Detector Calibration of the Micro-X Sounding Rocket X-ray Telescope

[1,2]D.C. Goldfinger, [3,4]J.S. Adams, [3]R. Baker, [3]S.R. Bandler, [2]N. Bastidon, [2]M.E. Danowski, [5]W.B. Doriese, [3]M.E. Eckart, [2]E. Figueroa-Feliciano, [1]S.N.T. Heine, [5]G.C. Hilton, [2]A.J.F. Hubbard, [3]R.L. Kelley, [3]C.A. Kilbourne, [2]R. Manzagol, [6]D. McCammon, [3]T. Okajima, [3]F.S. Porter, [5]C.D. Reintsema, [3]P. Serlemitsos, [3,4]S.J. Smith, [1,7]P. Wikus

[1]Massachusetts Institute of Technology, [2]Northwestern University, [3]NASA Goddard Space Flight Center, [4]University of Maryland, [5]National Institute of Standards and Technology, [6]University of Wisconsin, [7]now at Bruker BioSpin AG

Micro-X Introduction

This is a sounding rocket borne imaging spectrometer that uses an array of Transition Edge Sensors (TES) to perform microcalorimetry on incoming X-rays. The temperature control is achieved with an Adiabatic Demagnetization Refrigerator. Its first flight is planned to target the Puppis A supernova remnant to measure elemental abundances and to compare plasma diagnostics from resolved emission lines.

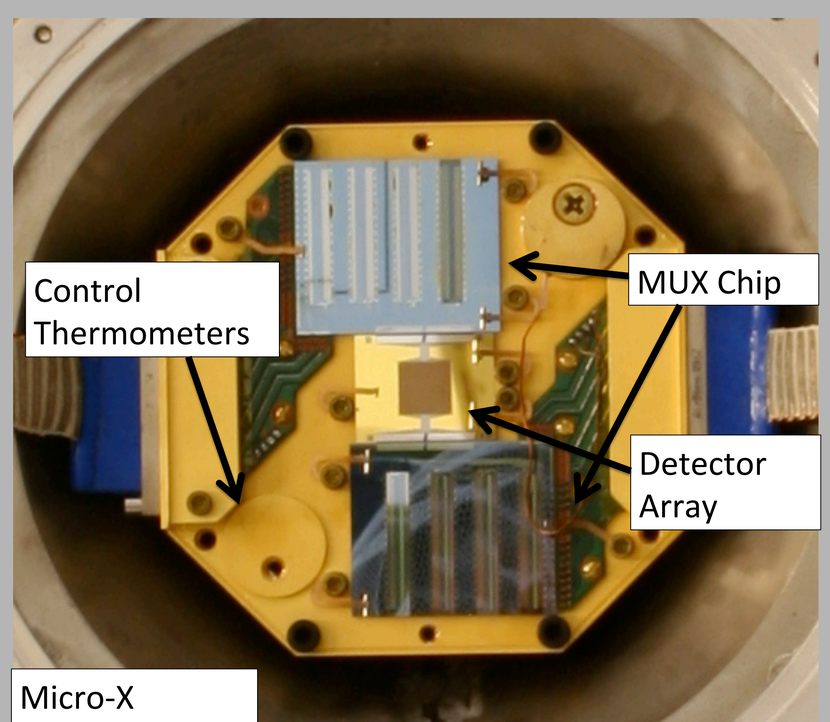
- Apogee of 299 km
- Observation time of 300 sec
- 128 pixel array
- Effective area of 300 cm^2
- Wolter type optic
- 2.6 arcmin PSF
- 11.8 arcmin Field of View
- Base temperature of 75 mK

