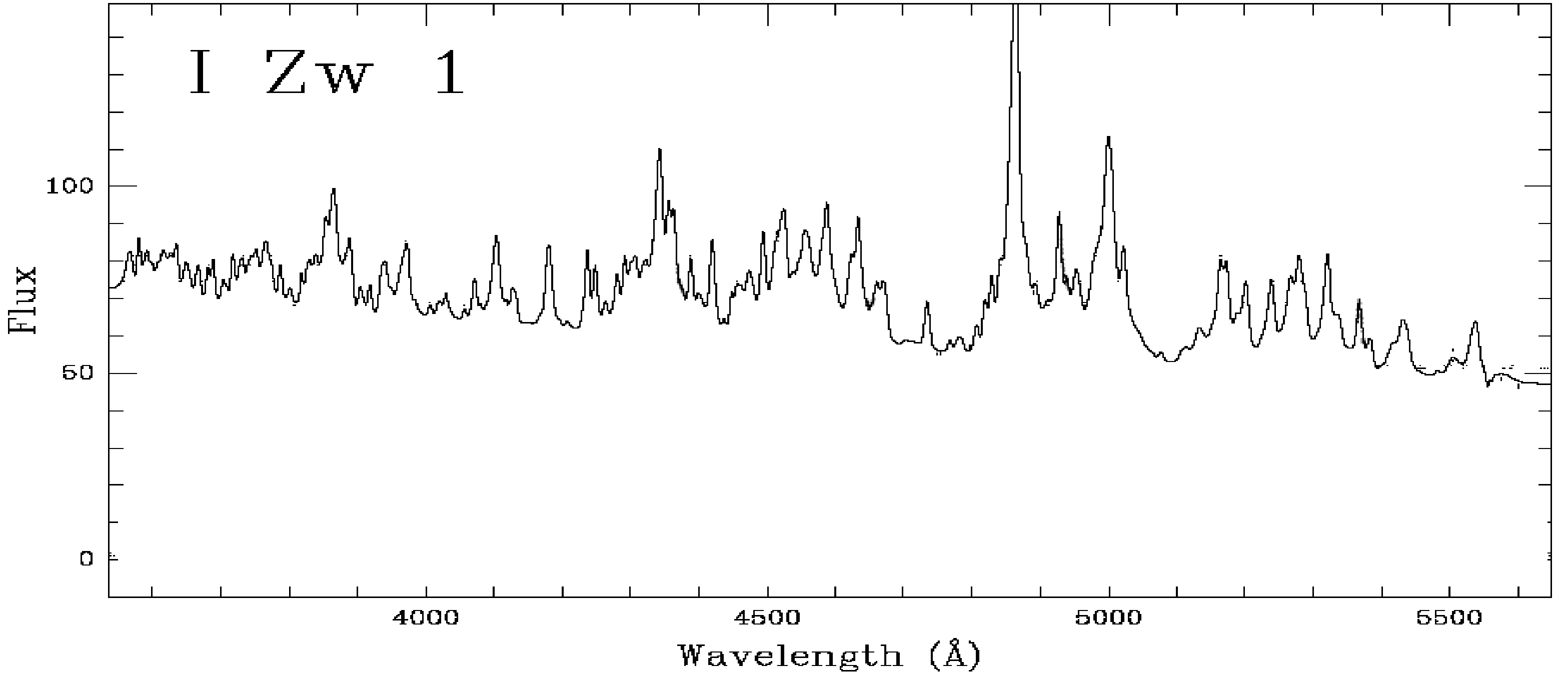
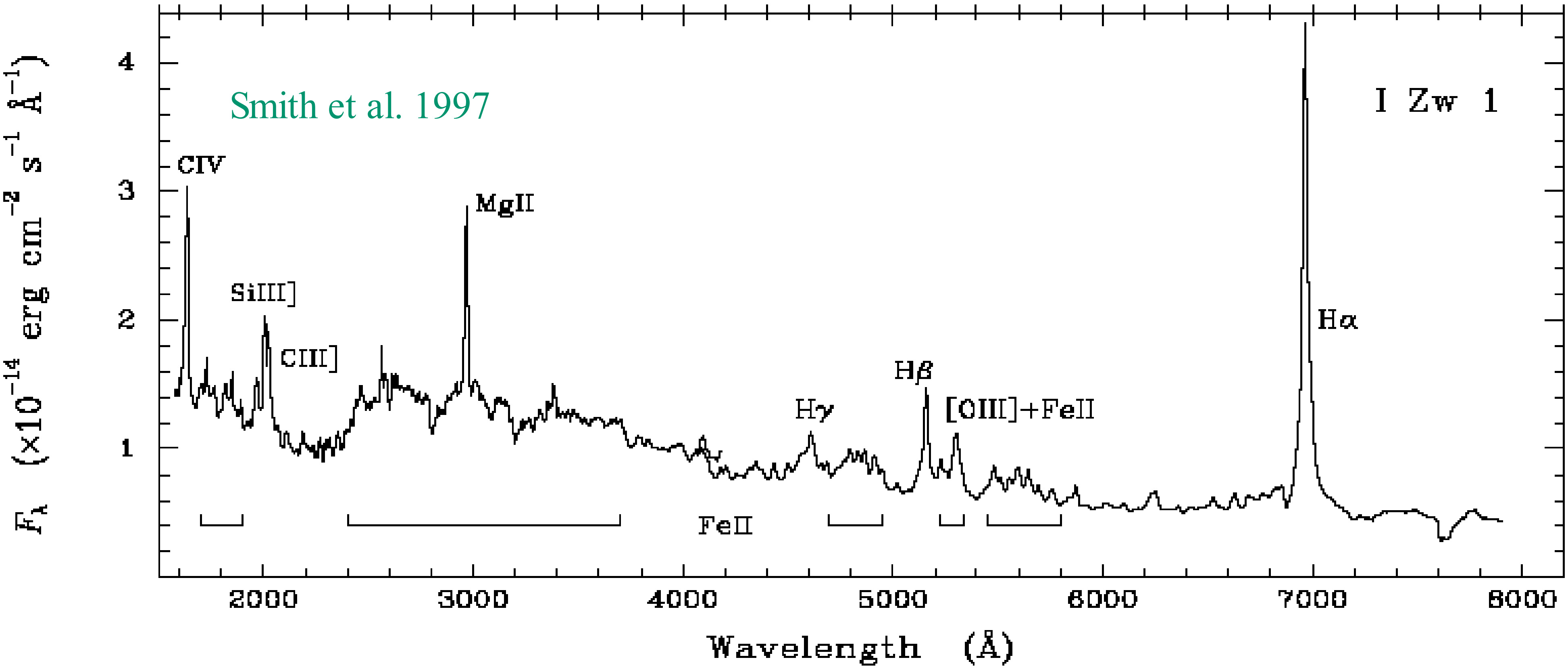
Fe II emission in AGN

