EBERHARD KARLS
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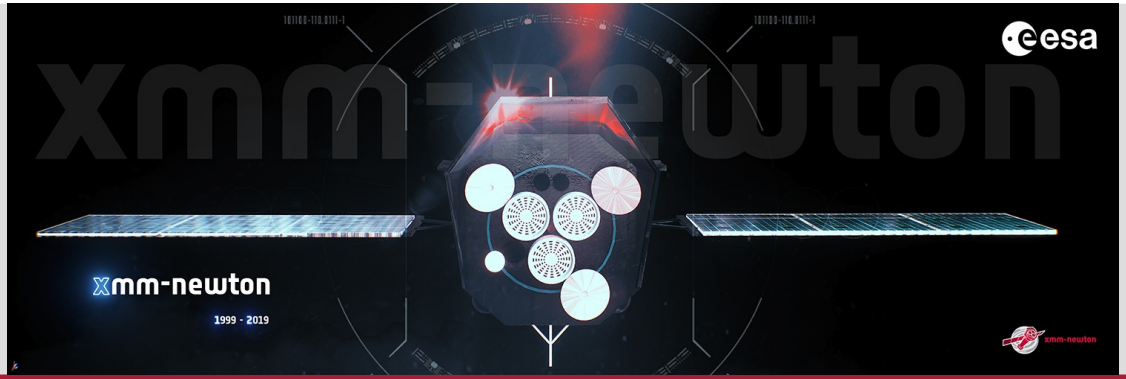
Institute of Astronomy and Astrophysics



CORRAREA

Cross-Calibration of the XMM-Newton EPIC pn and MOS Effective Areas

C. Pommranz (IAAT), M. Smith (ESAC), C. Tenzer (IAAT)

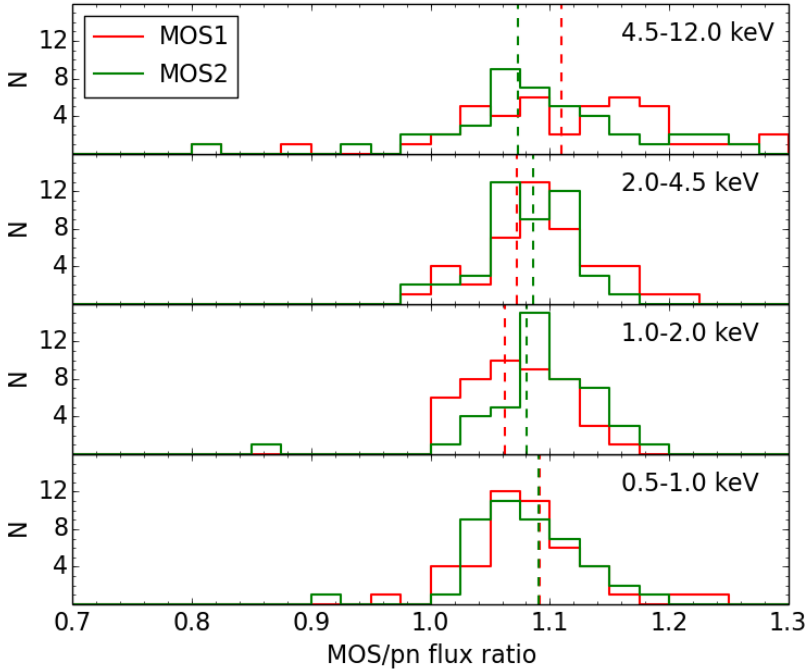
26.04.2023, Christian Pommranz – 15th IACHEC meeting

