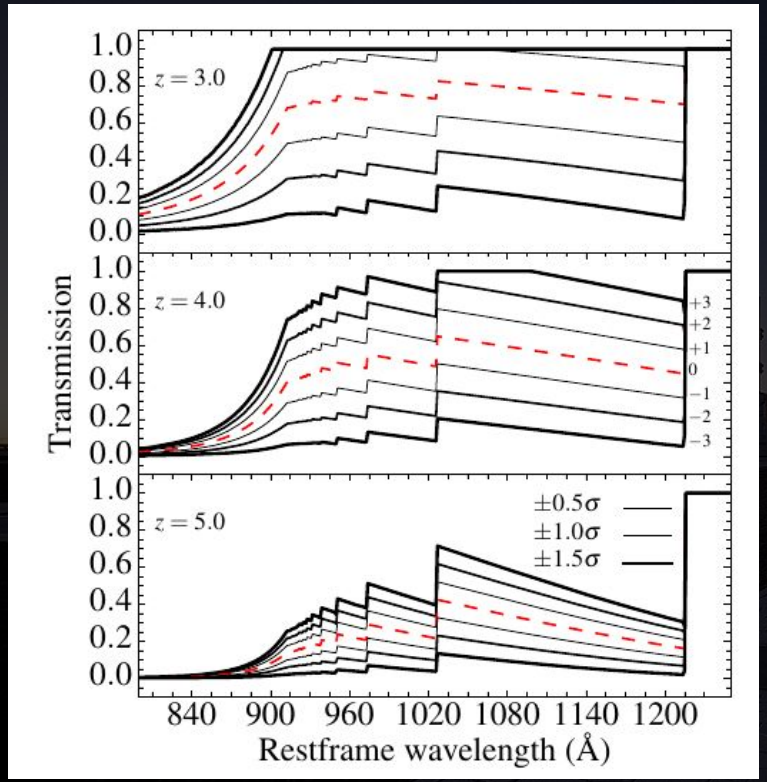
Madau+95



1-sigma range

Madau+95 provides +/- 1 sigma curves at z=3.5

Toward a free IGM



Thomas+17

Madau+95 provides +/- 1 sigma curves at z=3.5

We used this example from M95 and created an empirical modelisation to create additional IGM transmission at any redshift.

→ 6 news curves at any redshift

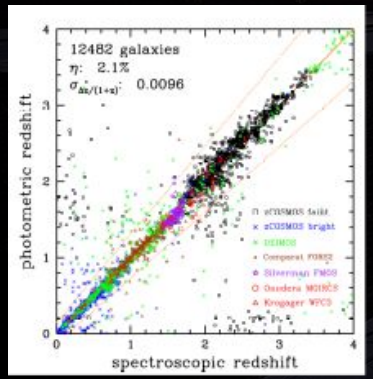
→ we can now try to measure the IGM transmission from high-z galaxies

VIMOS Ultra Deep Survey in a nutshell

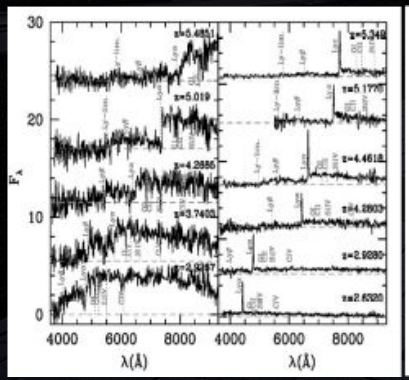
Slide made by OLF in 2013

- ESO Large Program: 640h
- Focused on 2<z<6
- 1 deg²
- 10,000 targets
- 3 fields: mitigate cosmic variance
- Selection: photo-z + SED + color, iAB≤25
- 14hr integration over 3600Å-9300Å
- 8000+ galaxies with 2<zspec<6.5

