XMM-Newton 2010 Science Workshop

Six years of XMM-Newton observations of NGC 1313 X-1 and X-2

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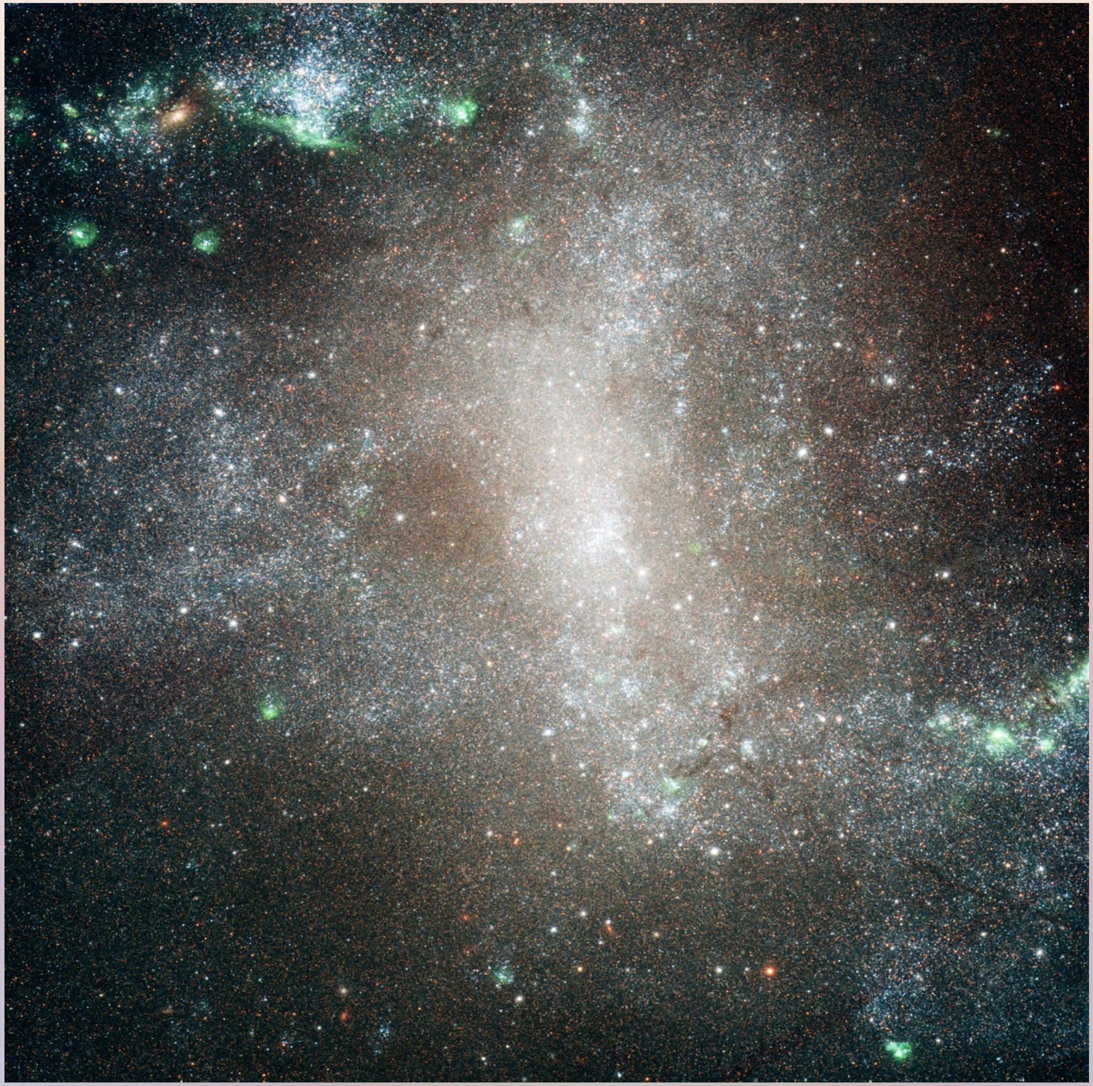
May 24, 2010

X-1 and X-2



We analyzed 17 XMM-Newton observations of NGC 1313, that cover a period from 2000 to 2006. The spectral analysis was carried out with XSPEC v.12.5.1.

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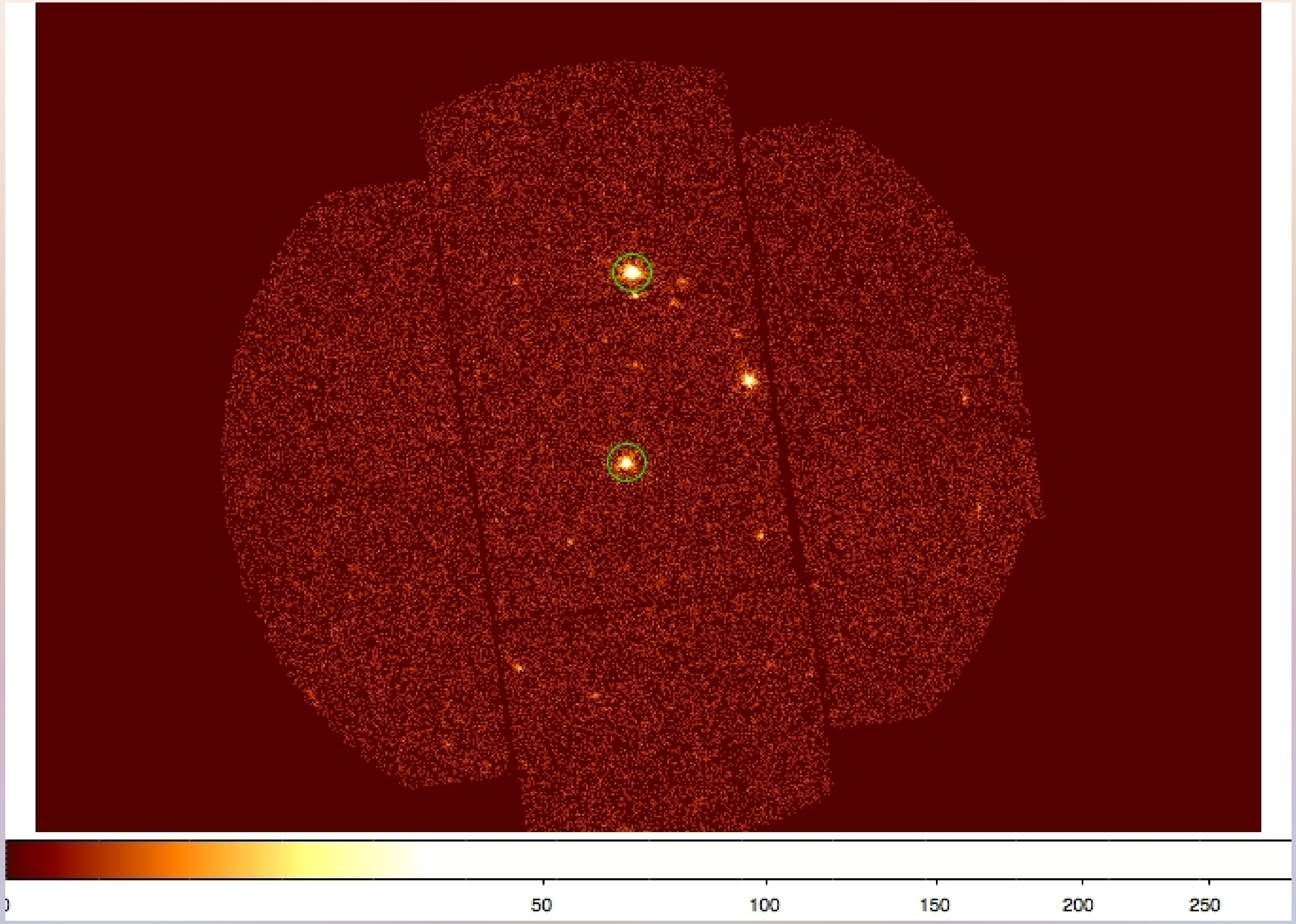

We analyzed 17 XMM-Newton observations of NGC 1313, that cover a period from 2000 to 2006. The spectral analysis was carried out with XSPEC v.12.5.1.

MODELING THE CONTINUUM

Miller et al.(2003) found that the continuum could be fitted with a soft component (multicolor blackbody disk) and a power-law. Scaling the mass with the normalization of the MCD component, they inferred the existence of an Intermediate Mass Black Hole.

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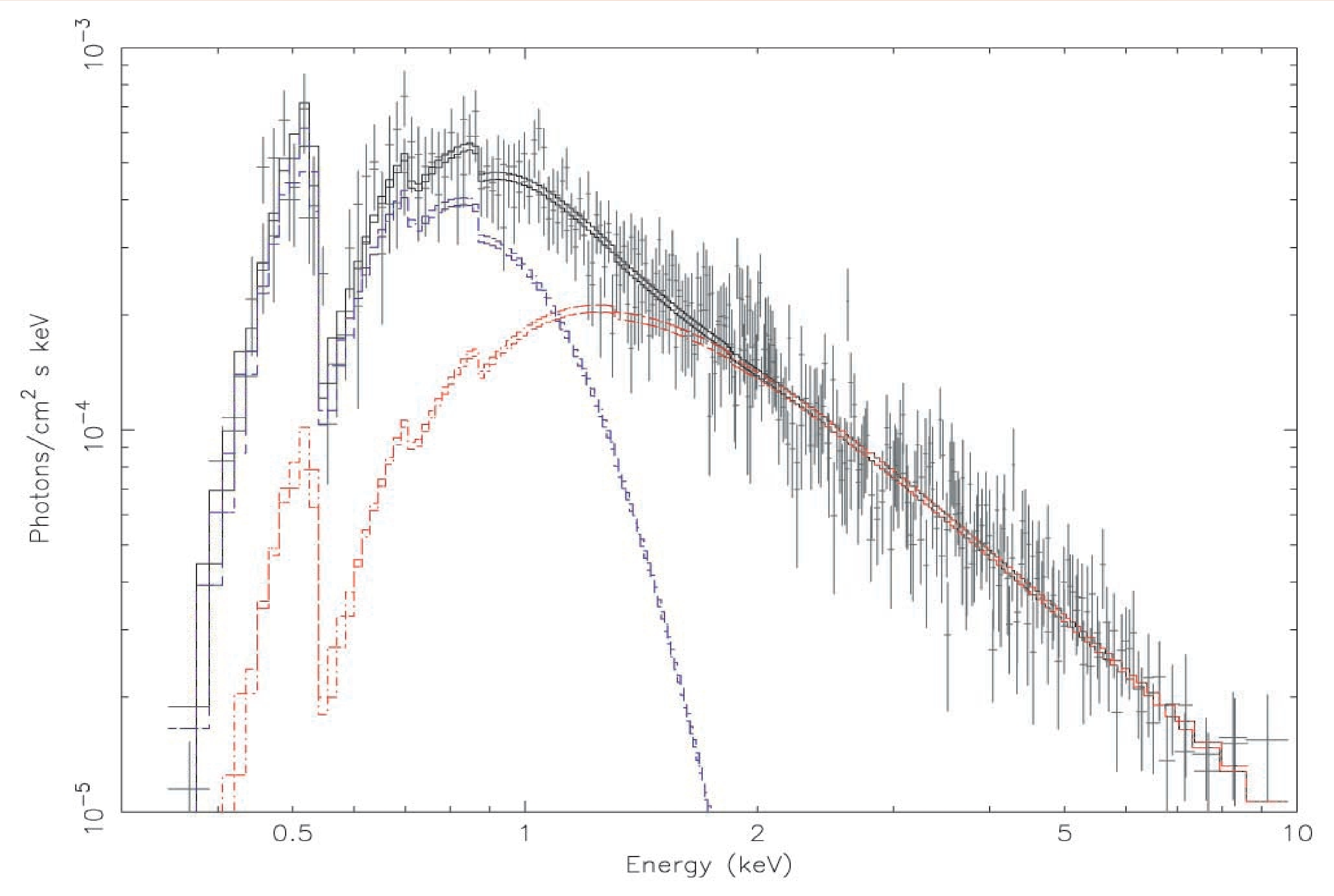

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Stobbart et al.(2006) showed the presence of spectral curvature above 2 keV in both sources. They explained it with an optically thick corona coupled to the disk at high accretion rates.

