RMFs and ARFs for eROSITA and XMM/EPIC-pn



Parador de La Granja, Spain

IACHEC, 2024 May 12 - 16

Konrad Dennerl, MPE











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How the initial eROSITA RMFs were derived

0.600 keV

1.250 keV

1.800 keV

10

22_24

4.000 keV

10 22_08

22_14

10

10



input: 29 ,monochromatic' spectra obtained in 2009 (!) with a prototype CCD at BESSY (Granato 2012)

How the initial eROSITA RMFs were derived



eROSITA RMF for single pixel events constructed from parameterization of ,monochromatic' spectra taken in 2009 with a prototype CCD at **BESSY**

RMFs and ARFs for eROSITA and XMM/EPIC-pn Parameterization of the EPIC-pn RMF



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Model Parameters for the EPIC pn RMF



Model Parameters for the EPIC pn RMF





Modeling the EPIC pn RMF at individual energies



Modeling the EPIC pn RMF at individual energies



Modeling the EPIC pn RMF at individual energies



Current RMF & ARF parameterization for XMM/EPIC-pn



Current RMF & ARF parameterization for XMM/EPIC-pn

n	0.10 0	0.15 0.	21 0.3	28 0.3	35 0.	44 0.	53 0.	66 0.	80 1.0	00 1.3	20 1.	50 1.	74 2	.20 2.	.70 3	.40 4	.20 5	.10 6	6.20 8	.00 10.	00 keV	sr	noothne	SS
ρ	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	value	weight	penalty
ecor	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.000	0.000
gamma	1.117	1.178	1.183	1.417	1.593	1.477	1.285	1.216	1.195	1.405	1.232	1.167	1.101	1.101	1.101	1.101	1.101	1.101	1.101	1.101	1.101	1.569	0.010	0.016
vtherm	0.672	0.671	0.673	0.678	0.695	0.697	0.806	0.952	1.034	1.089	0.999	0.959	0.970	0.970	0.970	0.970	0.970	0.970	0.970	0.970	0.970	0.358	0.100	0.036
sigma	0.583	0.874	0.759	0.704	0.859	0.806	0.845	0.880	0.875	0.887	0.982	1.094	1.219	1.219	1.219	1.219	1.219	1.219	1.219	1.219	1.219	1.077	0.010	0.011
sh_esep	0.857	0.908	1.254	1.169	1.133	1.227	1.182	1.260	1.241	1.371	1.190	0.987	0.786	0.786	0.786	0.786	0.786	0.786	0.786	0.786	0.786	1.780	0.010	0.018
sh_rnorm	0.623	0.628	0.524	0.502	0.497	0.542	0.633	0.681	0.953	1.090	1.138	1.122	1.012	1.012	1.012	1.012	1.012	1.012	1.012	1.012	1.012	0.867	0.100	0.087
sh_sig_l	0.401	0.412	0.495	0.496	0.574	0.615	0.540	0.507	0.364	0.344	0.334	0.313	0.288	0.288	0.288	0.288	0.288	0.288	0.288	0.288	0.288	0.283	0.010	0.003
sh_sig_r	1.251	1.165	1.043	1.139	1.176	1.140	0.966	0.738	0.424	0.407	0.471	0.464	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	0.448	1.399	0.010	0.014
shlf_rnorn	0.341	0.340	0.370	0.374	0.528	0.884	0.578	0.290	0.676	0.988	0.894	0.876	0.882	0.882	0.882	0.882	0.882	0.882	0.882	0.882	0.882	4.359	0.010	0.044
shlf_slope	-0.098	-0.098	-0.098	-0.098	-0.098	-0.098	-0.098	-0.098	-0.098	-0.098	-0.098	-0.098	-0.098	-0.098	-0.098	-0.098	-0.098	-0.098	-0.098	-0.098	-0.098	0.000	0.010	0.000
esc_rnorn	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000
egamma	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000
evtherm	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000
esigma	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	0.000	0.000	0.000
esh_esep	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000
esh_rnorn	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000
esh_sig_l	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000
esh_sig_r	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000
eshlf_rnm	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000
pat_frc	1.000	1.000	1.000	1.004	1.009	1.006	0.997	0.990	0.983	0.980	0.990	0.996	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.002	10.000	0.024

