So you think the Crab is described by a powerlaw spectrum!

Martin C. Weisskopf, Matteo Guianari ,
Steve O'Dell,Slava Zavlin,
Colleen Wilson-Hodge, & Ronald Elsner,

The Crab - ☺

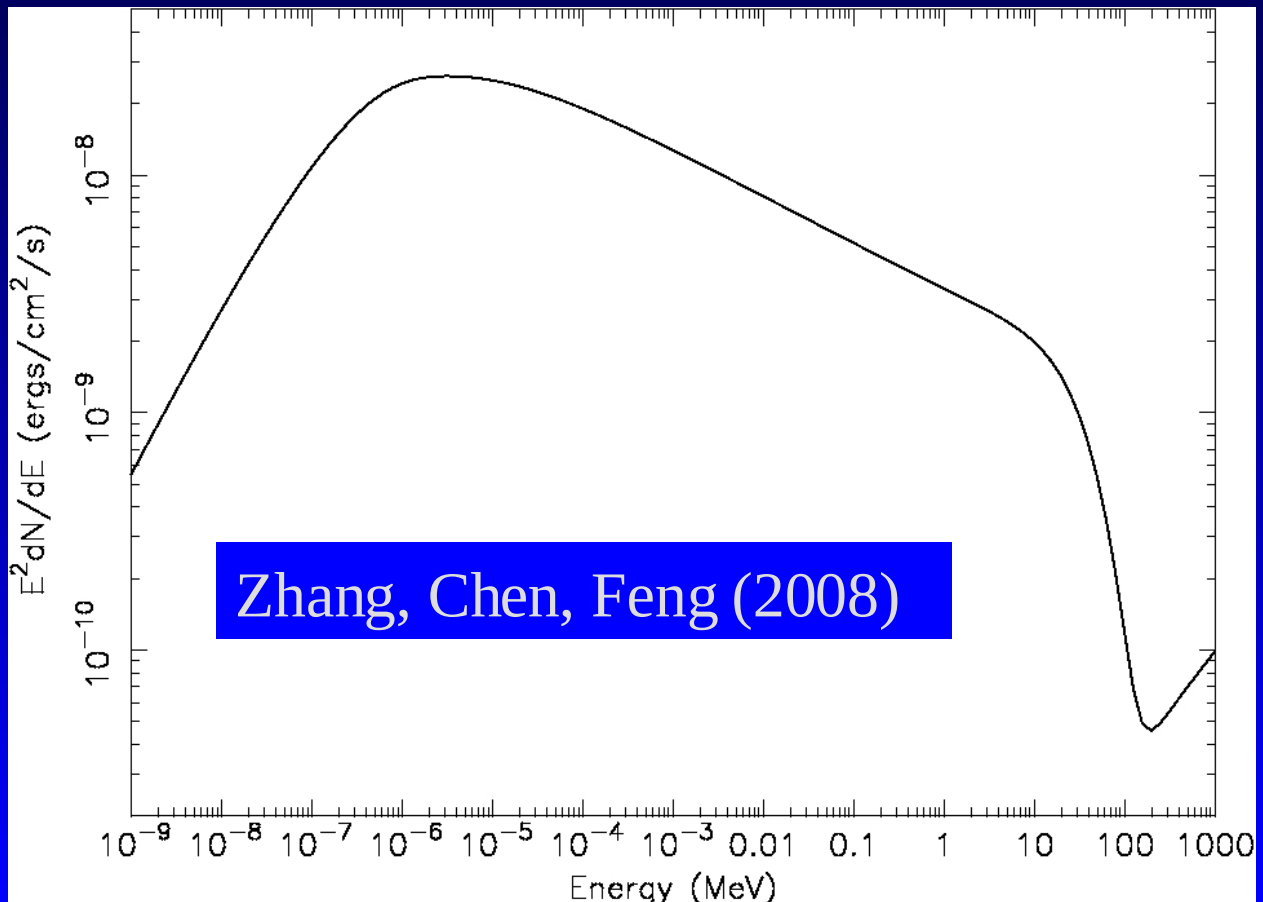
We examine the consequences for three observatories under two hypotheses

- The X-ray spectrum is described by a powerlaw
- The X-ray spectrum is not a powerlaw

- Rosat/PSPC (0.1-2.4 keV)
- RXTE/PCA (3-60 keV)
- XMM-Newton/EPIC-pn (0.3-10.0 keV)

The X-ray spectrum is described by a powerlaw

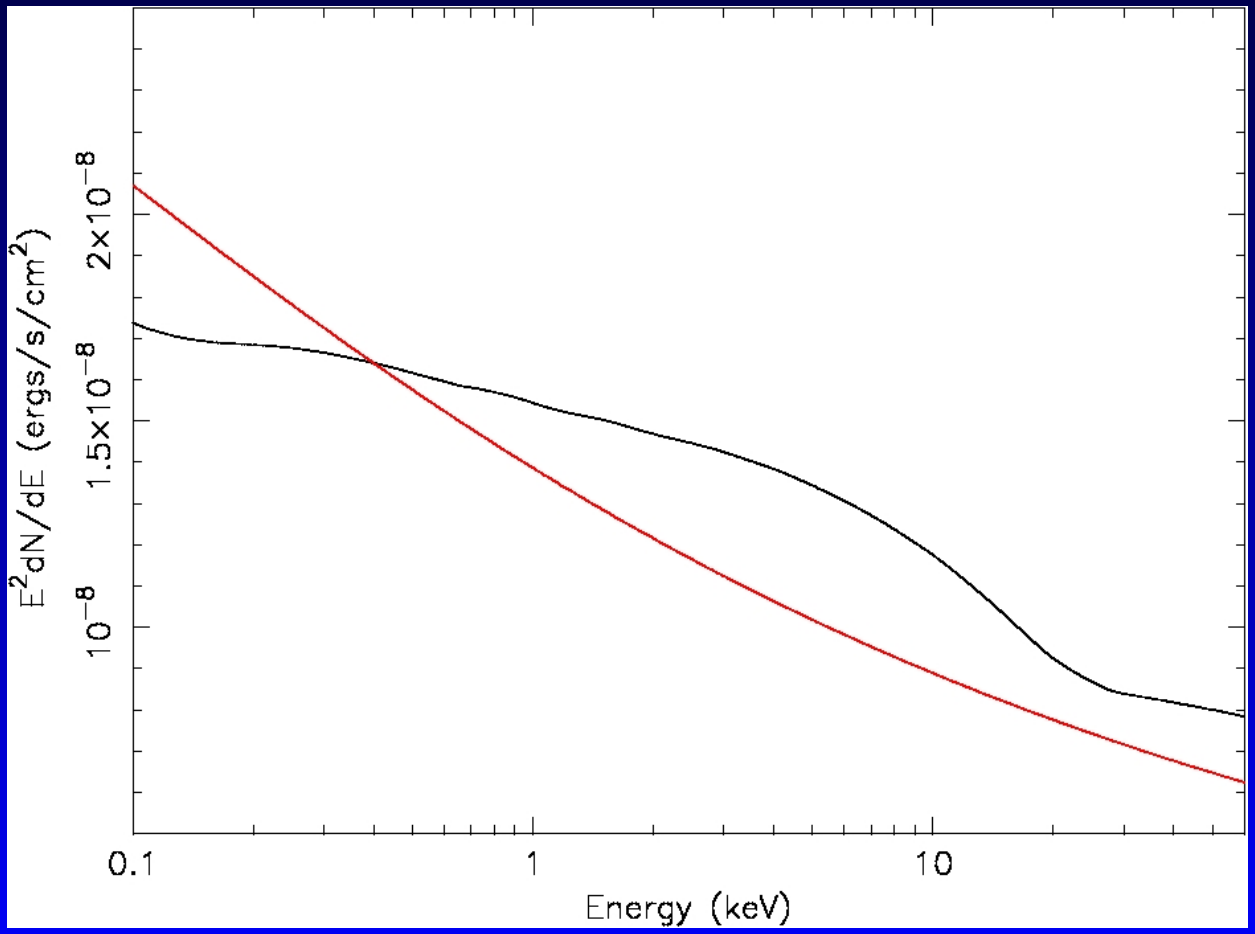
- But the X-ray spectrum must be concave downward!