Motivation

- Remaining spectral differences between EPIC-MOS and EPIC-pn data

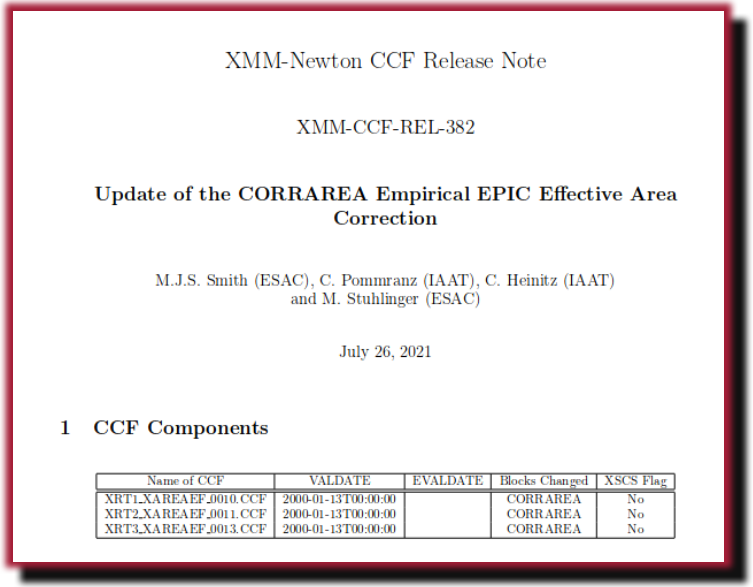
  → ~10% in terms of flux

- CORRAREA: Provide an empirical correction of the EPIC on-axis effective areas



Introduction

- Correction determined by cross-calibration of the EPIC effective areas
- Implemented as energy-dependent multiplicative factor in the ARFs
- Reference instrument: pn
- Correction for energies >2 keV
- **Fit-and-stack approach**
- **Updated correction function available in SAS as an option to arfgen**



XMM-Newton CCF Release Note

XMM-CCF-REL-382

Update of the CORRAREA Empirical EPIC Effective Area Correction

M.J.S. Smith (ESAC), C. Pommranz (IAAT), C. Heinitz (IAAT) and M. Stuhlinger (ESAC)

July 26, 2021

1 CCF Components

Name of CCF	VALDATE	EVALDATE	Blocks Changed	XSCS Flag
XRT1_XAREAEF_0010.CCF	2000-01-13T00:00:00		CORRAREA	No
XRT2_XAREAEF_0011.CCF	2000-01-13T00:00:00		CORRAREA	No
XRT3_XAREAEF_0013.CCF	2000-01-13T00:00:00		CORRAREA	No

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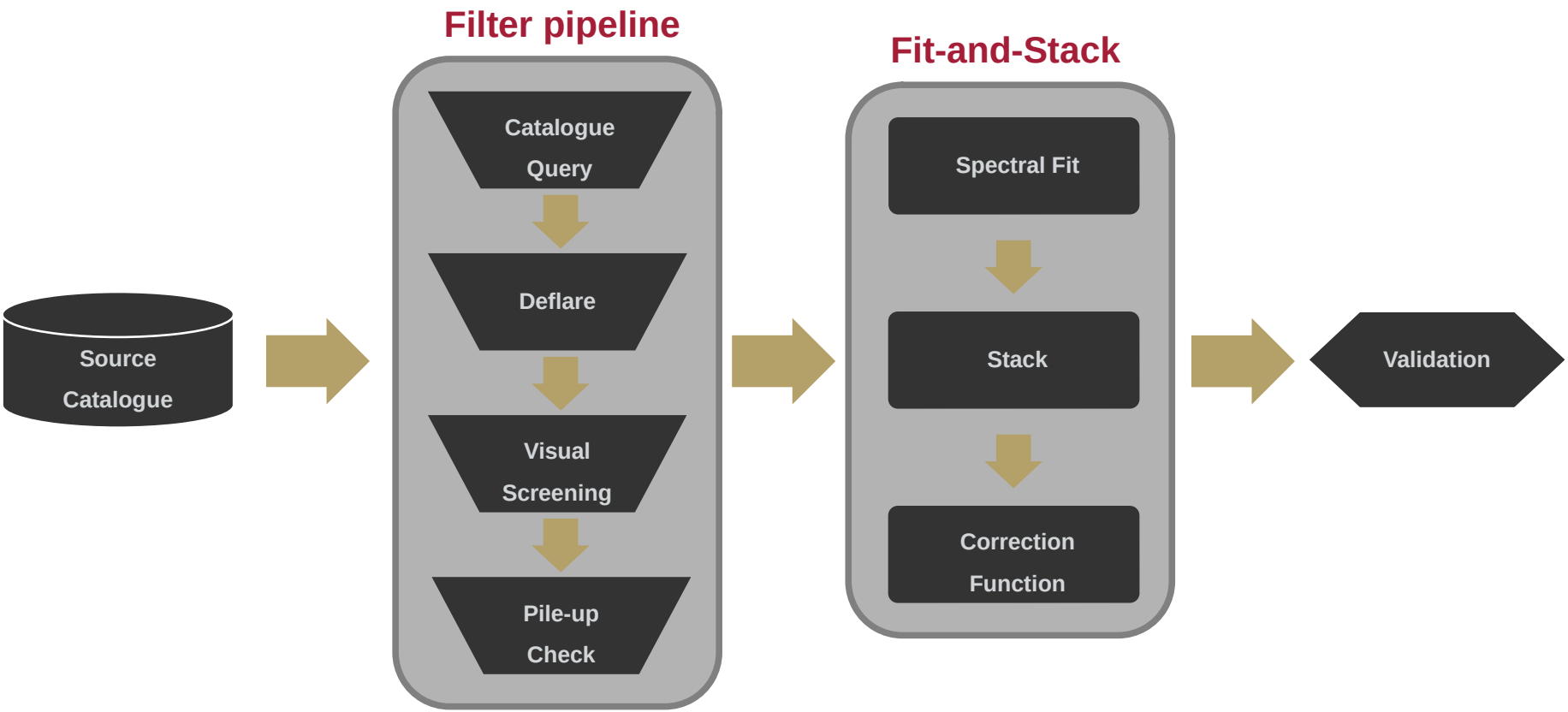
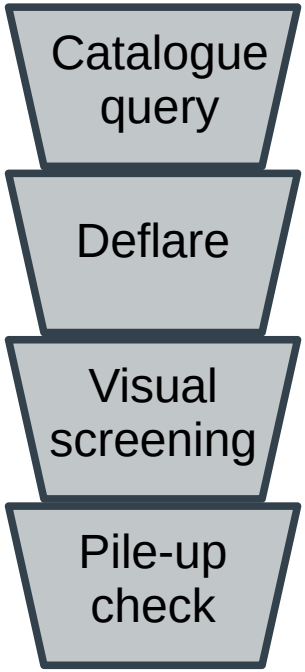
CORRAREA Pipeline