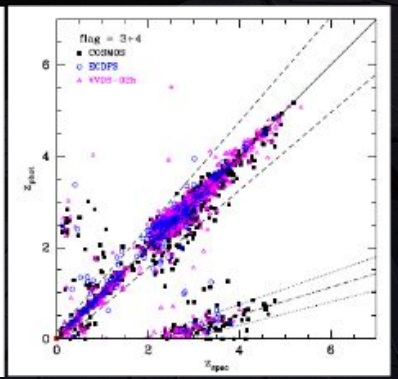
Selection



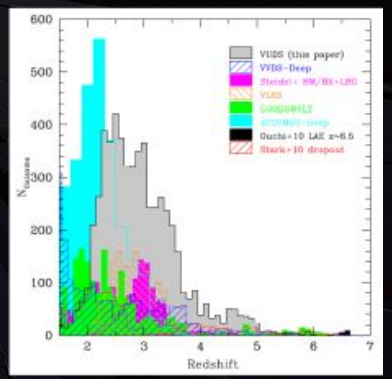
Spectra



Zphot-Zspec

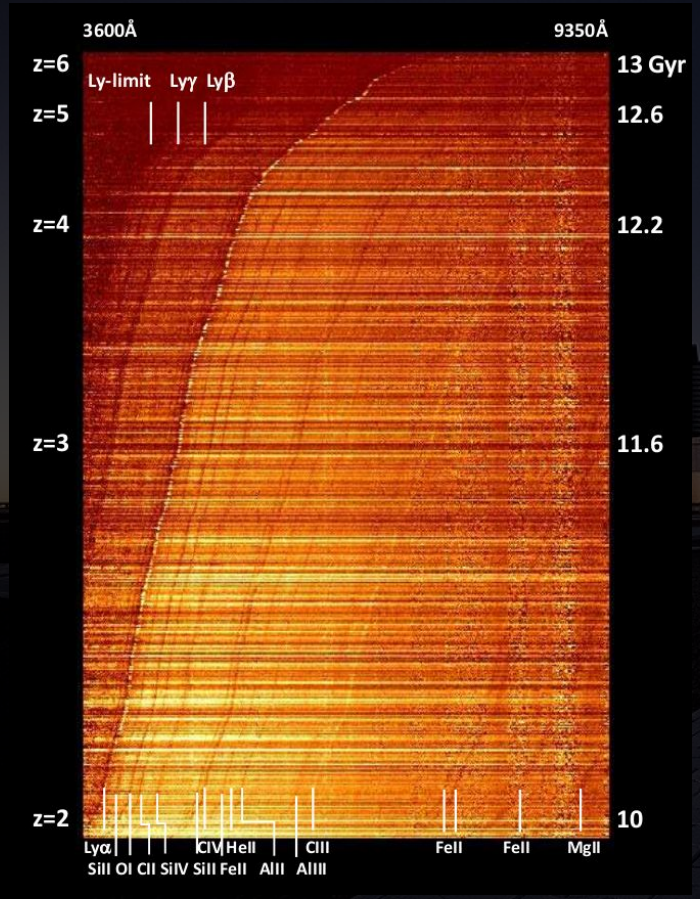


8000+ redshifts



VIMOS Ultra Deep Survey

Le Fevre+15

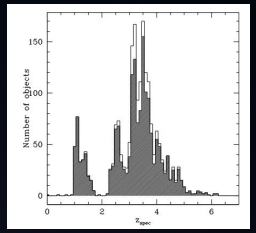


More than 60 papers have been published using VUDS data.
(Cf Lidia's talk tomorrow and VUDS poster)

Work on the final data release is on-going now and we hope to release everything by the end of the year or early 2023

