

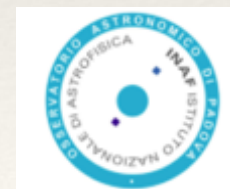


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# Quasars as cosmological standard candles

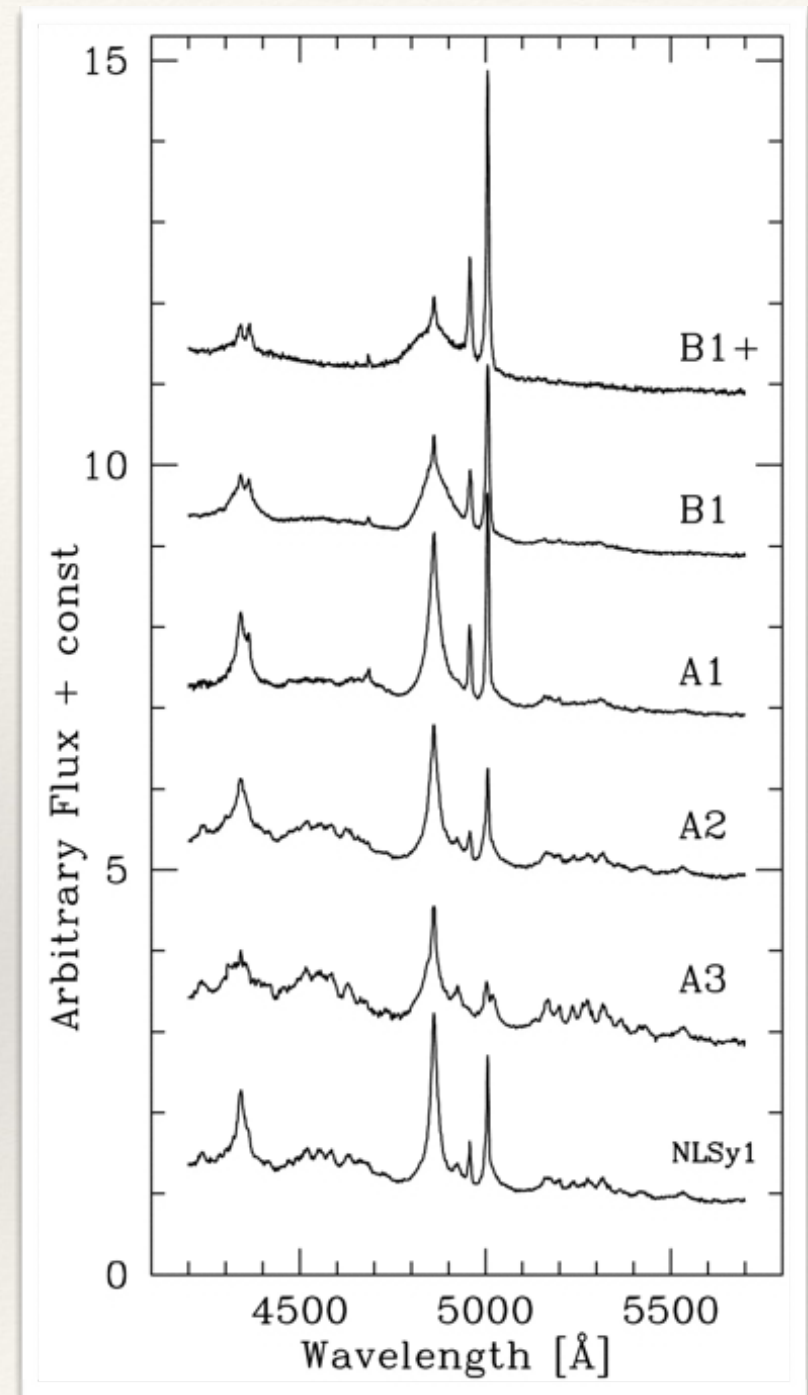
Alenka Negrete<sup>(1)</sup>

Deborah Dultzin<sup>(1)</sup>, Paola Marziani<sup>(2)</sup>, Jack Sulentic<sup>(4)</sup>, Donají Esparza<sup>(3)</sup>, Mary Loli Martínez-Aldama<sup>(4)</sup>, Ascensión del Olmo<sup>(4)</sup>  
1. IA-UNAM, 2. INAF-OAPD, 3. IRyA-UNAM, 4. IAA



# Eigenvector 1

- ❖ Introduced by Boroson & Green 1992, using a correlation matrix to make PCA over 17 parameters.
- ❖ The first eigenvector of this matrix is an anticorrelation between the strength of FeII vs. [OIII] $\lambda$ 5007 and the width of H $\beta$ .



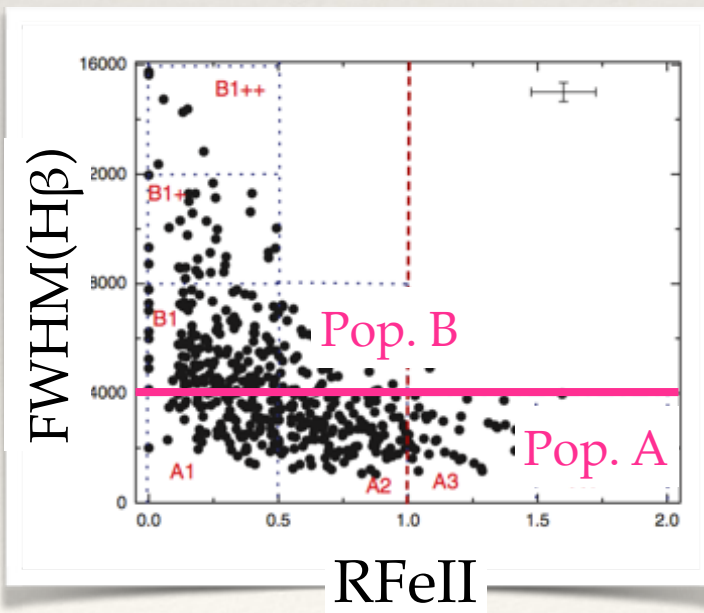
Sulentic+ 02

# Eigenvector 1

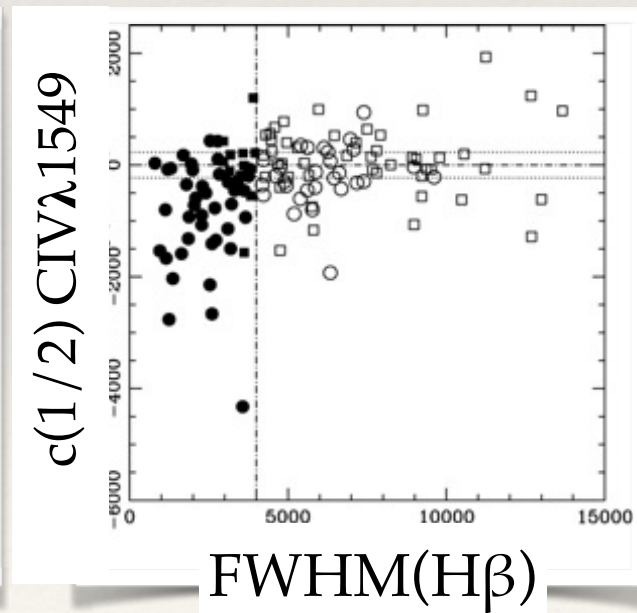
❖ Sulentic, Marziani & Dultzin-Hacyan ARA&A 2000, used ONLY parameters related to the Broad Lines.

