



**Thermal SNRs as Standard Candles:**  
**Summary from the 2008 IACHEC**  
**Working Group Sessions**



## Thermal SNR Working Group

XMM-Newton RGS	Andy Pollock (ESAC)
Chandra HETG	Dan Dewey (MIT)
XMM-Newton MOS	Steve Sembay (Leicester)
XMM-Newton pn	Frank Haberl (MPE)
Chandra ACIS	Joe DePasquale, Paul Plucinsky (SAO)
Suzaku XIS	Eric Miller (MIT)
Swift XRT	Andrew Beardmore, Olivier Godet (Leicester)
Models	Randall Smith (JHU/GSFC)



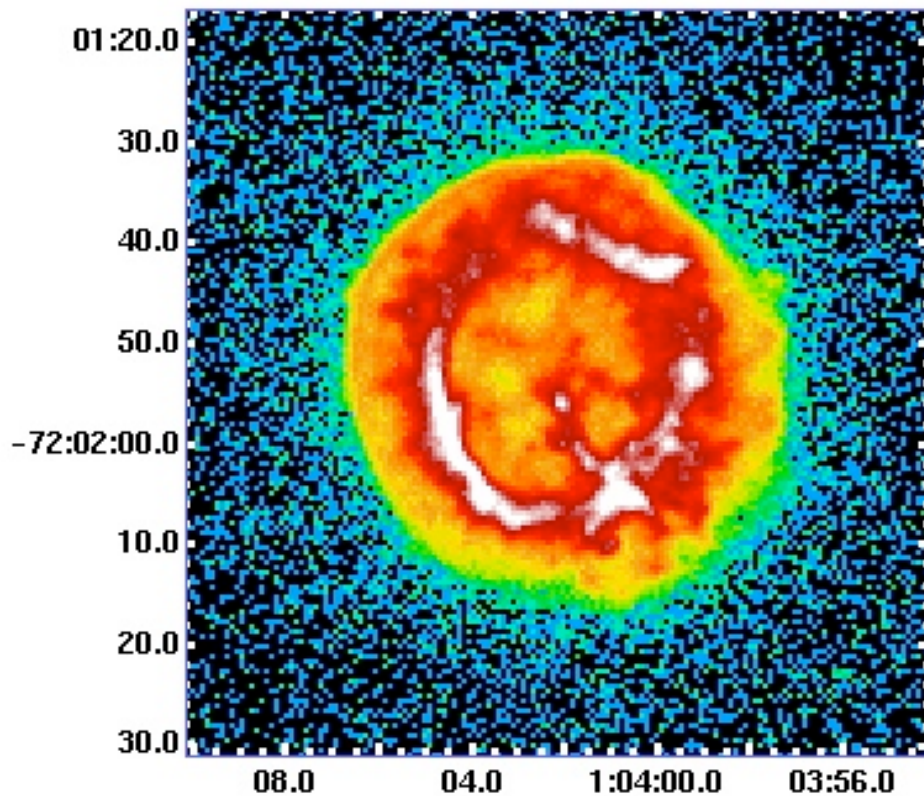
# Chandra X-Ray Observatory

CXC

## Gratuitous Pretty Pictures of E0102, DePasquale (SAO)

1.2 X 1.2 arcmin

### S3 Summed Data ~248 ks



### Three Color Image

Red: 0.2-75 keV, Green: 0.8-1.1 keV, Blue: 1.1-2.0 keV





## Construction of the Definitive E0102 Model

- Absorption:
- adopt Wilms et al. 2000 model as tbabs in XSPEC
  - adopt a two-component absorption, Galactic and SMC, Galactic component fixed at  $5.36 \times 10^{20} \text{ cm}^{-2}$  with Wilms abundances, SMC component is free to vary with abundances set to Russell & Dopita 1992 SMC abundances
- Continuum:
- adopt APEC no-line continuum model
  - adopt a two-component continuum, a relatively low-temperature component and a higher temperature component
- Line Emission:
- use Gaussians for the lines, 30-40 lines, currently under discussion
  - freeze energies to known values and set widths to zero
  - constrain normalizations of lines of same ionization state to values determined by the RGS and HETG

*This is NOT an astrophysical model, it is an empirical model !!!!*



## The Long and Arduous Path

- 1) RGS and HETG constrain SMC  $N_{\text{H}}$  and normalization and temperature of low-temperature APEC no-line continuum
- 2) MOS, pn, & XIS determine normalization and temperature of high-temperature APEC no-line continuum
- 3) RGS and HETG determine line fluxes from 0.3-2.0 keV

### RGS 2 fits (Haberl MPE):

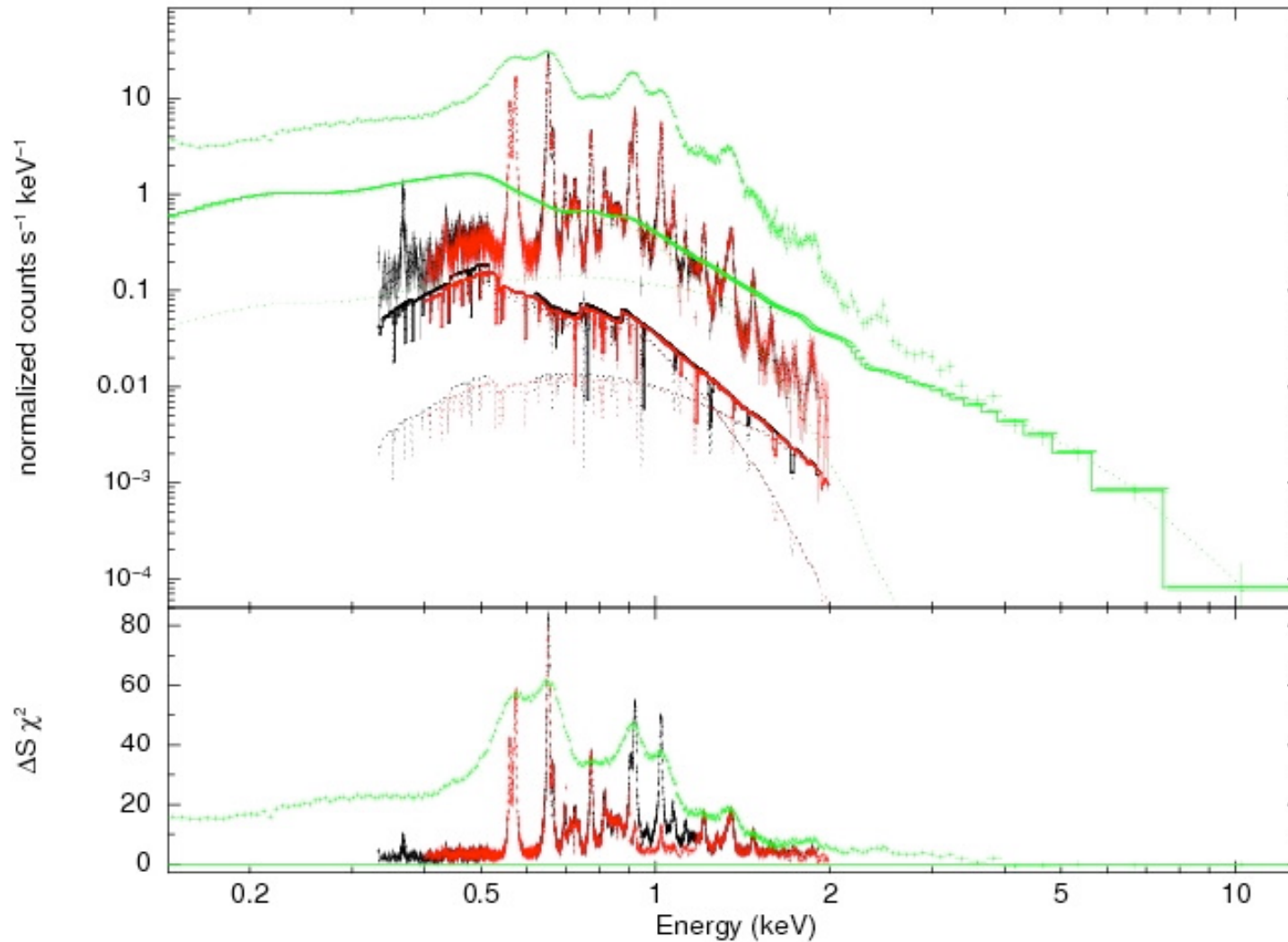
- SMC  $N_{\text{H}} = 5.76 \times 10^{20} \text{ cm}^{-2}$
  - low T APEC no-line continuum  $kT = 0.16 \text{ keV}$
  - high T APEC no-line continuum  $kT = 1.74 \text{ keV}$
  - line fluxes from 0.3-2.0 keV
- 4) MOS and pn determine line fluxes for lines above 2.0 keV
    - No additional lines needed!
  - 5) ALL instruments verified this model against their data
    - Model fits HETG data to within 4% (D/M ratio)
  - 6) Construct the definitive model based on the above:
    - Derive line normalization ratios for the strongest line complexes (O6, O7, Ne9, Ne10)
    - freeze all other parameters and fit fit fit
  - 7) And?



