Tests for contamination of the HRMA

Particulate contamination

AXAF Project Science

AXAF XRCF Pre-Calibration Review

NASA Marshall Space Flight Center

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Summary

Particulate contamination can alter HRMA performance.

- Diffractive scattering affects wings of HRMA point spread function.
    - Fraction of PSF in dust-produced wings is 0.3% ($F_{dust}/10^{-5}$).
    - Energy dependence is weak, unlike strong (E^2) dependence of diffractive scattering by surface microroughness.
    - Angular distribution is quasi-isotropic, unlike predominantly in-plane scattering by surface microroughness.
- Absorption reduces HRMA effective area.
    - Fraction of effective area lost to dust is 0.3% ($F_{dust}/10^{-5}$).

Primary tests for particulate contamination are FPC wing scans of PSF.

Secondary tests are parasitic or conditional.

- HSI shutter-focus images could confirm interpretation as dust.
- HSI ring-focus images could show azimuthal distribution of dust.
- FPC wing scans for sub-apertures would identify location of dust.

Primary test

Planned wing scans will obtain necessary data. No special test is required.

- Low-energy wing scans are most informative for measuring dust.

Contributions to PSF wings

Diffraction by limiting aperture:

$$\psi_{\text{aperture}}(\vartheta) \approx \frac{\lambda}{2\,(\Delta r)\,\pi^3\vartheta^3} \propto \frac{\lambda}{\vartheta^3}\ .$$

Diffractive scattering by particulates:

$$\psi_{\text{particulates}}(\vartheta) \approx 4\int_0^{(\frac{\lambda}{\pi\vartheta})} \left(\frac{2\pi a}{\lambda}\right)^2 q_s(\lambda, a)\,\frac{F_a(a)\,da}{4\pi\sin\alpha} \propto \frac{\bar{q}_s(\lambda)\,(\vartheta/\lambda)^{\Delta p}}{\vartheta^2}\,,\quad F_a \propto a^{-1-\Delta p}.$$

Diffractive scattering by surface roughness:

$$\psi_{\text{roughness}}(\vartheta) \approx 2\left(\frac{4\pi\sin\alpha}{\lambda}\right)^2 \left(\frac{2W_1(f)\,f}{2\pi\vartheta^2}\right) \propto \frac{(\lambda/\vartheta)^{\Delta s}}{\vartheta^2\lambda^2}\,,\quad f \approx \frac{\vartheta\sin\alpha}{\lambda},\ W_1 \propto f^{-1-\Delta s}.$$

