A survey of X-ray variability in AGN with XMM-Newton

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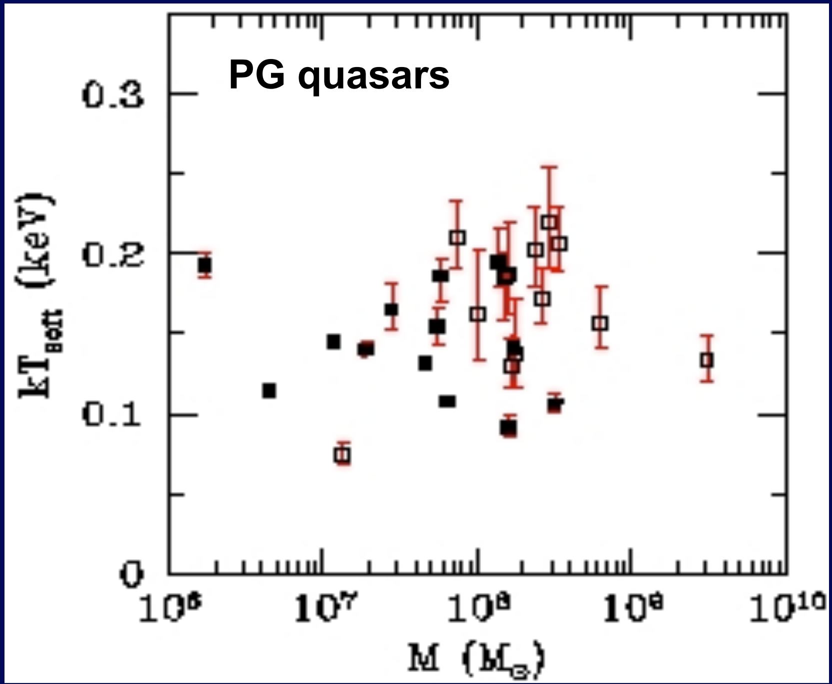
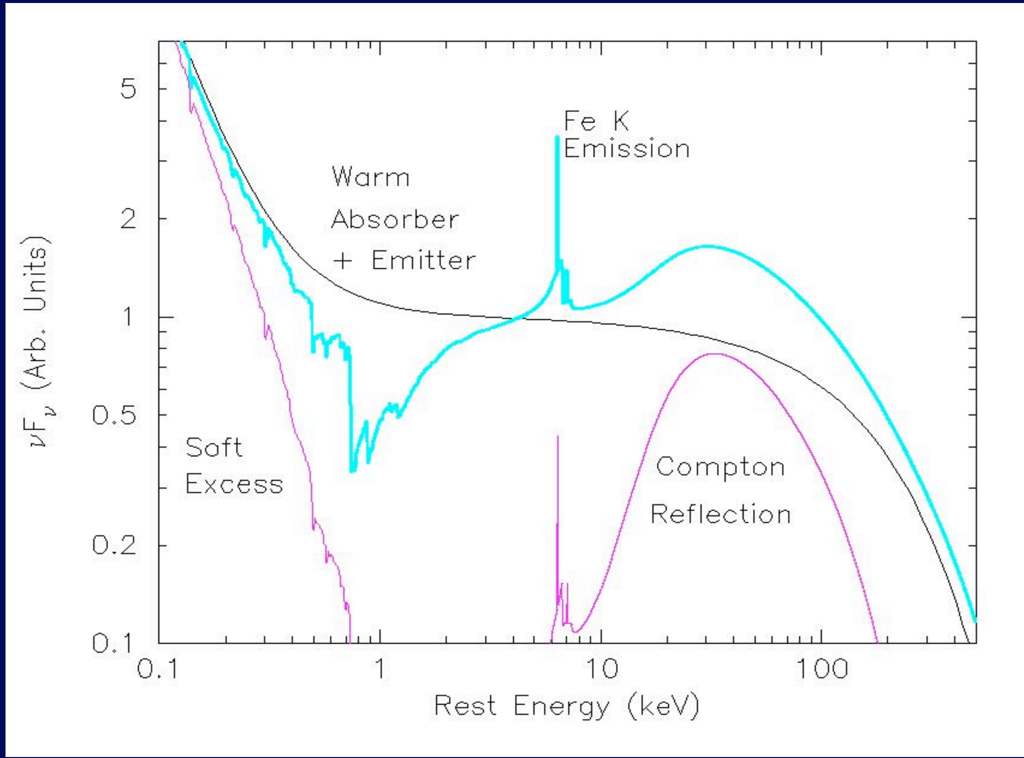
The soft excess problem:

Shakura Sunyaev accretion discs
$kT_{BB} \propto M_{BH}^{-1/4}$; $T_{BB} \propto L^{1/4}$

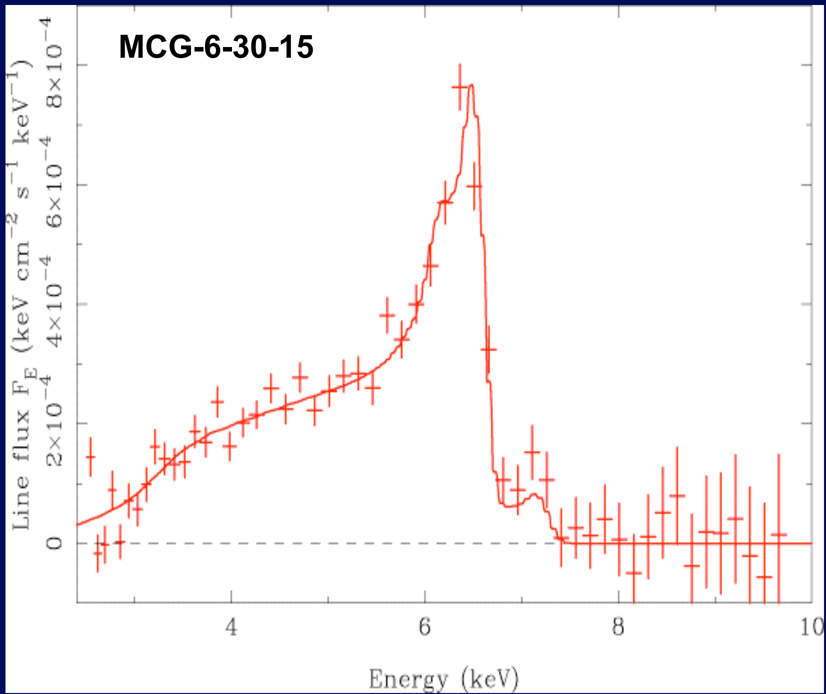


Gierlinski Done 2004

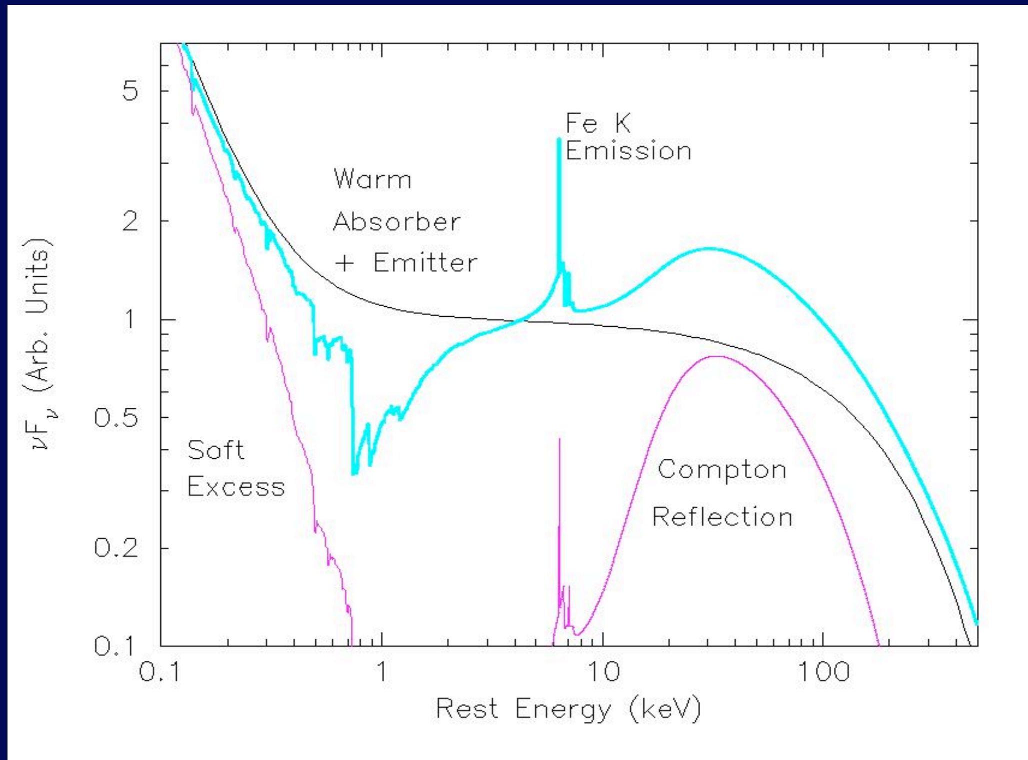


Soft excess tied to atomic processes?
Reflection? Absorption?
Is it variable?

The Broad lines problem



Tanaka et al. 1995; Fabian et al. 2002



New generation telescopes: confirm the presence of broad lines

Fabian et al. 2002; Guainazzi et al. 2006; Nandra et al. 2007

BUT a complex absorber could mimic a broad line

Pounds et al. 2003; Reeves et al. 2004; Turner et al. 2005; Miller et al. 2008

Open questions:

- Which is the nature of the soft excess? Is it variable?

- Are the broad lines real or an effect due to absorption? Are these variable?

Spectral degeneracy ⇒ no solution through mean spectra

⇒ X-ray Spectral Variability study
of 36 bright, type 1 AGNs

The sample of type 1 AGNs:

All the **Seyfert 1, 1.5 and NLS1** of the ROSAT all sky survey Shwope et al. (2000)

PSPC count rate > 0.2 counts/s

⇒ Flux$_{0.5\text{-}2\ keV}$ ≥ 2.4×10^{-12} erg s^{-1} cm^{-2}

B≥15° and z≤0.1

⇒ ~200 sources

XMM-Newton EPIC-pn

observation > 30 ks

⇒ **36 sources**

Source Name	M_{BH} $M_{\odot}$	$L_{0.2-10\ keV}$ erg s^{-1}	Source Type	pn time ks
Fairall 9	8.41	43.84	Sy1	30
ESO 198-G24	8.60	44.06	Sy1	31
NGC7213	7.95	42.48	Sy1.5	42
PICTOR A	7.60	43.67	Sy1	52
MS2254.9-3712	7.04	43.31	Sy1	71
CTS A08.12		43.35	Sy1	46
IC 4329A	7.00	43.59	Sy1	133
Ton S 180	7.09	44.41	NLS1/Sy1.2	30
HE 1143-1810		44.21	Sy1	31
MR2251-178		44.43	Sy1	64
HE 1029-1401	9.08	44.82	Sy1	46
NGC 985	8.05	43.78	Sy1	58
NGC 4593	6.73	43.15	Sy1	76
MKN 590	7.68	43.23	Sy1.2	107
NGC7469	7.09	43.56	Sy1.2	85
MKN 841	8.10	43.73	Sy1.5	46
I Zw 1	7.20	44.01	NLS1/Sy1	83
PG 1211+143	8.16	44.16	NLS1/Sy1	53
Mrk 335	7.15	43.80	NLS1/Sy1	32
NGC5548	7.83	43.65	Sy1.5	93
Mkn766	6.54	43.41	NLS1/Sy1.5	129
IRASF 12397+3333	6.66	43.76	NLS1/Sy1	78
Mkn478/PG1440+35	7.34	44.37	NLS1/Sy1	28
NGC4151	7.12	42.08	Sy1	57
NGC4051	6.28	41.91	NLS1/Sy1.5	117
MKN 110	7.40	44.26	NLS1/Sy1	47
Mkn 279	7.54	43.85	Sy1.5	30
IRAS 13224-3809	6.82	43.60	NLS1/Sy1	61
NGC3783	7.47	43.19	Sy1	136
MCG-6-30-15	6.19	42.87	Sy1.2	84
3C 390.3	8.45	44.66	Sy1/BLRG	52
1H 0707-495	6.31	43.46	NLS1	78
Mrk509	8.16	44.35	Sy1.2	85
Ark 120	8.18	44.24	Sy1	112
3C120	7.44	44.23	Sy1/BLRG	128
ARK 564	6.06	43.98	NLS1	99

The variability tools:

Root Mean Square variability or Fvar
"model and calibration independent"

