BLR: non radiative heating in strong Fe II emitters

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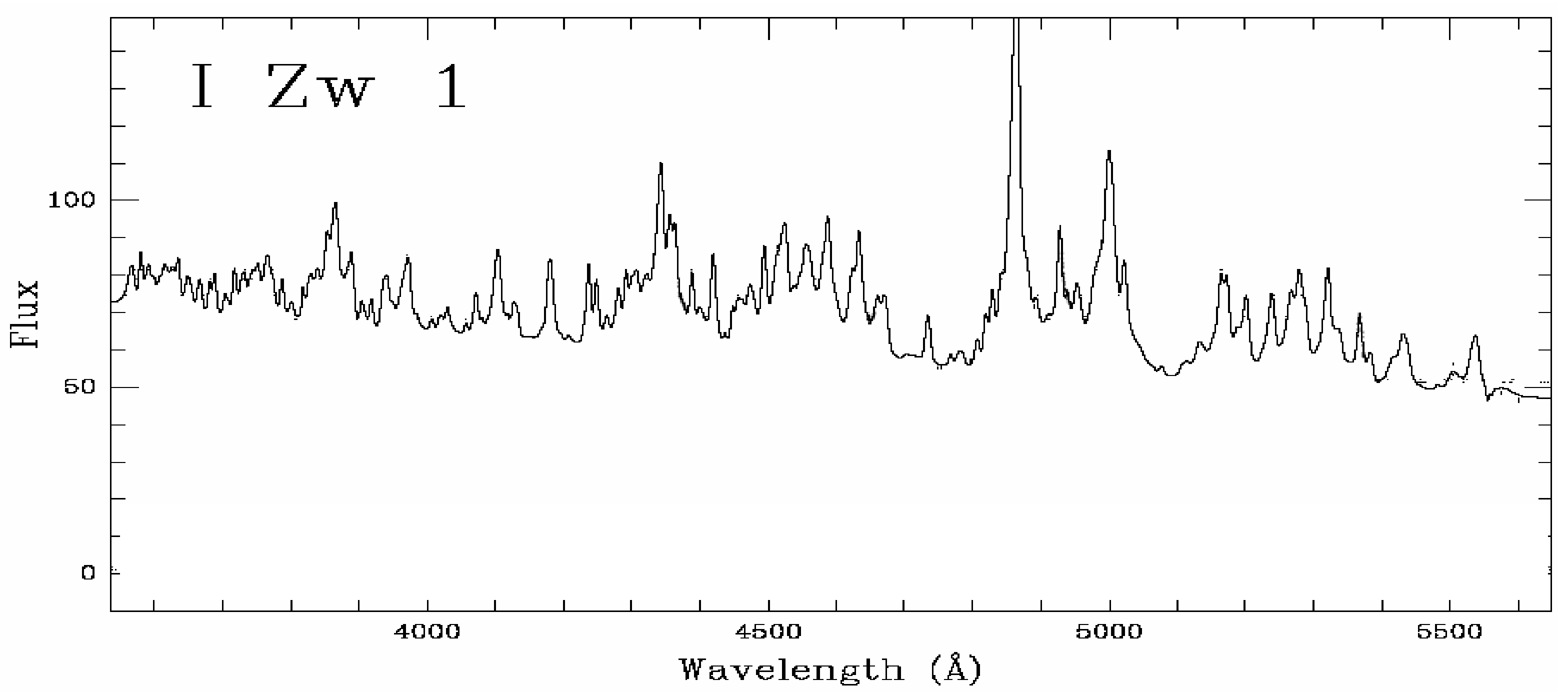
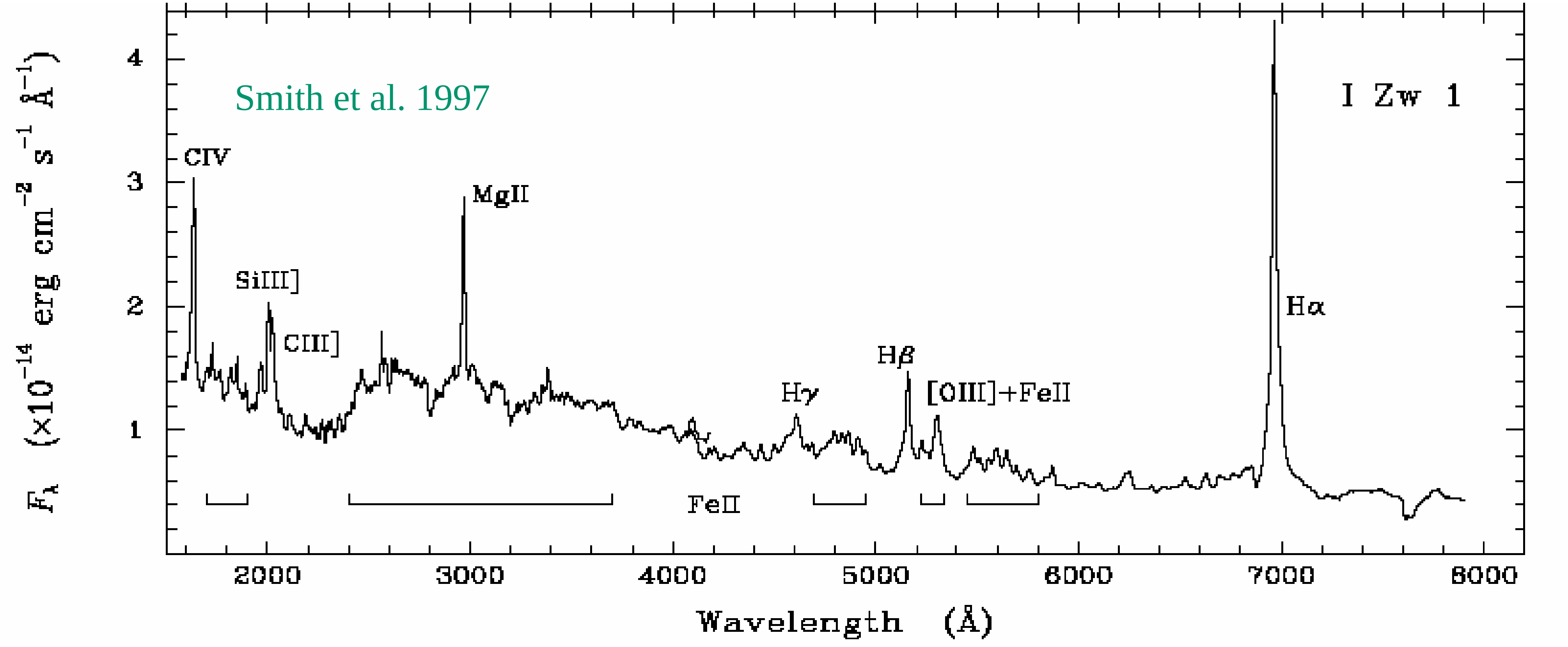