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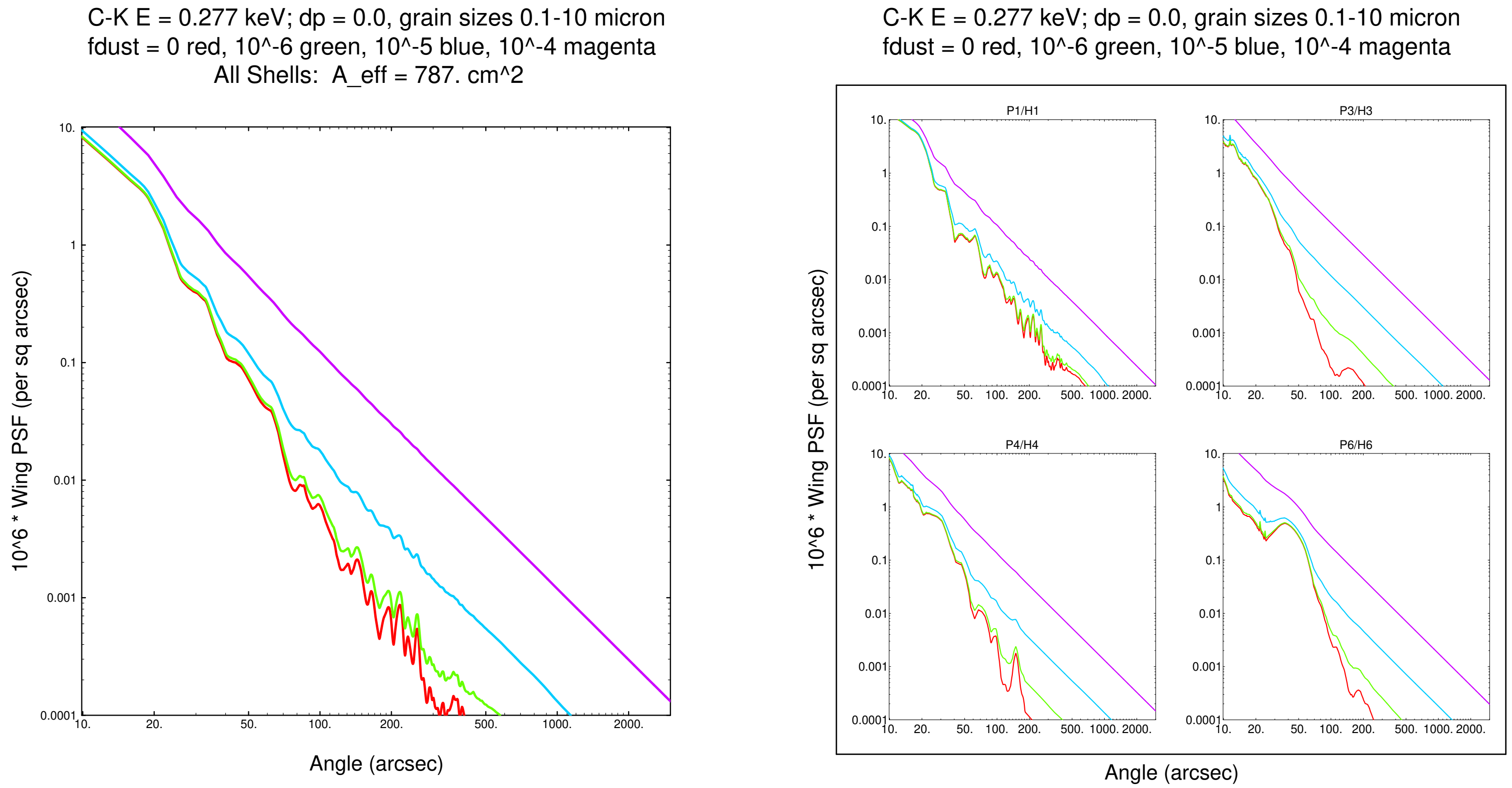
Particulate contamination *Part-5*