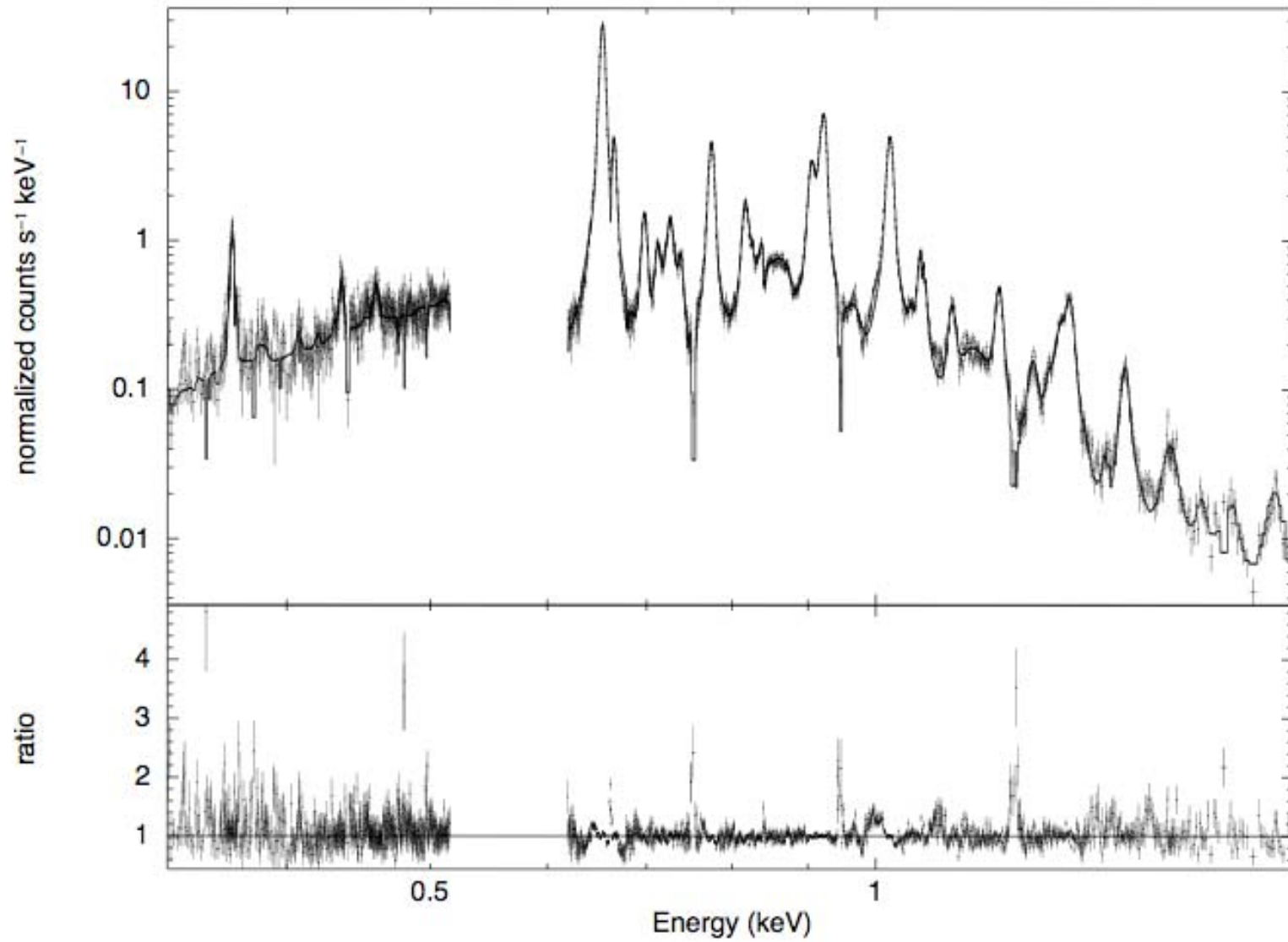
# Chandra X-Ray Observatory

CXC

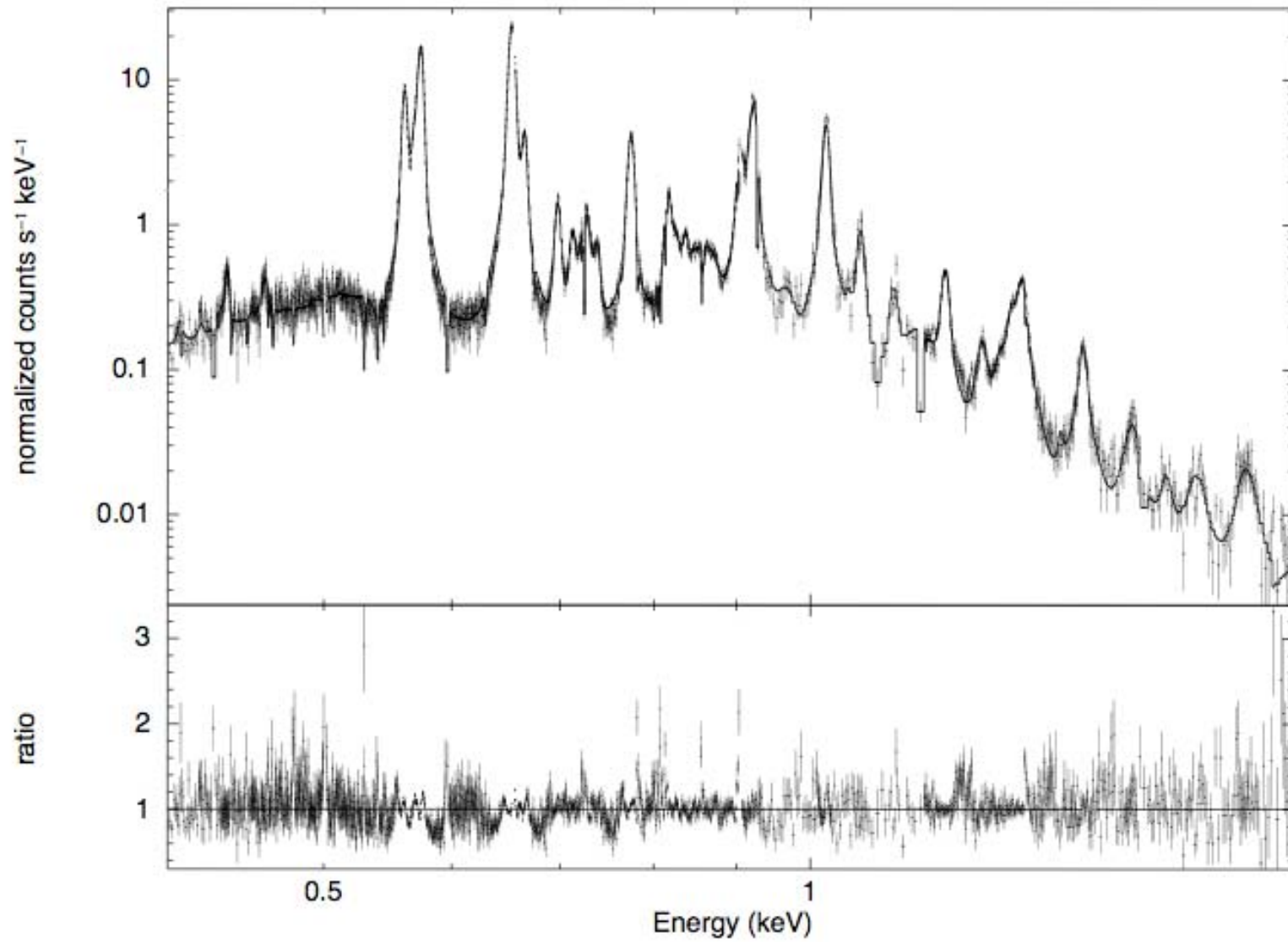
## Compare RGS model to pn data, Haberl (MPE) data and folded model