- X-rays } Sulentic, Marziani & Dultzin-Hacyan 2000,
- Optical } Sulentic+ 02, Marziani+ 03, Zamfir+ 10...
- UV } Sulentic+ 07, Negrete+ 14, Sulentic+ 17 submitted
- IR } Dulzin-Hacyan+ 99, Martínez-Aldama+ 15

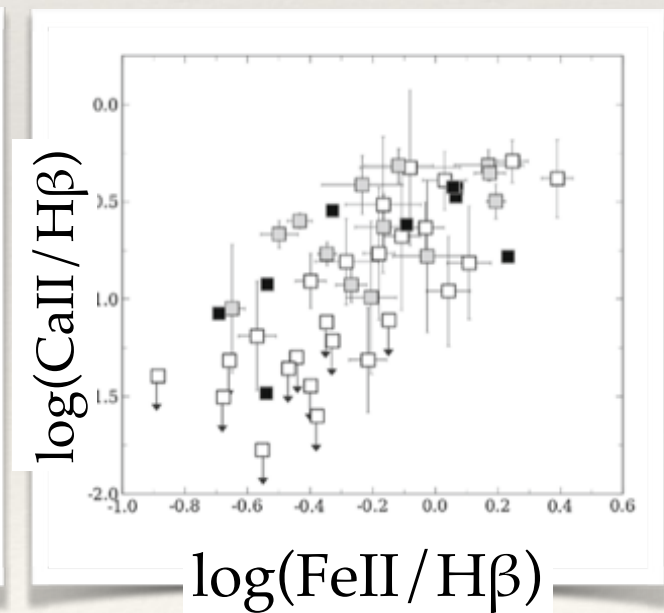
} 4DE1



Zamfir+ 10

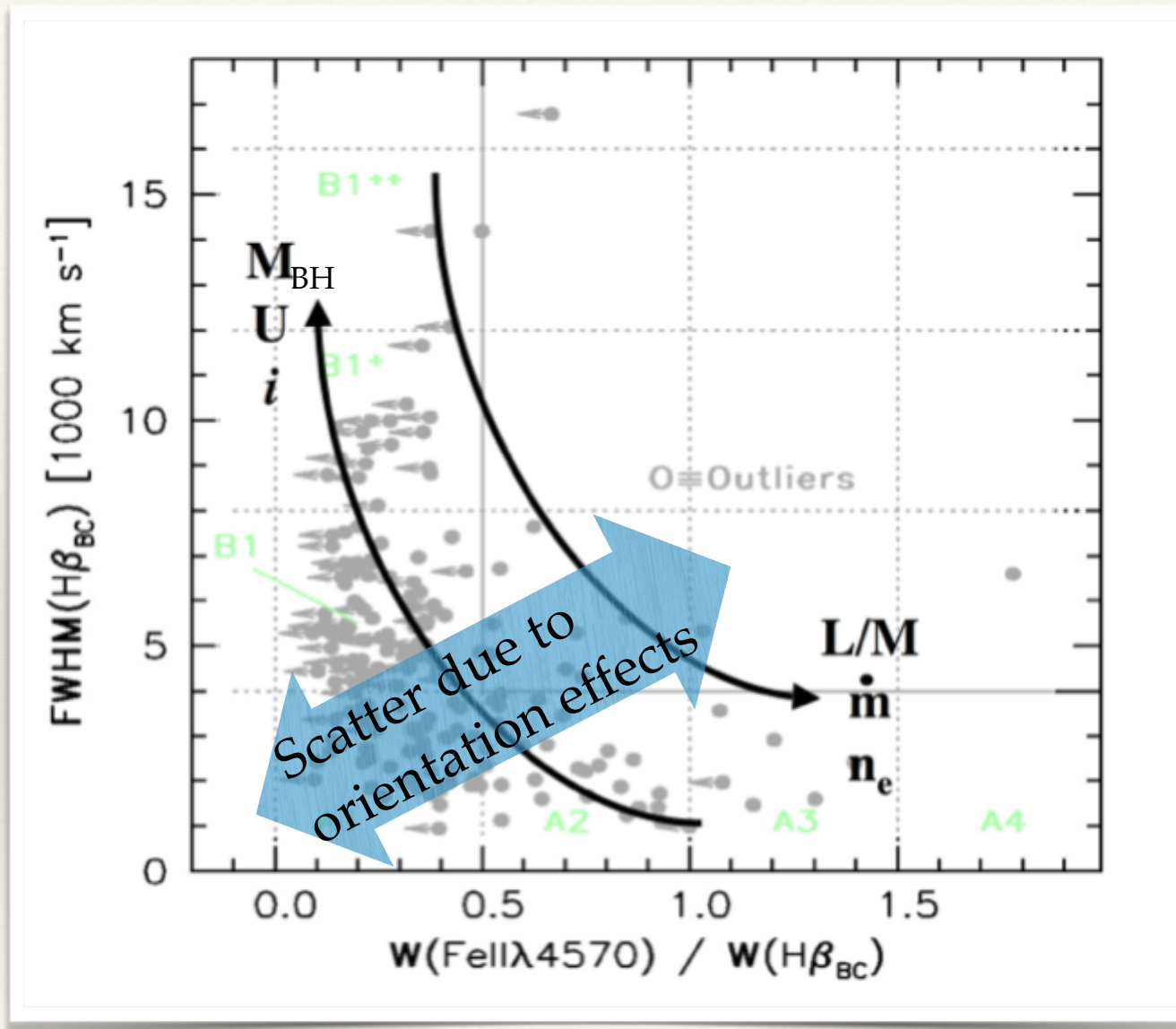


Sulentic+ 07, 17



Martínez-Aldama+ 15

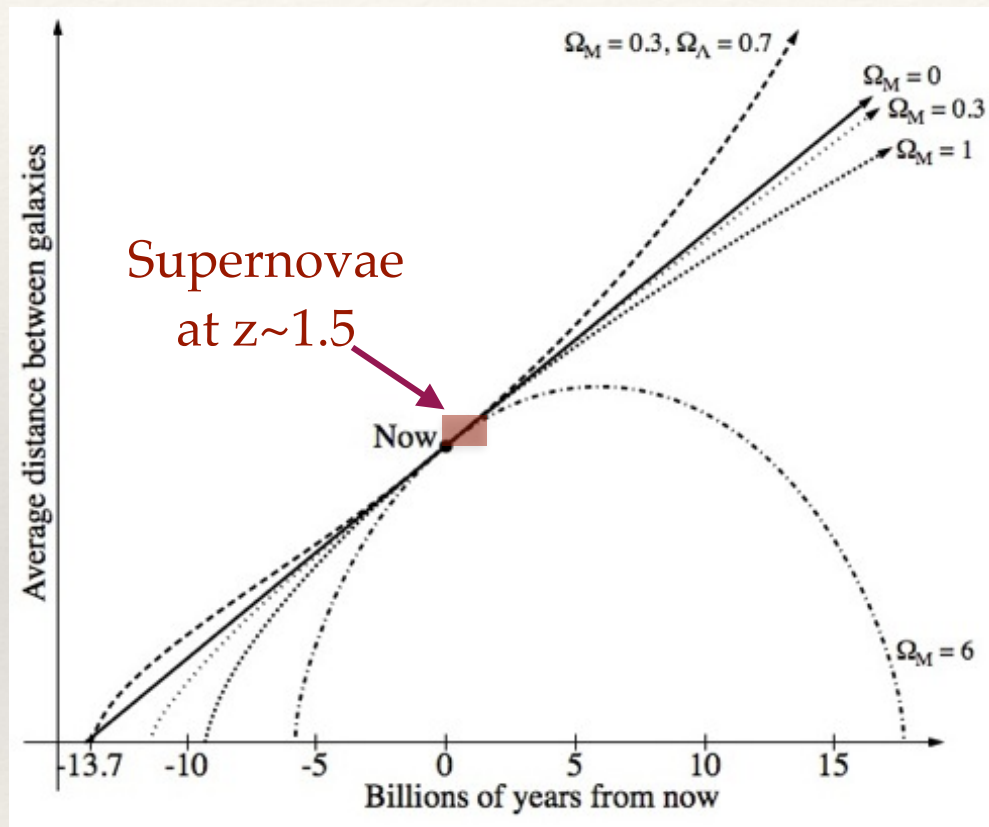
# Eigenvector 1



A surrogate “HR diagram” for AGN

# Why use quasars as standard candles?

Pros: Very numerous and luminous. We can find them up to  $z \sim 7$



LXr prop to Lbol

- ❖ Elisabetta Luso & Susana Bisogni talk
- ❖ (Luso & Risaliti 2016)
- ❖ Poster Damien Coffey

Cons: The intrinsic luminosity spans up to 4 orders of magnitude... contrary to candle concept!