Goncalves & Soria(2006) also questioned the robustness of the cool disc-blackbody spectral component.

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Analysis of the continuum with a power-law plus a multicolor blackbody spectrum (Feng & Kaaret 2006);

They showed an anti-correlation between the inner disk temperature and the disk luminosity.

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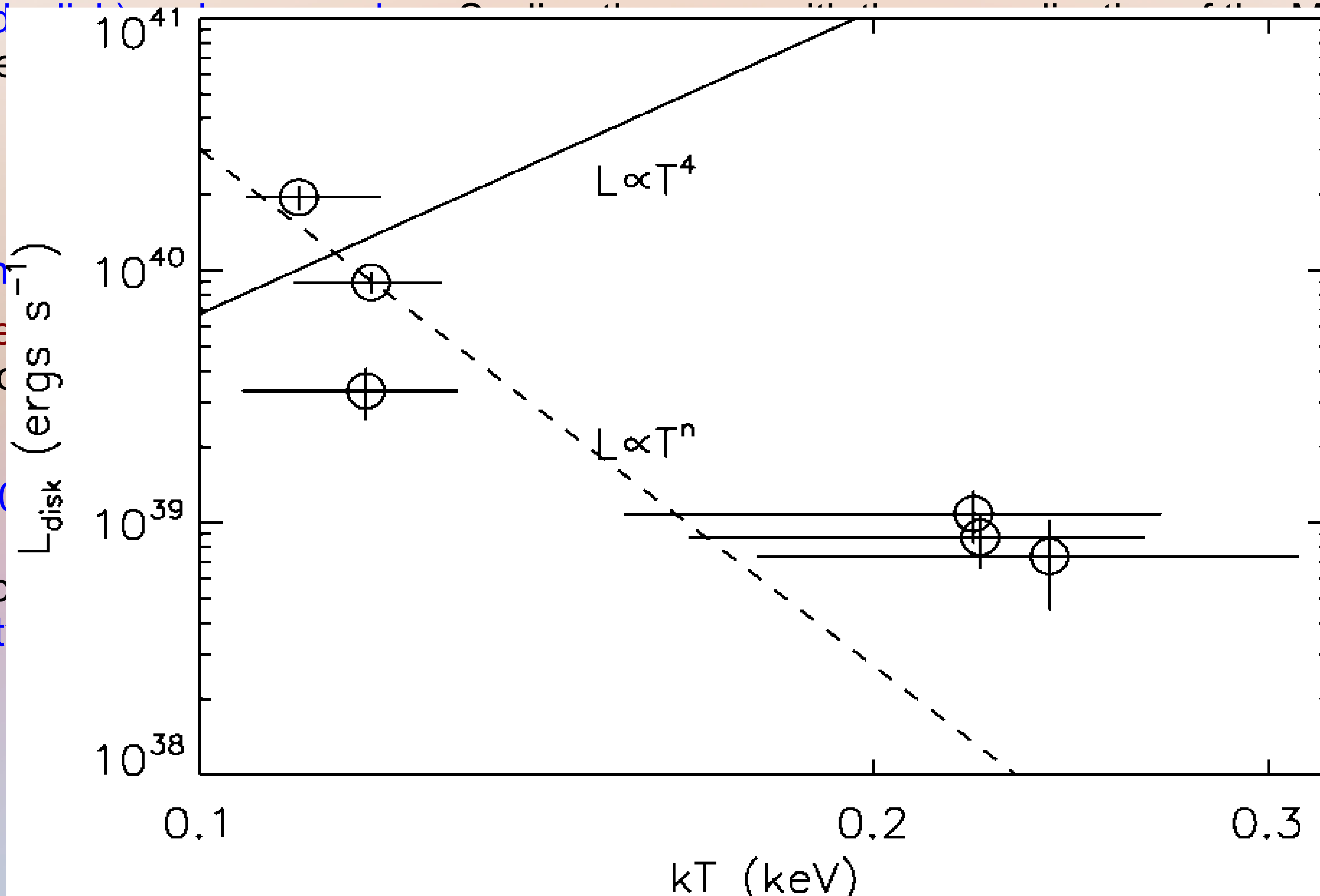

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Analysis of the continuum with a power-law plus a multicolor blackbody spectrum (Feng & Kaaret 2006);

They showed an anti-correlation between the inner disk temperature and the disk luminosity.

In the last, longest observation (2006, 122 ks long), NGC 1313 X-1 and X-2 appear to show a break in the spectrum at energies above ~ 3-5 KeV.

Gladstone et al.(2009) show that it can be modelled through a cool comptonizing corona atop the accretion disc.

MODELING THE CONTINUUM

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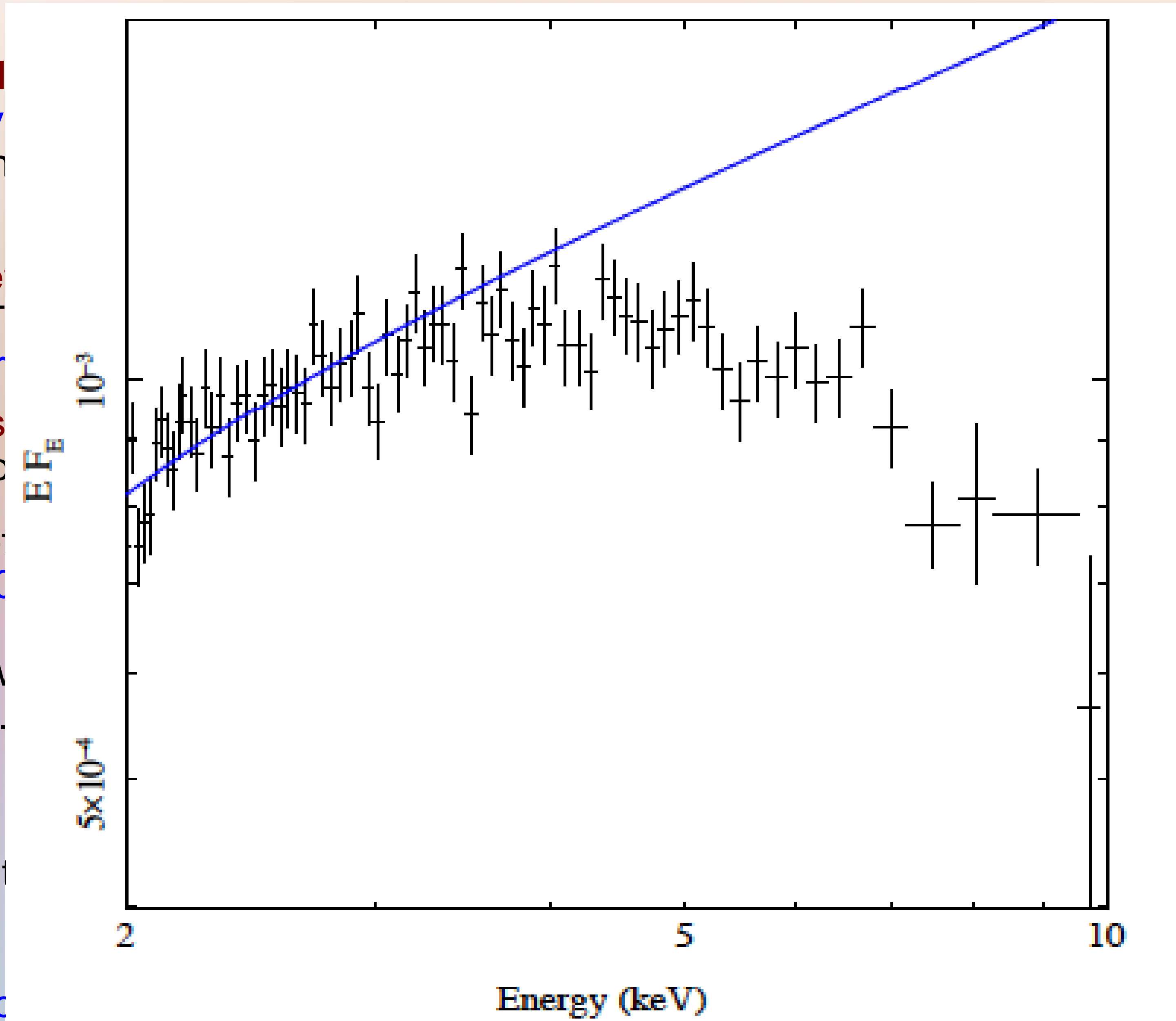

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COMPTT and EQPAIR

Gladstone et al. fitted the spectra of ULXs using a disc component plus two different comptonization models for the corona: COMPTT and EQPAIR.

COMPTT (Titarchuck 1994): analytic approximation to non-relativistic thermal comptonization which assumes that the seed photons for comptonization have a Wien spectrum.

EQPAIR (Coppi 1999): the model allows for a 'hydrib' plasma (thermal and non-thermal electron distributions) and calculates the resulting comptonizing spectrum without assuming that the electrons are non relativistic. The seed photons may have a disk or blackbody spectral distribution. For ULXs non-thermal processes are likely not to be important and hence we used the simplified version EQTHERM.

Fit with the tbabs*tbabs*(eqtherm+diskbb) model

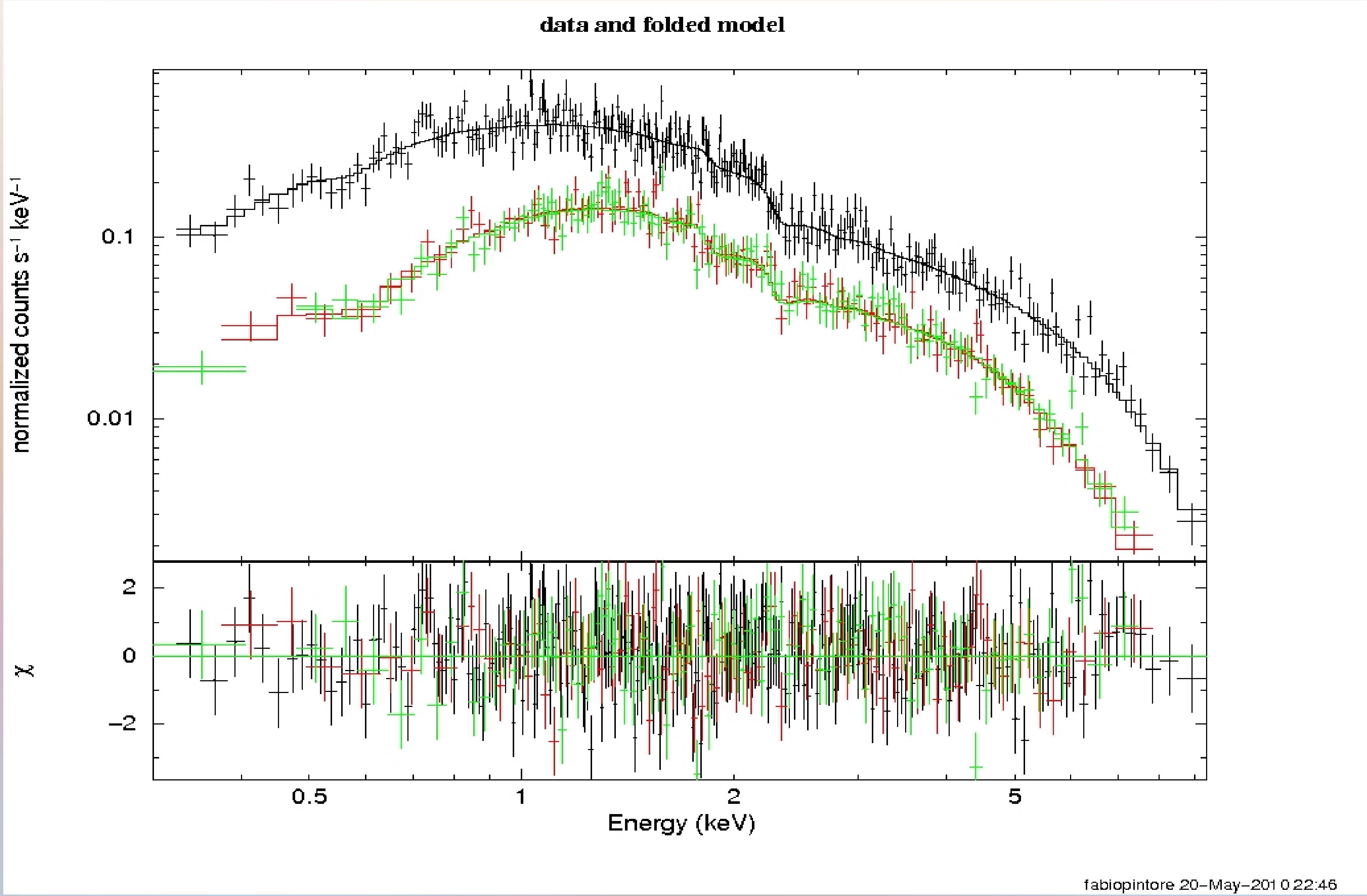
We consider the model: tbabs*tbabs*(eqtherm [comptt] + diskbb);

The first absorption column is kept fixed at $3.9*10^{20}$ cm^{-2} and represents Galactic absorption(*Dickey & Lockman 1990)*).

