



## 1E0102.2-7219 as a Standard Candle for X-ray Astronomy

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## Why Use E0102 as a Calibration Source for X-ray Astronomy?

- Well-characterized spectrum, both the Chandra HETG and XMM RGS have observed the object
- The spectrum is relatively simple by astrophysical standards, no or very little Fe, strong lines of O, Ne, and Mg
- Extended source so pileup effects are minimized
- Constant source
- The O and Ne lines sample an energy range in which the on-board calibration source does not have strong lines
- Low-energy part of the bandpass is always a challenge to calibrate

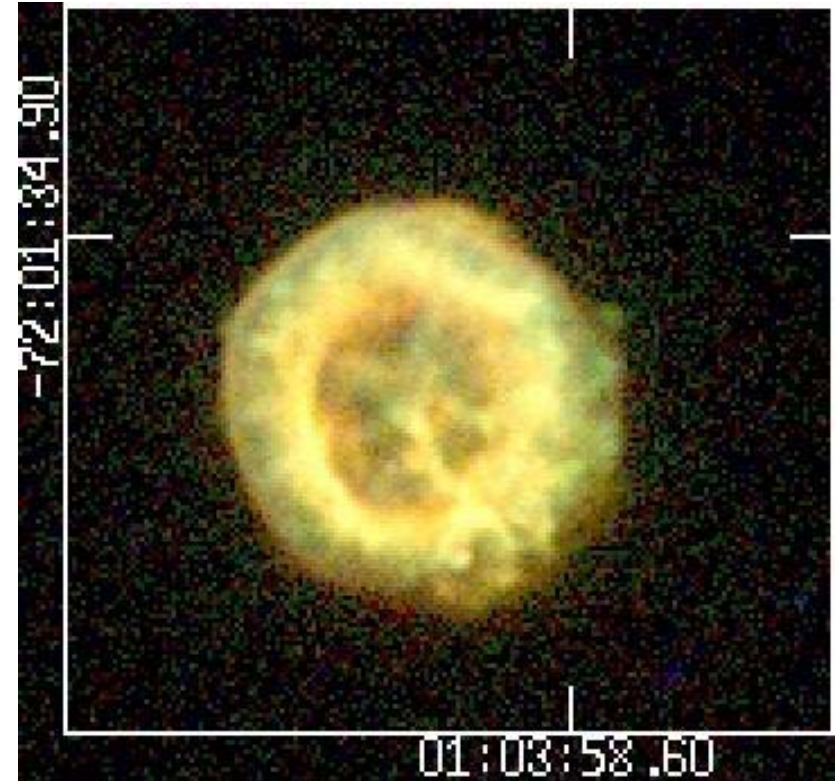
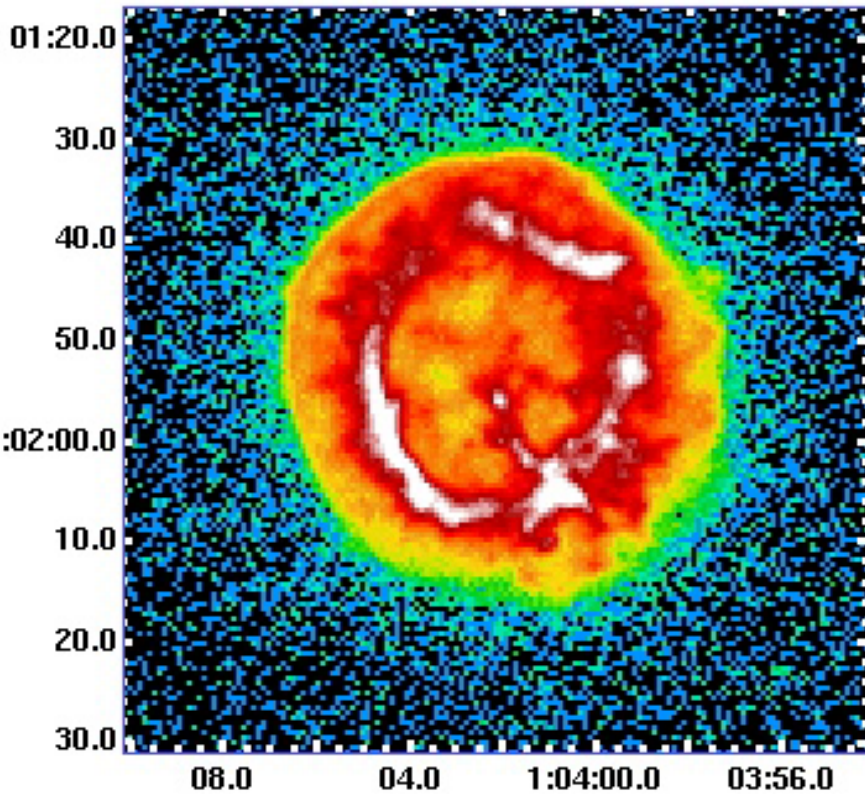
*We are VERY close to agreeing on the model spectrum !!!*



