MOS contamination and redistribution

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EPIC Cal meeting
22/23 May 2023

Overview

- Reminder of what was done previously
- Update of the contamination (mentioned last year)
- Update of the redistribution matrices
- Residual issues

Reminder of previous work and approach

- MOS RMF evolution previously determined/provided for each MOS
  - Patterns 0 and ≤ 12 (all)
  - Patch-core (r=14”), patch-wings (14”<r<36”) and out-of-patch (r > 36”)
  - 14 separate epochs (last in use since Sep. 2011)

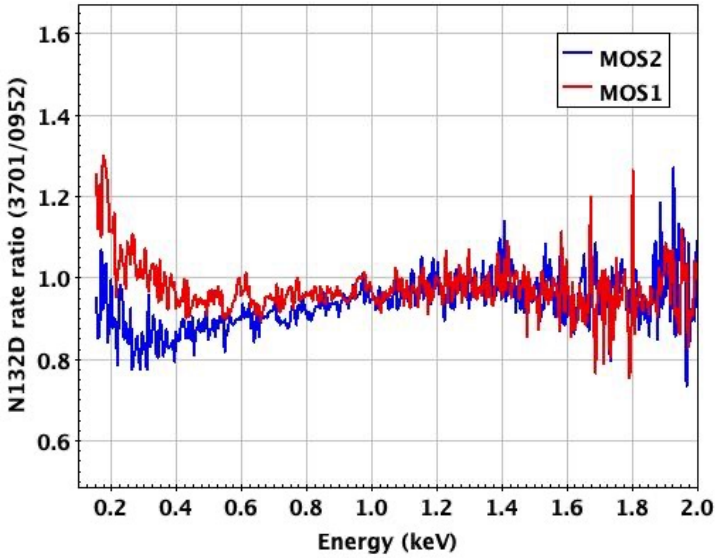
- Changes in redistribution and contamination can produce energy-dependent effects that are similar

- For MOS, previous work
  - Assumed/adopted (RGS) Carbon-based contaminant
  - Assumed contamination uniform across field (incl. patch)
  - Derived contamination first, from off-patch region
  - Derived RMF for patch regions with updated contamination model

Reminder of previous work and approach

- Work by J Kajava hinted at Oxygen being a better explanation of contaminant in one obs of 1E0102-72.

- Not needed in RXJ1856 data. Mixed signals from N132D



N132D [rev3701 / rev0952] identical extraction aperture/posn.

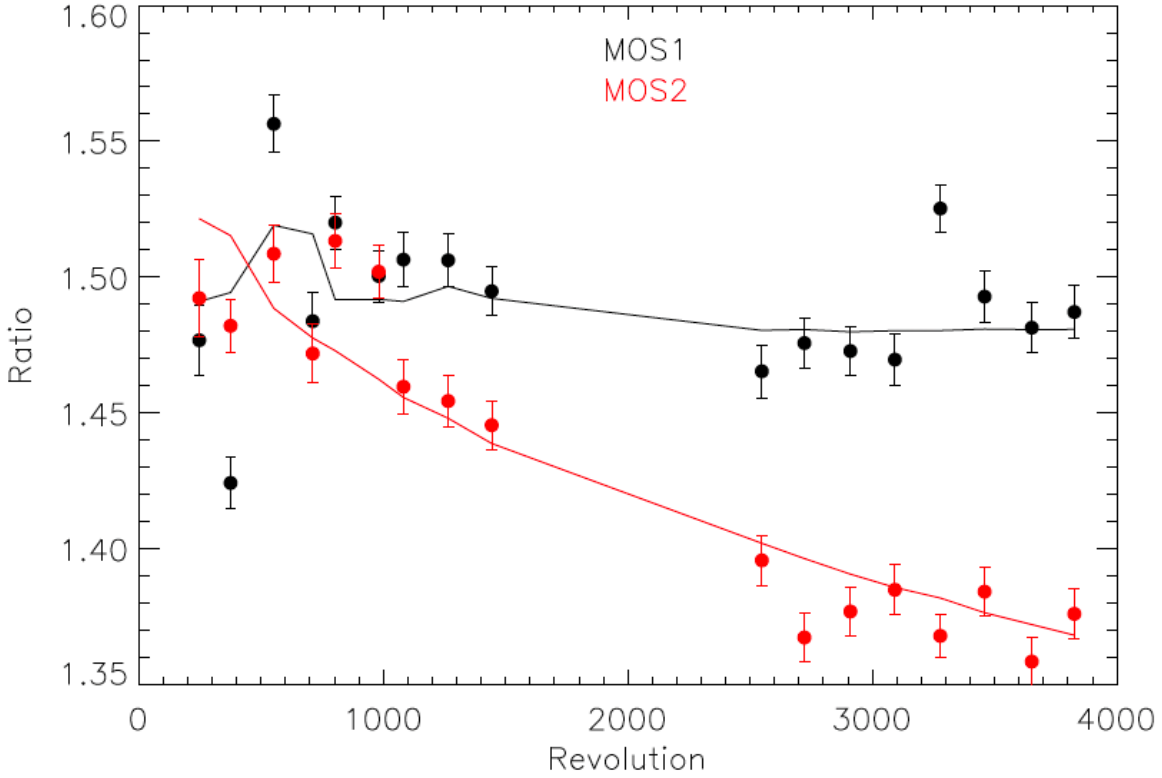
Excessive ratio at E < 0.30 keV in MOS1.

Minimum of profile near 0.5 keV for MOS1, and ~0.3 keV for MOS2. !!

Opted to assume Carbon-based absorber for consistency with earlier approach … but further investigation of a possible Oxygen component should be pursued.

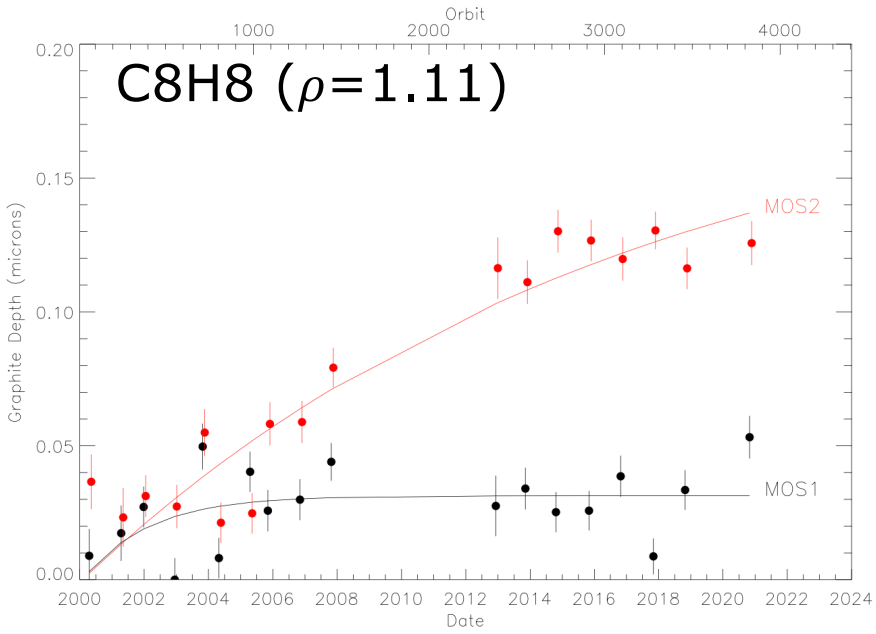
Contamination

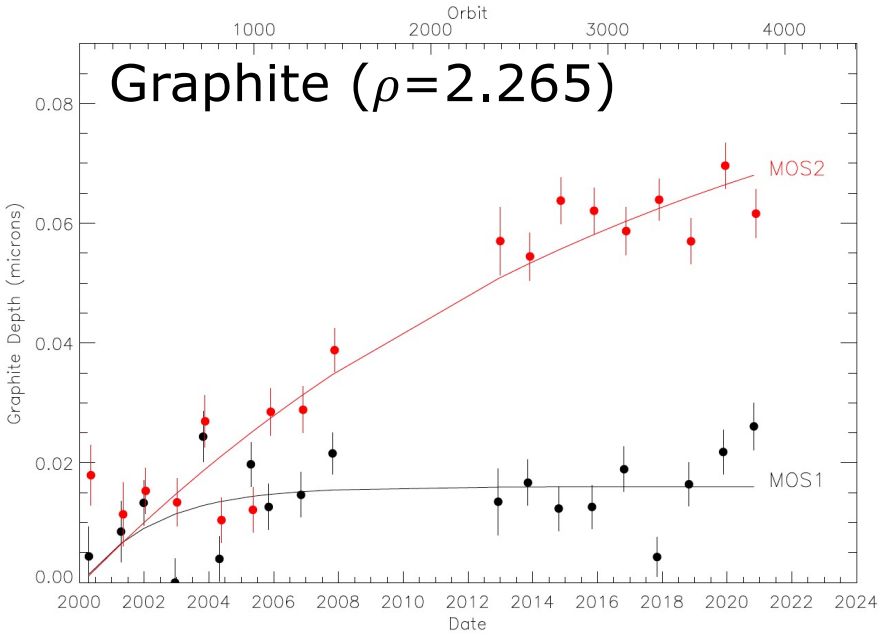
- C edge not distinguishable in spectra due to RMF effects
- Use off-patch observations of 1E 0102-72.3
- Use ratio of counts in 0.1-0.75 and 0.98-3.0 keV bands.
- Systematic trials of different thicknesses of Carbon-based absorber to match observed ratio for each observation.



