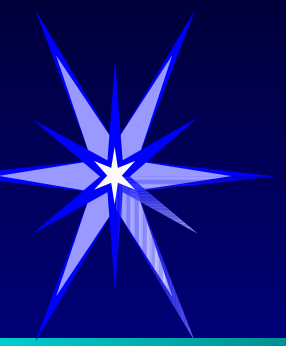

So you think the Crab is described by a power-law spectrum ☺

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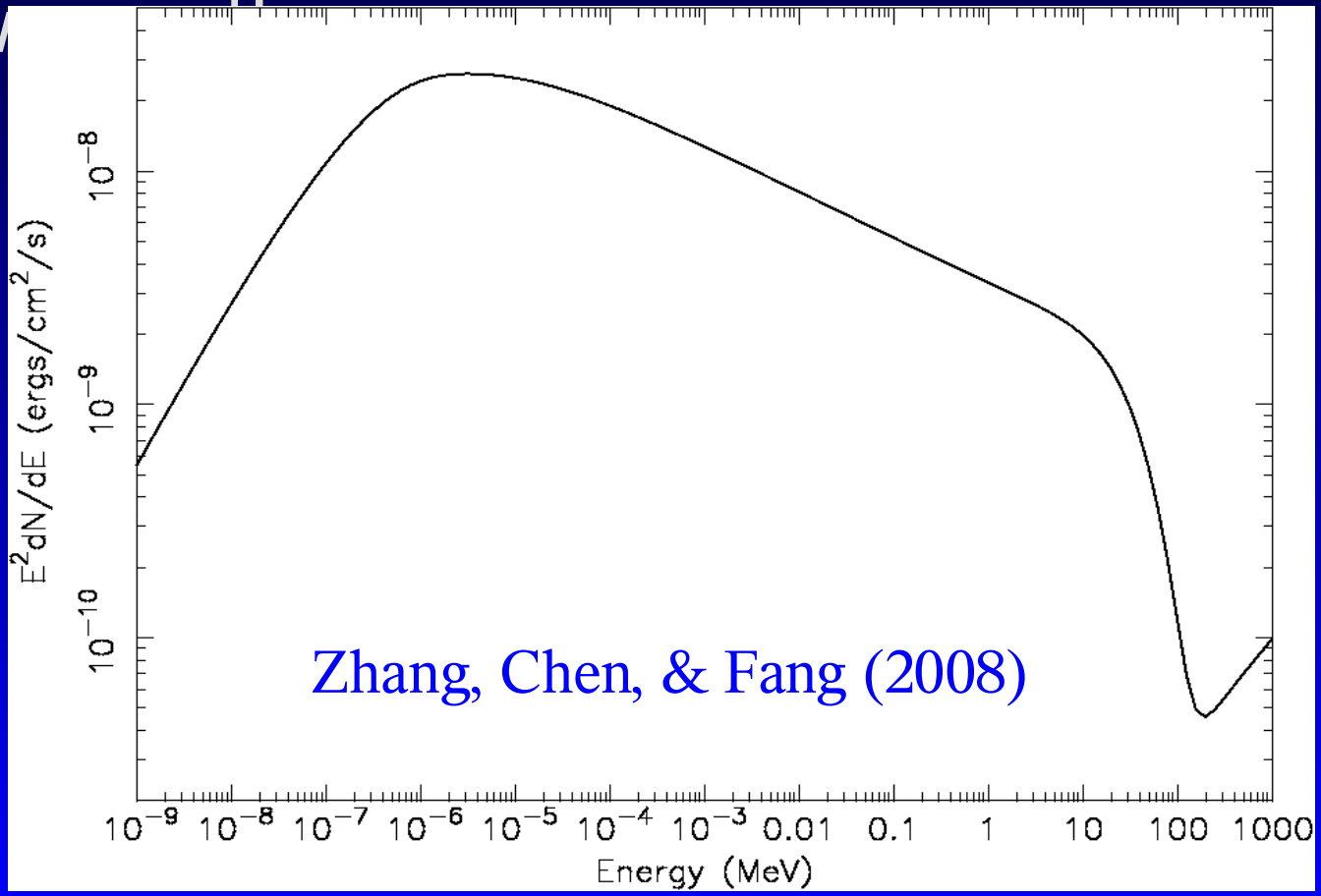
We examine two hypotheses about the Crab spectrum using three observatories.

- Hypotheses
  - A power law adequately describes X-ray the spectrum.
  - The X-ray spectrum is concave downward.
- Telescope/Instrument
  - ROSAT/PSPC (low energies)
  - RXTE/PCA (high energies)
  - XMM-Newton/EPIC-pn (intermediate energies)

Hypothesis 1: A power law describes the Crab's spectrum at X-ray energies.