When a disk component is necessary, we set the seed photons temperature of the corona equal to the inner disk temperature of the *diskbb*.

Fit with the tbabs*tbabs*(eqtherm+diskbb) model

X-1



X-1 (with comptt)

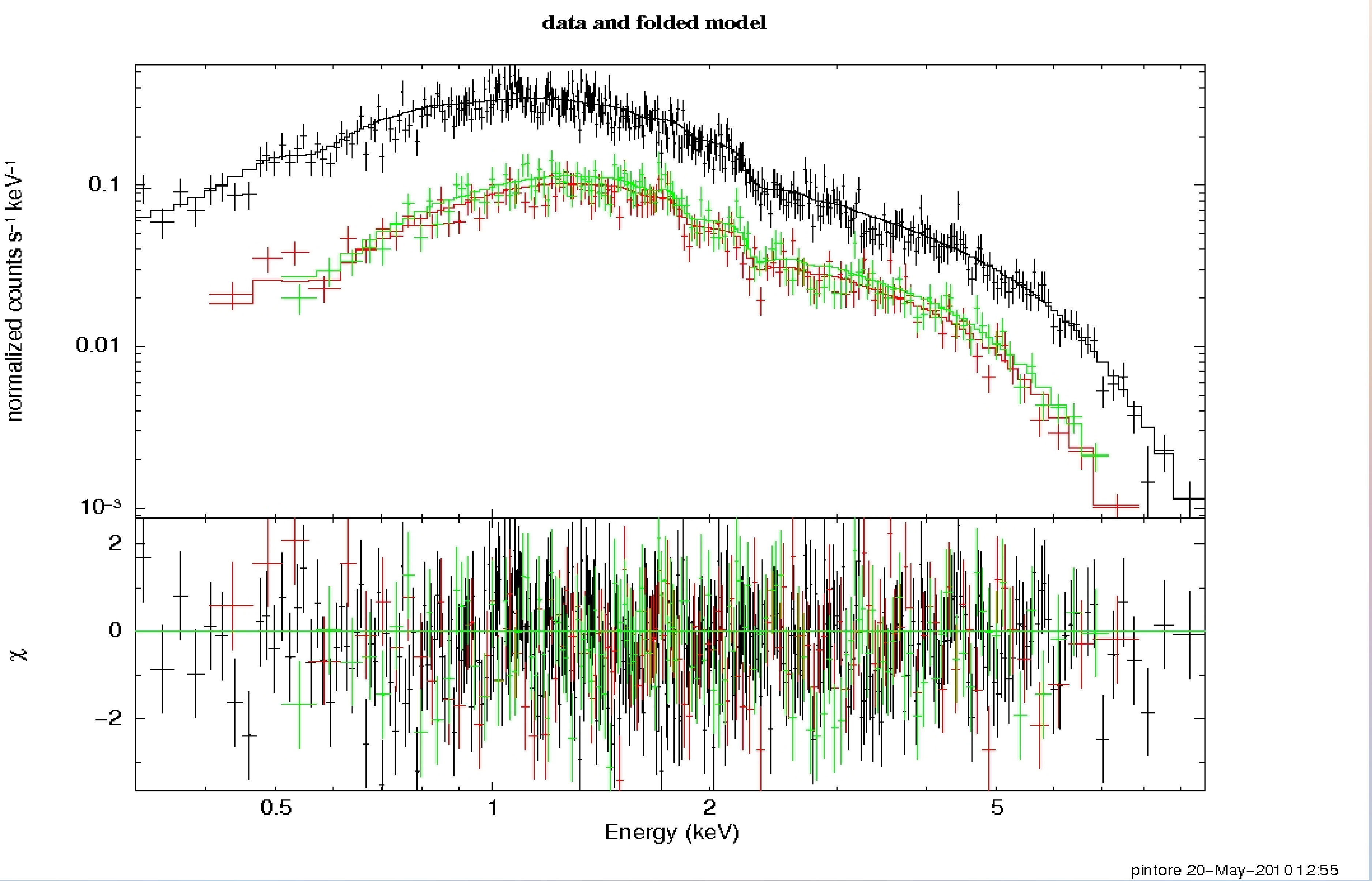
Obs.ID	Instruments	nH (10^{22} $part/cm^2$)	kT_{disk} (KeV)	kT_{corona} (KeV)	τ	0.3-10 KeV L_x (10^{39} erg/sec)	0.3-10 KeV L_{disk} (10^{39} erg/sec)	χ^2/dof
10/17/2000	PN/M1/M2	$0.23^{0.02}_{0.02}$	$0.231^{0.004}_{0.004}$	$2.24^{0.1}_{0.03}$	$8.2^{0.1}_{0.1}$	$7.3^{1}_{0.9}$	$2.00^{0.6}_{0.48}$	689.86/698
11/25/2003	M1/M2	$0.17^{0.05}_{0.05}$	$0.11^{0.02}_{0.02}$	$2.7^{0.4}_{0.4}$	$5.6^{0.5}_{0.4}$	10.9^{9}_{5}	...	23.12/39
12/21/2003	PN	$0.19^{0.07}_{0.06}$	$0.20^{0.03}_{0.04}$	$1.83^{0.2}_{0.07}$	$6.7^{0.2}_{0.2}$	11.5^{6}_{4}	...	195.47/227
12/23/2003	PN	$0.25^{0.02}_{0.02}$	$0.18^{0.02}_{0.02}$	$2.4^{0.3}_{0.2}$	$5.8^{0.3}_{0.3}$	10.9^{9}_{5}	...	66.93/76
12/25/2003	PN	$0.14^{0.05}_{0.06}$	$0.17^{0.05}_{0.04}$	$3.30^{0.7}_{0.7}$	$5.2^{0.8}_{0.7}$	$8.22^{8.6}_{5.0}$	...	14.51/13
01/08/2004	PN	$0.27^{0.05}_{0.05}$	$0.24^{0.01}_{0.01}$	$4.4^{0.2}_{0.2}$	$4.3^{0.2}_{0.2}$	10.8^{4}_{28}	$8.12^{0}_{6.7}$	184.56/176
01/16/2004	PN/M1/M2	$0.14^{0.1}_{0.07}$	$0.22^{0.04}_{0.05}$	$1.9^{0.2}_{0.1}$	$6.^{0.2}_{0.2}$	$9.29^{1.3}_{3.6}$	...	195.10/198
05/01/2004	M1/M2	$0.12^{0.06}_{0.08}$	$0.17^{0.05}_{0.04}$	$3.2^{0.3}_{0.2}$	$5.6^{0.3}_{0.3}$	$5.83^{4.1}_{2.7}$	...	106.03/103
06/05/2004	PN	$0.13^{0.04}_{0.03}$	$0.23^{0.02}_{0.02}$	$1.7^{0.1}_{0.04}$	$7.1^{0.1}_{0.1}$	14.0^{3}_{3}	...	512.21/544
08/23/2004	PN/M1/M2	$0.24^{0.01}_{0.01}$	$0.15^{0.007}_{0.007}$	$2.6^{0.1}_{0.1}$	$3.7^{0.1}_{0.1}$	$5.5^{1.3}_{1.1}$	...	234.06/233
11/23/2004	M1/M2	$0.11^{0.04}_{0.05}$	$0.18^{0.03}_{0.03}$	$3.22^{0.2}_{0.2}$	$5.53^{0.2}_{0.2}$	$7.1^{3.3}_{2.3}$	...	181.82/185
02/07/2005	PN/M1/M2	$0.29^{0.04}_{0.04}$	$0.208^{0.005}_{0.005}$	$2.71^{0.2}_{0.06}$	$7.0^{0.2}_{0.2}$	$8.93^{2.5}_{1.9}$	$2.68^{1.5}_{1}$	313.10/305
03/06/2006	PN	$0.24^{0.05}_{0.05}$	$0.28^{0.01}_{0.01}$	$1.17^{0.5}_{0.03}$	$12.3^{0.5}_{0.5}$	$4.7^{1.9}_{1.2}$	$1.28^{1.2}_{6.3}$	169.35/139
10/16/2006	PN/M1/M2	$0.25^{0.01}_{0.01}$	$0.228^{0.002}_{0.002}$	$2.08^{0.06}_{0.01}$	$8.65^{0.06}_{0.06}$	$7.00^{0.05}_{0.05}$	$2.0^{0.3}_{0.3}$	1624.29/1481

X-1 (with eqtherm)

Obs.ID	Instruments	nH (10^{22} $part/cm^2$)	kT_{disk} (KeV)	l_h/l_s	τ	0.3-10 KeV L_x (10^{39} erg/sec)	0.3-10 KeV L_{disk} (10^{39} erg/sec)	χ^2/dof
10/17/2000	PN/M1/M2	$0.21^{0.03}_{0.04}$	$0.27^{0.2}_{0.1}$	2.05	$9.43^{0.2}_{0.2}$	$7.2^{1.3}_{0.7}$	$2.2^{1.1}_{0.5}$	690.95/695
11/25/2003	M1/M2	$0.17^{0.05}_{0.04}$	$0.12^{0.2}_{0.2}$	1.18	$11.1^{1.0}_{0.9}$	$11.0^{2.5}_{1.7}$	...	22.98/38
12/21/2003	PN	$0.21^{0.06}_{0.05}$	$0.20^{0.1}_{0.1}$	0.54	$5.8^{0.2}_{0.2}$	$12.0^{2.1}_{2.9}$	...	198.04/226
12/23/2003	PN	$0.35^{0.02}_{0.02}$	$0.19^{0.3}_{0.4}$	4.02	$0.9^{0.3}_{0.3}$	$13.0^{2.2}_{1.7}$	...	69.25/75
12/25/2003	PN	$0.13^{0.02}_{0.02}$	$0.30^{0.3}_{0.2}$	2.45	$11.2^{0.4}_{0.4}$	$8.5^{1.7}_{1.1}$	...	15.56/11
01/08/2004	PN	$0.20^{0.05}_{0.05}$	$0.24^{0.2}_{0.1}$	1.29	$29.9^{0.2}_{0.2}$	$9.7^{2.1}_{1.2}$	$1.3^{1.2}_{0.8}$	183.05/175
01/16/2004	PN/M1/M2	$0.21^{0.06}_{0.05}$	$0.20^{0.1}_{0.2}$	2.21	$15.8^{0.3}_{0.3}$	$9.1^{3.4}_{1.5}$	...	194.96/197
05/01/2004	M1/M2	0	0	0	0	0	0	..
06/05/2004	PN	$0.21^{0.03}_{0.04}$	$0.20^{0.1}_{0.1}$	2.25	$3.8^{0.2}_{0.2}$	$14.2^{1.8}_{1.8}$	...	249.98/262
08/23/2004	PN/M1/M2	$0.23^{0.03}_{0.03}$	$0.17^{0.5}_{0.4}$	1.08	$10.6^{0.2}_{0.2}$	$4.3^{1.4}_{0.9}$	...	242.40/232
11/23/2004	M1/M2	$0.18^{0.01}_{0.01}$	$0.23^{0.3}_{0.2}$	1.67	$1.03^{0.1}_{0.1}$	$8.0^{1.1}_{0.6}$	...	167.41/184
02/07/2005	PN/M1/M2	$0.30^{0.05}_{0.04}$	$0.21^{0.3}_{0.5}$	5.86	$0.78^{0.2}_{0.2}$	$9.4^{2.2}_{1.6}$	$3.1^{3.7}_{1.4}$	313.44/304
03/06/2006	PN	$0.25^{0.06}_{0.04}$	$0.31^{0.2}_{0.2}$	2.17	$1.11^{0.2}_{0.2}$	$4.8^{2.5}_{1.9}$	$1.43^{7.8}_{3}$	171.42/138
10/16/2006	PN/M1/M2	$0.25^{0.02}_{0.02}$	$0.24^{0.1}_{0.1}$	1.18	$9.41^{0.1}_{0.1}$	$6.7^{0.9}_{0.7}$	$2.02^{0.13}_{0.09}$	1625.67/1480

