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

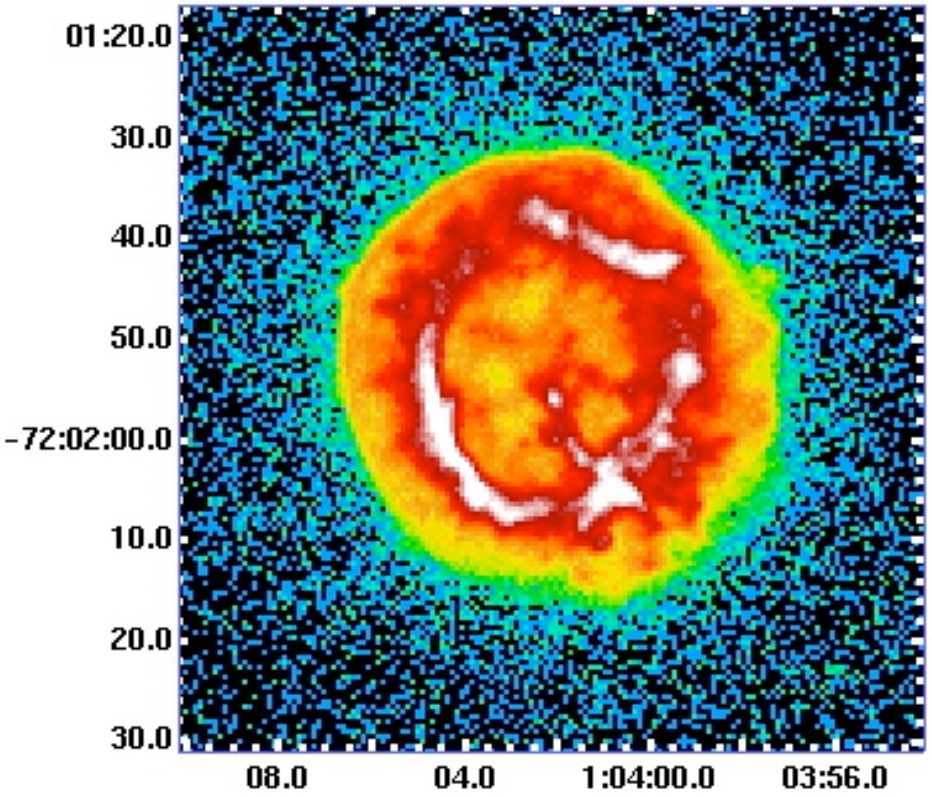
Thermal SNR Working Group

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)

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 x 10^{20} 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

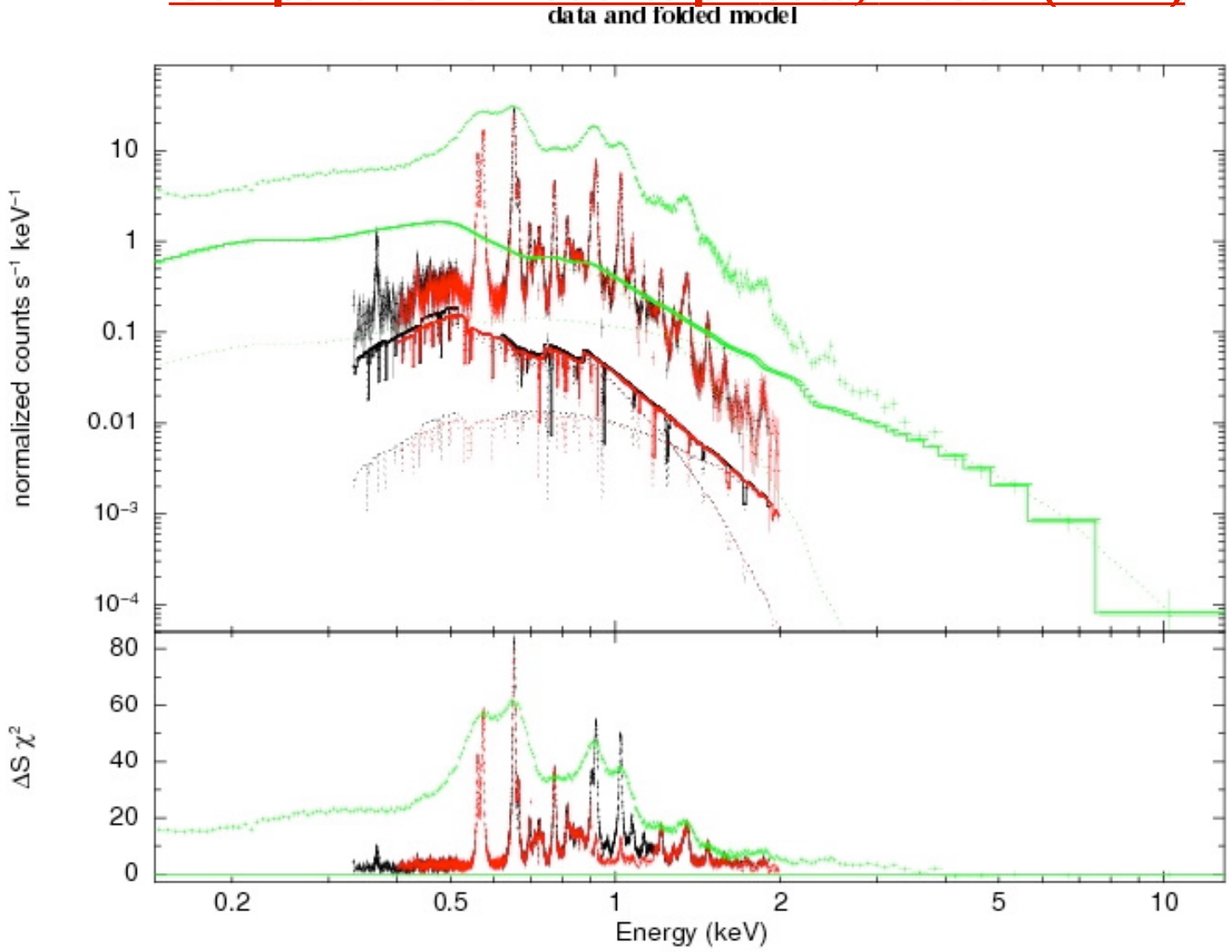
This is NOT an astrophysical model, it is an empirical model !!!!

