Background treatment in spectral analysis of low surface brightness sources

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EPIC background
working group meeting

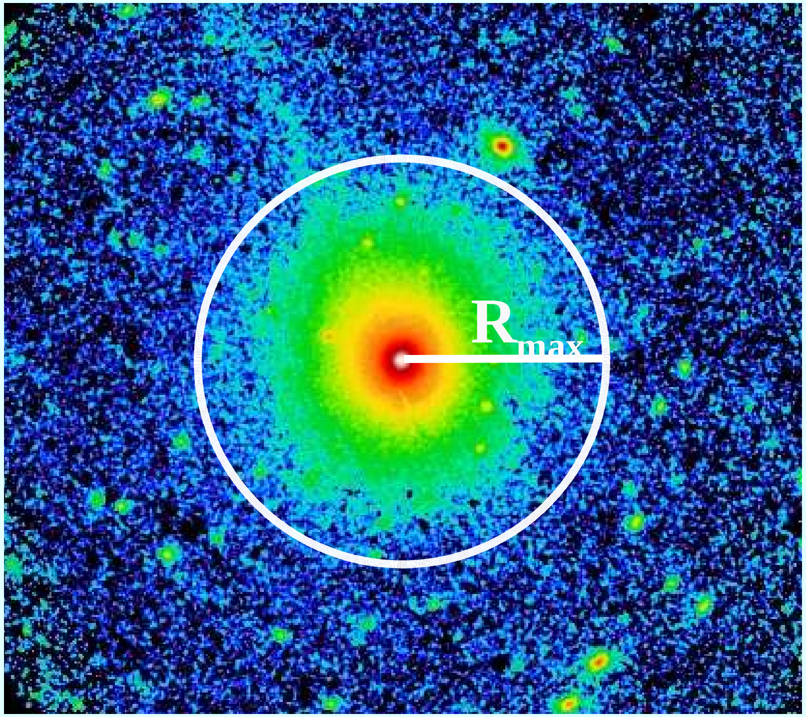
Garching, 2nd May 2006

SUMMARY

1. SPECTRAL ANALYSIS OF LOW SURFACE BRIGHTNESS SOURCES

4. BACKGROUND MODELING IN A HARD BAND (ABOVE 2 keV)

OUTER REGIONS OF CLUSTERS

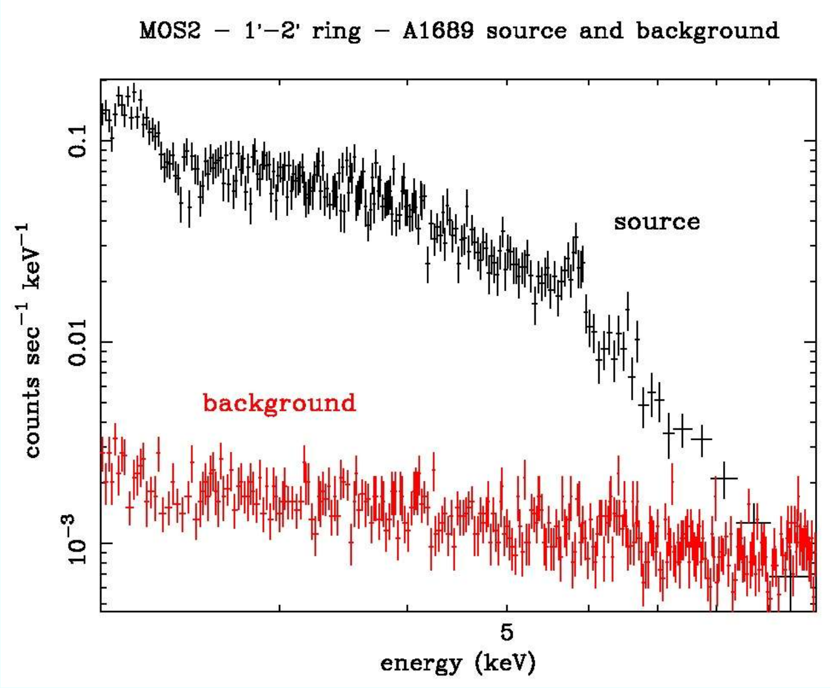


A1689
z = 0.183
kT ≈ 9 keV

ObsID 0093030101
Exposure time
36 ks (MOS)
29 ks (pn)

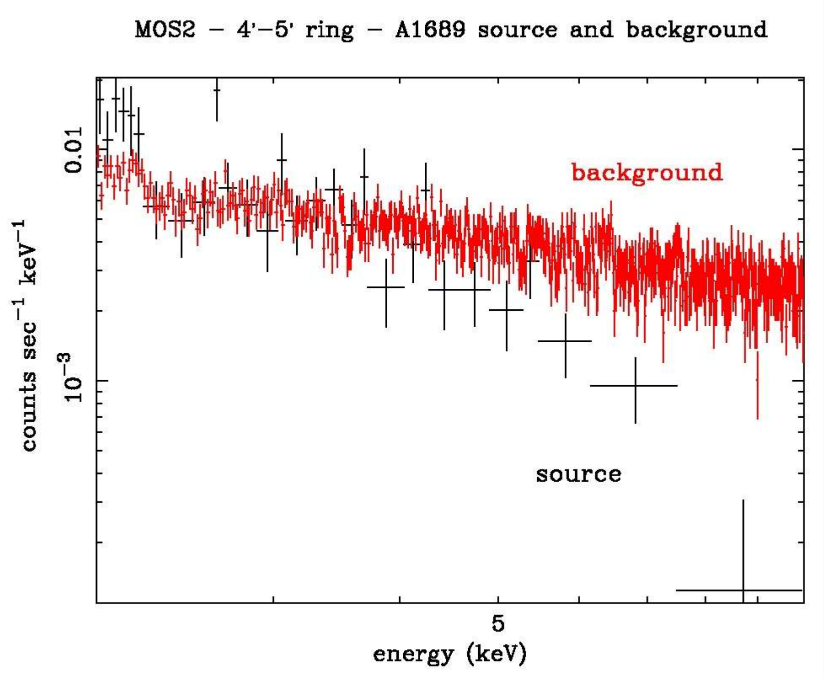
R_{max} = 5’ ≈ 0.9 Mpc ≈ 30% r_{180}

OUTER REGIONS OF CLUSTERS



Inner region

source >> background



Outer region

source ≈ background

SYSTEMATIC

UNCERTAINTIES

STATISTICAL (RANDOM)