We built an XSPEC Table Model using the data model from Zheng, Chen, & Feng

- Use Table Model with the appropriate response functions to determine if a particular experiment is sensitive to departure from a pure powerlaw
- Use the “fakeit” feature in XSPEC to create simulated data
- Insert the “wait 1” command to assure independence of the random number seeds!
- Perform 100 simulations for each situation

We also built a Table Model using the data model from Volpi et al. 2008



Additional XSPEC ingredients

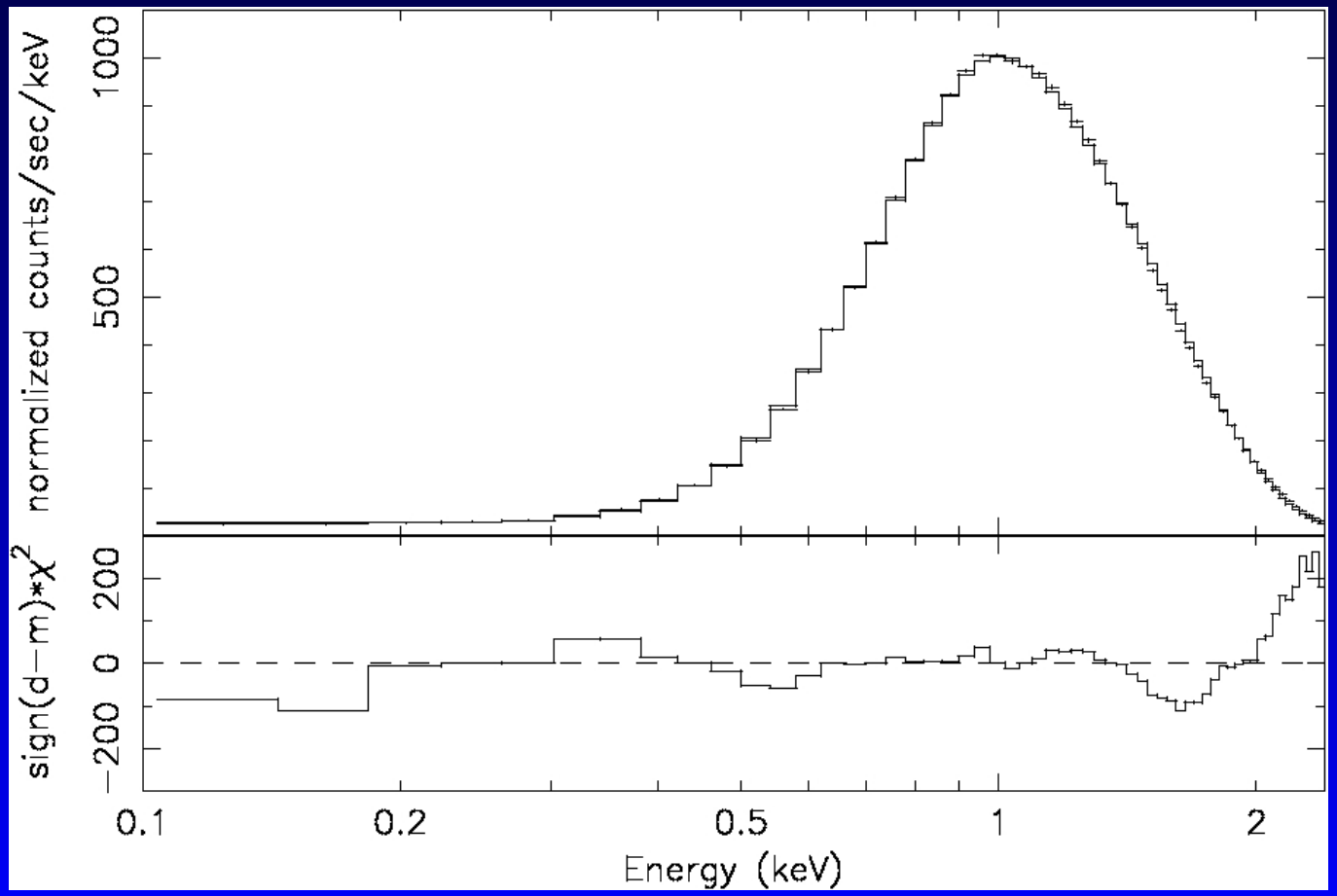
- *tbvarabs* for interstellar absorption
- Cross-sections set to *vern*
- Abundances set to *wilm*
- N_H set to 0.42×10^{22} cm^2 for all simulations
- Oxygen relative to hydrogen set to 0.676

ROSAT/PSPC

- Observation 500065p
- Use XSELECT
  - Source 2.5′ radius on pulsar
  - Background 4.5′-8.3′ annulus
- Response function *pspcb_gain1_256.rsp*
- Standard corrections applied.
- 6.4 ksec (deadtime corrected) exposure
- 6.16×10^6 counts in 0.1-2.4 keV band

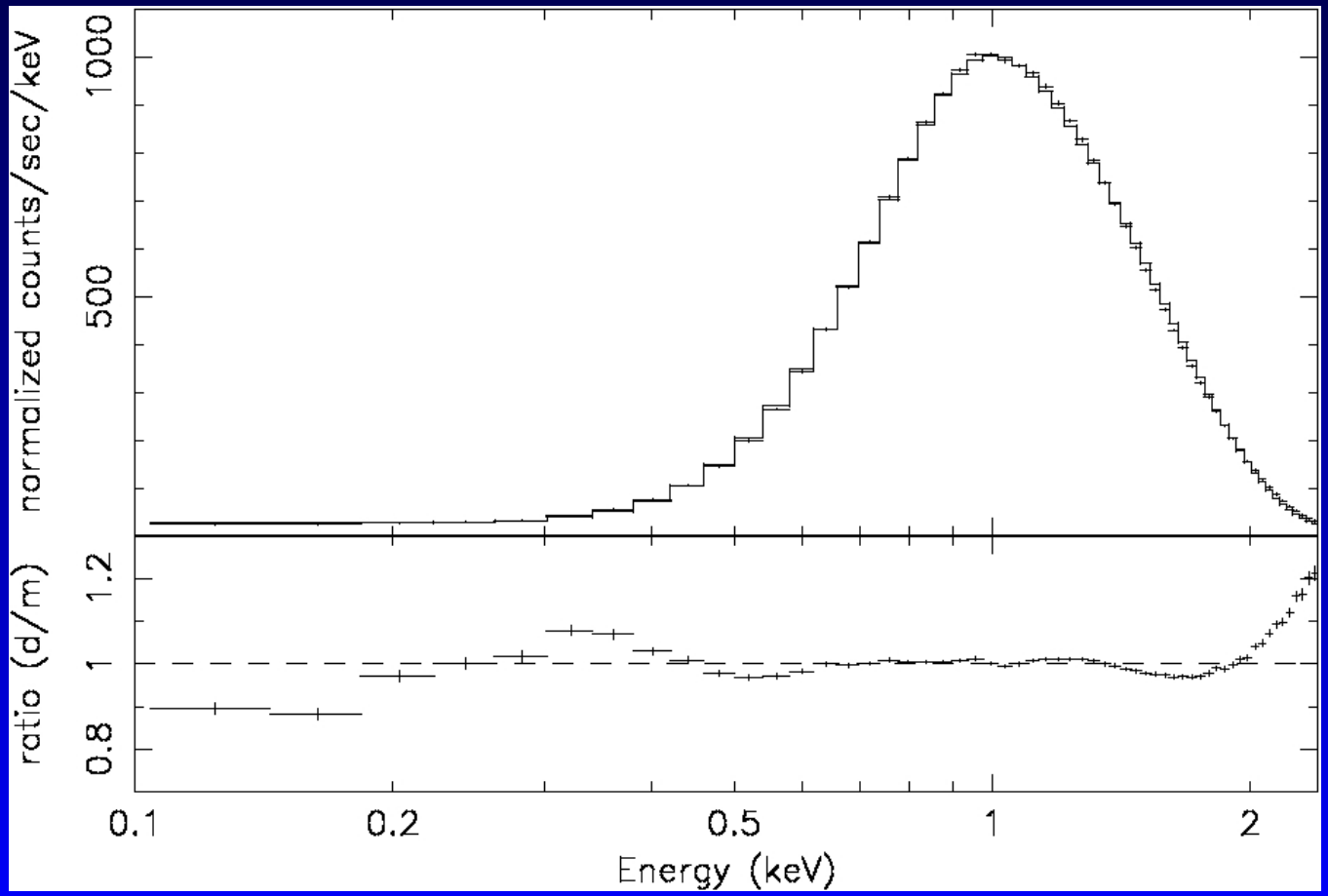
ROSAT/PSPC (0.1 – 2.4 keV) – the fit to a powerlaw is terrible!