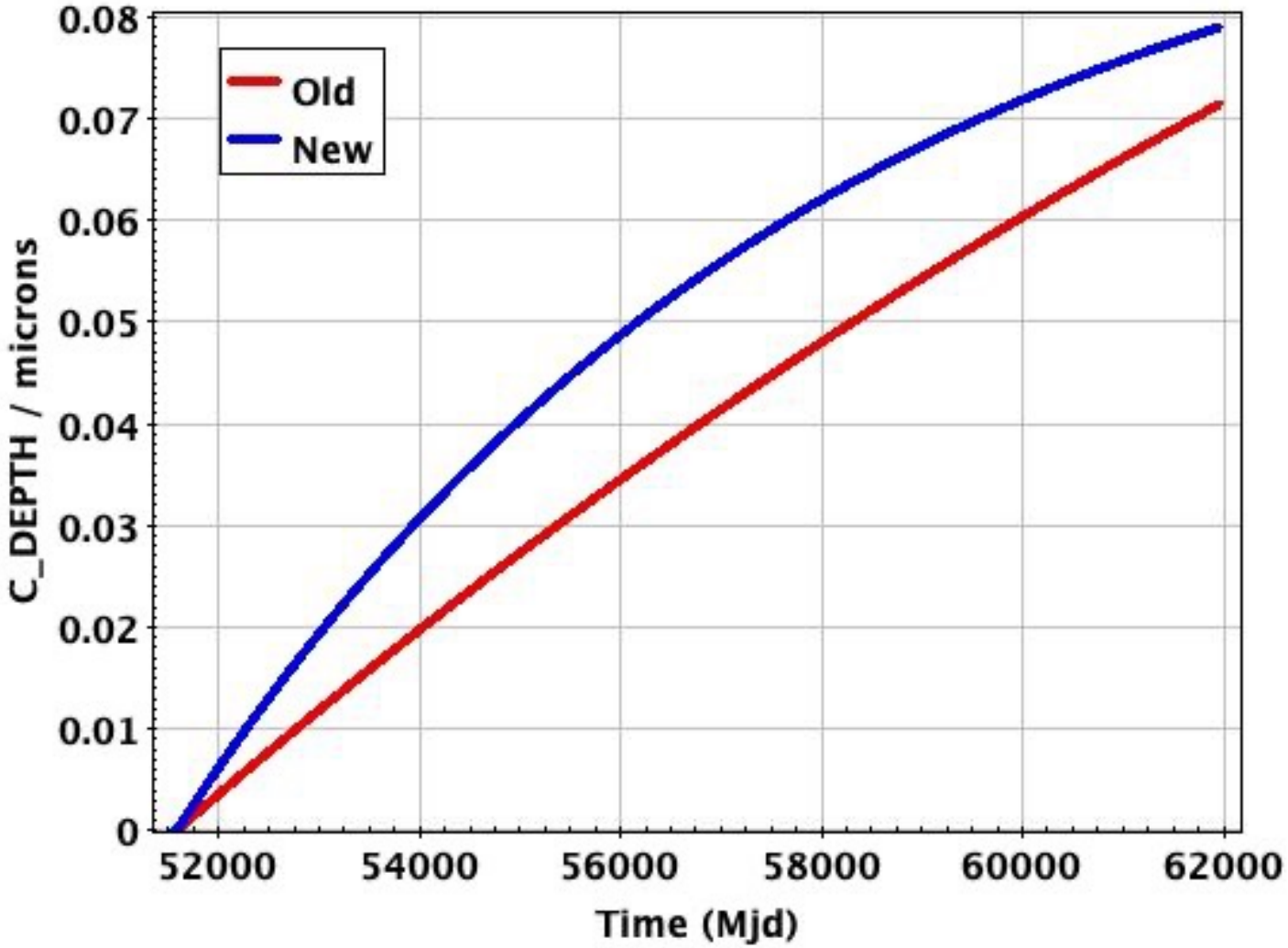
Contamination

Modelled as pure graphite or C8H8 – lower density requires larger layer thickness





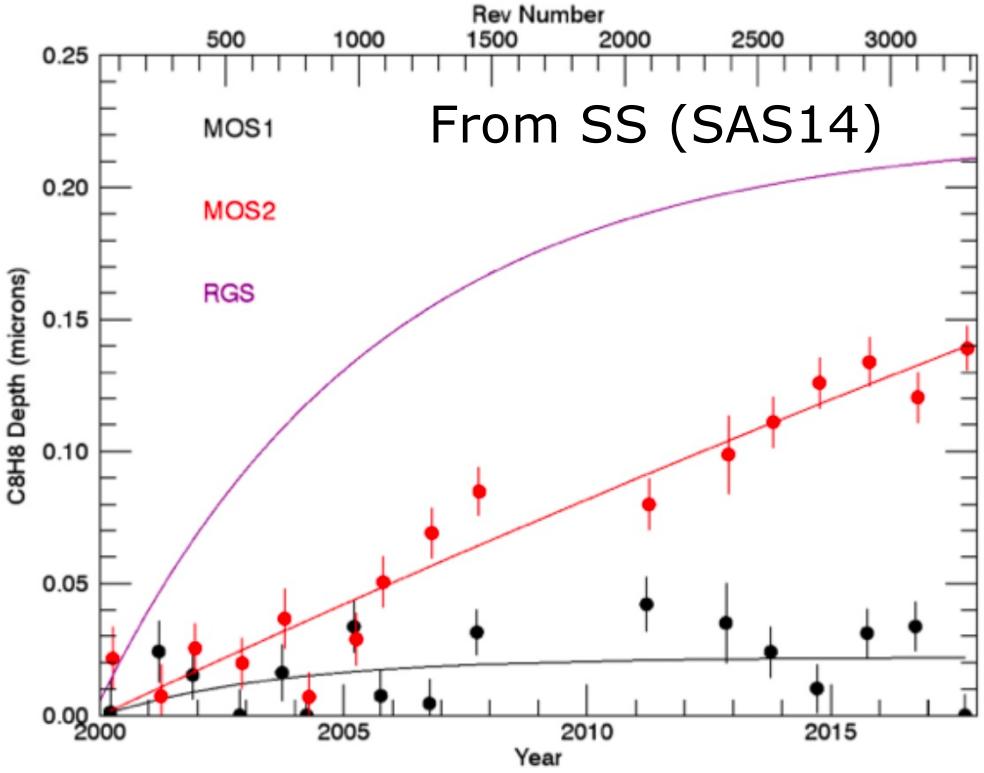
Contamination (Old CCF v New CCF)

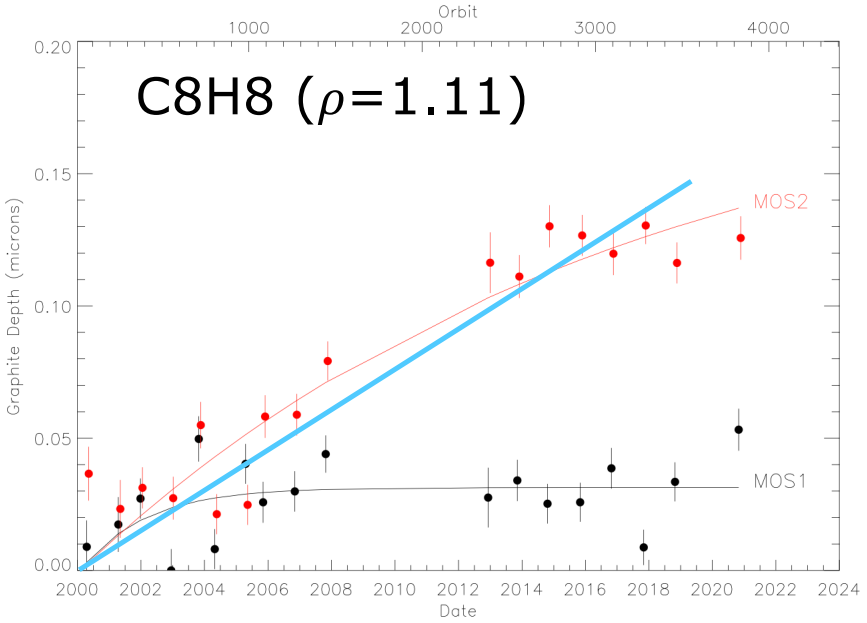


Layer depth larger than old function. Impact is ~5% on absorption.

