Status of

IACHEC Concordance

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(Chen+, 2019, JASA; Marshall+, 2021, *AJ*, 162, 254; Marshall+ in prep.)

The Goal

- The problems
  - Discrepant results from X-ray observatories in orbit
    - Cluster temperatures and fluxes
    - Blazar fluxes from simultaneous observations
    - SNR line fluxes
  - Imperfect ground cal, performance changes in flight
    - Instrument area priors a_i differ from "true values" A_i
  - No absolute calibrators across all bands in flight: no "true" F_j
- Specific task: derive $\hat{A}_i$ for optimal agreement

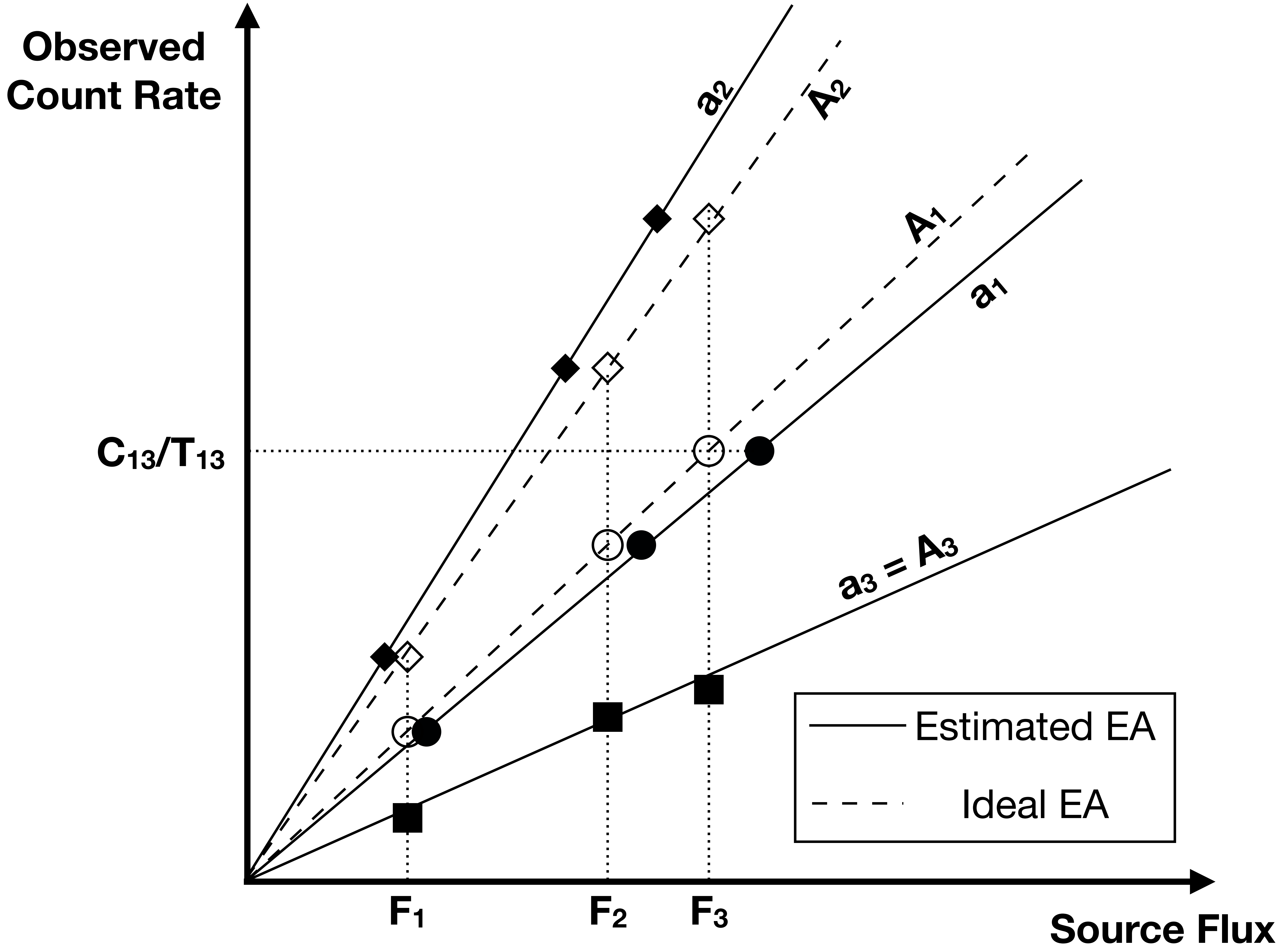
➡ Let flux $f_{ij} = c_{ij}/T_{ij}/a_i$

where a_i = prior on A_i

c_{ij} = observed counts

T_{ij} = known exposure time

The Problem, Graphically



Multiplicative Shrinkage

(Chen+ '19, JASA)

$$y_{ij} = B_i + G_j - \frac{\sigma_i^2}{2} + e_{ij} \quad , \quad y_{ij} \equiv \log(c_{ij}/T_{ij}) \quad , \quad B_i \equiv \log A_i \quad , \quad G_j \equiv \log F_j$$

$$\hat{B}_i = W_i(\bar{y}'_{i\cdot} - \bar{G}_i) + (1 - W_i)B_i \quad \text{and} \quad \hat{G}_j = \bar{y}'_{\cdot j} - \bar{B}_j$$

$$\tilde{y}'_{ij} = \tilde{y}_{ij} + 0.5\sigma_i^2 \ , \ \bar{y}'_{i\cdot} = \frac{\sum_{j=1}^{M} \tilde{y}'_{ij}\sigma_i^{-2}}{\sum_{j=1}^{M} \sigma_i^{-2}}, \quad \bar{y}'_{\cdot j} = \frac{\sum_{i=1}^{N} \tilde{y}'_{ij}\sigma_i^{-2}}{\sum_{i=1}^{N} \sigma_i^{-2}}, \quad \bar{G}_i = \frac{\sum_{j=1}^{M} \hat{G}_j\sigma_i^{-2}}{\sum_{j=1}^{M} \sigma_i^{-2}}, \quad \bar{B}_j = \frac{\sum_{i=1}^{N} \hat{B}_i\sigma_i^{-2}}{\sum_{i\in I_j} \sigma_i^{-2}}$$

$$W_i = \frac{M\sigma_i^{-2}}{\tau_i^{-2} + M\sigma_i^{-2}}$$

EA prior uncertainties

Data uncertainties

Previously: Assigning Priors

- Collecting ***prior*** (fractional) uncertainties on effective areas
- Cal scientists assessed their instruments