Fit with the tbabs*tbabs*(eqtherm+diskbb) model

X-2



X-2 (with comptt)

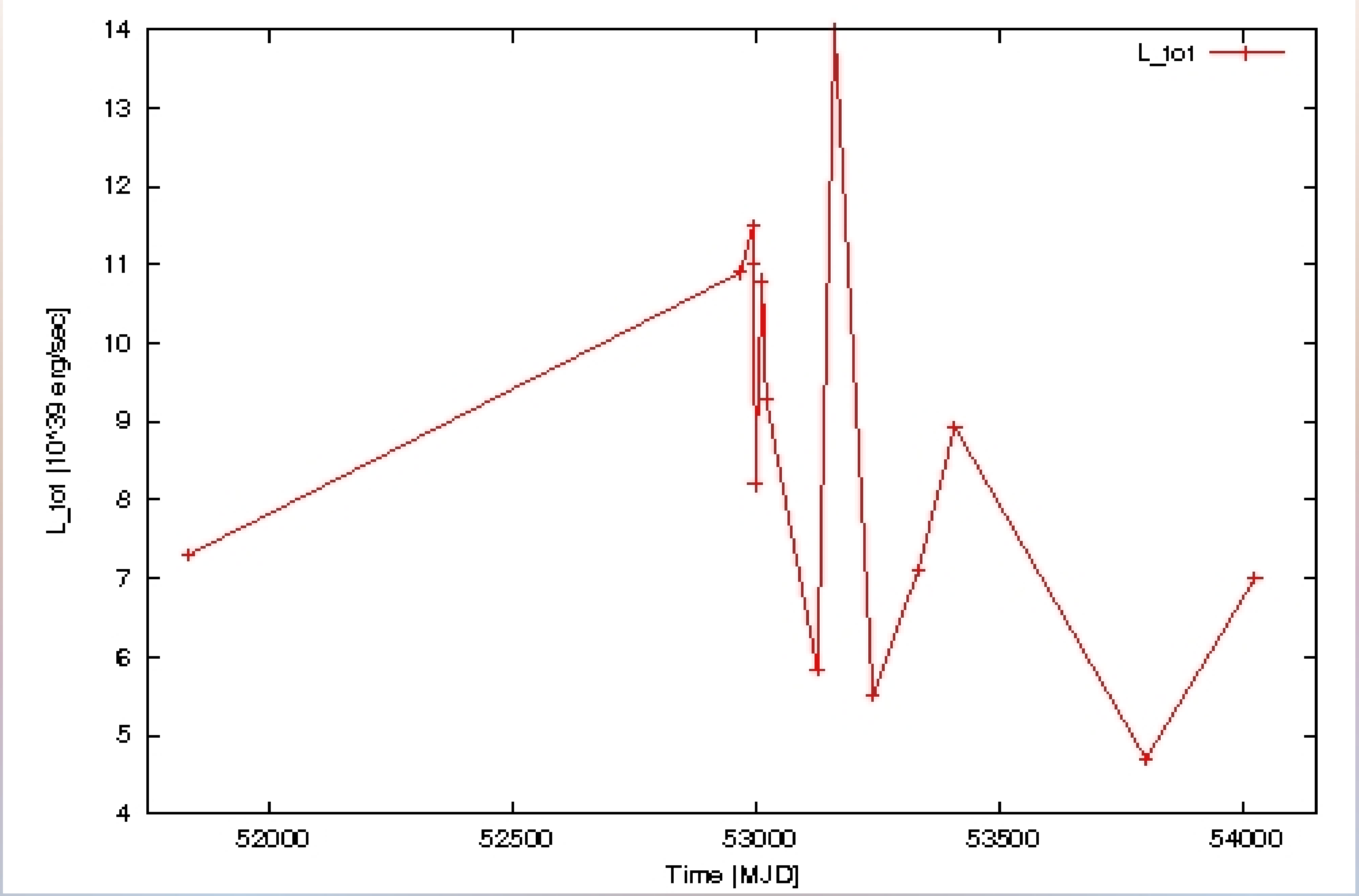
Obs.ID	Instruments	nH (10^{22} $part/cm^2$)	kT_{disk} (KeV)	kT_{corona} (KeV)	τ	0.3-10 KeV L_x (10^{39} erg/sec)	0.3-10 KeV L_{disk} (10^{38} erg/sec)	χ^2/dof
10/17/2000	PN	$0.14^{0.06}_{0.06}$	$0.17^{0.03}_{0.04}$	$3.33^{0.2}_{0.2}$	$4.4^{0.2}_{0.2}$	$1.7^{1.3}_{0.7}$	...	141.86/143
11/25/2003	PN/M1/M2	$0.03^{0.02}_{0.02}$	$0.26^{0.05}_{0.04}$	$1.18^{0.07}_{0.07}$	$12.7^{1}_{0.9}$	$5.1^{2.5}_{1.7}$	$5.6^{1.7}_{..}$	35.57/36
12/21/2003	PN/M1/M2	$0.13^{0.04}_{0.01}$	$0.29^{0.06}_{0.05}$	$1.58^{0.04}_{0.04}$	$10.5^{0.2}_{0.2}$	$7.1^{2.1}_{2.9}$	$5.2^{7.8}_{13.4}$	386.29/395
12/23/2003	PN/M1/M2	$0.04^{0.02}_{0.03}$	$0.27^{0.02}_{0.02}$	$1.69^{0.06}_{0.06}$	$10.2^{0.3}_{0.3}$	$7.6^{2.2}_{1.7}$	...	245.35/249
12/25/2003	PN/M1/M2	$0.15^{0.04}_{0.04}$	$0.30^{0.02}_{0.02}$	$1.5^{0.1}_{0.1}$	$8.7^{0.4}_{0.4}$	$3.5^{1.7}_{1.1}$	$7.4^{0.8}_{4.5}$	100.41/120
01/08/2004	PN/M1/M2	$0.13^{0.02}_{0.02}$	$0.25^{0.05}_{0.05}$	$1.91^{0.09}_{0.08}$	$6.5^{0.2}_{0.2}$	$2.7^{2.1}_{1.2}$	$3.6^{5.6}_{2.6}$	175.30/201
01/16/2004	PN/M1/M2	$0.13^{0.08}_{0.1}$	$0.17^{0.06}_{0.05}$	$2.6^{0.2}_{0.2}$	$5.5^{0.3}_{0.3}$	$2.5^{3.4}_{1.5}$	...	85.33/86
05/01/2004	M1/M2	$0.10^{0.09}_{0.09}$	$0.38^{0.4}_{0.1}$	$1.4^{0.1}_{0.1}$	$7.2^{0.7}_{0.7}$	$1.8^{1}_{1.3}$	$6.3^{1.1}_{5.9}$	55.41/46
06/05/2004	PN/M1/M2	$0.14^{0.04}_{0.03}$	$0.23^{0.04}_{0.04}$	$1.48^{0.03}_{0.03}$	$11.0^{0.2}_{0.2}$	$8.2^{1.8}_{1.8}$	$1.4^{2.1}_{1.0}$	515.23/507
08/23/2004	PN/M1/M2	$0.14^{0.04}_{0.05}$	$0.15^{0.03}_{0.03}$	$3.4^{0.2}_{0.2}$	$4.6^{0.2}_{0.2}$	$1.99^{1.4}_{0.9}$	...	162.21/132
11/23/2004	PN/M1/M2	$0.14^{0.04}_{0.05}$	$0.17^{0.01}_{0.01}$	$3.00^{0.1}_{0.1}$	$4.9^{0.1}_{0.1}$	$2.1^{1.1}_{0.65}$	...	215.02/238
02/07/2005	PN/M1/M2	$0.10^{0.02}_{0.01}$	$0.27^{0.05}_{0.04}$	$1.53^{0.03}_{0.03}$	$11.4^{0.2}_{0.2}$	$7.7^{2.2}_{1.6}$	$2.4^{3.7}_{1.4}$	491.14/486
03/06/2006	PN/M1/M2	$0.15^{0.04}_{0.01}$	$0.29^{0.06}_{0.04}$	$1.42^{0.02}_{0.02}$	$11.5.3^{0.2}_{0.2}$	$7.5^{2.5}_{1.9}$	$5.1^{7.8}_{3}$	577.03/603
10/16/2006	PN	$0.141^{0.01}_{0.007}$	$0.24^{0.02}_{0.02}$	$1.63^{0.02}_{0.02}$	$9.8^{0.1}_{0.1}$	$6.8^{0.9}_{0.8}$	$2.5^{1.3}_{0.9}$	843.58/854

X-2 (with eqtherm)

Obs.ID	Instruments	nH (10^{22} $part/cm^2$)	kT_{disk} (KeV)	l_h/l_s	τ	0.3-10 KeV L_x (10^{39} erg/sec)	0.3-10 KeV L_{disk} (10^{39} erg/sec)	χ^2/dof
10/17/2000	PN	$0.16^{0.02}_{0.02}$	$0.20^{0.03}_{0.04}$	1.45	$1.3^{0.2}_{0.2}$	$1.7^{1.3}_{0.7}$	...	139.38/145
11/25/2003	PN/M1/M2	$0.097^{0.05}_{0.04}$	$0.20^{0.05}_{0.04}$	1.93	$26.3^{1.0}_{0.9}$	$5.1^{2.5}_{1.7}$	...	58.86/62
12/21/2003	PN/M1/M2	$0.15^{0.03}_{0.04}$	$0.32^{0.06}_{0.05}$	1.49	$19.2^{0.2}_{0.2}$	$6.9^{2.1}_{2.9}$	$6.1^{7.8}_{3.4}$	385.68/394
12/23/2003	PN/M1/M2	$0.14^{0.01}_{0.02}$	$0.23^{0.02}_{0.02}$	2.09	$18.8^{0.3}_{0.3}$	$7.8^{2.2}_{1.7}$	...	245.73/248
12/25/2003	PN/M1/M2	$0.16^{0.01}_{0.01}$	$0.29^{0.02}_{0.02}$	1.06	$14.4^{0.4}_{0.4}$	$3.3^{1.7}_{1.1}$	$5.5^{0.8}_{4.5}$	101.48/119
01/08/2004	PN/M1/M2	$0.17^{0.02}_{0.02}$	$0.22^{0.05}_{0.05}$	1.04	$11.6^{0.2}_{0.2}$	$2.5^{2.1}_{1.2}$	$2.6^{5.6}_{2.6}$	252.41/200
01/16/2004	PN/M1/M2	$0.15^{0.02}_{0.02}$	$0.17^{0.06}_{0.05}$	1.49	$7.76^{0.3}_{0.3}$	$2.8^{3.4}_{1.5}$	...	85.49/85
05/01/2004	M1/M2	0	0	0	0	0	0	..
06/05/2004	PN/M1/M2	$0.21^{0.03}_{0.02}$	$0.23^{0.03}_{0.04}$	1.87	$20.5^{0.2}_{0.2}$	$8.4^{1.8}_{1.8}$	$4.2^{2.1}_{1}$	287.60/270
08/23/2004	PN/M1/M2	$0.21^{0.02}_{0.01}$	$0.19^{0.03}_{0.03}$	1.76	$0.6^{0.2}_{0.2}$	$1.3^{1.4}_{0.9}$	...	150.99/131
11/23/2004	PN/M1/M2	$0.16^{0.01}_{0.01}$	$0.21^{0.01}_{0.01}$	1.61	$1.2^{0.1}_{0.1}$	$1.4^{1.1}_{0.6}$	...	211.11/237
02/07/2005	PN/M1/M2	$0.165^{0.03}_{0.03}$	$0.25^{0.05}_{0.04}$	1.96	$21.9^{0.2}_{0.2}$	$7.8^{2.2}_{1.6}$	$3.0^{3.7}_{1.4}$	489.36/485
03/06/2006	PN/M1/M2	$0.19^{0.03}_{0.03}$	$0.31^{0.06}_{0.04}$	1.47	$22.7^{0.2}_{0.2}$	$7.4^{2.5}_{1.9}$	$6.5^{7.8}_{3}$	578.54/602
10/16/2006	PN	$0.18^{0.02}_{0.02}$	$0.28^{0.02}_{0.02}$	1.59	$18.0^{0.1}_{0.1}$	$7.1^{0.9}_{0.7}$	$4.6^{0.13}_{0.09}$	827.48/853