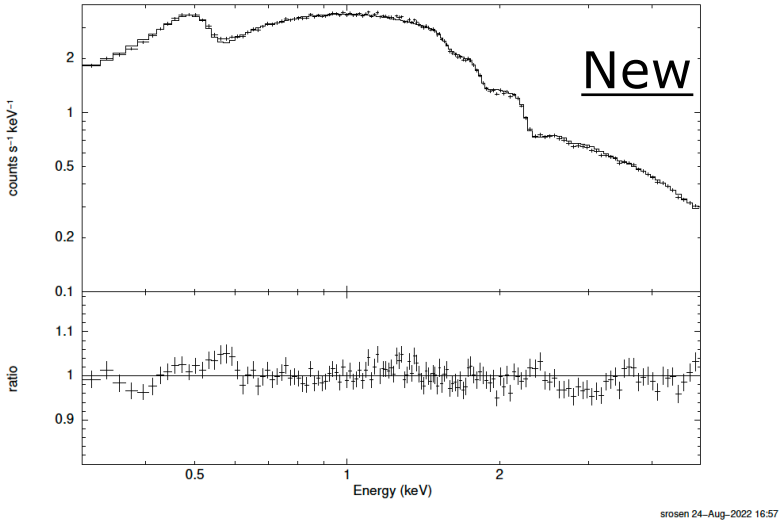
Contamination

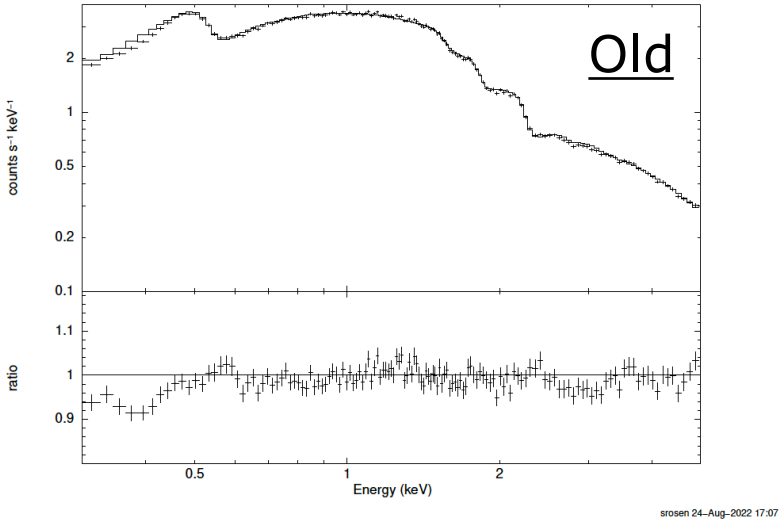
Unpublished update from S. Sembay showed better agreement with latest analysis. Related to density values adopted.





Contamination





MOS2 spectrum of 3C273 (rev 3768).

Model is double power-law that best fits pn data

Using new contamination model improves match for MOS2 at E< 0.5 keV

RXJ1856-3754 and 4XMM J111857.7+580323, also yield improved fits but negligible difference seen in CORRAREA sample (120 sources).

Use of new function important to reflect flattening of the growth of the contaminant layer.

Redistribution

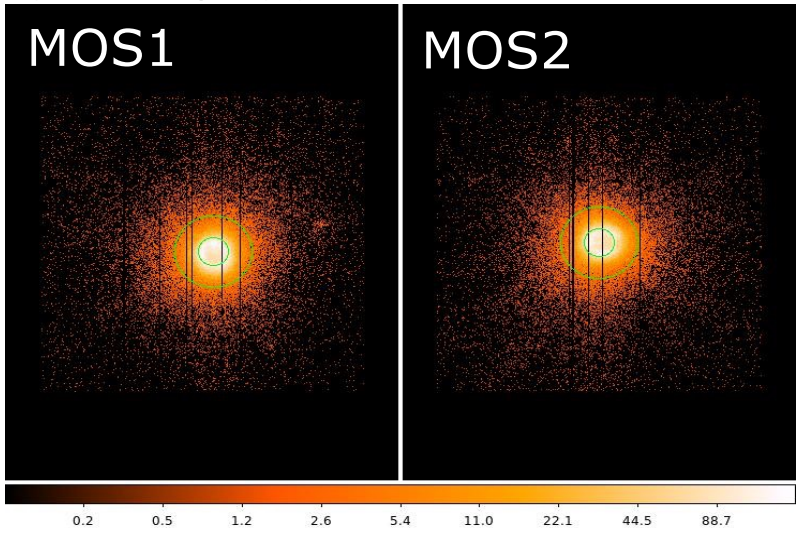
Source	Model input (IACHEC)
1E 0102-72.3	rgspn_mod_tbabs_tbvarabs_2apec_line_ratios_jd_v1.9.xcm
RX J1856.5-3754	burwitz.xcm (2-component BB model)
Zeta Pup	puppis_model.qdp

Epoch	Rev range	dates
15	2451-2750	2013-04-27 – 2014-12-16
16	2751-3050	2014-12-16 – 2016-08-05
17	3051-3350	2016-08-05 – 2018-03-26
18	3351-3650	2018-03-26 – 2019-11-14
19	3651-3950	2019-11-14 - current

