Soft X-ray line reflection in NLS1 galaxies

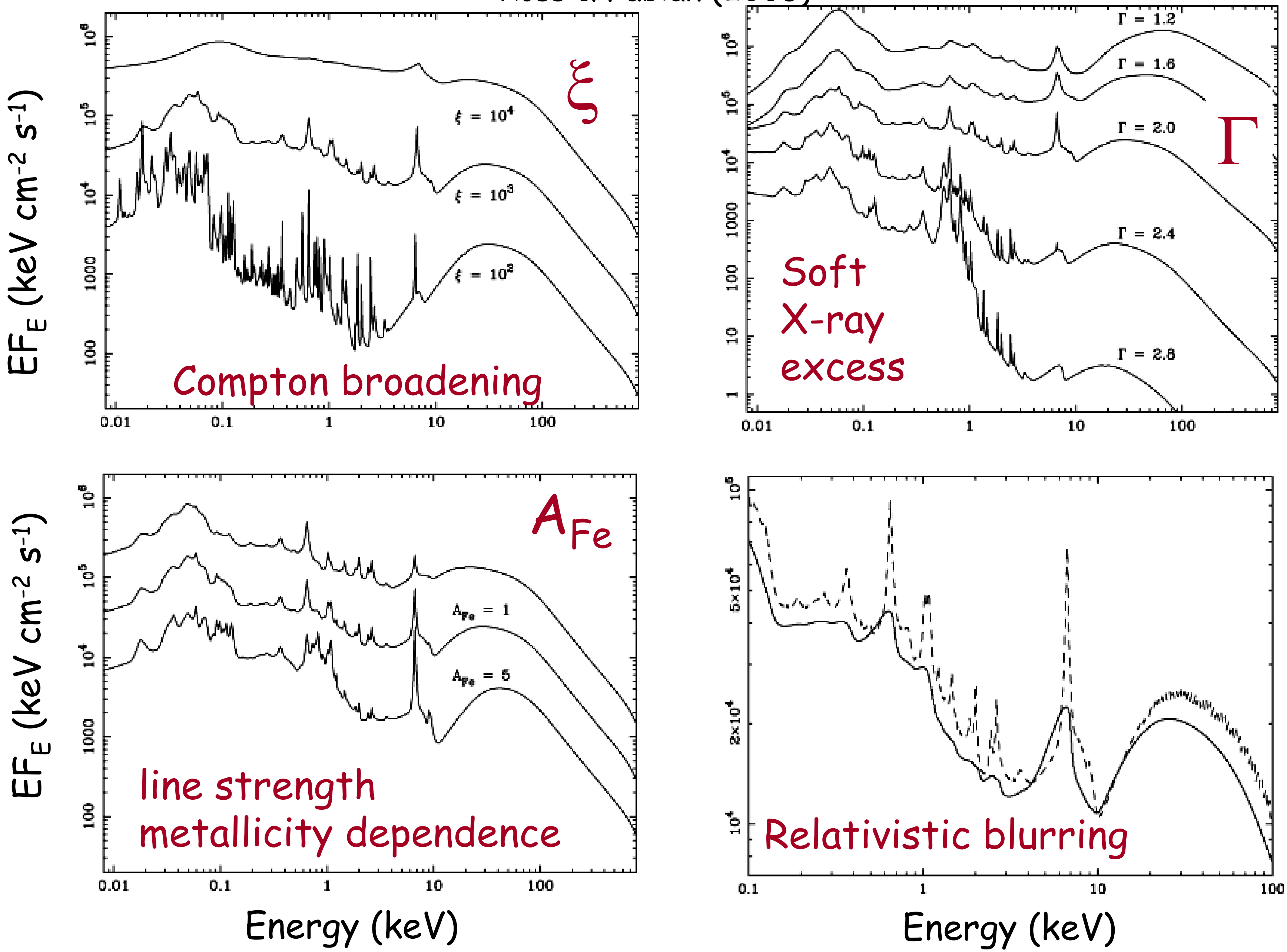
Th. Boller, A. Müller, A. Ibarra

MPE Garching
Excellence Cluster Universe Munich
XMM SOC, Villa Franca, Spain

1. The relativistic RM: Compton- and GR line broadening predictions
2. Reliability of spectral fitting in the limited RGS energy band
3. Results in the strong and weak field limit
4. Predictions for IXO

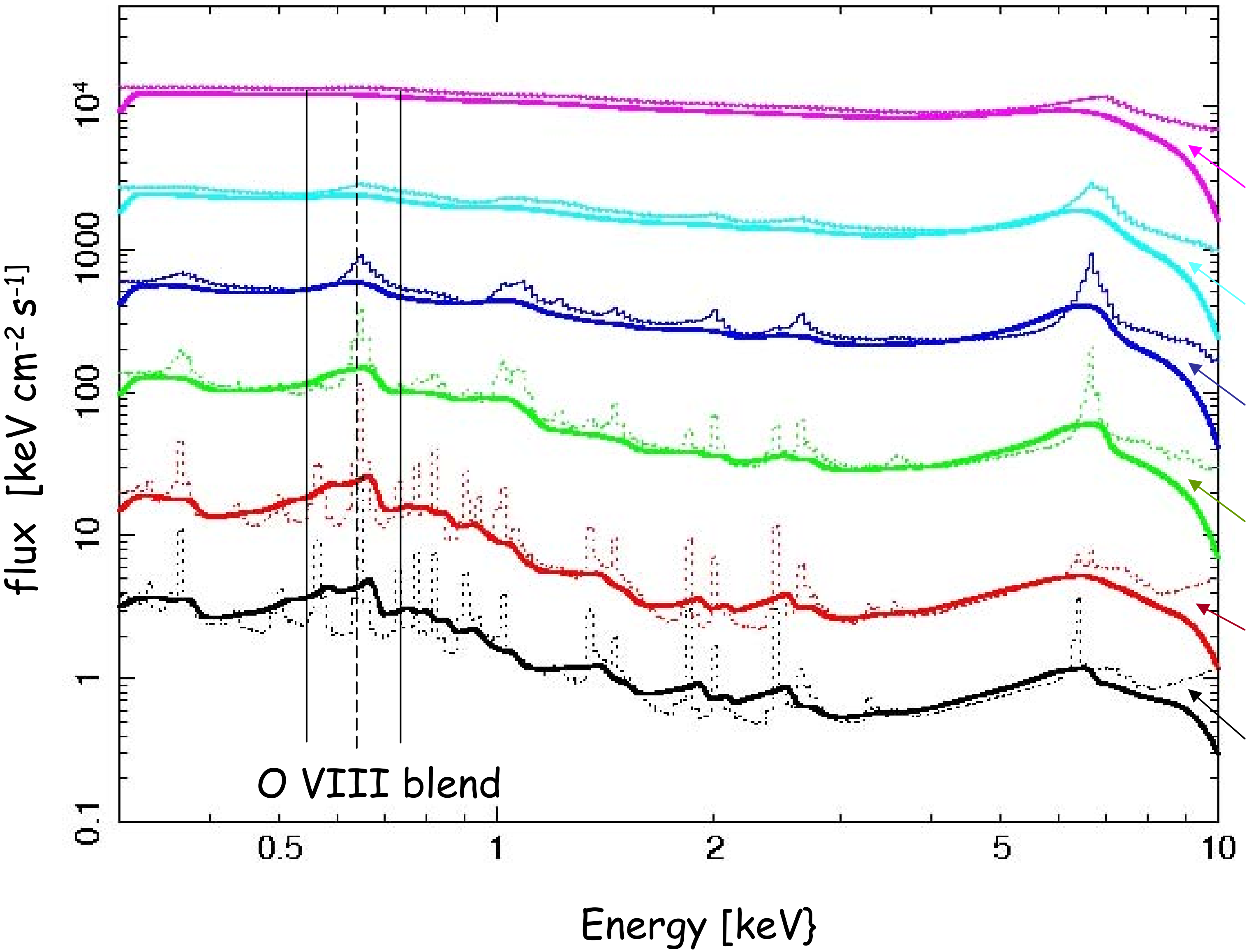
The relativistic RM: Compton- and GR line broadening

Ross & Fabian (2005)



Quantifying Compton broadening and relativistic blurring

dummyrsp 0.3 10 20000, Index=3, $R_{in}(G)=4.5$, $n_{powl}=1$, $n_{refl}=10^{-3}$



O VII/VIII blend

ξ (erg cm s^{-1})	Refl σ (eV)	Refl+ kdblur σ (eV)
5000	~400	~650
2000	200	400
1000	30	100
500	10	60
200	5	20
100	4	15

