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A detailed study of the XMM-Newton flaring particle background

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Effect of filters on particle flares

MOS1/MOS2 cameras simultaneously observing the same flaring episode with different filters detect substantially different count rates





EPIC-PN filters

- Due to energy loss, protons above threshold become detectable
- Filters stop low energy protons
- Thick filter stops protons up to higher energies

Proton spectrum is soft ⇒ <u>reduced background</u>

SP spectrum observed by XMM

- MOS peripheral CCDs in **low gain** mode (0.2-12 keV → 2-120 keV) with MOS1 & 2 with different filters (thin/thick)
- **Background** from faint time period (or Out Field of View region)



Old EPIC memories... Spectra with Thin and Thick filter



 $\Delta E \approx 40 \text{ keV} \text{ (for } E > 20 \text{ keV} \text{)}$

- MOS thin filter: 0.16 μ m polyimide + 0.04 μ m Al
- MOS thick filter: 0.33 μm polypropylene + 0.11 μm Al + 0.045 μm tin
- **Proton** energy loss from *NIST* Standard Reference Database 124 (considering also Detour Factor)

https://physics.nist.gov/PhysRefData/Star/Text/PSTAR.html

Detour Factor

Projected / CSDA

0.2555

0.2933

0.3245

0.3509

0.3738

0.4122

0.4434

0.4696

0.4921

0.5117

0.5291

0.5445

0.5773

0.6040

0.6263

0.6454

0.6620

0.6767



ALUMINUM

- Constructing the energy loss for each filter as if protons keep the same energy across the filter (only valid for small energy losses, i.e., short tracks)
- Empirical **model** of energy loss for each filter using:

 $dE(E) = \Delta E + c \cdot E \cdot exp(-E/E_f)$



$$\begin{split} & \Delta E_{thin} = 15 \pm 2 \text{ keV}, \\ & C_{thin} = 0.5 \pm 0.1, \\ & E_{f,thin} = 62 \pm 12 \text{ keV}, \\ & \Delta E_{thick} = 36 \pm 5 \text{ keV}, \\ & C_{thick} = 1.5 \pm 0.4, \\ & E_{f,thick} = 58 \pm 11 \text{ keV}, \end{split}$$

 We divide the filter thickness into 1000 bins, where the energy loss is constant between the initial and final energy and we integrate the energy loss





The energy loss only slightly depends on energy if the final energy is in the 2-120 keV range

MOS spectra: simultaneous fit

- Background subtracted spectra with diagonal response matrix
- Restricted to 20-120 keV band





MOS spectra: simultaneous fit

- Background subtracted spectra with diagonal response matrix
- Extended to 1-120 keV band



Empirical model of energy loss

Model: $F(E) = k \cdot (E + \Delta E + c \cdot E \cdot exp(-E/E_f))^{-\alpha}$

Best-fit in the 2-120 keV energy band:





Alpha energy loss in filters

- Constructing the energy loss for each filter as if
 Alpha particles keep the same energy across the filter
 (only valid for small energy losses, i.e., short tracks)
- Empirical model of energy loss for each filter using:

 $dE(E) = \Delta E + c \cdot E \cdot exp(-E/E_f)$



Alpha energy loss in filters



Work in progress (bachelor thesis)

• Energy loss in filters from **simulations**



Work in progress (bachelor thesis)

- Energy loss in filters from **simulations**
- Evaluate maximum contribution from **Alpha particles**
- Reconstruct SP spectrum from normal gain data (CCD1), assuming energy loss from low gain spectra
 - 42 scientific observations (e.g., PG 2112+059; Schartel et al. 2010, A&A 512, A75) in 4XMM_DR12 with MOS1/MOS2 with thin/thick filter ⇒ recovery of high background time intervals?
 - Possible observing strategy when background is more critical than effective area at the lowest energies (e.g., hard extended sources): PN and MOS2 with Thick filter (⇒ smaller SP contamination) and MOS1 with Thin filter (⇒ better model for SP spectrum)