UNCERTAINTIES

SYSTEMATIC

UNCERTAINTIES

STATISTICAL (RANDOM)

UNCERTAINTIES

SYSTEMATIC

UNCERTAINTIES

- **Cross-calibration MOS-pn**
- **Background knowledge**

SYSTEMATIC

UNCERTAINTIES

- **Cross-calibration MOS-pn**

relatively good in the hard band

2-10 keV

SYSTEMATIC

UNCERTAINTIES

- **Background knowledge**

NXB – continuum + fluorescence lines

SP – highly variable component

hard & soft light curves

+ IN FOV / OUT FOV ratio

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UNCERTAINTIES

- **Background knowledge**

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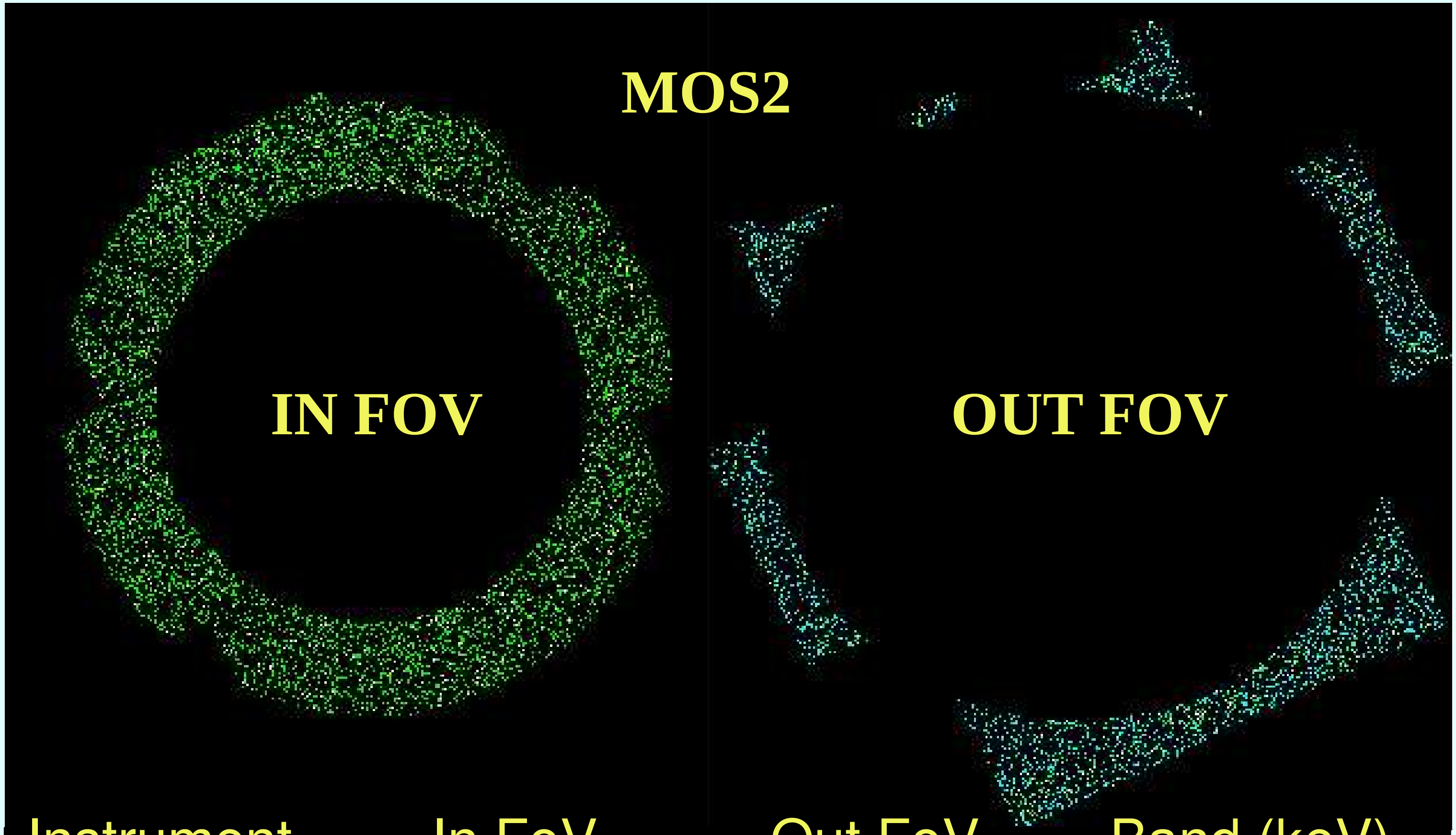
hard & soft light curves

+ IN FOV / OUT FOV ratio

(De Luca & Molendi, 2004)

IN FOV / OUT FOV DIAGNOSTIC



Instrument	In FoV	Out FoV	Band (keV)
MOS	R > 10’	R > 14’40”	6-12
pn	R > 10’	R > 15’50”	5-7.3 + 10-14

IN FOV / OUT FOV DIAGNOSTIC

$$R = \frac{SB_{inFOV}}{SB_{outFOV}} = \frac{counts_{inFOV}}{time_{inFOV} \; area_{inFOV}} \; \frac{time_{outFOV} \; area_{outFOV}}{counts_{outFOV}}$$

NO SP contamination → $R \approx 1$

LOW SP contamination → $R \leq 1.3$

HIGH SP contamination → $R \geq 1.3$

SYSTEMATIC

UNCERTAINTIES

STATISTICAL (RANDOM)

UNCERTAINTIES

What are the effects of the pure statistical uncertainties in determining interesting parameters, as temperature and density of the ICM, in the case of few counts/bin and a low S/N ratio, as in the outer regions of clusters of galaxies?

