OI and CaII observations in intermediate redshift quasars

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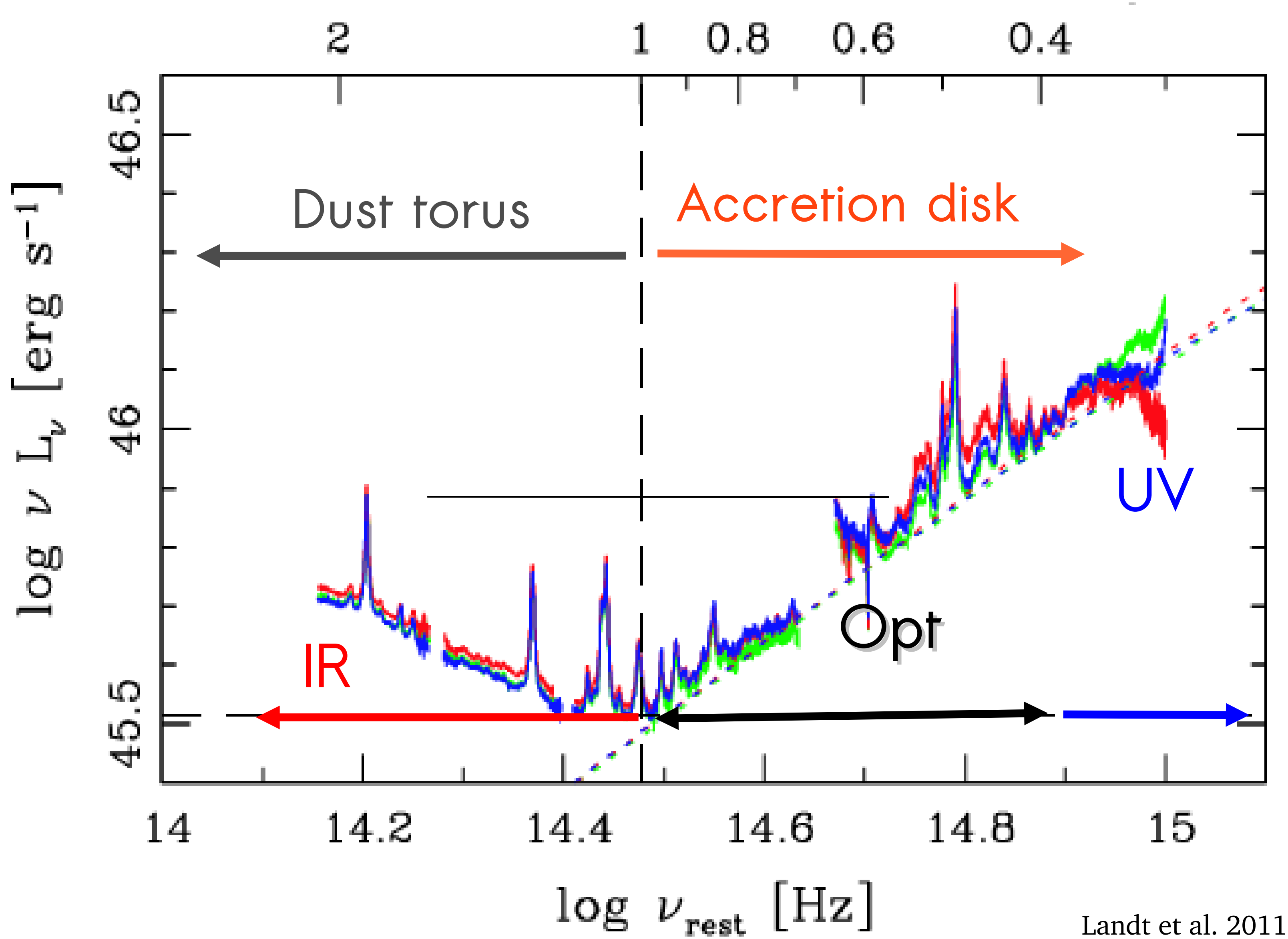
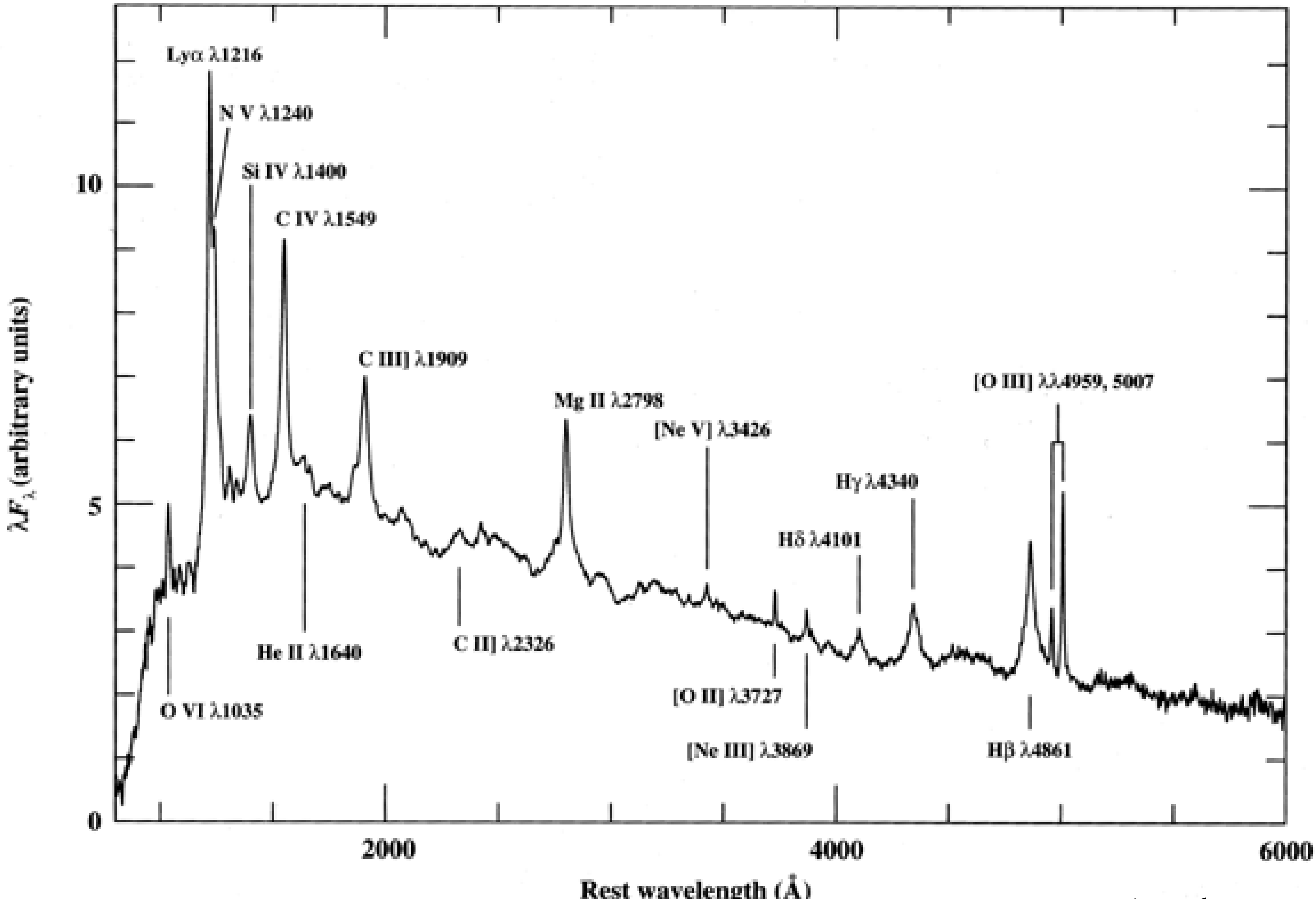
Guillermo Haro Workshop, 2015

What does a quasar spectrum say?



Landt et al. 2011

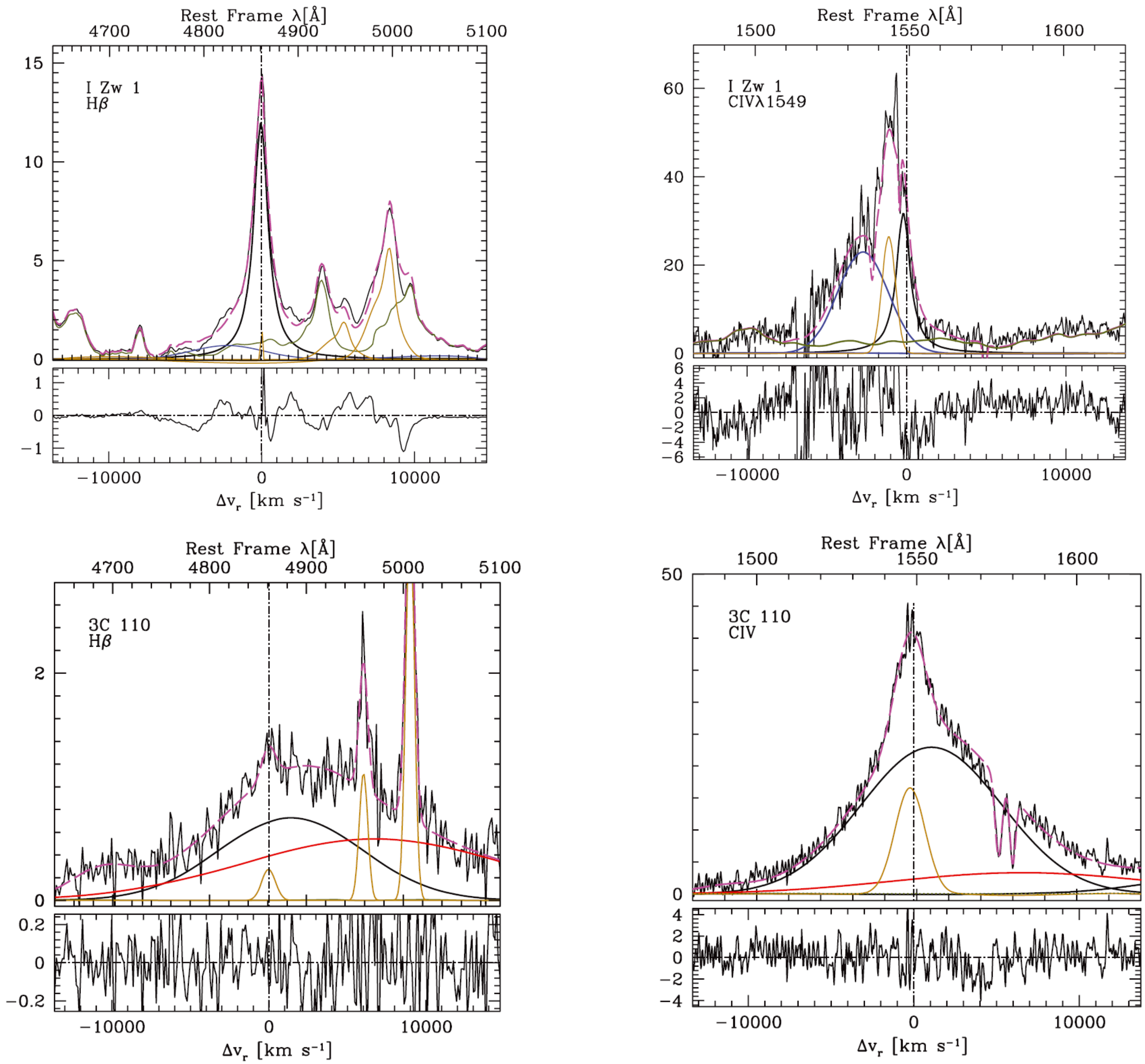
In a quasar spectra, we can observe different kind of lines which profiles change from object to object.



Francis et al. 1991

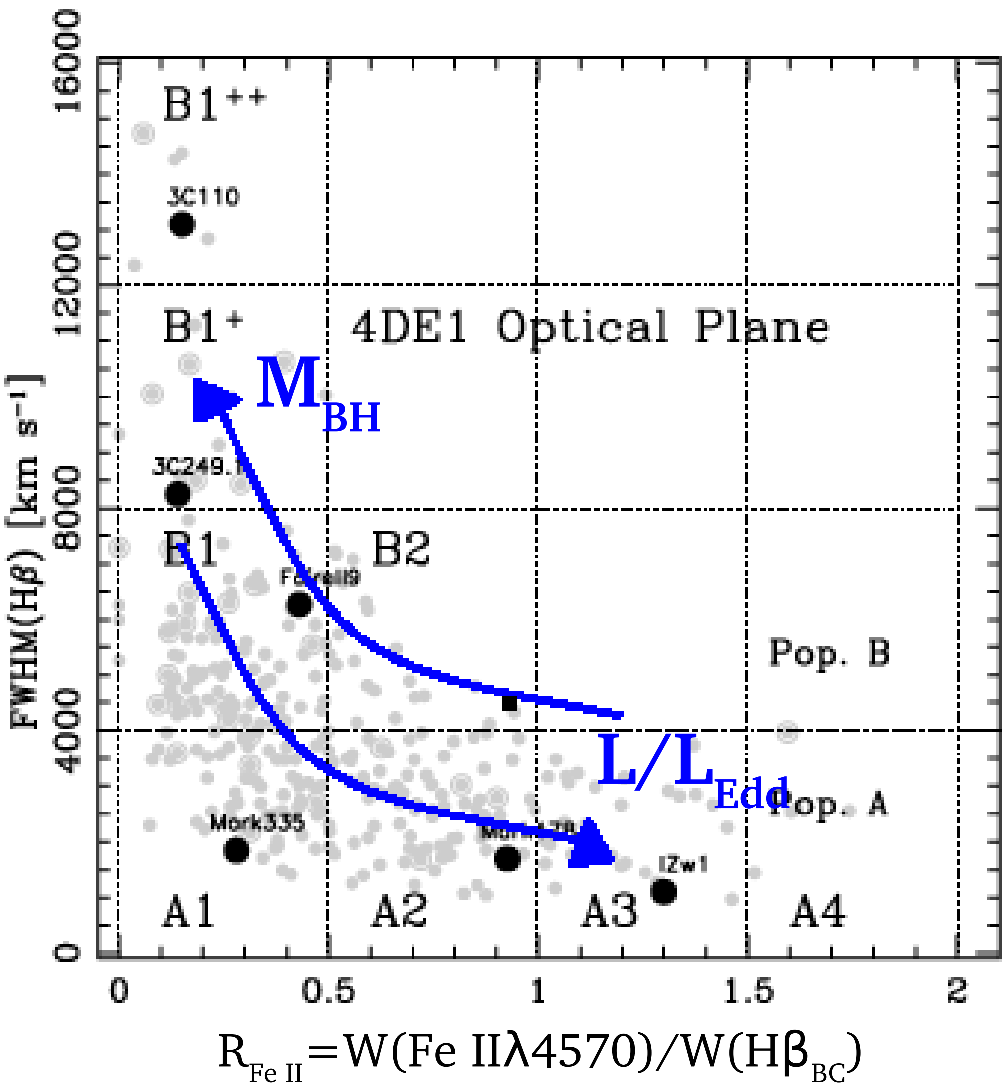
For example:

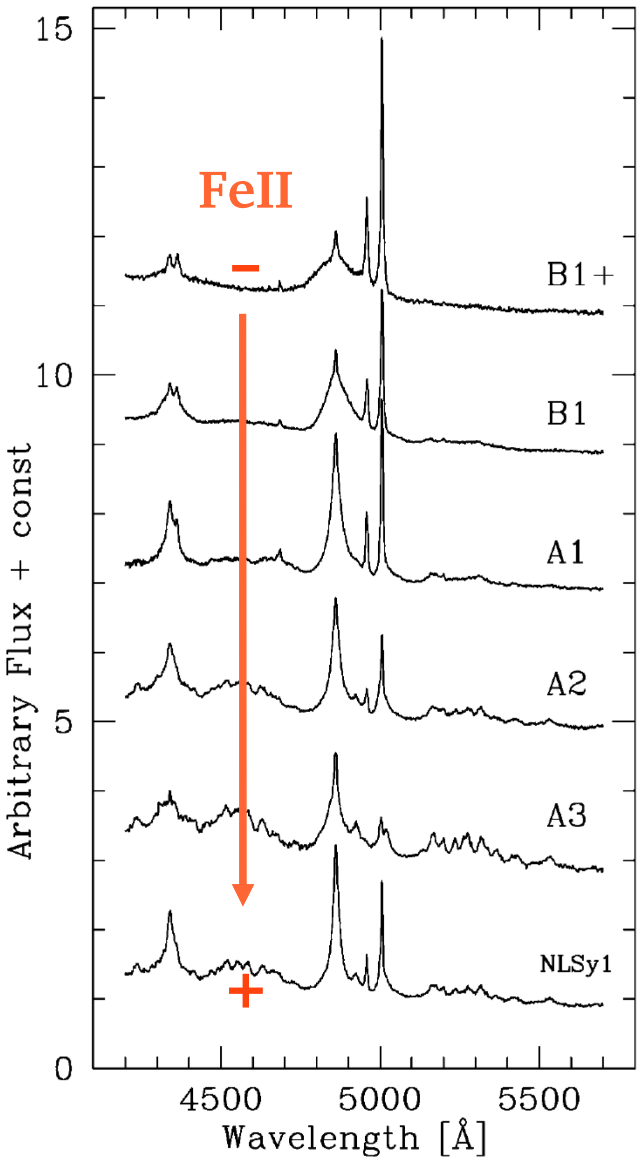
Hβ   C IV λ1549



Marziani et al. 2010

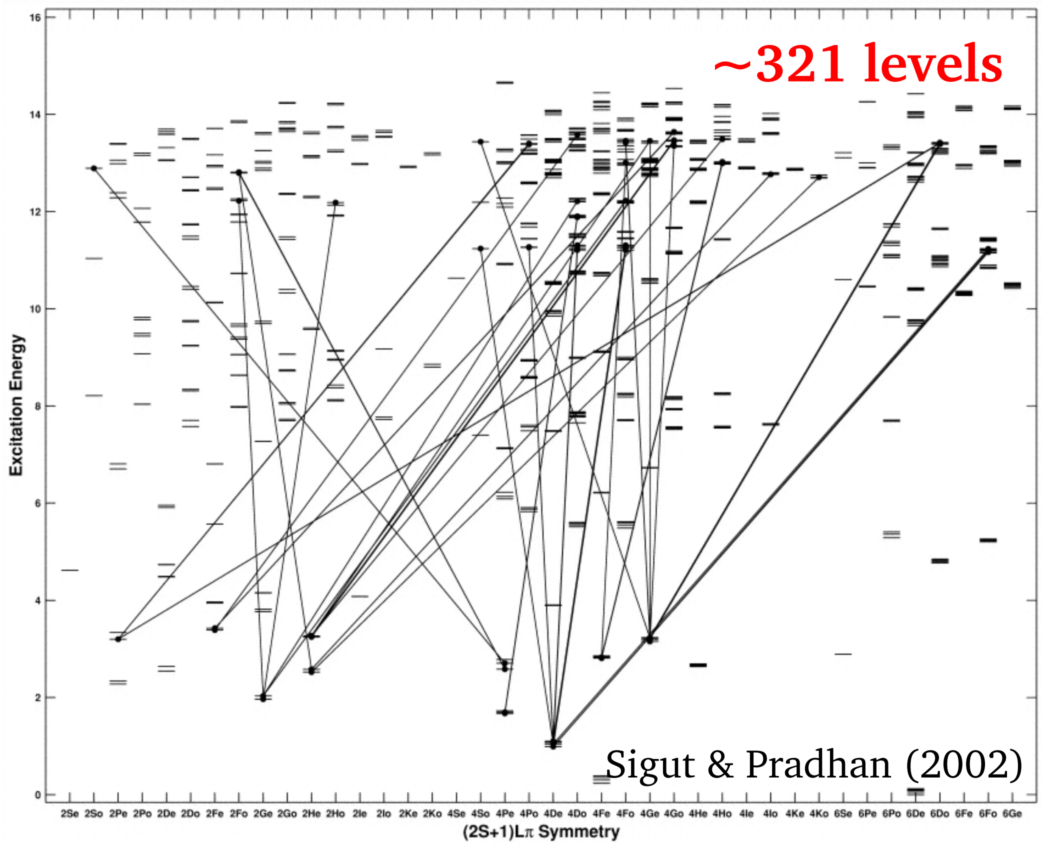
The **4D Eigenvector 1** offers an option to organize the properties observed at the AGNs type 1, where the FeII is one the most important parameters:





Marziani et al. 2010

FeII problem

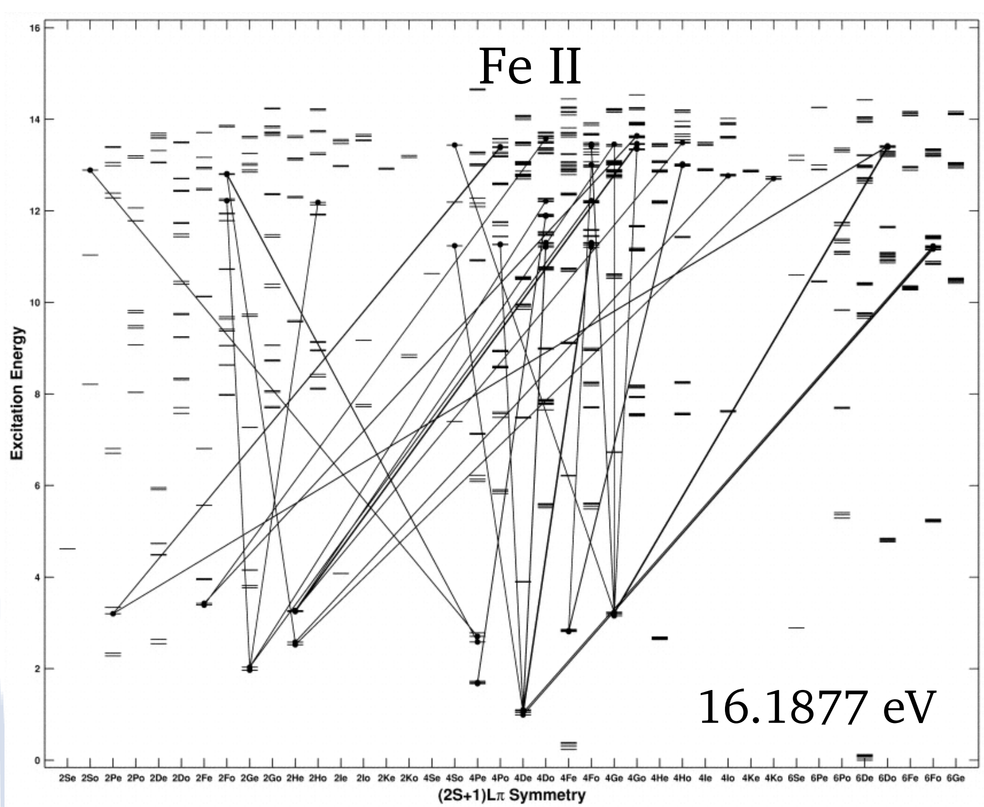


	Hβ	C IV	Fe II
T (°K)	10^4	$>10^4$	6000 - 8000
n_H (cm^{-3})	10^9	10^9	$>10^{11}$
N_H (cm^{-2})	10^{23}	10^{21-23}	10^{23-25}

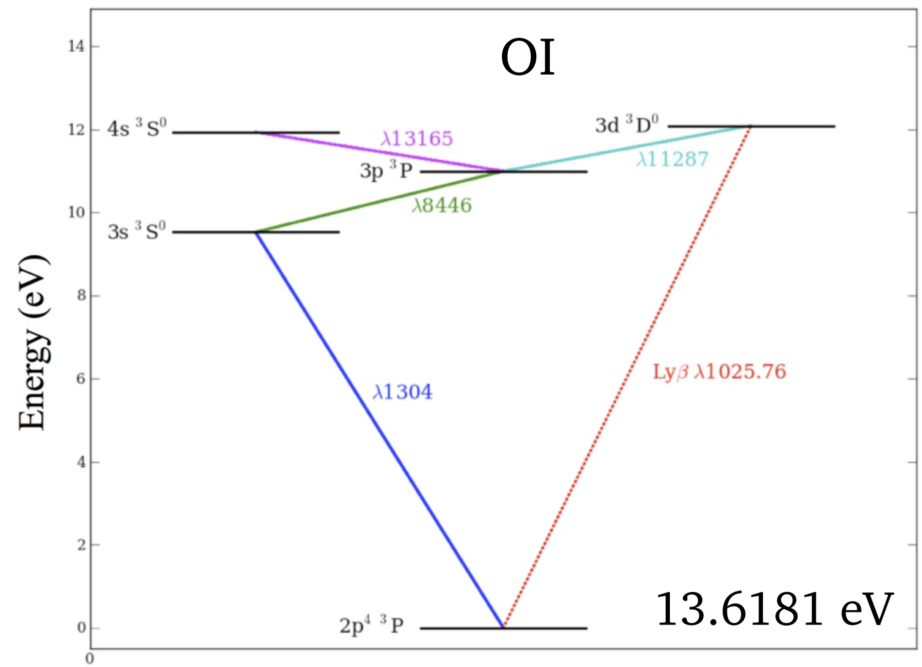
→ **The border of the accretion disk**

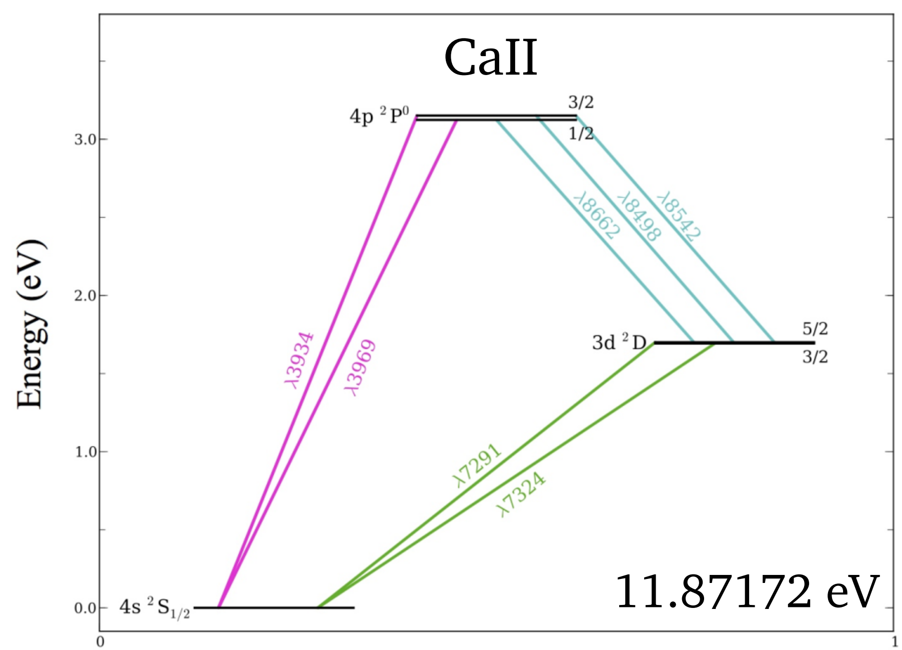
(Collin-Souffrin, 1979, 1980, 1987; Wills et al. 1985; Rodríguez-Ardila et al, 2002a,b; Sigut & Pradhan, 2002)

FeII has a complexity electronic structure, so we need easy ions to model the physical conditions in where the ion is emitted: CaII and OI.



Sigut & Pradhan (2002)





Previous works

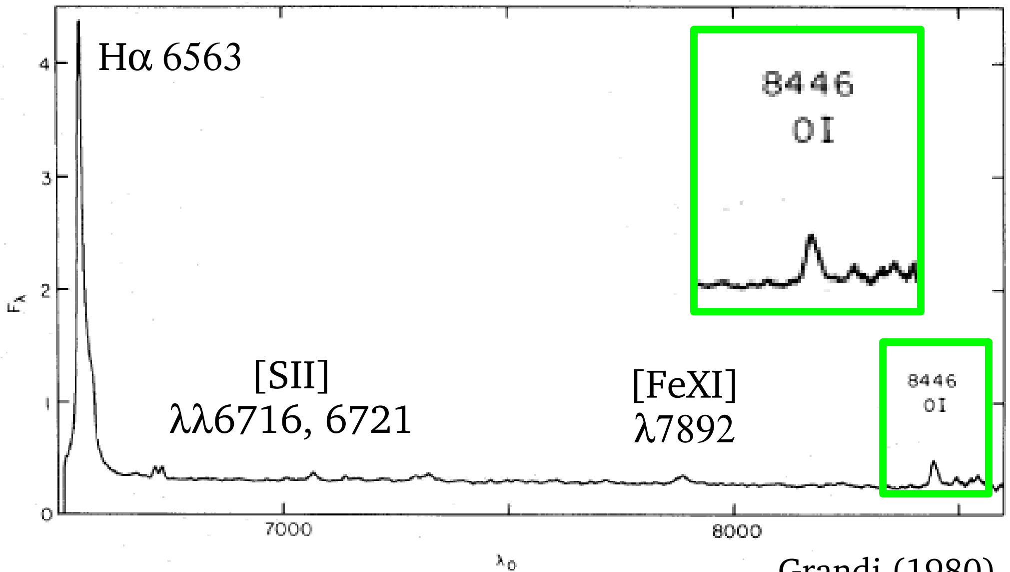
There are 5 theoretical and 4 observational works about the OI 8446 and the CaII IR triplet.

OI λ8446

- Grandi (1980)
  - 13 Sy1
  - z~0.1
  - OI only is emitted by the BLR

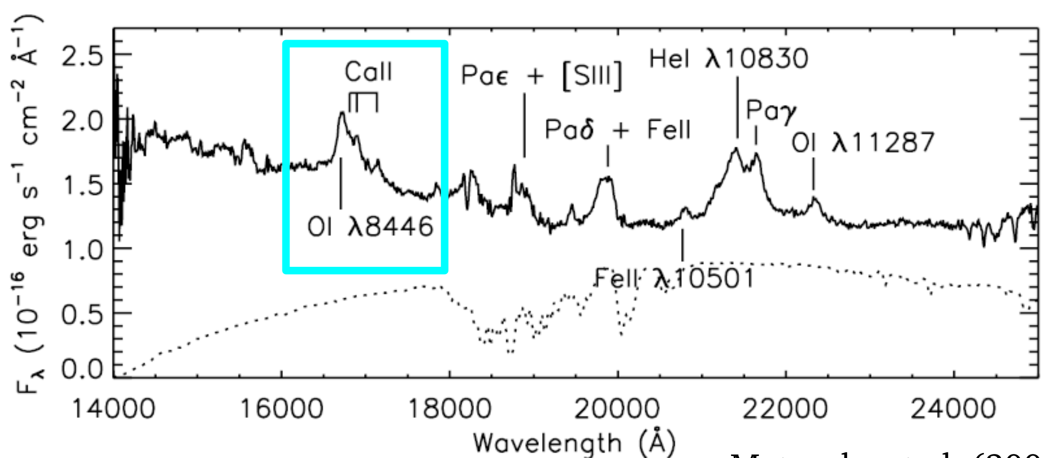
- Matsuoka et al. (2007, 2008)
  - 14 AGN (only one with z~1)
  - $n_H \sim 10^{11.5}$ cm^{-3}, U~$10^{-2.5}$

Ark 564, z=0.024



Grandi (1980)

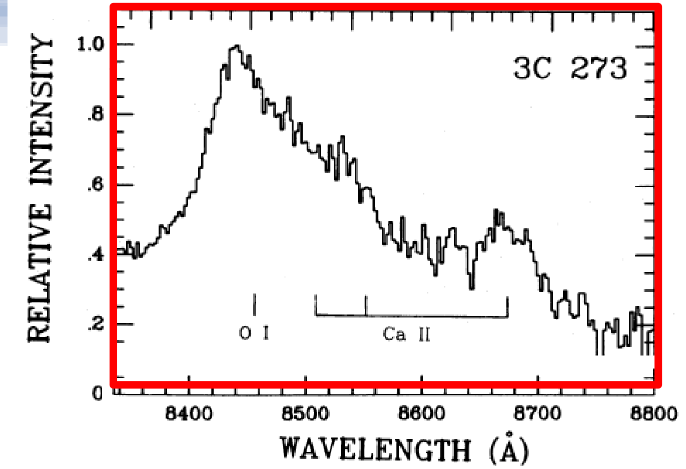
PG 1148+549, z=0.975



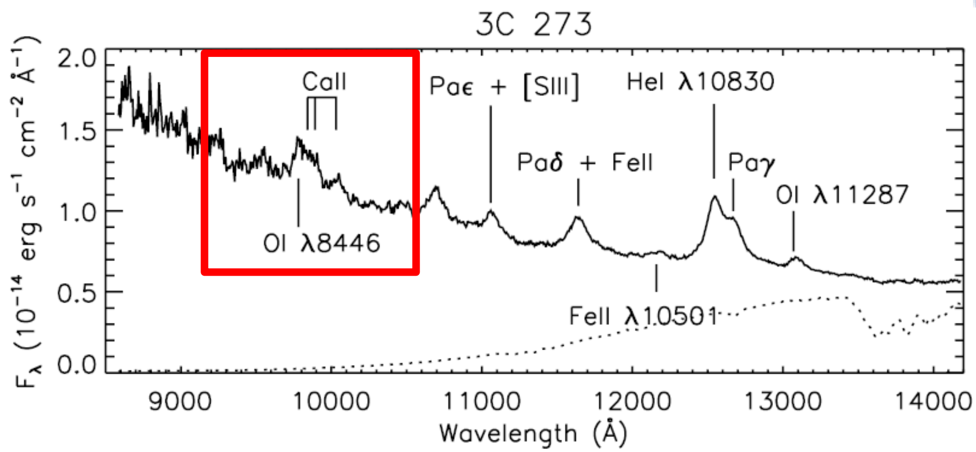
Matsouka et al. (2007)