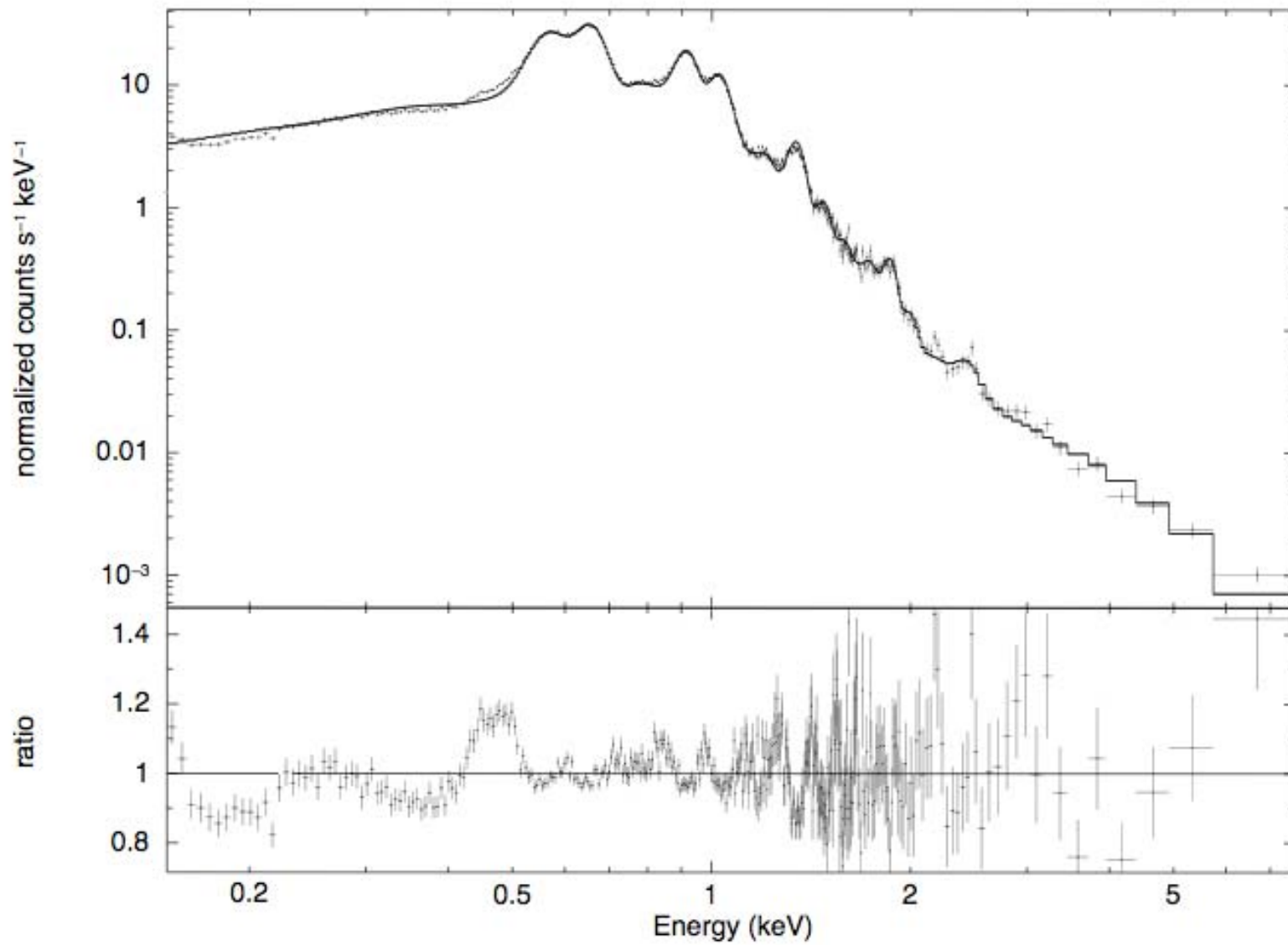
data and folded model

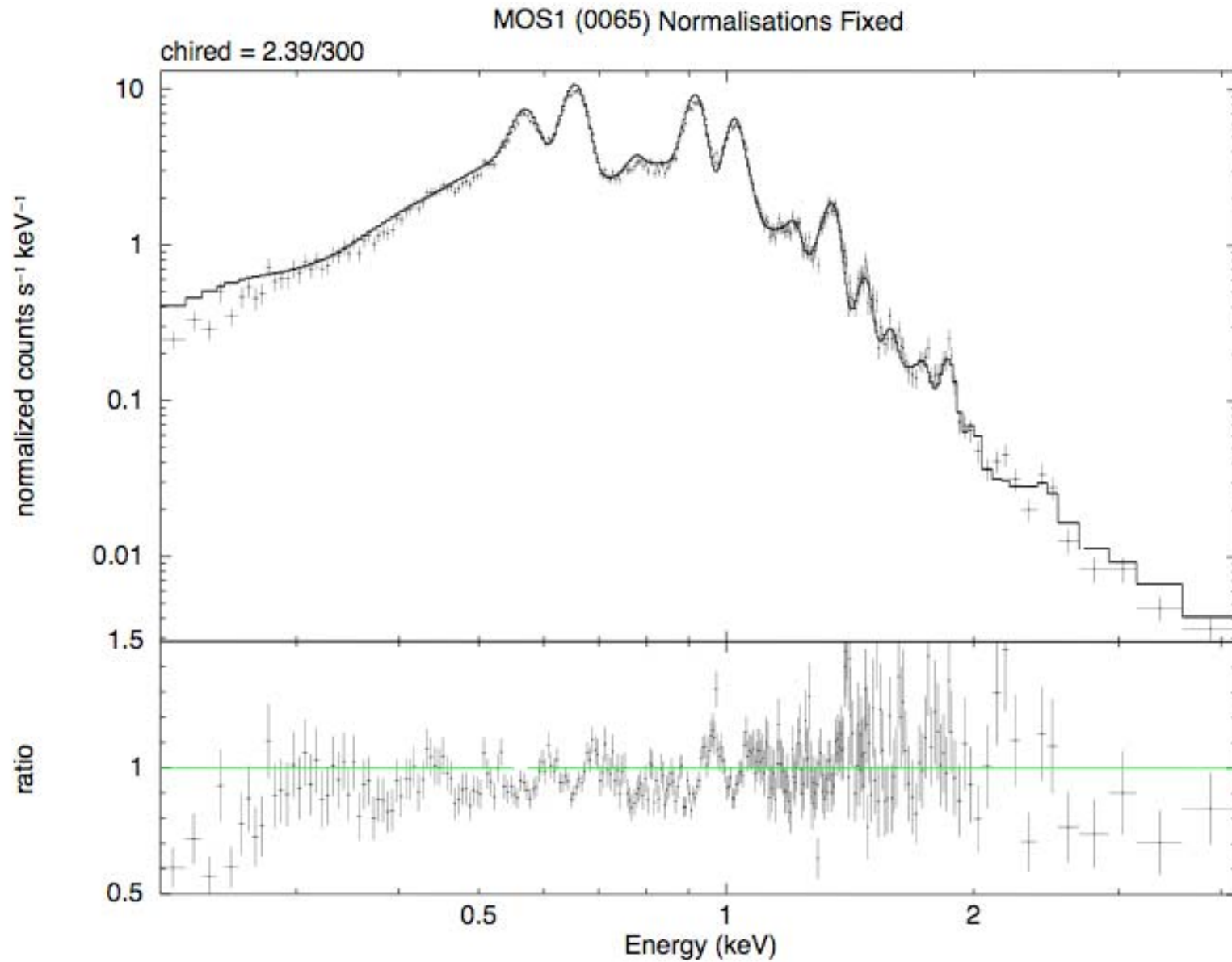


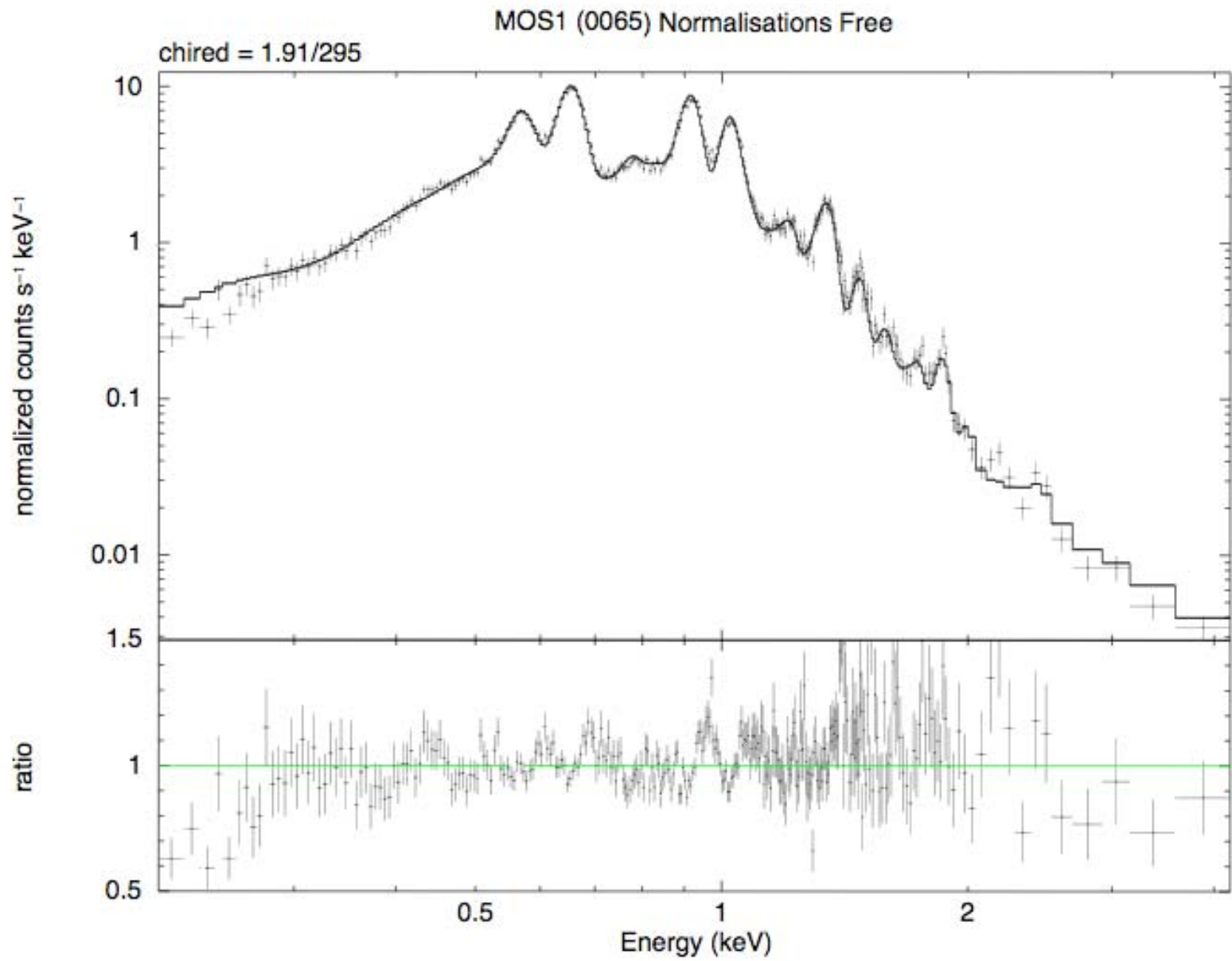