SIMULATION

GENERATION

ACCUMULATES “REAL” SPECTRUM

THERMAL + POWER LAW as BACKGROUND

SIMULATES N≈1000 DIFFERENT MEASURES

PERTURBING REAL SPECTRUM

WITH A POISSONIAN DISTRIBUTION

ANALYSIS

DIFFERENT METHODS

ANALYSIS METHODS

STANDARD

RENORMALIZED BACKGROUND SUBTRACTION

^{2} STATISTIC

WEIGHTED AVERAGE OF SINGLE MEASURES

STANDARD METHOD

TEMPERATURE (keV)		NORMALIZATION (arbitrary units)	
REAL	MEASURED	REAL	MEASURED
5.00	4.29 ± 0.02	5.50	5.27 ± 0.02
10.00	7.64 ± 0.06	5.50	5.38 ± 0.01

Temperature is UNDERESTIMATED by 15-25%

Normalization is UNDERESTIMATED by few percent

ANALYSIS METHODS

CASH + MODEL

BACKGROUND MODEL

CASH STATISTIC

WEIGHTED AVERAGE OF SINGLE MEASURES

CASH + MODEL METHOD

TEMPERATURE (keV)		NORMALIZATION (arbitrary units)	
REAL	MEASURED	REAL	MEASURED
5.00	4.45 ± 0.03	5.50	5.30 ± 0.02
10.00	7.9[illegible] ± 0.07	5.50	5.46 ± 0.01

