

Photoionised gas in Seyfert I Galaxies revealed through emission lines in high resolution spectra

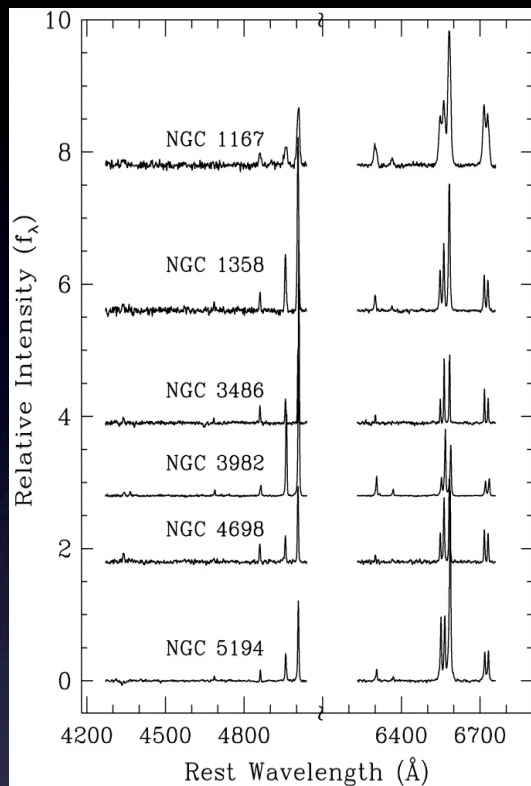
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Achille Nucita, Maria Santos-Lleo, Matteo Guainazzi
(ESAC)

Unification models

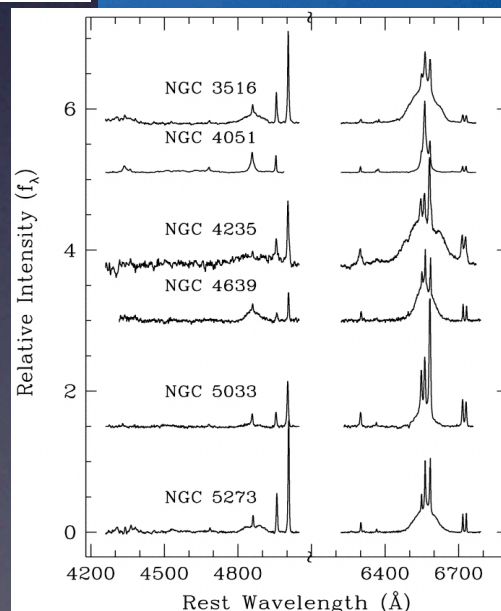
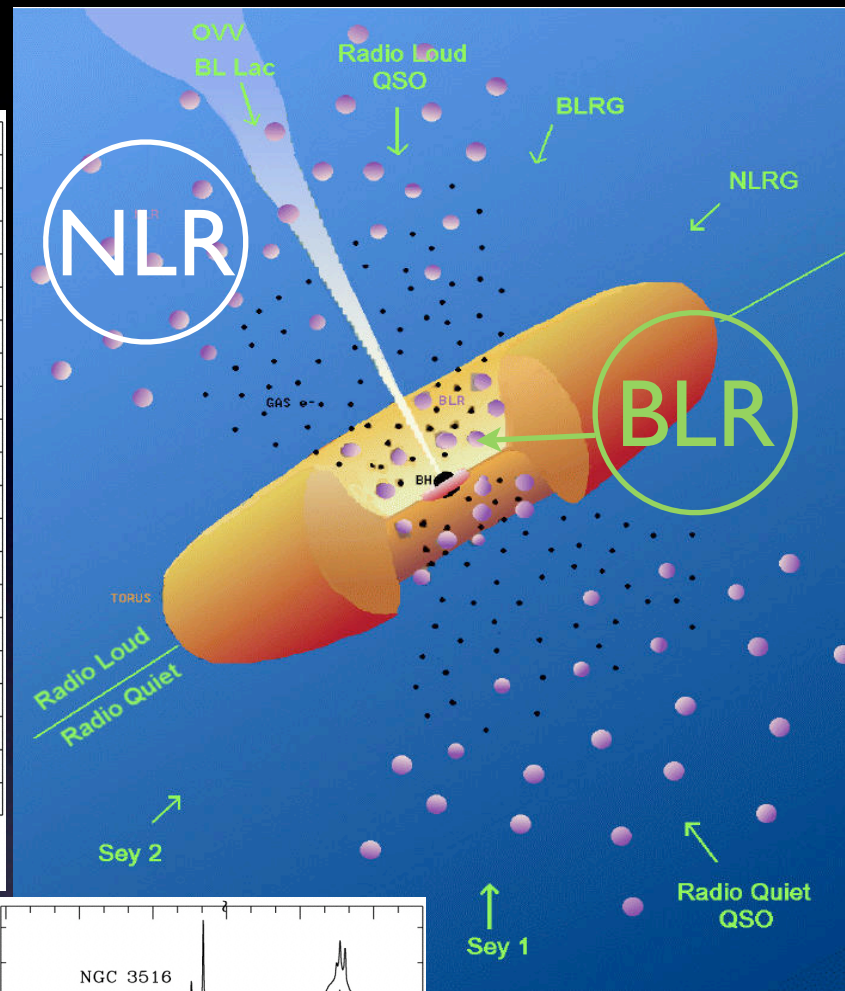
Seyfert 2

Narrow optical lines

($v \leq 1000 \text{ km s}^{-1}$)



(Ho et al. 1997)



(Ho et al. 1997)

Seyfert 1

Broad optical lines

($v \geq 1000 \text{ km s}^{-1}$)

Well established evidence for Compton thick torus on parsec-scale:

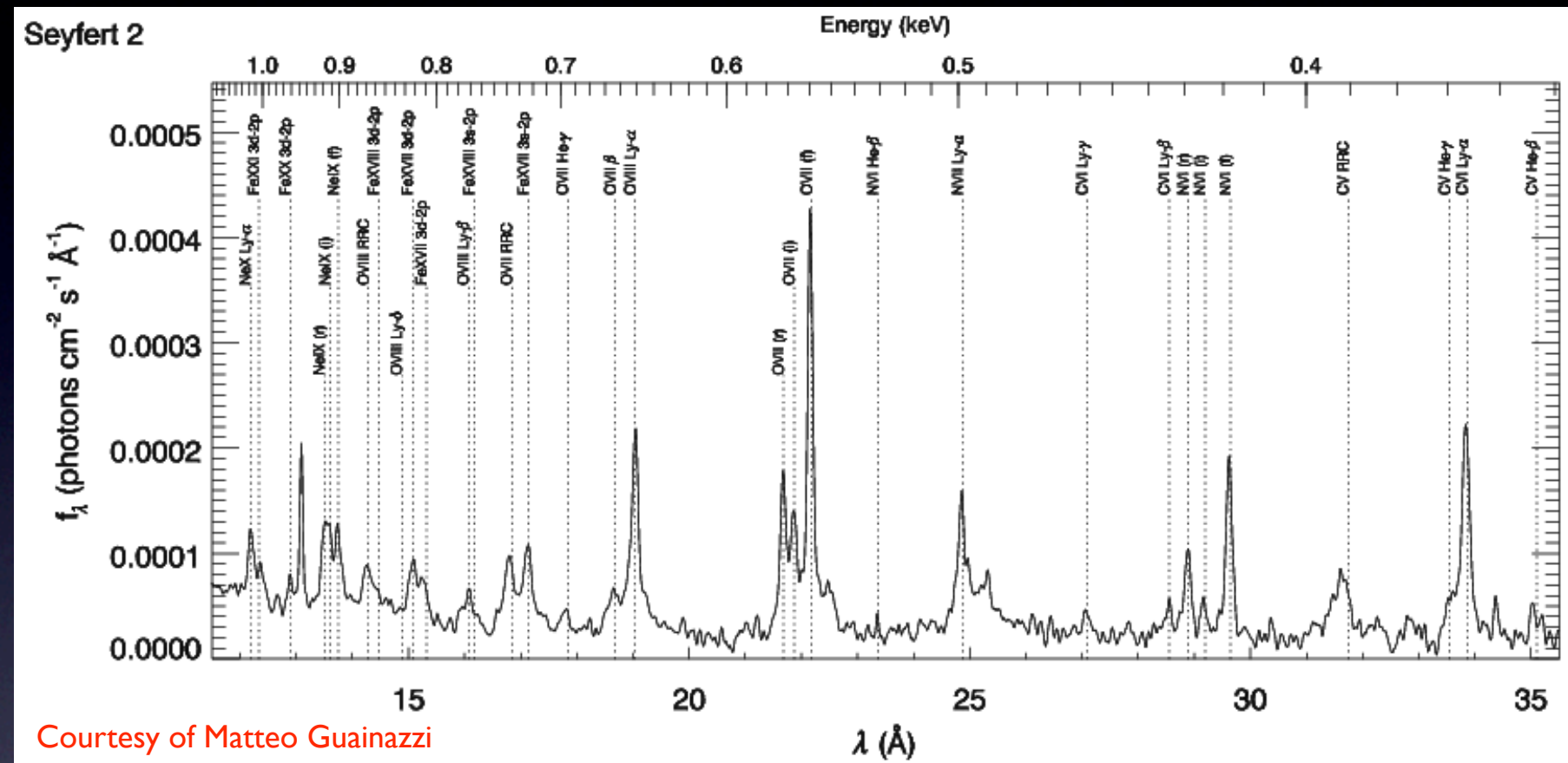
IR interferometry in Sy 2 NGC 1068 (Jaffe et al. 04)