Table 1. Effective Area Uncertainty Priors (τ_i)[a]

	Energy Bands (keV)								
Instrument	0.15-0.33	0.33-0.54	0.54-0.8	0.8-1.2	1.2-1.8	1.8-2.2	2.2-3.5	3.5-5.5	5.5-10
Astrosat SXT	···	15	15	10	10	10	10	10	10
Chandra ACIS	3	3	3	3	2.6	3.3	3.3	4.9	5
Chandra HETGS	···	···	10	5	4	4	4	5	7
Chandra LETGS	5	7	7	7	7	7	7	10	10
ROSAT PSPC	10	10	10	10	10	10	···	···	···
Suzaku XIS1	···	20	15	10	10	15	5	5	5
Suzaku XIS0,2,3	···	···	15	10	10	15	5	5	5
Swift PC/WT	···	15	10	7.5	7.5	10	5	5	5
XMM MOS1,2	20	10	6	6	6	6	6	6	10
XMM pn	2	2	2	2	2	2	2	2	3
XMM RGS	···	8	5	5	5	···	···	···	···

[a]The τ_i values are given as percentages. The ellipses indicate bandpasses where the instrument has an insignificant effective area.

Table 2. Effective Area Uncertainty Priors (τ_i)[a]

	Energy Bands (keV)						
Instrument	2.2-3.5	3.5-5.5	5.5-10	15-25	25-50	50-100	100-300
Astrosat CZTI	···	···	···	··· 20	20	20	25
Astrosat LAXPC	···	15	15	15	15	20	···
INTEGRAL IBIS	···	···	···	···	8	15	20
INTEGRAL SPI	···		···	···	5	5	5
NuSTAR	···	4	3	3	15	20	···
RXTE PCA	5	10	3	3	10	50	···
RXTE HEXTE	···	···	···	5	5	5	···
Suzaku HXD	···	···	···	20	20	20	20
Swift BAT	···	···	···	15	4	4	12

[a]The τ_i values are given as percentages.

Input Data

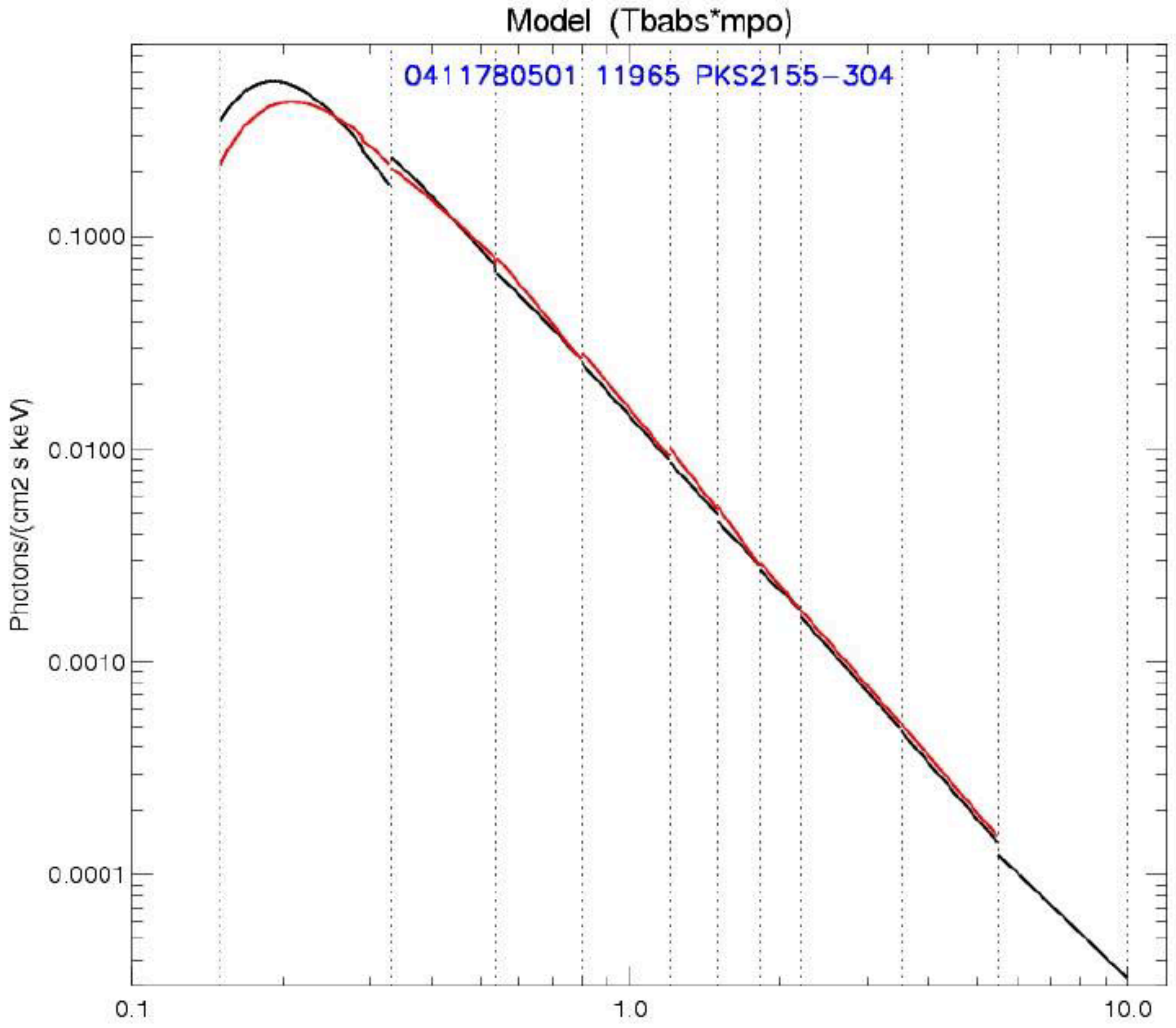
- Paper 1 (Chen+, 2019, JASA)
  - 1E0102 with 13 instruments (N=13), O & Ne (M=2)
  - 2XMM catalog targets, N=3, M=41; soft, medium, hard
  - XCAL bright targets, N=3, M=94-108; soft, medium, hard
- Paper 2 (Marshall+, 2021, *AJ*, 162, 254)
  - Same 3 sets as in Paper 1
  - Also Capella with Chandra gratings, N=8, M=15
  - Added correlations of XMM hard, medium, soft
  - Added corrlations of O, Ne fluxes of 1E0102
  - Used heterogeneous tau values

