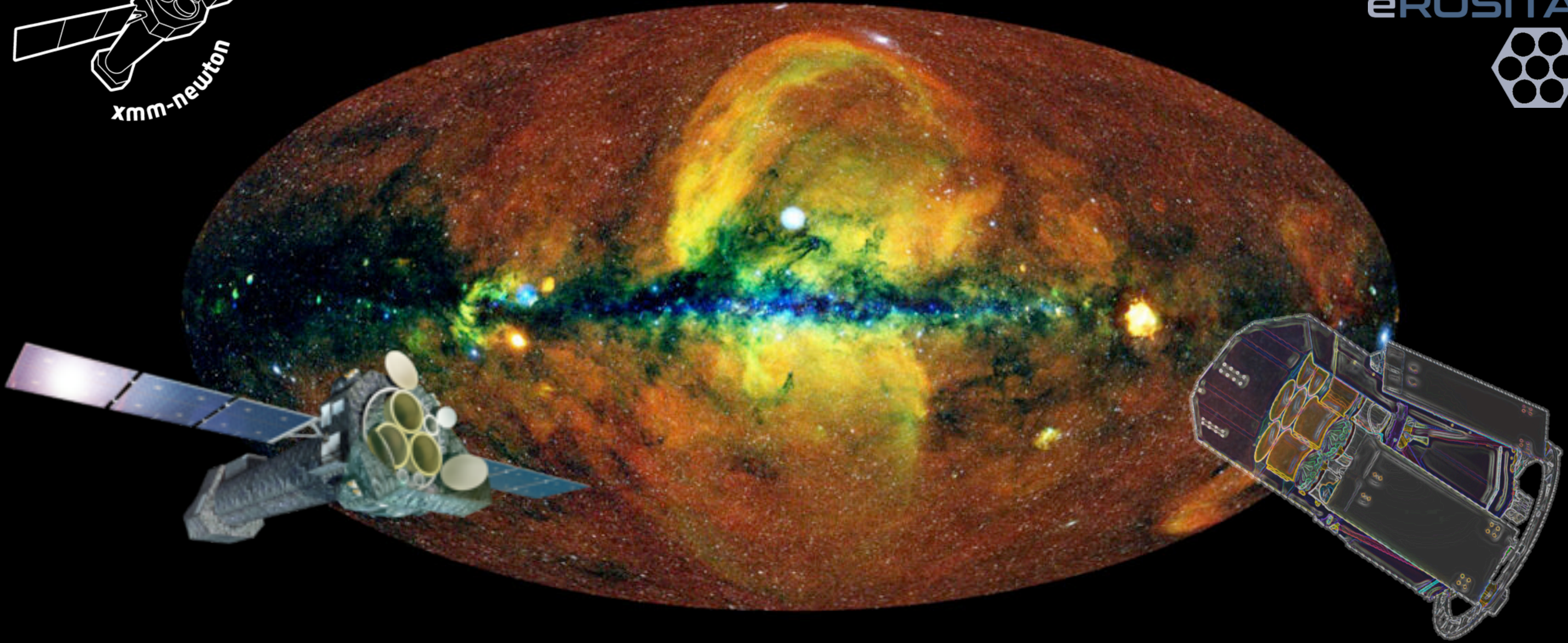
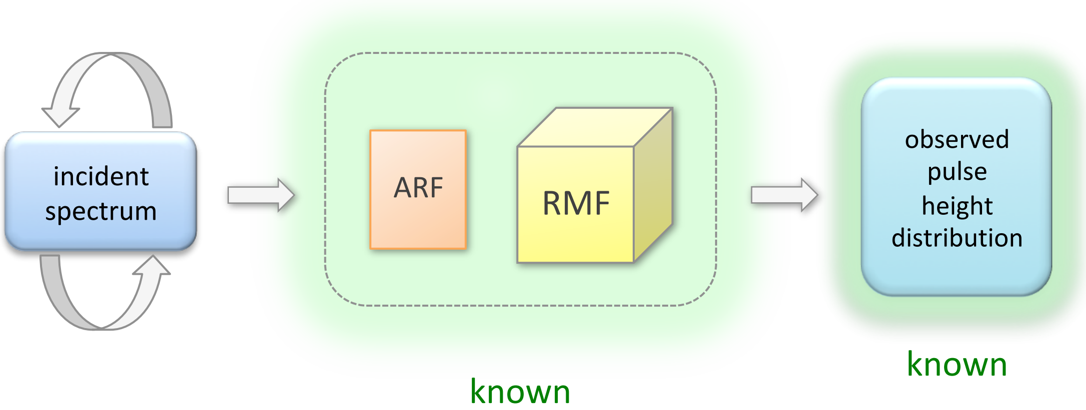
RMFs and ARFs for eROSITA and XMM/EPIC-pn