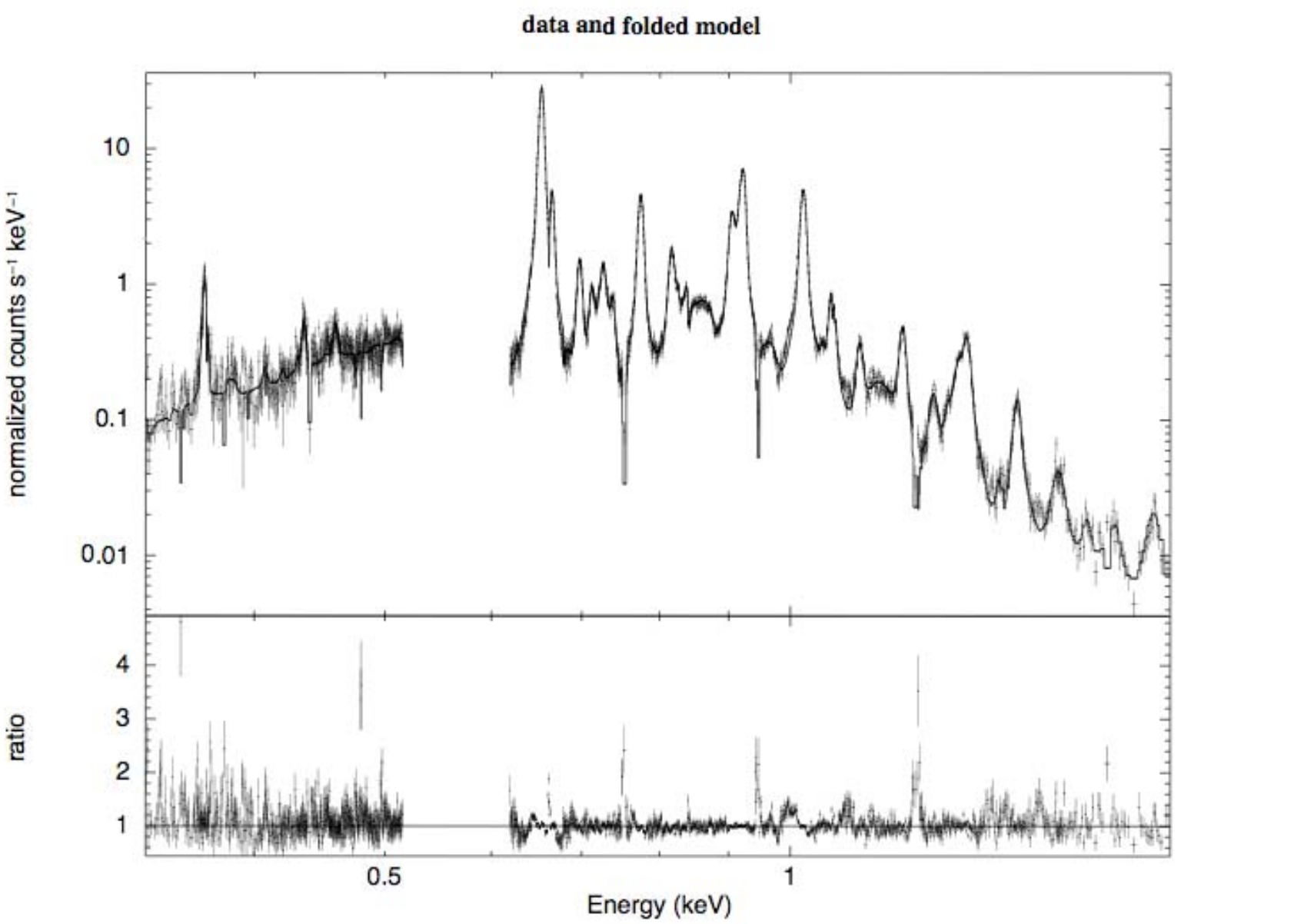
The Long and Arduous Path

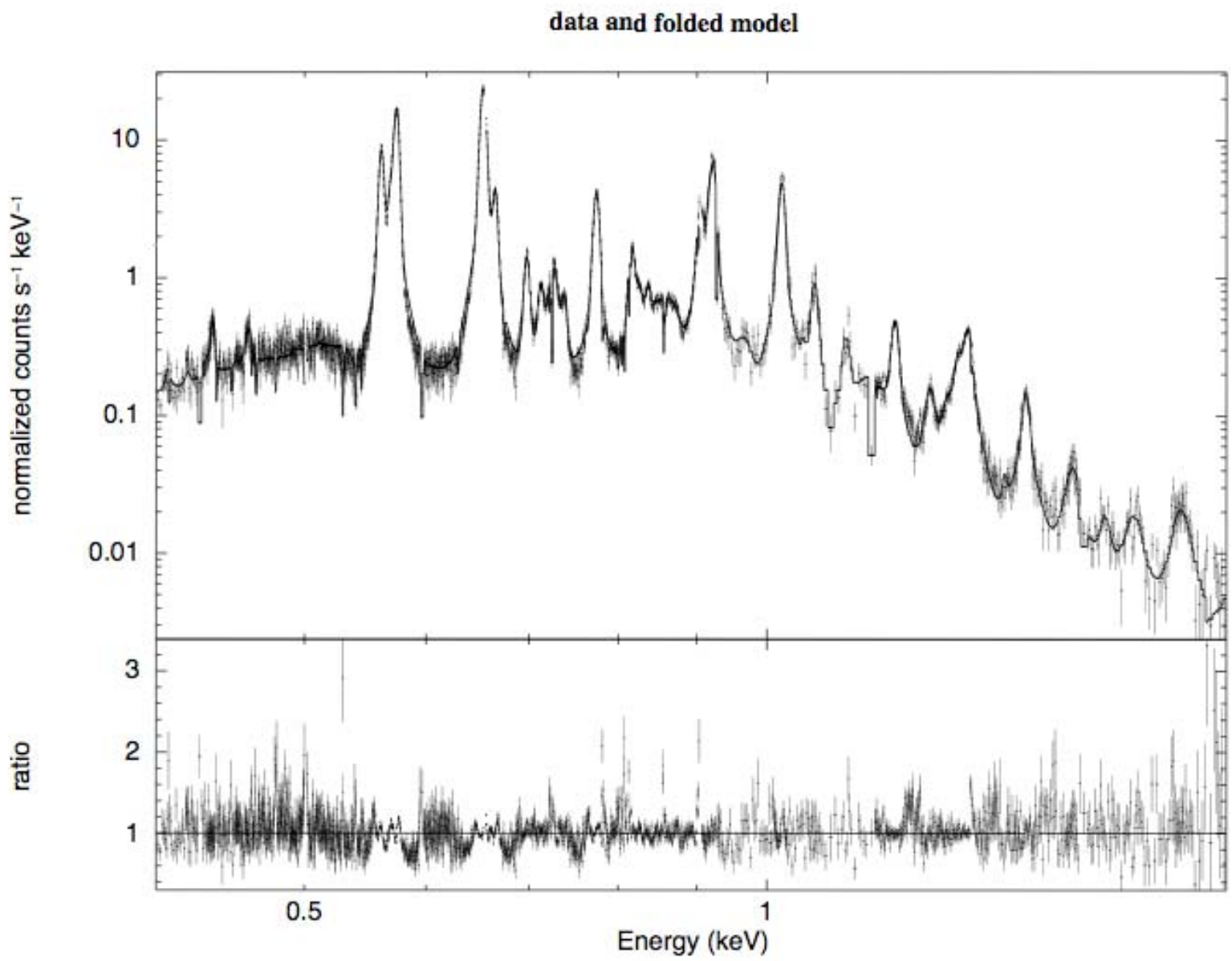
1) RGS and HETG constrain SMC N_H and normalization and temperature of low-temperature APEC no-line continuum
2) MOS, pn, & XIS determine normalization and temperature of high-temperature APEC no-line continuum
3) RGS and HETG determine line fluxes from 0.3-2.0 keV

   RGS 2 fits (Haberl MPE):
   - SMC $N_H = 5.76 \times 10^{20}$ cm^{-2}
   - low T APEC no-line continuum kT = 0.16 keV
   - high T APEC no-line continuum kT = 1.74 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?

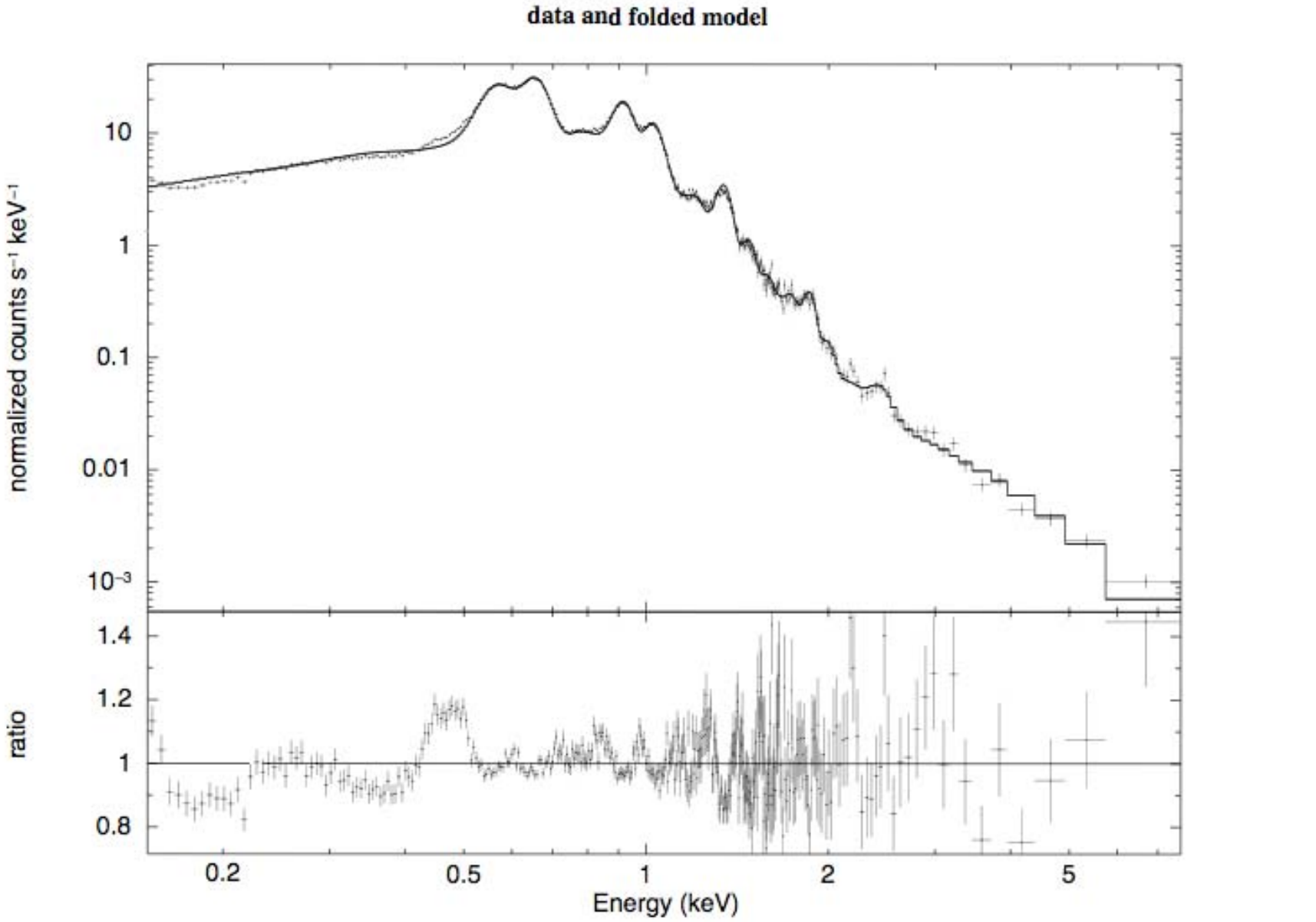
Compare RGS model to pn data, Haberl (MPE)