- $\chi^2/\nu = 3343/227$



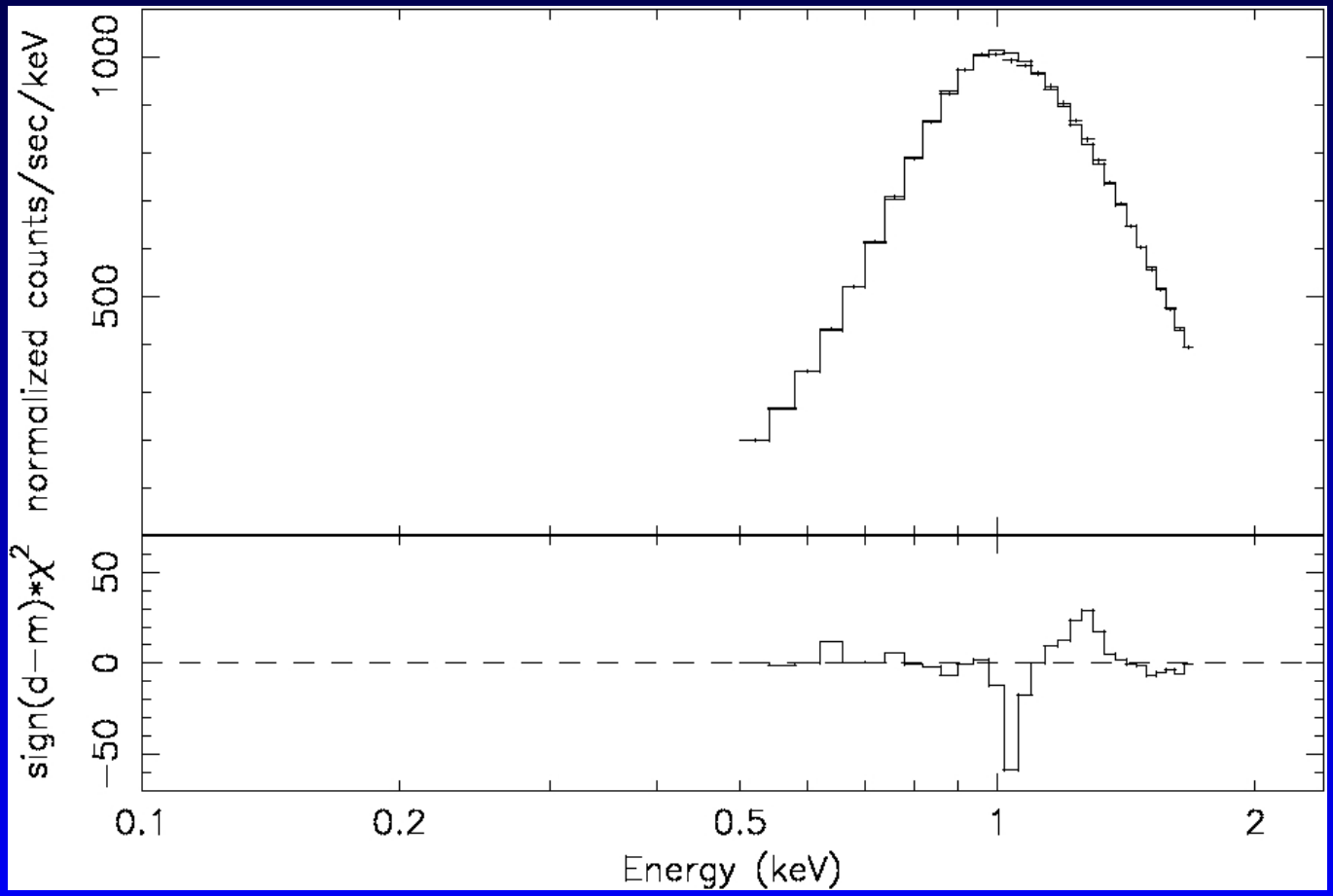
ROSAT/PSPC (0.1 – 2.4 keV) – the discrepancies are very large

- $\chi^2/\nu = 3343/227$



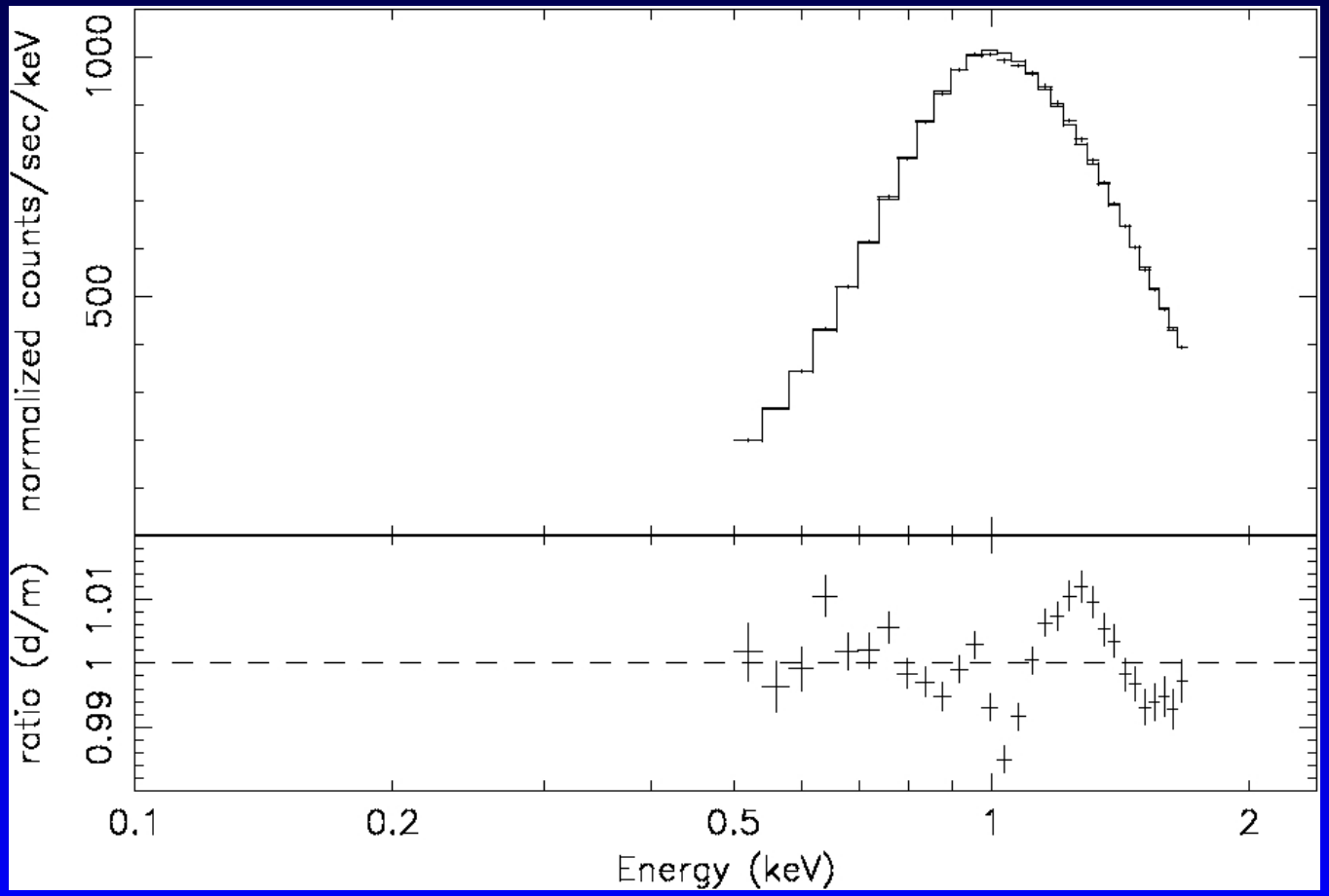
ROSAT/PSPC – narrowing the band doesn't completely help

