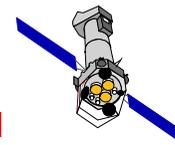

SAS - Scientific Validation

Bruno Altieri - XMM/SOC
on behalf of the SV Team

- *Matteo Guaianazzi*
- *Carlos Gabriel*
- *Matthias Ehle*



BA - SAX

XMM-Newton

EPIC TTD - Feb 7/8, 2001 ¹

SAS - Scientific Validation

SAS V5.0 released to the community in December 2000

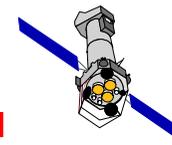
Necessary: to ensure a constant high quality of the SAS

> Scientific validation, using a reference data set for regular tests

Final goal of Scientific Validation

Info to “general SAS user”, containing :

- 1) which instrumental modes are fully supported by SAS
- 2) which scientific products SAS can produce
- 3) which accuracy is associated with the scientific products from SAS



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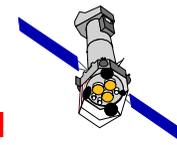
XMM-Newton

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SAS Scientific Validation: the reports

- Not possible to disentangle calibration and processing aspect of scientific analysis
 - > both aspects must be covered
- * SSC run pipeline on all the data checking completeness and “formal” correctness of products
 - > Report
- * Calibration Scientists estimate expected accuracy on SAS products
 - > Report (basically: CCF release notes)
- * SOC/VILSPA coordinates interactive analysis (start point: event lists from pipeline), checking scientific products. Comparison with CS estimated accuracy
 - > Report

Final report merging all three written by SOC/VILSPA for the WEB



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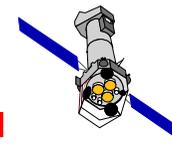
SAS Scientific Validation: the test cases

Test cases:

- all different observing modes of all instruments
- only good quality data
- limited to a small number of observations (man-power limitations)

Result: 18 observations - 30 cases

INSTRUMENT	MODE	DATA	OBSERVATION	#	ODF	PPS	REPORT
EPIC MOS	Full MOS	Lockman Hole	70 0123700101	1	y	y	y
	"	G21.5.09	60 0122700101	2	y	y	y
	"	AbDor	72 0123720201	3	y	n	n
	PRI PART W2	3C273	94 0126700301	4	n	n	n
	"	EXO0748-676	67 0123500101	5	y	n	n
	PRI PART W3	PKS0558-504	84 0125110101	6	n	n	n
	"	YYGem	69 0123710101	7	y	n	n
	PRI PART W4	PKS2155-304	87 0124930101	8	y	n	n
	PRI PART W5	PKS0558-504	84 0125110101	6	y	n	n
	PRI PART RFS	GRAB pulsar	56 0122330801	9	y	y	n
FAST UNCOMP	PKS2155-304	87 0124930201	10	y	n	n	
EPIC-PN	Full PN	Lockmann Hole	70 0123700101	1	y	y	y
	"	G21.5.09	60 0122700101	2	y	y	y
	Large Window	Mkn205	75 0124110101	11	y	n	n
	"	EXO0748-676	67 0123500101	5	y	n	n
	Small Window	PKS2155-304	87 0124930101	8	y	n	n
	"	YYGem	69 0123710101	7	y	n	n
	Fast Timing	Mkn421	84 0099280101	12	y	y	y
	"	AbDor	91 0126130201	13	n	n	n
	Fast Burst	PKS0558	42 0119100301	14	n	n	n
	RGS	HER+SES/SPEC	Mkn421	84 0099280101	12	y	y
"		AbDor	72 0123720201	3	y	n	n
"		Capella	54 0121920101	15	y	y/n	-
SPEC+Q		3C273	94 0126700301	4	n	n	n
"		AbDor	162 0123720301	18	y	n	n
OM	IMG	Lockmann Hole	70 0123700101	1	y	y	y
	IMG+GRISM	BPM 16274	81 0123920101	17	y	n	n
	FAST MODE						



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SAS Scientific Validation: the problems

Problems for the SAS 5.0 validation:

Input to SAS should be ODS (\geq V.10.2.3.)