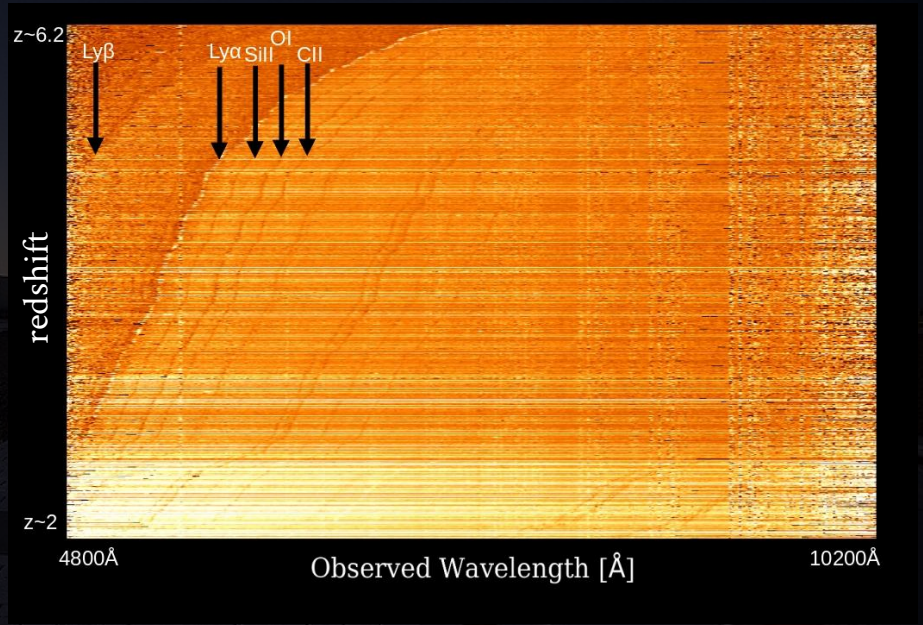
VANDELS

A deep VIMOS survey of the CANDELS UDS and CDFS fields



Large public survey with VIMOS as well focused on galaxies at z>1. (McLure+18, Pentericci+18)

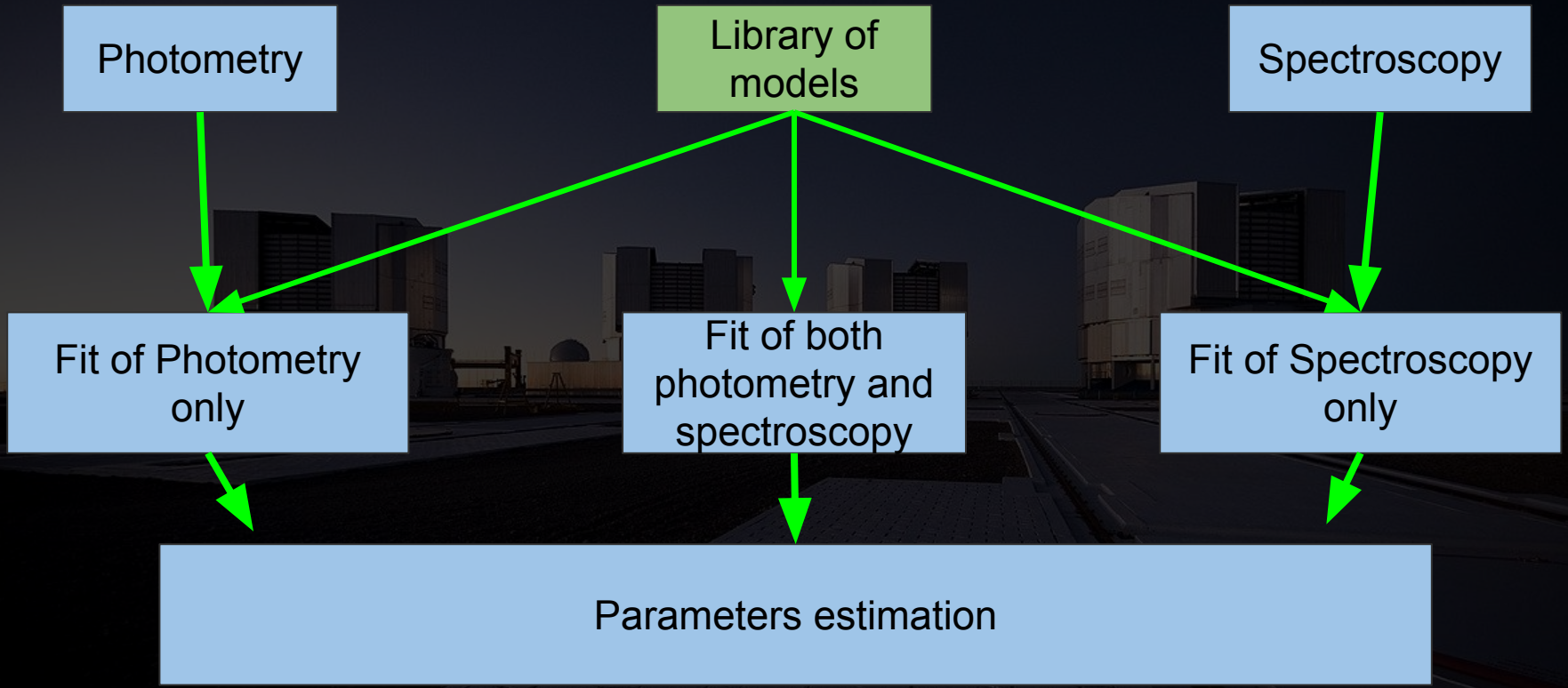
- 2100 galaxies observed
- Up to 80h of exposure time
- 2 fields: UDS and CDFS
- R~580 (medium resolution grism) and spectra from 4800Å to 10000Å.
- Final data release available. (Garilli+21)