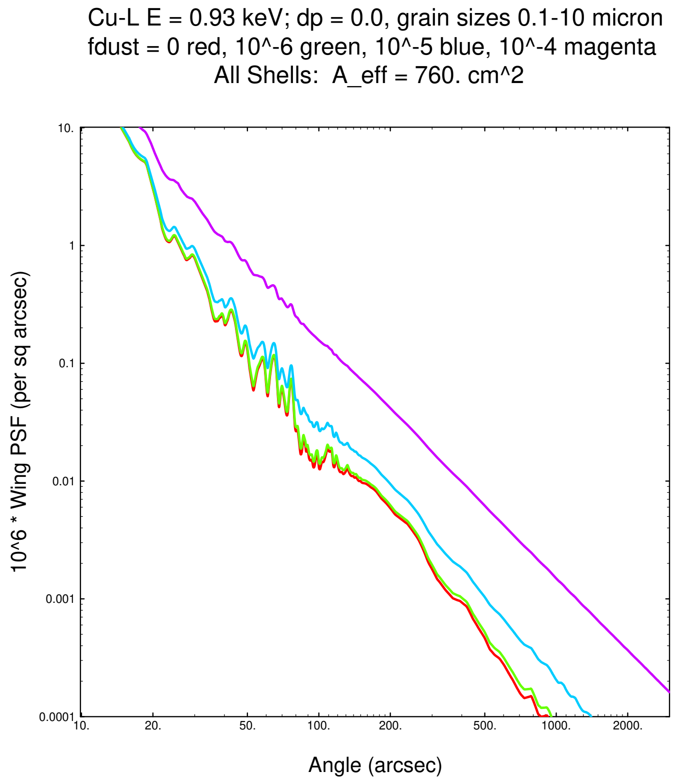
XRCF

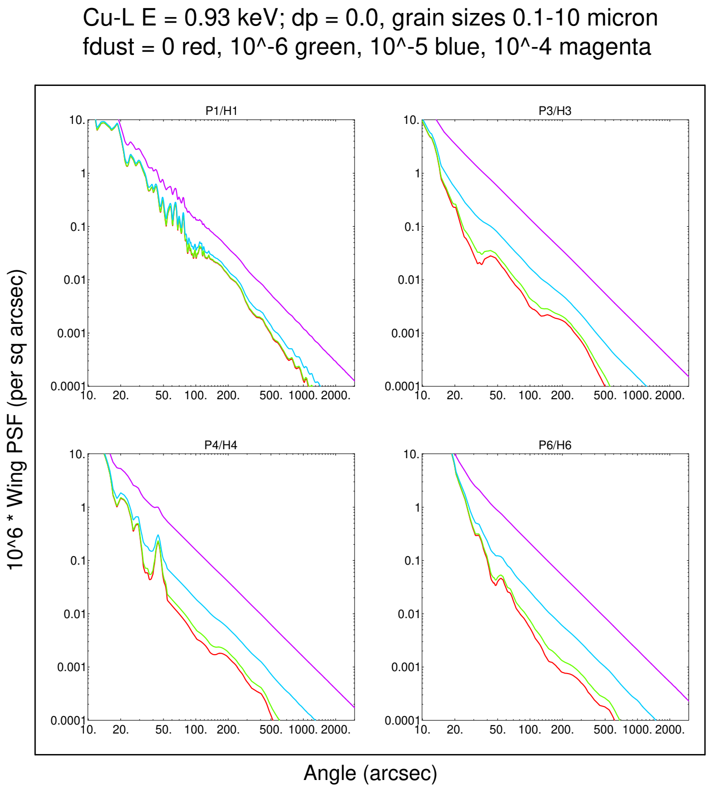
Wing PSF at 0.277 keV



Wing point spread function (PSF) at C-Kα (0.277 keV), for various levels of particulate contamination. The plots show the wing PSF (l) for the full HRMA and (r) for the 4 individual shells. The fractional areal coverage by dust (F_{dust}) is 0, 10^{-6}, 10^{-5}, and 10^{-4}.