Smith et al. 1997

A major characteristic of type 1 AGN:
the emission of Fe II from UV to near IR.

Large FeII strength: from null to several tens of Hβ
0 < Fe II λ4570 / Hβ < 10

In many AGN, Fe II emits half as much energy as all other emission lines together.
In a few cases it is the strongest contributor to the line spectrum.

Problems

After 40 years, explaining Fe II emission is still a problem.

We don't know where it is emitted, what are its abundance and the dominant excitation process (controversy).

Generally current models do not account:

- for the total Fe II luminosity
- for the line intensity ratios with other species
- for the intensity ratios between Fe II multiplets (e.g. $FeII_{opt}/FeII_{UV}$)

Optical and UV multiplets are not emitted in the same region (cf. e.g. Baldwin et al. 2004, Tsuzuki et al. 2006)

Where and how is Fe II emitted ?

What do we know?

From line widths and correlations with other species:

Fe II is emitted somewhere in the BLR (cf. e.g. Wilkes et al. 1999)
(but also in the NLR, cf. e.g. Véron-Cetty et al. 2004)

From variability and reverberation mapping we have a guess of the size of the BLR: few tens of light days (cf. e.g. Kaspi et al. 2000)

MODELS

In fact it is easy to obtain Fe II since

- Fe I is easily ionized (I.P. = 7.9 eV)
- Fe II is not easily ionized (I.P. = 16.2 eV)
- a low T is sufficient to excite Fe II lines (T > 4000K)

And indeed all standard photoionization models predict some Fe II emission.

Examples obtained with CLOUDY (Ferland 2002):

- $n = 10^6$ cm^{-3}, $U = 2.\ 10^{-3}$, $N_H = 4.\ 10^{20}$cm^{-2} $\Rightarrow$ Fe II λ4570/Hβ = 0.10
- $n = 10^{12}$ cm^{-3}, $U = 3.\ 10^{-3}$, $N_H = 2.\ 10^{23}$cm^{-2} $\Rightarrow$ Fe II λ4570/Hβ = 0.80

But we are far from: Fe II λ4570/Hβ = 8
as measured in IRAS 07598+6508 (cf. e.g. Véron-Cetty et al. 2006)

What are the Excitation Mechanisms ?

- continuum and line fluorescence
- collisional excitation (most efficient)

Standard models as the Locally Optimally emitting Clouds model (LOC, Baldwin et al., 1995) account for the Low Ionization Lines (LIL, Collin, 1986):

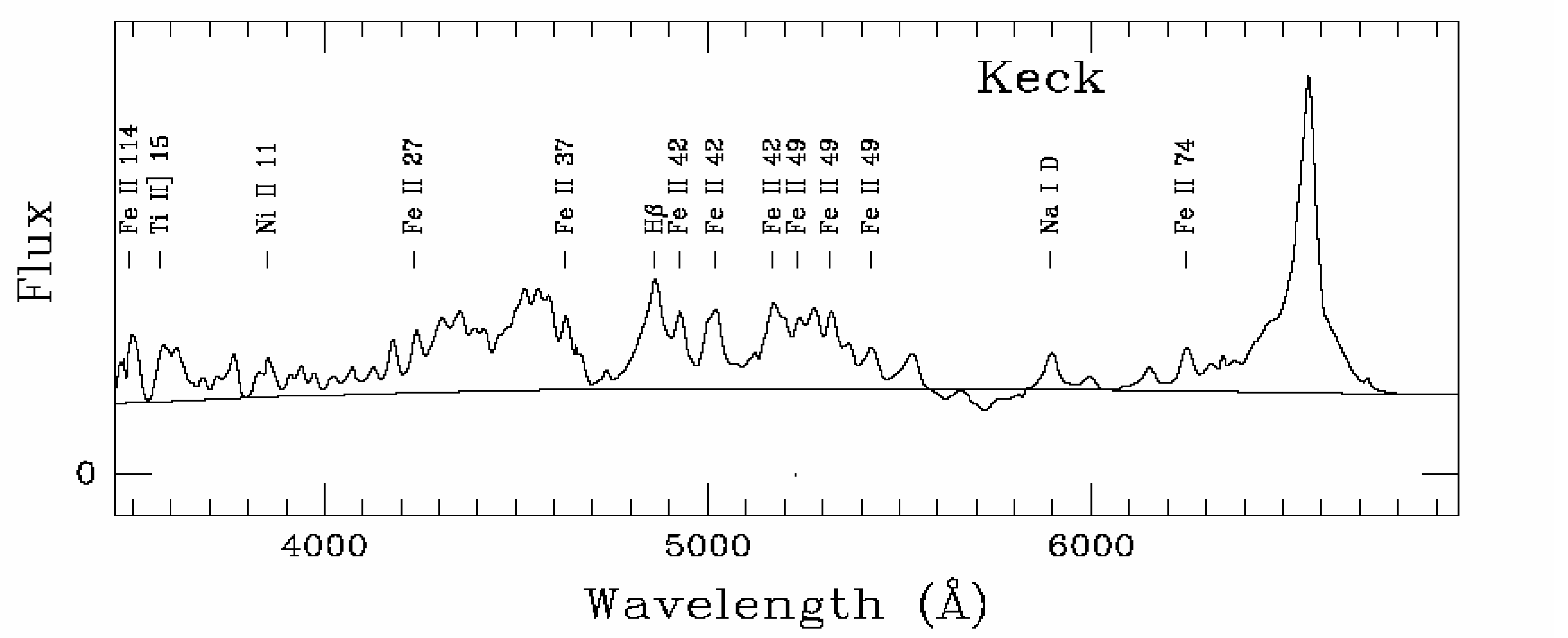
H I, He I, Mg II, Ti II, Na I, Ca II, Balmer Continuum
including a small contribution of Fe II and [Fe II].