LIGHT CURVE

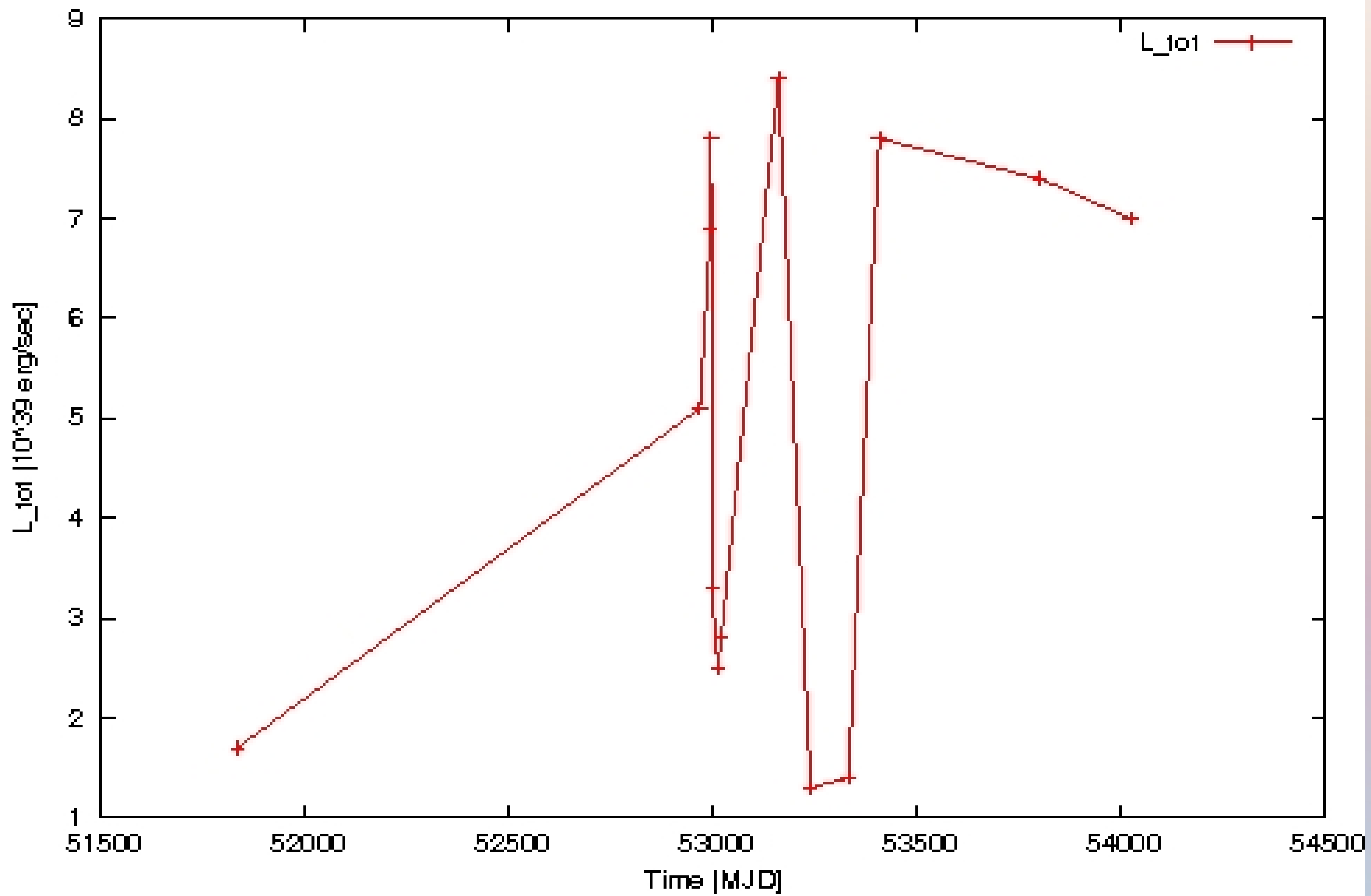
X-1



Typical variability of a factor 2!

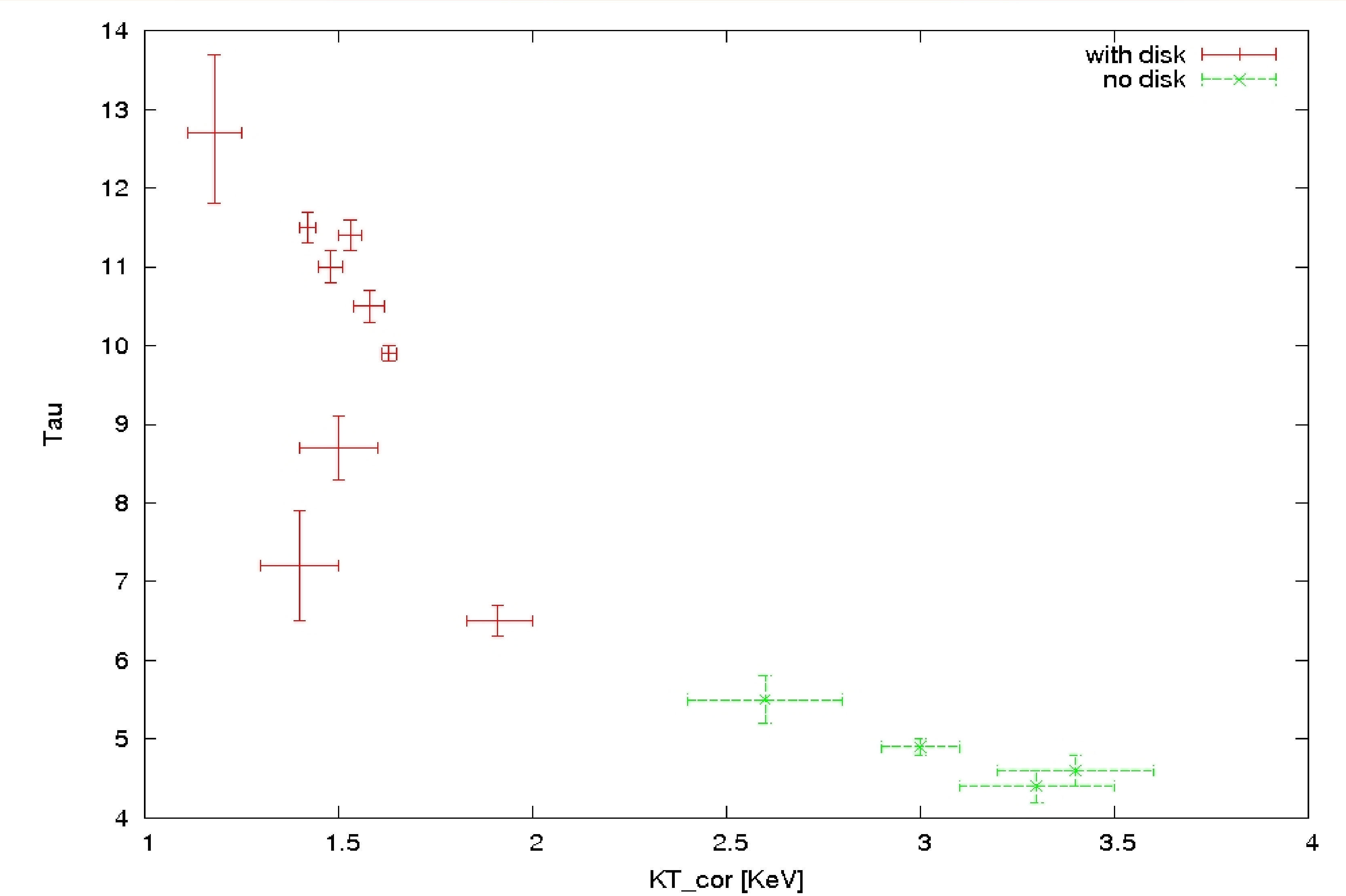
LIGHT CURVE

X-2



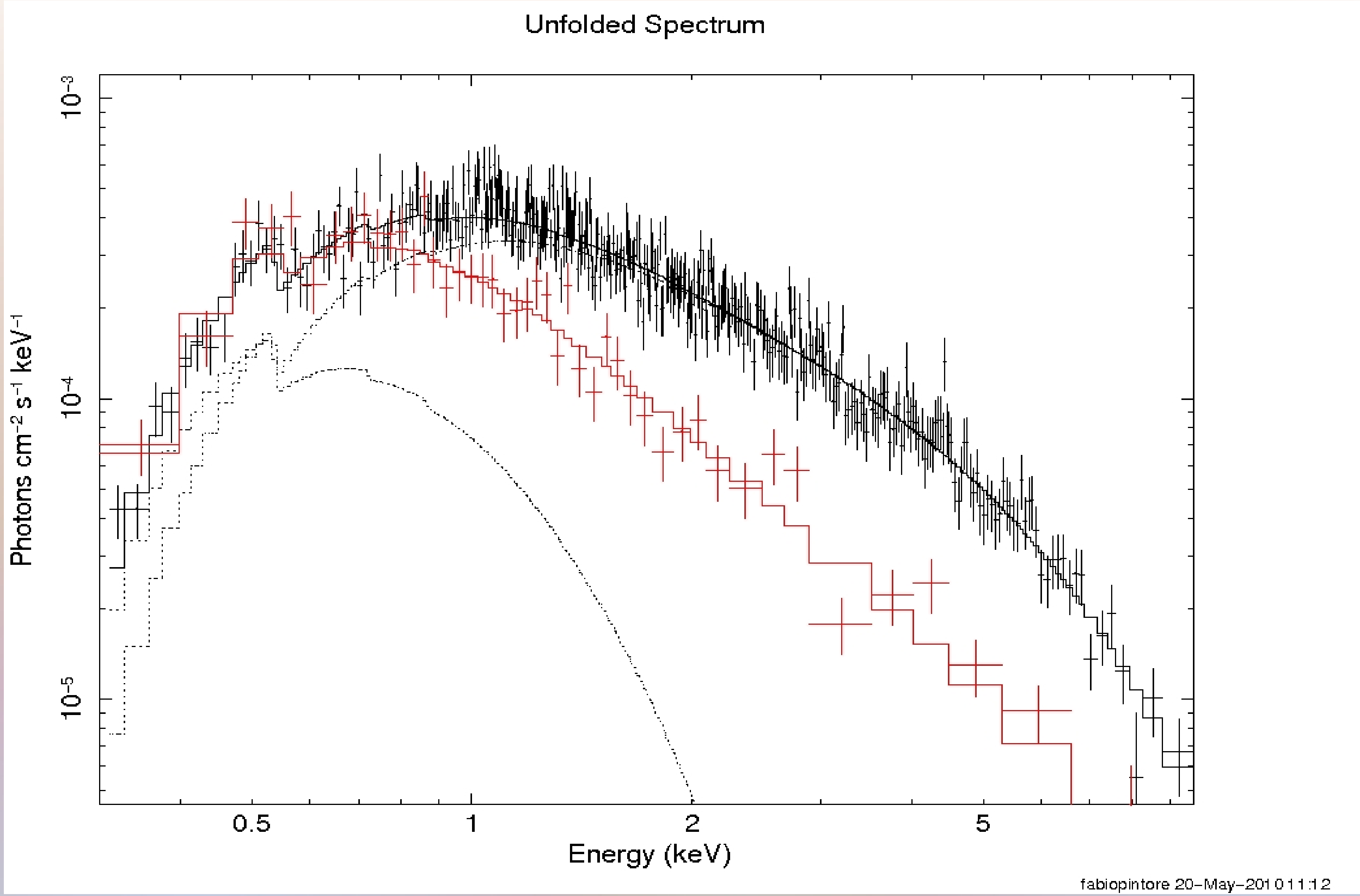
More pronounced 'flaring-type' variability!

