THE ORIGIN OF THE SOFT X-RAY EXCESS IN AGN

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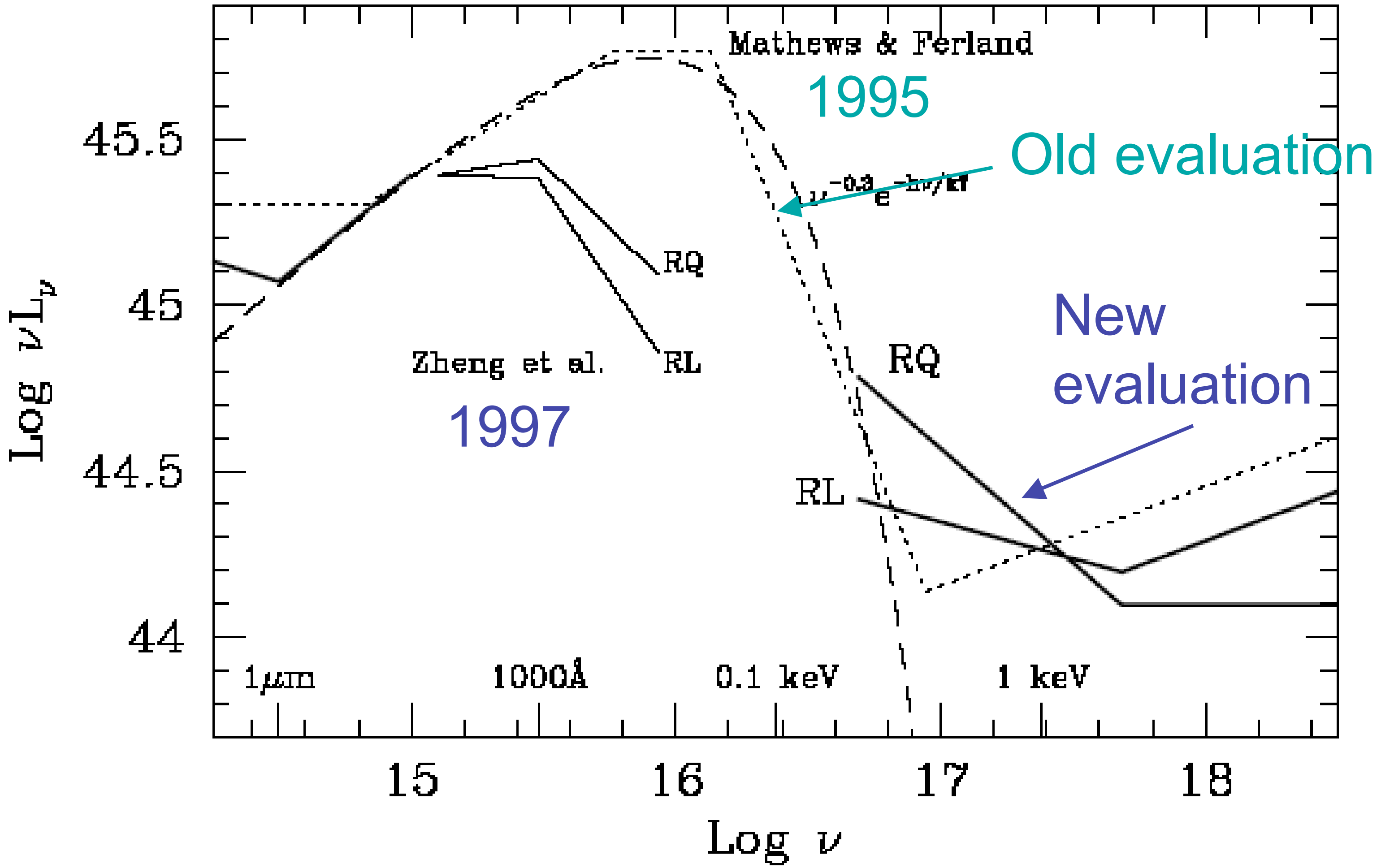
OUTLINE - PRELIMINARY WORK

- Samples of soft X-ray excess objects (50% QSOs)
- Pure reflexion models
- Pure absorption models (Gierlinski & Done 2004)
- Total constant pressure absorption models
- Simple calculations Mdot, R, f_{vol}, n_H,
- Hybrid scheme : reflexion + absorption
- (Escape probability vs. Full radiative transfer with ALI)

« SOFT X-RAY EXCESS » ALWAYS AROUND 1 KEV



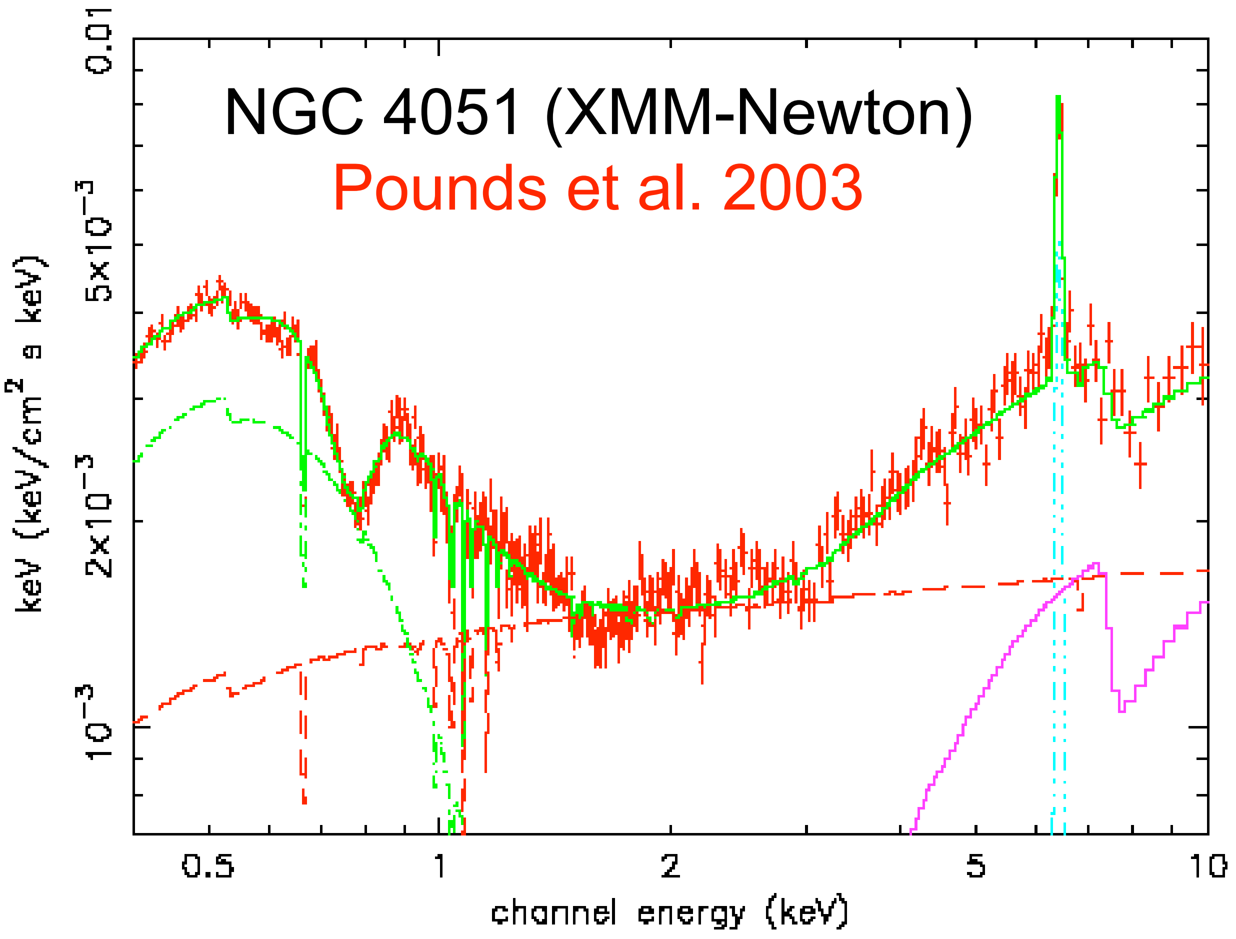
1995

Old evaluation

New evaluation

1997

Laor et al. 1997


NGC 4051 (XMM-Newton)

Pounds et al. 2003

Figure 15. The XSTAR 0.3–10 keV partial covering fit to the low state 2002 November observation of NGC 4051, showing the strong soft excess and a broad absorption trough at ∼0.76 keV. Also shown are the separate components in the fit: the unabsorbed power law (red), absorbed power law (pink), Gaussian emission line (blue) and blackbody (green). For clarity only the pn data are shown.

