BEST (Black Hole Evolution and Space Time) - Reviewers' comments and asnwers from the authors of the white paper.

Comment:
One might conclude from Figure 1 that the test of strong gravity comes mainly from the variation of polarization angle with energy in the 2-10 keV band. Is this inference correct? It would be helpful to know what specific science the hard-band (E>10 keV) polarimetery enables that could not be done in the soft-band alone.

Response:
Three figures are of interest in this context. Figure 1 shows the sensitivity (minimum detectable polarization, MDP, 99% confidence level) of the broadband polarimeter over the entire energy range for a 10 mCrab source (10^6 sec integration time). The figure shows that BEST achieves very comparable MDPs in the soft and hard X-ray bands.

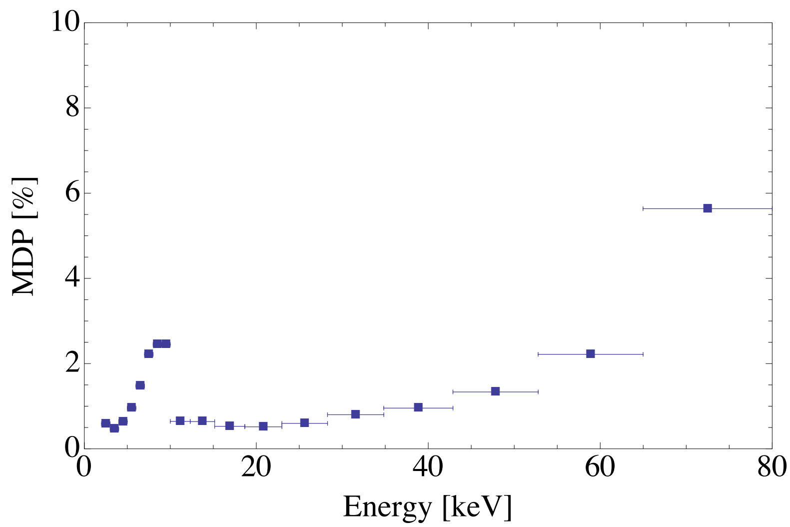

Figure 1: Minimum detectable polarization degree (MDP, 99% confidence level) for a 10^6 s BEST observations of a 10 mCrab source with a Crab spectrum.

Figure 2 shows the spectrum of Cygnus X-1 in the thermal state used by Guo, McClintock, Reid et al (2011) to fit the spin of the Cygnus X-1 black hole. The red solid line shows the modeled thermal disk emission, and the dashed blue, dashed green, and solid green lines show the powerlaw, reflected, and Fe-line components, respectively. The plot shows that BEST will be able to make precision measurements of the spectrum from 2 to ~70 keV. The information from >10 keV energies will be crucial for properly fitting the polarization properties of the thermal component at <10 keV.

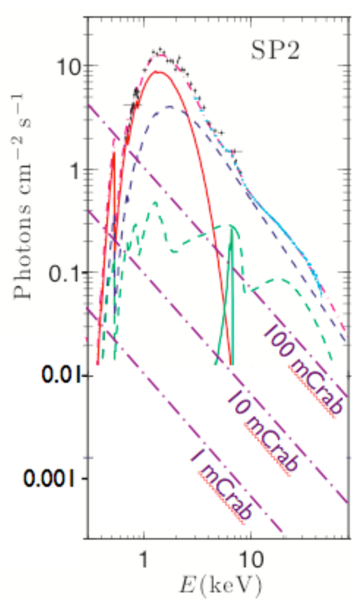

Figure 2: Spectrum of Cygnus X-1 used by Guo, McClintock, Reid et al. (2011) to fit the spin of the Cygnus X-1 black hole (see text for explanations).