Several X-ray measurements of ubiquitous narrow Fe K α line from Compton Reflection in type I AGN (Bianchi +07)

Obscured AGN at high resolution: average spectrum of a Seyfert 2

2 Ms RGS exposure of 33
Seyfert 2s

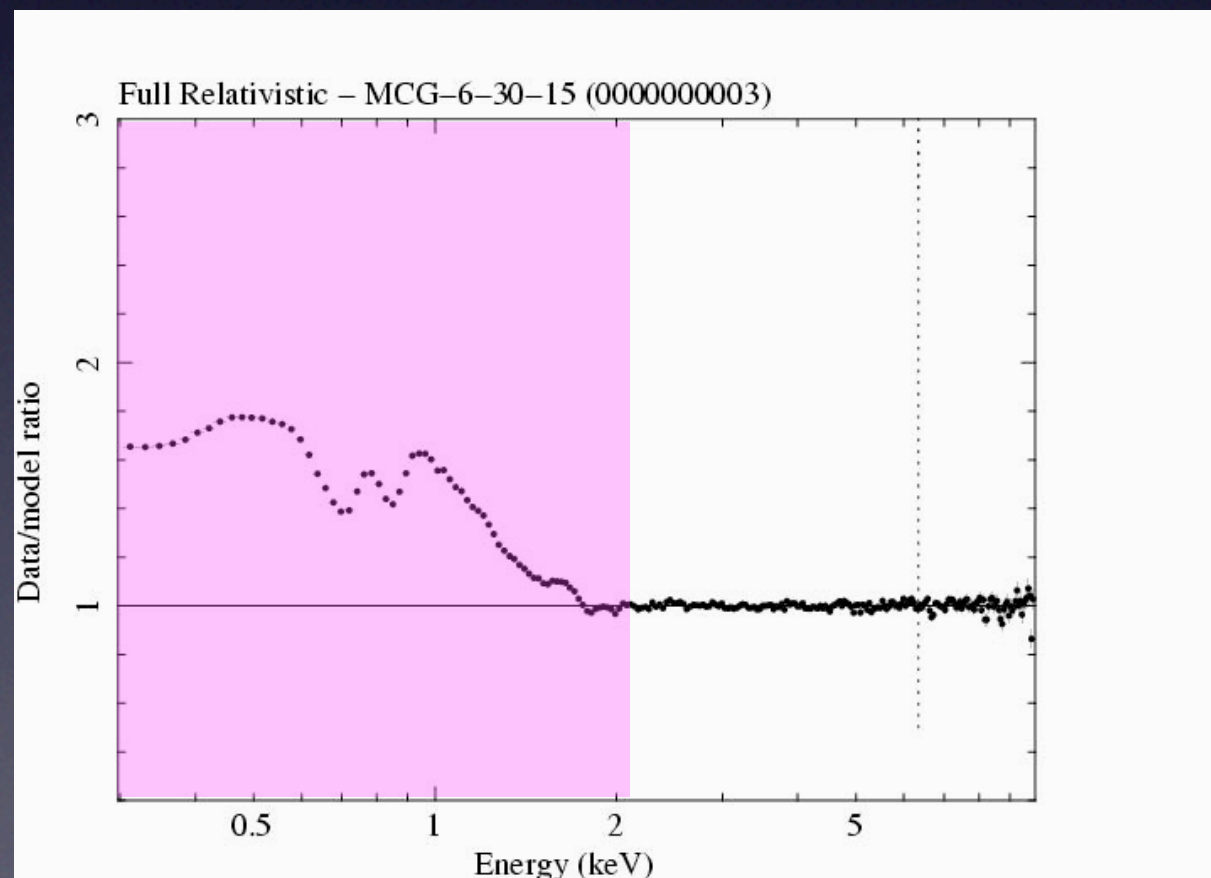
- CIELO catalogue of 69 obscured AGN (Guainazzi & Bianchi 07)
- Soft X-ray spectra dominated by transitions of H- and He-like O, Ne, C and high detection rate of narrow RRC of $T \sim \text{few eV}$, photoionisation by the AGN continuum.
- Large EW due to no continuum
- **Best studied case NGC 1068**, (Kinkhabwala+ 02)
see Dan Evans's talk



Spatial coincidence of HST O[III] and Chandra soft X-ray images of Seyfert 2s shows that soft-X-ray emission is mostly consistent with photoionisation in the extended NLR (Bianchi et al. 06)

Unobscured AGN at high resolution: average Seyfert 1 ?

- Direct view of the nuclear continuum
- In $\sim 50\%$ of sources, warm absorbers of numerous N_H , ξ
- Different flux levels (Sy2 are always soft X-ray obscured)



XMM-Newton
pn data-to-model
ratios of Seyfert 1:
variety of soft
X-ray shapes

Emission lines in Seyfert I: the case for Mrk 335

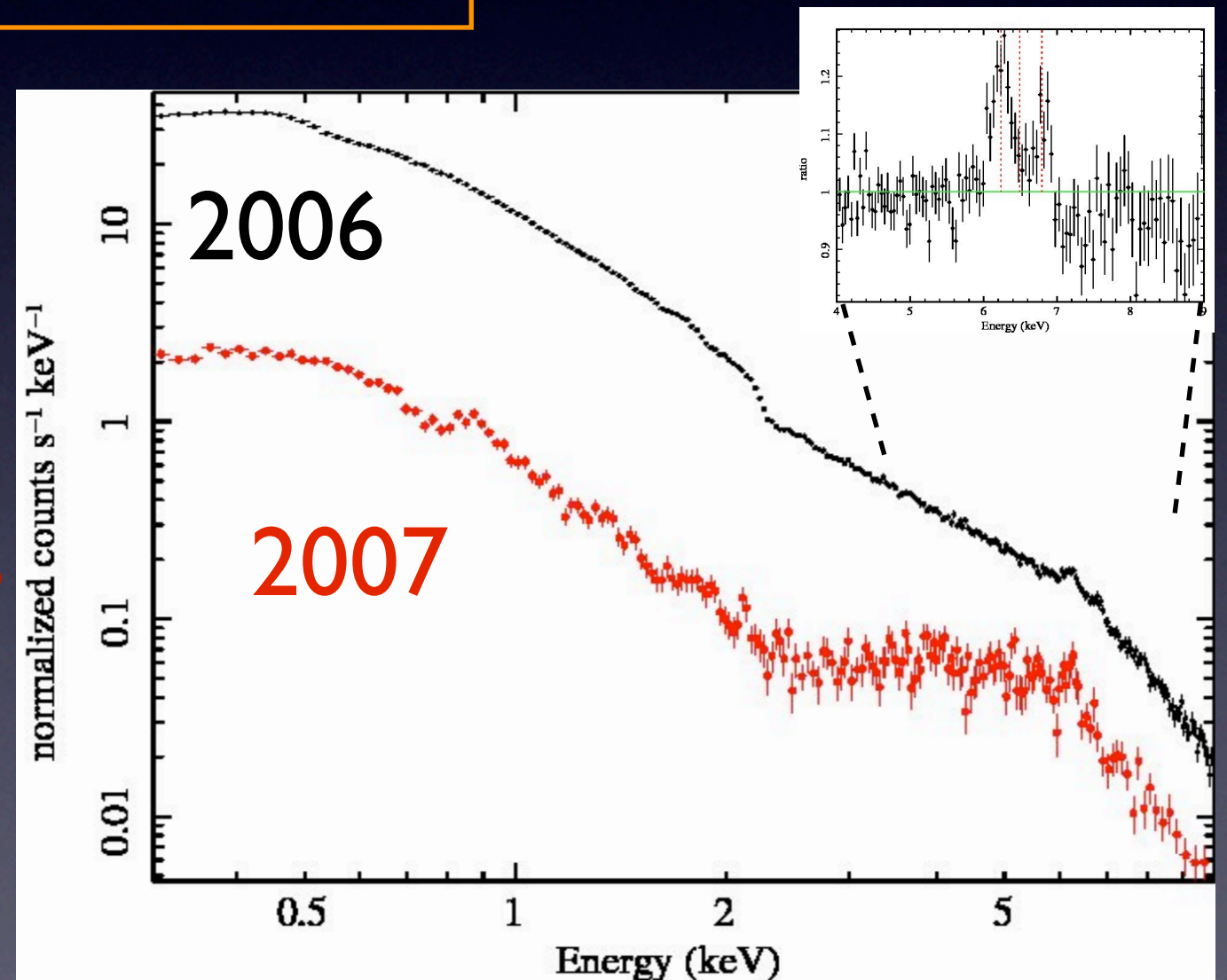
Date	Exp	Γ_{soft}	Flux _{soft}	Γ_{hard}	Flux _{hard}
-	(ks)	-	(10^{-12} cgs)	-	(10^{-12} cgs)
2007	22	2.84 ± 0.03	1.9 ± 0.1	1.02 ± 0.07	3.3 ± 0.8
2006	130	2.72 ± 0.01	32 ± 0.1	2.09 ± 0.01	18 ± 0.2

XMM-pn

XMM high state: usual Sey I continuum with complex Iron K line (O'Neill et al. 2007)

Swift, XMM low state: flux drop, flattening of hard X-ray spectrum possibly due to gas partially covering the AGN