## Gratuitous Pretty Pictures of E0102

S3 Summed Data ~100 ks

True Color Image





## Spectral Model: Calibration vs. Astrophysics

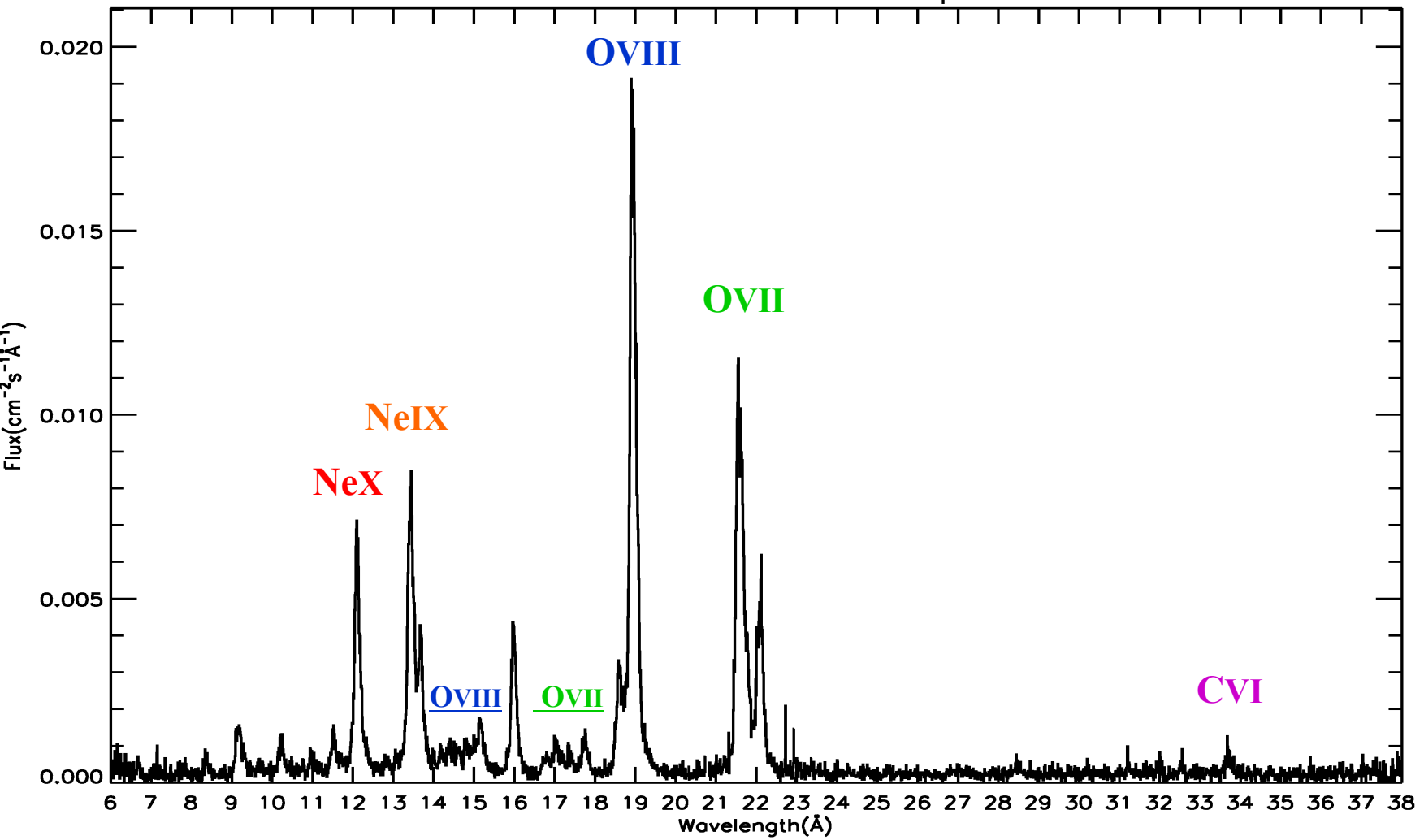
- **Primary Objectives are to measure the gain, the spectral redistribution function, and detection efficiency in the 0.5 -2.0 keV range**
- **Our immediate concern is to develop a model useful for calibration, not to develop an astrophysically-meaningful model,**
- **We use a model consisting of Gaussians for the lines identified by the HETG and RGS, a bremsstrahlung for the continuum, and a two component absorption (Galactic and SMC)**
- **Line energies are fixed at the true values and the widths of the Gaussians are fixed at zero, so the only parameter which varies is the normalization**
- **Pollock has added recombination edges to the RGS model and has non-zero widths for some of the lines**
- **When fitting CCD spectra, ratios of the F-I-R lines in a triplet are fixed to the RGS and/or HETG value**



# Chandra X-Ray Observatory

CXC

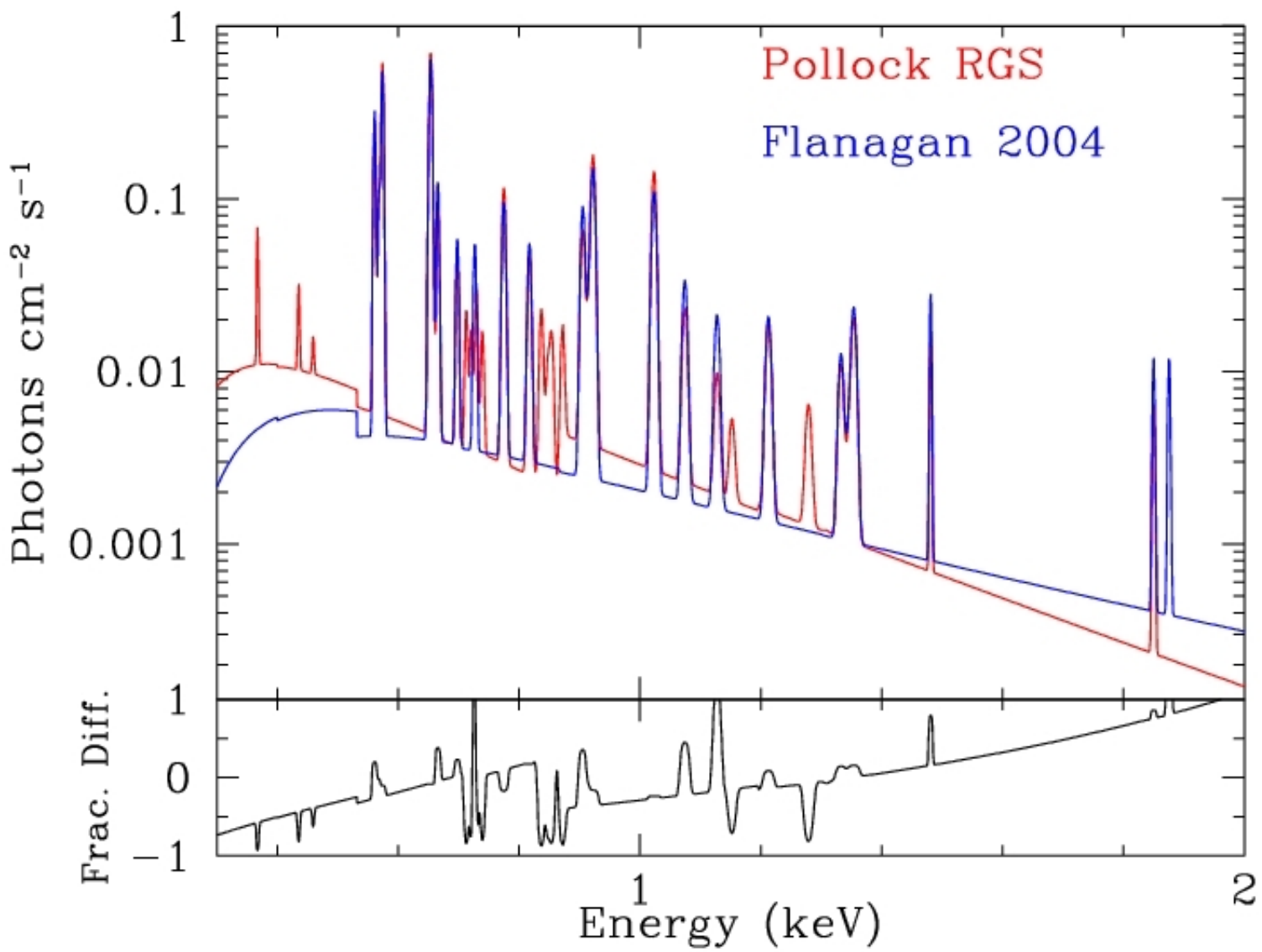
RGS Spectrum from Dollock  
SNR 1ES0102-7219 RGS fluxed spectrum





