Using 1E 0102.2-7219 and G21.5-0.9 to Cross-Calibrate *Chandra*, *XMM-Newton*, *Suzaku* & *Swift*

Paul Plucinsky on behalf of the IACHEC

International Astronomical Consortium for High Energy Calibration

www.iachec.org Next meeting is 12-15 April, 2010 Woods Hole, MA, USA

Thermal SNR Working Group

One of the "Standard candle" working groups.

This presentation is a summary report of this group's work:

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

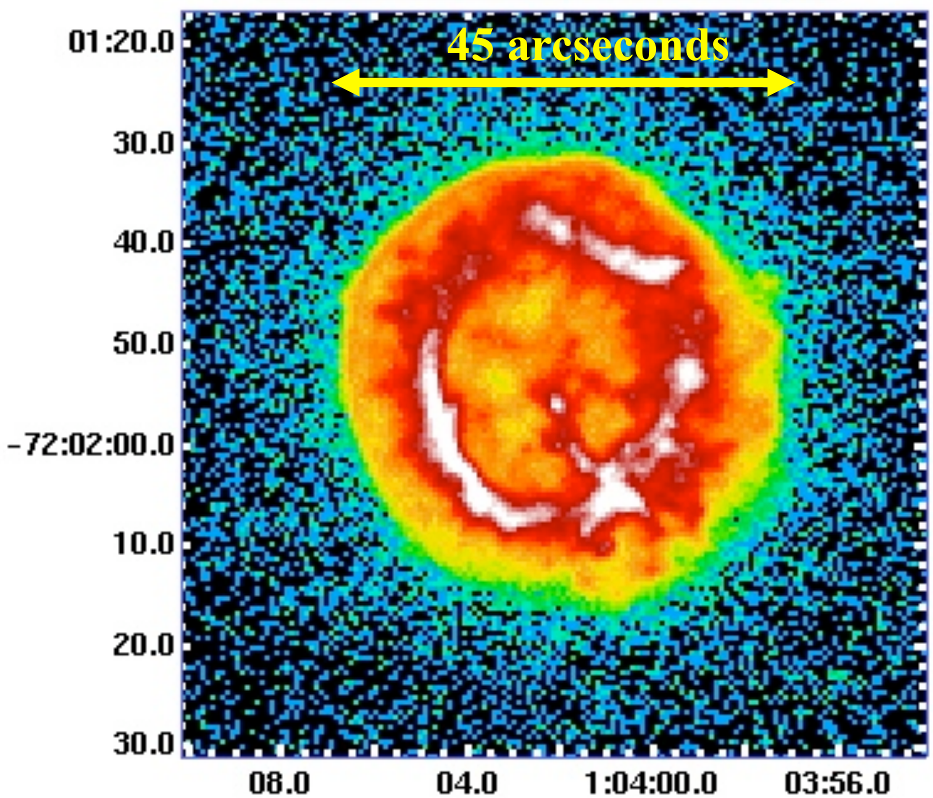
Plucinsky et al., 2008 SPIE, Vol. 7011, arXiv:0807.2176

1E 0102.2-7219

- Young (~1,000-2,000 yr) SNR in the SMC (D~61 kpc), classified as “O-rich” SNR
- Relatively simple morphology, but significant spectral variations

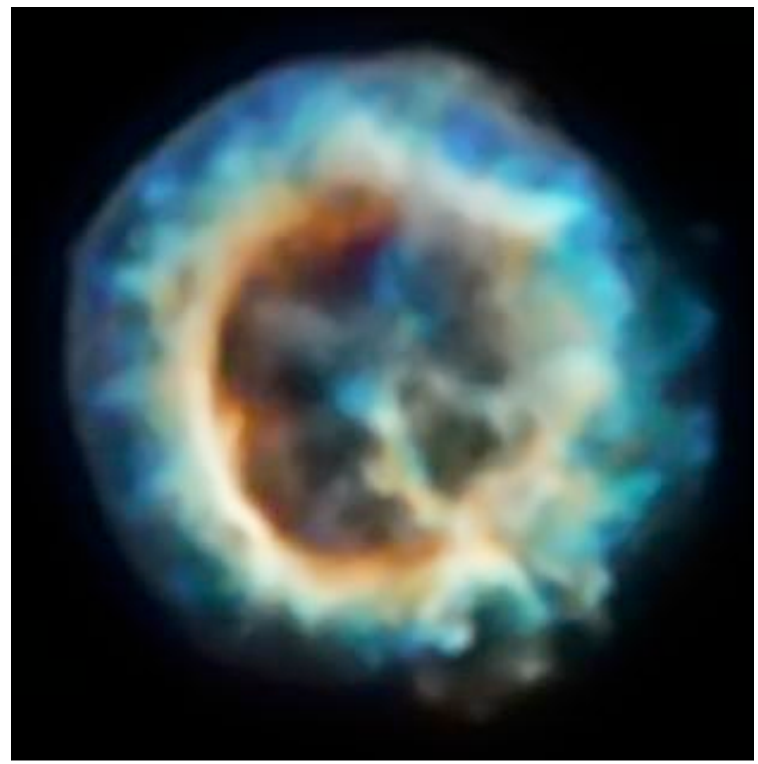
Chandra Images of E0102: S3 Summed Data ~248 ks

DePasquale (SAO)

