Quasars as cosmological standard candles

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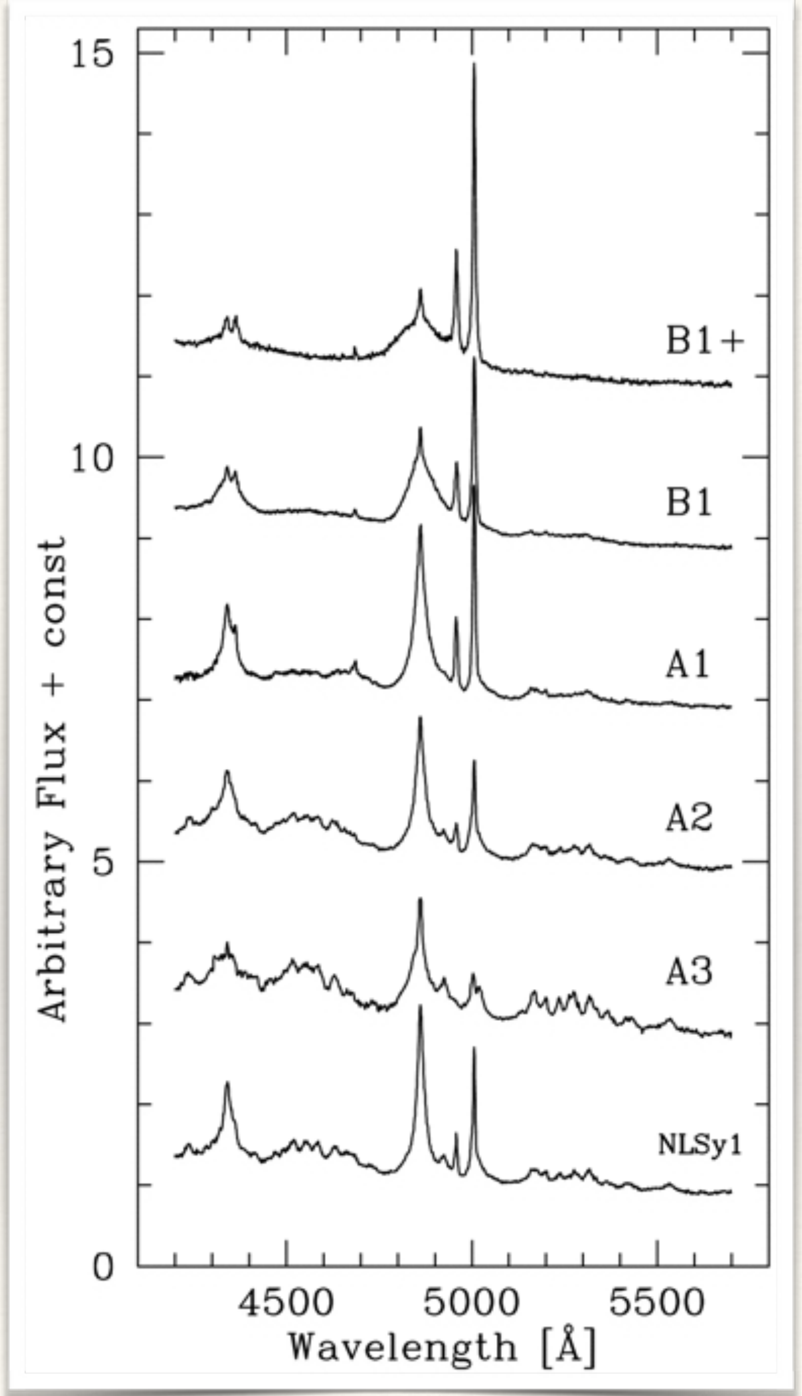
Eigenvector 1

- 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]λ5007 and the width of Hβ.