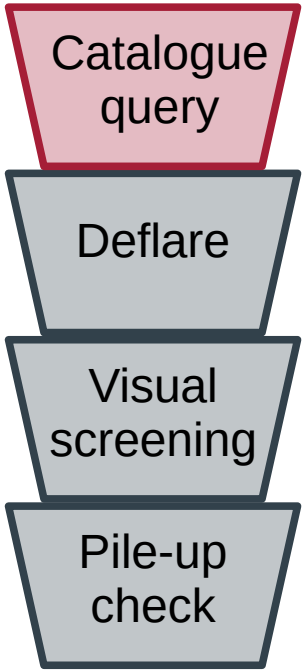


CORRAREA Filter Pipeline



- **Goal:** Select set of most suitable observations out of all available XMM-Newton observations (~9700 for 3XMM-DR7 catalog)
- High degree of automation
- Pipeline built of 4 main filter steps
  - Catalogue query
  - Deflare, define common Good Time Intervals (GTIs)
  - Visual screening
  - Pile-up check

3XMM-DR7 Catalogue Query (347 observations)



Selection criteria:

1.) point-like

2.) modes: Full Frame, Large Window, Small Window

3.) filters: Thin, Medium, Thick

4.) # of counts
- MOS: > 5000 cts
- pn: > 13 500 cts (0.2 - 12 keV)

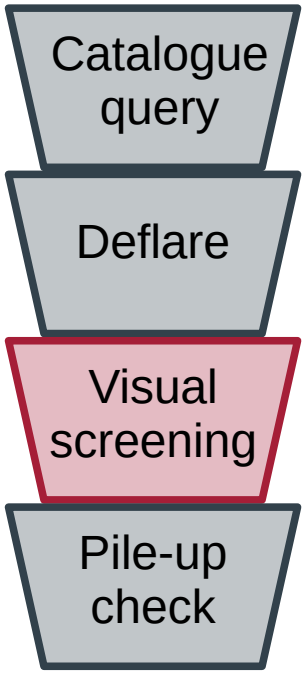
5.) count rates:
- MOS: < 0.7 (FF), < 1.5 (LW), < 4.5 (SW)
- pn: < 6 (FF), < 3 (LW), < 25 (SW)

6.) near on-axis (boresight-to-source distance < 2')

7.) out of the plane of the Galaxy (|galactic latitude| > 15 deg)

Final: Discard observations with multiple results (crowded fields)