Temperature is UNDERESTIMATED by 10-20%

Normalization is UNDERESTIMATED by few percent

ANALYSIS METHODS

BEST

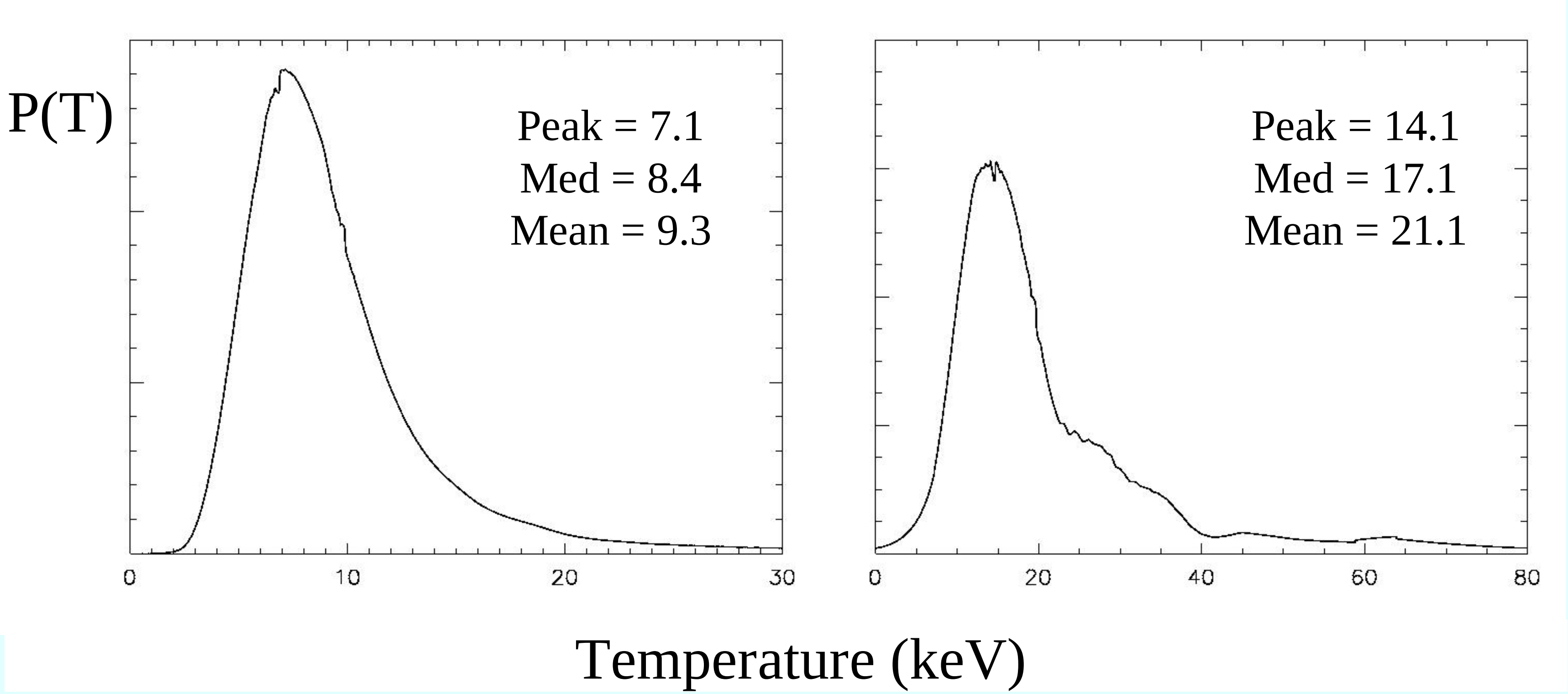
BACKGROUND MODEL

CASH STATISTIC

JOINED PROBABILITY DISTRIBUTION

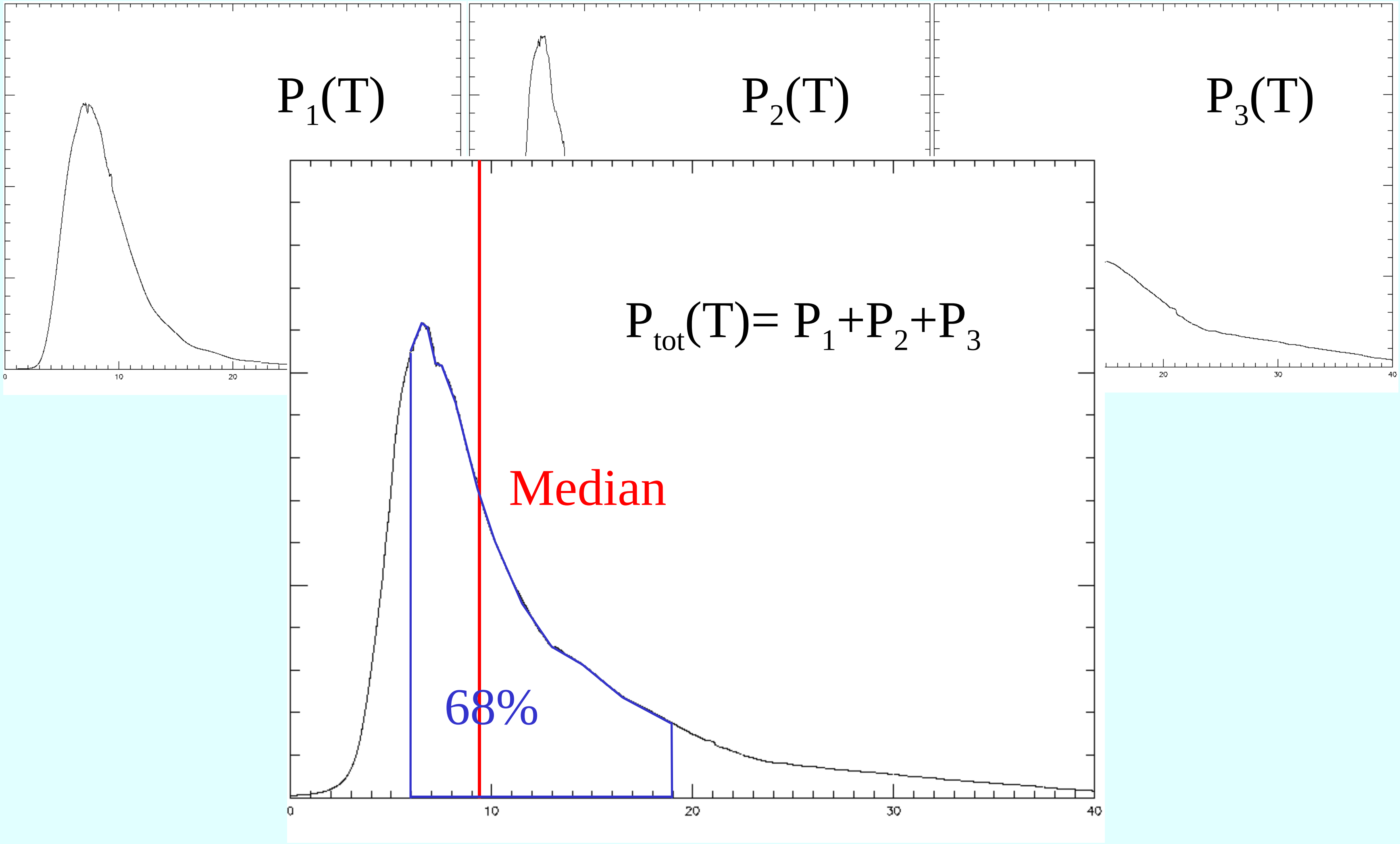
WEIGHTED AVERAGE OF “TRIPLETS”

