Empirical Corrections to the HRMA Ir M Edge Discrepancy

D. Jerius, H.M. Marshall, D.E. Graessle

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Introduction

Analysis of high resolution spectra of astronomical sources with expected power law spectral distributions reveals an unexpected spectral feature near the Ir MV edge at 2.1 keV[1].

Previous analyses attempted to use high signal to noise data from an observation of Mk 421, but they suffered from pileup, which greatly distorts the spectral shape near the edge. To avoid the problem with pileup, spectra from multiple exposures of lower flux (and hence pileup free) targets were added together.

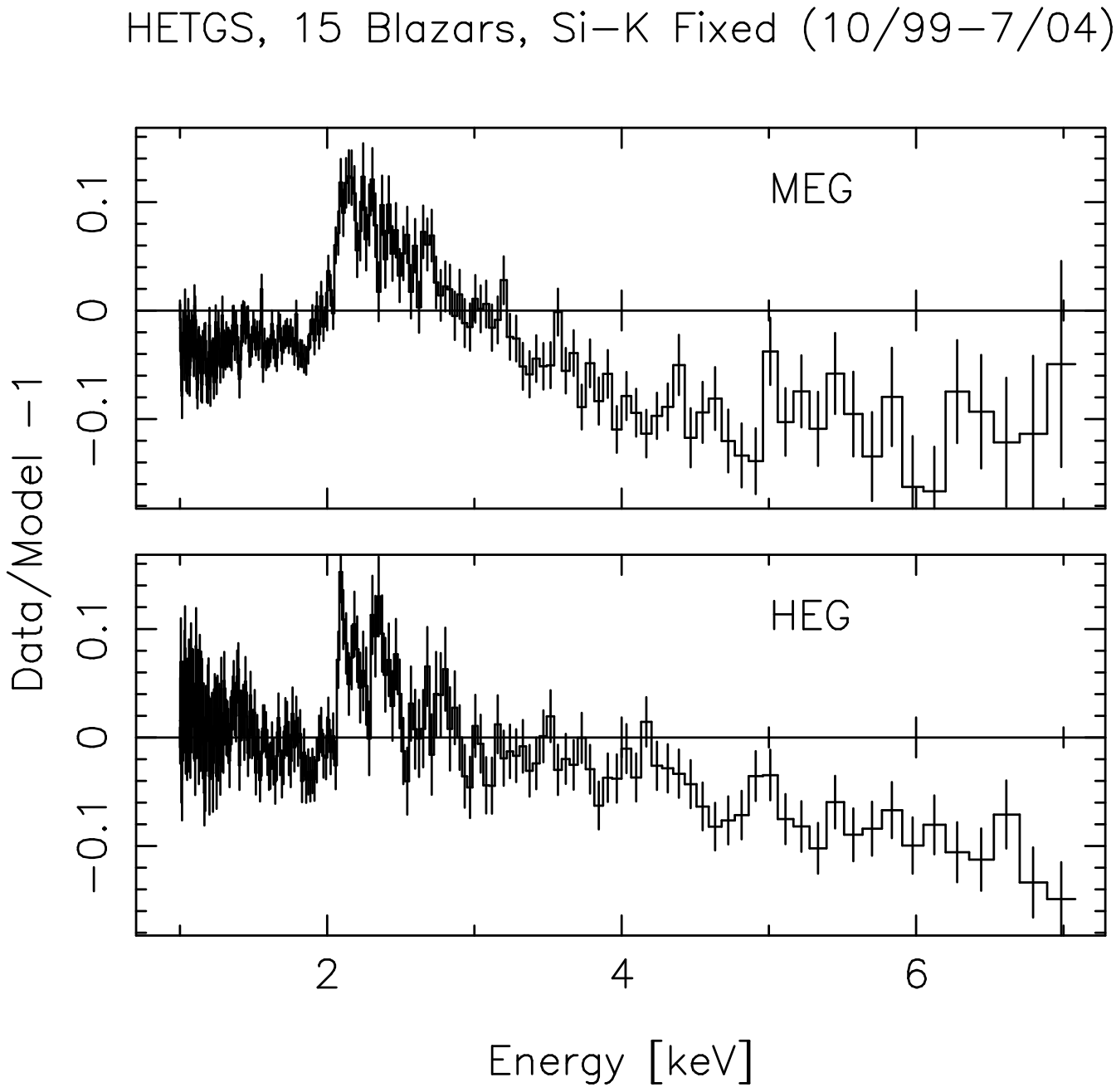
This analysis extends the earlier work by adding more spectra to the mix.

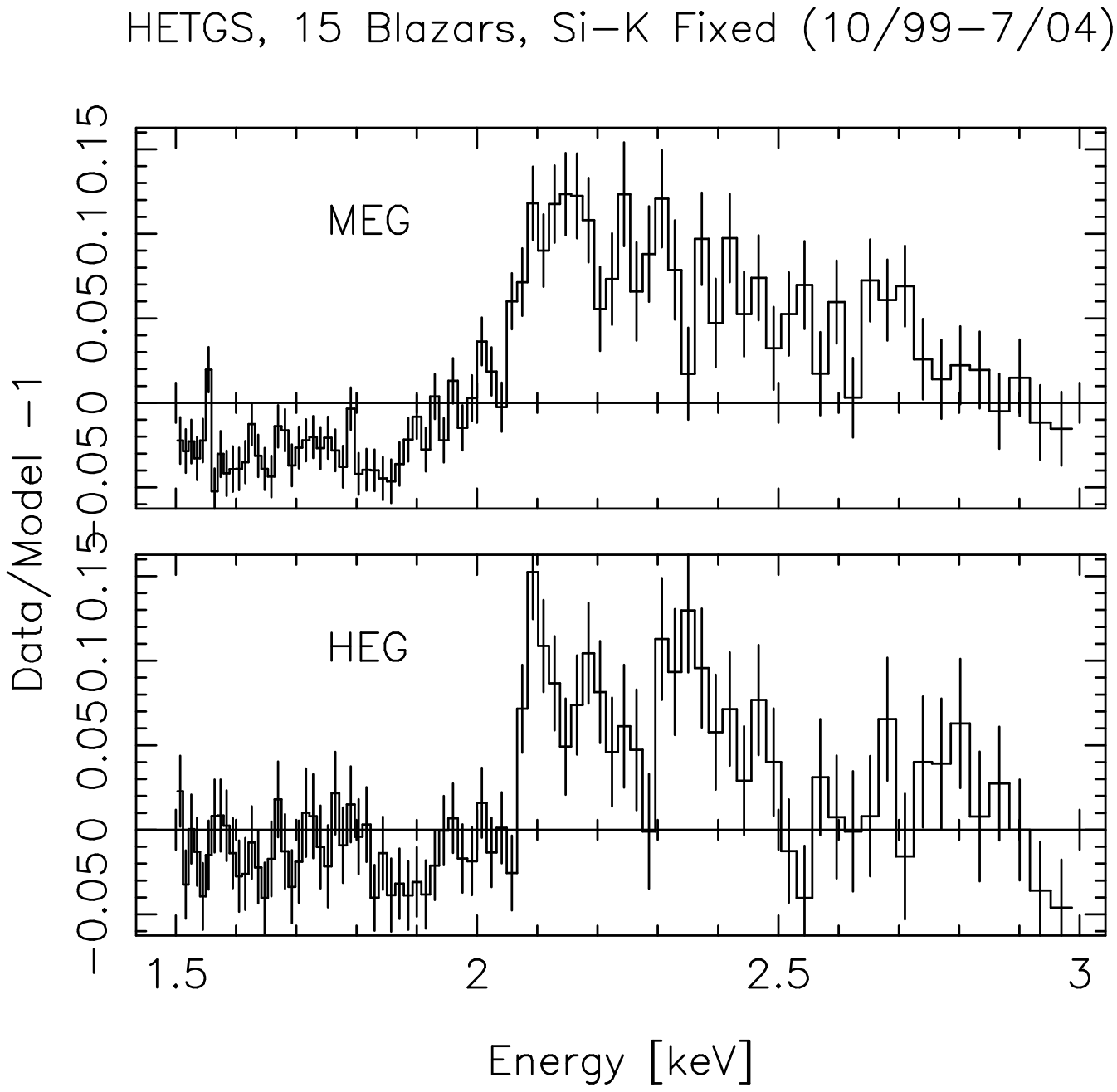
[1] Marshall *et al.*, 2003 CCW, http://asc.harvard.edu/ccw/proceedings/03_proc/presentations/marshall2/index.html