Triplete de CaII λ8498, λ8542, λ8662

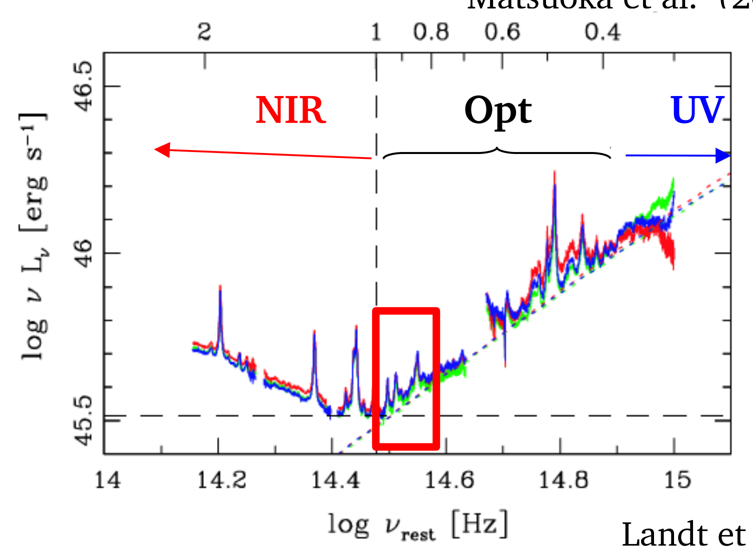
- Persson (1988)
  - 40 AGNs
  - z«1
  - CaII and OI are emitted at the same distance
- Joly (1989)
  - The physical conditions needed for CaII and FeII emission are the same.
- Ferland & Persson
  - CaII requires a shielded region, $N_C > 10^{25}$ cm^{-2}
- Dultzin et al. 1999
  - CaII and FeII intensities decrease as Hβ intensity increases.



Persson (1988)



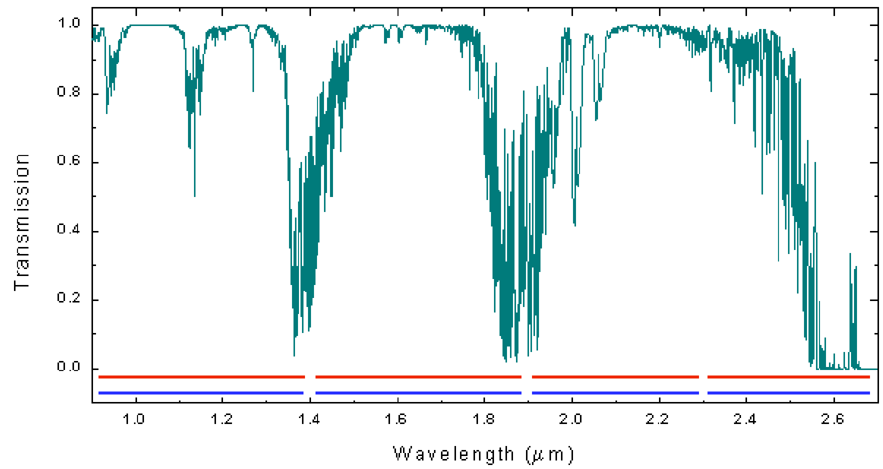
Matsuoka et al. (2007)



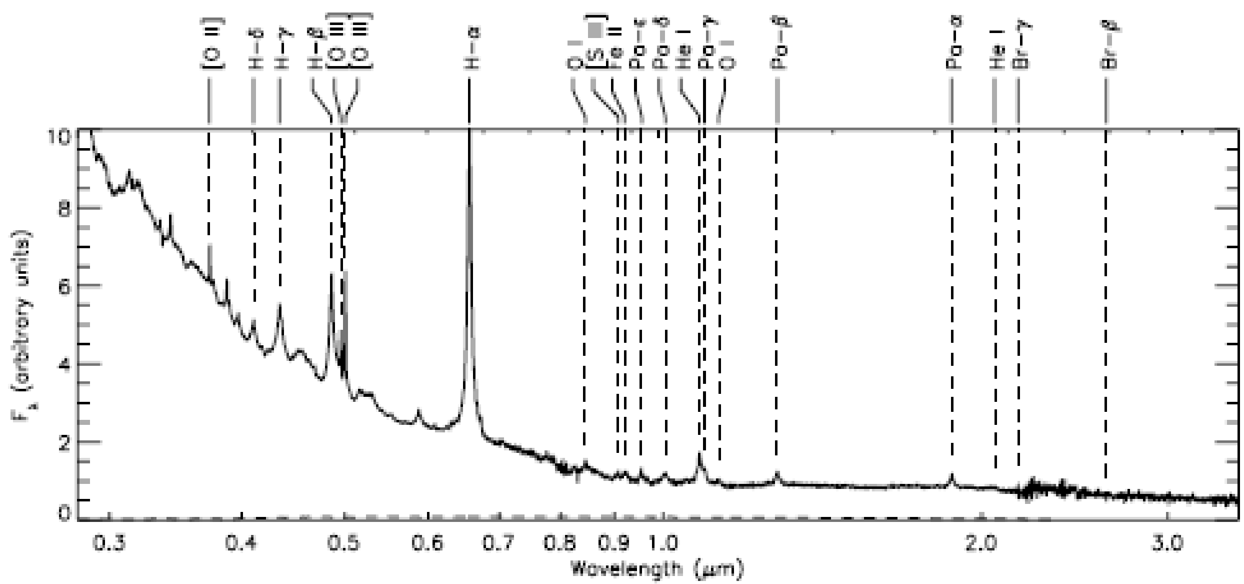
Landt et al. 2011

The NIR is very a **difficult region to observe**:

- The spectrum is contaminated by atmospheric telluric bands

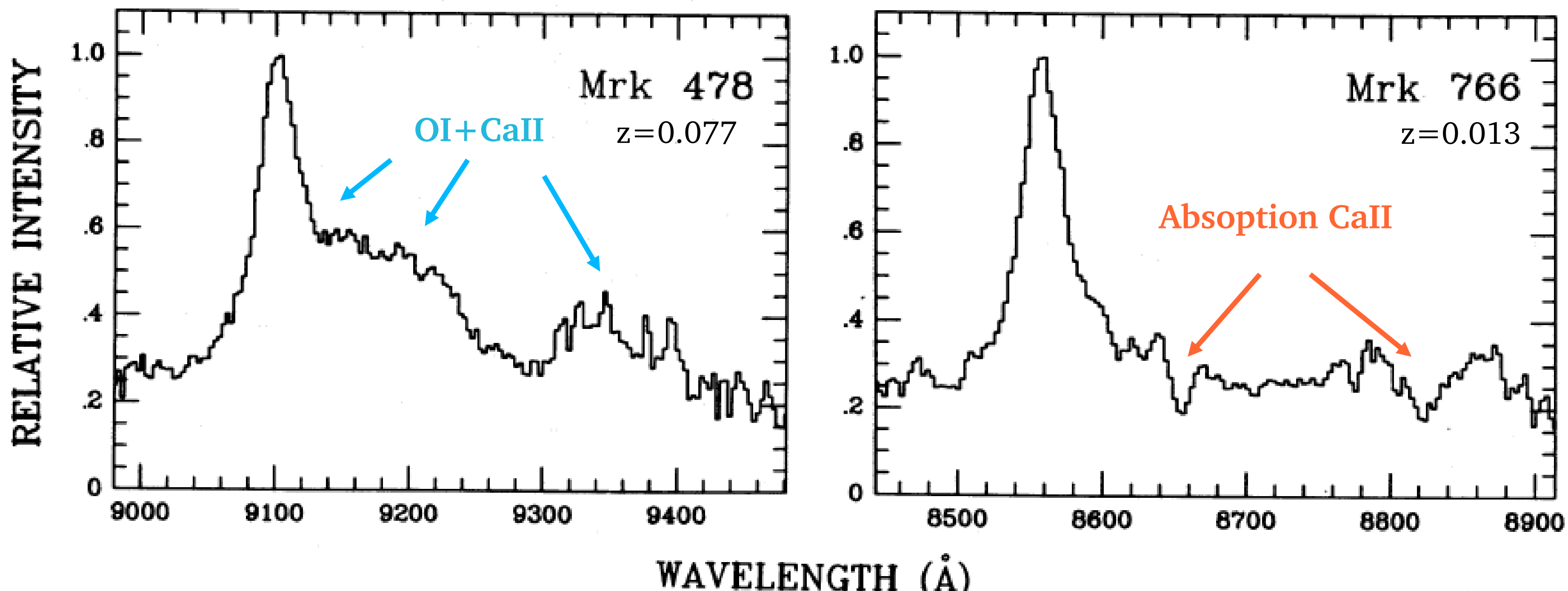


- OI and CaII show small equivalent widths, W~10-20 Å



Glikman (2006)

- In some sources, the emission lines are totally blended
- In some cases the host galaxy contribution is presented.



Persson (1988)

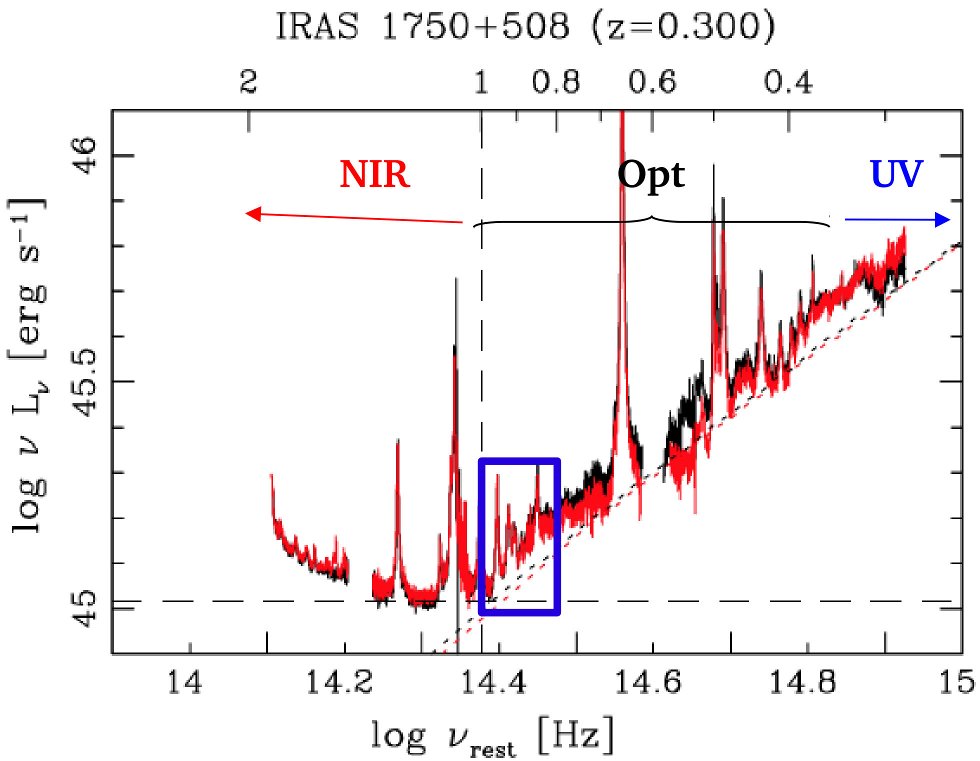
- ISAAC for many time was one of the few instruments available for moderate-resolution IR spectroscopy of **faint sources** like high-z quasars.

Also, the continum could be affected by other components:

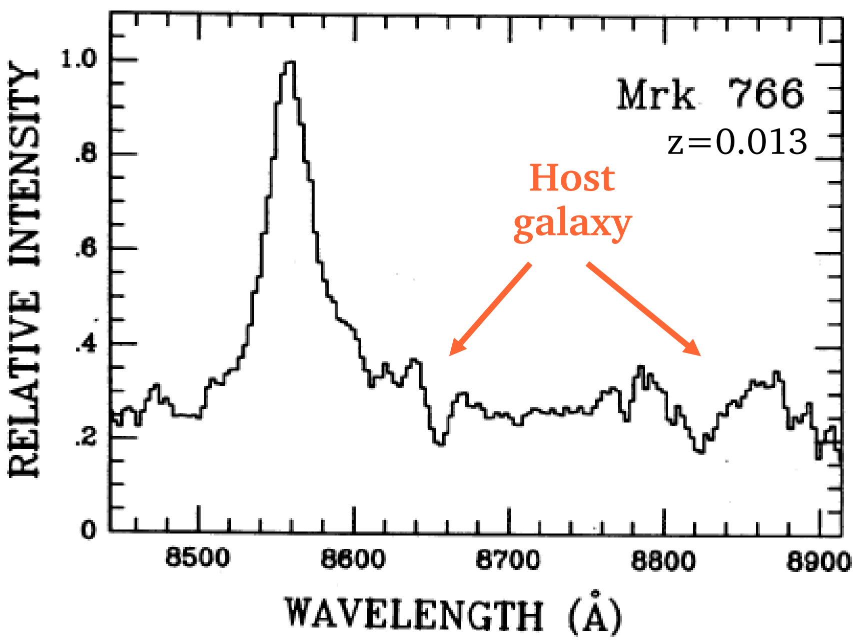
1) Accretion disk (---)

2) Hot dust torus, λ >1 μm

3) Host galaxy contribution



Landt et al. (2011)



A new sample of CaII+OI in quasar at intermediate redshift

With the objective to extend the samples previously analyzed, we observed 15 high luminous quasars at intermediate redshift, using the VLT-ISAAC (Martínez-Aldama et al. 2015).