Parador de La Granja, Spain IACHEC, 2024 May 12 - 16 Konrad Dennerl, MPE

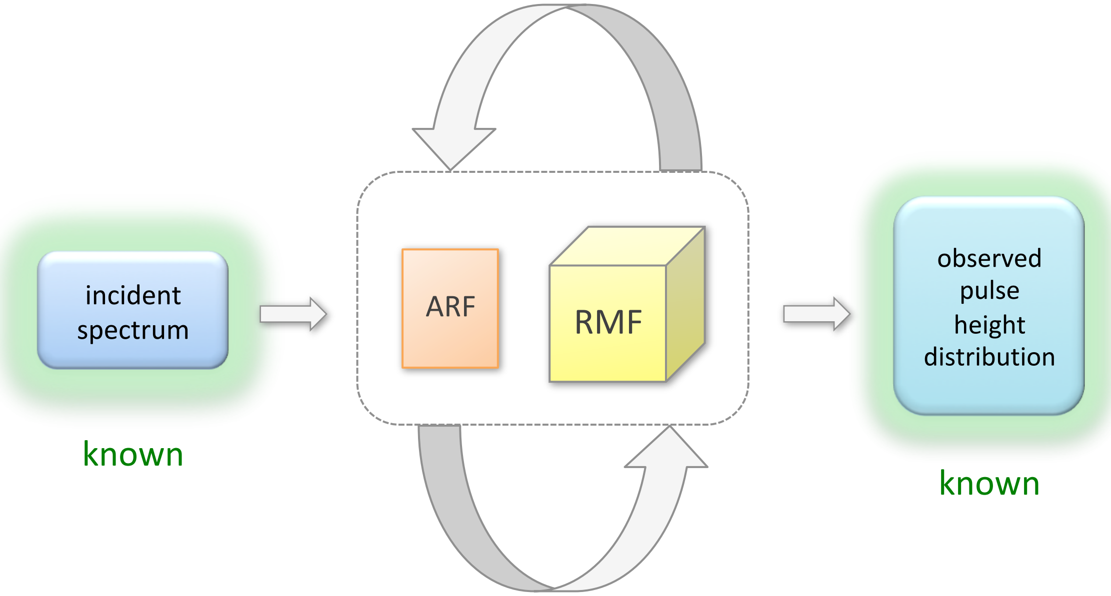
General properties of the ARF and RMF

ARF: „Ancillary Response File“, RMF: „Redistribution Matrix File“



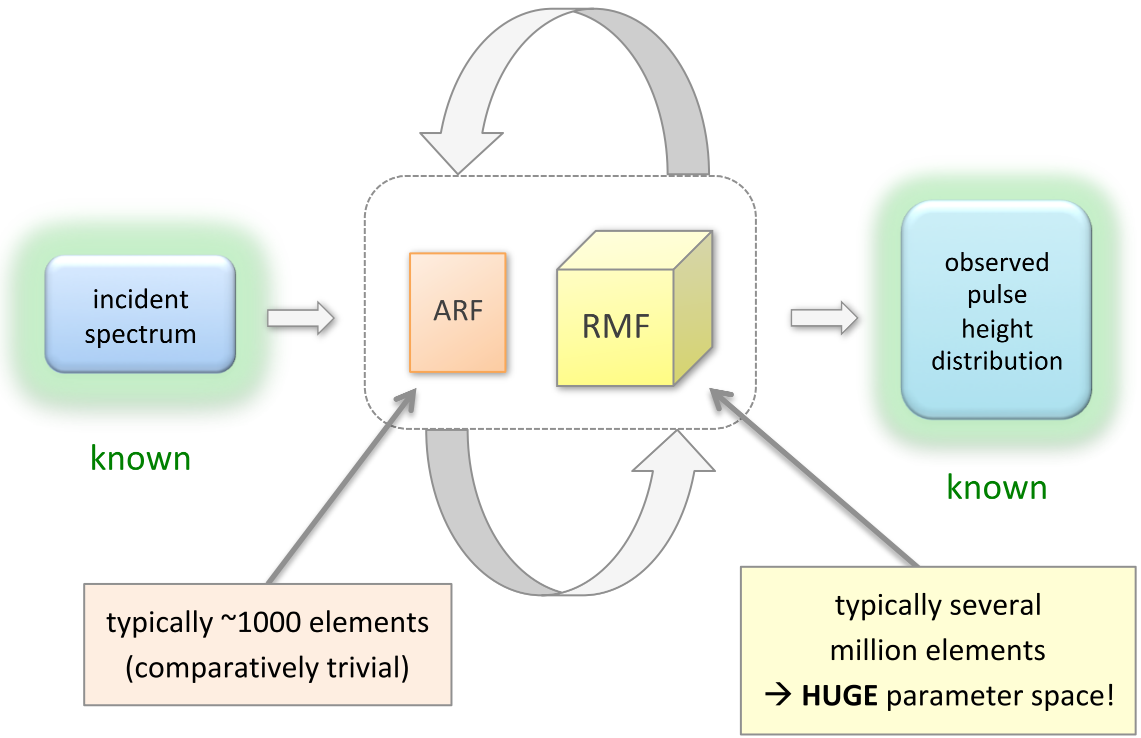
General properties of the ARF and RMF

ARF: „Ancillary Response File“, RMF: „Redistribution Matrix File“



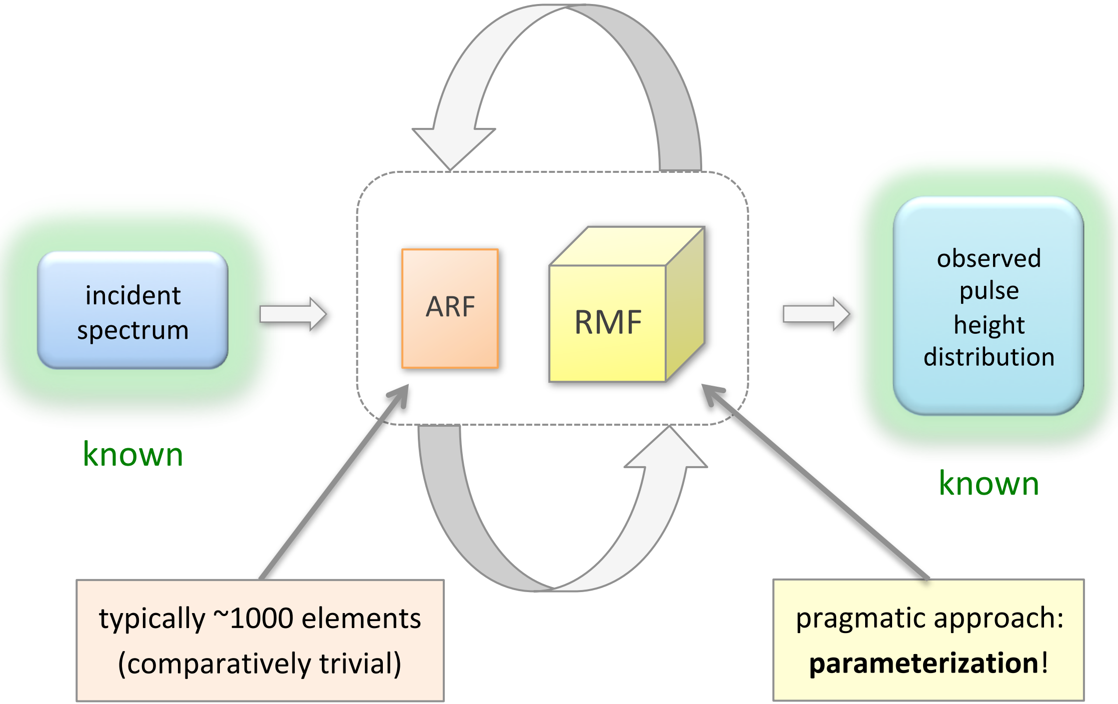
General properties of the ARF and RMF

ARF: „Ancillary Response File“, RMF: „Redistribution Matrix File“



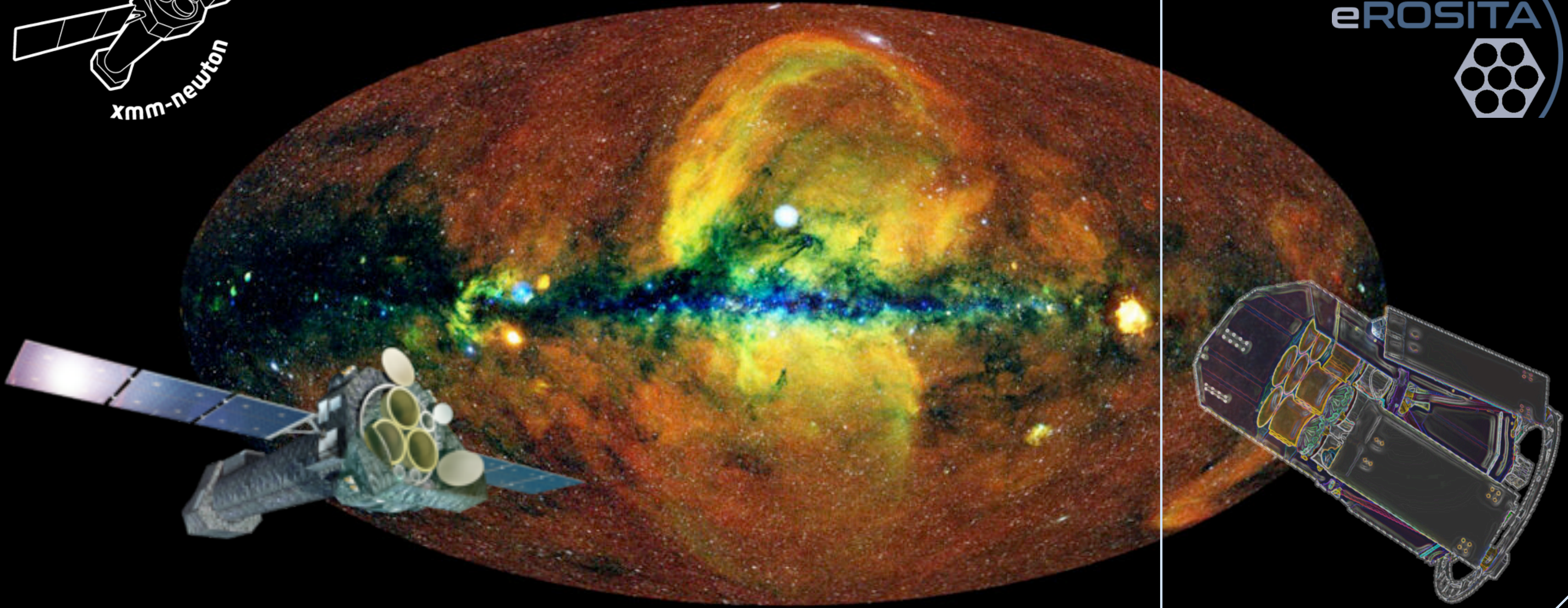
General properties of the ARF and RMF

ARF: „Ancillary Response File“, RMF: „Redistribution Matrix File“



RMFs and ARFs for eROSITA and XMM/EPIC-pn

Parameterization of the eROSITA RMF

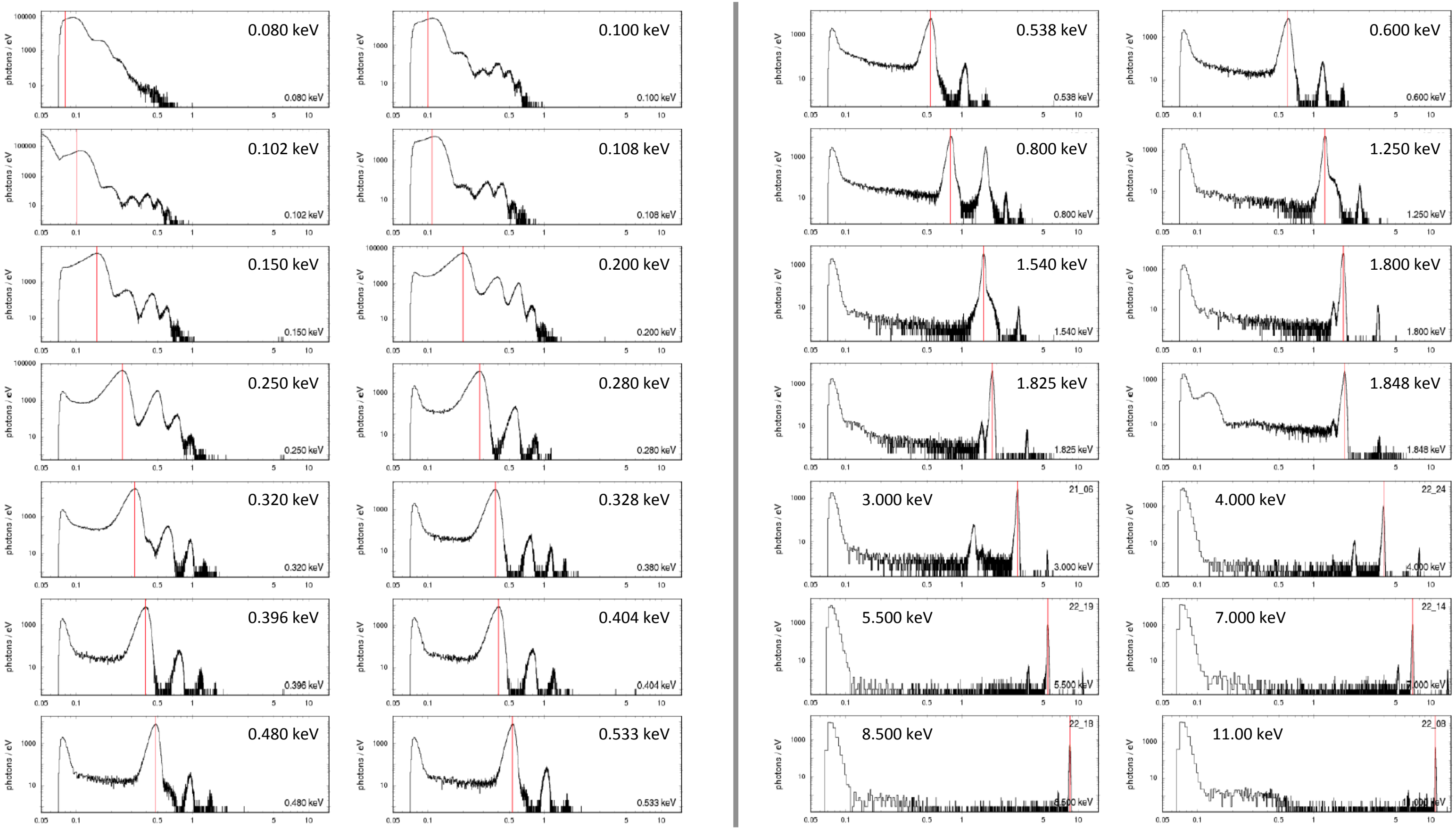


Parador de La Granja, Spain

IACHEC, 2024 May 12 - 16

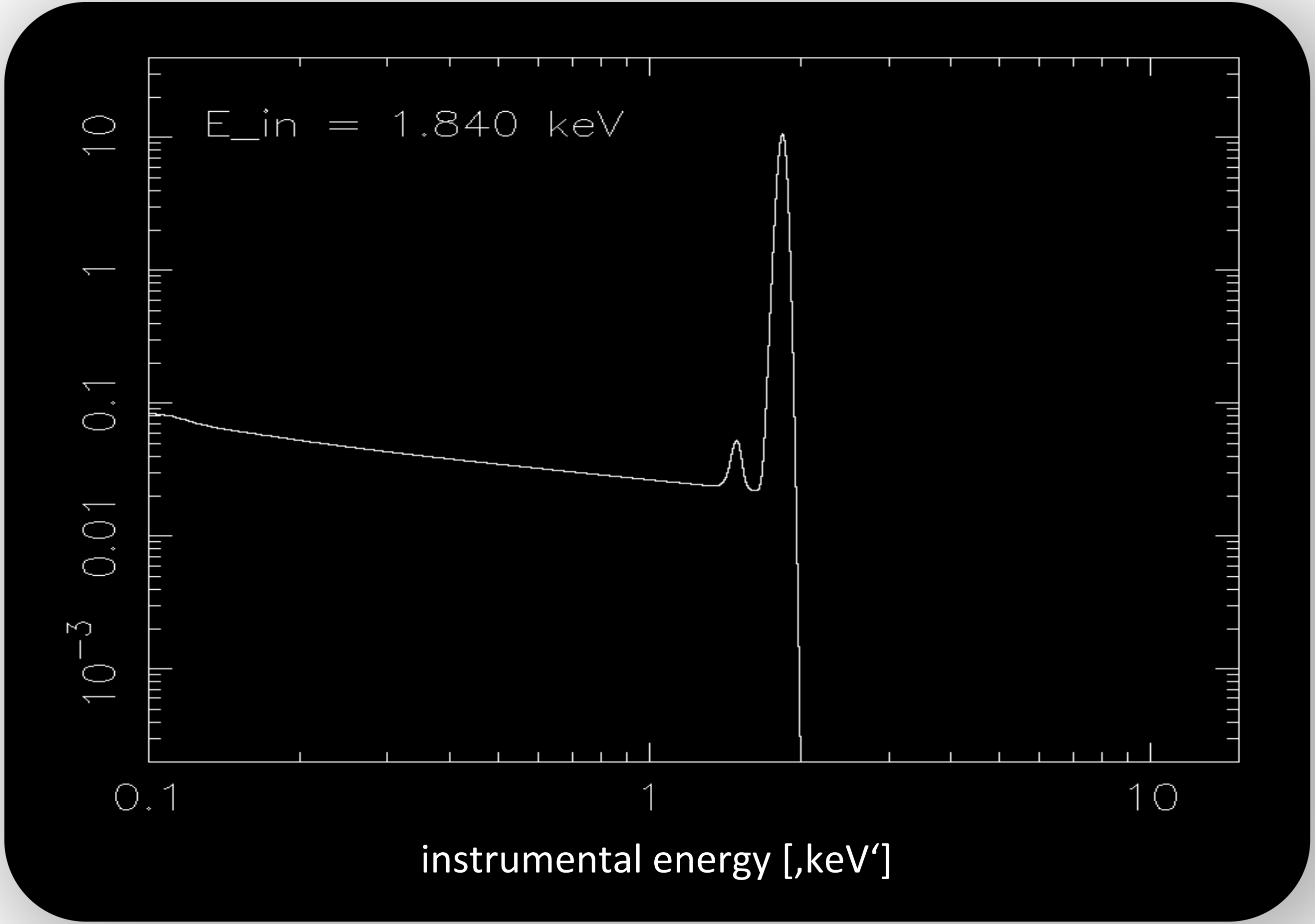
Konrad Dennerl, MPE

How the initial eROSITA RMFs were derived



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

How the initial eROSITA RMFs were derived



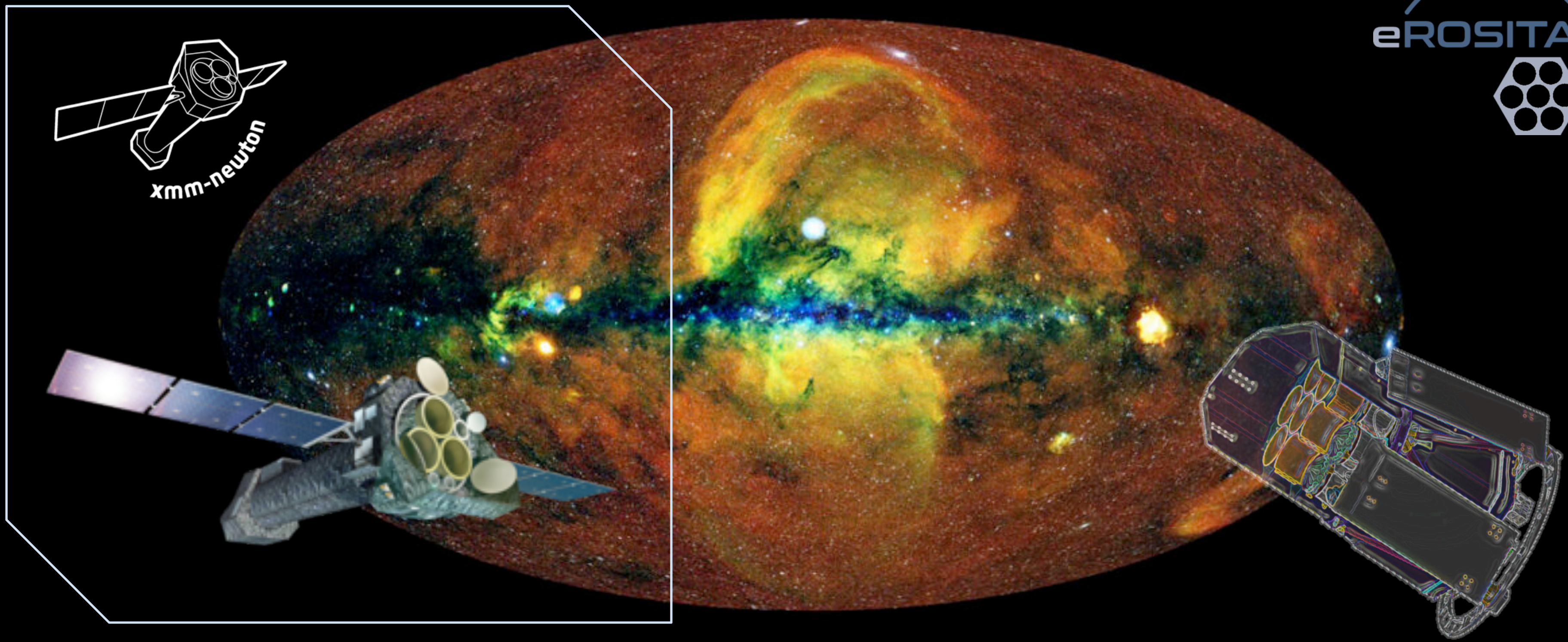
eROSITA RMF for single pixel events

constructed from parameterization of ‚monochromatic‘ spectra taken in 2009 with a prototype CCD at BESSY

RMFs and ARFs for eROSITA and XMM/EPIC-pn

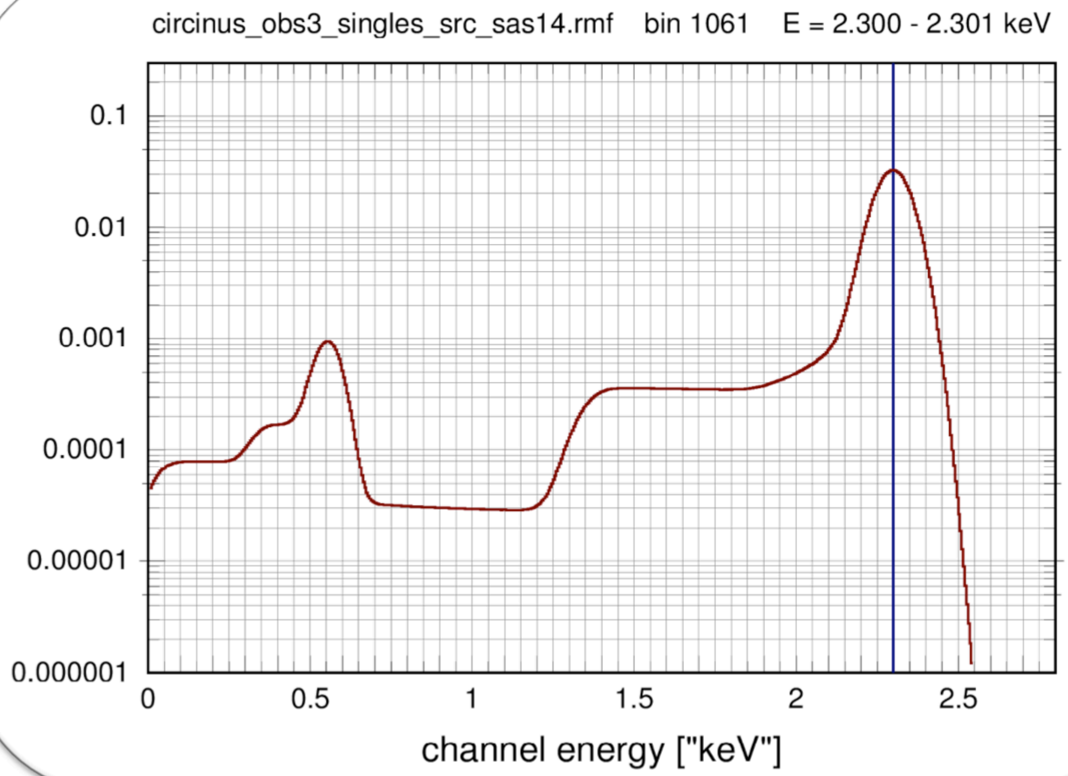
Parameterization of the EPIC-pn RMF

eROSITA

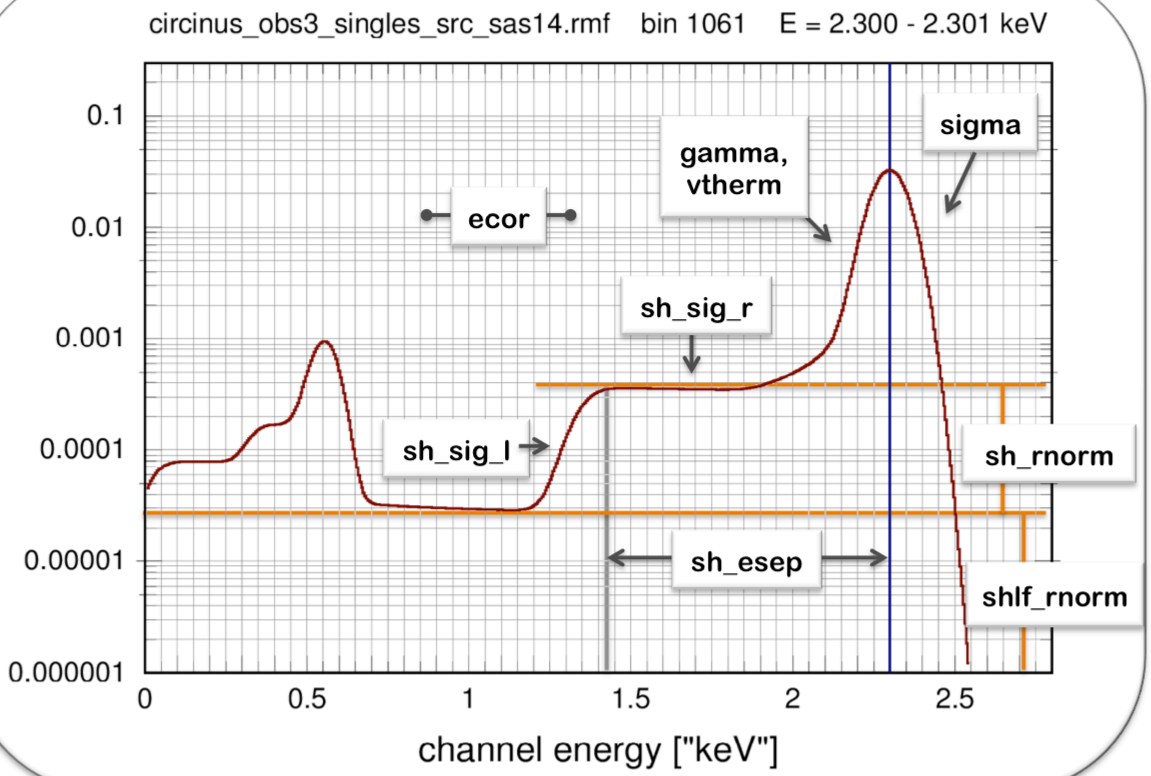


Parador de La Granja, Spain IACHEC, 2024 May 12 - 16 Konrad Dennerl, MPE

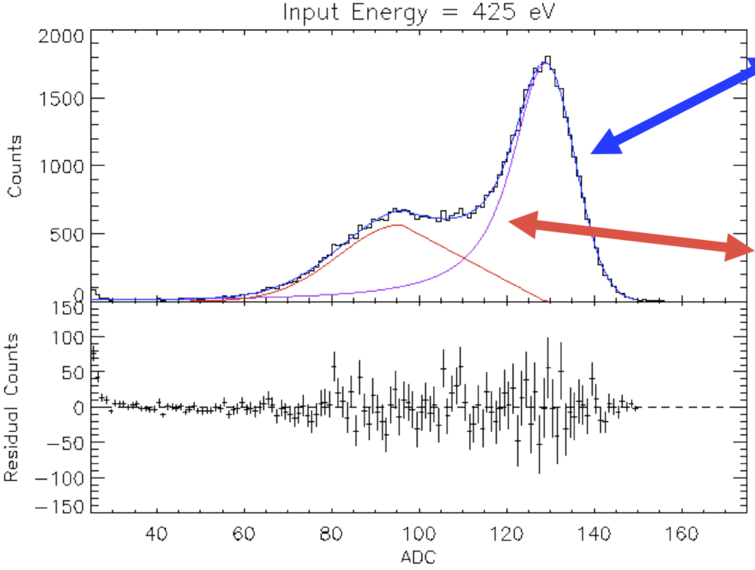
Model Parameters for the EPIC pn RMF



Model Parameters for the EPIC pn RMF



Descriptive Model: The VRMF Model



Main Peak

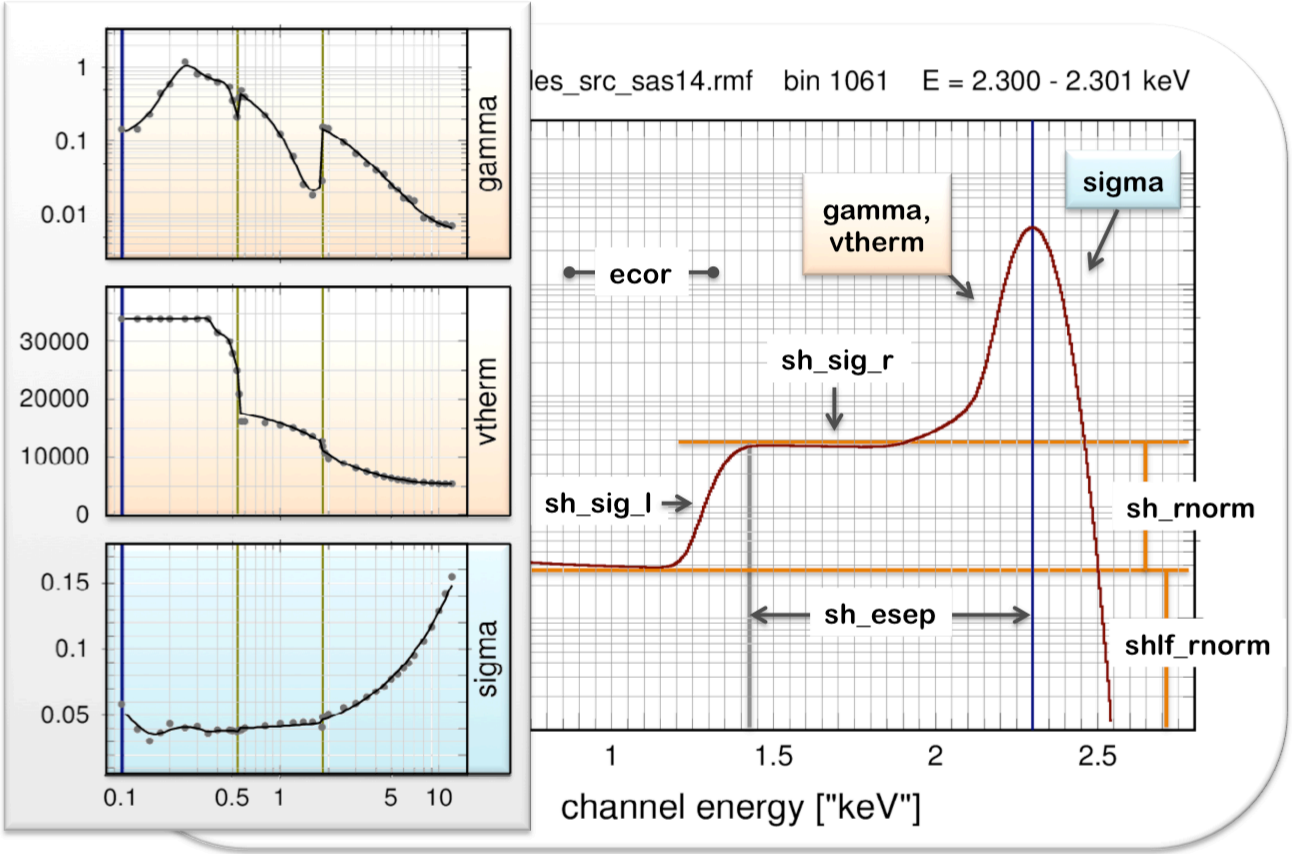
Blue Wing:
Gaussian

Red Wing:
Voigt Function

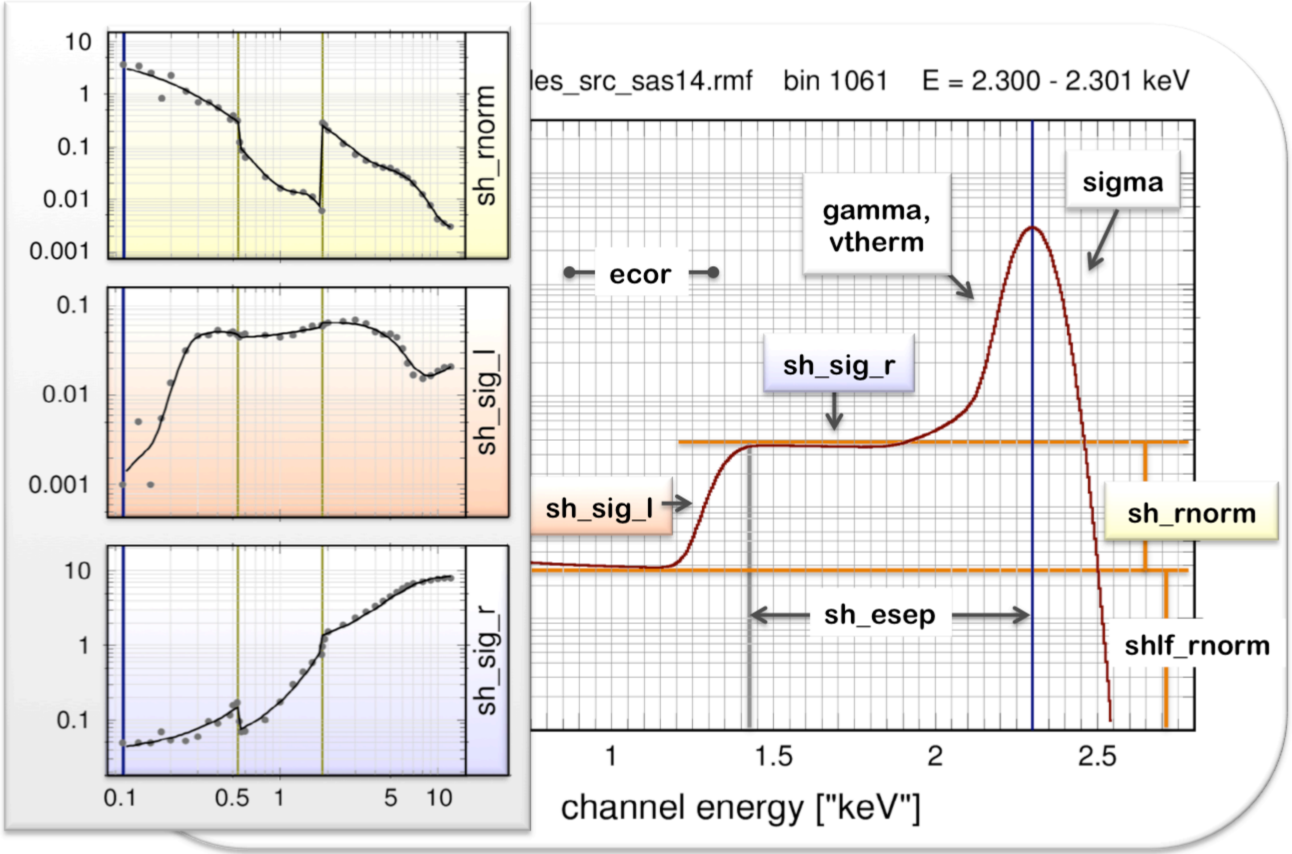
= Gaussian convolved with a Lorentian.

