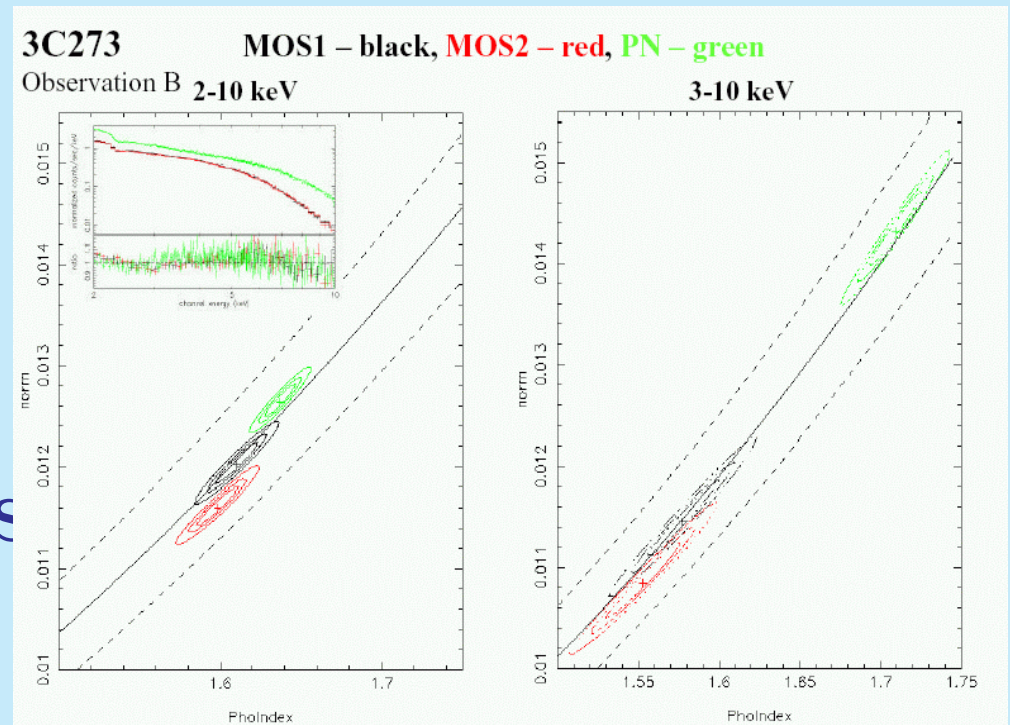


Testing the EPIC hard band calibration

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Some Preliminaries

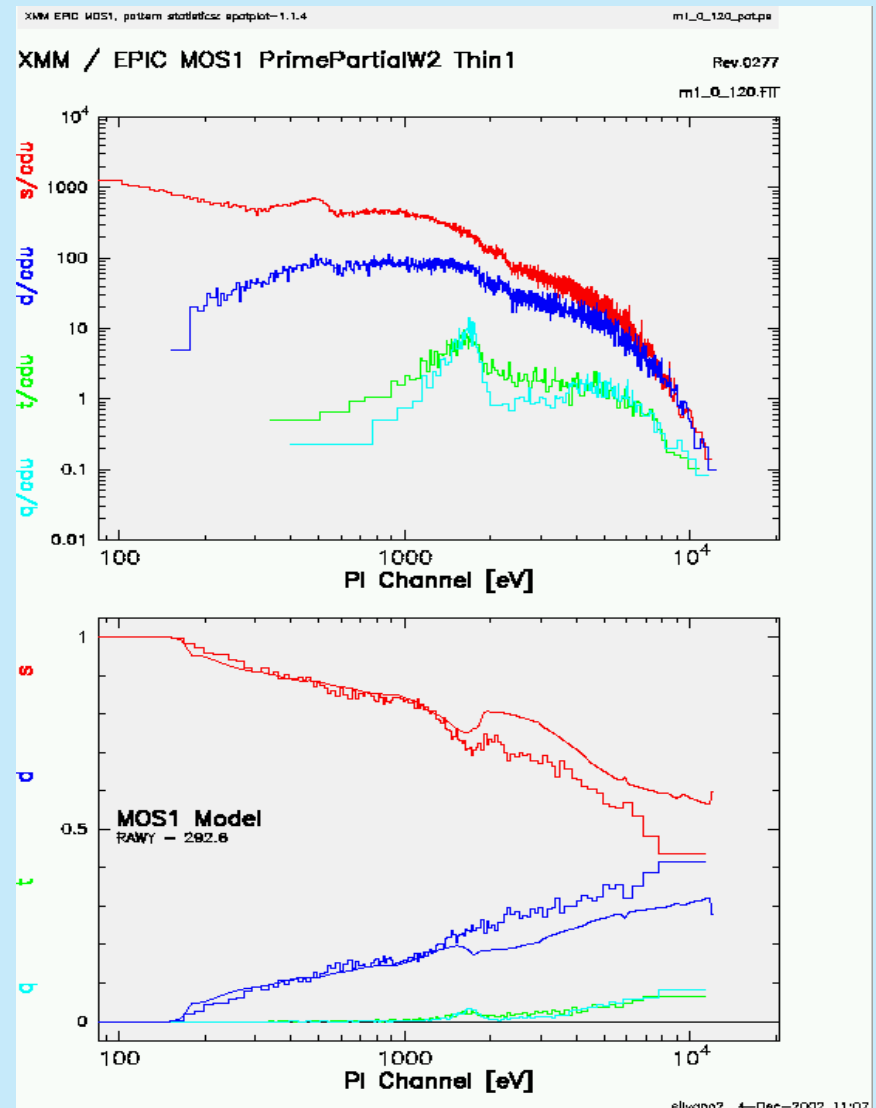
- 3C 273 analysis reported by G.Griffiths at ESTEC workshop (Nov 2001)