One of the last survey carried out with VIMOS

GOSSIP+ and SPARTAN

SPECTROSCOPIC AND PHOTOMETRIC FITTING TOOL FOR ASTRONOMICAL ANALYSIS



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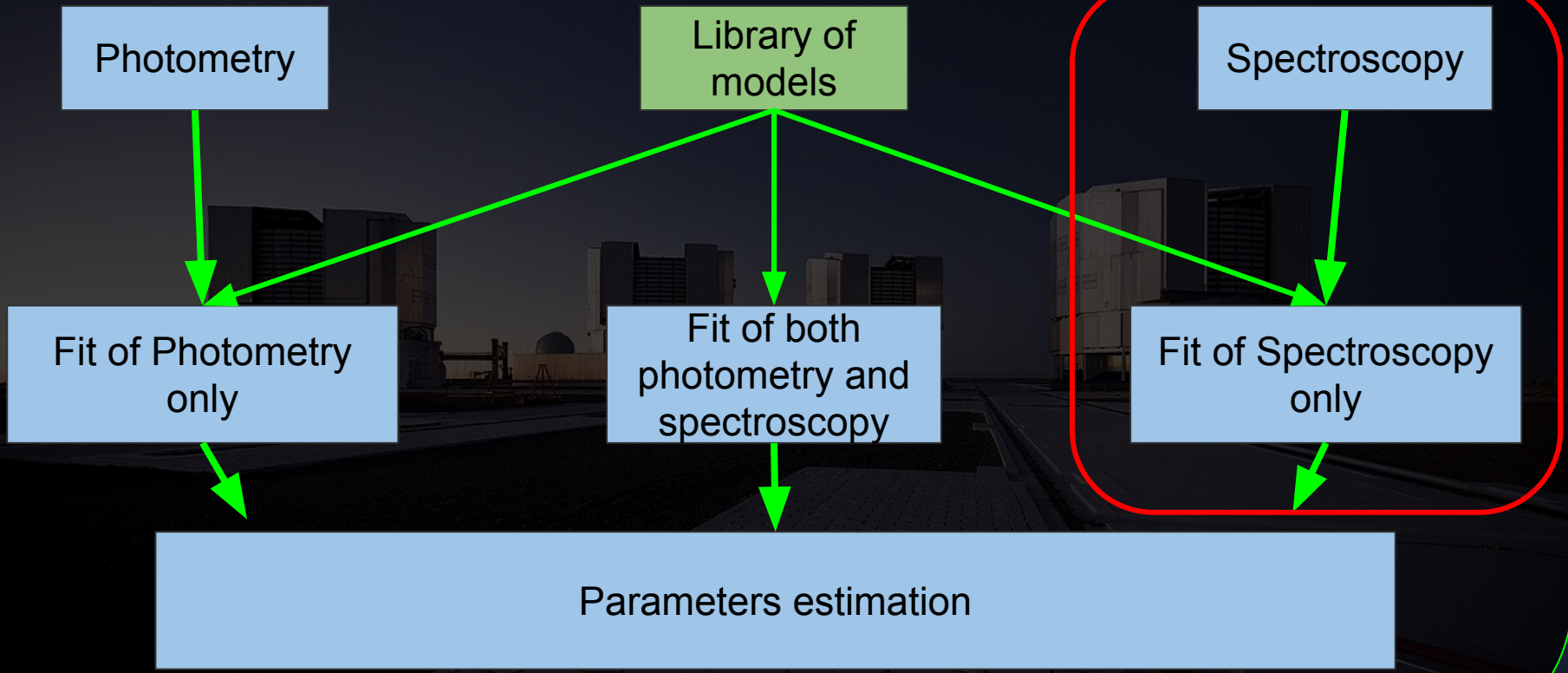
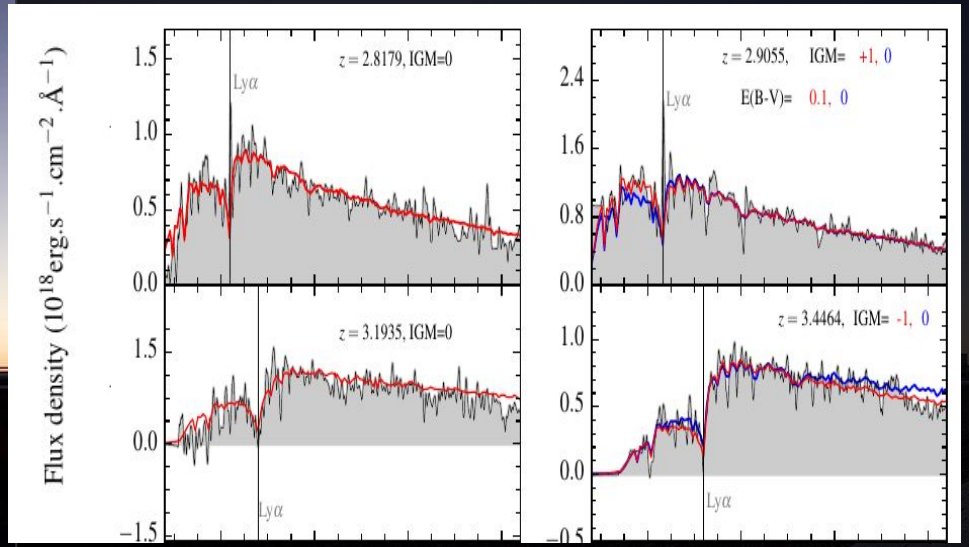