HOW TO EXPLAIN THIS EXCESS?

- Direct emission by the accretion disk impossible: T(disk) ≤ 20eV
- Emission by a comptonizing medium (T~200eV) difficult: T(corona) depends on variable T(disk)

↓

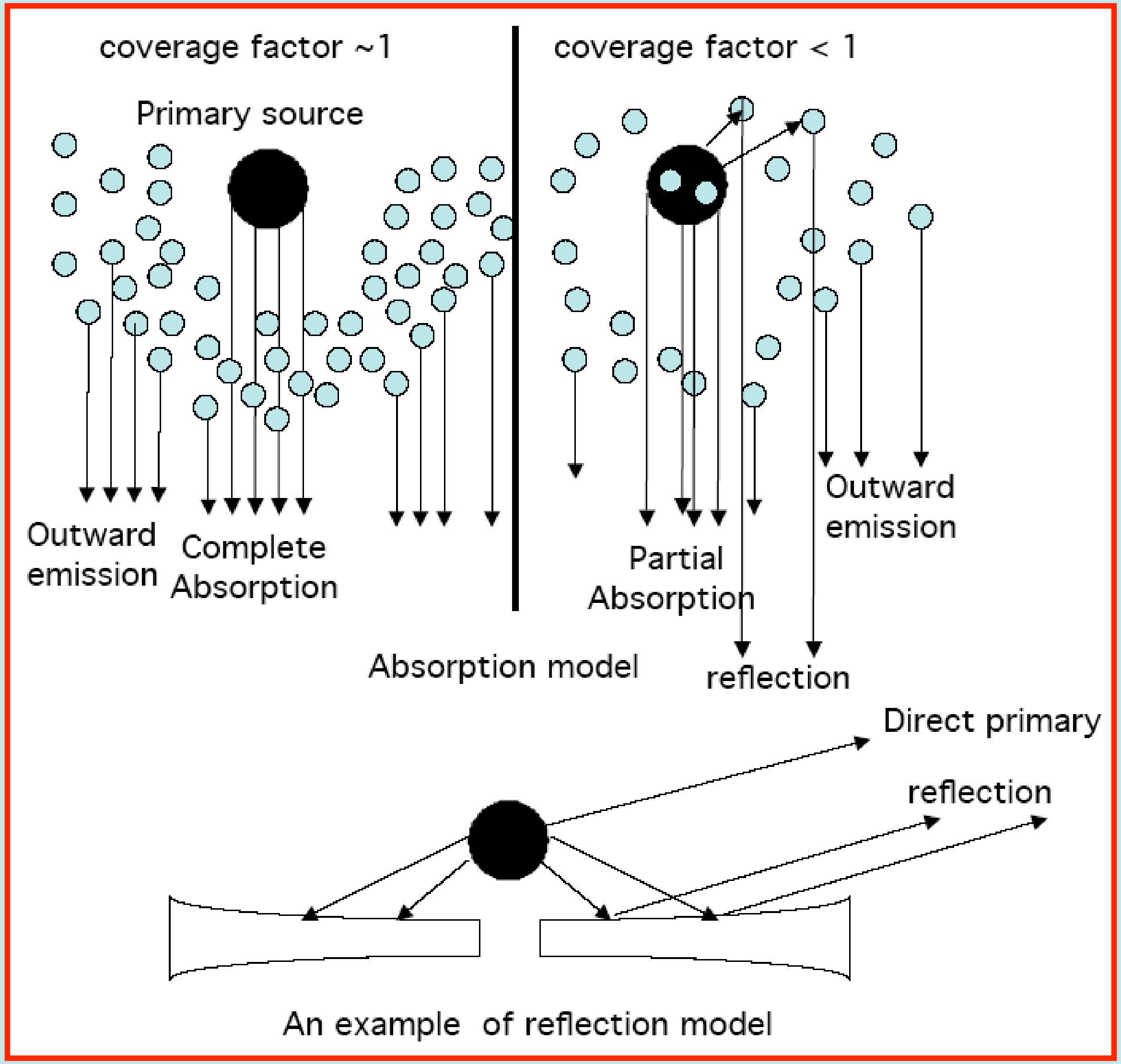
Atomic processes: numerous near 1 keV in a photoionized medium (T~10-100eV)

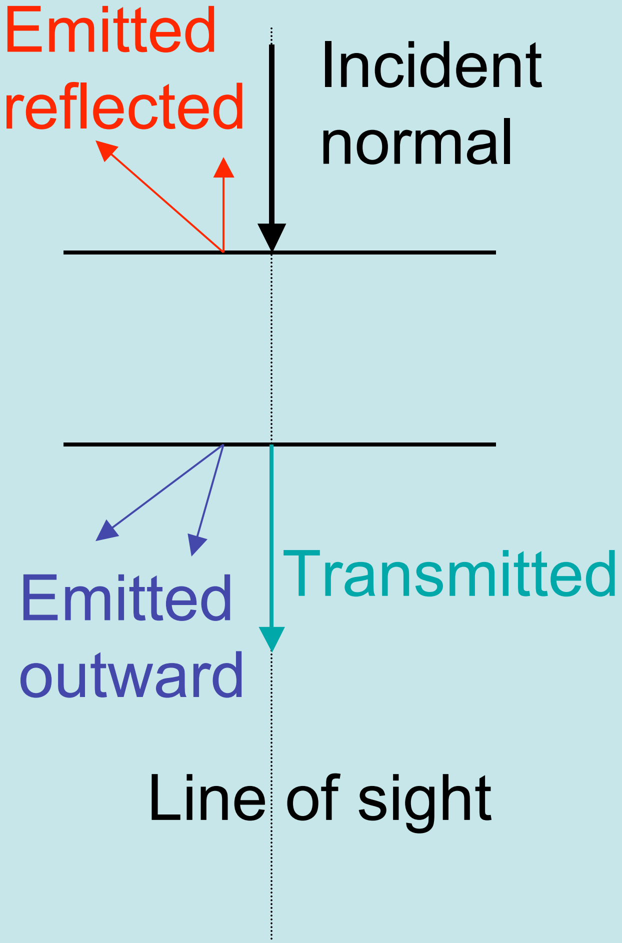
↓

Reflection or absorption by this medium

SOME MODELING SCHEMES

We test the most simple models: one component (clumpy or not)





