Questions *and Answers* for EPE, Dec 12 2011:

How will the much higher collecting area of EPE compensate for reduced spectral resolution specifically for WHIM measurements?

S/N for detection of WHIM absorption lines scales like sqrt(DeltaE/Area). Putting in the appropriate numbers for EPE and IXO, we find that EPE has 70% of the power of the IXO gratings. The simulations shown in Fig 6 were done using the EPE response and show that 20 AGN and 100 filaments are detectable with a 10ms program, essentially matching science return that could have been done with IXO.

How well do measurements on arc minute scales of turbulent velocities in clusters of galaxies constrain models?

Global turbulence values will be significant. The values will be weighted towards the central regions of clusters (since emissivity scales as density squared), but the results will be sensitive to models. Global turbulence is dominated by cluster dynamics (mergers, infall and internal dynamics). 1) Higher effective viscosity will reduce the global value, so global levels are a probe of that (very poorly known) quantity. 2) Turbulence levels will be a probe of dynamical state. If these values were available, they would take on a significance similar to temperatures.

With the limited angular resolution, how can it be determined if measurements of gas turbulence in clusters are due to AGN outbursts rather than to mergers?

Both of these questions point to the limitations of the 1 arcmin PSF. With this PSF, EPE will be limited to doing these measurements on nearby clusters, ie, the REFLEX survey where the radii are much bigger than 1 arcmin. Since these clusters are resolved, one can map the turbulence to see if it is higher in association with radio lobes (indicating AGN outburst) or higher along an extended feature (shock front). Note that the RELFEX clusters have already been imaged with ROSAT. Figure 9 shows that 200 km/sec turbulence is easily measured, matching what could be done with IXO. While EPE is clearly not IXO, it represents a very significant advance (20x more area) over the only planned calorimeter mission with US involvement, ASTRO-H.

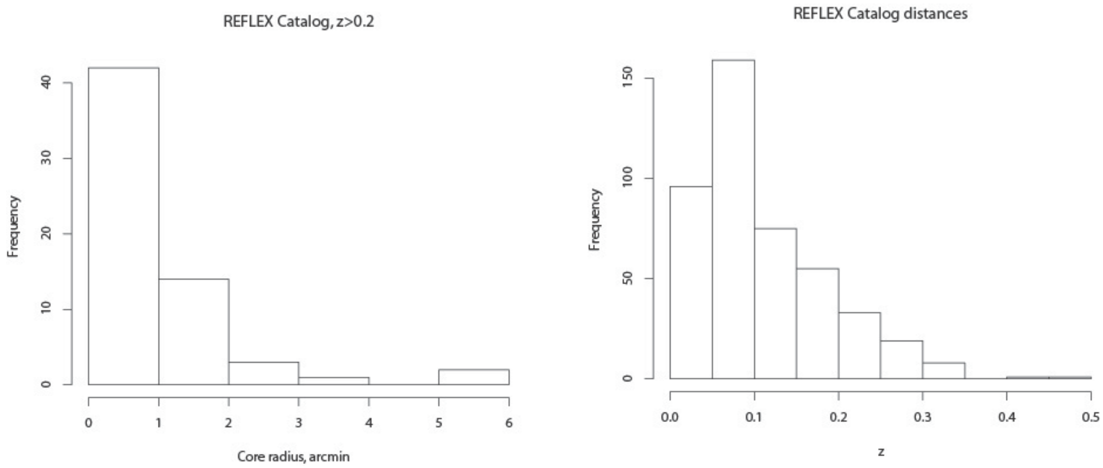
It isn't clear how observations of bursting neutron stars are carried out. Is the idea to stare at a burster with a high burst rate, or to trigger an observation with some other indication of bursting activity?

Both techniques could work. The simulations shown in Figure 10 are based on 4U1728-34, which bursts every few hours so a long stare would be highly effective.

Over what range of redshift will the metal enrichment measurements be made? Over what redshift range are measurements required to determine when and how the metals are produced?

