Anatomy of the AGN in NGC 5548:

The high energy view with XMM-Newton, NuSTAR and INTEGRAL

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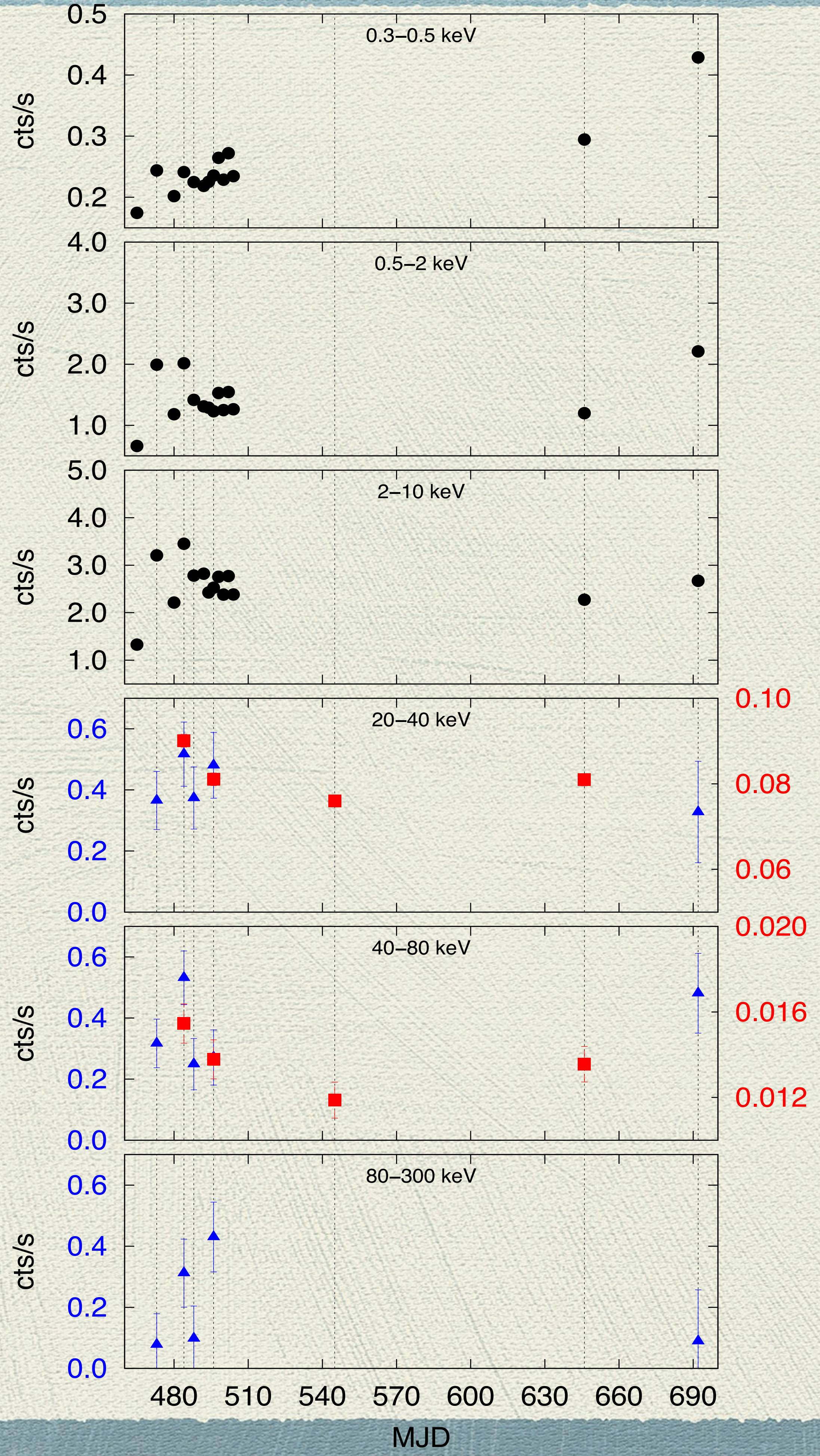
The X-ray universe
Dublin, June 18 2014

