Effects of a Warm ACIS Focal Plane on HETGS Spectroscopy

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Warm ACIS: Non-Issues

- Dispersion relation
  - Only depends on grating P, Rowland distance, ACIS scale
  - Effect on ACIS scale is negligible

- Line response function
  - Only depends on grating dP/P, HRMA PSF, ACIS pixel size
  - ACIS T does not affect these noticeably

- Grating efficiencies or HRMA area

- Cross dispersion profile
  - Determines aperture correction
  - Depends on HRMA PSF and Rowland geometry
Effects on HETGS EA

- Increased detector hot pixels
- Impact mitigated by dithering
- HEG/MEG and +1/-1 provide complementary data

Reduced detector QE

Order selection
- Separating orders — no problem due to wide order separation
- Accounting for PH selection fraction
  - Gain changes centroid of selection
  - RMF may be broader when warm
QE Effects (from NSS)

- Data:
  - θ¹ Ori C: 1999, 2002
  - θ¹ Ori C: 2019-2020
  - 4U 1626-67: 2018

- Result
  - No temperature dependence
  - Losses < 3% at -109°C
RMF Effects (from DPH)
RMF Effects 2

- Data sets
  - 4U 1626 (2018)
  - $\theta^1$ Ori C: 2019-2020
- Capella had poor gain correction

- Processing
  - Accumulate PH distributions
  - Fit Gaussians
  - Separate by $T$
RMF Effects 3

- Centroids
  - Slight variations in $<E/E_0>$
  - Assume $< 0.4\%$ shift
- Widths
  - $\sigma/E_0$ changes inconsistent
  - $-1.6 \pm 0.8\%$ for 4U 1626
  - $-9.6 \pm 1.2\%$ for $\theta^1$ Ori C
  - Assume $< 5\%$ smaller
RMF Effects Analysis

- RMF Center: Gaussian
- dominates OSIP
- **possible** weak change with FP_TEMP
- RMF tail
  - escape peak at 2 keV
  - otherwise < 2% of total
  - no change with FP_TEMP
- \(\rightarrow\) Concentrate on Gaussian
**Effect of Centroid Shift**

- Shifting RMF reduces power in OSIP region
- Model:
  \[
  f = \int_{-a}^{a} \phi(x)dx, \quad \phi(x) = \frac{1}{(2\pi)^{1/2}}e^{-(x-\mu)^2/2\sigma^2}
  \]
  \[
  x = E/E_0, \quad \mu = \bar{E}/E_0
  \]
- Let \(\mu = \mu_0 + \Delta \mu\)

  Then \(\delta f \approx \frac{a \Delta \mu}{(2\pi)^{1/2}}e^{-a^2/2}\)

- Verified approximation with simulation

- From DPH: \(\Delta \mu = 0.004, \sigma/E_0 = 0.038-0.014 (1-4 \text{ keV}) \rightarrow \Delta \mu/\sigma = \Delta (E/E_0)/\sigma = 0.1-0.3\)

- Gaussian model: \(\delta f = 0.05 - 0.35\% \text{ for } 99\% \text{ OSIP (}a = 2.58\); 0.1-1.1\% for 95\%

- \(\rightarrow \text{ Expect } < 1\% \text{ OSIP loss}\)
Effect of Wider RMF

- Wider RMF reduces power in OSIP region
- Same Gaussian model
- Let $\sigma = \sigma_0 + \Delta \sigma$
  
  Then $\delta f \approx \frac{2\Delta \sigma}{(2\pi)^{1/2}\sigma} e^{-\frac{a^2}{2}}$

- From DPH: $\Delta \sigma < 0.05$
- Gaussian model: $\delta f = 0.5\%$ for 99% OSIP; 1.3% for 95% (worst case)

  $\rightarrow$ Expect $< \sim 1\%$ OSIP loss
Conclusions

- Effect of higher T on QE looks negligible
- < 1% effect on OSIP due to possible shift of RMF centroid
- ~1% effect on OSIP due to possibly wider RMF
- Caveats:
  - Small RMF effects need more data
  - Some inconsistencies between data sets
- Impression: OK to use HETGS with warmer ACIS