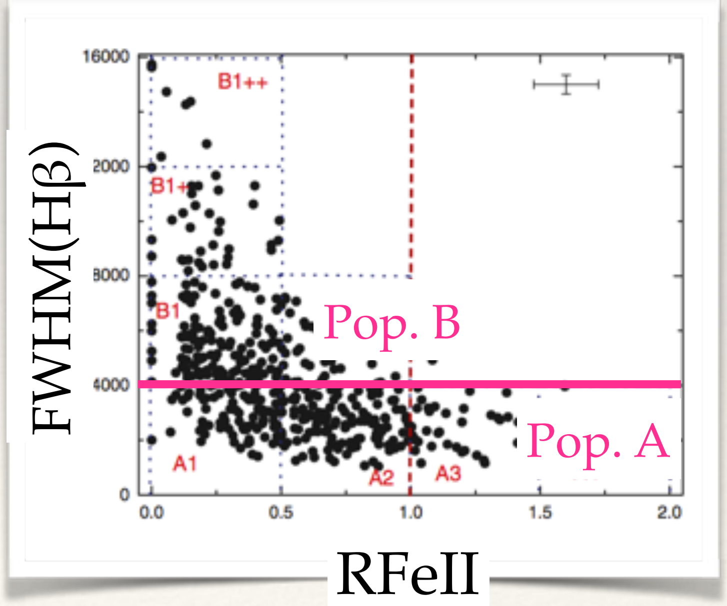


Sulentic+ 02

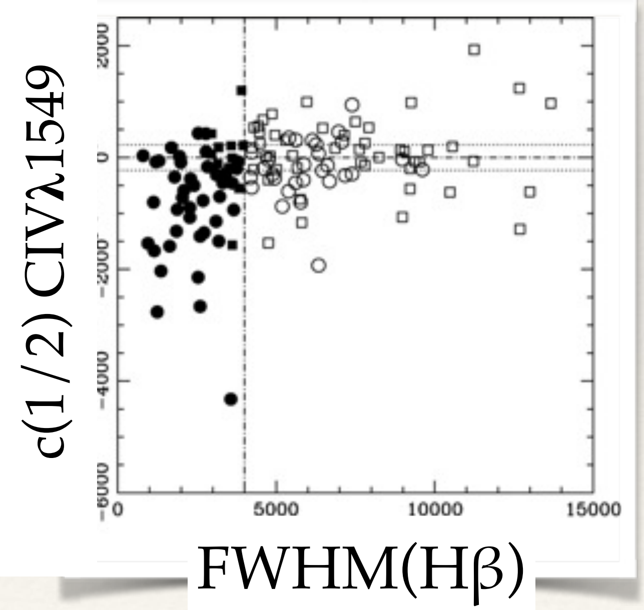
Eigenvector 1

- 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

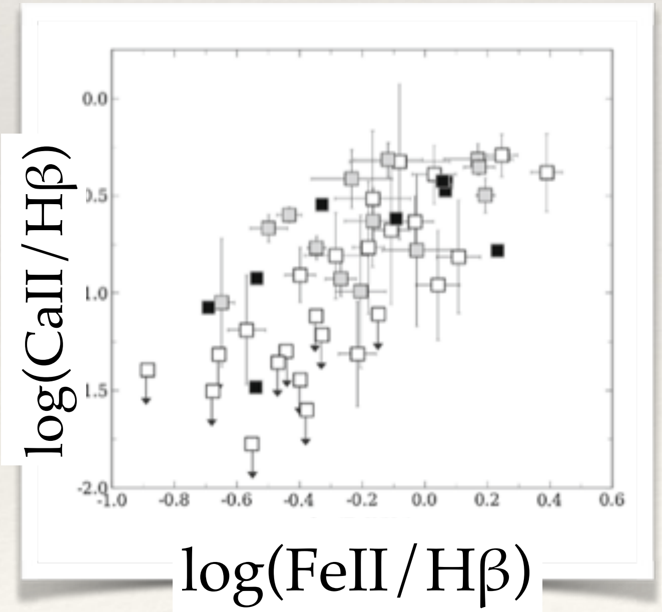
} 4DE1



Zamfir+ 10

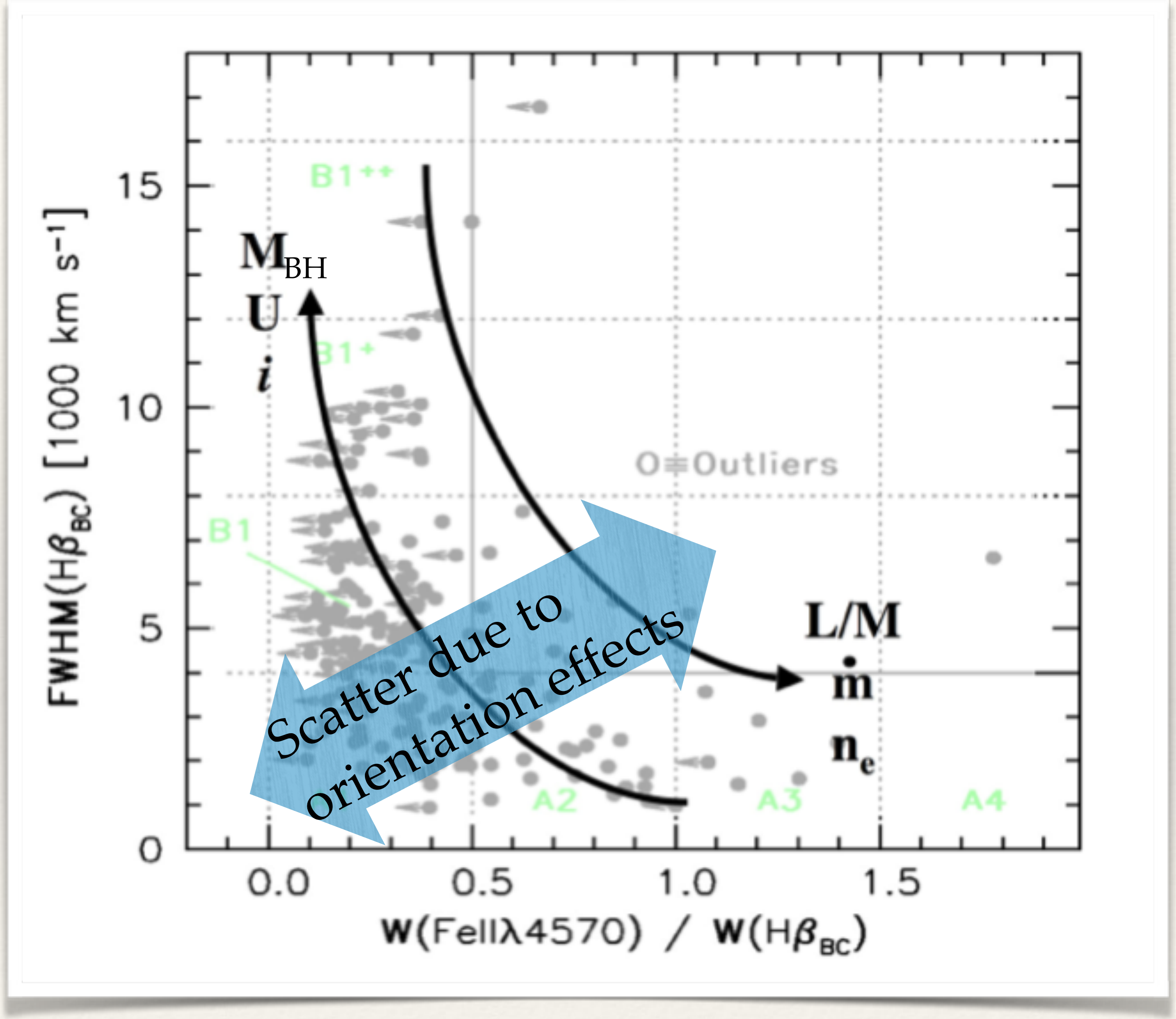


Sulentic+ 07, 17



Martínez-Aldama+ 15

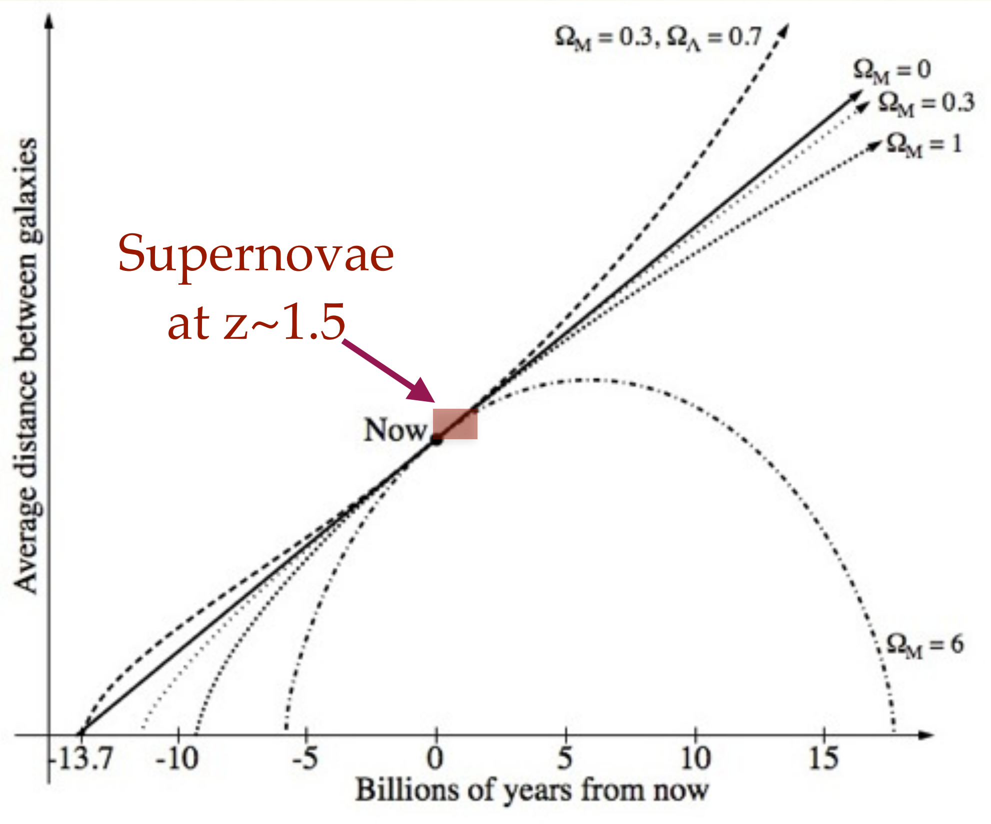
Eigenvector 1



A surrogate "HR diagram" for AGN

Why use quasars as standard candles?