High energy data

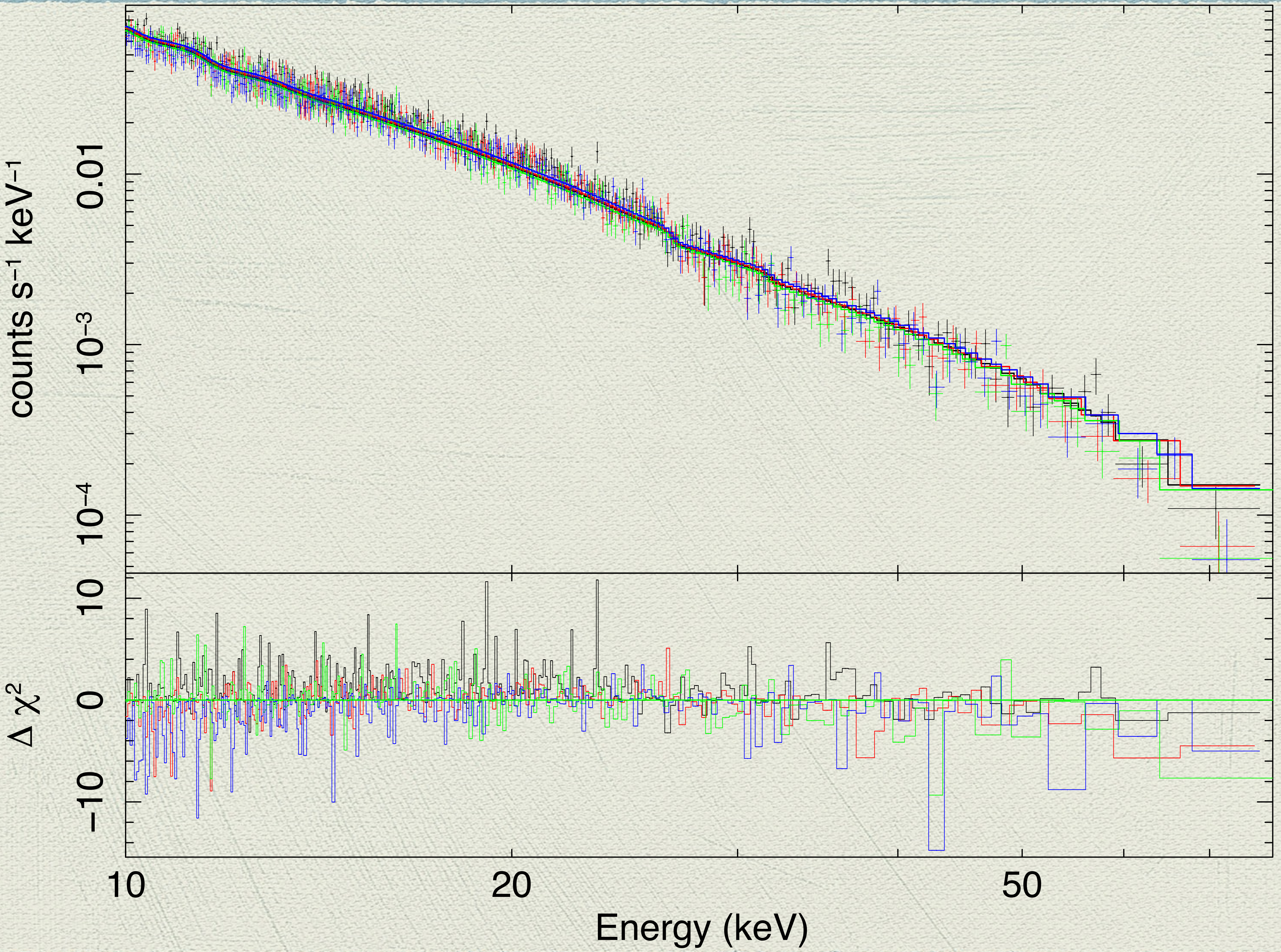
Obs.	Satellites	Obs. Id.	Start time (UTC) yyyy-mm-dd	Span (ks)
1	*XMM-Newton*	0720110401	2013-06-30	56
	INTEGRAL	10700010001	2013-06-29	100
2	*XMM-Newton*	0720110601	2013-07-11	56
	NuSTAR	60002044002/3	2013-07-11	100
	INTEGRAL	10700010002	2013-07-11	100
3	*XMM-Newton*	0720110701	2013-07-15	56
	INTEGRAL	10700010003	2013-07-15	100
4	*XMM-Newton*	0720111101	2013-07-23	56
	NuSTAR	60002044005	2013-07-23	96
	INTEGRAL	10700010004	2013-07-23	130
5	*Chandra*	16314	2013-09-10	120
	NuSTAR	60002044006	2013-09-10	96
6	*XMM-Newton*	0720111501	2013-12-20	56
	NuSTAR	60002044008	2013-12-20	96
7	*XMM-Newton*	0720111601	2014-02-04	56
	INTEGRAL	11200110003	2014-02-09	38