- Re-processing of reference data set necessary
- Capabilities for playback in VILSPA (still) very limited

>> some observations **only partly re-processed**

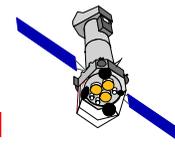
Pipeline system (not SAS) **showing some problems** for processing data

>> new version of PPS just produced

SAS itself **further developed** (“technical” tests going on at the same time)

Result: decision taken (by SAS-CCB) on

- * **public distribution of the SAS (Dec. 27, 2000)**
- * **data & SAS to be validated data set by data set**



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SAS Scientific Validation: first reports

Lockman Hole:

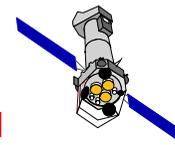
- * check basic SAS functionality on EPIC data in Full Frame mode
- * verify accuracy of XMM-Newton astrometry
- * check performances of sources detection tasks

General points on [pipeline](#) products:

- EPIC:**
- PPS running with some non-nominal values
 - bright columns in pn and MOS2 leading to spurious source detections
 - final EPIC source list a combination of individual source lists
 - mosaiced images not exposure-corrected
 - background maps and three-colors EPIC images not available

- RGS:** - sources in field too faint

- OM:** - detector coordinate images, combined observation source list and tracking star time series are missing



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SAS Scientific Validation: first reports

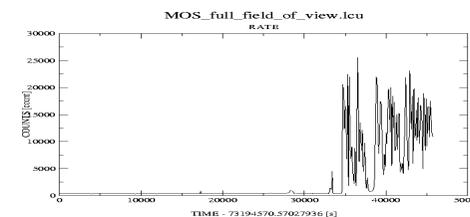
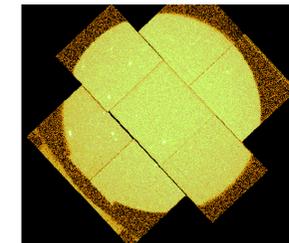
Lockman Hole (cont):

Interactive Analysis:

- **All** scientific products (images, spectra, light curves, filtered event lists) can be extracted on both MOS and pn (also using science-driven screening criteria)
- Source **detection** + lists creation tasks working properly:
 - * runs on images in $E=[0.5-10.]keV$, $E=[0.5-2.]keV$ and $E=[2.-10.]keV$

Selection cuts:

- First 32.7 ksec of observation accepted (high radiation at the end of observation)
- In addition to “normal” recommended selections (MOS: Flag=0, Pattern<=12, #XMMEA_EM true; pn: #XMMEA_EP true), bright column in pn-image manually removed
- Default parameter values used (in first instance)



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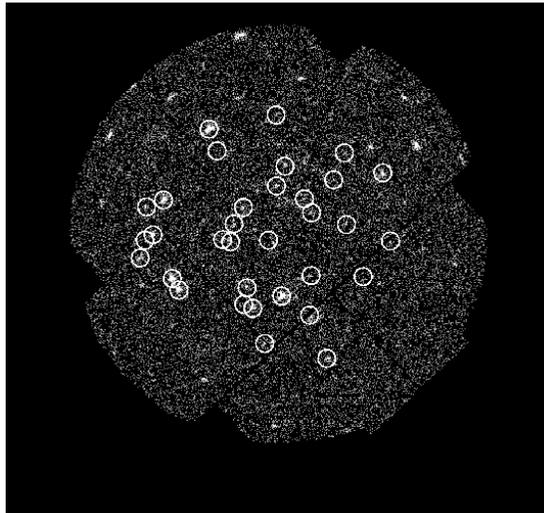
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SAS Scientific Validation: first reports

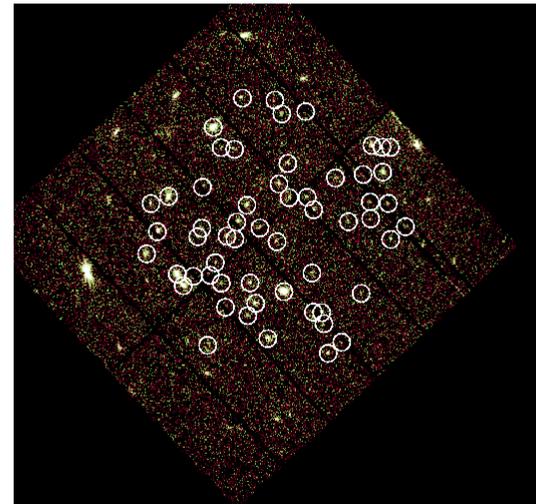
Lockman Hole (cont):