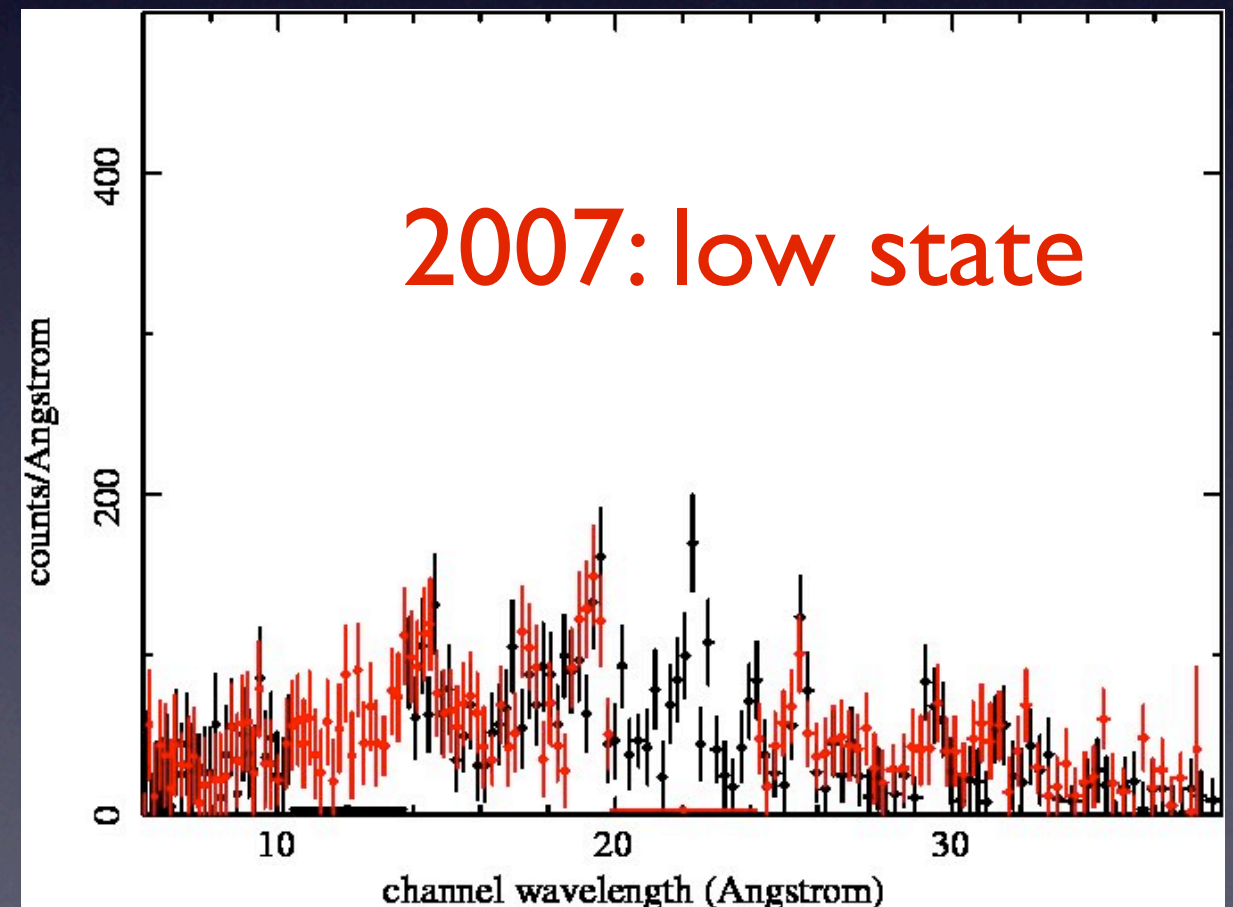
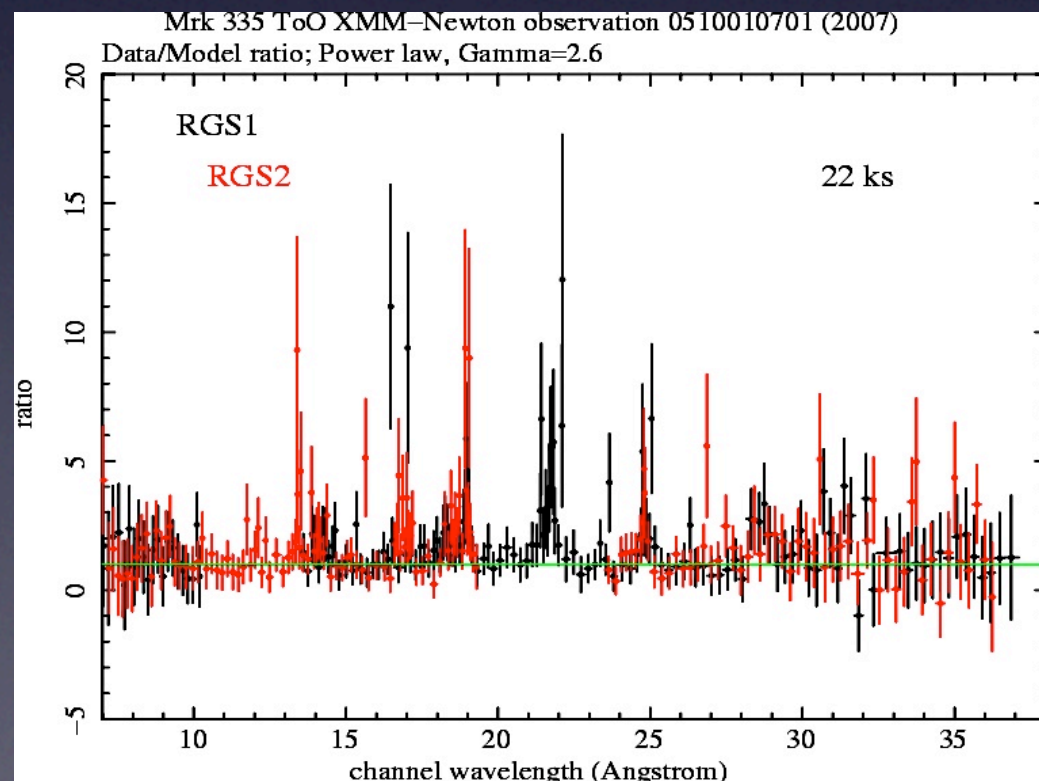
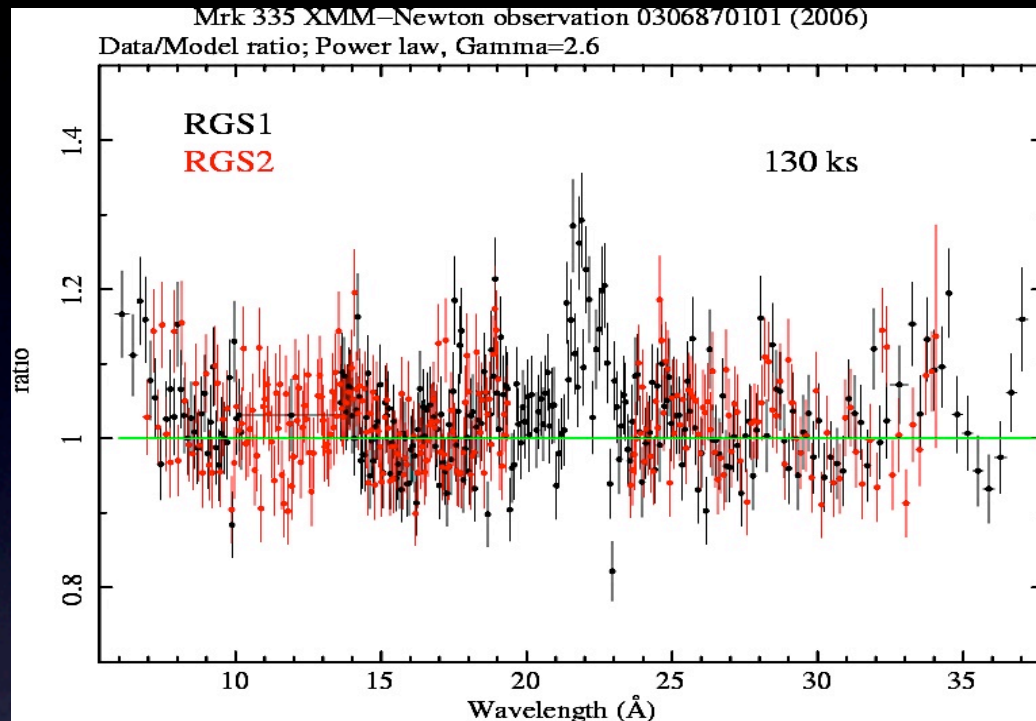
(Grupe et al. 2007, 2008)