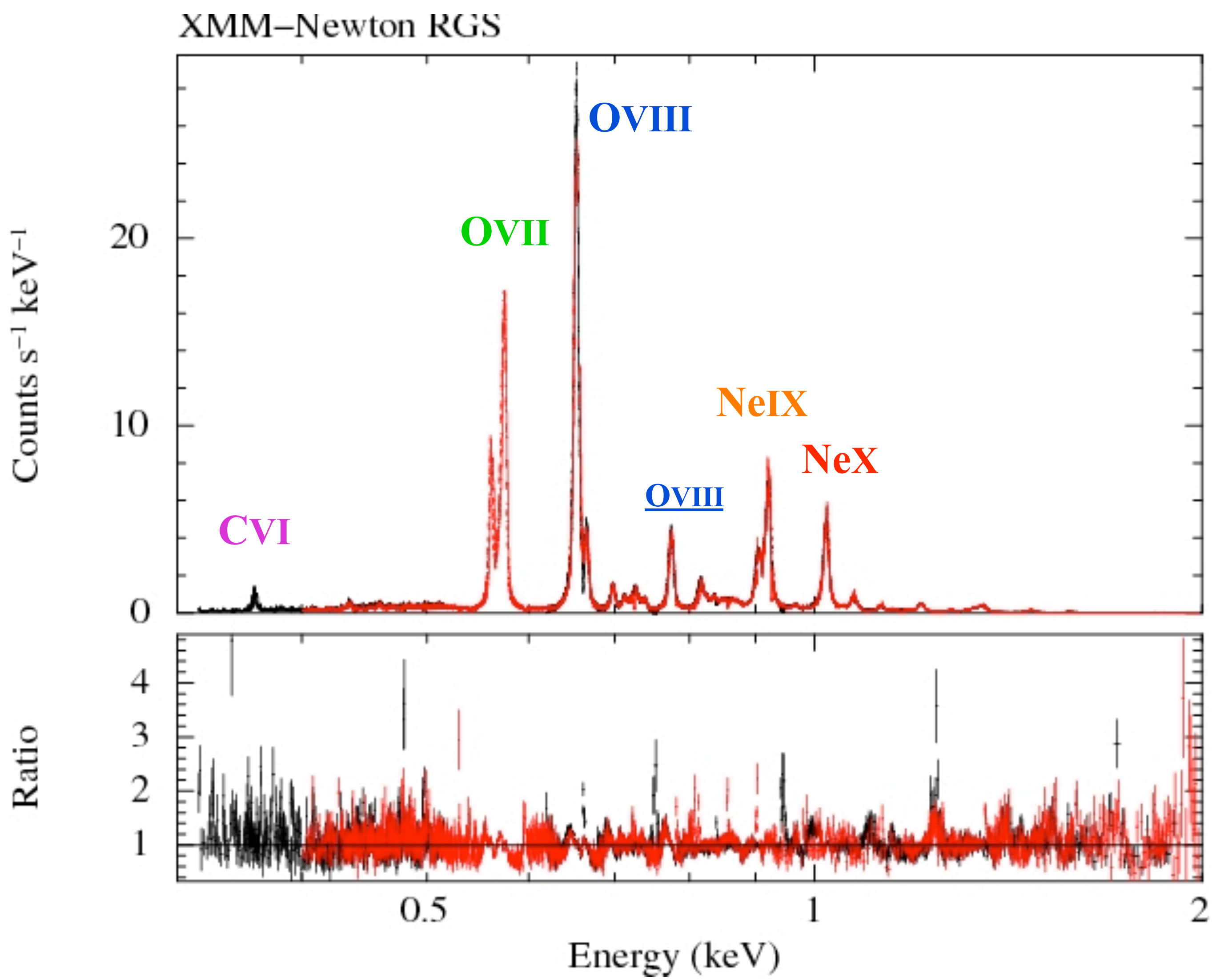


Three Color Image

Red: 0.2-0.75 keV, Green: 0.8-1.1 keV, Blue: 1.1-2.0 keV



XMM-Newton RGS Spectrum of E0102:



Haberl
Grinberg
(MPE)

Spectrum dominated by O & Ne,

little or no Fe emission

Calibration Objective

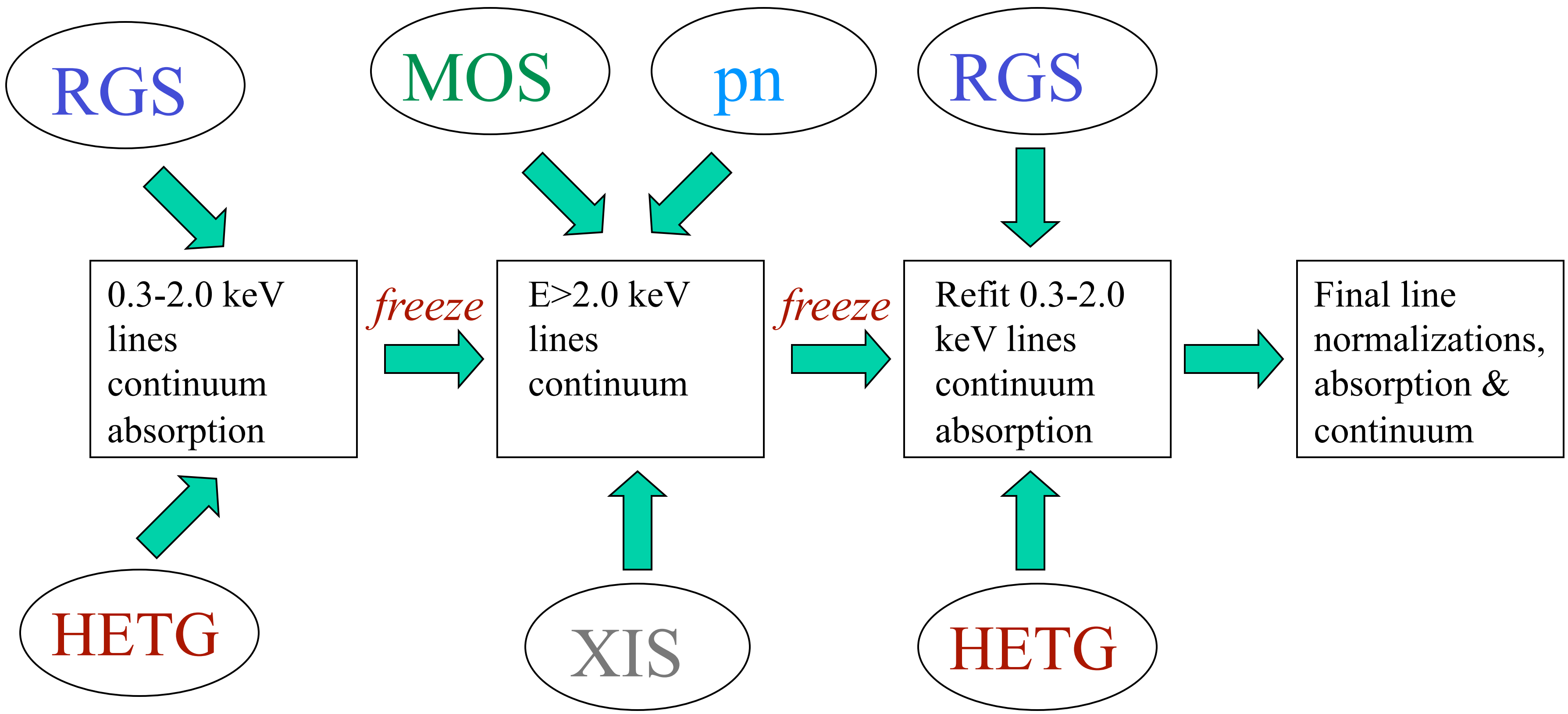
- our primary objective is to use the gratings data to develop a model which could be used to characterize deficiencies in the CCD response models
- we have developed a spectral model based on the strong lines observed in the HETG and RGS data and then fit all of the instruments with the ***same*** spectral model
- in particular, we compare the fitted normalizations of the OVII triplet (560-574 eV), the OVIII Ly-a (654 eV), the NeIX triplet (905-922 eV), and the NeX Ly-alpha line (1022 eV)
- another interesting question is how well do the RGS and HETG (and also the CCD instruments) agree for derived line fluxes in the 0.5-1.5 keV range ??