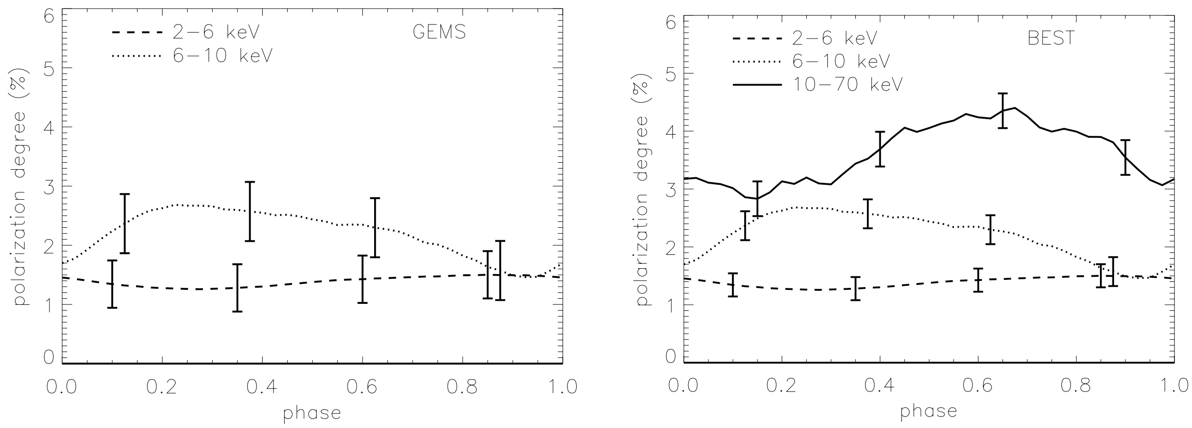

Figure 3: Polarization of the emission from a accreting black hole with a truncated thin disk surrounding a precessing torus, viewed from 70˚ inclination. The torus extends from R=6-10M, and is inclined 25˚ relative to the BH equatorial plane. The disk is emitting thermal seed photons at ~1keV, which get upscattered in the corona at a temperature of 50 keV. The error bars correspond to a 1000 s observation of a 2 Crab source with GEMS (left panel) and BEST (right panel). The simulated time corresponds to a typical duration of Quasi-Periodic Oscillation activity (simulation by J. Schnittman, 2011).

Figure 3 shows a simulation of a binary system with a precessing torus as observed with GEMS and with BEST. Whereas GEMS cannot resolve the phase dependent variability of the polarization degree, BEST can resolve it in the soft *and* in the hard X-ray bands. The phase-resolved information can be used to effectively constrain the geometry of the disk and the disk corona and to perform sensitive tests of models about the origin of the different emission components. The broadband polarization measurement capabilities of BEST are key for comprehensive tests of accretion disk models.

Comment:
Can you explain in detail how you get out to z=6?

We estimate that a 10^6 s observation will give ~1 detection at z=6. During the mission lifetime of 3-5 years, BEST might be able to detect 10-20 AGNs at z>6. These estimates are based on the $E < 10$ keV X-ray luminosity function (Ueda et al. 2003). The number of Compton-thick AGN was matched to z=0 Swift/BAT and INTEGRAL observations (Treister et al. 2009). The spectral shape was matched to the observed spectral shape and intensity of extragalactic X-ray background (Treister et al. 2009). The numbers at z>2 are uncertain. Our number estimates are based on straight extrapolation of the luminosity functions and are probably lower limits.

Comment:
The quoted AGN counts (380 in 12x12' with 10" HPD) seem to ignore confusion issues. If these are accounted for, does the expected redshift distribution (Fig 2) change much?

Response:
We estimate that confusion is not a serious concern for a point spread function of 10″ or better. The standard confusion criteria for a slope 5/2 differential logN-logS is 40beams/source. For 10" half power diameter (HPD) we would reach the confusion limit at 6900 sources per field. For a 30" HPD we would hit confusion at 690 sources per field – close to the projected 380 BEST sources per field for a 10^6 s observation.

Comment:
Can you add some detail on the cluster science?

Response:
The "halo" and "relic" sources in galaxy clusters give evidence for non-thermal particles in galaxy clusters. Depending on the energy spectrum of the non-thermal particles, we may or may not see inverse Compton emission in the hard X-ray band. Cluster radio sources and the bubbles they create may also transport or accelerate high-energy electrons which might be detectable in the hard X-ray band. So far we have only upper limits on the hard X-ray emission (e.g. Ajello et al. 2010, ApJ, 725, 1688). High angular resolution as that of NuSTAR and BEST is needed to observe with an angular resolution matched to the 'size' of the radio source and to produce images of particle accelerating regions.

Comment:
What is the expected polarization signal of an LMXB in outburst and how will BEST be able to "tighten the emission locale constraints?"