- $\chi^2/\nu = 331/116$



ROSAT/PSPC – the size of the problem is, however, dramatically reduced

- $\chi 2/\nu = 331/116$



ROSAT/PSPC – simulations indicate that the bad fits are ***not*** a consequence of hypothesis 1

	Counts/10^6	χ^2/ν	Γ	$N_H/10^{22}$	[O]
Z	6.16	(228± 21)/227	2.1921 ± 0.0063	0.4210 ± 0.0020	0.678 ± 0.016
V	6.16	(229± 22)/227	2.0701 ± 0.0057	0.4214 ± 0.0021	0.670 ± 0.013

ROSAT/PSPC - Conclusions

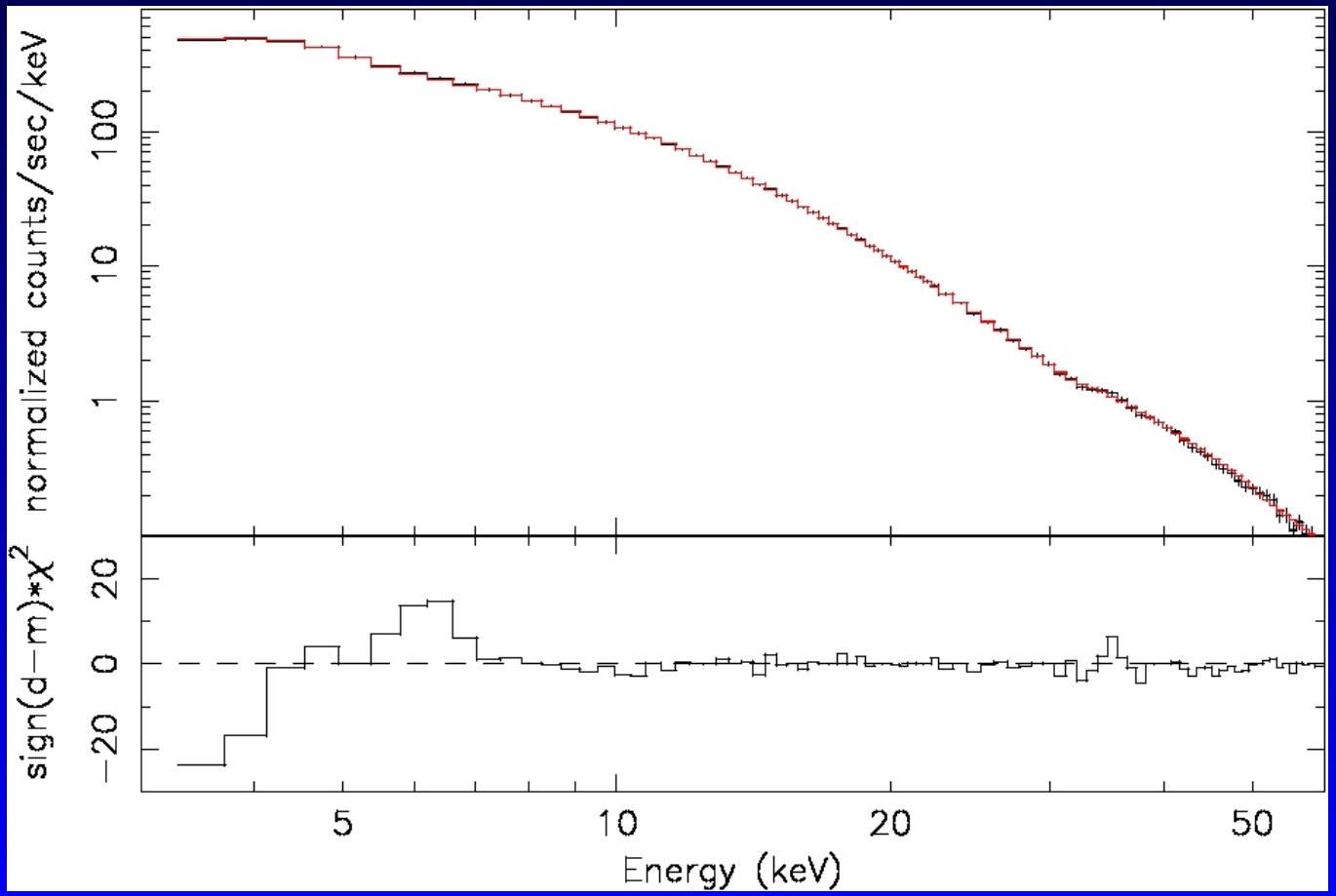
- The simulations indicate that the Crab ought to appear as a powerlaw to the instrument over the 0.1 to 2.4 keV band
- The response function is inaccurate at the 20% level over the full band
- The response function is inaccurate at the 1% level over the reduced (0.5-1.7 keV) band
- Since the data do not provide an acceptable fit to a powerlaw, the results may *not* be used to establish the Crab's parameters

RXTE/PCA

- Observation 50804-01-06
- Background estimated using PCABACKEST
- Data extracted with SAEXTRCT version 4.2e
- Estimated deadtime fraction was 5.1%
- Response obtained with PCARSP version 7.10
  - Used p2coll_96jun05.fits
- Crab was used to adjust portions of the response (Jahoda et al. 2006)
- Response allows for 0.5% systematic errors
- 6.7×10^6 counts in 3-60 keV band