E0102 as a Standard Candle

- strong lines below 1.5 keV to complement the on-board calibration sources at 1.5 and 5.9 keV
- relatively simple spectrum (bright lines should be well-separated at typical CCD resolution)
- extended source to minimize pileup effects but not too large such that the off-axis mirror response dominates the uncertainties and/or the RGS and HETG's resolution is degraded
- constant source

Process to develop a Definitive Model for E0102

- develop a model based on the high-resolution spectral data from the RGS (Rasmussen et al. 2001) and HETG (Flanagan et al. 2004) and fit all data with the ***SAME*** model
- use the high-resolution spectral data to identify and characterize the line emission from 0.3-2.0 keV
- use the MOS, pn, & XIS to determine lines and continuum above 2.0 keV



Construction of the Definitive E0102 Model

• concerted effort by RGS(Pollock,Haberl) and HETG(Dewey) to develop a model (Smith) which is consistent with ***both*** gratings instruments

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, includes bremsstrahlung, radiative recombination continua, and two-photon continuum

• adopt a two-component continuum, a relatively low-temperature component and a higher temperature component

Line Emission: • use Gaussians for the lines, start with bright lines and move down in flux

• freeze energies to known values and set widths to RGS-determined value

• 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 !!!!

Constraining the Parameters in the Model

• model has ~200 parameters, we will reduce the number of free parameters to 5 or 7 for our calibration objective of measuring the OVII, OVIII, NeIX, & NeX normalizations

Absorption:
- Galactic component fixed at 5.36 x 10^{20} cm^{-2}
- SMC component fixed at 5.75 x 10^{20} cm^{-2} with abundances set to Russell & Dopita 1992 SMC abundances

Continuum:
- low temperature APEC "No-Line" kT=0.164 keV, Norm=3.48 x 10^{-2} cm^{-5}
- high temperature APEC "No-Line" kT=1.736 keV, Norm=1.85 x 10^{-3} cm^{-5}

Line Emission:
- freeze energies to known values and set widths to RGS-determined value
- freeze normalizations of all lines except for OVII For, OVIII Ly-a, Ne IX Res, and Ne X Ly-a
- for OVII triplet and Ne IX triplet only one normalization is allowed to vary, the other line normalizations are set to the ratio determined by the RGS

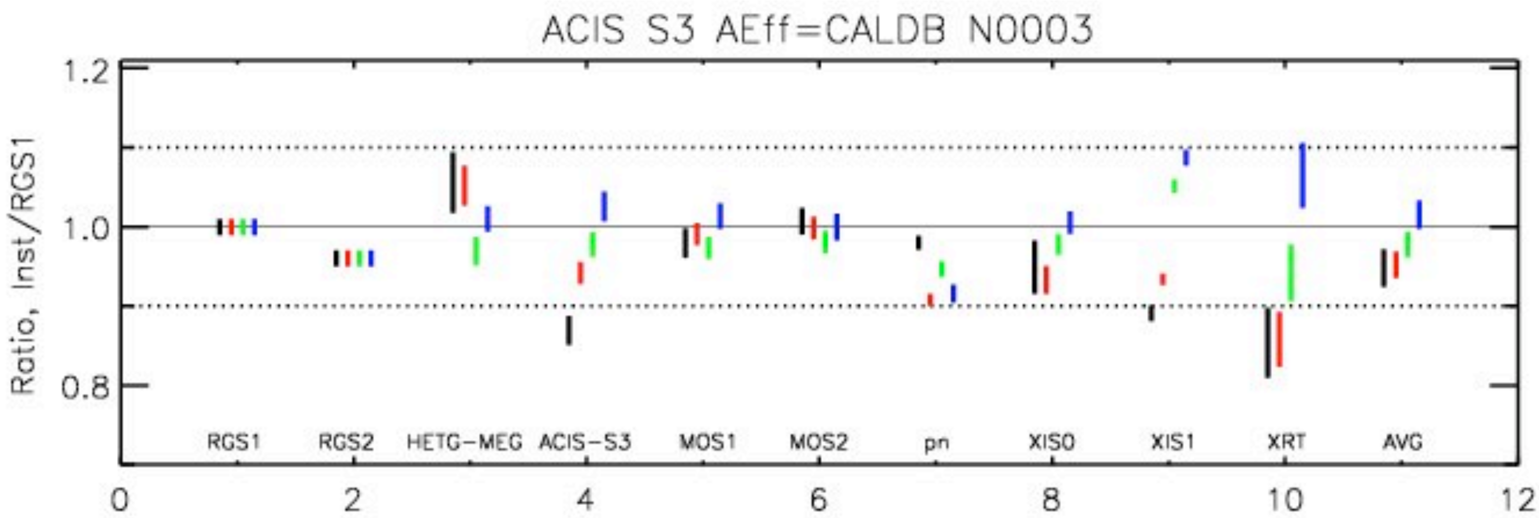
Scale Factor:
- overall normalization to account for different extraction regions

Gain:
- MOS and XIS saw a significant improvement with global gain adjustment

ACIS, pn, XRT have 5 free parameters, MOS, XIS have 7 free parameters

Comparison of OVII, OVIII, NeIX, & NeX Normalizations:

OVII black **OVIII red** **NeIX green** **NeX blue** ***Depasquale(SAO)***



- results above used the N0003 version of the Chandra mirror effective area
- 28 of 32 normalizations agree to within +/- 10%
- max differences are 23% at O VII, 24% at O VIII, 13% at Ne IX, and 19% at Ne X
- RGS, HETG, ACIS, MOS, XIS0 agree to within +/- 5% at Ne IX and Ne X
- ***HOWEVER***, a new version of the mirror effective area (N0004) was released in Jan 2009

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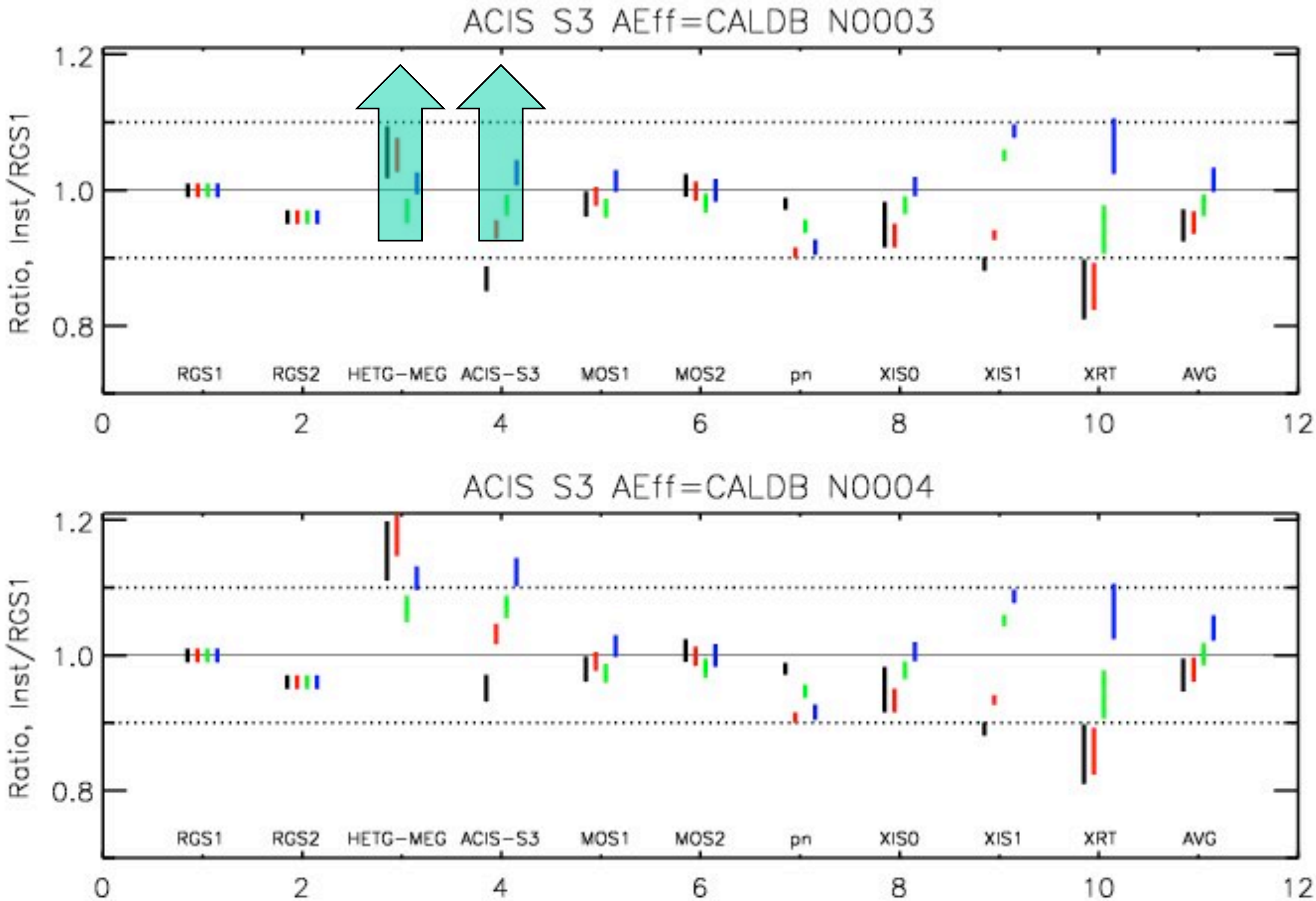


ACTIONs from Last IACHEC Meeting

1) Add the higher order O7 and O8 and Ne9 and Ne10 – Andy P.
2) Incorporate spatial distribution from Chandra in RGS analysis – Andy P.
3) Fit version 1.9 model with new ACIS contaminant model – Paul
4) Temporal analysis with MOS, pn, RGS. Is there any evidence any evidence that E0102 is changing – Frank, Steve, & Andy
5) Systematic pileup study with Chandra – Joe
6) Decide which weak lines are Fe and which are O & Ne – Andy
7) Pileup evaluation from other instruments, in particular RGS2 with slower readout - Andy P., Frank, Steve
8) Compare response on S1 (where HETG gets most of its data from E0102) and S3 – Paul, Joe

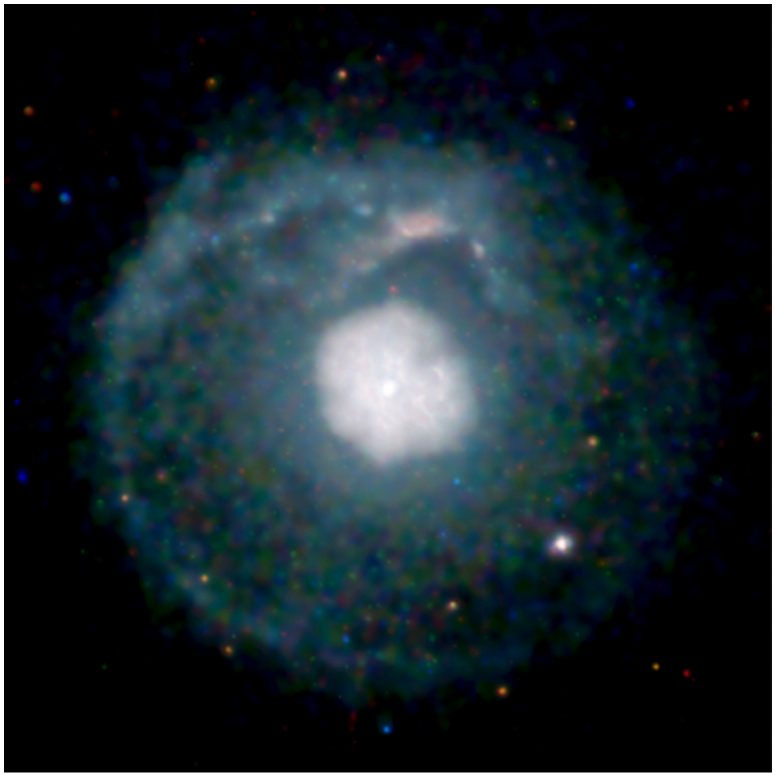
Non-Thermal SNR Working Group

Another of the "Standard candle" working groups.