Emitted reflected

Incident normal

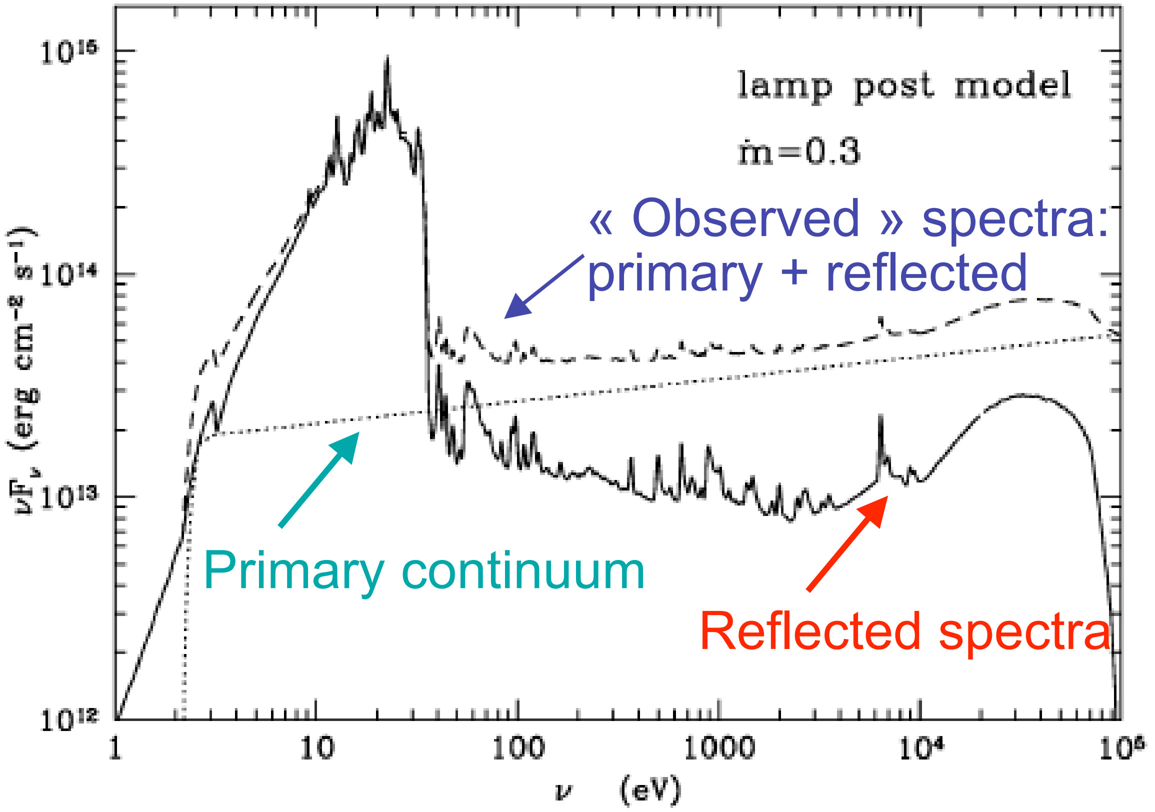
Emitted outward

Transmitted

Line of sight

MODEL WITH REFLECTION

Reflection of the primary continuum by the accretion disk:
very weak excess, unless primary is hidden
(Fabian et al. 2002: accretion rates near Eddington;
Crummy et al. 2005: relativistic light bending)

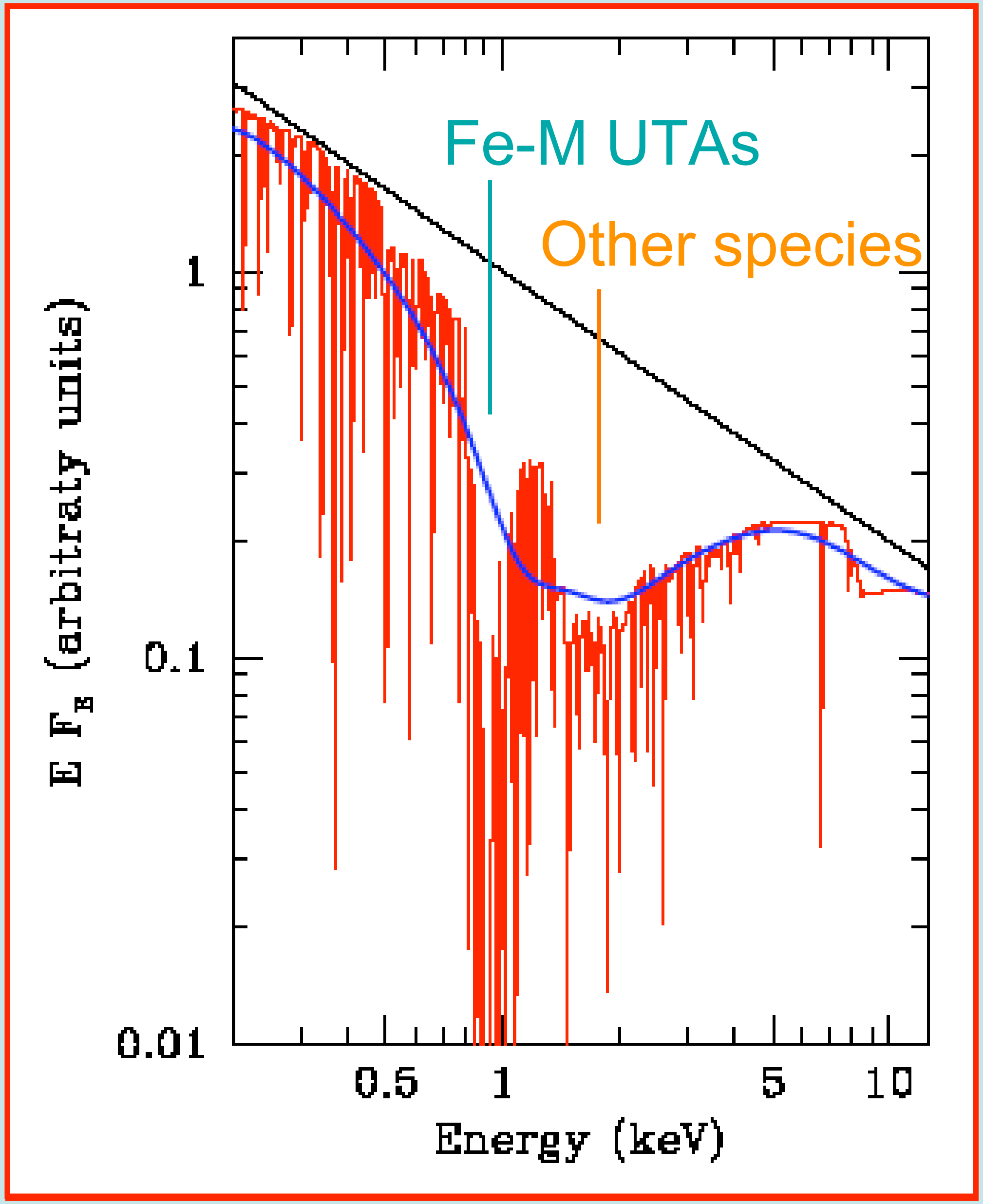


Rozanska, Dumont, Czerny, Collin 2002

PURE ABSORPTION MODELS: BASIC IDEA

- ξ=460
- PL α=1.7 [0.1-20] keV
- N=3.3 10^{23} cm^{-2}
- Turbulence 100 km.s^{-1}
- v/c=0.2 gaussian smearing
- Personal XSTAR grid

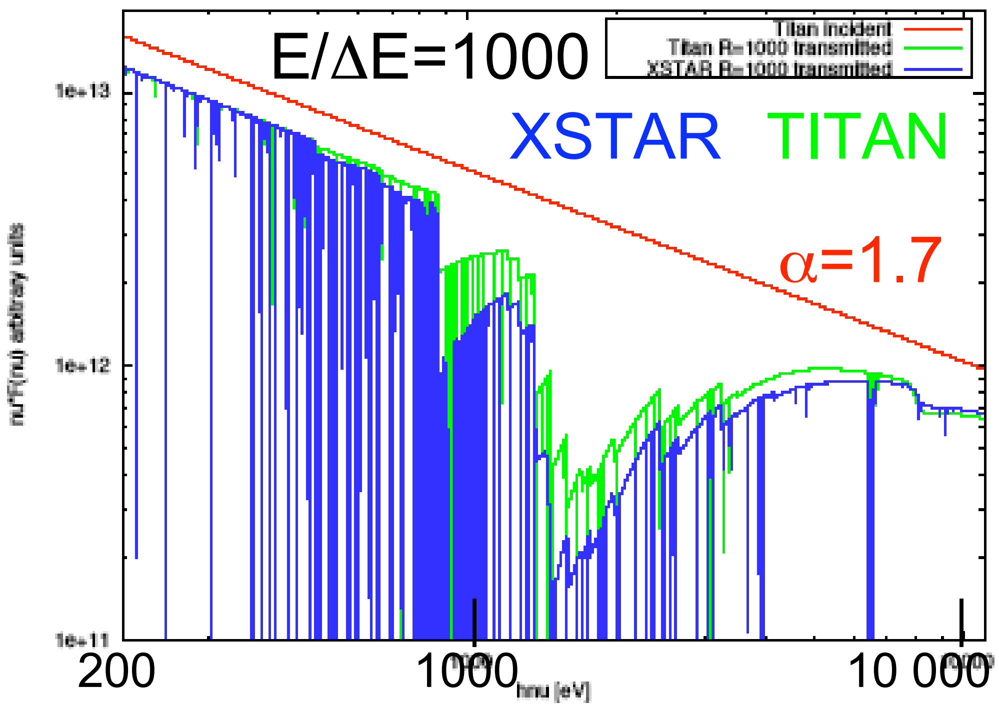
(n_H=10^{12} cm^{-3}, α=1)

