

Questions for EREXS:

Answers from EREXS:

Are there ways EREXS could address the IXO science objectives not discussed in the RFI response?

Yes. Several additional ways are listed in the file `erexs_final-EREXSedits.docx` and are repeated with more details (than in the RFI response) here:

What happens close to a Black Hole?

X-ray reflection spectra for a large sample (~200) of eROSITA survey (0.5-10 keV) AGN are constrained by EREXS-HXI spectra (5-300 keV). Also, the HXI scanning survey monitors state transitions in all BH-LMXBs in Galaxy, allowing higher sensitivity pointing integrations with the NF-HXI to measure QPOs and constrain space-time physics near the ISCO as well as BH masses.

When and how did super massive Black Holes grow?

HXI will measure primordial SMBH growth ($z > 6$) with discovery of high apparent luminosity (beamed) blazars, which are FSRQs. As noted in Ghisellini et al (2010, MNRAS, 405, 387), the BAT blazar PKS2149-306 at $z = 2.35$ could be detected by EXIST (or now EREXS) at $z = 8$. The wide-field HXI survey is essential for the discovery of these earliest, and rare (both intrinsically and due to beaming fraction) SMBHs, which would likely not have been discovered in narrow-field surveys with IXO. Their $< 20''$ HXI positions would be matched with eROSITA sources with rising 0.3-10 keV spectra that match (allowing for factors of ≤ 2 typical variability) the rising 5 – 50 keV HXI νF_ν SED spectra (cf. Fig. 13 of Ghisellini et al). Their redshifts would be measured by the pointed observation followup (to the scanning HXI survey) with the imaging nIR photometry and spectroscopy with the IRT on EREXS. *Without the rising SED measured by the HXI scanning survey at hard X-ray energies, these blazars would not be picked out from the enormous AGN sample of the eROSITA survey.*

How does large scale structure evolve?

HXI with its full-sky scanning survey will carry out a survey for AGN in galaxy clusters with $> 10X$ the sensitivity (at > 10 keV) of any previous survey (except for eROSITA at < 10 keV) which will constrain AGN feedback in clusters as well as cluster magnetic fields for clusters without AGN from detection or limits of hard emission produced by inverse Compton of diffuse radio emitting electrons scattering off the CMB.

How does matter behave at very high density?

As noted in the CST Panel Report, the HXI will detect short GRBs (SGRBs). As only partly noted in the EREXS response to the RFI, this will enable coincident detections and unique galaxy identifications with the HXI/IRT. This then enables significant constraints on the neutron star equation of state (NS-EOS) for both NS-NS and NS-BH mergers, as are now thought to constitute the majority of SGRBs (with NS-NS mergers likely the dominant source). Not mentioned in the RFI-response is that the small number of SGRB galaxy identifications with Swift (due to its relative inefficiency of detection of the harder

spectra SGRBs and the significantly lower brightness X-ray and optical afterglow brightnesses of their afterglows) are both overcome with HXI. The SGRB detection rate would be $\geq 3X$ higher, due to enhanced sensitivity at >200 keV, and the <10 - $20''$ SGRB locations *directly measured by HXI* will enable host galaxy identifications, and thus redshifts, for ALL events coincident with Advanced LIGO since the ALIGO detection limit is predicted to be ~ 400 Mpc for NS-NS mergers. The “precise” GW-chirp signal waveforms and distance, when combined with IRT redshifts, will enable not only a “precision” Hubble constant measurement for each SGRB host galaxy, but also constraints on the NS-EOS from the redshift-corrected GW vs. GRB waveforms.

Please comment on source confusion / identification issues for the AGN survey.