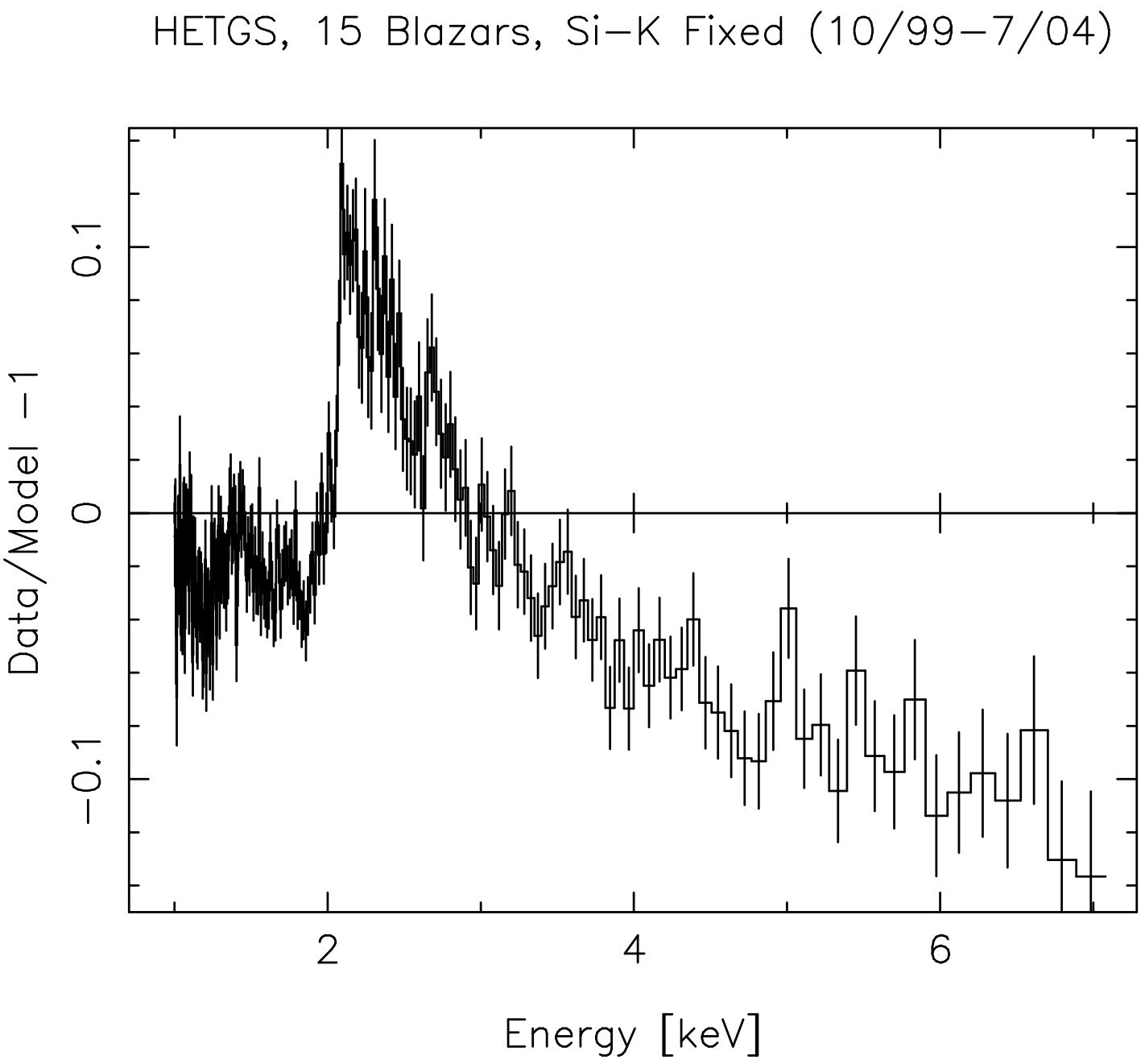
Observational Data

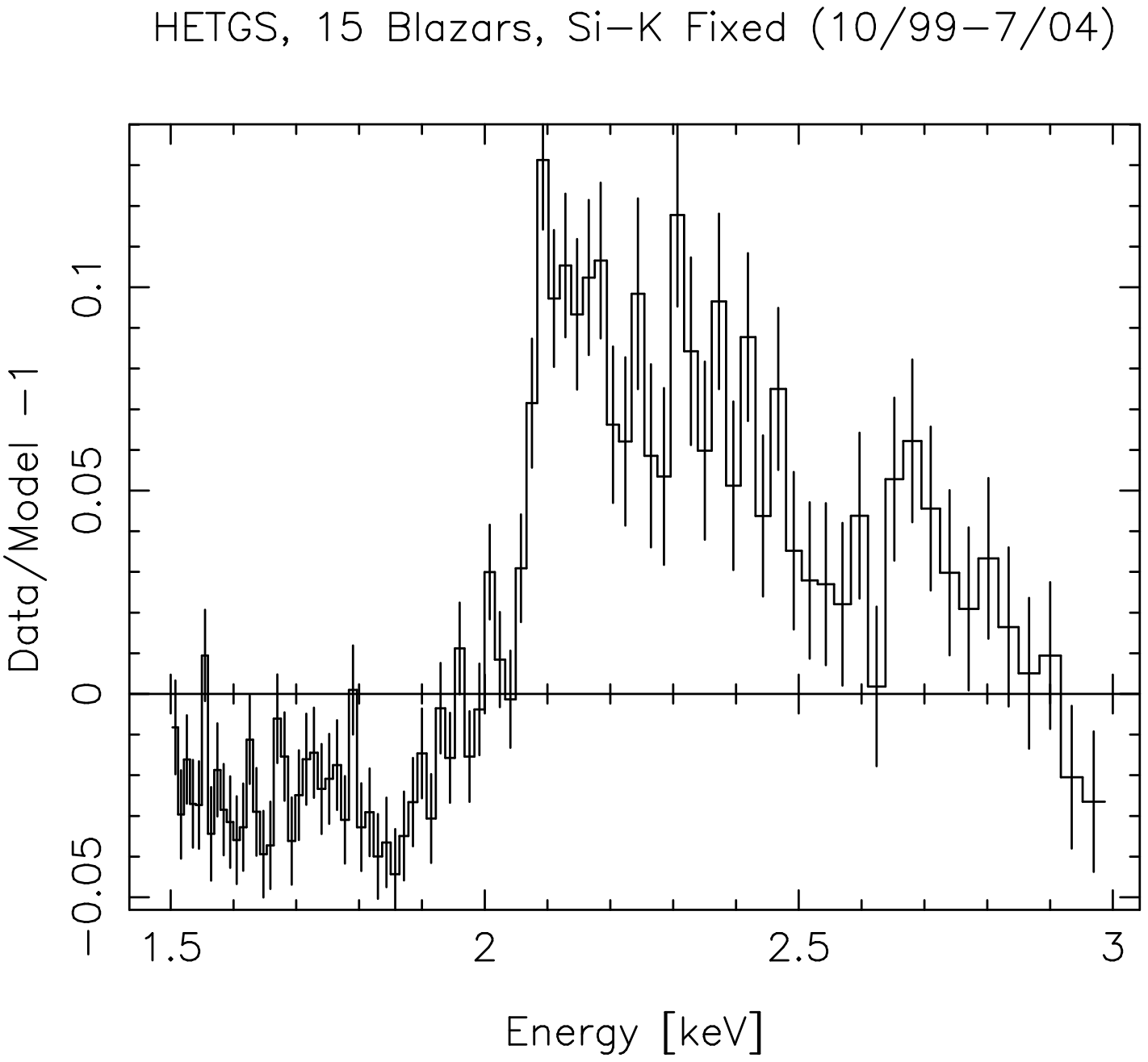
The fit residuals (shown in the next several slides) indicate that

- The residuals are at the $\sim 5-10\%$ level
- The feature appears in both the HEG and the MEG
- There are still problems fitting the overall source continua


HETGS, 15 Blazars, Si−K Fixed (10/99−7/04)
MEG
HEG
Data/Model −1
0.1
0
−0.1
2
4
6
Energy [keV]


HETGS, 15 Blazars, Si−K Fixed (10/99−7/04)
MEG
HEG
Data/Model −1
−0.15 −0.10 −0.05 0 0.05 0.10 0.15
−0.15 −0.10 −0.05 0 0.05 0.10 0.15
1.5
2
2.5
3
Energy [keV]


HETGS, 15 Blazars, Si−K Fixed (10/99−7/04)
Data/Model −1
0.1
0
−0.1
2
4
6
Energy [keV]


HETGS, 15 Blazars, Si−K Fixed (10/99−7/04)
Data/Model −1
0.1
0.05
0
−0.05
1.5
2
2.5
3
Energy [keV]

Origin of the Discrepancy

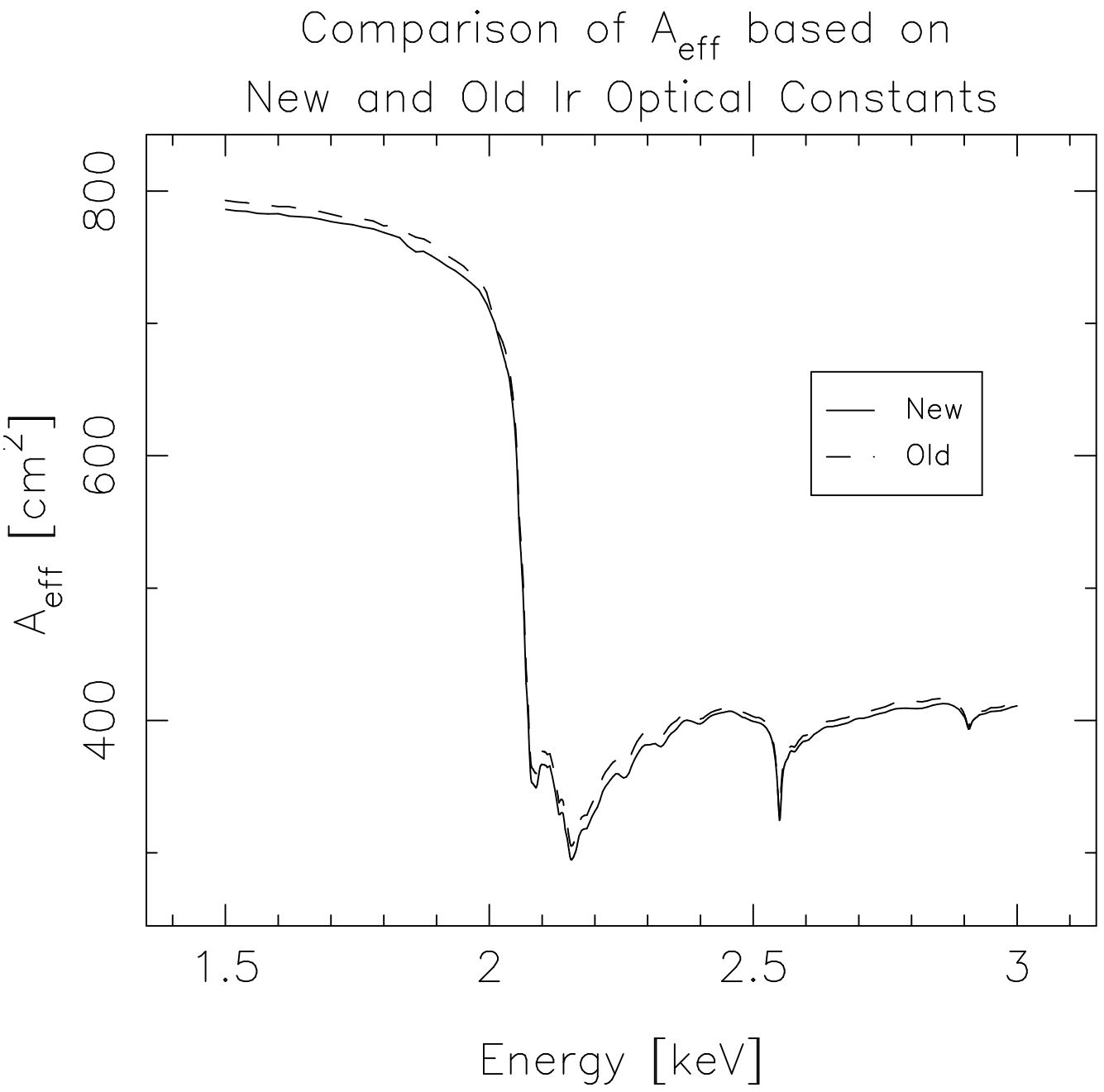
Iridium is found in *Chandra* only as the coating on the optics, so that is the obvious candidate. The most probable causes might be