- The Crab spectrum must be concave dow



We explored whether existing data are sensitive to departures from a power law.

- Used XSPEC table models of Crab spectral models
  - Zhang, Chen, & Fang (2008)
  - Volpi, Del Zanna, Amato, & Bucciantini (2008)
- Simulated data using the relevant response matrix.
  - Employed the XSPEC “fakeit” feature.
- Performed 100 simulations for each case.
  - Inserted the “wait 1” command in the scripts to ensure independence of random-number seeds.
- Fit each simulation result with a pure power

We applied consistent XSPEC settings in the simulations.

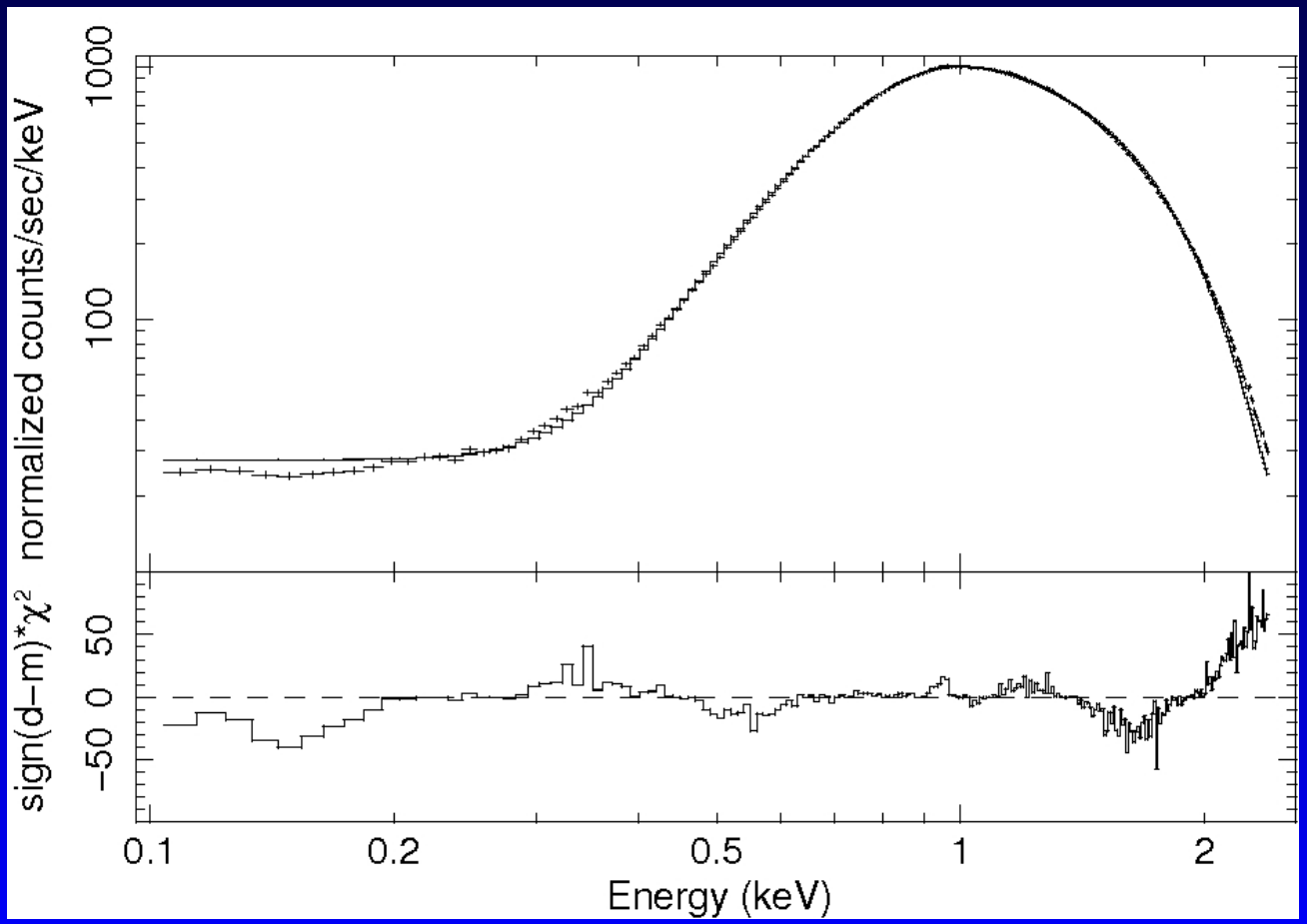
- Used *tbvarabs* for interstellar absorption.
- Set cross-sections to *vern*.
- Set abundances to *wilm*.
- Set N_H to 0.42×10^{22} cm^{-2} for the simulations.
- Set oxygen abundance [O] to 0.676 $[O]_{ISM}$.