Visual Screening



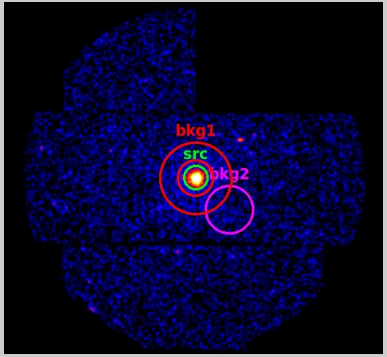
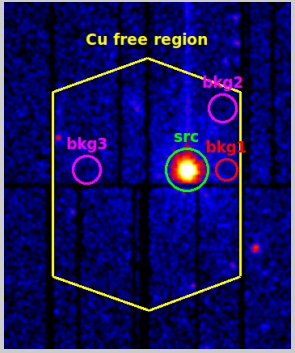
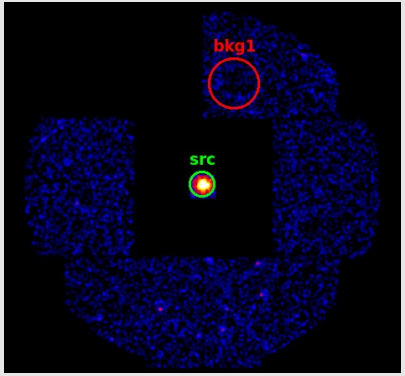
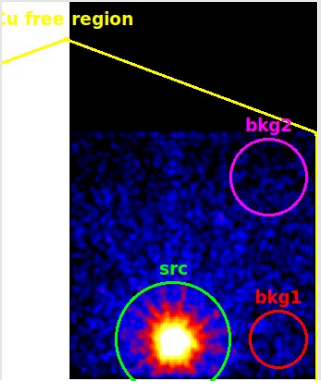
- Manual step (computer aided), but only needed once for new sources added to the sample
- Discard observations in case of:
  - Crowded fields
  - Extended targets, extended emission
  - Chip gaps and bad CCD columns close to the source
  - Chip loss (quadrant or entire detector)
- Definition of:
  - Maximum source extension radius
  - Background region
  - Physically motivated spectral model

Catalogue query

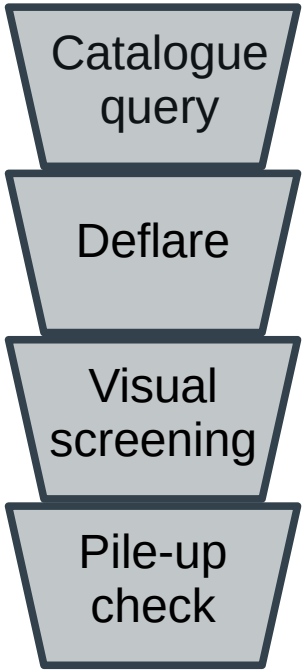
Deflare

Visual screening

Pile-up check

	MOS	pn
FF		
SW		

Number of Observations



→ 347 observations from initially ~9700 in catalogue

→ 333 observations, 13 removed

→ 262 observations, 71 removed

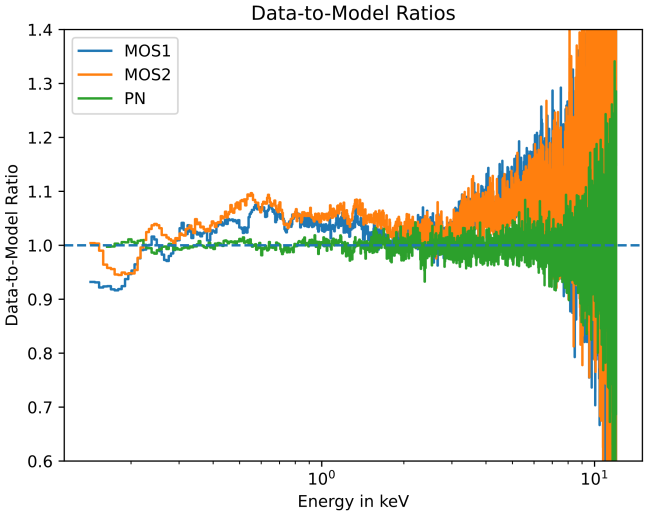
- 38 crowded fields
- 5 chip gaps
- 65 extended emissions
- 8 other