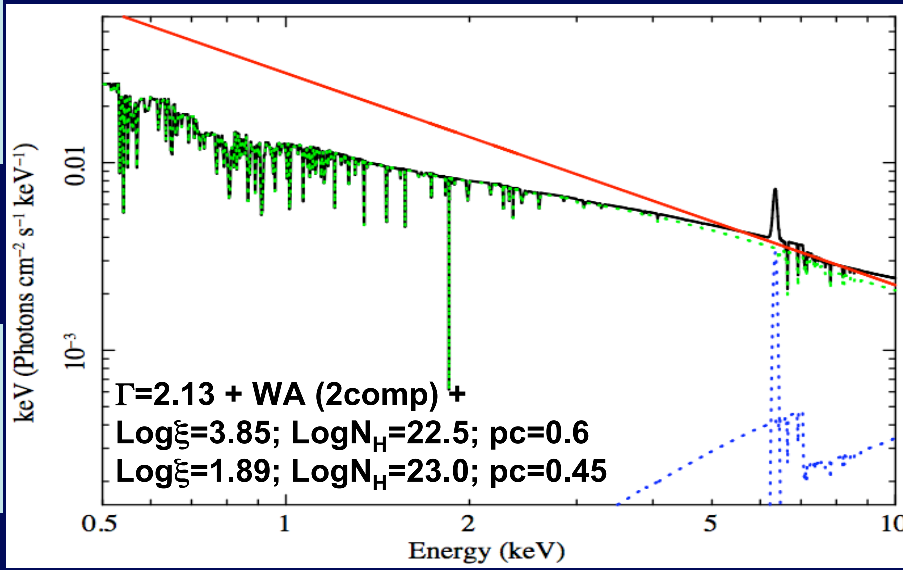
Vaughan et al. 2003; Ponti et al. 2004;Markowitz & Edelson 2004

$$RMS = \sqrt{\frac{S(E)^2 - <\sigma_{err}^2>}{<X(E)>^2}}$$

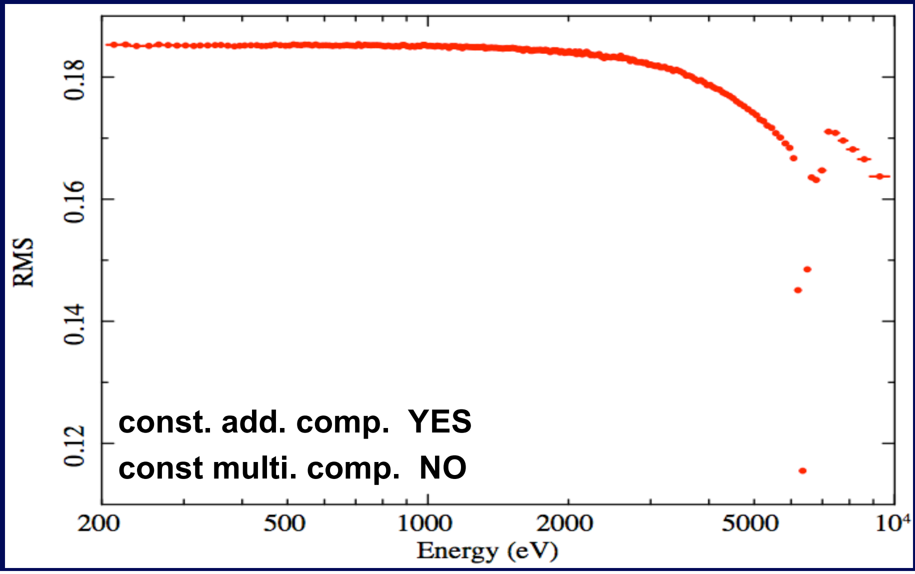
Total rms **"model independent"**
~ fourier resolved spectroscopy

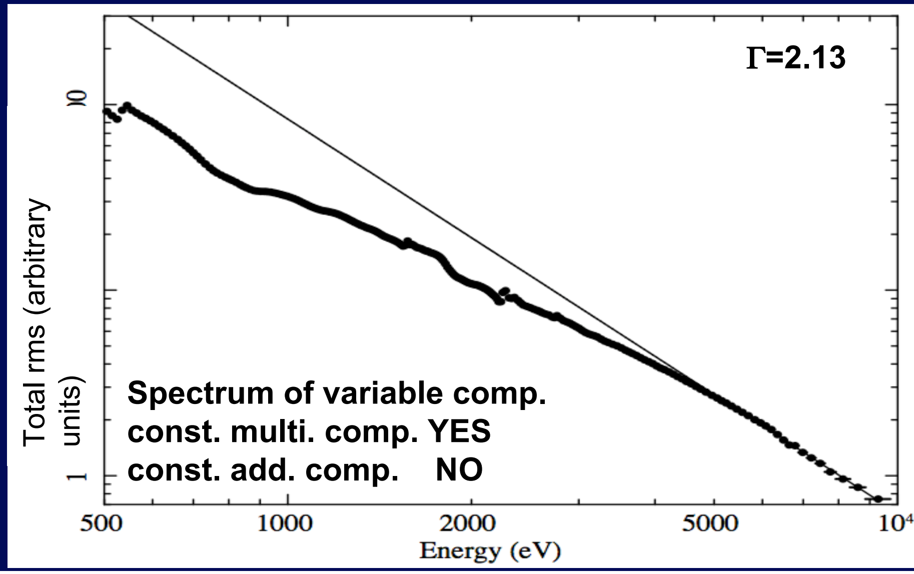
Revnivtsev et al. 1999; Papadakis et al. 2005

$$TotalRMS = \sqrt{\frac{S(E)^2 - <\sigma_{err}^2>}{\Delta E^2 * arf^2}}$$



Similar to Miller et al. 2008





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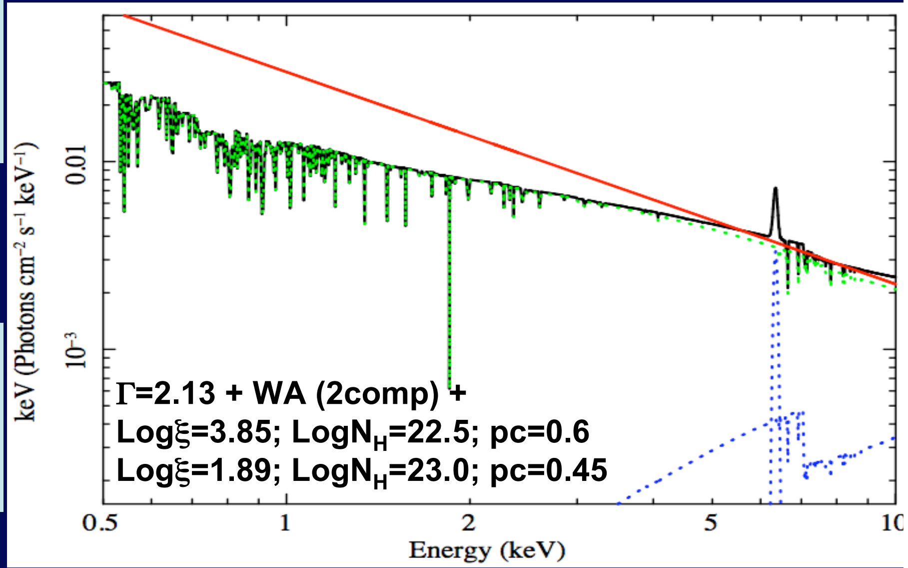

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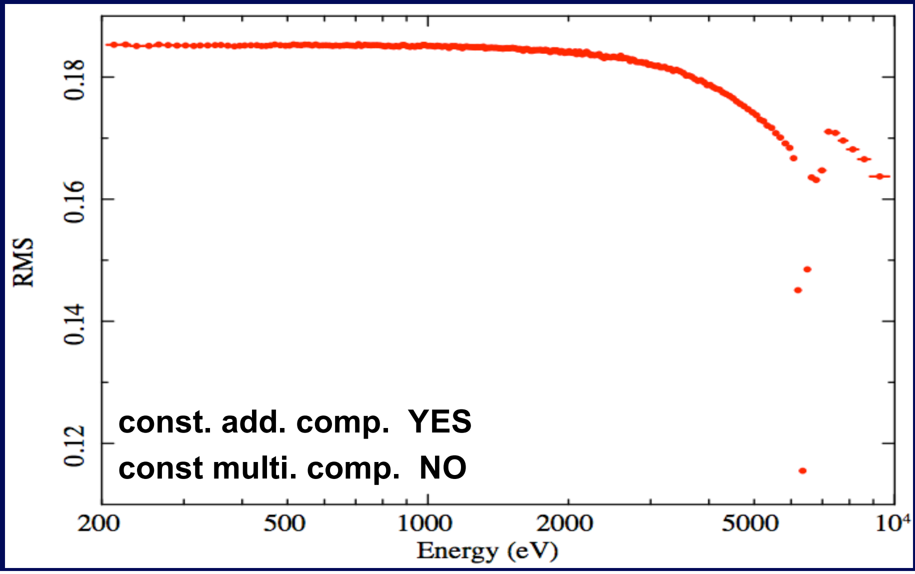
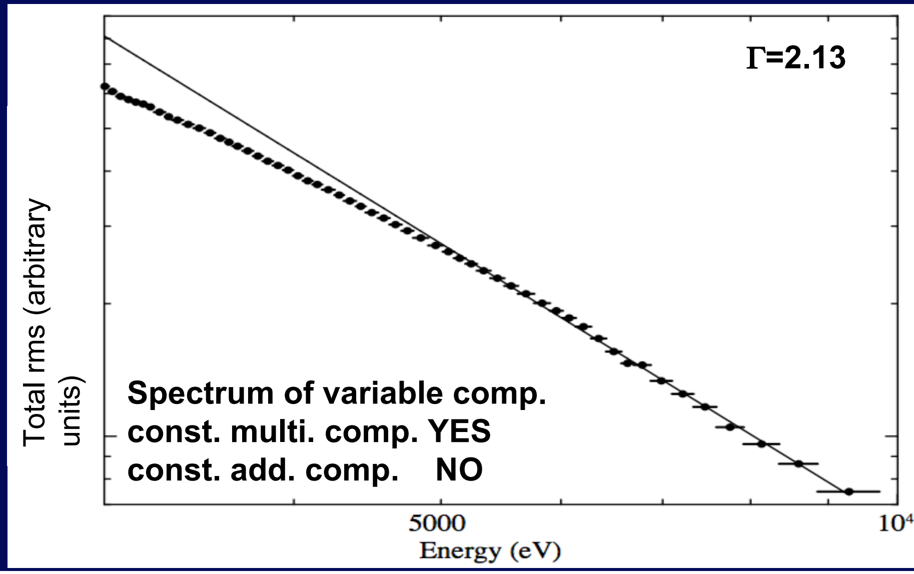
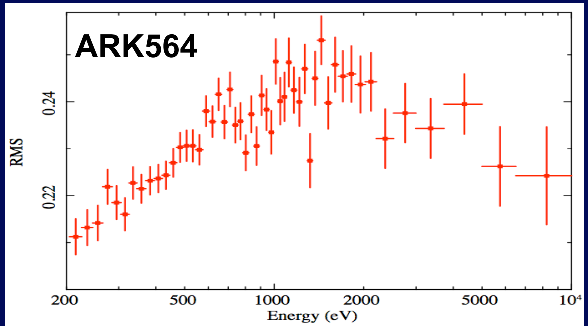
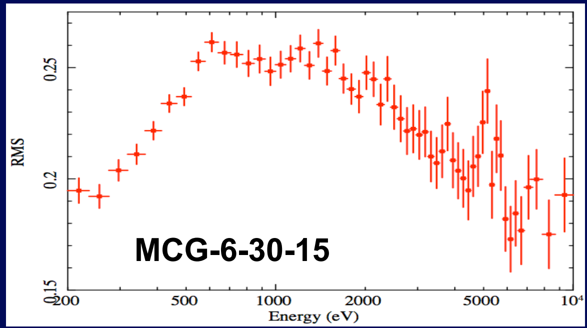


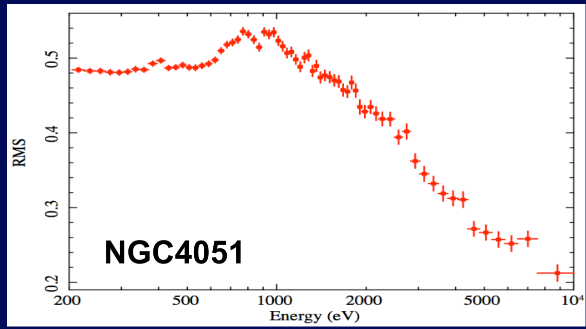


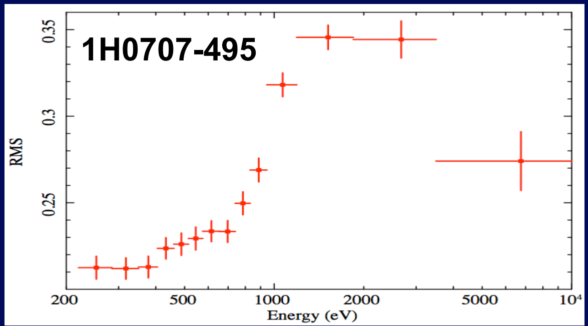
RMS spectra: group A

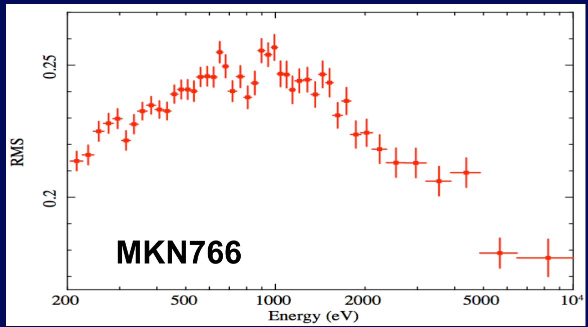
10 / 36 objects ⇒ less variable low and high energy