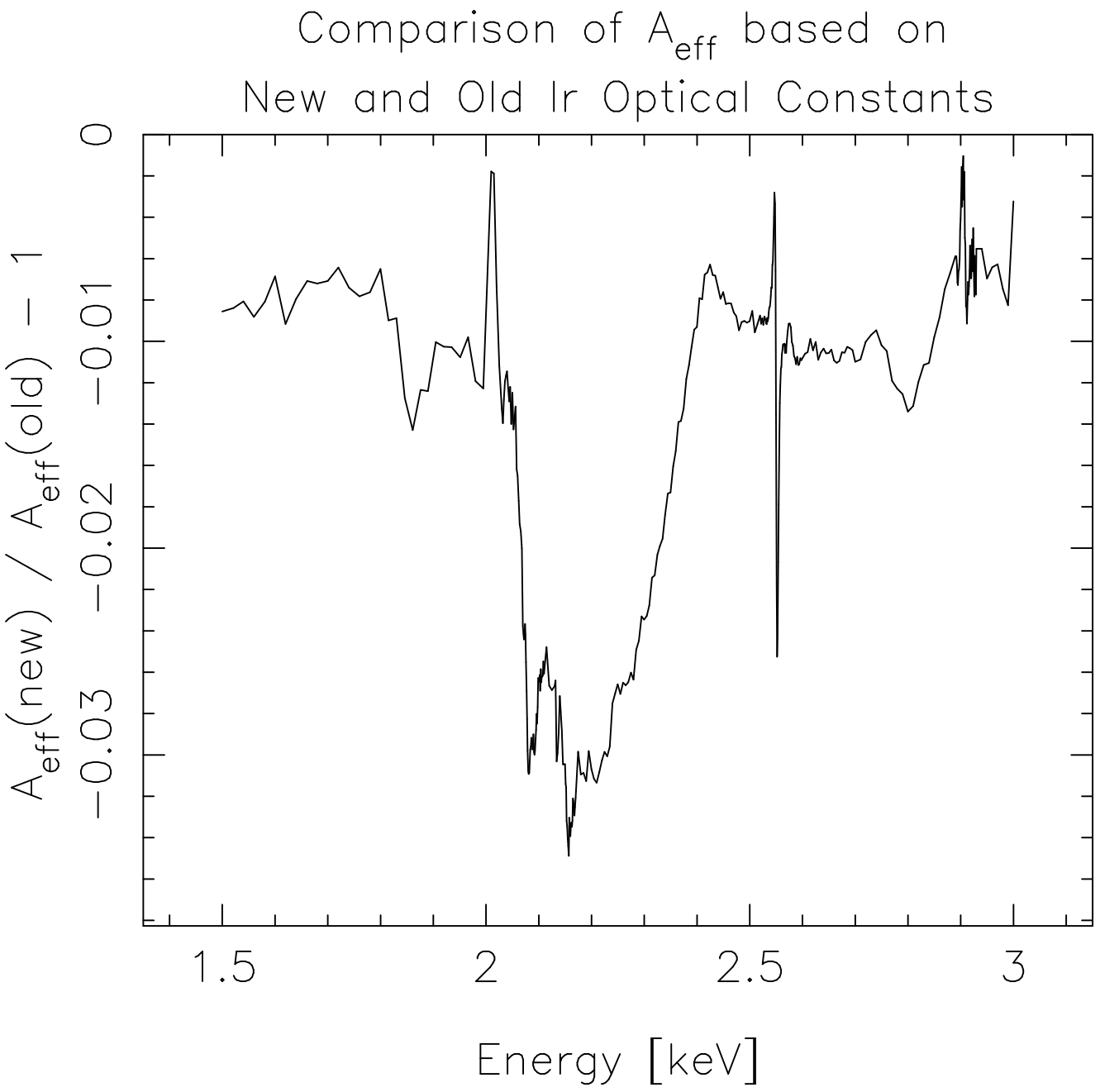
Errors in the Ir optical constants

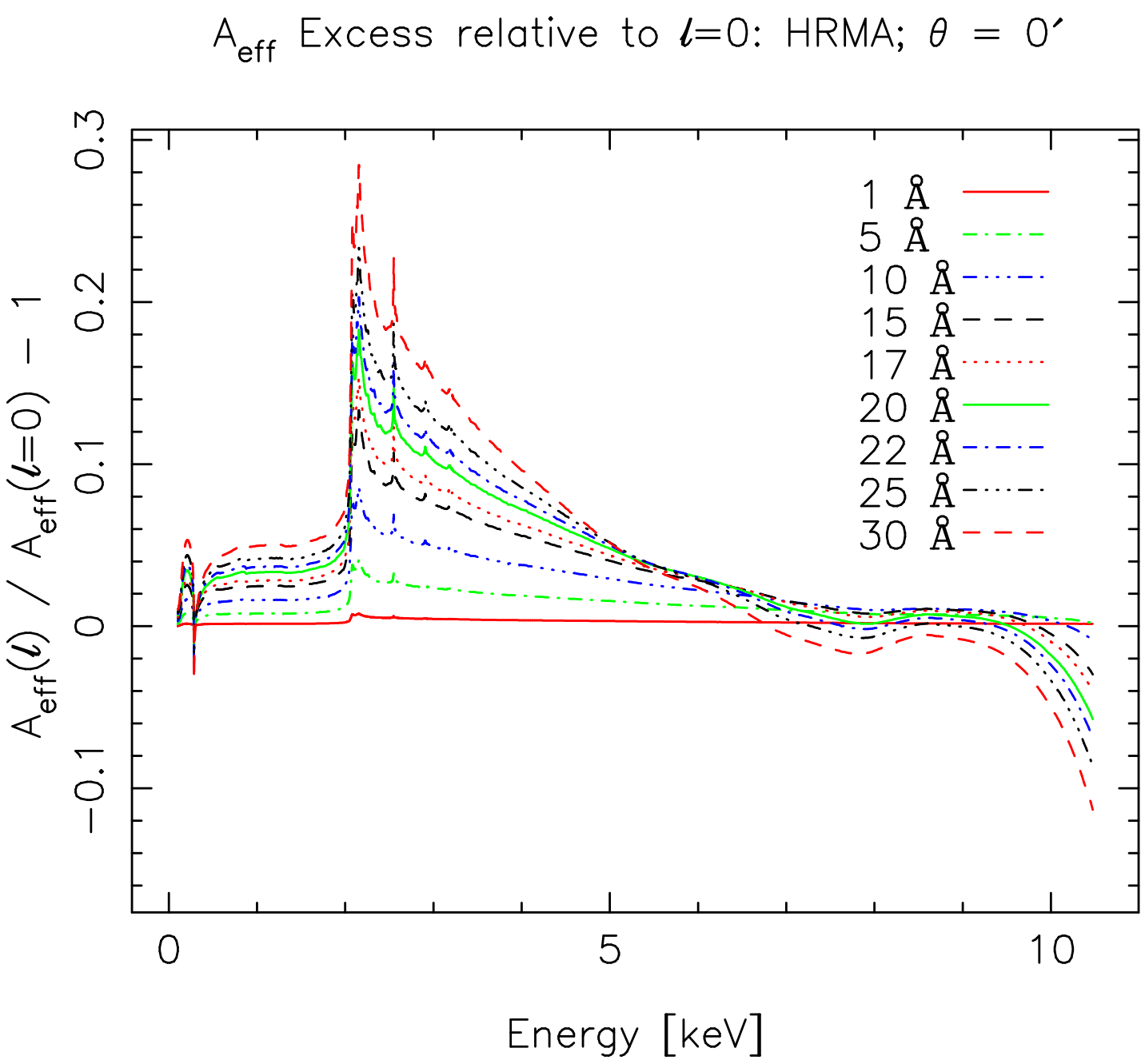
An error of 10% in the A_{eff} would require approximately a 5% error in the optical constants. This is rather large. Recent improvements in analysis of the optical constant data by Dale Graessle result in a $\sim 3\%$ change in the A_{eff}.