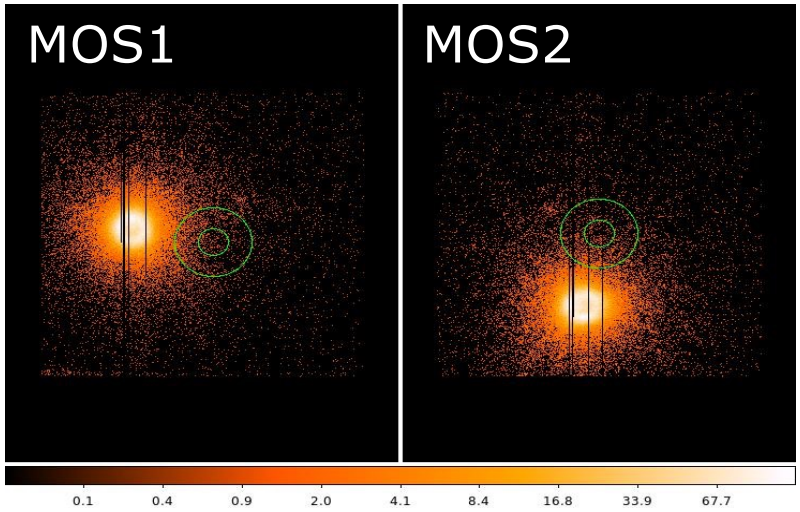
Redistribution

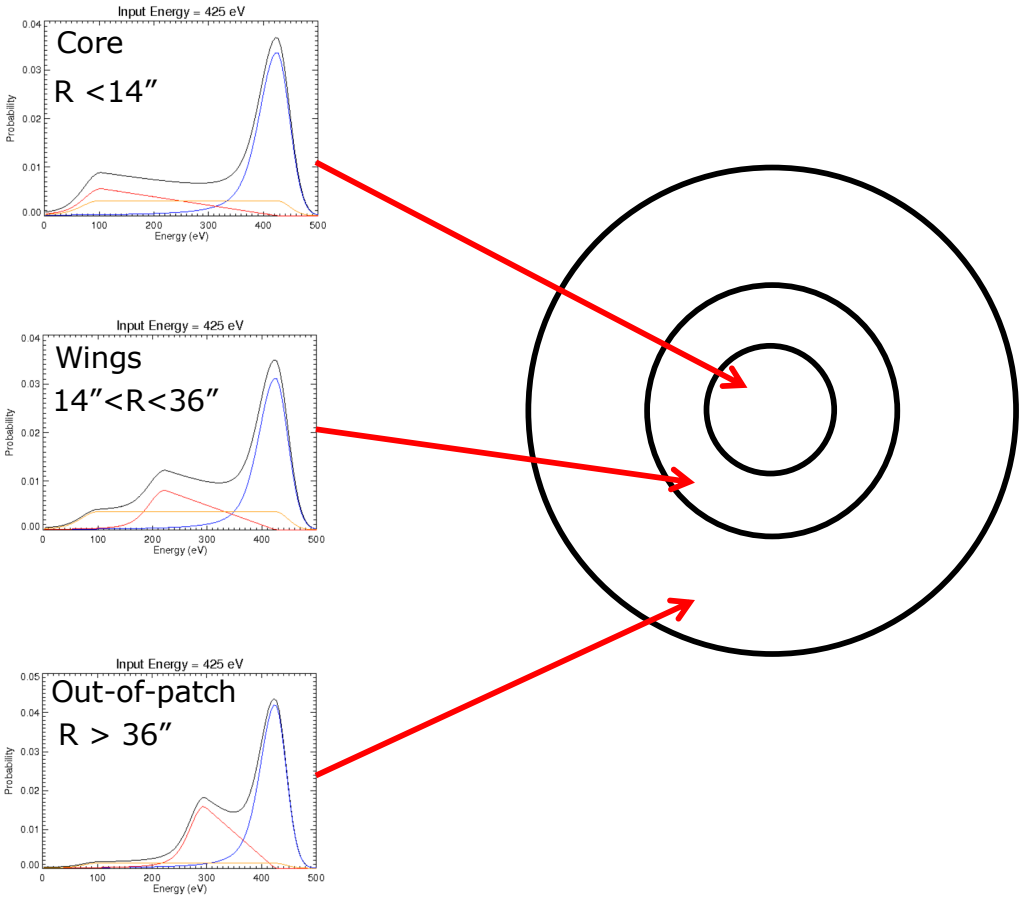
Revolution	Epoch	Obsid	Source	Location
2521	15	0727760101	RX J1856.5-3754	p
2706	15	0727760301	RX J1856.5-3754	p
2722	15	0412982301	1E 0102-72.3	p
2533	15	0561380601	Zeta Pup	p
2618	15	0727760201	RX J1856.5-3754	o
2722	15	0412982201	1E 0102-72.3	o
2540	15	0159361501	Zeta Pup	o
2909	16	0412982501	1E 0102-72.3	p
2817	16	0561380701	Zeta Pup	p
2989	16	0561380901	Zeta Pup	p
2910	16	0412982401	1E 0102-72.3	o
2794	16	0727760401	RX J1856.5-3754	o
2977	16	0727760601	RX J1856.5-3754	o
2911	16	0561380801	Zeta Pup	o
3111	17	0412983301	1E 0102-72.3	p
3279	17	0412983501	1E 0102-72.3	p
3075	17	0727761001	RX J1856.5-3754	p
3172	17	0561381001	Zeta Pup	p
3092	17	0412983201	1E 0102-72.3	o
3278	17	0412983401	1E 0102-72.3	o
3162	17	0727761101	RX J1856.5-3754	o
3276	17	0561381201	Zeta Pup	o
3459	18	0810880201	1E 0102-72.3	p
3645	18	0810880501	1E 0102-72.3	p
3454	18	0810840101	RX J1856.5-3754	p
3622	18	0810841401	RX J1856.5-3754	p
3361	18	0561381101	Zeta Pup	p
3543	18	0810870101	Zeta Pup	p
3646	18	0810870201	Zeta Pup	p
3459	18	0810880101	1E 0102-72.3	o
3358	18	0727761301	RX J1856.5-3754	o
3542	18	0810840201	RX J1856.5-3754	o
3826	19	0810880701	1E 0102-72.3	p
3804	19	0810841601	RX J1856.5-3754	p
3727	19	0810871301	Zeta Pup	p
3911	19	0810871401	Zeta Pup	p
3652	19	0810880301	1E 0102-72.3	o
3826	19	0810880601	1E 0102-72.3	o
3903	19	0810841701	RX J1856.5-3754	o

0412982301



0412982201





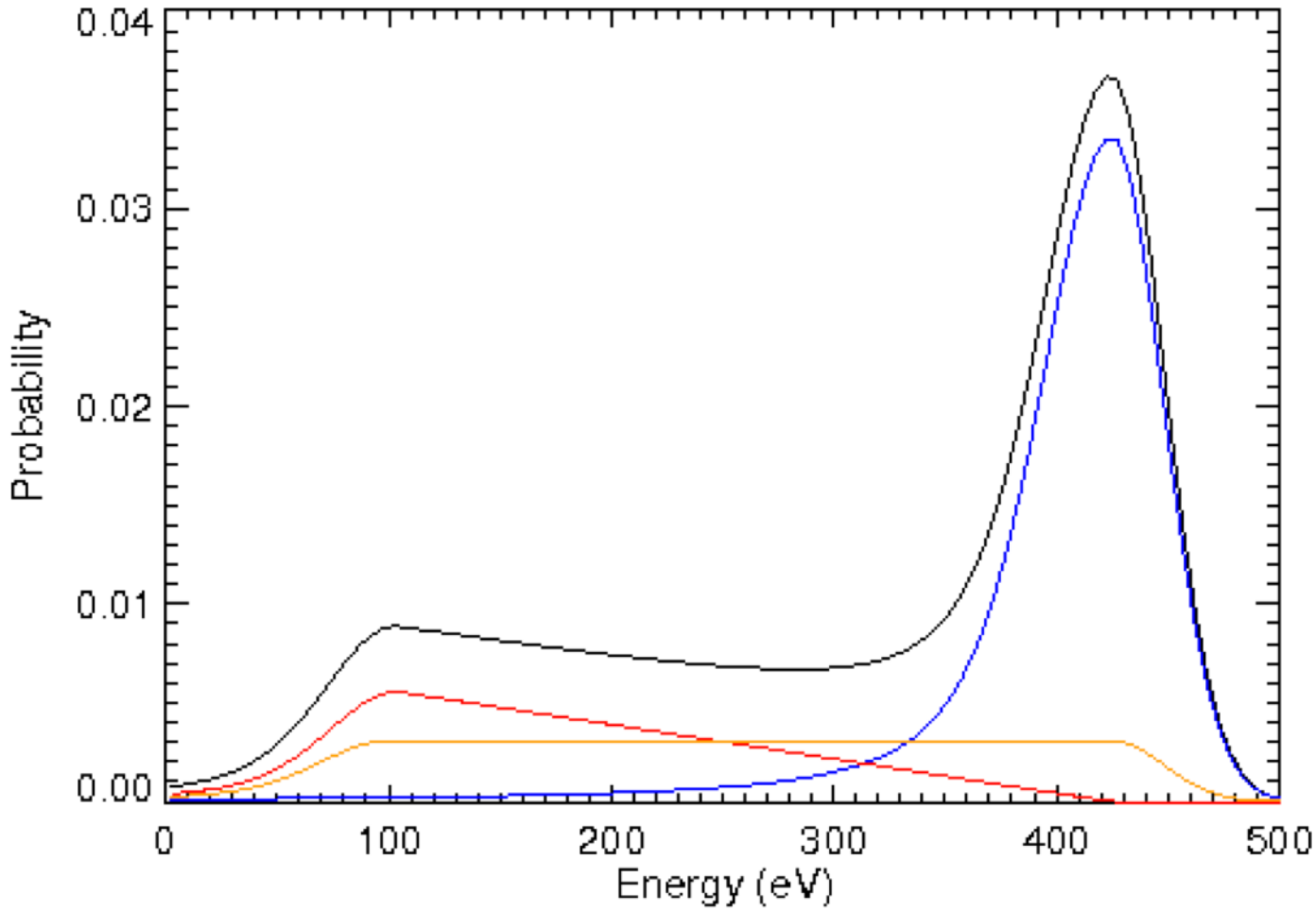
RMF created by *rmfgen* for a source on the patch

Weighted combination of core, wings and off-patch RMFs (area weighting if 'extended', PSF weighting if 'pointlike')