Pros: Very numerous and luminous. We can find them up to z~7



Supernovae at z~1.5

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 $\lambda_{\mathrm{Edd}} = L_{\mathrm{bol}}/L_{\mathrm{Edd}}$

2. Assuming **virial motions** of the BLR, we can describe the bolometric luminosity as

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

3. xA have **similar BLR physical parameters** (n_H and U; Negrete+ 12), so we can estimate the size of the BLR

$$r_{\mathrm{BLR}} \propto (L / n_H U)^{1/2}$$

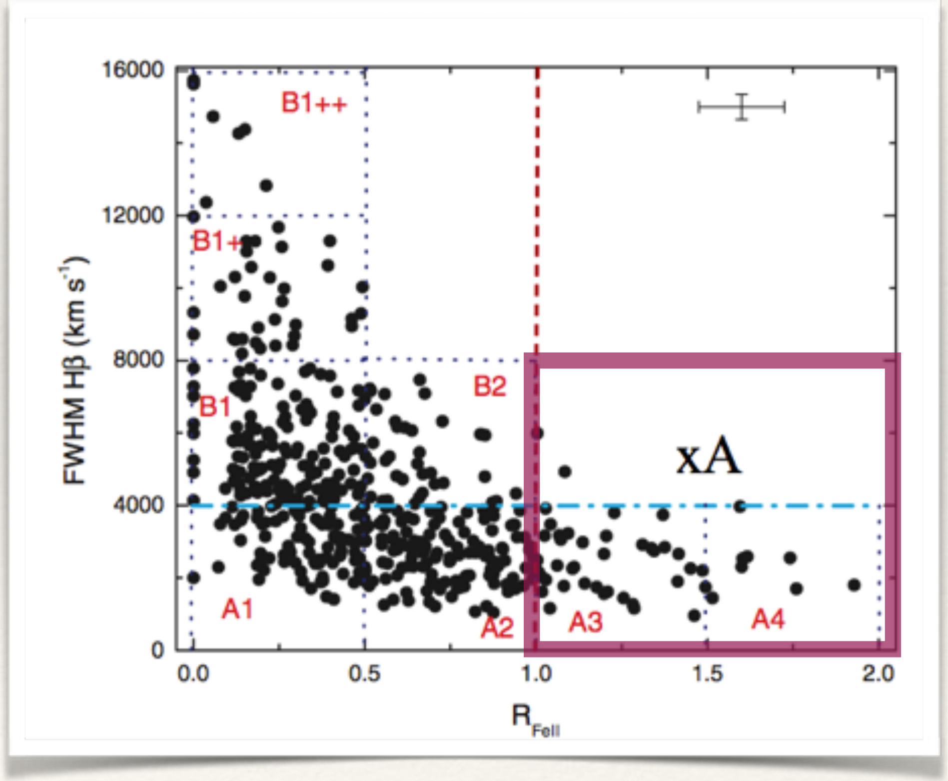
So, if we know v (or equivalently, the FWHM), we can derive a **z independent** "**virial luminosity**"

$$L_{\mathrm{vir}} \propto \lambda^2_{\mathrm{Edd}} (n_H U)^{-1} (v)^4$$

Where can we find xA?

- Optical region (low z):

RFeII > 1



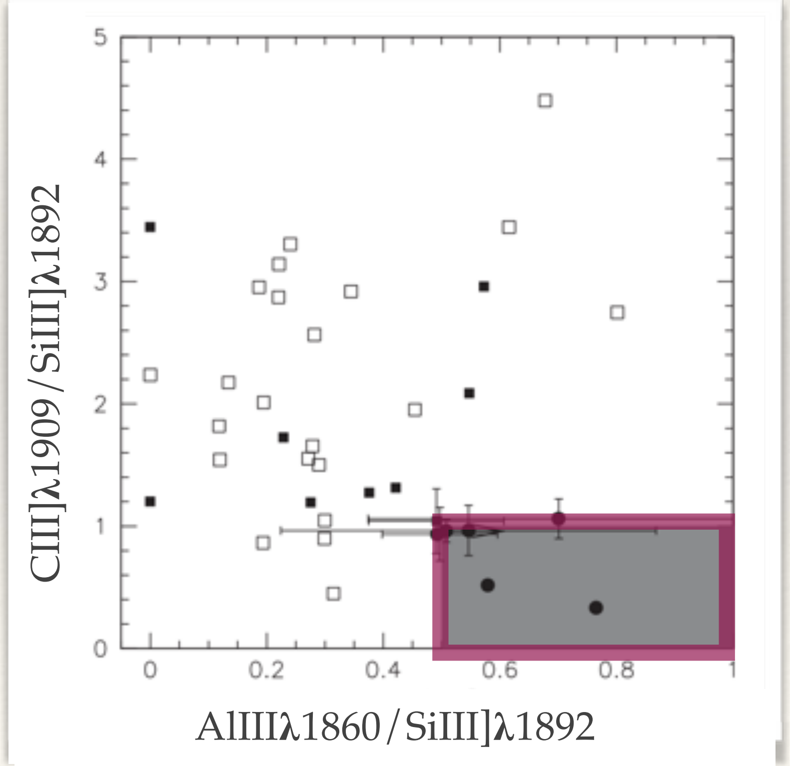
Zamfir+ 10

- UV region (high z)

Martinez-Aldama's talk:

AlIIIλ1860/SiIII]λ1892 ≥ 0.5

SiIII]λ1892/CIII]λ1909 ≥ 1.0



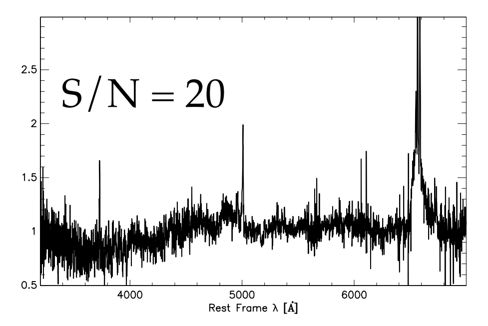
Marziani & Sulentic 14 (MS14)

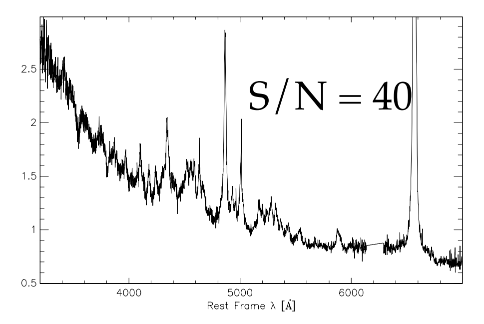
SAMPLES

Optical region ($z \leq 0.8$):

We started from the Shen+ 11 sample in the Hβ range, containing 19,450 objects.