M. Joly, M. Véron-Cetty, P. Véron

Observatoire de Paris-Meudon and Observatoire de Haute Provence (France)



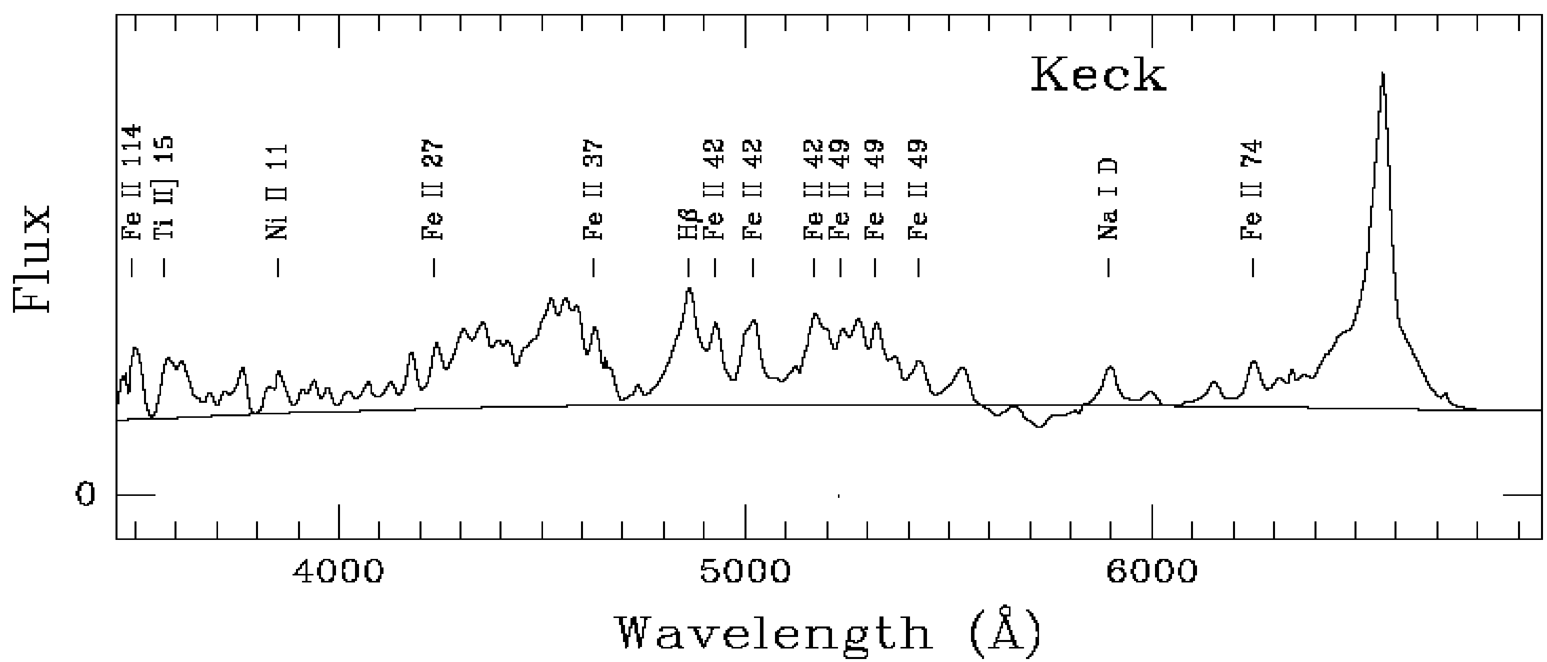


A major characteristic of type 1 AGN:
the emission of Fe II from UV to near IR.