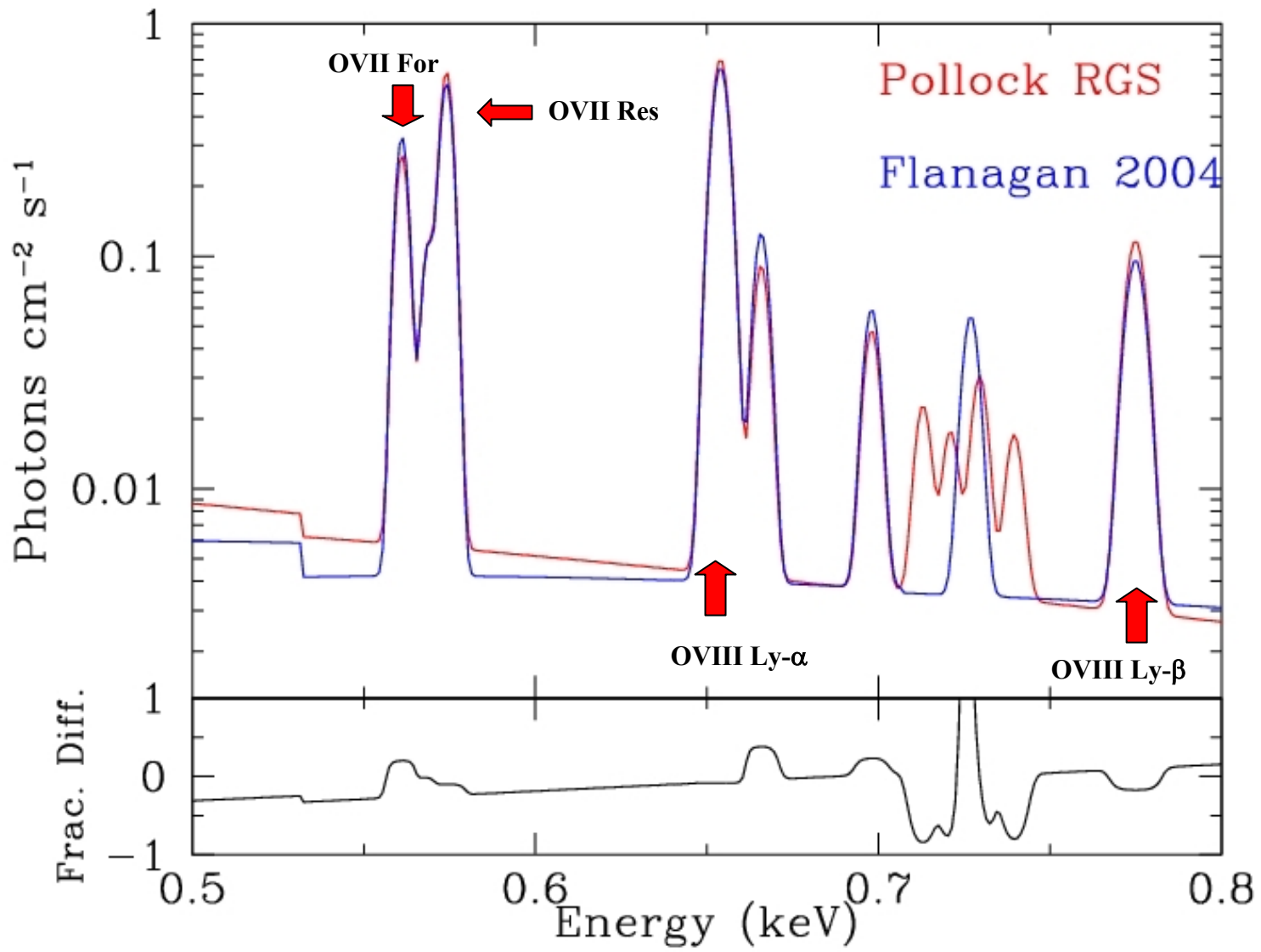
## Pollock RGS vs. Flanagan (2004) HETG

Adopt  
line  
widths  
from  
Pollock



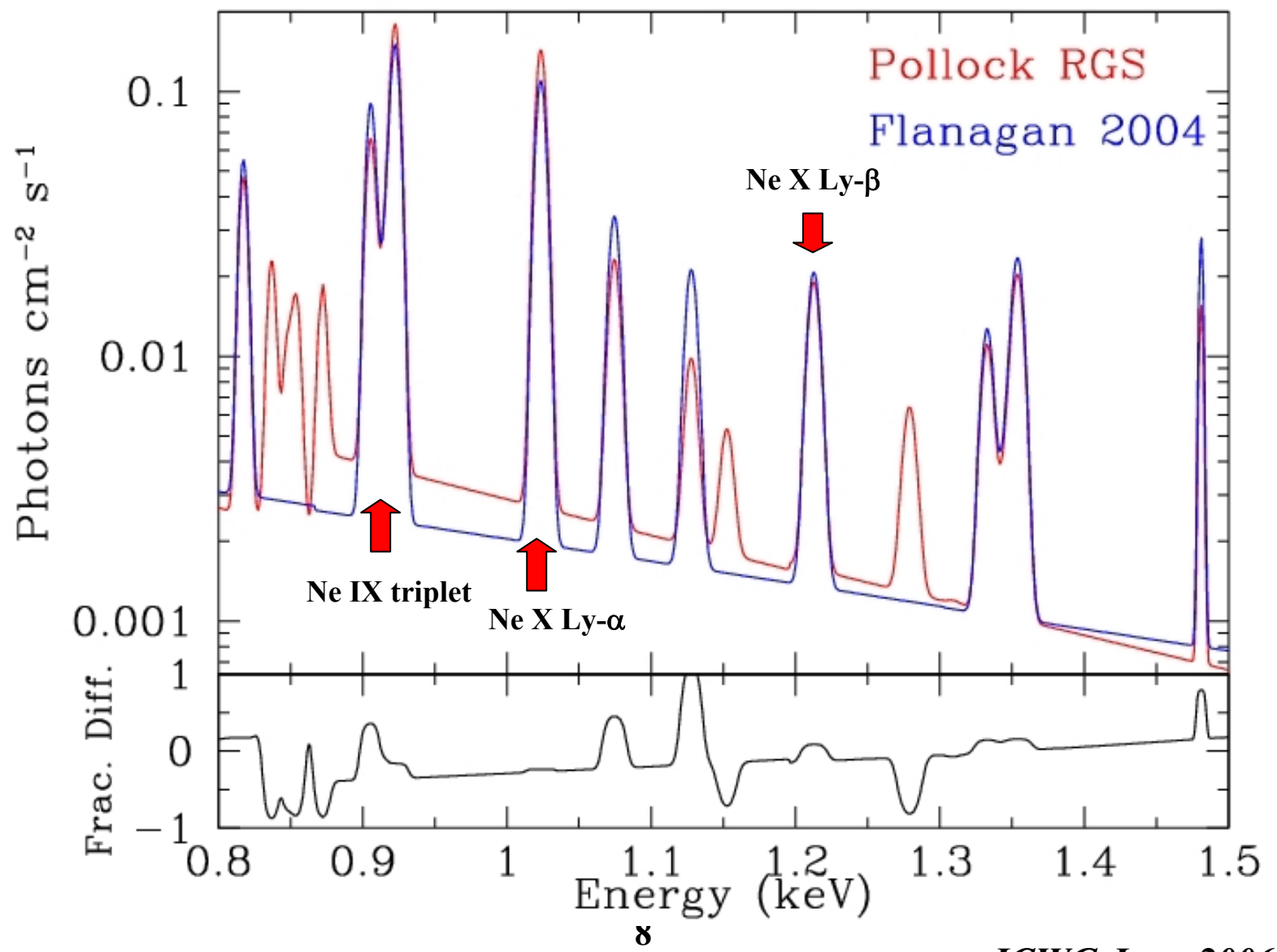


## Pollock RGS vs. Flanagan (2004) HETG (O line region)





## Pollock RGS vs. Flanagan (2004) HETG (Ne line