SEVENTH FRAMEWORK PROGRAMME
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ROMA TRE
UNIVERSITÀ DEGLI STUDI

A long simultaneous XMM-NuSTAR look of MCG-6-30-15

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and the NuSTAR AGN Physics WG

Santorini
Explosive transients: lighthouses of the Universe
September 16th, 2013

Overview

- Brief introduction on MCG-6-30-15
- The XMM-NuSTAR 2013 observational campaign
- Testing the two different scenarios
- Results
- Conclusions and future perspectives

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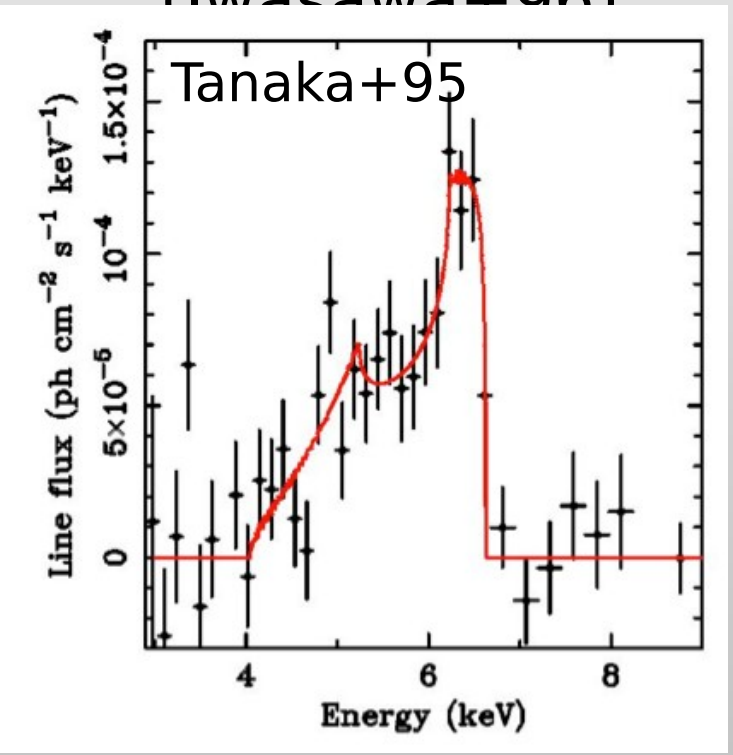
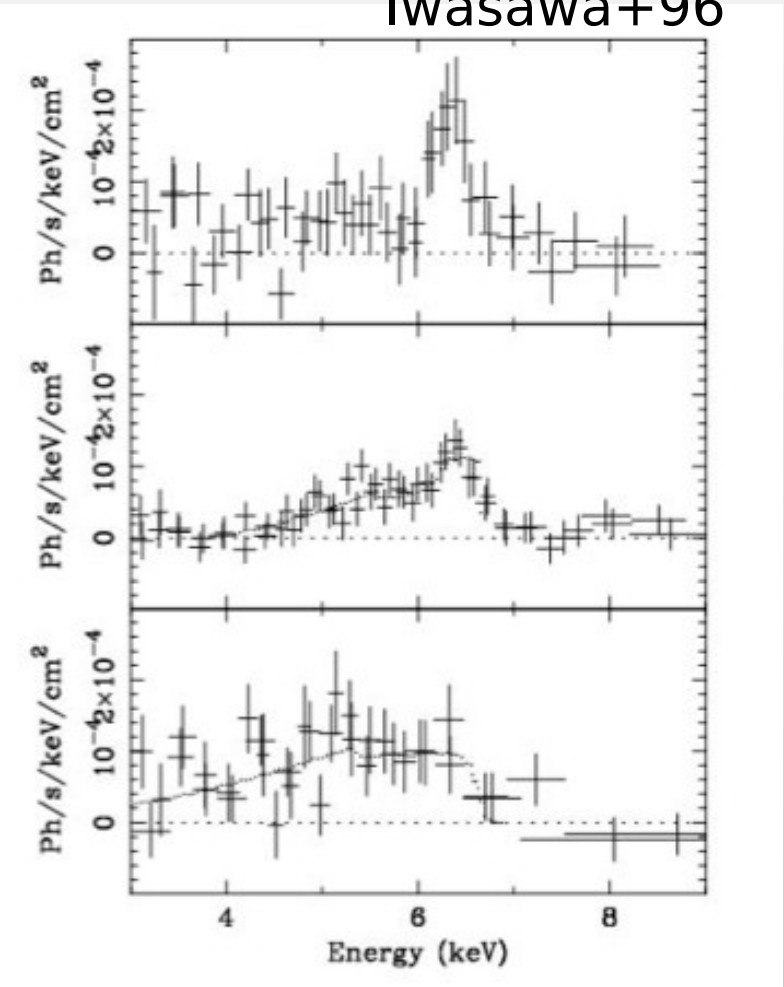
Introduction

Bright Sy 1 galaxy hosting the first broad Fe Kα line ever observed (Tanaka+95) and interpreted as originating from a rapidly spinning BH (Iwasawa+96)

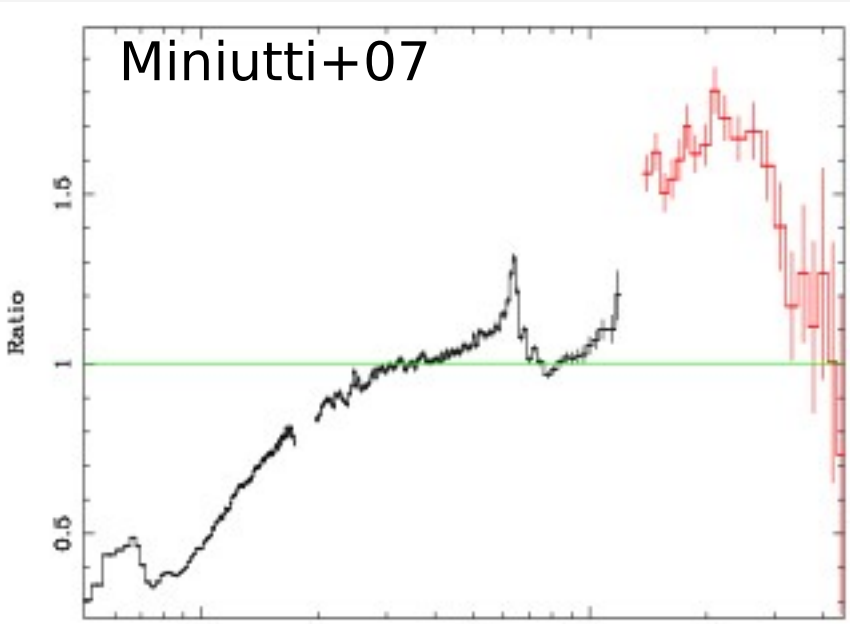


Iwasawa+96

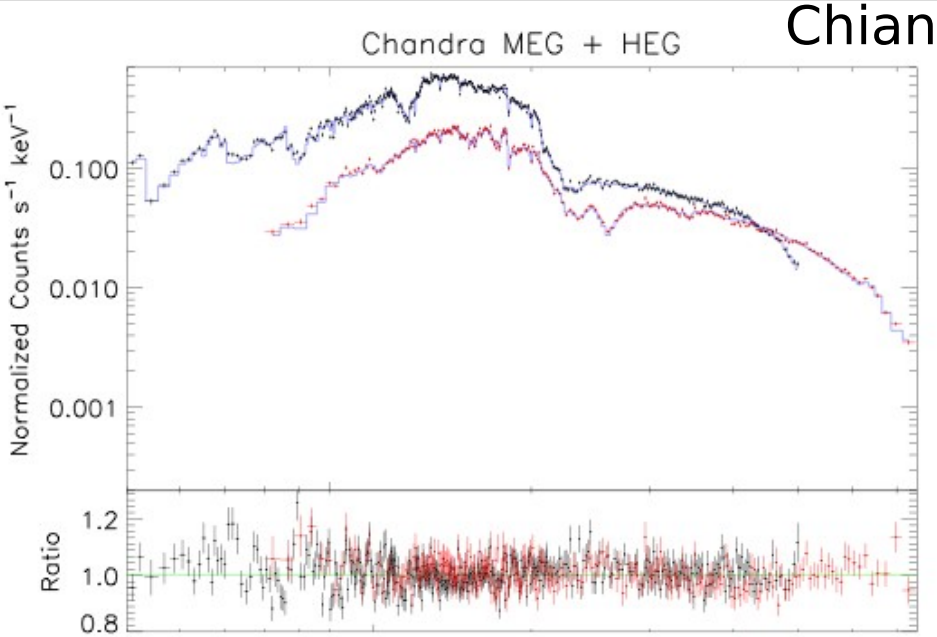


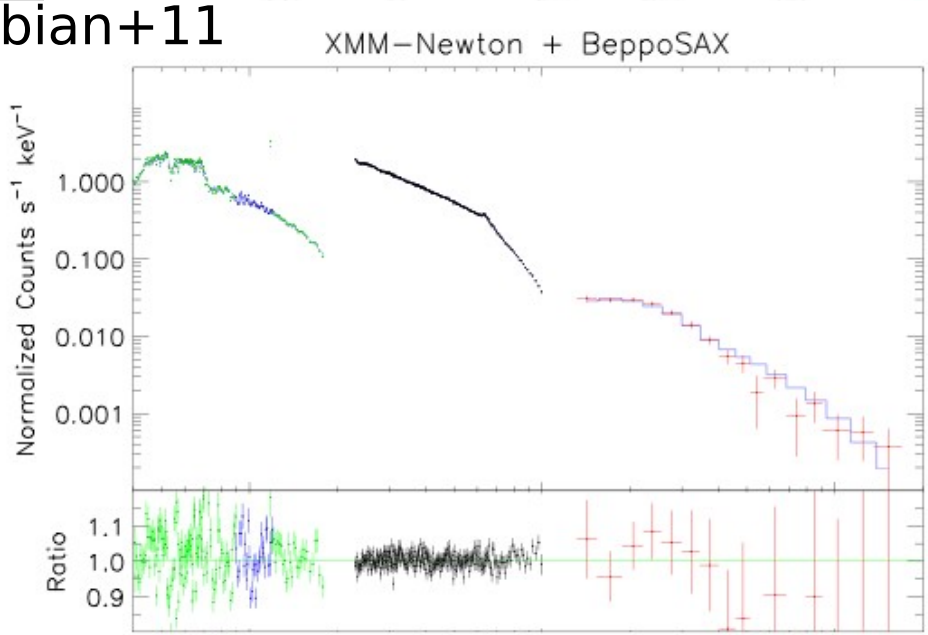
X-ray observations

Extensively observed in the X-rays:
•complex absorption
(Lee+01, Chiang&Fabian+11)
•strong refletion hump
(Miniutti+07)
•very broad Fe Ka line
(Brenneman&Reynolds+06)