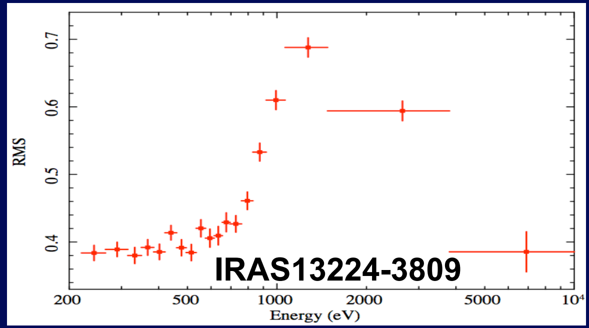


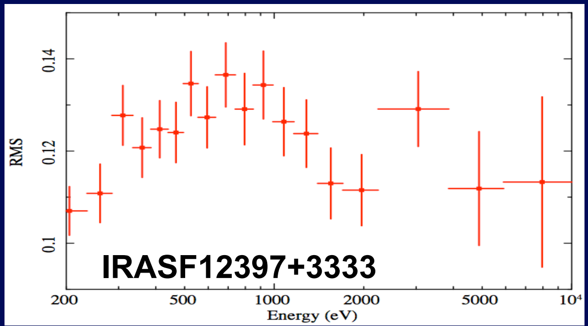


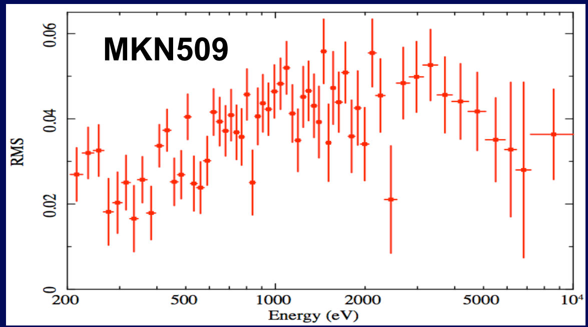


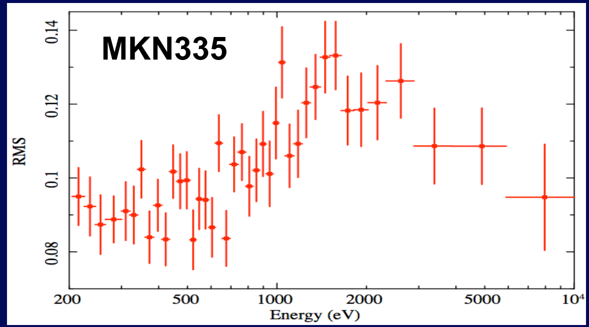


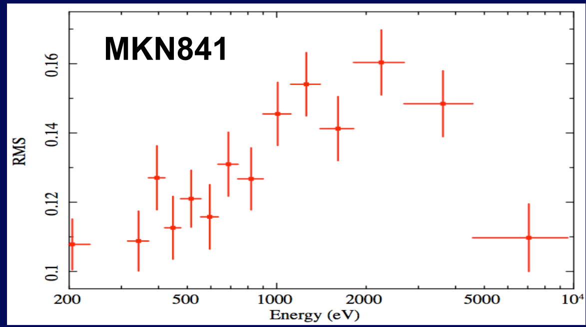








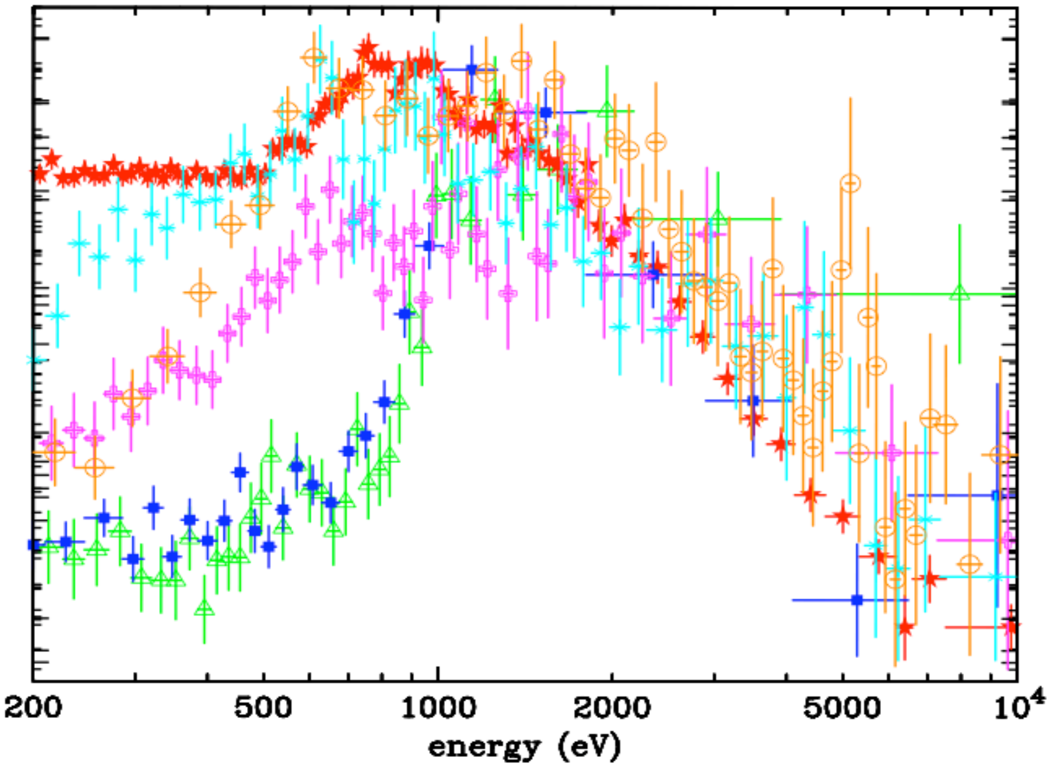




Ponti et al. in prep.

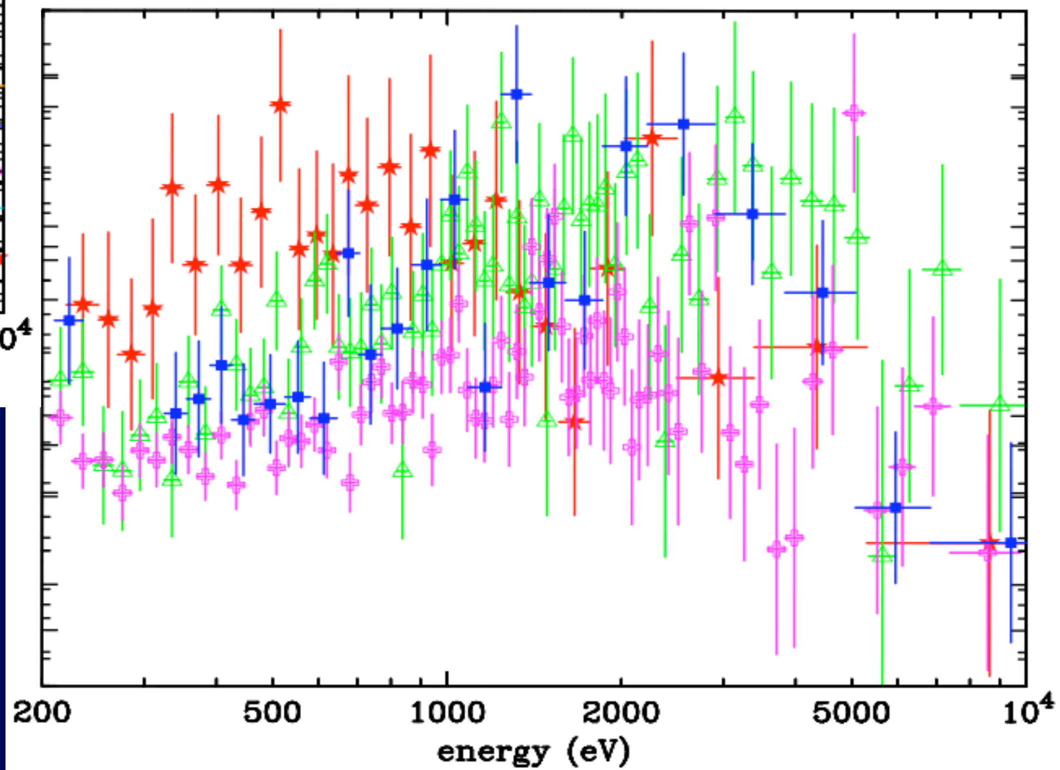
RMS spectra: group A

10 / 36 objects ⇒ less variability at low and high energy



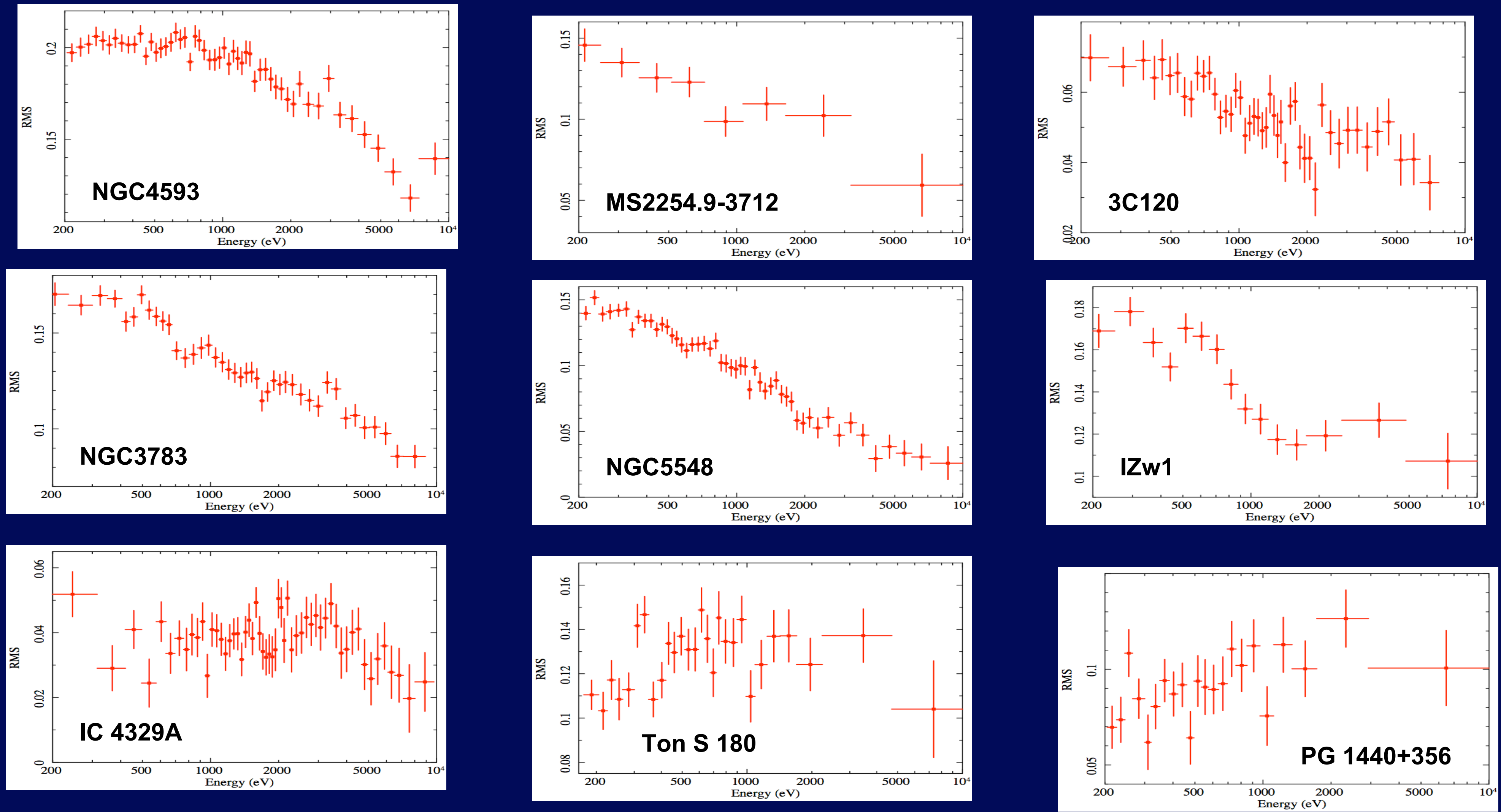
Smaller mass BHs

Higher mass BHs



RMS spectra: group B

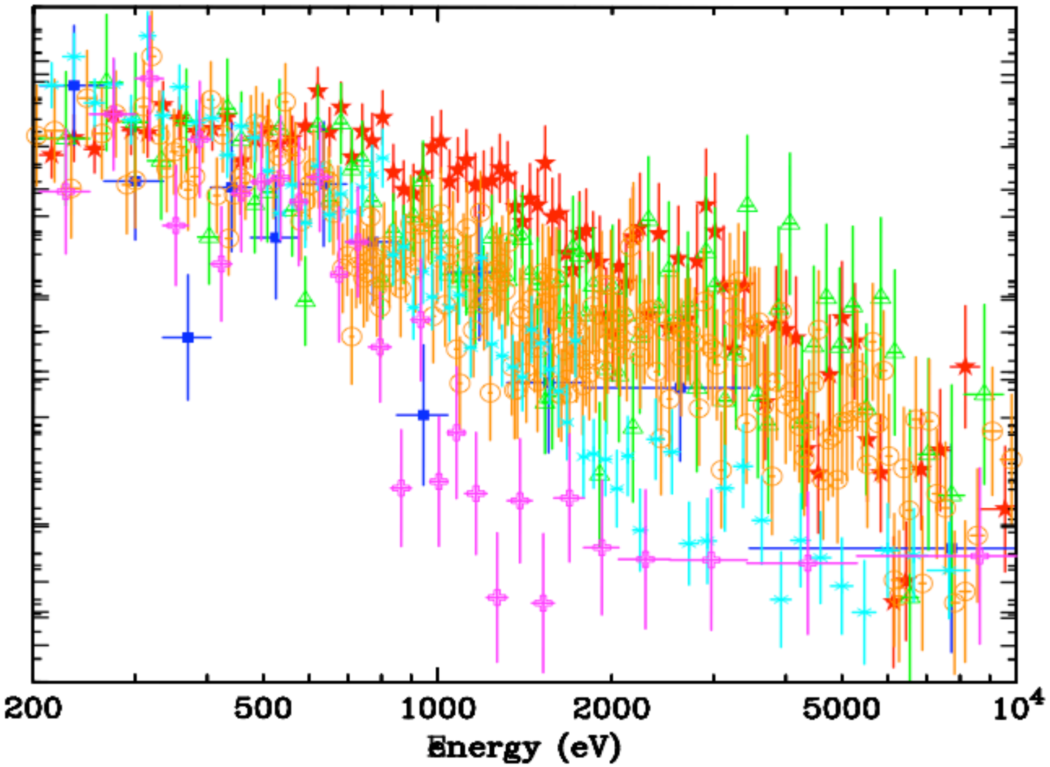
9 / 36 objects constant or lower variability with energy