EPIC Astrometry

SAS offers two background computations: “local” and “map” methods

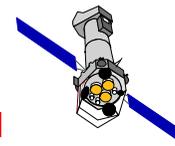


MOS 1



pn

Using “local” background detection and full energy band images



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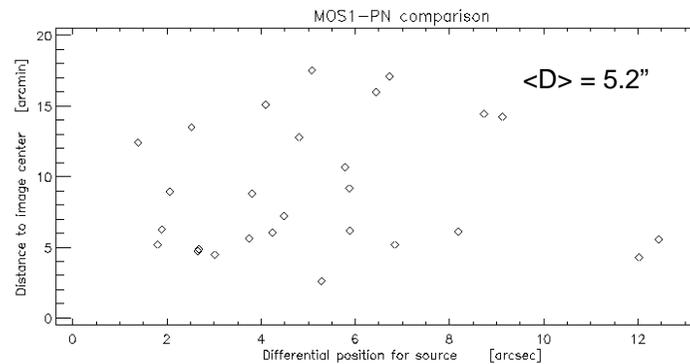
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Lockman Hole (cont):

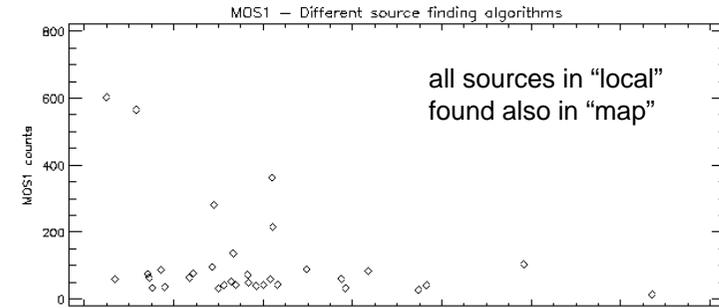
Differences in astrometry



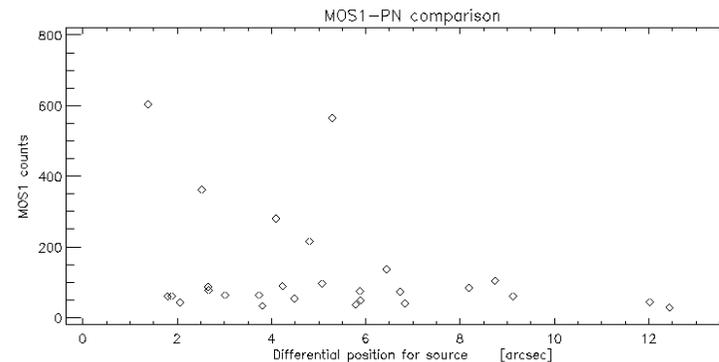
versus distance to image center

Common sources found:

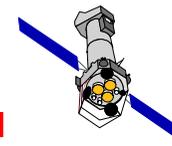
- * no correlation to position within image
- * large number of counts > more accuracy
- * high efficiency in finding algorithm
- * coordinates uncertainties not reliable



versus number of counts



versus number of counts



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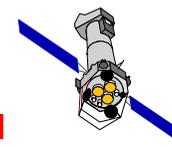
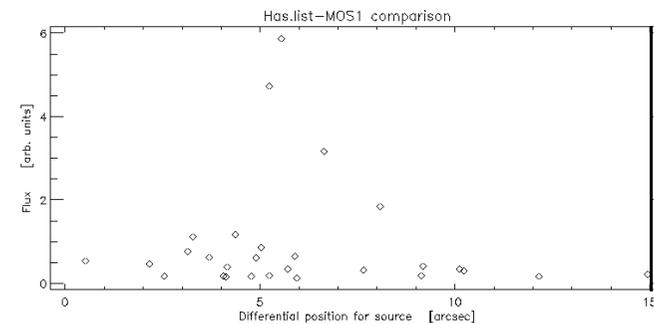
SAS Scientific Validation: first reports

Lockman Hole (cont):

Source finding efficiency	Meth\Inst	MOS1	MOS2	PN
Local	found	33	29	57
	common	0	23	25
	fakes	0	0	5
Map	found	71	73	116
	common		44 (14)	
	fakes	~ 50%	~50%	~50%

Absolute astrometry (using Hasinger et al 2001)

- * excellent agreement by detected sources:
(30 out of 33 MOS1, 26 out of 29 MOS2, 48 out of 57 PN)
- * mean distance to “nominal position”: 5.8”, 6.3” and 5.2” respectively
- * confirmation of wrong identification by “map” mode (eg. 49 out of 71 MOS1)



