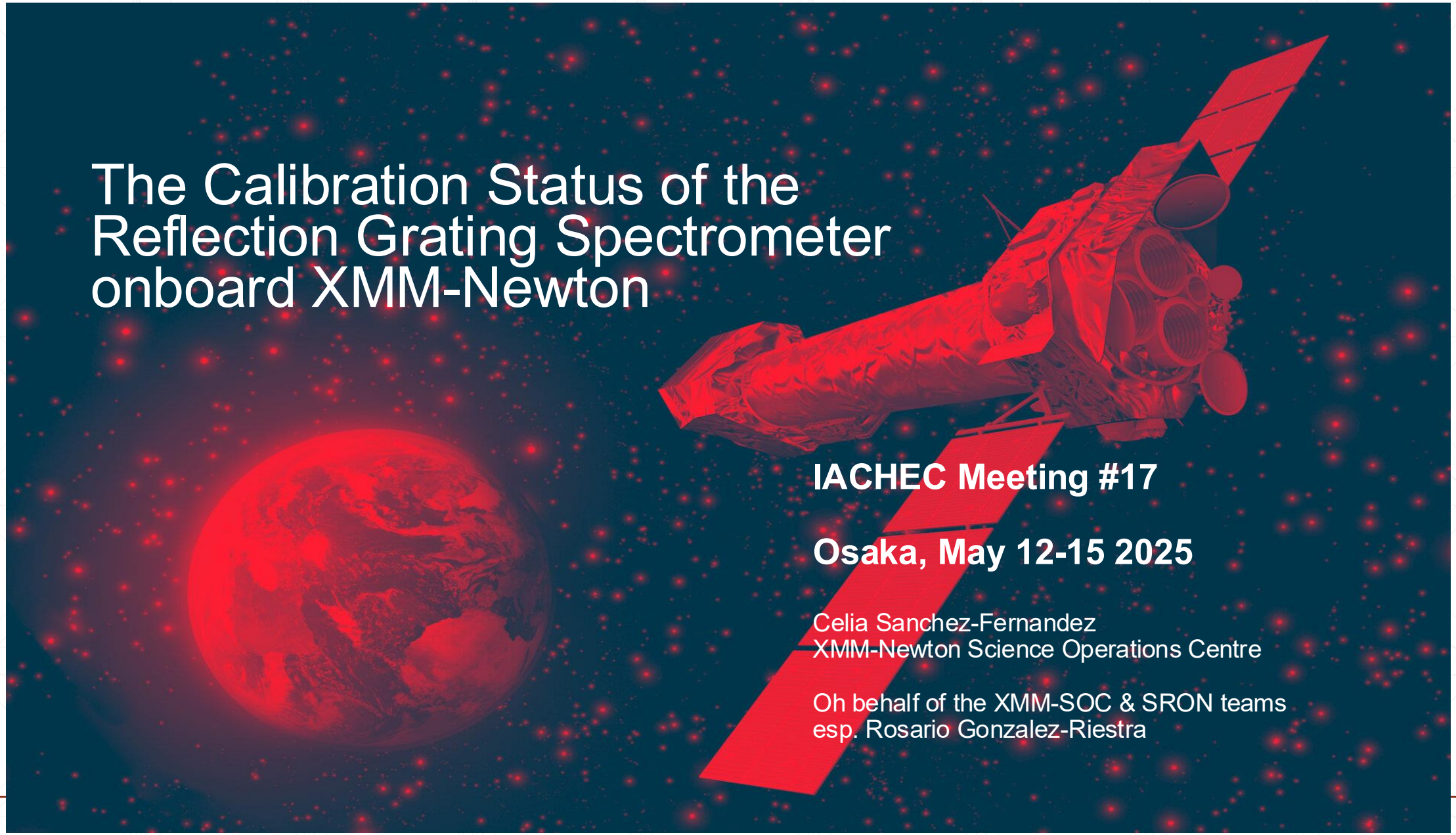
The Calibration Status of the Reflection Grating Spectrometer onboard XMM-Newton



IACHEC Meeting #17

Osaka, May 12-15 2025

Celia Sanchez-Fernandez
XMM-Newton Science Operations Centre

Oh behalf of the XMM-SOC & SRON teams
esp. Rosario Gonzalez-Riestra

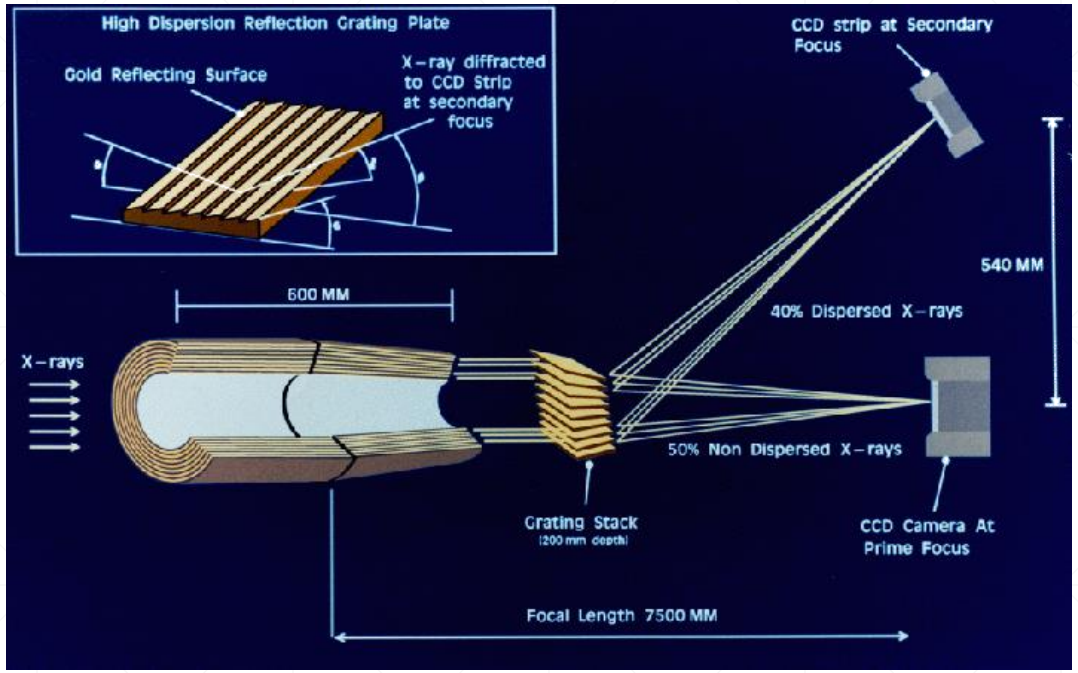
Outline

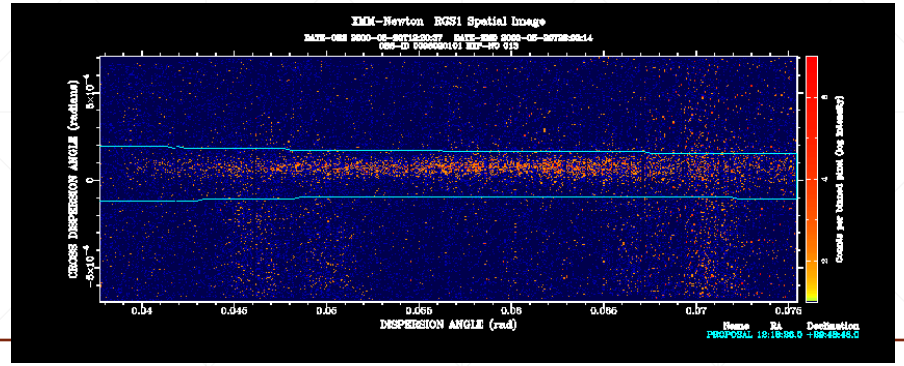
- **Introduction to RGS**

- **Operations and Instrument Status**
  - System Peak
  - Charge Transfer Efficiency
  - Bad Surface
  - Hot spots and hot columns

- **Calibration and Monitoring**
  - Wavelength Scale
  - Effective Area
  - Flux monitoring

The Reflection Grating Spectrometer (RGS)



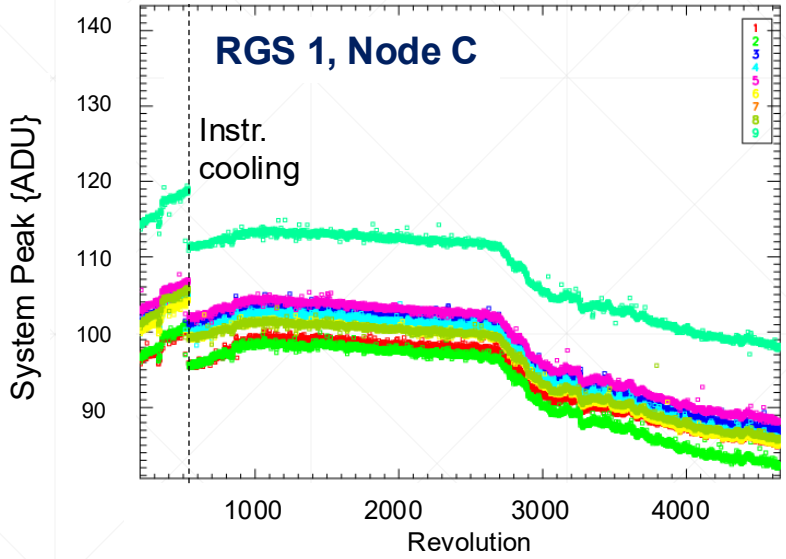


- 2 Reflection Grating Arrays behind 2 of the XMM mirrors
- RGAs continuously in the light-path, non switchable
- High sensitivity and resolution in [0.35-2.5]keV ([5-35]Å)
- FOV: ± 2.4 arcmin in cross-dispersion
- Line rich region: K-shell transitions of low-Z abundant elements (C, N, O, Ne, Si) and L-shell Fe transitions
- Camera: 9 back illuminated CCDs, readout in frame store mode
- 2 CCD readout channels non-operable (CCD#4 in RGS2, CCD#7 in RGS1)
- Since 2007, single node readout in RGS2

Operations & instrument status

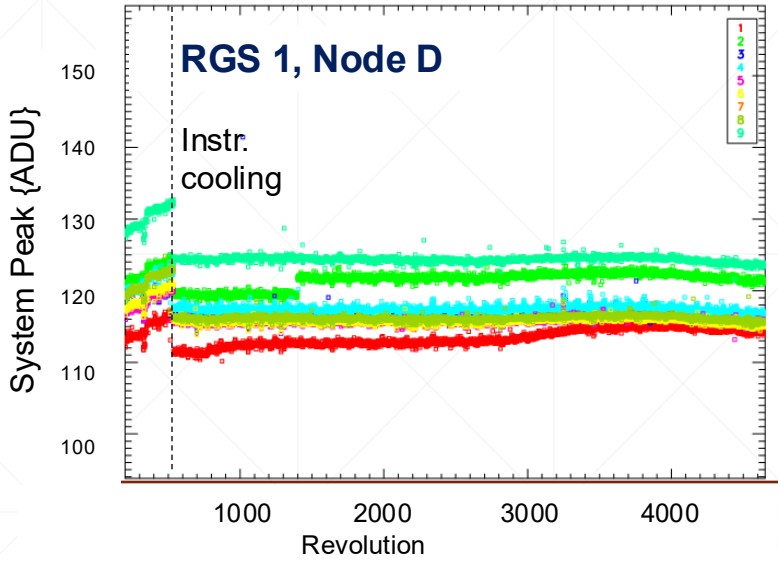
- Operations running smoothly
- Same operational configuration
- No instrumental anomalies
- No unexpected degradation of the instrumental parameters