→ 163 good observations, 70 piled-up, 29 vague cases

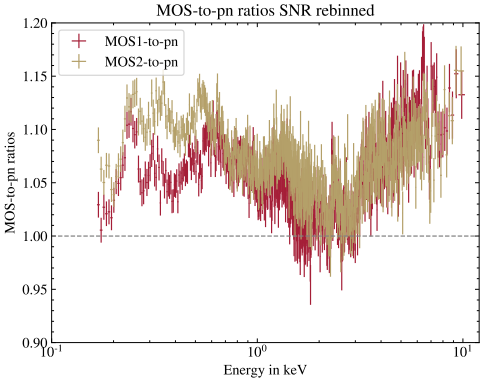
→ 120 „best“ observations for updated correction function

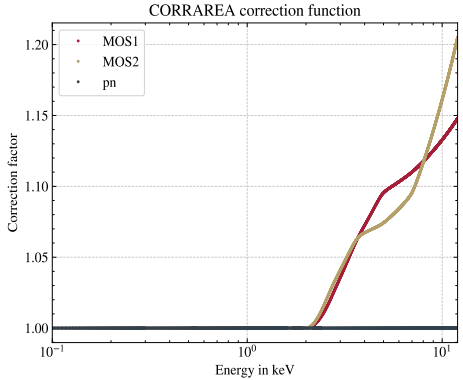
Fit-and-Stack

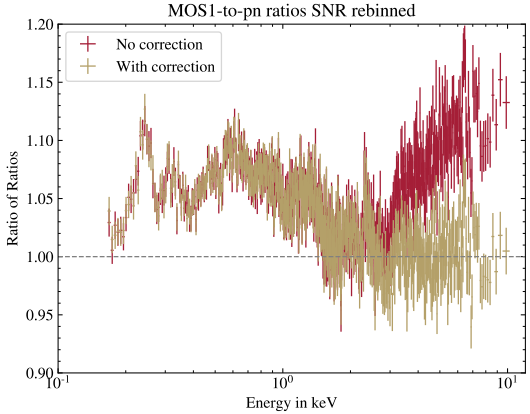
- Automatic fitting procedure using ISIS:
  1) Fit model with free parameters to EPIC-pn
  2) Apply model from 1) to EPIC-MOS data to derive model counts
- Stack data and model counts (expected counts + scaled background) per instrument
- Calculate data to model ratios

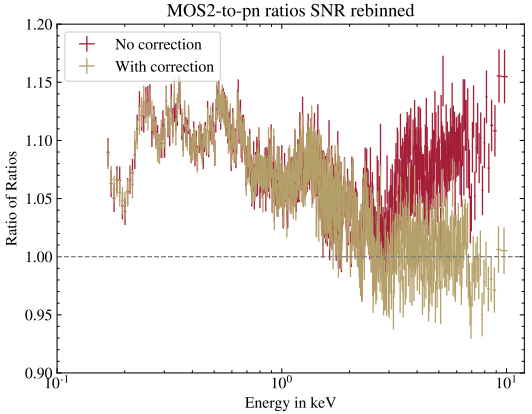


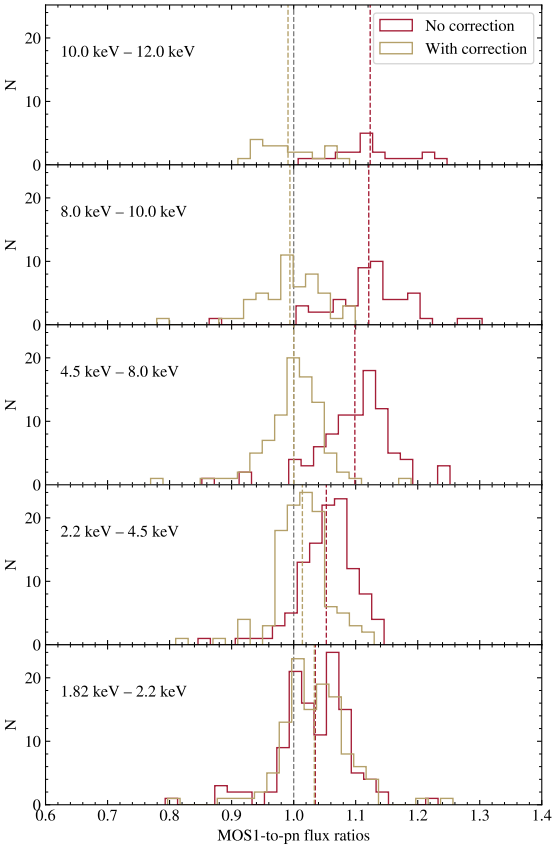
- Calculate MOS-to-pn ratios
- Correction function obtained using cubic spline fitting with seven nodes
- Correction only above 2 keV
- Final sample: **120 observations**