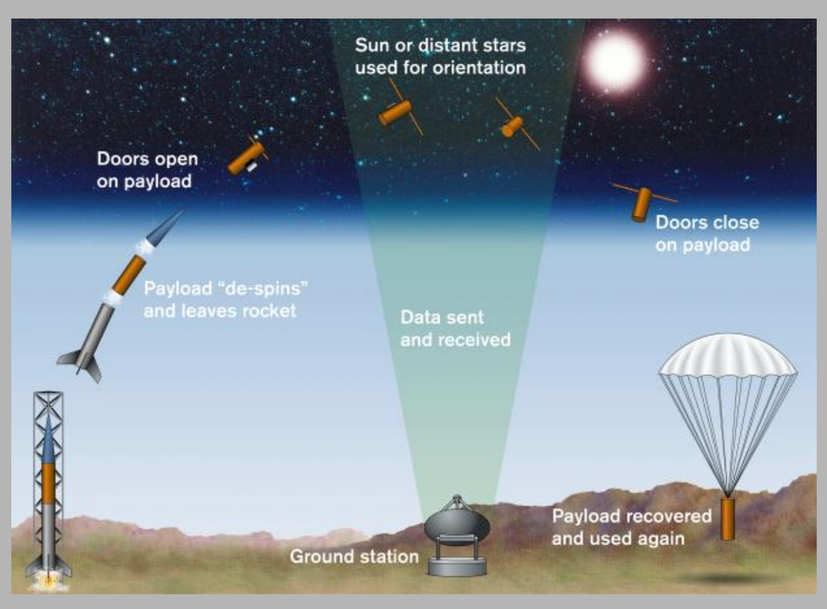
Updates on Status

- Cryostat moved to new, fully operational Micro-X lab at Northwestern University
- Passed the NASA design review; current design is approved for flight
- Beginning the final assembly of the cryostat with filters in launch configuration

Detector and Readout

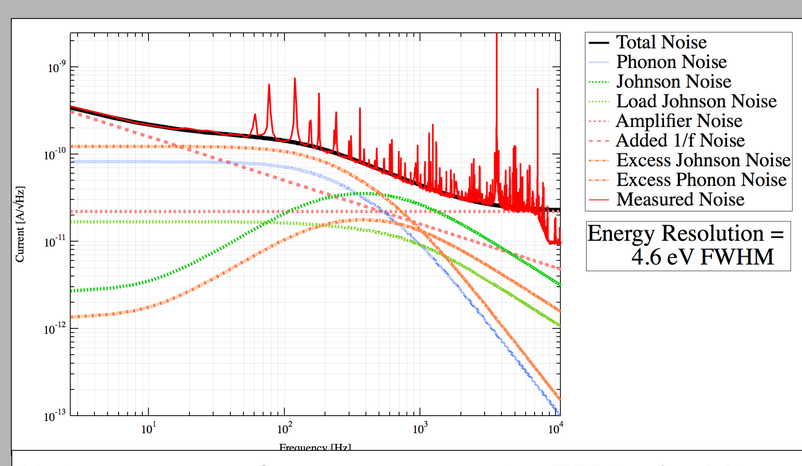
- Micro-X TESs are Mo/Au bilayers with transition temperatures of 120 mK
- Absorbers are composed of a 0.5 µm thick layer of Au and a 3.1 µm layer of Bi
- The detectors have a design resolution of 3 eV at 1 keV and have demonstrated 4.5 eV resolution on a non-multiplexing lab system at 6 keV
- Detector readout is achieved with a NIST designed, rocket flight qualified, variation on a time division multiplexing circuit