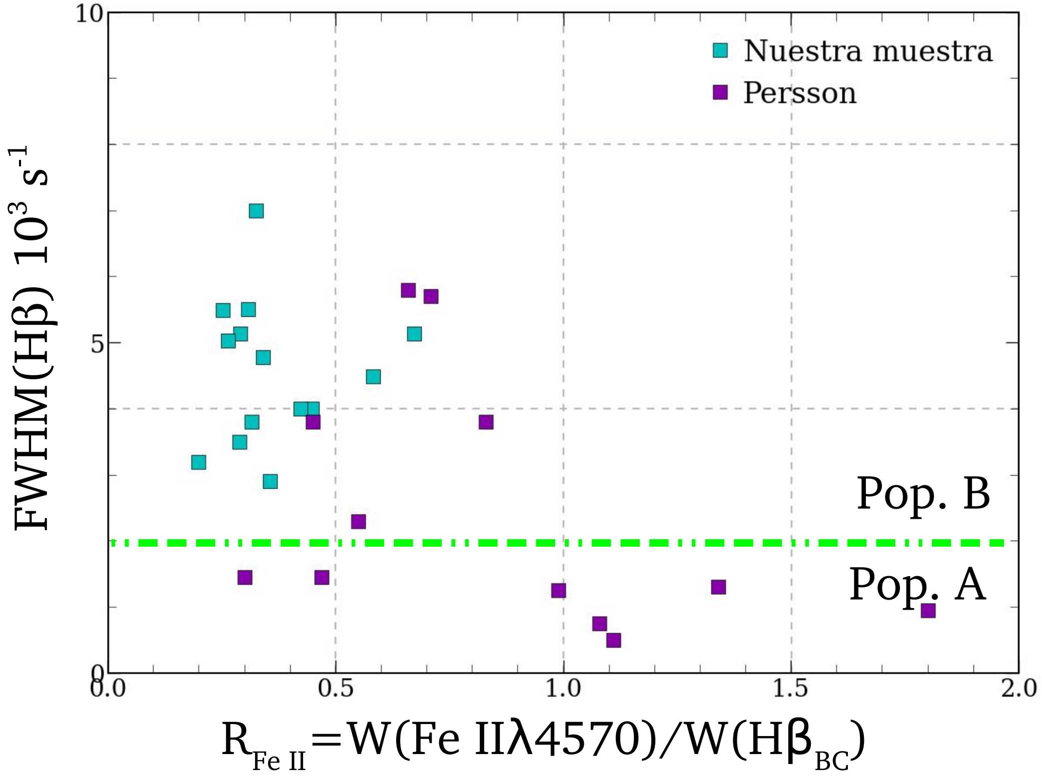
Object	z	m_B	M_B	Population	Date	Band	Seeing	S/N
HE0005–2355	1.4120	16.9	–27.6	B1	07/30/10	*K*	1.054	20
HE0035–2853	1.6377	17.0	–28.1	B2	07/27/10	*K*	0.840	55
HE0043–2300	1.5402	17.1	–27.9	A1	07/07/10	*K*	1.078	45
HE0048–2804	0.8467	17.3	–26.0	B1	07/27/10	*H*	0.863	35
HE0058–3231	1.5821	17.1	–27.9	B1	07/27/10	*K*	0.759	10
HE0203–4627	1.4381	17.3	–27.5	B1	07/02/10	*K*	1.184	25
HE0248–3628	1.5355	16.6	–28.2	A1	07/22/10	*K*	0.965	50
HE1349+0007	1.4442	16.8	–28.0	B1	04/15/10	*K*	0.749	20
HE1409+0101	1.6497	16.9	–28.3	B1	04/15/10	*K*	0.775	25
HE2147–3212	1.5432	16.8	–28.2	B2	06/12/10	*K*	0.847	20
HE2202–2557	1.5347	16.7	–28.1	B1	07/23/10	*K*	0.606	40
HE2259–5524	0.8549	17.1	–26.1	A2	05/25/10	*H*	1.863	10
HE2340–4443	0.9216	17.1	–26.3	A1	07/23/10	*H*	0.568	25
HE2349–3800	1.6040	17.5	–27.4	B1	06/12/10	*K*	0.789	20
HE2352–4010	1.5799	16.1	–28.8	A1	07/23/10	*K*	0.639	35

The NIR sample is complemented with the optical spectra observed with the same instruments (Sulentic et al. 2004, Marziani et al. 2009)

Sample selection

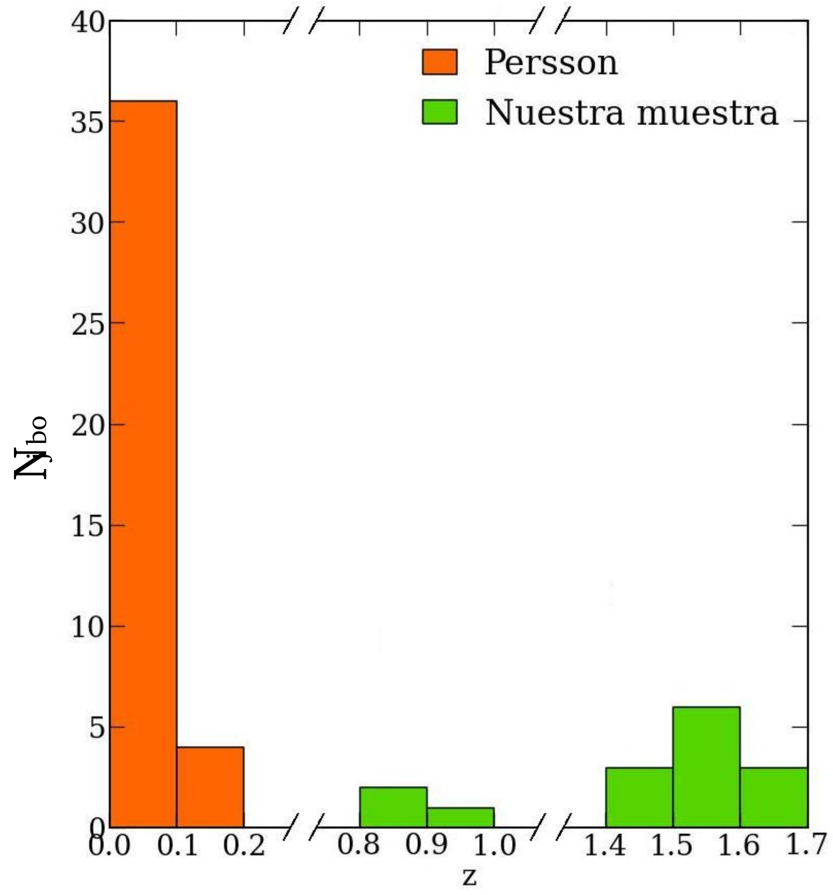
1er spectroscopic sample for QSO at $z \sim 1.5$

- High luminosity: $-26 \geq M_V \geq -29$
- Intermediate redshift: $0.854 < z < 1.649$
- IR atmospheric absorptions do not affect the Ca II and O I lines.



Persson sample

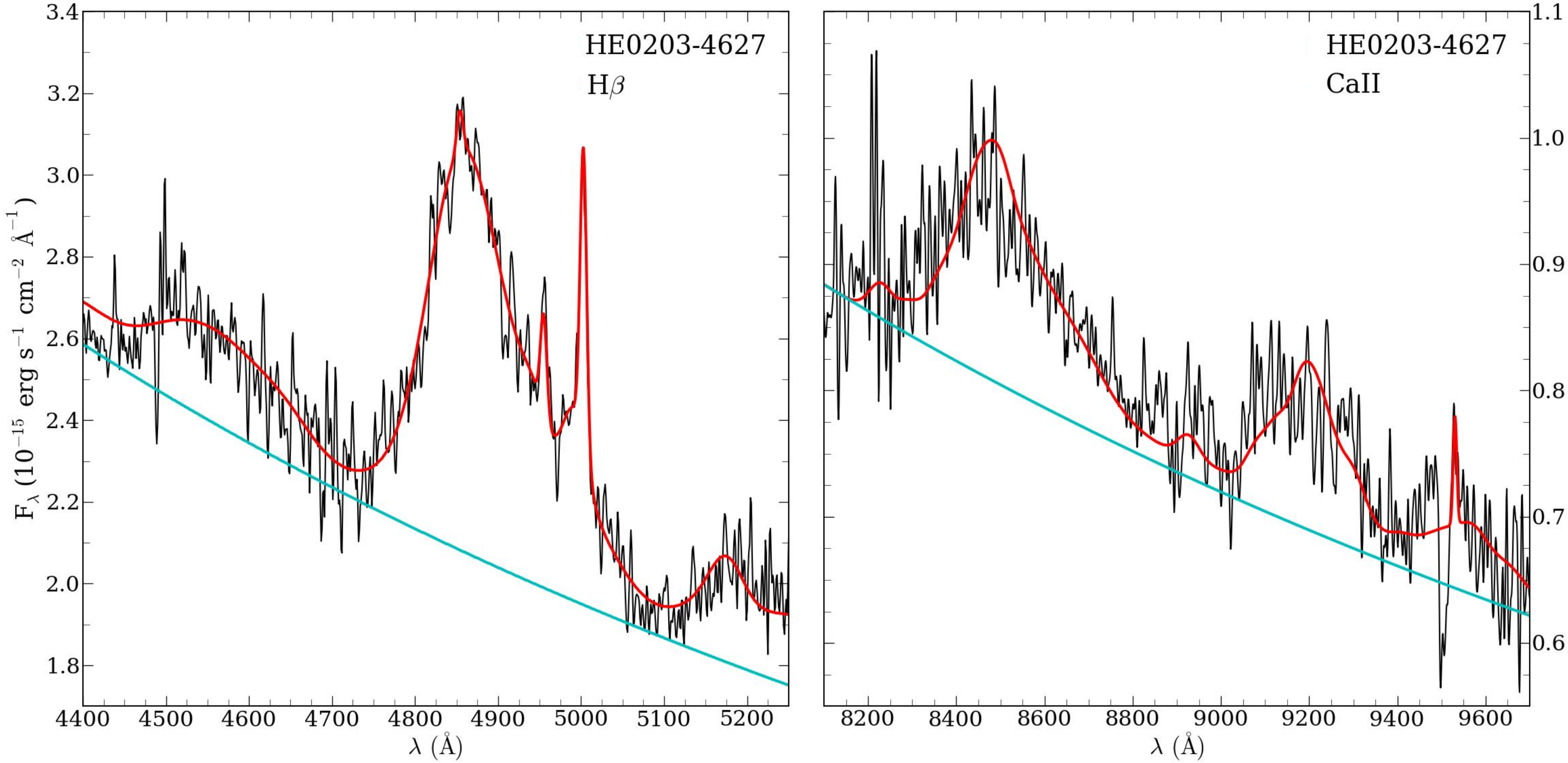
- Low luminosity
- Low redshift: $0<z<0.2$
- High FeII contribution, then high CaII contribution



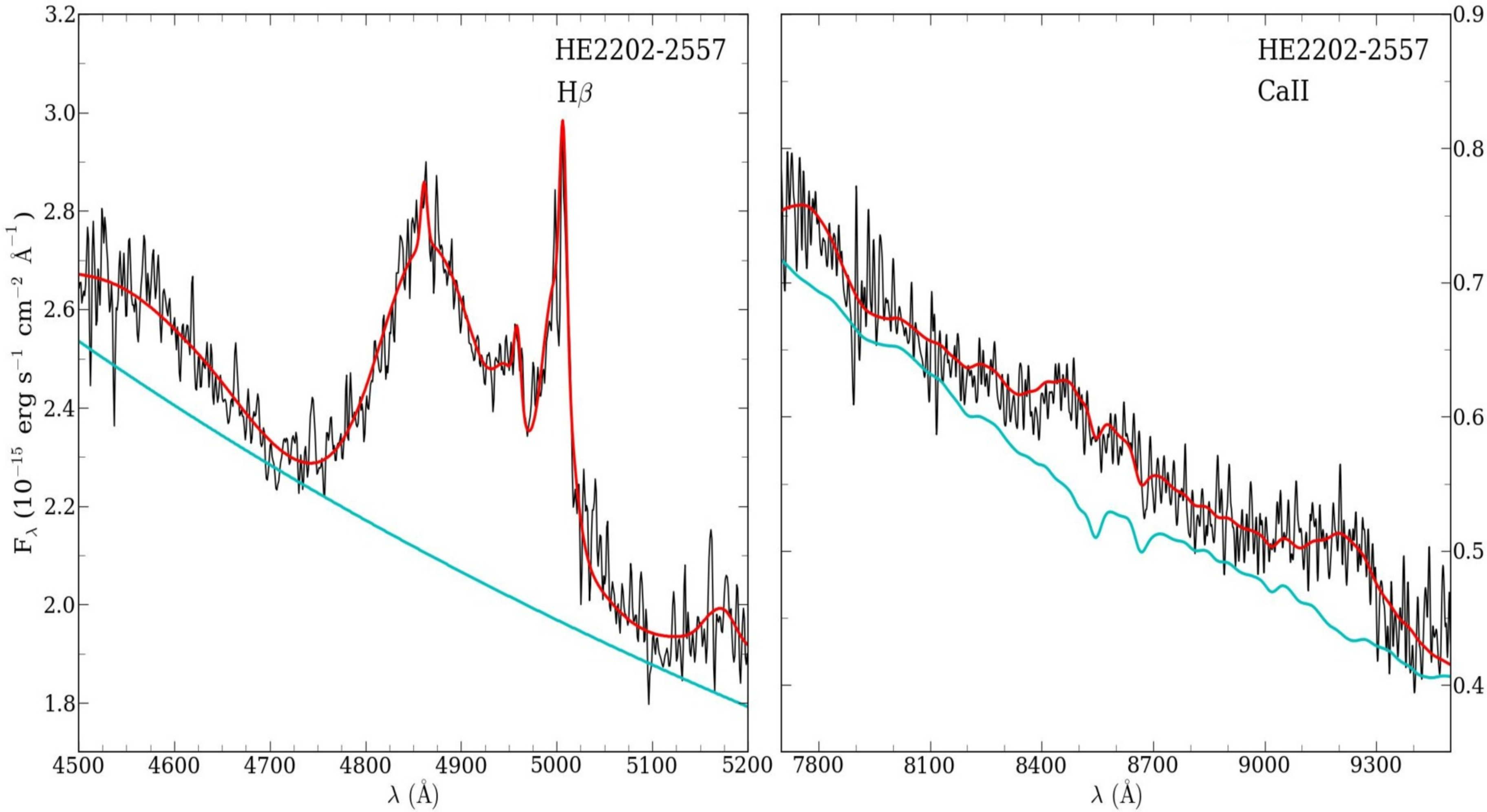
* * Fits * *

1) Continuum fitting

- ✓ Acretion disk (**local continuum**)
- ✓ Host galaxy .
- ✘ Dust torus, λ>1 μm



We could detect only one source with host galaxy contribution, ~50%. New SSP models were done by Yang Chen & Alessandro Bressan (in prep.)