The CST is correct to question whether the $<20''$ HXI positions (90% confidence radii for $>5\sigma$ source detections) are sufficiently accurate to enable unique AGN identifications. Whereas for EXIST this was overcome with the SXI (see next question), for EREXS (baseline, as proposed in response to RFI) with no SXI this is accomplished with the initial matching for each HXI source to the expected full-sky eROSITA catalog measured (by c. 2016, assuming a 2014 launch) for 0.3 – 10 keV. The projected eROSITA source positions are $\sim 5''$ and a sensitivity limit of $F_x(5-10 \text{ keV}) \sim 5 \text{ E-14 cgs}$ vs. the projected EREXS sensitivity (Fig. 7 in the RFI response) of $F_x(5-10 \text{ keV}) \sim 1 \text{ E-12 cgs}$ for the 2y scanning survey, or a factor $f \sim 20$ less than eROSITA. The total AGN sample expected for eROSITA is $N \sim 2E6$ vs. (for a $\log N$ - $\log S$ with $3/2$ slope) a total number for EREXS that is smaller by a factor $f^{1.5} \sim 90$, or a total EREXS sample of ~ 25000 AGN (not including some CT-AGN and blazars; see Fig. 2 in RFI response). These will be uniquely matched to eROSITA source positions since the random probability of 2 or more eROSITA AGN falling in a given $<20''$ EREXS error circle is $<0.6\%$. EREXS will then in its pointed mission phase get IRT spectra and redshifts for most of this sample, to measure AGN demographics. The harder response of EREXS will detect additional Compton Thick (CT) AGN and blazars not detected by eROSITA. These will be identified by IRT imaging and objective prism spectra over the whole $<20''$ error circle, with followup IRT slit spectra on either heavily absorbed or red-continuum (high z blazar candidate) objects to identify the likely counterpart and its redshift.

Clarify how SXI data requirements for science are mitigated since this instrument is not present (but still referenced).

As is clear from the EREXS response to the RFI, the EREXS concept is a minimal mass/cost version of the (much) larger EXIST concept, proposed to Astro2010, that preserves $\sim 70\%$ of the EXIST sensitivity. The reference(s) to the SXI in the response to the RFI were simply a hold-over from EXIST and should have been deleted. HOWEVER, the “SXI” can also be “explained” (as described in the response to the preceding question) as being the 0.3 – 10 keV scanning all sky survey to be carried out by c.2016-2018 with the eROSITA mission, now scheduled for launch in (presumably) 2014. This of course entails “risk” that eROSITA is not launched or somehow fails. In that event, the desirable full-sky ~ 0.5 – 10 keV survey to complement the EREXS survey could be met by adding a *significantly smaller (than proposed for EXIST) SXI soft-medium X-ray telescope to EREXS, perhaps (again) as a foreign contribution*. The existing Italian (Brera) copy of the Swift/XRT could be accommodated by moving the 5

NF-HXI modules on one side of the IRT (Fig. 6 of the RFI response) to be placed in front of the IRT; the increase in mass/power over the values in Table 1 would be <10%.

How are BH masses determined from HXI and IRT data in tidal disruption events and what observing cadence is required?

The HXI in *both its 2y scanning survey and followup 3y pointing survey* is a very effective survey for discovery of tidal disruption events (TDEs) of quiescent SMBHs due to the wide-field sky coverage of the WF-HXI modules in both scanning and pointing modes. The TDE rates of ~ 10 -30 per year are based on a ~ 1 -10% non-thermal hard flux fraction of the total Eddington accretion luminosity out to a detection radius of $R \sim 400$ Mpc and assuming isotropic emission. The much more luminous (apparently) beamed TDEs, like Swift J1644 (as referenced in the RFI response) would be detected out to much larger distances ($z \sim 0.7 - 1$) and thus in much larger numbers dependent on their beaming factors. In the “isotropic” case, the underlying SMBH masses would be constrained by comparison of the IRT lightcurves and spectra with detailed models: the expected ejection of \sim half the tidal debris onto high orbits. From IRT photometry (4 bands) and spectra ($R = 30$ or 1000), constraints on the SMBH mass can be derived by comparison with models (e.g. Strubbe and Quataert 2009, MNRAS, 400, 2070). The required IRT pointing cadence would be every $\sim 3 - 10$ d following the initial HXI detection (itself requiring a ~ 10 d integration) and then decreasing to every ~ 10 -30d. For beamed TDEs like Swift J1644, for which no spectroscopic outflows or thermal photometric signatures have been seen, it is possibly the sensitive nIR coverage of the IRT that would enable constraints since by analogy with beamed microquasar strong flares (e.g. from GRS1915+105), it is the non-thermal IR flux that follows the X-ray flaring. However detailed models are needed to predict how this will constrain the SMBH mass. Thus the “conventional” (isotropic) TDEs are the most likely to yield new constraints on SMBH mass from which SMBH demographics (in quiescent galaxies) and fundamental checks on the M-sigma relation(s) can be derived *from the significant samples of these events with prompt and ongoing cadence optical and especially nIR (to deal with dust effects) spectra that EREXS-HXI/IRT will provide.*