Characterization of Chandra's On-board ^{55}Fe Calibration Source using Microcalorimetry

Abby Besemer* and Donald Brandl

Physics Department, University of Wisconsin Madison

Abstract:

In May of 2000 it was determined that outgassed materials have been building up on Chandra's ACIS optical light blocking filters since its launch. In order to make accurate models of the distribution and thickness of the contaminants so that corrections to collected data can be made, the contaminant buildup has been tracked using Fe and Mn L-lines from the external ^{55}Fe calibration source. Uncertainty in the details of the source spectrum currently limit the accuracy of these determinations. We are obtaining a high energy resolution spectrum of the ACIS ^{55}Fe External Calibration source with microcalorimeter detectors that have ~5 eV FWHM energy resolution. This poster will show how we can measure the emission spectrum of a flight spare unit of Chandra's ^{55}Fe source.

^{55}Fe Calibration Source:

Chandra's ^{55}Fe External Calibration Source monitors the build up of contaminants on the CCDs and light blocking filters by measuring the ratio of the L-complex (Mn L-Fe L) flux to Mn Kα flux. Contaminants will partially absorb the lower energy L-complex emissions (~ .67 keV) but are transparent to the higher energy (~5.9 keV) Mn Kα photons. This L-complex line is a blend of Mn L and Fe L emission lines. (Their individual energies can be seen in Table 1.) Because Chandra's FI (front illuminated) CCDs only have an energy resolution of ~50eV FWHM in this energy range, these individual lines are not differentiable and appear as a single line as seen in Figure 1.

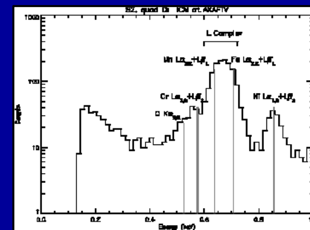
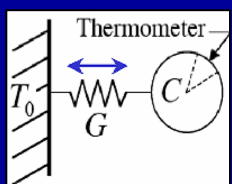


Figure 1: Present spectral composition of L-complex

K shell Emissions	
Mn K β1	6490.5eV
Mn K α1	5887.6eV
Mn K α2	5898.8eV
L shell Emissions	
Fe L α1,2	705eV
Fe L β1	718eV
Mn L α1,2	637.4eV
Mn L β2	648.8eV

Table 1: ^{55}Fe emissions

Microcalorimetry:



Microcalorimeters are composed of 3 basic parts: an absorber that absorbs the incident x-ray and thermalizes its energy, a thermometer to measure the change in temperature of the absorber, and a weak thermal link connected to the cold stage of the ADR that allows the absorber to return to its original temperature. When an x-ray strikes the HgCdTe absorber it creates a photoelectron which then thermalizes its energy and heats up the absorber. By applying a bias voltage, the change in the resistance of a semi-conductor thermistor due to the temperature increase can be read out as a change in voltage. The increase in temperature is proportional to the energy of the incident photon divided by the heat capacity of the absorber ($\Delta T = E/C$). The absorber will then cool back down to its equilibrium temperature with a time constant $\tau = C/G$, where C is the heat capacity of the absorber and G is the thermal conductance of the weak link.

Cooling:

In order to detect such a small increase in temperature, not only must the heat capacity of the absorbers be low (2.4 E-14 J/K), but they must also be cooled down to milli-Kelvin temperatures. The detectors are cooled down in various "stages" in order to reach such extreme temperatures. The outermost stage cools the detectors to 77K using liquid Nitrogen. The second stage uses liquid Helium to reduce the temperature to 4.2K. The next stage involves pumping on the He (reducing the pressure) which lowers its boiling point to 1.4K. Lastly, an Adiabatic Demagnetization Refrigerator (ADR) is then used to cool the detectors down to 50mK.

Setup:

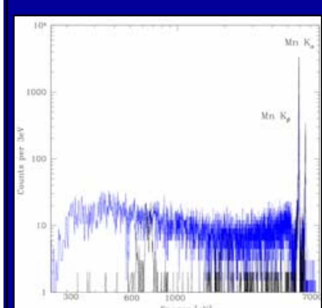


Figure 2: The ^{55}Fe spectrum before the magnetic trap was installed is shown in blue. The lower energy L emission lines are covered by a quasi-continuous background produced by Auger electrons.