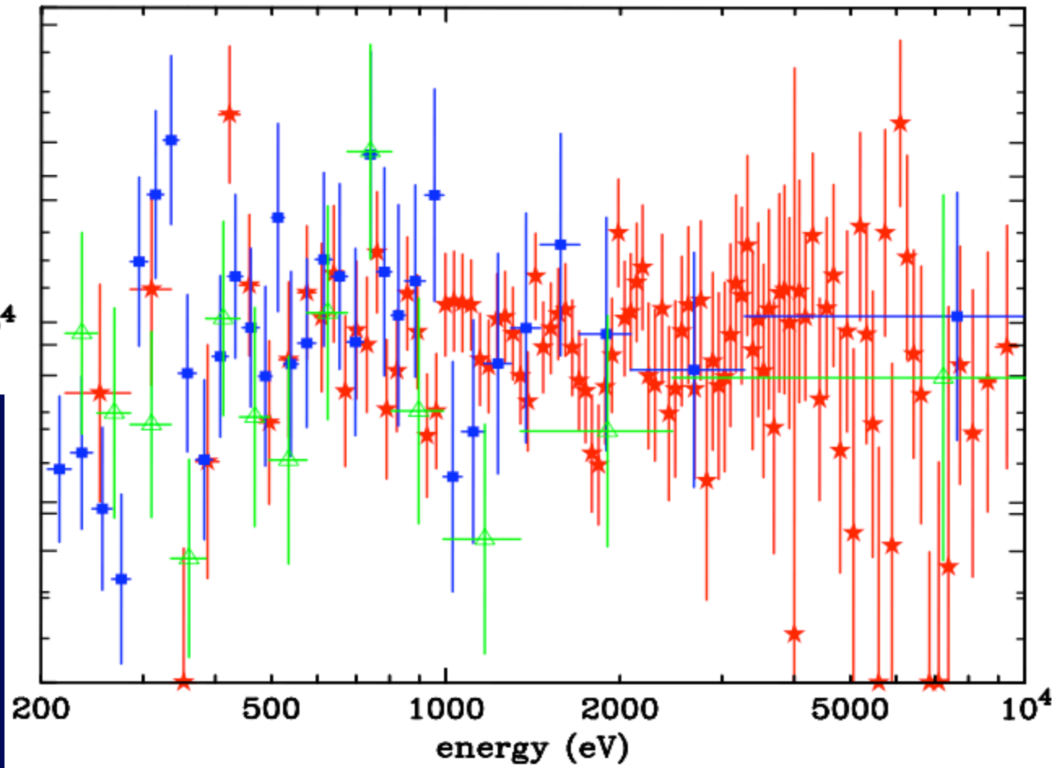
Ponti et al. in prep.

RMS spectra: group B

9 / 36 objects constant or lower variability with energy



Constant with energy



Decreasing with energy

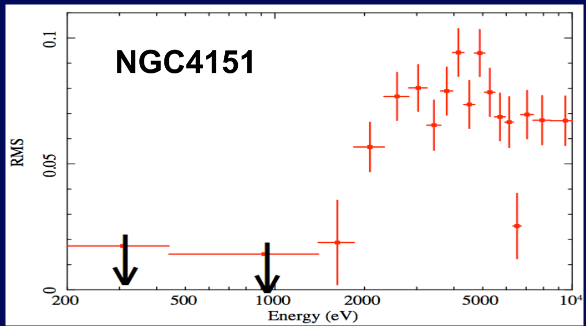
No peak between 0.5-2 keV

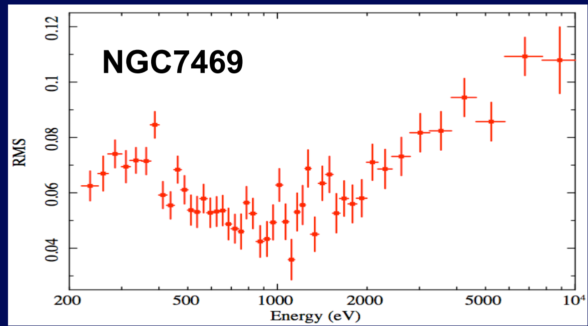
⇒ the wind constant

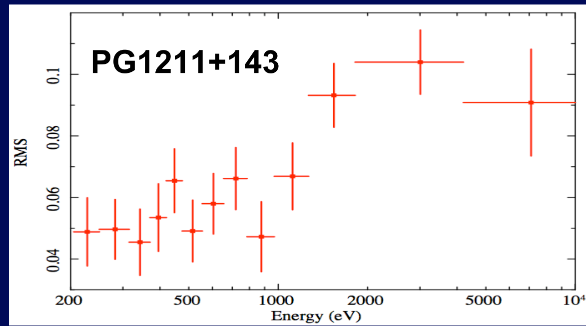
(in the absorption interpretation)

RMS spectra: peculiar and low variability objects

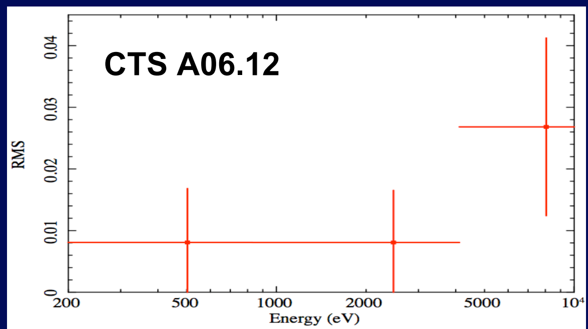
3 / 36 have peculiar variability

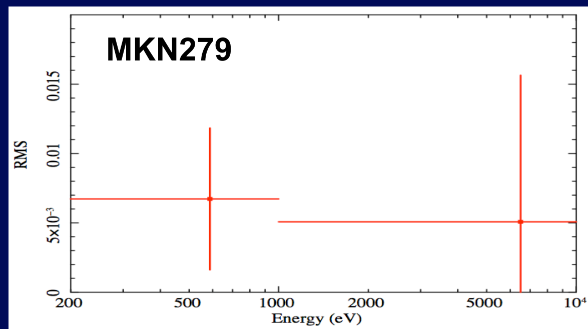




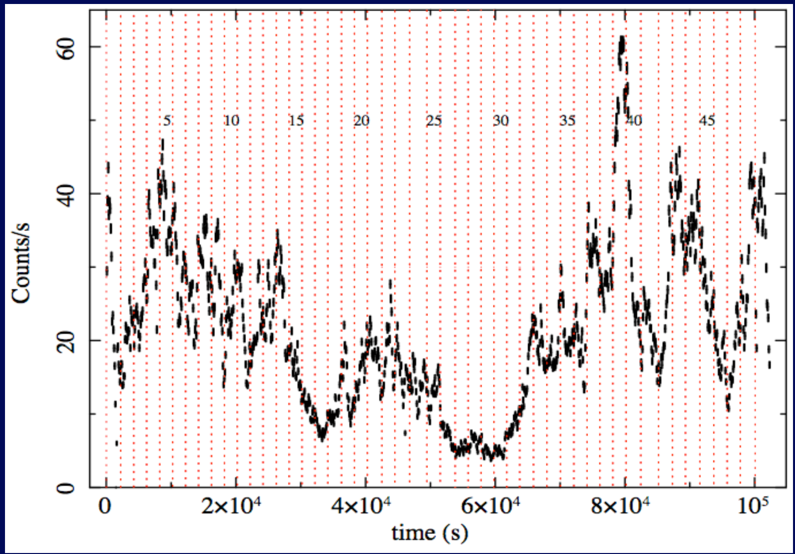


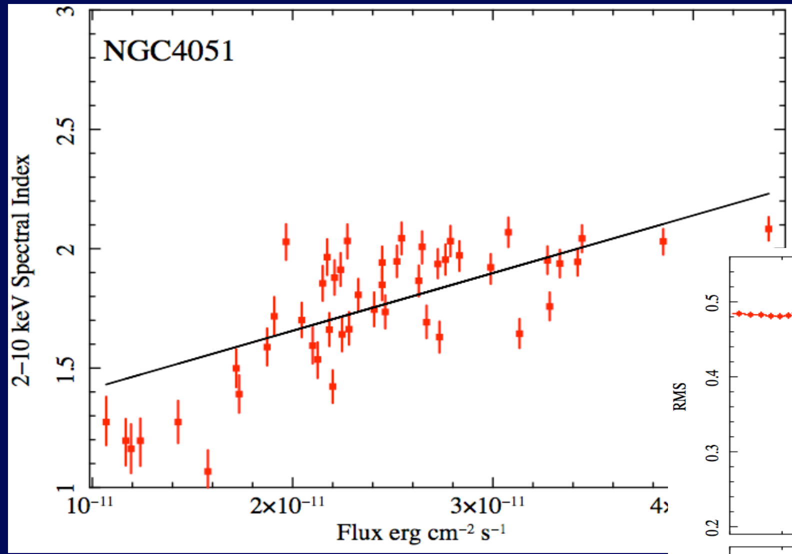
14 / 36 objects have variability < 4 %

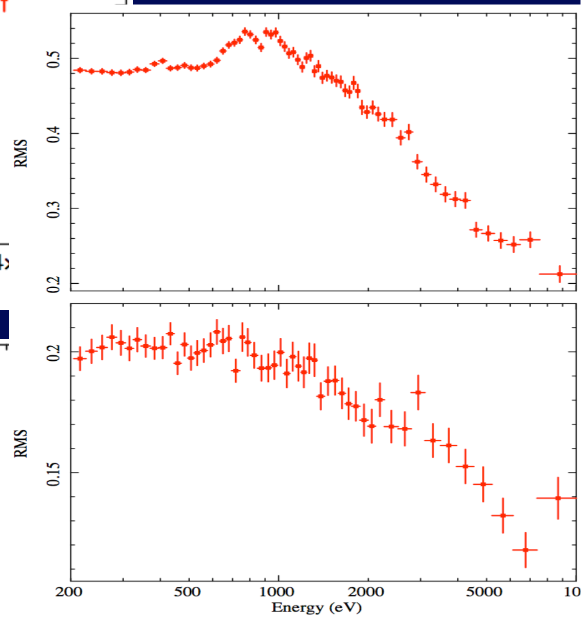


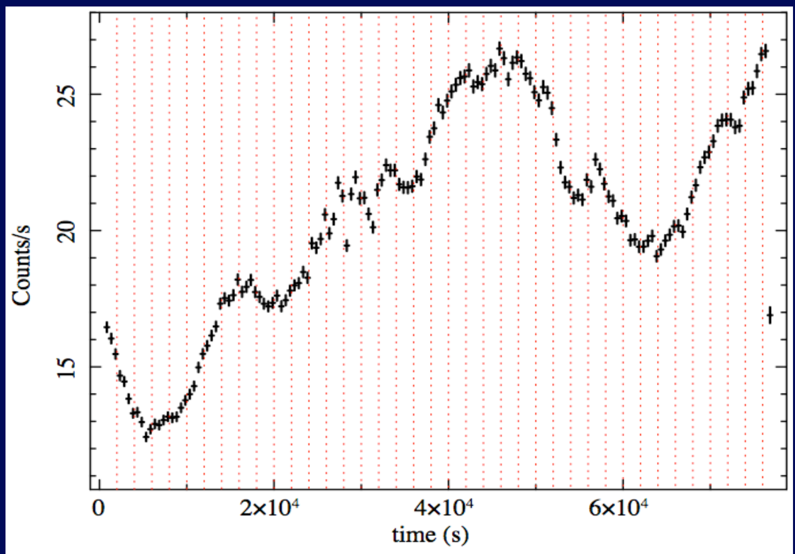


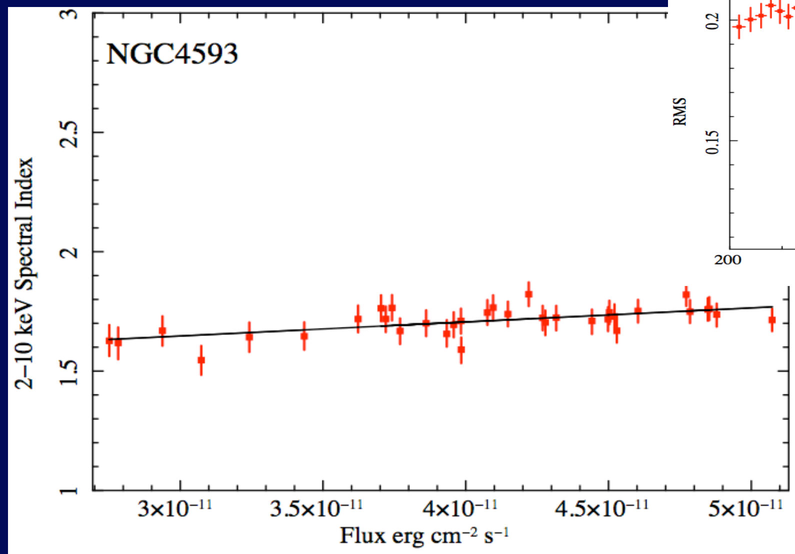
Deeper study: RMS simulations - time resolved spectral variability