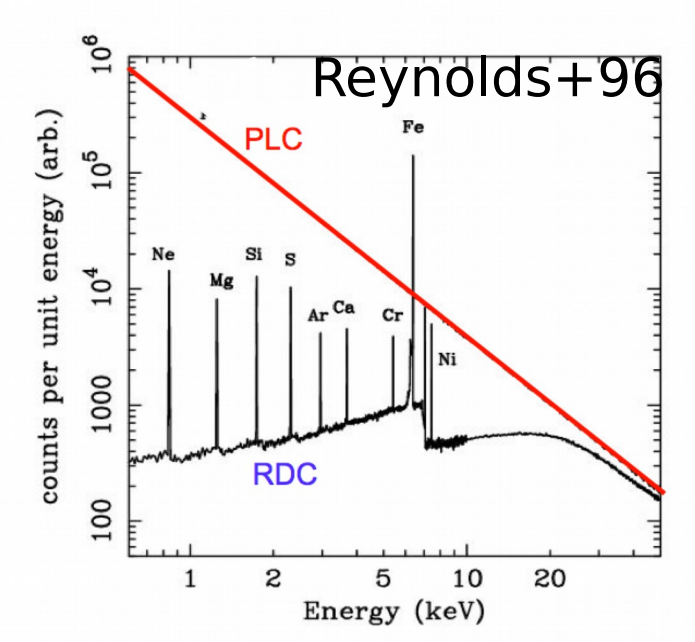


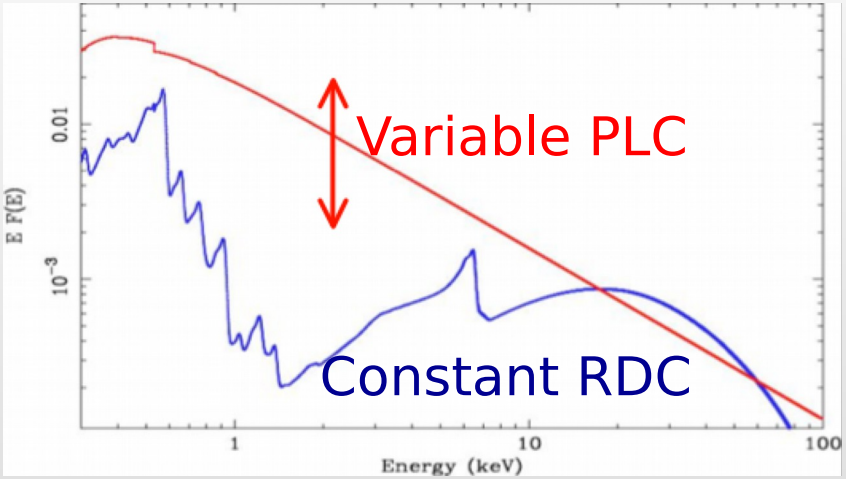
Chiang&Fabian+11



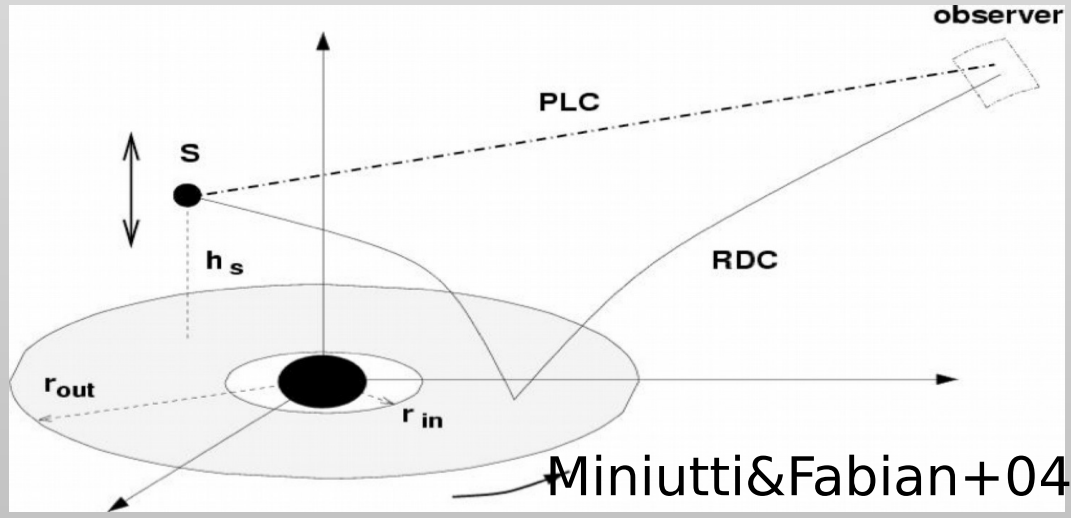


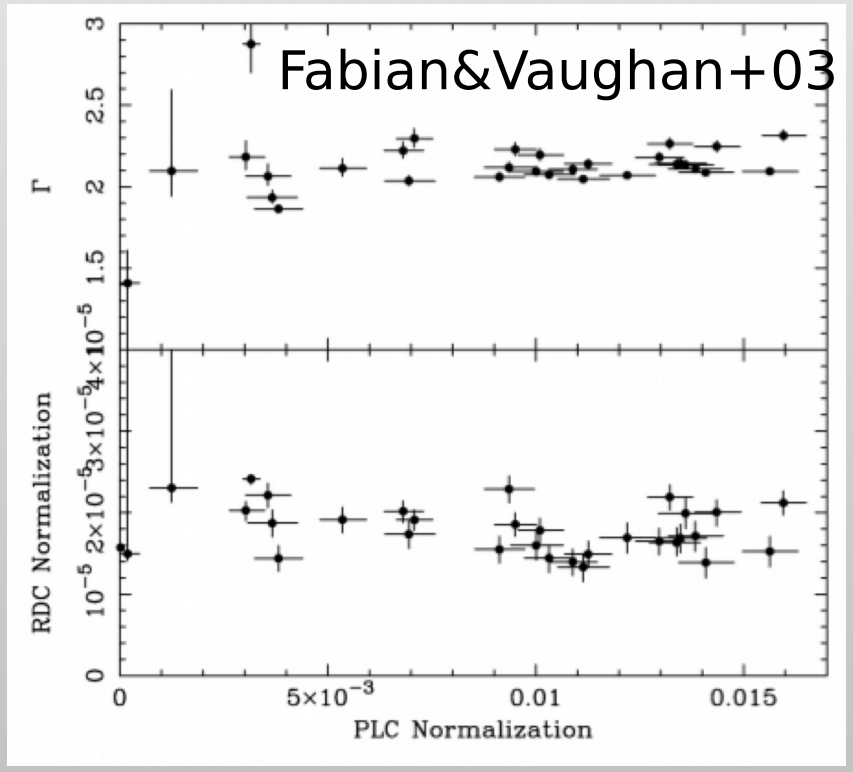
Reflection scenario





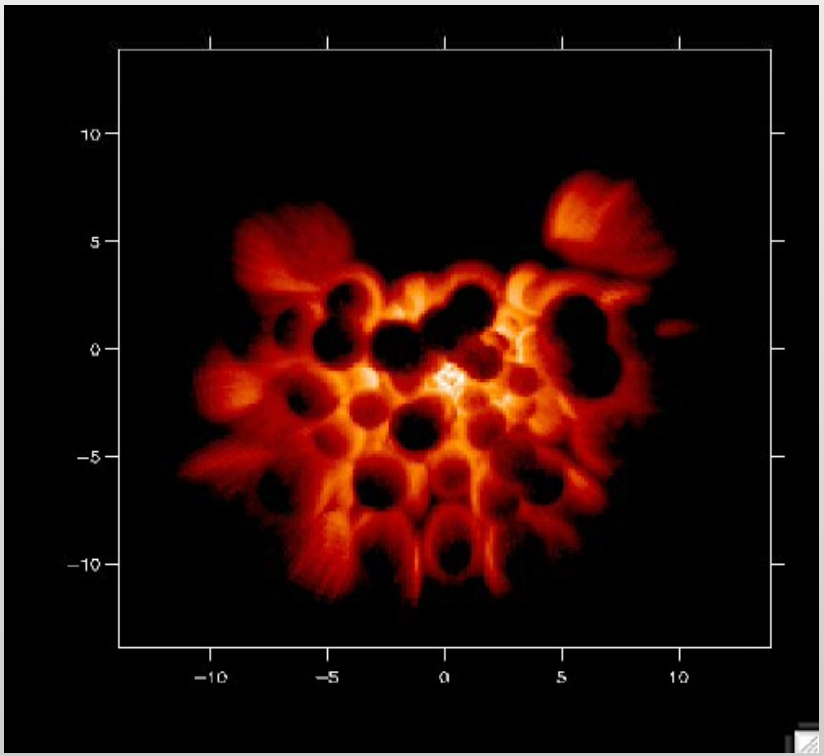
Light bending model: much of the flux is bent onto the disk giving a constant, strong RDC





Absorption scenario

An alternative interpretation explains the spectral variability in terms of absorption changes



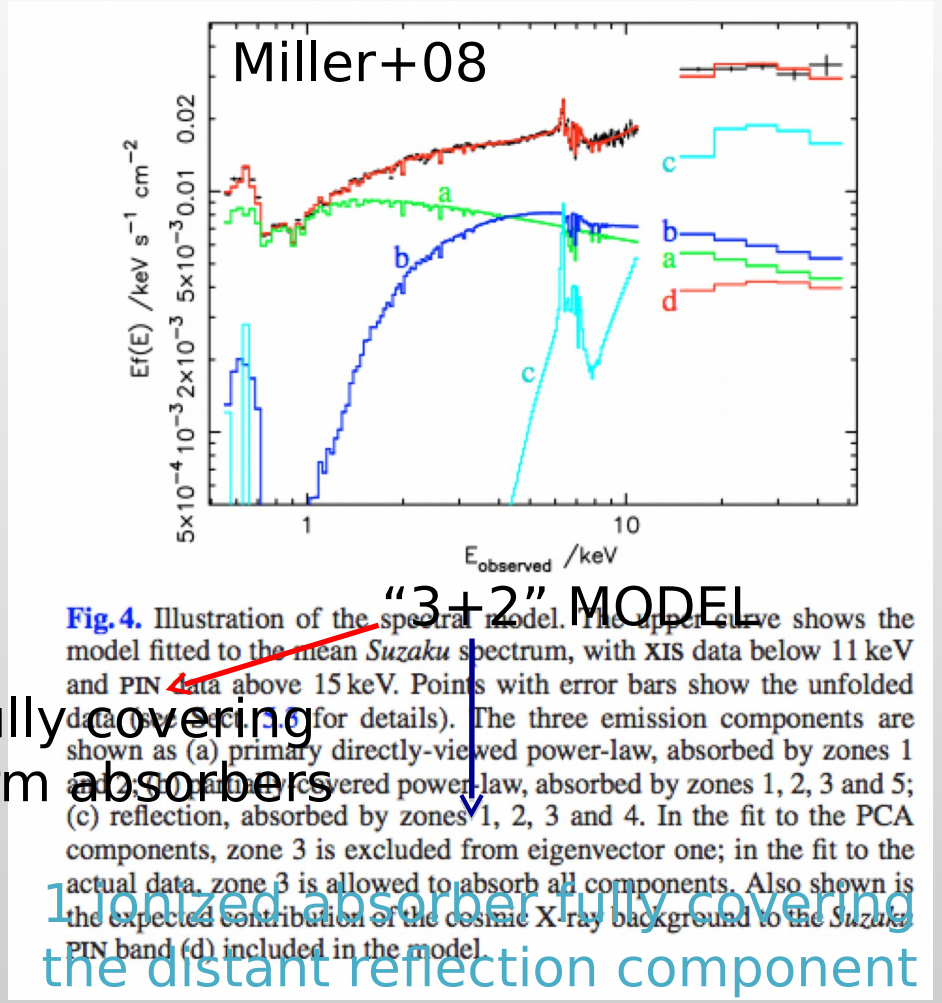


Fig. 4. Illustration of the spectral model. The upper curve shows the model fitted to the mean *Suzaku* spectrum, with XIS data below 11 keV and PIN data above 15 keV. Points with error bars show the unfolded data (see Sect. 3.6 for details). The three emission components are shown as (a) primary directly-viewed power-law, absorbed by zones 1 and 2; (b) partially-covered power-law, absorbed by zones 1, 2, 3 and 5; (c) reflection, absorbed by zones 1, 2, 3 and 4. In the fit to the PCA components, zone 3 is excluded from eigenvector one; in the fit to the actual data, zone 3 is allowed to absorb all components. Also shown is the expected contribution of the cosmic X-ray background to the *Suzaku* PIN band (d) included in the model.