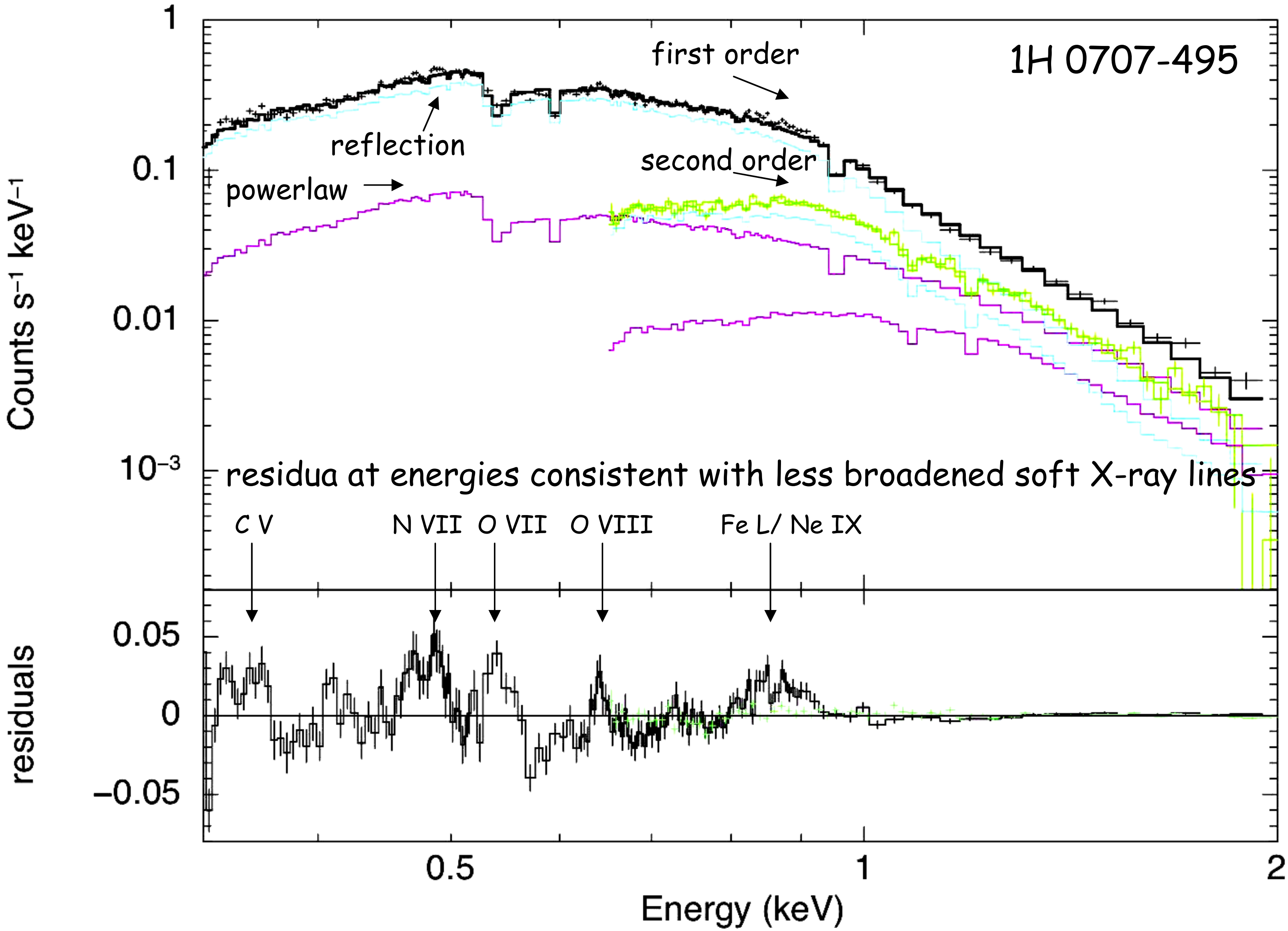
2. The NLS1 sample

Object	#OBS ID's	total RGS exp.	RGS counts	EPIC counts
1H0707	10	790 ks	130000	~ factor of 10
Ark 564	5	180 ks	310000	
Mrk 110	1	47 ks	40000	
Ton S180	2	50 ks	23000	
I Zw1	2	80 ks	14000	
IRAS 13224	1	64 ks	4200	
PG 1244	1	13 ks	3200	
PHL 1092	3	210 ks	2599	

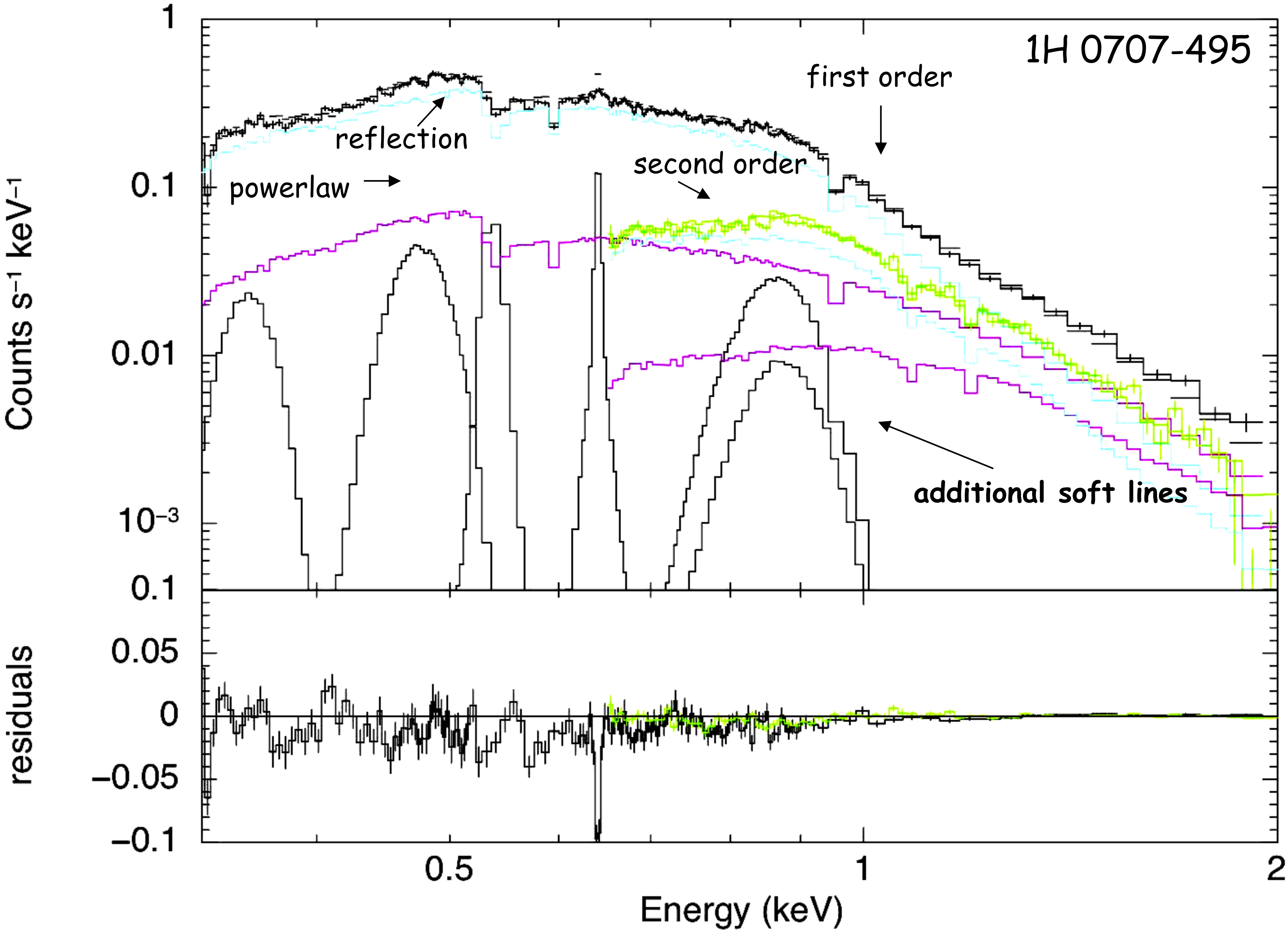
Relativistic reflection model fits to the merged RGS1/RGS2
first and second order spectra
for individual and the merged data sets