# Extreme accretion AGN in the 4DE1 parameter space

**However**, it has been found that most highly accreting quasars (Eddington ratio around one, which we call **Extreme Accretors, xA**) **have the same, intrinsic luminosity**, within the same errors as SNIa (Marziani & Sulentic 2014, **MS14**).

- ❖ In super Eddington accretion regime, a structure known as “**slim disk**” is expected to develop (Castello’s talk, Abramowicz et al. 1988).
- ❖ Quasars hosting slim disks should radiate at a well defined limit because their luminosity is expected to saturate close to the Eddington luminosity even if the accretion rate becomes super-Eddington (ADAF regime).

ADAF - Advection Dominated Accretion Flow

# Considerations

1. xA radiate close to Eddington Ratio  $\lambda_{\text{Edd}} = L_{\text{bol}}/L_{\text{Edd}}$
2. Assuming **virial motions** of the BLR, we can describe the bolometric luminosity as

$$L_{\text{bol}} \propto \lambda_{\text{Edd}} M_{\text{BH}} \propto \lambda_{\text{Edd}} r_{\text{BLR}} (v)^2$$

3. xA have **similar BLR physical parameters** ( $n_{\text{H}}$  and  $U$ ; Negrete+ 12), so we can estimate the size of the BLR

$$r_{\text{BLR}} \propto (L/n_{\text{H}} U)^{1/2}$$

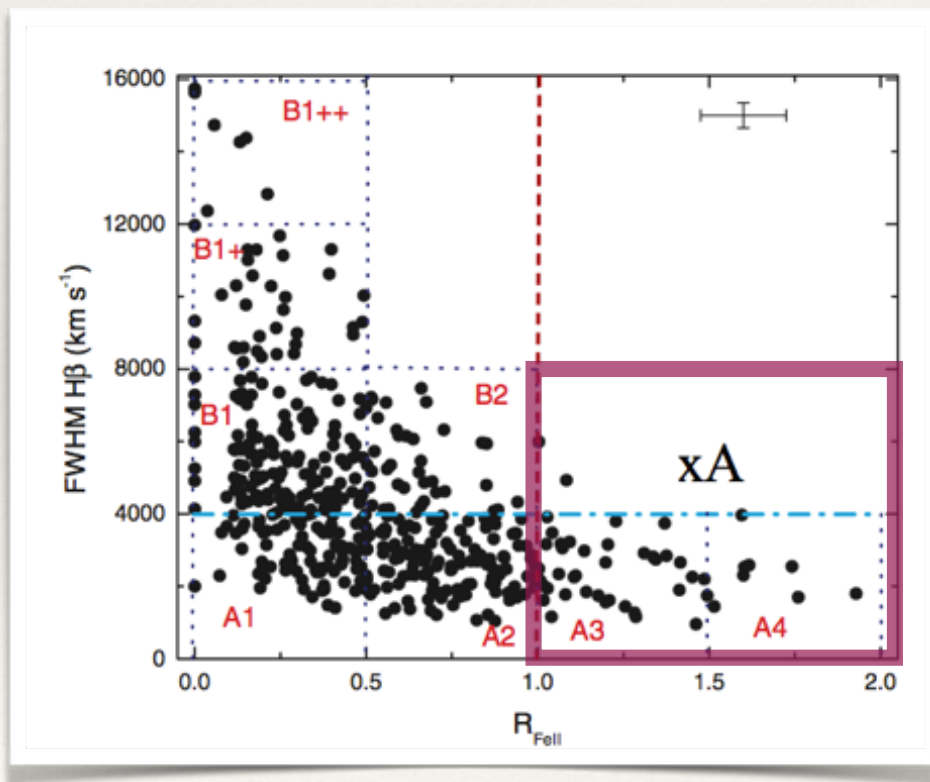
So, if we know  $v$  (or equivalently, the FWHM), we can derive a z independent “**virial luminosity**”

$$L_{\text{vir}} \propto \lambda_{\text{Edd}}^2 (n_{\text{H}} U)^{-1} (v)^4$$

# Where can we find xA?

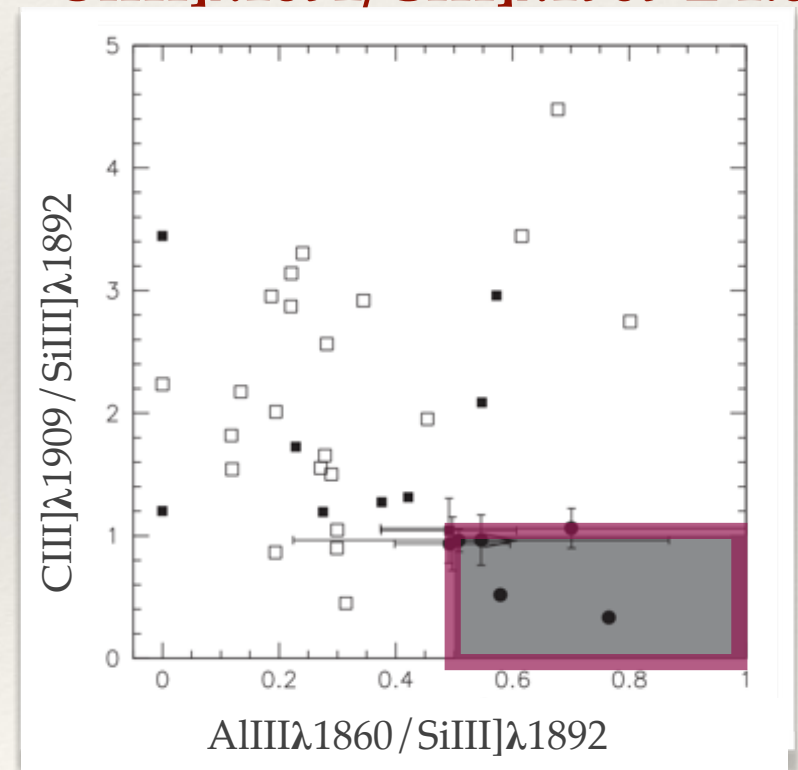
- ❖ Optical region (low z):

$$R_{\text{FeII}} > 1$$



Zamfir+ 10

- ❖ UV region (high z)  
Martinez-Aldama's talk:  
 $\text{AlIII}\lambda 1860 / \text{SiIII}\lambda 1892 \geq 0.5$   
 $\text{SiIII}\lambda 1892 / \text{CIII}\lambda 1909 \geq 1.0$