ROSAT/PSPC

- Analyzed ROSAT observation 500065p.
- Applied XSELECT apertures:
  - For source region, chose 2.5′ radius on pulsar.
  - For background region, chose 4.5′-8.3′ annulus.
- Used the response function *pspcb_gain1_256.rsp*.
- Applied standard corrections.
- Obtained 6.4-ks (deadtime-corrected) exposure.
- Acquired 6.164×10^6 counts in 0.1–2.4 keV band.

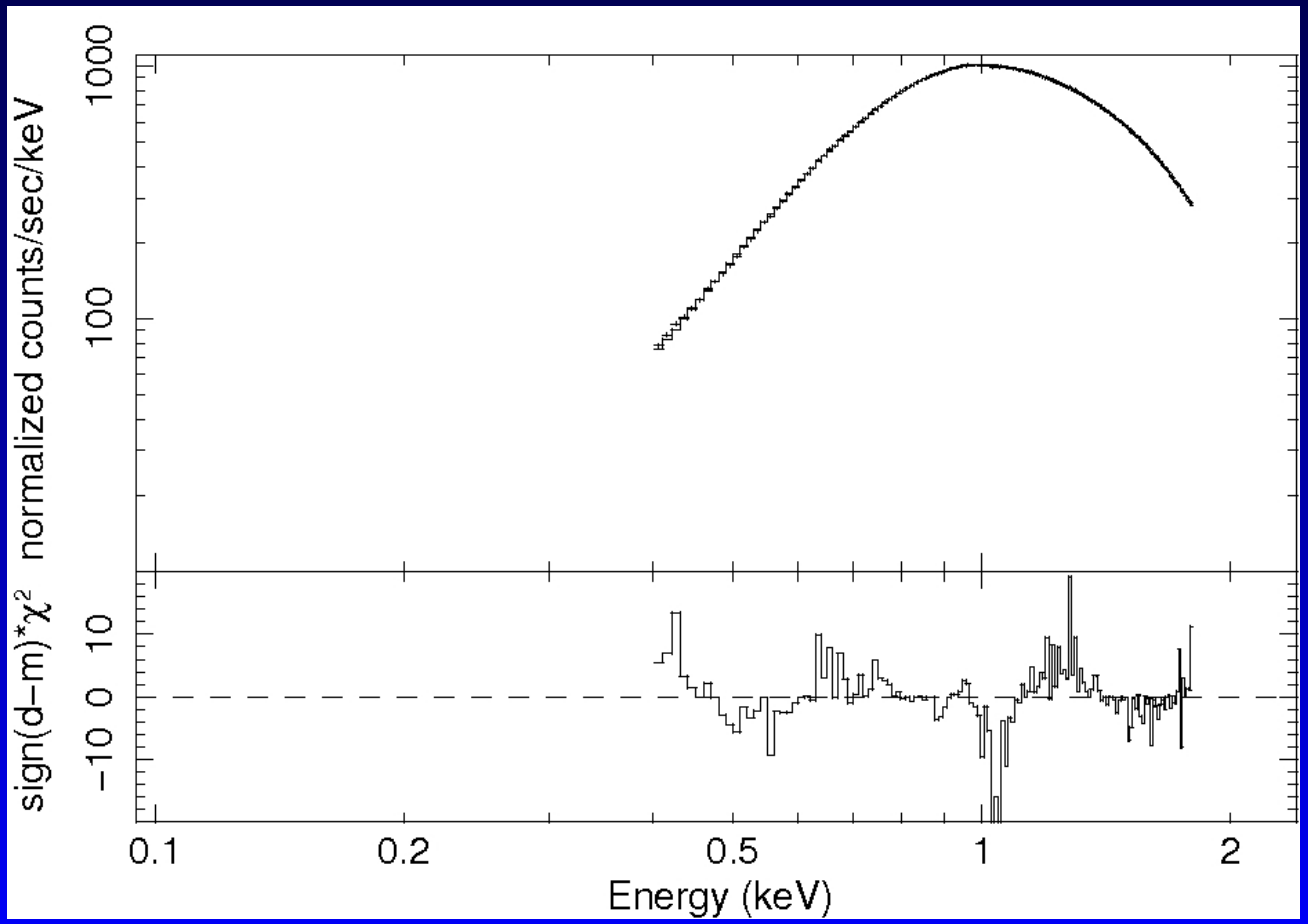
ROSAT/PSPC (0.1–2.4 keV): The fit to a power law is very poor.