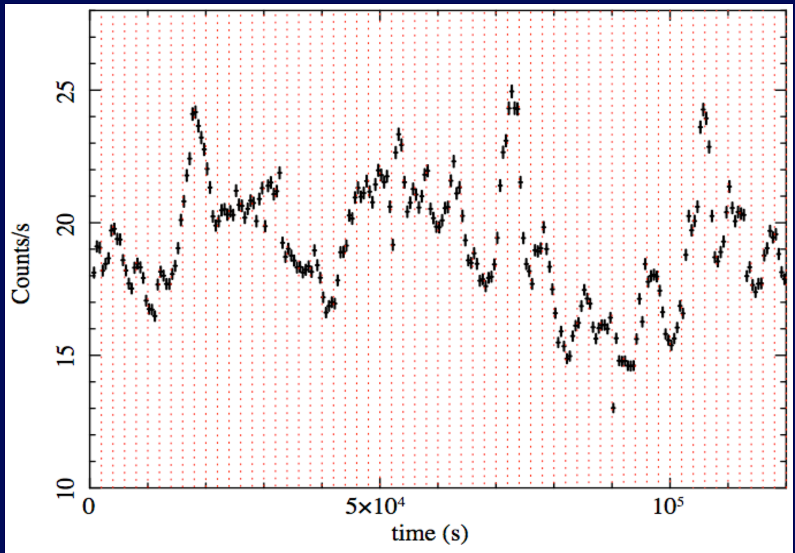


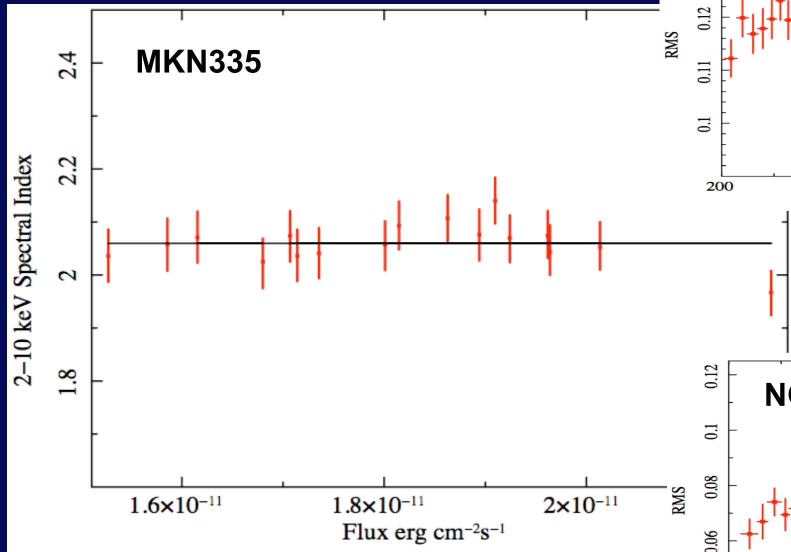


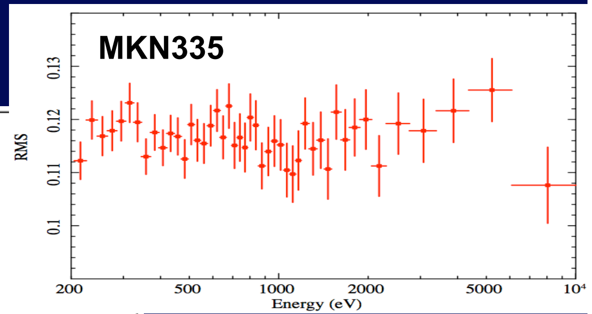


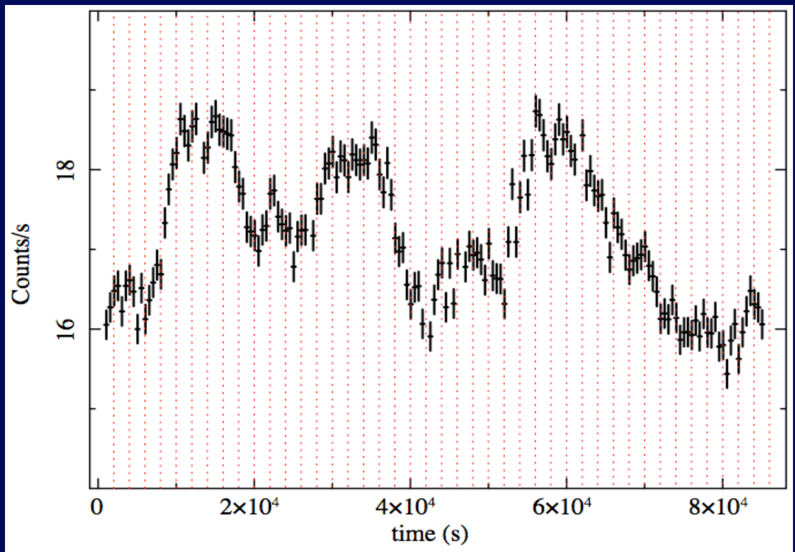
RMS simulation
assuming Γ-flux intrinsic

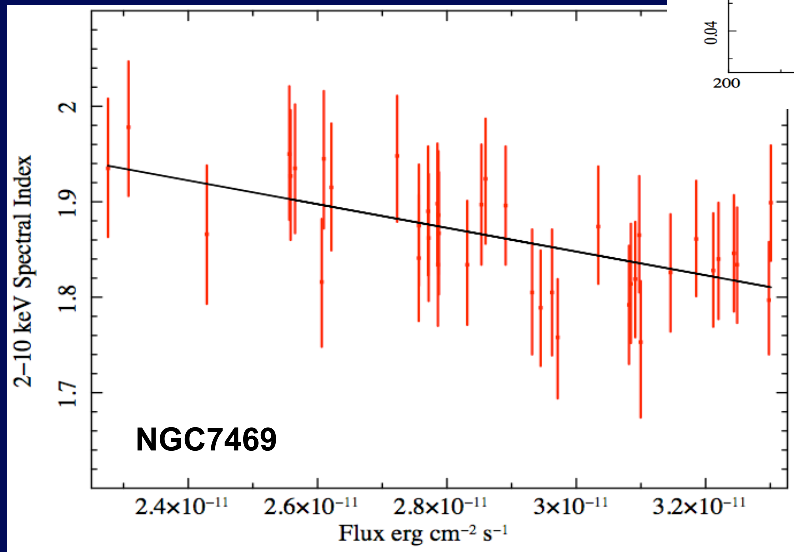
Deeper study: RMS simulations - time resolved spectral variability