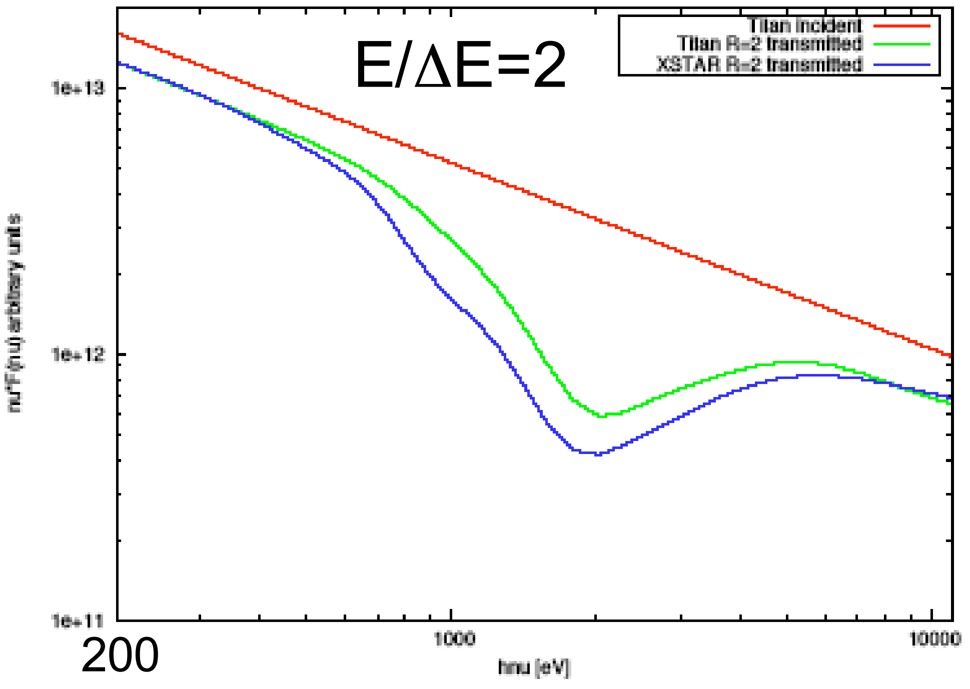


Gierlinski & Done 2004

COMPARISON BETWEEN XSTAR AND TITAN

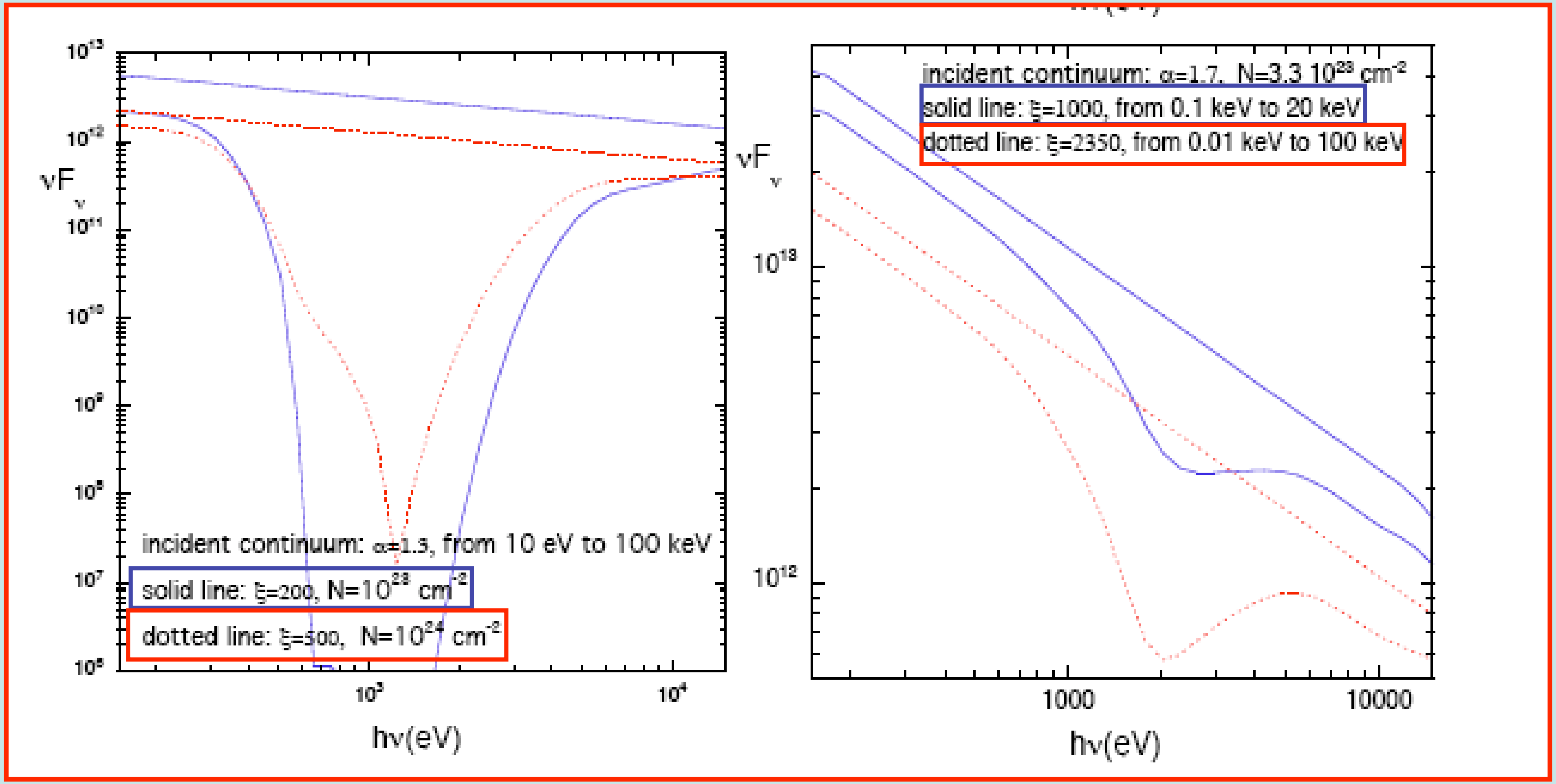
- XSTAR: 20 000 lines (including Fe-M UTAs)
- TITAN: 1000 lines
- Model: ξ=1000 [10eV-100keV]
- Diff. transmitted < 40% (<10% width at half max.): radiative transfer, energy balance, …
- UTAs not critical with such a smearing (not a WA)





PURE ABSORPTION CONSTANT DENSITY MODELS

Parameters: density nH=[10^5-10^{12}]cm^{-3}, abundances (cosmic), slope α>=1, type (power-law), incident energy range [10eV-100keV], ionisation parameter ξ=L/($n_H R^2$), column-density N