Mrk 335 RGS spectra

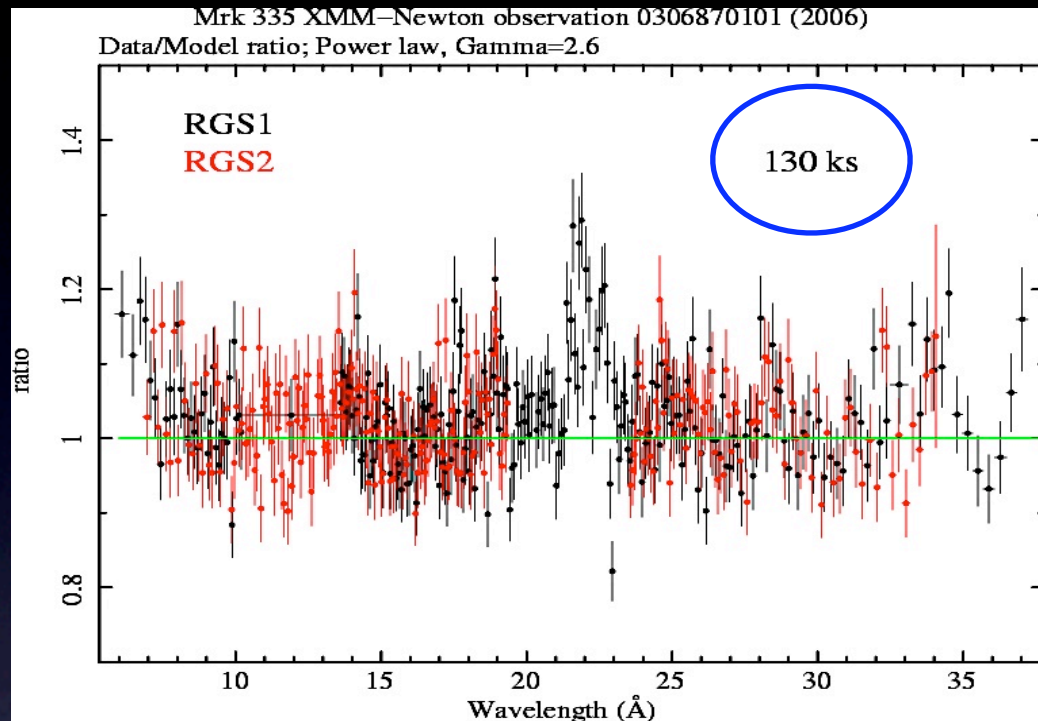
Data-to model (power law) ratios

2006 high state:
no warm absorber

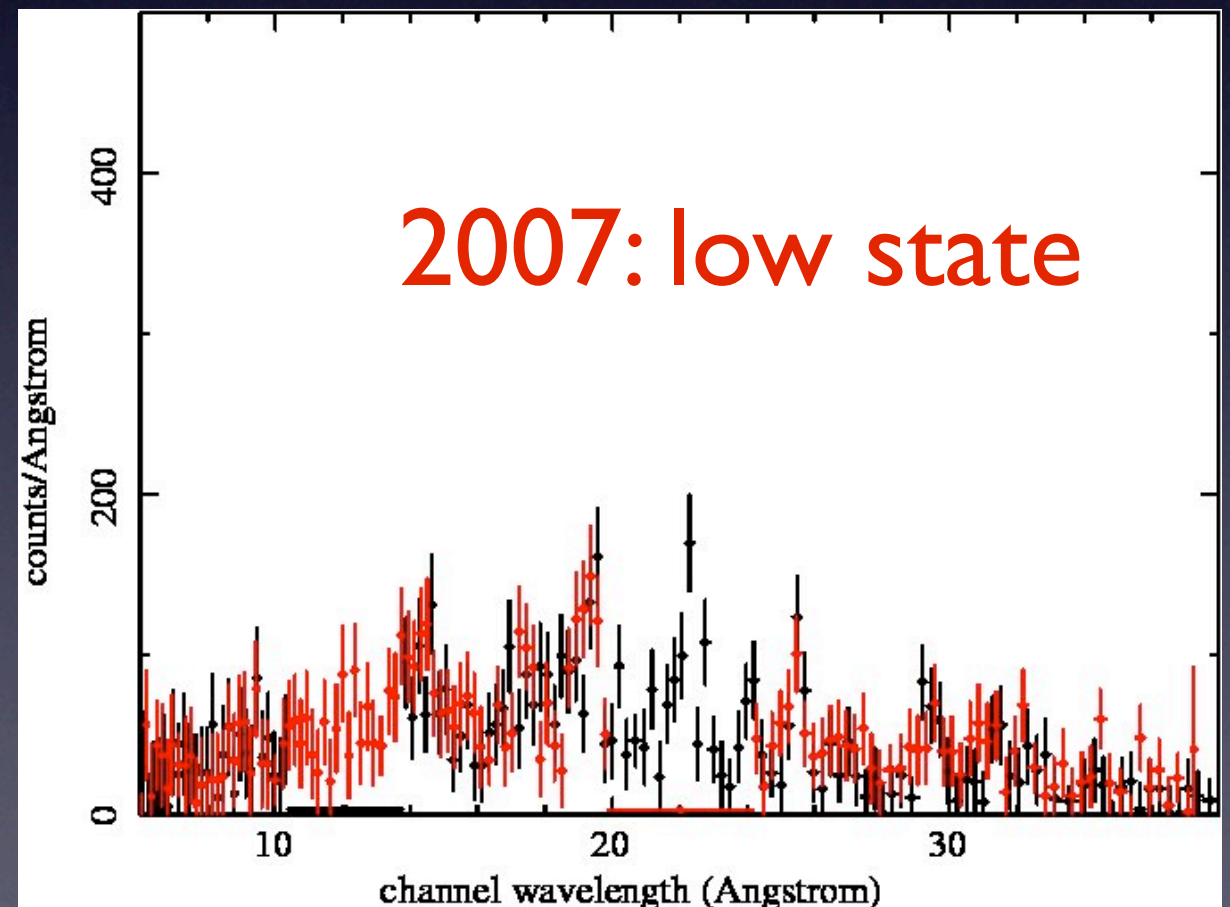
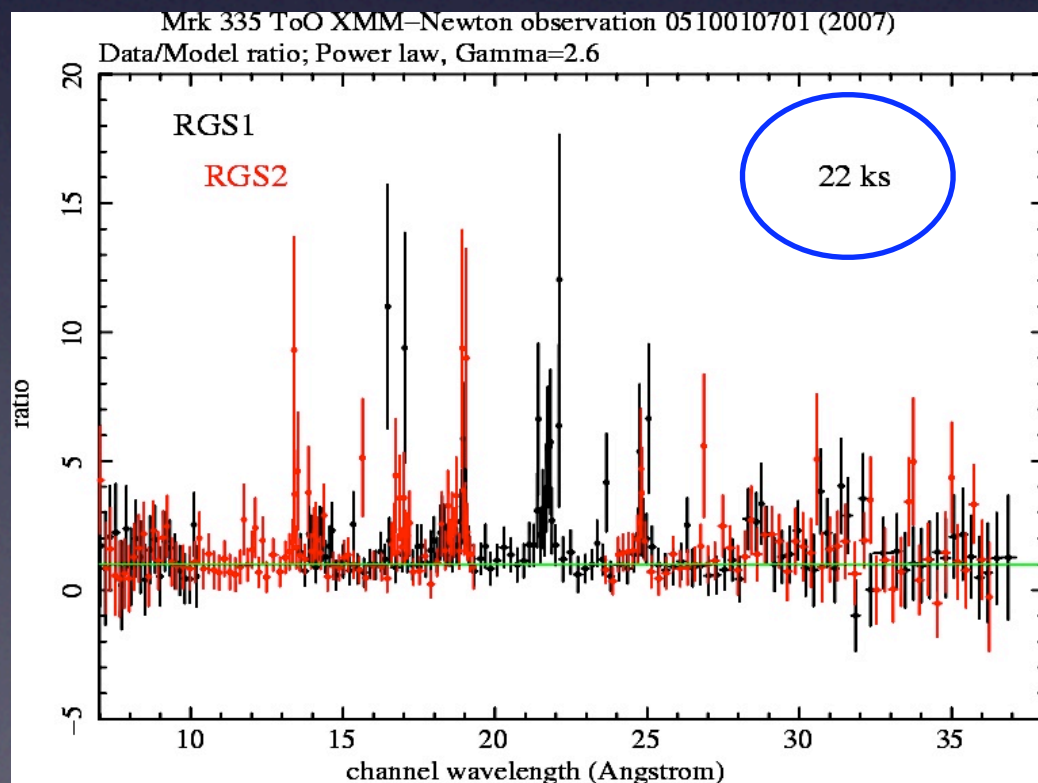