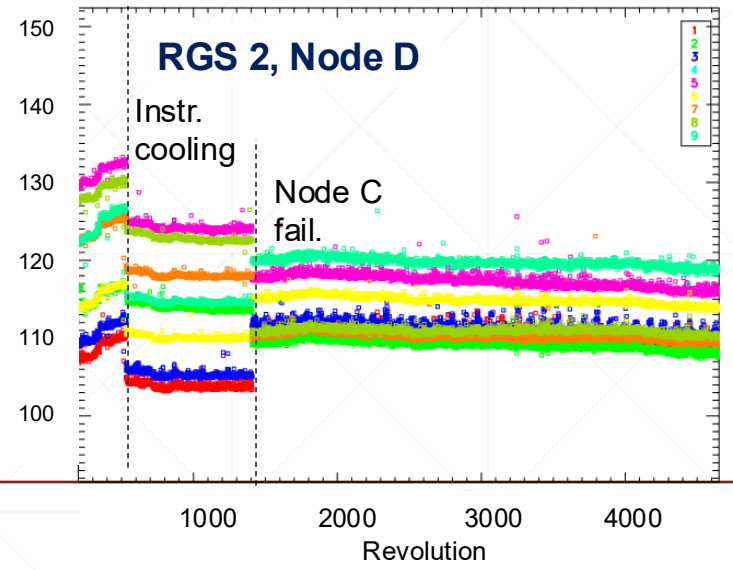
Instrument diagnostics: System Peak



System peak = readout noise + dark current

STABLE → NO NEED FOR CCF UPDATE

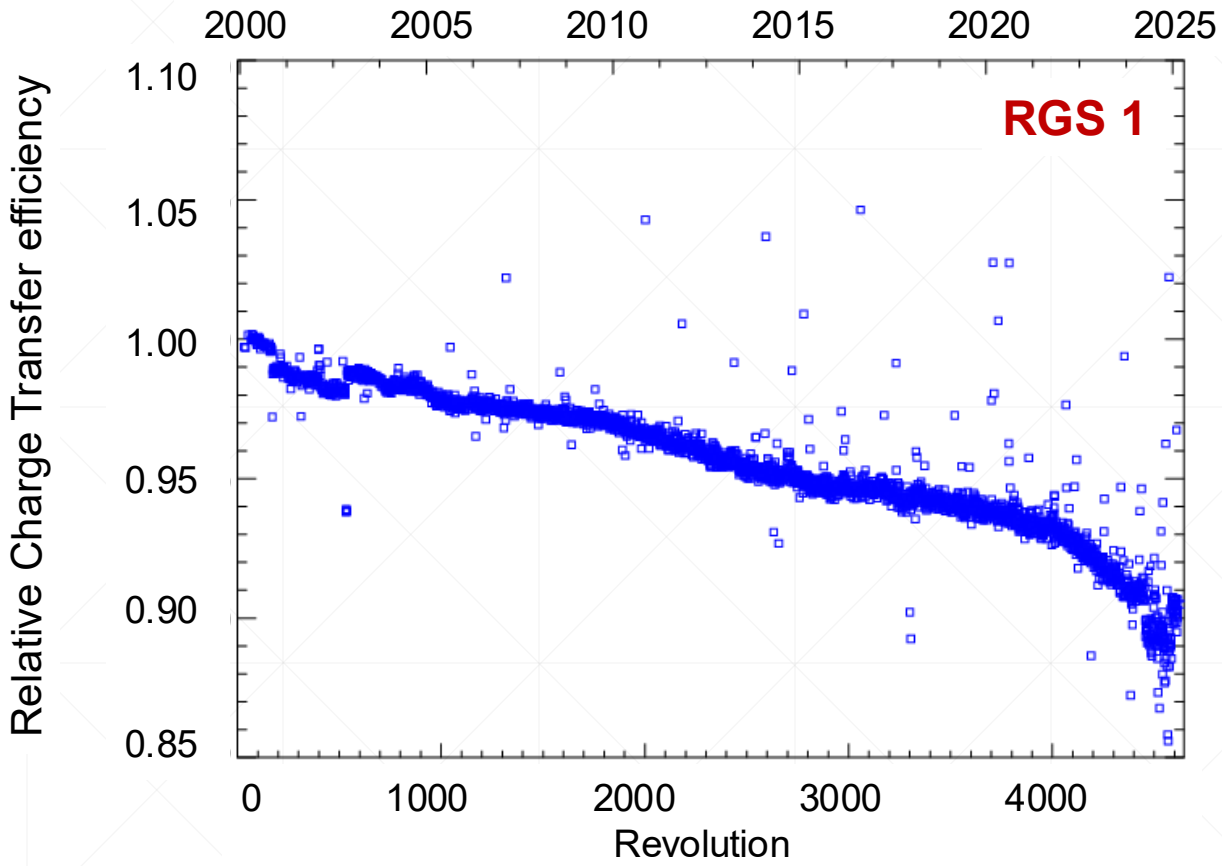


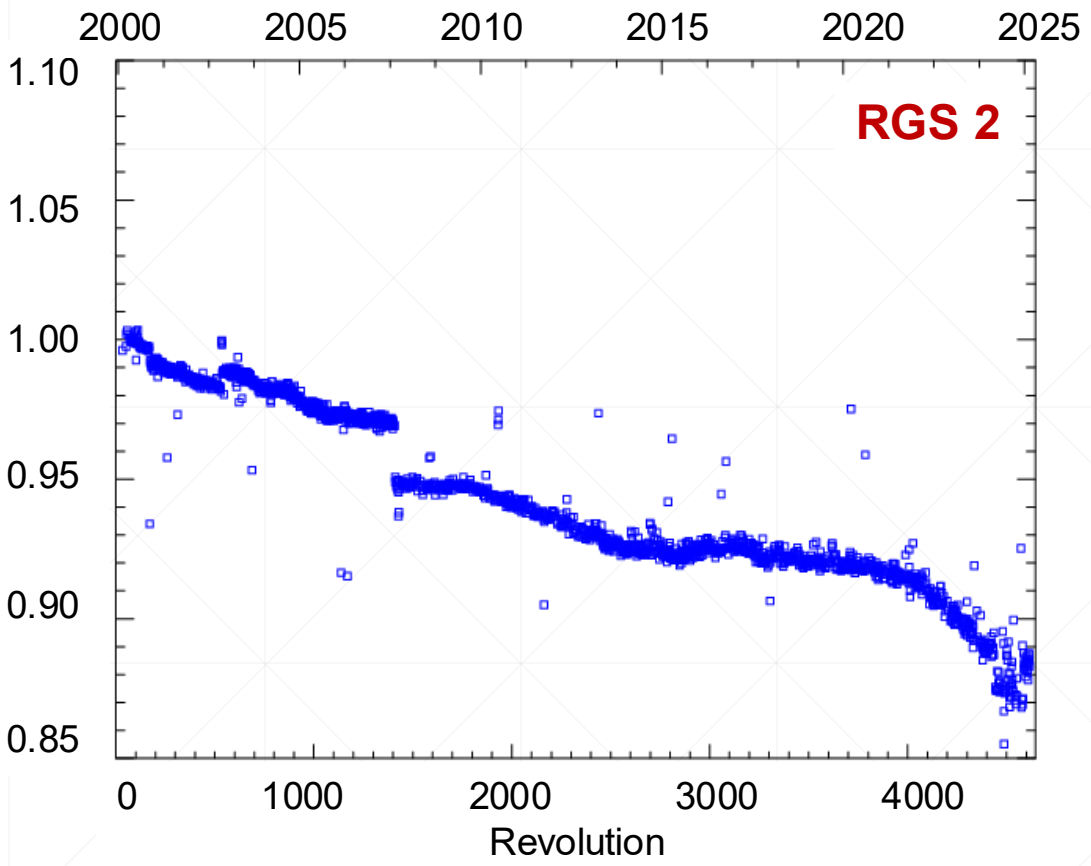


Instrument diagnostics: Charge Trasfer Efficiency (CTE)

Ability of the device to transfer charge from one potential well to the next.

Monitoring using internal calibration sources





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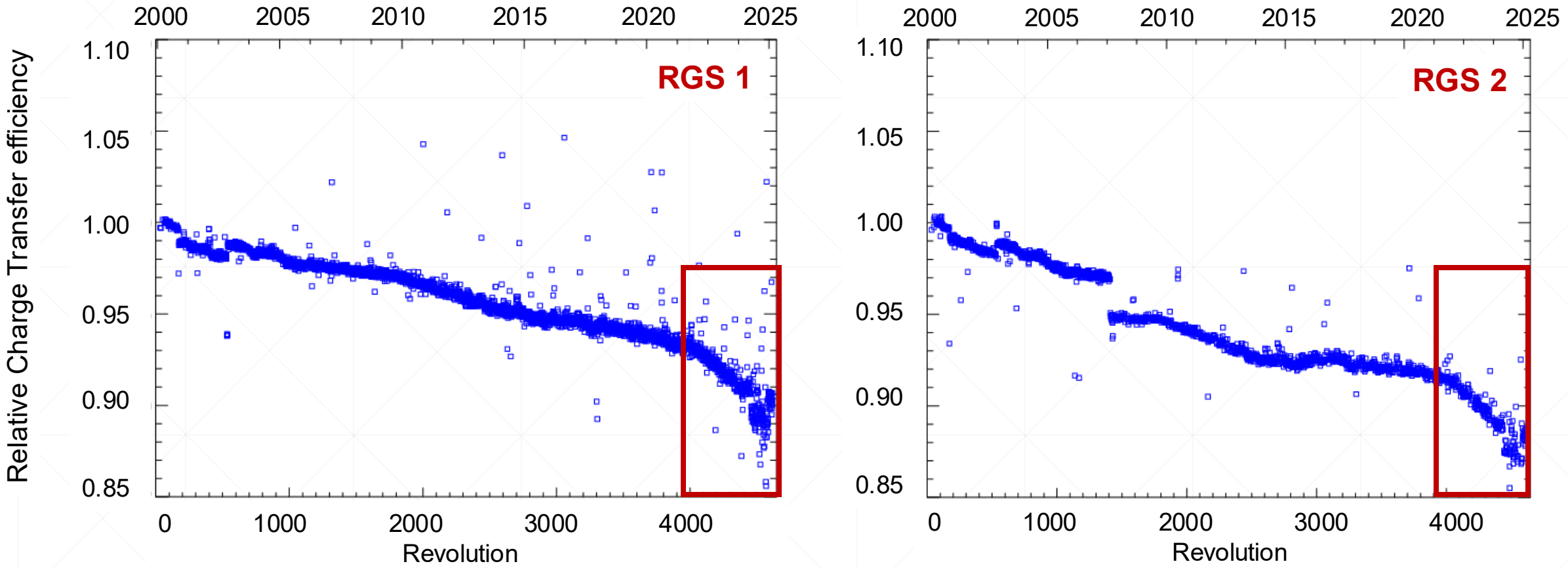
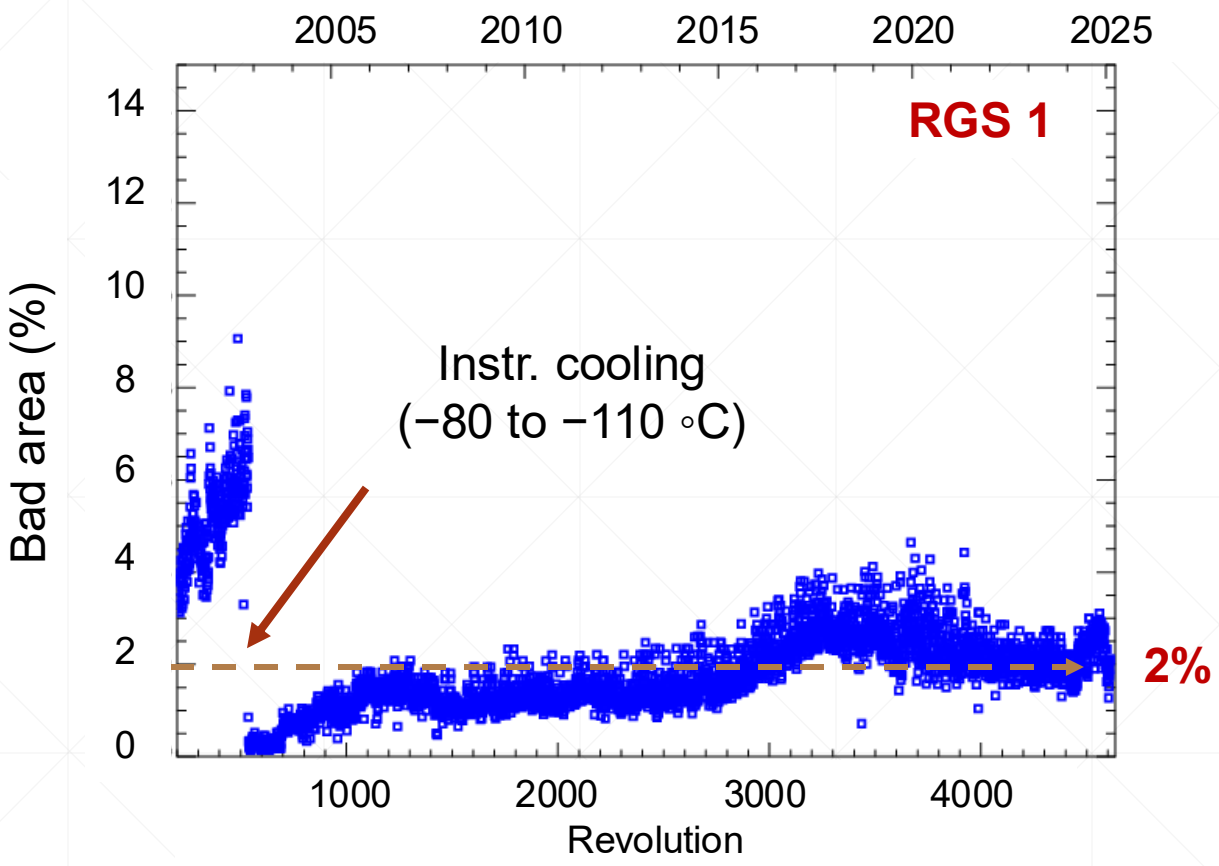