extension to the work by Blustin & Fabian 2009 on 1H0707

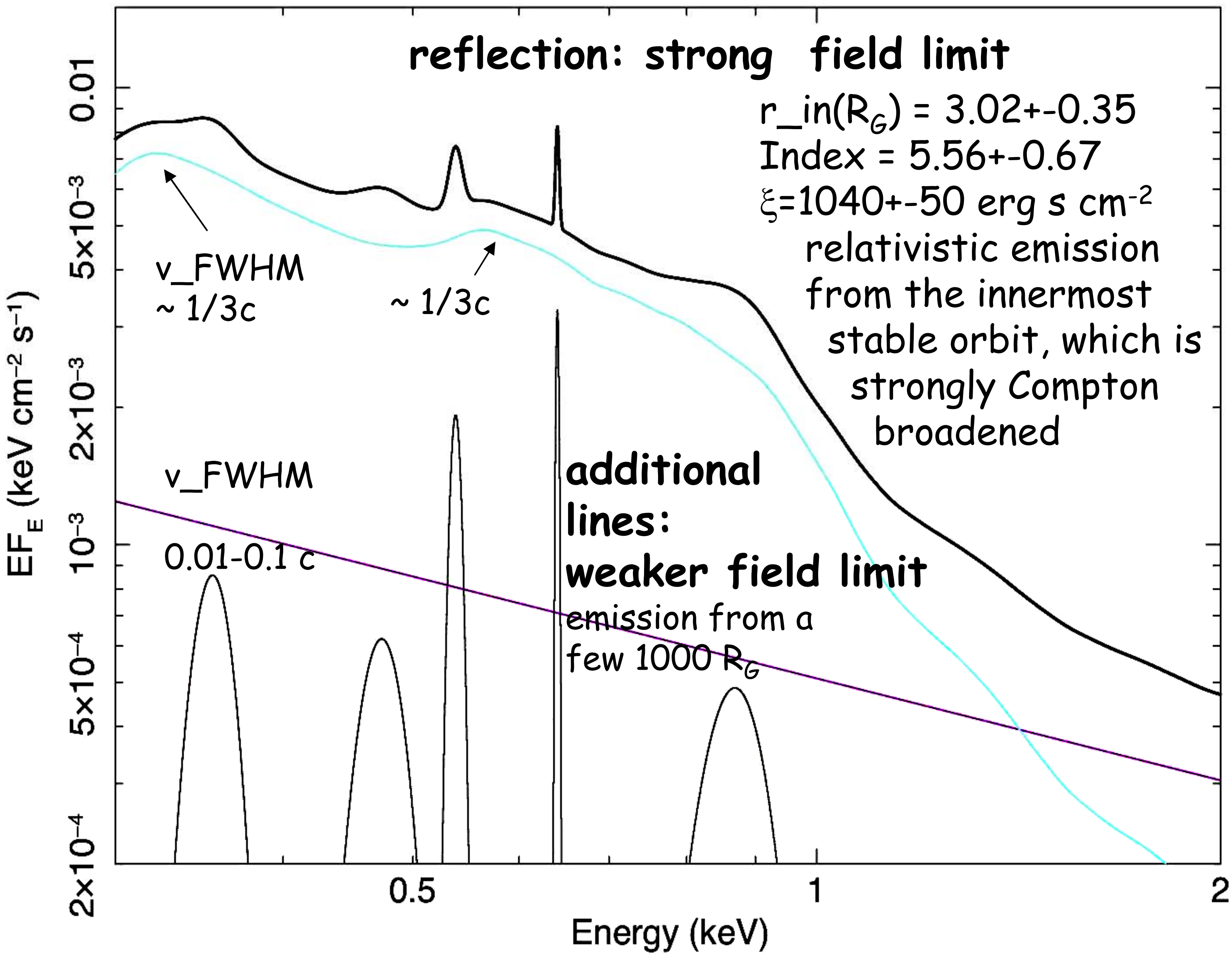
RGS relativistic reflection model fitting



RGS relativistic reflection model plus additional X-ray line fitting



Strong and weak field limit results for 1H0707



Relativistic reflection model fit parmeters and fit reliability in the limited RGS band ?

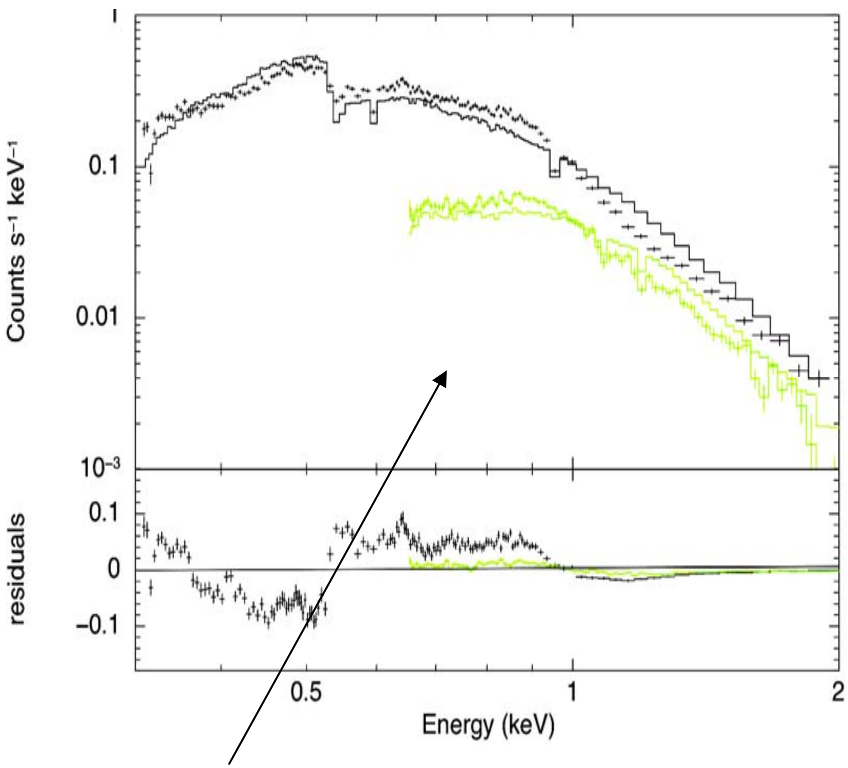
We have merged 10 individual XMM-Newton EPIC pn observations and 10 individual RGS observations for spectral fitting with the relativistic reflection model

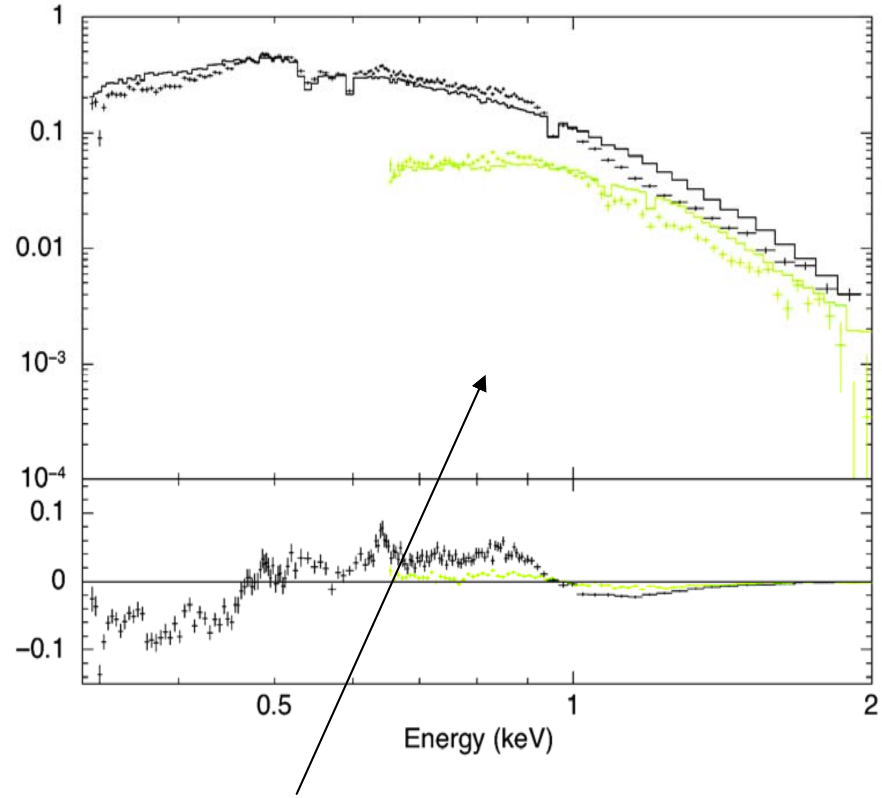
	NH [cm^{-2}]	Γ	n_{po} [10^{-4}]	index	r_in [R_G]	incl	Fe/solar	ξ	n_{refl} [10^{-8}]
RGS	7.6(0.3)	2.7(0.03)	5.7(0.9)	5.5(0.7)	3.0(0.3)	39(4)	3.9(0.3)	1040(50)	8.6(0.9)
EPIC	7.2(0.1)	2.7(0.0)	11.0(0.4)	6.4(0.3)	3.3(0.1)	37(2)	4.8(0.2)	1070(29)	9.0(0.5)

The model parameters from the two different instruments are consistent.

Reliable spectral fits can be obtained from the combined RGS1/RGS2 first and second order spectra, even in the limited RGS energy band.