Mrk 335 RGS spectra

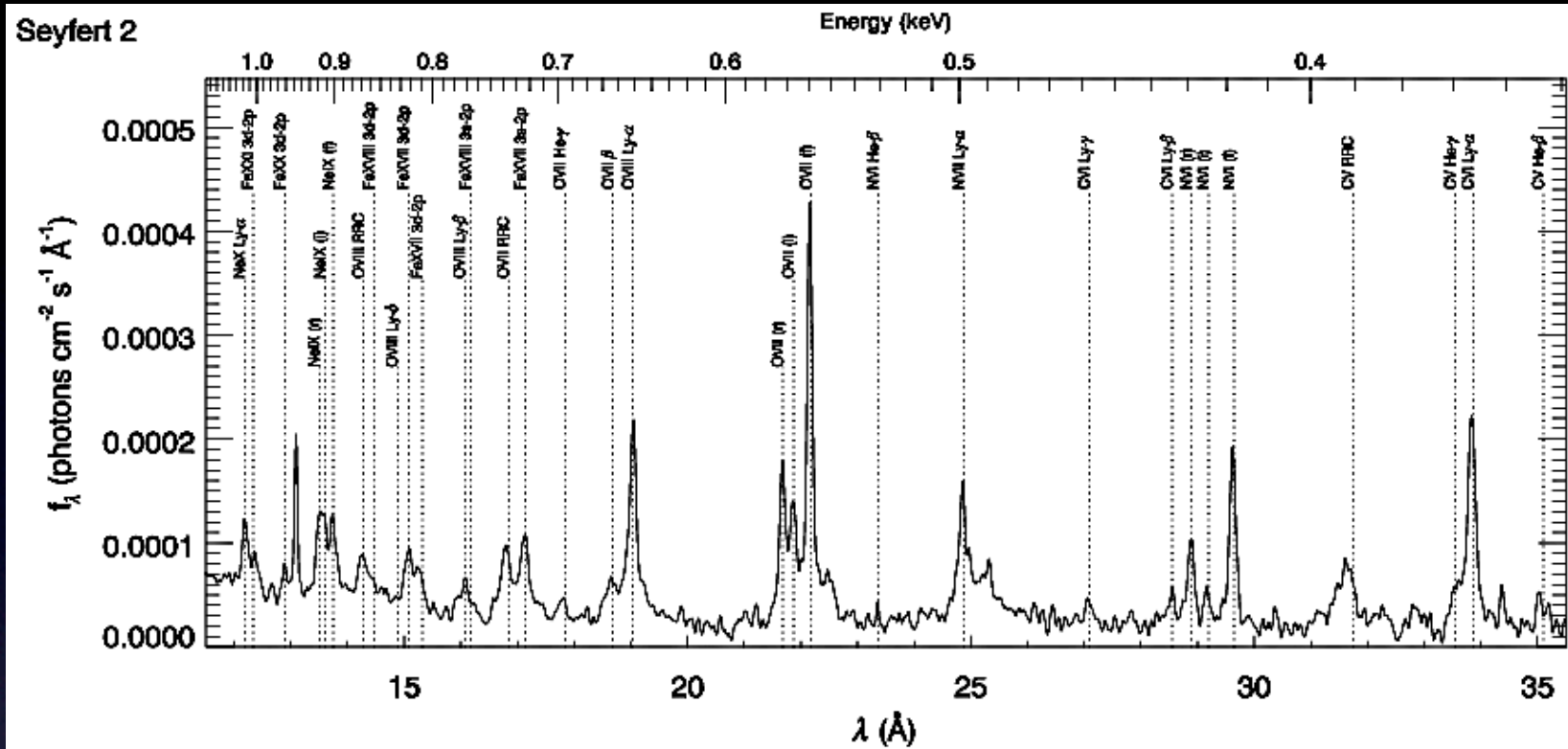
Data-to model (power law) ratios



2006 high state:
no warm absorber

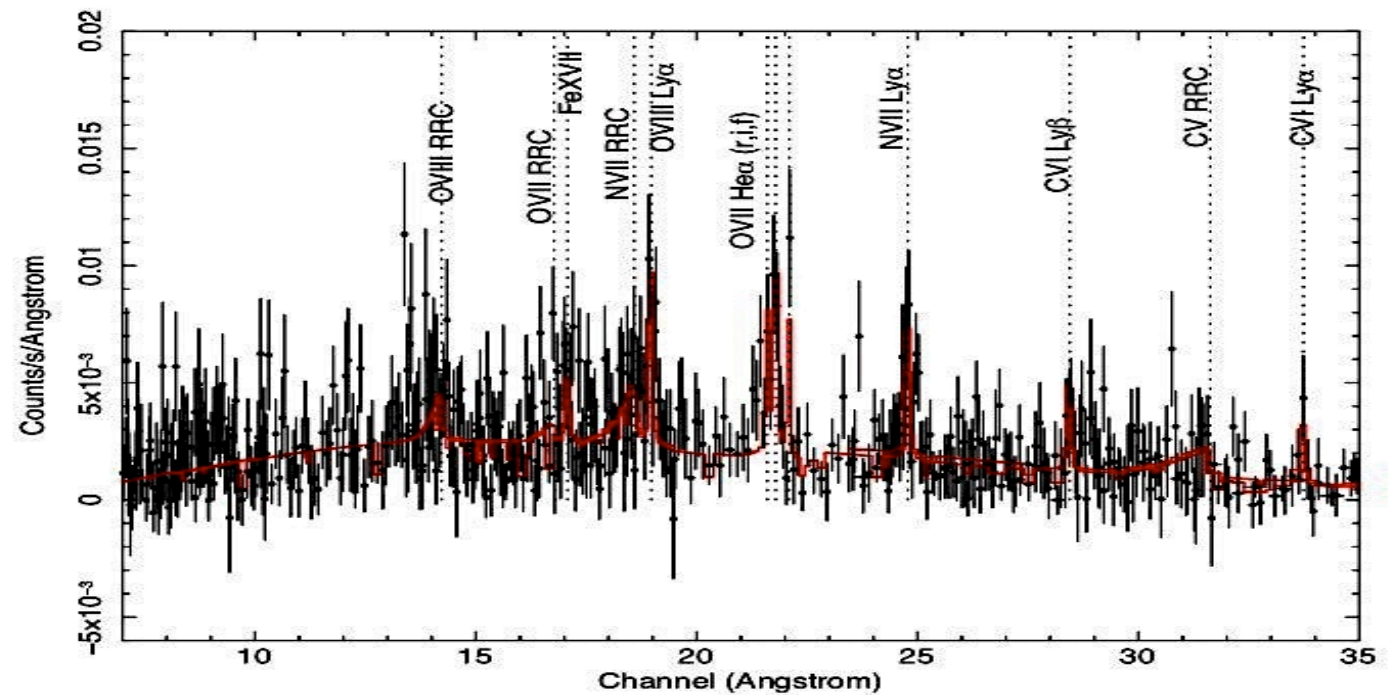


Analogy with Sy2 ?



Average Sy2

Soft X-ray lines in Mrk 335 may be signature of photoionisation in the NLR as for Sy2: the nuclear continuum drops, the NLR becomes visible in the X-rays, agreement with Unification scheme...

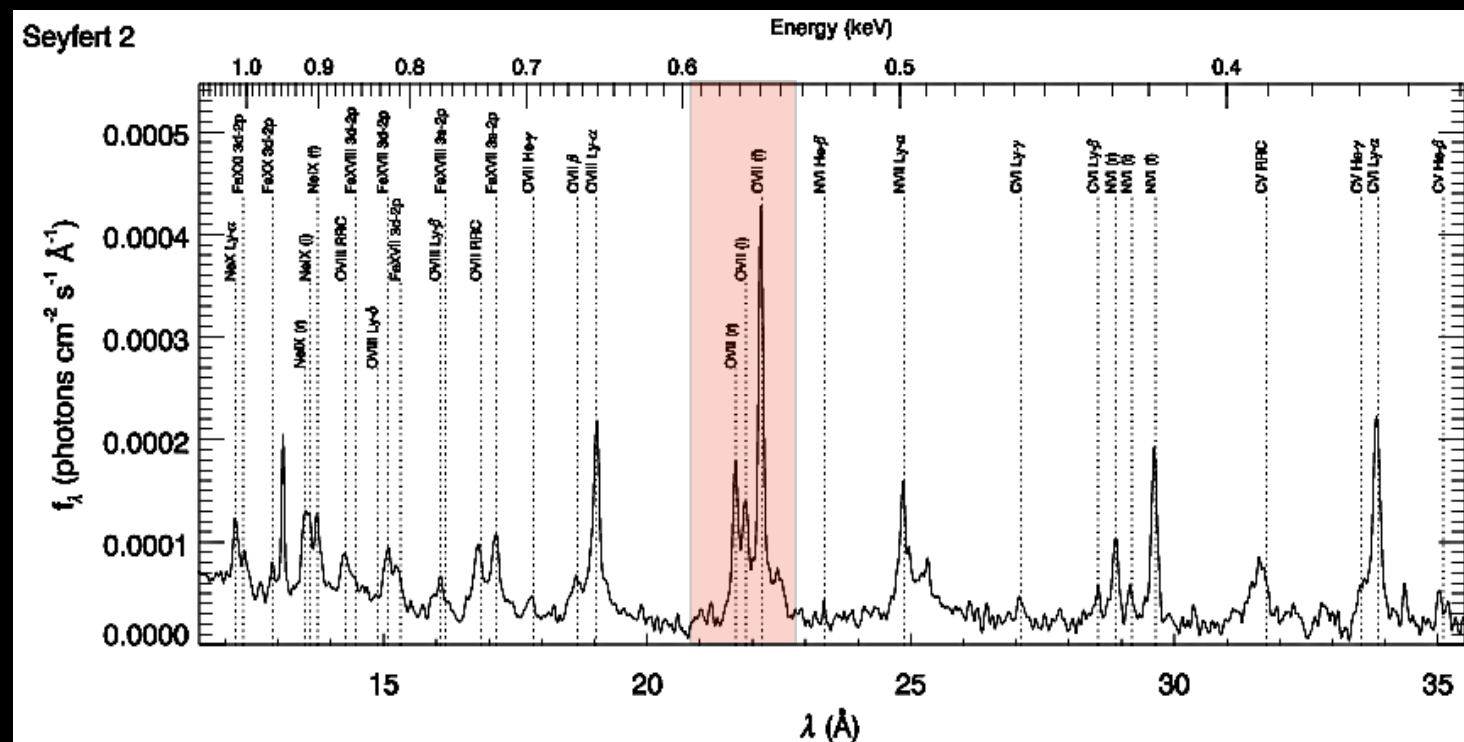
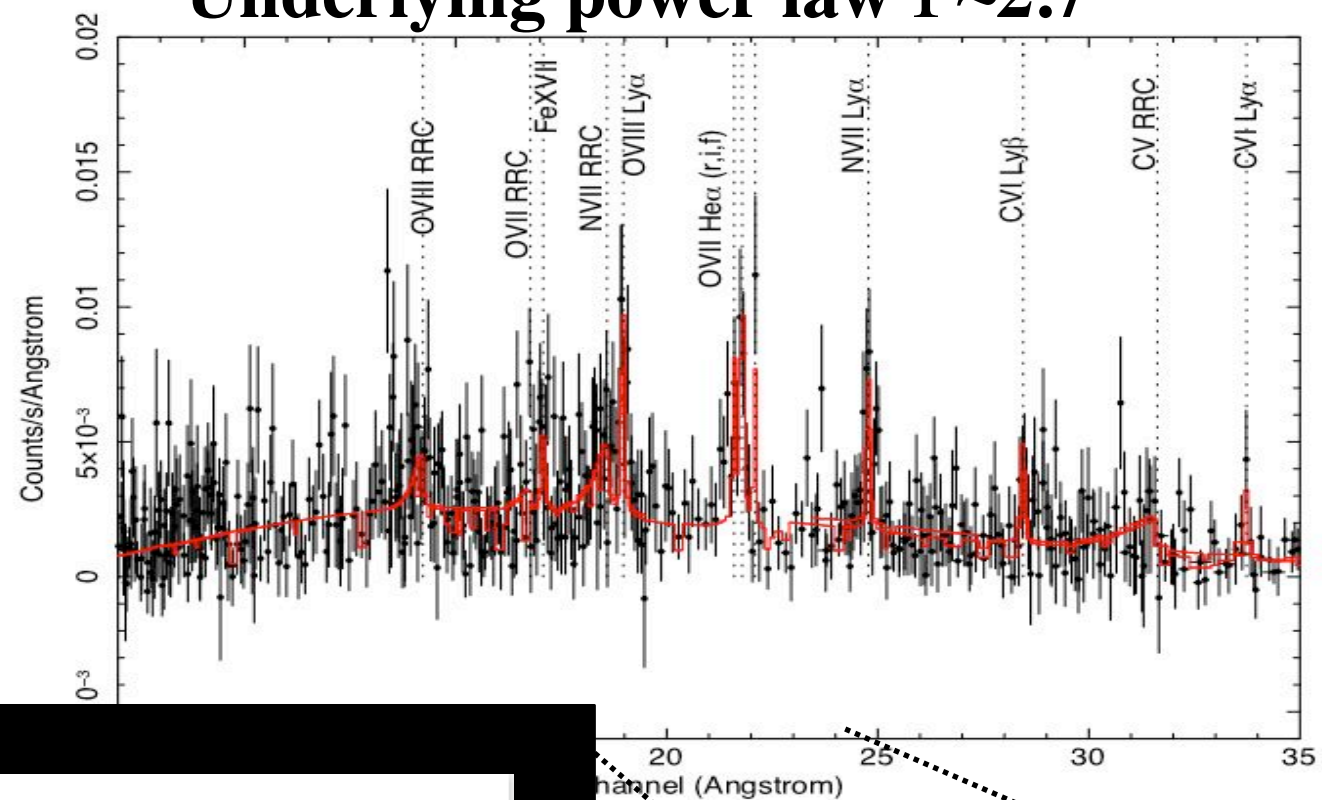