- $\chi^2/\nu = 3359/227$



ROSAT/PSPC (0.4–1.8 keV): Narrowing the band doesn't give an acceptable fit.

- $\chi^2/\nu = 435/137$



The poor fit for ROSAT/PSPC data is ***not*** a consequence of hypothesis 1.

- A power-law fit to the simulated Crab spectrum is statistically acceptable.

Counts/10^6	χ^2/ν	Γ	$N_H/(10^{22}\,cm^{-2})$	$[O]/[O]_{ISM}$
6.17	(230±23)/227	2. 1910±0.0060	0.4208±0.0020	0.677±0.014

Zhang et al.

Counts/10^6	χ^2/ν	Γ	$N_H/(10^{22}\,cm^{-2})$	$[O]/[O]_{ISM}$
6.16	(232±23)/227	2. 0705±0.0060	0.4212±0.0021	0.670±0.015

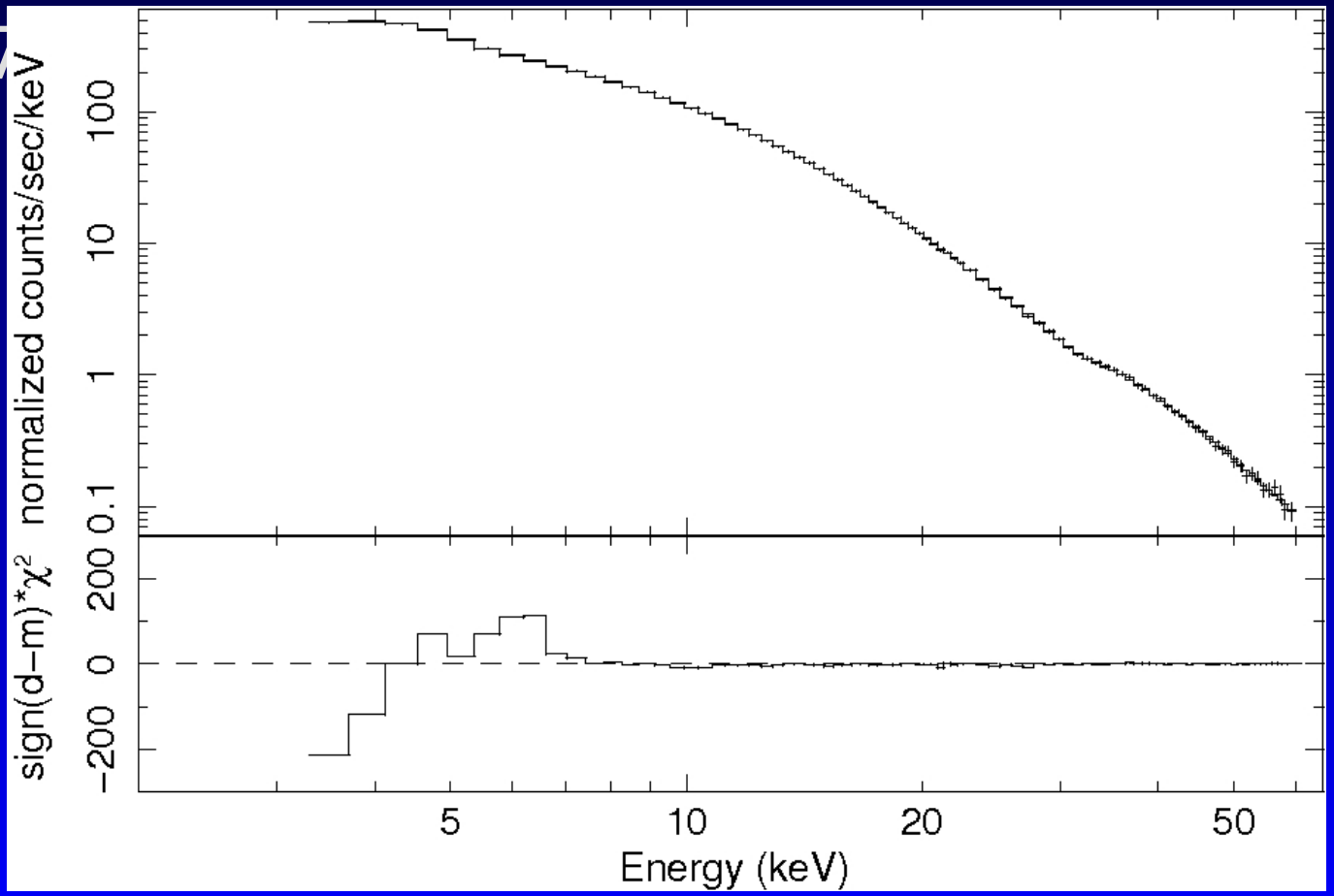
Volpi et al.