'HIGH'/'LOW' STATE (X-2, with COMPTT)



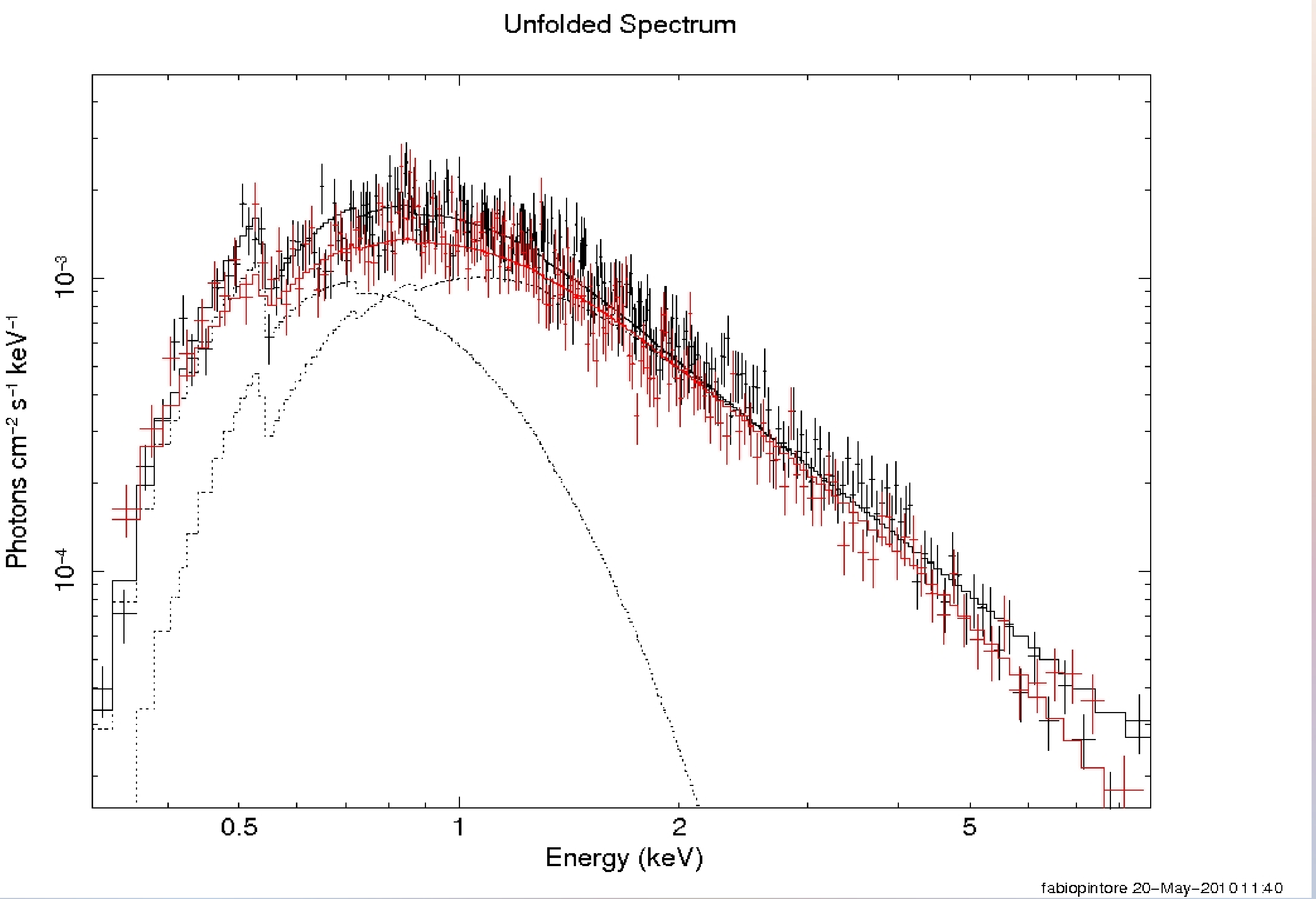
- 'HIGH' STATE: low temperature (~1.5 keV) and large optical depths (~10); a disc component is usually needed;
- 'LOW' STATE: higher temperature (~3 keV) and lower optical depths (~5); no disc component;

'High/low' state spectra of X-2



Comparison between spectra in the 'high'/'low' state. Evidence of a break at high luminosity. ~50% of the total luminosity is in the soft component. High energy tail shows opposite behaviour with respect to high/low state transitions in Galactic BH binaries.

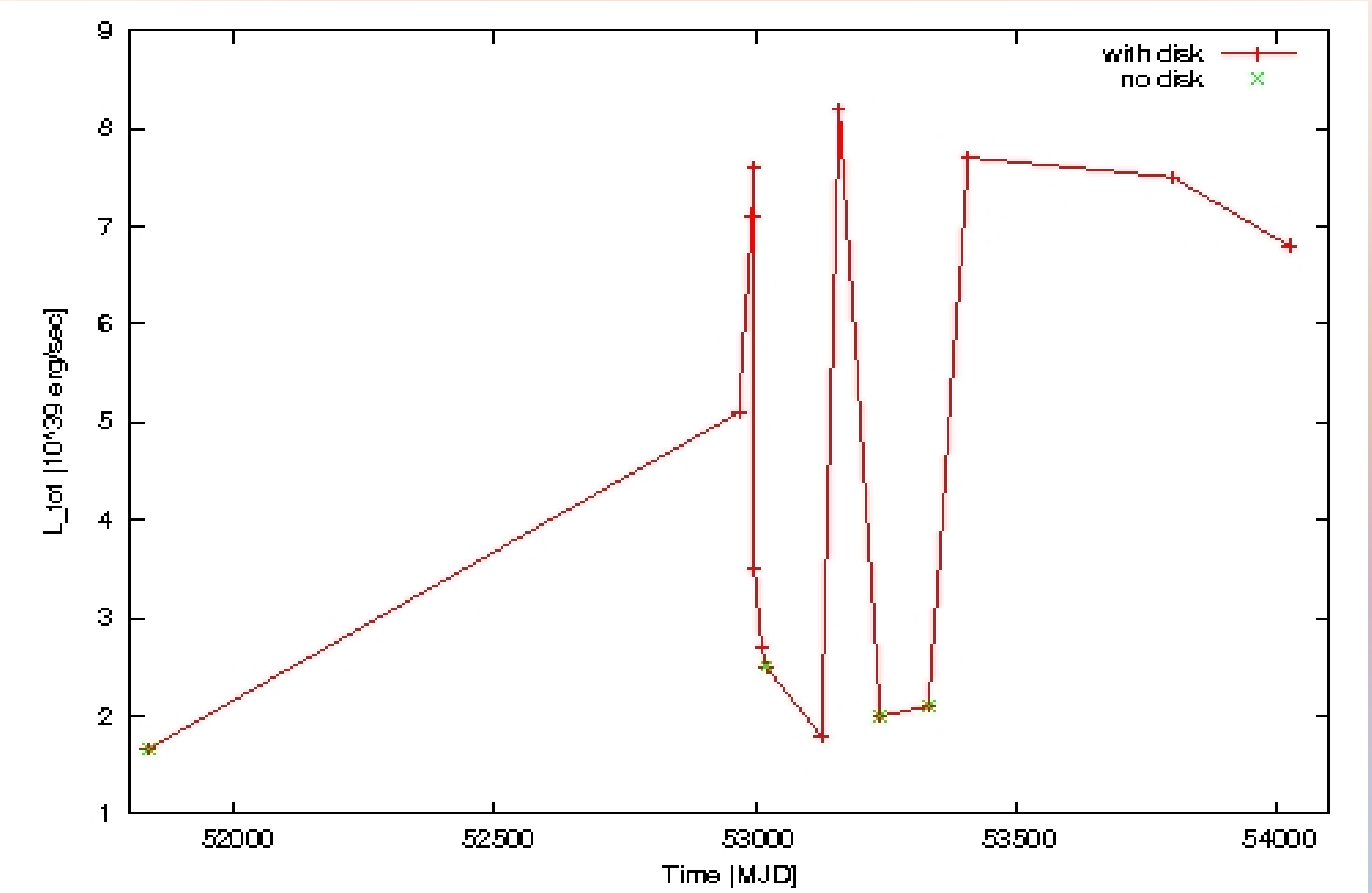
Spectral variability in X-1



Spectral variability much less pronounced.

LIGHT CURVE

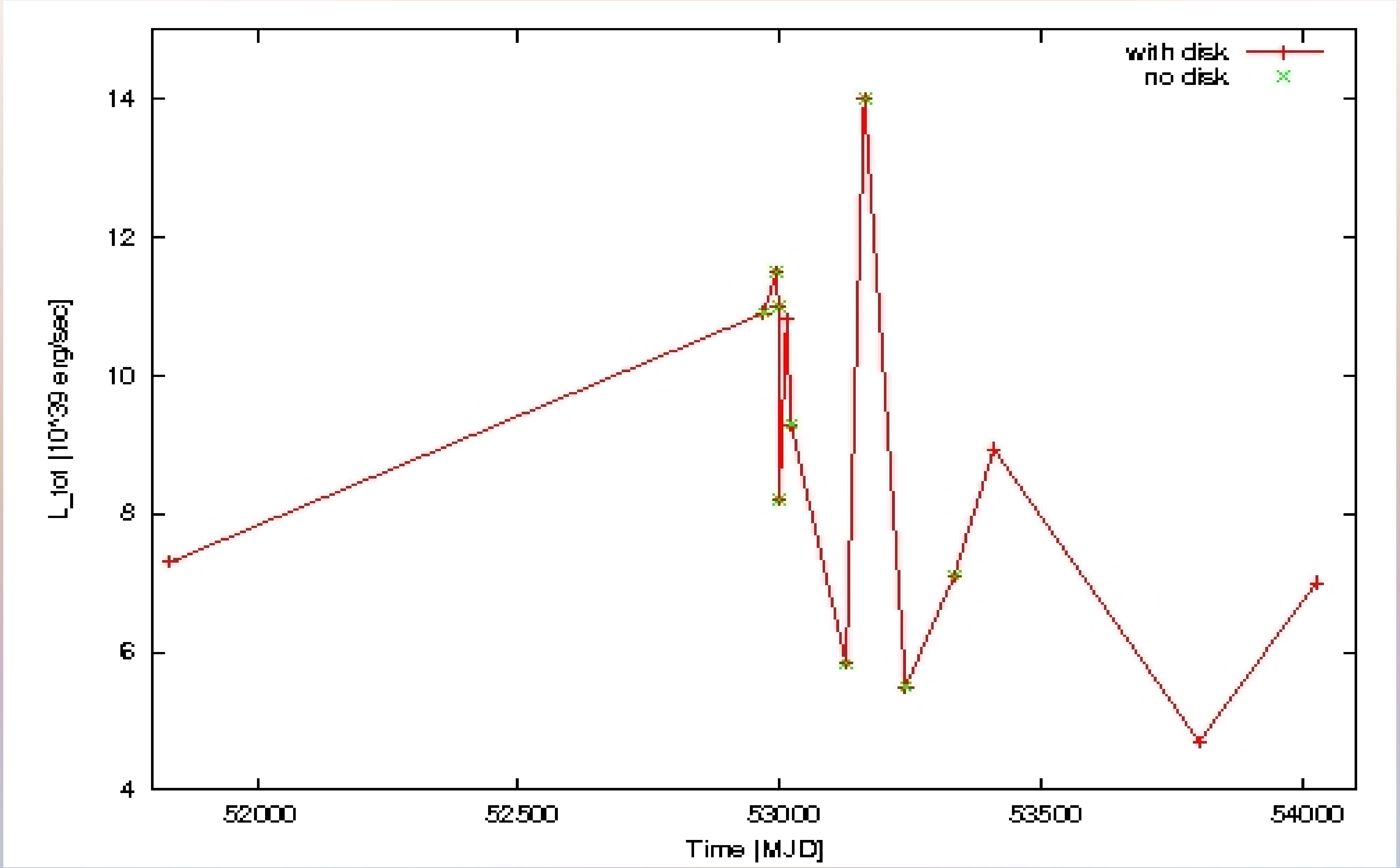
X-2



Lower luminosities: NO DISK!