data and folded model
normalized counts s⁻¹ keV⁻¹
10
1
0.1
0.01
ratio
4
3
2
1
0.5
1
Energy (keV)
fwh 21-May-2008 09:45


data and folded model
normalized counts s^{-1} keV^{-1}
10
1
0.1
0.01
ratio
3
2
1
0.5
1
Energy (keV)
fwh 21-May-2008 09:42

J



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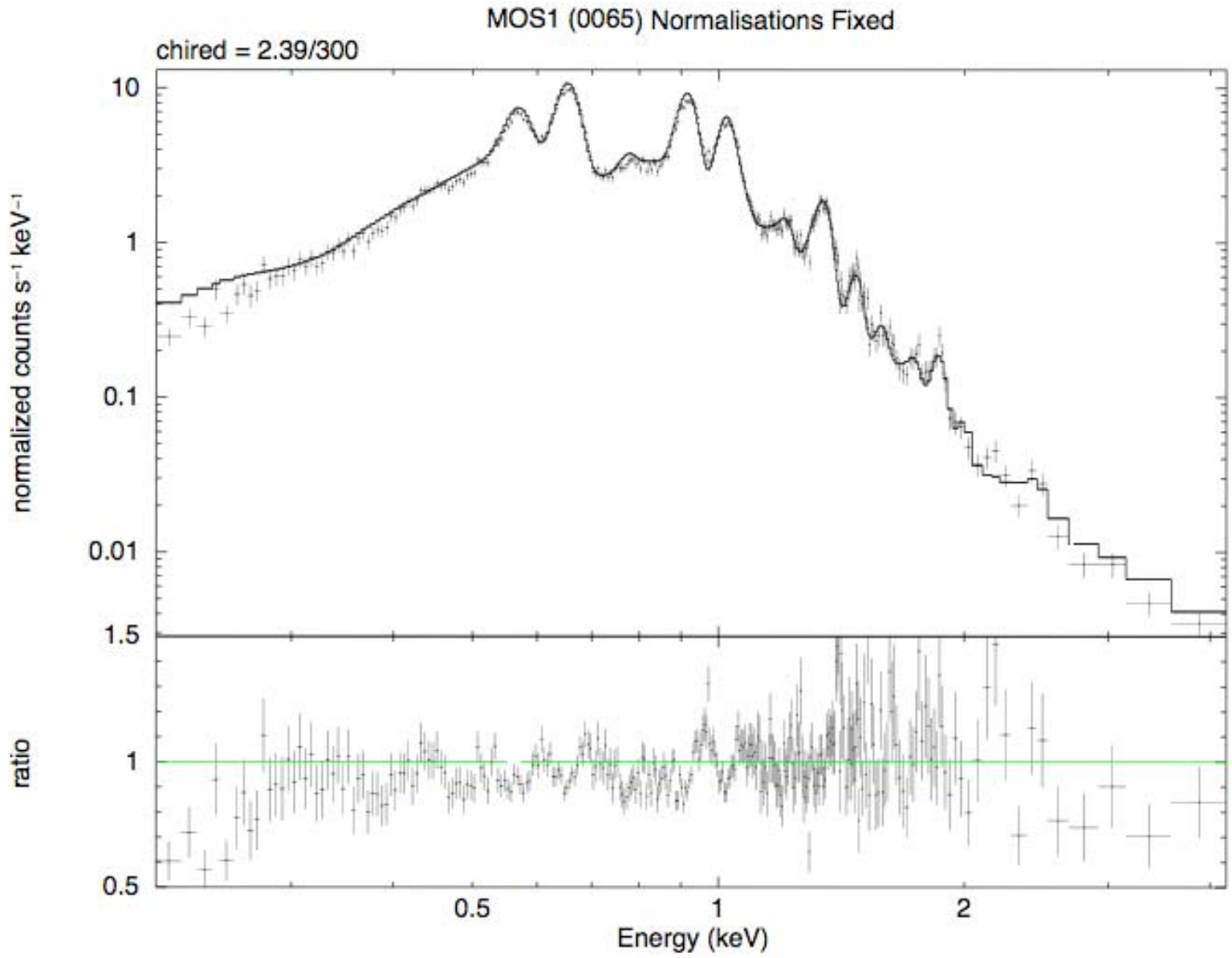
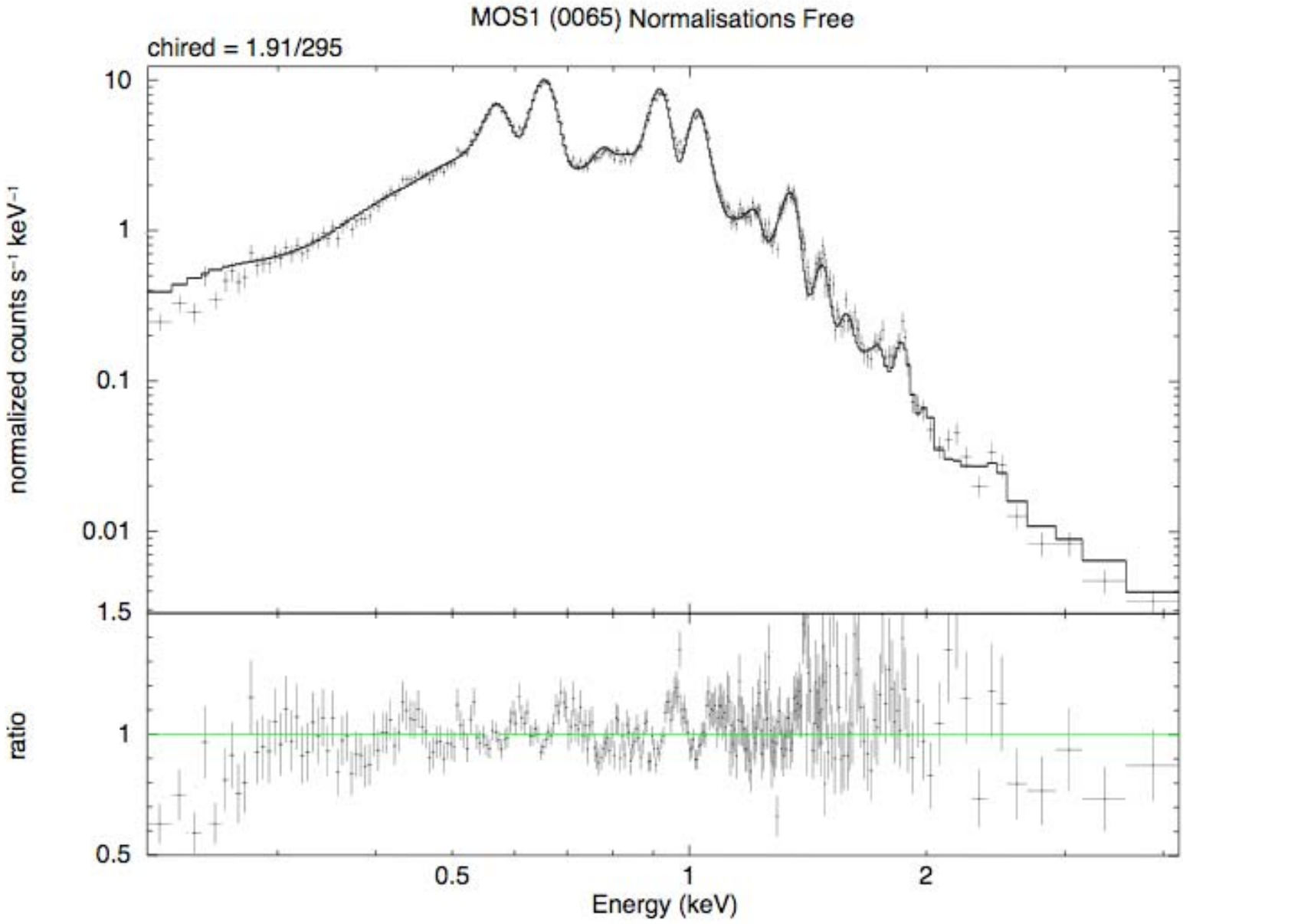
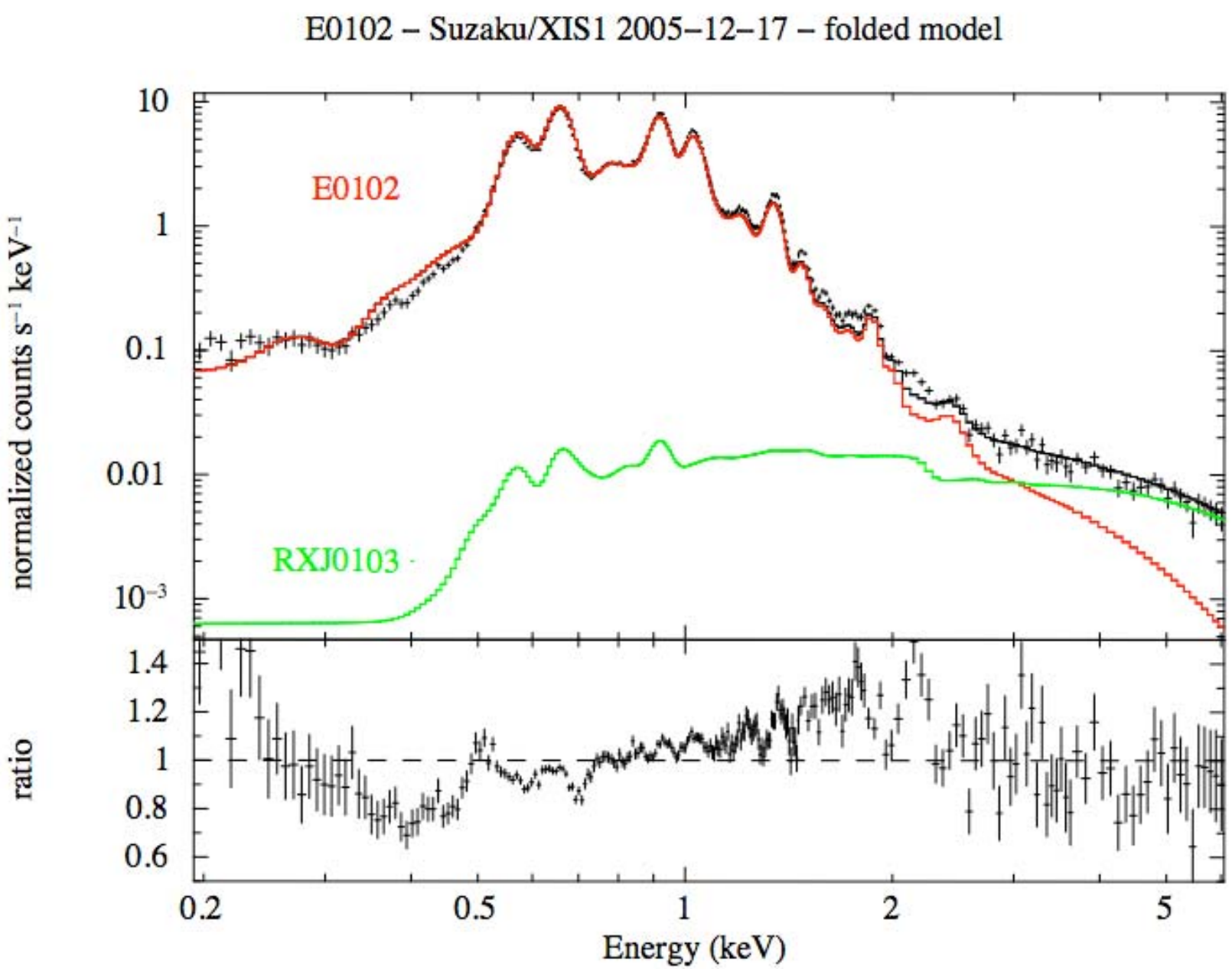
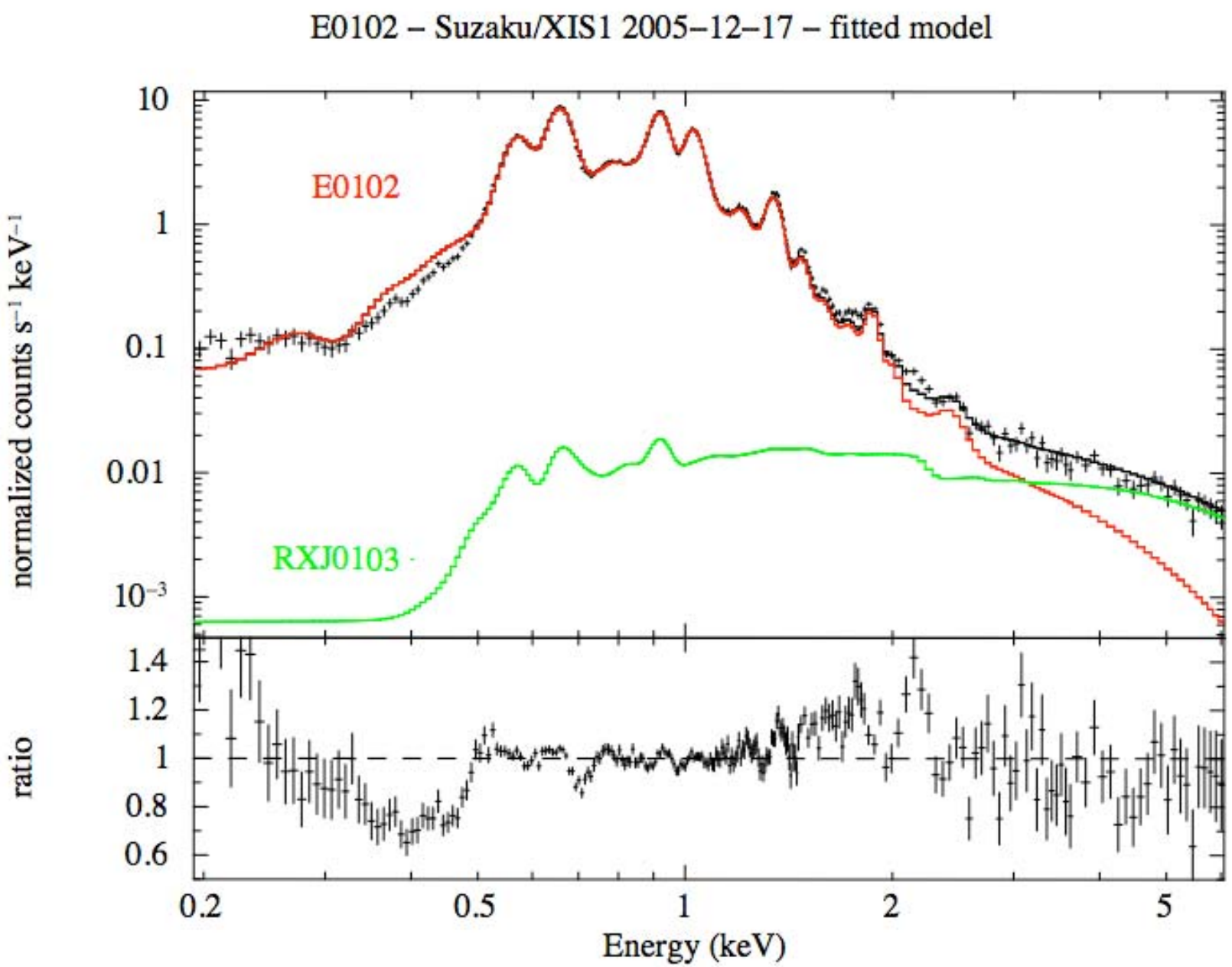
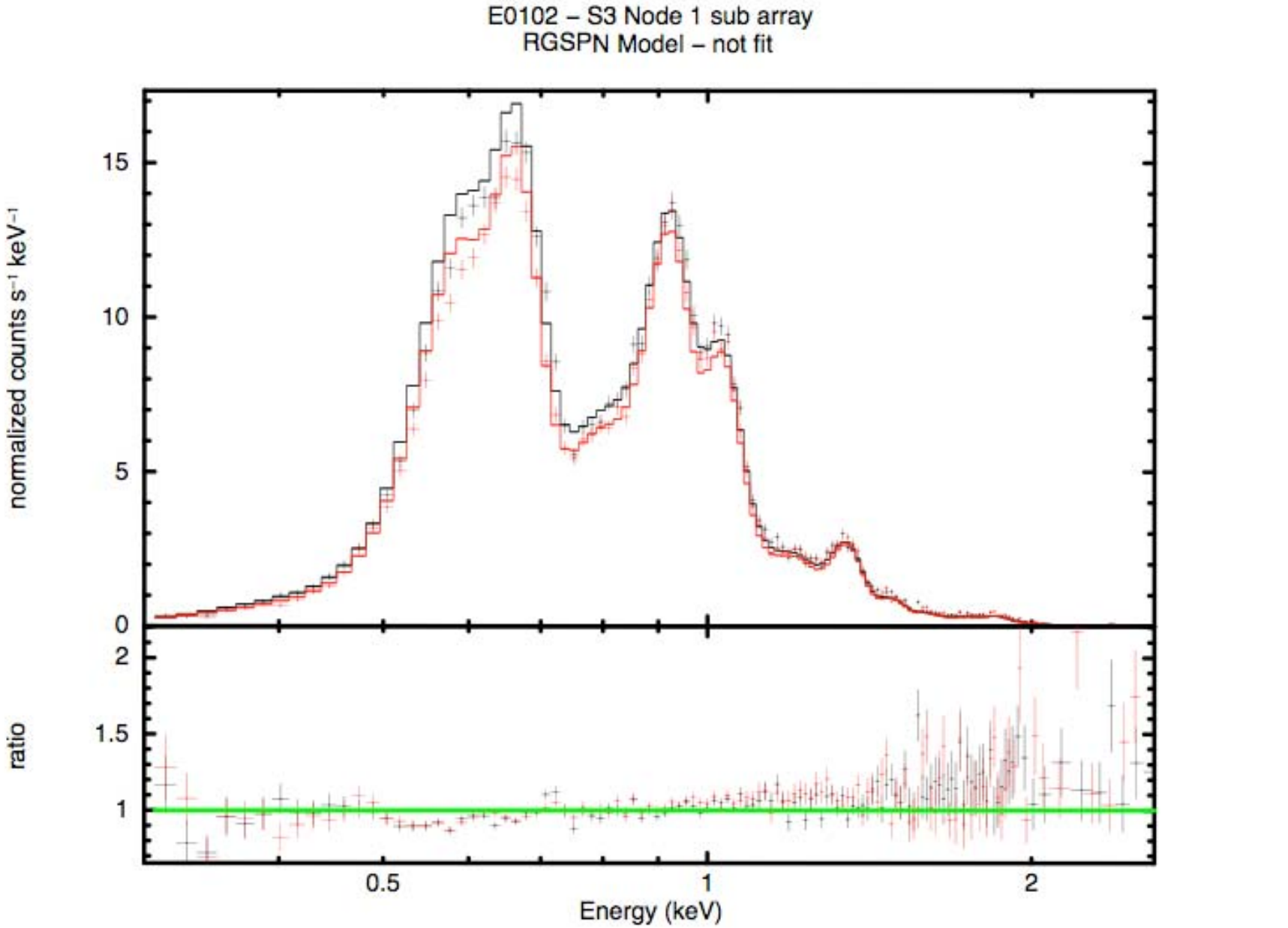