RXTE/PCA

- Analyzed observation 50804-01-03-00 (2000.12.16).
- Estimated background using PCABACKEST.
- Extracted data using SAEXTRCT version 4.2e.
- Used estimated deadtime fraction of 5.1%
- Obtained response with PCARSP version 7.10.
  - Used *p2coll_96jun05.fits*.
- Crab had been used in calibrating response matrix!
  - Jahoda et al. 2006

RXTE/PCA (3–60 keV): The fit to a power law is very poor.

- χ^2/ν = 883/86 (Set $N_H = 0.42 \times 10^{22}$ cm^{-2}; [O] = 0.67



The poor fit for RXTE/PCA data may be a consequence of hypothesis 1 (3.0-60.0 keV)

- A power-law fit to the simulated Crab spectrum is statistically acceptable for the Zhang et al. model.

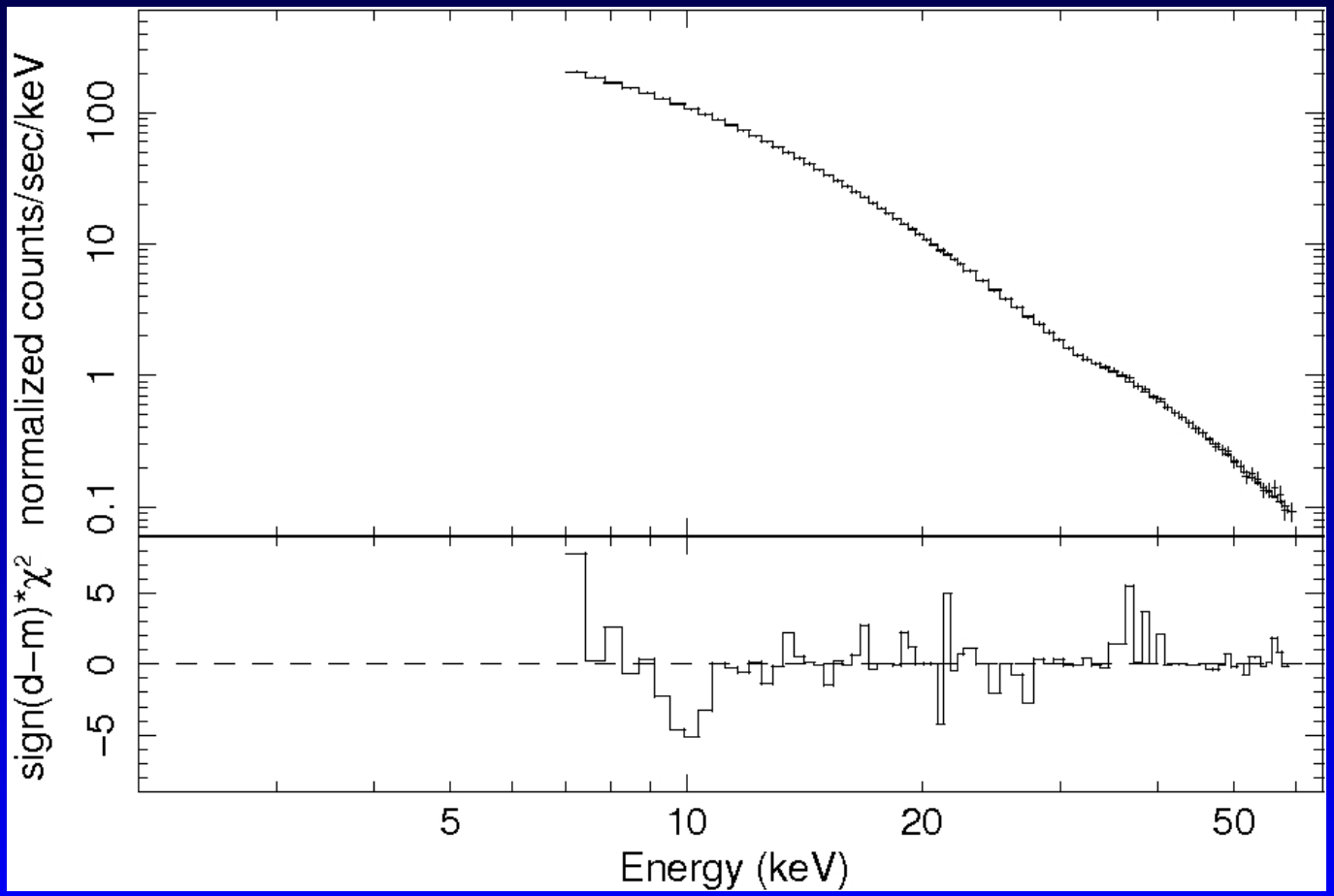
Counts/10^6	χ^2/ν	Γ	$N_H/(10^{22}\,cm^{-2})$	$[O]/[O]_{ISM}$
6.36	(86±12)/85	2.1958±0.0008	0.42 (fixed)	0.676 (fixed)

- A power-law fit to the simulated Crab spectrum is statistically unacceptable for the Volpi et al. model.