XMM / EPIC-pn RMF and ARF parameterization Small Window Mode

| n ° | .10 0 | .15 0.2 | 1 0.
 | .28 0. | 35 0. | .44 0. | 53 0. | 66 0. | 80 1.
 | 00 1. | 20 1.5 | 50 1.3
 | 74 2. | 20 2. | 70 3.4 | 10 42 | 20 5.
 | 10 6 | 20 8. | 00 10
 | .00 keV | sn | oothne | 68
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 | 18 | 19 | 20
 | 21 | value | weight | penal
 |
| car | 0.0 | 0.0 | 0.0
 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0
 | 0.0 | 0.0 | 0.0
 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0
 | 0.0 | 0.0 | 0.0
 | 0.0 | 0.000 | 0.000 | 0.00
 |
| amma | 1.162 | 1.216 | 1.211
 | 1.507 | 1.676 | 1.510 | 1.321 | 1.171 | 1.138
 | 1.191 | 1.119 | 1.060
 | 1.106 | 1.106 | 1.106 | 1.106 | 1.106
 | 1.106 | 1.106 | 1.106
 | 1.106 | 1.408 | 0.020 | 0.02
 |
| herm | 0.658 | 0.659 | 0.656
 | 0.672 | 0.692 | 0.737 | 0.826 | 0.964 | 1.041
 | 1.107 | 1.004 | 0.991
 | 1.014 | 1.000 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000
 | 1.000 | 0.346 | 0.100 | 0.03
 |
| gma | 0.858 | 0.859 | 0.851
 | 0.839 | 0.850 | 0.824 | 0.842 | 0.866 | 0.879
 | 0.900 | 0.949 | 0.971
 | 0.990 | 1.000 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000
 | 1.000 | 0.039 | 2.000 | 0.0
 |
| h_esep | 1.113 | 1.117 | 1.240
 | 1.217 | 1.206 | 1.200 | 1.195 | 1.206 | 1.183
 | 1.159 | 1.117 | 1.099
 | 1.079 | 1.079 | 1.079 | 1.079 | 1.079
 | 1.079 | 1.079 | 1.079
 | 1.079 | 0.106 | 0.100 | 0.01
 |
| h_morm | 0.519 | 0.536 | 0.503
 | 0.521 | 0.516 | 0.525 | 0.614 | 0.678 | 0.756
 | 0.823 | 0.884 | 0.941
 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000
 | 1.000 | 0.227 | 0.200 | 0.04
 |
| h_sig_l | 0.262 | 0.265 | 0.533
 | 0.584 | 0.630 | 0.624 | 0.467 | 0.610 | 0.505
 | 0.887 | 0.847 | 0.898
 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000
 | 1.000 | 2.133 | 0.010 | 0.02
 |
| h_sig_r | 1.333 | 1.214 | 1.115
 | 1.197 | 1.150 | 1.266 | 0.914 | 0.856 | 0.667
 | 0.821 | 0.925 | 1.076
 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000
 | 1.000 | 2.015 | 0.010 | 0.0
 |
| hlf_rnorm | 0.211 | 0.219 | 0.355
 | 0.658 | 0.496 | 0.693 | 0.662 | 0.344 | 0.826
 | 1.605 | 0.915 | 0.624
 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000
 | 1.000 | 14.069 | 0.005 | 0.0
 |
| hlf_slope | -0.082 | -0.082 | -0.082
 | -0.082 | ·0.082 | -0.082 | -0.082 | -0.082 | ·0.082
 | -0.082 | -0.082 | -0.082
 | -0.082 | -0.082 | -0.082 | -0.082 | 0.082
 | -0.082 | -0.082 | -0.082
 | -0.082 | 0.000 | 0.100 | 0.0
 |
| sc_morm | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000
 | 1.000 | 0.000 | 0.000 | 0.0
 |
| jamma | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000
 | 1.000 | 0.000 | 0.000 | 0.0
 |
| vtherm | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000
 | 1.000 | 0.000 | 0.000 | 0.0
 |
| sigma | 1.200 | 1.200 | 1.200
 | 1.200 | 1.200 | 1.200 | 1.200 | 1.200 | 1.200
 | 1.200 | 1.200 | 1.200
 | 1.200 | 1.200 | 1.200 | 1.200 | 1.200
 | 1.200 | 1.200 | 1.200
 | 1.200 | 0.000 | 0.000 | 0.0
 |
| sh_esep | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000
 | 1.000 | 0.000 | 0.000 | 0.0
 |
| sh_morm | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000
 | 1.000 | 1.000 | 1.000
 | 1.000 | 0.000 | 0.000 | 0.0
 |
| sh_sig_l | 1.000 | 1.000 | 1.000
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 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000
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 | 1.000 | 0.000 | 0.000 | 0.0
 |
| h_sig_r | 1.000 | 1.000 | 1.000
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| bli mm | 1.000 | 1.000 | 1.000
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| at_frc | 1.010 | 1.010 | 1.000
 | 1.002 | 1.007 | 1.001 | 0.995 | 0.990 | 0.989
 | 0.972 | 0.988 | 1.019
 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000
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| at_frc | 1.010 | 1.010 | 1.000
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0.017
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19 RMF shaping functions with 21 parameters each → 399 RMF parameters