Light curves:

- XMM (black)
- NuSTAR (red)
- Integral (blue)

NuSTAR spectra above 10 keV + simple power law



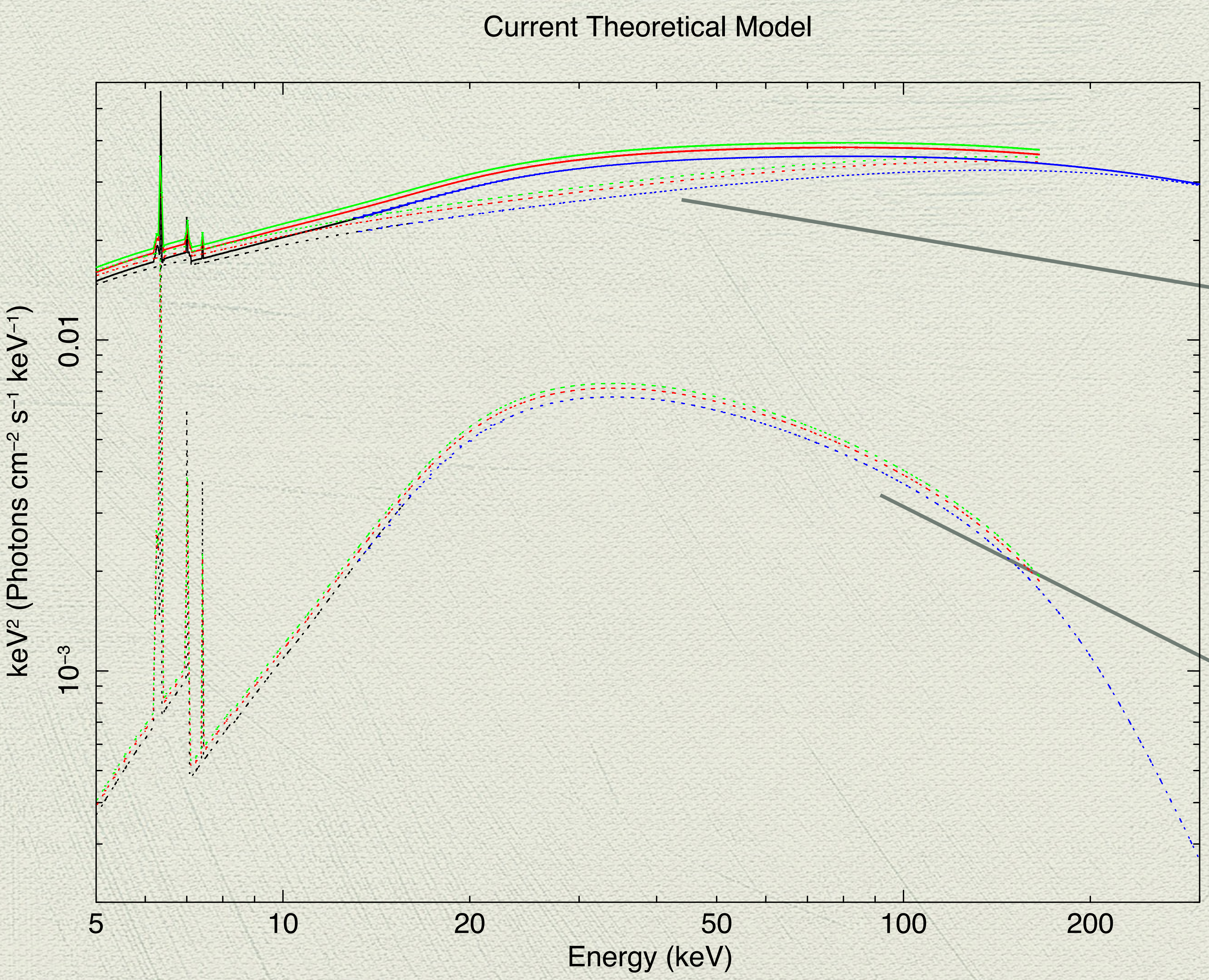
Spectral curvature above 10 keV

Table 2. Best-fit parameters of the fit above 10 keV, with a simple a power law or including a high energy cut-off. p is the F-test probability of chance improvement with the CUTOFFPL model.
[a]: *INTEGRAL* [b]: *NuSTAR* + *INTEGRAL* [c]: *NuSTAR*

	POWERLAW			CUTOFFPL				
Obs.	Γ	$F_{20-40\,\mathrm{keV}}$ ($\times10^{-11}$ erg/cm^2 s)	χ^2/dof	Γ	$F_{20-40\,\mathrm{keV}}$ ($\times10^{-11}$ erg/cm^2 s)	E_c (keV)	χ^2/dof	p
1[a]	$2.1^{+0.5}_{-0.4}$	$3.7^{+0.8}_{-0.9}$	9.5/10	1^{+2}_{-1}	3.5 ± 1.0	>40	7.2/9	0.12