- Large discrepancies btwn. Detectors



Revisit 3C 273 data making use of latest calibrations

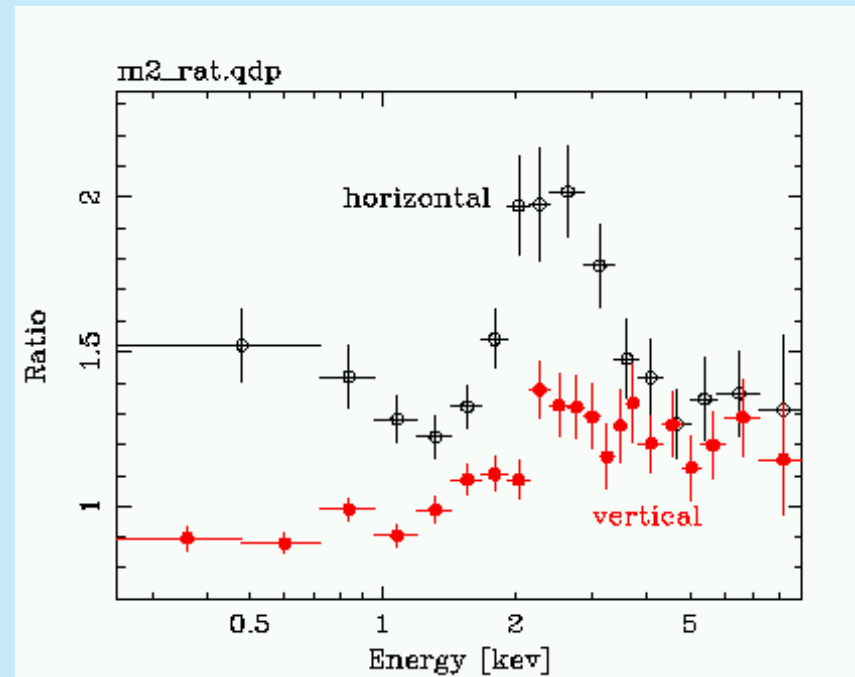
Looking out for pile-up

Various lines of analysis show that MOS data is affected by pile up. Above 2 keV singles are in deficit and doubles in excess.