Dampening factor
= 0 (Gaussian)
> 0 (Lorentz-like)

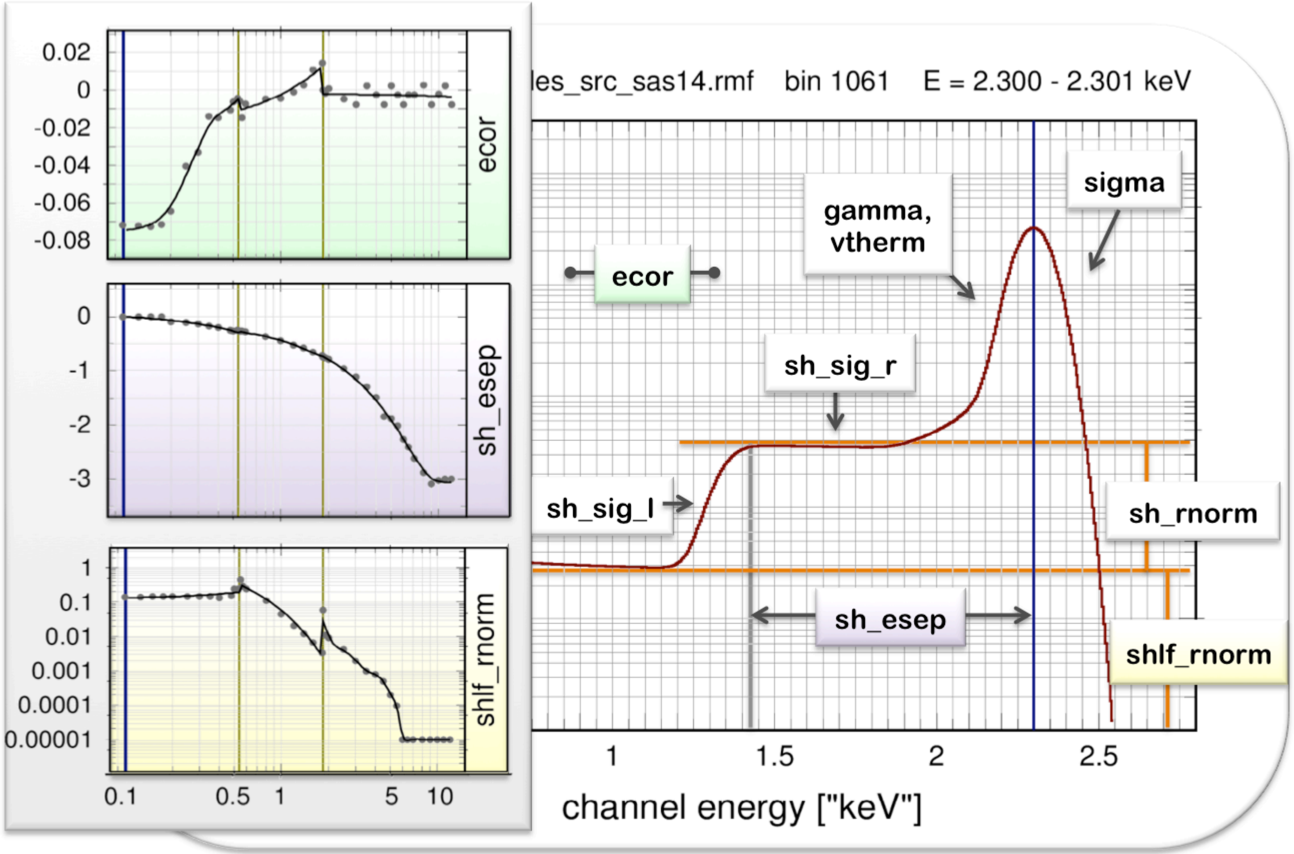
Modeling the EPIC pn RMF at individual energies



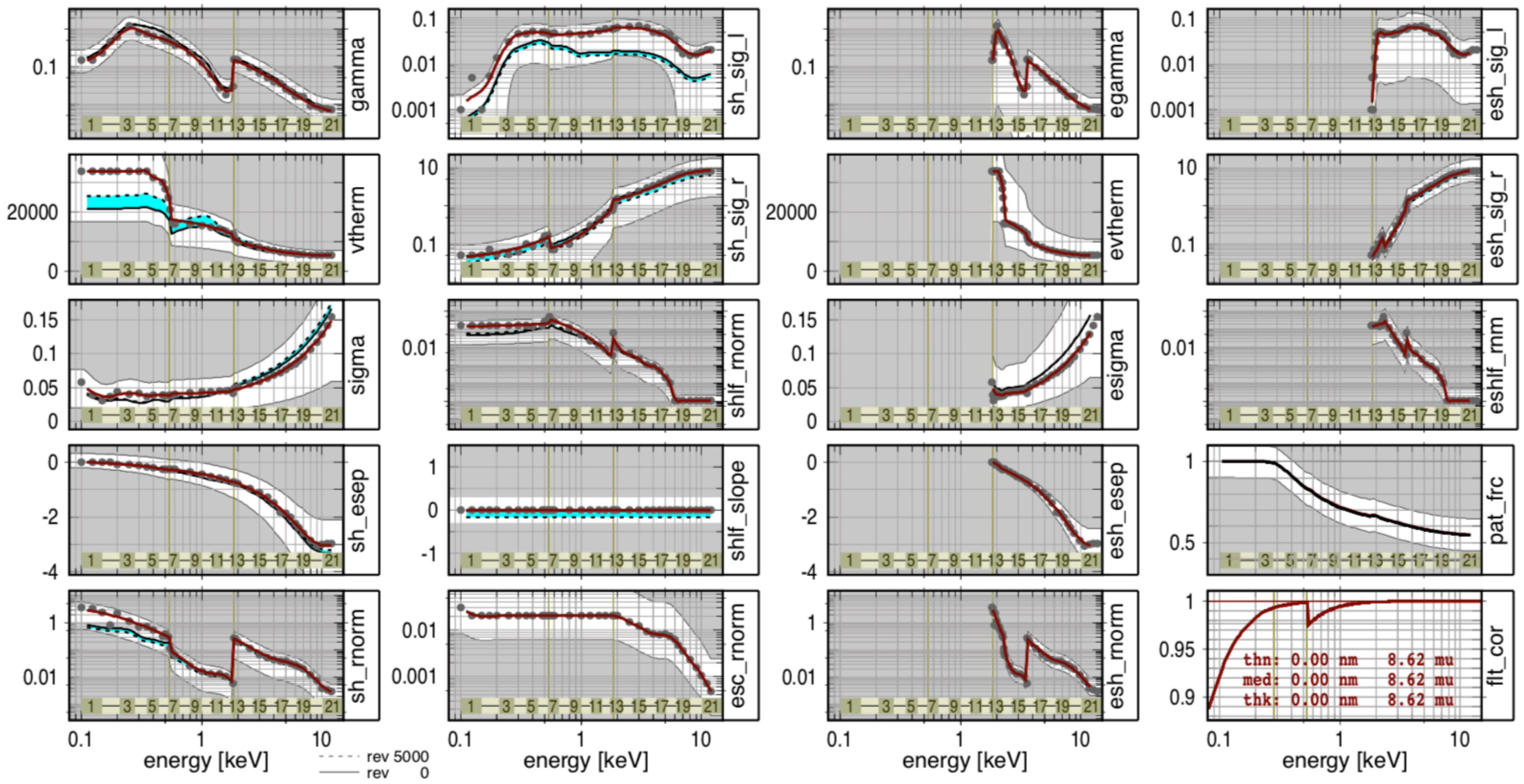
Modeling the EPIC pn RMF at individual energies



Modeling the EPIC pn RMF at individual energies



Current RMF & ARF parameterization for XMM/EPIC-pn



Current RMF & ARF parameterization for XMM/EPIC-pn

	0.10	0.15	0.21	0.28	0.35	0.44	0.53	0.66	0.80	1.00	1.20	1.50	1.74	2.20	2.70	3.40	4.20	5.10	6.20	8.00	10.00 keV	smoothness		
p	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_rnorm	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_rnorm	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_rnorm	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

p	0.10	0.15	0.21	0.28	0.35	0.44	0.53	0.66	0.80	1.00	1.20	1.50	1.74	2.20	2.70	3.40	4.20	5.10	6.20	8.00	10.00 keV	smoothness		
	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	1.162	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	0.028
vtherm	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	0.035
sigma	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	0.078
sh_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	0.011
sh_nrom	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	0.045
sh_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	0.021
sh_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	0.020
shlf_nrom	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	0.070
shlf_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	0.000
esc_nrom	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_nrom	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_nrm	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	1.010	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	1.000	1.000	1.000	1.000	0.018	0.100	0.002

t	0.10	0.15	0.21	0.28	0.35	0.44	0.53	0.66	0.80	1.00	1.20	1.50	1.74	2.20	2.70	3.40	4.20	5.10	6.20	8.00	10.00 keV	smoothness		
	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	1.000	0.000
gamma	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.000	1.000	0.000
vtherm	0.026	0.026	0.026	0.028	0.028	0.028	0.028	0.028	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.000	1.000	0.000
sigma	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.000	1.000	0.000
sh_esep	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	0.000	1.000	0.000
sh_nrom	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	0.000	1.000	0.000
sh_sig_l	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.000	1.000	0.000
sh_sig_r	-0.070	-0.070	-0.070	-0.070	-0.096	-0.096	-0.096	-0.096	-0.096	-0.096	-0.096	-0.096	-0.096	-0.096	-0.096	-0.096	-0.096	-0.096	-0.096	-0.096	-0.096	0.005	1.000	0.005
shlf_nrom	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	0.000	1.000	0.000
shlf_slope	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.340	0.000	1.000	0.000
esc_nrom	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	1.000	0.000
egamma	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	1.000	0.000
evtherm	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	1.000	0.000
esigma	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	1.000	0.000
esh_esep	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	1.000	0.000
esh_nrom	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	1.000	0.000
esh_sig_l	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	1.000	0.000
esh_sig_r	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	1.000	0.000
eshlf_nrm	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	1.000	0.000
pat_frc	0.39E-3	0.39E-3	0.39E-3	0.39E-3	0.39E-3	0.39E-3	0.39E-3	0.39E-3	0.39E-3	0.39E-3	0.39E-3	0.39E-3	0.39E-3	0.39E-3	0.39E-3	0.39E-3	0.39E-3	0.39E-3	0.39E-3	0.39E-3	0.39E-3	0.000	0.000	0.000

total penalty: 0.316

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 → 6 parameters

→ 27 ARF parameters

→ 426 parameters

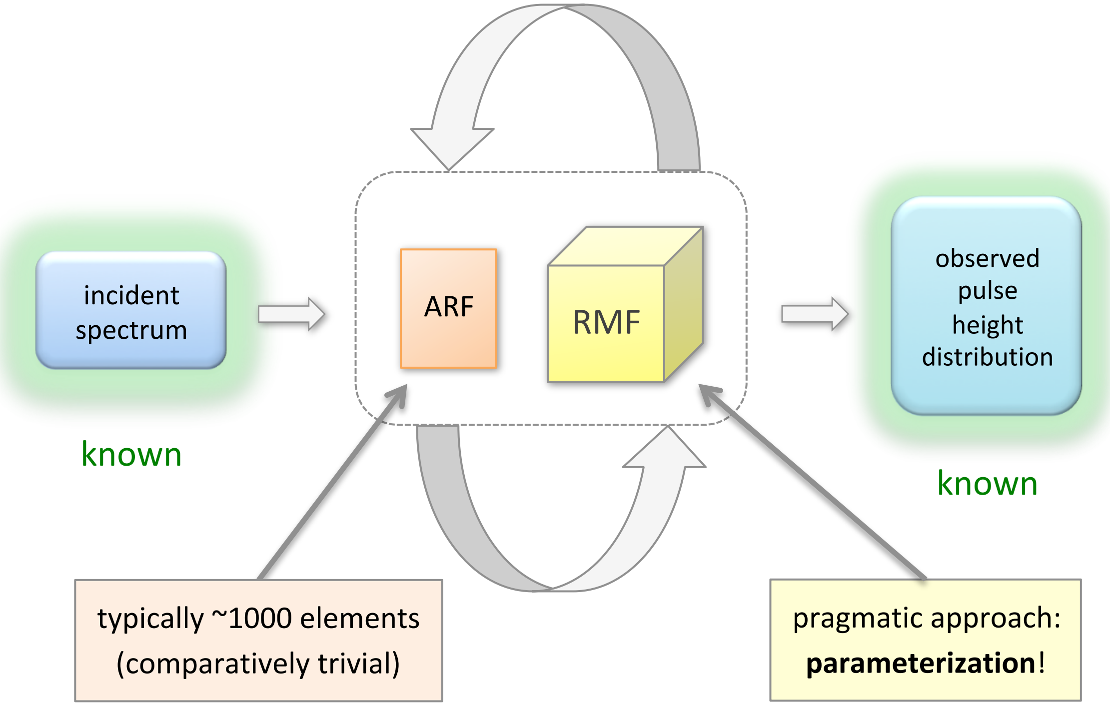
(linear) temporal dependence of each parameter