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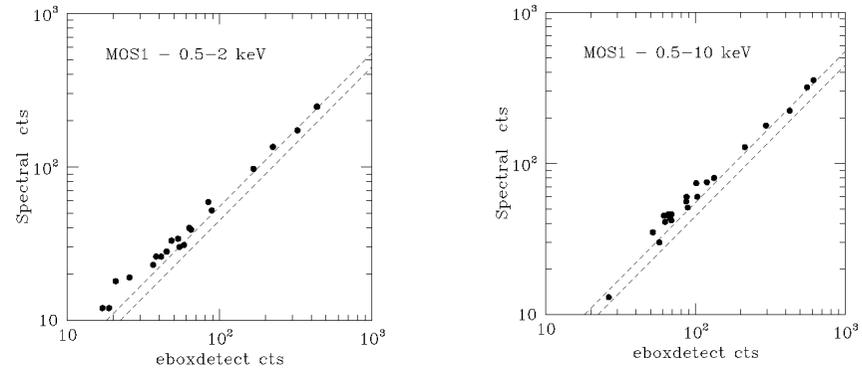
XMM-Newton

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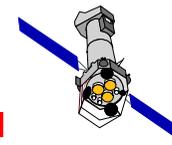
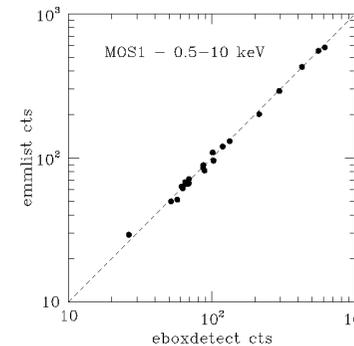
Lockman Hole (cont):

EPIC source count determination



source counts (eboxdetect) vs spectral integral (evselect)

- * 22 brightest sources extracted (22" box)
- * no PSF correction but encircled energy at 0.5 and 10 keV
- > counts estimation systematic uncertainty < 10%
- > very good agreement between eboxdetect and emlselect



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SAS Scientific Validation: first reports

G21.5-09:

- * check SAS EPIC response generator functionality
- * verify accuracy of spectral fitting for EPIC in [1-10 keV] region
- * verify cross-calibration between MOS and PN cameras

General points on [pipeline](#) products (in addition to the ones by Lockman Hole) :

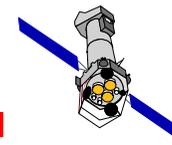
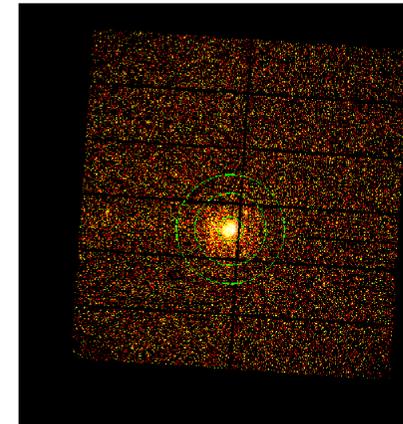
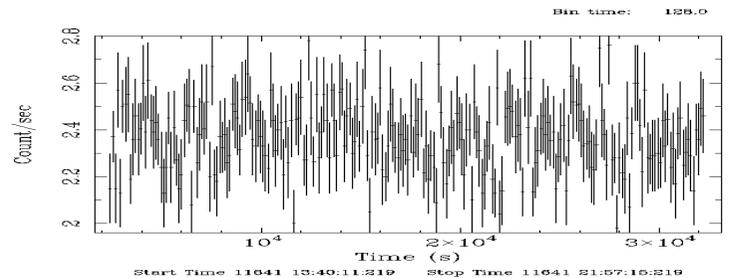
EPIC: - bright column in pn
- several spurious sources at outer upper edge of the pn chips