Comparision with other models





Power law model: χ^2_r=2.15
statistically not acceptable
strong and broad residua

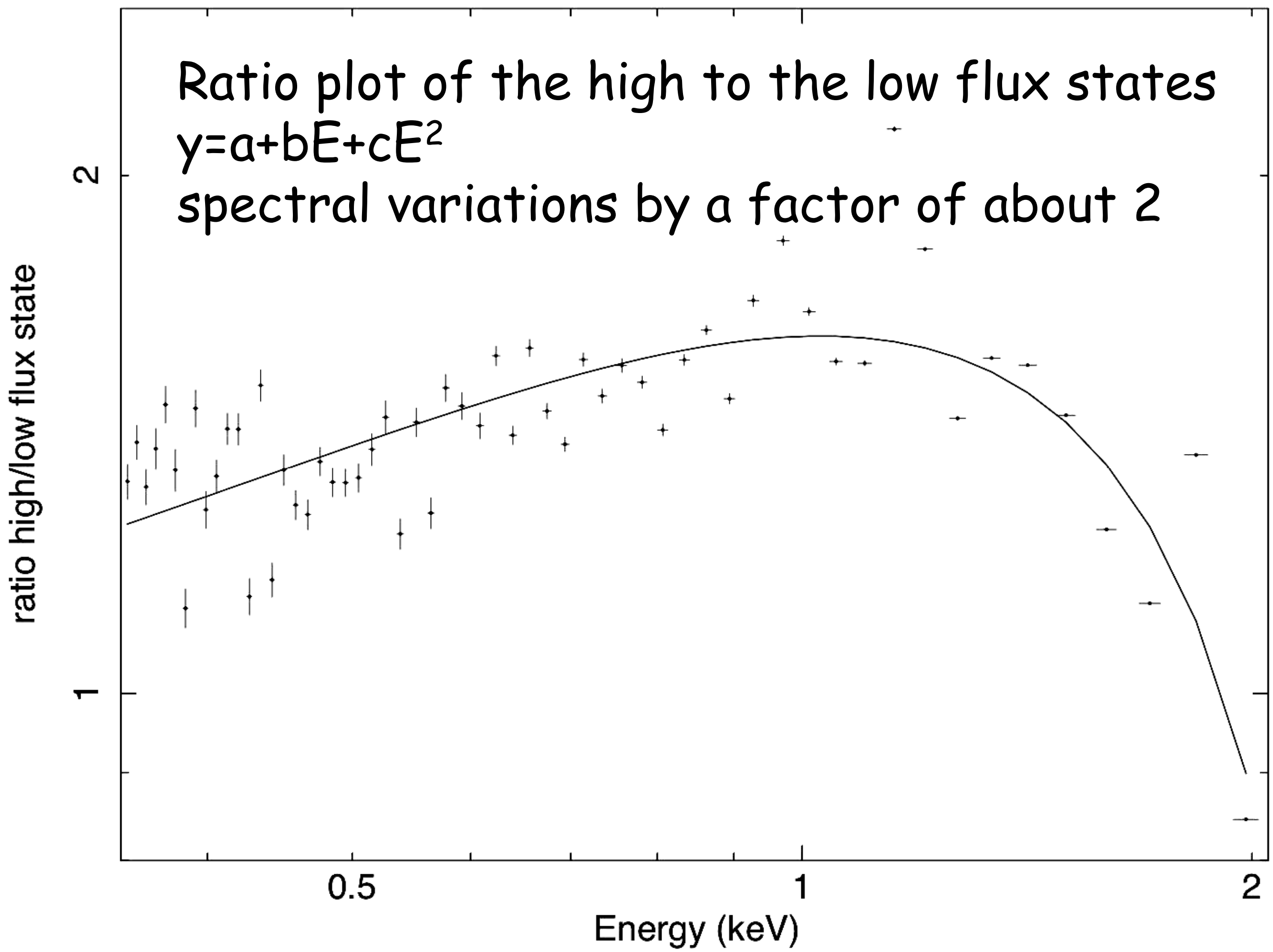
Power law plus black body model:
χ^2_r=2.31, Black body parameters remain unconstrained

pexriv with rel. blurring: χ^2_r=2.04
statistically not acceptable
most model parameters unconstrained

Partically ionized outflowing wind
: χ^2_r=2.16, column density and ionizaton parameter remain unconstrained

Variability and spectral fitting

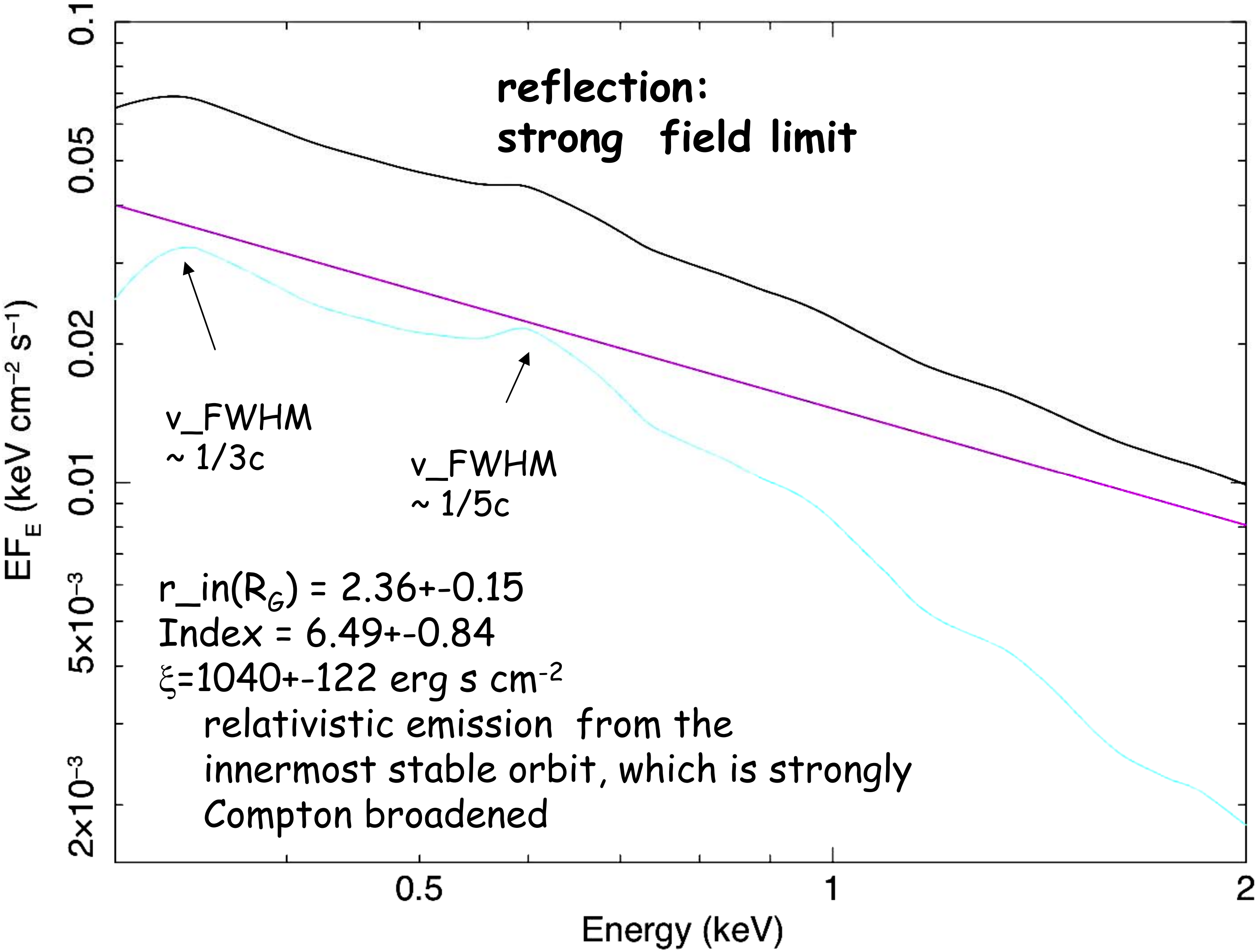
We have created a merged high flux and a merged low flux spectrum, with count rates of (0.25+-0.001) and (0.16+-0.001) counts s^{-1}.



fit parameter remain constant within the errors when fitting the high and low flux state

no spectral changes within the model parameters can be detected with the present statistics

Strong and weak field limit results for Ark 564



Comparision with other models for Ark 564

Power law model:
statistically not acceptable
strong and broad residua

pexriv with rel. blurring:
statistically not acceptable
most model parameters unconstrained

Power law plus black body model:
black body parameters
remain unconstrained

Partically ionized outflowing wind
statistically not acceptable
column density and ionizaton
parameter remain unconstrained

Only the relativistic reflection model provides a solid and
physically acceptable
statistical fit.