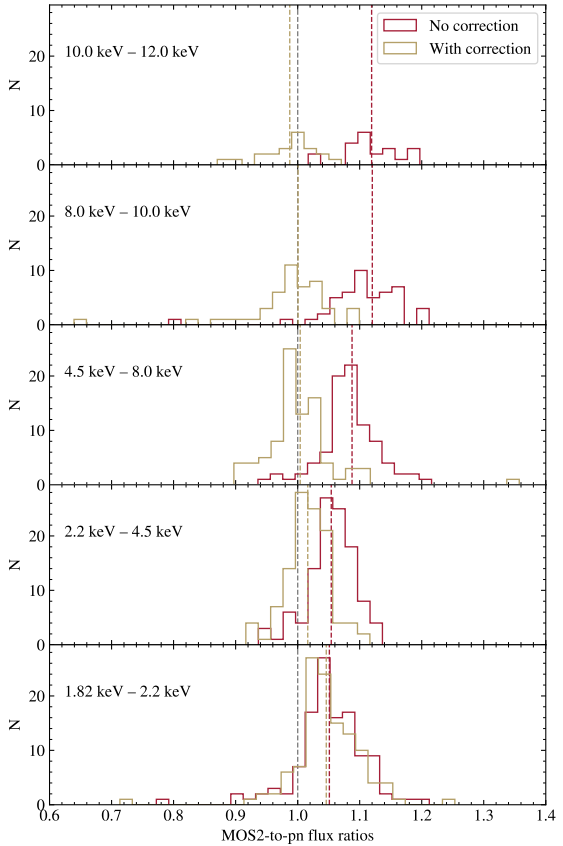






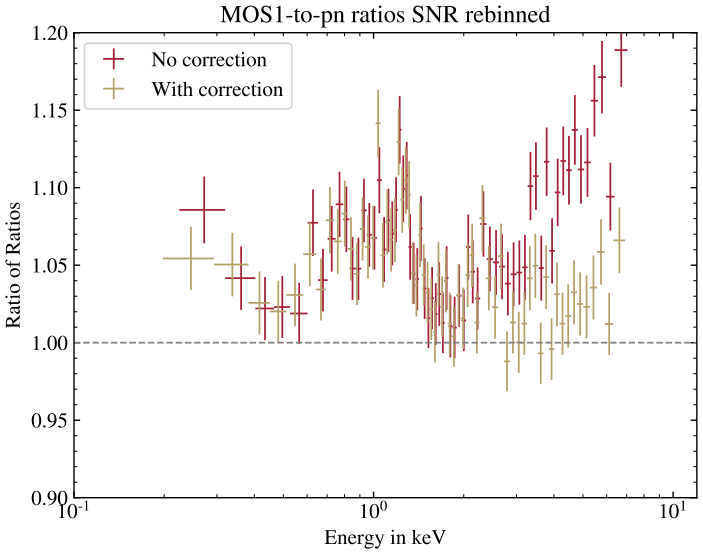


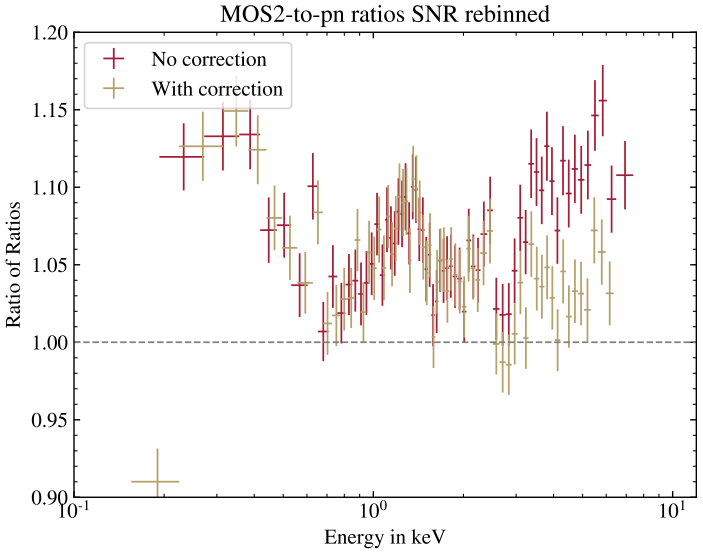

No correction
With correction
10.0 keV – 12.0 keV
8.0 keV – 10.0 keV
4.5 keV – 8.0 keV
2.2 keV – 4.5 keV
1.82 keV – 2.2 keV
N
MOS1-to-pn flux ratios