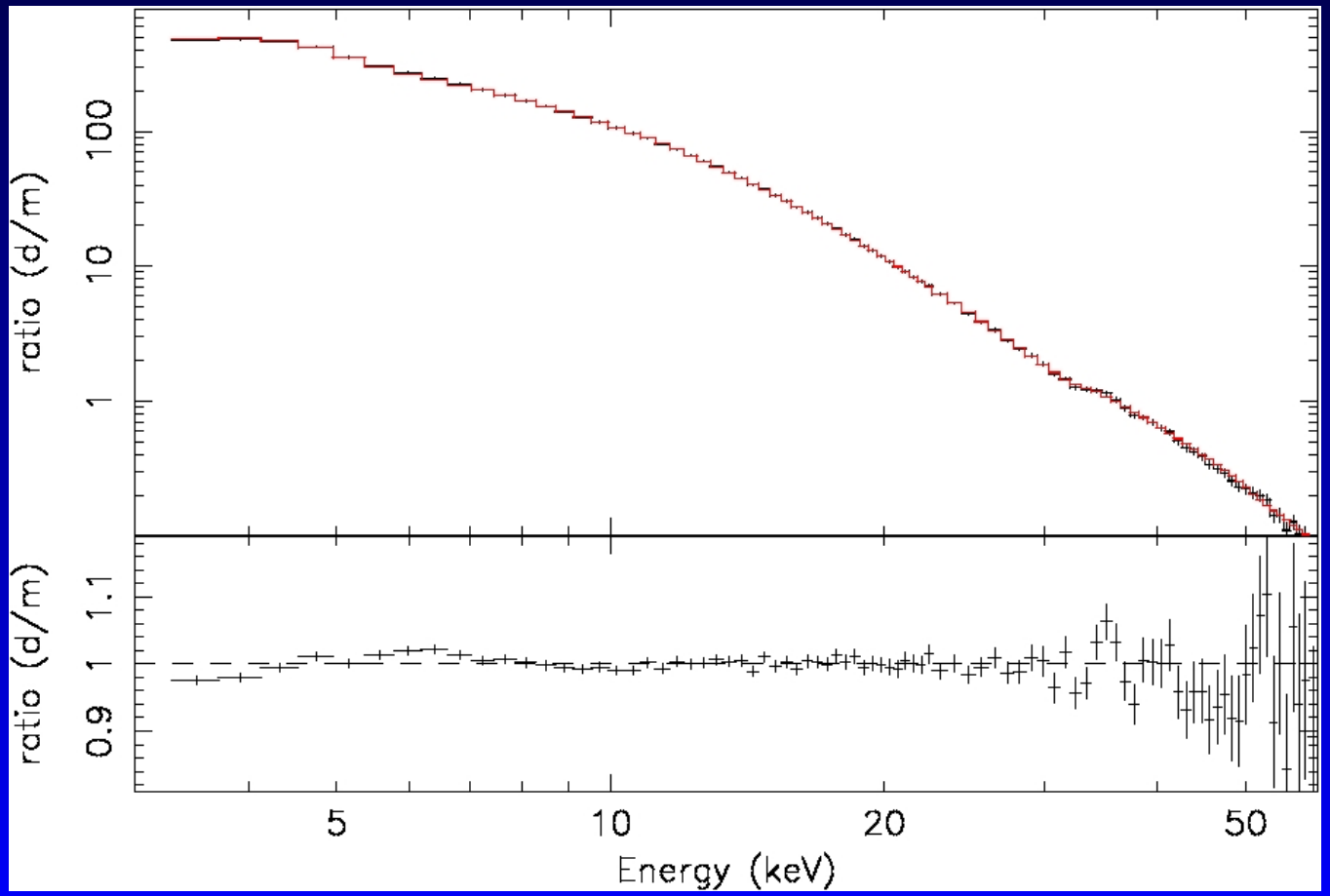
RXTE/PCA – initial analysis covering 3–60 keV yielded lousy fit

- $\chi^2/\nu = 166/86$ (N_H set to 0.42 x 10^{22} $cm^{2,}$ [O] set to 0.676)



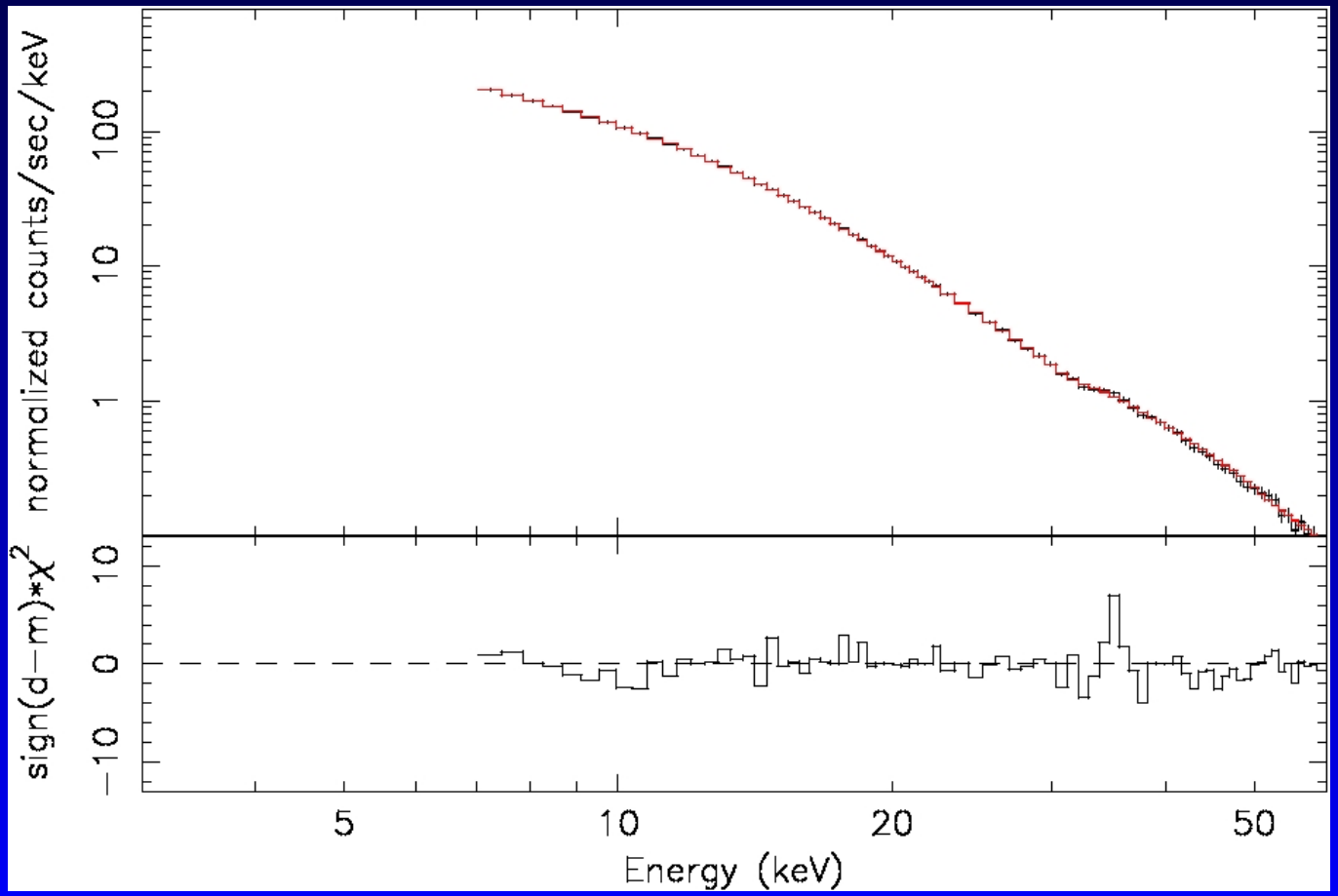
RXTE/PCA – The errors range from 1%-10%

$\chi^2/\nu = 166/86$ (N_H set to 0.42 x 10^{22} $cm^{2,}$ [O] set to 0.676)