2[b]	$1.60^{+0.02}_{-0.02}$	$3.85^{+0.06}_{-0.07}$	666/631	$1.3^{+0.1}_{-0.1}$	$3.87^{+0.04}_{-0.03}$	70^{+30}_{-20}	632/630	9E-9
3[a]	$2.5^{+0.6}_{-0.5}$	4.4 ± 1.0	12.7/10	1^{+2}_{-1}	$4.4^{+1.1}_{-0.7}$	>20	12.2/9	0.56
4[b]	$1.60^{+0.02}_{-0.02}$	$3.40^{+0.05}_{-0.07}$	553/572	$1.2^{+0.1}_{-0.1}$	$3.41^{+0.05}_{-0.37}$	60^{+20}_{-10}	518/571	1E-9
5[c]	$1.65^{+0.02}_{-0.02}$	$3.43^{+0.06}_{-0.07}$	629/562	$1.2^{+0.1}_{-0.1}$	$3.43^{+0.06}_{-0.07}$	50^{+17}_{-10}	583/56	7E-11
6[c]	$1.56^{+0.02}_{-0.02}$	$3.25^{+0.06}_{-0.05}$	586/549	$1.1^{+0.1}_{-0.1}$	$3.28^{+0.06}_{-0.06}$	37^{+7}_{-4}	495/548	7E-22
7[a]	$2.2^{+0.8}_{-0.6}$	$4.4^{+1.6}_{-1.4}$	9.9/10	2^{+2}_{-1}	$4.3^{+1.5}_{-1.3}$	>10	8.1/9	0.19