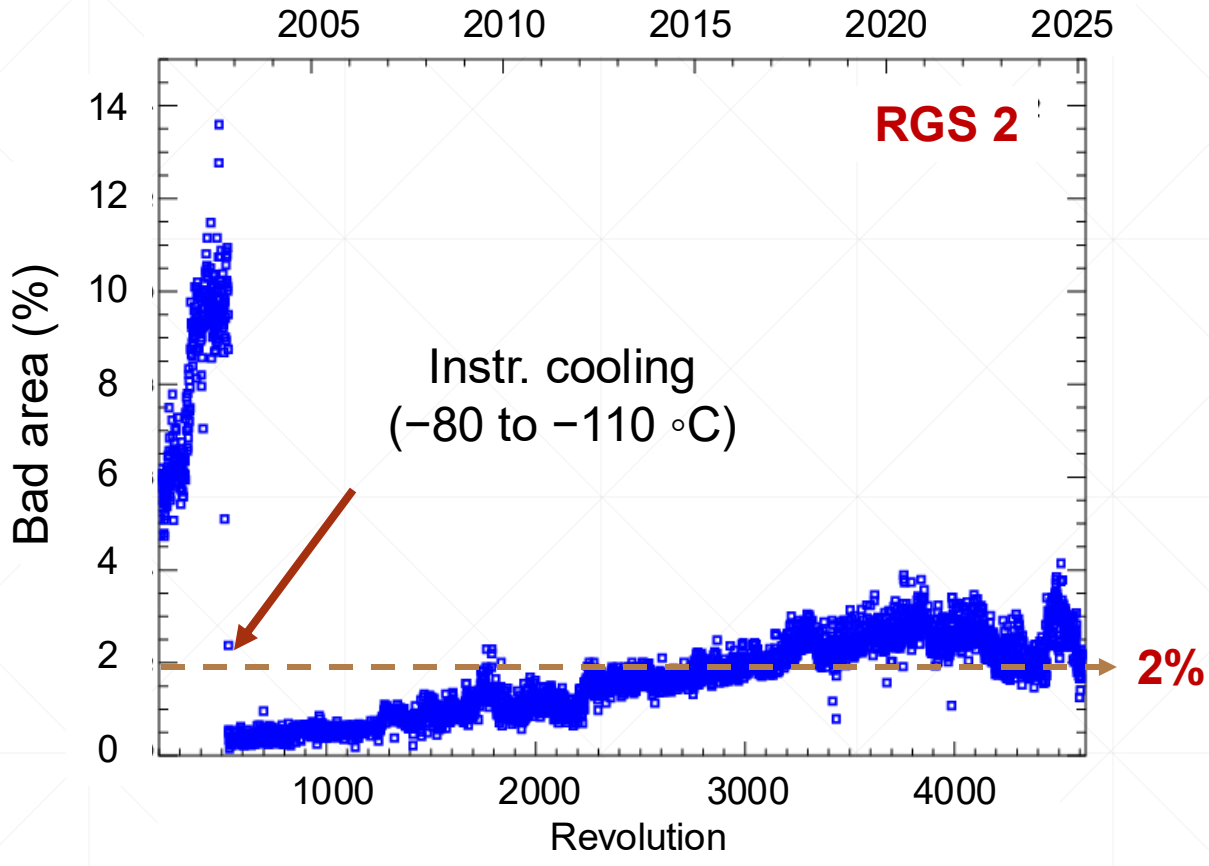
REASONS FOR RECENT DEVIATION FROM LINEAR DECREASE UNDER INVESTIGATION

Instrument diagnostics: Bad surface

Local defects and damage by cosmic rays in the depleted silicon material can give rise to hot pixels and columns.

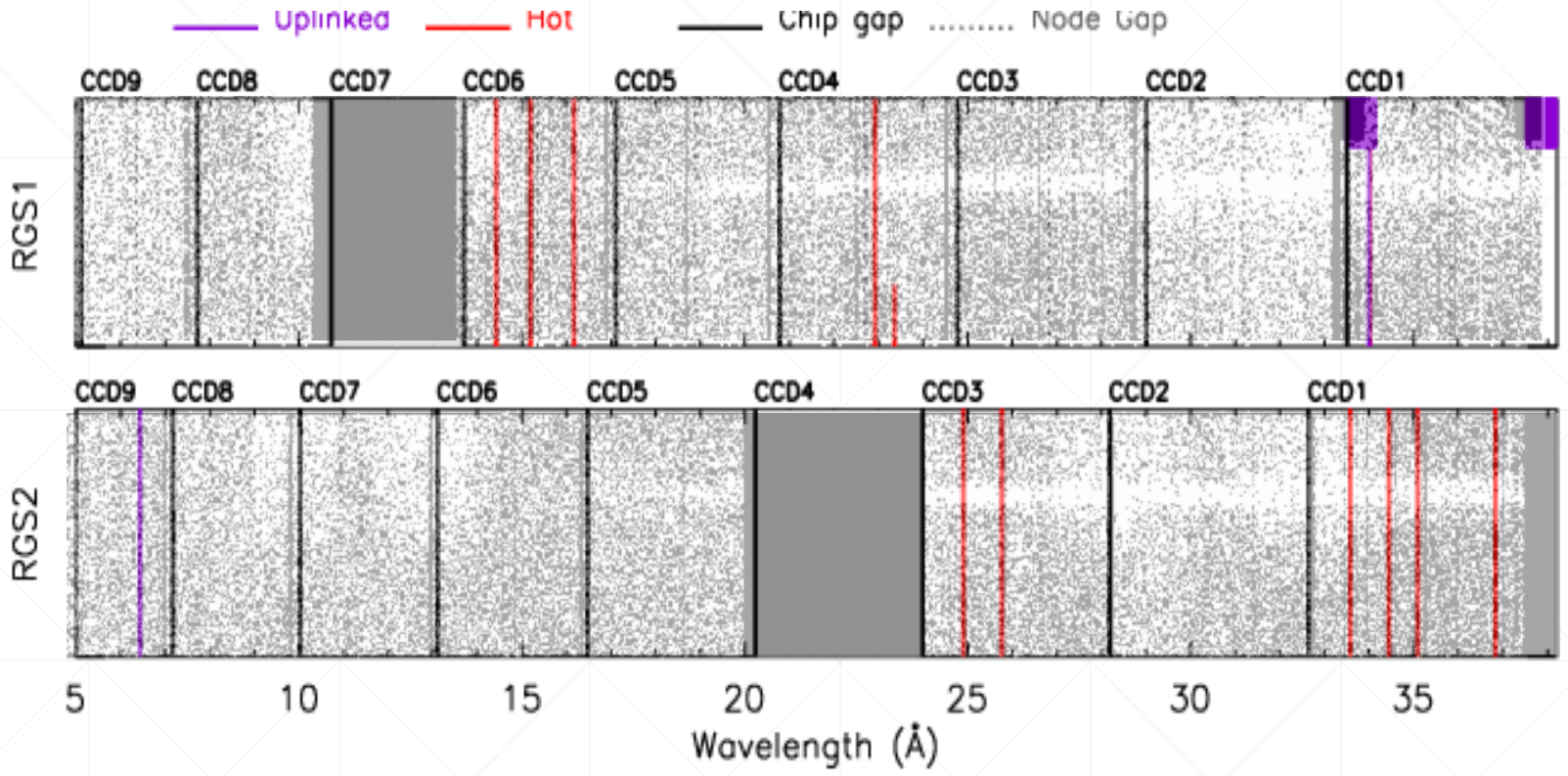


STABLE



Instrument diagnostics: Hot Columns

Local defects and damage by cosmic rays in the depleted silicon material can give rise to hot pixels and columns.



Columns ***rejected on-board***

1 in RGS1 CCD 1
1 in RGS2 CCD 9

Columns flagged as ***advisory*** in CCF

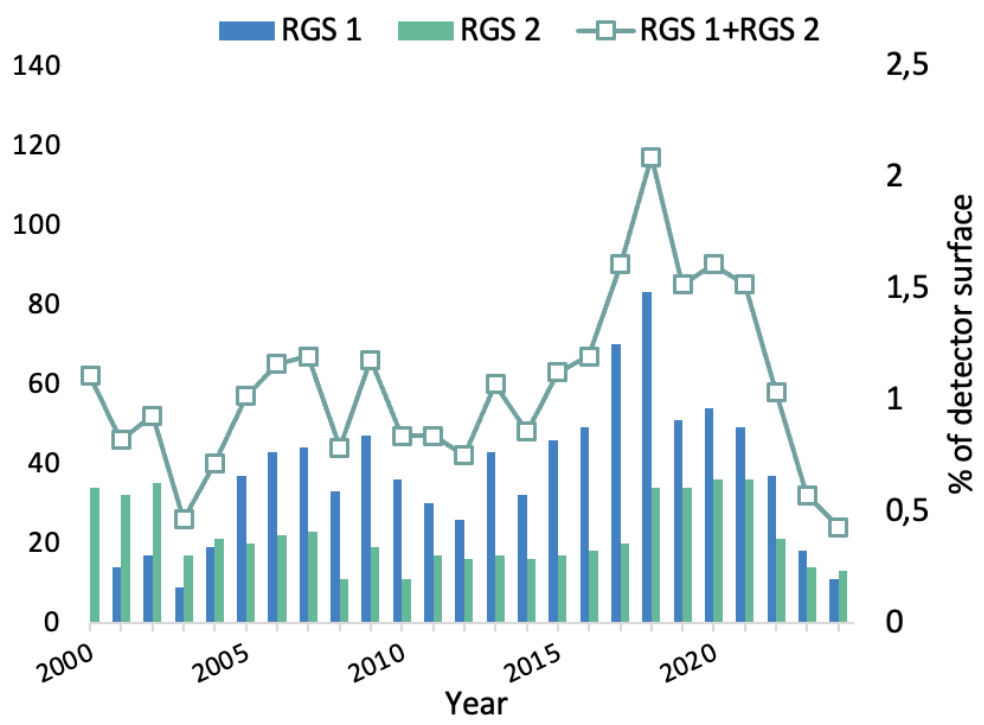
6 in RGS1 (3 in CCD6 + 2 in CCD4 +1 in CCD1)
6 in RGS2 (2 in CCD3 + 4 in CCD 1)