MOS1 (0065) Normalisations Fixed
chired = 2.39/300
normalized counts s⁻¹ keV⁻¹
10
1
0.1
0.01
1.5
1
0.5
ratio
0.5
1
2
Energy (keV)
sfs5 20-May-2008 16:22

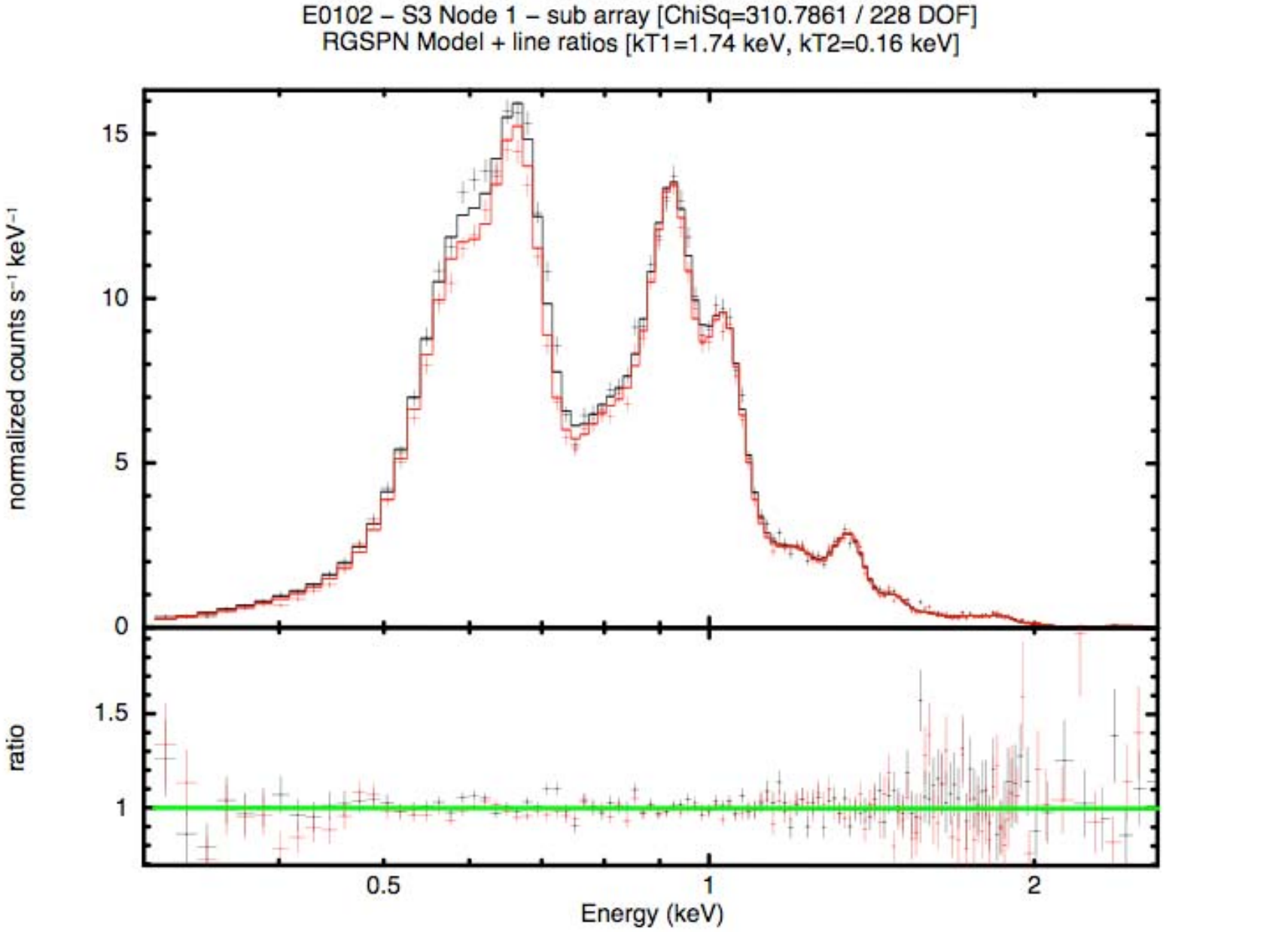
J


MOS1 (0065) Normalisations Free
chired = 1.91/295
normalized counts s⁻¹ keV⁻¹
10
1
0.1
0.01
1.5
1
0.5
ratio
0.5
1
2
Energy (keV)
sfs5 20-May-2008 16:25