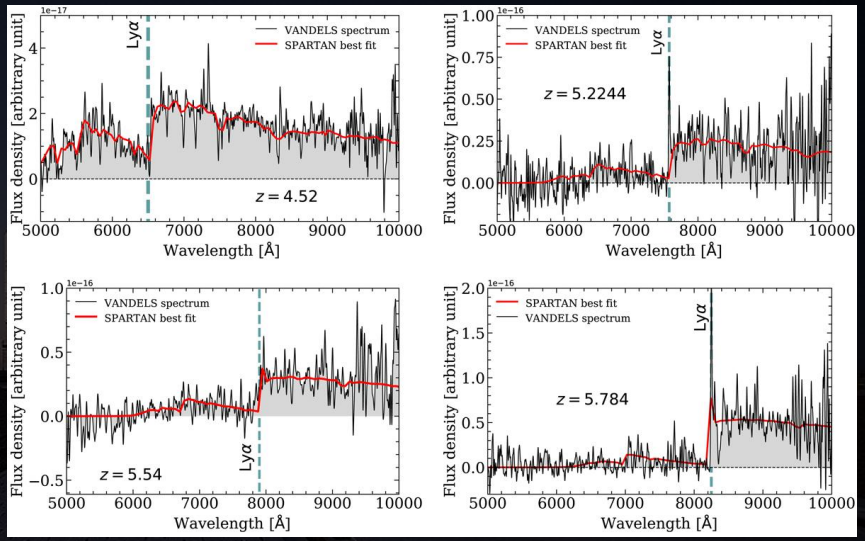
Example of spectral fitting

(VUDS x GOSSIP+)



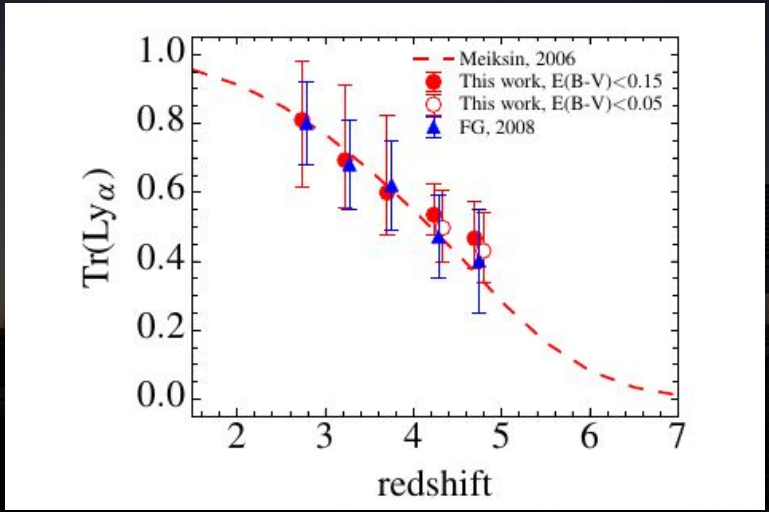
Thomas+17

(VANDELS x SPARTAN)



Thomas+20

IGM distribution from VUDS (Thomas+17)



