- UVIT-Grating Calibration Update
- UVIT/SXT light curves
- SXT RMF status, crab-calibrated ARF, handling pile-up
- UV/X-ray spectroscopy

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UVIT Gratings

- Two gratings in FUV arranged nearly perpendicular, one grating in NUV.
- Slit-less gratings useful for low resolution spectroscopy.
- Ruled with 400lines/mm on CaF2 substrate
- Dispersion on the detector plane 12A/arcsec (1st order) and 6A/arcsec (2nd order) (Tandon et al. 2017, 2020)

Parameter	FUV-Grating1	FUV-Grating2	NUV-Grating
Filter Wheel Slot number	4	6	4
IDs in APPS	4 - grating1 (FUV)	6 - grating2 (FUV)	4 - grating (NUV)
IDs in CCDLAB	FUV_Grating1	FUV_Grating2	NUV_Grating
This paper	FUV-G1	FUV-G2	NUV-G
IDs in Tandon *et al.* (2020)	FUV1	FUV2	NUV
IDs in Tandon *et al.* (2017)	2nd FUV grating (#66126)	1st FUV grating (#63771)	NUV grating (#66125)
IDs in UVIT Pipeline	F4	F6	F4
$m = -1$ peak λ	–	–	2100Å
$m = -2$ peak λ	~ 1400Å	~ 1500Å	–
Spectral resolution (FWHM)	14.6Å	14.6Å	33Å

Grating calibration based on earlier observations of HZ4 and NGC40 (Dewangan 2021, JAA).

Update on Grating calibration

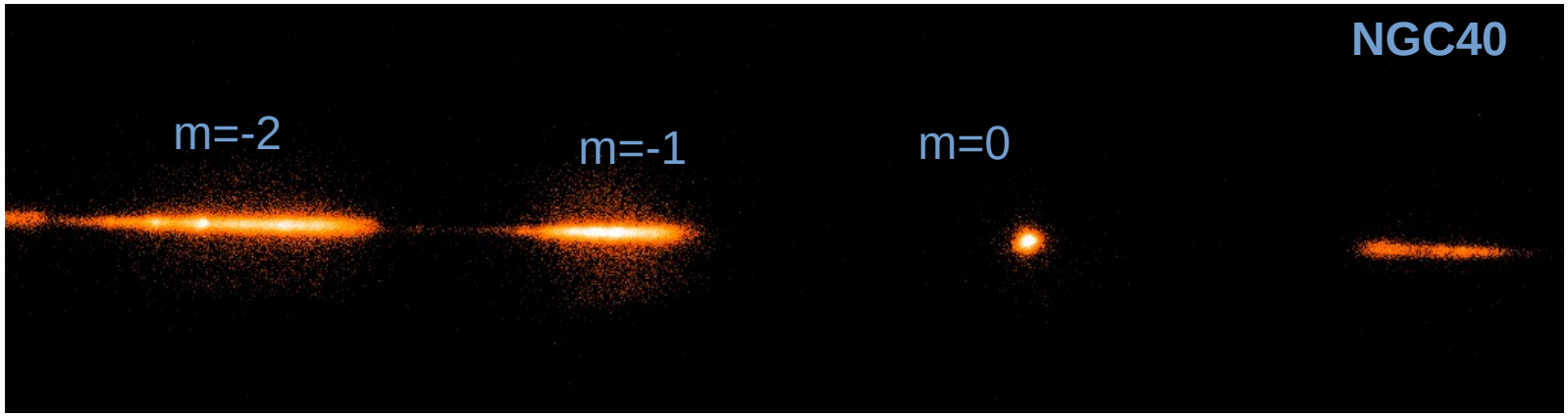
New Calibration Observations (C07 cycle)

- Two WDs : HZ4 and WD0308-565
- Three planetary nebulae: NGC40, NGC6302 & NGC6905

Proposal Id	Target Id	Observation Id	PI Name	Orbit	Version	L2 Pipeline Version	Source Name	RA	DEC	Instrument	Date Of Observation	Release Date
C07_015	T01	C07_015T01_9000005256	gulabd	37008	9.2	6.3	NGC40	3.254292	72.521944	UVT	02-Aug-2022	18-Aug-2023
C07_015	T02	C07_015T02_9000005258	gulabd	37009	2.2	6.3	NGC6302	258.435958	-37.103139	UVT	02-Aug-2022	18-Aug-2023
C07_015	T03	C07_015T03_9000005260	gulabd	37012	2.2	6.3	NGC6905	305.595792	20.104528	UVT	02-Aug-2022	18-Aug-2023
C07_015	T04	C07_015T04_9000005262	gulabd	37019	9.2	6.3	HZ4	58.841617	9.788371	UVT	02-Aug-2022	18-Aug-2023
C07_015	T06	C07_015T06_9000005264	gulabd	37023	2.2	6.3	WD0308-565	47.449658	-56.397059	UVT	03-Aug-2022	18-Aug-2023

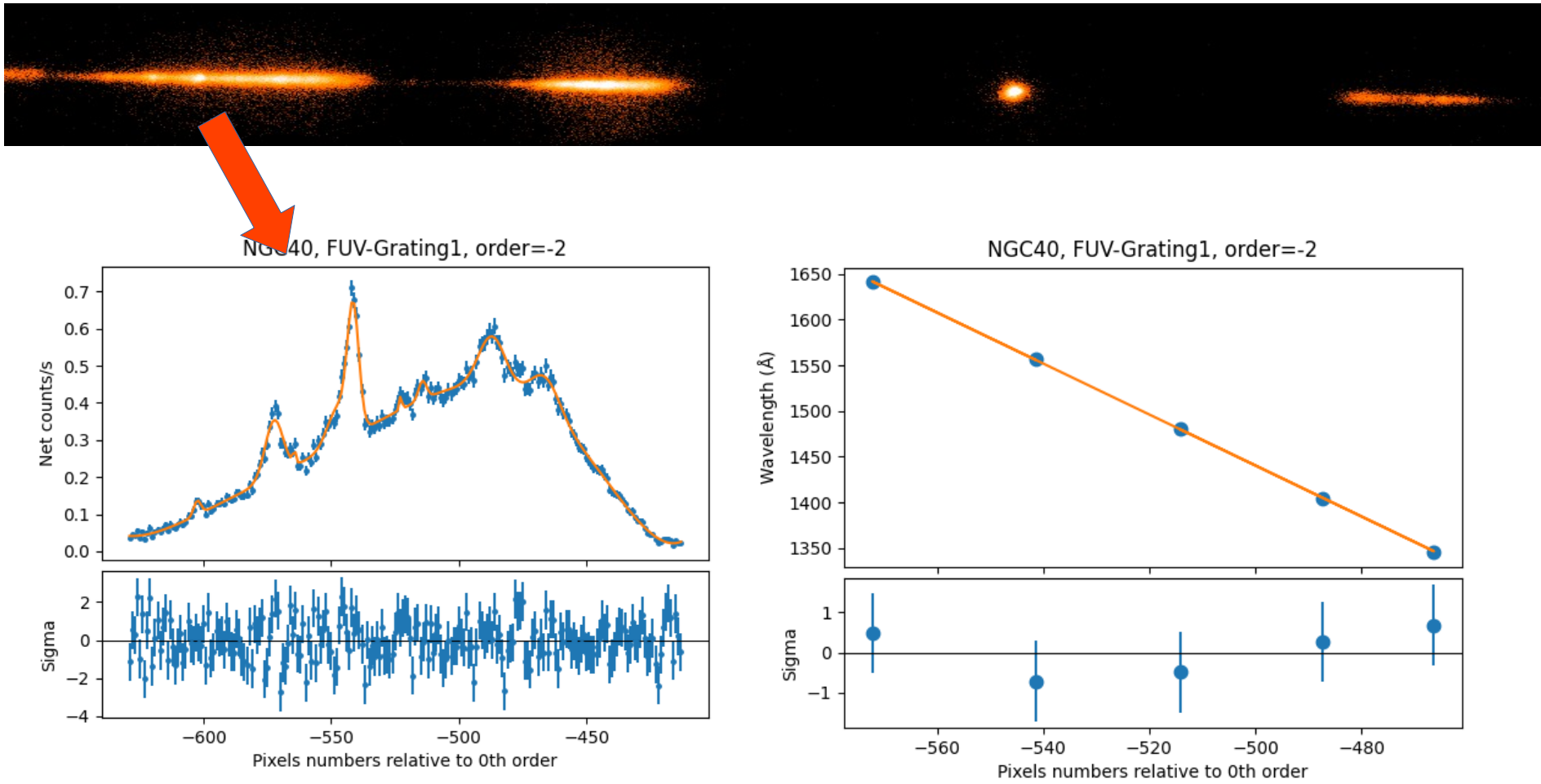
These data made available on 18th August 2022.

UVIT Grating spectral extraction



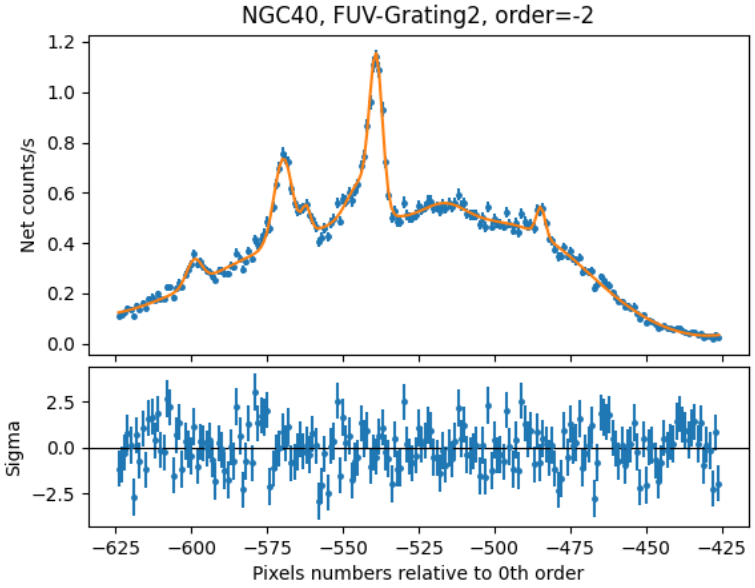
- Merged Level2 image (CCDLAB) in detector coordinates
- Identify 0, -1, -2 order spectra of the target of interest
- Extract 1d spectrum (Dispersion axis slightly tilted w.r.t. to X-axis (NUV-grating, FUV-grating1) or Y-axis (FUV-grating2)
- Counts Vs pixel numbers

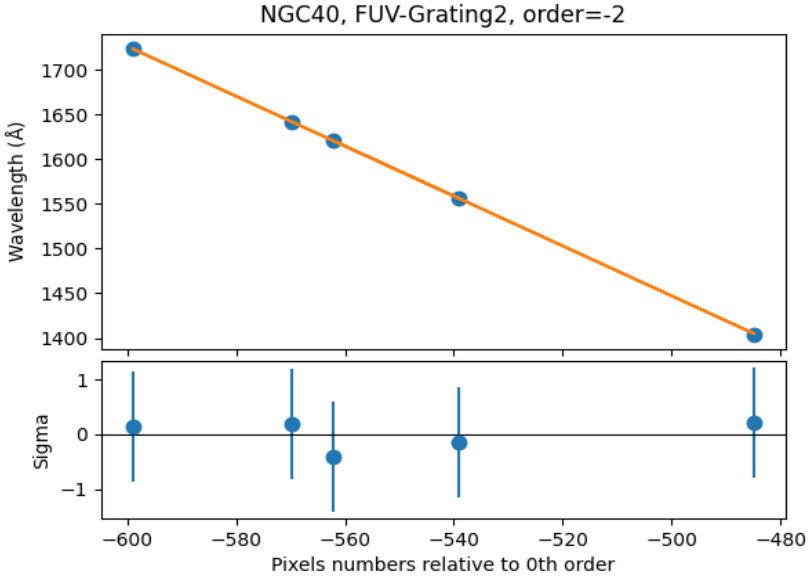
FUV-Grating1 order=-2: Wavelength calibration (NGC40)