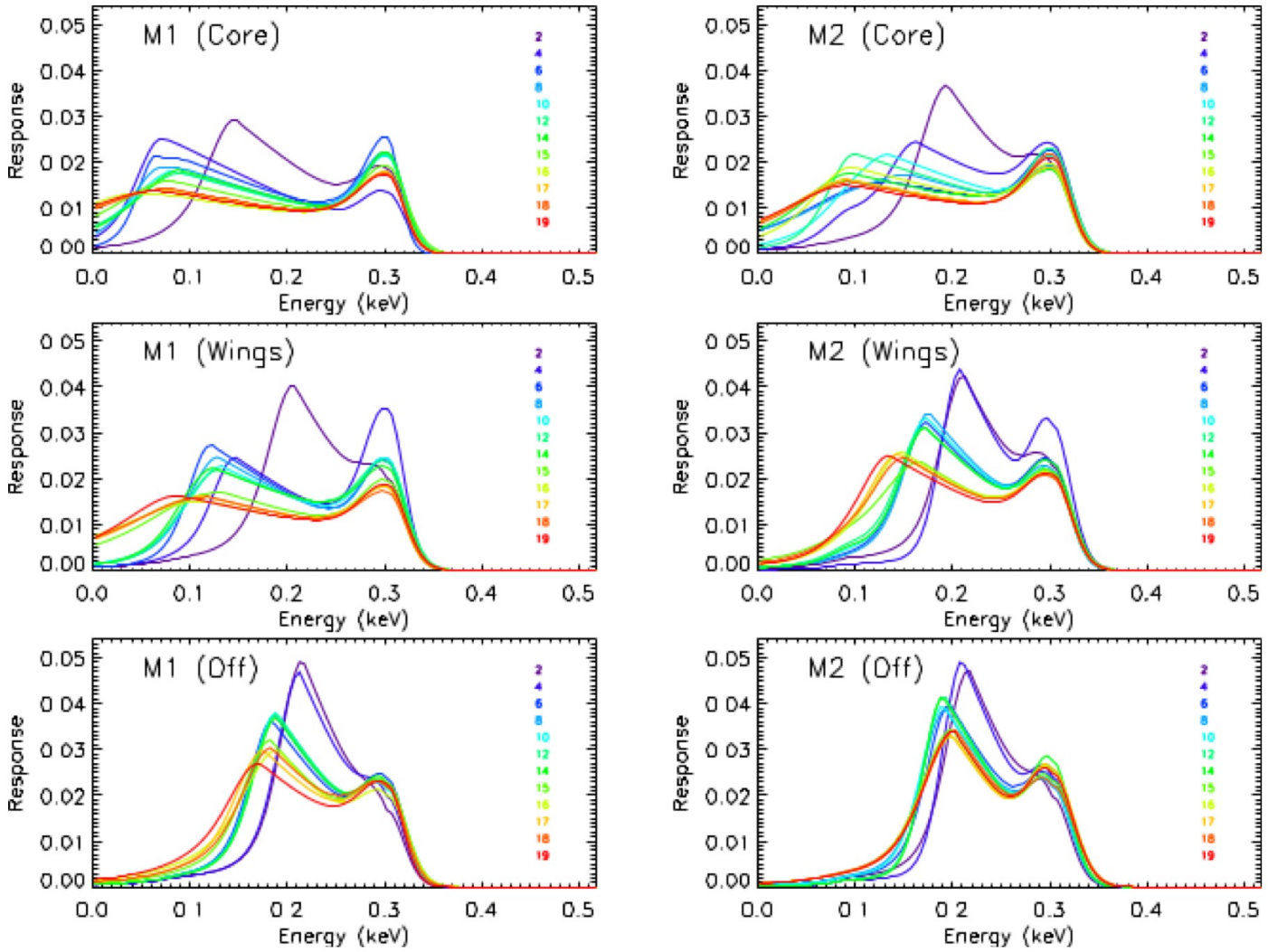
Redistribution

- Observed on patch (core and wings) and off-patch
- IACHEC source spectrum models adopted for consistency with previous analysis – maybe not optimum
- Columns showing hints of > 20eV gain shifts excluded (conservatively excluded columns from previous analyses too)
- ARFs include new contamination model
- Process iteratively modifies parameters of empirical redistribution function to optimize fit of data to IACHEC models (simultaneously for all spectra in the epoch (separately for each MOS, each patch region)
- Cal-closed data not used (lose constraints from Mn Kα,β in 5.8-6.5 keV)
- Potential residual gain shifts not fitted - encountered problems in many cases – would not expect a substantial impact – effect diluted by unshfited spectra in the epoch block.

Empirical redistribution profile



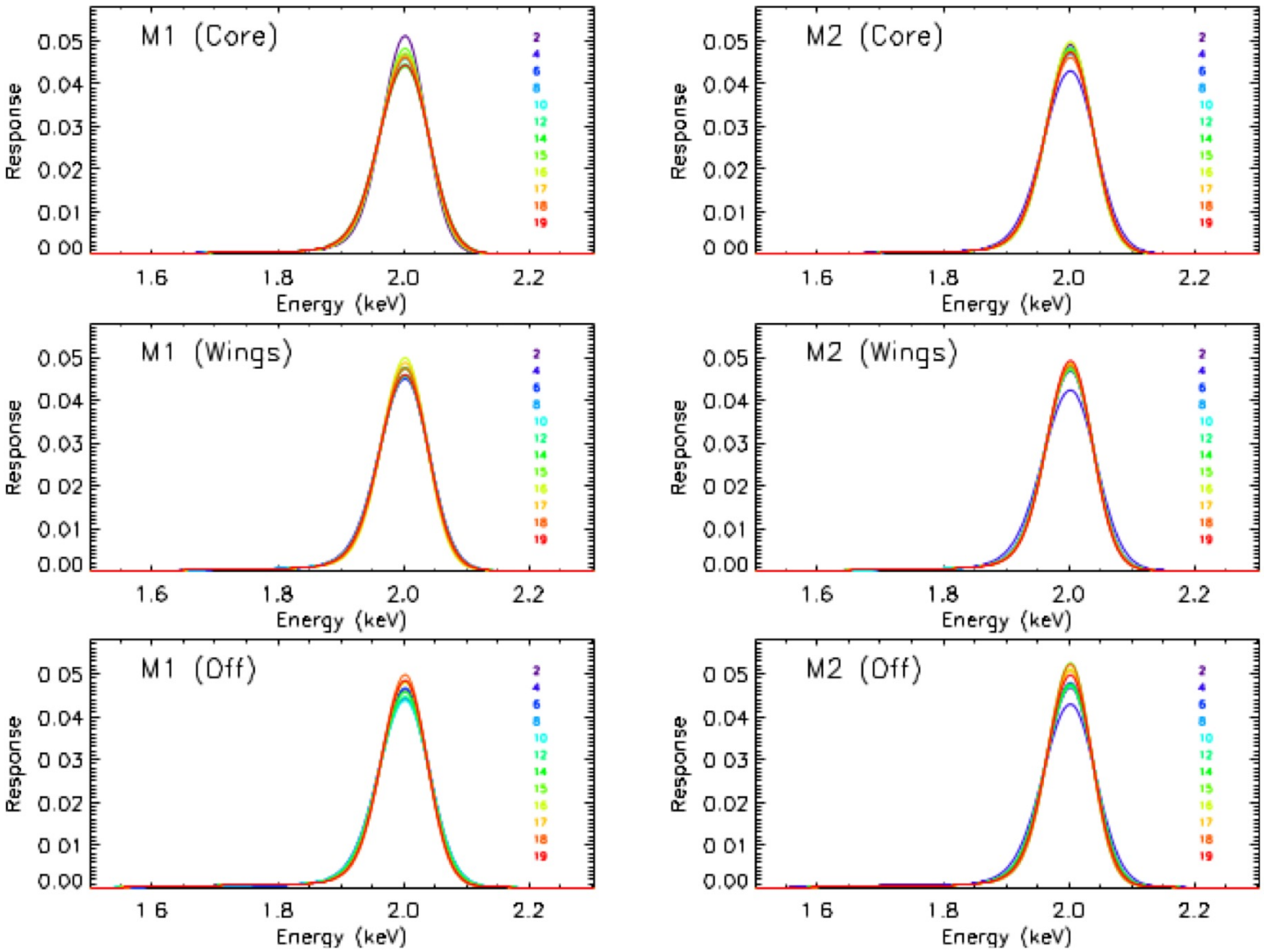
Redistribution evolution for 0.3keV photons



Evolution appears broadly systematic

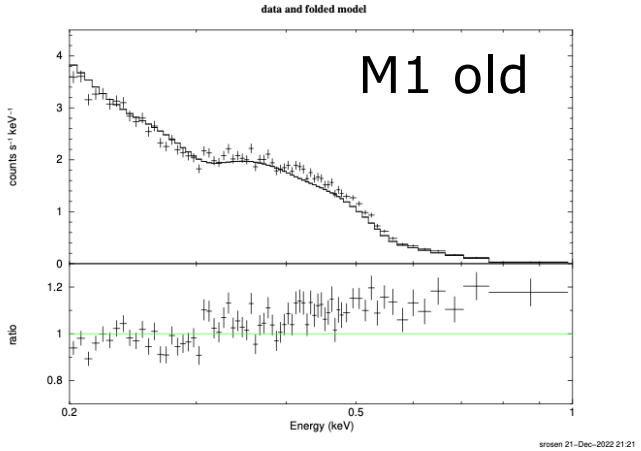
Indications of 'update' quantisation.