Strong and weaker field limit fitting results 1H 0707 and Ark 564

The obtained parameters from the relativistic reflection model suggest that the observe emission originates very close to the central black hole. **The inner radius of the emitting disc is ~3 R_G**, resulting into a black hole spin of about 0.8. The relativistic reflection model accounts for emission from the inner parts only, **probing the strong gravity field.**

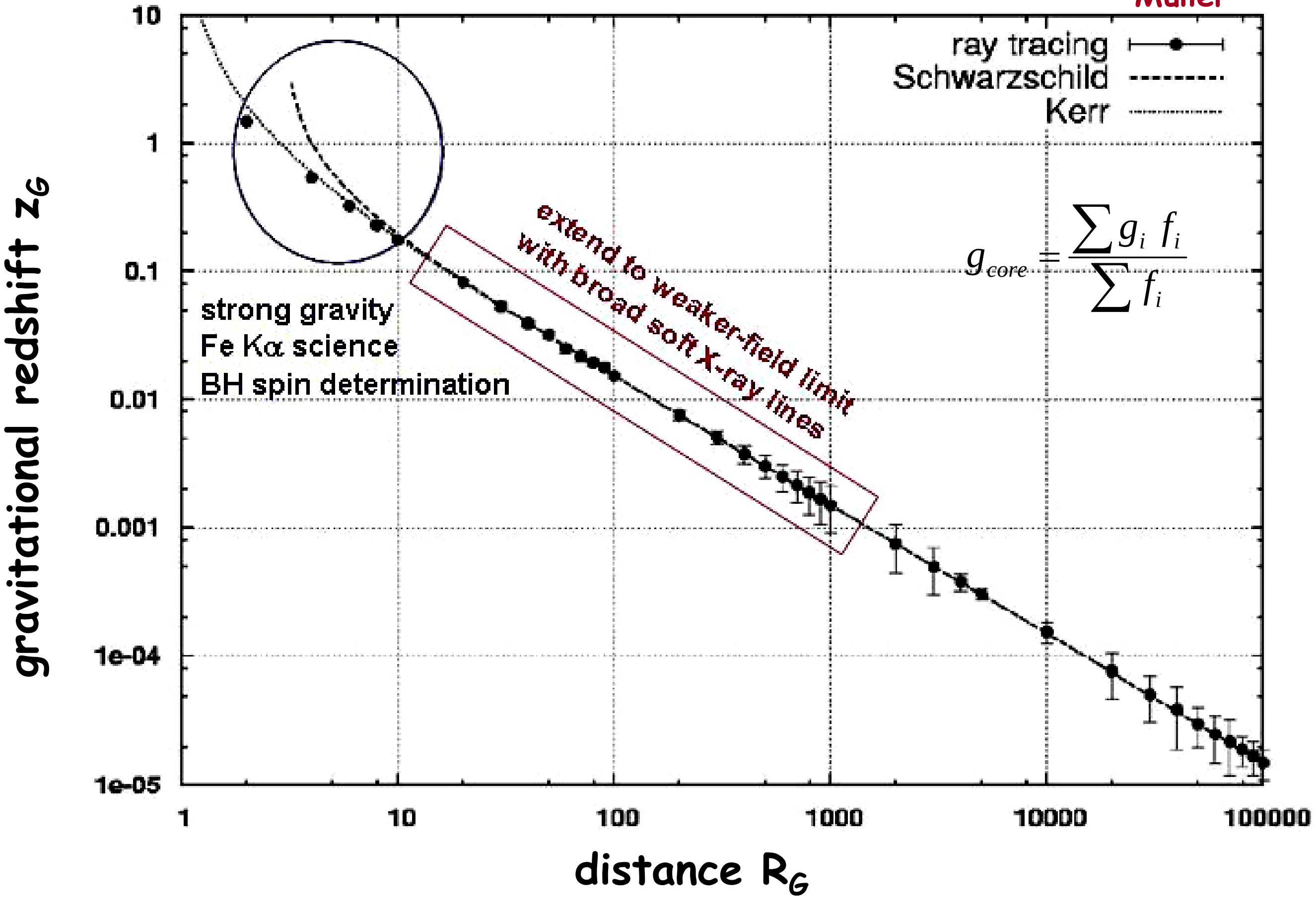
Strong gravity effects and strong Compton broadening affects this emission. The ionization parameter is ξ ~1000

The combination of emission close to the central black hole and ionization results into strong broadening of the lines included in the Ross & Fabian relativistic reflection model.

Furthermore, an acceptable data fit requires **additional less broadened soft X-ray** lines which are farther away from the black hole,**a few 1000 R_G**, and which **probe the weaker field limit**. These lines are not accounted for the relativistic reflection model and are most probably due to the high metallicity values obtained for NLS1s.

4. Predictions for IXO

Müller[06]



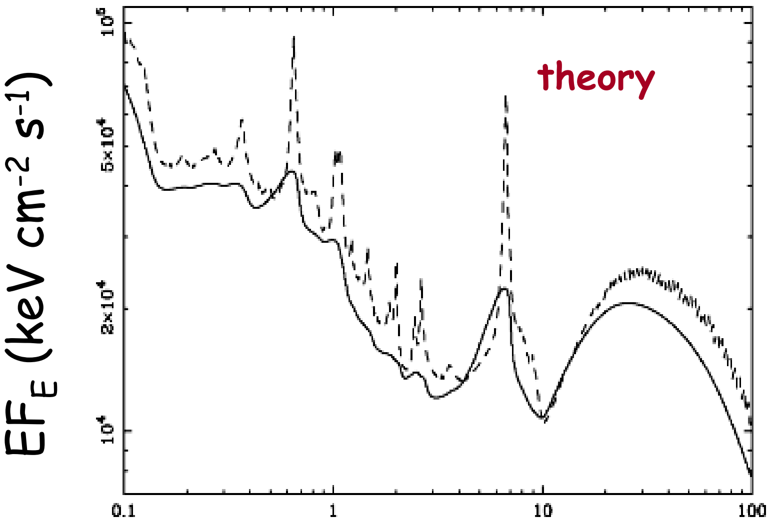
line profile measurements provide values for g_{core} which deliver the z_G and R_G

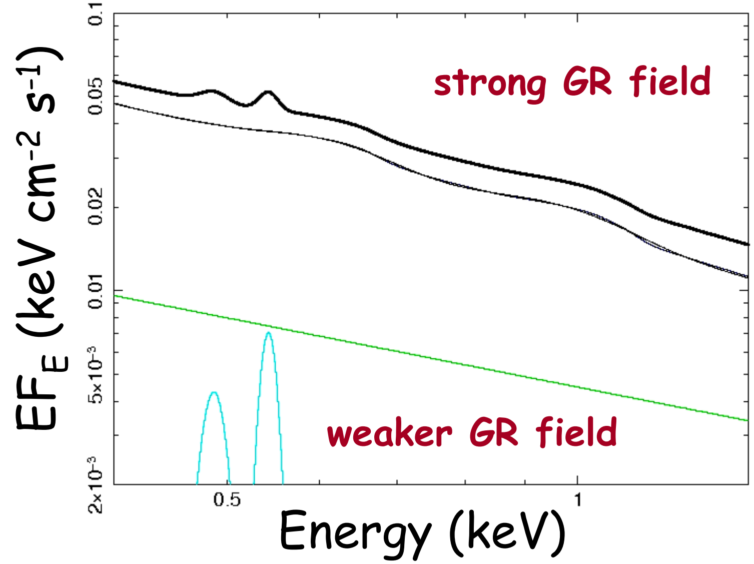
1. this allows to test GR prediction via IXO measurements

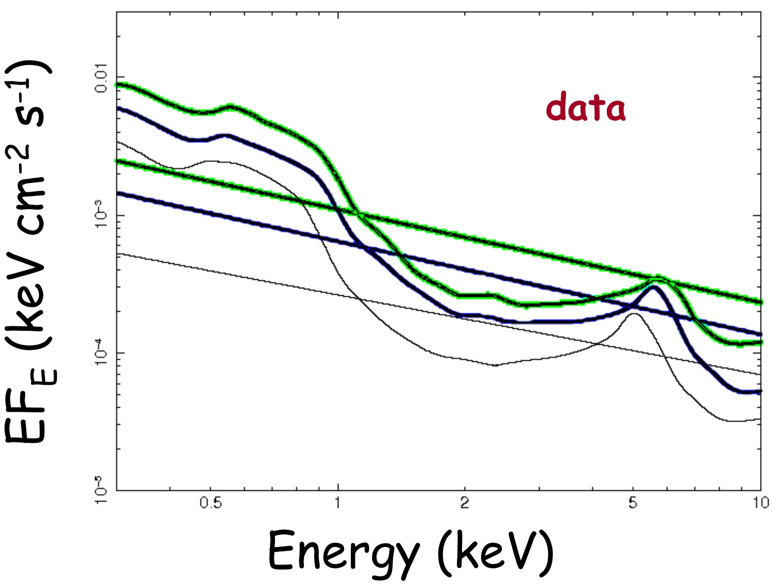
2. the Fe Kα measurements in the strong field regime can be extended to the weaker field limit by studying relativistic soft X-ray lines