21 parameters for correcting the energy dependence of the fraction of singles

2 correction functions for the filter transmission (O and C thickness) for each filter \rightarrow 6 parameters

→ 27 ARF parameters

➔ 426 parameters

(linear) temporal dependence of each parameter

→ 852 parameters

parameters can be fixed, coupled, tied, constrained, and determined for a given smoothness of the shaping function









ARF: "Ancillary Response File", RMF: "Redistribution Matrix File"



each iteration in computing the ARF and RMF requires to run spectral fits for all the data sets (EPIC-pn: currently 50 spectra for RXJ1856 and 45 spectra for 1E0102)

RX J1856-3754: Chandra LETGS



→ $nH = (7.2 + /-0.3) \times 10^{19} \text{ cm}^{-2}$ kT = 62.4 + /-0.4 eV $norm = (1.58 + /-0.06) \times 10^{5}$ [tbabs * bbodyrad]

1E 0102.2-7219: IACHEC model

Plucinsky et al. 2017 (A&A 597)

SNR 1E 0102.2-7219 as an X-ray calibration standard in the 0.5–1.0 keV bandpass and its application to the CCD instruments aboard *Chandra*, *Suzaku*, *Swift* and *XMM-Newton*

> Paul P. Plucinsky¹, Andrew P. Beardmore², Adam Foster¹, Frank Haberl³, Eric D. Miller⁴, Andrew M. T. Pollock⁵, and Steve Sembay²







XMM/EPIC-pn residuals for

1E0102 (45) and RXJ1856 (50)