CONSTANT DENSITY = TOO MUCH VARIATION AS A FUNCTION OF PARAMETERS

We need a « fine tuning » mechanism

↓

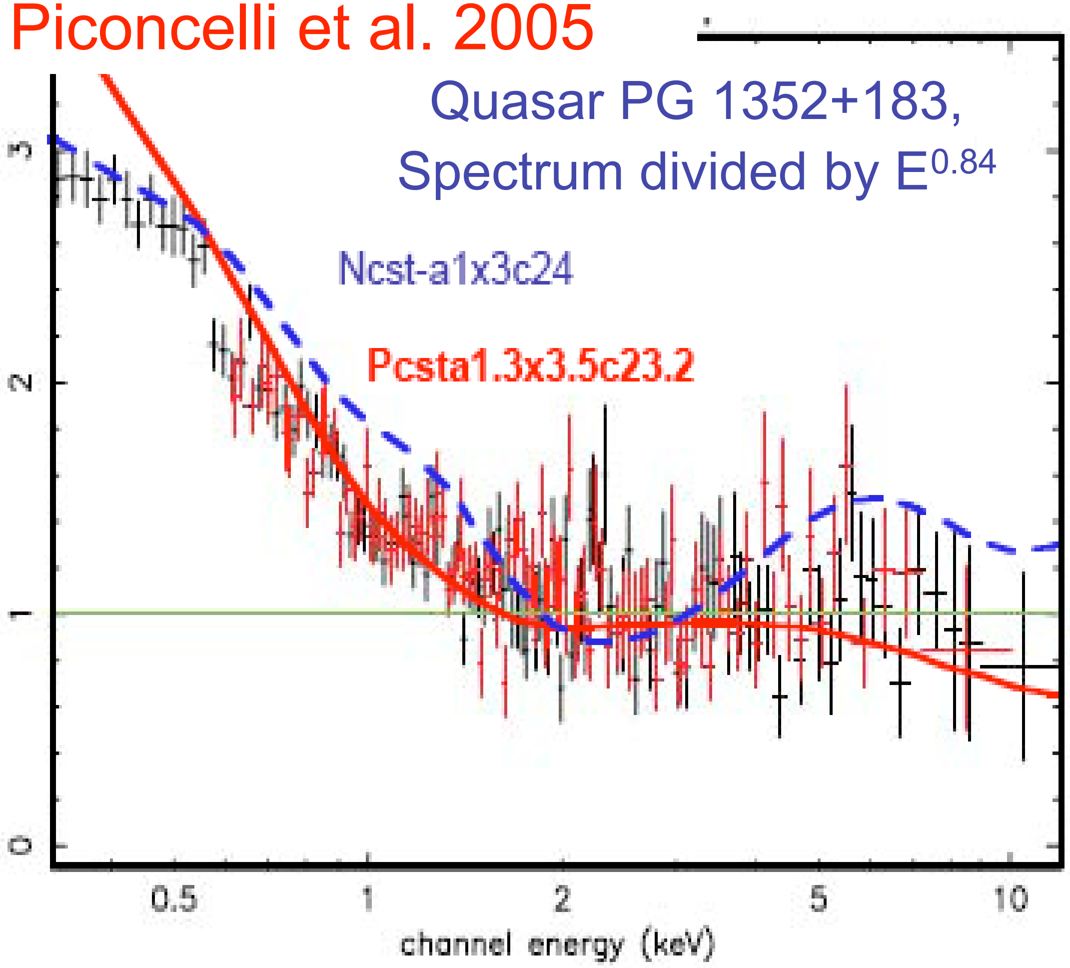
Total pressure equilibrium

(cf. A. Gonçalves talk)

Models (CGS units)

$F(E)=E$, $\xi=10^{3}$, $N=10^{24}$

$F(E)=E^{1.3}$, $\xi=10^{3.5}$, $N=10^{23.2}$



Piconcelli et al. 2005

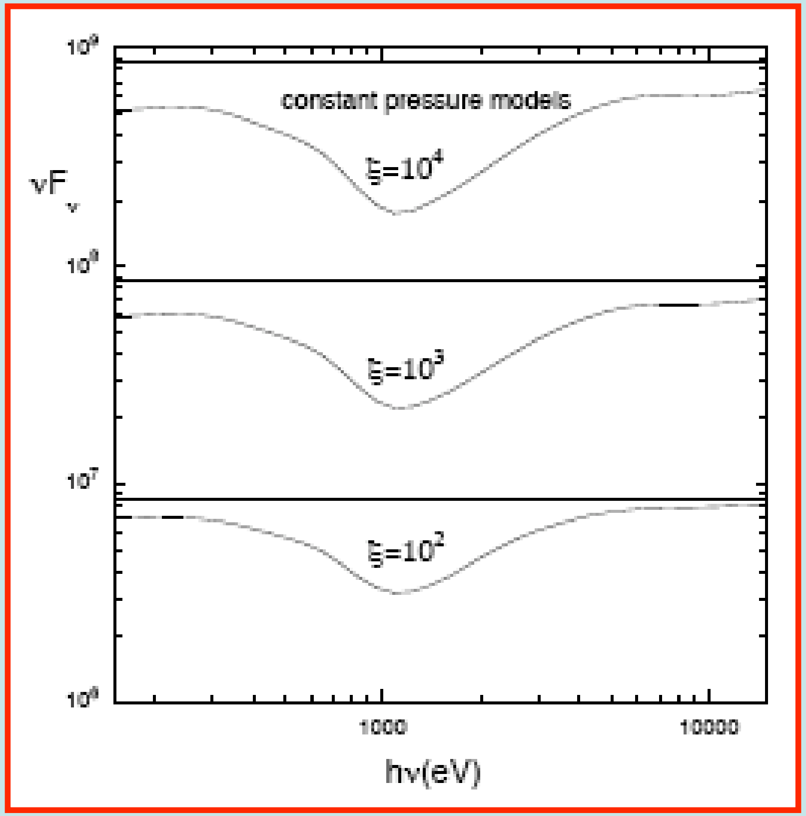
Quasar PG 1352+183, Spectrum divided by $E^{0.84}$

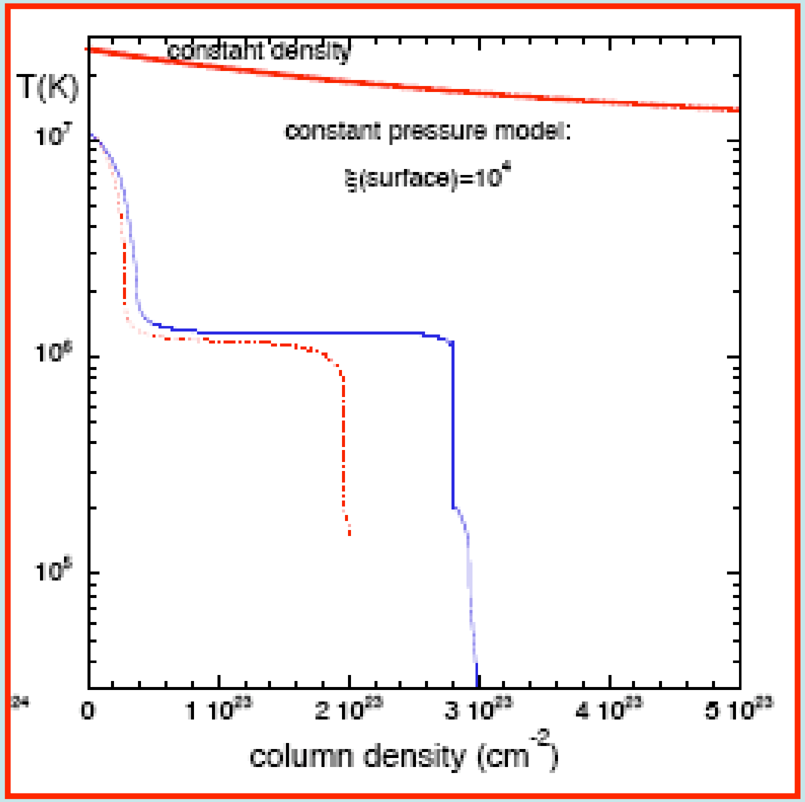
TOTAL CONSTANT PRESSURE = SIMILAR EXCESS FOR ALL VALUES OF PARAMETERS

Why ?

Constant width of temperature drop (2×10^{22} cm^{-2})