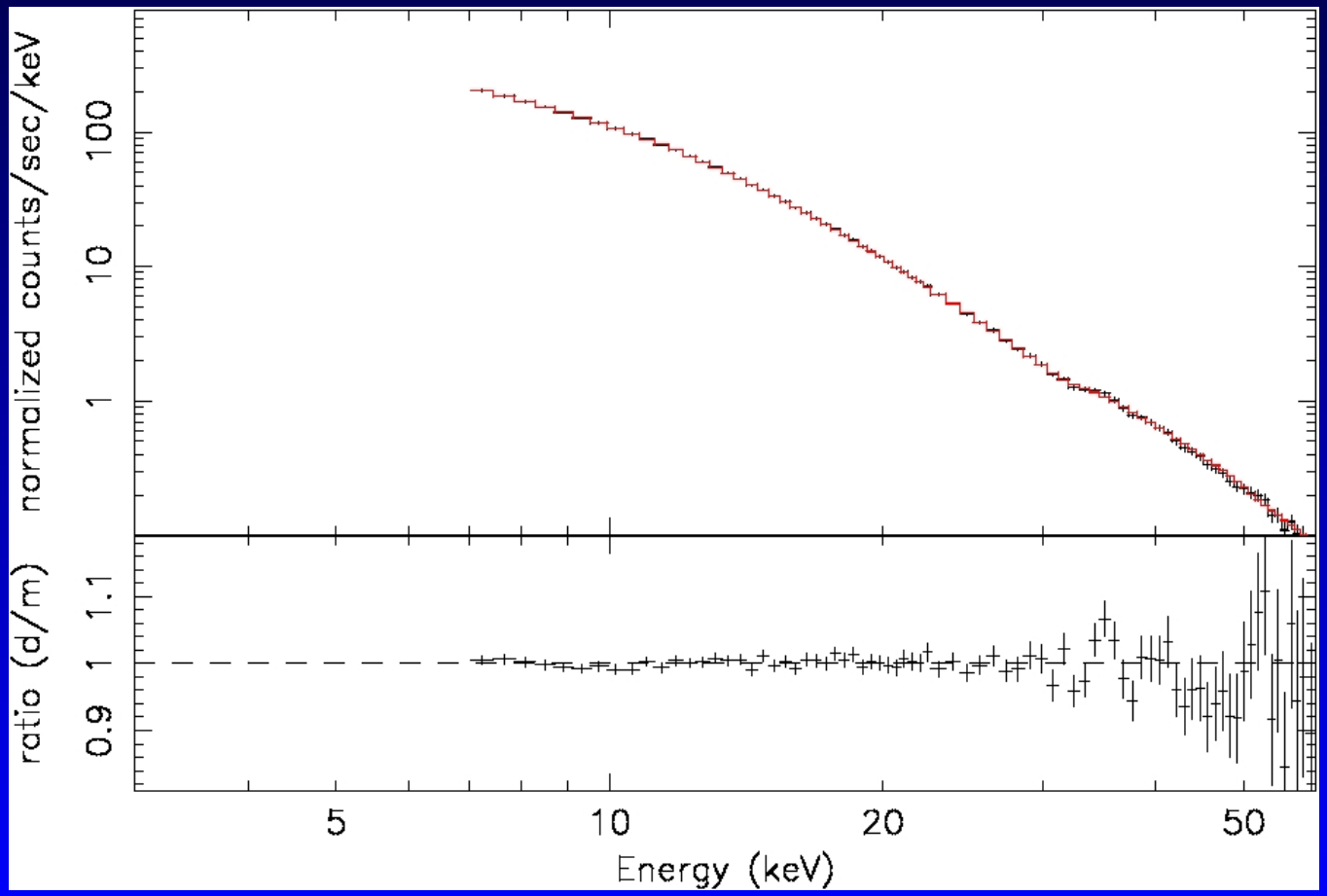
RXTE/PCA – reducing the bandwidth helps the fit significantly!

- $\chi^2/\nu = 34/43$ (N_H set to 0.42 x 10^{22} $cm^{2,}$ [O] set to 0.676)



RXTE/PCA – the percentage errors are significantly reduced

- $\chi 2/\nu = 34/43$ (N_H set to 0.42 x 10^{22} cm^2, [O] set to 0.676)



RXTE/PSPC – what do the models say?

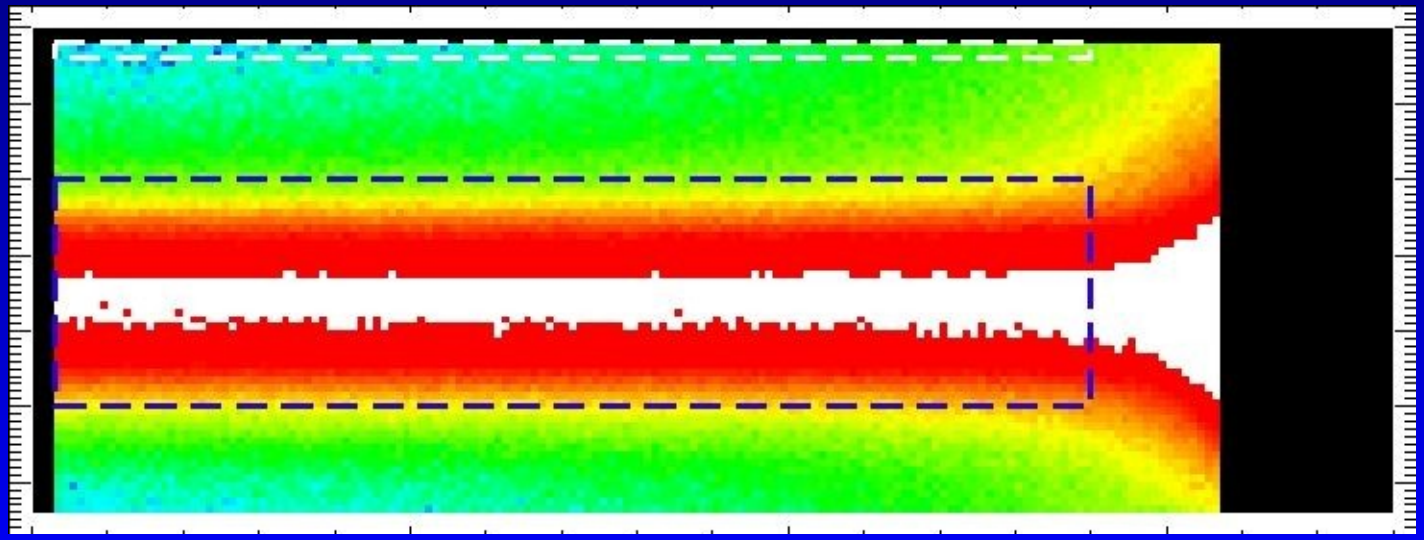
	Counts/10^6	χ^2/ν	Γ	$N_H/10^{22}$	[O]
Z	6.66	(59±11)/86	2.1959 ± 0.0008	0.42 (fixed)	0.676 (fixed)
V	6.66	(1174± 31)/86	2.22	0.42 (fixed)	0.670 (fixed)

RXTE/PCA - Conclusions

- The 3-60 keV response does not yield an acceptable fit of a powerlaw to the Crab data, and the 7-60 keV response does.
- The Zhang model for the Crab spectrum would imply that both fits should be acceptable, but the Volpi model the opposite
- This would seem (to us) to indicate problems with the RXTE response function
- It might be premature to rule out the validity of the Volpi model