region)



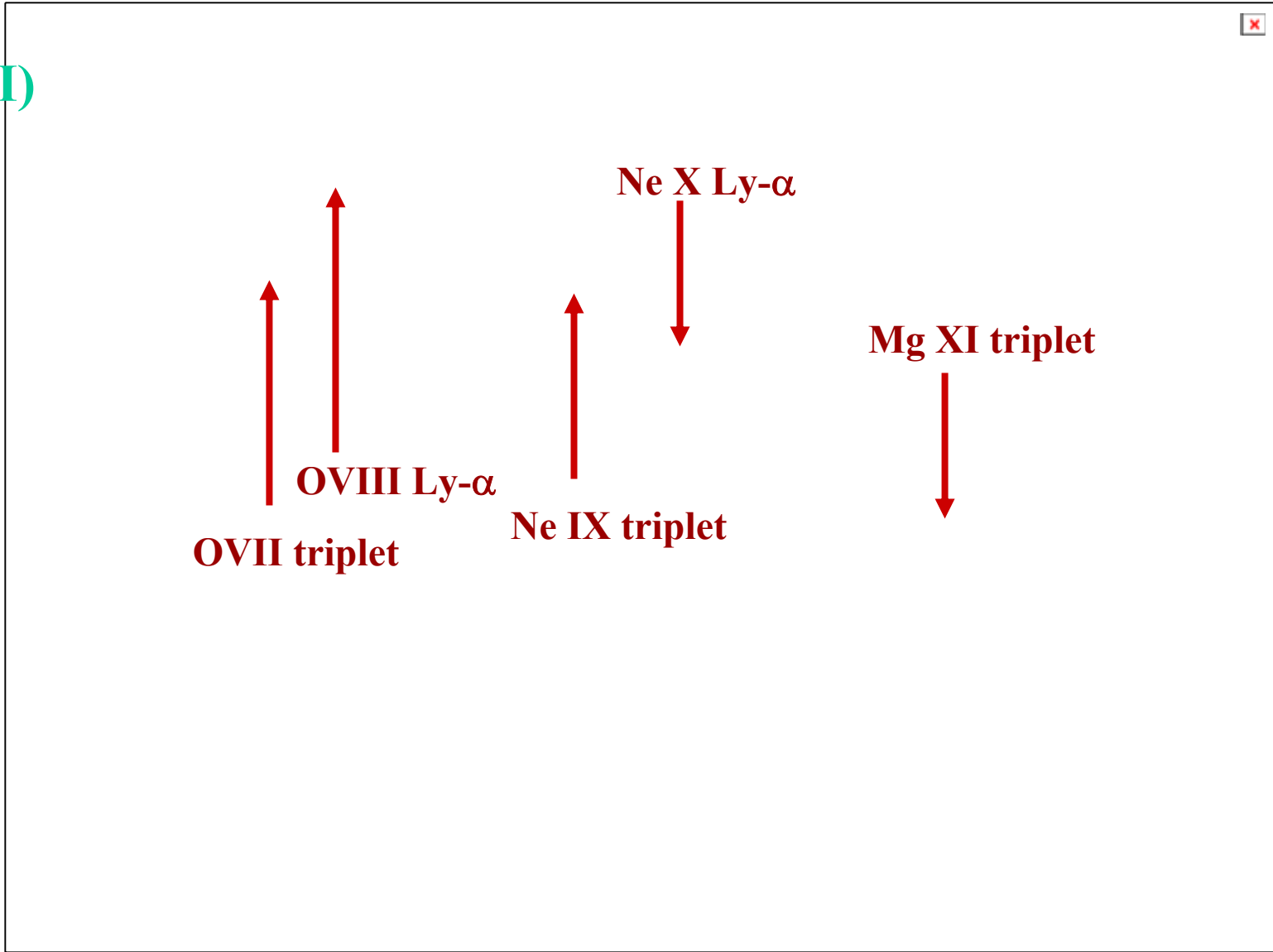


## Pollock RGS vs. Flanagan (2004) HETG Line Fluxes

Line	Flanagan Flux ( $10^{-4}$ photons $\text{cm}^{-2}$ $\text{s}^{-1}$ )	Pollock Flux ( $10^{-4}$ photons $\text{cm}^{-2}$ $\text{s}^{-1}$ )	Difference