E0102 – Suzaku/XIS1 2005–12–17 – folded model
E0102
RXJ0103
normalized counts s^{-1} keV^{-1}
ratio
Energy (keV)
10
1
0.1
0.01
10^{-3}
1.4
1.2
1
0.8
0.6
0.2
0.5
1
2
5


E0102 – Suzaku/XIS1 2005–12–17 – fitted model
E0102
RXJ0103
normalized counts s^{-1} keV^{-1}
ratio
Energy (keV)
10
1
0.1
0.01
10^{-3}
1.4
1.2
1
0.8
0.6
0.2
0.5
1
2
5


E0102 – S3 Node 1 sub array
RGSPN Model – not fit
normalized counts s⁻¹ keV⁻¹
15
10
5
0
ratio
2
1.5
1
0.5
1
2
Energy (keV)
jcsephdepasquale 20–May–2008 17:12



josephdepasquale 20–May–2008 17:09

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

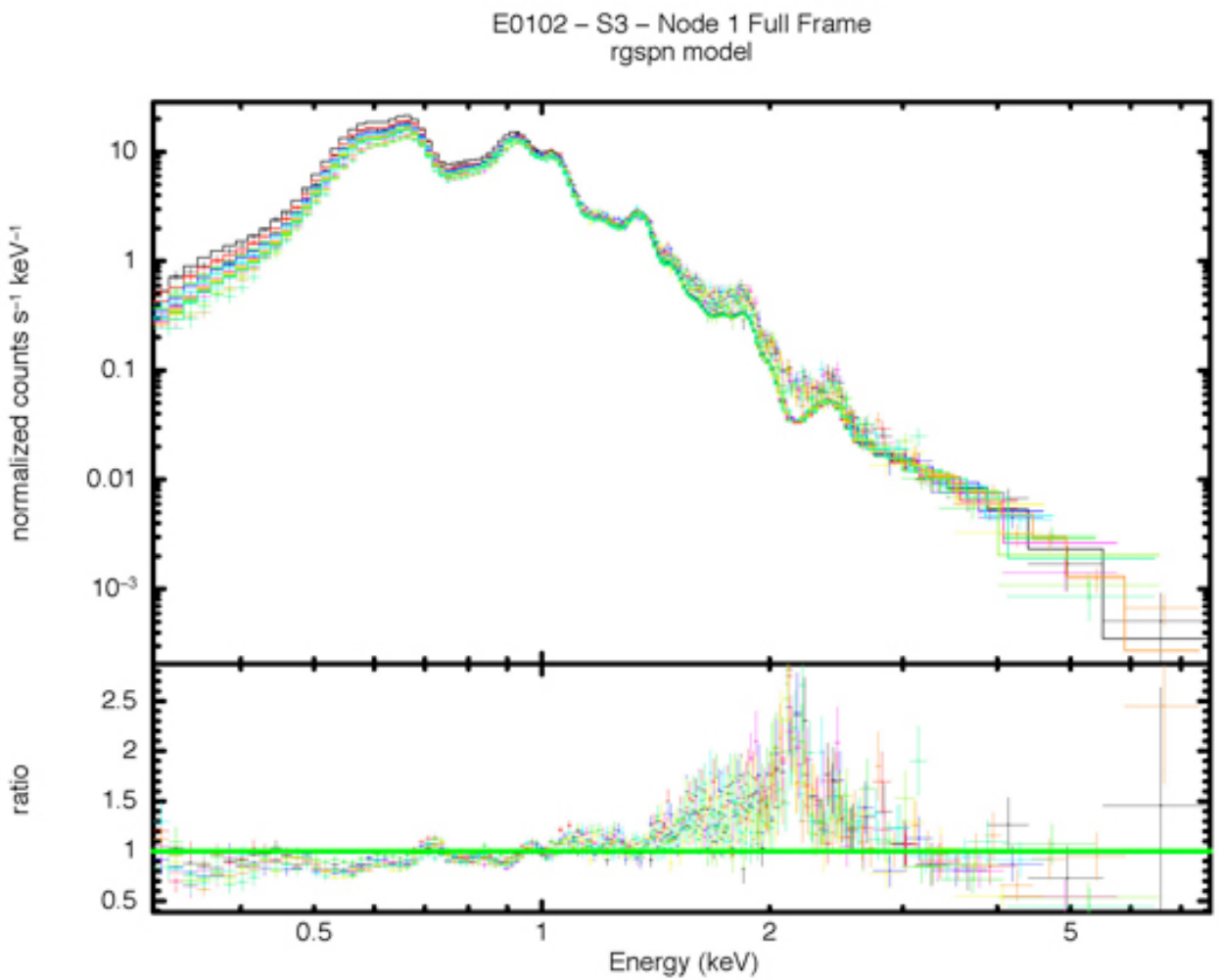
Instrument	Chi Sq	DOF
XMM: RGS 2	2.53	1853
XMM: RGS 1	2.85	1822
XMM: pn	3.58	365
XMM: MOS 1	1.91	295
XMM: MOS 2	2.08	295
Suzaku: XIS	5.95	246
Chandra: ACIS-S3	1.53	250

What is Next?

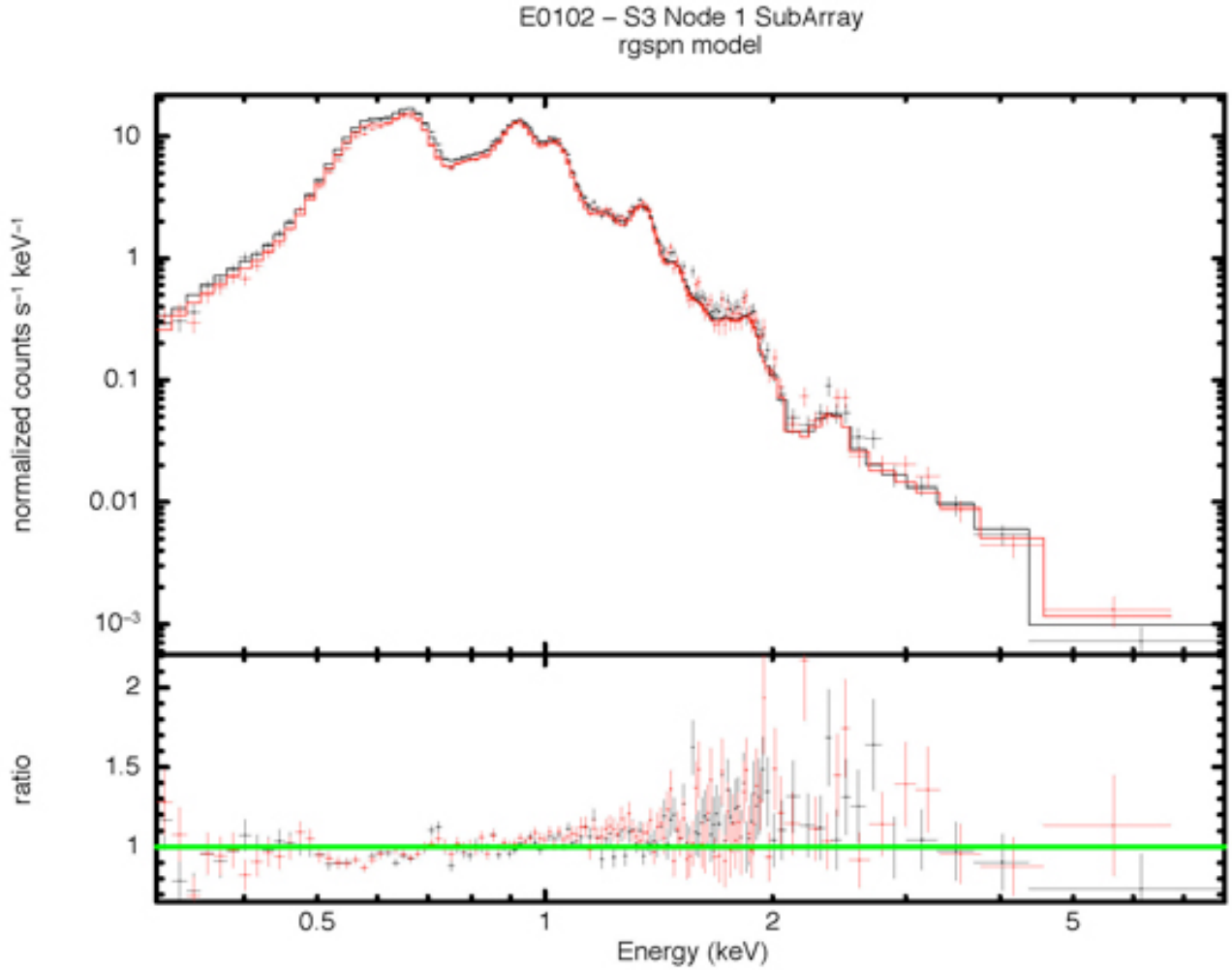
1) Further refine the model and distribute the final definitive model to the group
   - Still need HETG agreement on RGS-derived line fluxes
     - total counts agree within 4% (D/M ratio)
   - SPIE paper currently under construction, will be presented next month
   - submit a paper on this work to a 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