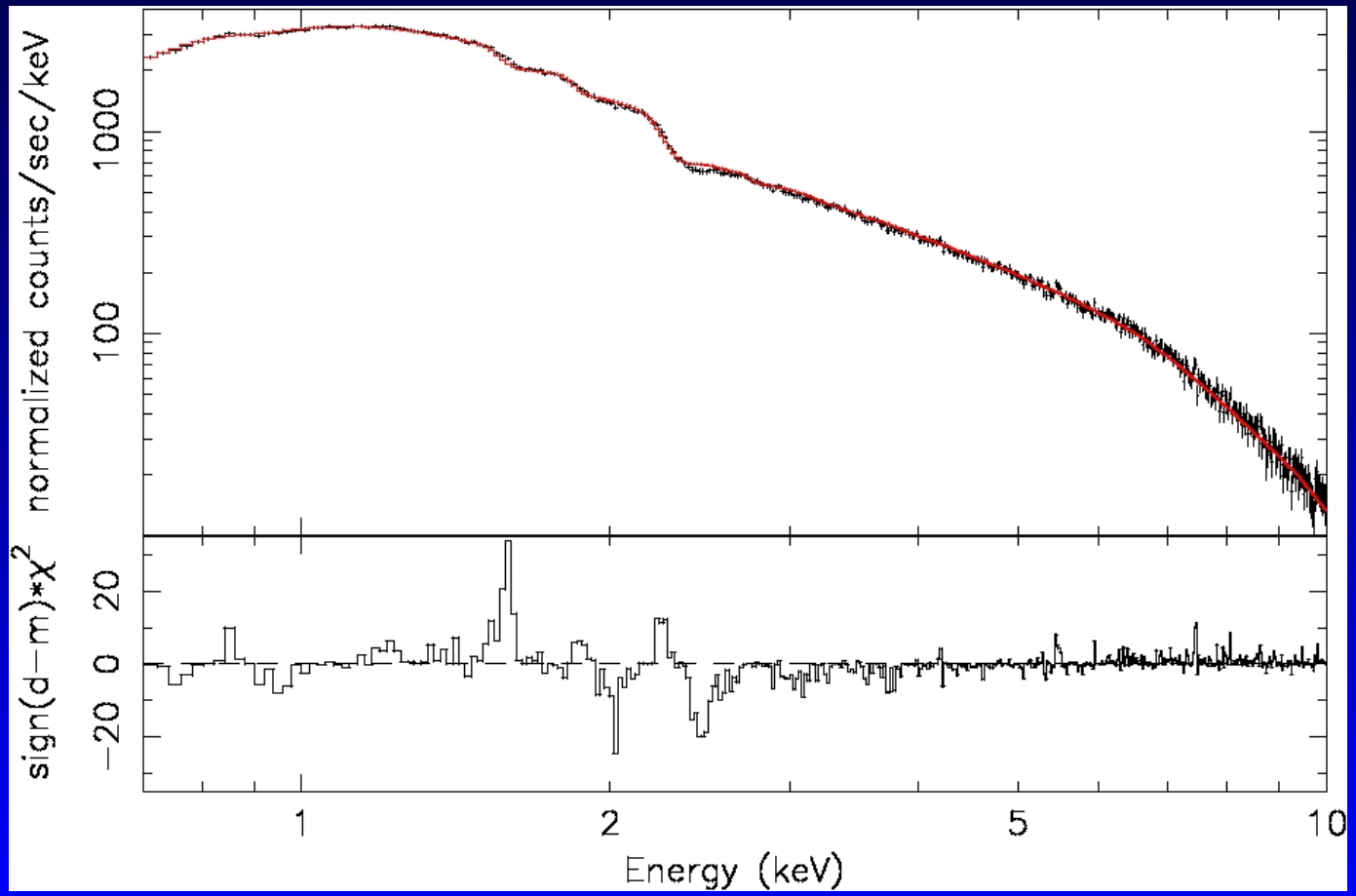
XMM-Newton EPIC-pn

- Burst mode data from #0160960401
  - Rev 874, 2004 Sept 16
- Used SAS 7.1.0 and epchain”
- Used “mfgen” and “arfgen”
- 2.68 x 10^6 counts in 0.3-10.0 keV band



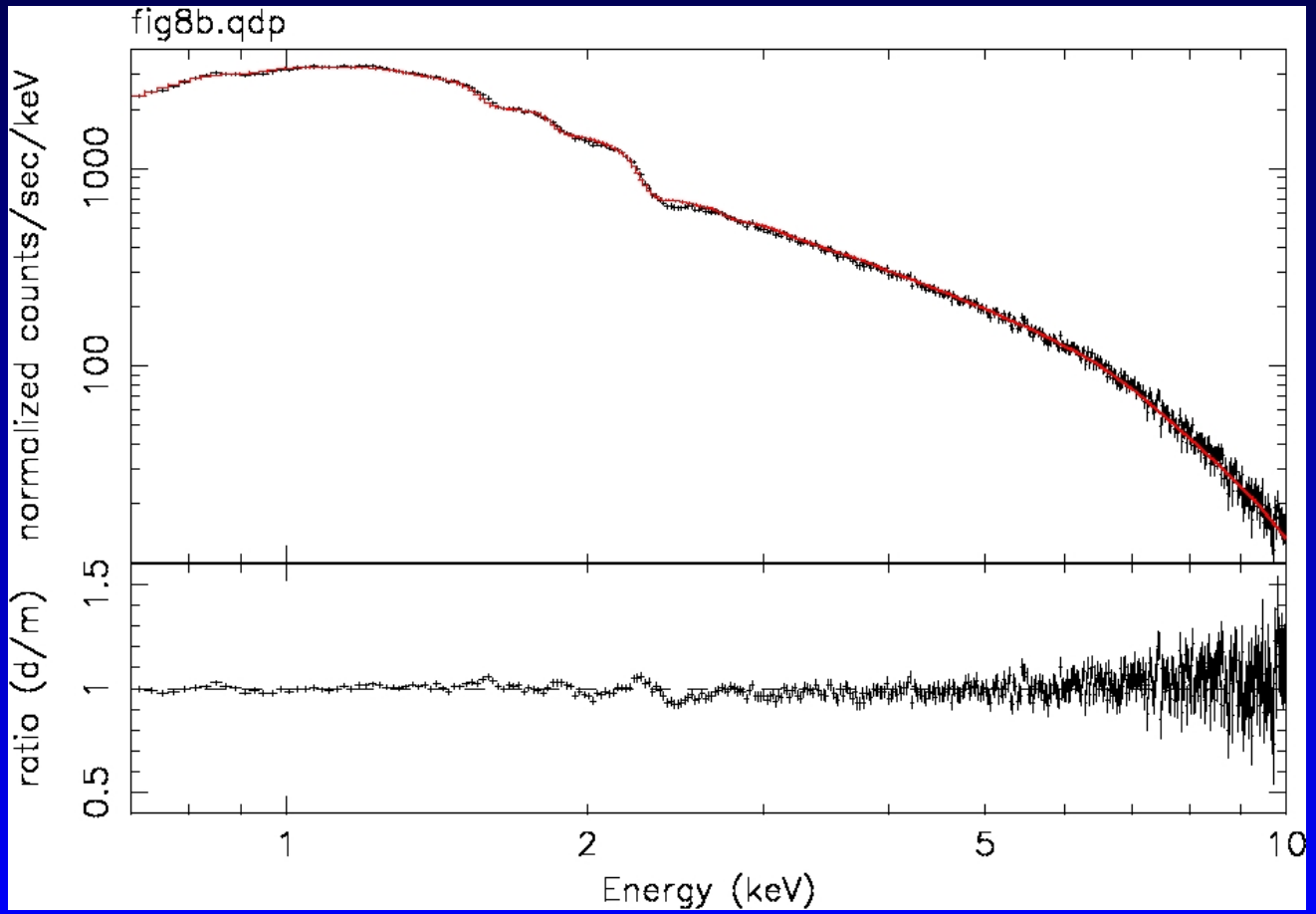
XMM-Newton Epic-pn – initial analysis covering 0.3–10.0 keV yields a lousy fit