STABLE → NO NEED FOR CCF UPDATE

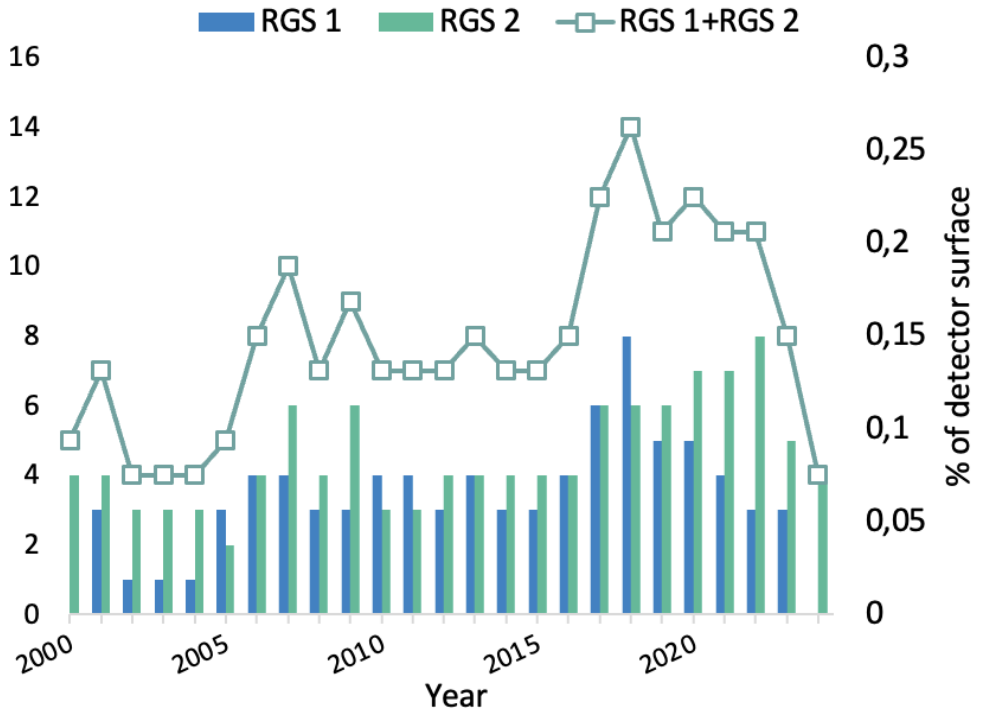
RGS Diagnostic Trend Analysis Reports

Instrument diagnostics: Hot Columns

Columns found hot in more than 25% of the observations

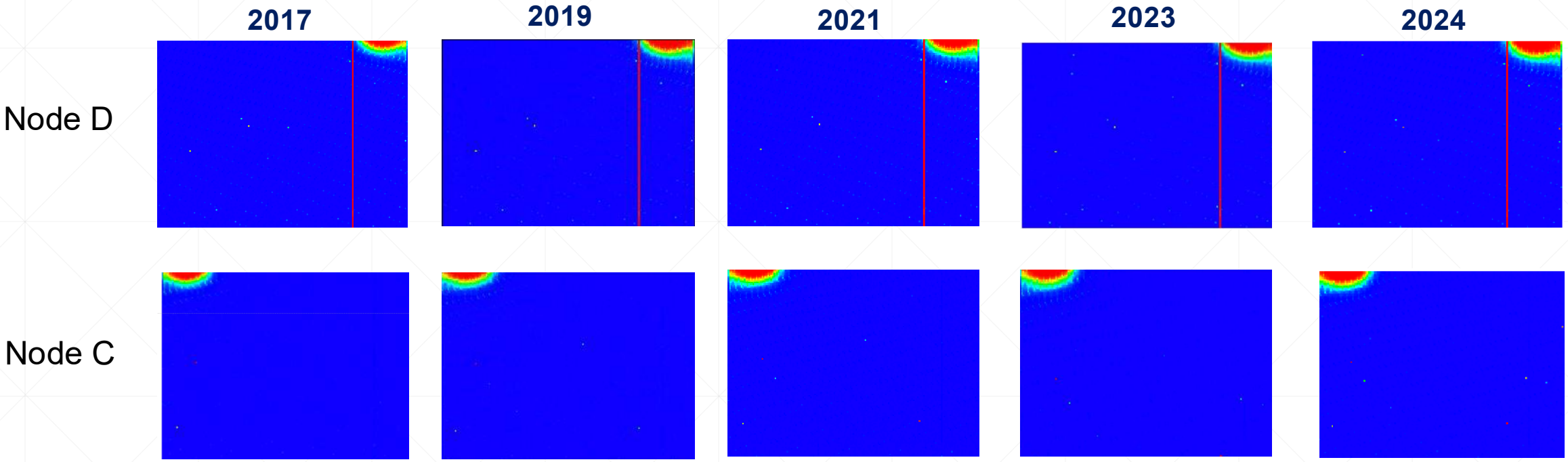


Columns found hot in more than 95% of the observations



RGS Diagnostic Trend Analysis Reports

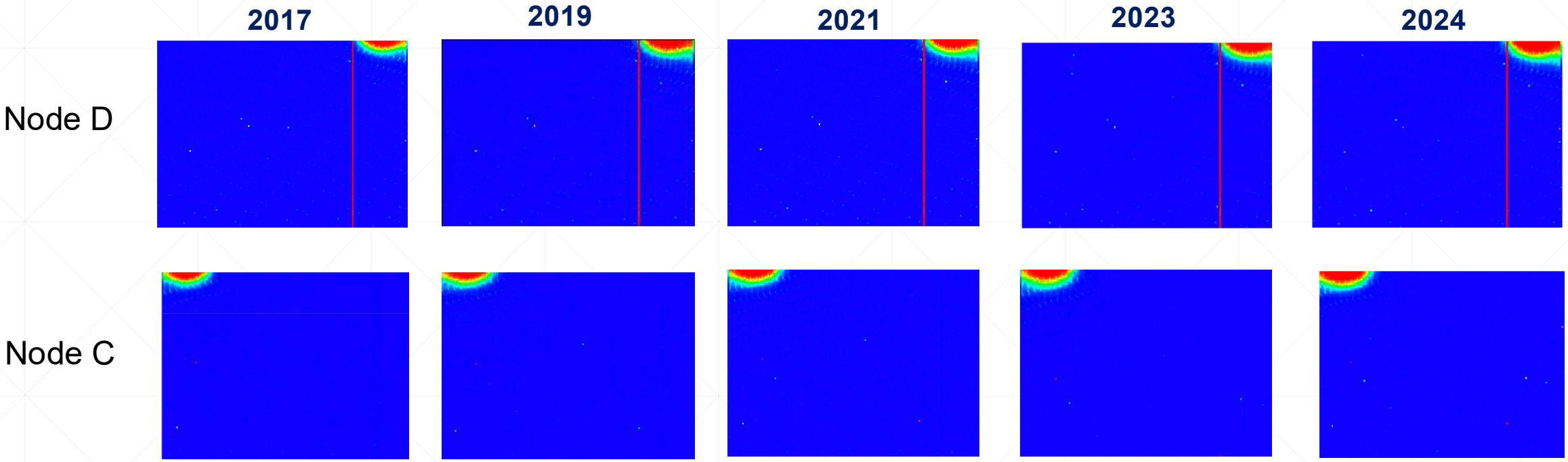
Instrument diagnostics: Hot Spots in CCD#1 of RGS1



RGS Diagnostic Trend Analysis Reports

- Following revolution 786 RGS1 CCD1 developed two hot spots.
- They show up symmetrically in RGS CCD1 only.
- Symmetry does not suggest radiation damage or aging of detector bench.
- Unknown origin: mechanical stress in detector?
- Initial growth during the first 2-3 years, stable at the moment.

Instrument diagnostics: Hot Spots in CCD#1 of RGS1



RGS Diagnostic Trend Analysis Reports

The onboard software excludes these areas from processing.

STABLE → NO NEED FOR CCF UPDATE

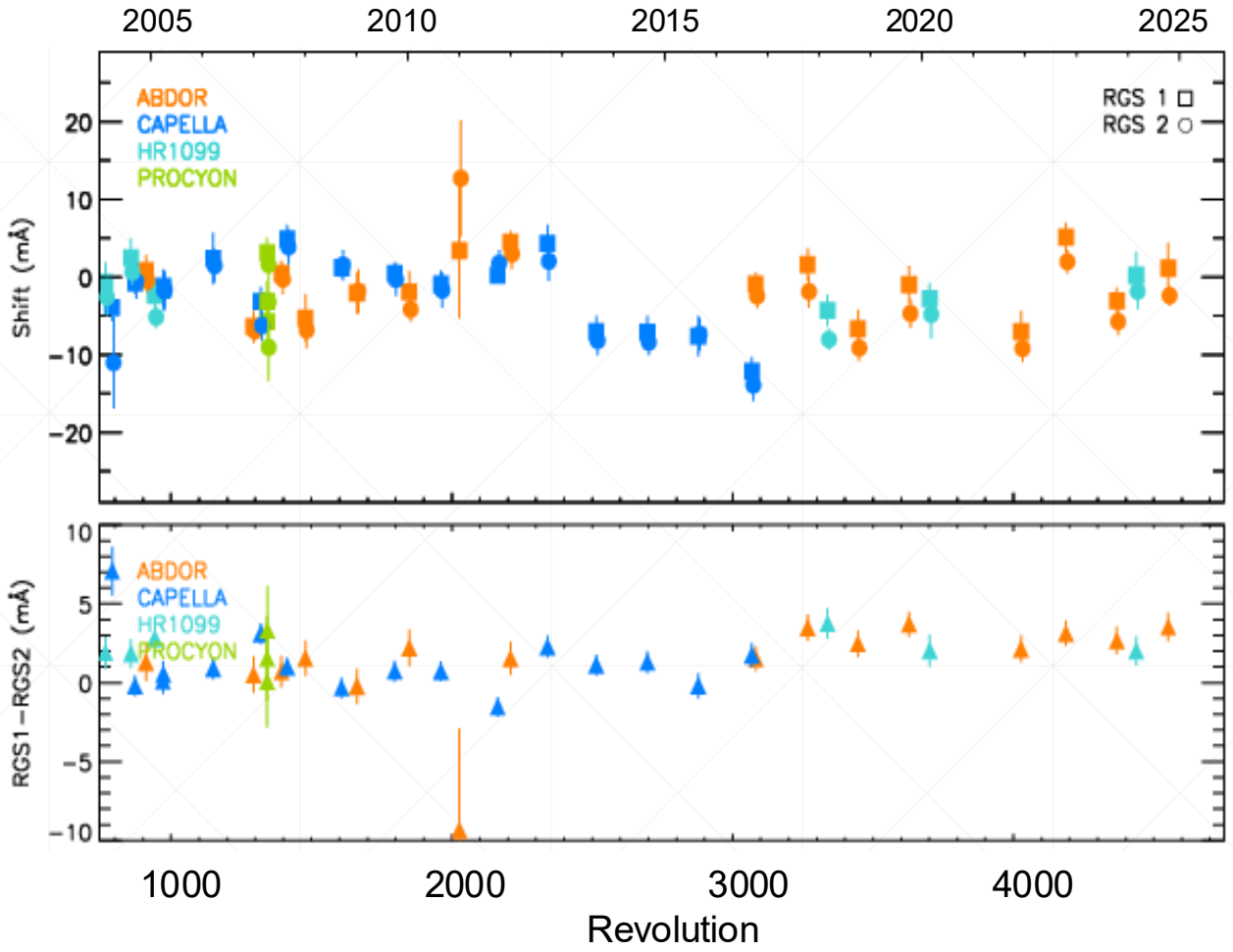
Calibration and Monitoring

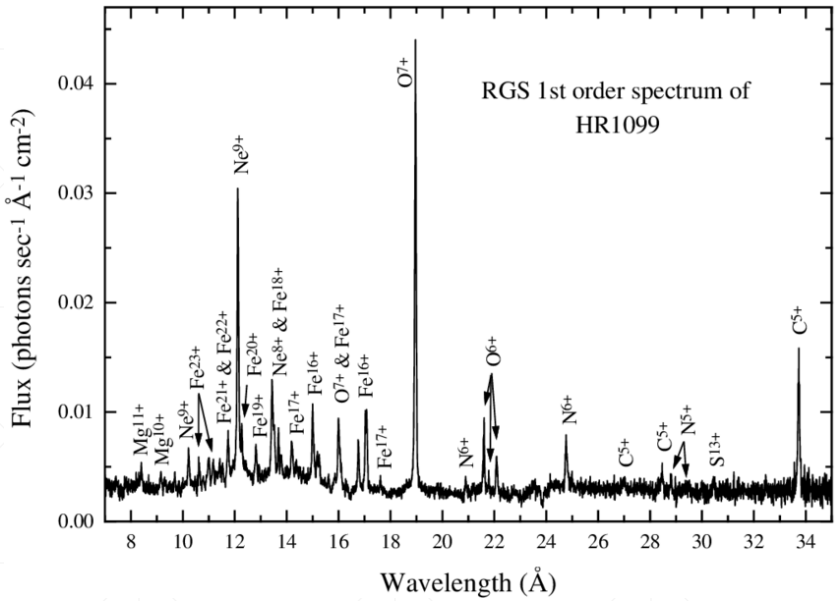
- Wavelength Scale
- Effective Area
- Flux monitoring

Calibration and Monitoring: Wavelength Scale

Relation between incoming photon energy and the most likely location where it will end up on the detector

Average line shifts per spectrum (2004 - 2024)





Brinkman+, 2000

Calibration and Monitoring: Wavelength Scale

Relation between incoming photon energy and the most likely location where it will end up on the detector