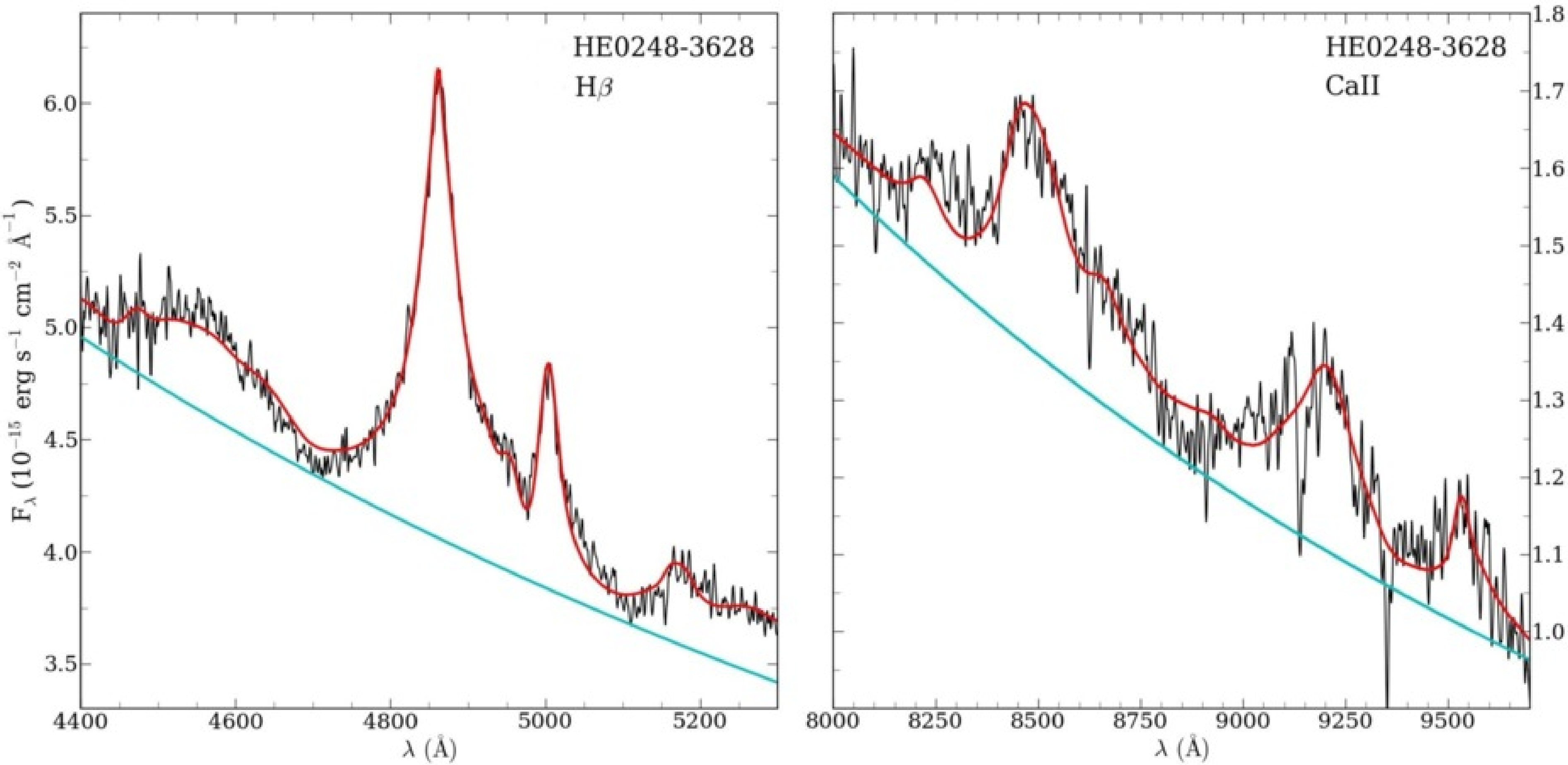
M_{host} = 1.13×10^{12} M_o

t_{host} = 2.4 Gyr

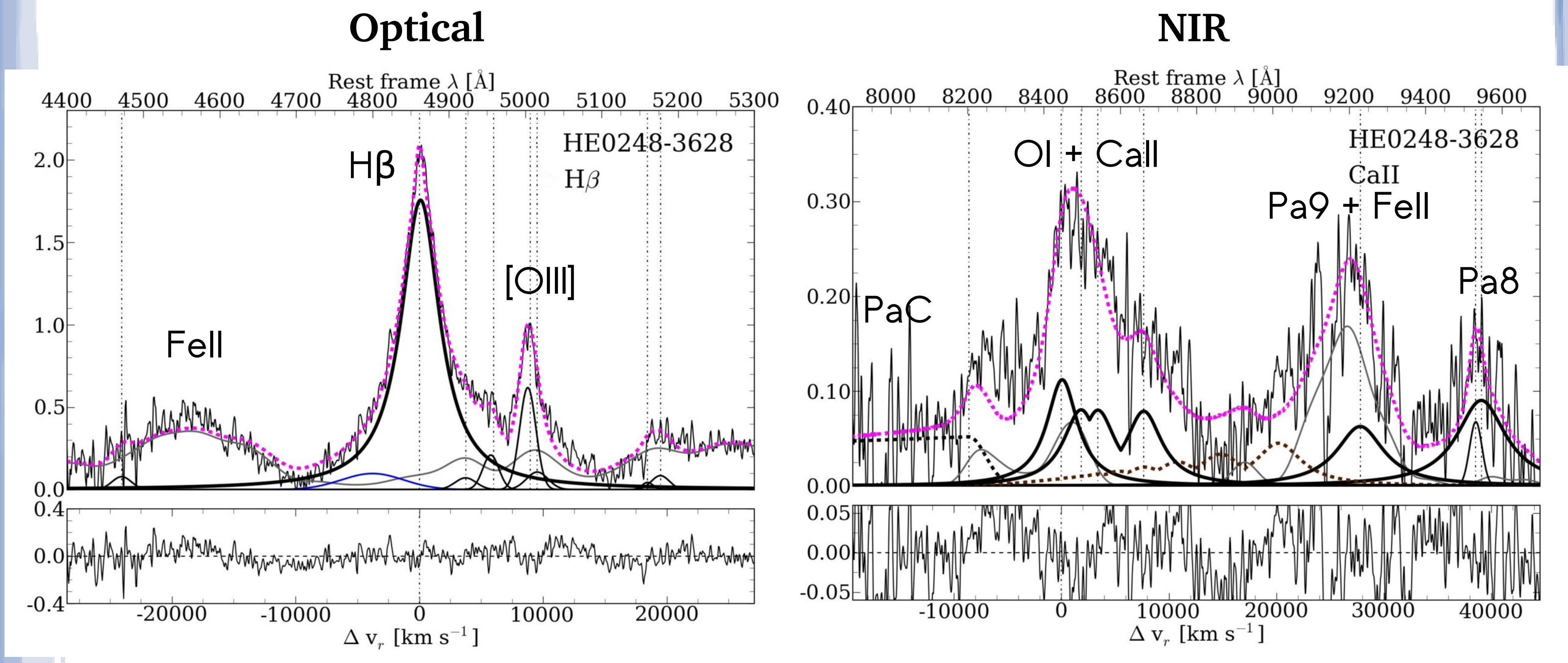
Z = $2Z_o$

Multicomponent fits

Pop. A



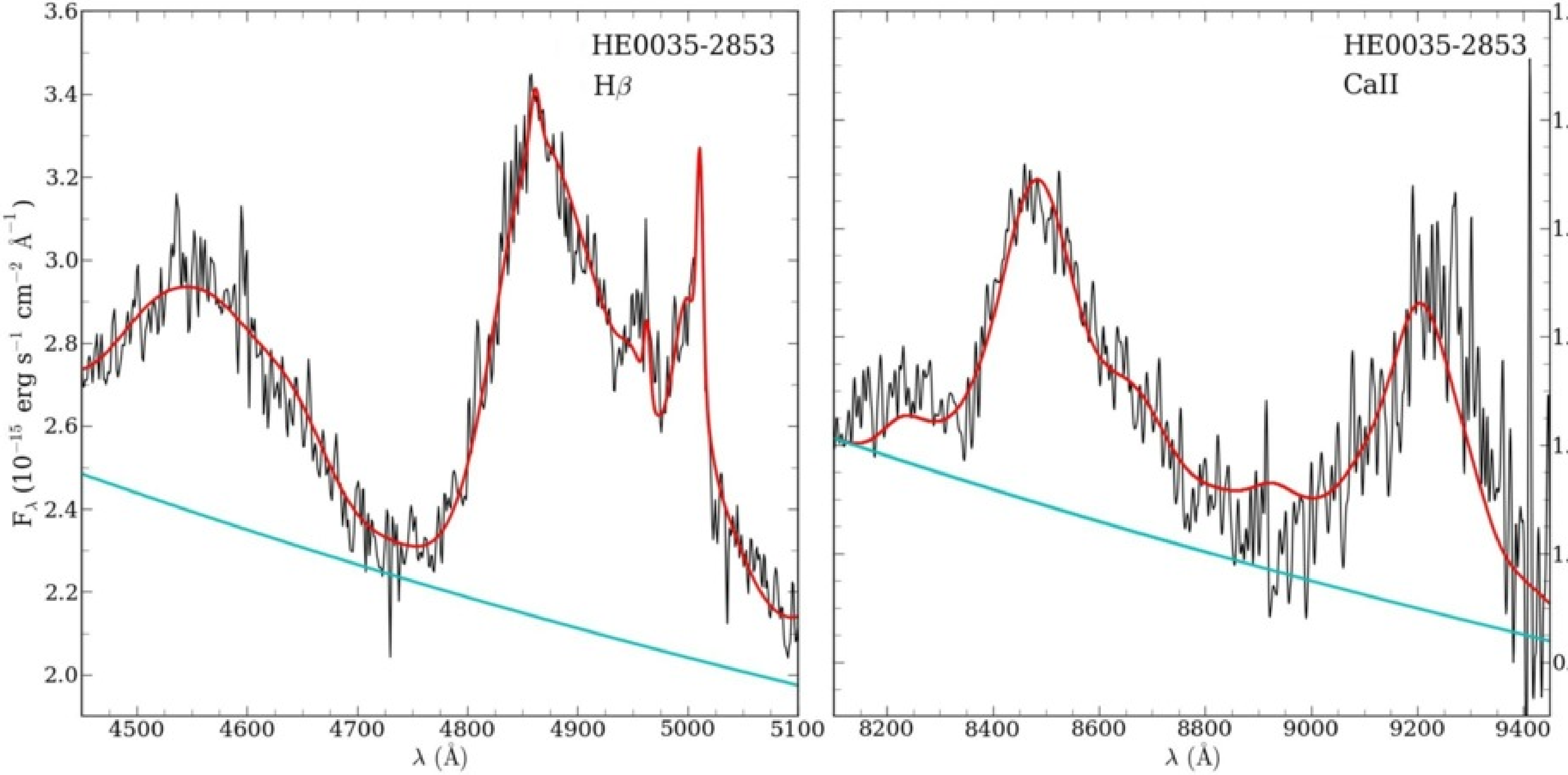
Pop. A



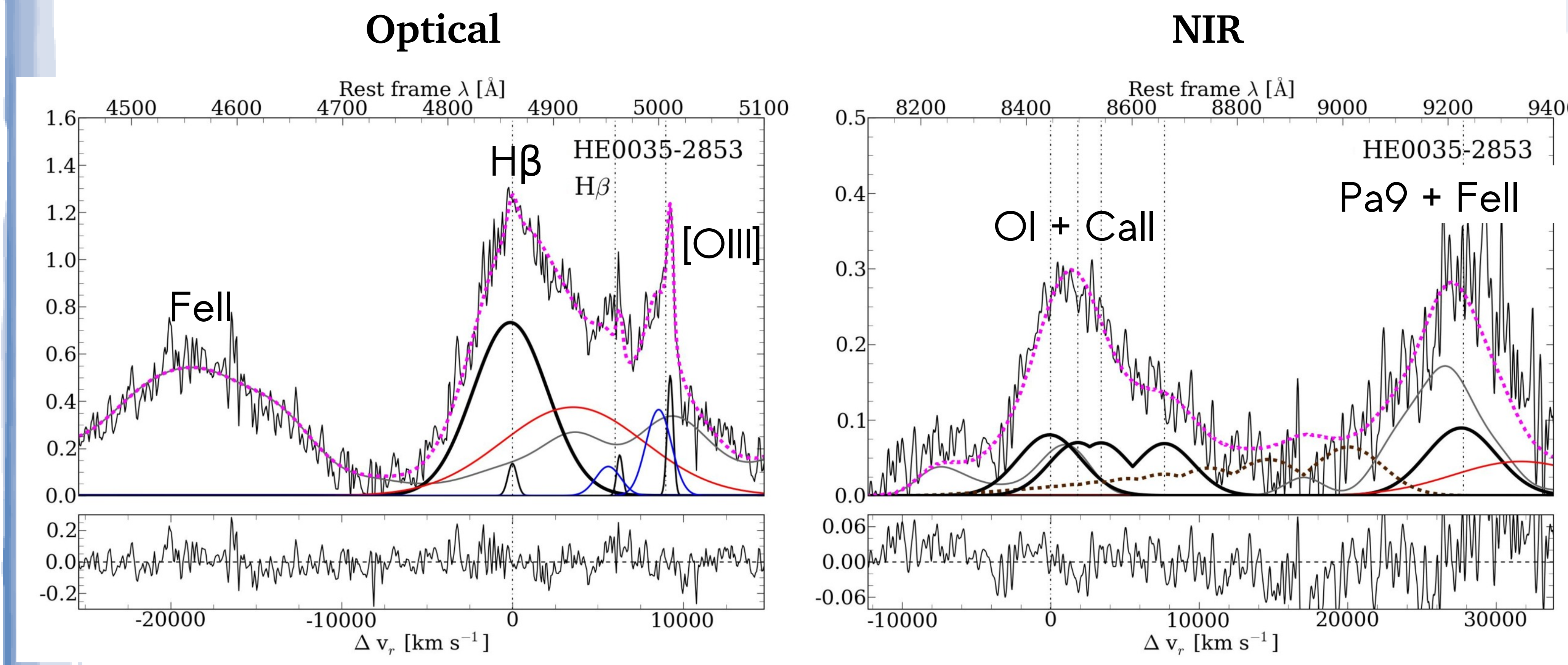
NIR FeII template (García-Rissmann et al. 2012)

High order Paschen Lines

Pop. B

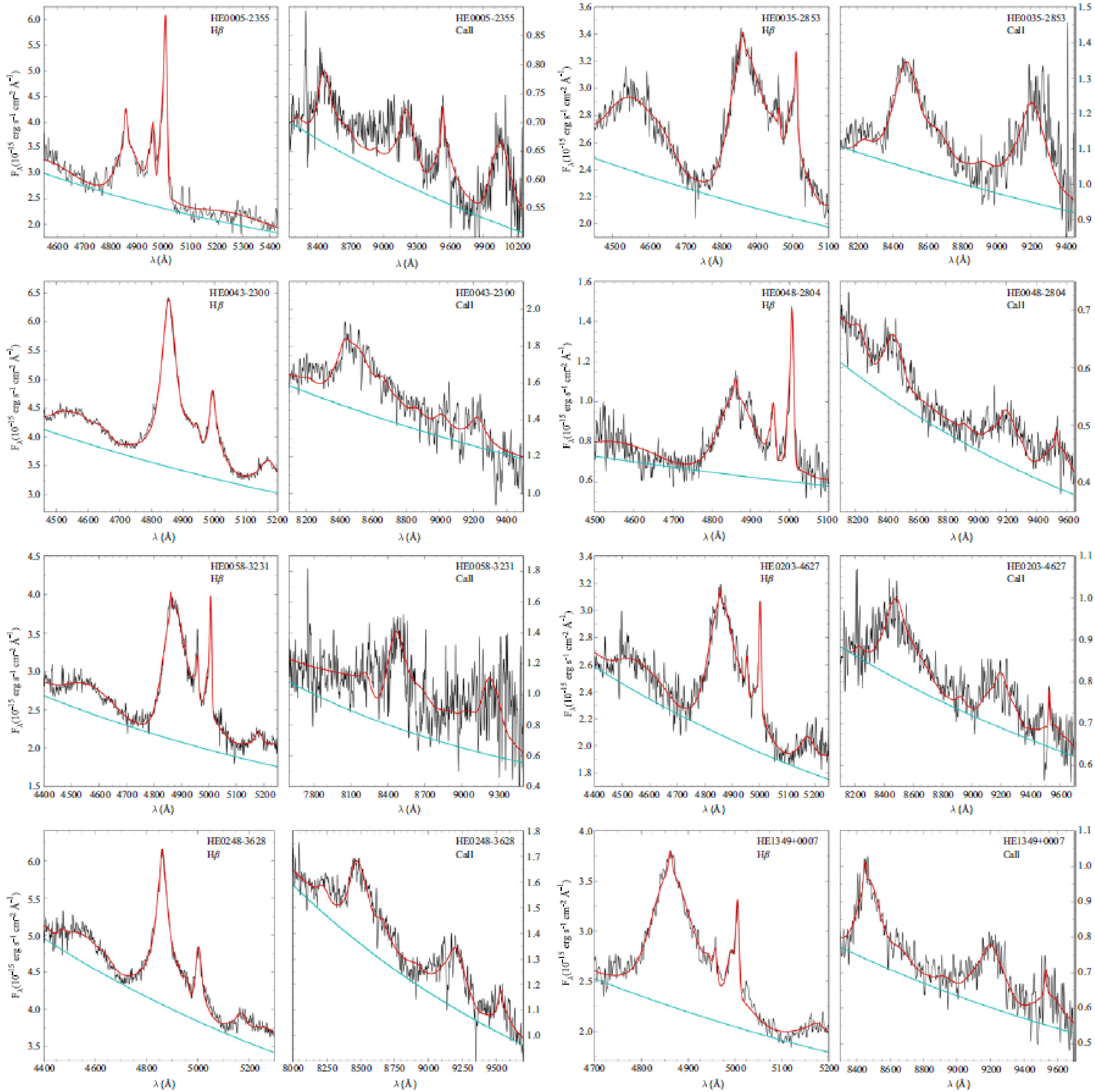

HE0035-2853
Hβ
HE0035-2853
CaII
F_λ (10^{-15} erg s^{-1} cm^{-2} Å^{-1})
λ (Å)
λ (Å)
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
4500
4600
4700
4800
4900
5000
5100
8200
8400
8600
8800
9000
9200
9400
1.5
1.4
1.3
1.2
1.1
1.0
0.9