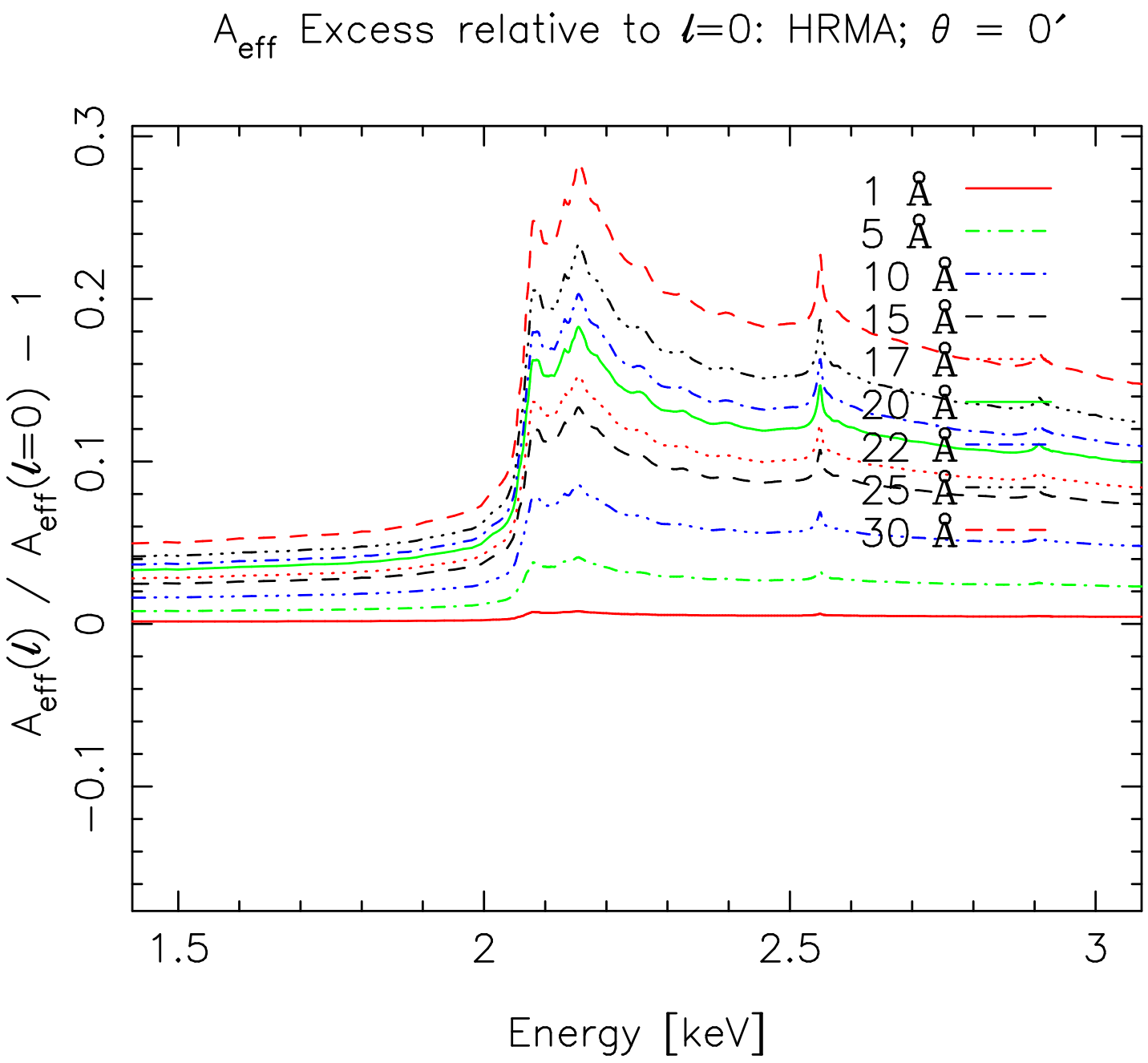
Contamination on the mirrors

There may be a very thin layer of hydrocarbon contamination on the optics. This is not unexpected, as the optics were at slight risk of exposure during manufacturing and assembly of the optical system. Prior to these findings, there were no quantitative indications of this.


Comparison of A_eff based on
New and Old Ir Optical Constants
A_eff [cm^2]
800
600
400
1.5
2
2.5
3
Energy [keV]
New
Old


Comparison of A_eff based on
New and Old Ir Optical Constants
A_eff(new) / A_eff(old) − 1
0
−0.01
−0.02
−0.03
1.5
2
2.5
3
Energy [keV]


A_eff Excess relative to ℓ=0: HRMA; θ = 0′
A_eff(ℓ) / A_eff(ℓ=0) − 1
0.3
0.2
0.1
0
−0.1
0
5
10
Energy [keV]
1 Å
5 Å
10 Å
15 Å
17 Å
20 Å
22 Å
25 Å
30 Å

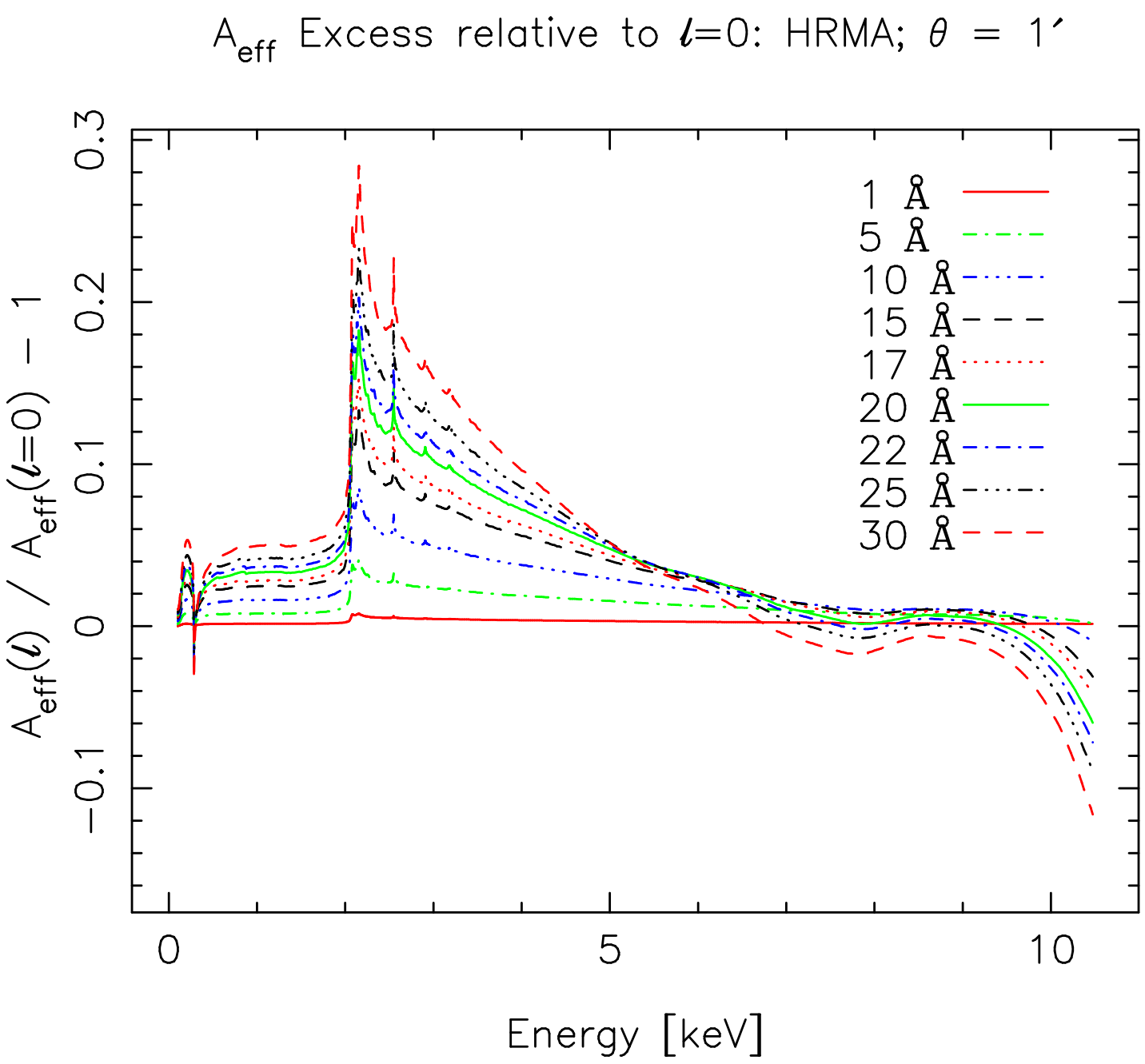

A_eff Excess relative to ℓ=0: HRMA; θ = 0′
A_eff(ℓ) / A_eff(ℓ=0) − 1
0.3
0.2
0.1
0
−0.1
1.5
2
2.5
3
Energy [keV]
1 Å
5 Å
10 Å
15 Å
17 Å
20 Å
22 Å
25 Å
30 Å