resulting from IACHEC and Chandra model spectra

and RMFs/ARFs obtained with rmfgen-2.8.7 and arfgen-1.104

5 0 -5	1 rev_0375 chi2r = 1.35	2 rev_0521 chi2r = 1.19 2 rev_0521 chi2r = 1.19 4 rev_052 chi2r = 1.19	3 rev_0552 chi2r = 1.08	• 4 rev_0616 chi2r= 1.08 • 4 rev_0616 chi2r= 1.08 • 4 rev_0616 chi2r	 5 rev_0888 chi2r= 1.27 12 3 4 5 6 7 8 9 011 13 15 16 102_30 Thick (38,190) 31 ks 	6 rev_1082 chi2r = 1.40 2 3 4 5 6 7 8 91(11) 13 15] 1e0102_30 Medium (37,190) 30 ks	7 rev 1165 chi2r = 1.17 7 rev 1165 chi2r = 1.17 7 rev 1165 chi2r = 1.17 12 3 4 5 6 7 8 99(011 3 15 1e0102_30 Thin1 (38,191) 30 ks	 8 rev_1265 chi2r = 1.23 8 rev_1265 chi2r = 1.23 9 14 15 16 7 18 91011 https://doi.org/10.1111/1111.115 1 e0102_30 Medium (38,190) 32 ks 	 9 rev_1351 chi2r = 1.17 <l< th=""></l<>
5 0 -5	 10 rev 1443 chi2r = 1.30 12 i3 i4 i5 i6 i7 i8 91011 i13 i15 100102,30 Medium (37,190) 37 ks 	0 11 rev_1531 chi2r = 1.25	12 rev 1636 chi2r = 1.18 14 15 16 7 18 9 00 11 13 15 16 10 2.30 Medium (37,190) 29 ks	0 13 rev_1711 chi2r = 1.06 13 rev_1711 chi2r = 1.06 14 start sta	• 14 rev_1807 chi2r = 1.23 14 rev_1807 chi2r = 1.23 12 13 l4 15 l6/7 l8 91011 l1 31 h5 1e0102_30 Medium (37,190) 29 ks	0 15 rev_1898 chi2r = 1.08	0 16 rev_2081 chi2r = 1.22	O 17 rev_2380 chi2r = 1.14 11 11 12 14 12 13 14 15 16 16 16 17 19 19 10 10 10 10 10 10 10 10 10 10	 18 rev_2380 chi2r = 1.17 14 15 1617 181910111 h31 h51 1e0102_30 Medium (37,190) 69ks
5 0 -5	 19 rev_2380 chi2r = 1.24 14 is 16/7 k1910chi1 k3 k5 12 3 14 is 16/7 k1910chi1 k3 k5 1e0102_30 Thick (37,190) 69 ks 	 20 rev_2548 chi2r = 1.16 1414 12 3 4 5 5 7 8 9 1011 13 15 1e0102_30 Thint (37,190) 32 ks 	© 21 rev_2722 chi2r = 1.28	22 rev_2722 chi2r = 1.44 44	 23 rev_2909 chi2r = 1.37 21 3 l4 l5 l6/7 l8/9 f0/11 1 31 lt5 1 e0102_30 Medium (37,190) 34 ks 	● 24 rev_3000 chi2r = 1.23 2 3 4 5 6 7 8 9 0 1 1 1 15 100102_30 Thick (38,191) 31 ks	© 25 rev_3000 chi2r = 1.01	O 26 rev_3000 chi2r = 1.11	● 27 rev_3000 chi2r = 1.19 ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓
5 0 -5	28 rev_3000 chi2r = 1.15 3 state of the	 29 rev_3000 chi2r = 1.05 6 rev_3000 chi2r = 1.05 6 rev_3000 chi2r = 1.05 7 rev_300 chi	 30 rev_3092 chi2r = 1.37 12 3 4 5 6 7 8 9 40 1 3 15 16 7 8 9 40 1 3 15 16 102_30 Medium (38,190) 36 ks 	31 rev_3111 chi2r = 1.17 <u>11415 in 1141 in 1142 in 11</u>	 32 rev_3278 chi2r = 1.50 32 rev_3278 chi2r = 1.50 14 I5 I6/7 [8]91011 I13 I15 1e0102_30 Medium (37,190) 44 ks 	 33 rev_3279 chi2r = 1.35 2 3 l4 l5 l6/7/8/91dr11 t3l lt5 1e0102_30 Medium (37,190) 39 ks 	 34 rev_3459 chi2r = 1.31 2 3 (4 (5 (6)7 (8)9)(011) (1 3) (15) 160102_30 Medium (37,190) 36 ks 	O 35 rev_3459 chi2r = 1.21	 36 rev_3645 chi2r = 1.33 2 (3) (4) (5) (6) (7) (8) (7) (7) (7) (7) (7) (7) (7) (7) (7) (7
5 0 -5	 37 rev_3652 chi2r = 1.50 1 y 445 is in the interval of the interval	 38 rev_3826 chi2r = 1.22 3 4 5 6 7 8 9 1011 1 3 15 1 e0102_30 Medium (38,190) 35 ks 	 39 rev_3826 chi2r = 1.28 34 15 16 7 18 19 10 11 11 11 15 1 40 102_30 Medium (37,190) 35 ks 	● 40 rev_4009 chi2r = 1.38 1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.	41 rev_4009 chi2r = 1.34 2 3 4 5 6 7 8 9 1011 13 15 100102_30 Medium (37,190) 39 ks	● 42 rev_4190 chi2r = 1.43	43 rev_4190 chi2r = 1.24 4	 44 rev_4373 chi2r = 1.26 45 rev_4373 chi2r = 1.26 45 rev_4373 chi2r = 1.26 46 rev_4373 chi2r = 1.26 47 rev_4373 chi2r = 1.26 47 rev_4373 chi2r = 1.26 48 rev_4373 chi2r = 1.26 48 rev_4374 chi2r =	 45 rev_4373 chi2r = 1.58 44 rev_4373 chi2r = 1.58 44 rev_4374 chi2r = 1.58 45 rev_4374 chi2r = 1.58 46 rev_4374 chi2r = 1.58 47 rev_4374 chi2r = 1.58 48 rev_44 chi2r = 1.58