RGS: - kind of Moiree pattern in RGS1 and RGS2 spectral plots

OM: - not operating in this observation, therefore no products

* all EPICs in Full Frame mode

* obs. not affected by radiation



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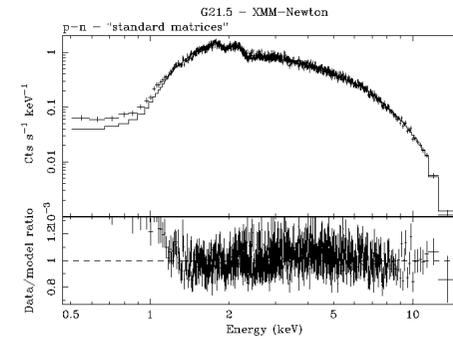
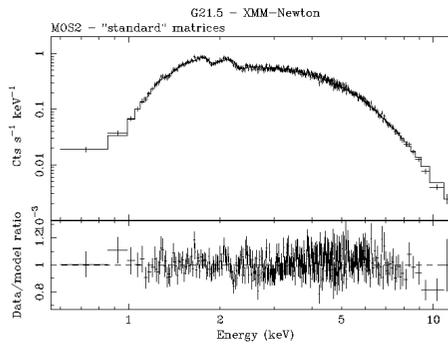
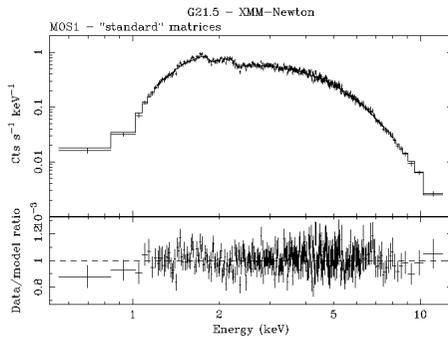
XMM-Newton

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SAS Scientific Validation: first reports

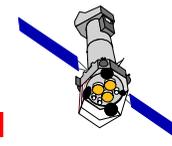
G21.5-09 (cont):

The threefold EPIC response matrices way: 1) run rmfgen + run arfgen
 2) run arfgen on "standard" redistribution file
 3) use "standard" response matrices
 Fit spectra with simple power-law with photoelectric absorption



Method	Γ	N_H (10^{22} cm^{-2})	2-10 keV flux ($10^{-11} \text{ erg s}^{-1} \text{ cm}^{-2}$)	χ^2/dof
MOS1				
1	1.87 ± 0.03	2.28 ± 0.04	5.54 ± 0.05	501.0/416
2	1.90 ± 0.03	2.35 ± 0.04	5.58 ± 0.05	473.9/416
3	1.84 ± 0.03	2.23 ± 0.04	5.42 ± 0.05	446.7/416
MOS2				
1	1.83 ± 0.03	2.22 ± 0.04	5.66 ± 0.05	533.9/416
2	1.87 ± 0.03	2.27 ± 0.04	5.66 ± 0.05	423.6/416
3	1.81 ± 0.03	2.17 ± 0.04	5.34 ± 0.05	439.0/416
pn				
1	1.905 ± 0.020	2.33 ± 0.04	5.27 ± 0.04	1536.3/1154
3	1.855 ± 0.019	2.28 ± 0.04	5.06 ± 0.04	1365.1/1155

- * excellent quality of fits in [1-10]keV band in all EPICs
- * residual dominated by statistical errors
- * systematic deviation from best fit model < 10%
- * clear excess by pn below 1 keV (but G21.5 highly absorbed)
- * best fit quality by the use of "standard" matrices
- * spectral indices in same instrument agree within 3%, column densities within 5% (MOS) and 2% (pn), fluxes within < 6%



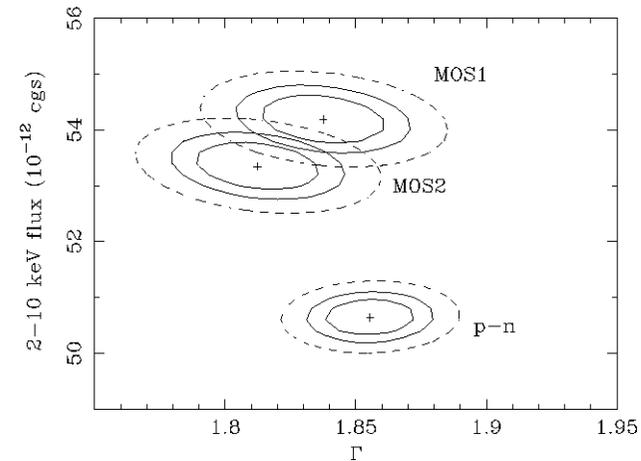
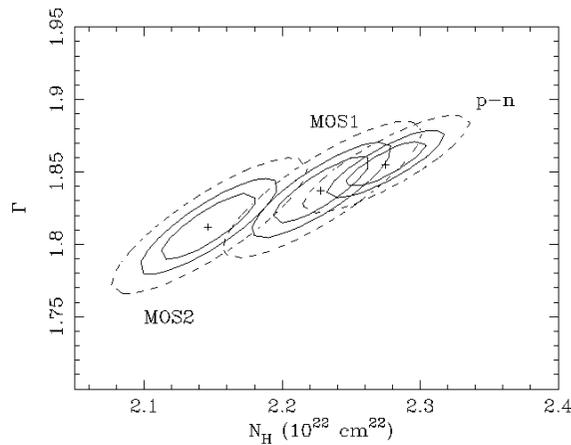
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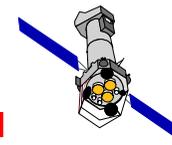
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SAS Scientific Validation: first reports