To get large Fe II emission something else is needed.
Pure radiative heating is not sufficient.

Need for an efficient heating like Mechanical Heating
plus high density and high column density.

IRAS 07598+6508
A strong Fe II emitter

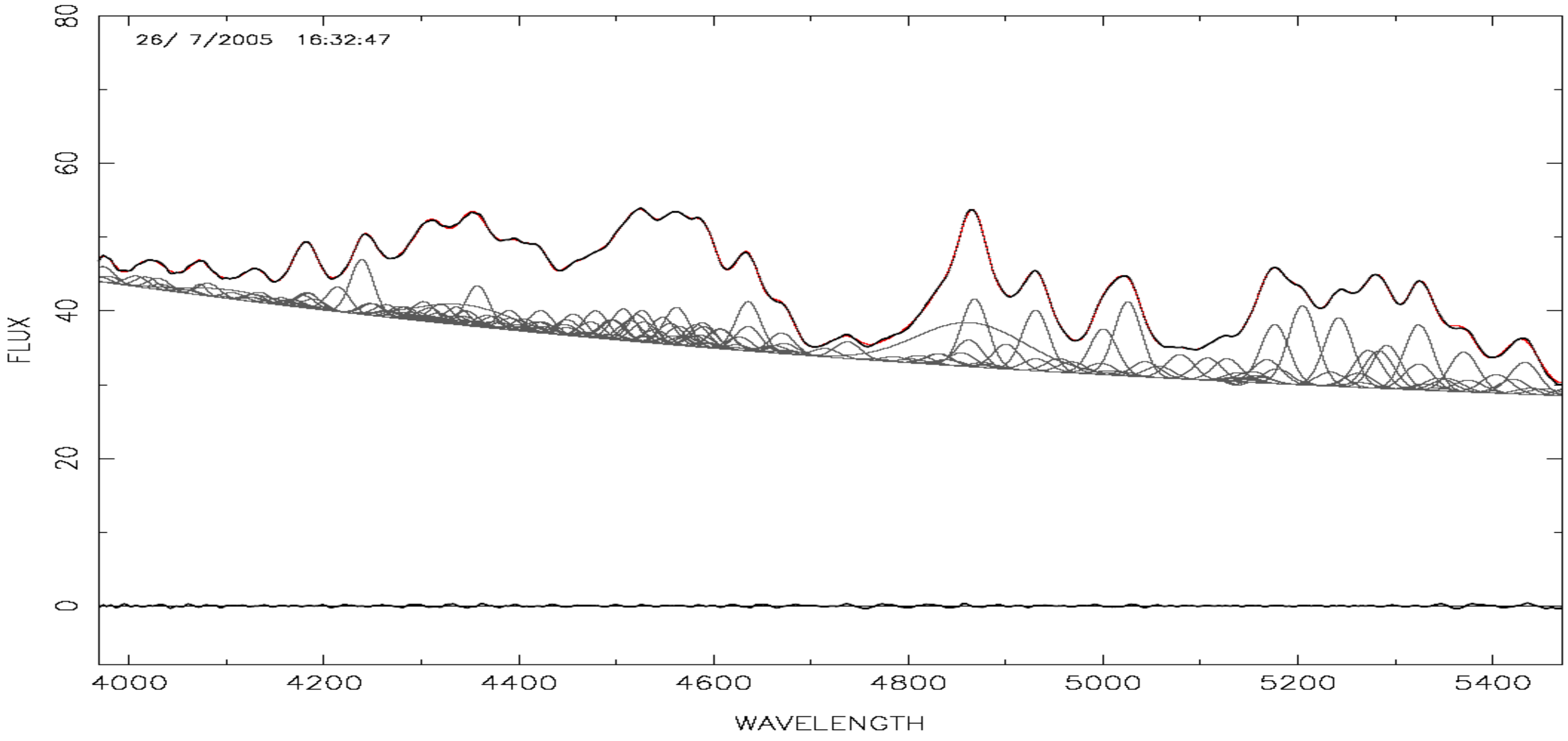
Boroson & Meyers (1992), Schmidt & Hines (1999), Lipari (1994), Ogle et al. (1999).