For nearby galaxies, the spectral resolution of the calorimeter will allow the relative fraction of SNIa and SNII to be determined via abundance differences.

The EPE background is estimated to be 2 x 10^{-14} ergs/cm^2/s/arcmin^2 (0.3-10keV), corresponding to 0.02 c/s in the 1 arcmin beam. The RELFEX catalog does contain ~50 clusters at $0.2<z<0.5$, and the core surface brightness of these clustes is well above this limit. These may not be resolved with EPE, but integrated abundances can be measured. See the figures below on the z distribution and core radius of REFLEX clusters.



Since the beam fills the detector field of view, how would instrument background be determined?
Do the effective area curves account for the fraction of the collecting area that actually falls on the detector plane?

The XMS as written in the RFI was very far from optimized. The solution to this (and several other) questions is the inner/outer XMS arrangement used in several of the RFIs. For EPE we would surround the inner 2 arcmin array with a 2x2 hydra outer array of 12'' = 600 micron pixels with 10eV resolution, extending the FOV out to 8 arcmin. This would require another 20x20 TES, would add ~$10m to the cost, and would bring the total number of TES to 1975, still less than planned for IXO. This then allows for the background to be measured and the area curves are approximately correct as shown.

Additionally, the non-sky instrument background can be determined from spectra taken prior to opening the cryostat gate valve - just as for Astro-E2 and Astro-H, and the addition of a simple filter wheel could block all external x-rays for repeated background measurements.

2.5 eV resolution corresponds to delta v of 117 km/s at 6.4 keV. How can the instrument resolve 100 km/s gas velocities (p. 6)?

Figure 9 on page 6 does not mean to imply that 117 km/sec can be resolved, only that with the 2.5eV resolution of the EPE XMS that 100 km/sec turbulence can be well separated from 200 km/sec. The figure is based on a simulation folded through the EPE response. Note that many of the other RFIs also show the same thing (ie, AXSIO, SAHARA).

What is the operational status of the "code division multiplexing" technique?

There are ongoing APRA and internally funded programs that should bring this to TRL 6 within 2 years.

8-channel CDM read-out has been demonstrated on pixels slower than is needed for EPE (see pdf attached). We have demonstrated 4-channel CDM while reading out 4 pixels of the faster type of pixels upon which the EPE design is based (75-micron pixels), and achieved under 4 eV energy resolution at 6 keV for this demonstration.

There is no doubt that greater development of this CDM multiplexing capability is needed for EPE - the same development that is also assumed for the AXSIO central array.

What is the distribution of energy resolution on the existing 32x32 pixel TES arrays?

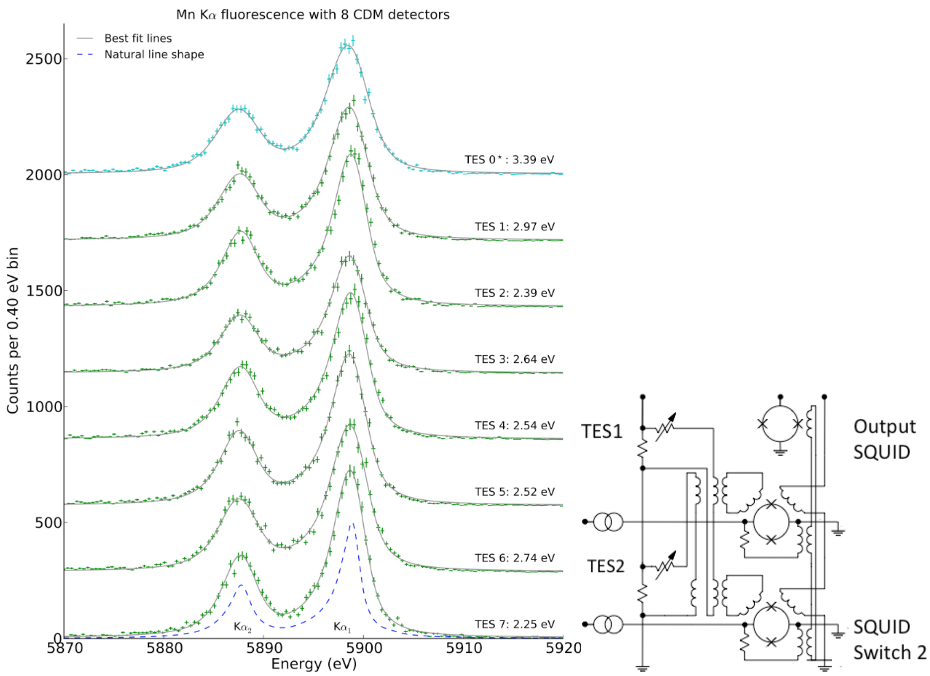
Not yet measured, but should be possible to calibrate this to sufficient accuracy to carry out the observations described herein.