Looking out for pile-up

In the absence of pile up, the ratio of bipix to monopix in the core and the wings of the PSF should be the same. The ratio of ratios: $(bi/mon)_{in}/(bi/mon)_{out}$ is a good indicator of pile up.



Pile up is most easily seen near edges where the number of true events drops rapidly. As a consequence of this strange residuals will show up when doing spectral fits, these may be mistaken for edge calibration problems!

Pattern 0 vs. Pattern 0-12 spectral fitting

Table 1: $\Delta\Gamma \equiv \Gamma_{p0-12} - \Gamma_{p0}$

Spectrum	$\Delta\Gamma$	$\Delta\Gamma$
	3-10 keV	4-10 keV
MOS1 0''-6''	-0.08 ± 0.04	-0.17 ± 0.06
MOS2 0''-6''	-0.06 ± 0.04	-0.10 ± 0.06
MOS1 6''-37.5''	0.02 ± 0.03	0.00 ± 0.05
MOS2 6''-37.5''	0.01 ± 0.03	0.02 ± 0.04

- In core pat.0-12 spectra are harder than pat. 0 spectra.
- In the wings pat.0-12 and pat.0 spectra yield consistent results.

Pattern 0-12 spectra are badly piled-up

Correcting for Pile-up

Cut out the core of the PSF.

Compare core with wing pat. 0 spectra, which are not substantially piled-up, making use of PSF corrected arfs.

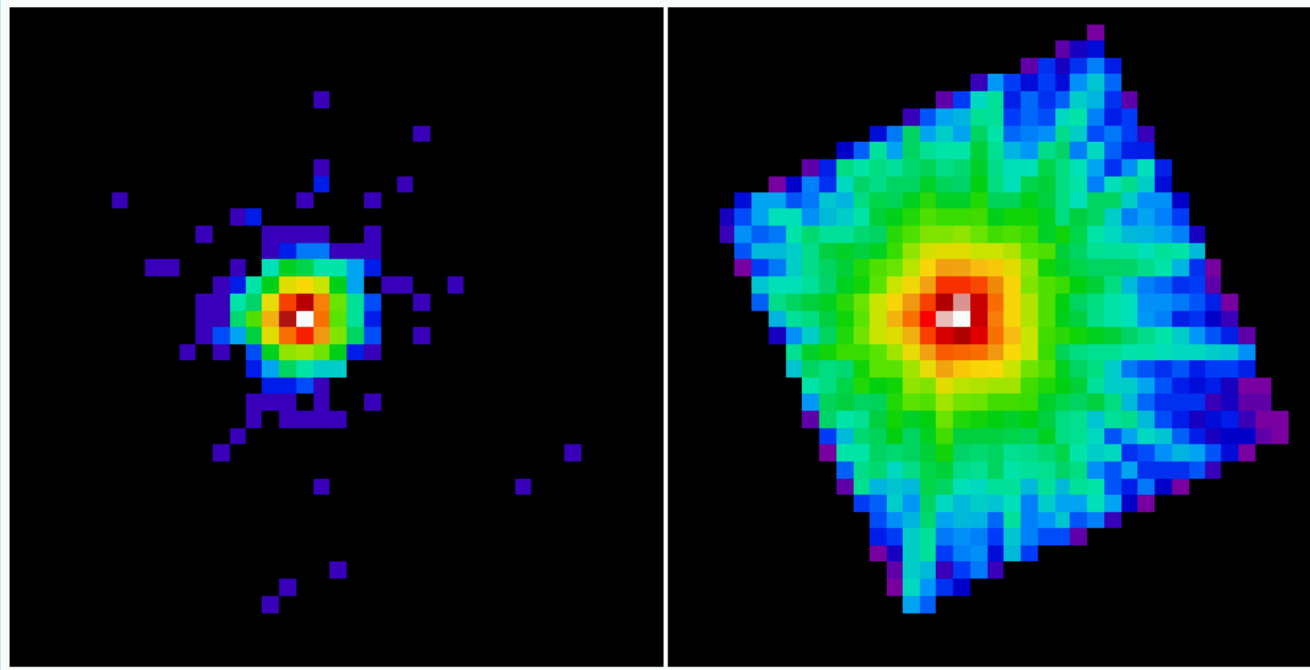
Table 2: $\Delta\Gamma \equiv \Gamma_{p0}(0'' - 6'') - \Gamma_{p0}(6'' - 37.5'')$