Response:
Along with stellar-mass black holes, accreting neutron stars are some of the brightest X-ray sources in the sky, making them ideal candidates for polarization studies. Like their BH cousins, NS binaries show strong evidence of a thin thermal disk surrounded by a hot, geometrically thick corona. However, unlike BHs, one unique characteristic of a NS is its solid surface, with which the accreting gas can collide and get heated to thermal temperatures a few times greater than that of the disk (Mitsuda et al. 1984). The detailed geometry of this boundary layer (i.e., its height above the disk, geometric and optical depth, and possible azimuthal asymmetries) should be manifest in the polarization signature. In particular, the scattering of high-energy photons from the boundary layer back off of the disk should be highly polarized and serve as a powerful probe of the physical mechanisms at play. With BEST, we will be able to observe both the low-energy emission dominated by the disk, as well as the 10 KeV flux dominated by the boundary layer. Thanks to the large collecting area, it will also be possible to get time-resolved polarization measurements, particularly exciting for NSs like GX340+0 and 4U1608-52, which both show strong QPO variability over a range of timescales (Gilfanov, Revnivstev, & Molkov 2003).

The outburst spectrum is a superposition of a thermal contribution (below around 15 keV) and a modest Comptonized continuum at higher energies. There is ambiguity in the relative contributions of these components because of the fairly limited spectral range in which statistically significant data have been acquired to date (e.g. RXTE for EXO 1745-248). The degree of polarization and its energy dependence essentially determines the average of the viewing angle with respect to the magnetic field directions sampled in the emission region. Low polarization suggests large emission volumes/surface areas, spanning both polar and equatorial locales. Higher polarization corresponds to smaller volumes. Contrasting these two provides refinement of Eddington luminosity values since these depend on the range of field directions and strengths sampled in the outburst region, because the opacity that controls the Eddington limit (and therefore the M/R determination) is sensitive to these magnetic field quantities.

Comment:
How is your science affected if the mirrors can only achieve 30" angular resolution?

An angular resolution of 30'' would reduce the flux detection threshold by a factor of ~3; furthermore, source confusion would start to limit the sensitivity for long exposures.

Comment:
The RFI states that the HPD diameter of the mirrors is 10" at 4.5 keV. How does the HPD vary from 4.5 keV to 70 keV?

We expect the resolution to degrade slightly from 4.5 keV to 70 keV. Quantitative characterization of this degradation will be measured as part of the multi-layer development in the next two years.

Comment:
Is 7% MDP enough to do IXO science, which had 1% MDP? (page 3, table 1), and how does this relate to the 1% MDP in the science matrix (page 2)?

Response:
In Table 1 on page 3 we used the symbol "‰" standing for "permill" (not for "percent"). The 2-10 keV polarization degree sensitivity is 7‰ = 0.7%. This number is consistent with the <1% sensitivity mentioned in the science matrix.

In Table 1 we included a conservative estimate of the >10 keV minimum detectable polarization degree of 3%. In the meantime we made more detailed simulations showing that the >10 keV MDP is actually lower, approximately 1%.

Comment:
Please provide the effective area curves for the TPC and high-energy polarimeter. The RFI states that the TPC has 99% detection efficiency at 2 keV and 10% at 8 keV. No numbers are provided for the high-energy polarimeter.

Response:

The detection efficiency of the high-energy polarimeter is 10% at 10 keV, 38% at 20 keV, and rises from 78% to 85% between 40 keV and 70 keV. The energy dependent mirror area is given in Figure 4. Please see Fig. 1 for the energy dependent minimum detectable polarization degree (MDP).

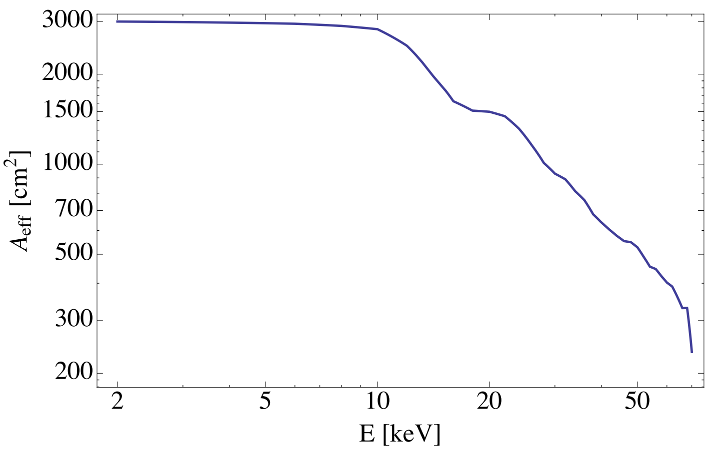

Figure 4: Effective area of the BEST mirrors as a function of energy.