G21.5-09 (cont): Spectral fitting cross correlation



- * spectral indices consistent for 99% confidence levels (90% CL for MOS cameras)
- * column densities only marginally consistent between MOS cameras
- * MOS best-fit flux values well in agreement (99% confidence interval), pn 6% lower



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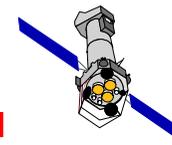
Mkn421:

- * check SAS scientific product generation for pn data in TIMING mode
- * verify accuracy of continuum spectral fitting in the RGS

General points on [pipeline](#) products (in addition to the ones by Lockman Hole) :

EPIC: - several observations not processed by PPS (Small window mode MOS&pn, MOS Fast uncompressed)

OM: - not operating in this observation, therefore no products



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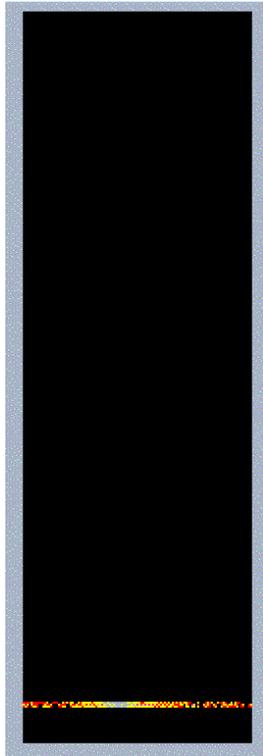
XMM-Newton

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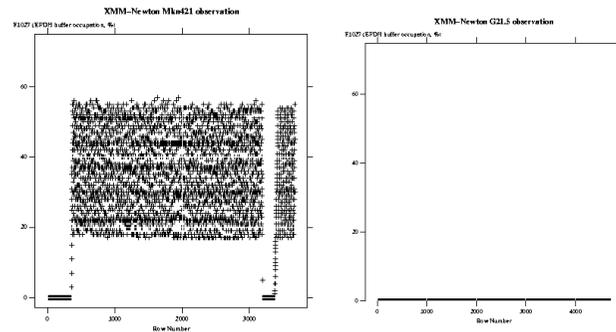
Mkn421 (cont.):

pn Timing mode data analysis:

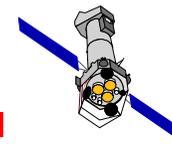
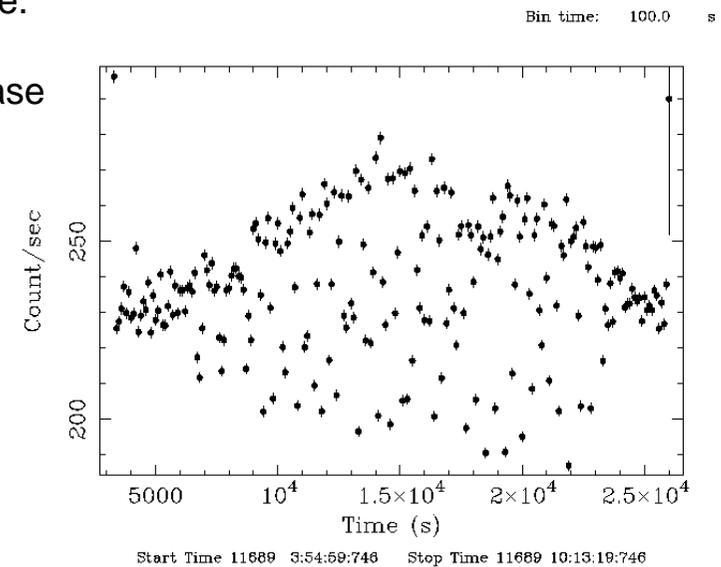


* light curve showing instrument going into “counting” mode because of too high telemetry rate.