ANALYSIS METHODS



Probability distributions of the temperature
are strongly ASYMMETRIC

ANALYSIS METHODS



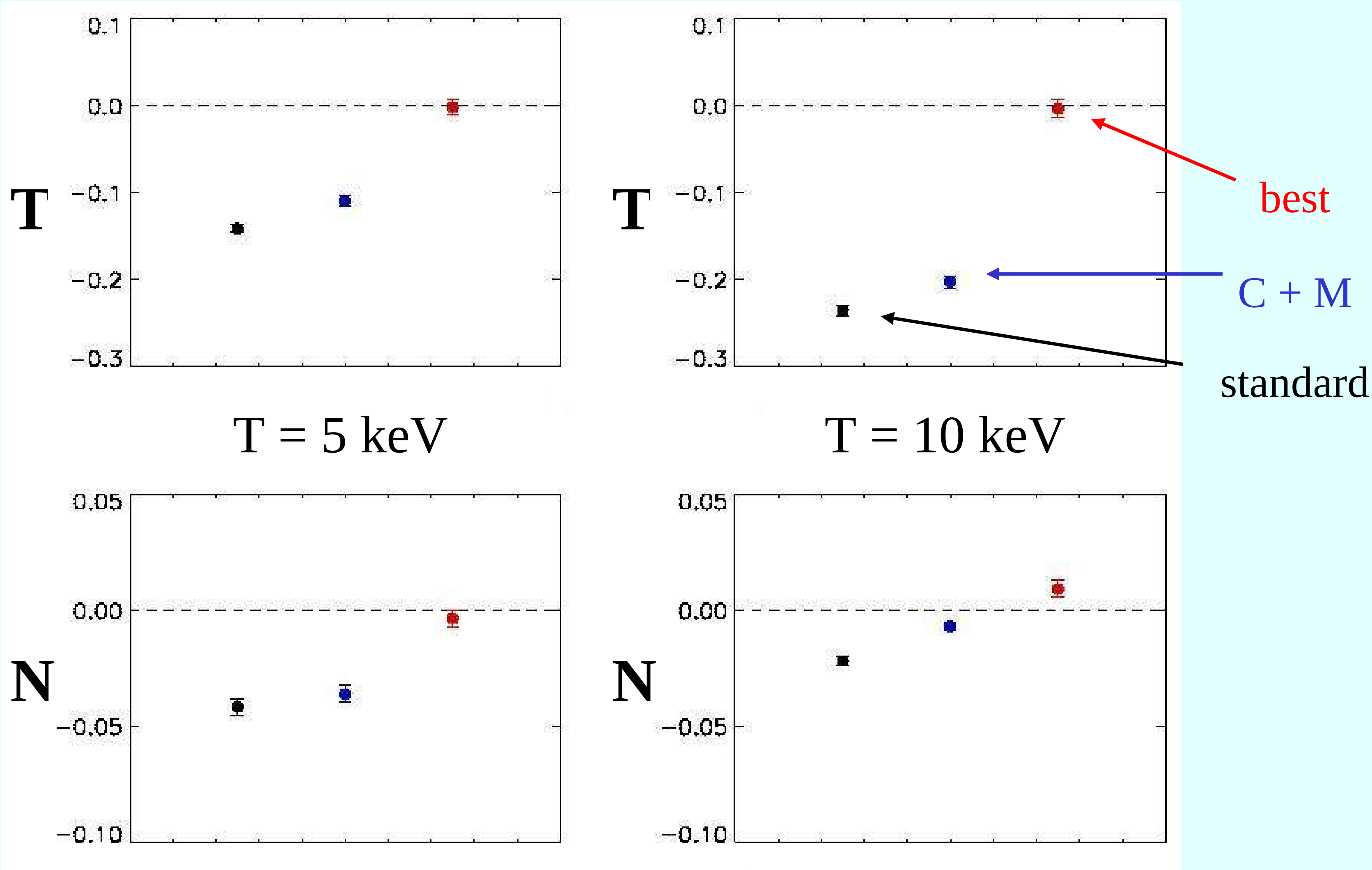
BEST METHOD

TEMPERATURE (keV)		NORMALIZATION (arbitrary units)	
REAL	MEASURED	REAL	MEASURED
5.00	4.99 ± 0.04	5.50	5.48 ± 0.02
10.00	9.96 ± 0.11	5.50	5.55 ± 0.01

Temperature is REMARKABLY correct (<0.5%)

Normalization is nearly correct (≈1%)

SUMMARIZING...



SUMMARIZING...

- **Background has to be modeled**
- **Cash statistic has to be used**
- **Probability distributions have to be joined in a particular way**

FURTHER ADVANTAGES IN MODELING BACKGROUND

- **NO pn OoT subtraction**
- **NO errors propagation**
- **MORE information about BKG**

NO pn OoT subtraction means...

modeling

Background ~~subtraction~~

~~Grouping of pn normal and OoT spectra to approximate gaussian errors~~

~~Direct subtraction of pn OoT spectrum with *mathpha*~~

~~Some error propagation~~

~~Loss of information on the original spectrum~~

Pn OoT is associated by *grppha*

NO information lost

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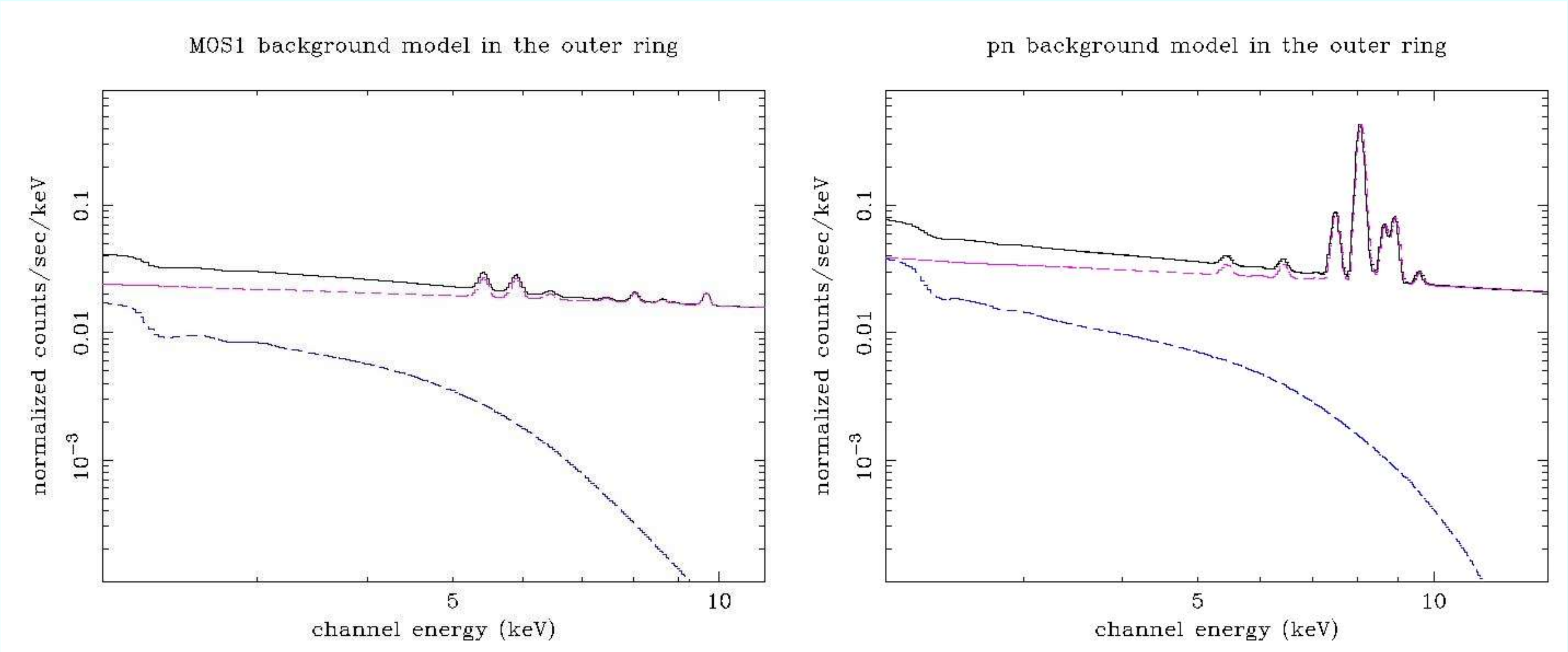
OUR BACKGROUND MODEL