VUDS x GOSSIP

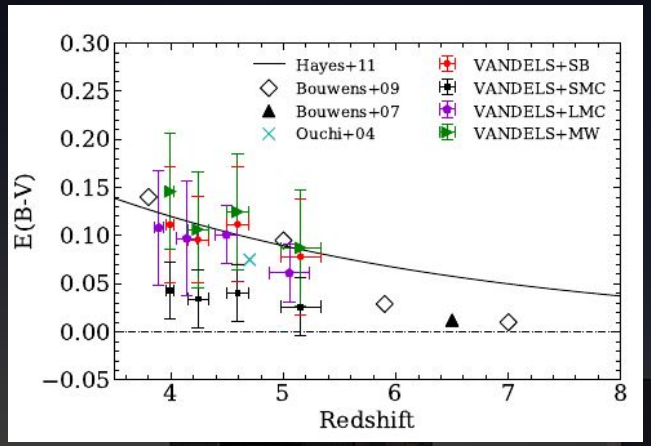
-IGM transmission decreases with redshift :
79% at z=2.75 and 46% at z=4.77
-Large dispersion at any redshift:
~15% at z=2.75 and ~9% at z=4.77

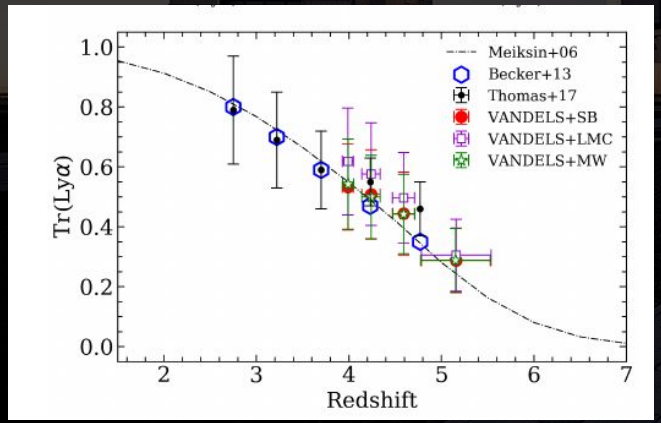
Indication of higher transmission at z > 4.

Difference can be reduced if E(B-V)max =0.05

→ IGM/Dust degeneracy

IGM distribution from VANDELS (Thomas+19)



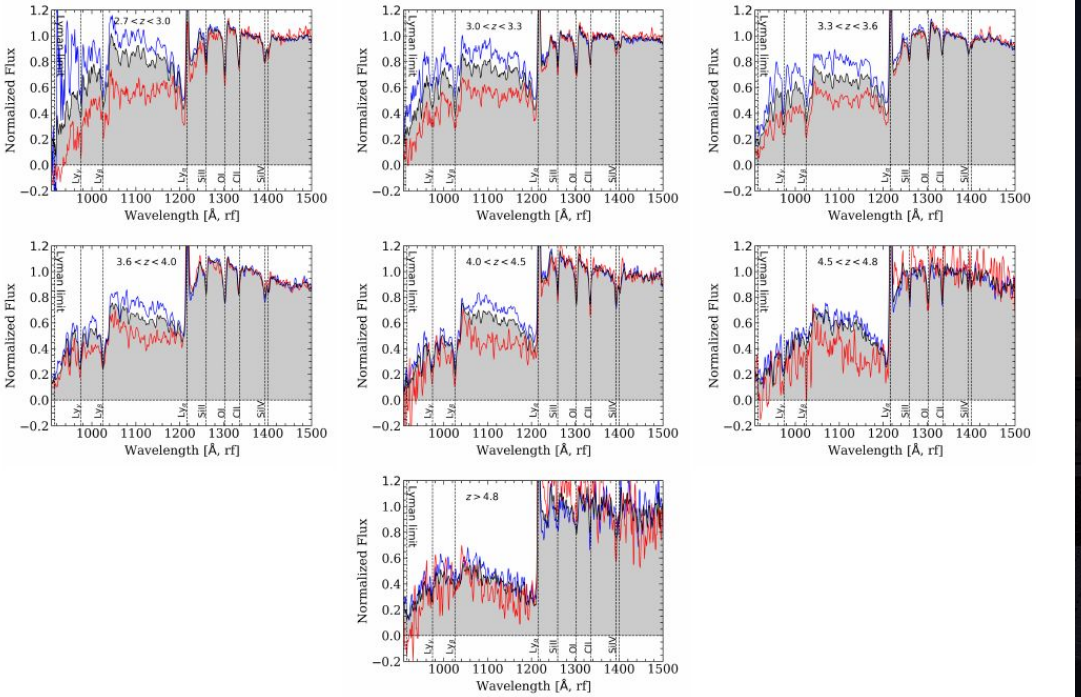


VANDELS x SPARTAN

First we estimate the dust extinction from photometry and then use these estimate to fix the dust parameter during spectral fitting.
→ Study of different dust prescription
Find that Calzetti's dust extinction allows us to reproduce better data from the literature (coherent with litterature)