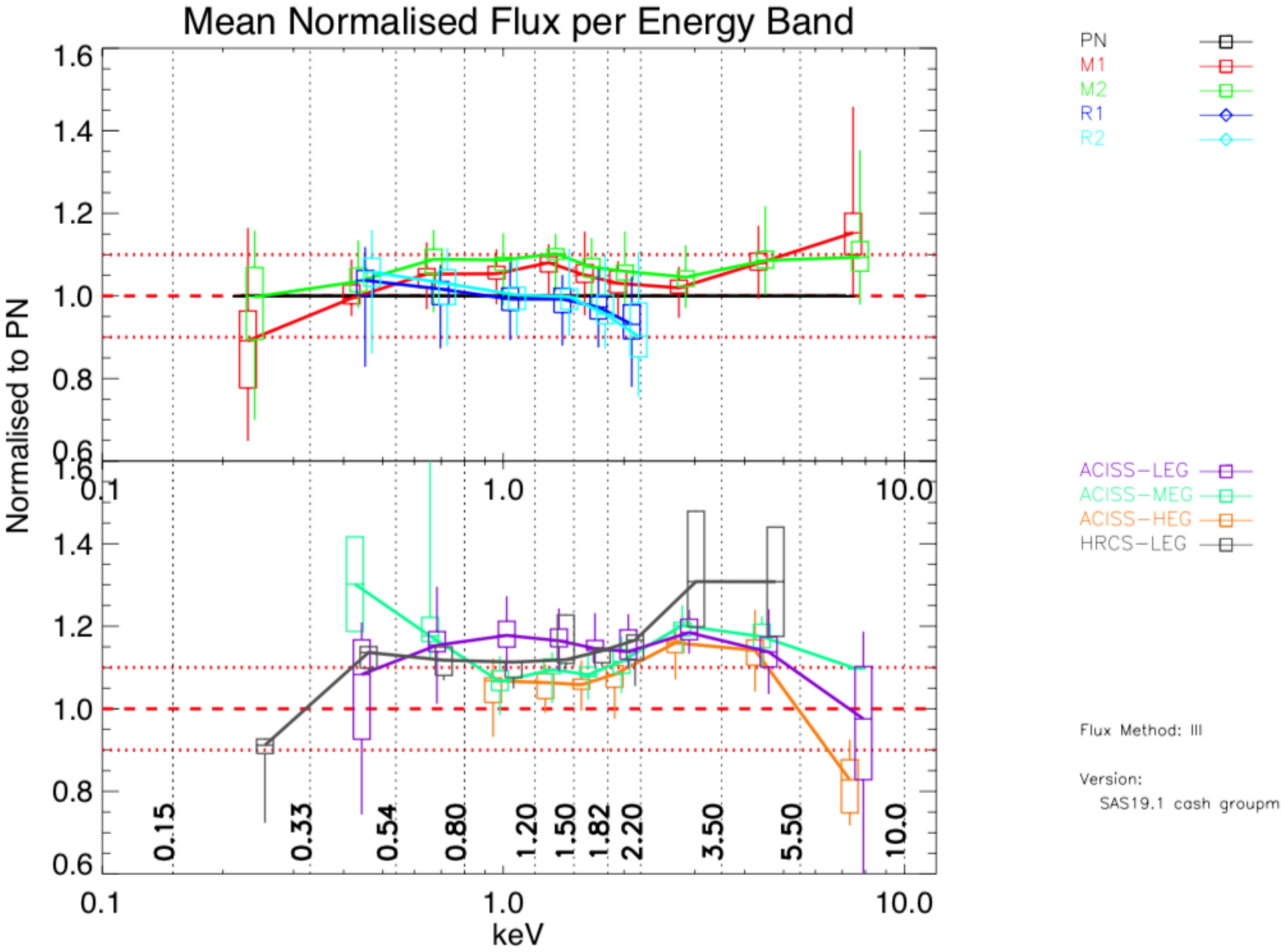
Table 5. *2XMM* Concordance Fluxes – Medium Band[a]

Target	pn		MOS1		MOS2	
	f_{ij}	σ_{ij}	f_{ij}	σ_{ij}	f_{ij}	σ_{ij}
1127-145	0.481	0.049	0.496	0.053	0.490	0.052
1E0919+515	0.053	0.053	0.069	0.066	0.068	0.065
4C06.41	0.131	0.015	0.142	0.017	0.143	0.018
APM08279+5255	0.085	0.041	0.088	0.042	0.082	0.040
CenX-4	0.088	0.035	0.089	0.022	0.091	0.023
CoD-33 7795	0.275	0.136	0.287	0.143	0.276	0.136
ESO323-G077	0.425	0.184	0.438	0.202	0.439	0.203
GRB080411	0.348	0.006	0.415	0.008	0.419	0.009
Holmberg IX	0.514	0.083	0.517	0.084	0.556	0.090
IRAS13197-1627	0.938	0.818	0.914	0.793	1.000	0.873
LBQS1228+1116	0.154	0.009	0.156	0.010	0.162	0.010
M31 NN1	0.173	0.005	0.196	0.007	0.195	0.007
MS0205.7+3509	0.283	0.087	0.304	0.095	0.293	0.092
MS1229.2+6430	0.326	0.086	0.356	0.092	0.355	0.101
NGC 1313	0.200	0.021	0.212	0.023	0.215	0.023
NGC 4278	0.281	0.032	0.291	0.035	0.307	0.037
NGC 5204 X-1	0.140	0.032	0.140	0.033	0.148	0.036
NGC 5204 X-1	0.192	0.034	0.195	0.035	0.196	0.036
NGC 5252	0.326	0.092	0.327	0.095	0.328	0.091

Sample Data (Marshall+ 2021)