Detector Noise

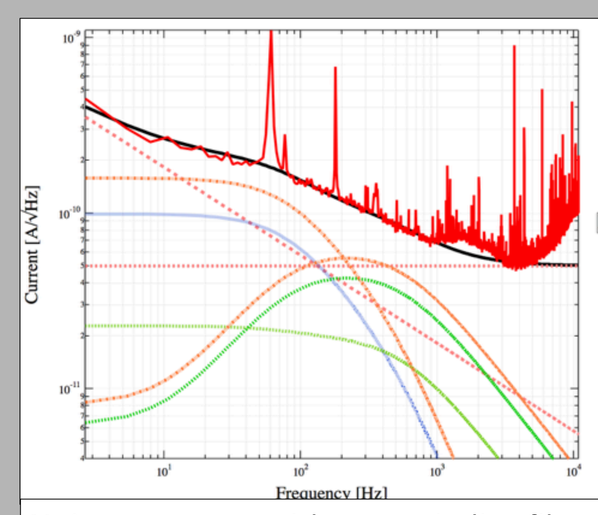
- We have modeled our TESs with the known design parameters and get a good fit to X-ray pulses.
- In order to fit the noise spectrum, excess noise needs to be added to the model, and the excess phonon-like noise is the dominant component of the integrated noise equivalent power (NEP).
- Total multiplexed electronics noise is 40 pA/√Hz, which is below the level of the detector noise



Noise spectrum for a representative TES in the Micro-X array, biased 30% into the transition. The sudden drop in the noise at 8.4 kHz is the rolloff frequency of the digital anti-alias filter that corrects for the effects from the decimation of data.

Radio Frequency Pickup

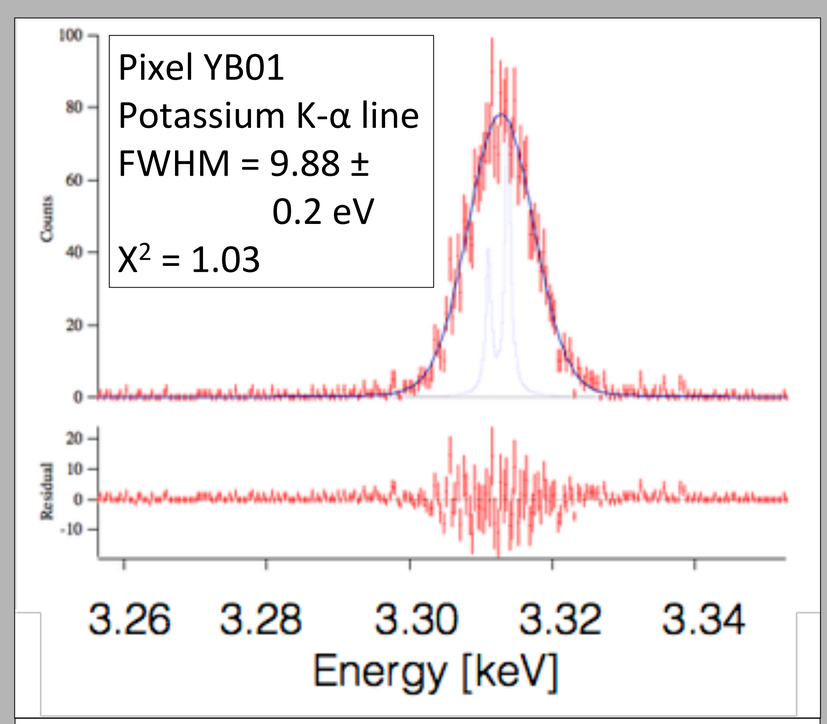
- We believe that the excess phonon noise is generated by RF pickup into the cryostat which manifests as heating in the detector.
- The flight box that interfaces between the cryostat and room temperature electronics allows more pickup than the laboratory equivalent. We are investing how to generate a tighter electrical seal.
- Susceptibility to this noise type varies from pixel to pixel. There is no pattern of which pixels are worse within the readout wiring scheme, so the noise has to enter the detectors directly.