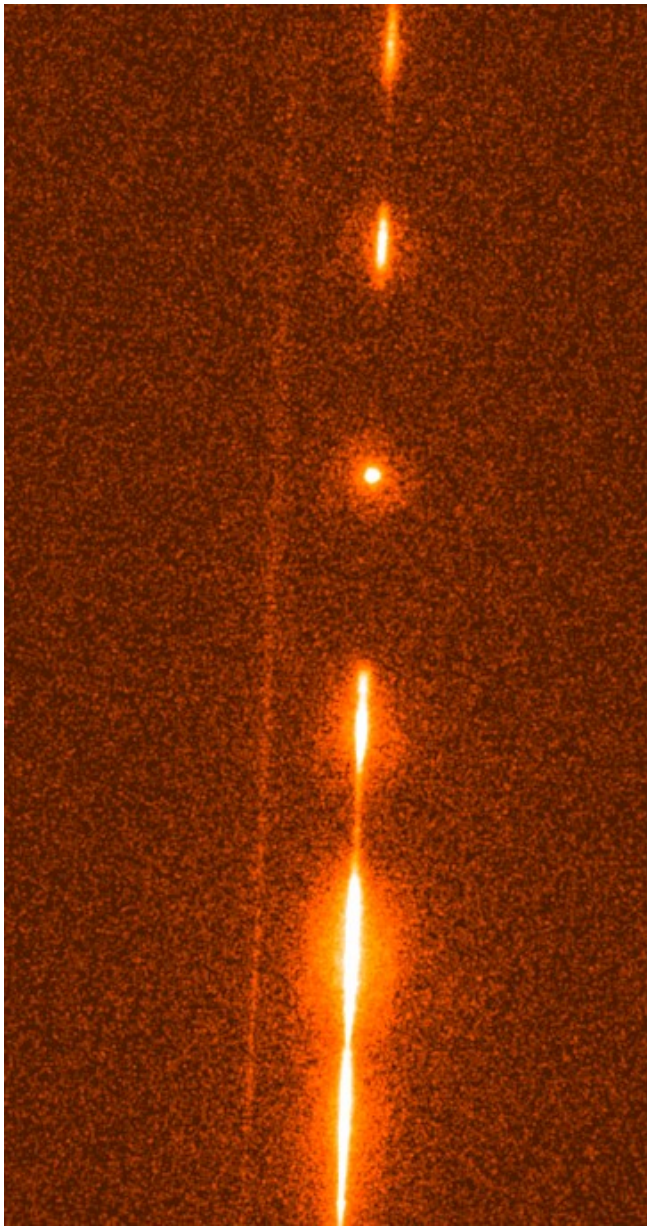


Lines identified from IUE spectra of NGC40 (Feibelman et al. 1999)

FUV-Grating2 order=-2: Wavelength calibration







Effective Area & Flux Calibration

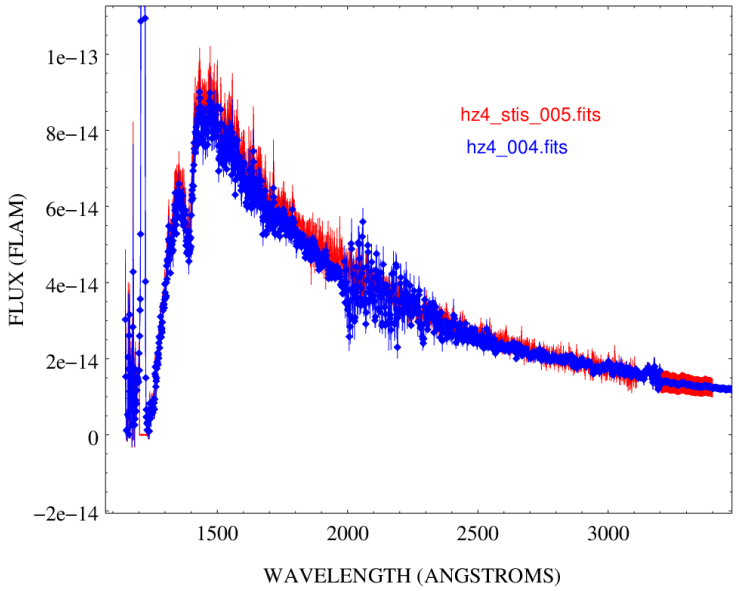
Use spectrophotometric standards such as a hot WD HZ4 or WD0308-564 with relatively featureless spectra

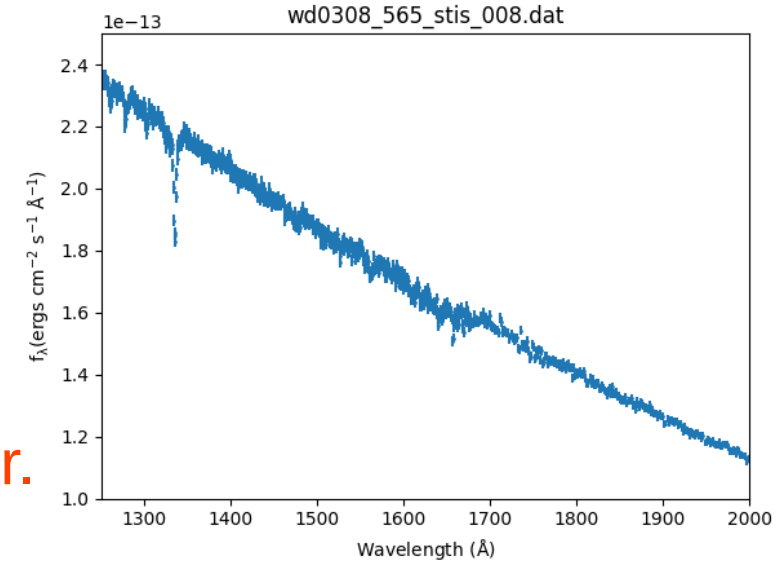
$$C(X) = \int R_{X\lambda} A_\lambda f_\lambda \left(\frac{\lambda}{hc}\right) d\lambda$$

$$C_X = \sum_\lambda R_{X\lambda} A_\lambda f_\lambda \frac{\lambda}{hc}$$

$$f_\lambda = \frac{C_\lambda (hc/\lambda)}{A_\lambda}$$

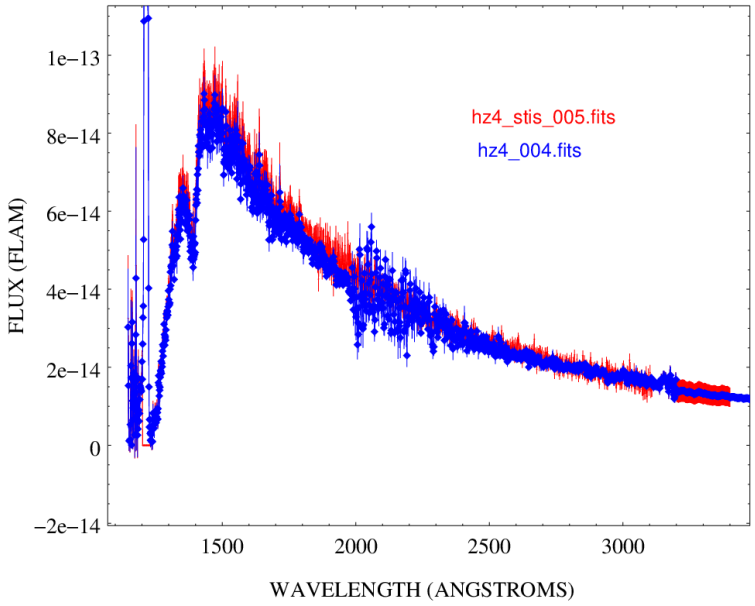
Dewangan 2021, JAA

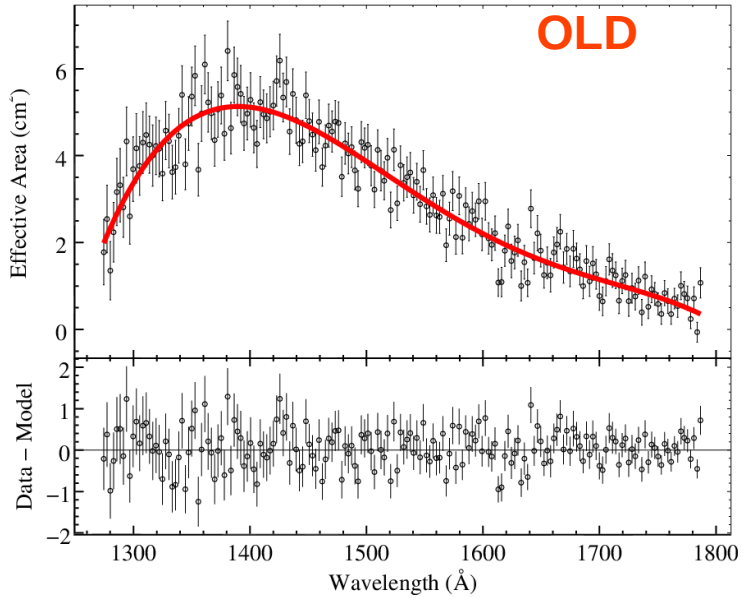


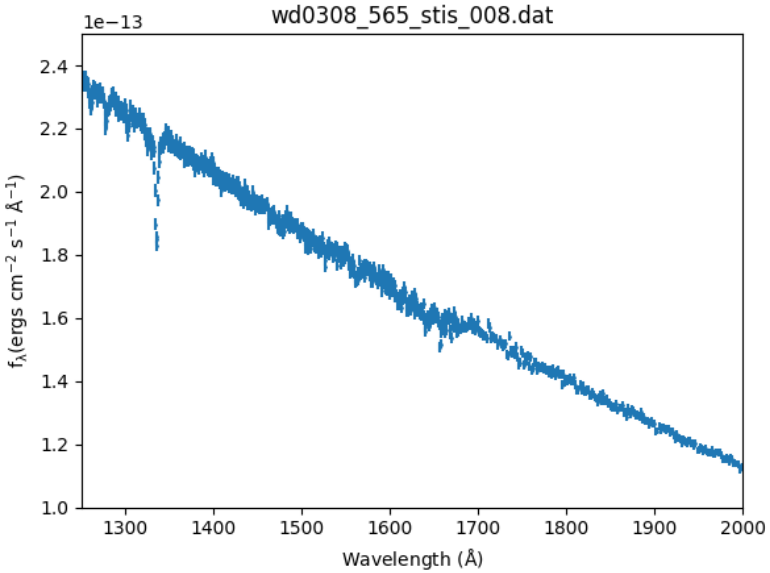


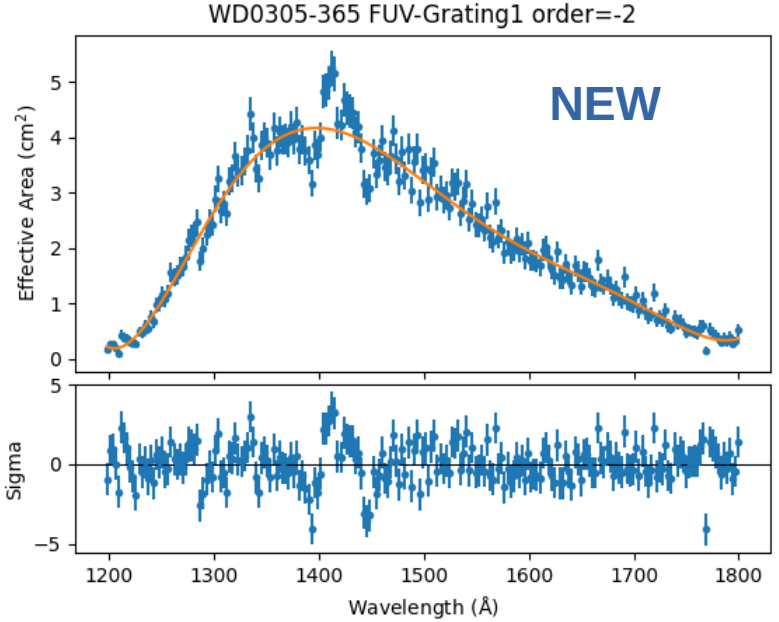
WD0308-565 : A better flux calibrator.