Paper 3: XMM/Chandra XCAL

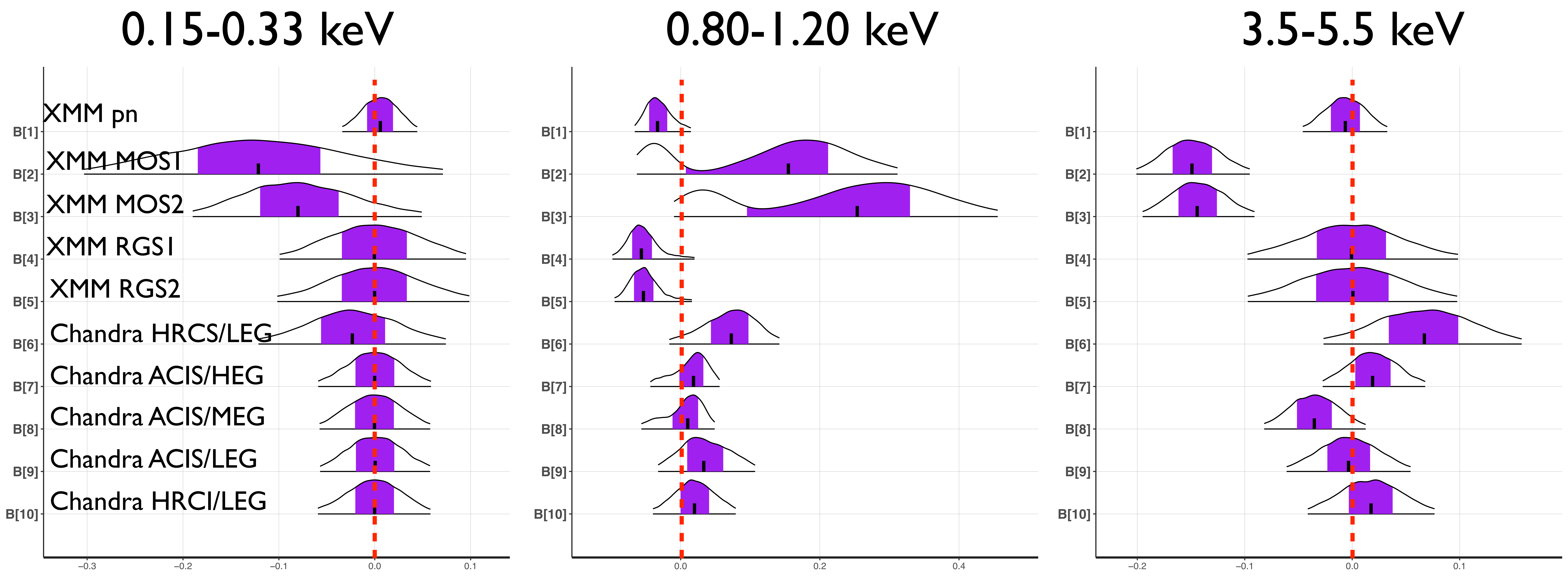




XCAL Time-Dependence

Default **before** SAS22

First Run (IACHEC 2024)