data and folded model



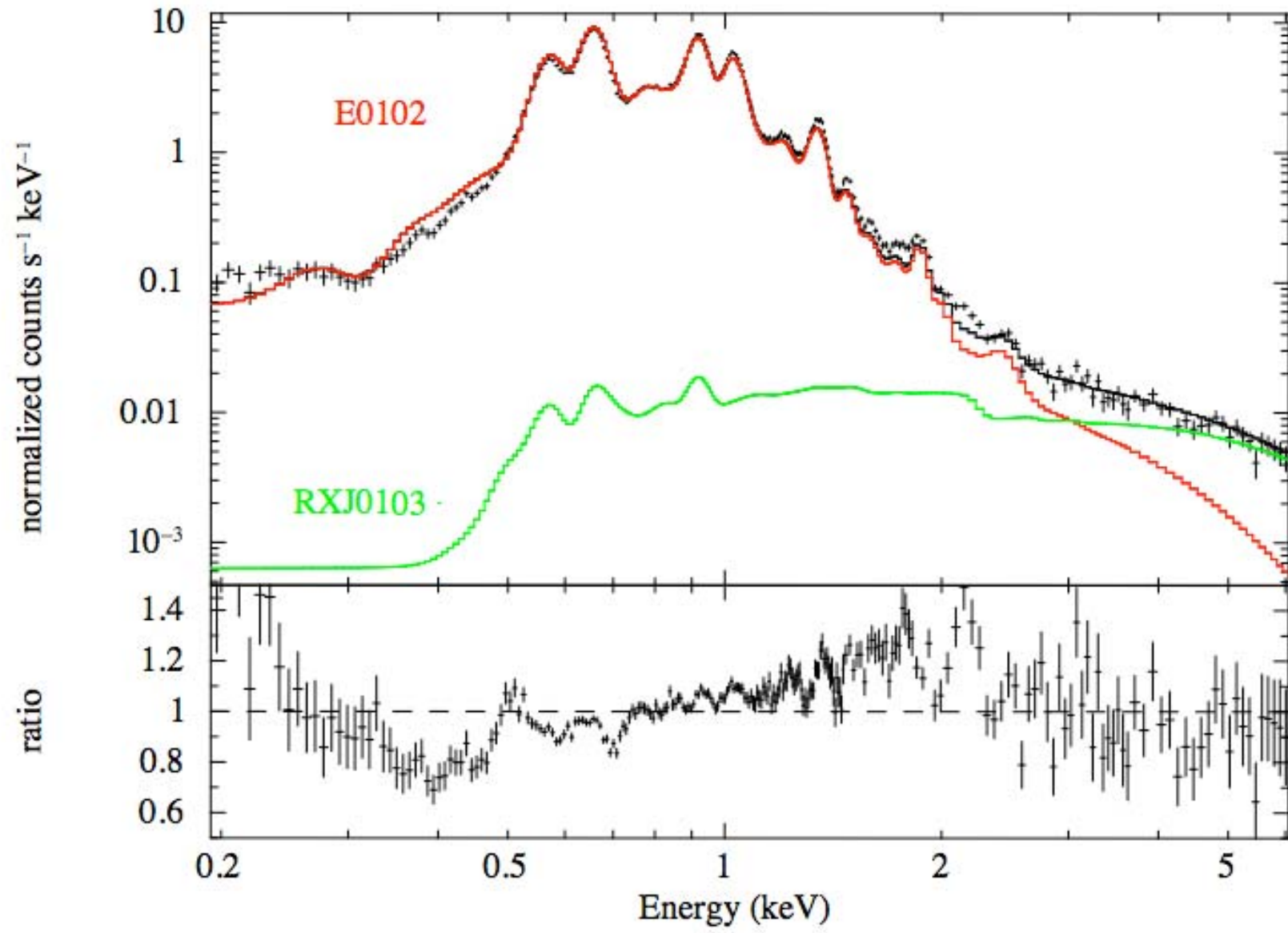
data and folded model



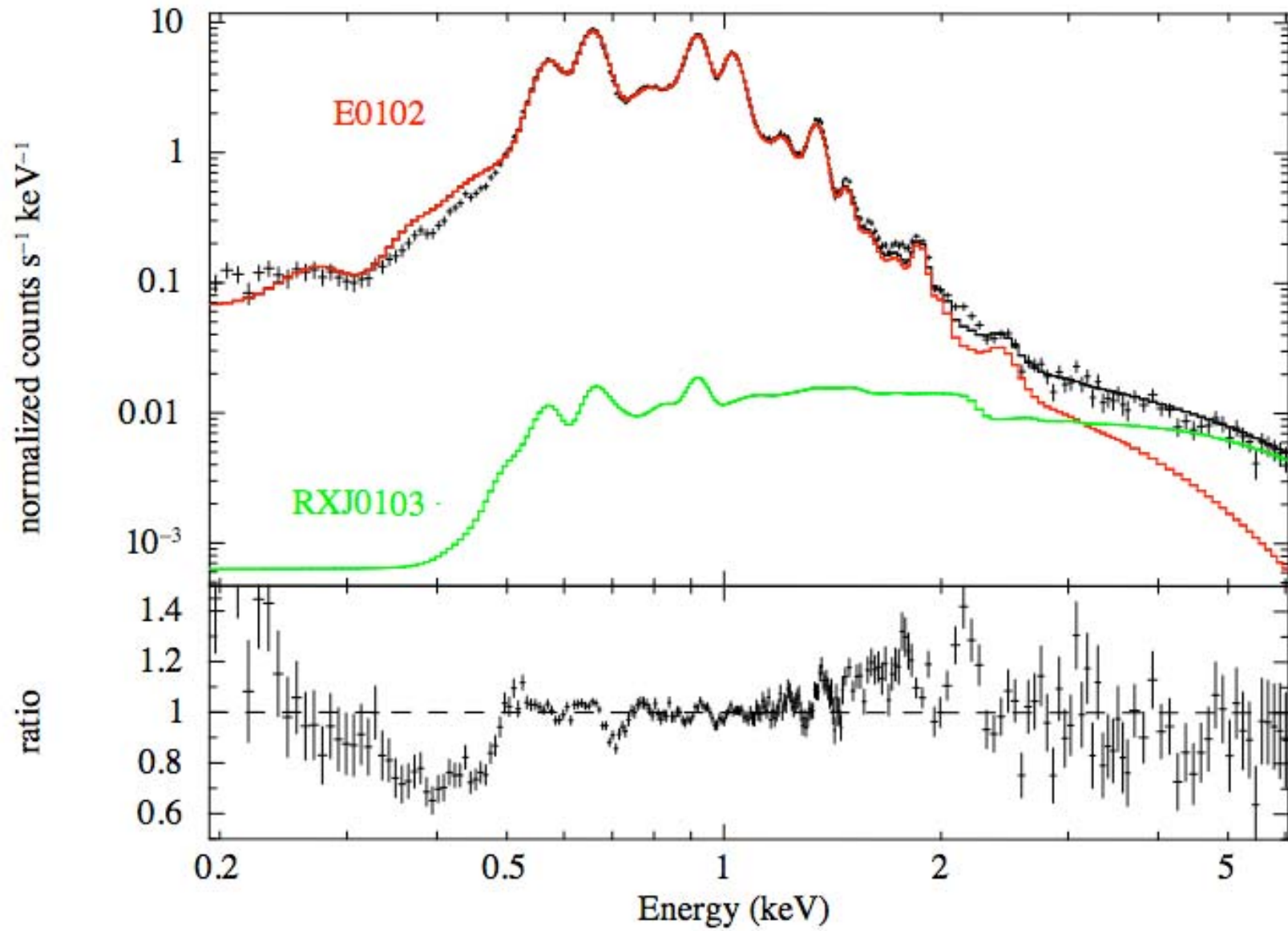




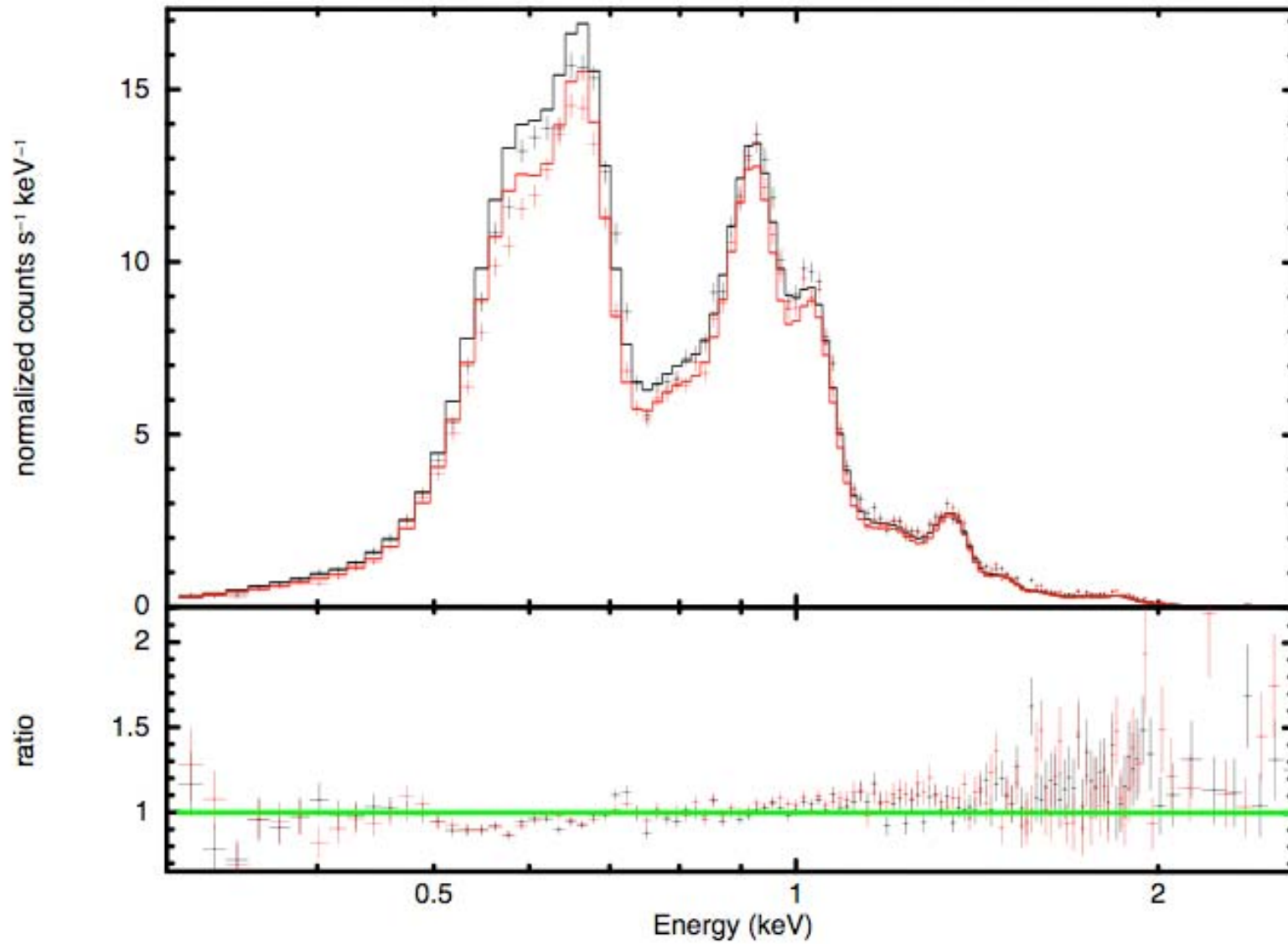