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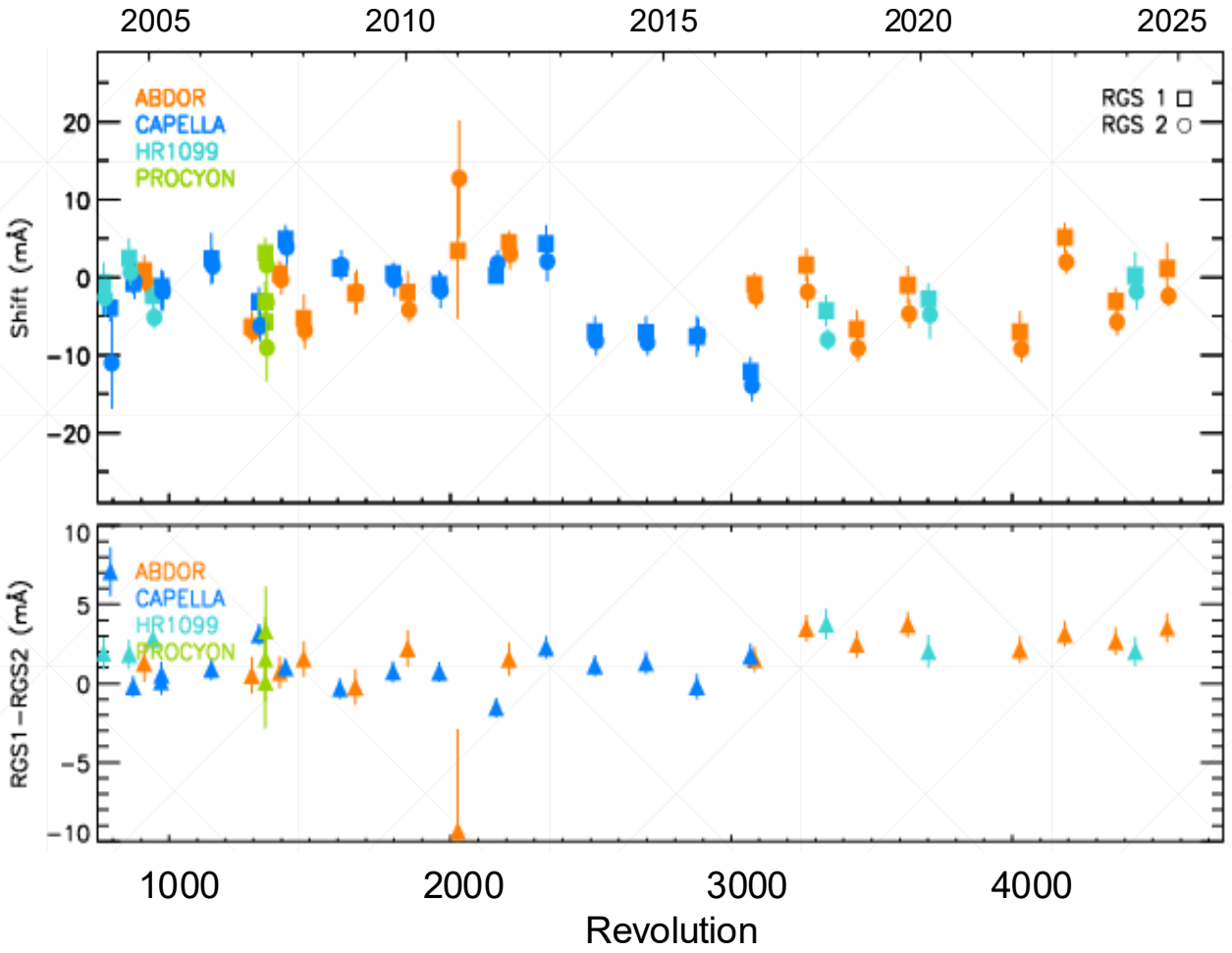
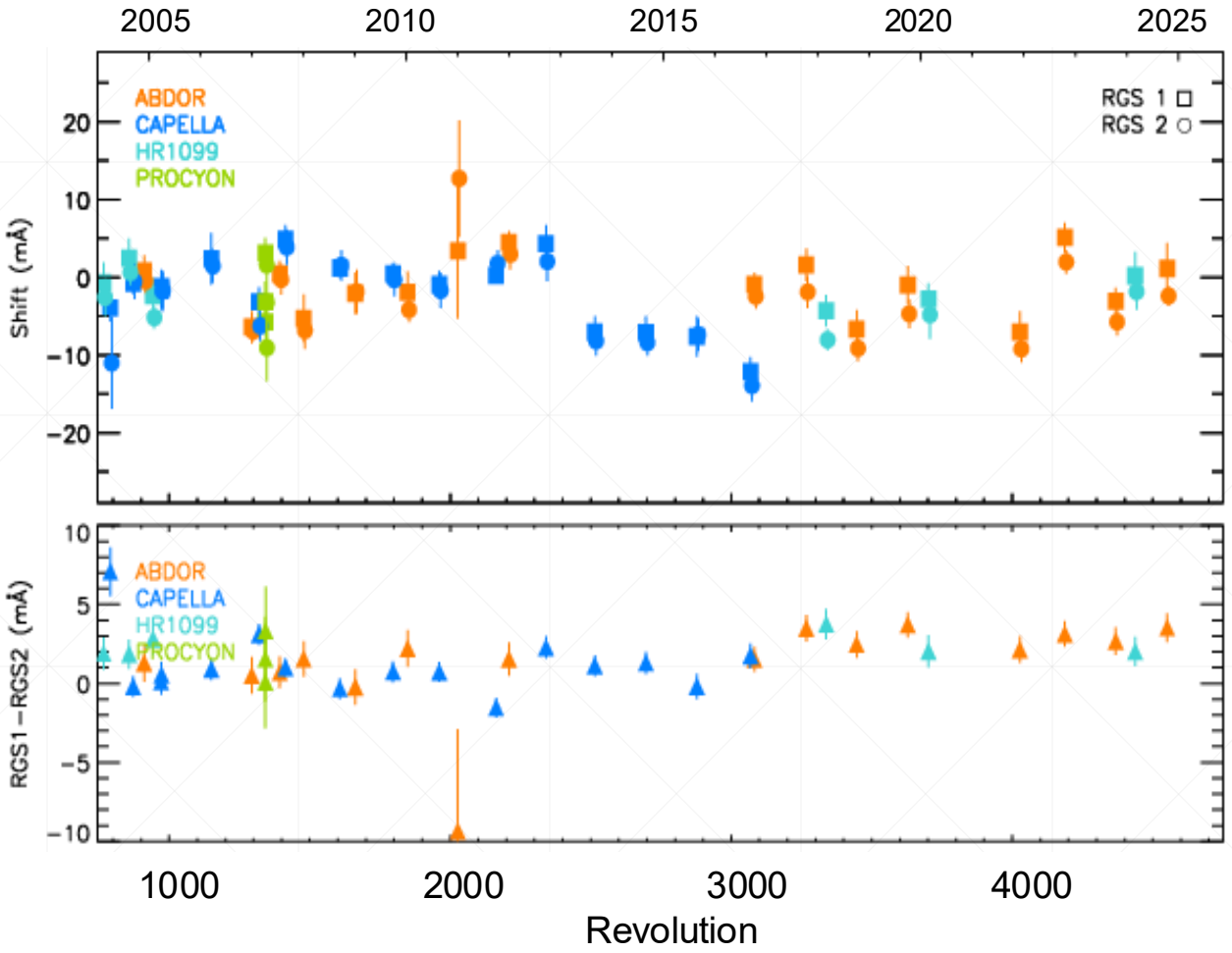


Shift of individual lines (median ± σ)	
RGS 1	RGS 2
1st order	
-2 ± 5 mÅ [335 lines]	-3 ± 5 mÅ [348 lines]
2nd order	
-2 ± 5 mÅ [206 lines]	-3 ± 5 mÅ [259 lines]

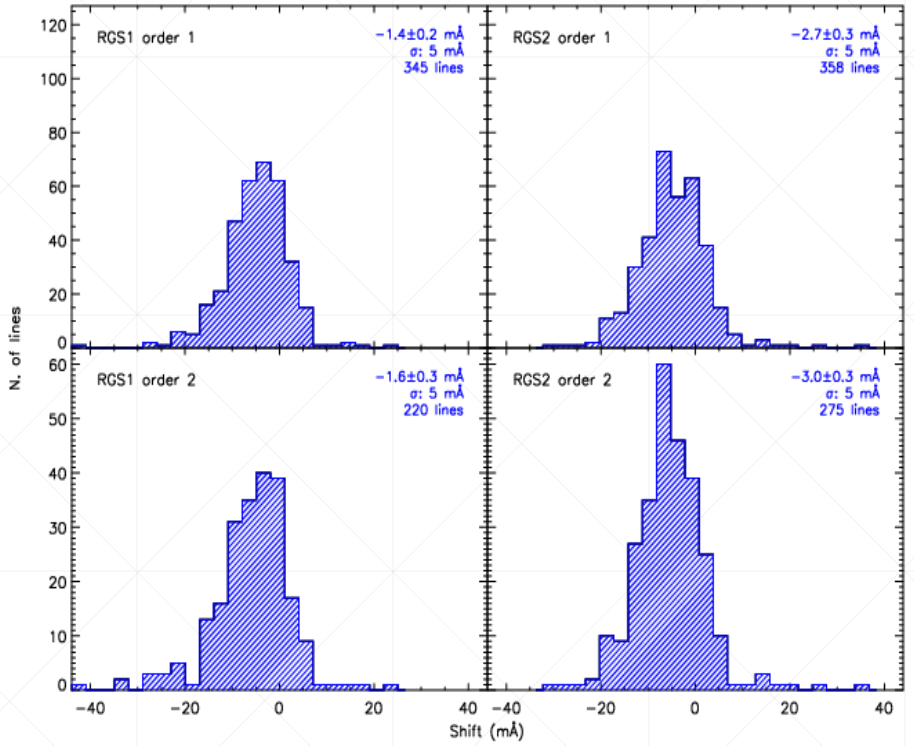
Calibration and Monitoring: Wavelength Scale

Relation between incoming photon energy and the most likely location where it will end up on the detector

Average line shifts per spectrum (2004 - 2024)



Line shifts distribution (2004 - 2024)



Calibration: Effective Area

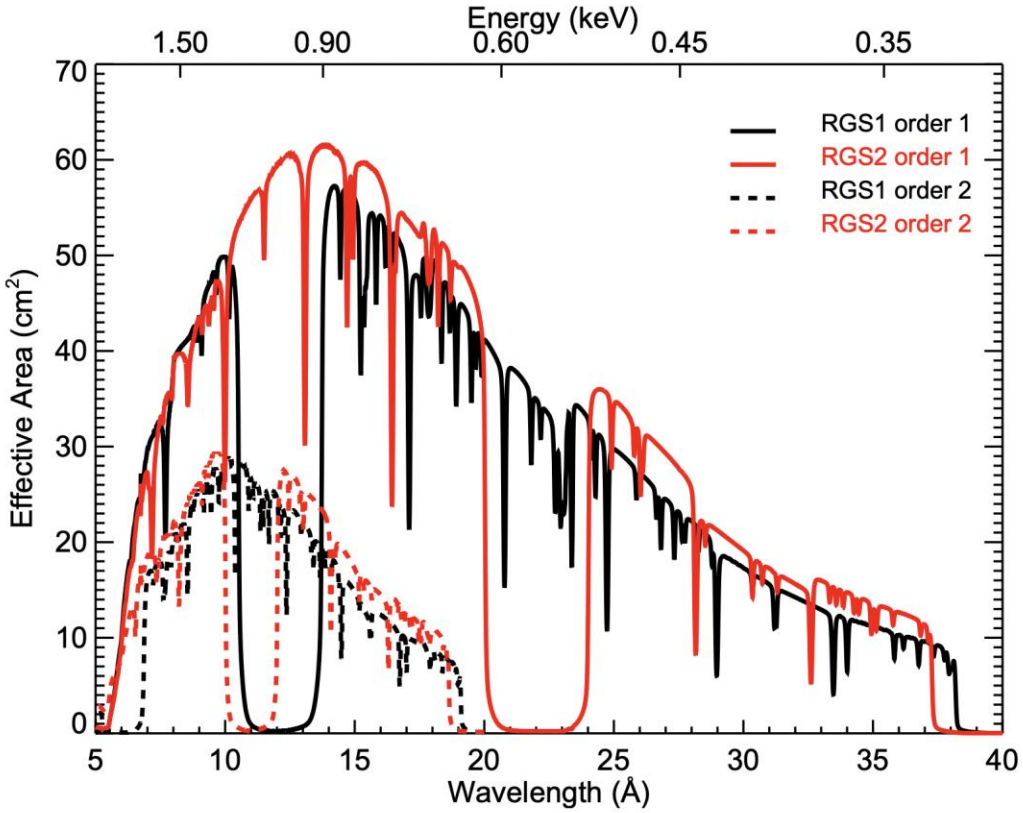
Three time-dependent **effective area corrections**:

- **Contamination correction**,
  Default in processing, rgsproc/rgsrmfgen parameter `dyneffareacorr=yes`

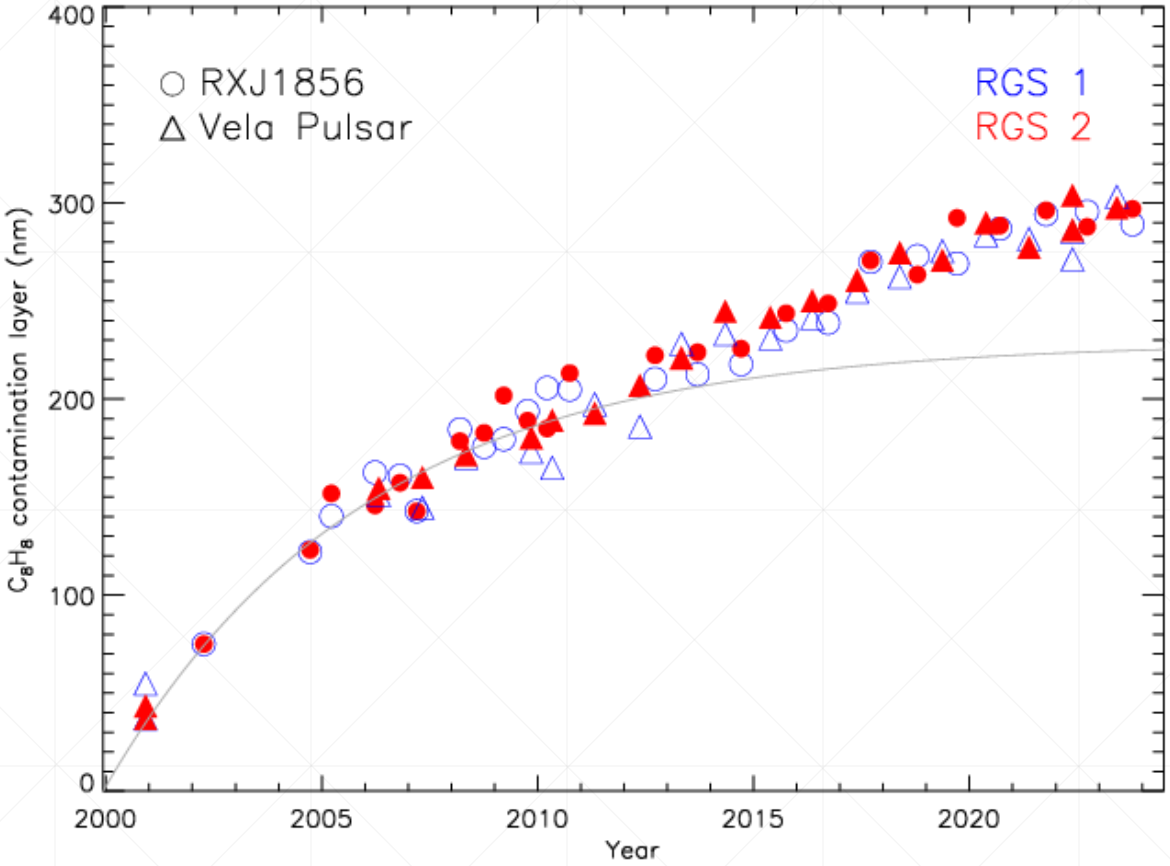
- **Time-dependent Small scale Effective Area correction**
Default in processing, rgsproc/rgsrmfgen parameter `witheffectivaeracorrection=yes`

- **Rectification Factors**
Correction with respect to EPIC-pn. Non-default option. can be applied with rgsproc/rgsrmfgen `withrectification=yes`

Corrections regularly monitored & updated.