OVII For	13.95	11.53	+17.3%
OVII Res	24.38	27.23	-11.7%
O VIII Ly- $\alpha$	37.31	40.65	-8.9%
O VIII Ly- $\beta$	6.37	7.78	-15.9%
Ne IX triplet	23.18	21.15	+8.8%
Ne X Ly- $\alpha$	9.72	12.70	-30.7%
Ne X Ly- $\beta$	2.07	1.87	+9.7%

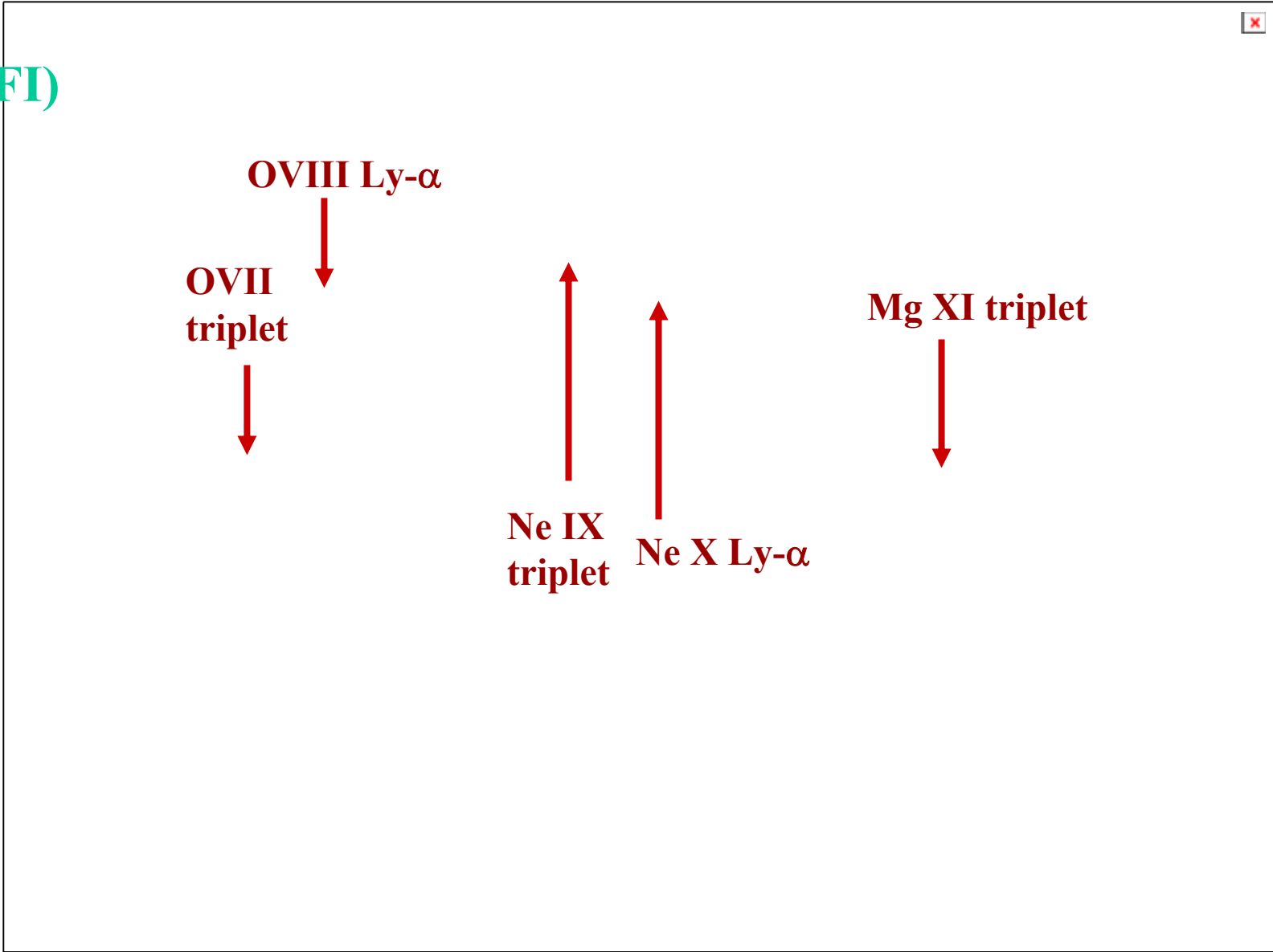


S3(B1)