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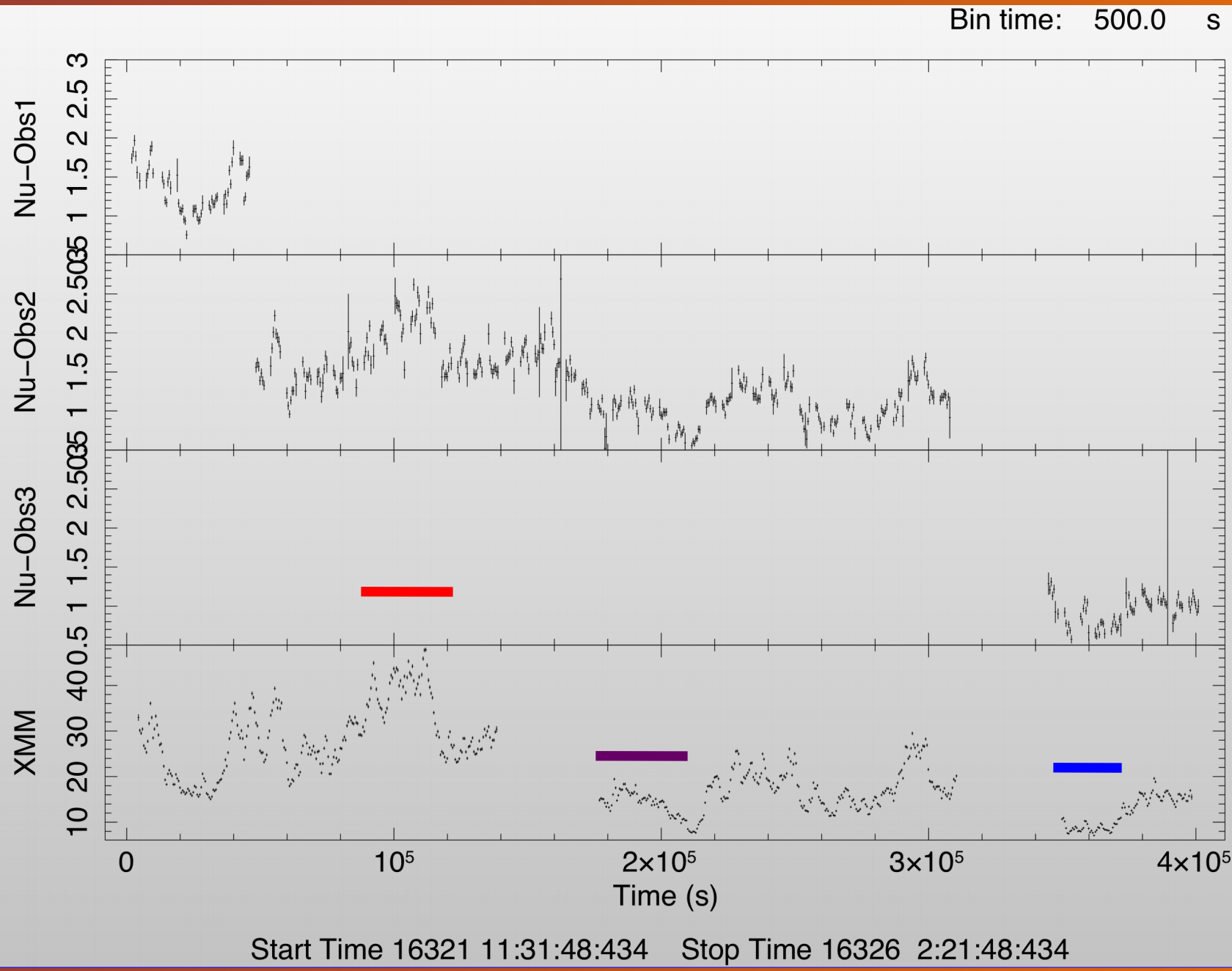
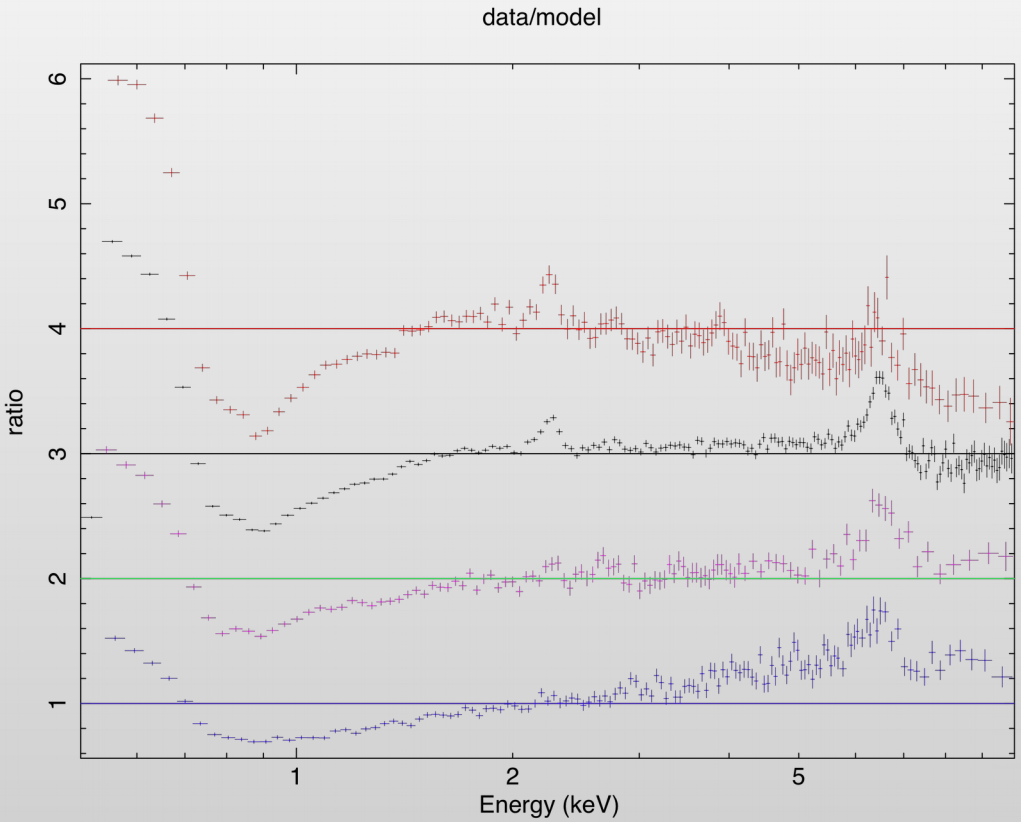
NuSTAR-XMM light curves

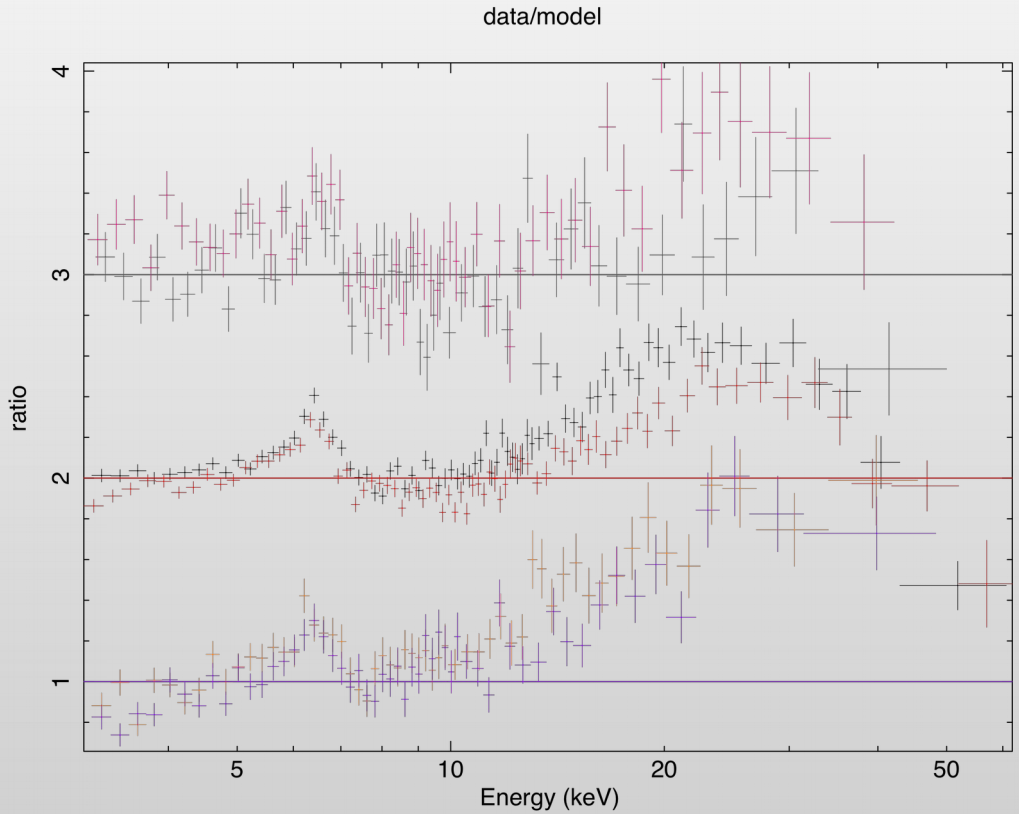


Spectral features

XMM-Newton EPIC-Pn



NuSTAR FpmA-FpmB



A broad Iron line, an intense soft excess and a strong Compton hump are present in the low flux spectrum (fit to a Γ=2 power law).