Pop. B



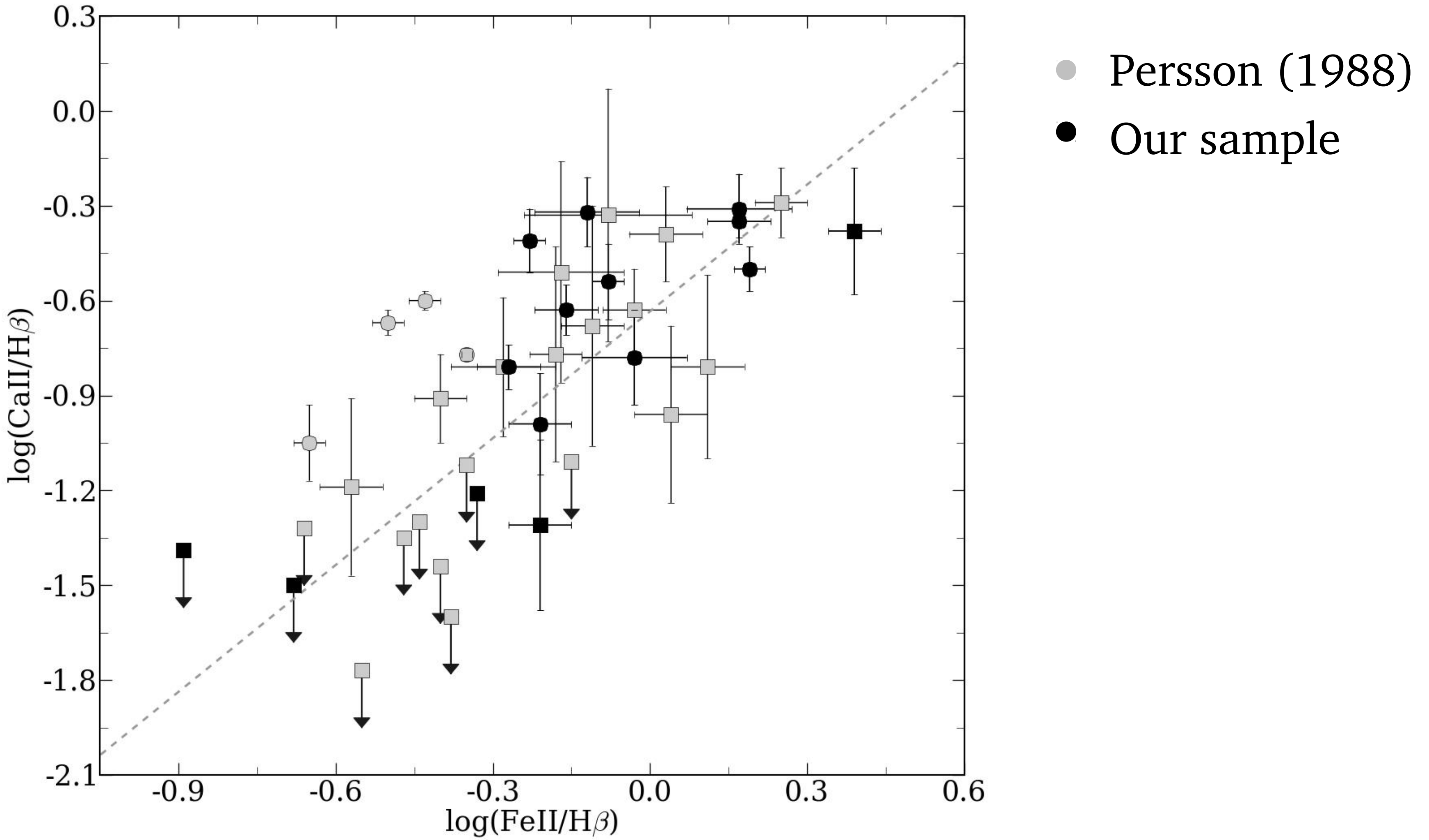
NIR FeII template (García-Rissmann et al. 2012)

High order Paschen Lines



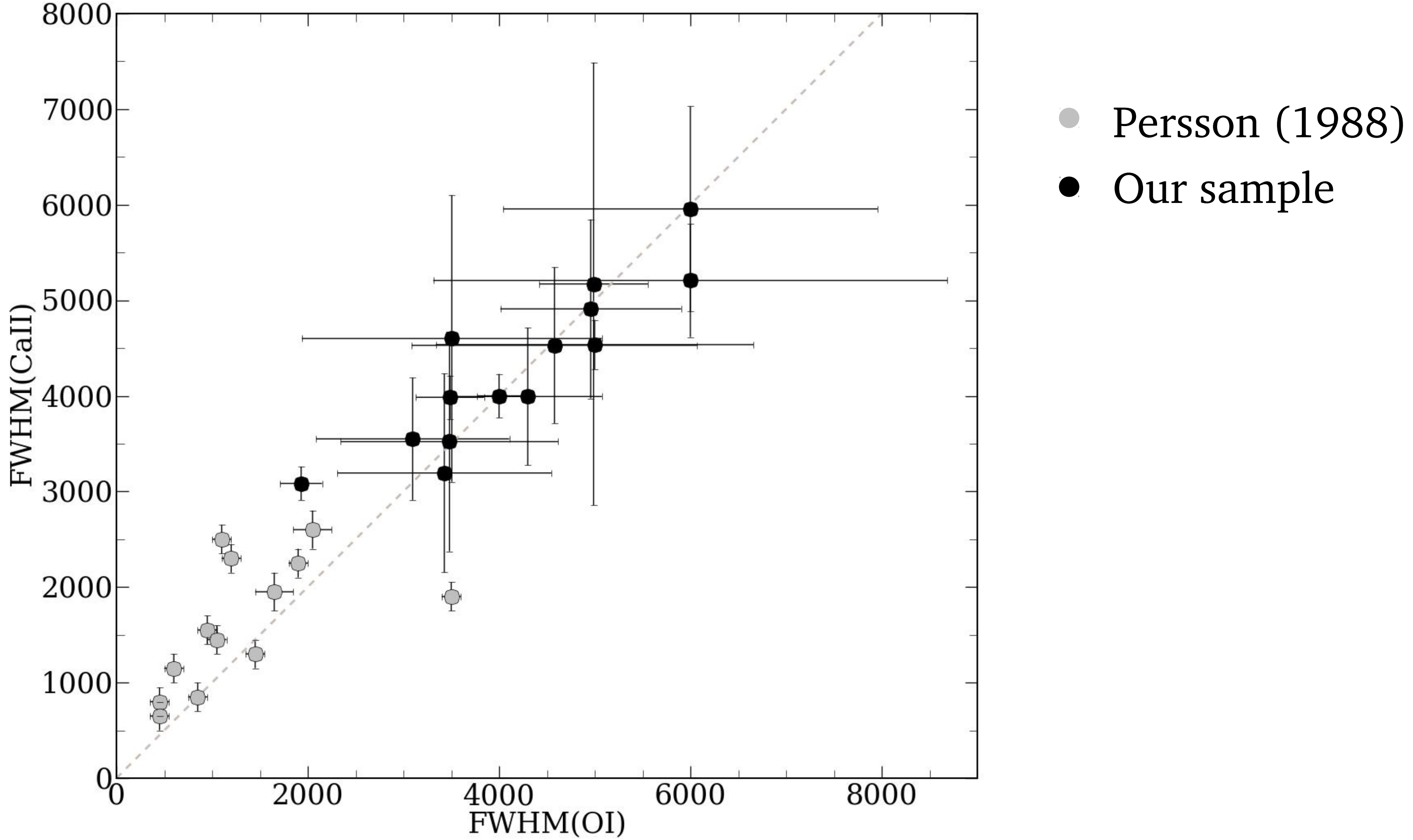
HE0005-2355
Hβ
HE0005-2355
CaII
HE0035-2853
Hβ
HE0035-2853
CaII
HE0043-2300
Hβ
HE0043-2300
CaII
HE0048-2804
Hβ
HE0048-2804
CaII
HE0058-3231
Hβ
HE0058-3231
CaII
HE0203-4627
Hβ
HE0203-4627
CaII
HE0248-3628
Hβ
HE0248-3628
CaII
HE1349+0007
Hβ
HE1349+0007
CaII
$F_\lambda(10^{-15}$ erg s^{-1} cm^{-2} Å^{-1})
λ (Å)

FeII-CaII relation



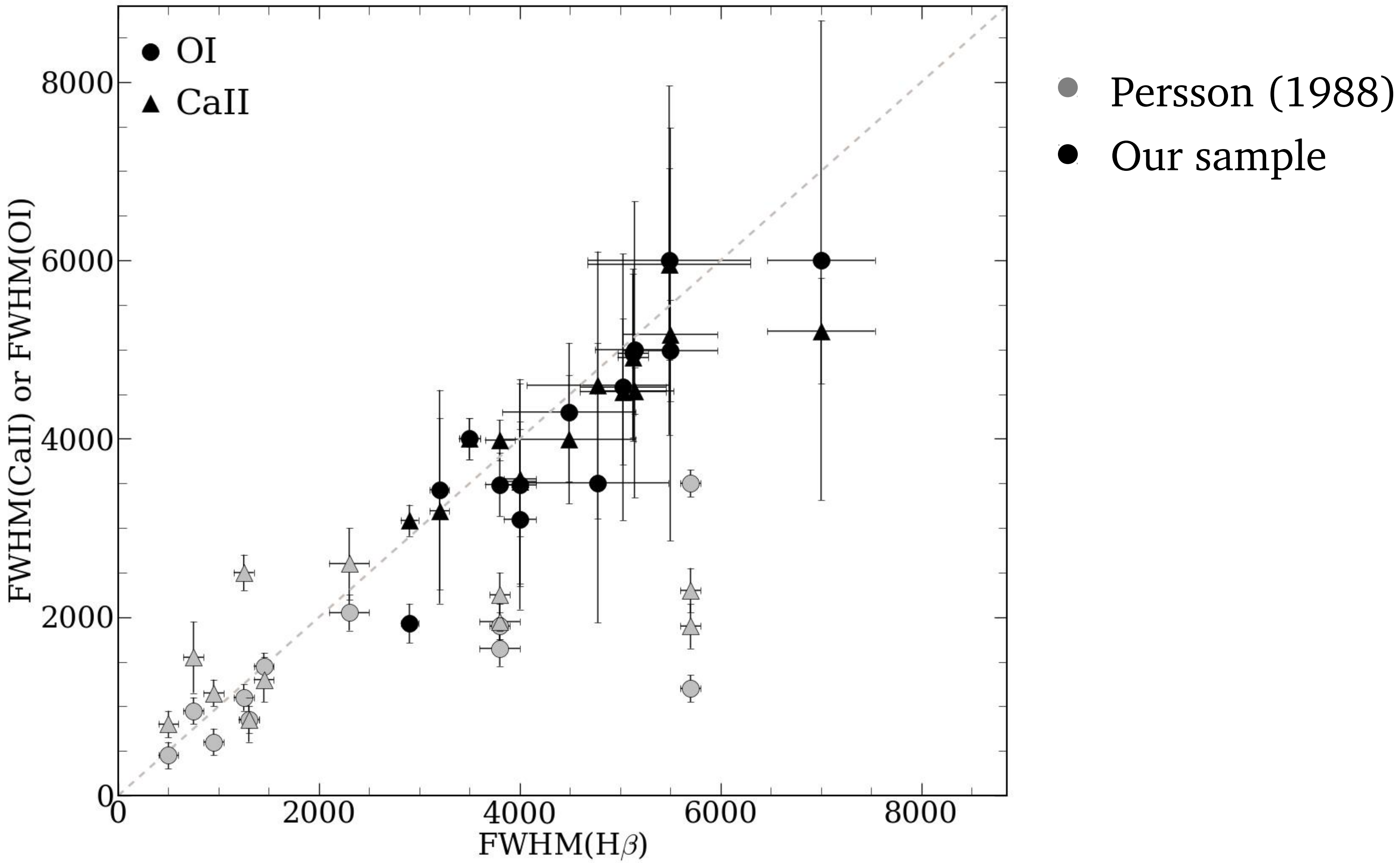
CaII and FeII follow the same behavior, then they are emitted in the same region (Persson,1988; Rodríguez-Ardilla et al. 2002, Matsouka et al. 2007, 2008, Martínez-Aldama et al. 2015)

Dynamic behavior



CaII and OI are emitted at the same distance of the central source (Persson, 1988, Rodríguez-Ardilla et al. 2002, Matsouka et al. 2007, 2008.), but not necessarily by the same region.

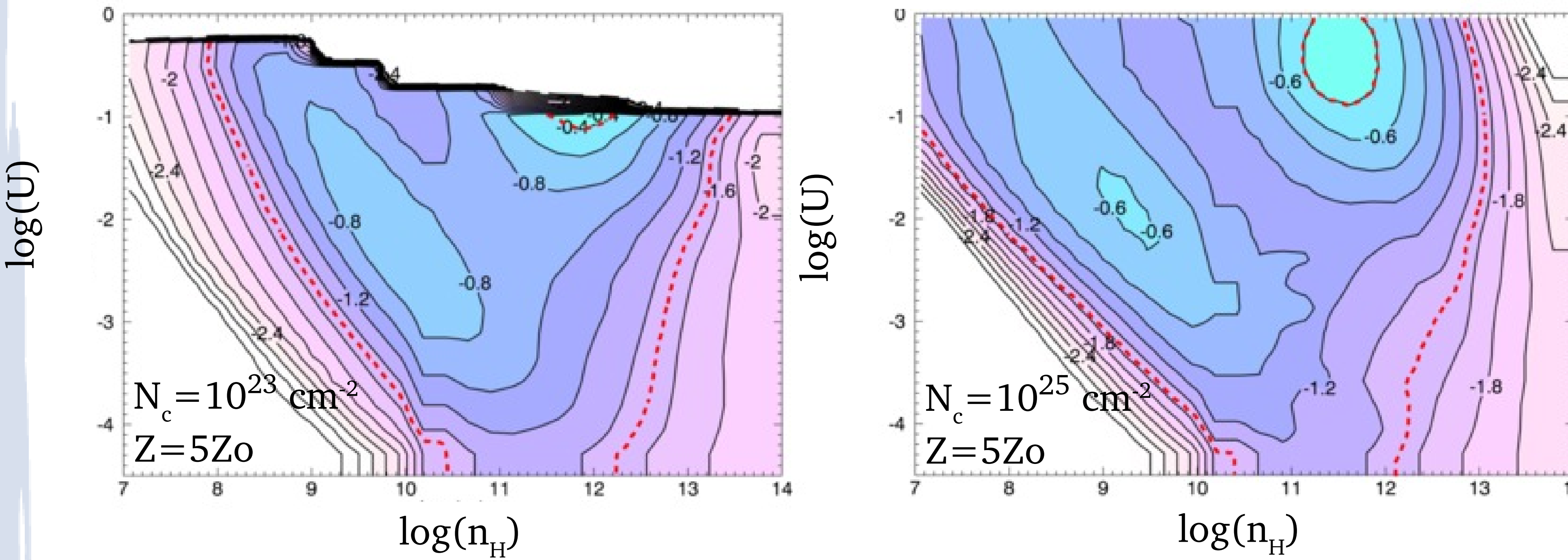
Hβ is emitted by a closer region of central source than CaII and OI.



Photoionization models

In order to find the physical conditions where the ions are emitted, we performed photoionization models using the code Cloudy (Ferland et al. 1998, 2013).

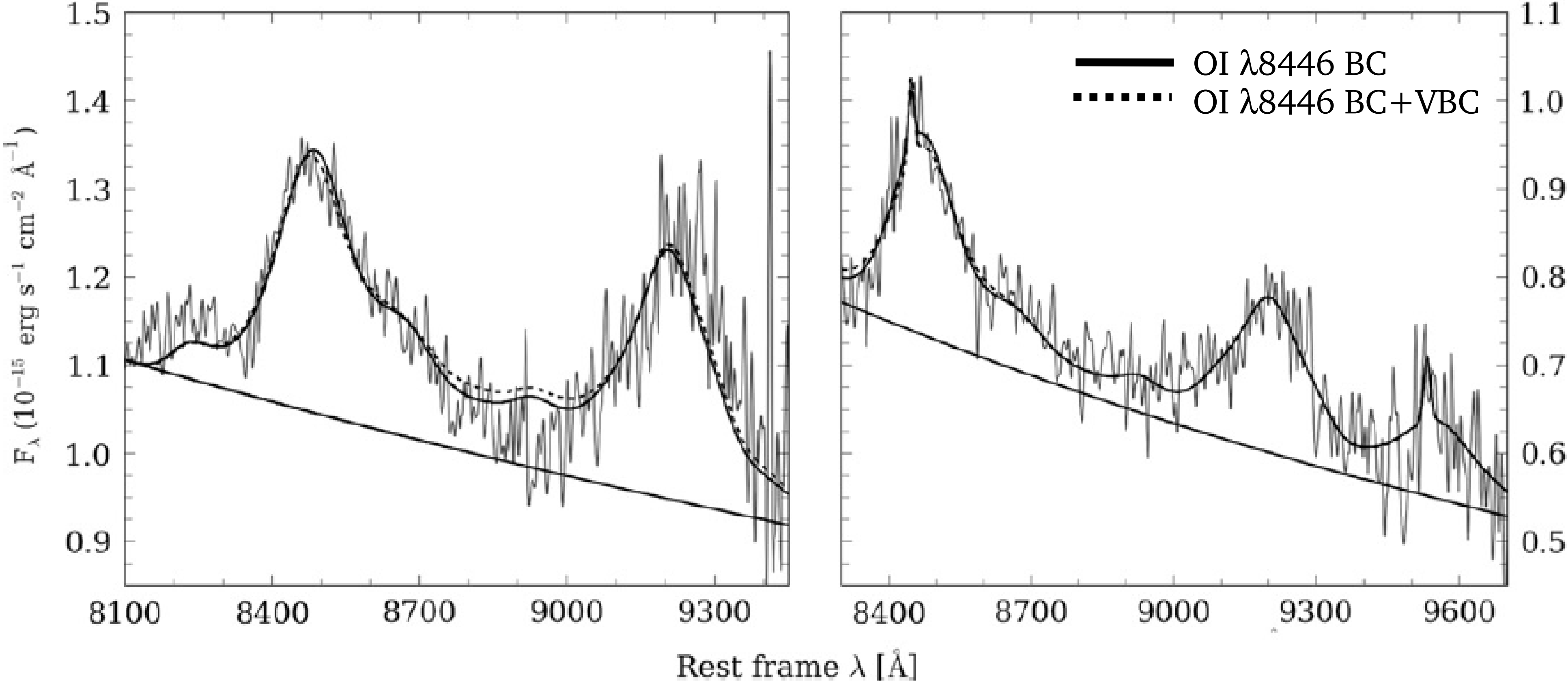
OI/Hβ



$$n_H=10^{9-11.5}\ cm^{-3},\ \log(U)<-1.0$$

OI 8446 can be emitted in a wide density range ($\sim 10^{9}$-10^{13} cm^{-3}), then it has to follow the same behavior than Hβ.