Calibration: Effective Area: Contamination

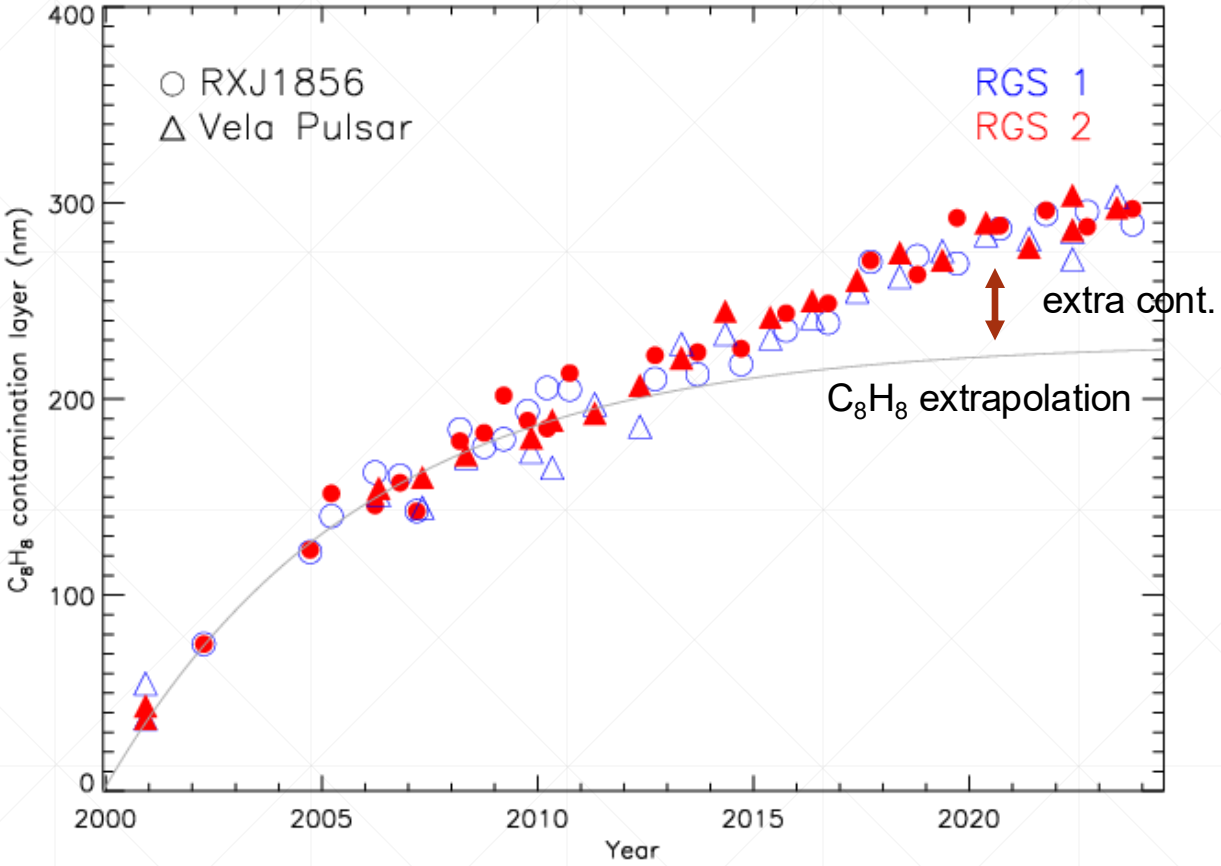


C_8H_8 contamination layer building up slowly (2nm/yr)

Thickness of contaminant proportional to flux @35Å

Contamination estimated from observations of RX J1856-3754 & Vela Pulsar

Calibration: Effective Area: Contamination



C_8H_8 contamination layer building up slowly (2nm/yr)

Thickness of contaminant proportional to flux @35Å

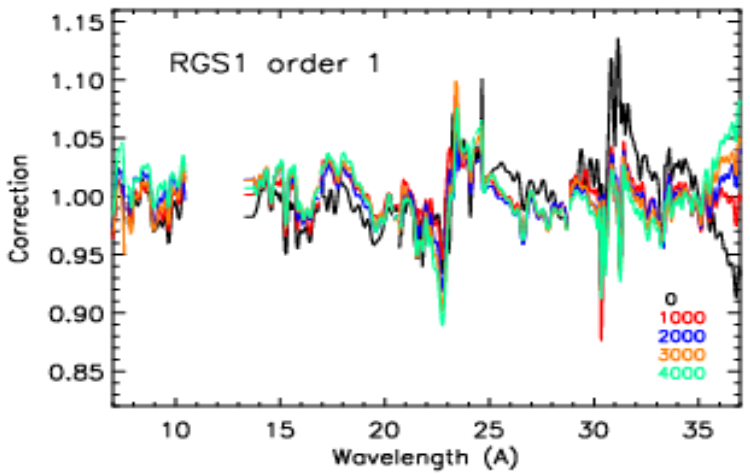
Contamination estimated from observations of RX J1856-3754 & Vela Pulsar

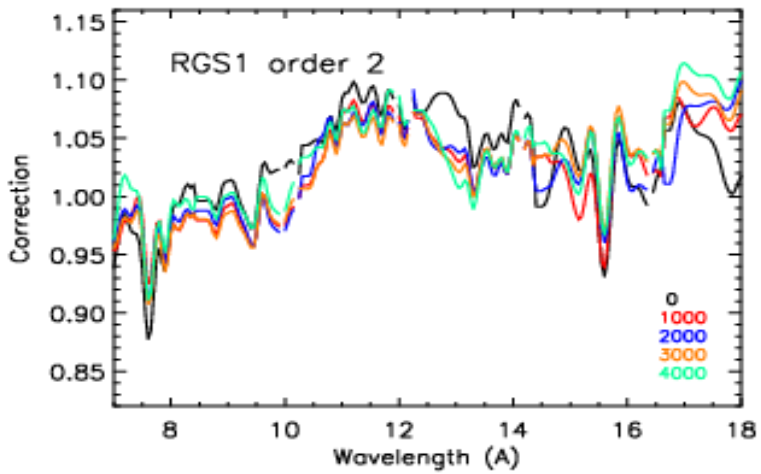
Since ~2015, extra contamination source, not consistent with C_8H_8

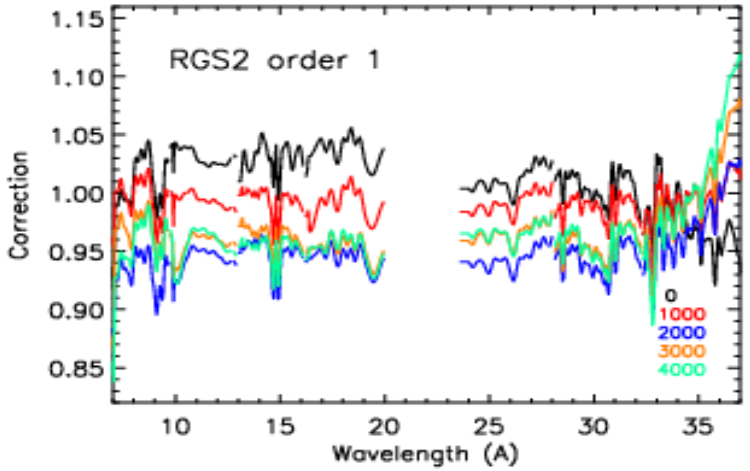
Nature of new contaminant unknown

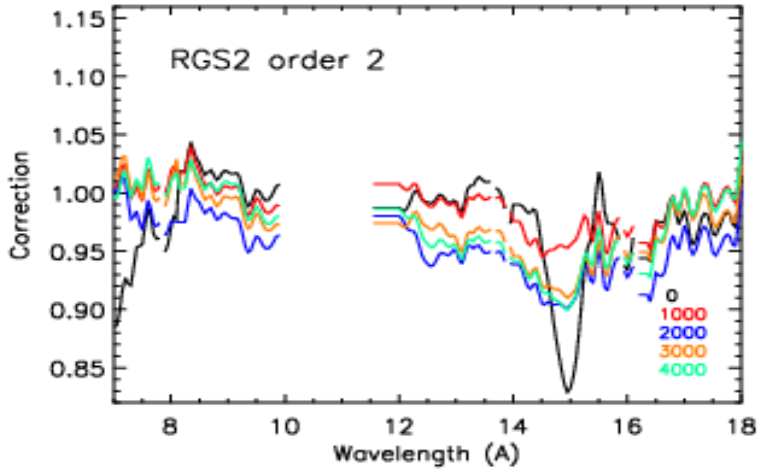
Empirically corrected in “Rectification Correction”

Calibration: Effective Area: Small Scale Correction









Cross-calibration RGS1-RGS2

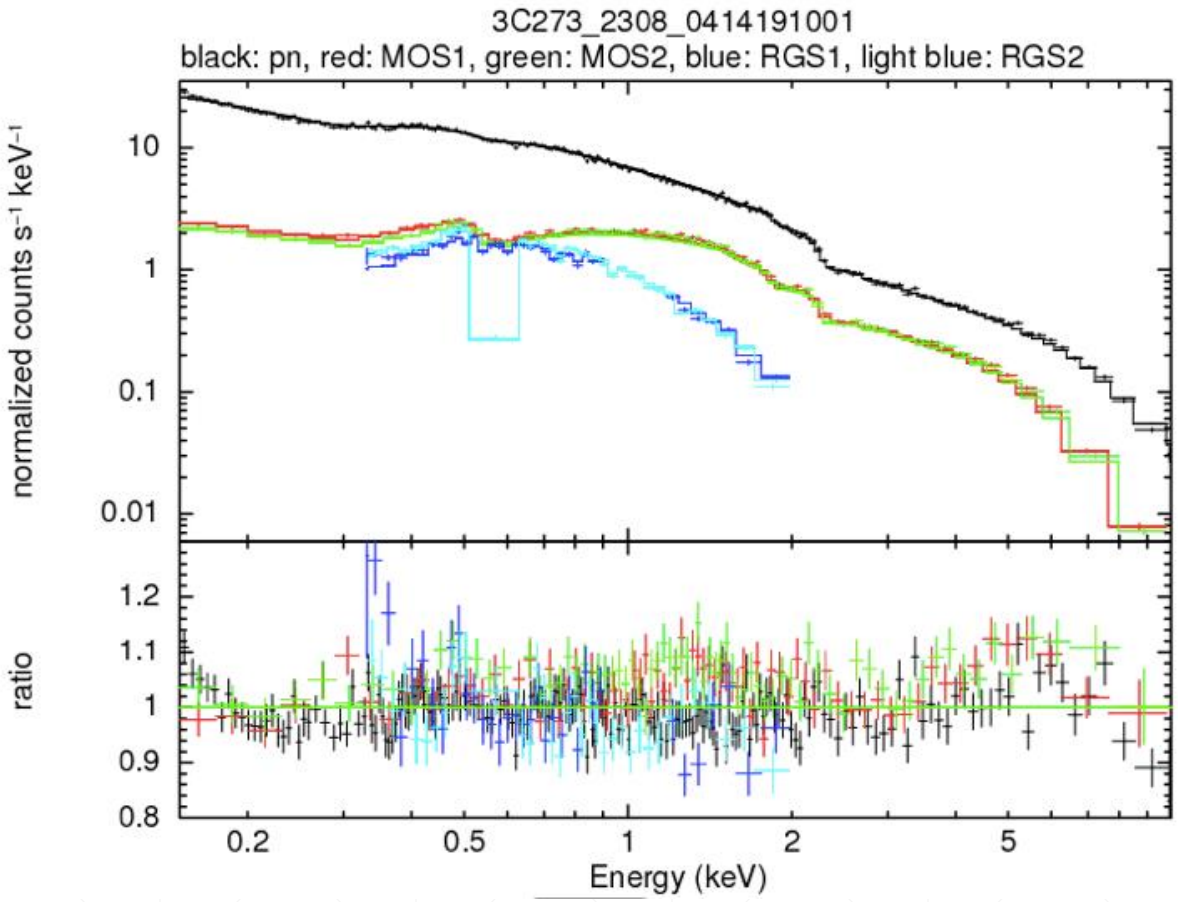
Implemented in April 2023.