IRAS 07598+6508

Véron-Cetty et al. (2006):

- identified 262 broad emission lines (FWHM = 1780 km/s)
- measured the line ratios referred to Hβ
- ran CLOUDY to infer the physical parameters of the BLR assuming for the excitation of Fe II:
  - first, photionization
  - then, additional mechanical heating



lines	λ	Keck	model 1 phot. "Kaspi" R=4 10^{17} n=10^{12} N_H=2 10^{23}
Hα	6563	5.86	3.25
Hβ	4861	1.00	1.00
Ca IIK	3934	0.22	0.63
Ca IIH	3969	0.19	0.46
He I	5876	0.00	2.62
Na I	5892	0.87	0.18
Fe II			
3910	3780-4040	1.23	0.74
4255	4080-4430	5.64	0.60
4570	4430-4685	7.91	0.84
4855	4800-4910	1.27	0.07
4975	4910-5040	4.23	0.52
5143	5100-5185	3.26	0.28
5318	5185-5450	8.20	0.65
6265	6100-6430	3.93	0.12
6565	6430-6700	1.15	0.25
Lα	1216	–	34.4
Fe II2355	2280-2430	–	4.1
Mg II	2800	–	11.4
Ba C	<3646	–	55.5
CaII T	8500	–	1.4

lines	λ	Keck	model 1 phot. "Kaspi" R=4 10^{17} n=10^{12} N_H=2 10^{23}	model 2 phot. +heating R=3 10^{19} n=10^{12} H=3 10^{46} N_H=10^{23}
Hα	6563	5.86	3.25	7.83
Hβ	4861	1.00	1.00	1.00
Ca IIK	3934	0.22	0.63	2.76
Ca IIH	3969	0.19	0.46	2.05
He I	5876	0.00	2.62	0.21
Na I	5892	0.87	0.18	6.60
Fe II				
3910	3780-4040	1.23	0.74	6.71
4255	4080-4430	5.64	0.60	28.3
4570	4430-4685	7.91	0.84	10.0
4855	4800-4910	1.27	0.07	6.68
4975	4910-5040	4.23	0.52	9.76
5143	5100-5185	3.26	0.28	11.0
5318	5185-5450	8.20	0.65	19.1
6265	6100-6430	3.93	0.12	0.68
6565	6430-6700	1.15	0.25	2.55
Lα	1216	–	34.4	37.0
Fe II2355	2280-2430	–	4.1	21.0
Mg II	2800	–	11.4	198.0
Ba C	<3646	–	55.5	2.7
CaII T	8500	–	1.4	11.8