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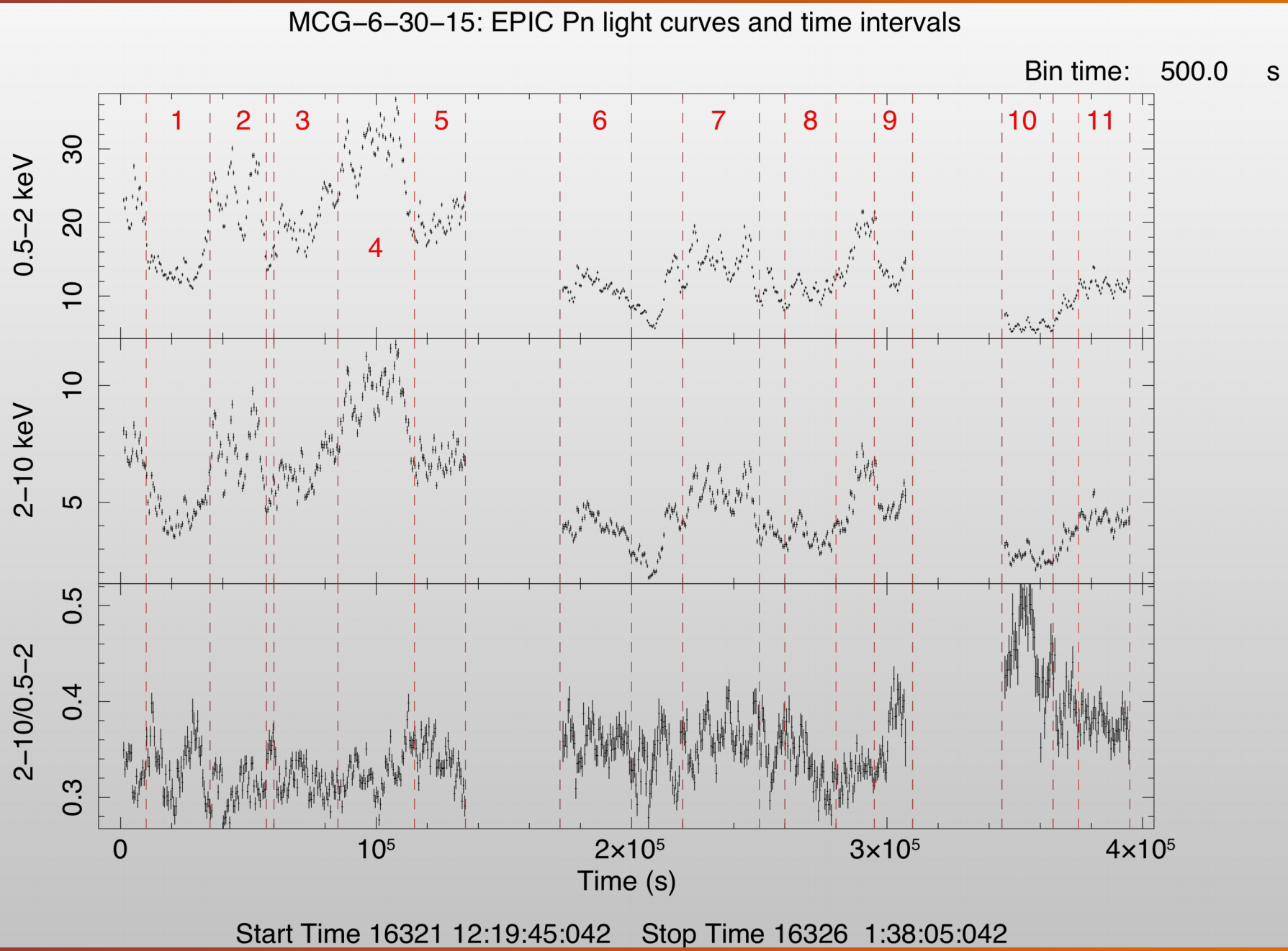
Fitting strategy



Fitting strategy

Warm Absorbers ⇄ Underlying Continuum

Combined RGS spectra → EPIC-Pn + NuSTAR FpmA,B

REFLECTION	ABSORPTION
2*XSTAR*DUST x (Xillver + Relconv*Xillver + zpow)	2*XSTAR*DUST x (XSTAR*Xillver + XSTAR*zpo + zpo)

XSTAR tables

XILLVER instead of REFLIONX:

http://hea-www.cfa.harvard.edu/~javier/xillver/

Iron UTA tables for dust

RELCONV for relativistic blurring:

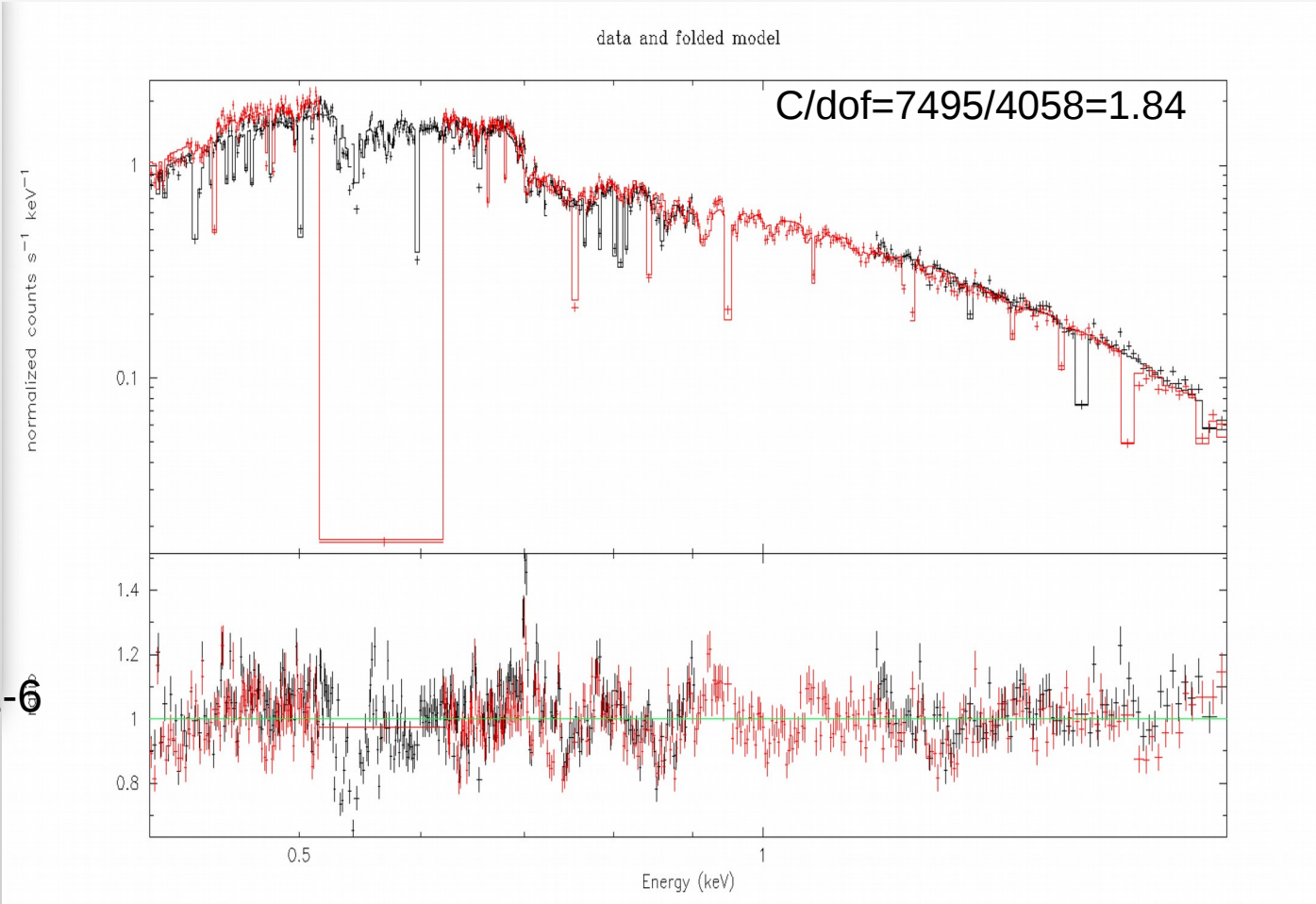
http://www.sternwarte.uni-

Combined RGS1+2 analysis

N_{H1} =(4.6 +/- 0.8) x10^{20} cm^{-2}
$log\xi_1$=1.47+/- 0.2
v~2000 km s^{-1}
N_{H2}=(1.3 +/- 0.2) x10^{20} cm^{-2}
$log\xi_2$=0.08+ 0.10
N_{H3}=(1.00+/- 0.04) x10^{22} cm^{-2}
$log\xi_3$=2.03+ 0.01
$logN_{Fe}$=17.32+/-0.02

xillver Norm = 9.3E-06 +/- 0.8E-6

Γ=2.03 +/- 0.02
norm 1.58E-02 +/- 0.02E-2



We then applied the combined best fit to the three separate RGS1+2 data sets

Separate RGS1+2 analysis

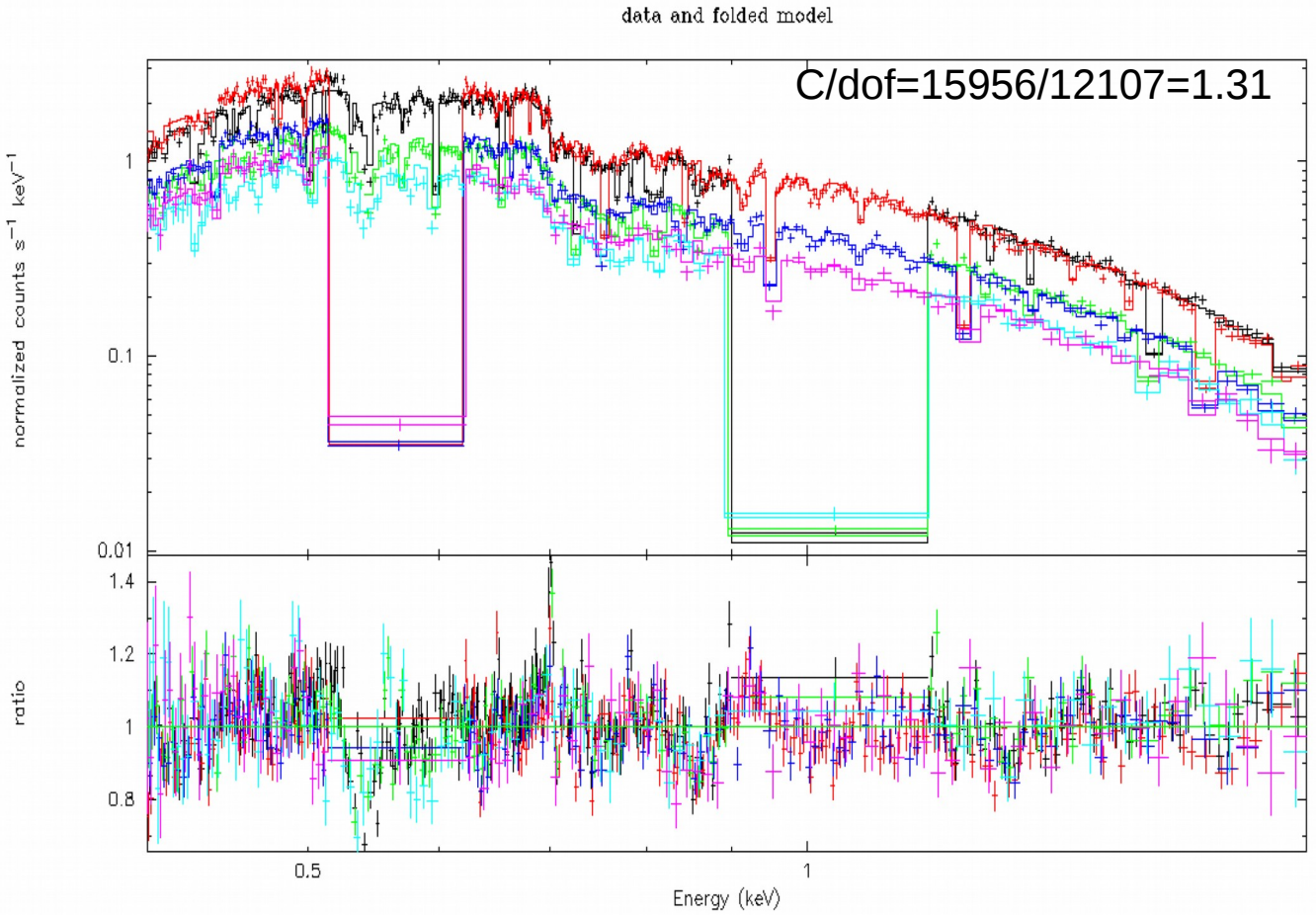
Orbit 1

N_{H1} (5.6 +/- 1.7) x10^{20} cm^{-2}
$\log\xi_1$ 1.82+/- 0.05
v~2000 km s^{-1}
N_{H2} (8.6 +/- 1.8) x10^{20} cm^{-2}
$\log\xi_2$ 1.47+ 0.05
N_{H3} (1.00+/- 0.04) x10^{22} cm^{-2}
$\log\xi_3$ 2.04+ 0.01
$\log N_{Fe}$ 17.33 +/- 0.02

xillver norm 9.3E-06 +/- 0.8E-06
Γ=2.03*
norm 1.58E-02 +/- 0.02E-2

Orbit 2

N_{H1} (4.0 +/- 1.8) x10^{20} cm^{-2}
$\log\xi_1$ 1.85+/- 0.1
v~2000 km s^{-1}
N_{H2} (2.9 +/- 0.5) x10^{20} cm^{-2}
$\log\xi_2$ 1.34+ 0.13
N_{H3} (1.00+/- 0.09) x10^{22} cm^{-2}
$\log\xi_3$ 2.02+ 0.02
$\log N_{Fe}$ 17.27 +/- 0.04
Γ=2.03
norm 1.22E-02 +/- 0.02E-02