Time and wavelength-dependent tabulations in the EFFAREACORR CCF for the calculation of RGS response matrices.

Calibration: Effective Area: Rectification Factors

RGS - EPICpn redundancy in 0.35-2 keV range helps to improve calibration

- Ratio of RGS / EPIC-pn fluxes in steps of 1Å
- Updated regularly to account for improvements in EPIC-pn and RGS calibrations, and with optimised EPIC-pn extraction regions.
- Data used: PKS2155 and 3C 273, EPIC-pn in Small Window Mode



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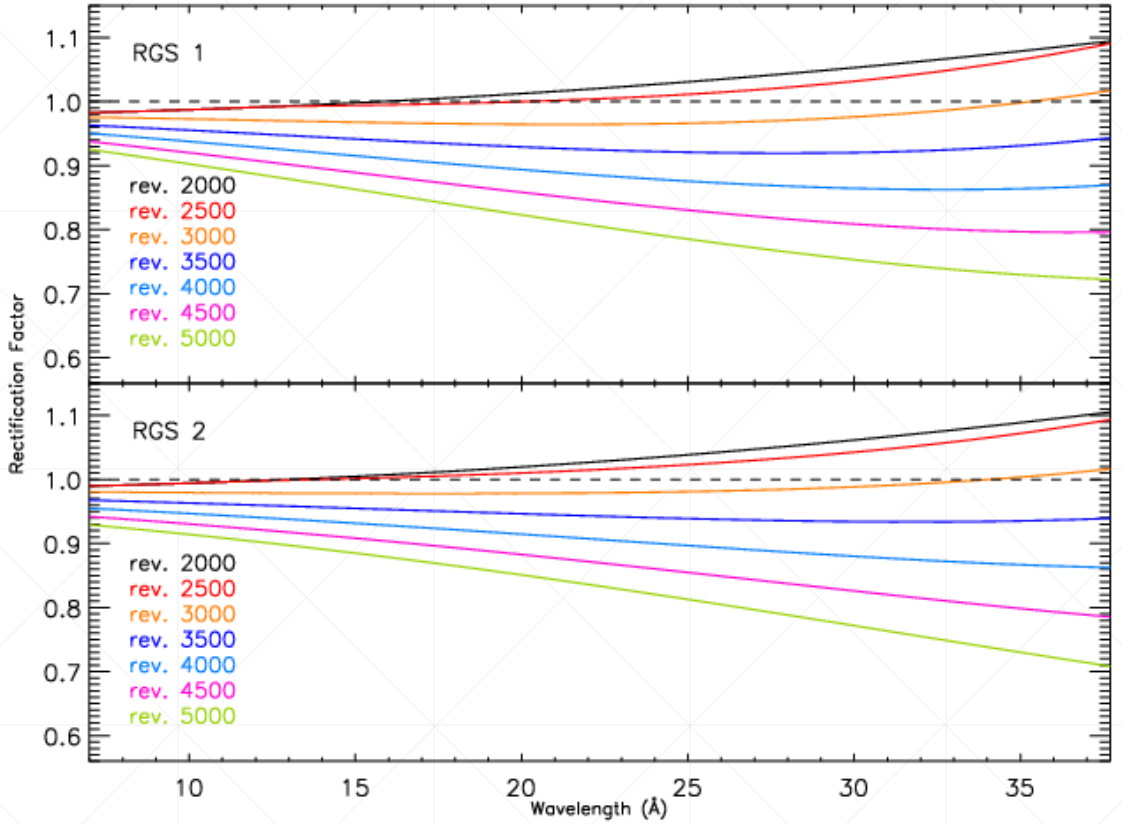
- Data used: PKS2155 and 3C 273, EPIC-pn in Small Window Mode

- Re-derived in September 2023 following the update of the Effective Area correction in April 2023

[Release Note: CAL-SRN-401]

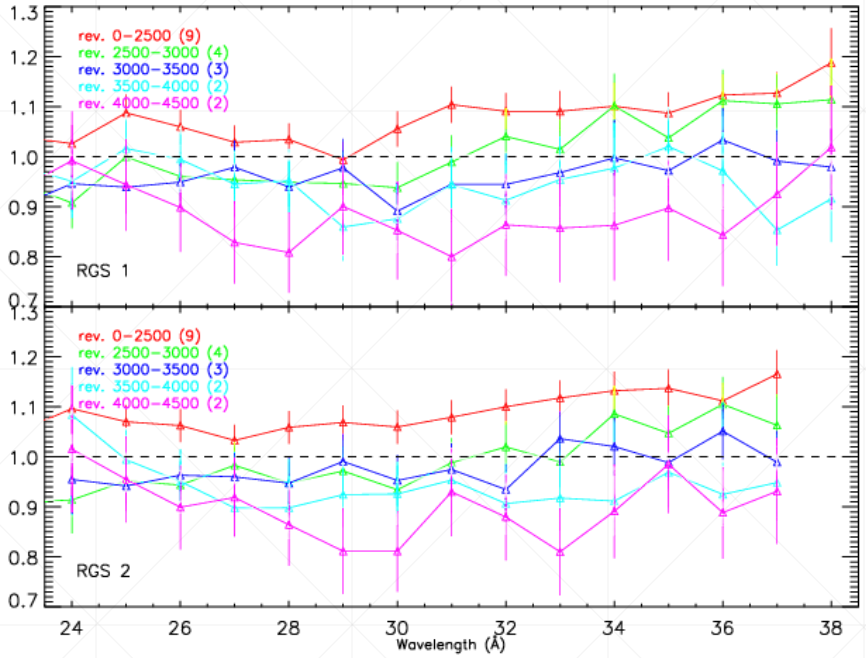


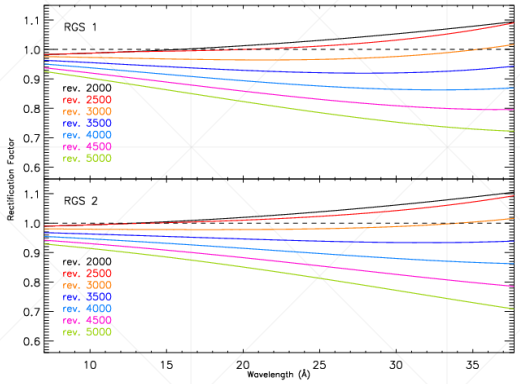
Update in progress based on data taken until January 2025

Calibration: Effective Area: Rectification Factors

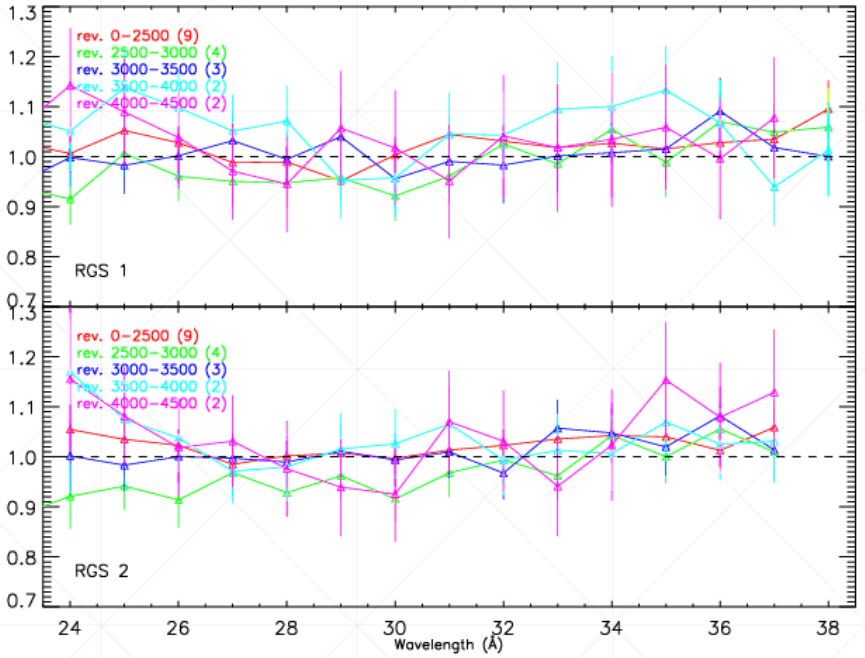
Cross-validation: Rect. Factors applied to ISN RXJ1856-3754

RGS/EPIC-pn Flux Ratio, no rect





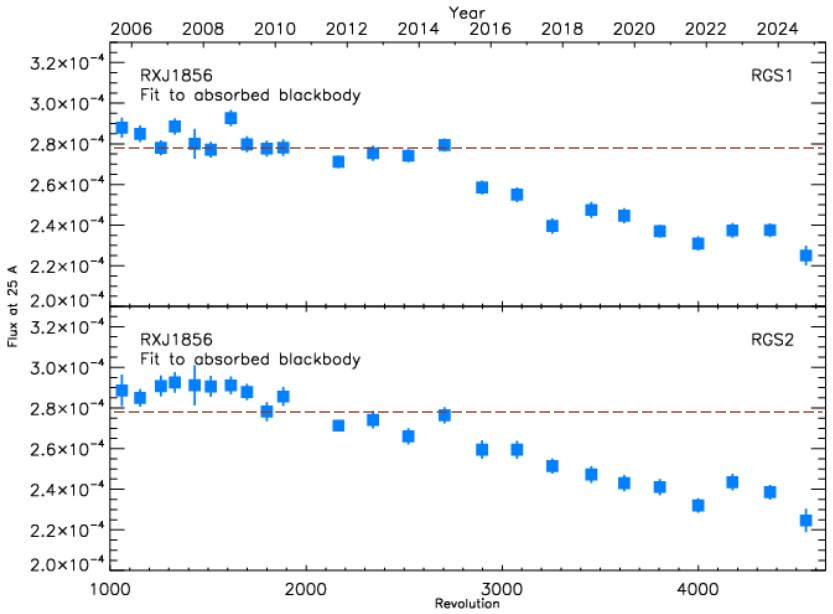
RGS/EPIC-pn Flux Ratio, with rect correction



Calibration: Flux monitoring

Flux derived from XSPEC fit to an absorbed BB. Fixed N_H=3.95 x 10^{19} $cm^{-2;}$ (Grandis et al. 2022)

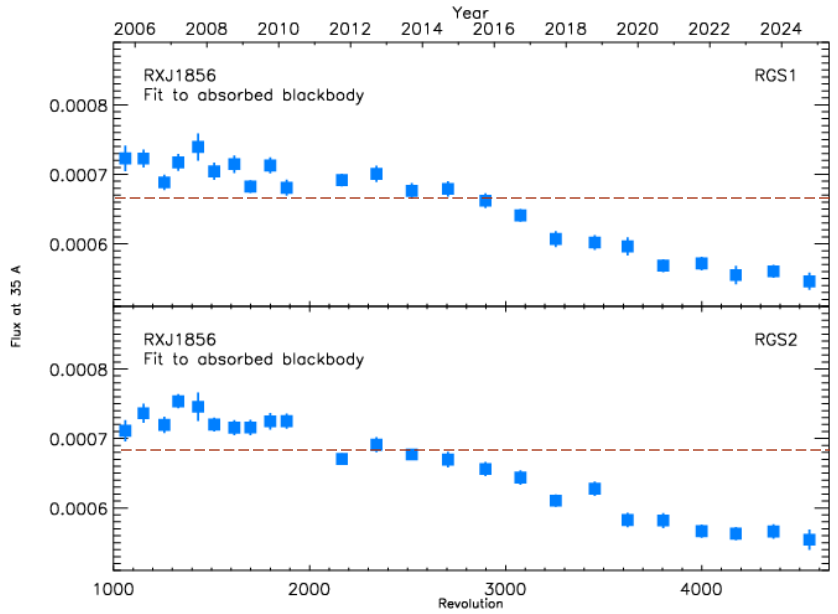
25Å



Flux (10^{-4} ph/cm^2/s/Å)