This group is just beginning its work:

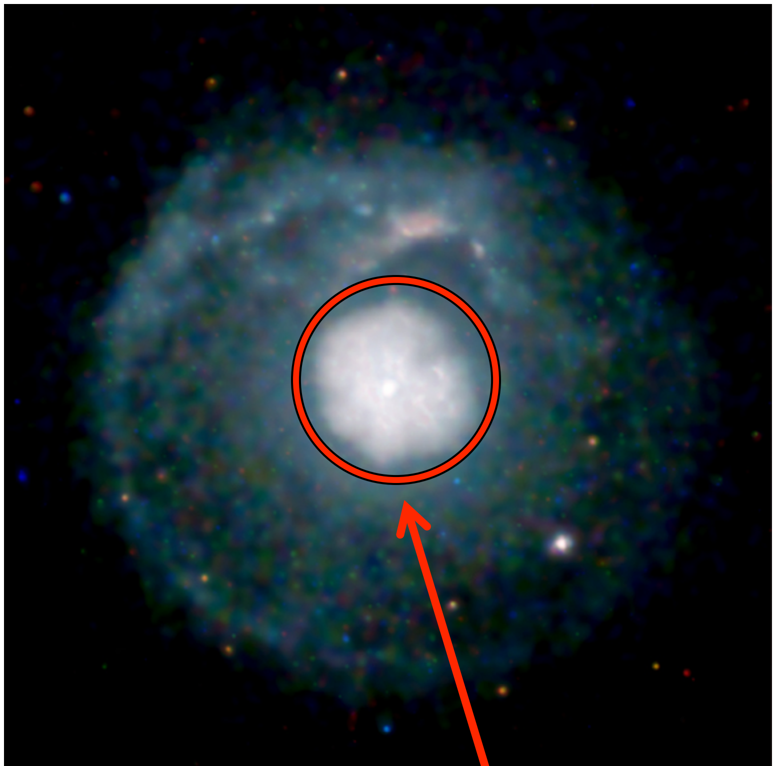
Suzaku XIS	Masahiro Tsujimoto (JAXA/ISAS) Chair
XMM-Newton MOS/pn	Matteo Guanazzi (ESAC), Andy Read (Leicester)
Chandra ACIS	Jenny Posson-Brown, Paul Plucinsky (SAO)
Swift XRT	Andy Beardmore
RXTE/PCA	Keith Jahoda
RXTE/HEXTE	Rick Rothschild
XMM-Newton RGS	Jelle Kastra

G21.5-0.9



- Galactic SNR, pulsar wind nebula with a faint thermal shell surrounding
- spectrum is heavily absorbed, can be well-fitted with a power-law
- multiple observations with Chandra and XMM, new Suzaku observations planned this Fall
- spectrum is remarkably simple, a single power-law provides an adequate fit but Chandra data show evidence of a small variation in the index
- deciding on a compromise extraction region will be crucial

G21.5-0.9



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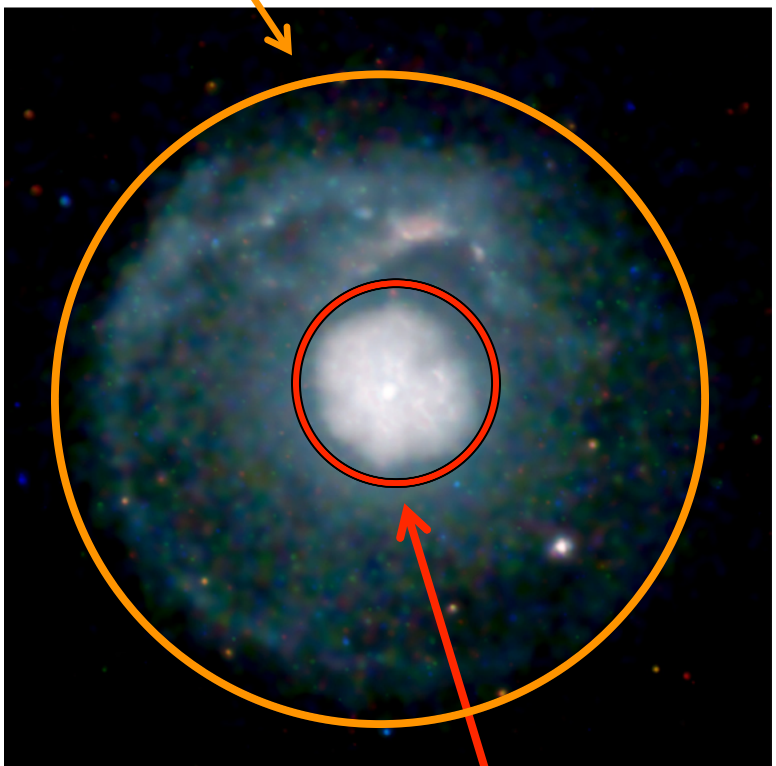
PWN, roughly size of Chandra and XMM extraction regions