No significant variation has been found in the warm absorbing structure

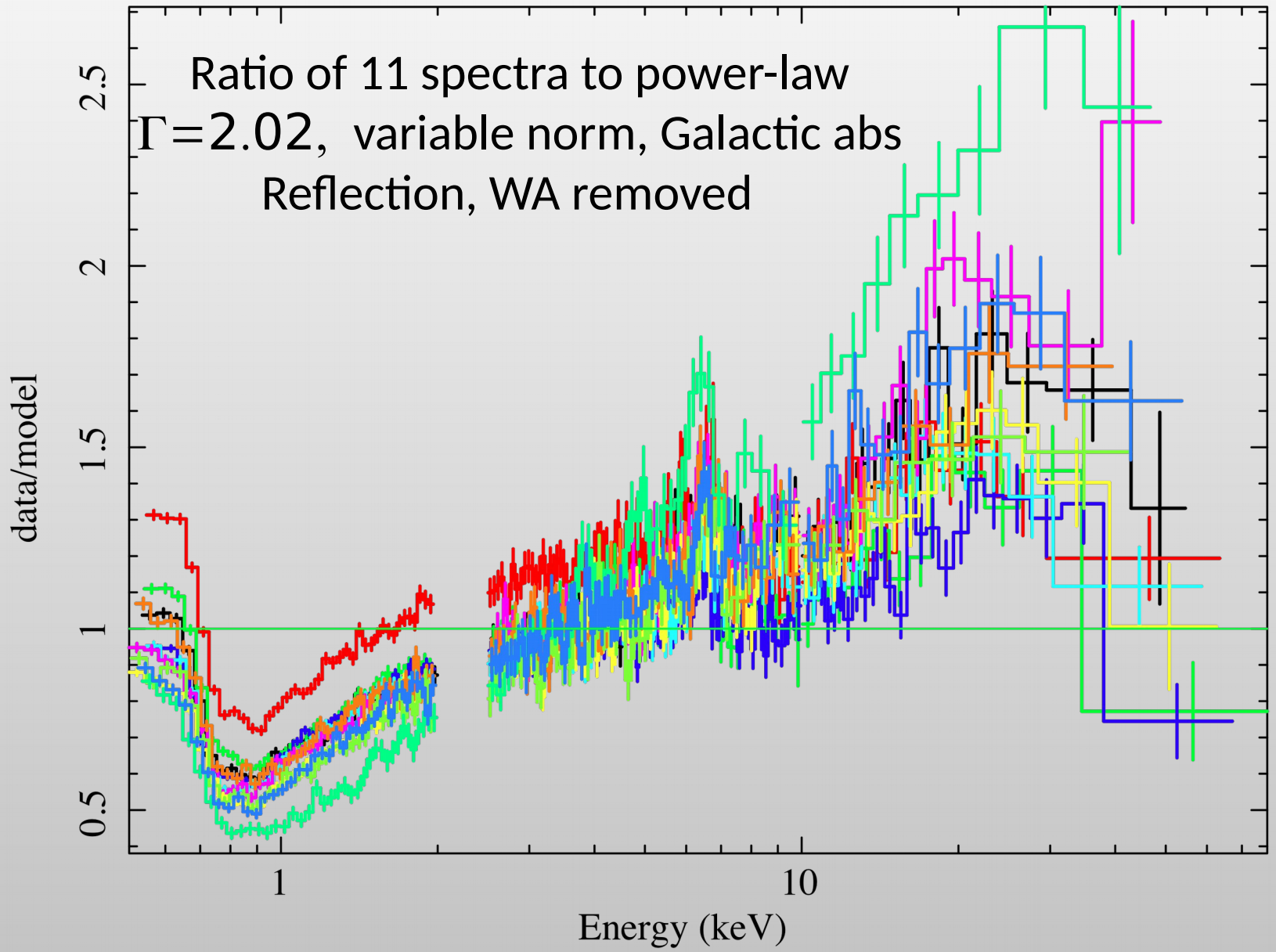
Orbit 3

N_{H1} (5.1 +/- 2.5) x10^{20} cm^{-2}
$\log\xi_1$ 1.75+/- 0.23
v~2000 km s^{-1}
N_{H2} (5.0 +/- 1.0) x10^{20} cm^{-2}
$\log\xi_2$ 1.3+/- 0.3

N_{H3} (0.88+/- 0.02) x10^{22} cm^{-2}
$\log\xi_3$ 2.00+ 0.03
$\log N_{Fe}$ 17.08 +/- 0.12

Γ=2.03
norm 0.8E-02 +/- 0.4E-03

Time resolved simultaneous analysis



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Results: reflection

Warm absorbers

$N_{H1}=(0.6\text{-}\underline{2.5})\ x10^{22}\ cm^{-2}$

$\log\xi_1=1.98 \pm 0.01$

$N_{H2}=(\underline{0.5}\text{-}3.0)\ x10^{21}\ cm^{-2}$

$\log\xi_2=1.27\pm0.02$

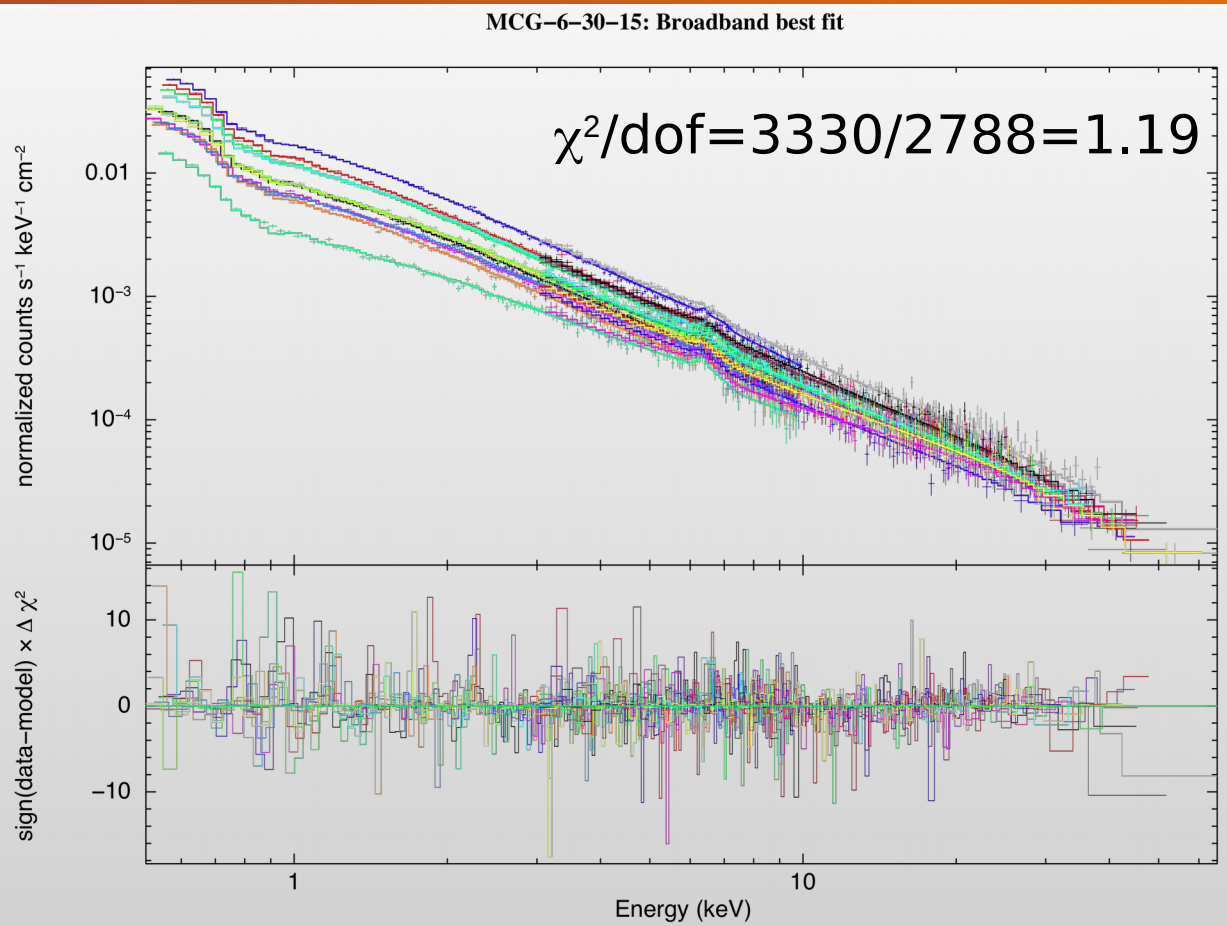
$\log N_{Fe}=16.6 \pm 0.2$

Reflection parameters

(q=3.0 a=0.998 incl=37°)