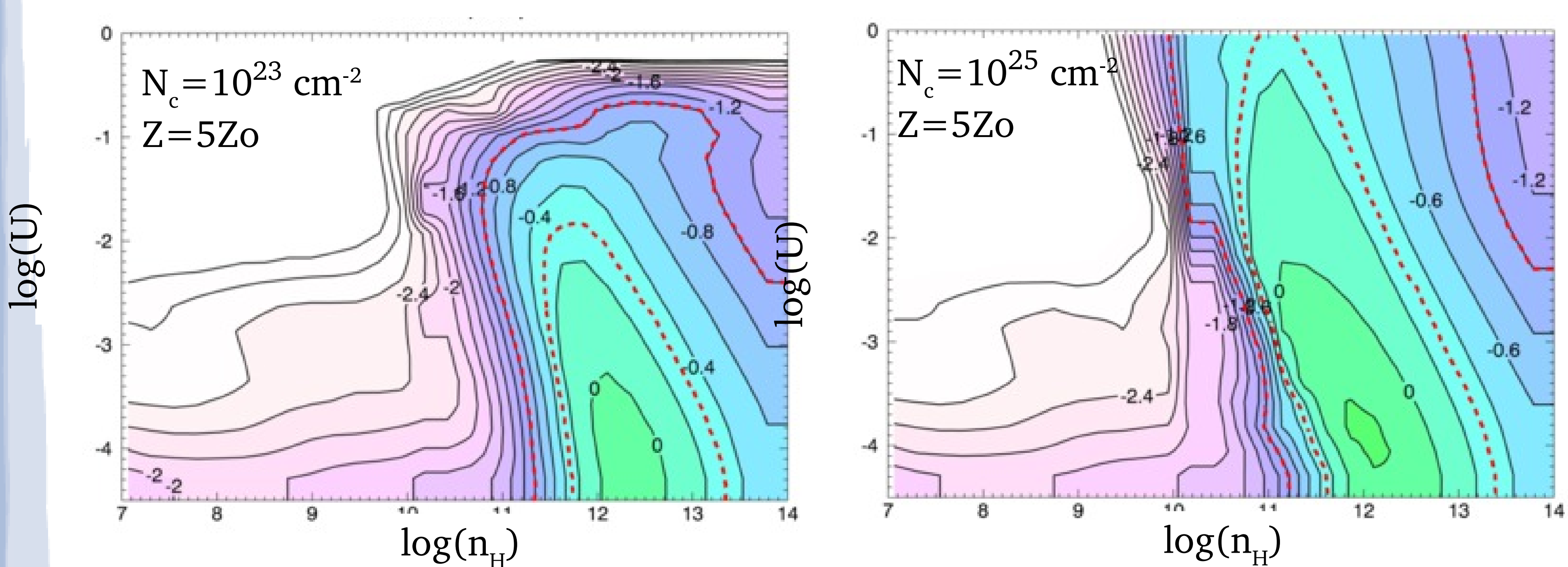
If OI has a similar behavior than Hβ, also it has to show a VBC, however the S/N of our spectra is not useful to detect this component.



Martínez-Aldama et al. 2015

On other hand, the CaII can be emitted only at high density regions:

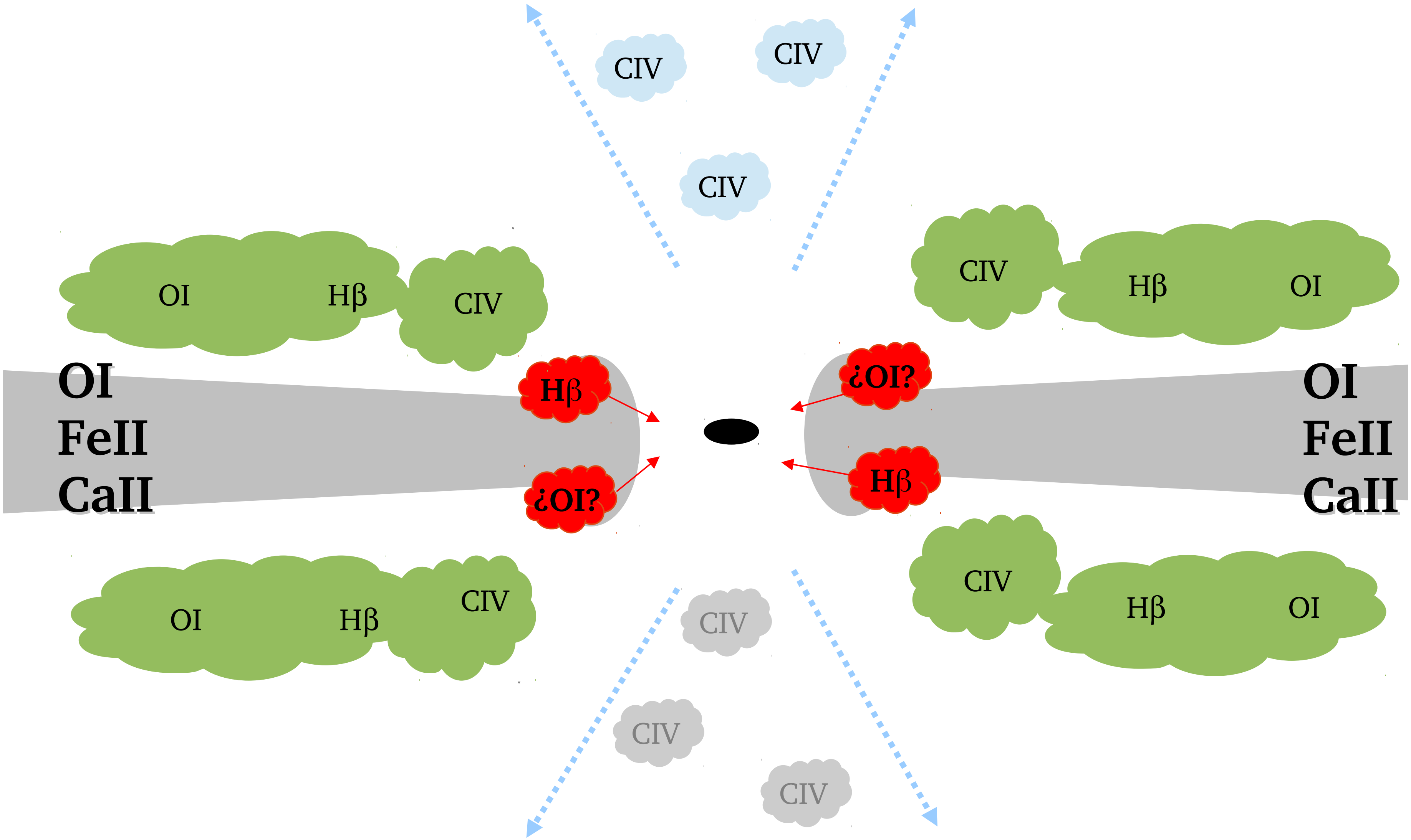
CaIII/Hβ



$N_c = 10^{25}$ cm^{-2}, $n_H > 10^{11}$ cm^{-3}, log(U) < -1.5

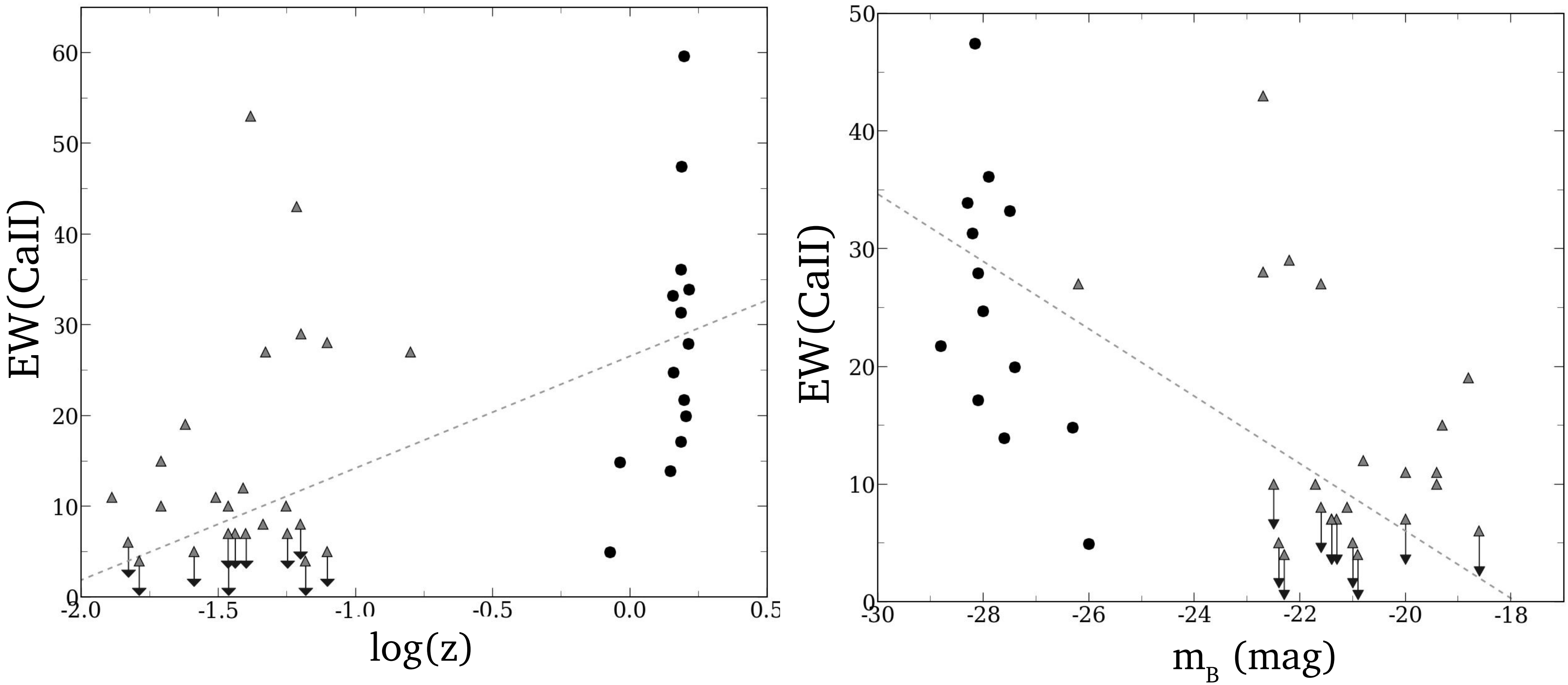
The physical conditions found are in agreement with the showed by FeII. This confirms thatboth ions are emitted at the same region, probably the border of the accretion disk (Joly 1987).

A possible geometry for the BLR



CaII, FeII and OI show the same dynamics, but they are not emitted at the same region.

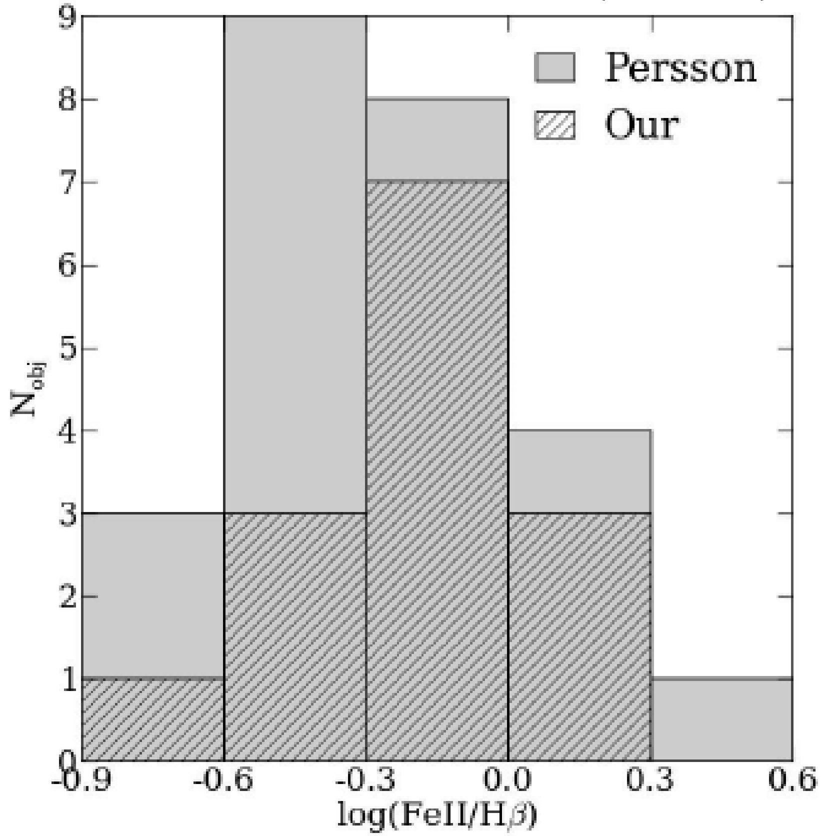
¿Is there a correlation with redshift and luminosity?



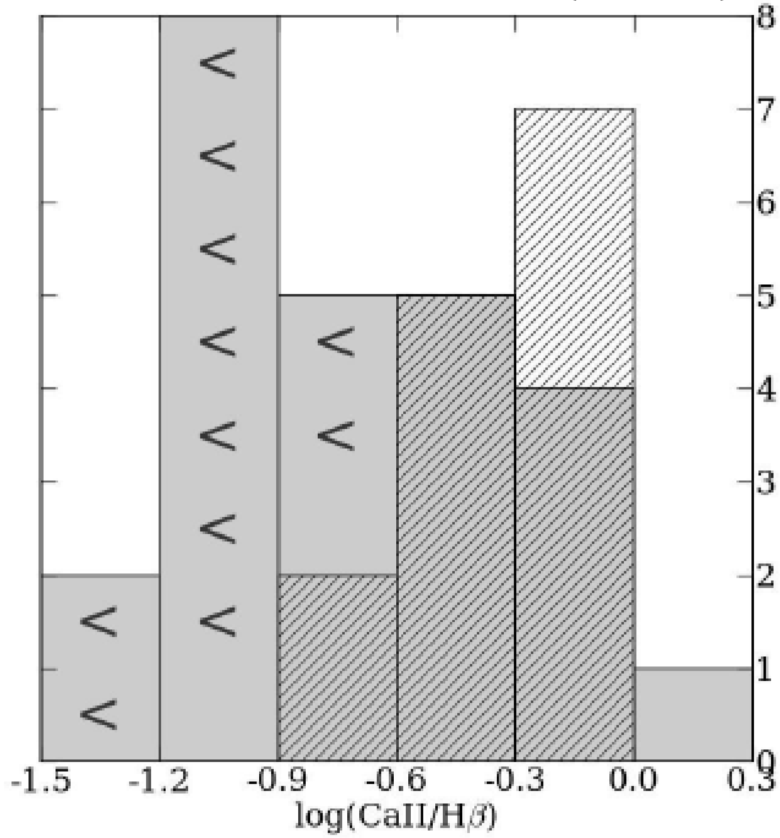
There is a different behavior in CaII for low and intermediate redshfit samples, that can be related with the formation of CaII, an α-element. However, there are a luminosity and redshift bias that can be affect this results.

If we compare the behavior of CaII and FeII in both sample, we can observe that CaII is slighly higher than FeII at intermediate redshift quasars. Then, the formation rate of CaII is high than FeII.