Thermal emission, Suzaku extraction region

G21.5-0.9



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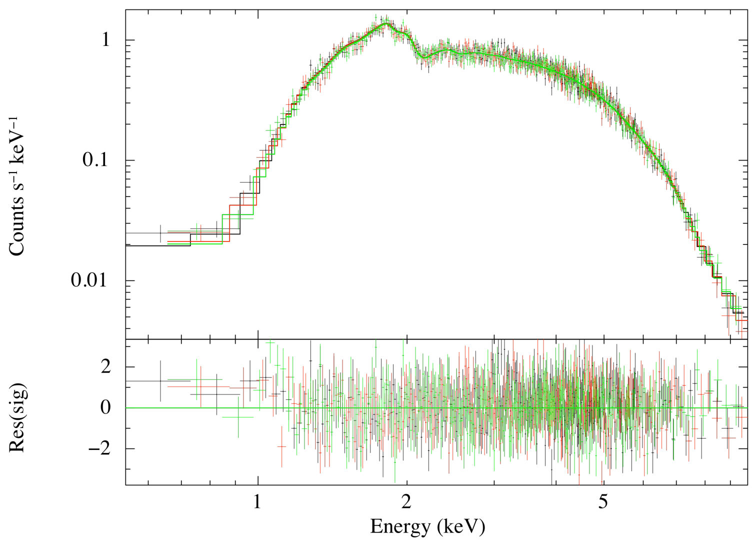
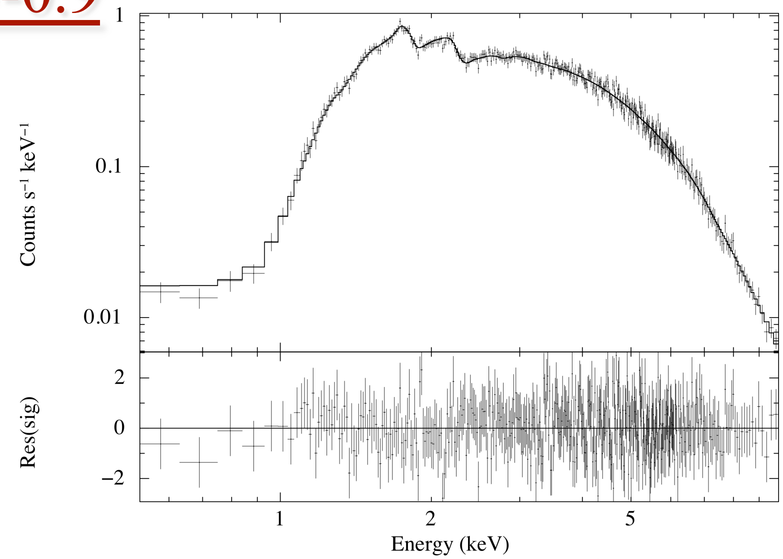
G21.5-0.9