FUV-Grating1 order=-2: Effective area and flux calibration

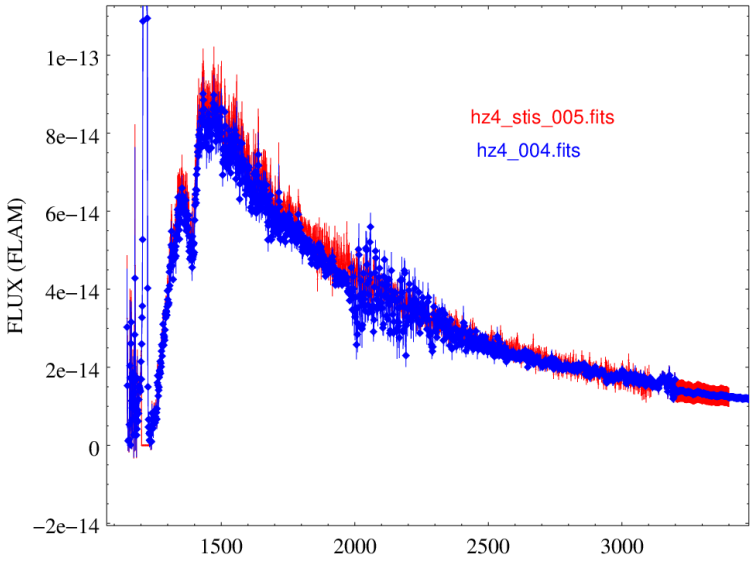


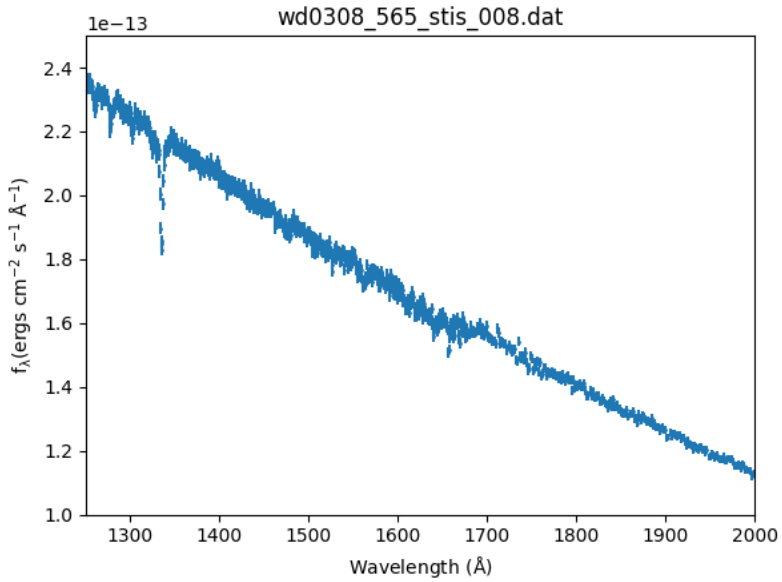


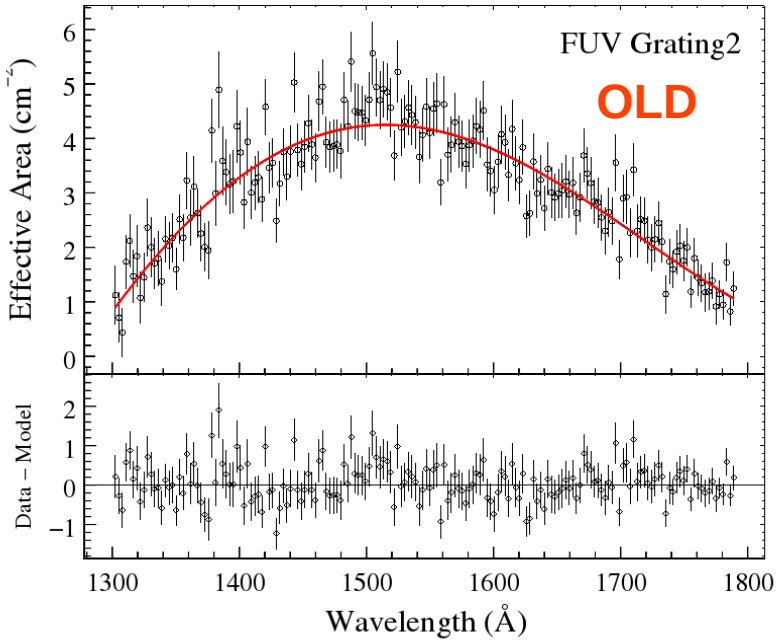


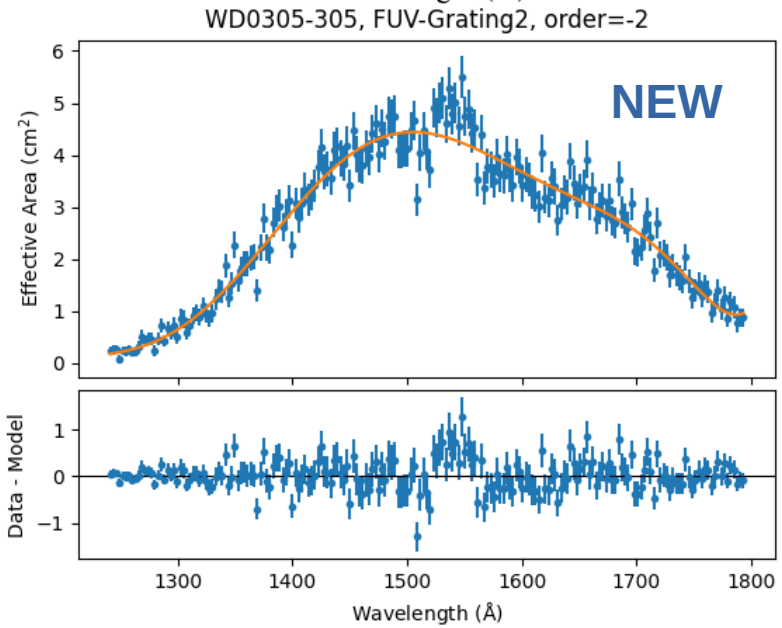


FUV-Grating2 order=-2: Effective area and flux calibration

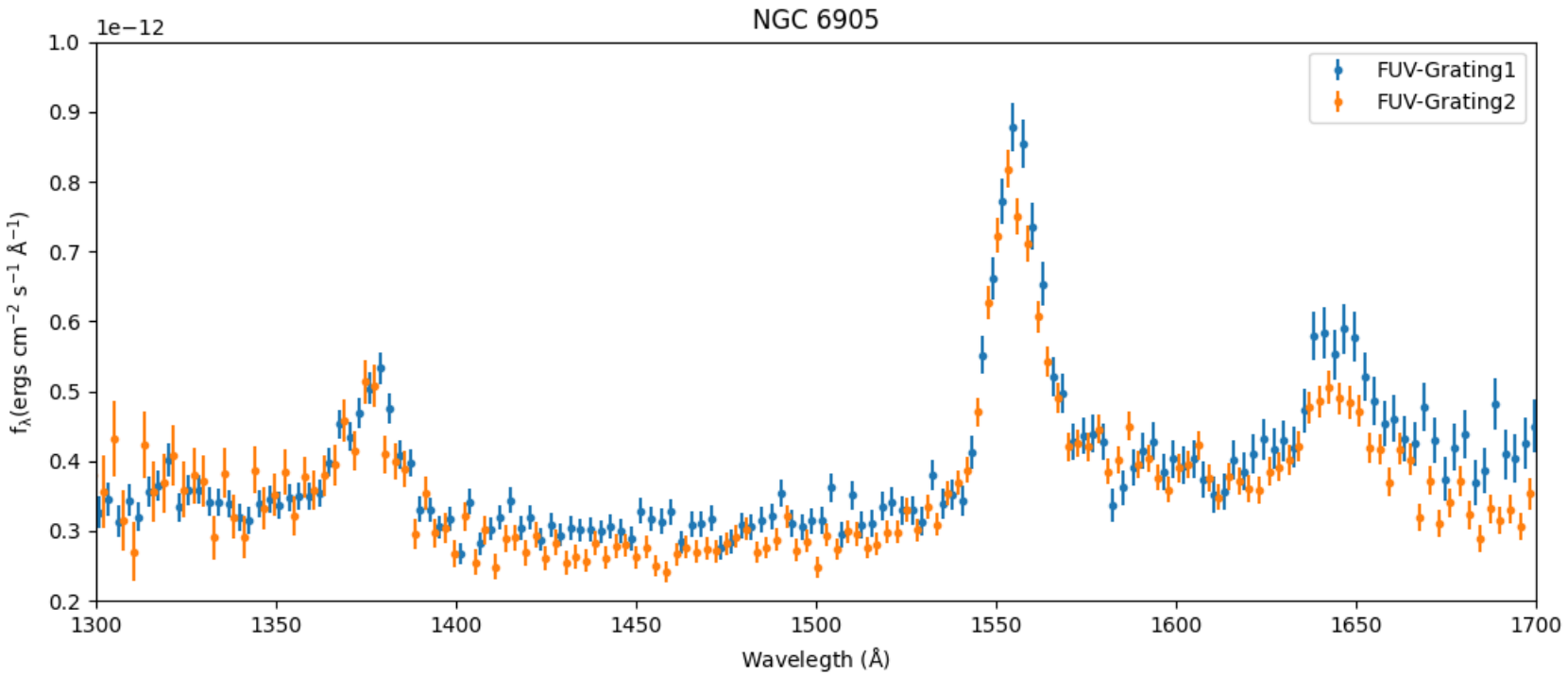






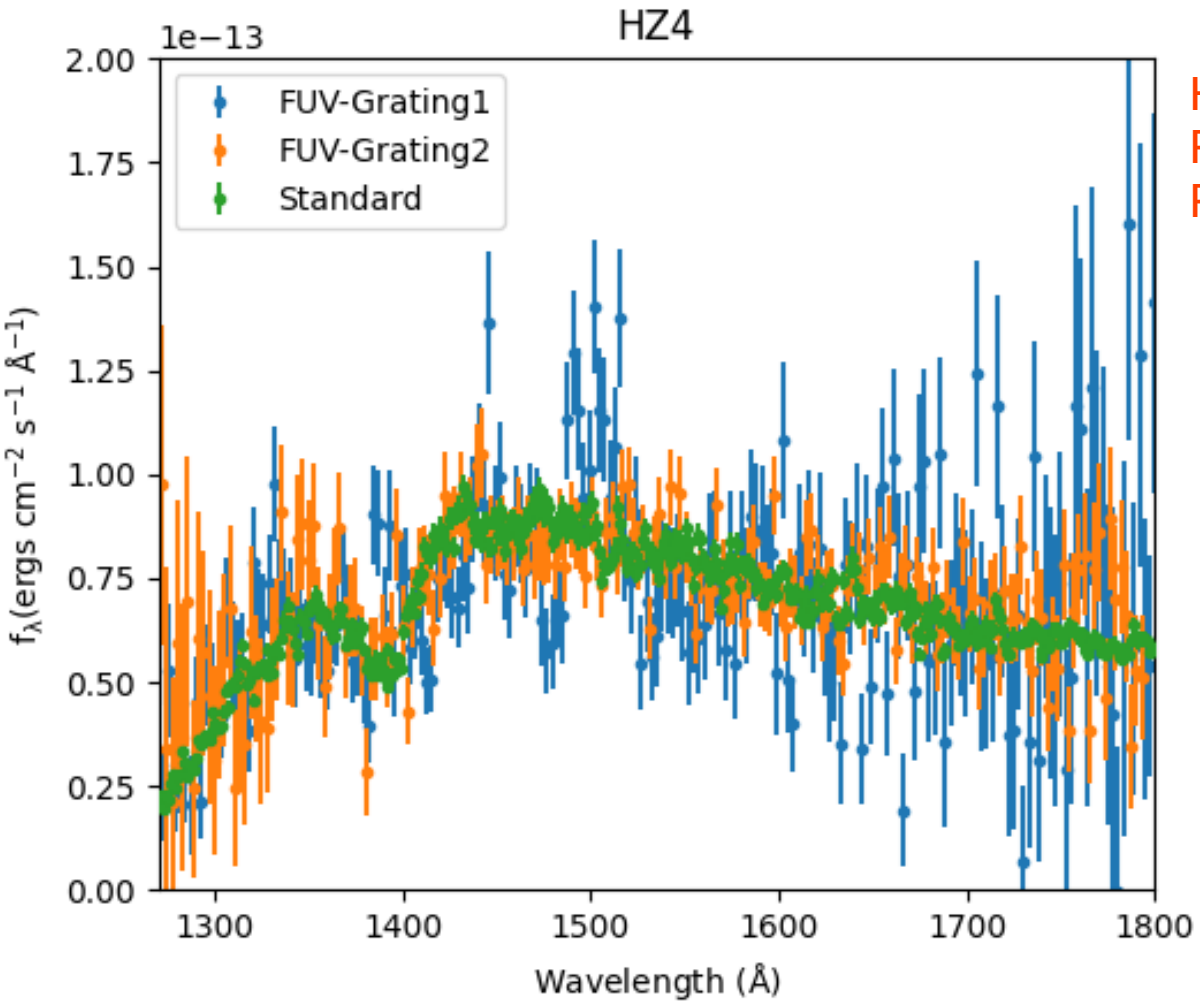


Checking Wavelength Calibration using NGC6905
(Wavelength calibration based on NGC40)



Checking flux calibration: HZ4