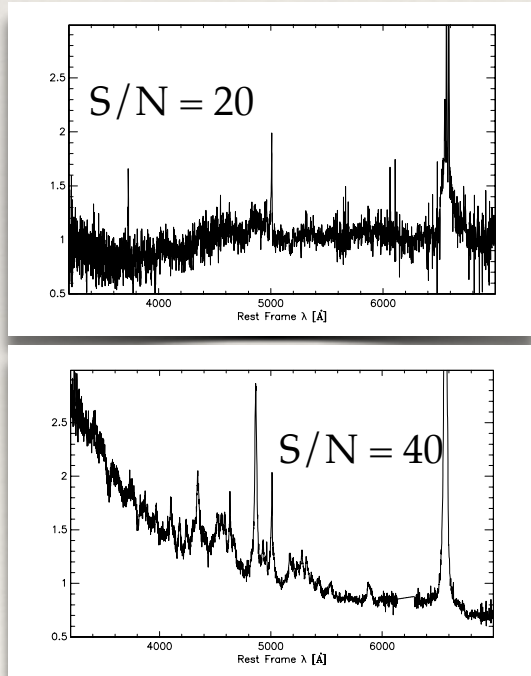
Marziani & Sulentic 14 (MS14)

# SAMPLES

Optical region ( $z \leq 0.8$ ):

We started from the Shen+ 11 sample in the  $H\beta$  range, containing 19,450 objects.

We limit our analysis to objects with  $S/N \geq 20$  (2,734 objects).

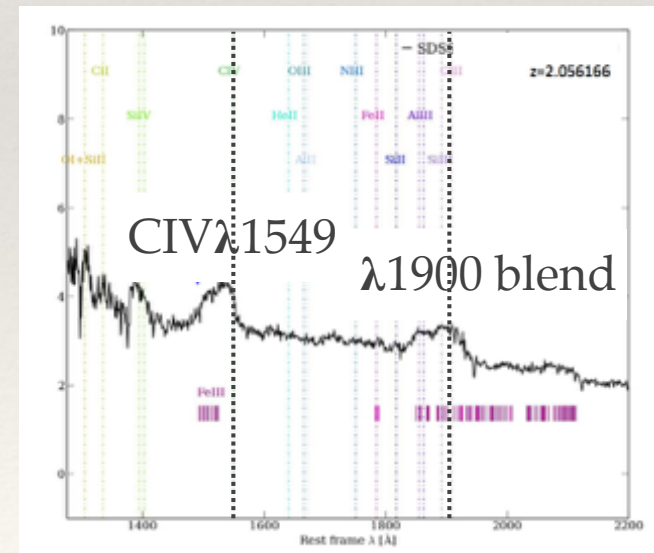


UV region ( $z = 2-3$ ):

Using the OSIRIS spectrograph in the GTC ~50 sources.

average  $S/N \sim 38$

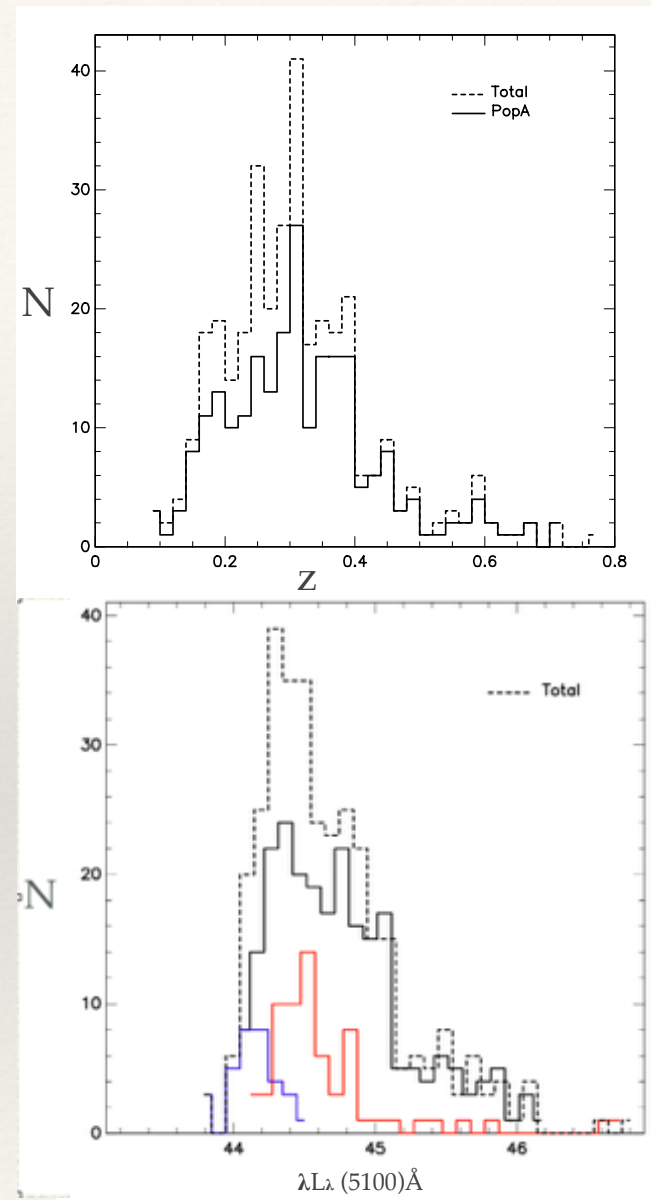
$M_B \sim 19.4$



# Low z sample

Using **automatic measurements** we selected

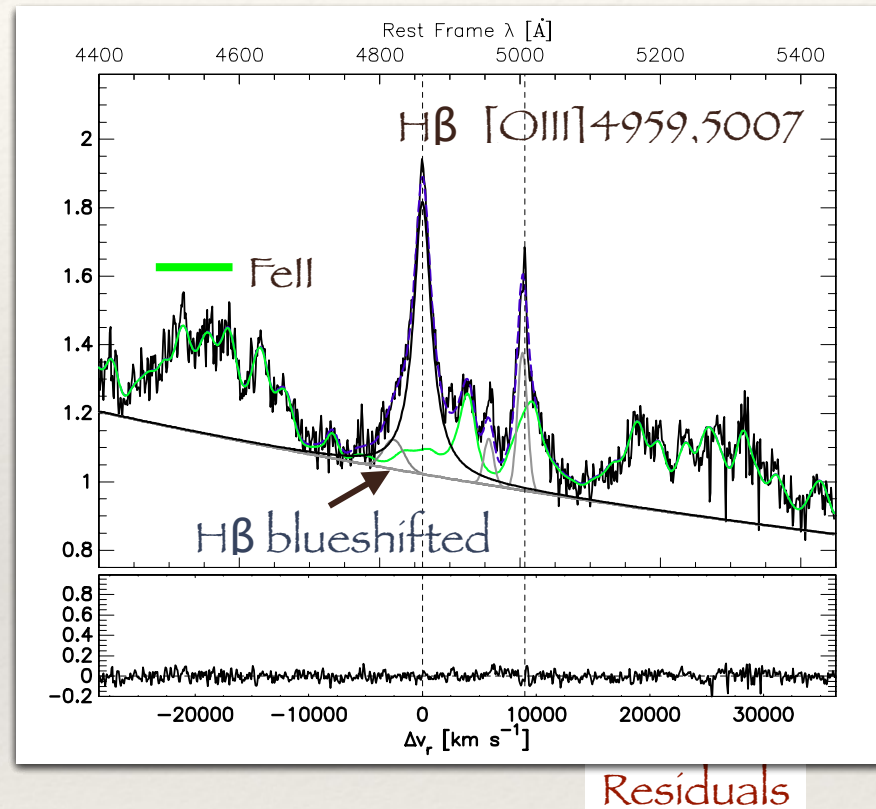
- ❖ **304** objects  $R_{FeII} \geq 1.0$ .
- ❖ and fitted these spectra individually.