I3(FI)

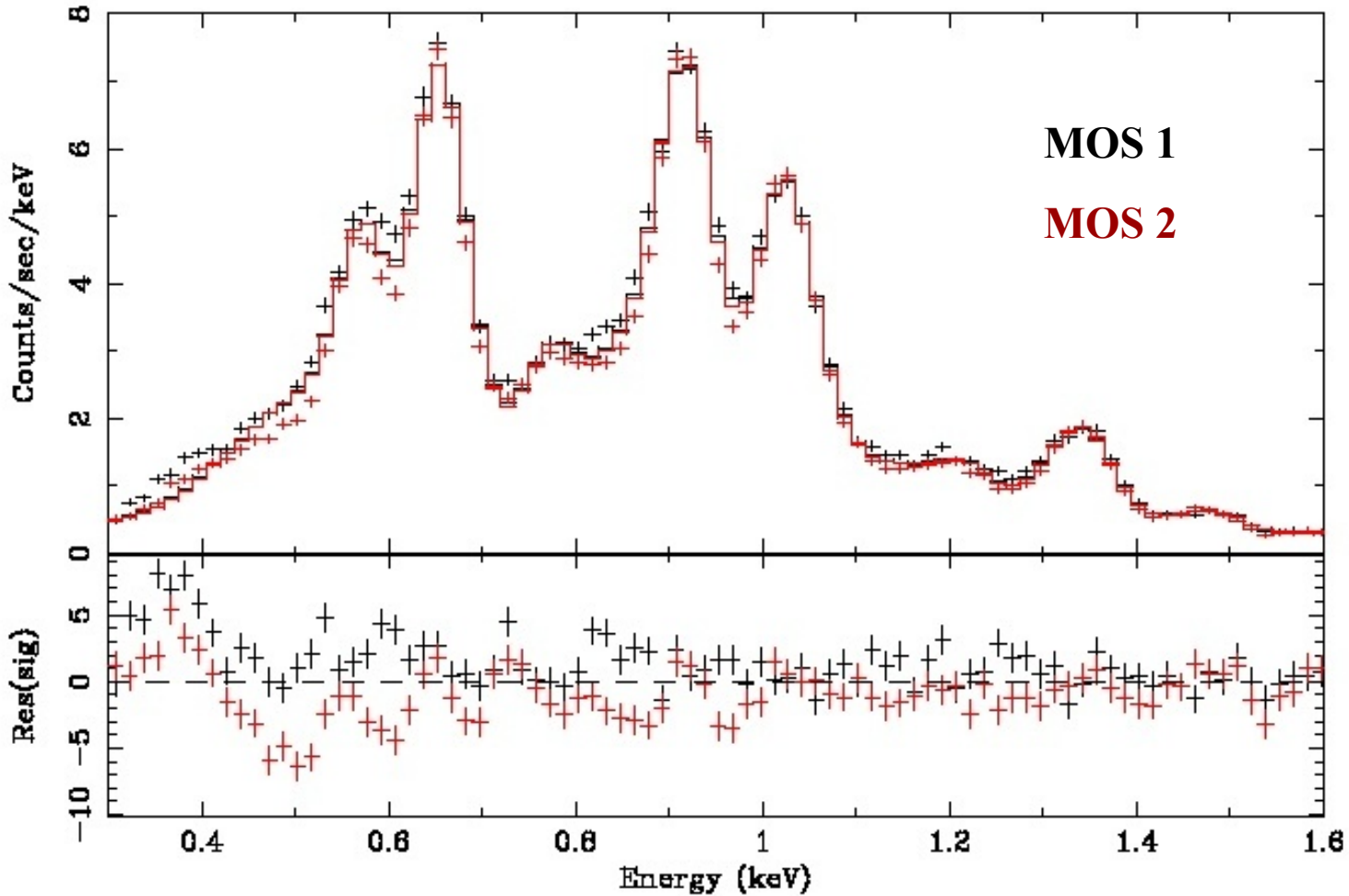




Thick Filter

Large Window

OBSID 0135722401: E0102, MOS1 & MOS2, linelist model, Red Chi = 5.8  
DOF=215, kT=0.743 keV, Thick Filter, Large Window