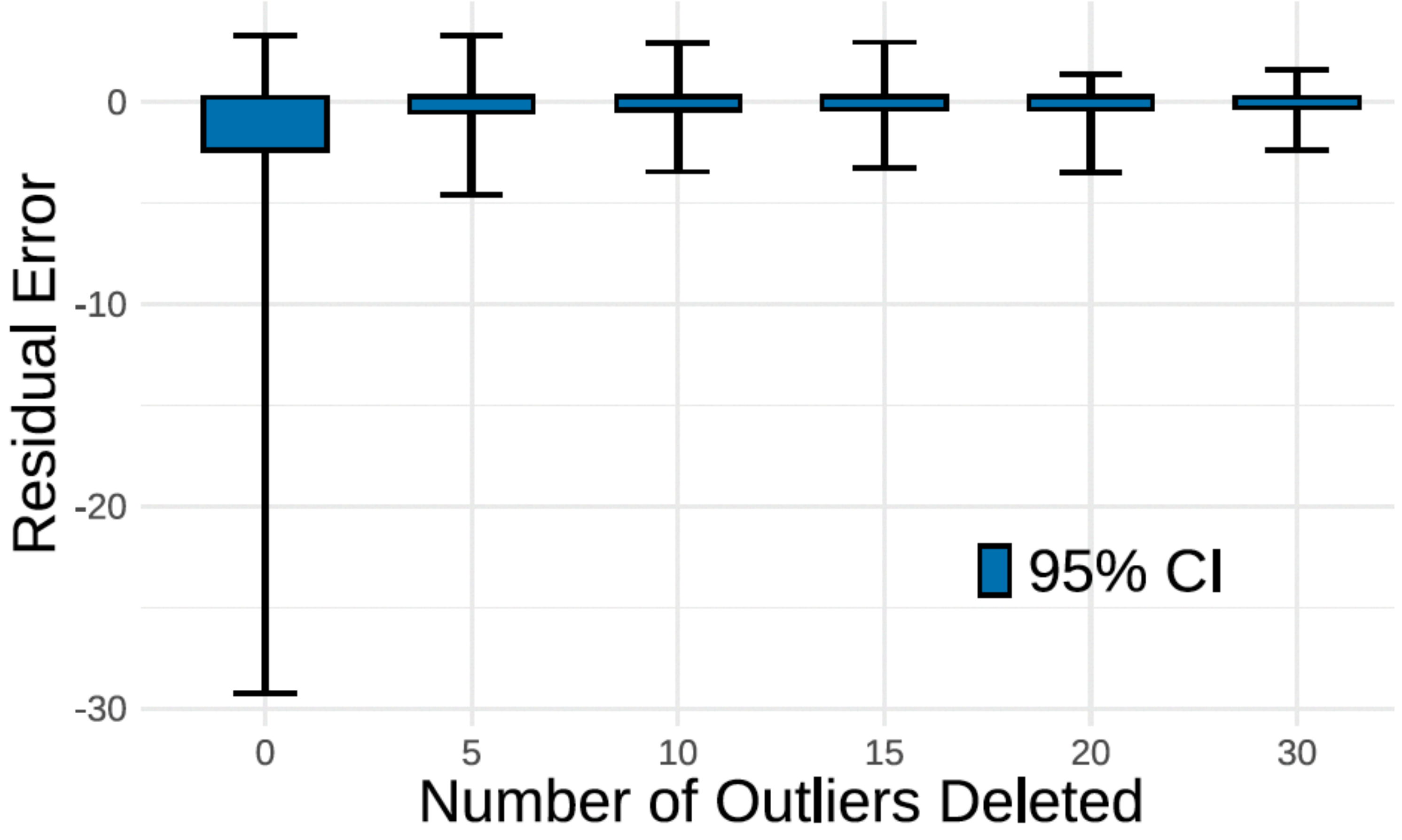


Progress on Paper 3

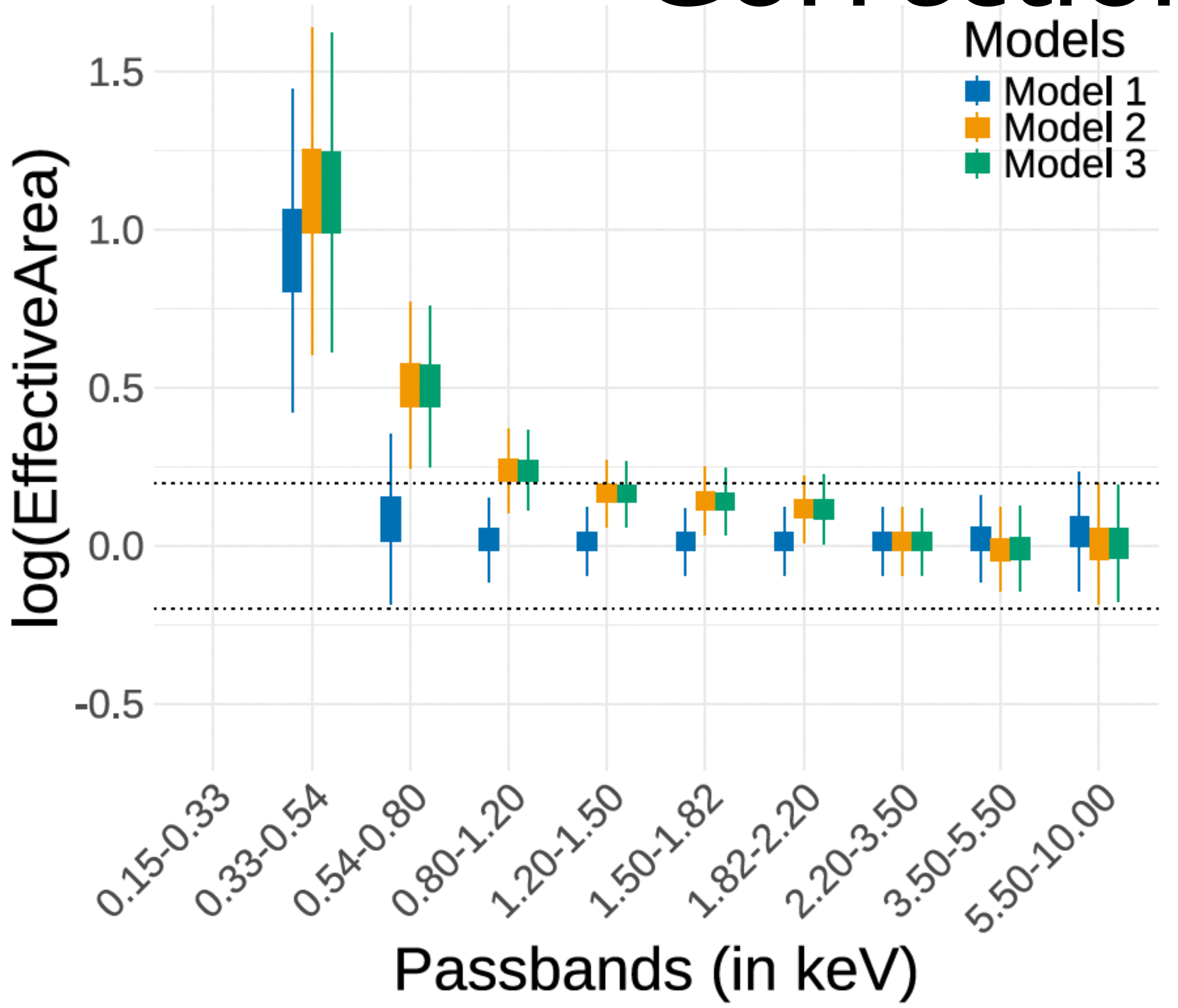
- Data prepared for analysis
- First analysis: same as used on 1E0102 (Marshall+ '22)
  - First run results (IACHEC 2024) are not very informative
  - Not all priors and EA correlations were used
  - No use of global spectral models
- New EA correlations computed using previous methods
- <u>Global</u> log-parabola spectral models to connect bandpass fluxes
- Tried time-dependence