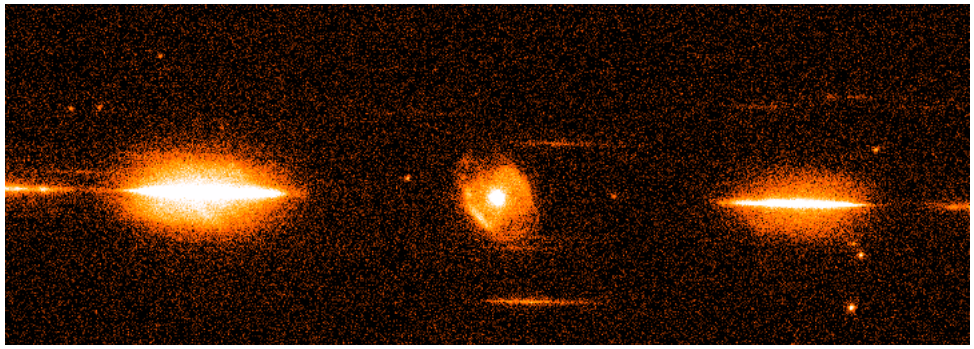
(Flux calibration based on WD0308-565)

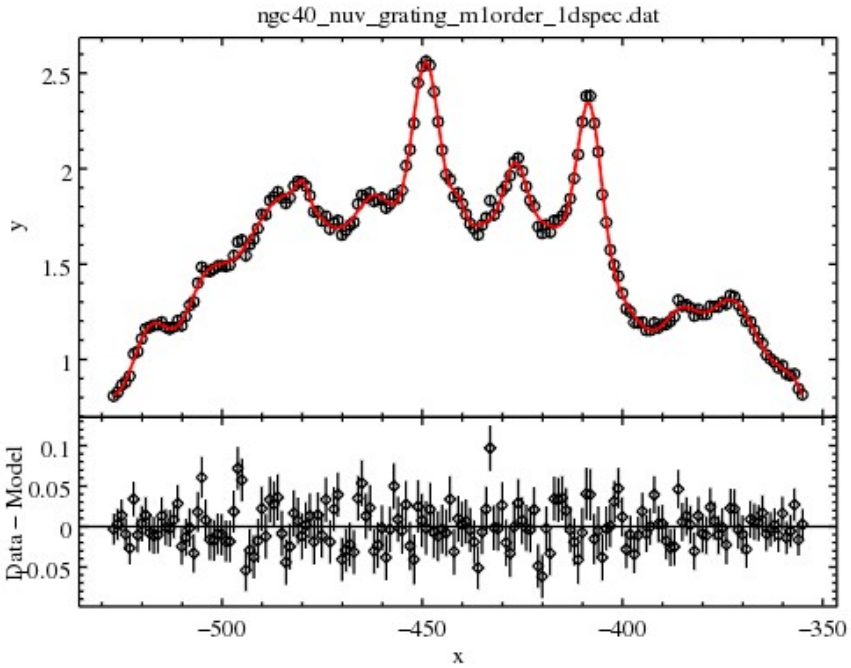


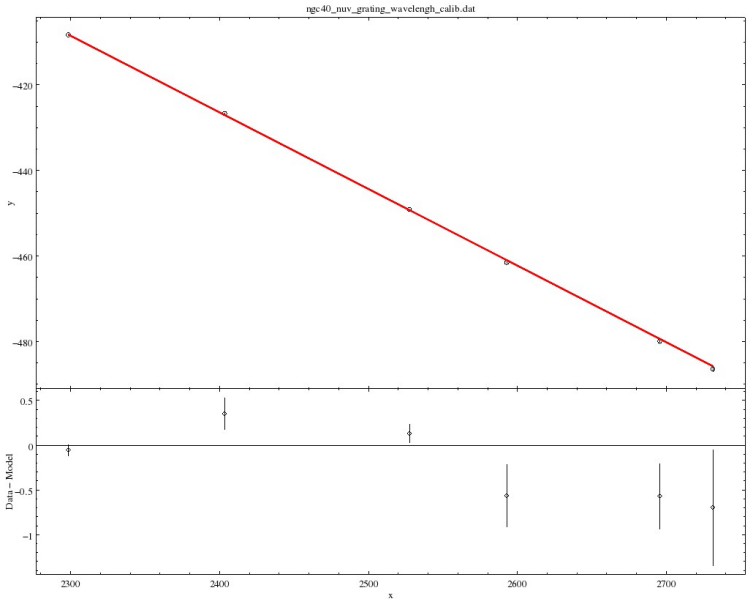
HZ4
FUV-G1 (Exposure:846s)
FUV-G2 (Exposure: 1322s)

Wavelength Calibration (NUV-grating)

- Planetary nebula NGC40 with a number of lines







nuv_lambdaA = -5.585562438209716 * pixels_m1_order + 18.055833282132344

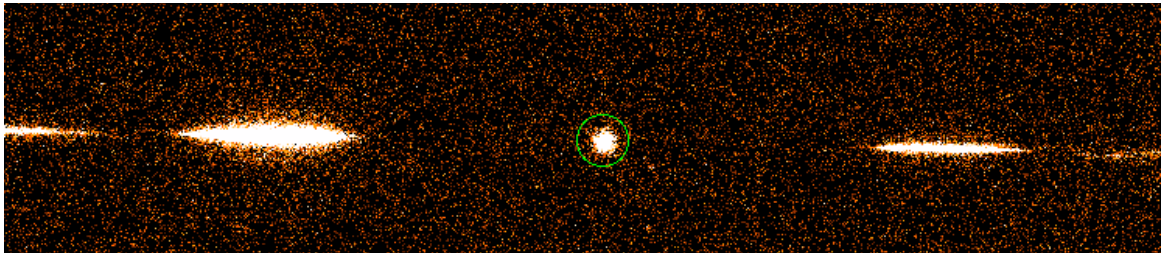
(Dewangan 2021, JAA)

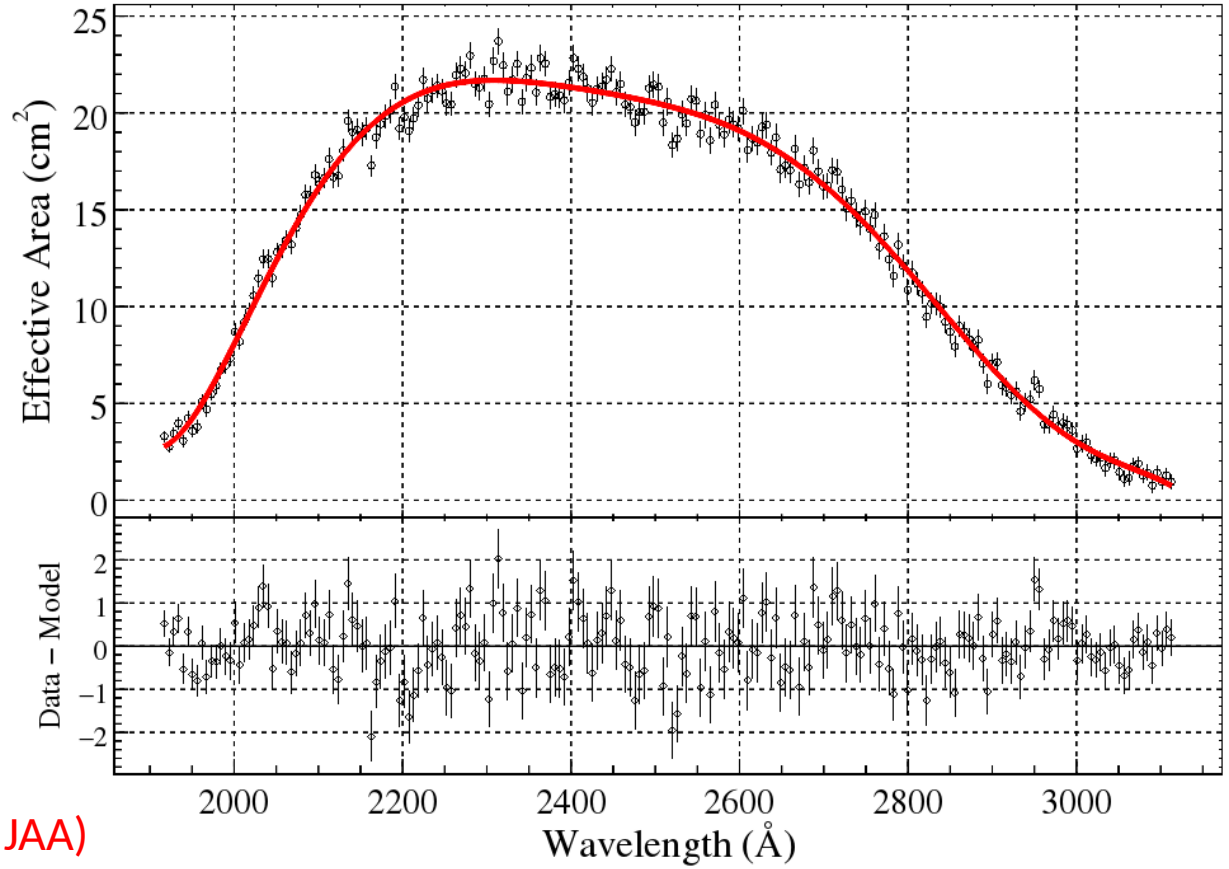
Flux calibration / effective area (NUV)