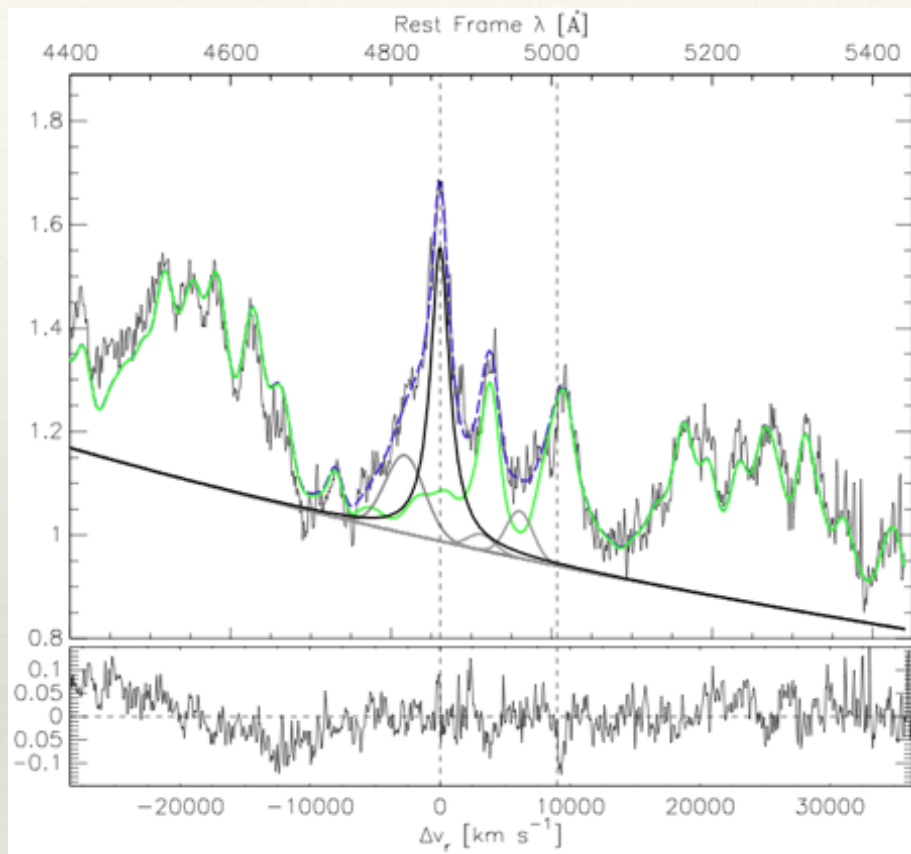
Negrete+ 17 in prep.

# Spectral fitting

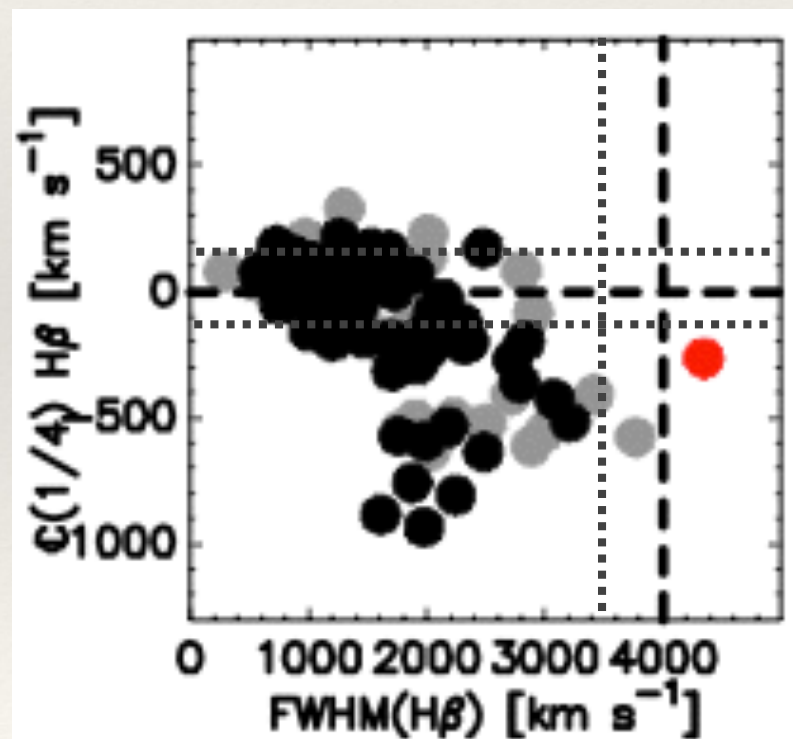
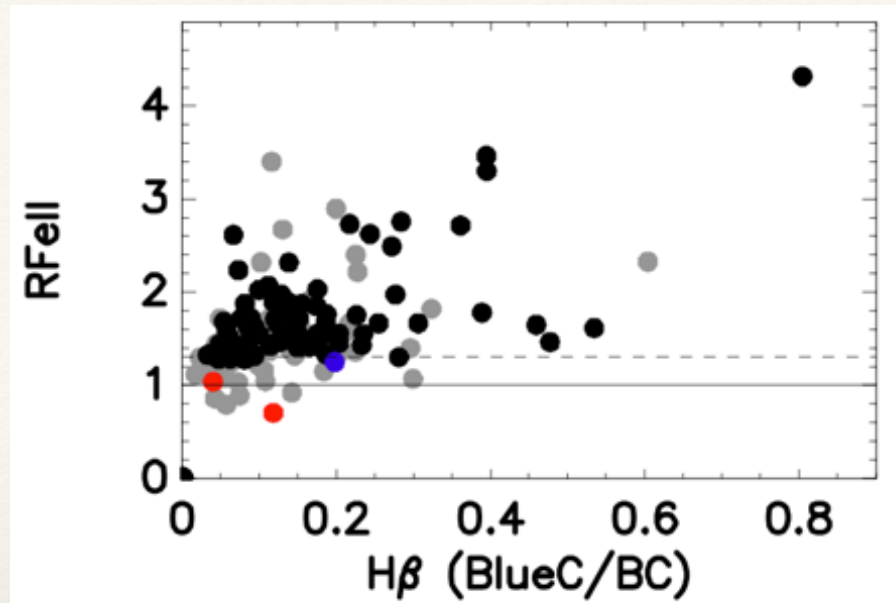
FeII blend, H $\beta$ , [OIII] $\lambda\lambda$ 4959,5007