This Fe II emission is highly variable from object to object.
$0 < \text{Fe II}\ \lambda 4570 / \text{H}\beta < 10$
Broad range of total strength: from null to several tens of Hβ

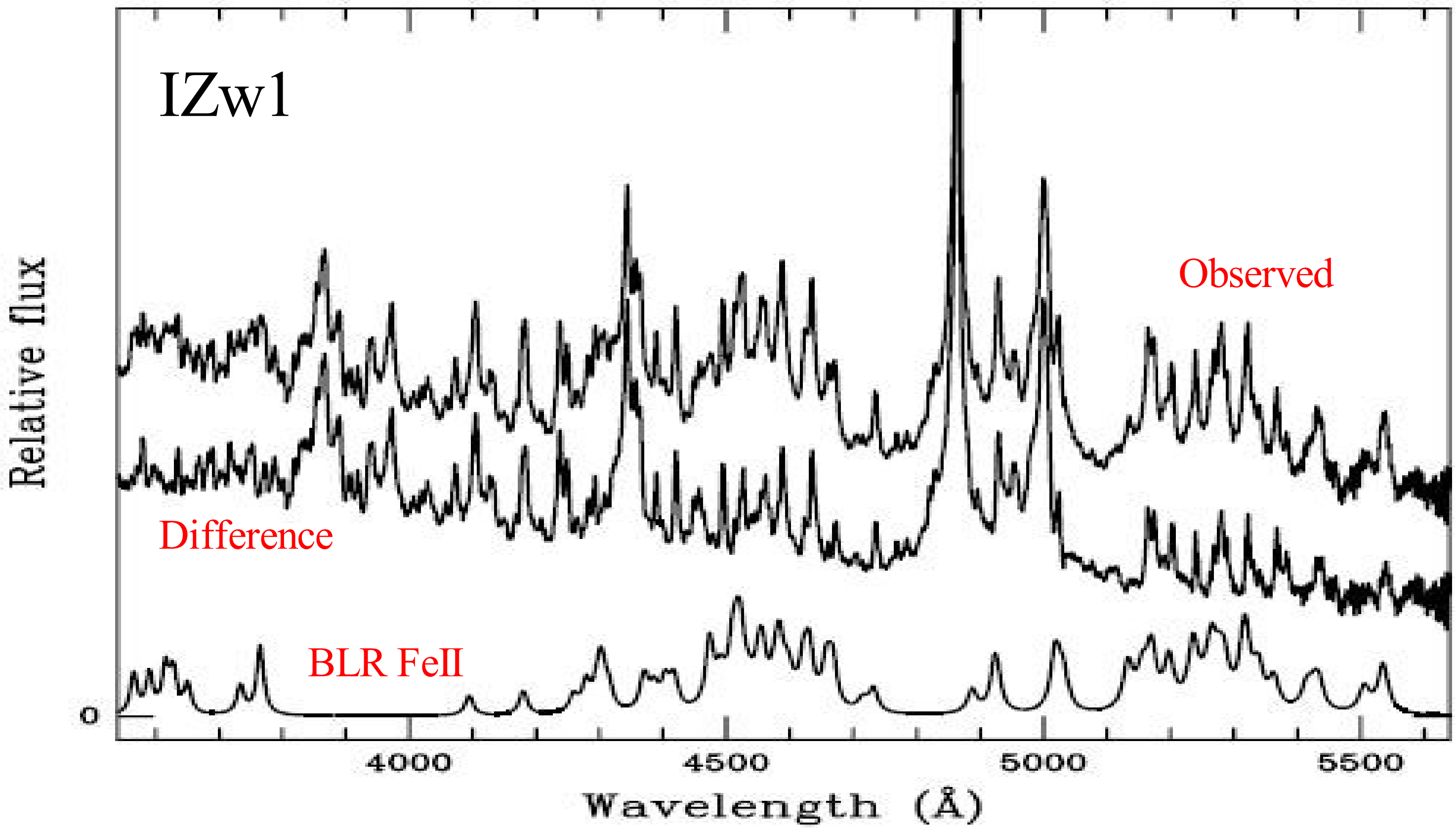
In a few cases FeII is the strongest contributor to the line spectrum.