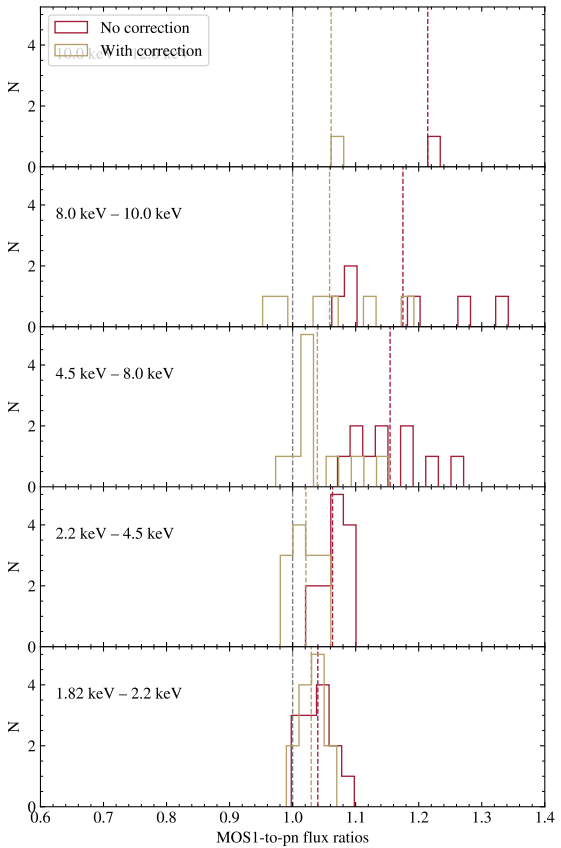

No correction
With correction
10.0 keV – 12.0 keV
8.0 keV – 10.0 keV
4.5 keV – 8.0 keV
2.2 keV – 4.5 keV
1.82 keV – 2.2 keV
N
MOS2-to-pn flux ratios

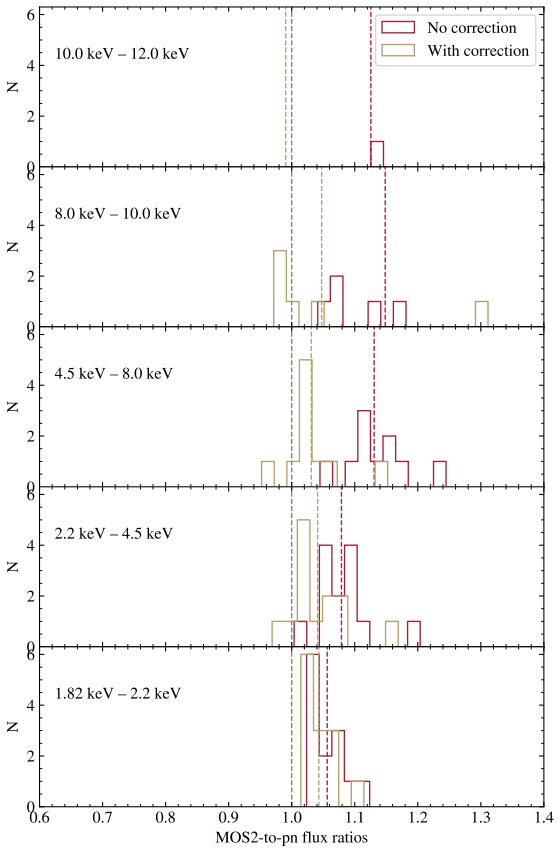
Sample of Recent Observations

- New sample from 4XMM-DR12: 13 non piled-up observations
- Recent observations: Revolution 3700+