Pileup is an Issue for ACIS



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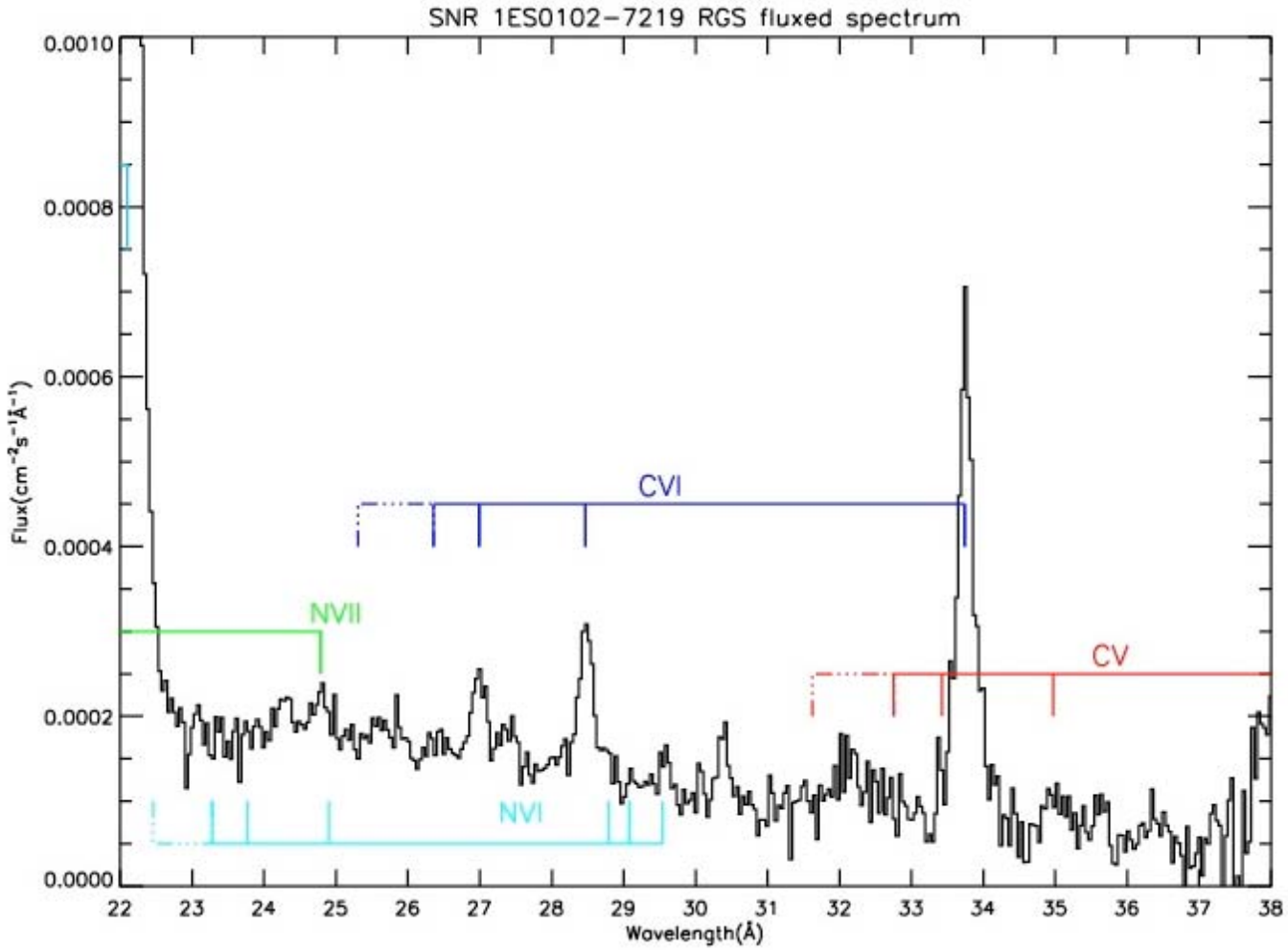
   - Pileup!
3) Report at next year's IACHEC meeting

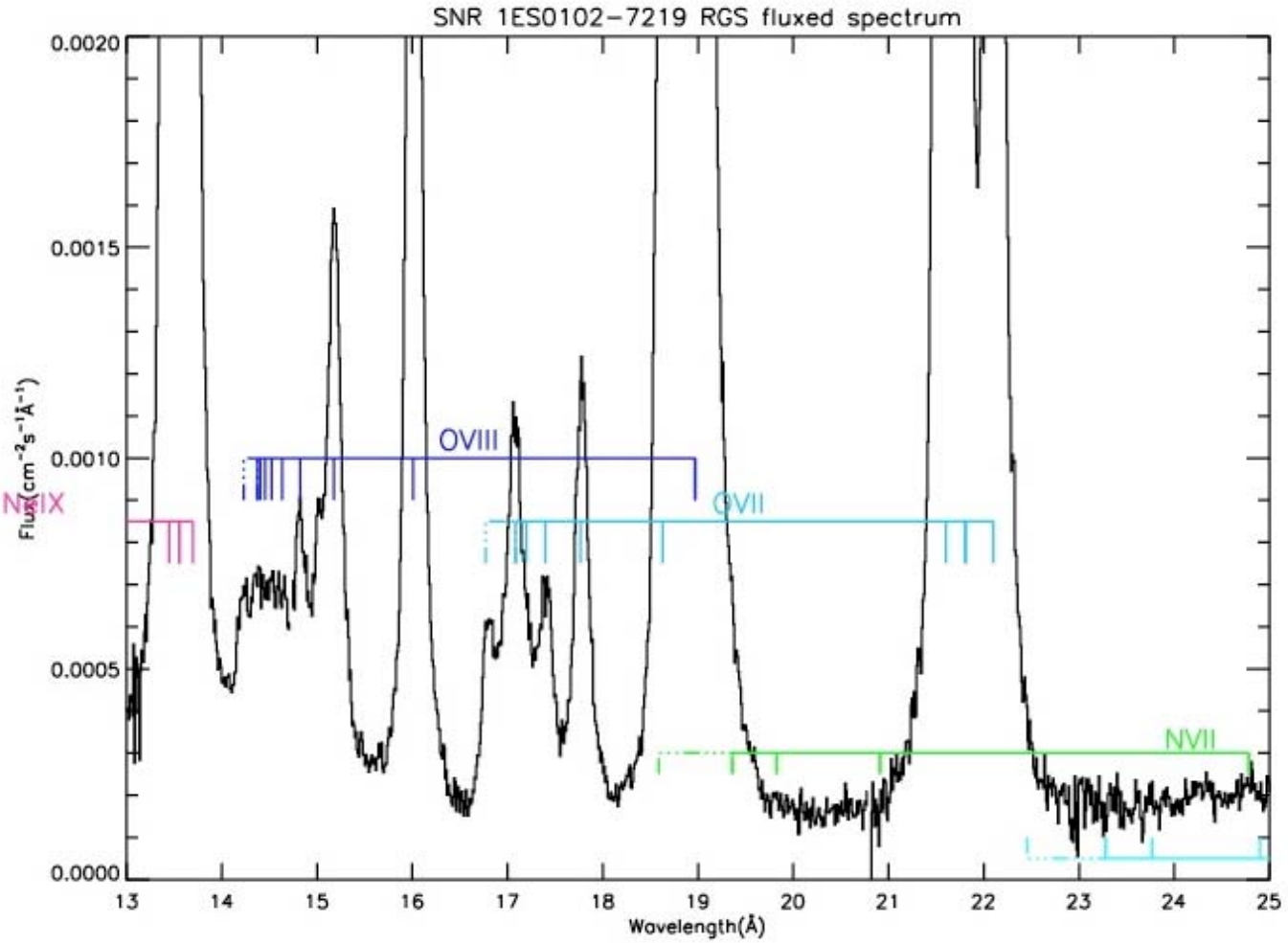
How Can the Gratings Constrain the Line Parameters ?