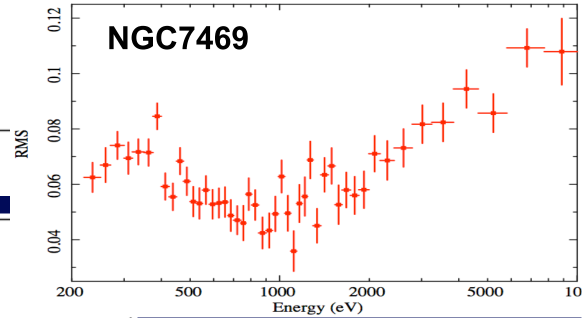






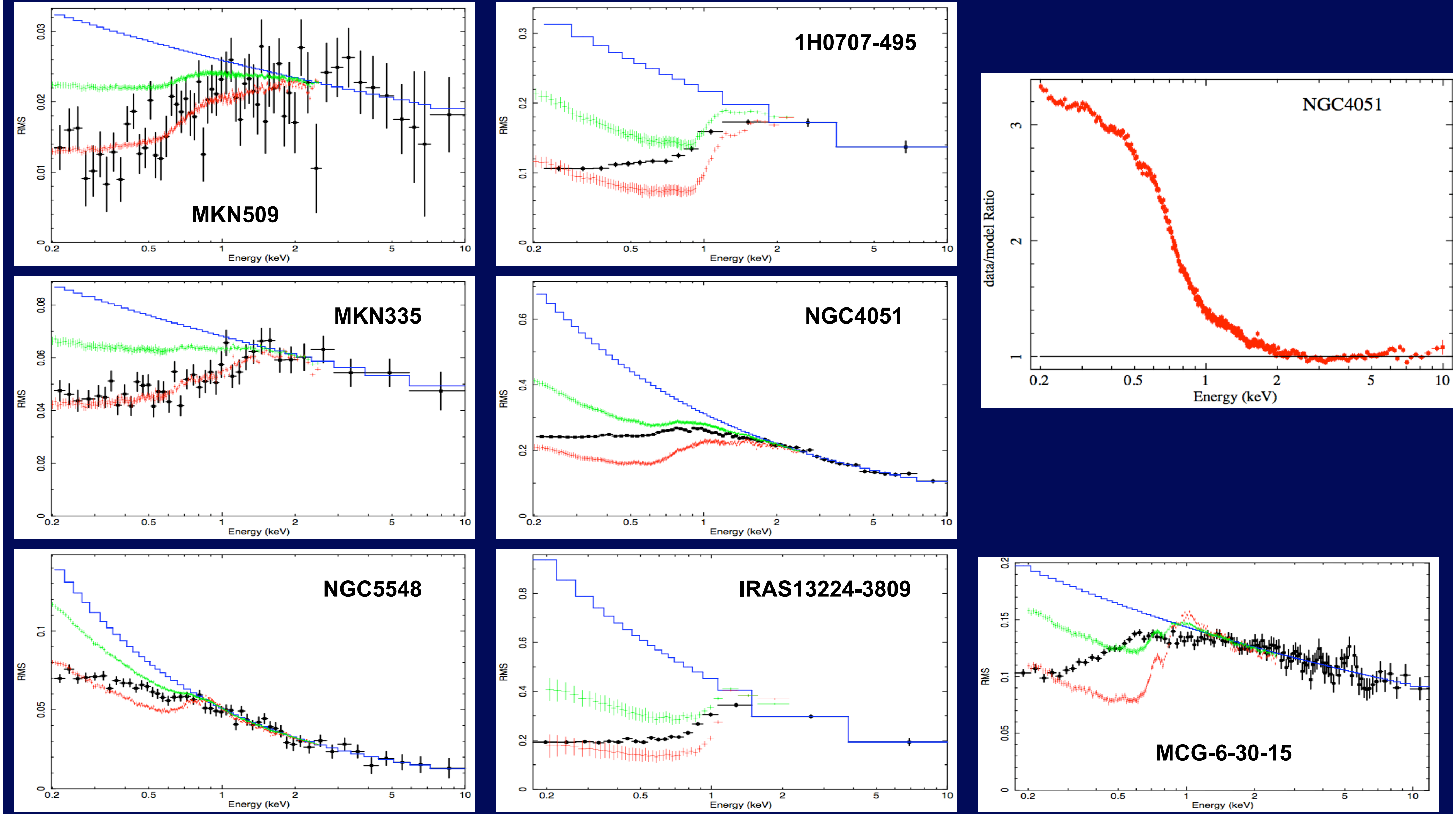






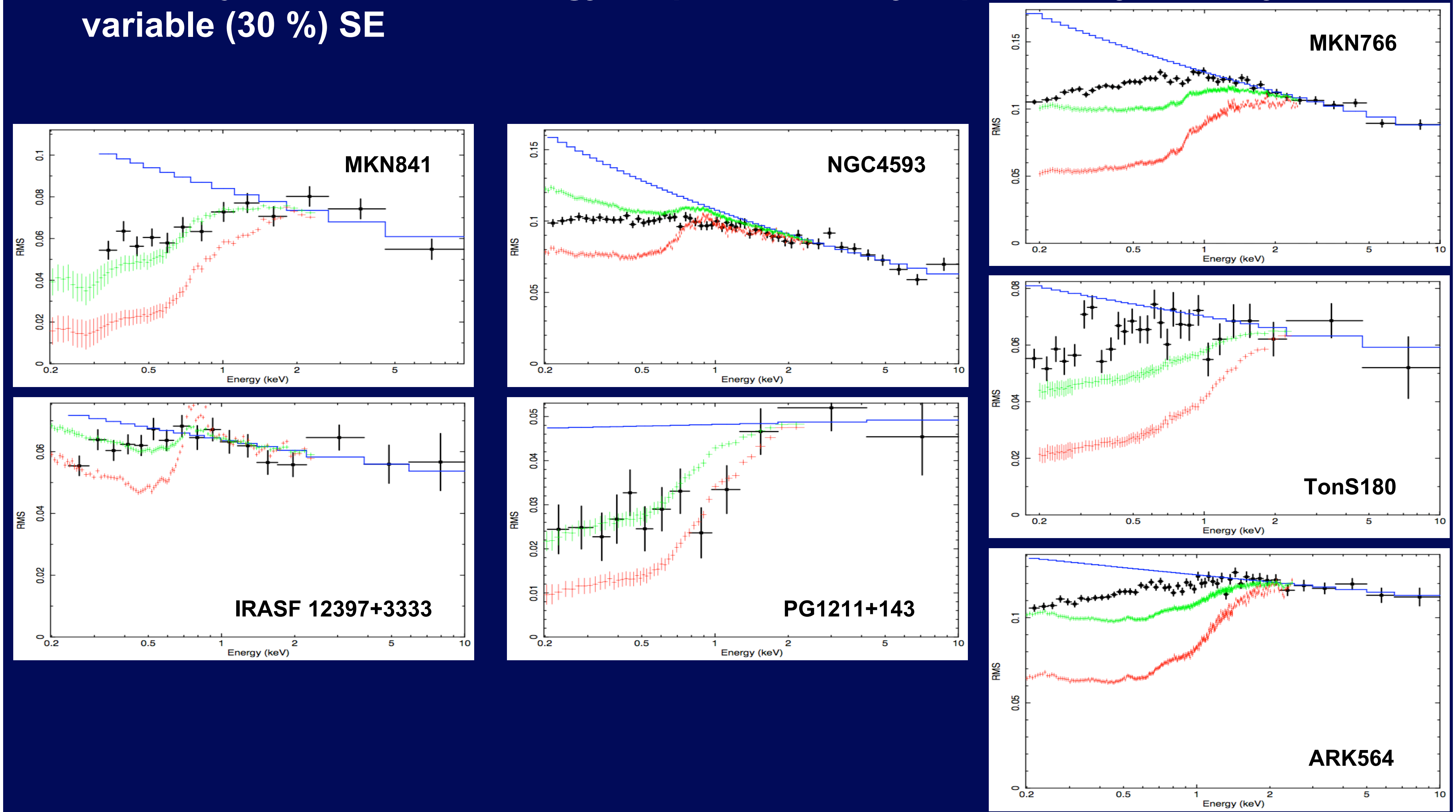
RMS spectra: Constant SE

7 / 21 objects ⇒ SE constant



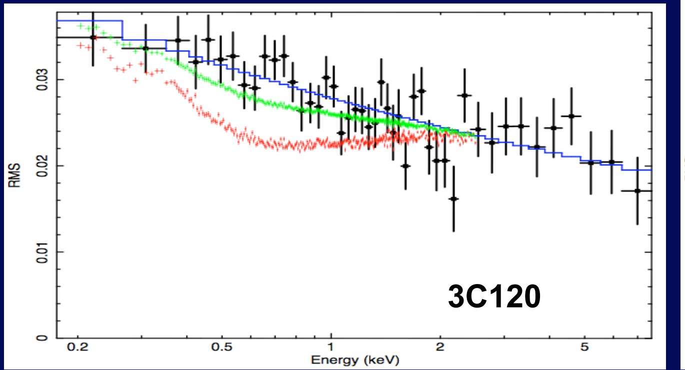
RMS spectra: slowly variable SE

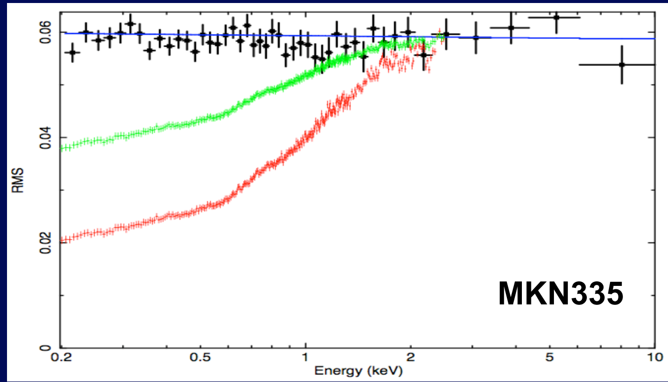
7 / 21 objects ⇒ the low energy drop of variability explained by a slowly variable (30 %) SE

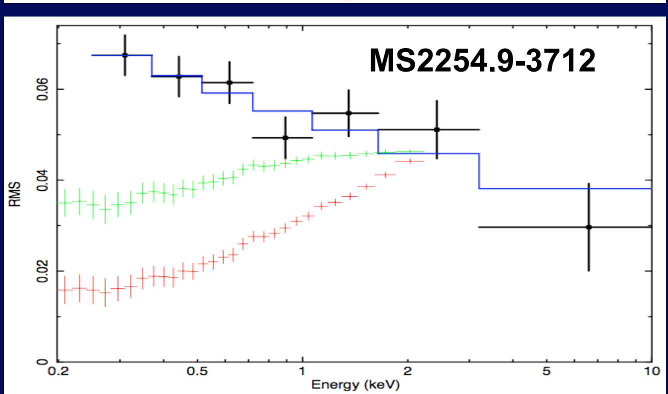


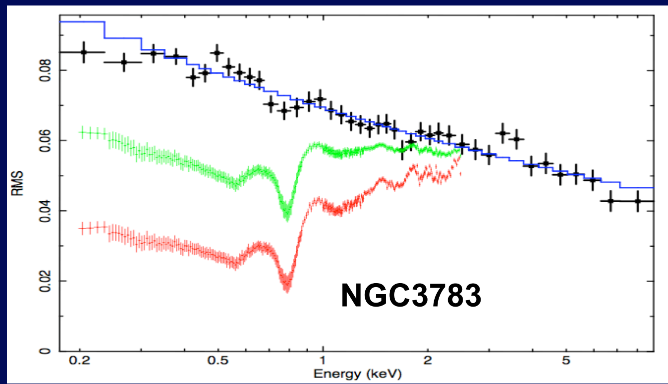
RMS spectra: variable SE

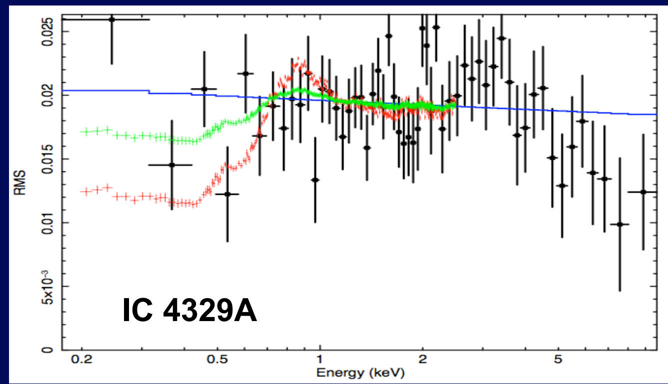
7 / 21 objects ⇒ SE as variable as the continuum (correlated)

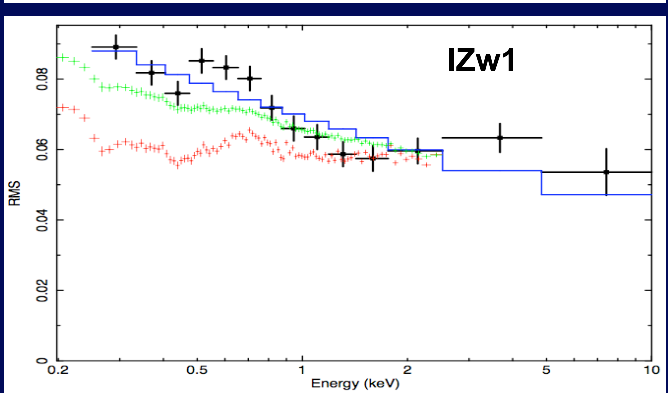


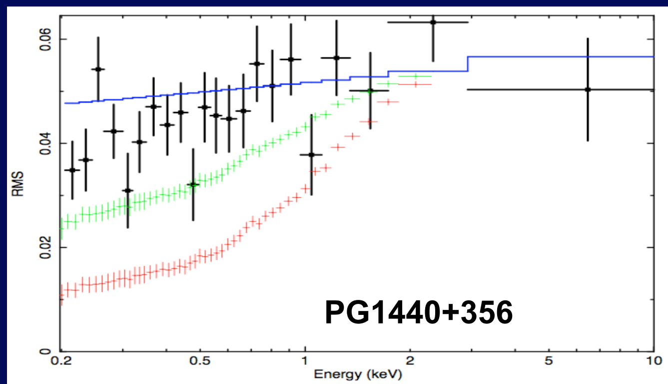












Flat RMS disfavour strong absorption (wind) interpretations

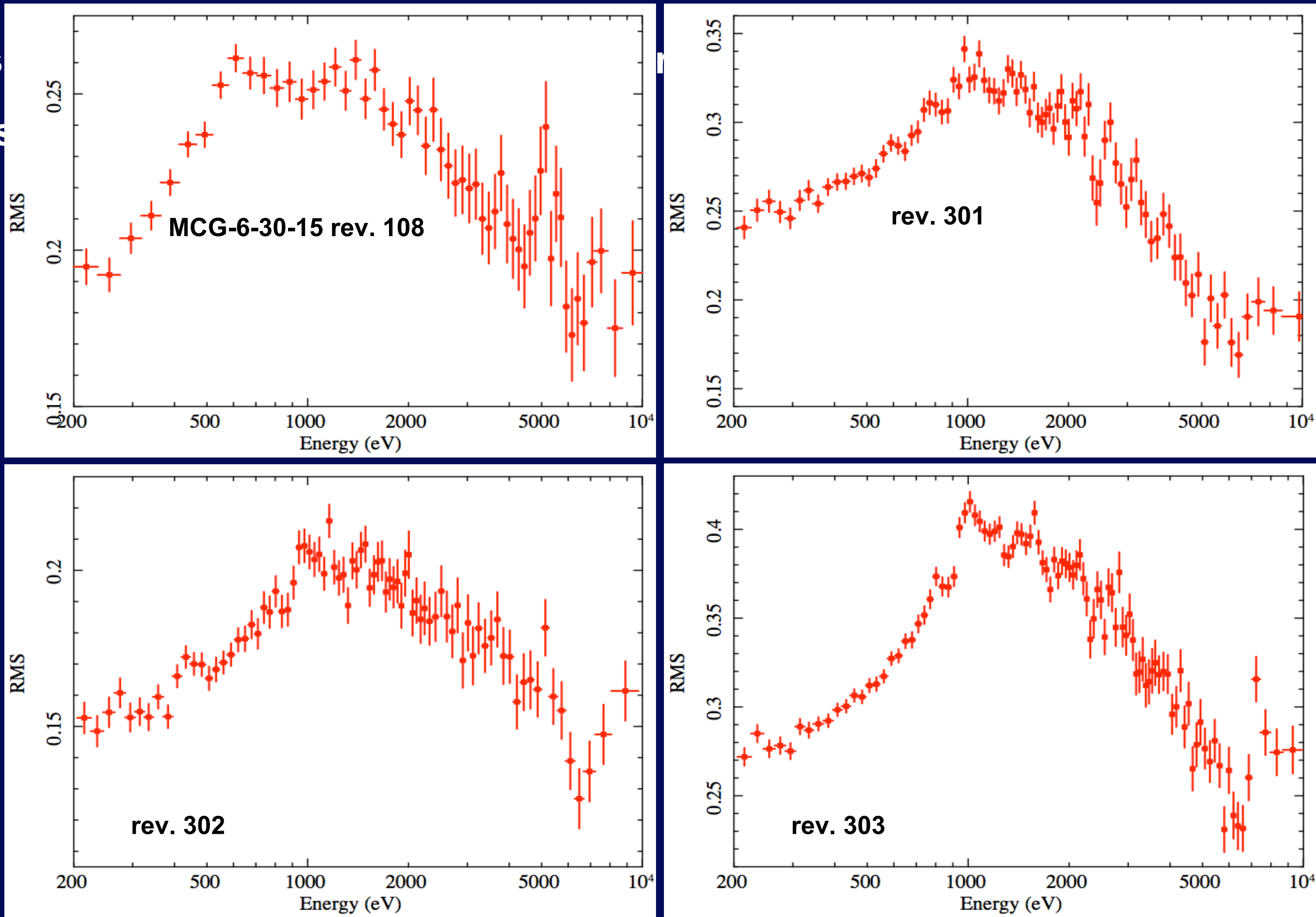
Stability of the RMS shape over time

- Is the RMS shape stable over time or does it vary between different observations of the same source?