- **NXB continuum**
- **NXB fluorescence emission lines**
- **Cosmic extragalactic background**

OUR BACKGROUND MODEL



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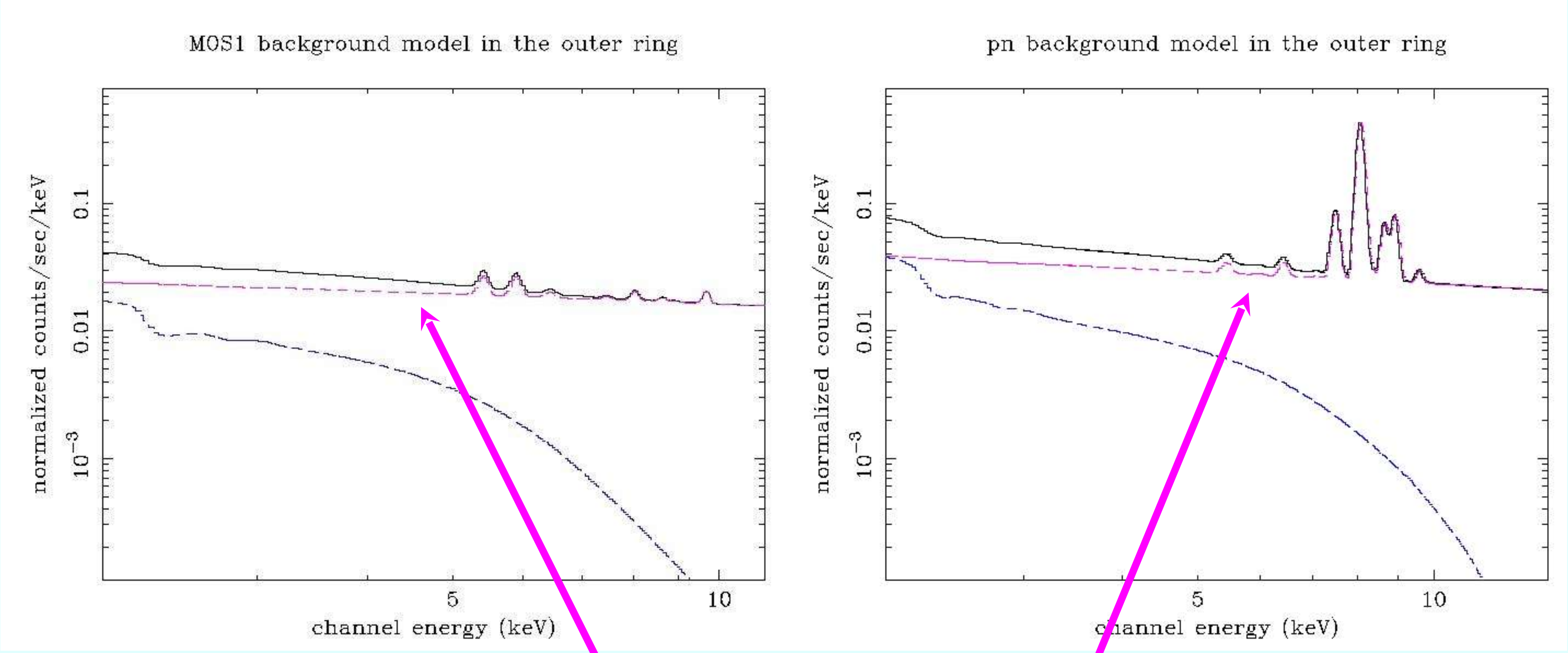
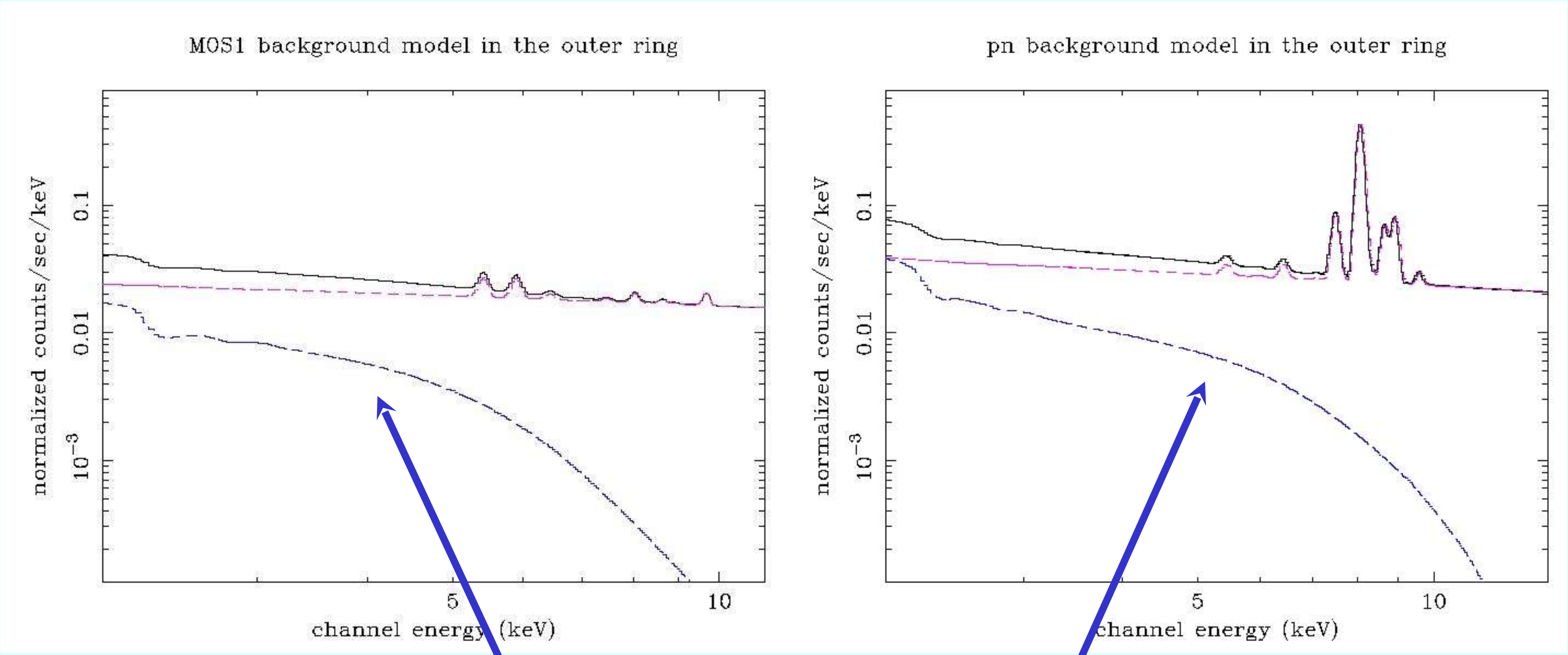