Noise spectrum without anti-alias filtering. This data is in a state more similar to the energy spectra below

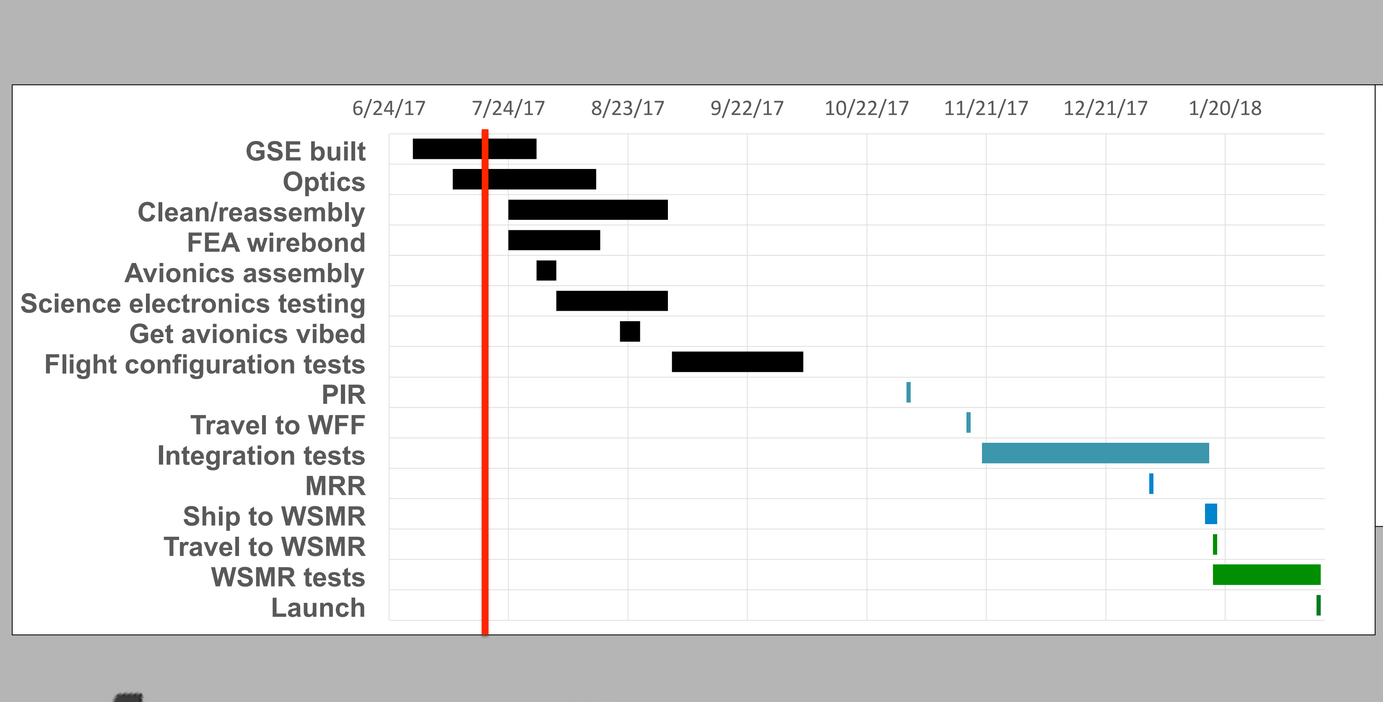
Energy Resolution

- Direct measurements of the energy resolution were made with our flight calibration source.
- The best measured resolution with the flight system is 9.88 eV which inferior to the NEP.
- Shifts in the baseline that are too sharp for our drift correction had contributed to this difference, but this can be made more stable with SQUID tuning.
- Low frequency lines that produce oscillations visible in the time domain provide the remainder of the gap.
- Filtering these lines in the time domain prior to the implementation of the phase-insensitive optimal filter may improve the energy resolution.



Energy spectrum of data taken on a Micro-X pixel, zoomed in on the K K-α line.

Energy spectrum of data taken on a Micro-X pixel, zoomed in on noise traces.



Timeline of remaining work until flight. Launch scheduled for February 2018.

Acknowledgements

This work was supported by a NASA Space Technology Research Fellowship. The Micro-X project is conducted under NASA grant NNX10AE25G.