Detector	$\Delta\Gamma$ 3-10 keV	$\Delta\Gamma$ 4-10 keV
MOS1	0.21 ± 0.04	0.10 ± 0.06
MOS2	0.21 ± 0.04	0.10 ± 0.05

PSF correction is not good enough

Correcting for pile-up

Diagonal patterns are excellent tracers of pile-up and can be used to estimate pile-up and derive a corrected spectrum.



Correcting for Pile-up

- $S(E) = S_{obs}(E) + S_{lost}(E) - S_{gain}(E)$
- *Under the assumption that third and higher order terms are not important:*

$$S_{lost}(E) = \frac{\gamma_1}{4\alpha_1} S_{dia-p0}(E) \quad S_{gain}(E) = \frac{1}{4} S_{dia}(E)$$

- Generalization to generic source described by PSF

$$\bar{S}(E) = \bar{S}_{obs}(E) + \frac{\gamma_1}{4\alpha_1} \bar{S}_{dia-p0}(E) - \frac{1}{4} \bar{S}_{dia}(E)$$

MOS Spectral Fitting

Detector	Γ	Γ
	3-10 keV	4-10 keV
MOS1 pat0-12	1.50 ± 0.02	1.50 ± 0.03
MOS1 pat0	1.54 ± 0.02	1.60 ± 0.03
MOS1 pat0 diacor	1.54 ± 0.02	1.62 ± 0.04
MOS2 pat0-12	1.57 ± 0.02	1.52 ± 0.03
MOS2 pat0	1.61 ± 0.02	1.62 ± 0.03
MOS2 pat0 diacor	1.62 ± 0.03	1.63 ± 0.04

Corrections are small, within the statistical errors.

At the rate of 3C 273 pile-up:

- Produces spurious features near edges.
- Significantly distorts pat 0-12 spectra.
- does NOT alter pat 0 spectra.