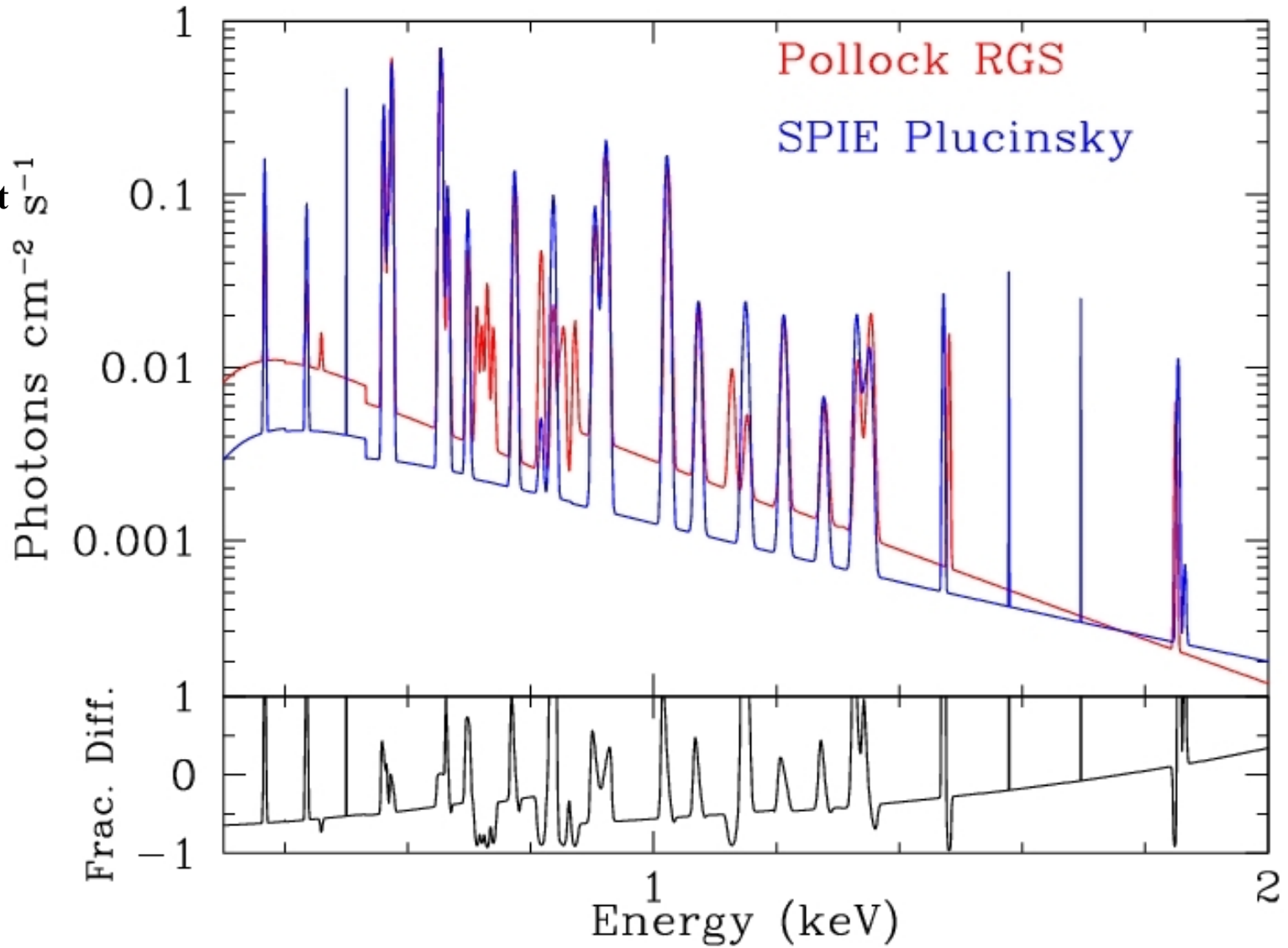
PN  
Thick  
Filter  
Small  
Window





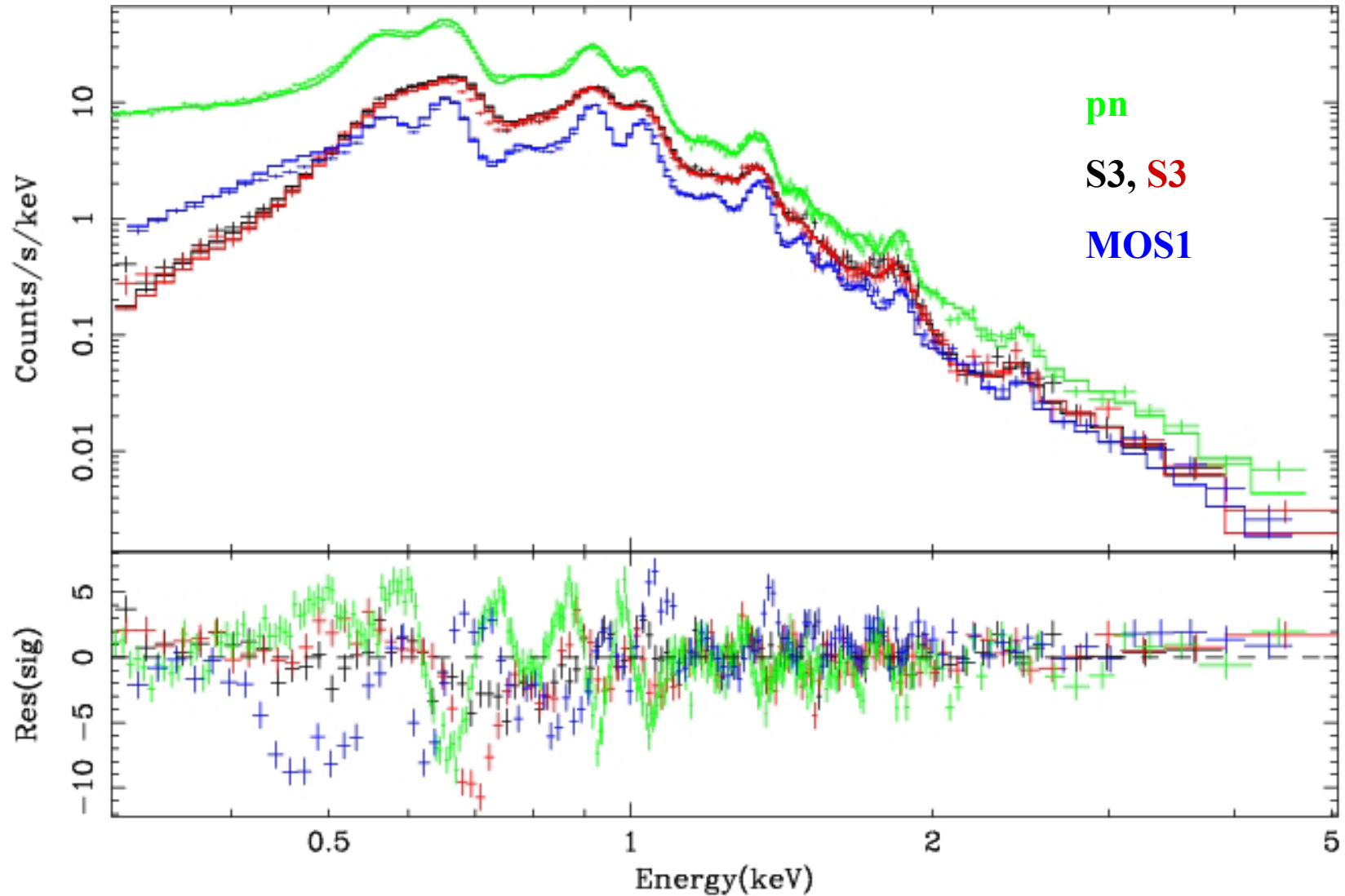
## Pollock RGS vs. SPIE Plucinsky (2006)