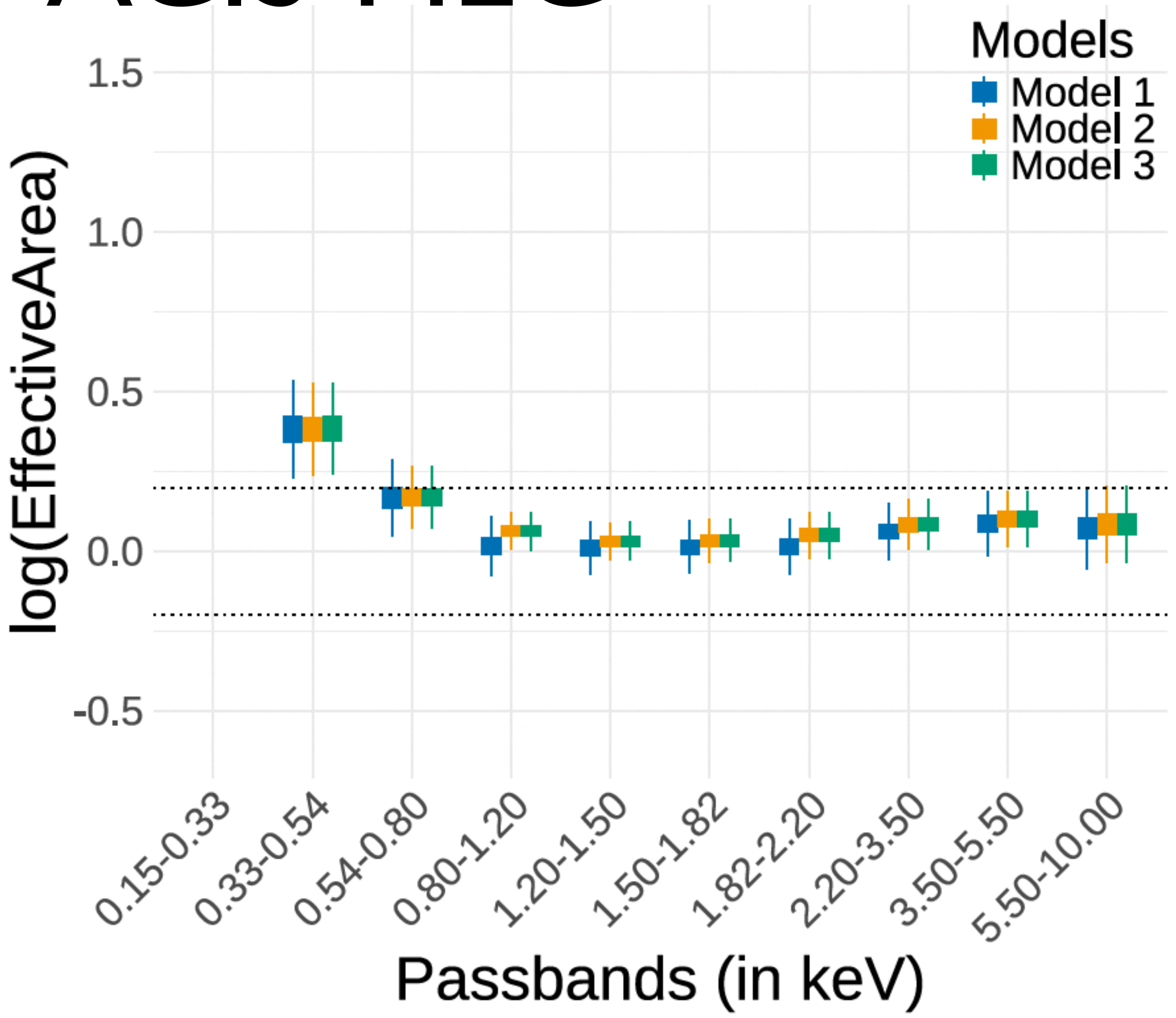
Progress on XCAL Blazars 1

- Need to remove outliers
  - Mostly MEG, 0.33-0.54 keV band
  - High flux cases due to pn pileup
- ACIS-MEG improves after removing 10 outliers
  - Still has issues below 1 keV