- Fit with a cut-off power law

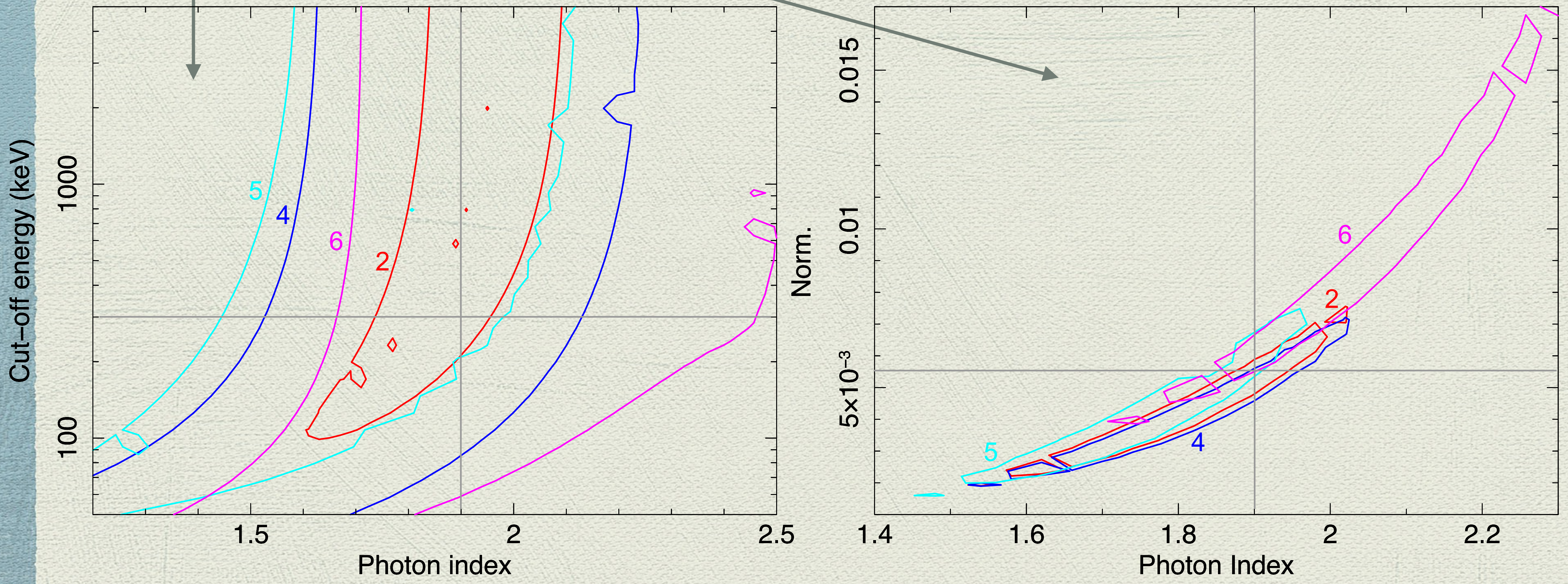
Constraining reflection: NuSTAR obs. above 5 keV
pexmon + phabs*cutoffpl



Primary power law: Γ=1.72, Ec>500 keV

Reflected: Γ(pex)≃1.9, Ec(pex)≃ 400 keV but poorly constrained

Constraining reflection: NuSTAR obs. above 5 keV
pexmon + phabs*cutoffpl



- The reflected component is consistent with being constant
- Final choice: Γ(pex)=1.9, Ec(pex)=300 keV, Norm(pex)=5.5E-3