-New data, new code → Similar results (that's reassuring)
-The two-step fitting seems to reduce the new degeneracy found in VUDS

VUDS+VANDELS IGM → IGM visualisation



Thomas et al +21

We create stack spectra in different redshift bins. In each bin we make 3 spectra:

- One with all galaxies whose IGM transmission is higher than the mean (see previous slide), **in blue**
- One with all galaxies whose IGM transmission is lower than the mean, **in red**
- One with all the galaxies **in gray**

The IGM variance is clearly visible at any reshift.

Comparison with QSO: VUDS+VANDELS

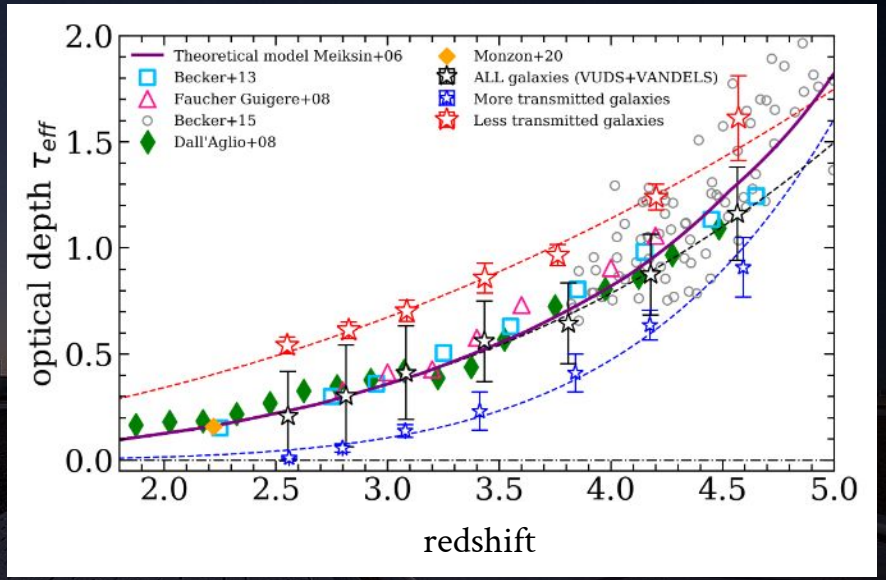
The IGM is generally studied using QSOs (e.g. Becker+13,+15). We compare our measurments from our galaxies to QSO's data using the optical depth with

$$\tau_{eff} = - \ln [Tr(Ly_{\alpha})]$$

Excellent agreement between galaxies and QSOs from different sources.

Fitting with a functional of the form :

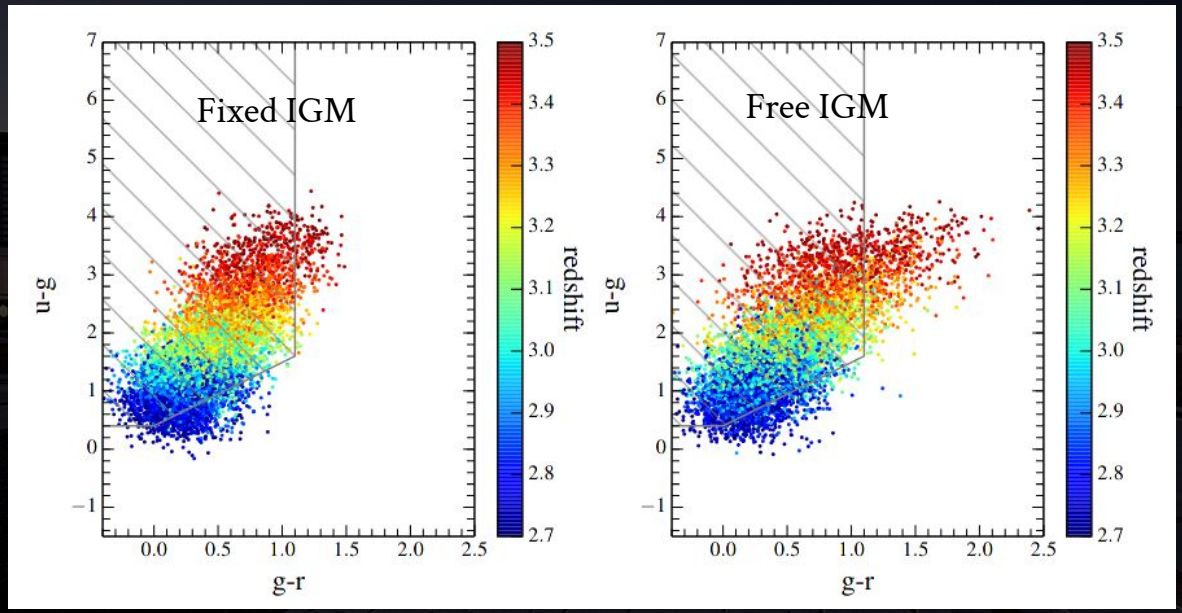
$$\tau_{eff} = A \times (1+z)^{\gamma}$$