Soft X-ray emission lines

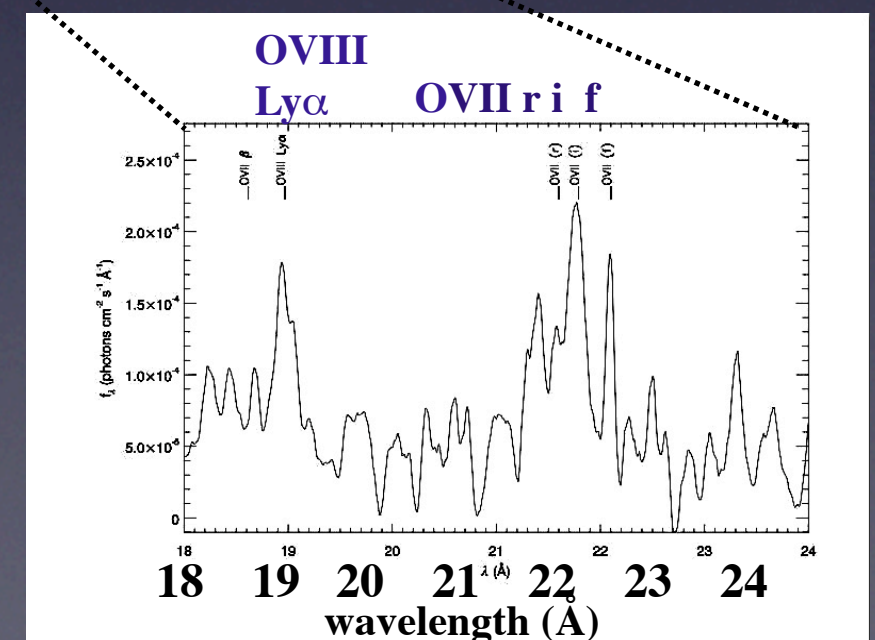
Detected emission lines

Transition	λ (lab) (Å)	Flux ¹ _{FWM=0} ph m ⁻² s ⁻¹	ΔC	Flux ² _{FWM(OV10)} ph m ⁻² s ⁻¹
FeXVII	17.073	< 0.05	$\Delta C=1$	0.06±0.04
OVII Heβ	18.627	< 0.03	$\Delta C=0$	0.06±0.04
OVI Lyα	18.969	0.20±0.04	$\Delta C=31$	0.27±0.05
OVII Heα (r)	21.600	0.10±0.06	$\Delta C=4$	0.17±0.08
OVII Heα (i)	21.790	0.26±0.08	$\Delta C=21$	0.31±0.09
OVII Heα (f)	22.101	0.17±0.07	$\Delta C=12$	0.16±0.07
NVII Lyα	24.781	0.13±0.05	$\Delta C=12$	0.18±0.05
CVI Lyβ	28.446	0.13±0.06	$\Delta C=13$	0.20±0.07
CVI Lyα	33.736	0.15±0.06	$\Delta C=8$	0.24±0.07

Underlying power law $\Gamma \sim 2.7$

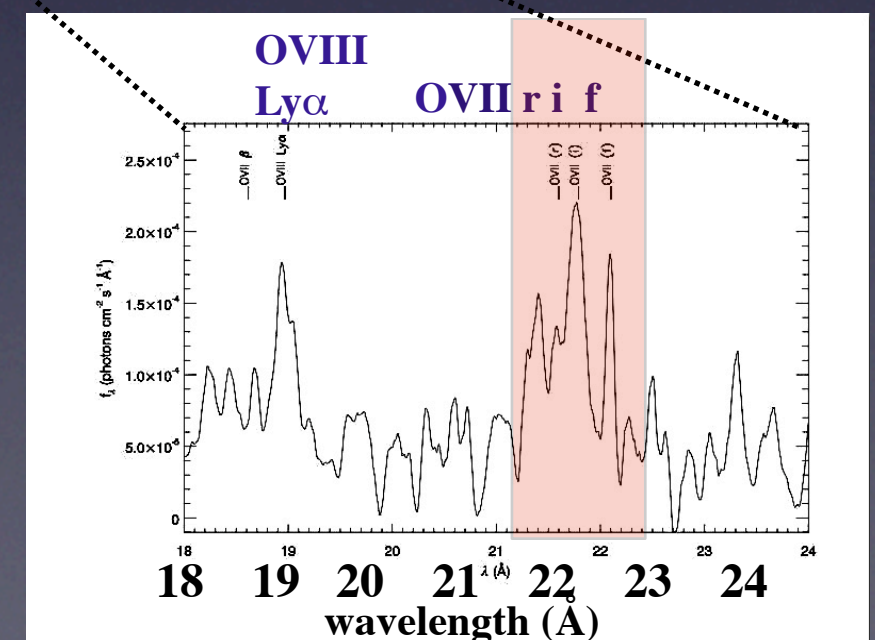


Average Seyfert 2 spectrum



Detected emission lines

Underlying power law $\Gamma \sim 2.7$



Average Seyfert 2 spectrum

Line ratio diagnostic and CLOUDY

Line ratios in
He-like O
triplet and line
fluxes for all
detections

+

CLOUDY
simulations

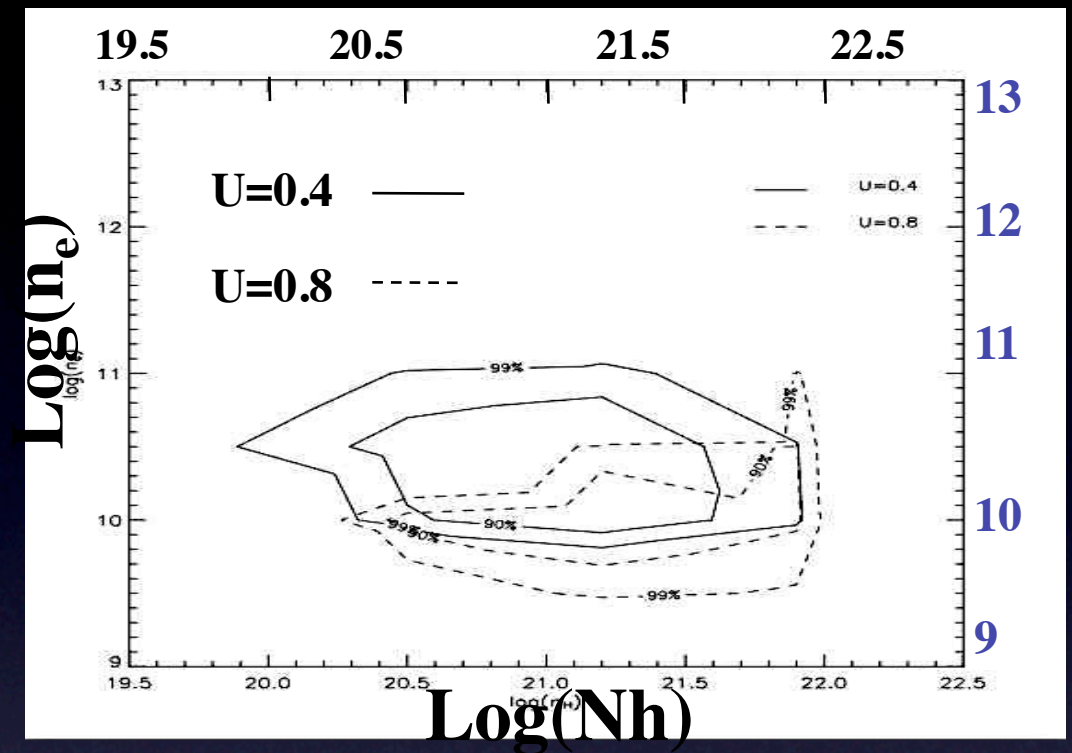
$R=f/i$ Density diagnostic
 $G=(f+i)/r$ Temperature diagnostic
(Porquet & Dubau 2000)