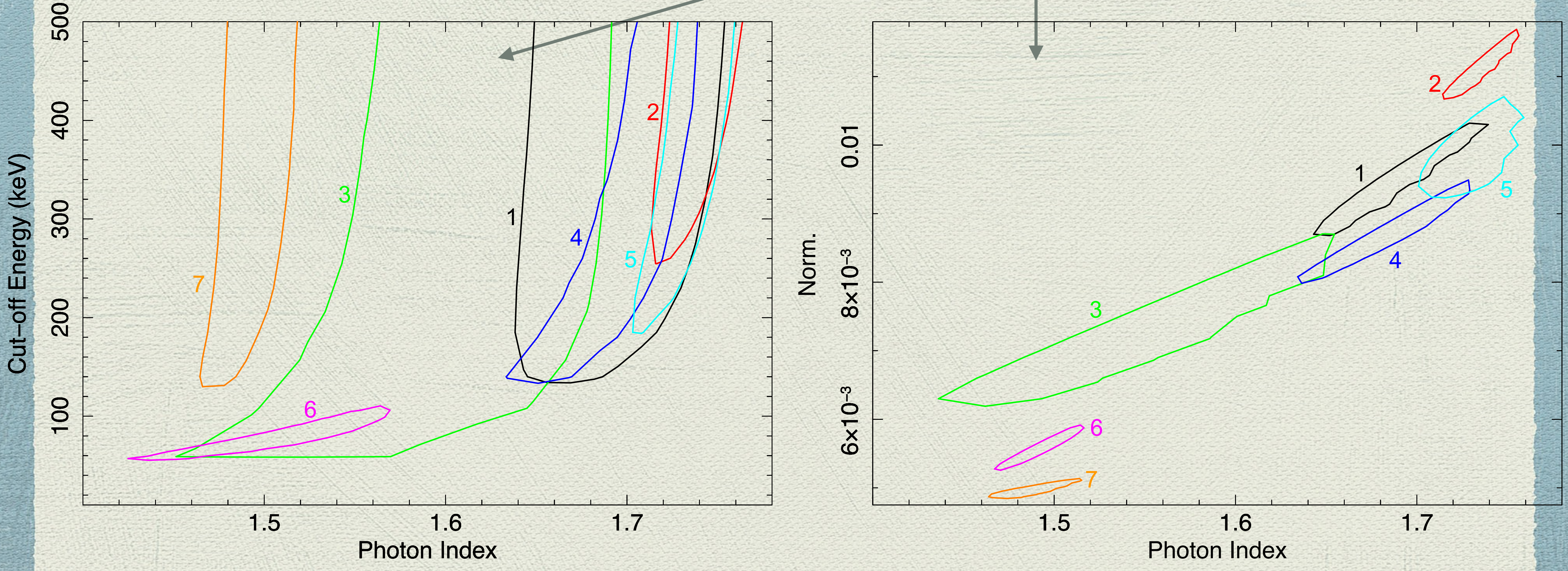
Broad-band fit:
WA[pexmon + pcfabs*pcfabs(cutoffpl+SE)]+NL

Table 3. Best-fit parameters of the primary power law and the absorber, when fitting the data down to 0.3 keV. The first, "thick" absorber, was not needed in obs. 5 (*Chandra* plus *NuSTAR*) and obs. 7.
E_c is in keV, $F_{1\,\mathrm{keV}}$ is in units of 10^{-2} ph/keV cm^2 s and N_H is in unis of 10^{22} cm^{-2}.

Obs.	Γ	E_c	$F_{1\,\mathrm{keV}}$	$N_H^{(1)}$	$C_F^{(1)}$	$N_H^{(2)}$	$C_F^{(2)}$	χ^2/dof
1	$1.70^{+0.04}_{-0.05}$	>100	$0.96^{+0.09}_{-0.09}$	9 ± 1	$0.29^{+0.05}_{-0.06}$	$0.75^{+0.03}_{-0.03}$	$0.797^{+0.006}_{-0.007}$	538/424
2	$1.74^{+0.01}_{-0.04}$	>250	$1.13^{+0.03}_{-0.07}$	$9.2^{+0.8}_{-0.9}$	$0.32^{+0.02}_{-0.03}$	$0.85^{+0.02}_{-0.02}$	$0.829^{+0.004}_{-0.003}$	1587/1393
3	$1.6^{+0.1}_{-0.2}$	>50	$0.7^{+0.2}_{-0.1}$	9^{+3}_{-2}	$0.27^{+0.06}_{-0.10}$	$1.06^{+0.06}_{-0.10}$	$0.81^{+0.01}_{-0.02}$	508/420
4	$1.68^{+0.05}_{-0.05}$	>150	$0.87^{+0.07}_{-0.06}$	$8.5^{+0.8}_{-0.7}$	$0.46^{+0.03}_{-0.03}$	$1.27^{+0.06}_{-0.06}$	$0.77^{+0.01}_{-0.01}$	1346/1329
5	$1.74^{+0.01}_{-0.03}$	>180	$1.00^{+0.05}_{-0.05}$	-	-	$1.8^{+0.2}_{-0.2}$	$0.62^{+0.03}_{-0.03}$	1113/1094
6	$1.49^{+0.05}_{-0.05}$	70^{+30}_{-20}	$0.56^{+0.05}_{-0.05}$	8 ± 2	$0.33^{+0.06}_{-0.06}$	$1.5^{+0.2}_{-0.1}$	$0.68^{+0.04}_{-0.04}$	1484/1308
7	$1.50^{+0.02}_{-0.02}$	>120	$0.50^{+0.01}_{-0.01}$	-	-	$0.44^{+0.04}_{-0.04}$	$0.678^{+0.007}_{-0.007}$	445/419