G21.5−0.9, S3 subarrays, (1553,1554, & 3693) wabs*pegpwrl, RedChi=1.03



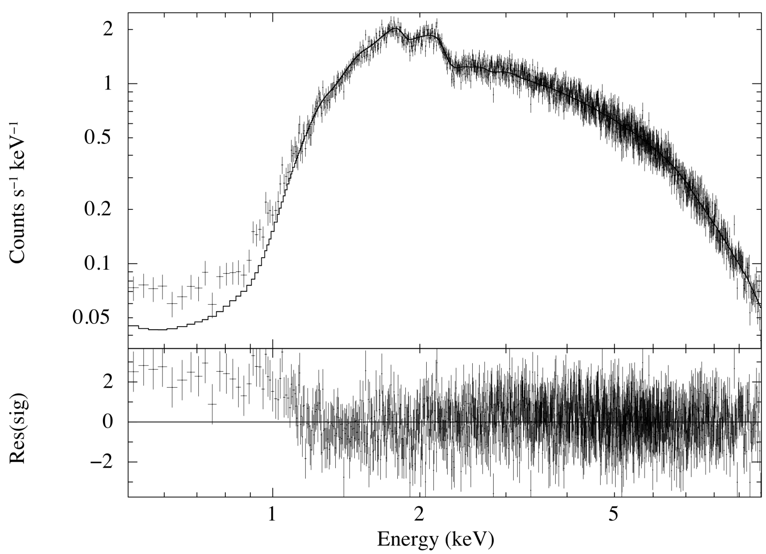
S3

G21.5−0.9, MOS1, OBS 0122700101, wabs*pegpwrl, RedChi=0.90



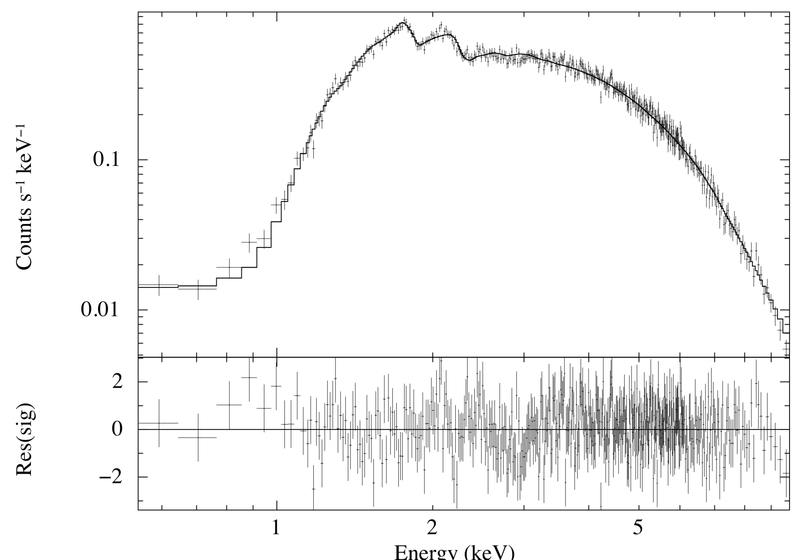
MOS1

G21.5−0.9, pn, OBS 0122700101, wabs*pegpwrl, RedChi=1.13



pn

G21.5−0.9, MOS2, OBS 0122700101, wabs*pegpwrl, RedChi=1.01



MOS2

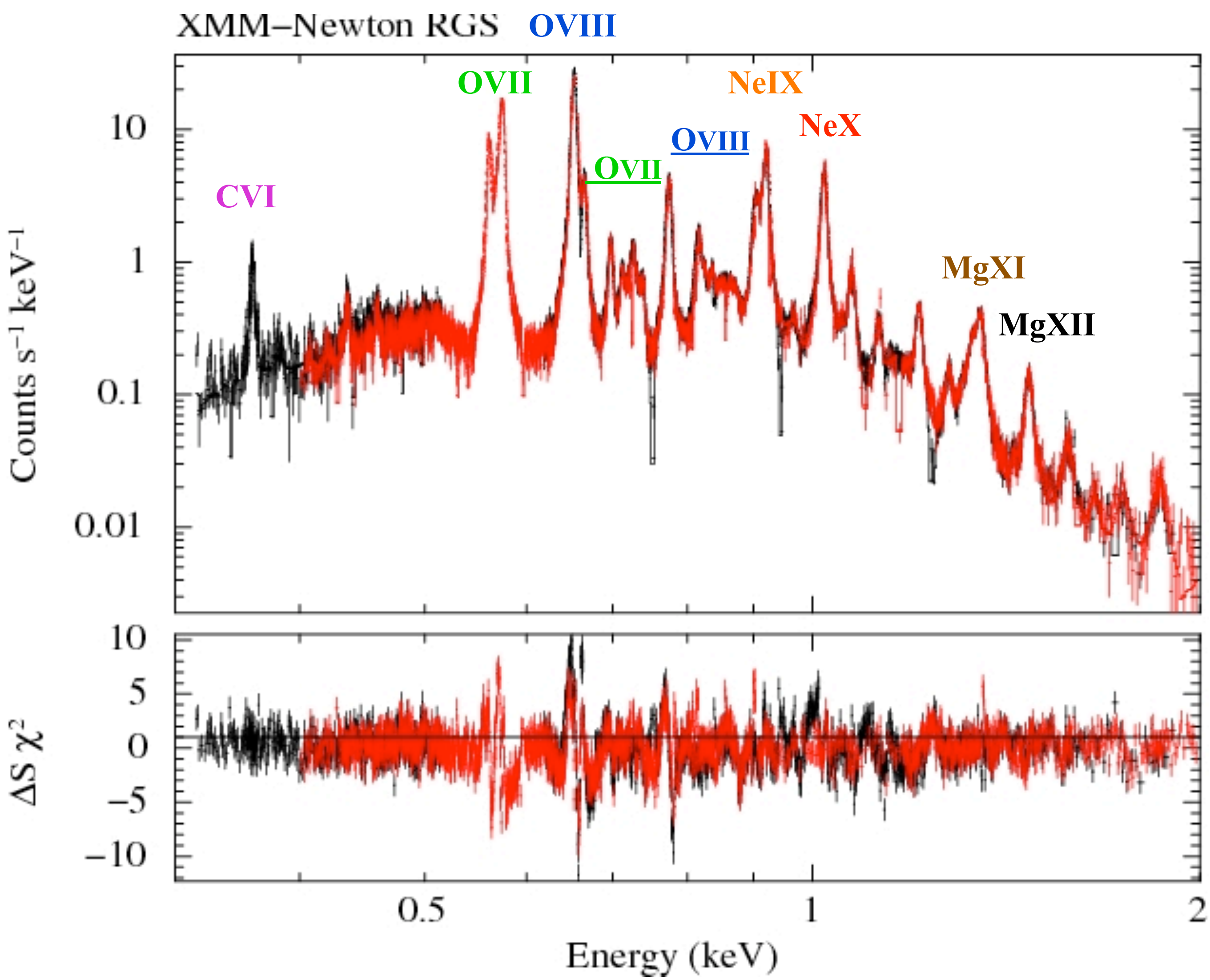
G21.5-0.9 Spectral Fit Results and 90% Confidence Limits

Instrument	NH(10^{22} cm^{2})	Index	Flux(10^{-12}) ergs cm^{-2} s^{-1}	Red Chi	DOF
MOS1	2.32[2.27,2.36]	1.83[1.81,1.86]	51.9[51.4,52.4]	0.90	404
MOS2	2.32[2.28,2.37]	1.87[1.84,1.89]	51.9[51.5,52.4]	1.01	403
pn	2.15[2.12,2.18]	1.79[1.77,1.81]	47.9[47.6,48.1]	1.13	1317
ACIS S3	2.31[2.27,2.34]	1.84[1.82,1.87]	65.7[65.1,66.2]	1.03	944

- excellent agreement between MOS1/2 and ACIS S3 on N_H and power-law index
- we need to resolve the extraction region issue before we compare the flux numbers carefully
- XMM data provided by Matteo G. and Andy R., ***thanks !***

Backup Slides

RGS Spectrum of E0102



Haberl Grinberg (MPE)