Corrections for ACIS-MEG



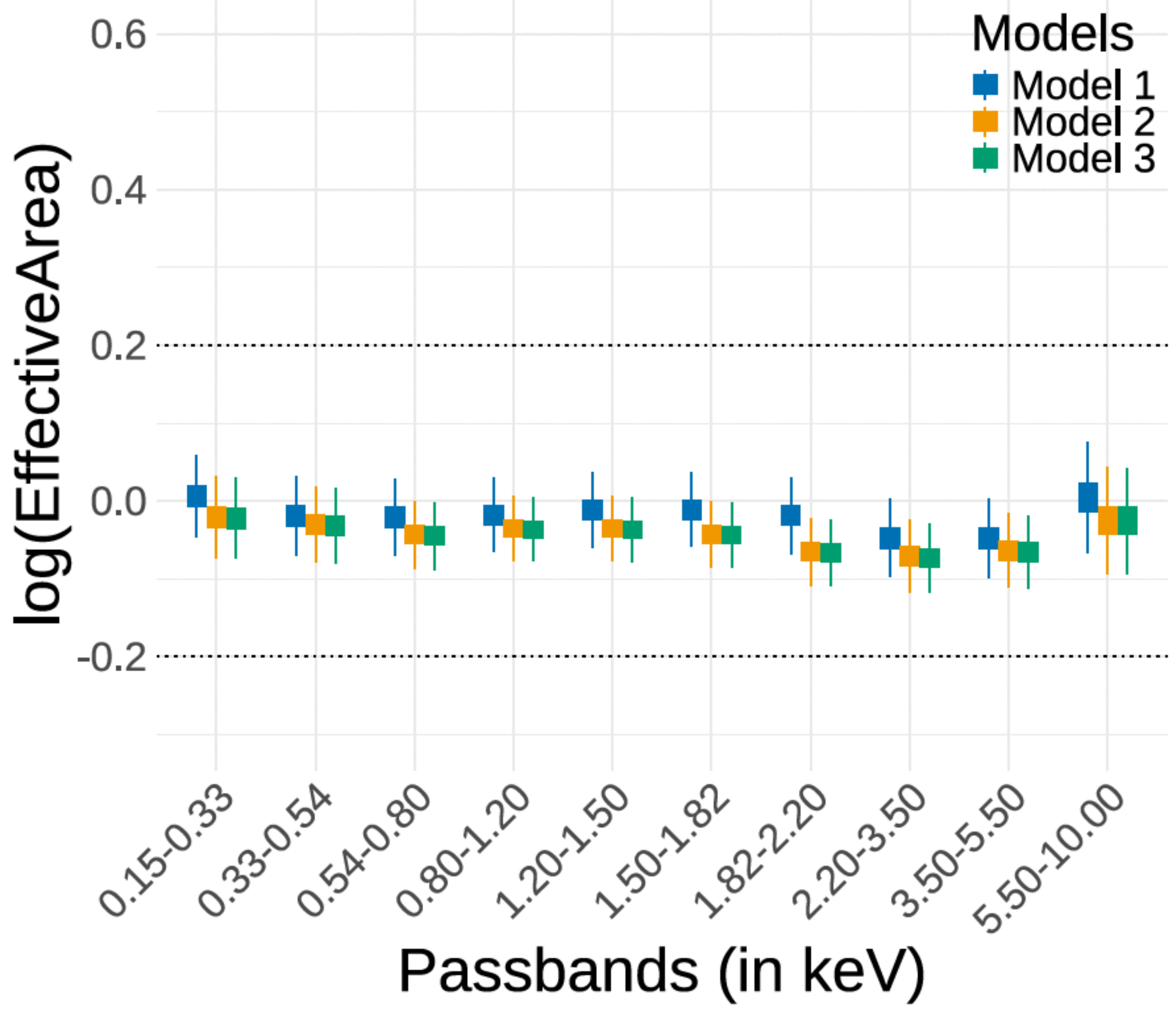


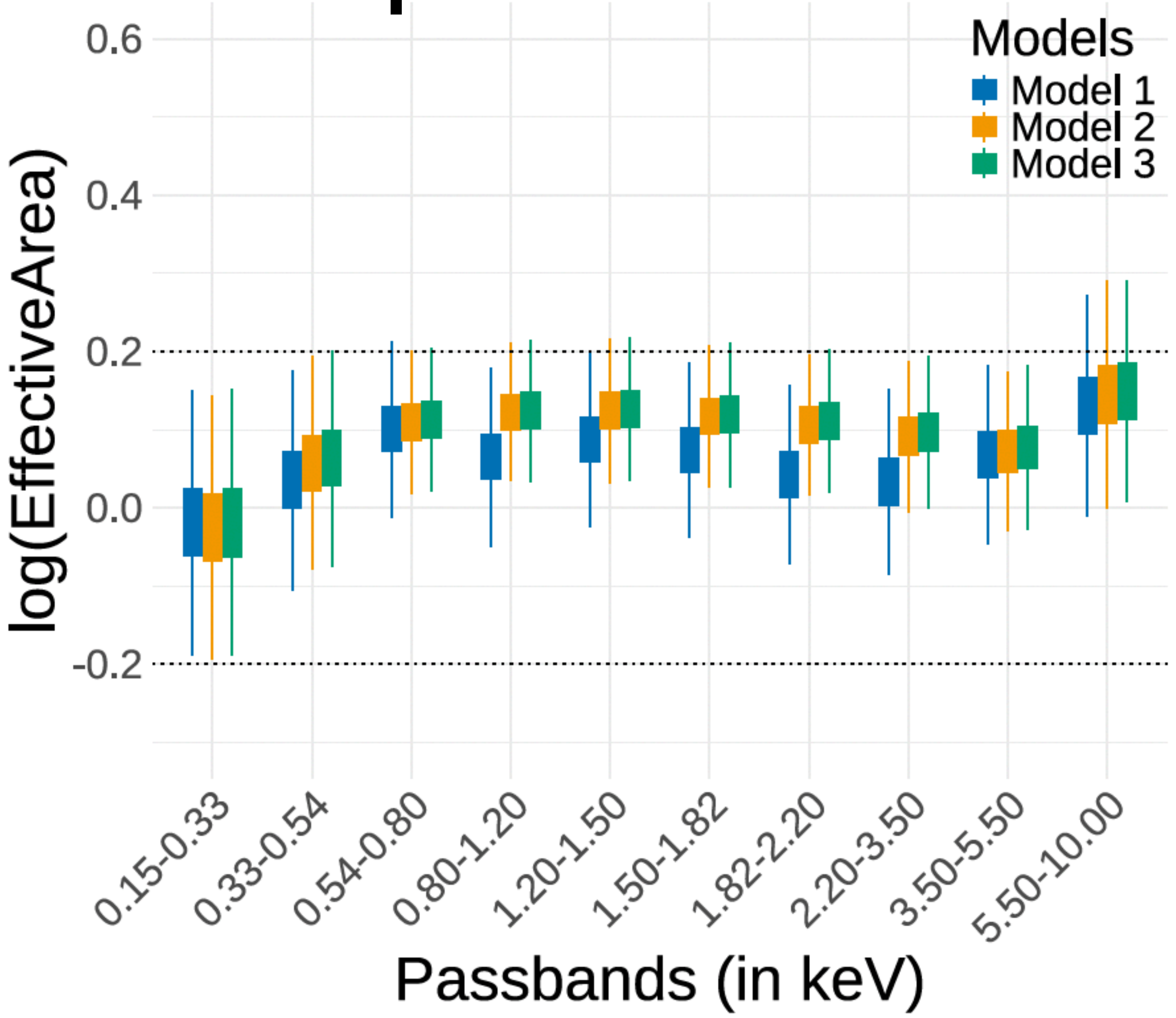
Concordance Status

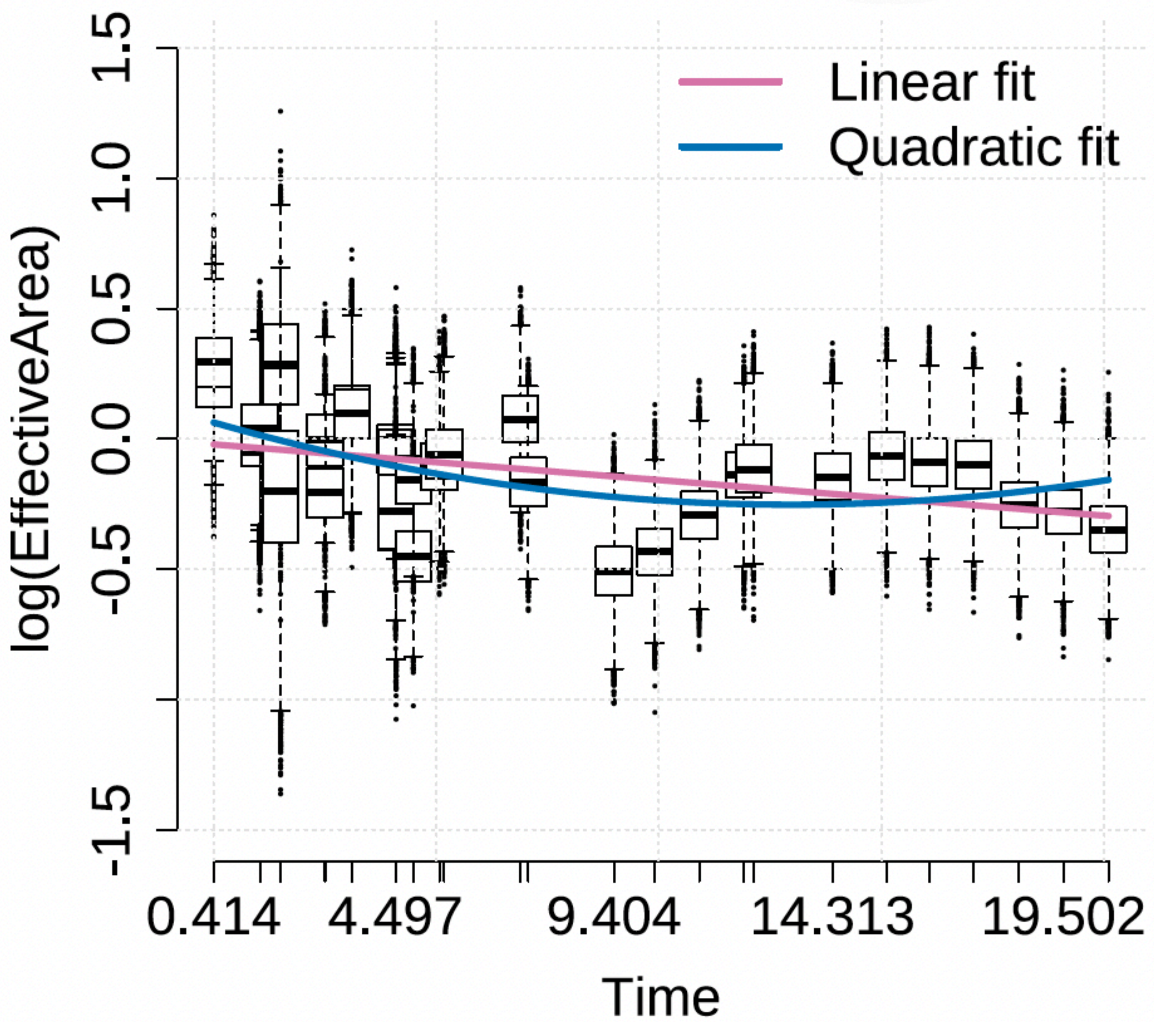
Progress on XCAL Blazars 2

- Preliminary results!
- Mild corrections may be needed for XMM pn
- Trying time dependence for all instruments
  - not working well
  - must refine models

Corrections for XMM pn





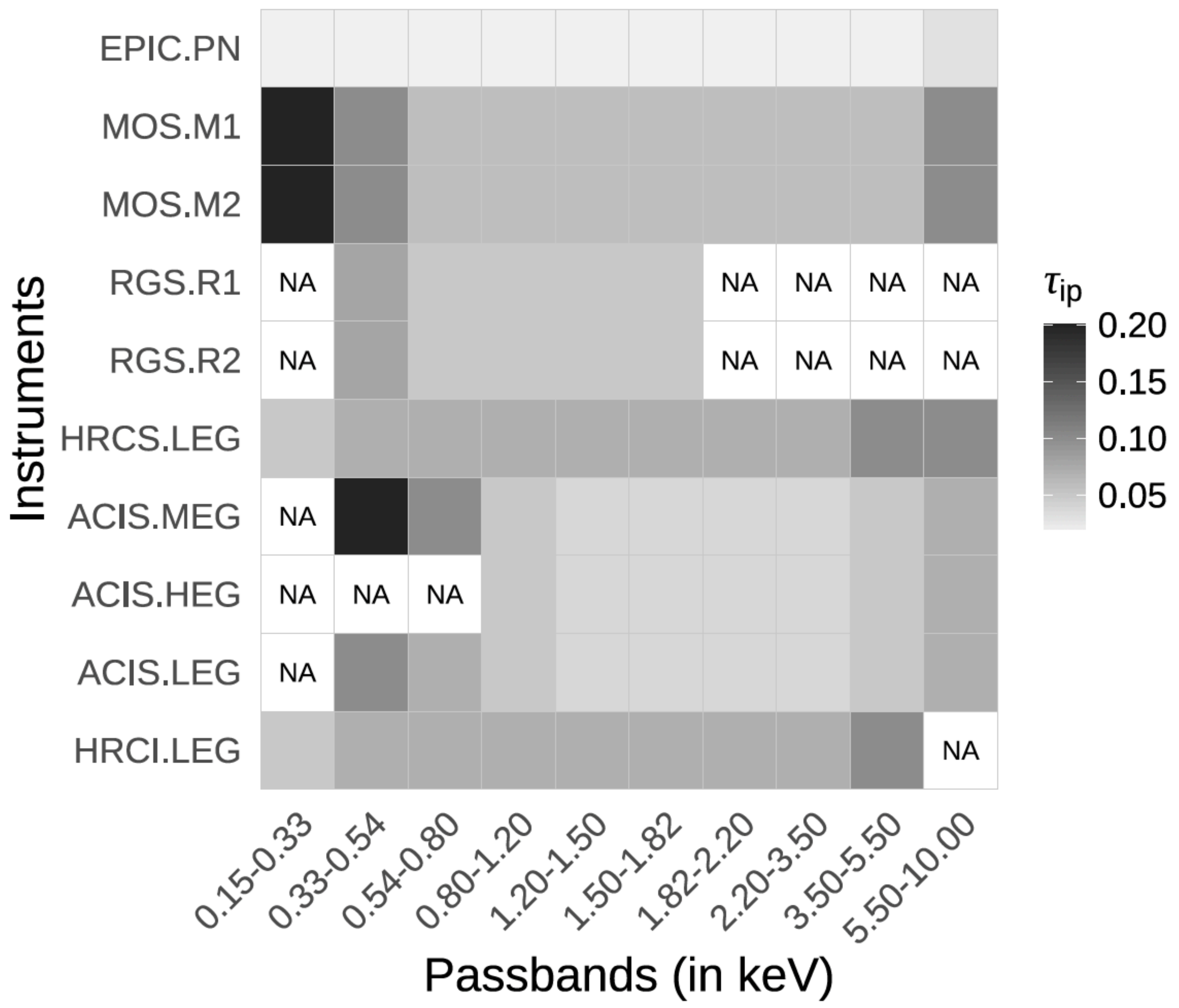


Time Dependence for XMM MOS2

Update Priors

Tau_Matrix (May 5, 2024)

	.15-.33	.33-.54	.54-.8	.8-1.2	1.2-1.5	1.5-1.8	1.8-2.2	2.2-3.5	3.5-5.5	5.5-10	15-25	25-50	50-100	100-300
XMM pn	2	2	2	2	2	2	2	2	2	3				
XMM M1	20	10	6	6	6	6	6	6	6	10				
XMM M2	20	10	6	6	6	6	6	6	6	10				
XMM R1		8	5	5	5	5								
XMM R2		8	5	5	5	5								
Chandra HRCS-LEG	5	7	7	7	7	7	7	7	10	10				
Chandra ACIS-MEG		20	10	5	4	4	4	4	5	7				
Chandra ACIS-HEG				5	4	4	4	4	5	7				
Chandra ACIS-LEG	10	10	7	5	4	4	4	4	5	7				
Chandra HRCI-LEG	5	7	7	7	7	7	7	7	10	10				



Concordance Plans

- Finish XMM/Chandra XCAL analysis
  - Review outliers
  - Revisit τ values, loosen as needed
  - Publish as Paper 3
- Collect more data for Concordance
  - Cluster fluxes (narrower bands?)
  - Include Crab fluxes to 300+ keV!