5 0 -5	○ 46 rev_0427 chi2r = 1.16	 0 47 rev_0878 chi2r = 1.25 1 4 15 1617 1819 1011 1131 1131 1 4 15 1617 1819 1011 1131 1131 1 156 Thin1 (28,190) 33 ks 	O 48 rev_0968 chi2r = 1.34 ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓	O 49 rev_1061 chi2r = 1.47	○ 50 rev_1153 chi2r = 1.16 1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.	○ 51 rev_1259 chi2r = 1.13	 52 rev_1330 chi2r = 1.51 14 15 16/7 18/91dh1 itsl htsl nj1856 Thin1 (28,191) 69 ks 	0 53 rev_1335 chi2r = 1.16 High 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Ο 54 rev_1432 chi2r = 1.27 1 1 1 2 3 4 15 15 α;1856 Thin1 37,190) 70 ks
5 0 -5	○ 55 rev_1432 chi2r = 1.15	○ 56 rev_1513 chi2r = 1.37 +++++++++ 2 3 4 5 6 7 8 9 ticht tist tist ng 1856 Thint (87,191) 75 ks	○ 57 rev_1616 chi2r = 2.41 1415 617 iB 910th1 h3 h5 nj1856 Thin1 (38,190) 69 ks	○ 58 rev_1699 chi2r = 1.27 1.11110 chi2r = 1.27 (1711) 12 3 4 5 6 7 8 91011 13 15 cj1866 Thin1 37,191) 69 ks	○ 59 rev_1800 chi2r = 1.22	0 60 rev_1883 chi2r = 1.35	○ 61 rev_1979 chi2r = 1.25 	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	O 63 rev_2165 chi2r = 1.07 b) b) b) b) b) f) b) b) b) b) b) f) b) b) b) b) b) b) f) b) b) b) b) b) b) b) f) b) b) <td< th=""></td<>
5 0 -5	○ 64 rev_2165 chi2r = 1.04 	○ 65 rev_2165 chi2r = 1.40	○ 66 rev_2165 chi2r = 1.08	0 67 rev_2261 chi2r = 1.17	0 68 rev_2341 chi2r = 1.21	0 69 rev_2429 chi2r = 1.52	 ○ 70 rev_2521 chi2r = 1.24 ○ 70 rev_1011111111 ○ 71 rev_1011111111111111111111111111111111111	O 71 rev_2618 chi2r = 1.19 <u>11 international field</u> H++++++ <u>12 3 4 5 6 7 6 91 chi1 h3 h5 </u> sqi 856 Thin1 (38,178) 74 ks	Ο 72 rev_2706 chi2r = 2.36 12 14 12 13 13 16 16 17 17 17
5 0 -5	 ○ 73 rev_2794 chi2r = 1.20 ○ 73 rev_2794 chi2r = 1.20 ○ 74 15 16/7 18/910/11 h3i h5i □ 2 13 14 15 16/7 18/910/11 h3i h5i □ 13 14 15 16/7 18/910/11 h3i h5i □ 13 14 15 16/7 18/910/11 h3i h5i 	0 74 rev_2897 chi2r = 1.49 1 2 1 3 14 15 16 17 18 9 10 11 11 31 11 51 ng1856 Thint (37,190) 82 ks	O 75 rev_2977 chi2r = 1.07	• 76 rev_2995 chi2r = 1.06 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	77 rev_2995 chl2r = 1.27 13 4 15 16 7 18 9 10 11 11 31 115 ng1856 Medium (38,190) 10 ks	$ \begin{tabular}{ c c c c c } \hline 0.78 rev_2995 chi2r = 0.94 \\ \hline 1.75 rev_2995 chi2r = 0.94 \\ \hline 1.75 rev_1995 rev_1^{-1} + 1.75 rev_2995 rev_1991 re$	● 79 rev_2995 chi2r = 0.97 # ¹ 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	80 rev_2995 chi2r = 1.30 10 10 11	O 81 rev_2995 chi2r = 0.99
5 0 -5	82 rev_3075 chi2r = 1.36 12 i3 i4 i5 i6/7 i8/9 tichti ih 3i ih 5i ng1856 Thint (37,190) 71 ks	○ 83 rev_3162 chi2r = 1.50 +++++ 2 3 4 5 6 7 8 91dh1 h3 h5 ng1856 Thin1 (38,176) 70 ks	0 84 rev_3255 chi2r = 1.32 +++++ 2 3 4 5 6 7 8 9 1 ch 1 13 15 nj 1856 Thin1 (38, 191) 75 ks	0 85 rev_3358 chi2r = 1.28	0 86 rev_3454 chi2r = 1.30 12 i 3 i 4 i 5 i 6 7 i 8 9 tót 1 i 3 i 15 i nj 1866 Thin1 (37, 191) 70 ks	○ 87 rev_3622 chi2r = 1.12 	0 88 rev_3720 chi2r = 1,74	0 89 rev_3804 chi2r = 1.80 ++++ 12'13 l4 l5 l6/7 l8191dh11 h31 h51 cj1856 Thin1 (37,190) 74 ks	90 rev_3903 chi2r = 1.48 91 12 34 15 α;1656 Thin1 (38,178) 70 ks
5 0 -5	O 91 rev_4000 chi2r = 1.97 1 4444 -	92 rev_4087 chi2r = 1.91	93 rev_4174 chi2r = 1.86 12'131415i617 Bl9tch11 h3 h5 nj1866 Thin1 (37,190) 74 ks	0 94 rev_4269 chi2r = 1.07	O 95 rev_4366 chi2r = 1.39 I + + ++++++ I + + +++++++ I + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 +				