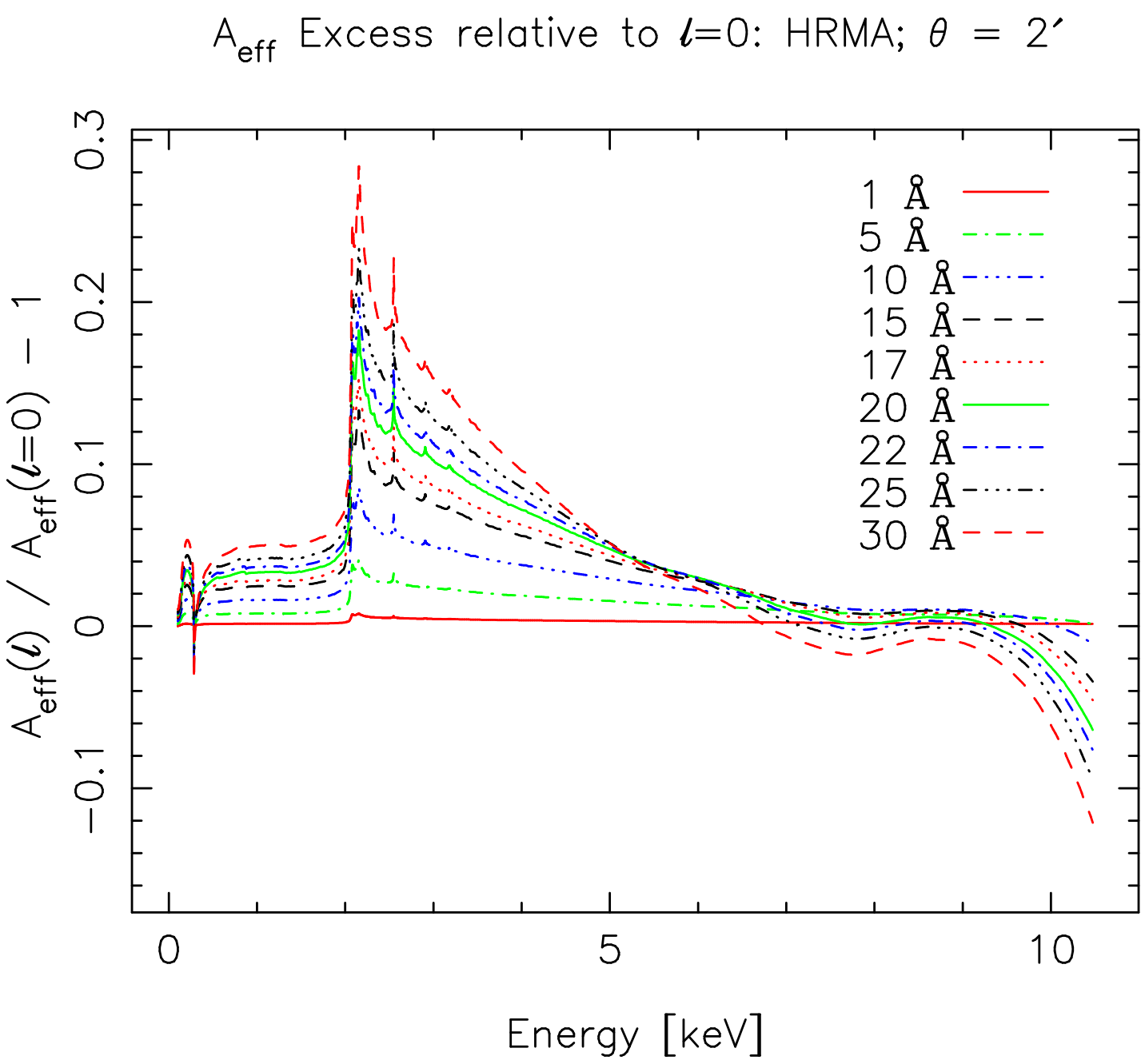
Effect of a Contamination layer on off-axis A_{eff}

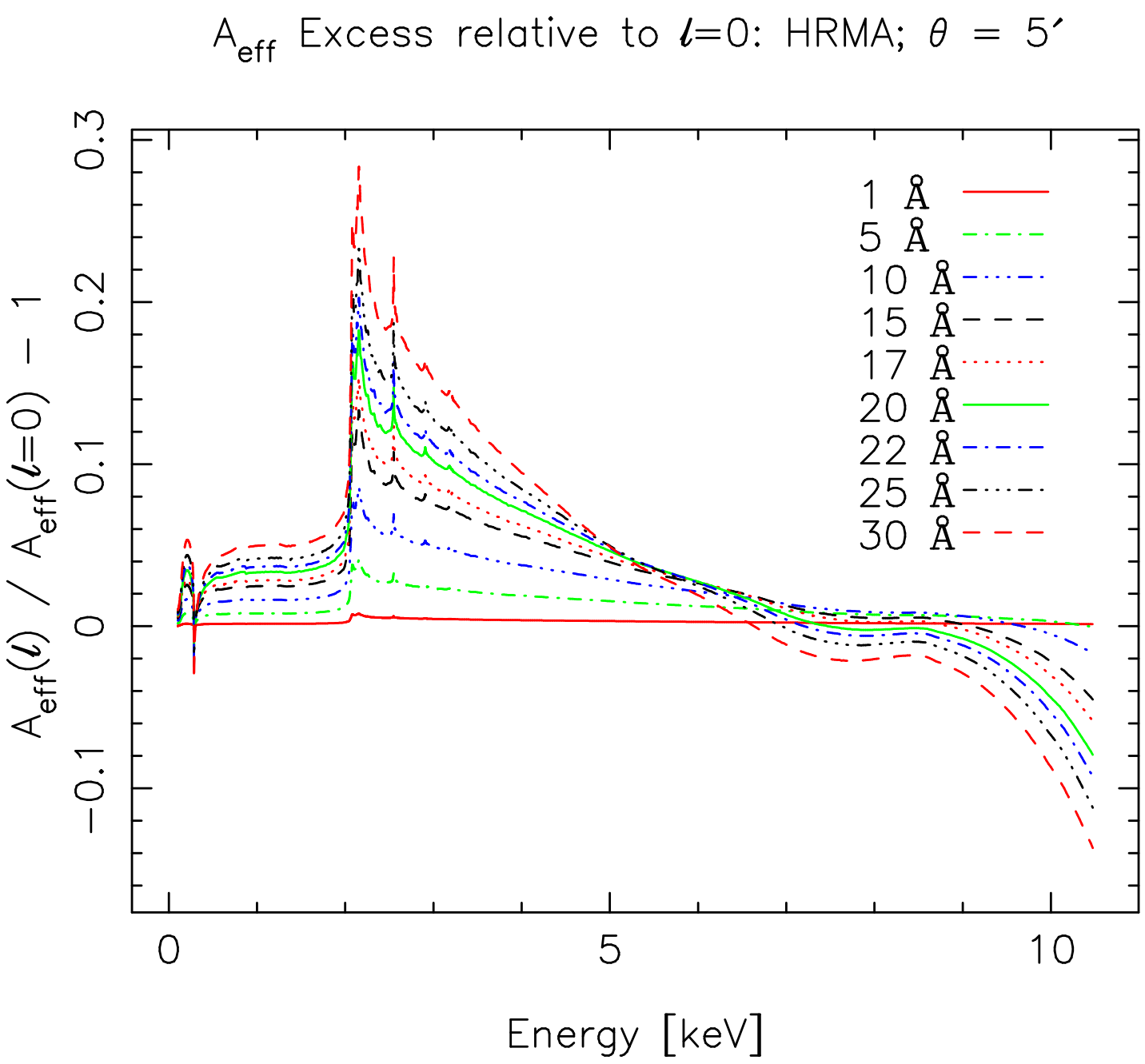
The optics depend upon very shallow grazing angles of the incident photons to achieve high reflectivity. This also increases the path length of the photons through the contamination layer, magnifying its effect. One of the concerns is that it might cause a change in the shape of the vignetting function.

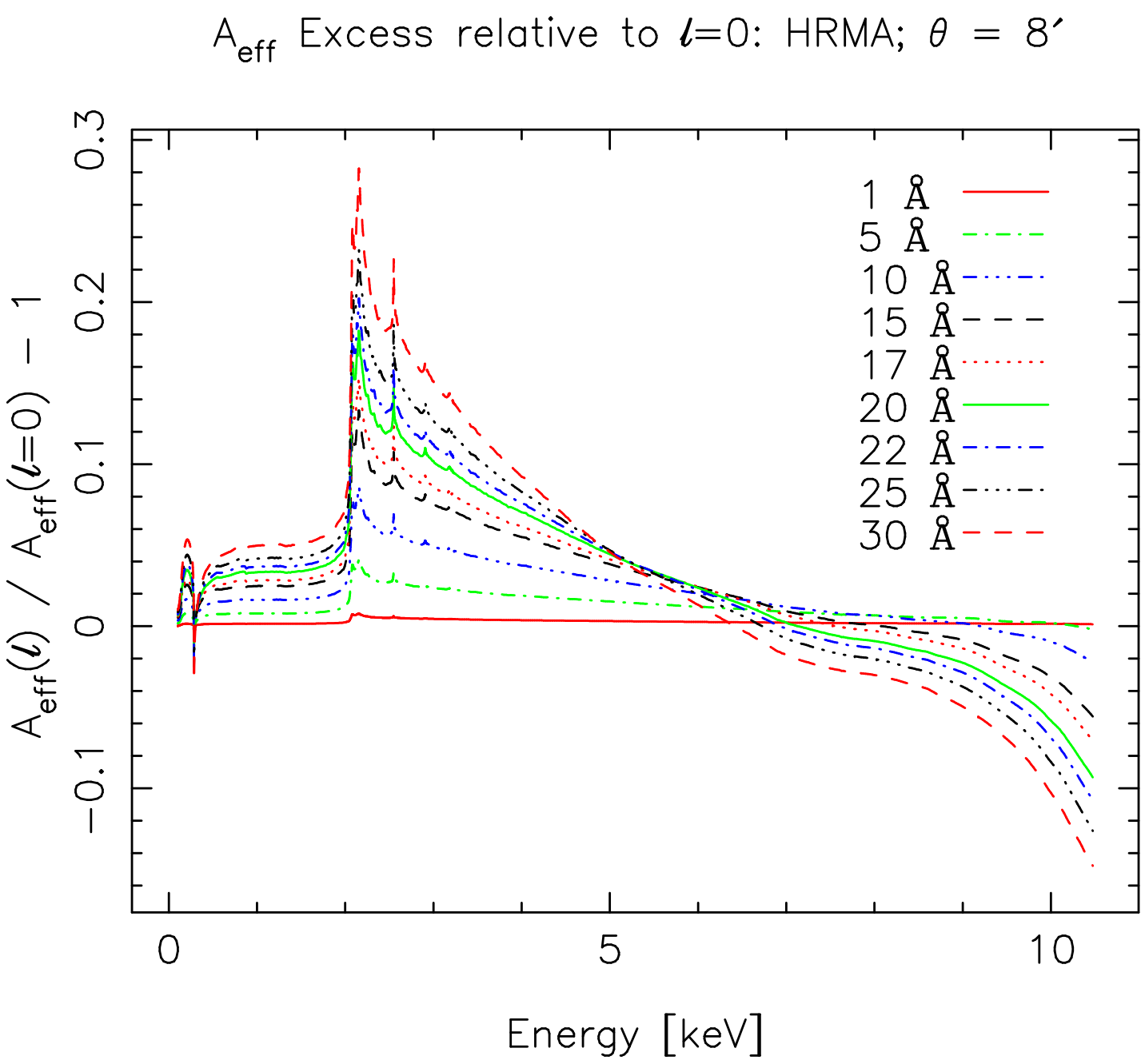
To study this, we have simulated the A_{eff} at various contamination layer thicknesses for several off-axis source positions.