NXB continuum + fluorescence lines

Cosmic X-ray background

OUR BACKGROUND MODEL



NXB continuum + fluorescence lines

Cosmic X-ray background

OUR BACKGROUND MODEL

NXB	**EPIC - MOS1 N**	**N**	**EPIC – MOS2 N**	**N**	**EPIC - pn N**	**N**
Closed	**57.7**	**1.7**	**57.3**	**1.7**	**97.5**	**3.9**
Blank fields	**57.5 ± 1.4**	**4.3**	**57.2 ± 1.7**	**5.1**	**95.1 ± 2.4**	**7.1**
Clusters	**60.9 ± 1.4**	**8.0**	**60.9 ± 1.2**	**6.6**	**100.1 ± 2.5**	**14.1**

CXB	EPIC - MOS1 N	N	EPIC – MOS2 N	N	EPIC - pn N	N
Expected	7.82	1.8	7.84	1.8	4.58	1.3
Blank fields	7.65 ± 0.47	1.4	7.26 ± 0.52	1.6	4.38 ± 0.48	1.4
Clusters	10.17 ± 0.42	2.4	9.72 ± 0.43	2.4	6.54 ± 0.29	1.7

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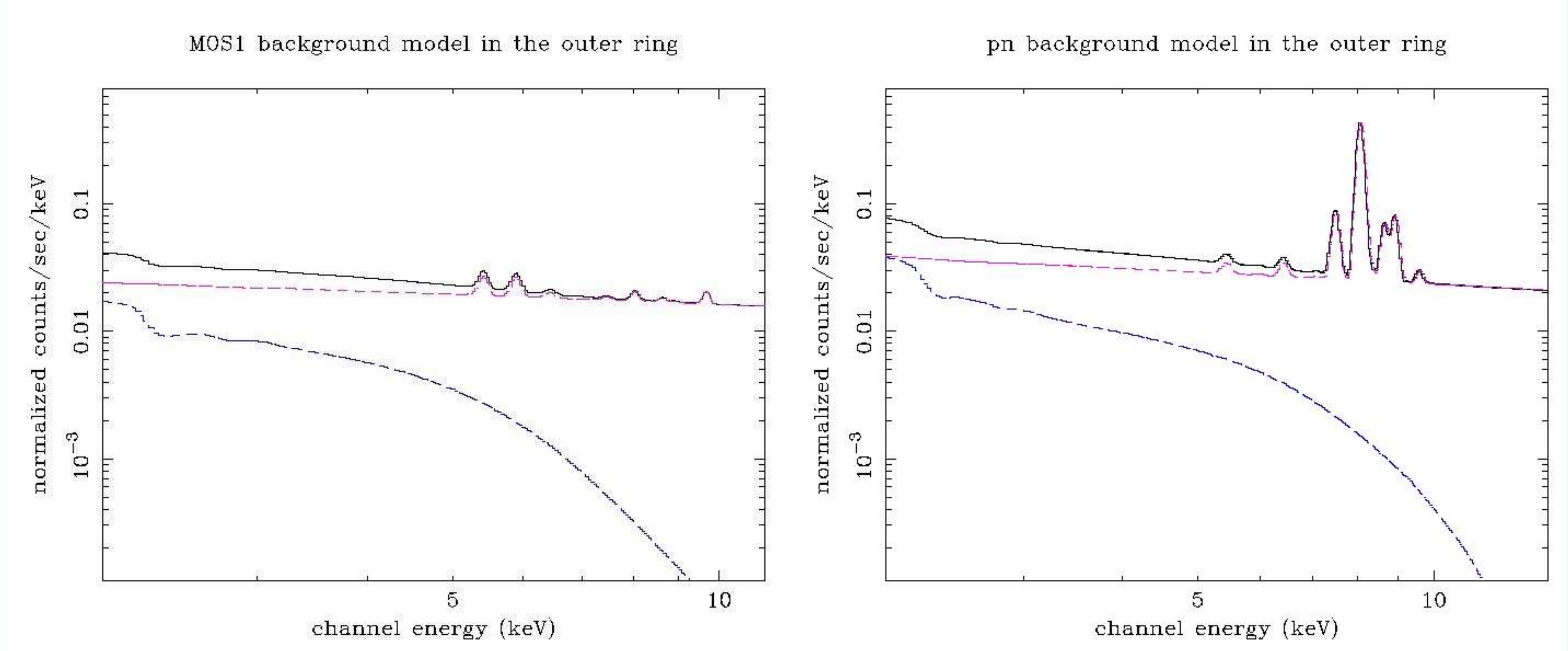
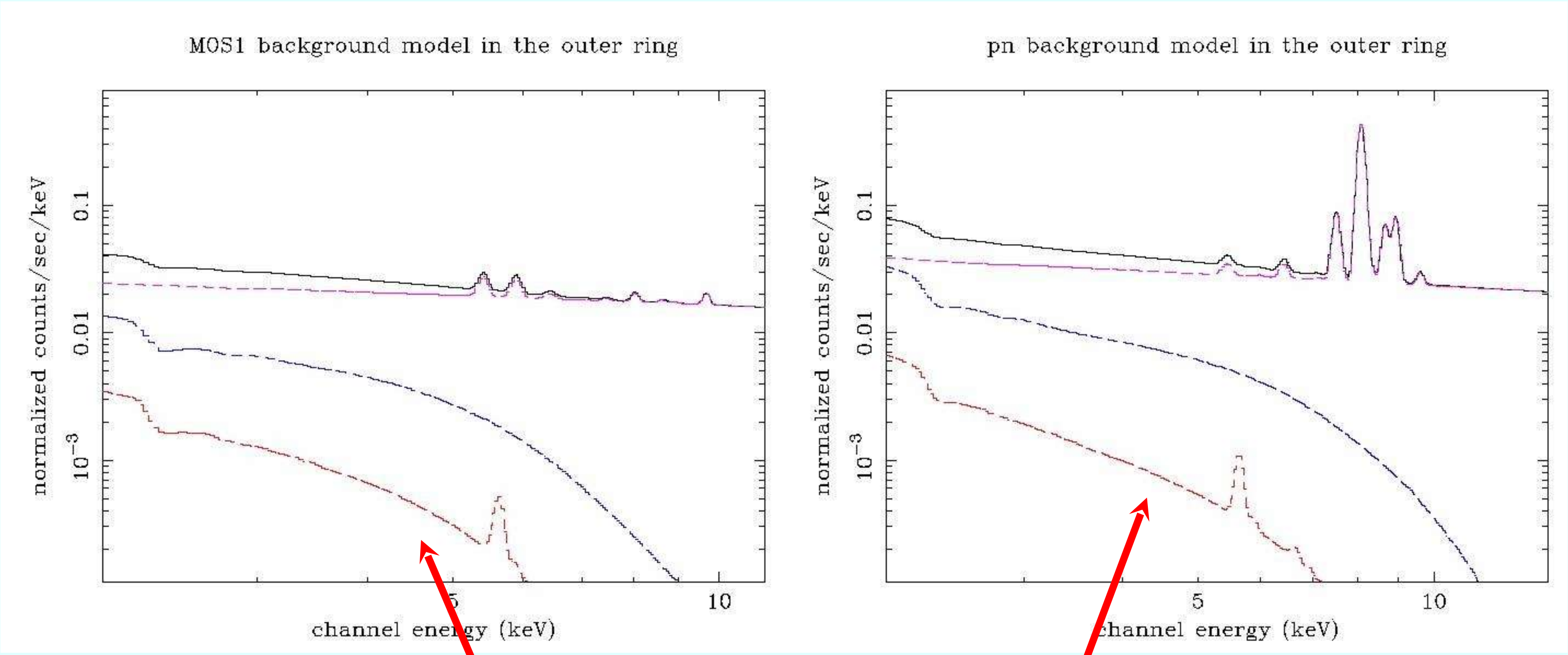
OUR BACKGROUND MODEL



NXB continuum + fluorescence lines

Cosmic X-ray background

OUR BACKGROUND MODEL



NXB continuum + fluorescence lines

Cosmic X-ray background

Cluster residual thermal component

OUR BACKGROUND MODEL

NXB	EPIC - MOS1		EPIC – MOS2		EPIC - pn	
	N	N	N	N	N	N
Closed	57.7	1.7	57.3	1.7	97.5	3.9
Blank fields	57.5 ± 1.4	4.3	57.2 ± 1.7	5.1	95.1 ± 2.4	7.1