1. Extract source / background 1d spectra

2. Wavelength calibration

3. Use standard spectrum of HZ4 measured with IUE/HST to derive effective area





(Dewangan 2021, JAA)

Grating spectral response

$$D(I) = T \int R(I,E)A(E)f(E)dE + B(I)$$

T : Exposure time

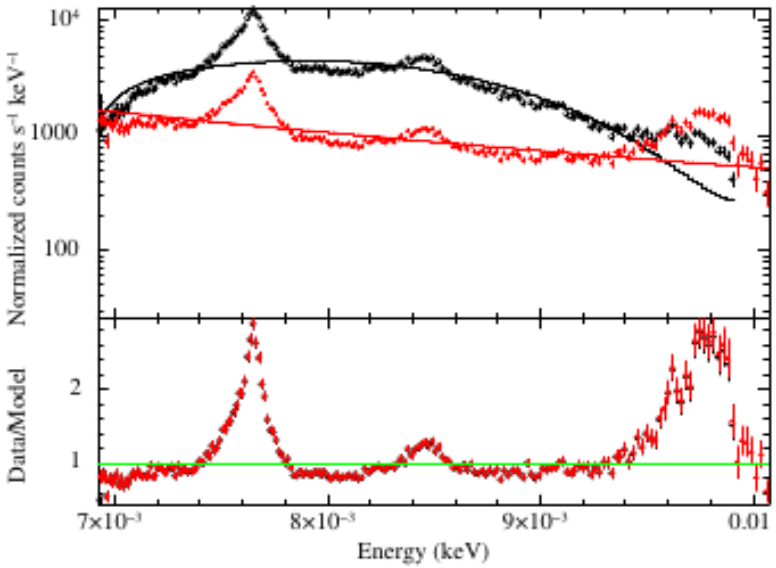
R(I,E) : redistribution matrix (pixel no. => channel I)
UVIT gratings - Gaussian response to delta function
FWHM: 38.4A (NUV-grating), 16A(FUV-grating1), 14A(FUV-grating2)

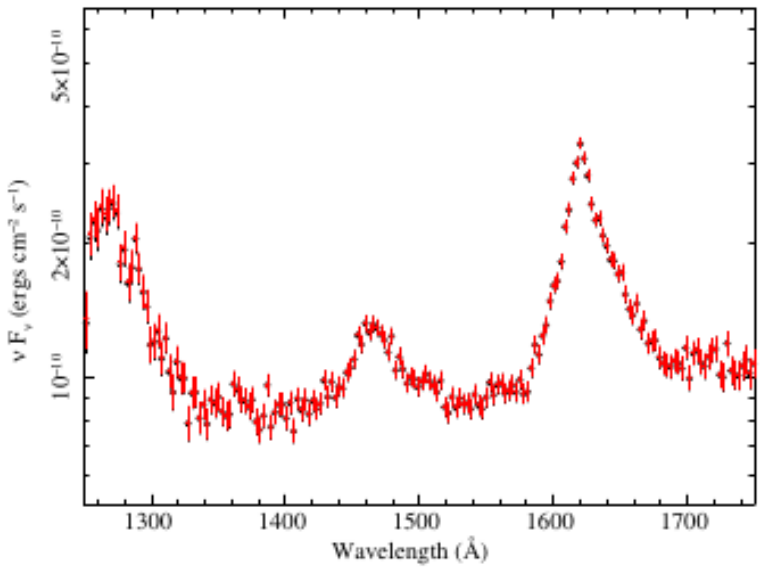
A(E) : energy-dependent effective area of the telescope and detector system (in cm2), Effective area curves derived for the gratings

f(E): Source spectrum (in photons/cm2/s/keV)

Spectral fitting: Fluxed Vs PHA spectrum

Fairall 9



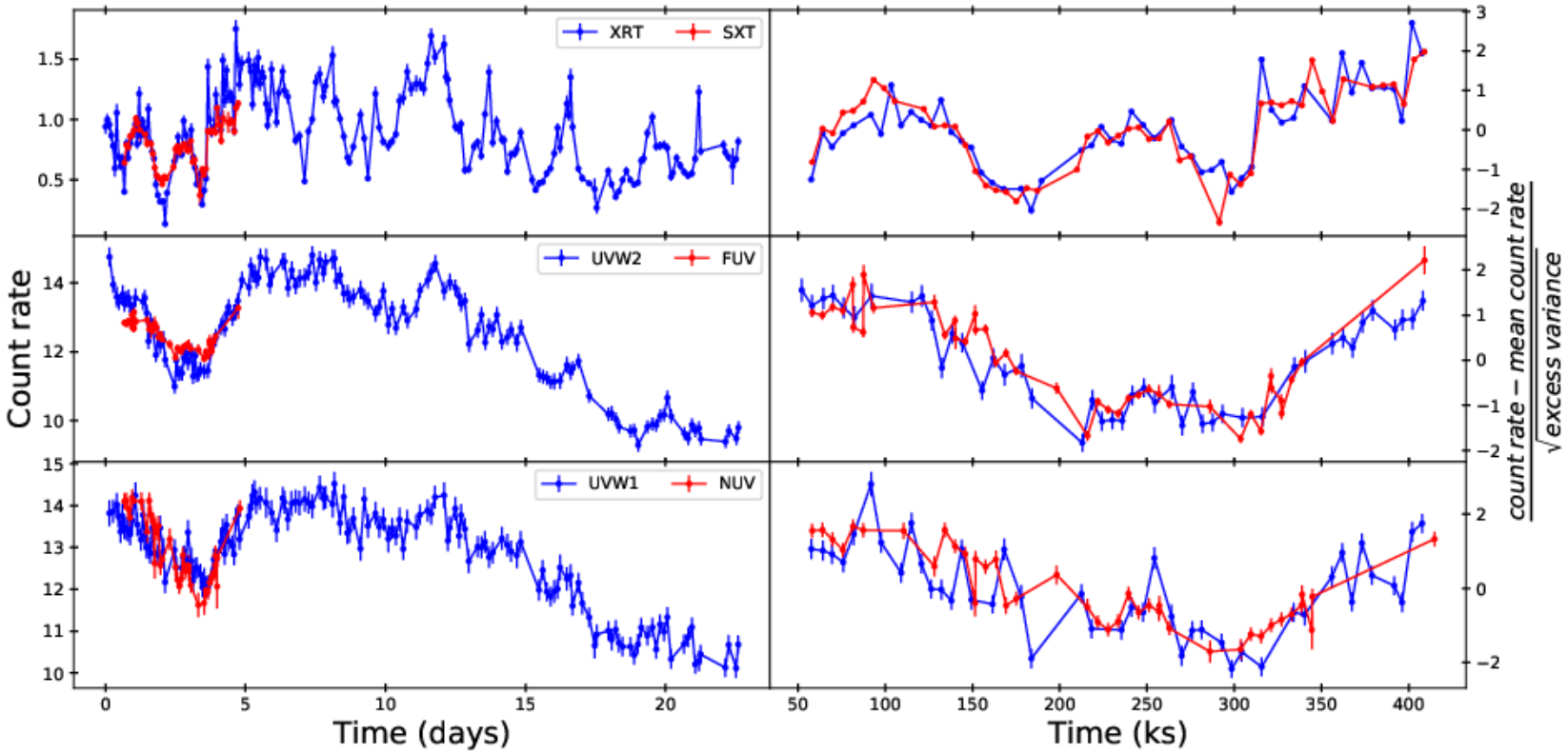


UVITTools.jl: A julia package for UVIT/Grating Analysis

(Available at Github, to be made public after the calibration update)

UV/X-ray light curves from AstroSat and Swift

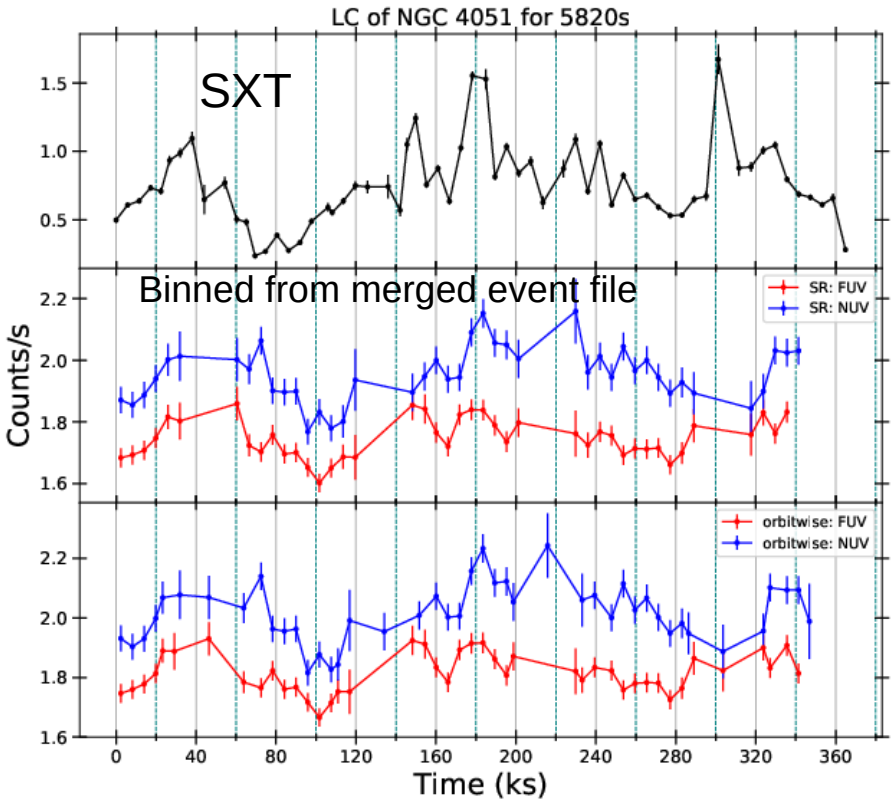
NGC4593 (4-day long AstroSat observations)