We limit our analysis to objects with **S/N ≥ 20** (2,734 objects).



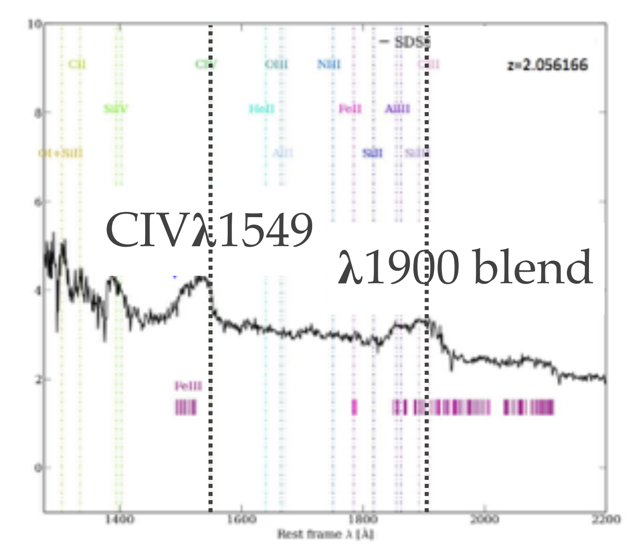


UV region ($z = 2\text{-}3$):

Using the OSIRIS spectrograph in the GTC ~50 sources.

average S/N ~ 38

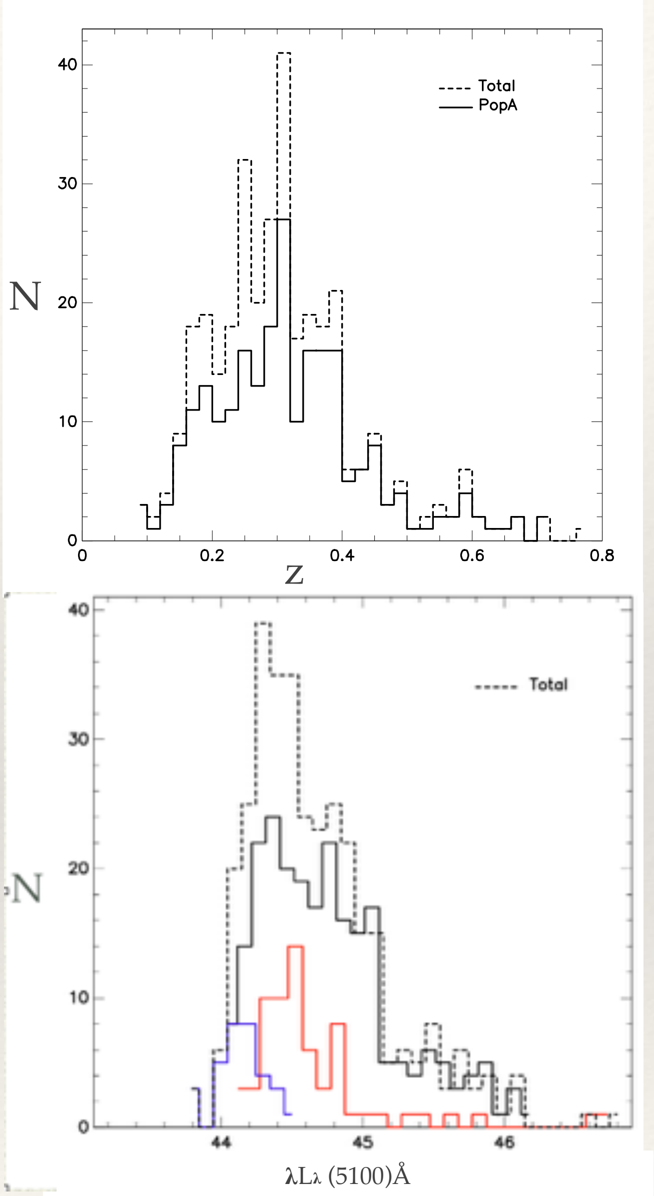
M_B ~19.4



Low z sample

Using **automatic measurements** we selected

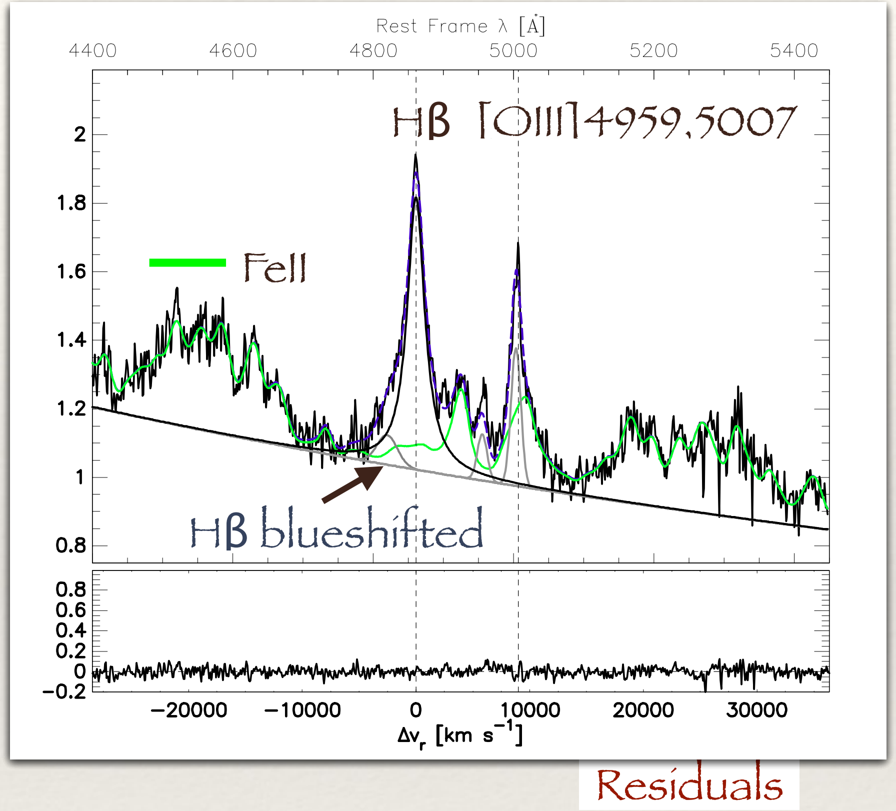
- 304 objects RFeII ≥ 1.0.
- and fitted these spectra **individually**.