→ **852 parameters**

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

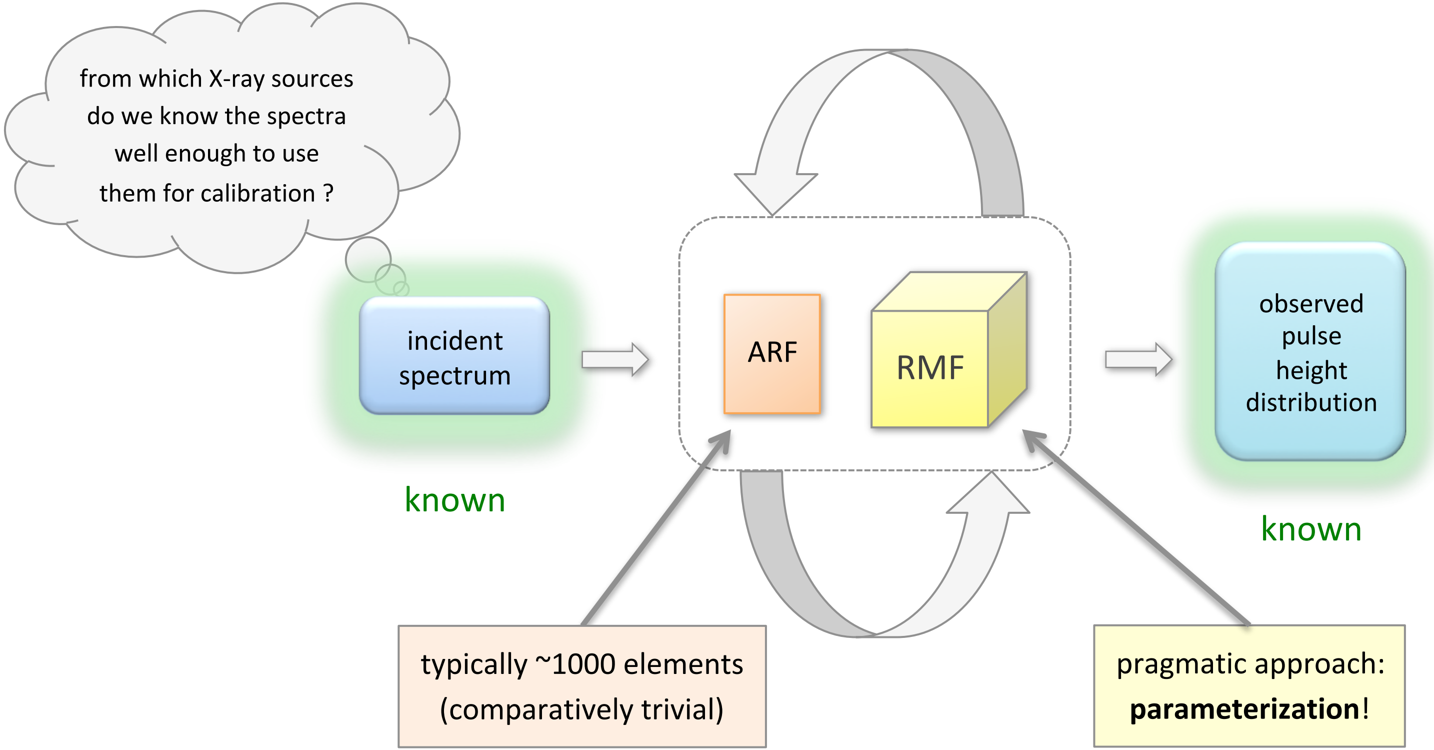
General properties of the ARF and RMF

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



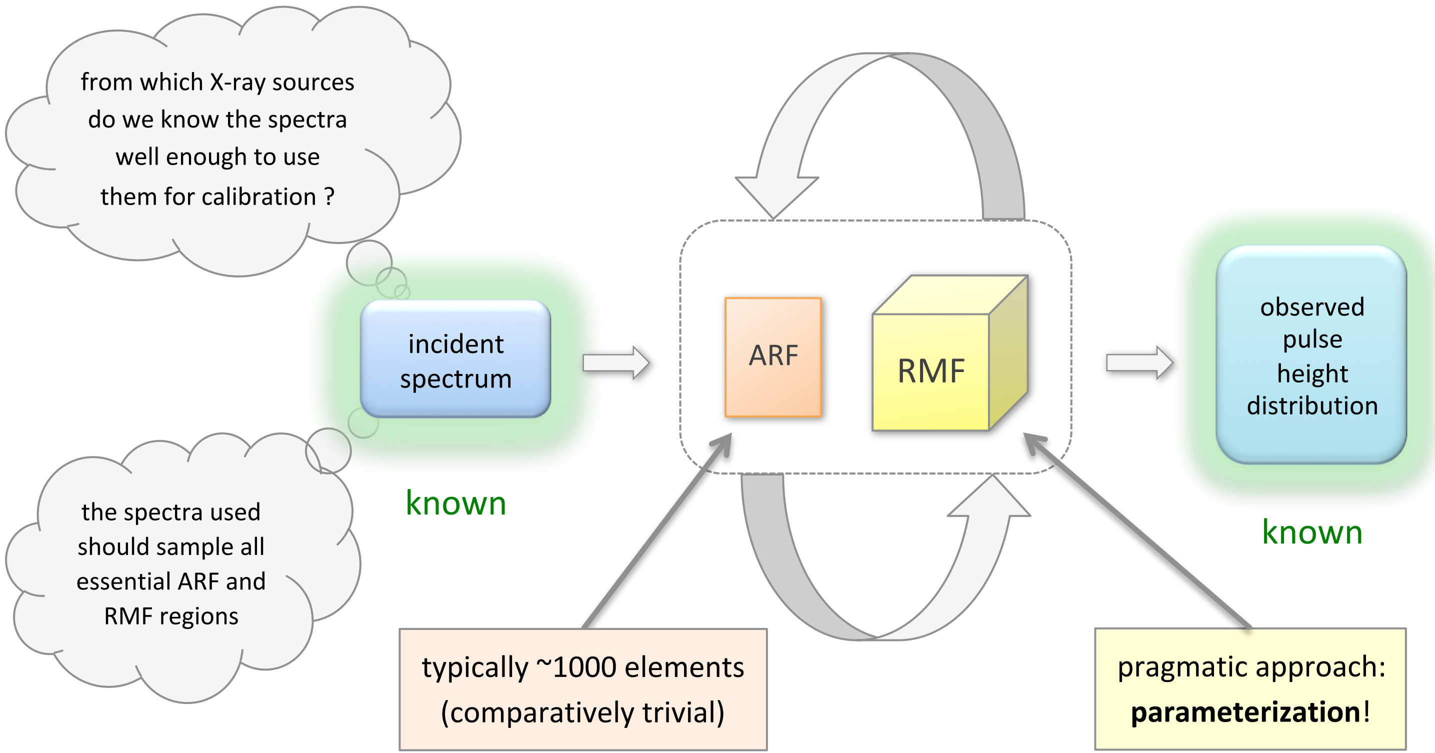
General properties of the ARF and RMF

ARF: „Ancillary Response File“, RMF: „Redistribution Matrix File“



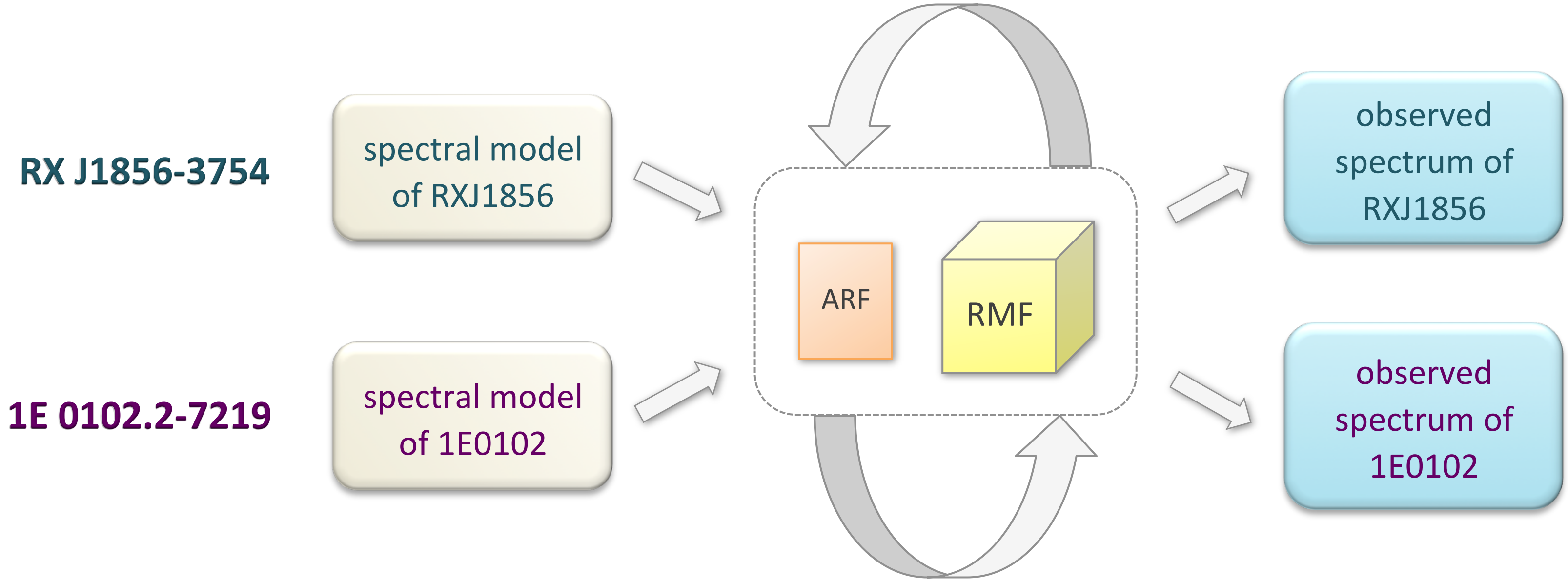
General properties of the ARF and RMF

ARF: „Ancillary Response File“, RMF: „Redistribution Matrix File“



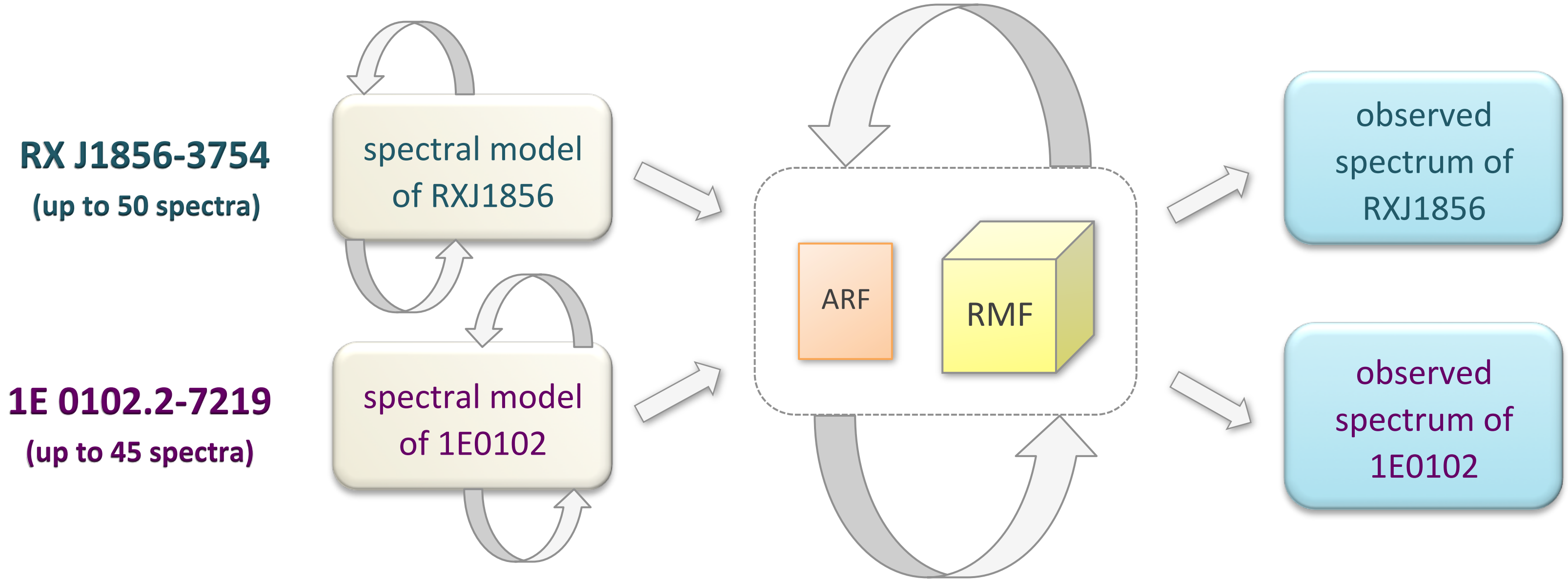
General properties of the ARF and RMF

ARF: „Ancillary Response File“, RMF: „Redistribution Matrix File“



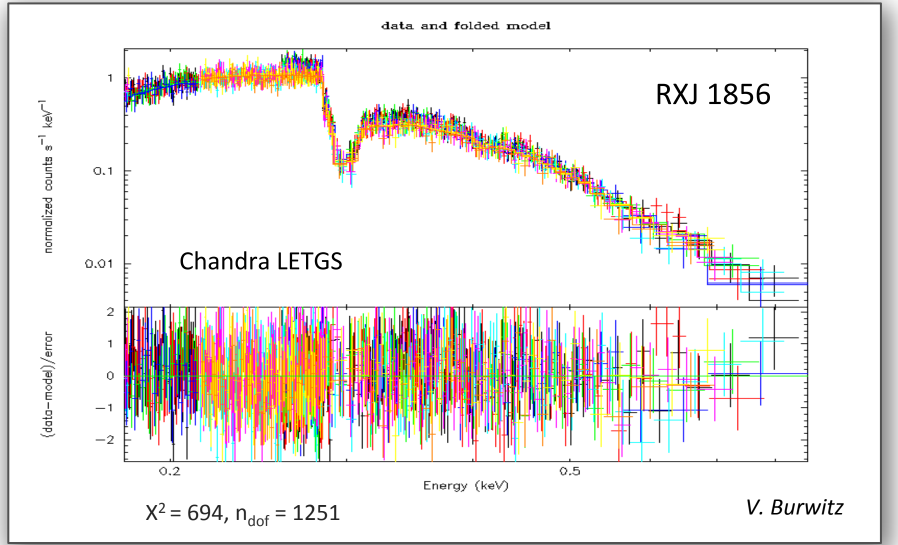
General properties of the ARF and RMF

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



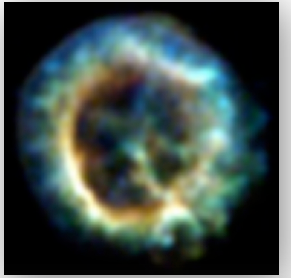
→ nH = (7.2 +/- 0.3) × 10^{19} cm^{-2}
kT = 62.4 +/- 0.4 eV
norm = (1.58 +/- 0.06) x 10^5
[tbabs * bbodyrad]

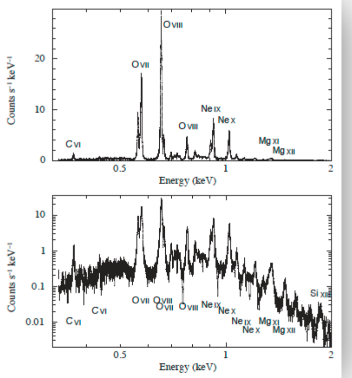
1E 0102.2-7219: IACHEC model

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. Plucinsky[1], Andrew P. Beardmore[2], Adam Foster[1], Frank Haberl[3], Eric D. Miller[4], Andrew M. T. Pollock[5], and Steve Sembay[2]



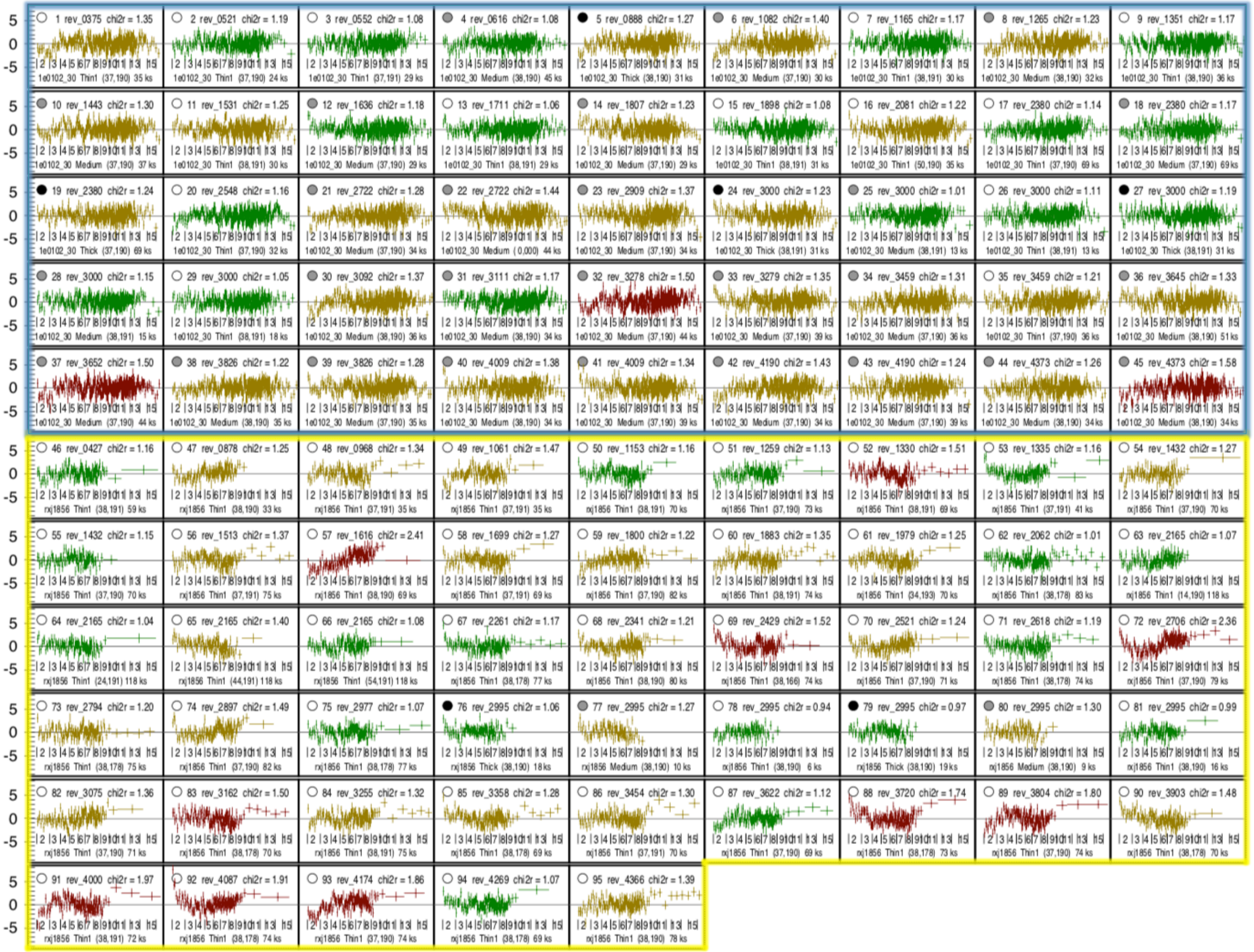


XMM/EPIC-pn residuals for

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



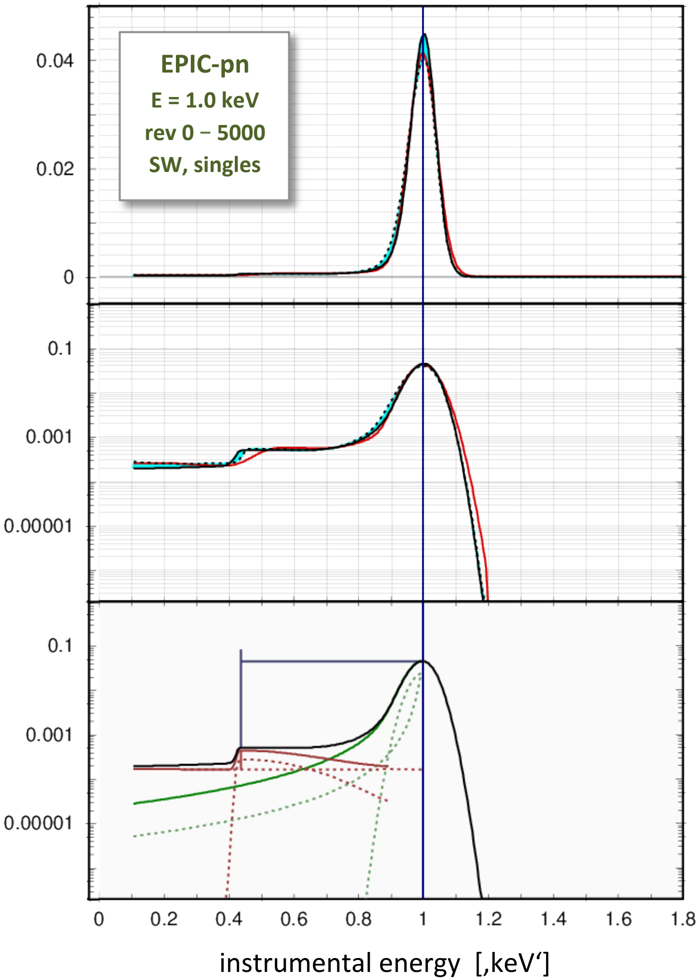
XMM/EPIC-pn residuals for

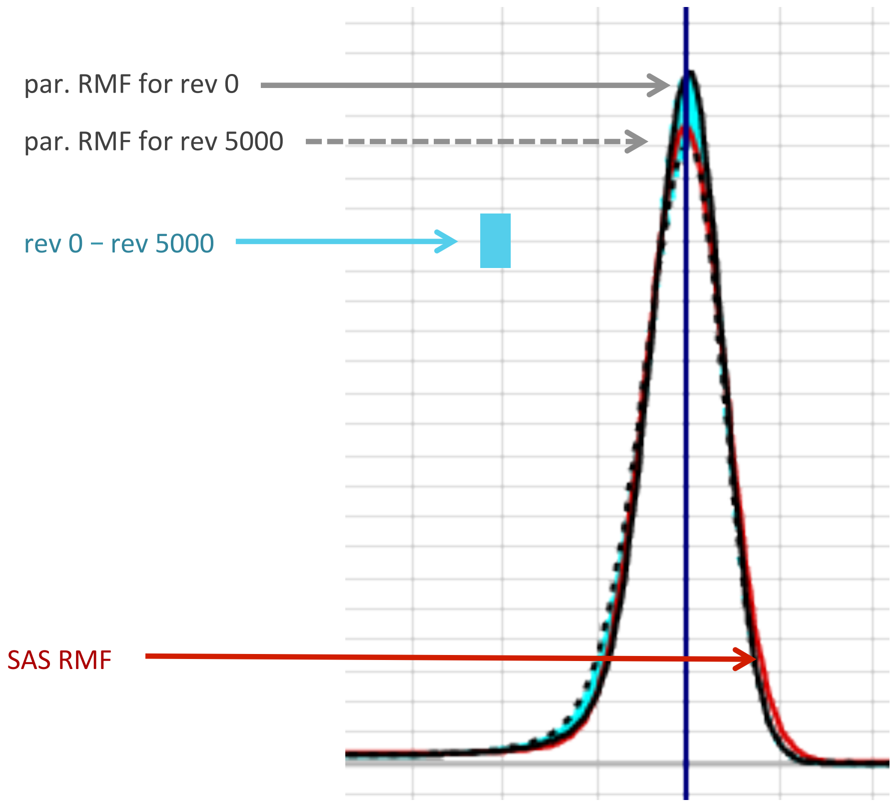
1E0102 (45) and RXJ1856 (50)

resulting from IACHEC and Chandra model spectra

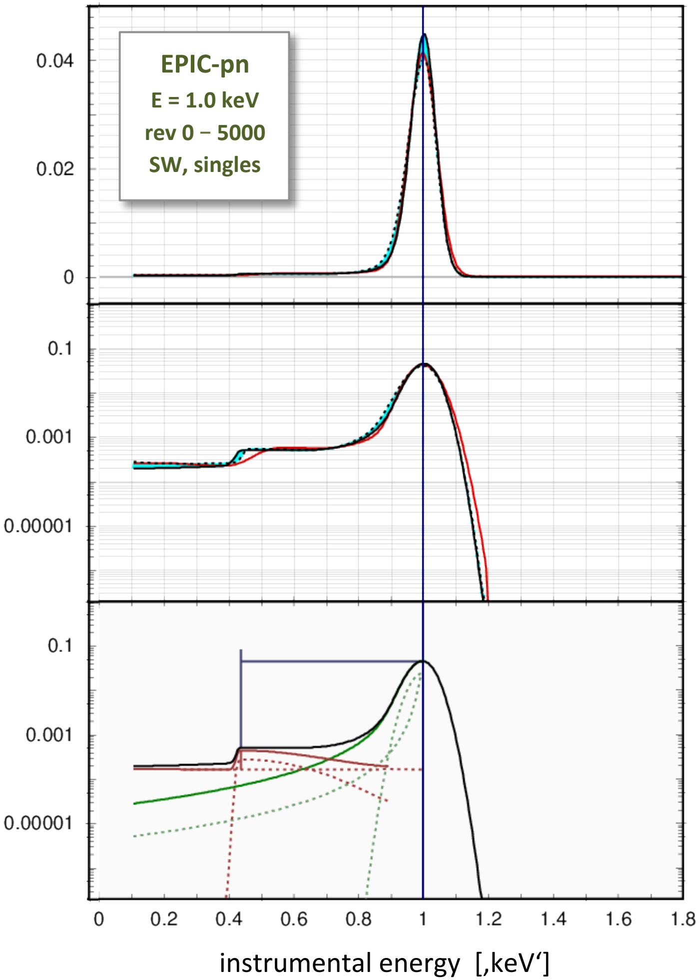
and parameterized RMFs and ARFs

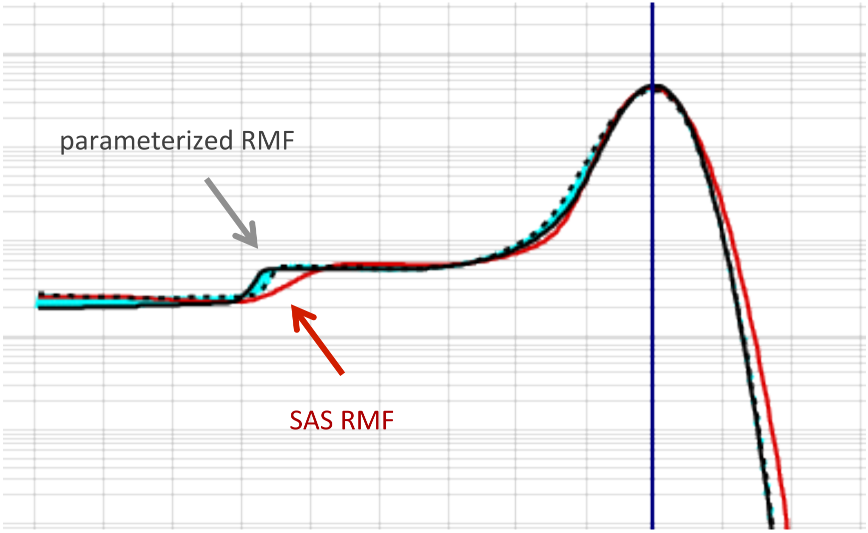
Temporal trend in the parameterized RMF



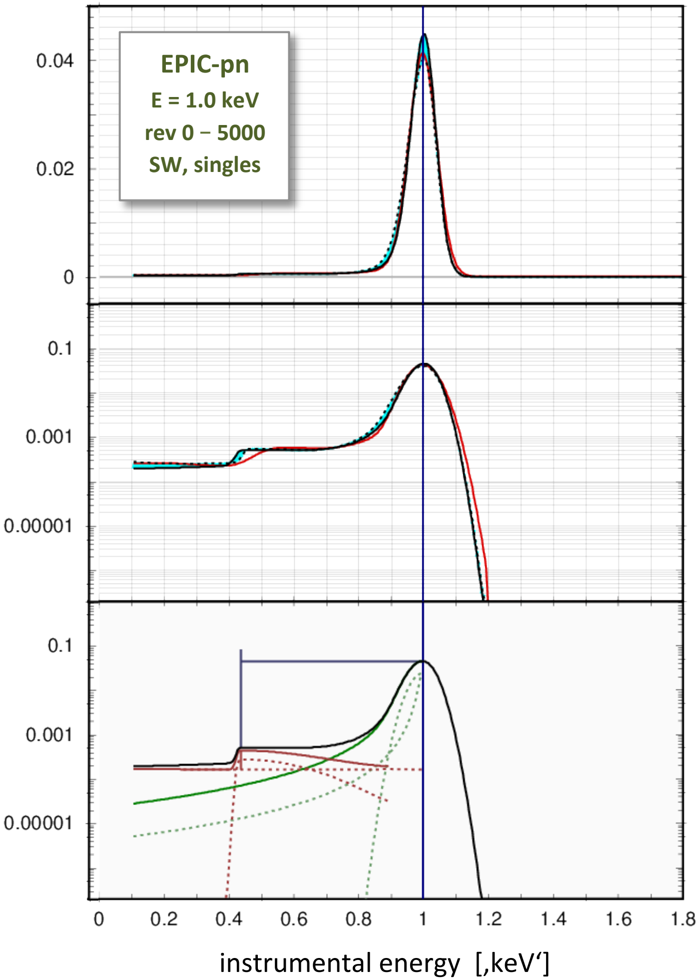


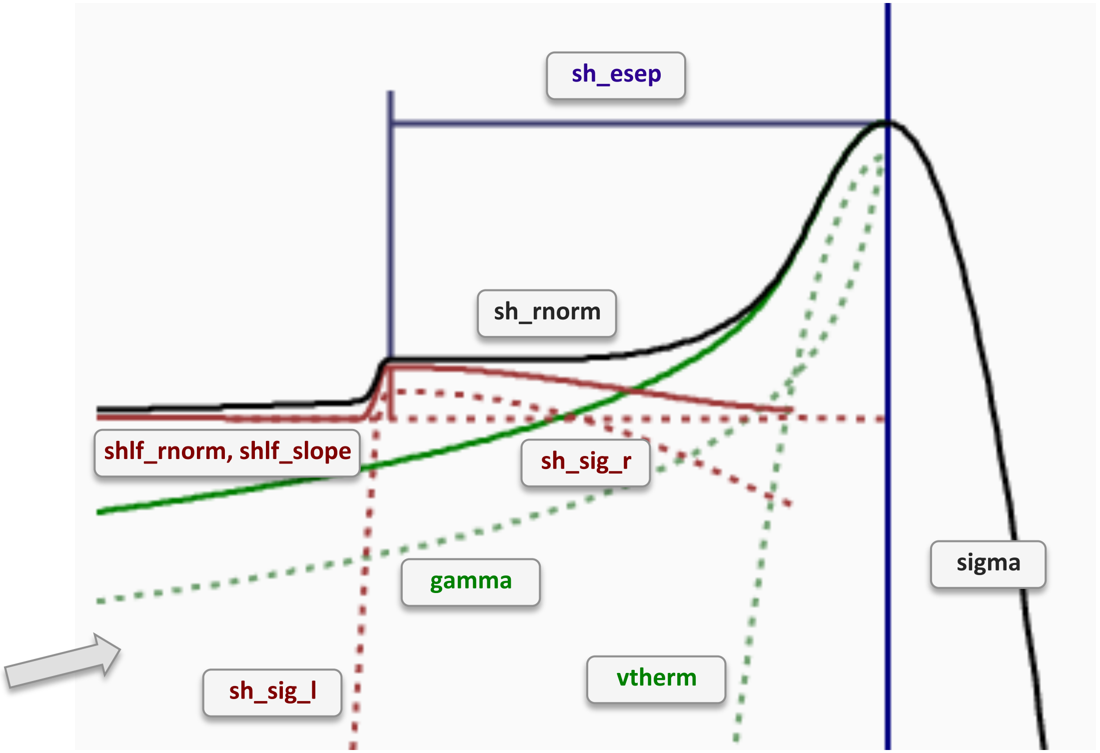
What has changed in the RMF ?