E0102 – Suzaku/XIS1 2005-12-17 – folded model



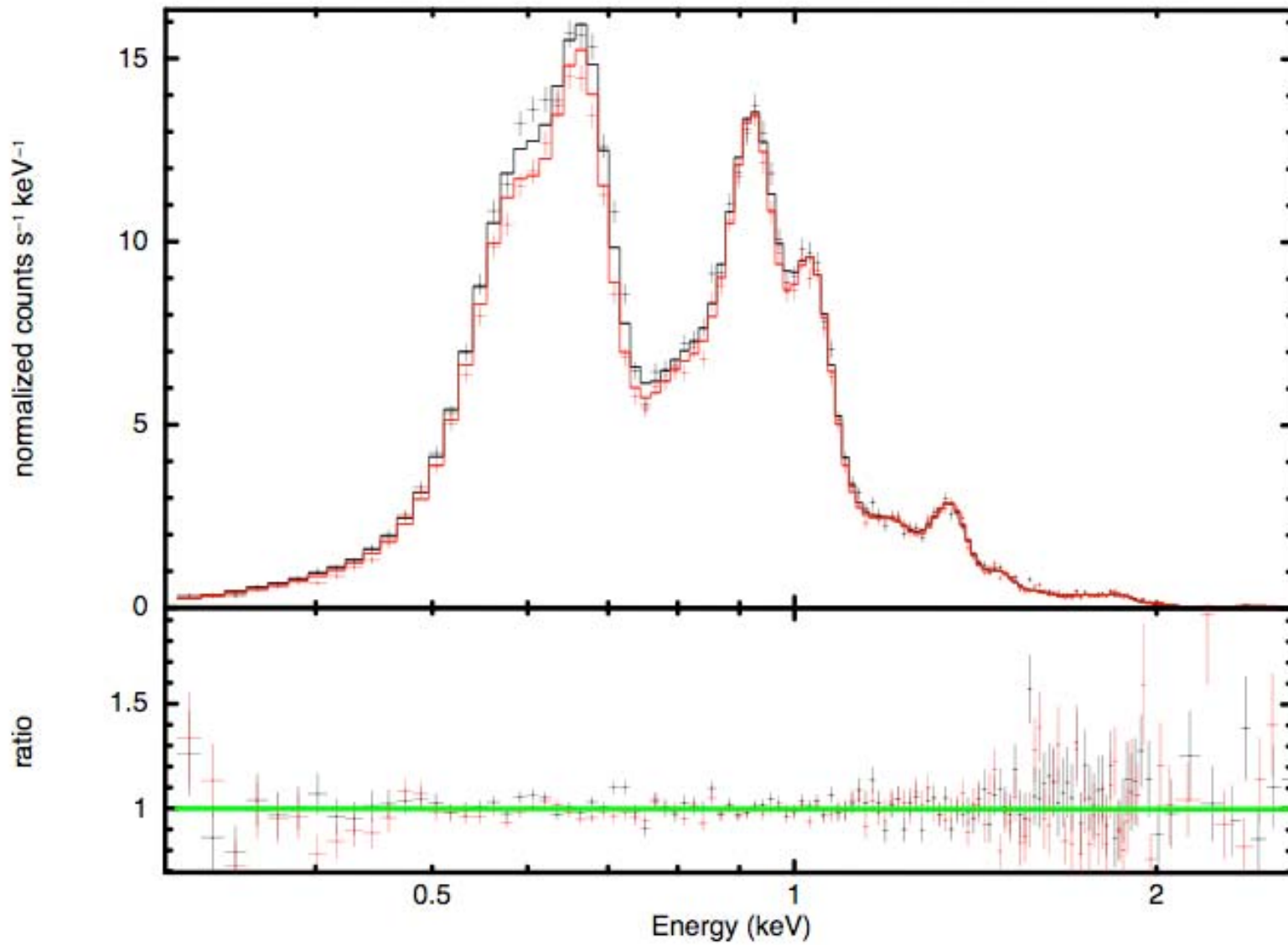
E0102 – Suzaku/XIS1 2005-12-17 – fitted model