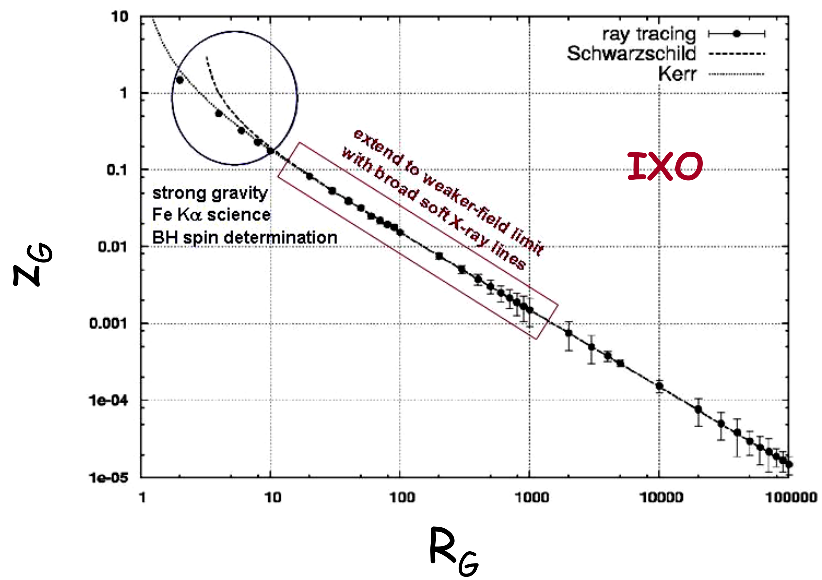
The End

RGS reflection model fitting results in the strong and weak field limit



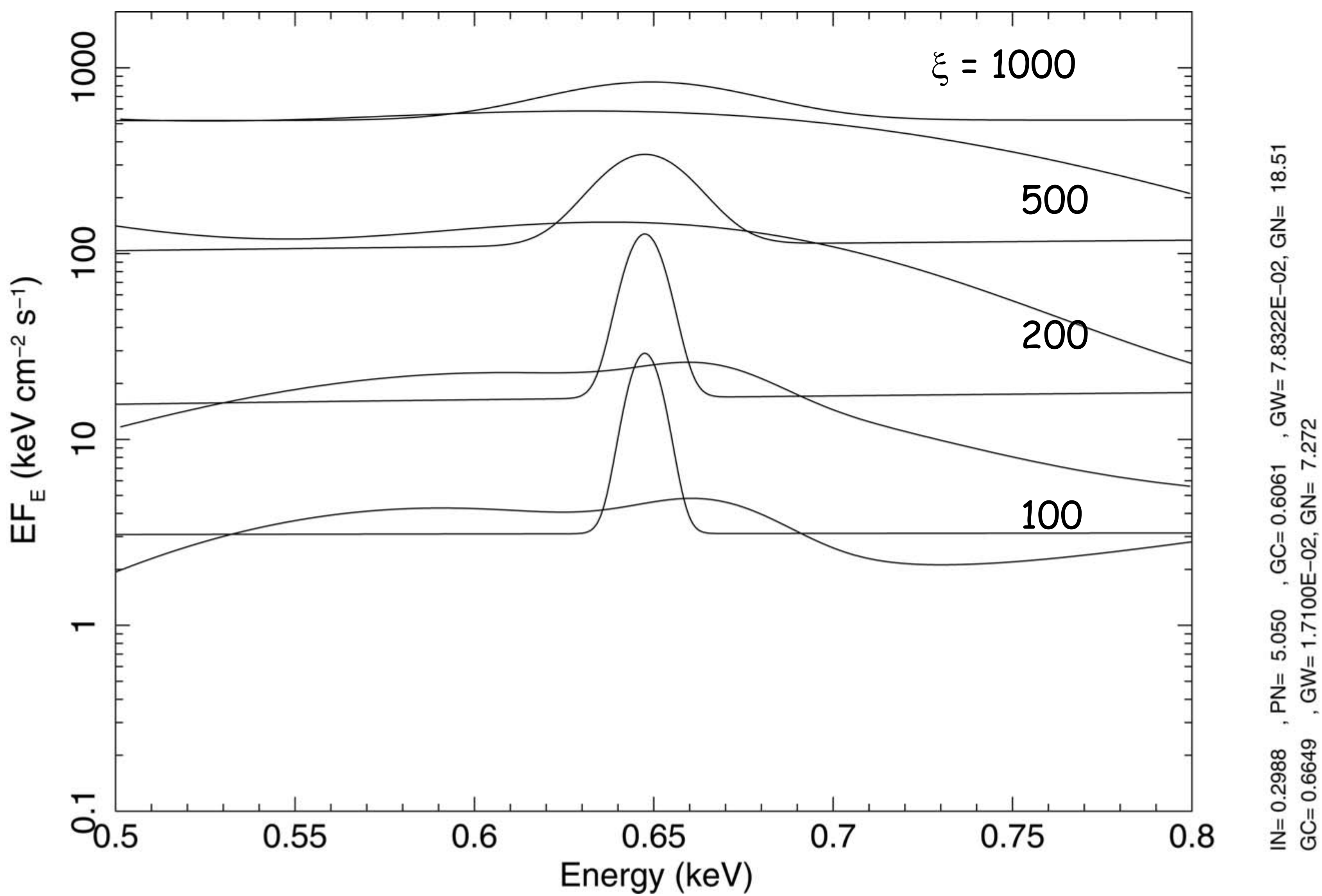






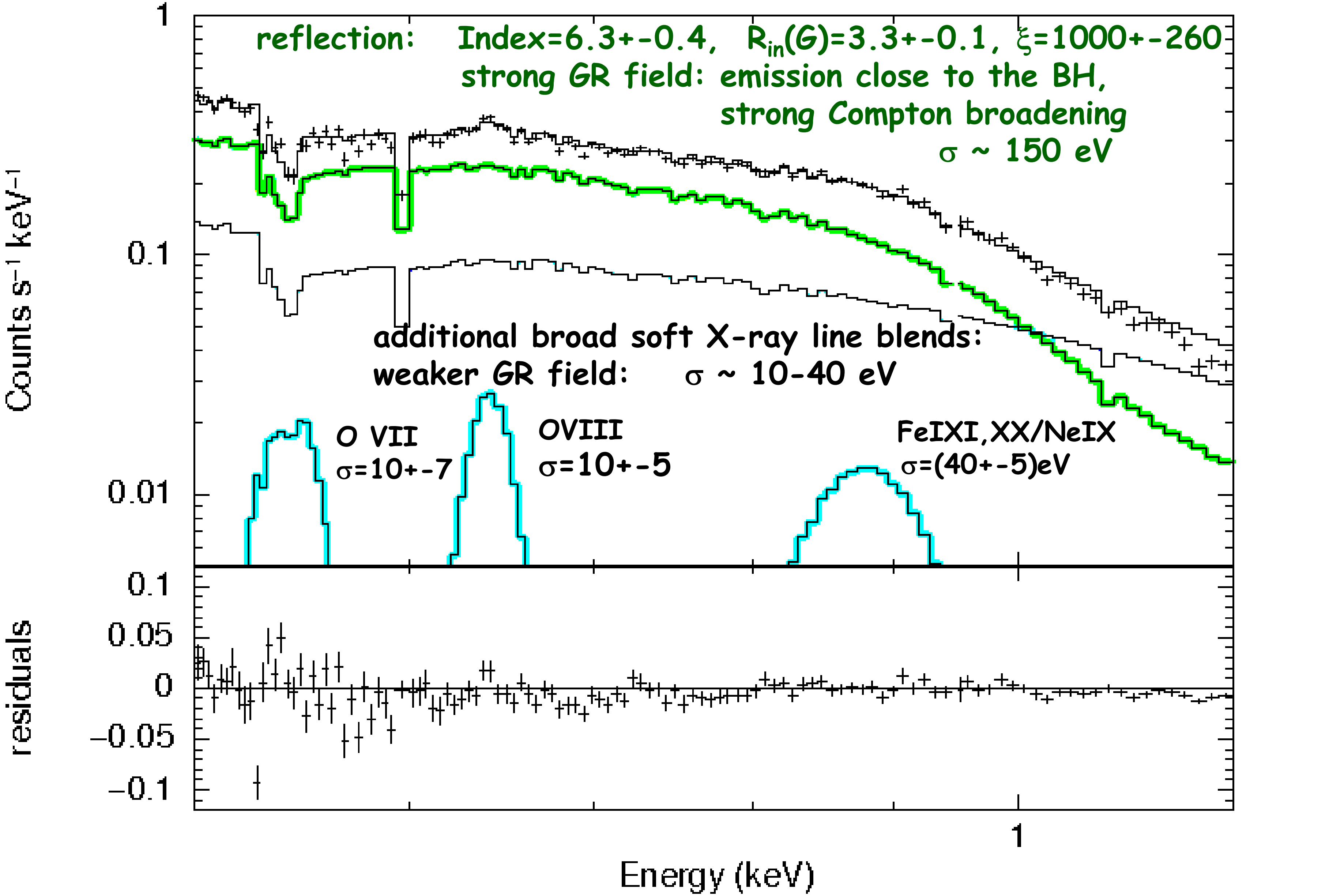
Appendix material

Line fit to RM for the O VII/OVIII blend with and without blurring

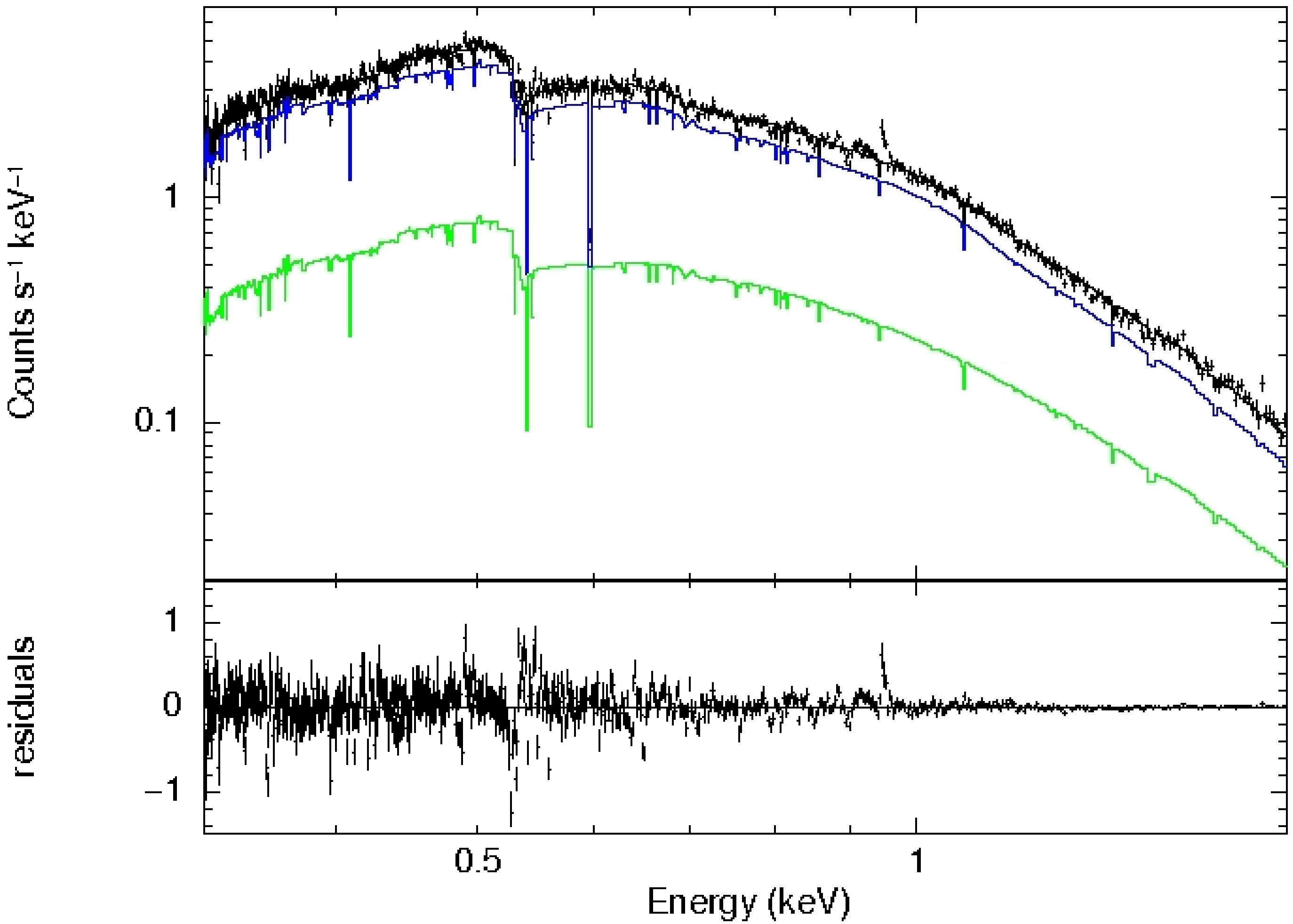


3. RGS RM fitting results in the strong and weak GR field limit

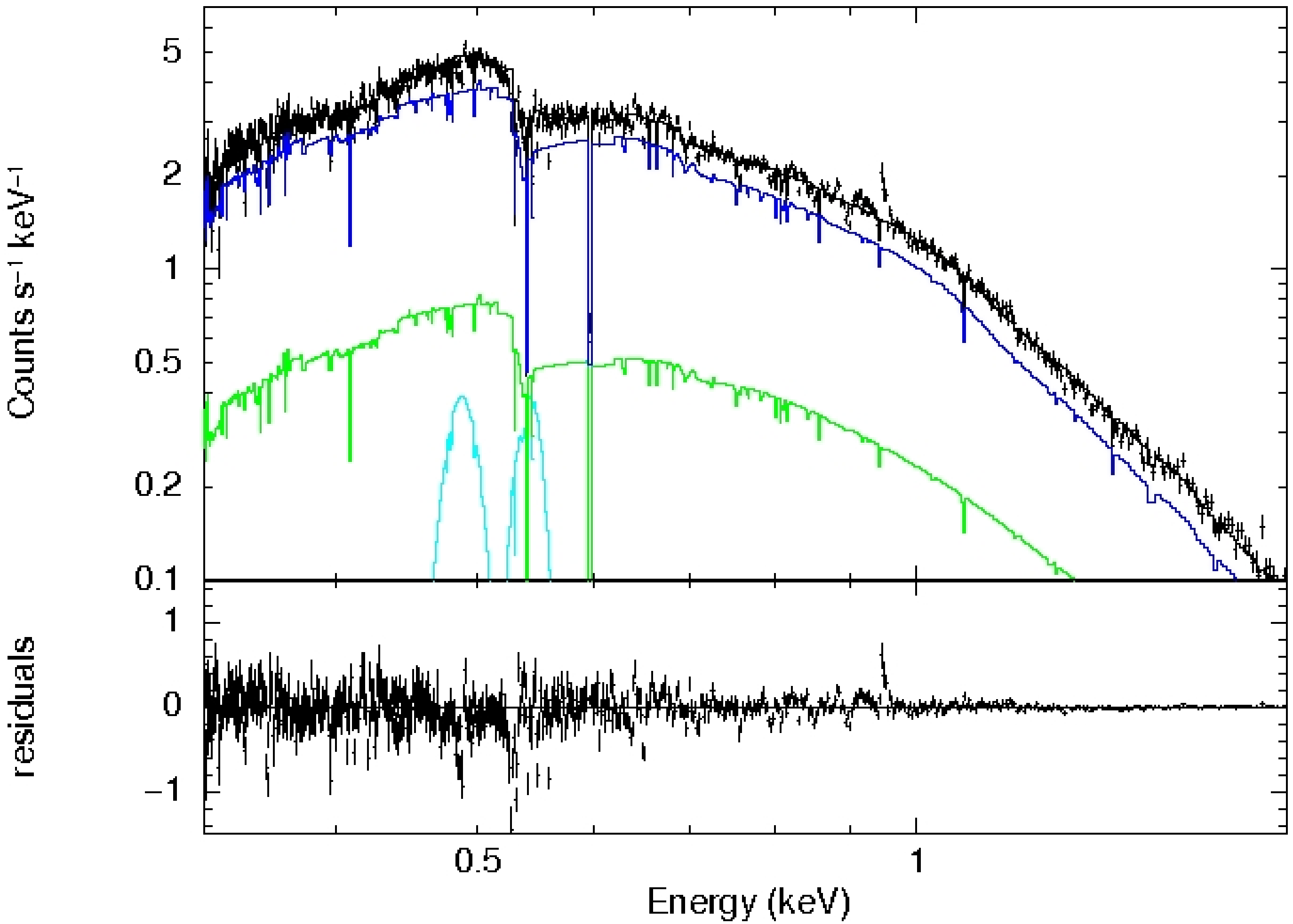
3.1 data plot for 1H0707



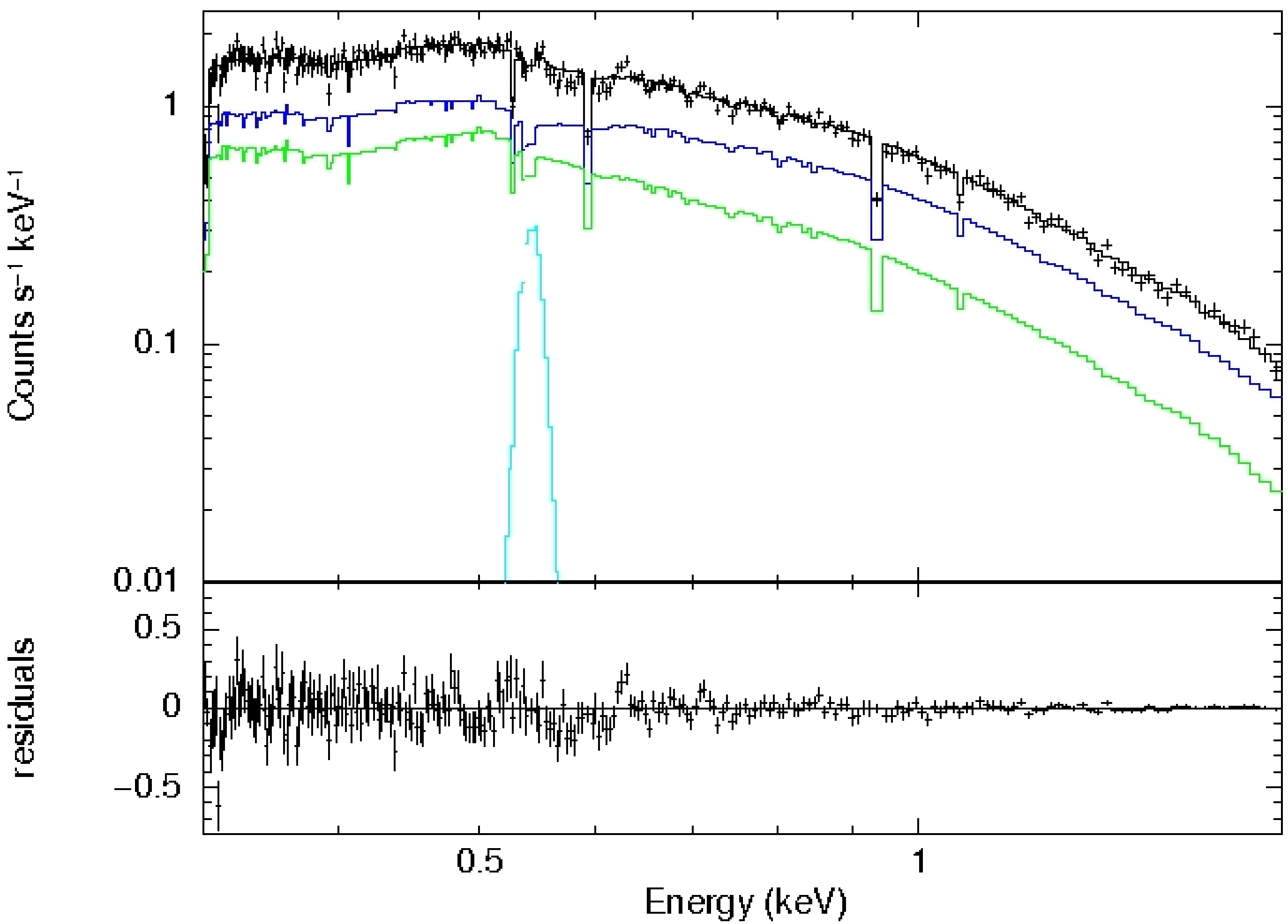