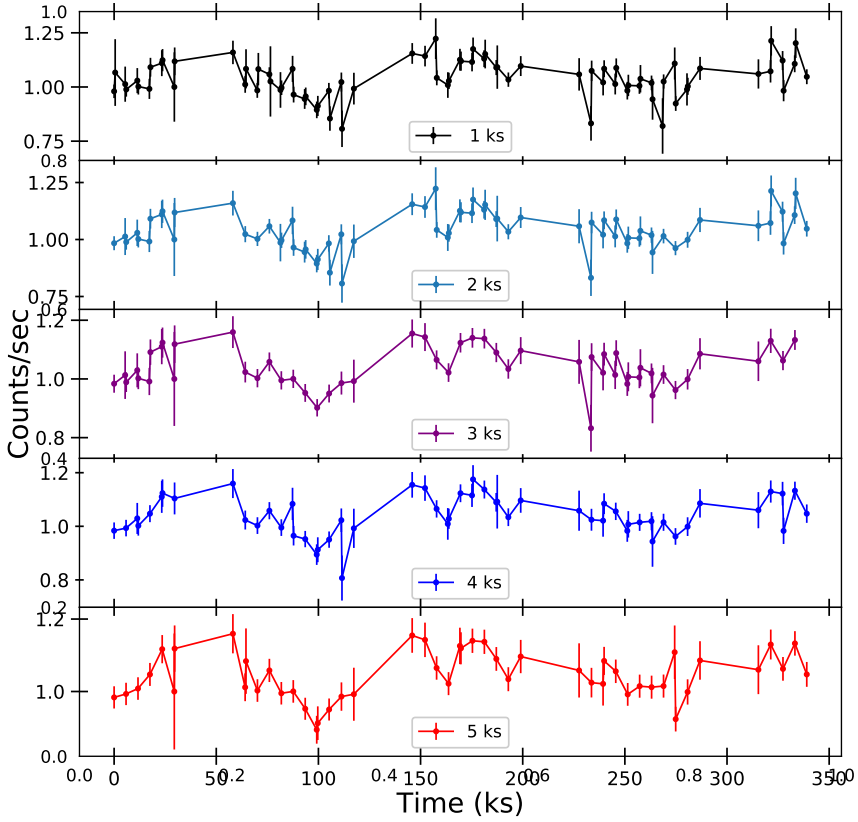


Kavita Kumari+GCD et al.

UV light curves from orbit-wise images and merged event files

Merged UVIT event files like X-ray event files, compatible with X-ray software

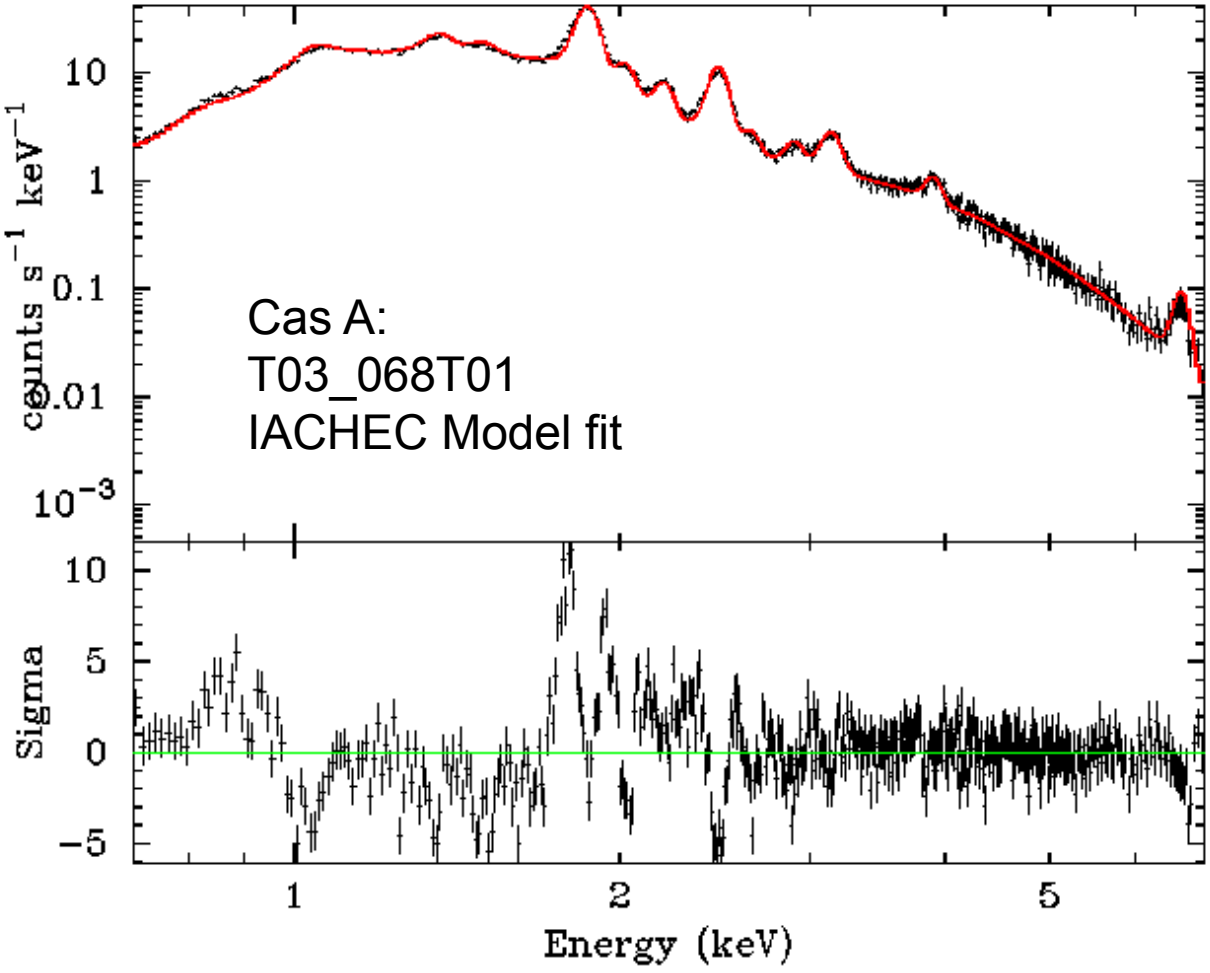




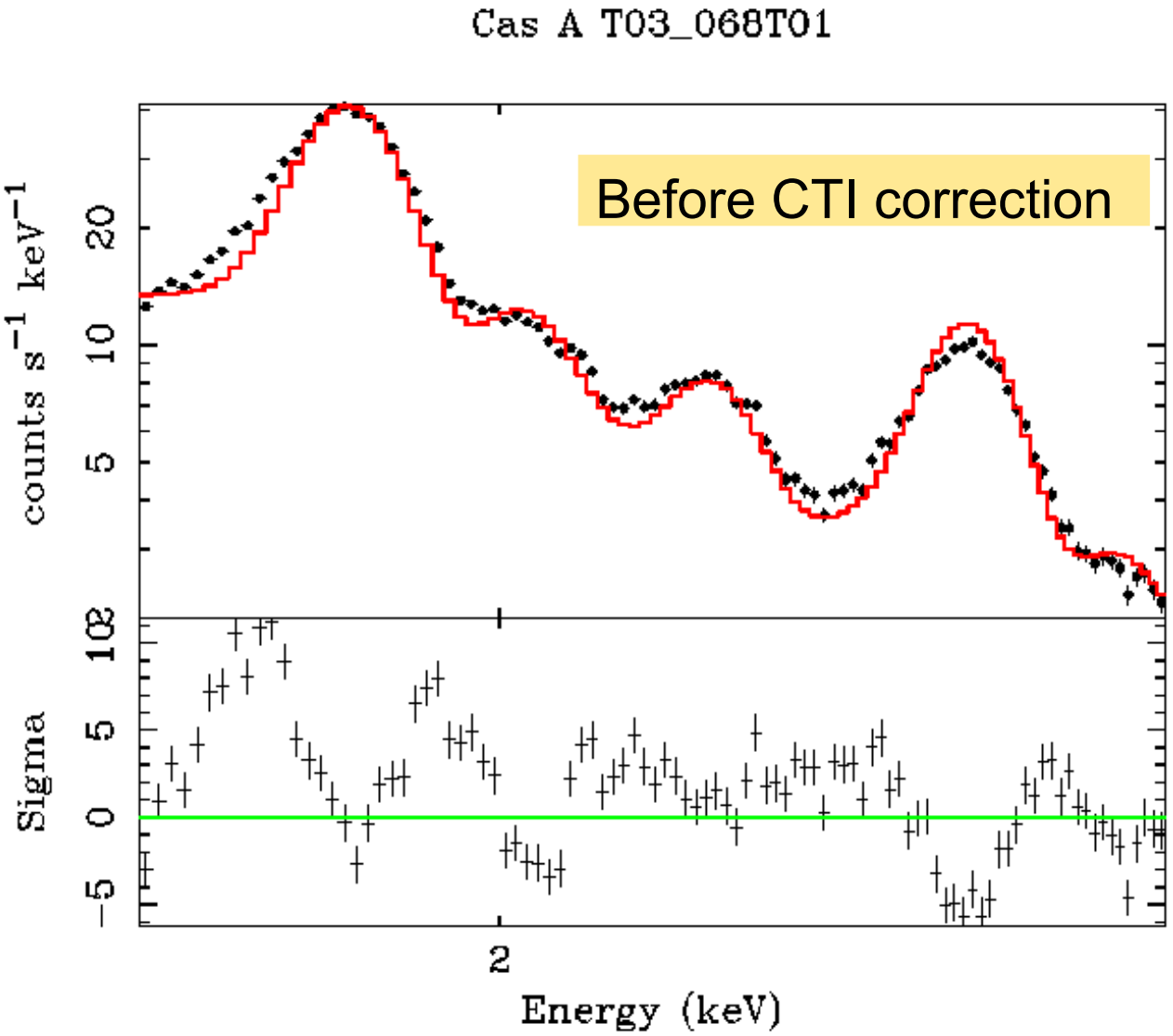
Kavita Kumari + GCD

SXT/RMF: Current status

Broadened RMF (CTI effects?)



SXT/RMF: broadened (CTI effect?)



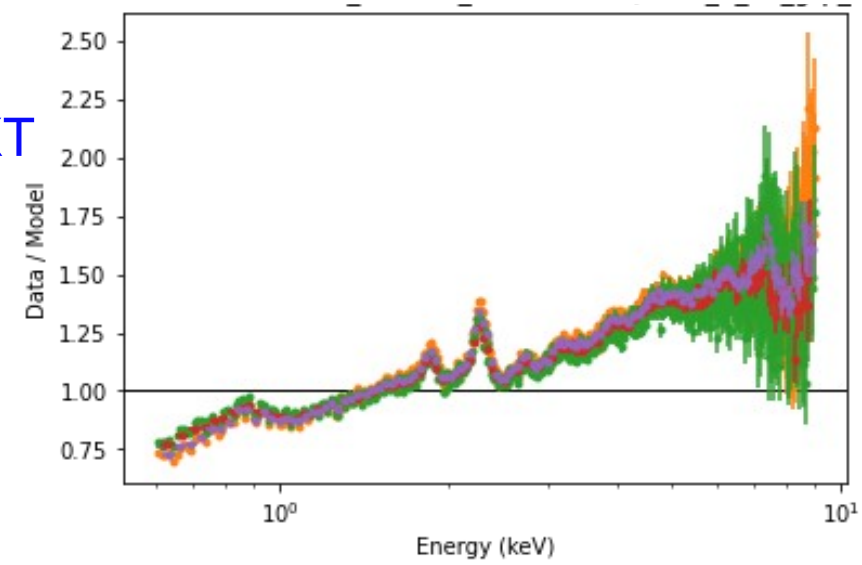
CTI correction now implemented in the Pipeline.