$\log\xi=0.2\text{-}3.0$

$A_{Fe}=1.56\pm0.32$

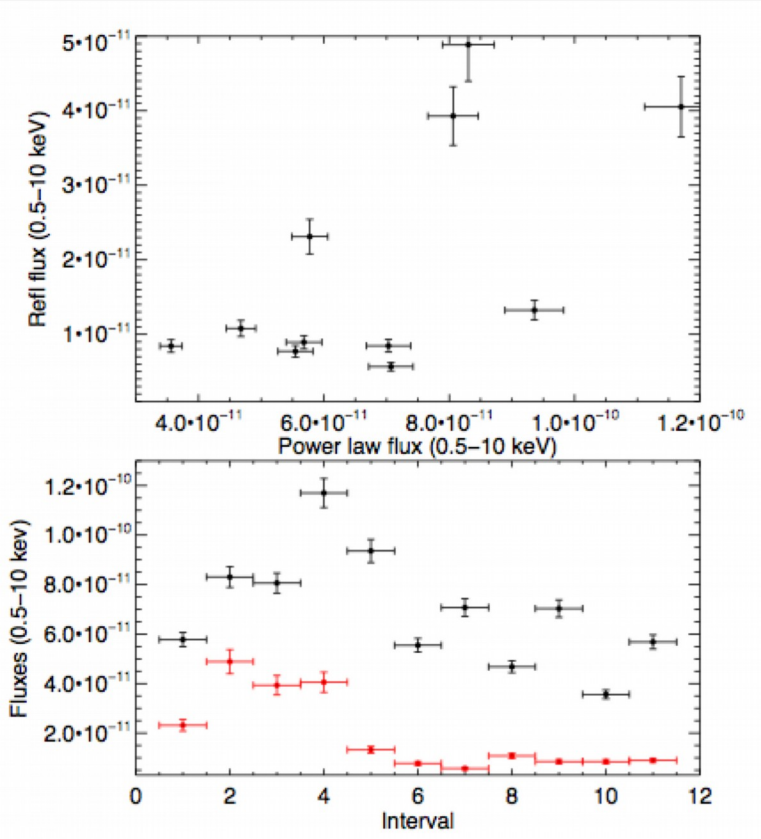


Primary emission parameters

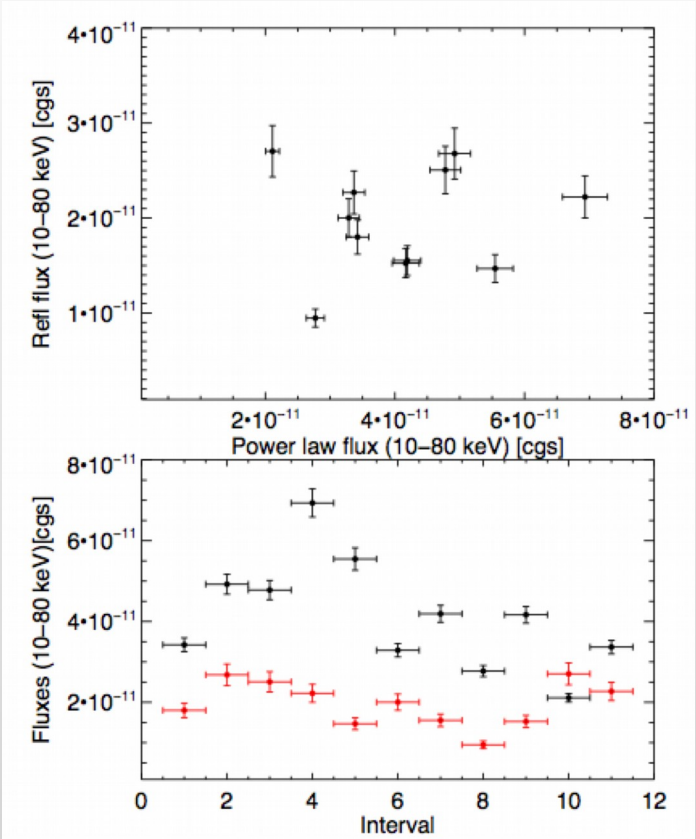
$\Gamma=2.050\pm0.005$

$E_c>100$ keV

RDC vs PLC fluxes



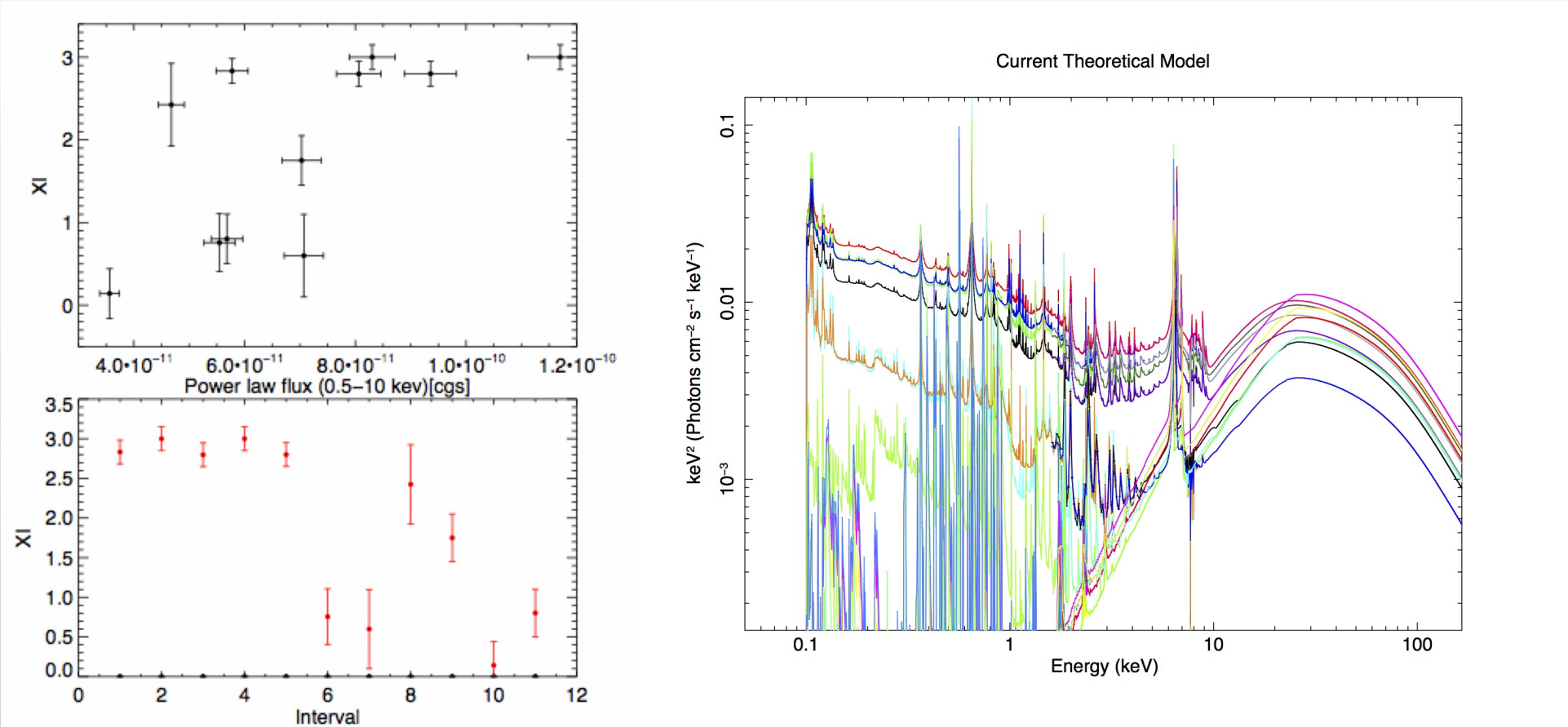
Variation of a factor ~2 observed in the RDC between 0.5-10 keV, in agreement with the PCA (Parker et al., submitted)



Constancy of the RDC between 10-80 keV (thanks to NuSTAR)

Marginal response from the accretion disk to the nuclear emission?

Accretion disk response



There is a response of the ionization state of the accretion disk to the variation of the PLC

Results: absorption

2 warm absorbers

$N_{H1}=(1.3\pm0.2)\ x10^{22}\ cm^{-2}$

$\log\xi_1=1.95\pm0.02$

$N_{H2}=(4.2\pm1.5)\ x10^{21}\ cm^{-2}$

$\log\xi_2=2.82\pm0.05$

$\log N_{Fe}=16.9\pm0.1$

Further absorbers

(Xillver: $\log\xi=2.4\pm0.05$; $A_{fe}=0.5\pm0.1_p$) ✓

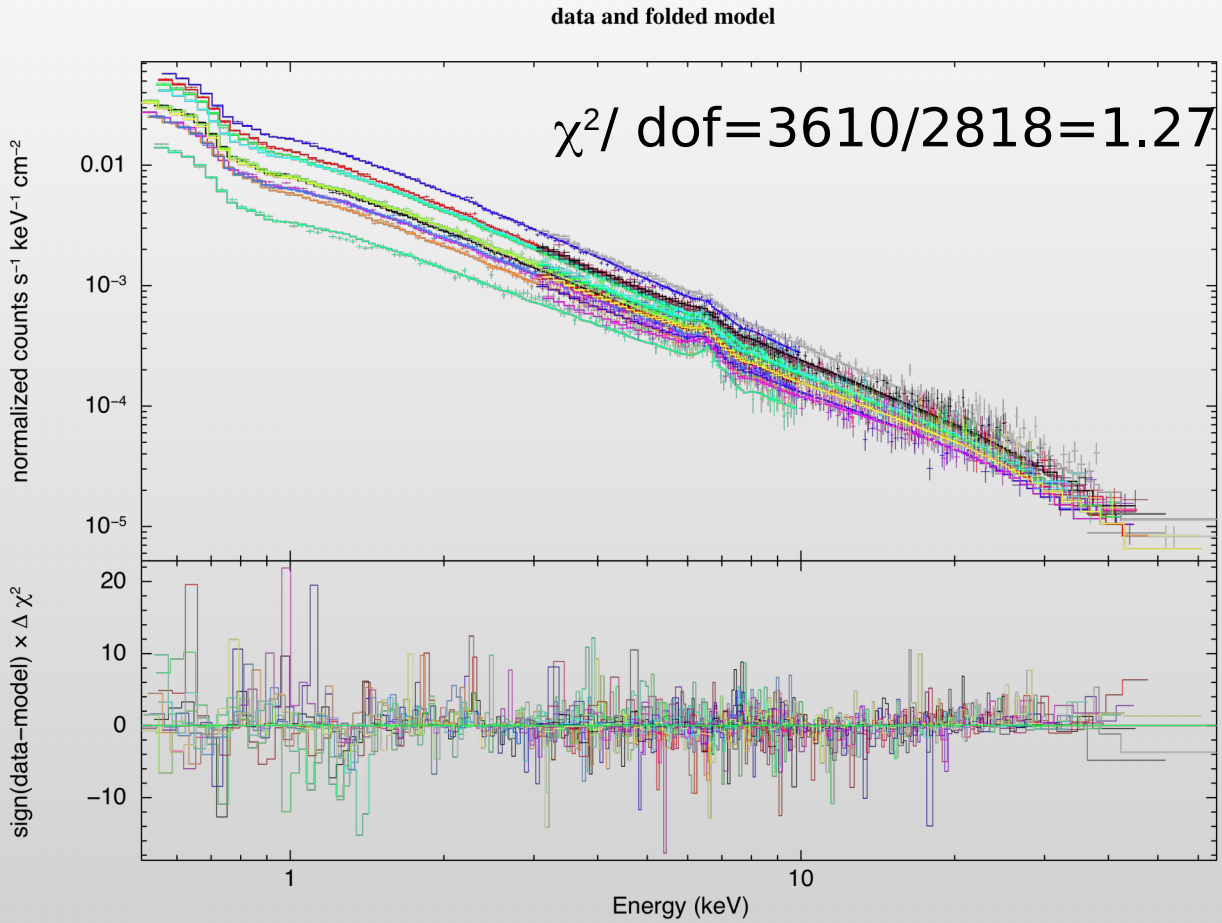
$N_{H3}=(3.0\pm0.4)\ x10^{23}\ cm^{-2}$ ✓

$\log\xi_3=2.11\pm0.01$

$N_{H4}=(0.3\text{-}27)\ x10^{21}\ cm^{-2}$

$\log\xi_4=(0.0015\pm0.0005)$ ✗

[almost neutral]