# H $\beta$ blue shift

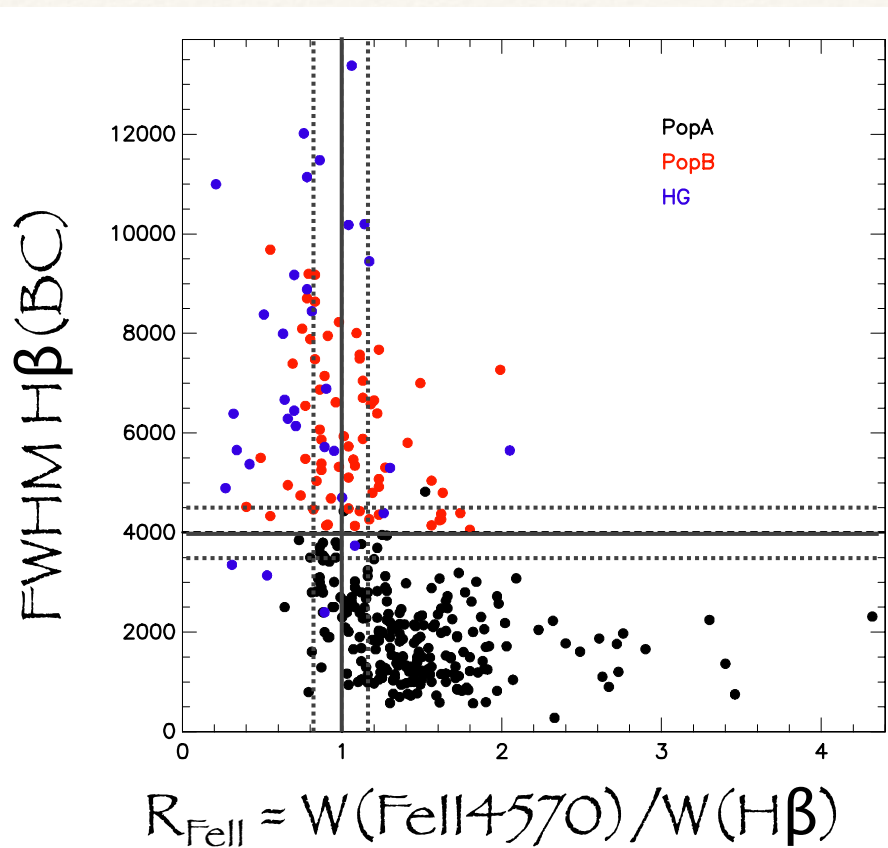


FeII blend, H $\beta$ , [OIII] $\lambda\lambda$ 4950,5007



Negrete+ 17 in prep.

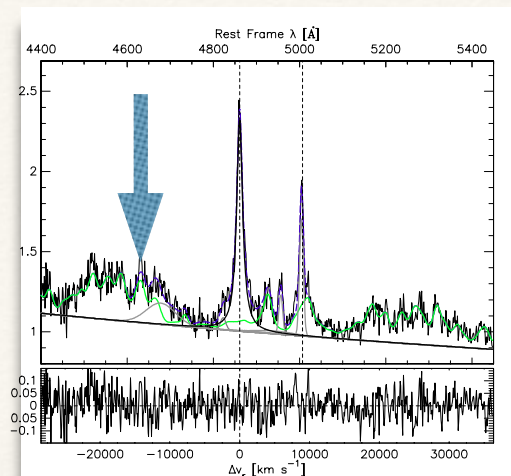
# No xA objects



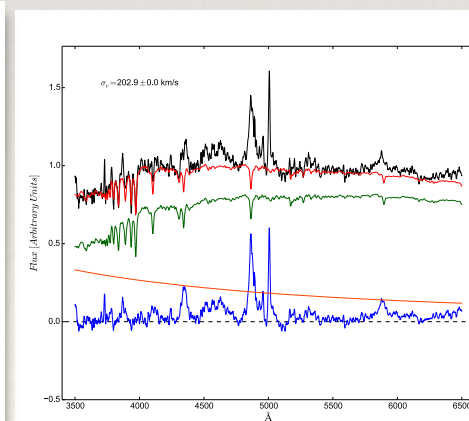
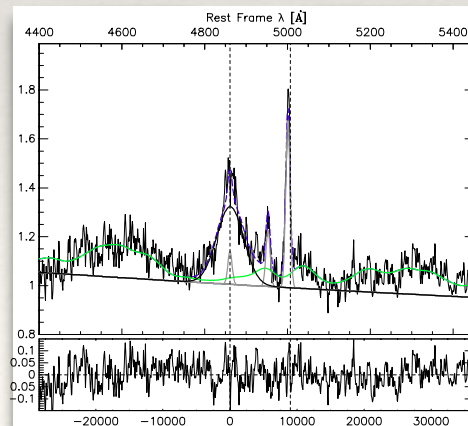
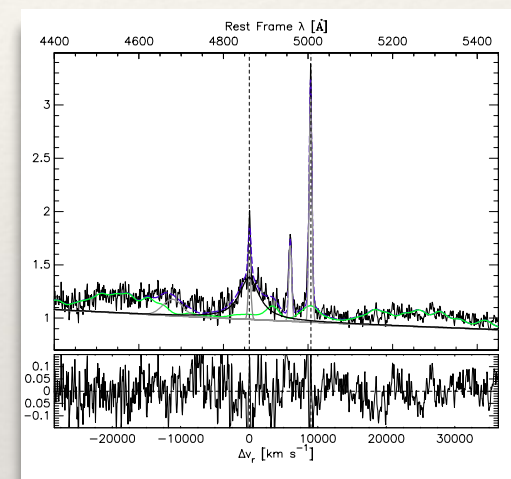
Host Galaxy contribution:

Ca H + K, MgI 5175 and Fe 5270

Hell $\lambda$ 4686  
contribution



Intermediate  
Objects



# Stronger restriction

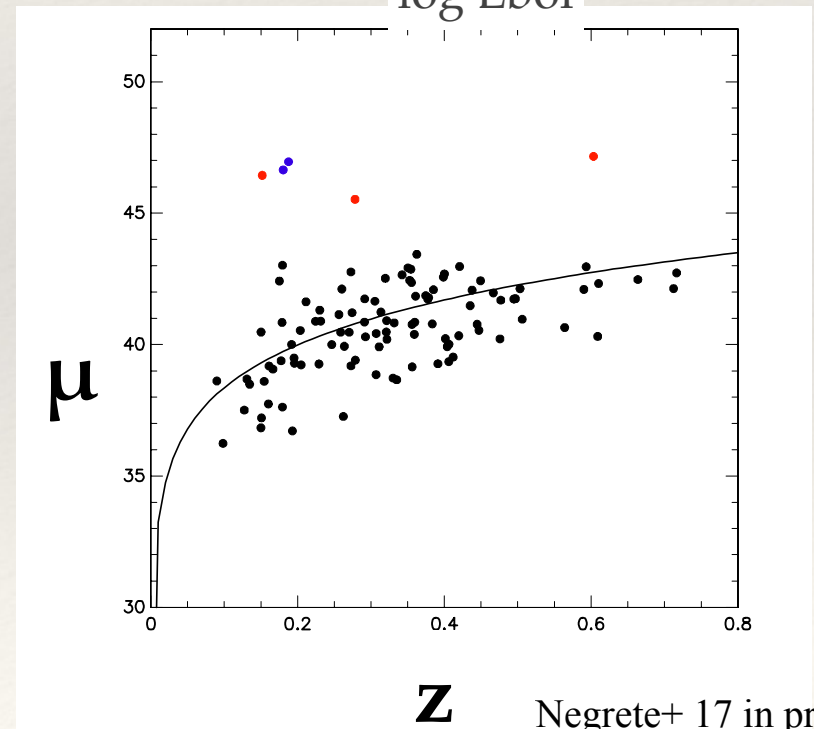
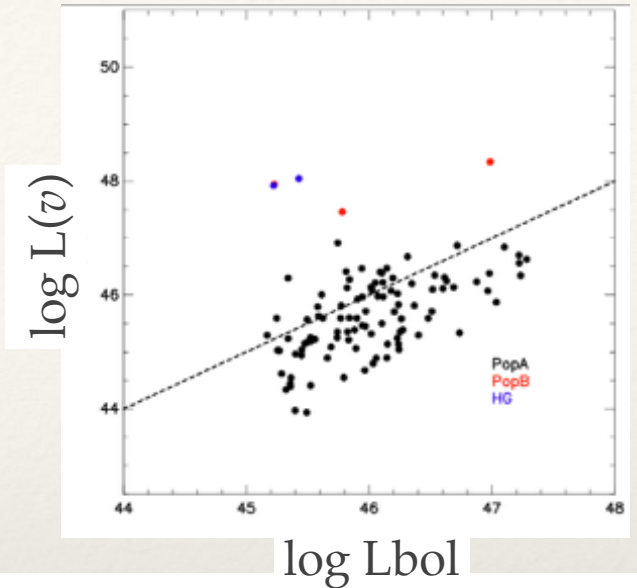
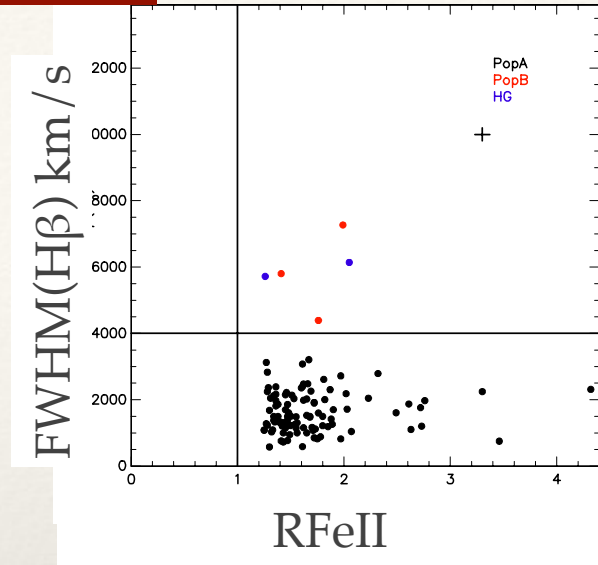
$$S/N \geq 25$$