- $\chi^2/\nu = 2383/1860$ $[(\chi^2 - \nu)/(2\nu)^{1/2} = 8.6]$



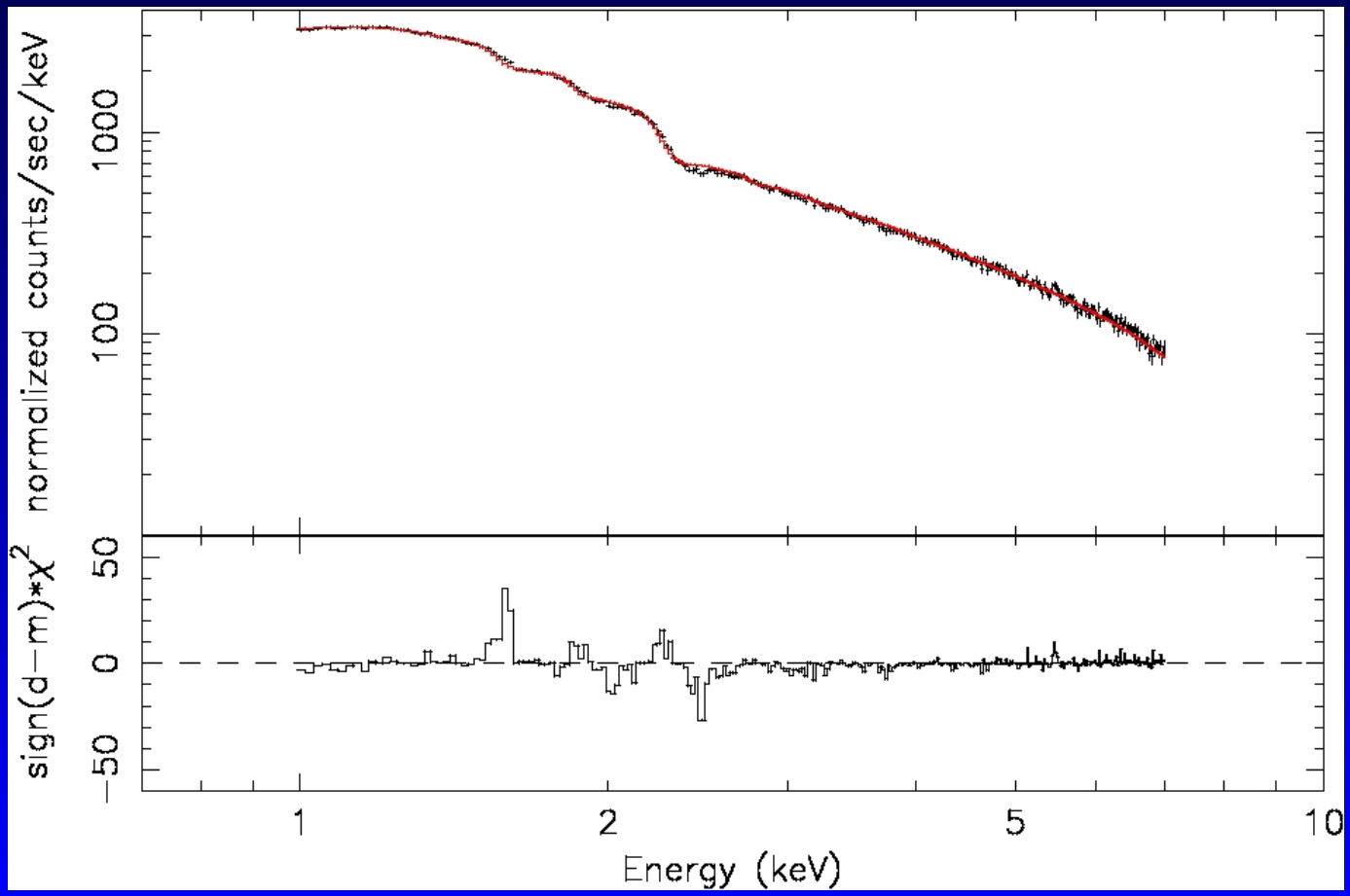
XMM-Newton Epic-pn – the size of the problem

- $\chi^2/\nu = 2383/1860$ $[(\chi^2 - \nu)/(2\nu)^{1/2} = 8.6]$



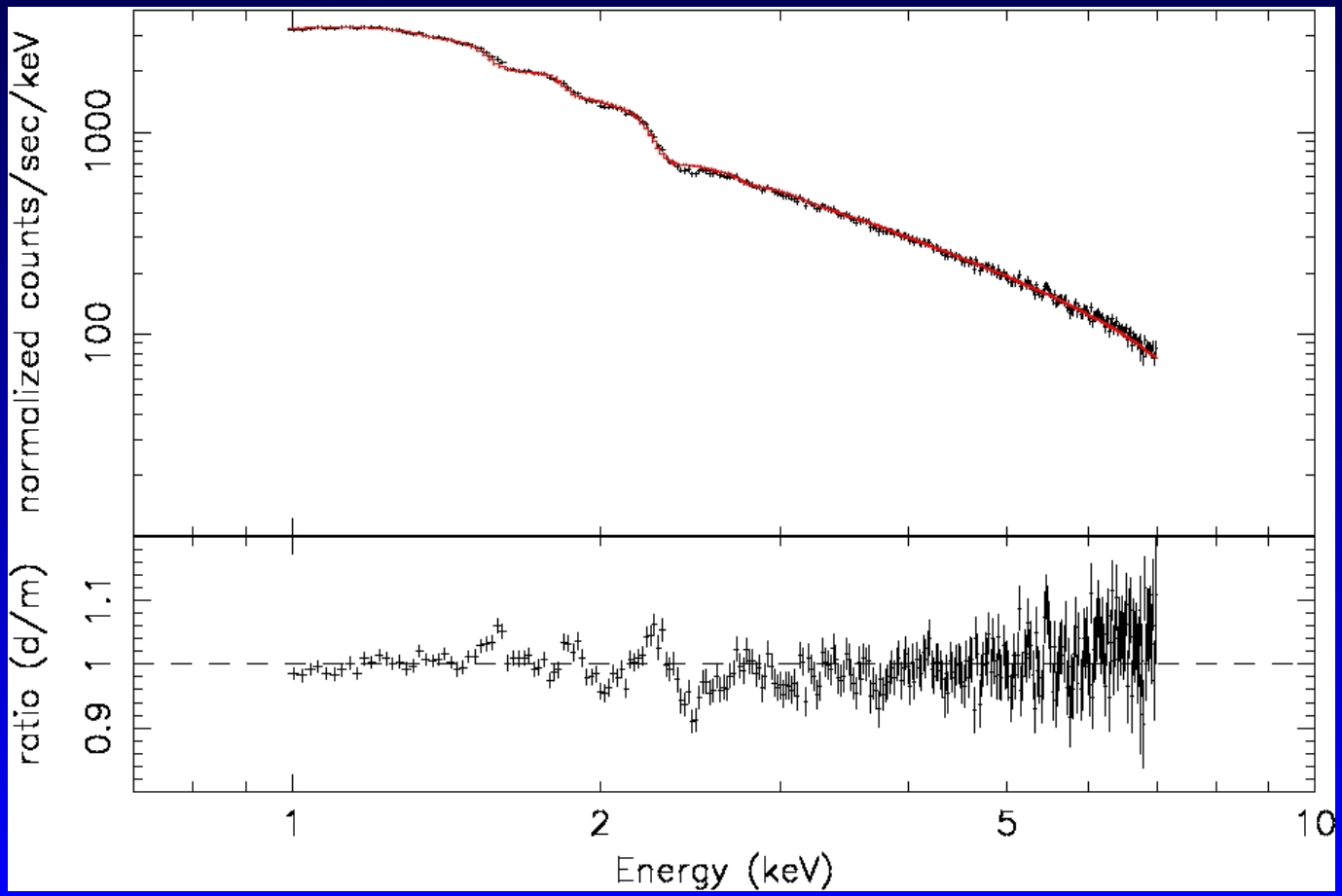
XMM-Newton Epic-pn – reduce the bandwidth?

- $\chi^2/\nu = 1655/1202$ $[(\chi^2 - \nu)/(2\nu)^{1/2} = 9.2]$



XMM-Newton Epic-pn – the size of the reduced problem

- $\chi^2/\nu = 1655/1202$ $[(\chi^2 - \nu)/(2\nu)^{1/2} = 9.2]$



XMM/EPIC-pn – Beginning to see the impacts of Model-V

	Counts/10^6	χ^2/ν	Γ	$N_H/10^{22}$	[O]
Z	2.68	(1882 ± 53)/1939	2.1986± 0.0022	0.437± 0.019	0.61 ± 0.10
V	2.68	(2031 ± 71)/1939	2.1140± 0.0021	0.518± 0.020	0.31 ± 0.08

$$(\chi^2 - \nu)/(2\nu)^{1/2} = 2.8$$

XMM/EPIC-pn - conclusions

- The 0.7-10.0 keV response does not yield an acceptable fit of a powerlaw to the Crab data
- The 1.0-7.0 keV response does not yield an acceptable fit of a powerlaw to the Crab data
- The Zhang and Volpi models for the Crab spectrum would imply that both fits should be acceptable,
- This would seem (to me) to indicate problems with the XMM-Newton response function at the few percent level

Conclusions (Full Bands)

	Fit	Z	V
Rosat	N	Y	Y
RXTE	N	Y	N
XMM	N	Y	Y/N