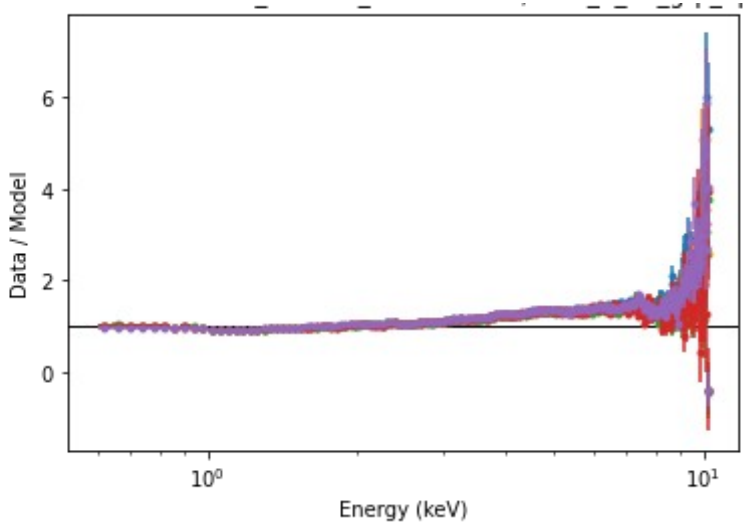
RMF needs to be checked.

Not a very serious issue for continuum sources, can be taken care by applying a Gaussian smoothing to RMF or the spectral model.

SXT/ARF & Crab

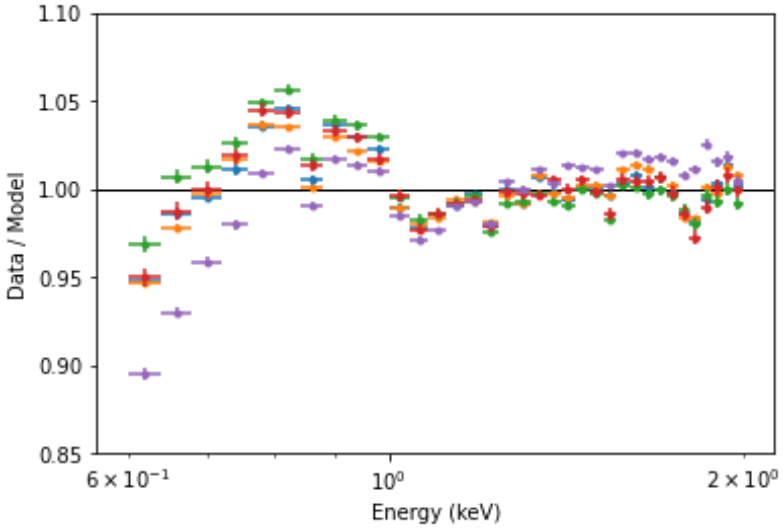
- Examined SXT/ARF for bright and hard source such as Crab. Six observations of Crab with CZTI & SXT pointing were analysed.
- Source extraction:
  Annular region 2-15 arcmin
- Used phabs*powerlaw with standard parameters for Crab. ARF used: sxt_pc_excl00_v04_20190608.arf (current ARF).
- Nearly steady performance
- Noticed gain-shift, which was then applied to the PHA files outside of XSPEC.





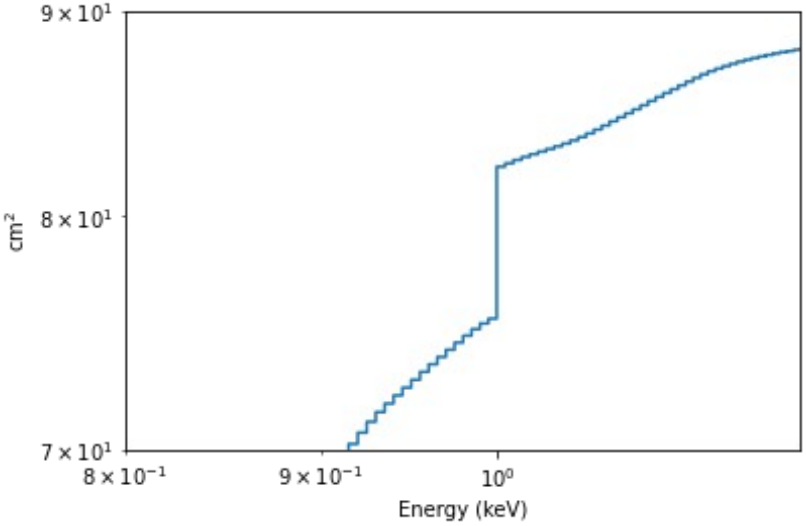
ARF recalibration with Crab

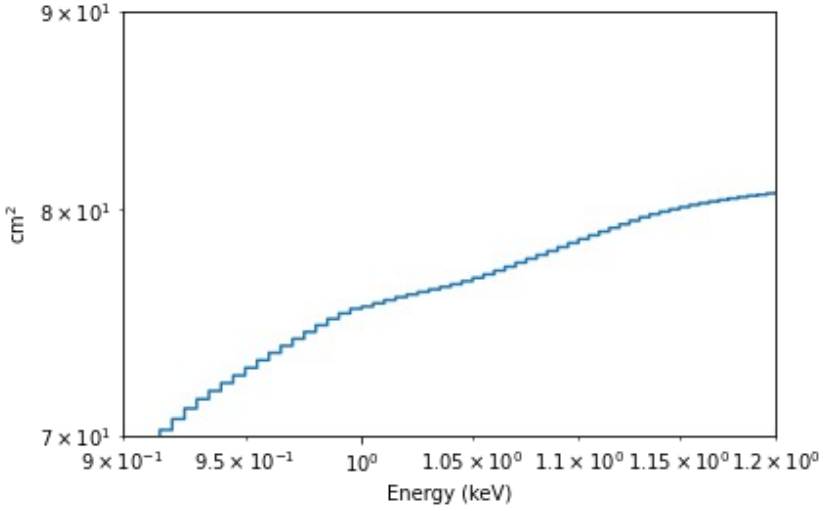
Gain-shifted Crab spectra refitted with the standard model, a sharp (vertical) jump in the ARF at 1keV that was causing strong residuals in the Crab spectra is noticed.



This jump is not like that caused by absorption edges. This jump is removed from the ARF by multiplying the ARF with a constant factor above 1keV.

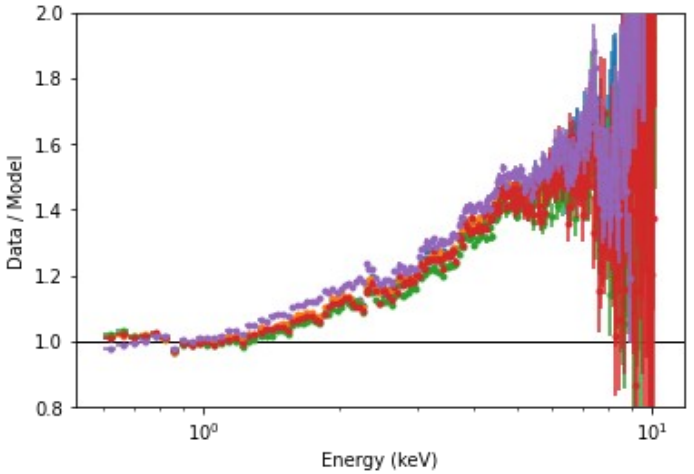
Current ARF:
sxt_pc_excl00_v04_20190608.arf



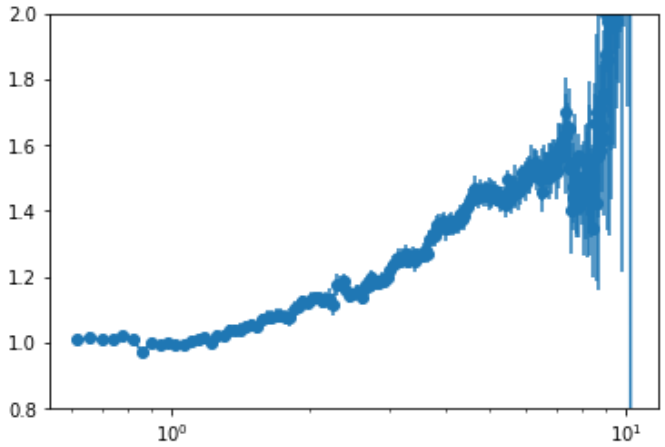


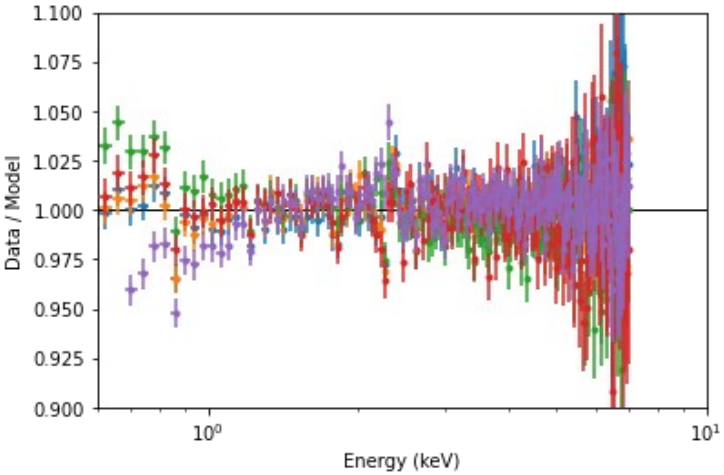
ARF recalibration with Crab

- Gain-shifted Crab spectra were again fitted with the modified ARF, and data-to-model ratios were derived.
- The ratios were found to be similar for different observations, and a mean ratio was derived

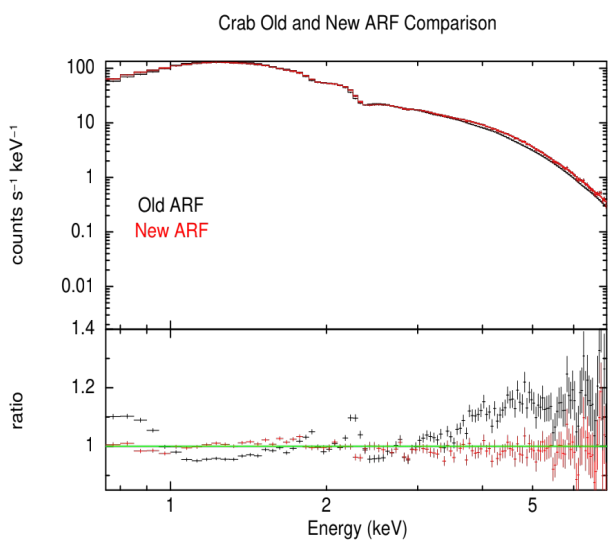


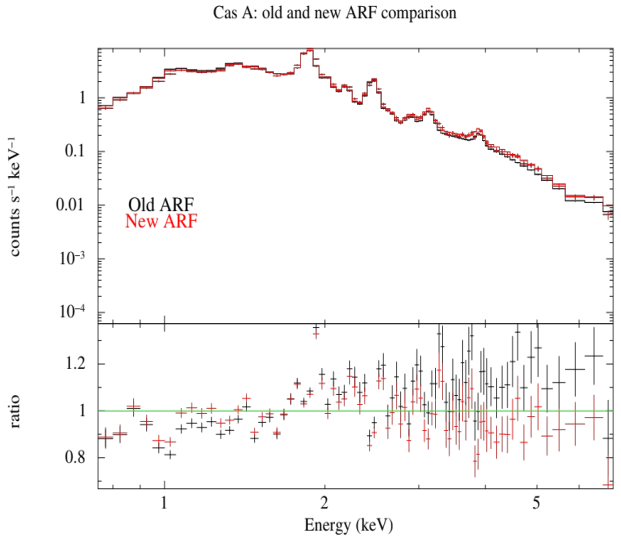
Mean ratio used to correct ARF above 1keV.