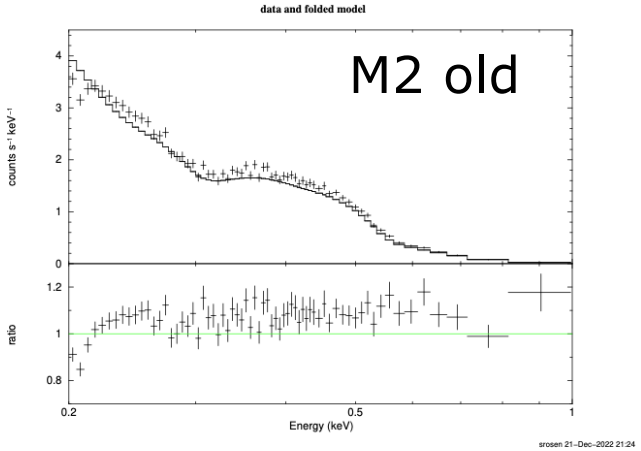
Redistribution evolution for 2.0keV photons

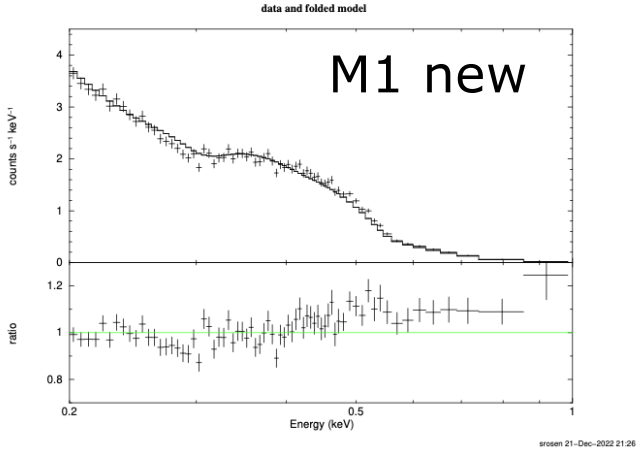


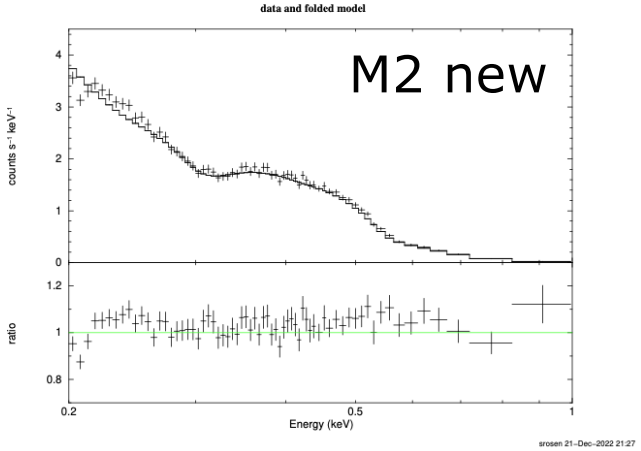
Tests with new/old RMFs

RXJ1856-3754 (Rev 3255)



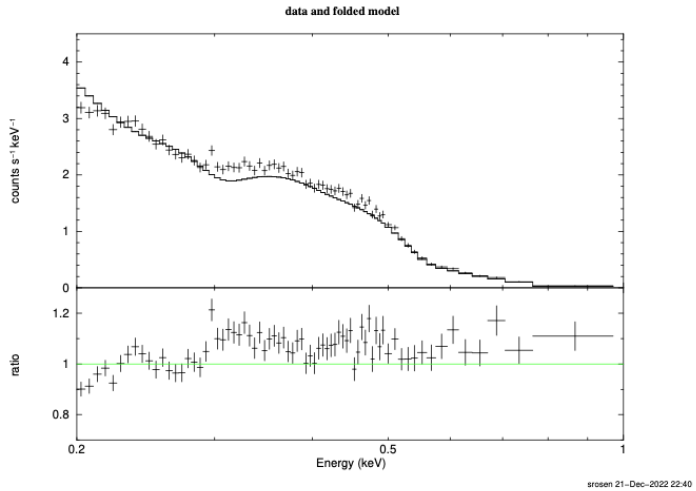


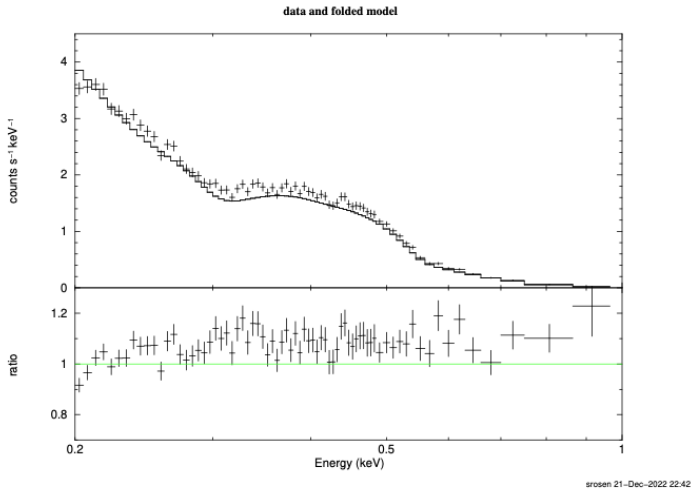


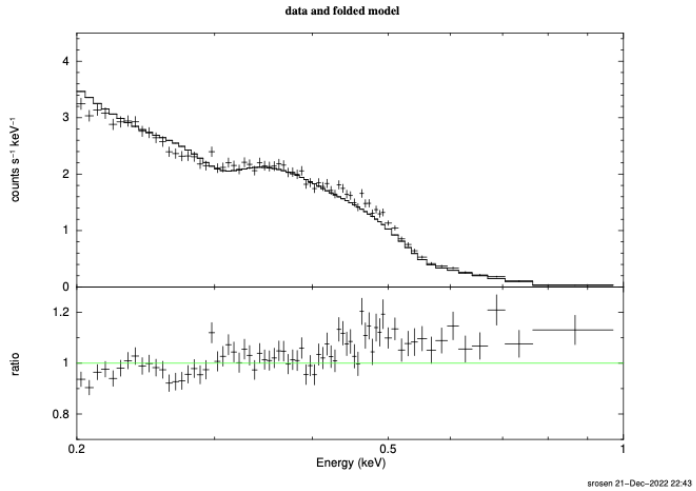


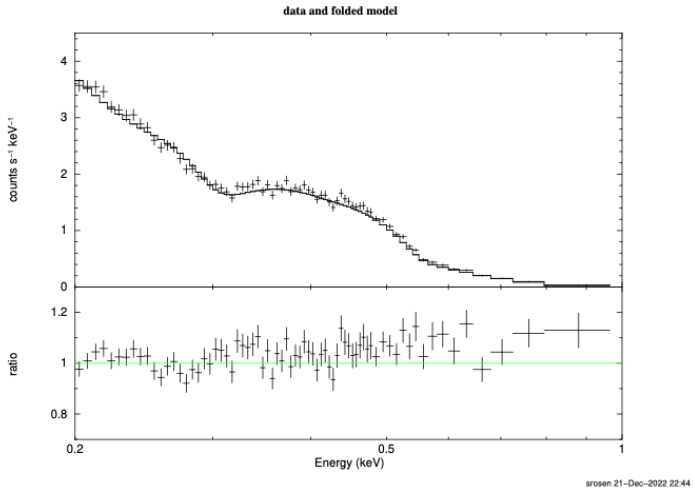
Tests with new/old RMFs

RXJ1856-3754 (Rev 4000)