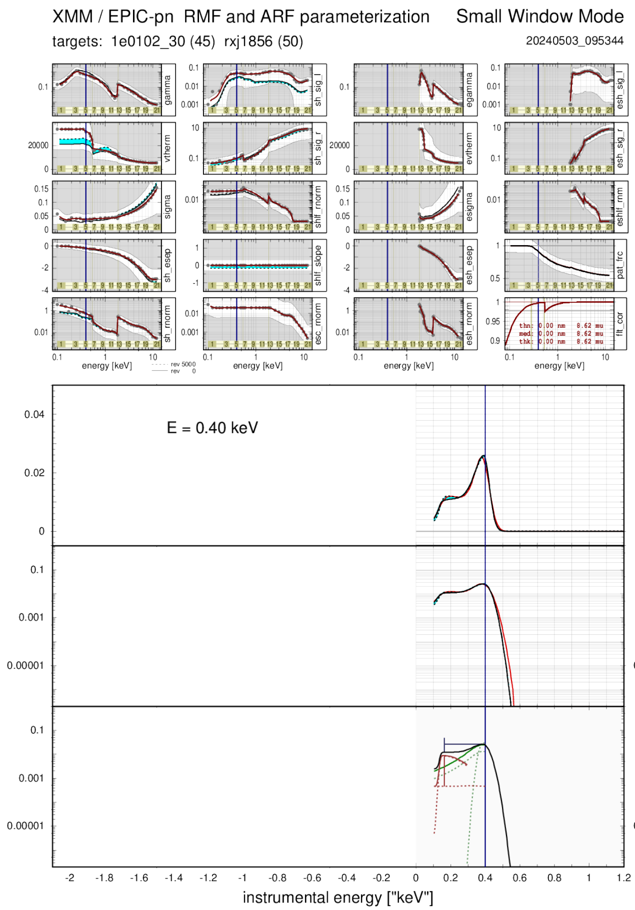


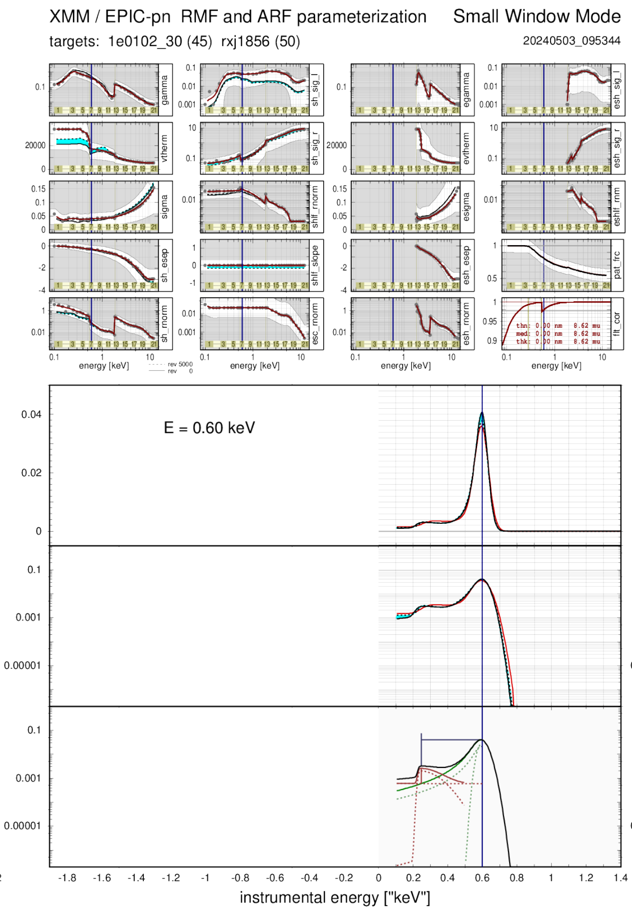
RMF construction details

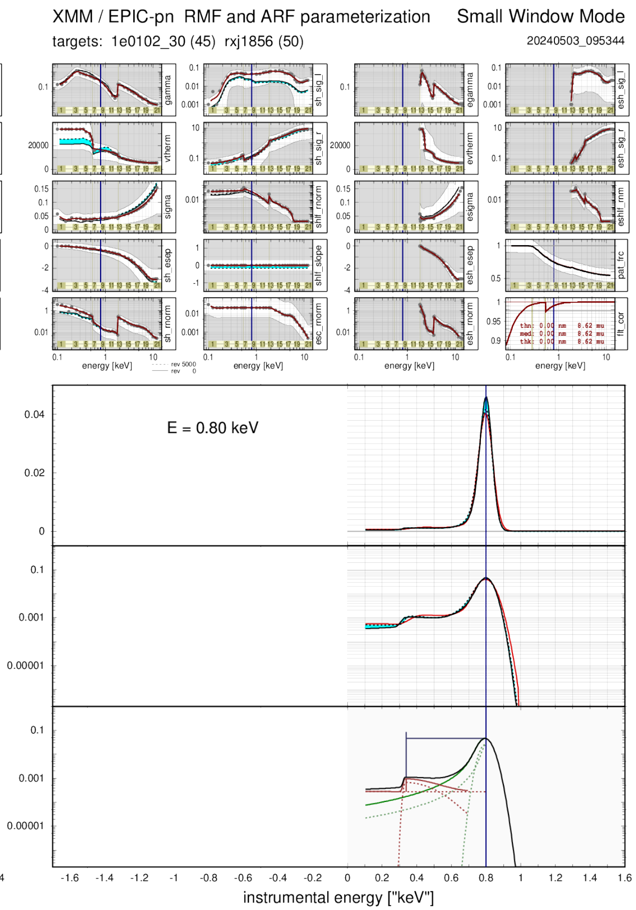




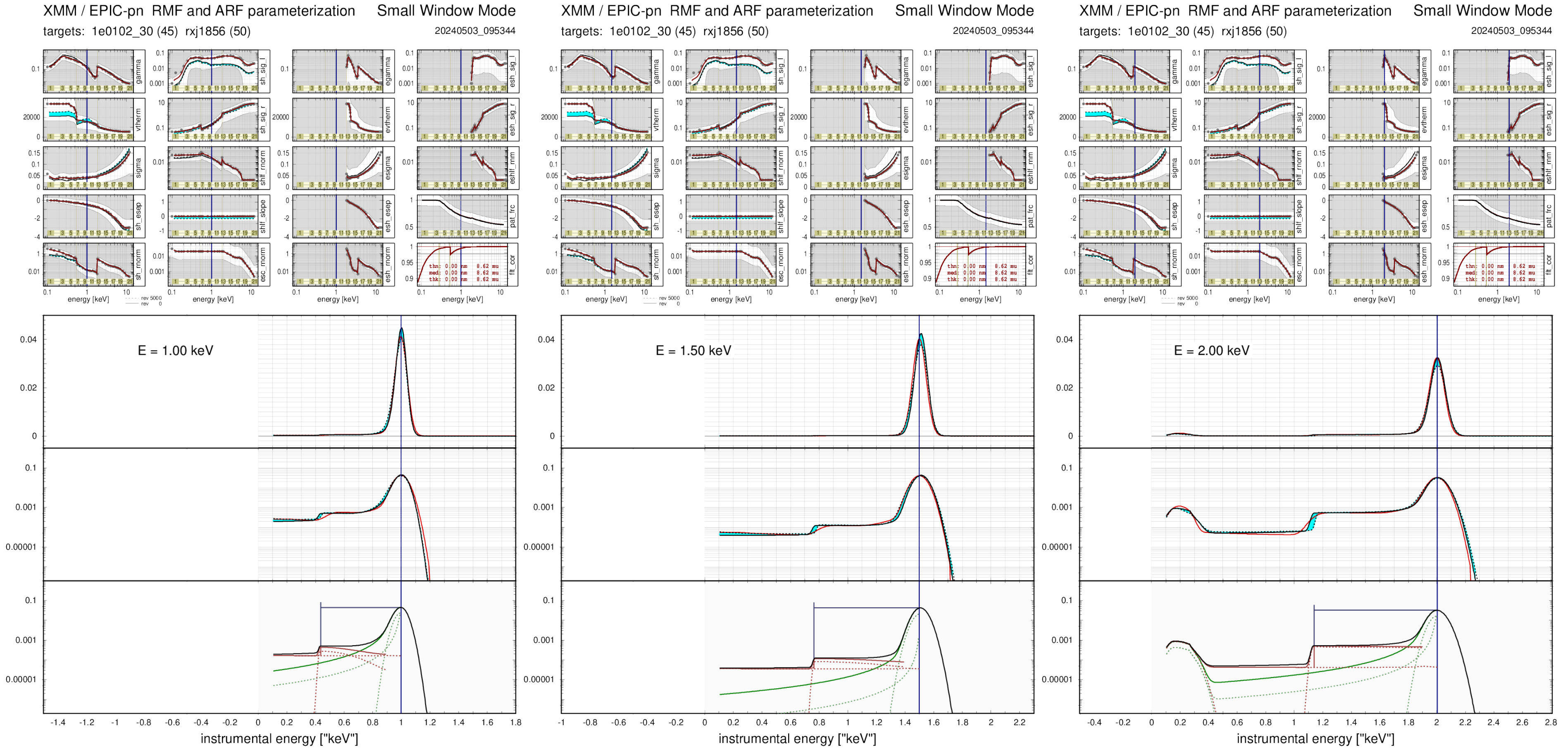
Sampling the parameterized RMF at 400, 600, and 800 eV





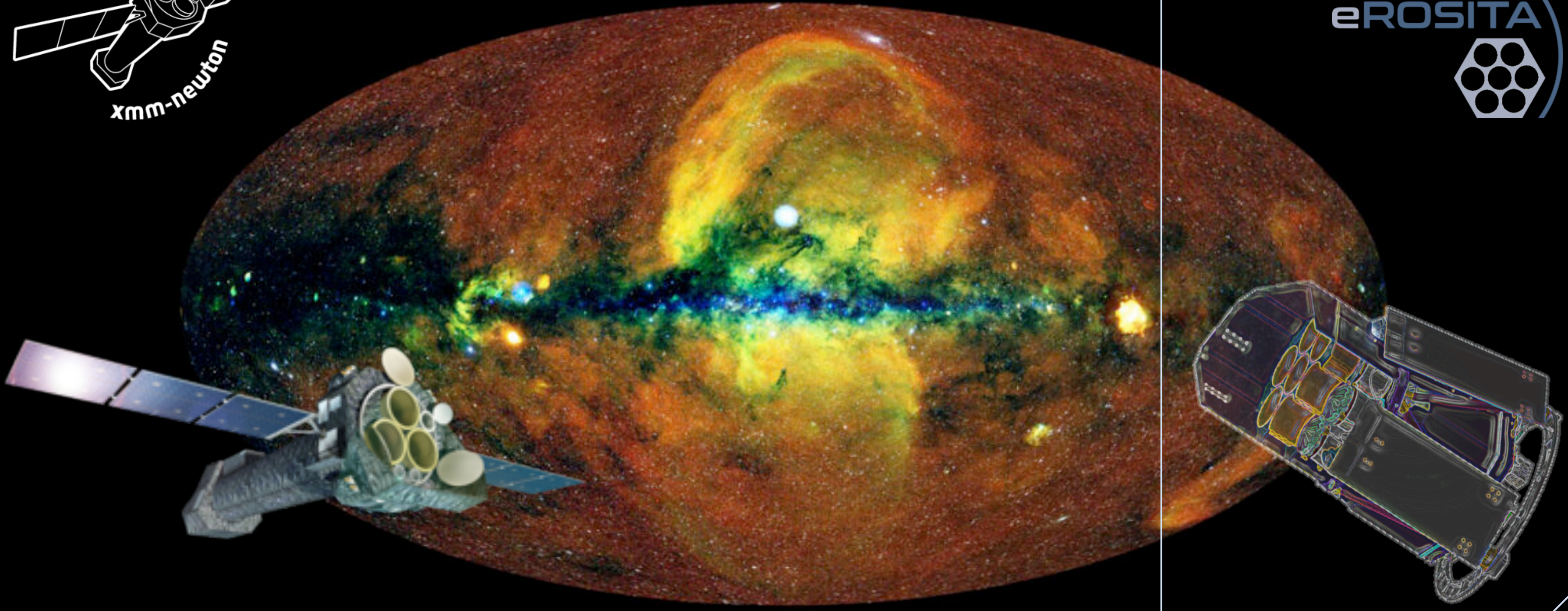


Sampling the parameterized RMF at 1.0, 1.5, and 2.0 keV

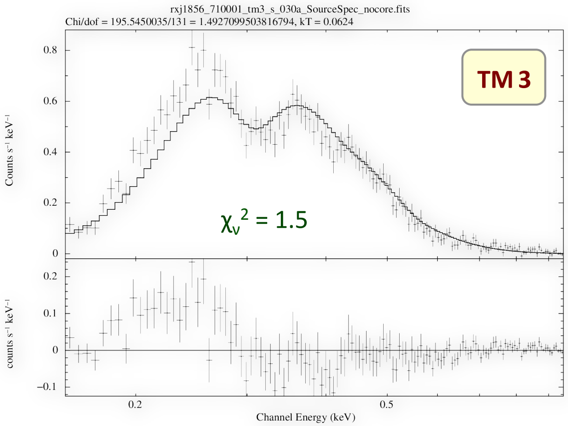


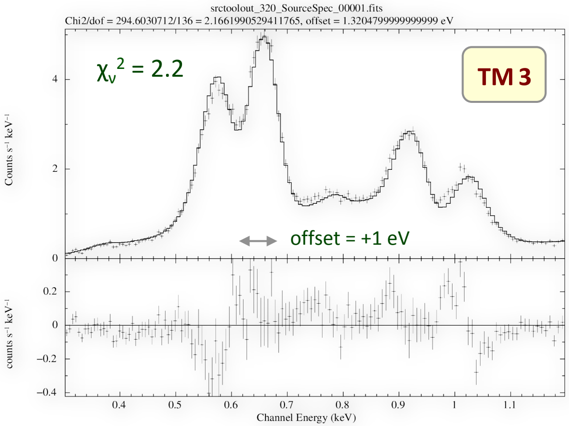
RMFs and ARFs for eROSITA and XMM/EPIC-pn

Results for eROSITA



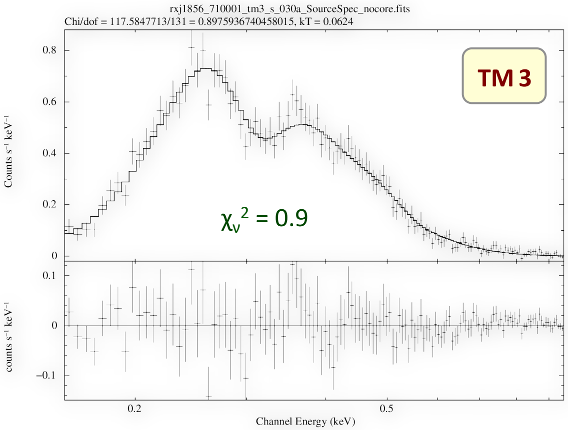
Parador de La Granja, Spain | IACHEC, 2024 May 12 - 16 | Konrad Dennerl, MPE

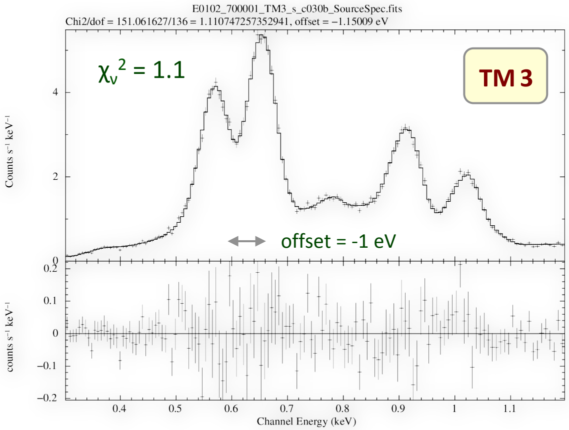




RX J1856-3754

1E 0102.2-7219





„Fitting“ the RMF and ARF for eROSITA

Method:

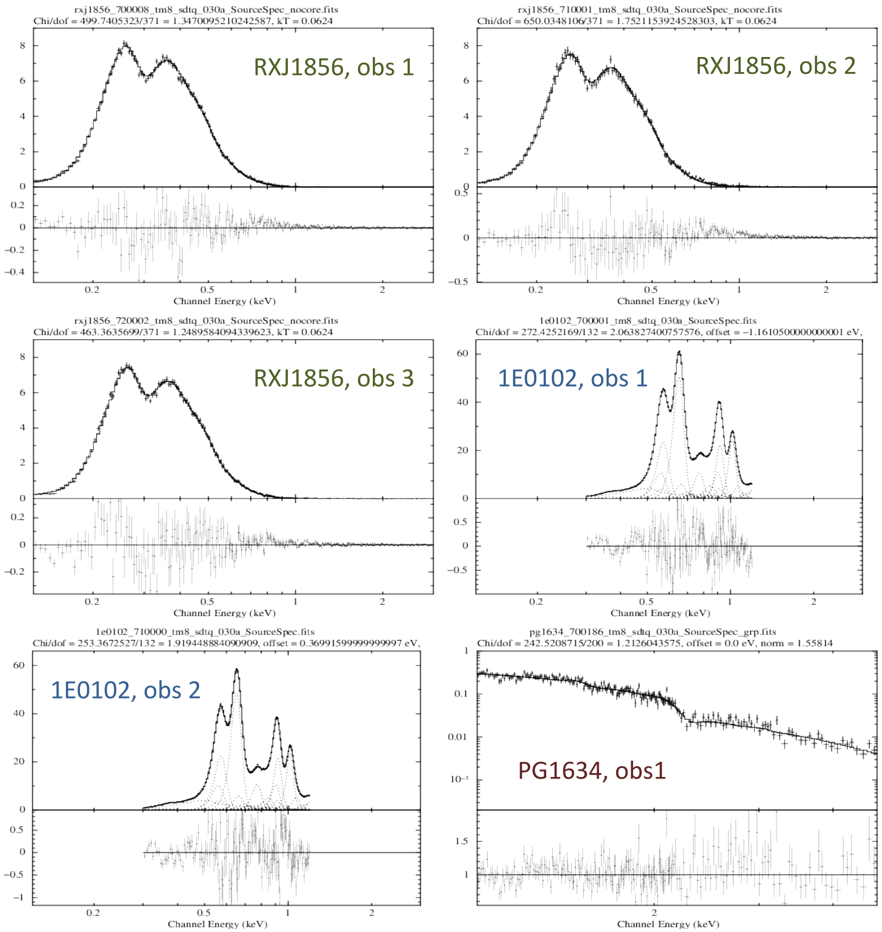
consider two sources with „reliable“ spectral models simultaneously:

RX J1856-3754

&

1E 0102.2-7219

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

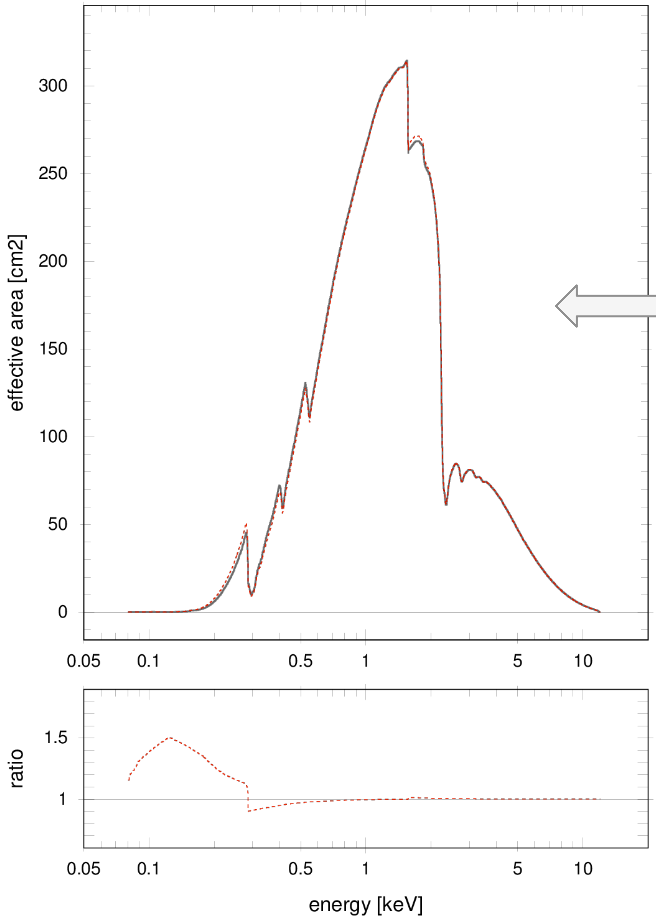


- ‚TM8' = TM1 + TM2 + TM3 + TM4 + TM6
  (sum of all CCDs with an on-chip Al filter)
- ‚sdtq': all valid pixel patterns
  (sum of singles, doubles, triples, quadruples)

→ 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

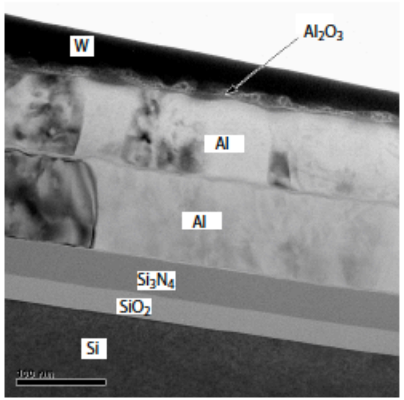
- also including PG1634+706 as a hard X-ray source

eROSITA ARF: what has changed ?