where OVII is dominant = maximum absorption trough



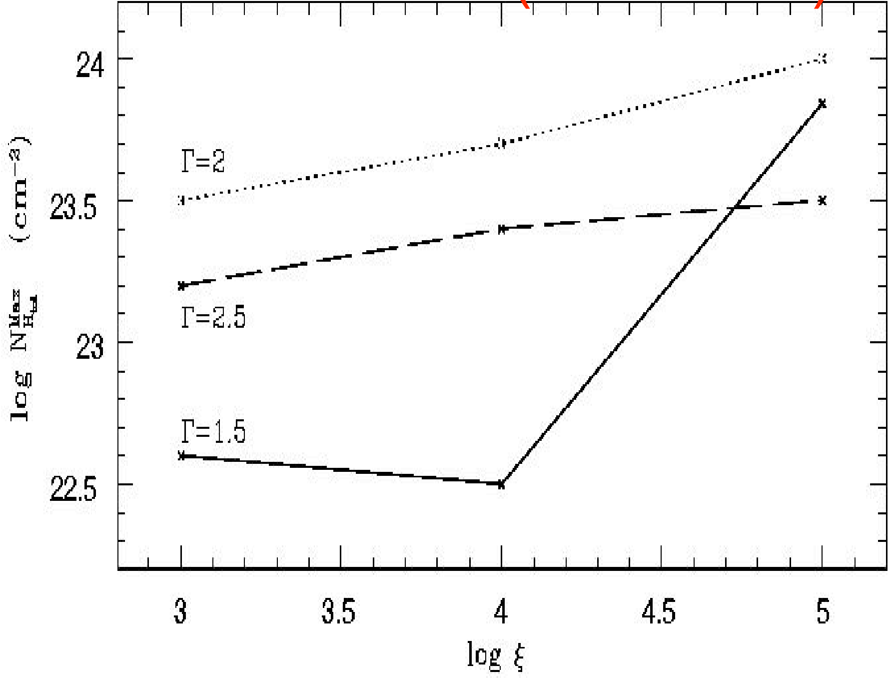


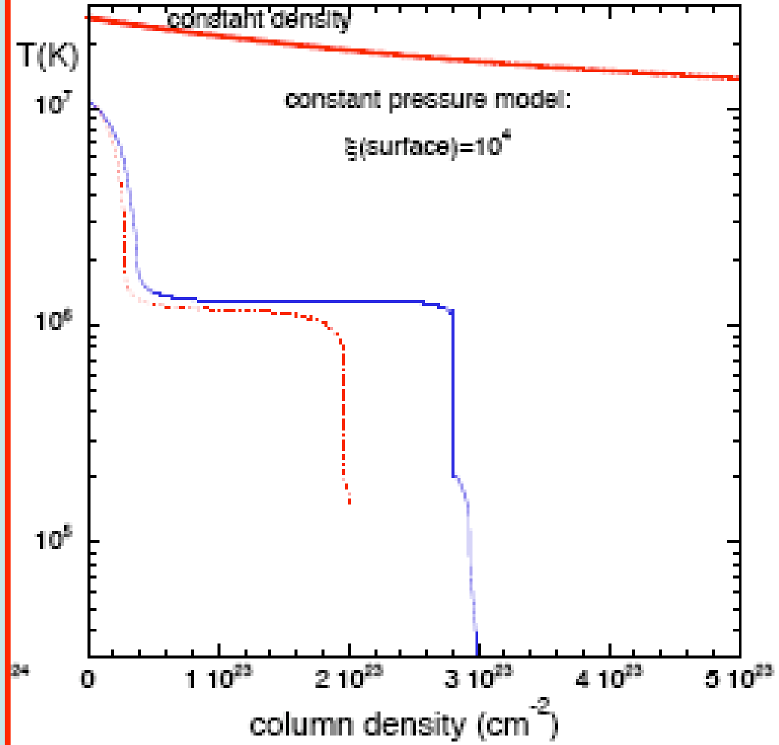
TOTAL CONSTANT PRESSURE = SIMILAR EXCESS FOR ALL VALUES OF PARAMETERS

Why ?

Constant width of temperature drop (2x10^{22} cm^{-2})
where OVII is dominant = maximum absorption trough
Not a gas pressure equilibrium

Rozanska et al. (submitted)





TOTAL CONSTANT PRESSURE = SIMILAR EXCESS FOR ALL VALUES OF PARAMETERS

Why ?
Constant width of temperature drop (2×10^{22} cm^{-2})
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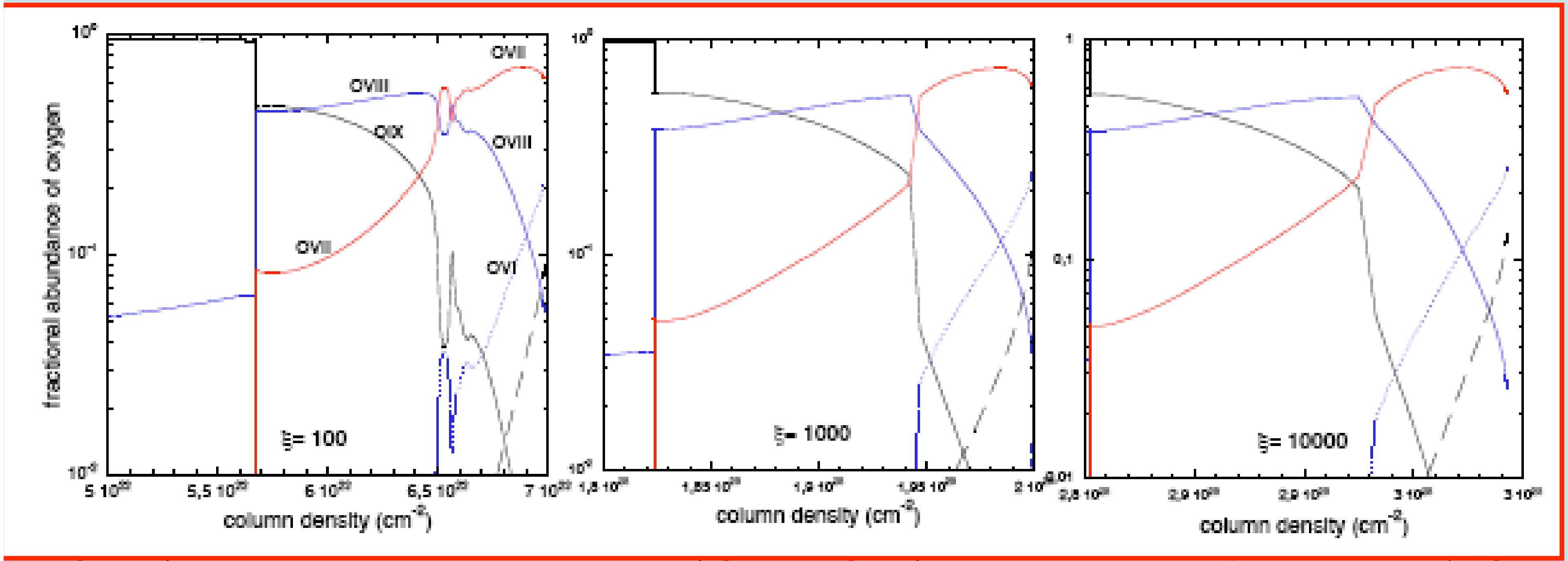
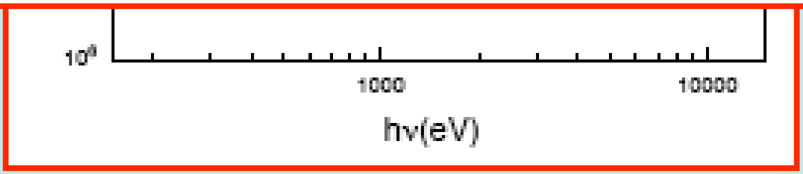
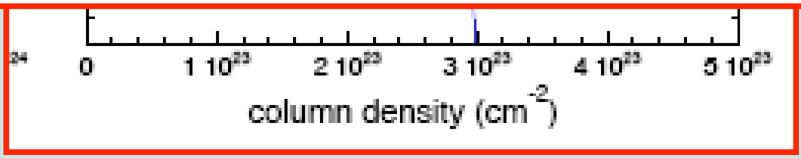