Stability of the RMS shape over time

- Is

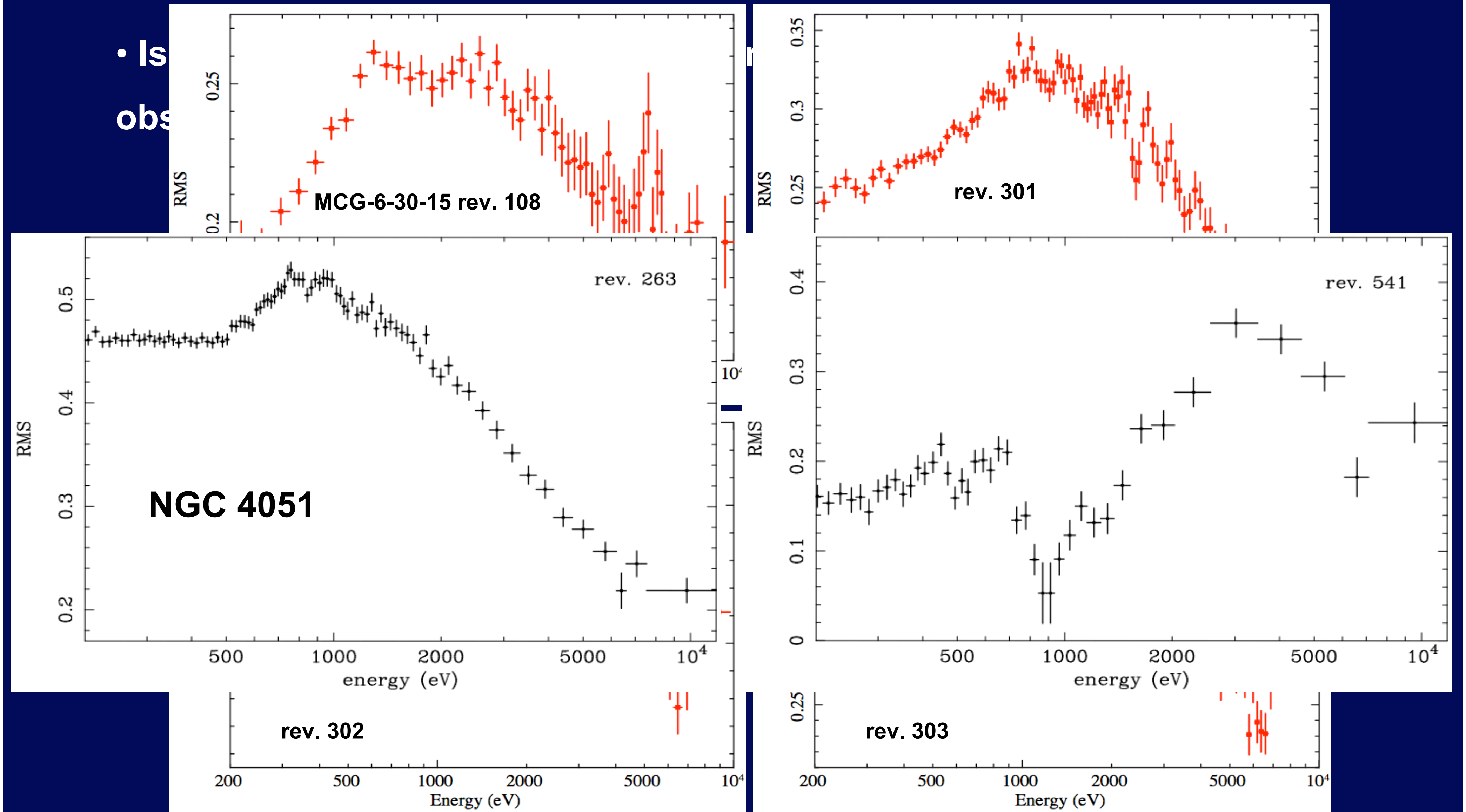
obs



Stability of the RMS shape over time

• Is

obs



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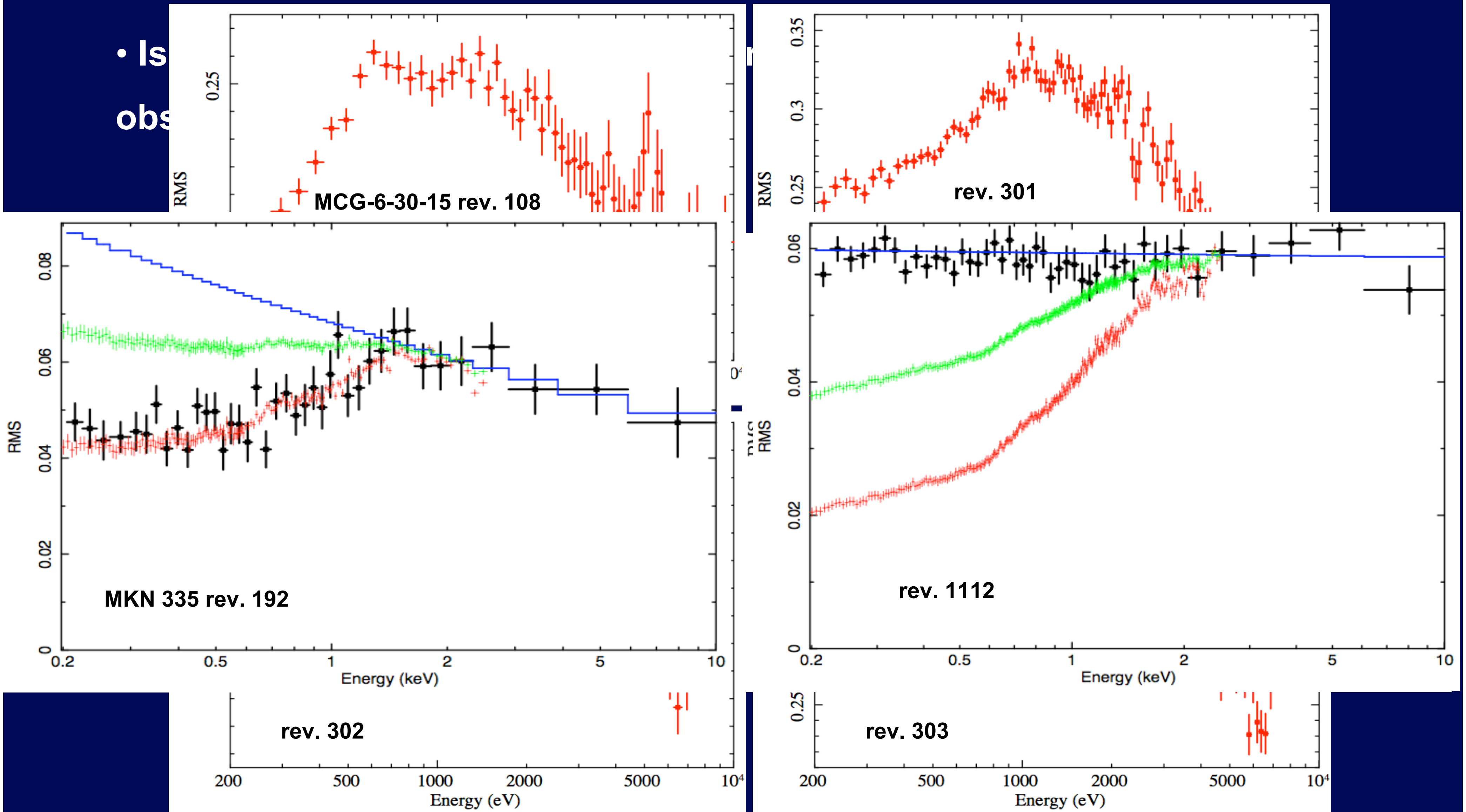
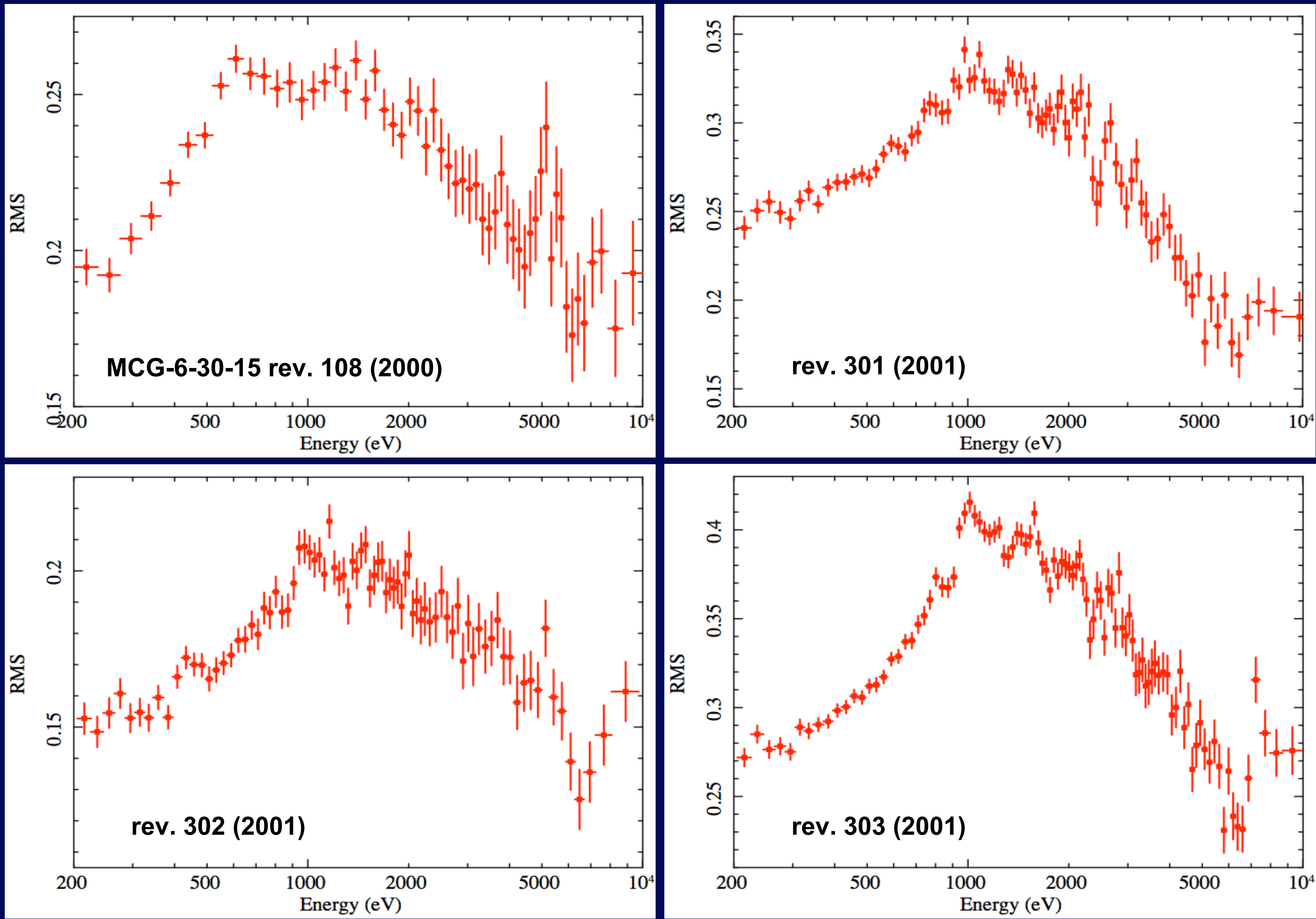


The variability of the Fe K line: MCG-6-30-15



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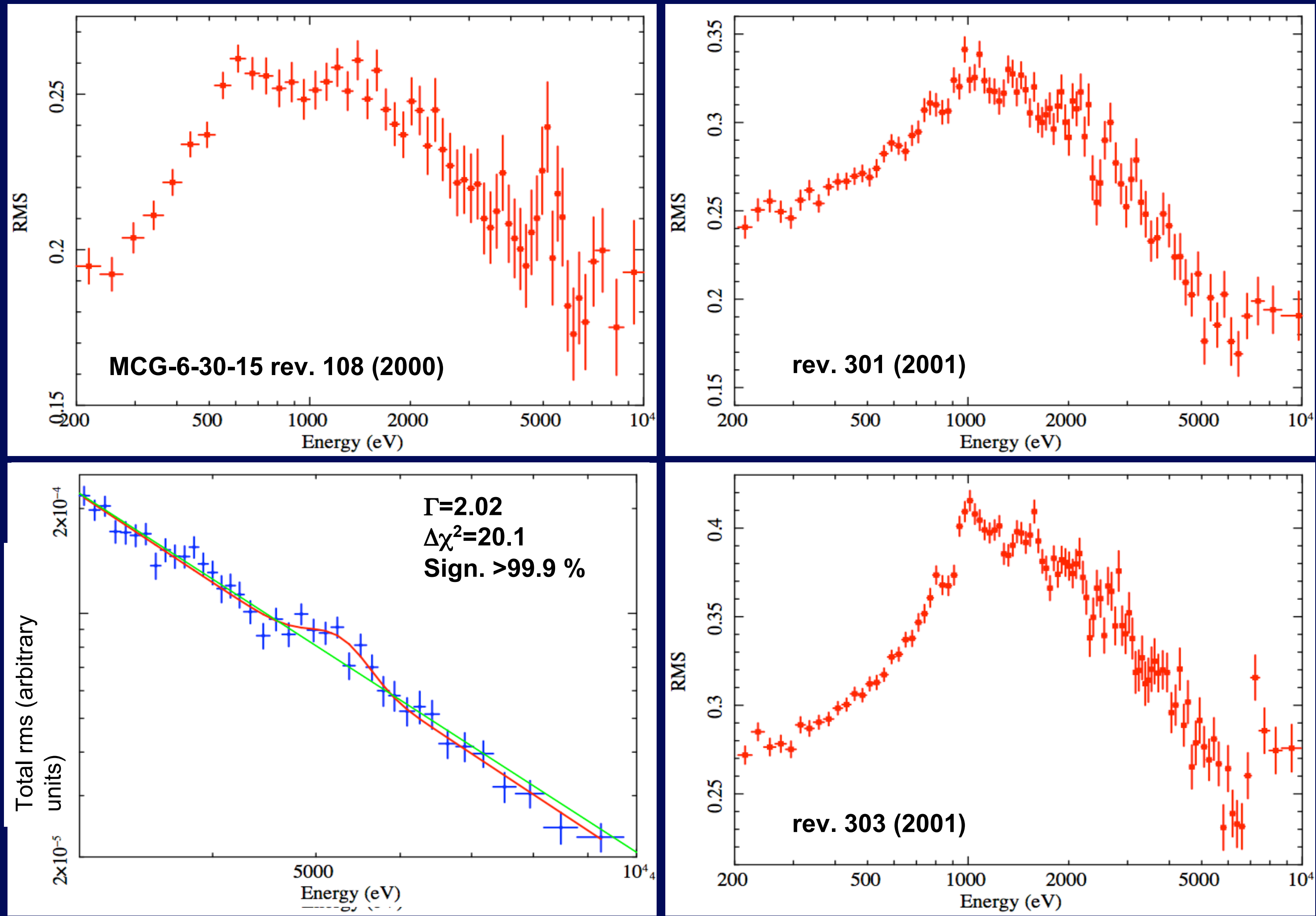