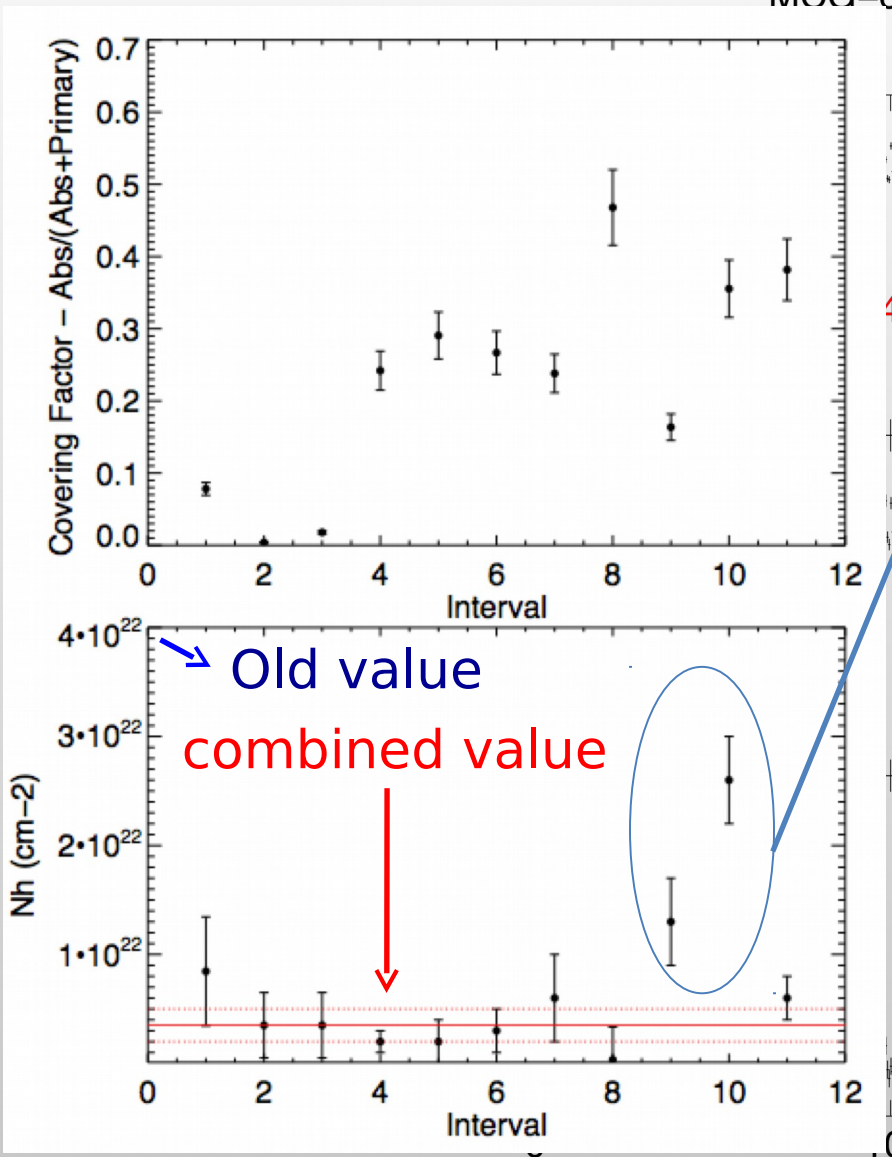


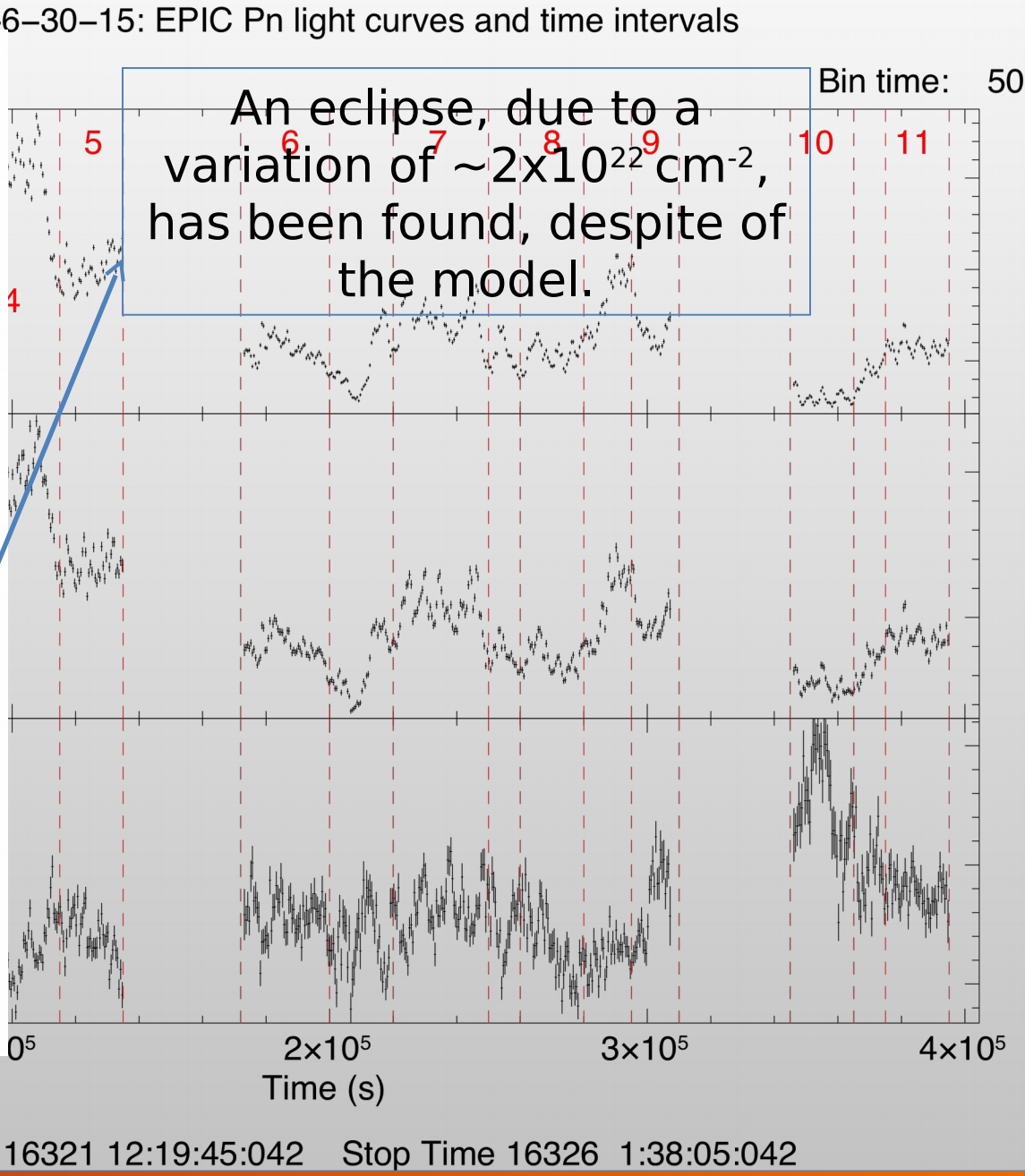
Primary emission parameters

$\Gamma=2.16\pm0.01$

$E_c>100$ keV

Covering factor time evolution





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Conclusions

- The warm absorbing structure is consistent with literature, except for the lack of highly ionized absorption lines;

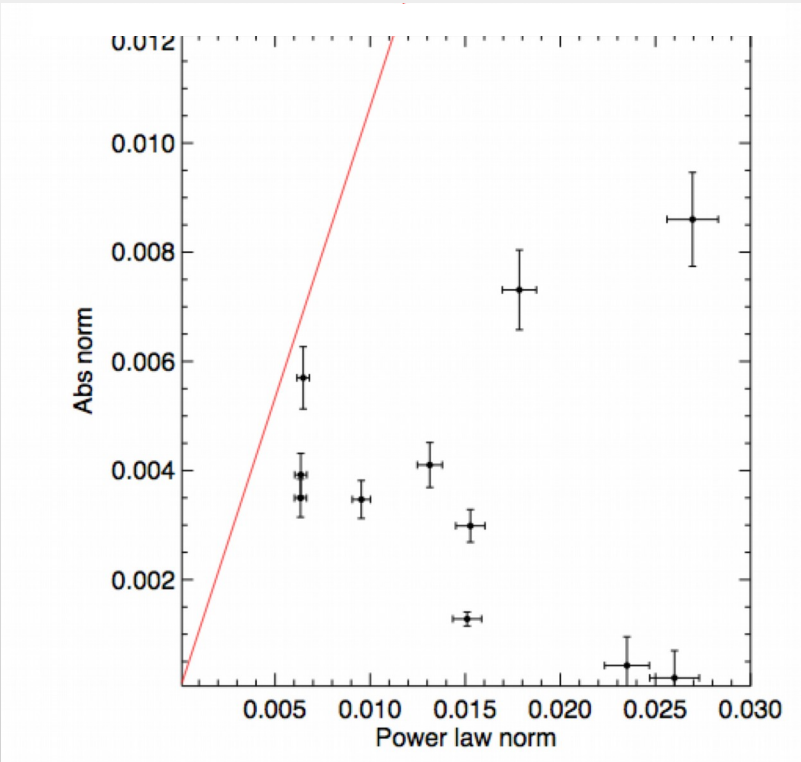
- The reflection scenario well explains the behavior of the source, from 0.4 keV up to 80 keV

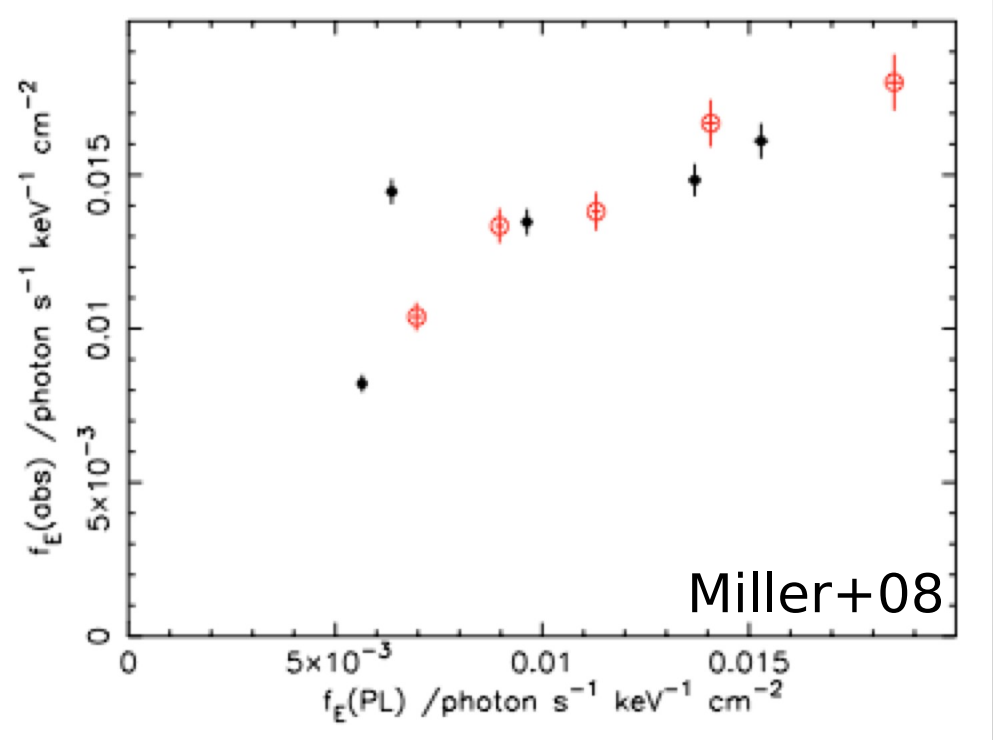
- Spectral variability can be explained in terms of strong variations of the PLC and to marginal variations in the RDC

- An alternative is that the spectral variability can be attributed to a change in covering fraction of the X-ray source AND to a change of $N_{H.}$