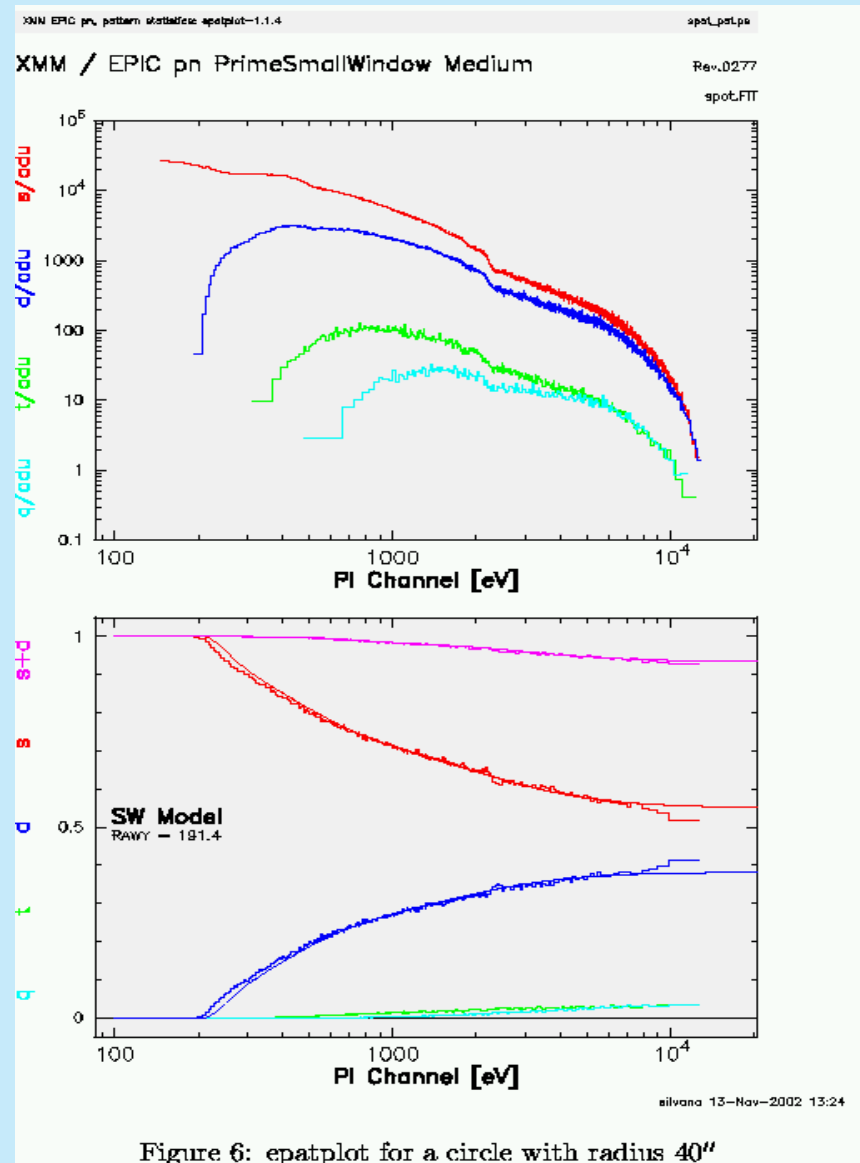
PN Spectral Fitting

Spectrum	Γ 3-10 keV	Γ 4-10 keV
PN S 0''-40''	1.65 ± 0.01	1.67 ± 0.01
PN D 0''-40''	1.62 ± 0.01	1.62 ± 0.01
PN S 5''-40''	1.67 ± 0.01	1.72 ± 0.02
PN D 5''-40''	1.63 ± 0.01	1.66 ± 0.02
PN S 10''-40''	1.67 ± 0.01	1.72 ± 0.02
PN D 10''-40''	1.63 ± 0.01	1.66 ± 0.02

Pile up cannot be very important:

- Singles and doubles spectra in different annuli differ by the same Δ
- Double spectra are STEEPER than single spectra
- Epatplot is ok

Epatplot for PN



Comparing EPIC MOS, EPIC PN and MECS

Spectrum	Γ 3-10 keV	Γ 4-10 keV
MOS1 pat0 diacor	1.54 ± 0.02	1.62 ± 0.04
MOS2 pat0 diacor	1.62 ± 0.03	1.63 ± 0.04
PN S 0''-40''	1.65 ± 0.01	1.67 ± 0.01
PN D 0''-40''	1.62 ± 0.01	1.62 ± 0.01
MECS23	1.63 ± 0.02	1.64 ± 0.03

- **MOS/PN cross cal: all measurements within Δ of 0.03 except for MOS1 3-10 measure**
- EPIC/MECS: all EPIC measurements except the MOS1 in the 3-10 keV band are in good agreement with the MECS measurement.

Substantial improvement over last year

Comparing EPIC MOS, EPIC PN and MECS for the June2000 obs.