black: initial ARF

red: modified ARF



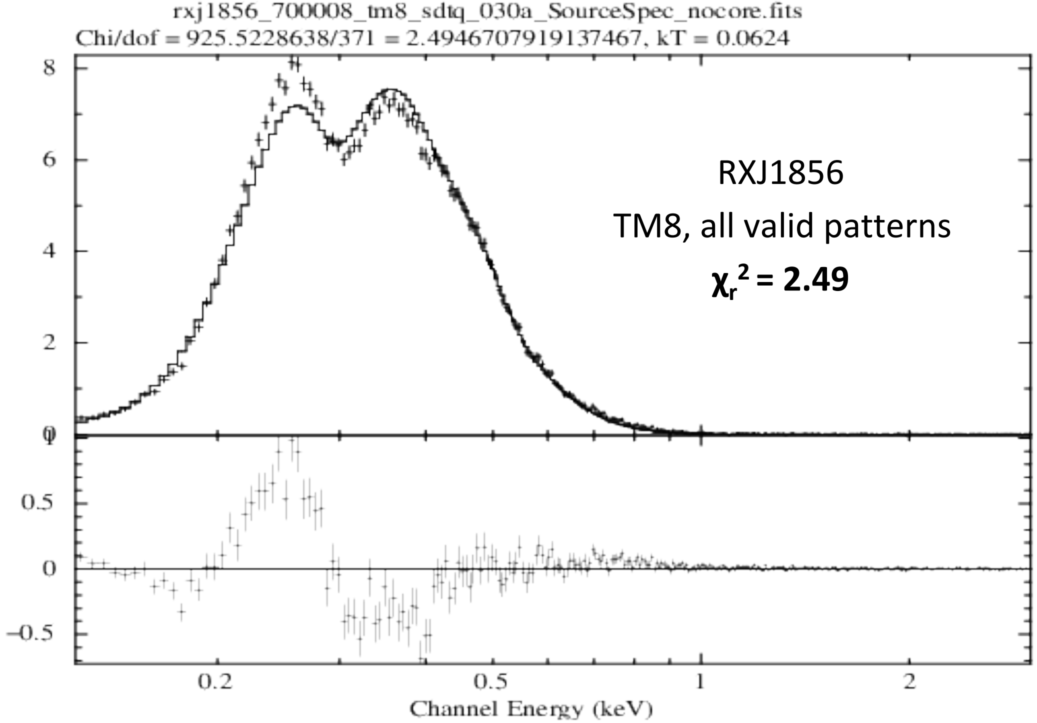
from Granato 2012

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

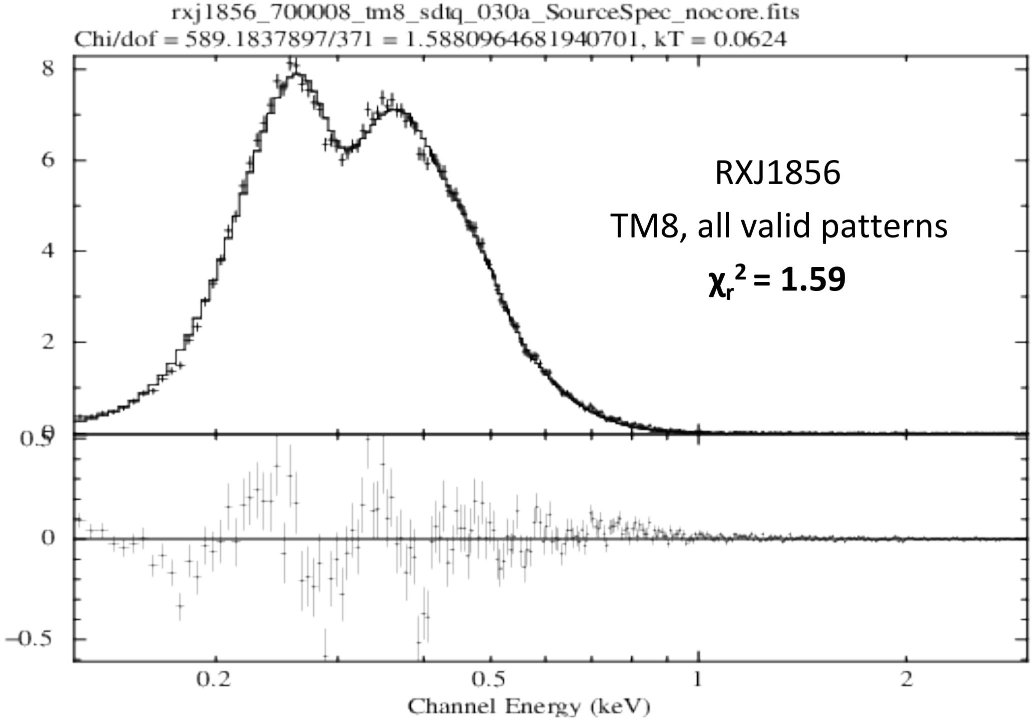


best-fit spectrum with

- unmodified RMF
- unmodified ARF

(both from ground calibration)

eROSITA and RXJ1856: interplay between ARF and RMF



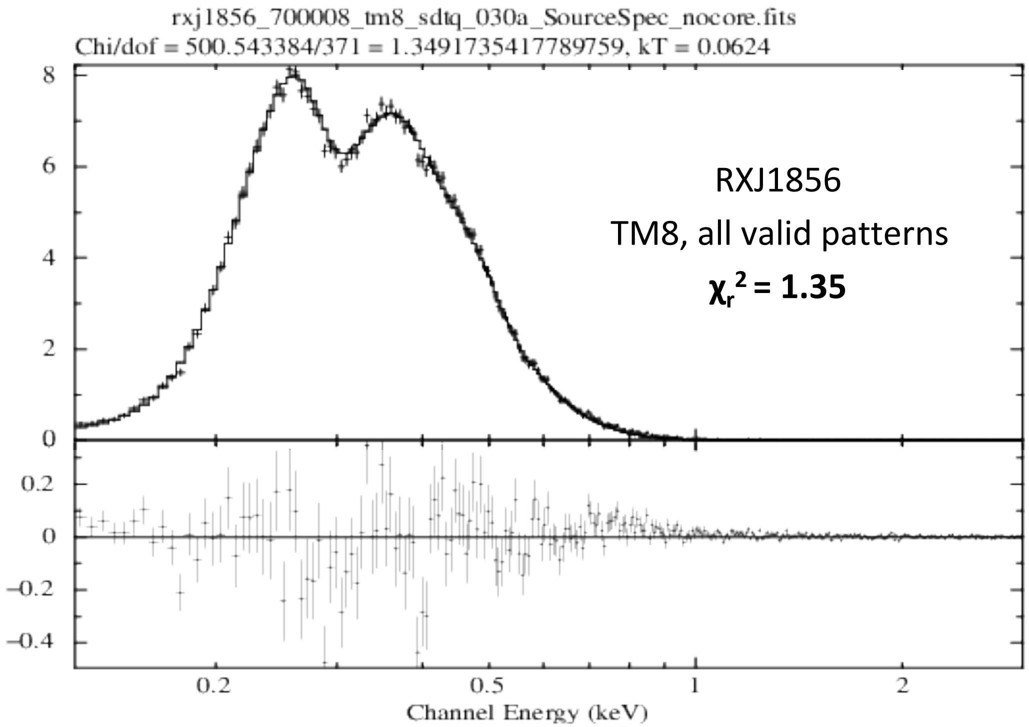
best-fit spectrum with

- 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

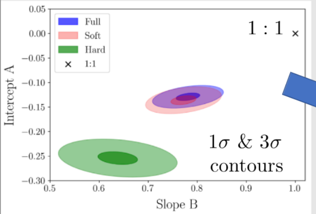
K. Migkas[1,2,3], D. Kox[2], G. Schellenberger[4], A. Veronica[2], F. Pacaud[2], T. H. Reiprich[2], Y. E. Bahar[5], F. Balzer[5], E. Bulbul[5], J. Comparat[5], K. Dennerl[5], M. Freyberg[5], C. Garrel[5], V. Ghirardini[5], S. Grandis[6], M. Kluge[5], A. Liu[5], M. E. Ramos-Ceja[5], J. Sanders[5], X. Zhang[5]

Using a single power law fit, we found that eROSITA shows a strong discrepancy with Chandra, measuring 25% and 38% lower $T_{\rm eROSITA}$ for $T_{\rm Chandra}$ = 4.5 keV and $T_{\rm Chandra}$ = 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 $T_{\rm eROSITA}$ for $T_{\rm XMM} \approx 2-7$ keV clusters, while there is a slightly better agreement for cooler systems.

→ test with PG 1634+706

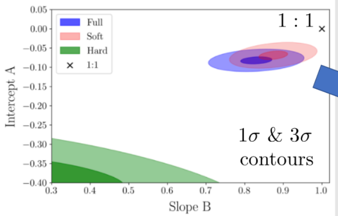
eROSITA vs Chandra: single power law



$> 10\sigma$ difference

- 20-30% lower eROSITA T for average-sized clusters
- Good agreement for low-T galaxy groups, large differences for massive clusters
- Hard band much more inconsistent

eROSITA vs XMM-Newton



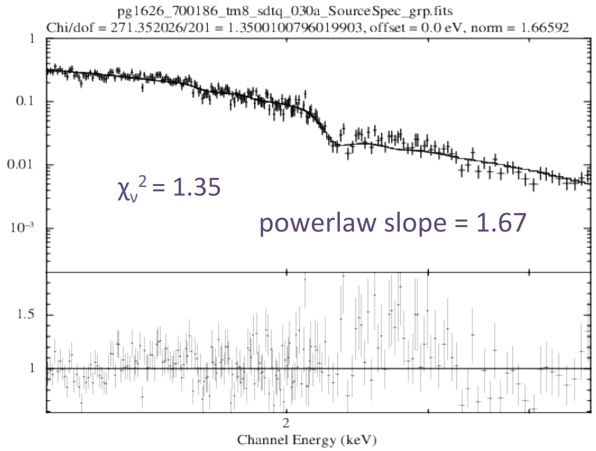
$\approx 5\sigma$ difference

- 10-20% lower eROSITA T for average-sized clusters
- Soft band shows marginally better consistency

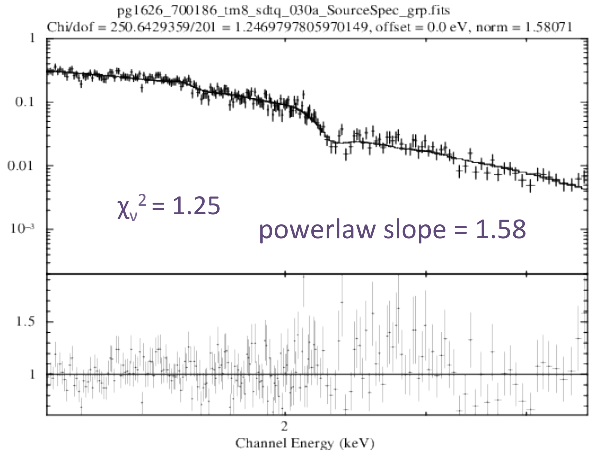
Testing the influence of the high energy ARF on PG1634

fit restricted to E = 1.0 – 4.8 keV

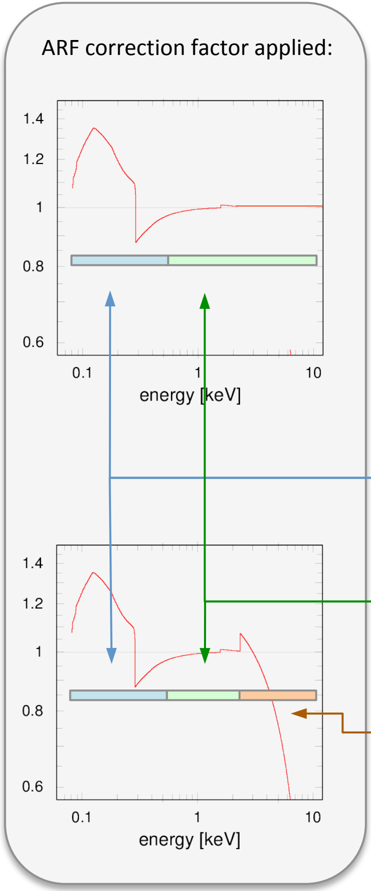
(to minimize possible complications due to n_H or background)



ARF used



ARF used

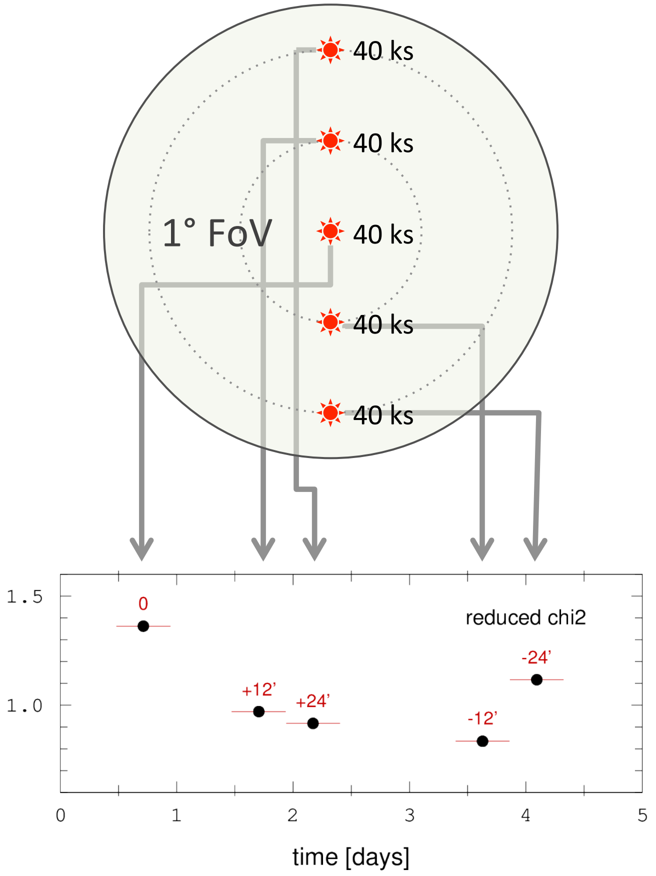


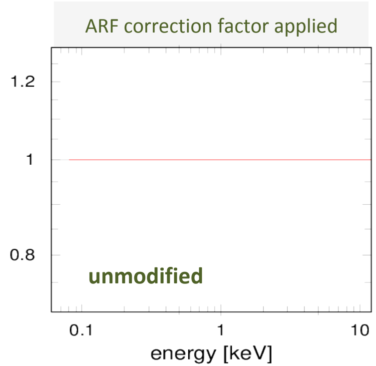
modification can be physically justified

from (unmodified!) ground calibration (except for small Al-K edge)

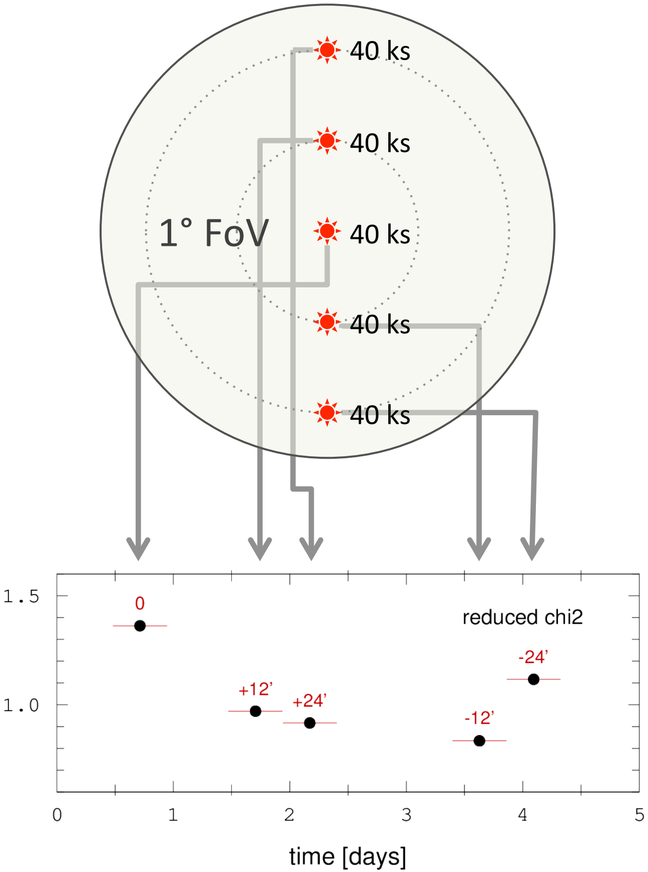
just for empirical test, no physical justification

PG 1634: fit quality obtained with unmodified ARFs and RMF

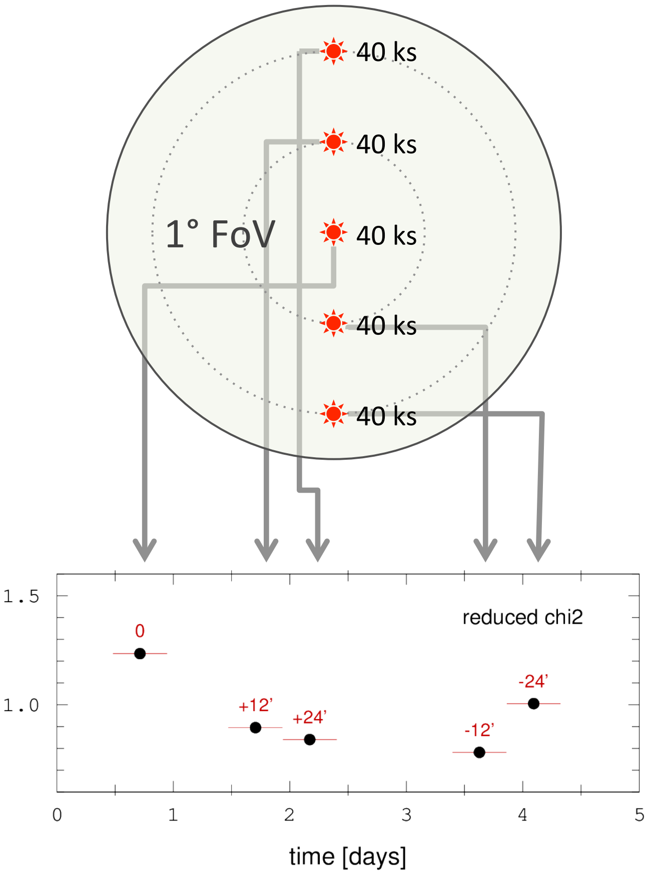


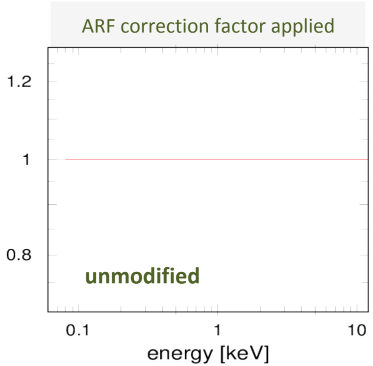


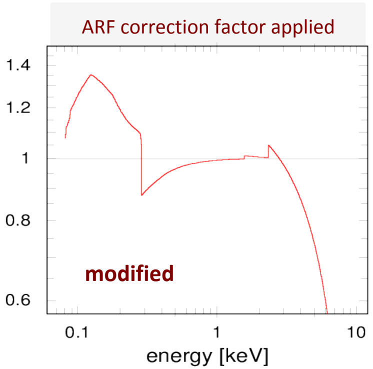
PG 1634: fit quality obtained with unmodified ARFs and RMF



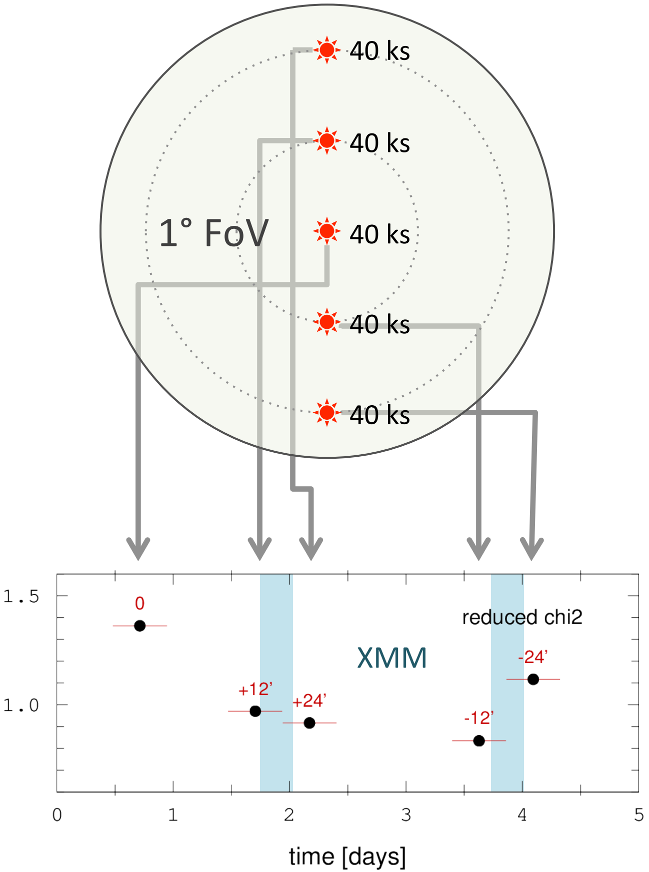
PG 1634: fit quality obtained with modified ARFs and RMF



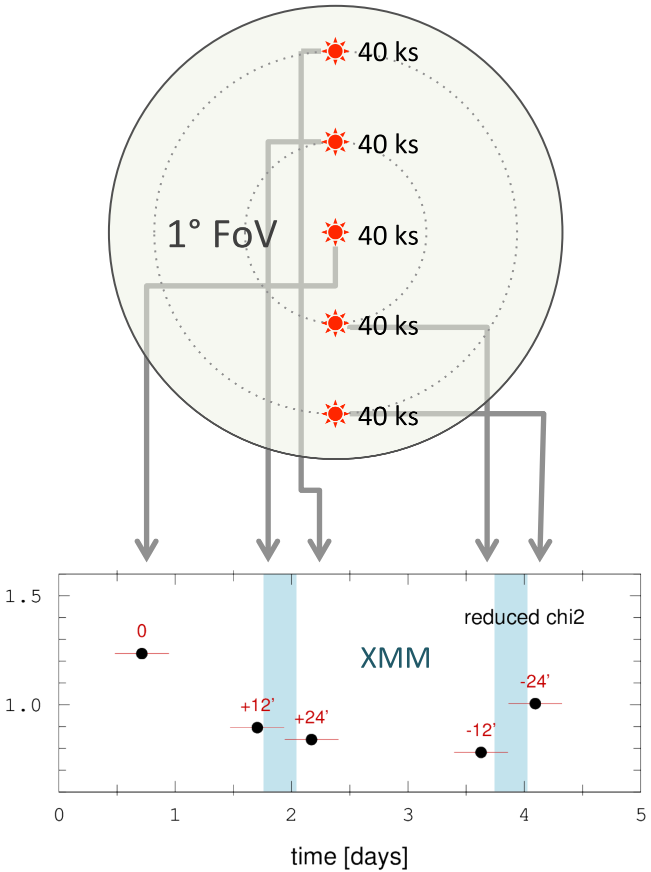


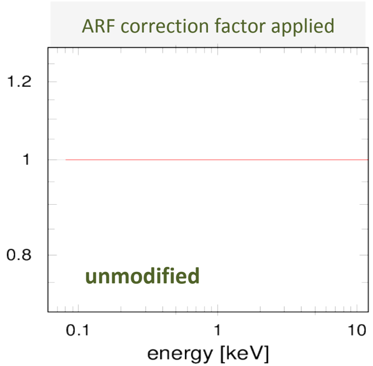


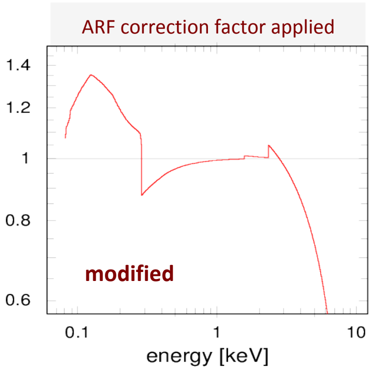
PG 1634: fit quality obtained with unmodified ARFs and RMF



PG 1634: fit quality obtained with modified ARFs and RMF







Comparison with XMM-Newton/EPIC-pn

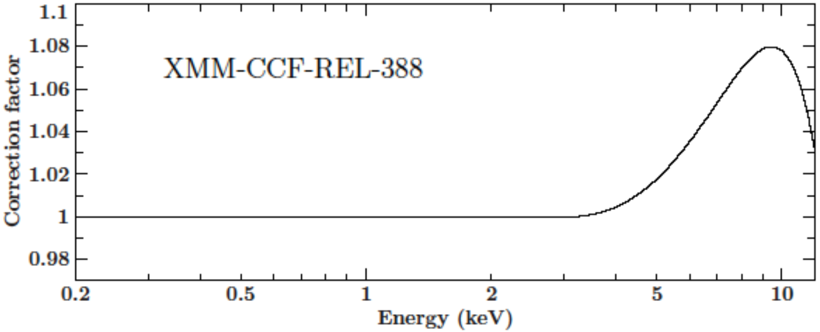


Figure 2: Final correction function to the EPIC-pn ARF description, taking into account the slope and shape difference to *NuSTAR* in the 3–12 keV band. These values are published in the `ABSCORRAREA` extension of `XRT3_XAREAEF_0014.CCF`.