See the example of the ULIG IRAS 07598+6508
(Boroson & Meyers, 1992; Schmidt & Hines, 1999;
Lipari, 1994; Ogle et al., 1999; Véron-Cetty et al., 2006).



Where are the emission regions?

From line widths and correlations with other species:
Fe II is emitted somewhere in the BLR (cf. e.g. Sulentic et al. 2000)
but also in the NLR (cf. e.g. Véron-Cetty et al. 2004).

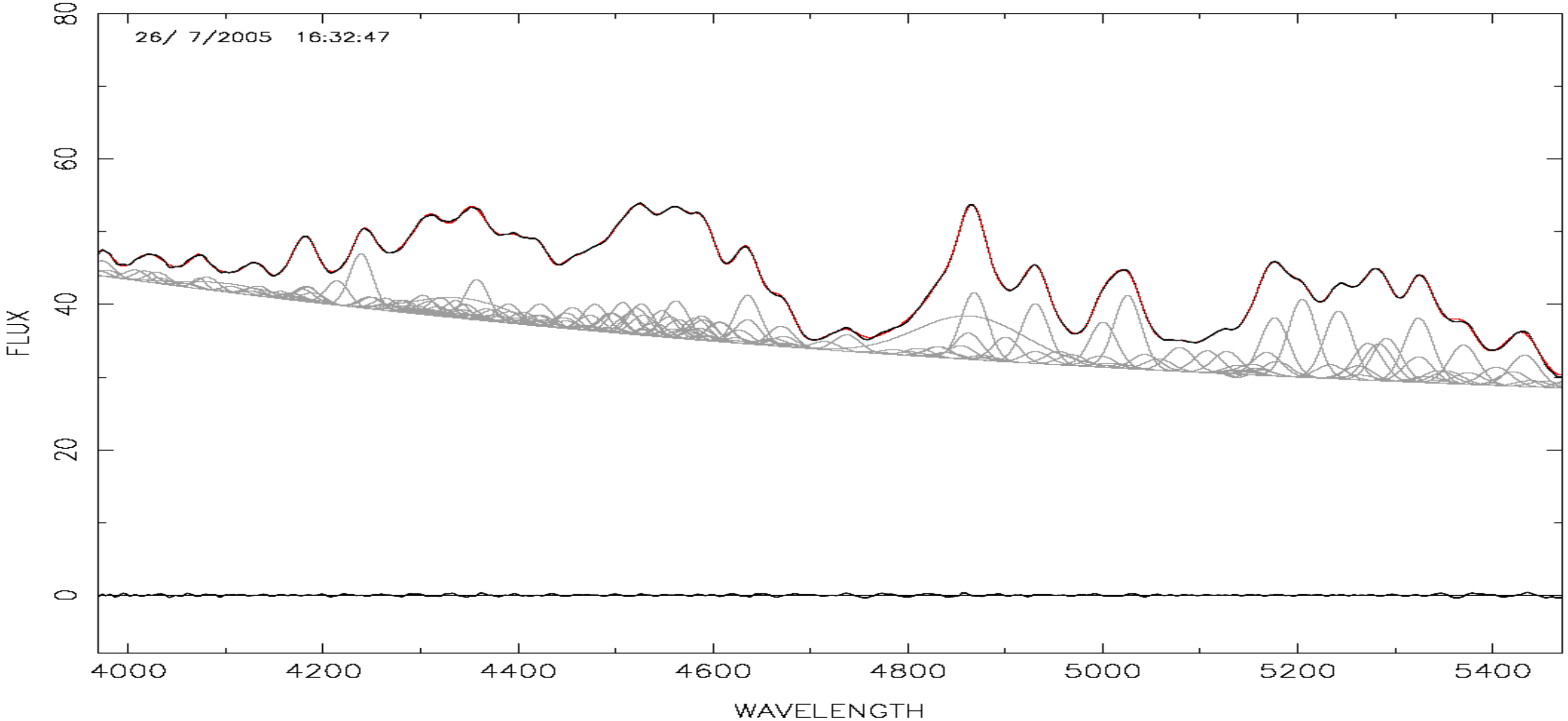


Detail Spectrum Analysis

Véron-Cetty et al. (2004, 2006):