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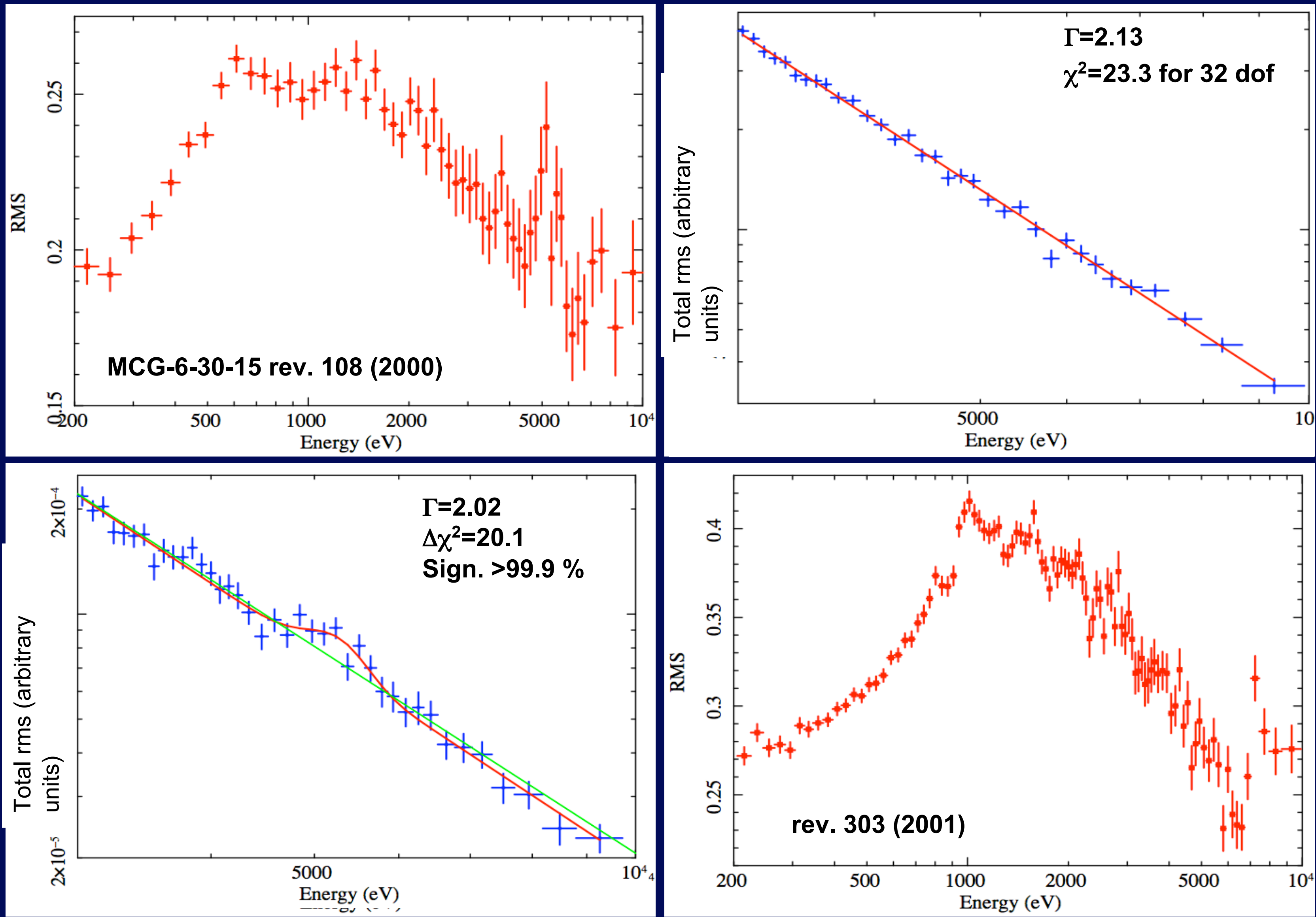
Revnivtsev et al. 1999; consistent with Papadakis et al. 2005



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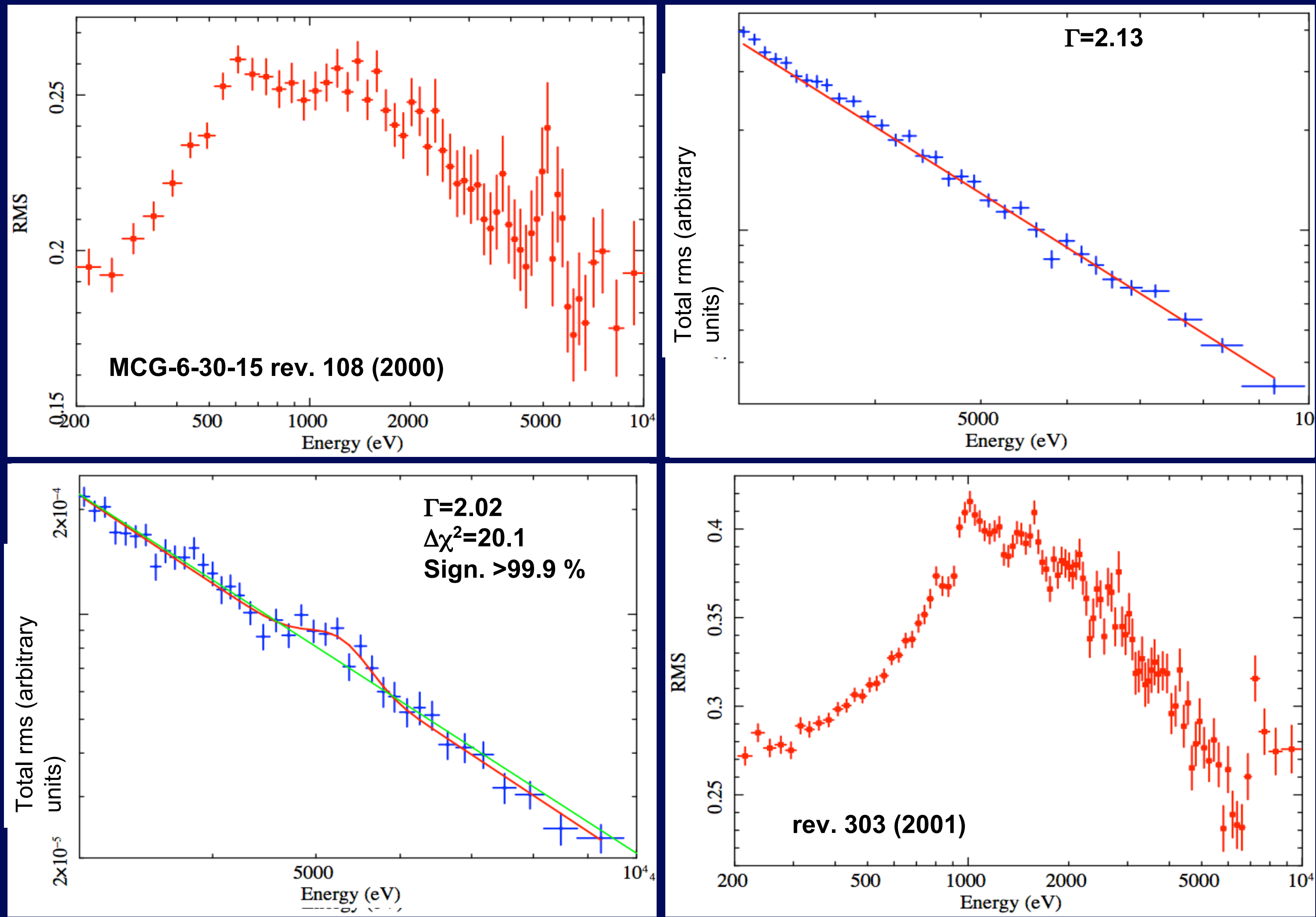

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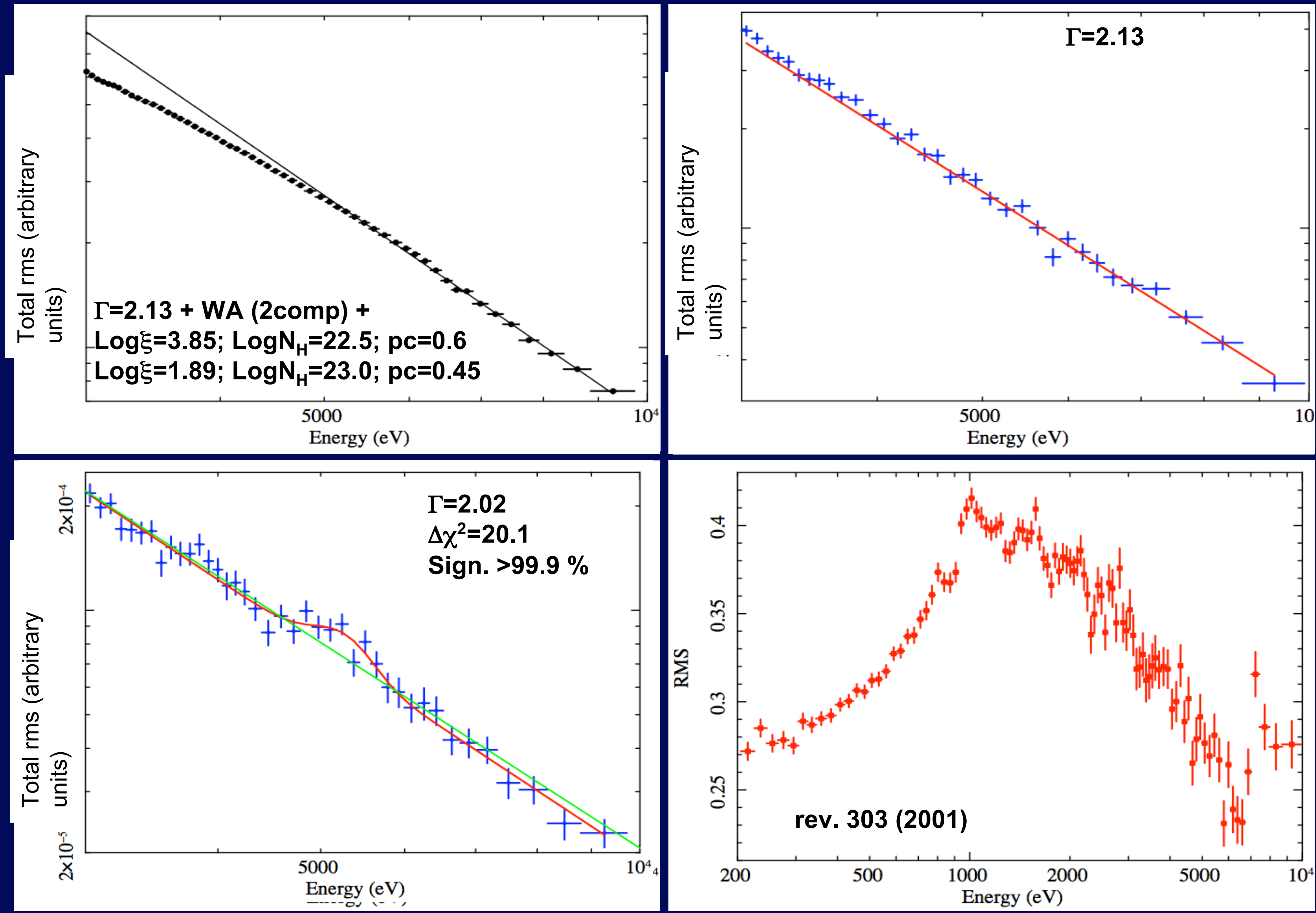
Revnivtsev et al. 1999; consistent with Papadakis et al. 2005



Summary:

BROADBAND VARIABILITY:

The RMS spectra generally show a shape with:
- lower variability at low and high energy and a peak around 0.7 to 2 keV
- a flat or decreasing variability with energy

The soft excess is either less variable or as variable as the continuum

~ 30 % ⇒ SE constant
~ 30 % ⇒ less variable than PL
~ 30 % ⇒ variable as PL

The RMS is not constant over time: the soft excess may appear sometimes constant, sometimes variable in the same source

The flat RMS shapes disfavour the models involving strong relativistic absorption

3-10 keV VARIABILITY:

The red tail of the Fe K line of MCG-6-30-15 shows a significant excess of variability in one over 4 XMM-Newton observations
The 3-10 keV total RMS spectrum ⇒ PL shape, without signatures of absorption

NGC7469: peculiar spectral variability ⇒ inverted $\Gamma_{2\text{-}10}$-flux relation