32x32 arrays of 75-micron pixels have been fabricated but not yet tested. The uniformity of performance in 8x8 arrays of these pixels with a lower Tc seems at least as good as those for regular sized TESs in arrays with planar wiring, and arrays with stripline wiring should improve uniformity even further (stray magnetic fields from current flowing in regular "planar" wiring has the potential to degrade uniformity). 32x32 arrays of 75 micron pixels with stripline wiring to all 1024 pixels have been designed and currently are being fabricated. In general, the potential problem of fields from currents that are closer to TESs in small pitch designs appears to be more than mitigated by the much smaller area of TESs - ie. the smaller TESs are much less sensitive to magnetic fields than larger ones. In addition, the 150-micron pitch of EPE will reduce this sensitivity further over 75-micron devices.

2.4.3 Update on Code Division multiplexer (CDM)

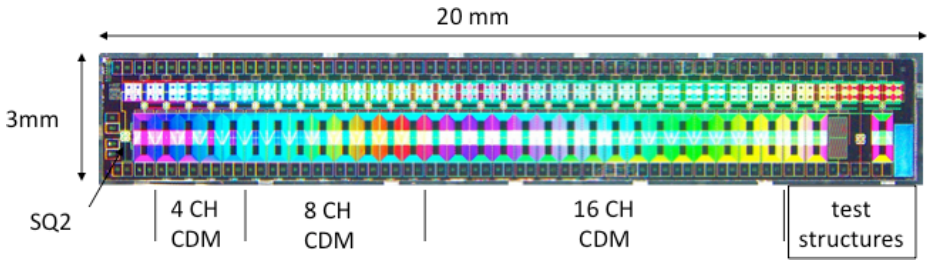
We have made very good progress on CDM. In the figure below (a) we show results from an 8-pixel CDM demonstration. The seven modulated pixels are all sub-3 eV. As is usual in CDM, pixel 0 is not switched like the other pixels, and so it has degraded resolution due to worse 1/f and pickup. We only include it here for completeness. Just as for the recent TDM measurements, the frame rate is t_row = 400 ns. For these measurements this frame rate is currently limited by the inability to pass data out through the digital feedback electronics any faster than this, the new room-temperature hardware necessary for this will be available soon. The 400 ns frame rate used for these measurements was somewhat conservative and not yet optimized. We estimate that it could currently be reduced down to 360 ns straightforwardly.

(a) (b)



(a) The resulting MnKα spectra from an 8-pixel CDM experiment using flux-couple code division multiplexing. (b) Fluxed coupled CDM circuit when just 2 TESs are coupled.

The amount of energy resolution degradation from CDM multiplexing can in principle be reduced by up to a factor of 5.7 over TDM for the read-out of 32 rows, and this factor reduces to 2.8 when considering 8 rows. A full characterization of the detector array that produced this result has not yet been completed and only rough estimates have been made of levels of energy resolution degradation that was due to the CDM read-out of between 0.2 and 0.4 eV.



Photograph and layout of CDM chip that incorporates 4, 8 and 16 row CDM readouts.

The same chip that produced the 8-pixel CDM results has been used to produce very similar results in a 4-pixel CDM measurement. The same chip also has a 16-channel CDM read-out capability, which will be demonstrated in the near future.