$$R_{FeII} \geq 1.25$$

Distance modulus

$$\mu = 5 \log \frac{d_L}{10pc}$$

$$\mu = 2.5 \log L(v) - 2.5 \log f_\lambda - 100.2$$



**Z** Negrete+ 17 in prep.

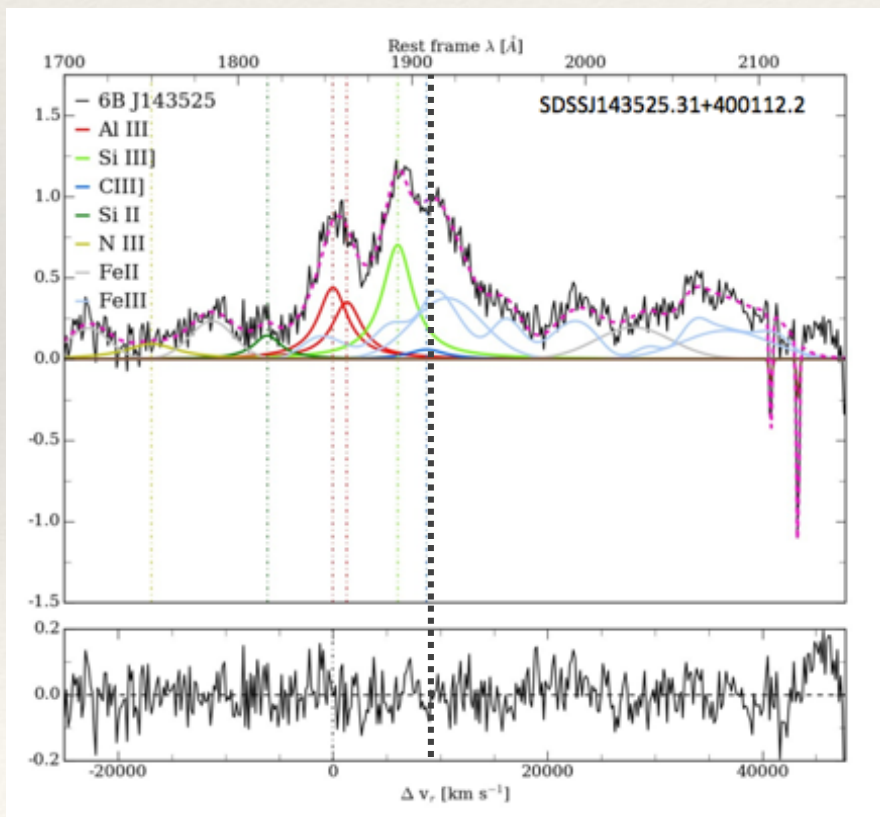
# High z UV region

❖  $\lambda 1900$  blend:

CIII] $\lambda 1909$ , SiIII] $\lambda 1892$ ,

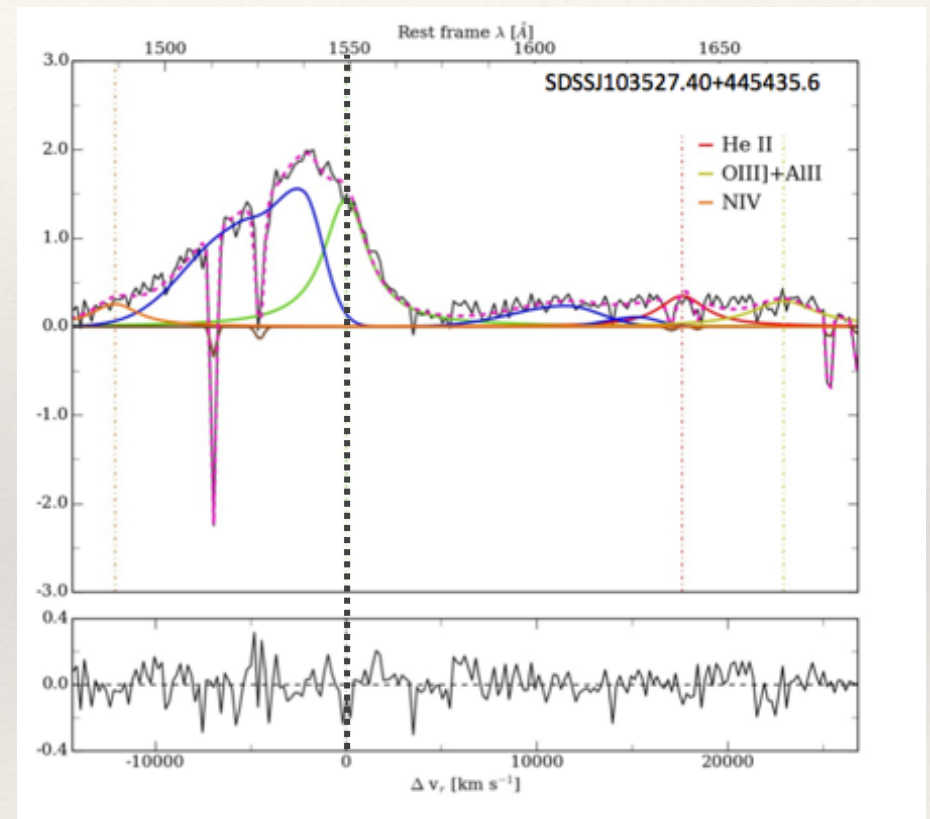
AlIII] $\lambda 1860$ , SiII] $\lambda 1814$ ,