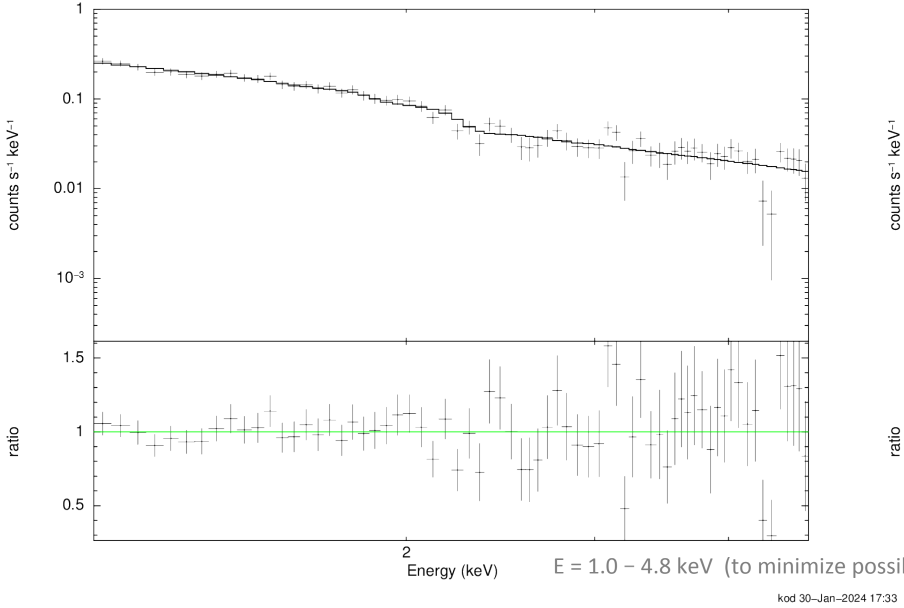
As of SAS 20.0 a new keyword `applyabsfluxcorr` is available, which will provide corrections to the effective area removing residuals between simultaneous fits of PN and NuSTAR observations. The correction is based on simultaneous calibration observations between both observatories. These corrections 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

with default ARF

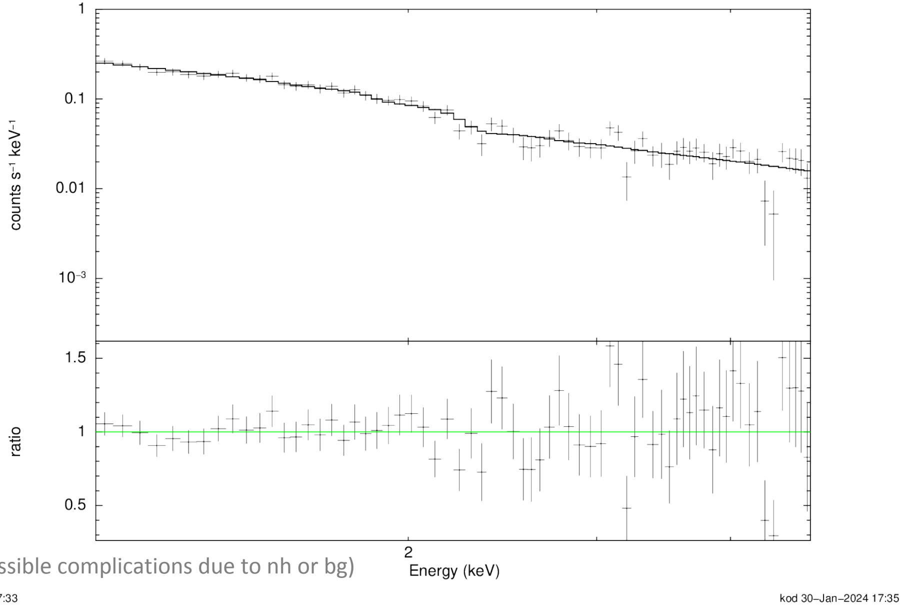


χ_ν^2 = 64.66 / 69

PhoIndex = 1.627 ± 0.046

norm = 2.74e-4 ± 0.08e-4

with ‚Nustar' ARF



χ_ν^2 = 64.69 / 69

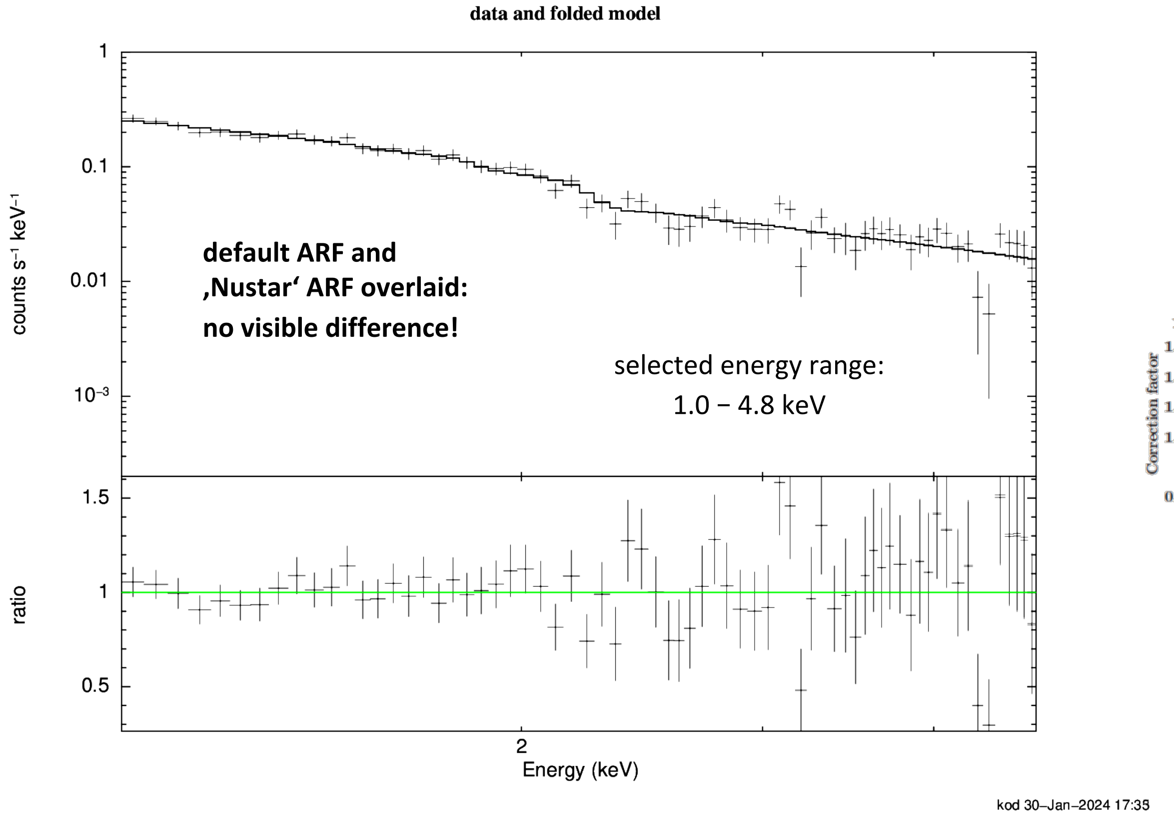
PhoIndex = 1.629 ± 0.046

norm = 2.75e-4 ± 0.08e-4

E = 1.0 – 4.8 keV (to minimize possible complications due to nh or bg)

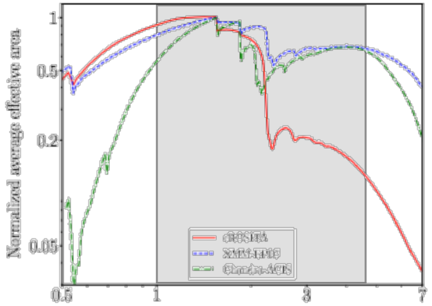
Comparison with XMM-Newton/EPIC-pn

obs 0852980301

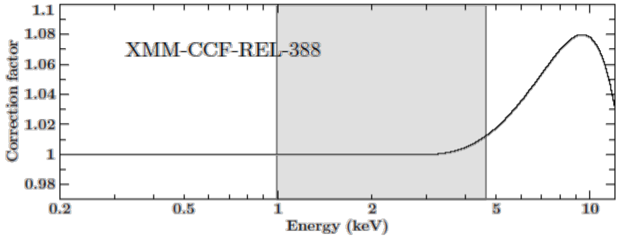


default ARF and ‚Nustar' ARF overlaid: no visible difference!

selected energy range: 1.0 – 4.8 keV

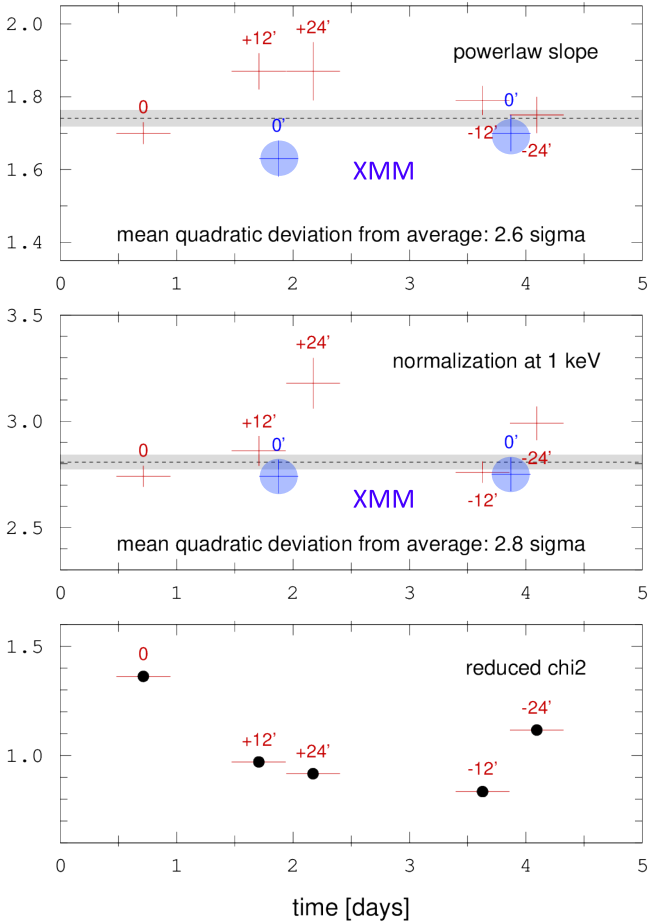


Migkas + 2024

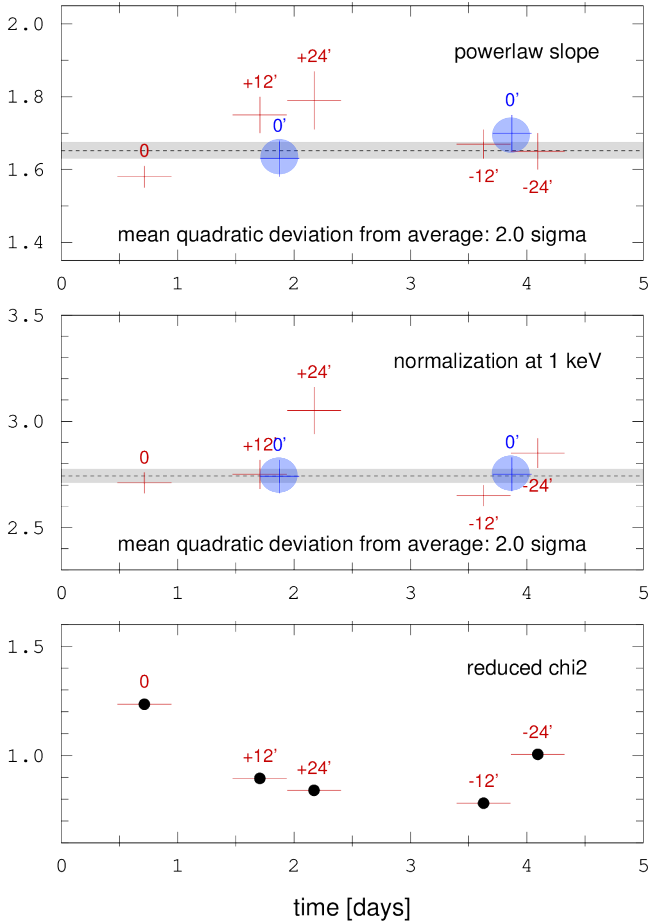


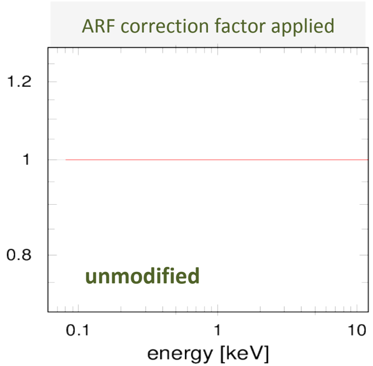
→ difference between default and ‚Nustar' ARFs not relevant for eROSITA!

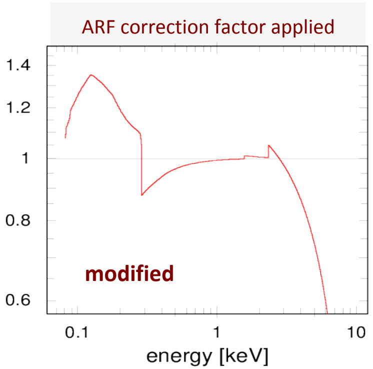
PG 1634: eROSITA and XMM/EPIC-pn with unmodified ARFs and RMF



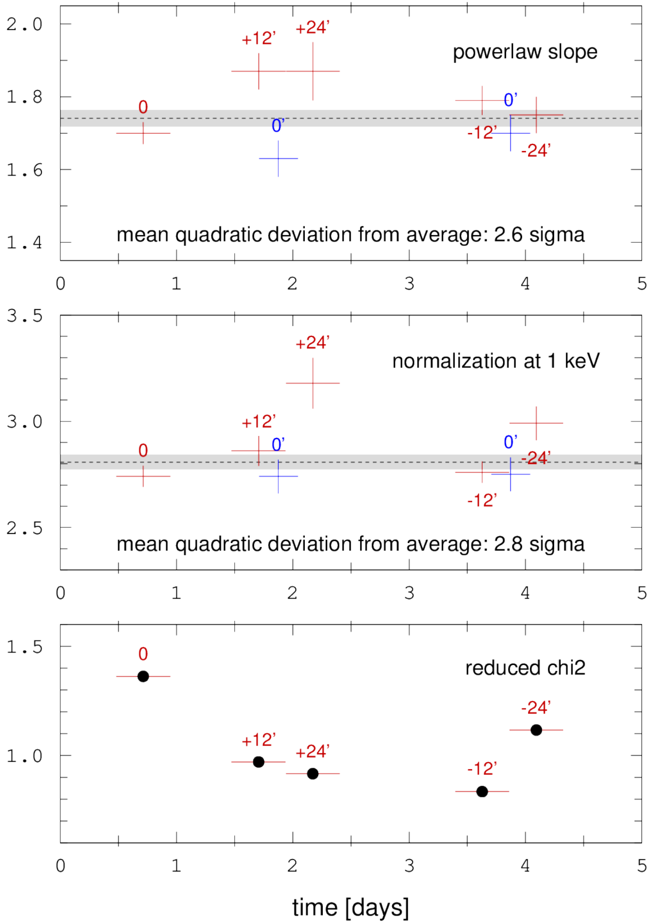
PG 1634: eROSITA and XMM/EPIC-pn with modified ARFs and RMF







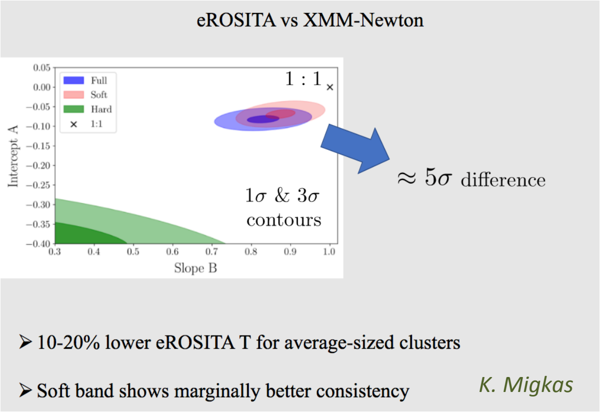
PG 1634: eROSITA and XMM/EPIC-pn with unmodified ARFs and RMF

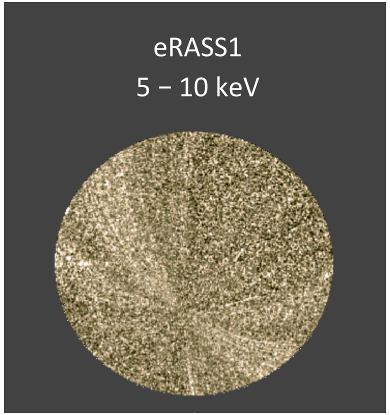


How significant is the „high energy issue" ?

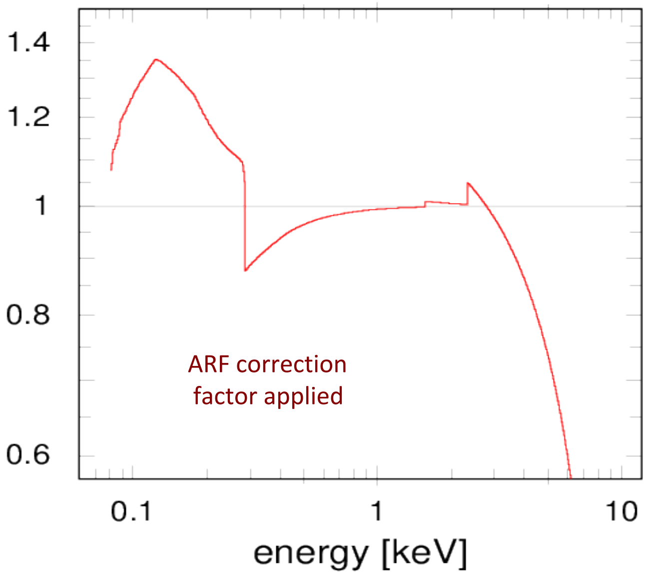
5 x 40 ks = **200 ks eROSITA** + 2 x 20 ks = **40 ks XMM** observations of PG 1634 exhibit only marginal differences within E = 1.0 − 4.6 keV, while above 5 keV eROSITA sees essentially only instrumental background

➢ how does this agree with the ≈ **5σ** difference found in galaxy cluster temperatures ?





→ scientifically more ‚reasonable' results with reduced ARF above 2.3 keV ..