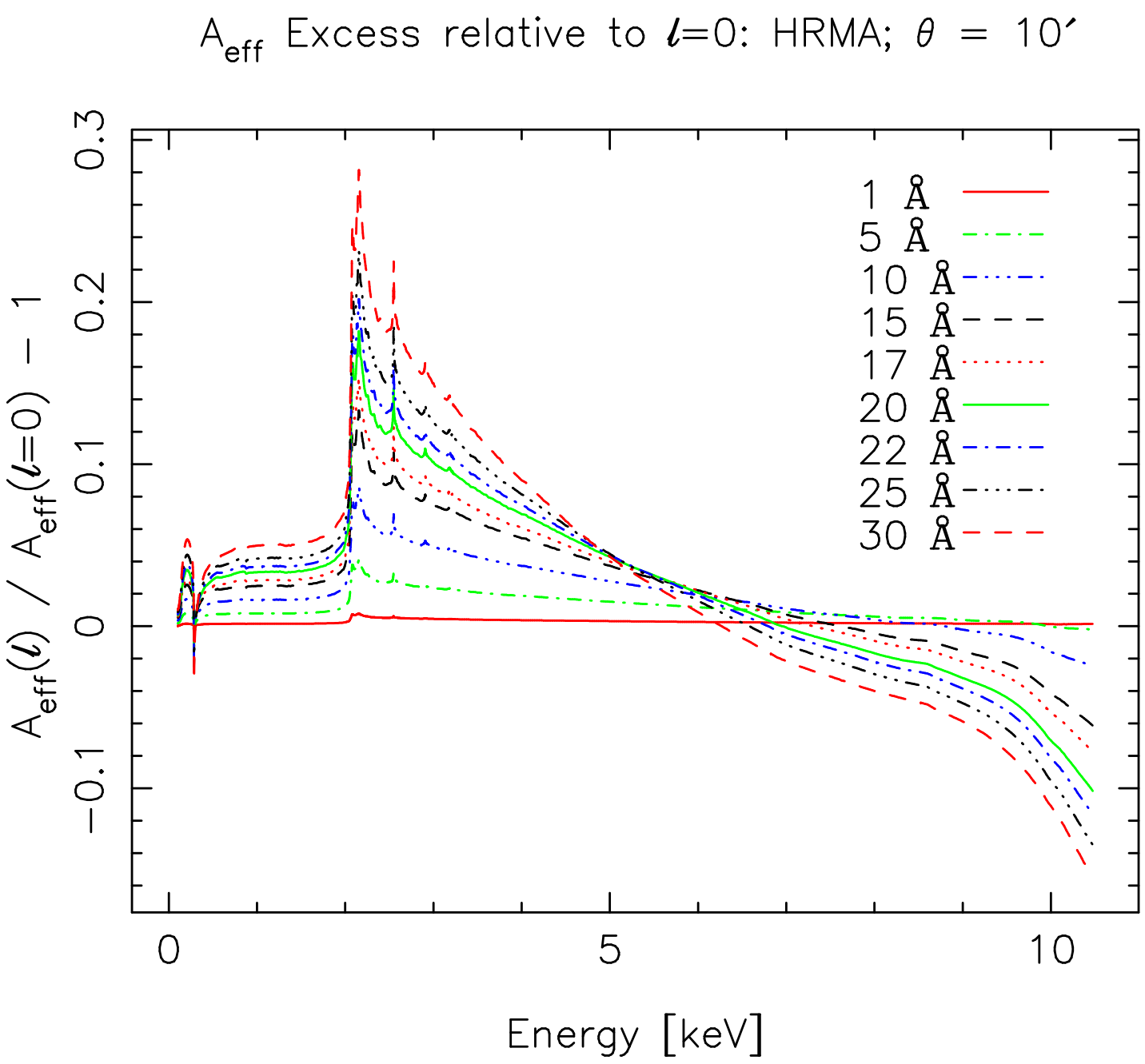
We present these results in two formats. The first is simply the ratio of the A_{eff} with a contamination layer to that without.


A_eff Excess relative to ℓ=0: HRMA; θ = 1′
A_eff(ℓ) / A_eff(ℓ=0) − 1
0.3
0.2
0.1
0
−0.1
0
5
10
Energy [keV]
1 Å
5 Å
10 Å
15 Å
17 Å
20 Å
22 Å
25 Å
30 Å


A_eff Excess relative to ℓ=0: HRMA; θ = 2′
A_eff(ℓ) / A_eff(ℓ=0) − 1
0.3
0.2
0.1
0
−0.1
0
5
10
Energy [keV]
1 Å
5 Å
10 Å
15 Å
17 Å
20 Å
22 Å
25 Å
30 Å


A_eff Excess relative to ℓ=0: HRMA; θ = 5′
A_eff(ℓ) / A_eff(ℓ=0) − 1
0.3
0.2
0.1
0
−0.1
0
5
10
Energy [keV]
1 Å
5 Å
10 Å
15 Å
17 Å
20 Å
22 Å
25 Å
30 Å

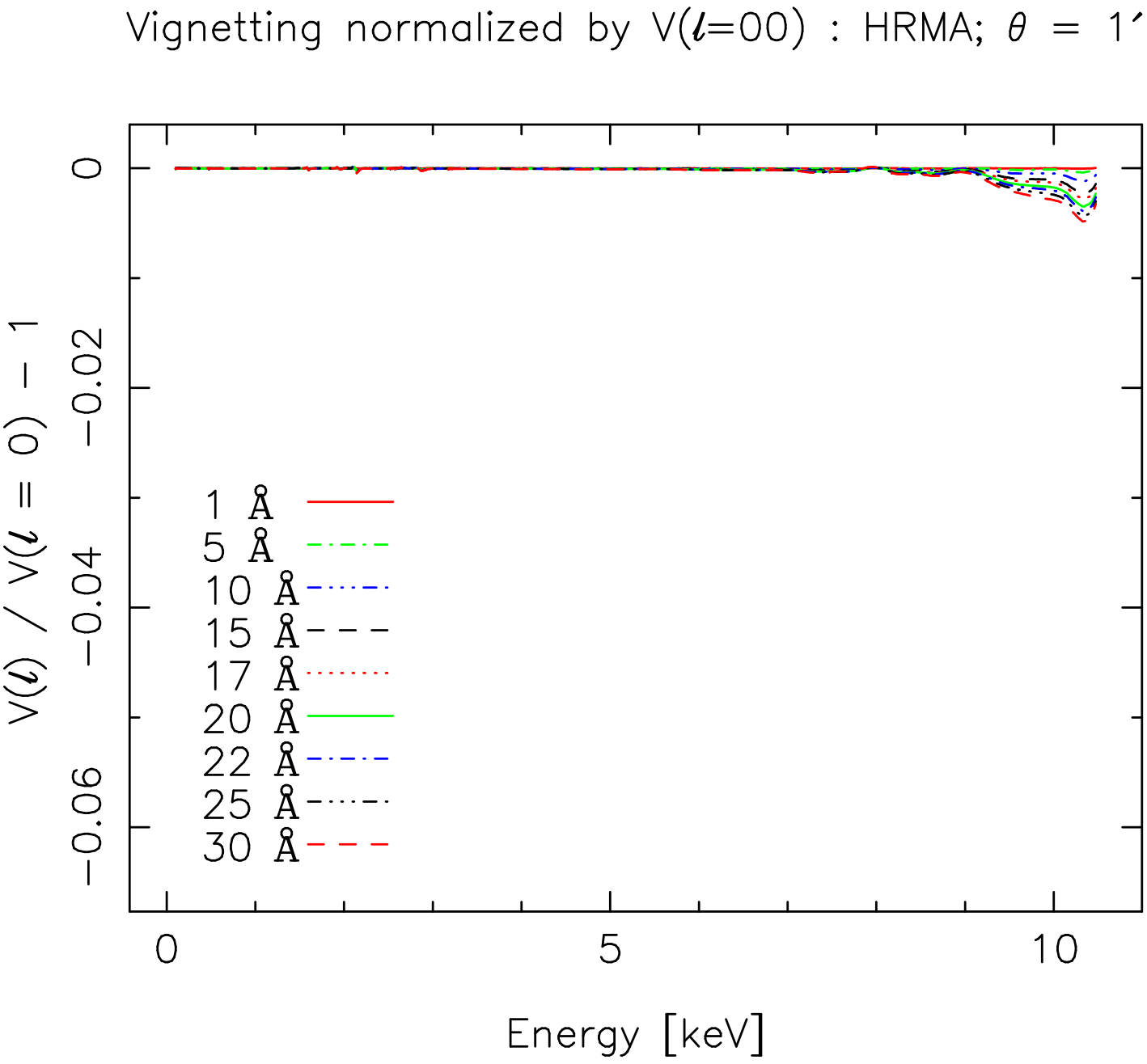

A_eff Excess relative to ℓ=0: HRMA; θ = 8′
A_eff(ℓ) / A_eff(ℓ=0) − 1
0.3
0.2
0.1
0
−0.1
0
5
10
Energy [keV]
1 Å
5 Å
10 Å
15 Å
17 Å
20 Å
22 Å
25 Å
30 Å