Fit the RGS data

Freeze line energies, allow widths and normalizations to vary

Cross-check against the HETG

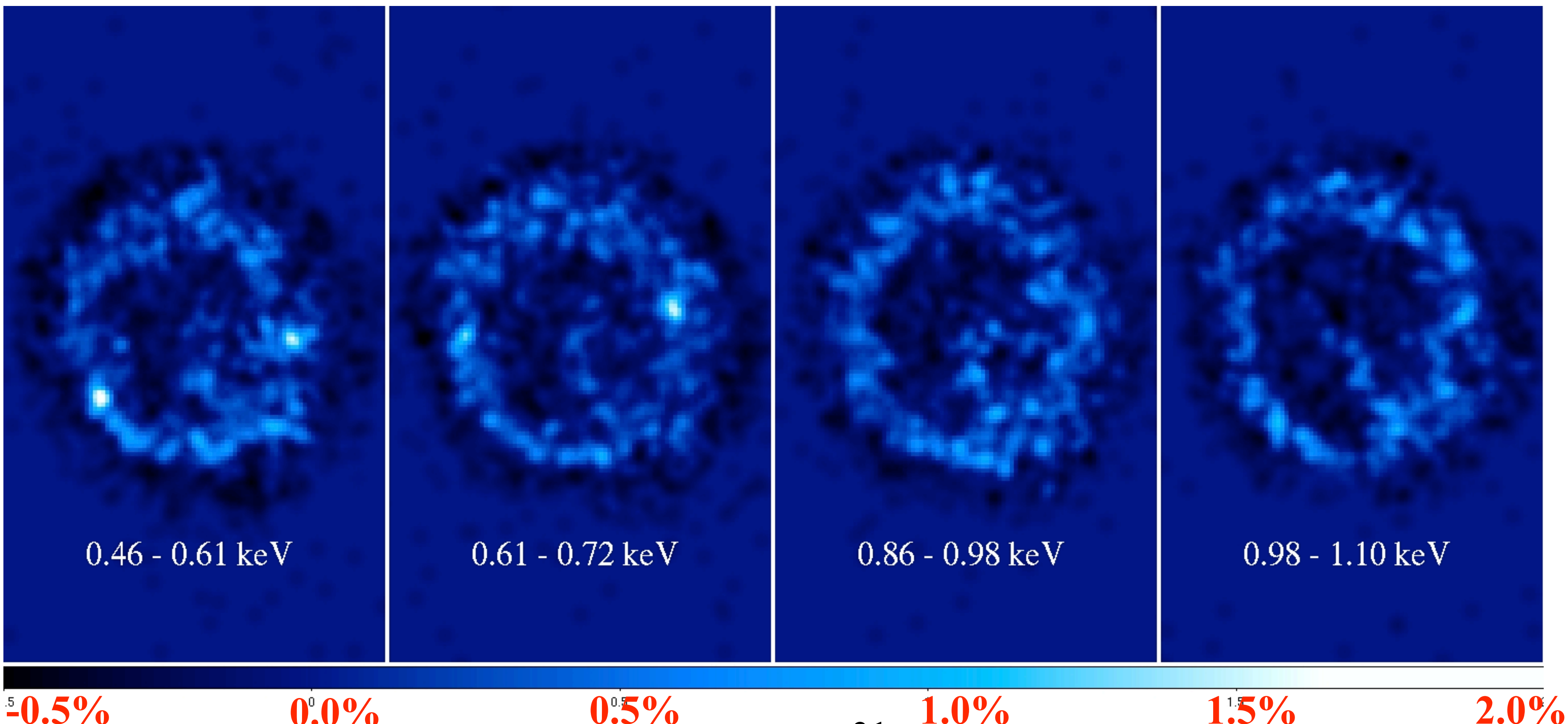
Model includes 52 lines

Is E0102 Constant ?

• Hughes et al. 2000, measure an expansion rate of 0.1%/yr comparing to ROSAT data over a 20 yr baseline

• comparison of Chandra data with a 7.2 yr baseline shows that total flux might have increased by about 9%, but this will need to be redone with the revised model for the ACIS contaminant

DePasquale(SAO))



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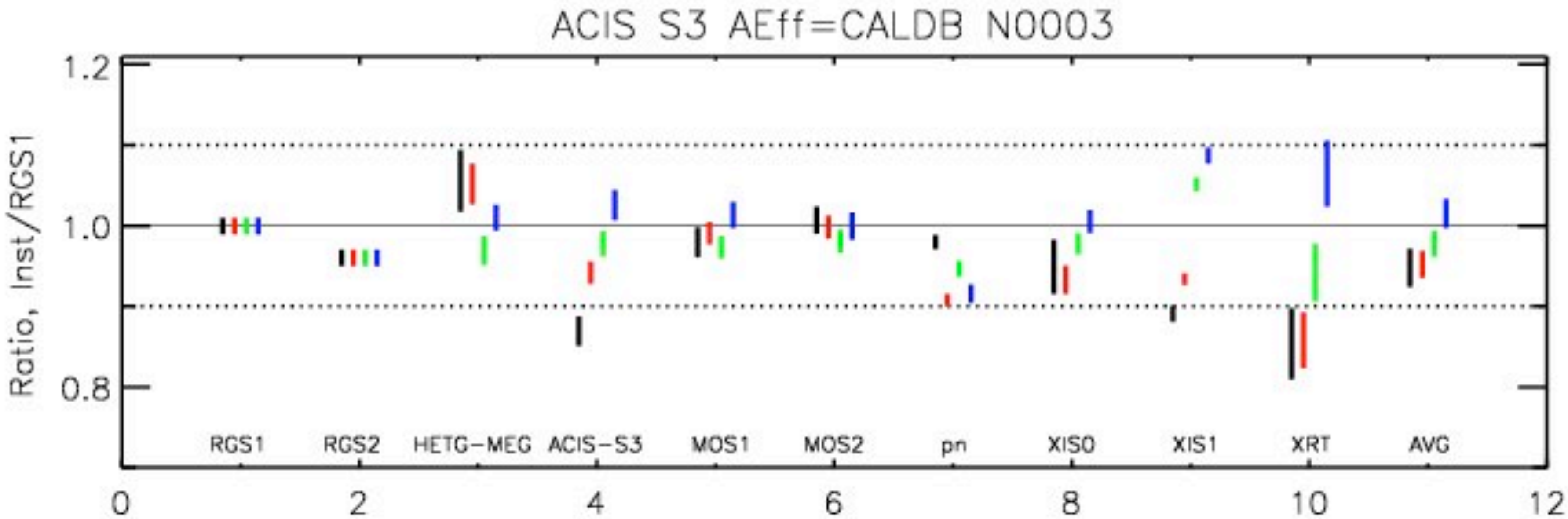

- 28 of 32 normalizations agree to within +/- 10%
- appears to be a 4% difference between RGS1 & RGS2 which is mostly independent of energy
- uncertainties are the statistical uncertainties and underestimate the true uncertainty
- MOS QE was adjusted in 2007 with the intent of improving agreement with the RGS
- ACIS, XIS, & XRT show similar trend with energy
- max differences are 23% at O VII, 24% at O VIII, 13% at Ne IX, and 19% at Ne X
- RGS, HETG, ACIS, MOS, XIS0 agree to within +/- 5% at Ne IX and Ne X

Summary:

- the E0102 model is available for download in XSPEC xcm format on the E0102 twiki: ``http://cxc.harvard.edu/twiki/bin/view.cgi/SnrE0102/WebHome"

- E0102 should be a calibration source for IXO, Spectrum-RG, ASTRO-H, and any other X-ray missions with significant response in the 0.3-2.5 keV bandpass

- the current generation of X-ray instruments agree mostly to within +/- 15% at ~570, 654, ~915, & 1022 eV

- we need to explore the reasons for the larger discrepancies, some possible explanations are:
  - ➢ model for absorption from contaminant on ACIS is wrong, update to the temporal model is in progress
  - ➢ pileup not properly modeled, especially for ACIS and XRT
  - ➢ time-variable effective area not correct, especially for ACIS, XIS
  - ➢ spectral redistribution function not correct, especially for pn