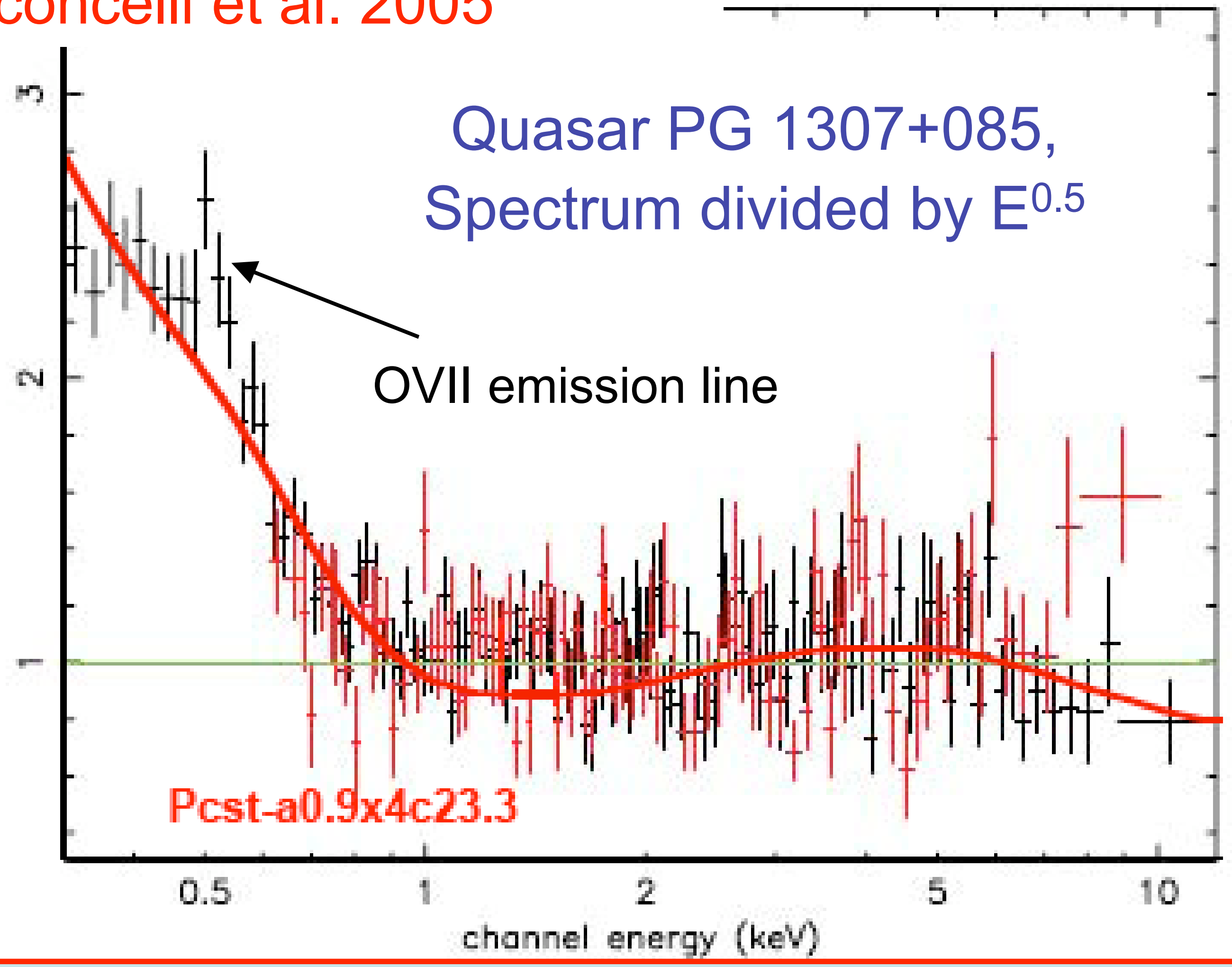




One TOTAL CONSTANT PRESSURE good visual fit

Model (CGS units): $F(E)=E^{0.9}$, $\xi=10^4$, $N=2\times10^{23}$

Piconcelli et al. 2005

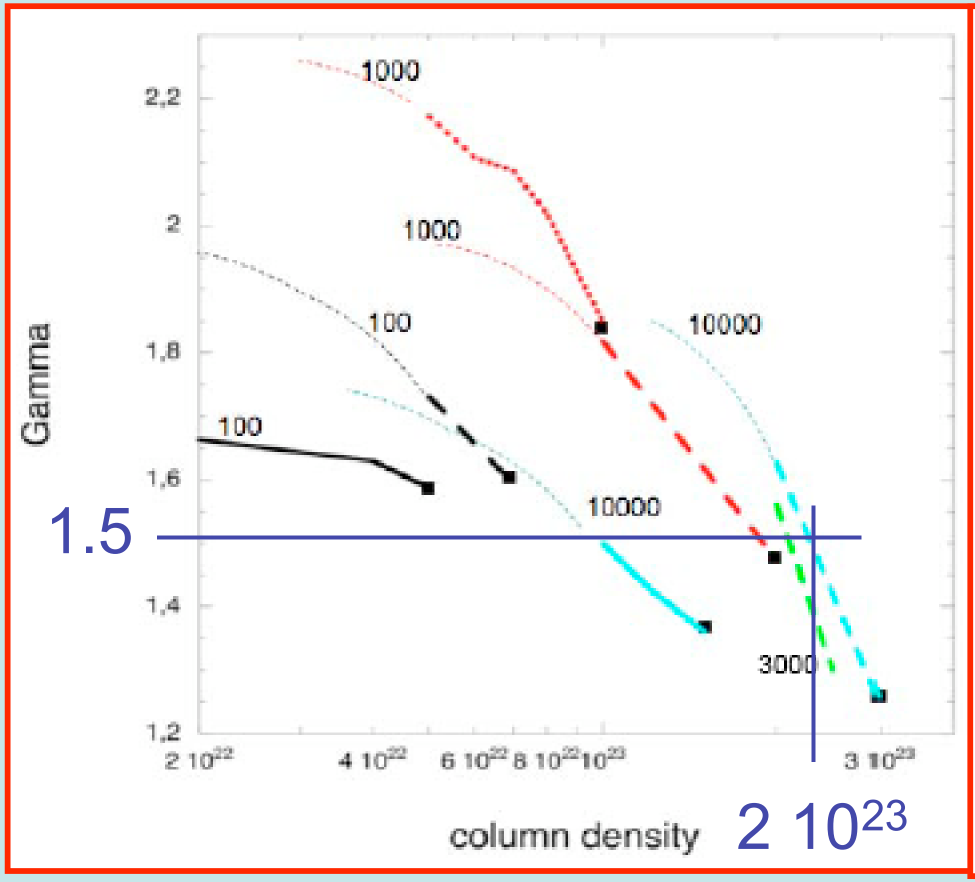


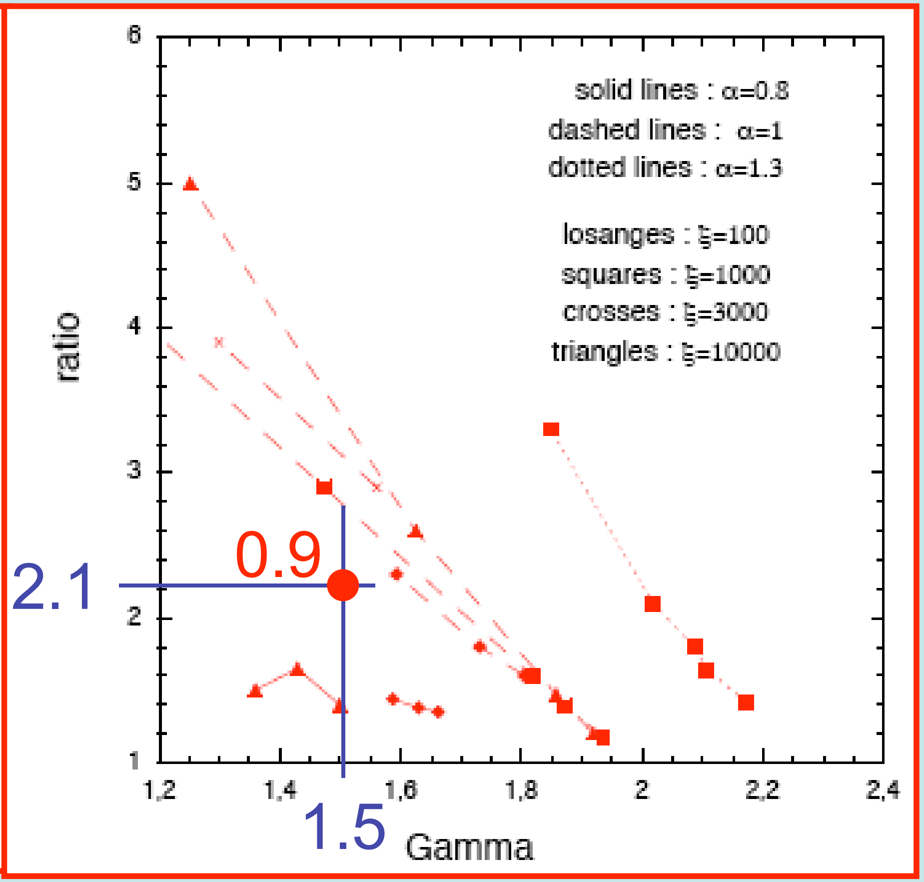
Quasar PG 1307+085, Spectrum divided by $E^{0.5}$