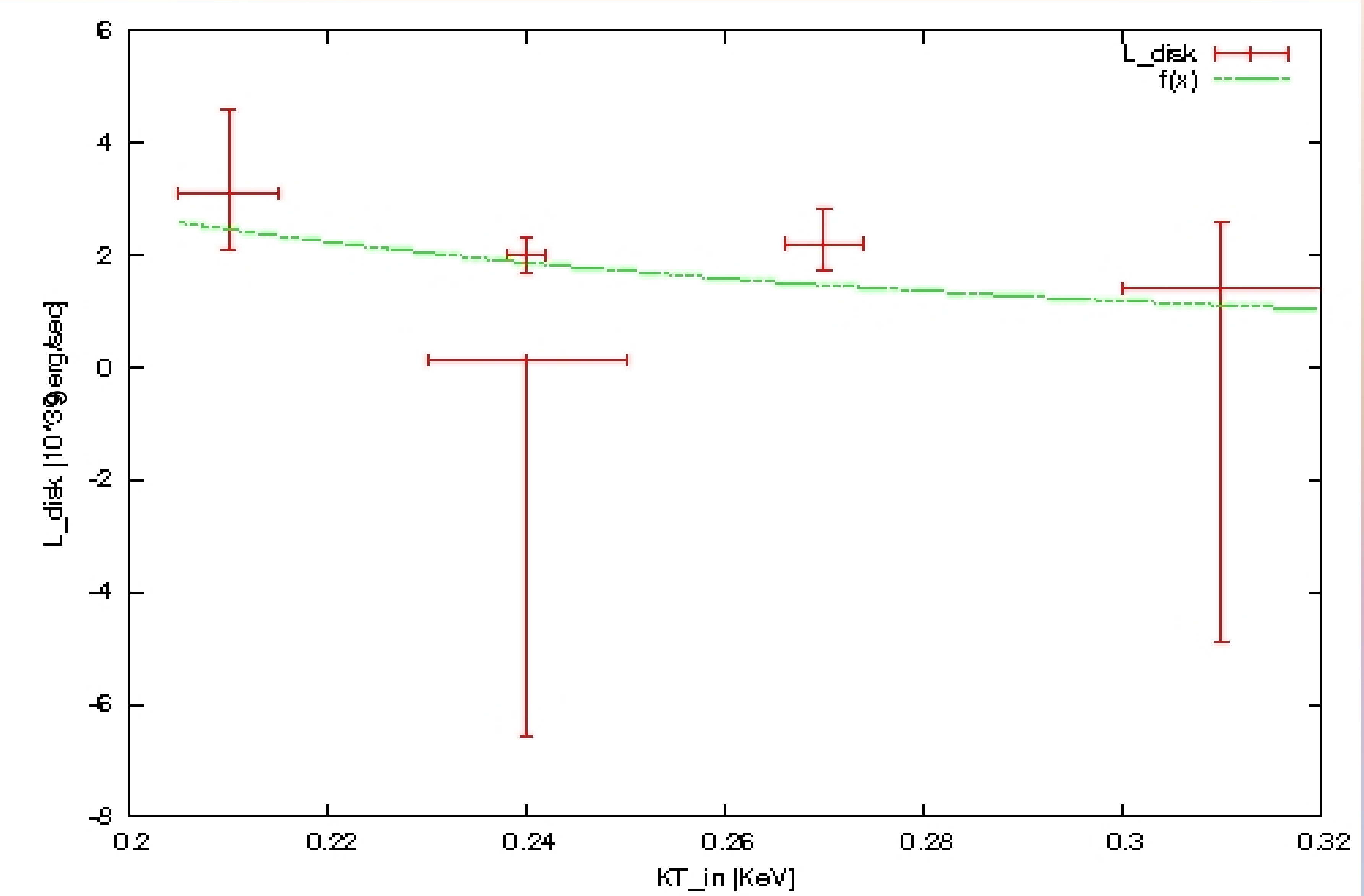
LIGHT CURVE

X-1



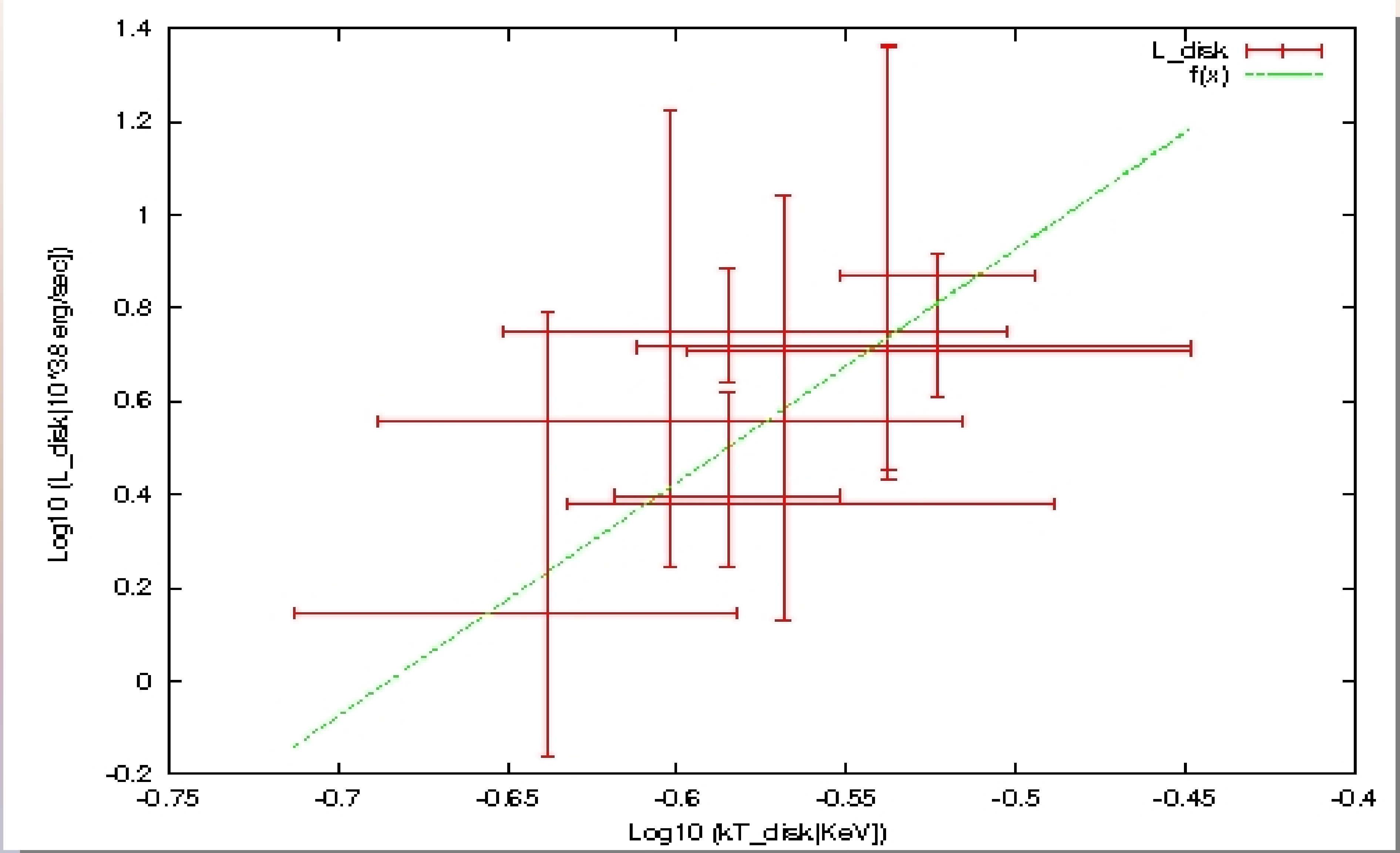
The soft component may or may not be needed, with no significant dependence on luminosity.

Ldisk vs KT_disk (X-1, with EQTHERM)



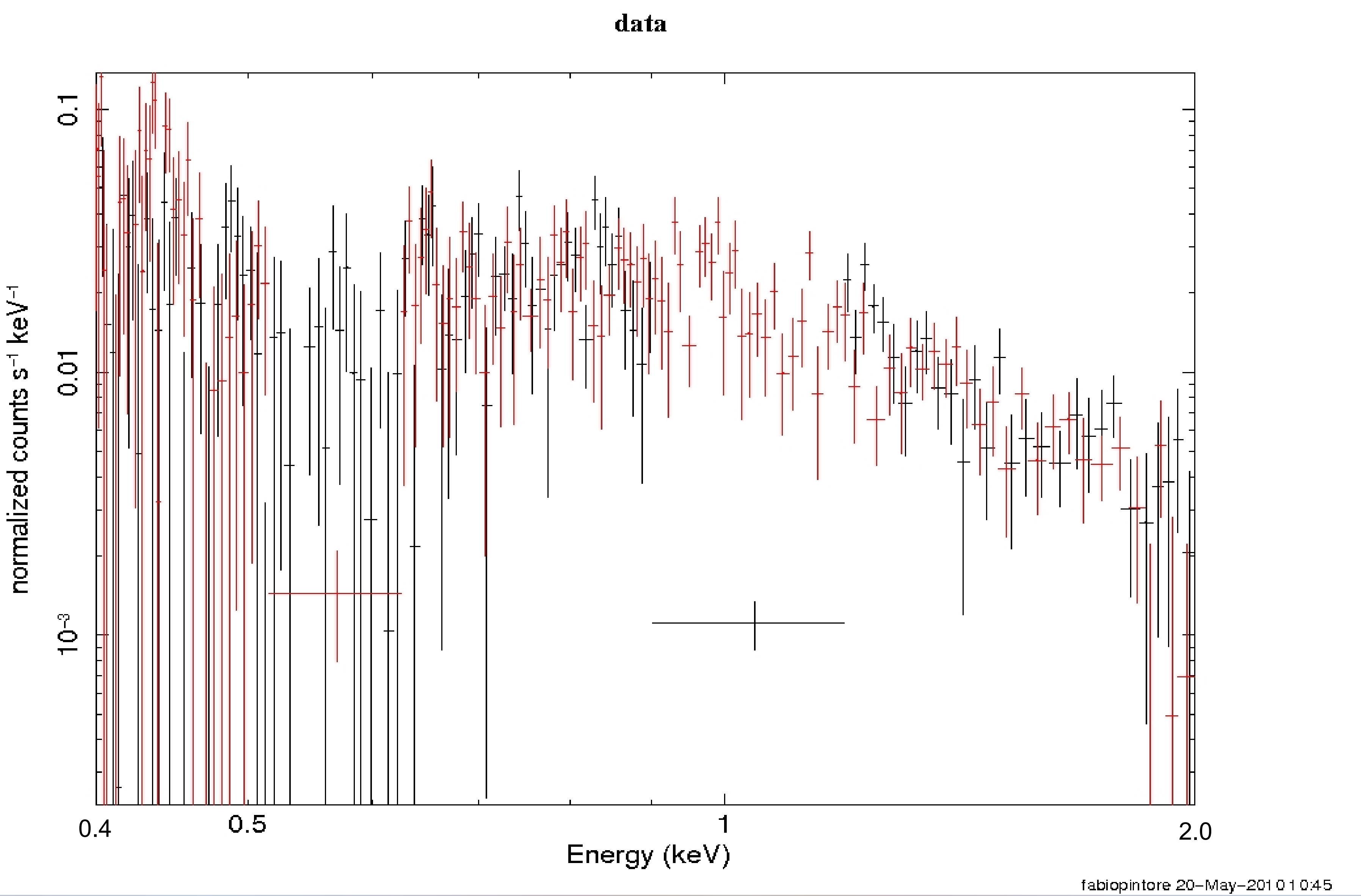
NO significant correlation ($L \sim T^{-0.2 \pm 5}$)!!!