XMM/EPIC-pn residuals for

1E0102 (45) and RXJ1856 (50)

resulting from IACHEC and Chandra model spectra

and parameterized RMFs and ARFs



Temporal trend in the parameterized RMF





What has changed in the RMF?





RMF construction details



Sampling the parameterized RMF at 400, 600, and 800 eV



Sampling the parameterized RMF at 1.0, 1.5, and 2.0 keV



RMFs and ARFs for eROSITA and XMM/EPIC-pn Results for eROSITA



Parador de La Granja, Spain

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"Fitting" the RMF and ARF for eROSITA

Method:

consider two sources with "reliable" spectral models simultaneously:

RX J1856-3754 & 1E 0102.2-7219

RX J1856-3754







Results obtained with parameterized RMF for eROSITA (,TM8 sdtq')



,TM8' = TM1 + TM2 + TM3 + TM4 + TM6 (sum of all CCDs with an on-chip Al filter)

,sdtq': all valid pixel patterns

(sum of singles, doubles, triples, quadruples)

- → combining data from 5 TMs and 4 pattern types before fitting requires a precise reconstruction of the absolute energy scale for each TM and each pattern type
- also including PG1634+706
 as a hard X-ray source

eROSITA ARF: what has changed ?







preliminary modeling:

Al thickness: -12 nm (assumed density: 2.7 g cm⁻³) C thickness: +20 nm (assumed density: 2.2 g cm⁻³)

eROSITA and RXJ1856: interplay between ARF and RMF



best-fit spectrum with ➤ unmodified RMF ➤ unmodified ARF (both from ground calibration)

eROSITA and RXJ1856: interplay between ARF and RMF



best-fit spectrum with unmodified RMF modified ARF* (both from ground calibration)

*Al layer reduced by ≈12 nm C layer increased by ≈20 nm

eROSITA and RXJ1856: interplay between ARF and RMF



best-fit spectrum with modified RMF modified ARF* (both from ground calibration)

*Al layer reduced by ≈12 nm C layer increased by ≈20 nm

eROSITA ARF at E > 2.3 keV

The SRG/eROSITA All-Sky Survey

SRG/eROSITA cross-calibration with Chandra and XMM-Newton using galaxy cluster gas temperatures

K. Migkas^{1,2,3}, D. Kox², G. Schellenberger⁴, A. Veronica², F. Pacaud², T. H. Reiprich², Y. E. Bahar⁵, F. Balzer⁵, E. Bulbul⁵, J. Comparat⁵, K. Dennerl⁵, M. Freyberg⁵, C. Garrel⁵, V. Ghirardini⁵, S. Grandis⁶, M. Kluge⁵, A. Liu⁵, M. E. Ramos-Ceja⁵, J. Sanders⁵, X. Zhang⁵

Using a single power law fit, we found that eROSITA shows a strong discrepancy with Chandra, measuring 25% and 38% lower T_{eROSITA} for $T_{\text{Chandra}} = 4.5$ keV and $T_{\text{Chandra}} = 10$ keV

eROSITA shows lower *T* than XMM-Newton as well, with the discrepancy being milder than the one with Chandra. For the full band, eROSITA measures 10 - 28% lower T_{eROSITA} for $T_{\text{XMM}} \approx 2-7$ keV clusters, while there is a slightly better agreement for cooler systems.