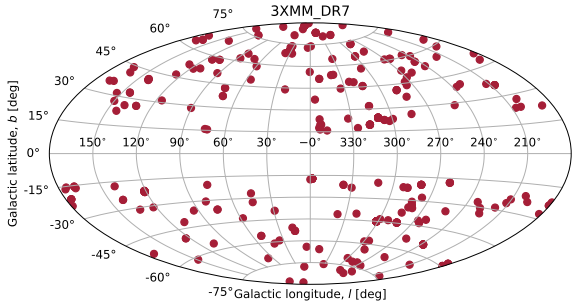


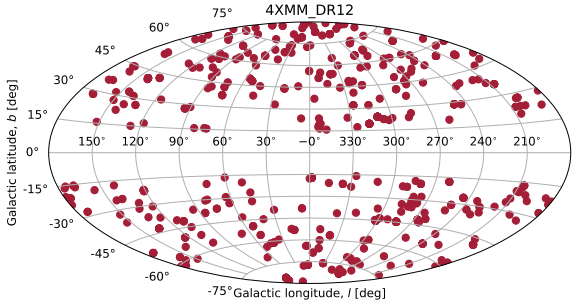


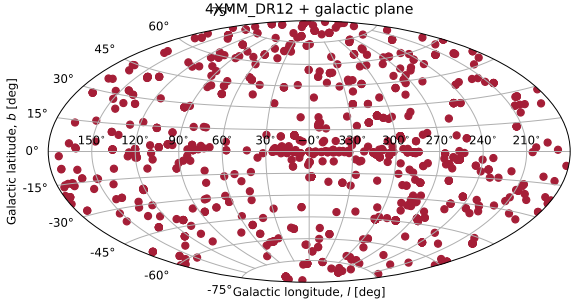
- New sample:
  7x SW, 3x LW, 3x FF
- CORRAREA sample:
  26x SW, 32x LW, 53x FF, 9x mixed

Enlarging the source sample

- 3XMM-DR7: **347 initial sources**
- 4XMM-DR12: **749 initial sources**
  - New candidates across all of XMM-Newton's lifetime
  - Previously filtered out due to missing PN fluxes in 3XMM catalogue
- Fit-and-stack potentially allows to include observations in the galactic plane:
  1076 initial sources







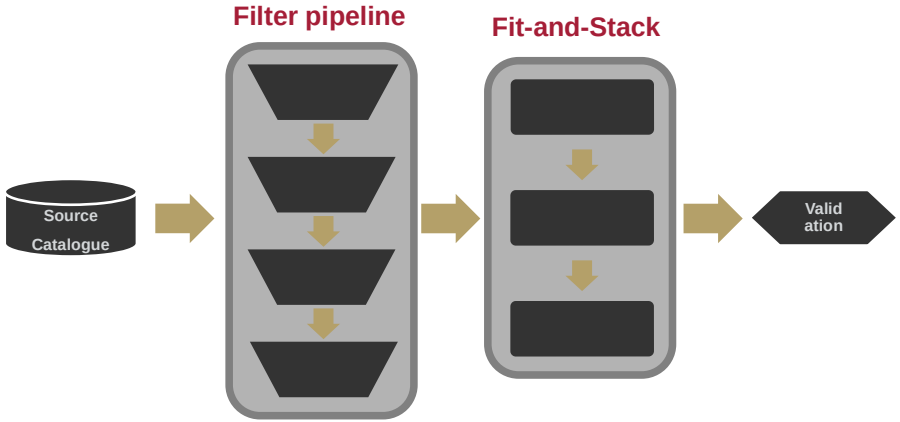
Automation

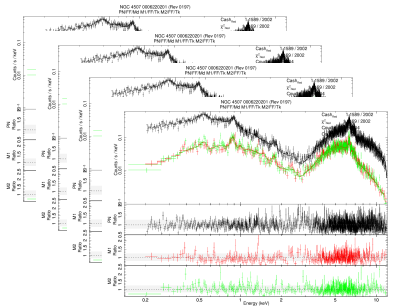
- CORRAREA is an **empirical** correction only
- Automation crucial for the CORRAREA project to allow for quick recalibration in case of
  - Updated CCF files
  - SAS updates
  - New Serendipitous Source Catalogue releases
- Calculate new CORRAREA correction function with:
  - New calibration files (CCFs): **Completely automated***
  - New SAS tools version: **Completely automated*** (except for API breaks)
  - New source catalog release (i.e. increase observation sample): Manual screening and model definition for new sources needed

  *** Visual sanity checks of interim results always recommended.**
- Currently porting to the Snakemake workflow management framework snakemake

Outlook

- Add new observations to the sample
  - Mode-dependent analyses
  - Time stability analysis
- *Beyond CORRAREA:*
  - Highly flexible automated pipeline and large sample of modelled sources can be used to investigate other calibration issues.
  - Cross-calibration of effective areas of instruments on other satellites





Thank you.

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