About 99% of all decays in the ^{55}Fe source leave a K-shell vacancy due to the capture of a K-shell electron. 75% of these vacancies are filled by transitions that result in the emission of an Auger electron rather then a Kα or Kβ photon. The Auger electrons scatter and lose various amounts of energy and when they hit the detector, they produce events that are indistinguishable from x-rays. Onboard Chandra these electrons are blocked by the optical blocking filters, but in order to get the relative line intensities without absorption correction we are not using a filter. Figure 2 shows the ^{55}Fe spectrum and the quasi-continuous background produced by Auger electrons.

The microcalorimeter detectors are mounted on a cold plate inside of the ADR and placed in front of a flight spare ^{55}Fe calibration source. To prevent Auger electrons from reaching the detector, a "magnetic trap" was installed between the detectors and the source. Electrons are deflected by Neodymium-Iron-Boron magnets with a field of ~2000 gauss and are then trapped by four levels of BeCu baffles that are aligned parallel to the source/detector as seen in Figure 3.

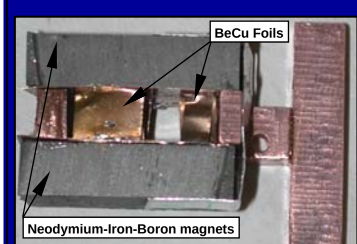


Figure 3: The magnetic trap assembly. The x-ray beam travels perpendicular to the paper through the gap in the BeCu foils where the detector is located. The foils trap the deflected and scattered electrons.

Results:

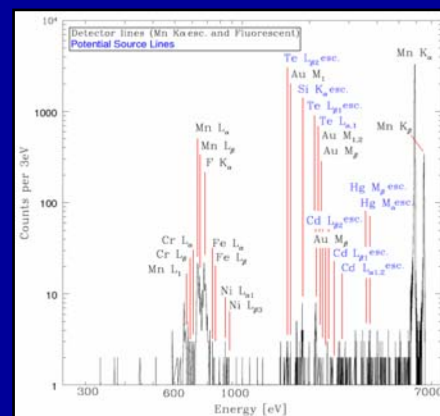


Figure 4: The ^{55}Fe source spectrum. The Mn Kα and Kβ emission lines can be seen on the far right and the L-lines are on the far left. The lines labeled in blue are characteristic of the CdHgTe detector (Mn Kα escape and fluorescence).

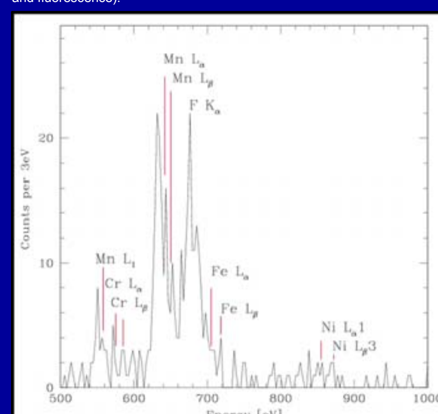


Figure 5: A close up of the ^{55}Fe L emissions. The energy resolution is currently ~7eV, but with increased statistics and further gain drift corrections we expect it to reach ~5eV.

Conclusions:

Current models of the L-complex line have been fit assuming equal contributions from the average Mn and Fe L lines. Although the data has yet to be corrected for detector efficiency and gain drifts, it seems safe to conclude the Fe L lines are actually less than 10% of the Mn L lines. Surprisingly, we have also found that F Kα (677 eV) is an important constituent of the L-complex line (about 0.38% of Mg Kα or about 115% of Mn Lαβ). The complex at 550eV (seen in Figure 1) had been speculated to contain bend of O Kα and Cr L emissions, but we find no evidence of the O Kα line from the source. There is a reasonably strong line consistent with Mn L1 at 552eV (at about .05% of Mn Ka) and the Cr L lines are weak (less than .016% of Mn Ka).

*Current address: Indiana University -abesemer@indiana.edu

Literature Cited:

C. Enss, D. McCammon. J Low Temp. Phys. 151, 2 (2007)

M. W. Bantz and J. A. Nousek. Science Instrument (SI) Calibration Report for the AXAF CCD Imaging Spectrometer (ACIS) 15 January 1999 http://www.astro.psu.edu/xray/docs/cal_report/node151.html.

A. Vikhlinin. Chandra X-ray Center. Chandra News. "Spatial Structure in the ACIS OBF contamination" 2004 http://cxc.harvard.edu/cal/Acis/Cal_prods/qeDeg/index.html.

Acknowledgements:

This work was supported by the National Science Foundation's REU program and the Department of Defense's ASSURE program through NSF Award AST-0453442.
Thank-you to my REU advisor; Dan McCammon.