OVII emission line

Pcst-a0.9x4c23.3

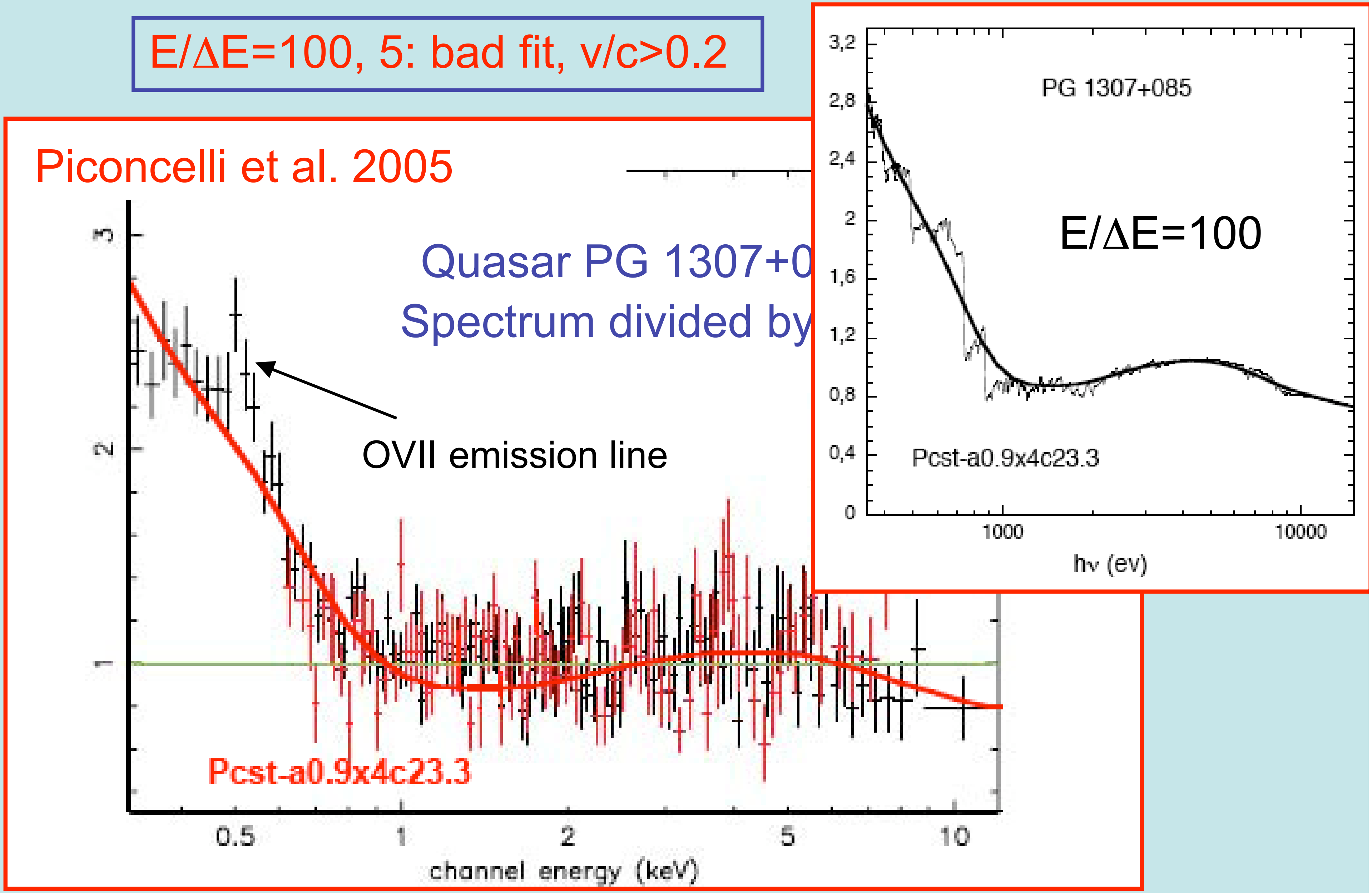
RULES FOR CONSTANT PRESSURE PARAMETERS





One TOTAL CONSTANT PRESSURE good visual fit

E/ΔE=100, 5: bad fit, v/c>0.2



Piconcelli et al. 2005

Quasar PG 1307+0

Spectrum divided by

OVII emission line

E/ΔE=100

PHYSICAL CONSEQUENCES OF ABSORPTION MODELS

- Spherical « Wind »: enormous ejected mass (Opening angle = 4π), $R/R_G > 50$ (unbound to BH)

$$\frac{\dot{M}_{\rm out}}{\dot{M}_{\rm Edd}} \sim 3\ 10^3\ f_{\rm vol}\ \left[\frac{R_{\rm Edd}}{0.3}\right] \left[\frac{V_{\rm out}}{0.2c}\right] \left[\frac{\eta}{0.1}\right] \left[\frac{10^3}{\xi}\right]$$

< 1 so $f_{\rm vol} < 3\ 10^{-4}$

$$\frac{R}{R_{\rm G}} \leq 10^6\ f_{\rm vol}\ \left[\frac{R_{\rm Edd}}{0.3}\right] \left[\frac{10^3}{\xi}\right] \left[\frac{3\ 10^{23}}{N}\right]$$

So $R/R_G < 300$

$$n_{\rm H} \geq \boxed{2\ 10^{12}} \left[\frac{R_{\rm Edd}}{0.3}\right] \left[\frac{10^3}{\xi}\right] \left[\frac{10^7 M_\odot}{M}\right] \left[\frac{300 R_{\rm G}}{R}\right]^2\ \ {\rm cm}^{-3}$$

- Quasi spherical accretion: $R/R_G \sim 25$ (very close to the BH, mixed with the primary continuum)

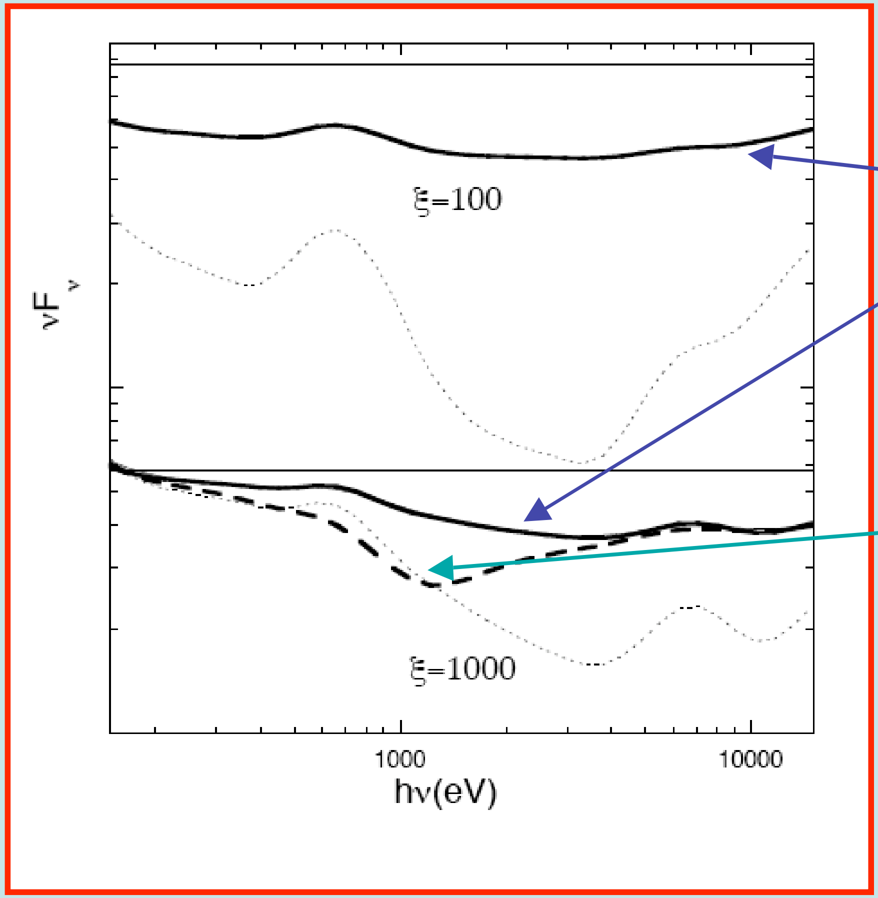
$$t_{\rm dyn} \sim \frac{R}{v_{\rm abs}} \sim \frac{1}{\Omega} = 5 \times 10^4 r_{10}^{3/2} M_7\ \ {\rm s}$$

So $t_{\rm dyn} \sim$ 1day

FOR BOTH CASES, A THIN ACCRETION DISK IS NEEDED FOR UV COUNTERPART

AN « HYBRID » SOLUTION: MORE SATISFYING

- Primary continuum : flare + accretion disk (cf. R. Goosmann PhD thesis)
- A modest absorbing wind



Primary continuum + Reflected spectrum from the disk

After absorption by a modest wind:

$\xi = 100$

$N = 10^{22}$ cm^{-2}

SUMMARY

- Pure reflection model can only explain very weak soft X-ray excess (Rozanska, Dumont, Czerny, Collin 2002, Fabian and Co., etc).
- Pure absorption model: it can explain some X spectra, but the absorbing medium must be in pressure equilibrium. Presently, due to the lack of an extended grid of models, we don’t know if it is able to model accurately all soft X-ray excess situations.
- Pure absorption model implies huge relativistic accretion rates, or a very particular spherical accretion flow structure.
- An hybrid model is more satisfying: a disk with flares, giving a primary spectrum UV-X which is absorbed by a modest relativistic wind.
- These models will be tested by Astro-E2 (good resolution spectrum above 10 keV) and by variability studies soft UV/X - hard X-rays.