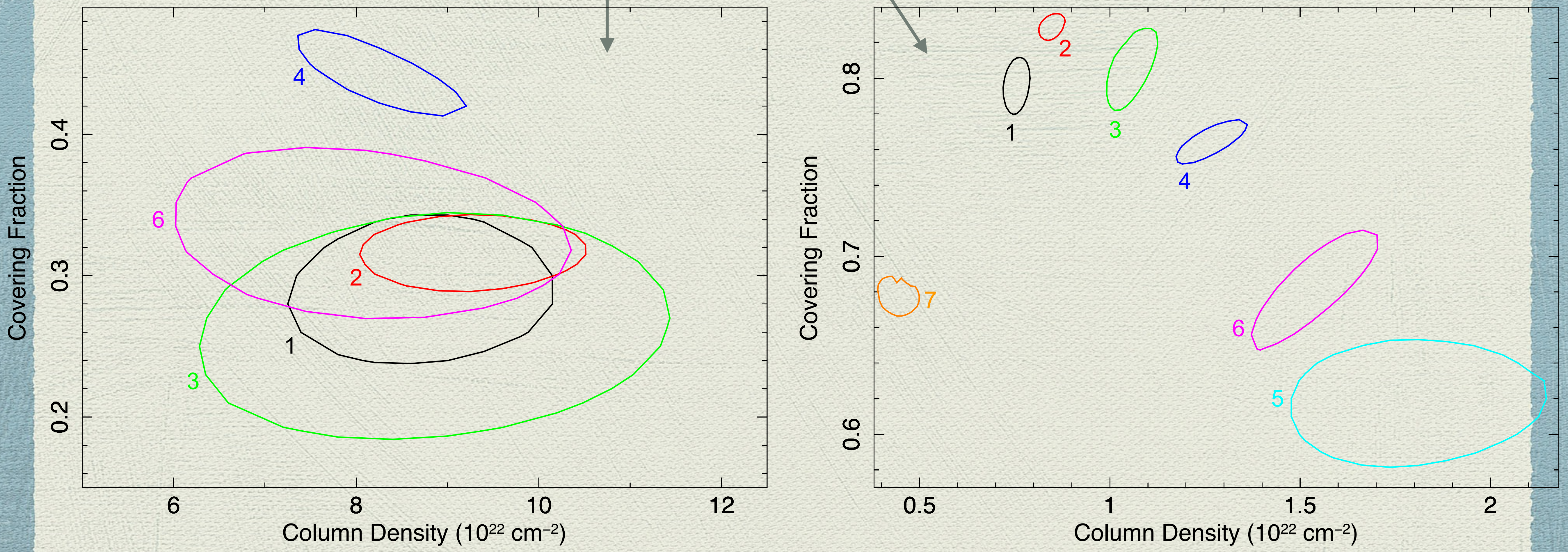
the thick obscurer
is not needed in Chandra obs. (low statistics)
and in the XMM obs. of Feb 4 (source is recovering)