RGS spectra 22-38 A from Pollock (ESAC)



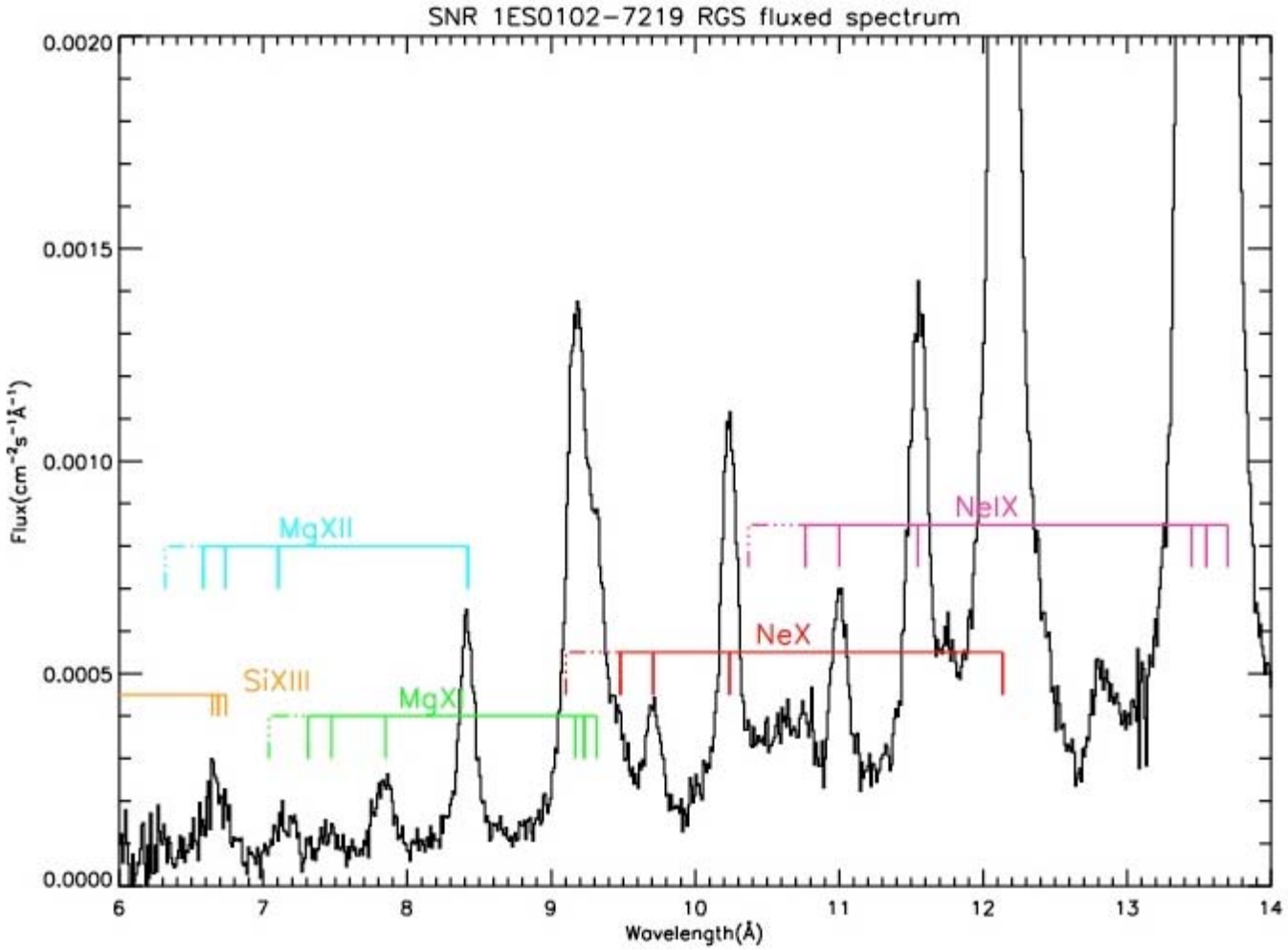
How Can the Gratings Constrain the Line Parameters ?

RGS spectra 13-25 A from Pollock (ESAC)

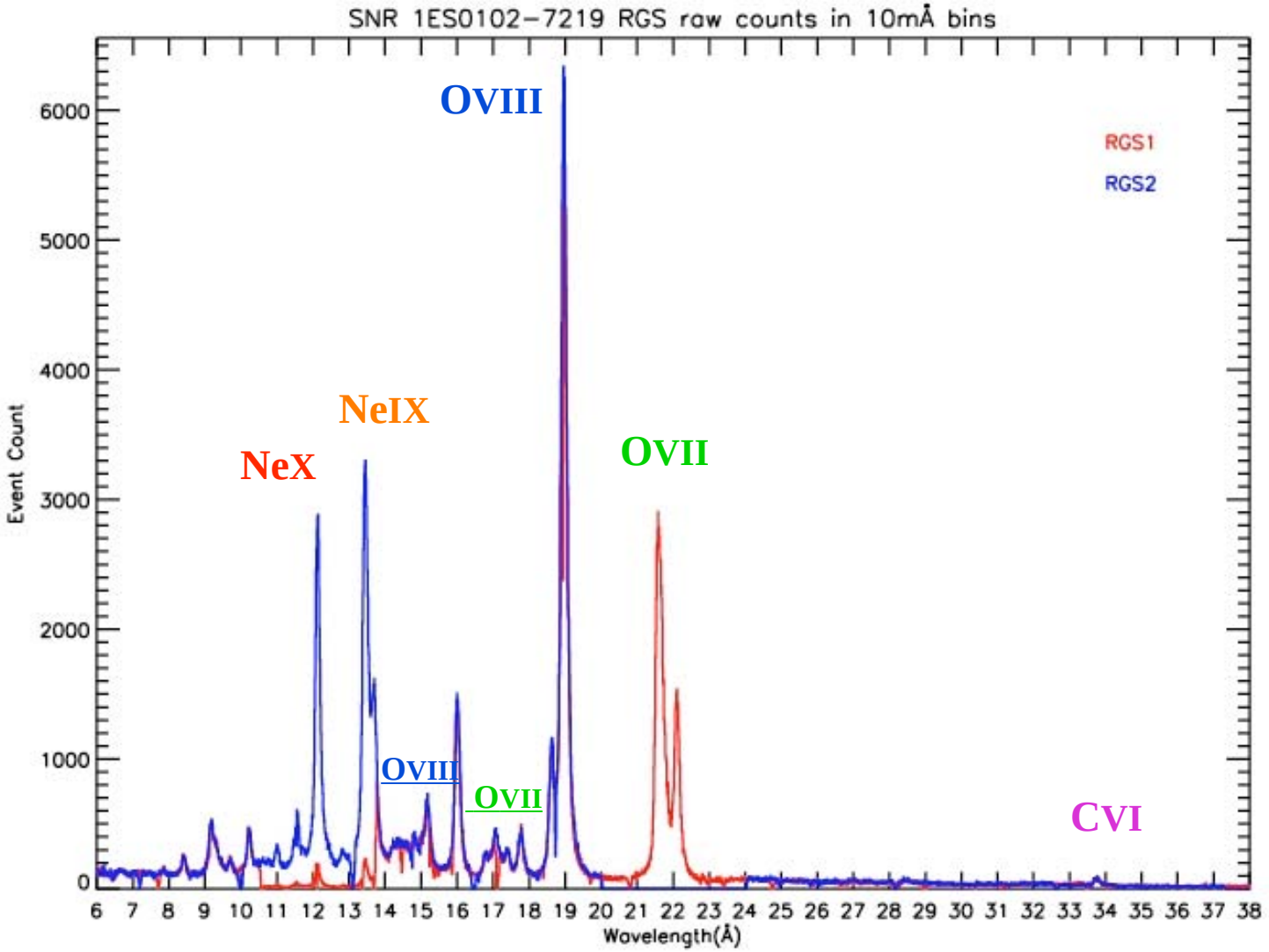


How Can the Gratings Constrain the Line Parameters ?

RGS spectra 6-14 A from Pollock (ESAC)



RGS Spectrum of E0102, Pollock (ESAC):



little or no Fe emission