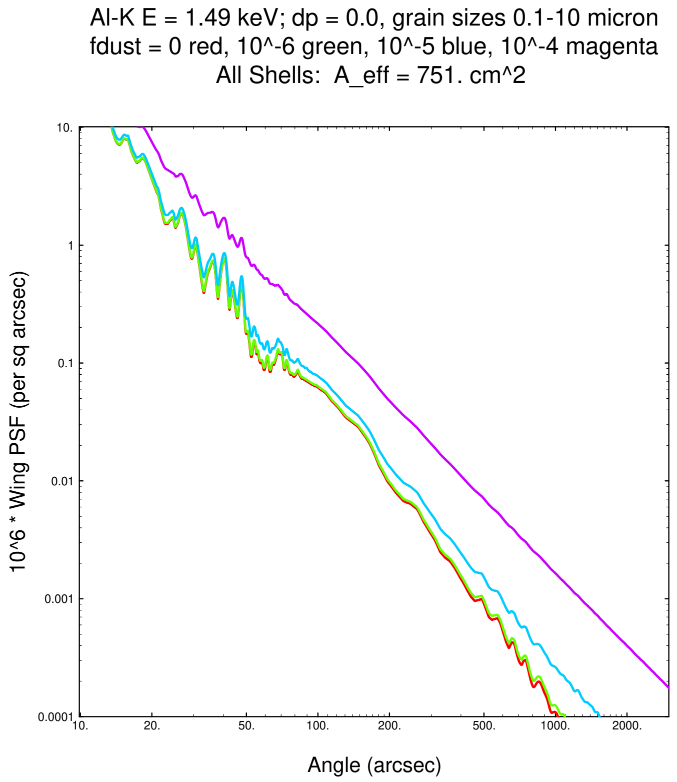
Wing PSF at 0.930 keV

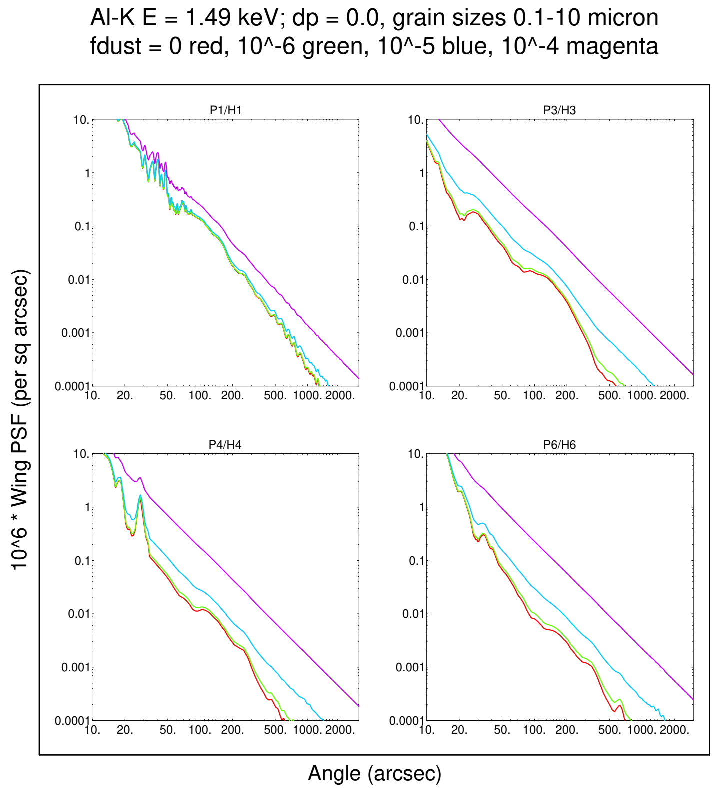




Wing point spread function (PSF) at Cu-Lα (0.930 keV), for various levels of particulate contamination. The plots show the wing PSF (l) for the full HRMA and (r) for the 4 individual shells. The fractional areal coverage by dust (F_{dust}) is 0, 10^{-6}, 10^{-5}, and 10^{-4}.