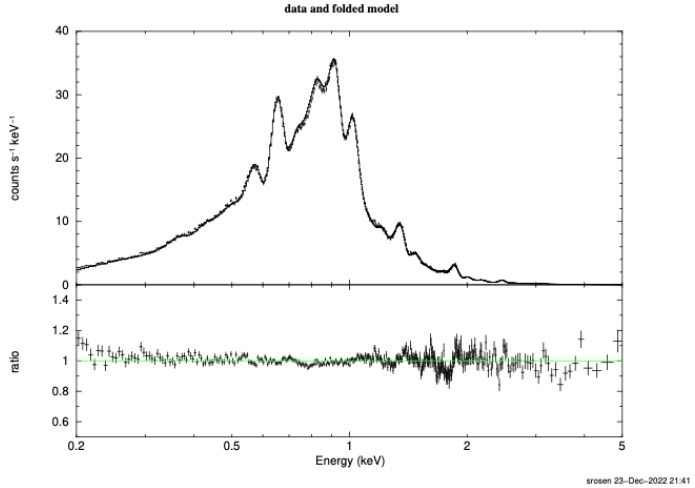


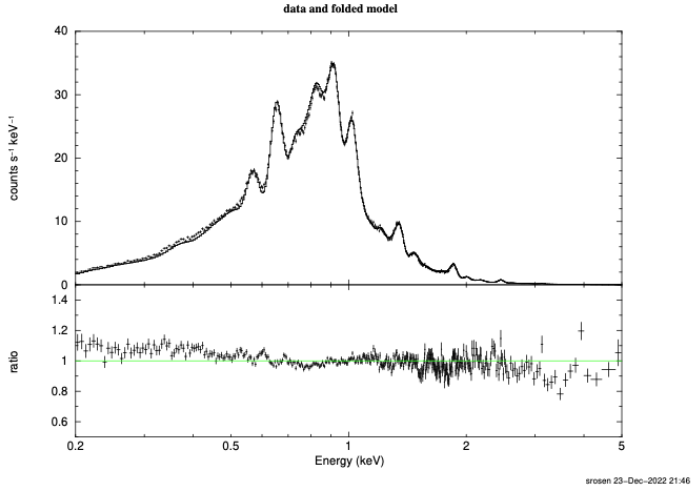


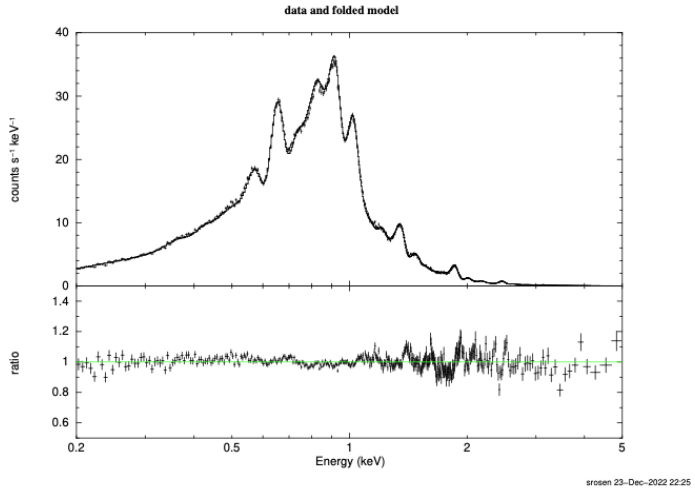


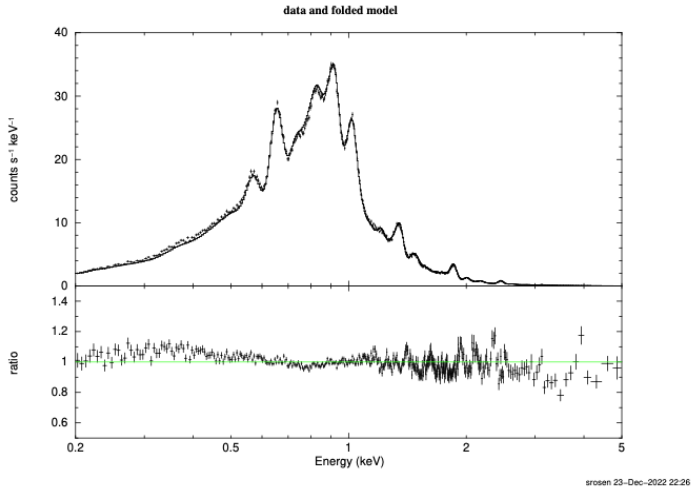
Tests with new/old RMFs

N132D (Rev 2593)



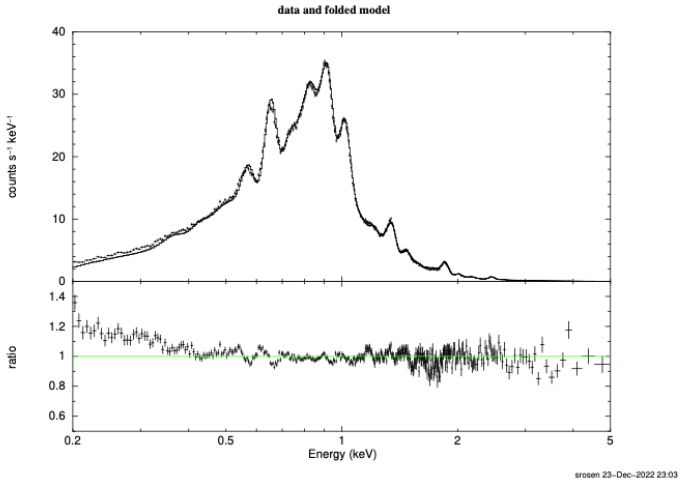


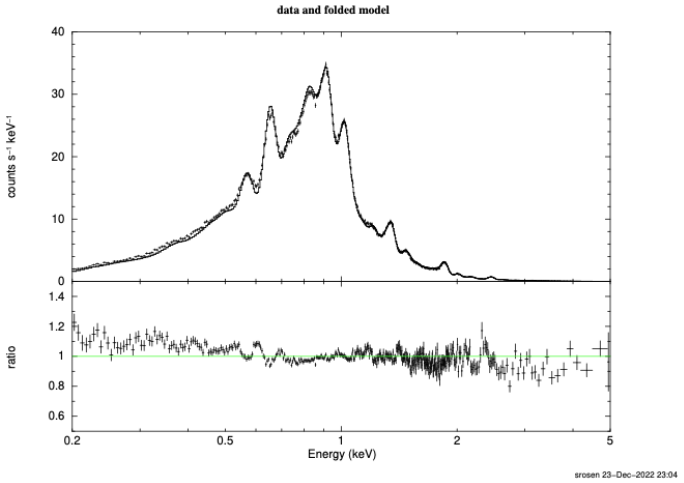


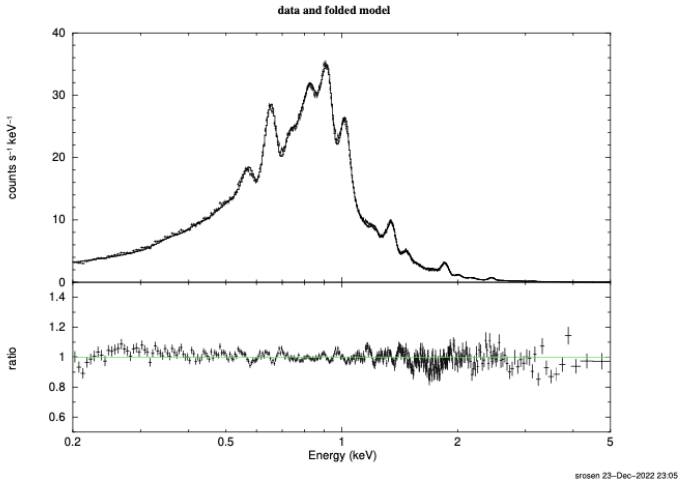


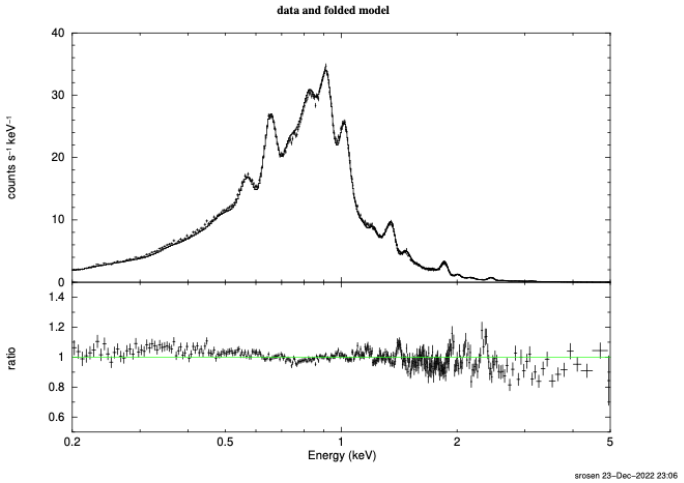
Tests with new/old RMFs

N132D (Rev 3701)