lines	λ	Keck	model 1 phot. “Kaspi” $R=4\,10^{17}$ $n=10^{12}$ $N_H=2\,10^{23}$	model 2 phot. +heating $R=3\,10^{19}$ $n=10^{12}$ $H=3\,10^{46}$ $N_H=10^{23}$	model 3 phot. +heating $R=5\,10^{18}$ $n=10^{14}$ $H=8\,10^{46}$ $N_H=5\,10^{23}$
Hα	6563	5.86	3.25	7.83	4.5
Hβ	4861	1.00	1.00	1.00	1.00
Ca IIK	3934	0.22	0.63	2.76	16.5
Ca IIH	3969	0.19	0.46	2.05	14.7
He I	5876	0.00	2.62	0.21	0.19
Na I	5892	0.87	0.18	6.60	10.9
Fe II					
3910	3780-4040	1.23	0.74	6.71	11.5
4255	4080-4430	5.64	0.60	28.3	6.51
4570	4430-4685	7.91	0.84	10.0	9.49
4855	4800-4910	1.27	0.07	6.68	1.86
4975	4910-5040	4.23	0.52	9.76	4.90
5143	5100-5185	3.26	0.28	11.0	3.68
5318	5185-5450	8.20	0.65	19.1	7.11
6265	6100-6430	3.93	0.12	0.68	1.86
6565	6430-6700	1.15	0.25	2.55	4.55
Lα	1216	–	34.4	37.0	1.2
Fe II2355	2280-2430	–	4.1	21.0	15.4
Mg II	2800	–	11.4	198.0	13.3
Ba C	<3646	–	55.5	2.7	1.0
CaII T	8500	–	1.4	11.8	48.0

lines	λ	Keck	model 1	model 2	model 3	model 4
			phot.	phot.	phot.	coll.
			“Kaspi”	+heating	+heating	
			$R=4\,10^{17}$	$R=3\,10^{19}$	$R=5\,10^{18}$	f=5%
			$n=10^{12}$	$n=10^{12}$	$n=10^{14}$	$n=10^{15}$
				$H=3\,10^{46}$	$H=8\,10^{46}$	$H=1.3\,10^{46}$
			$N_H=2\,10^{23}$	$N_H=10^{23}$	$N_H=5\,10^{23}$	$N_H=10^{25}$
Hα	6563	5.86	3.25	7.83	4.5	0.12
Hβ	4861	1.00	1.00	1.00	1.00	0.02
Ca II K	3934	0.22	0.63	2.76	16.5	0.88
Ca II H	3969	0.19	0.46	2.05	14.7	0.78
He I	5876	0.00	2.62	0.21	0.19	0.00
Na I	5892	0.87	0.18	6.60	10.9	0.50
Fe II						
3910	3780-4040	1.23	0.74	6.71	11.5	5.84
4255	4080-4430	5.64	0.60	28.3	6.51	7.52
4570	4430-4685	7.91	0.84	10.0	9.49	8.00
4855	4800-4910	1.27	0.07	6.68	1.86	1.12
4975	4910-5040	4.23	0.52	9.76	4.90	1.44
5143	5100-5185	3.26	0.28	11.0	3.68	2.32
5318	5185-5450	8.20	0.65	19.1	7.11	5.36
6265	6100-6430	3.93	0.12	0.68	1.86	2.32
6565	6430-6700	1.15	0.25	2.55	4.55	1.84
Lα	1216	–	34.4	37.0	1.2	1.12
Fe II 2355	2280-2430	–	4.1	21.0	15.4	6.48
Mg II	2800	–	11.4	198.0	13.3	1.20
Ba C	<3646	–	55.5	2.7	1.0	0.03
Ca II T	8500	–	1.4	11.8	48.0	3.68

CONCLUSION

The region emitting the FeII lines in strong FeII emitters is probably a region of high density, high column density, shielded from the central radiation and mechanically heated.

In order to make more progress in the understanding of the AGN Fe II emission, we need both:

- better theoretical models and atomic data,
- and high resolution, high S/N spectra of NLS1s (to be able to identify individual lines)