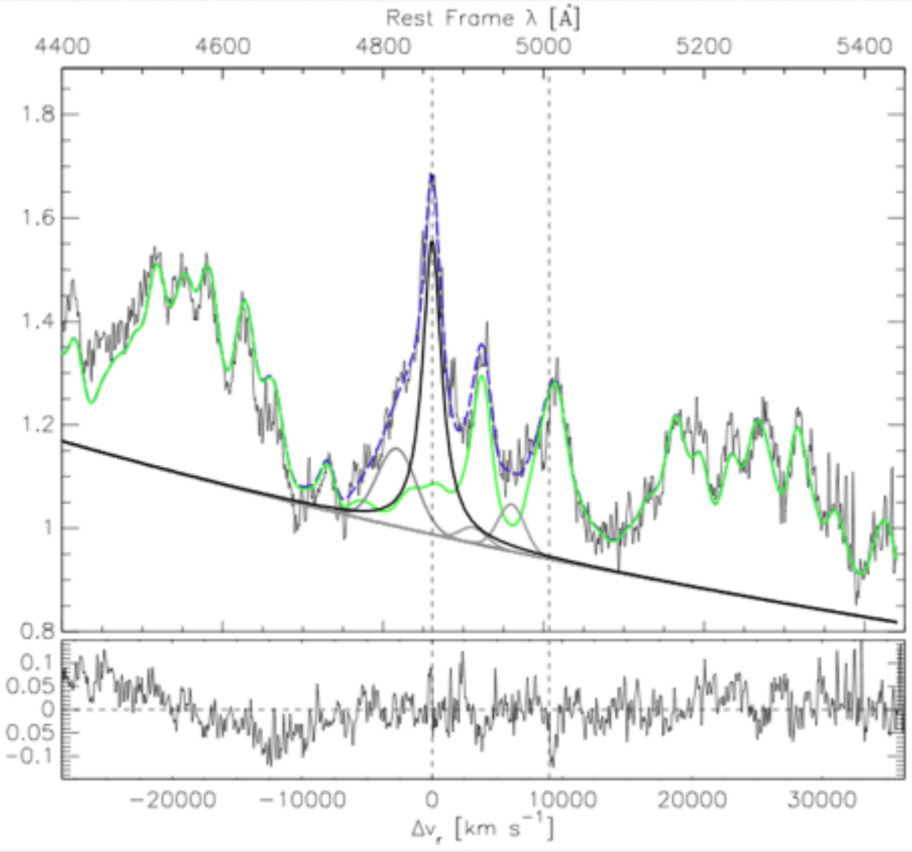
Negrete+ 17 in prep.