Ark 564 RM fit



Ark 564 RM + additional line fit



Mrk 110 RM + additional line fit



Basic results

1. RGS RM spectral fitting

the line emission from the RM is arising at the innermost stable orbit at ~ 3 R_G and is strongly comptonized

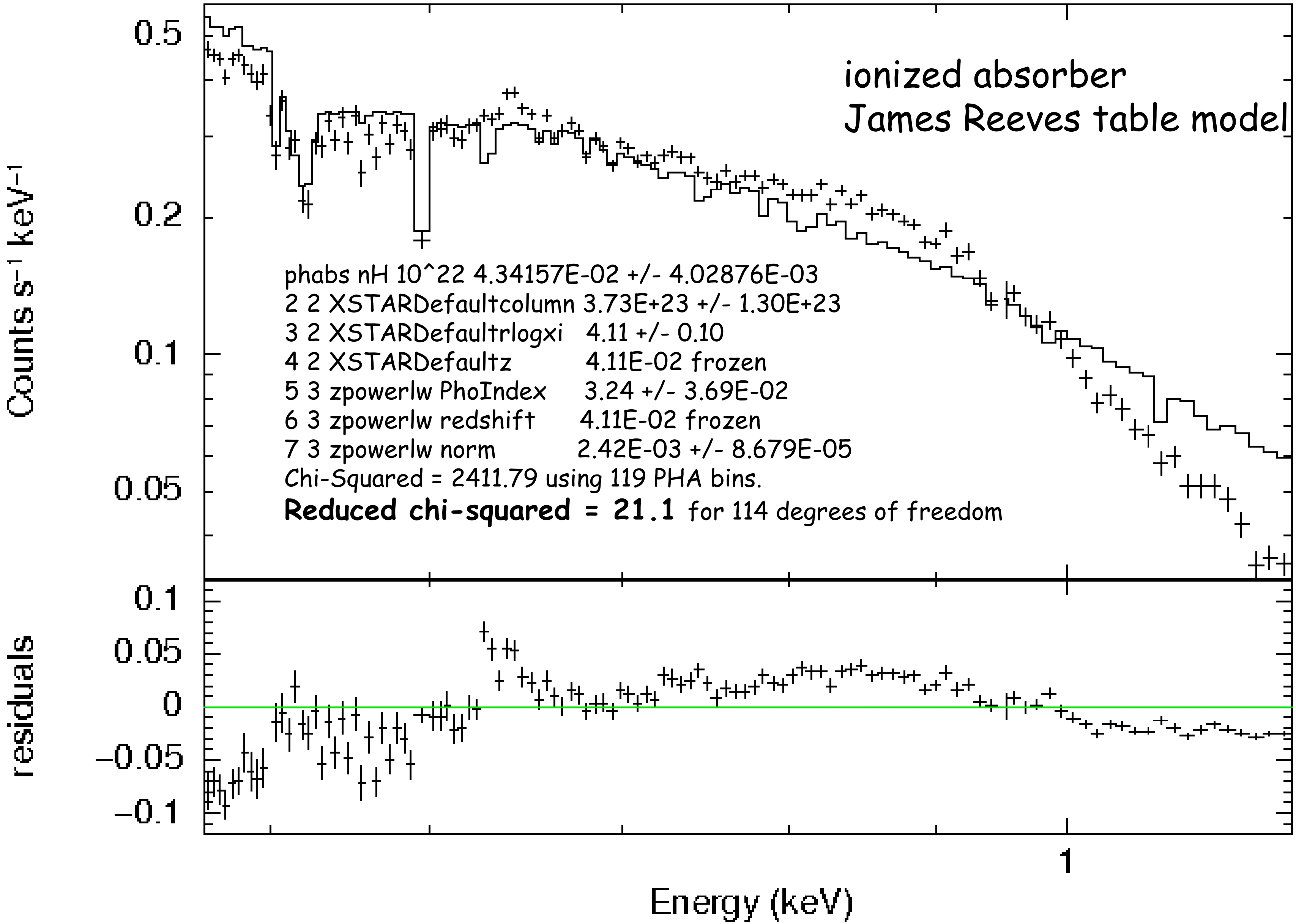
the FWHM values are about 1/3 c

RM RGS fitting probes General Relativity in the strong gravity field limit

2. additional soft X-ray lines

emission arising from larger distances ~1000 R_G

soft X-ray lines are extending GR to the to weaker gravity field limit


ionized absorber
James Reeves table model
phabs nH 10^22 4.34157E-02 +/- 4.02876E-03
2 2 XSTARDefaultcolumn 3.73E+23 +/- 1.30E+23
3 2 XSTARDefaultrlogxi 4.11 +/- 0.10
4 2 XSTARDefaultz 4.11E-02 frozen
5 3 zpowerlw PhoIndex 3.24 +/- 3.69E-02
6 3 zpowerlw redshift 4.11E-02 frozen
7 3 zpowerlw norm 2.42E-03 +/- 8.679E-05
Chi-Squared = 2411.79 using 119 PHA bins.
Reduced chi-squared = 21.1 for 114 degrees of freedom
Counts s⁻¹ keV⁻¹
0.5
0.2
0.1
0.05
residuals
0.1
0.05
0
−0.05
−0.1
1
Energy (keV)