Parameters range:

Electron density = 10^9 - 10^{11} cm $^{-3}$

Column Density = 10^{20} - 10^{22} cm $^{-2}$

log U (ionisation par) = 0.4-0.8



$$U = \frac{Q(H)}{4\pi r^2 n(H) c}$$

$$Q(H) = k \int_{\nu_1}^{\nu_2} \frac{\pi F_{\nu}}{h\nu} d\nu$$

Gas distance
within

$2 \times 10^{16-17}$ cm

Line ratio diagnostic and CLOUDY

Line ratios in
He-like O
triplet and line
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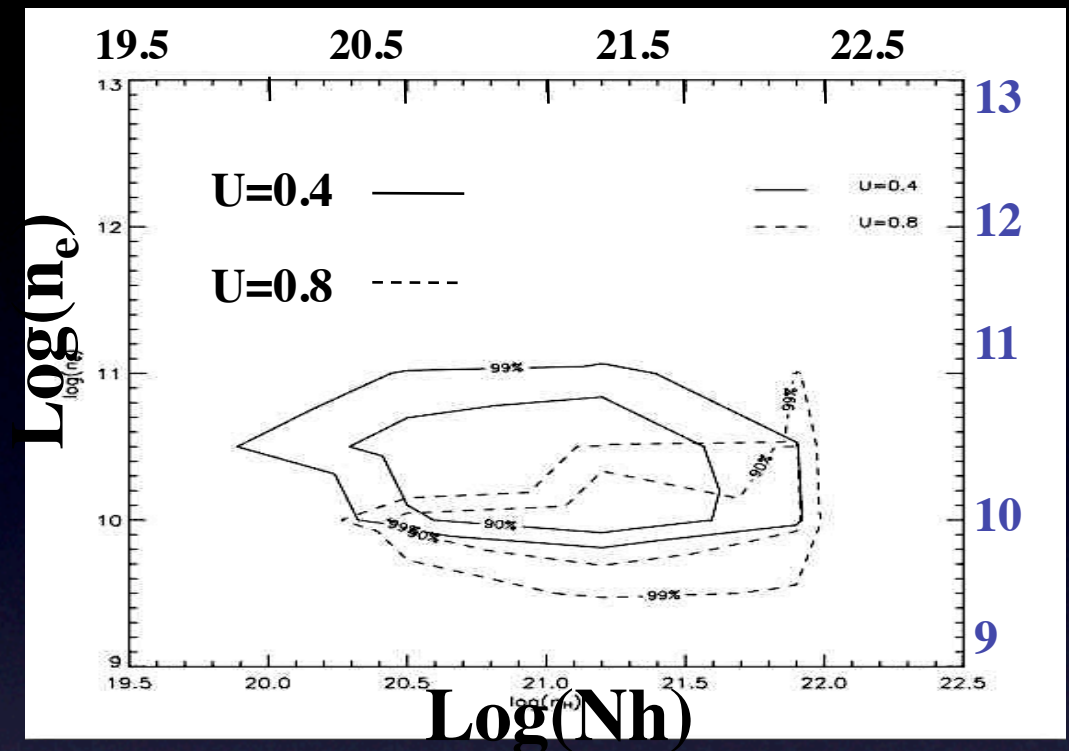
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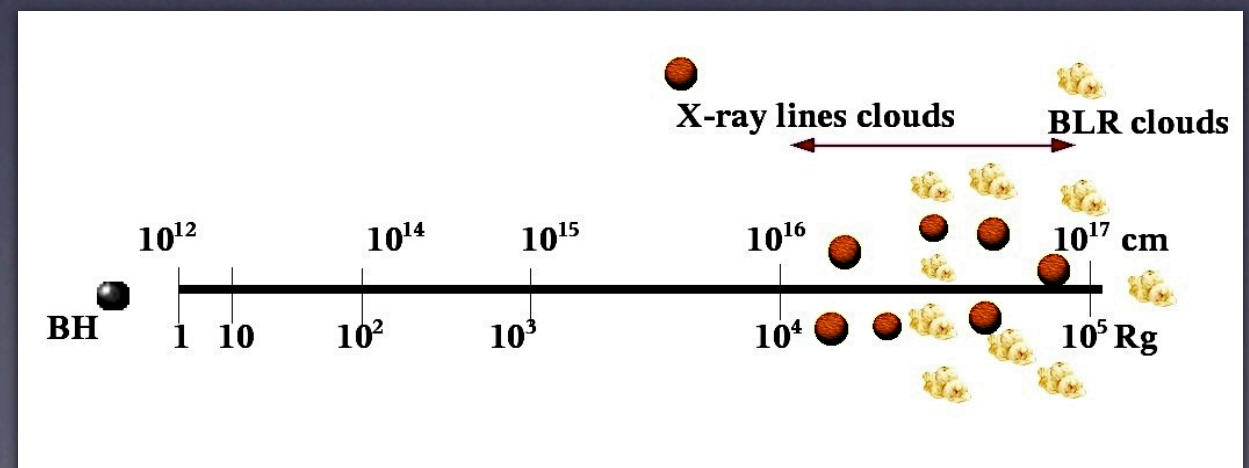
$$Q(H) = k \int_{\nu_1}^{\nu_2} \frac{\pi F_{\nu}}{h\nu} d\nu$$

Gas distance
within

$2 \times 10^{16-17}$ cm

From FWHM H β
line and BH mass

location consistent
with BLR clouds



Longinotti+ 2008 A&A 484 311L

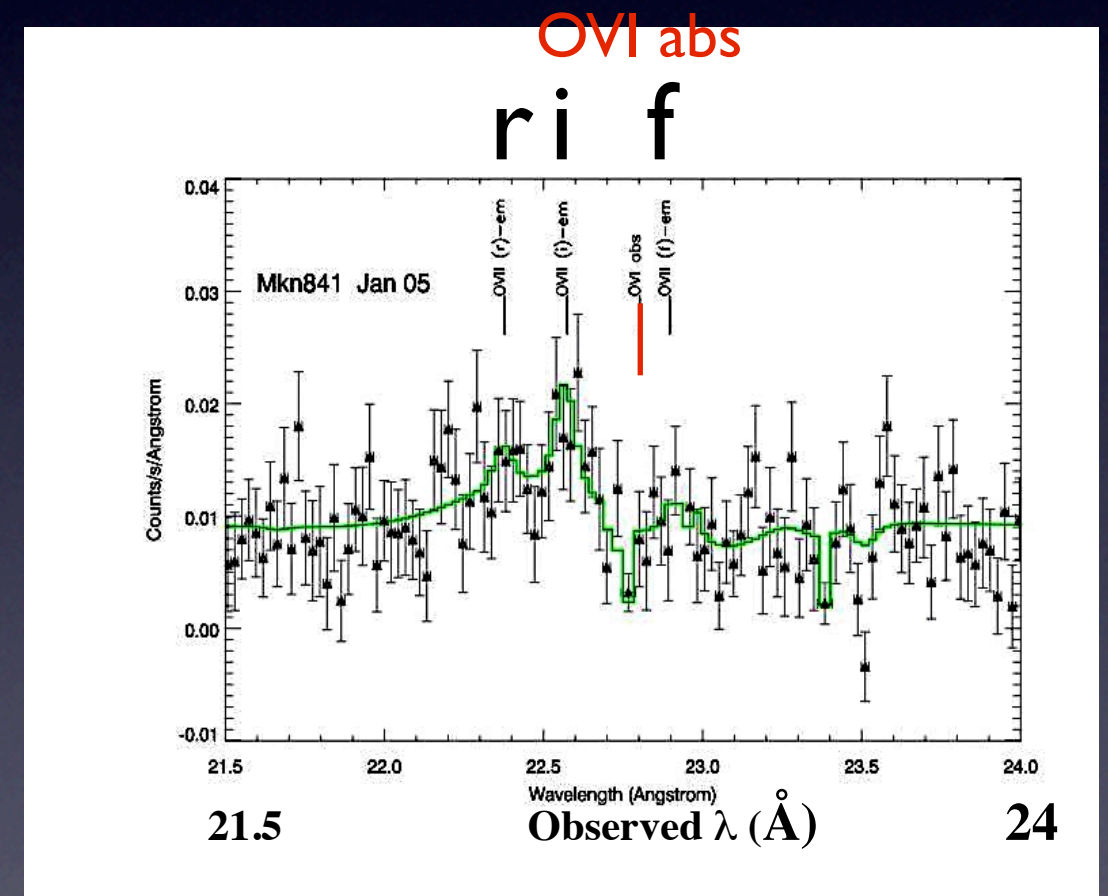
X-ray emission lines in the BLR: other sources

- NGC 7213 see next talk by S. Bianchi
- Mkn 279 Costantini et al. 2007
- Akn 564 Smith et al. 2008
and many more sources

- Mkn 841, two-phase warm
absorber and emission lines

Longinotti in prep.