\rightarrow test with PG 1634+706





Testing the influence of the high energy ARF on PG1634



fit restricted to E = 1.0 – 4.8 keV (to minimize possible complications due to $n_{\rm H}$ or background)

Channel Energy (keV)

PG 1634: fit quality obtained with unmodified ARFs and RMF





PG 1634: fit quality obtained with unmodified ARFs and RMF

PG 1634: fit quality obtained with modified ARFs and RMF



PG 1634: fit quality obtained with unmodified ARFs and RMF

PG 1634: fit quality obtained with modified ARFs and RMF



Comparison with XMM-Newton/EPIC-pn



Figure 2: Final correction function to the EPIC-pn ARF description, taking into account the slope and shape difference to NuSTAR in the 3–12 keV band. These values are published in the ABSCORRAREA extension of XRT3_XAREAEF_0014.CCF.

As of SAS 20.0 a new keyword applyabsfluxcorr is available, which will provide corrections to the effective area removing residuals between simultaneous fits of PN and NuSTAR observations. The correction is based on simultaneous calibration observations between both observatories. These corrections are intended to align the PN spectral shape better with the spectra from NuSTAR. Details on the corrections can be found in the corresponding release note, XMM-CCF-REL-388. The way to apply the correction is as follows,

arfgen spectrumset=PNsource_spectrum.fits arfset=PN.arf withrmfset=yes rmfset=PN.rmf \ badpixlocation=PNclean.fits detmaptype=psf applyabsfluxcorr=yes

Comparison with XMM-Newton/EPIC-pn 0852980301



norm = 2.74e-4 ± 0.08e-4

norm = 2.75e-4 ± 0.08e-4

Comparison with XMM-Newton/EPIC-pn

obs 0852980301





PG 1634: eROSITA and XMM/EPIC-pn with unmodified ARFs and RMF

2.0 +24 +12' powerlaw slope 1.8 -0' -12' -24' 1.6 XMM mean quadratic deviation from average: 2.6 sigma 1.4 2 3 0 1 4 5 3.5 +24' normalization at 1 keV 3.0 +12' 0' 0' XMM -12' 2.5 mean quadratic deviation from average: 2.8 sigma 0 1 2 3 4 5 1.5 reduced chi2 -24' +12' +24' 1.0 -12' 0 1 2 3 4 5

time [days]

PG 1634: eROSITA and XMM/EPIC-pn with modified ARFs and RMF



10

10

PG 1634: eROSITA and XMM/EPIC-pn with unmodified ARFs and RMF



How significant is the "high energy issue" ?

5 x 40 ks = **200 ks eROSITA** + 2 x 20 ks = **40 ks XMM** observations of PG 1634 exhibit only marginal differences within E = 1.0 - 4.6 keV, while above 5 keV eROSITA sees essentially only instrumental background

how does this agree with the ≈ 5o difference found in galaxy cluster temperatures ?





\rightarrow scientifically more ,reasonable' results with reduced ARF above 2.3 keV ..



modification at low energies:

Al thickness: -12 nm (assumed density: 2.7 g cm⁻³)

C thickness: +20 nm (assumed density: 2.2 g cm⁻³)

✓ PG1634

- 🖌 η Car
- ✓ cluster temperatures

.. but considerable modification required

would such a reduction of the ARF be compatible with PANTER measurements ?



Effective area determination (PANTER, on-axis)

ARFs measured at **PANTER**



Effective area determination (PANTER, on-axis)

ARFs measured at PANTER

ARF from ray-tracing , computed for perfect optics (curve never used!)



Effective area determination (PANTER, on-axis)

ARFs measured at **PANTER**

ARF from ray-tracing , computed for perfect optics (curve never used!)

ARF which we are using in eSASS

correction function applied



Effective area determination (PANTER, on-axis)

ARFs measured at **PANTER**

ARF from ray-tracing , computed for perfect optics (curve never used!)

ARF which we are using in eSASS

ARF which would improve results for

- ♦ PG 1634
- 🔶 η Car
- ♦ galaxy clusters (tbc)

correction function which would need to be applied



Monitoring SN 1987A with XMM and eROSITA



Chandreyee Maitra / MPE



Monitoring SN 1987A with XMM and eROSITA



Physical justification of ARF modification at high energies



- detailed and critical review of PANTER measurements going on
- detailed and critical review of ARF determinations for other missions helpful
- detailed and critical review of astrophysical observations also needed

RMFs and ARFs for eROSITA and XMM/EPIC-pn



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