FeII, FeIII



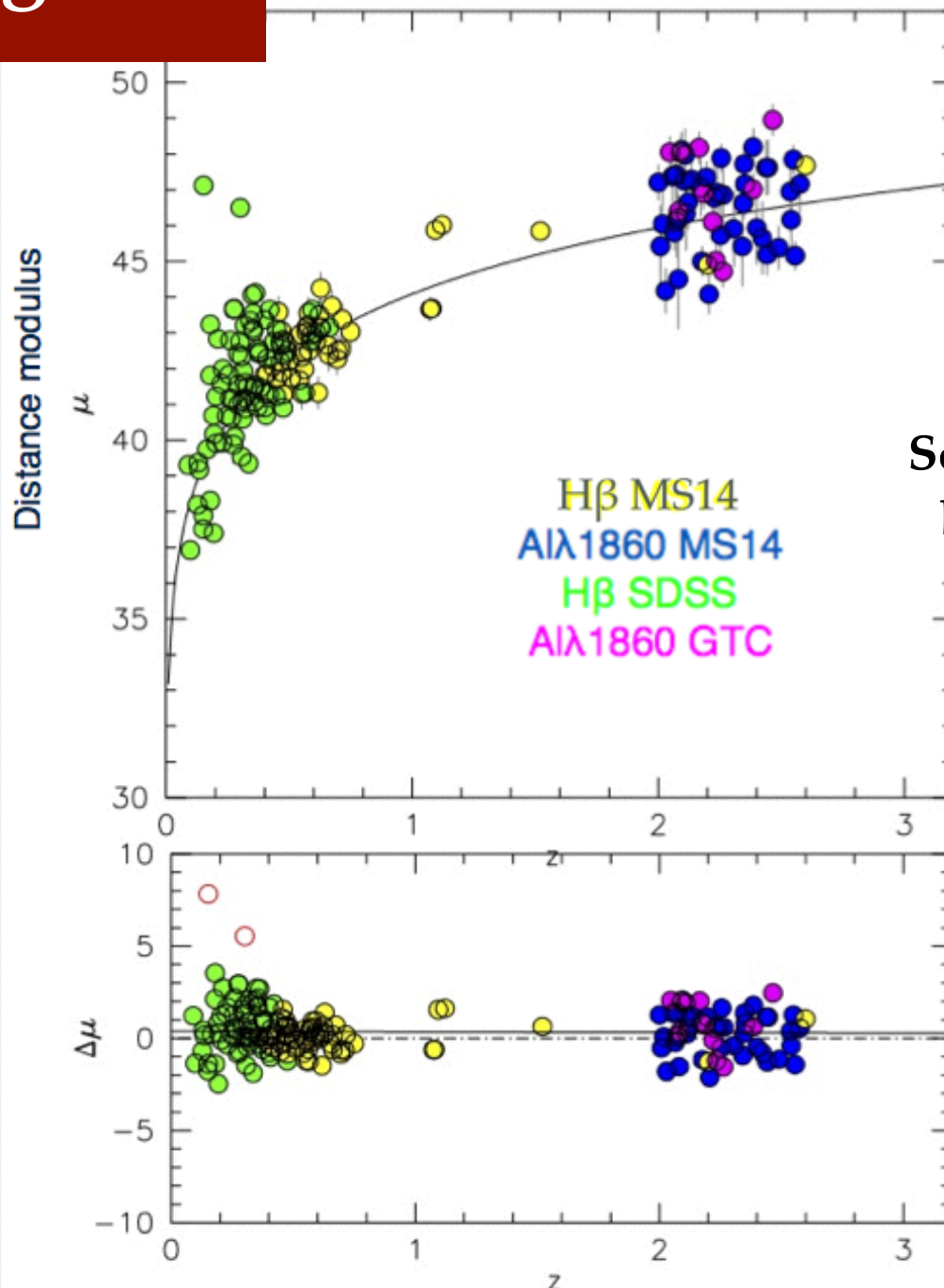
Martínez-Aldama+ 17 in prep.

❖ CIV $\lambda 1549$



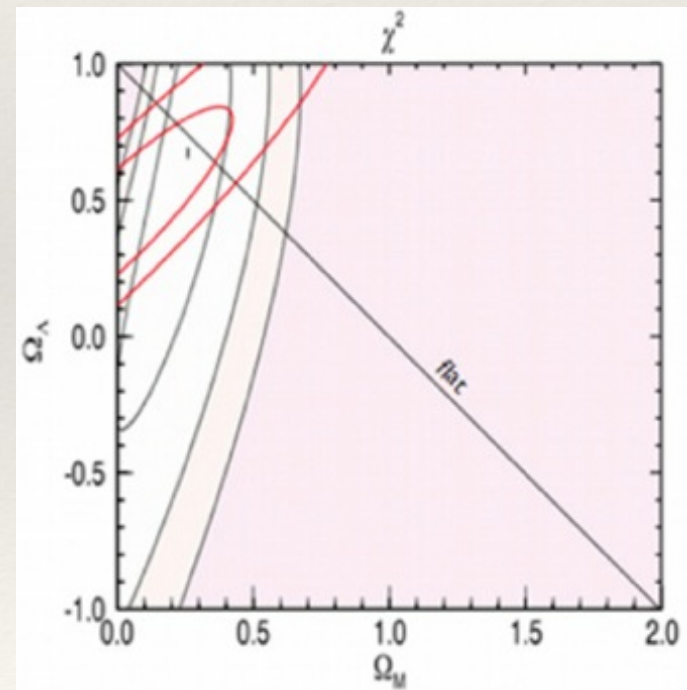
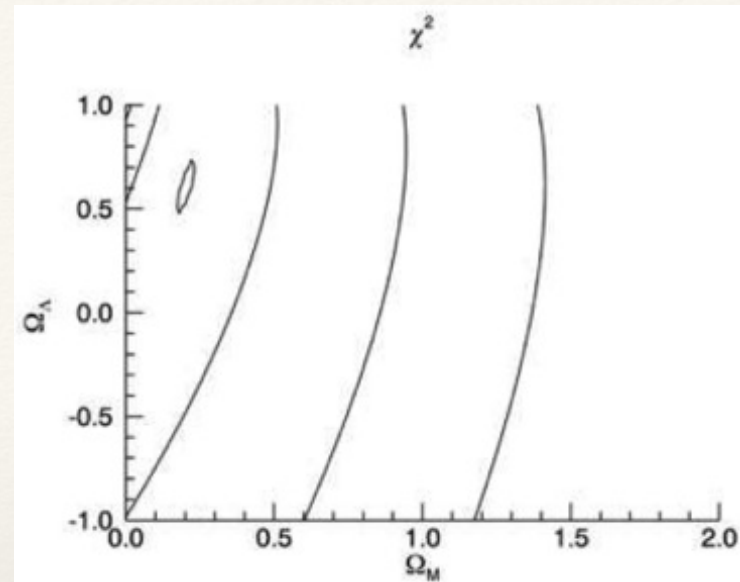
❖ SiIV+OIV] $\lambda 1400$

# Hubble Diagram



Broader H $\beta$   
profiles  
Scatter influenced  
by orientation?

- ❖ Constrains on  $\Omega_M$  from the MS14 data. A better constrain on  $\Omega_M$  is possible with a sample of  $x_A$ , carefully selected.
- ❖ Comparison between **supernovae** photometric survey (Campbell+ 13) at 1 and 2  $\sigma$  and the **mock sample** at 1, 2 and 3  $\sigma$  (MS14).



# CONCLUSIONS

- ❖ The 4DE1 is a very efficient diagram that organizes both observed and physical properties, in a **wide range of wavelengths** (from x-R to IR) and **redshifts** (at least up to  $z \sim 3.4$ ).
- ❖ Using the 4DE1 parameter space we can easily find the most extreme accreting quasars.
- ❖ They can be used as cosmological candles. We compute the “**virial luminosity**” independent of  $z$ , to build the Hubble diagram.
- ❖ The use of Extreme Accretors will allow to constrain  $\Omega_m$  and  $\Omega_L$ , with errors similar to the supernovae to much larger  $z$ .