- NGC 4051 Nucita et al. in prep.



NGC 405 I low state spectrum

A. Nucita, Y. Maruccia, M. Guainazzi, A.L. Longinotti et al.

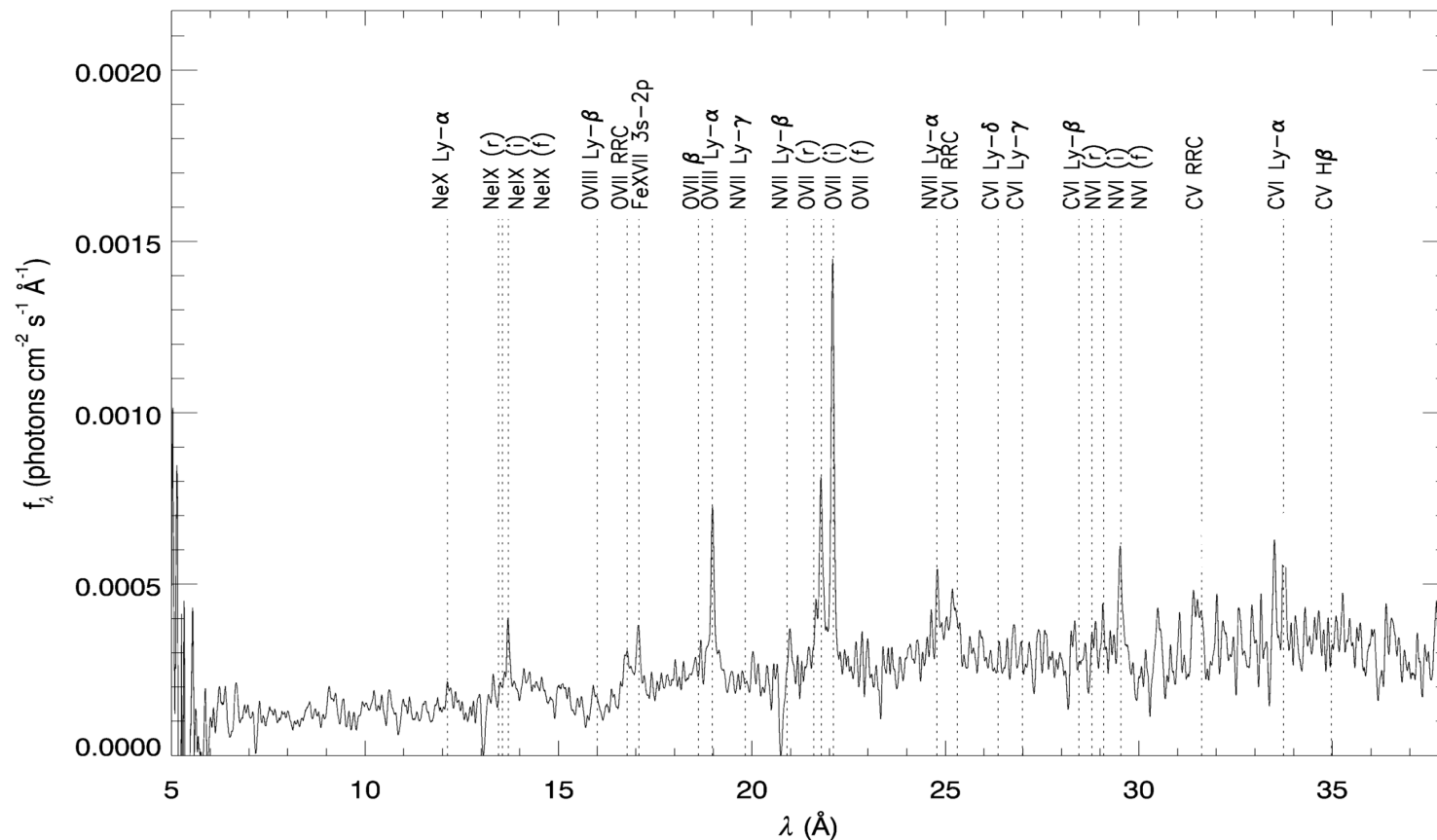


Table 1: NGC 4051 properties of the observed emission lines.

Line ID	$\lambda_{exp}(\text{\AA})$	$\lambda_{obs}(\text{\AA})$	v (kms ⁻¹)	Flux ($\times 10^{-14}$ cgs)	ΔC
<i>NeXLa</i>	12.132	12.207 ^{+0.106} _{-0.054}	1850 ⁺²⁶³⁰ ₋₁₃₄₀	1.35 ^{+0.94} _{-0.86}	2.6
<i>NVI_r</i>	28.787	---	---	$\lesssim 0.91$	0.9
<i>NVI_i</i>	29.082	29.074 ^{+0.022} _{-0.015}	-80 ⁺²²⁰ ₋₁₅₅	1.33 ^{+0.53} _{-0.66}	6.3
<i>NVI_f</i>	29.534	29.524 ^{+0.022} _{-0.015}	-110 ⁺¹⁵⁰ ₋₇₀	3.55 ^{+0.66} _{-0.79}	38.3
<i>OVIIL_b</i>	16.006	15.902 ^{+0.036} _{-0.041}	-1950 ⁺⁵⁷⁰ ₋₇₆₀	1.43 ^{+0.79} _{-0.71}	11.3
<i>FeXVII_{s2p}</i>	17.097	17.065 ^{+0.040} _{-0.021}	-556 ⁺⁷¹⁰ ₋₃₈₀	3.26 ^{+1.43} _{-1.53}	20.7
<i>OVIIL_{Hb}</i>	18.627	18.535 ^{+0.063} _{-0.091}	-1480 ⁺¹⁰²⁰ ₋₁₄₇₀	1.12 ^{+0.65} _{-0.65}	3.4
<i>OVIIL_{La}</i>	18.967	18.978 ^{+0.012} _{-0.020}	180 ⁺¹⁹⁰ ₋₃₁₀	7.01 ^{+1.19} _{-1.12}	135.2
<i>NVII_{Lg}</i>	19.826	---	---	---	---
<i>NVII_{Lb}</i>	20.910	20.985 ^{+0.039} _{-0.023}	1080 ⁺⁵⁵⁰ ₋₃₂₀	2.14 ^{+1.33} _{-1.17}	9.6
<i>OVIIL_r</i>	21.602	21.585 ^{+0.011} _{-0.015}	-230 ⁺¹⁵⁰ ₋₂₁₀	0.47 ^{+0.33} _{-0.38}	0.5
<i>OVIIL_i</i>	21.804	21.804 ^{+0.250} _{-0.173}	-4 ⁺³⁴³⁰ ₋₂₃₈₀	7.16 ^{+1.75} _{-1.58}	74.0
<i>OVIIL_f</i>	22.101	22.103 ^{+0.029} _{-0.019}	30 ⁺²⁵ ₋₂₅	15.04 ^{+2.13} _{-1.96}	237.9
<i>NVII_{La}</i>	24.779	24.797 ^{+0.027} _{-0.018}	220 ⁺³³⁰ ₋₂₂₀	2.02 ^{+0.91} _{-0.84}	16.9
<i>CVIL_d</i>	26.357	---	---	---	---
<i>CVIL_g</i>	26.990	26.957 ^{+0.067} _{-0.067}	-370 ⁺⁷⁴⁰ ₋₇₄₀	0.89 ^{+0.67} _{-0.85}	2.6
<i>CVIL_b</i>	28.465	28.324 ^{+0.070} _{-0.044}	-1490 ⁺⁷³⁴ ₋₄₇₀	1.22 ^{+0.96} _{-0.84}	5.6
<i>NeIX_r</i>	13.447	---	---	$\lesssim 0.76$	0.0
<i>NeIX_i</i>	13.550	---	---	$\lesssim 0.80$	0.1
<i>NeIX_f</i>	13.699	13.698 ^{+0.019} _{-0.016}	-24 ⁺⁴¹⁵ ₋₃₆₀	4.68 ^{+1.32} _{-1.18}	49.8
<i>CVIL_a</i>	33.734	33.762 ^{+0.027} _{-0.016}	250 ⁺²⁴⁰ ₋₁₄₀	3.46 ^{+1.27} _{-1.14}	28.8
<i>CVH_b</i>	34.973	35.261 ^{+0.086} _{-0.067}	2475 ⁺⁷³⁸ ₋₇₅₀	1.03 ^{+1.05} _{-0.92}	3.5

Preliminary results on gas conditions:

From RRC diagnostic $T \approx 3 \cdot 10^4$ K

Distance ~ 0.5 pc Size ~ 0.08 pc

- High state: well established two-phase warm absorber (Krongold et al. 07, Steenbrugge et al. 09)
- Low state: prominent emission lines (Pounds et. al 04)

Cloudy grids of models produced from the XMM observed UV/X-ray SED and fitted on the data; more definitive results expected after inclusion of warm absorber in the model

Conclusions

- Photoionised gas in AGN may lie also within the optical Broad Line Region
- Geometry, relation to BLR clouds and other physical properties need to be explored, e.g. connection of X-ray clouds with warm absorbers (see NGC4051) and with accretion disc
- More and more and more high resolution data need to be analysed: so far only Mrk 335