RGS1 2.6 +/- 0.2
RGS2 2.7 +/- 0.2

35Å



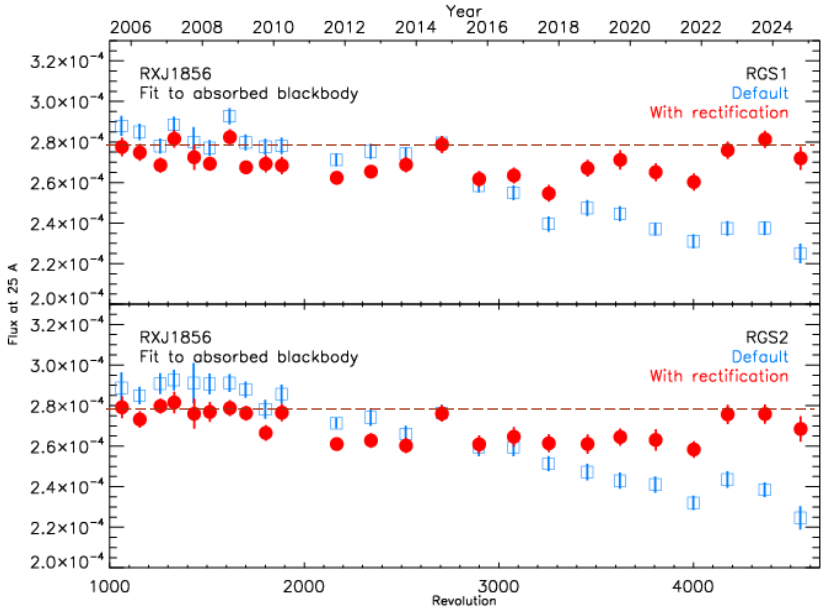
Flux (10^{-4} ph/cm^2/s/Å)

RGS1 6.6 +/- 0.6
RGS2 6.6 +/- 0.7

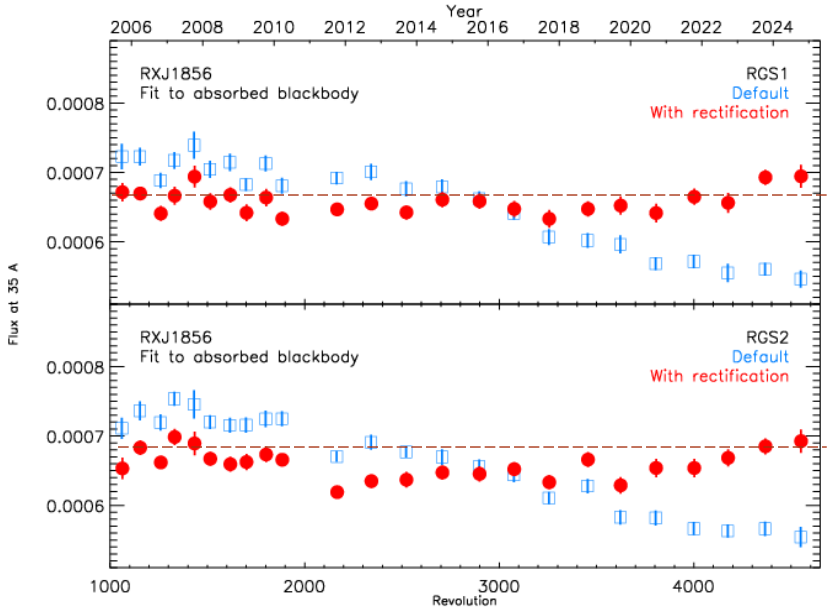
Calibration: Flux monitoring

Flux derived from XSPEC fit to an absorbed BB. Fixed N_H=3.95 x 10^{19} $cm^{-2;}$ (Grandis et al. 2022)

25Å



35Å



Flux (10^{-4} ph/cm^2/s/Å)

RGS1	2.6 +/- 0.2	2.7 +/- 0.1
RGS2	2.7 +/- 0.2	2.7 +/- 0.1

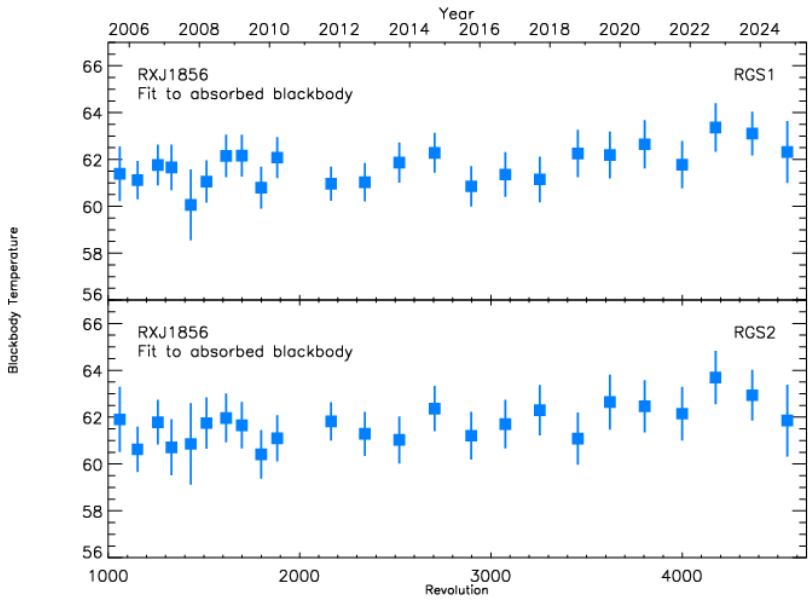
Flux (10^{-4} ph/cm^2/s/Å)

RGS1	6.6 +/- 0.6	6.6 +/- 0.2
RGS2	6.6 +/- 0.7	6.6 +/- 0.2

Calibration: Flux monitoring

Spectral parameters from XSPEC fit to an absorbed BB. Fixed N_H=3.95 x 10^{19} $cm^{-2;}$ (Grandis et al. 2022)

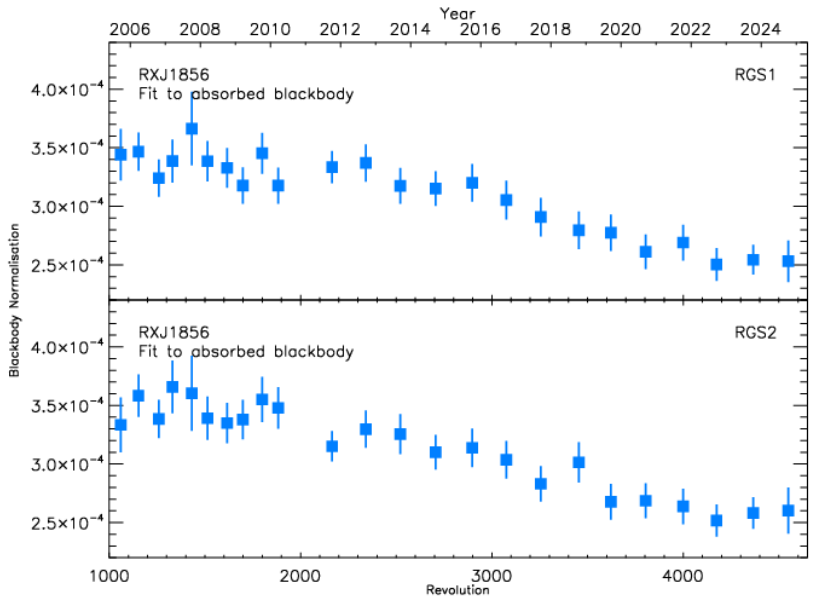
BB TEMPERATURE



kT (eV)

RGS1 61.7 +/- 0.8
RGS2 61.7 +/- 0.8

BB NORMALISATION



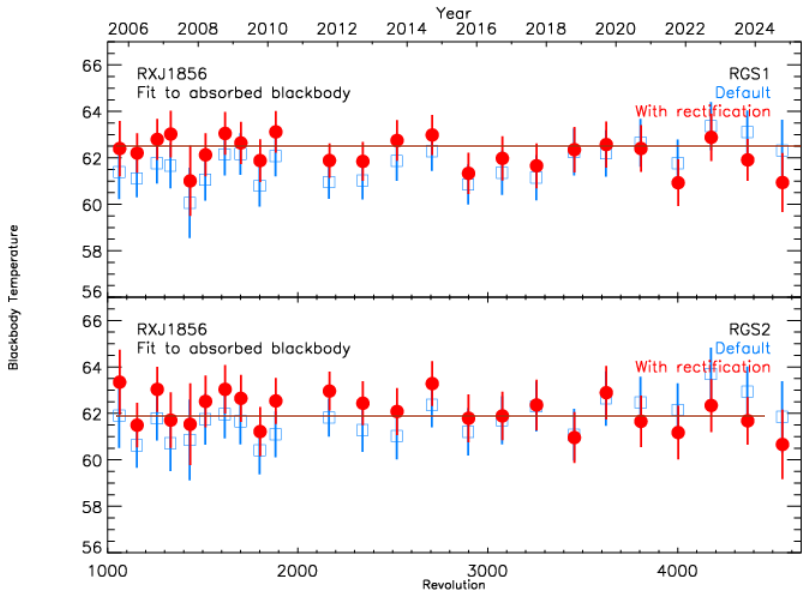
10^{-4} photons/cm^2/s/Å

RGS1 3.1 +/- 0.3
RGS2 3.1 +/- 0.4

Calibration: Flux monitoring

Spectral parameters from XSPEC fit to an absorbed BB. Fixed N_H=3.95 x 10^{19} $cm^{-2;}$ (Grandis et al. 2022)

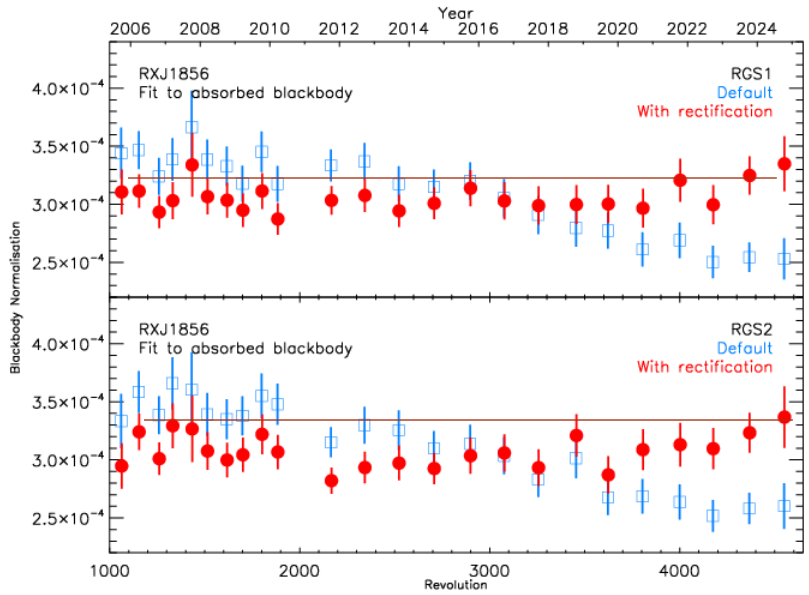
BB TEMPERATURE



kT (eV)

RGS1	61.7 +/- 0.8	62.2 +/- 0.7
RGS2	61.7 +/- 0.8	62.1 +/- 0.8

BB NORMALISATION



10^{-4} photons/cm^2/s/Å

RGS1	3.1 +/- 0.3	3.1 +/- 0.1
RGS2	3.1 +/- 0.4	3.1 +/- 0.1

Summary

Operations and Instrument Status

- Operations running smoothly
- No changes in hot columns / hot spots
- No unexpected behaviour in the instrumental performance, except for decrease in CTE
  -> CTI UPDATE IN PROGRESS

Wavelength scale

- Wavelength scale stable
- No significative trend with time
- No degradation in spectral resolution

Effective Area

- Variations in Effective Area continuously monitored
- Empirical corrections to take into account the observed change in Effective Area:
  - Effective area correction
  - Rectification correction **-> EFFAREACORR UPDATE IN PROGRESS**

EPIC and RGS calibration targets

Target	ks	Visits/yr	Main purpose	
1ES0102-72	35	2	EPIC effective area	
N132D	45	1	EPIC redistribution	
Crab	2x5	2	EPIC Timing	
Vela SNR	60	1	EPIC spectral resolution and contamination	
Zeta Puppis	45	0.5	EPIC Redistribution	
Zeta Puppis	60	1	EPIC/RGS long wavelength Effective area	Apr 2025
RXJ1856-3754	70	2	EPIC/RGS response and contamination	Mar 2025
HR 1099	50	0.5	RGS CTI and Gain Confirmation of the RGS wavelength scale	2026
AB Dor	100	1	Confirmation of the RGS wavelength scale	Oct 2024
Vela Pulsar	100	1	RGS Long wavelength response	May 2025
Mkn 421 in MPM	5x12	2	RGS Effective area	May 2025
Mkn 421 offset in XDSP	2x10	0.5	RGS CTI and Gain [offsets modified to ± 1.5 arcmin)	2026
1ES1553+113	30	1	XCAL Effective area	Feb 2025
3C 273	60	1	XCAL Effective area	Jan 2025
PKS 2155-304	50	1	RGS Effective area	Nov 2024

NEW

http://xmmweb.esac.esa.int/docs/documents/CAL-PL-0101-2-0.pdf