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CXB	**EPIC - MOS1**		**EPIC – MOS2**		**EPIC - pn**	
	N	**N**	**N**	**N**	**N**	**N**
Expected	**7.82**	**1.8**	**7.84**	**1.8**	**4.58**	**1.3**
Blank fields	**7.65 ± 0.47**	**1.4**	**7.26 ± 0.52**	**1.6**	**4.38 ± 0.48**	**1.4**
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	N	**N**	**N**	**N**	**N**	**N**
Expected	**7.82**	**1.8**	**7.84**	**1.8**	**4.58**	**1.3**
Blank fields	**7.65 ± 0.47**	**1.4**	**7.26 ± 0.52**	**1.6**	**4.38 ± 0.48**	**1.4**
Clusters	**8.51 ± 0.58**	**3.3**	**7.71 ± 0.57**	**3.2**	**4.76 ± 0.41**	**2.5**

OUR BACKGROUND MODEL

NXB FLUORESCENCE LINES

	EPIC – MOS1			EPIC – MOS2			EPIC - pn		
	CL	BF	SO	CL	BF	SO	CL	BF	SO
Cr	8.5	10.4	12.2	3.8	9.2	10.4	6.8	11.0	10.6
Mn	6.6	7.6	10.4	8.5	7.5	6.2	---	---	---
Fe	9.3	8.2	7.6	7.9	9.3	7.5	9.0	12.4	11.7
Ni	4.0	4.1	3.6	7.9	6.1	5.1	126.	128.	126.
Cu	4.6	5.0	5.5	2.2	4.5	3.9	883.	887.	877.
Zn	9.3	3.6	6.9	3.4	4.1	5.4	97.9	97.1	93.9
Au	10.3	10.6	12.4	12.2	8.9	7.9	---	---	---

CL = closed – BF = blank fields – SO = sources (clusters)

SUMMARY

- Background has to be modeled
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