Counts/10^6	χ^2/ν	Γ	$N_H/(10^{22}\,cm^{-2})$	$[O]/[O]_{ISM}$
6.36	(2970±109)/85	2.2180±0.0008	0.42 (fixed)	0.676 (fixed)

RXTE/PCA (7–60 keV): Narrowing the band does give a good fit.

- $\chi^2/\nu = 81.2/77 \qquad \Gamma = 2.1093 \pm 0.0018$

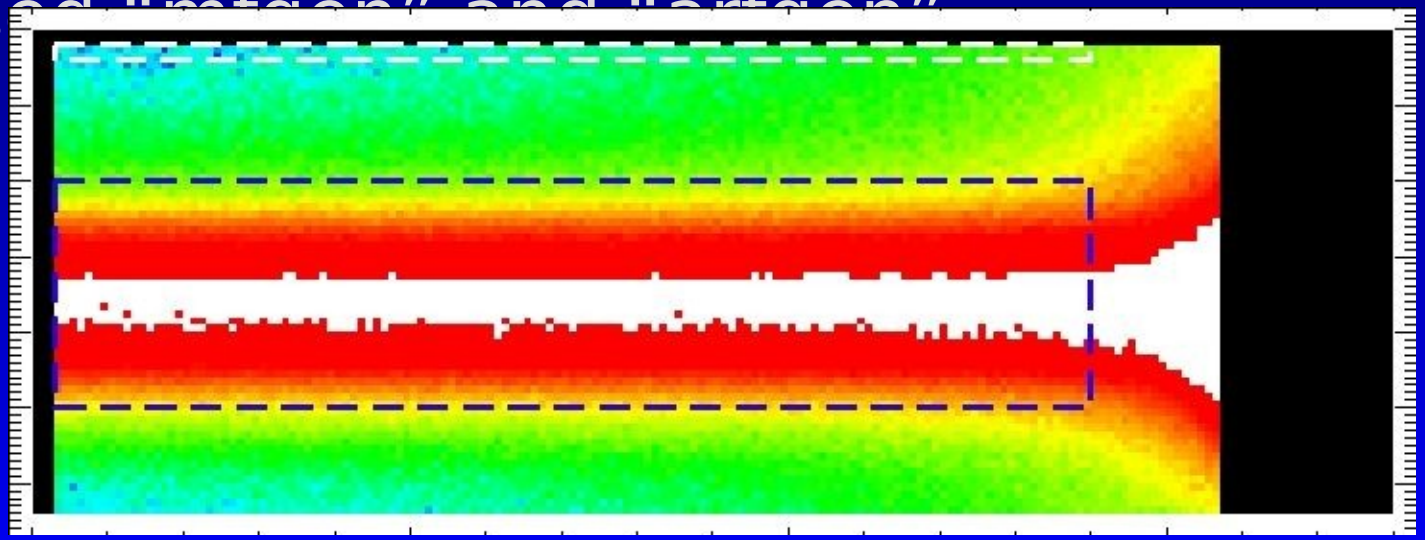


As before, the simulations disagree as to the outcome.

- Zhang et al. model $\chi^2/\nu = (76\pm14)/76$
- Volpi et al. model $\chi^2/\nu = (408\pm37)/76$