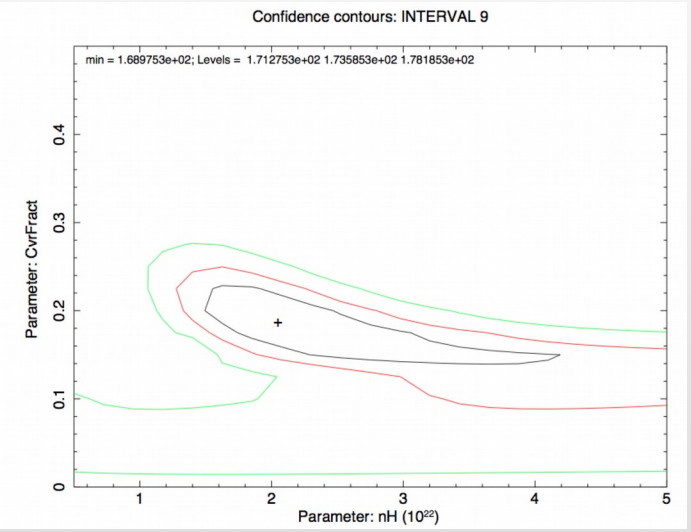
- Clear evidence of BLR eclipses have been found

Backup


Abs norm
Power law norm
0.012
0.010
0.008
0.006
0.004
0.002
0.005
0.010
0.015
0.020
0.025
0.030


f_E(abs) /photon s^{-1} keV^{-1} cm^{-2}
f_E(PL) /photon s^{-1} keV^{-1} cm^{-2}
0
5×10^{-3}
0.01
0.015
Miller+08

Backup


Confidence contours: INTERVAL 9
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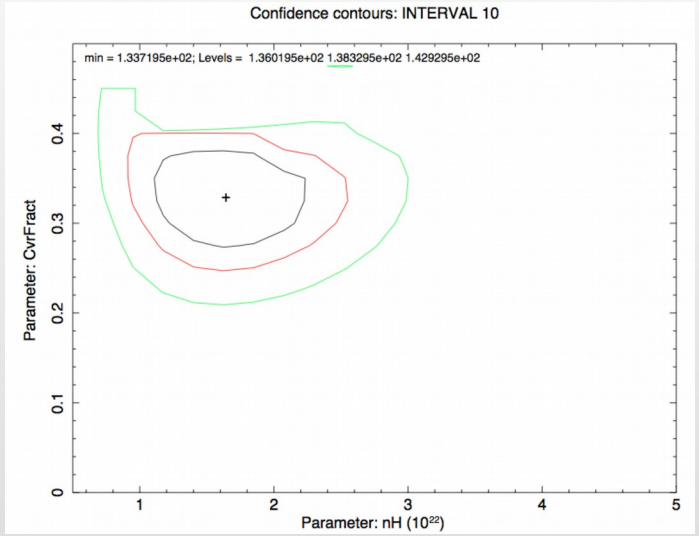
Parameter: CvrFract
Parameter: nH (10^22)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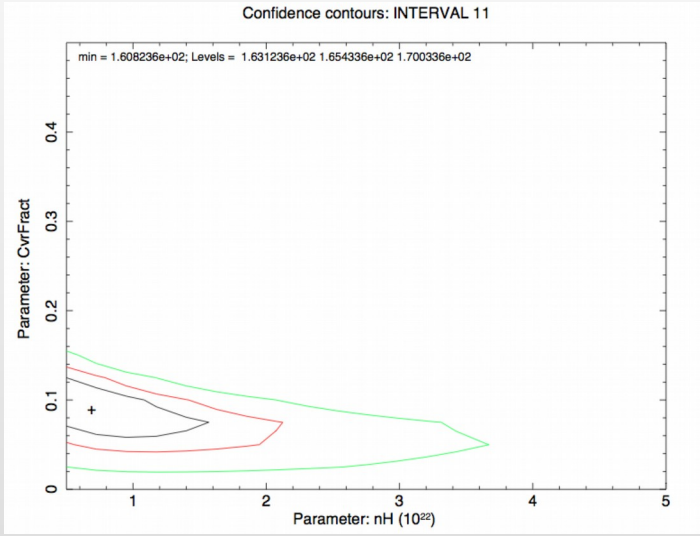
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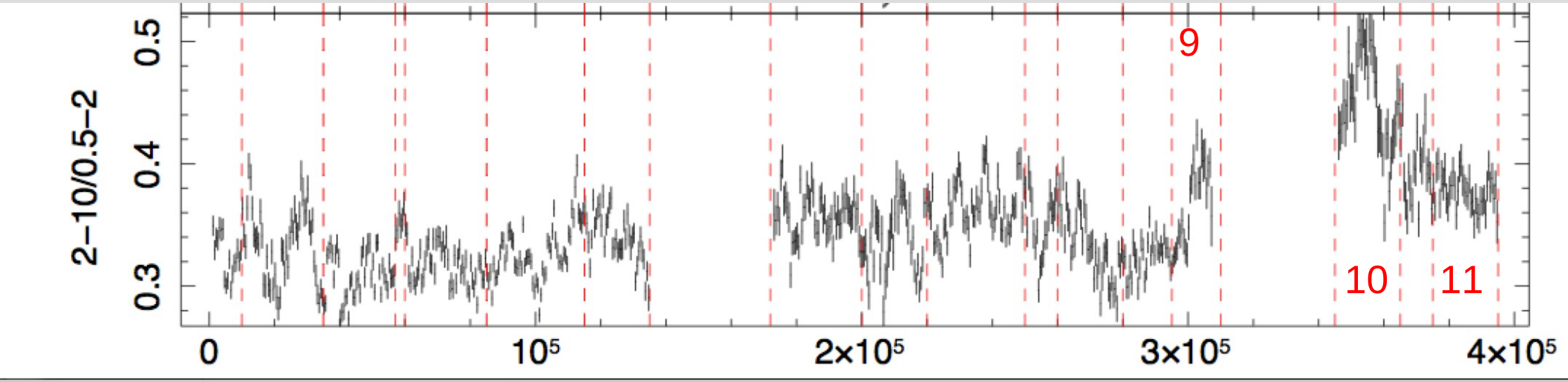
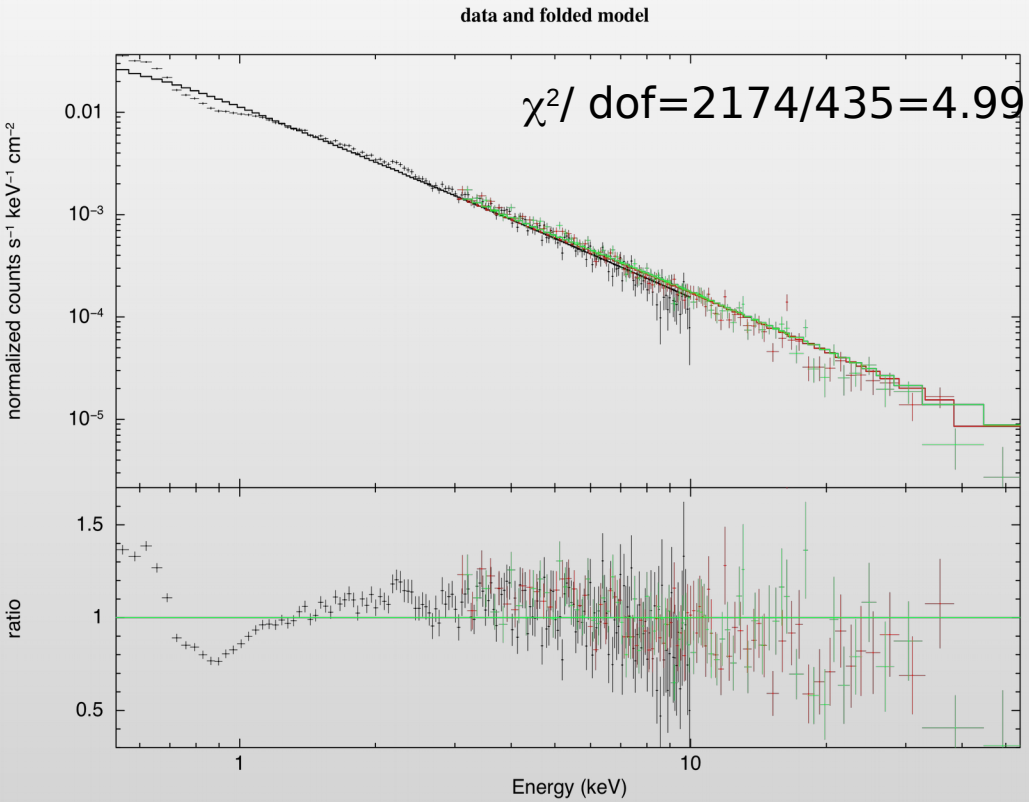
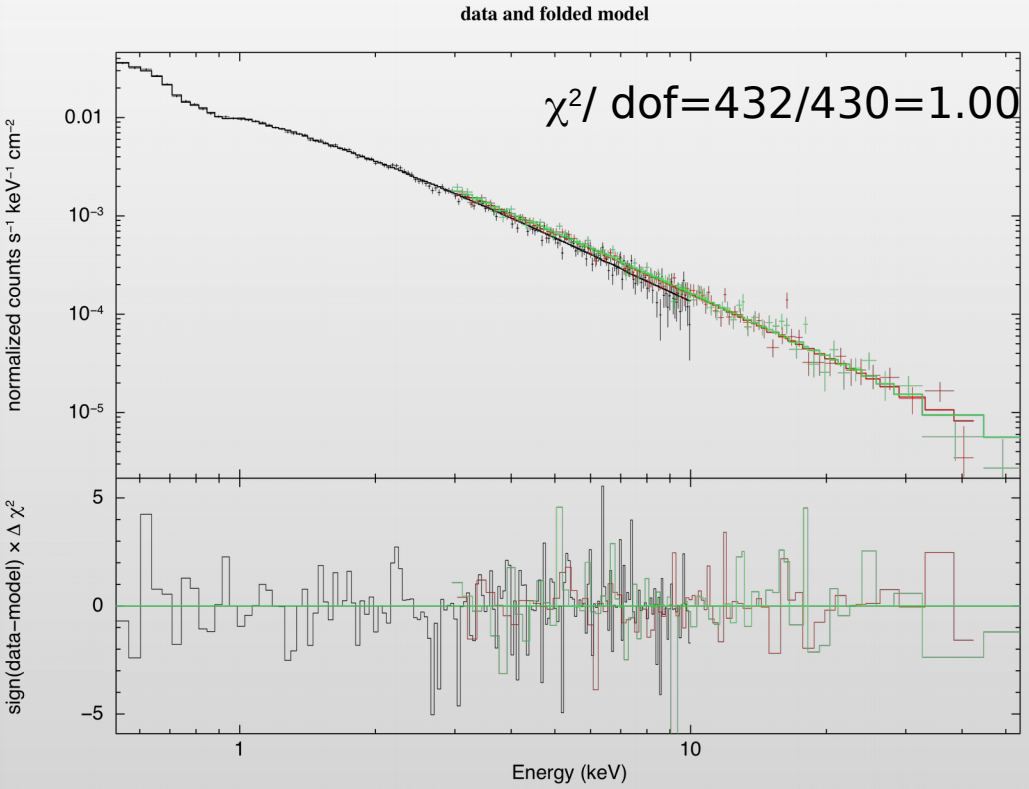
Parameter: nH (10^22)


2–10/0.5–2
9
10
11
0
10^5
2×10^5
3×10^5
4×10^5

Backup





Difference between the highest flux spectrum (42.19±0.07 cts/s) and a low flux one with constant HR (17.79±0.04 cts/s)

A first fit with an absorbed power law leads to strong residuals, mainly due to the warm absorbing structure

$N_{H1}=(9.8\pm2.5)\times10^{21}$ cm^{-2}

$\log\xi_1=2.0\pm0.1$

$\Gamma=2.16\pm0.03$

$N_{H2}=(2.1\pm1.9)\times10^{21}$ cm^{-2}

$\log\xi_2=1.4\pm0.2$

$\log N_{Fe}=17.2\pm0.3$