Plucinsky  
 Add some lines  
 from Pollock but  
 keeps  
 Bremsstrahlung  
 continuum





## Joint Fit With Line Energies Frozen





**S3: OBSID 3545, Red  $\chi^2=1.27$**

**S3: OBSID 6765, Red  $\chi^2=1.48$**

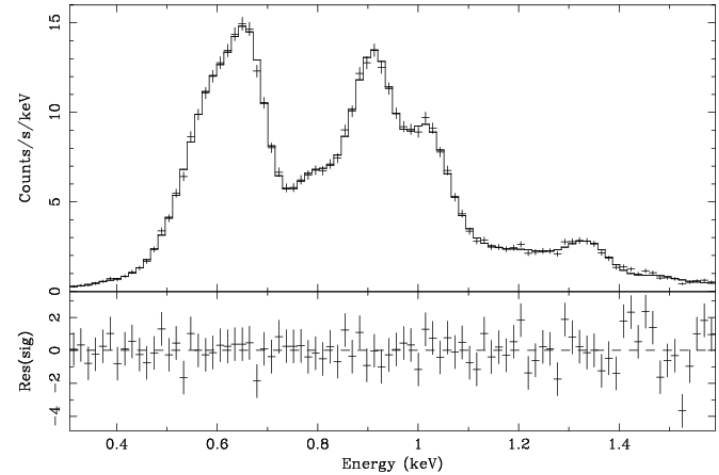
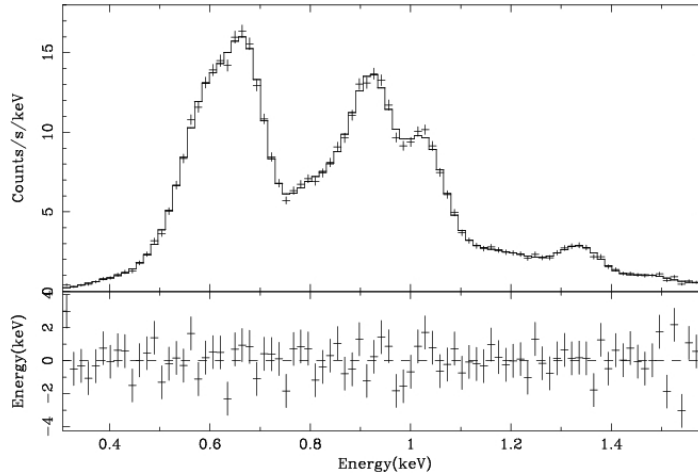
**Independent Fits:**

**SMC NH=5.65  
e20 cm<sup>-2</sup>**

**Bremsstrahlung  
kT=0.95 keV**

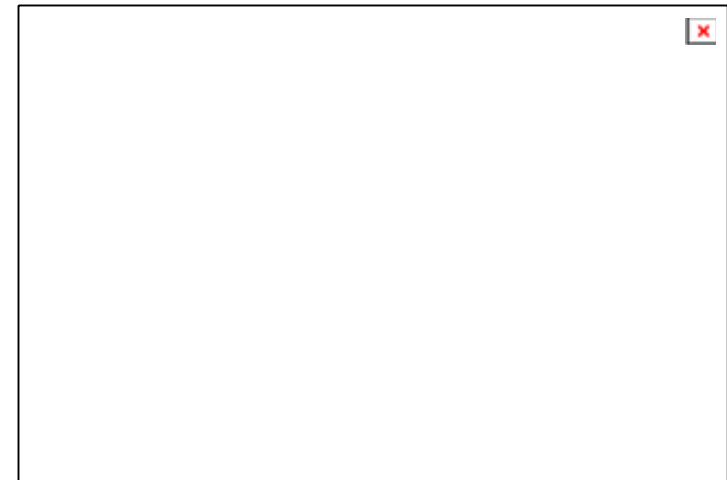
**and Ne line  
complexes  
energies free,**

**Normalizations  
free**



**pn, Red  $\chi^2=2.69$**

**MOS1, Red  $\chi^2=2.51$**





## O VII Ly $\alpha$ and Ne X Ly $\alpha$ Normalization Results

- Data sets fit independently, O and Ne line complexes are free to vary as a group
- SMC NH=5.65x10<sup>20</sup> cm<sup>-2</sup>, Bremsstrahlung kT=0.95 keV

OBSID	Instrument	O VIII Ly $\alpha$ Norm (x 10 <sup>-3</sup> photons cm <sup>-2</sup> s)	Ne X Ly $\alpha$ Norm (x 10 <sup>-3</sup> photons cm <sup>-2</sup> s)	Red $\chi^2$	DOF
3545 [90% CL]	ACIS S3 (node 1)	6.58 [6.44,6.94]	1.80 [1.73,1.88]	1.27	95
6765 [90% CL]	ACIS S3 (node 0)	6.92 [6.79,7.36]	1.77 [1.69,1.84]	1.48	93
0135720801 [90% CL]	pn	6.14 [6.09,6.19]	1.74 [1.72,1.76]	2.69	279
0135720601 [90% CL]	MOS1	6.42 [6.35,6.53]	1.71 [1.68,1.73]	2.51	92

- *Ne X Ly  $\alpha$  normalizations agree within ~6.0% for ACIS, pn, & MOS1*
- *Early S3 and MOS1 agree within ~2.0% for O VIII Ly  $\alpha$  normalizations*
- *Most recent S3 and pn disagree by ~18.0% for O VIII Ly  $\alpha$  normalizations*



## Let's Agree on a Model !!!!!!!

**Purpose:** to improve the low-energy response model of ACIS, MOS and pn CCD instruments

- 1) RGS and HETG agree on flux of bright lines
- 2) RGS and HETG compromise on existence of weak lines
- 3) RGS and HETG agree on widths for the lines
- 4) Select a continuum model and absorption
- 5) HETG team must analyze second epoch observations of E0102
- 6) Fit ACIS, MOS, and pn with the same model