Ldisk vs KT_disk (X-2, with COMPTT)



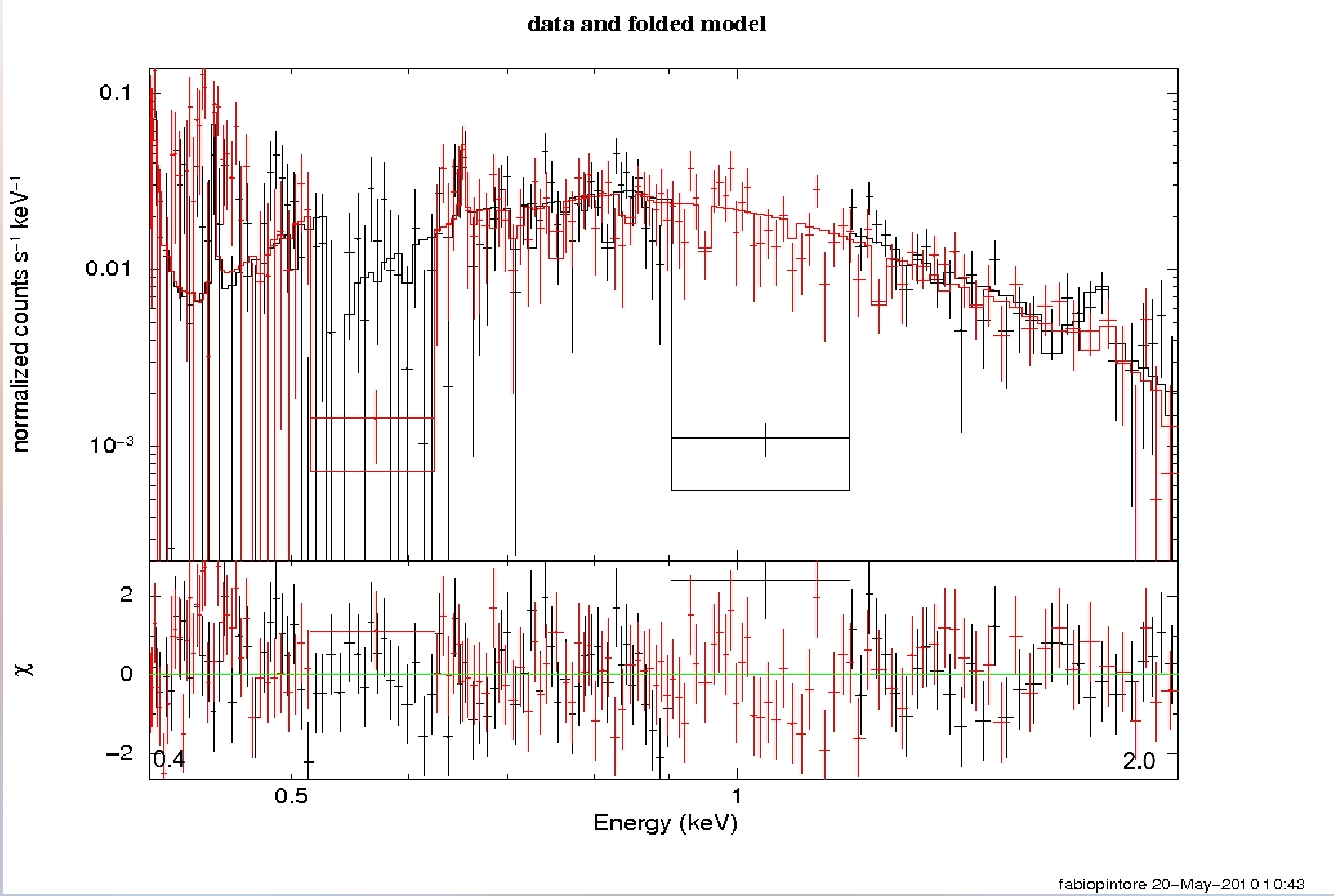
There is a significant correlation between L_{disk} and T_{in} ($L \sim T^{5.1\pm1.4}$).
With the EQTHERM model we find ($L \sim T^{2.1\pm0.5}$);

RGS ANALISYS FOR X-1



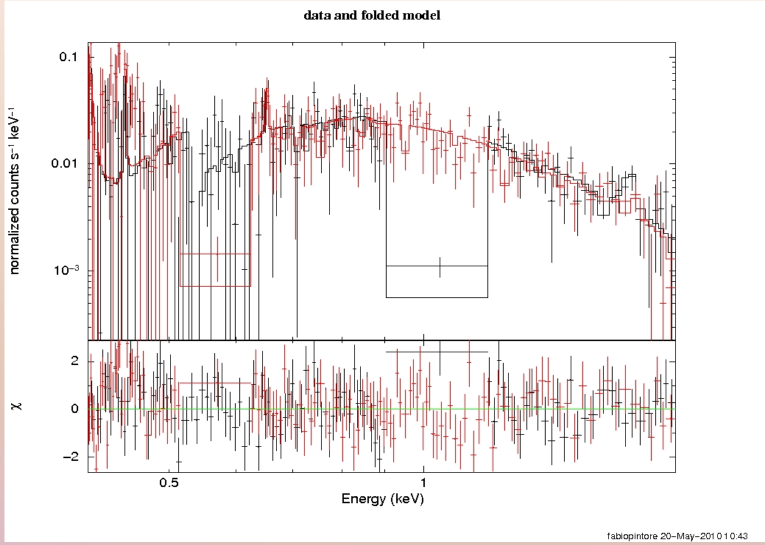
We re-fitted the EPIC-pn continuum using the tbvarabs model, that allows to vary the chemical abundances and we found approximately solar abundances. Then we fitted the RGS data with the EPIC-pn continuum in which the O and Fe abundances are fixed to 0.

RGS ANALISYS FOR X-1



We find 4 lines, two of them in absorption. The line at 1.74 KeV (Si) is instrumental.

RGS ANALISYS FOR X-1

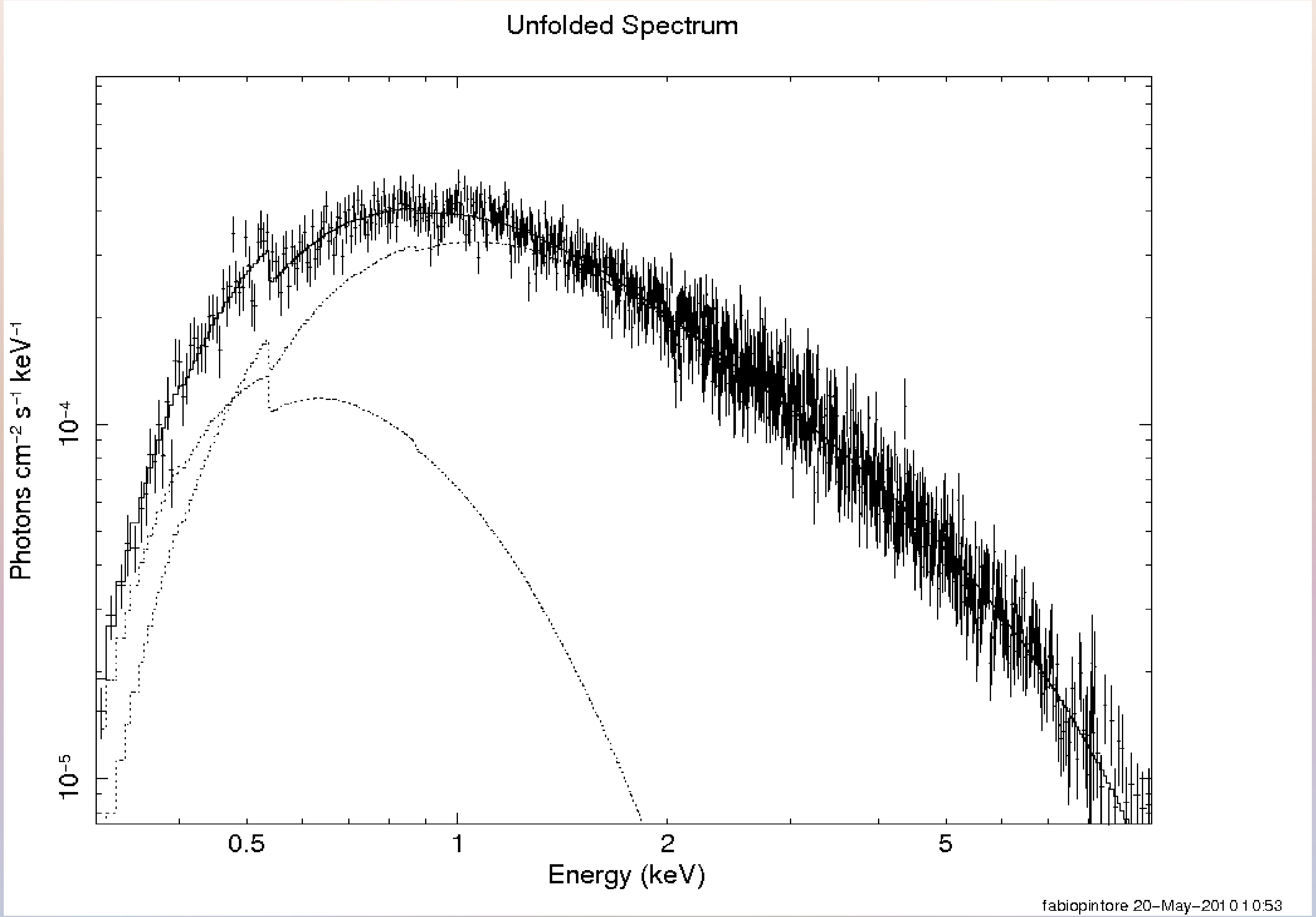


Lines	Energy (KeV)	Normalization $(photons/cm^{-2}s^{-1})$
O I (1s-1s2p)	0.535 ± 0.001	$(-5.2 \pm 0.2) \cdot 10^{-5}$
Fe I	0.709 ± 0.001	$(-1.2 \pm 0.2) \cdot 10^{-5}$
instrumental(Si)	1.748 ± 0.001	$(1.3 \pm 0.1) \cdot 10^{-5}$
O VIII	0.653 ± 0.001	$(2.5 \pm 0.2) \cdot 10^{-5}$
Edge	**Energy (KeV)**	**Absorption depth**
$Oxygen_{K-edge}$	0.536 ± 0.005	0.63 ± 0.01

From the edge, we find an abundances for Oxygen slightly above solar (1.3 solar metallicity).

ABUNDANCES IN X-2

If the O and Fe abundances are left free, the fit of the EPIC-pn spectrum gives sub-solar abundances;



The Oxygen abundance is 0.5 solar, while the Fe abundance is very low (consistent with zero).

CONCLUSIONS

We re-analysed in a homogeneous way all the XMM-Newton spectra of NGC1313 X-1 and X-2 using a disc plus comptonizing corona model:

- X-1: disc component needed only in some observations;

  - no correlation between disc luminosity and temperature;

  - this source may be entering the ultraluminous regime (Gladstone et al.2009),with a corona mass-loaded by a wind launched from a disc accreting at super-Eddington rates;

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- X-2: disc component present in the majority of the observations;

  - we found a correlation between the luminosity and temperature of the soft disc component;

  - possibly two spectral states;

    'high' state: the corona becomes denser and, at the same time, shrinks uncovering part of the disc;

    'low' state: the corona is hotter and more extended, covering a larger fraction of the disc;

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- Analysis of the RGS spectra appears to indicate that the environment of X-1 has typical solar abundance. On the other hand, fits with tbvarabs suggests sub-solar metallicity in the enviroment of X-2.


THANKS FOR THE ATTENTION