E0102 – S3 Node 1 sub array  
RGSPN Model – not fit



E0102 – S3 Node 1 – sub array [ChiSq=310.7861 / 228 DOF]  
RGSPN Model + line ratios [kT1=1.74 keV, kT2=0.16 keV]





## Results

- we are closer to a “definitive” spectral model for E0102
- we will quote agreement amongst the various instruments at OVII (560-574 eV), OVIII (654 eV), Ne IX (905-922 eV) and Ne X (1022 eV)

Instrument	O VII	O VIII	Ne IX	Ne X
XMM: RGS2	1.31E-03	4.39E-03	6.53E-04	1.38E-03
XMM: RGS 1	1.26E-03	4.21E-03	6.27E-04	1.32E-03
XMM: pn	1.24E-03	4.17E-03	6.20E-04	1.31E-03
XMM: MOS 1	1.22E-03	4.15E-03	6.20E-04	1.35E-03
XMM: MOS 2	1.27E-03	4.20E-03	6.28E-04	1.33E-03
Suzaku: XIS	1.18E-03	4.09E-03	6.84E-04	1.51E-03
Chandra: ACIS-S3	1.13E-03	4.15E-03	6.45E-04	1.45E-03



## Fit Results

Instrument	Chi Sq	DOF
XMM: RGS 2	2.53	1853
XMM: RGS 1	2.85	1822
XMM: pn	3.58	365
XMM: MOS 1	1.91	295
XMM: MOS 2	2.08	295
Suzaku: XIS	5.95	246
Chandra: ACIS-S3	1.53	250

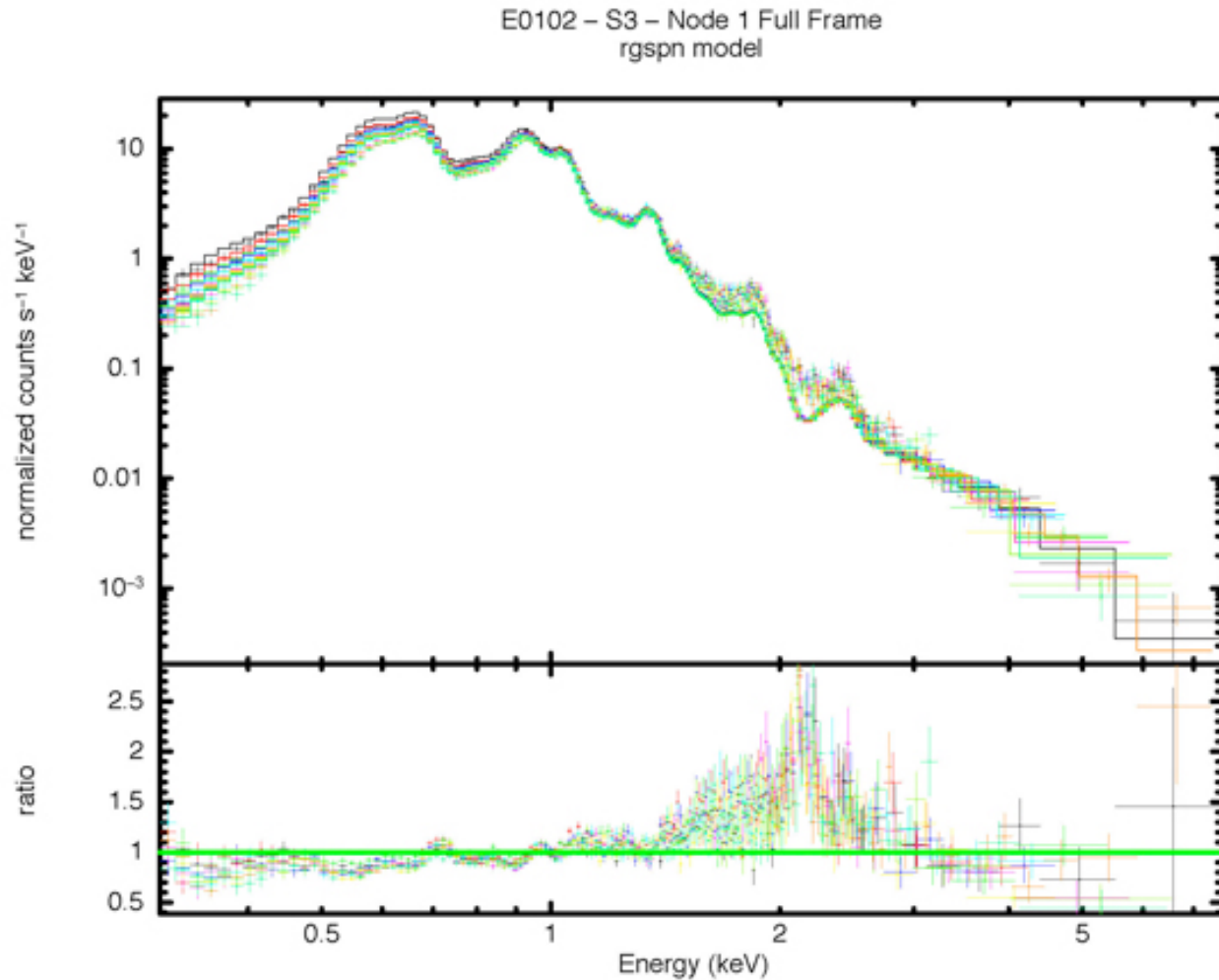


## What is Next?

- 1) Further refine the model and distribute the final definitive model to the group
  - Still need HETG agreement on RGS-derived line fluxes
    - total counts agree within 4% (D/M ratio)
  - SPIE paper currently under construction, will be presented next month
  - submit a paper on this work to a refereed journal within 6 months
  
- 2) Explore the calibration issues raised in fitting the calibration model
  - for example, the ACIS detector response & internal ACIS calibration
  - Pileup!