Thomas et al +21

Consequence

Simulation of two samples at 2.7<z<3.5 with and without a free IGM transmission to test the influence of the IGM on the selection of high-z galaxies



→ ~30% of the z>3.2 galaxies are missed by the selection

Summary

- Creation of an empirical model of IGM transmission based on M95 and M06 models. This allows to use SED fitting to compute the IGM in galaxies.

- The Intergalactic medium is clearly visible in high redshift galaxy spectra and can be measured!

- Very good agreement with the literature and QSO studies.

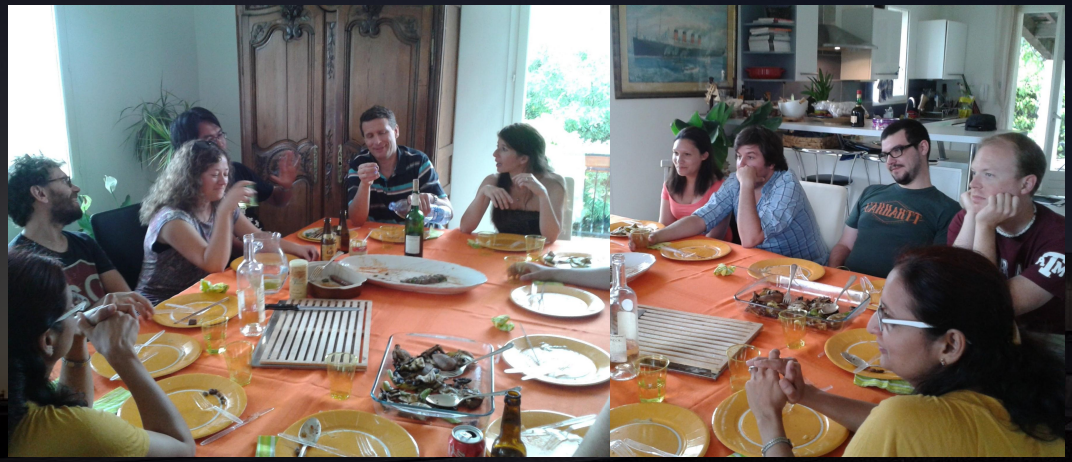
- In addition we find that the scatter in IGM transmission values is large. This can have important consequences for galaxy selection using LBG method.

References:

R. Thomas et al 2017. A&A, 597A, 88T • R. Thomas et al, 2020, A&A, 634A, 110T • R. Thomas et al 2021 A&A 650, A63• R. Thomas 2021, A&C, 3400427 • Le Fèvre, O et al 2015, A&A, 576A, 79L • Pentericci, L et al 2018, A&A, 616A, 174P • McLure, R. J. et al, MNRAS, 2018, 479, 25M • Becker, G et al, 2013, MNRAS, 430, 2067B • Becker, G et al, 2015, MNRAS, 447, 3402B

My small tribute to Olivier

VUDS-LAM team at Olivier's place



A lot of us joined LAM at the beginning of VUDS. Some as postdocs and some as PhD students (we were 3 at the same time!).

VUDS meeting @ LAM

That was quite a ride! With some crazy good moments. I will always be grateful to Olivier for the opportunity he gave me (us).