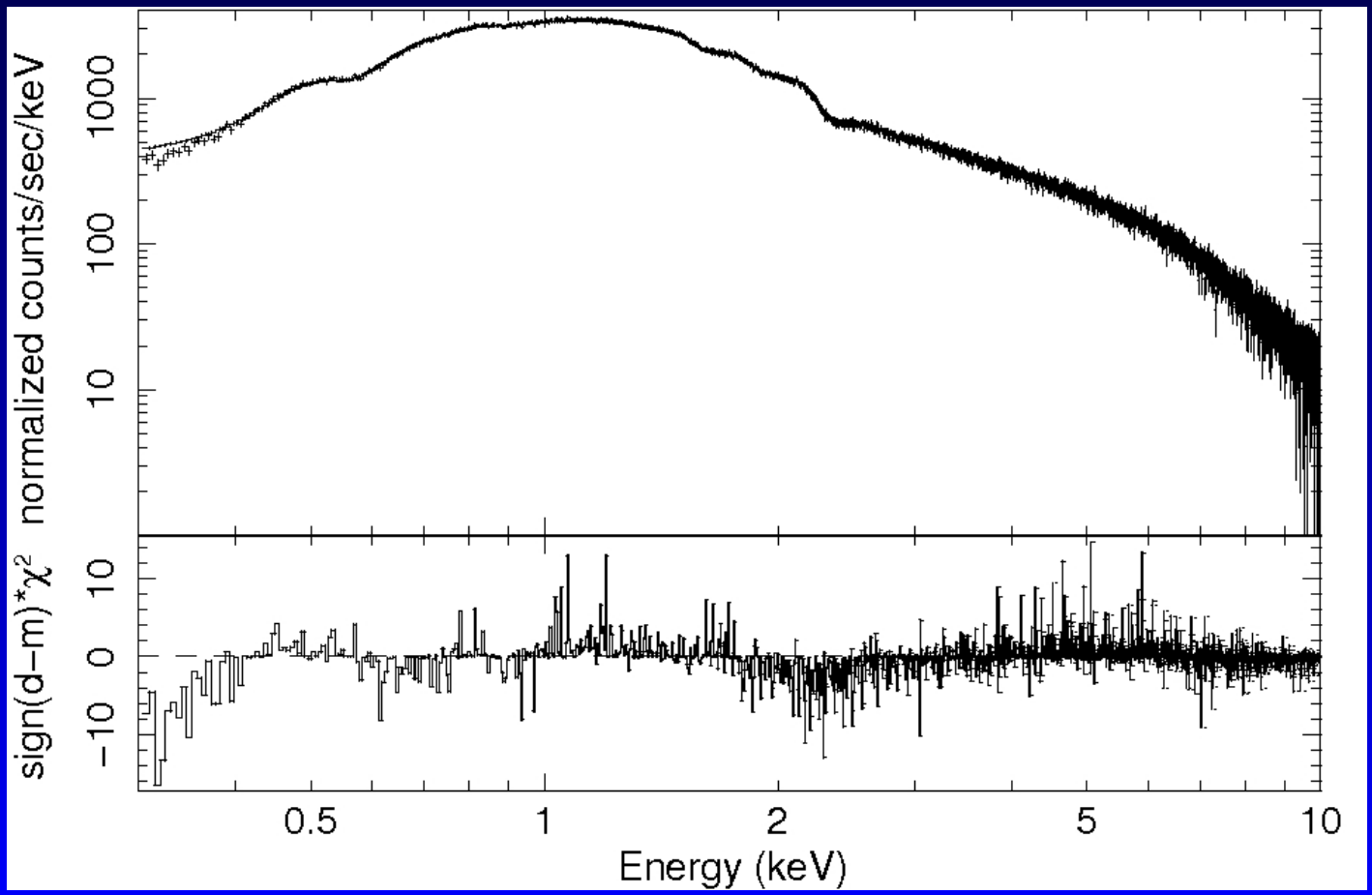
XMM-Newton EPIC-pn

- Analyzed burst-mode data from #0160960401.
  - Rev 874, 2004.09.16
- Used SAS 7.1.0 and “epchain”.
- Used “mfgen” and “arfgen”.



XMM–Newton EPIC-pn (0.3–10 keV): The fit to a power law is not good statistically.

- $\chi^2/\nu = 2321/1938 \quad [(\chi^2 - \nu)/(2\nu)^{1/2} = 6.2]$



The poor fit to XMM/EPIC-pn may be a consequence of hypothesis 1. (0.3-10.0 keV)

- A power-law fit to the simulated Crab spectrum is statistically acceptable for the Zhang et al. model.