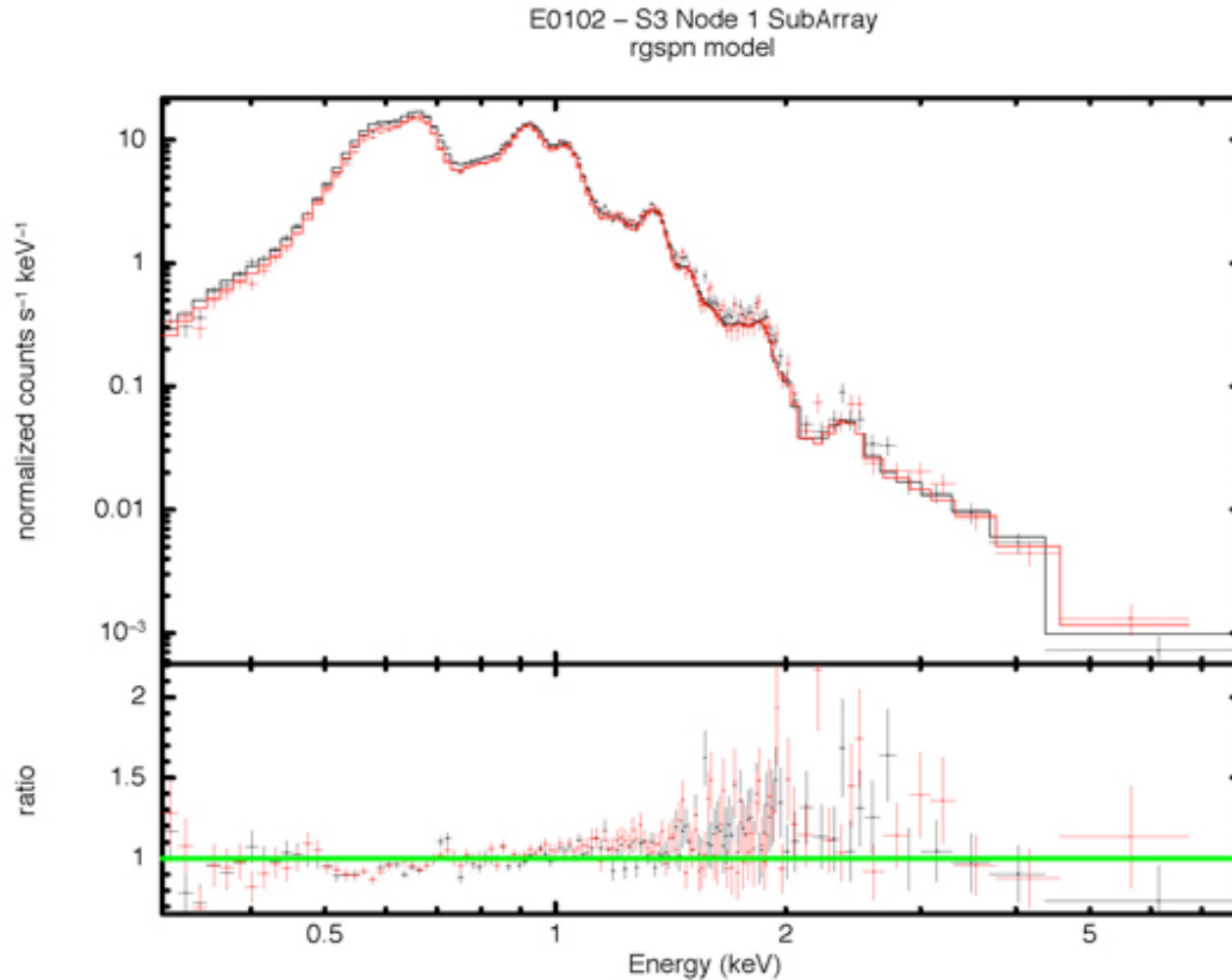
## Pileup is an Issue for ACIS



josephdepasquale 20-May-2008 10:07



## Pileup is an Issue for ACIS



josephdepasquale 20-May-2008 10:12



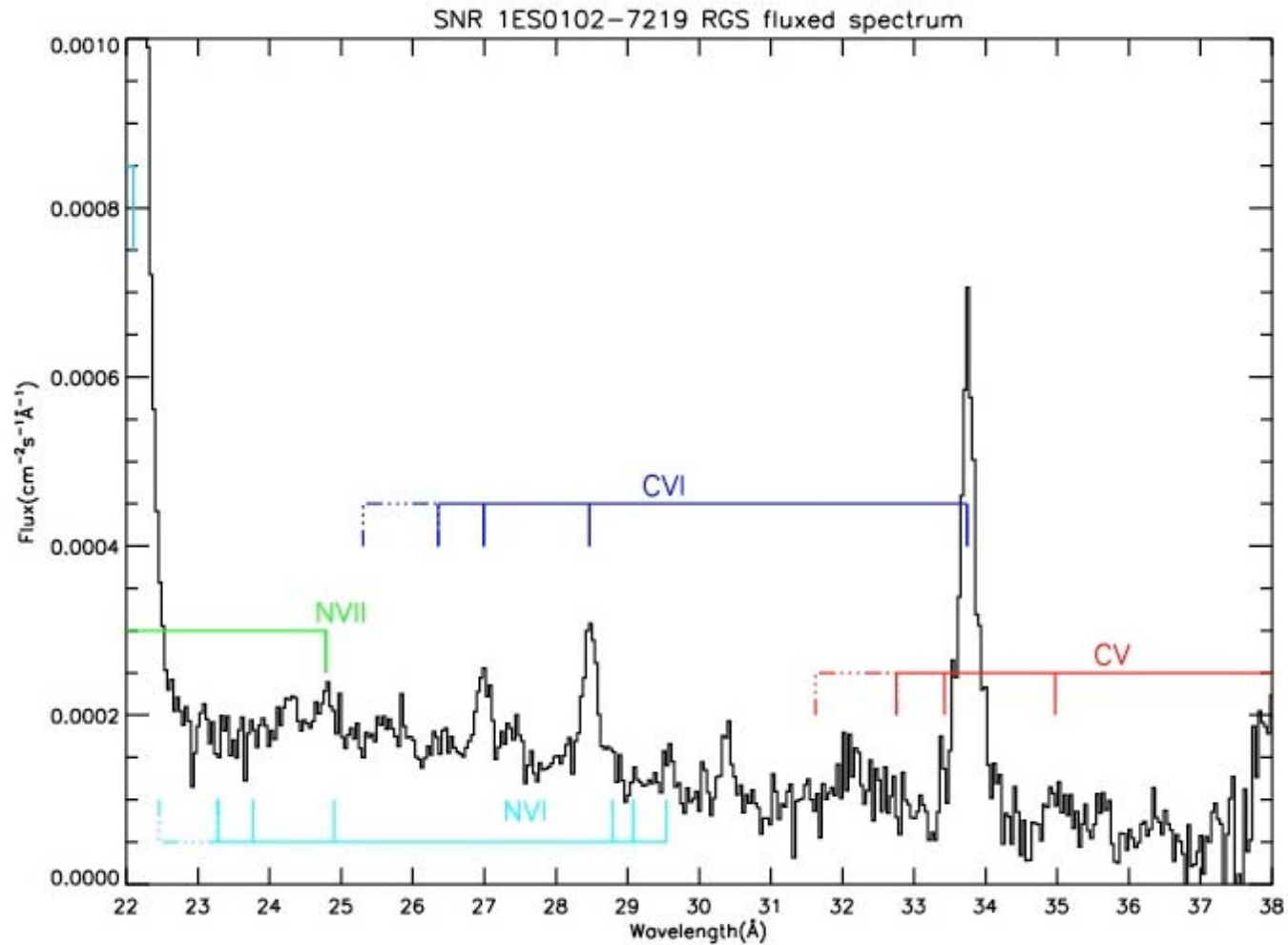
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  - Pileup!
- 3) Report at next year's IACHEC meeting



## How Can the Gratings Constrain the Line Parameters ?

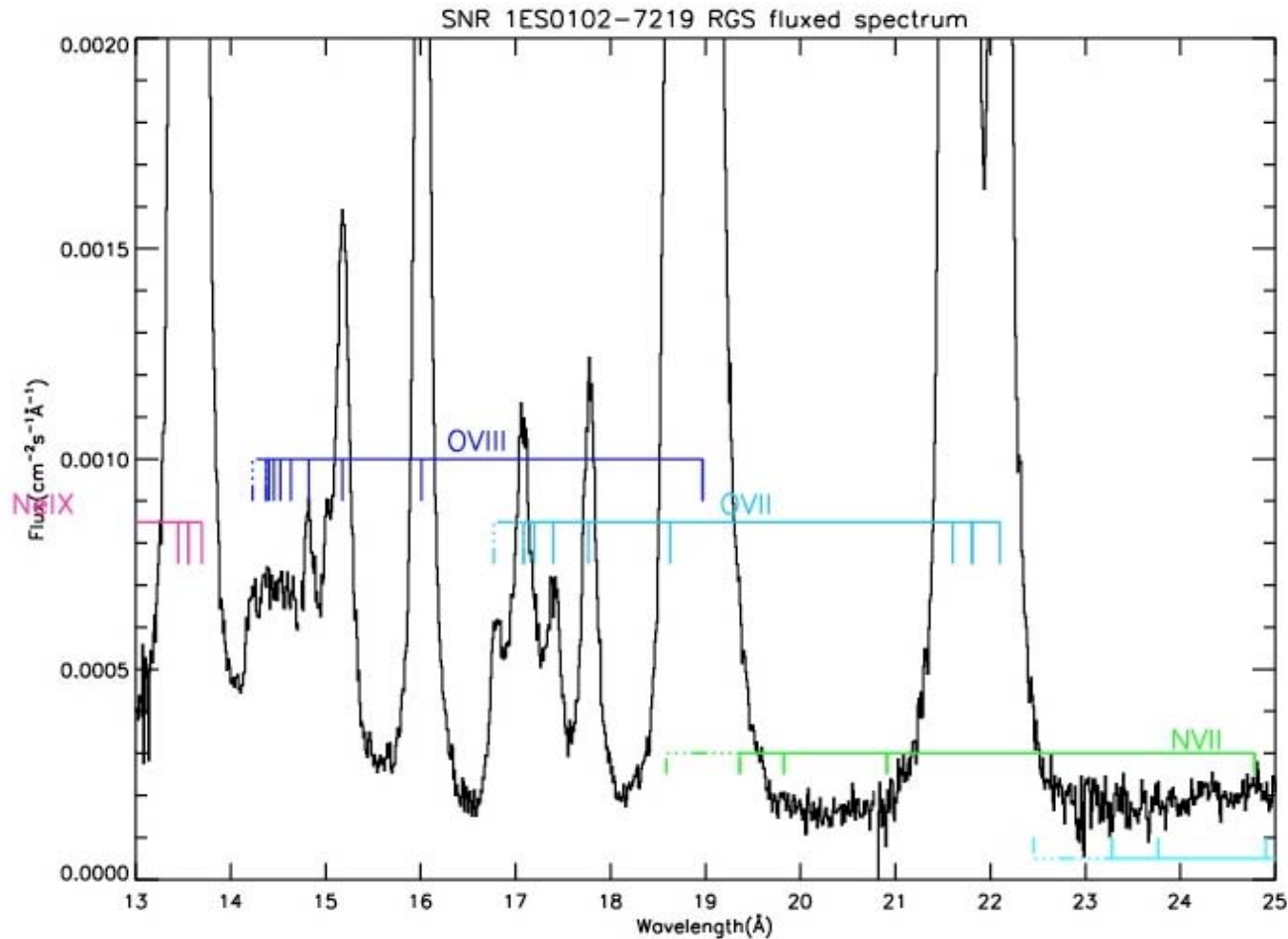
RGS spectra 22-38 Å from Pollock (ESAC)