- The new ARF provided similar fit to 1E0102 as the old ARF.
- Cas A (brighter source) - slight excess at higher energies.
- Possibly due to pile-up in the Crab data even above 2arcmin region. Excluding the inner 4 arcmin regions from the SXT on-axis observations, and correcting the ARF provided similar ratios for Crab and Cas A.





Useful for hard, absorbed, piled-up sources such as BHB.

PSF likely energy-dependent, ARF derived from annular region may not be appropriate for soft sources.

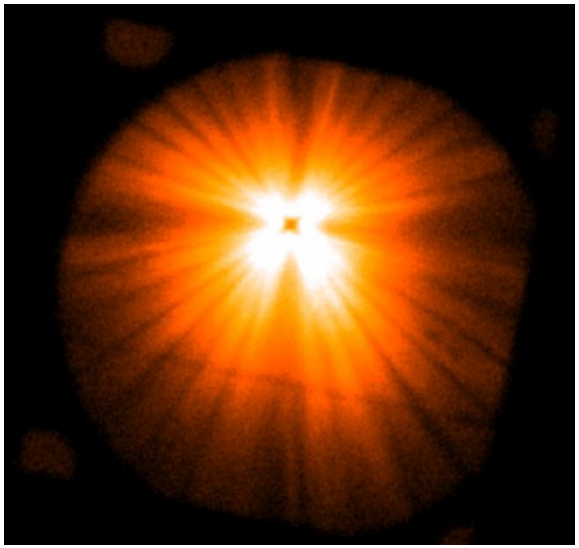
Need SXT data for bright, hard source but not affected with pile-up!

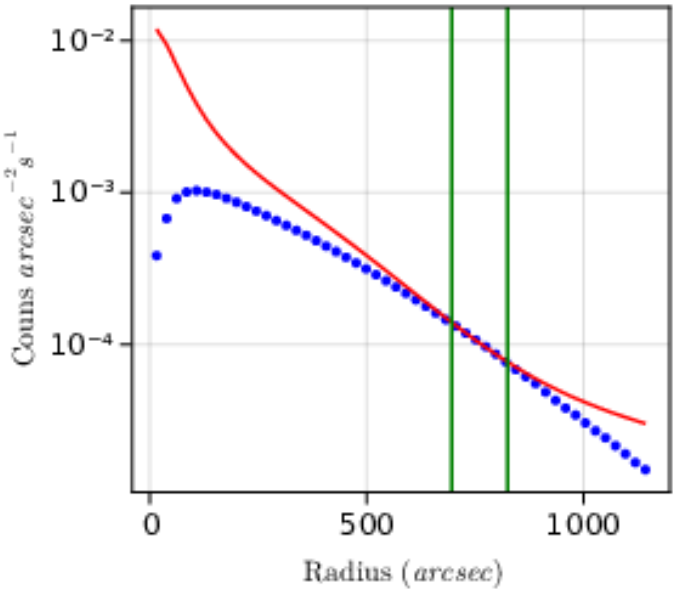
1. Long observations of Cas A to acquire S/N data above 2 keV
2. Simultaneous Swift/XRT and SXT observations of BHBs and Mkn421.

MAXI1820 : Pile-up correction

Heavily piled-up and observation (0.5-7keV flux = 6.5e-8cgs HS state)
Reduction in photon numbers in the inner and outer regions.

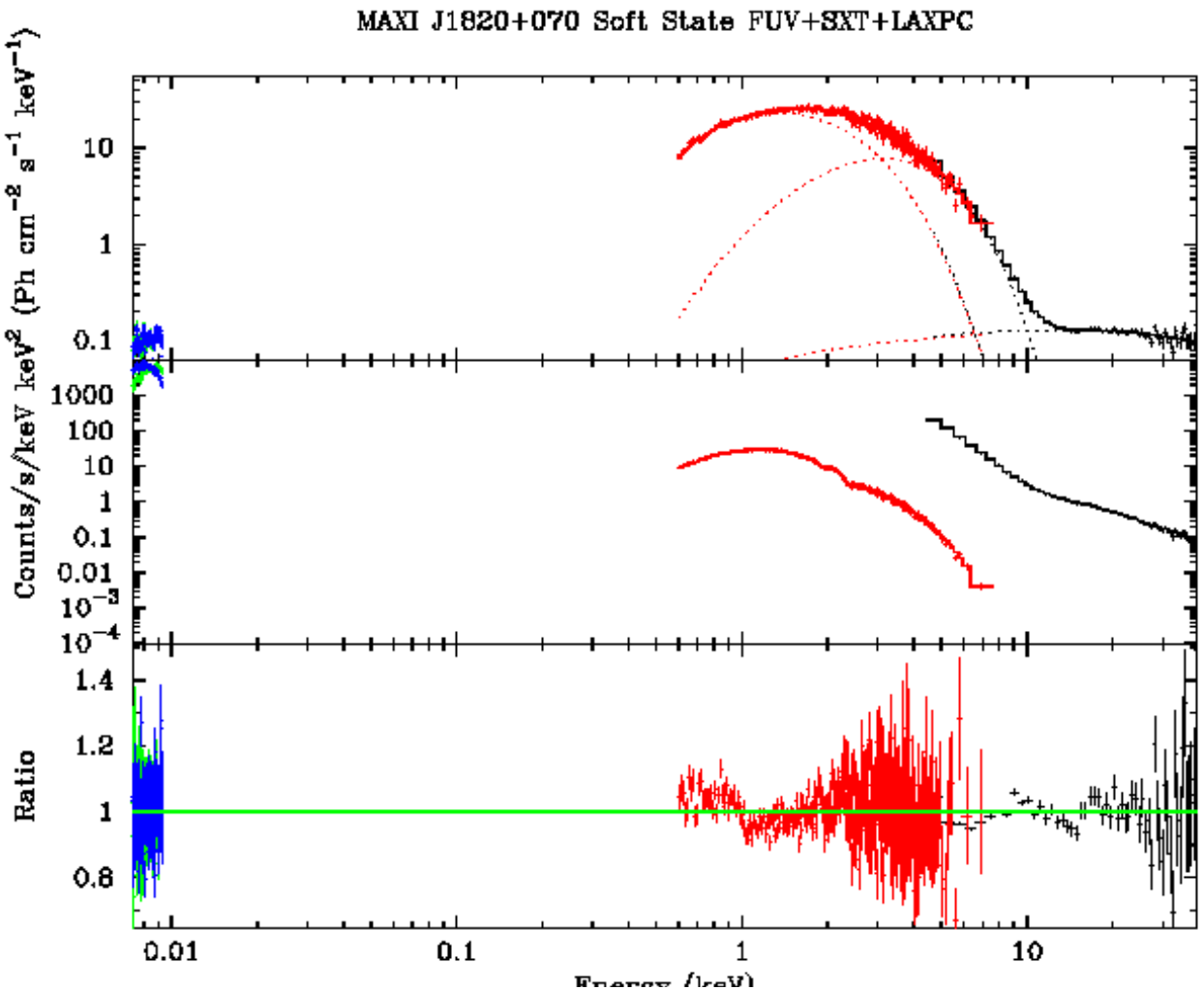
Derive SXT PSF using a bright source with no pileup – Mkn421.
Compare the SXT PSF with the radial profile of piled-up source.
Only a narrow range of radii (800-900 pixels) useful for extraction of spectrum. Use Crab-calibrated ARF for these radii.





MAXI J1820+070: Soft state

(FUV-Grating + SXT + LAXPC)



Relative Norms

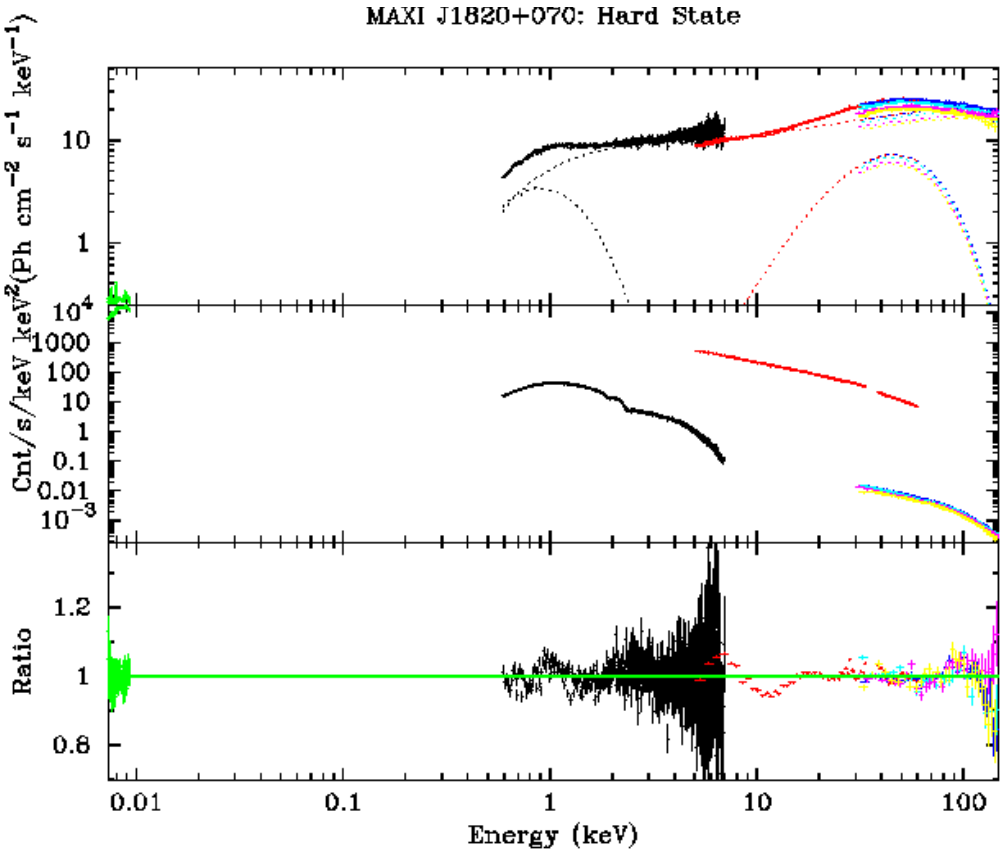
SXT: 1 (fixed)
LXP20: 1.056 +\- 0.004

FUV-G1: 1 (fixed)
FUV-G2: 1 (fixed)

Srimanta Benerjee+GCD

MAXI J1820+070: Hard State

(FUV-G + SXT + LAXPC + CZTI)



Relative Norms:

SXT: 1 (fixed)
LXP20: 0.75(-0.0014, +0.0016)
FUV-G2: 1.0 (fixed)

CZTI0: 0.75(+/-0.0056)
CZTI1: 0.70(+/-0.0055)
CZTI2: 0.64(+/-0.0052)
CZTI3: 0.60(+/-0.0051)

Sources with multiple spectral components NOT GOOD for UV/X-ray cross-calibration. Not a single UV/X-ray calibrator suitable for both UVIT and SXT. Crab piled up in SXT and extended in UV. Careful MW analysis of Crab required.

3C273 – multi-mission calibrator not observable with AstroSat. 1E0229+200 not UV bright. Need UV/X-ray observations of bright blazars simultaneously with other missions

Thanks