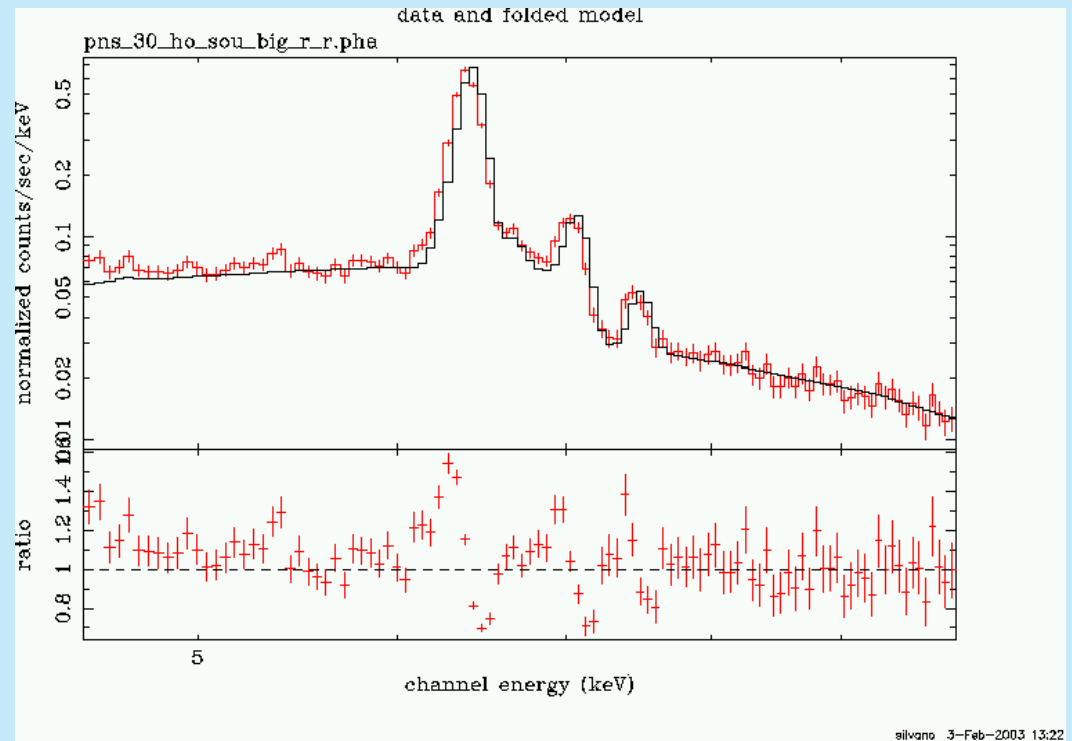
Spectrum	Γ 3-10 keV	Γ 4-10 keV
MOS1 pat0	1.57 ± 0.02	1.55 ± 0.03
MOS2 pat0	1.64 ± 0.02	1.63 ± 0.03
PN S 0''-40''	1.69 ± 0.01	1.72 ± 0.02
PN D 0''-40''	1.66 ± 0.01	1.66 ± 0.02
MECS23	1.63 ± 0.02	1.64 ± 0.03

- **MOS/PN: cross cal: MOS1 returns harder spectra, MOS2 and PND spectra agree, PNS are softer by about 0.05-0.06**
- **EPIC/MECS: MOS2 and PND agree with MECS, MOS1 is harder and PNS is softer**