> looking for strategy to cope with this case using proper Good Time Intervals



Instantaneous occupation fraction of science telemetry buffer in Mkn421 and G21.5



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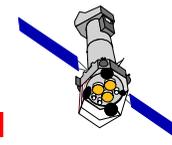
SAS Scientific Validation: first reports

Mkn421 (cont.):

RGS continuum spectral fitting

- * response matrices generated with **rgsrmfgen**
- * taking simultaneously for fitting the spectra of two exposures of each RGS - adding a constant factor for compensating ~ 16% flux difference
- * Following approach in Brinkman et al (A&A-XMM dedicated issue) we fit the RGS spectra with a broken power -law (adequate fitting both pn and MOS data):

		Γ_1	Γ_2	E_{break}	χ^2/DoF
RGS1	Brink.	1.76 +/- 0.01	1.94 +/- 0.01	0.89 +/- 0.04	1.68
	PPS	1.755 +/- 0.007	2.02 +/- 0.03	0.98 +/- 0.04	2.26
	rgsproc	1.785 +/- 0.006	1.91 +/- 0.02	1.07 +/- 0.06	2.12
RGS2	PPS	1.806 +/- 0.008	2.31 +/- 0.02	0.90 +/- 0.02	2.61
	rgsproc	1.86 +/- 0.01	2.16 +/- 0.09	0.88 +/- 0.01	2.24



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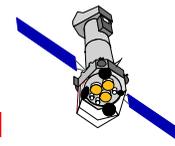
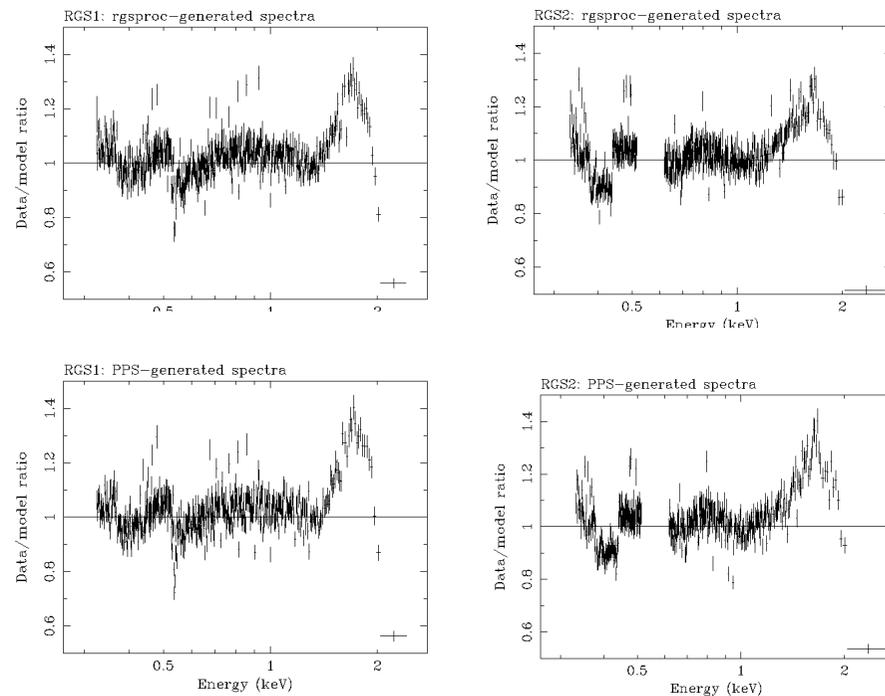
SAS Scientific Validation: first reports

Mkn421 (cont.):

RGS continuum spectral fitting (cont._)

- * no significant difference between PPS and rgsproc produced spectra
- * below 1.5 keV residuals well within +/- 10%
- * above 1.5 keV, effective area underestimated by up to 30% - 40%
- * CCD 2 most critical area (more pronounced in RGS2, noticed in CCF release notes)
- * absorption feature by $E_{\text{obs}} \sim 0.55$ keV (only in RGS1 because of lack of RGS2-CCD 4)

Fitting residuals:

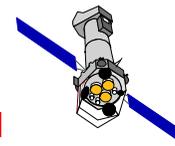


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Conclusions



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