- ✓ PG1634
- ✓ η Car
- ✓ cluster temperatures

.. but considerable modification required

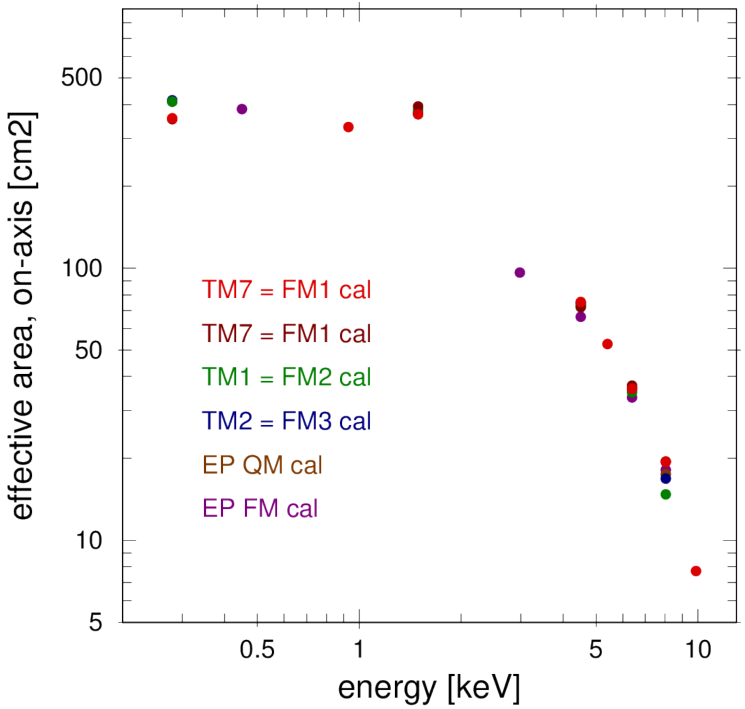
→ would such a reduction of the ARF be compatible with PANTER measurements ?

modification at low energies:

Al thickness: -12 nm (assumed density: 2.7 g cm^{-3})

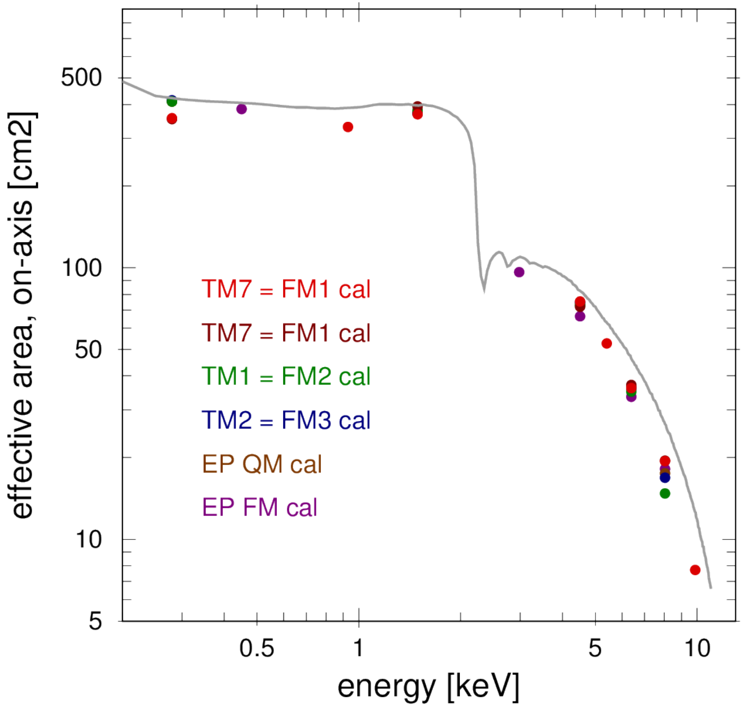
C thickness: +20 nm (assumed density: 2.2 g cm^{-3})

Effective area determination (PANTER, on-axis)



ARFs measured at PANTER

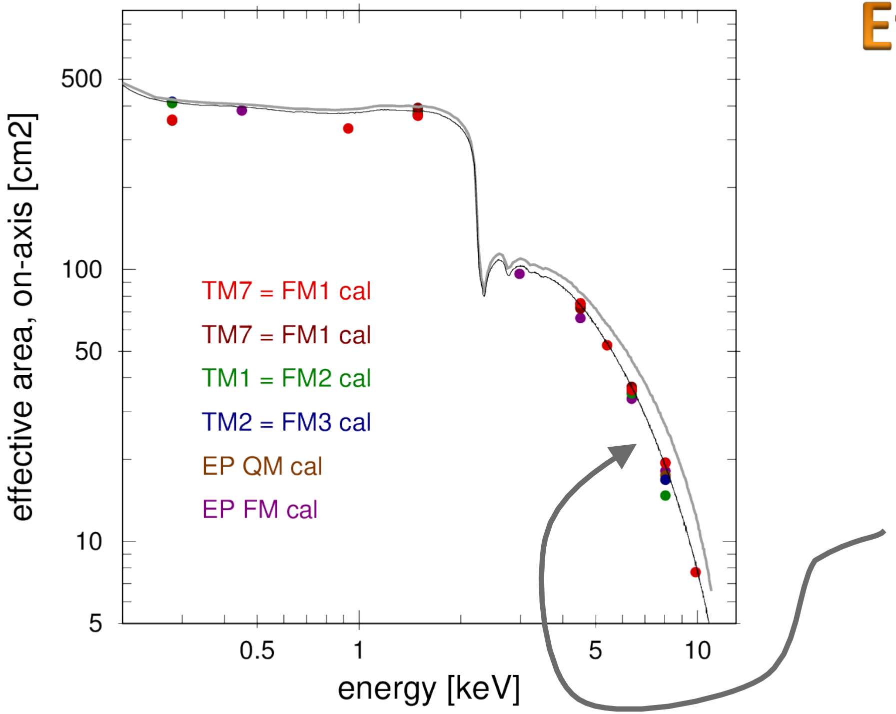
Effective area determination (PANTER, on-axis)



ARFs measured at PANTER

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

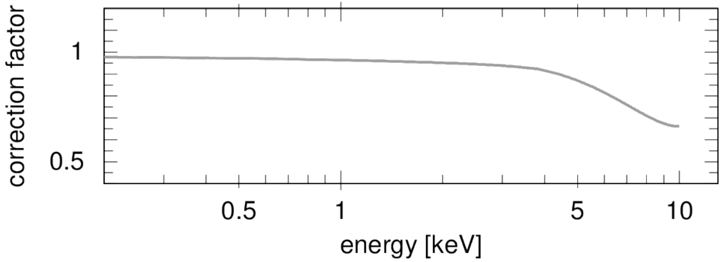
Effective area determination (PANTER, on-axis)



ARFs measured at PANTER

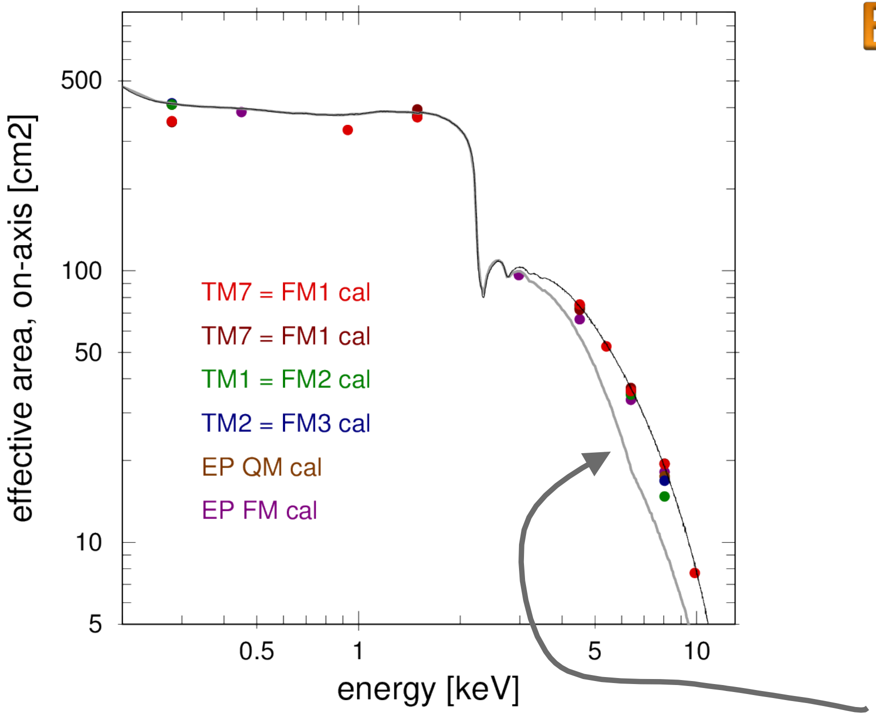
ARF from ray-tracing , computed for perfect optics (curve never used!)

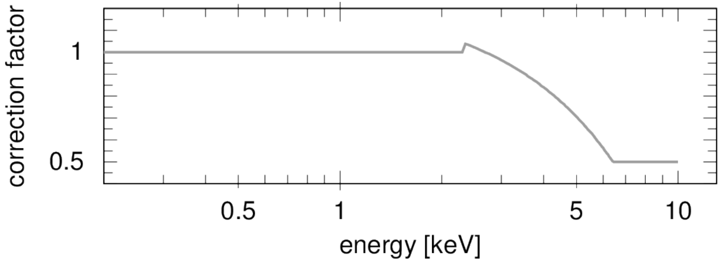
ARF which we are using in eSASS



correction function applied

Effective area determination (PANTER, on-axis)





ARFs measured at PANTER

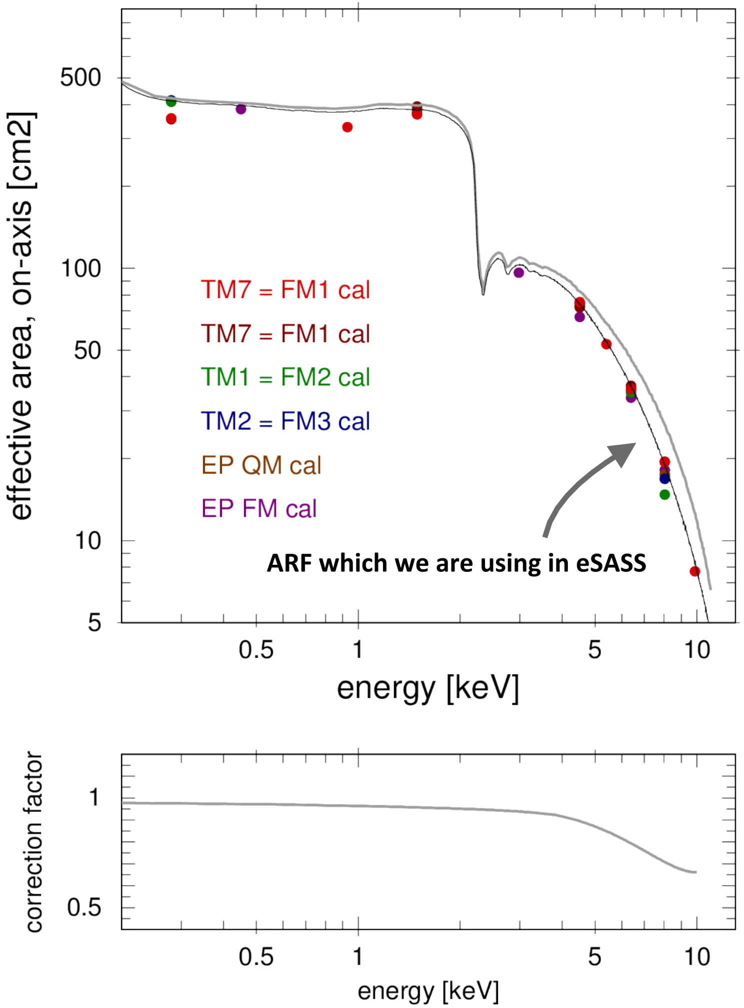
ARF from ray-tracing , computed for perfect optics (curve never used!)

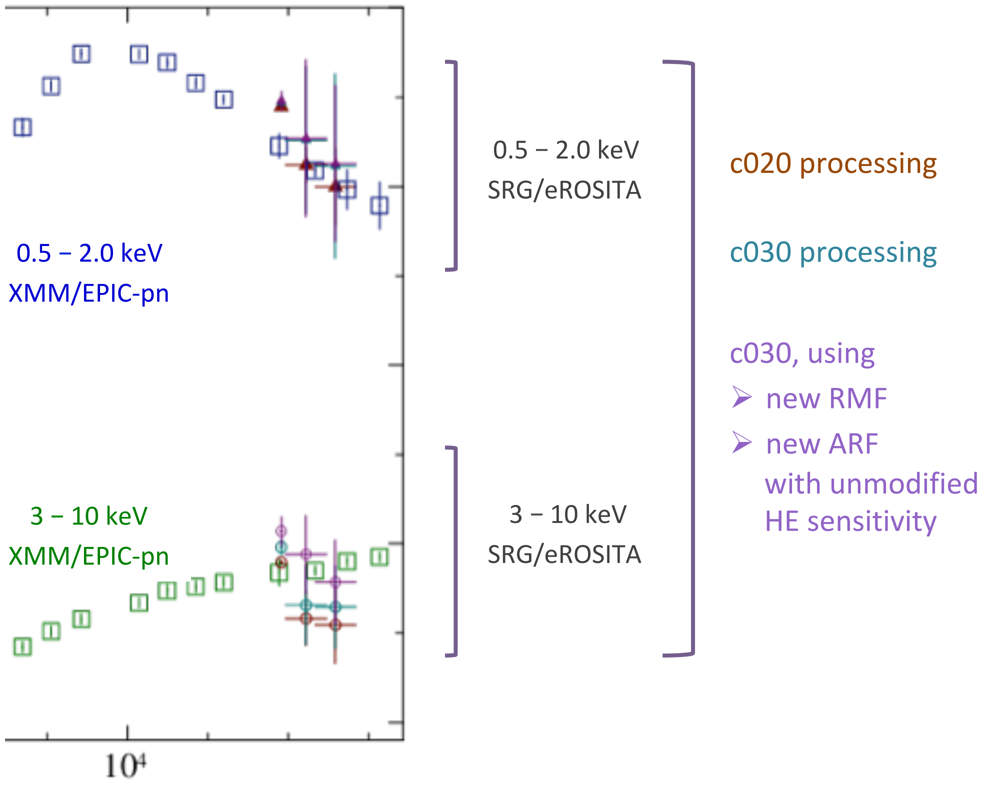
ARF which we are using in eSASS

ARF which would improve results for
- ✧ PG 1634
- ✧ η Car
- ✧ galaxy clusters (tbc)

correction function which would need to be applied

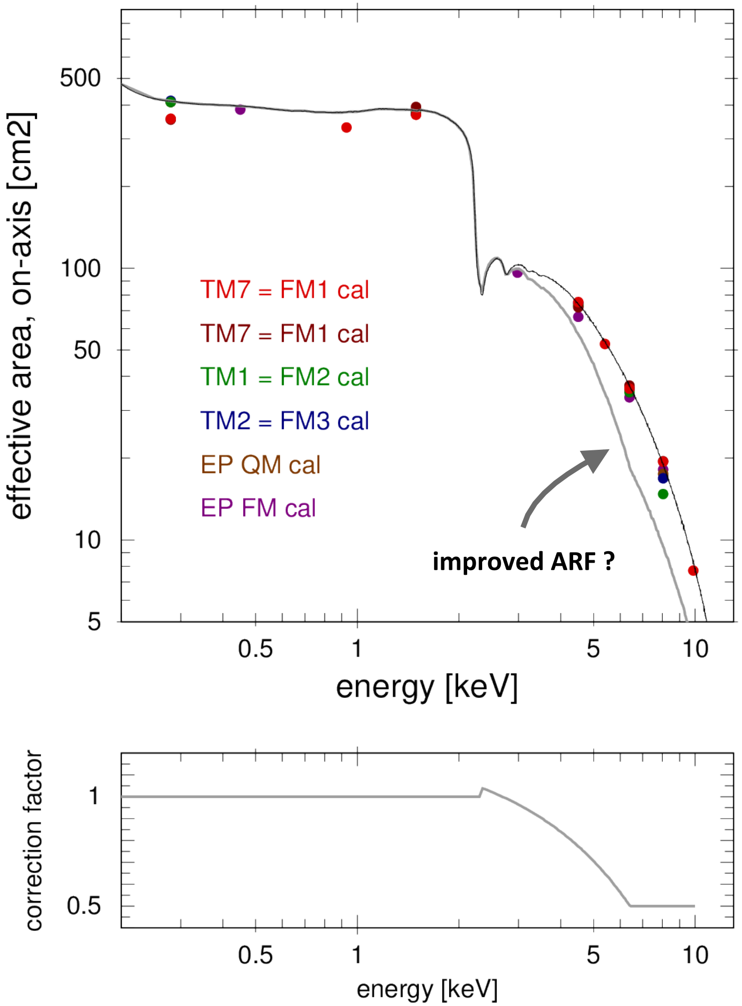
Monitoring SN 1987A with XMM and eROSITA

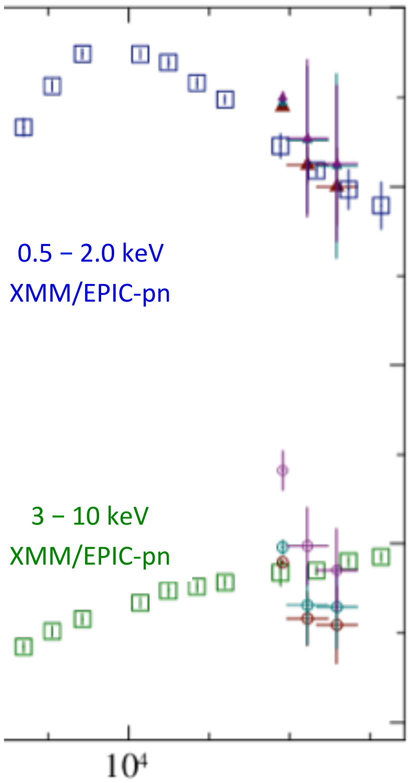




Chandreyee Maitra / MPE

Monitoring SN 1987A with XMM and eROSITA





0.5 – 2.0 keV
SRG/eROSITA

3 – 10 keV
SRG/eROSITA

c020 processing

c030 processing

c030, using

- new RMF
- new ARF with reduced HE sensitivity

Chandreyee Maitra / MPE

Physical justification of ARF modification at high energies

- ✧ PG 1634
- ✧ η Car
- ✧ galaxy clusters

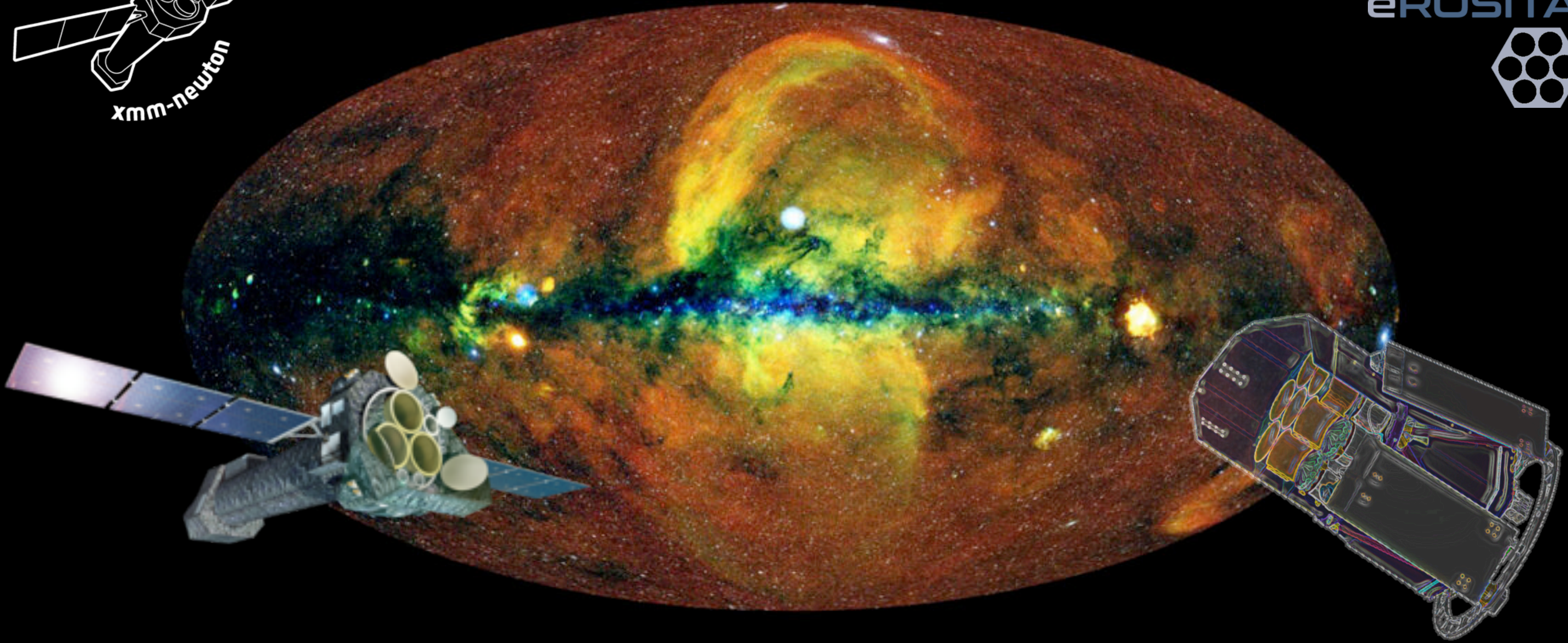
⇕

- ✧ SN 1987A

?

- ➢ 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



Parador de La Granja, Spain IACHEC, 2024 May 12 - 16 Konrad Dennerl, MPE