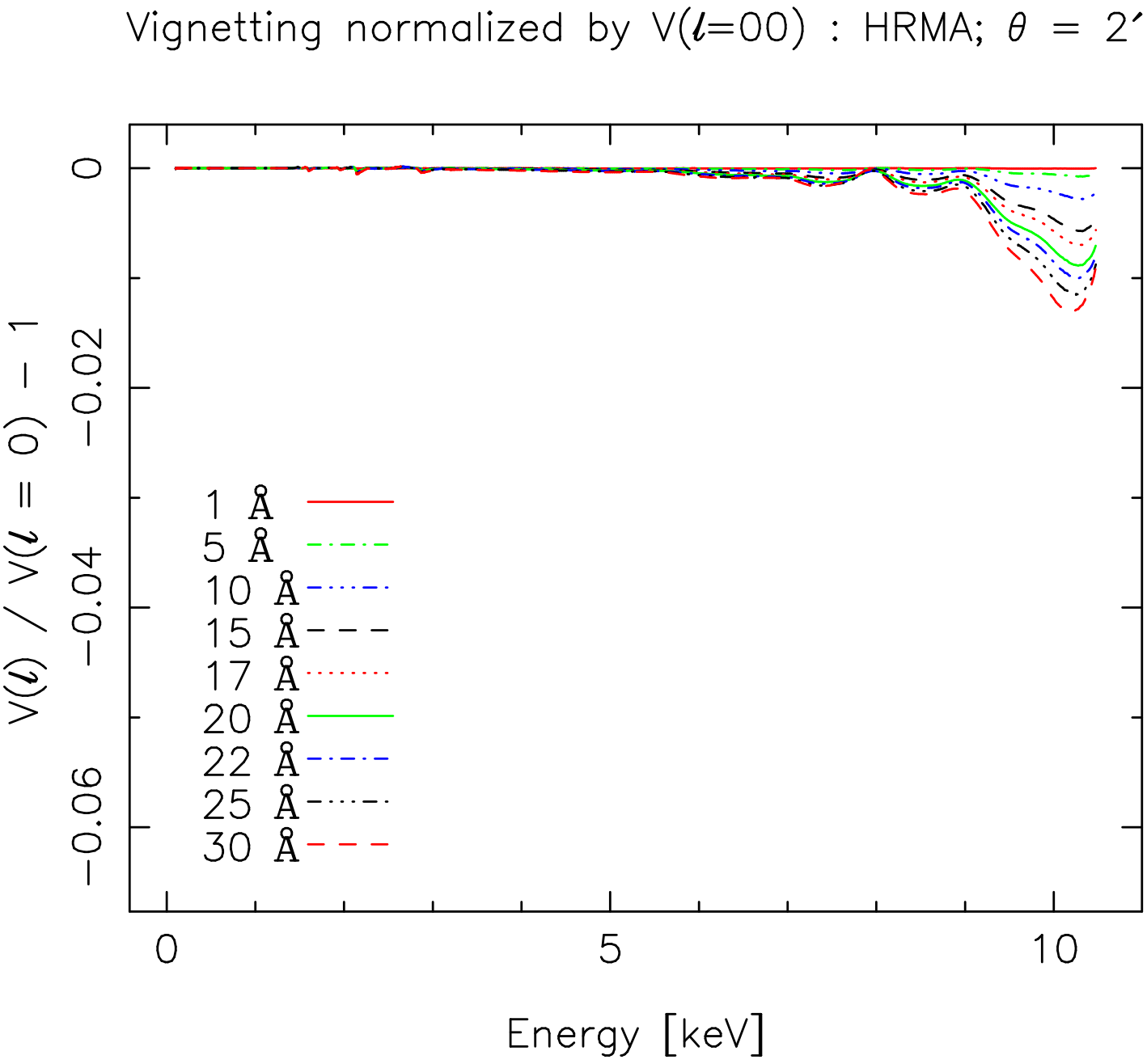

A_eff Excess relative to ℓ=0: HRMA; θ = 10′
A_eff(ℓ) / A_eff(ℓ=0) − 1
0.3
0.2
0.1
0
−0.1
0
5
10
Energy [keV]
1 Å
5 Å
10 Å
15 Å
17 Å
20 Å
22 Å
25 Å
30 Å

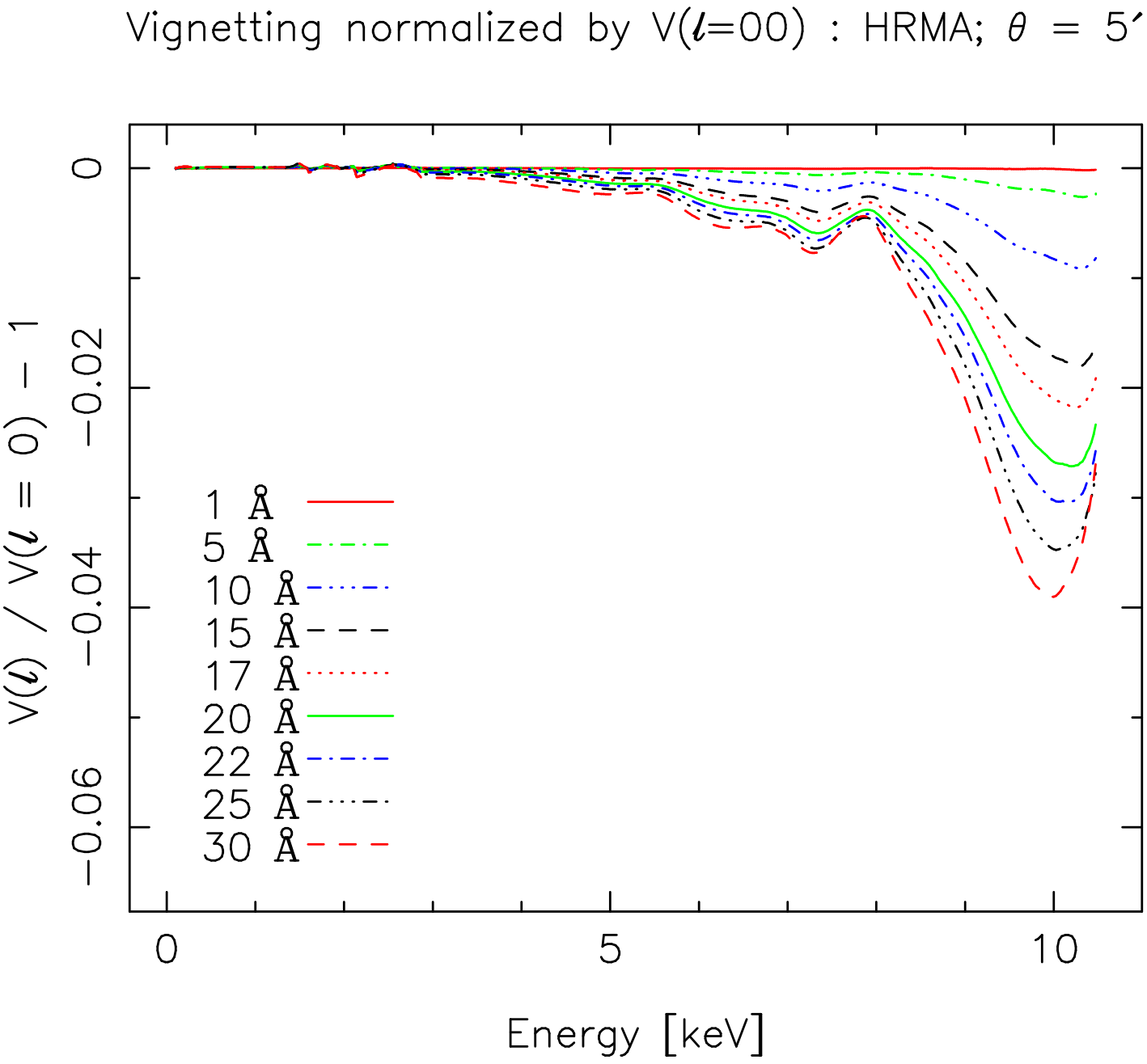
Effect of a Contamination layer on Vignetting