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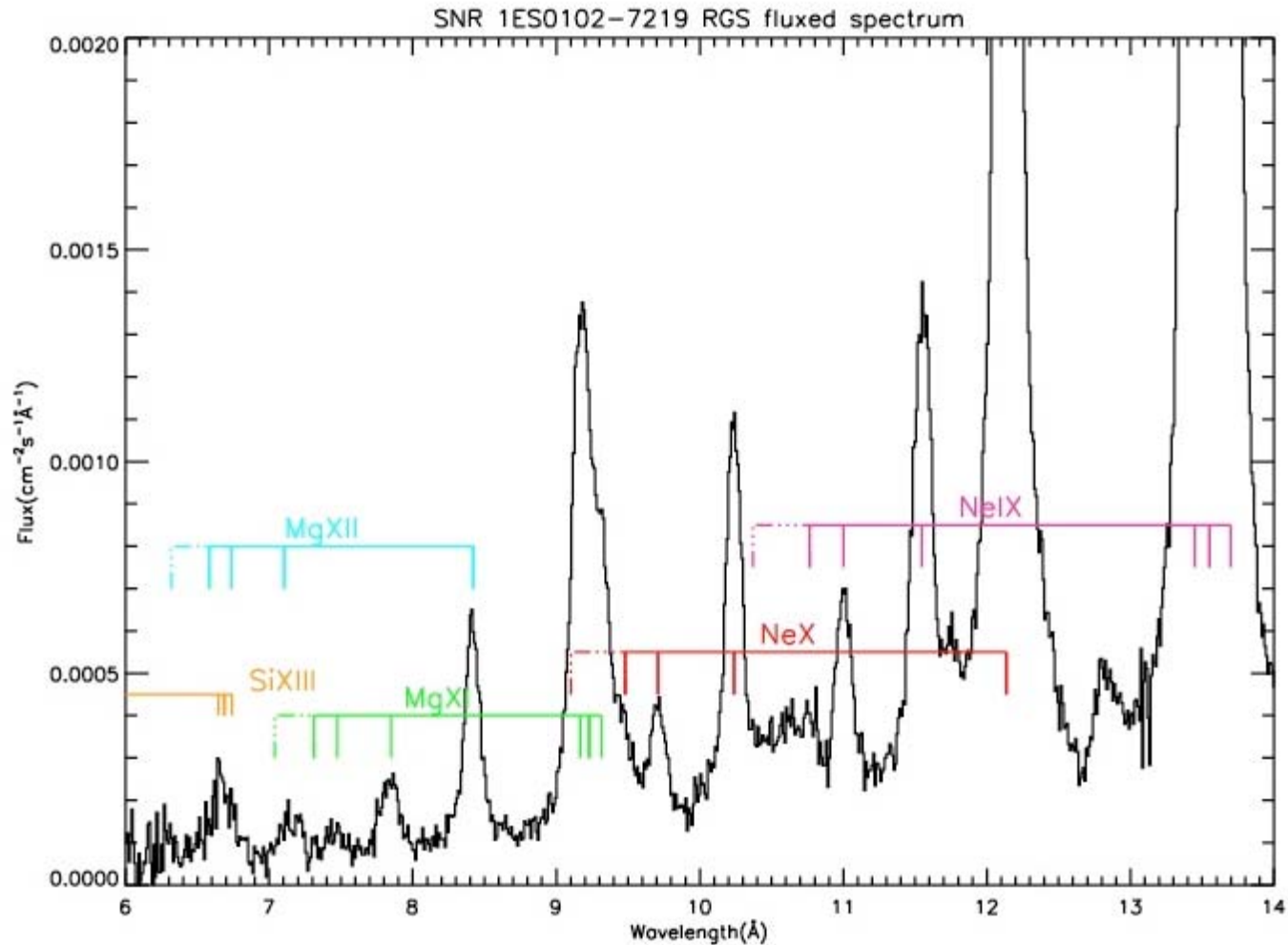
RGS spectra 13-25 Å from Pollock (ESAC)





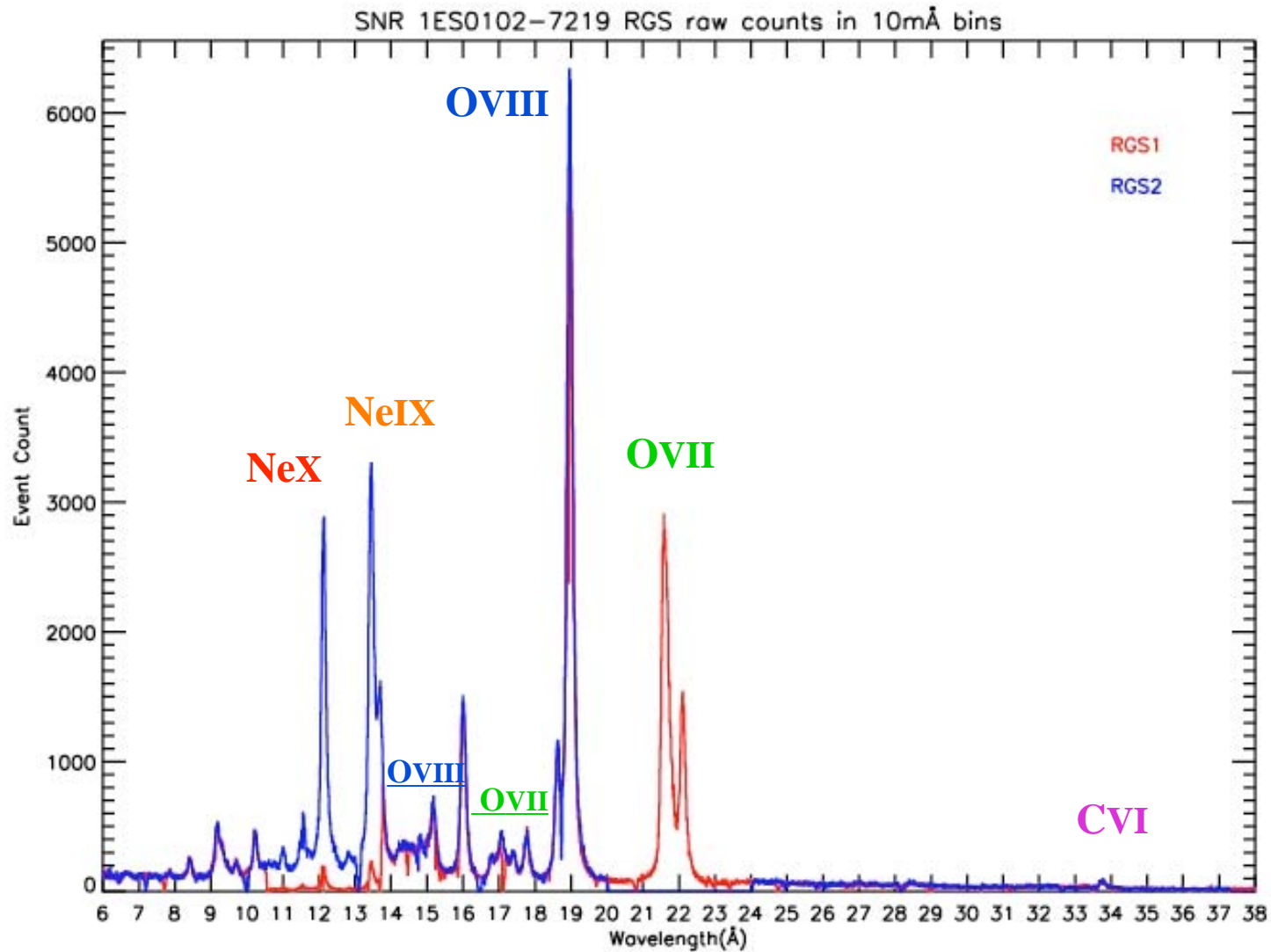
## How Can the Gratings Constrain the Line Parameters ?

RGS spectra 6-14 A from Pollock (ESAC)





## RGS Spectrum of E0102, Pollock (ESAC):



little or no  
Fe emission