FeII - t~10^9 años (SN Ia)



CaII - t~10^7 años (SN II)

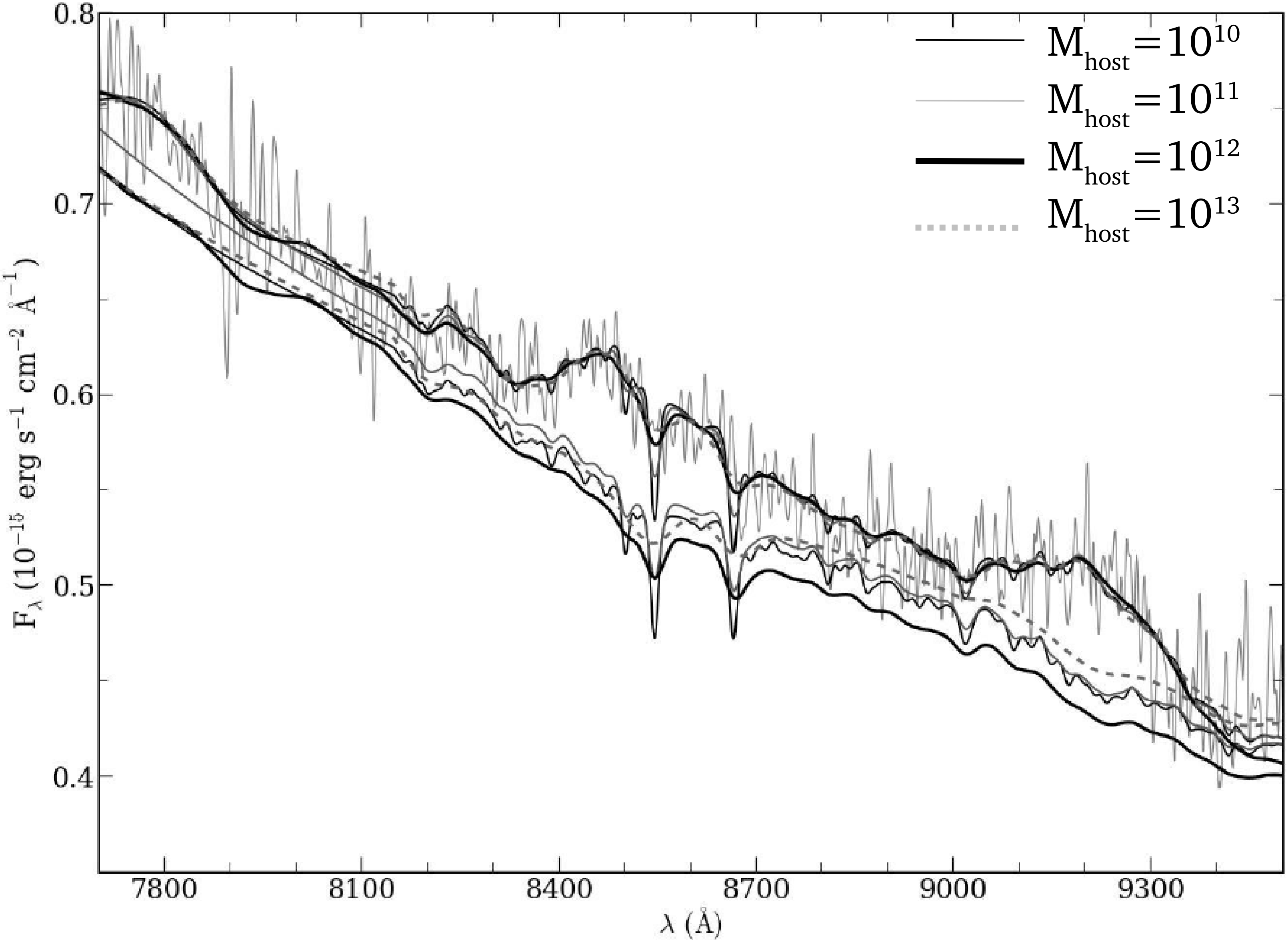


If CaII increases, it is due to a recent starburst at intermediate redshift quasars, that it is in agreement with previous results (Wyse & Gilmore 1998; Matteucci 2003).

Summary

- We could observed the CaII IR triplet in quasar at intermediate redshift.
- The relation between the CaII and FeII is confirmed at low and intermediate redshift. Then, both ions are emitted at the same region, probably the borders of the accretion disk.
- Altohugh OI and CaII show the same dynamic behavior, they are emitted by different regions according to the photoionization model results.
- A systematic difference between the CaII and FeII intensities could indicate that a recent starburst is enriching the gas of intermediate redshift quasars.

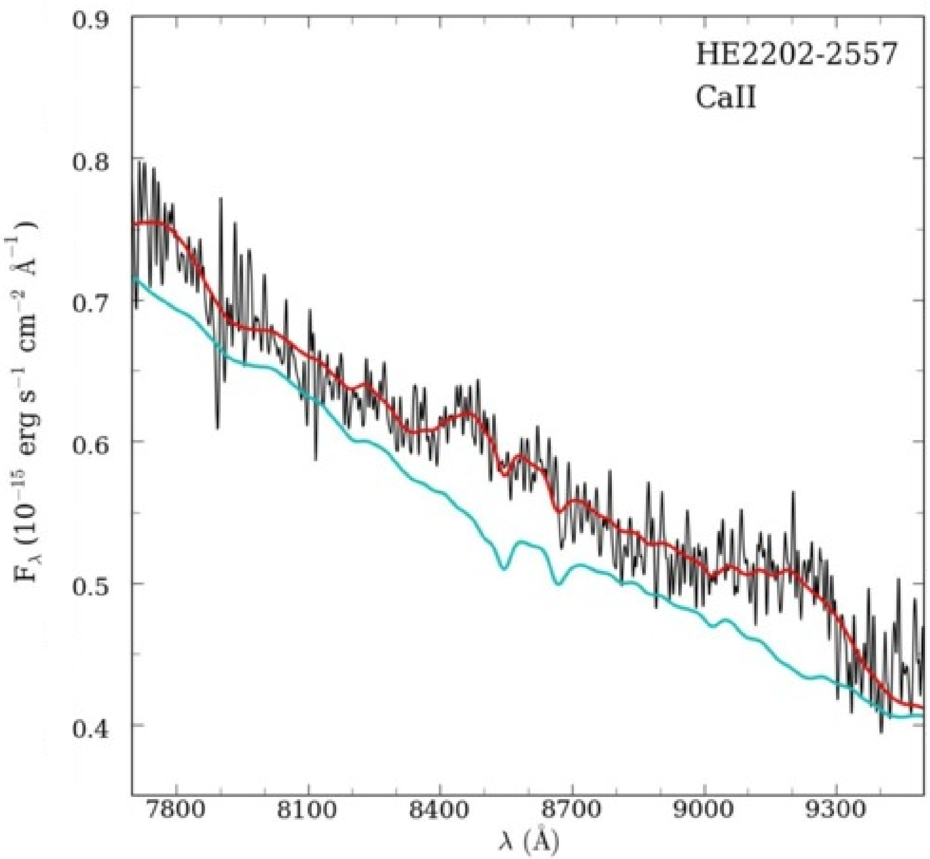
QSO with host galaxy contribution

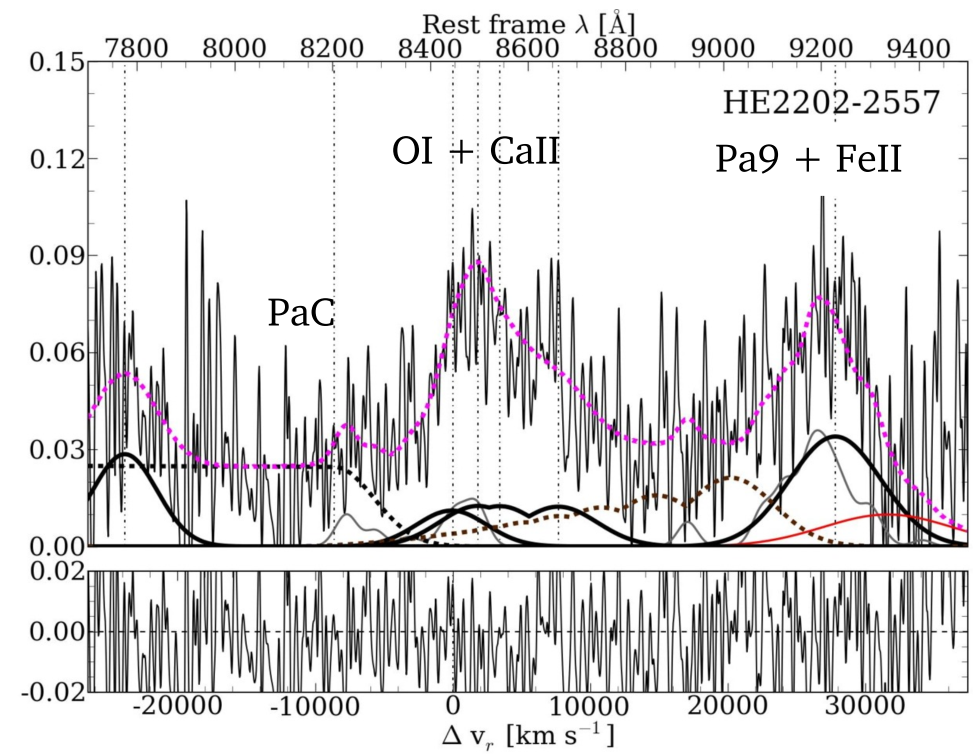


$M_{host} = 1.13x10^{12}\ M_o$

$t_{host} = 2.4$ Gyr

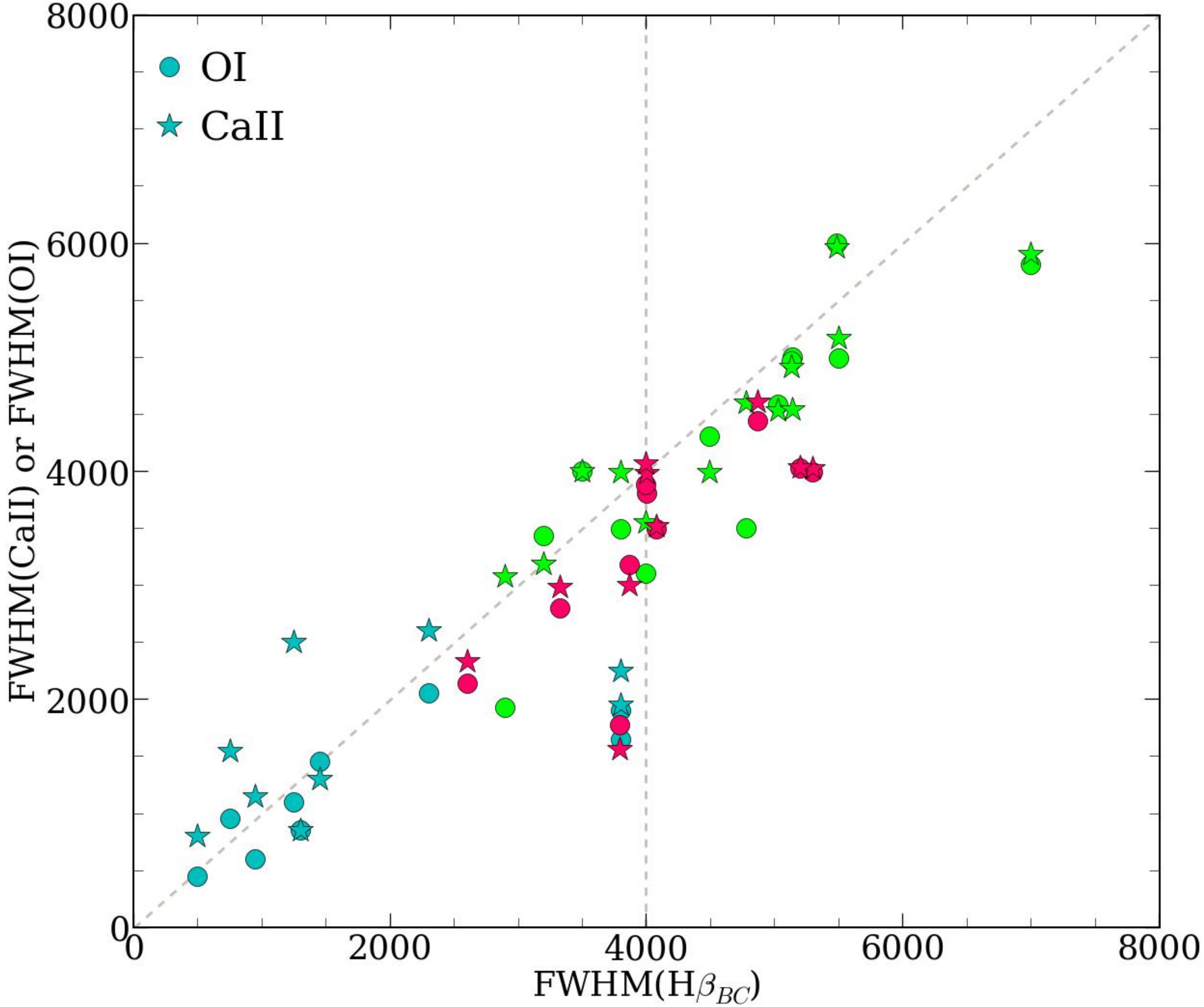
$Z = 2Z_o$

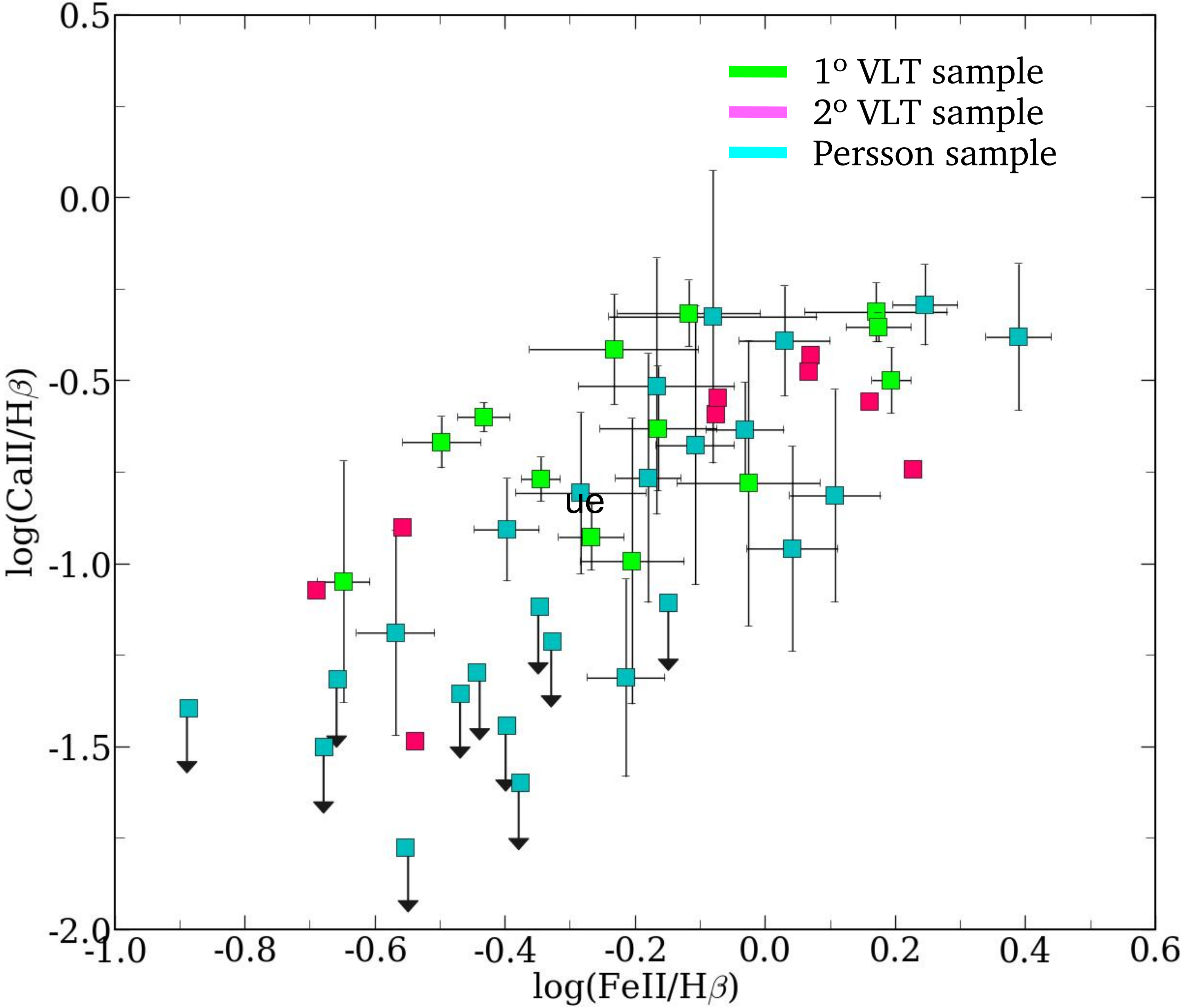




2º sample

1º VLT sample
2º VLT sample
Persson sample





1° VLT sample
2° VLT sample
Persson sample
log(CaII/Hβ)
log(FeII/Hβ)
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
ue