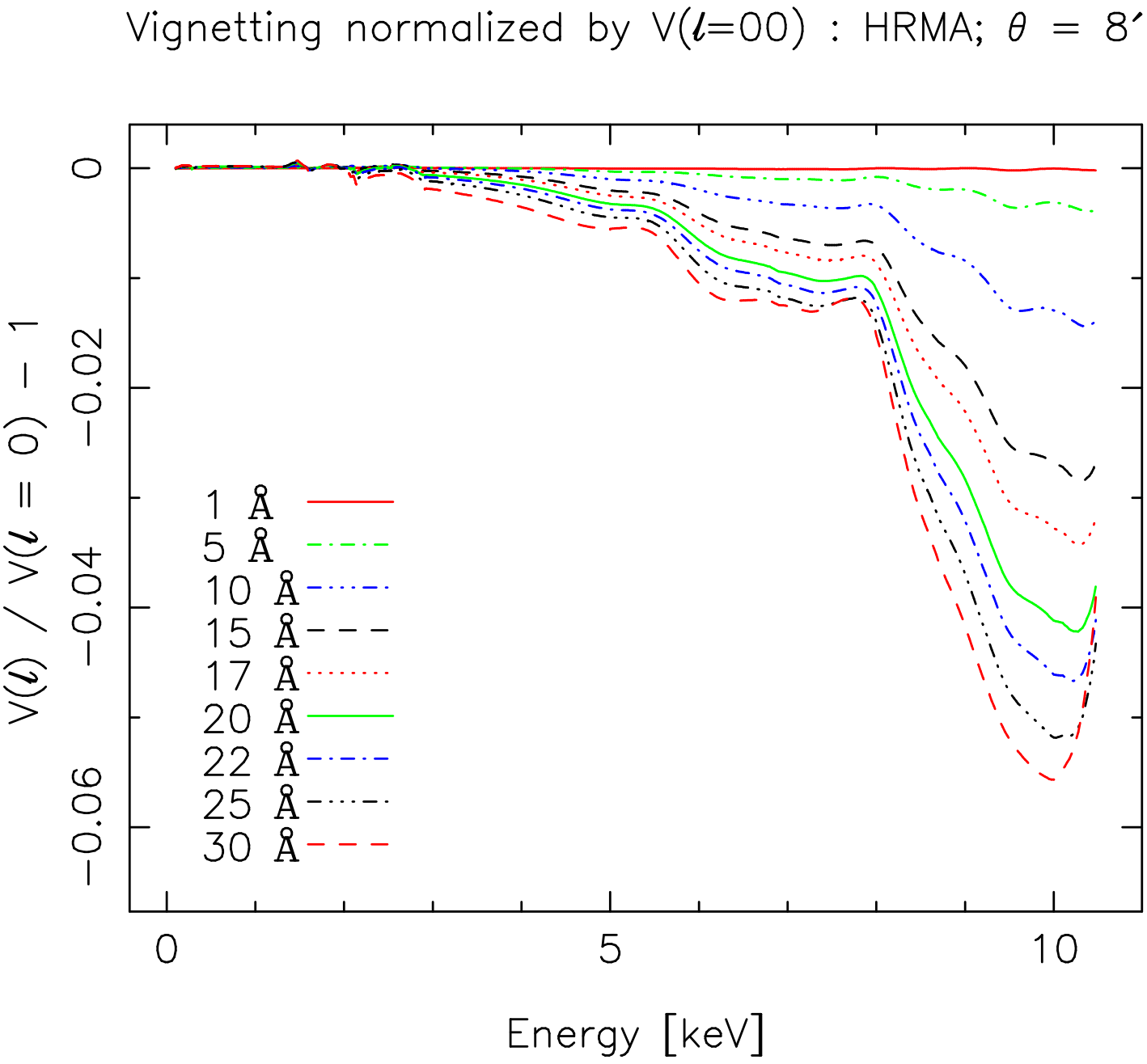
Another important consideration is how the spatial distribution of the vignetting function changes. In the next several slides, we plot the ratio of the vignetting functions.

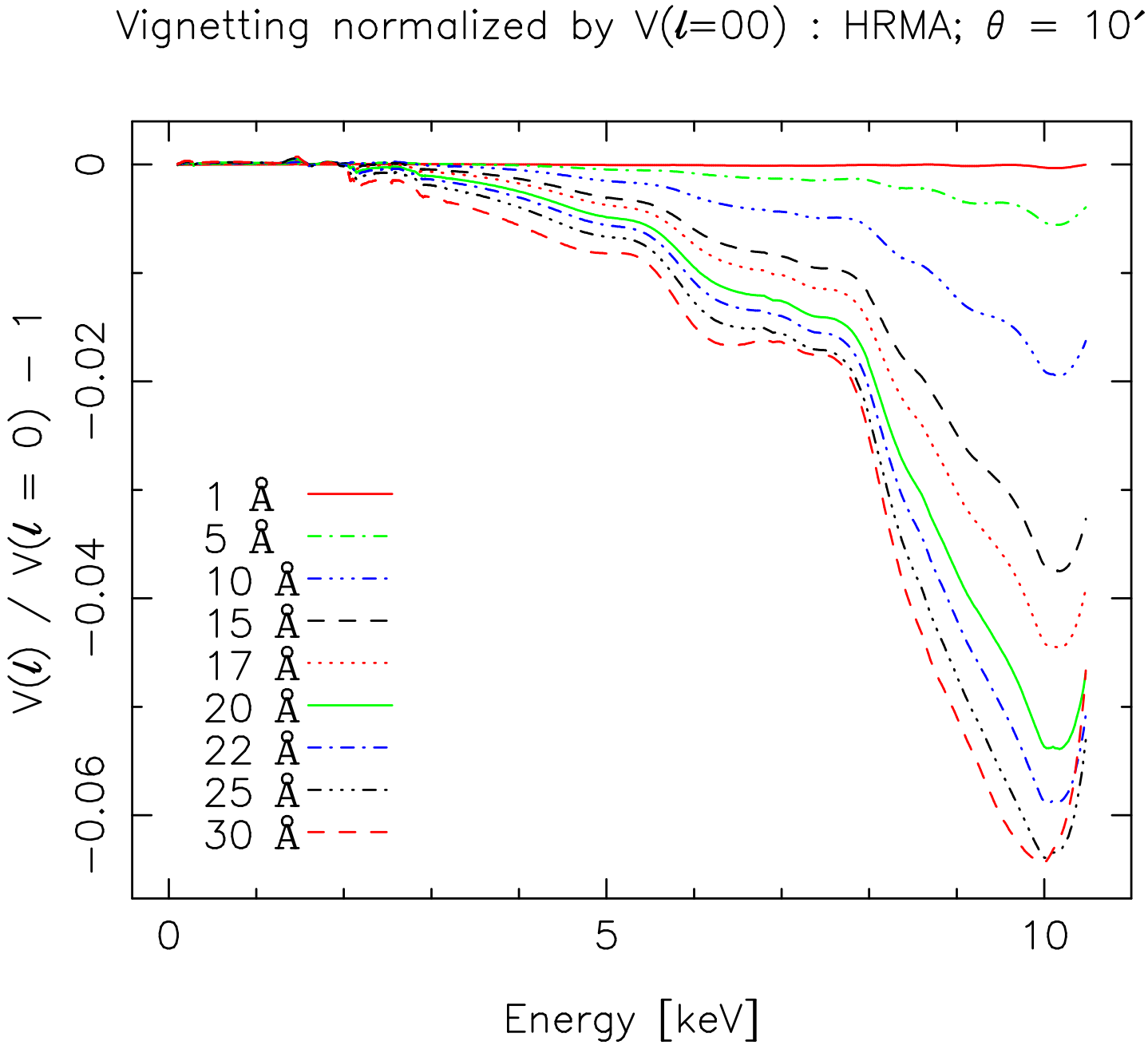
The functions have essentially the same shape; the difference is less than 1% for sources within 5′ of the optical axis at energies below 8 keV.


Vignetting normalized by V(ℓ=00) : HRMA; θ = 1′
V(ℓ) / V(ℓ = 0) − 1
0
−0.02
−0.04
−0.06
1 Å
5 Å
10 Å
15 Å
17 Å
20 Å
22 Å
25 Å
30 Å
0
5
10
Energy [keV]


Vignetting normalized by V(ℓ=00) : HRMA; θ = 2′
V(ℓ) / V(ℓ = 0) − 1
0
−0.02
−0.04
−0.06
0
5
10
Energy [keV]
1 Å
5 Å
10 Å
15 Å
17 Å
20 Å
22 Å
25 Å
30 Å


Vignetting normalized by V(ℓ=00) : HRMA; θ = 5′
V(ℓ) / V(ℓ = 0) − 1
0
−0.02
−0.04
−0.06
1 Å
5 Å
10 Å
15 Å
17 Å
20 Å
22 Å
25 Å
30 Å
0
5
10
Energy [keV]


Vignetting normalized by V(ℓ=00) : HRMA; θ = 8′
V(ℓ) / V(ℓ = 0) − 1
0
−0.02
−0.04
−0.06
1 Å
5 Å
10 Å
15 Å
17 Å
20 Å
22 Å
25 Å
30 Å
0
5
10
Energy [keV]


Vignetting normalized by V(ℓ=00) : HRMA; θ = 10′
V(ℓ) / V(ℓ = 0) − 1
0
−0.02
−0.04
−0.06
0
5
10
Energy [keV]
1 Å
5 Å
10 Å
15 Å
17 Å
20 Å
22 Å
25 Å
30 Å

Conclusions

- The most likely explanation for the discrepancy near the Ir edge is a very thin layer of hydrocarbon contaminant on the Chandra mirrors
- The layer is 15Åto 20Å.
- New Ir optical constants may change the above result slightly.
- The addition of a contaminant layer does not significantly change the spatial distribution of focal plane vignetting.