Spectral fitting

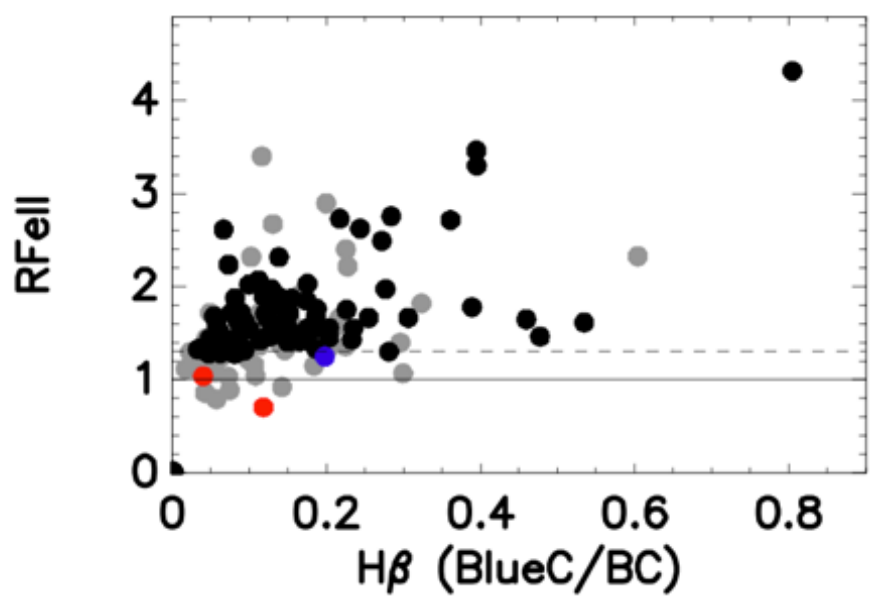
FeII blend, Hβ, [OIII]λλ4950,5007

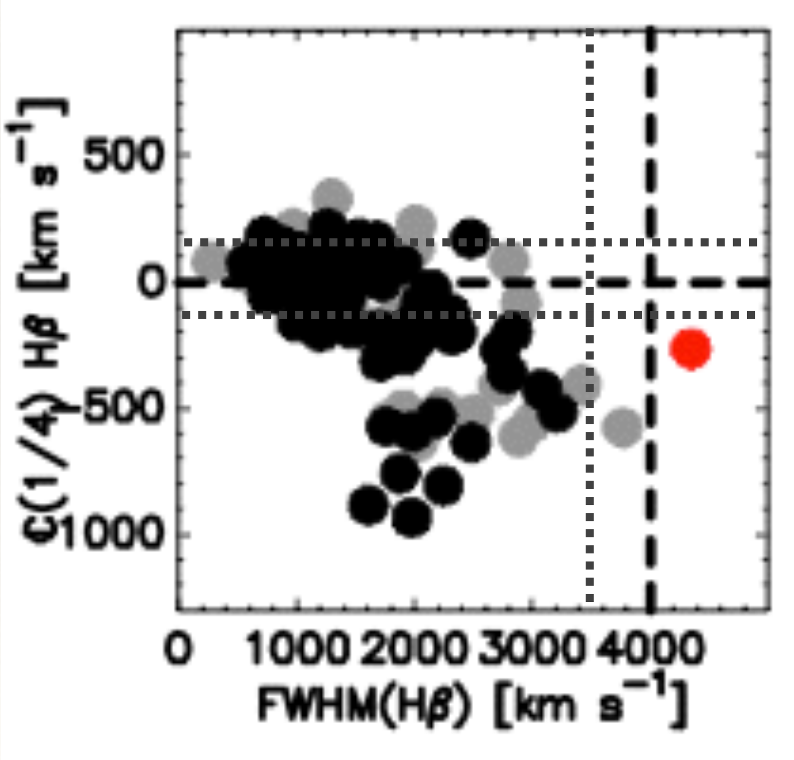


Hβ blue shift



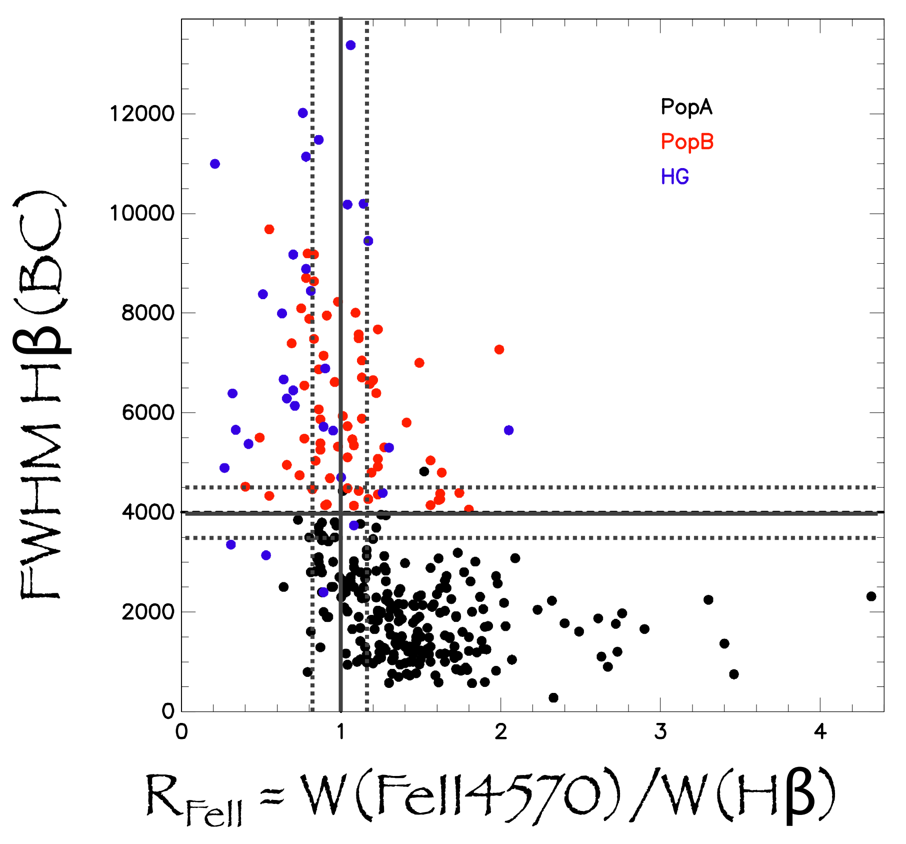
FeII blend, Hβ, [OIII]λλ4950,5007



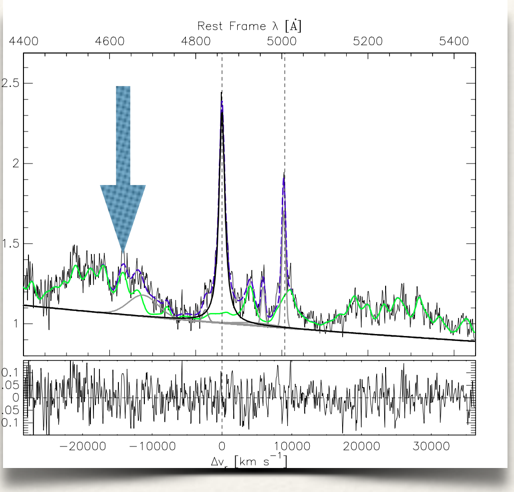


Negrete+ 17 in prep.

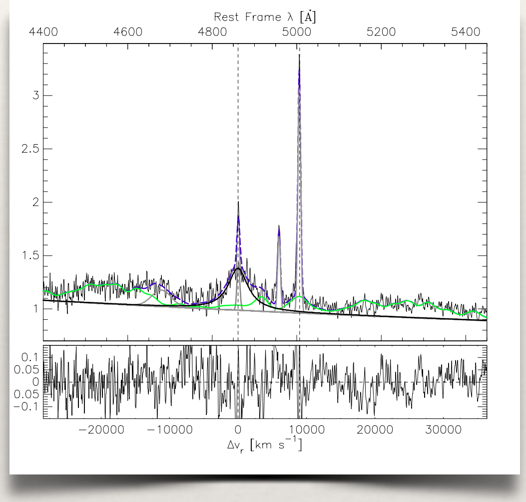
No xA objects



HeIIλ4686 contribution

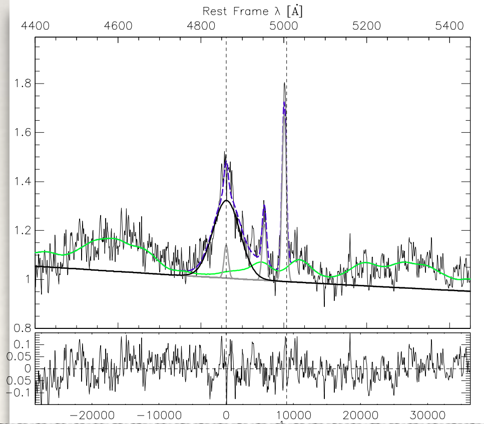


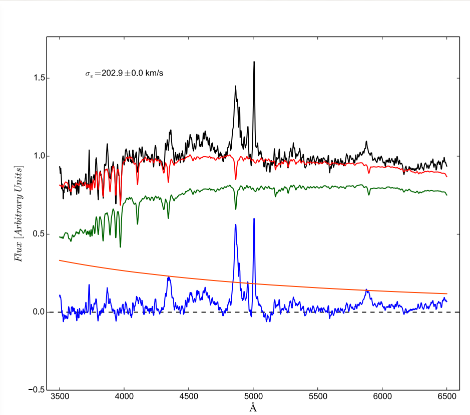
Intermediate Objects



Host Galaxy contribution:

Ca H + K, MgI 5175 and Fe 5270

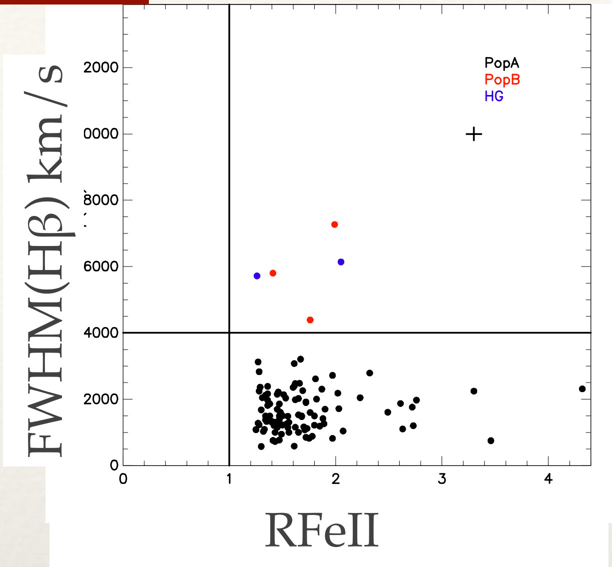


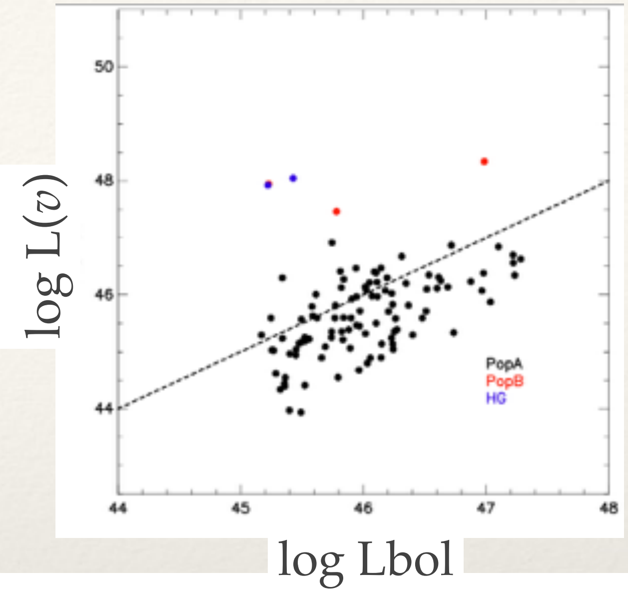


Stronger restriction

S/N ≥ 25

RFeII ≥ 1.25

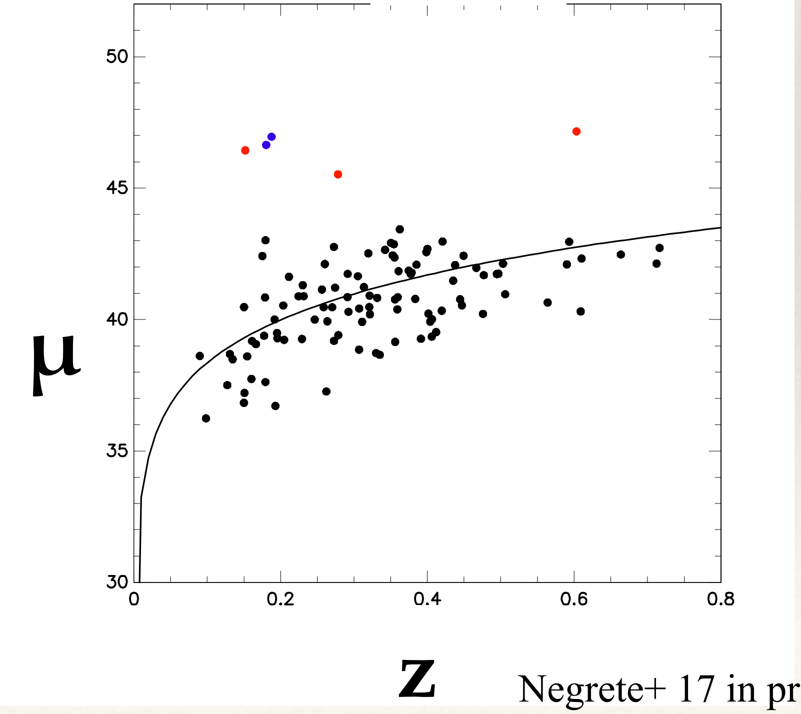




Distance modulus

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

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

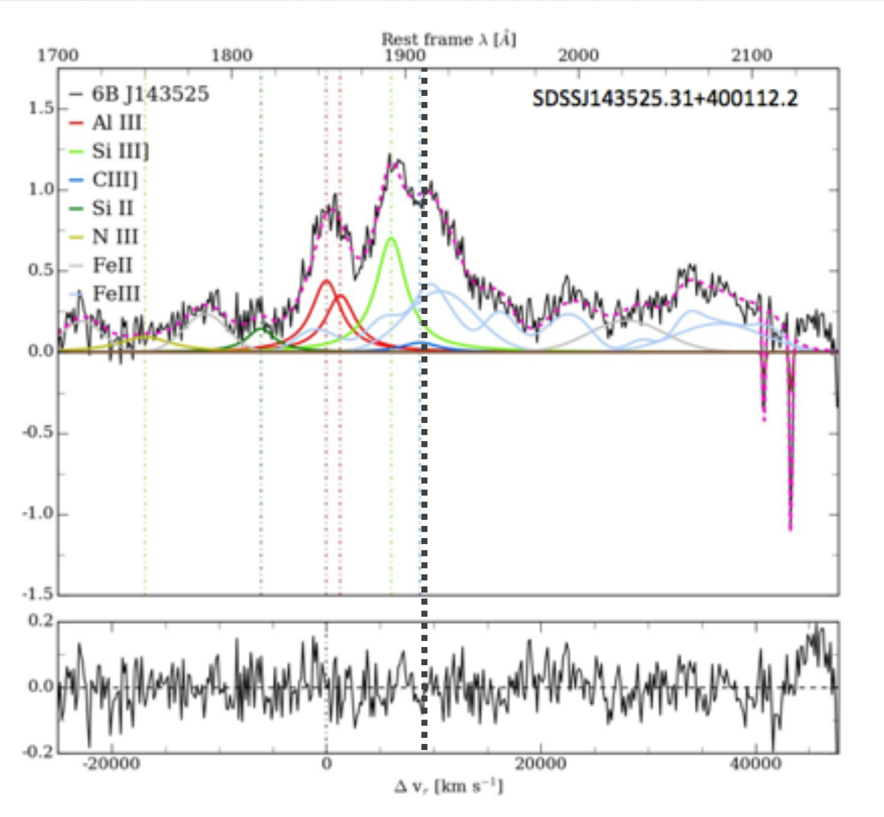


Negrete+ 17 in prep.

High z UV region

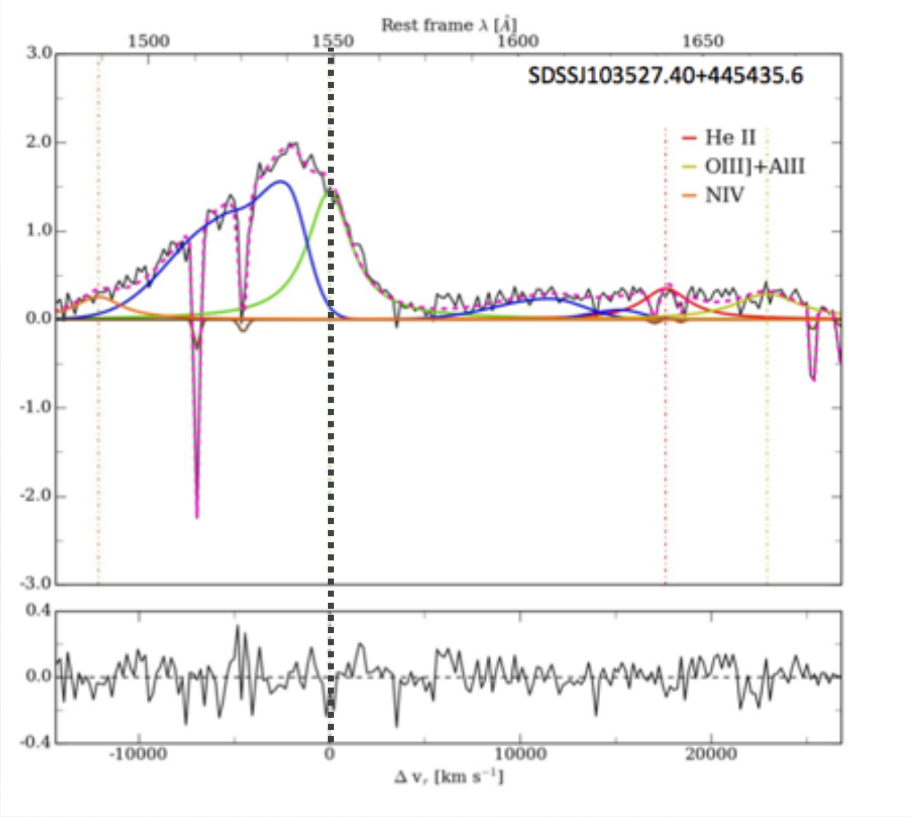
- λ1900 blend:

CIII]λ1909, SiIII]λ1892, AlIIIλ1860, SiIIλ1814, FeII, FeIII



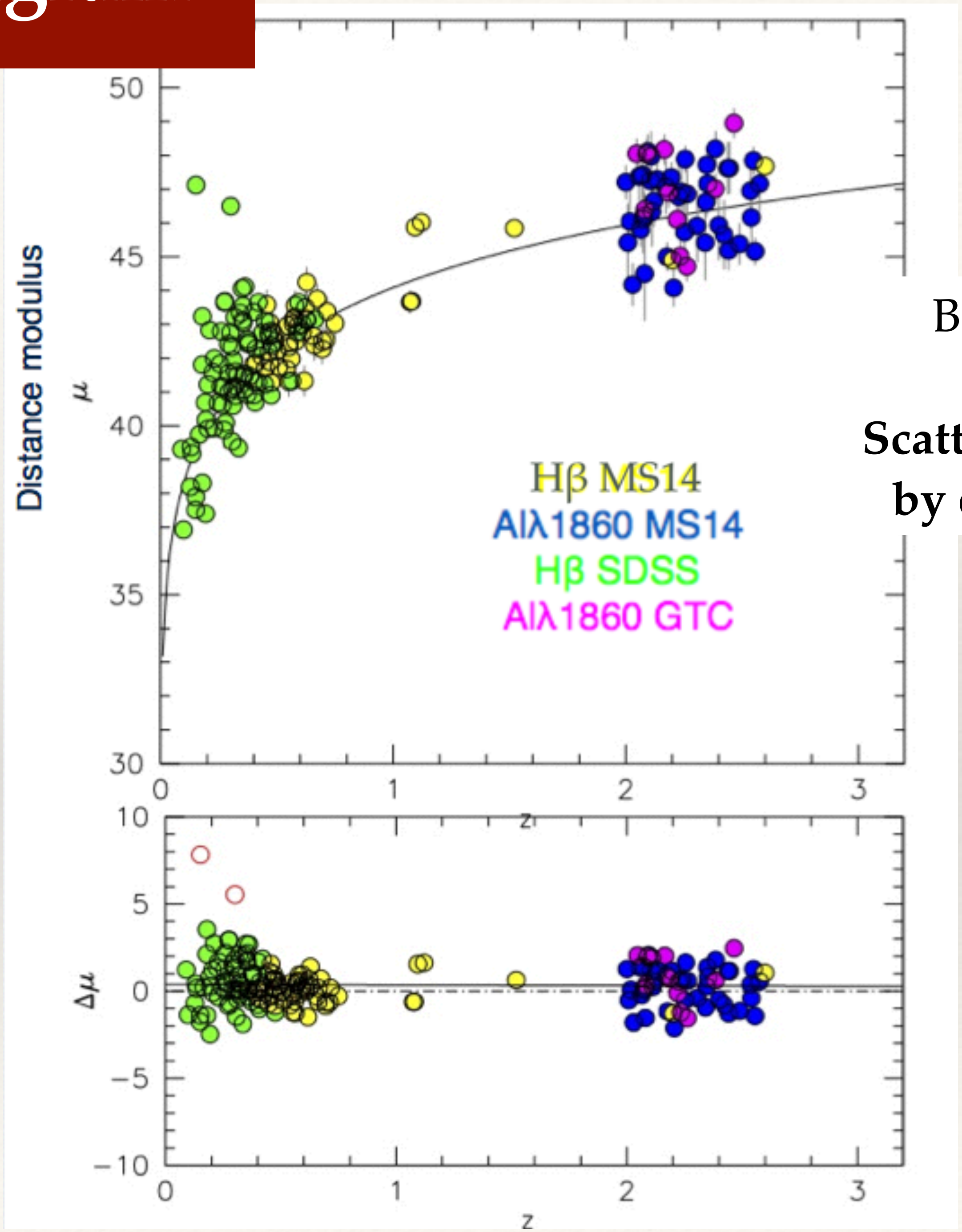
Martínez-Aldama+ 17 in prep.

- CIVλ1549



- SiIV+OIV]λ1400

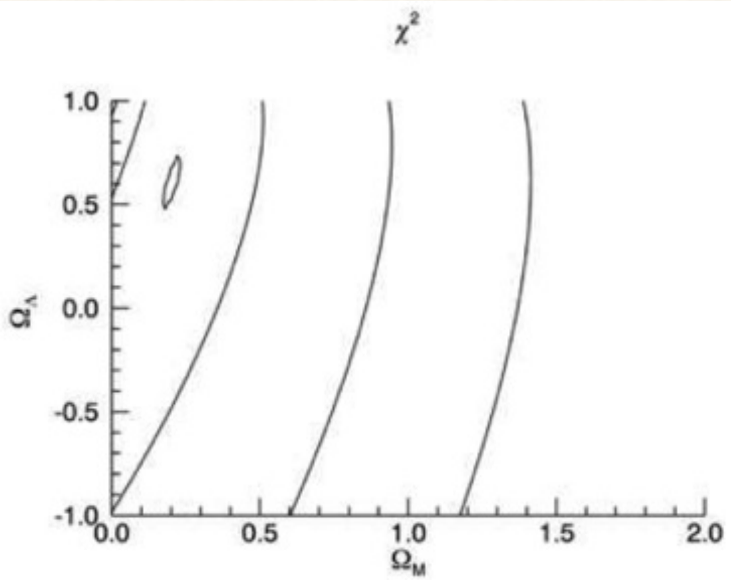
Hubble Diagram



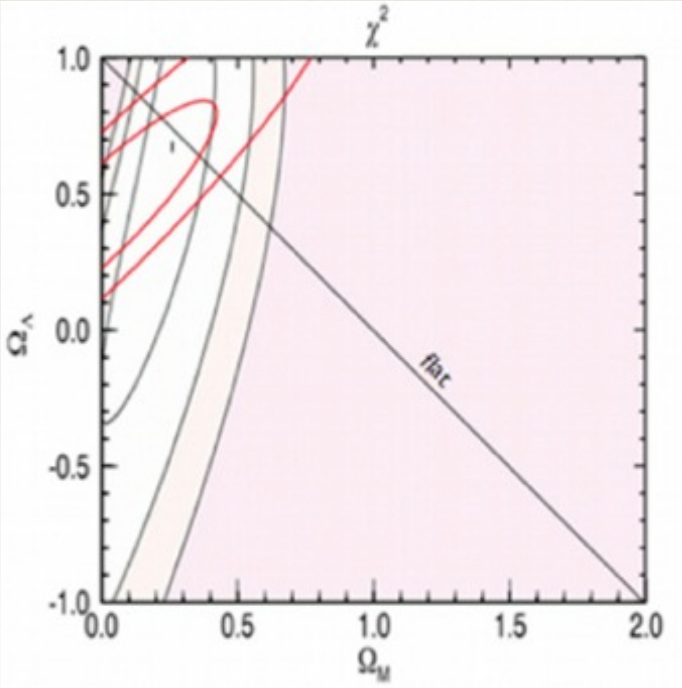
Broader Hb profiles

Scatter influenced by orientation?

- Constrains on Ω_M from the MS14 data. A better constrain on Ω_M is possible with a sample of xA, carefully selected.



- Comparison between **supernovae** photometric survey (Campbell+ 13) at 1 and 2 σ and the **mock sample** at 1, 2 and 3 σ (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~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 om y oL, with errors similar to the supernovae to much larger z.