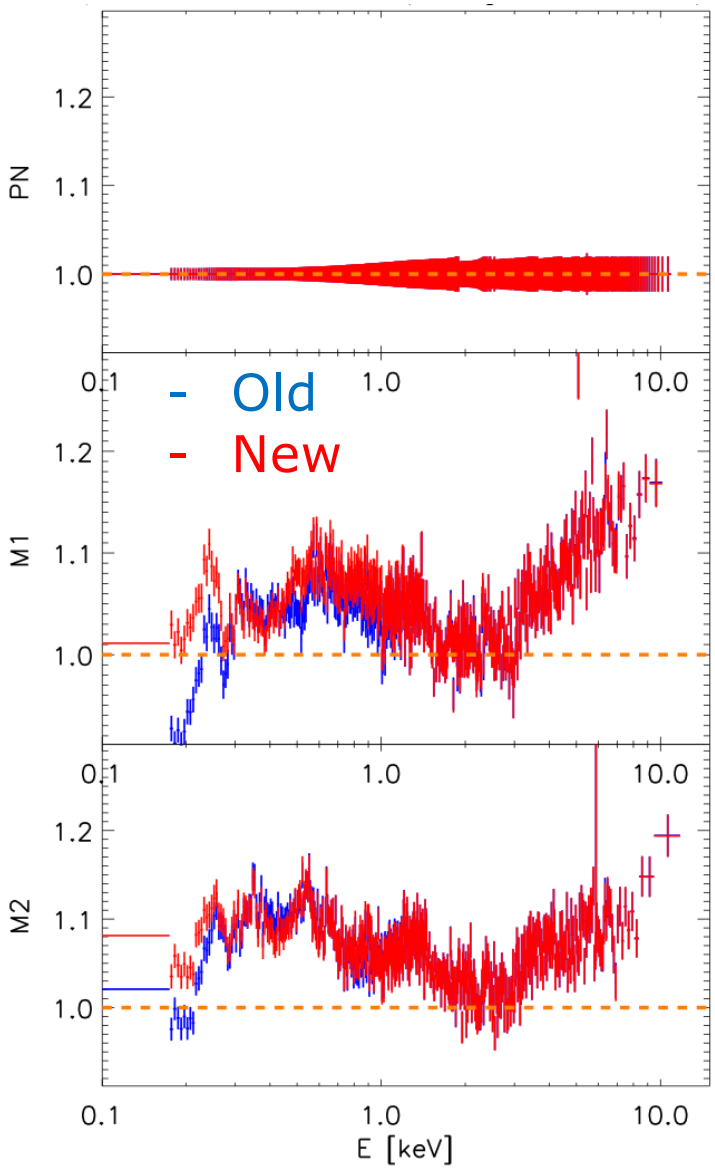








Tests with new/old RMFs



CORRAREA sub-sample (37 sources)

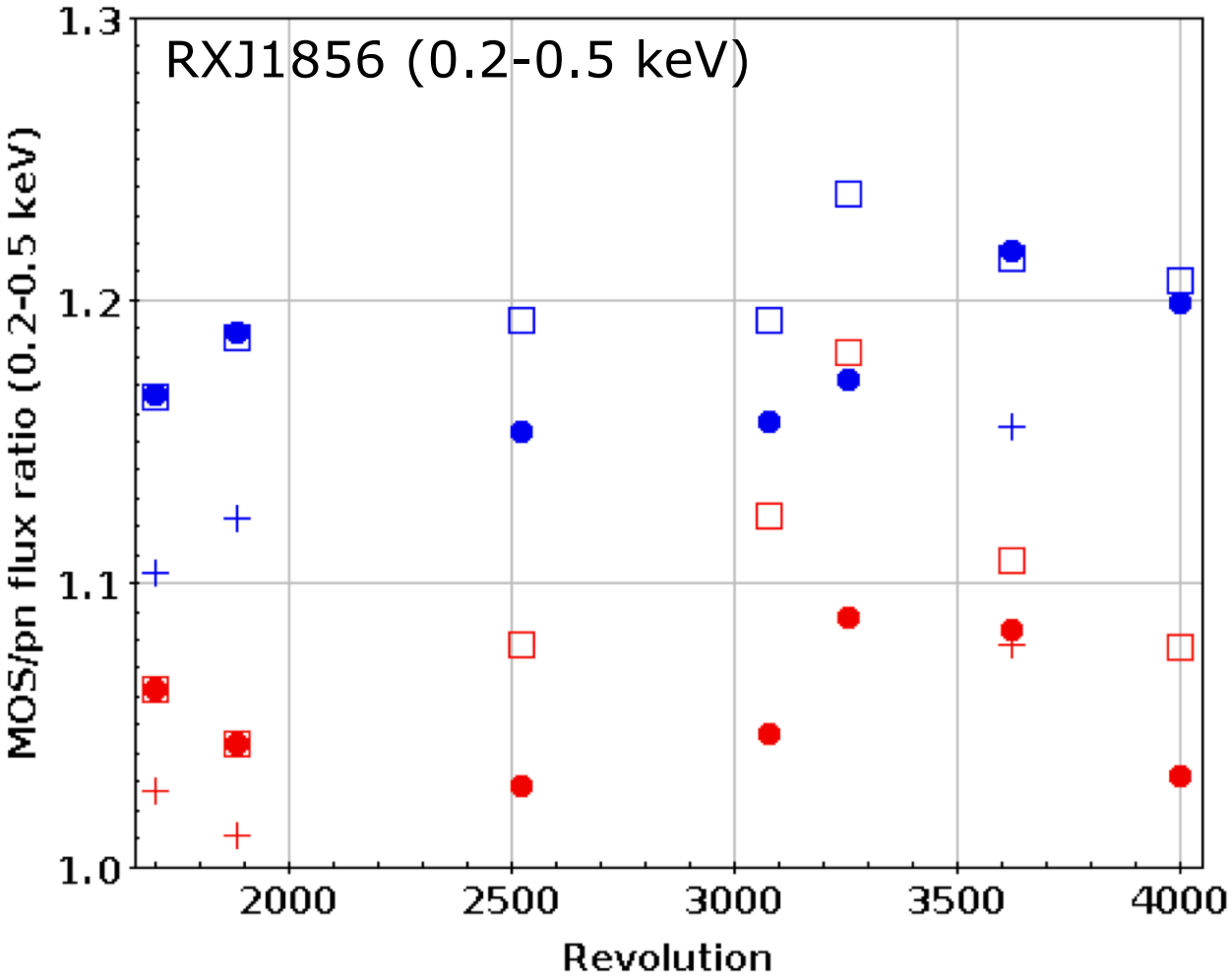
Spectral model profiles from literature, fitted to pn and then compared to MOS.

Residuals stacked

Improvement marginal

Tests with new/old RMFs

MOS1, MOS2: ● (old RMF), □ (new RMF),
+ old RMF/old contamination



- MOS2 fluxes 10-13% higher than MOS1
- New RMFs push MOS fluxes up by ~2-5%
- New contamination model increases fluxes by up to 5%
- Fluxes 'time-stable' [MOS1(RMS)~4%, MOS2(RMS)~2%]

Released CCFs

Name of CCF	VALDATE	EVALDATE	Blocks changed
EMOS1_CONTAMINATION_0002.CCF	2000-01-01		CONTAM_DEPTH
EMOS2_CONTAMINATION_0002.CCF	2000-01-01		CONTAM_DEPTH

Name of CCF	VALDATE	EVALDATE	Blocks changed
EMOSn_REDIST_0121.CCF	2013-04-27	2014-12-16	CCD_REDISTRIBUTION-k
EMOSn_REDIST_0122.CCF	2014-12-16	2016-08-05	CCD_REDISTRIBUTION-k
EMOSn_REDIST_0123.CCF	2016-08-05	2018-03-26	CCD_REDISTRIBUTION-k
EMOSn_REDIST_0124.CCF	2018-03-26	2019-11-14	CCD_REDISTRIBUTION-k
EMOSn_REDIST_0125.CCF	2019-11-14	NONE	CCD_REDISTRIBUTION-k

Conclusions and issues

- Contamination function updated. Redistribution matrices generated for 5 new epochs.

- Contamination function flattening. Greater depth in new curve likely largely a consequence of a different density value adopted for the absorber previously (SS got similar results in unpublished update).

- Redistribution functions for new epochs broadly evolve following earlier trends – some epoch 'quantisation', seen before.
- Low-energy peak moves to lower energies and shoulder broadens.

- For some test sources (e.g. RXJ1856, N132D), reduces discrepancy wrt pn data at E < 0.5 keV. But minimal improvement seen in CORRAREA subsample.

- New RMFs exacerbate flux difference cf pn for RXJ1856 by up to ~5% for M1

Conclusions and issues

- Revision of contamination suggests need to redo RMFs for all epochs, not just new ones
- Ideally permit gain shifts in fitting
- Where possible, include Cal-closed data for higher energy RMF constraints
- Use of most up-to-date IACHEC models
- PSF issues when extracting spectra offset from source centroid – absorbed into scalar when fitting but some residual energy dependence from PSF could be present.
- Ideally need to fit contamination and RMF simultaneously (plus assumption of spatial uniformity of contaminant) (and Eff area?) KD work on pn?