Broad-band fit:
WA[pexmon + pcfabs*pcfabs(cutoffpl+SE)]+NL



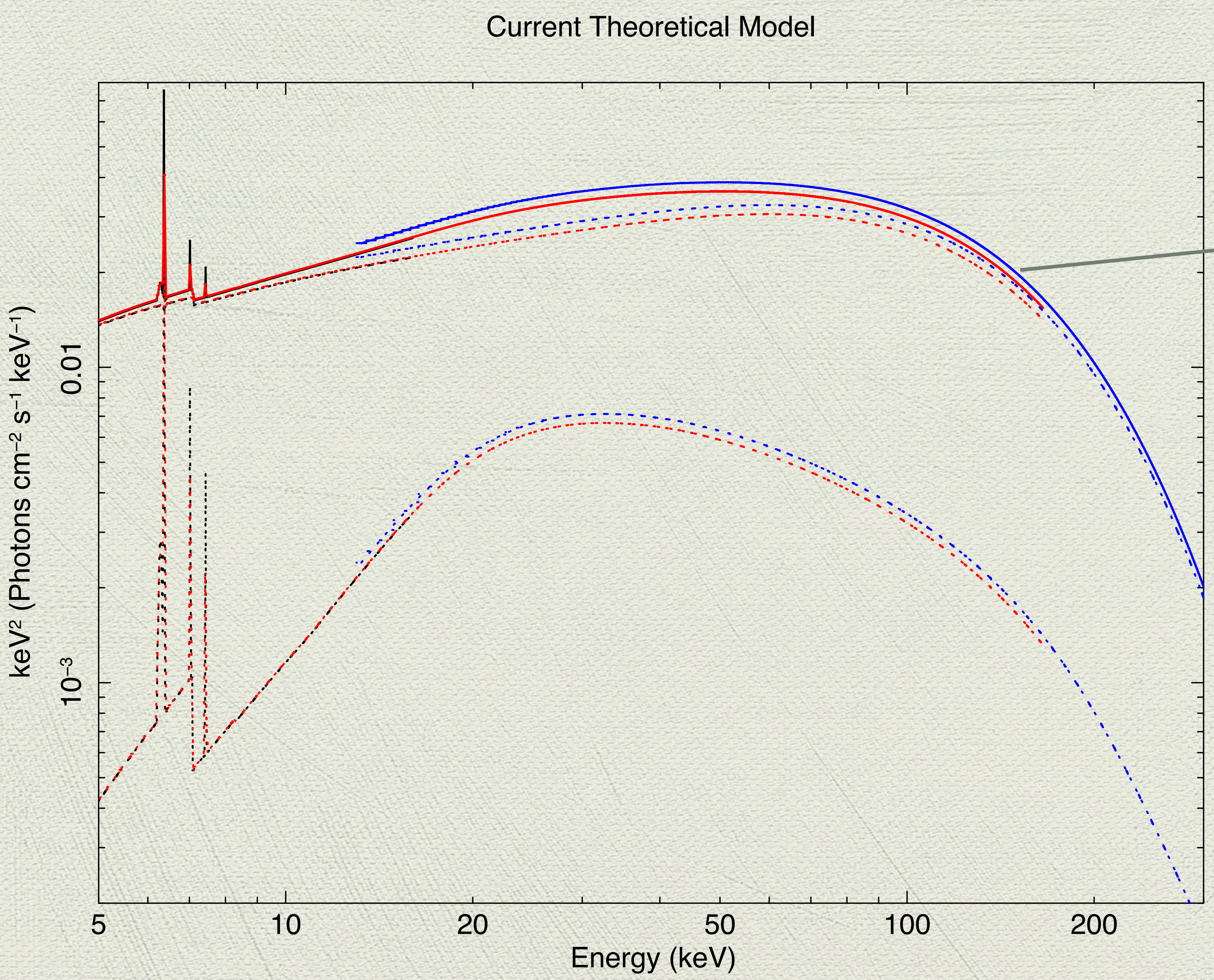
- Variability of high energy cut-off and spectral index

Broad-band fit:
WA[pexmon + pcfabs*pcfabs(cutoffpl+SE)]+NL



- Absorption variability

Test of Comptonization model (compps) on average spectrum



corona:
kT ≃ 40-50 keV
τ ≃ 2-3

Conclusions

- Spectral index varying between ~1.5 and ~1.7
- Evidence of high energy cut-off
- Reflected component is consistent with being constant (material distant at least a few light months from the primary source)
- Confirmation of the strong, partial covering and variable X-ray absorption
- Possibility to test Comptonization models (work in progress)