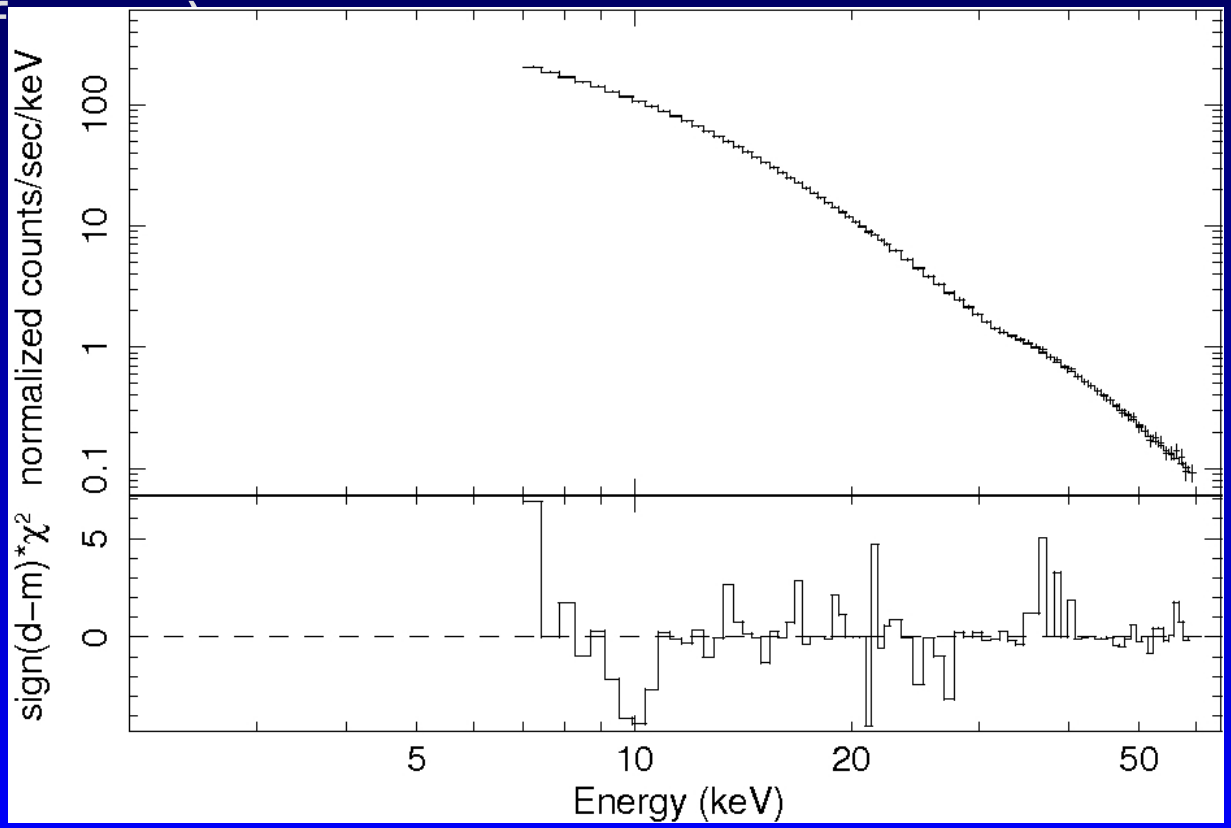
Counts/10^6	χ^2/ν	Γ	$N_H/(10^{22}\,cm^{-2})$	$[O]/[O]_{ISM}$
2.72	(1966±57)/1938	2.1968±0.0016	0.4220±0.0012	0.6800±0.0077

- A power-law fit to the simulated Crab spectrum is statistically unaccacceptable (3.2 σ) for the Volpi et al. model.

Counts/10^6	χ^2/ν	Γ	$N_H/(10^{22}\,cm^{-2})$	$[O]/[O]_{ISM}$
2.69	(2139±57)/1938	2.1044±0.0017	0.4260±0.0013	0.7109±0.0009

XMM/EPIC-pn (1.0–10 keV): Narrowing the band does give a good fit.

- $\chi^2/\nu = 1867/1800$ $\Gamma = 2.0637 \pm 0.0034$
  - $N_H = 0.3697 \pm 0.0043\ 10^{22}$ cm^{-2}; $[O]/[O]_{ISM} = 0.676$ (f



But, the models start to agree as to what should happen for the XMM data.

- Simulations with the Zhang et al. model can be fit with a power law.
- Simulations with the Volpi et al. model can be fit with a power law, but only marginally.
  - $\chi^2/\nu = 1925/1800$ (2.1 σ)

Some answers

- Is the Crab described by a power-law spectrum in the X-ray regime?
  - So far, “Maybe”.
    - XEUS beware!
- Do these observations establish the Crab is as a calibration standard?
  - Based upon these 3 experiments, “No”.

More work needs to be done.

- The ROSAT/PSPC response needs improvement.
  - It is important for determining overall normalization.
- XMM/EPIC-pn response may need improvement especially below 1.0 keV.
  - Unfortunately, burst-mode data do not allow accurate measurement of the norm.
- RXTE response may need work.
  - RXTE cannot help with the Crab, in that RXTE used the Crab as part of its calibration.
    - This may have been the wrong thing to do.

Don’t forget the absorption when considering a “calibration standard”.

- With any curvature present in the true underlying spectrum, it is possible to trade absorption for spectral index at low energies.
  - For example, we saw this for Volpi/XMM/1.0-10 keV.
  - Simply establishing the spectral index is not enough.