2001 results similar but not identical to 2000

Other Results: Circinus Galaxy

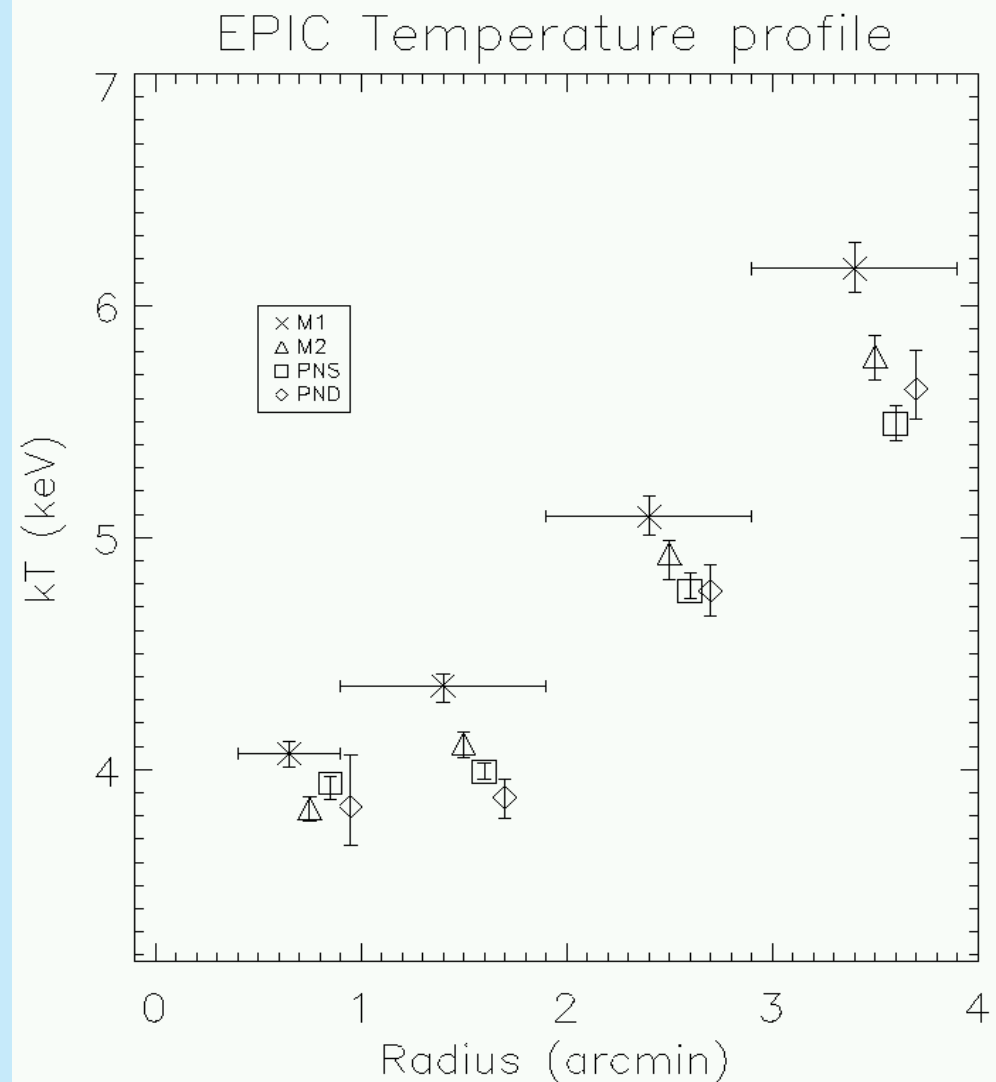
- Nearby intense Sey2, hard spectrum.
- Processed with SAS 5.4.1.
- MOS1 best fitting model harder than PNS spectrum.
- MOS2 best fitting model, is also harder than PNS spectrum, but not as much.
- PND best fitting model, is the closest to PNS spectrum, although still harder.



Results are qualitatively similar to those found for 3C 273

Other Results: Clusters

- T profile for typical CC cluster
- Processed with SAS 5.3.1.
- MOS1 temperature systematically higher than MOS2 PNS and PND which show reasonable agreement.



Summary

- Pile up is tricky, it can produce various kinds of effects, requiring adequate treatment. Diagonal events provide a PSF independent solution applicable in the moderate pile-up limit.
- HARD BAND cross-cal:
 - MOS1 returns harder spectra than all other instruments
 - MOS2, PNS and PND spectra are relativey close
 - PNS retrun softer spectra than PND (QE problem?)
- EPIC/MECS cross-cal:
 - MOS2, PND always agree with MECS
 - MOS1 harder than MECS
 - PNS sometimes harder than MECS sometimes not