- identified all the emission lines in I Zw1 and IRAS 07598+6508
- measured the line ratios referred to Hβ

IRAS 07598+6508



The emission regions

Optical Fe II is emitted in regions as different as:

- The NLR of I Zw1, a low-excitation region:
  H I, Ni II, Ti II, Si II, Cr II, [NII], [SII], [CaII], [OI], [FeII];
  no [OII] or [OIII]
  Fe II λ4570 / $H\beta_{narrow}$ = 3.1 $L_{\lambda 4570} = 7.10^{41}$ ergs s^{-1}

- The BLR of I Zw1:
  H I, He I, Na I D, Ti II, Si II; no HeII
  Fe II λ4570 / $H\beta_{broad}$ = 1.9 $L_{\lambda 4570} = 5.10^{42}$ ergs s^{-1}

- The nucleus of IRAS 07598+6508:
  HI, CaII H and K, NaI D; no HeI, HeII, no NLR
  Fe II λ4570 / Hβ = 8.0 $L_{\lambda 4570} = 10^{43}$ ergs s^{-1}

Physical Conditions in the NLR of I Zw1

[NII] → $Ne > 10^5$ cm^{-3} if $T \sim 8000$ K

[SII] → $10 < Ne < 10^5$ cm^{-3}

[OI] → $Ne \sim 10^7$ cm^{-3} if $T \sim 8000$ K

no [OII], [OIII] → very low ionization parameter, $Ne \sim 10^8$ cm^{-3}

Standard photoionization model using CLOUDY (Ferland 2002)

with $U = 4.10^{-5}$ and $N_H = 5.10^{17}$ cm^{-2}

FeII λ4570/Hβ cal = 0.30 FeIIλ4570/Hβ obs = 3.

Physical Conditions in the BLR of AGN

From variability and reverberation mapping we have a guess of the size of the BLR (cf. e.g. Kaspi et al. 2005):
few tens of light days

Using standard parameters for a BLR, i.e.:

$$n = 10^{12}\ \mathrm{cm}^{-3},\ U = 10^{-2},\ N_H = 10^{23}\ \mathrm{cm}^{-2}$$

CLOUDY photoionization models

FeII λ4570/Hβ = 0.9

1.9 for I Zw1
8.0 for IRAS 07598+6508

Some lines are much too strong in models:
HeII λ4686, HeI λ5876, Lyα, MgII, Balmer Continuum

Problems

Standard photoionization models are not able to explain the Fe II emission.

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)

A controversy: the dominant excitation process

What are the Excitation Mechanisms ?

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

both produced by radiative processes in standard models as the Locally Optimally emitting Clouds model (LOC, Baldwin et al., 1995).

LOC models 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.

The goal is to weaken the HII region and to strengthen the HI*

Need for an efficient heating like Mechanical Heating.

Models

Radiative + Mechanical Heating:

$n = 10^{12}\ cm^{-3}$ R = 1 to 10 pc
mechanical heating: 6.10^{45} ergs s^{-1}

FeIIλ4570/Hβ = 8.
Lα, MgII, FeIIUV, CaII, NaID much too strong

$n = 10^{14}\ cm^{-3}$ mechanical heating: 2.10^{46} ergs s^{-1}

better for MgII and FeIIUV but still too strong
worse for CaII, NaID

Need of a region producing only FeII?

Purely Collisional Models

Emission region shielded from the central source of radiation

Excitation and ionization only due to mechanical heating

	I Zw1	IRAS 07598+6508	
$L_{\lambda 4570}$	5.10^{42}	10^{43}	ergs s^{-1}
n	10^{14}	10^{15}	cm^{-3}
N_H	10^{24}	10^{25}	cm^{-2}
Heating	2.10^{44}	6.10^{44}	ergs s^{-1}
f	5 %	5 %	

CONCLUSION

The FeII emission is highly variable from object to object.
It is emitted in BLR and NLR of AGN.
In strong FeII emitters the emission region has probably
a high density and column density,
is shielded from the central source of radiation
and mechanically heated.

In order to make progress, we need both:

- better theoretical models and atomic data,
- high resolution, high S/N spectra in order to identify individual lines