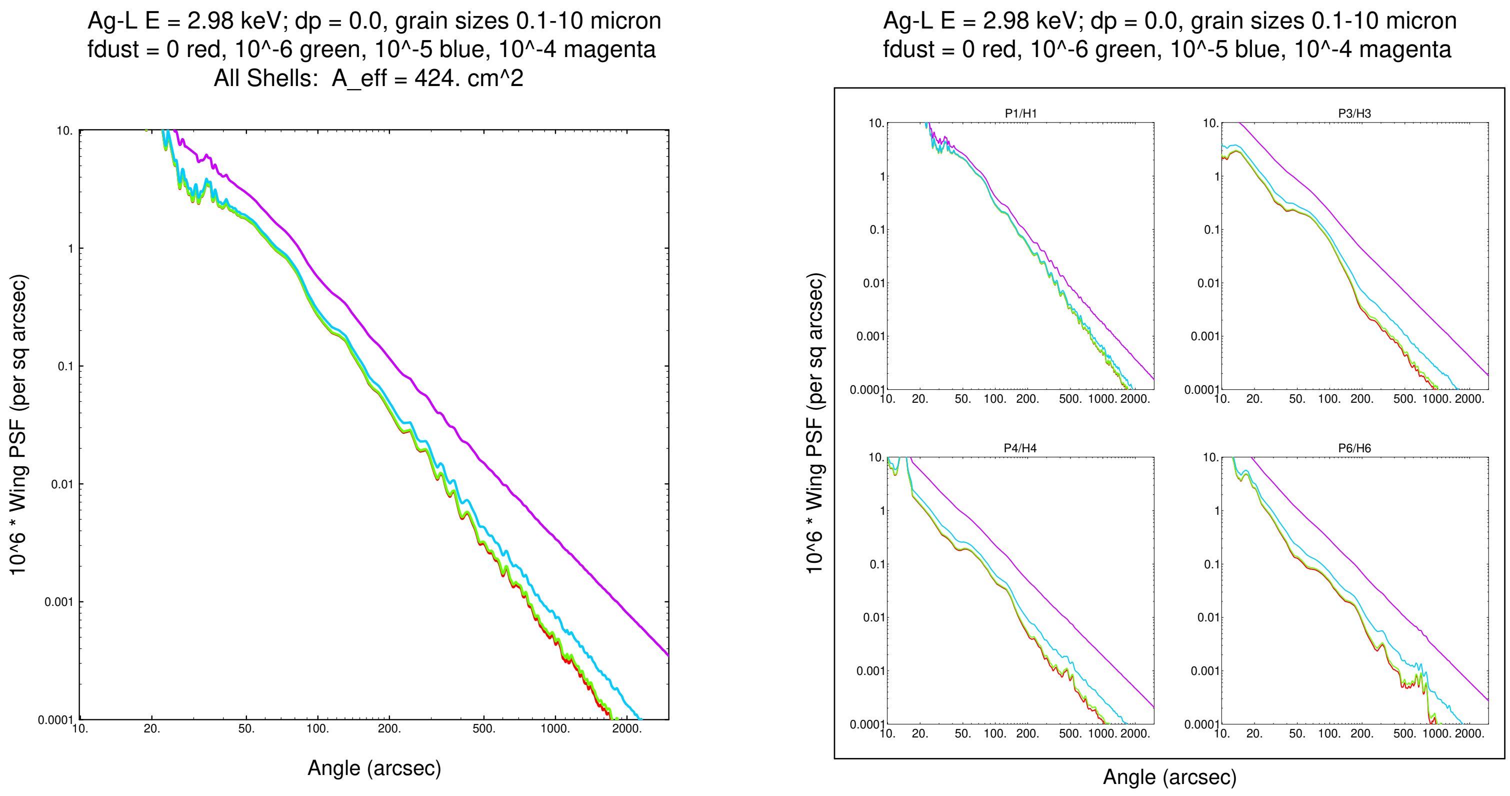
Wing PSF at 1.49 keV





Wing point spread function (PSF) at Al-Kα (1.49 keV), for various levels of particulate contamination. The plots show the wing PSF (l) for the full HRMA and (r) for the 4 individual shells. The fractional areal coverage by dust (F_{dust}) is 0, 10^{-6}, 10^{-5}, and 10^{-4}.

Wing PSF at 2.98 keV



Ag-L E = 2.98 keV; dp = 0.0, grain sizes 0.1-10 micron
fdust = 0 red, 10^-6 green, 10^-5 blue, 10^-4 magenta
All Shells: A_eff = 424. cm^2

Ag-L E = 2.98 keV; dp = 0.0, grain sizes 0.1-10 micron
fdust = 0 red, 10^-6 green, 10^-5 blue, 10^-4 magenta

Wing point spread function (PSF) at Ag-Lα (2.98 keV), for various levels of particulate contamination. The plots show the wing PSF (l) for the full HRMA and (r) for the 4 individual shells. The fractional areal coverage by dust (F_{dust}) is 0, 10^{-6}, 10^{-5}, and 10^{-4}.